Biomass System Training for Proper Sizing, M&V, Cx, Controls Integration, Feasibility Analysis, Energy Audits, Load Reduction EEMs, Lessens from the Trenches, and Other Relevant Energy Efficiency Topics

Presented by:

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Objectivity and Related Affiliations

Pyramid EES provides objective and independent third party assistance to customers. We have no equipment, manufacturer, or service affiliations that will affect our impartiality and ability to provide objective and independent services.

Topics Covered / Learning Objectives

Topics covered include but are not limited to:

1. Introduction to RHNY (Efficiency and brief emission mention) and web links,
2. Biomass System Introduction and components,
3. Share/explain numerous biomass system illustrations from manufacturers & recent projects,
4. M&V procedures and execution - General Introduction,
5. M&V - Specific to Biomass projects,
6. Cx general examples & biomass specific,
7. Building Peak Load determination methods, then real life examples,
8. Biomass System Sizing, Tandem Options & TES/Buffering,
9. Analysis of several building load profile types & how they impact biomass boiler sizing/operation,
10. Controls and controls integration, introduction to pneumatic vs. DDC controls,
11. Commercial Energy Audits procedures and how they support biomass projects,
12. Baseline Billing Analysis & Establishing a multi-year energy baseline,
13. Baseline and Proposed cases EUIs and many other figures of merits,
14. Numerous EEM suggestions and how they impact Biomass projects,
15. Biomass feasibility analysis examples (independent and district systems),
16. Biomass cost estimate components, checklists and why,
17. Other relevant topics,
18. Hydronics and boiler protection reminder,
19. Numerous recommendations and take home messages,
20. Visit to Boiler Manufacturer and/or a biomass site for real like illustrations.

Disclaimers

- The objective of this training is to provide you with guidance and assistance, and to enhance your awareness of what it may take to plan and implement a successful Measurement and Verification (M&V) process and how the collected data can benefit and support an ongoing Commissioning (Cx) and Troubleshooting activities. Many of the items included were based on my experience and lessons learned since 1990. I cannot be responsible for the results and consequences of adapting any or all of the items included in this introductory and multi-disciplinary biomass system sizing, M&V and Cx training seminar. Energy professionals may adapt all or part of the recommended procedures, as they find appropriate for their specific situations, at their own risk and responsibility.

- I make no attempts to provide you with specific and complete procedures for collecting building data, energy audits and performing commissioning activities. What I provide are guidelines, suggestions and lessons learned for your consideration, and adaption as you deem appropriate.

- All illustrations, diagrams, examples and explanations shown in this training are conceptual and are not intended as fully detailed installation drawings or project specifications. They are included for educational and illustrative purposes only and can be subject changes or updates without notice. No warranty is made as to the suitability of any drawings and/or data for a particular application - each application must be handled separately and based on its own site specific conditions.

Glossary of Terms, Abbreviations & Acronyms

AHU - Air Handling Unit

A1 Bldg - ****************

ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers

BMS - Building Management Systems

BOP - Balance of Plant

BTU - British Thermal Unit

CEA - Comprehensive Energy Audit

CEM - Certified Energy Manager

CGC - Cleaner Greener Communities (PON 2951)

Cx - Commissioning

DAA - Data Acquisition and Analysis

DBT - Dry Bulb Temperature

DCV - Demand Controlled Ventilation

DEA - Detailed Energy Analysis

DOAS - Desiccated Outdoor Air Systems

DOT - Department of Transportation

EA - Energy Audit or Energy Analysis

Econo - Economizer

EEM - Energy Efficiency Measure

EES - Energy Engineering Services

EFP - Existing Facilities Program

EMCS - Energy Management and Control System

EMS - Energy Management System

ERU - Energy Recovery Unit

ERV - Energy Recovery Ventilator

ESPC - Energy Savings Performance Contracting

FCU - Fan Coil Unit

FMS - Facility Management System

FTEs - Full Time Employees

GBE - Green Buildings Engineer

H&C - Heating and Cooling

HELE - High-Efficiency Low-Emissions

HVAC - Heating, Ventilating and Air-Conditioning Systems

IPMVP - International Performance Measurement and Verification Protocol

LEED AP - Leadership in Environmental and Energy Design Accredited Professional by USGBC

Glossary of Terms, Abbreviations & Acronyms Cont.

LP - Liquefied Propane

M&V - Measurement and Verification (can be for a plan, report or process)

NG - Natural Gas

D2 Bldg - ****************

NYS DOCCS - New York State Department of Corrections and Community Services

NYS DOCS - NYS Department of Correctional Services

NYS OGS - New York State Office of General Services

NYSERDA - New York State Energy Research and Development Authority

S3 Bldg - ***************

OA - Outside or Outdoor Air

OAT - Outside Air Temperature

OH&P - Overhead and Profit

PE - Professional Engineer

PFHX - Plate and Frame Heat Exchanger

PM - Project Manager

PON - Program Opportunity Notice (issued by NYSERDA)

PTAC - Packaged Terminal Air-Conditioning Unit

PTE - Part-Time Employee

R&R - Range and Relational Checks

RA - Return Air

REDGHG - The Regional Economic Development and Greenhouse Gas Reduction Program (PON 2571)

RH - Relative Humidity

RHNY - Renewable Heat New York (Governor's Initiative)

SCADA - System Control and Data Acquisition

SDC&IE - Sitre Data Collection and Impact Evaluation

SME - Subject Matter Expert

SOS - State of the State Address by Governor Cuomo

SPB - Simple Payback Period (years)

SPC - Standard Performance Contracting

TAS - Technical Assistance Study

TES - Thermal Energy Storage

TFS - Technical Feasibility Study

USGBC - United States Green Buildings Council

VAV - Variable Air Volume

VFD - Variable Frequency Drive

VRF - Variable Refrigerant Flow

VRV - Variable Refrigerant Volume

VSD - Variable Speed Drive

Section 1

Introduction to RHNY

Thank You NYSERDA for supporting HELE Biomass

Long History of Good Support:

- Clean Energy Research & Market Development (NYSERDA R&D Group) supported numerous research & demonstration projects & manufacturers,
- PON 2357 - High Efficiency Wood Pellet Boiler Heating Demonstration,
- REDGHG PON 2571 - The Regional Economic Development and Greenhouse Gas Reduction Program,
- CGC PON 2951 - Cleaner, Greener Communities, Phase-I & Phase-II,

RHNY Supports:

- Most recently (July 2014), Existing Facilities Program (EFP) **(RHNY PON 1219**) included HELE Pellet Boilers > **300,000 Btu/h (88 kW)** up to 5,000,000 Btu/h (1,465 kW) for large commercial installations.
- Renewable Heat New York (**RHNY PON 3010**) for HELE Boilers **≤ 300,000 Btu/h (88 kW)** (covers both HELE Pellet Boilers and Advanced 2-Stage Cordwood Gasification boilers) for residential and small commercial installations.
- Residential Pellet Stoves.
- Biomass support is not new to NYSERDA - 10 year history and expertise.
- National leadership and recognition (known in Alaska and Europe!).

Web links

http://www.nyserda.ny.gov/Energy-Efficiency-and-Renewable-Programs/Renewables/Renewable-Heat-NY/Large-Commercial-Pellet-Boiler.aspx

http://www.nyserda.ny.gov/Energy-Efficiency-and-Renewable-Programs/Renewables/Renewable-Heat-NY/Small-Commercial-Pellet-Boiler.aspx

Frequently Asked Questions about Renewable Heat New York

Residential Pellet Stove

Residential Advanced Cordwood Boiler

Small Commercial Advanced Cordwood Boiler

Small Commercial Pellet Boiler

▶ **Large Commercial Pellet Boiler**

Large Commercial Pellet Boiler Frequently Asked Questions

Training for Renewable Heat NY Contractors

Large Commercial Pellet Boiler

Incentives are available for high-efficiency, low-emission pellet boiler heating systems in new and existing facilities. A pellet boiler heating system includes a high-efficiency pellet-fired boiler, thermal energy storage, outdoor pellet storage, and necessary control systems. The pellet boiler(s) heating system must be installed in an efficient manner and displace boiler fuel-use at facilities without access to natural gas (such as oil, propane, and coal). Incentives are offered under this large commercial program to offset the installed system costs for systems with thermal output over 300 MBtu/h (88 kW).

Incentives

SYSTEM TYPE	INCENTIVE	MAXIMUM INCENTIVE PER FACILITY
Pellet Boiler Output over 300 MBtu/h (88kW)	20% of Total Installed Cost	$100,000
Tandem* Pellet Boilers Output over 300 MBtu/h (88kW)	25% of Total Installed Cost	$150,000

*A tandem boiler installation includes two or more smaller pellet boilers rather than one large pellet boiler and can minimize cycling to maintain efficiency, emissions, and maintenance costs in certain installations.

Incentives are based on the installed project costs. 80% of the incentive will be paid based on proof of installation and system commissioning. The remaining 20% will be paid at the end of the Measurement and Verification (M&V) period (up to 12 months) and when acceptable environmental and thermal performance has been achieved.

Design and Installation

The qualified pellet heating system must be designed by a qualified designer and installed by a qualified installer to ensure proper boiler system sizing and cost-effective design to maximize efficiency and minimize emissions. For more information see the list of **qualified technologies** [PDF], designers, and installers. For system eligibility requirements please refer to the **Renewable Heat NY Technical Guidance Document for Large Commercial Pellet Boilers** [PDF].

How to Apply

Apply through the Consolidated Funding Application.

Eligibility

For system eligibility requirements and program details see the RHNY Technical Guidance Document for Large Commercial Pellet Boilers [PDF].

Who To Contact

Matt McQuinn,
Assistant Project Manager

matt.mcquinn@nyserda.ny.gov
1-866-697-3732, Ext 3053

Qualified technologies list is undergoing continuous updates by adding manufacturers and links through an open solicitation

See Guidance Document for details

Qualified Pellet Technologies

Renewable Heat NY

NY WORKS for Energy

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Boiler	Boiler Size (Btu/hr)	Boiler Size (kW)*	Efficiency Based On HHV (%)	PM 2.5 (lb/MMBtu)	CO at 7% O2 (PPM)	Link to Company Website
TARM-Froling P4 Unit 8	27,000	8	87	0.035	17	http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html
TARM-Froling P4 Unit 15	51,000	15	86	0.030	17	http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html
TARM-Froling P4 Unit 20	68,000	20	87	0.028	31	http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html
Evo World 25P	85,000	25	85	0.019	212	http://www.evo-world.com/us-home.html
TARM-Froling P4 Unit 25	85,000	25	87	0.028	43	http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html
TARM-Froling P4 Unit 32	109,000	32	87	0.026	67	http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html
TARM-Froling P4 Unit 38	130,000	38	86	0.023	98	http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html
TARM-Froling P4 Unit 48	164,000	48	86	0.026	55	http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html
Evo World 50P	170,000	50	90	0.014	28	http://www.evo-world.com/us-home.html
TARM-Froling P4 Unit 60	200,000	60	85	0.030	10	http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html
TARM-Froling P4 Unit 80	270,000	80	86	0.033	11	http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html
Evo World 100P	340,000	100	88	0.019	74	http://www.evo-world.com/us-home.html
TARM-Froling P4 Unit 100	340,000	100	87	0.033	11	http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html
ACT CP 500	510,000	150	88	0.028	47	http://www.actbioenergy.com/products
Evo World 200P	680,000	200	87	0.023	20	http://www.evo-world.com/us-home.html
ACT CP 850	850,000	250	88	0.023	52	http://www.actbioenergy.com/products
ACT CP 1000	1,000,000	300	87	0.030	49	http://www.actbioenergy.com/products
ACT CP 1700	1,700,000	500	89	0.014	58	http://www.actbioenergy.com/products

* Kw is the unit boilers are measured by in Europe

- Frequently Asked Questions about Renewable Heat New York
- Residential Pellet Stove
- Residential Advanced Cordwood Boiler
- Small Commercial Advanced Cordwood Boiler
- **Small Commercial Pellet Boiler**
  - Small Commercial Pellet Boiler Frequently Asked Questions
- Large Commercial Pellet Boiler
- Training for Renewable Heat NY Contractors

Small Commercial Pellet Boiler

Incentives are available for the installation of qualified high-efficiency, low-emission pellet boiler heating systems with thermal storage for small commercial applications (less than 300,000 Btu/h).

Incentives

Incentives are 25% of installed costs based on system size:

BOILER SIZE (KW)	BOILER SIZE (BTU/HR)	MAXIMUM INCENTIVE
less than 25	86,000	$5,500
35	120,000	$9,000
50	171,000	$13,000
75	257,000	$20,000

Incentives are available on a first-come, first-served basis, and will only be reserved for customers once an application has been approved by NYSERDA. Incentives are paid upon approval of the Incentive Application directly to the Installer and passed on in the full amount to the customer. Incentives will not be provided directly to customers purchasing or installing the new system. Incentives are only available for new equipment and systems that have not been installed (partially or completely) prior to NYSERDA approval of a Project Application.

You may qualify for a Green Jobs - Green New York **Smart Energy Loan** to help pay for eligible project costs.

System Performance Requirements

SYSTEM MEASURES	LEVELS
Thermal Efficiency (HHV)	85%
Particulate Emissions	less than 0.080 lb/mmBtu
Carbon monoxide (CO) emissions	less than 270 ppm at 7% O_2

Pellets must be stored outside of the building as outlined in the **Program Manual**. The system must be a **qualified technology**.

How to Apply

- Complete the customer inquiry form
- You will be put you in touch with an installer
- The installer will prepare and submit necessary paperwork

Eligibility

New York State businesses without natural gas service

Who To Contact

Ryan Moore, Project Manager

ryan.moore@nyserda.ny.gov
1-866-697-3732, Ext 3267

For Installers/Contractors

For additional information on how to become a qualified installer and to sign up for upcoming training opportunities:

- Program documents and installer application
- Installer training schedule

- Frequently Asked Questions about Renewable Heat New York
- Residential Pellet Stove
- Residential Advanced Cordwood Boiler
- **Small Commercial Advanced Cordwood Boiler**
  - Advanced Cordwood Boiler Frequently Asked Questions
- Small Commercial Pellet Boiler
- Large Commercial Pellet Boiler
- Training for Renewable Heat NY Contractors

See Numerous other beneficial resources

Small Commercial Advanced Cordwood Boiler

Incentives are available for advanced cordwood boiler heating systems with full thermal storage for installations in the residential and small commercial sectors. The installation must include full thermal storage as outlined in the Program Manual. All systems must use **eligible boilers** [PDF].

Incentives and Financing

Incentives up to $8,000 are available. This amount is based on 20% of installed costs up to $4,000 per unit with an additional $4,000 for documented removal and destruction of a previously installed and functioning Outdoor or Indoor Wood Boiler. Incentives are available on a first-come, first-served basis, and will only be reserved for customers once an application has been approved by NYSERDA.

Incentives are paid upon approval of the Incentive Application directly to the Installer and passed on in the full amount to the customer. Incentives will not be provided directly to customers purchasing or installing the new system. Incentives are only available for new equipment and systems that have not been installed (partially or completely) prior to NYSERDA approval of a Project Application.

You may qualify for a Green Jobs - Green New York **Participation Loan** to help pay for eligible project costs.

Participation Details

Complete the **customer inquiry form** and you will be put you in touch with an Installer.

Participating Installers must have demonstrated technical competence in the design and installation of advanced cordwood boilers and have signed a written Participation Agreement with NYSERDA. Installers are responsible for preparing and submitting all necessary incentive paperwork to NYSERDA.

Last Updated: *08/28/2014*

How to Apply

- Complete the customer inquiry form
- You will be put you in touch with an installer
- The installer will prepare and submit necessary paperwork

Eligibility

New York State homeowner or business owner without natural gas service

Who To Contact

Ryan Moore, Project Manager

ryan.moore@nyserda.ny.gov
1-866-697-3732, Ext 3267

For Installers/Contractors

For additional information on how to become a qualified installer and to sign up for upcoming training opportunities:

- Program documents and installer application
- Installer training schedule

NYSERDA RHNY Points of Contact

NYSERDA Large Commercial (PON 1219)

- Matthew McQuinn | Assistant Project Manager, Implementation Services, Matt.McQuinn@nyserda.ny.gov, (518) 862-1090 Ext. 3053

NYSERDA Residential and Small Commercial (PON 3010)

- Ryan T. Moore| Project Manager, Residential Energy Services, Ryan.Moore@nyserda.ny.gov, (518) 862-1090 Ext. 3267

Introduction to RHNY

RHNY Large Commercial Program offers incentives for pellet-fired boiler systems that meet certain eligibility requirements. A NYSERDA Technical Consultant (TC) will work w/ applicant to confirm boiler system size, design, and installation meets RHNY program requirements:

- The incentive will be paid based on **20%** of the documented, allowable installation costs, up to a maximum of **$100,000** per project.
- When two or more smaller or tandem boilers are installed in place of a single boiler, the incentive is **25%** of allowable installation costs with a maximum of **$150,000** per proj.

Eligibility Requirements:

- Boiler(s) must be a **qualified** high-efficiency, low-emissions (HELE) pellet-fired boiler,
- The customer must agree to use **premium wood pellets** (not wood chips or low-quality pellets),
- Project must use **qualified** designers and installers,
- Pellet Storage must be **outdoors** and conform to applicable OSHA requirements,
- The large commercial facility must NOT have natural gas available,
- Pellet boiler(s) must be **properly sized** for the facility and incorporate backup fuel boilers,
- Include adequate thermal storage/**buffer** tank(s),
- Proper system and **controls integration** is required,
- Careful **stack** placement.

Introduction to RHNY - Cont.

- Measurement and Verification (**M&V**) for the first 12 months of operation (or for one complete heating season) will be required.
- M&V performance data may be collected using the applicant's energy management and control systems (**EMCS**) and/or by temporary data loggers installed by the TC.
- NYSERDA encourages the use of **in-house integrated controls** for monitoring and data collection since this gives the facility staff the ability to track system performance, ensuring sustained savings and reliable operation over the system life.
- If measured performance for the first 12 months is not deemed acceptable by NYSERDA, an additional 12-months of measured performance data will be required to demonstrate that any identified performance deficiencies have been addressed.
- **80%** of the total incentive will be paid once the system is installed, **commissioned** and is operating as intended.
- The remaining **20%** will be paid upon satisfactory completion of the M&V period illustrating satisfactory performance and efficient operation.

Introduction to RHNY - Cont.

- **Heating System Commissioning:** All commercial and institutional projects must include commissioning of the wood pellet heating system components. A data acquisition system and monitoring plan must be included to facilitate measurement and verification for the first heating season of operation.

- The applicant must provide clear written evidence that the system has been properly commissioned and operational according to the design intent.

Introduction to RHNY - Cont.

*Call for **Qualified Wood Pellet Boiler Technologies** for Renewable Heat NY*

Manufacturers should provide 1) a cover letter, 2) a test report by a technically competent independent third-party, and 3) warrantee information. The cover letter must accompany the application and if necessary convert any alternative units to the units as shown:

High-Efficiency and Low-Emissions Pellet Boiler Performance	
Thermal Efficiency (HHV)	85%
Particulate Matter Emissions (PM 2.5)	<0.080 lb/mmBtu
Carbon monoxide (CO) Emissions	<270 ppm at 7% O_2

Introduction to RHNY - Cont.

Call for ***<u>Qualified Advanced Cordwood Boiler Technologies</u>*** *for Renewable Heat NY*

Manufacturers should provide 1) a cover letter, 2) the BNL test method report completed by a technically competent independent third-party, 3) warrantee information and 4) letter of certification from NYSDEC. The cover letter must accompany the application and if necessary convert any alternative units to the units as shown:

High-Efficiency and Low-Emissions Advanced Cordwood Boiler Performance	
Annual Thermal Efficiency (HHV)	>=60%
Annual Particulate Matter Emissions (PM 2.5)	<0.32 lb/mmBtu
Annual CO Emissions	ppm at 7% O_2

Question - Based on the above two tables, why is the cordwood boiler <u>efficiency lower</u> than wood pellets and why is the cord wood boiler <u>emissions higher</u> than wood pellets? Note – Interesting discussion of Startup and End Phase Emissions is forthcoming in 3 slides.

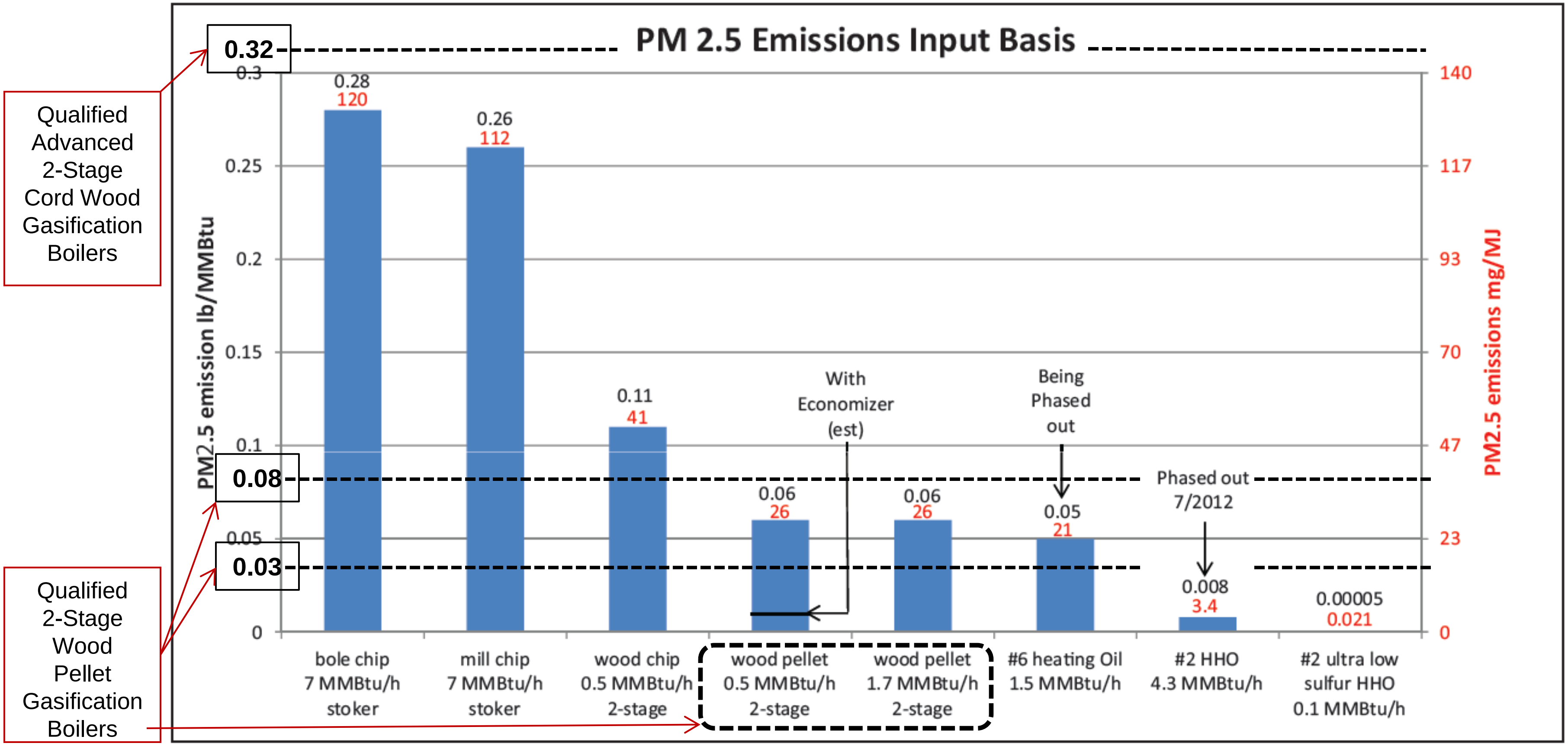


Figure 12. Comparative fine particulate matter (PM2.5) emissions from several fuel-heating technology combinations including wood chips, wood pellets, #5 fuel oil, and #2 home heating oil (HHO). (Rector, L. (2010), Chandrasekaran, S. et al. (2011), McDonald (2009))

Question - Name three major Emission Controls Options with biomass systems ?

Answers:

- Single Cyclone,
- Multi-Cyclone,
- Two multi-cyclones,
- Core Separator,
- Fabric Filter (Baghouse) with Cyclone,
- Baghouse and multi-cyclone,
- High efficiency Multi-cyclone,
- Electrostatic Precipitator (ESP),
- Back End Condensing Unit,

Mostly attained through post combustion controls.

Question - Why is this a big NO - NO?

Answer - Entrainment of exhaust gases and particles into the building air intakes and other opening (doors and windows) exposes building occupants and visitors to exhaust fumes/plume, CO and other contaminants and causes adverse health effects.

Boiler Sizing at ≤ 60% of Peak Heating Load for Large Commercial Systems

Proper Boiler Sizing - The EA must include data-based calculations or other acceptable engineering-based load calculations to determine the peak heating load for the facility (i.e., not the current installed boiler capacity). The pellet boiler must be sized to have a **maximum thermal output that is equal to or less than 60% of the facility peak heating load** to minimize boiler cycling.

However, if the total installed capacity of the boiler(s) exceeds 60% of the peak heating load, the EA must explain and demonstrate that other approaches or measures are being taken to minimize cycling and maintain acceptable efficiency, emissions, and maintenance costs (tandem boilers, TES, use boilers with attractive turn down ratio).

A higher incentive is provided through RHNY for tandem boilers to encourage this practice.

Residential Side Note - For residential pellet boilers, they can be sized to meet 100% of the heating load because at some point they may remove the existing oil or propane boilers.

Buffering / Thermal Energy Storage

Thermal Buffering / Storage. The pellet boiler system must include a thermal energy storage tank to optimize system response time, minimize boiler short-cycling, and minimize overheating upon unexpected shutdown. Systems must include **2.0 gallons of storage for each 1,000 Btu/h (MBtu/h) of boiler thermal output capacity** (based on the output capacity of one boiler in a tandem system). Tanks must be selected and designed to achieve good thermal stratification. Multiple benefits from TES include:

- a smaller number of on-off cycles,
- longer on times,
- increased system efficiency,
- reduced emissions,
- the ability to supplement auxiliary boilers during building peak demand,
- storage of excess heat during low heat demands,
- mitigation of slow response times found in biomass boilers compared to propane,
- serve as a hydraulic separator, etc.

Residential Side Note - For less than or equal to 25 kW boilers (85,000 Btu/h), they can use 119 gallons for residential (converts to $\geq$ 1.4 gal/1,000 Btu/h)

System and Controls Integration

System and Controls Integration. Proper integration of the pellet-fired boiler(s) into the existing overall boiler plant system is required. The **pellet boiler(s) must operate at full load most of the time in order to achieve the expected efficiency, fuel displacement, and emissions performance**.

The EA should list all of the boilers in the proposed system and explain how each one will all be controlled (i.e., control sequence of operation, boiler staging, varying firing rates, heating hot water set points, reset outside temp or building schedule, tank stratification sensors, etc.).

The EA must also explain the control strategy to lock out and re-initiate pellet boiler operation on a diurnal and seasonal basis.

Note - Reasonable boiler turn down ratios have been “claimed”, but have not been independently observed/verified at in the test laboratory for attaining both high efficiency and low emissions at low load conditions.

Outside Pellet Storage

Outside Pellet Storage. Pellets must be stored **outside** in a silo or other weather-proof storage container to minimize exposure to Carbon Monoxide (CO) produced during storage.

The design should consider long-term maintenance and repair concerns associated with the storage and conveyance equipment.

The design and operating practices should address the necessary OSHA concerns with confined space access.

Allowable vs. Non-Allowable Project Costs

Allowable Project Costs	Non-Allowable Project Costs
• Qualified and properly-sized HELE Pellet boiler(s) and ancillary equipment • Piping, pumps, valves, heat exchangers, boiler controls, tanks, boiler electrical • Automation and controls; interconnections between boiler systems and building controls; M&V Instrumentation • Pellet storage and handling equipment • Enclosures, buildings, foundations/pads • Appropriately sized thermal storage • Chimney and breaching • Instrumentation and M&V equipment • Other necessary Balance of Plant Components (BOP) • Reasonable design and construction fees	• Environmental remediation (old tank removal, asbestos, etc) • Controls and automation not related to boiler system or heating system (these may be eligible under other EFP programs) • Buildings and enclosures not related to boiler system • Excessive site preparation, boiler room construction, or structural work

Question - Why Biomass?

- High cost of #2 Fuel Oil and Propane,
- $$$ Savings through fuel displacement,
- Easily available local fuel,
- Reduce oil imports,
- Supports local economy and promotes job growth,
- Supports fuel diversity (hybrid heating plant) and offers some redundancy,
- Supports energy security and reduces reliance on imported fuels.

Technical Review Checklist and Responsibilities for RHNY- Large Commercial Pellet Boilers

Applicant Responsibility	NYSERDA / Technical Consultant (TC) Responsibility
CFA Application • Confirm basic project eligibility ○ no natural gas available to facility ○ boiler specifications ○ fuel specifications (premium pellets) ○ outdoor fuel storage	CFA Application • NYSERDA reviews application for basic program compliance and project eligibility
Engineering Analysis (EA) • Prepare EA including the following materials (or provide material to TC): ○ Baseline fuel use data (dates, amounts) for last 12 months (36 months preferred) ○ Baseline fuel costs ○ facility heat load calculations ○ estimated displaced fuel ○ estimated maintenance costs ○ schematic design concept • Provide Design Drawings / Documents ○ biomass and aux. boiler specifications (emissions, efficiency) ○ storage tank, pellet silo & conveyance layout ○ system schematic and control details • Provide estimated project costs	Engineering Analysis (EA) • TC reviews EA (or prepares EA on behalf of applicant) and makes an optional pre-install visit ○ confirm sizing and design concept ○ confirm savings and fuel displacement ○ review estimated project costs (and estimate EA stage incentive) • TC confirms design meets program requirements ○ biomass boiler eligibility ○ sizing, thermal storage, system control details ○ pellet storage outdoors ○ stack location in relation to neighboring buildings and stack height • TC prepares an EA Review Report • NYSERDA approves EA Review
M&V Plan Development • Provide instrumentation and controls related to monitoring and verification (M&V) • Review and accept M&V Plan prepared by TC	M&V Plan Development • TC develop M&V approach; define instrumentation and controls that applicant will provide • TC prepares M&V Plan • NYSERDA approves M&V Plan
Project Installation Report • Provide actual itemized as-built project cost data • Provide evidence that system has been commissioned and is operating as intended • Support M&V installation / operation	Project Installation Report TC come on site to confirm equipment installation matches EA and design documents TC reviews project costs and total incentive TC prepares PIR report; recommends incentive NYSERDA makes PIR incentive payment
M&V Data Collection and Reporting • Support data collection efforts as described in M&V Plan • Correct any performance deficiencies identified by NYSERDA/TC	M&V Data Collection and Reporting • TC collects data as described in M&V Plan • TC summarizes data, prepares M&V report. and makes incentive recommendation • NYSERDA makes M&V incentive payment

Technical Review Checklist and Responsibilities for RHNY- Large Commercial Pellet Boilers (1 of 3)

<table>
<tr><th>Applicant Responsibility</th><th>NYSERDA /
Technical Consultant(TC) Responsibility</th></tr>
<tr><td><u>CFA Application</u>
Confirm basic project eligibility
no natural gas available to facility
boiler specifications
fuel specifications (premium pellets)
outdoor fuel storage</td><td><u>CFA Application</u>
NYSERDA reviews application for basic program compliance and project eligibility</td></tr>
</table>

Technical Review Checklist and Responsibilities for RHNY- Large Commercial Pellet Boilers (2 of 3)

<table>
<tr><th>Applicant Responsibility</th><th>NYSERDA /
Technical Consultant(TC) Responsibility</th></tr>
<tr><td><u>Engineering Analysis (EA)</u>
• Prepare EA including the following materials (or provide material to TC):
  ○ Baseline fuel use data (dates, amounts) for last 12 months (36 months preferred)
  ○ Baseline fuel costs
  ○ facility heat load calculations
  ○ estimated displaced fuel
  ○ estimated maintenance costs
  ○ schematic design concept
• Provide Design Drawings / Documents
  ○ biomass and aux. boiler specifications (emissions, efficiency)
  ○ storage tank, pellet silo & conveyance layout
  ○ system schematic and control details
  ○ Provide estimated project costs</td><td><u>Engineering Analysis (EA)</u>
• TC reviews EA (or prepares EA on behalf of applicant) and makes an optional pre-install visit
  ○ confirm sizing and design concept
  ○ confirm savings and fuel displacement
  ○ review estimated project costs (and estimate EA stage incentive)
• TC confirms design meets program requirements
  ○ biomass boiler eligibility
  ○ sizing, thermal storage, system control details
  ○ pellet storage outdoors
  ○ stack location in relation to neighboring buildings and stack height
• TC prepares an EA Review Report
• NYSERDA approves EA Review</td></tr>
</table>

Technical Review Checklist and Responsibilities for RHNY- Large Commercial Pellet Boilers (3 of 3)

Applicant Responsibility	NYSERDA / Technical Consultant(TC) Responsibility
<u>M&V Plan Development</u> • Provide instrumentation and controls related to monitoring and verification (M&V) • Review and accept M&V Plan prepared by TC	<u>M&V Plan Development</u> • TC develop M&V approach; define instrumentation and controls that applicant will provide • TC prepares M&V Plan • NYSERDA approves M&V Plan
<u>Project Installation Report</u> • Provide actual itemized as-built project cost data • Provide evidence that system has been commissioned and is operating as intended • Support M&V installation / operation	<u>Project Installation Report</u> • TC come on site to confirm equipment installation matches EA and design documents • TC reviews project costs and total incentive • TC prepares PIR report; recommends incentive • NYSERDA makes PIR incentive payment
<u>M&V Data Collection and Reporting</u> • Support data collection efforts as described in M&V Plan • Correct any performance deficiencies identified by NYSERDA/TC	<u>M&V Data Collection and Reporting</u> • TC collects data as described in M&V Plan • TC summarizes data, prepares M&V report. and makes incentive recommendation • NYSERDA makes M&V incentive payment

RHNY Launch - July 29, 2014


nyserda
Energy. Innovation. Solutions.
CURRANRENEWABLEENERGY
SUNY CANTON
Clarkson University
Atmospheric Sciences Research Center
UNIVERSITY AT ALBANY State University of New York
Research...Knowledge...Solutions
Bioenergy Project Partners llc
Northeast Forest LLC
THE WILD CENTER
ADIRONDACK MUSEUM
Innovative Natural Resource Solutions LLC
UNIVERSITY of ROCHESTER MEDICAL CENTER
SUNY-ESF
Improve Your World
Vincent's Heating & Fuel Service
Pyramid EES
Energy Engineering Services, PLLC
UNH
NEW HAMPSHIRE
lopper
UNILUX
SUNY Cobleskill
ACT bioenergy
clean, green heating solutions
University at Buffalo
The State University of New York
CayugaNature CENTER
Thermo-Control
TROY BOILER WORKS
QUALITY • INTEGRITY
Lowell Center for Sustainable Production
UNIVERSITY OF MASSACHUSETTS LOWELL
Cooperative Extension
Tompkins County
EVOWORLD
Econoburn
High-Efficiency Wood-Fired Boilers
HYDRONIC SPECIALTY SUPPLY
NEW ENGLAND WOOD PELLET
FINGER LAKES RESOURCE CONSERVATION & DEVELOPMENT COUNCIL, INC.
TARM BIOMASS
Innovative Leaders in Alternative Heating Solutions
Advanced Combustion Wood Heating
Hudson Valley GRASS ENERGY
ALLIANCE FOR GREEN HEAT
clean, renewable & local
SP
bioenergy2020+
WITTUS
FIRE BY DESIGN
NESCAUM
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
BTEC
Biomass Thermal Energy Council
BROOKHAVEN NATIONAL LABORATORY

Section 2

Introduction to Advanced (Modern) Biomass Boiler Systems and illustrations of major Components from several manufacturers, projects and important concepts.

W!ld Center

Photo Courtesy of Ellen Burkhard, Ph.D., Sr. PM, NYSERDA R&D

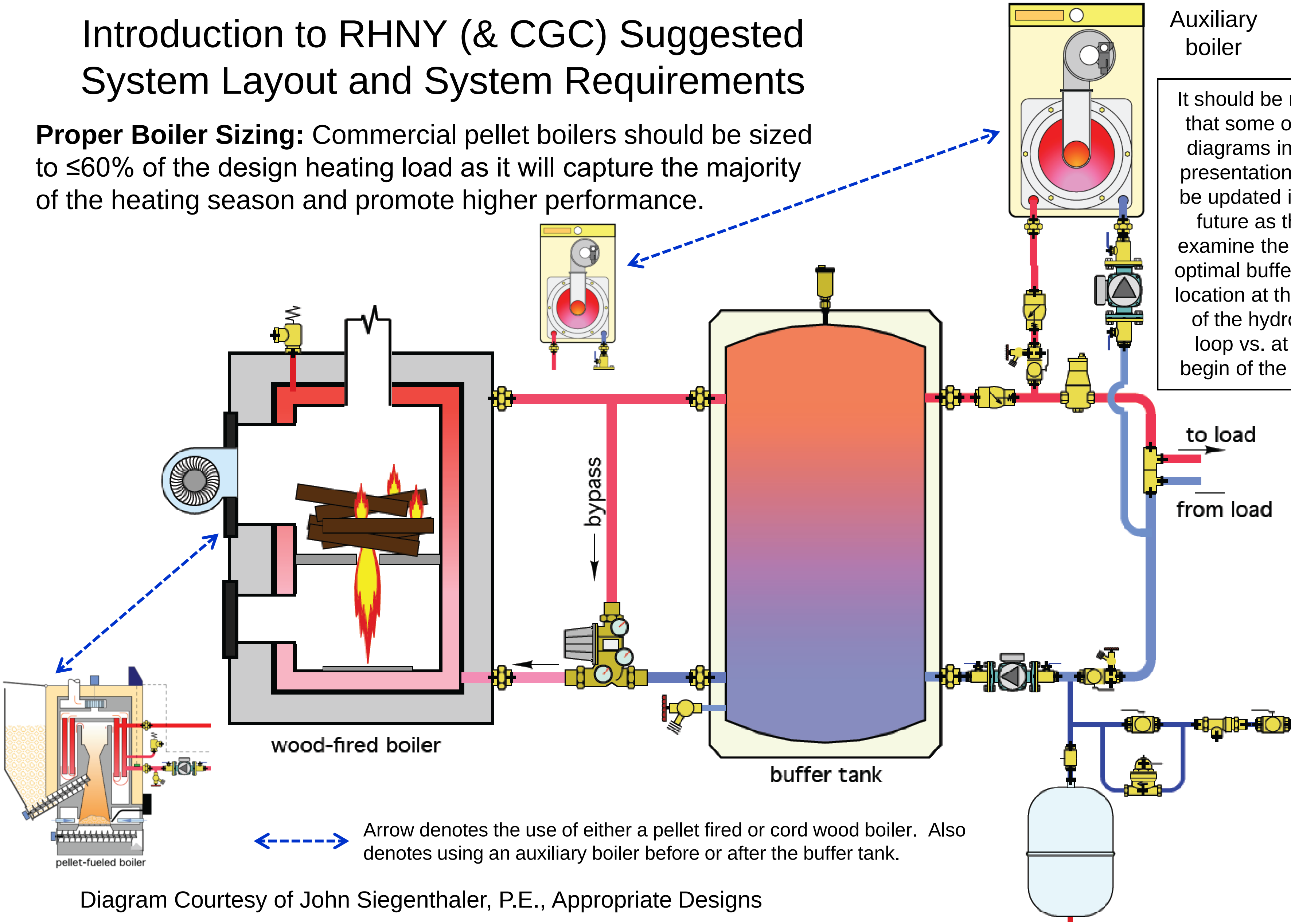
Thermal Energy Storage (TES) 20 Gal/10,000 Btu/hr requirements

85,000 Btu/hr (25 kW) pellet boiler.
170 gal TES by requirements, but
119 gal (non ASME) is allowed for
boilers ≤ 25 kW.

Large 2,500 gal (2 x 1,250 gal) TES

Introduction to RHNY (& CGC) Suggested System Layout and System Requirements

Proper Boiler Sizing: Commercial pellet boilers should be sized to ≤60% of the design heating load as it will capture the majority of the heating season and promote higher performance.

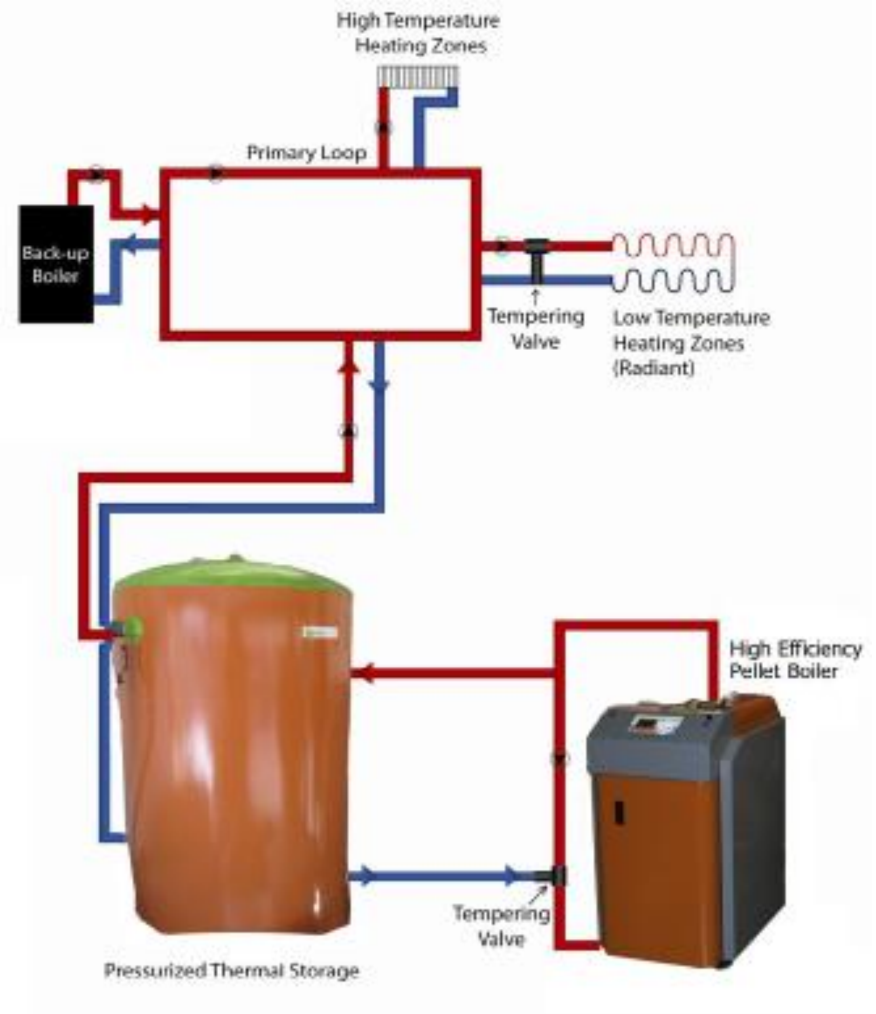


It should be noted that some of the diagrams in this presentation may be updated in the future as they examine the most optimal buffer tank location at the end of the hydronic loop vs. at the begin of the loop.

Arrow denotes the use of either a pellet fired or cord wood boiler. Also denotes using an auxiliary boiler before or after the buffer tank.

Diagram Courtesy of John Siegenthaler, P.E., Appropriate Designs

Introduction to RHNY (& CGC) Suggested System Layout and System Requirements



It should be noted that some of the diagrams in this presentation may be updated in the future as they examine the most optimal buffer tank location at the end of the hydronic loop vs. at the begin of the loop.

Diagram Courtesy of EvoWorld and TBW, Troy, NY

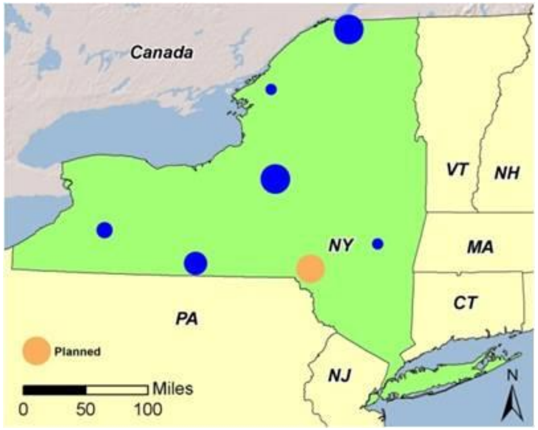
Outdoor Wood Pellet Silo

Biomass Boiler inside shipping container.

Bulk Wood Pellet Storage and Delivery

Containerized Installation Options - Easy, All Outside, Packaged

Pellet Plants in NYS - 500 kTon per year - now bulk delivery! & is increasing



Photos Courtesy of Ellen Burkhard, Ph.D., Sr. PM, NYSERDA R&D

Pellet Mill - Don't get your fingers stuck over there!

Photos Courtesy of Ellen Burkhard, Ph.D.

Question - Which of the Fuels below is considered "Premium" Wood Pellets and Why

Fuel Type: The eligible fuel type is a premium wood pellet. The premium wood pellets must be 100% wood composition. May not contain any heavy metals or plastics.

Photos Courtesy of Ellen Burkhard, Ph.D., NYSERDA R&D

Question - List Major Biomass Boiler Manufacturers (NY, US, & European)

Large Commercial Wood-Pellet Boilers:

- *ACT Bioenergy (Advanced Climate Technologies, LLC), Subsidiary of Unilux, Schenectady, NY,*
- *EvoWorld, of TBW (Troy Boiler Works), Troy, NY,*

Small Commercial and Residential Pellet Boilers:

- *EvoWorld, of TBW (Troy Boiler Works), Troy, NY,*
- *TARM-Froling,*
- *Okofen PE,*
- *Windhager BioWIN.*

Advanced Cordwood (2-Stage Gasification):

- *TARM-Froling (Froling),*
- *Econoburn,*
- *Others.*

Question - List Major Biomass System Components

Boiler:

- Combustion Chamber/Fire Door
- Fuel Feeding System
- Combustion Air Supply
- Boiler Controls, O_2 lambda sensor
- Heat Exchanger/fire tubes
- Exhaust/breaching/vent/barometric damper
- Fuel igniter/ash cleaning/ash removal

Heating System:

- Fuel Storage Silo/Bunker
- Fuel Conveyor/Auger System
- Building Automation System
- Water Connection
- Flue and Chimney
- Post combustion gas treatment (cyclone, ESP, filter)

Outline Courtesy of Dave Dungate, President, BPP (Bioenergy Project Partners) – with a few edits by Pyramid EES.

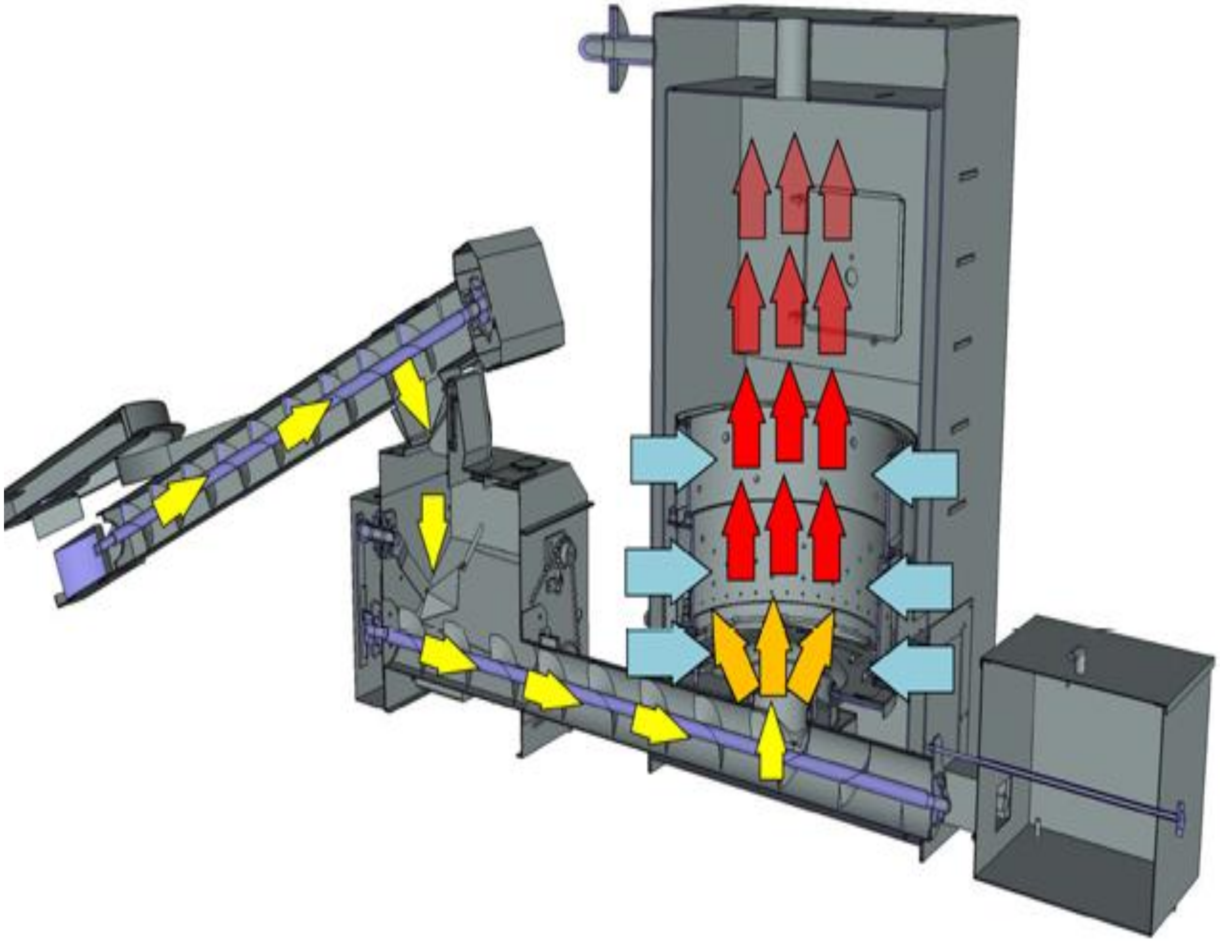
First Made-in-NY biomass boiler

First Made-in-NY Residential & Small Commercial EvoWorld biomass boilers
Northeast Biomass Heating Expo 2013
April 3 - 5, 2013

First Made-in-NY Commercial ACT biomass boiler (0.5 million Btu/hr)
The Adirondack Museum
Blue Mountain Lake, NY
January 7, 2014.

First Made-in-NY Commercial *ACT Biomass Boiler (Advanced Climate Technologies, LLC) by Unilux* - February 19, 2014.

Question - Identify High-Efficiency Wood Pellet Boiler **Components**

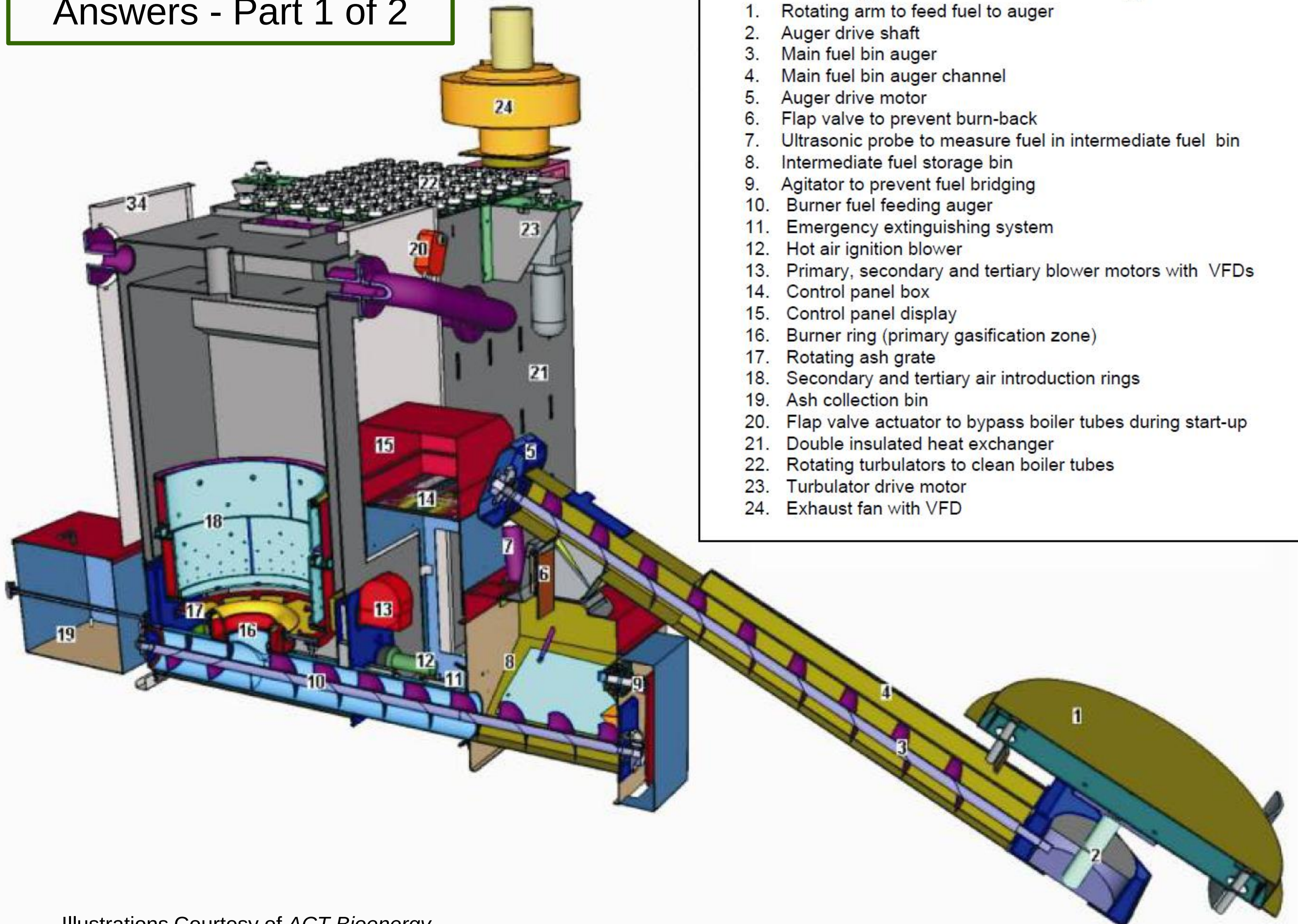


Illustrations Courtesy of *ACT Bioenergy Manual, Schenectady, NY (ACT is Advanced Climate Technologies, LLC)*

Answers - Part 1 of 2

ACT Bioenergy™ Boiler with fuel auger

1. Rotating arm to feed fuel to auger
2. Auger drive shaft
3. Main fuel bin auger
4. Main fuel bin auger channel
5. Auger drive motor
6. Flap valve to prevent burn-back
7. Ultrasonic probe to measure fuel in intermediate fuel bin
8. Intermediate fuel storage bin
9. Agitator to prevent fuel bridging
10. Burner fuel feeding auger
11. Emergency extinguishing system
12. Hot air ignition blower
13. Primary, secondary and tertiary blower motors with VFDs
14. Control panel box
15. Control panel display
16. Burner ring (primary gasification zone)
17. Rotating ash grate
18. Secondary and tertiary air introduction rings
19. Ash collection bin
20. Flap valve actuator to bypass boiler tubes during start-up
21. Double insulated heat exchanger
22. Rotating turbulators to clean boiler tubes
23. Turbulator drive motor
24. Exhaust fan with VFD

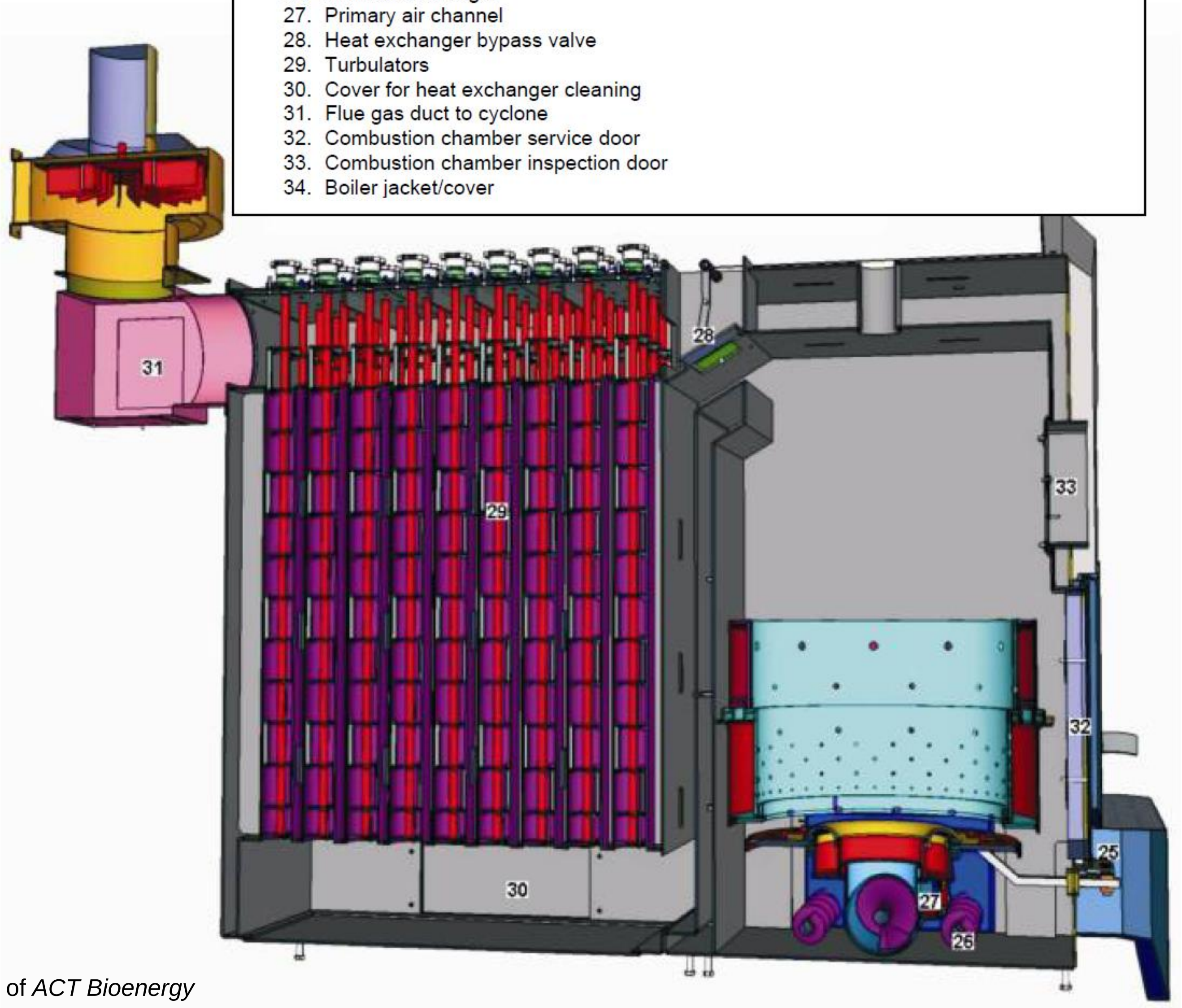


Illustrations Courtesy of *ACT Bioenergy*

Answers - Part 2 of 2

ACT Bioenergy™ Boiler with fuel auger

25. Grate cleaning drive arm
26. Ash removal auger
27. Primary air channel
28. Heat exchanger bypass valve
29. Turbulators
30. Cover for heat exchanger cleaning
31. Flue gas duct to cyclone
32. Combustion chamber service door
33. Combustion chamber inspection door
34. Boiler jacket/cover



Illustrations Courtesy of *ACT Bioenergy*

First Made-in-NY Residential & Small Commercial EvoWorld biomass boilers
Troy, NY
March 27, 2014

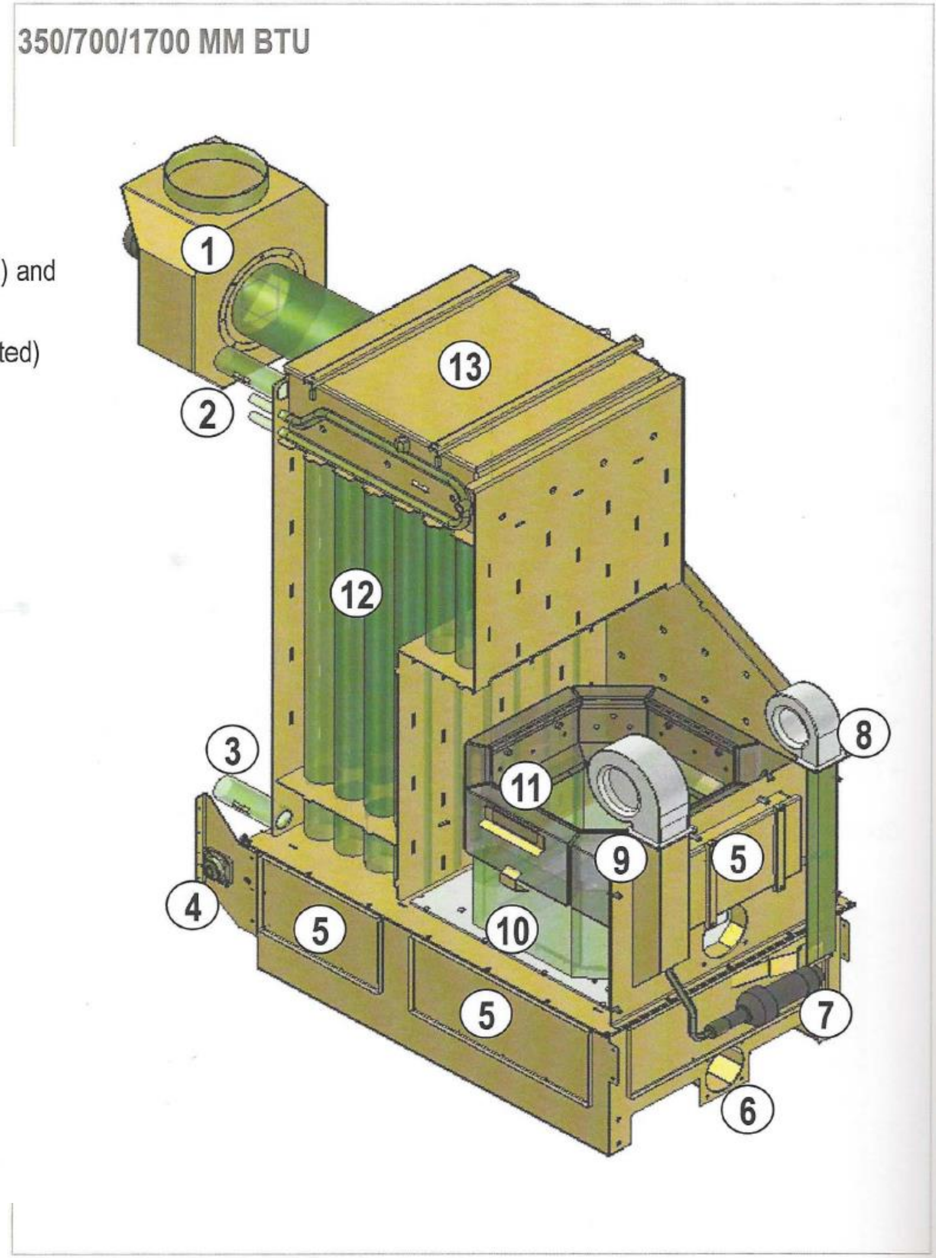
Troy Boiler Works manufactures the EvoWorld Biomass boilers showing highlights during the boiler and storage tank manufacturing process till completion - March 27, 2014

Question - Identify High-Efficiency Wood Pellet Boiler **Components**

Photo Courtesy of *EvoWorld, Troy, NY (Subsidiary of TBW (Troy Boiler Works)) - Taken at RHNY Launch 9/29/2014*

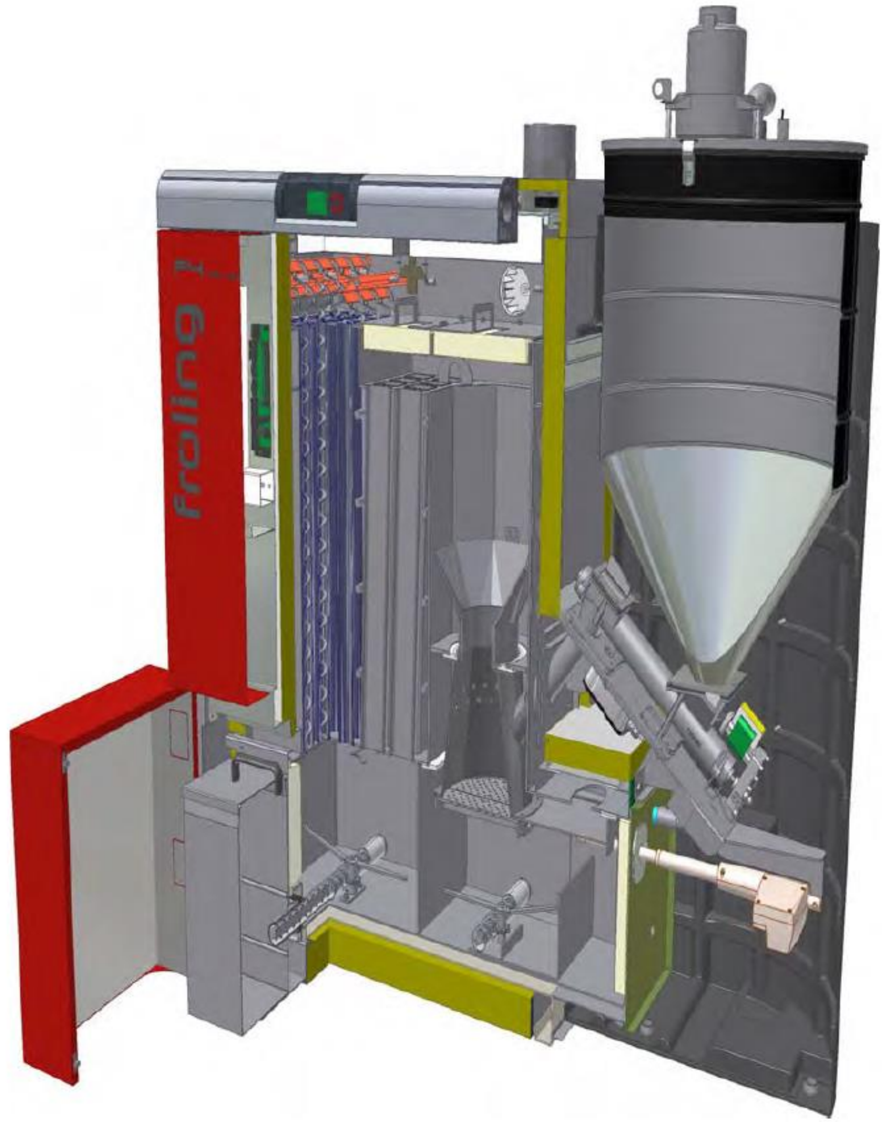
Answers

1. Fully modulating EXHAUST FAN
2. Water connection: FLOW (with temperature sensor integrated) and THERMAL VALVE (heat exchanger)
3. Water connection: RETURN (with temperature sensor integrated)
4. CLEANING SHAFT
5. SERVICE DOORS to maintain the unit
6. ASH DISCHARGE
7. HOT AIR GUN
8. Fully modulating PRIMARY FAN
9. Fully modulating SECONDARY FAN
10. STEP-GRATE combustion system
11. AFTERBURNING with secondary air
12. Self-cleaning 3-PASS HEAT EXCHANGER
13. TOP CAP



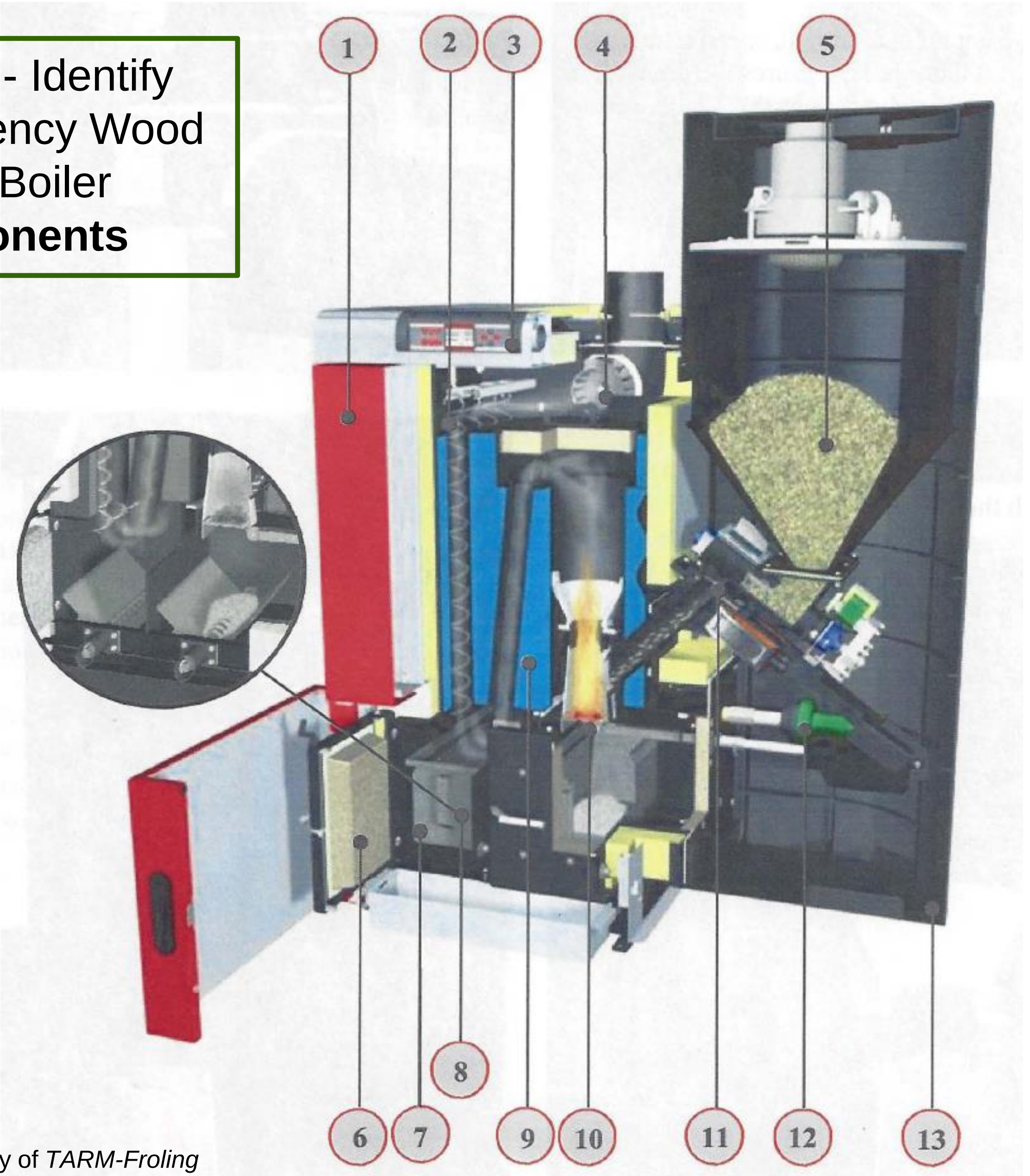
Illustrations Courtesy of *EvoWorld*

TARM-Froling



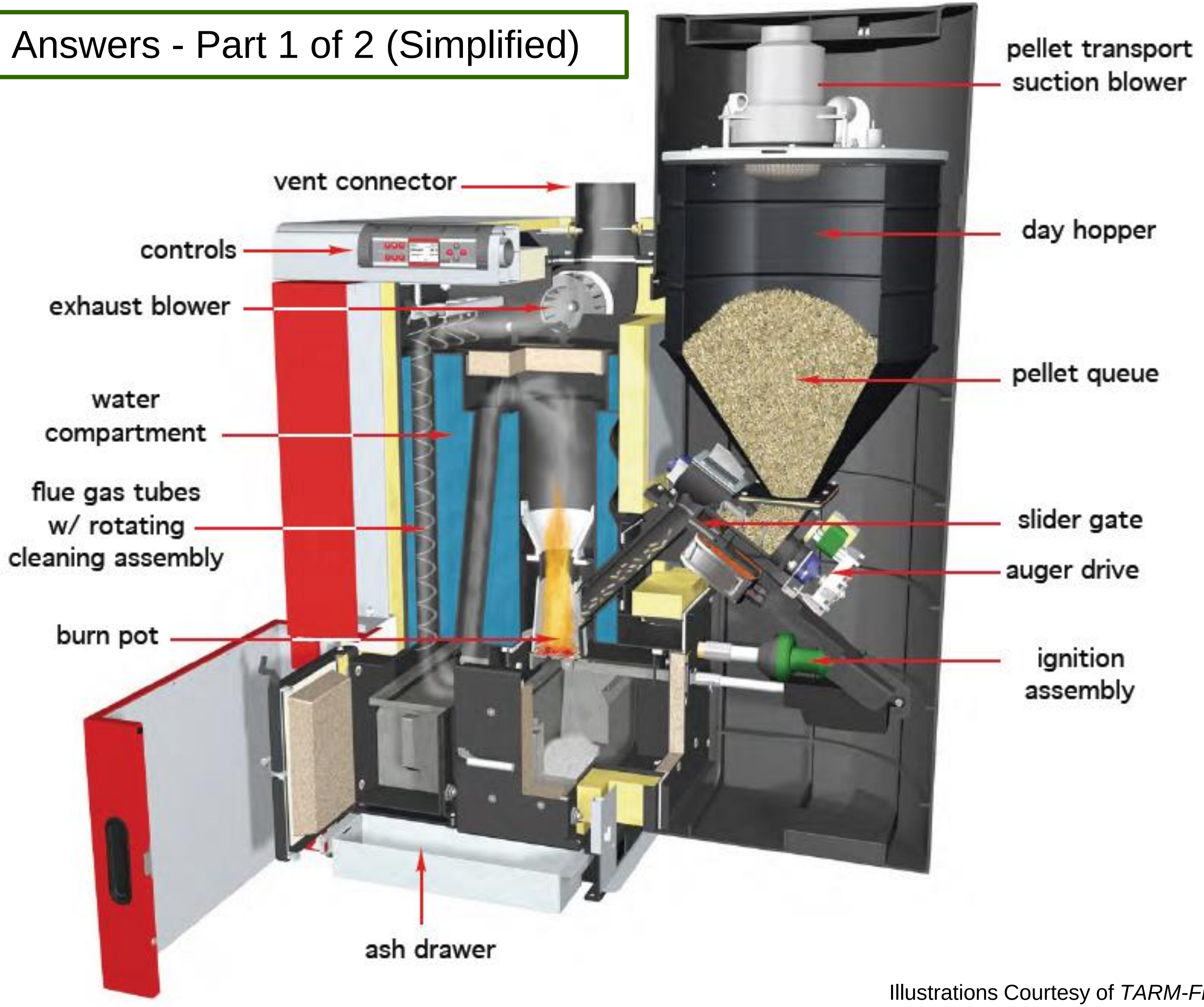
Illustrations Courtesy of *TARM-Froling*

<u>Question</u> - Identify High-Efficiency Wood Pellet Boiler **Components**



Illustrations Courtesy of *TARM-Froling*

Answers - Part 1 of 2 (Simplified)



Illustrations Courtesy of *TARM-Froling*

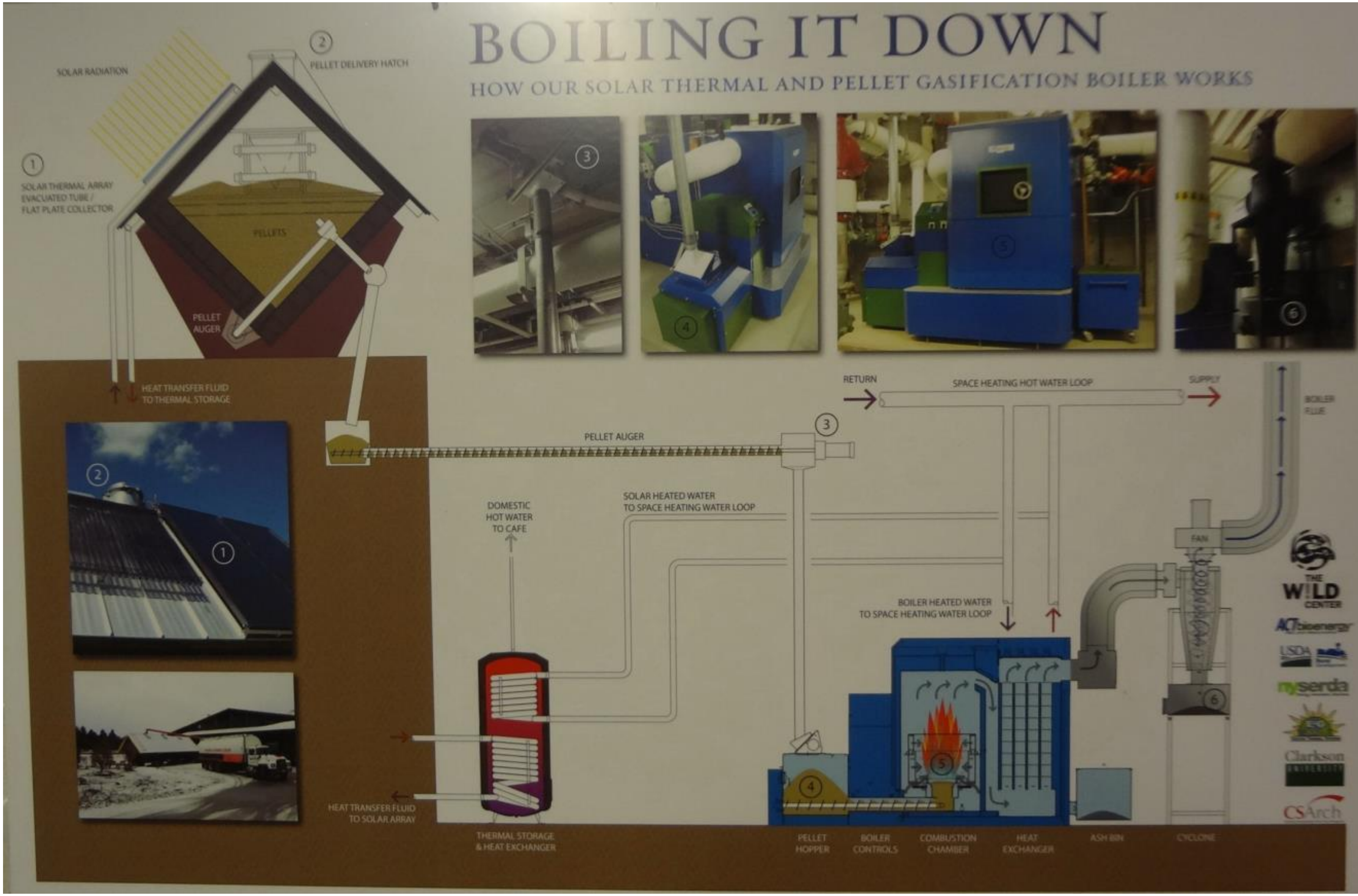
Answers - Part 2 of 2 (Detailed)

1. Insulated cleaning door for heat retention
2. **EOS** technology (Efficiency Optimization System) for high efficiency with automatic drive for continuous cleaning.
3. Lambdatronic P3200 microprocessor control.
4. Speed regulated induced draught fan for highest operating efficiency.
5. Spacious storage container with automatic pellet feed.
6. Insulated cleaning door for excellent heat retention.
7. Easy access ash container for easy emptying of ash. Large container size for a longer emptying interval.
8. The larger boilers have ash removal screws which transport the ash to two closed ash boxes.
9. Patented multiple-pass heat exchanger for variable boiler operation. The 3-pass heat exchanger guarantees the highest possible ash separation.
10. Automatic sliding grate for ash removal. Almost maintenance-free operation.
11. Tested sealed slider guarantees safe operation of the boiler.
12. Automatic ignition.
13. Special cyclone fitment with integrated silencer for quiet operation.

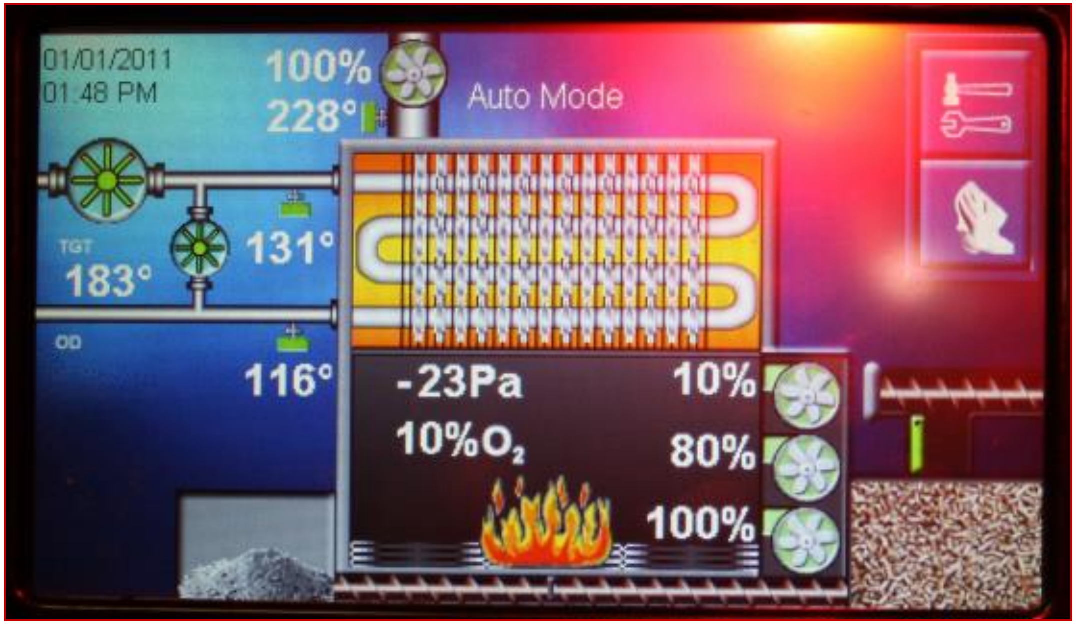
Illustrations Courtesy of *TARM-Froling*

W!ld Center Example

W!ld Center


BOILING IT DOWN
HOW OUR SOLAR THERMAL AND PELLET GASIFICATION BOILER WORKS
SOLAR RADIATION
PELLET DELIVERY HATCH
SOLAR THERMAL ARRAY
EVACUATED TUBE /
FLAT PLATE COLLECTOR
PELLETS
PELLET AUGER
HEAT TRANSFER FLUID
TO THERMAL STORAGE
PELLET AUGER
RETURN
SPACE HEATING HOT WATER LOOP
SUPPLY
BOILER FLUE
DOMESTIC
HOT WATER
TO CAFE
SOLAR HEATED WATER
TO SPACE HEATING WATER LOOP
BOILER HEATED WATER
TO SPACE HEATING WATER LOOP
FAN
HEAT TRANSFER FLUID
TO SOLAR ARRAY
THERMAL STORAGE
& HEAT EXCHANGER
PELLET
HOPPER
BOILER
CONTROLS
COMBUSTION
CHAMBER
HEAT
EXCHANGER
ASH BIN
CYCLONE
THE WILD CENTER
ACT bioenergy
USDA
nyserda
Clarkson
UNIVERSITY
CSArch

Like any other commercial boiler or chiller, Biomass boilers also have their own built-in microprocessor based control and display panels



Controls Courtesy of *ACT Bioenergy*

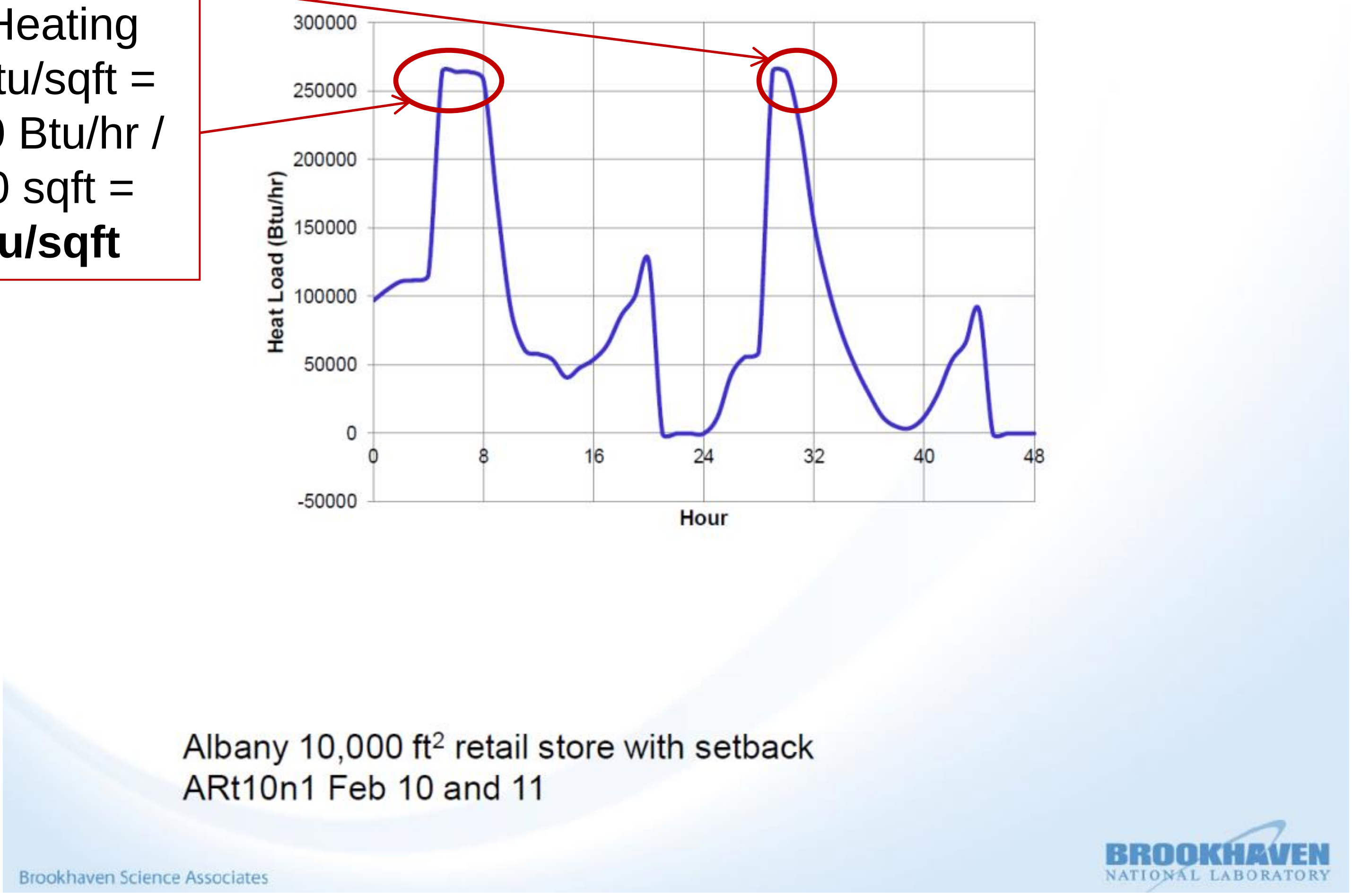
Five very important slides covering five important topics from five valuable guys:

1. Building heating load profile example,
2. Biomass boilers part load efficiency concerns,
3. Biomass boiler sized to provide 50% of the peak heating load; “small is beautiful or less is more”, charted vs. OAT,
4. Biomass vs. fuel oil consumption estimated monthly,
5. Recap on all of the above (put it all together).

Note - RHNY TCs are encouraged to visit demonstration sites like the Wild Center as well as biomass boiler manufacturers.

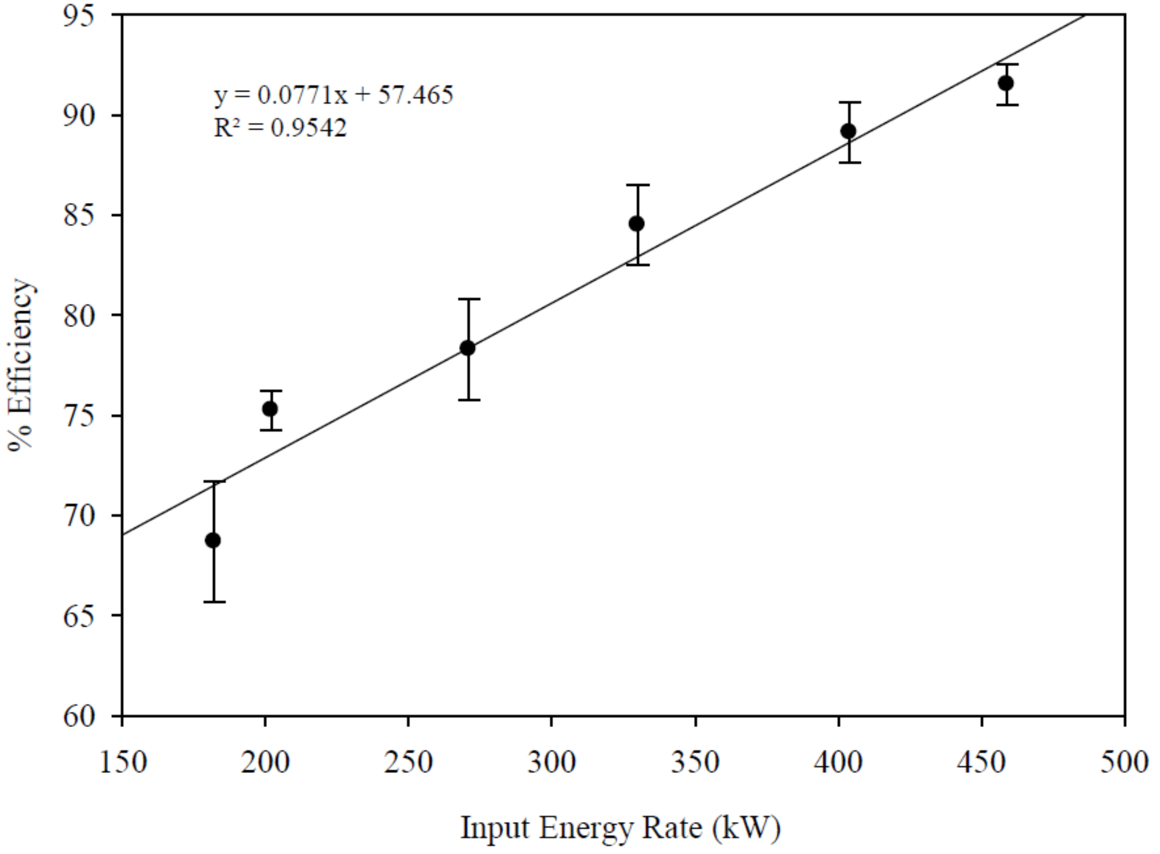
[1] Example of Diurnal Load Profile using Energy Modeling and/or Metering

Peak Heating Load Btu/sqft = 270,000 Btu/hr / 10,000 sqft = **27 Btu/sqft**



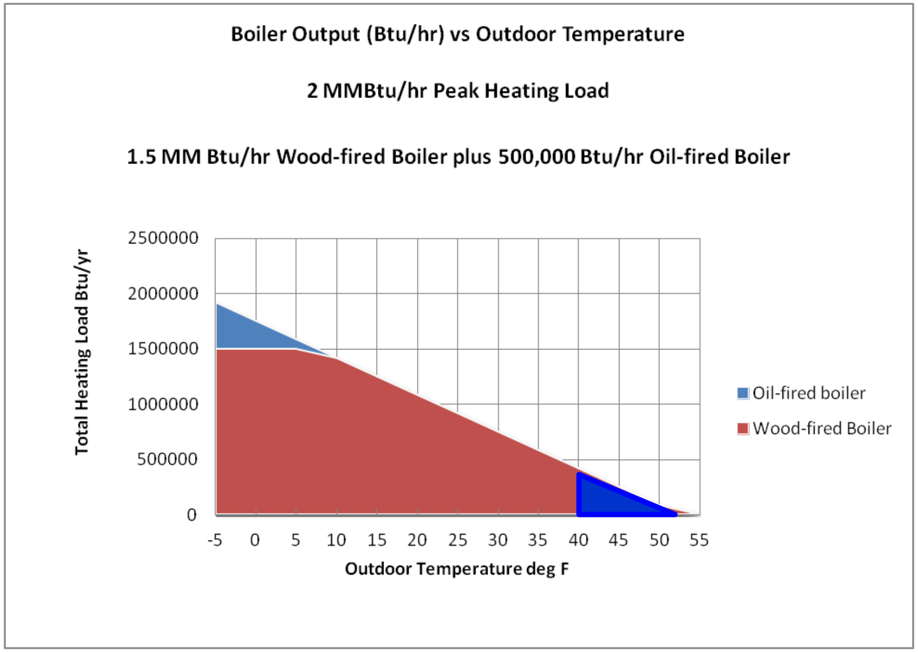
Courtesy of Dr. Thomas Butcher, BNL

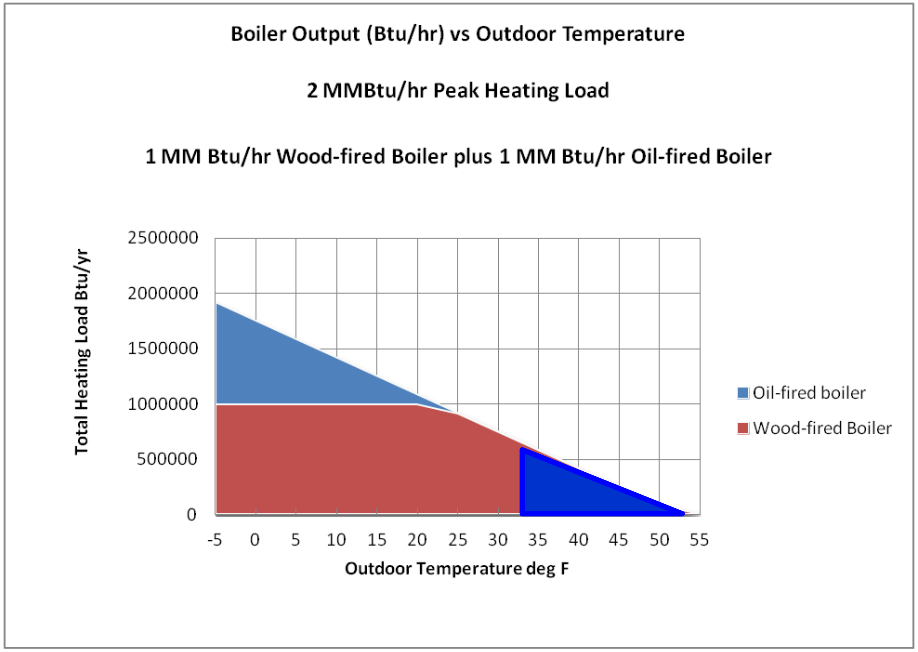
[2] Thermal efficiency of the Wild Center's 1.7 Million Btu/hr wood pellet boiler varies with load



Courtesy of Professor Philip K. Hopke, Ph.D. of Clarkson University

[3] Boiler Sizing Methods
"Small is beautiful" or "less is more"

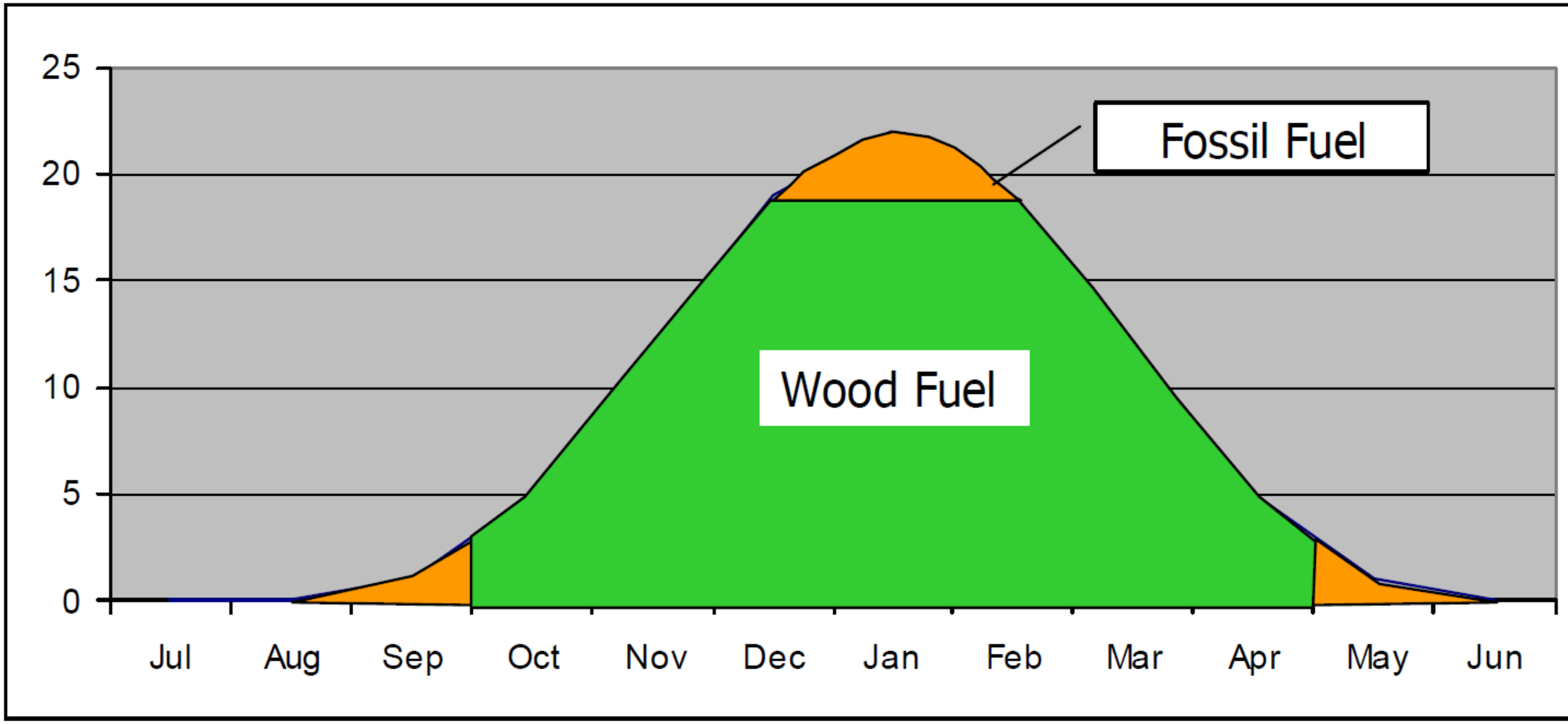




- **Wood-fired boiler sized to provide 50% of <u>peak heating load</u> (vs. 75%).**
- **Can meet entire bldg. heating load down to about 20 deg F (vs. 10 Deg F).**
- **Wood boiler meets ~80% of annual heating needs (vs. > 90%).**
- **Superior 80% to 85% targeted efficiency vs. mid 60s.**

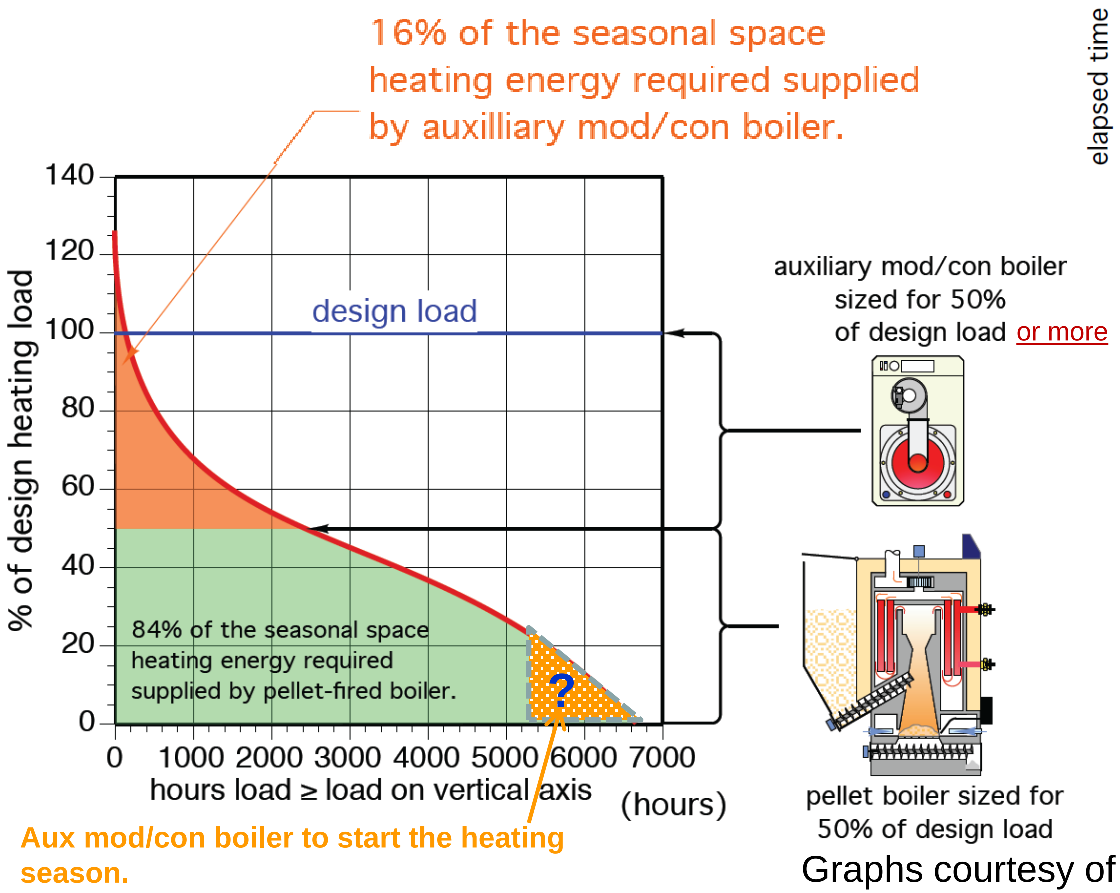
Graphs courtesy of Ray Albrecht 2013 Presentations

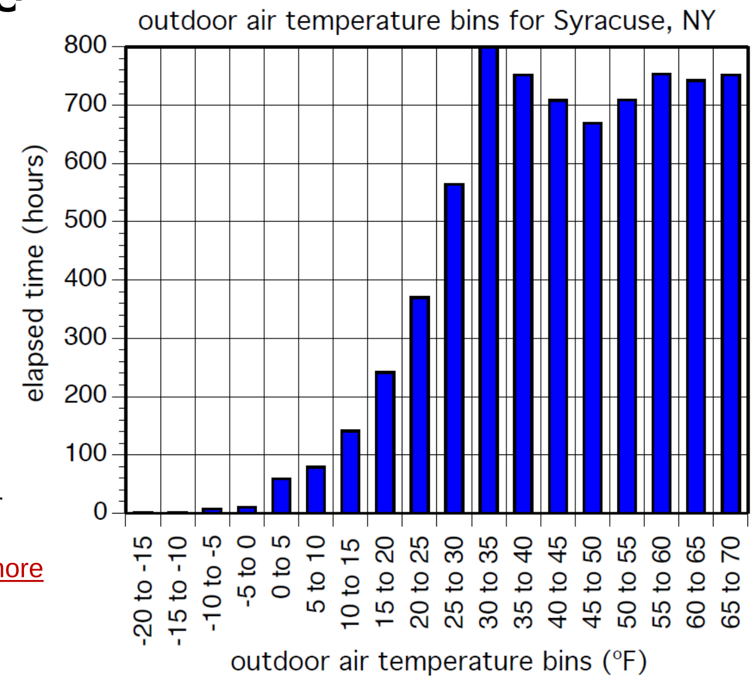
[4] Estimated Fuel Use Replaced by Biomass Boiler



Graph courtesy of David Dungate 2013 Presentations

[5] Temp Bins, Boiler Sizing, & Load Analysis, Let us put it all together!





Graphs courtesy of John Siegenthaler 2014 Presentations


Morning Coffee Break

Section 3

How the Energy Measurement and Verification (M&V) Process benefits the on-going Building Commissioning (Cx) and Troubleshooting Activities

This section offers a high level introduction of the process of Measurement and Verification (M&V) and the four (4) M&V Options offered by IPMVP (International Performance Measurement and Verification Protocols). It discusses establishing an energy baseline, billing analysis, M&V Plans, and M&V Execution.

Topics Covered / Learning Objectives

- **[A]** This section offers a high level introduction of the process of Measurement and Verification (M&V) and the four (4) M&V Options offered by IPMVP (International Performance Measurement and Verification Protocols). It discusses establishing an energy baseline, billing analysis, M&V Plans, M&V Execution, and a few other relevant topics.

- **[B]** The training then continues to discusses the data collection process, trend logging, setting up Range and Relational (R&R) Checks, Regressions, and other data analyses and practices required for a successful M&V process and system troubleshooting. It also lists several EEMs that are good candidates for M&V implementation using any of the 4 IPMVP options as appropriate - See the Energy Audit Section for this.

- **[C]** Finally, the training finally shares many lessons from the trenches regarding how collected M&V data and subsequent in depth data analyses were used. Ongoing system commissioning and troubleshooting were conducted to correct the HVAC&R system controls and operation to attain energy savings persistence and *fuel displacement* targets over a wide variety of diverse energy projects (10 Examples will be used in this training).

Section 3-A
Introduction to M&V (General)

This section offers a high level introduction of the process of Measurement and Verification (M&V) and the four (4) M&V Options offered by IPMVP (International Performance Measurement and Verification Protocols). It discusses establishing an energy baseline, billing analysis, M&V Plans, and M&V Execution.

Question - What Does M&V stand for and how can you define it?

M&V?

1. Measurement and Verification.
2. Measurement and Validation.
3. Metering and Verification.
4. Metering and Validation.
5. Monitoring and Verification.
6. Monitoring and Validation.
7. I do not really care what you call it, just do it right?

M&V Definition?

- Process for quantifying savings delivered by an EEM.
- Demonstrates how much energy the EEM has avoided using, rather than the total *cost* saved. The latter can be affected by many factors, such as energy prices.
- Enables the energy savings delivered by the EEM to be isolated and fairly evaluated.
- ***In addition to all of the above, M&V verifies the fuel displacement and financial savings attributable to biomass projects and supports protecting system components.***

- Various protocols for good practice in Measurement and Verification exist, including the International Performance Measurement and Verification Protocol (IPMVP), which defines common terminology and the key steps in implementing a robust M&V process.
- A key part of the M&V process is the development of an 'M&V Plan', which defines how the savings analysis will be conducted before the EEM is implemented. This provides a degree of objectivity that is absent if the savings are simply evaluated after implementation".

Courtesy of Wikipedia Definitions

Same applies to biomass projects where the EEM is actually adding biomass boilers to an existing fossil fuel plant coupled with other EEMs to support a sustainable and properly sized biomass heating project with TES/Buffer, etc. as defined earlier.

How to M&V?

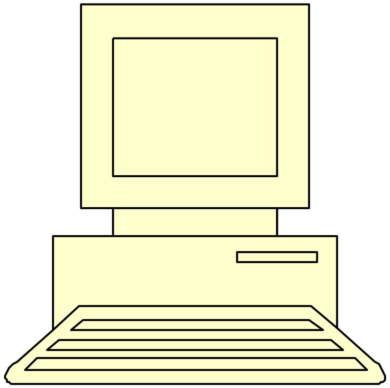
In General,

Energy Savings =

(Baseline or **Pre**-Installation energy Usage) -

(**Post** Installation Energy Usage).

It is not that simple!



My own opinion

- To me, M&V is just a matter of good energy management. It should be done and become part of most energy projects.
- Continuous M&V and Continuous Cx - They go hand in hand as they both rely on EMS data trends as well as many field observations and checks.
- Yes it can be done, it is not difficult, but let us do it right.

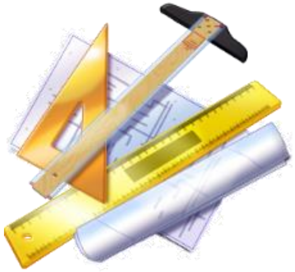
Question - Why Measurement & Verification?

1. Quantify energy and cost savings and *fuel displacement*,
2. Verify *properly sized boilers* and other support systems,
3. Ensure correct biomass system *operation, controls and integration* with existing heating systems, energy management and controls system (EMCS), and heat distribution systems,
4. Verify the effectiveness and benefits from *TES/buffering*,
5. Facilitate building and *System Commissioning (Cx)*& troubleshooting activities,
6. Support energy savings and performance validation.
7. Facilitate billing with campus style settings that have heat (or chilled water) sale agreements.

<< This slide is also under M&V Biomass “Specific” Section-7 due to its importance>>

"You cannot manage what you do not <u>measure</u>"

"You cannot expect what you do not <u>inspect</u>"



The alternative is, "Trust me - you saved!"

Question - How Many M&V Resources do we have?

- **ASHRAE Guideline 14P**, Measurement of Energy and Demand Savings,
- **FEMP** (Federal Energy Management Programs) M&V Guidelines for Federal Energy Projects,

- **IPMVP** (International Performance Measurement & Verification Protocol):
  - Concepts and Options for Determining Energy and Water Savings - Volume I,
  - Concepts and Practices for Improved Indoor Environmental Quality - Volume II,
  - Concepts and Practices in Renewable Energy Technologies Applications - Volume III,
  - Concepts and Options for Determining Energy Savings in New Construction - Volume III,
- **NEMVP** (North American Energy M&V Protocol) DOE.
- Trust me - you saved!, which is a NO-NO.
- The fox guarding the hen house.

ASHRAE Guideline 14P

ASHRAE GUIDELINE

Measurement of Energy and Demand Savings

FIRST PUBLIC REVIEW

April 2000

This draft has been recommended for public review by the responsible project committee. Public review of this proposed guideline has been authorized by a subcommittee of the Standards Committee. Instructions and a form for commenting are provided with this draft. Although reproduction of drafts during the public review period is encouraged to promote additional comment, permission must be obtained to reproduce all or any part of this document from the ASHRAE Manager of Standards, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. Phone: 404-636-8400, Ext. 502. Fax: 404-321-5478. E-mail: cramspeck@ashrae.org.

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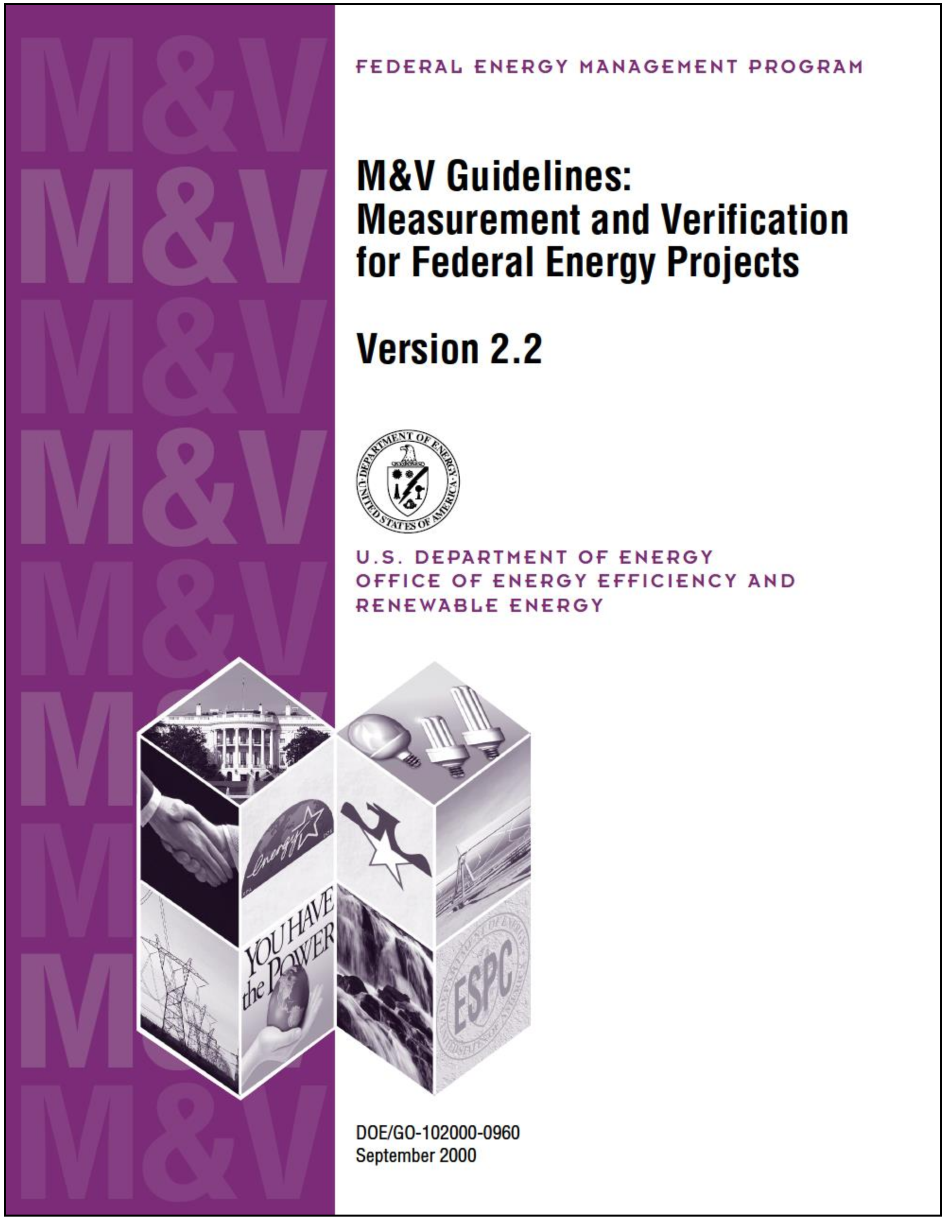

FEDERAL ENERGY MANAGEMENT PROGRAM

M&V Guidelines: Measurement and Verification for Federal Energy Projects

Version 2.2

U.S. DEPARTMENT OF ENERGY
OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

DOE/GO-102000-0960
September 2000

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Office of Energy Efficiency and Renewable Energy
Federal Energy Management Program
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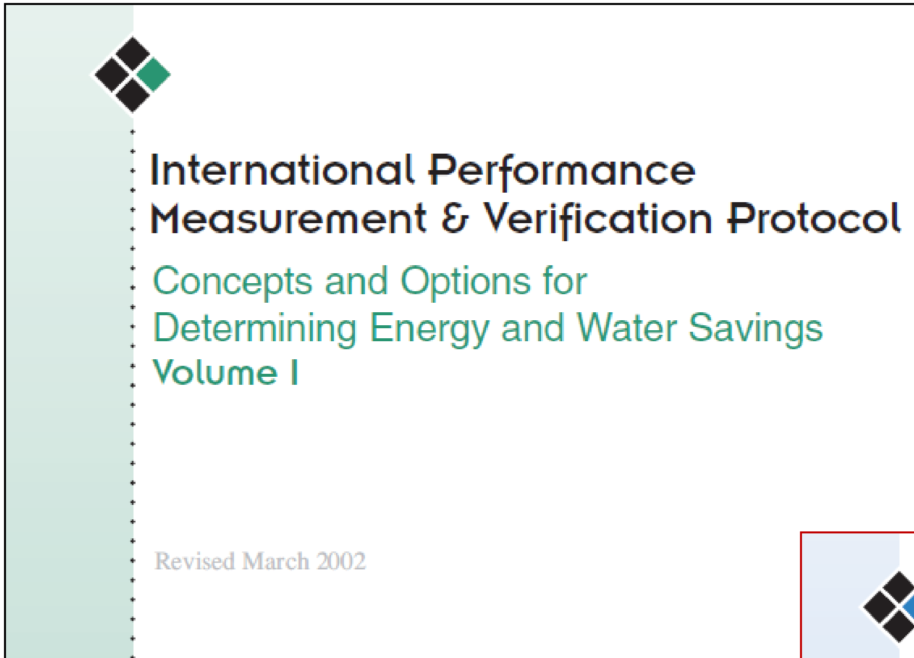
A U. S. Department of Energy national laboratory



International Performance Measurement & Verification Protocol

Concepts and Options for Determining Energy and Water Savings

Volume I

Revised March 2002

International Performance Measurement & Verification Protocol

Concepts and Practices for Improved Indoor Environmental Quality

Volume II

Revised March 2002

International Performance Measurement & Verification Protocol

Concepts and Practices for Determining Energy Savings in Renewable Energy Technologies Applications

Volume III

August 2003

International Performance Measurement & Verification Protocol

Concepts and Options for Determining Energy Savings in New Construction

Volume III

April 2003

EVO

EFFICIENCY VALUATION ORGANIZATION

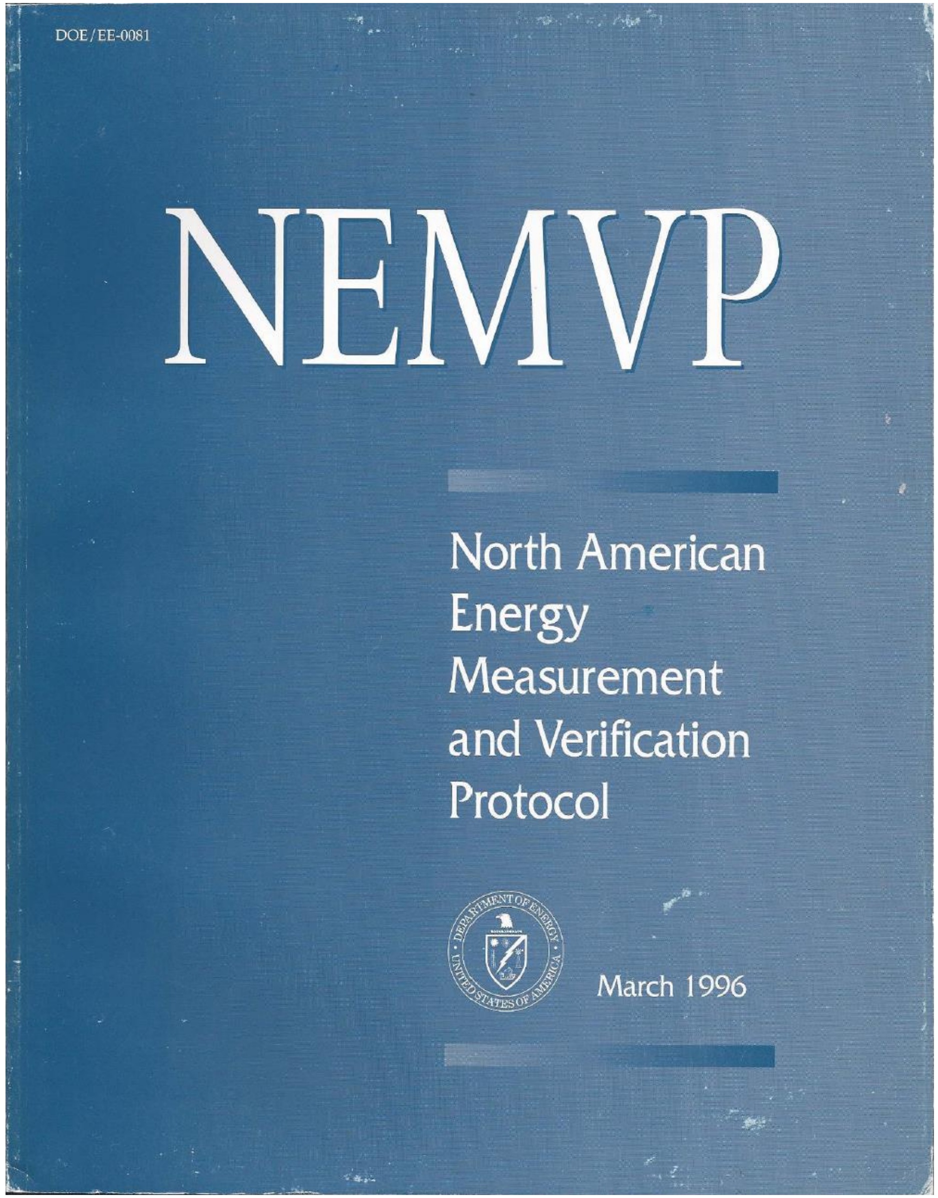
International Performance Measurement and Verification Protocol

Concepts and Options for Determining
Energy and Water Savings
Volume 1

Prepared by Efficiency Valuation Organization
www.evo-world.org

September 2010

EVO 10000 – 1:2010


DOE/EE-0081

NEMVP

North American Energy Measurement and Verification Protocol

March 1996

Question - What are the Famous Four (4) M&V Options and what is most appropriate for Biomass projects?

- **Option A - Stipulated Savings (with some measurements)**: This will be used with extreme caution and if the analysis is conservative and the savings are well supported and can be trusted without M&V.
- **Option B - Metered Savings of Equipment and Systems**: This is the most appropriate for many energy projects.
- **Option C - Whole Building Utility Billing Analysis**. This can be acceptable in very rare occasions at certain sites. For example, if there is a metered electrical feeder or panel that is solely serving "major" equipment that is directly impacted by an EEM. (pumping station or entire CHWP).
- **Option D - Calibrated Computer Simulation Models**: Ideal for new construction and can be used with caution in existing facilities. Nicely captures interactive effects, if the model is done correctly.
- **Option E** - Use an appropriate **hybrid** of the above in projects with multiple EEMs and as appropriate.

IPMVP Vol-I

Table 1: Overview of M&V Options

M&V Option	How Savings Are Calculated	Typical Applications
A. Partially Measured Retrofit Isolation Savings are determined by partial field measurement of the energy use of the system(s) to which an ECM was applied, separate from the energy use of the rest of the facility. Measurements may be either short-term or continuous. Partial measurement means that some but not all parameter(s) may be stipulated, if the total impact of possible stipulation error(s) is not significant to the resultant savings. Careful review of ECM design and installation will ensure that stipulated values fairly represent the probable actual value. Stipulations should be shown in the M&V Plan along with analysis of the significance of the error they may introduce.	Engineering calculations using short term or continuous post-retrofit measurements and stipulations.	Lighting retrofit where power draw is measured periodically. Operating hours of the lights are assumed to be one half hour per day longer than store open hours.
B. Retrofit Isolation Savings are determined by field measurement of the energy use of the systems to which the ECM was applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period.	Engineering calculations using short term or continuous measurements	Application of controls to vary the load on a constant speed pump using a variable speed drive. Electricity use is measured by a kWh meter installed on the electrical supply to the pump motor. In the baseyear this meter is in place for a week to verify constant loading. The meter is in place throughout the post-retrofit period to track variations in energy use.
C. Whole Facility Savings are determined by measuring energy use at the whole facility level. Short-term or continuous measurements are taken throughout the post-retrofit period.	Analysis of whole facility utility meter or sub-meter data using techniques from simple comparison to regression analysis.	Multifaceted energy management program affecting many systems in a building. Energy use is measured by the gas and electric utility meters for a twelve month baseyear period and throughout the post-retrofit period.
D. Calibrated Simulation Savings are determined through simulation of the energy use of components or the whole facility. Simulation routines must be demonstrated to adequately model actual energy performance measured in the facility. This option usually requires considerable skill in calibrated simulation.	Energy use simulation, calibrated with hourly or monthly utility billing data and/or end-use metering.	Multifaceted energy management program affecting many systems in a building but where no baseyear data are available. Post-retrofit period energy use is measured by the gas and electric utility meters. Baseyear energy use is determined by simulation using a model calibrated by the post-retrofit period utility data.

IPMVP Vol-III

Table 1:Overview of New Construction M&V Options

M&V Option	How Baseline is Determined	Typical Applications
A. Partially Measured Retrofit Isolation Savings are determined by partial measurement of the energy use of the system(s) to which an ECM was applied, separate from the energy use of the rest of the facility. Some parameters are stipulated rather than measured.	Projected baseline energy use is determined by calculating the hypothetical energy performance of the baseline system under post-construction operating conditions.	Lighting system where power draw is periodically measured on site. Operating hours are stipulated.
B. Retrofit Isolation Savings are determined by full measurement of the energy use and operating parameters of the system(s) to which an ECM was applied, separate from the rest of the facility.	Projected baseline energy use is determined by calculating the hypothetical energy performance of the baseline system under measured post-construction operating conditions.	Variable speed control of a fan motor. Electricity needed by the motor is measured on a continuous basis throughout the M&V period.
C. Whole Facility Savings are determined at the whole-building level by measuring energy use at main meters or with aggregated sub-meters.	Projected baseline energy use determined by measuring the whole-building energy use of similar buildings without the ECMs.	New buildings with energy-efficient features are added to a commercial park consisting of buildings of similar type and occupancy.
D. Calibrated Simulation Savings are determined at the whole-building or system level by measuring energy use at main meters or sub-meters, or using whole-building simulation calibrated to measured energy use data.	Projected baseline energy use is determined by energy simulation of the Baseline under the operating conditions of the M&V period.	Savings determination for the purposes of a new building Performance Contract, with the local energy code defining the baseline.

FEMP

Table 2.2: Overview of M&V Options

M&V Option	Performance and Operation Factors*	Savings Calculation	M&V Cost**
Option A—Stipulated and measured factors	Based on a combination of measured and stipulated factors. Measurements are spot or short-term taken at the component or system level. The stipulated factor is supported by historical or manufacturer's data.	Engineering calculations, component, or system models.	Estimated range is 1%-3%. Depends on number of points measured.
Option B—Measured factors	Based on spot or short-term measurements taken at the component or system level when variations in factors are not expected. Based on continuous measurements taken at the component or system level when variations are expected.	Engineering calculations, components, or system models.	Estimated range is 3%-15%. Depends on number of points and term of metering.
Option C—Utility billing data analysis	Based on long-term, whole-building utility meter, facility level, or sub-meter data.	Based on regression analysis of utility billing meter data.	Estimated range is 1%-10%. Depends on complexity of billing analysis.
Option D—Calibrated computer simulation	Computer simulation inputs may be based on several of the following: engineering estimates; spot, short-, or long-term measurements of system components; and long-term, whole-building utility meter data.	Based on computer simulation model calibrated with whole-building and end-use data.	Estimated range is 3%-10%. Depends on number and complexity of systems modeled.

*Performance factors indicate equipment or system performance characteristics such as kW/ton for a chiller or watts/fixture for lighting; operating factors indicate equipment or system operating characteristics such as annual cooling ton-hours for chillers or operating hours for lighting.
**M&V costs are expressed as a percentage of measure energy savings.

FEMP - Cont. 1

2.2.4 Determining Savings

After the ECM or system is installed, energy savings are determined at one time, continuously, or at regular intervals as agreed upon by the ESCO and the federal agency in the project-specific M&V plan.

Baseline energy use, post-installation energy use, and energy (and cost) savings can be determined using one or more of the following M&V techniques:

- Engineering calculations
- Metering and monitoring
- Utility meter billing analysis
- Computer simulations (e.g., DOE-2 analysis).

The savings calculation approach is generally dependent on the M&V option and method selected for the measure. In some instances, a combined M&V option approach is best suited for the measure. For example, for a building with multiple measures, a combination of Option A and Option B may be used for different measures.

If long-term monitoring is not used in the M&V technique, the ESCO and the agency must accept that the agreed-to savings will not equal the savings that would be determined through a process that involves rigorous analyses and measurements. If important values are stipulated, both parties should understand that the savings determination will tend to be less accurate than if measurements were used to determine the values.

Numerous factors can affect energy savings during the term of a contract. These factors include weather, occupancy, operating hours, equipment schedules,

FEMP - Cont. 2

Table 2.3: Summary of M&V Methods for Specific Energy Retrofits

Method	Section/ Chapter	ECM	Option	Approach
LE-A-01	III/7	Lighting efficiency	A	No metering
LE-A-02	III/7	Lighting efficiency	A	Spot metering of fixture wattage
LE-B-01	IV/13	Lighting efficiency	B	Continuous metering of operating hours
LE-B-02	IV/14	Lighting efficiency	B	Continuous metering of lighting circuits
LC-A-01	III/8	Lighting controls	A	No metering
LC-A-02	III/8	Lighting controls	A	Spot metering of fixture wattages
LC-B-01	IV/15	Lighting controls	B	Continuous metering of operating hours
LC-B-02	IV/16	Lighting controls	B	Continuous metering of lighting circuits
CLM-A-01	III/9	Constant load motors	A	Spot metering of motor kW
CLM-B-01	IV/17	Constant load motors	B	Continuous metering of motor kW
VSD-A-01	III/10	Variable speed drive retrofit	A	Spot metering of motor kW
VSD-B-01	IV/18	Variable speed drive retrofit	B	Continuous metering of motor kW, speed frequency, or controlling variables

FEMP - Cont. 3

Method	Section/ Chapter	ECM	Option	Approach
CH-A-01	III/11	Chiller retrofit	A	No metering
CH-A-02	III/11	Chiller retrofit	A	Verification of chiller kW/ton
CH-B-01	IV/19	Chiller retrofit	B	Continuous metering of new chiller and cooling load
CH-B-02	IV/19	Chiller retrofit	B	Continuous metering of new chiller and cooling equipment
GVL-B-01	IV/20	Generic variable load project	B	Continuous metering of end-use energy use
GVL-C-01	V/22	Generic variable load project	C	Utility bill regression analysis
GVL-C-02	V/23	Generic variable load project	C	Utility bill comparison
GVL-D-01	VI/25	Generic variable load project	D	Calibrated simulation model

FEMP - Cont. 4

Table 2.4: Summary of M&V Methods for Water Conservation Measures

Method	Section/ Chapter	ECM	Option	Approach
WCM-A-01	VII/27	Water conservation measure	A	Stipulated operating factors, spot-measured performance factors
WCM-A-02	VII/28	Water conservation measure	A	Spot-measured operating and performance factors
WCM-B-01	VII/29	Water conservation measure	B	Short-term or continuously measured operating and performance factors
WCM-C-01	VII/30	Water conservation measure	C	Historical and current utility meter or sub-meter data
WCM-D-01	VII/31	Water conservation measure	D	Calibrated simulation model

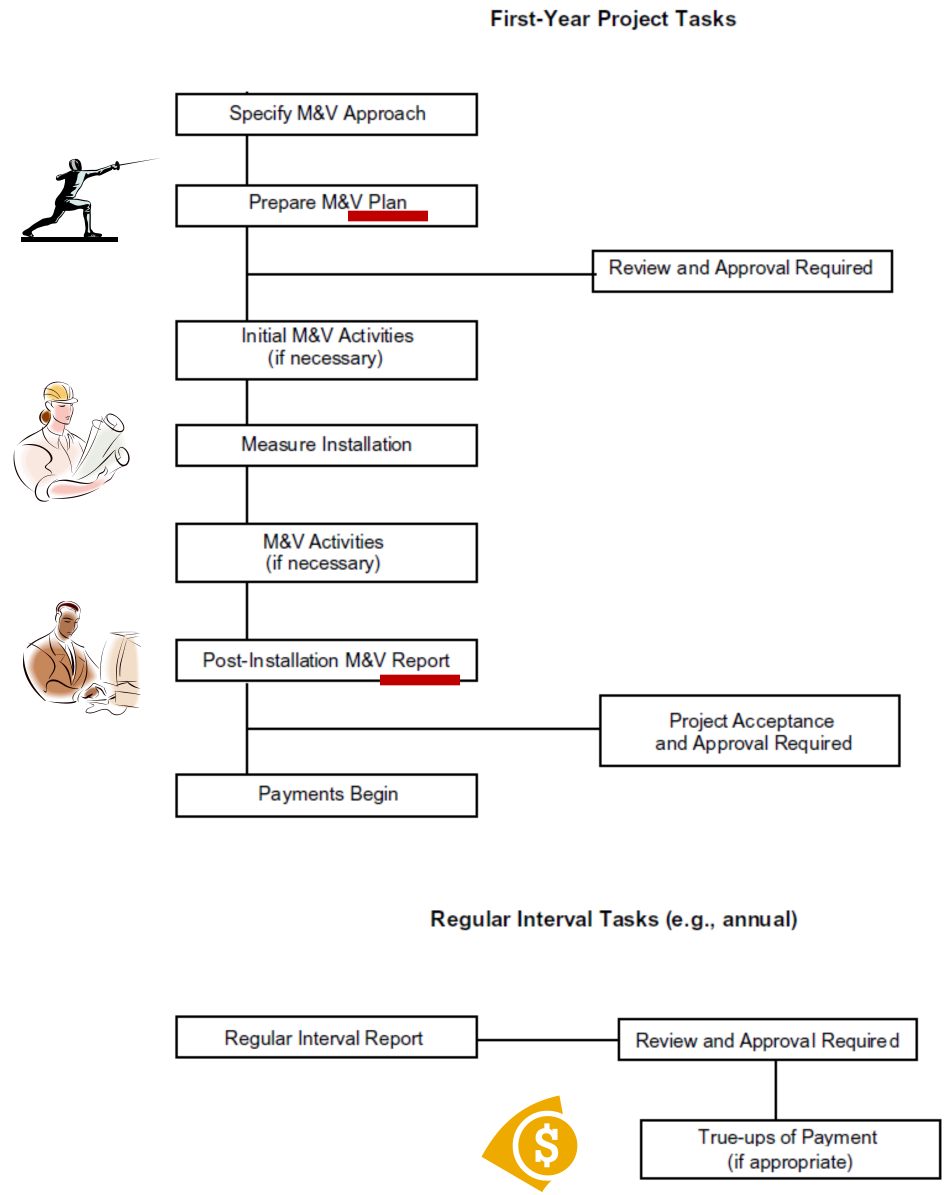
FEMP - Cont. 5

Table 2.5: Summary of M&V Methods for Other Project Categories

Method	Section/ Chapter	ECM	Option	Approach
NC-A-01	VIII/32	New construction	A	Stipulated operating factors, measured performance factors
NC-B-01	VIII/32	New construction	B	Measured operating and performance factors
NC-C-01	VIII/32	New construction	C	Baseline simulation, post-installation billing data
NC-C-02	VIII/32	New construction	C	Baseline stipulation, post-installation billing data
NC-D-01	VIII/32	New construction	D	Calibrated simulation model
OM-01	VIII/33	Operation and maintenance measures	A, B, C, D	Various
COG-01	VIII/34	Cogeneration projects	A, B, C, D	Various
REN-01	VIII/35	Renewable energy projects	A, B, C, D	Various

FEMP - Cont. 6

Figure 3.1: Overall Project Procedures



Other M&V Topics for discussion:

- Discussion of the importance of developing a reliable energy baseline and why.
- Baseline measurements.
- Regressions (before and after).
- M&V duration (1-week to 1-year or up to 3-years or more).
- Model calibrations (base and post), modeling challenges.
- Third party and independence (remember the story of the “fox guarding the hen house”).
- Weather files.
- USGBC LEED Requirements.
- Other Misc Topics.

Question - Suggested an M&V Plan Outline

An M&V Plan may include but is not limited to:

1. Project Description,
2. Selected M&V Options, and why, per EEM,
3. M&V Activities,
4. List of data points,
5. Savings Equations, Calculations, Regressions,
6. Tables,
7. Engineering units must be clear,
8. Schedule & Duration,
9. QC & Corrective Actions,
10. Ensure it is clear and straightforward with no ambiguity,
11. Define Roles and Responsibilities, etc.

Examples of M&V Equations

- Simple example of equations for calculating electricity and demand savings:

$$\text{kWh Savings}_t = \Sigma_u[(\text{kW/Fixture} \times \text{Quantity} \times \text{Hours of Operation})_{\text{baseline}}$$
$$-(\text{kWh/Fixture} \times \text{Quantity} \times \text{Hours of Operation})_{\text{post}}]_{t,\,u}$$

- Equations become more complex with variable loads, chillers, etc.

- There are hundreds or thousands of M&V equations depending on EEM type,

- Discuss accounting for interactive effects between lighting and cooling and heating,

- Biomass projects account for all of the above with special attention to fuel displacement calculations and measurements as discussed in more details later in this training,

M&V Report Suggested Outline

- Report components are somewhat similar to the M&V plan, but obviously there is more focus on reporting results and explanations for why results may vary from predicted savings.

- Someone may get embarrassed when M&V results are out!
- Remember, the M&V report is as good as the one who prepares it; it is not a one size that fits all. It is suggested that you have an independent and experienced 3rd party M&V agent to obtain reliable M&V results.

Question - What is the ideal duration for good energy baseline development in energy project and why?

- Baseline billing ranges from one year to three years. Three years is preferred to account for weather variations and changes in schedules, facility use, or major recent rehabilitation projects.
- Observe missing bills and apparently erroneous bills as certain billing correction opportunities may identify themselves easily ($$$ saving possible).
- Brief discussion of 1-week baselines and stipulations where appropriate only for certain electrical non-weather dependent EEMs like indoor lighting.

Obtain energy usage information

- Obtain hardcopies of some energy bills (not always),
- Electronic billing records (preferred if accurate),
- Hourly interval meter data,
- Water and Sewer Bills,
- EMCS Points Lists,
- EMCS Trend Logged Data (if available),
- Chiller/Boiler Logs,
- Process Logs,
- Utility Tariffs,
- Request deploying energy loggers (if possible) on major energy consuming equipment that has no available baseline data or logs.
- *Fuel tank level readings specially with biomass projects*.

Question - What general building benchmarks do you think work better for northeast climates (for M&V baseline & post retrofits)? Differentiate between general EUIs vs. Individual EEMs.

& what to do with the energy usage Info?

Process and analyze the data. This includes, but is not limited to:

- Normalize energy per square foot figures: Calculate $/ft2/year, kBtu/ft2/year, Btu/sqft/year, *Peak Btu/h/sqft (for the building vs. the heating plant)*, Watts/sqft, EFLH (elec and fuel), sqft/ton, $/occupant, $/product, etc.,
- Normalize energy use, using other indices such as number of students, number of inmates, number of hospital beds, number of manufactured products, etc.,
- Identify seasonal patterns, unusual spikes, consistency and accuracy of the data,
- Compute EUI (Energy Utilization Index) in kBtu/sqft/year using clearly defined conversion factors,
- Compare EUI to published benchmarks, if available,
- Compare EUI to similar facilities owned by the same customers or other customers, if available, for a campus or district settings, or multiple site,
- Other computations, as appropriate, for specialty facilities.

What to do with the energy usage info? Cont.

- Rank order facilities based on their importance and determine level of effort based on their rank,
- Identify obvious problems such as demand spikes, irregular demand profile, ratchets, *abnormal EFLHs*, and high energy usage intensities in general, etc.,
- Identify certain HVAC equipment abnormalities depending on the level of end use breakout of the baseline data,
- An advanced version of the billing analysis attempts to provide a baseline end use breakout/allocation for where the energy is consumed. This can be a very difficult task before conducting an energy audit*; however is a doable task after concluding the audit. A good end use breakout is part of a good baseline development.

* Expert Energy Professionals can put place holders early enough based on past experience with similar facilities.

Question - What is the difference between an annual building utility bill analysis and blood work in your annual physical exam?

Answer

- An annual utility bill analysis examines the heath conditions of a buildings and its associated energy consuming systems.
- While the blood work and your annual physical exam examines you health and living and eating habits?
- The answer is that there are many similarities despite coming from two different fields (medicine vs. engineering).

Congratulations!

Now you have completed Section 3-A of this training covering a high level introduction of the process of Measurement and Verification (M&V) and the four (4) M&V Options offered by IPMVP (International Performance Measurement and Verification Protocols). It also discussed establishing an energy baseline, billing analysis, M&V Plans, M&V Execution and a few other relevant topics.

We also made introductions regarding some biomass M&V specifics, but more will come later in this training.

Section 3-B
Data Collection Related Topics (General)

The training then continues to discusses the data collection process, trend logging, setting up Range and Relational (R&R) Checks, Regressions, and other data analysis and practices required for a successful M&V process and system troubleshooting.

It also lists several EEMs that are good candidates for M&V implementation using any of the 4 IPMVP options as appropriate.

- Data collection process,
- Trend logging,
- Setting up Range and Relational (R&R) Checks,
- Regressions, why?
- Good data analysis is required for a successful M&V process and system Cx and troubleshooting.

Baseline Examples/Types

ASHRAE Guideline 14P, Measurement of Energy and Demand Savings
First Public Review

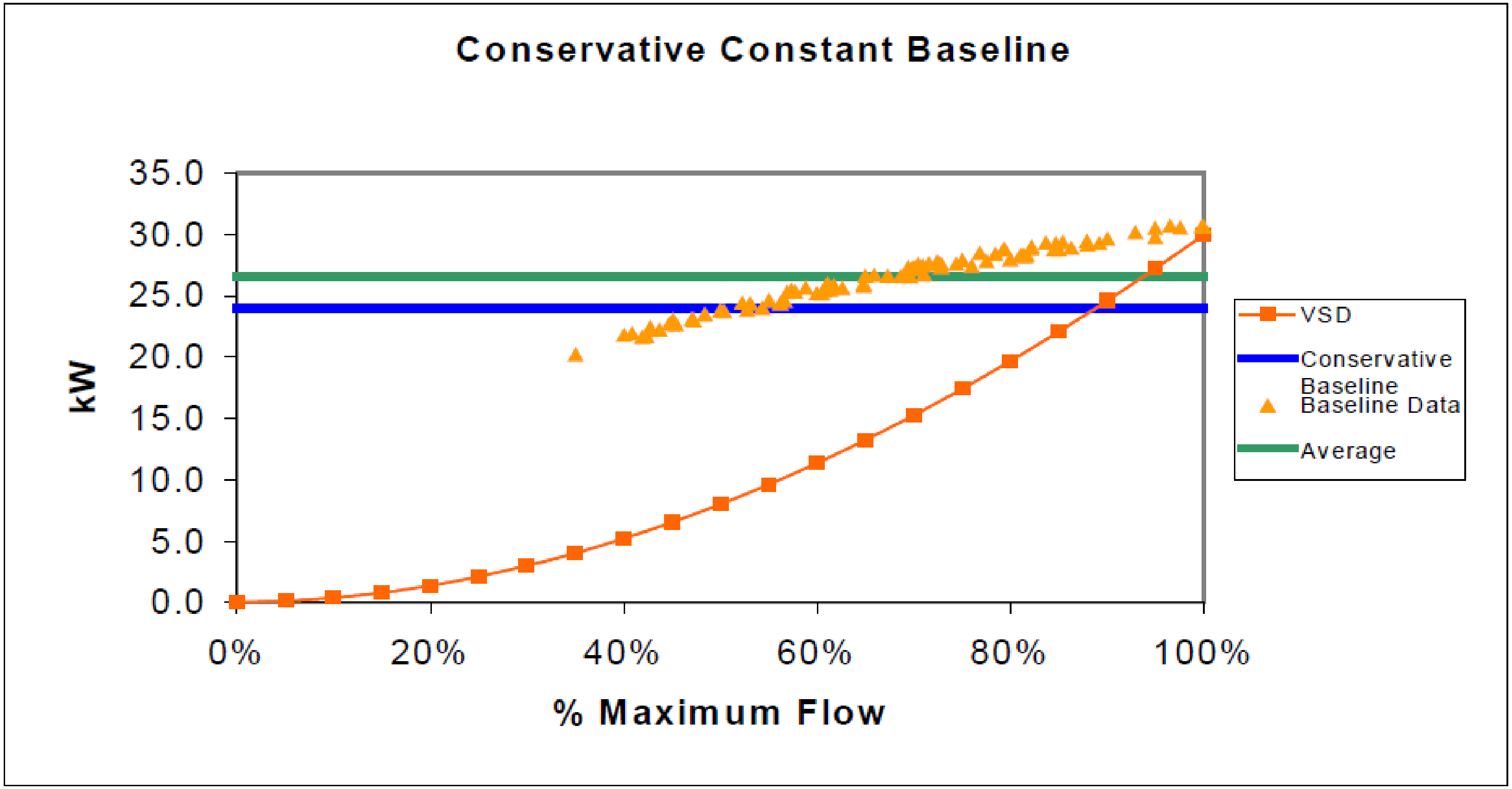


Figure C2.1-3: Assuming a Constant Baseline

The energy professional (Auditor, M&V or Cx Agent) may need to obtain building & system information & data about the following building end use categories, as appropriate, and may follow the suggested order below for successful EEM identification, M&V & Cx in large energy projects:

General/Facility Wide

- Envelope,
- Lighting,
- HVAC systems,
- DHW,
- Central plant (chillers, *boilers, PRVs, plant pumps*, etc.) - May be done first,
- Backup generators,
- TES (Thermal Energy Storage) for hot water, chilled water and ice,
- Electricity Storage (Batteries and Fly wheels),
- Distribution Systems (chilled water, primary hot water, DHW & steam),
- CHP & CCHP.

Specialty Systems

- Process equipment,
- Vertical transportation,
- Compressed air systems,
- Refrigeration equipment,
- Pools,
- Ice skating arenas,
- Power generation equipment (small, medium and large scale).

Note - All of the above were implemented in a sequential rolling base method during an audit and M&V implementation may follow.

Question - Provide examples of Knowledge areas and subjects that may support the M&V Specialist during <u>remote metering</u> with Large ESCOs?

Suggested answers include but are not limited to:

- Building Description and Pictures,
- HVAC System Description, Schedules, Capacities, etc.,
- Central Plant Description,
- Need to have a good understanding of building systems,
- Reported Building/System Operational Problems,
- Reported changes in building use and schedules during the M&V execution period,
- Site visits.
- Previous Audits and Implementation Status, if any,
- Other relevant project information.

Important Notes and Warnings Regarding Collecting Excessive amounts of unnecessary and irrelevant data

- Do not get overwhelmed with obtaining a significant amount of unnecessarily data points. Most of the time, 1-hour data interval is enough, while 15-minute is excellent, but shorter intervals are unnecessary for most EEMs.
- Out of 1,000 points in an EMS, you may only need ~ 100 to ~200 points, so select them carefully.
- It is your responsibility to select the proper data points that are appropriate for your project and EEMs.
- The combination of proper selection of data points and a good understanding of the systems and EEMs during the M&V process requires a certain level of expertise.
- The use of sketches and flow diagrams is needed during data analysis, especially where the M&V specialist is located 3,000 miles away from the site at the ESCO HQ.
- Use your discretion when selecting and using data points and M&V protocols and do not make this an overkill task for yourself; however, do it right.

Safety 1st during site visits and for M&V specialist who are at the site (vs. 3,000 miles away!)

- Eye Goggles,
- Helmet,
- Ear plugs,
- Gloves,
- Steel toed shoes/boots,
- Ladder (arrange with site if it will be needed),
- Watch your head,
- Watch your eyes,
- Watch your step and back/head, when taking photos,
- Extra care and qualification is needed with data logging equipment, especially when accessing electrical panels,
- Observe posted safety/warning signs,
- Be responsible and careful.
- Take *Confined Space Training*, if needed, including but not limited to OSHA Std. Num. 1910.146..

Question - What equipment do you need to conduct system troubleshooting and Cx investigations? Do you need all equipment at all times, and why?

Simple/Non-intrusive Tools

- Infrared thermometer,
- Flashlight,
- Light level meter, flicker checker or discriminator,
- CO_2 meter,
- RH meter (Psychrometer - Hygrometer),
- Tape measure,
- Camera (vital for taking pictures of the building, HVAC systems, proposed measure locations, nameplate data, etc.),
- Extra batteries,
- ASHRAE Pocket guide,
- Useful engineering charts and/or tables, including but not limited to the psychometric chart, Mollier Diagram, head loss calculators, steam tables, conversion factors, combustion efficiency tables for natural gas, fuel oil and wood, etc.,
- Calculator,
- Screw driver (Phillips & flathead).

Specialized Equipment

- Multi-meter,
- Infrared thermography equipment,
- Different types of data loggers,
- Power factor and power quality meters,
- Combustion efficiency test instruments and gas analyzers,
- Air flow and velocity measurement devices.

- This list can be expanded depending on the complexity of the measures analyzed as well at the audit level.
- Specialized metering can be done by the M&V and Cx team (if they have the skills) or can be subbed out to specialty subcontractors, as needed.

General Advice

- If enough spot measurements are taken during the audit, M&V or Cx activities, try to reconcile to the building peak electrical demand, if you can.
- If spot measurements are not taken, try to reconcile using simple equipment nameplate data for motors (fans and pumps), RTUs, lighting Watts/sqft, Misc load Watt/sqft, etc. You can apply reasonable load factors for motors if measurements are not taken to complete that test.
- You do not have to be very accurate at this stage of the work; just ensure that you are not missing any major electrical end uses during the site inspection.
- Be aware that the above may not be a simple task, however, an attempt to reconcile can give you some peace of mind before you conclude your audit.

Short-Term Monitoring Equipment

- If appropriate, take hand-held spot measurements of major end uses. These will produce data used to determine existing equipment loading and efficiency.
- Additionally, the field team may elect to install non-intrusive monitoring equipment for a short duration (typically 1 to 4 weeks). Duration and monitoring equipment type vary based on the type of building energy systems and EEMs being metered.
- Data obtained from the <u>short duration monitoring</u> will yield actual (but <u>partial</u>) operating patterns and equipment usage/schedule.
- This data will be very important in the analysis of end uses with unknown usage patterns or schedules (getting something is better than nothing).
- Monitoring of selected end uses will serve to verify pre and post retrofit equipment usage and schedules.
- Obviously, before investing in short term monitoring equipment, try to use the <u>*EMS trend logs and/or other site available logs*</u> as this can be the least expensive method of obtaining trended data from a building.

Question - Provide examples of at least 10 EEMs that you may have identified during your energy audit and your customer requested M&V on many of them.

Also, think which of the 4 IPMVP options are most appropriate - there is obviously no one right answer so let us just discuss this one.

Results Shown in the Energy Audit Section 6 later in this training.

Congratulations!

Now that you have completed Section 3-B of this training, we have discussed the data collection process, trend logging, setting up Range and Relational (R&R) Checks, Regressions, and other data analysis and procedures required for a successful M&V process and system troubleshooting.

We will later discuss (under Energy Audits Section) several EEMs that are good candidates for M&V implementation using any of the 4 IPMVP options as appropriate.

Section 3-C
Lessons from the Trenches & Cx (General)

The General M&V training finally shares many lessons from the trenches of how collected M&V data and subsequent in depth data analyses were used for ongoing system commissioning and troubleshooting to correct the HVAC&R system controls and operation to attain energy savings and *fuel displacement* persistence during a wide variety of diverse energy projects. Including but not limited to:

4.3 Commissioning

FEMP

System commissioning is the process of ensuring that as-built installed systems are functioning according to their design intent. Commissioning new or retrofit systems in buildings is one method of verifying the performance potential of an installed ECM or system. Thus, commissioning can be part of the M&V process. For complex ECMs, such as HVAC and central plant systems, commissioning is the preferred method of performance verification. Commissioning plans should be developed during the design phase after ECMs and building systems are identified.

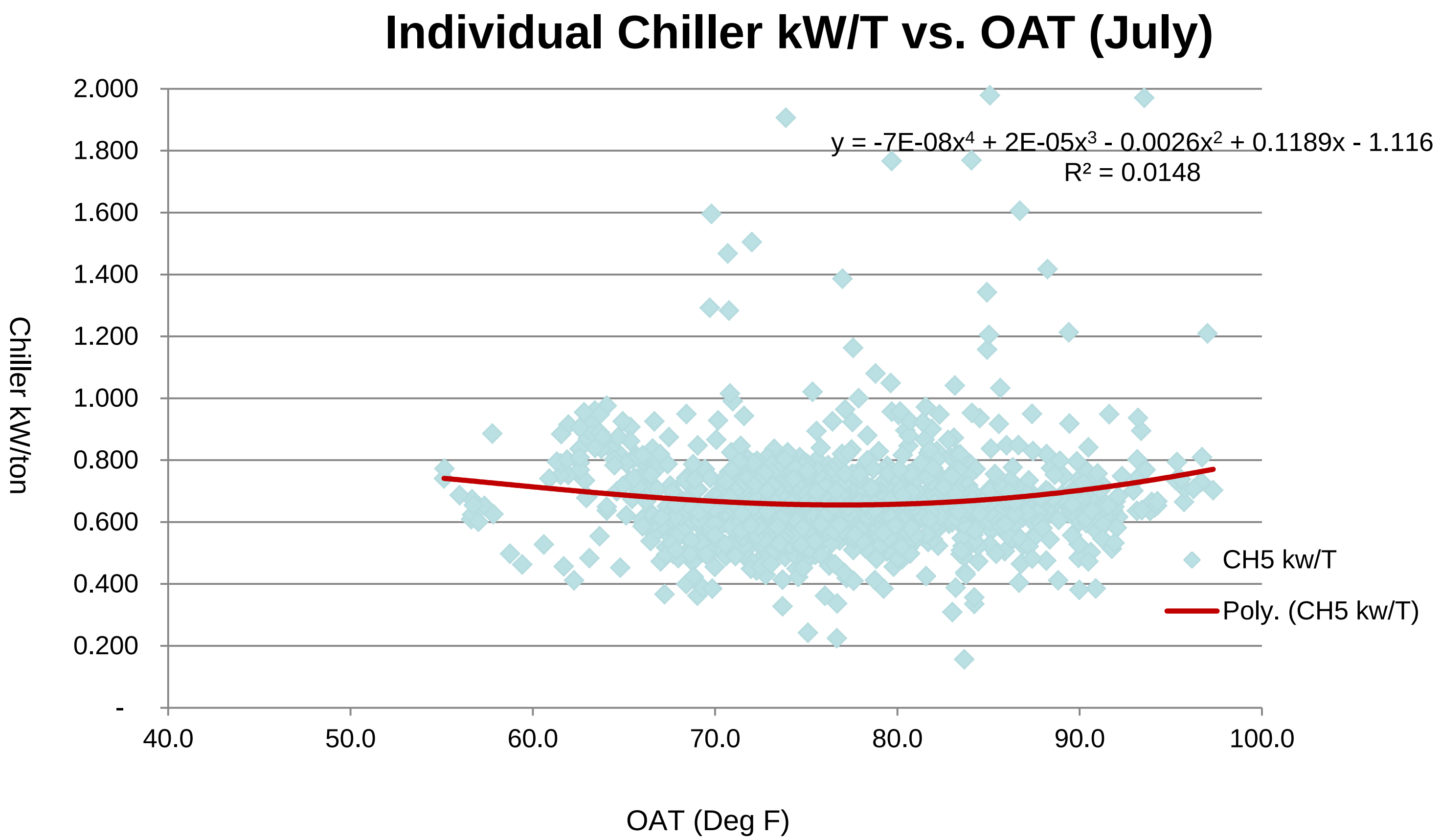
If buildings are to realize the full potential of proposed ECMs, adequate resources must be allocated to the commissioning process. This means that time scheduled for commissioning cannot be arbitrarily reduced, and an independent commissioning authority should be appointed. This person or agency should review the design documents to confirm that there is sufficient information to allow the systems to be correctly commissioned and should then oversee the complete commissioning process described in ASHRAE Guideline 1.

In addition to performing building commissioning, the design intent and correct operation of ECMs and systems should be documented for the building maintenance staff. Some ECMs such as natural ventilation, daylighting, nighttime flushing, and use of building thermal mass result in a building that behaves differently than a conventional building does. It is important that the commissioning contractor, building maintenance staff, and occupants understand how the building works. The federal agency may request the ESCO to conduct training sessions for the staff as part of the building commissioning to ensure that the ECMs and systems will be properly maintained and operated.

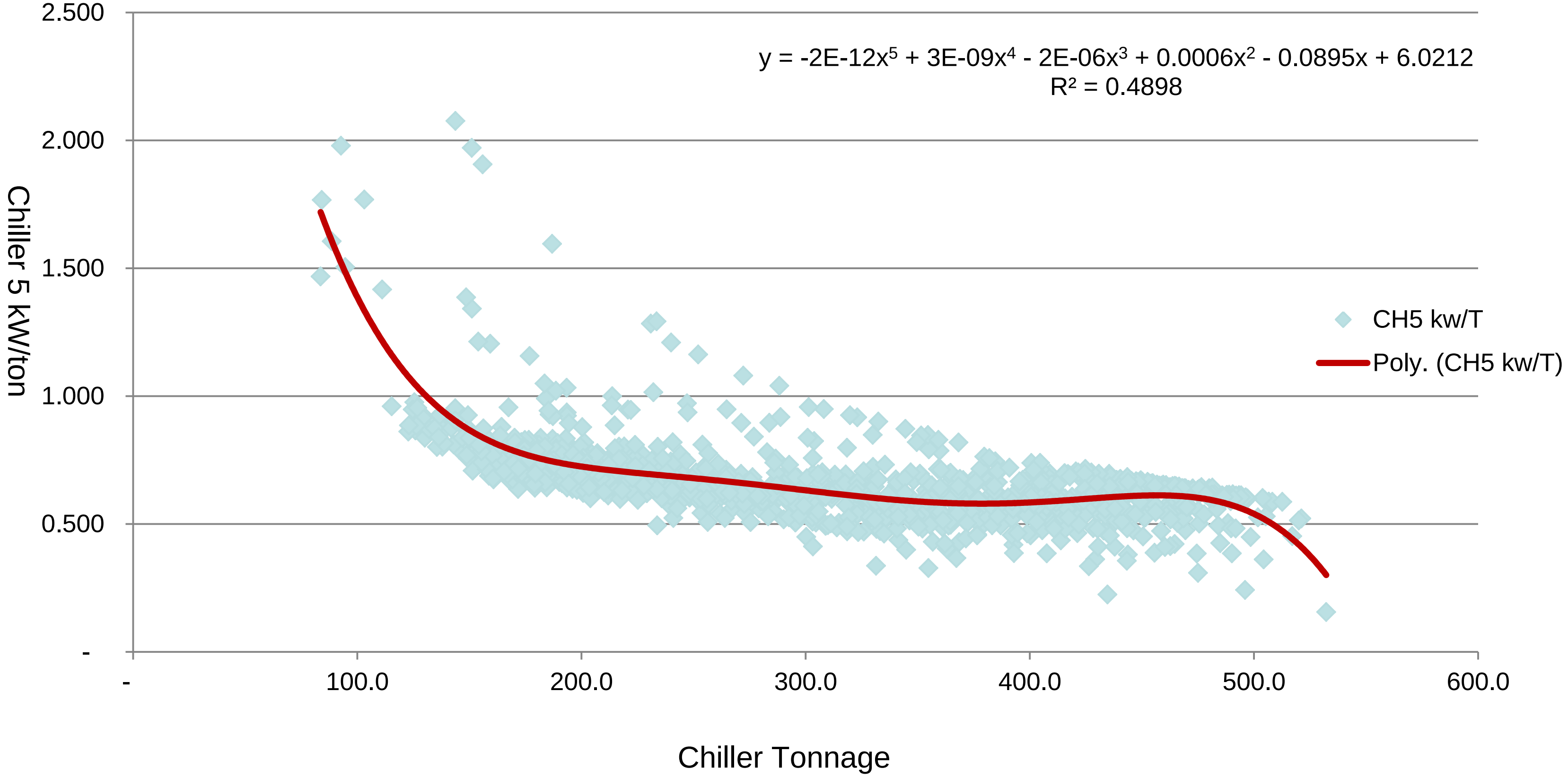
[3-C] - Varying M&V and Cx examples include, but were not limited to:

1. Lacking central chilled water plant wire-to-water efficiency,
2. Excessive equipment on-off cycling (*boilers*, compressors, fan and pump motors, etc.) & relevant efficiency and long term impacts,
3. VFDs not modulating as intended,
4. Uneconomic dispatch of CHP plants in small to large scale power generation projects,
5. Impacts on energy procurement contracts (electricity, natural gas, fuel, purchased steam, or purchased process hot water),
6. Boiler *Emission and Efficiency* impacts,
7. Location of district pumping differential-pressure (DP) switches, valve types (2 vs. 3-way), and bypasses on campus wide controls,
8. Heating and cooling systems fighting each other at varying building sizes and types,
9. Excessive outdoor air ventilation and fan operation caused by failed DCV/CO2 sensors,
10. Impacts of miss-calibrated sensors on building and system energy efficiency, and more, etc.

(1) Lacking central chilled water plant wire-to-water efficiency



Individual Chiller kW/T vs. Tonnage (July)



- Identified high condenser water temperature,
- Tubes fouling,
- Unnecessary Low CHW Temp Setpoint,
- Refrigerant charge issues,
- Miss-calibrated sensors,
- Issues with Tubes and bundles configuration/selection,
- Unnecessary bypass flow,
- Other gasket issues during installation,
- Level controllers issues,
- Lack of Optimization,
- Etc.

(**2**) Excessive equipment on-off cycling (*boilers*, compressors, fan and pump motors, etc.)

- Can be observed from measured data,
- Can cause early equipment failures,
- Indicates an excessively/oversized sized system (oversizing culture!)
- Sensor problems,
- Control issues,
- Deadband issues,
- A check of max acceptable on/off cycles per hour, per shift, per day, etc.
- Consider VFDs and modulating burners with frequent cycling, *only where appropriate*, as not all equipment can be controlled with such retrofits.

(**3**) VFDs not modulating as intended

- Very common problem in many VFD projects that intended savings are not realized,
- Caused by controls and Cx issues,
- VFDs are not supposed to solely be used as a two speed fan motor,
- Continue to use regressions to truly understand if VFDs are controlled to operate as intended,
- Check the Regression R^2 as you draw meaningful conclusions regarding square, near square or cubic relationship,
- Verify DP switch location and selection of 2-way and 3-way valves and bypasses.

(**4**) Uneconomic dispatch of CHP plants

- Do not run CHP to solely generate electricity with no thermal load.
- Do not run CHP to solely generate thermal with not enough elec load.
- Carefully examine commodity price fluctuation (elec and gas) and utility tariffs to optimally dispatch your CHP year round.
- Always run a “what-if” scenario between your CHP and the grid to compute third party independent savings.

Note that there are many CHP lessons learned that can also benefit *biomass* projects as either technology does not run solely on its own, it needs *full integration with surrounding MEP systems*.

(**5**) Impacts on energy procurement contracts (electricity, natural gas, *fuel*, purchased steam, or purchased process hot water)

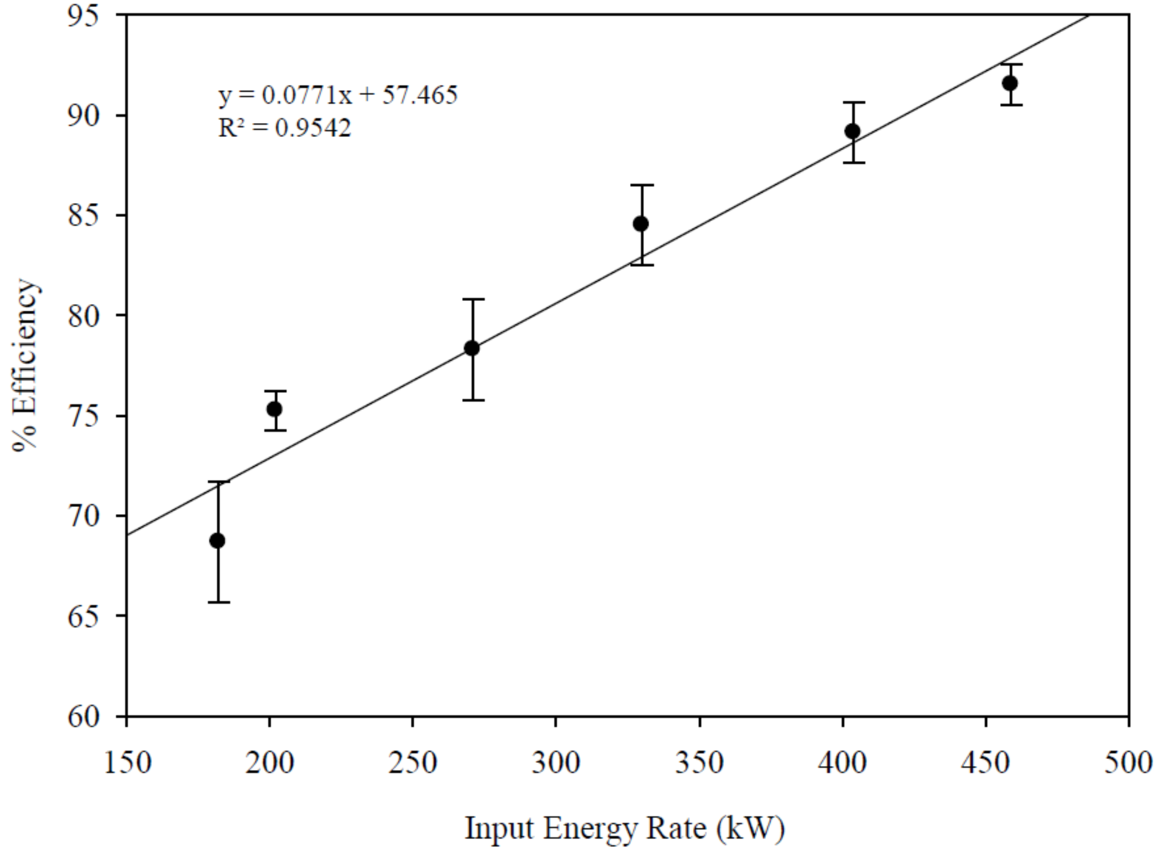
- In any energy project, examine all energy procurement contracts and stipulations as you start to save Watts and Btus, but also pay attention to $$$.
- For example, examine *long term oil and gas purchase contract* stipulations as part of your *boiler replacement or biomass boiler addition projects*, otherwise, you could get penalized. The fuel procurement group needs to communicate with energy eff group.
- Can steam unit cost $/Mlbs go up if you start to save steam, read the procurement contract fine print.
- I have a funny steam condensate condition story that was not in the steam purchase or heat sale agreement (if time permits).

Question - What are the varying impacts of oversizing biomass boilers and why? List at least three impacts.

(**6**) Boiler *Emission & Efficiency* Impacts

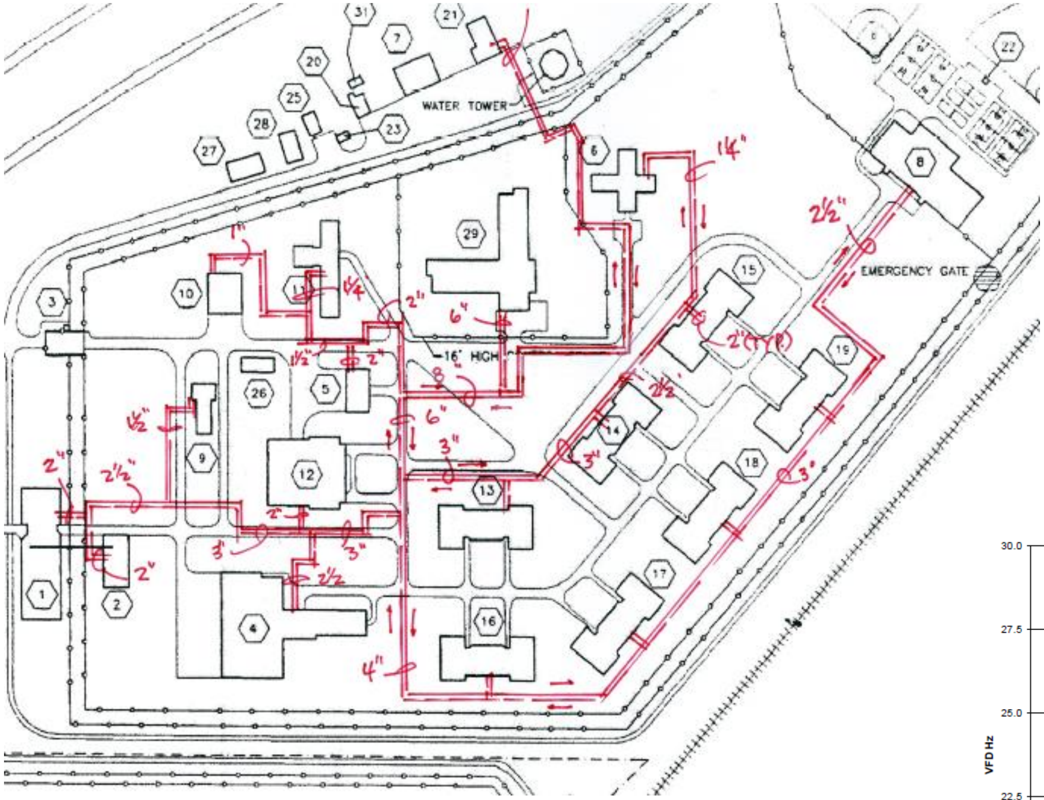
- Ex. Frequent *biomass boiler cycling* not only reduced their <u>efficiency</u>, but also increased their <u>emissions</u> (CO and PM 2.5), increased <u>maintenance</u> needs, and reduced <u>service life</u>.
- Further data analysis strongly indicated the need for *under-sizing the biomass boilers to attain a smaller number of on-off cycles, but with longer runtimes at higher/Full loads*, and coupled with *TES (Thermal Energy Storage)/Buffer Tanks*.
- Ongoing research and demonstration to attain both higher thermal efficiency and lower emissions through better part load performance and tandem/multiple boiler options. (win-win situation).
- Keep some of the existing Propane and/or Fuel oil boilers as supplemental or backup as you *utilize undersized biomass boilers and buffer tanks* for baseload.
- Upfront financial savings from installing smaller biomass boilers may result in surplus funding to include additional EEMs.
- Note - CO measurements suggested that additional research is needed to better understand *off gassing and the chemical reactions* from wood pellets and the need for well ventilated outside storage.

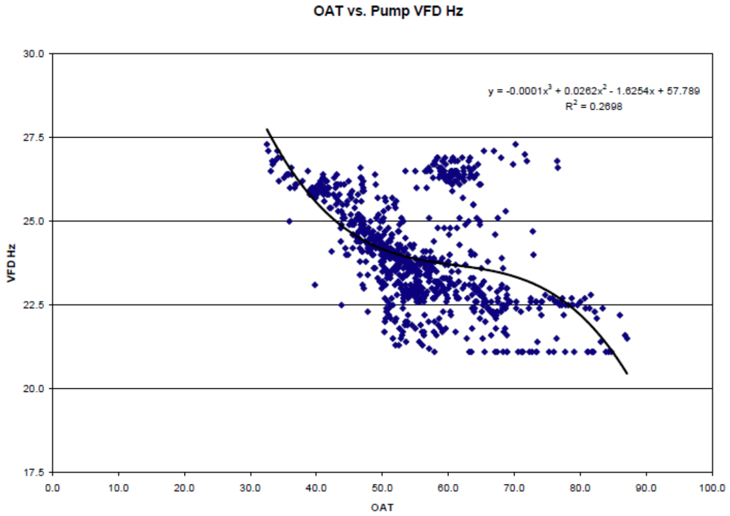
Thermal efficiency of the Wild Center's 1.7 Million Btu/hr wood pellet boiler varies with load



Courtesy of Professor Philip K. Hopke, Ph.D. of Clarkson University

(**7**) Location of district pumping differential-pressure (DP) switches, valve types (2 vs. 3-way), and bypasses on campus wide controls





- Careful location of DP switches in district heating systems,
- Careful selection of a combination of 2-way vs. 3-way valves,
- Balance between excessive bypass vs. no bypass at the end of the loop,
- System hydraulics calculations,
- Can you retrofit a 3-way valve to work as a 2-way valve? Issues, Valve stem safety, etc.
- System pressure relationship to valve operation (what happens if pressure is too low or too high).

(**8**) Heating and cooling systems fighting each other at varying building sizes and types

- It is a common problem, and at times, it is hard to detect,
- Why need 94 Deg SAT in the middle of summer in Atlanta, GA (using elec heat) while the other system (using an elec chiller) was supplying 50 Deg F air at the same time. Two (2) systems were clearly fighting each other for over 20 years due to a controls issue that caused well over $100K in increased fuel bills over the years!
- Numerous other examples exist,
- Discuss Upstate NY university campus with GTHPs terminal FCUs fighting each others.

(**9**) Excessive outdoor air ventilation and fan operation caused by failed DCV/CO2 sensors

- Space CO2 readings should also be taken at random,
- Examine location of CO2 sensors to prevent the building occupants from tampering with them (may put in central RA ducts),
- Fail safe position is 100% OA,
- Run comparisons between indoor and outdoor air and ensure updated R&R checks and alarms.

(**10**) Impacts of miss-calibrated sensors on building and system energy efficiency, and more, etc.

- Question - This is a wide subject with many examples, do you have any that you can share with us and add to what you have heard today before we break for lunch?

Question - What are the three most important items/skills you learned in this M&V and Cx Section today which, if applied properly, will positively contribute to you doing your job better?

Congratulations!

Now that you have completed Section 3-C of this training, we have shared many lessons from the trenches of how collected M&V data and subsequent in depth data analysis were used for ongoing system commissioning and troubleshooting to correct the HVAC&R system controls and operation to attain energy savings persistence, displace duel and reduce emissions during a wide variety of diverse energy projects.

This 3-part training illustrated how the collected M&V data and relevant data analysis could be used to draw meaningful conclusions and suggest actionable intelligence to sustain and enhance the building energy efficiency, sustainability and resiliency levels for the years to come.

Best of luck!

Section 3 Q/A & Lunch Break

Thank you

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Lunch Break

Section 4

Examples of Baseline Billing Analysis, Establishing a multi-year energy baseline, and Baseline and Proposed cases Heating and Electrical figures of merits

A1 Bldg Fuel Oil #2 Baseline Example

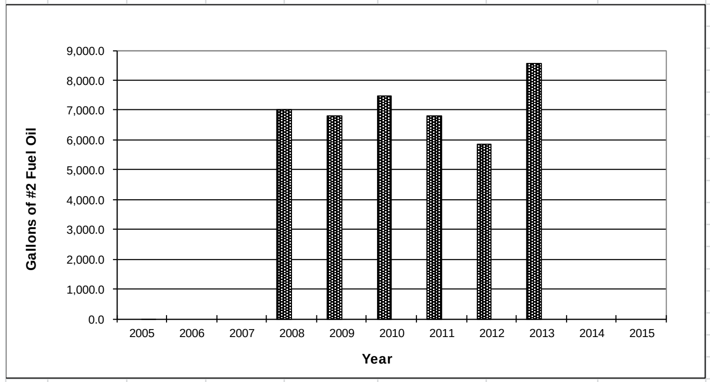
A1 Bldg

Fuel Oil #2 Bills for 2008-2013

Area (sqft) = 23,729

Yr Varies	Year	Dates From-To	Building Sqft	Annual HDD B 65	Quantity (Gallons/year)	Cost ($)	Cost ($/Gallon)	Gallons per HDD	Gallons per HDD per 1000 sqft	Exact Year
1	2005		23,729	8,143						
2	2006		23,729	7,237						
3	2007		23,729	8,072						
4	2008		23,729	8,003	6,997.8	$15,070.88	$2.15	0.87	0.0368	2008/2009
5	2009		23,729	7,980	6,819.9	$19,028.05	$2.79	0.85	0.0360	2009/2010
6	2010		23,729	7,128	7,463.1	$22,217.52	$2.98	1.05	0.0441	2010/2011
7	2011		23,729	7,302	6,786.7	$23,958.68	$3.53	0.93	0.0392	2011/2012
8	2012		23,729	6,963	5,863.0	$21,078.47	$3.60	0.84	0.0355	2012/2013
9	2013		23,729	8,100	8,543.0	$28,226.74	$3.30	1.05	0.0444	2013/2014
10	2014									
11	2015									
Total				68,928	**42,473.5**	**$129,580.34**	**$3.05**		**0.23609**	
Average				**7,579**	**7,078.9**	**$24,421.30**	**$3.48**	0.934	**0.03935**	

To Convert Gallons of #2 Fuel Oil to Btu, Multiply by	138,690
kBtu/year	981,775
kBtu/sqft/year	**41.37**
$/sqft/year (using 6 year average)	**$0.910**
$/sqft/year (using most recent 3 year average)	**$1.029**



Boiler IBR =	11.80	Gallons of Oil per Hour
Boiler Input Btu/hr =	1,636,542	Btu/hr
Boiler Output Capacity =	1,358,000	Btu/hr
Boiler Full Load Eff with Oil =	83.0%	
Boiler Normalized Output Capacity / sqft =	**57.23**	**Btu/sqft**
Boiler Output EFLH =	723.0	EFLH Per Year
ssumed Peak Building Load Factor of Boiler Capacity =	0.50	
Assumed Peak Building Load =	679,000	Btu/hr
Assumed Peak Building Load =	**28.6**	**Btu/sqft**
Assumed Building EFLH =	1,445.9	EFLH Per Year

A1 Baseline Electric Bills

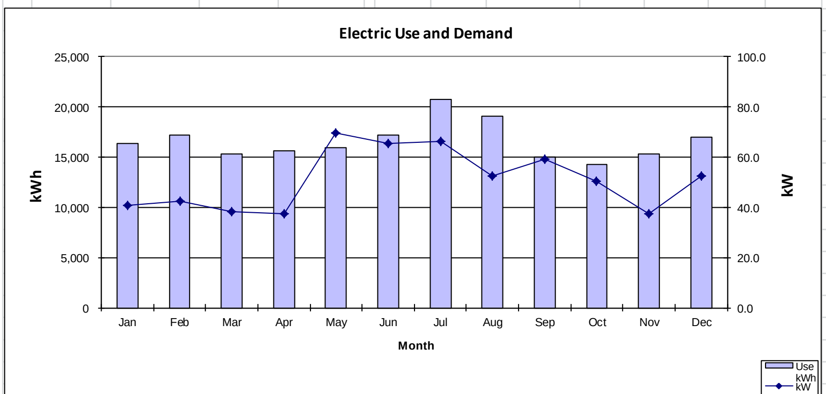
Figure 2013

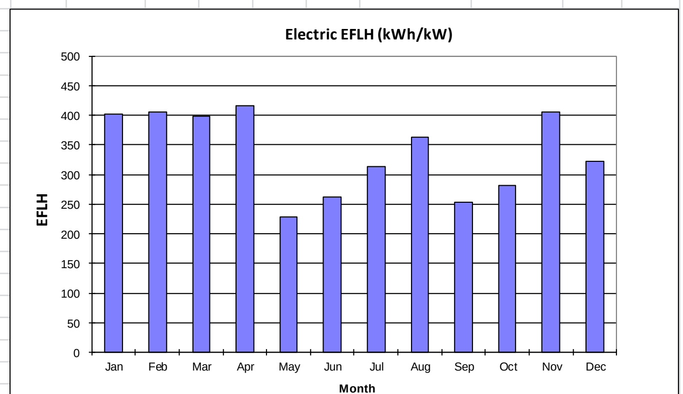
Electric Utility Bills for 2013

A1 Bldg

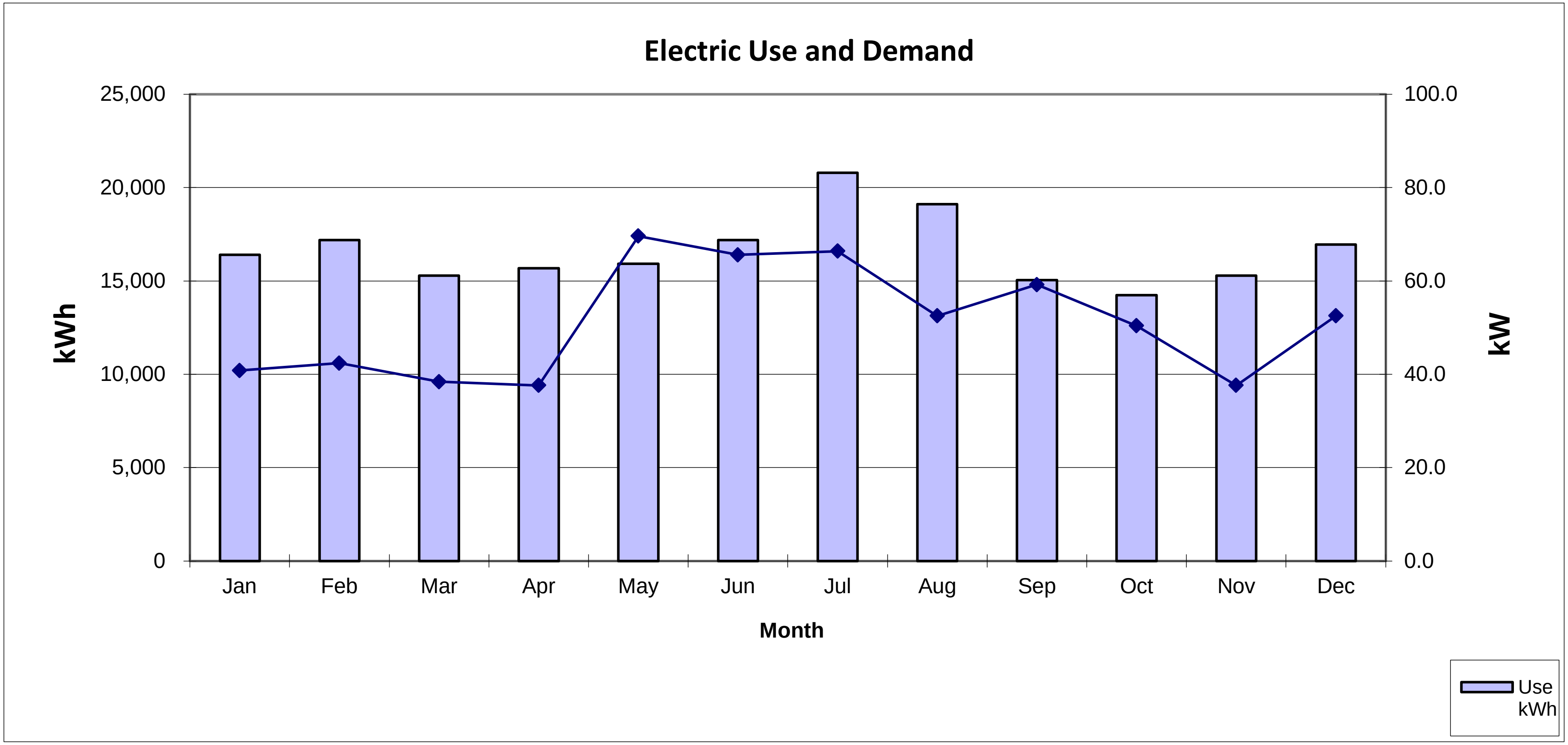
Area (sqft) = 23,729

#	*Month*	*Date From*	*Date To*	*Days Per Month*	On Peak kWh	Off Peak kWh	**Monthly Electricity Use kWh**	*Charge ($)*	*Charge ($/kWh)*	On Peak Demand kW	Off Peak Demand kW	*Electric Demand kW*	*Ratchet kW*	*Electric Demand W/sqft*	*Charge ($)*	*Charge ($/kW)*	*Other ($)*	*Other ($/kWh)*	*Tot Elec Cost ($)*	*Aggregate ($/kWh)*	*EFLH*	*Load Factor*
1	Jan	01/03/13	02/01/13	29			16,400		$0.000			40.8	NA	1.72		$0.00		$0.000	$1,813.69	$0.111	402	0.58
2	Feb	02/01/13	03/04/13	31			17,200		$0.000			42.4	NA	1.79		$0.00		$0.000	$1,227.52	$0.071	406	0.55
3	Mar	03/04/13	04/02/13	29			15,280		$0.000			38.4	NA	1.62		$0.00		$0.000	$1,473.01	$0.096	398	**0.57**
4	Apr	04/02/13	05/03/13	31			15,680		$0.000			37.6	NA	1.58		$0.00		$0.000	$1,383.94	$0.088	417	**0.56**
5	May	05/03/13	06/04/13	32			15,920		$0.000			69.6	NA	2.93		$0.00		$0.000	$1,854.62	$0.116	229	0.30
6	Jun	06/04/13	07/02/13	28			17,200		$0.000			65.6	NA	2.76		$0.00		$0.000	$1,911.29	$0.111	262	0.39
7	Jul	07/02/13	08/02/13	31			20,800		$0.000			66.4	NA	2.80		$0.00		$0.000	$2,406.67	$0.116	313	0.42
8	Aug	08/02/13	09/04/13	33			19,120		$0.000			52.5	NA	2.21		$0.00		$0.000	$2,017.87	$0.106	364	0.46
9	Sep	09/04/13	10/02/13	28			15,040		$0.000			59.2	NA	2.49		$0.00		$0.000	$1,690.34	$0.112	254	0.38
10	Oct	10/02/13	10/31/13	29			14,240		$0.000			50.4	NA	2.12		$0.00		$0.000	$1,391.94	$0.098	283	**0.41**
11	Nov	10/31/13	12/03/13	33			15,280		$0.000			37.6	NA	1.58		$0.00		$0.000	$1,318.93	$0.086	406	**0.51**
12	Dec	12/03/13	01/03/14	31			16,960		$0.000			52.5	NA	2.21		$0.00		$0.000	$1,835.62	$0.108	323	0.43
Total				365			**199,120**	$0	$0.000			613.0		25.84	$0	$0.00	$0	$0.000	**$20,325.44**	**$0.102**	4,057	0.46
											Max kW =	69.6	**W/sqft =**	**2.93**					Compare to maximum kW =		2,861	0.33
Percent of Total Electric Bill								0.0%							0.0%		0.0%		0.0%			
To convert kWh to Btu, multiply by							3,413															
kBtu/year							679,597															
kBtu/sqft/year							28.6															
kWh/sqft/year							**8.39**															
$/sqft/year								$0.00							$0.00		$0.00		**$0.857**			

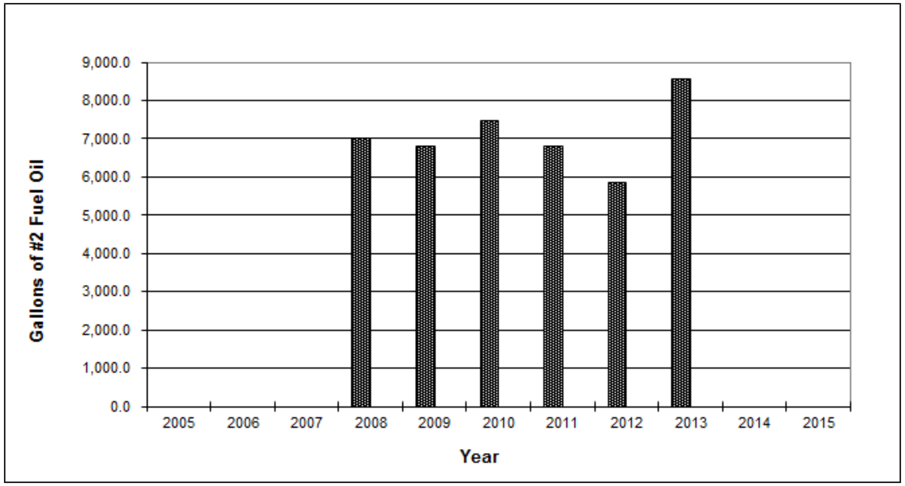




A1 Electric Load Profile



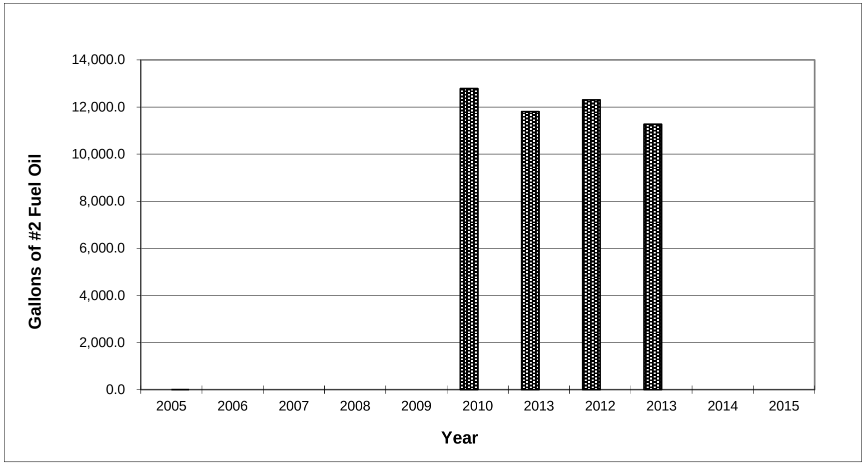
Sizing Example 1



- Boiler Output Capacity = 1,358,000 Btu/hr
- Building area = 23,729 ft^2
- Boiler Normalized Output Capacity / ft^2 = **57.23 $Btu/h/ft^2$**
- Observed Peak Building Load = 679,000 Btu/hr
- Observed Peak Building Load = **28.6 $Btu/h/ft^2$** Normalized
- Recommended Biomass Boiler Cap = **14.3 $Btu/h/ft^2$**
- Recommended Biomass Boiler Cap = 339,325 Btu/hr (100 kW)
- Other Recommendations & Lessons learned……

Baseline Oil Fired Boiler suffered from oversizing & cycling!

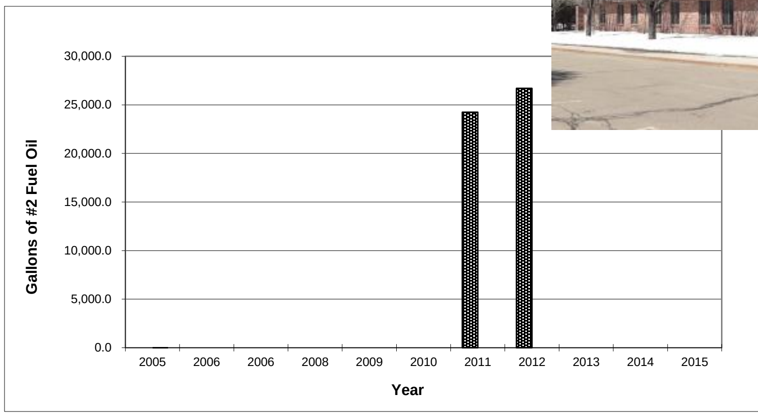
Sizing 2 - D2 Building



- Boiler Output Capacity = 712,000 Btu/hr per boiler
- Boilers installed in 2009
- Building area = 39,856 ft^2
- <u>Single</u> Boiler Normalized Output Capacity = **<u>17.9 Btu/h/ft^2</u>**
- <u>Two</u> Boilers Normalized Output Capacity = **<u>35.7 Btu/h/ft^2</u>**
- Estimated Peak Building Load = 925,600 Btu/hr
- Estimated Peak Building Load = **<u>23.2 Btu/h/ft^2</u>** Normalized
- Recommended Biomass Boiler Cap = **<u>11.6 Btu/h/ft^2</u>**
- Recommended Biomass Boiler Cap = 462,800 Btu/hr (136 kW)
- Other Recommendations & Lessons learned……

Two Existing Baseline Condensing Propane Fired Boilers experienced frequent # of Ignition cycles.

Sizing 3 - S3 Bldg



- Boiler Output Capacity = 1,900,000 Btu/hr per Boiler
- Boilers installed in 1996
- Building area = 38,875 ft^2
- Single Boiler Normalized Output Capacity = **48.9 $Btu/h/ft^2$**
- Two Boilers Normalized Output Capacity = **97.7 $Btu/h/ft^2$**
- Estimated Peak Building Load = 1,520,000 Btu/hr
- Estimated Peak Building Load = **39.1 $Btu/h/ft^2$** Normalized
- Recommended Biomass Boiler Cap = **19.5 $Btu/h/ft^2$**
- Recommended Biomass Boiler Cap = 760,000 Btu/hr (223 kW)
- Other Recommendations & Lessons learned……

Two Existing Baseline Fuel Oil #2/Kerosene Mix Fired Boilers Clearly Oversized.

Sizing Ex 4 - Biomass Boiler Sizing - Adirondack Museum

Examination of boiler sizing for the existing 2.74 million Btu/hr total input oil fired boilers as well as the new high efficiency wood pellet boiler: First Made-in-NY ACT biomass boiler (0.5 million Btu/hr single boiler).

- Total Existing Boiler Output Cap = 2,190,000 Btu/hr (@ 80% eff)
- Total Combined Building Floor Space = 51,000 ft^2
- Total Boiler Normalized Output Capacity / ft^2 = **43 Btu/h/ft^2**
- Estimated Peak Campus Load = **1,080,000 Btu/hr**
- Estimated Peak Campus Load Normalized = **21 Btu/h/ft^2**
- Recommended Biomass Boiler Cap = **500,000 Btu/hr** (150 kW)
- Recommended Biomass Boiler Cap Normalized = **10 Btu/h/ft^2**
- Installed TES = 1,500 Gallons (approximate volume of chilled water loop – however, take this with caution as it was not thermally stratified storage)

Sizing Example 5 - Wild Center - Tupper Lake

Bulk wood-pellet storage bin that was creatively built out of a re-purposed shipping container that also supports a solar-thermal hot water system.

- New and efficient building – LEED Certified.
- Building area = 54,000 ft^2
- Estimated Peak Building Load = ~ **18 to 23 Btu/h/ft^2**
  Normalized
- Installed Biomass Boiler Cap = **1,700,000 Btu/hr (500 kW)**
- Installed Biomass Boiler Cap = **31.5 Btu/h/ft^2**

Let us examine if it is oversized?

- Many Good Lessons learned:
  - Avoid oversizing.
  - Install TES/Buffer.
  - Use modulating propane fired boilers for backup fuel, low loads and peak loads, etc.
  - Controls integration and boiler sequencing,
  - CO Off gassing precautions.

Question - Provide a Sizing Summary for General Commercial Buildings in terms of Btu/h/ft^2 at three different levels!

- Boilers Normalized or Installed Output Capacity = **40 to 80 Btu/h/ft^2**
- Estimated Peak Building Heating Load = **20 to 40 Btu/h/ft^2** Normalized
- Recommended Biomass Boiler Capacity = **10 to 20 Btu/h/ft^2**
  < Carefully select between single or tandem biomass boilers >
- Let us average and call it the **60 / 30 / 15 Btu/h/ft^2** rule!

Important Note - There is no one size that fits all, those are just general ball park normalized ranges from past experience in New York State projects with building vintage anywhere from 30 to 100 years with varying system types, potential retrofits/rehabs over the years, varying insulation levels, infiltration rates, outdoor air flow rates, and added wings and extensions, etc.

Other Important Figures of Merit:

- **EFLH** simplified guidelines of **1,000**, **2,000** and **3,000** support the **60 / 30 /15 Btu/h/ft^2** discussed earlier.

- Put it all together so both peak sizing and operation are coordinated well to avoid oversizing; however, remember that there is no one size that fits all; those figures provide simplified, but valuable guidelines.

Question - What are the building system component that can be oversized with no issues?

1. High Eff Condensing Natural Gas Boilers.
2. Biomass Boilers.
3. Electric Chillers with VFDs.
4. Two-Stage Absorption Chillers,
5. Cooling Towers.
6. Pumps.
7. Fans.
8. Plate and Frame Heat Exchangers (PHHX).
9. None of the above.

In addition to:

1. Hot Fudge Sundae
2. Jacuzzi

Section 5

System Sizing!

Methods and Examples,
Building Peak Heating Load determination,
Biomass System Sizing,
Tandem Boiler Options,
Buffer tank sizing calculations,
All targeting complete and properly sized
Biomass Heating Systems.

System Sizing Methods

Major categories of tools for proper system sizing:

1. Computer Simulations,
2. Calculations,
3. Plant Logs,
4. Baseline Data Logging & Analysis,
5. Hybrid of the above.

Heating Load Determination Tools

- Hourly computer simulation programs (DOE-2, eQUEST, Energy-10 software, Manual-J, etc.)
- Vendor specific programs for simulation and/or calculation, as appropriate, (Trane-Trace, Carrier HAP, etc.)
- Simplified spreadsheet calculations,
- A combination of the above, as appropriate, and as needed, for specific measures. The selection of the analysis tool will also depend on the project detail/accuracy requirements & audit level.
- Hourly computer simulation programs and research tools (BLAST, TRNSYS).

Note - In any of the above, remember that garbage-in is garbage-out.

Heating Load Calculations from Available Plant Logs

- BTU Meters for GPM Delta T measurements,
- Fuel Oil Tank Level Readings (hardcopy printouts or electronic),
- Boiler Plant Logs (hardcopy and/or electronic),
- Smaller intervals preferred if possible: 15 min to 1 hour is ideal, 4 hour is okay, 8 to 24 hr is long but can be dealt with, 1-week you start to lose peaks, 1-month presents some analytical challenges.
- Regression against OAT, DD, and other independent variables such as bldg. schedules, setpoints and setbacks (like occ and unocc), other multi-variable regressions in industrial and process sites, etc.

Question - What else can you use for peak heating load determination besides sim/calc?

- Other measurements include but are not limited to burner runtime, nozzle size, fuel flow GPH at high vs. low firing rates to correlate with low (or design) temp bins to determine peak heating load for sizing.
- Due to building vintage, old fuel oil boilers will likely use a linkage type burner with high and low fire with no intermediate modulation and will likely not be monitored by a building EMS.
- Getting this data may be challenging.
- I will tell you my recent funny sizing story - I had to be creative when it was negative 8 Deg F!

Be aware of the ***Oversizing*** Culture !

- Oversizing is not going to work with biomass heating systems,
- It will have devastating short and long term impacts,
- **HELE** (High-Efficiency, Low Emissions) will become ~~**LEHE** (Low-Efficiency, High-Emissions)~~.
- Let us sharpen our pencils, dot the I's and cross the T's,
- Discuss a brief background of why the MEP and E/A US oversizing culture exists compared to Europe:
  - Some just want to burn "cheap" wood and deliver heat to buildings and homes so everyone is "happy" with no cold complaints using generously sized systems!
  - How about increased design, PM and CM fees and profit margins with "larger" systems!
  - Lack of building codes, training and knowledge specific to proper biomass system design and operation.
  - Lack of independent technical feasibility study, energy audit, buffer, proper controls and integration, etc.

Question

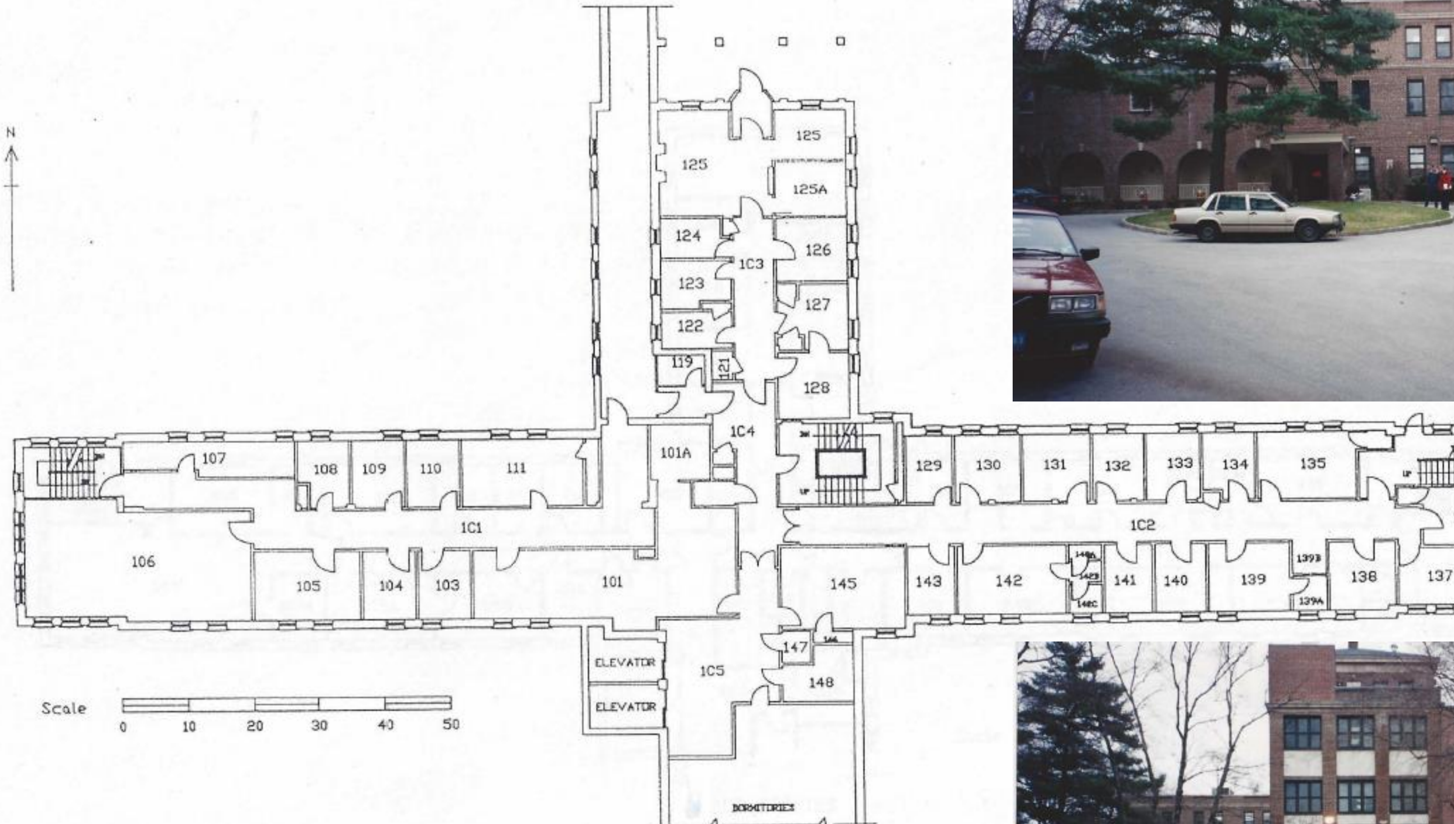
What are five most important building heat load components used as you determine the building peak heating and why?

Question

What is Typical normalized Btu/h/sqft peak heating load for commercial buildings and why?

(a general range is enough till we get into details next)

Let us size this building



Heating Load Worksheet

Zone Name:	VSS	
Area (ft^2):	32,980	
Indoor Conditions:		
Temperature	70 (F)	Occupied
Outdoor Conditions:		
Temperature	-1 (F)	
Ground Temp	42 (F)	

Building Section	Component	Area of Section (ft^2)	x	U-Value (Btuh/ft^2-F)	x	ΔT	=	Heat Gain (BTUh)
EXTERIOR WALLS	Grnd Flr	3,282.0		0.2		-71.0		-46,604
	1st Flr	3,000.0		0.2		-71.0		-42,600
	2nd Flr	3,220.0		0.2		-71.0		-45,724
	3rd Flr	3,164.0		0.2		-71.0		-44,929
WINDOWS & GLASS	Grnd Flr	810.0		0.5		-71.0		-28,755
	1st Flr	1,134.0		0.5		-71.0		-40,257
	2nd Flr	1,260.0		0.5		-71.0		-44,730
	3rd Flr	954.0		0.5		-71.0		-33,867
EXTERIOR DOORS	Grnd Flr	84.0		1.0		-71.0		-5,964
	1st Flr	42.0		1.0		-71.0		-2,982
	2nd Flr	0.0		0.0		-71.0		0
	3rd Flr	42.0		1.0		-71.0		-2,982
ROOFS	Grnd Flr	0.0		0.0		-71.0		0
	1st Flr	0.0		0.0		-71.0		0
	2nd Flr	1,380.0		0.1		-71.0		-9,798
	3rd Flr	7,012.0		0.1		-71.0		-49,785
GROUND LOSSES	Grnd Flr	8,392.0		0.05		-28.0		-11,749

Infiltration	(BTU/ft^3-F)	Volume (ft^3)	x	AC/hr	x	ΔT	=	Heat Gain (BTUh)
	0.018	263,840		1.1		-71.0		-370,906

Ventilation	(c_p)(ρ_{AIR})(min/hr)	x	cfm	x	O.A. Fraction	x	ΔT	=	Heat Gain (BTUh)
	1.08		32,980		0.1		-71.0		-252,891

Heating Load Worksheet

Insolation	Orientation	x	Area (ft²)	x	Solar Factor	x	Shading Coef	=	Heat Gain (Btu/hr)
	North		1,584		0		0.5		0
	South		1,458		0		0.5		0
	East		270		0		0.5		0
	West		324		0		0.5		0

Internal Gains	Watts/ft²	x	Area (ft²)	x	Usage Factor	x	BTUh/ Watt	=	Heat Gain (Btu/hr)
LIGHTING	2.3		32,980		0.60		3.413		155,334
PROCESS	1.5		32,980		0.70		3.413		118,189
			Heat Gain (BTUh/person)	x	Occupancy Factor	x	# of Perople	=	Heat Gain (Btu/hr)
PEOPLE	sensible		250		0.7		110		19,238

TOTAL HEATING LOAD	
Total	**-741,762**

Heating Load Density						
(Total Heating Load) / (ft²) =	(	-741,762	)/(	32,980.0	)	**-22.5**

Building Load Coefficient (BLC)						
(Total Heating Load) / (Design ΔT) =	(	-741,762	)/(	-71.0	)	**10,447**

Heating Load Worksheet

Zone Name:	VSS		
Area (ft^2):	32,980		
Indoor Conditions:			
Temperature	70 (F)		Unoccupied
Outdoor Conditions:			
Temperature	-1 (F)		
Ground Temp	42 (F)		

Building Section	Component	Area of Section (ft^2)	x	U-Value (Btuh/ft^2-F)	x	ΔT	=	Heat Gain (BTUh)
EXTERIOR WALLS	Grnd Flr	3,282.0		0.2		-71.0		-46,604
	1st Flr	3,000.0		0.2		-71.0		-42,600
	2nd Flr	3,220.0		0.2		-71.0		-45,724
	3rd Flr	3,164.0		0.2		-71.0		-44,929
WINDOWS & GLASS	Grnd Flr	810.0		0.5		-71.0		-28,755
	1st Flr	1,134.0		0.5		-71.0		-40,257
	2nd Flr	1,260.0		0.5		-71.0		-44,730
	3rd Flr	954.0		0.5		-71.0		-33,867
EXTERIOR DOORS	Grnd Flr	84.0		1.0		-71.0		-5,964
	1st Flr	42.0		1.0		-71.0		-2,982
	2nd Flr	0.0		0.0		-71.0		0
	3rd Flr	42.0		1.0		-71.0		-2,982
ROOFS	Grnd Flr	0.0		0.0		-71.0		0
	1st Flr	0.0		0.0		-71.0		0
	2nd Flr	1,380.0		0.1		-71.0		-9,798
	3rd Flr	7,012.0		0.1		-71.0		-49,785
GROUND LOSSES	Grnd Flr	8,392.0		0.05		-28.0		-11,749

Infiltration	(BTU/ft^3-F)	Volume (ft^3)	x	AC/hr	x	ΔT	=	Heat Gain (BTUh)
	0.018	263,840		1.1		-71.0		-370,906

Ventilation	$(c_p)(\rho_{AIR})$(min/hr)	x	cfm	x	O.A. Fraction	x	ΔT	=	Heat Gain (BTUh)
	1.08		32,980		0.1		-71.0		-252,891

Heating Load Worksheet

Insolation	Orientation	x	Area (ft^2)	x	Solar Factor	x	Shading Coef	=	Heat Gain (Btu/hr)
	North		1,584		0		0.5		0
	South		1,458		0		0.5		0
	East		270		0		0.5		0
	West		324		0		0.5		0

Internal Gains	Watts/ft^2	x	Area (ft^2)	x	Usage Factor	x	BTUh/ Watt	=	Heat Gain (Btu/hr)
LIGHTING	2.3		32,980		0.10		3.413		25,889
PROCESS	1.5		32,980		0.10		3.413		16,884
			Heat Gain (BTUh/person)	x	Occupancy Factor	x	# of Perople	=	Heat Gain (Btu/hr)
PEOPLE	sensible		250		0.0		110		0

TOTAL HEATING LOAD	
Total	**-991,750**

Heating Load Density						
(Total Heating Load) / (ft^2) =	(	-991,750	)/(	32,980.0	)	**-30.1**

Building Load Coefficient (BLC)						
(Total Heating Load) / (Design ΔT) =	(	-991,750	)/(	-71.0	)	**13,968**

Cooling Load Worksheet

Bldg Name:	VSS		
Area (ft^2):	32,980		
Indoor Conditions:			
Temperature	72	(F)	Occupied
Humidity	0.009	(lb/lb)	
Outdoor Conditions:			
Temperature	90	(F)	
Humidity	0.0133	(lb/lb)	
Ground Temp	64	(F)	

Building Section	Component	Area of Section (ft^2)	x	U-Value (Btuh/ft^2-F)	x	ΔT	=	Heat Gain (BTU/h)
EXTERIOR WALLS	Grnd Flr	3,282.0		0.2		18.0		11,815
	1st Flr	3,000.0		0.2		18.0		10,800
	2nd Flr	3,220.0		0.2		18.0		11,592
	3rd Flr	3,164.0		0.2		18.0		11,390
WINDOWS & GLASS	Grnd Flr	810.0		0.5		18.0		7,290
	1st Flr	1,134.0		0.5		18.0		10,206
	2nd Flr	1,260.0		0.5		18.0		11,340
	3rd Flr	954.0		0.5		18.0		8,586
EXTERIOR DOORS	Grnd Flr	84.0		1.0		18.0		1,512
	1st Flr	42.0		1.0		18.0		756
	2nd Flr	0.0		0.0		18.0		0
	3rd Flr	42.0		1.0		18.0		756
ROOFS	Grnd Flr	0.0		0.0		18.0		0
	1st Flr	0.0		0.0		18.0		0
	2nd Flr	1,380.0		0.1		18.0		2,484
	3rd Flr	7,012.0		0.1		18.0		12,622
GROUND LOSSES	Grnd Flr	8,392.0		0.05		-8.0		-3,357

Infiltration	(BTU/ft^3-F)	x	Volume (ft^3)	x	AC/hr	x	ΔT	=	Heat Gain (BTUh)
Sensible	0.018		263,840		1.1		18.0		94,033
	(BTU/ft^3-lb/lb)	x	Volume (ft^3)	x	AC/hr	x	ΔHumidity	=	
Latent	80.6		263,840		1.1		0.0043		100,586

Cooling Load Worksheet

Ventilation									Heat Gain
	$(c_p)(\rho_{AIR})$(min/hr)		cfm	x	O.A. Fraction	x	ΔT	=	(BTUh)
Sensible	1.08		32,980		0.1		18.0		64,113
	$(BTU/lb_W)(\rho_{AIR})$ x (min/hr)	x	cfm	x	O.A. Fraction	x	ΔHumidity	=	
Latent	4,840		32,980		0.1		0.0043		68,638

Insolation			Area		Solar		Shading		Heat Gain
	Orientation	x	(ft¯)	x	Factor	x	Coef	=	(Btu/hr)
	North		1,584		31		0.5		24,552
	South		1,458		60		0.5		43,740
	East		270		30		0.5		4,050
	West		324		186		0.5		30,132

Internal Gains			Area		Usage		BTUh/		Heat Gain
	Watts/ft²	x	(ft²)	x	Factor	x	Watt	=	(Btu/hr)
LIGHTING	2.3		32,980		0.8		3.413		207,112
PROCESS	1.5		32,980		0.9		3.413		151,957
			Heat Gain		Occupancy		# of		Heat Gain
			(BTUh/person)	x	Factor	x	Perople	=	(Btu/hr)
PEOPLE	sensible		250		0.9		110		24,735
	latent		200		0.9		110		19,788

TOTAL COOLING LOAD	
Sensible	**742,216**
Latent	**189,012**
SHR	**0.80**
Total (BTU/hr)	**931,228**
Total (tons)	**78**

Cooling Load Density						
(Total Cooling Load in BTU/hr) / (ft²)	=	931,228	/	32,980.0	=	**28.2**
(ft²) / (ton)	=	32,980.0	/	77.6	=	**425**

Building Load Coefficient (BLC)						
(Total Cooling Load) / (Design ΔT)	=	931,228	/	18.0	=	**51,735**

Question - What are Best Inventions, Discoveries, Products, Services, Hobbies, etc. (select top 6)

- Electricity
- Wheel
- Big Mac
- Sports Car
- Computer
- CHP
- Antibiotics
- M&V
- Cx
- iPhone
- Jacuzzi

- Sleep
- Slide ruler
- Scientific calculator
- Chocolate
- Coffee
- Baklavas
- Dentists
- Anesthesia
- High Definition TVs

- Computer games
- Nice weather
- Skiing
- Airplanes
- Good food
- Ice cream
- Properly sized High Efficiency Low Emissions Biomass Heating System (HELE) with Buffer

Question - Provide a Sizing Summary for General Commercial Buildings in terms of Btu/h/ft^2 at three different levels!

- Boilers Normalized or Installed Output Capacity = **40 to 80 Btu/h/ft^2**
- Estimated Peak Building Load = **20 to 40 Btu/h/ft^2** Normalized
- Recommended Biomass Boiler Cap = **10 to 20 Btu/h/ft^2**
  < Carefully select between single or tandem biomass boilers >
- Let us average and call it the **60 / 30 / 15 Btu/h/ft^2** rule!

Important Note - There is no one size that fits all, those are just general ball park normalized ranges from past experience in New York State projects with building vintage anywhere from 30 to 100 years with varying system types, potential retrofits/rehabs over the years, varying insulation levels, infiltration rates, outdoor air flow rates, and added wings and extensions, etc.

Buffer/TES Sizing - Hotwater

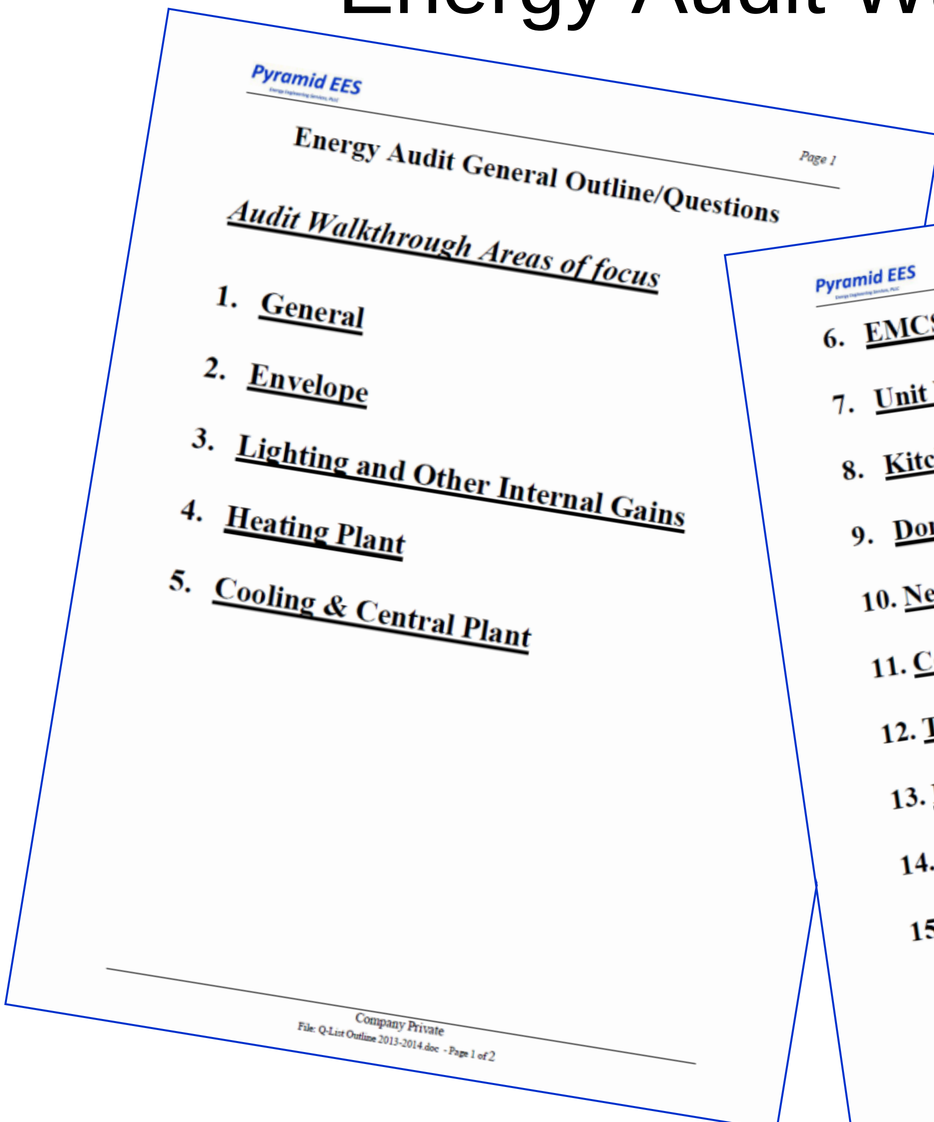
- **Basic Hot Water Buffer**: 2.0 gallons / 1,000 Btu/h of hot water boiler output capability.
- 8.34 lb/Gal x 1.0 Btu/(lb * F) x assumed ~ 60 F x 2.0 Gal = **1,000 Btu** of stored energy in a hot water buffer tank at 60 Deg F delta (thermocline) in each 2.0 Gallons of hot water stored **per Boiler MBH (1,000 Btu/h)**. This stores one full boiler output in the buffer tank less standby losses (use adequate tank insulation).
- Example - if the pellet boiler is off and the building load is 1/4th of pellet boiler capacity, TES can carry the building for 4 hours without struggling to run a biomass boiler at such low part loads and/or cycle it like crazy in the absence of a buffer tank.
- Use Tandem boilers to better handle low load conditions and reduce the TES/Buffer requirement of 2.0 gallons / 1,000 Btu/h to support the smaller hot water pellet boiler output capability.

Note - The above applies to med-large commercial pellet systems; However, advanced cord wood gasification boiler buffer tanks are sized differently and usually require a lot more TES (Usually equivalent to a complete 8 to 12 hour daily charge of cord wood).

Section 6

Energy Audit Walkthroughs, EEM Suggestions and How they impact Biomass Projects, with special focus on Heating load reduction, Controls and Systems Integration EEMs.

Energy Audit Walkthroughs



Pyramid EES

Page 1

Energy Audit General Outline/Questions

Audit Walkthrough Areas of focus

1. **General**
2. **Envelope**
3. **Lighting and Other Internal Gains**
4. **Heating Plant**
5. **Cooling & Central Plant**

Company Private
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Pyramid EES

6. **EMCS**
7. **Unit Ventilators, AHUs, HX**
8. **Kitchen**
9. **Domestic Hot Water**
10. **New additions, if any**
11. **Compressed Air, if any**
12. **Thermostats**
13. **Elevator, Escalators, and Conveying**
14. **Water Conservation Opportunities**
15. **Status of Utility Meters**

Company Private
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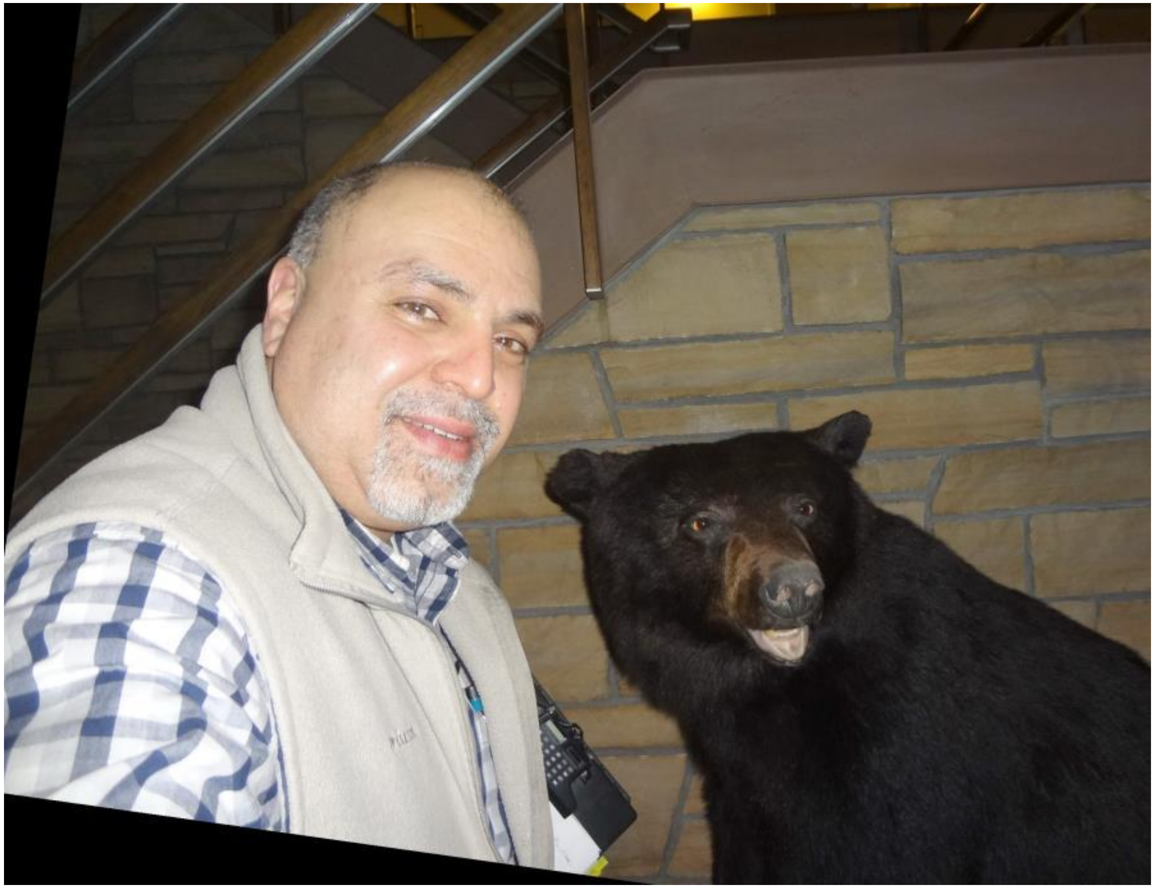
Ask for help when needed during the energy audit and seek expert opinions from locals who know the neighborhood best



Question - What is the difference between an energy audit and an IRS audit?

What is an Energy Audit/Assessment and Energy Auditor Responsibilities from my own perspective as a practicing energy efficiency professional?

1. An energy audit is a systematic review and inspection of an existing facility to understand its operation, existing systems, baseline energy usage for all fuels (electric, non-electric [NG, Oil, or Propane], biomass, landfill gas, purchased steam, site-generated steam, purchased hot water, purchased chilled-water, etc.), understand utility tariffs, and to identify existing problems.
2. Select buildings and/or systems with higher energy use intensities as first priority in case several buildings are audited within an existing complex or campus style settings. This may capture the buildings/systems with higher energy savings potential as first priority.
3. Propose energy efficiency measures (EEM) that provide short term, medium term, long term and master plan solutions that are appropriate for the facility under inspection to improve its energy efficiency, reduce maintenance, and *facilitate the integration with proposed biomass boilers*.

What is an Energy Audit/Assessment and Energy Auditor Responsibilities - Cont.

4. Complete a sequential/interacted analysis of EEMs using a variety of analytical tools as appropriate, compute energy economic feasibility, and present the proper level report to the customer.

5. Define and prioritize specific EEMs and energy management strategies that can be *integrated* into the site's on-going practices and future projects/programs.

6. Advance the customer into the next steps starting with EEM design, implementation approaches/schedules, *commissioning, documentation, M&V, training, project funding options, potential financial subsidies*, etc.

7. Adapt a goal oriented approach to ensure you reach the energy audit objectives.

Question - What is the suggested EEM Sequence of Insertion in Commercial Energy Audits and Why?

Hint - You are supporting HELE biomass projects so please do not forget about *heating loads reduction, System Integration & Controls* - items that are often overlooked

Suggested EEM Sequence

- Building External Loads (*Envelope*),
- Building Internal Loads/Gains, Lighting, Plug Loads, etc.,
- Process Loads,
- Building HVAC and other Mechanical and Energy Systems,
- *Controls* (HVAC, Primary & Secondary Systems)
- Domestic Hot Water Heaters (DHW),
- Kitchen,
- Laundry,
- Central Plants and Distribution,
- Combined Heat and Power (CHP & CCHP) & Distributed Generation (DG),
- Renewables,
- All of the above implemented in a *sequential rolling base method*.

Question - If time and funds are tight, how would you provide an energy assessment in the most cost effective manner?

Question - How many levels of energy audits do you think there are?, and why?

Question - Which level do you think is best for your project?

- Levels of audits/efforts (general categories)
  - Preliminary Energy Use Analysis,
  - Level-I,
  - Level-II,
  - Level-III (Investment Grade),
  - Hybrid Level Analysis, as appropriate.
- Clarification of Energy Audit Levels & Practical Recommendations

Question - Discuss the composition/qualifications of an energy audit team, customer involvement and what do you think is by far the most important item in the success of an energy audit that is <u>moving into implementation stage</u>?

- Who may be involved from the customer side? Everyone….
- Keys to a successful audit, as it pertains to facility staff: Involve them, provide sense of ownership, review their wish lists, provide economically feasible EEMs.
- Qualifications of an energy auditor and/or the energy audit team. A well rounded energy audit team should have expertise in many fields……
- Clearance Levels & Background Checks.

Question - What type of building information and data do you need to collect during your energy audit and why?

Question - How can you strike a balance between avoiding over collecting data and at the same time not missing collection of important data?

Question - How many teams are needed to conduct an energy audit?

The auditor must be well aware of the energy audit level and objective, customer needs, project budget, and the type and level of analysis needed for the measures identified during the energy audit.

The energy professional (Auditor, M&V or Cx Agent) may need to obtain <u>building & system information & data</u> about the following building end use categories, as appropriate, and may follow the suggested order below for successful EEM identification, M&V & Cx in large energy projects:

<u>General/Facility Wide</u>

- Envelope,
- Lighting,
- HVAC systems,
- DHW,
- Central plant (chillers, *boilers, PRVs, plant pumps*, etc.) - May be done first,
- Backup generators,
- TES (Thermal Energy Storage) for hot water, chilled water and ice,
- Electricity Storage (Batteries and Fly wheels),
- Distribution Systems (chilled water, primary hot water, DHW & steam),
- CHP & CCHP.

<u>Specialty Systems</u>

- Process equipment,
- Vertical transportation,
- Compressed air systems,
- Refrigeration equipment,
- Pools,
- Ice skating arenas,
- Power generation equipment (small, medium and large scale).

Note - All of the above were implemented in a sequential rolling base method during an audit and M&V implementation may follow.

Safety 1st during an energy audit

- Eye Goggles,
- Helmet,
- Ear plugs,
- Gloves,
- Steel toed shoes/boots,
- Ladder (arrange with site if it will be needed),
- Watch your head,
- Watch your eyes,
- Watch your step and back/head, when taking photos,
- Extra care and qualification is needed with data logging equipment, especially when accessing electrical panels,
- Observe posted safety/warning signs,
- Be responsible and careful.
- Take *Confined Space Training*, if needed, including but not limited to OSHA Std. Num. 1910.146..

Question - What equipment do you need to conduct an energy audit?

Do you need all equipment at all times, and why?

Simple/Non-intrusive Tools

- Infrared thermometer,
- Flashlight,
- Light level meter, flicker checker or discriminator,
- CO2 meter,
- RH meter (Psychrometer - Hygrometer),
- Tape measure,
- Camera (vital in taking pictures of the building, HVAC systems, proposed measure locations, nameplate data, etc.),
- Extra batteries,
- ASHRAE Pocket guide,
- Useful engineering charts and/or tables, including but not limited to the psychometric chart, Mollier Diagram, head loss calculators, steam tables, conversion factors, combustion efficiency tables for NG and fuel oil, etc.,
- Calculator,
- Screw driver (Phillips & flathead).

Specialized Equipment

- Multi-meter,
- Infrared thermography equipment,
- Different types of data loggers,
- Power factor and power quality meters,
- Combustion efficiency test instruments and gas analyzers,
- Air flow and velocity measurement devices.

- This list can be expanded depending on the complexity of the measures analyzed as well at the audit level.
- Specialized metering can be done by the Audit team (if they have the skills) or can be subbed out to specialty subcontractors, as needed.

General Advice

- If enough spot measurements are taken during the audit, M&V or Cx activities, try to reconcile to the building peak electrical demand, if you can.
- If spot measurements are not taken, try to reconcile using simple equipment nameplate data for motors (fans and pumps), RTUs, lighting Watts/sqft, Misc load Watt/sqft, etc. You can apply reasonable load factors for motors if measurements are not taken to complete that test.
- You do not have to be very accurate at this stage of the work; just ensure that you are not missing any major electrical end uses during the site inspection.
- Be aware that the above may not be a simple task, however, an attempt to reconcile can give you some peace of mind before you conclude your audit.

Short-Term Monitoring Equipment

- If appropriate, take hand-held spot measurements of major end uses. These will produce data used to determine existing equipment loading and efficiency.
- Additionally, the field team may elect to install non-intrusive monitoring equipment for a short duration (typically 1 to 4 weeks). Duration and monitoring equipment type vary based on the type of building energy systems and EEMs being metered.
- Data obtained from the short duration monitoring will yield actual (but partial) operating patterns and equipment usage/schedule.
- This data will be very important in the analysis of end uses with unknown usage patterns or schedules (getting something is better than nothing).
- Monitoring of selected end uses will serve to verify pre and post retrofit equipment usage and schedules.
- Obviously, before investing in short term monitoring equipment, try to use the *EMS trend logs and/or other site available logs* as this can be the least expensive method of obtaining trended data from a building.

Question - Provide examples of at least 10 EEMs that you may have identified during your energy audit and your customer requested M&V on some of them.

Also, think which of the 4 IPMVP options discussed earlier in an earlier Section of this training are most appropriate - there is obviously no one right answer so let us just discuss this one.

“Examples” of EEMs to look for during the Audit

- The objective here is NOT to provide an EEM master list but to provide a few examples of EEMs for your consideration, as appropriate.
- Remember the importance of the proper sequence of EEM insertion in order to not overestimate the predicted energy savings: *Load reduction*, HVAC systems energy efficiency, *controls integration*, distribution, central plant, CHP, renewables, and certain process applications.

Standard EEMs

Loads (*Reduce Building Loads*):

- Weather-stripping and air sealing,
- Building insulation (in an appropriate manner),
- Pipe and valve insulation,
- Air locks and air curtains at entrances,
- Window treatment, films, etc.

Other:

- Lighting (fixture replacement, controls, rezoning, dimming ballasts, DL, etc.),
- Water efficiency.

Standard EEMs continued

Central Heating:

- Leaky steam traps and steam trap maintenance programs,
- Install central heating controls at some of the old/large steam heated buildings where residents tend to open windows to alleviate space over-heating during mild weather conditions,
- Heat recovery of boiler blowdown,
- Stack economizer,
- Condensing boilers,
- Summer boilers (as appropriate),
- Burners with low turn down ratios,
- O_2 trim,
- Laundry and dryer conversion from electric to natural gas or steam, as appropriate,
- Other controls (setpoints, setbacks, schedule with OAT), etc.
- Kitchen hood controls coupled with AMU VFDs.

Standard EEMs continued

Electrical and Controls:

- VFDs, as appropriate,
- High efficiency motors,
- EMCS,
- Power house air compressor upgrades,
- Hot food card controls,
- High efficiency HVAC systems of any type not just code compliant equipment,
- DCV (Demand controlled ventilation),
- Eliminate simultaneous heating and cooling, and minimize unnecessary reheat,
- Time clocks,
- Optimal start and stop,
- Demand limiting, demand response, duty cycling, etc.,
- Economizers (dry bulb and enthalpy).

Creative EEMs (Central)

- Energy procurement: Interruptible vs. firm gas rates,
- De-energize parts of the steam and/or process hot water distribution,
- Eliminate unnecessary steam lines,
- Reduce steam distribution pressures, as appropriate,
- Satellite heating systems,
- Utilize existing dedicated year round DHW loop, in-place of energizing the process hot water in the summer,
- Heat recovery (heat wheels, air-to air, heat pipes, run around loops),
- Decouple cooling tower make-up water from sewer bills.

Powerhouse EEMs

- Boiler stack economizers (condensing and non-condensing types),
- PRV turbines (or let down turbines) in place of standard PRVs (constant enthalpy process),
- Convert the outer buildings from fuel oil, LPG, or steam to NG, as appropriate,
- High efficiency boilers,
- High efficiency district heating or cooling pumps and motors with VFDs, as appropriate.

New Space (Expansion) EEMs

- Careful selection between electric vs. non-elec chillers,
- High efficiency air-cooled chillers if water-cooled requires more maintenance,
- Proper zoning and rezoning,
- Review lighting foot-candle levels and OA CFM requirements in different spaces and ensure more efficient recent standards are adapted,
- Careful EMS system selection,
- DOAS (Dedicated Outdoor Air Systems) with heat recovery, especially with CBRN cautions,
- Radiant slabs and slab tempering,
- WWTP (waste water treatment plant) opportunities,
- Other EEMs as appropriate, etc.

Renewable, Progressive and non-standard EEMs

- CHP (combined heat and power) & CCHP,
- TES (thermal energy storage) - mainly a demand reduction measure and may not be viewed necessarily as a standard EEM,
- Chilled beams, VRVs and VFRs,
- Wind turbines,
- Radiant floors,
- Solar PV,
- Solar hot water heating or Solar walls (for air heating).

Controversial EEMs / Issues

They were classified as controversial (at times) because the auditor may face some push back from some customers under certain operating conditions for a variety of reasons (not discussed here): Such measures include but are not limited do:

- Disagreements about boiler layup procedures for summer savings,
- Avoid excessively sized equipment,
- Avoid energizing more boilers than needed,
- Wet and dry layup in summer,
- DCV, as appropriate,
- Training,
- Cx (Basic, startup, enhanced, ongoing) commissioning.

Again, the objective here was NOT to provide an EEM master M&V list, but to provide a few examples of EEMs that can undergo different IPMVP M&V Options, as appropriate. There are obviously other potential EEMs that I did not list above - use your imagination.

Post-Audit Walkthrough Topics, include, but are not limited to:

- Back to your office,
- Post-Audit Organization,
- Team Communication and Continued search for EEMs,
- Energy and Economic Analysis,
- Audit Report Writing & Layout,
- Baseline end use breakout,
- EEM Detailed Section,
- Next Steps: Design and Implementation,
- Next Steps: Feedback after Implementation and Operation,
- Additional Items to remember.

Congratulations!

Now that you have completed this Section of this training, you are now more familiar with the Energy Audit Walkthroughs, EEM Suggestions and How they may impact Biomass Projects, with special focus on Heating load reduction, Controls and Systems Integration EEMs.

Best of luck!

Afternoon Break & Light Refreshments

Section 7

M&V Guidance & Examples

Specific to Biomass Projects targeting Attaining and Verifying the Performance of Advanced Biomass Heating Systems and relevant EEMs

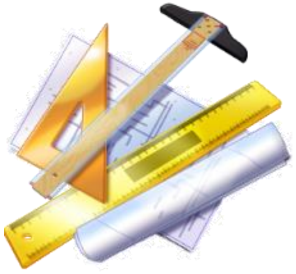
Question - Why Measurement & Verification?

1. Quantify energy savings and *fuel displacement*,
2. Verify *properly sized boilers* and other support systems,
3. Ensure correct biomass system *operation, controls and integration* with existing heating systems, energy management and controls system (EMS), and heat distribution systems,
4. Verify the effectiveness and benefits from *TES/buffering*,
5. Facilitate building and *System Commissioning (Cx)*& troubleshooting activities,
6. Support energy savings and performance validation,
7. Facilitate billing with campus style settings that have heat (or chilled water) sale agreements.

<< This slide is also under M&V & Cx “General” Section-3 due to its importance>>

"You cannot manage what you do not <u>measure</u>"

"You cannot expect what you do not <u>inspect</u>"



The alternative is, "Trust me - you saved!"

RHNY Biomass M&V Plan based on PON 1219 Technical Guidance Document for Large Commercial Pellet Boilers

The Guidance Document Stated "As part of the EA review process:

- The TC will work with the applicant to develop a Measurement and Verification (M&V) Plan describing what measurements will be required to verify performance over the entire heating season.
- The TC will work directly with the applicant to develop a mutually agreeable M&V approach and instrumentation details that will be documented in the M&V Plan".

“The M&V Plan may specify the some or all of following measurements and/or data collection requirements depending on the system arrangement:

1. Fuel and pellet delivery logs (dates and amounts), periodic tank level measurements or metering to track use over the M&V period (similar to baseline data included in the EA),

2. Runtime and cycle rate/count data for all the boilers collected at regular (at hourly or shorter) intervals over the monitoring period,

3. Supply and return temperatures (at hourly intervals) for the individual boilers and overall system as appropriate,

4. Hot water flow readings at hourly intervals over the monitoring period (to calculate thermal output and efficiency),

5. Wood pellet auger runtime or speed denoting hourly fuel supply to the boiler”.

"NYSERDA strongly encourages the applicant to install an *M&V-enabled control system* to collect this hourly data.

This M&V enabled control system will allow the facility staff to track system performance to ensure good performance over the long term.

Alternatively, the TC can supply and install temporary, battery-powered data loggers for the M&V period. In this case, the applicant must supply and install necessary sensors to support M&V (e.g., hot water flow meter) and support the TC's efforts to install the temporary M&V equipment at the site.

The TC may return to the site to collect the data loggers at the end of the M&V period, or ask the site to mail the data loggers back as appropriate".

<u>Question - What is the Best Terminology and Why?</u>

M&V, EMS, BMS, EMCS, DDC, DAA, SCADA, SDC&IE.

Additional M&V & Emissions Plan Data Points:

1. OAT DBT (Deg F) local preferred over weather station, or collect both and compare, ensure sensor calibration. WBT not needed but can be collected for overall data QC,

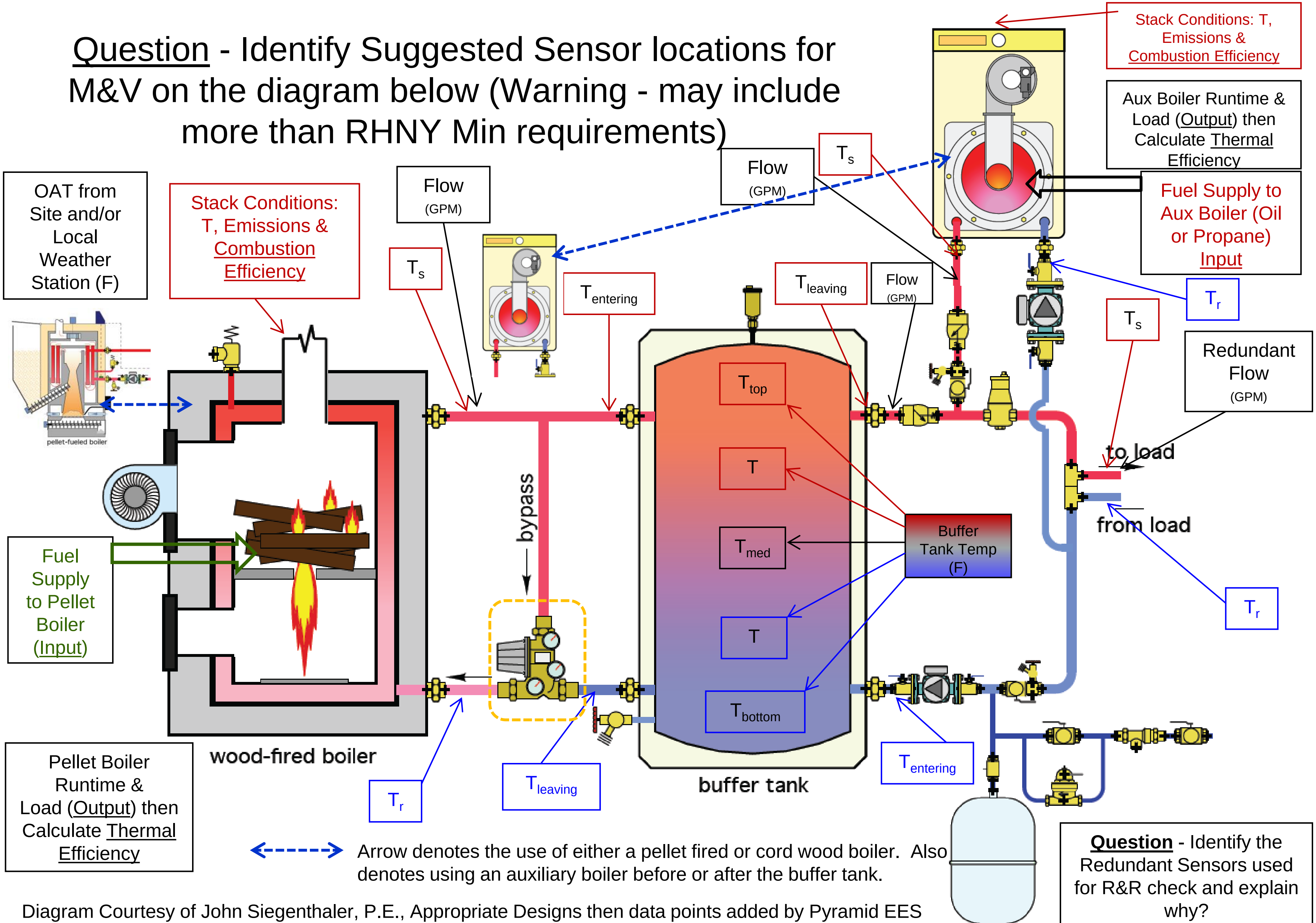
2. Stack Temperature,

3. Combustion Efficiency Monitoring (different from the calculated Overall thermal Efficiency),

4. Stack Gas Monitors or Emissions Analyzers (not required with RHNY as selected boilers have been pre-qualified already), can include but not limited to O_2, CO, CO_2, NO, NO_2, NO_x, (and PM2.5), all using proper engineering units,

5. CO Monitoring and Alarms where necessary.

Question - Identify Suggested Sensor locations for M&V on the diagram below (Warning - may include more than RHNY Min requirements)



Arrow denotes the use of either a pellet fired or cord wood boiler. Also denotes using an auxiliary boiler before or after the buffer tank.

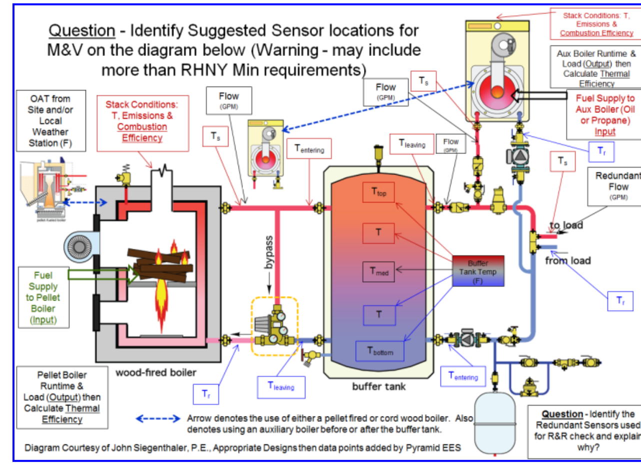
Diagram Courtesy of John Siegenthaler, P.E., Appropriate Designs then data points added by Pyramid EES

Sample M&V Calculations

- Load = 500 x GPM x Delta T
- Overall Thermal Efficiency = Output / Input
- Combustion Efficiency calculated from stack temperature and other readings
- EMCS Monitor data to determine savings, efficiencies, displacement, controls feedback, etc .
- Regressions for weather….
- See later for additional calculations.

Note 500 = 1.0 Btu/lb/F x 8.34 lb/Gal x 60 Min/hr (okay for Water but use lower C_p & density for Glycol-water mix)

M&V Data QC & Cx



- Verify sensor location,
- Sensor installed properly,
- Sensor calibration & data quality,
- Sensor communication and download capabilities,
- Sensor and logger protection,
- Data archival, retrieval, backup, and remote access,
- EMCS or SCADA Programing for both system controls and data acquisition and verify integration.
- Automatic and manual Range and Relational (R&R) Checks for optimal data QC,
- Speedy intervention when data issues are identified.

W!ld Center

Modulating Aux Propane Boilers

Thermal Energy Storage (TES)
20 Gal/10,000 Btu/hr requirements

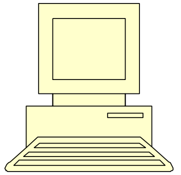
85,000 Btu/hr (25 kW) pellet boiler.
170 gal TES by requirements, but
119 gal (non ASME) is allowed for
boilers ≤ 25 kW.

Large 2,500 gal (2 x 1,250 gal) TES

Question - What else you should do, besides M&V, to attain successful HELE biomass project's multiple benefits including but not limited to efficiency, emissions, longevity and good economics, and why?

Besides M&V, you should also

1. Complete an energy study before recommending biomass (Ex. FlexTech),
2. Proper boiler sizing (deliberate undersizing) and include thermal storage,
3. Commissioning (Cx) through all project stages for proper systems integration,
4. Finally, implement M&V of heating system and component performance (Ex. EFP - Existing Facilities Program).



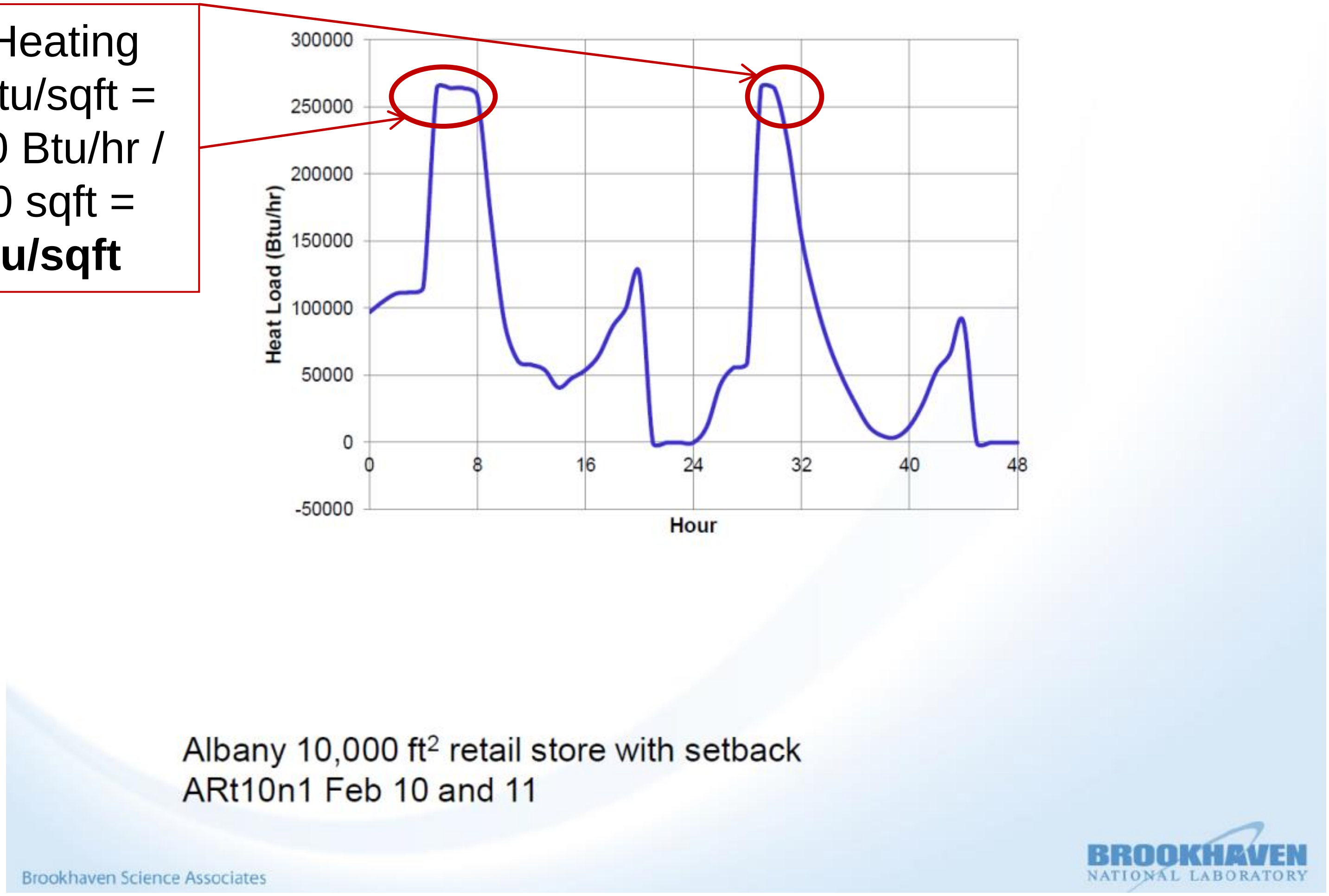
Five very important slides covering five important topics from five valuable guys:

1. Building heating load profile example,
2. Biomass boilers part load efficiency concerns,
3. Biomass boiler sized to provide 50% of the peak heating load; “small is beautiful or less is more”, charted vs. OAT,
4. Biomass vs. fuel oil consumption estimated monthly,
5. Recap on all of the above (put it all together).

Note - RHNY TCs are encouraged to visit demonstration sites like the Wild Center as well as biomass boiler manufacturers.

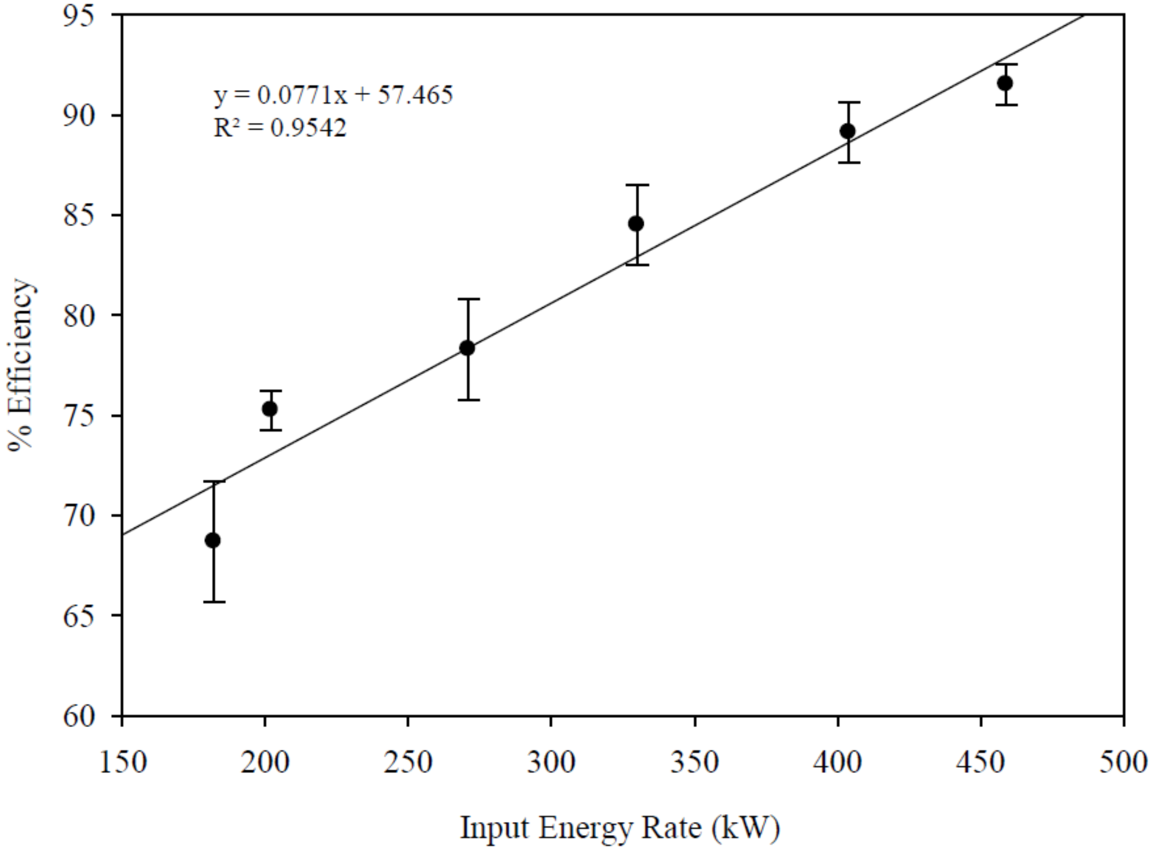
[1] Example of Diurnal Load Profile using Energy Modeling and/or Metering

Peak Heating Load Btu/sqft = 270,000 Btu/hr / 10,000 sqft = **27 Btu/sqft**



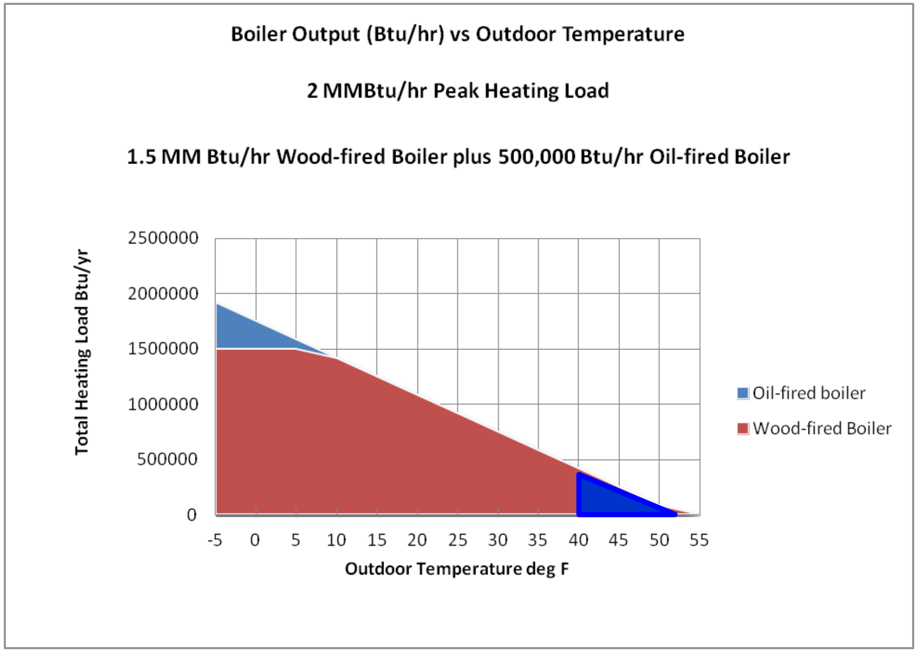
Courtesy of Dr. Thomas Butcher, BNL

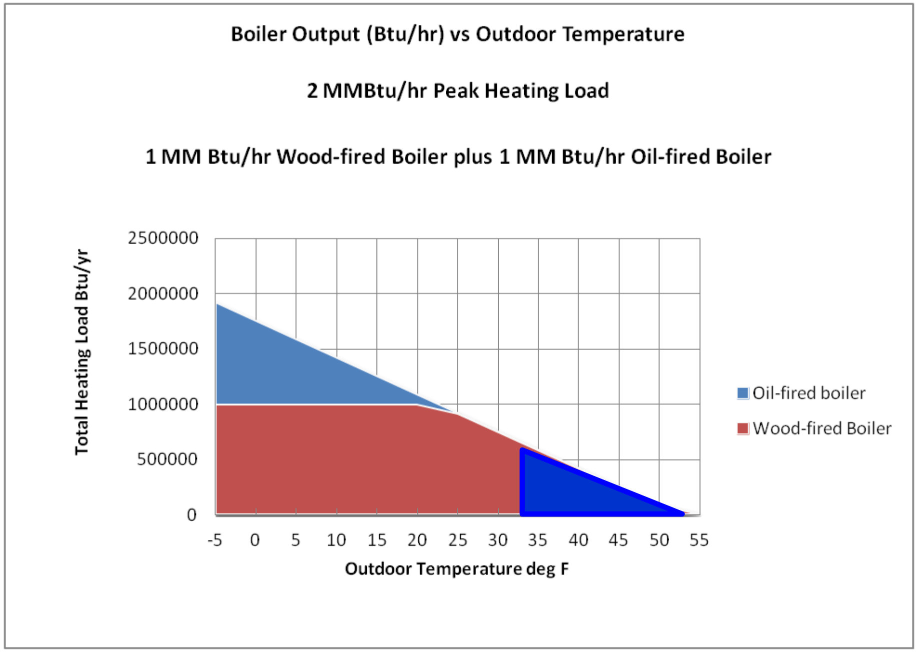
[2] Thermal efficiency of the Wild Center's 1.7 Million Btu/hr wood pellet boiler varies with load



Courtesy of Professor Philip K. Hopke, Ph.D. of Clarkson University

[3] Boiler Sizing Methods
"Small is beautiful" or "less is more"

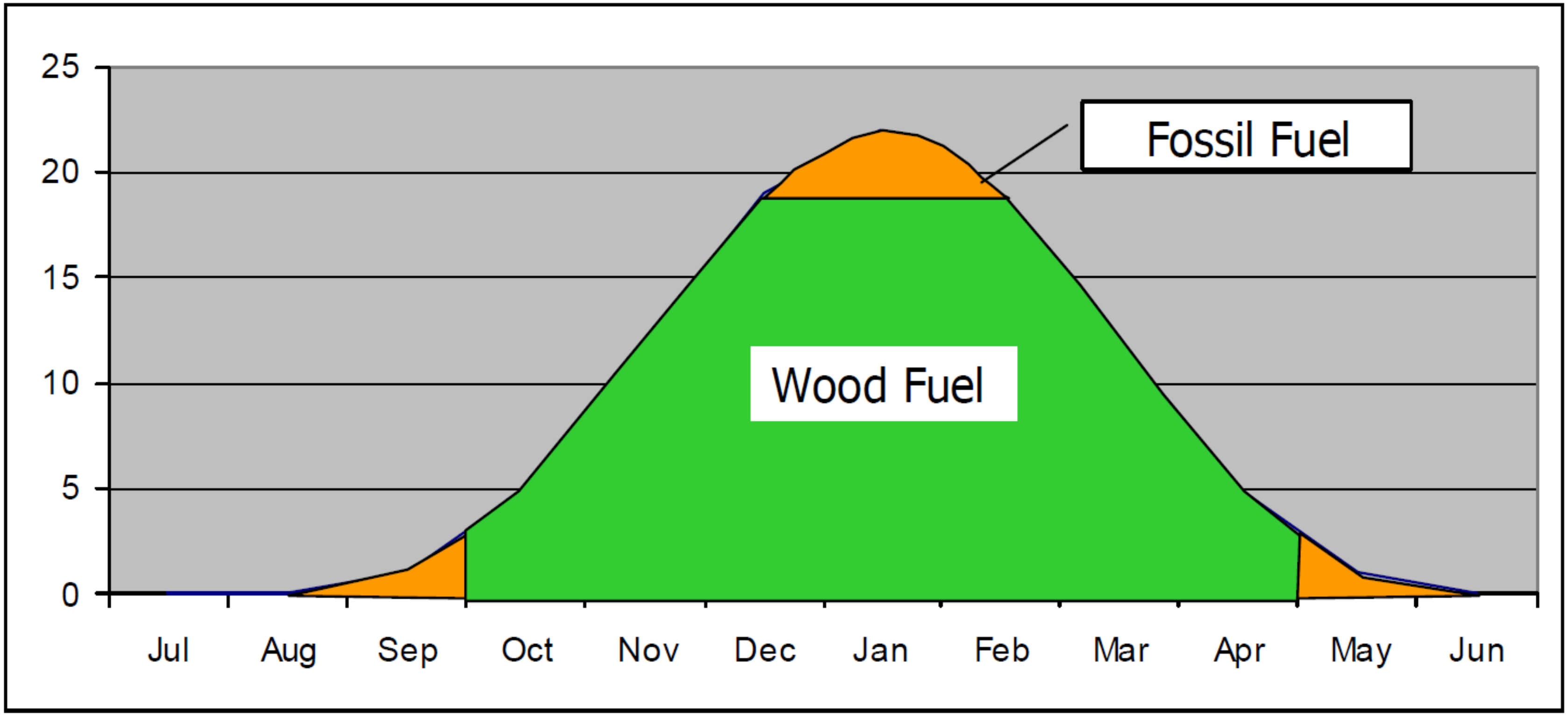




- **Wood-fired boiler sized to provide 50% of <u>peak heating load</u> (vs. 75%).**
- **Can meet entire bldg. heating load down to about 20 deg F (vs. 10 Deg F).**
- **Wood boiler meets ~80% of annual heating needs (vs. > 90%).**
- **Superior 80% to 85% targeted efficiency vs. mid 60s.**

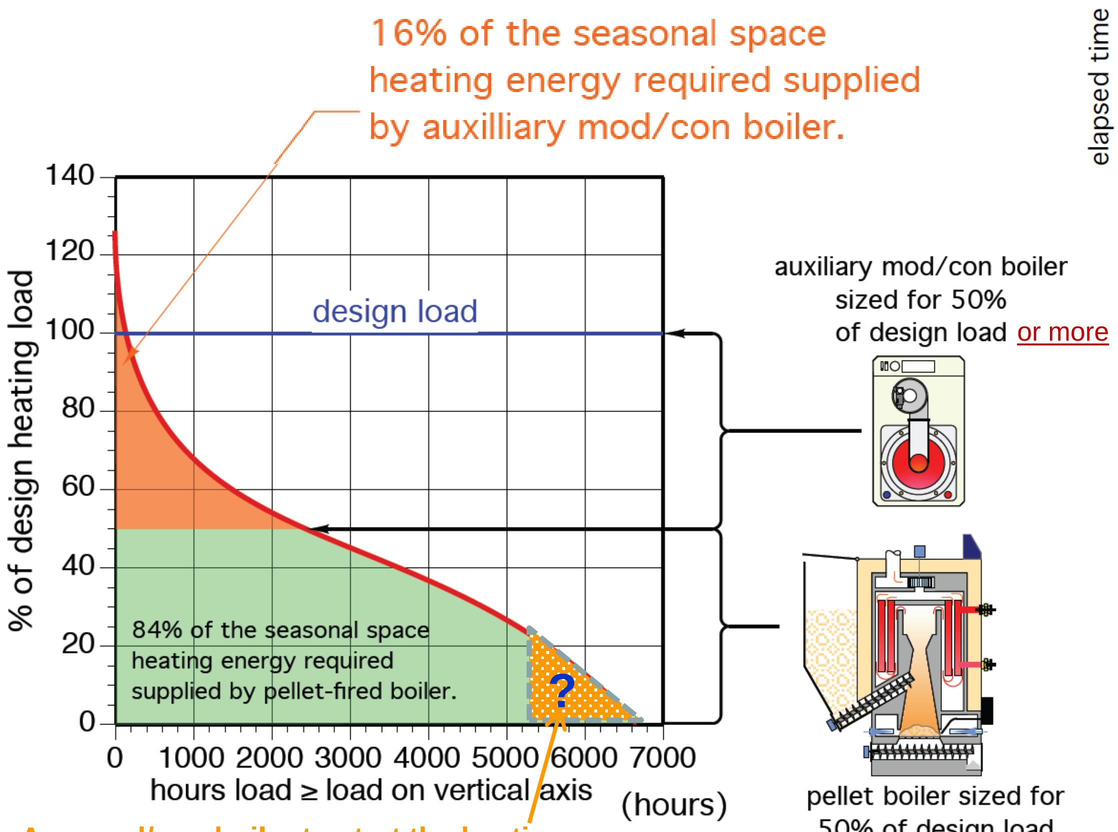
Graphs courtesy of Ray Albrecht 2013 Presentations

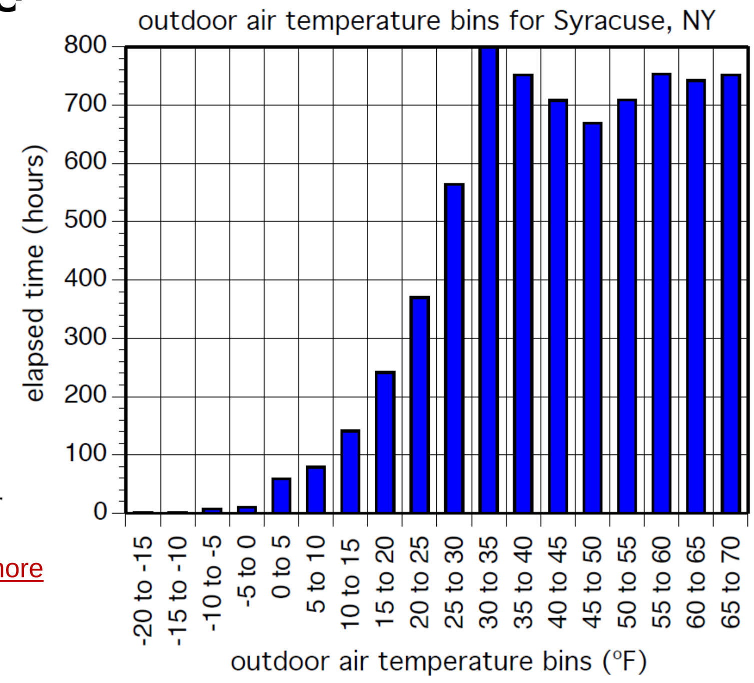
[4] Estimated Fuel Use Replaced by Biomass Boiler



Graph courtesy of David Dungate 2013 Presentations

[5] Temp Bins, Boiler Sizing, & Load Analysis, Let us put it all together!





Aux mod/con boiler to start the heating season.

Graphs courtesy of John Siegenthaler 2014 Presentations

Baseline data analysis, boiler sizing, includes, but is not limited to

- Normalize energy per square foot figures: $/ft^2/year, kBtu/ft^2/year (EUI elec & fuel), **Peak Btu/h/sqft**, Watts/sqft, EFLH, $/occupant, etc.
- Identify seasonal patterns, unusual spikes, consistency and accuracy of the data,
- Compute EUI (Energy Utilization Index) in kBtu/sqft/year using clearly defined conversion factors and to published benchmarks, to similar facilities.

Overview of Data Loggers and Sensors for Flow and Temperature Measurements

- Temperature measurement - Easy.
- Flows? More difficult……
  - Non-Intrusive - Ultrasonic or Electromagnetic.
  - Intrusive - Insertion Type.

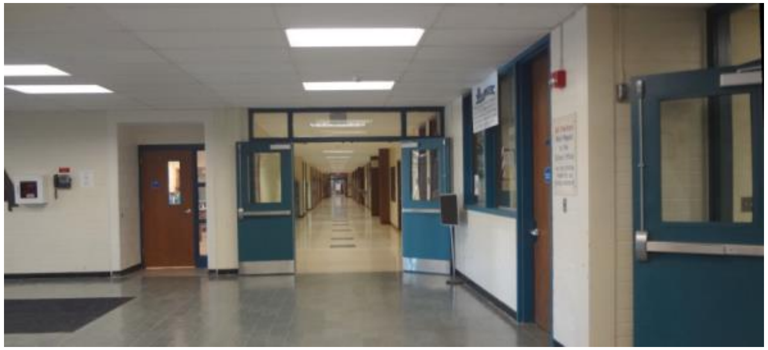
Courtesy of NMCP, Onicon and KRAL.

Considerations……

- Pipe Diameter/type,
- Fluid type, Conductivity,
- Density, viscosity, corrosiveness,
- Required accuracy level,
- Flow level and/or speed,
- Maintenance considerations,
- Budget,
- Etc.

Courtesy of Rosemont and Krohne.

Baseline Boiler Room Inspection



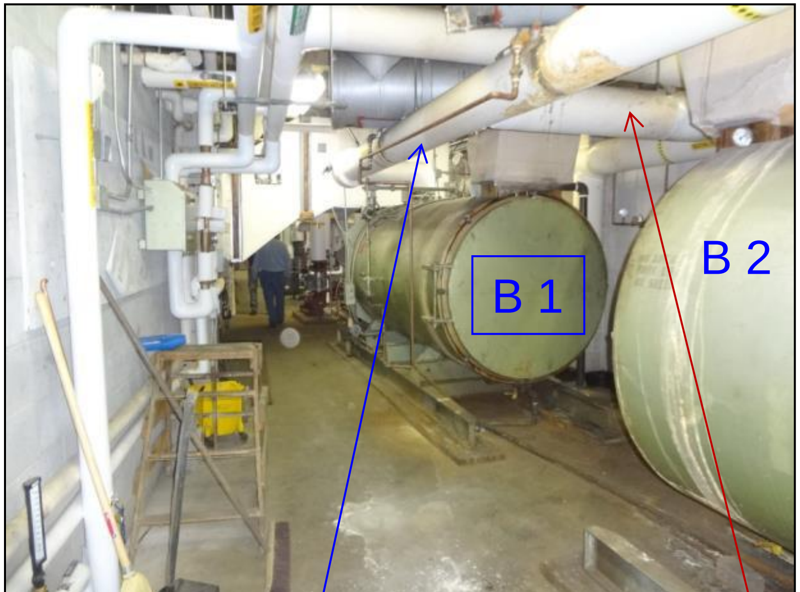
Mechanical-Boiler Room Details

2 primary heating hot water circ pumps interfacing with the 4 secondary/zone pumps via a decupling pipe.

Baseline - Two Existing Oil Fired Boilers with Nameplate data reflecting 5.0 million Btu/hr Output and 6.277 Million Btu/h Input, resulting in an **80% Boiler Efficiency** according to nameplate.

Roof Inspection

M&V Instrumentation Example - Planning

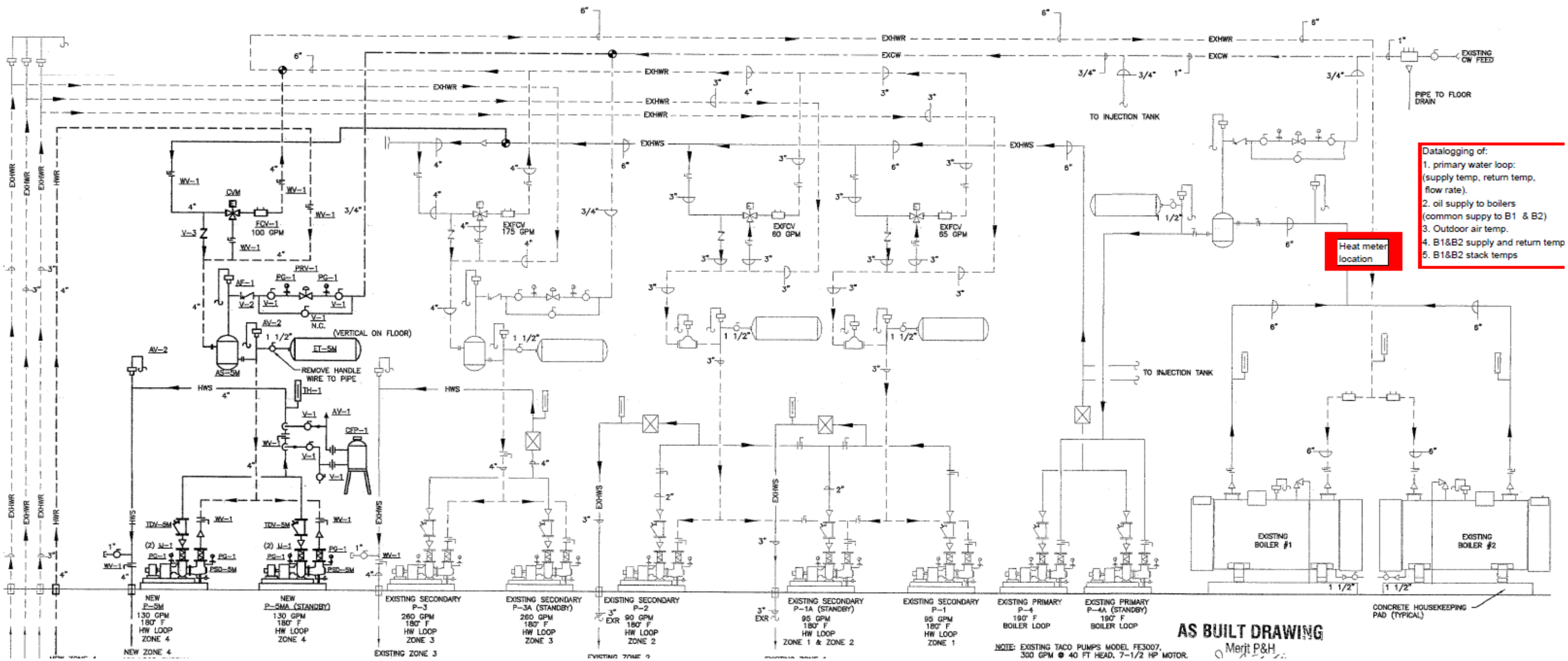


Boiler 1 Desired/Planned Flow Meter Location

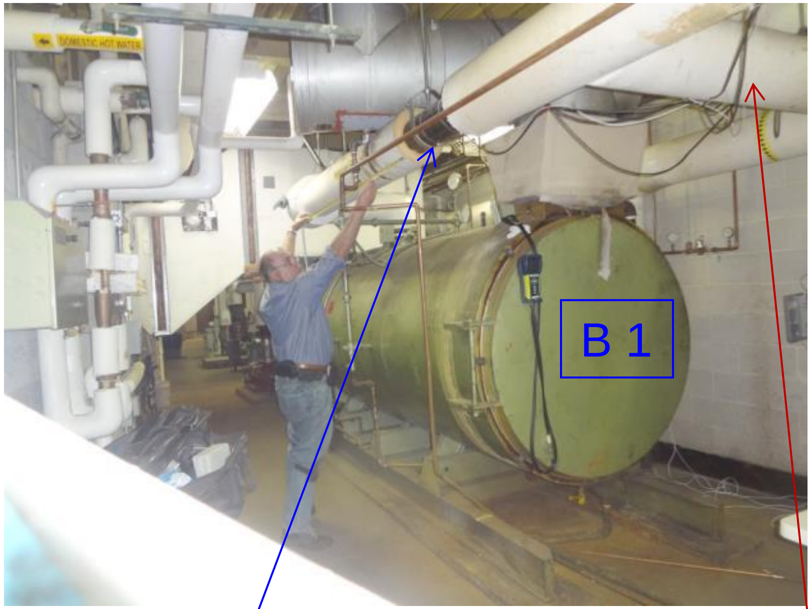
Boiler 2 Desired/Planned Flow Meter Location

Boilers 1 + 2 Desired Total Flow Meter Location on Common Heating Hot Water Header (Redundant total meter); however, Limited space!

Boiler Plant Piping Schematic and suggested Sensor Locations



M&V Instrumentation - Implementation



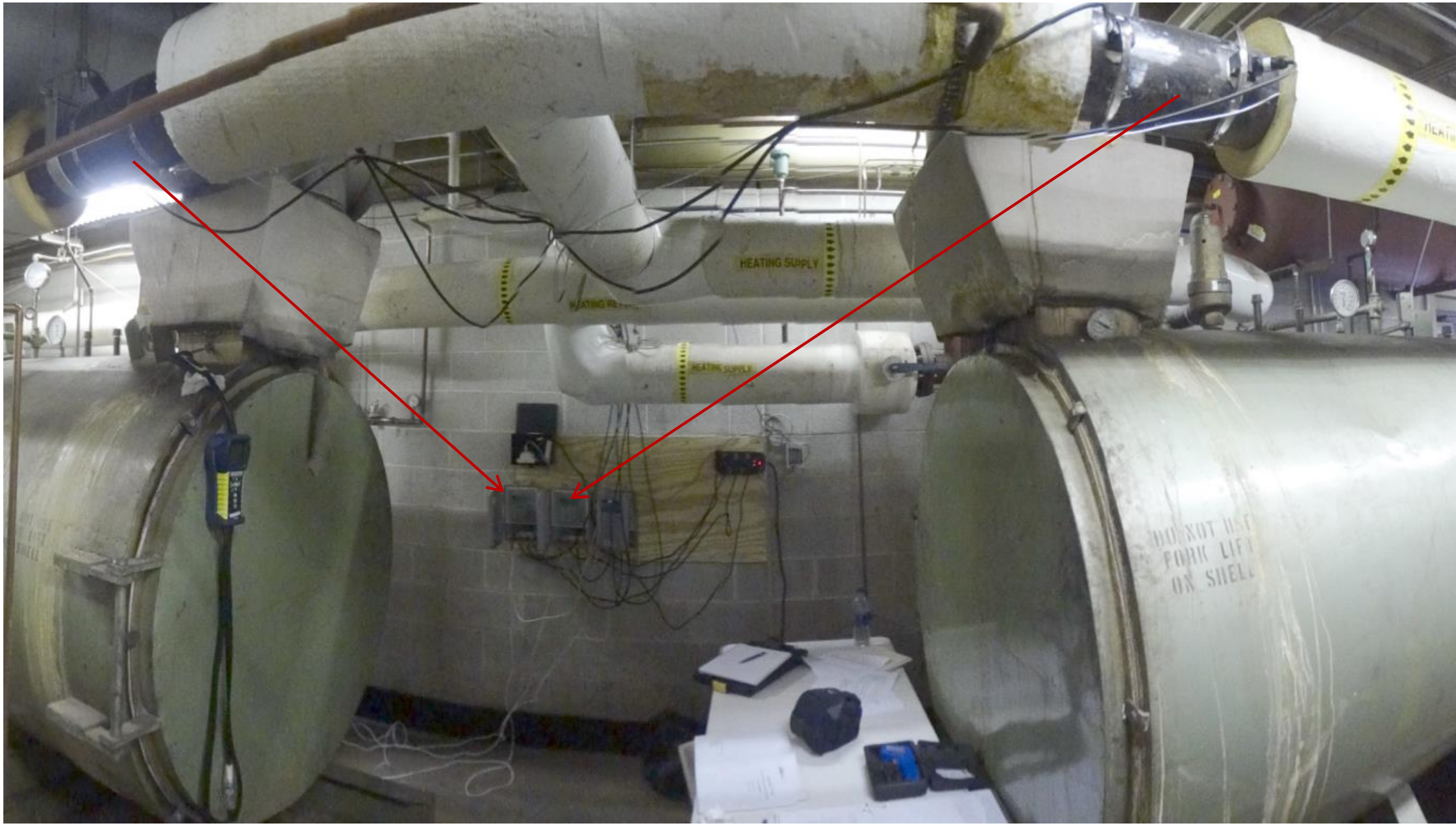
Boiler 1 Installed Flow Meter

Boiler 2 Installed Flow Meter

Boiler 1 + 2 Desired Total Flow Meter Location on Common Heating Hot Water Header (Redundant total meter); Located farther due to limited space!

M&V Instrumentation - Implementation

M&V Instrumentation - Implementation



M&V Instrumentation - Implementation

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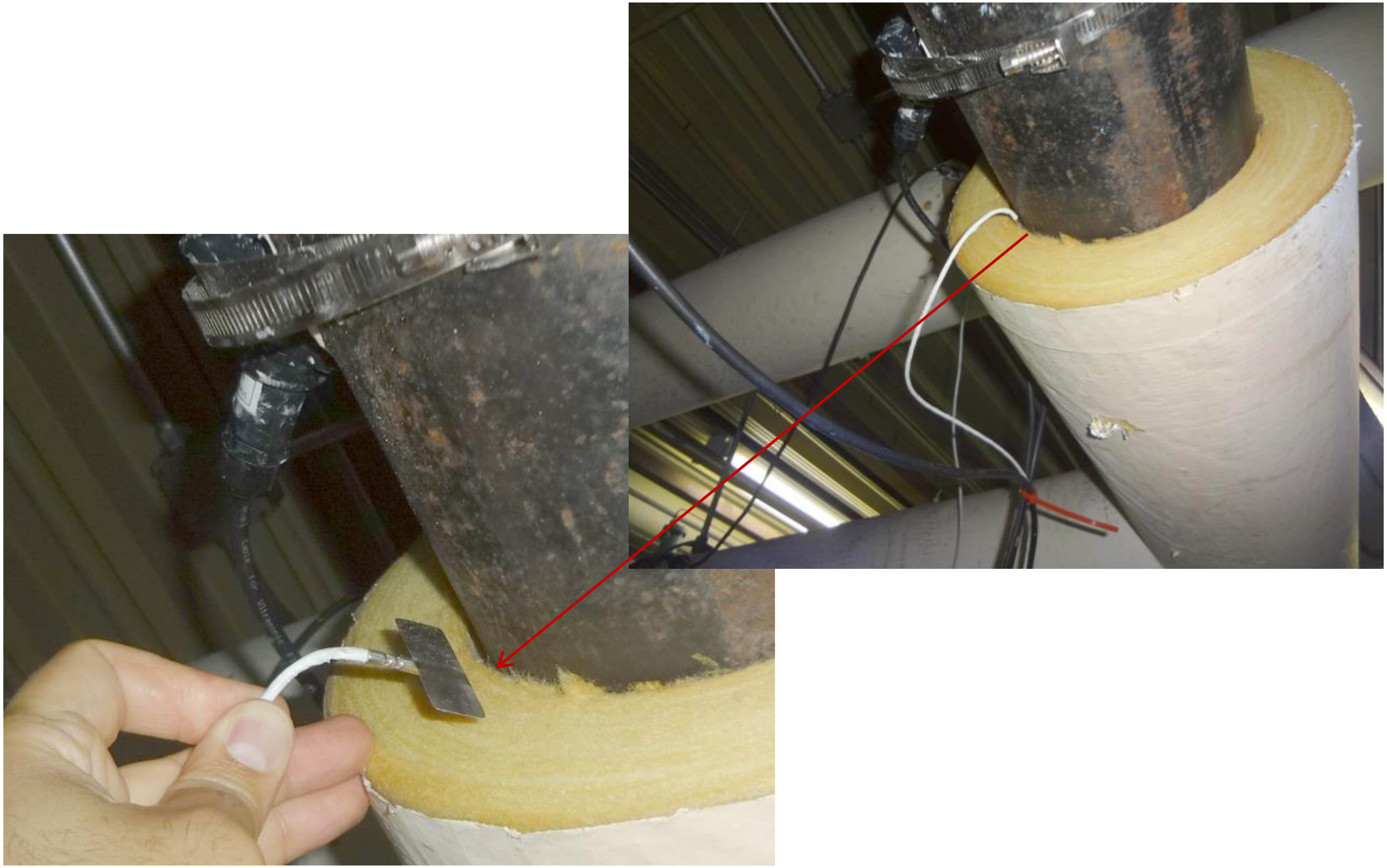
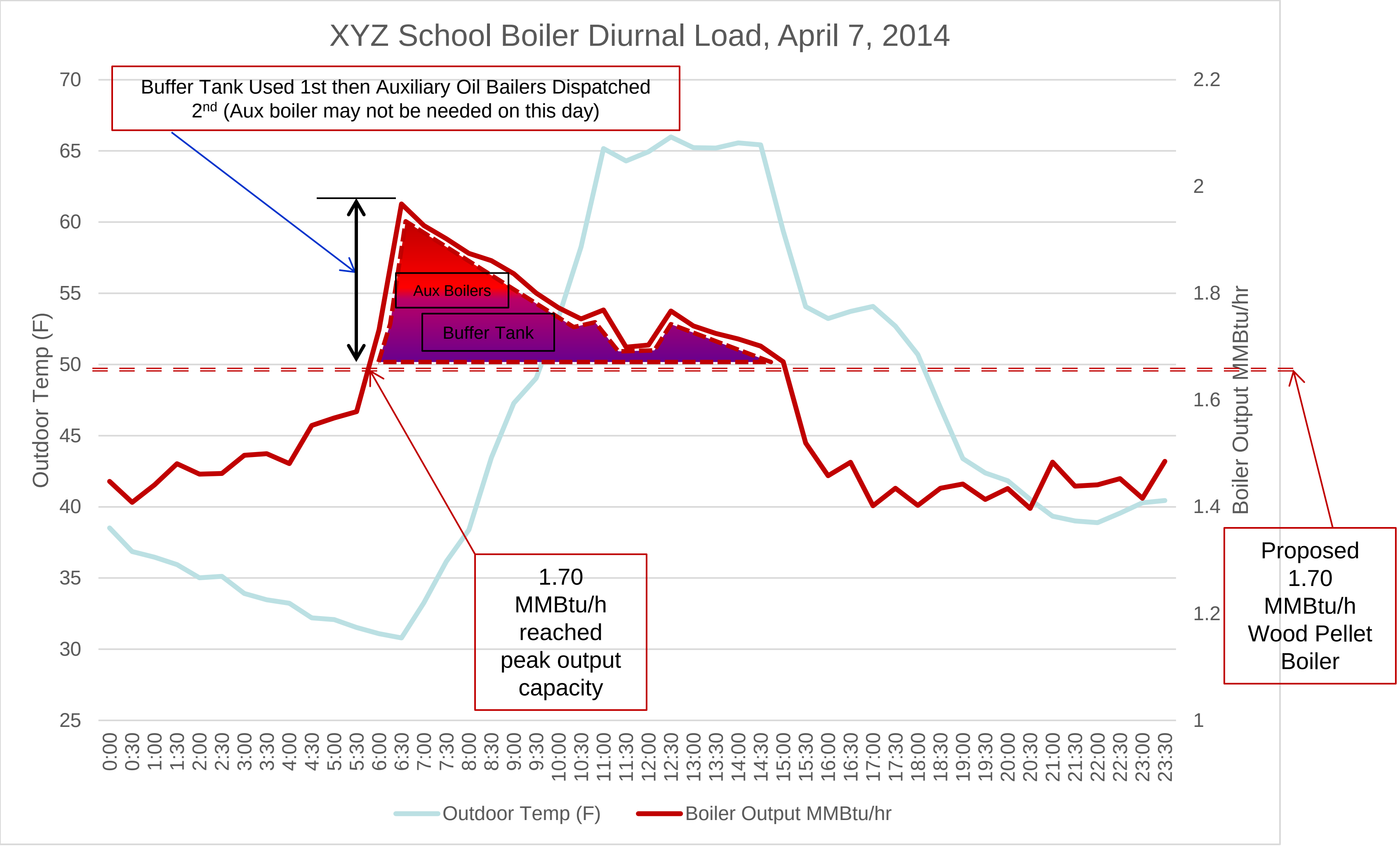


Swing Season Diurnal Heating Load Profile Using the Baseline Fuel Oil Boilers



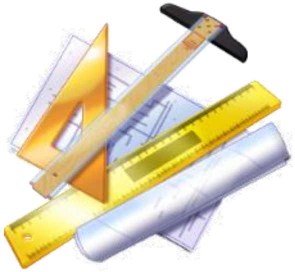
Challenges with Measuring Fuel Oil Flow

Better Fuel Oil Differential Flow Meter Locations

Siting Options of New Biomass Boilers follows CGC & RHNY Requirements

"You cannot manage what you do not <u>measure</u>"

"You cannot expect what you do not <u>inspect</u>"



The alternative is, "Trust me - you saved!"

Question - What are the most important take home messages in this section?

1. Biomass heating systems require a more careful approach,
2. Take baseline measurements of boilers with special focus on excessive on-off cycling, if any, as you carefully size the future biomass boiler(s). (Ex. Flex Tech and/or Existing Facility Program),
3. **Under-sizing** biomass boilers attains longer cycle/runtimes at higher/full loads & less cycling, especially when coupled with TES,
4. Use Thermal Energy Storage (TES)/buffer to reduce cycling and attain faster response time,
5. Existing propane and/or fuel oil boilers can serve as backup to baseloaded undersized biomass boilers & to meet peak load.
6. Must Commission, M&V and have independent review to ensure proper biomass system integration with existing heating systems, energy management systems, and heat distribution systems.

Congratulations!

We have complete the M&V Guidance & Examples with specific focus on Biomass Projects targeting Attaining and Verifying the Performance of Advanced Biomass Heating Systems and relevant EEMs

Best of luck!

Last break during Day-1 training

Section 8revised

Biomass analysis example

Presents the Energy and Economics Analysis for a Large Commercial Example, along with numerous normalized figures of merits, rules, etc.

Large Commercial Example Wood Pellet Preliminary Results 6/15/2014 (V3)

Option Number	1. Optimistic	2. Conservative	3. Long SPB	
SPB *Before* Incentive (Years) =	**8.7**	**10.7**	**12.6**	
Reduced SPB *After* Incentive (Years) =	**7.0**	**8.6**	**10.1**	
Fuel Oil Savings (Displacement) per year (Gallons) =	**32,446**	**34,610**	**36,773**	
Annual *Net* Cost Savings =	**$45,826**	**$47,034**	**$48,242**	**Variable #**

Electric Baseline based on blended $/kWh

Building Area Served (sq.ft.)	100,000	100,000	100,000	
Maximum Electric Demand (kW)	300.0	300.0	300.0	
Electric Energy Use (kWh / year)	850,000	850,000	850,000	
Electric Energy Cost ($ / year)	$90,000	$90,000	$90,000	
Peak Electric Demand (Watts / sq.ft.)	3.00	3.00	3.00	
Annual Electric Equivalent Full Load Hours (EFLH)	2,833	2,833	2,833	EFLH 1
Annual Electric Load Fraction (LF)	0.32	0.32	0.32	
Average blended (aggregate) electric cost ($/kWh)	**$0.106**	**$0.106**	**$0.106**	
To convert kWh to Btu, multiply by	3,413	3,413	3,413	
kBtu/year	2,901,050	2,901,050	2,901,050	
kBtu/sqft/year (EUI Electric)	29.0	29.0	29.0	Normalized EUI 1
Electric kWh/sqft/year	8.50	8.50	8.50	
Normalized Electric $/sqft/year	$0.90	$0.90	$0.90	
kWh per Million Btu of Site Electricity (kWh/MMBtu)	293.00	293.00	293.00	
Electricity Blended Unit Cost ($/MMBtu)	**$31.02**	**$31.02**	**$31.02**	Energy $/Million Btu 1

Fossil Fuel Baseline (#2 Fuel Oil) - Can also use Propane, Oil/Kerosene Mix, or other woods

Baseline Fuel Usage per year	43,262	43,262	43,262	
Fuel Units	Gallons of #2 Oil	Gallons of #2 Oil	Gallons of #2 Oil	
To Convert Fossil Fuel Units to Btu, Multiply by	138,690	138,690	138,690	
kBtu/year	6,000,000	6,000,000	6,000,000	
kBtu/sqft/year (Fuel EUI)	60.0	60.0	60.0	Normalized EUI 2
Million Btu/year (MMBtu/yr)	**6,000.0**	**6,000.0**	**6,000.0**	
Annual Fossil Fuel Cost	$151,417	$151,417	$151,417	
$/sqft/year	$1.51	$1.51	$1.51	
Fossil Fuel Unit Cost ($/Unit) i.e., $/Gallon	**$3.50**	**$3.50**	**$3.50**	
Fossil Fuel Unit Cost ($/MMBtu)	**$25.24**	**$25.24**	**$25.24**	Energy $/Million Btu 2

Large Commercial Example Wood Pellet Preliminary Results 6/15/2014 (V3)

Option Number	1. Optimistic	2. Conservative	3. Long SPB	
SPB *Before* Incentive (Years) =	**8.7**	**10.7**	**12.6**	
Reduced SPB *After* Incentive (Years) =	**7.0**	**8.6**	**10.1**	
Fuel Oil Savings (Displacement) per year (Gallons) =	**32,446**	**34,610**	**36,773**	
Annual *Net* Cost Savings =	**$45,826**	**$47,034**	**$48,242**	**Variable #**

Existing Boiler Plant Description

Number of Existing Boilers	4	4	4	
Boiler IBR (Fuel Units Per Hour) per Boiler	13.03	13.03	13.03	
Boiler Input per Boiler (Btu/hr) =	1,807,131	1,807,131	1,807,131	
Boiler Output Rated Capacity per Boiler (Btu/hr) =	1,500,000	1,500,000	1,500,000	
Boiler Full Load Efficiency per Boiler Nameplate =	83.0%	83.0%	83.0%	
Total Plant Output Capacity for all Boilers (Btu/hr) =	**6,000,000**	**6,000,000**	**6,000,000**	
Total Boiler Plant Normalized Output Capacity Btu/hr/sqft (i.e., for All Existing Installed Fossil Fuel Boilers) =	**60.00**	**60.00**	**60.00**	**Normalized Cap 1**
Existing Boiler Plant Output Annual EFLH =	1,000	1,000	1,000	EFLH 2
Assumed Peak Building Htg Load Factor of Boiler Capacity =	0.50	0.50	0.50	
Assumed Peak Building Heating Load (Btu/hr) =	**3,000,000**	**3,000,000**	**3,000,000**	
Assumed Peak Building Htg Load (Btu/hr/sqft) =	30.0	30.0	30.0	**Normalized Cap 2**
Assumed Peak Building Heating Load EFLH /year =	2,000	2,000	2,000	EFLH 3
Assumed Biomass Boiler Output Capacity Sizing Factor of the Peak Building Heating Load	**0.50**	**0.55**	**0.60**	**Variable 1**
Recommended Biomass Boiler Output Cap (Btu/hr)	**1,500,000**	**1,650,000**	**1,800,000**	
Recommended Biomass Boiler Output Btu/hr/sqft	**15.0**	**16.5**	**18.0**	**Normalized Cap 3**
Recommended Biomass Boiler Output Capacity (kW)	439	483	527	

Combined Baseline Usage (Elec + Fuel)

Combined for Electric Cost + Fuel Cost	**$241,417**	**$241,417**	**$241,417**	
Normalized for Electric Cost + Fuel Cost ($/sqft)	**$2.41**	**$2.41**	**$2.41**	
Combined for Electric + Fuel (kBtu/year)	**8,901,050**	**8,901,050**	**8,901,050**	
Combined for Electric & Fuel kBtu/sqft/year (Site EUI)	**89.0**	**89.0**	**89.0**	Normalized EUI 3

Large Commercial Example Wood Pellet Preliminary Results 6/15/2014 (V3)

Option Number	1. Optimistic	2. Conservative	3. Long SPB	
SPB *Before* Incentive (Years) =	8.7	10.7	12.6	
Reduced SPB *After* Incentive (Years) =	7.0	8.6	10.1	
Fuel Oil Savings (Displacement) per year (Gallons) =	32,446	34,610	36,773	
Annual *Net* Cost Savings =	$45,826	$47,034	$48,242	Variable #

Proposed Wood Pellet Plant Parameters

Proposed Boiler Capacity (Btu/h)	1,500,000	1,650,000	1,800,000	
Proposed Percent of Displaced Baseline Fuel	**75%**	**80%**	**85%**	Variable 2
Proposed Displaced Baseline Fuel (MMBtu/year)	4,500	4,800	5,100	
Proposed Biomass Boiler EFLH	3,000	2,909	2,833	EFLH 4
Fuel Oil Btu/Gallon Conversion	138,690	138,690	138,690	
Displaced Fuel Equivalent to #2 Fuel Oil	32,446	34,610	36,773	
>>>> **Displaced Gallons of Fuel per Boiler MBtu/h Capacity**	**21.63**	**20.98**	**20.43**	Normalized 4
Estimated HELE Fully Automatic Boiler Cost	**$120,000**	**$150,000**	**$180,000**	Variable 3a
Estimated BOP, Installation & Cx Costs, etc.	**$280,000**	**$355,000**	**$430,000**	Variable 3b
Estimated Total Installed Boiler Plant Cost *before* Incentives	**$400,000**	**$505,000**	**$610,000**	Variable 3c
>>>> **Estimated Installed Plant $/MBtu/h**	**$266.67**	**$306.06**	**$338.89**	Normalized 5
Ratio of boiler only cost to total installed and Cx-ed Proj Cost	**30.0%**	**29.7%**	**29.5%**	
Normalized Fossil Fuel Unit Cost ($/MMBtu)	$25.24	$25.24	$25.24	Energy $/Million Btu 2
Baseline Fossil Fuel Unit Cost Escalation Multiplier	1.00	1.00	1.00	
Displaced Baseline Fuel Cost per year	$113,563	$121,134	$128,704	

Proposed Wood Pellets Price as a Displacement Fuel

Cost of Wood Pellets per Ton (Basic Value)	$200	$200	$200	Keep same
Wood Pellet Cost Escalation Multiplier	1.00	1.00	1.00	Keep same
Cost of Wood Pellets per Ton	$200	$200	$200	Keep same
Pounds of Wood Pellets per Ton	2,000	2,000	2,000	
Btu Content of Wood Pellets per Pound	8,200	8,200	8,200	Keep same
Wood Pellets Caloric Value (MMBtu/Ton)	16.4	16.4	16.4	
Normalized Wood Pellets Unit Cost ($/MMBtu)	$12.20	$12.20	$12.20	Energy $/Million Btu 3
Needed Wood Pellets to displace Fossil Fuel (Ton/yr)	274	293	311	
Cost of wood pellets per year to displace fossil fuel	$54,878	$58,537	$62,195	
Net Annual Energy Cost Savings before O&M Expenditures	$58,685	$62,597	$66,509	
Silo Capacity (Tons)	40	40	40	
Estimated Silo Full fills per year to exceed	6.9	7.3	7.8	

Large Commercial Example Wood Pellet Preliminary Results 6/15/2014 (V3)

Option Number	1. Optimistic	2. Conservative	3. Long SPB	
SPB *Before* Incentive (Years) =	8.7	10.7	12.6	
Reduced SPB *After* Incentive (Years) =	7.0	8.6	10.1	
Fuel Oil Savings (Displacement) per year (Gallons) =	32,446	34,610	36,773	
Annual *Net* Cost Savings =	$45,826	$47,034	$48,242	Variable #
Electricity Needed to Run Additional Pumps & Parasitics per year				
Assumed Run Hours Per Year	5,110	5,475	5,840	Variable 4
Pump Electric at Full Load per Hour with VFD	5.28	5.28	5.28	
kWh/year estimate to run extra Pumping & Parasitics	27,002	28,931	30,860	
Average Cost of $/kWh	$0.106	$0.106	$0.106	
Annual Electrical Cost to Run the Pumps & Parasitics	$2,859	$3,063	$3,267	
Wood Pellet Plant Maintenance Costs/Year				
$/year	$10,000	$12,500	$15,000	Variable 5
Net Cost Savings				
Net Fuel Cost Savings - Pump Elec Cost - Maint Cost	$45,826	$47,034	$48,242	
Simple Payback (SPB) in years *before* Incentives				
Installed Cost *before* Incentive / Net Cost Savings	8.7	10.7	12.6	
Suggested Wood Pellet Boiler Plant Incentives				
Percent of Total Installed cost	20%	20%	20%	
Estimated Incentive Offer	$80,000	$101,000	$122,000	
Calculated % Incentive relative to ONLY HELE boiler material cost.	67%	67%	68%	
Net Installed Proj Cost *after* Incentive Deduction	$320,000	$404,000	$488,000	
>>>> Incentive $/MBtu/h of Boiler Installed Capacity	$53.33	$61.21	$67.78	Normalized 6
>>>> Incentive $/MMBtu of Annual Displaced Fuel	$17.78	$21.04	$23.92	Normalized 7
Simple Payback (SPB) in years *after* Incentives				
Installed Cost *after* Incentive / Net Cost Savings	7.0	8.6	10.1	

Notes:

Note 1 If we use better proposed wood pellet boiler efficiencies than the baseline fossil fuel boiler efficiencies, that will even increase the energy cost savings and shorten the simple payback period (SPB) presented above. However, this requires extremely good wood pellet boiler controls with TES and full system Cx to realize all the full displaced fuel targets possible from the proposed pellet system. We stayed conservative in this analysis and kept those as back pocket energy cost savings.

Note 2 Pipe thermal losses from biomass boilers to TES tanks to PFHX are assumed to be minimal and are less than the safety factor used under the boiler efficiency Note 1 above. Pipe selection and size are needed for not only for thermal losses calculations, but at times, as they also serve as an extension to the TES Tank Capacity through the water volume in pipes. This also facilitates additional biomass boiler capacity backup in case the existing Oil and/or Propane fired boilers fail. This is applicable to rare situations where oversized piping and fluid mass are used as additional TES capacity.

Note 3 The above analysis makes a clear distinction in terminology between fuel displacement vs. energy cost savings. It should be noted that we are NOT using energy savings anywhere in this analysis. It is either energy cost savings or displaced fuel.

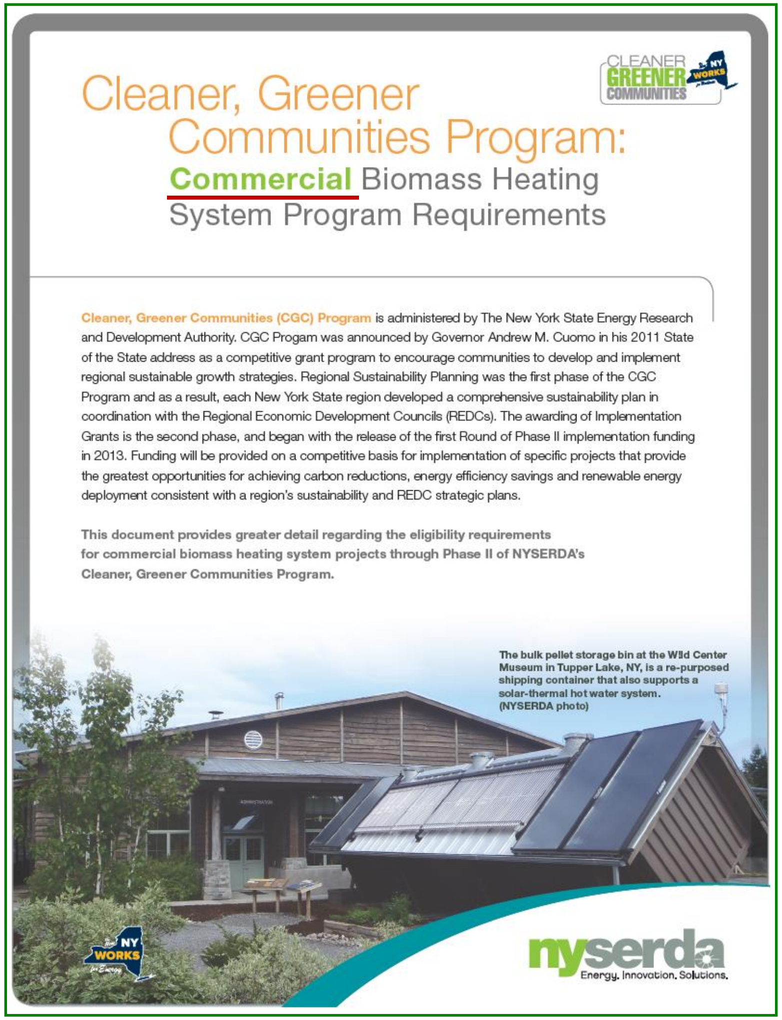
Section 9

Other relevant topics:

a) Cleaner, Greener Communities Program (CGC),
b) Hydronics and boiler protection reminder,
c) Highlights of Existing Building and Boiler Plant Controls, Future Controls Integration, Pneumatic vs. DDC, etc.

Cleaner, Greener Communities Program (CGC)

http://www.nyserda.ny.gov/Governor-Initiatives/Cleaner-Greener-Communities/Implementing-Smart-Development-Projects/Guidance-Documents.aspx

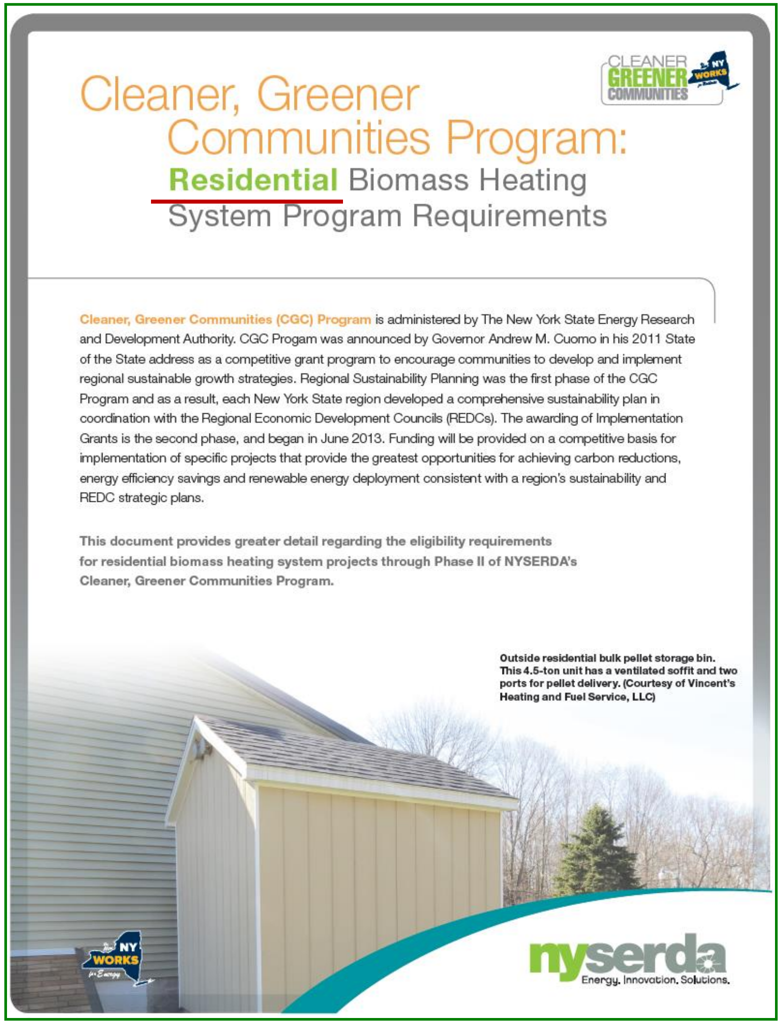


Cleaner, Greener Communities Program: Commercial Biomass Heating System Program Requirements

Cleaner, Greener Communities (CGC) Program is administered by The New York State Energy Research and Development Authority. CGC Progam was announced by Governor Andrew M. Cuomo in his 2011 State of the State address as a competitive grant program to encourage communities to develop and implement regional sustainable growth strategies. Regional Sustainability Planning was the first phase of the CGC Program and as a result, each New York State region developed a comprehensive sustainability plan in coordination with the Regional Economic Development Councils (REDCs). The awarding of Implementation Grants is the second phase, and began with the release of the first Round of Phase II implementation funding in 2013. Funding will be provided on a competitive basis for implementation of specific projects that provide the greatest opportunities for achieving carbon reductions, energy efficiency savings and renewable energy deployment consistent with a region's sustainability and REDC strategic plans.

This document provides greater detail regarding the eligibility requirements for commercial biomass heating system projects through Phase II of NYSERDA's Cleaner, Greener Communities Program.

The bulk pellet storage bin at the Wild Center Museum in Tupper Lake, NY, is a re-purposed shipping container that also supports a solar-thermal hot water system. (NYSERDA photo)



Cleaner, Greener Communities Program: Residential Biomass Heating System Program Requirements

Cleaner, Greener Communities (CGC) Program is administered by The New York State Energy Research and Development Authority. CGC Progam was announced by Governor Andrew M. Cuomo in his 2011 State of the State address as a competitive grant program to encourage communities to develop and implement regional sustainable growth strategies. Regional Sustainability Planning was the first phase of the CGC Program and as a result, each New York State region developed a comprehensive sustainability plan in coordination with the Regional Economic Development Councils (REDCs). The awarding of Implementation Grants is the second phase, and began in June 2013. Funding will be provided on a competitive basis for implementation of specific projects that provide the greatest opportunities for achieving carbon reductions, energy efficiency savings and renewable energy deployment consistent with a region's sustainability and REDC strategic plans.

This document provides greater detail regarding the eligibility requirements for residential biomass heating system projects through Phase II of NYSERDA's Cleaner, Greener Communities Program.

Outside residential bulk pellet storage bin. This 4.5-ton unit has a ventilated soffit and two ports for pellet delivery. (Courtesy of Vincent's Heating and Fuel Service, LLC)

Guidance Documents for CGC Phase II Implementation Grants

To Apply

- Consolidated Funding Application

Documents

- CGC Guidance Document - CGC Phase II, Round 2 Grants [PDF]
- Disclosure of Prior Findings of Non-Responsibility Form [PDF]
- Category 1 Fact Sheet [PDF]
- Announcement [PDF]
- Example Statement of Work [PDF] [DOCX]
- Project Benefits Report Template [PDF] [DOCX]
- Category 1: Terms and Conditions [PDF]
- Category 2: Sample Agreement [PDF]
- Category 3: Sample Agreement [PDF]
- Sustainability Indicator Guidance Document [PDF]
- Sustainability Indicators by Region [XLS]
- Creating EV-Ready Towns and Cities - A Guide to Planning and Policy Tools [PDF]
- Creating EV-Ready Towns and Cities - A Guide to Planning and Policy Tools - Addendum [PDF]
- NYS Standard Solar Permitting Form [PDF]
- LIPA Solar Energy System Fast Track Permit Application [PDF]
- Biomass Heating System Program Requirements - Commercial [PDF]
- Biomass Heating System Program Requirements - Residential [PDF]

See Commercial (8 Pages)
&
Residential (6 Pages)

CGC resources

CFA Webinar

View the CGC CFA webinar

Frequently Asked Question

View frequently asked questions for Cleaner Greener Communities Phase II [PDF]

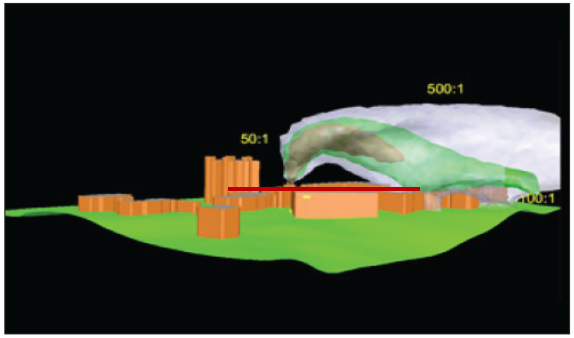


Figure 3. Vertical cross sectional diagram of the wake and cavity regions in the lee side of building. (Courtesy of M/E Engineering)

c) Stack Height: Stack heights should be consistent with good engineering practice to minimize the wake effects caused by buildings or terrain on emissions. The design of the exhaust stack and location should be done carefully to prevent exposure to building occupants and visitors or to people in frequently occupied outdoor areas such as playgrounds. The boiler's stack height must be sufficient to adequately disperse emissions from the immediate vicinity and prevent entrainment of exhaust gases and particles into the building air intakes and to minimize exposure at ground level adjacent to the building on which the stack is being located (Figure 3). Poor dispersion characteristics are generally associated with short stacks that have little plume rise. This happens when stacks are too short relative to the building height or the exhaust flow is not sufficient, resulting in the plume not escaping the building's aerodynamic effects and becoming entrained in or near the building. For example the stack should be a minimum of 5 feet above the highest point of a large flat building that it is heating and above the roof height of any other taller building within 100 feet of the unit. In no case should the stack height be at or below the building height. In addition, the stack should not be placed in close proximity to an air intake or operable window. Stack design should also minimize horizontal piping and bends. Projects at schools, hospitals and other locations with similar populations, must use dispersion techniques and engineering design considerations of the stack height and placement (see, for example www.epa.gov/ttn/scram/guidance_permit.htm for some EPA documents on good engineering stack height and modeling).

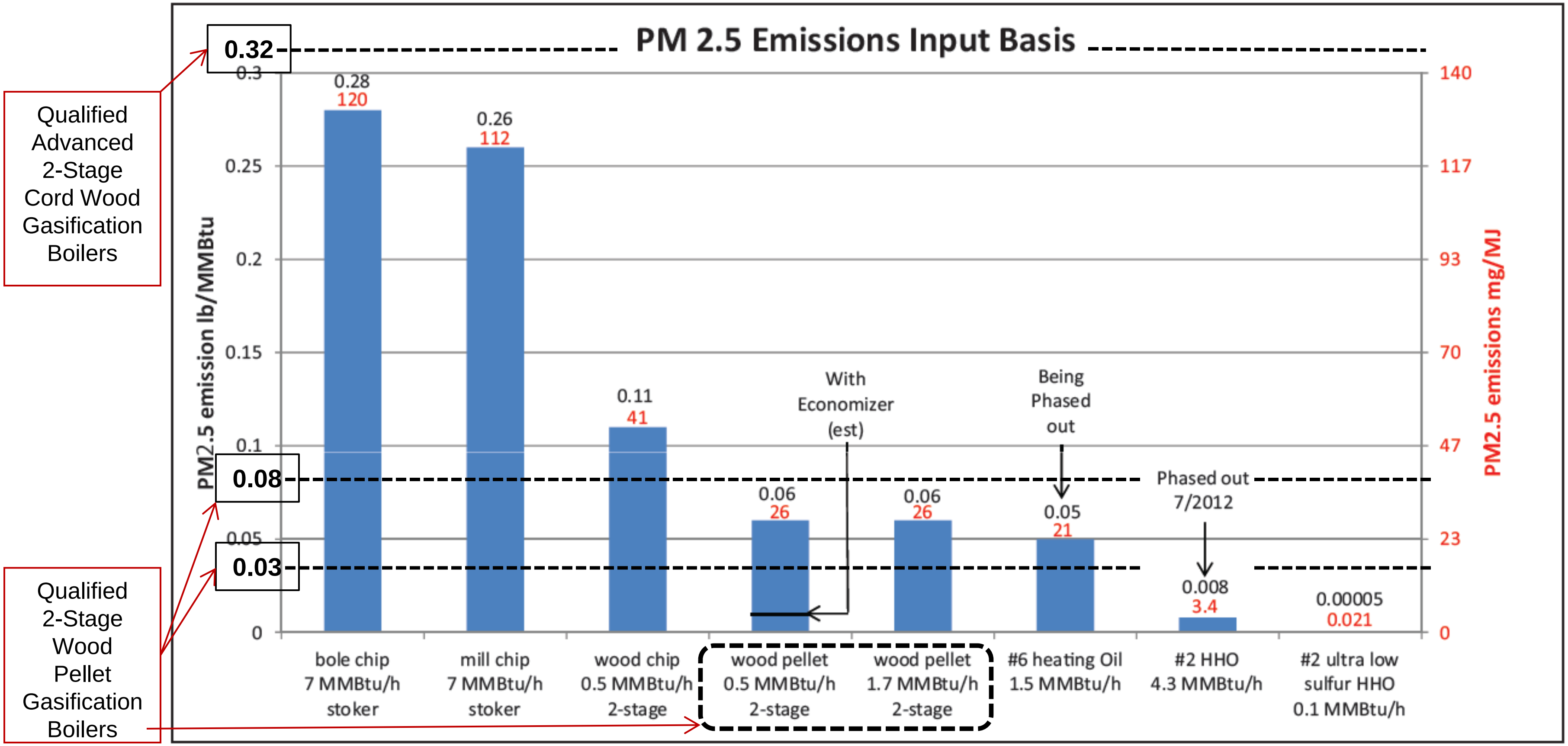


Figure 12. Comparative fine particulate matter (PM2.5) emissions from several fuel-heating technology combinations including wood chips, wood pellets, #5 fuel oil, and #2 home heating oil (HHO). (Rector, L. (2010), Chandrasekaran, S. et al. (2011), McDonald (2009))

Make sure you attend the Hydronics training

Hydronics for High Efficiency Biomass Boilers

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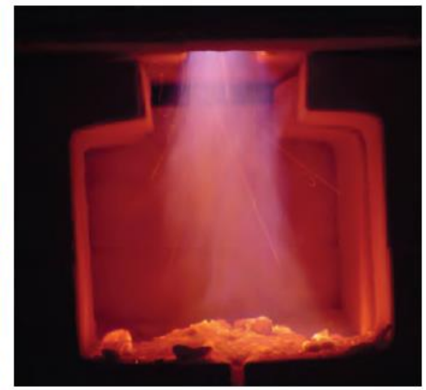

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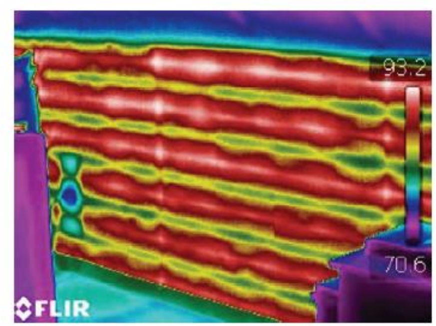
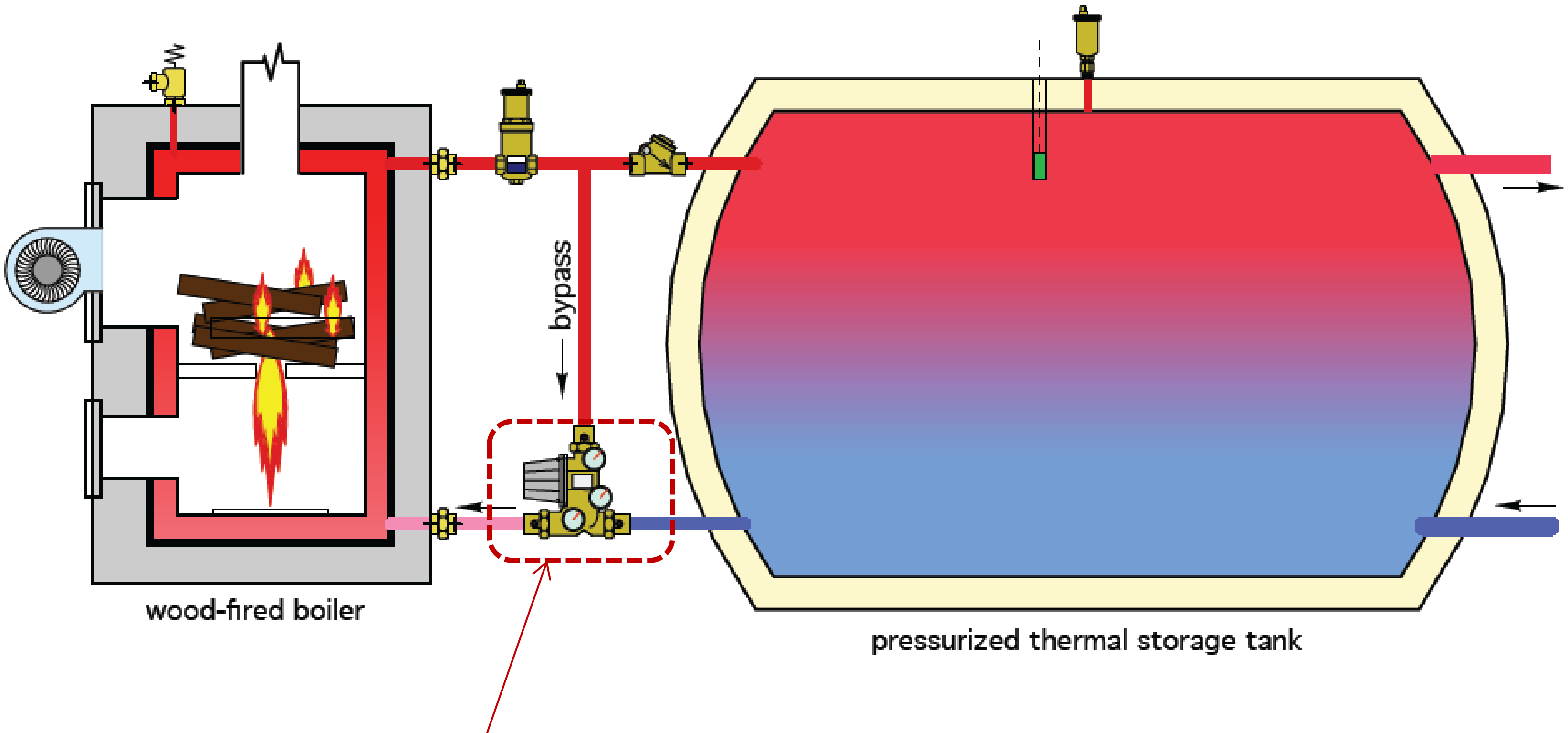




[1] Boiler Thermal Protection against low entering water temperature for both Biomass and Existing Fuel Oil or Propane Boilers. This is a MUST in terms of both Hydronics and Controls, otherwise, boilers can be thermally shocked and cracked.

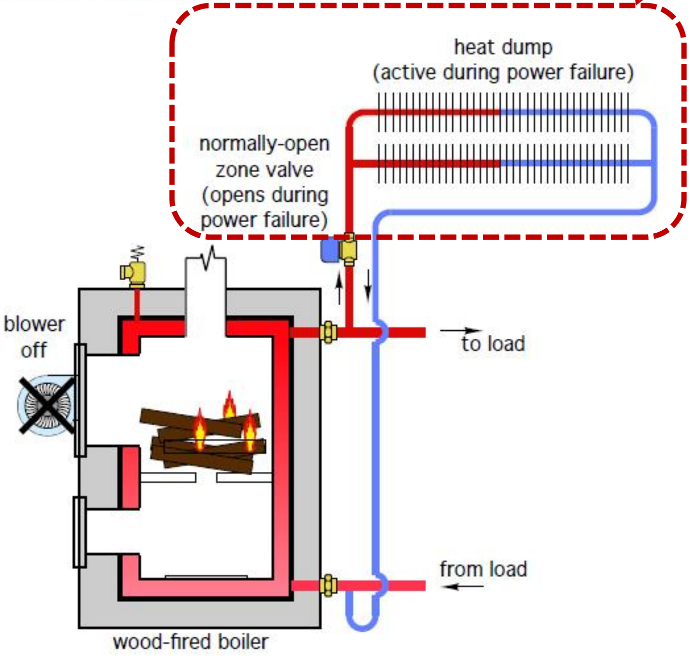
Courtesy of John Siegenthaler, P.E., Appropriate Designs

[2] Boiler Thermal Protection against overheating during Power failure.

Boiler protection:

- Against low entering water temperature
- Against overheating during power failure

creosote

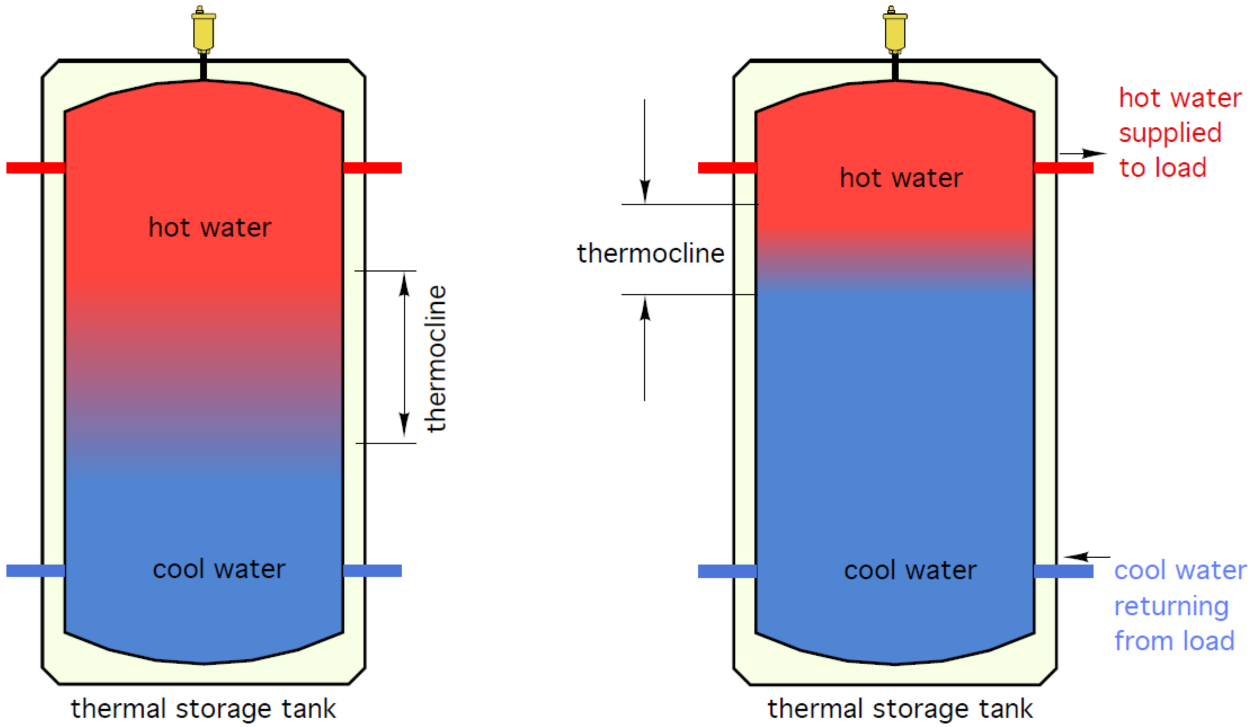


Courtesy of John Siegenthaler, P.E., Appropriate Designs

[3] Vertically Stratified Buffer Tanks are preferred over horizontal Buffer Tanks.

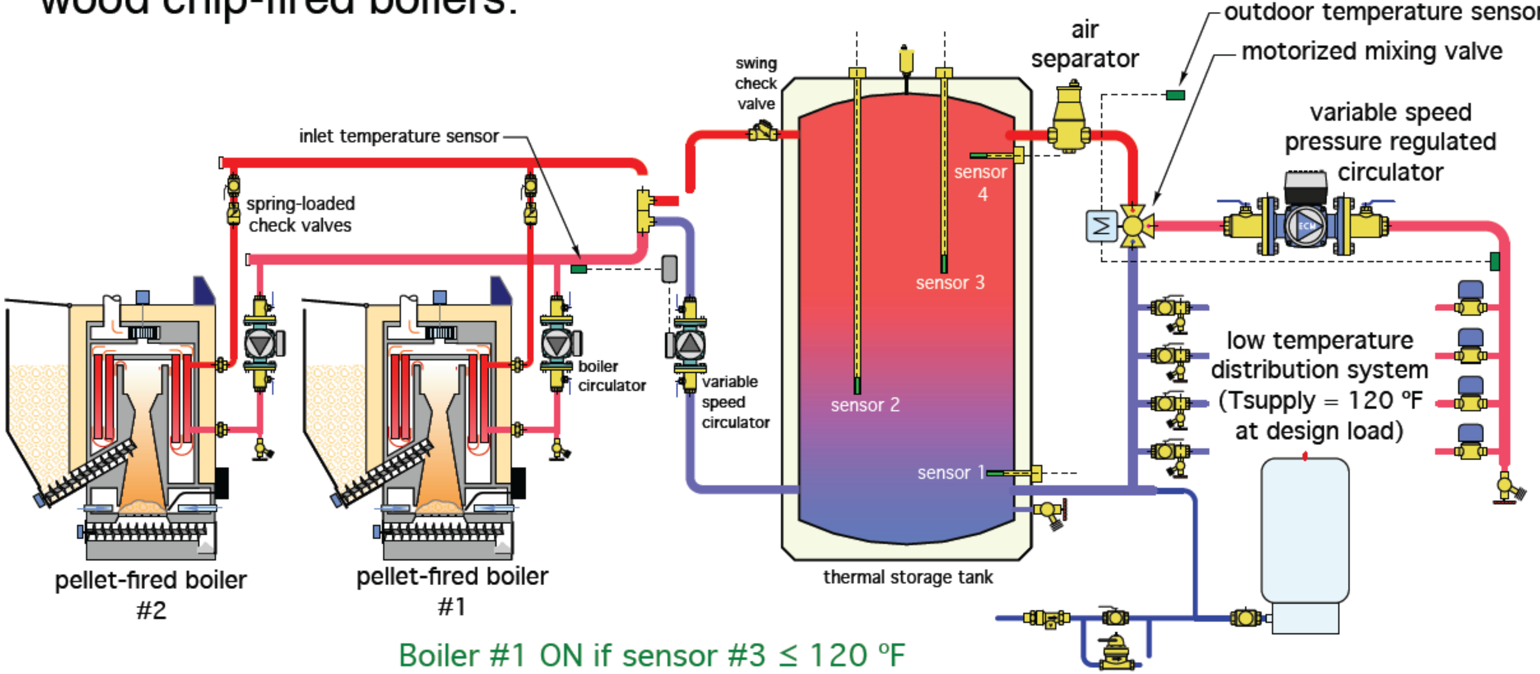
A thermal storage tank “at rest” will have a well defined **thermocline**, between cooler water at bottom, and hottest water at top.

As hot water is drawn from upper portion of tank, thermocline moves up. Cool water stacks from bottom.



Courtesy of John Siegenthaler, P.E., Appropriate Designs

This temperature stacking strategy can be used with two pellet-fired or wood chip-fired boilers.



Boiler #1 ON if sensor #3 ≤ 120 ºF

Boiler #2 ON if sensor #4 ≤ 120 ºF

Boiler #2 OFF if sensor #2 ≥ 180 ºF

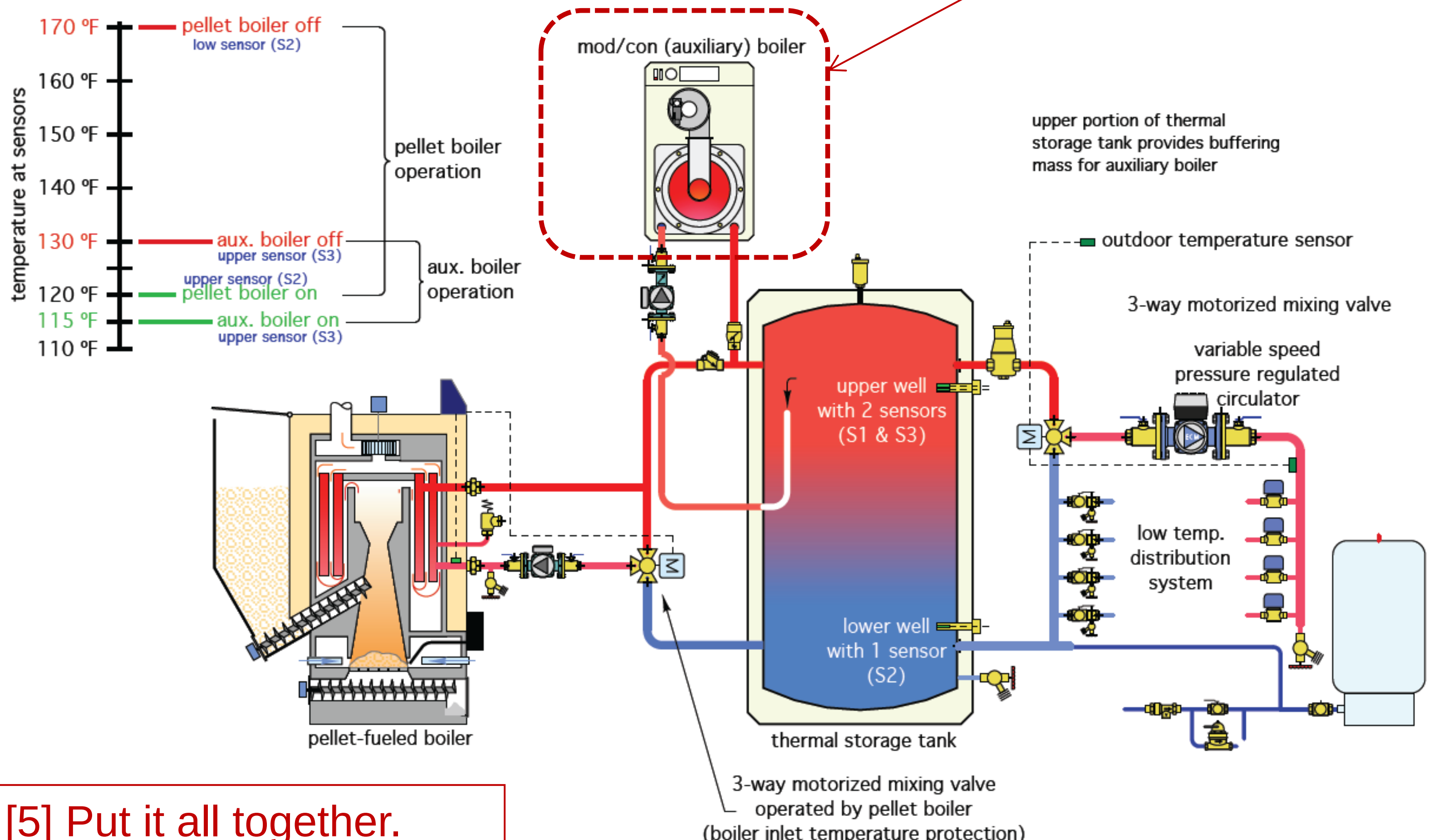
Boiler #1 OFF if sensor #1 ≥ 180 ºF

[4] Put it all together.

Courtesy of John Siegenthaler, P.E., Appropriate Designs

Same idea, but using variable speed circulator for boiler protection.

Temperature stacking strategy is different when second boiler is auxiliary boiler.



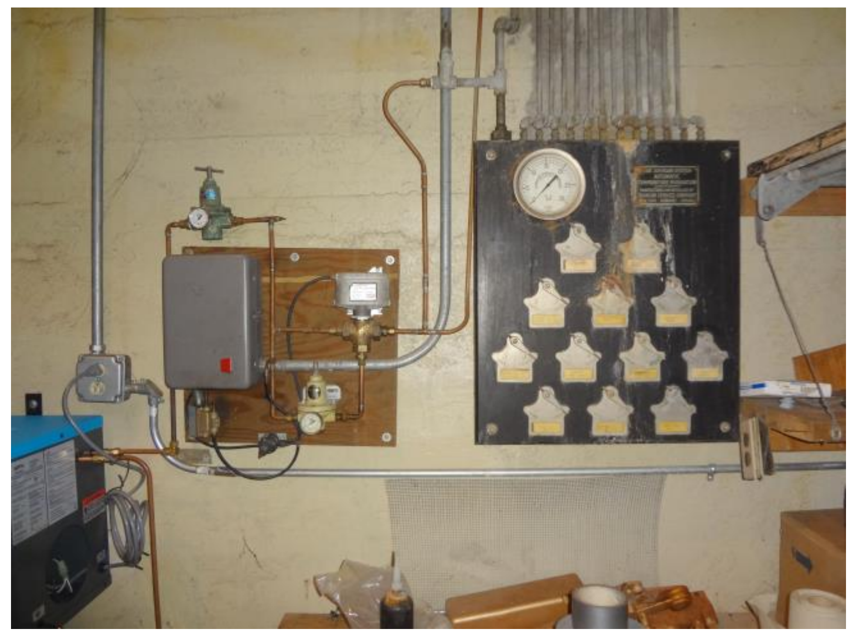
[5] Put it all together.

When ON, the mod/con aux. boiler operates at water temperature that allow for sustained flue gas condensation.

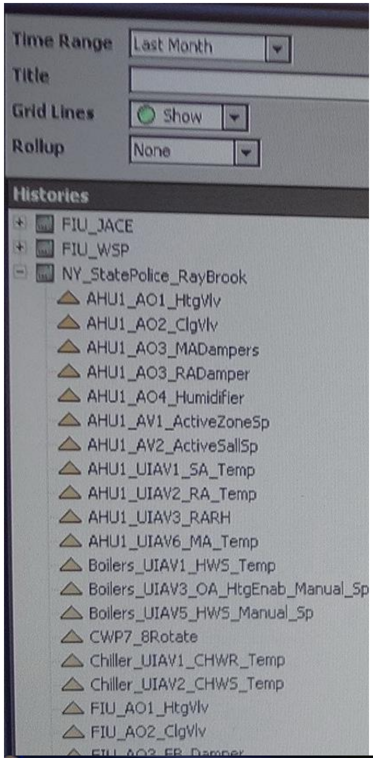
Courtesy of John Siegenthaler, P.E., Appropriate Designs

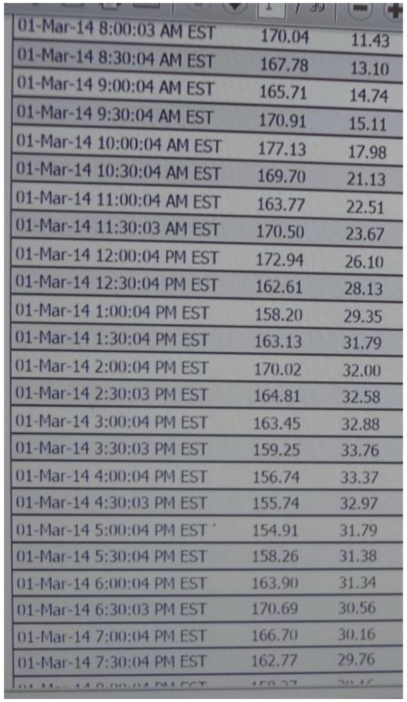
Highlights of Existing Building and Boiler Plant Controls, Future Controls Integration, Pneumatic vs. DDC, etc.

Controls - Old Pneumatics

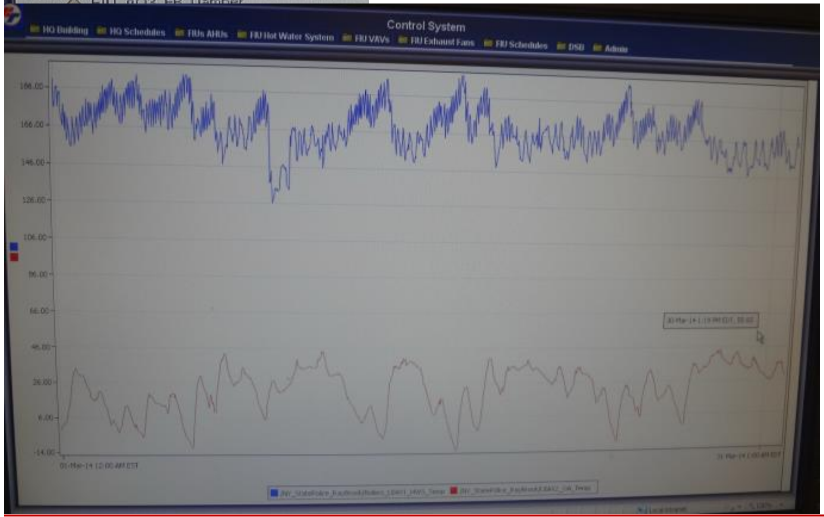


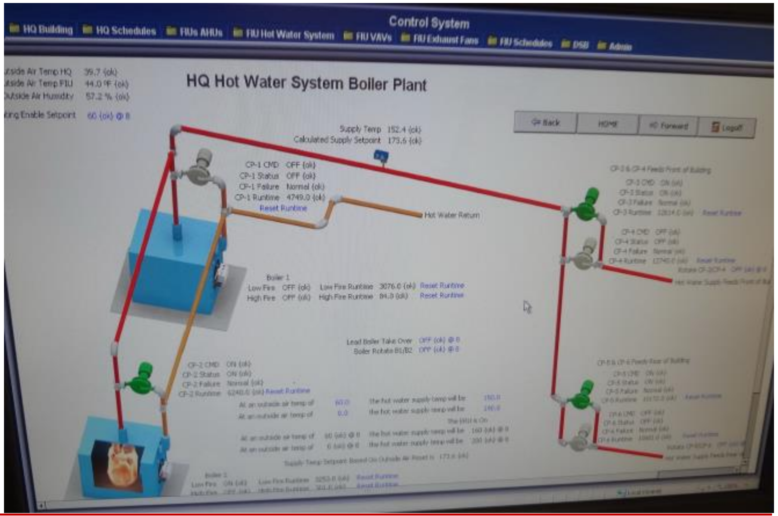
Controls - Newer DDC

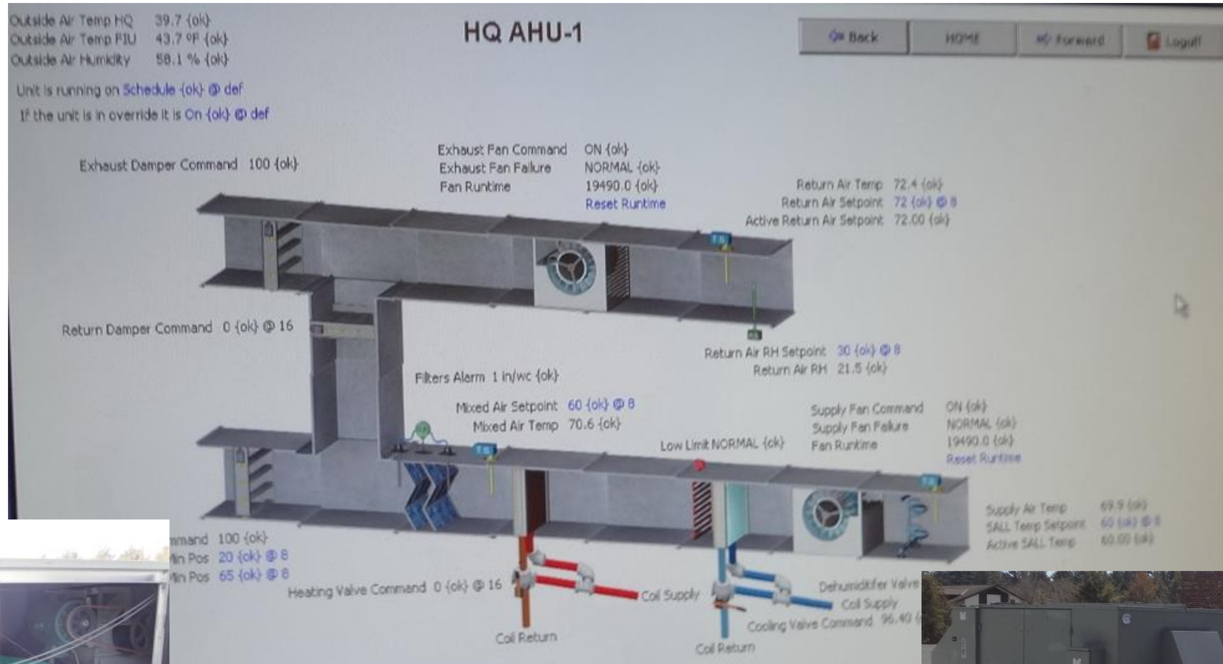


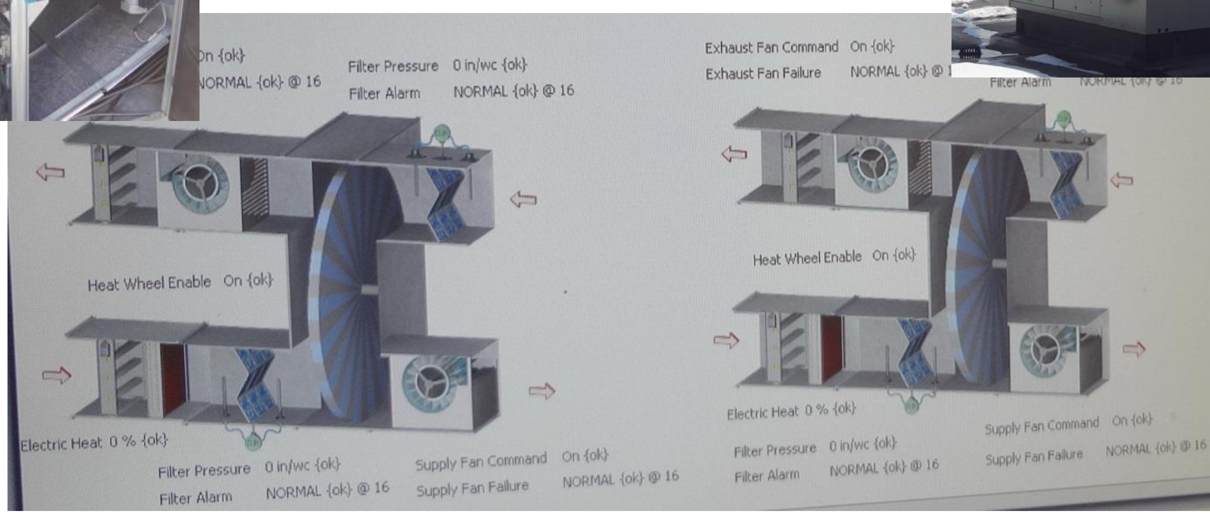


01-Mar-14 8:00:03 AM EST	170.04	11.43
01-Mar-14 8:30:04 AM EST	167.78	13.10
01-Mar-14 9:00:04 AM EST	165.71	14.74
01-Mar-14 9:30:04 AM EST	170.91	15.11
01-Mar-14 10:00:04 AM EST	177.13	17.98
01-Mar-14 10:30:04 AM EST	169.70	21.13
01-Mar-14 11:00:04 AM EST	163.77	22.51
01-Mar-14 11:30:03 AM EST	170.50	23.67
01-Mar-14 12:00:04 PM EST	172.94	26.10
01-Mar-14 12:30:04 PM EST	162.61	28.13
01-Mar-14 1:00:04 PM EST	158.20	29.35
01-Mar-14 1:30:04 PM EST	163.13	31.79
01-Mar-14 2:00:04 PM EST	170.02	32.00
01-Mar-14 2:30:03 PM EST	164.81	32.58
01-Mar-14 3:00:04 PM EST	163.45	32.88
01-Mar-14 3:30:03 PM EST	159.25	33.76
01-Mar-14 4:00:04 PM EST	156.74	33.37
01-Mar-14 4:30:03 PM EST	155.74	32.97
01-Mar-14 5:00:04 PM EST	154.91	31.79
01-Mar-14 5:30:04 PM EST	158.26	31.38
01-Mar-14 6:00:04 PM EST	163.90	31.34
01-Mar-14 6:30:03 PM EST	170.69	30.56
01-Mar-14 7:00:04 PM EST	166.70	30.16
01-Mar-14 7:30:04 PM EST	162.77	29.76






HQ AHU-1
Outside Air Temp HQ 39.7 {ok}
Outside Air Temp FIU 43.7 °F {ok}
Outside Air Humidity 58.1 % {ok}
Unit is running on Schedule {ok} @ def
If the unit is in override it is On {ok} @ def
Back
HOME
Forward
Logoff
Exhaust Damper Command 100 {ok}
Exhaust Fan Command ON {ok}
Exhaust Fan Failure NORMAL {ok}
Fan Runtime 19490.0 {ok}
Reset Runtime
Return Air Temp 72.4 {ok}
Return Air Setpoint 72 {ok} @ 8
Active Return Air Setpoint 72.00 {ok}
Return Damper Command 0 {ok} @ 16
Return Air RH Setpoint 30 {ok} @ 8
Return Air RH 21.5 {ok}
Filters Alarm 1 in/wc {ok}
Mixed Air Setpoint 60 {ok} @ 8
Mixed Air Temp 70.6 {ok}
Low Limit NORMAL {ok}
Supply Fan Command ON {ok}
Supply Fan Failure NORMAL {ok}
Fan Runtime 19490.0 {ok}
Reset Runtime
Heating Valve Command 0 {ok} @ 16
Coil Supply
Coil Return
Coil Supply
Coil Return

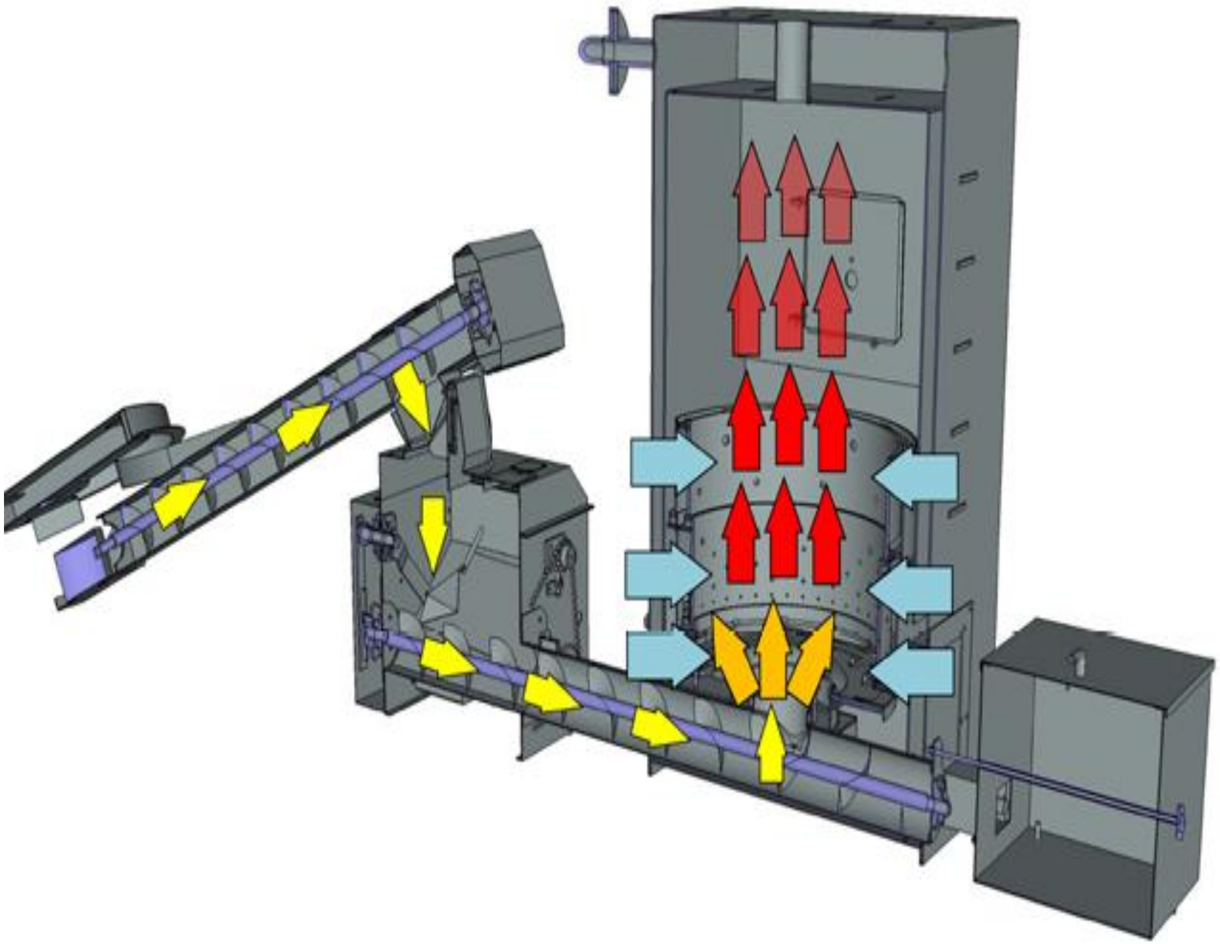

Filter Pressure 0 in/wc {ok}
Filter Alarm NORMAL {ok} @ 16
Exhaust Fan Command On {ok}
Exhaust Fan Failure
Heat Wheel Enable On {ok}
Heat Wheel Enable On {ok}
Electric Heat 0 % {ok}
Filter Pressure 0 in/wc {ok}
Filter Alarm NORMAL {ok} @ 16
Supply Fan Command On {ok}
Supply Fan Failure NORMAL {ok} @ 16
Electric Heat 0 % {ok}
Filter Pressure 0 in/wc {ok}
Filter Alarm NORMAL {ok} @ 16
Supply Fan Command On {ok}
Supply Fan Failure NORMAL {ok} @ 16

Section 10

Visit to Boiler Manufacturer and/or a biomass site (2nd day of training)

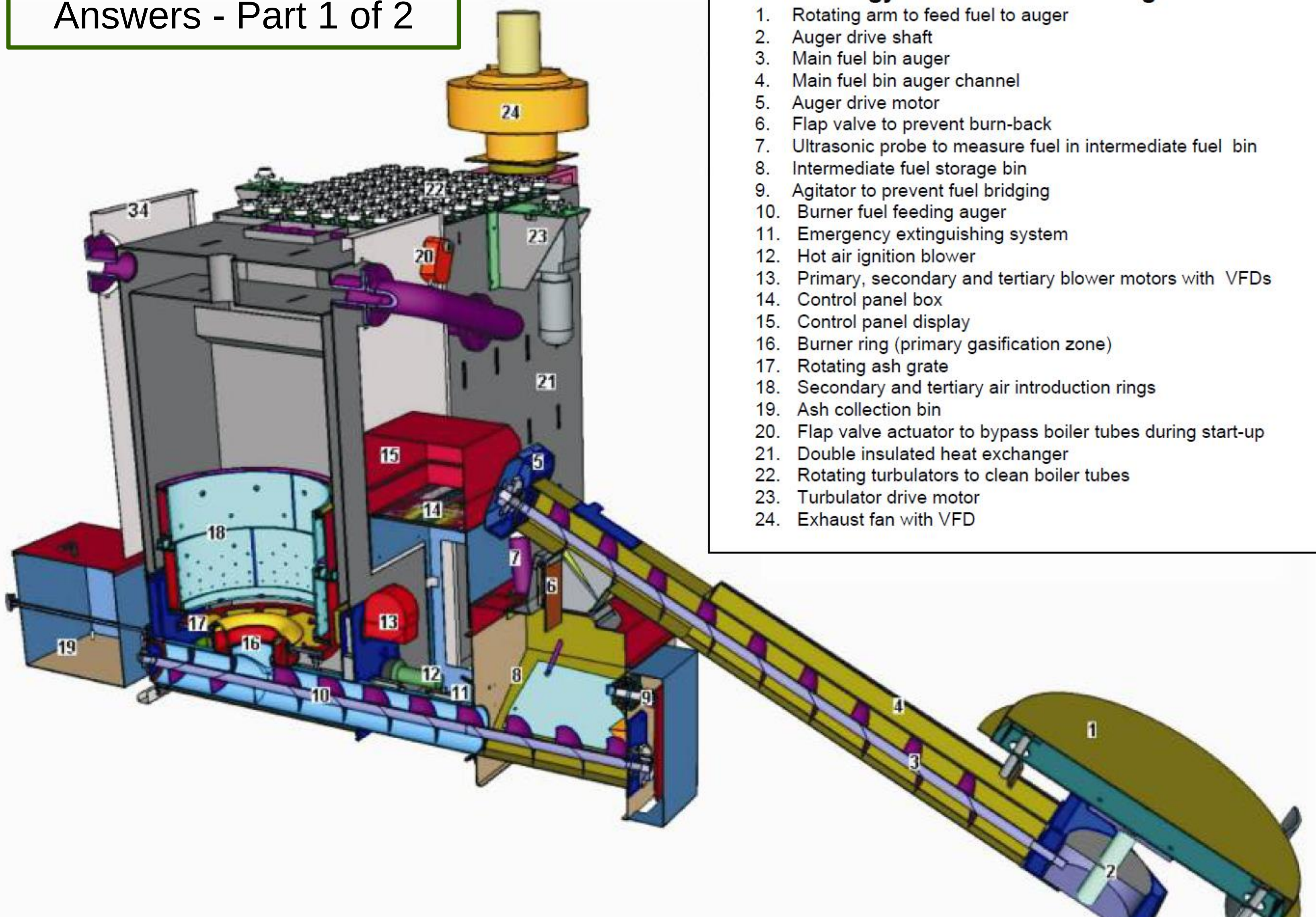
First Made-in-NY Commercial *ACT Biomass Boiler (Advanced Climate Technologies, LLC) by Unilux* - February 19, 2014.

Question - Identify High-Efficiency Wood Pellet Boiler **Components**



Illustrations Courtesy of *ACT Bioenergy Manual, Schenectady, NY (ACT is Advanced Climate Technologies, LLC)*

Answers - Part 1 of 2



ACT Bioenergy™ Boiler with fuel auger

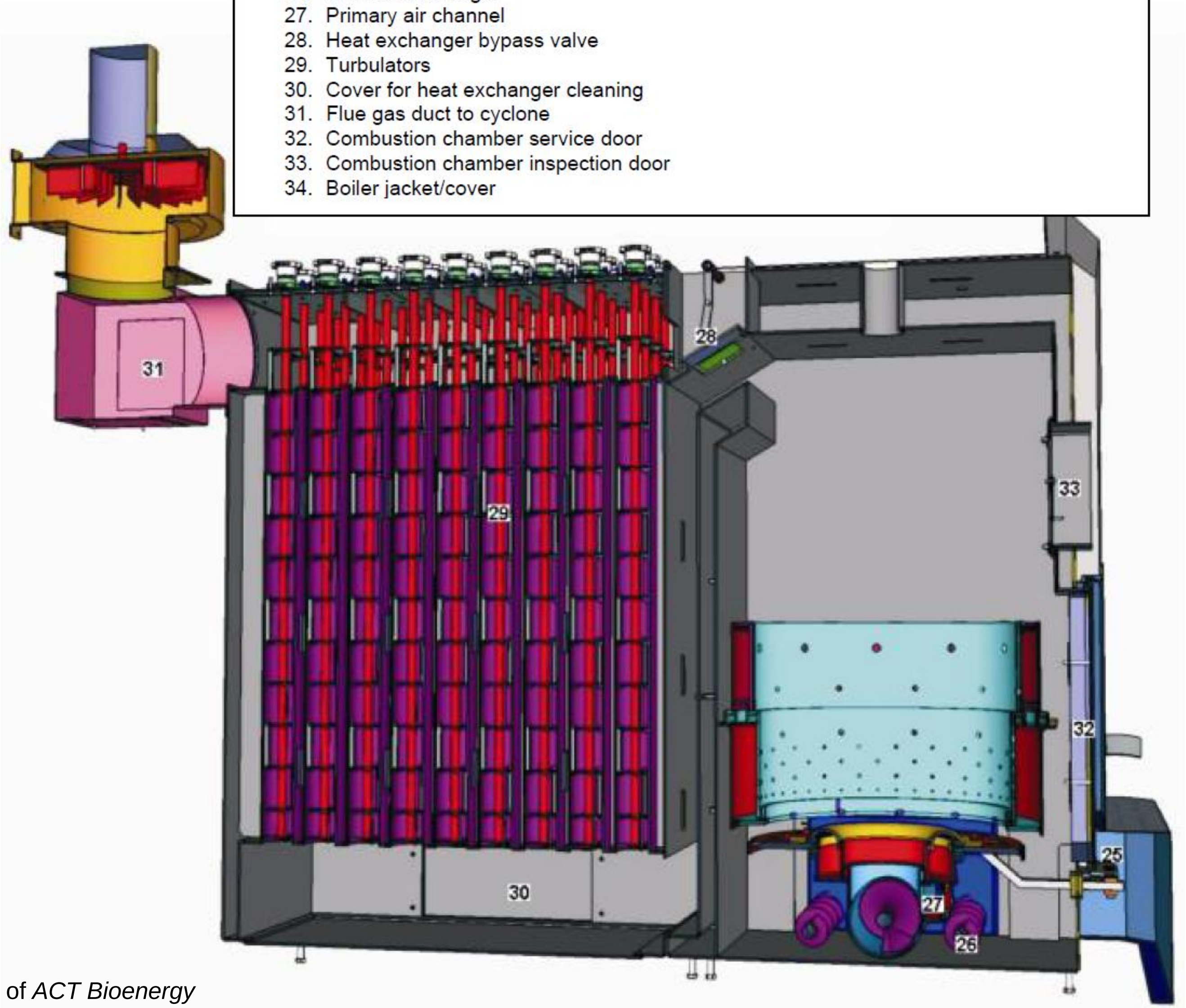
1. Rotating arm to feed fuel to auger
2. Auger drive shaft
3. Main fuel bin auger
4. Main fuel bin auger channel
5. Auger drive motor
6. Flap valve to prevent burn-back
7. Ultrasonic probe to measure fuel in intermediate fuel bin
8. Intermediate fuel storage bin
9. Agitator to prevent fuel bridging
10. Burner fuel feeding auger
11. Emergency extinguishing system
12. Hot air ignition blower
13. Primary, secondary and tertiary blower motors with VFDs
14. Control panel box
15. Control panel display
16. Burner ring (primary gasification zone)
17. Rotating ash grate
18. Secondary and tertiary air introduction rings
19. Ash collection bin
20. Flap valve actuator to bypass boiler tubes during start-up
21. Double insulated heat exchanger
22. Rotating turbulators to clean boiler tubes
23. Turbulator drive motor
24. Exhaust fan with VFD

Illustrations Courtesy of *ACT Bioenergy*

Answers - Part 2 of 2

ACT Bioenergy™ Boiler with fuel auger

25. Grate cleaning drive arm
26. Ash removal auger
27. Primary air channel
28. Heat exchanger bypass valve
29. Turbulators
30. Cover for heat exchanger cleaning
31. Flue gas duct to cyclone
32. Combustion chamber service door
33. Combustion chamber inspection door
34. Boiler jacket/cover



Illustrations Courtesy of *ACT Bioenergy*

Question - List Important Take Home Messages & Next Steps

1. Biomass heating systems require a more careful *integrated* approach,
2. ASAP, invest in a good quality comprehensive ASHRAE Level-II Building *Energy Audit*,
3. Audits must focus on the necessary <u>integration</u> between the proposed biomass heating system and the existing heating systems at the building under study,
4. Take *baseline* measurements of existing boilers with special focus on excessive on-off cycling, as you carefully size the future biomass boiler(s) at future design development stages of the project. (Ex. May utilize FlexTech and/or Existing Facility Program - EFP),
5. *Under-sizing* biomass boilers attains longer on cycles/runtimes at higher/full loads & less cycling, especially when coupled with Thermal Energy Storage (TES) or buffer tanks,
6. Use properly stratified *TES Buffer Tanks* to reduce boiler cycling, attain faster biomass system response time, higher efficiencies, and displace more fossil fuel,
7. Existing propane and/or fuel oil fired boilers can serve as backup to the *baseloaded* undersized biomass heating systems and to meet peak building heating loads that exceed the biomass plant output capacity,
8. Must Commission (*Cx*), Measure & Verify (*M&V*), and have *independent review* to ensure proper biomass system <u>integration</u> with existing heating systems, energy management systems, and heat distribution systems,
9. Comply with all of the RHNY *Eligibility Requirements* explained earlier in this training,
10. Address the above items and lead by example.

Disclaimers - Continued 1

- It is assumed that M&V and Cx processes will be completed by competent and experienced energy professionals who will select the appropriate tools and methods for their facilities, systems, and plants in order to identify, analyze and recommend appropriate Cx, controls improvements and controls integration procedures and other load reduction and energy efficiency measures (EEMs).
- It is also assumed that energy professionals follow all safety procedures and precautions during the Cx and system troubleshooting and they are solely responsible for their safety during any or all of such activities as they interface with systems including but not limited to mechanical, electrical, HVAC at varying conditions, with special focus on biomass heating systems, TES/buffering and appropriate fuel storage, etc.
- Many of the views and lessons included are mine and they do not necessarily represent the exact views of others.
- My intention is not to survey all available energy M&V methods and Cx actions, but to communicate to you my experience, some lessons learned, what worked and what did not work and with special focus on biomass heating systems, etc.

Disclaimers - Continued 2

- Overall, Proper biomass system sizing, M&V activities (and subsequent Cx findings) among the different energy agencies, as well as my own experience, should all be heading in the same general direction and have similar, but not exact, agendas and objectives. Despite certain variations, they mostly follow a systematic approach that should make sense, and should lead you towards conducting a successful system sizing and M&V/Cx processes.

- Finally, the contents of this document provide assistance toward planning for and implementing the “proper level and proper Option” of an M&V process. Therefore, it is strongly recommended that the energy professional carefully examine the intended purpose of M&V Plan Options (A, B, C or D) that is suitable for their facilities, customer objectives, project budgets, and the level of detail that is required, in order to determine what procedures to adapt and which lessons learned to benefit from. Again, not all Options and procedures included herein are required for all M&V and Cx activities; I just wanted to present several options and some checklists that the energy professionals may consider as they select items and procedures that suit their M&V and Cx needs.

Disclaimers - Continued 3

- Despite Pyramid EES being a professional New York State Engineering Firm, we have been referring engineering design and PE stamp requests to other MEP (Mechanical, Electrical and Plumbing) firms from our professional network to support our customers' MEP design requests. In conclusion, we currently do not provide traditional MEP design services, despite some requests from the industry. We also prefer if customers actually use their own preferred engineering firms of record, especially if they have been involved in earlier projects and if there is a good rapport established between the customer and their MEP firms.

- Additionally, our training and independent technical review and support may include recommendations of deploying data loggers, utilizing the boiler built-in onboard microprocessor control panels, building EMS, and ongoing data analysis, but excludes the detailed specifications of site specific installations of any intrusive or non-intrusive data loggers. As discussed, metering and logging provisions must be accounted for and included as an integral part of the design so they are done right from the beginning and done properly and are the responsibly of the customer, their MEP or E/A firm of record or their contractors.

Q/A

Thank you for Attendance and Participation

Khaled A. Yousef, PE, CEM, CDSM, LEED AP, GBE

Principal Energy Engineer

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Energy Engineering Services, PLLC

Energy Efficiency & Sustainability | Optimization | Modeling | Technical & Design Assistance | Master Planning | LEED Support | Commissioning | CHP | Biomass | R&D

Thank you nyserda Energy. Innovation. Solutions. *for your sponsorship*

End of Day-1 Classroom Training
will go to the biomass boiler factory tomorrow morning

END

