Building Science Corporation

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

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WATERLOO ENGINEERING

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 $btu/(h*ft^2)$) 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 ½ or 1/3 equivalent code-built home

Context

- 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 ΔT GPM)
  - This is significantly more than peak power demand for cooling or heating

Problem

- 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

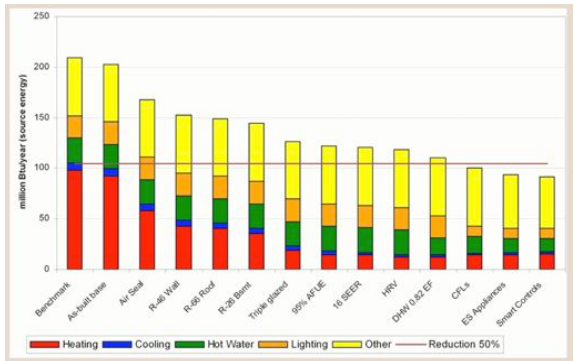
Low-energy houses

- 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

- 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

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**

One therm = 29.3 kWh

Simple Heating Analysis Apartment

- 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*24*7500 = 108 therms = $300/yr propane
  - Elec: 3000 kWh/yr @15 cents= $450/yr
- Heating airflow= 85 cfm @DT=50

Recommendations

- 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

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.

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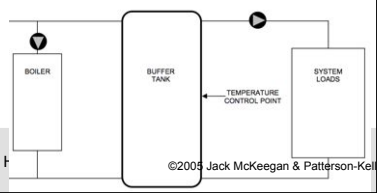
Combo System Warning

- 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



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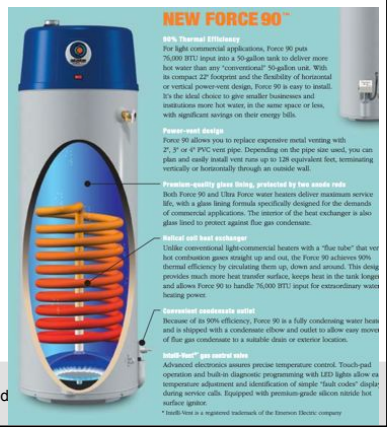
Newer Condensing Tanked systems

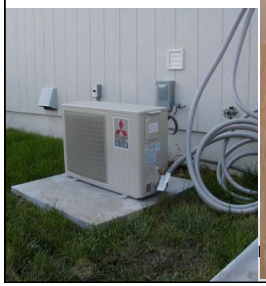
Allows for direct connection to air handler. No additional controls or plumbing

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



Ductless ~~Mini-split~~

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



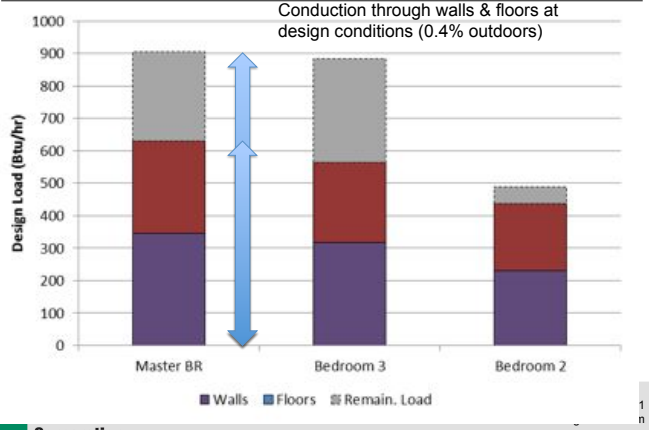
Mini-split

- 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

- 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 ΔT=5 F Hall-to-Bedroom



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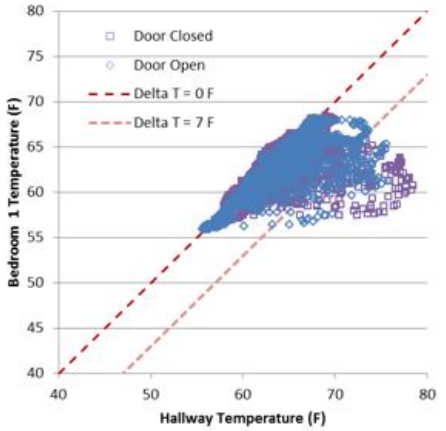
Hallway vs. Bedroom Correlations (BR1)



- Bedroom 1 (middle) used as storage
- Door closed 56% of time/open 44% of time
- Large temperature differences—many at door closed condition

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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

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Pros and Cons of Possible Solutions

- 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

- 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

- 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

Thank you for your time!

QUESTIONS??

Building AMERICA U.S. Department of Energy
Research Toward Zero Energy Homes

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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
- Wallas (Finland) has some sealed units