A Study on an IC Engine Operated on Landfill Gas with Syngas Addition

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Motivation

• Landfills are the largest human-generated source of CH_4, a potent greenhouse gas; thus, reducing CH_4 emitted from MSW landfills is one of best ways to mitigate global climate change.

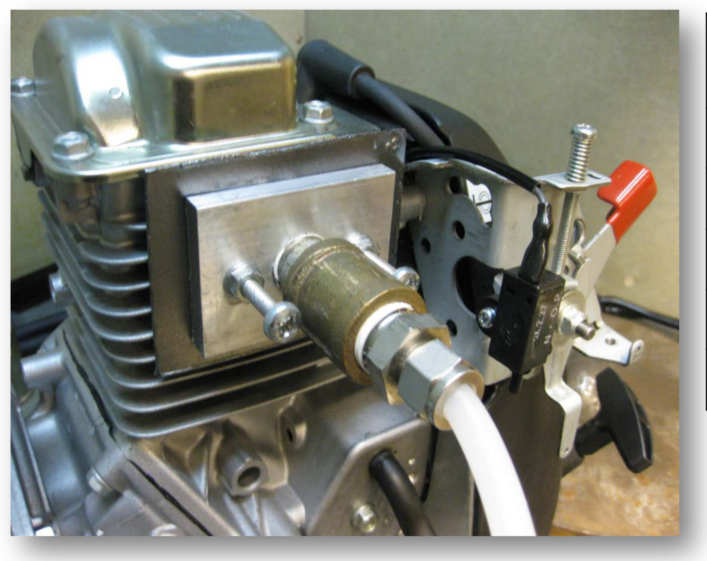
• Landfill gas to energy (LFGTE) projects capture approximately 85% of CH_4 emitted from MSW landfills, and prevent CH_4 from escaping into the atmosphere.

• Landfill gas (LFG) as a fuel: LFG mainly consists of CH_4 and CO_2, so its energy content is low and fluctuating, resulting in lack of flame stability, increased pollutant emissions and compromised fuel efficiency. Thus, supplementary fuel is needed to compensate for the low energy content.

• Syngas addition to LFG fuel can improve flame stability and reduce pollutant emissions without reducing combustor efficiency resulting from higher flame speed and lower ignition temperature of syngas.

• This research presents ***emissions results of a small IC engine fueled with simulated LFG with syngas addition.***

Description of the Tested Engine

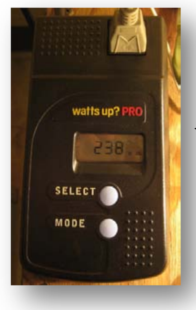


<Honda GC160E Engine>

Engine type	Air-cooled, 4-stroke, single cylinder
Compression ratio	8.5 : 1
Displacement	160cm³
Maximum output	3.7kW at 3600rpm
Dimensions (L × W × H)	337 × 369 × 331mm
Dry weight	11.5kg

• A small engine for power generation.

• A generator is connected to the engine, functioning as electrical loads with a load board.



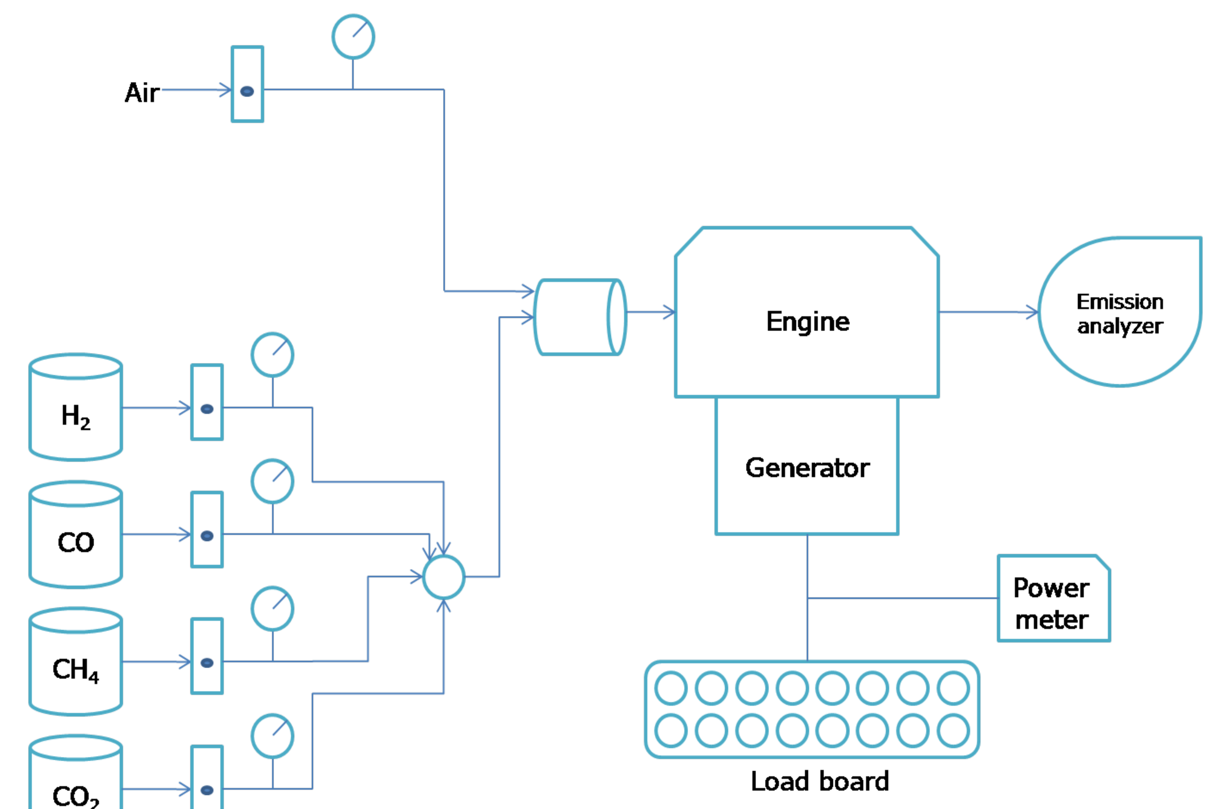
<Wattsup Pro Power Meter> <PRAMAC EG2800 Generator>

• A load board was plugged in a generator connected to the tested engine.

• As more bulbs were powered, the generator produced more electric power.

• The power the generator produced was measured by a power meter.

Experimental Schematic



• Four gases were used to create various simulated gaseous fuels: CH_4, CO_2, H_2, and CO.

• The range of conditions tested covered pure methane as a baseline to a simulated landfill gas (50% CH_4 & 50% CO_2) with 25% increments of CO_2 addition.

• H_2 and CO were introduced into a simulated landfill gas ranging from 5 to 15% to determine the effect of reformed landfill gas to syngas.

Adiabatic Flame Temperature Calculation

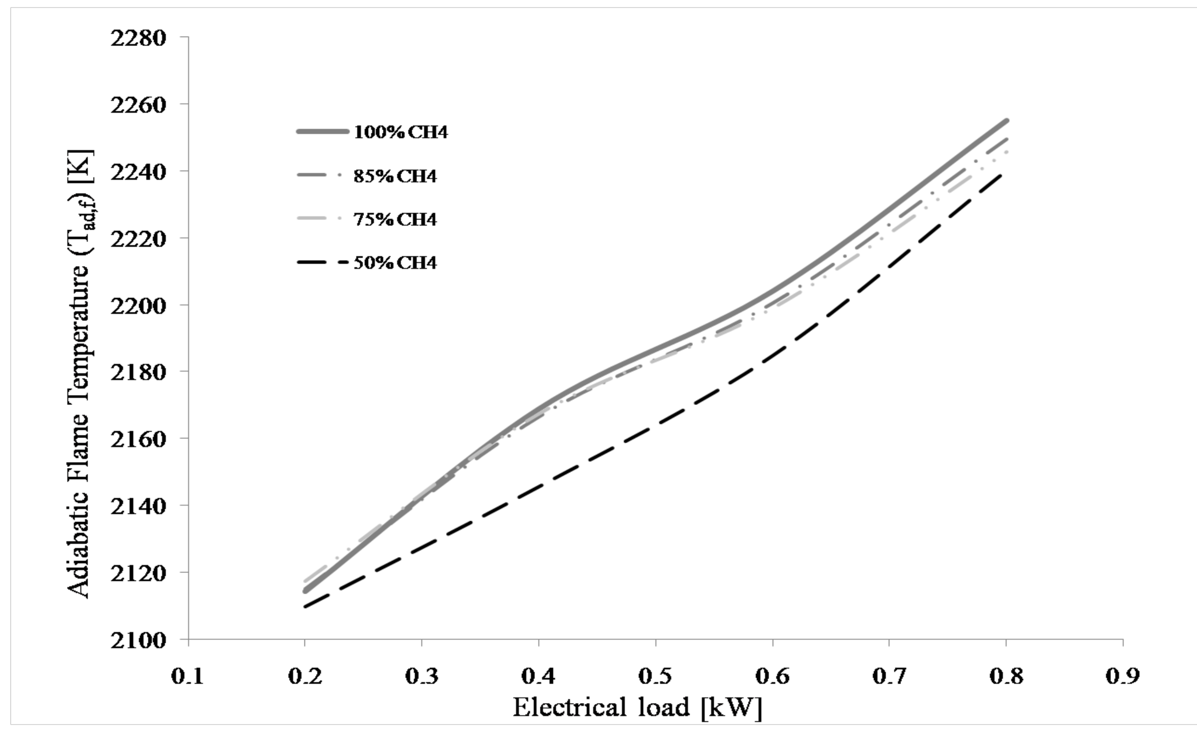


Figure 1: Adiabatic flame temperature calculation for compositions from pure methane to simulated LFG

• The temperatures are nearly constant, so *gas composition and the resulting chemistry of combustion* have more effects on emission changes rather than temperature effects.

• The all load conditions are ***near or above 2100K*** for all CO_2 concentrations.

Landfill Gas Operation Test

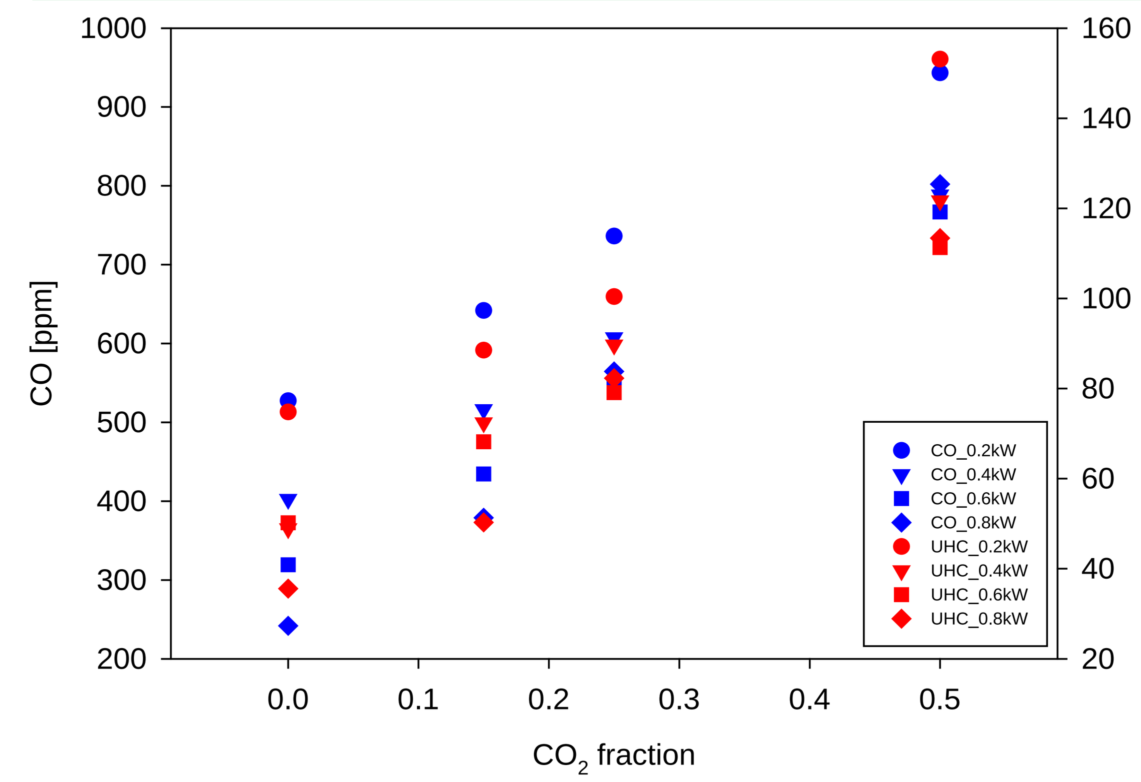


Figure 2: CO and UHC emissions measurements with CO_2 composition in the inlet fuel

• When CO_2 fraction in the inlet fuel mixture *increases*, CO and UHC emissions *increase*.

• Generally, CO and UHC emissions *decrease* as electrical load *increases*.

• CO and UHC emissions have a similar trend because they result from incomplete combustion.

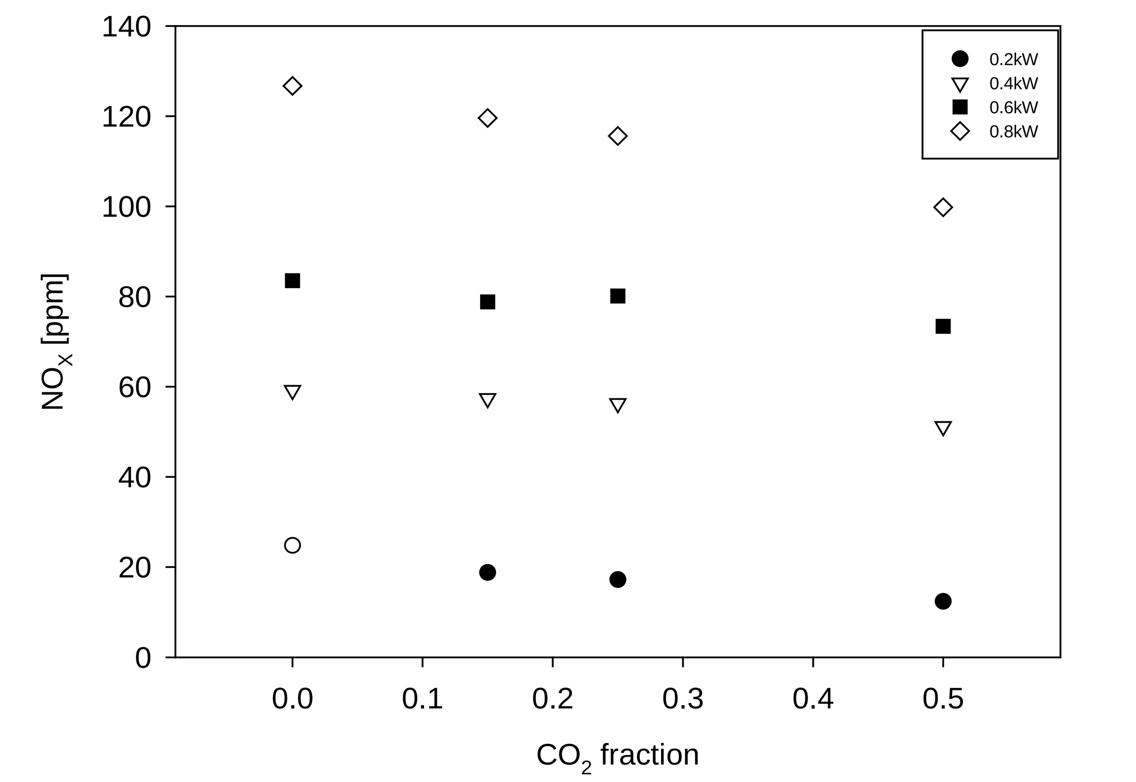


Figure 3: NO_X emissions measurements with CO_2 composition in the inlet fuel

• When CO_2 fraction in the inlet fuel mixture *increases*, NO_X emissions slightly *decrease*.

• Generally, NO_X emissions *increase* as electrical load *increases*.

• These conditions have the ***thermal (Zeldovich) mechanism*** more engaged which likely dominates the production of NO_X formation.

Comparison to LFGTE Technologies

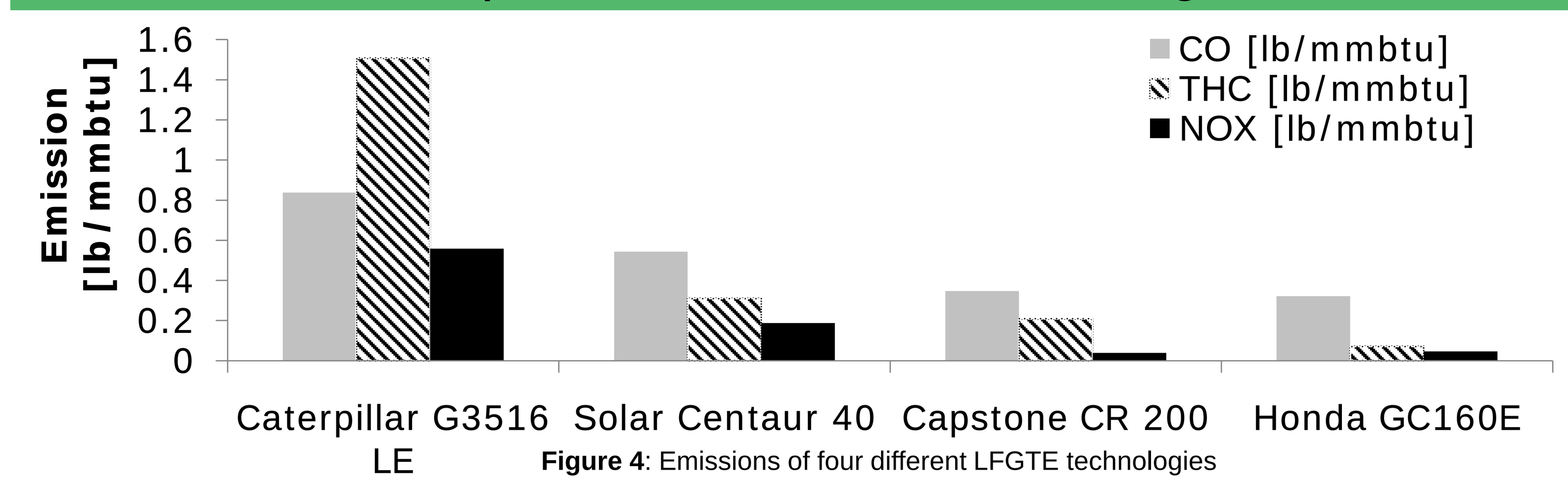


Figure 4: Emissions of four different LFGTE technologies

• Emissions are expressed as the mass of emitted pollutant per supplied fuel energy.

• The emissions from the Honda tested engine operating on the simulated LFG were compared to emissions from commercially operating LFGTE systems and were comparable. Therefore, results from this study can be considered representative of what would be expected in field operation.

Syngas (H_2/CO=2) Addition Test

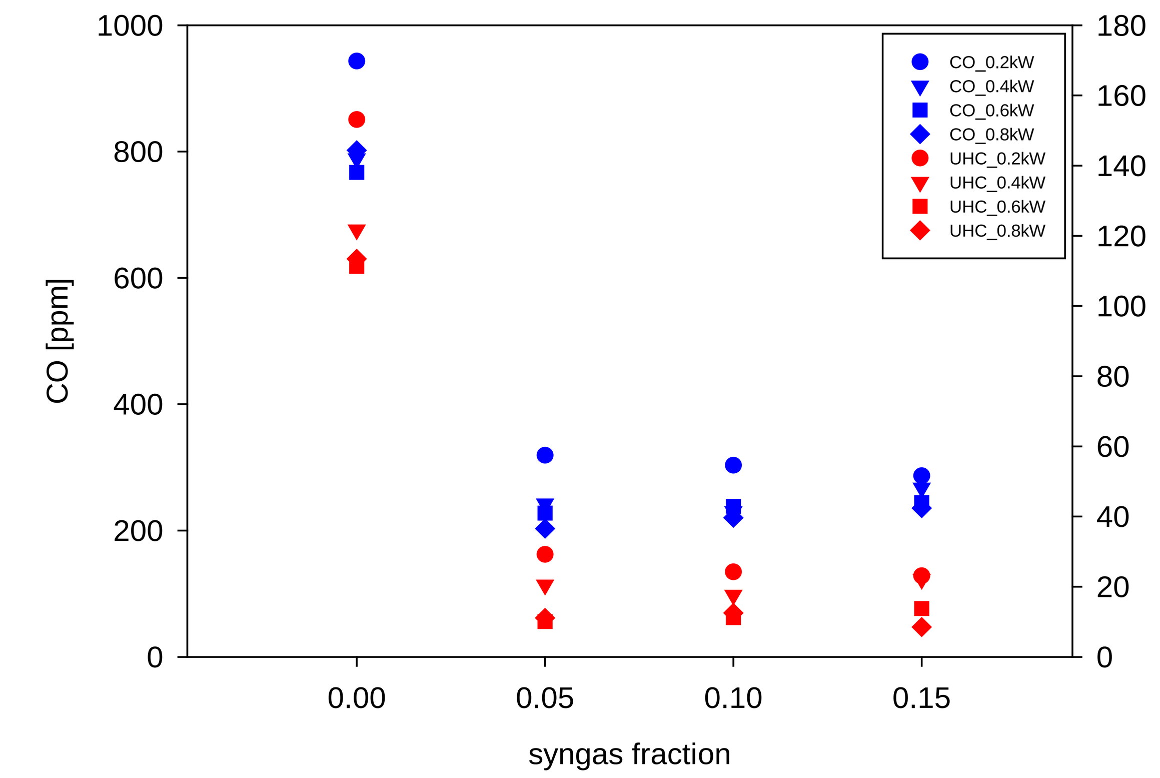


Figure 5: CO and UHC emissions measurement for simulated LFG with syngas addition

• The addition of syngas having the ratio of H_2/CO=2 *decreases* CO and UHC emissions significantly.

• The addition of *as little as 5% syngas* with the simulated LFG reduces the CO and UHC emissions for all load conditions.

• More syngas does not measurably reduce the emissions any further.

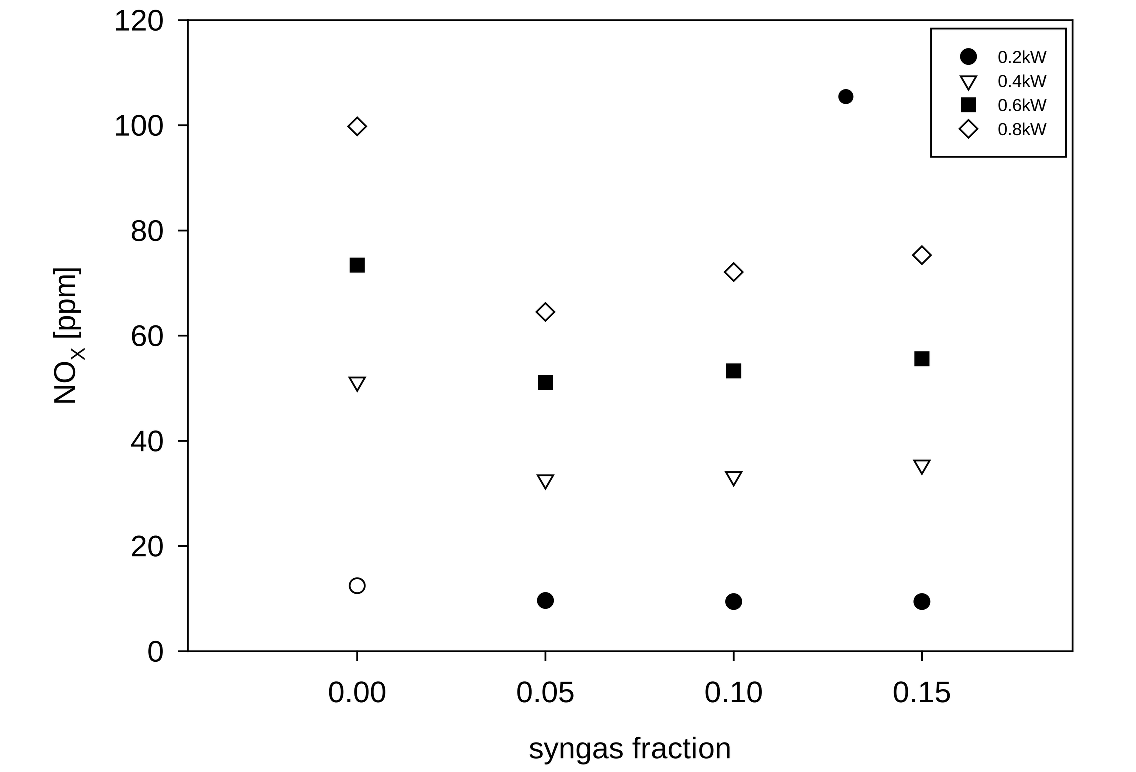


Figure 6: NO_X emissions measurement for simulated LFG with syngas addition

• The syngas addition decreases NO_X emissions.

• The reductions for NO_X are not as dramatic as the reductions in CO and UHC.

• The increase of syngas beyond 5% does not have a noticeable effect on NO_X emissions output.

Fuel Conversion Efficiency

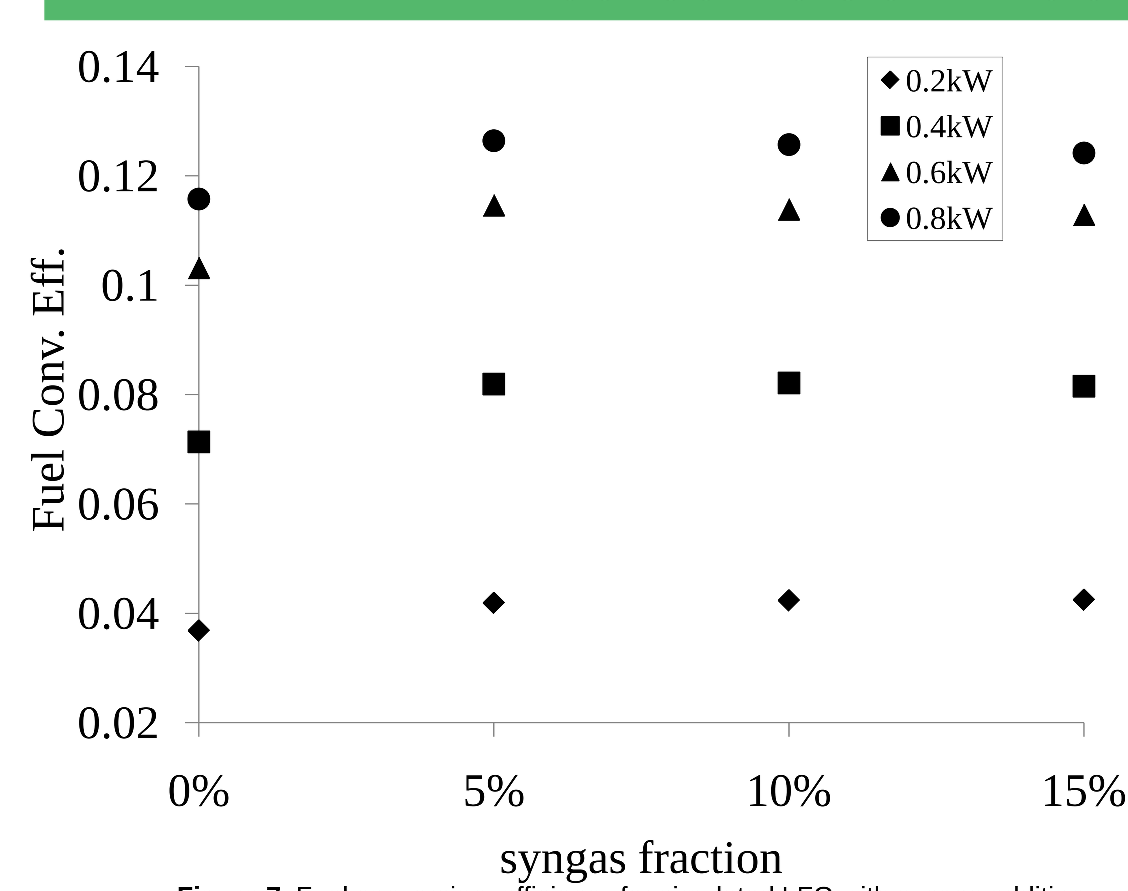


Figure 7: Fuel conversion efficiency for simulated LFG with syngas addition

• The addition of syngas improves fuel conversion efficiency.

•The fuel conversion efficiency remaining relatively stable for all syngas fractions.

• The reductions in emissions can be attributed to H_2 and CO creating a more reactive mixture allowing the combustion to be more complete.

Conclusions

• The CO and UHC emissions increased while the NO_X emissions decreased with the presence of CO_2 in fuel mixtures.

• The increase in engine loads resulted in the decrease in the emissions of CO and UHC and the increase in the emissions of NO_X.

• The syngas addition to LFG not only improved the fuel conversion efficiency but also reduced pollutant emissions.

• 5% syngas addition was most effective to reduce pollutant emissions.