ACEEE Hot Water Forum

Heating Water with Multi-Purpose Residential Heat Pumps

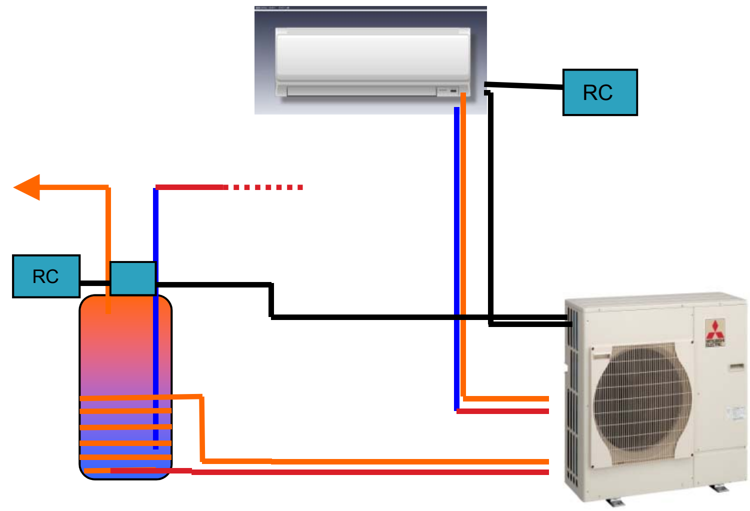
Paul Doppel

Senior Director

Industry & Government Relations

COOLING & HEATING

Live Better



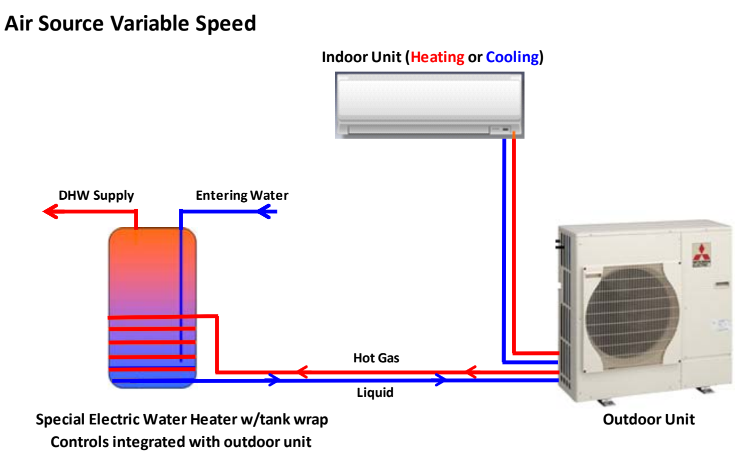
Paul L. Doppel

Paul Doppel has worked for Mitsubishi Electric Cooling & Heating since 2002, and was a brand manager before being promoted to his current position of Senior Director of Industry and Government Relations in 2012. A 34-year HVAC industry veteran, Doppel served as chairman of the TC 8.7 Variable Refrigerant Flow committee of ASHRAE from 2010 to 2012 and currently is the chairman, Ductless(VRF) Product Section, of the Air-Conditioning, Heating and Refrigeration Institute (AHRI).

Doppel also works with the DOE, utility companies, state governments and green building groups to enhance VRF technology education and applications. In 2009, Doppel was honored by AHRI with the Richard C. Schulze Distinguished Service Award, which is presented annually to individuals recognized for their unique contributions to the HVACR industry. He is retired from the United States Army Reserves after 30 years of service, and is a graduate of the United States Military Academy at West Point.

YEAR TWO

We've gone from here…



…to here

What did we talk about last year?

Presenter	Topic	Discussion Points
Paul Doppel	Overview and Introductions	• Ductless & VRF Overview • VRF Water Heating • Multi-split Heat Pump Flexibility
Dave Lis	Market Readiness	• Ductless Success in the Northwest Market • Utility Participation • Market Drivers
Wayne Reedy	How to Measure the Efficiency	• What to do with Complex Systems • ASHRAE Standard 206 Development • Testing Water Heating
Joe Bush	Testing to the Standard	• Applying the 206 Standard • Looking at the Results of Testing • Field Applications

Variable Refrigerant Flow (VRF)

- Zoning System
- Simultaneous Cooling and Heating (R2 and WR2)
- Multiple Indoor Units
- Two-pipe System
- INVERTER-driven Compressor
- Operates as a Heat Pump
- Up to 150% Connected Capacity

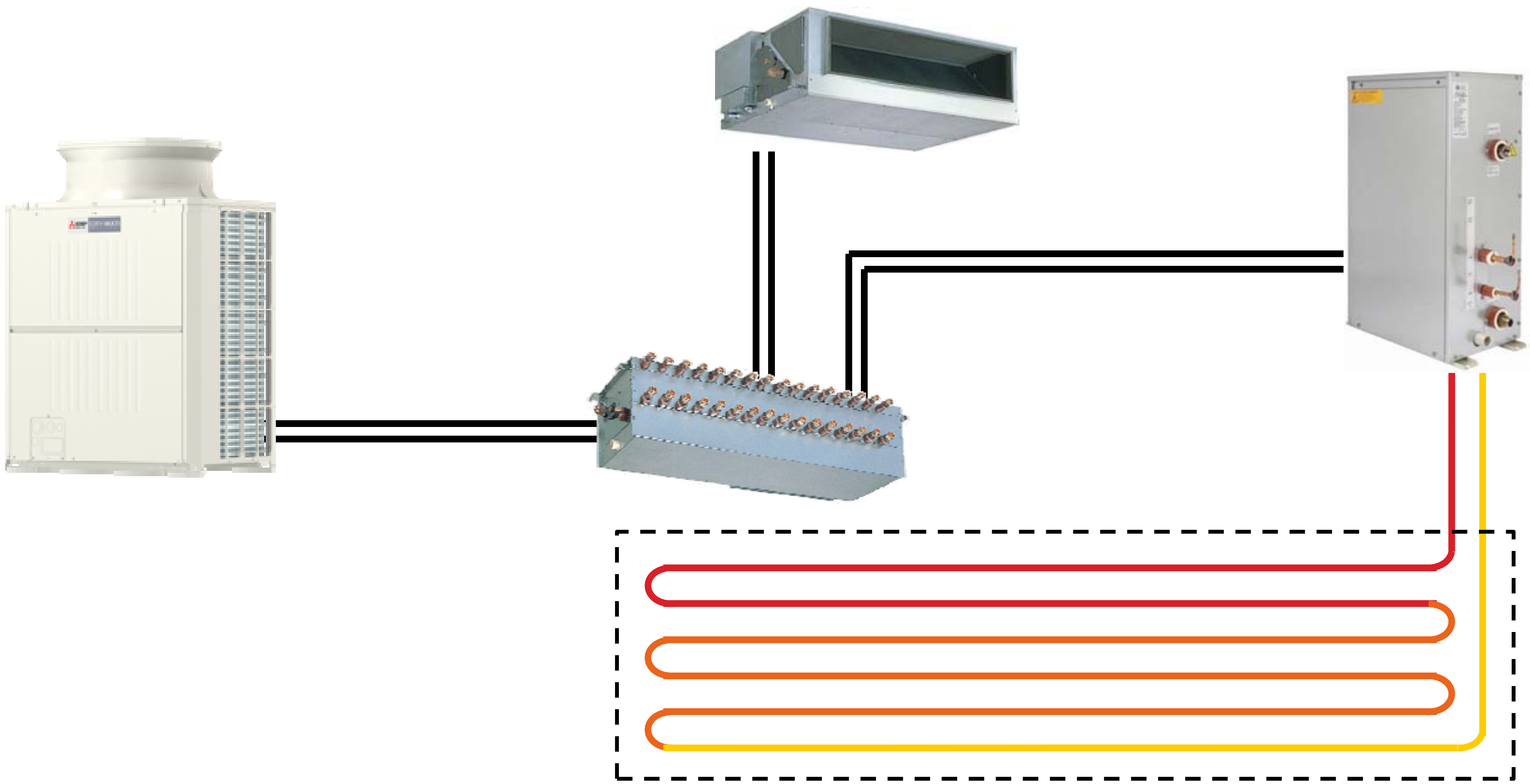
VRF (Variable Refrigerant Flow) Systems

Heat-Recovery System

What is the Hydronic Heat Exchanger?

- Refrigerant to Water Heat Exchanger
- Indoor Unit Available for use with CITY MULTI VRF Systems
- Creates opportunity to transfer energy from refrigerant to water
- Can be used to redirect “waste heat” from cooling operation to hydronic systems
- Referred to as HEX or Booster Unit
- HEX Unit (-AU) (36 MBH and 72 MBH)
  - Hot water: 86° F – 113° F
  - “Cool” water: 41° F – 86° F
- Booster Unit (-BU) (36 MBH)
  - Hot water: 86° F – 160° F
  - No “Cool” water option

Hydronic Heating System - Primary



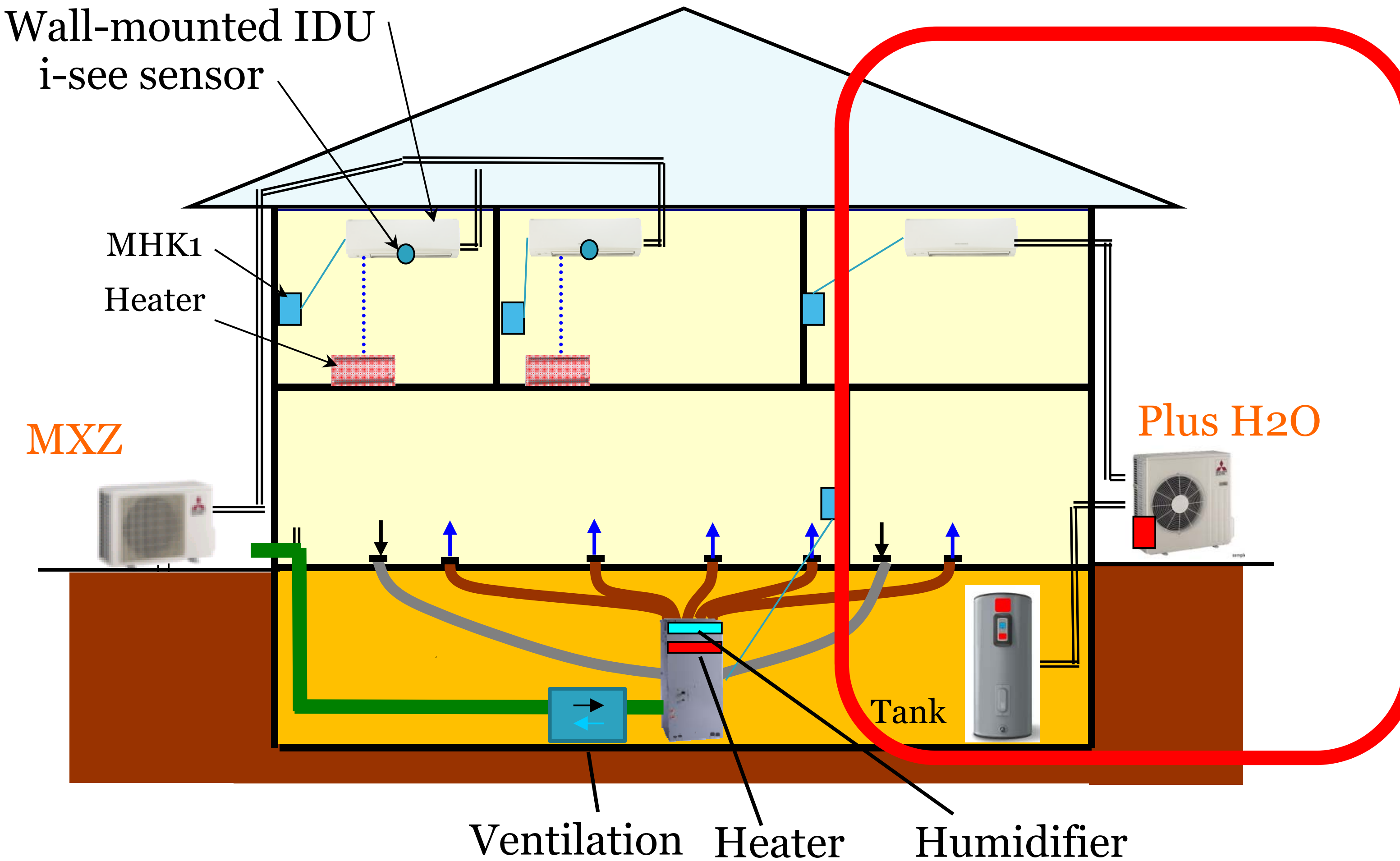
MITSUBISHI ELECTRIC
COOLING & HEATING
Live Better

Primary Heating System | Dedicated Outside Air System | Geothermal Application | Domestic Hot Water | Pool Heating

How can we apply this to Residential Ductless Systems?

Whole Home Solution-
Multi-position AHU, MXZ, Plus H2O

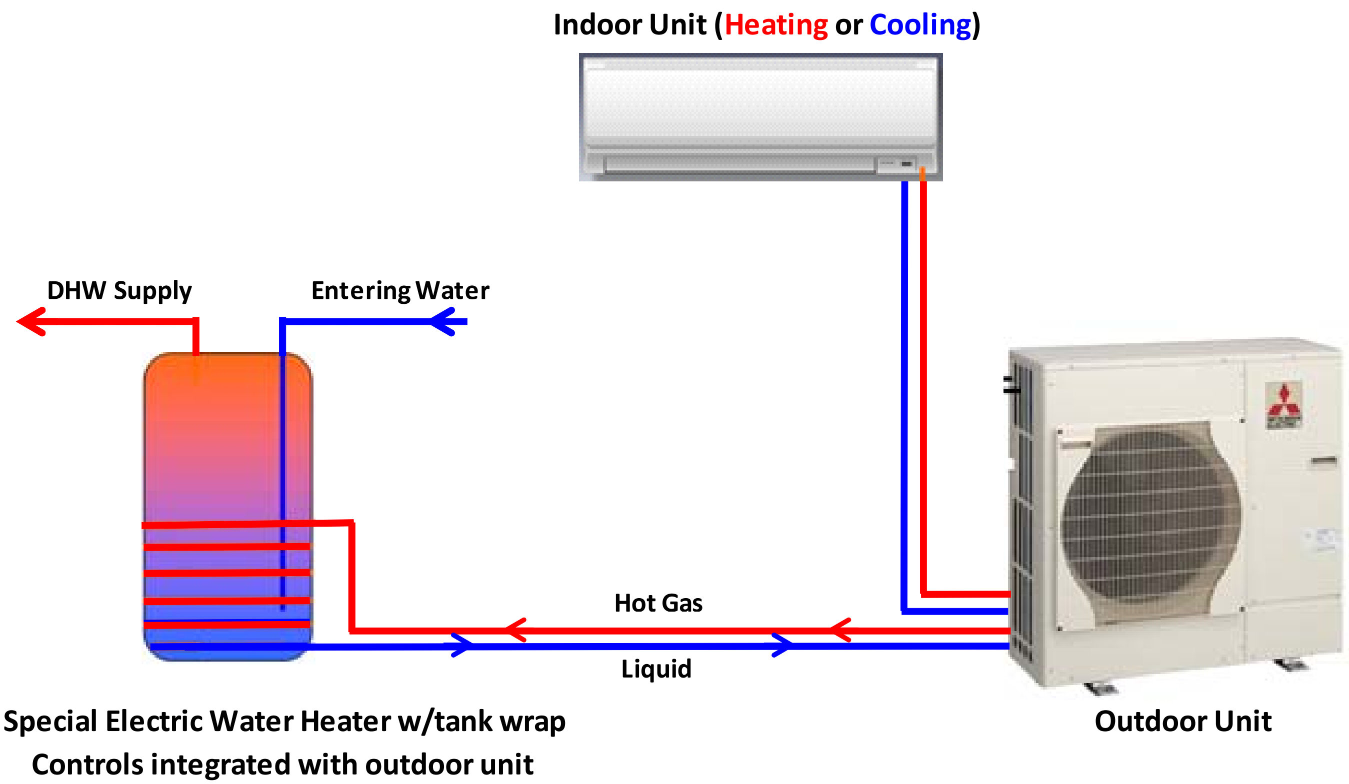
Confidential



Mitsubishi Residential System for Conditioning Space and Heating Water

Active Water Heating System - Can provide water heating

Air Source Variable Speed



Heating Water with Multi-Purpose Residential Heat Pumps

2015

Presenter	Topic	Discussion Points
Paul Doppel	Overview and Introductions	• What we said last year • VRF & Ductless Overview • This YEAR
Tim Roller	Testing to the Standard	• Applying the 206 Standard • Testing Plans • Looking at the Results of Field Testing
Dave Kresta	Field Testing & Market Readiness	• Ductless Success in the Northwest Market • Field Applications • Market Drivers & Utility Participation
Paul Doppel	How to Measure the Performance	• What to do with Complex Systems • How do we rate these systems? • Next Steps

Tim Roller

Tim Roller is a Senior Mechanical Design Engineer for Mitsubishi Electric Cooling & Heating. He has over 26 years experience in designing refrigeration systems for the supermarket industry and now for the HVAC market.

Tim has a Bachelor of Mechanical Engineering from the Georgia Institute of Technology in Atlanta, Georgia.

Before joining Mitsubishi Electric in November 2013, Tim worked for Hussmann (12 years) and Kysor//Warren (14 years).

Testing Multi-Purpose Residential Heat Pumps

The "Plus H2O" residential unit.

- The Mitsubishi Plus H20 system consists of an air-source heat pump, indoor unit and a water storage tank with refrigeration-to-water heat exchanger that provides space heating and cooling and domestic hot water
- Operates as a conventional residential VSMS heat pump system with a second refrigeration circuit for domestic hot water
- Second refrigeration circuit is only an active component of the system when a demand for hot water is required
- Cooling is measured in SEER, heating in HSPF and water heating in UEF

Mitsubishi Residential System for Conditioning Space and Heating Water

Available Modes

- Heating Space
- Cooling Space
- Heating Space + DHW
- Cooling Space + DHW (Heat Recovery)
- Dedicated Water Heating Only

Compressor operates from 20 – 110 Hz. Depending on Mode, Demand and Outdoor Ambient

Applying the 206 Standard

- Air Source Variable Speed
  - Available Tests
    - Mode A = Standard AHRI 210/240
    - Mode B = Heating/Cooling Space + Water Heating
    - Mode C = Dedicated Water Heating
    - Mode C = DOE 10 CFR Part 430

Applying Mode B of Standard 206

Mode A — Mode C

- Mode B = Heating/Cooling + Water Heating (8 tests)
  - *Mode B test cannot be used by us because of the locked compressor requirement. It causes our system to shutdown on mechanical protection (high pressure)*
  - *The length of Mode A testing ≠ the length of Mode C testing*

30 minutes — Approximately 180 minutes (3 hours)
DOE 1440 minutes (24 hours)

- Shorter the length of the Mode C tests.

Changes in the Test Procedures for Residential & Commercial Water Heaters
DOE 10 CFR Parts 429, 430 and 431

- Single draw pattern is being replaced with one of four patterns termed “very small usage”, “low usage”, “medium usage”, and “high usage”. The selection of the draw pattern to be used in the simulated-use test would be based upon the results of the First Hour rating test or the maximum GPM rating test
- The storage tank set point is lowered to 125ºF
- Termination temperature for the First Hour test is now when the delivery temperature drop to 15º below outlet water temperature
- 5.2.4 *Soak-In Period for Water Heaters with Rated Storage Volumes Greater than or Equal to 2 Gallons*
- UEF, uniform energy factor of a water heater instead of EF.

Computations:

Table III.3 Medium-Usage Draw Pattern

Draw #	Time During Test	Volume	Flow Rate	Vol.
1	0:00	15	1.7	
2	0:30	2	1	
3	1:40	9	1.7	**26**
4	10:30	9	1.7	
5	11:30	5	1.7	
6	12:00	1	1	
7	12:45	1	1	
8	12:50	1	1	
9	16:00	1	1	
10	16:15	2	1	
11	16:45	2	1.7	
12	17:00	7	1.7	
Total		**55**		

47% in 100 minutes

Computations:

Table III.3 Medium-Usage Draw Pattern

Draw #	Time During Test	Volume	Flow Rate	Vol.
1	0:00	15	1.7	
2	0:30	2	1	
3	1:40	9	1.7	**26**
4	10:30	9	1.7	
5	11:30	5	1.7	
6	12:00	1	1	
7	12:45	1	1	
8	12:50	1	1	
9	16:00	1	1	
10	16:15	2	1	
11	16:45	2	1.7	
12	17:00	7	1.7	
Total		**55**		

$$qw(tj) = \frac{V_{first}}{V_{day}} * \frac{Q_{HW}}{Time\ of\ Test}$$

Where

V_{first} = volume of water withdrawn in the first draw cluster (shown in gray)

V_{dy} = total volume of water drawn per day

$$qw(tj) = \frac{26}{55} * \frac{Q_{HW}}{1.67\ hours}$$

or

$$qw(tj) = .28 * Q_{HW}$$

Computations:

The energy used to heat water may be computed as

$$Q_{HW} = \sum_{i=1}^{N} V_i \, \rho C_{p,i} \left(\bar{T}_{del,i} - \bar{T}_{in,i} \right)$$

where

N = total number of draws in the draw pattern
V_i = the volume withdrawn for the *i*th draw (i = 1 to N), gal (L)
ρ = the density of the water at the water temperature measured at the point where the flow rate volume is measured, lb/gal (kg/L)
C_{pi} = the specific heat of the water of the *i*th draw evaluated at $(\bar{T}_{del,i} + \bar{T}_{in,i})/2$, Btu/(lb•°F) (kJ/(kg•°C))
$\bar{T}_{del,i}$ = the average water outlet temperature measured during the *i*th draw (i = 1 to N), °F (°C)
$\bar{T}_{in,i}$ = the average water inlet temperature measured during the *i*th draw (i = 1 to N), °F (°C)

Mode B components:

$$SEER = \frac{\sum_{j=1}^{8}\left(\frac{q(tj)}{N}\right)}{\sum_{j=1}^{8}\left(\frac{e(tj)}{N}\right)}$$

and

$$qw(tj) = \frac{Q_{HW}}{Time\ of\ Test}$$

Where

- q(tj) = the cooling capacity at the bin temperature
- qw(tj) = the energy to heat water at the bin temperature
- e(tj)=electrical power consumption of the outdoor unit at the bin temperature
- ew(tj)= electrical power consumption of the water heater at the bin temperature

Mode B components:

$$COOL_{ca} = \frac{\sum_{j=1}^{8}\left(\frac{q(tj)}{N} + \frac{qw(tj)}{N}\right)}{\sum_{j=1}^{8}\left(\frac{e(tj)}{N} + \frac{ew(tj)}{N}\right)}$$

Where

- q(tj) = the cooling capacity at the bin temperature
- qw(tj) = the energy to heat water at the bin temperature
- e(tj)=electrical power consumption of the outdoor unit at the bin temperature
- ew(tj)= electrical power consumption of the water heater at the bin temperature

Testings Plans

- DOE 10 CFR revision of Appendix E to subpart B of Part 430 goes in effect after December 31, 2015.
- Use part of the draw pattern for combined testing.
- Compare single modes of operation testing, combined mode testing, and field testing results to set the criteria for a Combined mode of operation rating.

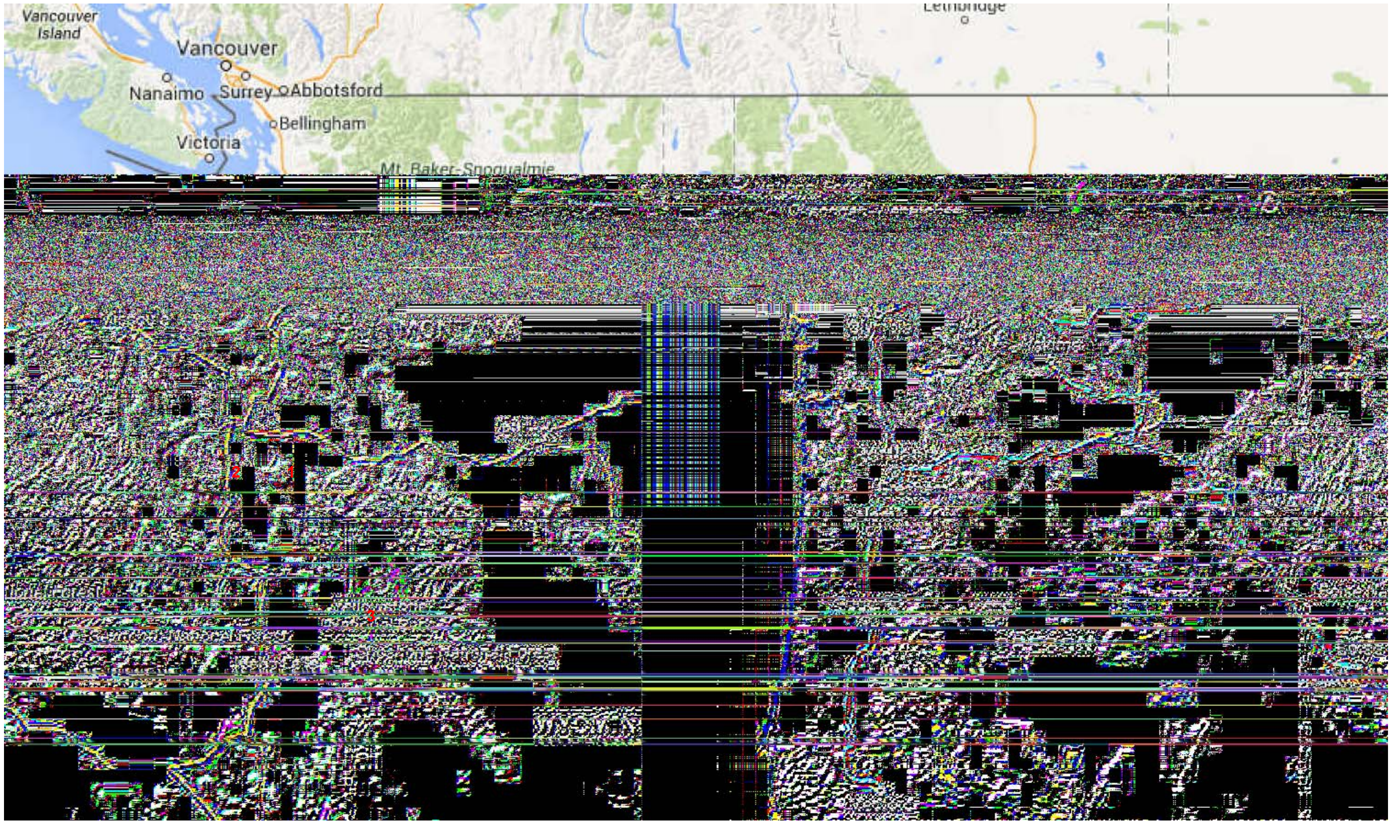
Field Testing

- Field Testing
- 3 in the Northwest

- Full equipment monitoring
  - Power consumption
    - Heating
    - Cooling
    - Water Heating
  - Capacity
    - Heating
    - Cooling
    - Water Heating
  - Usage Trends
  - Energy Savings

Field Testing

- 3 test sites in the Northwest

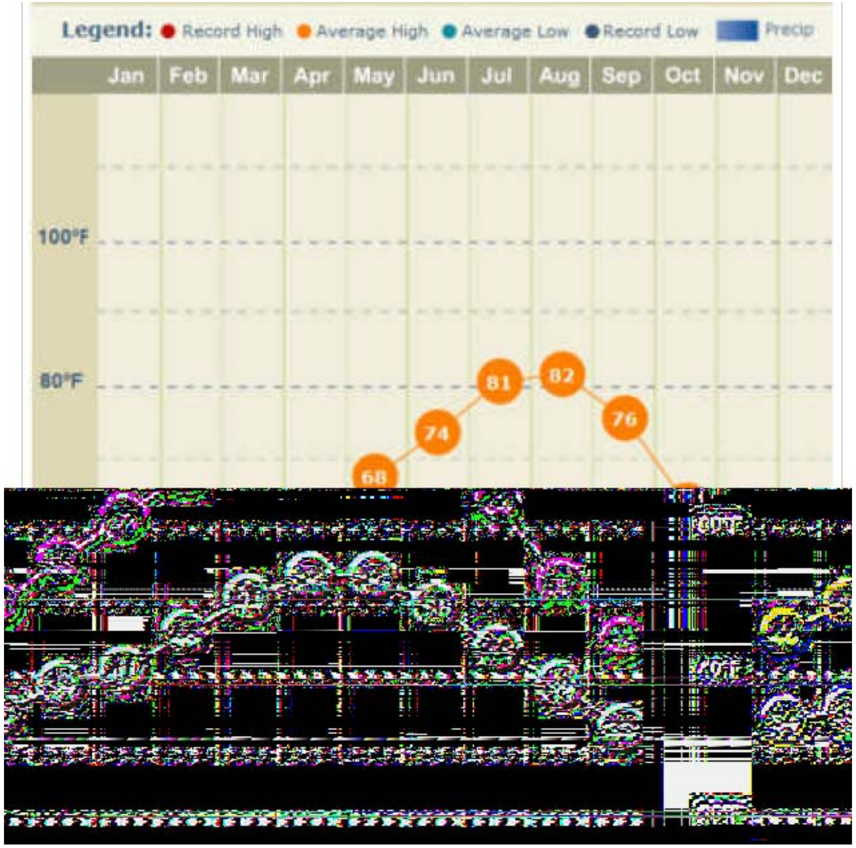


Field Trial – Home 1

Gresham, OR 97030
Family size of 3, single story home
Water Heater in conditioned space
Temperature around Tank - Upper 60s

Currently electric water heater, in-wall electric blower heaters in living and dining rooms, electric resistance radiant ceiling heat in the rest of the house.

The indoor unit is installed in the living room which will also condition the air in the connected common area consisting of the dining room, kitchen, and family/entry room

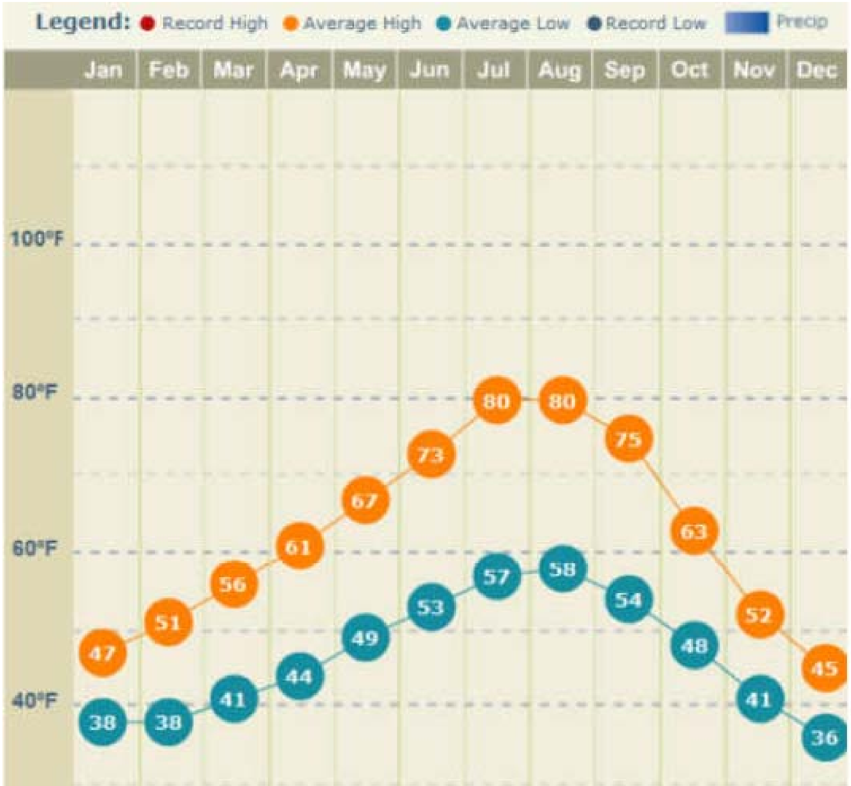


Field Trial – Home 2

Portland, OR 97219
Household occupancy of 7
Water Heater in Basement
Temperature around Tank - mid 50s

Currently electric water heater,
electric resistance heat

The indoor unit is installed in a common area consisting of the living room and kitchen



Field Trial – Home 3

Bend, OR 97702

Family size of 2, single story home with a vaulted ceiling in common area. Temperature around Tank – Upper 60s

Currently electric water heater, electric forced air furnace.

The indoor unit is installed in the entry room which will also condition the air in the connected common area consisting of the living room and kitchen

Early Field Test Results

First round of field testing yielded both encouraging results (heating/cooling) and room for improvement (water heating)

Home	Cooling Efficiency	Heating COP	Heating Efficiency	Water Heating COP	% Water Heat Done by Elements
SW Portland	21.5	3.4	11.6	1.9	27%
Gresham	21.7	3.5	11.9	1.7	32%
Bend	19.0	3.2	10.9	1.7	10%
Average	**20.7**	**3.4**	**11.5**	**1.8**	**23%**

Dave Kresta

Dave Kresta is a Senior Product Manager in NEEA's Emerging Technology group. In his role, Dave helps NEEA build a "pipeline" of commercially available energy efficiency technologies for the region. He has been a driver in the advancement of HPWH technology and markets for the last four years, and DHP technology and markets for 2 years.

Dave has over 20 years of comprehensive experience in developing and bringing high tech products to market, leading and managing product initiatives at a variety of high tech companies in the Portland area, and has been at NEEA for 5 years. He has a B.S in Computer Engineering from the University of Michigan, an MBA from Portland State University, and is currently pursuing a graduate degree in Urban Studies from Portland State.

Back to Paul for a wrap-up

Where do we GO from here???

Potential Target Markets

- Single-family (electric space + electric water)
  - 95% baseboard heated homes – 478k homes
  - 100% eFAF homes – 224k homes
- SF new construction (low load homes)
- Manufactured homes (new and retrofit)
- Multi-family?

The MARKET is there!

The NEED is there!

Challenges

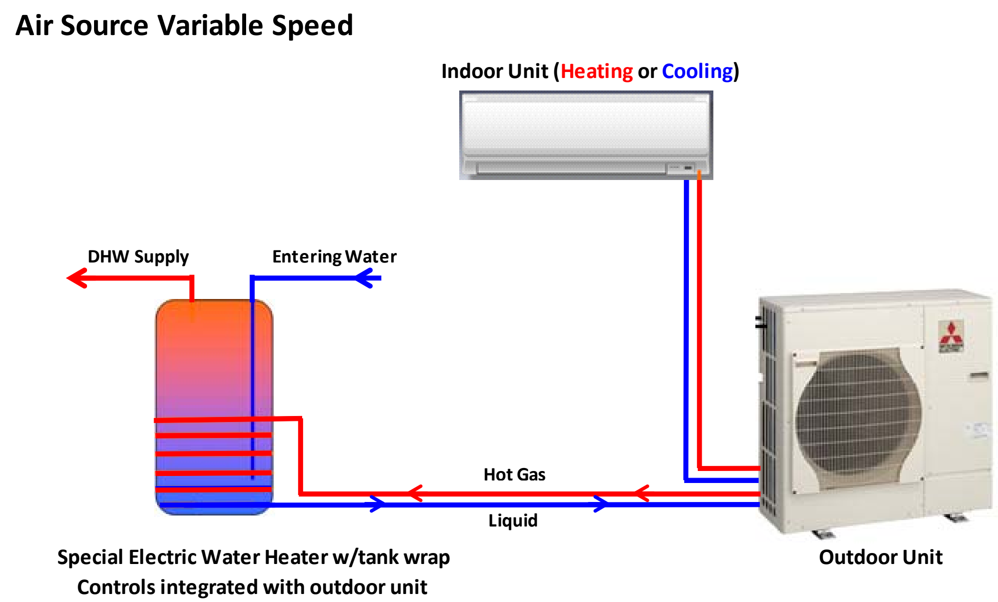
How do we test the system?

How do we Identify the results?

How do we meet customer expectations?

Combined Test Procedure

The system may operate is several modes:



- Space Conditioning
  - Space cooling
  - Space Heating
- Water Heating
- Space cooling and water heating
- Space heating and water heating

Identifying Test Results

Combining:

Mode A Heating and Cooling Performance

Mode C Dedicated Water Heating

	Standard Heat Pump		Expected Combined Appliance	
System Performance Results	SEER	22.45	*SEERca*	+
	HSPF	10.45	*HSPFca*	+
	EF*	2.20	*Efwca*	+ -

***Per DOE Test Procedure 10 CFR Part 430**

Identifying Test Results

The system may operate is several modes:

- Space Conditioning
  - Space cooling → **SEER**
  - Space Heating → **HSPF**
- Water Heating → **EF**
- Space heating and water heating **Most Challenging**
- Space cooling and water h[illegible]g [illegible]**st EFFICIENT**

SEER

Meeting CUSTOMER expectations…

The RIGHT product

At the RIGHT price

Or with a little help from our friends

At the RIGHT…

energy savings

Questions and Answers

Thank You!!

MITSUBISHI ELECTRIC Cooling & Heating
1340 Satellite Boulevard, Suwanee, GA 30024
Office: 678-275-8801 | Mobile: 678-777-5131
Email: pdoppel@hvac.mea.com
Website: http://www.mehvac.com/