Equipment Considerations for Landfill Gas Generator Sets: Total Cost of Ownership

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What Am I Doing Here?

- One year ago in Baltimore ….
  - Siloxane measurement presentation (SCS)
  - What is the siloxane reading on this LFG sample?
- Several labs …. different results!
  - No wrong answers, just different points of view.
  - Unit conversion nuances / Different test conditions / Different standards / Same standard, different insight.
- Hard to compare results without solid understanding of measurement techniques.

What Am I Doing Here?

- Somewhat similar scenario for genset data.
- Hard to compare estimates for total cost of ownership in LFGTE projects (5,10, 20 years)

  - How many kWe will this genset deliver at my job site?
  - What will be the engine fuel consumption at site?
  - What additional equipment does the genset require?
  - What assumptions are built into this O&M cost estimate?

Equipment Considerations for LFG Gensets

Agenda

- Equipment Ratings
- Capital Costs
- Efficiency v. Capacity
- Maintenance & Repair Cost

Ratings – Auxiliary Equipment Power

- For diverse technical and commercial reasons, many published kWe ratings do not include the power required to drive REQUIRED equipment
  - Pumps: water, oil
  - Inlet gas compressors
  - Radiator cooling fan
- If not taken into account, this could make the apparent genset kWe capability and efficiency larger than it is.

Ratings – Auxiliary Equipment Example

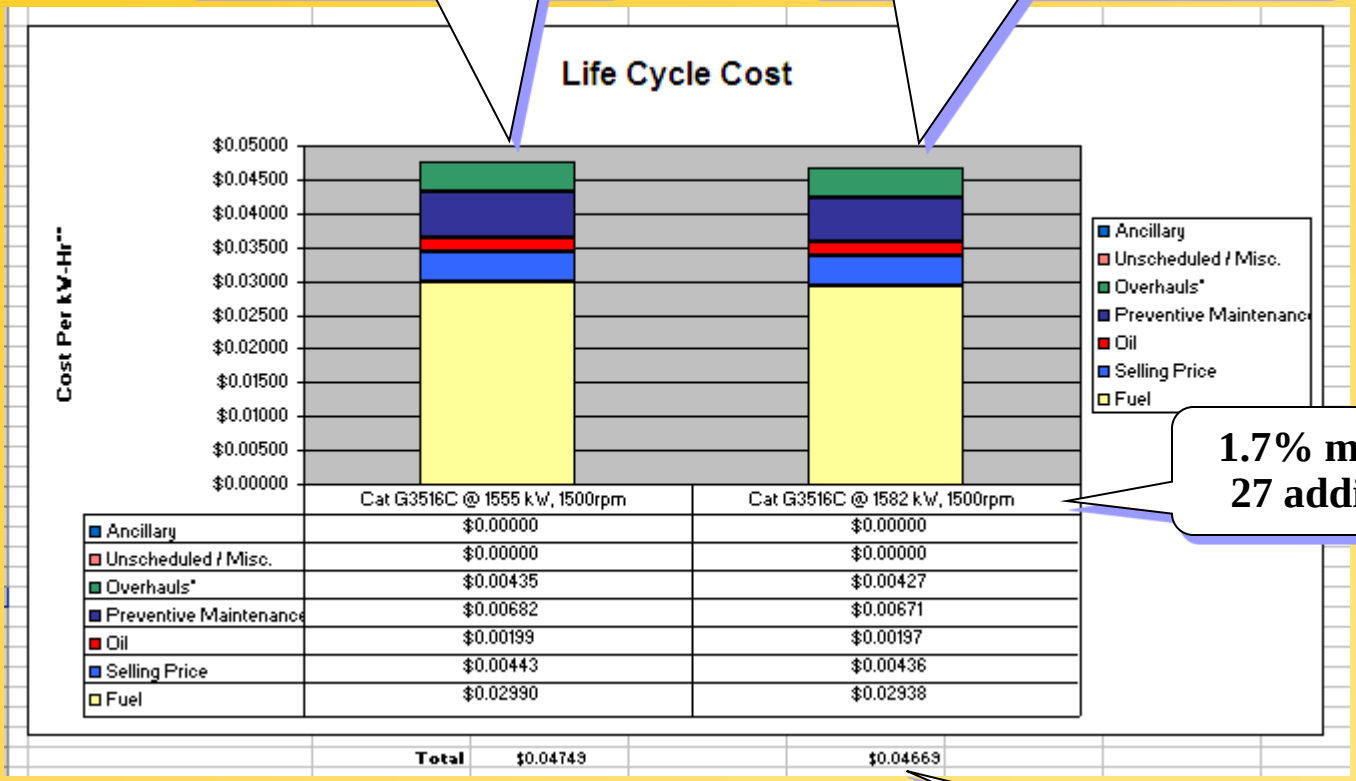
- Example: Cat gas engine ratings
  - Std. genset: Rating with water pumps (engine-driven)
  - CHP genset: Rating w/o water pumps (electric)
  - All Cat gas gensets rated w/o cooling fan losses (electric)

- CAT CHP genset: 2x electric water pumps consume approximately 30 kWe
  - Jacket water (JW), separate circuit aftercooler (SCAC)
  - Cost to operate: $13,000 to $25,000 per year

Life Cycle Cost & Water Pumps – G3516C

With Water Pumps

Without Water Pumps



	Cat G3516C @ 1555 kW, 1500rpm	Cat G3516C @ 1582 kW, 1500rpm
Ancillary	$0.00000	$0.00000
Unscheduled / Misc.	$0.00000	$0.00000
Overhauls*	$0.00435	$0.00427
Preventive Maintenance	$0.00682	$0.00671
Oil	$0.00199	$0.00197
Selling Price	$0.00443	$0.00436
Fuel	$0.02990	$0.02938
Total	$0.04749	$0.04669

1.7% more power; 27 additional kW

1.7% lower operating costs

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Ratings – Power Factor

- Genset kWe ratings depends on p.f. assumed for the load. Higher p.f. = higher kWe rating.
- However, p.f. of the load is site-specific.
  - Classical electrical engineering calculations and genset ratings developed around estimated ‘real-life’ p.f 0.8
  - Modern industrial sites: p.f. between 0.8 and 0.95
- Manufacturers moving to 1.0 p.f. ratings
- Customers need to adjust rating for their p.f.

Electrical Rating - Power Factor

CONTINUOUS 1950 ekW 2438 kVA
50 Hz 1500 rpm 400 Volts

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TECHNICAL DATA

Generator Set — 1500 rpm/50 Hz/400 Volts		DM 5831	DM 5833	DM 5835	DM 5837
G3520C Gas Generator Set					
Emission level (NOx)	mg/Nm³	447	221	464	230
Aftercooler SCAC (Stage 2)	Deg C	54	54	32	32
Package Performance (1)					
Power Rating @ 0.8 pf (with 2 water pumps and without fan)	ekW Continuous	1950	1950	1950	1950
Power Rating @ 0.8 pf (with 2 water pumps and without fan)	kVA Continuous	2438	2438	2438	2438
Power Rating @ 1.0 pf (with 2 water pumps and without fan)	ekW Continuous	1977	1977	1977	1977
Electric Efficiency @ 1.0 pf (ISO 3046/1) (2)	%	39.5	38.6	39.4	38.6
Mechanical Power (with 2 water pumps and without fan)	bkW	2026	2026	2026	2026
Fuel Consumption (3)					
100% load without fan	Nm³/hr	507	517	507	519
75% load without fan	Nm³/hr	391	399	393	403
50% load without fan	Nm³/hr	275	281	277	284
Altitude Capability (4)					
At 25° C (77° F) ambient, above sea level	M	350	350	360	222

A 1.0 p.f. Offers a 1.4% rating advantage (27 additional kW) over 0.8 p.f.

- Caterpillar publishing new gas genset ratings at both 0.8 and 1.0 pf.
- If a 0.8 p.f. rating was not published, a customer could overestimate his annual energy sale revenues by $23,000.

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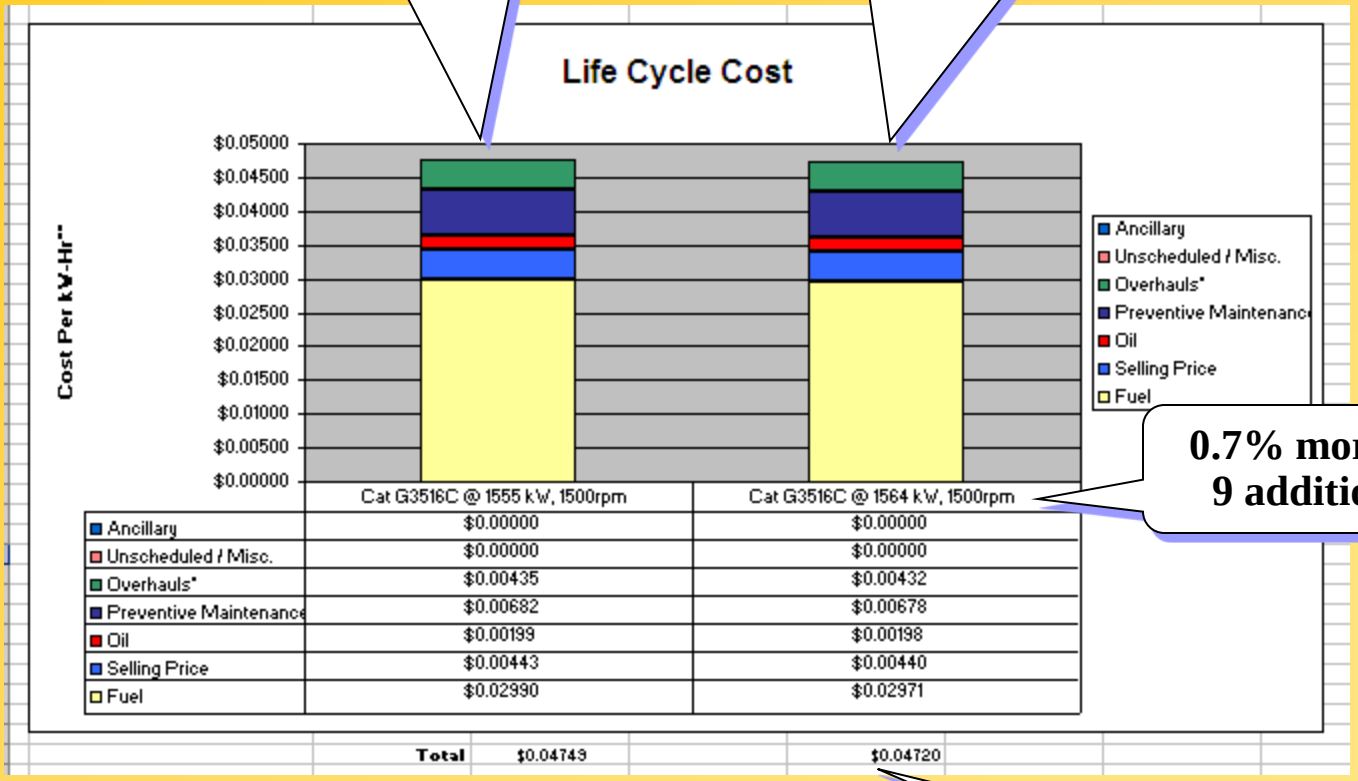
Compare G3516C

Difference: 0.8 vs. Unity Power Factor

0.8 Power Factor

1.0 (Unity) Power Factor



	Cat G3516C @ 1555 kW, 1500rpm	Cat G3516C @ 1564 kW, 1500rpm
Ancillary	$0.00000	$0.00000
Unscheduled / Misc.	$0.00000	$0.00000
Overhauls*	$0.00435	$0.00432
Preventive Maintenance	$0.00682	$0.00678
Oil	$0.00199	$0.00198
Selling Price	$0.00443	$0.00440
Fuel	$0.02990	$0.02971
Total	**$0.04749**	**$0.04720**

0.7% more power; 9 additional kW

0.2% lower operating costs

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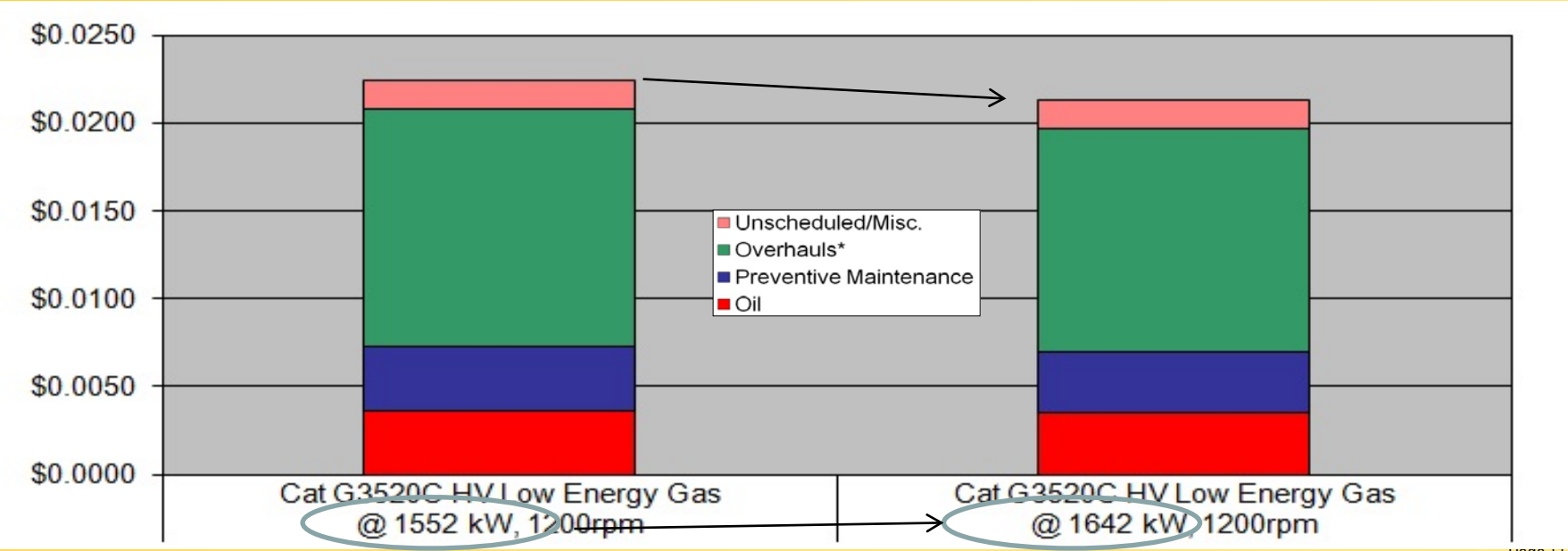
Combined Effect

Scenario 1

- Sell Power to Industry @0.8PF
- Engine Powered Pumps
- Engine Powered Fans

Scenario 2

- Sell Power to Utility @0.95PF
- Electric Pumps (grid power)
- Electric Fan (grid power)



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Other Ratings Considerations

- ISO vs. nominal ratings, fuel efficiency
- Ratings w/ no exhaust backpressure
- IEC losses calculations
- Rating listed at ISO rating conditions vs. IEC
- Minimum Methane Number requirements

Capital Cost – Gas Compression Skid

- Some engines require high inlet gas pressures
  - E.g. Cat G3600 family, pre-chamber design, 150psi
  - A gas compression skid is REQUIRED for operation.
- Other gas engines accept low inlet pressures
  - E.g. Cat G3520C requires only 1.5-5 psi LFG
  - Only a simple gas regulator is needed for operation
- A fair comparison of G3612 v. G3520C cost of ownership needs to include the capital and maintenance cost of the gas compression skid.

Capital Cost – Siloxane Treatment

- Higher efficiency engines accept less LFG contaminants than lower efficiency engines.
- Depending on site specifics, high efficiency engines often REQUIRE specialized siloxane removal (gas conditioning skids).
- A fair comparison of cost of ownership needs to include the capital and maintenance cost of the gas conditioning skid.

Efficiency v. Capacity

- Electrical Efficiency: % or energy input to the generator set that gets converted to electrical output. (kW)

- Capacity Factor: % of time the generator set is in operation and producing ekW. (Operational Availability)

- Both factors play a key role in maximizing the revenues of your power generation project.

Same Capacity, Different Efficiency

	Unit A	Unit B
Gen set kW	1000	1000
Gas Price $/mmbtu	$ 2.00	$ 2.00
Value of Energy Produced $/MW-hr	$ 70.00	$ 70.00
Generator Efficiency	97.0%	97.0%
Engine Heat Rate BTU/min	145,000	135,000
Capacity Factor	96.0%	96.0%
Generator Set Electrical Efficiency	39.2%	42.1%
Fuel Consumed/yr mmbtu	73,163.52	68,117.76
Cost of Fuel/Year	$ 146,327	$ 136,236
MW-Hour produced	8,410	8,410
Fuel Cost /MW-hr	$ 17.4000	$ 16.2000
Value of Power Produced	$ 588,672	$ 588,672
Net Revenue (Fuel Cost vs Power Produced)	$ 442,345	$ 452,436

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Same Efficiency, Different Capacity

	Unit A	Unit B
Gen set kW	1000	1000
Gas Price $/mmbtu	$ 2.00	$ 2.00
Value of Energy Produced $/MW-hr	$ 70.00	$ 70.00
Generator Efficiency	97.0%	97.0%
Engine Heat Rate BTU/min	135,000	135,000
Capacity Factor	96.0%	90.0%
Generator Set Electrical Efficiency	42.1%	42.1%
Fuel Consumed/yr mmbtu	68,117.76	63,860.40
Cost of Fuel/Year	$ 136,236	$ 127,721
MW-Hour produced	8,410	7,884
Fuel Cost /MW-hr	$ 16.20	$ 16.20
Value of Power Produced	$ 588,672	$ 551,880
Net Revenue (Fuel Cost vs Power Produced)	$ 452,436	$ 424,159

What affects each factor?

- Efficiency:
  - Product design/technology/quality.
  - Fuel quality.
- Capacity
  - Product design/technology/quality.
  - Service capability
  - Parts Availability.

Maintenance and Repair Considerations

Cost ← Maintenance & Repair Cost

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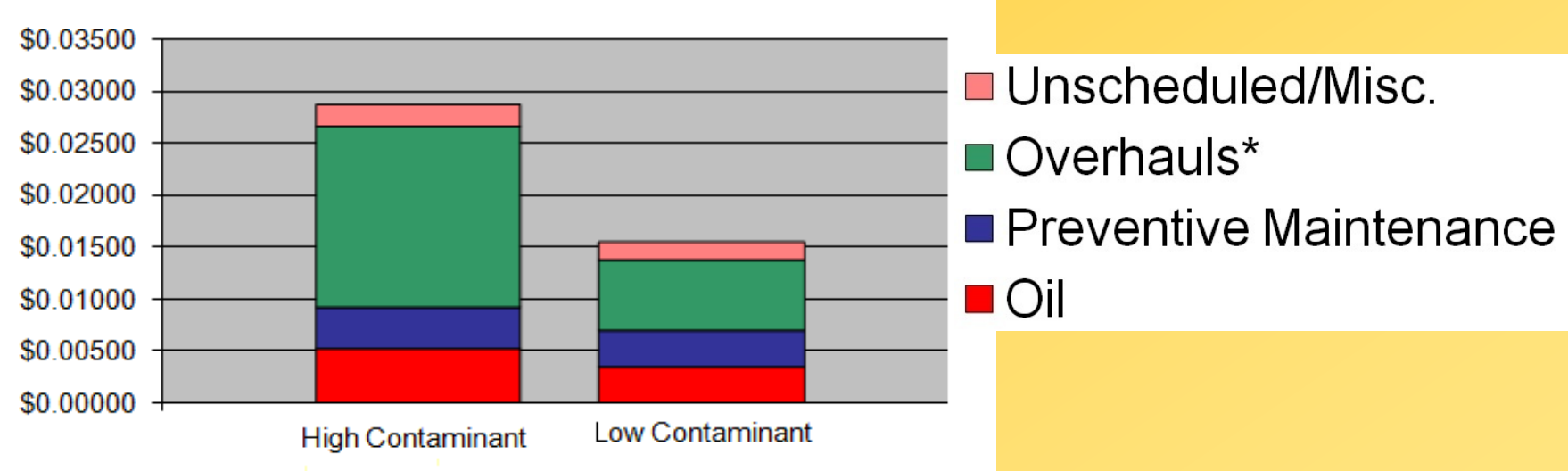
kWh ← Per unit Electricity Sold

- Cost Factors
  - Preventive Maintenance
  - Scheduled Maintenance
  - Unplanned Repairs
- kWh Production
  - Parasitic Losses (Pumps / Fans)
  - Capacity Factor (Fuel Availability)
  - Ambient Conditions (Deration)
  - Power Factor (Gen Eff.)

Fuel Quality Impact on M&R Costs

Cost / kWh



Contaminants : Ammonia, Halides, Siloxanes, Hydrogen Sulfide

Assumed Overhaul Schedule (Top End, In Frame, Major)

High Contaminant= 7k, 21k, 35k Hours

Low Contaminant= 18k, 54k, 90k Hours

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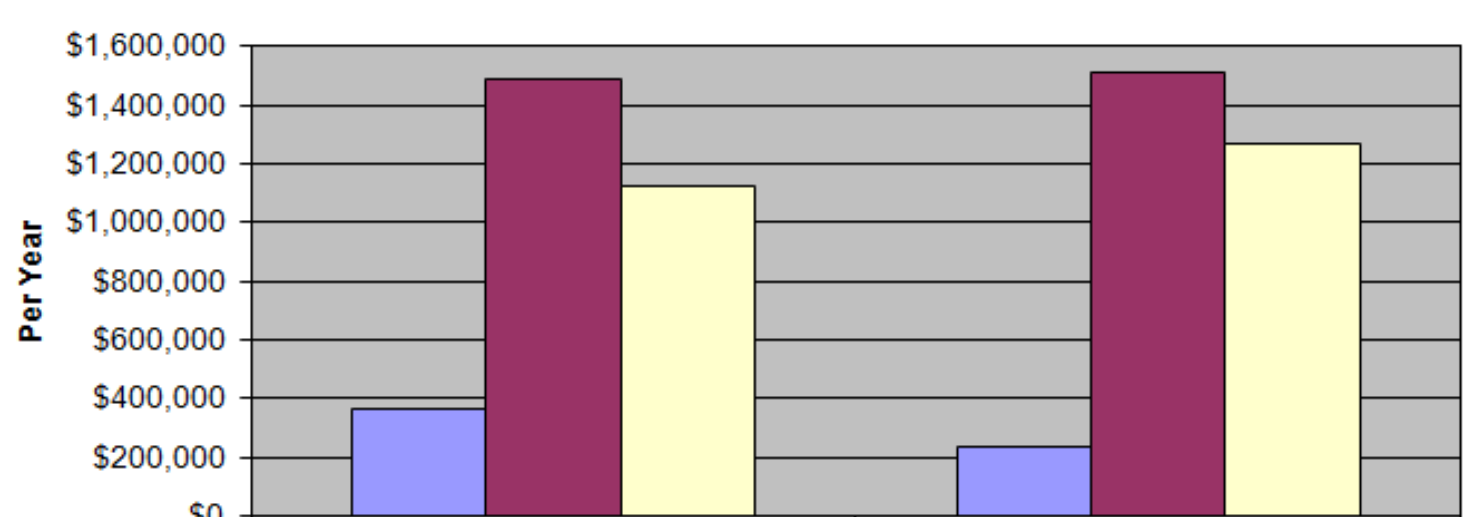
Fuel Contaminants & Bottom Line

G3520C 1600kW Genset



	High Contaminant	Low Contaminant
Cost	$361,752	$236,039
Revenue	$1,489,729	$1,507,947
Profit	$1,127,977	$1,271,908

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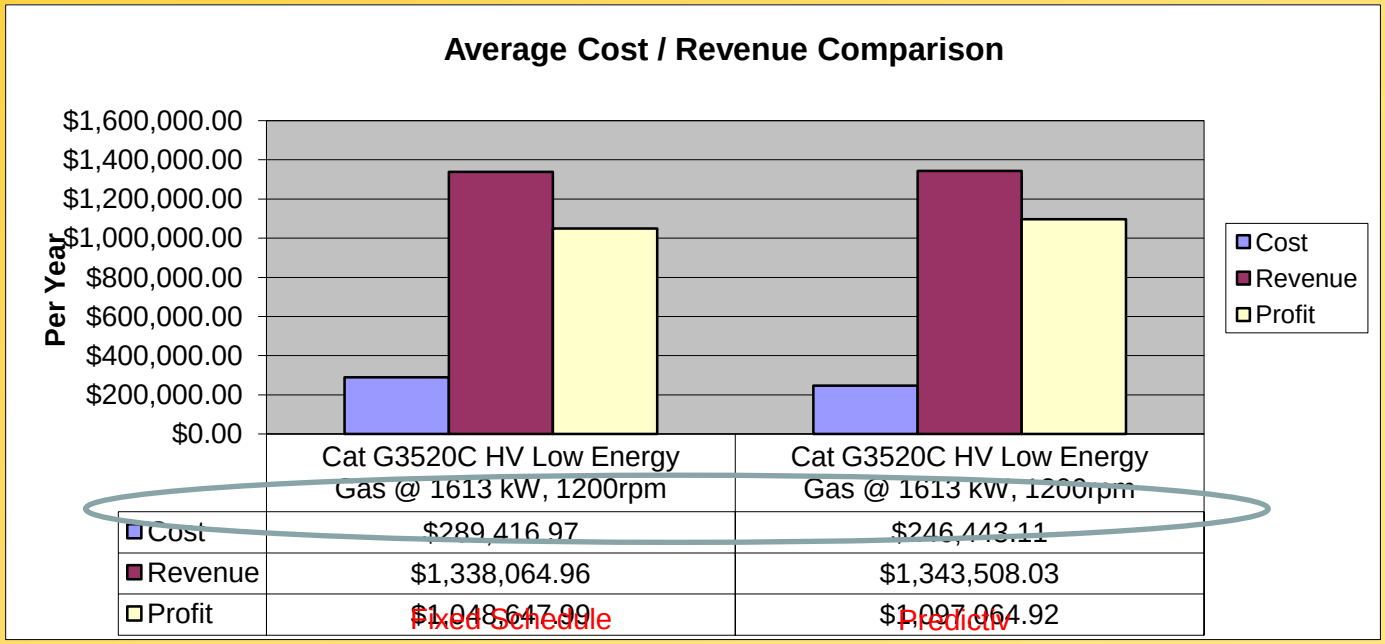
Repair Risk Management

- Scheduled repairs per service manual intervals
- Predictive Repair Scheduling
  - Valve Recession, Oil Consumption, Fuel Consumption, Exhaust Emissions



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Other Operation, M&R Considerations

- Methodology to schedule engine interventions
  - B10 or B50 life?
- Oil consumption costs
- Estimated v. Guaranteed M&R costs.

Thank you!

For additional information, please contact your nearest Caterpillar dealer:

http://www.cat.com/dealer-locator

Online:

http://www.cat.com/power-generation/generator-sets/gas-generator-sets/

E-mail:

lopez_mauricio_a [at] cat [dot] com, 954-885-3172

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