

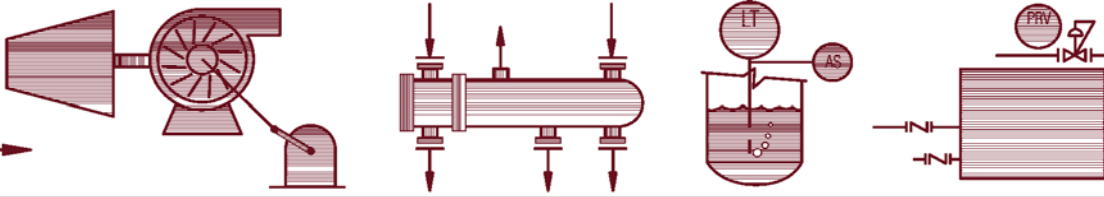
# ENERGY SOURCE

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## ESI

The Steam and Power *SPECIAL FORCES*®

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## CASE STUDY

# St. Paul Biomass Cogeneration Power Plant

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**A** combined heat and power (CHP) plant located in St. Paul, MN began commercial operations in April of 2003. To develop this facility, Cinergy Solutions, Inc. and District Energy St. Paul (DESP) (through an affiliate Market Street Energy Company) entered into an agreement with Northern States Power (NSP), a subsidiary of Xcel Energy, to provide 25 megawatts (MW) of electricity produced from St. Paul area waste biomass. The new CHP plant is located adjacent to District Energy St. Paul's downtown thermal plant. The project sells heat under a 20-year contract to District Energy St. Paul.

This facility was built by Cinergy Solutions, an affiliate of Cinergy Corp., and designed and engineered by ESI Inc. of Tennessee. The project was completed and started to produce steam and electricity within 19 months from the release for engineering.

This CHP plant is the largest wood-fired combined heat and power plant in the United States serving a district energy system. The facility includes a field-erected wood-fired boiler designed to provide 1250 psig/950°F superheated steam to a nominal 37 MW steam turbine generator. A portion of the 310,000 pph of steam is extracted at 20 psig and utilized to provide hot water to District Energy St. Paul.

This electrical generation technology is among the most energy-efficient solutions. The combined heat and power process captures more than 50 percent of the waste heat generated by traditional generation systems and converts it to steam. Therefore, this process can operate at more than two times the efficiency of conventional electricity-only power plants, resulting in twice the useful end-energy for the same raw energy input. The project's electric power is used in the Minneapolis/St. Paul area thus avoiding the transmission losses associated with remotely generated electricity.

The CHP plant has been a positive addition to the City of St. Paul. It has brought several environmental advantages to the community. However, the design, construction, and operation of a wood-fired power facility in the downtown of a major city has many challenges.

### ENERGY SOURCE

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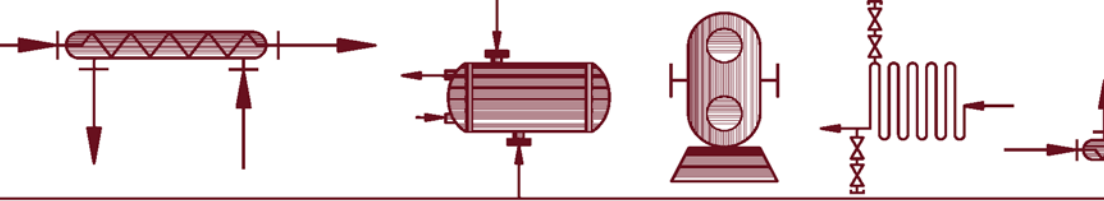
If you have any suggestions or comments about the newsletter feel free to call us at 770-427-6200 or e-mail us at [energysource@esitenn.com](mailto:energysource@esitenn.com).

**Deanna White**  
Managing Editor

### The Site

Designing, building, and operating a wood-fired steam and power generation facility in an urban area is a challenge in and of itself, and this facility proved to be no exception. Many of the issues are a direct result of the facility's location. Probably the chief and most difficult to overcome is the site itself. The heating plant is nestled on a 2-acre site in the heart of downtown St. Paul. The space available for construction of the new facility consisted of a space approximately 100' wide by 400' long. In fact, the plant's next door neighbors are the Minnesota Science

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## CASE STUDY... *Continued from Page 1*

Museum, Central Library, the Ramsey County Building, and several large hotels. The plant is in a floodplain since it is bounded by the Mississippi River on the south. A typical wood-fired facility of this size would be installed on at least 3 acres. Because of the lack of space, the unit was designed in a vertical orientation with the precipitator mounted on the roof of the turbine generator building and the cooling towers on the roof of the main boiler.

Because of the location downtown, the height and the mass of the power plant and its external appearance relative to the long-term development plan for the downtown area became the central issues in the plant's permitting by the City of St. Paul. Numerous meetings with the St. Paul Development Corp., environmental groups, and residential committees resulted in a significant reduction in the physical size of the plant. In order to comply with the architectural requirements, the plant exterior is mostly a copper siding with a combination of masonry, glass, and aluminum siding.

Significant efforts were devoted to sound mitigation, and specific engineering features were installed in order to comply with the applicable regulations and with the requirements of the power plant neighbors. Extensive sound level monitoring was conducted prior to the start, during and after the completion of the construction.

The flow of trucks into and out of the site was another major obstacle. A facility this size requires approximately 70 trucks a day to supply wood at the maximum burn rate. In addition, the city ordinance will only allow truck traffic during the daylight hours. This means that trucks must discharge wood every 15 minutes to keep the facility online. To compensate for this, the facility was designed with redundant live bottom receiving hoppers that allow two trucks to discharge at any given time.

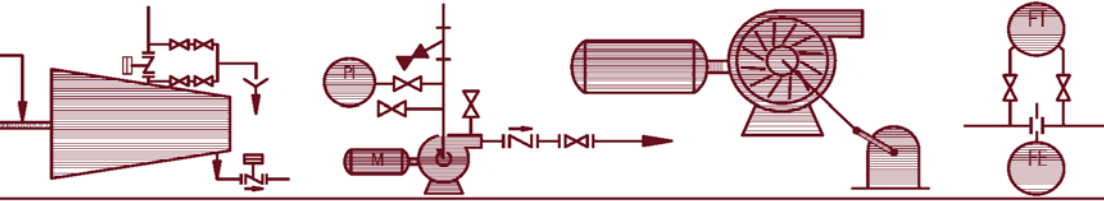
Site space made construction tremendously difficult. There was virtually no laydown area on-site. Therefore, a separate marshalling yard had to be set-up and all deliveries had to be coordinated daily to insure equipment was delivered in the proper sequence. Since there was no space available for a mobile construction crane, the unit was erected using a large tower crane which was supported by concrete caissons and tied into the building steel.

### **The Cycle**

The plant is sized to produce approximately 50% of the District Heating plant's maximum heat load. Because of this, the facility cycle was designed around District Energy's hot water distribution system. The 310,000 pph Foster Wheeler designed stoker-fired boiler produces steam at 1250 psig and 950°F. All of the steam, with the exception of a small load used for process heating, is directed to the throttle of a General Electric axial flow turbine. The facility is designed to function in two different modes. In the winter months, the system sacrifices electrical power generation to produce thermal energy for the heating plant. In the summer months, when the heating load is minimal, the system is designed to maximize power production. The turbine is equipped with a single controlled extraction. The extraction is sized to deliver up to 250,000 pph of steam at 20 psig to two steam/water heat exchangers providing hot water used for heating the City of St. Paul buildings. The balance of the steam is directed to an axial flow condenser. When the heating load is low during the summer months, steam bypasses the first extraction and is directed to the condenser. Even in the winter months the turbine can still produce 29 MW of electricity.

The Foster Wheeler boiler is an open pass unit complete with an economizer and tubular air heater. The economizer is designed to raise the boiler feedwater temperature from 250°F to 425°F while the air heater heats the combustion air to approximately 550°F. The boiler is equipped with a Detroit Stoker HydroGrate vibrating stoker which is fed by five Detroit Stoker windswept spouts. This arrangement does a very good job of combusting the wood and automatically de-ashes the grate on a timed cycle.

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**CASE STUDY...** *Continued from Page 2*

The keys to properly combust biomass are to pay attention to the three T's of combustion: Time, Temperature, and Turbulence. The time part of the equation is taken care of by a generously sized furnace. The furnace was specified with a minimum of 4.0 seconds of residence time from the grate to the primary superheater. This gives the wood adequate time to burn out prior to leaving the combustion zone. Temperature necessary for combustion is provided from the heated combustion air from the air heater. Turbulence is provided from an overfire air system which injects high pressure air at various levels above the grate. This system insures that the hydrocarbons are fully combusted prior to exiting the furnace. The boiler is also equipped with natural gas-fired burners capable of providing 450 mmbtu/hr in the event of a wood system outage.

**The Wood Handling System**

Due to the limited site space, a creative approach to the fuel handling system was necessary. For example, the system does not include any fuel sizing equipment. There was simply no room for it. Therefore, all wood is processed off-site and trucked in sized to less than 4". In addition, belt type bucket elevators are utilized to gain vertical height since there is not enough distance to utilize a belt conveyor with the proper angles. To avoid many common pitfalls associated with conveying wood, a conservative approach was taken in the design. Conveyor angles were kept as shallow as possible with none exceeding 20° from the horizontal. Slow conveyor



*President George W. Bush toured District Energy St. Paul and cited the biomass project as a national model for innovative energy production during his visit to St. Paul on May 17, 2001.*



*The heating plant is nestled on a 2-acre site in the heart of downtown St. Paul.*

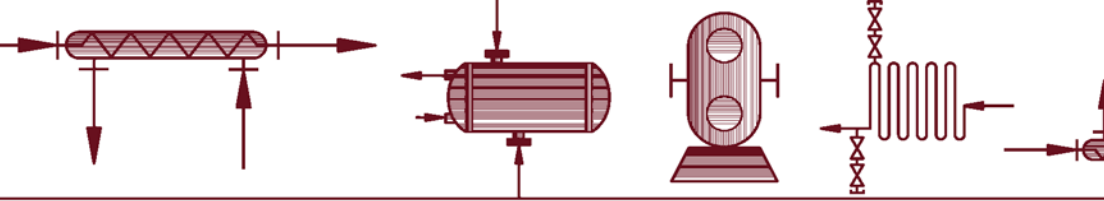


*Due to site space, a large tower crane which was supported by concrete caissons and tied into the building steel was used to erect the unit.*



*70 trucks/day are required to supply wood at the maximum burn rate.*

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**CASE STUDY...** *Continued from Page 3*

speeds, less than 300 feet per minute, are selected to insure material remains on the belt and dusting is minimized. In addition, all chutes and transitions were designed with negative angles to avoid pluggage.

The wood is discharged by self-unloading trucks onto two live bottom reciprocating hoppers approximately 24' by 40' each. The reciprocating hoppers discharge onto a short belt and then to a bucket elevator. A lump breaker is used to break-up any frozen material from the hoppers prior to the belt. Fuel is then conveyed using belt conveyors to two concrete storage silos capable of storing 16 hours of fuel. The fuel unloading system to the silos is designed to convey 200 tph of material or over 3 times the burn rate. The silos are each equipped with live bottom screw reclaimers which discharge to another bucket elevator. From there the material is discharged onto a conveyor belt which feeds the boiler. Inside the boiler house, fuel is conveyed via a drag chain to five separate twin screw metering bins. Each of the five metering bins is designed to convey 25% of the total boiler wood requirements so that if one is down for maintenance the other four can carry the plant load. The speed of each of the metering bins is controlled to match the burn rate via variable frequency drives. The feed system downstream of the silos is rated to deliver 85 tph, or at least 1.5 times the burn rate.

**Environmental**

The new facility has several environmental advantages. Over 280,000 tons per year of wood waste is used to power the facility. A substantial portion of the wood waste comes from downed trees, trimmings and branches from the Minneapolis/St. Paul area. Making use of this wood waste solves what has been an ongoing disposal problem for this waste material.

Besides renewable energy, one of the most positive benefits this biomass-fired facility brought the community is lower emissions than the existing coal-fired boilers. The wood-burning facility has significantly reduced air pollution by displacing coal, reducing sulfur dioxide emissions (SO<sub>2</sub>) by 80 percent, roughly 600 tons per year, and particulates by 50 percent and reducing fossil fuel derived carbon dioxide emissions (CO<sub>2</sub>), the chief greenhouse gas that contributes to global warming, by roughly 283,000 tons per year. Table I is a summary of the permit limitations for the facility.

Table I. Summary of the Permit Limitations

Pollutant	Emissions Limit (lb/mmBtu)
PM	0.03
Opacity	10%
NO <sub>x</sub>	0.15
CO	0.30

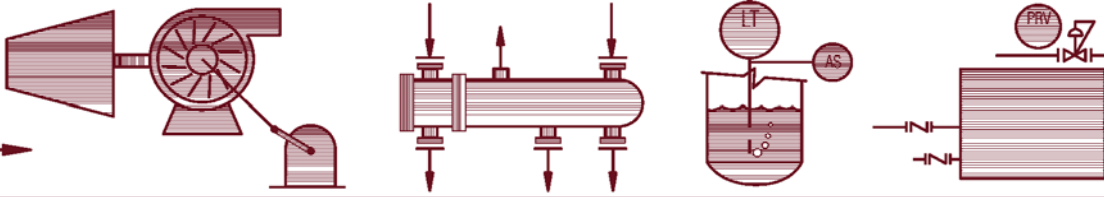
To achieve these limits, the system employs several different technologies. Particulate matter for the system is controlled using a three-field electrostatic precipitator. Although NO<sub>x</sub> generation is relatively low from a wood-fired boiler, the system employs a urea-based Selective Non-Catalytic Reduction (SNCR) system to

further reduce the NO<sub>x</sub>. By carefully controlling the injection of a urea reagent, NO<sub>x</sub> production from the system can be reduced by over 40%. Control of carbon monoxide (CO) in a power boiler is typically achieved by proper combustion techniques. The chief tool in reduction of CO in a wood-fired boiler is the careful control and placement of air throughout the unit. By injecting a high percentage (50% of the total combustion air) of air above the grate, CO levels can be held in check.

**Economics**

The St. Paul Biomass plant is economically viable mainly due to the fact that this is a cogeneration facility receiving income from the sale of electricity to Northern States Power and the sale of steam to District Energy St. Paul. A Power purchase agreement with

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Northern States Power provides favorable pricing for the electricity delivered to the Northern States Power Grid. The agreement also specifies availability requirements. The electricity production costs are between 4-5 cents/KWh.

In summary, this state-of-the-art wood-fired facility provides the City of St. Paul an environmentally-friendly, energy-efficient solution that will satisfy their needs into the foreseeable future.



## Energy Efficiency & Conservation Tips

When properly evaluated and applied, energy efficiency and conservation programs generally have a good Return on Investment (ROI) for both existing and new facilities. The following areas are important when initiating such a program for a steam and/or power generating facility:

**Pumps**

- Verify the type of pump selected is proper for the application
- Make sure the actual system operating conditions are within the range recommended by the pump manufacturer
- Inspect pumps on an annual basis and keep clearances within factory tolerances
- Make sure that the system design considers operating conditions, for example evaluate the use of minimum recirculation valves versus orifice plates
- Verify the controls selected are based on life cycle cost (Variable Frequency Drives (VFD) versus control valve and constant speed)

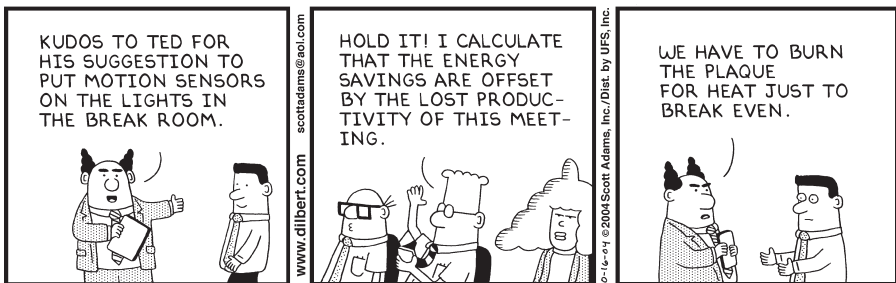
**Fans**

- Select the most efficient type for the application (axial, centrifugal backward curved, centrifugal forward curved, radial – in general descending efficiency order)
- Keep internals clean and clearances within factory tolerances
- Verify the controls selected are based on life cycle cost (Variable Frequency Drives (VFD) versus control damper and constant speed)

**Steam Cycle**

The most efficient overall cycle design is often overlooked, especially in smaller industrial plants. When evaluating one should consider:

- Boiler/Power Plant design versus process needs including turndown, peak, and normal loads
- Impact of changes or additions to the steam system
- Necessity for system redundancy and its impact on life cycle costs



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