Welcome to:

Dual Integrated Appliances as an Energy and Safety Solution for Low-Income Weatherization

Webinar Coordinated and Hosted by:

NorthernSTAR

Building America Partnership

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building America U.S. Department of Energy

University of Minnesota

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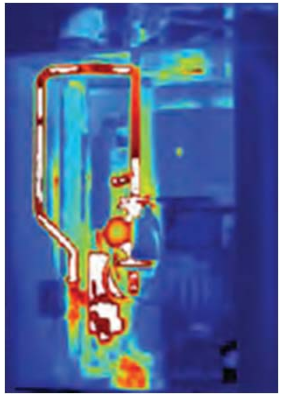
Dual Integrated Appliances as an Energy and Safety Solution for Low-Income Weatherization



Introduction

Chuck Booten, National Renewable Energy Laboratory

Pat Huelman, University of Minnesota

Part One

Rebecca Olson, Sustainable Resources Center

Jake McAlpine, Sustainable Resources Center

Ben Schoenbauer, Center for Energy and Environment

Part Two

Armin Rudd, Building Science Corporation

Ryan Kerr, Gas Technology Institute

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building AMERICA U.S. Department of Energy

UNIVERSITY OF MINNESOTA Driven to Discover℠

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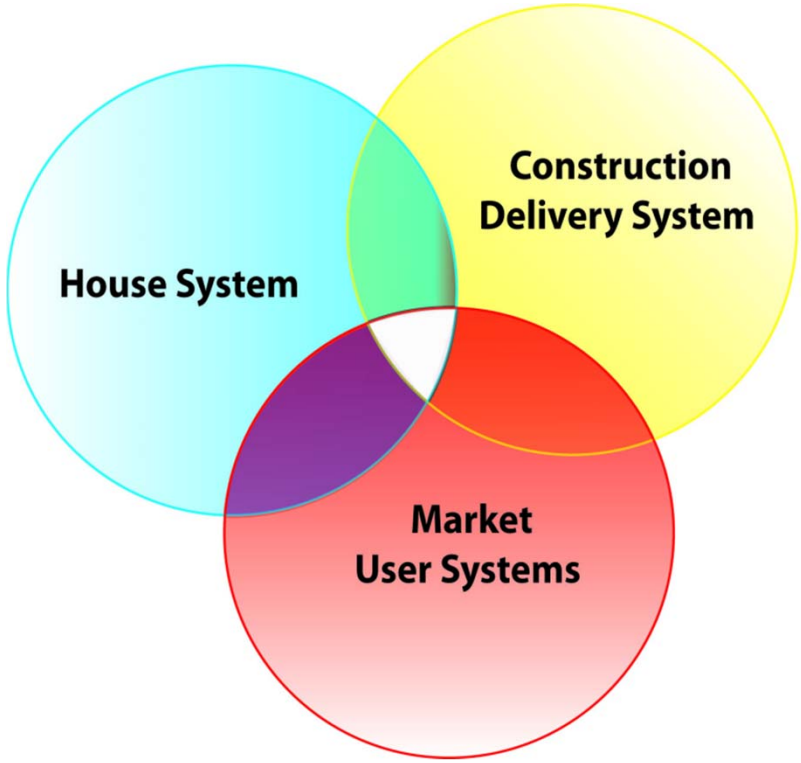
Building America Partnership

Exploring the next generation of high performance homes for cold climates

- Building science as our compass
- Research as our guide

Taking a total systems approach

- House (physical) system
- Construction delivery system
- Market-consumer-user system



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Research and deployment of a whole-house, systems engineering approach selecting the least costly and highest value home features including:

- Climate-specific designs
- Highly-efficient walls, foundations, roofs
- Super-efficient windows & doors
- Passive solar space & water heating
- State-of-the-art heating & cooling systems
- Advanced hot water, appliances, lighting
- Solar thermal and solar electric systems
- Moisture resistant construction
- Healthy indoor air

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Research Team Lead: University of Minnesota

- Cold Climate Housing Program – Pat Huelman
- Center for Sustainable Building Research – John Carmody

Research Team Partners

- Center for Energy and Environment – David Bohac
- Building Knowledge, Inc. – Ed VonThoma
- Energy Center of Wisconsin – Dan Cautley
- Wisconsin Energy Conservation Corp. – Carter Dedolph

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Research Partners

- Building Green
- Conservation Technologies
- Hunt Utilities Group, LLC
- McGregor Pearce
- Minnesota Pollution Control Agency
- University of Wisconsin-Madison
- Verified Green
- Wagner Zaun Architecture Inc.

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Building Enclosure

- CertainTeed
- DuPont - Building Innovations
- Johns Manville
- BASF

Windows and Fenestration

- Andersen Corporation
- Cardinal Corporation
- Marvin Windows and Doors

Mechanical Systems

- AIM
- AO Smith
- Panasonic
- RenewAire
- Venmar Ventilation

Builders/Remodelers/Suppliers

- Christian Builders
- JET Construction & Remodeling
- Lumber Dealers Supply
- Nor-Son Construction
- Northway Construction
- TDS Custom Construction
- Thompson Homes
- Wausau Supply Company
- Cobblestone Homes
- Van's Heating & Air Conditioning
- Amaris Custom Homes

Professional/Community

- MN Office of Energy Security
- NARI

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Research Portfolio for 2011

- High Performance New Homes
  - Field demonstration and assessment
  - Window selection guide
- Energy Audit Assessment
  - House characterization
  - Comparison and analysis
- Foundation Insulation Systems
  - New construction
  - Retrofit applications for both interior and exterior
- Project Overcoat
  - Exterior insulation systems focused on 1-1/2 story homes
- Integrated Space & Water Heating Systems
  - Laboratory testing
  - In-situ monitoring in WX homes

Building Technologies Program

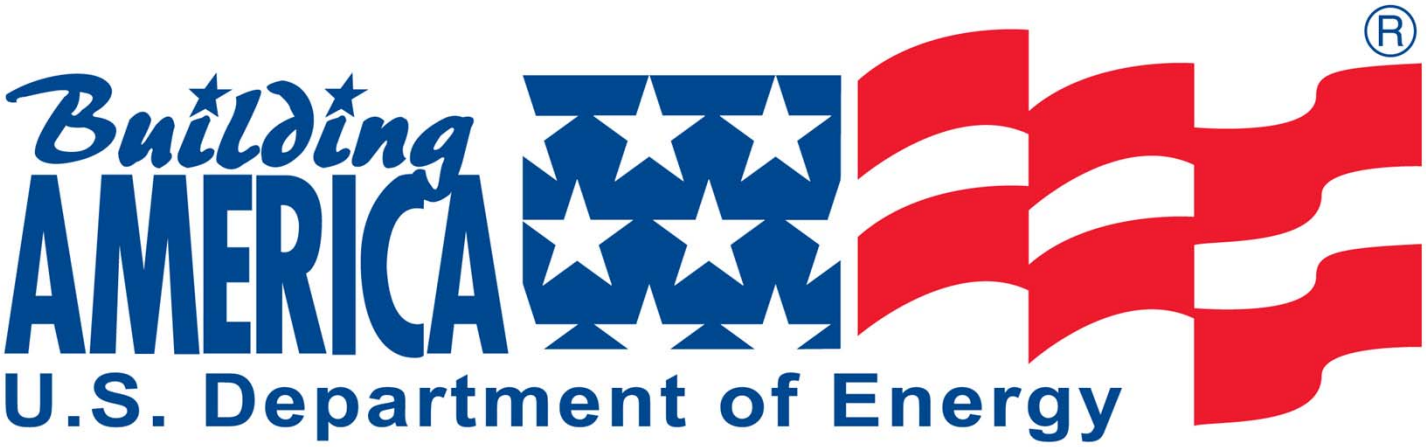
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building America: Introduction
October 19, 2011

Chuck Booten
Chuck.booten@nrel.gov

Introduction to Building America

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



- Reduce energy use in new and existing residential buildings
- 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

www.buildingamerica.gov

15 Industry Research Teams

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

CARB
Consortium for Advanced Residential Buildings

Alliance for Residential Building Innovation (ARBI)

BA-PIRC

IBACOS
Home Quality + Performance

NAHB RESEARCH CENTER

NorthernSTAR Building America Partnership

Building America Retrofit Alliance (BARA)

bsc Building Science Corporation

BIRA
BUILDING INDUSTRY RESEARCH ALLIANCE
...a catalyst for change

Fraunhofer USA

ARIES Collaborative

DOW Building Solutions

Habitat Cost Effective Energy Retrofit Program

Building Energy Efficient Homes for America (BeeHa)

PARR
The Partnership for Advanced Residential Retrofit

N.E.L.C.
The National Energy Leadership Corps

Center for Energy and Environment

Sustainable Resources Center
Creating Healthy & Efficient Homes

NorthernSTAR
A Building America partner in research, innovation, and real home solutions.

Using Dual Integrated Appliances to Improve Low Income Weatherization Energy Efficiency

Schoenbauer, Oct. 2011

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Creating Healthy & Efficient Homes

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Becky Olson – Sustainable Resources Center

Weatherization: What it is

A. Federally funded, state-controlled, assigned regions
B. Low-income housing, single & multi-family
C. Energy retrofits must pay for themselves in energy savings over their lifetime.
D. $6500/home average
E. 2-3 hour audit & diagnosis, mechanical retrofit, air sealing & insulation inc. H&S, inspection

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Becky Olson – Sustainable Resources Center

How this project came about

- Weatherization is able to seal homes tighter and tighter
- Leads to combustion safety issues
- Requires sealed combustion
- Requirements on savings vs. installed cost rule out high efficiency water heaters
- Forced to use safety budget to install 60% direct vent tanks with very little energy savings
- SRC replaces furnaces in 47% of the homes they weatherize and water heaters in 48%
- SRC got a Sustainable Energy Resources for Consumers (SERC) grant to look at using a DIA

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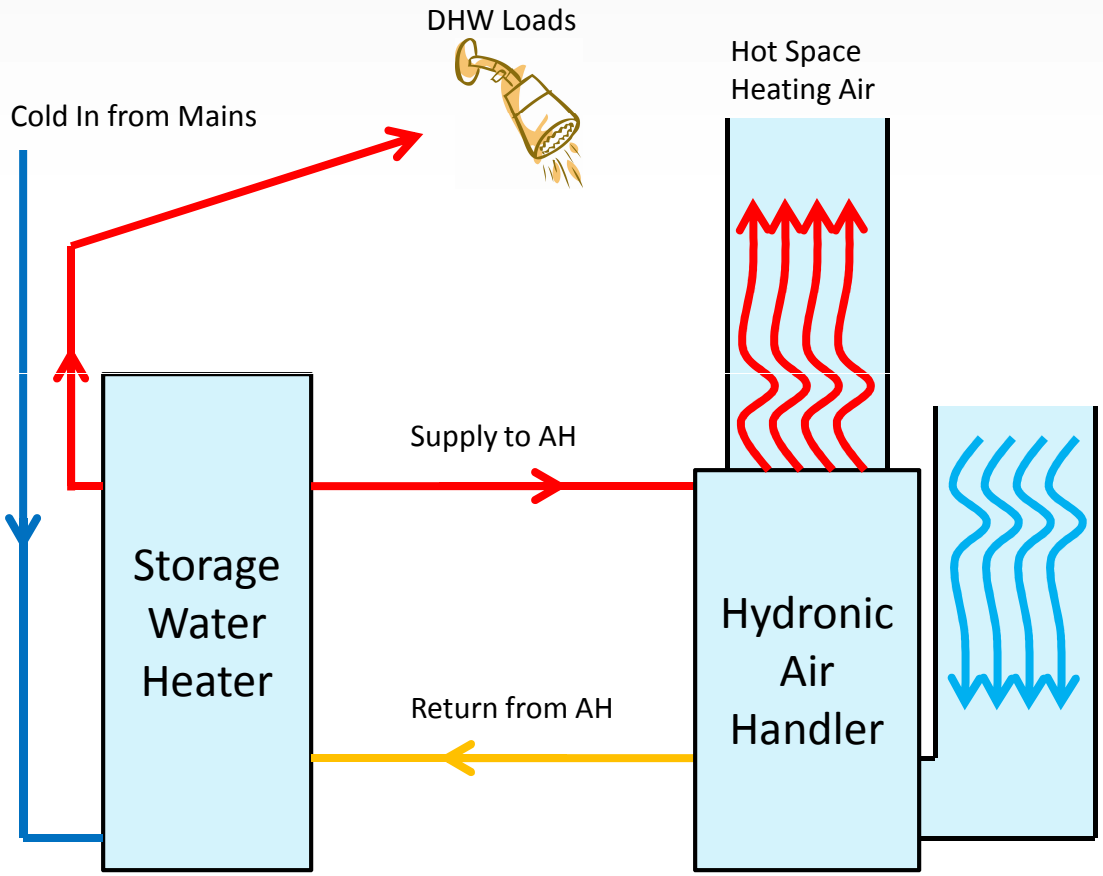
Jake McAlpine – Sustainable Resources Center

What is a Dual Integrated Appliance?

A. A mechanical system that uses one heating plant (natural gas burner) to provide both space heating and hot water
B. Space heating side can be either hydronic or forced air
C. Systems can use a closed or open heating loop

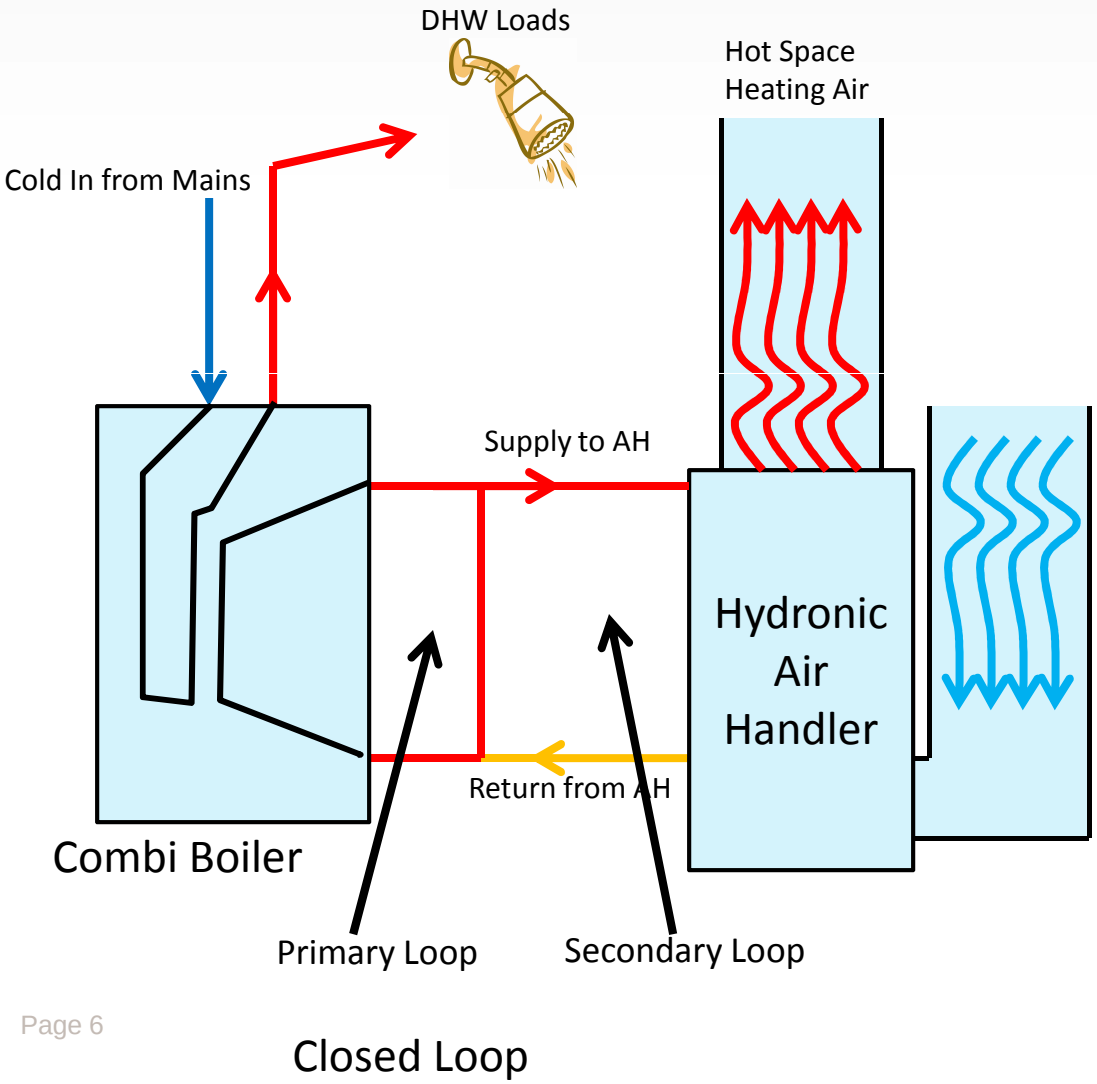
This project will look at natural gas forced air DIA systems. Boiler based systems will be closed loop and water heater systems have an open loop.

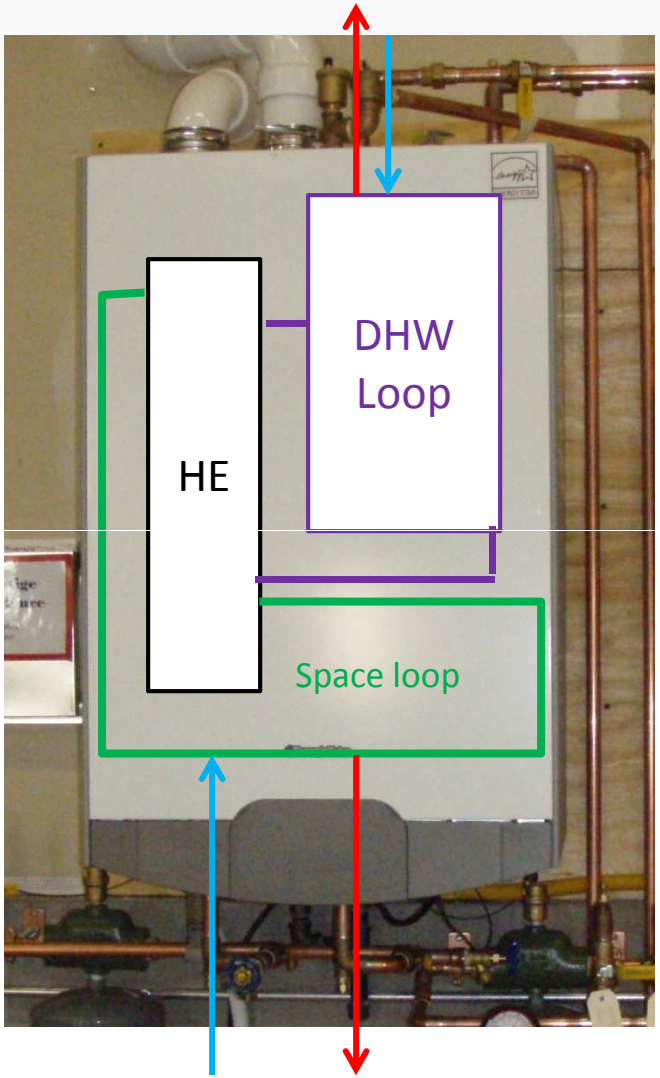
Storage water heater based system



Open Loop

Combi boiler based system





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Jake McAlpine – Sustainable Resources Center

Why Dual-Integrated Appliances?

+ Two high efficiency heaters (space and water) in one package
  - potentially cheaper
  - Simpler, less maintenance
+ Sealed combustion (Direct vent systems)
  - Eliminates combustion safety issues
+ Further reduction in air infiltration
  - Removal of make up air inlets
  - Sealing chimneys

Installation and Sizing

PROBLEM

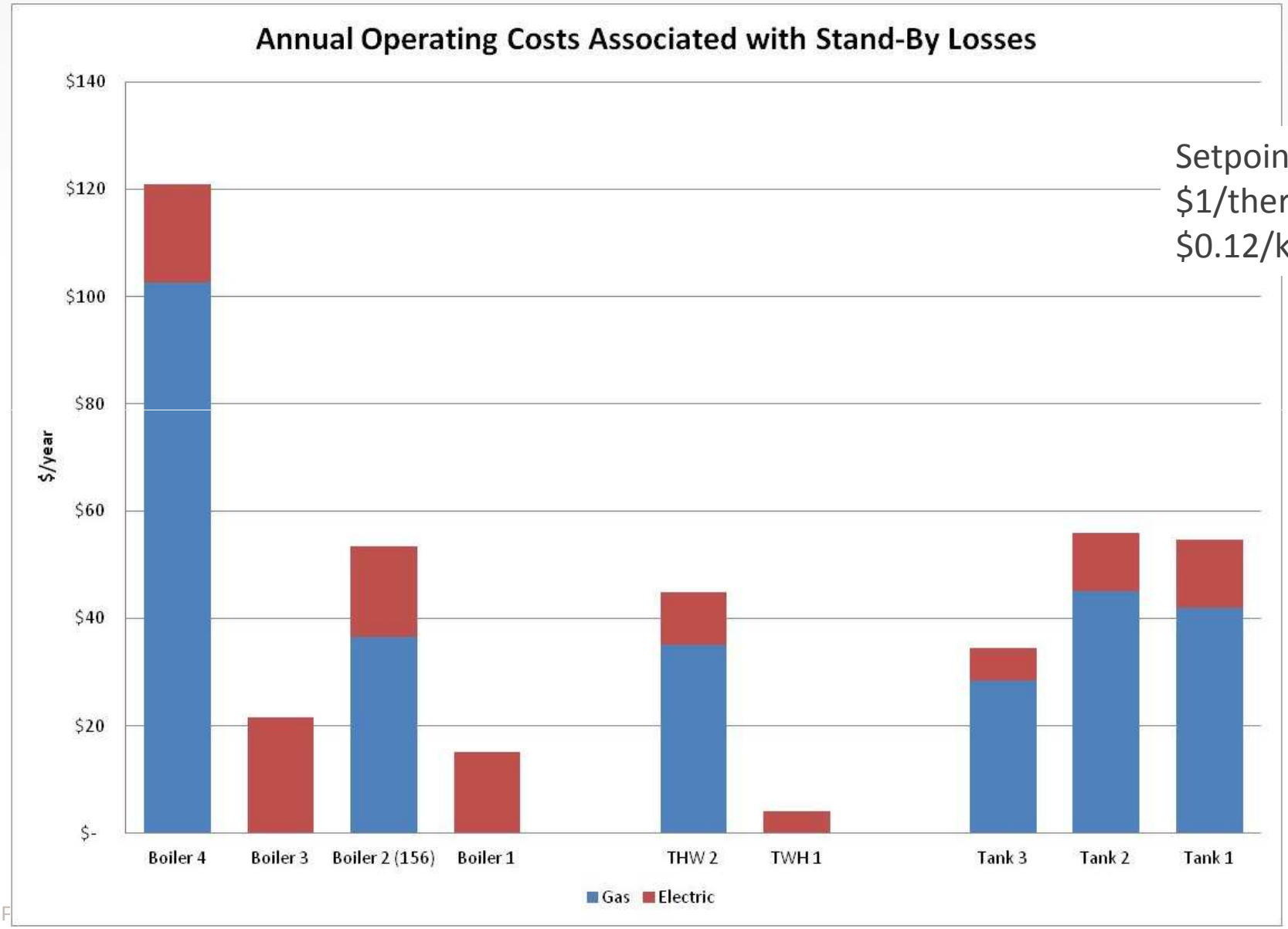
- Some contractor's had little experience
- System schematics often developed on site
- Little or no sizing information provided
- System components came from several manufacturers
- Manufacturer's settings may not lead to best performance

- Decided to design and optimize systems in a laboratory
- Could then provide contractors with more detail installation guidelines


DELL

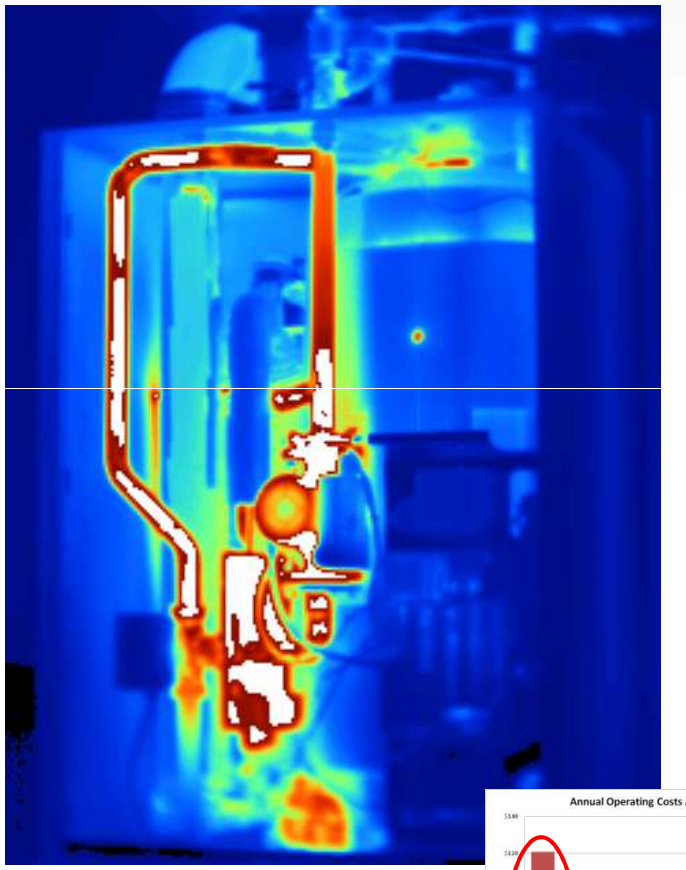
Lab work

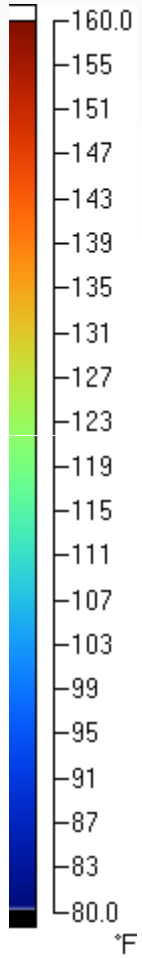
- Idle losses
- Steady state efficiency
- Air handler capacity testing
- Full system tests
  - Cyclical performance
  - Maximum capacity

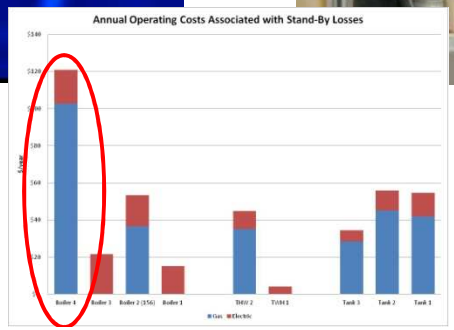


Setpoint = 140 F
$1/therm
$0.12/kWh

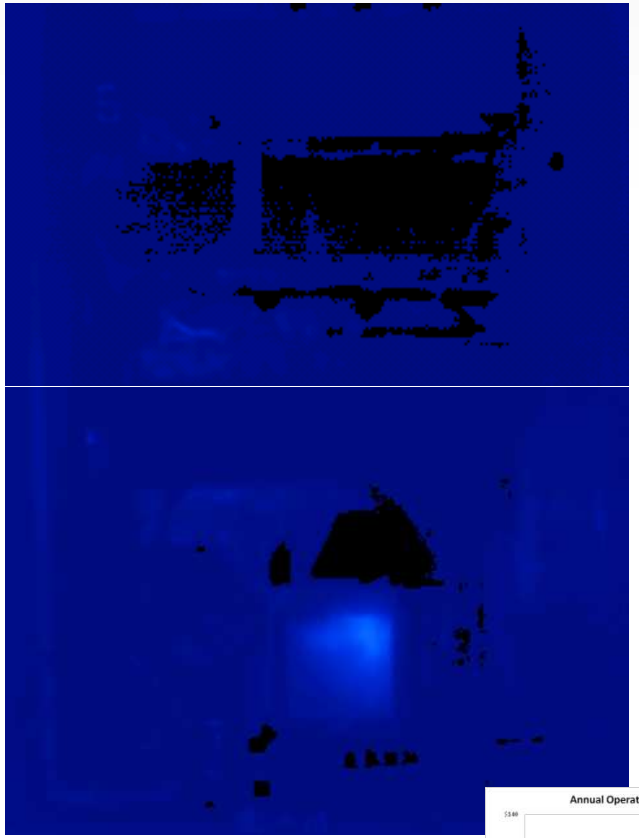
Boiler 1 – Combi boiler with 12 gal DHW tank

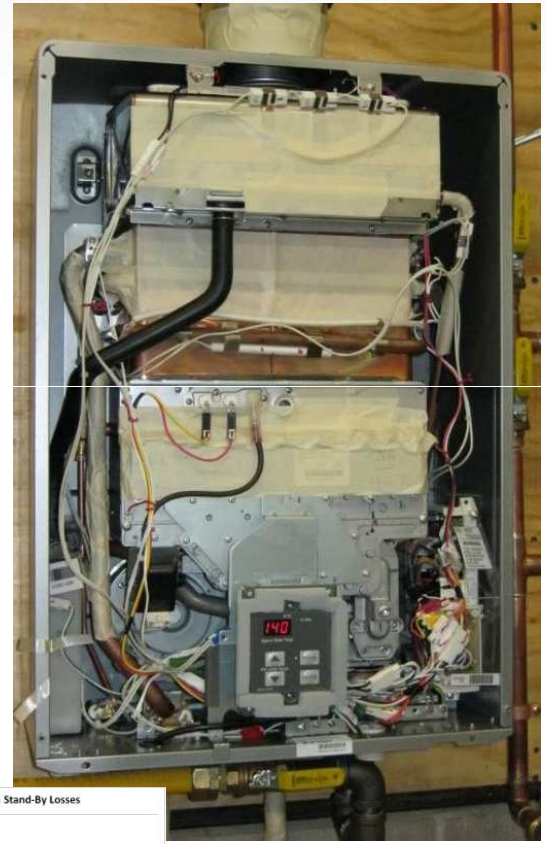


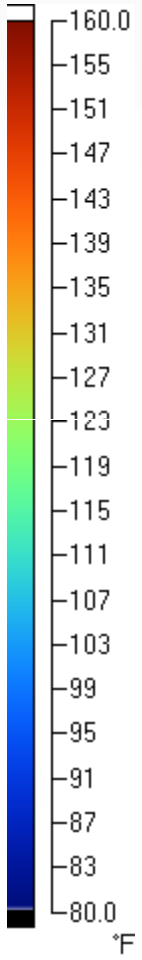




TWH 1






160.0
155
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107
103
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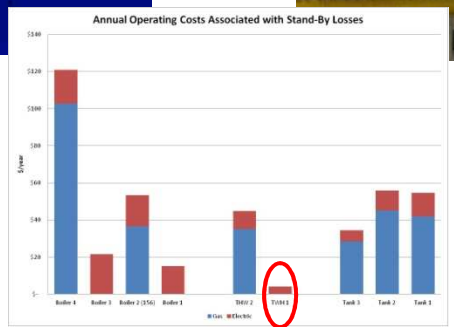
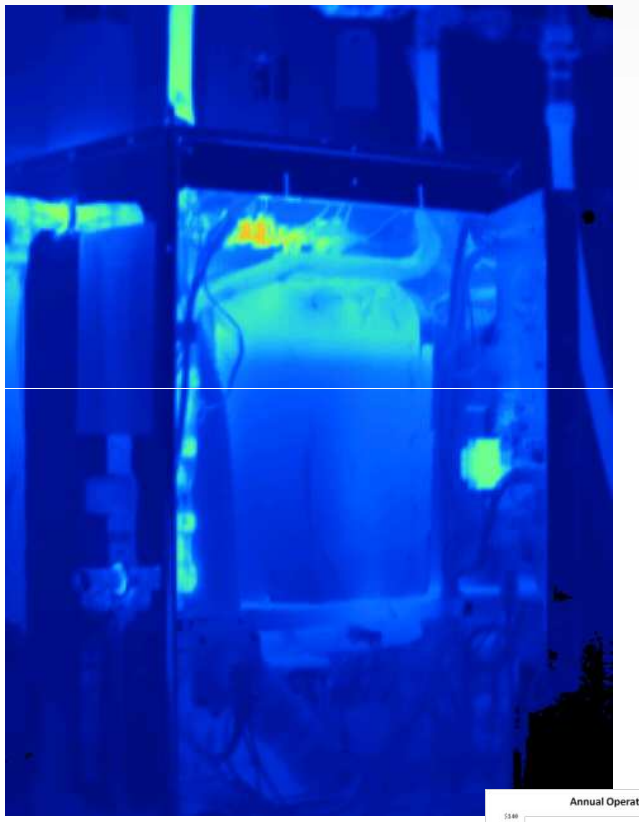
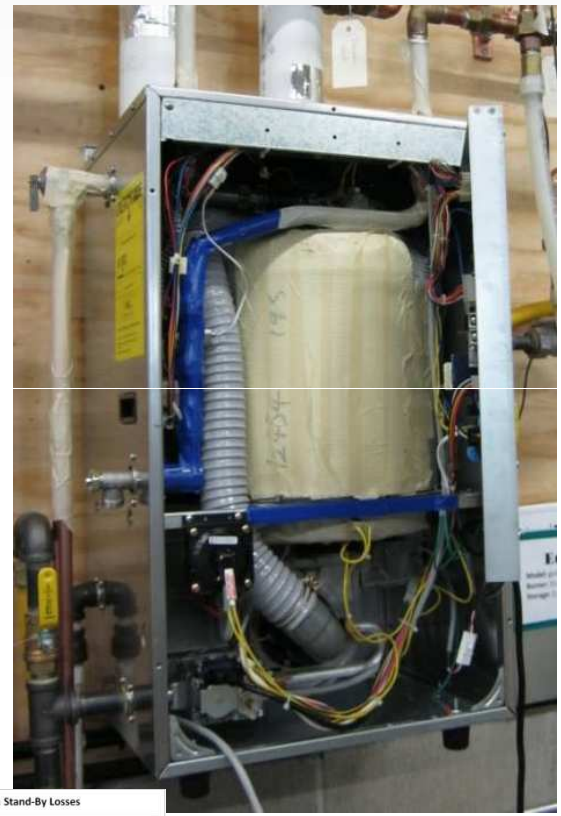
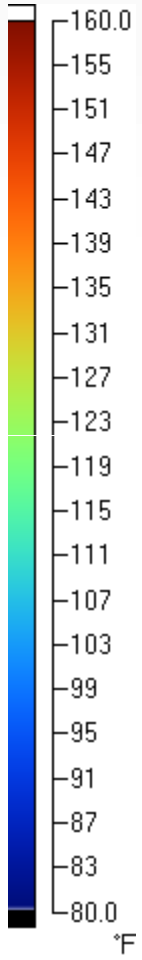
87
83
80.0
°F

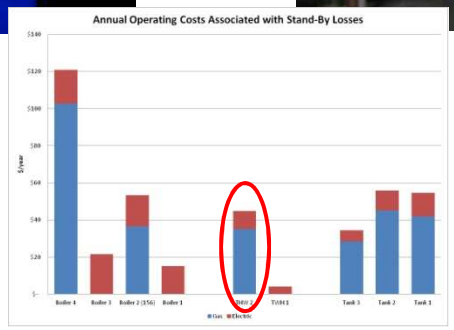

Annual Operating Costs Associated with Stand-By Losses

TWH 2 – Storage Tankless Hybrid

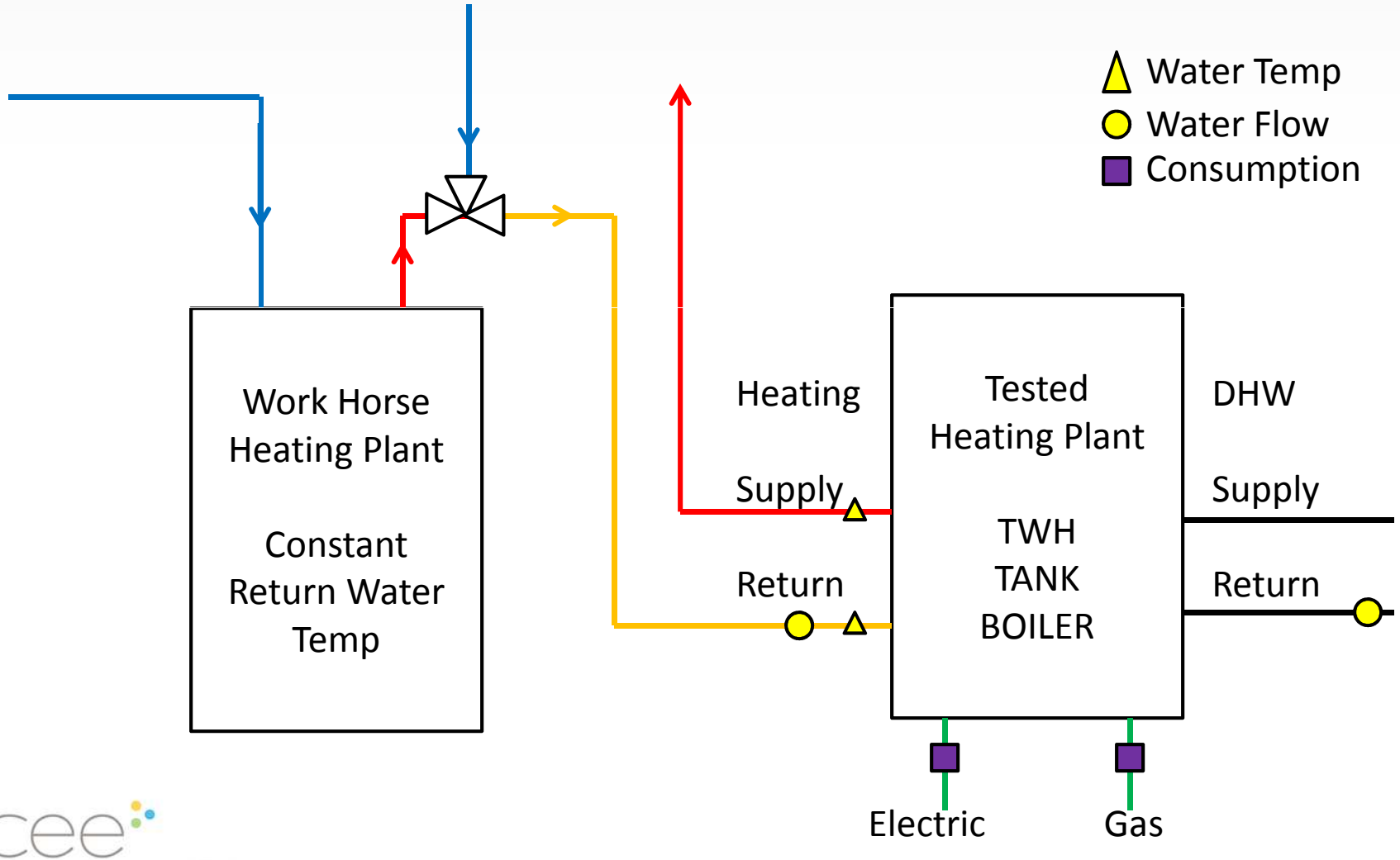


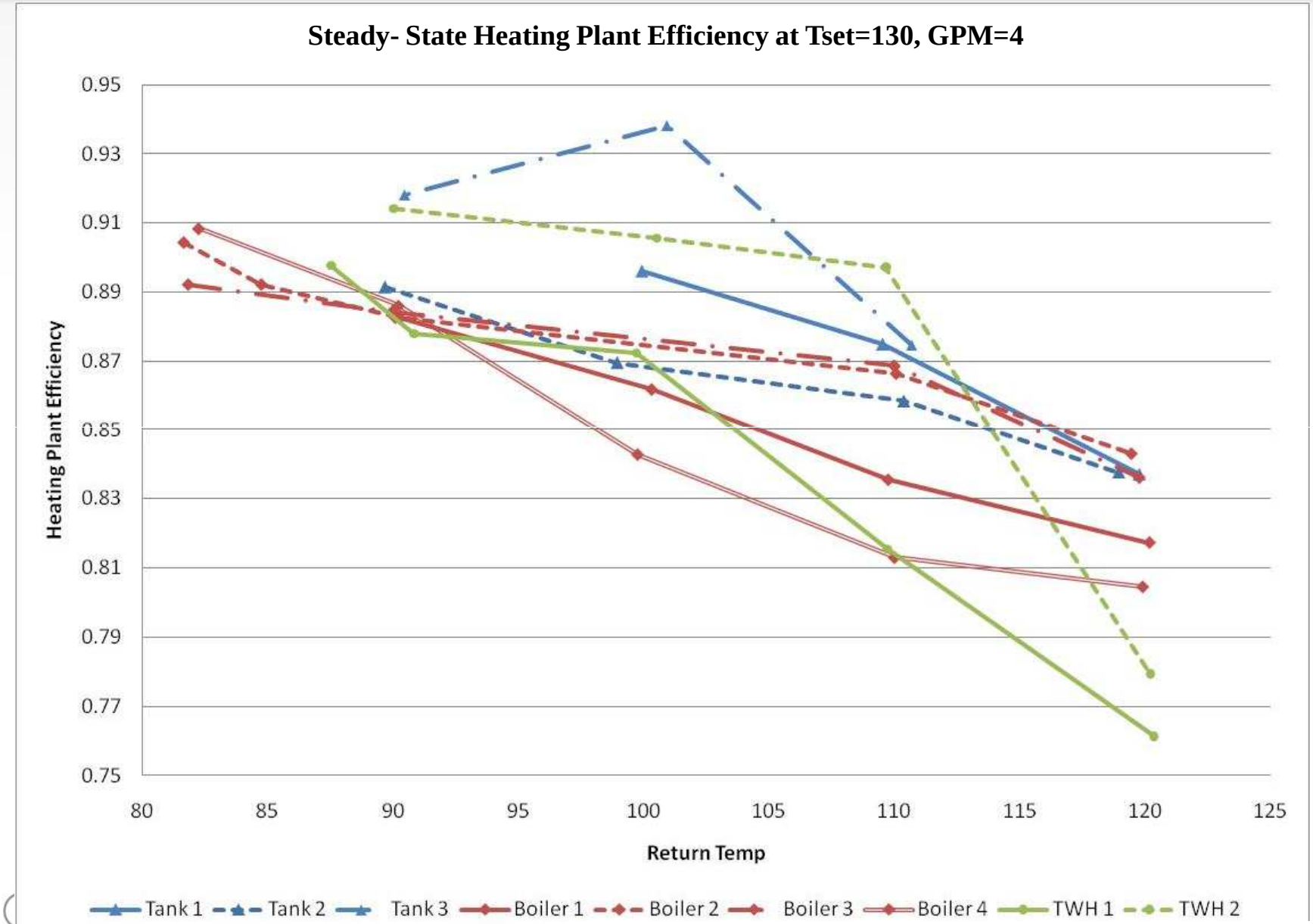






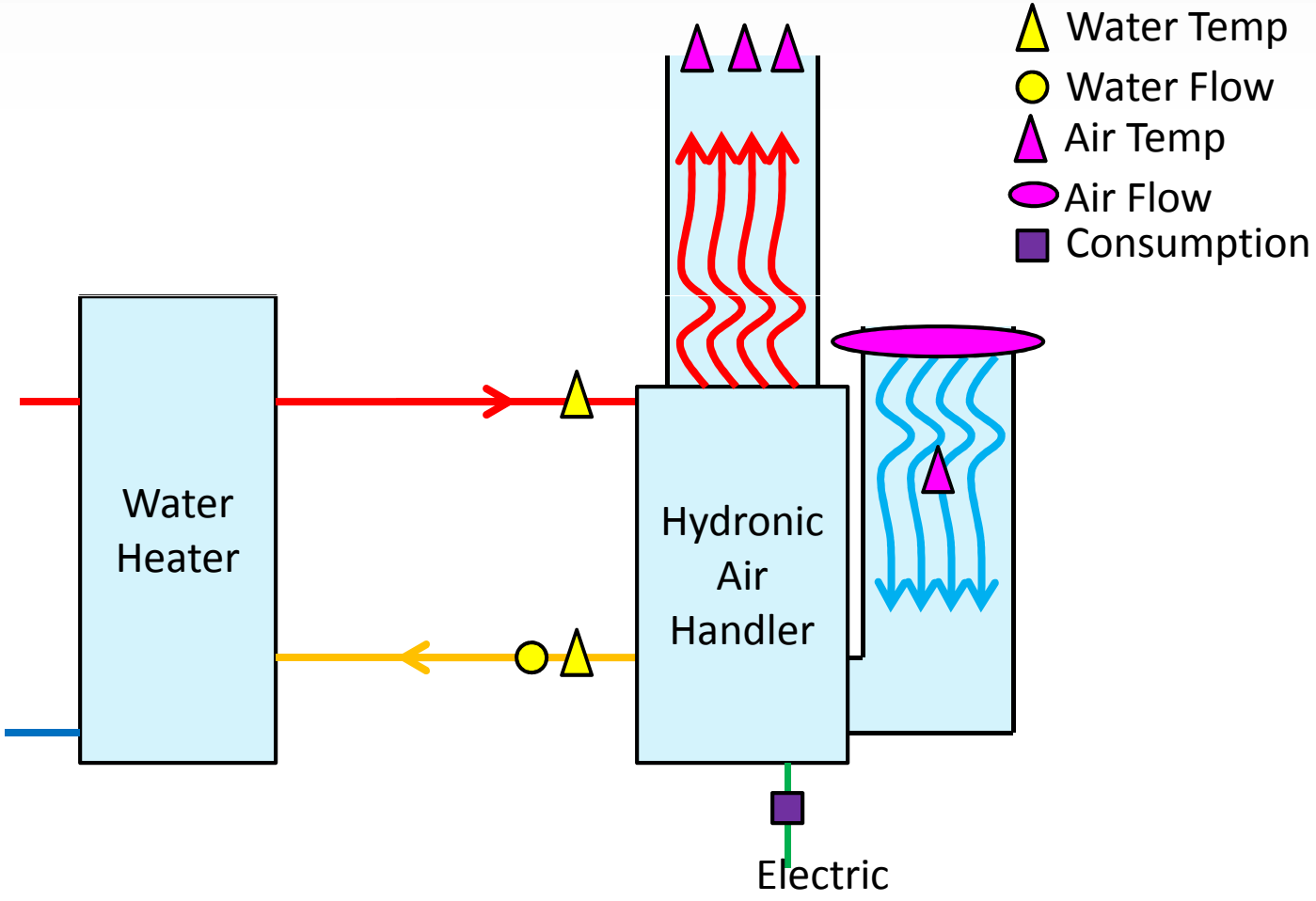
Steady-State Simulated Heating Load Test





Going from 90% to 80% increase heating bills about $150/year in MN

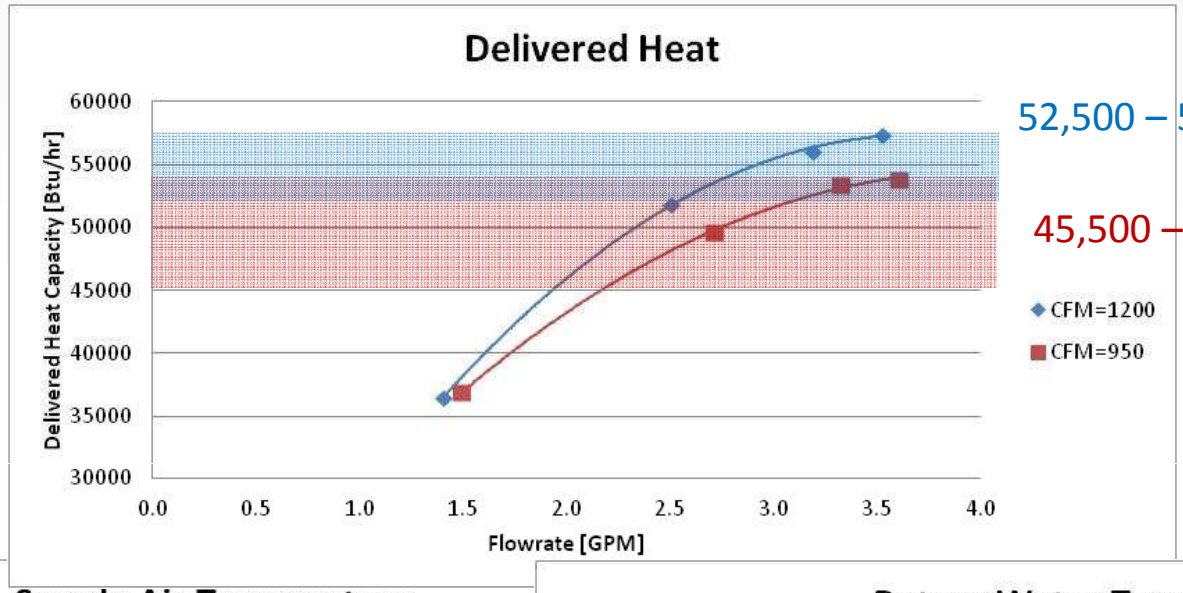
Air Handler Capacity Tests



Air Handler Performance Mapping

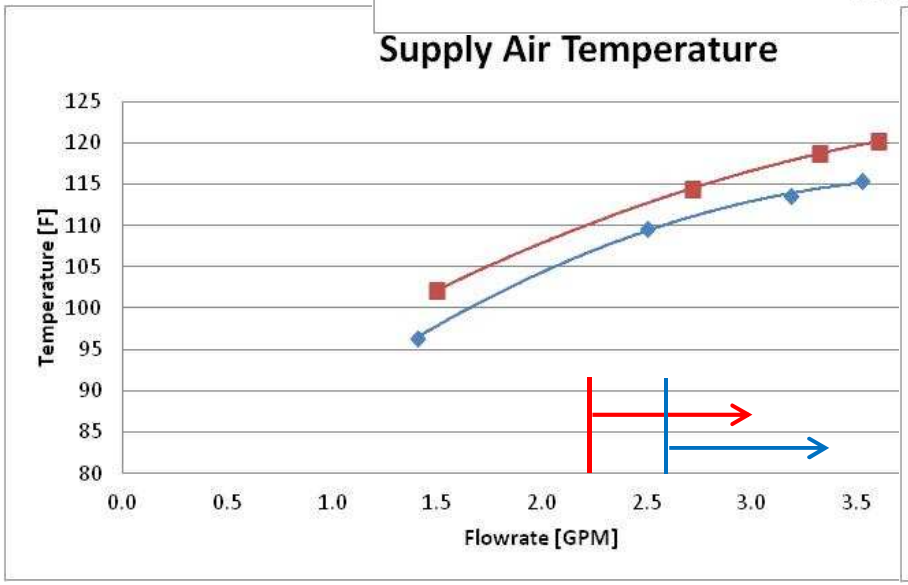
+ Minimum supply air temperature (110 F) for comfort dictates minimum flow rate
+ Maximum return water temperature (105 F) dictates maximum flow rate
+ Coil capacity is bounded by these flow rates

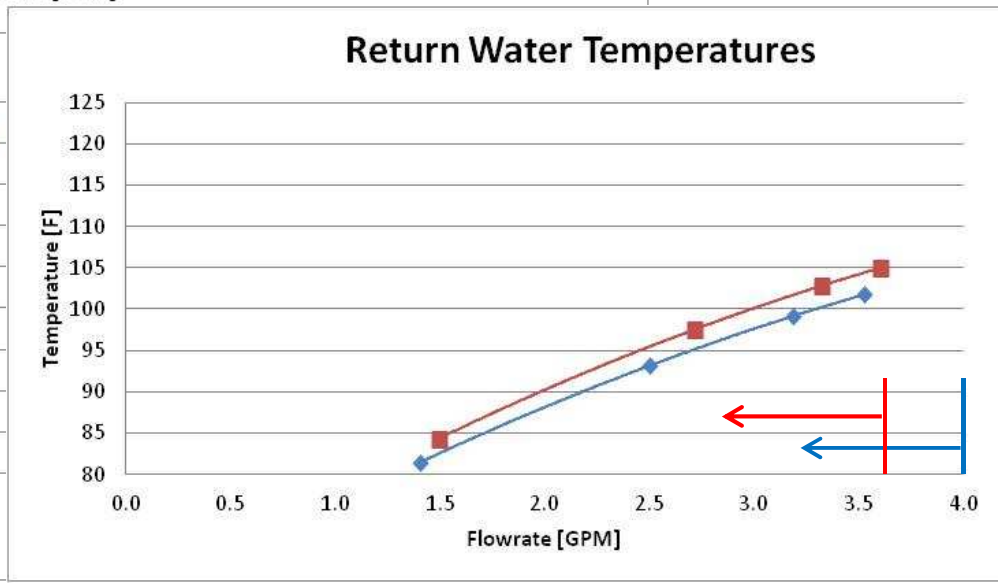
Air Handler Performance Mapping



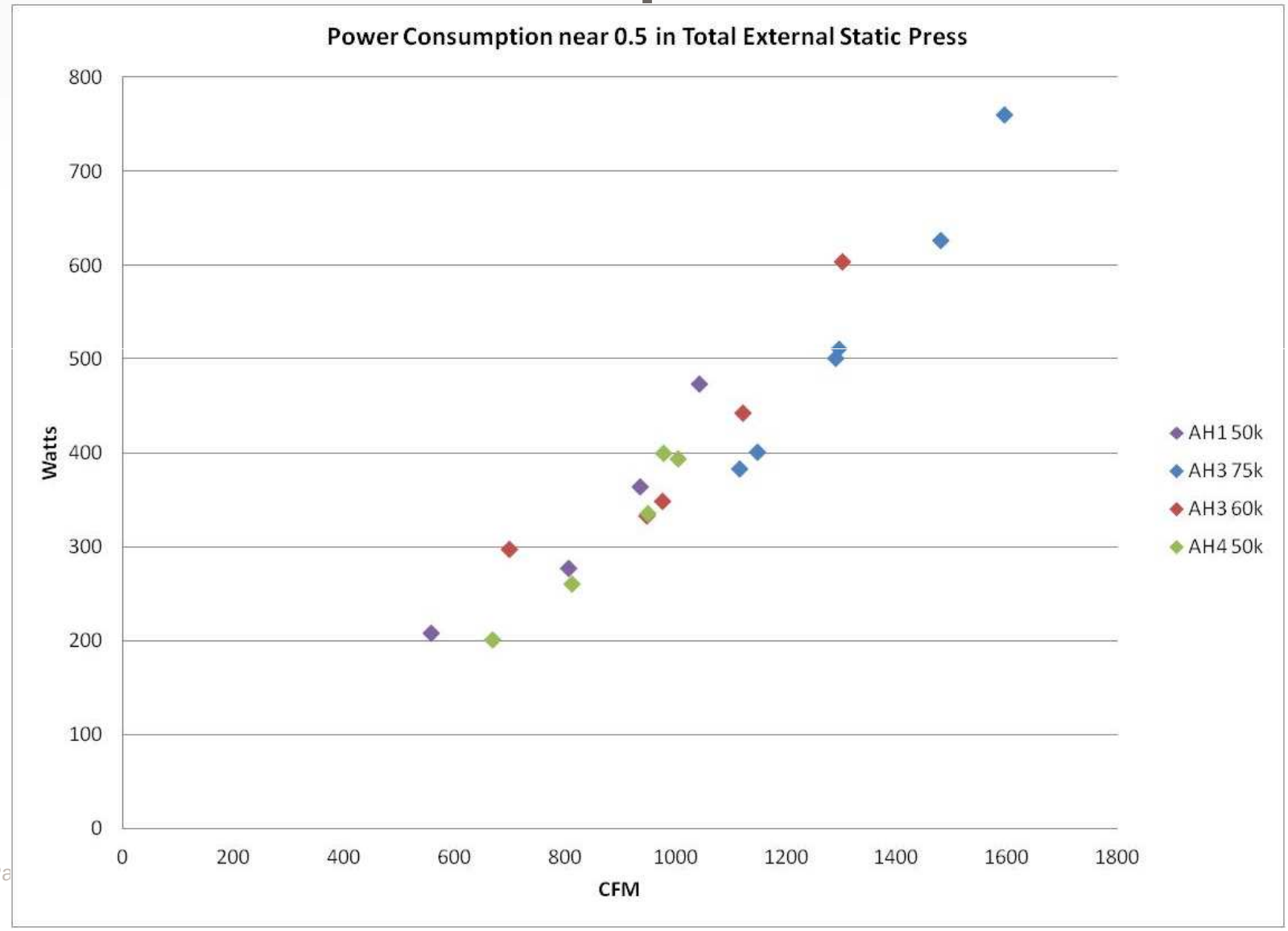
52,500 – 57,000 kBtu/hr

45,500 – 54,000 kBtu/hr

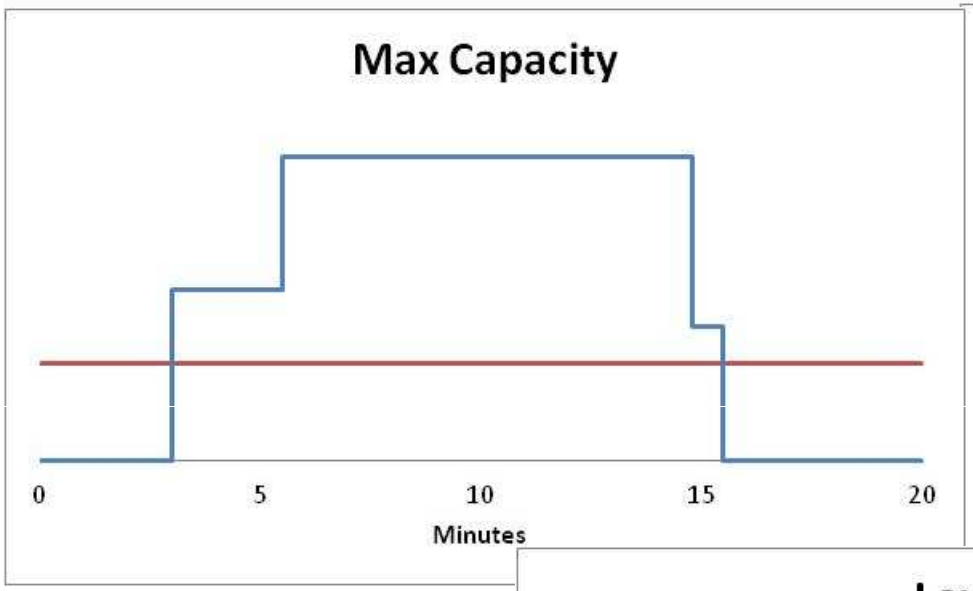


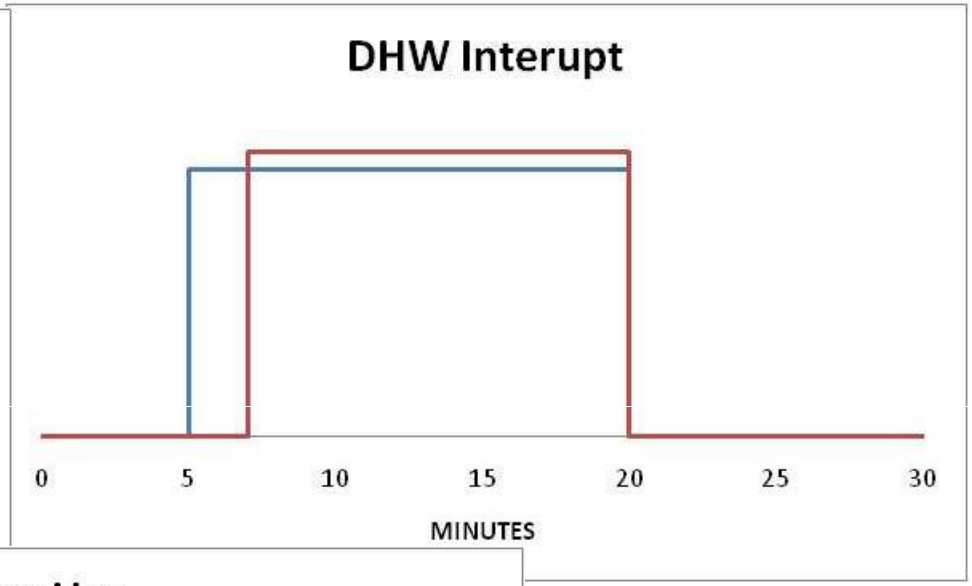


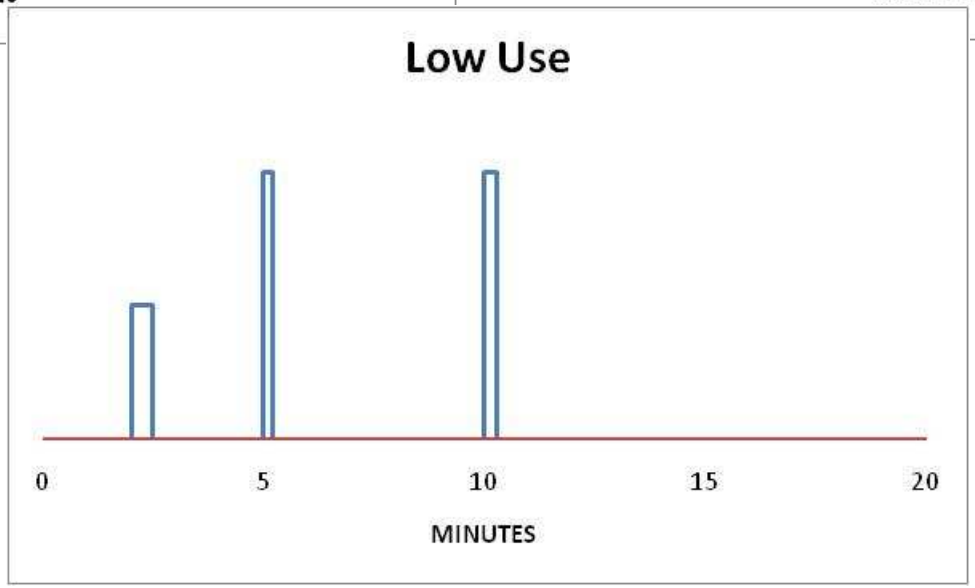
Electrical Consumption



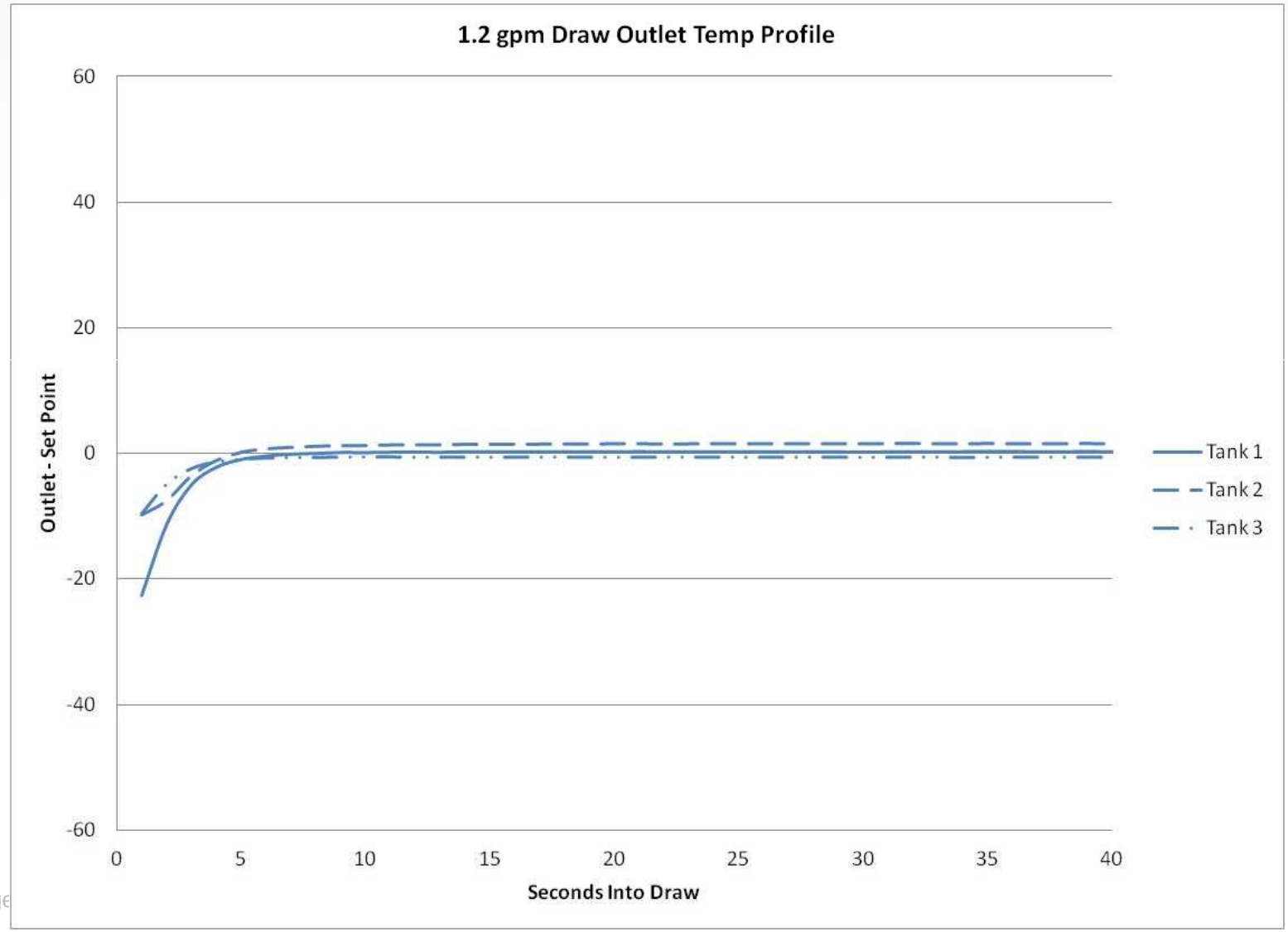
Full System Tests



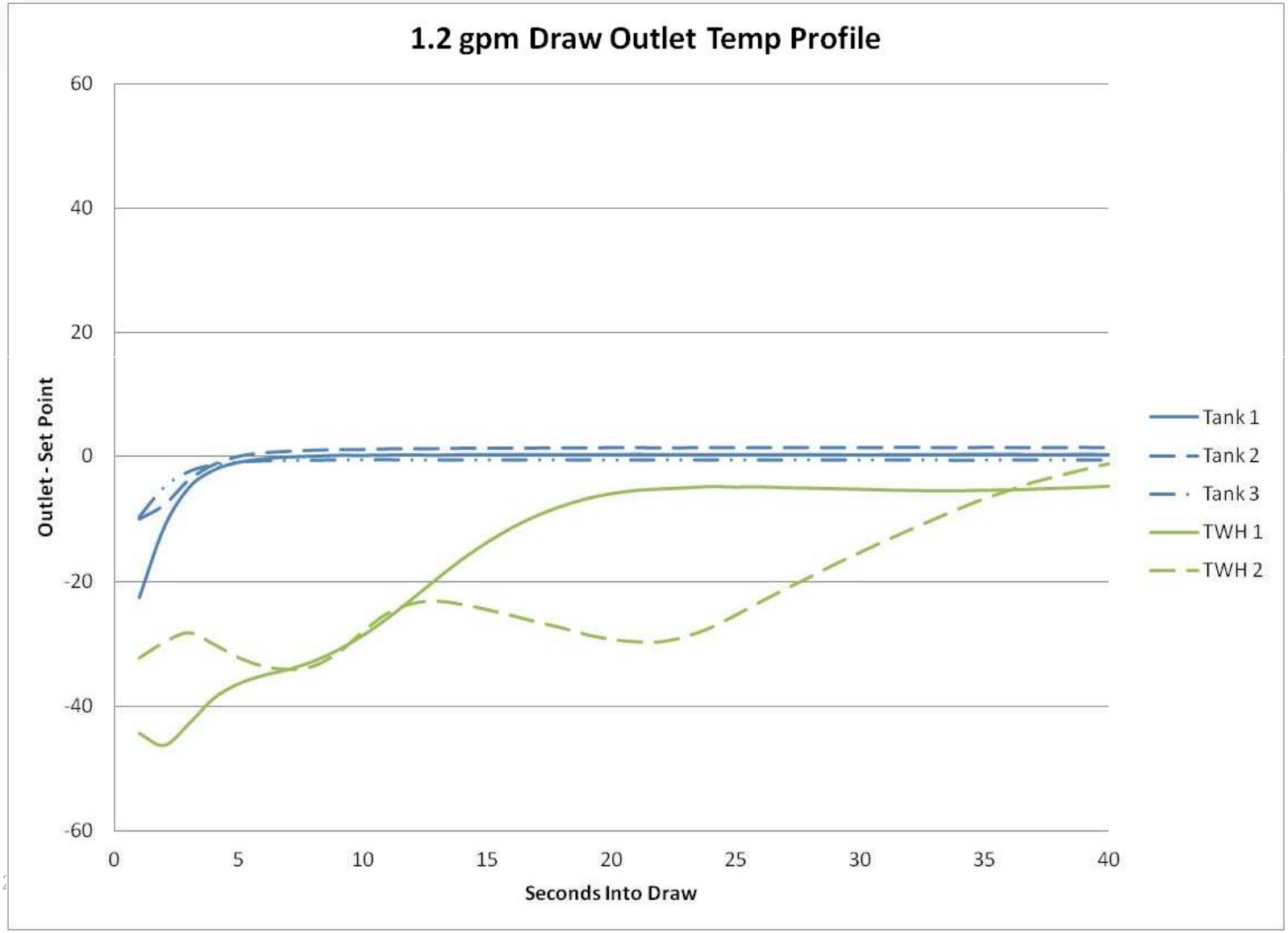




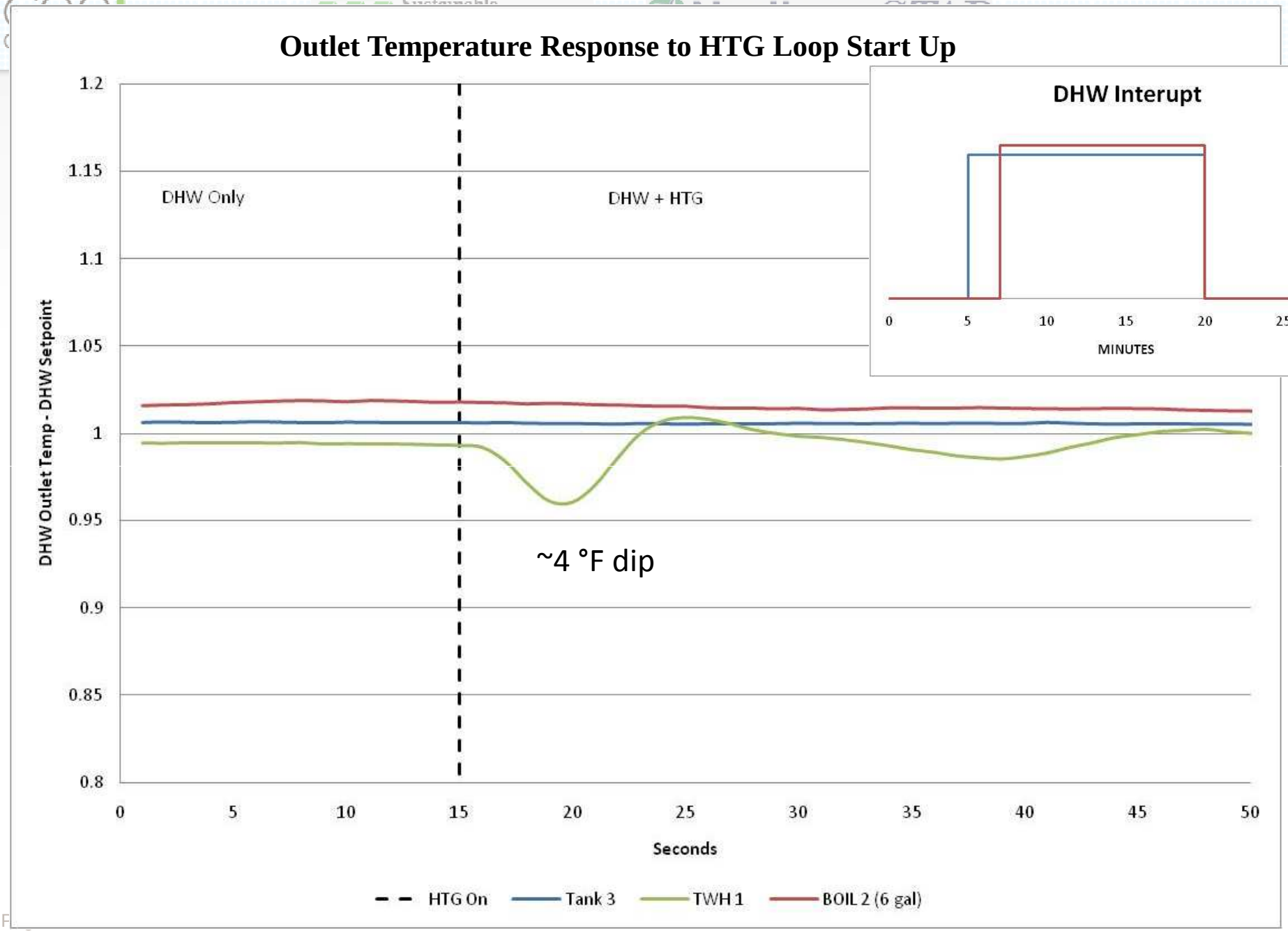
Low Use Transient Performance



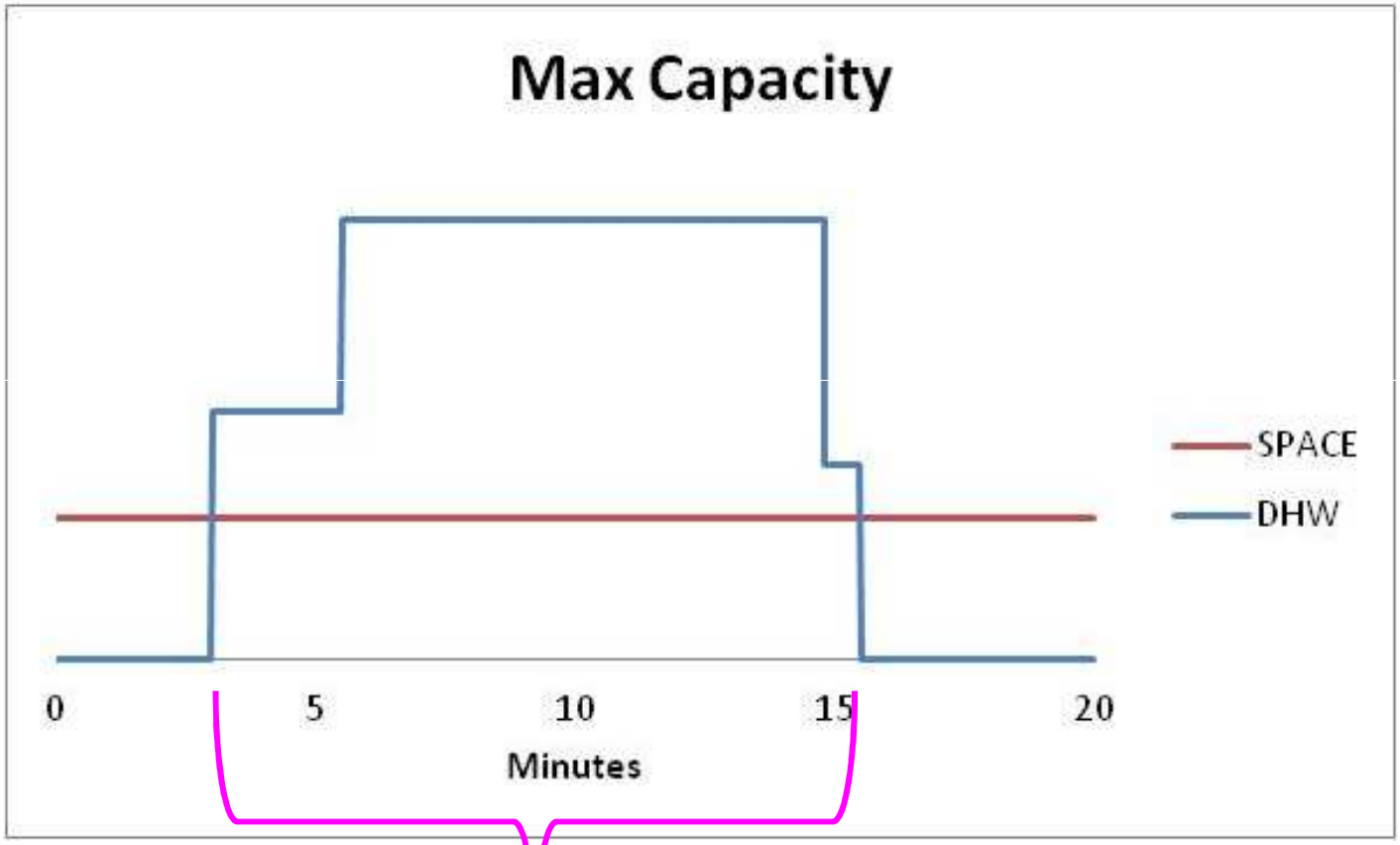
Low Use Transient Performance



Low Use Transient Performance

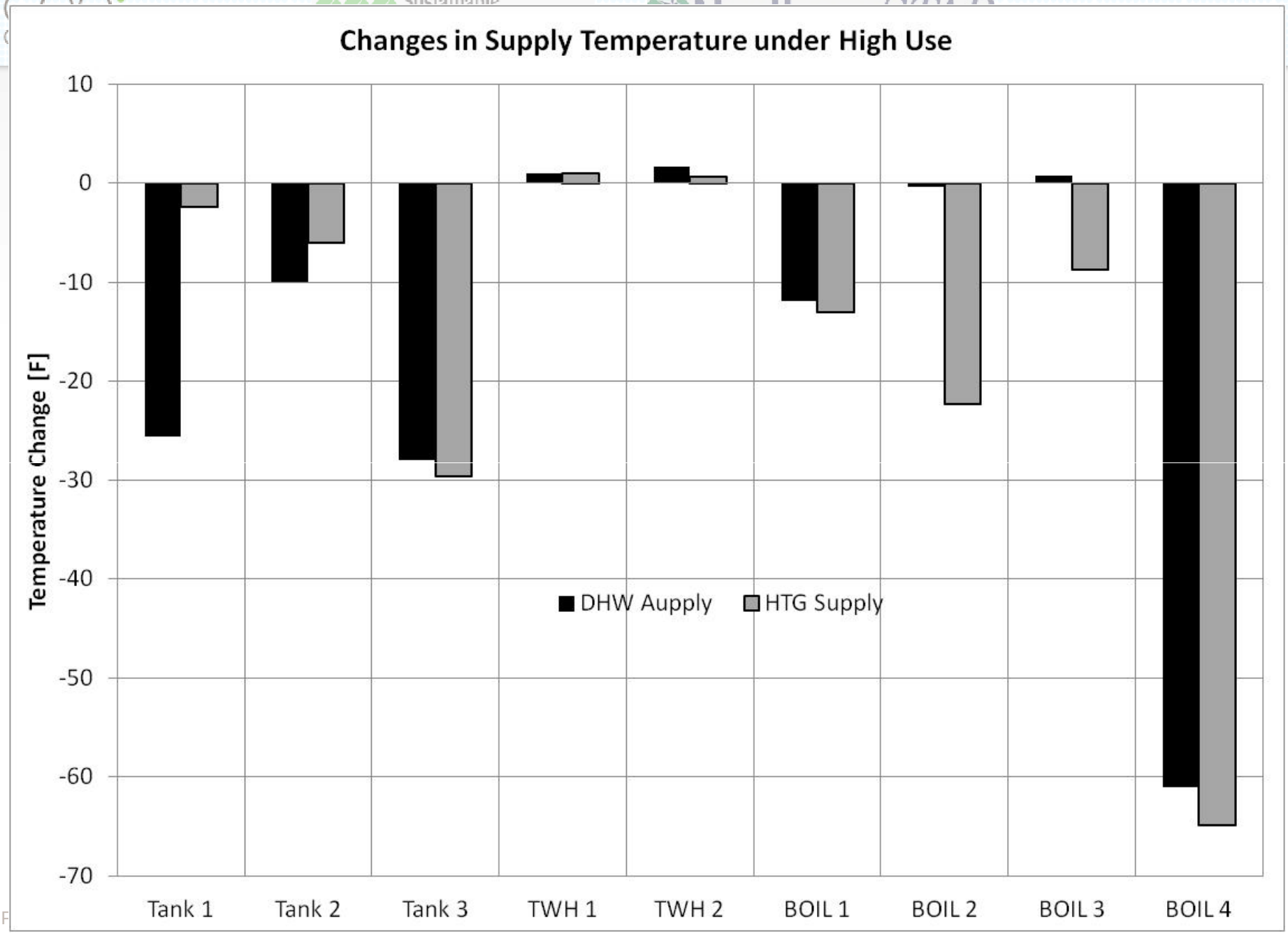

Outlet Temperature Response to HTG Loop Start Up
DHW Interupt
DHW Only
DHW + HTG
~4 °F dip
DHW Outlet Temp - DHW Setpoint
Seconds
MINUTES
HTG On
Tank 3
TWH 1
BOIL 2 (6 gal)

Max Capacity Testing



Next Slide

Heating Load	20 MIN	40,000 Btu/hr
Shower 1	12 MIN	70,000 Btu/hr
Shower 2	10 MIN	55,000 Btu/hr


Changes in Supply Temperature under High Use
Temperature Change [F]
10
0
-10
-20
-30
-40
-50
-60
-70
DHW Aupply
HTG Supply
Tank 1
Tank 2
Tank 3
TWH 1
TWH 2
BOIL 1
BOIL 2
BOIL 3
BOIL 4

Sizing

+ Little or no sizing information provided by manufacturers
+ Systems typically sized by manufacturer's rep or installer without strong reference materials

+ We developed a sizing guide
+ Based on heating plant input rate and storage size
+ Compared to number of showers and estimated heating load
+ Example: a storage water heater with 130 kBtu/hr input and 50 gallons -> 60 kBtu/hr heating load and 1 shower

Field Implementation and Monitoring

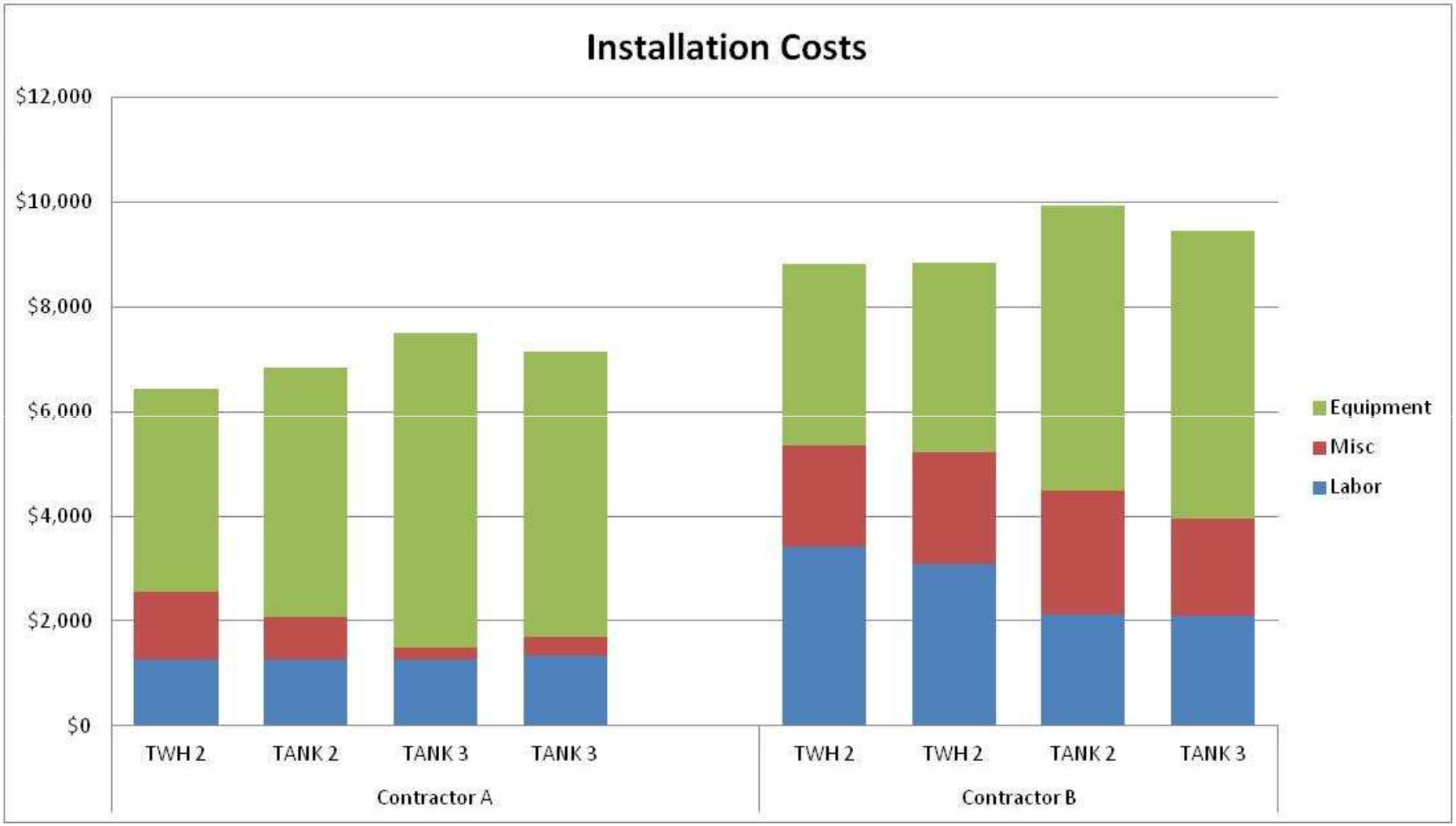
- 400 installs in Minnesota before March 2012
  - Utility bill analysis on all 400 sites
  - Detailed pre/post monitoring on 20 sites

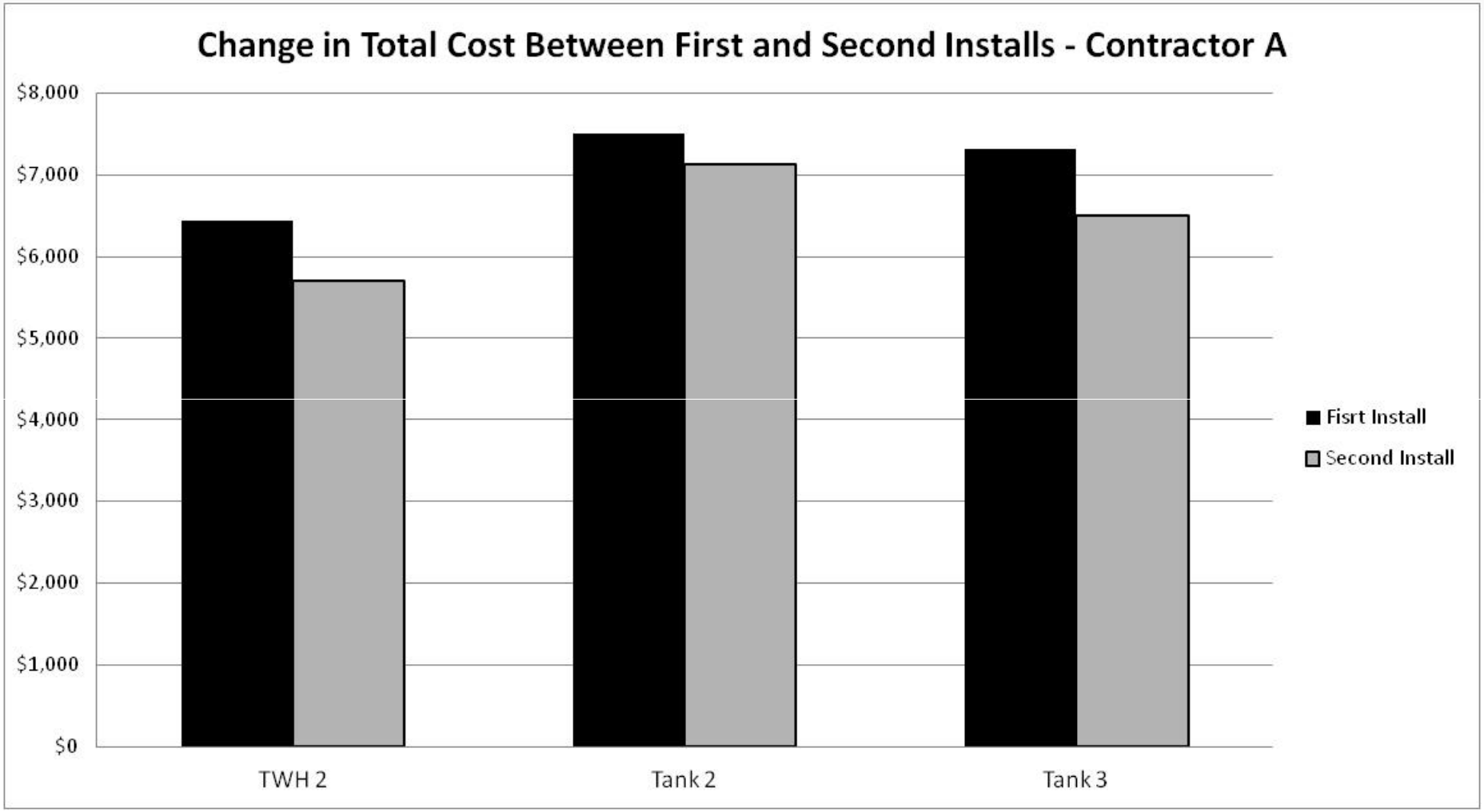
Installations to Date: Systems/Cost

+ Data from 12 sites with completed installs and 2 with bids

WH/Boiler	AH	Install Cost	Contractor
TANK 2 - 100/55	AH3 75000	$7,135	A
TANK 2 -130/55	AH3 75000	$7,508	A
TANK 2 - 130/55	AH3 75000	$9,453	B
TANK 2 - 100/55	AH3 75000	$10,900	C
TANK 2 - 130/55	AH3 75000	$10,900	C
TANK 3 - 130/34	AH3 75000	$6,495	A
TANK 3 - 130/34	AH3 75000	$6,835	A
TANK 3 - 150/34	AH3 75000	$7,312	A
TANK 3 - 150/50	AH3 90000	$9,925	B
TWH 2 - 145/2	AH3 75000	$5,696	A
TWH 2 -145/2	AH1	$6,100	B
TWH 2 - 199/2	AH3 75000	$6,432	A
TWH 2 - 199/2	AH3 75000	$8,830	B
TWH 2 - 145/2	AH3 60000	$8,909	B

Mostly sites with high water hardness which affected product selection. High water hardness will not be a concern for all homes.

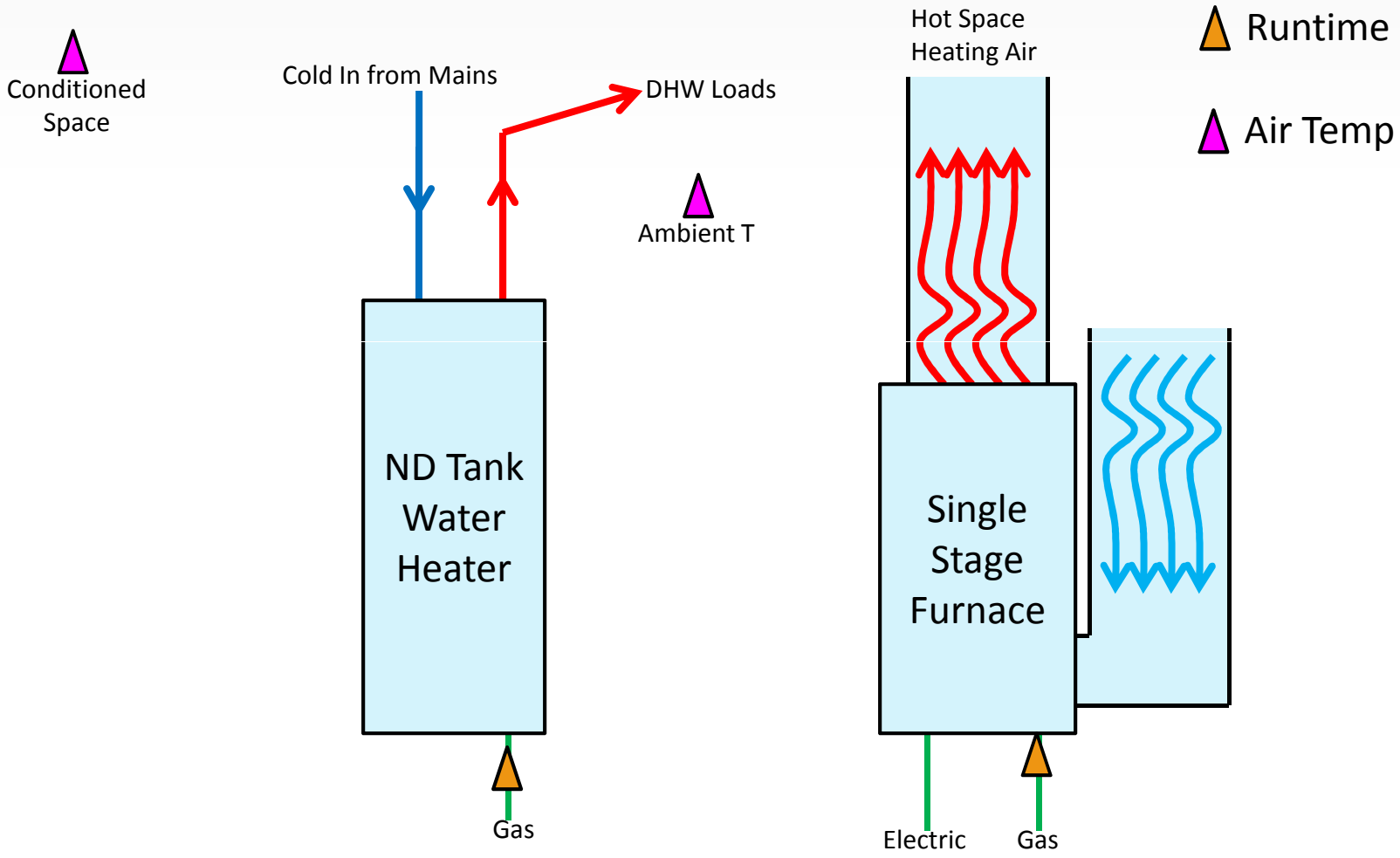

Installation Costs
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$0
TWH 2
TANK 2
TANK 3
TANK 3
TWH 2
TWH 2
TANK 2
TANK 3
Contractor A
Contractor B
Equipment
Misc
Labor


Change in Total Cost Between First and Second Installs - Contractor A
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
TWH 2
Tank 2
Tank 3
Fisrt Install
Second Install

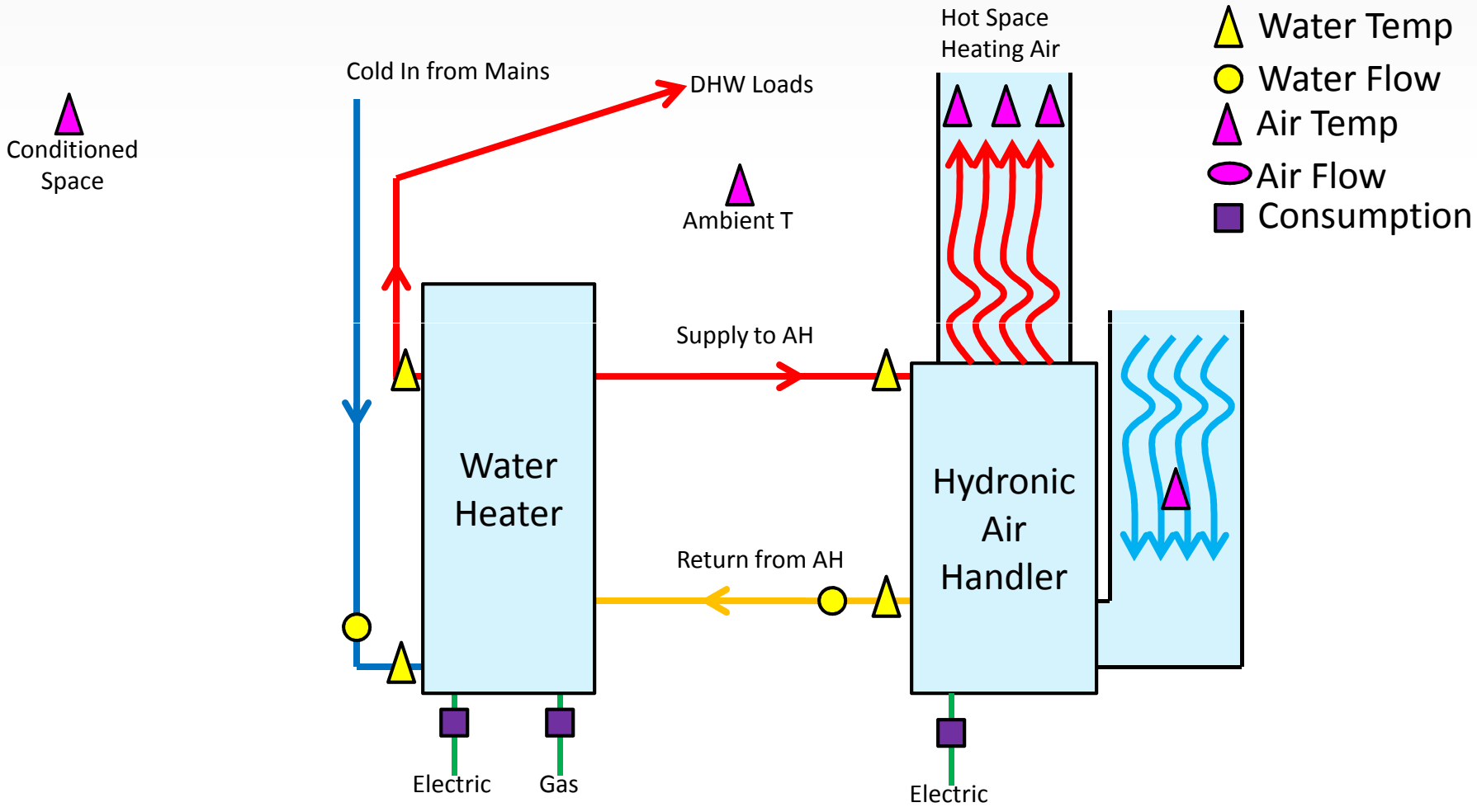
Field Study: Expected Results

+ Better understanding of installed costs for different systems after contractors have become familiar
+ System design specifications and quality control requirements
+ Installed efficiencies of DIA systems and savings potential

Existing Equipment



DIA Installation



Space Heating Load, kBtu/hr	30-35	35-40	40-50
Showers in house	1	1	2
Showerers (age 13+)	1-4	1-4	3+
Navien ch-210	X	X	X
Rinnai q175c	X	X	X
Eternal GU195S	X	X	w/ DHW priority
Rinnai RC98i	X	X	w/ DHW priority
Vertex	X	X	
HTP ph100-55	X	X	larger unit – 80 gal, 130kBtu input
American PG10 34-130	X	X	larger unit – 50 gal, 150kBtu input

U.S. Department of Energy
Energy Efficiency and Renewable Energy
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Building Technologies Program

Building America
U.S. Department of Energy
Research Leading to Zero Energy Homes

Field Experience with Tankless Hot Water Heaters Used in Combination Space and Domestic Hot Water Heating Systems

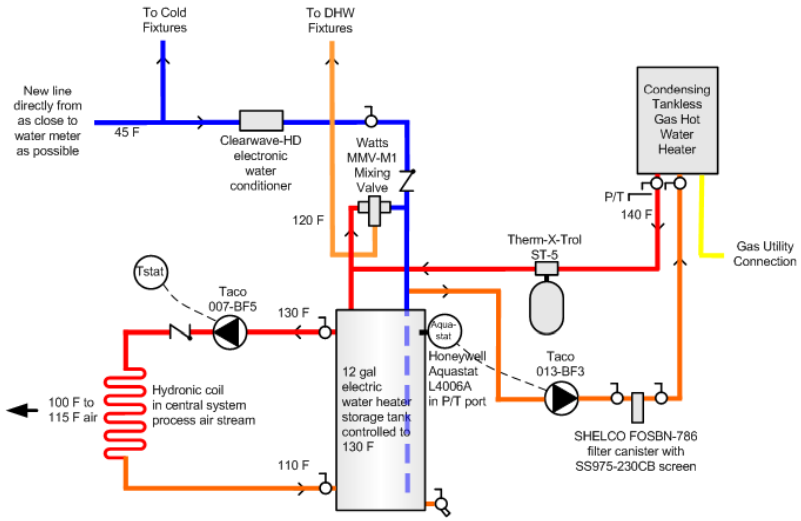
For:
Northstar webinar on Dual Integrated Appliances
October 19, 2011

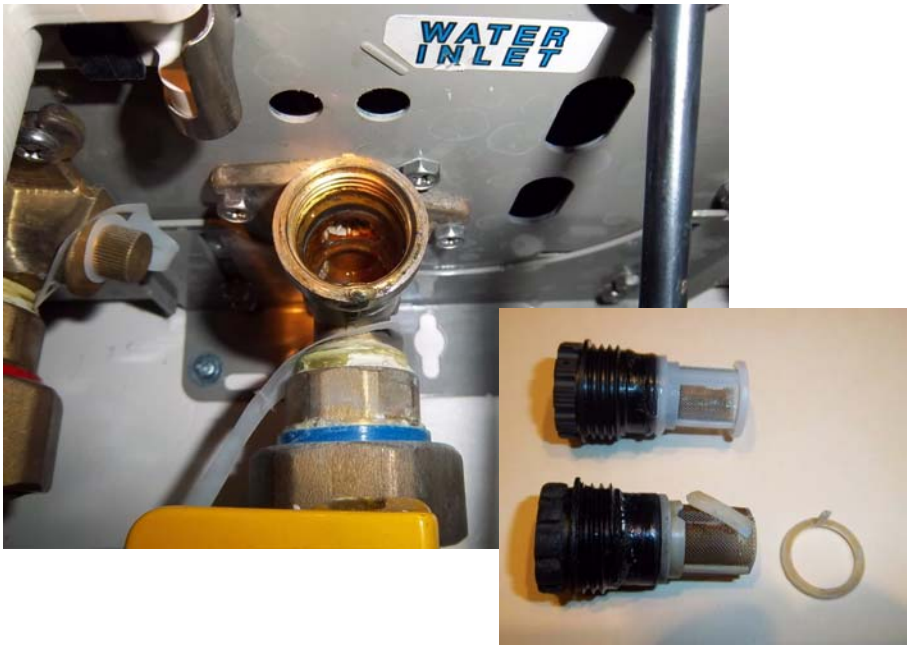
By:
Armin Rudd
Building Science Corp.
www.buildingscience.com

Combination space and domestic hot water heating system with tankless gas water heater and small storage/manifold tank. Installed at NYSERDA deep energy retrofit project in a 2-family building in Utica, NY.

Rinnai RC80 HPI ODH Tankless Water Heater
Rinnai 045 AHB Hydronic Air Handler (ECM fan)

Combi system with condensing gas-fired tankless heater
(Installed in NYSERDA Utica, NY project in Fall 2010)





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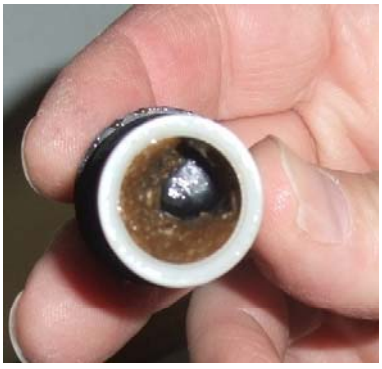
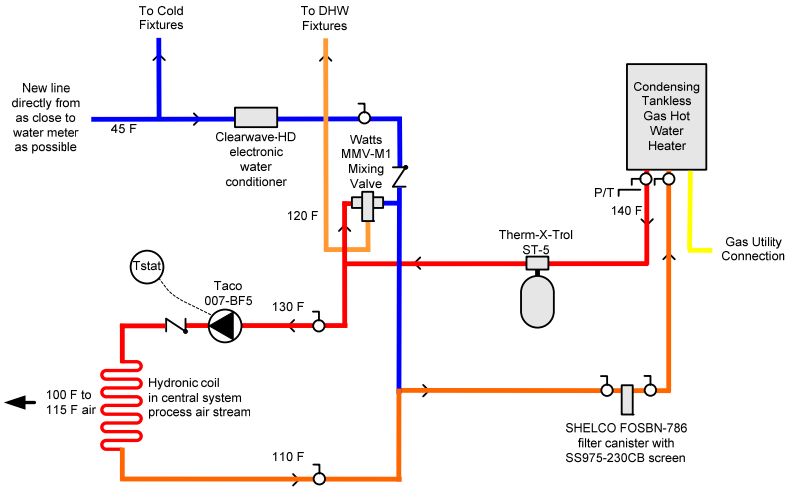
Dried mineral precipitate from inlet strainer

Same operational problems with inlet strainer clogging, plus more!



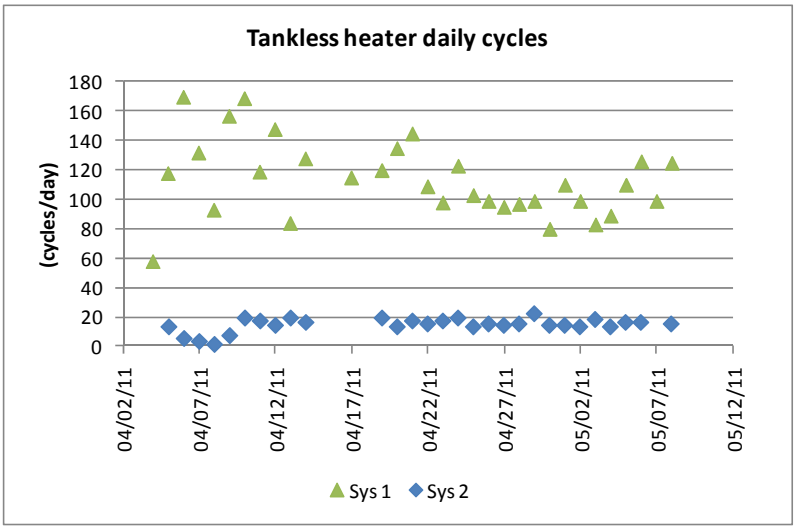
Combi system with condensing gas-fired tankless heater,
Small storage tank removed for one system
(modified in NYSERDA Utica, NY project in Winter 2011)

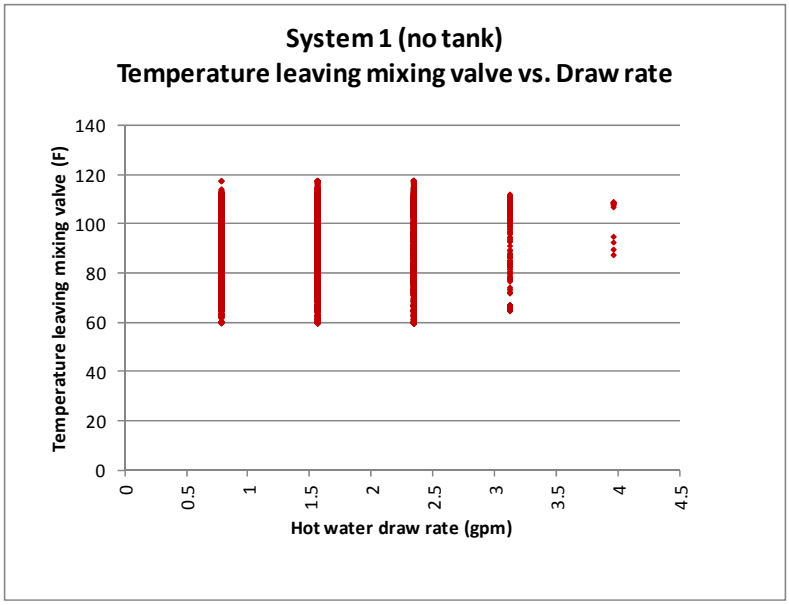


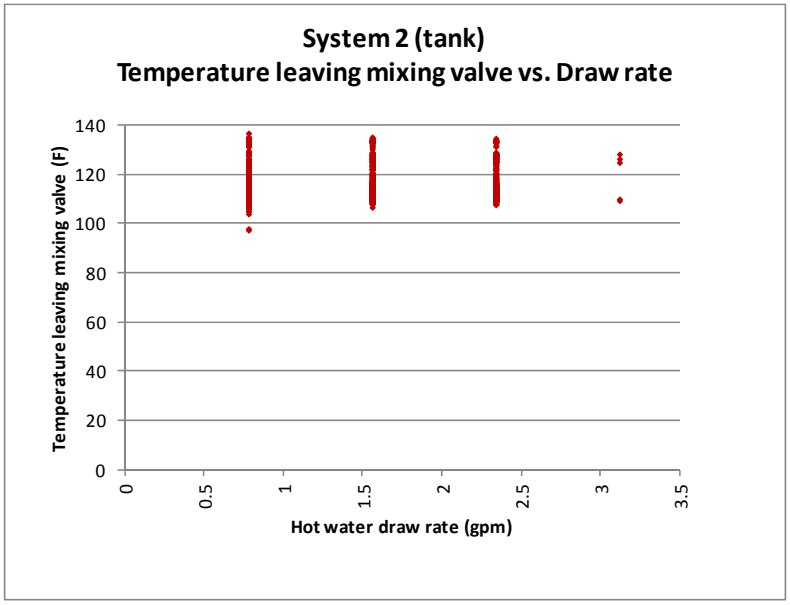
Data Collection

Output channel #	Name	Description	Units	Sensor
1	Array ID	(indicates type of data output as: 1 s, 1 min, 1 h, 1 day, or equipment on/off status)		
2	Year			
3	Jul day			
4	h/min			
5	sec			
6	Tret	heating return air temperature	(F)	Type T thermocouple
7	Tsup	heating supply air temperature	(F)	Type T thermocouple
8	Tmains	mains water temperature	(F)	Type T thermocouple
9	Tmixout	mixing valve water temperature	(F)	Type T thermocouple
10	Thtsup	heating coil inlet water temperature	(F)	Type T thermocouple
11	Thtret	heating coil outlet water temperature	(F)	Type T thermocouple
12	Tdhwhtrin	water heater inlet temperature	(F)	Type T thermocouple
13	Tdhwhtrout	water heater outlet temperature	(F)	Type T thermocouple
14	ahuNow	air handler unit on/off status		Veris current sensor
15	whtrNow	water heater on/off status		Veris current sensor
16	ahuRT	air handler unit runtime	(s)	Veris current sensor
17	whtrRT	water heater runtime	(s)	Veris current sensor
18	ahuCycles	air handler unit on/off cycles		Veris current sensor
19	whtrCycles	water heater on/off cycles		Veris current sensor
20	ahuWh	air handler unit electrical energy	(W-h)	IMS true RMS watt-hour meter
21	whtrWh	water heater electrical energy	(W-h)	IMS true RMS watt-hour meter
22	dhwFlow	water heater water flow	(gal)	Omega water flow meter 75 pulse/gal
23	natgas	water heater gas flow	(cf)	AC-250 temperature-compensated gas meter with IMAC pulser .125 ft^3/pulse

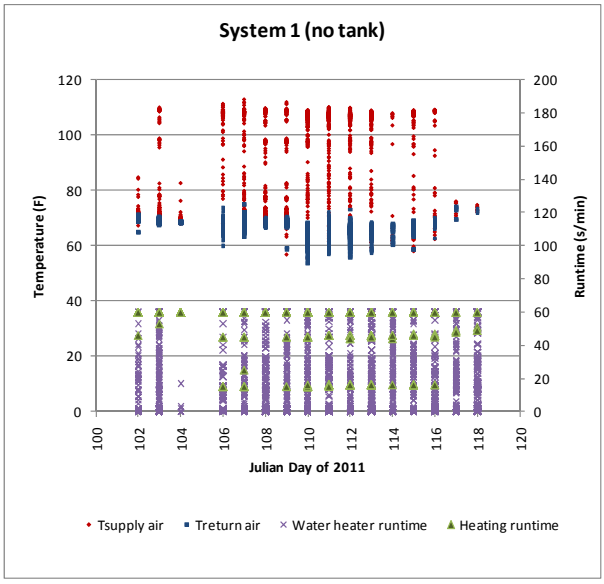
Water heater cycles per day was <u>much</u> higher without the tank



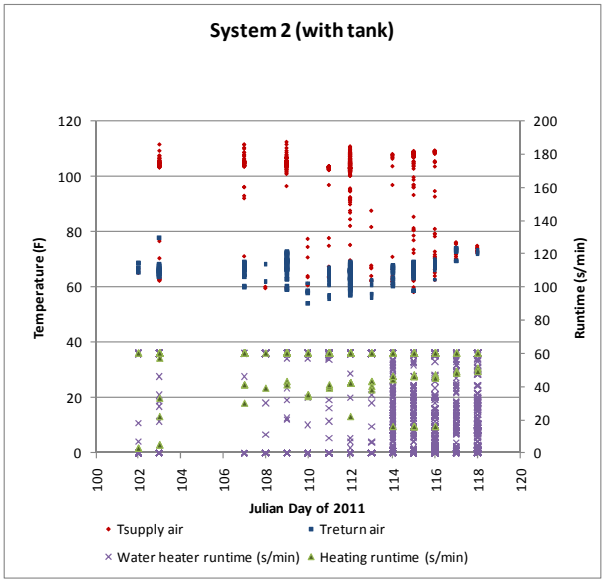




System without tank has wide range of supply air temperature



System with tank has narrow range of supply air temperature



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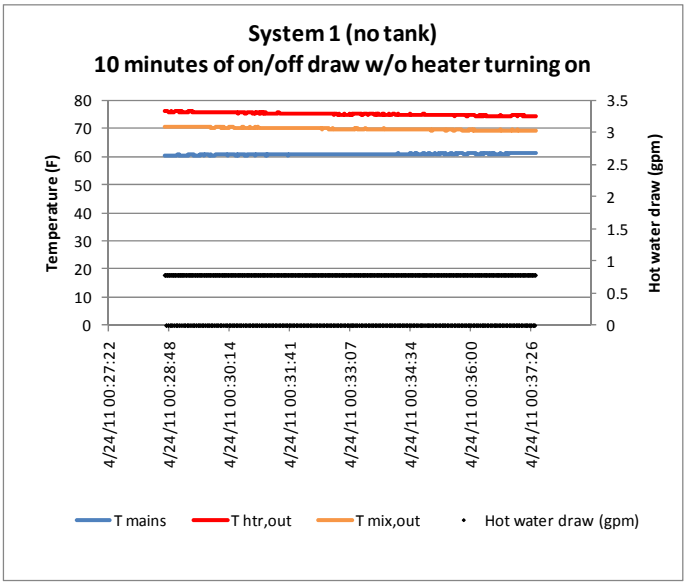
System without tank provides room temperature water at low draw rates



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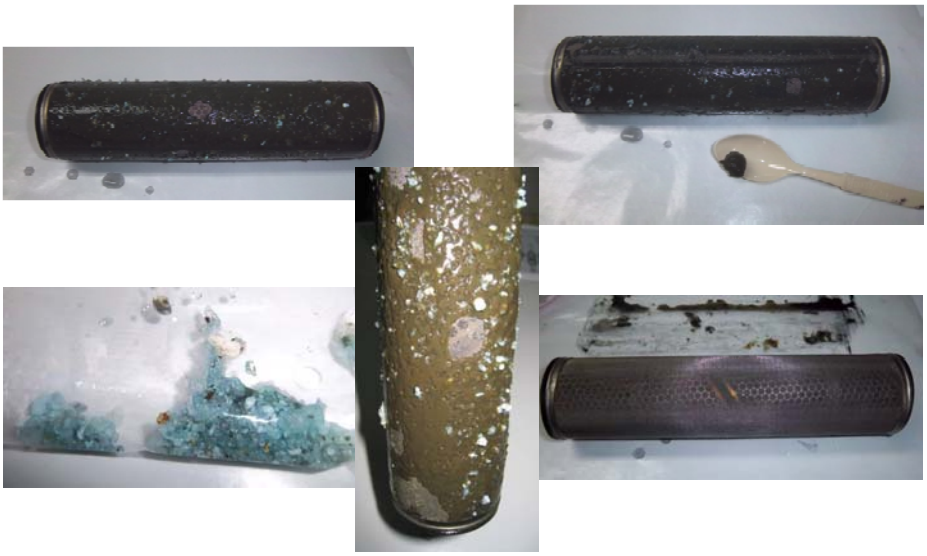
Externality Complications (you may own it)

Externality Complications (you may own it)

Mineral precipitate and crystals collected on Shelco 230 micron strainer, after about one year. Would have clogged the Rinnai strainer many, many times.



Replacement of 4 yr old aluminum anode rod with magnesium rod

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Scale removed from galvanized dielectric union fittings several weeks after installation of electronic water conditioner

the Energy to Lead

DIA meets EE Programs

Ryan Kerr
Emerging Technologies Manager, End Use Solutions
PARR Program Manager
Gas Technology Institute

PARR
The Partnership for Advanced Residential Retrofit

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GTI Overview

- Not-for-profit research, with 65+ year history
- Facilities
  - 18 acre campus near Chicago
  - 200,000 ft^2, 28 specialized labs
  - Other sites in OK and AL
- Staff of 250
- Experiencing substantial growth

Flex-Fuel Test Facility

Offices & Labs

Energy & Environmental Technology Center

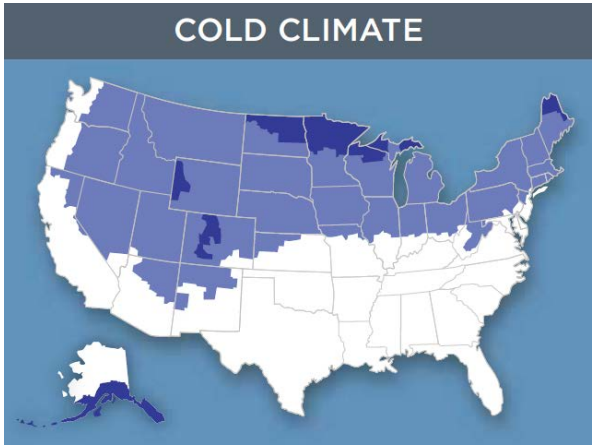
PARR Overview

> Midwest region, cold climate focus

1. Seven-state Midwest region with a Chicago “hub”
2. Systems and whole home solutions for cold climate
3. Targeting high potential building stock with opportunities for energy savings AND scalability

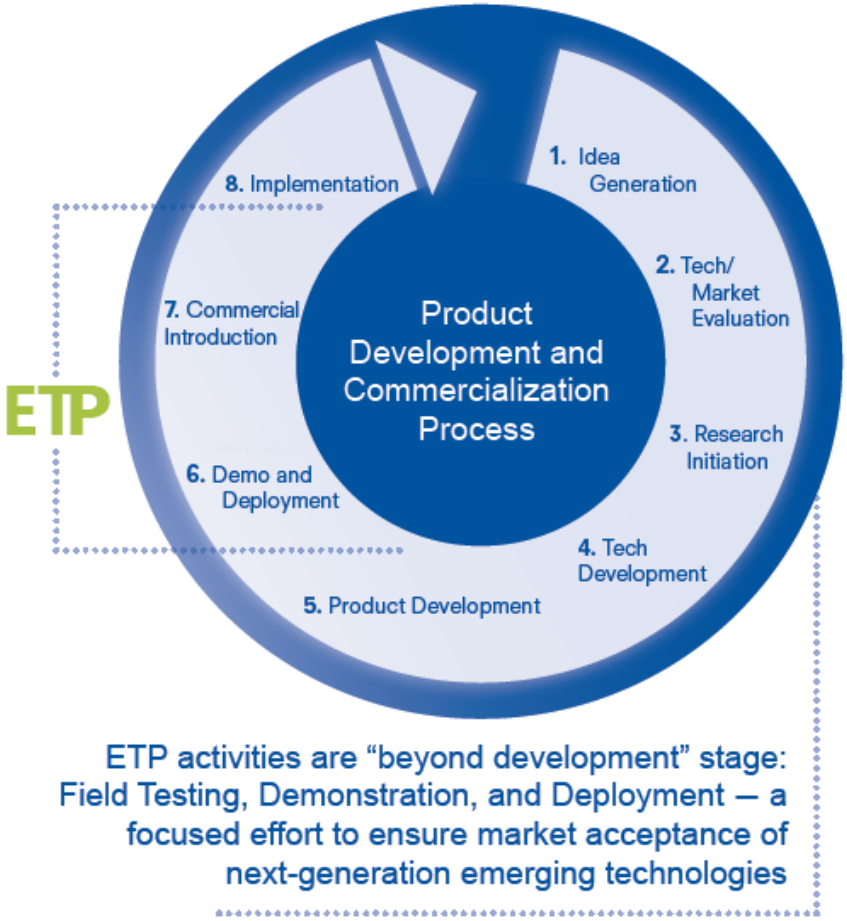
1.

2.



3.

Emerging Technology Program Overview



Emerging Technologies

Emerging technologies are new, energy efficient technologies, systems or practices that have significant energy savings potential but have not yet achieved sufficient market share to be considered self-sustaining or commercially validated within a given region or state.

ETP: Program Activities

- Key activities include:
  - **Technology Assessments**
    - Characterizing energy use, costs, benefits, market opportunities, energy savings potential and barriers
  - **Demonstrations**
    - Build awareness, market channels
    - Target unknowns, build program data
  - **Training, education, and outreach**
  - **Developing solutions to** program, market and technical **barriers**

What Does ETP Do?

ETP is designed to help companies identify and evaluate the most promising products and integrated solutions, assess their suitability for future use in utility energy efficiency programs, and deliver comprehensive program guidelines for successful full scale deployment.

Residential Integrated Space & Water Heat System: The Basics

ETP Emerging Technology Program

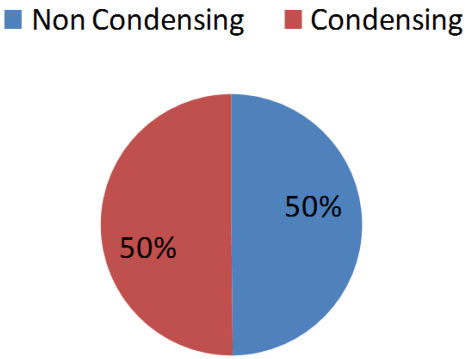
- High efficiency tank or tankless water heater (90 EF+), combined with hydronic air handler
- Technology ‘concept’ has been around for years, but only recently have major manufacturers begun manufacturing truly integrated systems at cost-competitive prices
- For purpose components, DHW prioritization
- Currently available in marketplace, few takers
- New systems offer better capacity for larger homes

gti

Residential Integrated System: EE Programs Perspective

- Proposes regional furnace standards to require Northern Regions to raise the AFUE for non-weatherized gas furnaces from 80% to 90%
  - Full effect in 2013
- Condensing furnaces already represent half of national furnace shipments
- Decreasing opportunity for gas savings
- High efficiency water heating programs face challenging economics (e.g. TRC), especially with low gas prices
  - Improves utility/customer value proposition for water heating by piggy-backing on larger space heating load

2009 National Furance Shipments



Residential Integrated System: Customer Perspective

- Opportunity for significant energy and energy cost savings
- Improved payback, using one high efficiency device for two end use loads
- New, pre-engineered systems supported by major manufacturers offer improved reliability and cost-effectiveness while reducing system design and installation errors

EXAMPLE:

Tankless:	$1,550
AHU:	$ 750
	$2,300

EXAMPLE:

Furnace:	$1,500
Heater:	$ 700
	$2,200

Thank You

Ryan Kerr

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Mobile: 224.735.0264

ETP Emerging Technology Program

Emerging Technology Program (ETP)

Addressing implementation barriers and associated risks related to market acceptance and adoption of emerging technologies.

Improved energy efficiency is a shared policy goal around the world; it is often the most economic and readily available means of improving energy security and reducing carbon emissions. New technology is essential to further energy efficiency improvements and to move toward a cleaner, more sustainable energy future.

Emerging Technology Program (ETP) — A newly established collaborative program managed by Gas Technology Institute (GTI) — is focused on accelerating the commercialization and adoption of the latest energy efficient technologies. The program is designed to help companies identify and evaluate the most promising products and integrated solutions and assess their suitability for future use in utility energy efficiency programs.

GTI's industry-leading expertise provides the information and resources required to help advance market acceptance of emerging technologies for near- to mid-term implementation. ETP strives to create market pull by deployment of natural gas solutions at a desired scale, leading to self-sustaining commercial viability and impact.

Effective Industry Collaboration

Collaborative ETP initiatives provide an opportunity for companies to share insights, leverage energy efficiency funds and help increase the transfer of tech-nology between upstream innovations and the marketplace.

ETP also offers access to GTI services and capabilities for energy efficiency program planning, implementation and assessment. GTI and its partners can work with your company to tailor or modify initiatives to address company or regionally specific needs and opportunities. We can also support a regulatory submission for ETP authorization. GTI has a long history of working collaboratively with utility companies, regulatory agencies, local state/federal government, non-government organizations, manufacturers, channel partners, trade allies and other stakeholders to reduce the time and cost of getting new technology to market.

ETP activities are "beyond development" stage: Field Testing, Demonstration, and Deployment — a focused effort to ensure market acceptance of next-generation emerging technologies

ETP Emerging Technology Program