Keeping Your Cool: How to Make a CHP Project Successful

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Outline of Presentation

- Overview of NBC and Bucklin Pt. WWTF
- Background of CHP Project
- Discussion of Issues Addressed During Design
- Status of Project
History of Narragansett Bay Commission

- Formed in 1982 by State of Rhode Island
- Operates 2 WWTP’s, CSO facilities and regional collection system
- Significant Efforts in Green energy
  - Installed 3 1.5 MW wind turbines in 2012 at Fields Point WWTF
  - New LEED certified admin building at FPWWTF
  - Current in planning phase for 10 MW solar facility
  - CHP project at Bucklin Point WWTF using existing digester gas
- With all projects, NBC would be generating 83% of annual usage
- Goal of energy neutrality in economically beneficial manner
Bucklin Point WWTF

• Formerly the Blackstone Valley District Commission
• Became part of NBC in 1992
• 28 miles of interceptor sewers and 3 pumps stations
• Biological nutrient removal secondary plant
  • ADFW ~18MGD. Secondary capacity of 46 MGD. Peak wet weather capacity of 116 MGD
  • MLE process upgraded to 4 stage BNR to meet TN of 5 mg/l (2014)
  • UV disinfection for dry weather flow
• Existing anaerobic digesters for solids stabilization
• Hot water boilers for beneficial use of digester gas
Extensive preliminary work performed by NBC staff

Identified basic elements of CHP project at BPWWTF
  - Technical support by SCS Engineers
  - Performed initial technology selection. Engines recommended based on gas quality and higher electrical efficiency
  - Initial review of gas treatment concepts. H2S removal recommended although not required
  - Initial project economics

No interest in back-feeding to electrical utility
  - Reduced project costs. Costs for interconnection highly variable

With existing anaerobic digesters in place, project looked like a winner....
Detailed Technical Issues Needed to be Overcome

• Gas Quality
• Gas Production Rates
• Natural gas usage/blending
• Electrical Distribution/usage/interconnection
• Air permitting
Gas Quality – Siloxane concentrations

- Siloxanes are silica based derivatives of personal care products
- Turns into abrasive sand like substance
- Varying negative impacts
  - Reduce boiler transfer efficiency
  - Increase gas treatment O&M costs
  - Create significant wear on cylinders
- BP experience
  - Estimated boiler efficiency reduced from 80% to 30%
  - Up to ½ in thick on boiler surfaces
Impacts to Project

- Measured siloxane concentrations an order of magnitude higher than typical. Measured at 29.9 ppm.
- Significant potential increase in project cost (capital and O&M) for gas treatment
- NBC initiated and identified personal care product manufacturer discharging to system creating elevated concentrations
- Ongoing sampling to verify reduction to conventional levels. Measured at 1.9 ppm after manufacturer stopped production
Design Gas Flow Rate

- What gas flow condition should be used for design and for sizing of the engine?
- Gas flow meters vs. mass balance calculations?
- 2009 feasibility study mass balance calcs showed significant variability as well
Key Impacts

• Digester gas production sets engine sizing
  • Establishes baseline electrical production
  • Impacts to candidate manufacturers for procurement considerations
  • Considerations for natural gas blending

• Gas flow meters are notoriously un-reliable
  • New thermal dispersion meters installed in 2015

• Considerations for natural gas blending for multiple reasons

• Driver for electrical output and integration with existing electrical system
Relationship between Engine Sizing and Daily Gas Production
## Conceptual Project Payback

| Size each, kW | Net kW electric power actually made | Annual digester gas use availability | NG fuel cost per hour | Yearly value of added electric power | Yearly cost of added natural gas | Estmd project cost, approx. million $ | Grant or rebate, approx. million $ | Cost with rebate, approx. million $ | Cogen heat output, million Btuh | Yearly electric power cost savings | Digester gas treatment cost per kWh | Engine O&M unit cost, per kWh | O&M cost total, per year | Project’s yearly cost savings | Grand total yearly savings | Project simple payback, years | 10 Year NPV (at 5%) | 20 Year NPV (at 5%) |
|---------------|-------------------------------------|--------------------------------------|----------------------|-------------------------------------|---------------------------------|-----------------------------------|-------------------------------|-----------------------------------|---------------------------------|----------------------------------|-----------------------------|-----------------------------|---------------------------|--------------------------|------------------------|----------------------|----------------------|
| 820           | 504                                 | 90%                                  | $0                   | $396,985                           | $0                              | $2.7                                 | $0                            | $2.7                             | 3                               | $396,985                         | $0.013                       | $0.016                      | $129,987                 | $266,998                | $267,000                | 10.1                  | -$377,000             | $646,000              |
| 1,000         | 624                                 | 90%                                  | $0                   | $492,064                           | $0                              | $3.3                                 | $0                            | $3.3                             | 3                               | $492,064                         | $0.013                       | $0.016                      | $157,560                 | $334,504                | $335,000                | 9.9                   | -$378,000             | $906,000              |
| 1,000         | 935                                 | 90%                                  | $2.71                | $737,154                           | $21,391                         | $3.3                                 | $0                            | $3.3                             | 3                               | $737,154                         | $0.013                       | $0.016                      | $198,540                 | $517,223                | $517,000                | 6.38                  | $1,209,000            | $3,191,000            |
| 1,100         | 633                                 | 90%                                  | $0                   | $498,855                           | $0                              | $3.6                                 | $0                            | $3.6                             | 3                               | $498,855                         | $0.013                       | $0.016                      | $159,529                 | $339,326                | $339,000                | 10.7                  | -$673,000             | $626,000              |
| 1,100         | 1,035                               | 90%                                  | $3.40                | $815,994                           | $26,768                         | $3.6                                 | $0                            | $3.6                             | 3                               | $815,994                         | $0.013                       | $0.016                      | $212,920                 | $576,305                | $576,000                | 6.30                  | $1,394,000            | $3,602,000            |
| 633           | 591                                 | 90%                                  | $0                   | $466,257                           | $0                              | $2.3                                 | $0                            | $2.3                             | 3                               | $466,257                         | $0.013                       | $0.016                      | $150,076                 | $316,181                | $316,000                | 7.2                   | $477,000              | $1,689,000            |
| 633           | 568                                 | 90%                                  | $#447,811            | $1,1834                            | $-1,1834                        | $2.3                                 | $0                            | $2.3                             | 3                               | $447,811                         | $0.013                       | $0.016                      | $147,125                 | $302,521                | $303,000                | 7.5                   | $364,000              | $1,525,000            |
| 848           | 572                                 | 90%                                  | $0                   | $451,316                           | $0                              | $3.1                                 | $0                            | $3.1                             | 3                               | $451,316                         | $0.013                       | $0.016                      | $145,743                 | $305,573                | $306,000                | 10.0                  | -$384,000             | $789,000              |
| 848           | 783                                 | 90%                                  | $1.88                | $617,317                           | $14,847                         | $3.1                                 | $0                            | $3.1                             | 3                               | $617,317                         | $0.013                       | $0.016                      | $174,422                 | $428,049                | $428,000                | 7.1                   | $680,000              | $2,321,000            |
2 Engine Phased Solution

- Sizing based on 620 kW engine with future 2\textsuperscript{nd} engine
  - Sizing fit historical data best
  - Allowed for most high efficiency engine supplies
  - Best compatibility for typical electrical demands
  - Minimal gas blending (only for daily flow variation's)

- Acceptable initial project payback

- Improvements project economics based on smaller investment for second engine. Safe solution
## Specifics on Engines

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<th>Manufacturer and Engine Generator Model</th>
<th>Electric output, kW</th>
<th>Fuel input to the engine</th>
<th>Heat output, MMBtu per hour</th>
<th>Exhaust emissions</th>
<th>Remarks</th>
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<td>DG Fuel, cfm</td>
<td>Btu per kWhr</td>
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- Per natural gas fuel data
- Per low Btu fuel (digester gas)
- Set at engine’s best efficiency
- Per natural gas fuel data
- Set at engine’s best efficiency
- Per natural gas fuel data
Natural Gas Blending

• Identified as good tool to improve operation
• Concerns over daily gas variability
• Help with managing daily gas flow variations in lieu of expensive digester gas storage
• Useful during start up for stable operation and isolation of the digester

• Potential economic benefits
  • Use “spark gap” to projects advantage
  • Excessive gas use increases O&M costs
Design Approach for Blending a Balance Between Annual and Daily Gas Flows

OPTION 3

- Engine Fuel Consumption
- Supplement with a small amount of Natural Gas
- Gas Production

GAS PRODUCTION
Cubic Feet/Hour

TIME OF DAY

Brown and Caldwell
Issues Associated with Blending

- Variations in experience with selected engine suppliers
  - Difficulty based differing BTU values
  - Had to design around “worst case scenario”
  - Specified stand alone blending system
  - Allowed for manufactures to self perform if experienced.
  - Choose to design for future engine

- Coordination with Gas utility
  - Define who performs extension of existing gas line
  - Existing gas meter rated at 16,000 cfh
  - Max demand of single engine (Start up condition) 22,000 cfh
Regulatory Considerations

- Air Emissions
  - Preliminary calculations performed to determine major source threshold
  - Uncertainty associated with permitting process and unknown engine performance
    - Many agencies driving towards MACT
  - Risk associated with construction delays and or increased O&M cost

- Electrical Inteconnection
  - Significant changes in application process if back-feeding
  - Issues onsite electrical distribution network
  - Determines new interconnecting switchgear requirements
Creative Solutions

• Confirmed decision to not pursue electrical backfeeding
  • Output of CHP system below minimum electrical demand

• Worked with RIDEM to eliminate risk of additional exhaust treatment
  • Confusing regulations required multiple reviews and discussions (BC and NBC)

• Performed preliminary permit application with design

• Developed timeline within construction documents to mitigate schedule and cost impacts
Current Status

• Bids received and awarded to low bidder
  • Engineers Estimate - $4.9 million
  • Low Bid - $6.44 million (Approximately $1.55M in grants expected)

• Engine selected met expectations
  • Reputable supplier packager
  • Air permitting process in progress

• NBC able to secure grants to improve project financials

• Updated project payback approximately 14 years
Final Payback

Cumulative Cash Flow

Biogas Engine Payback

Year

Capital Cost after grants = $4,890,000

$0

$2,000,000

$4,000,000

$6,000,000

$8,000,000

$7,272,577

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Key Lessons Learned

• Driving for highest payback isn’t always best approach
• Must define and constantly work to meeting project goals
• Understanding all aspects of technical limitations and issues
  • Many of these can be very site specific. No rules of thumb.
• Managing construction budget can be complicated
  • Basing decisions on conceptual or preliminary cost estimate can be challenging
• Potential for increased savings with addition of 2\textsuperscript{nd} engine
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QUESTIONS