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
  - ADWF ~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

Project Specifics

- 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

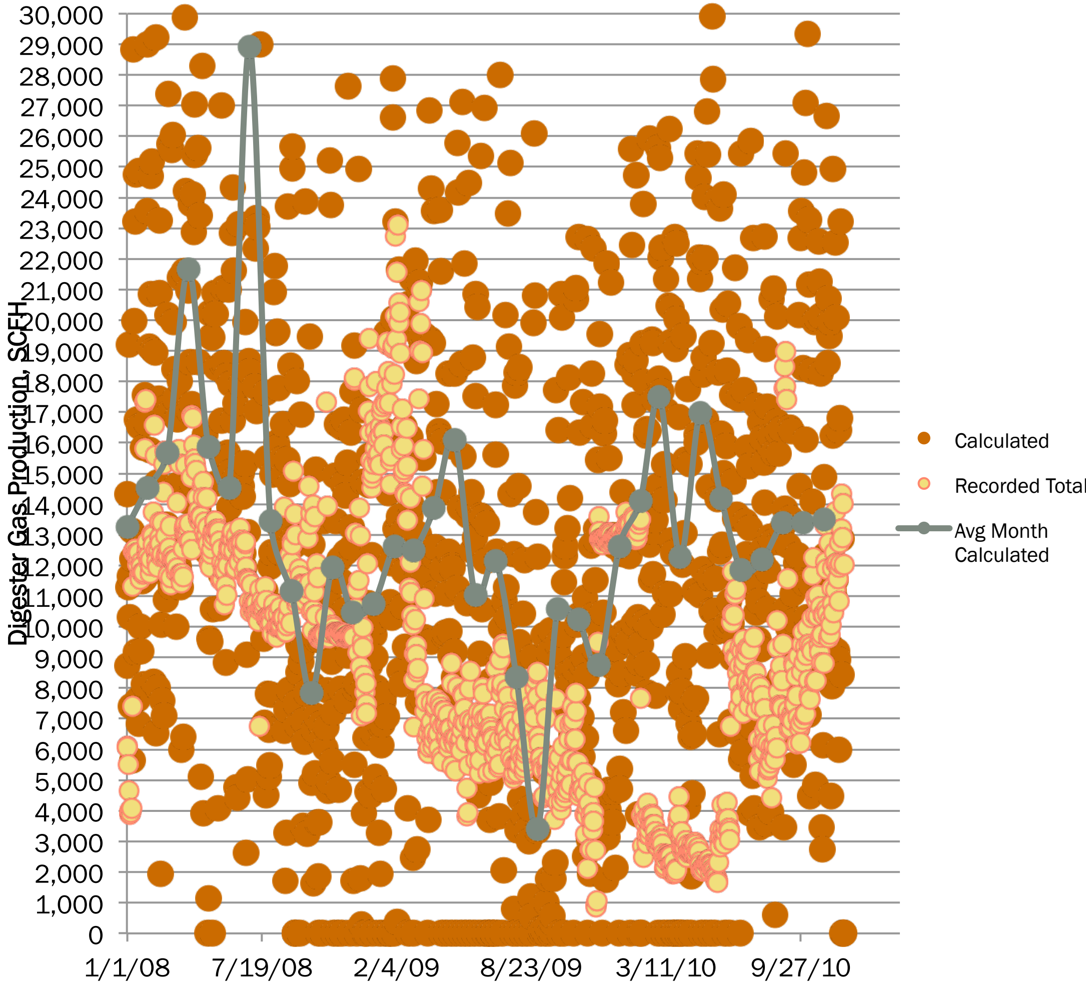
- Siloxanes are silica based derivatives of personal care products
- Turns into abrasive sand like substance
- Varying negative impacts
  - Reduce boiler transfer efficiency
  - Increase gas treatment O&M costs
  - Create significant wear on cylinders
- BP experience
  - Estimated boiler efficiency reduced 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

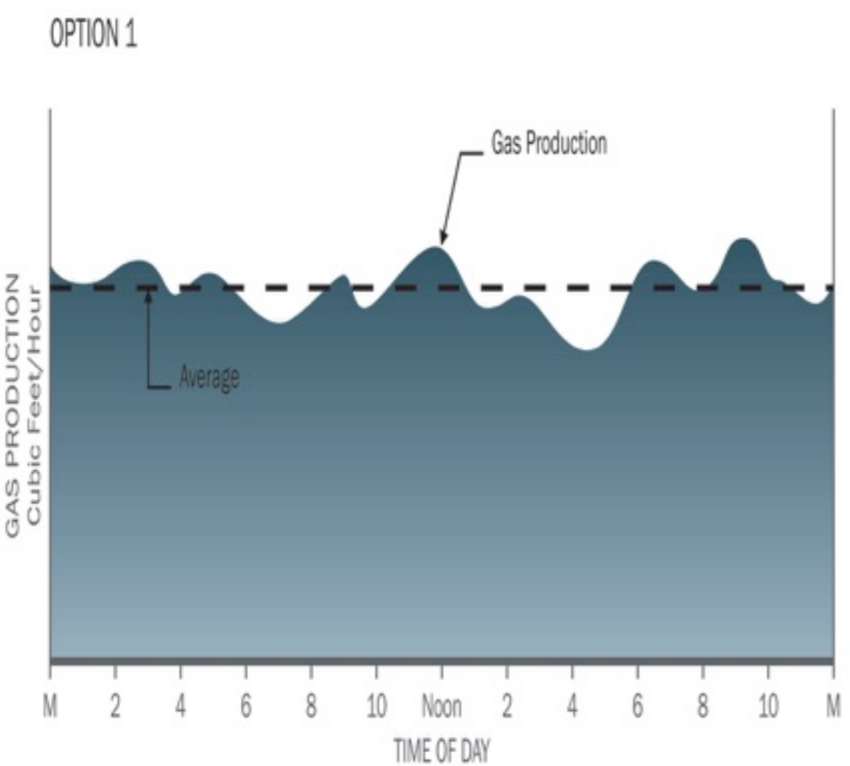
- What gas flow condition should be used for design and for sizing of the engine?
- Gas flow meters vs. mass balance calculations?
- 2009 feasibility study mass balance calcs showed significant variability as well

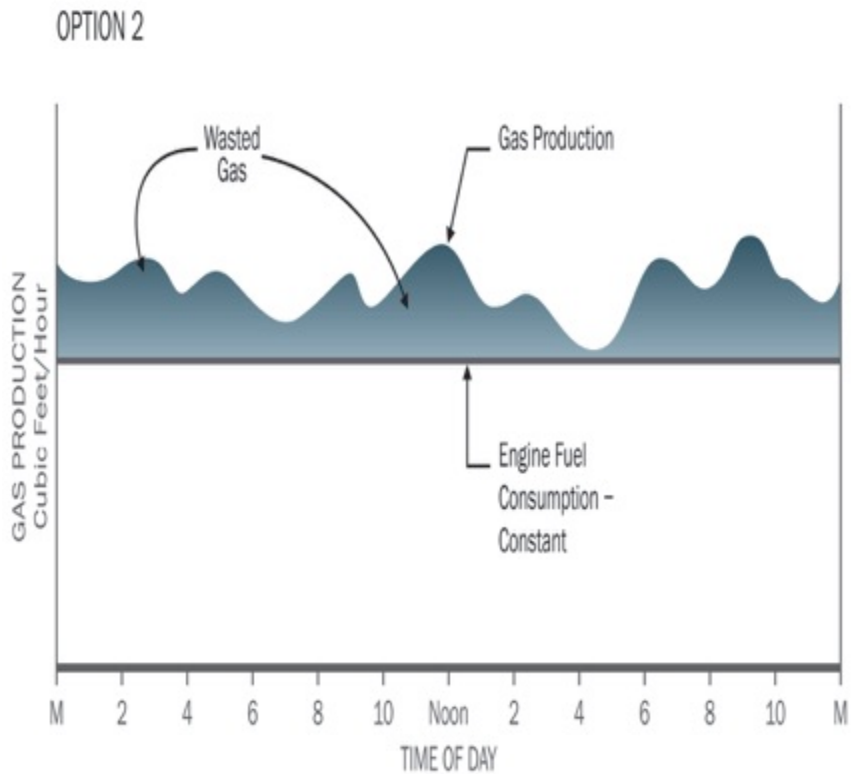


Key Impacts

- 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 avail-ability	NG fuel cost per hour	Yearly value of added electric power	Yearly cost of added natural gas	Estmtd project cost, approx, million $	Grant or rebate, million $	Cost with rebate, approx mill $	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	-$1,834	$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 2nd 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

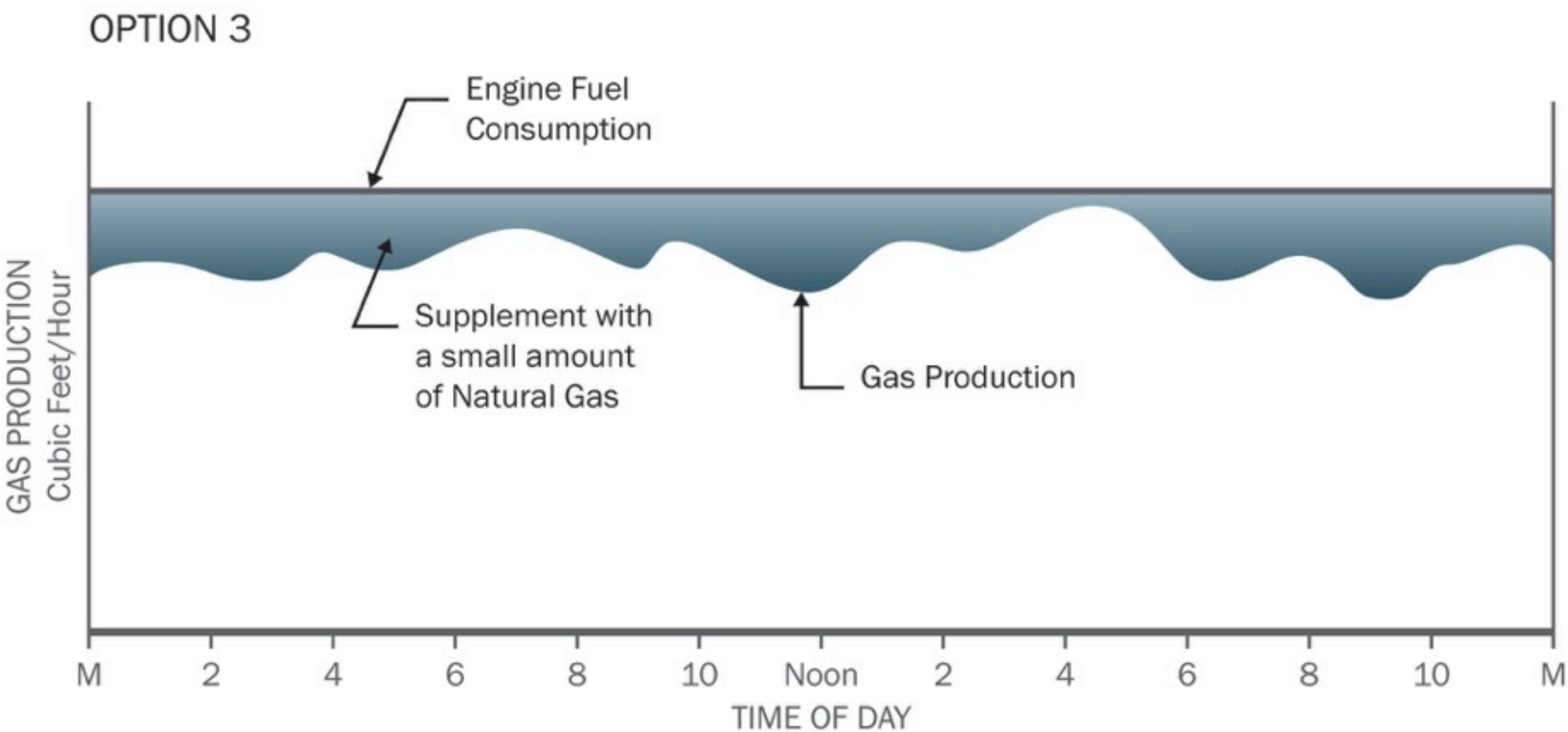
Specifics on Engines

Manufacturer and Engine Generator Model	Electric output, kW	Fuel input to the engine			Heat output, MMBtu per hour	Exhaust emissions		Remarks
		MMBtu per hour, LHV	DG Fuel, cfm	Btu per kWhr		NOx	CO	
Caterpillar G3512LE[a]	586	5.86	175	10,009	3.40	2.0	1.9	Per natural gas fuel data
Caterpillar G3516LE[e]	823	9.05	269	11,010	4.05	2.0	3.1	Per low Btu fuel (digester gas)
GEJenbacher J312	633	5.67	169	8958	2.68	1.1	NA	Set at engine's best efficiency
Guascor SFGLD480[b]	649	6.07	181	9351	NA	2	1.5	Per natural gas fuel data
MWM TCG 2016[c]	600	4.95	147	8324	2.85	<1.1	<2.65	Set at engine's best efficiency
Waukesha VGF36GLD[d]	642	6.06	180	9445	2.61	2.0	1.3	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



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

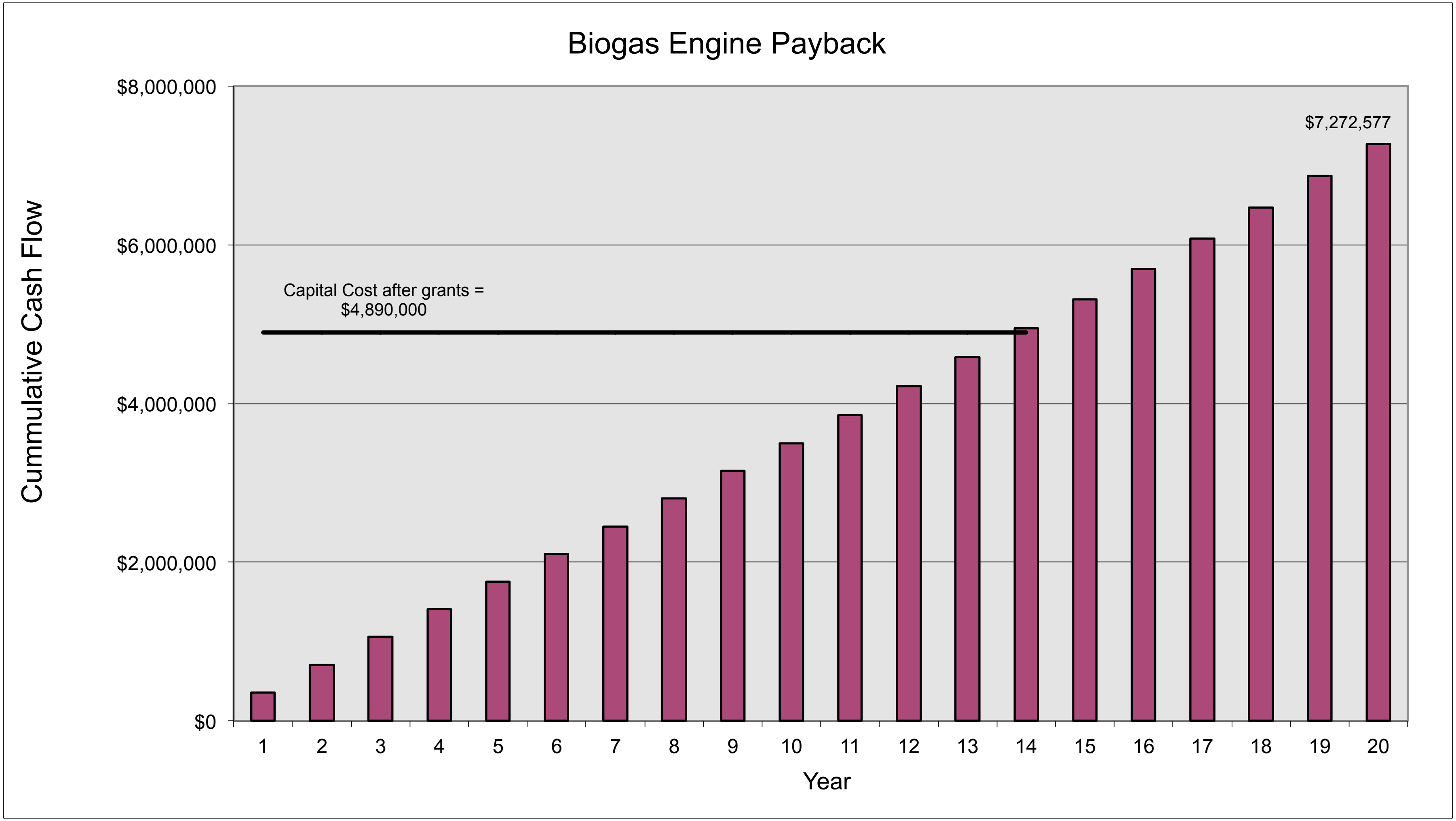
Creative Solutions

- 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



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^{nd} engine

Acknowldegments

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QUESTIONS