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Learning Objectives

- Why are low load buildings a problem
- What solutions are available
- What are pros and cons of different systems
- How are multi's different than single family

University of Waterloo

The Enclosure is too Good?!?

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bsc Building Science Corporation

General Mech Requirements

- Heating production
- Cooling production
- Ventilation
- Domestic hotwater (DHW) production
- Distribution of heat, cool, fresh air
- Filtration (remove particles generated)
- Exhaust of pollutants (range, elevator, trash)

The New World

- Heating / cooling loads shrinking!
  - Better insulation, airtightness, windows
  - Multi-unit = small exterior enclosure area
- DHW is can be larger energy demand
  - Only efficient appliances can reduce DHW use
- A useful definition of load heating load is a residential building with space heating loads of less than 2 times DHW

New World Examples

- 20 x 25 ft = 600 sf 1 BDR interior apartment
  - 20*9 ft height = 180 sq ft enclosure area
  - 33% windows = 60 sq ft
- R20 wall, R4 window, 20 F outdoor temp.
  - (120/20+60/4) * (70-20) = (6 + 15) * 50
  - **1050 Btu/hr conduction** losses (!)
- Achieve 0.40 cfm/sq ft @75 Pa airtightness
  - 18 cfm leakage natural = **950 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: 2.5-3.5 kBtu/hr (<1 kW)
  - Corner apartment up to 4-5 kBtu/hr (1.5 kW) ….
- Heat loss coefficient 50-70 Btu/F/hr
- If we use HDD65 = 4500
  - (50 to 70)*24*4500 = 54-75 therms < $100/yr
  - 1465-2200 kWh/yr <$160/yr
- If we use HDD50=1229 …. Negligible
- If 2.5 kBtu/hr, airflow= 50 cfm @DT=50

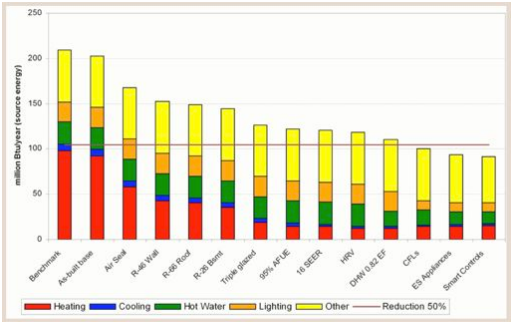
Low-energy houses

- 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)
  - High specs, simple buildings gets demand lower

Domestic HotWater

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

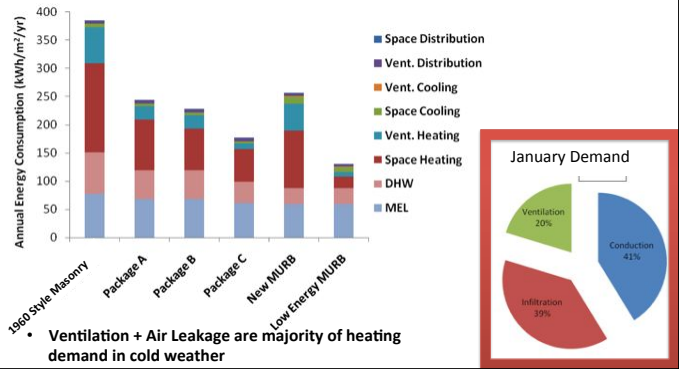
Small MA house



Graph 1: Parametric Study

Toronto Example

- Heating is biggest load (50%) in old bldgs
- Major reductions possible, but MELs are hard to reduce …



- **Ventilation + Air Leakage are majority of heating demand in cold weather**

So what's the problem

- Smallest condensing furnaces are 40 kBu/hr
- Two-stage furnaces allow for low stage fire at 30 kBtu/hr
- But most hours are at fractions of peak design
- How does the system work with a hourly heat loss of 5 to 10 kBtu/hr?
  - Runs for 10 to 20 min/hour (two fires/hour?)
  - Short cycling (wear & tear, inefficiency)
  - But must provide ductwork for 30 kBtu/hr

95% of the hours are at 70% or lower load
50% of hours at 33% load or lower

Wilkes-Barre, Pennsylvania

AVG T	BIN RANGE			TOT	J	F	Mr	A	My	Jn	Jl	A	S	O	N	D	% TOT	CUM %	% LOAD
63	62	to	64	335				23	45	46	40	45	102	23	11		5.22	5.22	2.78
61	60	to	62	308				20	45	45	48	40	59	40	10	1	4.80	10.02	5.56
59	58	to	60	200				17	39	33	13	42	36	16	3	1	3.12	13.14	8.33
57	56	to	58	273	4		4	29	71	36	22	21	32	45	8	1	4.26	17.40	11.11
55	54	to	56	351	8	4	6	38	68	32	10	17	46	89	31	2	5.47	22.87	13.89
53	52	to	54	285	5	3	28	48	42	16	6	2	38	51	47	1	4.44	27.32	16.67
51	50	to	52	232	2	3	16	35	38	11	1		32	64	27	3	3.62	30.93	19.44
49	48	to	50	238	1	7	18	52	22	5			33	42	47	11	3.71	**34.64**	**22.22**
47	46	to	48	258		4	27	45	23	1			28	58	51	21	4.02	38.67	25.00
45	44	to	46	227	2	2	30	55	22				8	53	39	16	3.54	42.20	27.78
43	42	to	44	287	4	5	69	76	24				12	48	30	19	4.47	46.68	30.56
41	40	to	42	180	3	8	56	42	10				5	26	15	15	2.81	**49.49**	**33.33**
39	38	to	40	273	8	20	50	50	32				4	40	41	28	4.26	53.74	36.11
37	36	to	38	337	24	23	80	46	20				4	41	60	39	5.25	59.00	38.89
35	34	to	36	257	24	31	39	28	11					18	59	47	4.01	63.00	41.67
33	32	to	34	313	46	50	53	8	4					10	69	73	4.88	67.88	44.44
31	30	to	32	360	50	62	71	9						9	68	91	5.61	73.50	47.22
29	28	to	30	298	44	79	45	12						4	49	65	4.65	78.14	50.00
27	26	to	28	187	45	32	34	6							22	48	2.92	81.06	52.78
25	24	to	26	207	85	28	28								13	53	3.23	84.28	55.56
23	22	to	24	142	62	24	32								1	23	2.21	86.50	58.33
21	20	to	22	180	45	45	30								7	53	2.81	89.30	61.11
19	18	to	20	155	37	47	17								1	53	2.42	91.72	63.89
17	16	to	18	105	38	33	7									27	1.64	93.36	66.67
15	14	to	16	113	38	47	3									25	1.76	**95.12**	**69.44**
13	12	to	14	85	46	22	1									16	1.33	96.45	72.22
11	10	to	12	54	18	31										5	0.84	97.29	75.00
9	8	to	10	52	21	26										5	0.81	98.10	77.78
7	6	to	8	38	22	14										2	0.59	98.69	80.56
5	4	to	6	21	17	4											0.33	99.02	83.33
3	2	to	4	16	12	4											0.25	99.27	86.11
1	0	to	2	17	14	3											0.27	99.53	88.89
-1	-2	to	0	13	9	4											0.20	99.73	91.67
-3	-4	to	-2	13	6	7											0.20	99.94	94.44
-5	-6	to	-4	4	4												0.06	100.00	97.22
-7	-8	to	-6														0.00	100.00	100.00
				6,414															

Table 1. A BIN-HOUR chart for Wilkes-Barre, PA showing the average number of hours spent at each outdoor temperature in the range of temperatures for which heating is normally required. A similar chart can be made for virtually any location.

Functions

Five Critical functions are needed

- Ventilation
  - "fresh air"
  - Dilute / flush pollutants
- Heating
- Cooling
- Humidity Control
- Air filtration / pollutant Removal
  - Remove particles from inside and outside air
  - Remove pollutants in special systems

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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.

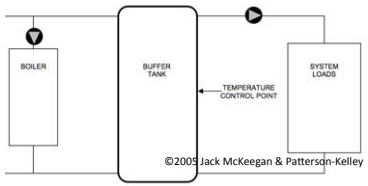
Low speed fan setting and lower water temperature (120 F) allows for whole house heating of homes with just 8-15 kBtu/hr peak

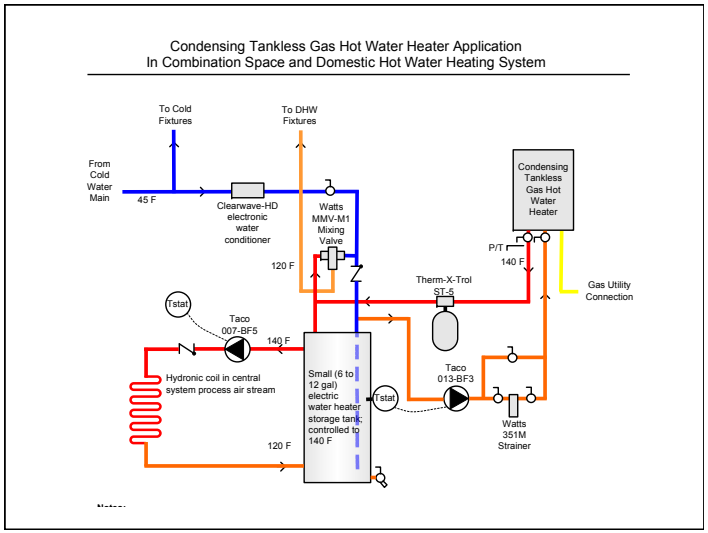
Combo Systems

- 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.

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

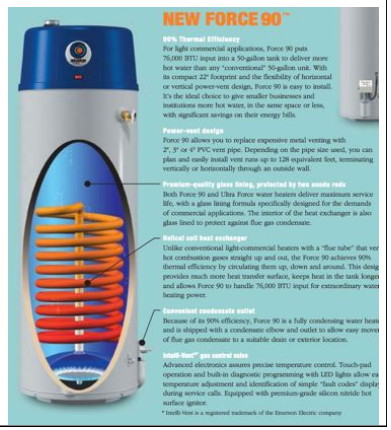




Newer Condensing Tanked systems

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.



Heat+cool: Ducts provides distribution, can add ventilation, no DHW

Split Heat Pumps

- An option for Zone 3-4?
  - Eg Portland Seattle Tacoma 20 F design temp
- 2 ton HP produce about 16 kBtu/hr @20F

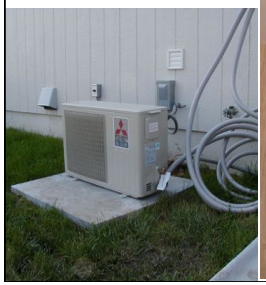
SSZ160241A* / CA*F3636*6A* + TXV / MBE1600-1** Goodman SEER16 model

	Outdoor Ambient Temperature															
	65	60	55	50	47	45	40	35	30	25	20	17	15	10	5	0
MBh	30.2	28.6	26.9	25.1	24.0	23.3	21.6	19.9	18.7	17.3	15.9	15.0	14.4	13.0	11.5	10.0
ΔT	31.9	30.2	28.4	26.6	25.4	24.6	22.9	21.1	19.8	18.3	16.8	15.9	15.3	13.7	12.2	10.6
kW	1.79	1.75	1.72	1.68	1.7	1.65	1.62	1.58	1.68	1.64	1.60	1.58	1.56	1.52	1.48	1.45
Amps	8.4	7.8	7.3	6.9	6.7	6.6	6.2	5.9	5.7	5.4	5.2	5.1	5.0	4.7	4.4	4.2
COP	4.93	4.76	4.57	4.37	4.22	4.13	3.91	3.69	3.26	3.08	2.91	2.79	2.71	2.49	2.27	2.03
EER	16.9	16.3	15.6	14.9	14.4	14.1	13.4	12.6	11.2	10.5	9.9	9.5	9.3	8.5	7.7	6.9
Hi PR	349	334	322	307	300	295	283	272	260	249	239	233	229	220	212	203
Lo PR	144	133	125	115	108	104	96	85	77	69	60	56	54	46	40	33

Seasonal COP 3-3.5, cooling included, standard equipment, <<$3000

Ductless Mini-split

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

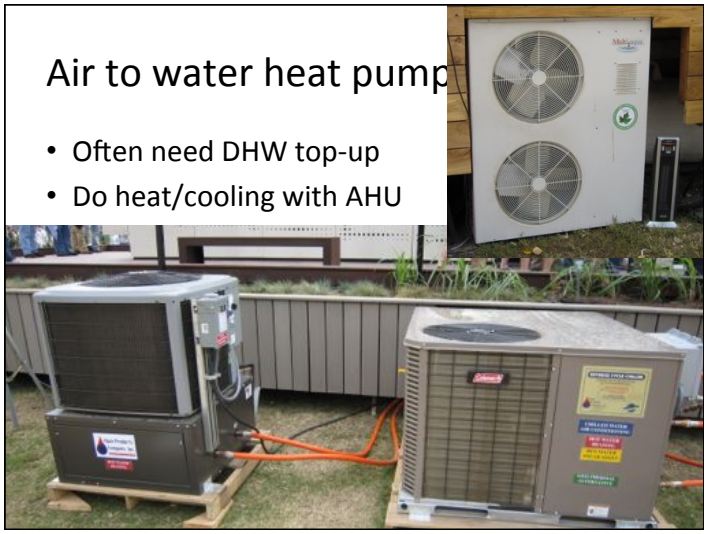


Mini-split

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

Air to water heat pump

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



Electric Resistance

- Electric heat
  - Cheap to buy, high operating cost, high GHG
- Baseboard / Cove
  - Impact on space design
- Radiant heat mats
  - Floor/ceiling
  - 10-15 W/sf capacity
  - Need 300-600W per room

Multi-unit Issues

- Metering: per suite or per building
- Fuel-Source: Gas or all-electric
  - Carbon? Dollars? Energy?
- DHW or just space heat?
- Is Cooling necessary?
- Grouping: Central, unit, or mix?
- Equipment owned per suite or per building?
- Perceived access to apt issues?

Central vs Distributed

- Central systems often
  - reduce capital cost per unit output of *plant*
  - Increase distribution costs dramatically
  - Increase distribution energy losses
  - Decrease redundancy
  - Increase complexity
  - Make sub-metering expensive/difficult
  - Take advantage of load diversity

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!
Any Questions?

This concludes The American Institute of Architects Continuing Education Systems Program