TECHNICAL GUIDANCE DOCUMENT

Renewable Heat NY
Large Commercial Pellet Boilers

This document provides detail regarding the participation options, requirements and incentives available for high-efficiency, low emissions pellet-fired boiler heating systems through the Renewable Heat NY Program (RHNY). Incentives are offered on a performance basis through the Existing Facilities Program (EFP), with initial incentive payments upon installation and subsequent payments after completion of an M&V period.

1. Overview

The Renewable Heat NY program will offer incentives for pellet-fired boiler systems that meet certain eligibility requirements. A NYSERDA Technical Consultant (TC) will work directly with the applicant to confirm the boiler system size, design and installation meets the program requirements for the RHNY program. The incentive will be paid based on 40% of the documented, allowable installation costs, up to a maximum of $200,000 per project. When two or more smaller or tandem boilers are installed in place of a single boiler, the incentive is 45% of allowable installation costs with a maximum of $270,000 per project. RHNY will provide up to an additional $40K for the installation of condensing or electrostatic precipitator emission control technologies on eligible boilers at K-12 schools, healthcare facilities, and other buildings with sensitive populations.

Eligibility Requirements

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

Measurement and Verification (M&V) for the first 12 months of operation (or for one complete heating season) will be required. M&V performance data may be collected using the applicant's energy management and control systems (EMCS) and/or by temporary data loggers installed by the TC. NYSERDA encourages the use of in-house integrated controls for monitoring and data collection since this gives the facility staff the ability to track system performance, ensuring sustained savings and reliable operation over the system life.

If measured performance for the first 12 months is not deemed acceptable by NYSERDA, an additional 12-months of measured performance data will be required to demonstrate that any identified performance deficiencies have been addressed. 80% of the total incentive will be paid once the system is installed, commissioned and is operating as intended. The remaining 20% will be paid upon satisfactory completion of the M&V period illustrating satisfactory performance and efficient operation.

2. Technical Review Process

Engineering Analysis

The applicant is encouraged to submit an Engineering Analysis (EA) – also known as an energy study – to NYSERDA for review. If the applicant does not provide an EA, the assigned TC will work with the applicant to compile an EA to submit to NYSERDA. Once NYSERDA has received the EA, the TC will review the baseline loads, project savings fuel displacement estimates, total estimated installed system costs, simple payback, and other economic indicators / figures of merit. The EA must include fuel delivery logs or tank level readings for at least 1 year of normal operation (3 years preferred) or other information that was used in the energy calculations. The TC will also review the proposed system design to ensure it is consistent with the program requirements. The TC and NYSERDA may make a pre- installation visit to site in the course of reviewing and/or developing the EA. The EA must provide boiler specifications that demonstrate the proposed pellet-fired boiler system meets the efficiency and emissions requirements:

- **High-Efficiency Wood Pellet Boiler Requirements**. The boiler must be fully-automatic and have sensors and controls to optimize combustion performance (i.e., lambda control). The boiler thermal efficiency must be at least 85% based on higher heating value (HHV) at full load conditions.
- **Pellet Boiler Emission Requirements.** Emissions for fine particles (PM) must meet the requirements of no more than 0.080 lb per million Btu based on fuel input. More stringent requirements of 0.030 lb per million Btu are required for installations at facilities with sensitive populations including schools, hospitals, nursing homes and other facilities with similar populations. Carbon Monoxide must be under 270 ppm at 7% Oxygen. The boiler stack height must be designed in accordance with good engineering practice to ensure proper dispersal of emissions, prevent entrainment by air intakes, and minimize the risk of exposure to building occupants.

Qualified pellet boiler systems are discussed in Section 3. The details and rationale for these pellet boiler system requirements are given in Section 4.

The EA and design documents must also demonstrate that the proposed system will meet the following design requirements:

- **Proper Boiler Sizing**. The EA must include data-based calculations or other acceptable engineering-based load calculations to determine the peak heating load for the facility (i.e., not the current installed boiler capacity). The pellet boiler must be sized to have a maximum thermal output that is equal to or less than 60% of the facility peak heating load to minimize boiler cycling. If the total installed capacity of the boiler(s) exceeds 60% of the peak heating load, the EA must explain and demonstrate that other approaches or measure are being taken to minimize cycling to maintain acceptable efficiency, emissions, and maintenance costs. The use of multiple pellet boilers in tandem is encouraged by a higher incentive.

- **Thermal Buffering / Storage**. The pellet boiler system must include a thermal storage tank to optimize system response time and minimize boiler short-cycling and overheating upon unexpected shutdown. Systems must include 2.0 gallons of storage for each 1,000 Btu/h (MBtu/h) of boiler thermal output capacity (based on the output capacity of one boiler in a tandem system). Tanks must be selected and designed to achieve good thermal stratification.
- **System and Controls Integration**. Proper integration of the pellet-fired boiler(s) into the existing overall boiler plant system is required. The pellet boiler(s) must operate at full load most the time in order to achieve the expected efficiency, fuel displacement, and emissions performance. The EA should list all the boilers in the proposed system and explain how the individual boilers will all be controlled (i.e., boiler staging, varying firing rates, hot water set points, tank stratification sensors, etc.). The EA must also explain the control strategy to lock out and re- initiate pellet boiler operation on a diurnal and seasonal basis.
- **Outside Pellet Storage.** Pellets must be stored outside in a silo or other weather-proof storage container to minimize exposure to Carbon Monoxide (CO) produced during storage. The design should consider long-term maintenance and repair concerns associated with the storage and conveyance equipment. The design and operating practices should address the necessary OSHA concerns with confined space access.

The details and rationale for these requirements are given in Section 4.

M&V Plan

As part of the EA review process, the TC will work with the applicant to develop a Measurement and Verification (M&V) Plan describing what measurements will be required to verify performance over the entire heating season. The TC will work directly with the applicant to develop a mutually agreeable M&V approach and instrumentation details that will be documented in the M&V Plan. The M&V Plan may specify the some or all of following measurements and/or data collection requirements depending on the system arrangement:

- Fuel and pellet delivery logs (dates and amounts), periodic tank level measurements or metering to track use over the M&V period (similar to baseline data included in the EA)
- Runtime and cycle rate/count data for all the boilers collected at regular (at hourly or shorter) intervals over the monitoring period
- Supply and return temperatures (at hourly intervals) for the individual boilers and overall system as appropriate
- Hot water flow readings at hourly intervals over the monitoring period (to calculate thermal output and efficiency)

- Wood pellet auger runtime or speed denoting hourly fuel supply to the boiler

NYSERDA strongly encourages the applicant to install an M&V-enabled control system to collect this hourly data. This M&V enabled control system will allow the facility staff to track system performance to ensure good performance over the long term. Alternatively, the TC can supply and install temporary, battery-powered data loggers for the M&V period. In this case, the applicant must supply and install necessary sensors to support M&V (e.g., hot water flow meter) and support the TC's efforts to install the temporary M&V equipment at the site. The TC may return to the site to collect the data loggers at the end of the M&V period, or ask the site to mail the data loggers back as appropriate.

Project Installation Report (PIR)

Once the installation is complete, the system is commissioned, and operating as intended, the TC will visit the site to prepare a Project Installation Report (PIR). The TC will confirm the pellet boiler and relevant support systems have been installed consistent with the design intent described in the NYSERDA-approved EA. Any adjustments to the savings or fuel displacement estimates will be made at this time. The applicant must provide written evidence that the system has been properly commissioned and operational according to the design intent.

The details of the M&V process documented in the M&V Plan will also be confirmed and finalized by the TC. If the applicant's control system is being used, regular data transfer procedures will be established. If the TC is installing data loggers, that process will be completed.

The applicant must also provide acceptable documentation verifying the allowable project installation costs in order to establish the total incentive for the project. *Examples* of allowable and non-allowable project costs are listed in the table below. NYSERDA reserves the right to exclude project costs it deems to be non-allowable for final determination of the total incentive.

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

The TC will prepare the PIR and make recommendation to NYSERDA for incentive payment to the applicant. Normally NYSERDA will pay 80% of the total incentive upon acceptance of the PIR.

M&V Data Collection and Reporting

After the first 12 months of data collection (or at the completion of one complete heating season) the TC will assemble all the data required in the M&V Plan and prepare an M&V report. The performance of the system in terms of energy savings and fuel displacement will be summarized. The measured data will also be reviewed to confirm that system operation and control are consistent with the original design intent and acceptable performance practices. If performance is acceptable, the TC will recommend to NYSERDA that the remaining 20% of the total incentive be paid to the applicant.

If a serious operating problem is identified by M&V results, the TC may recommend that the problem be addressed and that M&V continue for an additional 12 months.The TC will support with the applicant's effort to rectify the issue. In this case, the incentive payment may be postponed or partially paid at NYSERDA's discretion.

If the applicant's M&V-enabled control system (and/or facility staff) allows for more frequent data collection and data retrieval, then the TC may complete an intermediate M&V report after the first few months of the M&V period. This accelerated review can help to ensure the applicant receives the full incentive in the shortest possible time.

NYSERDA reserves the right to request fuel delivery logs for an additional 24 months beyond the M&V period (and after full incentive payout).

3. Qualified Systems, Designers and Installers

All projects must use pellet boiler equipment and systems that meet the program requirements. NYSERDA will maintain a list of qualified commercial equipment on the RHNY website. Similarly, all projects must engage qualified designers and installers. The NYSERDA RHNY website will maintain a list of designers and installers who are qualified service providers.

4. Detailed Description of Pellet Boiler Requirements

This section provides additional details as well as the rationale for program requirements given above (adapted from the Cleaner, Greener Communities Program: Commercial Biomass Heating System Program Requirements, May 2014)

Fuel Type

The eligible fuel type is a premium wood pellet. The premium wood pellets must be 100% wood composition with no construction or demolition debris such as pressure treated or painted wood (which may contain heavy metals such as copper, chromium, arsenic, lead and cadmium) or plastic binders or fillers. Pellets must have a calorific value of no less than 8,000 Btu/lb based on higher heating value, low ash content (<1%), low moisture content (<8%), chlorides less than 300 ppm and no other additives (0%). Other commercially-available fuel types in NYS (for example green wood chips and grass pellets) cannot facilitate high-efficiency and low emissions performance even in advanced technology boilers at this time. Applicants agree to use only premium pellets in their pellet boiler for the life of the project. Applicants are advised to obtain a bulk fuel price quote from two pellet suppliers where possible.

High-Efficiency Wood Pellet Boiler

Qualified pellet boilers will be listed on NYSERDA RHNY web site. Boilers must be fully automatic, low mass (low volume) and have sensors and controls to optimize combustion performance. This is most easily achieved using a staged combustion design with lambda control (i.e., oxygen trim controls). The wood pellet boiler must have a minimum thermal efficiency of 85% at rated output using the higher heating value (HHV) of the pellet fuel if tested using an input/output method. Alternatively a simple full load, steady-state combustion efficiency measurement by the stack loss method (Canadian Standards Association B415) may be used, but in this case, the minimum efficiency requirement is 88% HHV. Where a combustion efficiency measurement is used, the return water temperature must be greater than 130°F.

Low Emissions from Combustion

Fine Particles (PM): The wood pellet boiler heating system for commercial installations must have a PM emissions rate of no more than 0.080 lb per MMBtu of fuel input on a high heating value basis. This emission rate is comparable to that of No. 6 fuel oil. All institutional applications at schools, health care facilities, nursing homes, or other locations with similar sensitive populations, must have a PM emissions rate of no more than 0.030 lb/MMBtu. Applicants are strongly encouraged to include advanced emissions control technology to achieve emissions rates lower than these basic requirements. Emissions control technologies such as condensing economizers can also improve energy efficiency of the heating system. Applicants are required to submit emissions performance verification results of the same boiler model and pellet fuel combination. Testing for PM must have been performed by an independent third-party using the U.S. Environmental Protection Agency (EPA) Conditional Test Method 39, EPA Federally Referenced Methods 5 and 202, or EPA Other Test Method 15.Alternatively, European Norm 303-5 test results may also be considered, but must include dust and organic gases.

Carbon Monoxide (CO): The wood pellet boiler must have a flue gas CO concentration at rated output of no more than 270 ppm at 7% oxygen at high load. Emissions performance must be verified by an independent third-party and submitted to NYSERDA for review and approval. For health and safety, a CO detection system and alarm must be included in the boiler room design. For commercial heating projects, the CO monitoring system must have the ability to sound an audible alarm, and trigger automatic pellet boiler shutdown if necessary. Alternative measures meeting this level of safety will also be considered. For pellet boiler projects at schools, the CO monitoring system and or boiler must have the ability to provide notification to facilities staff via phone or internet of a boiler shutdown.

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

Health Considerations: The New York State Department of Health recently released a Prevention Agenda to promote a healthy and safe environment (www.health.ny.gov/prevention/prevention_agenda/2013-2017/). Some communities in NYS experience very high concentrations of wood smoke comprised of fine particulate matter and CO. One goal of the Prevention Agenda is to "reduce exposure to outdoor air pollutants with a particular focus on burdened communities."

Consistent with this goal, pellet boilers must be designed to minimize the potential for adverse health and safety effects. If the installation will be near sensitive populations (e.g. schools, hospitals, nursing facilities) an evaluation of the potential health and environmental effects must be performed. This evaluation should include a comparison of potential pellet boiler emissions and thermal efficiencies to displaced fuels systems (e.g., oil, propane gas, etc.), discussion of proposed fuel delivery mechanisms and storage, and consideration of potential wind patterns and terrain as it may influence exposure from emissions – which will be informed by the dispersion techniques and engineering design considerations described above in c) Stack Height and may require dispersion modeling.

All projects proposed for schools must meet NYS Education Department requirements. Applicants should talk to NYSED Facilities Planning early in the planning phase of a pellet heating project.

Proper Boiler Sizing

The high-efficiency wood pellet boiler must be properly sized for the application with particular attention to avoid oversizing the boiler. Boilers must be sized and systems planned to optimize performance throughout the heating season using plant controls and thermal storage. Use of a cleaner fuel heat source during heating season shoulders (late October or March/April) and for supplemental needs is strongly encouraged (e.g., like a high efficiency fully modulating condensing propane boiler). These cleaner heat sources may include, for example, properly and carefully sized propane- or oil-fired boilers and solar thermal sources. A bin-hour analysis of heating needs based on an energy audit, previous heating needs, and historical local temperatures during the heating season should be performed. The annual heat load profile, diurnal heat load profile on demand day, and diurnal heat load profile on a shoulder day should also be determined. Commercial pellet boilers should be sized to ≤60% of the design building peak heating load as it will capture the majority of the heating season and promote higher performance. The use of two smaller boilers to achieve this is acceptable and provides improved effective turn-down ratio. Higher loads exceeding the maximum pellet boiler output capacity may be met by utilizing an existing propane- or oil-fired boiler, a new boiler, staging of wood pellet boilers, or some other strategy involving careful energy management and thermal storage. Low loads, common during shoulder months, can be met by a carefully sized auxiliary boiler with attractive turn down capabilities or other energy management strategy. One may determine the system size more easily and more accurately from a well-established measured baseline in the energy study. Special attention should be paid in the heating system design to cycling of the existing boiler that may result during standby mode after the pellet boiler is installed and operational.

Thermal Storage

Pellet heating systems must include thermal storage to minimize boiler cycling and to assist in energy management strategies. The minimum size thermal storage should be based on the boiler manufacturer's recommendation for the application and size of the boiler, but it must not be less than 2.0 gallons per 1,000 Btu/h of the pellet boiler rated output capacity. For example, a commercial 1.0 MMBtu/h boiler would require a minimum storage of 2,000 gallons. For projects consisting of two pellet boilers, the thermal storage volume may be sized to the volume corresponding to the smaller pellet boiler if consistent with meeting demand response time.

Outside Pellet Storage

Pellets can produce high levels of dust and off-gas CO in storage presenting an explosion hazard and health and safety concerns. Carbon monoxide is a colorless, odorless gas that has health effects below the levels at which common CO alarms are triggered. There have been cases of fatalities aboard ships carrying pellets and in commercial bulk storage facilities in Europe. Research is underway in Europe, Canada and NYS to better understand the chemical reaction that produces the CO. According to the US EPA:

CO can cause harmful health effects by reducing oxygen delivery to the body's organs, such as the heart and brain, and tissues. At extremely high levels, CO can cause death. Exposure to CO can reduce the oxygen-carrying capacity of the blood. People with several types of heart disease already have a reduced capacity for pumping oxygenated blood to the heart, which can cause them to experience myocardial ischemia (reduced oxygen to the heart), often accompanied by chest pain (angina), when exercising or under increased stress. For these people, short-term CO exposure further affects their body's already compromised ability to respond to the increased oxygen demands of exercise or exertion.

Due to concerns regarding explosive dust and CO exposure and the absence of a documented effective ventilation strategy for pellet storage, all pellet storage must be outside of the building.

Confined spaces are areas that are: 1) large enough for a person to enter to perform work, 2) have limited means of ingress and egress, and 3) are not intended for human occupancy. Pellet storage silos meet these criteria and because of the CO off-gassing, require an Occupational Safety and Health and Administration (OSHA) permit. Project costs for bulk pellet storage silos and pellet conveyance systems are allowable. Applicants should identify fire and building code and health and safety features including all applicable training requirements for personnel. Signs communicating potential CO hazards associated with bulk pellet storage must also be posted.

Energy Management System and Controls

The high-efficiency pellet boiler heating system must be integrated with the existing building energy management system and communicate effectively in order to optimize boiler operation (pellet and existing boilers) to meet seasonal and diurnal heating needs of the particular building's heat load. The system design should consider a strategy that optimizes the use of both the base-loaded pellet boiler and thermal storage tank and the temperature requirements of the heat distribution system.

For example, consider a 25,000-square-foot school with a nighttime setback. Figure 1 shows the heat load (Btu/h) for two days in February. Notice the building has a large demand in the early morning (425,000 Btu/h) to make up heat from the nighttime setback. By approximately 11 a.m., the building load reduces to zero due in part to solar gain.

By using a large enough thermal storage tank for quick response to the demand and a properly sized boiler, the call for heat may be met with a smaller boiler without the need for additional heat input from the existing boilers. The hot water storage can be recharged during periods when there is little call for heat in the building, which, in this case, is several hours each day. Steps should be taken to minimize cycling of any standby boilers.

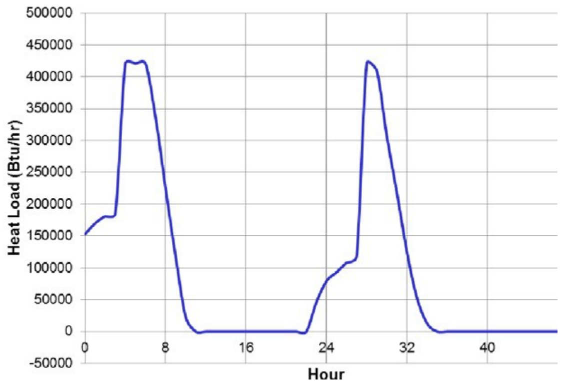

Figure 1. Diurnal heat load profile for a 25,000 square foot school building. (Courtesy of Brookhaven National Laboratory)

5. Additional Information

Pellet Production in New York State

There are nine pellet mills in NYS with an annual capacity of 500,000 tons per year (Figure 2). Several manufacturers produce premium wood pellets that are low in ash and moisture content, and contain no construction debris or non-wood additives. Some mills have pellets that also meet criteria for sustainability by the Forest Stewardship Council or Sustainable Forestry Initiative certification.

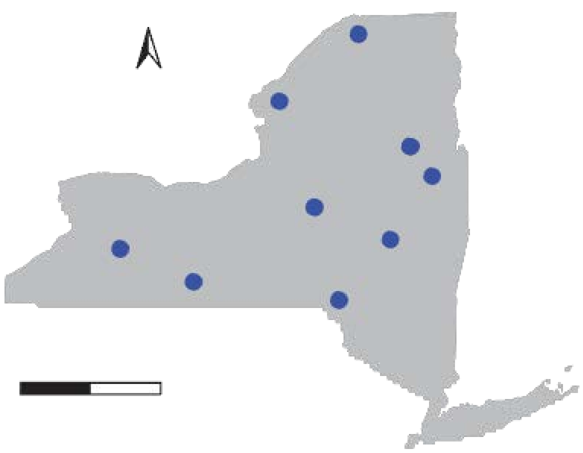

Figure 2. Wood pellet production in NYS

High-Efficiency Pellet Boiler Demonstrations

NYSERDA works with manufacturers across NYS to develop advanced, high-efficiency and low emissions heating technologies, regardless of fuel type. As interest in biomass heating has increased, NYSERDA has undertaken efforts to support a clean biomass industry in NYS, including funding demonstrations to measure and verify system performance. Research to date has shown that wood pellets combusted in an advanced boiler yields the highest and most consistent performance among the biomass fuels.

Advanced Climate Technologies Bioenergy LLC, of Schenectady, NY, produced the first Made-in-NY commercial high-efficiency pellet boiler. High performance is achieved via staged combustion that includes a flue gas oxygen (lambda) sensor to promote optimum combustion conditions. A 1.7 million Btu per hour boiler was demonstrated at the Wild Center Museum in Tupper Lake, New York. The performance of the boiler was measured by Clarkson University's Center for Air Resources Engineering and Science, and was able to achieve high-efficiency (>85%) at full load, similar to the efficiency level of an oil-fired heating system. A solid fuel system's performance decreases more rapidly under a reduced load than propane-, natural gas-, or oil-fired heating systems. Thermal storage can help mitigate these losses. The Wild Center did not have thermal storage, and annual efficiency was measured to be about 65%. Despite this, the cost difference between wood pellets and propane yielded an annual fuel savings of $31,000 or about 45%. Clarkson University has recommended adding a thermal storage tank with an anticipated additional annual savings of $5,000.

A second manufacturer, EvoWorld of Troy, NY, is manufacturing high-efficiency wood pellet boilers for both commercial and residential applications.

School Children – a Unique Population

Other states have focused their biomass heating programs on schools because they are large energy users and face ever increasing budget constraints. However, children comprise a population uniquely susceptible to air pollution.

According to the 2009 NYS Asthma Surveillance Report, 11% of children (ages 0–17) have asthma, which exposure to fine particulate matter (PM2.5) is known to exacerbate. In NYS, the commitment to reducing exposures to PM2.5 has included retrofitting more than 2,800 school buses with diesel emission control devices. In selecting school heating technologies, it is essential to avoid installing systems that emit more PM2.5 and other pollutants (CO, NOx) than existing heating systems. Due to this concern, the NYS High Performance Schools (NY-CHPS) Guideline States:

> *While the use of renewable resources is important in New York State, schools must also evaluate potential environmental effects from the use of renewable resources. Combustion of biomass for example could cause circumstances where the products of combustion are not properly dispersed (as a result of equipment technology or localized climatic conditions), thereby creating a potential health impact for students, staff and community members.*

In addition, the New York State Education Department Manual of Planning and Standards (Part V, S501(b)) states:

> *A school building must provide for the health, comfort, and safety of children, teachers, and other occupants. No mechanical equipment or construction materials*

shall be used, nor any type of construction permitted, which will endanger the health, safety, or comfort of all occupants in the school building.

Fine Particulate Matter (PM2.5) Emissions Performance

US EPA and other agencies are concerned about fine particle pollution because as stated on EPA's website:

Health studies have shown a significant association between exposure to fine particles and premature mortality. Other important effects include aggravation of respiratory and cardiovascular disease, decreased lung function, asthma attacks, heart attacks, and cardiac arrhythmia. Individuals particularly sensitive to fine particle exposure include older adults, people with heart and lung disease, and children.

PM2.5 is a pollutant of concern from all combustion systems. NYSERDA-funded research has shown that the highest emissions are from a green wood chip–stoker boiler heating system at 0.28 lb MMBtu. The high-efficiency staged combustion boiler with a premium wood pellet fuel, which has much lower moisture content, has approximately 75% lower emissions. This is about the same as PM2.5 emissions from a No. 6 oil-fired boiler and more than seven times higher than PM2.5 emissions from a No. 2 oil- fired boiler, and 1,000 times higher than PM2.5 emissions from an oil-fired boiler burning ultra-low sulfur heating oil. As of July 2012, all No. 2 heating oil in NYS must be ultra-low sulfur, which is commonly used in schools.

To reduce fine particle emissions from a high-efficiency pellet boiler, Clarkson University will install and evaluate a condensing economizer on a high-efficiency pellet boiler. This emission control technology has the advantage of increasing energy efficiency while removing PM2.5, and it is anticipated that the resulting emissions will be 100 times higher than those from an oil-fired boiler burning ultra-low sulfur heating oil.