WESLEYAN
UNIVERSITY

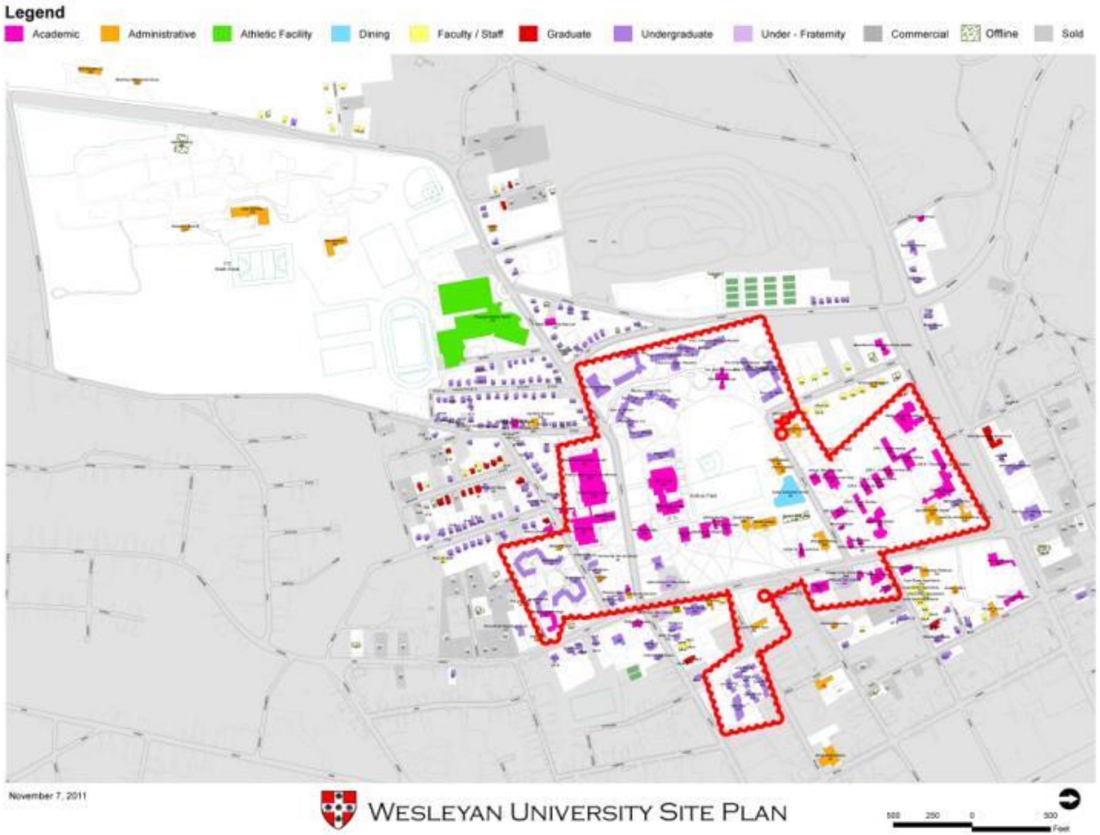
Microgrid Planning Study, Design, & Implementation

Community

Wesleyan University – Middletown, CT

- 3,000 students
- 1,300 faculty and staff
- 320 acres
- 312 buildings
- 3,000,000 sf.
- 2,250,000 sf, 80 buildings receive steam/chilled water from central plant and are on Wesleyan's 5 kV/15 kV electrical distribution system

Site plan


Legend
Academic
Administrative
Athletic Facility
Dining
Faculty / Staff
Graduate
Undergraduate
Under - Fraternity
Commercial
Offline
Sold
November 7, 2011
WESLEYAN UNIVERSITY SITE PLAN
Feet

History

- Established 5 kV electrical distribution system in 1960
- Began conversion from 5 kV to 15 kV electrical distribution system in 2008
- Installed 2.5 mW reciprocating gas engine cogeneration system in 2008

- In 2008 produced approximately 80% of demand
- In 2008 supplied domestic and heating hot water for 500 beds
- In 2008 added 3,200 pounds of steam to the steam loop from first cogen

Self Study

- In October 2011, a snow storm caused 80% of Connecticut to loose power, including Wesleyan
- Wesleyan buildings were without utility power for 3 -8 days
- Without power Wesleyan cannot establish a shelter for faculty, staff, or students
- Without power, ongoing experiments in the science buildings can be destroyed along with important material stored in freezers
- Without power, food is lost in dining venues

Best Practices

Improving Reliability

- The existing cogeneration system was used to power parts of campus once it was clear that the outage would be longer than a day
- The consequences of the outage were studied recognizing that emergency power reliability is an important part of business continuity and campus safety
- Soon after a study of campus power reliability was undertaken
- In response to the storm the State of Connecticut Department of Energy and Environmental Protection (DEEP) created incentive programs for cogeneration systems and microgrids (where facilities are connected to localized power generation sources)

Options for emergency power

The following options were evaluated by Wesleyan for their ability to provide emergency power, their ability to provide a return on investment and their impact on the environment:

- Fuel cells set up as combined heat and power
- Solar
- Wind
- Standby emergency generators
- Cogeneration micro-turbines
- Cogeneration gas engines

Power reliability & capacity matrix

Option	Increased Reliability	Increased Capacity	Impact on Neighbors	Return on Investment	Cost	Alternate Funding Available	Estimated Cost	Estimated ROI	
Make modifications to existing CoGen, switching, engine upgrades APPROVED	●	○	●	●	●	no	$ 150,000	5 years	
Install larger CoGen at CPP, 3.5 MW, sell Jenbacher 2.4 MW, est. net cost	●	●	●	●	○	yes, from PURA*	$ 4,000,000	$ 4,000,000	
Install diesel generator at Vine Street, emergency/maybe peak shaver	●	●	○	○	◉	no	$ 2,000,000	$ 2,000,000	
Install gas CoGen at Freeman, 500 KW - No connection to campus	◉	◉	○	●	○	yes, from PURA	$ 1,978,760	20 years	
Install gas CoGen at Freeman, 1.5 MW - Connection to campus cost included	●	●	○	●	○	yes, from PURA	$ 3,478,760	10 years	includes cost to con
Install capacitor bank at Vine Street	●	○	●	○	◉	no	$ 2,000,000	$ 2,000,000	
Install emergency generator at Freeman, diesel or gas TBD	●	◉	○	○	●	no	$ 950,000	$ 950,000	
Install emergency generator at Usdan/Fayerweather, diesel or gas TBD	●	◉	○	○	●	no	$ 800,000	none	
Install emergency generator at Hall-Atwater/Shanklin, diesel or gas TBD	●	◉	○	○	●	no	$ 850,000	$ 850,000	
Install emergency generator at Exley, diesel or gas TBD	●	◉	○	○	●	no	$ 1,100,000	$ 1,100,000	
Install Fuel Cell at Freeman, say 1.5 MW	●	◉	○	○	○	yes, PPA, LREC	$ 7,500,000	$ 7,500,000	
Solar at Long Lane - 1.5 MW	◉	◉	◉	◉	○	yes, PPA, ZREC	$ 7,000,000	$ 7,000,000	
Connect Freeman to Vine Street	●	◉	●	$30,305/yr ◉	●	no	$ 578,760	19 years	
Increase speed to eliminate old 5 K substation at Vine Street	●	○	●	○	○	no	$ 4,500,000	$ 4,500,000	
Buildings to be added to Vine Street/CoGen									
156 High							$ 520,000		
(Bayit)							incl		
(Religion)							incl		
(International House)							incl		
Public Safety	●	○	○	○	●	no	$ 120,000		
Eclectic	●	○	○	○	●	no	$ 80,000		
Open House	●	○	○	○	●	no	$ 80,000		
Romance Languages	●	○	○	○	●	no	$ 130,000		
Russell House	●	○	○	○	●	no	$ 160,000		
UR	●	○	○	○	●	no	$ 80,000		
Court Street Apartments	●	○	○	○	●	no	$ 120,000		
East Asian Studies	●	○	○	○	●	no	$ 250,000		
GLSP	●	○	○	○	●	no	$ 120,000		

Good or none ●

Fair or partial ◉

Bad or poor ○

*PURA = State of Connecticut "Public Utilities Regulatory Authority"

Cost - >2,000,000 is ○

Cost / schedule - detail

Printed: 10/19/2012

Wesleyan University
Campus Power Reliability and Emergency Power
October 19, 2012

	Building	Notes	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028
CoGen at Freeman Athletic Center																			
CoGen Study at Freeman Athletic Connected to Campus	All Campus	Complete	$ 7,500																
Existing CoGen Island Mode Test - Review/Modify CoGen as Needed - Work Scheduled for Christmas 2012	All Campus	Design Ongoing		$ 150,000															
Design CoGen at Freeman - Part 1 - Planning and Schematic Design, CEFIA Application	All Campus	Design Ongoing		$ 71,610															
Design CoGen at Freeman - Part 2 - CD's and Construction Administration	All Campus			$ 178,390	$ 75,000														
Air Permitting for CoGen at Freeman	All Campus			$ 90,000															
Order Engine/HRSG/SCR/Enclosure	All Campus			$ 1,200,000	$ 200,000														
Freeman Athletic - Connect Freeman Athletic to 15 K Switchgear at Vine Street, Buy CLP Transformer	Freeman	Design on hold			$ 625,000														
Install CoGen at Freeman (must connect Freeman to 15 K Vine Street for this project)	All Campus			$ 458,257	$ 1,023,263														
SUBTOTAL			$ 7,500	$ 2,148,257	$ 1,923,263	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
						Total Cost Freeman CoGen =		$ 4,079,020	(includes feeder from Vine Street to Freeman)										
Upgrade Existing Transformers from 5 kV Loop to New 15 kV Loop																			
Butterfield A, CS, CN - transformer and switchboard replacement	Butterfield A, CS, CN	Complete	$ 107,000	$ 381,000															
Remove loop 5 12 cable for scrap	Butterfield to Vine Street	Scheduled for Fall 2012		$ (40,000)															
Design balance of 5 kV to 15 kV Expansion Projects	All Campus	Design on hold			$ 105,000														
Nicolson Dormitory - transformer and switchboard replacement	Nicolson					$ 180,000													
Andrus, West College - transformer and switchboard replacement	Andrus, West College					$ 190,000													
Wesshop - transformer and switchboard replacement	Wesshop						$ 180,000												
Olin/Clark - transformer and switchboard replacement	Olin/Clark							$ 280,000											
Judd (feeds Chapel, Theater, Zelnick, Albritton, PAC) - transformer and switchboard replacement	Judd								$ 280,000										
Hewitt - transformer and switchboard replacement	Hewitt									$ 190,000									
VVO - transformer and switchboard replacement	VVO									$ 160,000									
World Music (feeds 281 High, 287 High, DAC, Skull/Serpent) - transformer and switchboard replacement	World Music										$ 390,000								
Art Studios North - transformer and switchboard replacement	Art Studios North											$ 400,000							
Dance Studios - transformer and switchboard replacement	Dance Studios												$ 410,000						
Davison Infirmary - transformer and switchboard replacement	DAC													$ 170,000	★ 5 kV loops and gear removed from campus				
Demolish existing 5 kV gear for scrap, remove final campus loop cabling	All Campus														$ 95,000				
SUBTOTAL			$ 107,000	$ 341,000	$ 105,000	$ 370,000	$ 180,000	$ 280,000	$ 280,000	$ 350,000	$ 390,000	$ 400,000	$ 410,000	$ 170,000	$ 95,000	$ -	$ -	$ -	$ -
Extend 15 K Loop to Locations NOT on Existing Campus Loop																			
156 High, Bayit, Religion, International House - new transformer and replace switchboard	156 High														$ 624,000				
Public Safety - new transformer and replace switchboard	PS															$ 144,000			
Eclectic - new transformer replace switchboard	Eclectic															$ 96,000			
Open House - new transformer and replace switchboard	Open House															$ 96,000			
Romance Languages - new transformer and replace switchboard	Romance Languages																$ 156,000		
Russell House - new transformer and replace switchboard	Russell House																$ 192,000		
UR - new transformer and replace switchboard	UR																	$ 96,000	
Court Street Apartments - new transformer and replace switchboard	Court Street Apartments																	$ 144,000	
FEAS - new transformer and replace switchboard	FEAS																		$ 300,000
GLSP - new transformer and replace switchboard	GLSP																		$ 144,000
SUBTOTAL			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 624,000	$ 336,000	$ 348,000	$ 240,000	$ 444,000

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028
Total Annual Cost	$ 114,500	$ 2,489,257	$ 2,028,263	$ 370,000	$ 180,000	$ 280,000	$ 280,000	$ 350,000	$ 390,000	$ 400,000	$ 410,000	$ 170,000	$ 719,000	$ 336,000	$ 348,000	$ 240,000	$ 444,000
Total Cumulative Cost	$ 114,500	$ 2,603,757	$ 4,632,020	$ 5,002,020	$ 5,182,020	$ 5,462,020	$ 5,742,020	$ 6,092,020	$ 6,482,020	$ 6,882,020	$ 7,292,020	$ 7,462,020	$ 8,181,020	$ 8,517,020	$ 8,865,020	$ 9,105,020	$ 9,549,020

Total cost for CoGen at Freeman, including 15 K Expansion to Freeman =	$	-
Total cost to complete the 5 K to 15 K expansion (Freeman NOT included) =	$	2,925,000
Total cost to add balance of classroom/residence hall/dining buildings to 15 K loop =	$	1,992,000

Escalation considered at 1.5%

Cogeneration – gas engine – combined heat and power (CHP) selected

- Place a gas powered reciprocating engine in or near a building to provide electricity and waste heat

- A number of colleges, universities, and secondary schools are installing gas engine cogeneration systems such as – Clark, Wellesley, Amherst, Smith, UConn, Yale, Harvard, Fairfield, MIT, Williams, UMass, Trinity, Loomis, Avon Old Farms, SUNY Syracuse Environmental Science, CCSU, Duke, SUNY Westbury and Plymouth State

Pros and Cons

- Pros
  - Used in a cogeneration system they can be efficient and also provide emergency power when required
  - Relatively low maintenance
  - Best return on investment of any option
  - Good emissions ratings, lower emissions than utility generators
  - Higher system efficiency than utility generators because the heat from the engine is used

Pros and Cons

- Pros (continued)
  - Replaces gas used for production of an equivalent quantity of steam and hot water
  - Replaces gas used for production of an equivalent quantity of electricity with reduced emissions

- Cons

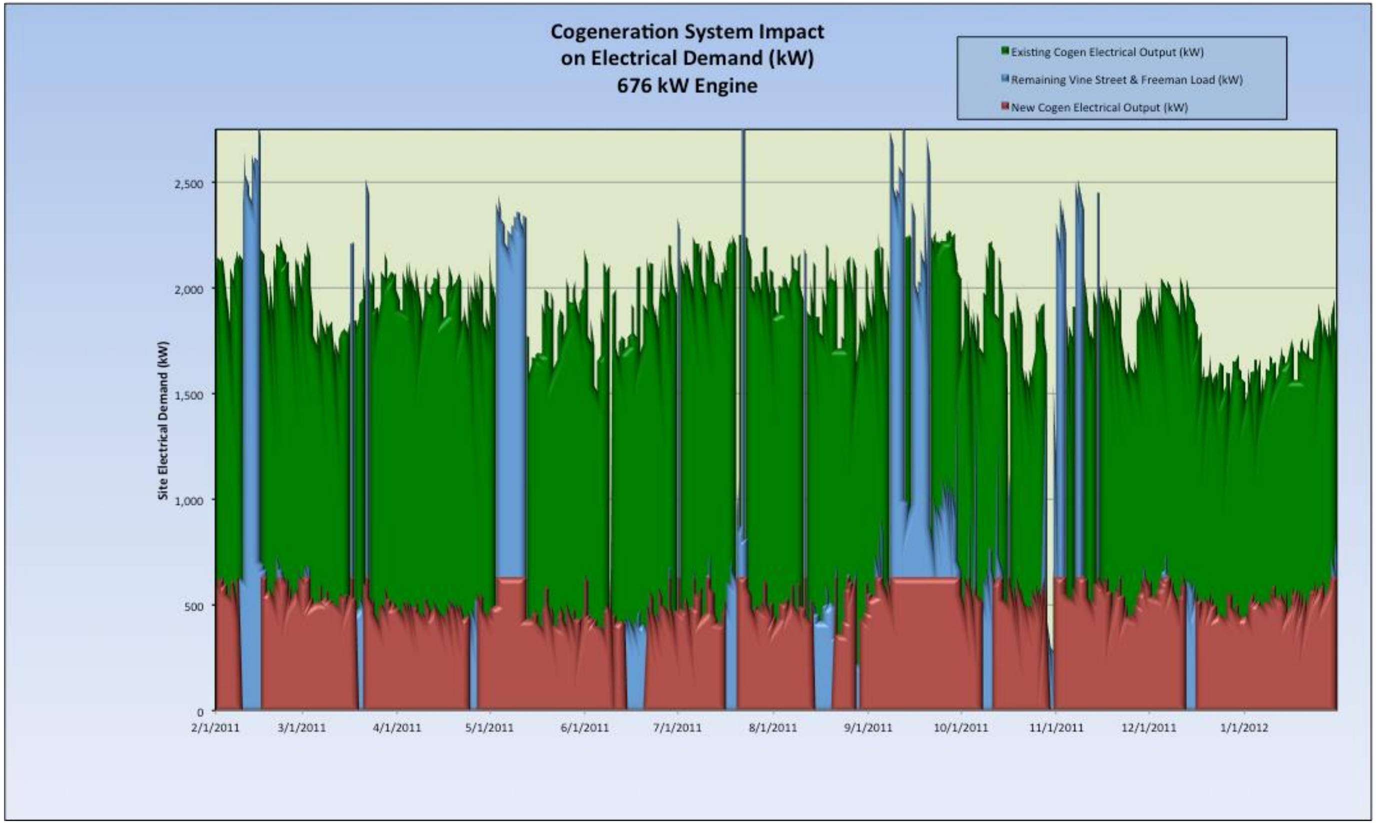
Conclusion

- Several technologies investigated including Fuel Cells, solar, wind, stand alone generators and cogeneration with gas engines. The final selection was CHP using a reciprocating natural gas engine
- Multiple engines modeled. Final selection based on optimal ROI is rated for 676 kW
- Suitable location identified as Freeman Athletic Center mechanical space.
- Engine provides steam to the campus loop, hot water to serve pool heating, domestic hot water, and heating loads of the 280,000 sf facility

Conclusion continued

- New unit is connected to Vine Street substation via new feeder by adding Freeman to the campus electrical distribution system
- Current electrical load on Vine Street with existing cogen and Freeman is ~8,126 mWh annually
- The new engine will produce 4,635 mWh annually

Cogeneration system impact



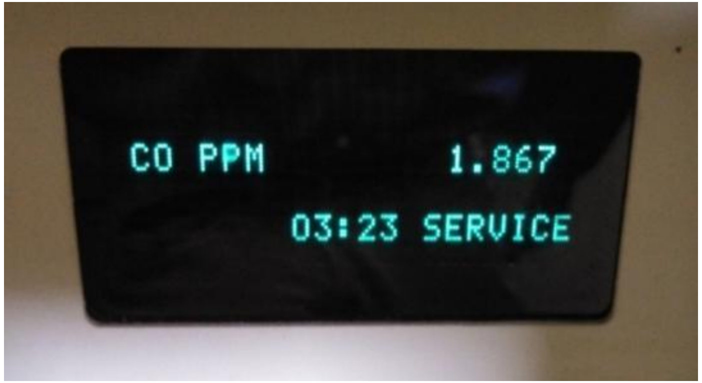
Cost

- Total CHP installation cost: $3,550,000 (includes SCR)
- Total duct bank/interconnection cost: $620,000
- Expected savings net of service agreement & renewable energy credits
  - Fossil fuel & CL&P savings: $304,177
  - Expected maintenance agreement cost: ($120,785)
  - Expected renewable energy credit revenue: $ 46,350
  - **Net annual savings: $ 229,742**
- CEFIA rebate: $300,000
- DEEP Microgrid Grant: $650,000
- Simple payback: 14 years (includes domestic hot water changes)

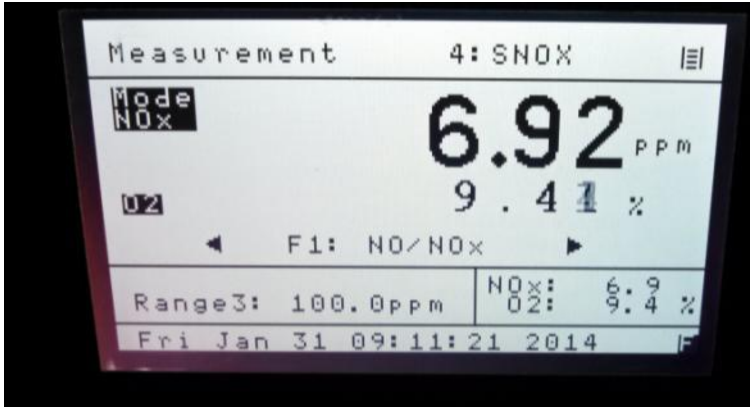
Schedule

- Feasibility – April/May 2012
- Engine selection – June/July 2012
- Engine bidding – July/September 2012
- Engine order – November 2012
- Engine delivery – August 2013
- Air permitting – October 2012 to July 2013
- Installation – September 2012 to March 2013
- First fire – January 2014
- Utility interconnect – February 2014

Compliance


CO PPM 1.867
03:23 SERVICE

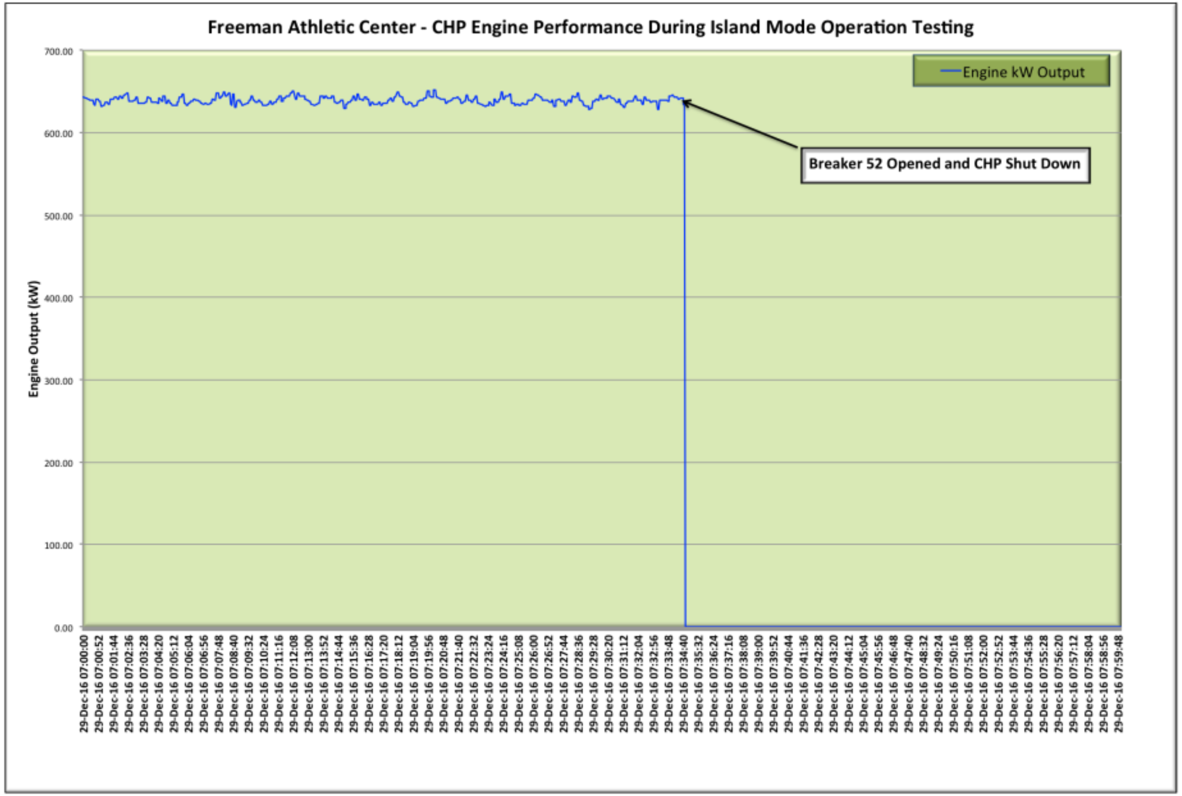

Servomex
+09.3
ALARM
ALARM DISPLAY
RANGE
STATUS
INSTRUMENT
FLOW
TRC Windsor
1420C 2725
Servomex
+06.6
ALARM
ALARM DISPLAY
1440 Gas Analyser


Measurement 4: SNOX
Mode NOx
6.92 ppm
O2 9.41 %
F1: NO/NOx
Range3: 100.0ppm
NOx: 6.9
O2: 9.4 %
Fri Jan 31 09:11:21 2014

Island Mode Testing: 12/29/16

- Report from the Connecticut Department of Energy & Environmental Protection (DEEP)
- Highlighting the load additions and subtractions observed during testing
- Additional data includes hours of operation operating in parallel and island mode, dates/times of unplanned outages and fuel usage data

Island Mode Testing: 12/29/16



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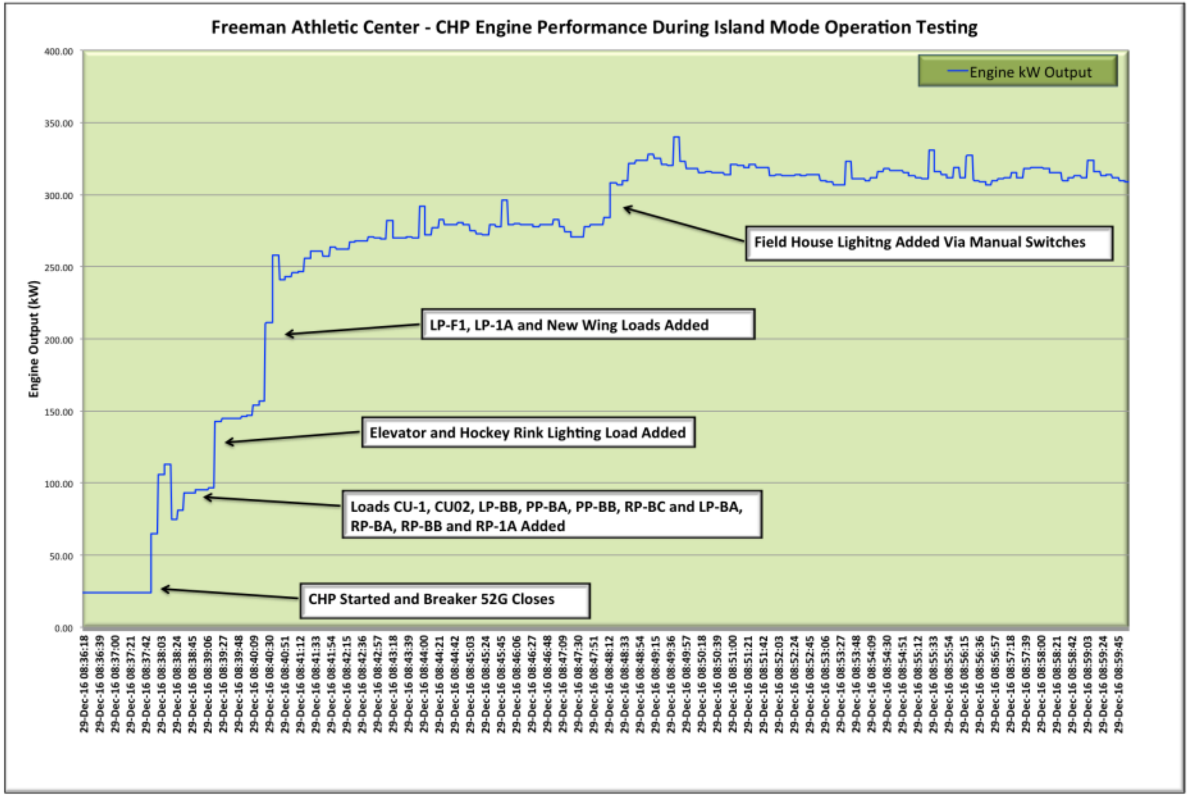
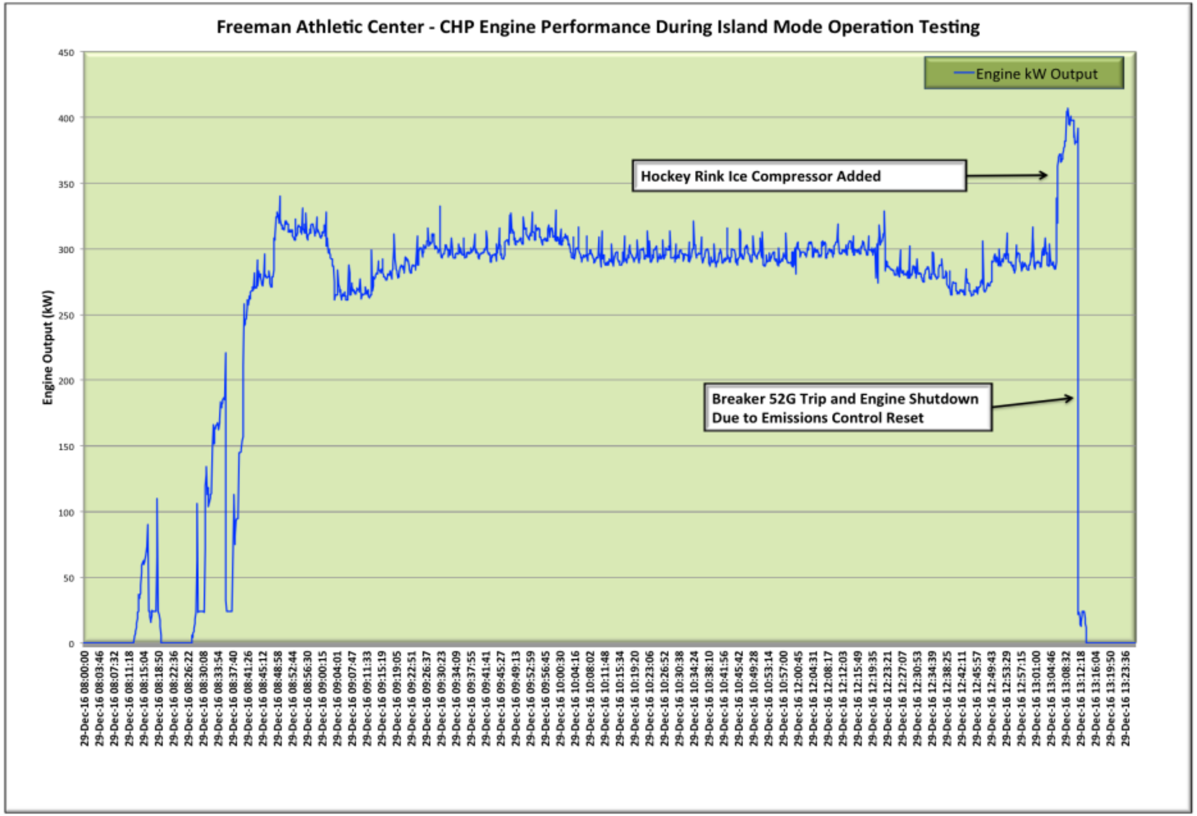
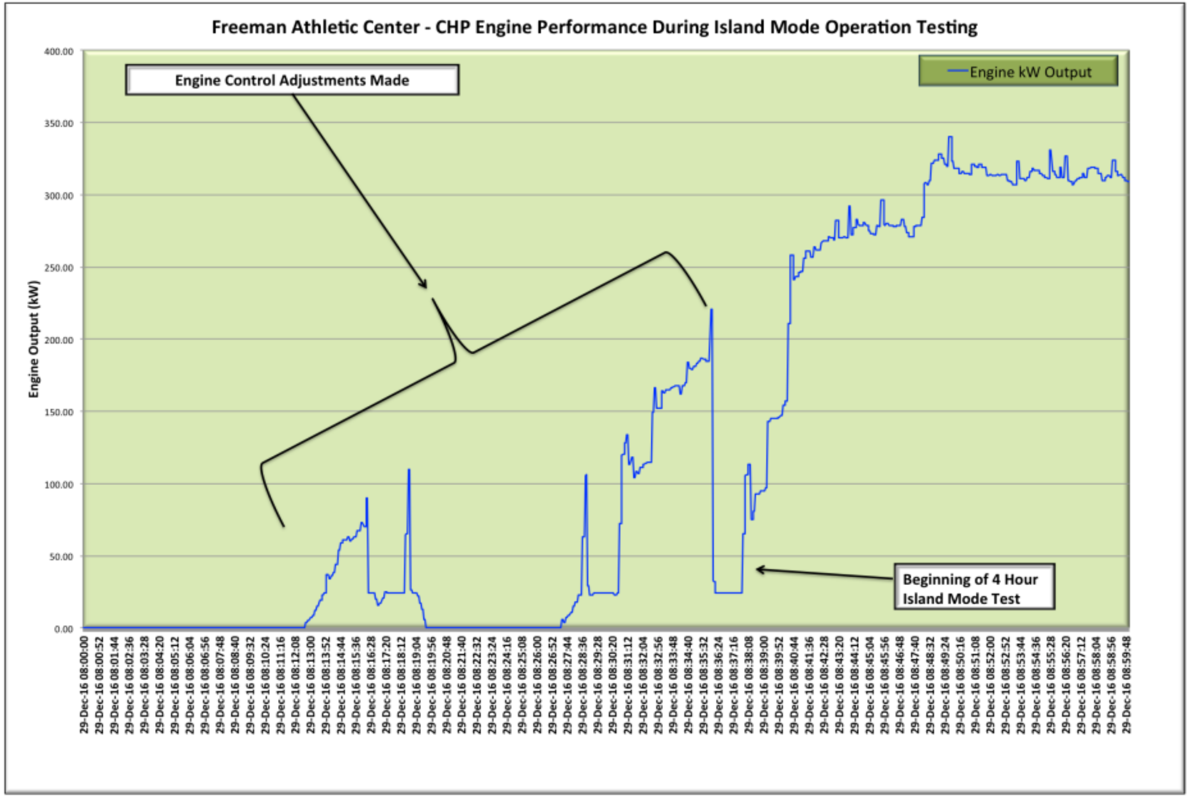


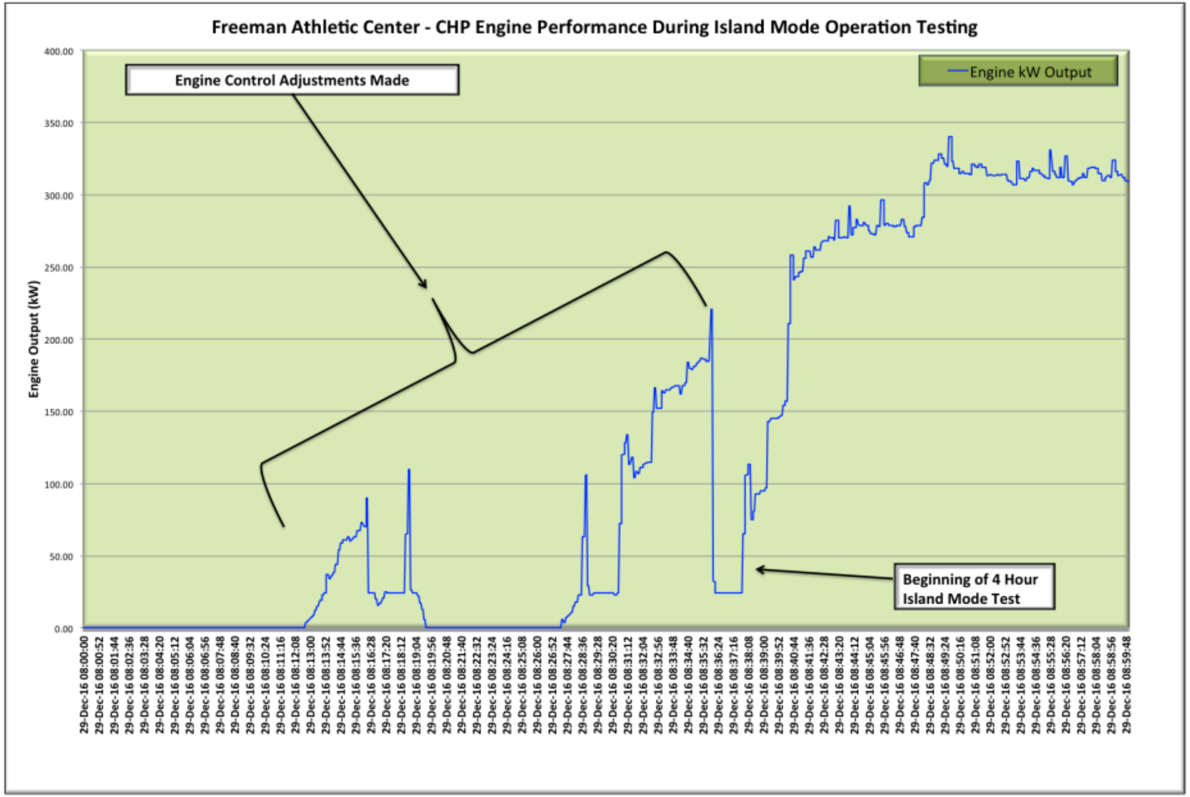
Island Mode Testing: 12/29/16



Island Mode Testing: 12/29/16



Island Mode Testing: 12/29/16



Reporting

Start Time
1/31/2014 11:45 AM
End Time
1/31/2014 12:45 PM

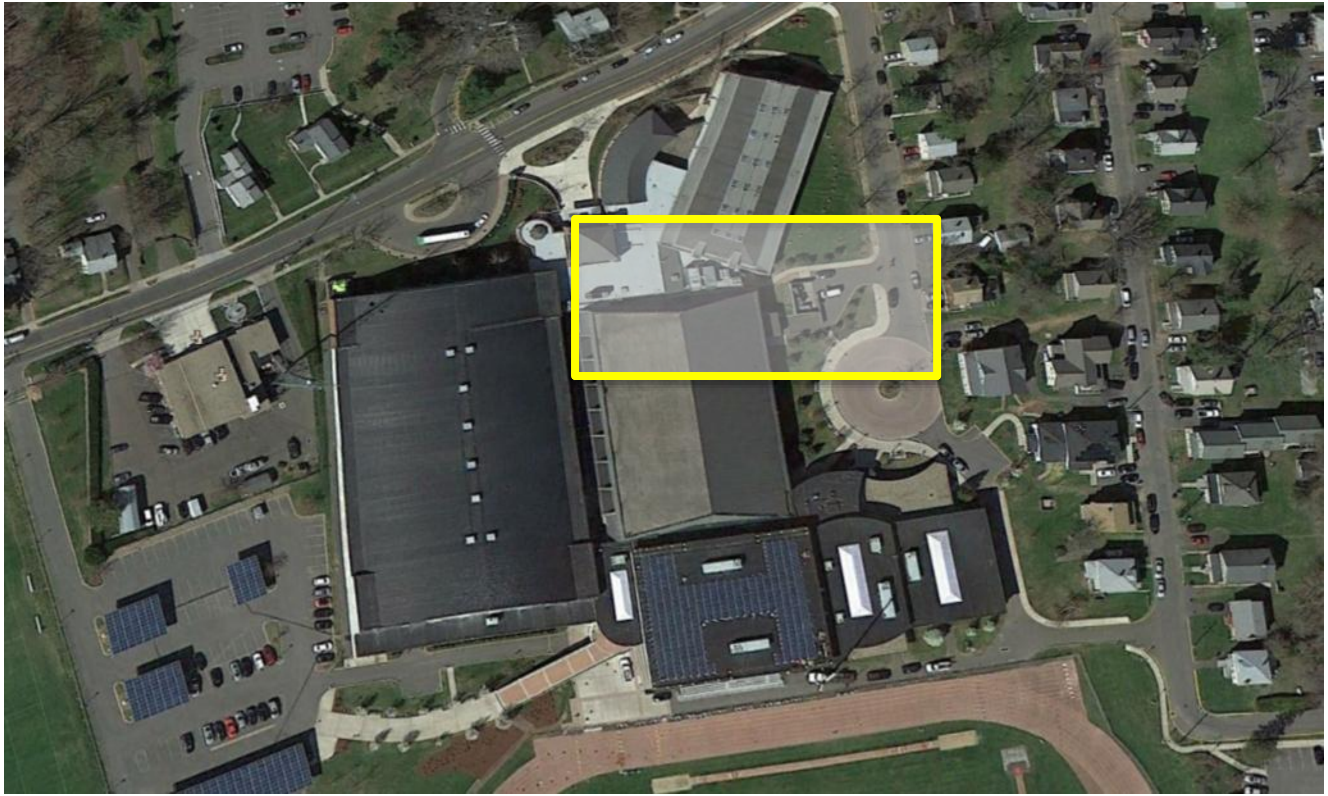
WESLEYAN UNIVERSITY

Freeman Athletic Center Emissions Testing Report

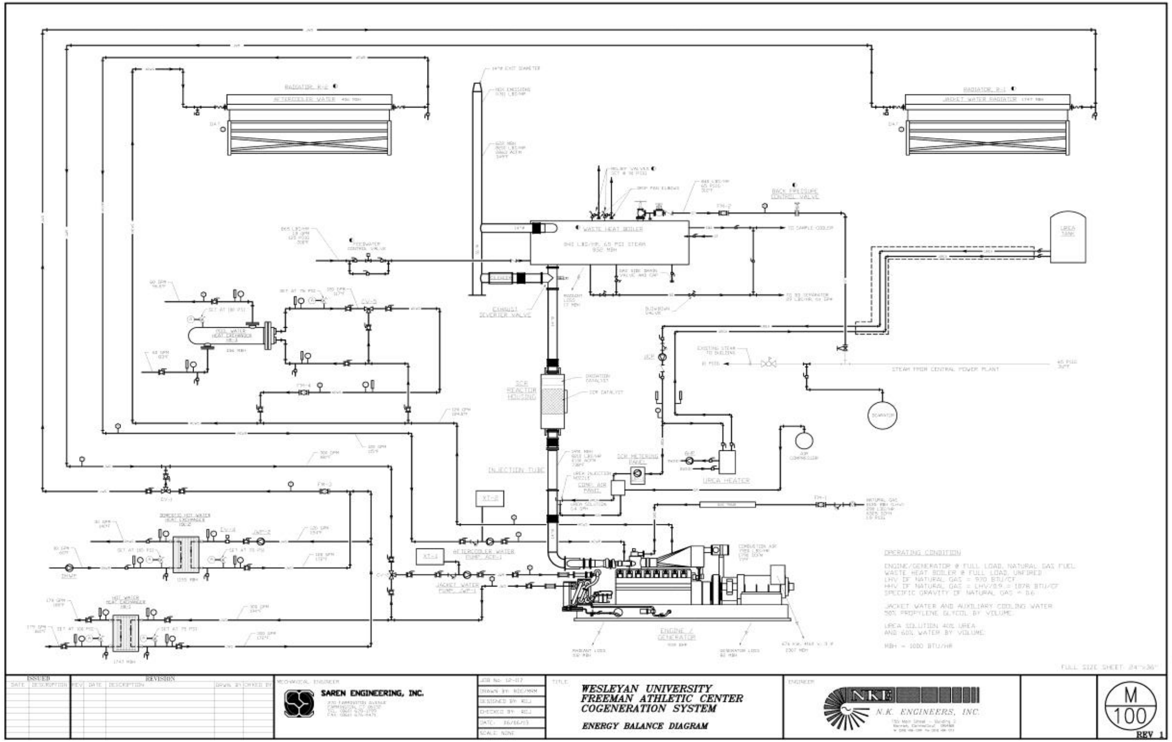
Duration: 1m

Description:	Freeman Outside Air Temperature	Freeman Outside Air Relative Humidity	Freeman Generator Output	Freeman Genset Gas Flow Total	Freeman Genset SCR Inlet Pressure	Freeman Genset SCR Outlet Pressure	Freeman Genset SCR Inlet Temperature	Freeman Genset SCR Outlet Temperature	Freeman Genset SCR Urea Flow	Freeman Genset SCR Urea Pressure
PI Tag:	CCS.TT_OAT	CCS.AT_OAH	CCS.G2_KW	CCS.GenGasTotal	CCS.G2_SCR_PressIn	CCS.G2_SCR_PressOut	CCS.G2_SCR_TempIn	CCS.G2_SCR_TempOut	CCS.G2_SCR_UreaFlow	CCS.G2_SCR_UreaPress
Units:	°F	%	kW	Mcf	"WC	"WC	°F	°F	GPH	PSIG
31-Jan-14 11:45:00	40.62	31.75	653	137	7.09	4.75	732.15	722.00	1.90	18.34
31-Jan-14 11:46:00	40.75	32.21	653	137	7.20	4.82	732.08	722.00	1.90	18.36
31-Jan-14 11:47:00	40.89	41.51	652	137	7.16	4.82	732.50	722.00	1.90	18.23
31-Jan-14 11:48:00	41.14	38.62	653	137	7.13	4.82	732.61	722.00	1.90	18.09
31-Jan-14 11:49:00	41.56	34.79	653	137	7.09	4.82	732.23	722.00	1.89	18.00
31-Jan-14 11:50:00	41.98	29.63	653	138	7.06	4.82	732.00	722.00	1.89	18.06
31-Jan-14 11:51:00	42.40	28.29	653	138	7.02	4.82	732.00	722.00	1.89	18.13
31-Jan-14 11:52:00	42.71	32.04	653	138	6.98	4.82	732.00	722.27	1.89	18.20
31-Jan-14 11:53:00	42.63	29.51	653	138	6.95	4.82	732.00	723.00	1.89	18.27
31-Jan-14 11:54:00	42.53	31.49	652	138	6.91	4.82	732.00	722.23	1.89	18.34
31-Jan-14 11:55:00	42.42	31.80	652	138	6.88	4.82	732.00	722.00	1.89	18.41

Microgrid 2nd generator location



Design – electrical power and energy balance



Keys to Success

- Select the right engineering team
- Do your permitting homework: First
- Begin discussions with Utility, State and Local Agencies Early
- Model your load and demand duration curves accurately; Preferably 5 years of data
- Track, measure and model your thermal loads – Site-specific and campus wide

Keys to Success

- ROI
- Select the service organization in parallel of your prime mover and packager
- Interview the service team
- Understand lines of communication
- Visit the manufacturer and packager prior to selection

Keys to Success

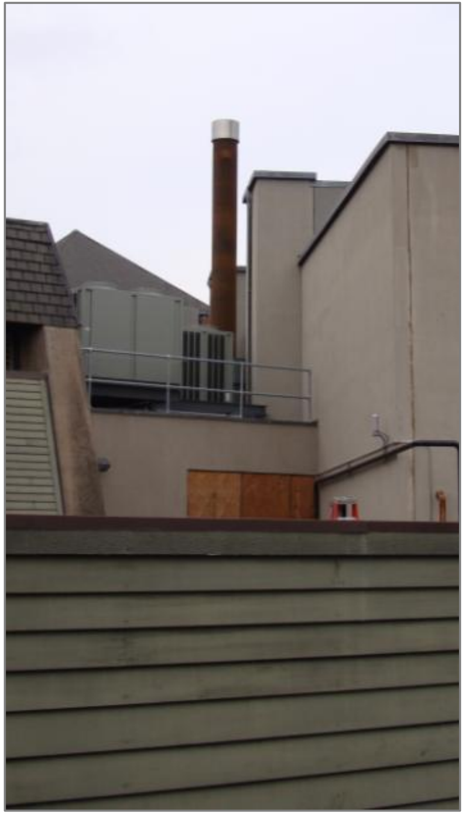
- Establish relationships up and down the supply chain
- Involve your supplier, packager and service organization with BOP issues/decisions

Questions?

Project photos

Project photos

Project photos



Project photos