

# Methods for Producing Hydrogen-Rich Syngas in MSW Gasification

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**Abstract**—Although municipal solid waste (MSW) is a concern in many countries, it may be a highly appealing alternative feedstock for gasification to create sustainable gas fuels. The creation of hydrogen syngas from MSW gasification has received a lot of attention. The employment of a catalyst in the MSW gasification process is known to boost the gasification reactor's performance in producing hydrogen-rich syngas. Furthermore, the co-gasification approach is frequently utilized to increase syngas quality and gasification efficiency. This paper discusses many ways for gasifying MSW for the generation of hydrogen rich syngas. Catalytic gasification, co-gasification, and a modified gasification system are the gasification methods under consideration.

**Index Terms**—MSW, gasification, hydrogen, syngas, catalytic, co-gasification.

## I. INTRODUCTION

Municipal solid waste (MSW) generated at a rate of thousands of tons per day is a concern in many nations. On the other hand, MSW is an intriguing material to investigate, particularly for the production of bio-syngas with a high hydrogen concentration. Hydrogen is expected to become a future fuel source as the world's population grows and energy demands rise. Hydrogen has a large heat capacity. It is capable of creating electrical energy with minimal pollutants when burnt or utilized in a fuel cell, but sadly, at the moment, 98 percent of electrical energy is derived from fossil fuels [1]. As a result, it is extremely difficult to manufacture hydrogen from renewable raw materials, particularly MSW.

Gasification is a method capable of converting MSW into bio-syngas containing hydrogen. TRL 7 for gasification to process MSW, biomass, or coal has been achieved, which is greater than TRL 4-5 for biologic conversion and TRL 2-4 for electrochemical conversion [1]. The cost of creating hydrogen from biomass and MSW is still relatively high, ranging from 1.21 to 2.42 \$/kg and 3.22 \$/kg [2], respectively, or three to four times more expensive than steam methane reforming (SMR), which costs 0.75 \$/kg [3]. Many factors impact the cost of hydrogen generation, including technology and gasification procedures. The concentration of hydrogen syngas generated by a gasification plant is dependent on it, therefore understanding it will be useful in obtaining better development directions for hydrogen generation from MSW.

MSW has a distinct and complicated composition from

city to city, and even the daily output varies. People's behavior, economic condition, area, time of day, and weather all have a substantial impact on the composition of MSW. MSW consists of paper, plastic, textiles, and other biomass in industrial city regions with community behavior capable of sorting garbage effectively. The calorific value of MSW ranges from 9 to 44 MJ/kg due to its varied components. This difference in MSW is significant to investigate further in terms of the quality of syngas generated by the gasification process. The approach employed must be tailored to the MSW circumstances in order to produce best hydrogen syngas yields.

Gasification is one of the most widely utilized ways for converting MSW into an energy source in the form of syngas. Thermochemical processing of MSW results in syngas rich in  $H_2$  and CO. Gasification is more beneficial than other thermochemical processes because it transforms solid fuels to combustible gases [4]. Several studies on MSW gasification have been carried out [2], [5]–[10]. To attain the maximum hydrogen content in the MSW gasification product, many approaches have been explored. The employment of a catalyst in gasification is thought to boost the amount of hydrogen syngas produced during the gasification process. MSW gasification using a marble waste catalyst has been shown to create 44.6 percent hydrogen [10]. In another study [5], Calcined Olivine catalyst was employed in steam gasification MSW, and the maximum hydrogen yield was 53.29 mol percent, and the greatest  $H_2$  yield was 38.60 mol  $H_2$ /kg-MSW found at the highest temperature of 950 °C. It's worth debating how the type of catalyst affects the gasification performance.

Another approach for increasing hydrogen syngas levels is to blend various feedstocks in a single gasification system. This is sometimes referred to as Co-Gasification. In gasification systems, the integration of materials has a distinct and intriguing effect to investigate. Optimal feedstock mixing has the potential to increase syngas quality. Co-gasification with wood pellets as input material mixed with algae in the fluidized bed gasifier has been studied [11]. The results revealed that adding 10% wt algae to the wood increased the output of CO,  $H_2$ , and  $CH_4$  syngas by 3-20%, 6-31%, and 9-20%, respectively. Meanwhile, the addition of this 10% wt algae was shown to cut  $CO_2$  production by 3-18%. In addition, waste tire gasification with pine bark was used in another study to improve syngas output [12]. The findings of co-gasification of waste tire and pine bark demonstrate that increasing the amount of pine bark can enhance the flow rate of  $H_2$  at 900 °C. The mixing of different gasification materials is known to have an influence on the syngas outcomes, either positively or negatively. It is

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worthwhile to debate in order to establish the best material composition for producing hydrogen syngas via MSW gasification.

In this study, we will deal with various major strategies for increasing hydrogen syngas generation in the MSW gasification system. In this scenario, we'll see if catalytic gasification and co-gasification are the best options for producing hydrogen-rich syngas. This paper also presents various different strategies that might potentially be applied in MSW gasification.

## II. METHODOLOGY

Because this study is based on a review of the literatures, this article will provide several comparisons from prior studies, focusing on catalytic gasification and co-gasification in MSW. Various catalysts used in MSW gasification are examined and reviewed in order to identify the extent to which they have an influence on raising hydrogen syngas. Co-gasification of diverse materials is also discussed in the hopes that it may be used as a reference in future study on enhancing hydrogen syngas in MSW gasification. Other ways for gasifying MSW that have the potential to increase hydrogen syngas will also be demonstrated. An evaluation of the numerous procedures presented was carried out at the end of the study. It is intended that conclusions may be formed on the most recent approved method for MSW gasification.

## III. RESULT AND DISCUSSION

Municipal Solid Waste (MSW), an inevitable byproduct of city life, is known to have a significant amount of hydrocarbons, making it an appealing possibility for energy recovery. The main benefit of Trash-to-Energy (WtE) conversion is that it eliminates waste, provides energy products, and reduces pollutants [13]. Several obstacles were discovered along the road in the transformation of MSW into energy, particularly with gasification technology. Among them are those concerning how to improve the quality of the gas generated, how to create gas with a high concentration, high carbon conversion efficiency, preventing ash agglomeration, and tar formation as a result. The composition of MSW in each city undoubtedly necessitates distinct treatments in order for them to be utilized properly.

TABLE I: CHARACTERISTIC OF MSW IN JATIBARANG LANDFILL SEMARANG, INDONESIA [14]

Proximate		Ultimate	
Moisture Content	20 wt. %	C	43.71 wt. % db
Fixed Carbon	12.82 wt. %	H	7.74 wt. % db
Volatile Matter	77.67 wt. %	N	1.95 wt. % db
Ash	9.51 wt. %	O	36.69 wt. % db
HHV	15.53 kJ/kg	S	0.40 wt. % db
LHV	16.01 kJ/kg	Ash	9.51 wt. % db

For example, the following are the characteristics of MSW in the Indonesian city of Semarang. The following data was collected from the Jatibarang Landfill in Semarang,

Indonesia. Table I shows the MSW characteristic provided in the form of proximate and ultimate analysis of the MSW sample in the Jatibarang Landfill Semarang.

These distinctive qualities undoubtedly necessitate adequate treatment in order to get maximum outcomes in the gasification process. The approach described below can be used to boost the generation of hydrogen syngas from MSW gasification.

### A. Catalytic Gasification

Catalysts have been extensively researched in the MSW and biomass gasification processes [5], [6], [9], [10], [15], [16]. Catalysts are used for a variety of purposes, including (1) tar cracking, (2) lowering gasification temperatures, and (3) enhancing steam reforming and water gas shift reactions in order to create hydrogen-rich gas and more product gas [5]. The previous study [6] discovered NiO on modified dolomite (NiO/MD) as a catalyst for hydrogen-rich gas generation via steam gasification of MSW. MSW samples were collected at an MSW transfer site in Wuhan, China. The sample is dominated by textile materials (19.95 wt%), wood (11.4 wt%), kitchen rubbish (42.37 wt%), plastic (9.57 wt%), and paper (16.71 wt%). MSW dried naturally in 8 days, with a moisture level of roughly 9.34 percent. The results suggest that the NiO/MD catalyst may boost H<sub>2</sub> output during steam gasification. At 800 °C and a S/M ratio of 1.23, H<sub>2</sub> yield rose from 21.9 g H<sub>2</sub>/kg MSW to 80.68 g H<sub>2</sub>/kg MSW. The application of a NiO/MD catalyst is also known to reduce tar production, with tar conversion reaching 99.0 percent at a temperature of 800 °C. This demonstrates that NiO/MD is suitable for removing tar content from MSW gasification.

This demonstrates that NiO/MD is well suited to efficiently remove tar from MSW gasification in order to create hydrogen gas. As a result of these findings, it is clear that NiO/MD has a beneficial influence on MSW gasification. Yield H<sub>2</sub> increases significantly. On the other hand, the catalyst benefits the tar formed during gasification. It is, however, impacted by other variables such as temperature and the S/M ratio. Temperature and S/M ratio optimization can improve the performance of the NiO/MD catalyst for gasification syngas products.

Another research [5] investigated the use of Calcined Olivine as a catalyst for steam gasification of municipal solid waste. Gasification of MSW was examined utilizing calcined dolomite as a catalyst in a bench-scale fixed bed reactor. MSW samples are processed in a raw material hopper equipped with an airtight closing mechanism and a maximum capacity of 2 L. The material was continually delivered into the reactor during the experiment using a continuous screwdriver mechanism whose spin was controlled by an inverter. 200 g of calcined dolomite was kept in stainless tubes prior to each experiment. The hopper is loaded with the grated MSW sample. Once the desired temperature is obtained, the MSW feedstock and steam are fed into the gasifier continuously at the same rate of 0.257 kg/hour and 0.198 kg/hour, respectively. This catalyst is being added to boost the generation of H<sub>2</sub> and CO syngas. The analysis is being conducted to ascertain the influence of the catalyst and reactor temperature on the syngas/product yield and composition. At the greatest temperature of 950 °C, the

highest H<sub>2</sub> concentration was 53.29 mol percent, and the highest H<sub>2</sub> production was 38.60 mol H<sub>2</sub>/kg-MSW. Calcined dolomite greatly enhances the quality of product gas and reduces tar output. On the other hand, dry gas yield and carbon conversion efficiency rose significantly (385.29 and 144.52 percent, respectively), but charcoal yield declined by 35.72 percent. It is influenced by vapor, which increases the concentration of H<sub>2</sub> and CO<sub>2</sub> and decreases the concentration of CO, CH<sub>4</sub>, C<sub>2</sub>H<sub>4</sub>, and C<sub>2</sub>H<sub>6</sub>. A similar research studied the influence of the steam-to-MSW ratio on the formation of H<sub>2</sub> syngas [17]. H<sub>2</sub> and CO<sub>2</sub> levels grew in lockstep with the S/M ratio rise. At the greatest S/M ratio of 1.04, the maximum H<sub>2</sub> content was 53.22 mol percent, the highest H<sub>2</sub> yield was 42.98 mol H<sub>2</sub>/kg-MSW, and the highest prospective H<sub>2</sub> output was 59.83 mol H<sub>2</sub>/kg-MSW.

TABLE II: HYDROGEN PRODUCTION WITH MSW CATALYTIC GASIFICATION

Feedstock	Catalyst	Optimum Condition	H <sub>2</sub> Content	Ref
MSW	Calcined Olivine	Temperature 950°C, S/M Ratio 0.77	53.29 mol%	[5]
MSW	Calcined Olivine	Temperature 900°C, S/M Ratio 1.04	53.22 mol%	[17]
MSW	NiO on Modified Dolomite (NiO/MD)	Temperature 800°C, S/M Ratio 1/23	55.78 vol%	[6]
Wet MSW	CaO	Temperature 750°C and ratio [Ca]/[C] 0.7, Moisture 40%	49.42 vol%	[18]
MSW	Marble Waste	Temperature 900°C, steam rate 5ml/min, & 20ml/min N <sub>2</sub> Supply.	44.6 vol%	[10]
MSW	Ce-Ni/C	Temperature 850 °C, S/C ratio 3.6, 0.25Ce-15% Ni/C	37.76 vol%	[16]
Wet MSW	Ni-CaO-Hf O <sub>2</sub>	Temperature 850 °C, N <sub>2</sub> supply 50 mL/min, C/MSW Ratio 1.0	47.1 vol%	[19]

The gasification of MSW using a marble waste powder catalyst resulted in the generation of hydrogen-enriched syngas [10]. MSW samples were collected at a residential neighborhood adjacent to Dalian University of Technology in Dalian, People's Republic of China. Only the organic components of MSW were included in this study (i.e., kitchen trash, paper, textiles, grass/wood, and plastic). The experiment was conducted by combining marble waste powder with municipal solid trash at a ratio of (0, 0.25, 0.5, 0.75, 1). H<sub>2</sub> and CO were determined to be 32.4 percent and 14.8 percent, respectively, in the testing findings without marble waste powder. The addition of marble waste powder increased the output of H<sub>2</sub> and CO syngas by 38.6–44.6 percent and 14.6–19.4 percent, respectively. Additionally,

marble waste powder increased CCE from 62.4 to 86.1 percent and decreased tar content from 12.4 to 5.2 percent. Marble waste powder is an appealing economic alternative since its usage as a catalyst in the marble processing sector may help offset losses caused by waste buildup and disposal expenses [10]. Marble waste as a catalyst also has advantages in the MSW gasification process, most notably in terms of boosting the performance of hydrogen syngas generation.

A technique for producing hydrogen-rich syngas from wet MSW gasification has been developed utilizing CaO in conjunction with a carbon dioxide capture mechanism. Wet MSW is combined with CaO as a gasification feedstock for processing in the gasification reactor. CaO works as both a carbon dioxide absorber and a catalyst in this situation, resulting in hydrogen-rich syngas during the MSW gasification process [18]. The study examined the influence of moisture content, the molar ratio of calcium oxide to carbon in wet MSW ([Ca]/[C]), and reactor temperature on H<sub>2</sub> production and gas composition. The greatest volumetric concentration of H<sub>2</sub> was 49.42 vol%, and the highest yield was 277.67 ml/g-MSW, which was found at a moisture content of 40%, a reactor temperature of 750 °C, and a [Ca]/[C] ratio of 0.7 [18]. According to these findings, the optimal [Ca]/[C] ratio for increasing H<sub>2</sub> production and concentration is 0.7. CaO serves as a catalyst and CO<sub>2</sub> trap in this situation. CaO interacts with CO<sub>2</sub> to form solid CaCO<sub>3</sub> [CaO + CO<sub>2</sub> → CaCO<sub>3</sub>(s)]. CaO's catalytic involvement was demonstrated by a substantial increase in H<sub>2</sub> production. The catalytic impact increased the H<sub>2</sub> yield from 64.68 ml/g-MSW to 277.67 ml/g-MSW.

A study was done[16] utilizing Ce-Ni/C as a catalyst in the MSW gasification process. This catalyst is being added to boost the amount of hydrogen syngas generated during MSW gasification. The Ce-Ni/C catalyst with a Ni/C ratio of 0.25Ce-15% was able to enhance the hydrogen concentration from 14.64 to 37.76 percent. With carbon as a support and a 15% Ni content as the primary component, a catalyst supported by Ce-15% Ni/C may effectively raise the yield of H<sub>2</sub> in synthesis gas while also increasing output. In another study, HfO<sub>2</sub> is used as a stabilizer and promoter for the Ni-CaO catalyst system in the gasification of MSW. The addition of HfO<sub>2</sub> as a promoter to the Ni-CaO catalyst increased the H<sub>2</sub> concentration from 40.8 to 47.1 percent. This work established that HfO<sub>2</sub> may be employed as a promoter to enhance the performance and stability of the Ni-CaO catalytic system [19].

In another study, a Ni-Fe-based catalyst was also used in the MSW gasification process. The use of this catalyst is supported by waste tire derived char (WTC) to increase the syngas content of the gasification product. The research was carried out on a fixed-bed reactor for wet MSW gasification [20]. The catalytic gasification performance was studied. The use of a Ni-Fe-based catalyst with the support of WTC was able to increase the concentration of H<sub>2</sub> from 29.26% to 38.24–42.15%. The resulting H<sub>2</sub> yield also increased from 212 to 396–487 mL/g MSW. Another benefit of using this catalyst is to reduce tar content. Tar content can be reduced from 9.11% to as low as 2.15% using Ni-WTC catalyst. It is interesting that inexpensive materials such as WTC can support Ni-Fe-based catalysts in order to improve wet MSW

gasification performance.

Table II contains further research on MSW gasification using a catalyst. The hydrogen concentration generated by several MSW gasification tests varies significantly. This, of course, is dependent on the catalyst utilized. Additionally, as previously noted, the syngas production is affected by the properties of MSW in various places. Temperature, ER, S/M ratio, and catalyst/MSW ratio optimization can all have an effect on catalyst performance in MSW gasification. Numerous issues remain to be investigated in greater depth at a later date.

### *B. Co-Gasification*

Co-Gasification is a process that utilizes two or more materials as a feedstock for gasification. This mixing is done to ensure that the gasification feedstock has the optimum content and properties. A feedstock with an appropriate composition is expected to benefit the gasification process, particularly in terms of hydrogen syngas output. To boost syngas generation, waste tire gasification with pine bark was undertaken [12]. The co-gasification of waste tires and pine bark shown that increasing the amount of pine bark increased the flow rate of  $H_2$  at 900 °C. When pine bark was added at a temperature of 800 °C, the  $H_2$  flow rate fell initially and then rose when the pine bark mixture exceeded 50%. The overall yield value grew in lockstep with the ratio of pine bark addition, except for the ratio W3:P1 at 800 °C. In general, the yield of  $H_2$  and peak flowrate of  $H_2$  are greater at 900 °C than at 800 °C for the same mixture ratio, since the temperature promotes cracking processes.

Another research [21] created an innovative three-stage method for co-gasification of MSW with high-alkaline coal charcoal. The modeled MSW is pyrolyzed in the first stage, partially processed raw syngas is oxidized in the second stage, and finally reduced with high alkaline coal char to generate high grade syngas. Three electric furnaces heat the three-stage process, with the first stage controlled at 450, 550, and 650 °C for pyrolysis, the second stage controlled at 800 °C for oxidation, and the final stage controlled at 800, 900, and 1000 °C for reduction. Experimentally, the influence of temperature and equivalence ratio (ER) on syngas production was determined, as well as the concentrations of condensed tar and HCl species. The results indicate that  $H_2$ , CO, and  $CH_4$  concentrations in synthesis gas remain steady at 41.9vol%, 29.3vol%, and 7.49vol%, respectively, while the lower heating value (LHV) reaches 12.2MJ/  $Nm^3$ . The two major pollutants found in generated gas may be kept to as low as 11.3mg/ $Nm^3$  (tar content) and 17.6mg/ $Nm^3$  (HCl content) [21]. As a result of this research, it can be concluded that combining MSW material with highly alkaline charcoal improves syngas production. Additionally, co-gasification is capable of reducing pollutants, particularly tar and HCl.

Other study has examined the synergistic impact of co-gasification of MSW and biomass using a fixed bed gasifier [22]. The research demonstrates that temperature is critical after the ER exceeds 0.3 in terms of gas output and carbon conversion ratio in co-gasification. A positive synergistic impact occurs when the ER is less than 0.1-0.2 and the temperature is more than 800-900°C, whereas a negative synergistic effect occurs when the ER is greater than

0.3-0.4. When bottom ash co-gasification is developed, it is envisaged that potassium in the bottom ash will remain in sulfur-containing compounds due to the increased temperature and ER. Meanwhile, potassium chloride is likely to contain potassium at lower temperatures and ER. The high calcium concentration is more readily concentrated in tiny particles and incorporated into the aluminosilicate, resulting in the creation of adhering ash particles that can considerably enhance melting agglomeration [22].

Co-gasification using wood pellets as raw material in conjunction with algae has also been performed in a fluidized bed gasifier [11]. The purpose of this study is to investigate gas output, ash behavior, and agglomeration. The results indicated that adding 10% wt algae to wood increased the output of CO,  $H_2$ , and  $CH_4$  syngas by 3-20%, 6-31%, and 9-20%, respectively. Meanwhile, adding 10% weight of algae reduced  $CO_2$  output by 3-18%. The addition of macroalgae to wood enhanced the rate of carbon conversion somewhat, but the addition of microalgae reduced the rate of carbon conversion by 8%. The sodium concentration of macroalgae and microalgae is three times that of wood, whereas the potassium level is 19-35 times that of wood. As a result of the macroalgae's high alkali metal concentration, the char conversion rate was boosted, resulting in an increase in CO and  $H_2$  yields. In terms of ash behavior and agglomeration, adding 10% wt algae to wood resulted in a considerable change in the composition of fly ash. The inclusion of macroalgae clearly increased the Na content of fly ash while lowering the Si and Ca contents. The inclusion of this algae has a significant effect on both bed agglomeration and the character and content of the coating layer, which clearly demonstrates variations in the studied fuel combination. The aggregation process is influenced by the initial composition of algae as fuel contaminating minerals. The coating layer generation and agglomeration process are both reactive. It is triggered when alkaline substances react directly with the bed particles, forming silicates with low melting points.

Another recent study demonstrated a co-gasification model using the Aspen Plus software. Municipal solid waste (MSW) and switchgrass (SG) co-gasification were modeled to determine the effect of steam/feed ratio and co-gasification ratio on gasification performance [23]. The results showed that the carbon conversion efficiency (CCE) and cold gas efficiency (CGE) were 48.9% and 39.92%, respectively, which were obtained for air-steam gasification with a temperature of 800 °C, steam/feed ratio 1.2, and co-gasification ratio of 40%.  $H_2$  concentration increased from 12.41 vol% to 13.66 vol% at increasing steam/feed ratio 0.8 to 1.2. However, referring to the results of the low hydrogen concentration, further development of co-gasification with this type of material is necessary. Optimization of reactor conditions needs to be studied in order to produce high levels of hydrogen syngas.

### *C. Modified Gasification System*

This approach alters the gasification system's design, optimizing the phases that the material travels through throughout the gasification process. Its objective is to maximize the efficiency of each stage of the gasification

process.

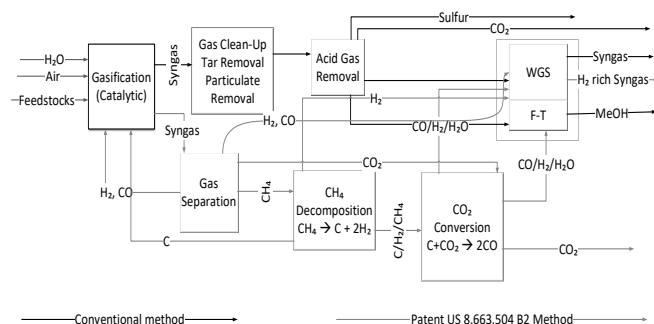


Fig. 1. Schematic of the gasification process in US Patent 8,663,504 B2.

The typical approach involves immediately processing the syngas produced by the gasification reactor in the gas clean-up, tar, particle, and acid gas removal blocks. Unlike the gasification process described in US Patent 8,663,504 B2, the syngas produced by the gasification reactor will be separated using gas separation. To maximize syngas yield, CH<sub>4</sub>, H<sub>2</sub>, CO, and CO<sub>2</sub> are separated and treated individually. This enables direct syngas separation, allowing for the anticipated syngas optimization. However, as demonstrated by this process, syngas separation has the potential to introduce flaws. A four-step process with rigorous parameters for each stage, if optimization is not carried out on each stage, the entire process would be disrupted, resulting in suboptimal syngas production. At the conclusion of the procedure, CO<sub>2</sub> and H<sub>2</sub>O remain, which might result in a poor heating value. At the conclusion of the procedure, H<sub>2</sub> is not separated, resulting in the absence of a pure H<sub>2</sub> product. Adding a reactor to separate the syngas, on the other hand, leads in a rise in equipment expenses.

The steam gasification of biomass was carried out utilizing the Decoupled Dual Loop Gasification (DDLG) technique using pine sawdust as the feedstock and calcined olivine as the catalyst [24]. Three distinct reactors are used to separate the processes of fuel pyrolysis and gasification, tar cracking/reforming, and char combustion. The separation process seeks to optimize the reactions that occur, by adjusting the settings of each reactor indefinitely in order to get an ideal process.

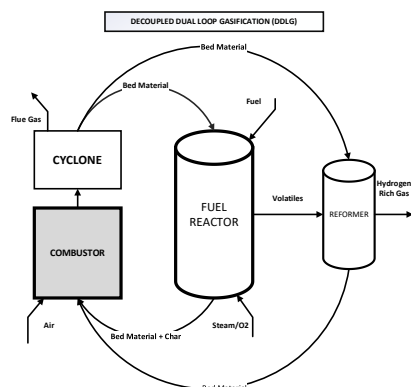


Fig. 2. Schematic of decoupled dual loop gasification (DDLG) system.

Fuel gasification is carried out in a fuel reactor in the DDLG system. The combustor reactor, which is coupled to the fuel reactor, generates heat. Gasification byproducts from the fuel reactor are highly flammable and contain syngas and

tar, which are sent to the reactor reformer. Methane interacts with steam in the reformer reactor at high temperatures ( $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$ ). Additionally, the reactor enables methane to be decomposed into hydrogen and carbon ( $\text{CH}_4 \rightarrow \text{C} + 2\text{H}_2$ ). Additional hydrogen can be generated by employing carbon monoxide in the water gas shift process ( $\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$ ). This, however, may be a problem, as CO<sub>2</sub> is formed at the conclusion of the process, and as we all know, CO<sub>2</sub> is a gas that cannot be burnt. When the temperature in the fuel reactor and the reformer reactor is increased, the result of the research utilizing this approach is an increase in the concentration of H<sub>2</sub>. The rise in temperature in the fuel reactor, on the other hand, results in a modest increase in tar yield. This may be anticipated by optimizing the reformer reactor process. It is well established that increasing the temperature in the reformer reactor can result in a decrease in tar production and an increase in H<sub>2</sub> concentration. Calcined olivine's catalytic activity can boost dry gas yield by 17% and lower tar output by 73%. This investigation generated a hydrogen concentration of 40.8 vol percent [24]. Calcined Olivine is a very affordable active component that may be employed in-situ as a catalyst to lower the tar content of biomass gasification fuel gas [25].

#### IV. CONCLUSION

Gasification is one of the methods that might be used to convert MSW to hydrogen-rich syngas. Numerous strategies exist for optimizing hydrogen syngas as a gasification product. Catalytic gasification, co-gasification, and other changes to the gasification system are among them. According to the reviewed literature, the current approach that provides the greatest concentration of hydrogen syngas is gasification of MSW using a NiO/MD catalyst, which produces 55.78 vol percent H<sub>2</sub>. CaO is recommended as a catalyst when using wet MSW as a gasification feedstock. CaO is well recognized for its ability to reduce moisture content, and this catalyst can also improve the quality of syngas. However, this process cannot be stated to be the optimum way in general, as the gasification outcomes will be determined by the diverse features of MSW in other places. Other gasification conditions and characteristics also have an influence. By optimizing each stage of the gasification process, the efficiency of gasification may be increased, resulting in the desired hydrogen-rich syngas. Experiments and other investigations are still required to ascertain the optimal strategy for MSW gasification.

Future study may focus on the properties of MSW and the gasification method employed to achieve the best possible gasification of MSW. The employment of catalysts or the combination of untested materials might be an intriguing area of investigation. Additionally, research on the financial and environmental impacts of MSW gasification is intriguing. Hydrogen produced from MSW is projected to be a cost-effective and ecologically beneficial alternative energy source.

#### CONFLICT OF INTEREST

The authors declare no conflict of interest.



# AUTHOR CONTRIBUTIONS

Afif Faishal conducted the data collection and wrote the paper draft. Prof. Suyitno contributed to analyze, review, language correction and revised the draft into final paper. Muhammad Hisjam contributed to review the final paper. All authors had contributed to this research and approved the final paper.

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