Plasma gasification of biomass using a nitrogen plasma reactor to produce synthesis gas for small communities

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Introduction

- **Rapid industrialisation and agriculture has led to the increase available solid biomass waste.**

- This solid biomass waste **‘problem’** is a solution to our energy needs.
- Solid waste management needs to adopt some strategies:

  -Resource recovery through waste recovery.

  -Elimination of biomass land filling disposals.

  -Design environmentally responsible chemical conversion technologies.

  -Sustainable small scale thermal processes which are modular and flexible in their applications.

Challenges and opportunities

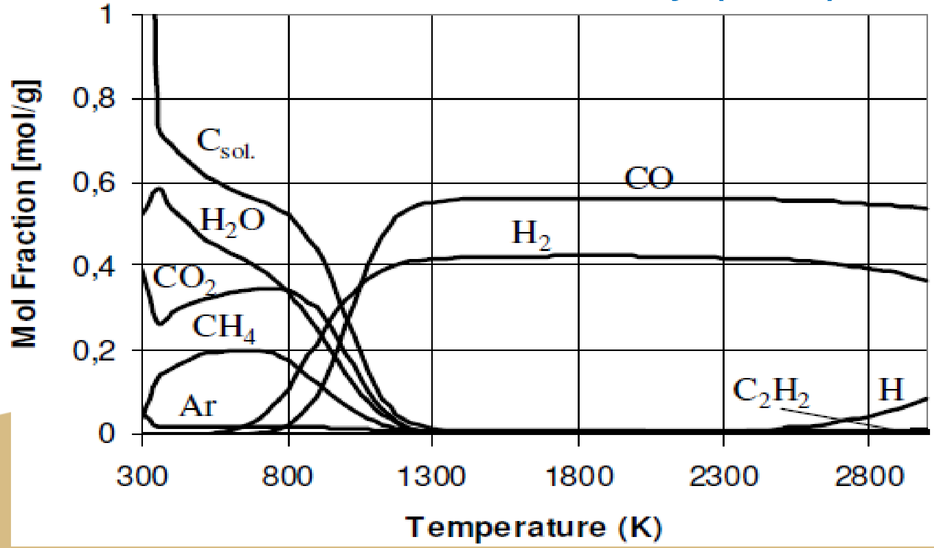
Challenges

- Global growth of energy demand is not balanced with its availability.
- 20% of methane emissions generated from landfills while 8% from manure management (EPA 2016).
- Limit global temperature rise to less than 2 °C above pre-industrial levels – the internationally agreed goal (COP21).

Opportunities

- Heating value of biomass indicates waste to energy plants are feasible.
- Production of valuable gas (syngas from waste biomass).
- Plasma gasification is a unique and is among the best opportunities to mitigate these challenges.

Hrabovsky (2011)



Background: Plasma gasification

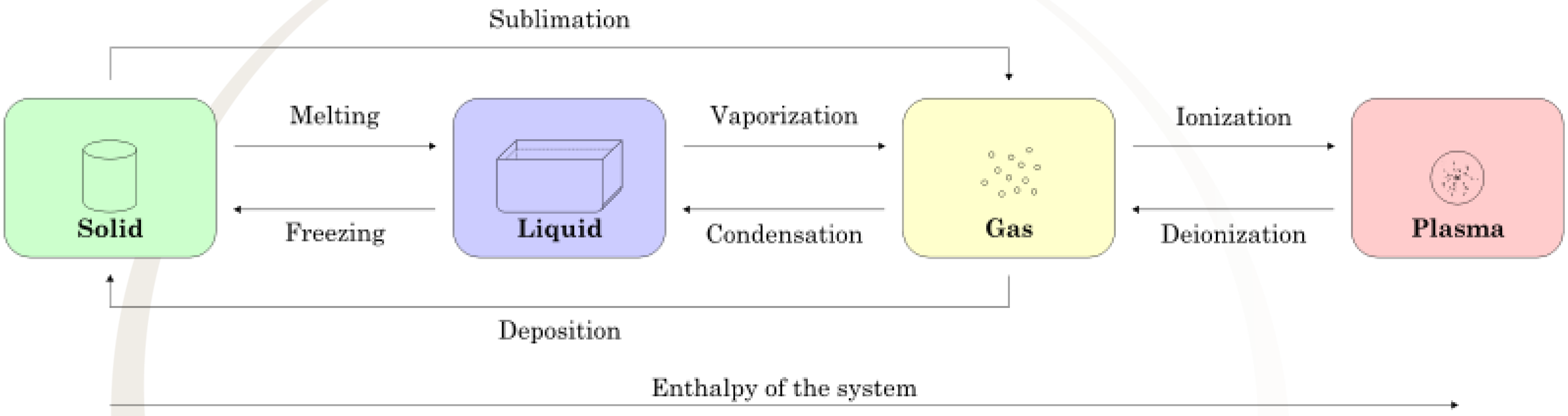
Initially technology was applied to nuclear waste industry.

Later adapted and applied to waste gasification processes and produce **syngas.**
-effectiveness of the process.
-due to high demand for energy.

Syngas is a mixture of gases containing mainly hydrogen H_2 and carbon monoxide (CO) and minor quantities of CO_2, H_2O and CH_4.

Syngas is used directly as:
-fuel for electricity generators.
-feed for Fischer Tropsch process in crude oil production.

What is Plasma?



Matter in “ordinary” conditions presents itself as **solid, liquid** and **gas.**

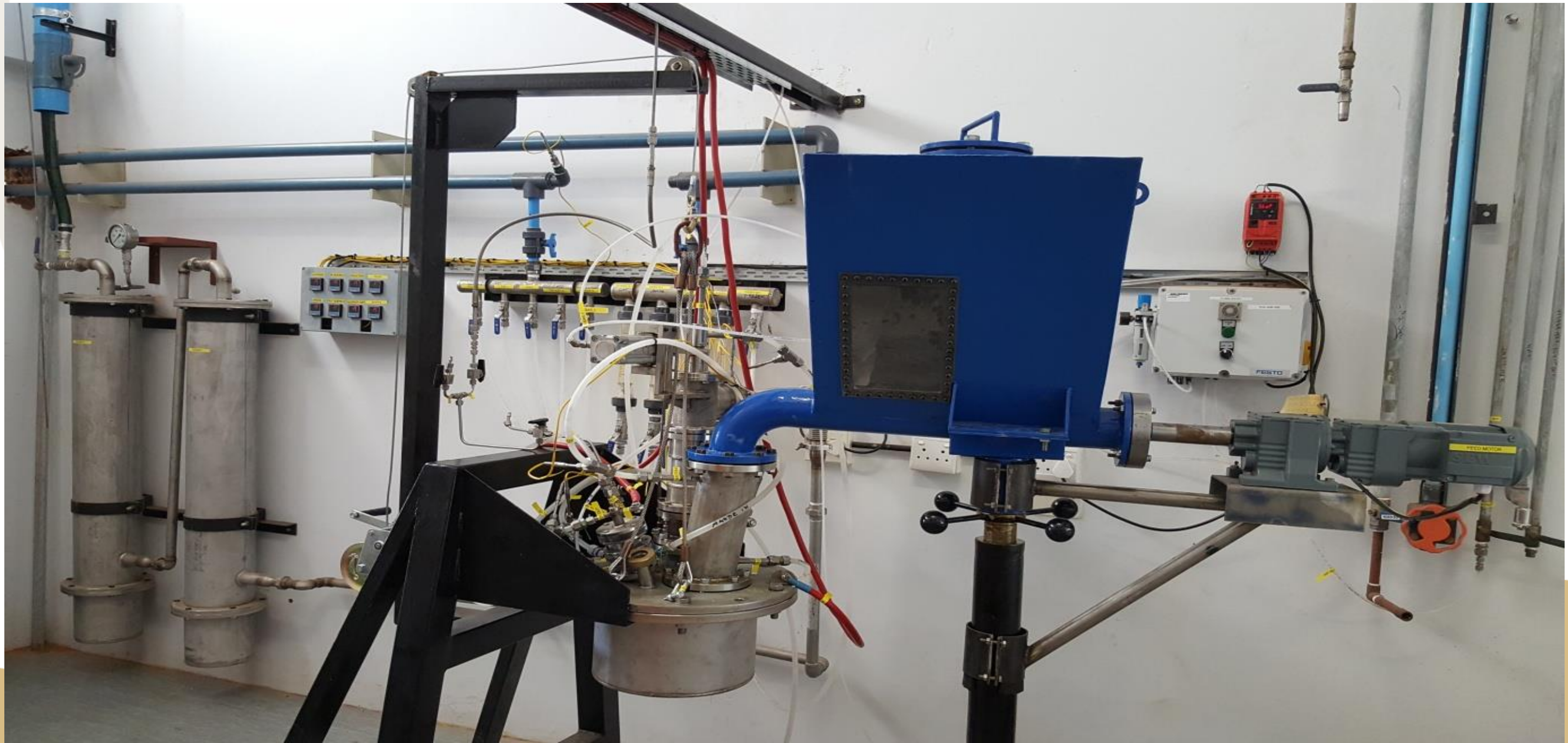
Plasma = The 4th state of matter.

Heating a gas at very high temperatures lead to ionization of atoms and turns it into plasma.

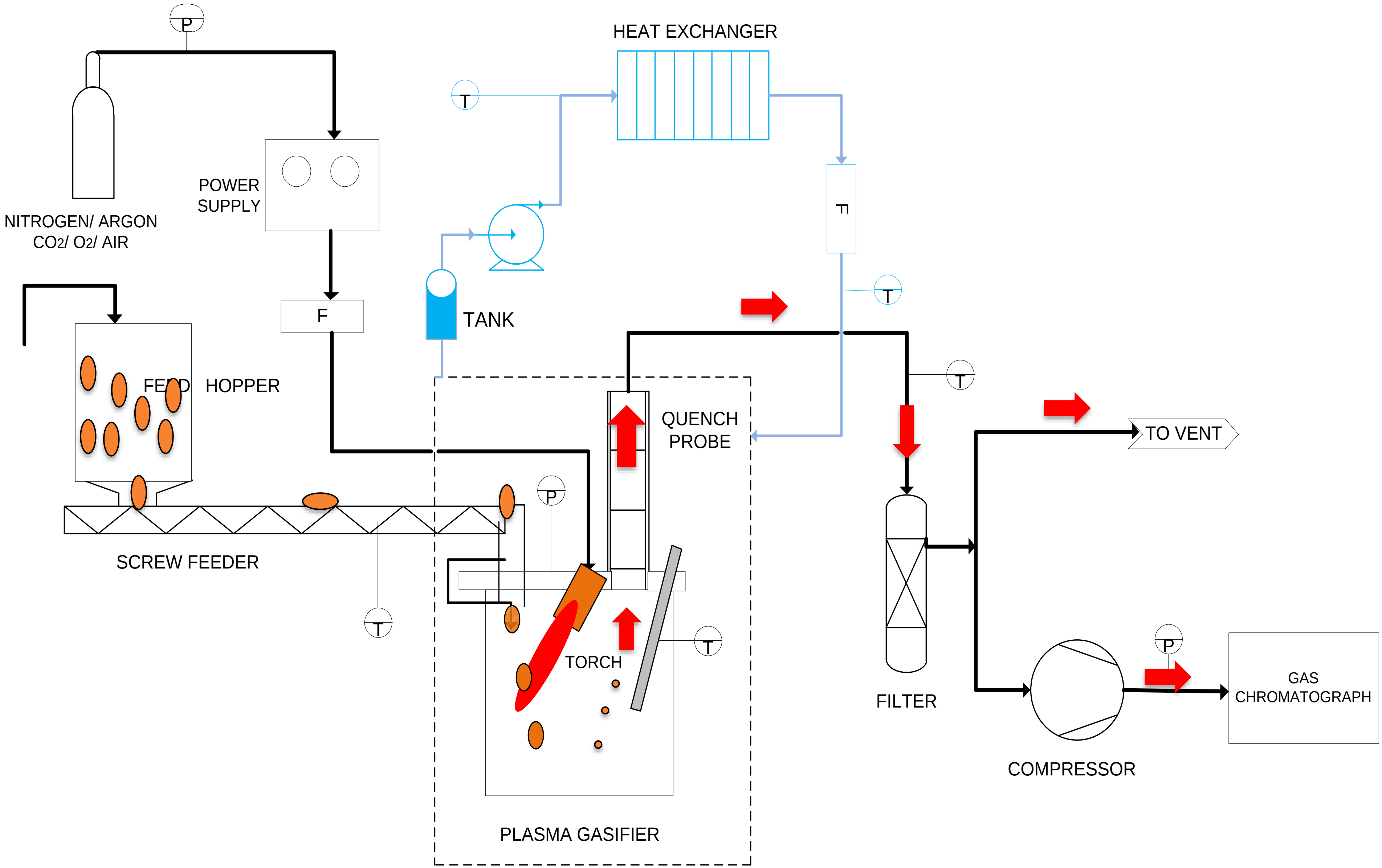
Lightning is an example of plasma from nature.

View of the laboratory plasma gasifier

- Plasma torch is the central part of the plasma gasification process.
- Operates at atmospheric pressure.
- Other components: Ionized gas, waste feed stock, power supply.
- Inside vessel is lined with ceramic refractory and sealed with stainless steel.
- Plasma arc converts organic waste is into synthesis gas.



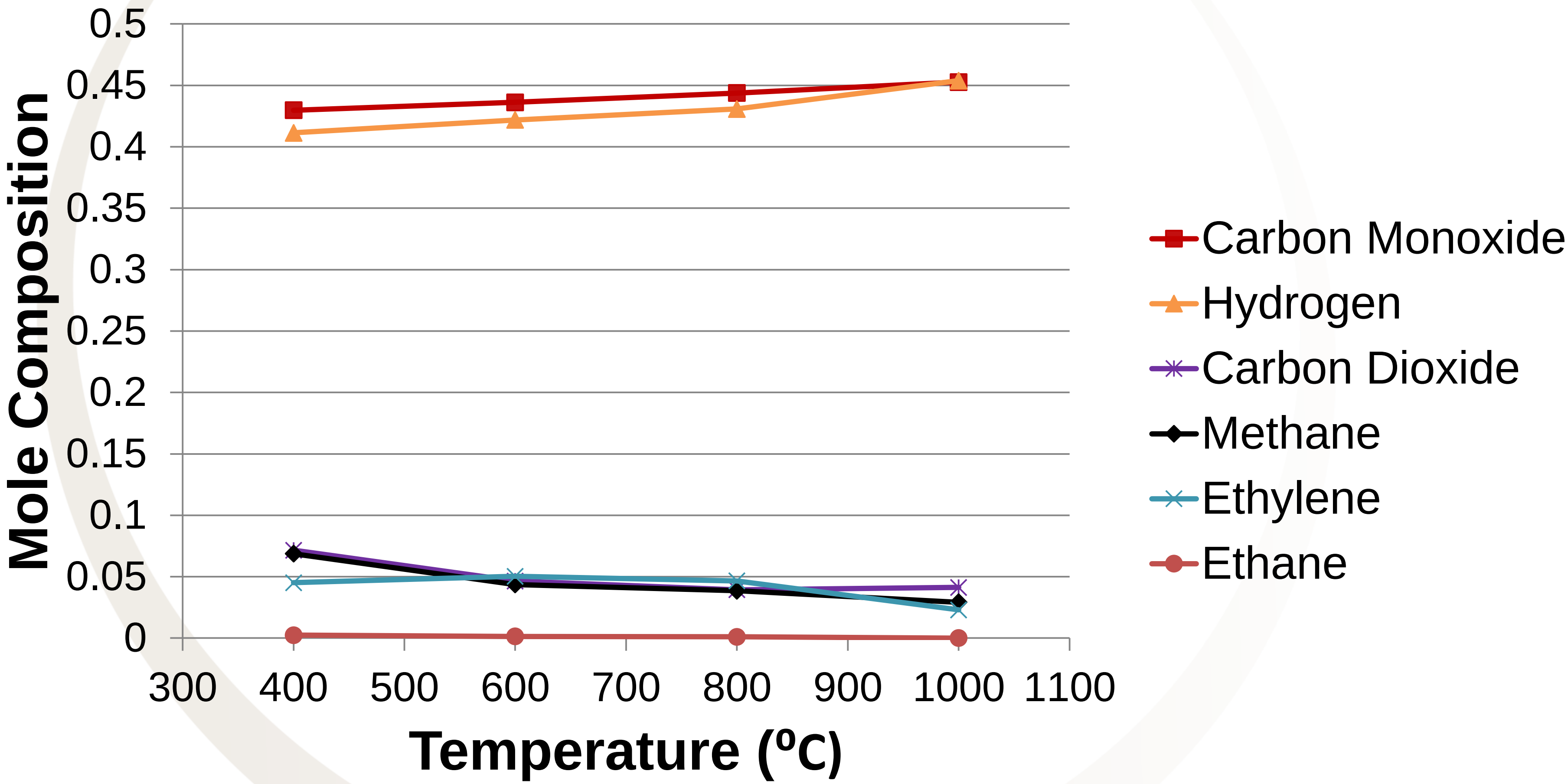
Process Flow Diagram



Characteristics of feed material

Proximate analysis		Ultimate analysis		Calorific value
(As received)		(As received)		5.18 (kWh/(kg)
Volatile matter	71.59	C	47.7 (48.4)	
Ash	2.44	H	6.04 (6.1)	
Moisture	6	O	43.84 (45.3)	
Fixed carbon	25.95	N	0.234 (0.21)	
-	-	S	Not Det	(Renew., 2004)

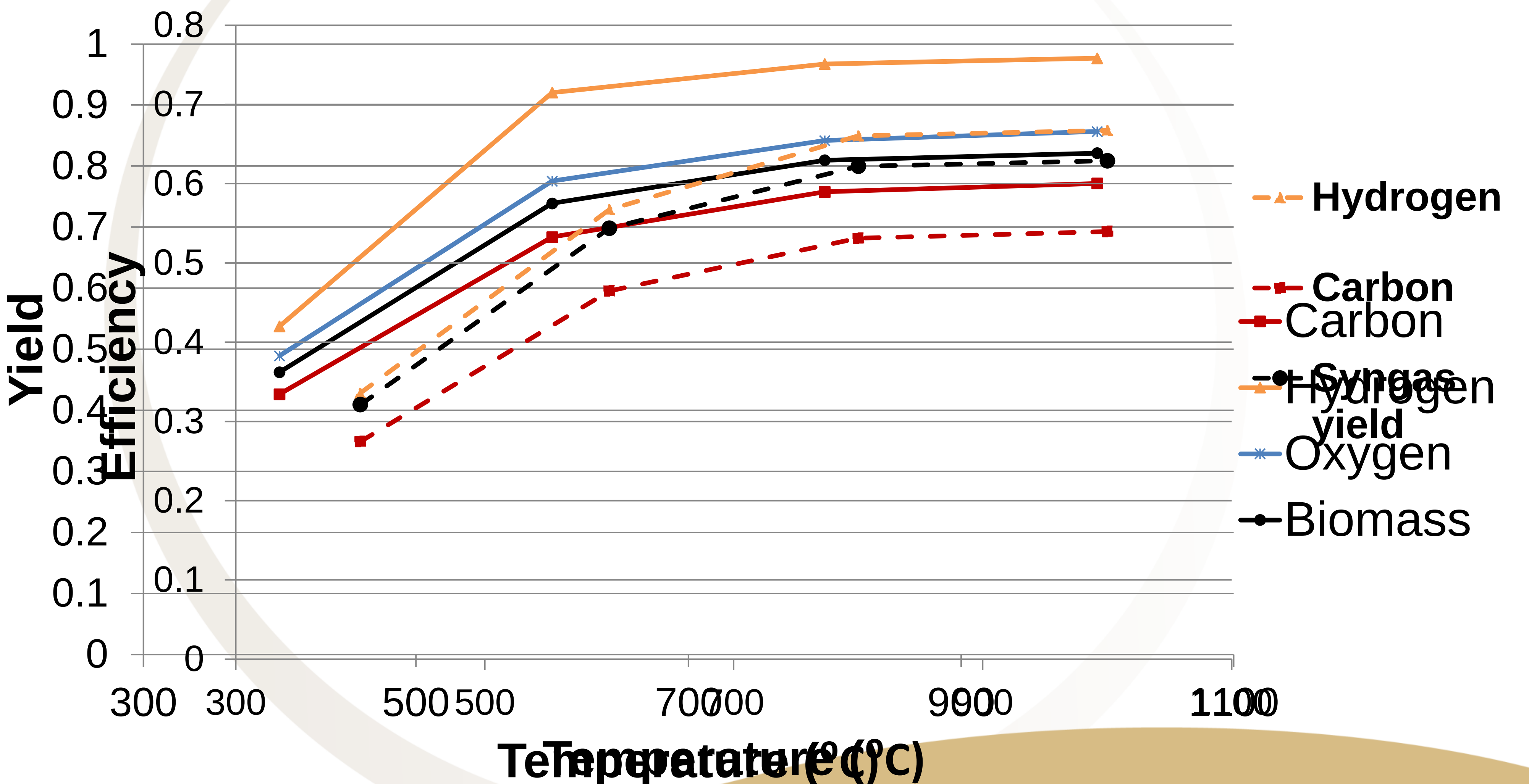
Change in the mole concentration of the product gas with temperature (Pyrolysis).



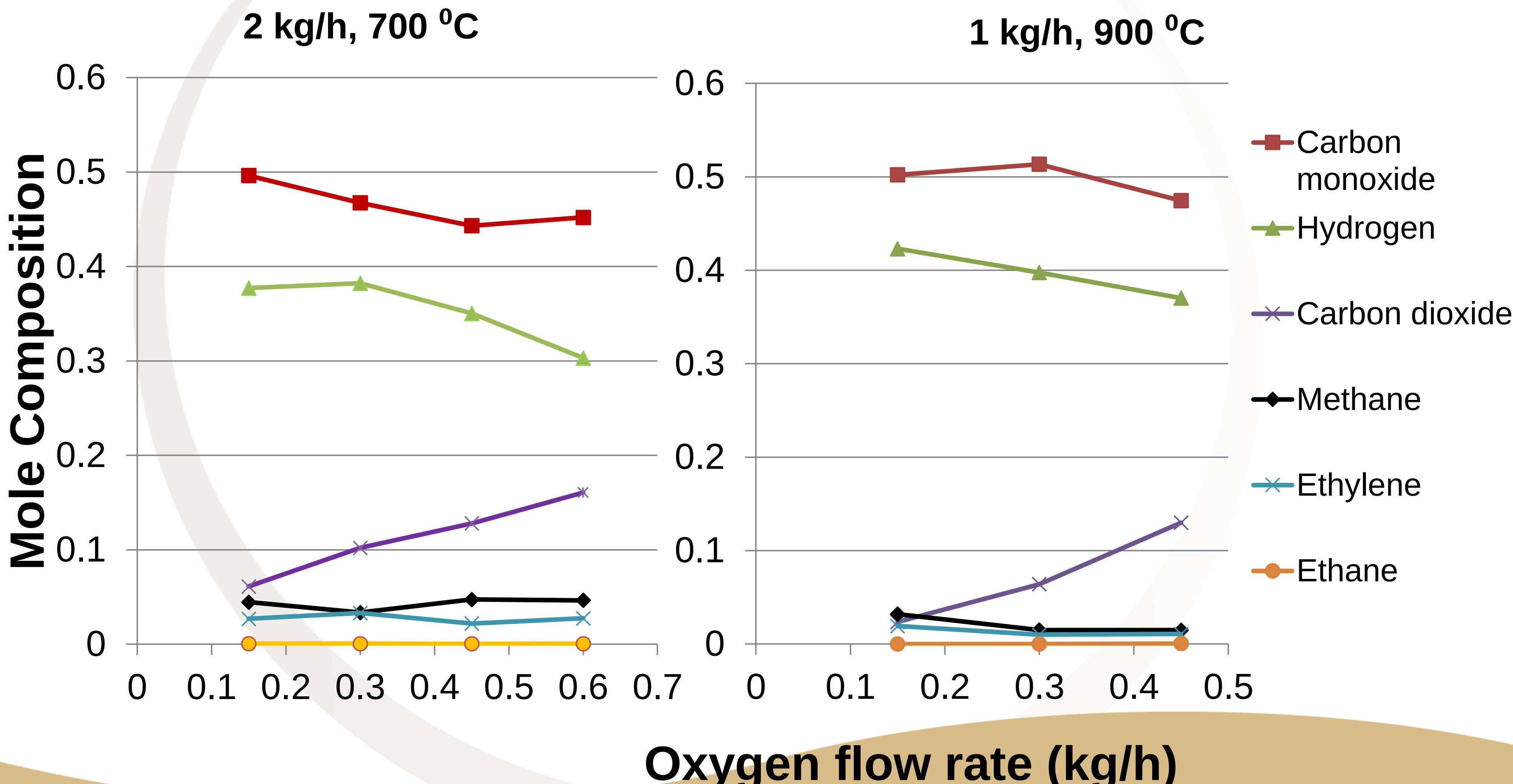
Yield and Efficiency

H yield = $\frac{\text{H atoms in the product gas}}{\text{H atoms in } feed}$

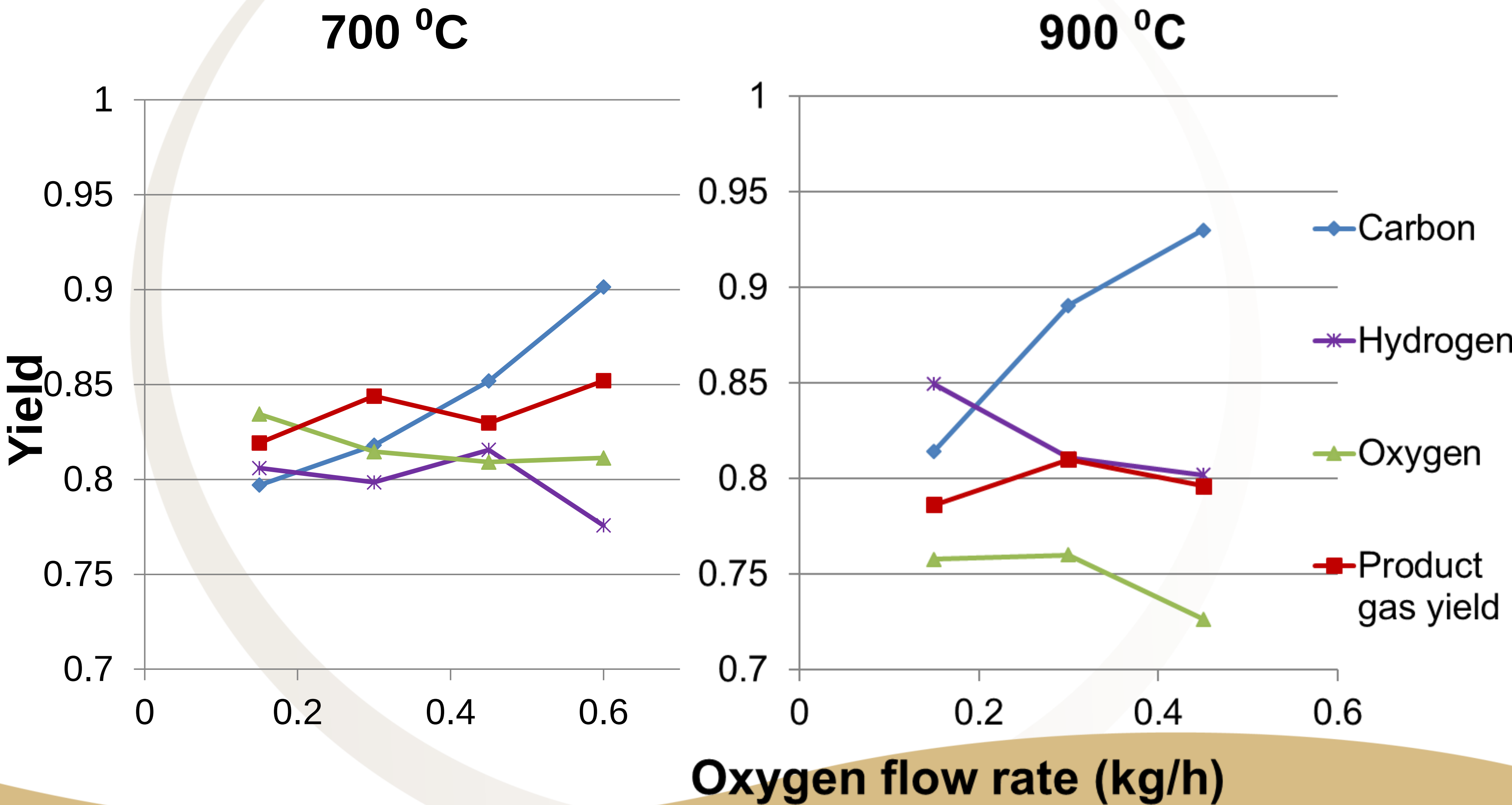
H efficiency = $\frac{\text{H atoms in the H2 product}}{\text{H atoms in } feed}$



Gasification



Yield



700 ^{0}C
900 ^{0}C
Yield
1
0.95
0.9
0.85
0.8
0.75
0.7
0
0.2
0.4
0.6
Carbon
Hydrogen
Oxygen
Product gas yield
Oxygen flow rate (kg/h)

Application of the plasma system in communities

Municipality

-Reduce biomass waste that is sent to landfills.

-Reducing methane emissions.

-Unlocks the greatest amount of energy from waste that can be converted to electricity.

- Employment opportunities.
- Use waste from farming/ timber for energy.
- Can also be used for municipal waste.
- Environmental benefits (reduce waste, reduce GHG).

Conclusions

-The molar H_2/CO ratio for the product gas obtained for pyrolysis at temperatures 400 ^0C, 600 ^0C, 800 ^0C and 1000 ^0C was ~1:1.

-The results have shown that adding O_2 resulted in a decrease of the H_2 yield, with an increase in CO_2 production.

-Cost benefit analysis (good syngas quality vs heat and work losses)

-Plasma gasification holds a potential to add to the supply of renewable resource in these times of uncertain energy supplies if the process is designed efficiently.

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Thank you