the Energy to Lead

Combination space and water heating systems

Energy & Environmental Building Alliance

Excellence in Building Conference & Expo

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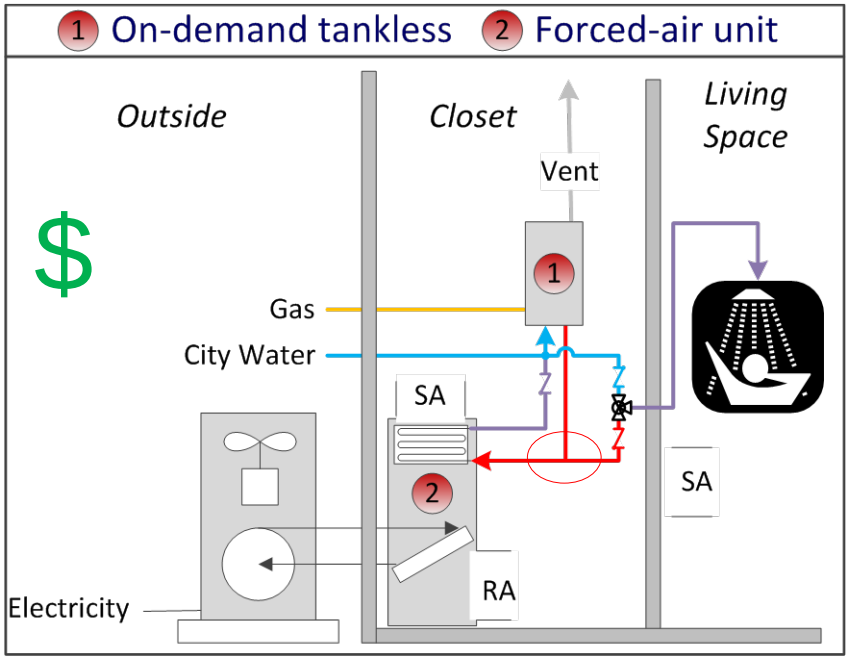
Learning Objectives for Combis

- Technology and market landscape
- System performance in lab
- System performance in-field
- What is next for the technology

Vintage Combi

Forced-air Combi Technology



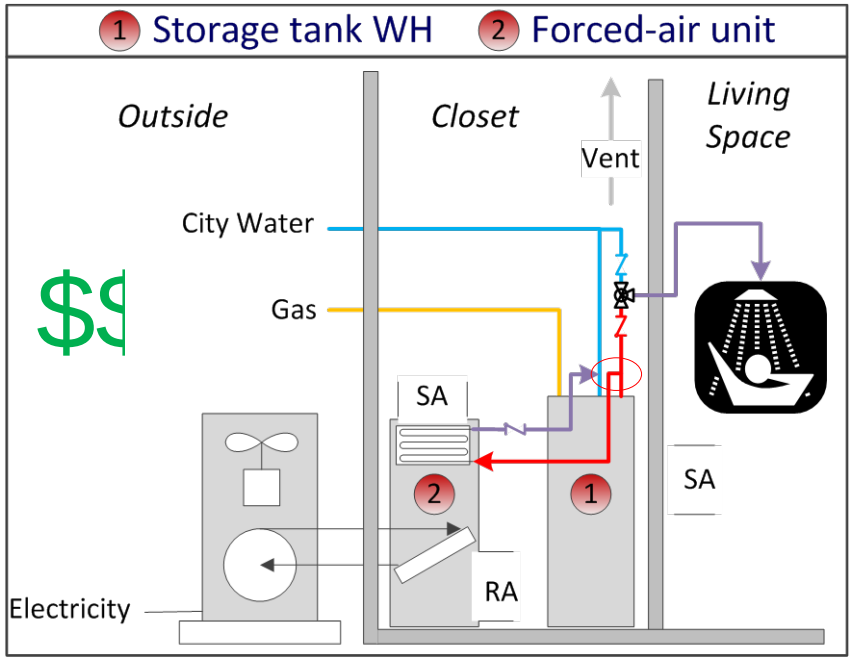
> Pump timer needed

> DHW priority naturally

> Flow switch protects pump

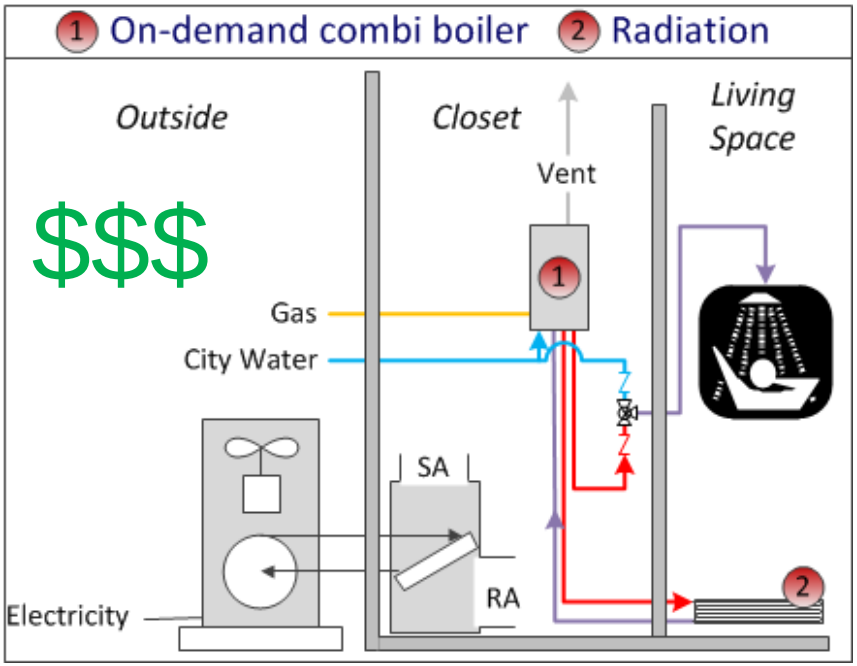
> Condensing water heaters

> Combined loop DHW/SH



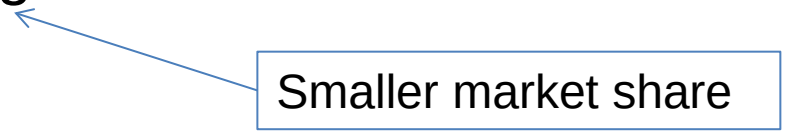
Combi Boiler Technology

- Condensing water heaters
- Isolated SH loop from DHW
- No pump timer needed
- DHW priority by water heater
- Typically designed for higher temperatures than tankless
- Incorporate outdoor reset
- Residential and Commercial models
- Separate from AC system



Condensing Combi Landscape

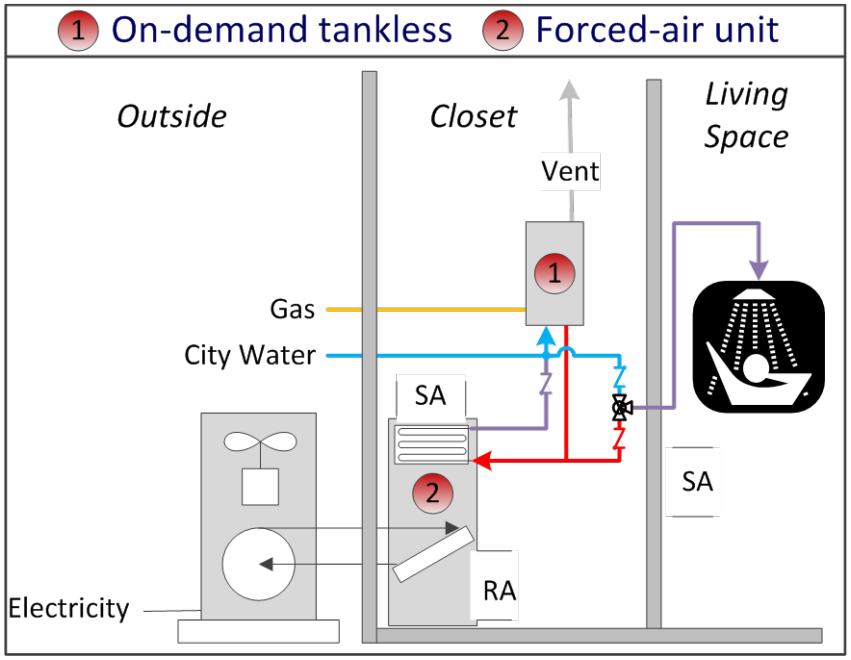
- Packaged combis (dual/triple integrated appliances)
  - Rheem, Dettson, Rinnai/First Co, Heat Transfer Products (storage)
- Mix-and-match condensing tankless water heaters
  - Rheem, Rinnai, Takagi, Navien, Bosch, Grand Hall, Quietside, etc.
- Mix-and-match condensing storage water heaters
  - AO Smith, American, Bradford White
- Mix-and-match FAUs
  - First Company, Enerzone, Comfort-Aire, SunTherm, Rheem, Dettson, etc.
- Combi Boilers
  - Rinnai, Navien, Laars, Triangle Tube, Heat Transfer Products, etc.



Tankless-FAU Benefits/Challenges

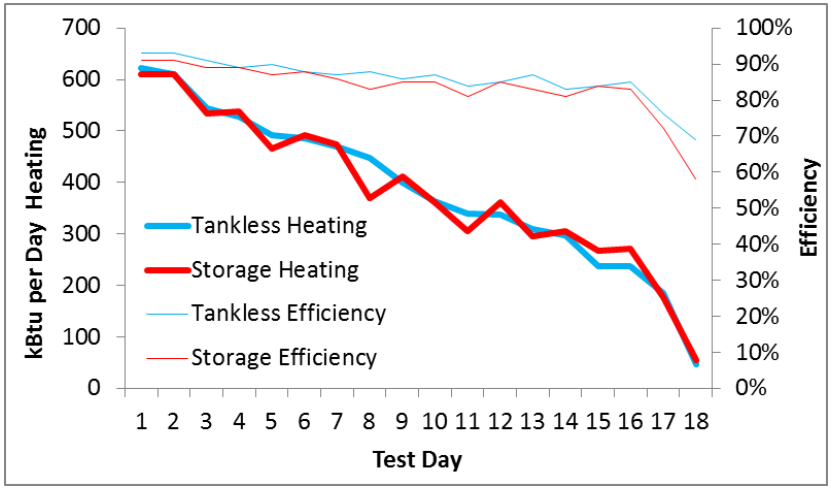
> Tankless/FAU Benefits
  - Lowest cost combi option
  - High efficiency and capacity
  - Easy forced-air integration
  - Space savings, no floor space, outdoor, attic

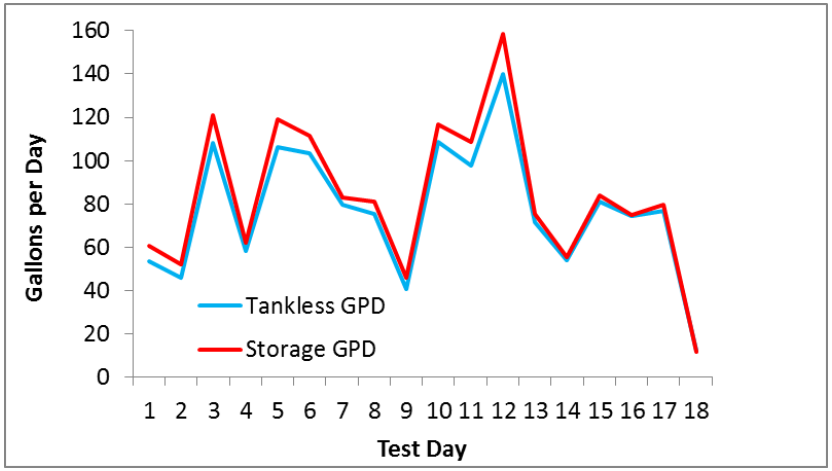
> Tankless/FAU Challenges
  - Sizing delema (SH/DHW)
  - Inconsistent condensing
  - Typical tankless issues
  - Pump timer
  - Contractor unfamiliarity



  - Complexity/field engineering
  - System tweaking to achieve high efficiencies.

Tankless vs. Storage Combis in Lab

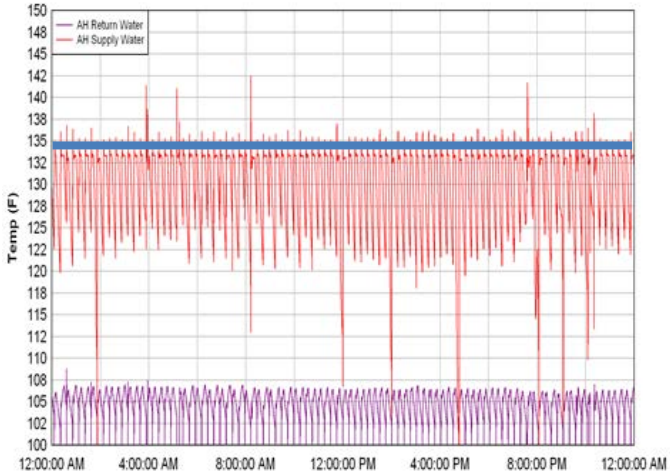


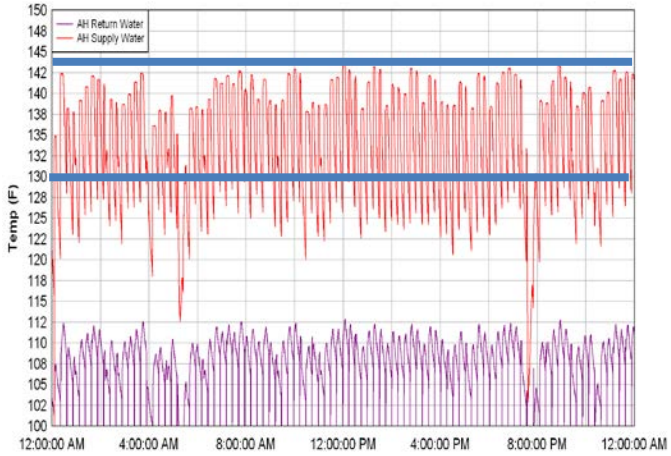


- Mid-80% to low-90%
- Big eff. drop at low loads
- Systems “fine-tuned”
- Tankless combis had slightly better efficiencies
- Costs for condensing storage vs tankless similar

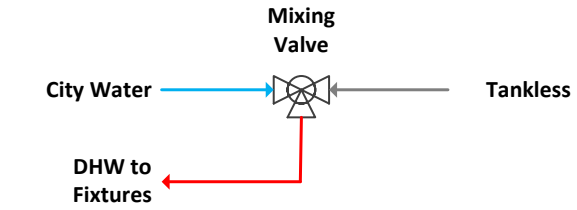
Tankless vs. Storage Combis in Lab

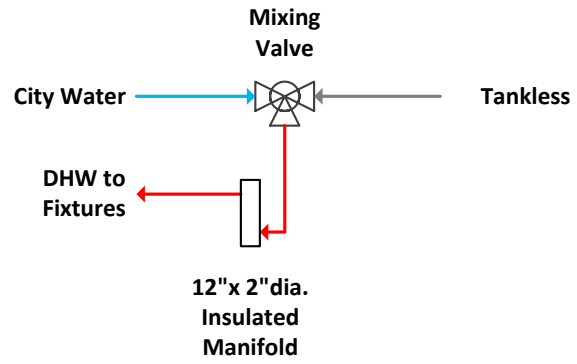
- Tankless: very consistent heat loop water temp
  - +/-2°F from set point
  - Consistent supply air temp
- Storage: temperature stratification in tank
  - Within 10°F to 15°F of setting
  - Inconsistent supply air temp
  - Using side taps for htg loop
  - Maybe better with top taps

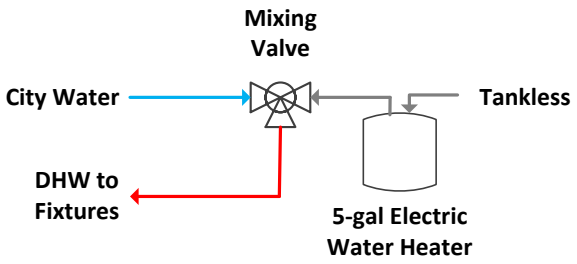


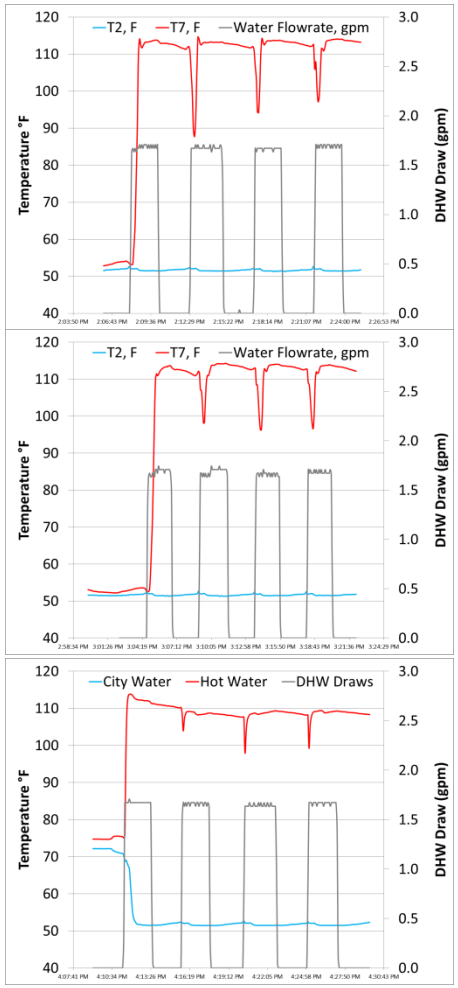


Cold Water Sandwich









- No control measure
- 27°F sandwich
- Drops below 90°F (cool)

- ¼-gal manifold (low-cost)
- 15°F sandwich (still ~100°F)
- 44% improvement

- 5-gal electric water heater
- Higher cost ($350)
- 6°F sandwich
- 81% improvement

GTI Tankless-FAU Combi Field Work

- Combi field demos: 10 units in NY
  - All 10 homes monitored for 1 year

- Combi pilots: 36 units in IL, CA, and CT
  - Nicor: 5 homes monitored for 1 year
  - SoCal: 30 homes, 5 will be monitored
  - UIL: 3 homes monitored for ~5 months so far

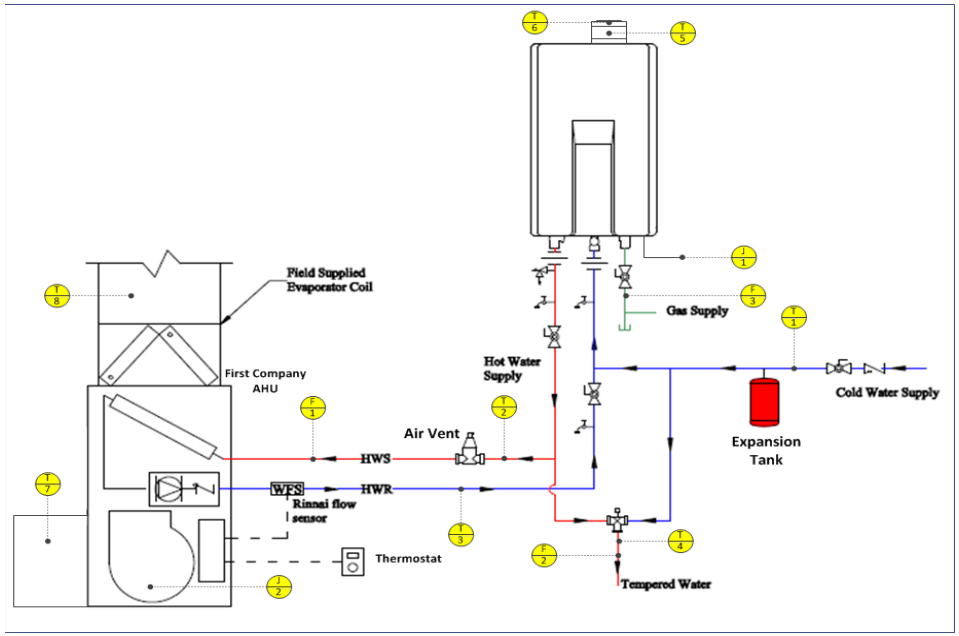
- Combi laboratory testing and development
  - Combi enhancements and guidelines
  - Advanced FAU development (with Auburn)

NYSERDA/Nicor Demo/Pilot Scopes

> Determine performance attributes of tankless-FAU combis

> 12 months of in-field monitoring (weather normalization)

- Trained contractors
- Recruited host-sites
- Analyzed gas bills
- Contractor load calcs
- Manufacturer approvals
- Contractor installed **w/o GTI intervention**
- GTI commissioned
- Data collected/reduced



Code Misperception and a Barrier Broken Down

- Major distributer in Illinois service territory had perception that combi systems were prohibited
- Past installations in the region where sited with specific code violations and ingrained in the trade
  - There must be provisions that prohibit potable water from standing in the heat transfer unit when not in use
  - Units must bear a statement on the rating plate indicating suitability for potable water heating and space heating
- Manufacturers had long since resolved those issues
- Code misperception alleviated through training

NYSERDA/Nicor Performance Results

Host Site Cumulative Data	Therm Savings Combi Versus Baselines		Percent Savings 0.59 DHW 80% SH	Percent Savings 0.59 DHW 90% SH
	0.59 DHW 80% SH	0.59 DHW 90% SH		
Nicor	127.5	4.0	9.4%	0.0%
NYSERDA	129.5	42.5	13.0%	4.6%

PARR
The Partnership for Advanced Residential Retrofit

Building America U.S. Department of Energy — Industrialized Housing Partnership

Nicor					
Site-System	1B	2B	3B	4B	5B
Cumulative Eff.	82.8%	88.0%	86.4%	85.6%	82.8%

NYSERDA										
Site-System	1G	2A	3A	4B	5C	6B	7D	8E	9F	10A
Cumulative Eff.	74.4%	77.3%	90.3%	82.0%	72.0%	82.4%	92.2%	93.0%	91.7%	87.4%

- Systems D, E, and F used third-party AHUs designed specifically for use with condensing water heaters (maximized thermal transfer across hot water coils)

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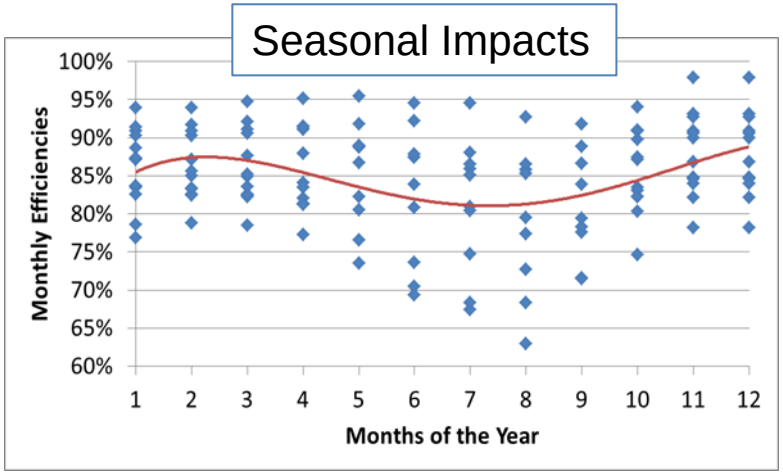
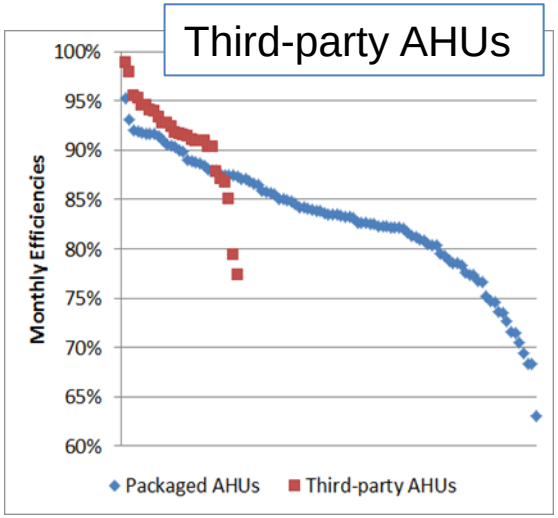
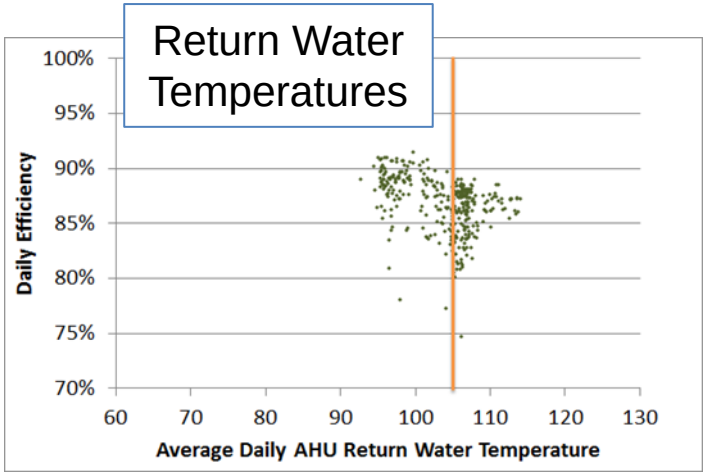
Field Data Observations

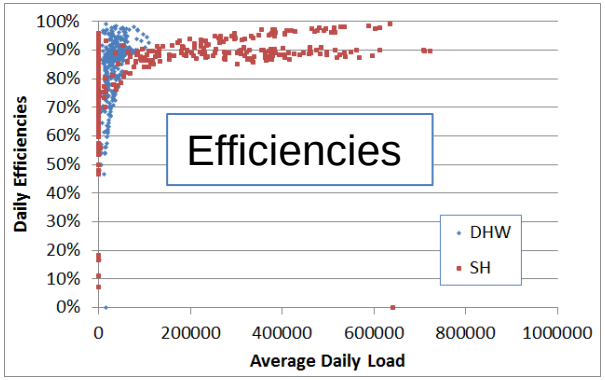






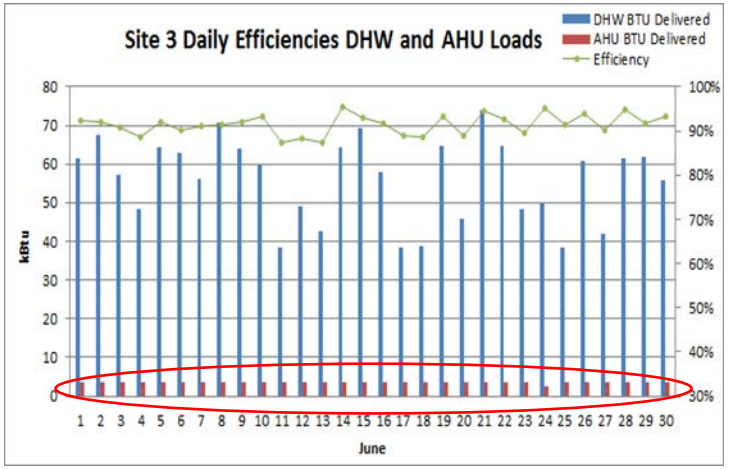
Corresponds with CEE research

Center for Energy and Environment



Pump Timer Problem

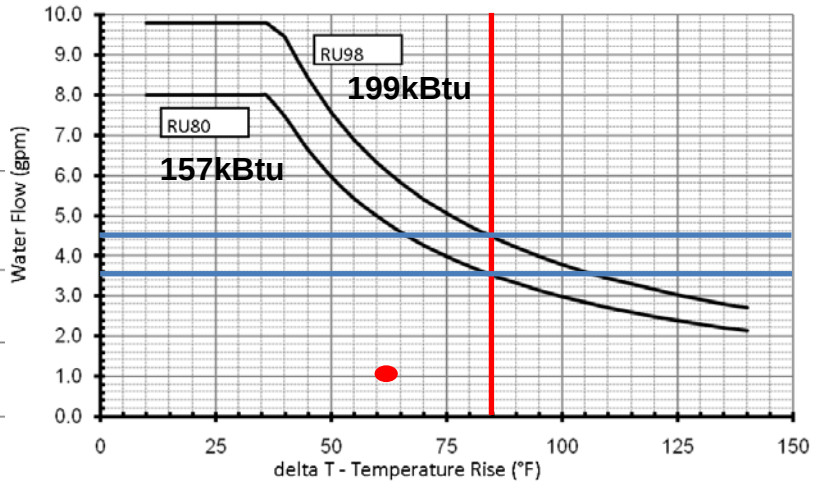
- Why heating loads in the summer?
- AHU manufacturers incorporate pump timers to circulate water every 6 hours (Legionella)
- Circulates for ~30 seconds even in the summer… and the burner comes on
- Heats air conditioned supply air briefly ~85°F

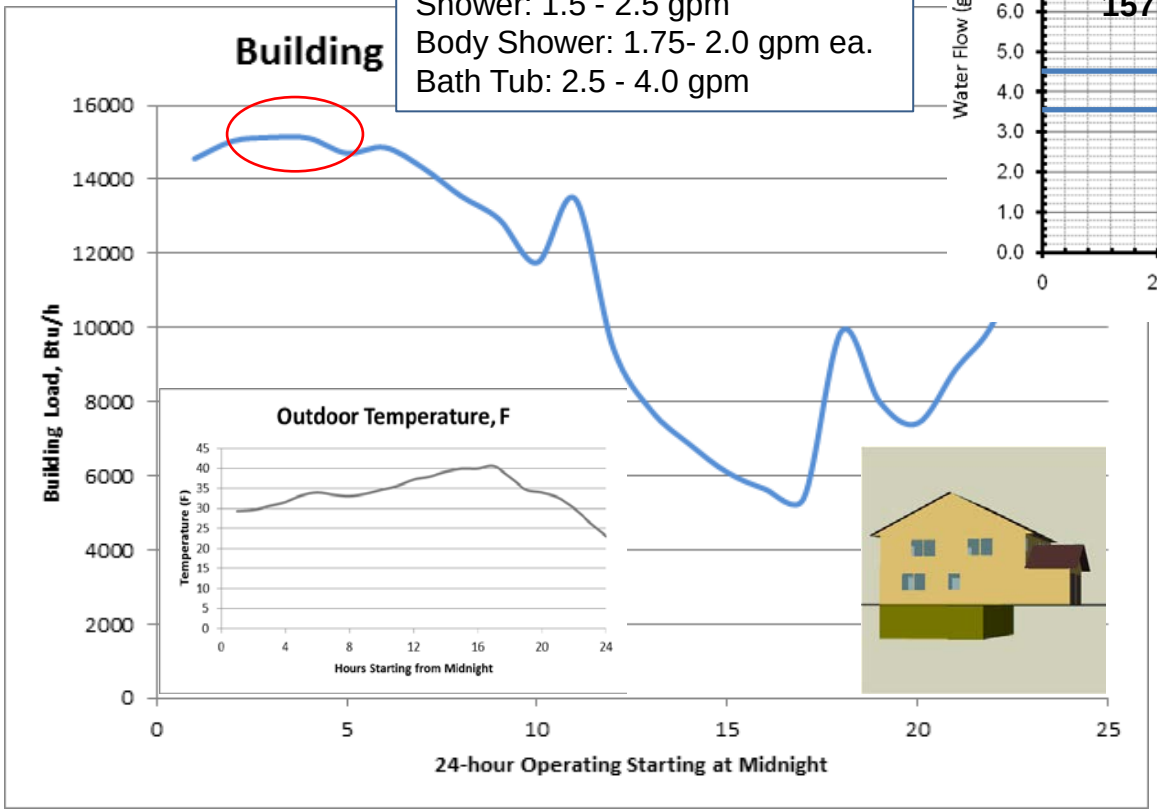


- Pump timer for combi forces 199k btuh burner on for ~2 minutes per day
  - ~6k btu per day just to circulate AHU water
- For reference: storage WH standby losses might use 40k to 50k btu per day
- Need a better solution!
  - Part of GTI's upcoming laboratory work with Auburn University

DHW/Space Heating Mismatch

Typical Flow Rates
Dishwasher: 0.5 - 1.0 gpm
Sink: 0.5 - 2.0 gpm
Washing Machine: 2.0 - 2.5 gpm
Shower: 1.5 - 2.5 gpm
Body Shower: 1.75- 2.0 gpm ea.
Bath Tub: 2.5 - 4.0 gpm





More than 10:1 turndown for typical space heating

Sizing Recommendations for Tankless-FAU Combis

- Water heater objectives
  - Size water heater based on DHW demands
  - Avoid tendency to oversize tankless based on unrealistic DHW demand scenarios
    - Install low-flow fixtures (old houses)
- Hydronic FAU objectives
  - Size FAU based on heating/cooling load calcs (e.g. Manual J)
    - Best to use an FAU with integrated hydronic/refrigerant coils
  - Maximize heat transfer across the FAU hot water coil
    - Adjust air flow to maintain min 110°F supply air
    - Adjust water flow to maintain max 105°F water return to FAU
  - Outside 15-60kBtuh - maybe not suitable for condensing combi

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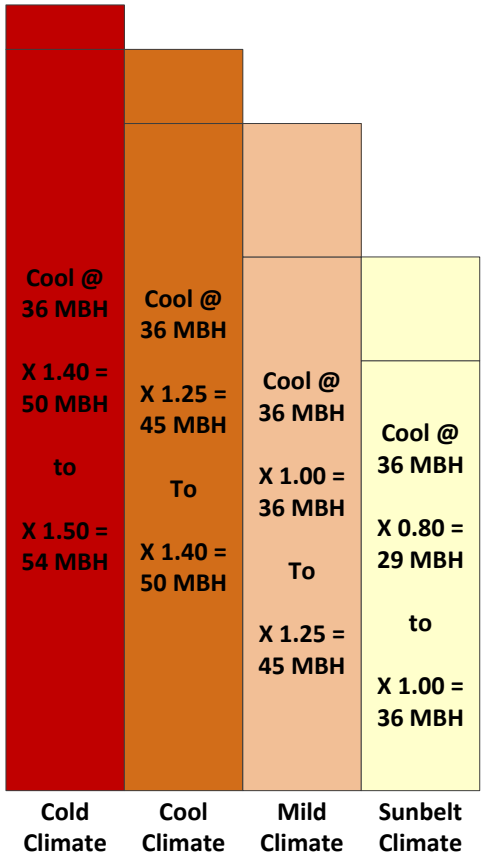
Load Calculations from Field

- Typical ~2,000 sq-ft, 3 tons cooling
- Readily available hydronic FAUs well-matched with typical homes
  - 30 to 60 MBH
- Condensing tankless plenty of capacity for space heating and DHW
  - 120 to 199 MBH
- What about ZNE homes?
  - 15 to 30 MBH heating?
  - Combi system product gap?



Installation Guidelines

A) Shutoff with thermal expansion (ASSE-rated)

B) Mixing valve with certified check valves

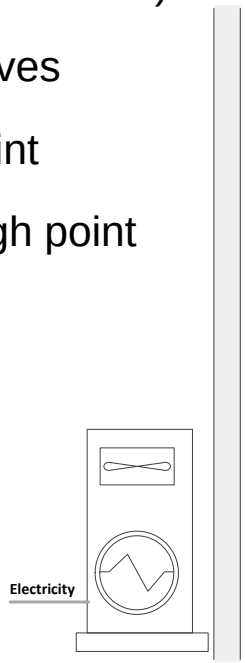
C) Shutoff with manual bleed at low point

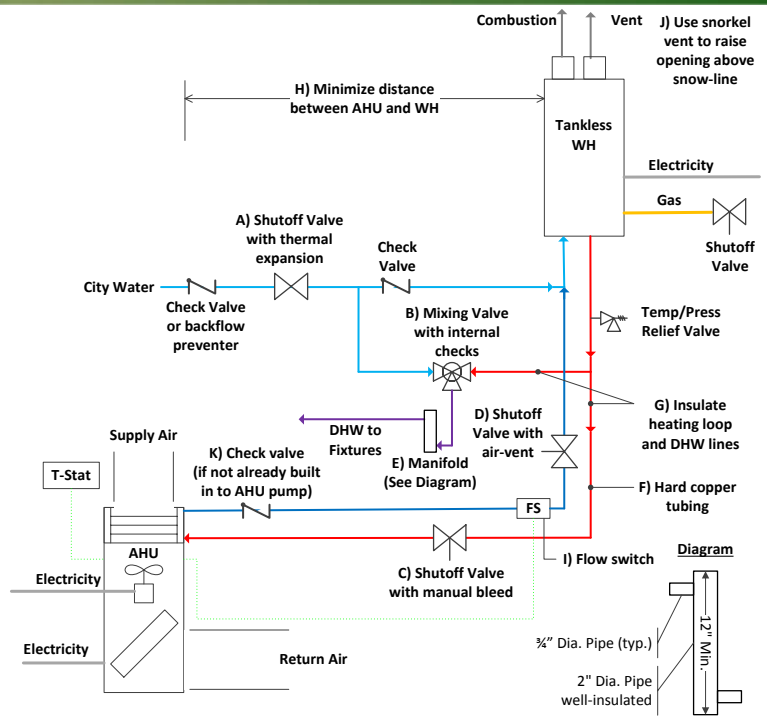
D) Shutoff with automatic air vent at high point

E) 2” dia. by 12” long manifold
- For cold-water sandwich

F) Min ¾” hard copper tubing
- Plastic harbors Legionella

G) Insulate SH loop and DHW supply





H) Minimize distance between FAU-tankless, and minimize all piping pressure losses

I) Flow switch protects FAU pump from min flow (DHW priority happens naturally)

J) Snorkel vent raises vent opening above snow-line in cold climates

K) Check valve prevents back flow during DHW draws, prevents thermal siphoning

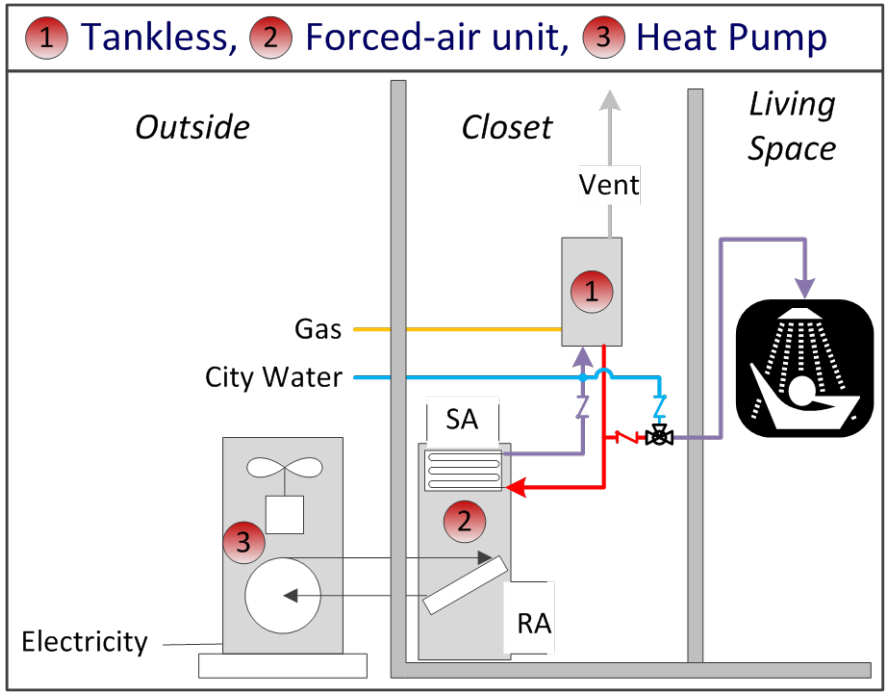
Looking Ahead

- Widespread contractor education is key to market expansion
- Installed costs need to come down by about 15% to 25% to make combis marginally acceptable in terms of utility total resource cost
  - Average of 130 therms saved per year
  - Average of 11.5% DHW and SH gas saved per year
  - Compared to conventional furnace at 80% AFUE and water heater at 0.59 EF
  - Combi cost $5,750 vs. $3,500 to $3,800 for traditional equipment
- Maximize opportunities for better efficiencies through better system integration and advanced system/product design
- Better understand how well combis compare to other heating systems

Triple Integrated Appliances

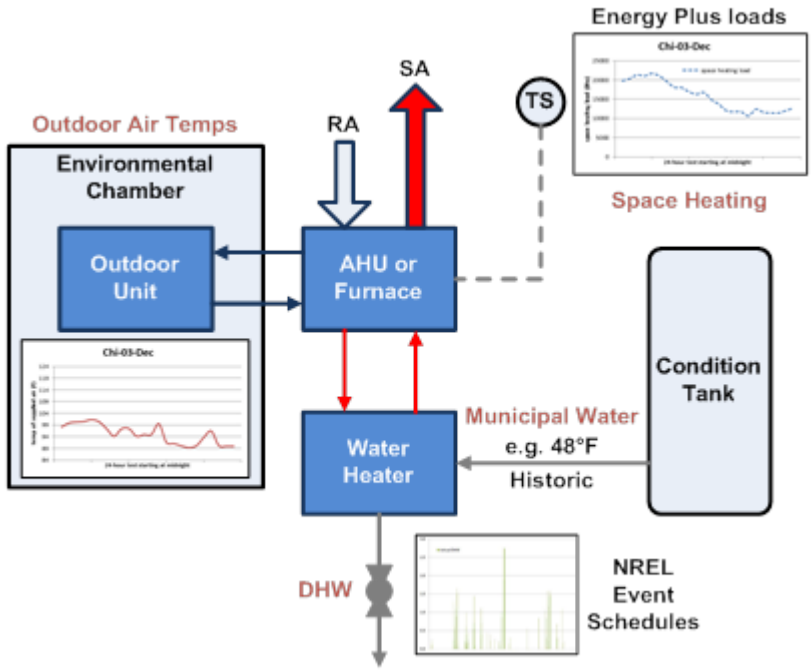
- Auburn University Advanced AHU
  - Cooling, Heating, DHW
  - EHP/Gas WH integration
  - Improve coil thermal transfer
  - Eliminate pump timer?
  - Reduced installation cost
- AO Smith (Takagi 120kBtuh tankless water heater)
- Carrier electric heat pump
- 5-unit demo (NYSERDA)
- Pretesting in lab through UTD
- Field demos in 2015

Maximize opportunities for better efficiencies (High and low loads)

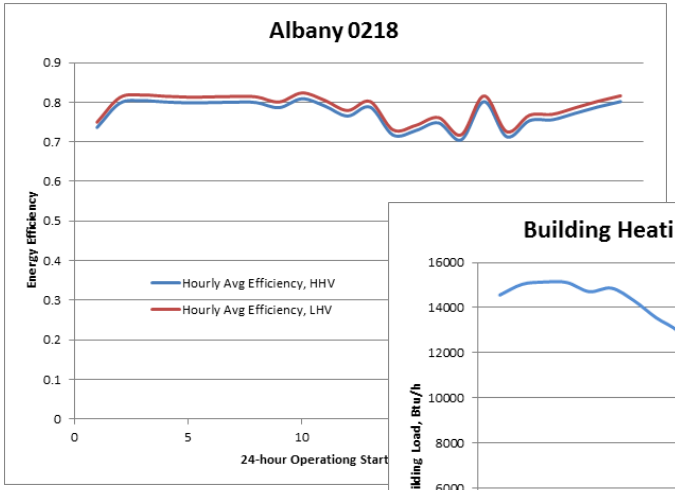


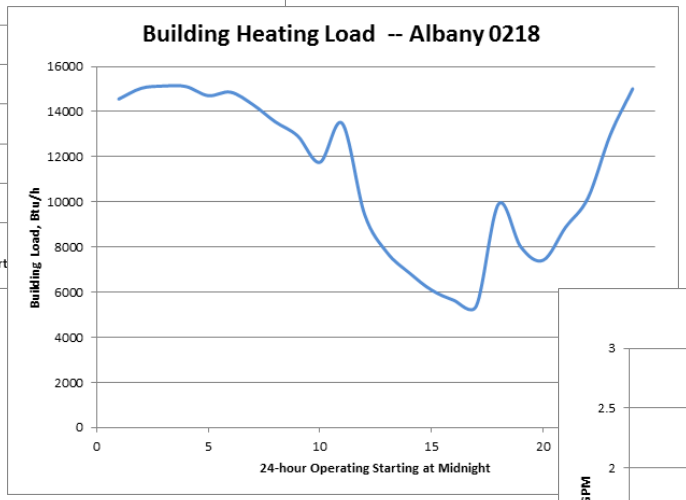
24-Hour Profile Testing in Laboratory

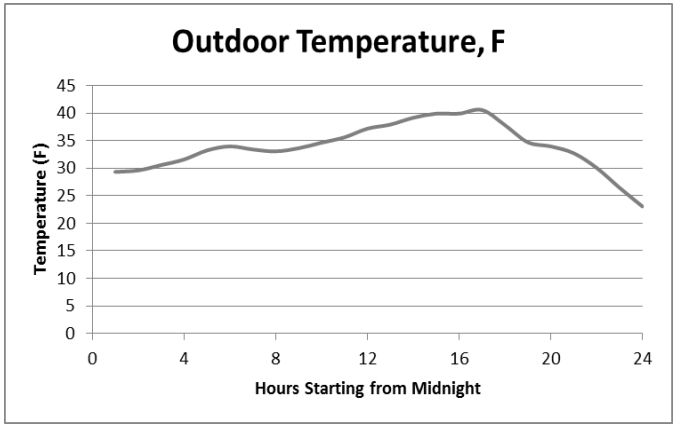
- Have field results for combis, but how do they compare to traditional equipment?
- Lab test methodology
  - SH loads and thermostat calls
  - DHW draws and flows
  - Outdoor air temperatures
  - Municipal water inlet temperatures
- Simulates as-installed field conditions in controlled lab setting
- Can compare performances of different systems on equal footing

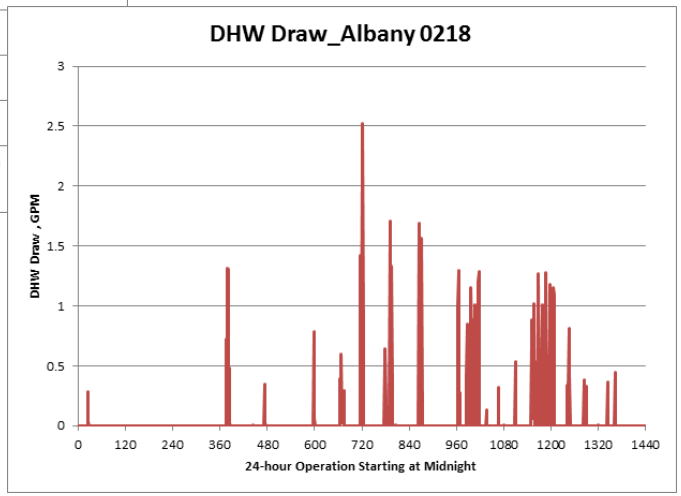


As-Installed Controlled Conditions









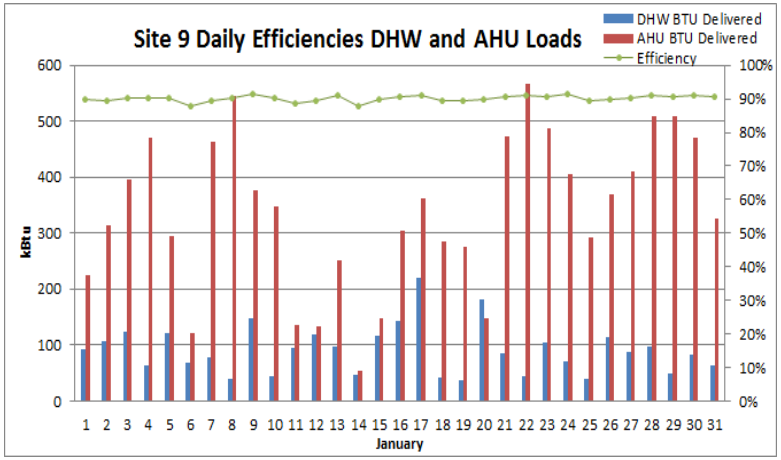
Competitive Performance

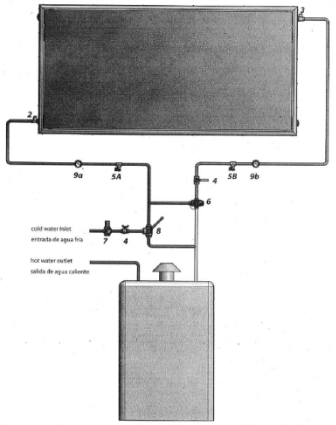
- Test systems against as-installed space and water heating loads typical to residential applications
- Conduct tests under controlled conditions in the laboratory where as-installed conditions can be consistently replicated

System	Type	Space Heating	Water Heating
BL	Gas	Conventional Forced-air Furnace	Conventional Storage Water Heater
1	Gas	Condensing Forced-air Furnace	E-star Storage Water Heater
2	Gas	Tankless* + Hydronic Furnace	Tankless* Water Heater
3	Gas	Absorption GHP + Hydronic Furnace	Tankless* Water Heater
4	Gas Electric	Hybrid EHP + Tankless* + Hydronic Furnace	Tankless* Water Heater
5	Electric	Traditional EHP	Resistance Water Heater
6	Electric	Traditional EHP	EHP Water Heater

Zero Energy Ready Homes

- Technology solution
  - High efficiency space and DHW
  - Minimizes fossil fuel
  - Can integrate solar thermal
- Business solution
  - Some gas utilities no longer offering residential, high efficiency, stand-alone water heater incentives because TRCs too low
  - Combi systems can raise water heating efficiencies along with space heating efficiencies
  - Builders need only install one system – saves space and installation costs





Questions?