WASTE TO FUEL PROGRAM
CITY OF MANTECA WQCF

September 18, 2019

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HERWIT ENGINEERING

ICM
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WESTERNWATER

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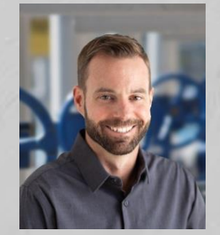
Gregory Harris, PE

Funding Partners:

California Energy Commission (CEC)
San Joaquin Valley Air Pollution Control District (SJVAPCD)



Luke McGarva

Background

WQCF - Biogas and Biosolids Utilization Plan

- Undertaken to evaluate existing infrastructural needs and opportunities for management of biosolids and biogas at the WQCF.
- Existing Infrastructure
  - Waste Activated Sludge (WAS) Pump Station
  - Waste activated sludge thickening with dissolved air floatation (DAF)
  - Two 60-foot diameter anaerobic digestors of primary and thickened WAS
  - Anaerobic digester control building with associated equipment
  - Biogas utilization facilities consist of the following:
  - Gas candle-style flare used to burn waste biogas
  - Boilers to heat anaerobic digesters
  - 450 kW Waukesha Model F3512 GLD biogas fired electrical generator(currently abandoned)
- Regulatory Environment
  - National Pollution Discharge Elimination System (NPDES) permit,
  - United States Environmental Protection Agency (US EPA) Standards for the Use or Disposal of Sewage Sludge (40 Code of Federal Regulations (CFR) Part 503),
  - State Water Resources Control Board (SWRCB) Water Quality Order No. 200-10-DWQ (also known as the State General Order).
  - SJVAPCD Rule 4307 Boilers, Steam Generators, and Process Heaters - 2.0 MMBtu/hr to 5.0 MMBtu/hr.
  - SJVAPCD Rule 4311 Flares
  - SJVAPCD Rule 4702 Internal Combustion Engines

Background

WQCF - Biogas and Biosolids Utilization Plan

Background

WQCF - Biogas and Biosolids Utilization Plan

Biosolids

- Could not meet Class B requirements for a portion of the year.
- Existing Digesters could not meet 15-day hydraulic retention time (HRT) for current maximum month loading, and average loading conditions when one digester is out of service for cleaning. An additional 60-foot diameter digester must be on line by 7.7 mgd.
- Disposal at Landfill problematic with nonconformance, impending organics rules, and new contracts with Forward.

Biogas

- Existing Biogas boilers could not meet emissions standards of SJVAPCD.
- The boilers were in very poor condition, and well beyond their useful life.
- Biogas could not meet Rule 4307 reduction of incoming H2S in digester gas.
- The biogas flare could not meet emissions limits for SJVAPCD Rule 4311, 4801, and Best Available Control Technology (BACT) Guideline 1.4.4
- Flaring Biogas to atmosphere continuously and biogas not effectively utilized.

Digesters

- The domes on the existing Digesters were no longer structurally sound, and leaked gas to atmosphere.

Background
Solid Waste

- Address legislation for food waste diversion from landfills (AB1826 etc.)
- The initial primary goal of the City is to achieve 75% diversion of municipal solid waste, a goal of Assembly Bill (AB) 341 and SB 1383.
- During drafting of the Master Plan the State passed AB 1826, requiring recycling of commercial generated organic waste. This legislation, along with AB 32, altered the primary emphasis of the Master Plan, such that the 75% municipal solid waste diversion goal will include a significant component of organics recycling.
- After drafting and initial review of the Master Plan the California Air Resources Board (ARB) issued a concept paper regarding development of regulation to control short-lived climate pollutants (SLCP), pursuant to Senate Bill (SB) 605. Subsequently SB 1383 supports 50% diversion of all organic waste by 2020 as outlined in AB 341, and 75% diversion by 2025.
- For the City to meet these proposed requirements the City will need to recycle both commercial and residential organic waste.
- With full implementation, residential processing and disposal costs could be reduced up to 80%, and the City could produce up to 500 diesel gallon equivalents (DGE) of renewable-compressed natural gas (R-CNG).

Background

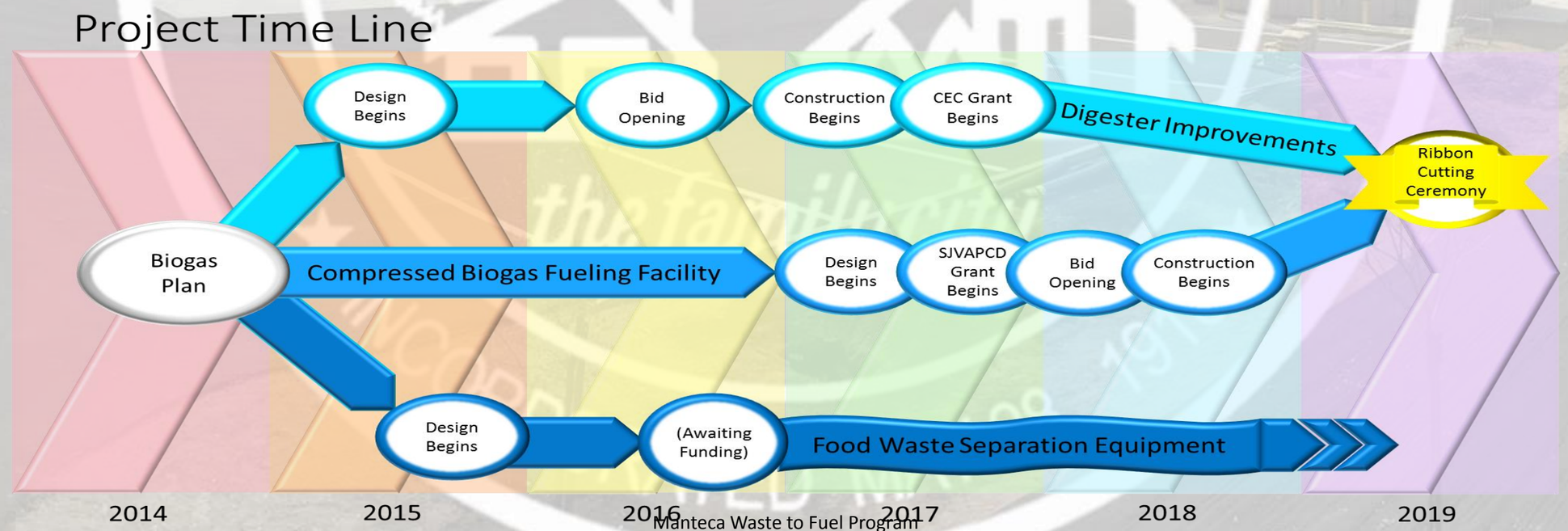
Synergies

- Biogas utilization and fuel needs of solid waste fleet
- Added digester for digestion system redundancy, extra gas production and growth capacity.
- Economy of scope, floating roofs for gas storage in lieu of fixed roofs for minimal added cost (~$18,500 additional per roof to switch floating roof; $843,000 total for two roofs).
- Clearing, grubbing, earthwork and foundations, general civil, electrical, communication, etc.
- Expansion of new building, SCADA, and various integrated systems
- Land currently available for expansion, but under development pressure. No land acquisition cost now.
- Regional organics disposal needs

Timeline

- Award Biogas/Biosolids and Solid Waste planning contracts — April 2014
- Program projects added to CIP — February 2016
- Biogas and Biosolids Utilization Plan completed — April 2016
- Begin design of Digester Improvements Project — June 2015
- Apply for CEC Grant — March 2016
- Apply for SJVAPCD Grant — April 2016
- Receive Notice of Acceptance SJVAPCD Grant — June 2016
- Complete design and advertise Digester Improvements — July 2016
- Bid Opening – Digester Improvements Project — August 2016
- Award construction contract digester; NTP — December 2016
- SJVAPCD grant agreement executed — July 2017
- CEC grant agreement executed — July 2017
- Begin design of (CBFF) — March 2017
- Complete design and advertise CBFF — December 2017
- Bid Opening CBFF — February 2018
- Award construction contract CBFF; NTP — May 2018
- Substantially complete phase II of Digester — June 2019
- Substantially complete phase III of Digester — June 2019
- Substantially complete CBFF, — pending (in functional testing)
- Final complete digester — pending
- Final complete CBFF — pending

1. CBFF: Compressed Biogas Fueling Facility, Phase II Project



Funding

Capital Funding

- Municipal Rate payer funds
  - Loan to Solid Waste from Sewer for initial capital investment, to be repaid with interest ~1.5%
- Municipal Bonds
- CEC Alternative and Renewable Fuel and Vehicle Technology Program Grant ($3.004M)
- SJVAPCD Public Benefit Program, Alternative Infrastructure Project Grant ($1.893M)

RIN Credit and LCFS

- RINs compensate capital investment by providing increased future cash flow.
- Energy Policy Act of 2005 and Energy Independence and Security Act of 2007 created the Renewable Fuel Standard (RFS).
- Under RFS, Renewable Identification Numbers (RINs) Utilized to track marketable new assets.
- RIN is equivalent to 77,000 BTUs of renewable fuel energy.
- D3 versus D5 credits:
  - D3 credits comprise Cellulosic Biofuels - Cellulosic ethanol, cellulosic naphtha, cellulosic diesel, Renewable CNG/LNG, etc.
  - D5 credits comprise Advanced Biofuels - Sugarcane ethanol, renewable heating oil, biogas, etc.

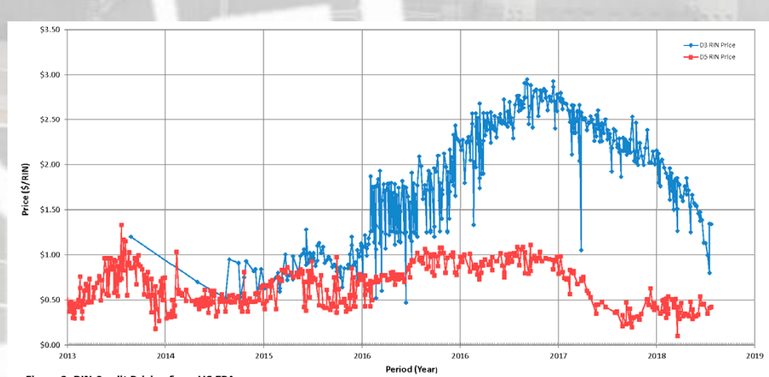
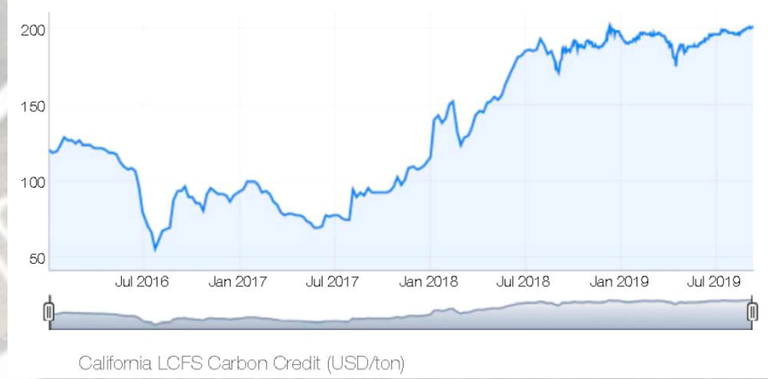


Figure 2. RIN Credit Pricing from US EPA



Environmental Benefits

Solid Waste Stream

<u>Organics removal</u>

- Food Waste
- FOG

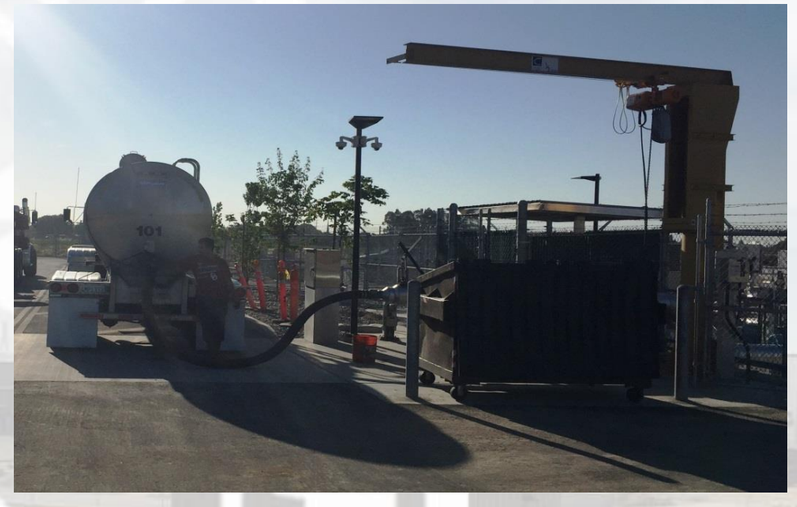
<u>Cleaner, reliable fuel supply</u>

- Renewable CNG from Biogas
- Periodic shut downs at Clean Energy, and/or Ripon

<u>Replacement of old diesel burning trucks</u>

- Older trucks had to be replaced to meet new emissions control regulations.

<u>Reduce Greenhouse Gas emissions from Landfills</u>



Environmental Benefits

WQCF Emissions

<u>Replaced Old Flare</u>

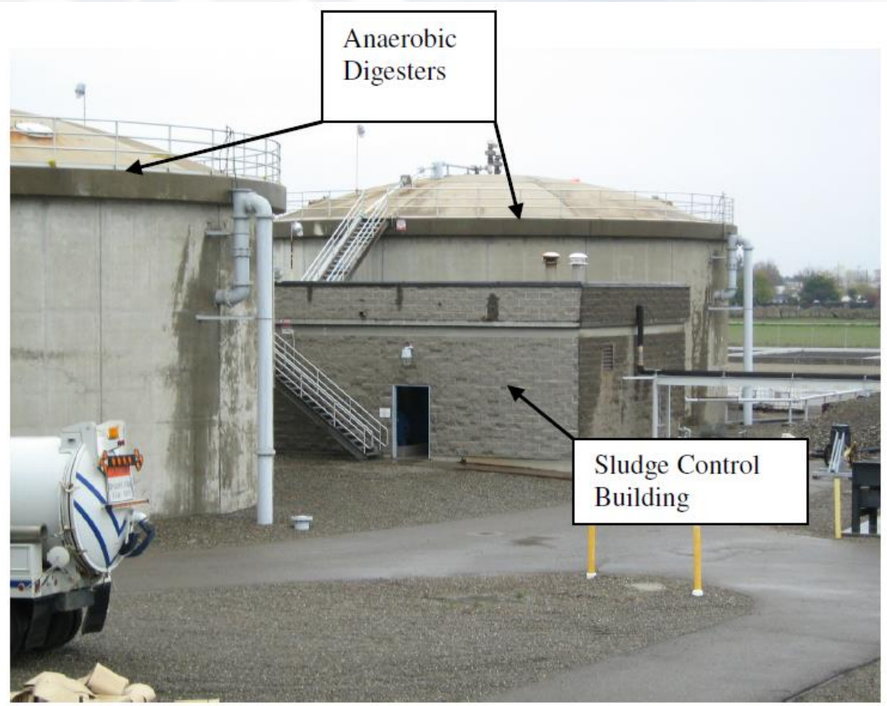
- Grandfathered, sulfur non-compliant candle flare, Reduce NOx and CO_2
- Unreliable, hard to restart

<u>Replaced Old Boilers</u>

- Grandfathered, sulfur non-compliant boilers, reduce NOx and CO_2
- Old, undersized

<u>Rehabilitated Existing Digesters</u>

- Leaking gas and undersized (Operational since 1983)



Environmental Benefits

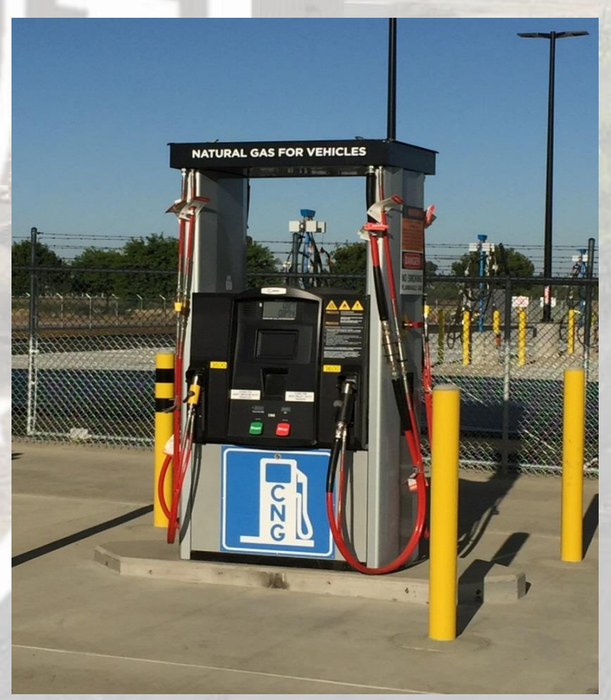
Renewable Fuel

<u>Offsets Diesel Usage</u>

- Reduce emissions of aromatic carcinogens
- Offset about 115,000 DGE/yr initially; 810,000 DGE/yr at buildout
- (Usage about 35 to 40 DGE per day per truck on average.)
- Have been acquiring CNG Heavy Fleet replacements since the Waste to Fuel Program began development in 2015.
- Currently have 9 CNG Garbage trucks in a fleet of 24. (Also 2 CNG Vacter/Vacon trucks acquired.)

<u>Produces a sustainable renewable fuel – R-CNG</u>

- Produces fuel from readily-available, reliable, consistent waste streams - wastewater solids, FOG, and food wastage
- Preliminary estimates of carbon intensity for CARB pathway for the Food to Waste Program could range from +15 CO2e /MJ to -35 CO2e /MJ
- As part of RIN and LCFS application, formal CARB pathway modeling will be performed.



<u>Reduces risk of polluting groundwater and surface waters</u>

- R-CNG doesn't pool and infiltrate or runoff.

Project Costs

CAPEX

- Construction, CM, Design, Permitting Cost ~$34,220,000.
- Food Receiving, FOG Receiving, and CNG Production & Dispensing Cost ~$15,600,000.
- Staff PM ~$365,000 loaded cost, ~$210,000 attributable to CNG related.
- Modeling, and application to generate RIN and LCFS Credits ~$50,000.

OPEX

- O&M Agreement for CNG Maintenance ~$65,000 per year upto $250,000 per year.
- Daily staff rounds for CNG Inspection ~$7,000 per year.
- O&M Agreement for BioCNG ~$10,000 per year, one time ~$25,000 first year.
- O&M staff maintenance for BioCNG ~$12,000 annually.
- O&M for Sulfatreat ~$45,000 annually.
- Ferric Chloride ~$250,000 annually.

Replacement

- BioCNG, Compressors and Blowers, and Dispensers in 10 years (Est. cost $3.15M).
- Expansion – add second BioCNG unit, 3 more rack of high pressure tanks, 2 more compressors, and other minor ancillaries in 5 years(Est. cost $3.7M).

Project Revenues

Revenues from Sale of Diesel

- Unit Conversions
  - Standard unit for fuel dispensing is the Gasoline Gallon Equivalent (GGE).
  - For Heavy Fleet Vehicles sometimes Diesel Gallon Equivalent (DGE) is used.
  - Diesel Gallon Equivalent is ~129,500 BTU, Gasoline Gallon Equivalent is ~114,000 BTU, Biogas is ~77,000 BTU at STP.
  - BTU rating of CNG gas changes depending on purity, temperature and pressure; Ideal Gas Law (PV=nRT).
  - (1 GGE is equal to 126 cuft of CNG at standard conditions. 1 DGE equal to 1.1360 GGE.)
- Market Price
  - City pricing structure slightly more stable than retail market and less costly because purchase in bulk monthly or bimonthly.
  - Price range from ~$1.74 to ~$4.28 per gallon for the City with the recent average of ~$3.43 per gallon. Retail Market prices are higher.
  - local CNG prices range from
    - $1.30 to $3.36 per gge at PG&E Stockton since 2007; March pricing $2.86 per gge.
    - $2.02 to $2.94 per gge at City of Ripon since 2009; August pricing $2.94 per gge.
    - $2.37 to $3.20 per gge at Clean Energy Lathrop since 2016; May pricing $3.20 per gge.

Project Revenues

Revenues from Sale of RINS Credits

- Market Price and Volatility
  - D3 Price range from $0.52 to $2.93 per gasoline gallon equivalent (GGE) with a average of ~$2.02 (σ=$0.54) since 2016 (~$3.40 per DGE).
  - D5 Price range from $0.15 to $1.15 per gasoline gallon equivalent (GGE) with a average of ~$0.71 (σ =$0.24) since 2016 (~$1.19 per DGE).
- Reimbursement to Brokers
  - Typically about 30% to 50% depending on project size and credit type.
- Expected Value after brokers fees
  - Initial expected sales w/ 10 CNG trucks total 109,000 DGE/yr for revenue after broker fees of between ~$300k and ~$445k, depending of RIN type.
  - w/ 16 CNG trucks total 182,500 DGE/yr for revenue after broker fees of between ~$505k and ~$745k, depending of RIN type.

Revenues from Sales of LCFS Credits

- Market Price
  - Biogas from food waste LCFS Credit price ~$22 per mmBTU.
  - Biogas from municipal wastewater LCFS Credit price ~$14 per mmBTU.
  - Revenue ~$145,000 growing to ~$200,000 at 16 trucks (WW only) net fees

Revenues from FOG

- Market Price
  - FOG tipping fee range from $9.75 to $326.00 per 1000 gallon with Manteca preliminary fee estimate at about $90 to $165 per 1000 gallon.

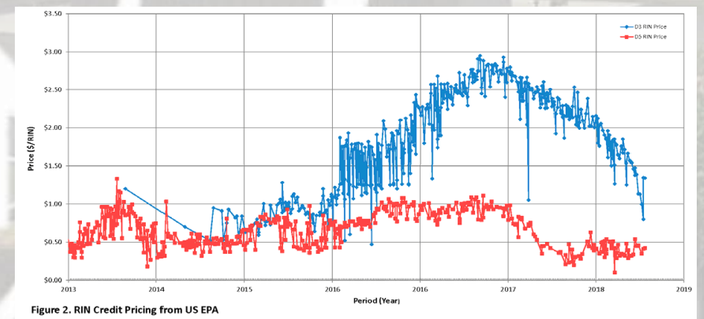
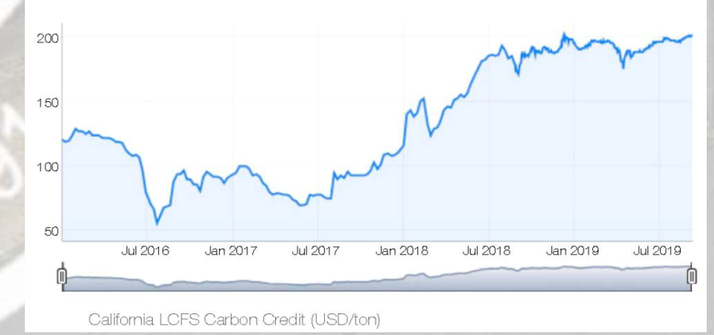


Figure 2. RIN Credit Pricing from US EPA



Planning Considerations

Siting, Sizing and Location

- Involve Stakeholders early and keep them involved
- Access to PG&E Gas Main with capacity to support facility.
- Proximity to DAF, Primary Sludge, and Centrifuges
- Redundancy for down time for cleaning and repairs,
- Capacity for 15 day retention for Class B treatment.
- Sizing Tanks and cycle times, e.g. FOG Storage, Gas Storage, Dispensing times

CEQA and Environmental

- Meet with stakeholders and conduct public outreach early.
- Habitat mitigation can be expensive on per acre basis.
- Schedule Biologist coordinated with disturbance activities.

Geotechnical considerations

- Soils, compaction, compressibility of subsoils, differential settlement
- Seismic liquifaction and consolidation.
- Drainage.
- Groundwater and dewatering.

Design Considerations

Drawings

- Grades and slope arrows, notes and call outs are critical, nothing is obvious to the contractor – Errors and Omissions
- Coordinate drawings
- What you push to the contractor to interpret can be very problematic, since their bids may anticipate something other than designed by manufacturers
- Coordinate details and get written buy off from vendors
  - Boiler #3
  - Westech Floating Roofs and Ballast blocks
- Clarity and understanding in use of existing standards, e.g. CalTrans, City, etc..

Specifications

- There is always another way to conduct the work than considered in design.
- Clarity and understanding in use of existing standard specifications, e.g. CalTrans, City, etc..
- Include measurement and payment sections
- Multiple bid items and unitize cost to allow adjustment later

Front End

- Review and revise as needed; More effort here will save on future headaches.

Bidding Considerations

<u>Prebidding</u>

- Coordinate with PG&E and local agencies (SSJID) for easements, connections/metering, and other approvals - It can take them a very long time to get supporting work completed.

<u>Bidding</u>

- Multiple bid walks to hedge against schedule conflicts - scheduled at least two weeks advance at time of noticing.
- Longer bidding periods, complicated projects requiring very specialized subcontractors differing from normally associated with Primes
- Longer Q&A periods
- Clearly disclose coordination requirements for Granting agencies, operations and other projects onsite.
- Clearly disclose PG&E and other utilities coordination requirements.

Construction Considerations

Schedule and structure of subcontractor agreements

- Primes tend to be generalized to the Wastewater Industry, but a specialized subcontractor is required for a major portion requires psuedo design-build for custom CNG facilities.
  - Each specialized CNG subcontractor has their own standard designs and practices.
  - Specialized subcontractors tend to come from private commercial industry, less familiar with public agency statutory requirements and project delivery standards; contracts need to be well-defined, and some flexibility may be required but limited.
    - Laws of State of California, Jurisdiction San Joaquin County needs to be clearly defined

Construction defects and deficiencies

- Concrete cracks and paving defects
- Coatings on piping and fittings
- Steel welding

Construction Claims

- About 97 CPRs
- Ignorance in Bidding
  - Foam Roofing
  - Ballast blocks
  - Roof support
- Lack of Clarity

A little more effort and time in planning, design, inspection and testing can save a lot of headaches and cost during construction.

Operational Considerations

Issues

- Interaction with other operational activities - Too many concurrent construction projects.
- Transition and hand over from contractor to operations
- CNG Startup required daily sometimes hourly interaction with the Contractor because each system of the CNG process was relying on another to be able to run correctly.
- Flare startup had issues - Flame kept going out and not restarting.
- Blower staging caused issues with the performance of the Boilers - Low pressure caused the Boilers to surge.
- BioCNG Waste Off-Gas boiler took a long time to get tuned, 5 weeks – Substantial overtime incurred due to monitoring and call outs.
- Floating Lid Levels were not balanced - Digester #4 would be at high level before Digester #3's lid would start to rise.
- Added complexity and operational flexibility may not translate to an intuitive system – pressure meters on sludge pumps overpressurized when valving shut.
- Equipment failures after installation - Meters and pumps, SCADA alarms, chemical line pumps, etc..

What went well

- Relationship between the contractor, construction management, construction engineer, PW engineer, and plant staff. Many obstacles were overcame and everyone worked as a team.

Take Away

ROI (DF of 2.5%) on this project exceeds 18 years (incl. cyclic Replacement/Rehabilitation Cost). Project make simple financial sense under current configuration. This project was developed anticipating future growth. With future expansion in 5 to 10 years it drops to less than 17 years. (D5 RINs and LCFS credits for biogas contributions from food waste lead to even higher returns and faster pay off).

Environmental and Financial Benefits to the City exceed the expenditure required, if CAPEX and OPEX are well managed and controlled, and supply is developed to meet demands:

- Active, knowledgeable management is critical.
- Synergies and Economy of scope are important consideration to optimize CAPEX.
- Coordination with Operations, Regulators, Permitting Agencies, PG&E are critical.
- A slightly greater increase in expenditures in planning and design can save substantially in construction and future OPEX.
- Economy of scale is critical, the initial investment allows for substantial cost reductions in future expansions, which were planned into design.
- LCFS Credits will improve return on investment, but it is not clear by how much until the CARB model for this system is developed.

Any Questions (or comments)?

For more information, please feel free to contact:

- Project Manager: Bret Swain, PE, MS, MBA
  bswain@ci.manteca.ca.us
  (209) 456-8418

Or go to the City website at:

https://www.ci.manteca.ca.us/PublicWorks/Pages/Waste-to-Fuel-Program.aspx

Attachment

Table 2.3-1 Digester Facilities

Table 2.3-1, Digester Facilities

Item	Value
Anaerobic Digesters	
Number	2
Inner Diameter, ft	60
Sidewall Height, ft	26
Max Water Depth, ft	25.33
Capacity, Each, gal	523000
Gas Storage Capacity, ft^3	29000
Sludge Heating Pumps	
Equipment Number	P1111, P1112, P113
Motor Size, Each, hp	5
Pump Capacity, Each	150 gpm @ 20 ft
Sludge Heat Exchangers	
Equipment Number	ME1131, ME1132
Heat Capacity, Each, Btu/hr	750,000
Hot Water Boilers	
Equipment Number	ME1161, ME1162
Heat Capacity, Each, Btu/hr	2,000,000 input, 1,600,000 output
Hot Water Circulation Pumps	
Equipment Number	P1121, P1122
Motor Size, Each, hp	2
Pump Capacity, Each	150 gpm
Digester Mixing Pumps	
Equipment Number	P1101, P1102
Motor Size, Each, hp	20
Pump Capacity, Each	13200 gpm @ 9 ft

Attachment

Table ES-1, Diversion Program Phases

Table ES-1, Diversion Program Phases

Diversion Program (By Priority)		Annual Tons Diverted	Annual Tons Landfilled	% Diversion
Existing Programs		85,222	57,467	60%
Proposed New Diversion Programs				
Required By AB 1826	1. Commercial Self Haul Food Waste	1500	55,967	61%
	2. Commercial Source Separated Food Waste	1910	54,057	62%
3. WQCF Biosolids to Land Disposal		8000	46,057	68%
4. Residential Brown Bin CRV Capture		669	45,388	68%
5. Residential Food Waste		9128	36,260	75%
6. Brown Bin Recycling non CRV		4950	31,310	78%

Attachment

Table 2.4-1, Dewatering Process Performance

Table 2.4-1, Dewatering Process Performance

Category	Parameter	Value
Sludge Feed	Type of sludge	Anaerobically digested primary and thickened waste activated sludge
	Solids concentration, %	1.5-2.5
	Temperature Sludge,° F	60-98
	Volatile solids content, %	60-65
	pH	7.0- 7.5
	Maximum particle size, in	1
	Flow rate, gpm	185
	Solids Loading, dry lbs/hr	1,540
	Minimum solids capture, %	95
	Maximum polymer dosing, lb/dry ton solids	23
Dewatered Cake	Solids concentration achieved, %	19

Attachment

Table 3.0-1, Manteca Biosolids Loading

Parameter	6.5 MGD Average	6.5 MGD Peak Month	10 MGD Average	10 MGD Peak Month
Influent Characteristics				
Plant Influent flow, mgd	6.5	6.5	10	10
Influent BOD Concentration, mg/l	317	317	317	317
Influent TSS Concentration, mg/l	279	279	279	279
Primary Solids Wasted				
Dry solids, lb/day	9,829	12,737	15,120	19,593
% Solids (average)	3.21	3.21	3.21	3.21
Flow, gal/day	36,679	47,531	56,423	73,118
Secondary Solids Wasted				
Dry solids, lb/day	5,784	7,550	8,832	11,549
% Solids (average)	0.85	1.1	1.3	1.7
Flow, gal/day	80,208	81,216	80,208	81,216
TWAS to Digesters				
Dry solids, lb/day	5,727	7,474	8,745	11,432
% Solids (average)	3.1	3.1	3.1	3.1
Flow, gal/day	22,152	28,909	33,823	44,218
Digested Biosolids to Dewatering				
Dry solids, lb/day	9,026	11,729	13,845	18,003
% Solids (average)	1.8	1.8	1.8	1.8
Flow, gal/day	58,832	76,440	90,246	117,336
Biosolids Disposal				
Dry solids, lb/day	8,575	11,143	13,153	17,103
% Solids (average)	19	19	19	19
Cake Produced, wet tons/day	22.6	29.3	34.6	45.0

Attachment

Table 9.1-2, City of Manteca Biogas Generation With FOG

Parameter	6.5 MGD Average	6.5 MGD Peak Month	10 MGD Average	10 MGD Peak Month
Biosolids Only				
Total VSS, Loading, lbs/day	13,059	16,964	20,039	26,045
VSS Converted, lbs/day	6,530	8,482	10,019	13,022
Gas Production, cf/lb-VSS Converted	16.5	16.5	16.5	16.5
Gas Production, cf/day	107,741	139,949	165,319	214,871
Higher Heating Value, BTU/cf	620	620	620	620
Higher Heating Value, BTU/day	66,799,141	86,768,393	102,498,085	133,220,049
Higher Heating Value, BTU/hr	2,783,298	3,615,350	4,270,754	5,550,835
Biosolids Combined with FOG				
Total Gas Production, cf/day	133,551	167,986	204,997	258,005
Higher Heating Value, BTU/cf HHV	655	655	655	655
Higher Heating Value, BTU/day	87,540,188	110,073,318	134,372,310	169,073,779
Higher Heating Value, BTU/hr	3,647,508	4,586,388	5,598,846	7,044,741
Increase in Heating Value, %	31.0%	26.9%	31.1%	26.9%

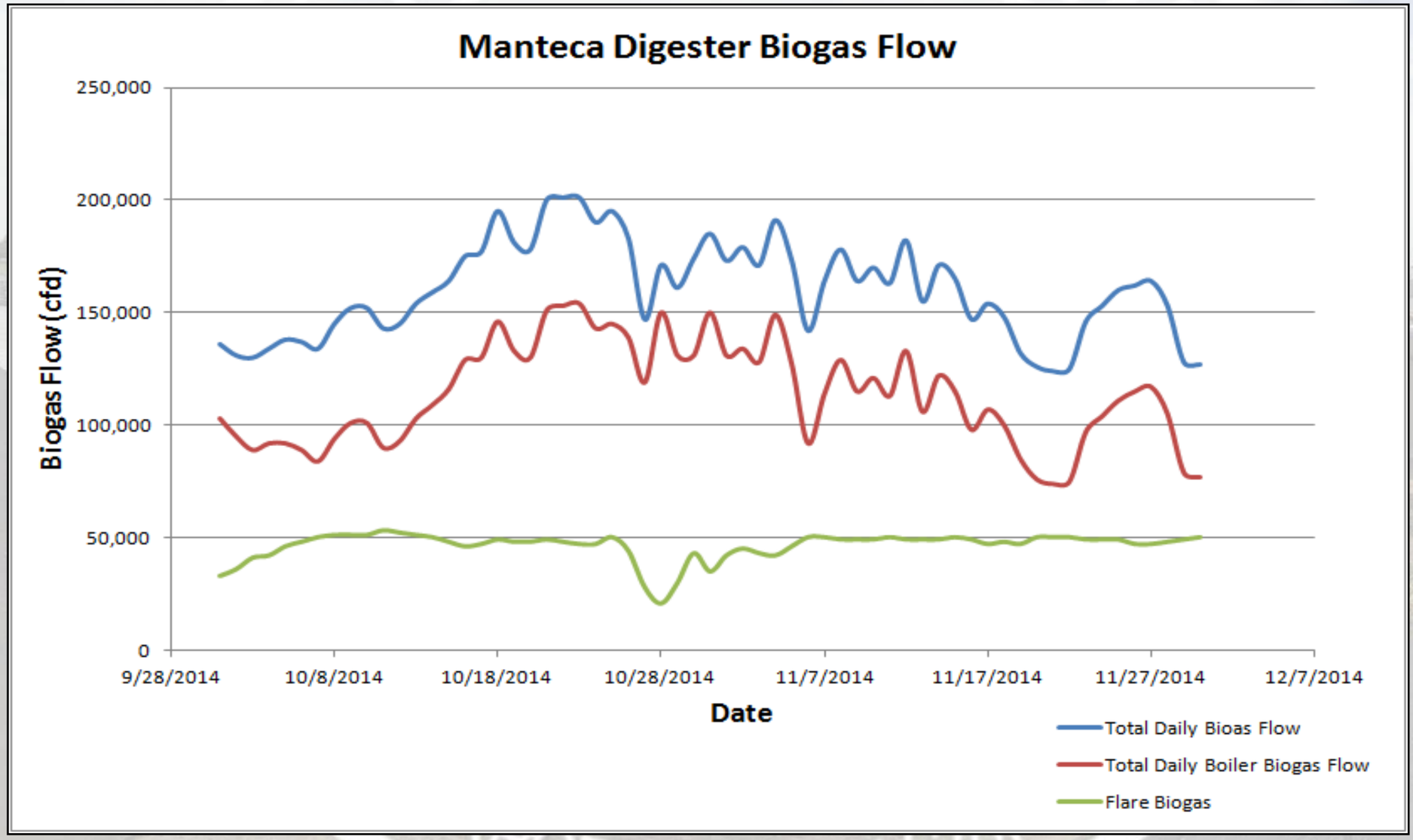
Attachment

Table 9.2-3 & 9.2-4, City of Manteca Biogas Generation from Food Waste

Parameter	Phase 1 Commercial Organics/ Self Haul	Phase 2 Commercial Organics/ Food Waste	Phase 3 Residential Organics/ Food Waste
Food Waste			
Generated, tons/year	1,500	1,910	9,128
Program Participation, %	100%	75%	61%
Received, wet tons/year	1,500	1,432	5,568
Total Food Waste Flow, gal/day	3,696	3,529	13,720
Total Gas Production, cf/day	17,951	17,143	66,634
Higher Heating Value, BTU/cf HHV	650	650	650
Higher Heating Value, BTU/day	11,667,936	11,142,888	43,312,032
Higher Heating Value, BTU/hr	486,164	464,287	1,804,668
Cumulative Increase in Heating Value vs Biosolids Only, %	17.5%	34.1%	99%

Attachment

Figure 7.0-1, Manteca Biogas Daily Production - 2014



Attachment

Figure 1. Weekly Retail Diesel Prices for California

Attachment

Figure 2. RIN Credit Pricing from US EPA data

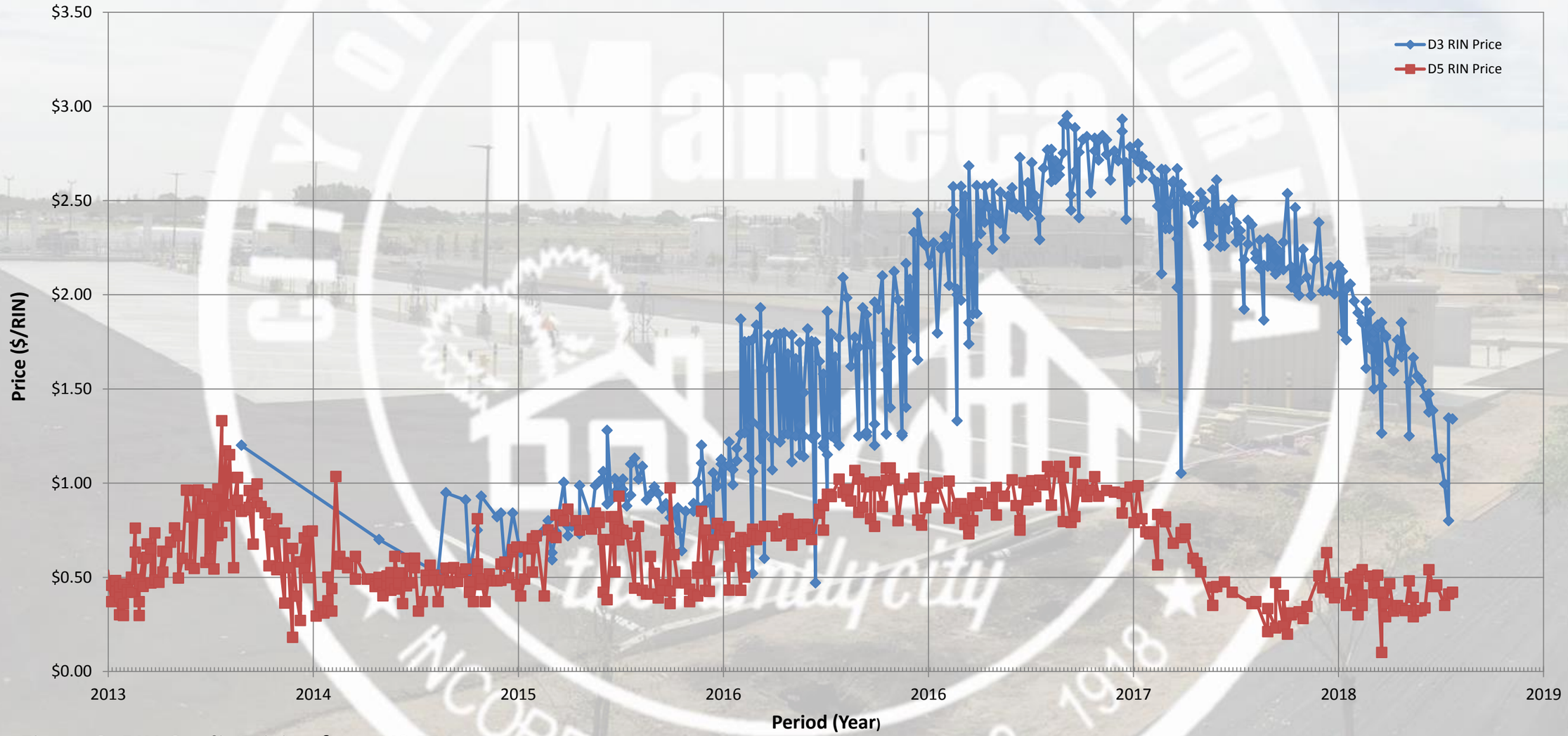


Figure 2. RIN Credit Pricing from US EPA

Attachment

Figure 3. LCFS Credit Market Prices

Attachment
Awards

- 2018 - Engineering achievement from California Water Environment Association - North San Joaquin Division (CWEA-NSJ)

- 2018 - 3rd place for engineering achievement California Water Environment Association (CWEA)

- 2019 - recipient of the Water Environment Federation (WEF) Project Excellence Award

References

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- https://www.ci.manteca.ca.us/PublicWorks/Engineering/CEQA_NEPA/ITMM Manteca WQCF Projects_Digester and Digester Control Bldg. Improvements Project_AECOM_241-300-50.pdf
- https://www.ci.manteca.ca.us/PublicWorks/Documents/Manteca Biosolids and Biogas Plan - Final.pdf
- https://www.ci.manteca.ca.us/PublicWorks/Documents/36266 - Solid Waste Master Plan (Final).pdf
- https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information
- https://advancedbiofuelsusa.info/us-cellulosic-waiver-credit-likely-to-be-1-77-in-2019-platts-analytics/
- http://www.altfuelprices.com/stations/MU1E2GI8W8TUEB0AGW2LGKC2
- http://altfueltoolkit.org/resource/the-lcfs-credit-price-calculator/
- Low Carbon Fuel Standard Simplified Calculator & Benefits of Co-digestion Presentation at CASA Biosolids & Renewable Energy Innovation Seminars. Anthy Alexiandes, CARB, September 11, 2019