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## What are the Best HVAC Solutions for Low-Load, High Performance Homes?



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### What is Low-load? - Definition(s)

- Residence that requires a heating capacity of less than +/-25 kBtu/hr or cooling / heat-pump system capacity of less than 1.5 to 2 tons
  - Standard cooling equipment available in 1.5-2 ton and up
  - Standard heating equipment available in 40 kBtu/hr and up
- Peak load intensity per unit floor area (  $W/m^2$  or  $btu/(h \cdot ft^2)$ ) less than about 12-15 Btu/hr per sq ft and cooling under one ton per 1200-1500 sq ft
  - Different rules for distribution, mixing, duct sizes apply at these low loads
- Less than  $\frac{1}{2}$  or  $\frac{1}{3}$  equivalent code-built home



Low-Load HVAC Solutions

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## Context

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- New low-load houses consume almost as much DHW energy as space-conditioning
- Therefore ...
  - Hard to address HVAC without considering DHW
- Required power output for DHW is around 75-125 kBtu/hr to meet 2-3 GPM draw
  - (Btu/hr = 500  $\Delta T$  GPM)
  - This is significantly more than peak power demand for cooling or heating

## Problem

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- Over-sized AC means poor latent control, short cycling reduces durability and comfort
- Over-sized heating (2x or more) requires much larger ducts and vents for no benefit
- Short-cycling furnace can limit comfort
- Small 12-24 kBtu/hr modulating condensing gas furnaces could be built easily be built...
- PS Small units usually more expensive. Standard units are cheap

## Low-energy houses

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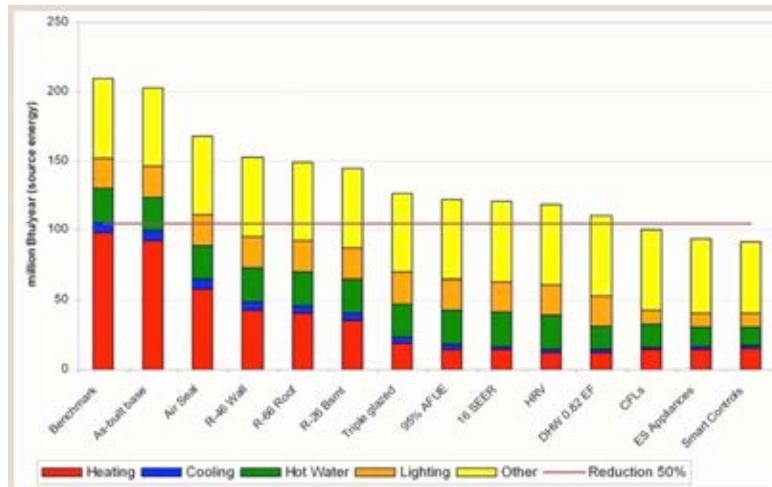
- Peak demand for super-insulated 2000 sf
  - Often 20 kBtu/hr or less, usually under 30
  - Townhouses often under 12 kBtu/hr
- Annual space heating demand usually under 7500 kWh/yr
  - (e.g. 200 therms)
  - Higher specs, simple buildings gets demand lower

## Domestic HotWater

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- Typical US household (census data)
  - 4000 kWh demand +/- (136 therm)
  - National *consumption* 5600 kWh (192 therm)
- Typical 5 unit + building. Use /unit
  - 2500 kWh demand (86 therm)
  - 3575 kWh/yr estimated *use* (122 therm)

## Small MA house



**Graph 1: Parametric Study**  
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## Multi-unit apartments

- 25 x 30 ft = 750 sf 1 BDR interior apartment
  - 25\*9 ft height = 225 sf sq ft enclosure area
  - 40% windows = 90 sq ft
- R20 wall, R4 window, 0 F outdoor temp.
  - $(135/20+90/4) * (70-0) = (6.75 + 22.5) * 70$
  - **2050 Btu/hr conduction losses (!)**
- Achieve 0.40 cfm/sq ft @75 Pa airtightness
  - 24 cfm leakage natural = **1680 Btu/hr air leakage loss**
- Ventilation (New World needs it)
  - 30 cfm /w/66%HRV = **1600 / 500 Btu/hr ventilation**

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One therm = 29,3 kWh

## Simple Heating Analysis Apartment

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- Peak design load: 4.25 kBtu/hr (<1.25 kW)
  - Corner apartment up to 6 kBtu/hr (2 kW) ....
- Heat loss coefficient 60 Btu/F/hr
- If we use HDD65 = 7500
  - $60 \times 24 \times 7500 = 108$  therms = \$300/yr propane
  - Elec: 3000 kWh/yr @ 15 cents = \$450/yr
- Heating airflow = 85 cfm @ DT=50

## Recommendations

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- No perfect solution for all
- Major question:
  - all electric or
  - Gas+ electric
- Cooling important or not?
  - humidity?
- Ventilation

## Choices

- Furnace is still a good choice if you have natural gas and loads over 10-15 kBtu/hr
  - Choose smallest condensing unit, lock out high fire
- Combo Systems
  - Use high-efficiency DHW system to provide heating
  - Space heat can be fan coil, radiator, floor
  - Can be integrated into ventilation, filtration
- Size of duct/coil often fixed by cooling system

Combo system: gas hotwater heater



**Rinnai**

**37AHB Series Hydronic Furnace**

Part of the Rinnai Tankless Heating System

PATENT PENDING



**FEATURES**

- Four models covering a range of heating capacities
  - 27,100 to 96,300 BTU/hour
- Multi-position (upflow, downflow, horizontal left, horizontal right) without modifications \*
  - Modifiable for side-entry return air

The optimum in hydronic technology, the newly designed Rinnai® multi-position hydronic furnaces offer a unique solution for a wide variety of small- and medium-sized residential and light commercial applications. They are compact and ready to fit in tight spaces which may include, but not limited to, attics, basements, closets, crawlspaces, and utility rooms.



Low speed fan setting and lower water temperature (120 F) allows for whole house heating of homes with just 8-15 kBtu/hr peak

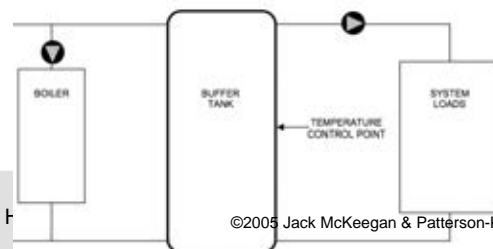
## Combo Systems

- Condensing Tankless heaters
  - Beware minimum output
  - Most units are 15 to 35 kBtu/hr minimum
- Unless storage is provided, min output equals min output of heating system
  - This means duct sizes, coils, etc.



## Combo System Warning

- Provide buffer capacity
  - Eg a storage tank
- Limits short-cycling when loads are small (eg 10-30% of min. boiler output)
- Buffer tank avoids cold slug complaints too





## Newer Condensing Tanked systems

Allows for direct connection to air handler. No additional controls or plumbing

May be lowest cost solution for pretty high efficiency in small apartments, homes, with little cooling needs.



Low-Load

**NEW FORCE 90™**

**98% Thermal Efficiency**  
For light commercial applications, Force 90 puts 76,000 BTU input into a 50-gallon tank to deliver more hot water than any "conventional" 50-gallon unit. With its compact 22" footprint and the flexibility of horizontal or vertical power-vent design, Force 90 is easy to install. It's the ideal choice to give smaller businesses and institutions more hot water, in the same space or less, with significant savings on their energy bills.

**Power-vent design**  
Force 90 allows you to replace expensive metal venting with 2", 3" or 4" PVC vent pipe. Depending on the pipe size used, you can place and easily install vent runs up to 128 equivalent feet, terminating vertically or horizontally through an outside wall.

**Premium-quality glass liners, protected by two coats of resin**  
Both Force 90 and Ultra Force water heaters deliver maximum service life, with a glass lining formula specifically designed for the demands of commercial applications. The interior of the heat exchanger is also glass lined to protect against flue gas condensation.

**Vertical and heat exchanger**  
Unlike conventional light-commercial heaters with a "flat tube" flue that combustion gases straight up and out, the Force 90 achieves 98% thermal efficiency by circulating them up, down and around. This design provides much more heat transfer surface, keeps heat in the tank longer and allows Force 90 to handle 76,000 BTU input for extraordinary water heating power.

**Decentralized maintenance outlet**  
Because of its 98% efficiency, Force 90 is a fully condensing water heater and is shipped with a condensate elbow and outlet to allow easy removal of flue gas condensate to a suitable drain or exterior location.

**Smart-Flow™ gas control valve**  
Advanced electronics assure precise temperature control. Diagnostic operation and built-in diagnostic programming with LED lights allow on temperature adjustment and identification of simple "troubleshoot" displays during service calls. Equipped with precision-grade silicon nitride fire surface igniter.

\* Intelli-Tank is a registered trademark of the Emerson Electric Company.

## Ductless Mini-split

Modulating= follows load profile  
Available in small sizes  
BUT, don't provide ventilation or DHW



## Mini-split

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- Space distribution from 7kBtu/hr head?
- Aesthetics or exposed heads
- May be excellent point cooling sol'n with combo heating / ventilation

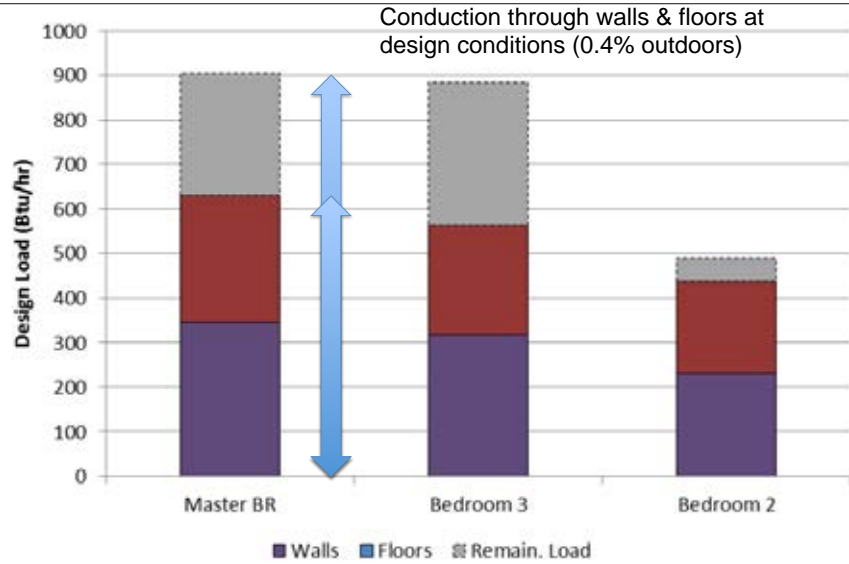


## Single Point Heating Background

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- Used successfully with other superinsulated projects (~R-40 walls, triple glazed windows)
- SWA work: small distribution fans to bedrooms (81 CFM total)
- Conclusion: distributes ventilation air, not heat
- Need ventilation fan when bedroom doors are closed for good ventilation distribution
- Doors closed, ventilation fan on, outdoors ~20°F: Bedrooms dropped ~5°F overnight

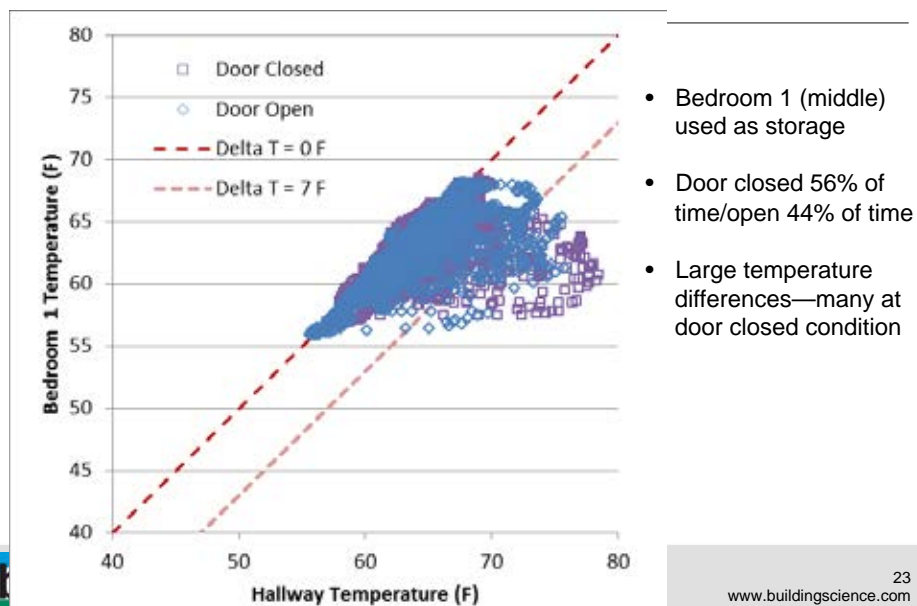
## Heat Flow at $\Delta T=5$ F Hall-to-Bedroom



Corporation

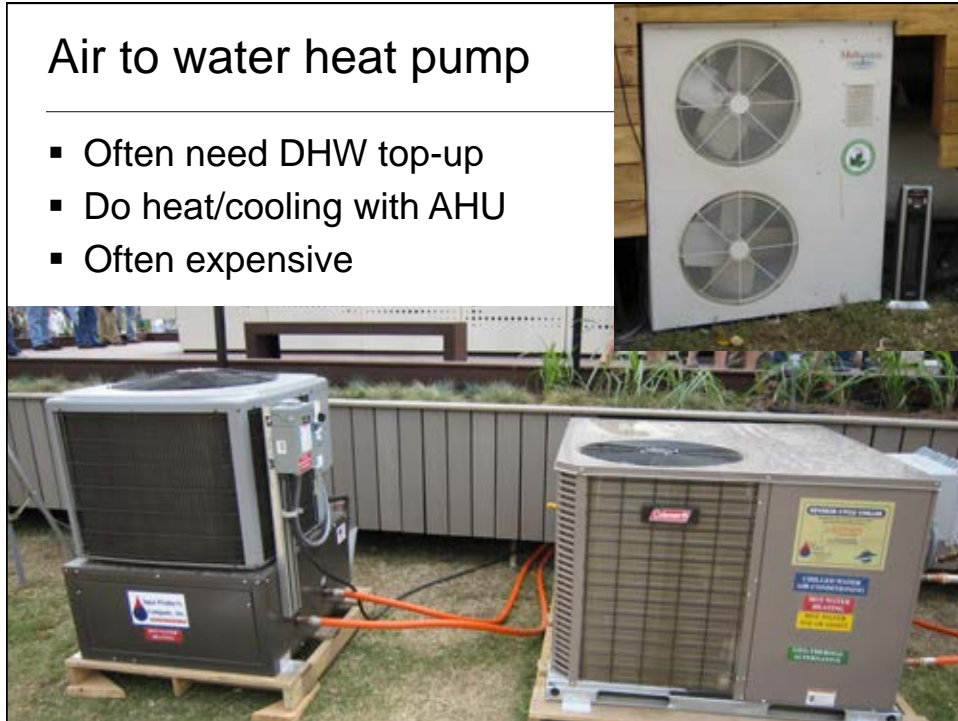
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## Hallway vs. Bedroom Correlations (BR1)



## Air to water heat pump

- Often need DHW top-up
- Do heat/cooling with AHU
- Often expensive



## Pros & Cons of existing solutions

- Condensing furnace + nat gas hotwater heater
  - Furnace too large, hotwater heater not very efficient
  - 2 ton AC often too large
- Air-source heatpump + nat gas hotwater heater
  - 2 ton unit may be over-sized for cooling in cold climates
  - Hotwater heater not too efficient
- Tankless combo system with small air handler
  - Can be tweaked and tuned to meet any heating need
  - 2 ton AC is often too large
  - Not an all-electric solution, installation requires care

## Pros and Cons of Possible Solutions

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- New technology variable Heat pumps
  - Allow all electric, heating+cooling solution in one unit
- Air-to-water HP look good if expensive, but ...
  - Getting 120-140°F or more water for DHW is not very efficient (source energy vs gas)
- Air-to-Air HP look good, small capacities
  - Cost effective, HSPF>11, SEER>20, modulating output
- Meeting peak loads in cold climates is challenging
  - Air-to-air HP now down to -5F reliably
  - Air-to-water perhaps 10F, but DHW?

## Ventilation, Filtration, Mixing

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- Central air-based systems allow for ventilation mixing, and filtration
  - Dedicated HRV ducts costs a fair bit
- Ductless mini-splits don't help this!
- Only some water-based heat pumps do this
- Can integrate HRV/etc. into combo systems

## Conclusions

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- We don't have simple systems for low-load that do all of DHW, space heating, cooling, ventilation
- We have some that get close
  - Combo system with mini-split cooling
  - Mini-split heat/cool plus resistance DHW



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**Thank you for your time!**

**QUESTIONS??**



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## Gas Fireplaces

- Output  
5000-20000 Btu/hr output
- through-wall vented
  - Specify sealed combustion
  - Specify millivolt systems that work with no electricity
- Heat output is low, but so is efficiency (60%+/-)
- Direct-vent is, alas, not sealed combustion



## Small Marine heaters

- use diesel/oil or propane
- Not very efficient, but small, and pretty!
- Biggest concern: need sealed combustion

WEIGHT	P9000 - 15LBS P12000 - 22LBS
HEIGHT	P9000 - 11" P12000 - 19"
WIDTH	P9000 - 8.88" P12000 - 10.25"
DEPTH	P9000 - 7.25" P12000 - 8.13"
FLUE SIZE	2.5" OD double wall flue pipes, 20" long
FUEL CONSUMPTION	P9000 - 5.7hrs / 1LB P12000 - 4.5 hrs / 1LB
HEAT OUTPUT	P9000 - 5,500-7,500 BTU P12000 - 7,000-9,700 BTU
FLAME WINDOW	P9000 - 22.3 sq in P12000 - 32 sq in
BLOWER FAN	Standard 12VDC .17amp
EXHAUST CAP	4.75" Tall

