ENERGY CENTER
OF WISCONSIN

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Small Commercial HVAC

Surveying the Frontier of Energy Efficiency

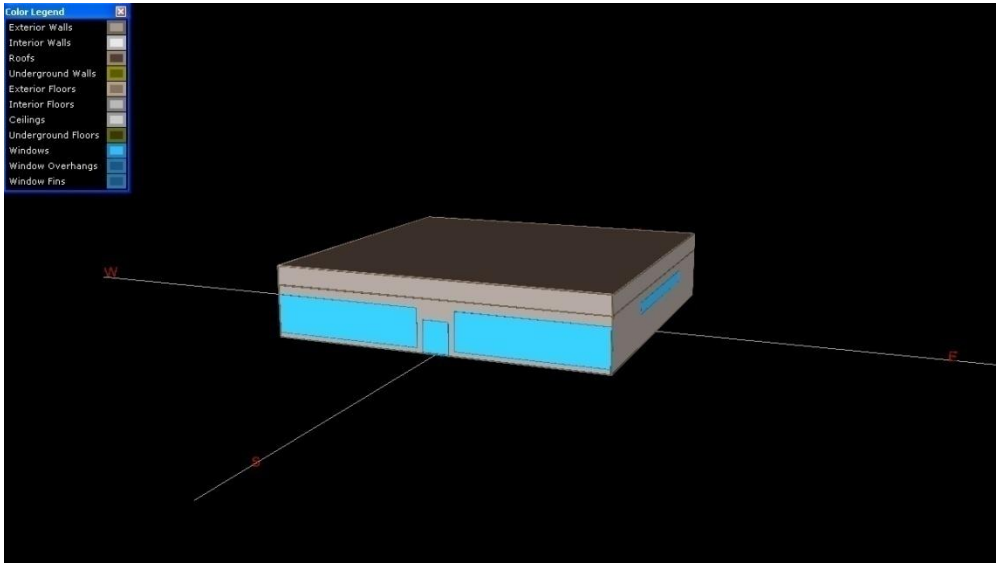
Lee DeBaillie, PE
Energy Center of Wisconsin

SEEK • LEARN • ACT

Overview

- Focus on small commercial buildings
- Focus on HVAC
- Focus on electric savings
- Demonstrate savings through energy model results

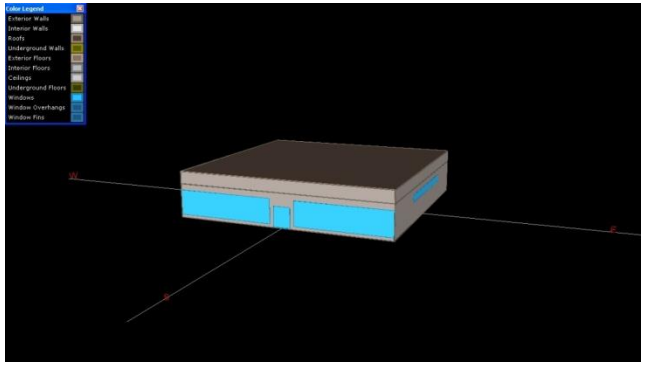
Energy Model

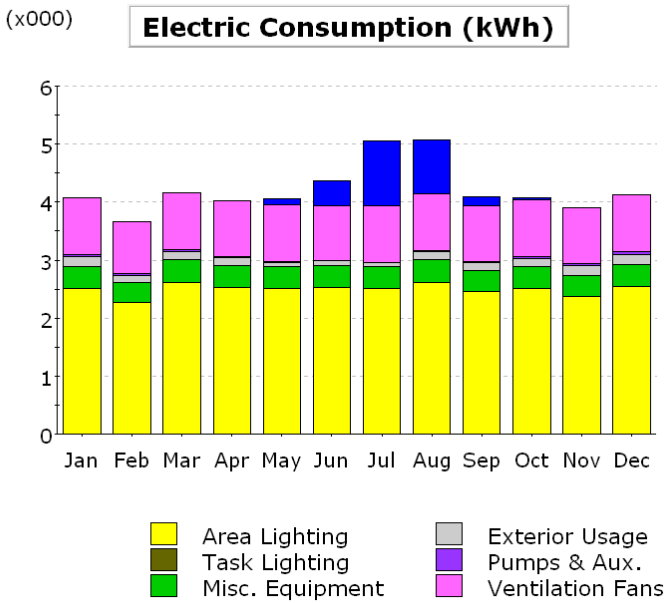


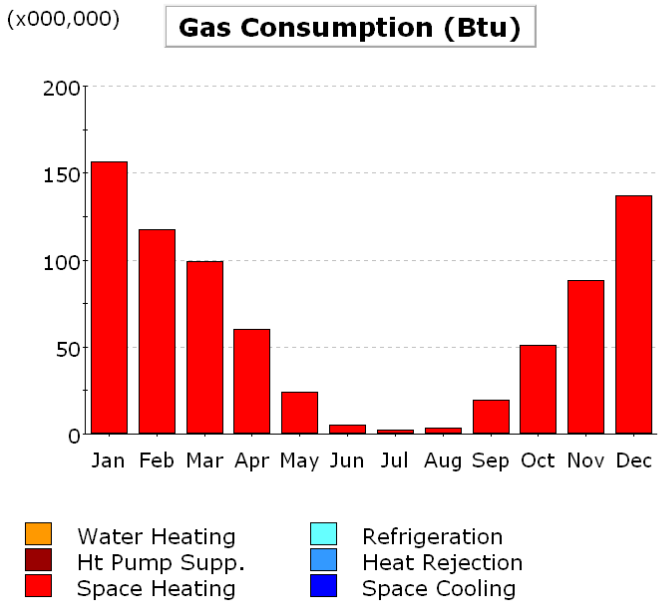
- 5,000 square foot retail store Grand Rapids MN
- MN energy code, climate zone 7 (northern MN)
- Open 7am to 7pm Mon-Sat, 10am-4pm Sun
- Roof Top Unit (RTU) – DX cooling, gas-fired heating
- Electricity $0.10/kWh; Natural Gas $0.80/therm

Energy Model

Baseline results

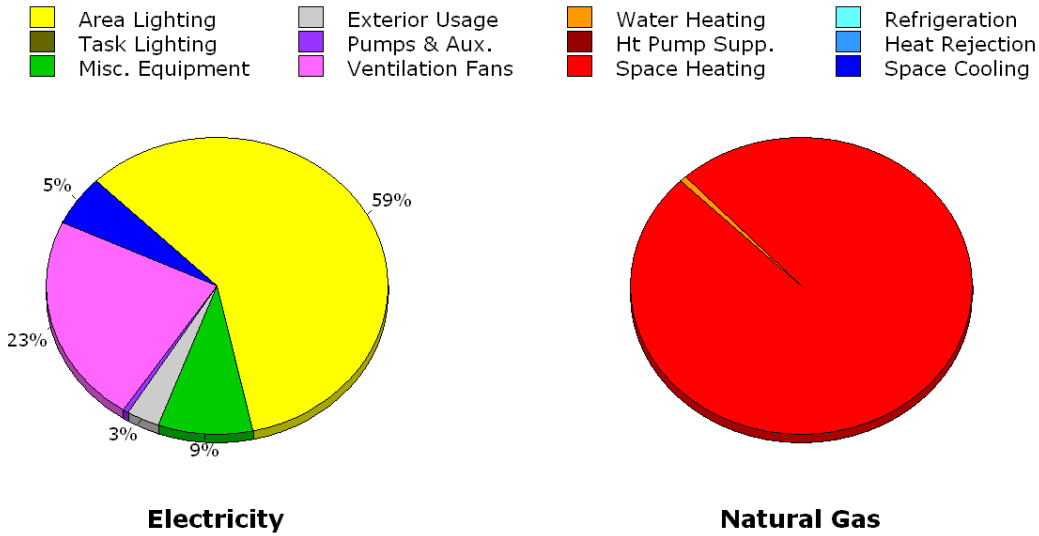


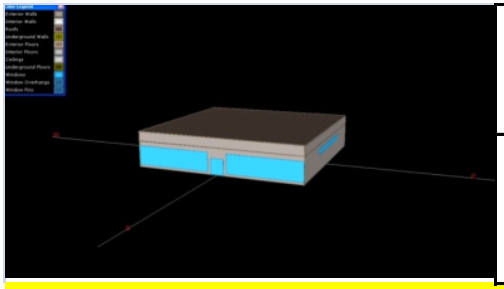




Energy Model

Baseline Results





Energy Model Results

	Building Electric [kWh]	Fan Electric [kWh]	Cooling Electric [kWh]	Electric Savings [kWh]	Building Gas [therms]	Gas Savings [therms]	Total Energy Cost
Baseline Building	50,647	11,551	2,775	-	7,637	-	$11,775

Conventional Small HVAC

- **Typical system: packaged rooftop unit (RTU)**
  - **Direct expansion cooling, gas-fired heater**
  - **5-10 tons cooling capacity**

Source: PNNL

- **Also - some residential systems < 5 tons**

Conventional Small HVAC

1/2 of U.S. commercial floor space is conditioned by RTUs

Source: Lennox

Conventional Small HVAC - Pros

- Low first cost
- Fairly reliable for heating and cooling
- Relatively simple and known technology
- Network of installers/maintainers
- Rooftop installation – does not use up internal space

Conventional Small HVAC - Cons

- Rooftop location
  - Out-of-site, out-of-mind
  - Difficult to access
  - Weather degradation
- Maintenance
  - On-going preventative maintenance, ideally with remote monitoring

Conventional Small HVAC - Cons

Source: Battelle

Conventional Small HVAC - Cons

Source: California Energy Commission: Small HVAC System Design Guide

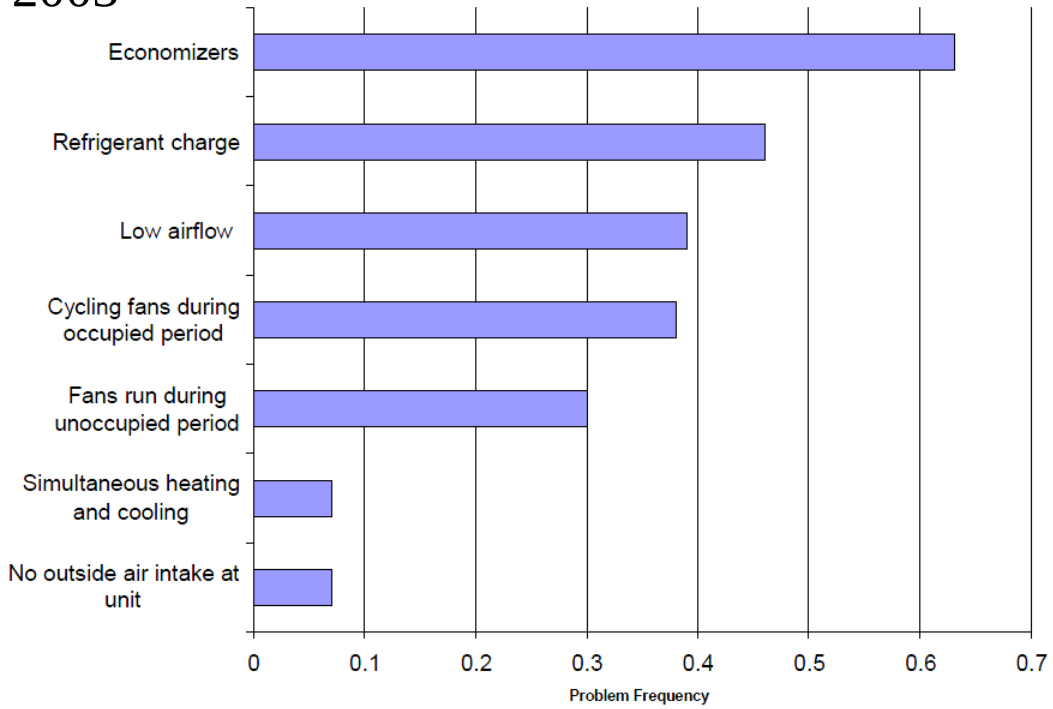
Conventional Small HVAC - Cons

Figure 4. Frequency of Problems Observed in PIER Study

This figure shows the frequency of several of the common problems observed in the PIER study behind this Design Guide.

CA Field Study 2003

- 75 buildings
- 215 RTUs



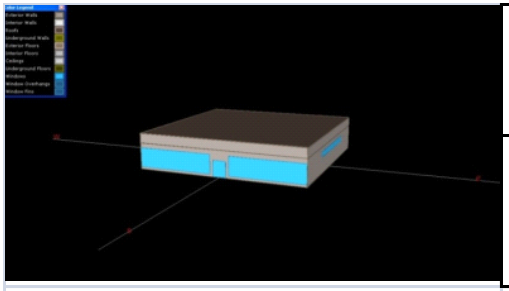
Source: California Energy Commission: Small HVAC System Design Guide

Conventional Small HVAC - Cons

- Design and Installation
  - Low bids
  - Tight schedules
  - Units are often oversized
- Commission the system
  - Especially airflows, fan control and economizer operation.

Efficient RTU Systems

- RTUs are frequently over-sized
  - Air-Conditioning Contractors of America
    - ACCA Manual N – light commercial HVAC sizing



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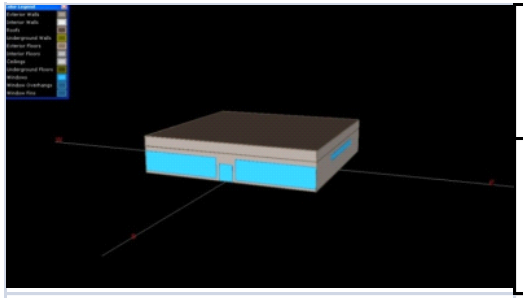
Efficient RTU Systems

- **Shut off supply fan during unoccupied times**
  - **Need commercial thermostats with separate fan scheduling capability**
  - **Do not ventilate - motorized outdoor air dampers stay closed**



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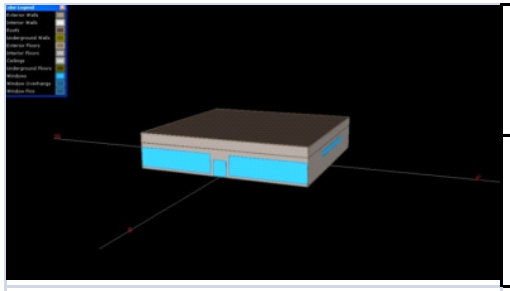
Fans off unoccupied	48,158	8,978	2,858	2,289	5,579	1,848	$9,879

Efficient RTU Systems

- **Fix the air-side economizer**
- **Required for systems over 3,000 cfm (MN)**



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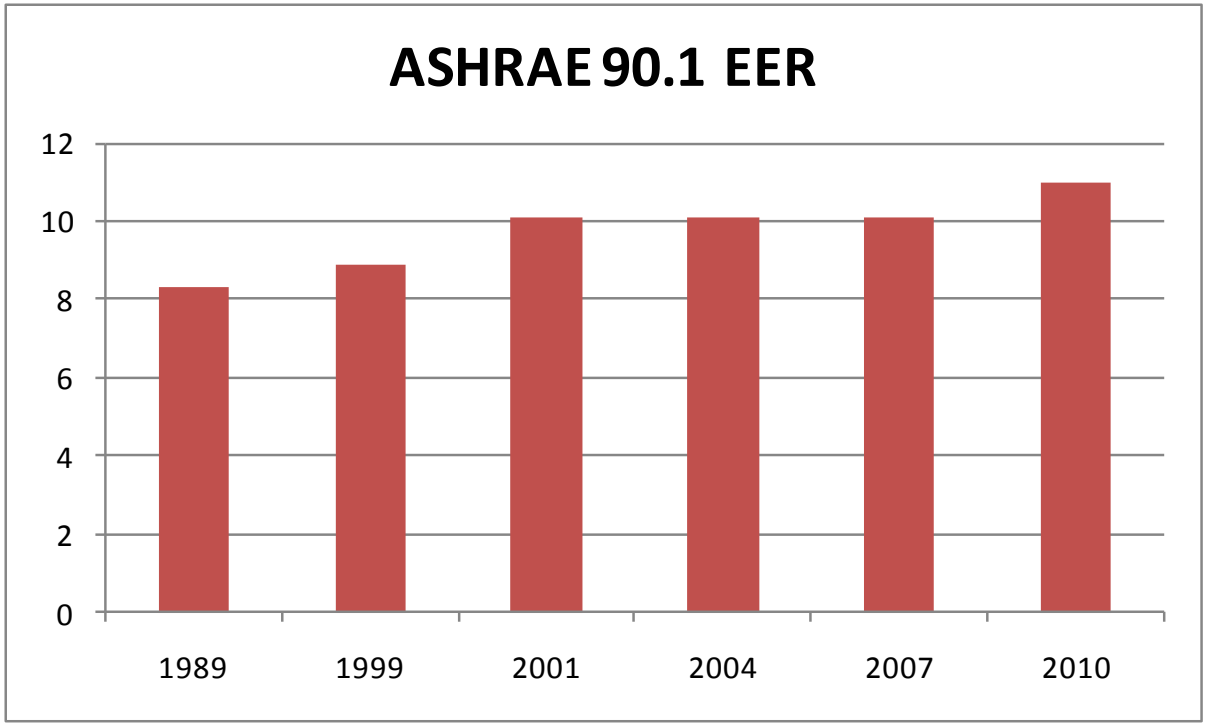
Efficient RTU Systems

- **Efficient AC system**
  - **Specify high Energy Efficiency Ratio (EER)**
  - **See Consortium for Energy Efficiency (CEE) for recommendations**
  - **EER reflects air-conditioner efficiency at peak cooling load**
    - **New – Integrated Energy Efficiency Ratio (IEER) for part-load efficiency** (ASHRAE 90.1-2010)

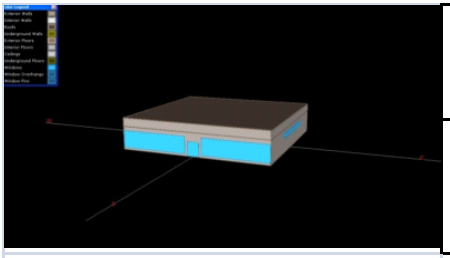
Efficient RTU Systems

- EER minimums for 10 ton RTU



Efficient RTU Systems

- **Baseline: ASHRAE 90.1-2004 EER=9.5**
- **Proposed: CEE Tier 2 EER=12.0**



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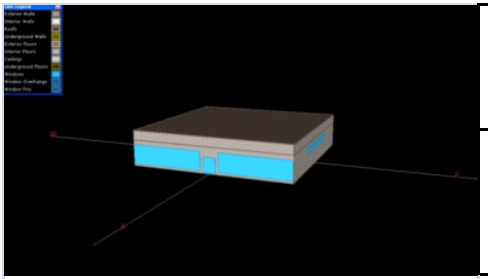
Improve EER from 9.5 to 12	47,404	8,978	2,104	648	5,579	0	$9,803

Efficient RTU Systems

- **Efficient air distribution system**
  - **Reduce resistance to airflow**
  - **MN code limit is 1.2hp/1,000cfm** (<20,000cfm, constant volume)



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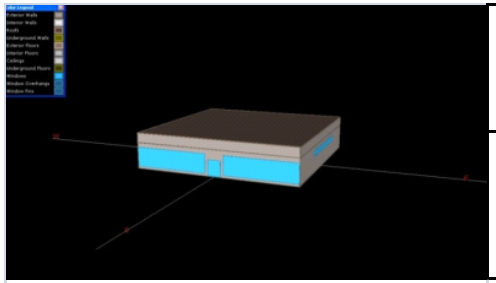
Duct resistance 1.5" to 1.0"	44,323	5,986	2,015	3,081	5,694	-115	$9,587

Efficient RTU Systems

- **ASHRAE 90.1-2010: Section 6.4.3.10**
- **Single Zone Variable-Air-Volume Controls**
- **Section b: Effective January 1, 2012 all air-conditioning equipment and air-handling units with direct expansion cooling and a cooling capacity at AHRI conditions greater than or equal to 110,000 Btu/hr that serve single zones shall have their supply fans controlled by two-speed motors or variable-speed drives. At cooling demands less than or equal to 50%, the supply fan controls shall be able to reduce the airflow to no greater than the larger of the following:**
  - **1) Two-thirds of the full fan speed, or**
  - **2) The volume of outdoor air required to meet the ventilation requirements of Standard 62.1.**

Efficient RTU Systems

- **Variable speed supply fan**



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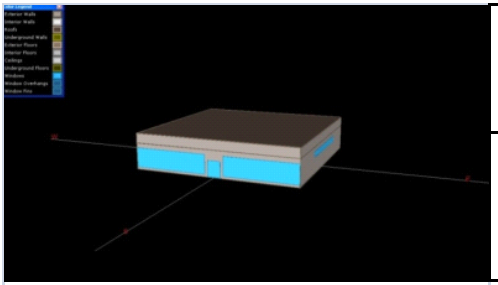
Variable speed supply fan	38,958	687	1,950	5,365	5,683	11	$9,042

Efficient RTU Systems

- **Demand Control Ventilation**
  - **Good application for single zone RTUs**
  - **CO2 meter calibration is an issue**
  - **Required in MN energy code for densely occupied spaces** **(40+ people per 1,000 ft2)**

Efficient RTU Systems

- **Demand Control Ventilation**



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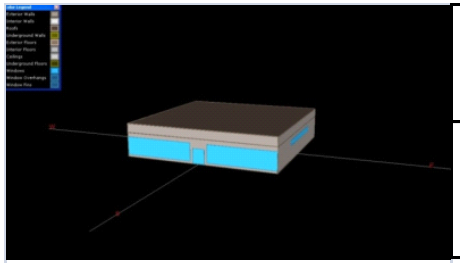
Demand Control Ventilation	39,056	686	2,049	-98	4,404	1,279	$8,029

Efficient RTU Systems

- **Ventilation Heat Recovery**



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Demand Control Ventilation	39,056	686	2,049	-98	4,404	1,279	$8,029
Heat Recovery Ventilation	40,457	1,474	2,084	-1,401	3,406	998	$7,371

For conventional RTUs…

- **The good electric savers are:**
  - **Fans off during unoccupied times**
  - **Improve EER and IEER**
  - **Reduce airflow resistance in distribution systems**
  - **Variable or multi-speed fans**

The Frontier: Advanced HVAC Systems

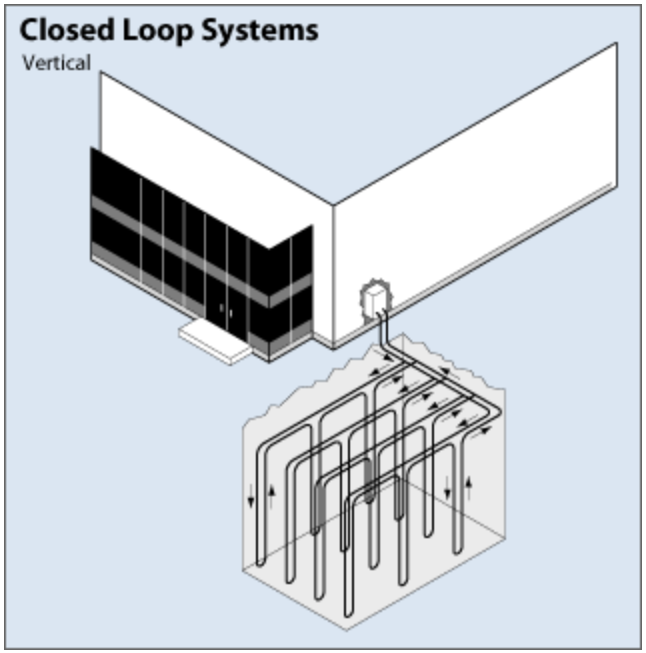
- **The Theory** (from larger HVAC systems)
  - **Separate ventilation from heating & cooling**
    - **Simplifies equipment**
    - **Easier to do ventilation heat recovery**
    - **Move air only for ventilation (health)**
    - **Move heat with water (heating and cooling)**

The Frontier: Advanced HVAC Systems

- **The Theory**
  - **Single zone heating and cooling**
    - **Reduce fan power and eliminate reheat energy**
  - **Scavenge waste heat**
    - **Move heat from excess to need (cooling to heating)**
  - **Low temp heating and high temp cooling**

Ground Source Heat Pumps

- Pump heat into or out of the ground.
- Ground loops are vertical, horizontal, or surface water.
- Can be small single zone HP units, or large central system.
- They work well in the right situations – reduces total energy cost and consumption



Source: energysaver.gov

Ground Source Heat Pumps

- **What's the right situation for GSHPs?**
  - **Economic: lower electric costs, higher gas costs, lower installation cost, lower maintenance**
  - **Balanced annual heating and cooling loads**
  - **Correct design and installation of ground loop is critical for performance and lower first cost**
  - **Fan power reduction – zone level with dedicated outdoor air**
  - **Larger buildings**
    - **Simultaneous heating and cooling loads**
    - **Eliminates reheat of larger HVAC systems**

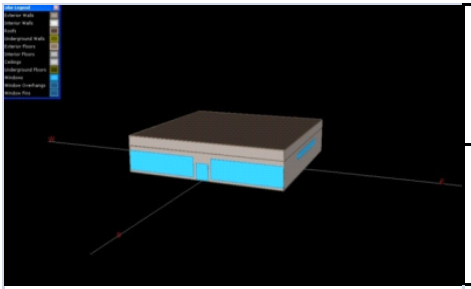
Ground Source Heat Pumps

- **Benefits**
  - **Energy cost savings and source savings**
  - **Reduced summer electric peak demand**
    - **Increased winter demand**
  - **No outdoor equipment, loop has long life**

Ground Source Heat Pumps

Advanced HVAC Attributes	
Possible	Separate ventilation from heating and cooling
Yes	Move heat with water
Possible	Single zone heating and cooling
Possible	Simultaneous heating and cooling - move heat
Yes	Low temperature heating and high temperature cooling

Ground Source Heat Pumps



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Ground-source heat pumps	60,529	1,824	1,795	-12,477	51	5,528	$6,694

Variable Refrigerant Flow

- **VRF or VRV™**
  - **Is a heat pump – air or water-source**
  - **Multi-speed fans and variable speed compressors**
  - **Move and share heat between spaces with refrigerant**
  - **Good for retrofits – Asia market**
  - **Cautious optimism – ideal applications**

Source: Johnson Controls

Variable Refrigerant Flow

- **Caution for small buildings**
  - **Air-source VRF in northern climates is a problem without gas supplement or internal heat generation**
  - **Installation and maintenance experience may be missing outside larger metro areas**
  - **Lack of in-field performance studies in U.S.**

Variable Refrigerant Flow

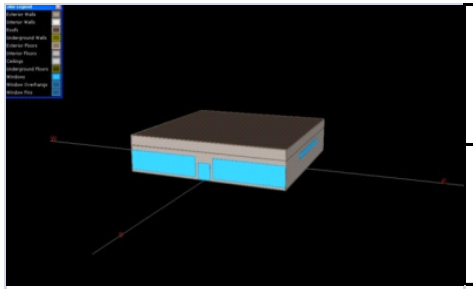
- More cautions
  - Lots of refrigerant
  - Difficult to model or evaluate
  - Integrating outside air
  - Minimum efficiencies now in ASHRAE 90.1-2010

Variable Refrigerant Flow

Advanced HVAC Attributes	
Yes	Separate ventilation from heating and cooling
Yes	Move heat with water (refrigerant and water option)
Yes	Single zone heating and cooling
Possible	Simultaneous heating and cooling - move heat (limit 20 tons)
Yes	Low temperature heating and high temperature cooling

Variable Refrigerant Volume

- **Performance – VRV with gas heat backup**



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VRV with gas back-up	53,840	982	1,430	-5,788	2,876	2,703	$7,685

Questions?