Possibilities of waste to energy systems based in the co-gasification of municipal solid waste and coal in Colombia

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Energy from municipal waste

This is one of the best alternatives for sustainable handling of waste.

Mass burning is generally the preferred option.

Syngas production from waste has also been tried with mixed success.

This presentation proposes an alternative based on co-combustion with coal as a possible route, applied preferably to the treating of municipal solid waste and biosolids from small or medium sized municipalities, producing less than 200 tons of waste per day, with the aim of generating electric energy.

For this, a theoretical model is proposed.

MSW properties

Case		As Generated	Separated
Water content	% wet basis	45,58	24,93
Carbon	% dry basis	42,70	38,50
Hydrogen	% dry basis	5,93	5,35
Oxygen	% dry basis	37,95	34,22
Ashes	% dry basis	13,42	21,93
High heat value (dry basis)	KJ/kg	16.244	14.647
Lower heat value (wet basis)	KJ/kg	8.129	10.111

W… average quality of MSW in the city of M… c materials and high in water content).

S… moving 75 % of organic, 50 % of paper, 20 … ss, 60 % of cardboard and 50 % of metals o… would amount to a 45 % of the initial as generated MSW.

Coal properties considered

Water content	% wet basis	7,20
Carbon	% dry basis	68,77
Hydrogen	% dry basis	4,55
Nitrogen	% dry basis	1,27
Oxygen	% dry basis	12,08
Sulfur	% dry basis	0,45
Ashes	% dry basis	12,87
High heat value (dry basis)	KJ/kg	25.911
Lower heat value (wet basis)	KJ/kg	23.155

Good quality coal is quite abundant in Colombia.

The following chemical reactions were considered for the equilibrium calculations. No methane generation was considered. Sulfur was controlled by the addition of calcium carbonate at a mass ratio of 0.0163 to coal.

$$C+CO_2 \leftrightarrow 2CO \qquad (1)$$

$$CO+H_2O \leftrightarrow CO_2+H_2 \qquad (2)$$

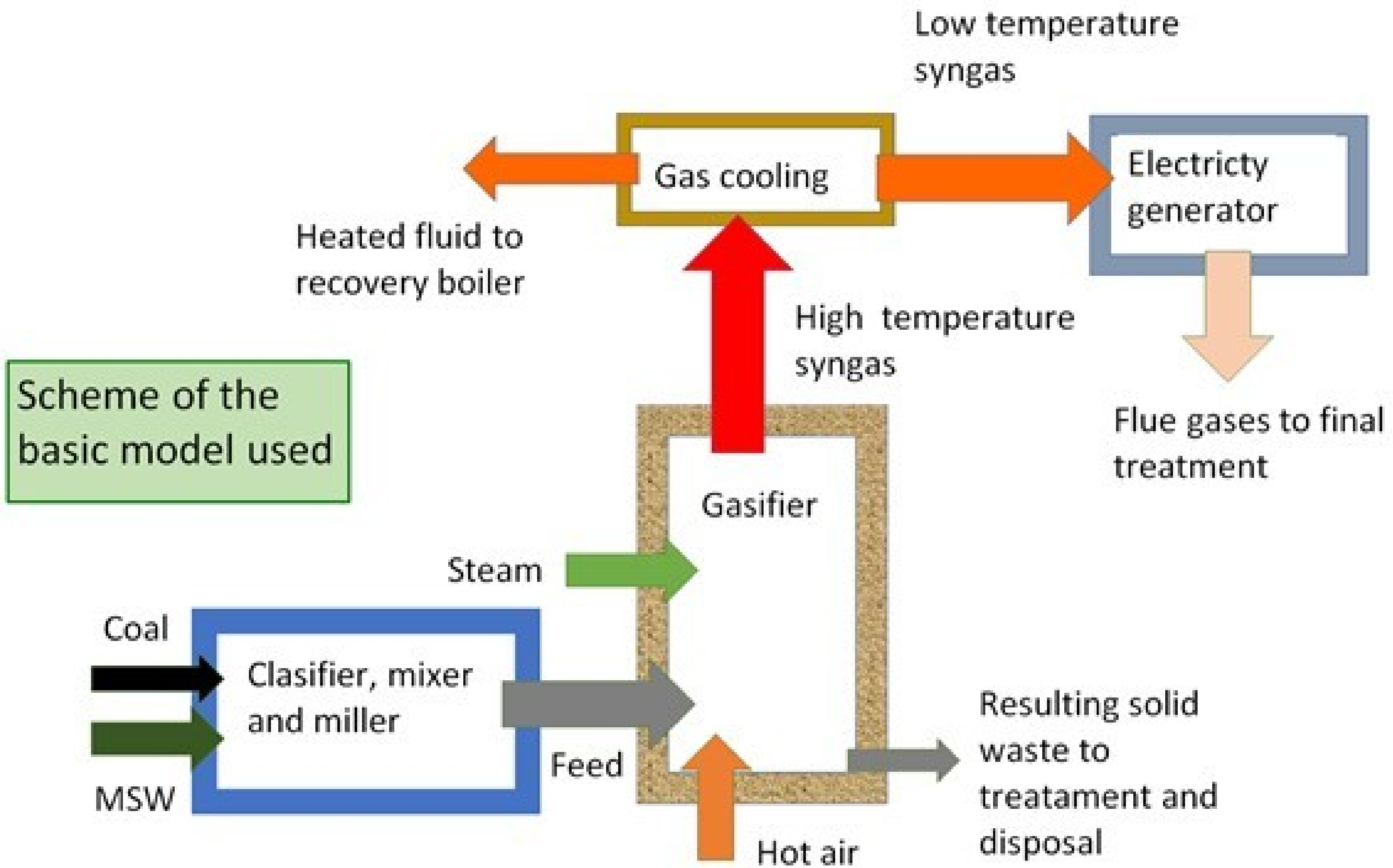
$$H_2+1/2\ O_2 \leftrightarrow H_2O \qquad (3)$$

$$C+H_2O \leftrightarrow CO+H_2 \qquad (4)$$

$$C+1/2\ O_2 \leftrightarrow CO \qquad (5)$$

$$CO+1/2\ O_2 \leftrightarrow CO_2 \qquad (6)$$

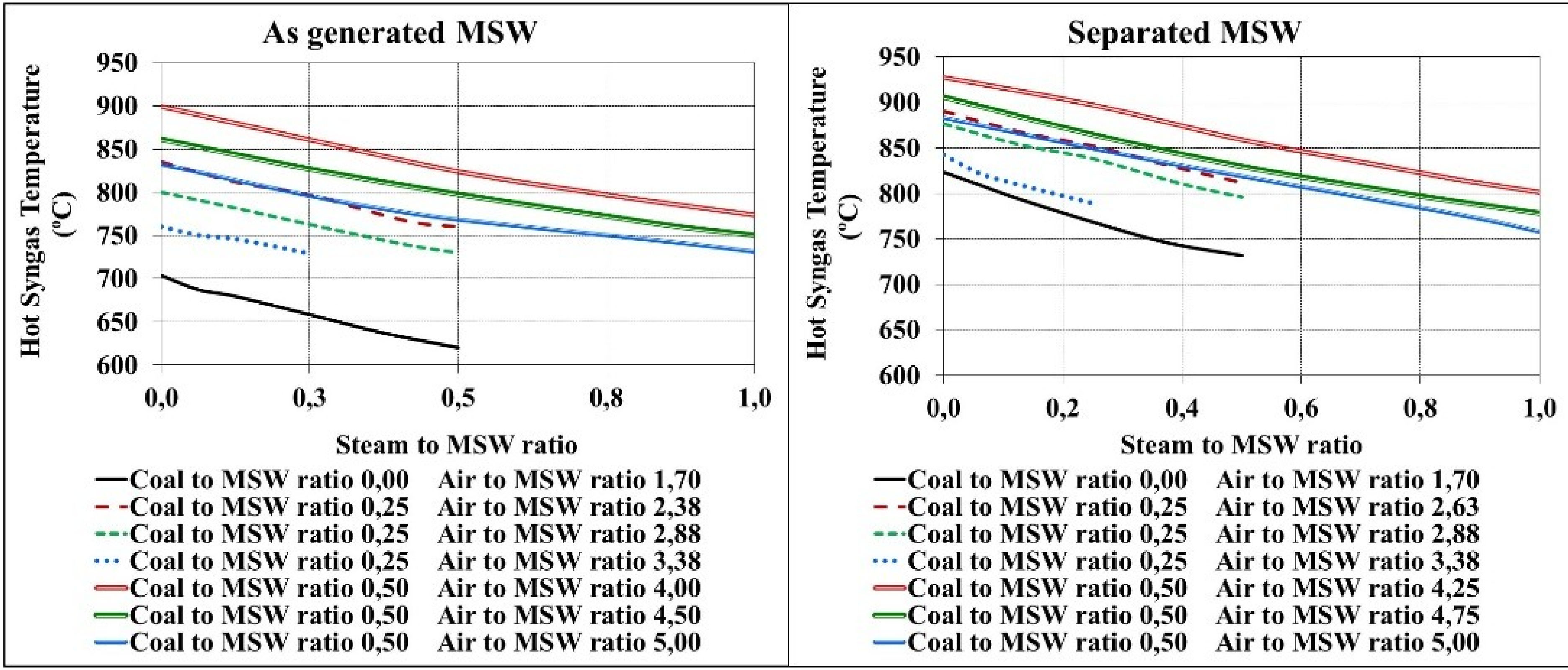
$$C+O2 \leftrightarrow CO_2 \qquad (7)$$


Low temperature syngas
Gas cooling
Electricty generator
Heated fluid to recovery boiler
High temperature syngas
Flue gases to final treatment
Scheme of the basic model used
Gasifier
Steam
Coal
Clasifier, mixer and miller
Feed
MSW
Hot air
Resulting solid waste to treatament and disposal

Iterative model calculation

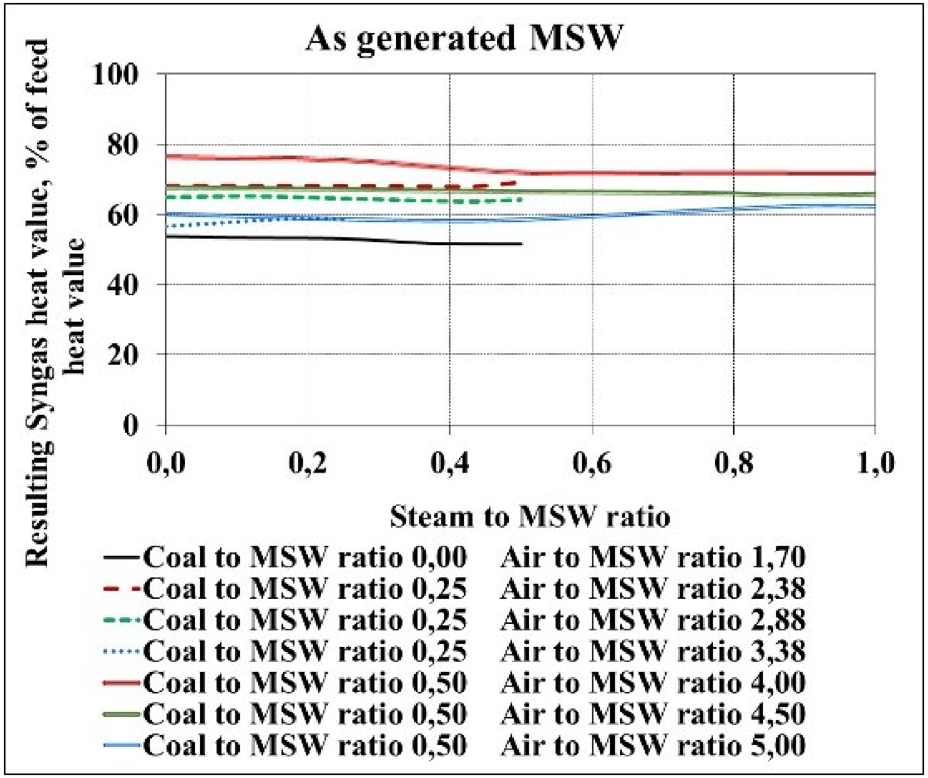
- Final syngas temperature is assumed
- Volumetric fractions of CO_2, CO, H_2 and H_2O in syngas are assumed
- Fractions of C converted as per reactions 1, 4 and 5 are assumed
- Fraction of O_2 converted as per reaction 3 and forming CO are assumed
- Fraction of CO converted as per reaction 2 is assumed
- With partial syngas fractions equilibria constants for reactions 1 to 7 are found.
- With syngas temperatures equilibria constants for reactions 1 to 7 are found.
- A convergence limit was established for the comparison of these two equilibria constants. This was set as less than 15 % maximum error for each reaction.
- Mass balance was checked for each specie with a convergence limit of 5 %
- Energy balance was performed. A convergence limit of 5 % was established.

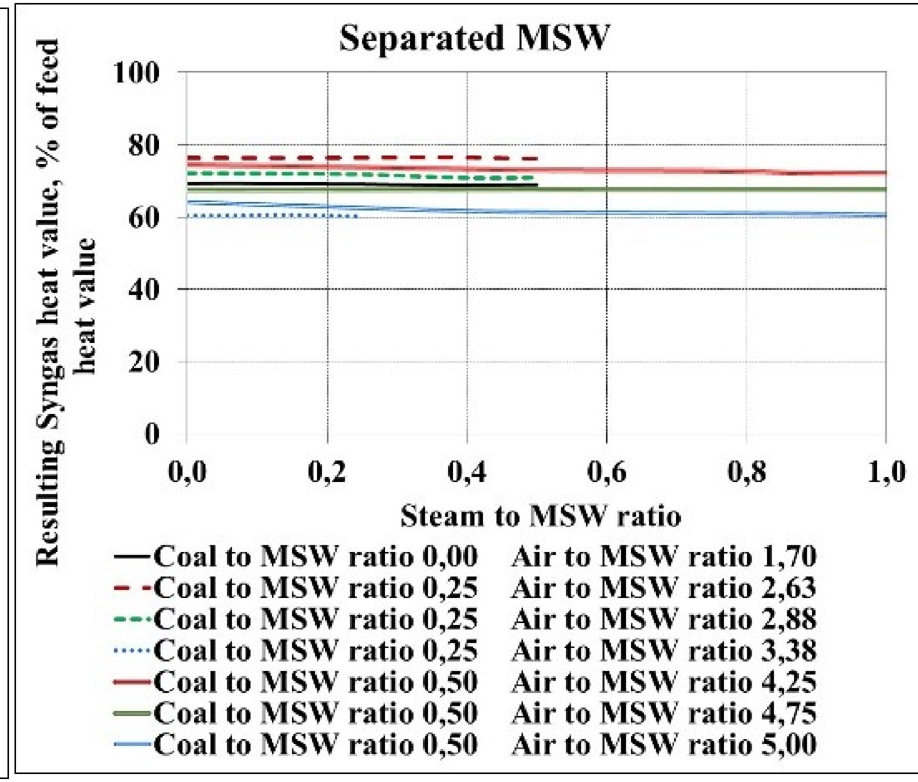
Results of the iterations for all major variables.



Syngas temperatures increase with higher coal to MSW ratios. For each ratio there is a characteristic curve which indicates higher temperatures for lower air to MSW ratios and lower temperatures for higher steam to MSW ratios.
Temperatures tend to be higher for the case of the separated MSW.

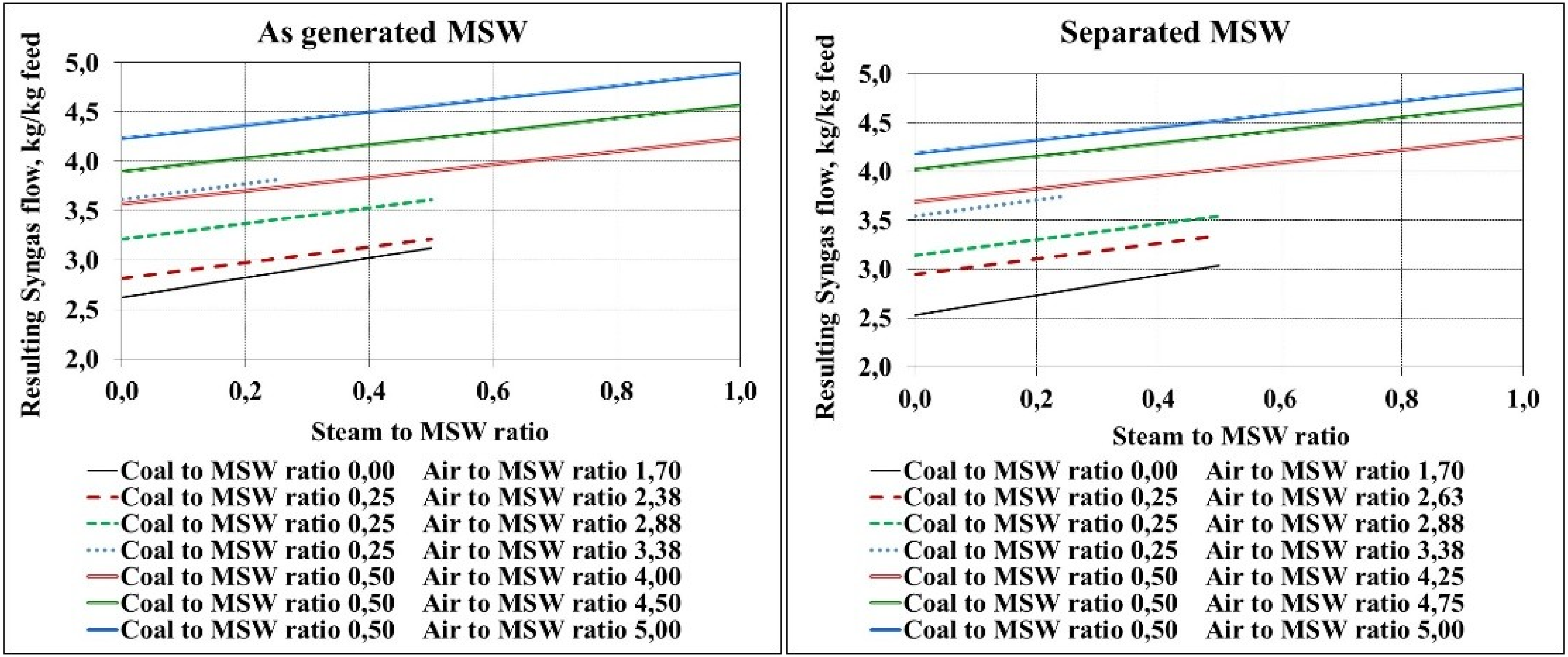
This figures indicates ranges. With no coal the range of air to MSW ratios was in the neighborhood of 1.70. At higher coal to MSW ratios the air to MSW ratio can be higher, all the way to 5.0. Syngas temperatures will be between 600 and 940 °C.



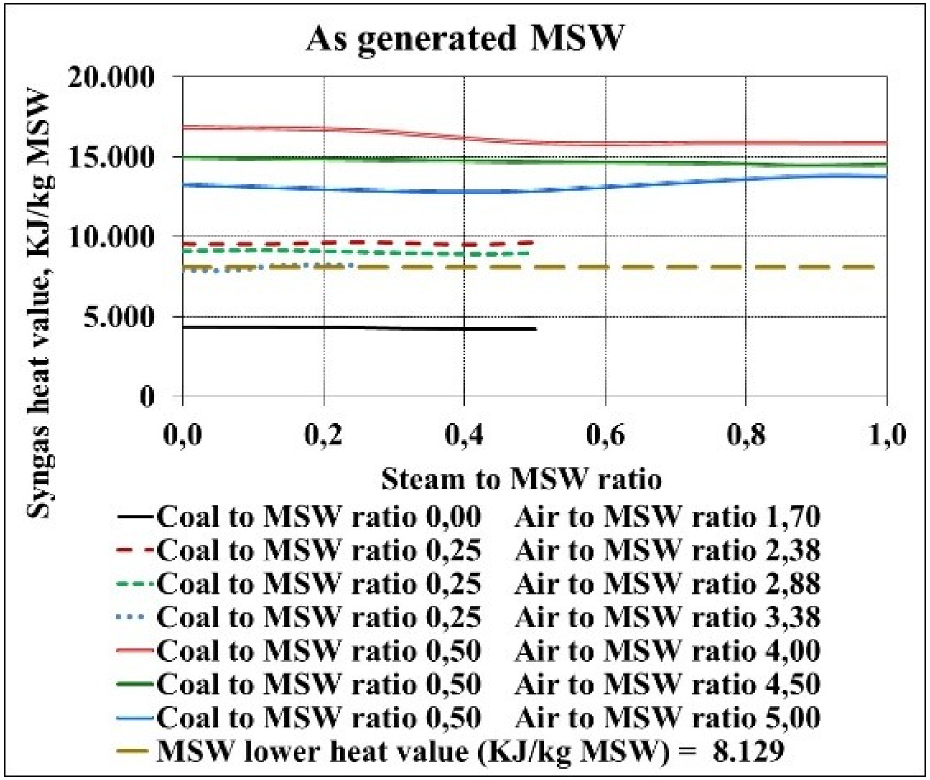


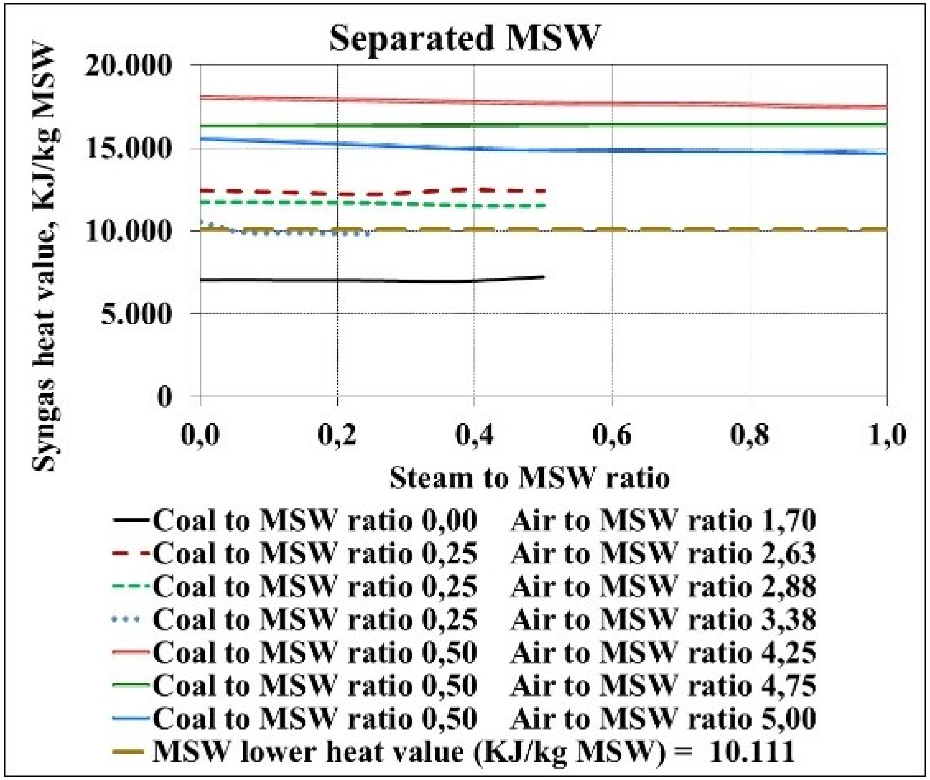
Syngas heat values tend to increase for higher coal to MSW ratios, but this was not entirely consistent.

Syngas heat value simulations showed percentages between 60 and 80 % of feed heat value and this do not change with steam to MSW ratios and tend to decrease with air to MSW ratios.



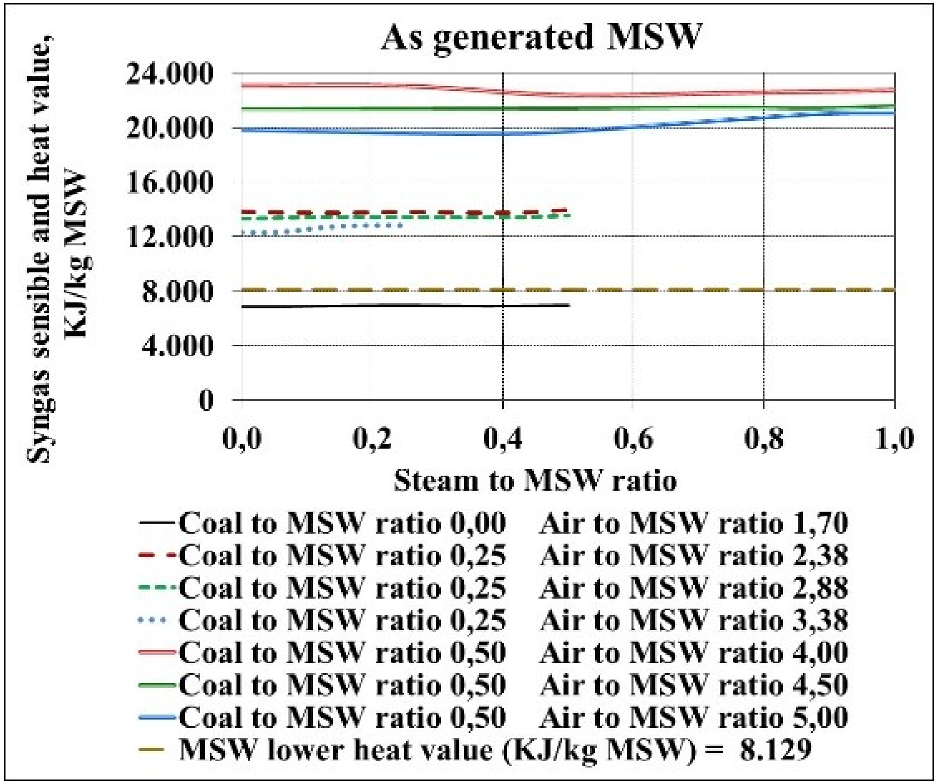
Syngas flow is linearly related to the studied variables. It increases with air to MSW ratio and with steam to MSW ratios. The values for the simulated range oscillate between 2.5 and 5.0 kg of syngas per kg of material feed. The syngas flow is, basically, the result of adding the incoming flows, discounting the ashes emissions. The behavior and the ranges are quite similar for both situations of MSW studied.

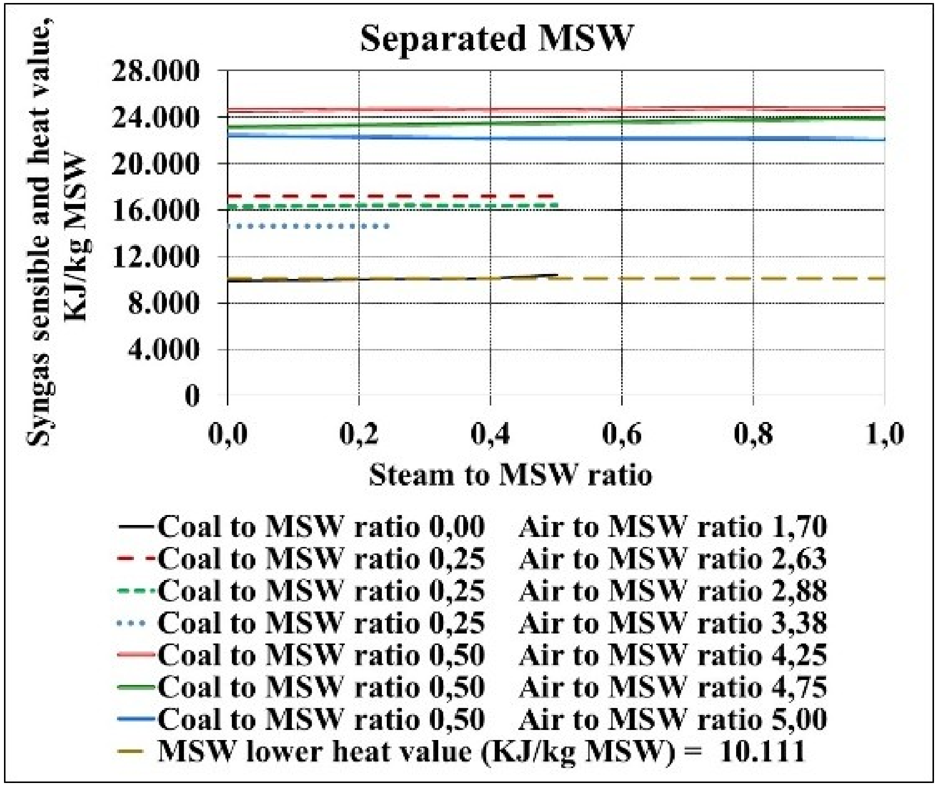




Syngas heat value is quite independent of steam to MSW ratio. It increases with air to MSW ratios and, of course, with coal to MSW ratios.

As compared to the MSW lower heat value, it tends to be lower, as expected, for the case of no coal co-gasification. Maximum values tend to be double as compared to MSW heat value, obviously because the impact of coal co-gasification





These figures show the total energy content of the syngas, adding its heat value to the sensible heat associated to syngas temperature. Those two amount to a value close to the energy value coming from the total feed.

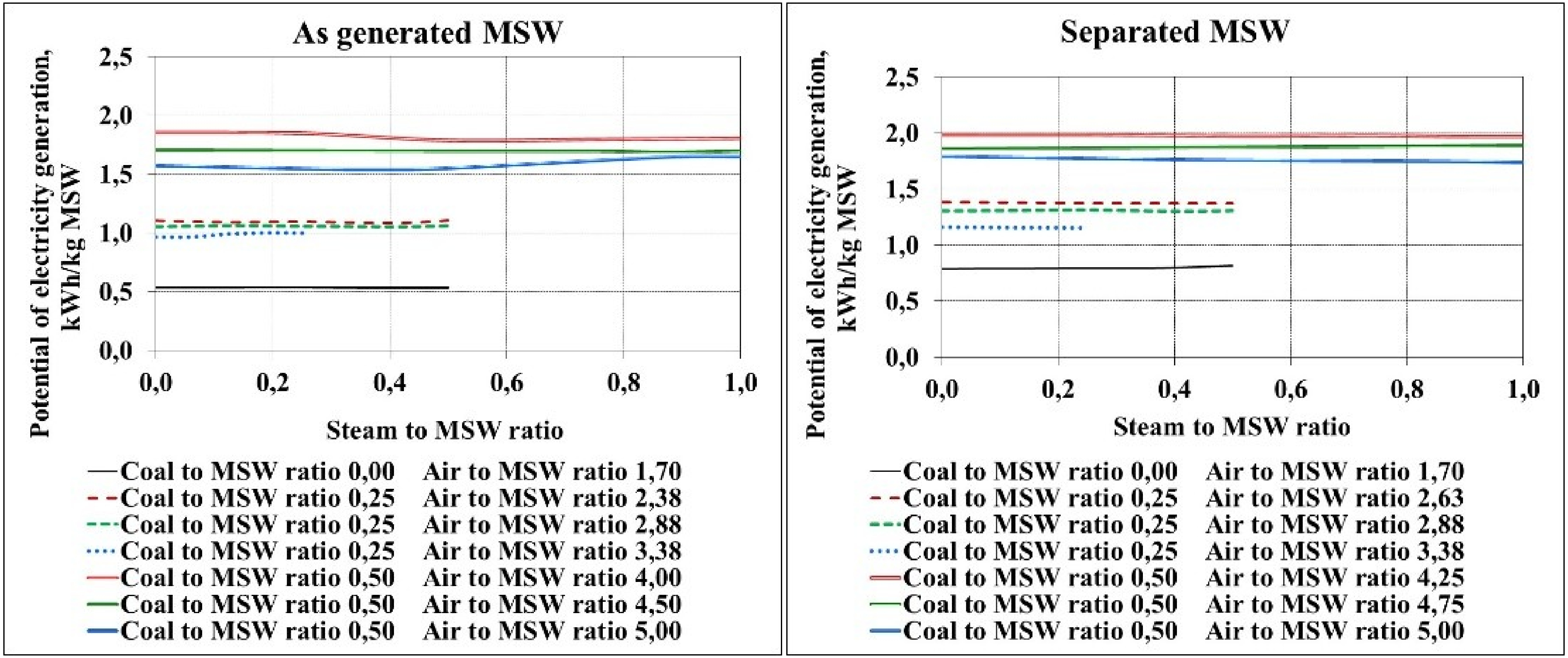
It must be said that the incoming hot air and the steam contribute with some energy also, which adds to the outgoing syngas heat value and sensible heat.

Potentials in the syngas to generate electricity

The sensible heat potential can be used to generate mechanical work and electricity, removing the sensible heat in a Rankine cycle. To determine the potential for this a Carnot cycle efficiency was calculated using as hot temperature the syngas temperature and as cold temperature the ambient value (25°C). With this Carnot efficiency an estimation was obtained of a real efficiency based on existing Rankine cycles in which it is possible to get about a 35 % of the Carnot efficiency .

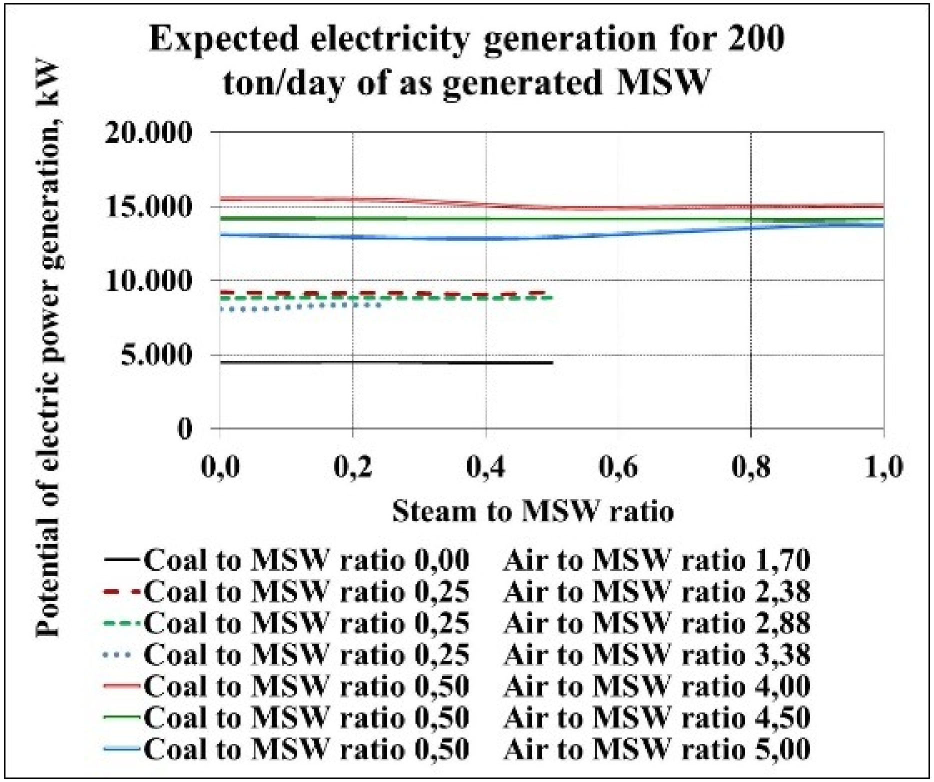
A second contribution was based on expecting an efficiency of 30 % for the cycle used to make use of the combustion heat value of the syngas, considering that it could be taken to an internal combustion engine.

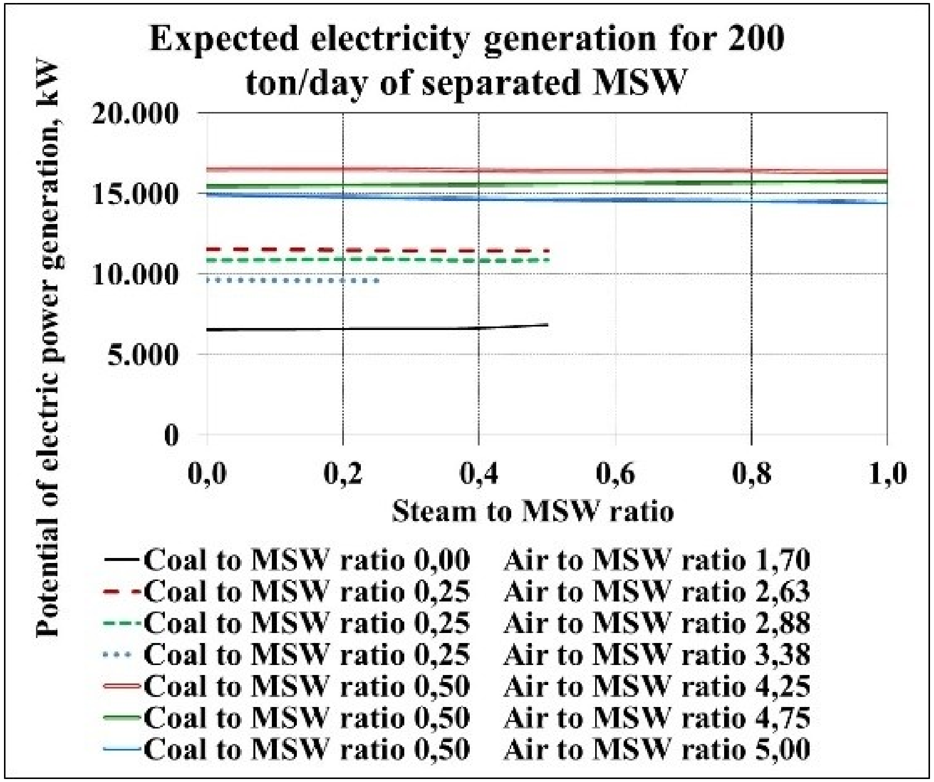
Combining these two efficiencies, in proportion to the existing contributions (that of heat value and that of sensible heat in the energy content of the syngas), it was possible to estimate the total efficiency of transformation to electricity and the total potential for electricity generation.



These figures show the potentials for electricity generation. It is not affected by steam to MSW ratios. It is highly dependent on coal to MSW ratio and it is higher for lower air to MSW ratios.

The potentials are higher for the case of separated MSW (between 0.75 and 2.2 kW per kg of MSW as compared to a range between 0.5 and 2.0 kW per kg of MSW for the as generated MSW case)





These figures show the expected electrical generation for a plant processing 200 tons of MSW per day.

These capacities will be between 4800 kw and 16000 kW for the as generated MSW and between 6500 and 17000 kW for the separated MSW. They are not affected by steam to MSW ratio, increase clearly with coal to MSW ratio and decrease with air to MSW ratio.

Per capita electricity generation potential with syngas plants for the considered cases in Colombia

Parameter	units	As generated	Separated
MSW in Colombia	kg/person day	0,50	0,24
Electricity generated - low	kWh/kg MSW	0,55	0,70
Electricity generated - high	kWh/kg MSW	1,80	2,00
Electricity generated - low	kWh/kg person-day	0,28	0,17
Electricity generated - high	kWh/kg person-day	0,90	0,49
Average Electricity consumption in Colombia	kWh/kg person-day	3,90	
Electricity			

Conclusions (1)

The theoretical model showed quite consistent results.

It was possible to develop a way of estimating syngas characteristics for the gasification of MSW in co-gasification, within practical working ranges for the studied variables.

This, under two extreme conditions for the MSW: as generated in a town with high organic material content and after separation of 55 % of the initial waste for recycling and organics treatment (for example by biological composting and digestion).

The model allowed to find the working ranges for steam to MSW ratios (between 0 to 1.0); air to MSW (between 1.7 and 5), for co-gasification with coal and coal to MSW ratios in the range of 0.0 to 0.5

Conclusions (2)

The gasification can generate electricity in all these ranges, with potentials that go from 0.5 to 2.2 kWh per kg of MSW.

For the case of a plant processing 200 ton of MSW per day, the generation capacities would be between 4800 and 17000 kW.

These capacities are entirely within the electricity needs of a country like Colombia. They are between 0.28 and 0.90 kWh per person per day, for the current per capita MSW generated in the country. These figures are to be compared to the current daily electricity per capita use, which is 3.90

Conclusions (3)

This work can be used as a conceptual basis for future work seeking indications on systems that could be feasible. This will help doing the correct steps.

Engineering and design are very important components of the technology necessary to impulse WtE in a country as these systems require detailed studies and planning activities and it is advisable to do the projects considering all the engineering stages.

In the solution of the problems, there is ample space to develop a region, as compared to relying only on external provided solutions. MSW co-gasification with coal seems to be a possible alternative.

Acknowledgments

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