Introduction to the Fundamentals of the Proper Commissioning Process - Supporting a wide range of simple to complex buildings, technologies and projects

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Course Description - **Stage-I** - (1 of 5)

This course presents an overview to the ***proper commissioning (Cx) process*** starting with what is Cx? It presents the most known six (6) types of Cx (Total Cx, Continuous Cx, Ongoing Cx, Re-Cx, Retro-Cx, & Cx Light or Custom Cx), the 4 proper phases of the Cx process, how to plan for Cx, the Cx team's composition and their Roles and Responsibilities; it then offers an intro to the required checklists, forms and tests to conduct proper Cx, and how to plan for and generate a beneficial Cx report for existing and new buildings and systems targeting high performance.

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Topics Covered / Learning Objectives - Stage-I - (2 of 5)

Understand ***well-integrated*** and ***holistic*** project development and Cx approaches to support successful HVAC, MEP and building automation systems (EMS/BMS/SCADA) installations covering a wide variety of conventional, progressive and renewable heating and cooling systems and technologies in varying building types and sizes covering residential, commercial, institutional, industrial facilities (& even laboratories & mission critical facilities!).

Cx *is part of* ***IDP*** *(Integrated Design Process)*.

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Topics Covered / Learning Objectives - Stage-I - (3 of 5)

Be aware of the numerous Commissioning (Cx) ***procedures and requirements*** based on major Cx references by the **U.S. DOE** (The Model Cx Plan - Construction Phase Cx Plan), the US DOE funded **BCxA** (Building Commissioning Association), **ACG** (AABC Cx Group), the well-known and widely accepted **ASHRAE** Guideline 0 (The Cx Process), ASHRAE Guideline 1 (The HVAC Cx Process), as well as numerous respected other resources, all coupled and illustrated by the authors own in-depth expertise and experience in the field over the last 3 decades, domestically in the U.S. as well as internationally, supported by real life examples, some were quite painful and expensive.

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Topics Covered / Learning Objectives - Stage-I - (4 of 5)

- Make a differentiation between ***existing*** and ***new*** buildings and provide an overview of suggested additional sensors to incorporate during the design and construction phases to support new building Total Cx then Ongoing Cx moving forward using those built-in sensors for both monitoring based Cx & M&V if needed).
- Identify key systems within a facility that are better candidates or higher priorities for commissioning compared to other systems as sorted by their energy use, demand intensities, more critical to facility operation in terms of occupant comfort, productivity, customer revenues, IEQ and safety.

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Topics Covered / Learning Objectives - Stage-I - (5 of 5)

- Be aware of a few of the known ***barriers*** impeding implementation of the proper Cx process in numerous projects and know how to avoid them through good customer and project team education.
- Be aware of the proper Cx process from A to Z and see what happens when the proper process was not followed based on multiple real life examples. Some lessons were real painful and expensive! ***Over 20 lessons learned categories are presented*** (but will be elaborated on further during future Stage-II of this course as such optional and in-depth detail cannot be covered in the short Stage-I course).

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Topics Covered / Learning Objectives - Completion of the last Introductory **Stage-I**, then move to **Stage-II**. - (1 of 5)

Due to the 1- to 2- hr time restriction in the **Introductory Cx Stage-I Course**, the in-depth Cx [1] **PFCs** (Prefunctional Checklists) and [2] **FPTs** (Functional Performance Tests) that are technology specific and cover several known HVAC/MEP systems will be presented separately, along with other relevant [3] **Cx procedure details** and [4] **Lessons Learned details** (caused by lack of Cx in several example projects); All will be made available in the full day **Stage-II** Cx course (in the future presenting a full Cx hands-on Workshop - where [5] a **Site Visit** of commissioned systems may also be offered).

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Topics Covered / Learning Objectives - Stage-II - (2 of 5)

- During Stage-II of this course, it elaborates and emphasizes the importance of Cx and illustrates the devastating impacts of lack of Cx by sharing details of numerous ***lessons learned*** from biomass heating system commercial installations pertaining to several High-Efficiency and Low-Emission Biomass Heating projects.
- The course covers varying sizes and a wide range of installations and layouts.

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Topics Covered / Learning Objectives - Stage-II - (3 of 5)

- Presents how following the core 4-Phase Cx process ([1] Cx During **Pre-Design** Phase, [2] Cx During **Design** Phase, [3] Cx During **Construction**, and [4] Cx During **Occupancy & Operations**) may have prevented many of the above problems from occurring; all coupled by valuable and in-depth Cx **PFC and FPT technology specific examples** and it presents other Cx procedures and details.

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Topics Covered / Learning Objectives - Stage-II - (4 of 5)

- Topics presented include, but are not limited to, system sizing, controls, systems integration between existing oil/propane boiler plants and the new biomass heating boiler plants, Commissioning (Cx), Testing, Adjusting and Balancing (TAB), Thermal Energy Storage (TES), hydronics, boiler venting, mechanical room layouts, differences between stick-built vs. containerized boiler plant options, project management (PM), construction management (CM), and project roles and responsibilities (R&R) from A to Z.

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Topics Covered / Learning Objectives - Stage-II - (5 of 5)

- Promotes well-integrated and holistic project development approaches to support successful biomass installations and support the entire biomass heating industry.
- Also shares a list of valuable conclusions, recommendations, suggested next steps, and valuable take home messages.
- Finally, audience will acquire other benefits and skills that will support them in their daily job besides biomass heating.

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Important Cx Related Definitions, Sources & Resources

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In general, Commissioning is a systematic process of inspecting and testing building systems to ensure that they are installed properly and operate in accordance with the design intent.

Listed below are General Definitions and elaborations in relation to Commissioning &TAB.

These are based on industry-accepted standards and cover **all phases** of the project. Quotations below come from *several* valuable ASHRAE (and other) References published over the last 20+ years:

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Very Important Slide

"***Total Building Commissioning Process (TBCxP)***:

- **ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process)** defines the **Cx Process** as "*A quality-focused* ***process*** *for enhancing the delivery of a project. The process focuses upon verifying and documenting that the facility and all of its systems and assemblies are planned, designed,* ***installed, tested****, operated, and maintained to meet the Owner's Project Requirements*".

- "The Cx ***Process*** ***begins*** at project inception during the *Predesign Phase* and continues for the life of the facility through the *Occupancy/Operations Phase*. During the Predesign Phase, the OPR are determined and documented by the Cx Team, which includes the Owner, Cx Authority (CxA), design professionals, operation and maintenance personnel, occupants, and users. Throughout each phase of the project, deliverables (drawings, specifications, submittals, construction, training, documentation, etc.) are verified against the OPR".

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Total Building Commissioning Process (TBCxP):

Per ASHRAE, The Commissioning Process, also published by NIBS (National Institute of Building Sciences) as Guideline 0, fully supports the Total Building Commissioning Process.

Very Important Slide

- Q. What does Total Mean?
- **Total = Holistic = Thorough = Complete = Extensive = Multi-Phase = Full 4-Phase Cx Process = Spans from pre-design all the way into occupancy = The Cadillac = Get it done right all the way from the project beginning to its end, be thorough and do not cut corners.**

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A Comprehensive Total Building Commissioning Process (TBCxP) takes place in Four (4) Phases of the project:

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Per the ASHRAE **Cx Guidelines**, Total Commissioning can take place in **4 Phases**:

1. Cx During Pre-Design Phase,
2. Cx During Design Phase,
3. **Cx During Construction**, and
4. Cx During Occupancy & Operations.

ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process) defines the **Cx Process** as "*A quality-focused process for enhancing the delivery of a project. The process focuses upon verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements*".

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Types of Buildings in need of Commissioning:

1. Cx of ***Existing*** Buildings.
2. Cx of ***New*** Buildings.
3. Cx of *Existing* Buildings that are undergoing ***Substantial Renovations***.

Make a differentiation between the 3 building types and determine additional sensors to incorporate during the design and construction phases to support the Total Building Cx Process (TBCxP) for new and substantially renovated buildings and to facilitate Ongoing Cx moving forward in both bldg types using those new built-in sensors for both monitoring based Cx (MBCx) (& M&V if needed).

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*"**Commissioning (or the Commissioning Process)**:*

[FYI - Old Reference Slides Only]

- **ASHRAE Guideline 1-1996 (The HVAC Commissioning Process)** defines the Cx Process as "*the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent. In this guideline, commissioning begins with planning and includes design, construction, start-up, acceptance and training, and can be applied throughout the life of the building*".
- **CA Cx Guide for Existing Buildings** stated that "*Building Commissioning (Cx) is a systematic quality assurance **process** that spans the entire design and construction process. Building commissioning helps ensure that a new building's performance meets owner expectations by verifying and documenting that building systems and components are planned, designed, installed, tested, operated, and maintained to meet the owner's requirements (OPR)*".

Can remove the old optional FYI slide with the older Definitions, but kept to compare improvement in definition language.

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Why *Commissioning*?

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Question - Why *Commissioning*? (*Solid Fuels or Biomass* Htg System Examples)

1. Ensure correct biomass system *operation, **controls** and **integration*** with existing heating systems, energy management and controls system (EMCS), and heat distribution systems.
2. Verify *properly sized boilers* and other support systems.
3. Verify the effectiveness and benefits from *TES/buffering*.
4. Support future quantification of energy and cost savings and, performance validation and *fuel displacement*.

Optional Technology Specific Slide Example

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Question - Why *Commissioning*? (*Solid Fuels or Biomass* Htg System Examples)

1. Facilitate accurate and fair billing with campus style settings that have heat (or chilled water) sale agreements.
2. Use your imagination after your review of the detailed lessons learned slides (shown later in the Detailed Course Stage-II) and how many problems could have been avoided from the beginning "***IF***" proper Cx was implemented from the beginning, which would have been much less costly than the system corrections that were implemented after a significant amount of system troubleshooting and retro-Commissioning.

Optional Technology Specific Slide Example

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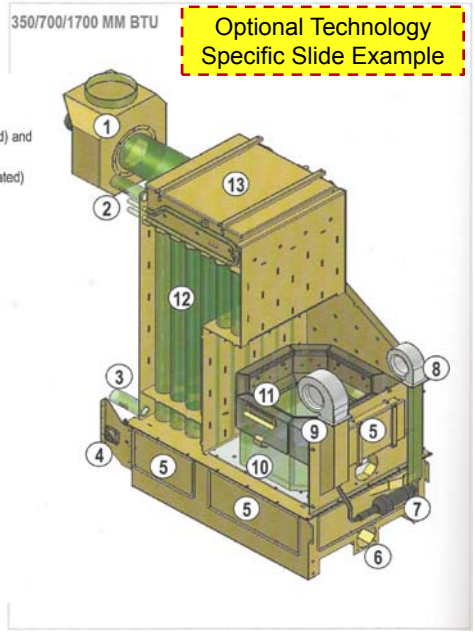
Answers

Optional Technology Specific Slide Example

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



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Q/A - Why *Commissioning*? (General to All Systems) (1 of 2)

- ✓Provide a "**quality-oriented process** for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria" (ASHRAE Guideline 0-2005).
- ✓The purpose of G0-2005 & 2013 is to "describe the Commissioning Process capable of verifying that a facility and its systems meet the Owner's Project Requirements (OPR)" (ASHRAE Guideline 0-2013) ; & Basis of Design (BOD).

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Q/A - Why *Commissioning*? (General to All Systems) (2 of 2)

Optional Slide

- ✓ Provide the owner with:
  - ✓ "***Comprehensive quality assurance program***, beginning with the **predesign phase** of the project, continuing through the **design** and **construction** phases, and culminating in sustainable **operation** by the owner's staff".
  - ✓ "Commissioning is a programmed series of quality assurance, documentation, and testing activities that are performed specifically to ensure that the ***finished facility operates as intended***"
  - ✓ (The Bldg Cx Handbook 2nd Edition).

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How Much does *Commissioning*? Cost? & How Much can *Commissioning* Save?

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Q/A - How Much does *Commissioning* Cost? (General to All Systems) (1 of 3)

- ✓ Cx will generally and will definitely add cost to the project's first cost including Cx & TAB, but it will save a lot of energy and money over the building lifecycle cost (BLCC) cost over a 30 to 50 or even a 100 year period.
- ✓ The bottomline is that be aware that the "***the cost of building commissioning is less than the cost of not commissioning your new facilities***." (The Bldg Cx Handbook 2nd Edition).

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Q/A - How Much does *Commissioning* Cost? (General to All Systems) (2 of 3)

- ✓ Fact - Building commissioning is important for the success of capital construction projects and should be budgeted for during all project phases.
- ✓ Cx has an attractive return on investment (ROI) and is much better than a CD.
- ✓ Simply, you cannot afford not to Commission.

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Q/A - How Much does *Commissioning* Cost? (General to All Systems) (3 of 3)

- ✓ Cx has numerous benefits, one of which is that it *helps fill gaps* in the needed coordination that generally lacks in many projects and as such *communication and coordination is key* to the success of this Cx process.
- ✓ Cx supports a well-Integrated Design Process (IDP).

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Q/A - How Much Can *Commissioning* Save in terms of energy and other non-energy savings? (General to All Systems) (1 of 4)

In 2004, Lawrence Berkeley National Laboratory estimated $18 billion per year of potential savings from commissioning throughout the United States. Simply addressing the top 13 faults in commercial buildings alone has a potential savings of **$3.3 - $17 billion per year**.

Top 13 Faults in Commercial Buildings:

1. Duct Leakage.
2. HVAC system operates continuously during unoccupied period.
3. Lighting system illuminating space during unoccupied period.
4. HVAC system improperly balanced.
5. Improper refrigerant charge.
6. Economizer dampers operating Incorrectly.
7. Insufficient evaporator airflow.
8. Improper controls setup / commissioning.
9. Control component failure or degradation.
10. Software programming errors.
11. Improper controls hardware installation.
12. Air-cooled condenser fouling.
13. Valve leakage.

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Q/A - How Much Can *Commissioning* Save in terms of energy and other non-energy savings? (General to All Systems) (2 of 4)

- Per US DOE and Pacific Northwest National Lab, A study that included 643 buildings across the U.S. suggests that correcting the deficiencies found during the commissioning process resulted in **16%** median whole-building energy savings in existing buildings and **13%** in new construction, with payback times of **1.1 years** and **4.2 years**, respectively.
- It also found that projects that incorporated a thorough commissioning process attained nearly twice the overall median level of savings and five times the savings of the least thorough projects.

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Q/A - How Much Can *Commissioning* Save in terms of energy and other non-energy savings? (General to All Systems) (3 of 4)

- Per US DOE and Pacific Northwest National Lab, Energy savings of new building commissioning can be significant.
- Since they depend on several factors, including building type, location, and the scope of the commissioning process, they are usually presented as a range.
- A comprehensive study found the value of energy savings from commissioning to range from **$0.02 - $0.19/sqft**,
- and the value of non-energy savings resulting from commissioning to range from **$0.23 - $6.96/sqft**, as shown in the table below.

Savings from Commissioning		
Description	Range of Values	Expected Annual Savings for a Theoretical 100,000 sq. ft. Building
Value of Energy Savings	$0.02 - $0.19/sq. ft.	$2,000 - $19,000
Value of Non-Energy Savings	$0.23 - $6.96/sq. ft.	$23,000 - $696,000

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Q/A - How Much Can *Commissioning* Save in terms of energy and other non-energy savings? (General to All Systems) (4 of 4)

- Per US DOE and Pacific Northwest National Lab, through proper commissioning these savings can actually increase over time.
- This may seem counterintuitive, but studies have found that when commissioning includes training, and in some cases, installation of permanent metering and feedback systems, improvements in system performance can persist for years after commissioning.
- This finding should reassure building owners that new-construction commissioning can be very durable, and that outcomes will result in savings for the lifetime of the building.

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Commissioning Process Key Component Definitions

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Cx Plan:

- **ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process)** defines the **Cx Plan** as "*A document that outlines the organization, schedule, allocation of resources, and documentation requirements of the Commissioning Process*".
- **ASHRAE Guideline 1-1996 (The HVAC Commissioning Process)** defines the **Cx Plan** as "*a document defining the commissioning process, which is developed in increasing detail as the project progresses through its various phases*".

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Cx Authority (or Cx Agent):

- **ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process)** defines the **Cx Authority (CxA or CA)** is "*An entity identified by the Owner who **leads**, plans, schedules, and coordinates the commissioning team to implement the Commissioning Process*".
- **ASHRAE Guideline 1-1996 (The HVAC Commissioning Process)** defines the Cx Agent as "*the designated person, company, or agent who **implements** the overall commissioning process*".
- **ASHRAE Standard 202-2013 (Cx Process for Buildings & Systems)** states on Page 27 under Subsection G2.1 that "*The primary role of the CxA is to verify achievement of the OPR throughout the project, from Predesign Phase through Occupancy/Operations Phase. The owner could perform the CxA role*".

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Cx Reporting:

ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process) defines:

- The **Cx Process Progress Report** as "*A document that details activities completed as part of the Commissioning Process and significant findings from those activities, which is continuously updated during the course of a project. Usually incorporated into the Commissioning Plan as an ongoing appendix*".
- The **Cx Process Report** as "*A document that records the activities and results of the Commissioning Process. Usually developed from the final Commissioning Plan with all of its attached annexes*".

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Testing, Adjusting, and Balancing (TAB):

- Per **ASHRAE Standard 111-2008 (Measurement, Testing, Adjusting and Balancing of Building HVAC Systems)**,
- The PURPOSE of the standard is "*To provide uniform procedures for measurement, testing, adjusting, balancing, evaluating, and reporting the performance of building heating, ventilating, and air-conditioning systems in the field*",
- while the SCOPE Section of the same document states "*This standard applies to building heating, ventilating, and air-conditioning (HVAC) systems of the **air-moving** and **hydronic** types and their associated heat transfer, distribution, refrigeration, electrical power, and control subsystems*".

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Q. What happens when well-integrated and holistic project development approaches were **not** followed and there was **NO Commissioning**?

List 3 examples.

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Issues Summary & Highlights of Major Findings (Main Categories - Group 1 of 3):

Optional Technology Specific Slide

1. Lack of **TAB** (Test, Adjust and Balance).
2. Lack of **Cx** (Commissioning) process, Issues Logs & Project Coordination Meetings .
3. Lack of complete **Control Sequences of Operation**, & Systems **integration**.
4. Inadequate **Designs**, **Drawings** & **Specification** details.
5. Lack of proper **design review by independent 3rd party** & Lack of an **Energy Audit** before design.
6. Numerous **system pressurization**, & **HX** (heat exchanger) location & sizing issues.
7. **Pumping, Piping, Valving, VFD** & other **Hydronic issues**.

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Issues Summary & Highlights of Major Findings (Main Categories - Group 2 of 3):

Optional Technology Specific Slide

8. Incomplete **Pump/Valve Schedules**, & lacking other documentation.
9. No accurate **as-built drawings** *before* & *after* the biomass project.
10. Unclear **Roles and Responsibilities** among project team members during all project phases.
11. Inadequate and Improper **TES (thermal energy storage)** Tanks.
12. Existing Propane/Oil Boiler plant problems were not resolved *before* *adding* biomass boilers.
13. Bldg **Peak Heat Load Determination** and **Pellet Boiler Sizing** Issues.

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Issues Summary & Highlights of Major Findings (Main Categories - Group 3 of 3):

Optional Technology Specific Slide

14. Issues with **3-way mixing valves** serving biomass boiler & downstream from tank.
15. Lack of enough **BTU meters**, **M&V**, & motor status **CTs**.
16. Lack of **PT Ports** makes it impossible to TAB systems and troubleshoot.
17. ESCO, Design Engineer & Installer lack the necessary biomass (and MEP) system **knowledge & experience**.
18. Issues with **Pellet Boiler reliability** and robustness.
19. Boiler **Container**, BOP (Balance of Plant), Boiler **venting**, & Misc other MEP and/or code issues.
20. ESCO Financial Issues; Oil Prices?; Any one else to blame?
21. Issues with Certain Government Procurement Processes.

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Besides the most thorough and Comprehensive Four (4) Phase Total Building Commissioning Process (TBCxP), the "other" varying types & phases of Commissioning include, but are not limited to:

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Per the ASHRAE **Cx Guidelines**, Total Commissioning can take place in **4 Phases**:

1. Cx During Pre-Design Phase,
2. Cx During Design Phase,
3. **Cx During Construction**, and
4. Cx During Occupancy & Operations.

ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process) defines the **Cx Process** as "*A quality-focused process for enhancing the delivery of a project. The process focuses upon verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements*".

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Per the ASHRAE **Cx Guidelines**, the varying types of Commissioning include, but are not limited to:

1. **Total Building Cx Process (TBCxP) [Inclusive of all 4 Phases]**.
2. Continuous Cx Process.
3. Ongoing Cx Process (OCx).
4. Re-Cx.
5. Retro-Cx.
6. Cx Light (or Custom Cx).

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Commissioning (Other Types):

- **ASHRAE Guideline 0-2005 (The Commissioning Process)** defines the **Continuous Commissioning Process** as "*A continuation of the Commissioning Process well into the Occupancy and Operations Phase to verify that a project continues to meet current and evolving Owner's Project Requirements. Continuous Commissioning Process activities are ongoing for the life of the facility. Also see Ongoing Commissioning Process*".

- **ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process)** defines the **Ongoing Commissioning Process (OCx)** as "*A continuation of the Commissioning Process well into the Occupancy/Operations Phase to verify that a project continues to meet current and evolving Owner's Project Requirements. Ongoing Commissioning Process Activities occur throughout the life of the facility; some of these will be nearly continuous in implementation, and others will be either scheduled or unscheduled (as needed)*".

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Commissioning (Other Types):

- **ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process)** defines the **Re-Commissioning** as "*An application of the Commissioning Process requirements to a project that has been delivered using the Commissioning Process. This may be a scheduled recommissioning developed as part of an Ongoing Commissioning Process, or it may be triggered by use change, operations problems, or other needs*".

- **ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process)** defines **Retro-Commissioning** as "*The Commissioning Process applied to an existing facility that was not previously commissioned. This guideline does not specifically address retrocommissioning. However, the same basic process should be followed from Predesign through Occupancy and Operations to optimize the benefits of implementing the Commissioning Process philosophy and practice*".

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***Commissioning (Other Types)*:**

- **ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process)** defines the **Basis of Design (BoD)** as "*A document that records the concepts, calculations, decisions, and product selections used to meet the Owner's Project Requirements and to satisfy applicable regulatory requirements, standards, and guidelines. The document includes both narrative descriptions and lists of individual items that support the design process*".

- **ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process)** defines **Owner's Project Requirements (OPR)** as "*A document that details the functional requirements of a project and the expectations of how it will be used and operated. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information. (The term Project Intent is used by some owners for their Commissioning Process Owner's Project Requirements.)*".

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***Commissioning (Other Types)*:**

USGBC - LEED New Construction (NC) Reference Guide Energy & Atmosphere (EA) Credits Prerequisite 1: Required Point - Fundamental Commissioning of the Building Energy Systems; Completion of the following commissioning process activities by the Design & Cx Team:

1. Designate *qualified* & *independent* **CxA entity** to lead, review & oversee completion of Cx process activities.
2. Owner document the Owner Project Requirements (**OPR**).
3. Design Team develop the Basis of Design Document (**BOD**).
4. CxA develop **Cx Plan**.
5. Design Team to Develop & Incorporate **Cx Requirements** into Construction Documents (**CDs**) i.e., in Specs.
6. Project Team **Implement Cx Plan**.
7. **Verify installation & performance** of commissioned systems.
8. Complete summary **Cx Report**. (Results reported directly to owner)

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***Commissioning (Other Types)*:**

USGBC - LEED NC Ref. Guide Energy & Atmosphere Credits: ***Optional Credit*** - **Enhanced Commissioning of the Building Energy Systems**. Intent: "Begin the commissioning process ***early*** during the design process and execute additional activities ***after*** system performance verification is completed". Completion of ***more*** Cx process activities by Design & Cx Team:

1. Satisfy all Fundamental Cx Requirements (See earlier slide).
2. CxA complete mid-construction stage Cx Design Review of **OPR** & **BOD** then,
3. **back-check** necessary updates completed in subsequent design submission.
4. CxA review **contractor submittals** of commissioned systems for compliance with OPR & BOD.
5. Design Team to Develop **System Manual** for operating staff to understand and operate all commissioned systems.
6. Verify completion of all operating personnel (and occupants) **training** completed.
7. CxA **10 month operations review**.

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Commissioning Team Members & Determination of their Roles & Responsibilities

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Determination of Roles & Responsibilities

1. Customer, Owner, or Applicant.
2. Project Manager of the Owner (**PM**).
3. Construction Manager (**CM**).
4. Architect, Design engineer of record, (MEP, **E/A** or A/E Firm), with special focus on Mechanical and/or HVAC.
5. General Contractor (**GC**).
6. Mechanical Contractor (**MC** or **MEP**).
7. Test, Adjust & Balance Contractor (**TAB** or **T&B**).
8. Commissioning (**Cx**) Authority (**CxA**), or Cx Oversight Consultant.
9. Specialty Sub-contractors (especially in large projects) such as:
10. Controls Contractor (**CC**) - EMCS Vendor, System Integration Contractor, low voltage contractor.
11. Electrical Contractor (**EC**).
12. M&V Agent, or **M&V** Consultant, or M&V Contractor.
13. Boiler Manufacturer.
14. Boiler Testing & Boiler Cx Contractor.
15. Thermal Energy Storage Tank Manufacturer/Vendor.
16. Other Equipment Manufacturers / Suppliers such as HX, Silo, Valves, Underground Pipes, etc.
17. Local authorities or authorities having jurisdiction over the project (needed for obtaining certain permits and/or to ensure compliance with all local codes, rules and regulations),
18. ESCO (Energy Services Company).
19. Funding Agency or Financing Agency.
20. Utility: Fuel supplier & Pellet Supplier.
21. Specialty Consultants (in certain complex projects).

Very Important Slide

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The Commissioning Scoping Meeting (1 of 2)

1. The CxA (through the GC or CM) will schedule, plan and conduct a Cx scoping meeting w/ the ***Entire Cx Team***.
2. At the meeting, Cx parties are introduced, Cx process is reviewed, and management and reporting lines are determined.
3. Construction Phase ***Cx Plan*** is reviewed, process questions are addressed, lines of reporting and communication are determined, and the work products list is discussed.
4. Other discussion topics include the general list of each party's responsibilities, responsibility for development of startup plans for each piece of equipment, and the proposed commissioning schedule.

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The Commissioning Scoping Meeting (2 of 2)

5. Meeting outcome is that each team member will have a better understanding of the Cx process and of their ***Specific Roles and Responsibilities***.
6. Meeting also provides the CxA with additional information required to finalize the Cx Plan, including the anticipated Cx Sch & the varying forms.
7. GC, CM or CxA keep notes from Mtg and distribute them to each team member.
8. Prior to this meeting, the CxA is given, by the GC (or CM or A/E), all drawings and specifications and the construction schedule by trade.

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The Core of the Construction Phase Cx Process:

Prefunctional Checklists (PFCs)
&
Functional Performance Testing (FPTs)

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[1] Prefunctional Checklists (PFCs)

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Prefunctional Checklists (PFCs) - (1 of 4)

- Document that equipment and systems are properly installed and operational so that functional performance testing may proceed without unnecessary delays.
- Each piece of equipment receives full prefunctional checkout by the installing contractor.
- **No sampling strategies are allowed**.
- Pre-Functional Performance Testing ***must be successfully completed prior*** to formal functional performance testing of equipment or subsystems.

Very Important Point

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Prefunctional Checklists (PFCs) - (2 of 4)

- Prefunctional checklists are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., proper fan belt tension, valve installed in proper direction, proper oil level provided, labels affixed, gauges in place, sensors calibrated, etc.).
- However, some PFC items entail simple testing of the function of a component, a piece of equipment or system (such as measuring the voltage imbalance on a 3-phase pump motor, verifying that a fan rotates in the proper direction, etc.).
- ***The word prefunctional refers to "before" functional testing***.

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Prefunctional Checklists (PFCs) - (3 of 4)

- Prefunctional checklists augment and are combined with the manufacturer's start-up checklist and plan.
- Contractors typically already perform some, if not many, of the prefunctional checklist items the commissioning authority will prescribe.
- However, unfortunately, not all contractors document in writing the execution of these checklist items.
- Put all Prefunctional checklists developed for this project in **Appendix C** of the Cx Plan.

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Prefunctional Checklists (PFCs) - (4 of 4)

- Procedures must be documented in writing by the installing technician using the standard checklists developed and/or co-developed by the CxA as well as the manufacturer's start-up checklist and/or a satisfactory/comprehensive combination of both following whatever is more stringent and best for the project.
- The CxA does not witness much of the prefunctional checklist execution, except for testing of larger or more critical pieces of equip and some spot-checking of minor equipment.

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[2] Functional Performance Testing (FPTs)

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Functional Performance Testing (FPTs) - (1 of 3)

- Functional performance testing (FPT) is the *dynamic* testing of systems (rather than just components) under full operation.
- Ex.: The variable speed district loop Glycol pumps are tested interactively with the individual building's heat exchanger modulating terminal control valves to verify that pump speed ramps up and down to maintain differential pressure at setpoint.
- More complex dynamic testing for example will also involve the pellet boiler sequencing and integration with the operation of the oil and propane boilers in the individual building MERs.

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Functional Performance Testing (FPTs) - (2 of 3)

- Generally, systems are tested under various modes, such as during low and intermediate heating (or cooling) loads, shoulder seasons, high loads, component failures, unoccupied (or setback) mode, varying outside air temperatures, power failure, etc.
- The systems are run through all of the control system's sequences of operation and components are verified to be responding as the sequences state.

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Functional Performance Testing (FPTs) - (3 of 3)

- The commissioning authority develops (and/or co-develops) the functional test procedures in a sequential written form, and then coordinates, oversees and documents selected actual testing;
- All testing is performed by the installing contractor or vendor under the guidance (and/or the direction) of the CxA.
- Put the project specific functional test forms available to date in **Appendix D**, while make a note that some others may still be forthcoming if not ready yet.

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Suggested Issues & Resolution Log (or Deficiencies Log) Detailed Layout/Table & Minimum Content Requirements

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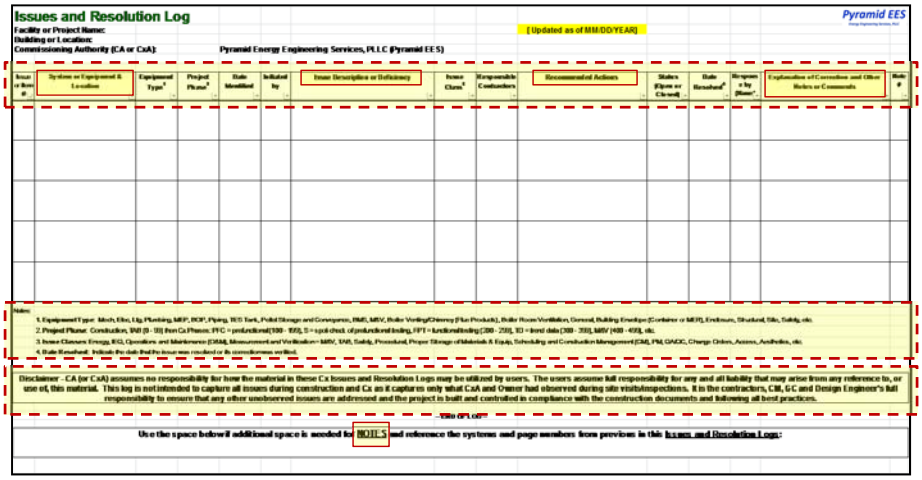
Issues & Resolution Log (Deficiencies Log) - (1 of 3)


Issues and Resolution Log

Facility or Project Name:
Building or Location:
Commissioning Authority (CA or CxA): Pyramid Energy Engineering Services, PLLC (Pyramid EES)

(Updated as of MM/DD/YEAR)

Pyramid EES

Issue or Item #	System or Equipment & Location	Equipment Type[1]	Project Phase[2]	Date Identified	Initiated by	Issue Description or Deficiency	Issue Class[3]	Responsible Contractors	Recommended Actions	Status (Open or Closed)	Date Resolved[4]	Response by (Name)	Explanation of Correction and Other Notes or Comments	Note #

Notes:
1. Equipment Type: Mech, Elec, Ltg, Plumbing, MEP, BOP, Piping, TES Tank, Pellet Storage and Conveyance, BMS, M&V, Boiler Venting/Chimney (Flue Products), Boiler Room Ventilation, General, Building Envelope/Enclosure (Envelope or MEP), Enclosure, Structural, Site, Safety, etc.
2. Project Phase: Construction, TAB (0 - 99) then Cx Phases: PFC = prefunctional (100 - 199), S = spot-check of prefunctional testing, FPT = functional testing (200 - 299), TD = trend data (300 - 399), M&V (400 - 499), etc.
3. Issue Classes: Energy, IEQ, Operations and Maintenance (O&M), Measurement and Verification = M&V, TAB, Safety, Procedural, Proper Storage of Materials & Equip, Scheduling and Construction Management (CM), PM, QA/QC, Change Orders, Access, Aesthetics, etc.
4. Date Resolved: Indicate the date that the issue was resolved or its correction was verified.

Disclaimer - CA (or CxA) assumes no responsibility for how the material in these Cx Issues and Resolution Logs may be utilized by users. The users assume full responsibility for any and all liability that may arise from any reference to, or use of, this material. This log is not intended to capture all issues during construction and Cx as it captures only what CxA and Owner had observed during site visits/inspections. It is the contractors, CM, GC and Design Engineer's full responsibility to ensure that any other unobserved issues are addressed and the project is built and controlled in compliance with the construction documents and following all best practices.

Use the space below if additional space is needed to NOTE S and reference the systems and page numbers from previous in this Issues and Resolution Log:

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Issues & Resolution Log (Deficiencies Log) - (2 of 3)

1. Issue or Item #
2. System or Equipment & Location
3. Equipment Type[1]
4. Project Phase[2]
5. Date Identified
6. Initiated by
7. Issue Description or Deficiency
8. Issue Class[3]
9. Responsible Contractors
10. Recommended Actions
11. Status(Open or Closed)
12. Date Resolved[4]
13. Response by (Name)
14. Explanation of Correction and Other Notes or Comments
15. ~~Note#~~

1. **Equipment Type**: Mech, Elec, Ltg, Plumbing, MEP, BOP, Piping, TES Tank, Pellet Storage and Conveyance, BMS, M&V, Boiler Venting/Chimney (Flue Products), Boiler Room Ventilation, General, Building Envelope/Enclosure, Structural, Site, Safety, etc.
2. **Project Phase**: Construction & TAB (0 - 99); then Cx Phases: PFC = prefunctional (100 - 199), S = Spot-Check of prefunctional testing, FPT = functional testing (200 - 299), TD = Trend Data (300 - 399), M&V (400 - 499), etc.
3. **Issue Classes**: Energy, IEQ, O&M, M&V, TAB, Safety, Procedural, Proper Storage of Materials & Equip, Scheduling CM, PM, QA/QC, Change Orders, Access, Aesthetics, etc.
4. **Date Resolved**: Indicate the date issue was resolved or its correction was verified.

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Issues & Resolution Log (Deficiencies Log) - (3 of 3)

- Disclaimer - CA (or CxA) assumes no responsibility for how the material in these Cx Issues and Resolution Logs may be utilized by users. The users assume full responsibility for any and all liability that may arise from any reference to, or use of, this material. This log is not intended to capture all issues during construction and Cx as it captures only what CxA and Owner had observed during site visits/inspections. It is the contractors, CM, GC and Design Engineer's full responsibility to ensure that any other unobserved issues are addressed and the project is built and controlled in compliance with the construction documents and following all best practices.
- -- END OF LOG –
- Use the space below if additional space is needed for NOTES and reference the systems and page numbers from previous in these Issues and Resolution Logs:

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Commissioning Schedule & Typical General Scheduling Issues & Warnings

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Cx Scheduling & Issues & Warnings

The following sequential priorities shall be followed:

1. Equipment is not "temporarily" started (for heating or cooling) until pre-start checklist items and all manufacturers' pre-start procedures are completed and moisture, dust and other environmental and building integrity issues have been addressed.
2. **Functional testing is not begun until prefunctional checklists, start-up and TAB are completed** for a given system (this does not preclude a phased approach).
3. The controls system and equipment it controls are not functionally tested until all points have been calibrated and pre-functional testing completed.
4. TAB is not performed until the controls system has been sufficiently functionally tested by the CC and approved by the GC (or CM), A/E and CxA for TAB work.

Very Important Slide

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Overview of the Construction Phase Commissioning Process

Keep Slide for Stage-II Course

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Overview of Commissioning Process - (1 of 4)

1. Cx during construction ***begins*** with a "commissioning scoping meeting", conducted by the CxA preferably within 60 to 90 days of the beginning of construction, where the Cx process is reviewed with Cx team members.
2. Additional meetings will be required throughout construction to plan, coordinate, schedule future activities, and resolve problems. The additional meetings will be scheduled as needed by the GC (or CM).
3. Equipment documentation shall be submitted to the CxA during normal submittals, including detailed start-up procedures.
4. The CxA develops (and/or oversees the development of) prefunctional checklists (PFC) and submits blank forms to the GC (or CM) for assignment and distribution to the subcontractors. Subcontractors shall complete FPCs during the start-up process.

Keep Slide for Stage-II Course

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Overview of Commissioning Process - (2 of 4)

5. In general, the checkout and performance verification proceeds from simple to complex; from component level to equipment to systems and intersystem levels. Prefunctional checklists must be completed and returned to the CxA ***before*** functional testing begins.
6. Contractors, under their own direction and/or preferably via schedule coordination with the GC (or CM), execute and document the prefunctional checklists (PFC) and perform start-up and initial checkout. The GC or CM (and at times the CxA for selected equipment) document the completion of the PFCs and startup procedures according to the approved plans and using the PFC forms provided by the CxA and whatever other sources of documentation and forms they desire to use for best documentation. This may require the presence of the CxA as a witness upon start-up of selected equipment.

Keep Slide for Stage-II Course

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Overview of Commissioning Process - (3 of 4)

7. CxA develops (and/or oversees the development of) specific equipment and system functional performance test (FPT) procedures and forms.
8. FPTs are executed by the contractors and the appropriate forms are properly completed under the guidance (and/or the direction) of the CxA. The Contractors and/or CM/GC) properly and thoroughly document the functional performance test results using the appropriate forms provided by the CxA for the CxA's review. Any deficiencies are recorded by the CxA (and/or the Contractors or CM) on the **Commissioning Issues Log**.
9. Items of non-compliance in material, installation, or setup are corrected at the contractor's expense, and the deficient system will be retested.
10. CxA (and CM) review O&M documentation for completeness.

Keep Slide for Stage-II Course

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Overview of Commissioning Process - (4 of 4)

11. Contractors submit to the CxA through the GC (or CM) training plans, and the CxA reviews and pre-approves training plans before training by the contractors can proceed. The GC (or CM) coordinates any training provided by the contractors. The CxA verifies that training was completed as required.
12. Seasonal or other deferred testing is conducted, as specified or required.
13. CxA prepares a final report to document the results of the commissioning process.
14. CxA returns to the site approximately 8 to 10 months into the 12-month warranty period to review current building and system operation with facility staff and address the any conditions or outstanding issues related to the owner's project requirements.
15. CxA develops a re-commissioning management manual for the owner, as needed.

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Key Cx Phase Process Flow Charts

Very Important Slides

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Figure 5-1: Typical Construction Phase Commissioning Activity Flow Chart

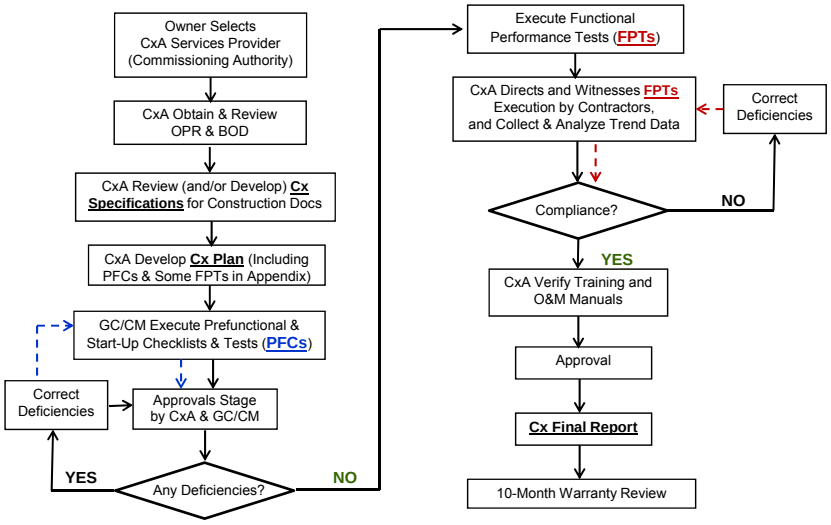

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Figure 5-2: Start-up, Prefunctional Checklists (PFCs) & Initial Checkout Forms Development

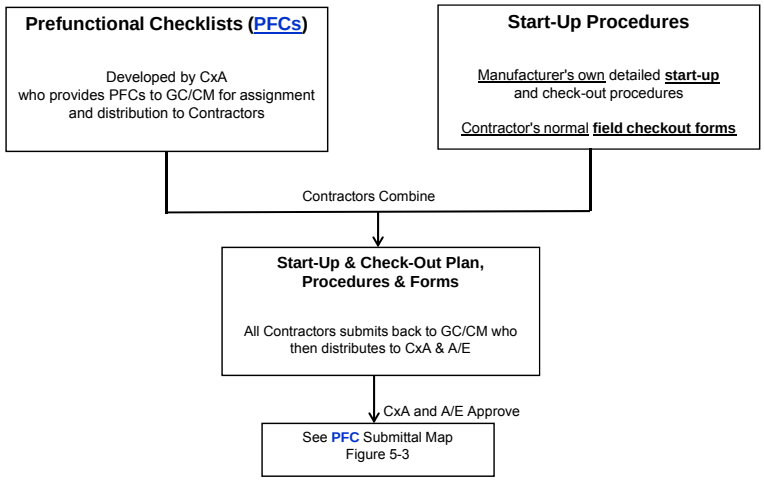

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Figure 5-3: Prefunctional Checklist (PFC) & Start-up Report Submittal Map

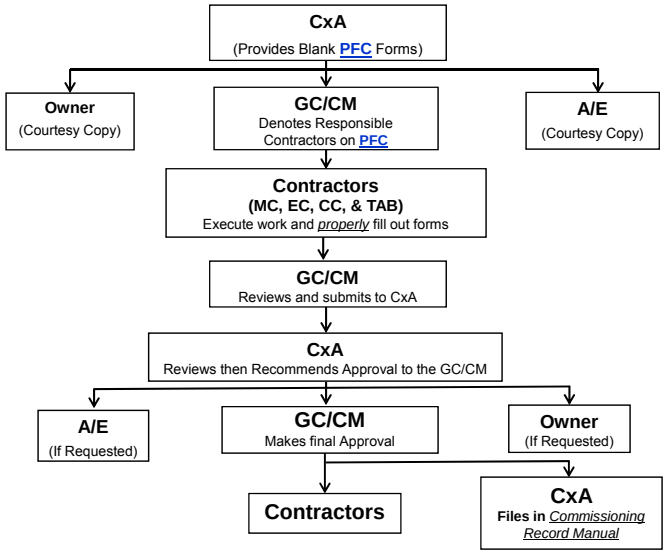

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Figure 5-4: Functional Performance Test (FPTs) Forms Development

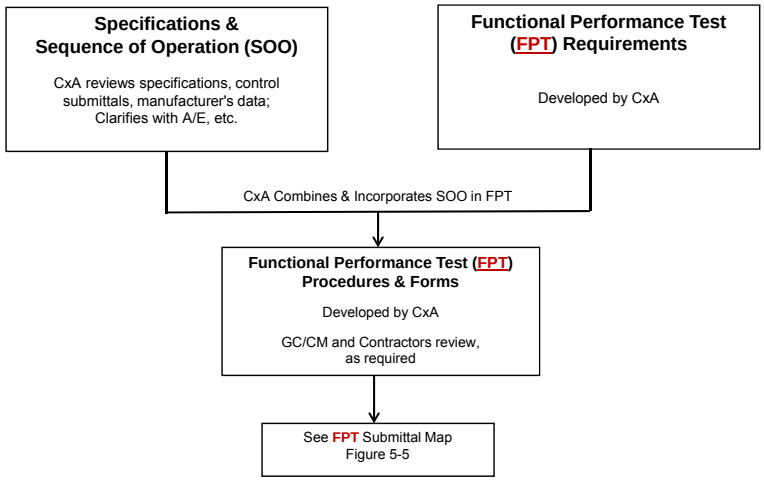

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Figure 5-5: Functional Performance Test (FPT) Submittal Map

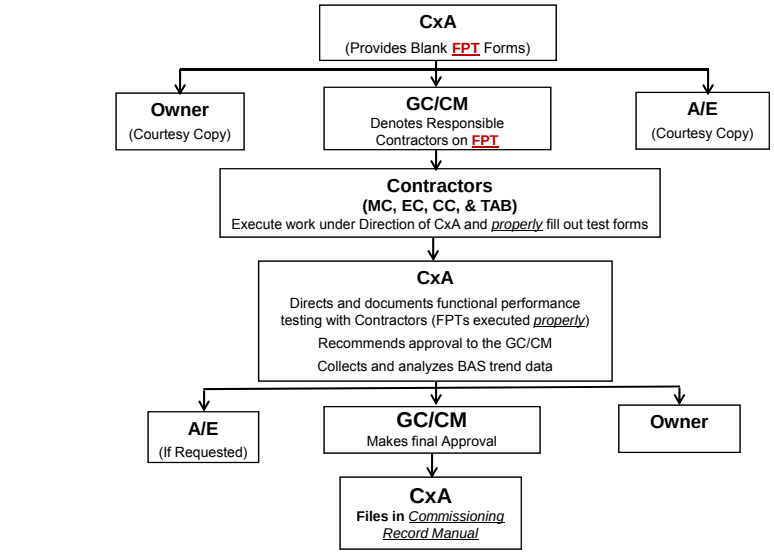

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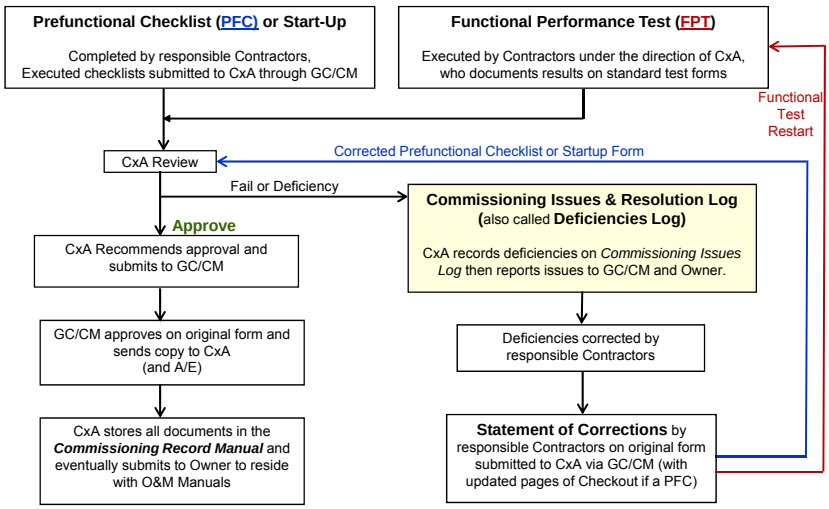
Figure 5-6: Prefunctional Checklist (PFC) & Functional Performance Testing (FPT) Approval Process

This chart begins with the Prefunctional Checklist or the Functional Performance Test that was already completed.



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Suggested Commissioning Plan Detailed Outline

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Cx **Plan** Detailed Outline - (1 of 9)

- Glossary of Terms and Abbreviations
- Objectivity and Related Affiliations
- Notice
- Acknowledgments
- Table of Content

- **Section 1.0 - Project Overview**:
- 1.1 Background & Project History.
- Recap on OPR (& BOD).

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Cx **Plan** Detailed Outline - (2 of 9)

- 1.2 - Description of Building Energy Systems & Features:
  - All Buildings (Age, Envelope, Lighting, HVAC Systems, Schedules, etc.).
  - The Boiler Room.
- 1.3 - Key Abbreviations and key Definitions:
  - Commissioning (or the Commissioning Process)
  - Cx Plan
  - Cx Authority (or Cx Agent)
  - Testing, Adjusting, and Balancing (TAB)
  - [See Definitions presented earlier in the Slides]
- 1.4 - Purpose of the Commissioning Plan.
- 1.5 - Cx Scope (& 1.6 - List of Commissioned Systems).
- 1.7 - Spec Sections (Referenced for supporting Cx).
- 1.8 - Spec Relevant Notes.

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Cx **Plan** Detailed Outline - (3 of 9)

- **Section 2 - General Building Information**
  - Includes but not limited to Bldg & Proj Description, Location, Building Type, Floor Area, Number of Stories, Owner, Construction Period, Construction Schedule [See Appendix B], Cx Schedule [See Appendix B].
- **Section 3 - Commissioning Team Members**
  - Table 3-1 includes all Commissioning Team Members complete contact Info, Agency Name, Member Name, Title, Address, email, Phones (landline and Mobile), web page).
- **Section 4 - Roles and Responsibilities**
- 4.1 - Cx Team Members
- 4.2 - General CxA Management Plan
- 4.3 - General Description of Team Member Roles

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Cx **Plan** Detailed Outline - (4 of 9)

- **Section 5 - Commissioning Process**
  - 5.1 Overview….
  - 5.2 Commissioning Scoping Meeting
  - 5.3 Final Commissioning Plan - Construction Phase
  - 5.4 Site Observation (& Site visits schedule)
  - 5.5 Misc. Meetings (to be scheduled as needed)
  - 5.6 Misc. Management Protocols & flow of Docs.)
  - 5.7 Progress Reporting (& Cx Issues & resolution log)
  - 5.8 Initial Submittals and Documentation
    - 5.8.1 Standard Submittals
    - 5.8.2 Special Submittals, Notifications and Clarifications

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Cx **Plan** Detailed Outline - (5 of 9)

- **Section 5 - Commissioning Process (Cont.)**
- **5.9 Prefunctional Checklist (PFC), Tests & Start-Up**:
  - 5.9.1 Overview
  - 5.9.2 Start-up Plan
  - 5.9.3 Execution of Checklists and Start-up
  - 5.9.4 Deficiencies and Non-Conformance
  - 5.9.5 Testing and Balancing
  - 5.9.6 Controls Checkout Plan
- **5.10 Functional Performance Test (FPT) Development and Verification Procedures:**
  - 5.10.1 Overview
  - 5.10.2 Scope of Testing
  - 5.10.3 Development Process
  - 5.10.4 Testing Plan Overview and Schedule

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Cx **Plan** Detailed Outline - (6 of 9)

- **Section 5 - Commissioning Process (Cont.)**
- **5.11 Execution of Functional Testing Procedures**
  - 5.11.1 Coordination and Scheduling
  - 5.11.2 Deficiencies and Retesting
  - 5.11.3 Facility Staff Participation
  - 5.11.4 Sampling
  - 5.12 O&M Manuals and Warranties
    - 5.12.1 Standard O&M Manuals
    - 5.12.2 Commissioning Record
    - 5.12.2a O&M Manuals General Format
  - 5.13 Training and Orientation of Owner Personnel
  - 5.14 Warranty Period

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Cx **Plan** Detailed Outline - (7 of 9)

- **Section 6 - Written Work Products**
  - 6.1 Overview of Work Products [Described later in PP Slides]
  - 6.2 Commissioning **Final Report** [Suggested Detailed Outline shown later]
- **Section 7 - Commissioning Schedule**
  - 7.1 General Scheduling Issues
  - 7.2 Commissioning Schedule [Include in Appendix B]

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Cx **Plan** Detailed Outline - (8 of 9)

- **Section 8.0 - Appendices**
  - Appendix A - Owner's Project Requirements (OPR) Docs
  - Appendix B - Construction Schedule
  - Appendix C - **Prefunctional Checklists (PFC)** (Can be Editable & Executable).
  - Appendix D - **Functional Performance Testing (FPT)** Requirements and Test Forms (Can be Editable and Executable)
  - Appendix E - Selected Spec Sections calling for Cx, TAB, and Varying Test Requirements (based on the Contract Documents)

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Cx **Plan** Detailed Outline - (9 of 9)

- **Section 8.0 - Appendices (Cont.)**
  - Appendix F - Selected Construction Phase Application/Implementation forms in support of both the Prefunctional and the Functional Performance Testing.
  - Appendix G - Other Appendices TBD as needed.
- **End**
  - Review Notes and Other Comments by Cx Plan Users.

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Suggested Commissioning Report Outline

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Commissioning **Report Outline** - (1 of 5)

Cx report to be prepared by CxA and shall include, but is not limited to:

- **Executive Summary**, project overview, & relevant project background, & concise list of Exec level findings, conclusions & recommendations. All to fit within a few pages.
- Generally, the use of photographs and other graphic illustrations is encouraged.
- List of project participants and their roles.
- Building and energy system descriptions.
- Overview of commissioning and testing scope.
- A general description of the testing and verification methods used.

The above is to be followed by a detailed description of the testing and verification methods used coupled with necessary illustrations.

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Commissioning **Report Outline** - (2 of 5)

For each piece of commissioned equipment, the report shall contain the disposition of the commissioning authority regarding the adequacy of the equipment, documentation and training meeting the contract documents in the following areas:

- Equipment meeting spec.
- Equipment installation.
- Functional performance and efficiency.
- Equipment documentation and design intent.
- Operator training.

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Commissioning **Report Detailed Findings** - (3 of 5)

- Present results of the Cx project in more detail; keeping in mind that the main focus of Cx effort was ensuring systems & equipment operate efficiently and reliably so predicted savings and/or fuel displacements are achieved.
- Confirm (as applicable and as practicable) that the CxA has also reviewed submittals and inspected systems and equipment to determine if they meet minimum requirements set forth by the project initial Technical Feasibility Study [Dated], the design documents [Dated] and the OPR and BOD [Dated] and any other relevant resources.
- All Deficiencies and/or outstanding items shall be reported as detailed below:

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Commissioning **Report Details** - (4 of 5)

Cx report shall also address the following items:

- All outstanding non-compliance items shall be specifically listed.
- Recommendations for improvement to equipment or operations, future actions, commissioning process changes, etc. shall also be provided.
- Each non-compliance issue shall be referenced to the specific functional test, inspection, trend log, etc. where the deficiency is documented.
- The functional performance and efficiency section for each piece of equipment shall include a brief description of the verification method used (i.e., manual testing or BAS trend data analysis) and include observations and conclusions from the testing.
- CxA to produce graphs from the data to make trends more apparent so that system operation issues can be more easily diagnosed. Graphical data displays are key to successfully illustrate the completion of the testing and operation of the tested equipment and systems.

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Commissioning **Report Details & Appendix** - (5 of 5)

During reporting on the above items, include any Appendix type or lengthy material into well organized and tabbed Appendices. This can include but is not limited to:

- Selected parts of the additional trend data plots beyond what was necessary in the body of the report.
- Detailed Cx Issues & Resolution Logs.
- Also include the complete project contact list for the record.
- Additional equipment submittals that were provided during the Cx process, but were not necessarily part of the bid Docs.
- Any project awards or certificates that are worth sharing.
- Final Cx Plan & PFCs (by now should have already been submitted to Owner, GC (or CM)) do not have to be part of the final report, but will be stored in the Cx Record Manual, that will be referenced as part of the Cx report.

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PDH Questions / Answers for Assessment of Learning

Select Only Five (5) Q/A for Stage-I Course and keep the rest for Stage-II Course

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PDH Questions / Answers - (Q/A 1)

- **Q1** - Commissioning is just a quick site visit in the afternoon from 2 to 4 PM, with no need for any preparation or any forms or any formalities; Let's get it over with, quickly and just move on. True or False?
- **A1** - False.

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PDH Questions / Answers - (Q/A 2)

- **Q2** - Per the ASHRAE Cx Guidelines, what are the primary Phases for the Commissioning process?
- **A2** - [1] Cx During **Pre-Design Phase**, [2] Cx During **Design Phase**, [3] Cx During **Construction**, and [4] Cx During **Occupancy & Operations**.
- It is definitely not a quick visit for casual system testing.

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PDH Questions / Answers - (Q/A 3)

- **Q3** - What is one of the best definitions for the Cx Process, and why?
- **A3** - Per ASHRAE Guideline 0-2005 & 2013 (The Commissioning Process), it defines the Cx Process as "A quality-focused process for enhancing the delivery of a project. The process focuses upon verifying and documenting that the facility and all of its systems and assemblies are **planned**, **designed**, **installed**, **tested**, **operated**, and **maintained** to meet the **Owner's Project Requirements**".

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PDH Questions / Answers - (Q/A 4)

- **Q4** - Is the **Cx Plan**, **PFCs**, **FPTs**, **proper execution of all forms**, **Issues Logs** then **Cx Report** enough for conducting Cx? True or False?
- **A4a** - Yes and No!
- **A4b - Yes**; If you are only doing Construction Phase Cx.
- **A4c - NO**; If the intention is a comprehensive Cx process during all project phases starting from:
  - [1] Cx During Pre-Design Phase,
  - [2] Cx During Design Phase,
  - **[3] Cx During Construction**,
  - and [4] Cx During Occupancy & Operations.
  - Therefore, phase 3 only does not suffice for a comprehensive process; & phases 1, 2 & 4 must be done.

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PDH Questions / Answers - (Q/A 5)

- **Q5** - How many members are in the Commissioning Team and how often do they need to communicate?
- **A5** - Varies anywhere from 6 to over 20 depending on the project size and complexity and the number of disciplines involved.
  - CxA regularly communicates with all members of the commissioning team, keeping them apprised of commissioning progress and scheduling issues through memos, progress reports, etc.
  - At a minimum, there should be webinars (and/or site visits) every 2 weeks by the GC, PM (and CxA is present) to discuss and address all project issues during construction and not wait till the PFC and FPT stages.
  - Early CxA involvement and coordination with all team members is a must.

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Keep some of the following slides in Stage-I as reference material only (and/or provide a quick overview of selected important slides depending on audience level);

Otherwise, move them under Separate Stage-II.

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PDH Questions / Answers for Assessment of Learning

Only Five (5) Q/A: Q1 to Q5 were presented in Stage-I Course.

Keep Q6 to 11 for Stage-II Course.

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PDH Questions / Answers - (Q/A 6)

- **Q6** - Can the GC start **FPT** before **PFC** (and why yes or no)?
- **A6** - The word prefunctional refers to ***before*** functional testing.
  - Functional Performance Testing must be successfully completed ***prior to*** formal functional performance testing of equipment or subsystems.
  - PFCs basically document that equipment and systems are properly installed and operational so that functional performance testing ***may proceed without unnecessary delays***.

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PDH Questions / Answers - (Q/A 7)

- **Q7** - What are the most important 3 items you gathered from this presentation (besides having lunch)?

- **A7** - Must have a full Cx team and their roles and responsibilities are well define upfront.
  - Complete all PFCs well before FPTs
  - Maintain and stay on top of Issues & Resolution Logs (deficiencies log) during ALL project phases and do a great job.
  - Take Cx seriously for the future of your project and *educate* the Owner of the importance of Cx.

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PDH Questions / Answers - (Q/A 8)

- **Q8** - List a few of the known ***barriers*** impeding the implementation of the proper Cx process in numerous projects and how to avoid them?

- **A8a** - Lack of knowledge of the multiple benefits of Cx.
- Lack of Cx budgets.
- Bad value engineering, where Cx can be removed from proj!
- Lack of requiring Cx by law (i.e., Cx may not be part of building code) in some areas.
- Lack of customer and project team education.
- Lack of qualified Cx contractors.
- Lack of good project leadership in the first place.
- **A8b** - Educate, Educate, Educate all team members (starting with owner) & budget for Cx like any other important project item.

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PDH Questions / Answers - (Q/A 9)

- **Q9** - What are a few of the most important ASHRAE guidelines and standards that best define and describe the commissioning process?
- **A9** - ASHRAE Guideline 0-2005 & 2013 (**The Commissioning Process**).
- ASHRAE Guideline 1-1996 (**The HVAC Commissioning Process**).
- ASHRAE Guideline 1.1 - 2007 (HVAC&R Technical Requirements for the Commissioning).
- ASHRAE Standard 202-2013 (Cx Process for Buildings & Systems).
- ASHRAE Standard 111-2008 (Measurement, Testing, Adjusting and Balancing of Building HVAC Systems).
- ASHRAE Guidelines 11-2009 (Field testing of HVAC controls components).
- See other Guidelines issues by the Associated Air Balance Council (AABC) or more specifically AABC Commissioning Group (ACG).

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PDH Questions / Answers - (Q/A 10)

Q10 - What are most knows organizations issuing Cx Certifications?

A10 - ASHRAE, AABC/ACG, AEE, BCA/BCxA/BCCB, Univ. of Wisconsin-Madison, NEBB.

- **[1] ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers**
  - BCxP - Building Commissioning Professional Certification
  - CPMP - Commissioning Process Management Professional
- **[2] AABC = Associated Air Balance Council**
- **ACG = AABC Commissioning Group**
  - CxA - Certified Commissioning Authority (Certification issues by ACG)
  - CxTs - Certified Commissioning Technicians (Certification issues by AABC or ACG)
  - EMP - Energy Management Professional (Certification issues by ACG)
- **[3] AEE = Association of Energy Engineers**
  - CBCP - Certified Building Commissioning Professional
- **[4] BCxA = Building Commissioning Association**
- **BCCB = Building Commissioning Certification Board**
  - CCP - Certified Commissioning Professional
  - ACP - Associate Commissioning Professional
  - BEMP - Building Energy Modeling Professional Certification (Certification issues by ASHRAE & is a prerequisite for the CCP certification)

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PDH Questions / Answers - (Q/A 10 Cont.)

Q10 - What are most knows organizations issuing Cx Certifications?

A10 - ASHRAE, AABC/ACG, AEE, BCxA/BCCB, Univ. of Wisconsin-Madison, NEBB.

- **[5] University of Wisconsin-Madison.**

  Descriptions of Certifications for Educational Achievement:
  - QCxP - Qualified Commissioning Process Provider.
  - BECxP - Building Enclosure Commissioning Process Provider.
  - CxA+BE - Commissioning Authority + Building Enclosure.

  Descriptions of Certifications for Educational Achievement Plus Project Experience:
  - CxAP - Commissioning Process Authority Professional
  - CxM - Commissioning Process Manager
  - CxTS - Commissioning Process Technical Service Provider
  - GCxP - Green Commissioning Process Provider
- **[6] NEBB - National Environnemental Balance Bureau.**
  - BSC CP - Building System Commissioning Certified Professional
  - BSC CxCT - Building System Commissioning Certified Technician
  - CxPP - Commissioning Process Professional Certified Professional
  - RCx-EB CP - Retro-Commissioning of Existing Buildings Certified Professional.

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PDH Questions / Answers - (Q/A 10 Cont.)

Q10 - What are most knows organizations issuing Cx Certifications?

A10 - ASHRAE, AABC/ACG, AEE, BCxA/BCCB, Univ. of Wisconsin-Madison, NEBB.

- **[7] NIBS - National Institute of Building Sciences (Defines the Total Building Cx Process).**
  - NCBC - National Conference on Building Commissioning.
- **[8] SMACNA - Sheet Metal & Air Conditioning Contractors' National Association.**
  - SMACNA HVAC System Commissioning Manual.

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PDH Questions / Answers - (Q/A 11)

- **Q11** - Per the ASHRAE Cx Guidelines, what are the varying types of Commissioning and why are there that many?
- **A11a** - [1] Total Building Cx Process (TBCxP).
- [2] Continuous Cx Process.
- [3] Ongoing Cx Process (OCx).
- [4] Re-Cx.
- [5] Retro-Cx.
- [6] Cx Light (or Custom Cx).
- **A11b** - Cx Type variations depend on whether the building is **existing** or **new**, or if it has been commissioned in past, and if that past Cx was adequate, etc.

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Suggested Commissioning Management Protocols

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Commissioning Management Protocols - (1 of 2)

	Issue	Protocol
1	For requests for information (RFI) or formal documentation requests:	The CxA goes first through the GC (or CM) *then* through the contractors.
2	For minor or verbal information and clarifications:	The CxA goes directly to the informed party.
3	For notifying contractors of deficiencies: Keep Slide for Stage-II Course	The CxA documents deficiencies through the GC (or CM), but may discuss deficiency issues with contractors prior to notifying the GC (or CM). The A/E is also informed of deficiencies identified by the CxA.
4	For scheduling **functional tests**:	The CxA schedules functional tests through the GC (or CM).
5	For scheduling commissioning meetings:	The GC (or CM) selects the date, in coordination with the CxA, and makes necessary arrangements for the meeting.
6	For making a request for significant changes:	**The CxA has no authority to issue change orders.**

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Commissioning Management Protocols - (2 of 2)

	Issue	Protocol
7	For making small changes in specified sequences of operations: Keep Slide for Stage-II Course	**Generally, the CxA may *not* make changes to specified sequences without approval from the A/E.** In limited situations, however, the CxA may recommend making small sequences of operations changes to improve efficiency or control or to correct deficiencies, through the responsible contractor, but shall document the change and provide all changes of specified sequences to the CM, GC and A/E. Responsible suggestions shall be made preferably in consultation and coordination with the GC (or CM), the CC and the major equipment maker impacting and/or impacted by the sequence of operation changes as applicable).
8	Contractors disagreeing with requests or interpretations by the CxA shall:	Attempt to resolve with the CxA first. Then work through the GC (or CM), who will work with CxA directly to resolve the situation.
9	For scheduling training:	The CxA may provide input for and do some coordination of training, but does not do the scheduling; Scheduling done through the GC (or CM).

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Suggested
Written Work Products

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Written Work Products (1 of 3)

	Product	Developed By
1	Final commissioning plan	CxA
2	Meeting minutes	CxA, GC (or CM)
3	Commissioning schedules	GC (or CM) with Contractors and CxA
4	Equipment documentation submittals	GC (or CM) and Contractors
5	Sequence clarifications	CC, Boiler manufacturer, Hydronics Consultant, A/E, or a combination of the above, as needed.
[6]	Prefunctional checklists (PFC)	CxA (& with support from GC (or CM), CC, Subcontractors and the Boiler Manufacture, as needed).
[7]	Start-up and initial checkout plan	GC and Contractors (compilation of existing documents)
[8]	Start-up and initial checkout forms filled out	GC (or CM) and Contractors

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Written Work Products (2 of 3)

	Product	Developed By
9	Final TAB report	TAB Subcontractor
10	Commissioning Issues Log (deficiencies)	CxA
11	Commissioning Progress Record	CxA
12	Deficiency reports	CxA (& also based on executed functional test forms completed by contractors).
[13]	Functional performance tests (FPC) and forms	CxA (& with support from GC (or CM), CC, Subcontractors and the Boiler Manufacture, as needed).
[14]	Executed functional test forms	GC (or CM) and Contractors

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Written Work Products (3 of 3)

	Product	Developed By
15	O&M manuals	GC (or CM) and Contractors
16	Commissioning record manual	CxA
17	Overall training plan	GC (or CM) with Contractors; and reviewed by CxA
18	Specific training agendas	GC (or CM) with Contractors; and reviewed by CxA
19	Final commissioning report	CxA
20	Recommissioning Management Manual	CxA
21	Miscellaneous Cx-related approvals	GC (or CM), A/E and CxA

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Suggested Project Close-out Documents

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Project Completion & Closeout Docs (1 of 3)

1. Provide all **Equipment Warranty** documentation.
2. Provide all equipment **Installation**, and **O&M Manuals**.
3. Provide all as-installed and complete **Equipment Submittals** as part of the O&M Manuals.
4. Define all related **O&M Roles and Responsibilities** moving forward between the Service Contractor, Boiler Maker, and the Site Owner in terms of scopes and schedules.
5. Secure **Service Agreements** to support the site in the future at a minimum with the **Mechanical Service Contractor** and preferably with the **Controls Contractor**. Ensure all agreements have enough detail in terms of scope details and frequent of services.
6. Provide **As-Built Mechanical Drawings** & as-built/updated equipment & pump & HX schedules.
7. Provide **As-Built Wiring (& Control) Diagrams**.
8. Provide **As-Built Architectural & Structural Drawings** & all project related drawings not include above.

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Project Completion & Closeout Docs (2 of 3)

9. Provide **As-Built Control Sequences of Operation (SOO)** especially after many control changes were done during system Cx. Ex. Clearly spell out how the pellet boilers are controlled using external commend as opposed to the tank upper and lower Temperature sensors for on/off signals to the pellet boilers.
10. Provide updated & final as-built **Controls Submittals** including all sensors covering all hardware, all software, all updated drawings & all details.
11. Provide written Standard Operating Procedures (**SOPs**) and access credentials for all information needed to successfully run the plant BMS, acquire data from the BMS and from all Monitoring based Cx equipment for Ongoing Cx and verification of as intended operation of all systems.
12. Provide the updated and **As-Built Test and Balance (TAB) Report**.
13. Secure a reliable and quality **Supply Source of Pellets**.

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Project Completion & Closeout Docs (3 of 3)

14. Completion of adequate customer **Controls Training**.
15. Completion of adequate customer **Boiler Training**.
16. Completion of adequate customer other **BOP Training** and system components (water softener, glycol system, chemicals, etc.).
17. **Training Manuals** for all training(s) for entire system and all BOP.
18. Attach clear **Equipment & Pipe Labels** that indicate flow direction everywhere for your flag ship projects.
19. Verify **full sets of soft & hard copies** of the items listed above are provided & easily accessible to those needing them for proper system operation, maintenance, trend logging, ongoing Cx, and project demonstration for success stories.
20. Include **Other Documentation** as need such as all proj permits, inspection records, financial and legal project paperwork, or items of project relevance not included above, etc.

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Project Completion & Closeout Cx Docs (1 of 1)

1. **Cx Plan** (Updated as necessary).
2. **OPR** & **BOD** (Updated as necessary).
3. **Training Manual** for entire system and all BOP.
4. **System O&M Manual** for entire system & all BOP.
5. **Issues and Resolution Log** (Closeout & completed).
6. Final **Cx Report**.
7. Convene **Lessons Learned Workshop** (Optional, but strongly recommended).
8. **Other TBD** as needed on case by case basis.

Suggested List Courtesy of ASHRAE Cx Resources

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Glossary of Terms, Abbreviations & Acronyms

See end of slides for the full Glossary of Terms, Abbreviations & Acronyms.

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Q/A

Thank you all for Attendance and Participation

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Suggested **End** of the Stage-I Cx Course

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End

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Formal **Beginning** of the in-depth Stage-II Cx Course;

(Satisfactory Completion of Stage-I is a Prerequisite ***before*** beginning Stage-II).

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In-depth PFCs, FPTs, Lessons Learned & other detailed Slides and Pictorial Examples for Stage-II Only

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Detailed Review and Hands-on Examples of Prefunctional Checklists (PFCs)

[Appendix C]

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Switch from PP Slides to PFCs Appendix-C XLS or PDF Files during that Section of the Detailed Course

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Detailed Review and Hands-on Examples of Functional Performance Testing (FPTs)

[Appendix D]

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Switch from PP Slides to FPTs Appendix-D XLS or PDF Files during that Section of the Detailed Course

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Start with a Brief Overview of Biomass Heating Systems during a brief Section of the Detailed Course Stage-II only as a refresher over the next few slides;

However, the audience should have reviewed the other detailed "*Introduction to Properly Sized Advanced HELE (High-Efficiency, Low-Emission) wood-pellet based Biomass Boiler Heating Systems and the Renewable Heat New York (RHNY) Governor's Initiative*" as a pre-requisite to fully understand the forthcoming in-depth lessons learned section primarily caused by *lack of system Cx during different phases* of a few selected earlier projects.

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Thermal Energy Storage (TES)
2 Gal/1,000 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

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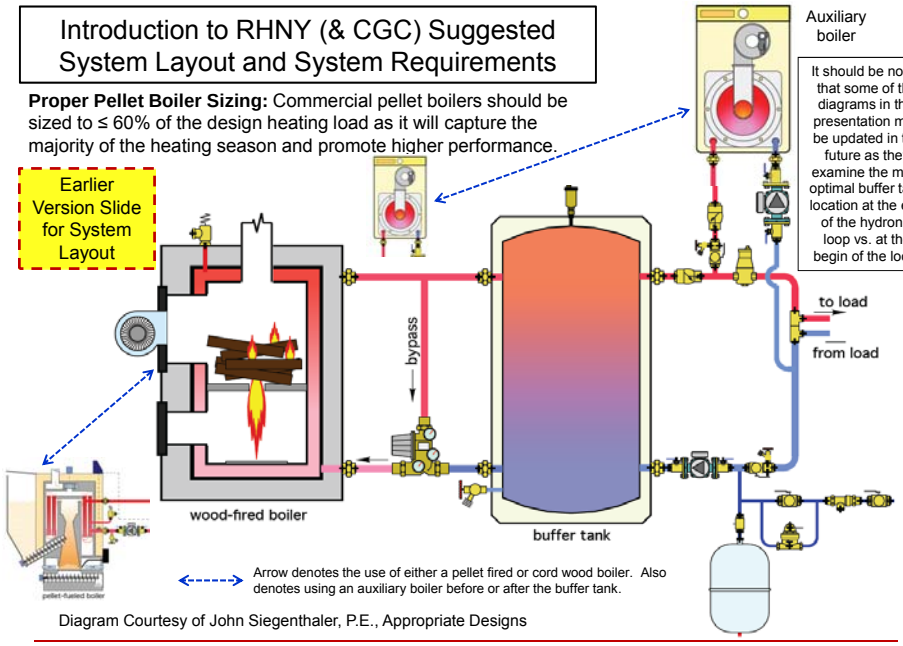
Introduction to RHNY (& CGC) Suggested System Layout and System Requirements

Proper Pellet 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.

Earlier Version Slide for System Layout



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.

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 John Siegenthaler, P.E., Appropriate Designs

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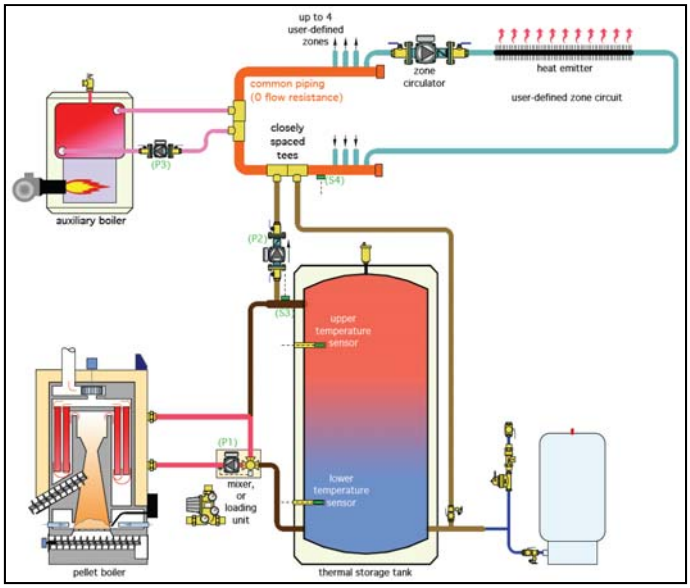
Introduction to RHNY - Suggested System Layout (1 of 3)



It should be noted that some of the diagrams in this presentation may be updated in the future as they examine the most optimal system component locations and may vary based on site specific conditions.

Updated Slide

Diagram Courtesy of PBSSIM.

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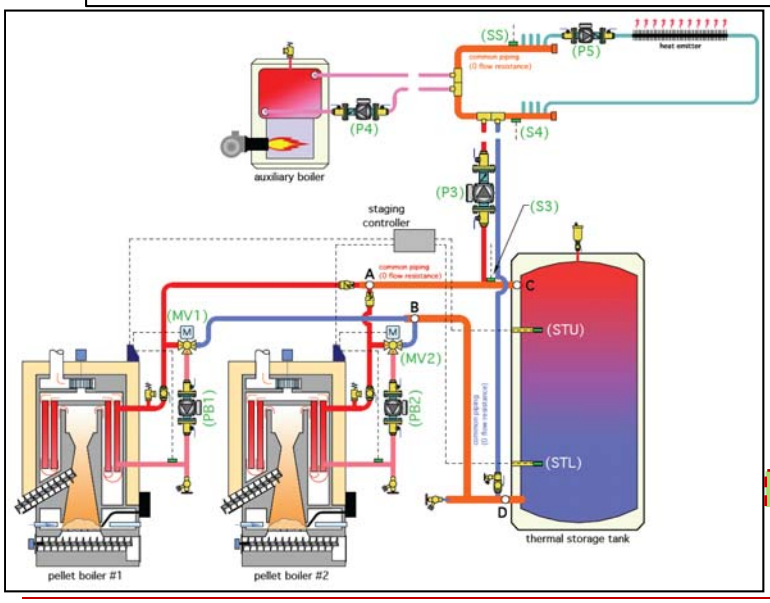
Introduction to RHNY - Suggested System Layout (2 of 3)



It should be noted that some of the diagrams in this presentation may be updated in the future as they examine the most optimal system component locations and may vary based on site specific conditions.

Updated Slide

Diagram Courtesy of PBSSIM.

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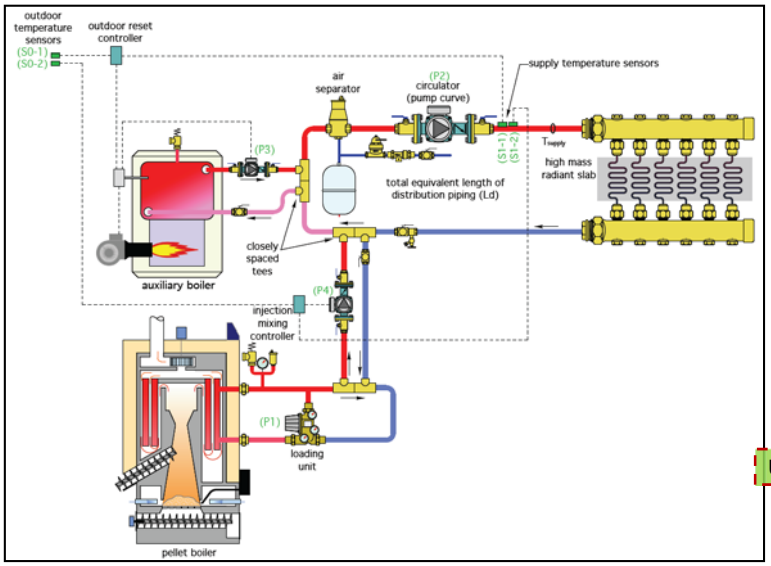
Introduction to RHNY - FYI - System Layout (3 of 3) with no TES. This is not recommended - Must use TES.



It should be noted that some of the diagrams in this presentation may be updated in the future as they examine the most optimal system component locations and may vary based on site specific conditions.

Updated Slide

Diagram Courtesy of PBSSIM.

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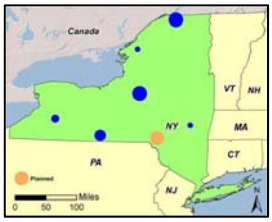
Pellet Plants in NYS - 500 kTon per year - now with bulk delivery! & is increasing



Photos Courtesy of NYSERDA

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Question - List Major Biomass System Components

Boiler:

- Combustion Chamber/Fire Door.
- Fuel Feeding System (Primary Auger and Stoker Auger).
- Combustion Air Supply.
- Boiler Controls, O_2 lambda sensor.
- Heat Exchanger/fire tubes.
- Exhaust/breaching/vent/barometric relief damper.
- Fuel igniter/ash cleaning/ash removal.
- Boiler Controller, Log File and Remote access capabilities.

Other BOP and Heating System:

- Fuel Storage Silo/Bunker.
- Fuel Conveyor/Auger System.
- EMCS or Building Automation System.
- Water Connections, Primary/Secondary Pumping, Controls Valves, Check Valves.
- Flue and Chimney and proper Boiler room venting.
- Post combustion gas treatment (cyclone, ESP, filter).

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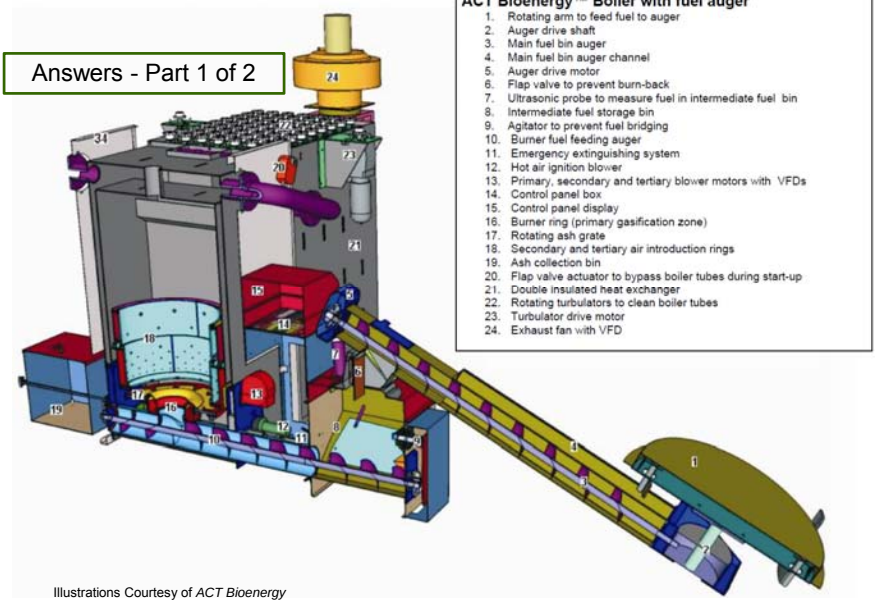
Answers - Part 1 of 2



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*

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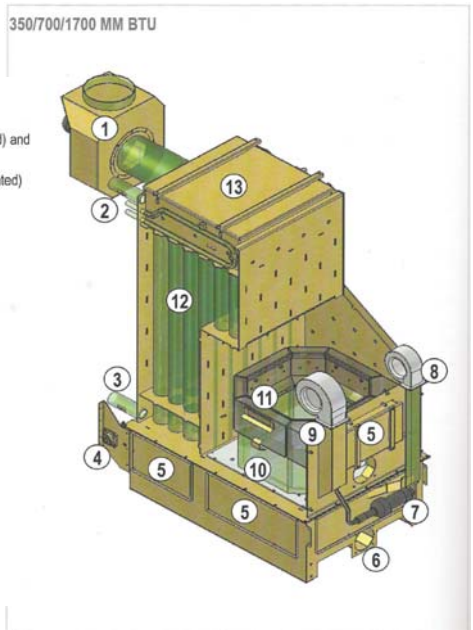
Answers



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*

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Optional Slide

Brief Boiler Sizing Examples Section

(Only 2 Optional Slides)

Alternative methods

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Sizing Ex 4 - Biomass Boiler Sizing - ADM4

Optional Slide

Examination of boiler sizing for the existing 2.74 million Btu/hr oil fired boilers total input rating 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 extreme caution as it was not thermally stratified vertical storage)

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Sizing Example 5 - WC5

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.

Optional Slide

- 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**
  Examine if and why it is oversized?
- Many Good Lessons learned:
  - Avoid oversizing.
  - Install TES/Buffer tank.
  - Use modulating propane fired boilers as auxiliary heat sources and auxiliary fuel, during very low loads and as peak load supplement, etc.
  - Controls integration and boiler sequencing,
  - CO Off gassing precautions.

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In-depth Review of the Issues Summary & Highlights of Major Findings under 3 Main Categories:
Group 1 of 3 (Items 1 to 7)
Group 2 of 3 (Items 8 to 13)
Group 3 of 3 (Items 14 to 21)

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Issues Summary & Highlights of Major Findings (Main Categories - Group 1 of 3):

Required Technology Specific Slide.

1. Lack of **TAB** (Test, Adjust and Balance).
2. Lack of **Cx** (Commissioning) process, Issues Logs & Project Coordination Meetings .
3. Lack of complete **Control Sequences of Operation**, & Systems **integration**.
4. Inadequate **Designs**, **Drawings** & **Specification** details.
5. Lack of proper **design review by independent 3rd party** & Lack of an **Energy Audit** before design.
6. Numerous **system pressurization**, & **HX** (heat exchanger) location & sizing issues.
7. **Pumping, Piping, Valving, VFD** & other **Hydronic issues**.

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Issues Summary & Highlights of Major Findings (Main Categories - Group 2 of 3):

Required Technology Specific Slide.

8. Incomplete **Pump/Valve Schedules**, & lacking other documentation.
9. No accurate **as-built drawings** *before* & *after* the biomass project.
10. Unclear **Roles and Responsibilities** among project team members during all project phases.
11. Inadequate and Improper **TES (thermal energy storage)** Tanks.
12. Existing Propane/Oil Boiler plant problems were not resolved *before* *adding* biomass boilers.
13. Bldg **Peak Heat Load Determination** and **Pellet Boiler Sizing** Issues.

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Issues Summary & Highlights of Major Findings (Main Categories - Group 3 of 3):

Required Technology Specific Slide.

14. Issues with **3-way mixing valves** serving biomass boiler & downstream from tank.
15. Lack of enough **BTU meters**, **M&V**, & motor status **CTs**.
16. Lack of **PT Ports** makes it impossible to TAB systems and troubleshoot.
17. ESCO, Design Engineer & Installer lack the necessary biomass (and MEP) system **knowledge & experience**.
18. Issues with **Pellet Boiler reliability** and robustness.
19. Boiler **Container**, BOP (Balance of Plant), Boiler **venting**, & Misc other MEP and/or code issues.
20. ESCO Financial Issues; Oil Prices?; Any one else to blame?
21. Issues with Certain Government Procurement Processes.

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[1] Issues & Observations - (TAB):

1. Lack of complete Heating Plant **TAB** w/ pellet boiler flows, oil boiler flows, both sides of HX (loop side and building side).
2. **Incomplete & one-time TAB does not suffice**; Projects needed an **iterative TAB process** till completion.
3. **As-built TAB (and as-built drawings verifications)** were seriously lacking despite being core prerequisites to making subsequent plant decisions.
4. Lack of **PT Ports** made it impossible to TAB the systems and troubleshoot.
5. Pressure taps & balancing valves should've been installed **downstream** of pumps for future test & balance (not upstream).




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[2, 3 & 10] Issues & Observations - (Cx & Controls):

1. Lack of System **Commissioning (Cx)** during ALL project phases from design to construction & operation; See Cx Definitions at end of slides.
2. Lack of complete/detailed **issues & resolution logs**. Can also be called events log or deficiencies log.
3. Lack of complete **Control Sequences of Operation** and **System Integration** covering the operation and controls of the entire **hybrid heating plant**, pellet boilers, TES tanks, all pumps, valves, oil/propane boilers; Also need to address **oil/propane boiler cycling**.
4. Proper implementation of control sequences require an ***interactive* programming process** to revisit the control sequence impacts after their initial settings, then adjust and reprogram as necessary, in an iterative manner until stable system operation is attained. This could take a few weeks of back and forth (or seasons) until completed successfully; not a one day trip!

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[4, 5 & 6] Issues & Observations - (HX & Operating Pressures):

1. Lack of design engineer and/or ESCO understanding of the **Pellet Boiler's 185 Deg F max leaving temp and 30 psig max operating pressure (i.e., the boiler's pressure relief valve setting)**.
   b) Incorrect 200 Deg F leaving temperature "assumption" resulted in incorrect HX sizing.
   c) Exceeding 30 psig necessitated adding a HX.
2. Installation of **Undersized HX (heat exchangers)** between district loop side & building side caused by incorrect loop temperature assumptions & incorrect temperature drop assumptions everywhere (on both sides of the HX).
3. To reduce pellet boiler pressure, **HX was incorrectly installed** in between boiler & TES tank, as opposed to in between the tank & the loop. Expensive relocation needed to serve as proper pressure break.

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[4, 5 & 6] Issues & Observations - (System Operating Pressures):

1. **Suspected pump cavitation, system pressurization and trapped air issues were caused by P-2 district loop pump installed on incorrect pipe on the loop return pipe as opposed to the loop supply pipe.**
2. P-2 suspected to pull air from negative pressure areas/connections upstream of district loop pipe due to incorrect P-2 location.
3. Lack of pump schedule and lack a thoughtful pressure gradient curve to estimate suction and discharge pressures before installations.
4. See drawing on next slide.

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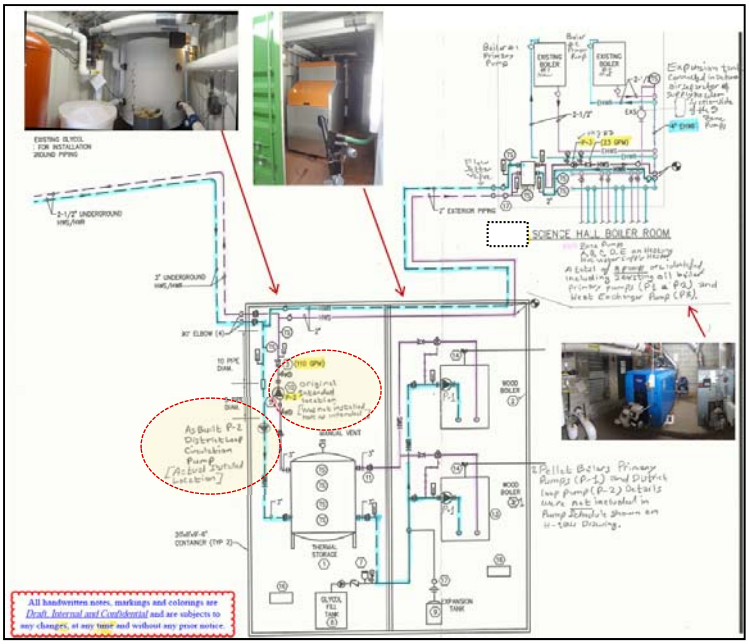

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[5 & 7] Issues & Observations - (Oil/Propane Boiler Plant Piping & Re-Piping):

1. **Do not** rush and proceed with biomass heating projects without a full understanding of the *existing* heating plant & DHW heating in terms of as-builts, piping, valving, controls, and the original design intent. Determine if enhancements or corrections are needed well ***before*** moving forward with the biomass boilers' addition. Must Plan ahead & Cx during Proj. Planning.
2. Ex - Suggestion - Re-pipe small oil boiler for year-round use as opposed to only Summer DHW Use. This will reduce large oil boiler cycling in winter after adding the pellet boiler. Do the proper loads analysis and do the necessary control modifications.

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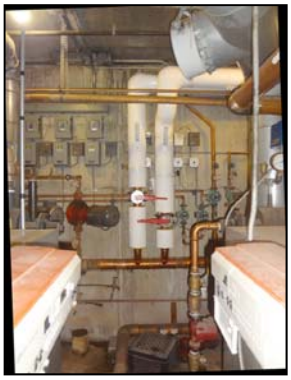
[5 & 7] Issues & Observations - (Oil/Propane Boiler Plant Piping & Re-Piping):



1. Suggestion - Injecting the pellet loop heat in the return header leading to the oil/propane boilers (***upstream*** of propane boilers) is a safe and simple means of injecting pellet heat into an existing distribution (as opposed to injecting ***downstream***);
2. However, that being said, ensure that there are piping provisions to ***bypass*** the existing oil/propane boilers when they are not needed, otherwise, they act as radiators and wastefully dissipate heat into the boiler room and up the stack.

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[11] Issues & Observations - (TES Tanks):

1. Use of ineffective, inadequate, small, **short and fat 4-pipe TES** (with a poor aspect ratio) caused tank to be ineffective for storage; Therefore, it was suggested using an alternative **2-pipe, vertically stratified TES tank with more storage capacity** and better aspect ratio; At a minimum, investigate if the existing 4-pipe tank can be re-piped/converted into a 2-pipe tank. Additionally, evidence of tank valve leaks were observed.
2. Verify tanks have **horizontal perforated diffusers** or preferably **diffuser trays** so the entering and leaving water does not upset the tank thermal stratification.
3. The entering/leaving bottom TES tank pipes were not low enough and the upper TES tank pipes were not high enough. They should have been as far away from each other as possible.
4. Inadequate as-built documentation of whether the tank diffusers or trays were installed, and if yes, if they were properly installed.

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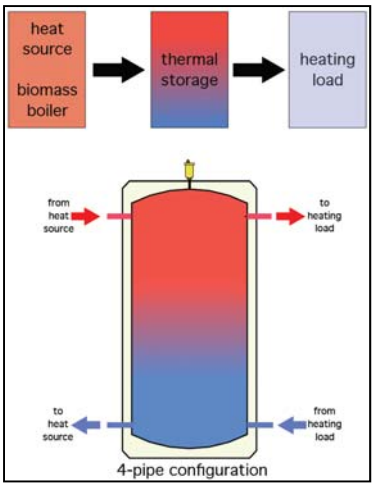
TES Evolution (Original 4-Pipe Configuration vs. Modern 2-Pipe Configuration)



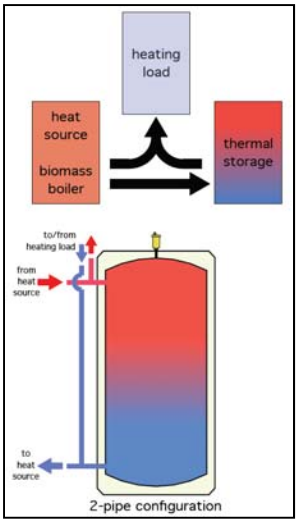


Diagram Courtesy of John Siegenthaler, P.E., Appropriate Designs

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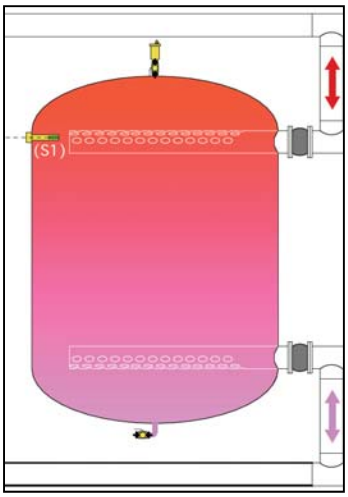
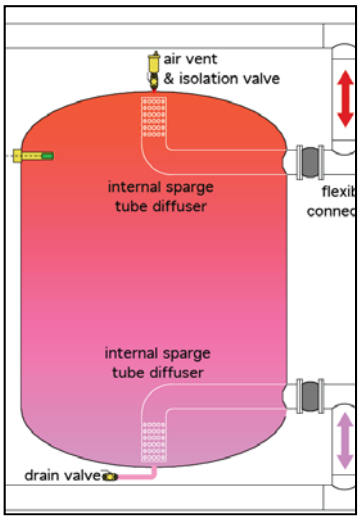
Improved Low Velocity Diffusers in Modern 2-Pipe Tank Configurations to attain better thermal stratification?





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

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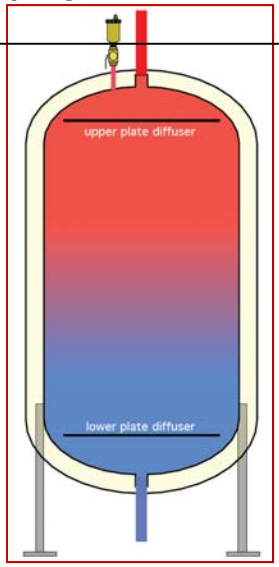
Consider using internal flow diffuser plates rather than sparge tube diffusers. The plates would likely be lower cost, and offer less flow resistance.



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- Up to this point, there were enough slides for the short 54-minute presentation averaging 2-minutes per slide (+ 6 minutes for Q/A); however, past this point, it will need more time than the 1.0 hr available.
- More slides are included later for reference only for attendees who desire to review more lessons learned past this point; A high level overview will be presented; unless the 2.0 hr is available…..
- Go to the Take Home Messages & Next Steps section, then to the Questions to conclude on time.

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[3, 7 & 11] Issues & Observations - (**Pumping, VFD Pumping, 3-Way mixing valves, & TES**):

1. Lack of pump controls and flow balancing upstream and downstream of TES Tank. Ensure all pumps are well controlled to utilize the true benefits of a 2-pipe tall tank. Lack of pump controls can upset the tank stratification if either side over pumps and if **flows between the P-1 primary boiler loops and P-2 secondary district loop were not balanced**. Typically, P-1 is fixed speed, but P-2 is preferably variable speed to more accurately respond to load, but unfortunately this was not always followed, causing problematic system operation and ineffective use of the thermally un-stratified TES tank.

2. Uncontrolled, **unintentional, and excessive operation of the pellet boiler pump** after the pellet boiler de-energizes caused an inverted temperature profile in the vertical TES tank and dissipated a good part of the thermal energy (that was supposed to have been stored in the tank) into the boiler room via the pellet boiler shell through radiation, convection, and stack losses. This was caused by a software issue from the pellet boiler.

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[11 & 14] Issues & Observations - (3-Way valves, VFD Pumping, & TES):

1. The **3-way mixing valve** serving the biomass boiler suffered from operational and control issues including both types: self-contained thermostatically controlled or electrically actuated/controlled (by the pellet boiler). Issues included but were not limited to valve stem issues, valves wired in reverse, valves installed in opposite direction, valves did not completely close or fully seat (causing unintentional bypassing), etc.
2. Valve operational issues observed at multiple installations, but issues were not documented in a clear issues log and a thorough testing, Cx and TAB process was not followed from the beginning of project.
3. Verify operation of the **3-way mixing valve** between the tank and the system as part of TAB. Hot water resets will be more important with pellet boiler projects and will *expand the effective BTU storage capacity and full utilization of the TES tank*. At times, the desired valve was not even installed; The design engineer originally planned for it, but the ESCO requested it be removed or installed did not install it.

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[4] Issues & Observations - (Drawings & Specs):

1. Project **Specifications** were not provided.
2. However, when specs were provided, they were problematic, for example:
3. **Lengthy project specifications lacked the detail and needed focus** regarding the biomass heating system. At times, specs were several hundred pages long, but without the needed focus on the biomass project; Strongly caution against unthoughtful copy and paste from existing spec templates!
4. Additionally, lengthy standard specs from a wood chip project were mistakenly used in a wood pellet project; for example, a cyclone was not installed in the pellet project despite being mentioned in the wood chip project specs.
5. This was just a brief example of using improper specs, but there were many other examples.

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[4 & 5] Issues & Observations - (Drawings & Specs):

1. **Drawings** lacked the biomass heating system design details with specific focus on the pellet boiler connection to TES and the tank full details. Unclear system schematics that lacked the necessary detail were not acceptable and caused numerous problems later on during construction and later during system operation.
2. Lack of proper **design review by independent 3rd party** in the past caused numerous issues that went unidentified during all project phases. All should have been addressed in a timely manner before building the biomass project. It should be a design-build process and not a build-design process.
3. Design engineering firm selection should consider whether they have enough central plant, hydronics, controls, Cx and biomass system experience; and a good relationship with TAB contractors to facilitate any back and forth TAB process.

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[17] Issues & Observations - (Level of Experience):

1. Lack of the **necessary biomass knowledge** and system-specific needs by both the Design Engineer and the Controls Contractor. Both relied on the ESCO's biomass and non-biomass heating systems experience, which later proved to be inadequate.
2. **Lack of ESCO experience, project leadership, and knowledge about what it takes to commence a proper design through implementation/Cx/Start-up process to attain reliable operation**. This led to removing Cx and TAB details from project documents with no understanding of the consequences of such removals. Additionally, there was no understanding of the necessary in-depth energy and engineering knowledge of the BOP and MEP support systems needed to attain a reliable biomass heating system installation, controls and operation.
3. Mechanical contractor blindly implements parts of the design and does a good job with what appears to be quality construction and quality workmanship, but unfortunately with no thought whether the design was appropriate or not. Despite the contractors' general MEP and HVAC experience, the **mechanical contractor lacked biomass heating system experience** and relied on the engineers' drawings (& lacking specifications).

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[18] Issues & Observations - (Unreliable Operation):

1. Biomass boilers **operational and reliability issues** were reported, and manufacturer appeared to have been addressing issues expeditiously; however, a detailed **issues and resolution log** was not provided.
2. Replaced **broken turbulator**, as needed. Requested certain manufacturer to explain what caused it to break and how to avoid that in the future.
3. There is currently ongoing efforts to enhance the **reliability of other boiler sensors and components** and get better error messages and complete boiler Installation & O&M Manuals & full documentation.
4. Repeated failures of boiler **burner rings** caused some pellet boilers to be down for extended periods of time until parts were installed by the manufacturer.

Note - **Biomass boilers unreliable operation** vs. frequent **short cycling** were two separate problems caused by different reasons ranging from both boiler maker reliability vs. BOP and controls related issues. Those two should not be confused.

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[18] Issues & Observations - (Unreliable Operation):

1. **O_2 sensor issues (lambda sensors?)**. Were detailed calibration, setup and Cx procedures followed?

2. **3-way mixing valve** issues were faced in multiple sites.
3. Sight glass and **photo cell** issues (near the front panel).
4. **Vacuum sensor** issues in multiple sites.
5. Needed to **reboot** the boiler several times to get the updated firmware/boiler control updates and the data logging on thumb drive resumed and to ensure boiler resumes desired normal operation.

6. **Pellet fill level sensor** malfunction (or becomes dusty and requires cleaning).
7. **Igniter malfunction** - Needed replacement.
8. **Unreliable internet connection** prevented boiler maker from remote access for viewing, receiving alarm notifications, & troubleshooting.

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[2, 10, 17 & 20] Issues & Observations - (ESCO Experience, Project Communication & Roles & Responsibilities):

1. **ESCO Financial**, cash flow issues and project interruptions.
2. Issues from ESCO Financial pressures caused QC issues and reduction in project scope, sometimes in an unthoughtful manner, like removing some of the necessary control valves, TAB and Cx from project scope.
3. Did ESCO have adequate knowledge of negative impacts of what was being cut from the scope of work?
4. **Poor communication and relationship** between the ESCO and the General Contractor.
5. **Poor communication and relationship** between the Customer and the ESCO.
6. **Lack of the necessary project coordination meetings** during all project phases.
7. Is the **drop in oil prices in 2015/2016 to blame? NO** - Although oil prices had some negative contribution to the problems, there were numerous other factors above that made certain projects dysfunctional.
8. Oil Prices? Prices may not stay that low for a long time, but we cannot predict the future.
9. Unclear **Roles and Rresponsibilities** among multiple project entities and during all project phases.

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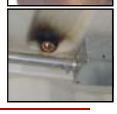
[19] Issues & Observations - (The Boiler Container):








1. **Questionable quality of pellet boiler container construction**. Multiple leaks observed, both originating from inside the container and from the outside shell.
2. **Backup ceiling-mounted electric unit heaters (~ 3.0 kW) did not energize as intended during the dead of winter 2015/2016** when the pellet boiler system was down and the container (including the pellet boilers and the TES tank) were stone cold. Luckily it was filled by PG30 that should not freeze. **Boiler & BOP needed to be tested after exposure to extreme cold and investigate if that added to the gasket leaks in the container as well**.
3. Missing actuator for container combustion intake air louvers (and/or container ventilation louvers) may have been deliberately eliminated by the ESCO. This presented a freeze hazard in winter if boilers are down for extended duration during frigid weather with no backup electric heat.
4. Another site had a dysfunctional actuator for boiler room air intake grill so the same freezing concern was shared since the expansion tank was sitting right next to the cracked open grill.
5. No floor drains in container. Should it be rubberized floor?
6. Why un-insulated boiler container in the Northeast? Examine the use of insulation, but available space presents challenges if insulated from the inside, but okay if insulated from the outside for an additional cost.

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[19] Issues & Observations - (Boiler Venting):

1. Gap in the stainless steel (SS) chimney; Soot (and fly ash) observed inside the boiler container.
2. Black smoke residue was observed on top of the 2 metal chimneys; indicative of incomplete combustion; Cycling, etc.?
3. Verify there was no pellet boilers excessive cycling if user or CxA has access to the historic log file and/or BTU meter data; however, no data was log provided.
4. Should include CO alarm response as part of the future control sequences.
5. Address barometric relief damper inconsistency between specs vs. implementation. Suggest use of a better quality positive pressure seal SS barometric relief damper due to multiple benefits.
6. As biomass boilers take away load from the oil/propane boilers, examine the application of **brick chimney inner lining** to address potential condensation issues after the pellet plant starts to operate. Stainless steel lining preferred.

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[13] Issues & Observations - (System Sizing):

1. In Proj A - Inaccurate building areas leading to misleading **normalized peak heat load calculations.**
2. Proj A - Inaccurate Peak Heat Load Calculations - The installed **1.4 million Btu/h** biomass boiler container had a correct size, despite the ESCO's incorrect normalized peak heat load determination (based on incorrect building areas) resulting in **93.1 Btu/h/sqft (2,700,000 Btu/h / 29,000 sqft)**. The 93.1 was **triple** the peak heat load of **27.6 Btu/h/sqft (2,200,000 Btu/h / 79,635 sqft)** that was independently estimated by Pyramid EES.
3. Proj B - Unclear **bldg. peak heat load** determination due to no baseline measurements & no TAB; causing peak load assessment to widely vary from 1.1 to 2.3 million Btu/h depending on the calc. method used (Bldg Area = 57,261 sqft). This impacts the sizing of the future biomass boilers and the 3rd oil boiler claimed to be needed for redundancy, but no TAB evidence was submitted to substantiate the needed redundancy claims.

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[13] Issues & Observations - (System Sizing & EEMs):

1. Size new pellet boilers based on updated building heat load determinations, and preferably after factoring in EEM savings that were identified in the energy audit. EEM suggestions from real projects include but are not limited to:
2. Apply DCV controls on future Unit Ventilators to reduce building loads.
3. Control OA dampers.
4. Complete numerous building envelope upgrades.
5. Ensure that the future controls scope provides for better zoning (and space comfort) than existing as project converts from pneumatic controls to DDC.
6. Consider low-temperature heat emitters when specifying new radiators, UVs & RTUs.
7. Implement heating hot water resets as part of the new controls using the 3-way mixing valve at the plant and the new VFD pump.
8. Generally, implement any other EEMs and capital projects that reduce building heating loads *before* finalizing system sizing (use holistic project approach).
9. Question - Can unreliable and uncalibrated Energy Models be used to reliably predict EEMs savings in an energy audit? Ans. Absolutely NO, but why?
10. **STOP - Do not put the cart before the horse and do not rush in any biomass boiler projects before conducting an ASHRAE Level-II or-III energy audit.**

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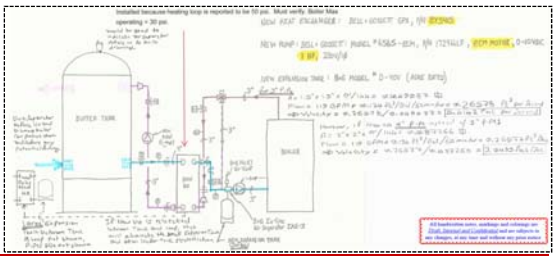
[3, 7, 8 & 9] Issues & Observations - (Drawings, Hydronics & Controls):

1. The ESCO treating the pellet boiler container as a **black box** and marginalizing the roles of the Design Engineer and the Controls Contractor were major project setbacks.
2. Incomplete **Pump/Valve Schedules in drawings.**
3. No accurate **as-built drawings** other than an incomplete hand sketch.
4. Moving forward, verify that the heat generated from the oil boilers does not get inadvertently directed back into the storage tank. Hydronic & controls detail were needed.
5. Examine the different scenarios of controlling the biomass boilers; from the tank upper and lower temperature sensors or from the loop temperatures vis external command.
6. Could not verify pellet boiler manufacturer claims that the pellet boilers can modulate down to a certain point (say 30%). Requested data to illustrate such operation, but no logged data was provided.
7. Unclear about the required heating hot water distribution temperatures to satisfy the existing heat emitters at the building at varying OATs.



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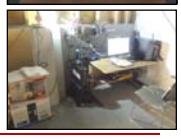
[15] Issues & Observations - (M&V Misc):

1. Lack of enough **BTU meters** & other **M&V instrumentation.** Only 1 BTU meter deployed at district P-2 (downstream from TES tank to the loop), but no with no M&V data to clearly show how much heat was delivered to each of the district buildings, HX effectiveness, etc.
2. Thermal wells were shown on the TES tank diagram, but thermocouples were not inserted in 3 out of 5 of them (the middle ones). More vertical sensors would support better evaluation of the TES tank operation.
3. Lack of M&V Data Points - More M&V data points and trend-logged data were needed "*You cannot manage what you do not measure*".
4. Loss of M&V data occurred due to simple reasons such as a power outage; At a minimum, use a UPS to keep the data collection system running for several hours to prevent such data loss, and check the data periodically to reduce unpleasant surprises.
5. Ensure proper installation of ultrasonic flow transducers & temperature sensors on pipe surfaces & in wells to obtain accurate BTU meter data. More can be elaborated on this topic separately in an M&V training.
6. Data collection using the boiler built-in microprocessor panels, Modbus and remote access presented challenges depending on the boiler manufacturer; Not all manufacture provided such built-in features.



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[15] Issues & Observations - (Misc M&V & Sensors):

1. Sub-metering of Selected Loads (served by oil, propane or electricity) supports a better baseline development, boiler sizing process, and better understanding and analysis of multiple end uses; Besides space heating and DHW heating needs, there is also the commercial kitchen cooking, dishwashing, laundry, sterilization, incineration, etc.
2. Carefully set the BMS to Trend log the needed M&V Data points; in some cases, despite having capable EMS, they were not set for trend logging.
3. Protect the data collection equipment through proper shields and clear signs to prevent from accidentally tampering with it causing loss of data, (especially if any construction activity is surrounding the data collection system).
4. Include local OAT as part of M&V, is it part of the existing BMS now?
5. Verify accuracy of pressure gauge displays.
6. Uncertain how deep the tank thermal wells were. The deeper the better (minimum of 6" desired).
7. Thermal wells lacked the application of proper thermal grease.
8. BTU meter flow transducers lacked the application of proper acoustic coupling compound.

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[19] Issues & Observations - (Insulation):

1. Tank insulation: Removable blankets are preferred over permanent fiberglass or spray foam insulation. In either case, maintain ≥ R-24 insulation. In some projects, it was too late to examine insulation options as the less expensive fiberglass insulation was already applied. First cost was a major factor in selecting the use of permanent fiber over removable blankets; Blankets were needed for better tank access to pipes an fittings and for tank troubleshooting when leaks were observed.
2. Verify that the existing heat trace controls do not run unnecessarily and in a wasteful manner if OAT is above freezing. Heat trace elements were located on the above ground hot water loop pipes between the boiler container and the building.
3. Why use an un-insulated boiler container in the Northeast? Examine additional insulation, but available space may present a challenge. Standard shipping containers were typically tight both horizontally & vertically.

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[19] Issues & Observations - (Misc):

1. DHW tank was set at 140 Deg F with no setback.
2. O&M Staff Training needs.
3. Ensure proper coordination between the cyclone fan and the induced draft fan speeds.
4. Observed damaged pellets in the day hopper and a lot of pellet dust, this was an indication of why boiler operation problems and some error messages were received. Change pellet suppliers was necessary.
5. Cover exposed USB port at the pellet boiler (& M&V Equipment) to protect from dust.
6. Verify calculations if the 25 to 36 Ton silo is undersized for extended pellet boiler operation during frigid weather conditions.
7. Suggestion - Empty the pellet silo before the summer to prevent potential interior condensation that can damage the pellets and cause issues with operation of the auger assembly. Additionally, properly seal the bottom of the silo to prevent moisture entry and impacts from splashing rain water. Not following the above caused the pellets to absorb moisture, get wet, clog the auger, and prevent the boiler from first operation in the fall.

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General Issues Summary & Observations - (***Despite the many Lessons Learned, Is there hope? - Ans. Yes, but how, see below***):

1. The above conglomerate of issues resulted in a need for requesting and generating an as-built set of drawings, TAB, numerous design then construction corrections, complete Cx and plant sequences, etc. The hybrid plants could not run reliably in its current state, which is why the site went back to solely operating the oil or propane boilers (Until the system makeover project was completed to address most of the identified issues, which was a very expensive repair and correction process).
2. The above represents a summary of what was observed during site visits and subsequent analyses, but **there could be more issues that were not identified**. This was likely due to lacking biomass boiler test and startup information at some sites. Also, the operation and modulation of the pellet boiler itself has not been verified under all load conditions and for operation periods that are long enough to illustrate reliable pellet boiler operation.
3. Despite the above issues, there is a path for corrections (a system makeover) if the customer is willing to invest in system corrections by addressing the above items and as summarized in the Section Titled "**Take Home Messages & Next Steps**".
4. General Continuing Education and Training (M&V, Cx, TAB, and Hydronics) were needed for all team members. This has to be done correctly and there were no other option. Training is an investment and shall be funded as part of the project budget.
5. Boiler manufacturer installer training with specifics and hands on detail were needed – that is being addressed separately.
6. Address the above items and lead by example.

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Misc Other Relevant Discussion Topics

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TBD more slides if Needed, but there is enough above already for the detailed Stage-II Course

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Take Home Messages & Next Steps (**Questions**)

1. Based on what has been discussed earlier, list 3 to 5 Major “Take Home Messages for your projects Next Steps” ?
2. If you were to select the most substantial item, what would you select and why?

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Take Home Messages & Next Steps

1. In general, biomass heating systems *require* a more *careful, thorough, integrated and methodical* approach than conventional oil or gas heating systems. Can Update Slide Later
2. Invest in good quality comprehensive ASHRAE Level-II or -III Building Energy Audits *before* making any further major design and/or capital improvement project decisions.
3. Moreover, district biomass heating systems serving multiple buildings and HXs require *additional attention* compared to single building systems.
4. Make next system makeover steps only *after* a careful review of the reported *Issues Summary & Observations* including lack of **Cx**, TAB, Sequences, updated drawings, updated pump/valve schedules, hydronic details, HX reminders, independent 3rd party design review, take/verify as-built Temperature and Flow measurements, and provide proper documentation, etc.

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Take Home Messages & Next Steps - Cont.

5. In general, the design engineering firm selection (or design-build firm selection) in such projects should illustrate that they have enough central plant, hydronics, controls, Cx & biomass system experience (and a good relationship with competent TAB contractors); Any additional needed skills shall be sought via training and/or sub-consulting with experts. Can Update Slide Later
6. Future design, controls and TAB/Cx work scopes shall consider all the points brought up in this presentation covering ***both*** the building's secondary systems (distribution and all UVs and AHUs) and the primary systems; i.e., the hybrid oil/biomass boiler project with full TAB, flows and controls integration of all systems (all boilers, all pumps, all pipes, all modulating valves, all balancing valves, all check valves, HXs, all tank [TES and expansion], etc.) to mitigate against any "potential" system pressurization, flow imbalances or control conflicts between the two boiler types and between the primary and secondary systems to attain and operate a successful baseloaded biomass heating plant with supplemental oil heating capacity.

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Take Home Messages & Next Steps - Cont.

7. Take *baseline measurements* to troubleshoot the operation of the new/existing oil boilers, determine their measured output, and have better baseline resolution for M&V.
8. Take *baseline measurements* and bench mark for major hotwater, steam and direct propane end uses, including but not limited to the mixed fuel kitchen: Propane Cooking, Steam Cooking & Steam for Dishwasher booster (from the steam fired propane boiler), Exhaust fans flow and their electricity usage, etc.
9. Take *baseline measurements* and bench marks for major end uses like the electric kitchen or summer DHW boiler before making any further capital decisions like CHP, which may not be an appropriate measure for the building.
10. Generally, taking selected *baseline measurements* and bench marks for major end uses as exemplified above is part of good energy management and control enhancements. Invest in as-built building HVAC system TAB before adding any biomass heating systems.

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Take Home Messages & Next Steps - Cont.

11. Consider the list of *EEMs* included earlier in this presentation as part of future capital project thoughts and/or Master Energy Plans and obviously add more as you find appropriate. Approach meaningful and well thought through improvements as opposed to rushed ones to avoid any further system issues (like the existing oil boilers suspected suppressed capacity with no TAB work); start with making plans to correct the existing oil boiler plant issues during planning for the biomass projects, do both in an integrated approach preferably using the same competent design firm and suggest they seek knowledge in needed areas and attend necessary trainings as discussed earlier.
12. *Under-sizing* biomass boilers attains longer on cycles/runtimes at higher/full loads & less off cycles, especially when coupled with Thermal Energy Storage (TES) tanks. Carefully consider the different biomass boiler sizing calculation options presented earlier in this presentation (or the other presentation). Additionally, an undersized/properly sized *tandem biomass boiler* setup could provide better pellet plant performance during part load conditions.

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Take Home Messages & Next Steps - Cont.

13. Completely revise the TES Buffer Tank design: Use *2-pipe tank* vs. 4-pipe tank, use a much taller tank with more storage capacity, use either horizontal perforated diffusers or preferably diffuser trays. This is to reduce potential future pellet boiler cycling, attain faster biomass loop response times, higher efficiencies, and displace more fossil fuel.
14. Unfortunately, however, a taller tank with more storage capacity cannot be accommodated in the limited capacity container (ceiling height limitations). An additional external larger vertical elaborate TES tank was not discussed due to cost and needed piping changes to accommodate a second TES tank.

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Take Home Messages & Next Steps - Cont.

15. Moving forward, (1) carefully design all the pipes, pumps, VFDs and valves according to observations in the independently generated system assessment Memos to attain *better balance upstream and downstream of the TES tank to enhance its thermal stratification.* In another case, do the same (2) after relocating the heat exchanger to its new and correct location between the tank and loop as opposed to its current incorrect location between the biomass boiler and the tank. In another case, do the same (3) after relocating P-2 from the return to the supply side of the loop pipes and after upsizing all 3 heat exchangers to address several issues identified from the current setup (to prevent the P-2 pump cavitation, reduce trapped air, and alleviate building bottlenecked HX capacity).
16. Existing fuel oil fired boilers can serve as backup or supplement to undersized biomass heating systems and to meet peak building heating loads that exceed the future baseloaded biomass heating plant output capacity; However, ensure the oil boilers have good turn down capabilities, which is not always the case, causing them to frequently cycle….. Consider upgrading the existing oil boiler controls to prevent them from frequent cycling.

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Take Home Messages & Next Steps - Cont.

17. Review stack considerations, especially once the biomass boilers take away heating load from the existing oil boilers, to address any potential condensation issues in the existing brick stack and consider the needed stainless steel inner liner.
18. Must Methodically Design, Commission, TAB, Measure & Verify (M&V), and have independent design reviews to ensure proper biomass system integration with existing heating systems, energy management systems, and heat distribution systems throughout the entire process from design through operation and M&V.

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Take Home Messages & Next Steps - Cont.

19. After updating the control sequences, arrange for at least a full day of *formal controls and/or EMS training* and ensure that the plant staff have the necessary knowledge to operate the control system, set up trend logs, and do basic to mid level troubleshooting of controls.
20. STOP - Do not rush in any oil boiler or pellet boiler sizing decisions before taking the baseline measurements and performing the TAB recommendations included earlier in this presentation.
21. STOP - Do not rush in alternative biomass boiler pump selections (3.0 hp in place of existing 1.5 hp) to do an “apparent” quick fix that does not guarantee addressing all of the issues identified in this memo - We say NO to band aid approach; Use a full, integrated and methodical design approach starting with developing a complete set of drawings along with TAB *before* and *after* any system corrections/enhancements preferably completed by the same contractor to attain project continuity.

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Take Home Messages & Next Steps - Cont.

22. Before moving further with a project, carefully review the suggested list of *Roles and Responsibilities* and have a clear path moving forward with clear roles for each member of the project team during all project phases, and with a call for clear collaboration, communication and transparency among the team members proceeding with existing system corrections and future capital projects.
23. Comply with the applicable *RHNY Eligibility Requirements* explained earlier as best practices (and *minimum* requirements) and *exceed* them where needed for the betterment of the project; there is no one size that fits all, Biomass heating project is more complex than an average commercial oil or propane boiler heating projects.
24. Address the above items and lead by example and contact us with any question you may have.

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Take Home Messages & Next Steps (**Questions**)

1. What have you learned today that can support your other MEP projects, besides just biomass?
2. Out of all of what you have learned today, how much of it is biomass heating system specific vs. generally applicable to any other engineering projects?
3. Before concluding this session, define in your own terms Cx & TAB? You now know why the trainer focused on Cx and TAB as part of system troubleshooting. Definitions will be shared shortly.
4. List major Cx and TAB references you know of or have used in your job.

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Project Completion & Closeout Cx Docs (4 Slides)

Suggested recap on the project Completion & Closeout documents; Start w/ Stage-I 3 slides then this 4th slide for Cx Specifics.

1. **Cx Plan** (Updated as necessary).
2. **OPR** & **BOD** (Updated as necessary).
3. **Training Manual** for entire system and all BOP.
4. **System O&M Manual** for entire system & all BOP.
5. **Issues and Resolution Log** (Closeout & completed).
6. Final **Cx Report**.
7. Convene **Lessons Learned Workshop** (Optional, but strongly recommended).
8. **Other TBD** as needed on case by case basis.

Suggested List Courtesy of ASHRAE Cx Resources

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- ASHRAE, founded in 1894, is a global society advancing human well-being through sustainable technology for the built environment. The Society and its more than 50,000 members worldwide focus on building systems, energy efficiency, indoor air quality, refrigeration and sustainability. Through research, standards writing, publishing, certification and continuing education, ASHRAE shapes tomorrow's built environment today. More information can be found at www.ashrae.org/news."
- As some of the above tasks were not yet fully completed in this project (TAB and Cx), we included the above definitions to best support and guide the reader of this Presentation Report during project next steps.

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Glossary of Terms, Abbreviations & Acronyms

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Glossary of Terms, Abbreviations & Acronyms - 1

A/E - Architect and Design Engineers
A1 Bldg - **********
ACCA - Air Conditioning Contractors of America
ACT - Air Changes Per Hours (a measure of building infiltration rate)
ADM4 Bldg - **********
AEE - Association of Energy Engineers
AHU - Air Handling Unit
AMU - Air Makeup Unit
ANSI - American National Standards Institute
ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASI - Architect's Supplemental Instructions
ASME - American Society of Mechanical Engineers
Avg - Average
BAS - Building Automation System (similar to EMS or EMCS)
BFP - Boiler Feedwater Pumps
BLCC - Building Life Cycle Cost Analysis Program by US DOE
BMS - Building Management Systems
BO - by others
BOD - Basis of Design
BOP - Balance of Plant
BTU - British Thermal Unit
Btu/h - British Thermal Unit per Hour
CA - Commissioning Authority
CC - Controls Contractor
CCHP - Combined Cooling Heat and Power
CD - Construction Documents
CEA - Comprehensive Energy Audit
CEM - Certified Energy Manager
CGC - Cleaner Greener Communities (A NYSERDA program that includes biomass installations)
CGC - Cleaner Greener Communities (for Biomass Heating System Program Requirements)
CHP - Combined Heat and Power
CHW - Chilled Water
CIPP - Commercial/Industrial Performance Program
CM - Construction Manager
CO - Carbon monoxide gas - harmful emissions
CS - Current Transformer
CT - Cooling Tower
CT - Current Transformer
CT Sensors - Current Transducer for measuring Amperage and/or On/Off Motor Status

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Glossary of Terms, Abbreviations & Acronyms - 2

Cx - Commissioning
Cx Plan - Commissioning Plan Document
Cx Report - Commissioning Report
Cx Report - Commissioning Report
D2 Bldg - **********
DA - Deaerator Tank in Steam Systems
DAA - Data Acquisition and Analysis
DAS - Data Acquisition System
DBT - Dry Bulb Temperature
DCV - Demand Controlled Ventilation
DD - Annual Heating Degree Days (typically base 65 °F)
DDC - Direct Digital Control
DEA - Detailed Energy Analysis
Deg C - Degrees Centigrade or Celsius
Deg C = (Deg F - 32) x 5/9
Deg F - Degrees Fahrenheit
Deg F = (1.8 x Deg C) + 32
DHW - Domestic hot water
DOAS - Desiccated Outdoor Air Systems
Doc - Document
DOE - United Stated (US) Department of Energy
DP - Differential Pressure
E/A - Engineering/Architectural
EA - Energy Audit or Energy Analysis
EA Credit - Energy and Atmosphere LEEEC Credit by USGBC
EB - Existing Building
EC - Electrical Contractor
ECIPP (Enhanced CIPP), and most recently EFP
ECM - Energy Conservation Measure
ECM Motor - Electronically Commutated Motor
Econo - Economizer
EEM - Energy Efficiency Measure
EES - Energy Engineering Services
EF - Exhaust Fan
Eff - Efficiency
EFLH - Equivalent Full Load Hours
EFP - Existing Facilities Program
EMCS - Energy Management and Control System
EMS - Energy Management System
ERU - Energy Recovery Unit

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Glossary of Terms, Abbreviations & Acronyms - 3

ERV - Energy Recovery Ventilator
ESCO - Energy Services Company
ESPC - Energy Savings Performance Contracting
EUH - Electric Unit Heater
EUIs - Energy Utilization Indices
FCU - Fan Coil Unit
FIMS - Facility Improvement Measures
FlexTech - NYSERDA's Flexible Technical Assistance Program
FMS - Facility Management System
FPT - Functional Performance Test
FT - Functional Performance Test
ft^2 - square feet
FTEs - Full Time Employees
Gal - Gallon
GBE - Green Buildings Engineer
GC - General Contractor (prime)
GD - Guidance Document
GPH - Gallons per Hour (units measuring oil flow into the boiler burner)
GPM - Gallons per Minute (units for measuring fluid flow)
GSA - U.S. General Services Administration.
GTHP - Geothermal Heat Pump
H&C - Heating and Cooling
HDD - Annual Heating Degree Days (typically base 65 °F)
HELE - High-Efficiency Low-Emissions
HOO - Home Heating Oil
HVAC - Heating, Ventilating and Air-Conditioning Systems
HW - Hot Water
HWRT - Hot Water Return Temperature
HWST - Hot Water Supply Temperature
HWT - Hot Water Temperature
HX - Heat Exchanger
IAQ - Indoor Air Quality
IB - Informational Bulletins
IC - Implementation Contractor - Hired by NYPA to support some NYS funded Projects
IDP - Integrated Design Process
IEQ - Indoor Environmental Quality
Info - Information
IP Units - Imperial or English units of measurements (inch-pound), widely used in the US
IP Units - Inch-Pound Units
IPMVP - International Performance Measurement and Verification Protocol

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Glossary of Terms, Abbreviations & Acronyms - 4

k - Thousand

kW - The unit boiler capacities are measured by in Europe

LAN - Local Area Network

lb - pound

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

Linkage Burner - Boiler burner set to fixed air-to-fuel ratio through mechanical shaft, also referred to as jackshaft control, likely calibrated once or twice a year. Serves many old / existing boilers. Can be set to hi/low fire with no in between modulation. Fixed relationship across firing range results in lower efficiencies than linkageless burners.

Linkageless Burner - Boiler burner programmed to use a linkageless modulating burners that varies air-to-fuel ratio cross the firing range and is equipped with VFD forced draft fans and O2 trim package. Represents an available control option in many modern boilers. Varying relationship across the firing range results in better efficiencies than linkage burners.

LP - Liquefied Propane

LWCO - low water cut off switch

M - Motorized (applies to an electrically actuated modulating valve)

M - Thousand

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

m^3/h - Meter^3 per Hour (units for measuring fluid flow)

m^3/hr (1) = 1,000 L/m^3 / (3.78541 Liters/Gallon x 60 minutes / hr) = 4.402869614 GPM

MBCx - Monitoring-Based Commissioning

MBH - Boiler rated output capability (1,000 Btu/h)

MC - Mechanical (HVAC and Plumbing) Contractor

MEP - Mechanical, Electrical and Plumbing

MER - Mechanical Equipment Room

Mlbs - 1,000 pounds of steam

MM - Million

MRHL - manual reset high limit switch

MV - Modulating Valve (can be 2-way or 3-way Valve)

N/A - not applicable

NC - New Construction

NCP - New Construction Program

NESCAUM - Northeast States for Coordinated Air Use Management.

New Additions in Sept 2019 when I was Finalizing the Cx Documents

New Items for the Cx Presentation

NG - Natural Gas

NY - New York

NYPA - New York Power Authority

NYS - New York State

NYS DEC - New York State Department of Environmental Conservation

NYSERDA - New York State Energy Research and Development Authority

O&M - Operating and Maintenance

OA - Outside or Outdoor Air

OAT - Outside Air Temperature

OH&P - Overhead and Profit

OPR - Owner's Project Requirements

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Glossary of Terms, Abbreviations & Acronyms - 5

OS - Operating System

OSHA - Occupational Safety & Health Administration

P - Pump

PA - Project Application

PB - Pellet Boiler

PC - Prefunctional Checklist

PDH - Professional Development Hours

PE - Professional Engineer

PECI - Portland Energy Conservation, Inc. - Developed The Model Commissioning Plan - Construction Phase Version 2.05 under the initial sponsorship of the U.S. Department of Energy and later sponsorships by the Oregon Office of Energy and PECI. As PECI later switched its focus, the Cx, PFC and FPT material was transferred, managed and updated by BCA - BCxA (Building Commissioning Association).

PFC - Prefunctional Checklist

PFHX - Plate and Frame Heat Exchanger

PG - Propylene glycol mix - antifreeze

PID - Piping and Instrumentation Diagram

PIR - Post Installation Report

PLC - Programmable Logic Controller

PM - Project Manager

PM 2.5 - Fine particulate matter emission - an air pollutant - refers to tiny particles or droplets in the air that are 2.5 microns or less in width.

POC - Point of Contact

PON - Program Opportunity Notice (a solicitation issued by NYSERDA)

PP - Per Person

PPM - Parts per million (A unit to measure Carbon monoxide (CO) Emissions)

PQ - Power Quality

PRVs - Pressure Reducing Valves or Pressure Regulating Valves

PSD - Proposed System Design

psia - pounds per square inch absolute pressure (applies to hot water, steam or refrigerant systems)

psig - pounds per square inch gauge pressure (applies to hot water, steam or refrigerant systems)

PT Ports - Pressure and Temperature Ports needed for TAB work

PTAC - Packaged Terminal Air-Conditioning Unit

PTE - Part-Time Employee

PV - Photovoltaic

PWD - Password

Q - Energy (can be input, output, loss, stored, created, space or building heat load, etc.)

QC - Quality Control

R&D - Research and Development

R&R - Range and Relational Checks (to verifications the quality of collected data)

R&R - Roles & Responsibilities

RA - Return Air

RAT - Return Air Temperature

RDD - Research and Development and Demonstration

RE - Renewable Energy Systems

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Glossary of Terms, Abbreviations & Acronyms - 6

REDC - Regional Economic Development Councils
REDGHG - The Regional Economic Development and Greenhouse Gas Reduction Program (PON 2571)
RFI - Requests for Information
RFP - Request for Proposal
RH - Relative Humidity
RH&C - Renewable heating and Cooling.
ROI - Return on Investment
RTDs - Resistance Temperature Detectors (basically temperature sensors)
RTU - Rooftop Unit
S3 Bldg - **********
SAAF - Site Assessment Application Form
SAR - Site Assessment Report
SAT - Supply Air Temperature
SC - Sheet Metal Contractor
SCADA - System Control and Data Acquisition
SF - Supply Fan
SI Units - International or Metric System Units of Measurements
SME - Subject Matter Expert
SOO - Sequence of Operations
SOPs - Standard Operating Procedures
SOPs - Written Standard Operating Procedures
SOS - State of the State Address by Governor Cuomo
SPC - Standard Performance Contracting
Spec - Specifications
SPt - Setpoint (can be for temperature or pressure)
Sqft - Square Feet
SS - Supply Setpoint Temperature
SSPC - Standing Standard Project Committee by ASHRAE
STL - Lower (bottom) Tank Setpoint Temperature (Boiler OFF T Setting)
STU - Upper (top) Tank Setpoint Temperature (Boiler ON T Setting)
Subs - Subcontractors to General
TAB - Testing, Adjusting, and Balancing
TAS - Technical Assistance Study
TC - Technical Consultant
TES - Thermal Energy Storage Tank (can also be a slab)
TFS - Technical Feasibility Study
T_r - Return Temperature (or Entering Temperature)
T_s - Supply Temperature (or Leaving Temperature)
UH - Unit Heater
UPS - Uninterrupted Power Supply (a battery backup)

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Glossary of Terms, Abbreviations & Acronyms - 7

USGBC - United States Green Buildings Council
UV - Unit Ventilator
VAV - Variable Air Volume
VFD - Variable Frequency Drive
VRF - Variable Refrigerant Flow
VRV - Variable Refrigerant Volume
VSD - Variable Speed Drive
WBT - Wet Bulb Temperature
WC - Water Closet
WC5 Bldg - **********

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Glossary of Terms, Abbreviations & Acronyms - 8

Not Sorted Alphabetically; It groups selected the Commissioning related Organization and Certifications together:

TBCxP - Total Building Cx Process as defined in ASHRAE Guideline 0 & NIBS

[1]

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

BCxP - Building Commissioning Professional Certification (Certification issued by ASHRAE)

CPMP - Commissioning Process Management Professional (Certification issued by ASHRAE)

[2]

AABC - Associated Air Balance Council

ACG - AABC Commissioning Group

CxA - Certified Commissioning Authority (Certification issues by ACG)

CxTs - Certified Commissioning Technicians (Certification issues by AABC or ACG)

EMP - Energy Management Professional (Certification issues by ACG)

[3]

AEE - Association of Energy Engineers

CBCP - Certified Building Commissioning Professional (Certification issued by AEE)

[4]

BCxA - Building Commissioning Association

BCA - Building Commissioning Association

BCCB - Building Commissioning Certification Board

CCP - Certified Commissioning Professional (Certification issued by BCCB and BCxA)

ACP - Associate Commissioning Professional (Certification issued by BCCB and BCxA)

BEMP - Building Energy Modeling Professional Certification (Certification issues by ASHRAE & is a prerequisite for the CCP certification)

[5]

University of Wisconsin-Madison

Descriptions of Certifications for Educational Achievement:

QCxP - Accredited Qualified Commissioning Process Provider

BECxP - Accredited Building Enclosure Commissioning Process Provider

CxA+BE - Accredited Commissioning Authority + Building Enclosure

Descriptions of Certifications for Educational Achievement Plus Project Experience:

CxAP - Commissioning Process Authority Professional

CxM - Commissioning Process Manager

CxTS - Commissioning Process Technical Service Provider

GCxP - Green Commissioning Process Provider

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Glossary of Terms, Abbreviations & Acronyms - 9

[6]

NEBB - National Environmental Balance Bureau

BSC CP - Building System Commissioning Certified Professional

BSC CxCT - Building System Commissioning Certified Technician

CxPP - Commissioning Process Professional Certified Professional

RCx-EB CP - Retro-Commissioning of Existing Buildings Certified Professional

[7]

NIBS - National Institute of Building Sciences (Defines the Total Building Cx Process).

NCBC - National Conference on Building Commissioning.

[8]

SMACNA - Sheet Metal & Air Conditioning Contractors' National Association

[9] Misc Other Abbreviations

BPA - Bonneville Power Administration.

BPI - Building Performance Institute.

BPA - Building Performance Association.

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Q/A

Thank you all for Attendance and Participation

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End

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