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Residential End Uses: Historical Efficiency Data and Incremental Installed Costs for Efficiency Upgrades

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Residential End Uses: Historical Efficiency Data and Incremental Installed Costs for Efficiency Upgrades

The residential sector comprises equipment consuming various fuels and providing different end-use services. When replacing equipment, consumers may choose to purchase equipment that meets minimum federal equipment efficiency standards, or they may opt for higher-efficiency equipment, such as equipment that meets or exceeds ENERGY STAR® specifications. Consumers may also choose to purchase or retrofit different types of equipment, which may require additional costs (e.g., for ducts, exhaust vents, natural gas lines, or electrical connections) to install. The stock mix of equipment types, efficiency levels, and fuels consumed directly affects total residential sector energy consumption.

EIA's Residential Energy Consumption Survey (RECS) provides information on the total equipment stock and energy consumption within existing buildings; however, the survey does not directly gather information such as equipment cost or annual equipment purchase trends by efficiency level. The Residential Demand Module (RDM) of the National Energy Modeling System (NEMS) incorporates these and other inputs as part of its technology choice component.

The contract report in Appendix A provides historical shipment data for residential equipment by efficiency range, allowing EIA to represent current trends in residential markets that affect energy use. The report in Appendix B identifies costs associated with switching fuels and equipment types for select residential major end uses. Both reports are used to develop assumptions for the *Annual Energy Outlook 2018* (AEO2018) cycle.

Appendix A and Appendix B should be cited as reports by Navigant Consulting, Inc. prepared for the U.S. Energy Information Administration.

APPENDIX A

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ENERGY

Residential End Uses: Area 1: Historical Efficiency Data

Prepared for: U.S. Energy Information Administration

Prepared By: Navigant Consulting, Inc.

Final Report for Area 1: February 17, 2015

Navigant Reference: 173668

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February 17, 2015

Under Area 1, EIA requested an annual time series of equipment-specific efficiency data.

» Area 1 Objectives:

- Develop historical shipment data for residential equipment, segmented by efficiency range, so that EIA can better represent current trends in residential markets that impact energy use
- Enhance the quality of EIA products and help maintain relevancy and consistency with changing energy markets through improved representation of equipment efficiency in the Residential Demand Module (RDM) and the National Energy Modeling System (NEMS)

We leveraged publically available data sources to develop historical shipments categorized by efficiency levels.

- Two publically available sources provide enough information to categorize shipments according to "Standard Level" and "ENERGY STAR Level"
  - ENERGY STAR Unit Shipment Data Annual Summary Reports
    - The Environmental Protection Agency (EPA) began collecting shipment data for ENERGY STAR qualified products beginning in 2003, and posts the results on their website
    - The shipment data include the number of ENERGY STAR qualified shipments for a given year, and the estimated market penetration, expressed as a percentage
    - EPA also archives all historical specification levels for ENERGY STAR qualified products, and the dates in which the specifications came into effect
    - Using these historical specification levels, we can map efficiency levels to the number of shipments in a given year
  - Department of Energy (DOE) Building Technologies Office (BTO) Appliance Standards Program
    - Rulemaking Technical Support Documents (TSD) each include a chapter on Shipments Analysis that contains historical shipment data for a given equipment type
- We can subtract the number of ENERGY STAR shipments from the total shipments in the TSD to get all equipment shipments that do NOT qualify for the ENERGY STAR label
- We can then map the minimum efficiency standards through history to the number of non-ENERGY STAR shipments to get the number of shipments that fall between the minimum efficiency standard and the ENERGY STAR specification

We leveraged publically available data sources to develop historical shipments categorized by efficiency levels.

1 DOE TSD Data	2 ENERGY STAR Data	3 Reconcile Data Sources	4 Map Historical Standards
As part of DOE's analysis for minimum efficiency standards, DOE collects historical shipments of equipment. Typically trade organizations, such as the Air-conditioning Heating Refrigeration Institute (AHRI), submit this data.	Since 2003, EPA has published annual shipments of ENERGY STAR qualified products. From 1998-2009 DOE estimated the fraction of sales that are ENERGY STAR qualified for four different products: clothes washers, dishwashers, refrigerators, and Room Air Conditioners.	Use the two data sources to split shipments into two efficiency categories: Minimum Standard to just below ENERGY STAR qualified shipments, and ENERGY STAR qualified shipments.	Use the historical minimum energy efficiency standards and ENERGY STAR specifications to label the two different shipment groupings.

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ENERGY STAR and DOE TSD data provided enough information to categorize 10 years of shipments by efficiency level.

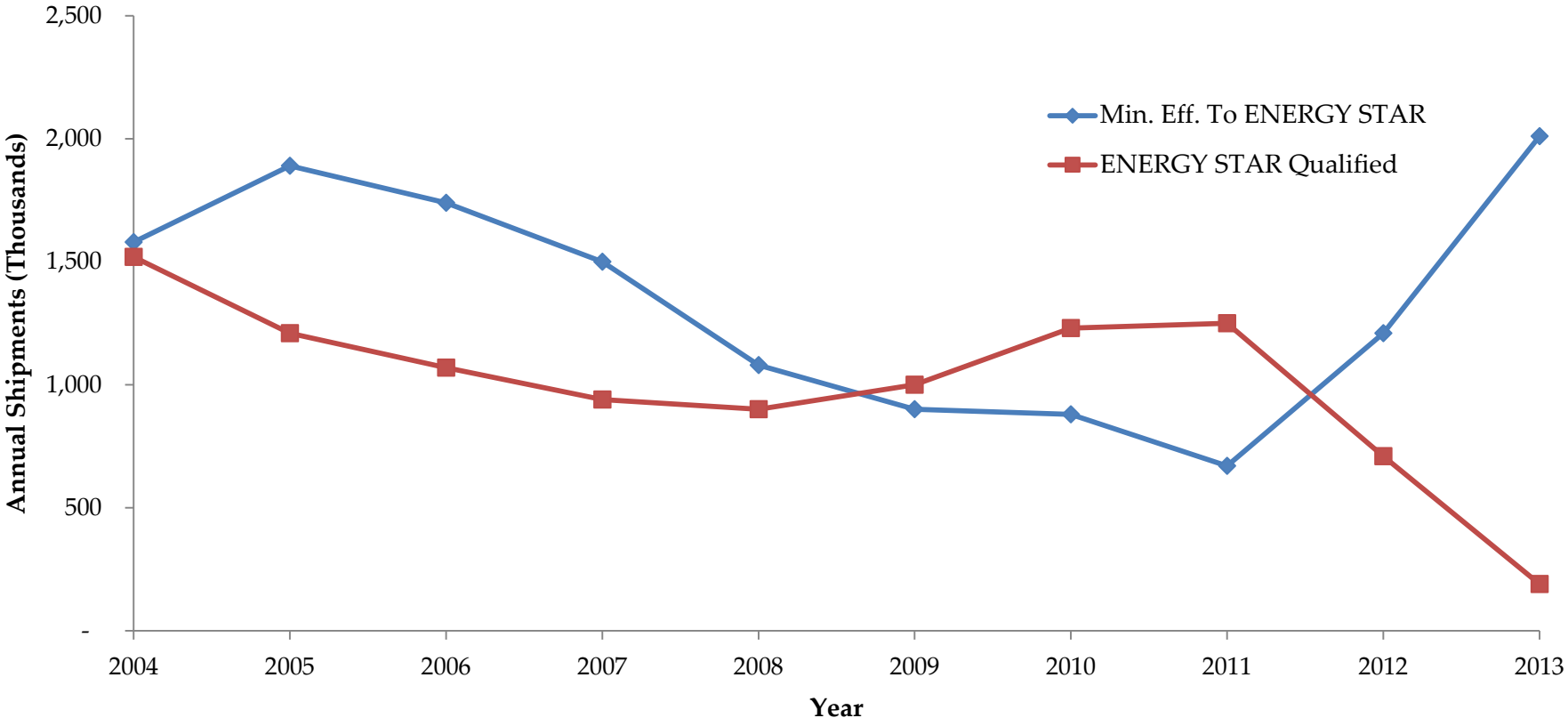
	Table 1—Gas Furnace Shipments (number of units) Categorized by Efficiency Level (Annualized Fuel Utilization Efficiency)		
Year	78-89**	≥90	Total
1992*			1,800,000
1993			2,230,000
1994			2,310,000
1995			2,220,000
1996			2,460,000
1997			2,380,000
1998			2,550,000
1999			2,690,000
2000			2,690,000
2001			2,670,000
2002			2,800,000
2003			2,870,000
2004	1,580,000	1,520,000	3,100,000
2005	1,890,000	1,210,000	3,090,000
2006	1,740,000	1,070,000	2,810,000
2007	1,500,000	940,000	2,440,000
2008	1,080,000	900,000	1,990,000
2009	900,000	1,000,000	1,900,000
2010	880,000	1,230,000	2,110,000
2011	670,000	1,250,000	1,920,000
2012	1,210,000	710,000	1,920,000
2013	2,010,000	190,000	2,200,000

*Cannot categorize data from 1992-2003. All shipments have efficiencies greater than the minimum standard, Annualized Fuel Utilization Efficiency (AFUE) 78%.

**There are likely very few units in this category with efficiencies greater than 80%. According to AHRI's product database, there are no available units with AFUE 82%-89%.

ENERGY STAR shipments of natural-gas furnaces have fallen in recent years.

Figure 1—Historical Shipments VS Time



The sharp drop in ENERGY STAR qualified shipments in 2012 and 2013 is likely due to the ENERGY STAR specification of 90% AFUE for southern states, and 95% AFUE for northern states that took effect in 2012.

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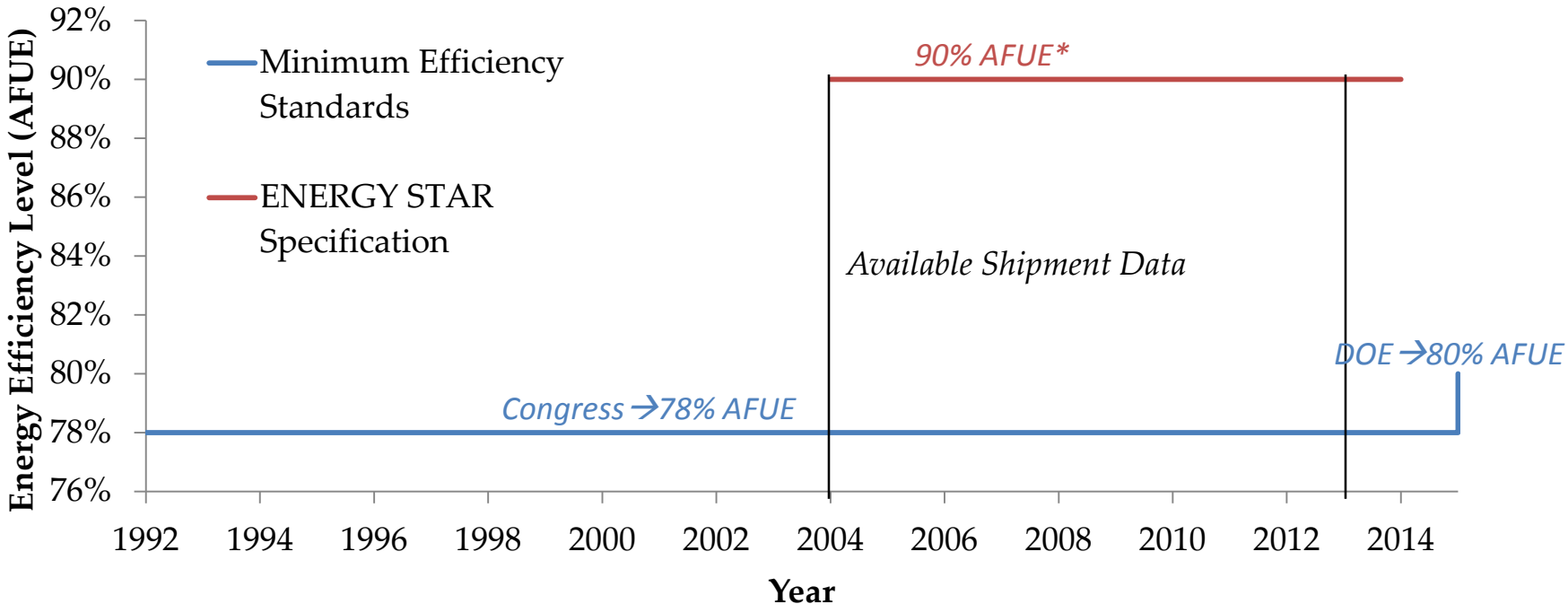
We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 2—Historical Efficiency Standards



In 2012, EPA set a new regional ENERGY STAR specification of 90% AFUE for southern states, and 95% AFUE for northern states. The specification defines the following states as southern states: Alabama, American Samoa, Arizona, Arkansas, California, Delaware, District of Columbia, Florida, Georgia, Guam, Hawaii, Kentucky, Louisiana, Maryland, Mississippi, Nevada, New Mexico, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Texas, and Virginia.

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Details about the data.

Data Sources (also see References Section)

1. Standard Level Shipments
   - **2011-06-06 Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners, Heat Pumps, and Furnaces. Chapter 9: Shipments Analysis** provides historical shipment data for three furnace equipment types: Non-weatherized gas furnaces, Mobile home gas furnaces, Oil fired furnaces.
     - Because non-weatherized gas furnaces dominate the market, we excluded the mobile home gas furnaces from the data presented above.
     - All of the data was submitted by AHRI to DOE, and data is presented from 1972-2009.
   - AHRI also presents historical shipment data for residential gas furnaces on its website from 1994-2013.
     - However, it aggregates mobile home furnace shipments and non-weatherized gas furnace shipments.
     - Therefore, to get the number of non-weatherized gas furnaces from 2010-2012, calculated the average ratio of mobile home furnace shipments to non-weatherized gas furnace shipments over the past 20 years from the TSD data. We then applied this ratio to the total number of residential gas furnace shipments to calculate the number of non-weatherized gas furnace shipments from 2010-2013.
2. ENERGY STAR Level Shipments
   - EPA has collected annual shipment data for residential gas furnaces since 2004, and publishes the shipment data in their annual report.

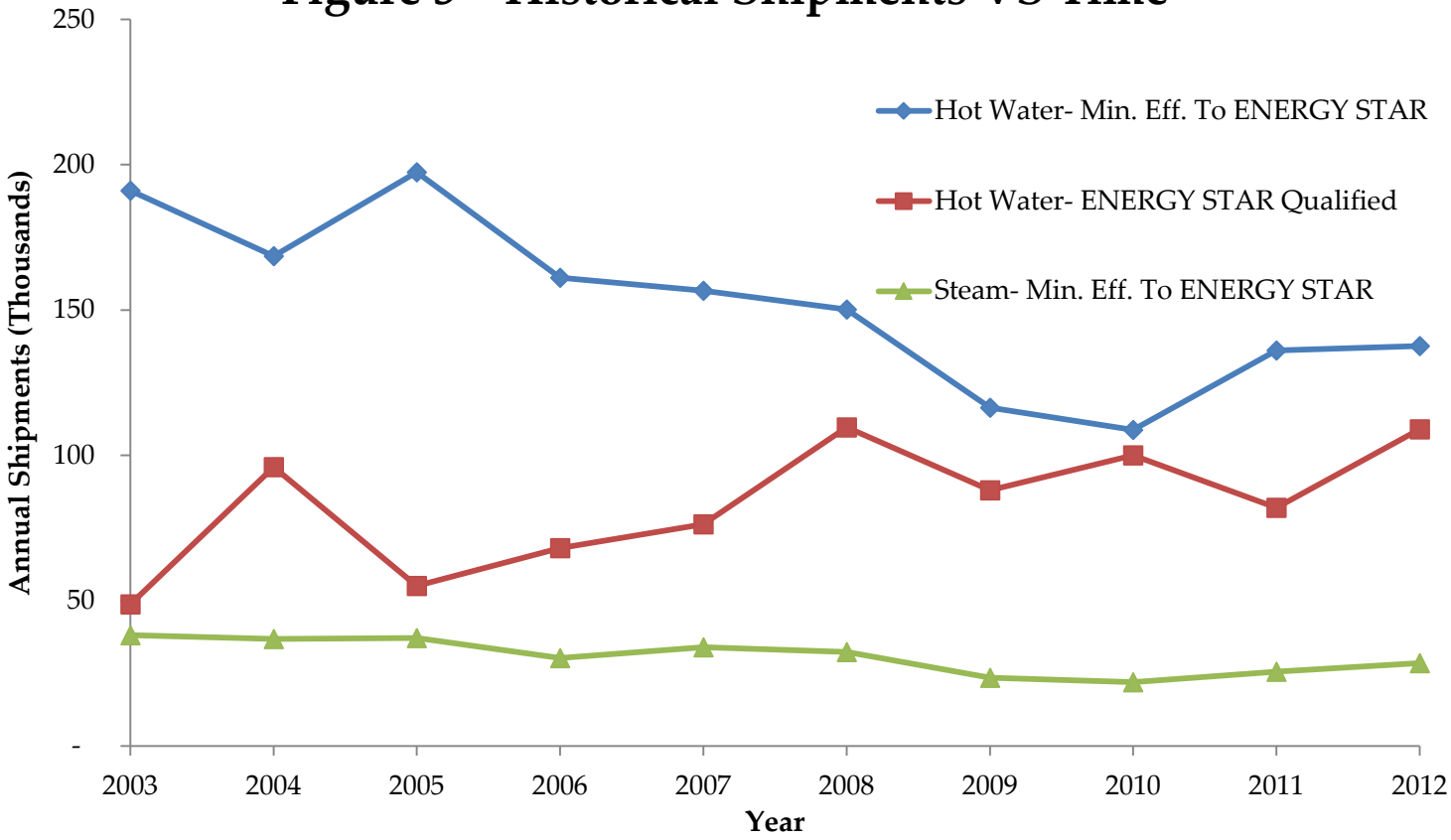
For hot-water boilers, ENERGY STAR and DOE TSD data provided enough information to categorize 10 years of shipments by efficiency level.

	Table 2—Gas Boiler Shipments (number of units) Categorized by Efficiency Level (AFUE)					
	Steam		Hot Water			Total
Year	75-84	80-84	80-84	82-84	≥85**	
1992*	27,347					187,921
1993	28,661					209,804
1994	32,167					232,772
1995	28,438					203,479
1996	30,564					216,300
1997	32,248					225,772
1998	29,484					204,260
1999	32,531					223,061
2000	36,904					250,270
2001	36,205					248,439
2002	34,836					249,122
2003	38,105		191,074		48,769	277,948
2004	36,846		168,588		96,000	301,434
2005	37,127		197,374		55,091	289,592
2006	30,243		161,129		68,102	259,474
2007	33,932		156,660		76,309	266,901
2008	32,374		150,137		109,605	292,116
2009	23,540		116,370		88,000	227,910
2010	21,957		108,711		100,000	230,668
2011	25,615		136,112		82,000	243,727
2012		28,516		137,590	109,000	275,106

*Cannot categorize data from 1992-2002 for Hot Water Boilers. All shipments have efficiencies greater than the minimum standard, AFUE 80%.
**There are likely very few units in this category with efficiencies between 86-89% AFUE. According to AHRI's product database, there are few available units with 86%-89% AFUE.

ENERGY STAR qualified shipments of natural-gas boilers are approaching 50 percent of the market.

Figure 3—Historical Shipments VS Time



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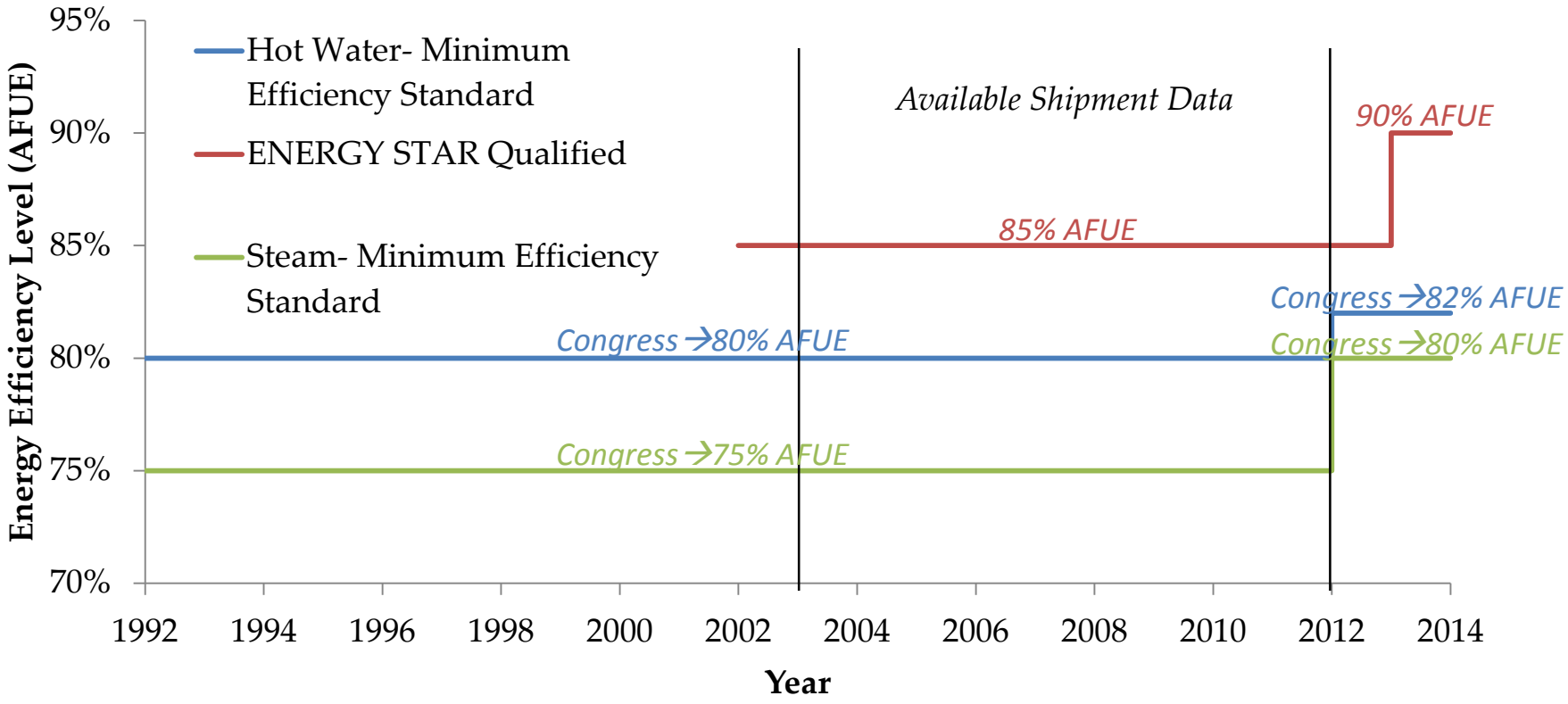
We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 4—Historical Efficiency Standards



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Assumptions about the data.

Data Sources (also see References Section)

1. Standard Level Shipments
   - **Technical Support Document (Notice of Data Availability—NODA) Appendix 9-B Additional Data on Shipments of Residential boilers** provides historical shipment data for gas, oil, and electric boilers, all categorized by steam or hot water output.
     - DOE received historical shipments of boilers categorized by fuel type from AHRI (1969-2000) and Appliance Magazine (1960-2008).
     - DOE then used a limited data set from a Pacific Northwest National Laboratory (PNNL) report to calculate the fraction of the fraction of boilers shipped to the residential market, and applied that fraction to the larger data set.
     - DOE also used another limited data set from the same PNNL report and AHRI to calculate the fraction of boilers with a hot water output, and applied that fraction to the larger data set.
     - Details of the methodology can be found here: http://www.regulations.gov/#!documentDetail;D=EERE-2012-BT-STD-0047-0011ENERGY STAR level shipments
2. ENERGY STAR has collected annual shipment data for residential boilers since 2003.

The ENERGY STAR and DOE TSD data provided enough information to categorize 4 years of shipments by efficiency level.

	Table 3—Gas Water Heater Shipments (number of units) Categorized by Efficiency Level (EF)					
	Storage		Instantaneous	Total Storage	Total Instantaneous	Total
Year	.575-.66	≥.67***	≥.82			
1999*				4,620,000		4,620,000
2000				4,590,000		4,590,000
2001				4,620,000		4,620,000
2002				4,670,000		4,670,000
2003				4,800,000		4,800,000
2004**				4,910,000	80,000	4,990,000
2005				4,670,000	150,000	4,820,000
2006				4,360,000	230,000	4,590,000
2007				4,100,000	300,000	4,400,000
2008				3,750,000		3,750,000
2009				3,520,000		3,520,000
2010	3,240,000	426,000	360,000	3,670,000	360,000	4,030,000
2011	3,600,000	100,000	316,000	3,700,000	316,000	4,016,000
2012	3,610,000	101,000	317,000	3,710,000	317,000	4,027,000
2013	3,860,000	151,000	372,000	4,010,000	372,000	4,382,000

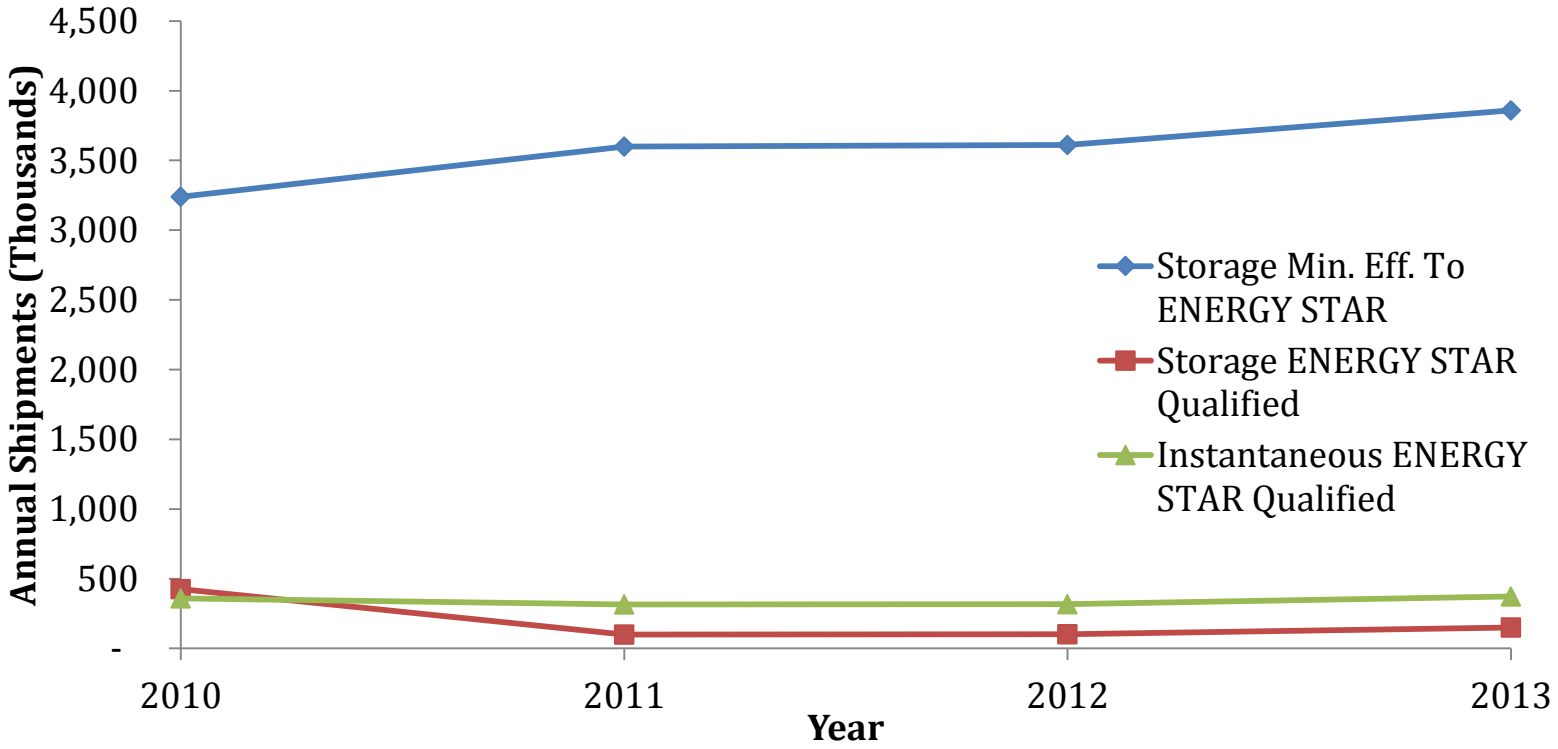
*Cannot categorize storage water heater data from 1999-2009 by efficiency. All storage water heater shipments from 1999-2003 have efficiencies greater than the minimum standard, EF .525. All storage water heater shipments from 2004-2009 have efficiencies greater than the minimum standard, EF .575.

**Cannot categorize instantaneous water heater data from 2004-2007 by efficiency. All instantaneous water heater shipments from 2004-2007 have efficiencies greater than the minimum standard, EF .62.

***There are likely no shipments of units in this category with an EF greater than .72. According to the AHRI database, there are no units with an EF between .72-.81. There is a single manufacturer of an EF .82 unit, but this only became available in 2013, and 2013 market penetration is likely very low. Also, we cannot explain the large variations in shipments between 2010 and 2013—the source confirms the data.

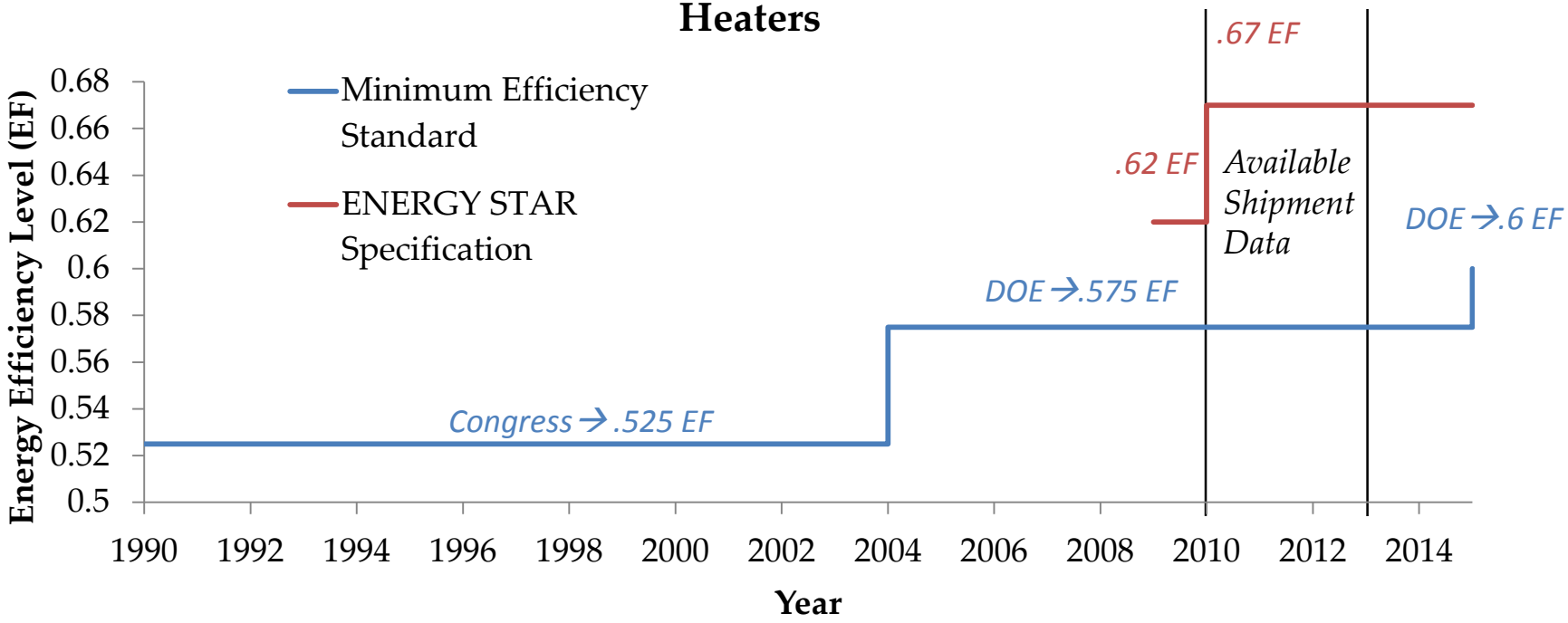
Although instantaneous water heater shipments are only approximately 10% of total water heater shipments in 2013, they make up a larger portion of the ENERGY STAR market than storage units do.

Figure 5—Historical Shipments VS Time



We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 6—Historical Efficiency Standards for Storage Water Heaters

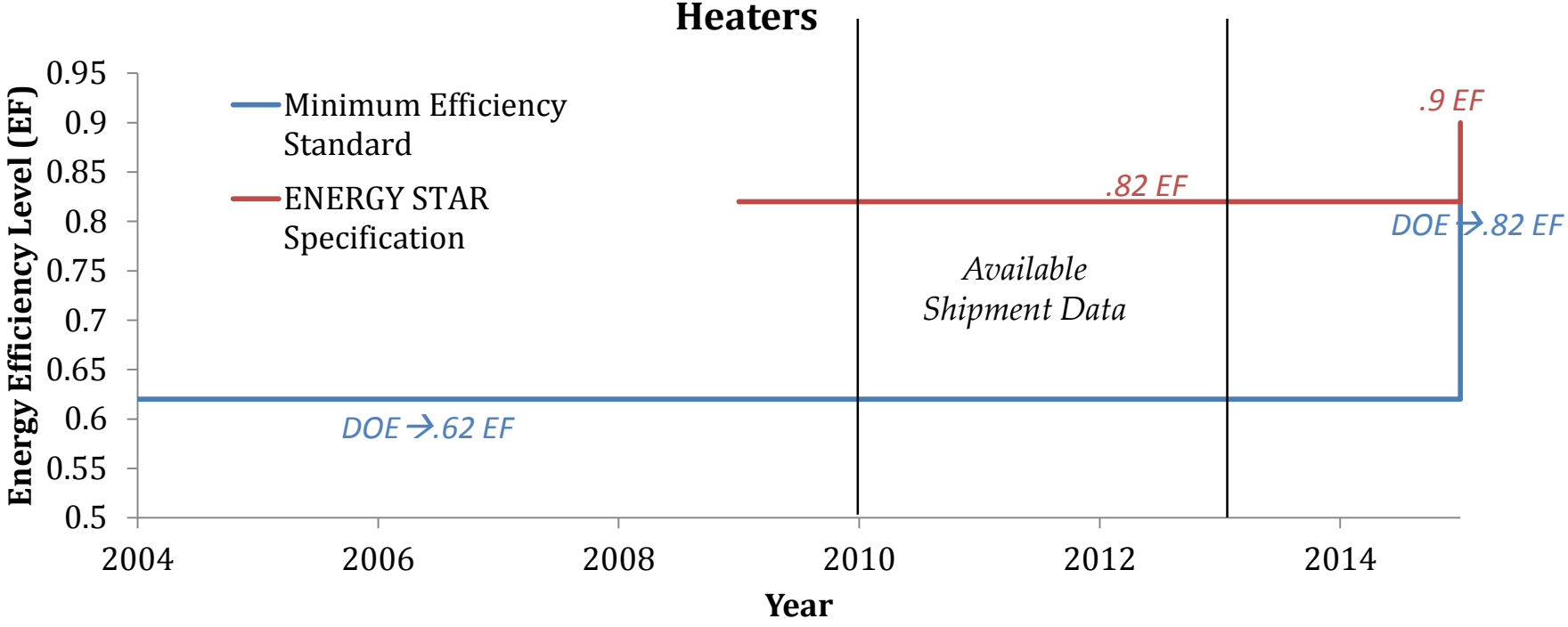


Assumed storage volume of 50 gallons because this is the average volume of currently available water heaters according to the AHRI product database.

Version 3.0 of the ENERGY STAR specification, which takes effect 4/16/2015, specifies an EF of .67 for units with a storage volume of ≤ 55 gallons, and EF .77 for units with a storage volume > 55 gallons

We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 7—Historical Efficiency Standards for Instantaneous Water Heaters



The efficiency level categorization was based on applicable ENERGY STAR and minimum standard efficiency levels.

Data Sources (also see References Section)

1. Standard Level Shipments
   - The DOE TSD has shipment data for total residential gas storage water heaters from 1951-2009, and for total residential gas instantaneous water heaters from 2004-2007. All of the data were submitted by AHRI to DOE.
   - In addition, the AHRI website contains the identical data set for storage water heater units, but also extended to 2013.
2. ENERGY STAR Shipments
   - ENERGY STAR has only collected shipment data for residential gas water heaters from 2010 to 2013.
   - For instantaneous water heater shipments from 2010-2013, the only data source available was the ENERGY STAR shipment reports. The data in Table 3 therefore does not account for instantaneous water heater shipments that are not ENERGY STAR qualified. However, according to the AHRI product database, 381 out of 383 units available are ENERGY STAR qualified. This indicates that ENERGY STAR qualified instantaneous water heater shipments likely accounts for almost all instantaneous water heater shipments.

Clothes dryers only recently became an ENERGY STAR product, so we could not categorize this shipment data into efficiency groupings.

Year	Table 4—Gas Clothes Dryer Shipments (number of units) Categorized by Efficiency Level (EF) ≥2.67*
1993	1,156,000
1994	1,239,000
1995	1,169,000
1996	1,193,000
1997	1,195,000
1998	1,307,000
1999	1,444,000
2000	1,480,000
2001	1,384,000
2002	1,490,000
2003	1,616,000
2004	1,660,000
2005	1,707,000
2006	1,614,000
2007	1,530,000
2008	1,353,000
2009	1,283,200
2010	1,287,700
2011	1,221,100
2012	1,117,800

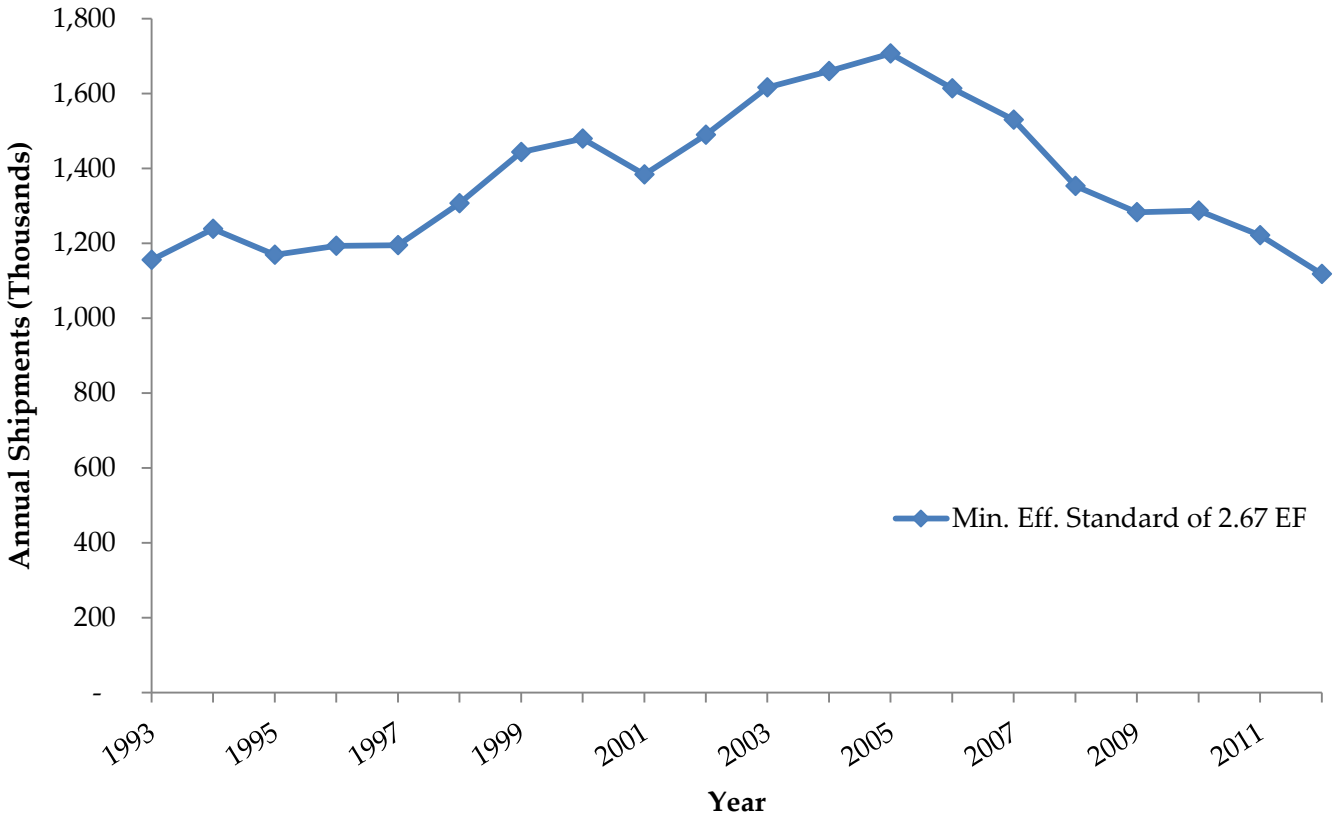
*According to data from the California Energy Commission Appliance Efficiency Database, almost all gas clothes dryer models have an EF between 2.7-2.89. There has also been few regulations driving energy efficiency improvements of clothes dryers from 1993-2012. Therefore, it is likely that most shipments have an EF between 2.7-2.89. A new minimum standard and a new ENERGY STAR specification is set to take effect in 2015, which should drive efficiency improvements in gas clothes dryers in the future.

	Table 5—Residential Gas Clothes Dryer Market Share (%) Categorized by EF **	
	2005	2006
2.67-2.74 EF	25	28
2.75-2.84 EF	42	44
>2.85 EF	32	27

**Data from 2011 Technical Support Document Residential Clothes Dryers and Room Air Conditioners, Appendix 5-b Table 5-b.3.2. Association of Home Appliance Manufacturers (AHAM) submitted these data.

Clothes dryers only recently became an ENERGY STAR product, so we could not categorize this shipment data into efficiency groupings.

Figure 8—Historical Shipments VS Time



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The efficiency level categorization was based on the applicable minimum efficiency standard.

Data Sources (also see References Section)

1. Standard Level Shipments
   - The DOE TSD has shipment data for total residential gas clothes dryers from 1993-2008.
   - Data from 2009-2012 is from the Appliance Magazine Statistical Reports.

The ENERGY STAR and DOE TSD data provided enough information to categorize 9 years of shipments by efficiency level.

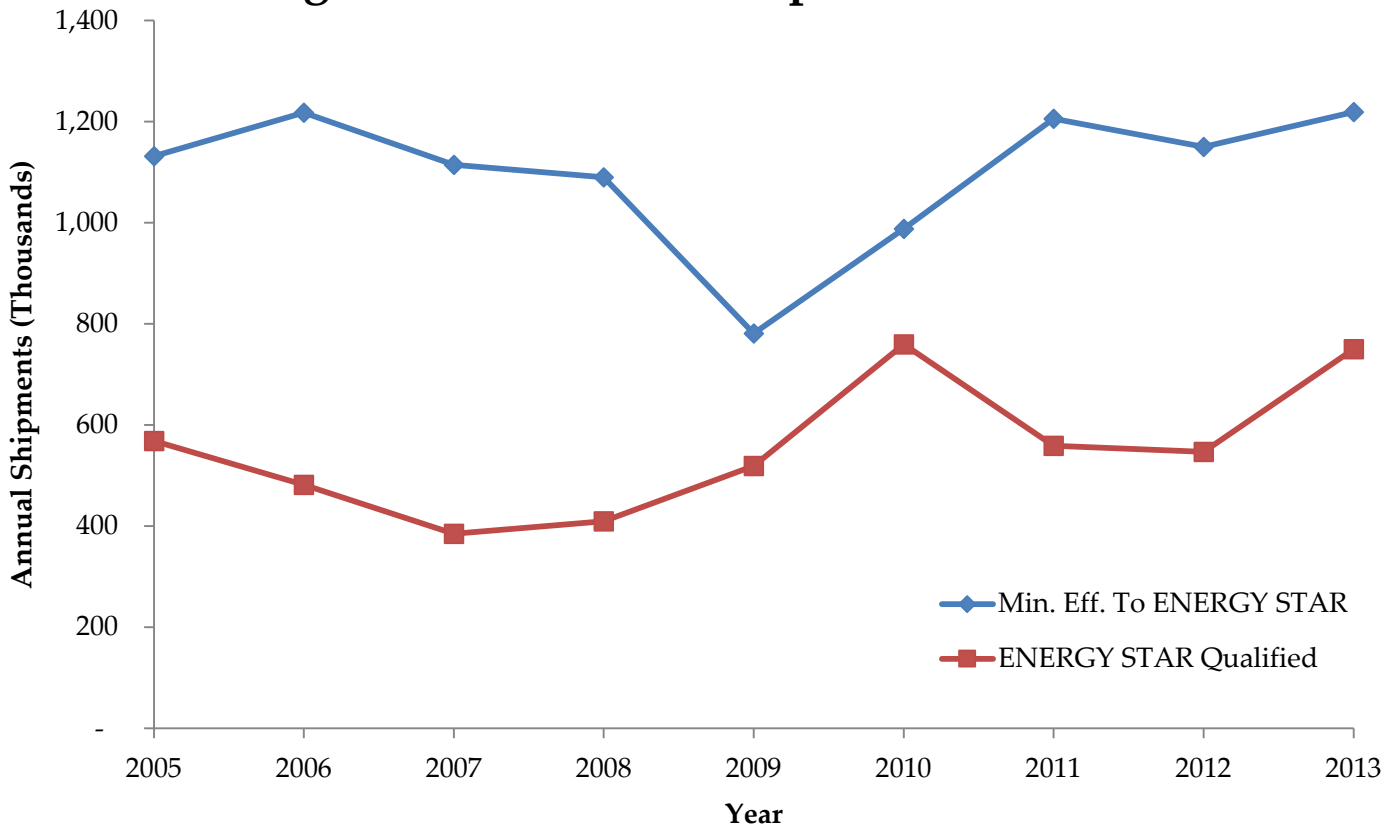
	Table 6—Air Source Heat Pump Shipments (number of units) Categorized by Efficiency Level (SEER/HSPF)						
Year	10/6.8-13/8	≥13/8	13/7.7-14/8.2	≥14/8.2	13/7.7-14.5/8.2	≥ 14.5/8.2 **	Total
1992*							600,000
1993							670,000
1994							770,000
1995							780,000
1996							870,000
1997							850,000
1998							950,000
1999							970,000
2000							1,000,000
2001							1,100,000
2002							1,100,000
2003							1,300,000
2004							1,500,000
2005	1,132,000	568,421					1,700,000
2006			1,218,000	481,895			1,700,000
2007			1,115,000	385,340			1,500,000
2008			1,090,000	410,065			1,500,000
2009					781,000	519,000	1,300,000
2010					988,000	760,000	1,400,000
2011					1,206,000	559,000	1,500,000
2012					1,150,000	547,000	1,400,000
2013					1,219,000	750,000	1,600,000

*Cannot categorize data from 1992-2004 by efficiency. All shipments from 1992-2004 have efficiencies greater than the minimum standard, Seasonal Energy Efficiency Ratio (SEER) 10 Heating Seasonal Performance Factor (HSPF) 6.8.

**Most of these shipments likely do not have a SEER greater than 17. According to the AHRI product database, approximately 90% of the units that are ENERGY STAR qualified (SEER 14.5 HSPF 8.2) have a SEER between 14.5 and 16.9. However, in recent years, manufacturers have introduced cold-climate heat pumps having 18 to 21 SEER (or higher) and 10 to 13 HSPF. Sales are probably 1% or 2% of the market, but are growing rapidly as a result of promotions in the northeast and northwest.

ENERGY STAR shipments are currently about 46 percent of residential ASHP shipments.

Figure 9—Historical Shipments VS Time



The ENERGY STAR specification and minimum standard changed during this date range. Therefore, the above chart includes data at multiple efficiencies.

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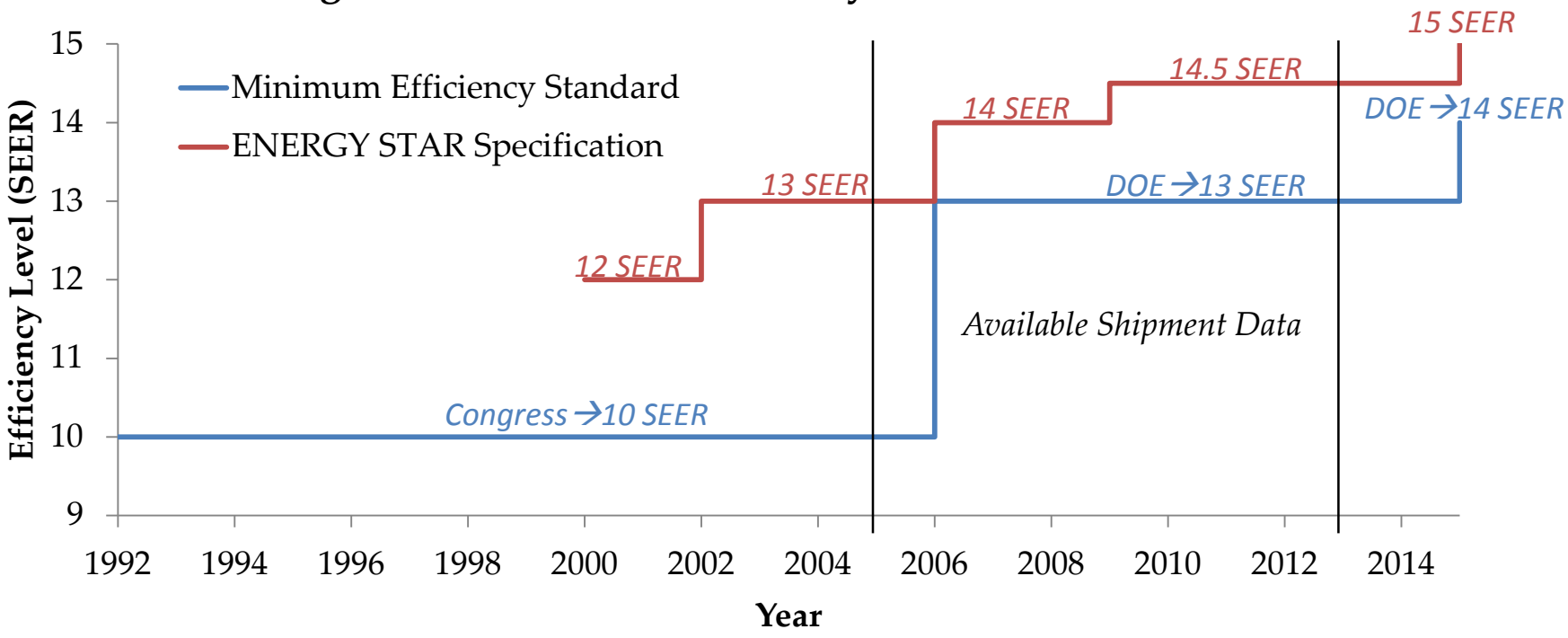
We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 10—Historical Efficiency Standards (SEER)



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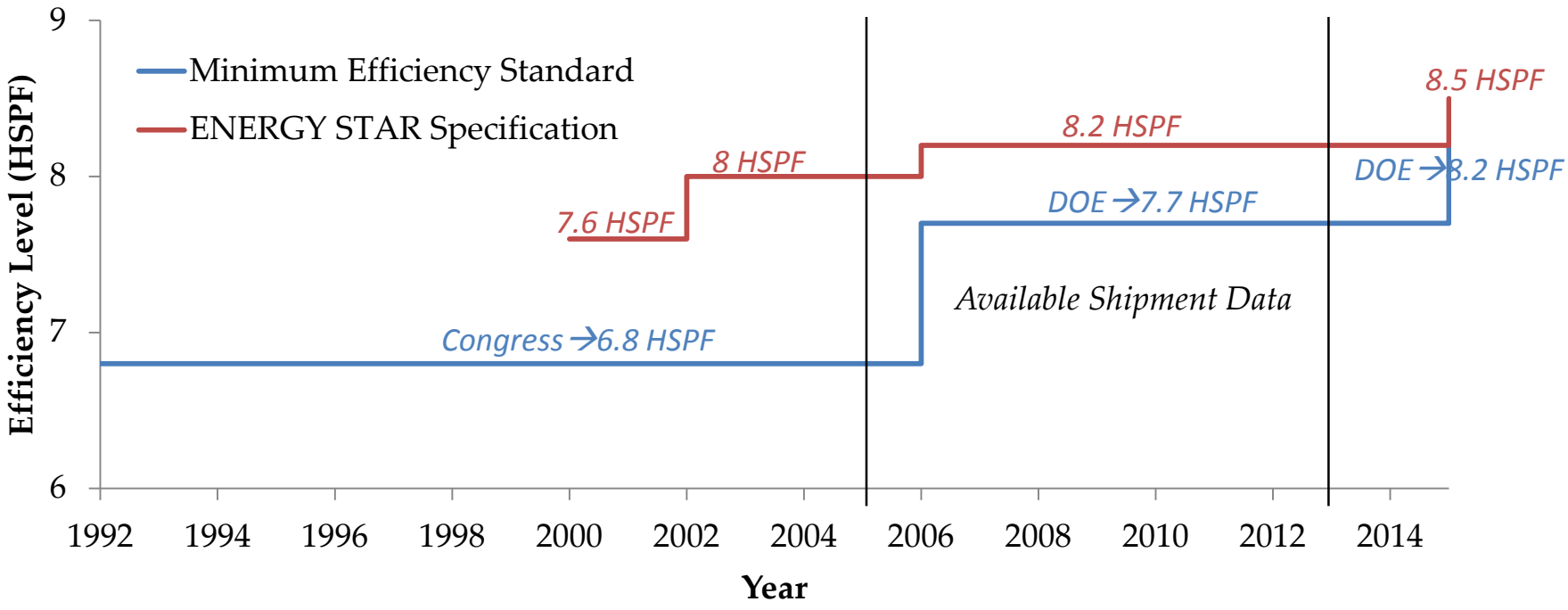
We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 11—Historical Efficiency Standards (HSPF)



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Key assumptions (also see References Section).

1. Standard level shipments
   - DOE TSD has shipment data from 1972-2009 broken out by split heat pumps and single package heat pumps. Because split heat pumps dominate the market, we only presented those numbers above.
   - AHRI maintains the data set as well, and extends to 2013, but does not disaggregate split system and single package.
     - Took the average over 1993-2009 and applied to the overall shipments to get number of split units.
2. ENERGY STAR Shipments
   - ENERGY STAR shipment data available from 2005-2013

The ENERGY STAR and DOE TSD data provided enough information to categorize 9 years of shipments by efficiency level.

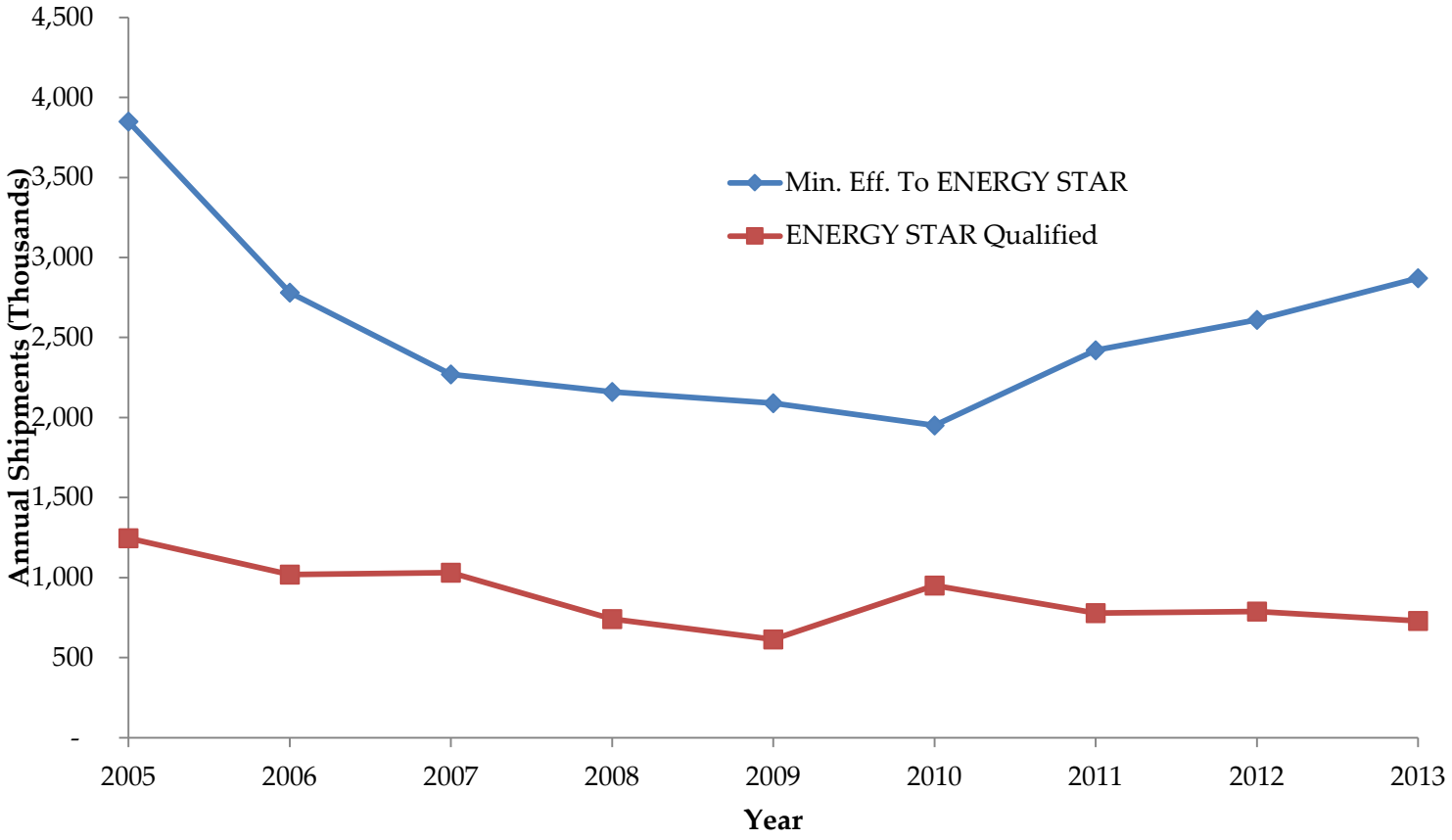
	Table 7—Central Air Conditioner (CAC) Shipments (number of units) Categorized by Efficiency Level (SEER)						
	10-12.5	≥13	13-13.5	≥14	13-14	≥14.5**	Total
1992*							2,100,000
1993							2,300,000
1994							2,900,000
1995							3,000,000
1996							3,400,000
1997							3,100,000
1998							3,700,000
1999							4,000,000
2000							4,000,000
2001							3,700,000
2002							4,100,000
2003							4,000,000
2004							4,200,000
2005	3,850,000	1,245,729					5,100,000
2006			2,780,000	1,018,552			3,800,000
2007			2,270,000	1,031,664			3,300,000
2008			2,160,000	740,228			2,900,000
2009					2,090,000	614,000	2,700,000
2010					1,950,000	950,000	2,900,000
2011					2,420,000	779,000	3,200,000
2012					2,610,000	788,000	3,400,000
2013					2,870,000	730,000	3,600,000

*Cannot categorize data from 1992-2004 by efficiency. All shipments from 1992-2004 have efficiencies greater than the minimum standard, SEER 10.

**Most of these shipments likely do not have a SEER greater than 17. According to the AHRI product database, approximately 90% of the units that are ENERGY STAR qualified (SEER 14.5) have a SEER between 14.5 and 16.9. The highest efficiency unit available today is a SEER 26.

Shipments of ENERGY STAR CACs have fallen since 2010 to about 20 percent of the market, possibly in response to increased ENERGY STAR requirements.

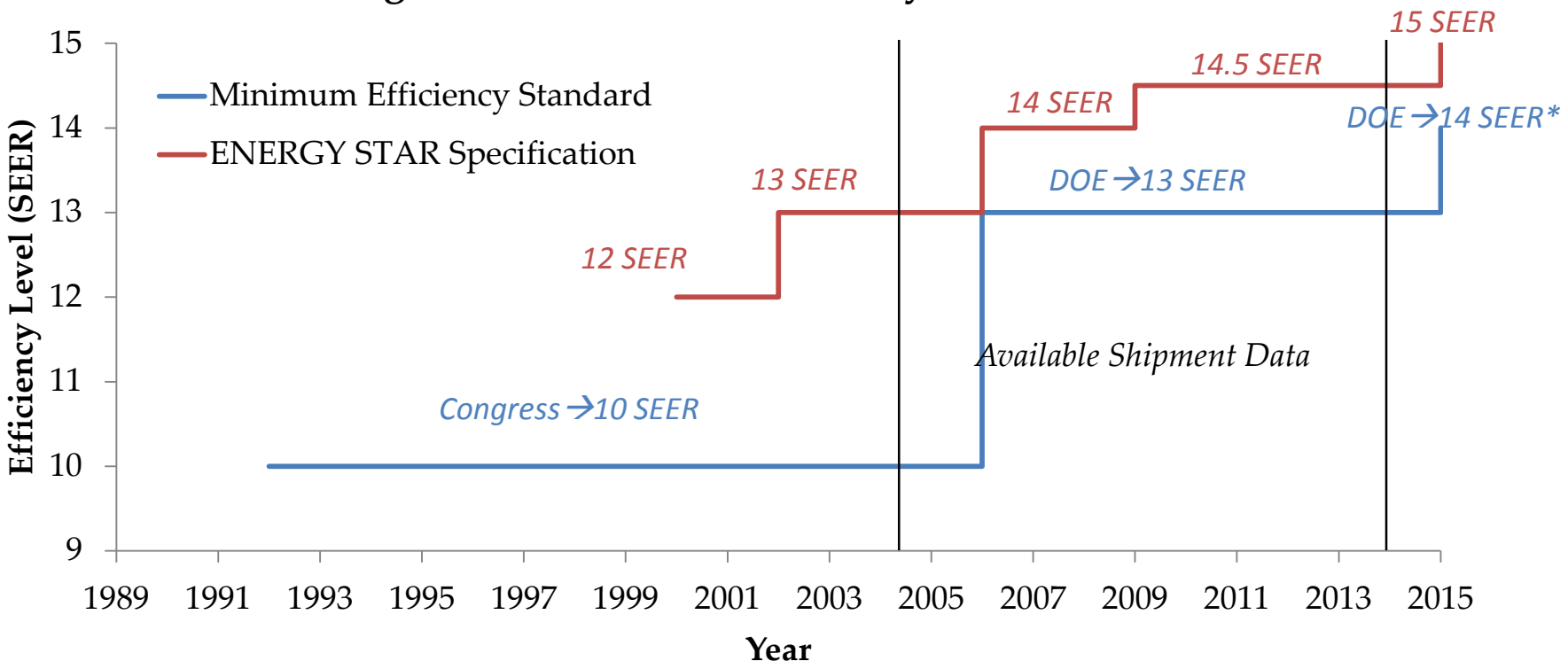
Figure 12—Historical Shipments VS Time



The ENERGY STAR specification and minimum standard changed during this date range. Therefore, the above chart includes data at multiple efficiencies.

We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 13—Historical Efficiency Standards



*The minimum efficiency standard effective January 1, 2015 is a regional standard. The SEER 14 standard applies to the following states: Alabama, Arkansas, Delaware, Florida, Georgia, Hawaii, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and Washington DC. For all other states, the standard is SEER 13.

NAVIGANT ENERGY

Key assumptions about the data (also see References Section).

1. Standard level shipments
   - DOE TSD has shipment data from 1972-2009 broken out by split air conditioners and single package air conditioners. Because split air conditioners dominate the market, we only presented those numbers above.
   - AHRI maintains the data set as well, and extends to 2013, but does not disaggregate split package and single package.
     - Took the average over 1993-2009 and applied to the overall shipments to get number of split units.
2. ENERGY STAR Shipments
   - ENERGY STAR shipment data available from 2005-2013

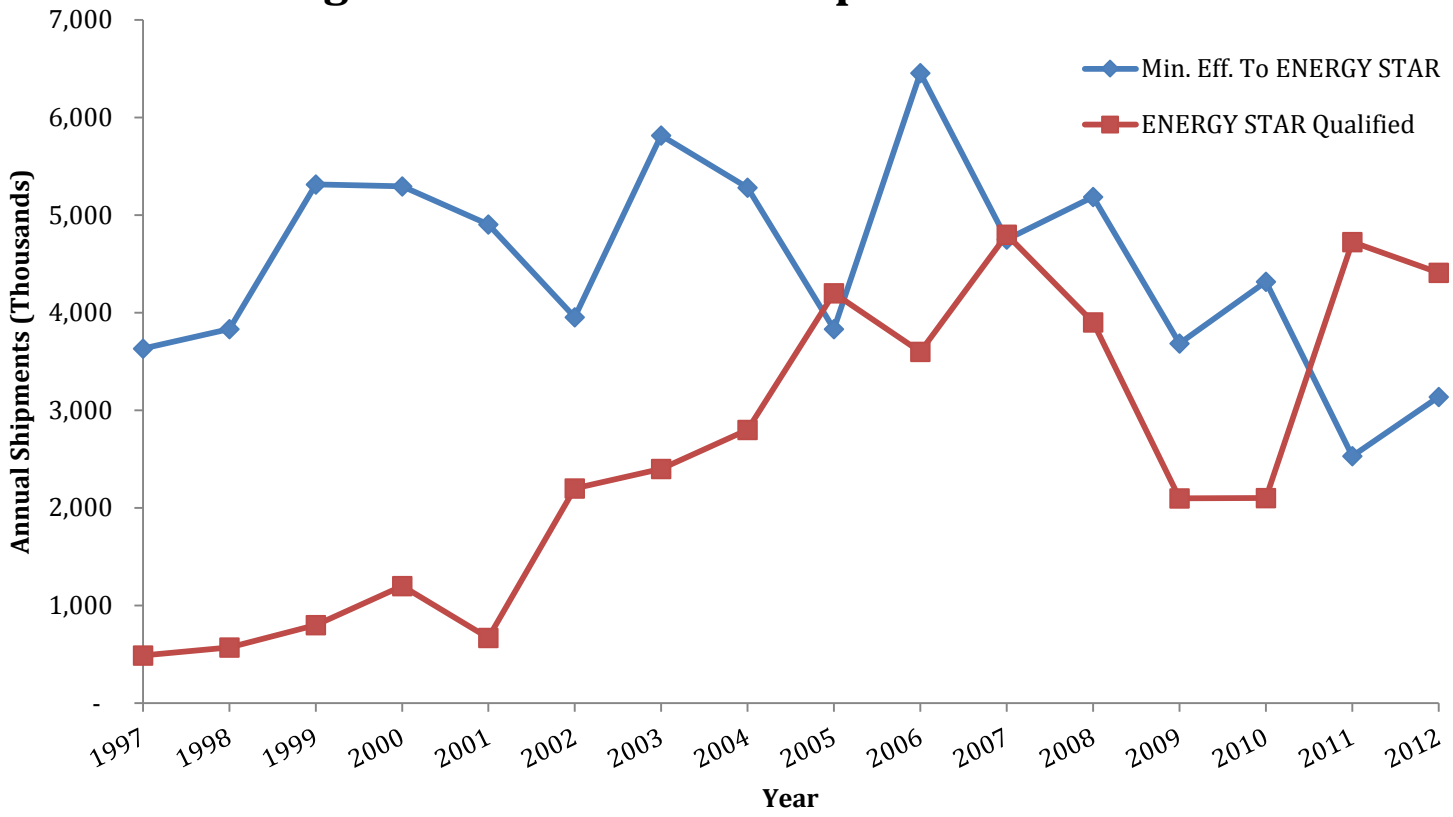
The ENERGY STAR and DOE TSD data provided enough information to categorize 16 years of shipments by efficiency level.

	Room Air Conditioner Shipments (number of units) Categorized by Efficiency Level (EER)				
	9-10.35	>10.35	9.8-10.7	≥10.8	Total
1997	3,633,000	490,000			4,123,000
1998	3,833,000	570,000			4,403,000
1999	5,314,000	800,000			6,114,000
2000			5,296,000	1,200,000	6,496,000
2001			4,905,000	670,000	5,575,000
2002			3,953,000	2,200,000	6,153,000
2003			5,816,000	2,400,000	8,216,000
2004			5,282,000	2,800,000	8,082,000
2005			3,832,000	4,200,000	8,032,000
2006			6,455,000	3,600,000	10,055,000
2007			4,750,000	4,800,000	9,550,000
2008			5,185,500	3,900,000	9,085,500
2009			3,685,600	2,100,000	5,785,600
2010			4,317,400	2,101,000	6,418,400
2011			2,532,400	4,724,000	7,256,400
2012			3,136,800	4,411,000	7,547,800

*Efficiency levels are for room air conditioners without a reverse cycle, with louvered sides, and at a capacity range of 8,000-13,999 BTU/hr. The standard and ENERGY STAR specifications change with different capacity ranges, and whether or not the unit has a reverse cycle or contains louvered sides.

ENERGY STAR shipments of Room Air Conditioners have gained market share, reaching 58 percent of the market in 2012.

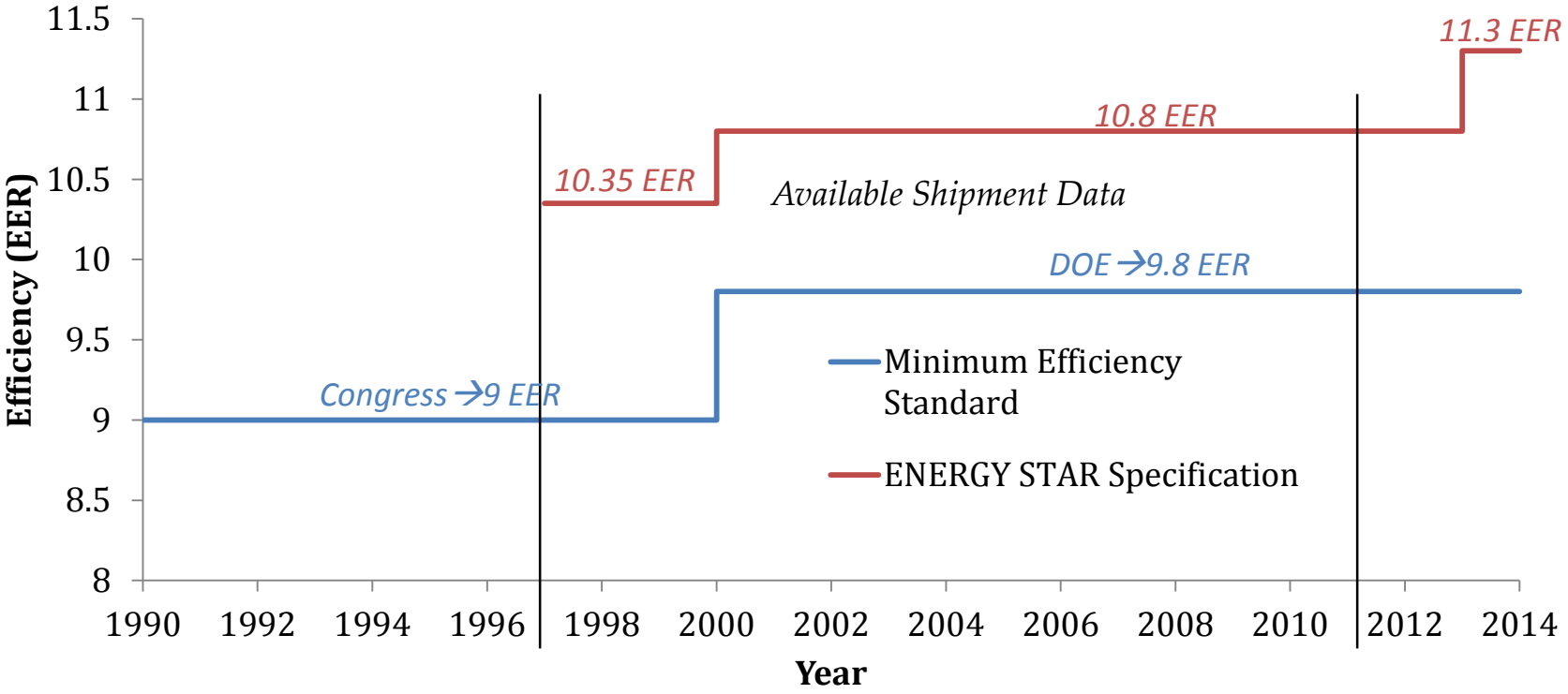
Figure 14—Historical Shipments VS Time



The minimum standard changed during this date range. Therefore, the above chart includes data at multiple efficiencies.

We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 15—Historical Efficiency Standards



Efficiency levels are for room air conditioners without a reverse cycle, with louvered sides, and at a capacity range of 8,000-13,999 BTU/hr. The standard and ENERGY STAR specifications change with different capacity ranges, and whether the unit has a reverse cycle or contains louvered sides.

In June 1, 2014, a new standard is set to take effect with a new efficiency metric, Combined Energy Efficiency Ratio (CEER), which takes into account off-mode and standby-mode energy consumption (EERE 2011). The new standard will be 10.9 CEER for units without a reverse cycle, with louvered sides, and a capacity between 8000-13000 Btu/hr (EERE 2011).

NAVIGANT ENERGY

Key assumptions about the data (also see References Section).

1. Standard level shipments
   - Data from 1997-2006 is submitted by AHAM to DOE
   - Data from 2007-2012 is from Appliance Magazine Statistical Reports
   - Assumed that efficiency levels were for non-reverse cycle louvered sides units, as they account for approximately 90% of the market according to DOE TSD

2. ENERGY STAR Shipments
   - For 1997-2009, DOE estimated market share of ENERGY STAR qualified room air conditioners
     - Multiplied this fraction by total shipments to get ENERGY STAR qualified units
   - For 2010-2012 EPA collected shipment data for qualified room air conditioners and presented in their annual shipment reports.

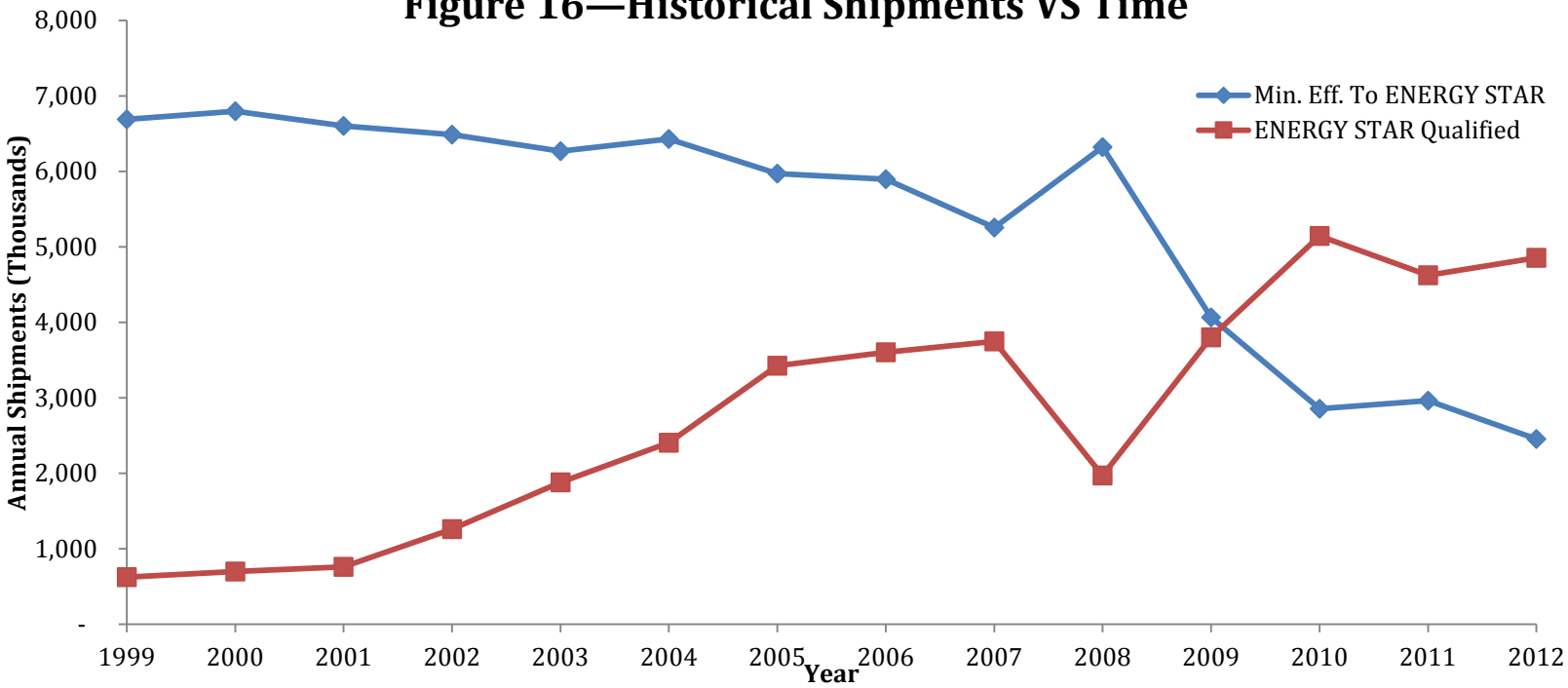
The ENERGY STAR and DOE TSD data provided enough information to categorize 14 years of shipments by efficiency level.

	Table 9—Clothes Washer Shipments (number of units) Categorized by Efficiency Level (Modified Energy Factor—MEF)**												
Year	1.18 EF*-2.5 EF	>2.5 EF	1.18 EF-1.25	≥1.26	1.04-1.41	≥1.42	1.26-1.71	≥1.72	1.26-1.79	≥1.8	1.26-1.99	≥2	Total
1994***													6,161,000
1995													6,080,000
1996													6,225,000
1997													6,326,000
1998													6,835,000
1999	6,691,000	622,000											7,313,000
2000	6,798,000	697,000											7,495,000
2001			6,604,500	757,500									7,362,000
2002			6,485,000	1,260,000									7,745,000
2003			6,267,000	1,879,000									8,146,000
2004					6,427,000	2,405,000							8,832,000
2005					5,970,000	3,424,000							9,394,000
2006					5,897,000	3,603,000							9,500,000
2007							5,255,000	3,747,000					9,002,000
2008							6,322,000	1,970,000					8,292,000
2009									4,065,000	3,800,000			7,865,000
2010									2,855,000	5,144,000			7,999,000
2011											2,960,800	4,625,000	7,585,800
2012											2,452,500	4,856,000	7,308,500

*The minimum efficiency standard was in Energy Factor until 2004.
**All efficiency levels are for standard sized top loading units.
***Cannot categorize data from 1994-1998 by efficiency. All shipments from 1994-1998 have efficiencies greater than the minimum standard, EF 1.18.

Despite increasing efficiency requirements, ENERGY STAR shipments of clothes washers reached 66 percent of the market in 2012.

Figure 16—Historical Shipments VS Time

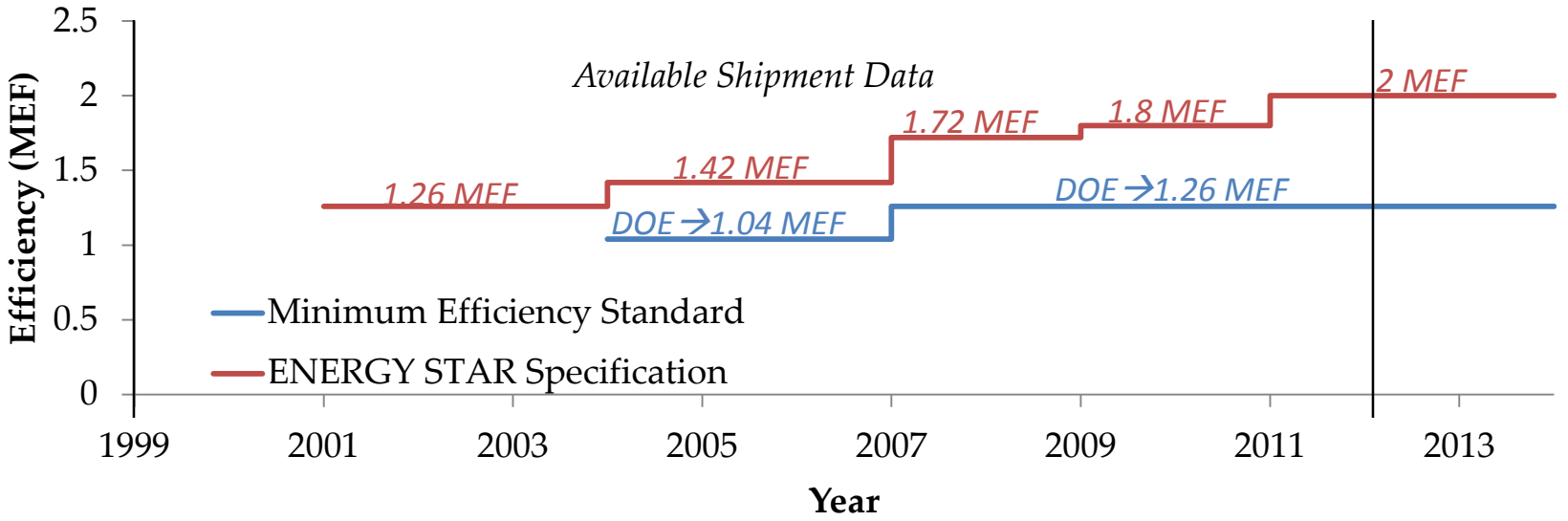


The ENERGY STAR specification and minimum standard changed during this date range. Therefore, the above chart includes data at multiple efficiencies.

Although the efficiency levels presented are for top-loading clothes washers, it is important to note the shift in the market that has occurred over this time frame towards greater penetration of front loading units, which are inherently more efficient. From 1994-1997, top-loading units at the minimum efficiency level (EF 1.18) dominated the market. In 1997, front loading units entered the market at efficiency levels between MEF 1.42-1.72, but only comprised a small fraction of shipments (Navigant). All of these units qualified for ENERGY STAR. By 2006, front-loading units comprised 30% of sales, with all units qualifying for ENERGY STAR (EERE 2012). At this time, top-loading units were still predominantly at the minimum efficiency standard, but 5% of top-loading clothes washers were ENERGY STAR qualified (EERE 2012). From 2006-2012, front-loading clothes washers continued to increase in efficiency keeping pace with ENERGY STAR, and sales percentage has increased to approximately 50% (EERE 2012 and Navigant). Top-loading clothes washers continue to dominate the lower end efficiencies in the market, but a greater percentage of top-loading sales qualify for ENERGY STAR.

We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 17—Historical Efficiency Standards



The minimum efficiency standard metric changed in 2004 from Energy Factor (EF) to Modified Energy Factor (MEF) to reflect a new test procedure. The MEF efficiency metric includes energy consumption associated with operating the clothes washer, the energy to heat the water used for washing, and the necessary energy required to dry the clothes after washing. EF, however, did not include the energy consumption associated with clothes drying (D&R 2008).

From 1994- 2004, the minimum efficiency standard was 1.18 EF, as mandated by congressional act (EERE 2012). The ENERGY STAR specification from 1997 to 2001 was 2.5 EF (ENERGY STAR). In 2001, the ENERGY STAR specification was defined with a MEF of 1.26, and in 2004 the minimum standard converted to a MEF of 1.04 (EERE 2012).

In the future, minimum efficiency standards and ENERGY STAR Specifications will use a new energy efficiency metric, Integrated Modified Energy Factor (IMEF). The new test procedure for calculating an IMEF takes into account energy consumption associated with standby mode and off mode in addition to the energy consumption considered for calculating an MEF (EERE 2012).

Key assumptions about the data (also see References Section).

1. Standard level shipments
   - Data from 1992-2005 is submitted by AHAM to DOE in TSD
   - Data from 2006-2010 is from Appliance Magazine Statistical Reports in TSD
   - 2011 and 2012 from Appliance Magazine Statistical Reports, but not in the TSD
2. ENERGY STAR Shipments
   - For 1999-2009, DOE estimated market share of ENERGY STAR qualified clothes washers
     - Multiplied this fraction by total shipments to get ENERGY STAR qualified units
   - For 2010-2012 EPA collected shipment data for qualified clothes washers and presented in their annual shipment reports.
   - In addition, cannot find the specification set in 2000 or earlier, so assumed 1.26 MEF

The ENERGY STAR and DOE TSD data provided enough information to categorize 13years of shipments by efficiency level.

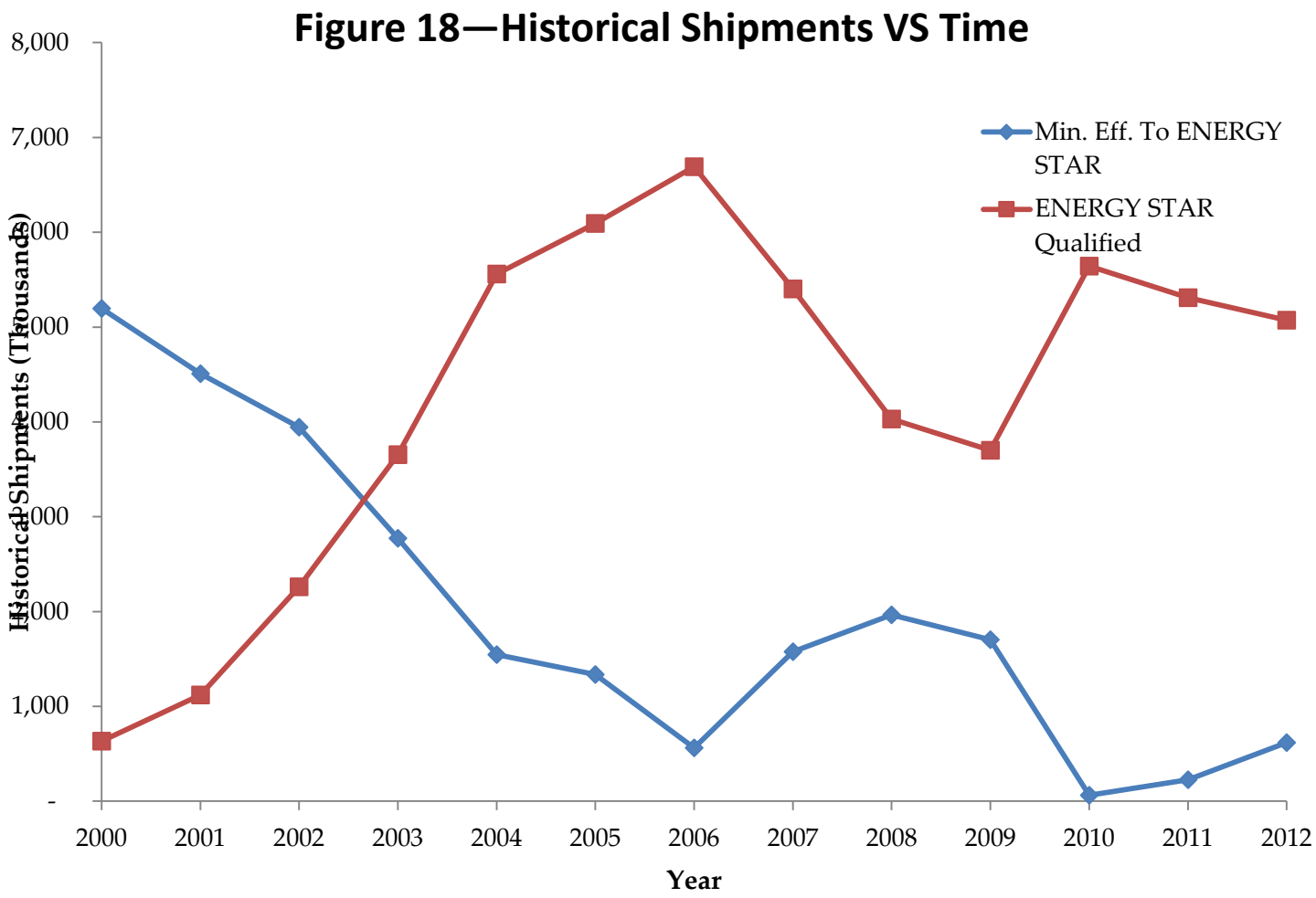
	Table 10—Dishwasher Shipments (number of units) Categorized by Efficiency Level of Maximum Annual Energy Usage**										
	Energy Factor (EF)				Annual Energy Usage (kWh/yr)						Total
Year	.46-.57	≥.58	.46-.64	≥.65	355-325	≤324	355-308	≤307	355-296	≤295	
1995*											4,346,000
1996											4,606,000
1997											4,826,000
1998											5,144,000
1999											5,712,000
2000	5,194,800	632,200									5,827,000
2001	4,508,000	1,119,000									5,627,000
2002	3,945,000	2,262,000									6,207,000
2003	2,772,000	3,656,000									6,428,000
2004	1,546,000	5,560,000									7,106,000
2005	1,336,000	6,092,000									7,428,000
2006	561,000	6,691,000									7,252,000
2007			1,576,000	5,401,000							6,977,000
2008			1,965,000	4,030,000							5,995,000
2009					1,704,000	3,700,000					5,404,000
2010					64,000	5,644,000					5,708,000
2011							226,000	5,309,000			5,535,000
2012									616,500	5,072,000	5,688,500

*Cannot categorize data from 1995-1999 by efficiency. All shipments from 1995-1999 have efficiencies greater than the minimum standard, EF .46.

**Shipments that are not ENERGY STAR qualified are likely right at the minimum efficiency standard. According to the DOE CCMS database, most units that do not qualify for ENERGY STAR are at the minimum standard. Units that are ENERGY STAR qualified can have annual energy usages that are much less than the ENERGY STAR specification. According to the CCMS database, approximately 66% of available units today have an Annual Energy Usage (kWh/yr) between 285-255 kWh/yr.

The EF and Annual Energy Usage values are representative of standard sized units.

ENERGY STAR dishwashers have dominated the market for several years.

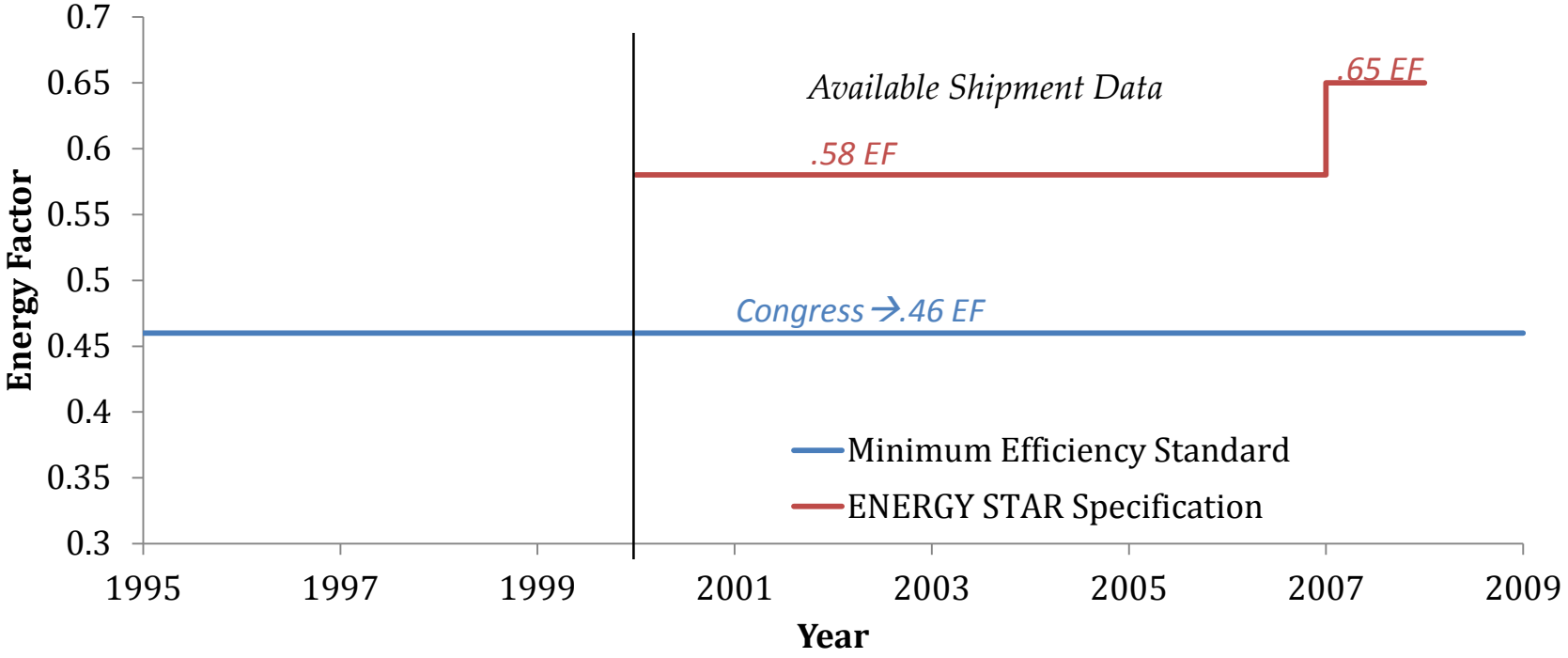


The ENERGY STAR specification and minimum standard changed during this date range. Therefore, the above chart includes data at multiple efficiencies.

NAVIGANT ENERGY

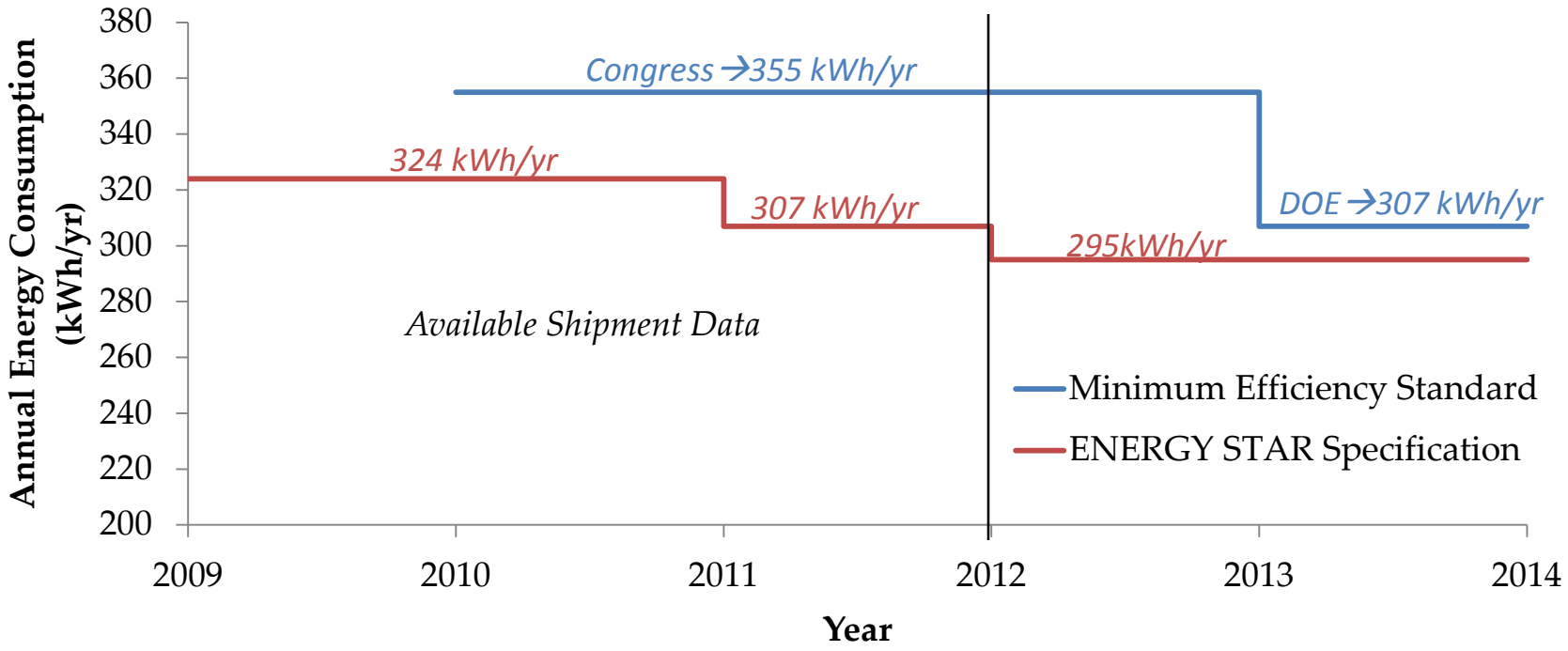
We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 19—Historical Efficiency Standards



We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 20—Historical Efficiency Standards



In 2009, new minimum standards and ENERGY STAR specifications were set using maximum annual energy consumption (kWh/yr) instead of EF. The standards above are for standard sized units.

NAVIGANT ENERGY

Key assumptions about the data (also see References Section).

1. Standard level shipments
   - Data from 1992-2005 is submitted by AHAM to DOE in TSD
   - Data from 2006-2010 is from Appliance Magazine Statistical Reports in TSD
   - 2011 and 2012 from Appliance Magazine Statistical Reports, but not in the TSD
2. ENERGY STAR Shipments
   - For 2000-2009, DOE estimated market share of ENERGY STAR qualified dishwashers
     - Multiplied this fraction by total shipments to get ENERGY STAR qualified units
   - For 2010-2012 EPA collected shipment data for qualified dishwashers and presented in their annual shipment reports.

The ENERGY STAR and DOE TSD data provided enough information to categorize 15 years of shipments by efficiency level.

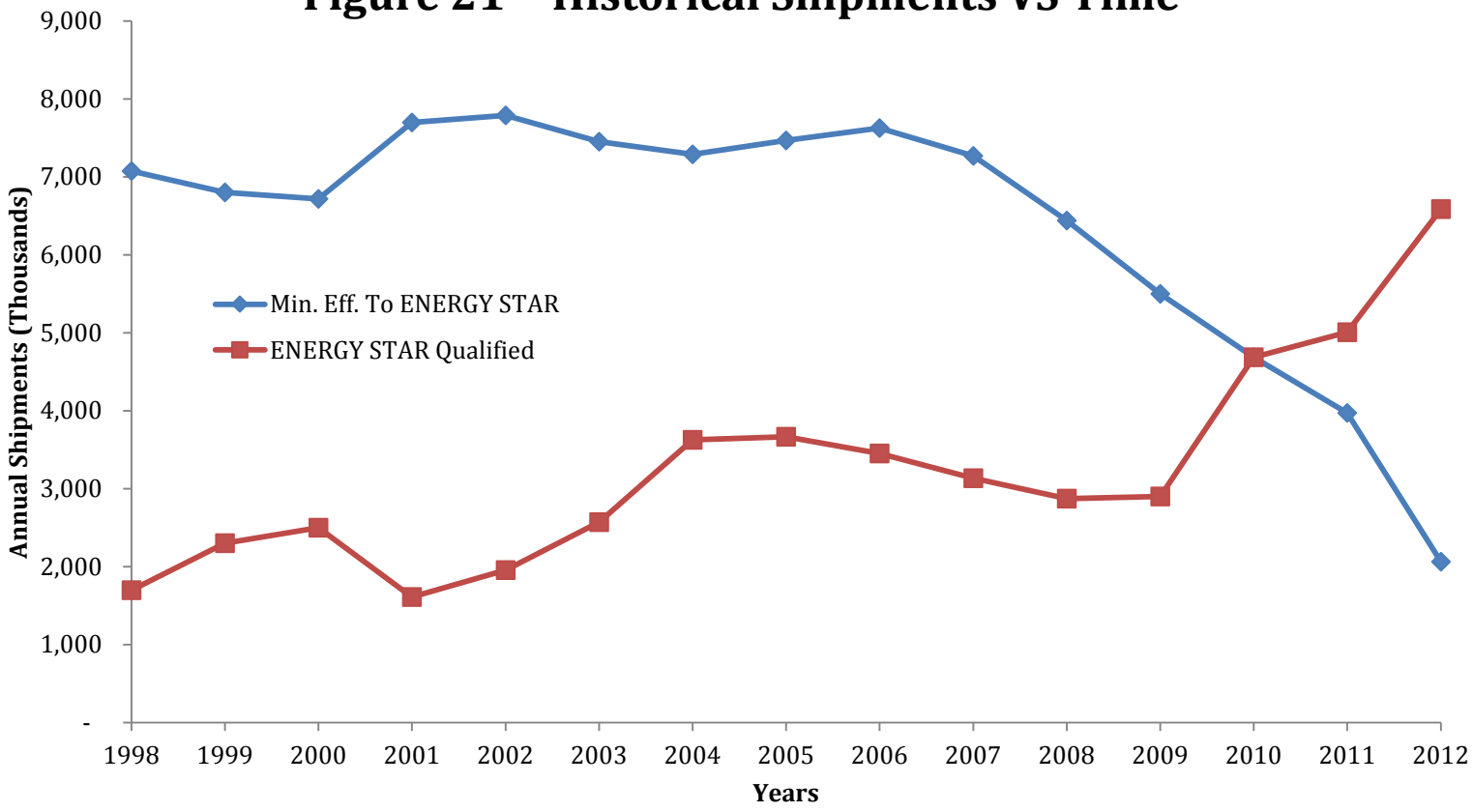
	Table 11—Refrigerator Shipments (number of units) Categorized by Maximum Annual Energy Use (kWh/yr)*								
Year	713-643	≤642	528-477	≤476	528-450	≤449	528-423	≤422	Total
1998	7,074,000	1,700,000							8,774,000
1999	6,799,000	2,300,000							9,099,000
2000	6,717,000	2,500,000							9,217,000
2001			7,695,000	1,610,000					9,305,000
2002			7,788,000	1,956,000					9,744,000
2003			7,451,000	2,570,000					10,021,000
2004					7,288,000	3,625,000			10,913,000
2005					7,468,000	3,667,000			11,135,000
2006					7,625,000	3,452,000			11,077,000
2007					7,269,000	3,133,000			10,402,000
2008							6,437,600	2,872,000	9,309,600
2009							5,497,400	2,900,000	8,397,400
2010							4,684,900	4,684,000	9,368,900
2011							3,972,700	5,008,000	8,980,700
2012							2,062,600	6,585,000	8,647,600

*According to the DOE Compliance Certification Management System (CCMS) database, refrigerators available today are predominantly just at the minimum efficiency standard, and just at the ENERGY STAR specification. For units that are not ENERGY STAR qualified, there are almost no available that are much more efficient than the standard. For units that are ENERGY STAR qualified, there are only a handful that are significantly more efficient than the ENERGY STAR specification. From this, we can assume that shipments over time have likely tracked the minimum efficiency standard and the ENERGY STAR specification.

The maximum annual energy consumption values are a weighted average of refrigerators with side-mount, bottom-mount, and top-mount freezers according to market share (EERE 2011).

From 2010 to 2012, ENERGY STAR refrigerator shipments rapidly gained market share, reaching 76 percent of the market in 2012.

Figure 21—Historical Shipments VS Time



The ENERGY STAR specification and minimum standard changed during this date range. Therefore, the above chart includes data at multiple efficiencies.

We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 22—Historical Efficiency Standards

The maximum annual energy consumption values are a weighted average of refrigerators with side-mount, bottom-mount, and top-mount freezers according to market share (EERE 2011). Typical volumes for each type of refrigerator were used in the calculations for annual energy consumption according to the EIA 2013 Technology Forecast.

Key assumptions about the data (also see References Section).

1. Standard level shipments
   - Data from 1995-2005 from AHAM 2005 Factbook
   - Data from 2006-2010 is from Appliance Magazine Statistical Reports
   - 2011 and 2012 from Appliance Magazine Statistical Reports
2. ENERGY STAR Shipments
   - For 1999-2009, DOE estimated market share of ENERGY STAR qualified refrigerators
     - Multiplied this fraction by total shipments to get ENERGY STAR qualified units
   - For 2010-2012 EPA collected shipment data for qualified refrigerators and presented in their annual shipment reports
   - In addition, cannot find the specification set in 1998, 1999, or 2000, so assumed same as specification in 2001

The ENERGY STAR and DOE TSD data provided enough information to categorize only 3 years of shipments by efficiency level.

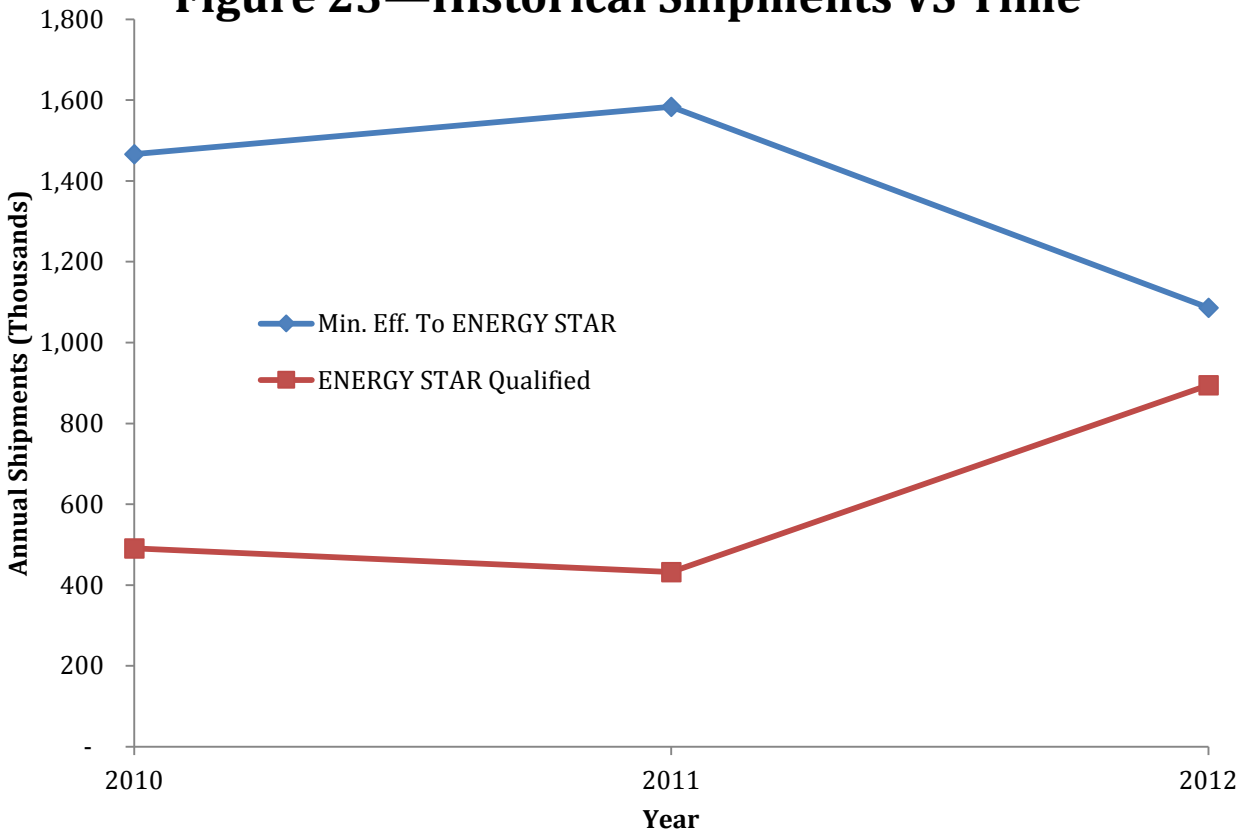
	Table 12—Freezer Shipments (number of units) Categorized by Maximum Annual Energy Use (kWh/yr)**		
	402-323	≤362	Total
1995*			1,558,000
1996			1,548,000
1997			1,490,000
1998			1,627,000
1999			1,987,000
2000			1,963,000
2001			2,215,000
2002			2,535,000
2003			2,523,000
2004			2,516,000
2005			2,226,000
2006			2,147,700
2007			1,992,100
2008			2,098,600
2009			2,043,300
2010	1,466,600	491,000	1,957,600
2011	1,583,700	432,000	2,015,700
2012	1,086,300	895,000	1,981,300
2013		542,000	-

*ENERGY STAR qualified shipments available in 2013, but not total freezer shipments

**According to the DOE CCMS database, freezers available today are predominantly just at the minimum efficiency standard, and just at the ENERGY STAR specification. For units that are not ENERGY STAR qualified, there are almost no available that are much more efficient than the standard. For units that are ENERGY STAR qualified, there are only a handful that are significantly more efficient than the ENERGY STAR specification. From this, we can assume that shipments over time have likely tracked the minimum efficiency standard and the ENERGY STAR specification.
The Maximum annual energy consumption values are a weighted average of chest and upright freezers according to relative fractions of shipments (Appliance Magazine 2013).

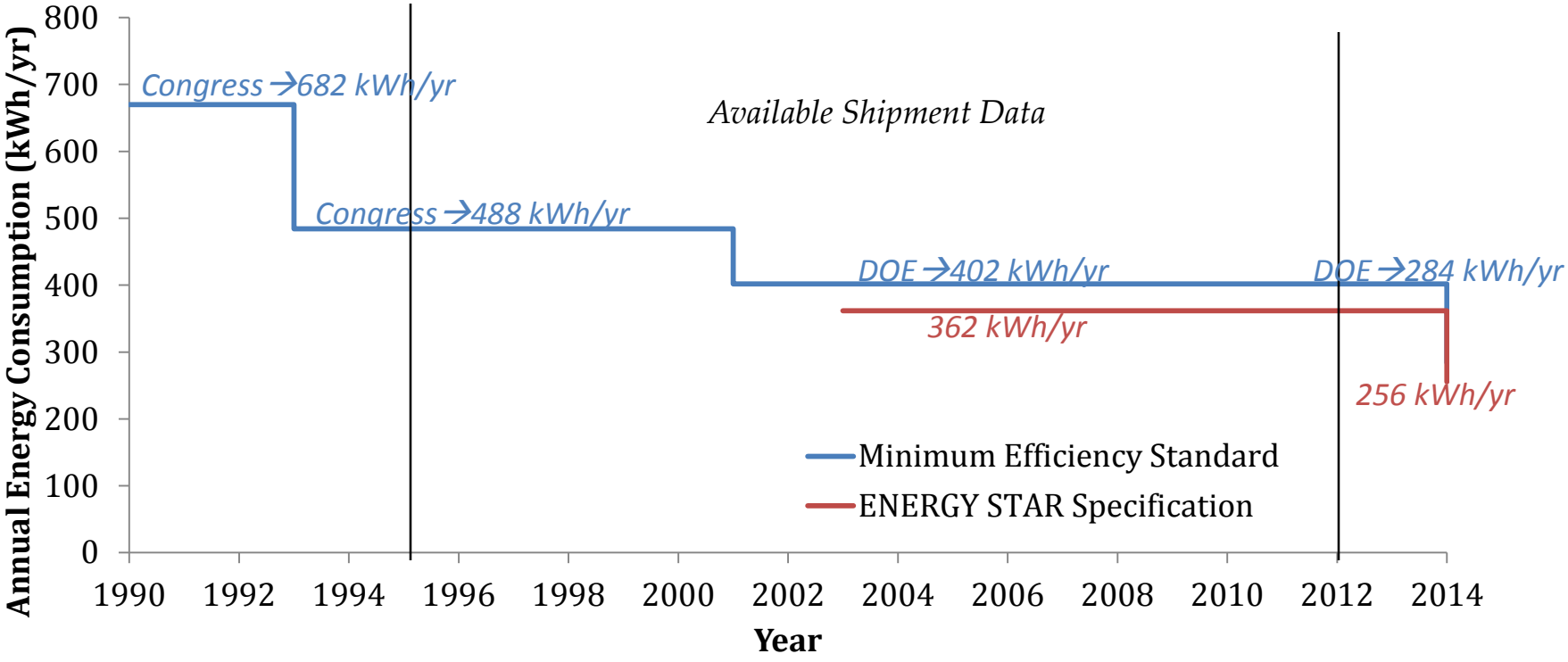
ENERGY STAR shipments of freezers reached 45 percent of the market in 2012.

Figure 23—Historical Shipments VS Time



We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 24—Historical Efficiency Standards



The Maximum annual energy consumption values are a weighted average of chest and upright freezers according to relative fractions of shipments (Appliance Magazine 2013). Typical volumes for each type of freezer were used in the calculations for annual energy consumption according to the EIA 2013 Technology Forecast.

NAVIGANT ENERGY

Key assumptions about the data (also see References Section).

1. Standard level shipments
   - Data from 1995-1996 from DOE Refrigerators and Freezers TSD
   - Data from 1997-2012 is from Appliance Magazine Statistical Reports
2. ENERGY STAR Shipments
   - For 2010-2012 EPA collected shipment data for qualified freezers and presented in their annual shipment reports.

Available data do not provide a breakdown by efficiency level for electric water heaters.

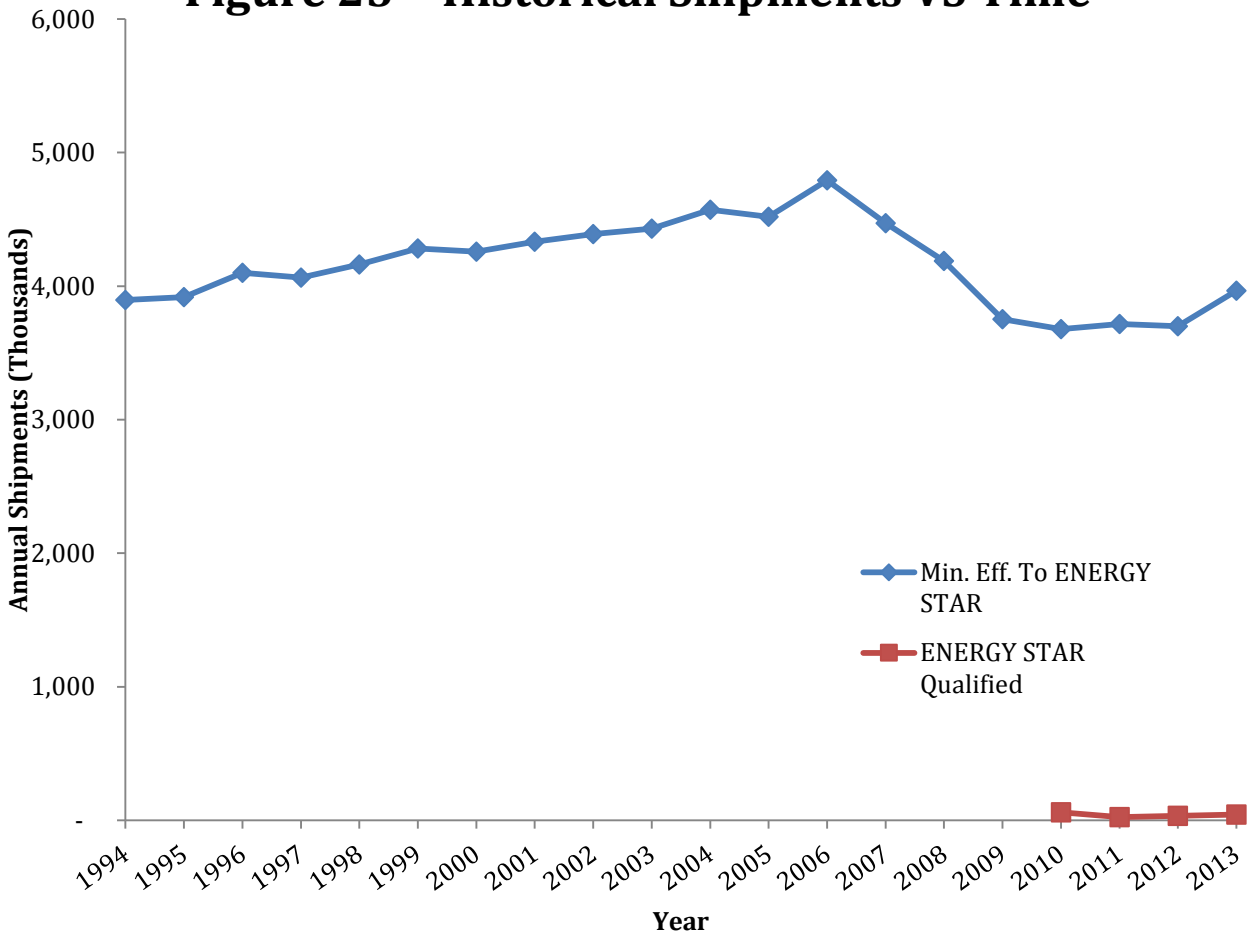
	Table 13—Electric Water Heater Shipments (number of units) Categorized by Efficiency Level (EF)			
Year	.864-.99*	.904-.99*	≥2 **	Total
1994	3,896,839			3,896,839
1995	3,916,993			3,916,993
1996	4,100,665			4,100,665
1997	4,062,975			4,062,975
1998	4,162,654			4,162,654
1999	4,281,199			4,281,199
2000	4,257,433			4,257,433
2001	4,333,170			4,333,170
2002	4,390,495			4,390,495
2003	4,429,880			4,429,880
2004		4,572,932		4,572,932
2005		4,518,598		4,518,598
2006		4,791,640		4,791,640
2007		4,470,232		4,470,232
2008		4,189,451		4,189,451
2009		3,751,994		3,751,994
2010		3,677,597	59,000	3,736,597
2011		3,715,882	23,000	3,738,882
2012		3,699,988	34,000	3,733,988
2013		3,965,478	43,000	4,008,478

*Assumed the upper bound for EF is 0.99 because this is the technical limit of an electric resistance water heater.

** Heat pump water heaters (HPWHs) are required for EFs greater than 1. HPWHs did not obtain significant market penetration until introduction of the ENERGY STAR specification. HPWHs were introduced to the US market in the 1980's. Sales grew to 8,000 to 10,000 units/year, but then declined to perhaps 2,000 to 3,000 units/year when the major manufacturers left the market (due to low consumer demand and high warranty costs).

Heat Pump Water Heaters have only achieved about 1% market penetration according to ENERGY STAR data.

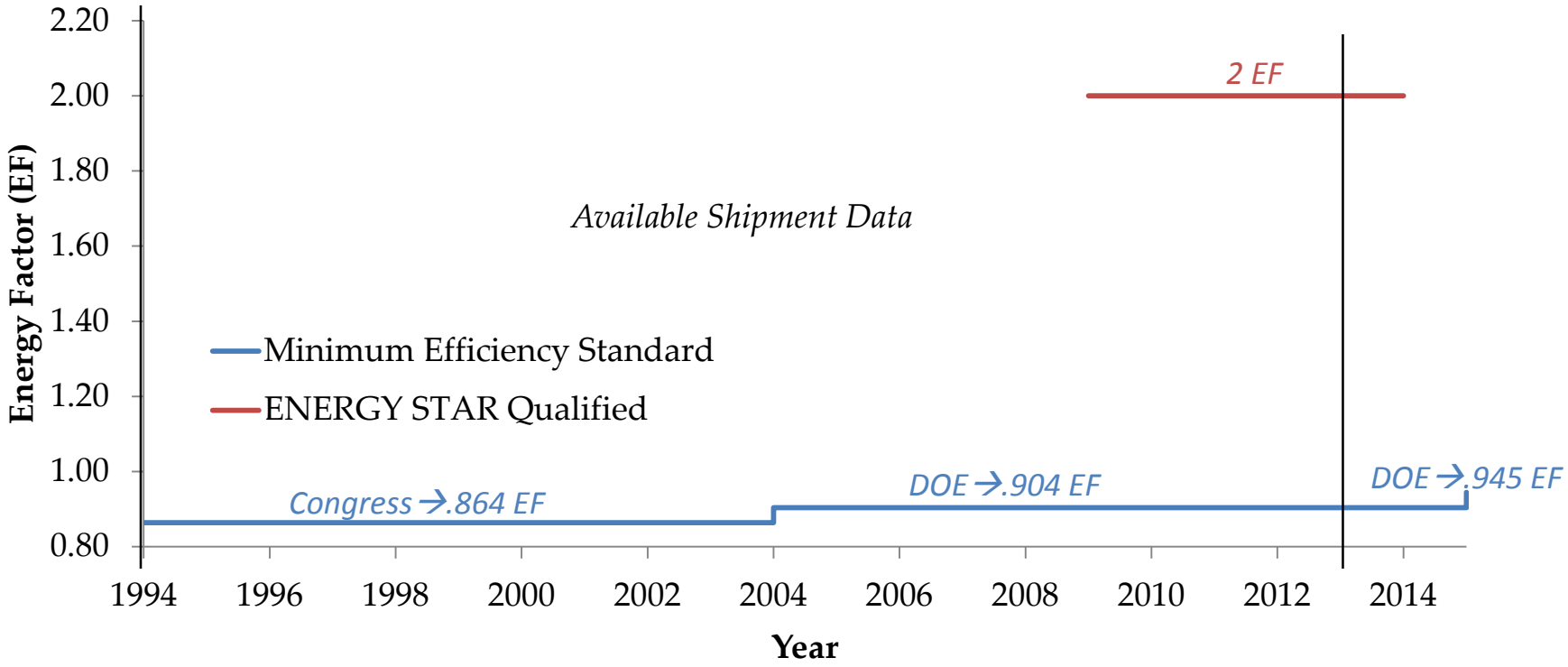
Figure 25—Historical Shipments VS Time



NAVIGANT ENERGY

We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 26—Historical Efficiency Standards



EF shown is for a water heater size of 50 gallons (minimum efficiency standard is a function of volume).

Key assumptions about the data (also see References Section).

1. Standard level shipments
   - Data from AHRI's website.
2. ENERGY STAR Shipments
   - Shipments of heat pump water heaters available from 2010-2013.

Clothes dryers only recently became an ENERGY STAR product, so we could not categorize this shipment data by efficiency.

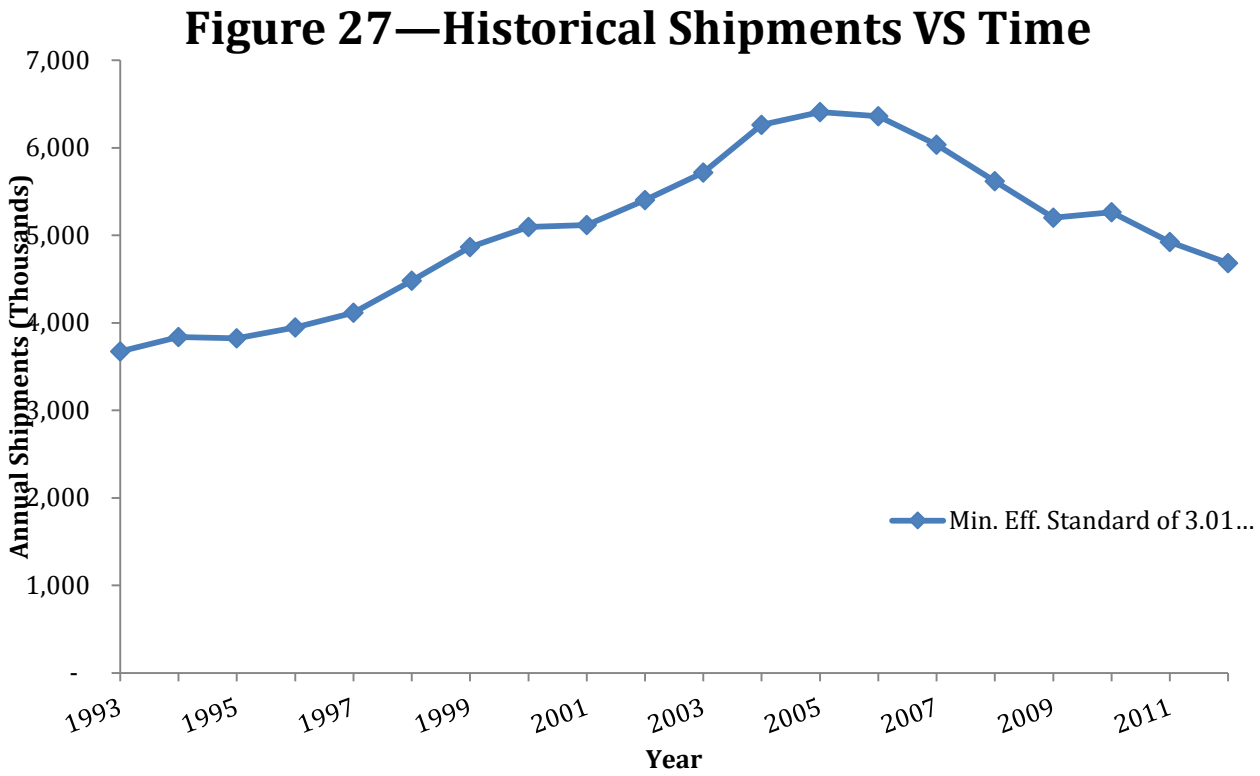
	Table 14—Electric Clothes Dryer Shipments (number of units) Categorized by Efficiency Level (EF)
	≥3.01*
1993	3,674,000
1994	3,838,000
1995	3,823,000
1996	3,947,000
1997	4,115,000
1998	4,482,000
1999	4,865,000
2000	5,095,000
2001	5,117,000
2002	5,402,000
2003	5,718,000
2004	6,262,000
2005	6,408,000
2006	6,360,000
2007	6,035,000
2008	5,620,000
2009	5,201,000
2010	5,263,100
2011	4,925,700
2012	4,684,700

	Table 15—Residential Gas Clothes Dryer Market Share (%) Categorized by EF*	
	2005	2006
3.01-3.09 EF	26	33
3.1-3.29 EF	74	67
3.2-3.29 EF	-	-
>3.29 EF	-	-

*Data from 2004 Technical Support Document Residential Clothes Dryers and Room Air Conditioners, Appendix 5-b Table 5-b.3.2. Association of Home Appliance Manufacturers (AHAM) submitted these data.

*According to data from the California Energy Commission Appliance Efficiency Database, presented in the 2011 TSD, almost all electric clothes dryer models have an EF between 3.00-3.19. There has also been few regulations driving energy efficiency improvements of clothes dryers from 1993-2012. Therefore, it is likely that most shipments have an EF between 3.00-3.19. A new minimum standard and a new ENERGY STAR specification is set to take effect in 2015, which should drive efficiency improvements in electric clothes dryers in the future.

Electric clothes dryer shipments dropped from their peak of 6.4 million in 2005 to 4.7 million in 2012.



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The efficiency level categorization was based on the applicable minimum efficiency standard.

Data Sources

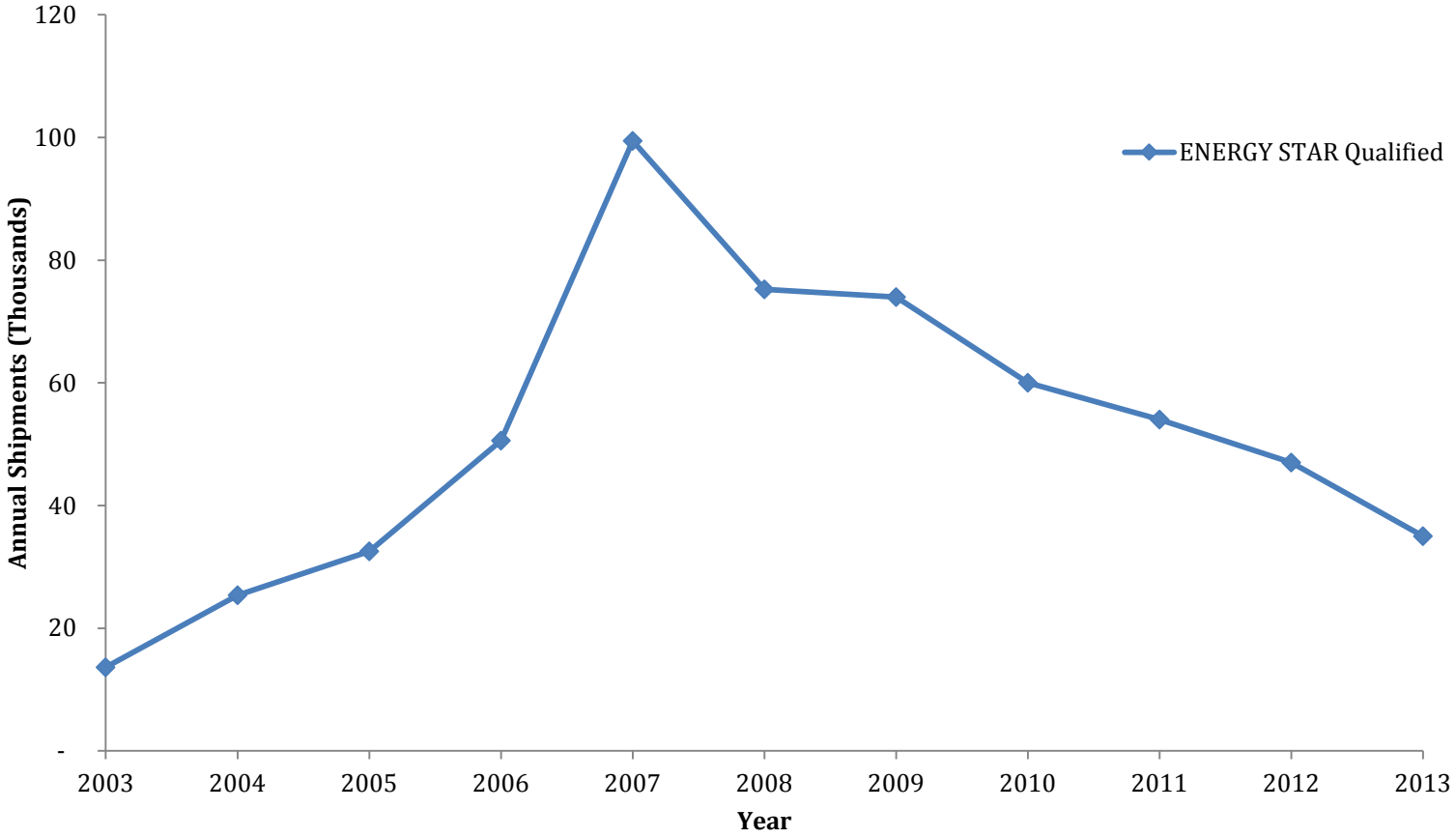
1. Standard Level Shipments
   - The DOE TSD has shipment data for total residential electric clothes dryers from 1993-2008.
   - Data from 2009-2012 is from the Appliance Magazine Statistical Reports.

No sources breakout multiple efficiency levels for geothermal heat pumps.

	Table 16—Geothermal Heat Pump Shipments Categorized by Efficiency Level (EER/COP)			
Year	≥14.1/3.3	≥16.1/3.5	≥17.1/3.6	Total
1994				14,000
1995				16,000
1996				15,000
1997				18,000
1998				19,000
1999				21,000
2000				18,000
2001				13,000
2002				18,000
2003	13,631			13,631
2004	25,351			25,351
2005	32,517			32,517
2006	50,583			50,583
2007	99,451			99,451
2008	75,229			75,229
2009	74,000			74,000
2010	60,000			60,000
2011		54,000		54,000
2012			47,000	47,000
2013			35,000	35,000

ENERGY STAR geothermal heat pump shipments dropped from a 2007 peak of 99,000 to 35,000 in 2013 based on ENERGY STAR data.

Figure 28—Historical Shipments VS Time



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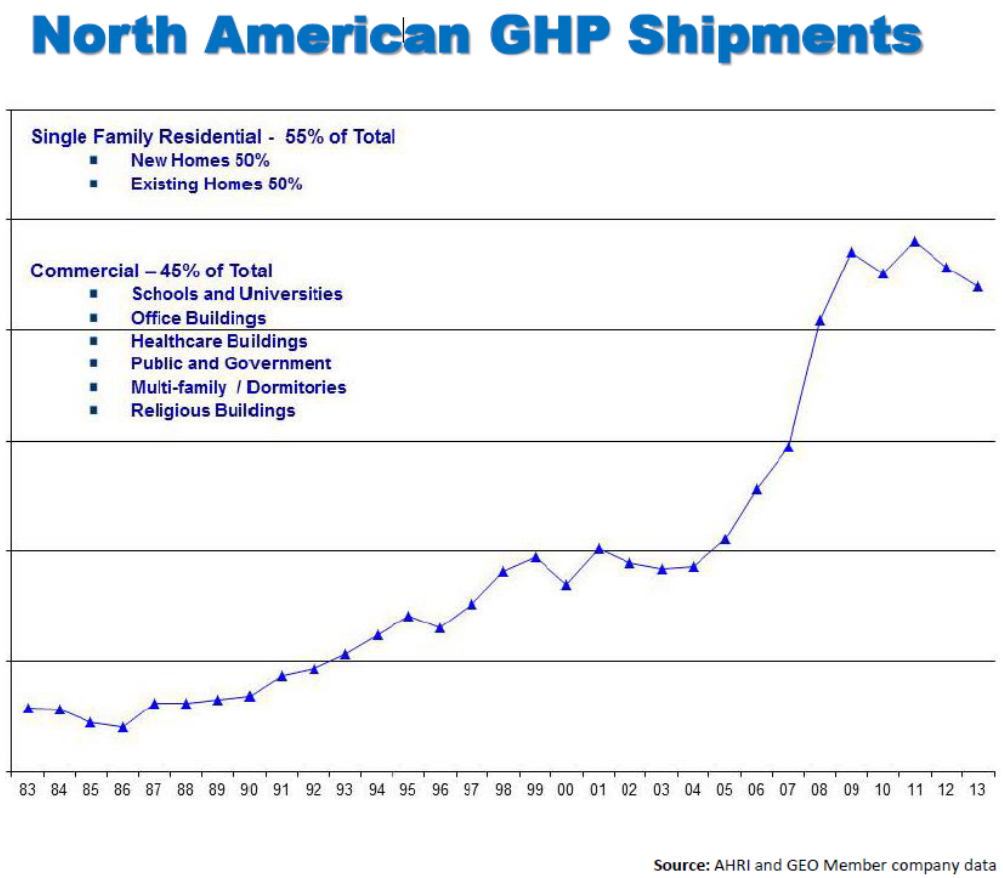
Since the early 1980's, shipments have continuously increased until 2009 for combined residential and commercial sector geothermal heat pumps.



This figure provided by, "Geo—The Geothermal Exchange Organization," compiles shipment data from AHRI and GEO company data. This figure demonstrates trends in geothermal heat pump shipments, but the absolute numbers of shipments could not be shared.

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Key assumptions about the data (also see References Section).

1. Shipments from 1994-2002
   - Data comes from the EIA Geothermal Heat Pump Manufacturing Activities reports
     - The reports aggregates shipments of units for residential and commercial sectors. The reports also present the shipments in terms of total capacity broken out by sector.
       - Assuming 3 Tons/unit, we can convert the shipments of rated capacity to the number of unit shipments.
2. Shipments 2003-2013
   - Data comes from the ENERGY STAR Annual Shipment reports.

Available shipment data for general service lamps are not broken down by efficacy range, but are broken down by technology.

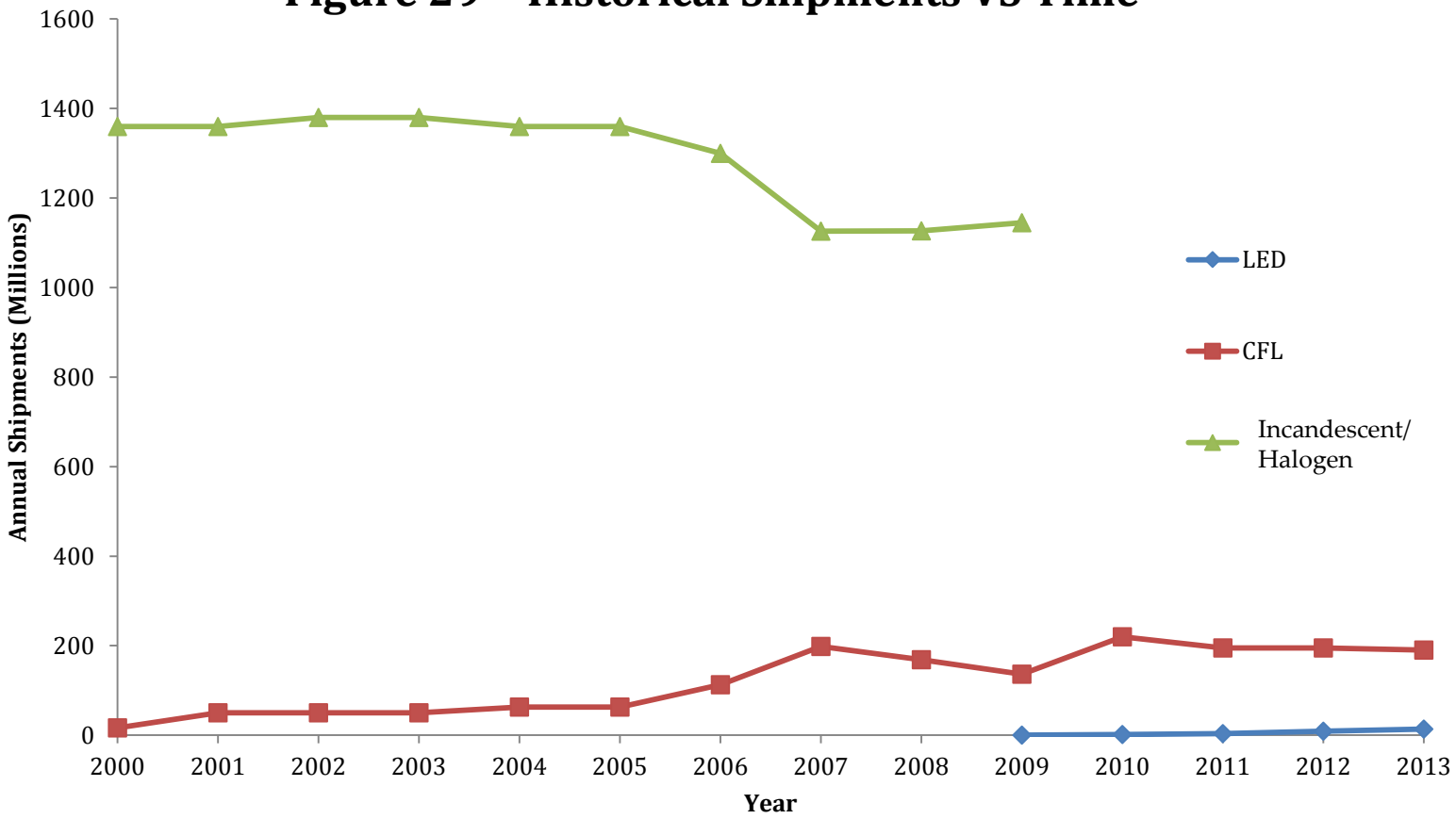
Table 17—Lighting Shipments (number of bulbs) Categorized by Technology			
Year	Light Emitting Diode (LED)*	Compact Fluorescent Lamp (CFL)	Incandescent/ Halogen**
2000		16,500,000	1,360,000,000
2001		50,000,000	1,360,000,000
2002		50,000,000	1,380,000,000
2003		50,000,000	1,380,000,000
2004		62,500,000	1,360,000,000
2005		62,500,000	1,360,000,000
2006		112,500,000	1,300,000,000
2007		198,500,000	1,125,600,000
2008		168,500,000	1,126,400,000
2009	320,000	136,000,000	1,144,800,000
2010	1,170,000	220,000,000	
2011	3,800,000	195,000,000	
2012	9,000,000	195,000,000	
2013	13,900,000	190,000,000	

*Shipments of LEDS will likely increase as well as they get closer to cost equivalency with CFLs. There were likely no shipments of residential LEDs prior to 2009.

**A new standard took effect in January 2014 as defined in Energy Independence Security Act (EISA) 2007. According to EISA 2007, 40 and 60 Watt incandescent bulbs no longer met the standard. This could have lead to a sharp decrease in incandescent shipments. In addition, 100 Watt and 75 Watt bulbs already no longer met the standard as of 2012 and 2013 respectively. One thing to note, however, is that DOE does not have the authority to enforce this standard.

LEDs are beginning to gain a measurable share of the market for general service lamps.

Figure 29—Historical Shipments VS Time



Key assumptions (also see References Section).

- Incandescent/Halogen Shipments
  - Data comes from the ENERGY STAR CFL Market Profile: Data Trends and Market Insights report.
    - Because this data is not specific to the residential market, assumed 80% of shipments are for the residential sector.
- CFL Shipments
  - 2000-2009 shipments come from the ENERGY STAR CFL Market Profile: Data Trends and Market Insights report.
    - Because this data is not specific to the residential market, assumed 50% of shipments are for the residential sector.
  - 2010-2013 shipments come from the ENERGY STAR annual shipment reports.
    - These reports estimate the fraction of ENERGY STAR qualified shipments compared to total equipment shipments. This fraction was used to calculate the total number of CFL shipments.
    - Because this data is also not specific to the residential sector, we assumed that 50% of the CFL shipments are for the residential sector.

Key assumptions (Cont.)

» LED Shipments
- 2009-2012 shipments comes from the EERE report, "Adoption of Light-Emitting Diodes in Common Lighting Applications."
- 2013 shipments come from the EERE report, "Solid-State Lighting Research and Development Multi-Year Program Plan," April 2014.
- Both reports estimate the number of cumulative LED installations for multiple different lamp types in all building types.
  - The cumulative installation numbers can easily be converted to annual shipments
  - In addition, we made several assumptions to convert these data to the number of shipments of LED General Service Lamps for the residential sector.

Applicable Bulb Type		Fraction that are General Service Lamps		Fraction that are Residential Sector Shipments
A-Type	X	100%	X	50%
Directional		67%		25%
Decorative		50%		100%

Kerosene furnaces are rare in the U.S., and we have not been successful in securing shipment data.

» Central furnaces operating on kerosene are very rare in the US

» Most kerosene "furnaces" are actually portable, unvented heaters

Available sources provide 10 years of shipment data by efficiency range for Liquefied Petroleum Gas (LPG) furnaces.

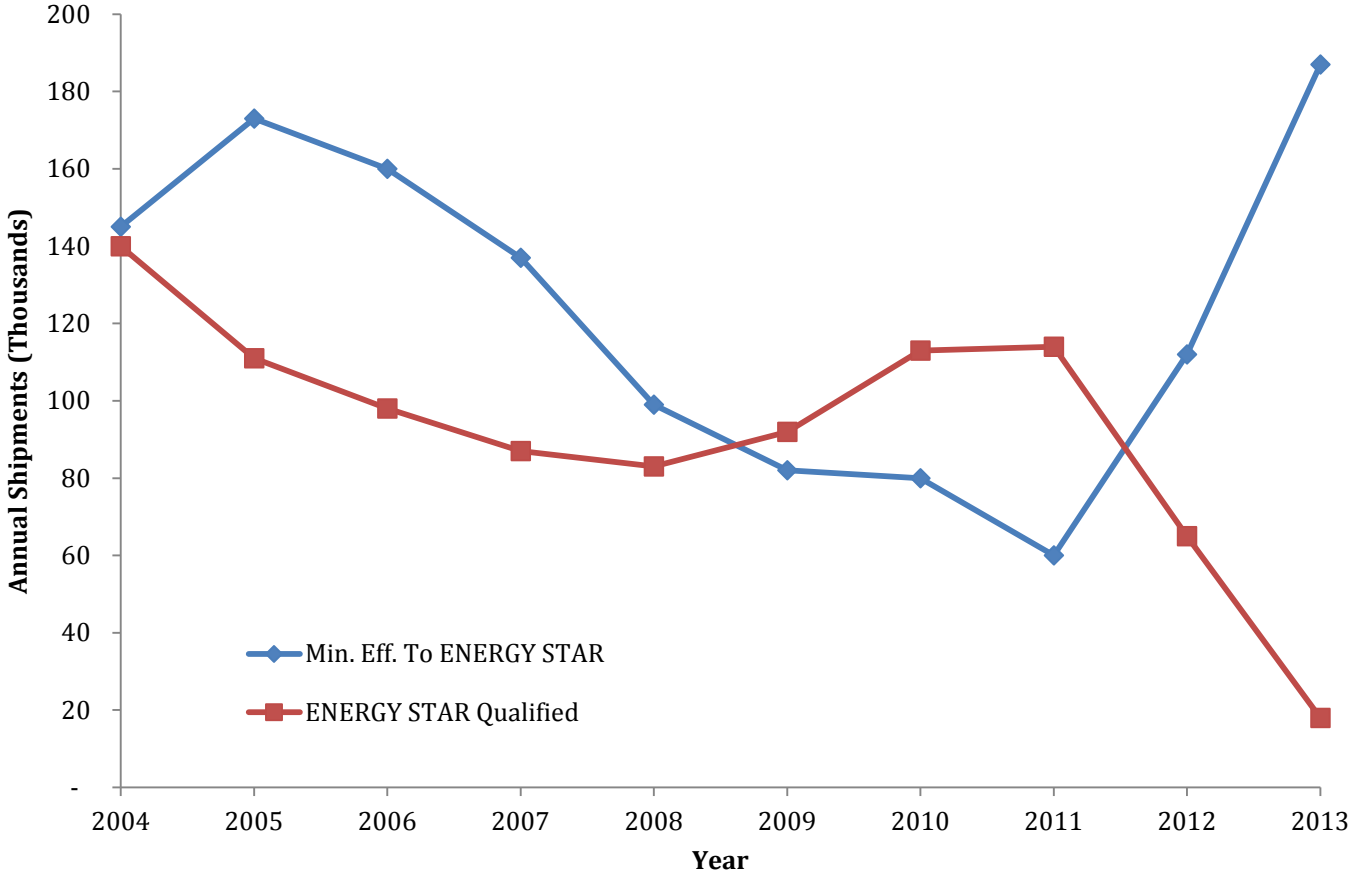
	Table 18—LPG Furnace Shipments (number of units) Categorized by Efficiency Level (AFUE)		
Year	78-89**	≥90	Total
1992*			165,000
1993			204,000
1994			212,000
1995			203,000
1996			225,000
1997			218,000
1998			234,000
1999			247,000
2000			247,000
2001			245,000
2002			257,000
2003			263,000
2004	145,000	140,000	285,000
2005	173,000	111,000	284,000
2006	160,000	98,000	258,000
2007	137,000	87,000	224,000
2008	99,000	83,000	182,000
2009	82,000	92,000	174,000
2010	80,000	113,000	193,000
2011	60,000	114,000	174,000
2012	112,000	65,000	177,000
2013	187,000	18,000	205,000

*Cannot categorize shipments from 1992-2003. All shipments, however, will be greater than or equal to the minimum efficiency standard, AFUE 78%.

**There are likely very few units in this category with efficiencies greater than 80%. According to AHRI's product database, there are no available units with AFUE 82%-89%.

Market share of ENERGY STAR LPG furnaces dropped precipitously between 2011 and 2013, falling from 66 to 9 percent of total shipments.

Figure 30—Historical Shipments VS Time



The sharp drop in ENERGY STAR qualified shipments in 2012 and 2013 is likely due to the ENERGY STAR specification of 90% AFUE for southern states, and 95% AFUE for northern states that took effect in 2012.

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Details about the data.

Data Sources (also see References Section)

1. Standard Level Shipments
   - **2011-06-06 Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners, Heat Pumps, and Furnaces. Chapter 9: Shipments Analysis** provides historical shipment data for three furnace equipment types: Non-weatherized (installed indoors) gas furnaces, Mobile home gas furnaces, Oil fired furnaces.
     - Because non-weatherized gas furnaces dominate the market, we excluded the mobile home gas furnaces from the data presented above.
     - All of the data was submitted by AHRI to DOE, and data is presented from 1972-2009.
   - AHRI also presents historical shipment data for residential gas furnaces on its website from 1994-2013.
     - However, it aggregates mobile home furnace shipments and non-weatherized gas furnace shipments.
     - Therefore, in order to get the number of non-weatherized gas furnaces from 2010-2012, calculated the average ratio of mobile home furnace shipments to non-weatherized gas furnace shipments over the past 20 years from the TSD data. We then applied this ratio to the total number of residential gas furnace shipments to calculate the number of non-weatherized gas furnace shipments from 2010-2013.
   - Because shipments in both sources do not differentiate between natural gas and LPG shipments, assumed that 8% of gas furnace shipments used LPG. This number is based on data from the 2011 TSD.
2. ENERGY STAR Level Shipments
   - EPA has collected annual shipment data for residential gas furnaces since 2004, and publishes in their annual report.

Available sources provide 4 years of shipment data by efficiency range for LPG water heaters.

	Table 19—Gas Water Heater Shipments (number of units) Categorized by Efficiency Level (EF)					
	Storage		Instantaneous	Total Storage	Total Instantaneous	Total
Year	.575-.66	≥.67***	≥.82			
1999*				315,000		315,000
2000				313,000		313,000
2001				315,000		315,000
2002				318,000		318,000
2003				327,000		327,000
2004**				335,000	250,000	585,000
2005				319,000	252,000	571,000
2006				297,000	253,000	550,000
2007				280,000	273,000	553,000
2008				255,000		255,000
2009				240,000		240,000
2010	221,000	29,000	24,000	274,000	24,000	298,000
2011	245,000	7,000	21,000	273,000	21,000	294,000
2012	246,000	7,000	22,000	275,000	22,000	297,000
2013	263,000	10,000	25,000	298,000	25,000	323,000

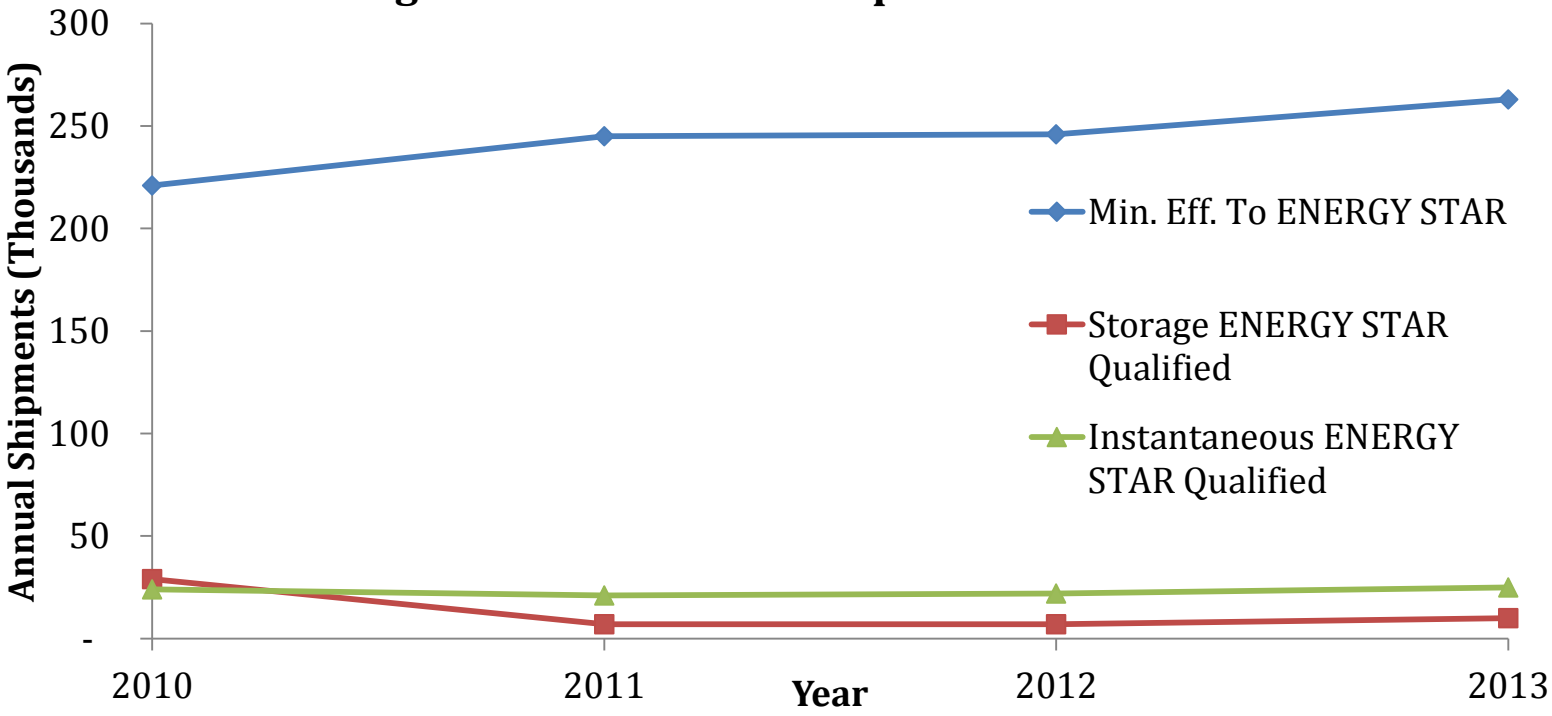
*Cannot categorize storage water heater data from 1999-2009 by efficiency. All storage water heater shipments from 1999-2003 have efficiencies greater than the minimum standard, EF .525. All storage water heater shipments from 2004-2009 have efficiencies greater than the minimum standard, EF .575.

**Cannot categorize instantaneous water heater data from 2004-2007 by efficiency. All instantaneous water heater shipments from 2004-2007 have efficiencies greater than the minimum standard, EF .62.

***There are likely no shipments of units in this category with an EF greater than .72. According to the AHRI database, there are no available units with an EF between .72-.81. There is a single manufacturer of an EF .82 unit, but this only became available in 2013, and market penetration is likely very low at this time.

Although instantaneous water heaters are only approximately 10% of total water heater shipments, they make up a larger portion of the ENERGY STAR market than storage units do.

Figure 31—Historical Shipments VS Time



The efficiency level categorization was based on applicable ENERGY STAR and minimum standard efficiency levels.

Data Sources (also see References Section)

1. Standard Level Shipments
   - The DOE TSD has shipment data for total residential gas storage water heaters from 1951-2009, and for total residential gas instantaneous water heaters from 2004-2007. All of the data were submitted by AHRI to DOE.
   - In addition, the AHRI website contains the identical data set for storage water heater units, but also extended to 2013.
   - Because shipments in both sources do not differentiate between natural gas and LPG shipments, assumed that 6% of gas storage water heater shipments used LPG. This number is based on data from the Buildings Energy Data Book 2010: Table 5.4.1.
2. ENERGY STAR Shipments
   - ENERGY STAR has only collected shipment data for residential gas water heaters from 2010 to 2013.
   - For instantaneous water heater shipments from 2010-2013, the only data source available was the ENERGY STAR shipment reports. The data in Table 19 therefore does not account for instantaneous water heater shipments that are not ENERGY STAR qualified. However, according to the AHRI product database, 381 out of 383 units available are ENERGY STAR qualified. This indicates that ENERGY STAR qualified instantaneous water heater shipments likely capture close to the total number of instantaneous water heater shipments.

The ENERGY STAR and DOE TSD data provided enough information to categorize 9 non-consecutive years of shipments by efficiency level.

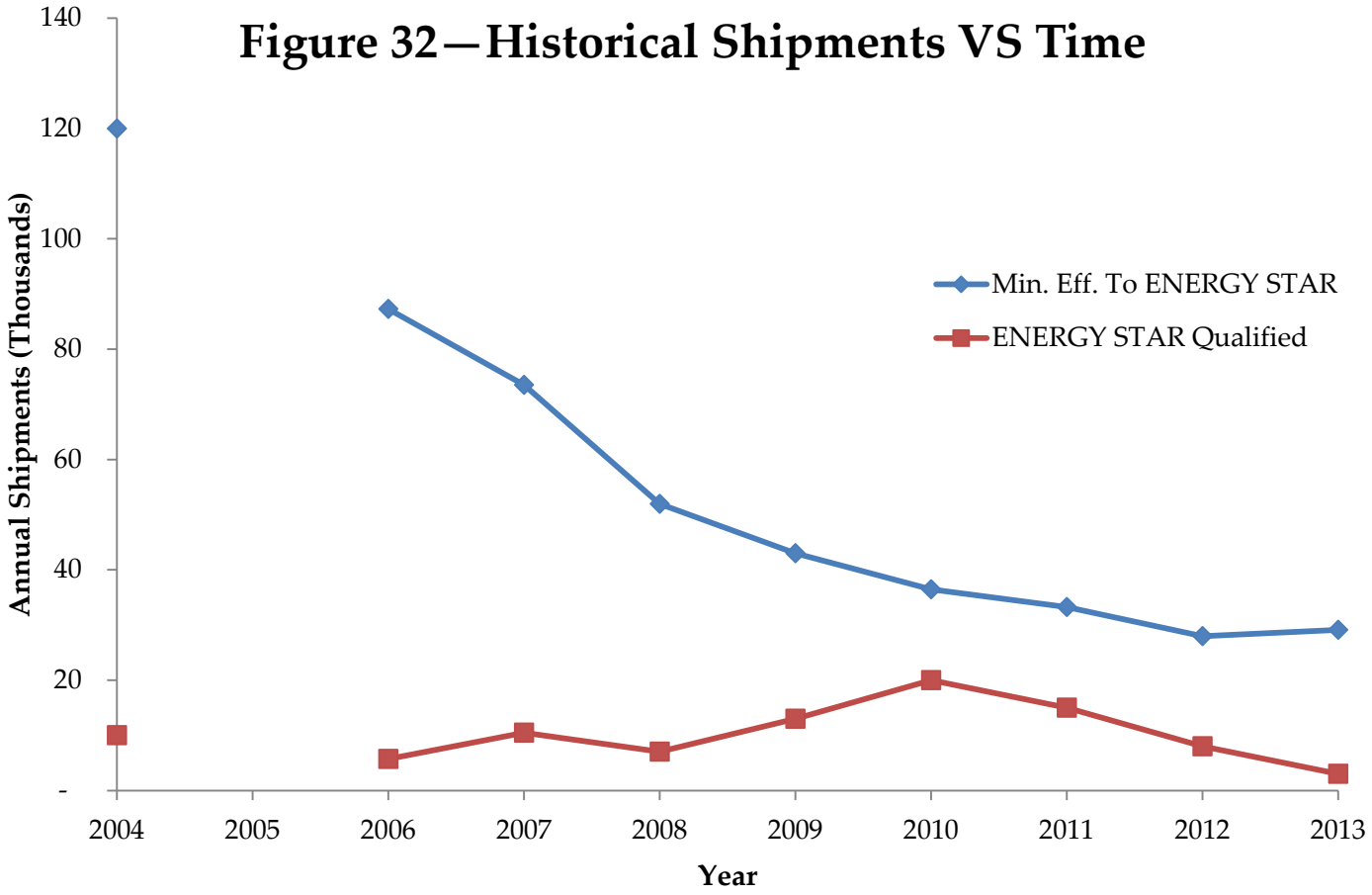
	Table 20—Oil Furnace Shipments (number of units) Categorized by Efficiency Level (AFUE)						
Year	78-89	≥90	78-82	≥83	78-84	≥85***	Total
1994*							141,000
1995							149,000
1996							164,000
1997							135,000
1998							152,000
1999							124,000
2000							128,000
2001							125,000
2002							121,000
2003							123,000
2004	120,000	10,000					130,000
2005**							111,000
2006			87,269	5,731			93,000
2007			73,508	10,492			84,000
2008					51,945	7,055	59,000
2009					43,000	13,000	56,000
2010					36,445	20,000	56,445
2011					33,247	15,000	48,247
2012					27,980	8,000	35,980
2013					29,144	3,000	32,144

*Cannot categorize data from 1994-2003. All shipments have efficiencies greater than the minimum standard, AFUE 78%.

**Cannot categorize data in 2005. ENERGY STAR shipments were presented aggregated with gas furnace shipments

***There are likely very few shipments greater than AFUE 87%. According to AHRI's product database, 90% of the units that are greater than the ENERGY STAR specification of AFUE 85%, fall between AFUE 85% and 87%.

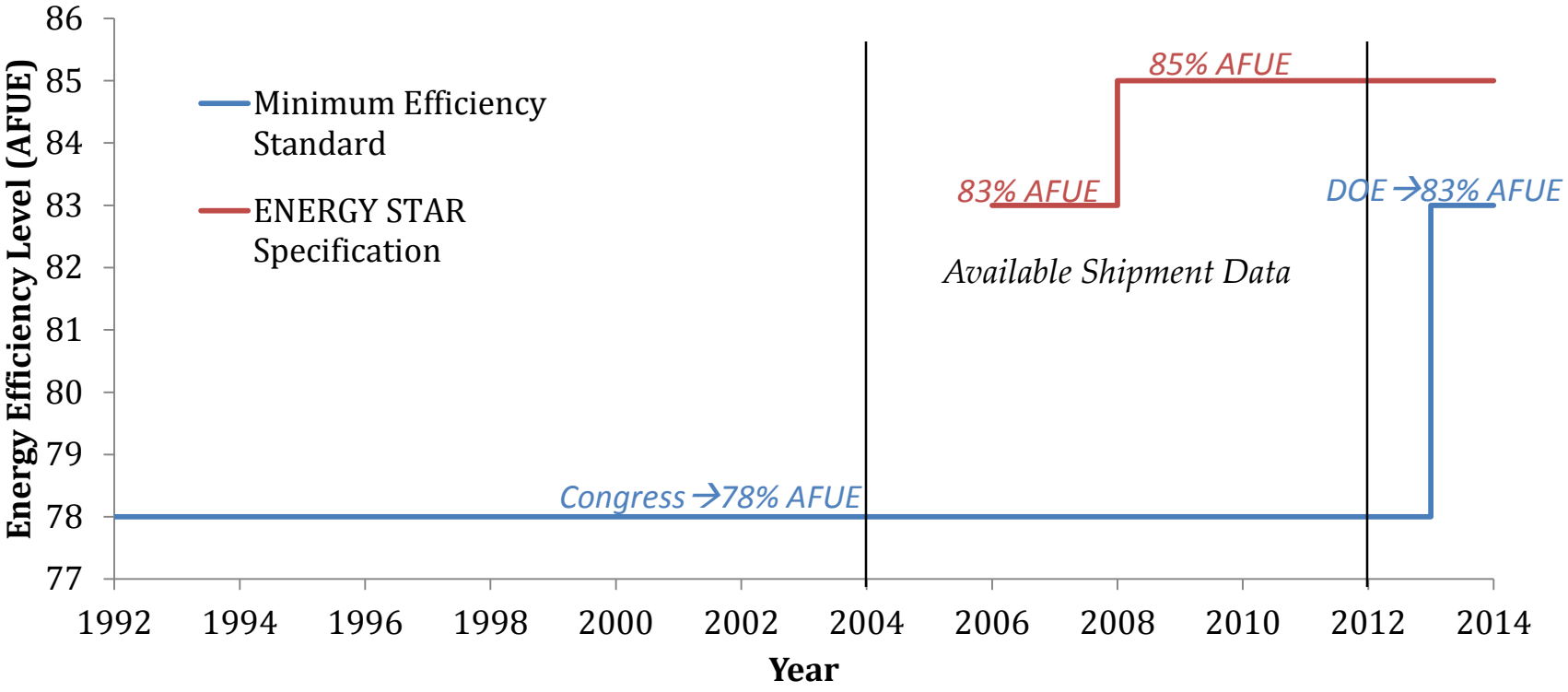
Shipments for both ENERGY STAR and standard-efficiency oil furnaces are falling over time.



In 2005, oil-fired and gas-fired ENERGY STAR qualified shipments were grouped together.

We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 33—Historical Efficiency Standards



EPA has ENERGY STAR qualified shipments for 2004. However, the specification during this time was not specific to any fuel type, and was 90% AFUE for all furnaces.

Key assumptions about the data.

1. Standard level shipments (also see References Section)
   - Data from DOE TSD submitted by AHRI from 1972-2009
   - Data from 2010-2013 is directly from AHRI website
   - All for non-weatherized oil furnaces
2. ENERGY STAR Shipments
   - EPA has total ENERGY STAR qualified shipments from 2004-2012
   - In 2005 shipments of gas and oil were combined, so difficult to distinguish the fuel types for that category.
   - ENERGY STAR specification in before 2006 was not fuel-specific. Specification set at 90% AFUE for all furnaces.

The ENERGY STAR and DOE TSD data provided enough information to categorize 9 non-consecutive years of shipments by efficiency level for hot-water boilers.

	Table 21--Oil Boiler Shipments (number of units) Categorized by Efficiency Level (AFUE)					
	Steam		Hot Water			Total
Year	80-84	82-84	80-84	84-85	≥85	
1992*	13,427					155,866
1993	13,902					155,724
1994	16,544					185,689
1995	15,372					164,681
1996	17,349					178,039
1997	18,025					177,428
1998	17,504					165,614
1999	18,398					167,638
2000	18,555					154,205
2001	18,115					170,458
2002	16,814					170,381
2003	17,706		80,239		89,441	187,386
2004	19,460		52,444		115,000	186,904
2005	17,256		69,308		83,434	169,998
2006**	16,016					143,547
2007	15,494		31,075		99,226	145,795
2008	11,061		57,634		75,151	143,846
2009	9,616		22,626		76,000	108,242
2010	9,951		31,340		75,000	116,291
2011	9,084		35,611		64,000	108,695
2012		7,483		27,952	57,000	92,435

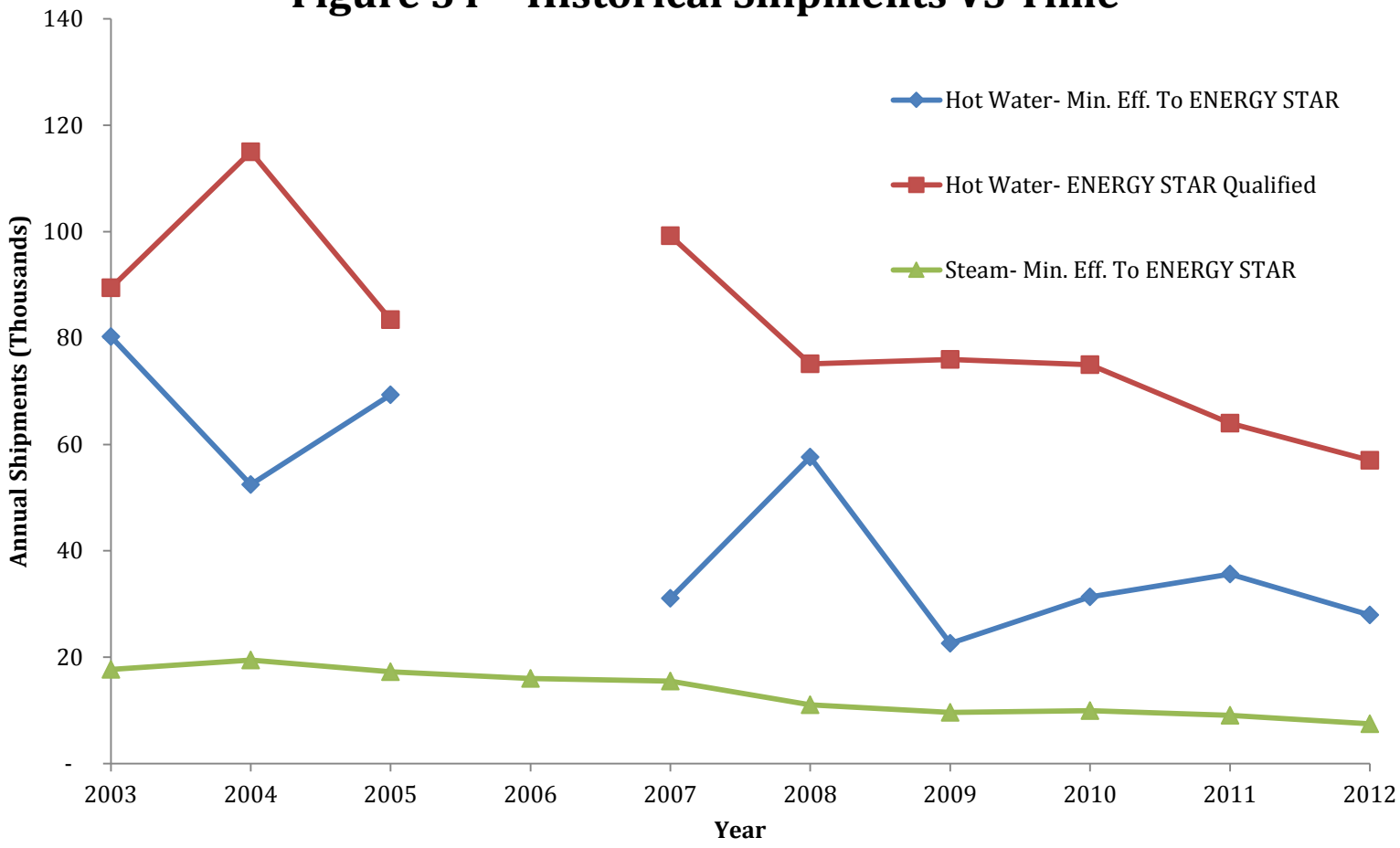
*Cannot categorize Hot Water Boiler Shipments from 1992-2002. All shipments, however, will be greater than or equal to the minimum efficiency standard, AFUE 80%.

**Cannot categorize Hot Water Boiler Shipments in 2006. There appears to be an error in the ENERGY STAR dataset, as ENERGY STAR lists the number of ENERGY STAR qualified shipments as being greater than the total number of oil boiler shipments for that year.

***There are likely very few shipments with an AFUE greater than 87%. According to AHRI's product database, 85% of the units that are greater than the ENERGY STAR specification of AFUE 85% have an AFUE between 85% and 87%.

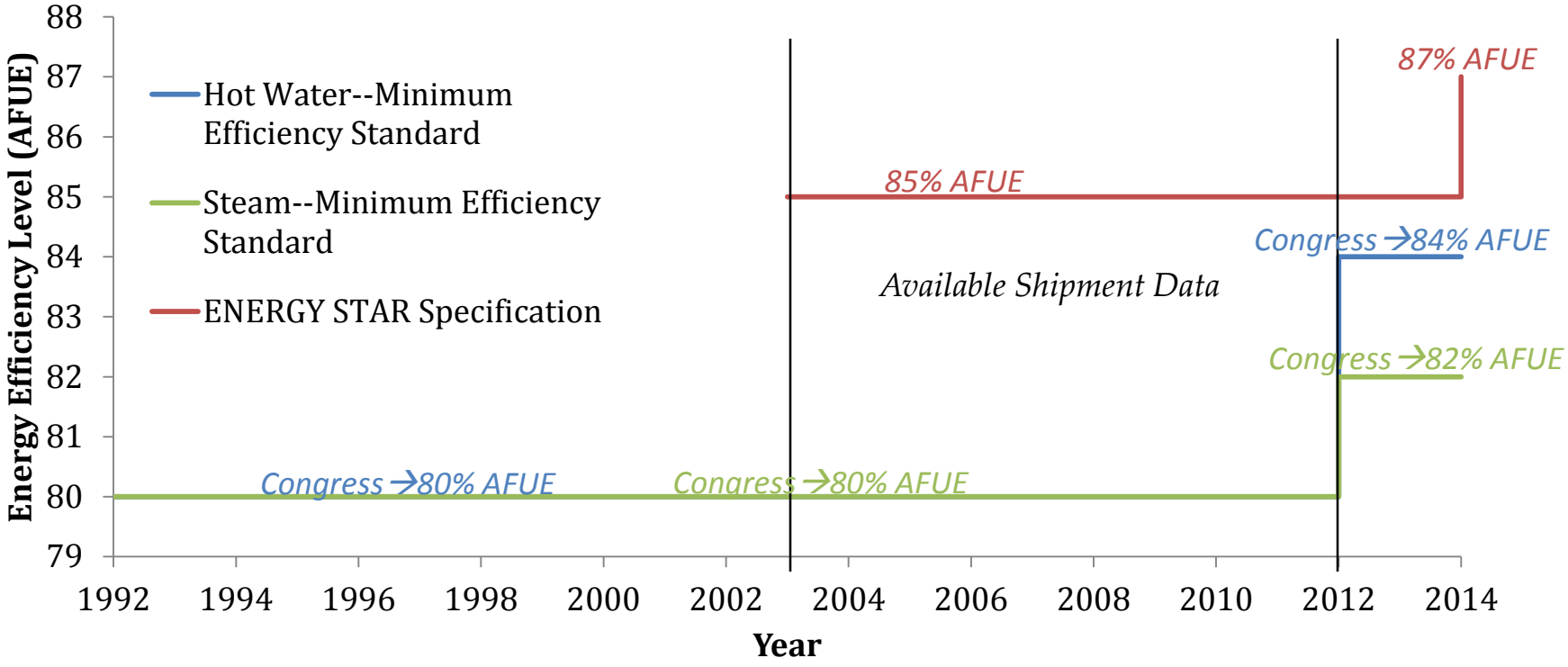
Shipments for all types and efficiencies of oil boilers are falling.

Figure 34—Historical Shipments VS Time



We mapped historical shipments to ENERGY STAR specifications and minimum energy efficiency standard levels for a given year.

Figure 35—Historical Efficiency Standards



EPA has ENERGY STAR criteria pre-dating 2003. However, it is difficult to track down when the effective date of these specifications were. The specifications were identical to the 2003-2012 specification of 85% AFUE

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Key assumptions about the data.

1. Standard level shipments (also see References Section)
   - Data from DOE NODA TSD from 1992-2012
   - There are many manipulations of the data submitted by AHRI detailed in appendix 9A of the TSD
2. ENERGY STAR Shipments
   - EPA has total ENERGY STAR qualified shipments from 2003-2012

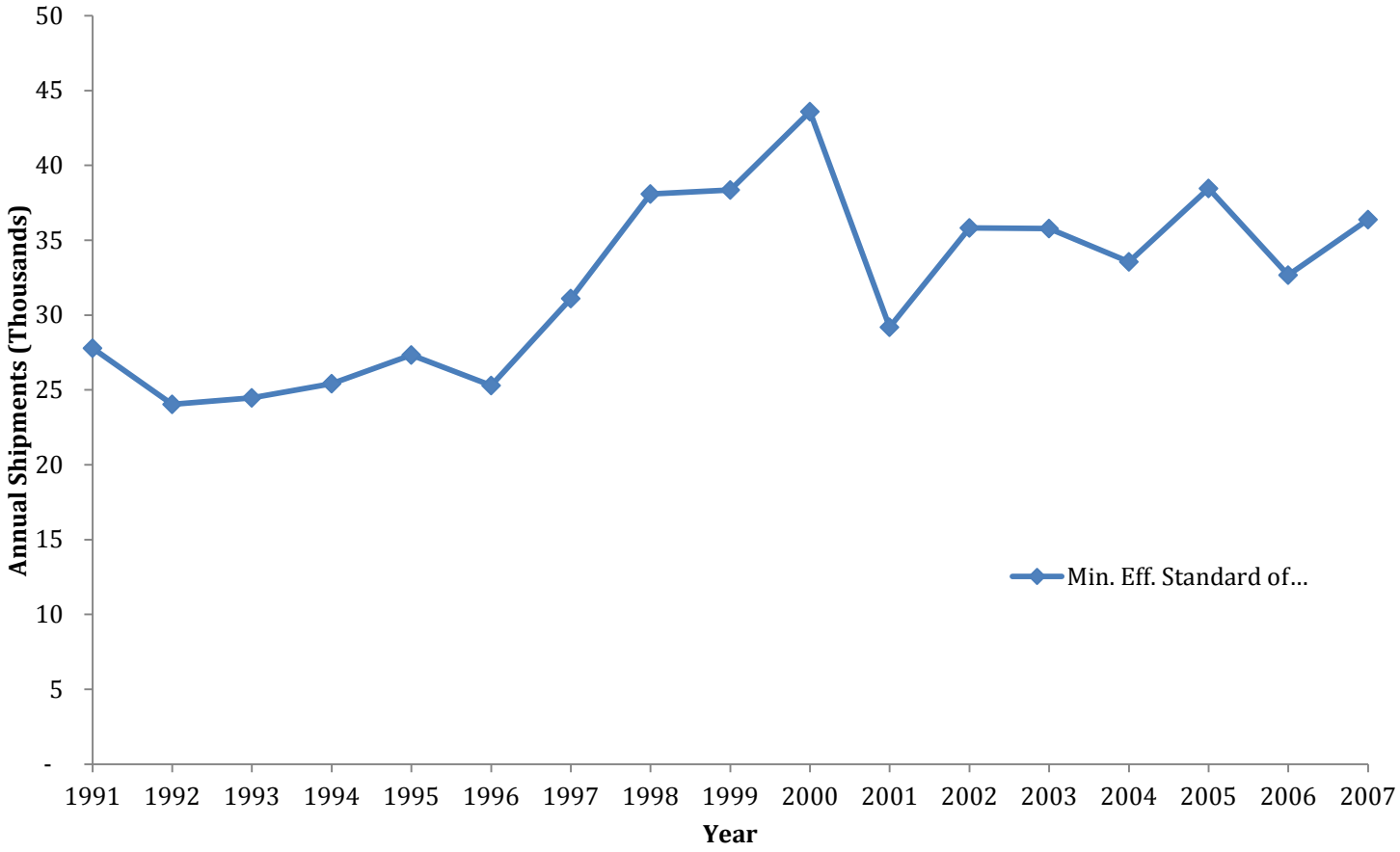
Data are not available to categorize shipments of oil-fired water heaters by efficiency.

Table 22—Oil Storage Water Heater Shipments (number of units) Categorized by Efficiency Level (EF)	
Year	≥.533
1991	27,798
1992	24,045
1993	24,473
1994	25,420
1995	27,329
1996	25,298
1997	31,113
1998	38,090
1999	38,358
2000	43,589
2001	29,184
2002	35,834
2003	35,777
2004	33,564
2005	38,452
2006	32,671
2007	36,387

*There are likely no shipments with an EF greater than .68 because this is the most efficient unit available according to AHRI's product database. In addition, most shipments are likely less than EF .63 because all but one of the available units have an EF less than .63.

Annual shipments for oil-fired water heaters have been modest for decades.

Figure 36—Historical Shipments VS Time



Key assumptions about the data.

1. Standard level shipments (also see References Section)
   - Data from DOE 2010 TSD for Residential Water heaters. Shipments available from 1951-2007.
   - Energy Factor calculated using 30 gallon storage volume, which is the typical volume of an oil storage water heater according to the 2013 EIA Technology Forecasts.

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List of Acronyms

AFUE—Annual Fuel Utilization Efficiency

AHAM—Association of Home Appliance Manufacturers

AHRI—Air-Conditioning, Heating & Refrigeration Institute

BTO—Building Technologies Office

CAC—Central Air Conditioner

CCMS—Compliance Certification Management System

COP—Coefficient of Performance

DOE—Department of Energy

EER—Energy Efficiency Ratio

EERE—Office of Energy Efficiency & Renewable Energy

EF—Energy Factor

EISA—Energy Independence and Security Act

EPA—Environmental Protection Agency

HPWH—Heat Pump Water Heater

HSPF—Heating Seasonal Performance Factor

IMEF—Integrated Modified Energy Factor

LPG—Liquefied Petroleum Gas

MEF—Modified Energy Factor

NEMS—National Energy Modeling System

NODA—Notice of Data Availability

PNNL—Pacific Northwest National Laboratory

RDM—Residential Demand Module

SEER—Seasonal Energy Efficiency Ratio

TSD—Technical Support Document

APPENDIX B

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ENERGY

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

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January 9, 2015

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.

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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