Ductless Hydronic Distribution Systems

Welcome to the Webinar! We will start at 1:00 PM Eastern Time

Be sure that you are also dialed into the telephone conference call:

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Date: November 8, 2011

Building America U.S. Department of Energy

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- Promote building science and systems engineering / integration approach
- "Do no harm": Ensure safety, health and durability are maintained or improved
- Accelerate adoption of high performance technologies

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Today's Speakers

David Springer is co-founder and current president of Davis Energy Group (DEG), and has led DEG's work in the Building America program since 2002. He participates in a variety of projects involving building energy efficiency and renewable energy systems, including HVAC design, performance monitoring and evaluation, technology development, and codes and standards development..

Bill Dakin, P.E., Engineering Manager, has served on the DEG staff since 1993, overseeing DEG's design consulting and building energy analysis services. He is a skilled building energy analyst and also manages utility and government sponsored research and design projects, and provides critical design and analysis support for Building America. Mr. Dakin is a LEED Accredited Professional and is the technical advisor for DEG's LEED-Homes program.

Christine Backman is a Staff Engineer at DEG focusing on energy modeling, performance analysis, and evaluation and optimization of energy efficient technologies in buildings. She is a skilled user of modeling programs including BEopt, EQuest, EnergyPro, Energy Gauge, and TRNSYS. A self-described "Excel Ranger", she applied her statistical abilities to evaluate utility bill data and produce one of the few Building America community closeout studies completed.

Building America Webinar:

Ductless Hydronic Distribution

Alliance for Residential Building Innovation

November 14, 2011

The ARBI Team

Alliance for Residential Building Innovation

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Webinar Objectives

- Review research gaps in distribution systems identified through the Building America process
- Review current knowledge on distribution system characteristics and design options
- **Summarize results of analyses conducted on hydronic vs. ducted distribution**
- Identify future research needs and opportunities

Building America Strategy

- Standing Technical Committees identify gaps and barriers in specific areas:
  - Building enclosures
  - Space conditioning (HVAC)
  - Water heating
  - Home energy management
  - Test methods
  - Implementation
- STC's develop strategic plans
- Teams coordinate to conduct targeted research

Gaps Identified by HVAC STC

- Heating & Cooling Equipment
  - Lack of availability of small capacity heating & cooling systems
  - Excessive fan energy use
- Distribution
  - Low cost space conditioning distribution strategies for low load homes
  - Effectiveness of zoned systems

Primary HVAC Issues

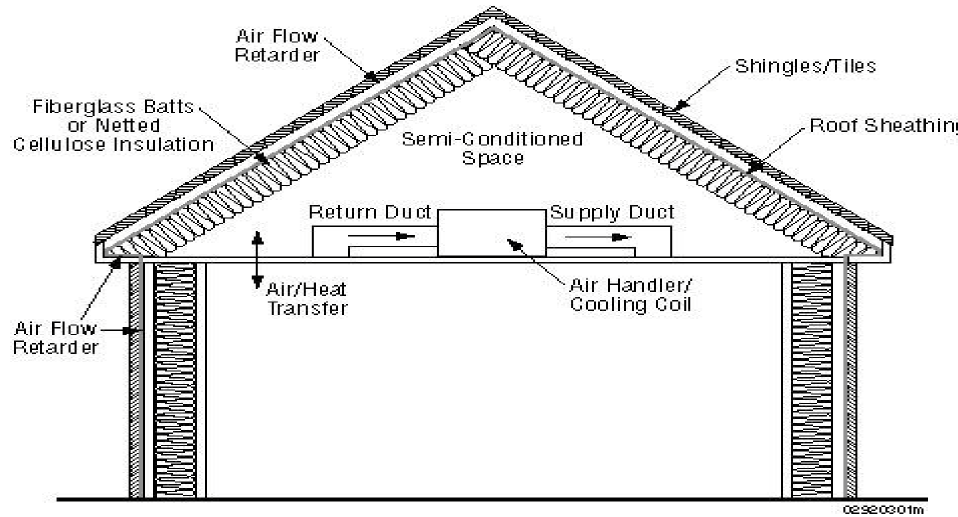
- Ducts in non-conditioned spaces (esp. attics) have a low distribution efficiency and alternatives are costly:
  - Creating non-vented, conditioned attics or interior chases for ducts
  - Multi-split variable refrigerant flow systems
- Most conventional equipment is oversized for houses with small loads
  - Cycling losses
  - Poor humidity control in humid climates
- Forced air zoning is problematic
  - Systems cannot vary airflow capacity with the number of zones calling for heating or cooling
  - Duct over-sizing, dump zones, and/or bypass dampers compromise efficiency

Alternatives to Ducts in Attic

- Non-vented attics
- Ducts in conditioned space
- Mini/Multi split heat pumps
- Ductless Hydronic
  - Definition – What is ductless hydronic distribution?
  - All Electric
  - Gas/Electric

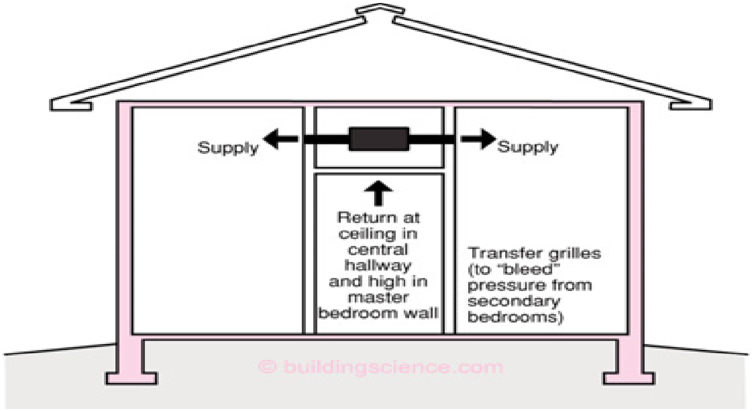
Non-Vented Attics

- Sealing and insulation at roof line is costly
- Moisture problems have been identified
- Area of insulated roof/ceiling is increased



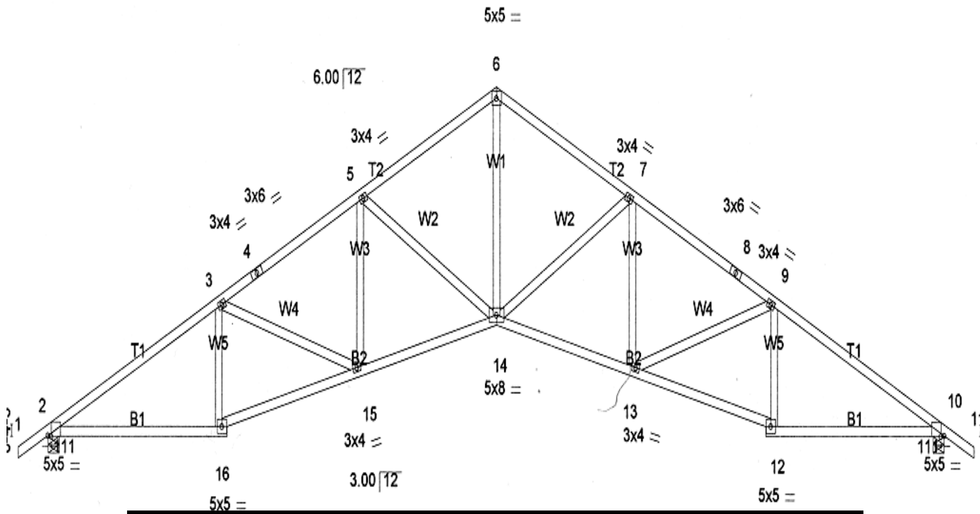
Duct Chases

- Affect architecture
- Requires two trips by drywall installer
- Limited space for furnace or air handler



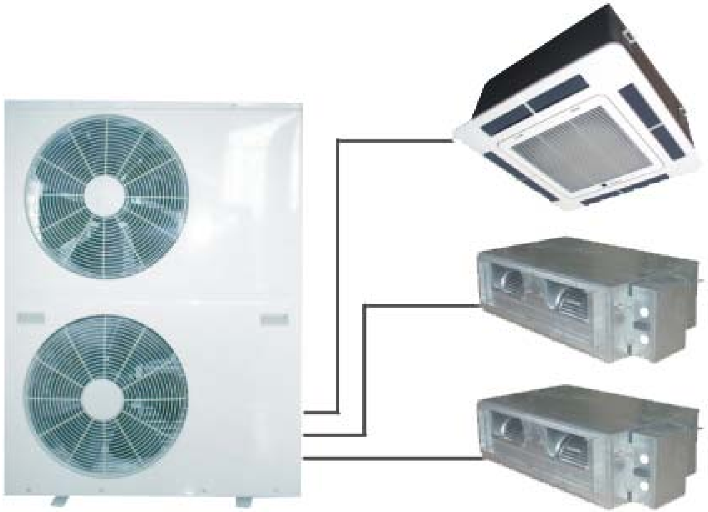
Modified "Plenum" Trusses

- Can limit location of diffusers
- Limited space for furnace or air handler
- Added cost to create air & thermal barriers



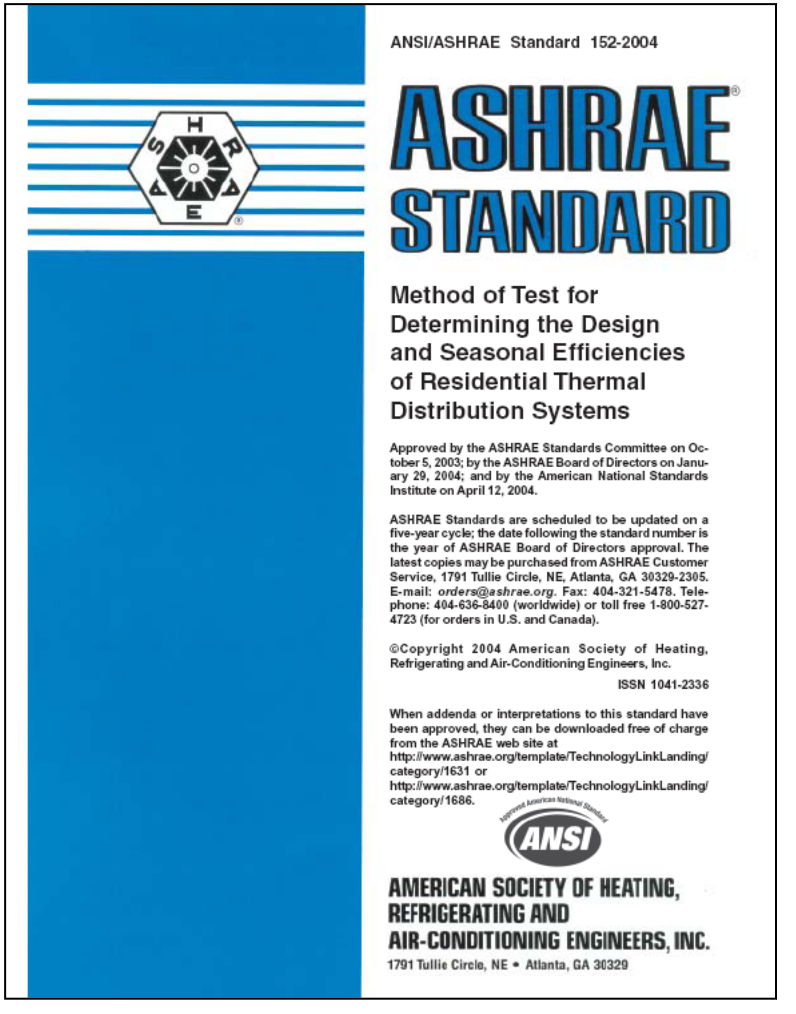
Multi-Split Heat Pumps

- Allow supply terminals to be distributed without the need for ducting
- Require costly variable refrigerant flow compressors
- Limited allowable vertical and total refrigeration line length
- Installation quality is critical



ASHRAE Standard 152

- Can be used to define distribution efficiency for ducted systems
- Hydronic chapter is undergoing revision
- Will provide a means of comparing distribution alternatives (except mini & multi-splits)


ANSI/ASHRAE Standard 152-2004

ASHRAE STANDARD

Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems

Approved by the ASHRAE Standards Committee on October 5, 2003; by the ASHRAE Board of Directors on January 29, 2004; and by the American National Standards Institute on April 12, 2004.

ASHRAE Standards are scheduled to be updated on a five-year cycle; the date following the standard number is the year of ASHRAE Board of Directors approval. The latest copies may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: *orders@ashrae.org*. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide) or toll free 1-800-527-4723 (for orders in U.S. and Canada).

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When addenda or interpretations to this standard have been approved, they can be downloaded free of charge from the ASHRAE web site at http://www.ashrae.org/template/TechnologyLinkLanding/category/1631 or http://www.ashrae.org/template/TechnologyLinkLanding/category/1686.

ANSI

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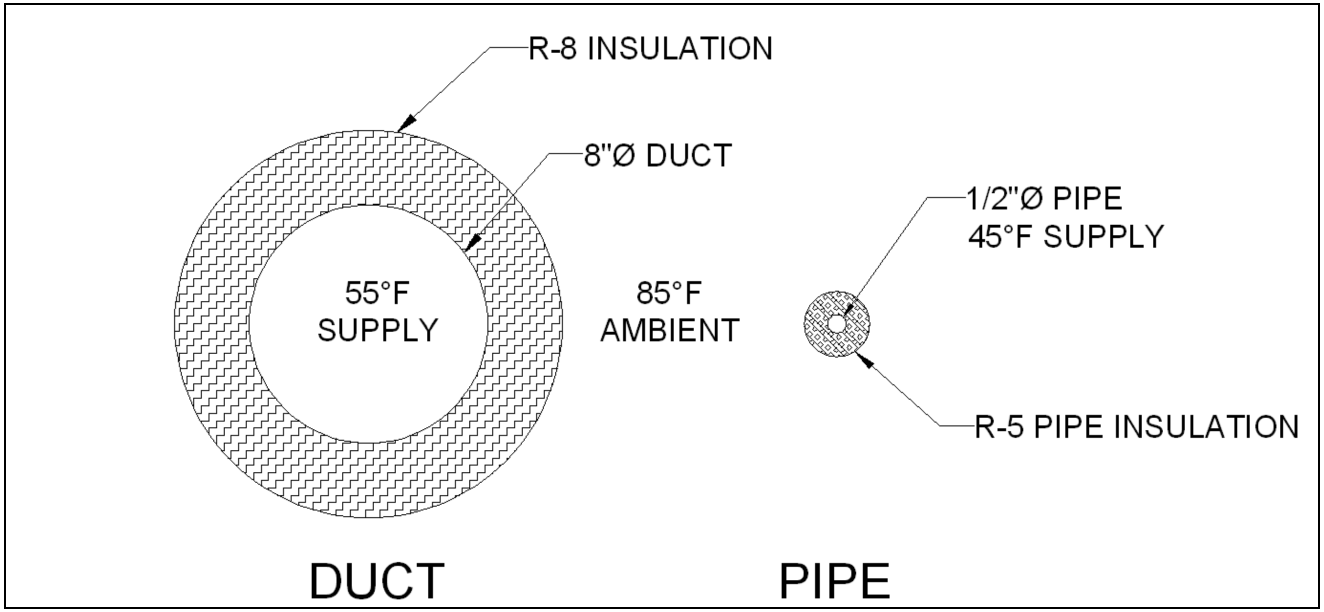
Project Hypothesis

- Hydronic distribution offers a better value proposition than ducts:
  - Lower heat losses from conduits (pipes vs. ducts)
  - Less energy required to move fluid (pumps vs. fans)
  - Easier to seal against leakage
  - Pipes can be routed under attic insulation or through framing without modifying the structure
  - Easier to transport and install pipes than ducts
  - Easier to zone
  - Potential for off-peak storage and integration with solar and heat recovery

Duct vs. Pipe Heat Loss



- Assume 5,000 Btuh of cooling delivery
- Ducted Air Delivery
  - 167 cfm ➡ 8"Ø duct = 12.8 Btuh thermal loss
- Hydronic Chilled Water Delivery
  - 0.7 gpm ➡ ½"Ø pipe = 4.6 Btuh thermal loss (64% Savings)

Fan vs. Pump Energy

@ 1,000 cfm & 365 W/ 1000 cfm

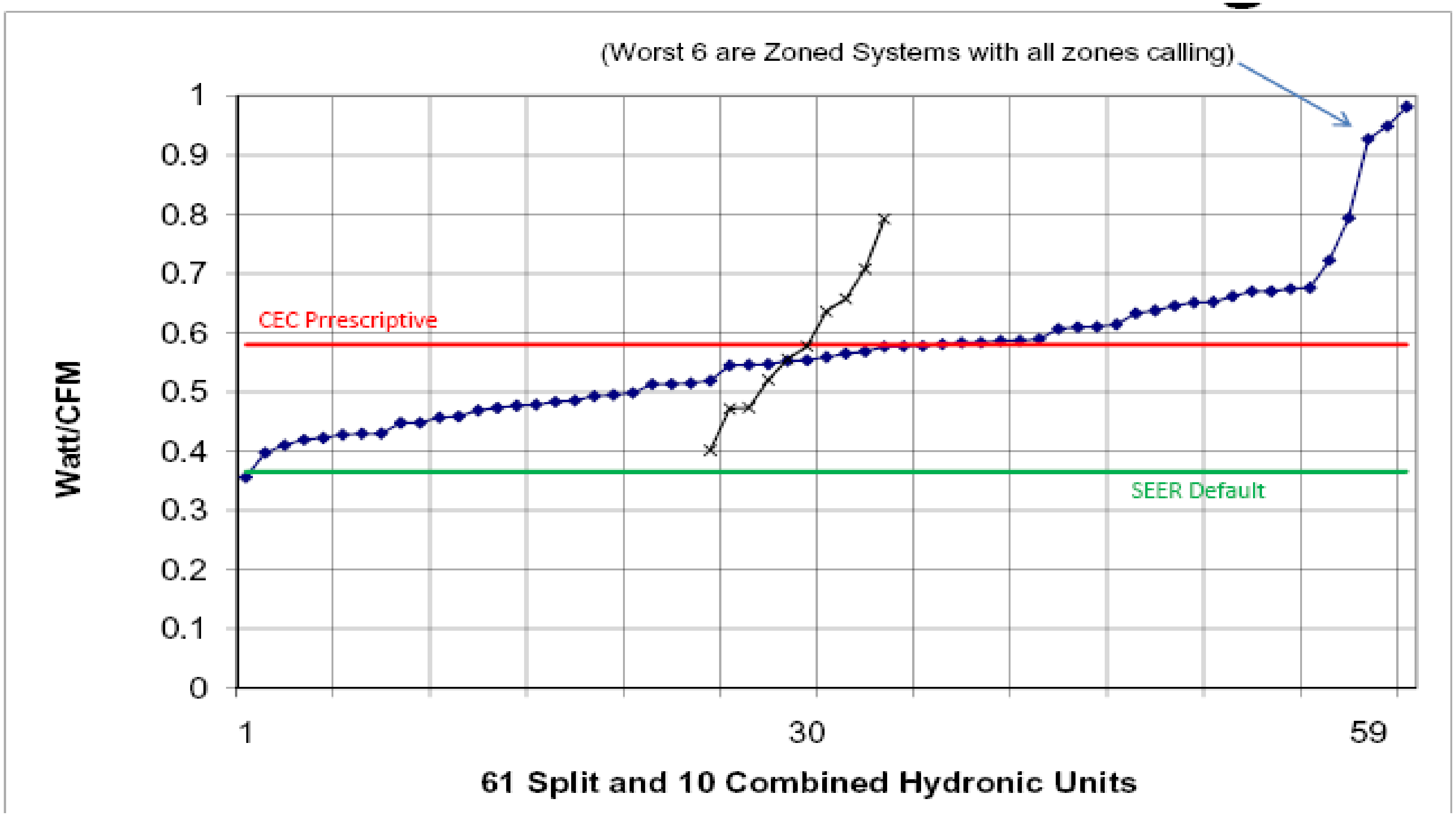
= 365 W

+

135 W + 164 W ≈ 300 W

Fan vs. Pump Energy

Measured Cooling Fan Power – Ducted Systems



2010 Study (Wilcox, Chitwood, Proctor)

Fan vs. Pump Energy

@ 1,000 cfm & 0.50 in w.c.

= 590 W

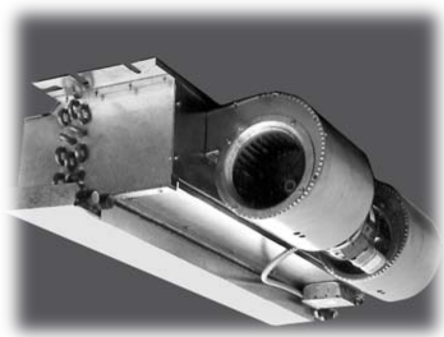
+

135 W + 164 W ≈ 300 W

Terminal Delivery Options

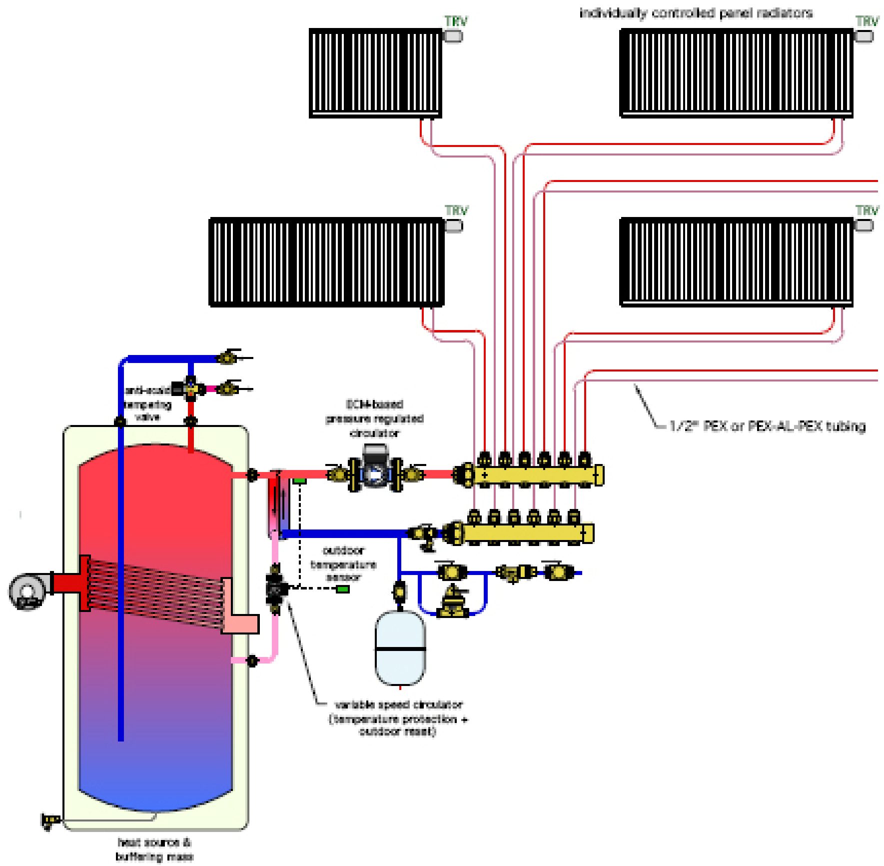
Delivery Options	Load Type
"Pancake" fan coil or ceiling cassette	Heating or Cooling
Baseboard Convector	Heating Only
Wall Radiators	Heating Only
Ceiling Panels	Heating or Cooling
Slab-on-Grade Radiant Floor	Heating or Cooling*
Raised Foundation Radiant Floor	Heating Only
Valence	Heating or Cooling

*Dry climates with exposed concrete or tile floors only



Delivery Systems - Piping

- Pipes vs. Ducts
  - Piping is easier to transport & install than ducting
  - Reduced thermal losses
  - Relative costs
    - ➢ 8” R-8 duct - $2.51/ft
    - ➢ ½” R-5 PEX - $2.13/ft
- Home Run Piping
  - Route piping direct from heat source to terminal (no branching)
  - Reduced water volume
  - Reduced thermal losses

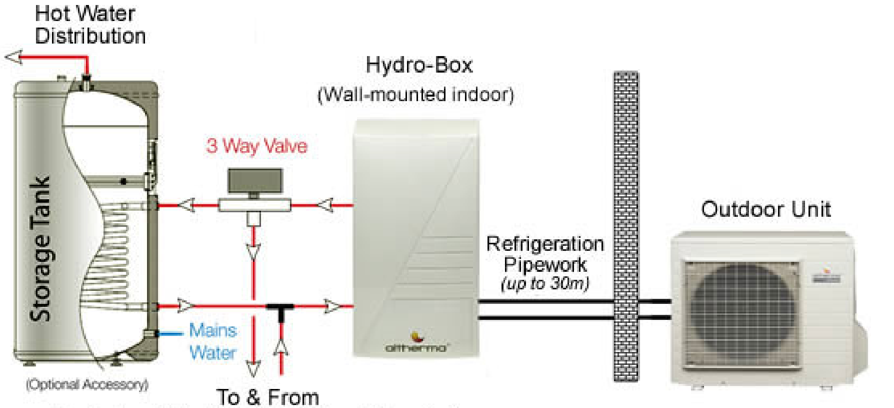


Hot-Chilled Water Sources

- Heating Only - Gas
  - Dedicated boiler
  - Two-function boiler/water heater
  - Combined system (with or without heat exchanger)

Hot-Chilled Water Sources

- Heating & Cooling – Electric
  - Air-to-water heat pump
  - Three function heat pump
- Heating & Cooling – Gas/Electric
  - Boiler or water heater
  - Chiller (air conditioner with refrigerant-to-water heat exchanger)

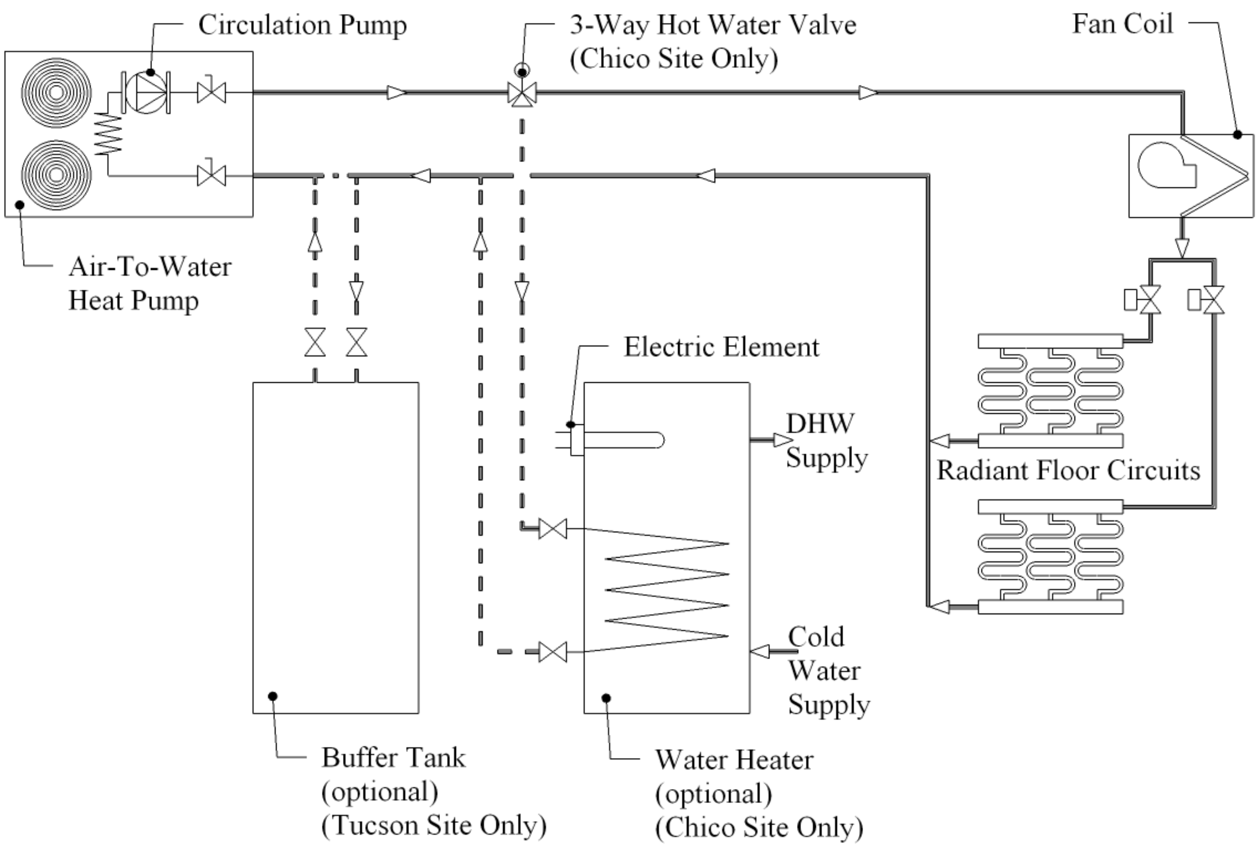


Current Research Projects

La Mirada Homes – Tucson Arizona

Cana House – Chico California

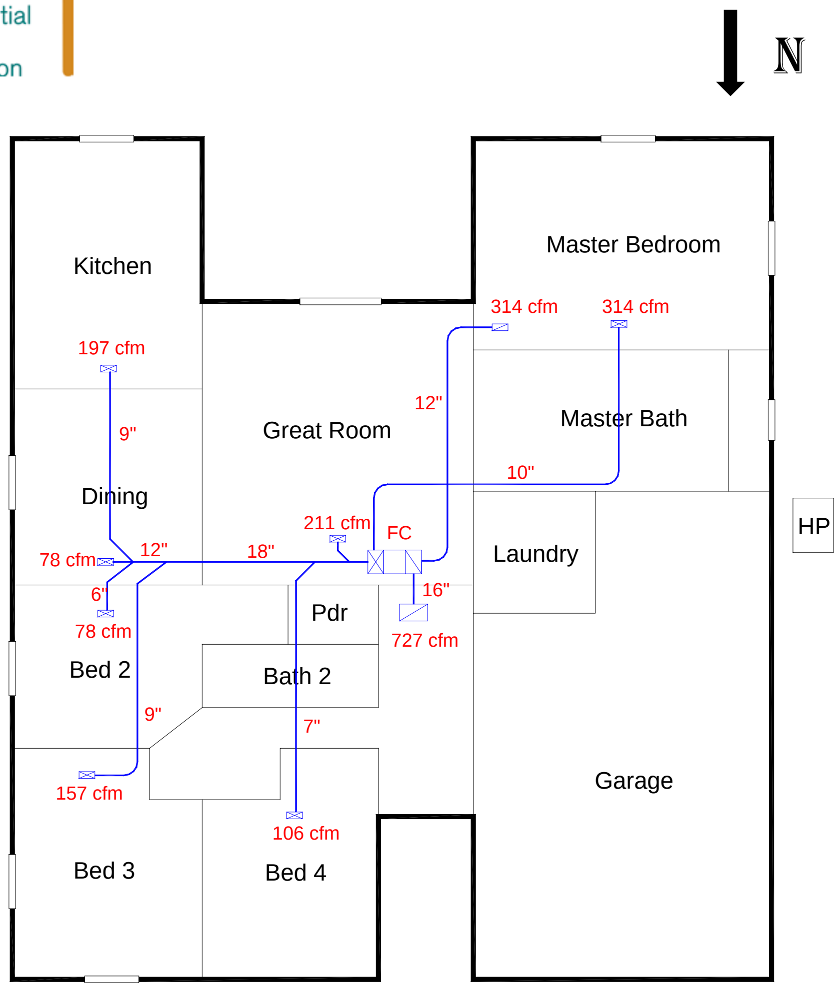
Mixed Mode Distribution in Hot-Dry Climates



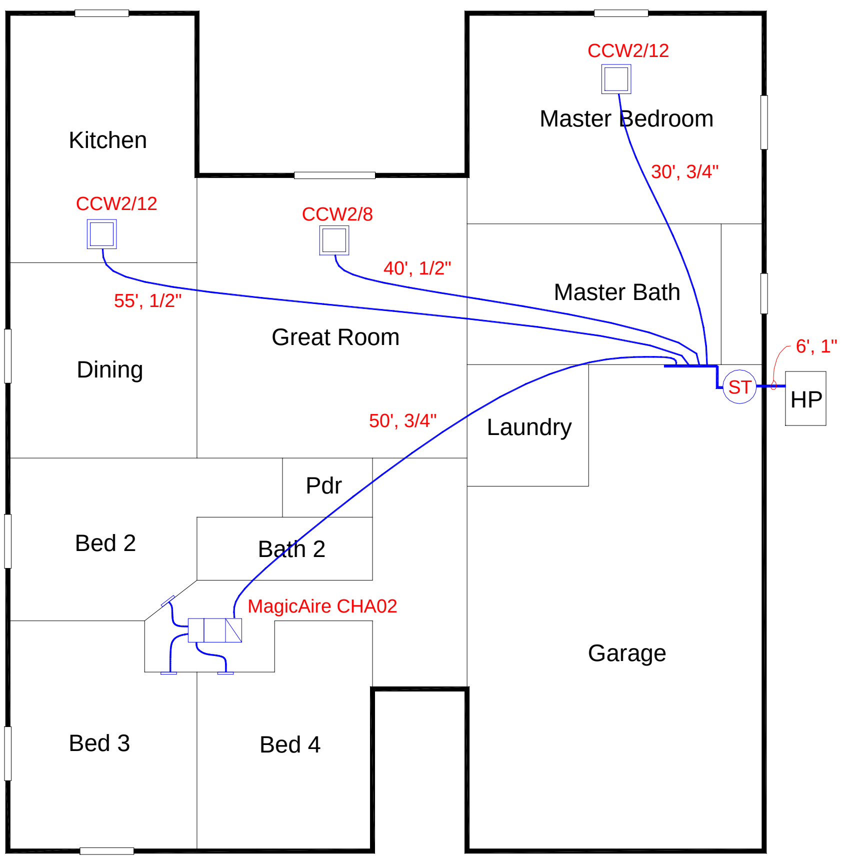
Basic Modeling Approach

- Used TRNSYS to model forced air and hydronic distribution systems
- 2400 ft^2 house, design based on Building America Simulation Protocols
- Sizing based on ACCA Manual J & D and standard methods for hydronic systems
- Hydronic system assumes forced-air distribution using ceiling-mounted cassettes (appropriate for all climates and building types)
- Similar 13 SEER heat pumps used in both cases

Hydronic vs. Duct Layouts



Ducted Forced Air

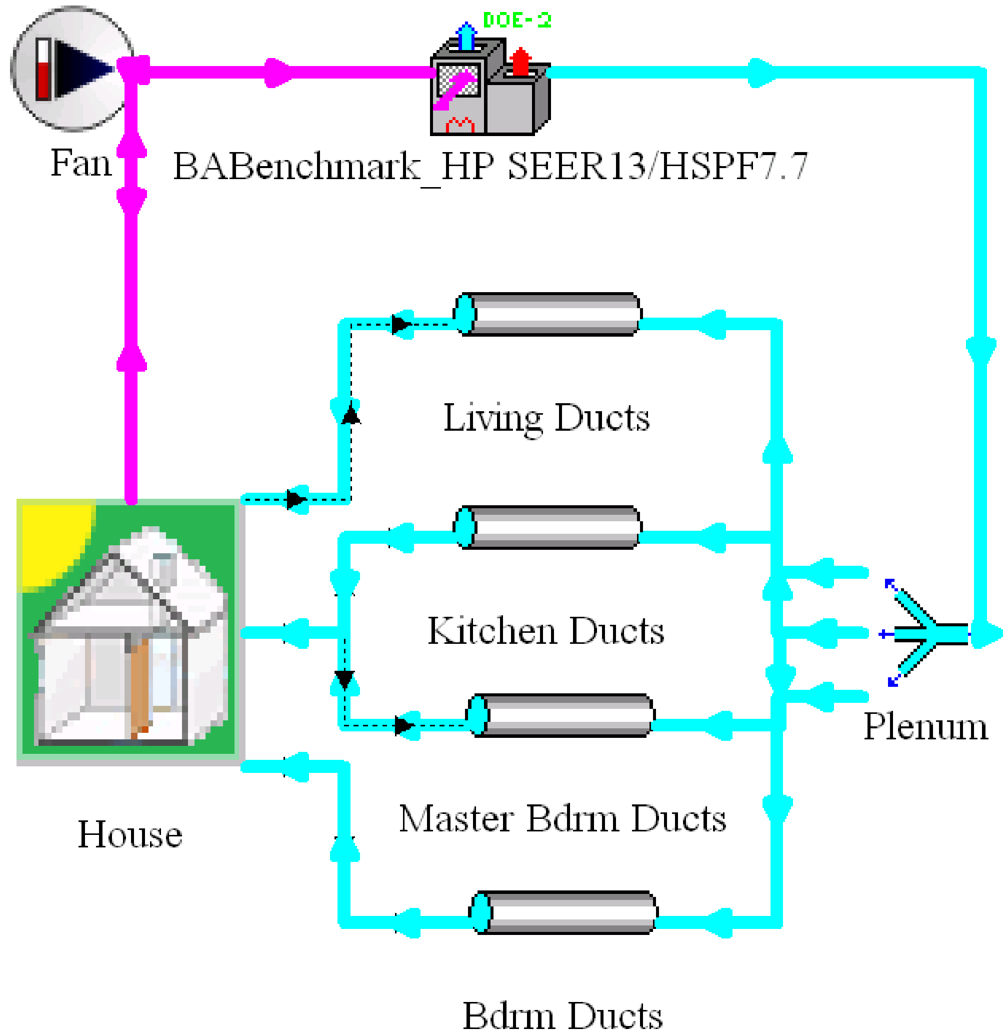


Ductless Hydronic

Energy Use Comparison - Methods

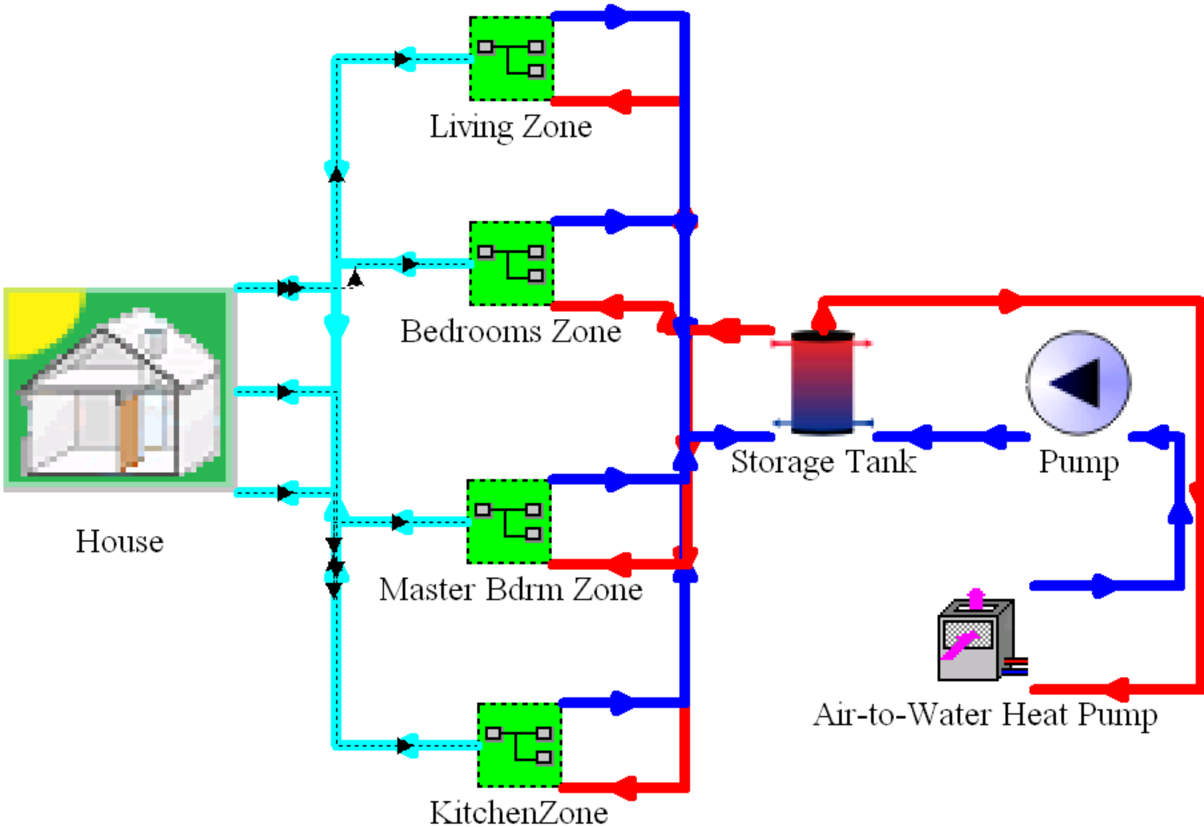
TRNSYS Model

- Base Case
  - Forced air ducted system
  - Single zone
    - 1 thermostat
  - Air to air heat pump
  - Blower Fan
    - 900 CFM
    - 327 W



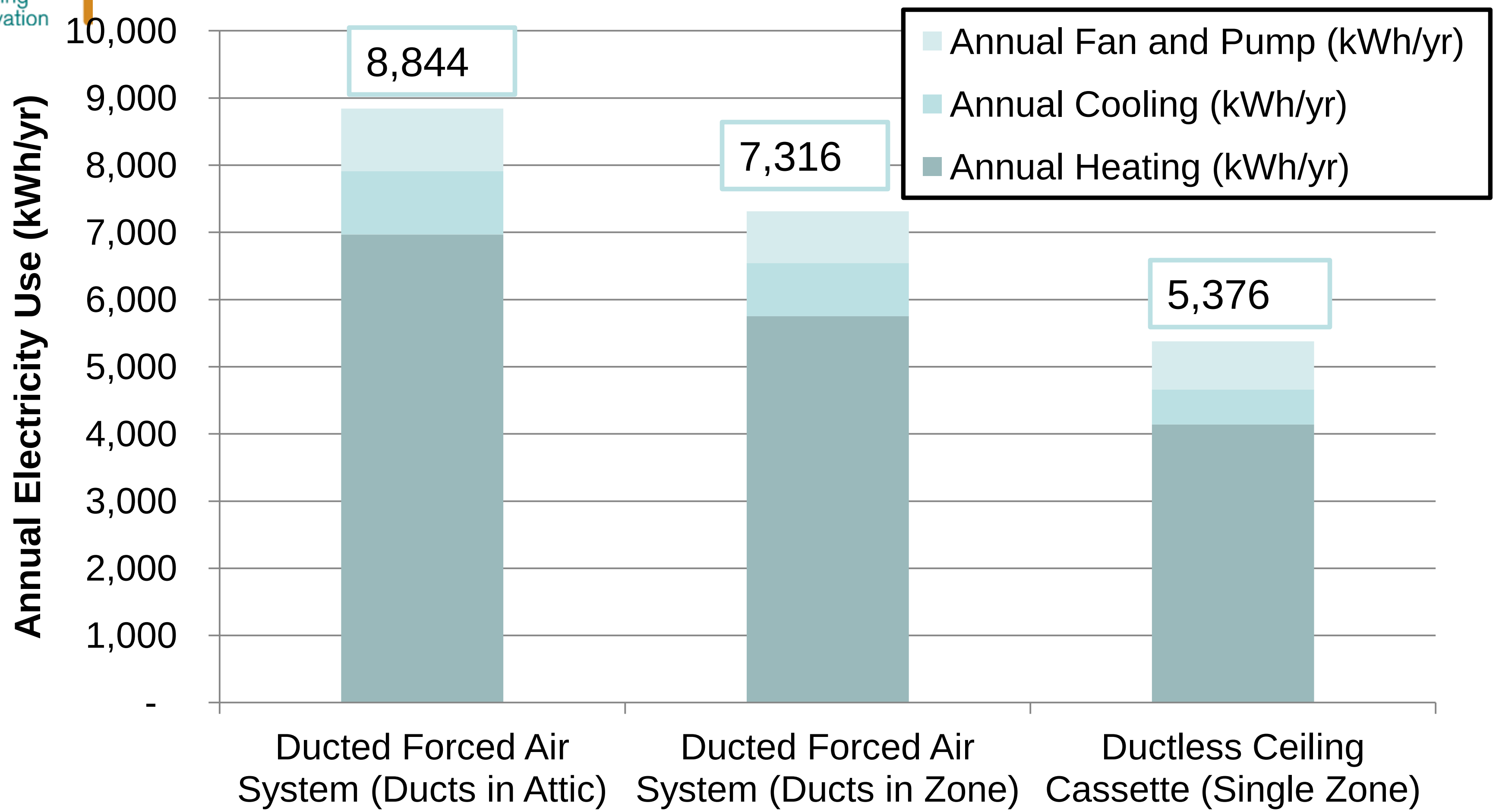
Energy Use Comparison - Methods

TRNSYS Model



- Ductless Hydronic
  - 4 Ceiling Cassettes
    - Airdale Model
      - 250 CFM/room
      - 0.14 CFM/Watt
  - Single zone
    - 1 thermostat
  - Air to-water heat pump
    - Altherma specs

Energy Use Comparison - Results



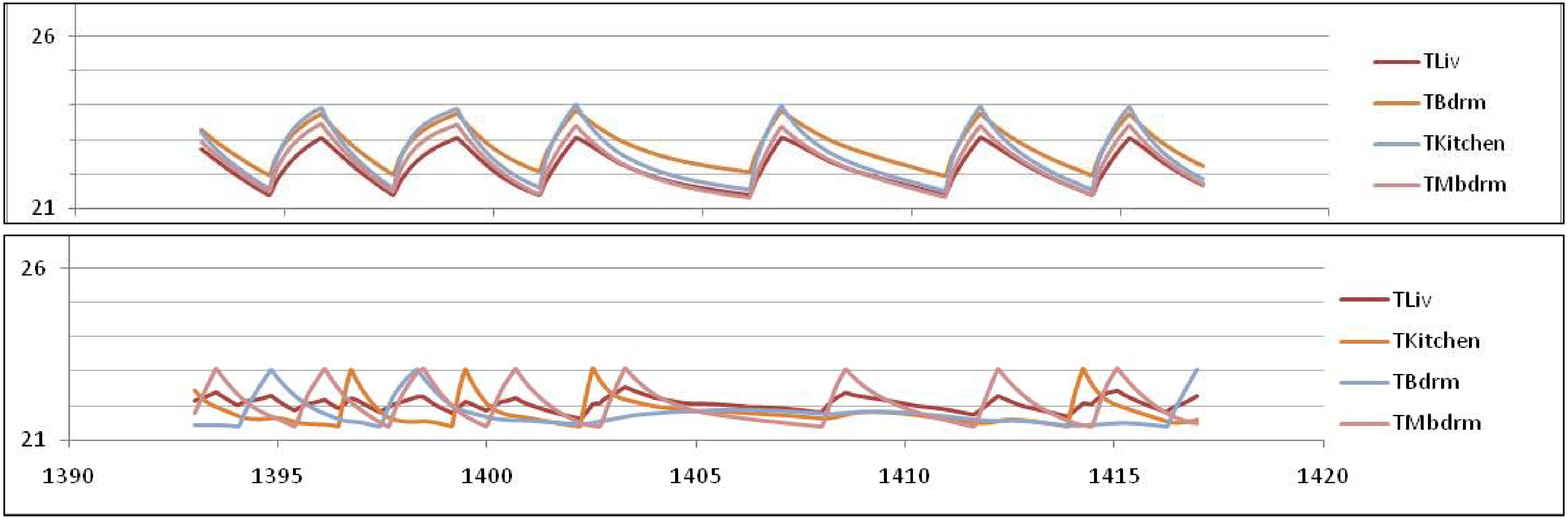
Delivery Efficiency

Distribution Energy Savings	Delivered Energy by Heat Pump (MBtu/yr)	Fan and Pump Energy (kWh/yr)
Ducts in Attic	56.0	972.8
Ductless	47.7	714.9
% Savings	**15%**	**27%**

Energy Use Comparison - Results

Zoning Impacts

System Type	Annual Heat Pump (kWh/yr)	Annual Pump (kWh/yr)	Annual Fan (kWh/yr)	Total (kWh/yr)
Ductless-Single Zone	4661	193	522	5376
Ductless-4 Zones	4724	188	657	5570
Savings	-63	5	-136	-194
% Savings	-1%	3%	-26%	-4%



Hour of the Simulation

Further Modeling Objectives

- Generic Air-to-Water Heat Pump model
- Delivery Methods-Radiant Floor or Ceiling Panels
- Climate Zone Impacts
- Building Load Impacts

Estimated Savings

System Type	Annual Heating (kWh/yr)	Annual Cooling (kWh/yr)	Annual Fan and Pump (kWh/yr)	Total (kWh/yr)
Ducted Forced Air System (Ducts in Attic)	6,967	944	933	**8,844**
Ductless Ceiling Cassette (Single Zone)	4,139	522	715	**5,376**
	Estimated Annual Savings			**3,468**
	Estimated Annual Cost Savings			**$390**

Cost savings based on $0.113/kWh (National Avg. Electricity Rate)

Comparative Costs

BASE HEAT PUMP COSTS	
HP Air Handler & coil	$872
Diffusers	$49
Return Grilles	$19
Ducts	$745
TOTAL	$1,685

HYDRONIC SYSTEM COSTS	
Manifolds	$53
Piping	$357
Airdale air handlers (3)	$6,103
MagicAire air handler	$400
Heat pump heat exchanger	$1,200
Diffusers	$23
Return Grille	$5
Buffer Tank (50 gal)	$407
Pumps, heat pump & zone	$371
Air separator	$103
Expansion tank	$29
Switching relay	$48
TOTAL	$9,099

- Costs based on heat pump systems for layouts shown
- Approximate incremental costs only included for Aqua Products heat exchanger package (heat pump costs assumed equal)
- Labor costs included only for distribution duct and hydronic piping
- Incremental cost = $7414
- Air handlers are 67% of hydronic system cost

Neutral Cost Analysis

- Savings would support an incremental cost of $5421
- High cost of terminal units is the greatest cost component
- Use of small, distributed air handlers would result in a positive cash flow

CASH FLOW	
Annual Cost Savings	$390
Incremental Cost for Hydronic Distribution	$7,414
Amortized Incremental Cost (6%, 30 years)	$533
Annual Positive Cash Flow	-$143

Summary

- Simulations show significant energy savings relative to ducted systems
- Additional savings may result from zoning
- Equipment gap: inexpensive, ceiling-mounted forced air terminal units
- Radiant floor distribution would likely cost less than the specified forced air units
- Additional product offerings and increased volume would improve market viability
- Trades would need to adapt to provide both plumbing and HVAC services

Next Steps

- Evaluate for different climates
- Comparative field test of systems
  - Radiant floor distribution (in process)
  - Forced air distribution
- Work with TESS on TRNSYS model verification
- Develop performance maps for air-to-water heat pumps