HVAC, Water Heating and Appliance R&D: Combined Heat and Power (CHP)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Introduction: Benefits of CHP

Recognizing the benefits of CHP and its current underutilization as an energy resource in the United States, the Obama Administration has a **goal** to achieve 40 gigawatts (GW) of new, cost-effective CHP by 2020. As discussed in the August 2012 DOE and EPA report, **Combined Heat and Power: A Clean Energy Solution**, achieving this goal would:

- Increase total CHP capacity in the United States by 50% in less than a decade
- Save energy users $10 billion per year compared to current energy use
- Save 1 quadrillion Btu (Quad) of energy — the equivalent of 1% of all energy use in the United States
- Reduce emissions by 150 million metric tons of carbon dioxide (CO_2) annually — equivalent to the emissions from over 25 million cars
- Result in $40-$80 billion in new capital investment in manufacturing and other U.S. facilities over the next decade

Source: http://www.energy.gov/eere/amo/benefits-combined-heat-and-power

Introduction: Benefits of CHP

CHP can:

- **Enhance our energy security** by reducing our national energy requirements and help businesses weather energy price volatility and supply disruptions
- **Advance our climate change and environmental goals** by reducing emissions of CO_2 and other pollutants
- **Improve business competitiveness** by increasing energy efficiency and managing costs
- **Increase resiliency of our energy infrastructure** by limiting congestion and offsetting transmission losses
- **Diversify energy supply** by enabling further integration of domestically produced and renewable fuels
- **Improve energy efficiency** by capturing heat that is normally wasted.

Source: http://www.energy.gov/eere/amo/benefits-combined-heat-and-power

Introduction: BTO's HVAC, WH and Appliance

Program Goals:

BTO's ultimate goal is to reduce the average energy use per square foot of all U.S. buildings by 50% from 2010 levels. Emerging Technologies Program's goal is to enable the development of cost-effective technologies capable of reducing a building's energy use per square foot by 30% by 2020 and cutting a building's use by 45% by 2030, relative to 2010 high-efficiency technologies.

HVAC/WH/Appliances goals require by 2020 that the potential energy use intensity (EUI) for:

- HVAC would be 60% lower
- WH would be 25% lower
- Appliances would be 15% lower
- All relative to 2010 energy-efficient baseline

Two-pronged approach to accelerate the development of new technologies:

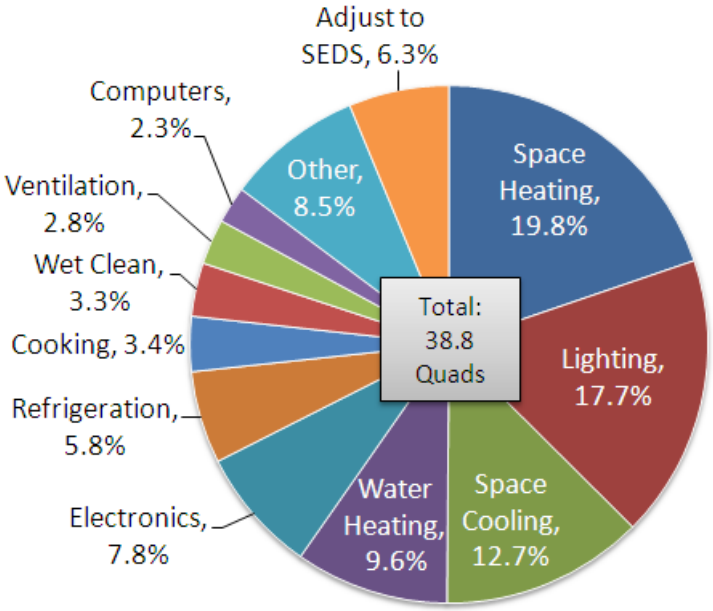
1) Accelerate the development of **near term** technologies that have the potential to save significant amount of energy (including cost reduction activities, bending the cost curve)
2) Accelerate the development of the **next generation** of technologies that have the potential of "leapfrogging" existing technologies by pursuing entirely new approaches (including crosscutting efforts)

The goal is to develop technologies that save energy and reduce our environment burden while introducing them in the simplest application first, highest probability of success.

The challenge…

- In addition to individual end-use solutions, integrated solutions are also pursued
- Energy cascading (using the waste heat from one process as the source of energy for another) is utilized
- Optimizing energy use in a building, an optimum point instead of just a local minimum (single end-use)
- Broad approach includes pursuing crosscutting technologies that enable better HVAC, water heating and appliances
- *Not working in a vacuum*, most equipment is covered by appliance standards
- Engage manufacturers and BTO deployment teams
- ***Efficiency first***

Buildings Primary Energy Consumption



CRADAs: *Collaborative Research and Development Agreements*

Potential and Challenges for CHP

Small-Scale CHP offers significant Technical Potential:

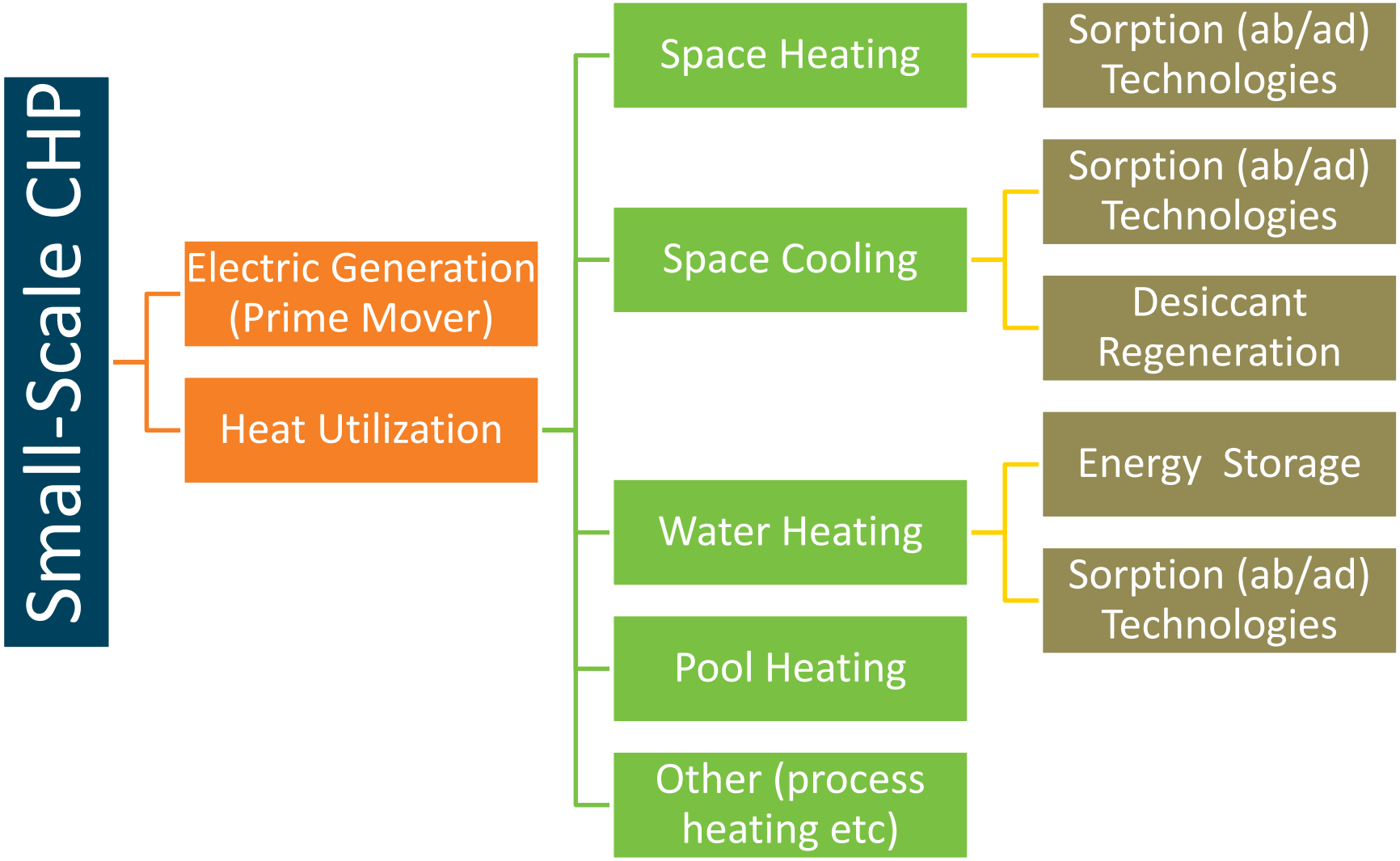
- Residential: 2.9 quad
- Small Commercial (under 50,000 sq.ft.): .9 quad
- Total: 3.8 quad

Unless costs of small-scale CHP systems are reduced, energy-cost savings alone will not provide an attractive return for most end users

- According to the Gas Technology Institute ("MicroCHP Draft Final Report Excerpts," 2013), the costs of existing small-scale CHP systems suitable for buildings are at least 5 times too high for significant market penetration to occur
- BTO's own analysis, existing small-scale CHP technologies based on gas turbines would not result in primary energy savings for commercial buildings, since the prime mover efficiency (i.e., the electrical efficiency) is less than that of the grid, and the 2030 heating energy efficiency for commercial buildings projected by the *2010 Annual Energy Outlook* would be at least as good as existing small-scale CHP technologies

Depending on how they are valued, "other benefits" can make small-scale CHP more attractive.

Heat Utilization: Potential uses



BTO: Multi-Function Fuel-Fired Heat Pump

PROJECT OBJECTIVE:

Oak Ridge National Laboratory is developing and promoting the market introduction of a fuel-fired, multifunction residential heat pump that can achieve the 20% heating, ventilation, and air conditioning (HVAC) and 60% water heating energy savings required to meet the Building Technologies Office (BTO) goal of 50% reduction in building energy use by 2030. Specific objectives include:

- Reducing primary energy consumption by 30%, with a cooling source coefficient of performance (COP) of 1.3 and a heating source COP of 1.5
- Reducing water heating energy consumption by 80%
- Improving the reliability of the electric grid by reducing peak power demand by 85%
- Using natural gas, an abundant U.S. energy resource, as a fuel
- Reducing emissions of carbon by 30%, nitrogen oxide by 30%, and sulfur dioxide by 95%
- A generator/alternator and battery set sufficient to power all electrical items (fans, controls, etc.) and provide capability to start and operate even when the electric grid is unavailable due to inclement weather events or other causes.

PERFORMERS:

Lead Performer:

- Oak Ridge National Laboratory - Oak Ridge, TN

Partners:

- Southwest Gas - Las Vegas, NV
- IntelliChoice Energy - Las Vegas, NV
- NextAire - Las Vegas, NV

Source: http://www.energy.gov/eere/buildings/downloads/multi-function-fuel-fired-heat-pump-0

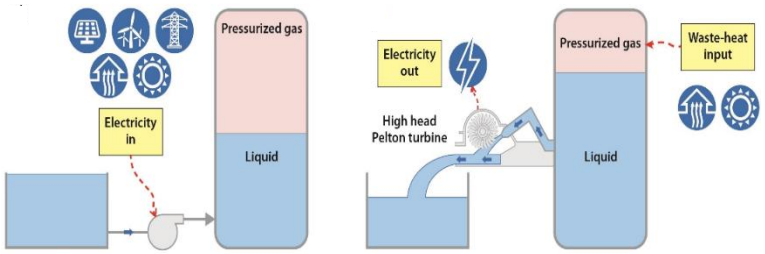
Novel Ground-Level Integrated Diverse Energy Storage (GLIDES) Coupled with Building Air Conditioning

Technical Summary

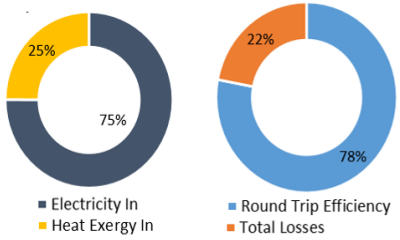
- Efficient, building-integrated electrical energy storage systems will play a key role in achieving high levels of renewable energy penetration and in increasing electrical grid resilience.
- Novel Ground-Level Integrated Diverse Energy Storage (GLIDES) System, invented and demonstrated at ORNL, offers a more attractive alternative to battery storage at nearly half the cost.
- Proposed activity will integrate GLIDES with the building air-conditioning system. This integrated will give the combined system the potential to reach an energy storage roundtrip efficiency of >70% (equal to or better than lead acid batteries) while simultaneously enhancing the HVAC COP by 35% by lowering the air-conditioning condensing temperature.
- Low cost, high efficiency, the capability to integrate low-grade heat and long life are the main advantages of this technology.

Impact

- Proposed system reduces the energy requirements of air-conditioning systems by lowering the condensing temperature. When it is lowered by 11°C, the COP is improved by up to 35% for a typical air-cooled chiller.
- Reducing the energy requirements of AC systems.
- Enables smarter building-grid integration.
- **Enabling use of low-grade heat.**



Schematic diagram of novel GLIDES energy storage technology during charging (left) and discharging (right)



Simulated energy storage performance summary of GLIDES prototype

	Lead acid battery	Proposed technology
Storage cost ($/kWh)	$350-600	$180–300
Storage efficiency (%)	70–85	70–82
HVAC COP improvement (%)	0	~35
Estimated energy Savings (TBtu)	0	1,341

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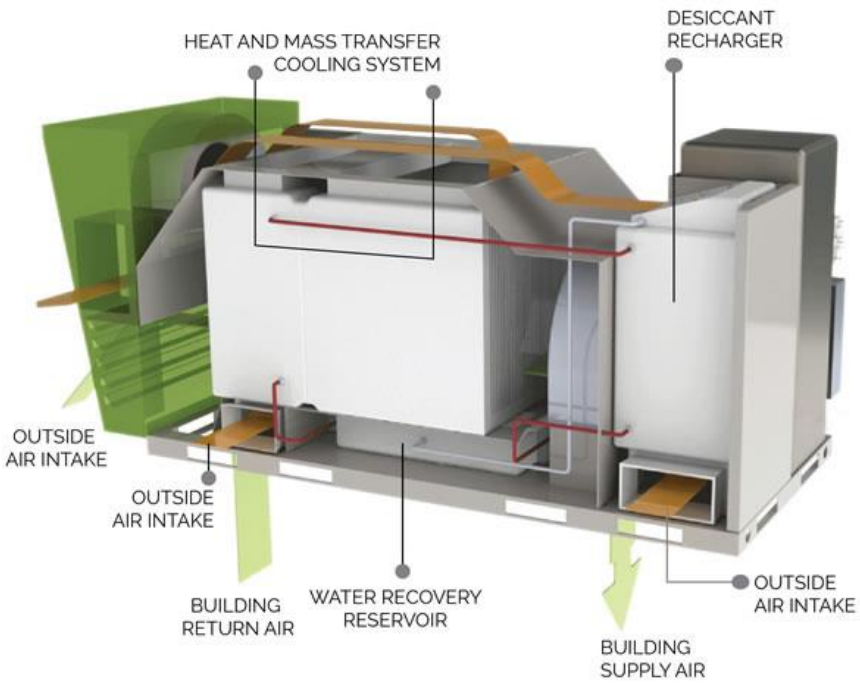
Small Business Voucher (SBV): BePower Technologies

- Testing at ORNL, SBV program
- Cogeneration system that produces electricity, heating and air conditioning (A/C)
- Fuel Cell-HVAC (FC-HVAC) system
- Evaluate under various conditions, a 5 kW system that ***uses natural gas*** to produce electricity, space cooling, and dehumidification in a single packaged unit for both commercial and residential applications
- Water neutral (no hook up or condensate drain lines required)

Be Power Tech
Be Cool, Be Green, Be Power



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Technical Challenges

Factors	Market Barriers
Cost and Economics	High initial capital costs. Low initial sales volumes translates to high production costs.
Operation	Some systems have long startup times and others have slow transient performance.
Peak power	Peak power demands require the unit ramp up quickly or provide this power through alternative methods (grid, storage, etc).
Reliability	Immature technology translates to low reliability, high warranty costs and poor market acceptance.
Emissions	Energy generation for consumption in buildings is a major cause of acid rain, smog, and greenhouse gas emissions. This is a barrier for non-fuel cell microCHP.
Grid Connectivity	Traditionally, utility electric power systems have not been designed to accommodate active generation and storage at the distribution level.
Non-coincidence	Non-coincidence of thermal and electric loads combined with the lack of cost-effective energy storage.
Maintenance requirements	High maintenance requirements are a major market barrier.
Integration into building systems	Requires the simultaneous success of two technologies or end uses.

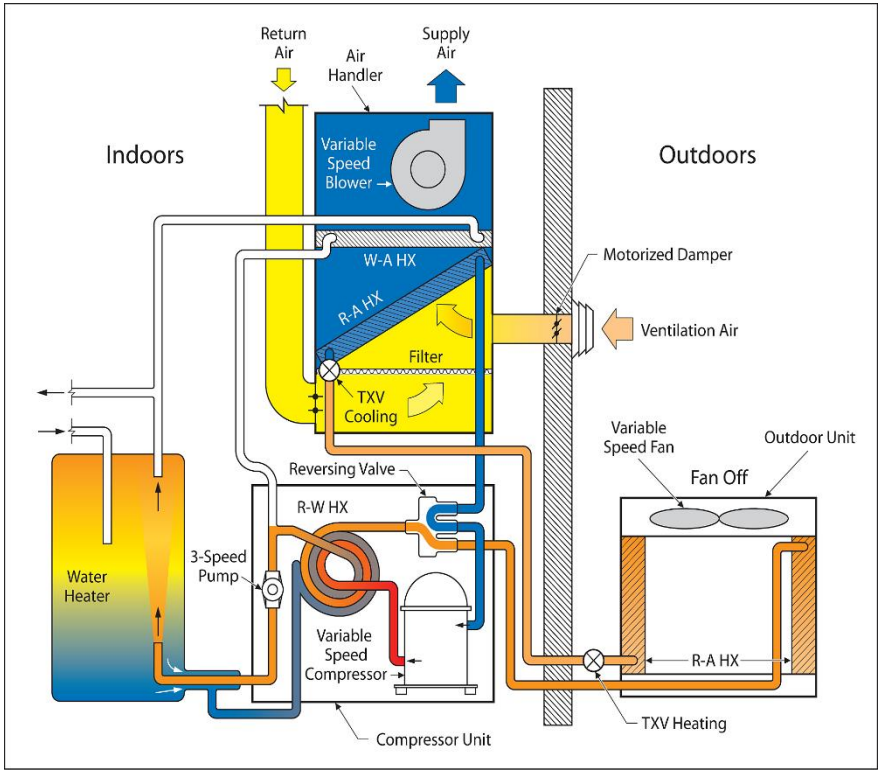
Integration into building systems: Air-source integrated heat pump (AS-IHP)

HVAC Integrated Heat Pump (IHP) Technologies

- Energy cascading is the process of using the waste (or residual) heat from one process as the energy source for another
- Concept is to merge several end-use together, generate a new solution, coupling things together
- Good example exists today from BTO's integrated heat pump work where the waste heat from the AC is used to heat water for free with energy saving potentials approaching 50% when HVAC and water heating is coupled
- Efficient high-capacity water heating

- Key Issues:
  - Balance of charge and flow control among operational modes (SC, SH, WH and combined SC+WH and SH+WH)
  - Determination of optimal component speed ranges for different modes

- CHP can learn from this example
  - Heat utilization for Water Heating
  - System approach
  - Balancing watering with other functions
  - Methods of Test to communicate to consumers benefits



AS-IHP system concept

Possible AS-IHP packaging approach

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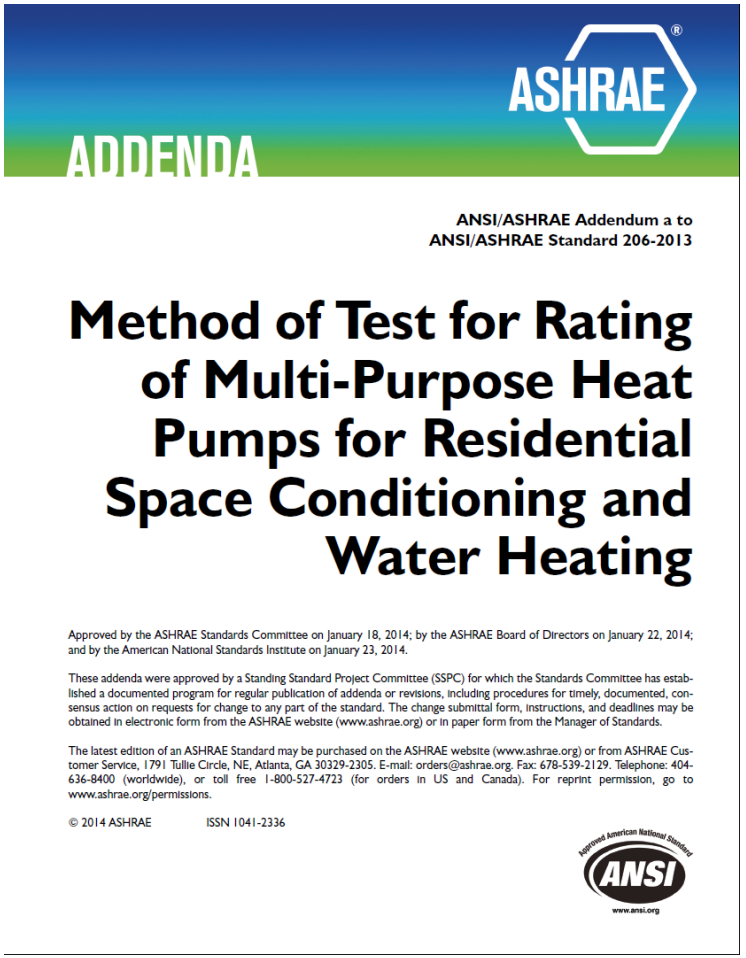
Integration into building systems: Air-source integrated heat pump (AS-IHP)

ASHRAE Standard 206: Method of Test for Rating of Multi-Purpose Heat Pumps for Residential Space Conditioning and Water Heating

- Development of a uniform method-of-test along with performance descriptors understandable by the consumer, followed by establishment of a rating standard, will facilitate market penetration of these energy saving appliances.

- The endpoint of the project will be rating standards that will allow consumers to make informed comparisons of the energy performance of integrated appliances to that of a suite of separate-function appliances.
- EnergyStar, tax credits, utility rebates etc…


ASHRAE

ADDENDA

ANSI/ASHRAE Addendum a to
ANSI/ASHRAE Standard 206-2013

Method of Test for Rating of Multi-Purpose Heat Pumps for Residential Space Conditioning and Water Heating

Approved by the ASHRAE Standards Committee on January 18, 2014; by the ASHRAE Board of Directors on January 22, 2014; and by the American National Standards Institute on January 23, 2014.

These addenda were approved by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Manager of Standards.

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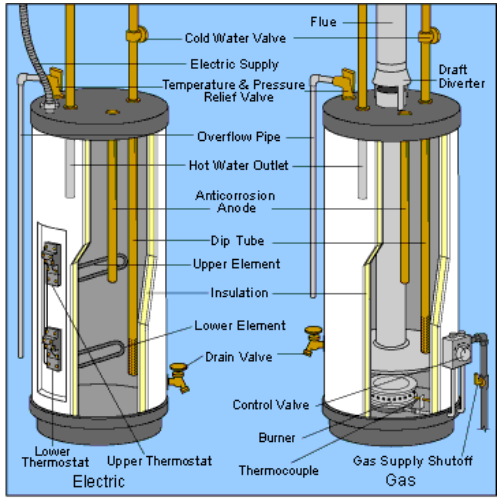
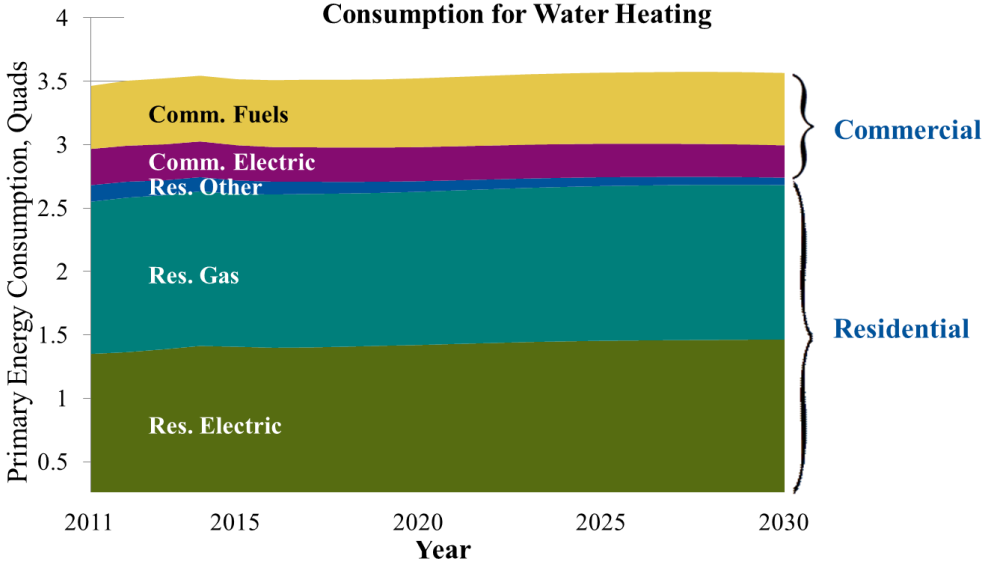
Water Heating: Background

- Water heater shipments averaged 9.2 million units per year over the last 10 years.
- Evenly split between electric and gas.
- Electric units have gained market share in recent years because new housing construction was concentrated in the South, where electric water heating predominates.
- Roughly 80 percent of new units replace old units; the remaining 20 percent are used in new construction.
- Residential energy use for water heating constitutes nearly 80% of all water heating energy consumption.
- Existing residential water heaters in U.S homes are primarily storage-tank type as opposed to tankless.



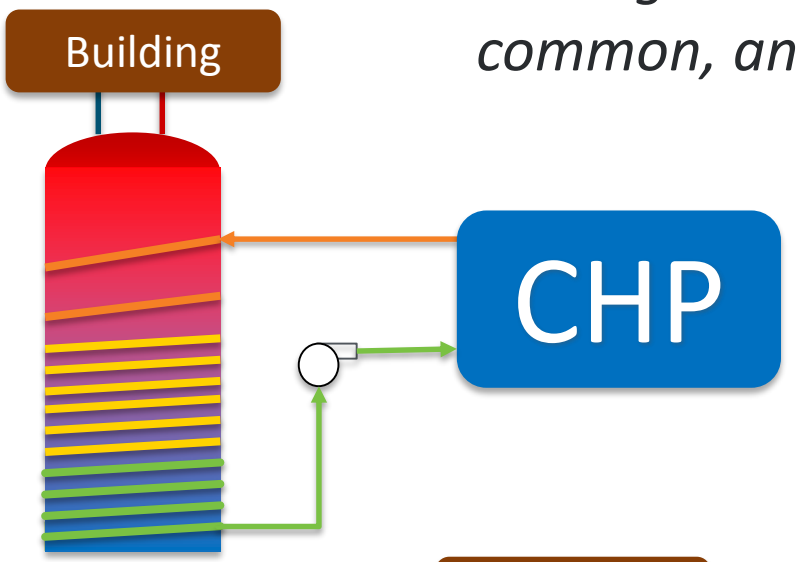
2014 AEO (Early Release) Projected Primary Energy Consumption for Water Heating



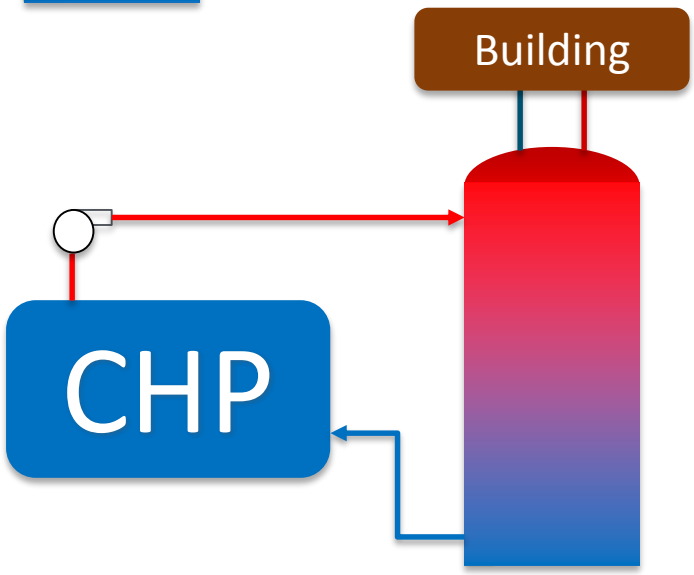
Source: Energy Information Administration's (EIA) Annual Energy Outlook (AEO)

Water Heating: Integration to CHP (illustrative)

Serving heating loads is the simplest, most common, and generally most economic use.



- Wrap-around water heating design



- Water circulating inside water heater

HVAC: Integration to CHP (illustrative)

Serving heating loads is the simplest, most common, and generally most economic use.

Integrated Heating & Water Heating System

- Powered by Tankless Technology
- One Source for home heating, cooling and water heating
- Compatible with air conditioners and heat pumps
- Available in 32 to 90 thousand BTUH capacities

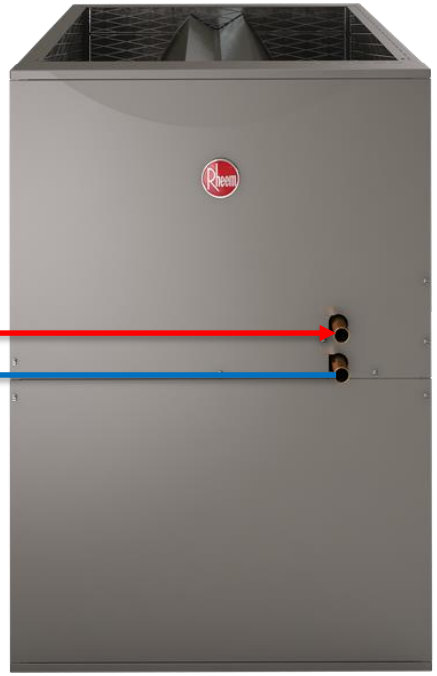
Source: http://www.rheem.com/products/integrated_systems/

HVAC: Integration to CHP (illustrative)

Serving heating loads is the simplest, most common, and generally most economic use.

Replace the tankless water heater with the CHP, from previous picture

CHP



Hydronic Air Handler

- Low profile design
- Left or right side electric connections
- Stainless steel water pump

Source: http://www.rheem.com/products/integrated_systems/

Thank You and Contact Info…

The HVAC/Water Heating/Appliance subprogram develops cost effective, energy efficient technologies with national labs and industry partners. Technical analysis has shown that heat pumps have the technical potential to save up to 50% of the energy used by conventional HVAC technologies in residential buildings. Our focus is on the introduction of new heat pumping technologies, heat exchanger technologies, and advanced appliances, e.g., refrigerator and clothes dryers. Heat exchangers are used not only in air conditioning, heating, water heating and refrigeration but also in nearly every application that generates waste heat, a major crosscutting research opportunity. We are also pursuing non-vapor compression technologies, which have the potential to replace or be integrated with conventional vapor compression technologies, can provide 50% reductions in energy consumption, and have extremely low-global warming potential.

http://energy.gov/eere/buildings/hvac-water-heating-and-appliances

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