APPENDIX A

FINAL

EIA - Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case

Presented to:

U.S. Energy Information Administration

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DISCLAIMER

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Objective

The objective of this study is to develop baseline and projected performance/cost characteristics for residential and commercial end-use equipment.

- 2005 and 2007 baselines, as well as today's (2010)
  - Review of literature, standards, installed base, contractor, and manufacturer information.
  - Provide a relative comparison and characterization of the cost/efficiency of a generic product.
- Forecast of technology improvements that are projected to be available through 2035
  - Review of trends in standards, product enhancements, and Research and Development (R&D).
  - Projected impact of product improvements and enhancement to technology.

The performance/cost characterization of end-use equipment developed in this study will assist EIA in projecting national primary energy consumption.

Input from industry, including government, R&D organizations, and manufacturers, was used to project product enhancements concerning equipment performance and cost attributes.

- Technology forecasting involves many uncertainties.
- Technology developments impact performance and cost forecasts.
- Varied sources ensure a balanced view of technology progress and the probable timing of commercial availability.
- All cost forecasts are shown in real, 2010 dollars.

Definitions

The following tables represent the current and projected efficiencies for residential and commercial building equipment ranging from the installed base in 2005 and 2007, to the highest efficiency equipment that is expected to be commercially available by 2035, assuming incremental adoption. Below are definitions for the terms used in characterizing the status of each technology.

- 2005/2007 Installed Base: the currently installed and "in use" equipment for that year. Represents the installed stock of equipment, does not represent sales.
- 2010 Current Standard: the minimum efficiency required by current standards, or typical where no standard exists.
- Typical: the average, or "typical" product being sold in the particular timeframe.
- ENERGY STAR: the minimum efficiency required to meet the ENERGY STAR criteria, where applicable.
- Mid-Level: middle tier high-efficiency product available in the particular timeframe.
- High: the product with the highest efficiency available in the particular timeframe.

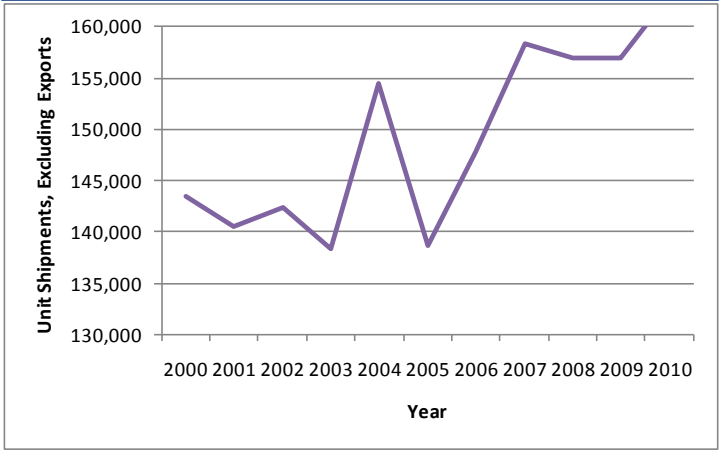
The market for the reviewed products has changed since the analysis performed in 2007 and is reflected in the efficiency and cost characteristics.

- Over the past three years, the Environmental Protection Agency (EPA) established ENERGY STAR specifications for a number of new products, including residential water heaters.
- Typical air conditioners have improved efficiencies as a result of increased Federal standards or otherwise. In 2007, the typical Energy Efficiency Ratio (EER) for a residential room air conditioner was 10.0, today it is 10.8; the typical EER for a commercial rooftop air conditioner was 10.1, today it is 11.2.
- Overall, there has been an increased market acceptance of energy efficient products driven by initiatives such as LEED and other green building programs.

Historical Shipment Data

Due to the severe recession and dramatic contraction in the housing market, over the past few years there has been a trend of decreased appliance shipments, except in commercial appliances where a specific trend is not evident. In 2010, shipments have increased across all appliance types.

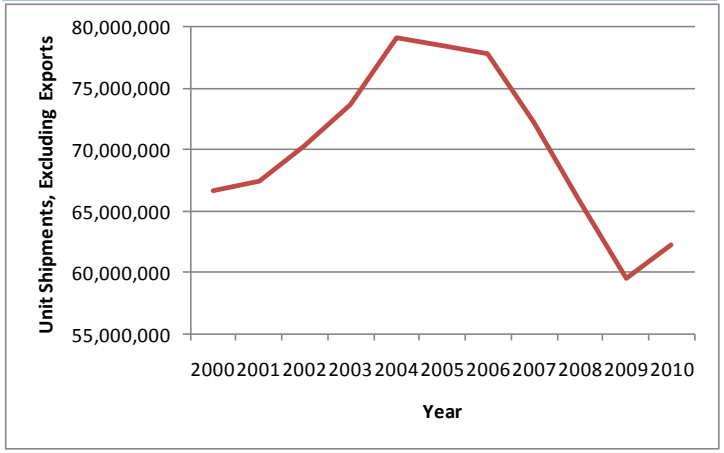
Commercial Appliances



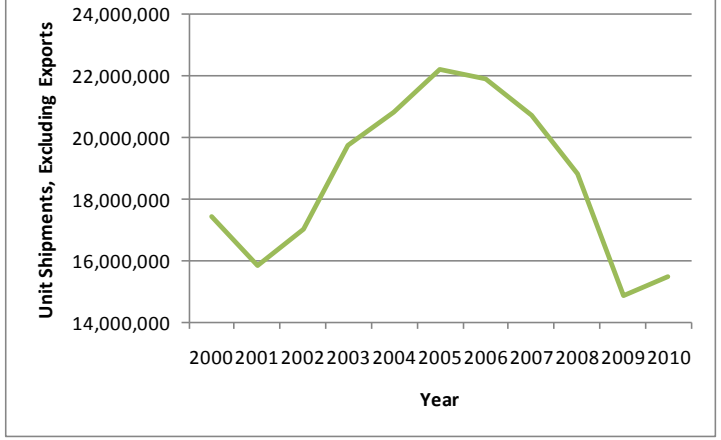
Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Throughout the presentation, shipment trends for specific products are depicted. Overall, the recession and contraction of the housing market has significantly affected each product.

Major Appliances



Comfort Conditioning



Performance / Cost Characteristics » Residential Gas-Fired Water Heaters

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Capacity (gal)	40	40	40	40	50	40	50	40	50	40	50
Energy Factor	0.6	0.59	0.62	0.67	0.85	0.62	0.85	0.62	0.85	0.62	0.85
Average Life (yrs)	9-15	9-15	9-15	9-15	9-15	9-15	9-15	9-15	9-15	9-15	9-15
Retail Equipment Cost ($)	470-510	470-510	480-510	780-810	1500-3000	450-500	1380-2880	450-500	1250-2750	450-500	1200-2700
Total Installed Cost ($)	920-960	920-960	930-960	1230-1260	1950-3450	900-950	1830-3330	900-950	1700-3200	900-950	1650-3150
Annual Maintenance Cost ($)	-	-	13	17	17	13	17	13	17	13	17

- The current Federal standard, which came into effect in January 2004 mandates an EF of 0.59 for a 40-gallon water heater. The equation for the Federal standard is:

  EF=0.67-(0.0019*Gal), which is used to expand the analysis to a greater range of storage capacities.

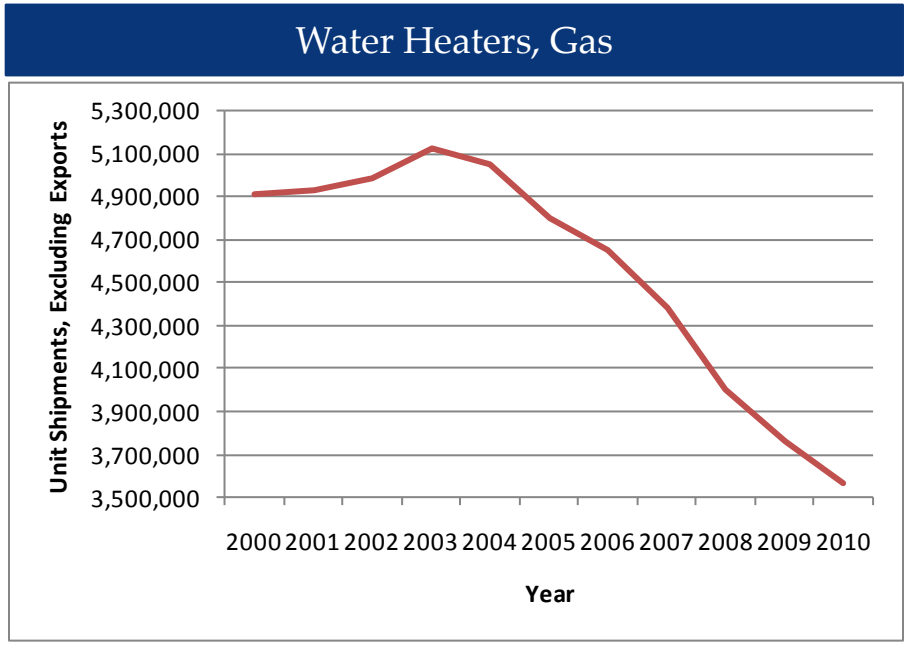
- An updated Federal standard will go into effect on April 16, 2015. The equation for the Federal standard is:

  EF=0.675-(0.0015*Gal) for a volume ≤ 55 gallons and

  EF=0.8012-(0.00078*Gal) for a volume > 55 gallons

- Per discussions with National Labs, there is a potential trend towards a capacity of 50 gallons after 2020.
- Gas-fired water heater capacities typically fall between 30 and 75 gallons.
- As part of the heating products Federal standards rulemaking, a high efficiency model was examined, EF=0.77 at 40 gallons, which represents a condensing unit with two inches of insulation and a power vent.
- The cost of installation is approximately $450, which is higher than electric water heaters for a number of reasons, which includes an extra 1.5 hours of labor for 2 plumbers that is required for gas units.

Since the last analysis was performed in 2007, there has been a decrease in residential gas-fired water heater shipments.



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Performance / Cost Characteristics » Residential Oil Water Heaters

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	Mid-Level	High	Typical	High	Typical	High	Typical	High
Typical Capacity (gal)	30	30	30	30	30	30	30	30	30	30	30
Energy Factor	0.5	0.53	0.54	0.62	0.68	0.62	0.68	0.62	0.68	0.62	0.68
Average Life (yrs)	9	9	9	9	9	9	9	9	9	9	9
Retail Equipment Cost ($)	1200-1300	1300-1400	1350-1450	1450-1550	1600-1700	1440-1540	1600-1700	1420-1520	1600-1700	1420-1520	1600-1700
Total Installed Cost ($)	1800-1900	1900-2000	1950-2050	2050-2150	2200-2300	2040-2140	2200-2300	2020-2120	2200-2300	2020-2120	2200-2300
Annual Maintenance Cost ($)*	-	-	157	157	157	157	157	157	157	157	157

- The current Federal standard, which came into effect in January 2004 mandates an EF of 0.53 for a 30-gallon water heater. The equation for the Federal standard is:

  EF=0.59-(0.0019*Gal), which is used to expand the analysis to a greater range of storage capacities.

- An updated Federal standard will go into effect on April 16, 2015. The equation for the Federal standard is:

  EF=0.68-(0.0019*Gal)

- Oil-fired water heaters often have small tanks with larger input ratings, relative to natural gas and electric residential water heaters.
- No condensing oil-fired, storage residential water heaters currently exist on the U.S. market, hence the range of efficiencies tops out at near-condensing efficiency levels.
- The max-tech model on the market is achieved using a proprietary "turbo flue" design.

Performance / Cost Characteristics » Residential Electric Resistance Water Heaters

DATA	2005	2010	2010		2020		2030		2035	
	Installed Base	Current Standard	Typical	High	Typical	High	Typical	High	Typical	High
Typical Capacity (gal)	50	50	50	50	50	50	50	50	50	50
Energy Factor	0.9	0.9	0.92	0.95	0.95	0.96	0.95	0.96	0.95	0.96
Average Life (yrs)	13-15	13-15	13-15	13-15	13-15	13-15	13-15	13-15	13-15	13-15
Retail Equipment Cost ($)	250-300	250-300	275-325	350-375	350-375	400-450	350-375	400-450	350-375	400-450
Total Installed Cost ($)	550-600	550-600	575-625	650-675	650-675	700-750	650-675	700-750	650-675	700-750
Annual Maintenance Cost ($)*	-	-	6	6	6	6	6	6	6	6

* Annual Maintenance Cost is negligible

- The current Federal minimum efficiency standard, which went into effect in January 2004, requires an EF of 0.90 for a 50-gallon electric resistance water heater. The equation for the Federal standard is:

  EF=0.97-(0.00132*volume), which is used to expand the analysis to a greater range of storage capacities.

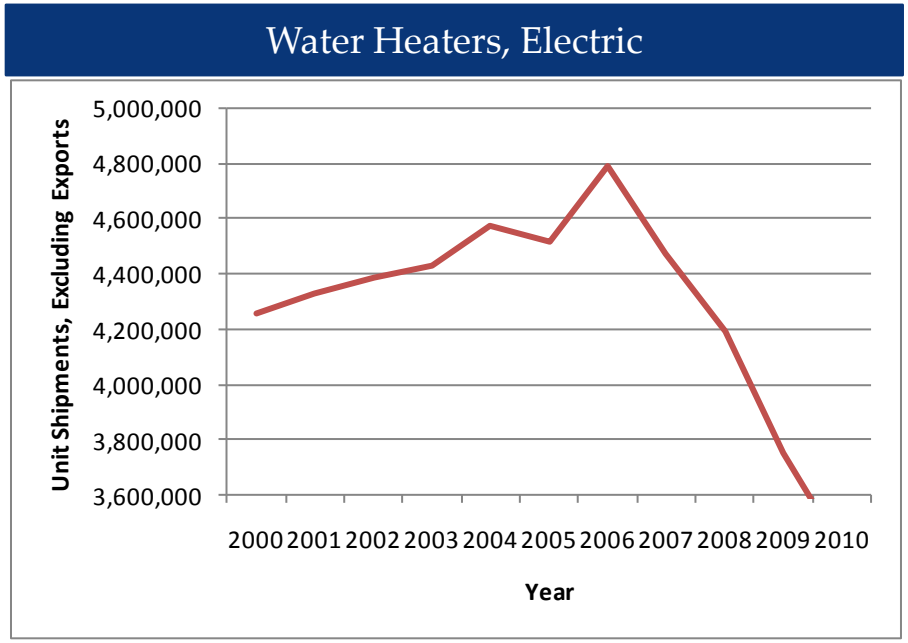
- An updated Federal standard will go into effect on April 16, 2015. The equation for the Federal standard is:

  EF=0.96-(0.0003*Gal) for a volume ≤ 55 gallons and

  EF=2.057-(0.00113*Gal) for a volume > 55 gallons

- Electric resistance water heater capacities usually range between 30 and 119 gallons.

Since the last analysis was performed in 2007, there has been a decrease in residential electric resistance water heater shipments.



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Performance / Cost Characteristics » Residential Heat Pump Water Heaters

DATA	2005	2010		2020		2030		2035	
	Installed Base	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Capacity (gal)	50	50	50	50	50	50	50	50	50
Energy Factor	2	2	2.35	2	2.35	2	2.35	2	2.35
Average Life (yrs)	13-15	13-15	13-15	13-15	13-15	13-15	13-15	13-15	13-15
Retail Equipment Cost ($)	1400-1700	1400-1700	1500-2000	1300-1600	1500-2000	1300-1600	1500-2000	1250-1550	1500-2000
Total Installed Cost ($)	1500-2200	1500-2200	1600-2500	1400-2100	1600-2500	1400-2100	1600-2500	1350-2050	1600-2500
Annual Maintenance Cost ($)	15	15	15	15	15	15	15	15	15

Performance / Cost Characteristics » Residential Heat Pump Water Heaters

- There is not a unique Federal standard for heat pump water heaters (HPWH). Because integrated HPWHs are in the same product class as electric resistance water heaters under DOE's classifications, the Federal standard that applies to electric resistance water heaters applies here as well.
- Since 1990, significant R&D efforts have gone into developing HPWHs. Improvements have advanced efficiency and reliability; however, the high first cost still precludes high-volume market penetration.
- Although there is an installed base listed for 2005, the market penetration of HPWHs was quite low at that time.
- Three major domestic storage water heater manufacturers (Rheem , AO Smith, and GE) have an integrated HPWH model on the market; however, new and established competitors offer integrated or retrofit units (for existing electric or indirect storage water heaters).
- Stiebel Eltron has an 80 gallon, 2.5 energy factor high efficiency HPWH. This unit was not included in the analysis presented on the previous slide because it has a significantly larger capacity than the units included, making for a difficult comparison.
- Sales are estimated to be limited and driven in part by rebates and tax credits at the utility, local, state, and Federal level. Hence, it is not surprising that all HPWH products on the market meet ENERGY STAR minimums and that no HPWH products are being offered below the ENERGY STAR efficiency level.
- While resistive heating elements are virtually 100% efficient at transferring heat to the water inside a water heater, there is a jump in efficiency when heat pump technology is adopted since the COP of heat pump systems is usually between 2 and 3, at least on a seasonal basis.
- Due to the typically slow rate at which heat pumps raise the water temperature in a storage water heater, it is not unusual for heat pump systems to use resistive heat for some proportion of the water heating process to meet consumer expectations. All HPWH systems examined by DOE allow the consumer to adjust the HPWH behavior.

Performance / Cost Characteristics » Residential Instantaneous Water Heaters

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Capacity (BTU/h)	185	185	185	185	185	185	185	185	185	185	185
Energy Factor	0.82	0.82	0.82	0.82	0.98	0.82	0.98	0.82	0.98	0.82	0.98
Average Life (yrs)	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20
Retail Equipment Cost ($)	1050-1150	1050-1150	1050-1150	1050-1150	2150-2250	1050-1150	2150-2250	1050-1150	2150-2250	1050-1150	2150-2250
Total Installed Cost ($)	1550-1650	1550-1650	1550-1650	1550-1650	2650-2750	1550-1650	2650-2750	1550-1650	2650-2750	1550-1650	2650-2750
Annual Maintenance Cost ($)	85	85	85	85	85	85	85	85	85	85	85

- Most instantaneous hot water heaters sold in 2010 are gas-fired and have an efficiency of 0.80 EF or above, which is also the qualifying criteria for ENERGY STAR
- Navien manufactures the highest efficiency gas-fired model currently available on the market, which has an EF of 0.98. This is achieved through the use of electronic ignition, powered direct venting, and through condensing the flue gases.
- All of the major water heater manufacturers now offer an instantaneous model, all of which are imported and private-labeled.
- The maintenance cost includes cleaning the water inlet filter and the heat exchanger of mineral deposits and replacing the water valve approximately once every five years for all energy efficiency levels of instantaneous water heaters.
- When replacing a storage water heater with an instantaneous water heater, there are significant additional costs to upsize the gas supply line to 3/4 inch from the typical ½ inch and change the venting.

Performance / Cost Characteristics » Residential Solar Water Heaters

DATA	2005	2010	2010	2020	2030	2035
	Installed Base	Current Standard	Typical / ENERGY STAR[2]	Typical[2]	Typical[2]	Typical[2]
Typical Capacity (sq. ft.)	42-63	NA	42-63	42-63	42-63	42-63
Overall Efficiency (Solar Fraction)	0.5	NA	0.5	0.5	0.5	0.5
Solar Energy Factor	2.5	NA	2.5	3	3.5	3.5
Average Life (yrs)	20	NA	20	20	20	20
Retail Equipment Cost[1] ($)	3300-5200	NA	3300-5200	3000-4700	2600-4100	2600-4100
Total Installed Cost[1] ($)	7600-10000	NA	7600-10,000	7300-9500	6900-8900	6900-8900
Annual Maintenance Cost ($)	25	NA	25	25	25	25

[1] Costs are for an indirect (active closed loop) system, including tank and backup heater. Smaller capacity/cost systems are typical for southern & western states (>2/3 of the current market). Higher capacity/cost systems are required in colder/cloudier regions.

[2] ENERGY STAR requires OG-300 rating from SRCC. Most installations use SRCC rated collectors; a high efficiency option is not applicable.

- ENERGY STAR requires an OG-300 rating from the Solar Rating and Certification Corporation (SRCC). Most installations use SRCC rated collectors, so there is no high efficiency category.
- Solar water heaters (SWHs) can be either active or passive. An active system uses an electric pump to circulate the heat transfer fluid; a passive system has no pump. Most solar water heaters in the United States are the active type.
- Solar water heaters are also characterized as open loop (also called "direct") or closed loop (also called "indirect"). An open-loop system circulates household (potable) water through the collector. A closed-loop system uses a heat transfer fluid (water or diluted antifreeze, for example) to collect heat and a heat exchanger to transfer the heat to household water.
- Solar fraction represents the fraction of total annual water heating energy met by the solar water heater. A backup water heating system is required with SWHs, and it is typically most economical to size the system to provide about 50% of water heating energy (solar fraction = 0.5).
- Solar Energy Factor (SEF) is defined by the SRCC as the useful energy delivered by the system divided by the total electrical and/or fossil fuel required for backup heating, pumping, and controls (the free solar energy input is neglected).
- Over 2/3 of the current SWH market is in the southern or western US (including Hawaii). The collector area of 42 ft^2 would be typical for these areas. Colder areas of the US would require a larger collector (63 ft^2).
- Installed costs are higher for colder areas where larger collectors are required. Costs also vary widely depending on collector quality, type of system, and site-specific characteristics.

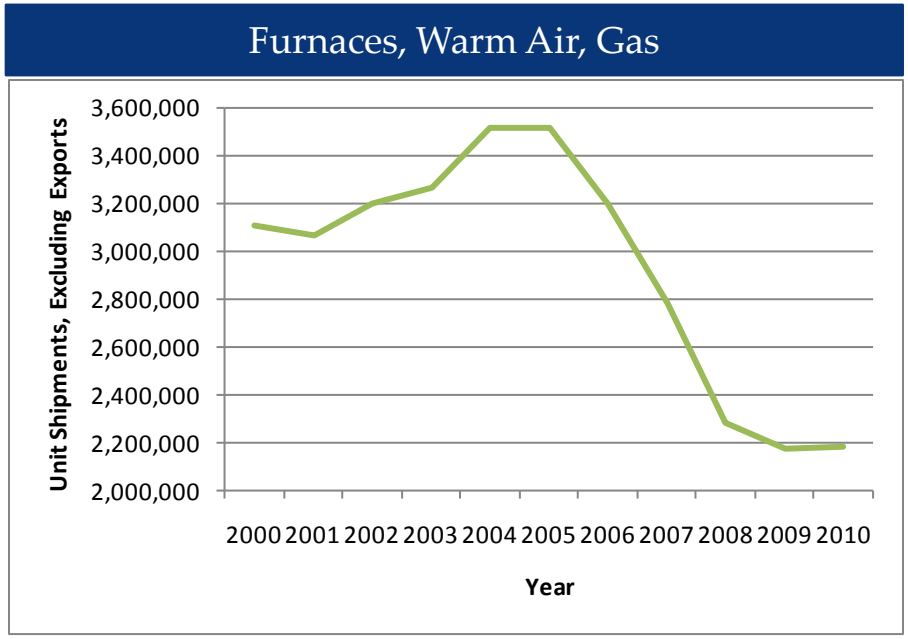
Performance / Cost Characteristics » Residential Gas-Fired Furnaces

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)	75	75	75	75	75	75	75	75	75	75	75
AFUE (%)	78	78	80	90	98	90	98	90	98	90	98
Electric Consumption (kWh/yr)	780	780	430	371	340	371	340	371	340	371	340
Average Life (yrs)	15-25	15-25	15-25	15-25	15-25	15-25	15-25	15-25	15-25	15-25	15-25
Retail Equipment Cost ($)	700-800	700-800	700-800	1200-2200	2200-3200	1200-2200	1700-1800	1200-2200	1700-1800	1200-2200	1700-1800
Total Installed Cost ($)	2000-3000	2000-3000	2000-3000	2500-3000	3500-4000	2500-3000	3000-3500	2500-3000	3000-3500	2500-3000	3000-3500
Annual Maintenance Cost ($)	50	50	50	50	50	50	50	50	50	50	50

Performance / Cost Characteristics » Residential Gas-Fired Furnaces

- The current standard for residential gas-fired furnaces is 78% AFUE; however, virtually all furnaces on the market have an AFUE of 80% or better.
- The minimum criteria for an ENERGY STAR qualified gas-fired furnace is 90% AFUE.
- York and Lennox manufacture the highest efficiency models currently available on the market, which have an efficiency of 98%.
- Condensing furnaces use an additional heat exchanger to extract additional energy from the flue gases; some models also have variable speed blowers, which decrease electrical energy consumption, and inducer fan systems, which usually have modulating gas valves to allow the furnace to modulate in very small increments, providing an AFUE boost of a few percent.
- Non-condensing AFUE levels for natural gas top out at around 81%; above this level, the potential for exhaust gas condensation increases. This condensate is corrosive and will breach the appliance or vent over time and hence allow flue gases into the structure.
- High-efficiency condensing furnaces typically have aluminized steel heat exchangers and low NO_x emissions, flexible installation, direct vent, and sealed combustion systems. The furnace does not use room air for combustion, but instead draws the combustion air directly from outdoors.
- Depending on the location of the home, piping materials in use, and other considerations, condensing furnaces may need an acid neutralizer and/or lift pump for the condensate.
- Furnaces may contain PSC or electronically commutated motors (ECM) fan motors, though the type of motor has no impact on the AFUE measurement. It only impacts SEER/EER of the associated air conditioner.

Since the last analysis was performed in 2007, there has been a decrease in gas-fired furnace shipments.



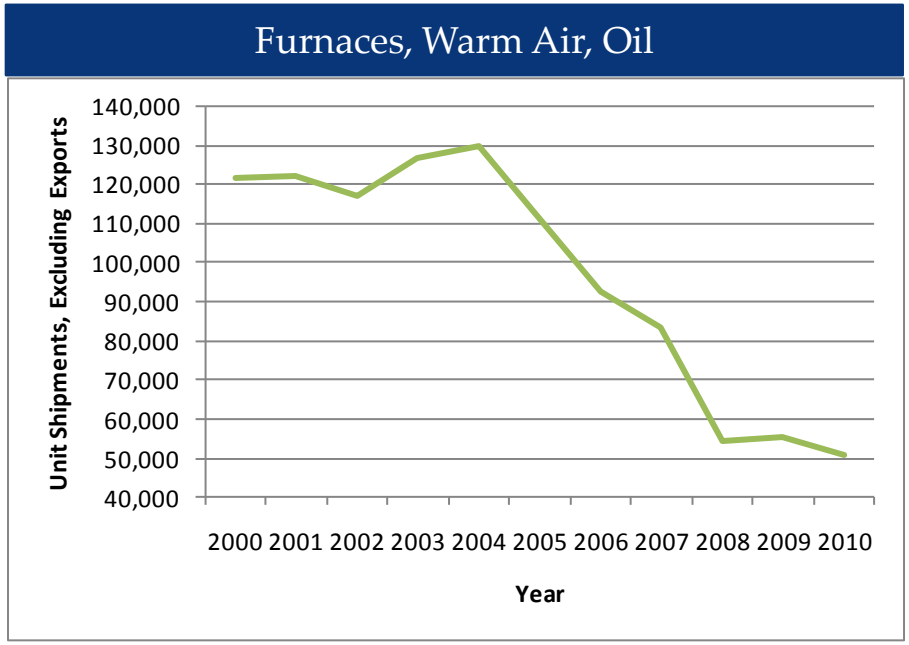
Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Performance / Cost Characteristics » Residential Oil-Fired Furnaces

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)	105	105	105	105	105	105	105	105	105	105	105
AFUE (%)	80	78	80	85	98	82	98	82	98	82	98
Electric Consumption (kWh/yr)	1001	1001	1001	944	900	950	900	950	900	950	900
Average Life (yrs)	15-25	15-25	15-25	15-25	15-25	15-25	15-25	15-25	15-25	15-25	15-25
Retail Equipment Cost ($)	2000-2200	2000-2200	2000-2200	2200-2800	3200-3800	1900-2100	3200-3800	1800-2000	3200-3800	1775-1975	3200-3800
Total Installed Cost ($)	3000-3500	3000-3500	3000-3500	3500-4000	4500-5000	2900-3100	4500-5000	2800-3000	4500-5000	2775-2975	4500-5000
Annual Maintenance Cost ($)	120	120	120	120	120	120	120	120	120	120	120

- The current NAECA Standard for oil-fired, forced air furnaces is 78% AFUE.
- The ENERGY STAR criteria for oil-fired furnaces is 85% AFUE.
- Since the latent heat content of oil is lower than that for either propane or natural gas, oil-fired appliances can typically operate at a higher AFUE rating than comparable gas-fired appliances before condensation issues arise.
- There are condensing residential oil-fired furnaces on the market that operate at about 95% AFUE. They have a tiny market share (<1%), due to market acceptance issues.
- Condensate from condensing oil furnaces is typically even more corrosive than that of gas-fired systems due to the higher sulfur content in fuel oil. Hence, condensing oil furnaces also likely require the use of an acid neutralizer.
- Oil-fired furnaces, like gas-fired furnaces, achieve condensing conditions through the use of a secondary heat exchanger. Typically, these heat exchangers use a high-grade stainless steel (Al29-4C) as the primary heat exchange surface.
- Sooting is an issue for all oil-fired appliances, but secondary heat exchangers, with their narrow passages, are even more prone to be plugged by soot. Because of this, oil furnaces require frequent cleaning and maintenance.

Since the last analysis was performed in 2007, there was initially a decrease with a recent slight increase in oil-fired furnace shipments.



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Performance / Cost Characteristics » Residential Hydronic Heating Systems (Boilers)

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)	105	105	105	105	105	105	105	105	105	105	105
AFUE (%)	78	80	82	85	98	82	98	82	98	82	98
Average Life (yrs)	20-30	20-30	20-30	20-30	20-30	20-30	20-30	20-30	20-30	20-30	20-30
Retail Equipment Cost ($)	1000-1100	1000-1800	1200-2000	2100-2500	2500-3500	1200-2000	2500-3500	1200-2000	2500-3500	1200-2000	2500-3500
Total Installed Cost ($)	2800-2900	2800-3800	3000-4000	4000-4500	4500-5500	3000-4000	4500-5500	3000-4000	4500-5500	3000-4000	4500-5500
Annual Maintenance Cost ($)	130	130	130	130	130	130	130	130	130	130	130

- The NAECA standard for hot-water residential gas boilers is 80% AFUE, while the ENERGY STAR standard for boilers is 85% AFUE. The highest available efficiency is 98% AFUE.
- Hydronic systems represent about 6% of all U.S. residential heating systems.
- The bulk of U.S. boiler sales is for non-condensing boilers, primarily manufactured in North America. These are typically high-mass systems whose heat exchangers are made of iron or steel and which have simple on/off burners.
- Due to incentives and market pressure, the U.S. boiler industry has been shifting towards also providing condensing boilers. Most of these boilers are private-labeled products sourced from Europe, where the hydronic market is much bigger and condensing appliances are much more common and/or required by law.
- Typically, condensing boilers are low-mass in construction with modulating burners, variable-speed inducer fan systems, sealed powered direct-vent combustion, multiple sensor technologies, and electronic ignition and control.
- Most value-added components for condensing boilers are sourced abroad, even when the condensing boiler is assembled in North America (i.e. heat exchanger, gas valve, burner, blower systems, sensors, and/or controls).

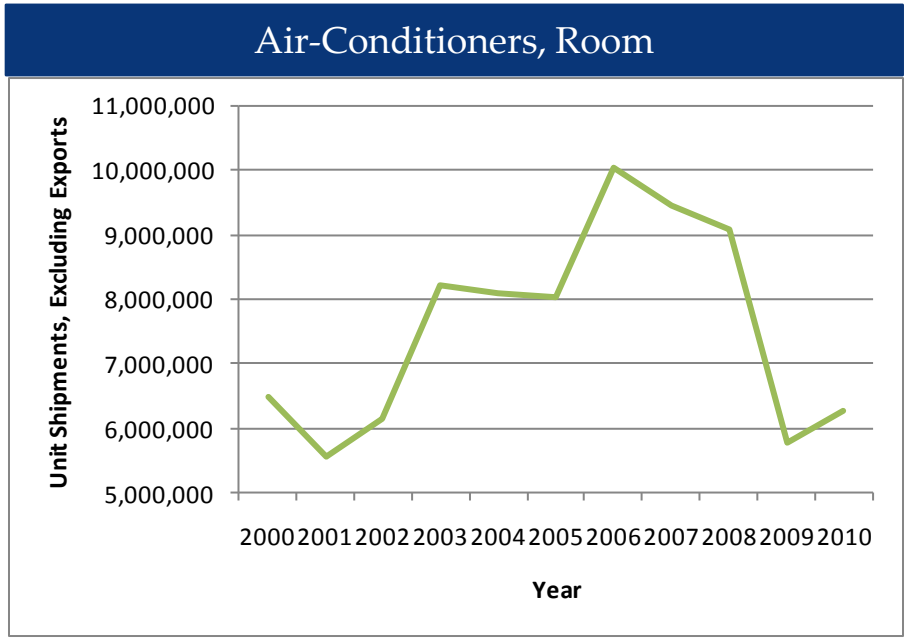
Performance / Cost Characteristics » Residential Room Air Conditioners

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
EER	8.7	9.8	9.8	10.8	11.5	11.0	11.5	11	13	11.2	13
Average Life (yrs)	9-13	9-13	9-13	9-13	9-13	9-13	9-13	9-13	9-13	9-13	9-13
Retail Equipment Cost ($)	190-265	230-300	230-300	250-320	400-470	250-320	400-470	250-320	480-550	250-320	480-550
Total Installed Cost ($)	190-265	230-300	230-300	250-320	400-470	250-320	400-470	250-320	480-550	250-320	480-550
Annual Maintenance Cost ($)*	-	-	-	-	-	-	-	-	-	-	-

* Annual Maintenance Cost is negligible

- The residential room air conditioners analyzed in this study are window room air conditioners.
- The ENERGY STAR criteria requires an EER of 10.8, which also represents the most common efficiency on the market.
- According to the AHAM Directory of Certified Products, the most efficient product on the market has an EER of 11.5. Based on the DOE Building Technologies Program (BTP) R&D, it is anticipated that units may reach an EER of 13.0 by 2030.
- A wider range of costs reflects a variation in the marketplace
- It is assumed that the homeowners will install their own room air conditioner.
- Efficiency improvements are attained by:
  - Higher efficiency compressor and fan motors, and
  - An increased heat transfer area in the evaporator and condenser through the use of larger heat exchangers, finer fin spacing, micro-channel heat exchangers, and similar design options.
- According to the ACEEE – AHAM Consensus Agreement, the Federal standards will be updated in 2014 from 9.8 to 11.0

Since the last analysis was performed in 2007, there has been a decrease in room air conditioner shipments.



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Performance / Cost Characteristics » Residential Central Air Conditioners

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)	36	36	36	36	36	36	36	36	36	36	36
SEER	10.2	13	13.7	14.5	24	14	24	14.5	24	15	24
Average Life (yrs)	14-19	14-19	14-19	14-19	14-19	14-19	14-19	14-19	14-19	14-19	14-19
Retail Equipment Cost ($)	1000-1500	2000-2500	2050-3750	2500-4200	6500-13500	2500-4200	6500-13500	2500-4200	6500-13500	2750-4250	6500-13500
Total Installed Cost ($)	2500-2700	2500-3500	2550-4750	3000-5200	7000-14500	3000-5200	7000-14500	3000-5200	7000-14500	3250-5250	7000-14500
Annual Maintenance Cost ($)	20-120	20-120	20-120	20-120	20-120	20-120	20-120	20-120	20-120	20-120	20-120

- The current NAECA minimum SEER is 13.0.
- The ENERGY STAR criteria is 14.5 SEER and 12 EER for split systems, which is close to the efficiency of the typical product on the market.
- Energy efficiency is driven by several factors:
  - Heat exchanger (surface area, number of tube rows, tube & fin vs. micro-channel)
  - Compressor choices (i.e., type of compressor and single-stage vs. two-stage vs. variable-speed operation)
  - Fan motor choices (PSC vs. ECM fan motors on inside and outside)
  - Control choices (i.e., piston, TXV, or EEV expansion devices)

  As an example, above 16 SEER, units typically have very large heat exchangers, an ECM evaporator fan motor and a two-stage scroll compressor.
- Variable-speed compressor technology typically leads to a significant SEER boost, but does not affect the EER. Manufacturers have used the SEER boost to develop high-SEER condensing units with smaller enclosures.
- Efficiency levels beyond 21 SEER are made possible through combining existing large heat exchangers with variable-speed compressors, ECM fan motors, and EEVs.

Performance / Cost Characteristics » Residential Air Source Heat Pumps

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)	36	36	36	36	36	36	36	36	36	36	36
HSPF (Heating)	6.8	8	8	8.2	10.7	8.1	10.8	8.3	10.9	8.5	11
SEER (Cooling)	10	14	14	14.5	22	14.2	23	15	24	15.3	25
Average Life (yrs)	14-16	14-16	14-16	14-16	14-16	14-16	14-16	14-16	14-16	14-16	14-16
Retail Equipment Cost ($)	3500-4000	4000-4500	4000-4500	5500-6000	7000-7500	4700-5200	7100-7600	6000-6500	7200-7700	6200-6700	7300-7800
Total Installed Cost ($)	4500-5500	4400-5500	4400-5500	5900-7000	7400-8500	5100-6200	7500-8600	6400-7500	7800-8700	6600-7700	7700-8800
Annual Maintenance Cost ($)	120	120	120	120	120	120	120	120	120	120	120

- The NAECA minimum HSPF is 7.7 and the minimum SEER is 13.
- The ENERGY STAR criteria states a minimum HSPF of 8.2 and a minimum SEER of 14.5.
- Heat pumps are generally sized to meet the cooling load of the house. When the heating load exceeds heat pump heating capacity, resistance heat is supplemented; however, when the heating capacity exceeds the heating load, the heat pump starts and stops more frequently, causing wear and tear on the components and an overall loss of efficiency. Multi-stage and/or variable-speed compressors can help, as does sophisticated refrigerant management.
- High efficiency cooling does not necessarily lead to high efficiency heating. The range of SEER/HSPF combinations is very broad.

Performance / Cost Characteristics » Residential Ground Source Heat Pumps

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)	36	36	36	36	36	36	36	36	36	36	36
COP (Heating)	3	3.1	3.1	3.5	4.3	3.1	5	3.1	5	3.1	5
EER (Cooling)	12	13.4	13.4	16.1	23	13.4	30	13.4	30	13.4	30
Average Life (yrs)	25	25	25	25	25	25	25	25	25	25	25
Retail Equipment Cost ($)	4000-6000	4000-6000	4000-6000	5000-7000	7000-9000	4000-6000	7000-9000	4000-6000	7000-9000	4000-6000	7000-9000
Total Installed Cost ($)	9000-11000	9000-11000	9000-11000	10000-12000	12000-14000	9000-11000	12000-14000	9000-11000	12000-14000	9000-11000	12000-14000
Annual Maintenance Cost ($)	70	70	70	70	70	70	70	70	70	70	70

- There are currently 19 ground source heat pump manufacturers in the US.
- Heating COP does not correlate with cooling EER (coefficient of determination, R^2 = 0.62). The highest efficiency GSHP is the Envision by WaterFurnace International, Inc. (30 EER & 5.0 COP).
- The ENERGY STAR® criteria for water-to-air ground source heat pumps are:

Type	Tier 1 (12/1/2009)		Tier 2 (1/1/2011)		Tier 3 (1/1/2012)	
	Heating COP	Cooling EER	Heating COP	Cooling EER	Heating COP	Cooling EER
Closed Loop	3.3	14.1	3.5	16.1	3.6	17.1
Open Loop	3.6	16.2	3.8	18.2	4.1	21.1
Direct Expansion	3.5	15	3.6	16	3.6	16

- The most common ground source heat pump is a closed-loop system in which water or an anti-freeze solution is circulated through plastic pipes buried underground. Open loop systems that employ ground water or surface water (e.g., open well, pond, lake) are used in some parts of the country, but water supply and water quality issues impose limitations on such applications.
- Installation cost is for a closed loop system and includes necessary accessories. The ground loop heat exchanger represents a majority of the installation cost.
- Electronically commutated motors (ECMs) improve performance on high end models.

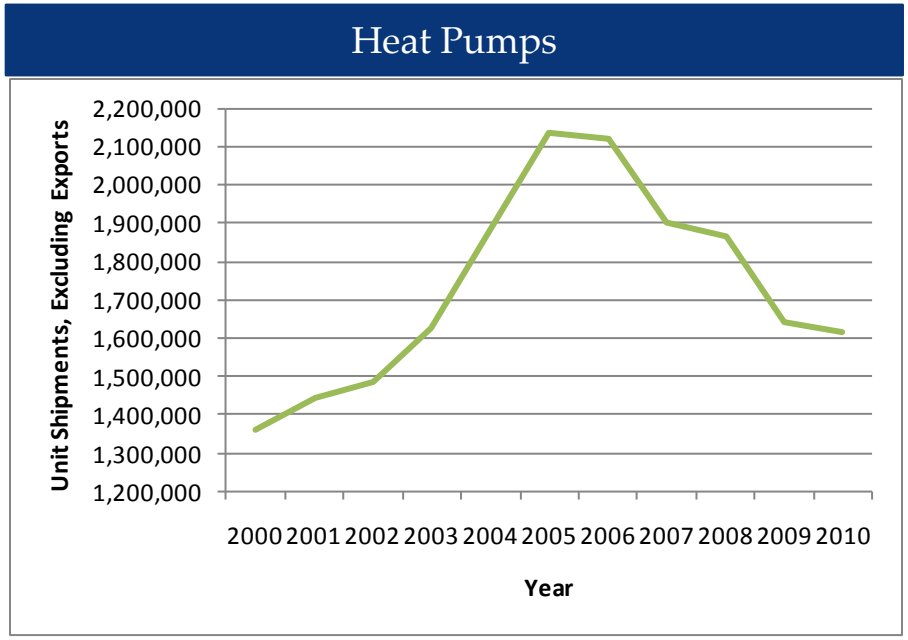
Performance / Cost Characteristics » Residential Gas Heat Pumps

DATA	2005	2010	2010	2020	2030	2035
	Installed Base	Current Standard[1]	Typical	Typical	Typical	Typical
Typical Capacity (kBTU/h)	60	60	60	60	60	60
Heating (GCOP)	1.3	NA	1.3	1.3	1.3	1.3
Cooling (GCOP)	0.6	NA	0.6	0.7	0.7	0.7
Annual Electric Use (kWh/yr)	2000	2000	2000	1500	1500	1500
Average Life (yrs)	15	15	15	15	15	15
Retail Equipment Cost ($)	6500-7500	6500-7500	6500-7500	6500-7500	6500-7500	6500-7500
Total Installed Cost ($)	8500-9500	8500-9500	8500-9500	8500-9500	8500-9500	8500-9500
Annual Maintenance Cost ($)	150	150	150	150	150	150

[1]NAECA does not cover residential gas heat pumps, but the CEC Title 24, Part 6 Section 112 does indicate minimum cooling efficiency for gas heat pumps.

- Residential Gas Heat Pumps are not currently covered by NAECA. CEC Title 24, Part 6 Section 112 does indicate cooling efficiency requirements for gas heat pumps, and two residential size units are listed there; Robur and Yazaki. Both units are 5-ton cooling capacity, a size typically associated with larger homes. The Yazaki unit offers cooling only and appears to be available only in Europe at the moment. Since only one product is available, no mid-level or high efficiency categories are included.
- The data represents air-source absorption heat pumps. Gas engine-driven vapor compression heat pumps are available in other parts of the world; York formerly offered the Triathlon gas engine-driven heat pump in the US. It is possible to couple either technology to the ground (ground source) rather than the atmosphere (air source).
- The absorption heat pump is a gas-fired, ammonia-water absorption cycle, combined with a high-efficiency low-pressure boiler integrated into one outdoor unit.
- The cooling efficiency of a gas-fired air source absorption heat pump is considerably lower than for an electric air source heat pump. Heating efficiency of an air source heat pump (electric or gas-fired absorption) decreases as outdoor temperature decreases; however the gas-fired absorption heat pump recovers waste heat from the combustion process to improve heating efficiency.
- Gas-fired cooling equipment currently comprises less than 1% of the residential air conditioning/heat pump market.

Since the last analysis was performed in 2007, there has been a decrease in both air source and ground source heat pump shipments.



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Performance / Cost Characteristics » Residential Refrigerator / Freezer

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Capacity (cu. ft.)*	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6
Energy Consumption (kWh/yr)	840	453	475	408	285	475	285	475	285	475	285
Average Life (yrs)	12-19	12-19	12-19	12-19	12-19	12-19	12-19	12-19	12-19	12-19	12-19
Retail Equipment Cost ($)	200-400	400-500	400-500	425-525	800-1200	400-500	800-1200	400-500	800-1200	400-500	800-1200
Total Installed Cost ($)	200-500	400-600	400-600	425-625	800-1300	400-600	800-1300	400-600	800-1300	400-600	800-1300
Annual Maintenance Cost ($)**	6	6	6	6	6	6	6	6	6	6	6

* Capacity is the nominal volume (not adjusted volume)
**Annual Maintenance Cost is negligible

Performance / Cost Characteristics » Residential Refrigerator / Freezer

- The current NAECA standard for a typical top-mount refrigerator/freezers is 453 kWh/yr while the typical top-mount refrigerator/freezer currently consumes approximately 475 kWh/yr. The best available top-mount refrigerator/freezer uses 285 kWh/yr.
- According to NAECA standards, for a refrigerator/freezer to qualify as ENERGY STAR, it must be at least 20% more energy efficient than the minimum Federal government standard. This equates to an annual energy use of approximately 408 kWh/yr.
- EISA 2007 requires that DOE publish a final rule no later than December 31, 2010 to determine whether to amend the standards in effect for products manufactured on or after January 1, 2014.
- A wider range of costs reflects a variation in the marketplace
- Improvement opportunities include:
  - Higher efficiency and/or variable-speed compressor systems
  - Larger heat exchangers
  - Permanent-magnet fan systems (vs. SPM and PSC fan motors)
  - Demand defrost systems
  - Vacuum-insulated panels
  - Thicker insulation (though at a loss of consumer utility)
  - Better gasketing
  - Refrigerants (Isobutane vs. R134a)
- All manufacturers are using at least some of these technologies in an attempt to reach ENERGY STAR qualification.
- According to the ACEEE – AHAM Consensus Agreement, the Joint Stakeholders agree to jointly petition DOE to initiate a rulemaking by January 1, 2012 to be completed by December 31, 2012 to revise the test procedure for refrigerators/freezers to incorporate measured ice maker energy use. Additionally, the Federal standards will be revised in 2014. For top-mount units without ice makers, the standard is represented by 7.35 AV+ 207.0 and for units with ice makers, the standard is represented by 7.65 AV+ 267.0, where AV is the adjusted volume.[1]

[1]Adjusted Volume (AV) for refrigerators is calculated as follows: AV = (Fresh Volume) + 1.63 x (Freezer Volume). When the new rulemaking is published, the formula for AV will become: AV = (Fresh Volume) + 1.76 x (Freezer Volume).

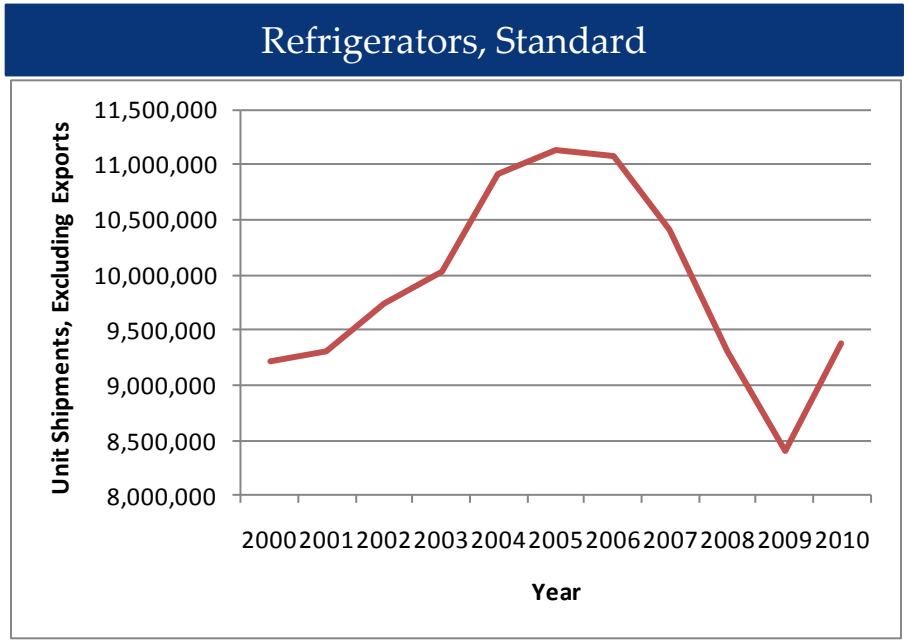
Performance / Cost Characteristics » Residential Refrigerator / Freezer

- This analysis focuses on top-mount refrigerator-freezers because they have the largest market share of all refrigerator-freezer product classes at 50.6%*. The market share for bottom- and side-mount refrigerator-freezers are as follows:
  - Bottom-mount: 12.5%*
  - Side-mount: 26.9%*
- When looking at all product classes, the energy consumption ranges from approximately 790 kWh/yr** to 230 kWh/yr, with the typical energy consumption at the current standard level.
- There are also significant differences in average equipment cost across the product classes:
  - Top-mount: $400-$1500
  - Bottom-mount: $800-$2800
  - Side-mount: $1000-$1800

* 2008 data from Technical Support Document
** A product operating at this level is less efficient than the current Federal standard

Sources: CEC, AHAM, Technical Support Document

Since the last analysis was performed in 2007, there has been a decrease in standard residential refrigerator / freezer shipments.



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

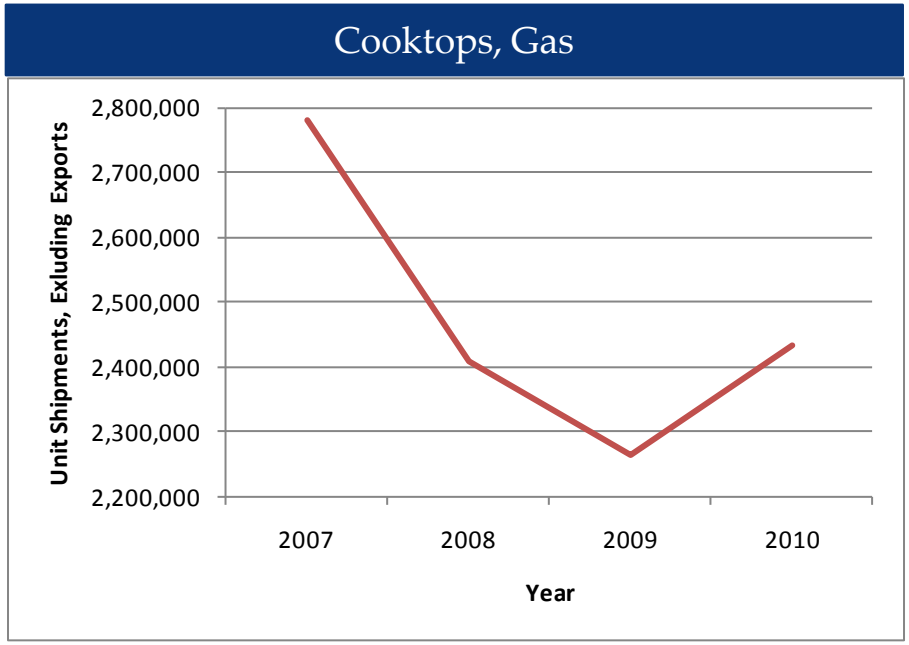
Performance / Cost Characteristics » Residential Natural Gas Cooktops

DATA	2005	2010		2020		2030		2035	
	Installed Base	Typical	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)	9-12	9-12	9-12	9-12	9-12	9-12	9-12	9-12	9-12
Cooking Efficiency (%)	38	39.9	42	39.9	42	39.9	42	39.9	42
Average Life (yrs)	17-18	17-18	17-18	17-18	17-18	17-18	17-18	17-18	17-18
Retail Equipment Cost ($)	225-300	250-350	375-450	250-350	375-450	250-350	375-450	250-350	375-450
Total Installed Cost ($)	275-350	300-400	425-500	300-400	425-500	300-400	425-500	300-400	425-500
Annual Maintenance Cost ($)*	-	-	-	-	-	-	-	-	-

* Annual Maintenance Cost is negligible

- Efficiency levels vary little for cooktops on the market.
- The typical model on the market has a cooking efficiency of 39.9% and the highest efficiency model on the market has a cooking efficiency of 42%.

Since the last analysis was performed in 2007, there has been a decrease in residential natural gas cooktop shipments.



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Data is unavailable for dates prior to 2007.

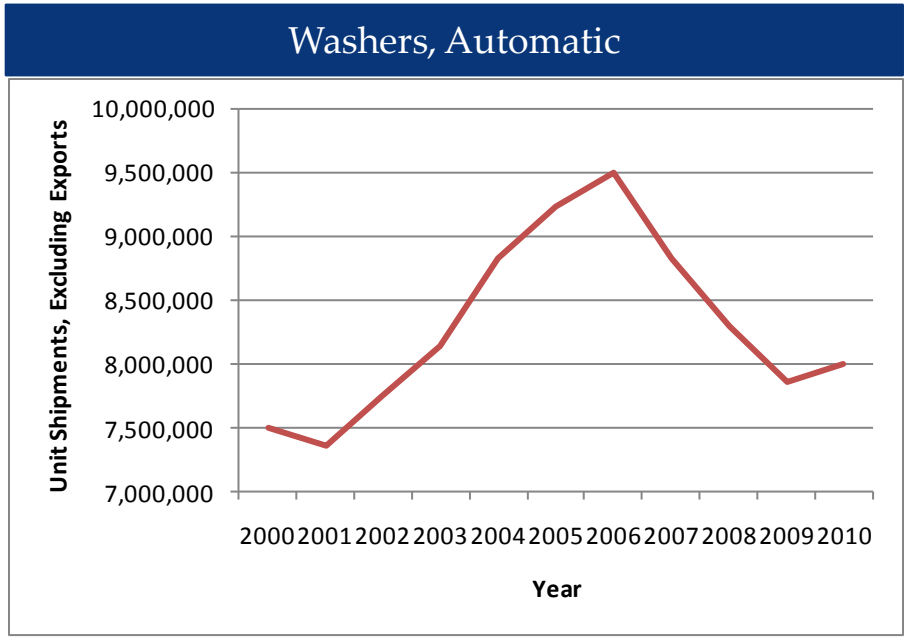
Performance / Cost Characteristics » Residential Clothes Washers

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Capacity (ft3)	3	3.2	3	2.7	3.5	2.7	3.5	2.7	3.5	2.7	3.5
Modified Energy Factor (ft3/kWh/cycle)	2	1.26	2	2	3.88	2.2	3.88	2.2	3.88	2.2	3.88
Average Life (yrs)	12-15	12-15	12-15	12-15	12-15	12-15	12-15	12-15	12-15	12-15	12-15
Water Consumption (gal/cycle)	14	30	11	20	13	11	13	11	13	11	13
Hot Water Energy (kWh/cycle)	0.4	0.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Machine Energy (kWh/cycle)	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dryer Energy (kWh/cycle)	0.7	1.0	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Retail Equipment Cost ($)	550-700	360-440	550-700	550-700	800-900	550-700	850-950	550-700	850-950	550-700	850-950
Total Installed Cost ($)	650-800	460-540	650-800	650-800	900-1000	650-800	950-1050	650-800	950-1050	650-800	950-1050
Annual Maintenance Cost ($)*	-	-	-	-	-	-	-	-	-	-	-

* Annual Maintenance Cost is negligible

- This analysis examined front-loading residential clothes washers. It should be noted that there are high efficiency top-loading residential clothes washers on the market as well, though front-loaders are inherently more efficient than top-loaders.
- The current standard for standard-size front-loading and top-loading clothes washers is a modified energy factor (MEF) of 1.26. The ENERGY STAR criteria is 2 MEF; however, the most common front-loading models on the market exceed the ENERGY STAR criteria and have a MEF of 2.2.
- Only clothes washers with capacities of greater than 1.6 ft^3 are eligible to earn ENERGY STAR.
- Energy efficiency improvement opportunities include:
  - Higher efficiency motors and higher spin speeds
  - Better load sensing (soiling and size and type of load)
  - Better controls / greater number of wash programs
- The annual maintenance cost for residential clothes washers is negligible.
- According to the ACEEE – AHAM Consensus Agreement, the Federal standards front-loading residential clothes washers will be updated in 2015 (and will remain current through the 2018 standard updates) to a MEF of 2.2 and a water factor (WF) of 4.5

Since the last analysis was performed in 2007, there has been a decrease in automatic residential clothes washer shipments.



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Performance / Cost Characteristics » Residential Clothes Dryers

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	Mid-Level	High	Typical	High	Typical	High	Typical	High
Typical Capacity (ft^3)	7	7	7	7	7	7	7	7	7	7	7
EF (lb/kWh)	electric: 3.01 gas: 2.67	electric: 3.01 gas: 2.67	electric: 3.1 gas: 2.75	gas: 2.85	electric: 3.16 gas: 3.02	electric: 3.17 gas: 2.81	electric: 4.51 gas: 3.02	electric: 3.17 gas: 2.81	electric: 4.51 gas: 3.02	electric: 3.17 gas: 2.81	electric: 4.51 gas: 3.02
Average Life (yrs)	12-19	12-19	12-19	12-19	12-19	12-19	12-19	12-19	12-19	12-19	12-19
Retail Equipment Cost ($)	electric: 400-500 gas: 450-550	electric: 400-500 gas: 450-550	electric: 450-550 gas: 550-600	gas: 650-750	electric: 550-650 gas: 850-950	electric: 450-550 gas: 550-600	electric: 650-750 gas: 850-950	electric: 450-550 gas: 550-600	electric: 650-750 gas: 850-950	electric: 450-550 gas: 550-600	electric: 650-750 gas: 850-950
Total Installed Cost ($)	electric: 500-600 gas: 600-700	electric: 500-600 gas: 600-700	electric: 675-775 gas: 700-800	gas: 800-900	electric: 700-800 gas: 950-1050	electric: 675-775 gas: 700-800	electric: 900-1000 gas: 950-1050	electric: 675-775 gas: 700-800	electric: 900-1000 gas: 950-1050	electric: 675-775 gas: 700-800	electric: 900-1000 gas: 950-1050
Annual Maintenance Cost ($)*	-	-	-	-	-	-	-	-	-	-	-

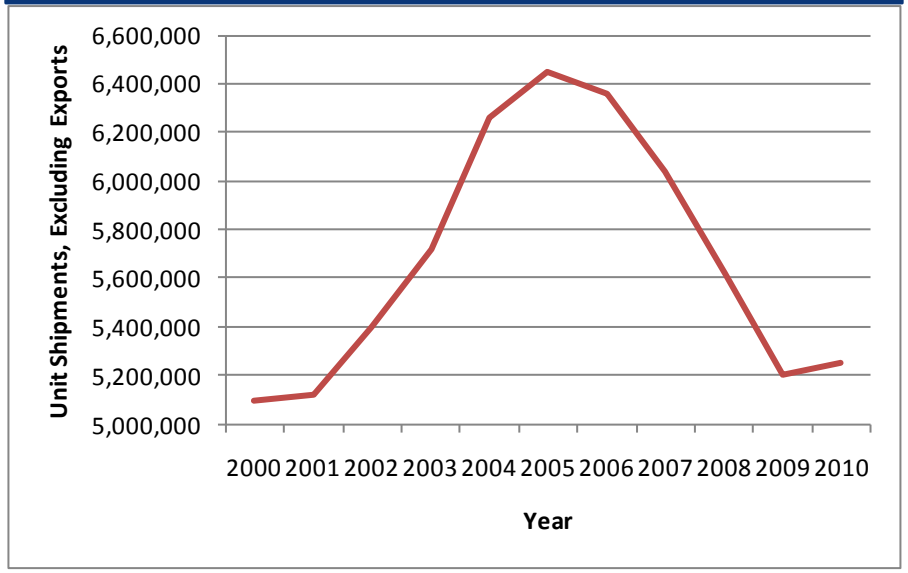
* Annual Maintenance Cost is negligible

Performance / Cost Characteristics » Residential Clothes Dryers

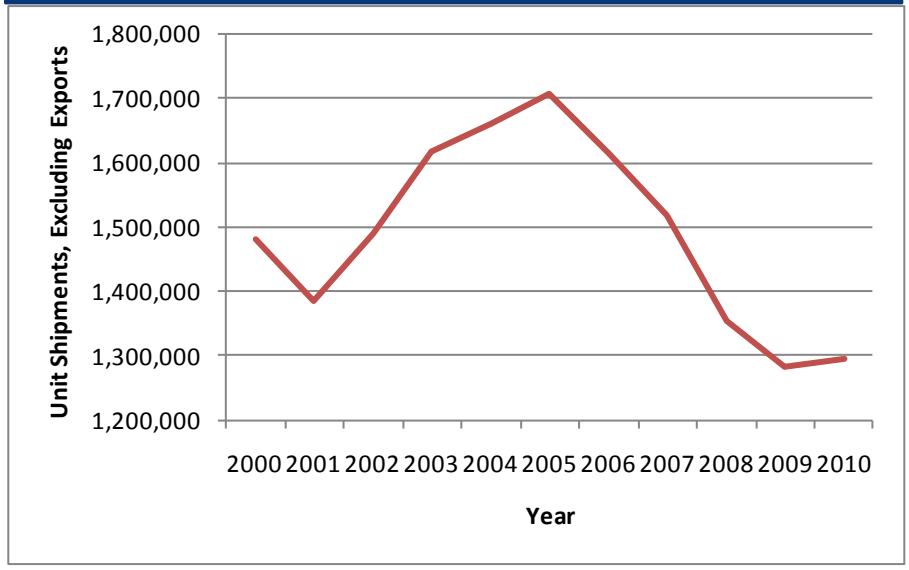
- The test procedure for residential clothes dryers was recently amended to include a new efficiency metric, combined energy factor (CEF), which adds a measure of standby/off-mode power. Although EF and CEF are both expressed in lbs/kWh of energy use, they can not be compared side-by-side since they are calculated differently.
- There are both gas and electric models of clothes dryers on the market:
  - For gas clothes dryers, the standard efficiency is 2.67 lb/kWh (CEF = 3.14 lb/kWh)
  - For electric clothes dryers, the standard efficiency is 3.01 lb/kWh (CEF = 3.55 lb/kWh)
- Improvement opportunities include:
  - Multi-step or modulating heat
  - Higher efficiency drum motors
  - Inlet air pre-heat
  - Heat pump (for electric clothes dryers): heat pump residential clothes dryers are currently available in Europe and are anticipated to make it to the US market by 2020.
  - Better control systems for cycle termination (not reflected per the current test procedure, however)
- No ENERGY STAR incentives currently exist to motivate manufacturers to adapt to existing energy efficiency opportunities. This is an especially important factor for heat pumps due to the high initial cost and the potential reliability issues.
- The high electric clothes dryer EF value of 4.51 represents a product with heat pump technology, which is planned to enter the market around 2020.
- According to the ACEEE – AHAM Consensus Agreement, the Federal standards will be revised in 2015.
  - For gas clothes dryers, the standard efficiency will be 2.81 lb/kWh (CEF = 3.30 lb/kWh)
  - For electric clothes dryers, the standard efficiency will be 3.17 lb/kWh (CEF = 3.73 lb/kWh)

Since the last analysis was performed in 2007, there has been a decrease in residential clothes dryer shipments.

Dryers, Electric



Dryers, Gas



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

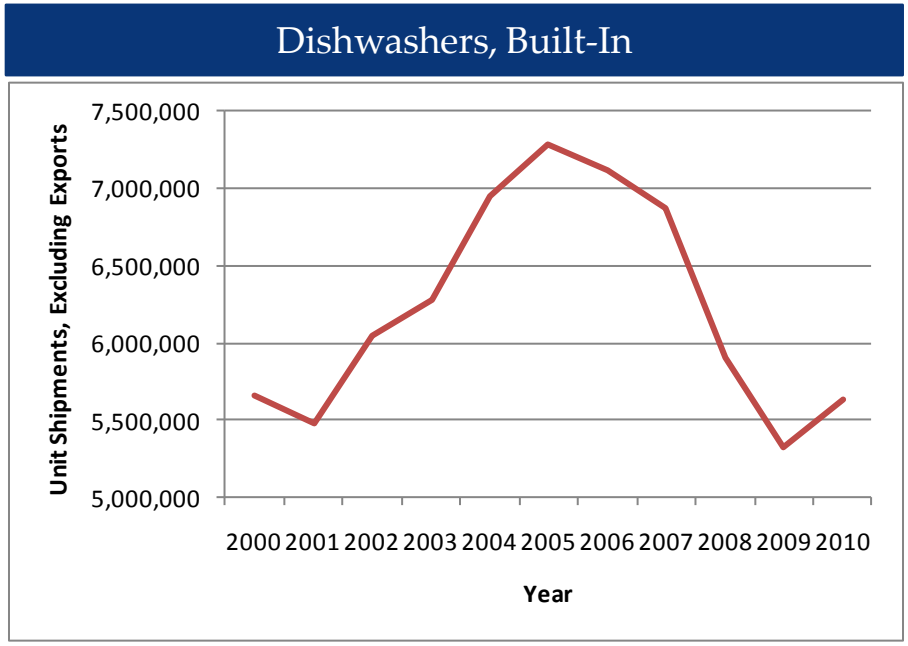
Performance / Cost Characteristics » Residential Dishwashers

DATA	2005	2010	2010			2020		2030		2035	
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical	High	Typical	High	Typical	High
Typical Annual Use (kWh/yr)	720	355	355	324	190	307	190	307	190	307	190
Efficiency (cycle/kWh)	0.30	0.61	0.61	0.66	1.13	0.70	1.13	0.70	1.13	0.70	1.13
Annual Hot Water Energy Use (kWh/yr)	286	261	261	185	100	180	100	180	100	180	100
Average Life (yrs)	10-13	10-13	10-13	10-13	10-13	10-13	10-13	10-13	10-13	10-13	10-13
Retail Equipment Cost ($)	200-300	200-300	200-300	300-1200	900	200-300	900	200-300	900	200-300	900
Total Installed Cost ($)	300-400	300-400	300-400	400-1300	1200	300-400	1200	300-400	1200	300-400	1200
Annual Maintenance Cost ($)	-	-	-	-	-	-	-	-	-	-	-

* Annual Maintenance Cost is negligible

- The current standard was established by the EISA 2007 amendments to EPCA and stipulates a maximum of 355 kWh/yr of energy use and 6.5 gal/cycle of water use for standard sized dishwashers, which typically handle eight place settings plus six serving pieces.
- The current ENERGY STAR qualifying criteria require a maximum of 324 kWh/yr of energy use and 5.8 gal/cycle of water use for standard sized dishwashers.
- We are assuming that a typical residential dishwasher completes 215 cycles/year
- The most efficient dishwasher has an annual energy use of 190 kWh/yr, but at a high retail price and very small market share. Typical high efficiency units have an EF closer to the current standard.
- Dishwasher annual energy use is based on the U.S. DOE test procedure. This procedure is based on total energy use - including motor, dryer, booster heater (if present), and for hot water required from the water heater. The previous U.S. DOE test procedure was based on a usage estimate of 322 cycles per year, but as of September 2003 a new test procedure of 215 cycles per year was implemented.
- Efficiency improvement opportunities include:
  - Better soil sensing in the water, the filter, and the controls to make use of that
  - Water distribution (small pipes, fine filter, small sump, alternating water use)
  - Inline water heater (to minimize sump volume)
  - High-efficiency, variable-speed pump motor
  - Vent assembly to help drying of dishes
- According to the ACEEE – AHAM Consensus Agreement, the Federal standards will be revised in 2013. The updated standard stipulates a maximum of 307 kwh/year and 5.0 gal/cycle of water use.

Since the last analysis was performed in 2007, there has been a decrease in residential dishwasher shipments.



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Performance / Cost Characteristics » Commercial Gas-Fired Furnaces

DATA	2003	2007	2010	2010		2020		2030		2035	
	Installed Base		Current Standard	Typical	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)*	400	400	400	400	400	400	400	400	400	400	400
Combustion Efficiency (%)**	76	77	80	80	82	80	90	80	91	80	93
Average Life (yrs)	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20
Retail Equipment Cost ($)	1800-2000	2000-2400	2700-2900	2700-2900	2900-3200	2700-2900	3360-3660	2700-2900	3830-4130	2700-2900	4060-4360
Total Installed Cost ($)	2800-3000	3000-3500	3050-3275	3050-3275	3275-3625	3050-3275	3735-4035	3050-3275	4205-4505	3050-3275	4435-4735
Annual Maintenance Cost ($)	300	300	300	300	300	300	300	300	300	300	300

*Capacity is *input*
** Gas furnaces less than 225,000 Btu/hr are rated by AFUE. Furnaces larger than 225,000 Btu/hr must been an 80% combustion efficiency.

- EPACT standard for a gas-fired furnace is 80% combustion efficiency at maximum rated capacity.
- According to the U.S. DOE, combustion efficiency is a measure of how effectively the heat content of a fuel is transferred into usable heat.
- Commercial furnace efficiency ranges are as wide as those for residential and the technology options are similar (though usually scaled up).
- Besides scale, commercial units can differ in terms of the control system (i.e. integration with a Building Management System, twinning, or other staging strategies) and they may also use a heat recovery system to pre-heat inlet air.
- The maintenance cost is based on two cleanings per year.

Performance / Cost Characteristics » Commercial Oil-Fired Furnaces

DATA	2003	2007	2010	2010	2020	2030	2035
	Installed Base		Current Standard	Typical	Typical	Typical	Typical
Typical Capacity (kBTU/h)*	400	400	400	400	400	400	400
Thermal Efficiency (%)	81	81	81	82	82	82	82
Average Life (yrs)	17-20	17-20	17-20	17-20	17-20	17-20	17-20
Retail Equipment Cost ($)	3000-3600	3000-3600	3000-3600	3600-3700	3600-3700	3600-3700	3600-3700
Total Installed Cost ($)	3575-4125	3575-4125	3575-4125	4125-4225	4125-4225	4125-4225	4125-4225
Annual Maintenance Cost ($)	300	300	300	300	300	300	300

* Capacity is *input*

- Commercial oil-fired furnaces with a capacity of 225,000 BTU/h or more must meet a thermal efficiency standard of 81% as stipulated in ASHRAE Standard 90.1-2007. The ASHRAE standard also mandates that furnaces that are not within the conditioned space must not have jacket losses that exceed 0.75% of the input rating.
- According to the U.S. DOE, thermal efficiency is interpreted as what is commonly known as "combustion efficiency" in other contexts, *i.e., 100 percent minus percent* flue loss
- The maintenance cost is based on two cleanings per year.

Performance / Cost Characteristics » Commercial Electric Boilers

DATA	2003	2007	2010	2020	2030	2035
	Installed Base		Typical	Typical	Typical	Typical
Typical Capacity (kW)*	165	165	165	165	165	165
Efficiency (%)	98	98	98	98	98	98
Average Life (yrs)	15	15	15	15	15	15
Retail Equipment Cost ($)	6000-7000	6000-7000	6000-7000	6000-7000	6000-7000	6000-7000
Total Installed Cost ($)	7500-9000	7500-9000	7500-9000	7500-9000	7500-9000	7500-9000
Annual Maintenance Cost ($)	100-150	100-150	100-150	100-150	100-150	100-150

* Capacity is *output*

- There are currently no Federal standards associated with electric boilers.
- The costs shown are for one 165kW unit, which would equate to a steady load of approximately 550,000 Btu/hr.
- Service life is determined mainly by water quality. Water conditioning (e.g., filters, softeners, de-alkizers, chemical feeders) may be necessary for a given application.
- Annual maintenance in a typical application would include draining the unit for removal of any accumulated scale or sludge buildup.
- Minor end-use inefficiencies for electric boilers result from heat loss through the boiler (jacket losses).

Performance / Cost Characteristics » Commercial Gas-Fired Boilers

DATA	2003	2007	2010	2010			2020		2030		2035	
	Installed Base		Current Standard	Typical	Mid-Range	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)*	800	800	800	800	800	800	800	800	800	800	800	800
Combustion Efficiency (%)	76	77	80	80	90	98	80	98	82	98	82	98
Average Life (yrs)	20-30	20-30	20-30	20-30	20-30	20-30	20-30	20-30	20-30	20-30	20-30	20-30
Retail Equipment Cost ($)	5000-6000	7000-9000	9000-11000	9000-11000	13500-16500	22500-27500	13500-16500	22500-27500	13500-16500	22500-27500	13500-16500	22500-27500
Total Installed Cost ($)	12000-13000	14000-16000	16000-18000	16000-18000	20500-23500	29500-34500	20500-23500	29500-34500	20500-23500	29500-34500	20500-23500	29500-34500
Annual Maintenance Cost ($)	450	450	450	450	450	450	450	450	450	450	450	450

* Capacity is *output*

- The current requirement for gas-fired boilers is a minimum combustion efficiency of 80% at the maximum rated capacity.
- Similar technologies to the those used in the residential market can be leveraged in the commercial arena. The higher efficiency units typically include electronic ignition, power burners, and improved heat exchangers. They may even condense and/or pre-heat incoming air.
- Since the last ASHRAE standard was published, ASHRAE has changed the metric for stating the efficiency of most classes of commercial boilers, excluding large oil hot water and large gas hot water boilers. Federal standards express efficiency in terms of combustion efficiency while efficiency levels in ASHRAE 90.1-2007 are expressed in terms of thermal efficiency. The thermal efficiency descriptor, as used in Standard 90.1-2007, accounts for jacket losses as well as flue losses, while combustion efficiency only accounts for flue losses.
- Small, gas-fired, hot water, commercial packaged boilers (input capacity between 300,000 and 2,500,000 Btu/hr) are the largest commercial packaged boiler equipment class in the market.

Performance / Cost Characteristics » Commercial Oil-Fired Boilers

DATA	2003	2007	2010	2010		2020		2030		2035	
	Installed Base		Current Standard	Typical	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)*	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Thermal Efficiency (%)	79	80	83	83.5	98	83.5	98	83.5	98	83.5	98
Average Life (yrs)	25	25	25	25	25	25	25	25	25	25	25
Retail Equipment Cost ($)	11000-12000	11000-12000	12300-13400	12300-13400	24000-26000	12300-13400	24000-26000	12300-13400	24000-26000	12300-13400	24000-26000
Total Installed Cost ($)	15000-16000	15000-16000	16600-17700	16600-17700	30000-35000	16600-17700	30000-35000	16600-17700	30000-35000	16600-17700	30000-35000
Annual Maintenance Cost ($)	110-155	110-155	110-155	110-155	110-155	110-155	110-155	110-155	110-155	110-155	110-155

* Capacity is *output*

- Commercial oil-fired boilers must meet a thermal efficiency standard of 83%.
- The higher efficiency units typically include improved heat exchangers, and multi-step or variable-output power burners.
- Since the last ASHRAE standard was published, ASHRAE has changed the metric for stating the efficiency of commercial boilers. Federal standards expresses efficiency in terms of combustion efficiency while efficiency levels in ASHRAE 90.1-2007 are expressed in terms of thermal efficiency. The thermal efficiency descriptor, as used in Standard 90.1-2007, accounts for jacket losses as well as flue losses, while combustion efficiency only accounts for flue losses.

Performance / Cost Characteristics » Commercial Gas-Fired Chillers[1]

DATA	2003		2007		2010		2020		2030		2035	
	Installed Base: Absorp-tion	Installed Base: Engine - Driven	Installed Base: Absorp-tion	Installed Base: Engine - Driven	Absorp-tion	Engine-Driven	Absorp-tion	Engine-Driven	Absorp-tion	Engine-Driven	Absorp-tion	Engine-Driven
Typical Capacity (tons)*	150-1500	400	150-1500	400	150-1500	400	150-1500	400	150-1500	400	150-1500	400
COP	1.0	1.5	1.0	1.5	1.1	1.8	1.2	1.8	1.3	1.8	1.3	1.8
Average Life (yrs)	23	25	23	25	23	25	23	25	23	25	23	25
Retail Equipment Cost ($/ton)	600-750	700-800	600-750	700-800	600-750	700-800	600-750	700-800	600-750	700-800	600-750	700-800
Total Installed Cost ($/ton)	750-900	850-950	750-900	850-950	750-900	850-950	750-900	850-950	750-900	850-950	750-900	850-950
Annual Maintenance Cost ($/ton)	15-30	35-45	15-30	35-45	15-30	35-45	15-30	35-45	15-30	35-45	15-30	35-45

* Capacity is *output*

[1]This analysis assumes a water-cooled chiller; both gas-fired chiller types (absorption and engine-driven) are shown.

- Gas-fired chillers are available as either air-cooled (~25-50 tons) or water-cooled (150+ tons). This analysis includes only water-cooled chillers. Two direct-fired gas chiller technologies are in the market; absorption and engine-driven.
- Direct gas firing provides high enough temperatures to operate double effect absorption chillers, which operate at a 50-60% higher COP than single effect absorption chillers. Triple effect absorption chillers are expected to boost cooling COP another 50% beyond that of a double effect chiller. Prototype direct-fired triple effect absorption chillers have been tested by York and Trane, but are not commercially available. Some absorption chillers can be operated in reverse to provide heating; these are referred to as chiller/heaters.
- Gas-fired engine-driven chillers pair conventional vapor compression technologies (typically screw or centrifugal compressors) with natural gas powered reciprocating engines. Gas-fired engine-driven chillers exhibit higher peak cooling COP than absorbers, and engine modulation results in even better part load performance. Future efficiency improvements for engine driven chillers are not anticipated. Engine driven chillers allow the opportunity to recover waste heat on site for useful purposes.

Performance / Cost Characteristics » Commercial Centrifugal Chillers

DATA	2003	2007	2010			2020		2030		2035	
	Installed Base		Typical[2]	Mid[3]	High	Typical	High	Typical	High	Typical	High
Typical Capacity (tons)*	350	350	350	350	350	350	350	350	350	350	350
Efficiency [full-load/IPLV] (kW/ton[1])	0.70 / 0.67	0.70 / 0.67	0.58 / 0.55	0.56 / 0.45	0.48 / 0.39	0.56 / 0.45	0.46 / 0.36	0.56 / 0.45	0.46 / 0.36	0.56 / 0.45	0.46 / 0.36
COP [full-load/IPLV] [1]	5.0 / 5.2	5.0 / 5.2	6.1 / 6.4	6.3 / 7.8	7.3 / 9.0	6.3 / 7.8	7.6 / 9.7	6.3 / 7.8	7.6 / 9.7	6.3 / 7.8	7.6 / 9.7
Average Life (yrs)	25	25	25	25	25	25	25	25	25	25	25
Retail Equipment Cost ($/ton)	250-350	250-350	250-350	300-400	400-500	300-400	400-500	300-400	400-500	300-400	400-500
Total Installed Cost ($/ton)	300-450	300-450	300-450	350-500	450-600	350-500	450-600	350-500	450-600	350-500	450-600
Annual Maintenance Cost ($/ton)	15-30	15-30	15-30	15-30	15-30	15-30	15-30	15-30	15-30	15-30	15-30

* Capacity is *output*

[1]COP and kW/ton efficiencies listed are for full load rated conditions as well as integrated part load value (IPLV), which is more indicative of annual performance.
[2]2010 typical efficiency based on ASHRAE 90.1-2007.
[3]2010 mid efficiency based on FEMP recommendations.

- For most chiller applications the seasonal performance (represented by the integrated part-load value; IPLV) is more indicative of performance than the full-load performance at rated conditions. The IPLV does not necessarily correlate well to the full-load efficiency, so both efficiency parameters are listed in the comparison table.
- The ASHRAE 90.1-2007 minimum efficiency requirements for centrifugal chillers greater than 300 tons capacity are the same as for 90.1-2004 (COP=6.10 full-load; COP=6.40 IPLV).
- The Federal Energy Management Program (FEMP) recommends a full -load efficiency of 0.56 or less kW/ton for base-loaded chillers or an integrated part-load value efficiency of 0.45 kW/ton for chillers with seasonally variable loads.
- The highest efficiency centrifugal chillers incorporate some of the following:
  - Variable speed compressors
  - greater heat exchanger surface areas; enhanced tube configurations (counterflow)
  - Optimized fluid flow velocities
  - High efficiency electric motors
  - Improved turbomachinery design, resulting in higher compressor efficiency
  - Better piping and valving, including electronic expansion valves
  - Evaporative condenser for the heat rejection equipment
- Installed costs vary widely depending on equipment needed for installation (e .g. crane) and size of system. This is a mature market with centrifugal chillers representing 75% of commercial chiller sales larger than 200 tons.

Performance / Cost Characteristics » Commercial Reciprocating Chillers

DATA	2003	2007	2010			2020		2030		2035	
	Installed Base		Typical[2]	Mid[3]	High	Typical	High	Typical	High	Typical	High
Typical Capacity (tons)*	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200
Efficiency [full-load/IPLV] (kW/ton[1])	1.26 / 1.15	1.26 / 1.15	1.26 / 1.15	1.23 / 0.90	1.00 / 0.80	1.23 / 0.90	1.00 / 0.80	1.23 / 0.90	1.00 / 0.80	1.23 / 0.90	1.00 / 0.80
COP [full-load/IPLV] [1]	2.80 / 3.05	2.80 / 3.05	2.80 / 3.05	2.86 / 3.91	3.52 / 4.40	2.86 / 3.91	3.52 / 4.40	2.86 / 3.91	3.52 / 4.40	2.86 / 3.91	3.52 / 4.40
Average Life (yrs)	20	20	20	20	20	20	20	20	20	20	20
Retail Equipment Cost ($/ton)	400-500	400-500	400-500	450-550	500-600	450-550	500-600	450-550	500-600	450-550	500-600
Total Installed Cost ($/ton)	475-600	475-600	475-600	525-650	575-700	525-650	575-700	525-650	575-700	525-650	575-700
Annual Maintenance Cost ($/ton)	25-40	25-40	25-40	25-40	25-40	25-40	25-40	25-40	25-40	25-40	25-40

* Capacity is *output*

[1]COP and kW/ton efficiencies listed are for full load rated conditions as well as integrated part load value (IPLV), which is more indicative of annual performance.
[2]2010 typical efficiency based on ASHRAE 90.1-2007.
[3]2010 mid efficiency based on FEMP recommendations.

- For most chiller applications the seasonal performance (represented by the integrated part-load value; IPLV) is more indicative of performance than the full-load performance at rated conditions. The IPLV does not necessarily correlate well to the full-load efficiency, so both efficiency parameters are listed in the comparison table.
- Reciprocating chillers are most cost effective for small loads. Reciprocating chiller market share continues to be supplanted by screw chiller market share.
- Reciprocating chillers can be used in either air-cooled or water cooled applications. Reciprocating chillers shown in the data are air-cooled. Air-cooled chillers are less efficient than the water-cooled models. Listed efficiencies include matched condensers and their associated energy use (as required for compliance with ASHRAE 90.1-2010).
- The ASHRAE 90.1-2007 minimum efficiency requirements for air-cooled reciprocating chillers are the same as for 90.1-2004 (COP=2.80 full-load; COP=3.05 IPLV).
- The most recent Federal Energy Management Program (FEMP) recommendations for reciprocating chillers (published 11/03) include a full -load efficiency of 1.23 or less kW/ton for base-loaded chillers or an integrated part-load value efficiency of 0.90 kW/ton for chillers with seasonally variable loads.
- The highest efficiency reciprocating chillers incorporate some of the following:
  - Multiple compressors for staged capacity control
  - Improved heat-exchangers

Performance / Cost Characteristics » Commercial Screw Chillers

DATA	2003	2007	2010			2020		2030		2035	
	Installed Base		Typical[2]	Mid[3]	High	Typical	High	Typical	High	Typical	High
Typical Capacity (tons)	100-300	100-300	100-300	100-300	100-300	100-300	100-300	100-300	100-300	100-300	100-300
Efficiency [full-load/IPLV] (kW/ton[1])	1.26 / 1.15	1.26 / 1.15	1.26 / 1.15	1.22 / 0.94	0.94 / 0.79	1.22 / 0.94	0.94 / 0.79	1.22 / 0.94	0.94 / 0.79	1.22 / 0.94	0.94 / 0.79
COP [full-load/IPLV] [1]	2.80 / 3.05	2.80 / 3.05	2.80 / 3.05	2.88 / 3.74	3.02 / 4.45	2.88 / 3.74	3.02 / 4.45	2.88 / 3.74	3.02 / 4.45	2.88 / 3.74	3.02 / 4.45
Average Life (yrs)	20	20	20	20	20	20	20	20	20	20	20
Retail Equipment Cost ($/ton)	300-400	300-400	300-400	350-450	400-500	350-450	400-500	350-450	400-500	350-450	400-500
Total Installed Cost ($/ton)	375-500	375-500	375-500	400-525	450-575	400-525	450-575	400-525	450-575	400-525	450-575
Annual Maintenance Cost ($/ton)	10-50	10-50	10-50	10-50	10-50	10-50	10-50	10-50	10-50	10-50	10-50

* Capacity is *output*

[1]COP and kW/ton efficiencies listed are for full load rated conditions as well as integrated part load value (IPLV), which is more indicative of annual performance.
[2]2010 typical efficiency based on ASHRAE 90.1-2007.
[3]2010 mid efficiency based on FEMP recommendations.

- For most chiller applications the seasonal performance (represented by the integrated part-load value; IPLV) is more indicative of performance than the full-load performance at rated conditions. The IPLV does not necessarily correlate well to the full-load efficiency, so both efficiency parameters are listed in the comparison table.
- Screw chillers are available from ~50-1100 tons but are most cost effective for small (<300 tons) loads. Screw chillers dominate the current market for small to mid-size chillers.
- Screw chillers can be used in either air-cooled or water cooled applications. Screw chillers shown in the data are air-cooled. Air-cooled chillers are less efficient than the water-cooled models. Listed efficiencies include matched condensers and their associated energy use (as required for compliance with ASHRAE 90.1-2010).
- The ASHRAE 90.1-2007 minimum efficiency requirements for air-cooled screw chillers are the same as for 90.1-2004 (COP=2.80 full-load; COP=3.05 IPLV).
- The most recent Federal Energy Management Program (FEMP) recommendations for 150+ ton screw chillers (published 12/10) include a full -load efficiency of 1.22 or less kW/ton for base-loaded chillers or an integrated part-load value efficiency of 0.94 kW/ton for chillers with seasonally variable loads.
- The highest efficiency screw chillers incorporate some of the following:
  - Variable speed compressors and/or multiple compressors
  - Improved heat-exchangers

Performance / Cost Characteristics » Commercial Scroll Chillers

DATA	2003	2007	2010	2020	2030	2035
	Installed Base		Typical	Typical	Typical	Typical
Typical Capacity (tons)	20-140	20-140	20-140	20-140	20-140	20-140
Efficiency [full-load/IPLV] (kW/ton[1])	1.26 / 1.15	1.26 / 1.15	1.19/0.80	1.19/0.80	1.19/0.80	1.19/0.80
COP [full-load/IPLV] [1]	2.80 / 3.05	2.80 / 3.05	2.96/4.40	2.96/4.40	2.96/4.40	2.96/4.40
Average Life (yrs)	20	20	20	20	20	20
Retail Equipment Cost ($/ton)	300-400	300-400	350-450	350-450	350-450	350-450
Total Installed Cost ($/ton)	400-500	400-500	450-550	450-550	450-550	450-550
Annual Maintenance Cost ($/ton)	35-50	35-50	35-50	35-50	35-50	35-50

* Capacity is *output*

[1]COP and kW/ton efficiencies listed are for full load rated conditions as well as integrated part load value (IPLV), which is more indicative of annual performance.

- For most chiller applications the seasonal performance (represented by the integrated part-load value; IPLV) is more indicative of performance than the full-load performance at rated conditions. The IPLV does not necessarily correlate well to the full-load efficiency, so both efficiency parameters are listed in the comparison table.
- Scroll chillers can be used in either air-cooled or water cooled applications. Scroll chillers shown in the data are air-cooled, which is most common. Air-cooled chillers are less efficient than the water-cooled models. Listed efficiencies include matched condensers and their associated energy use (as required for compliance with ASHRAE 90.1-2010).
- The most recent Federal Energy Management Program (FEMP) recommendations for <150 ton scroll chillers (published 12/10) include a full -load efficiency of 1.19 or less kW/ton for base-loaded chillers or an integrated part-load value efficiency of 0.80 kW/ton for chillers with seasonally variable loads.
- The highest efficiency screw chillers incorporate some of the following:
  - Multiple compressors for staged capacity control
  - Improved heat-exchangers

Performance / Cost Characteristics » Commercial Rooftop Air Conditioners

DATA	2003	2007	2010	2010			2020		2030		2035	
	Installed Base		Current Standard	Typical	Mid-Range	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)*	90	90	90	90	90	90	90	90	90	90	90	90
Efficiency (EER)	9.2	10.1	11.2	11.2	12	13.9	11.5	13.9	11.5	13.9	11.5	13.9
Average Life (yrs)	15	15	15	15	15	15	15	15	15	15	15	15
Retail Equipment Cost ($)	3300-4500	4000-5100	5500-6500	5500-6500	7000-8000	20000-21000	5500-6500	20000-21000	5500-6500	20000-21000	5500-6500	20000-21000
Total Installed Cost ($)	5000-6200	5700-7000	7500-8500	7500-8500	9000-10000	22000-24000	7500-8500	22000-24000	7500-8500	22000-24000	7500-8500	22000-24000
Annual Maintenance Cost ($)	150-300	150-300	150-300	150-300	150-300	150-300	150-300	150-300	150-300	150-300	150-300	150-300

* Capacity is *input*

- Effective January 1, 2010, the minimum efficiency standards for commercial rooftop air conditioners are as follows:

Air-Cooled Products	Efficiency Standards
≥ 65 - < 135 kBtu/h	11.2/11.0 EER
≥ 135 - < 240 kBtu/h	11.0/10.8 EER

- Above, two EERs are listed. The first refers to systems with electric resistance heat or no heating, and the second refers to systems with all other heating system types that are integrated into the unitary equipment.
- This analysis examined 90,000 BTU/h (7.5 ton), cooling only units.
- The high efficiency unit includes a variable capacity digital scroll compressor, which saves energy during off-design hours, approximately 17% annual energy savings over a typical unit.

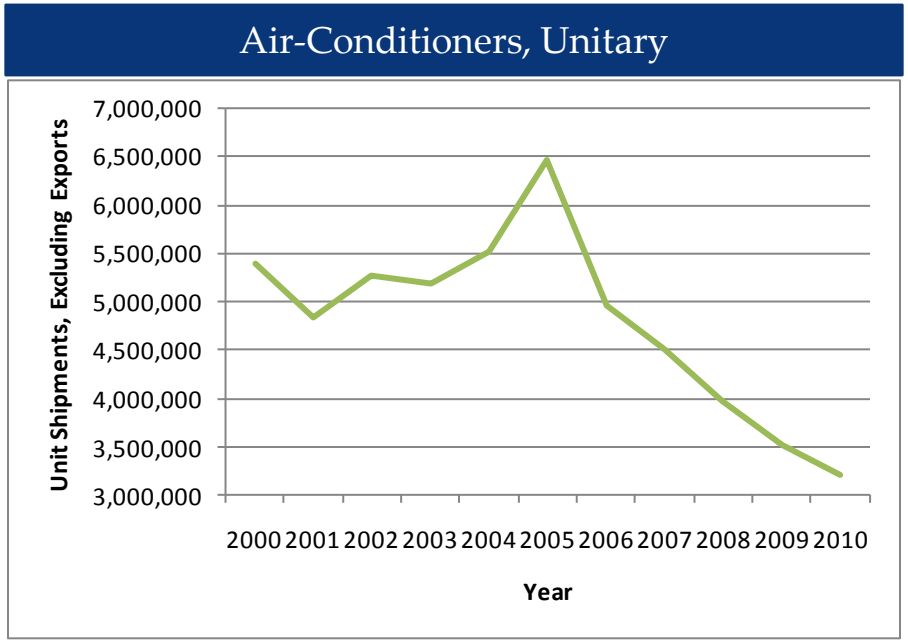
Performance / Cost Characteristics » Commercial Gas-Fired Engine-Driven Rooftop Air Conditioners

DATA	2003	2007	2010	2020	2030	2035
	Installed Base		Typical	Typical	Typical	Typical
Typical Capacity (tons)	25	25	11	11	11	11
Heating COP	NA	NA	1.4	1.4	1.4	1.4
Cooling COP	0.7	0.7	1.1	1.1	1.1	1.1
Average Life (yrs)	30	30	30	30	30	30
Retail Equipment Cost ($/ton)	775-835	775-835	3200-3300	2000-2100	1000-1100	1000-1100
Total Installed Cost ($/ton)	1200-1300	1200-1300	3700-3800	2500-2600	1500-1600	1500-1600
Annual Maintenance Cost ($)	55	55	55	55	55	55

* Capacity is *output*

- The only gas-fired engine-driven rooftop unit currently available in the US market is by Nextaire (an Aisin Seiki product line). It is an 11 ton heat pump with dual scroll compressors, variable refrigerant flow, and a variable speed supply fan. Engine coolant heat recovery improves the heating mode COP. This heat pump was introduced in 2010.
- There are currently no Federal requirements on gas-fired engine-driven rooftop air conditioners or heat pumps.
- Annual sales of the engine-driven rooftop heat pump are currently estimated at less than 5,000 units per year. Nextaire expects the cost of their 11-ton unit to drop to approximately $12,000 within the next 15 years as a result of increasing sales volume which will allow more production automation and reduced manufacturing cost.

Since the last analysis was performed in 2007, there has been a decrease in unitary (rooftop) air conditioner shipments.



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

This data includes both residential and commercial units. It should be noted that the vast majority of rooftop air conditioners are residential, not commercial.

Performance / Cost Characteristics » Commercial Rooftop Heat Pumps

DATA	2003	2007	2010	2010		2020		2030		2035	
	Installed Base		Current Standard	Typical	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)*	90	90	90	90	90	90	90	90	90	90	90
Efficiency (EER)	9.3	9.8	11.0/ 10.8**	11.0	12.0	11	12	11	12	11	12
COP (Heating)	3.1	3.2	3.3	3.3	3.4	3.3	3.4	3.3	3.4	3.3	3.4
Average Life (yrs)	15	15	15	15	15	15	15	15	15	15	15
Retail Equipment Cost ($)	3500-4500	4000-5000	5000-6000	5000-6000	5500-6500	5000-6000	5500-6500	5000-6000	5500-6500	5000-6000	5500-6500
Total Installed Cost ($)	5000-6500	6000-7100	6500-7300	6500-7300	7900-9500	6500-7300	7900-9500	6500-7300	7900-9500	6500-7300	7900-9500
Annual Maintenance Cost ($)	100-150	100-150	100-150	100-150	100-150	100-150	100-150	100-150	100-150	100-150	100-150

* Capacity is *output*

** The first EER refers to systems with electric resistance heat or no heating, and the second refers to systems with all other heating system types that are integrated into the unitary equipment.

- Effective January 1, 2010, the minimum efficiency standards for commercial rooftop heat pumps are as follows:

Air-Cooled Products	Efficiency Standards
≥ 65 - < 135 kBtu/h	11.0./10.8 EER 3.3 COP @47^{0}F
≥ 135 - < 240 kBtu/h	10.6/10.4 EER 3.2 COP @47^{0}F

- Above, two EERs are listed. The first refers to systems with electric resistance heat or no heating, and the second refers to systems with all other heating system types that are integrated into the unitary equipment.

Performance / Cost Characteristics » Commercial Ground Source Heat Pumps

DATA	2003	2007	2010		2020		2030		2035	
	Installed Base		Typical	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBTU/h)*	80-100	80-100	80-100	80-100	80-100	80-100	80-100	80-100	80-100	80-100
COP (Heating)	3.4	3.5	3.5	4.9	3.5	4.9	3.5	4.9	3.5	4.9
EER (Cooling)	13.8	14	14	27.8	14	27.8	14	27.8	14	27.8
Average Life (yrs)	20	20	20	20	20	20	20	20	20	20
Retail Equipment Cost ($)	7000-8000	7000-8000	7000-8000	10000-12000	7000-8000	10000-12000	7000-8000	10000-12000	7000-8000	10000-12000
Total Installed Cost ($)	14000-15000	14000-15000	14000-15000	17000-20000	14000-15000	17000-20000	14000-15000	17000-20000	14000-15000	17000-20000
Annual Maintenance Cost (¢/sqft)	12-15	12-15	12-15	12-15	12-15	12-15	12-15	12-15	12-15	12-15

* Capacity is *output*

- There is no Federal standard for commercial ground source heat pumps.
- Commercial design applications vary in size, style, and configuration.
- The most common ground source heat pump is a closed-loop system in which water or an anti-freeze solution is circulated through plastic pipes buried underground. Open-loop systems employ groundwater, or surface water such as a pond or lake, but water supply and water quality issues impose limitations on such applications.
- Input and output ratios (i.e., efficiencies) of a given machine change with different entering water temperatures, air flow rates, water flow rates, and relative humidity.
- Useful life is based on the expected life of the compressor. Replacement cost would be less than installed cost, since the ground loop is already in place and would have a useful life much longer than the compressor. A closed-loop system can last up to 50 years.
- There is an expectation that large, central facilities are used in commercial buildings. This is not always the case. Distributed, small units with zonal ducting and controls are almost always more efficient and less expensive.

Performance / Cost Characteristics » Commercial Electric Resistance Heaters

DATA	2010		2020		2030		2035	
	Small	Large	Small	Large	Small	Large	Small	Large
Typical Capacity (kBTU/h)*	17	170	17	170	17	170	17	170
Efficiency (%)	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Average Life (yrs)	18	18	18	18	18	18	18	18
Retail Equipment Cost ($)	500-700	3400-3800	500-700	3400-3800	500-700	3400-3800	500-700	3400-3800
Total Installed Cost ($)	600-800	3500-3900	600-800	3500-3900	600-800	3500-3900	600-800	3500-3900
Annual Maintenance Cost ($) **	-	-	-	-	-	-	-	-

* Capacity is *output*

** Annual Maintenance Cost is negligible

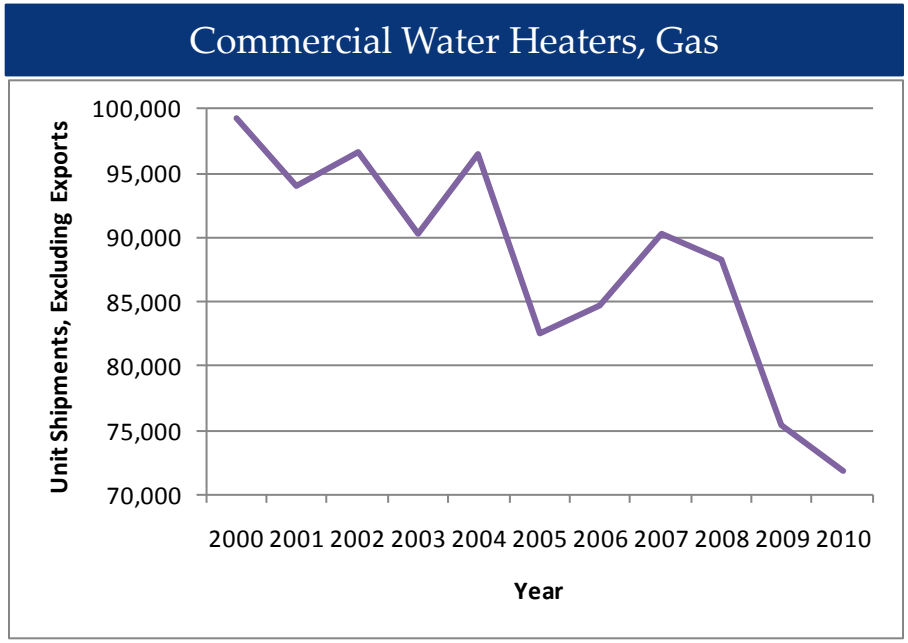
- This analysis examined electric unit heaters
- Electric unit heaters range in capacity from 14 to 170 kBtu/hr, with 17 and 170 kBtu/hr being the most typical units on the market
- Electric resistance heaters are considered 100% efficient because there is no heat loss through ducts or combustion. For this analysis, the efficiency is 98% to account for IR losses and fan inefficiency.
- Installation time and costs are estimated to be minimal

Performance / Cost Characteristics » Commercial Gas-Fired Water Heaters

DATA	2003	2007	2010	2010		2020		2030		2035	
	Installed Base		Current Standard	Typical	High	Typical	High	Typical	High	Typical	High
Typical Capacity (gal)	100	100	100	100	100	100	100	100	100	100	100
Typical Input Capacity (kBTU/h)	200	200	200	200	200	200	200	200	200	200	200
Thermal Efficiency (%)	77	78	80	80	96	80	96	80	96	80	96
Average Life (yrs)	12	12	12	12	12	12	12	12	12	12	12
Retail Equipment Cost ($)	2800-4200	3000-4500	3500-4500	3500-4500	5000-6500	3500-4500	5000-6500	3500-4500	5000-6500	3500-4500	5000-6500
Total Installed Cost ($)	3200-4700	3500-5000	4000-5000	4000-5000	5500-7000	4000-5000	5500-7000	4000-5000	5500-7000	4000-5000	5500-7000
Annual Maintenance Cost ($)	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200

- Commercial gas-fired water heaters with a capacity of 75,000 BTU/h or more must meet a thermal efficiency standard of 80% as stipulated in ASHRAE Standard 90.1-2007.
- Baseline units are constructed quite similarly to residential units, though typically at higher storage and/or input capacities.
- High-efficiency, integrated commercial storage water heaters feature condensing heat exchangers , consisting of either stainless or enameled tubing and an inducer fan system or power burner. Other designs incorporate an external heating module with a storage tank assembly. Either design approach can yield a condensing appliance.
- Maintenance for water heaters consists of sediment and scale removal once or twice per year. Estimated cost for a gas water heater would be $100 per year for one cleaning performed by a plumber.

Since the last analysis was performed in 2007, there has been a decrease in commercial gas-fired water heater shipments.



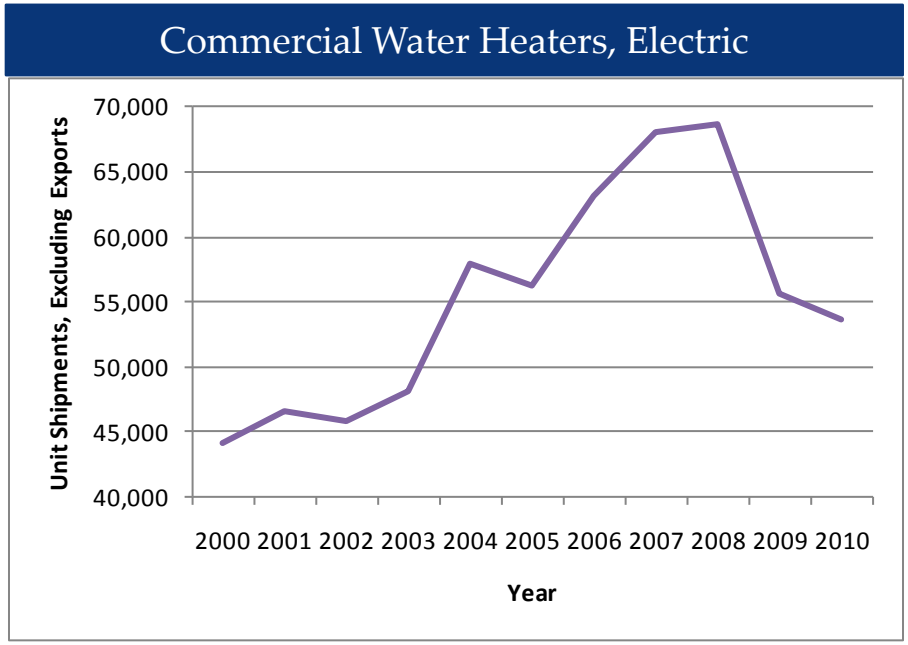
Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Performance / Cost Characteristics » Commercial Electric Resistance Water Heaters

DATA	2003	2007	2010	2010	2020	2030	2035
	Installed Base		Current Standard	Typical	Typical	Typical	Typical
Typical Capacity (gal)	120	120	120	120	120	120	120
Typical Capacity (kW)	45	45	45	45	45	45	45
Thermal Efficiency (%)	98	98	98	98	98	98	98
Average Life (yrs)	14	14	14	14	14	14	14
Retail Equipment Cost ($)	3400-5300	3400-5300	3400-5300	3400-5300	3400-5300	3400-5300	3400-5300
Total Installed Cost ($)	4000-6000	4000-6000	4000-6000	4000-6000	4000-6000	4000-6000	4000-6000
Annual Maintenance Cost ($)	50	50	50	50	50	50	50

- The EPACT standard will remain in effect for electric water heaters.

Since the last analysis was performed in 2007, there has been a decrease in commercial electric resistance water heater shipments.



Source: Appliance Magazine 2010, U.S. Appliance Shipment Statistics Monthly: January 2011

Performance / Cost Characteristics » Commercial Oil-Fired Water Heaters

DATA	2003	2007	2010	2010			2020		2030		2035	
	Installed Base		Current Standard	Typical	Mid-Range	High	Typical	High	Typical	High	Typical	High
Typical Capacity (gal)	70	70	70	70	70	70	70	70	70	70	70	70
Typical Input Capacity (kBTU/h)	300	300	300	300	300	300	300	300	300	300	300	300
Thermal Efficiency (%)	78	79	78	80	82	85	80	85	80	85	80	85
Average Life (yrs)	12-20	12-20	12-20	12-20	12-20	12-20	12-20	12-20	12-20	12-20	12-20	12-20
Retail Equipment Cost ($)	4100	4150	4100	4200	4300	4400	4200	4400	4200	4400	4200	4400
Total Installed Cost ($)	4600	4650	4600	4700	4800	4900	4700	4900	4700	4900	4700	4900
Annual Maintenance Cost ($)	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200

- Commercial oil-fired water heaters with a capacity of 105,000 BTU/h or more must meet a thermal efficiency standard of 78% as stipulated in ASHRAE Standard 90.1-2007.
- Condensing commercial water heaters do not exist, the highest attainable efficiency with oil-fired storage water heaters is thus about 86% TE.
- Maintenance for commercial oil-fired water heaters consists of sediment and scale removal once or twice per year.

Performance / Cost Characteristics » Commercial Gas-Fired Instantaneous Water Heaters

DATA	2003	2007	2010	2010		2020		2030		2035	
	Installed Base		Current Standard	Typical	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBtu/hr)	180-230	180-230	180-230	180-230	180-230	180-230	180-230	180-230	180-230	180-230	180-230
Thermal Efficiency (%)	76	77	80	84	85	84	85	84	90	84	90
Average Life (yrs)	20	20	20	20	20	20	20	20	20	20	20
Retail Equipment Cost ($)	500-750	600-850	800-1000	1250-1300	1350-1450	1250-1300	1350-1450	1250-1300	1350-1450	1250-1300	1350-1450
Total Installed Cost ($)	650-900	750-1000	900-1250	1500-1800	1600-2000	1500-1800	1600-2000	1500-1800	1600-2000	1500-1800	1600-2000
Annual Maintenance Cost ($)	-	-	-	-	-	-	-	-	-	-	-

* Annual Maintenance Cost is negligible

- Commercial gas-fired instantaneous water heaters with a capacity of 200,000 BTU/h or more must meet a thermal efficiency standard of 80% as stipulated in ASHRAE Standard 90.1-2007.
- Commercial instantaneous systems use similar technologies for improving energy efficiency as residential systems; however, unlike condensing residential systems, condensing commercial systems typically do not use multiple heat exchangers.
- Depending on the manufacturer, input ratings for condensing systems usually top out at 800,000 BTU/h, requiring the use of multiple units for staging purposes; however, there are reliability, comfort, and efficiency benefits to staging multiple units.
- When replacing a storage water heater with an instantaneous water heater, there may be significant additional costs to upsize the gas supply line and change the venting.

Performance / Cost Characteristics » Commercial Electric Booster Water Heaters

DATA	2003	2007	2010	2020	2030	2035
	Installed Base		Typical	Typical	Typical	Typical
Typical Capacity (kBtu/hr)	100-200	100-200	100-200	100-200	100-200	100-200
Thermal Efficiency (%)	98	98	98	98	98	98
Average Life (yrs)	3-8	3-8	3-8	3-8	3-8	3-8
Retail Equipment Cost ($)	1200-1500	1200-1500	1200-1500	1200-1500	1200-1500	1200-1500
Total Installed Cost ($)	1400-1700	1400-1700	1400-1700	1400-1700	1400-1700	1400-1700
Annual Maintenance Cost ($) *	-	-	-	-	-	-

* Annual Maintenance Cost is negligible

Performance / Cost Characteristics » Commercial Gas Booster Water Heaters

DATA	2003	2007	2010			2020		2030		2035	
	Installed Base		Current Standard	Typical	High	Typical	High	Typical	High	Typical	High
Typical Capacity (kBtu/hr)	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200	100-200
Thermal Efficiency (%)	79	79	80	80	90	82	92	85	95	85	95
Average Life (yrs)	3-8	3-8	3-8	3-8	3-8	3-8	3-8	3-8	3-8	3-8	3-8
Retail Equipment Cost ($)	5000-6000	5000-6000	5000-6000	5000-6000	10000-11000	5000-6000	10000-11000	5000-6000	10000-11000	5000-6000	10000-11000
Total Installed Cost ($)	5300-6300	5300-6300	5300-6300	5300-6300	10300-11300	5300-6300	10300-11300	5300-6300	10300-11300	5300-6300	10300-11300
Annual Maintenance Cost ($)	150	150	150	150	150	150	150	150	150	150	150

- Booster water heaters are installed, often at the point of use, in series with the main service water heating system to boost service water temperatures. The main service water heating system may provide 110-140°F water, and the booster water heater may increase that temperature to 180-195°F. Typical commercial applications for booster water heaters include commercial dishwashers, laundromats, hospitals, and car washes.
- There is currently no energy efficiency standard for electric booster water heaters. Gas booster water heater minimum efficiency is dictated by ASHRAE Standard 90.1-2007 under the "gas instantaneous water heaters" category.
- Booster water heaters typically have short lifetimes because of high usage and extreme temperatures.
- Typical sales are small due to the limited number of applications.

Appendix A
Data Sources

Navigant Consulting, Inc.
1801 K Street, NW, Suite 500
Washington, D.C. 20006
(202) 973-2400

www.navigantconsulting.com

Data Sources » Residential Gas-Fired Water Heaters

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical / High		
Typical Capacity (gal)	AHRI / Distributors	EERE			AHRI / Distributors	NCI		
Energy Factor	AHRI	EERE	AHRI	ENERGY STAR	AHRI			
Average Life (yrs)	EERE							
Retail Equipment Cost ($)	Distributors	EERE			Distributors			
Total Installed Cost ($)	Distributors / RS Means 2010	EERE			Distributors / RS Means 2010			
Annual Maintenance Cost ($)	EERE							

Data Sources » Residential Oil Water Heaters

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	Mid-Level	High	Typical / High		
Typical Capacity (gal)	AHRI / Distributors	EERE	AHRI		EERE	NCI		
Energy Factor	AHRI	EERE	AHRI					
Average Life (yrs)	Ka-BOOM!							
Retail Equipment Cost ($)	Distributors	EERE						
Total Installed Cost ($)	Distributors / RS Means 2007	EERE						
Annual Maintenance Cost ($)	EERE							

Data Sources » Residential Electric Resistance Water Heaters

SOURCES	2005	2010	2010		2020	2030	2035
	Installed Base	Current Standard	Typical	High	Typical / High		
Typical Capacity (gal)	AHRI / Distributors	EERE			NCI		
Energy Factor	AHRI	EERE	DEER, 2008	AHRI			
Average Life (yrs)	EERE						
Retail Equipment Cost ($)	Distributors	EERE					
Total Installed Cost ($)	Distributors / RS Means 2010	EERE					
Annual Maintenance Cost ($)	EERE						

Data Sources » Residential Heat Pump Water Heaters

SOURCES	2005	2010		2020	2030	2035
	Installed Base	ENERGY STAR	High	Typical / High		
Typical Capacity (gal)	AHRI	EERE		NCI		
Energy Factor	AHRI	ENERGY STAR	AHRI			
Average Life (yrs)	ACEEE, 2007	EERE				
Retail Equipment Cost w/o Tank($)	RS Means 2010 / ACEEE, 2007	EERE / Distributors				
Total Installed Cost w/o Tank ($)	RS Means 2010 / ACEEE, 2007	EERE / Distributors				
Annual Maintenance Cost ($)	EERE					

Data Sources » Residential Instantaneous Water Heaters

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical / High		
Typical Capacity (BTU/h)	EERE					NCI		
Energy Factor	Distributors	EERE	AHRI	ENERGY STAR	Distributors			
Average Life (yrs)	ENERGY STAR	EERE						
Retail Equipment Cost w/o Tank ($)	Distributors / RS Means 2010	EERE						
Total Installed Cost w/o Tank ($)	DEER, 2008	EERE						
Annual Maintenance Cost ($)	NCI	EERE						

Data Sources » Residential Solar Water Heaters

SOURCES	2005	2010	2010	2020	2030	2035
	Installed Base	Typical	Typical	Typical		
Typical Capacity (sq. ft.)	SRCC			SAIC		
Overall Efficiency (Solar Fraction)	0.3-0.5 (RETScreen); 0.58-0.83 (SRCC); 0.5-0.75 (EERE)					
Solar Energy Factor	ENERGY STAR range=0.53-47, median=2, average=2.83					
Average Life (yrs)	20 year system life (EERE); Collector warranties are 10 years (ENERGY STAR/SRCC)					
Retail Equipment Cost[1] ($)	RS Means					
Total Installed Cost[1] ($)	RS Means					

[1]Costs are for an indirect (active closed loop) system, including tank and backup heater. Smaller capacity/cost systems are typical for southern & western states (>2/3 of the current market). Higher capacity/cost systems are required in colder/cloudier regions.
[2]ENERGY STAR requires OG-300 rating from SRCC. Most installations use SRCC rated collectors; a high efficiency option is not applicable.

Data Sources » Residential Gas-Fired Furnaces

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical / High		
Typical Capacity (kBTU/h)	AHRI		Distributors		AHRI	NCI		
AFUE (%)	AHRI	EERE		ENERGY STAR	AHRI			
Electric Consumption (kWh/yr)	AHRI	EERE			AHRI			
Average Life (yrs)	Appliance Magazine, 2005	EERE						
Retail Equipment Cost ($)	EERE				Distributors			
Total Installed Cost ($)	EERE							
Annual Maintenance Cost ($)	EERE							

Data Sources » Residential Oil-Fired Furnaces

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical / High		
Typical Capacity (kBTU/h)	AHRI			Distributors	AHRI	NCI		
AFUE (%)	AHRI	EERE	AHRI	ENERGY STAR	AHRI			
Electric Consumption (kWh)	AHRI	EERE						
Average Life (yrs)	Appliance Magazine, 2005	EERE						
Retail Equipment Cost ($)	EERE			Distributors	EERE			
Total Installed Cost ($)	EERE							
Annual Maintenance Cost ($)	EERE							

Data Sources » Residential Hydronic Heating Systems (Boilers)

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical / High		
Typical Capacity (kBTU/h)	EERE					NCI		
AFUE (%)	AHRI	EERE		ENERGY STAR	EERE			
Average Life (yrs)	Appliance Magazine, 2005	EERE						
Retail Equipment Cost ($)	EERE							
Total Installed Cost ($)	EERE							
Annual Maintenance Cost ($)	EERE							

Data Sources » Residential Room Air Conditioners

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical / High		
Typical Capacity (kBTU/h)	Distributors		AHAM			NCI		
EER	Distributors	Federal Standard	AHAM	ENERGY STAR	AHAM			
Average Life (yrs)	Appliance Magazine, 2005	Ka-BOOM!	Ka-BOOM! / Appliance Magazine, 2010					
Retail Equipment Cost ($)	Distributors							
Total Installed Cost ($)	Distributors							
Annual Maintenance Cost ($)	NCI							

Data Sources » Residential Central Air Conditioners

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical / High		
Typical Capacity (kBTU/h)	Distributors		EERE			NCI		
SEER	Distributors	Federal Standard	EERE	ENERGY STAR	EERE			
Average Life (yrs)	Appliance Magazine, 2005	EERE						
Retail Equipment Cost ($)	Distributors		EERE / Distributors					
Total Installed Cost ($)	Distributors	EERE						
Annual Maintenance Cost ($)	NCI	EERE						

Data Sources » Residential Air Source Heat Pumps

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical / High		
Typical Capacity (kBTU/h)	Distributors / Product Literature		AHRI			NCI		
HSPF (Heating)	AHRI	Federal Standard	AHRI	ENERGY STAR	AHRI / CEC			
SEER (Cooling)	AHRI	Federal Standard	AHRI	ENERGY STAR	AHRI / CEC			
Average Life (yrs)	EERE							
Retail Equipment Cost ($)	Distributors / RS Means 2010 / NCI	EERE						
Total Installed Cost ($)	Distributors / RS Means 2010 / NCI	EERE						
Annual Maintenance Cost ($)	NCI							

Data Sources » Residential Ground Source Heat Pumps

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	Mid-Range	High	Typical / High		
Typical Capacity (kBTU/h)	AHRI/SAIC					NCI		
COP (Heating)	SAIC	ASHRAE 90.1-2007, ENERGY STAR						
EER (Cooling)	SAIC	ASHRAE 90.1-2007, ENERGY STAR						
Average Life (yrs)	System life 25 years, ground loop life 50 years (EERE)							
Retail Equipment Cost ($)	Distributors / CEC							
Total Installed Cost ($)	Distributors / CEC							
Annual Maintenance Cost ($)	SAIC							

Data Sources » Residential Gas Heat Pumps

SOURCES	2005	2010	2010	2020	2030	2035
	Installed Base	Current Standard	Typical	Typical		
Typical Capacity (kBTU/h)	Manufacturer/SAIC			SAIC		
Heating (GCOP)	Manufacturer/SAIC	Manufacturer/SAIC	Manufacturer/SAIC			
Cooling (GCOP)	Manufacturer/SAIC	CEC/T24	Manufacturer/SAIC			
Annual Electric Use (kWh/yr)	Manufacturer/SAIC					
Average Life (yrs)	SAIC					
Retail Equipment Cost ($)	SAIC					
Total Installed Cost ($)	SAIC					
Annual Maintenance Cost ($)	SAIC					

Data Sources » Residential Refrigerator / Freezer

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical / High		
Energy Consumption (kWh/yr)	Distributors	ENERGY STAR	CEC	ENERGY STAR	CEC	NCI		
Average Life (yrs)	Appliance Magazine, 2005	Ka-BOOM!	Ka-BOOM! / Appliance Magazine, 2010					
Retail Equipment Cost ($)	EERE / Distributors	EERE						
Total Installed Cost ($)	Distributors / RS Means 2010							
Annual Maintenance Cost ($)	NCI	EERE						

Data Sources » Residential Natural Gas Cooktops

SOURCES	2005	2010		2020	2030	2035
	Installed Base	Typical	High	Typical / High		
Typical Capacity (kBTU/h)	Distributors / Product Literature	EERE		NCI		
Cooking Efficiency (%)	Distributors / Product Literature	EERE				
Average Life (yrs)	Appliance Magazine, 2005	Appliance Magazine, 2010				
Retail Equipment Cost ($)	EERE					
Total Installed Cost ($)	EERE					
Annual Maintenance Cost ($)	NCI / EERE					

Data Sources » Residential Clothes Washers

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical / High		
Typical Capacity (ft3)	Distributors	CEC		ENERGY STAR	CEC	NCI		
Modified Energy Factor (ft3/kWh/cycle)	Distributors	Standards	CEC	ENERGY STAR	CEC			
Average Life (yrs)	Appliance Magazine, 2005 / EERE	Ka-BOOM! / Appliance Magazine, 2010						
Water Consumption (gal/cycle)	EERE / Distributors	CEC						
Hot Water Energy (kWh/cycle)	EERE / Distributors							
Machine Energy (kWh/cycle)	EERE / Distributors							
Dryer Energy (kWh/cycle)	EERE / Distributors							
Retail Equipment Cost ($)	EERE / Distributors			DEER, 2008	EERE / Distributors			
Total Installed Cost ($)	RS Means 2010			DEER, 2008	RS Means 2010			
Annual Maintenance Cost ($)	NCI							

Data Sources » Residential Clothes Dryers

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	Mid-Level	High	Typical / High		
Typical Capacity (ft3)	NCI	CEC			CEC / Distributors	NCI		
EF (lb/kWh)	NCI	EERE						
Machine Energy (kWh/cycle)	NCI	EERE						
Average Life (yrs)	NCI	Ka-BOOM! / Appliance Magazine, 2010						
Retail Equipment Cost ($)	NCI	EERE						
Total Installed Cost ($)	NCI	EERE						
Annual Maintenance Cost ($)	EERE	EERE						

Data Sources » Residential Dishwashers

SOURCES	2005	2010	2010			2020	2030	2035
	Installed Base	Current Standard	Typical	ENERGY STAR	High	Typical / High		
Typical Annual Use (kWh/yr)	Product Literature	EERE	Distributors	ENERGY STAR	CEC	NCI		
Efficiency (cycle/kWh)	NCI	EERE		CEC				
Average Life (yrs)	Appliance Magazine, 2005	Ka-BOOM! / Appliance Magazine, 2010						
Retail Equipment Cost ($)	EERE	Distributors			EERE			
Total Installed Cost ($)	EERE	DEER, 2008		DEER, 2008	EERE			
Annual Maintenance Cost ($)	NCI							

Data Sources » Commercial Gas-Fired Furnaces

SOURCES	2003	2007	2010	2010		2020	2030	2035
	Installed Base		Current Standard	Typical	High	Typical / High		
Typical Capacity (kBTU/h)	Arthur D. Little, 1997		AHRI			NCI		
AFUE	ASHRAE Standard 90.1-2004		ASHRAE Standard 90.1-2004 / CEC	AHRI				
Average Life (yrs)	2003 ASHRAE Handbook – HVAC Applications		Appliance Magazine, 2010					
Retail Equipment Cost ($)	RS Means 2010/ NCI / Distributors		RS Means 2010					
Total Installed Cost ($)	RS Means 2010/ NCI / Distributors		RS Means 2010					
Annual Maintenance Cost ($)	RS Means 2010/ NCI / Distributors							

Data Sources » Commercial Oil-Fired Furnaces

SOURCES	2003	2007	2010	2010	2020	2030	2035
	Installed Base		Current Standard	Typical	Typical		
Typical Capacity (kBTU/h)	NCI / Distributors / AHRI		AHRI		NCI		
Thermal Efficiency (%)	ASHRAE Standard 90.1-2004	AHRI	AHRI / CEC	AHRI			
Average Life (yrs)	2003 ASHRAE Handbook – HVAC Applications		Appliance Magazine, 2010				
Retail Equipment Cost ($)	RS Means 2010						
Total Installed Cost ($)	RS Means 2010						
Annual Maintenance Cost ($)	NCI / Distributors						

Data Sources » Commercial Electric Boilers

SOURCES	2003	2007	2010	2020	2030	2035
	Installed Base		Typical	Typical		
Typical Capacity (kW)	BSRIA			SAIC		
Efficiency (%)	SAIC					
Average Life (yrs)	ASHRAE 2007 HVAC Applications					
Retail Equipment Cost ($)	RS Means/SAIC					
Total Installed Cost ($)	RS Means/SAIC					
Annual Maintenance Cost ($)	RS Means/SAIC					

Data Sources » Commercial Gas-Fired Boilers

SOURCES	2003	2007	2010	2010			2020	2030	2035
	Installed Base		Current Standard	Typical	Mid-Range	High	Typical / High		
Typical Capacity (kBTU/h)	Arthur D. Little / Building Services Research and Information Association & Ducker Research Company, 1997, 1998	NCI	EERE				NCI		
Combustion Efficiency (%)	ASHRAE Standard 90.1-2004		CEC	AHRI					
Average Life (yrs)	Building Services Research and Information Association & Ducker Research Company, 1997, 1998 / Appliance Magazine, 2005		EERE						
Retail Equipment Cost ($)	CEC / RS Means 2010	DEER, 2008	EERE / Appliance Magazine, 2010						
Total Installed Cost ($)	CEC / RS Means 2010	NCI	EERE / Appliance Magazine, 2010						
Annual Maintenance Cost ($)	NCI		EERE / Appliance Magazine, 2010						

Data Sources » Commercial Oil-Fired Boilers

SOURCES	2003	2007	2010	2010		2020	2030	2035
	Installed Base		Current Standard	Typical	High	Typical / High		
Typical Capacity (kBTU/h)	Building Services Research and Information Association & Ducker Research Company, 1997, 1998	NCI	EERE			NCI		
Combustion Efficiency (%)	ASHRAE Standard 90.1-2004			AHRI				
Average Life (yrs)	Building Services Research and Information Association & Ducker Research Company, 1997, 1998 / NCI		EERE					
Retail Equipment Cost ($)	Distributors / RS Means 2010 / NCI		EERE					
Total Installed Cost ($)	Distributors / RS Means 2010 / NCI		EERE					
Annual Maintenance Cost ($)	NCI		EERE					

Data Sources » Commercial Gas-Fired Chillers

SOURCES	2003		2007		2010		2020		2030		2035	
	Installed Base: Absorp-tion	Installed Base: Engine-Driven	Installed Base: Absorp-tion	Installed Base: Engine-Driven	Absorp-tion	Engine-Driven	Absorp-tion	Engine-Driven	Absorp-tion	Engine-Driven	Absorp-tion	Engine-Driven
Typical Capacity (tons)	BSRIA/Distributors											
Efficiency (kW/ton)	Product Literature/SAIC											
COP												
Average Life (yrs)	2007 ASHRAE Applications Handbook/Distributors											
Retail Equipment Cost ($/ton)	Distributors/RS Means/SAIC											
Total Installed Cost ($/ton)												
Annual Maintenance Cost ($/ton)												

Data Sources » Commercial Centrifugal Chillers

SOURCES	2003	2007	2010			2020		2030		2035	
	Installed Base		Typical	Mid	High	Typical	High	Typical	High	Typical	High
Typical Capacity (tons)	US Census		SAIC								
Efficiency (kW/ton)	DEER/FEMP/Product Literature							SAIC			
COP											
Average Life (yrs)	2007 ASHRAE Applications Handbook										
Retail Equipment Cost ($/ton)	RS Means/Distributors/SAIC										
Total Installed Cost ($/ton)											
Annual Maintenance Cost ($/ton)	SAIC										

Data Sources » Commercial Reciprocating Chillers

SOURCES	2003	2007	2010			2020		2030		2035	
	Installed Base		Typical	Mid	High	Typical	High	Typical	High	Typical	High
Typical Capacity (tons)	BSRIA / DEER		SAIC								
Efficiency (kW/ton)	DEER/FEMP/Product Literature							SAIC			
COP											
Average Life (yrs)	Manufacturers										
Retail Equipment Cost ($/ton)	RS Means/Distributors/SAIC										
Total Installed Cost ($/ton)											
Annual Maintenance Cost ($/ton)	SAIC										

Data Sources » Commercial Screw Chillers

SOURCES	2003	2007	2010			2020		2030		2035	
	Installed Base		Typical	Mid	High	Typical	High	Typical	High	Typical	High
Typical Capacity (tons)	SAIC										
Efficiency (kW/ton)	DEER/FEMP/Product Literature							SAIC			
COP											
Average Life (yrs)	Manufacturers										
Retail Equipment Cost ($/ton)	RS Means/Distributors/SAIC										
Total Installed Cost ($/ton)											
Annual Maintenance Cost ($/ton)	SAIC										

Data Sources » Commercial Scroll Chillers

SOURCE	2003	2007	2010	2020	2030	2035
	Installed Base		Typical	Typical	Typical	Typical
Typical Capacity (tons)	SAIC/Manufacturers					
Efficiency [full-load/IPLV] (kW/ton[1])	Product Literature			SAIC		
COP [full-load/IPLV]						
Average Life (yrs)	Manufacturers					
Retail Equipment Cost ($/ton)	RS Means/SAIC					
Total Installed Cost ($/ton)						
Annual Maintenance Cost ($/ton)	SAIC					

Data Sources » Commercial Rooftop Air Conditioners

SOURCES	2003	2007	2010	2010			2020	2030	2035
	Installed Base		Current Standard	Typical	Mid-Range	High	Typical / High		
Typical Capacity (kBTU/h)	AHRI / NCI						NCI		
Efficiency (EER)	ASHRAE Standard 90.1-2004	Distributors / NCI	EERE		AHRI				
Average Life (yrs)	2003 ASHRAE Handbook – HVAC Applications		Appliance Magazine, 2010						
Retail Equipment Cost ($)	NCI / LBNL, 2003	Distributors / NCI / DEER, 2008	EERE		Distributors				
Total Installed Cost ($)	NCI / LBNL, 2003	Distributors / NCI / DEER, 2008	EERE		Distributors				
Annual Maintenance Cost ($)	EERE								

Data Sources » Commercial Gas-Fired Engine-Driven Rooftop Air Conditioners

<table>
<tr><th rowspan="2">SOURCES</th><th>2003</th><th>2007</th><th>2010</th><th>2020</th><th>2030</th><th>2035</th></tr>
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<tr><td>Typical Capacity (tons)</td><td colspan="6">Distributors</td></tr>
<tr><td>Heating COP</td><td colspan="2">NA</td><td>Product Literature</td><td colspan="3" rowspan="6">Distributors/SAIC</td></tr>
<tr><td>Cooling COP</td><td colspan="3">Product Literature</td></tr>
<tr><td>Average Life (yrs)</td><td colspan="3" rowspan="4">Distributors/SAIC</td></tr>
<tr><td>Retail Equipment Cost ($/ton)</td></tr>
<tr><td>Total Installed Cost ($/ton)</td></tr>
<tr><td>Annual Maintenance Cost ($)</td></tr>
</table>

Data Sources » Commercial Rooftop Heat Pumps

SOURCES	2003	2007	2010	2010		2020	2030	2035
	Installed Base		Current Standard	Typical	High	Typical / High		
Typical Capacity (kBTU/h)	AHRI					NCI		
Efficiency (EER)	ASHRAE Standard 90.1-2004		EERE					
COP (Heating)	NCI / EERE		EERE					
Average Life (yrs)	2003 ASHRAE Handbook - HVAC Applications							
Retail Equipment Cost ($)	Distributors / RS Means 2010 / NCI / DEER							
Total Installed Cost ($)	Distributors / RS Means 2010 / NCI / DEER							
Annual Maintenance Cost ($)	Distributors / RS Means 2010 / NCI / DEER							

Data Sources » Commercial Ground Source Heat Pumps

SOURCES	2003	2007	2010		2020	2030	2035
	Installed Base		Typical	High	Typical / High		
Typical Capacity (kBTU/h)	GHPC				NCI		
COP (Heating)	IGSPHA / GHPC						
EER (Cooling)	GHPC						
Average Life (yrs)	GHPC						
Retail Equipment Cost ($)	NCI / Distributors						
Total Installed Cost ($)	NCI / Distributors						
Annual Maintenance Cost (¢/sqft)	GHPC						

Data Sources » Commercial Electric Resistance Heaters

DATA	2010		2020		2030		2035	
	Small	Large	Small	Large	Small	Large	Small	Large
Typical Capacity (kBTU/h)	Distributors		NCI					
Efficiency (%)	NCI							
Average Life (yrs)	Technology Cost and Performance File for Commercial Model for AEO2010							
Retail Equipment Cost ($)	Distributors							
Total Installed Cost ($)	Distributors							
Annual Maintenance Cost ($)	NCI							

Data Sources » Commercial Gas-Fired Water Heaters

SOURCES	2003	2007	2010	2010		2020	2030	2035
	Installed Base		Current Standard	Typical	High	Typical / High		
Typical Capacity (gal)	Arthur D. Little / Distributors / AHRI			AHRI		NCI		
Typical Input Capacity (BTU/h)	Arthur D. Little / AHRI		CEC		AHRI			
Thermal Efficiency (%)	EERE / ASHRAE Standard 90.1-2004			AHRI				
Average Life (yrs)	Building Services Research and Information Association & Ducker Research Company, 1997, 1998 / Appliance Magazine, 2005							
Retail Equipment Cost ($)	Distributors / CEC / NCI		Distributors					
Total Installed Cost ($)	Distributors / CEC / NCI							
Annual Maintenance Cost (¢/sqft)	NCI							

Data Sources » Commercial Electric Resistance Water Heaters

SOURCES	2003	2007	2010	2010	2020	2030	2035
	Installed Base		Current Standard	Typical	Typical		
Typical Capacity (gal)	NCI / Product Literature		AHRI		NCI		
Typical Capacity (kW)	Product Literature						
Thermal Efficiency (%)	Product Literature	ASHRAE Standard 90.1-2004	AHRI				
Average Life (yrs)	Appliance Magazine, 2005 / Building Services Research and Information Association & Ducker Research Company, 1997, 1998	Appliance Magazine, 2005					
Retail Equipment Cost ($)	Distributors / NCI	Distributors					
Total Installed Cost ($)	Distributors / NCI	NCI					
Annual Maintenance Cost ($)	NCI						

Data Sources » Commercial Oil-Fired Water Heaters

SOURCES	2003	2007	2010	2010			2020	2030	2035
	Installed Base		Current Standard	Typical	Mid-Range	High	Typical / High		
Typical Capacity (gal)	NCI	AHRI / NCI					NCI		
Typical Input Capacity (kBTU/h)	NCI	AHRI / NCI	AHRI / CEC						
Thermal Efficiency (%)	NCI	ASHRAE Standard 90.1-1999	ANSI / ASHRAE / IESNA Standard 90.1-2007	AHRI / CEC					
Average Life (yrs)	NCI	Appliance Magazine, 2005							
Retail Equipment Cost ($)	NCI	Distributors / NCI							
Total Installed Cost ($)	NCI	Distributors / NCI	NCI						
Annual Maintenance Cost ($)	NCI	Distributors / NCI	NCI						

Data Sources » Commercial Gas-Fired Instantaneous Water Heaters

SOURCES	2003	2007	2010	2010		2020	2030	2035
	Installed Base		Current Standard	Typical	High	Typical / High		
Typical Capacity (gal)	Building Services Research and Information Association & Ducker Research Company, 1997, 1998 / AHRI	AHRI	Building Services Research and Information Association & Ducker Research Company, 1997, 1998 / AHRI			NCI		
Thermal Efficiency (%)	AHRI		ANSI / ASHRAE / IESNA Standard 90.1-2007					
Average Life (yrs)	EERE							
Retail Equipment Cost ($)	CEC / NCI / Distributors	Distributors / NCI						
Total Installed Cost ($)	CEC / NCI / Distributors							
Annual Maintenance Cost ($)	CEC / NCI / Distributors							

Data Sources » Commercial Electric Booster Water Heaters

<table>
<tr><th rowspan="2">DATA</th><th>2003</th><th>2007</th><th>2010</th><th>2020</th><th>2030</th><th>2035</th></tr>
<tr><th colspan="2">Installed Base</th><th>Typical</th><th colspan="3">Typical</th></tr>
<tr><td>Typical Capacity (gal)</td><td colspan="3">SAIC/Distributors</td><td colspan="3" rowspan="6">SAIC</td></tr>
<tr><td>Thermal Efficiency (%)</td><td colspan="3" rowspan="2">Product Literature</td></tr>
<tr><td>Average Life (yrs)</td></tr>
<tr><td>Retail Equipment Cost ($)</td><td colspan="3" rowspan="3">SAIC/Distributors</td></tr>
<tr><td>Total Installed Cost ($)</td></tr>
<tr><td>Annual Maintenance Cost ($)</td></tr>
</table>

Data Sources » Commercial Gas Booster Water Heaters

SOURCES	2003	2007	2010	2010		2020	2030	2035
	Installed Base		Current Standard	Typical	High	Typical / High		
Typical Capacity (gal)	Distributors/SAIC					SAIC		
Thermal Efficiency (%)	Product Literature							
Average Life (yrs)	Product Literature/SAIC							
Retail Equipment Cost ($)	Distributors/SAIC							
Total Installed Cost ($)								
Annual Maintenance Cost ($)								

Appendix B
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www.navigantconsulting.com

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