



A Comparison of Landfill Gas to Energy Technologies

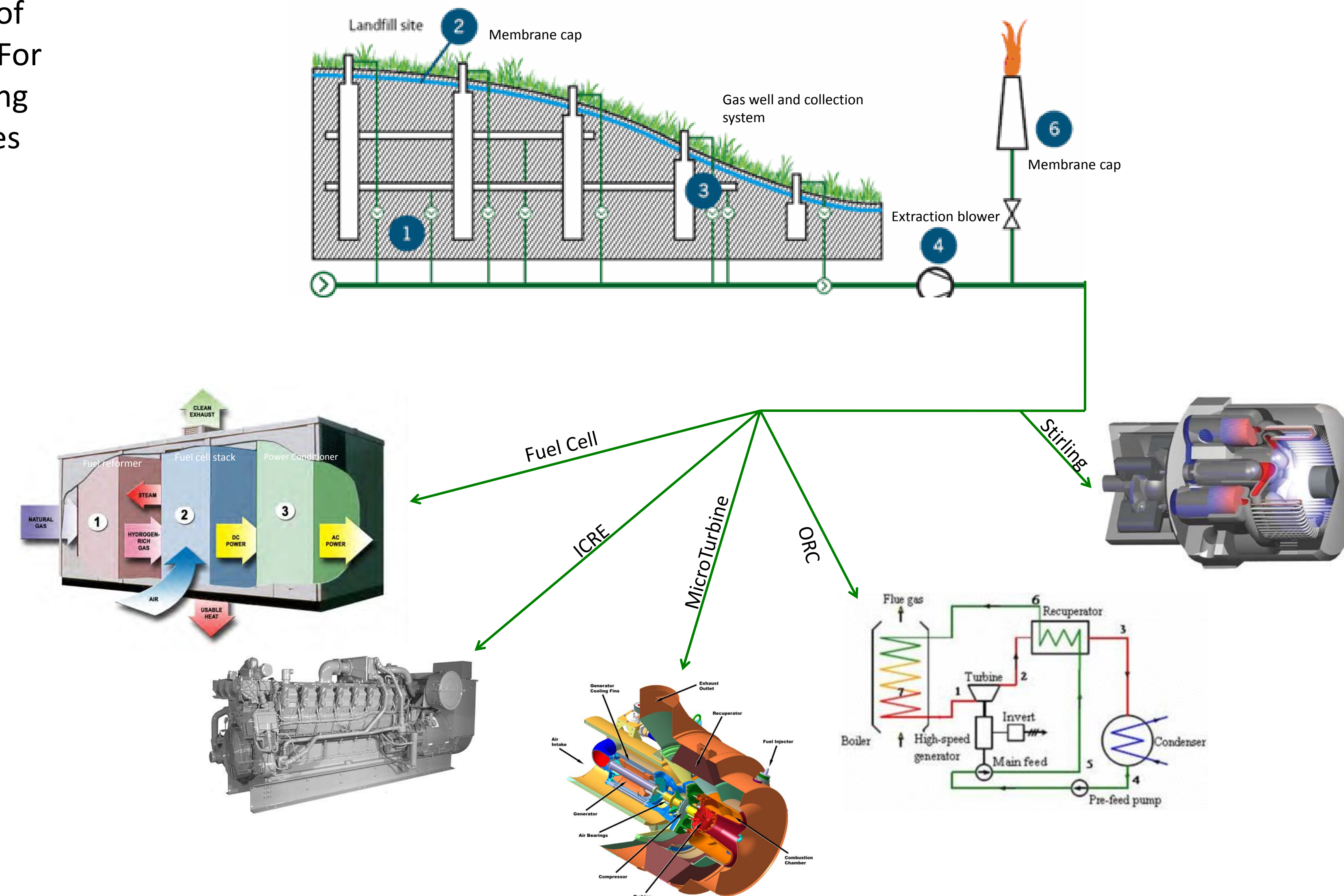
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Introduction

The purpose of this study is to investigate and compare the efficiency, economics and environmental impacts of different landfill gas to energy (LFGTE) technologies. For this study one specific model from each of the following technologies was studied to understand the differences between the technologies:

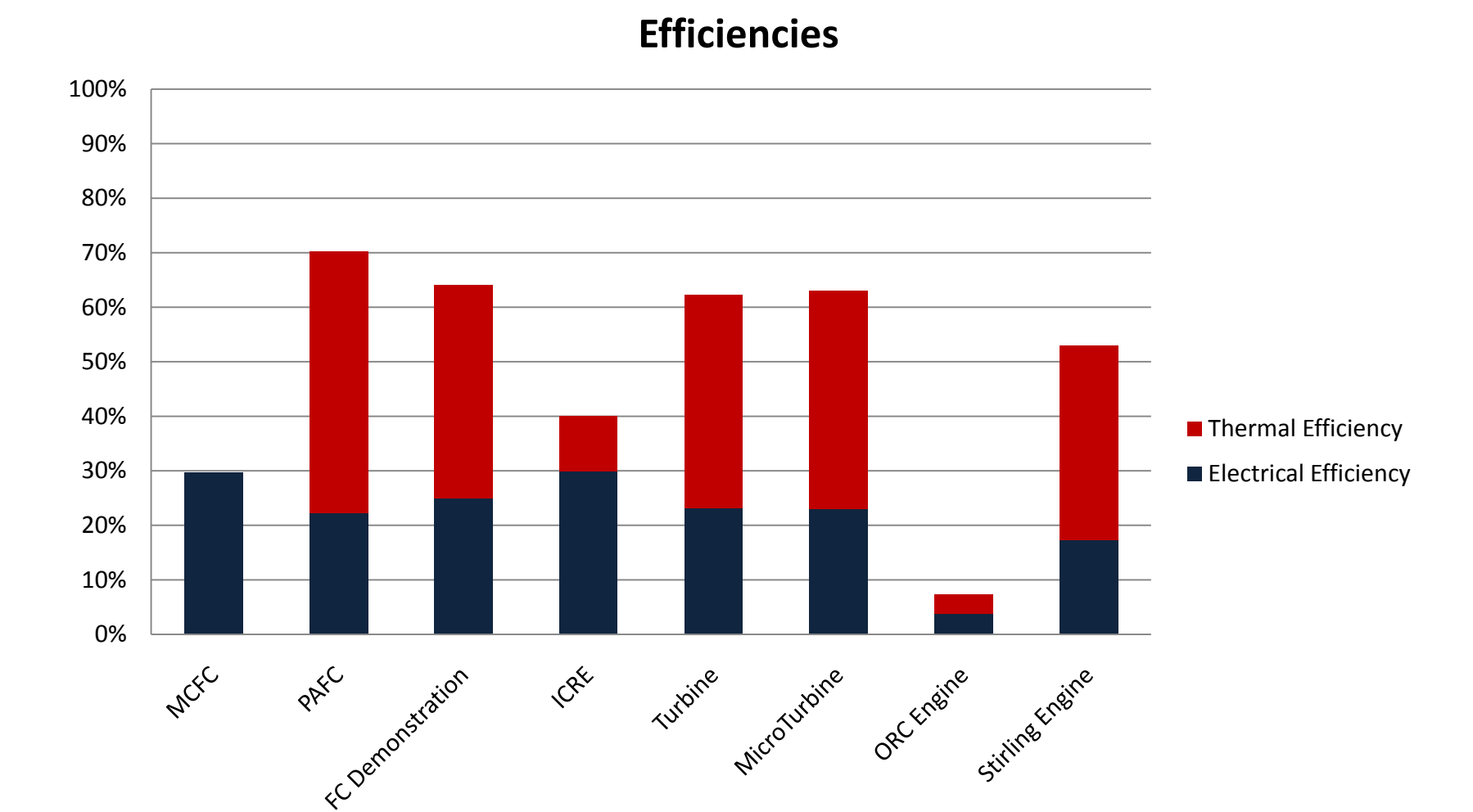
- molten carbonate fuel cell
- phosphoric acid fuel cell
- internal combustion reciprocating engine (ICRE)
- gas turbine
- microturbine
- organic rankine cycle (ORC) engine
- stirling cycle engine

Values are derived primarily from product specific information or if specifications were unattainable, accepted industry norms were used.



Energy Balance

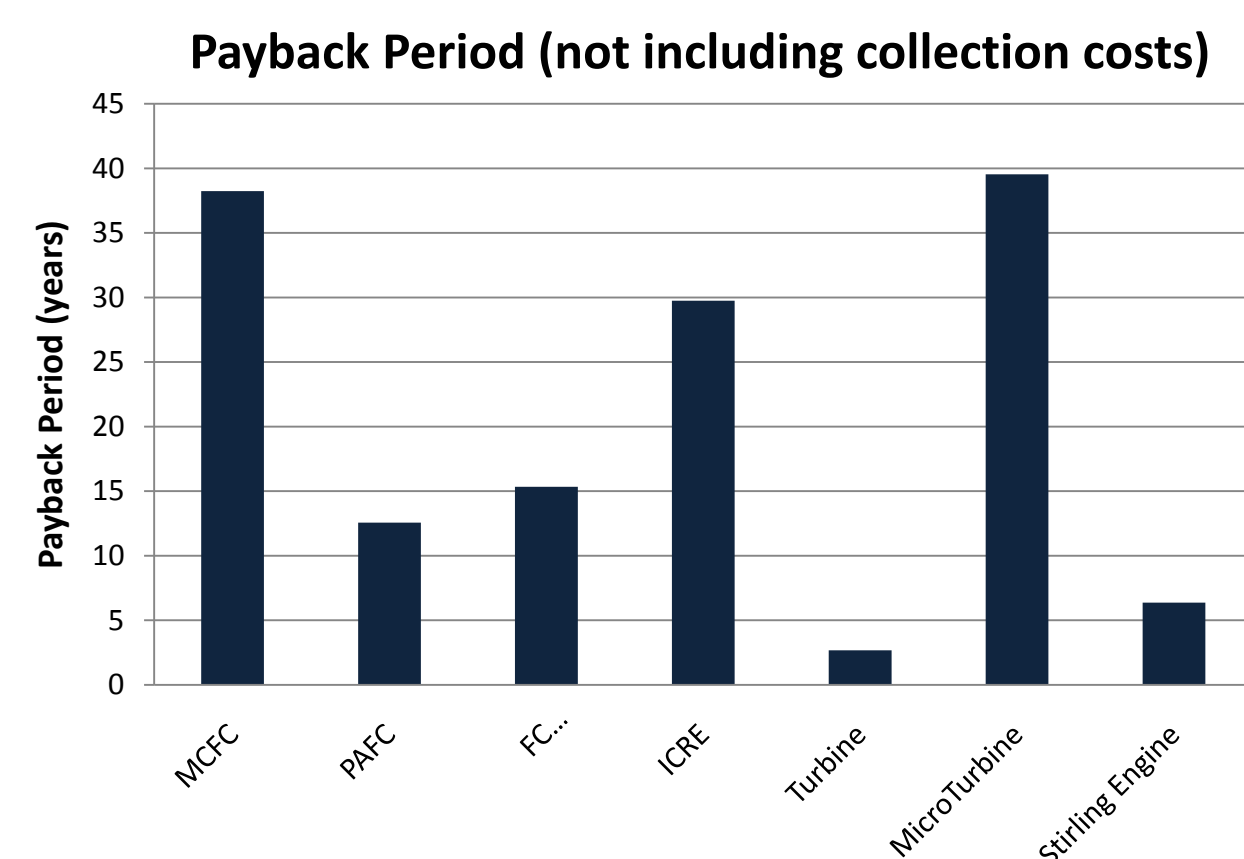
Since the gas must be collected, cleaned and sometimes compressed, the rated efficiencies of different technologies cannot be compared justly. Thus this study takes into account upstream energy needs.



Energy Conversion type	Rated Efficiency		Final Efficiency	
	Electrical	CHP	Electrical	CHP
FUEL CELLS				
- Molten Carbonate				
- Fuelcell Energy DFC1500	47%	47%	30%	30%
- Phosphoric Acid				
- Purecell	36%	64%	22%	70%
- CT demonstration-purecell	38%	77%	25%	64%
ICRE				
- Caterpillar G3516 LE	31%	41%	30%	40%
TURBINE				
- Solar Centaur 40 (CAT)	28%	67%	23%	62%
MICROTURBINE				
- Capstone CR 200	33%	73%	23%	63%
ORGANIC RANKINE CYCLE				
- Tri-O-Gen	5%	8%	4%	7%
STIRLING CYCLE ENGINE				
- Stirling Biopower	20%	55%	17%	53%

Cost Analysis

Costs: capital and O&M costs of the collection system, cleaning/compression system, and energy production system (capital including engineering and soft costs).
Revenue: sale of electricity and steam.



The cleaning system needed to take the LFG to NG quality for these units produces liquid CO₂ which can be sold

Energy Conversion type	Including Collection Costs		Not Including Collection Costs	
	Net Profit (\$/kWh)	Payback Period	Net Profit (\$/kWh)	Payback Period
FUEL CELLS				
- Molten Carbonate				
- Fuelcell Energy DFC1500	-5.1	40.8	-4.6	38.2
- Phosphoric Acid				
- Purecell	-1.5	13.5	-1.0	12.6
- FC demonstration	-4.6	21.4	-2.0	15.3
ICRE				
- Caterpillar G3516 LE	-1.6	35.9	-1.2	29.7
TURBINE				
- Solar Centaur 40	3.2	3.8	3.7	2.7
MICROTURBINE				
- Capstone CR 200	-9.4	43.4	-8.3	39.5
ORC ENGINES				
- Tri-O-Gen	-10.9	never	-7.0	never
STIRLING CYCLE ENGINE				
- Stirling Biopower	1.0	8.8	2.2	6.4

Many landfills are required to collect their gas and either vent or flare it. Thus it may already exist on the site or in the budget

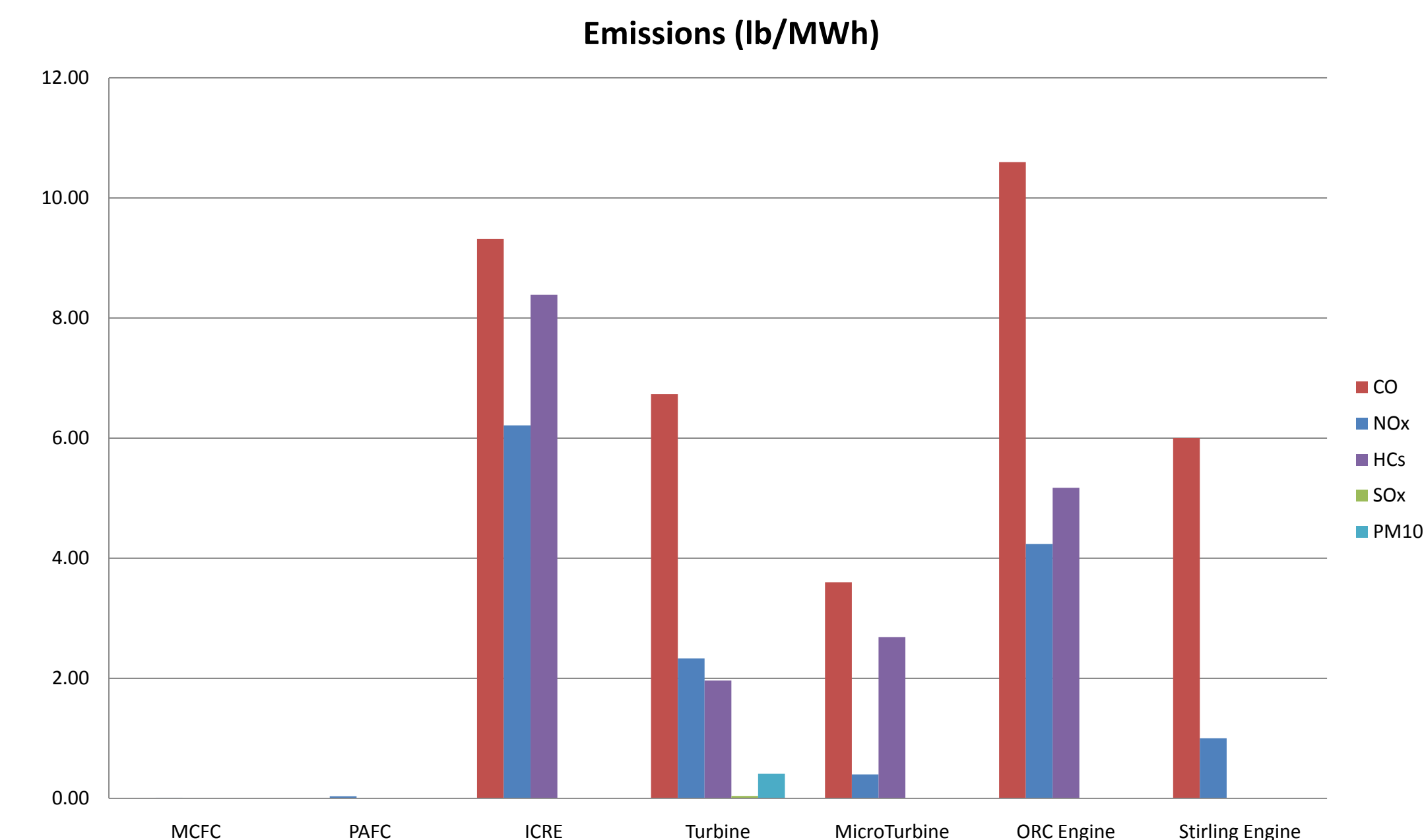
Check out the turbine!

Feeling discouraged? tax credits or emissions reductions credits would bring down the cost and local energy demand could increase the price of steam and electricity.

The net profit includes the capital cost as a loan with 7% interest paid annually over 20 years

The Payback period assumes the capital has been paid in full with no interest accumulating

Emissions



NOTE: A blank space corresponds to an emission that was not rated for that unit and a 0 corresponds to negligible

Energy Conversion type	emissions (lb/mmBtu and lb/MWh)						
	CO	CO2	NOx	SOx	HCS	PM10	
FLARES							
- PEI-Open	0.037		0.068		0.8		
- PEI-Enclosed	0.15		0.06		0.4		
FUEL CELLS							
- Molten Carbonate							
- Fuelcell Energy DFC1500		135	0.001	0.00001	0	0.000003	
- Purecell		980	0.01	0.0001	0	0.00002	
Phosphoric Acid							
- Purecell	0.001	119	0.004	0	0	0	
- FC demonstration-purecell	0.01	1120	0.04	0	0	0	
ICRE							
- Caterpillar G3516 LE	0.838	227	0.558		0.8		
- Solar Centaur 40 (CAT)	9.32	2533	6.21		8.4		
TURBINE							
- Solar Centaur 40 (CAT)	0.543	146	0.188	0.003	0.2	0.03	
- Capstone CR 200	6.73	1813	2.33	0.04	2.0	0.4	
MICROTURBINE							
- Capstone CR 200	0.348		0.039		0.2		
- Capstone CR 200	3.60		0.40		2.7		
ORGANIC RANKINE							
- Tri-O-Gen	0.150		0.050		0.4		
- Tri-O-Gen	10.60		4.24		5.2		
STIRLING CYCLE							
- Stirling Biopower	0.344		0.057				
- Stirling Biopower	6.00		1.00				