MEASUREMENT AND VERIFICATION PLAN

FOR

CHP SYSTEM AT
SUNY-ESF

Revised
May 2012

Submitted to:

NYSERDA
17 Columbia Circle
Albany, NY 12203

Submitted by

CDH Energy Corp.
PO Box 641
2695 Bingley Rd
Cazenovia, NY 13035
(315) 655-1063
www.cdhenergy.com

SUNY ESF
1 Forestry Drive
Syracuse, NY 13210
315-470-4934

:

Project Team:

NYSERDA Project Manager:

Scott Larsen
NYSERDA
17 Columbia Circle
Albany, NY 12203
518-862-1090 x 3208
lsl@nyserda.org

Facility Personnel:

Michael Kelleher
Project Leader
mkellehe@esf.edu
315-470-4934

Bruce Marcham
Physical Plant
bmarcham@esf.edu
315-470-6797

Jim Sahm, IT

SUNY College of Environmental Science and Forestry (ESF)
1 Forestry Drive
Syracuse, NY 13210

Controls Contractor:

Mike Grigus (sp?)
Pasco Controls / Alerton
5860 Belle Isle Road Syracuse, NY 13209
315-488-0262

Design Engineer:

Jean Zangor, P.E.
Van Zelm Engineers
10 Talcott Notch Road
Farmington, CT 06032
860-284-5064 ext 359
jzangor@vanzelm.com

Overview

The plan describes the monitoring and verification system that will be provided to quantify the performance of the CHP system at SUNY-ESF. This plan is a deliverable to NYSERDA as part the funding agreement (under NYSERDA PON 1931). The plan describes the CHP system and provides the rationale for all the measurements taken to quantify its performance. It also describes how the collected data will be transferred to the NYSERDA website. The plan also describes additional measurements that will be taken to measure the total energy performance of the energy systems on campus. The appendix describes several screens that will be developed into a Kiosk for the Lobby of the Gateway Building to quantify energy flows, efficiencies and overall system performance.

System Description

The SUNY College of Environmental Science and Forestry (SUNY-ESF) is currently constructing the new Gateway Building. The building includes a range of sustainable technologies to meet the thermal and electrical needs of the new building as well as four other neighboring buildings on campus. The thermal plant includes a mix of biomass and natural gas boilers to provide steam. A 275 kW backpressure steam turbine extracts electric power from the 125 psig output from the boiler and provides 15 psig steam to meet the thermal loads on campus. The system also includes three natural-gas-driven 65 kW Capstone Microturbines with a Heat Recovery Steam Generator (HRSG) to produce 15 psig steam.

SUNY-ESF current buys steam from the Syracuse University (SU) central plant. This Combined Heat and Power (CHP) system will displace those steam purchases while also providing a portion of the power needs on campus.

The biomass boiler system is a Chiptec wood pellet biomass gasification boiler with a steam capacity of 8,000 lb/hr at 125 psig. The biomass boiler is supplemented by a similarly-sized natural gas boiler from Bryan Steam. These two boilers produce sufficient steam to meet the thermal loads in the Gateway building as well as four other nearby campus buildings (Jahn, Baker, Moon, and part of Illick). The wood-fired boiler will operate base-loaded for approximately 8 months of the year. The natural gas boiler will follow the thermal loads in the winter and the swing seasons. The plant also includes a smaller 2,475 lb/h natural gas boiler that will operate to meet the campus loads in the summer when the wood boiler is off. Overall, the steam system is expected to meet 77% of the campus loads on an annual basis.

The steam produced with these two 125 psig boilers runs through a Carrier Microsteam™ backpressure turbine to produce power. The Microsteam™ unit can produce 275 kW of power with a steam input of 17,000 lb/h at 125 psig. Steam leaves the turbine at 15 psig to meet the campus loads. The 15 psig steam pressure is compatible with the current heating systems on campus, which were originally designed to use 15-30 psig steam (produced by running 110 psig campus steam through a pressure reducing valve (PRV) and de-superheating station). The net result is that electricity will be efficiently produced by extracting energy from the steam flow. The thermal energy (enthalpy x mass flow) lost from the steam is directly converted into power. So the fuel-to-electricity conversion factor is essentially equal to the fuel-to-thermal conversion efficiency of the boiler plant.

All generated power feeds into the 480 Volt distribution panel in the Gateway Building (see Figure 5). The steam turbine has an induction generator that is grid-excited, so it can only operate in parallel with the utility. Similarly the photovoltaic inverter can only operate in parallel with the grid. The three Capstone microturbines have black-start capability and can produce power independently. A Kirkey with a manual transfer switch allows the turbines to be disconnected from the grid in order to serve the emergency loads in panel CHPH-L-1. The Kirkey ensures that the microturbines must be disconnected from the main panels (i.e., utility grid) before switching to the emergency loads during an outage.

Table 1. Steam Boiler Specifications

Unit #	Boiler	Manufacturer	Natural Gas Input (MBtu/h)	Rated Steam Output (lb/h)	Rated Pressure (psig)
B-1	Wood Boiler	Chiptec	-	8,000	125
B-2	Gas Boiler	Bryan	10,500	8,658	125
B-3	Summer Blr	Bryan	3,000	2,475	30
HRSG-1	HRSG	Cain Industries	-	850	15
				19,983	

Table 2. Steam Turbine Specifications

Unit #	Manufacturer	Rated Power (kW)	Rated Steam Inlet		Rated Steam Outlet		Output Voltage (V)
			(lb/h)	(psi)	(lb/h)	(psi)	
STG-1	Carrier	275	17,000	125	12,000	15	460

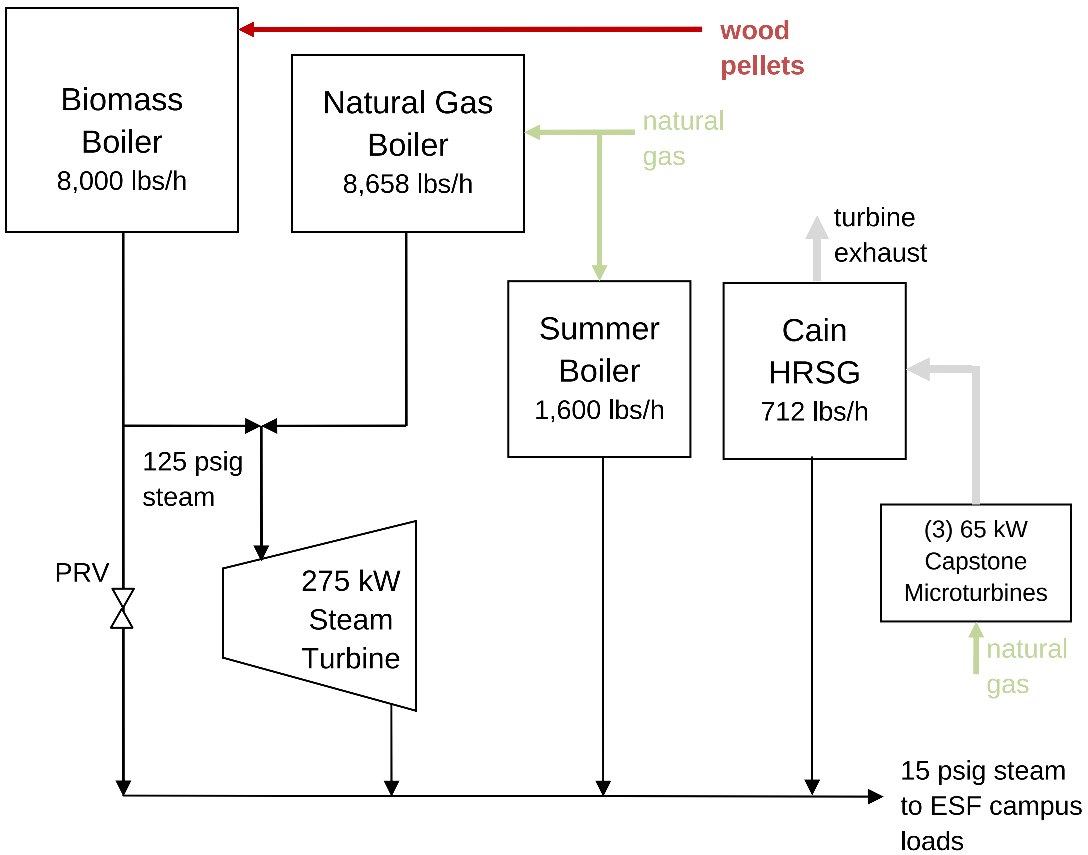

Figure 1. Schematic of ESF CHP System

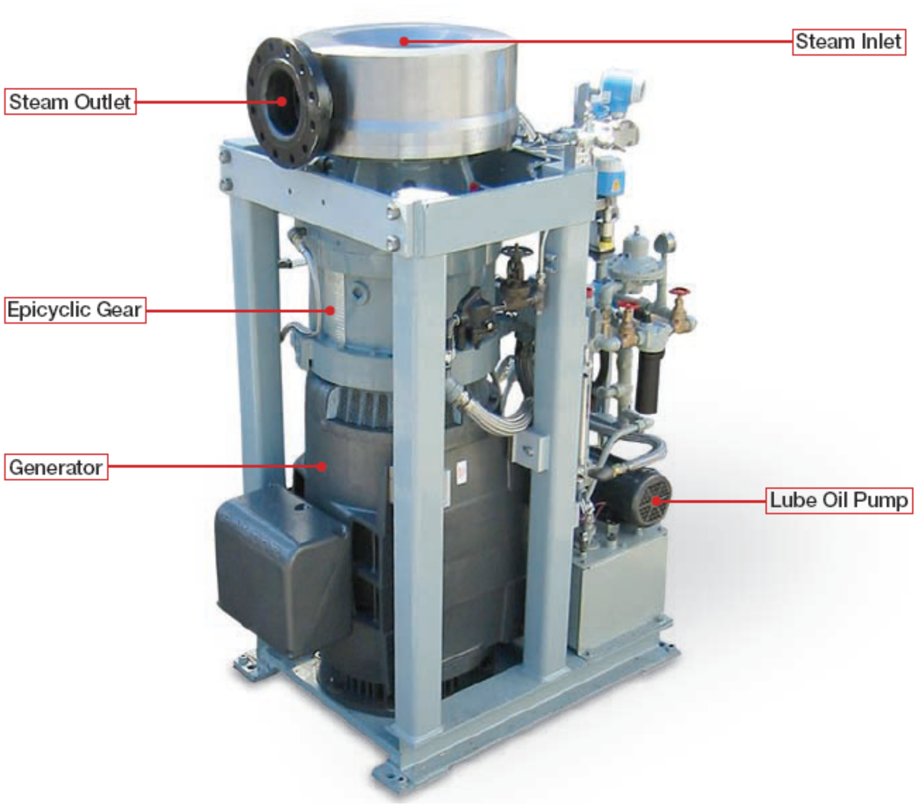

Figure 2. Carrier 275 kW Microsteam™ Backpressure Steam Turbine

The second part of the CHP system is a Reliaflex Modular Power System, that includes three 65 kW natural-gas fueled Capstone microturbines. The system includes a Cain Heat Recovery Steam Generator (HRSG) which produces 712 lb/h of 15 psig steam to meet campus loads. These three microturbines will run year round, producing electricity and steam to meet campus loads.

Table 3. Capstone Microturbine Specifications

Unit #	Manufacturer	Rated Power (kW)	Inlet Gas		Output Voltage
			(psig)	(std CF/h)	(V)
MCT-1	Capstone	65	75-80	840	480
MCT-2	Capstone	65	75-80	840	480
MCT-3	Capstone	65	75-80	840	480
		195		2,520	

65 kW Capstone

Cain ESG1 Exhaust Steam Generator

Figure 3. Main Components of Microturbine System

Monitoring Approach

In order to quantify the performance of the system, the data points listed in Table 4 and shown in Figure 4 and Figure 5 will be monitored by the Building Management System (BMS). These points will quantify the performance of the CHP system and its components as well as the impact the system has on total facility loads and utility purchases. The power produced by the on-site generators and photovoltaic array (**WST, WMT_O, WPV_O**) will be measured along with the total purchased power in the Gateway building (**WT_I**). In some instances the Gateway Building may generate excess power that will be exported to the rest of campus, so this exported power (**WT_E**) will also be measured with a bidirectional power meter. The microturbines and PV inverter may have a slight power draw when the units are not producing power; that will be measured with bi-directional meter as well (**WMT_I, WPV_I**).

The total steam load on the system is the sum of the loads in each of the served buildings (Gateway, Jahn, Baker, Illick, or **FSL_B1** to **FSL_B4**). The locations of these campus buildings are shown in Figure 6. The steam produced by each major system is also tracked for the high pressure side (**FSH_GB, FSH_WB**) as well as for the low pressure side (**FSL_SUM, FSL_HRSG**). The steam input to the Carrier turbine (**FSH_ST**) will also be tracked to confirm when steam is flowing through that component and to understand its thermal conversion efficiency.

The fuel conversion efficiency (FCE) and electrical efficiency of the microturbine system will also be tracked by measuring the gas input (**FGMT**), power output (**WMT_O**), and thermal output

(**FSL_HRSG**). Similarly gas boiler efficiency can be tracked by determining gas input (**FGB**) and respective steam outputs.

The Chiptec boiler controls also have a method to infer the woodchip input rate (**FGB**) from the auger speed. This data will be used to estimate the flow (in lb/h) and it will be compared to the delivery logs to prove its validity.

Table 4. Measured Data Points

Point Name	Description	Eng Units	Notes / Location
WU	Campus Utility Meter	kW, kWh	Ngrid meter (from EPO acct)
WT_I	Gateway Main Meter (Sub 1A) Import	kW, kWh	facility meter
WT_E	Gateway Main Meter (Sub 1A) Export	kW, kWh	facility meter
WMT_O	Power Output from 3 Microturbines	kW, kWh	in Main Panel or MCTP-L-1
WMT_I	Power Draw by 3 Microturbines (when off)	kW, kWh	in Main Panel or MCTP-L-1
WST	Power Output from Steam Turbine	kW, kWh	in Main Panel
WPV_O	Power Output from PV Inverter	kW, kWh	in Main Panel
WPV_I	Power Draw by PV Inverter (when off)	kW, kWh	in Main Panel
PH	Steam Pressure in 125 psig Header	psig	
PL	Steam Pressure in 15 psig Header	psig	
FWP	Wood Pellet Flow Rate	lb/h	inferred from auger rotation
FSH_WB	Steam Flow from Wood-fired Boiler (125)	lb/h	
FSH_GB	Steam Flow from Gas Boiler (125)	lb/h	
FSH_ST	**Steam Flow into Turbine (125)**	**lb/h**	**not on drawing**
FSL_SUM	Steam Flow from Summer Boiler (15)	lb/h	
FSL_HRSG	Steam Flow from HRSG (15)	lb/h	on drawing M3.05
FC_WB	Condensate Flow to Wood-fired Boiler	gpm	
FC_GB	Condensate Flow to Gas Boiler	gpm	
FC_SUM	Condensate Flow to Summer Boiler	gpm	
FC_HRSG	Condensated Flow to HRSG	gpm	added after submital
TC	Temperature of Condensate	F	
FGMT	Microturbine Gas Use	CF/h	on drawing M3.05
FGB	Boiler Gas Use (both boilers)	CF/h	on drawing M3.05 (both boilers)
FSL_B1	Steam Flow to Building 1 (Gateway)	lb/h	
FSL_B2	Steam Flow to Building 2 (Jahn)	lb/h	
FSL_B3	Steam Flow to Building 3 (Baker)	lb/h	
FSL_B4	Steam Flow to Building 4 (Ilick)	lb/h	

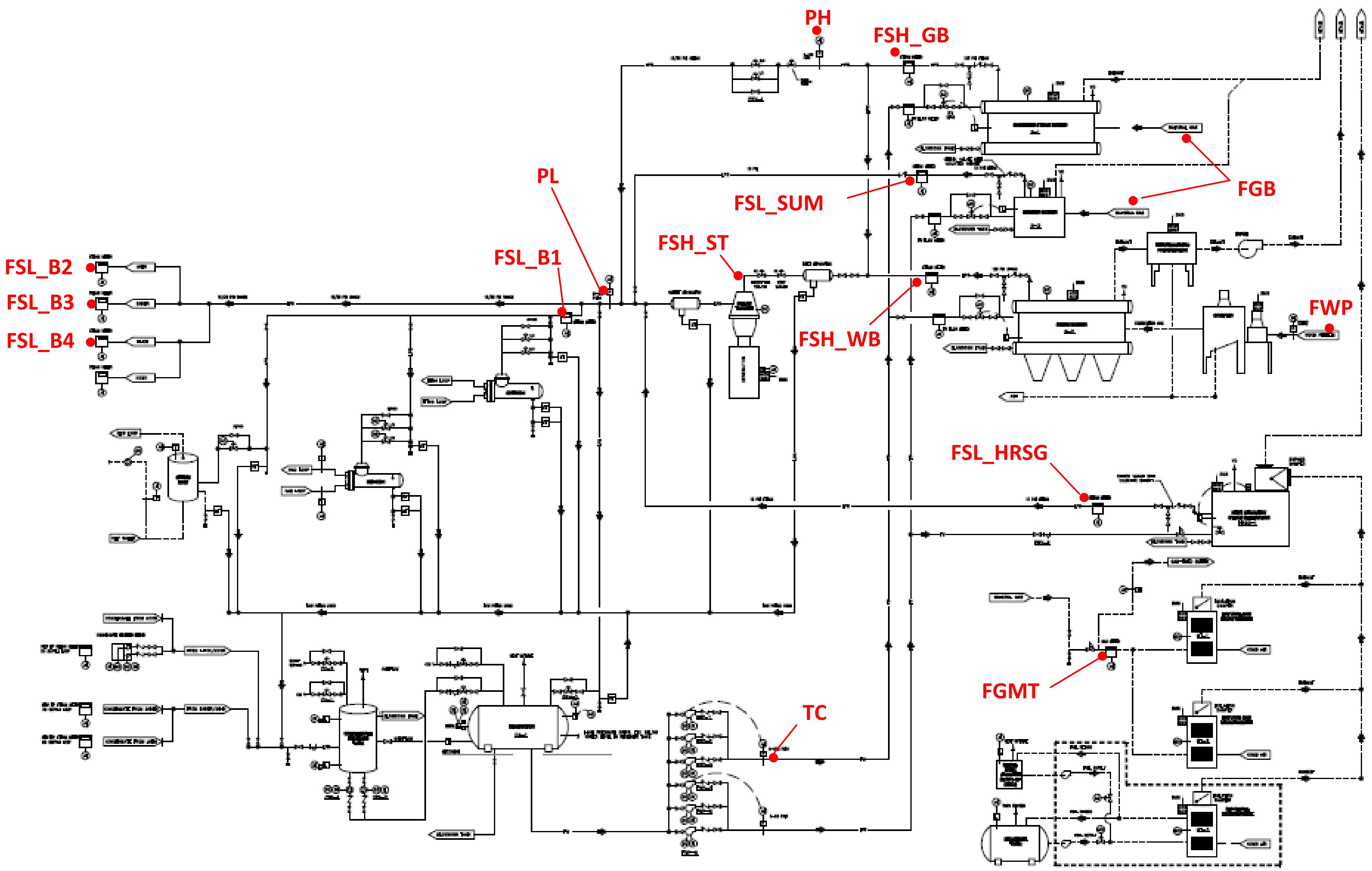

Figure 4. Schematic of Building Steam and Gas Piping (with data points shown as red) from Drawing M3.05

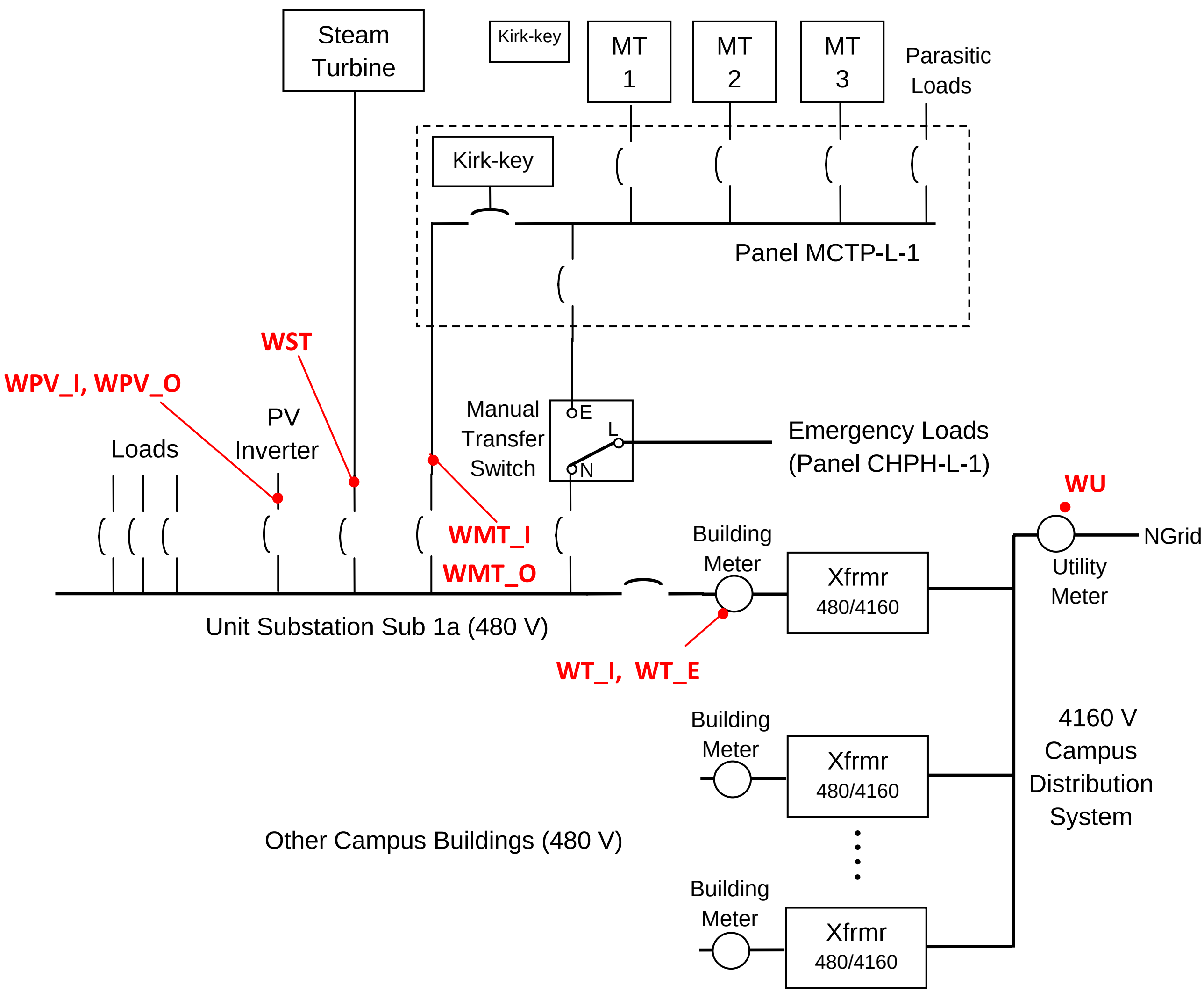

Figure 5. Simplified On-Line Schematic of Electrical System

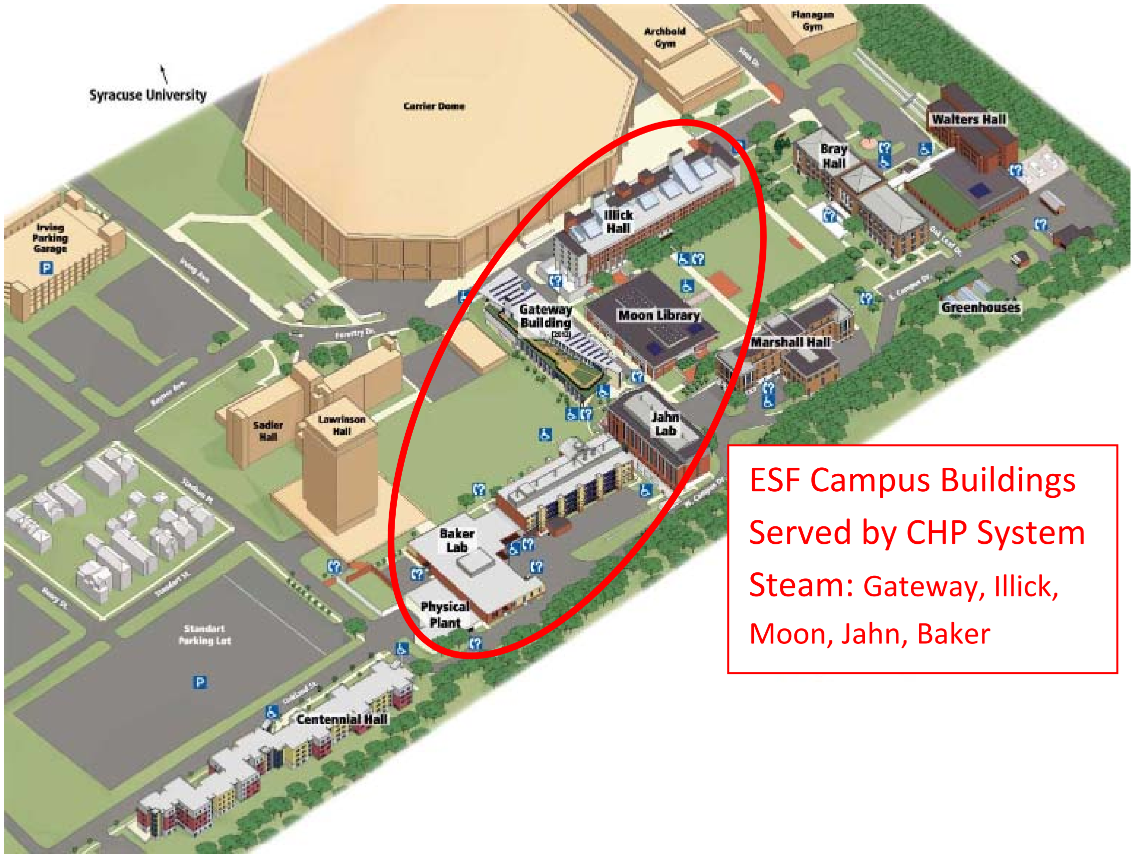

Figure 6. Map of ESF Campus Showing Buildings Connected to the CHP Steam System

The data listed above in Table 4 will be collected by the Alerton building management system (BMS). The BMS will record the readings at 15-minute intervals (as averages or totals). This data will be saved into log files that can be automatically transmitted to the NYSERDA's web site operator FTP or HTTP transfer. The data transfer rate should be at least once each hour to enable the kiosk to be frequently updated.

There are several manual meter readings that will be helpful in understanding system performance. These are summarized in Table 5 below.

Table 5. Data to be Manually Recorded

Manual Readings	Data to Record
Wood Pellet Delivery Logs	tons & date/time for each delivery
Steam from SU Plant to Illick	Steam Consumption, lbs per month
Steam from SU Plant to Baker	Steam Consumption, lbs per month
Steam from SU Plant to Jahn	Steam Consumption, lbs per month

Calculated Quantities

The NYSERDA CHP website requires overall performance information for system. To fit the framework of the website the microturbine system and back pressure steam turbine must be treated separately (listed in the web site as two different systems). The calculate values for the microturbine and backpressure steam turbine are listed in Table 6 and Table 7, respectively.

Table 6. Summary of Calculated Quantities for the NYSERDA CHP Website –Microturbine CHP System

Net MT Power (kW)	= **WMT_O** – **WMT_I**
Fuel Input (CF/h)	= **FGMT**
Thermal Output (MBtu/h)	= **FSL_HRSG** x h_{st}
Electrical Efficiency (% LHV)	$= \frac{3.413 \times (WMT\_O - WMT\_I)}{FGMT \times H_{fg}}$
Fuel Conversion Efficiency (% LHV)	$= \frac{3.413 \times (WMT\_O - WMT\_I) + FSL\_HRSG \times h_{st}}{FGMT \times H_{fg}}$
Facility Power (kW)	= **WT_I** – **WT_E**
Other Facility Gas Use (CF/h)	= **FGB**

Notes: h_{st} (Btu/lb) will be determined for 15 psig steam based on pressure (**PL**) and condensate temperature (**TC**).
H_{fg} for natural gas is 0.93 MBtu/CF.

Table 7. Summary of Calculated Quantities for the NYSERDA CHP Website –Steam Turbine System

Net MT Power (kW)	= **WST**
Thermal Output (MBtu/h)	= **FSH_ST** x $h_{st,h}$ – **WST** x 3.413
All other Data	na

APPENDIX
Description of Kiosk

ESF also plans to make a series of Kiosk screens to indicate the performance of total CHP system including the wood-fired and gas-fired boilers. The goal is to understand the energy flows and efficiencies in the system.

The Kiosk screens will show the state of the system at various time scales (e.g., last hour, day-so-far, yesterday, month-to-date, year-to-date, etc.). We propose to develop two screens to provide an at-a-glance understanding of system performance:

- Energy Components, Energy Flows and Consumption. This diagram shows the fuel consumption, energy outputs, and loads breakdown, in their respective units, for the campus system. The conversion efficiency of each component will be shown and the contribution of each component to meeting campus needs is calculated.

- Overall Energy Flows and Conversion Efficiency. This diagram summarizes the overall energy flows, conversion efficiencies, and losses in the same energy units. It provides a good "first-law" understanding of the system and highlights the losses in the system. The different value or quality of the various energy streams is not stressed in this diagram. We will make the relative size of the bars change with the magnitude of each load.

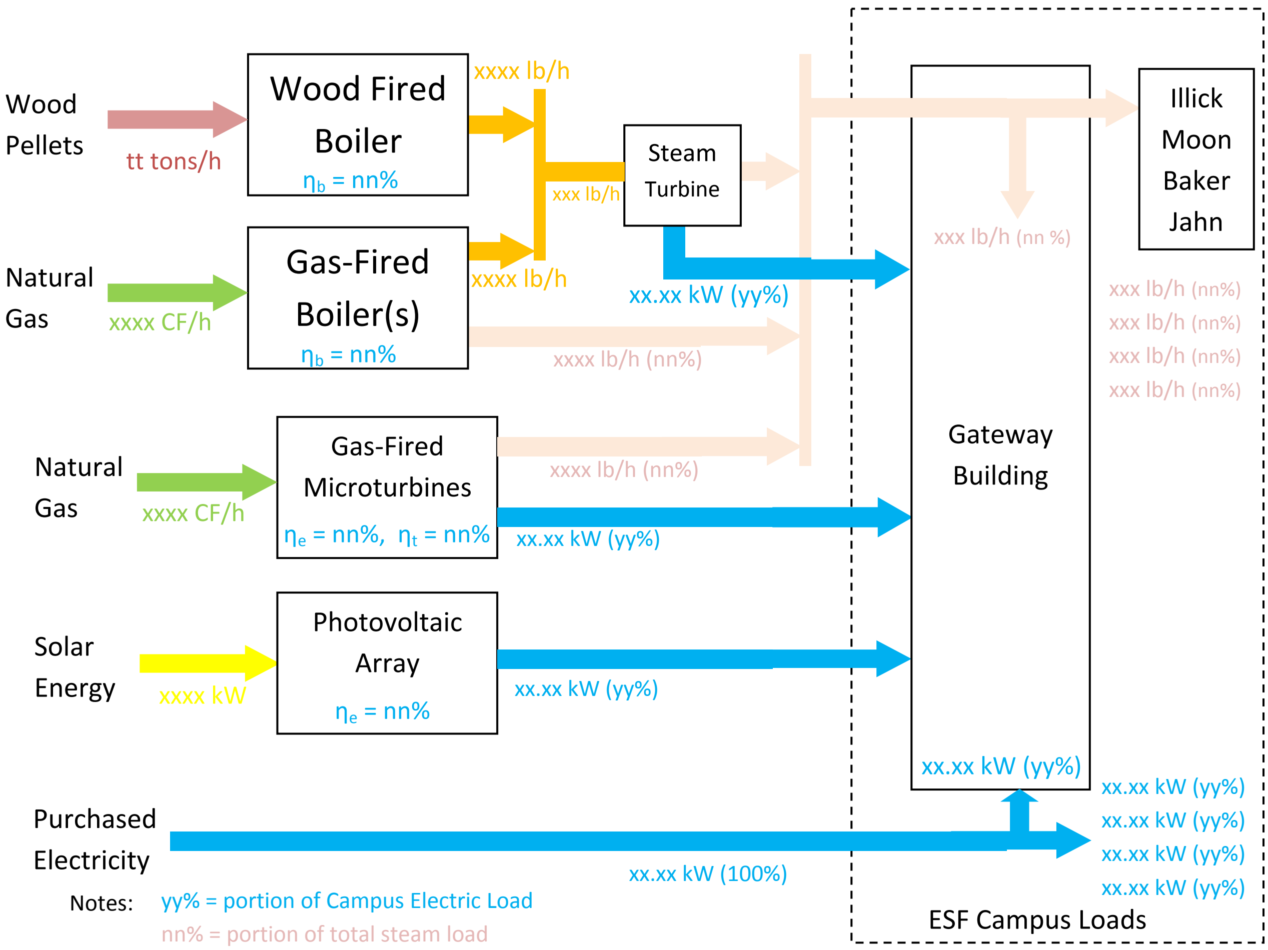

Figure A-1. Kiosk Screen showing Energy Components, Energy Flows and Consumption

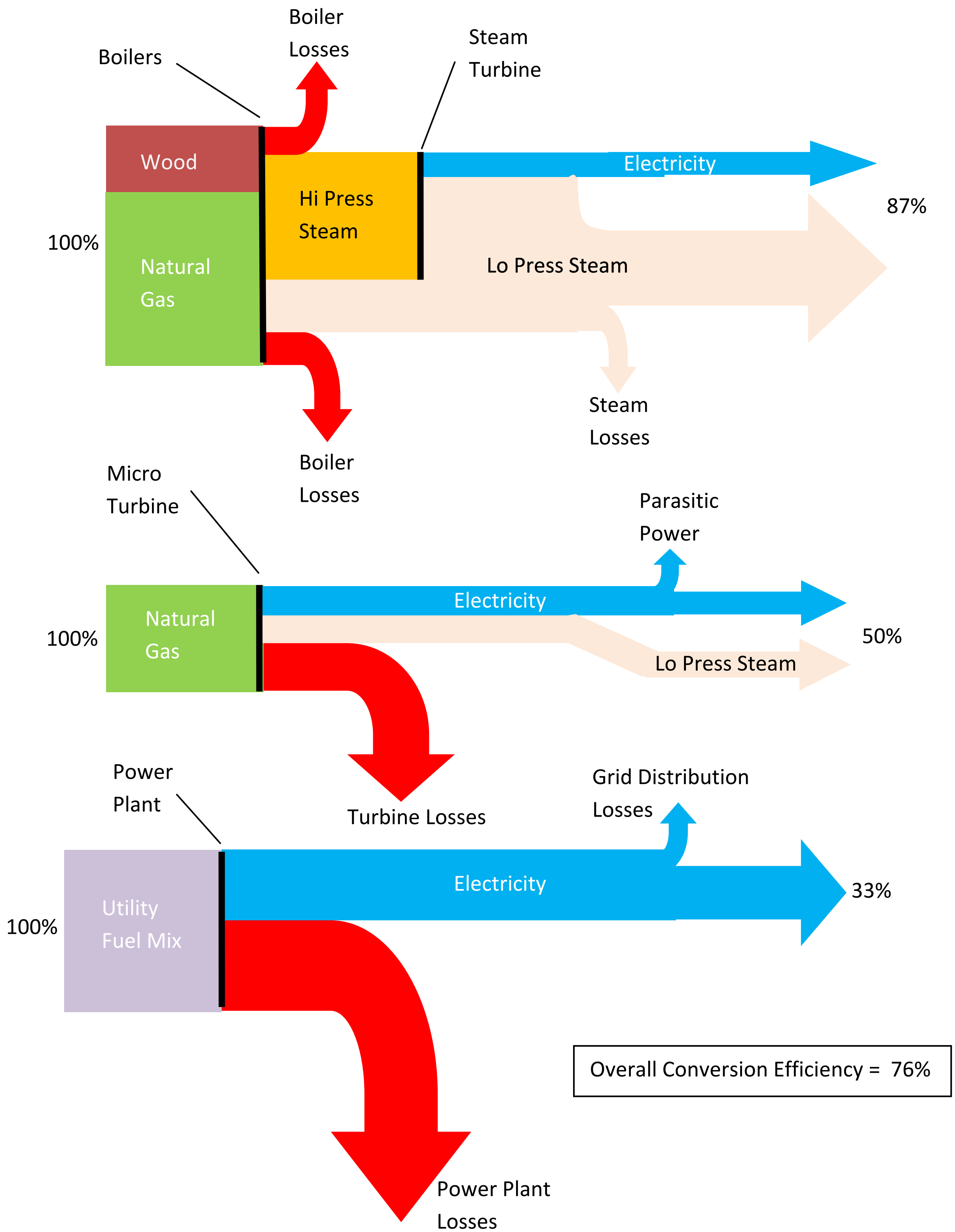

Figure A-2. Kiosk Screen showing Energy Flows and Losses