# <u>DESIGN CREDIT REPORT</u>

# TOPIC: **WASTE VALORIZATION**

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**November 2023**

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# CHAPTER-1
# INTRODUCTION

Waste management is a critical concern in contemporary society, with escalating rates of waste generation posing significant environmental challenges. In our project, we focus on the burgeoning issue of [solid waste], which has reached unsustainable levels, impacting ecosystems and public health.

Firstly, we aim to develop an efficient gasification process for solid waste.Gasification is a process that converts organic or fossil fuel-based carbonaceous materials into synthetic gas such as carbon monoxide, hydrogen, and carbon dioxide.

Secondly, we concentrate on the processes of extracting valuable metals for reuse and the safe removal of hazardous materials during the disposal of solar panels. Motivated by the urgency to adopt sustainable practices, the project's objectives include generating valuable synthetic gas and Utilizing e-waste.

**Objectives:**

- The primary focus is on efficiently converting solid waste through gasification and optimizing burner design for increased efficiency.

- Additionally, the initiative aims to address challenges related to the disposal of end-of-life solar panels, with a specific emphasis on extracting valuable metals and safely removing hazardous materials.

# CHAPTER-2

## Literature review

Waste valorization is a process that transforms waste materials into valuable resources, emphasizing sustainability and environmental benefits. It involves techniques such as gasification to efficiently convert solid waste into useful products. The approach aims to optimize resource recovery, reduce environmental impact, and promote circular economy principles by extracting value from materials that would otherwise be discarded. Waste valorization contributes to both waste management and sustainable resource utilization efforts.

Traditional waste management practices, including landfill disposal and incineration, have substantial environmental impacts. Landfills generate methane, a potent greenhouse gas, contributing to climate change. Incineration releases pollutants and emits greenhouse gasses, further worsening air quality and environmental health. Both methods can contaminate soil and water, posing risks to ecosystems and human health. Additionally, the energy-intensive nature of incineration adds to the carbon footprint. These environmental drawbacks underscore the urgency for more sustainable waste management approaches to mitigate these adverse effects.

Various technologies and methods play a crucial role in waste valorization, with a focus on extracting useful metals and employing gasification techniques. Advanced metal extraction processes, such as hydrometallurgy and pyrometallurgy, enable the recovery of valuable metals from electronic and industrial waste. Gasification, on the other hand, involves converting solid waste into syngas, a versatile fuel. This process not only reduces the volume of waste but also produces a valuable energy source. Integrating these methods into waste valorization strategies promotes resource efficiency, minimizes environmental impact, and contributes to a more sustainable approach to waste management.

# CHAPTER-3

# Methodology

## A). Co-Gasification

Solid waste encompasses the discarded or nonessential solid materials produced from human activities in residential, industrial, or commercial settings. In our context, we are specifically addressing municipal waste such as plastics and garden waste. This targeted approach recognizes the prevalence of these materials and emphasizes their significance in waste management considerations.

In our approach, we employed gasification, a transformative process that converts organic materials, including waste, biomass, or coal, into a versatile mixture of gasses known as syngas (synthetic gas). In this process, controlled partial combustion in an oxygen-starved environment breaks down complex carbon-based materials into simpler compounds, unlocking their energy potential for sustainable applications.

Before proceeding for gasification we need to do feedstock preparation,
It involves the pre-treatment and conditioning of raw materials. This process typically includes shredding, drying, and sizing the feedstock, optimizing its physical and chemical properties. Effective feedstock preparation ensures uniformity, enhances reactivity, and improves the efficiency of the gasification process by facilitating the breakdown of organic materials into syngas.

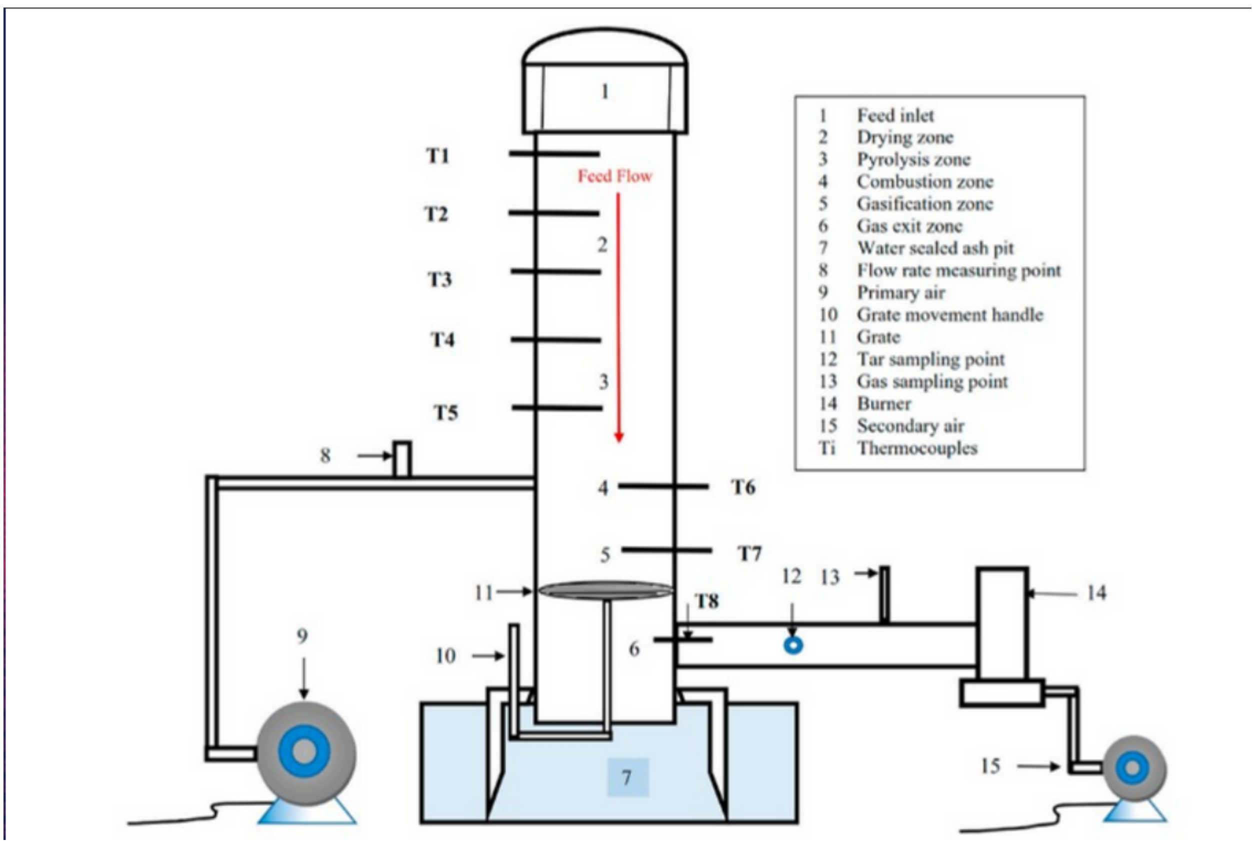
In our current project, we focused on Co-gasification, a specialized field within gasification that involves the simultaneous use of multiple feedstocks. Specifically, in our study feedstocks that we worked with were made of paper,plastics, leather  and textile.

Now let’s us understand how we had done  gasification step by step :

- Gasifier Setup- Gasification experiments are carried out in a fixed bed downdraft gasifier.. The gasifier operates autothermally with a feed rate of 10-15 kg/h and has a holding capacity of 40 kg. There are four points around the gasifier that are designated for primary air supply, facilitated by a blower.

- Measurement tools-Temperatures, flow rates, and gas composition are measured, and tar content is analyzed using gas chromatography.Gas quantity and calorific value are estimated using nitrogen balance.
- Process-
    1. In each experimental run, 25 kg of feedstock is loaded into the gasifier and ignited with a butane torch.
    2. Gas composition and tar sampling commence, with gas collected at intervals for analysis.
    3. The burner flame quality serves as an indicator of gas production.After feed consumption, the gasifier is cooled, and residue is collected for analysis.
    4. The process is considered steady-state when the temperature stabilizes.

By making  variations in grate movement, equivalence ratio, and feedstock type, we can get different results; it will be covered in the upcoming chapters.




## B.) Extraction and Removal of Metals

Another type of solid waste is solar waste, which refers to the end-of-life or decommissioned solar panels. Solar waste includes materials such as metals and glass from these panels. Managing solar waste is crucial for environmental sustainability, requiring proper recycling or disposal methods to minimize its impact on ecosystems and human health.

Before moving ahead let us first discuss about different types of solar panels-

- Crystalline Silicon Solar Panels (Monocrystalline and Polycrystalline)
- Copper Indium Gallium Selenide (CIGS) solar panels
- Cadmium Telluride (CdTe) thin-film solar panels.

Here in this project we will focus on Polycrystalline Silicon Solar Panels as they are the most used solar for home appliances in India.

## Composition:

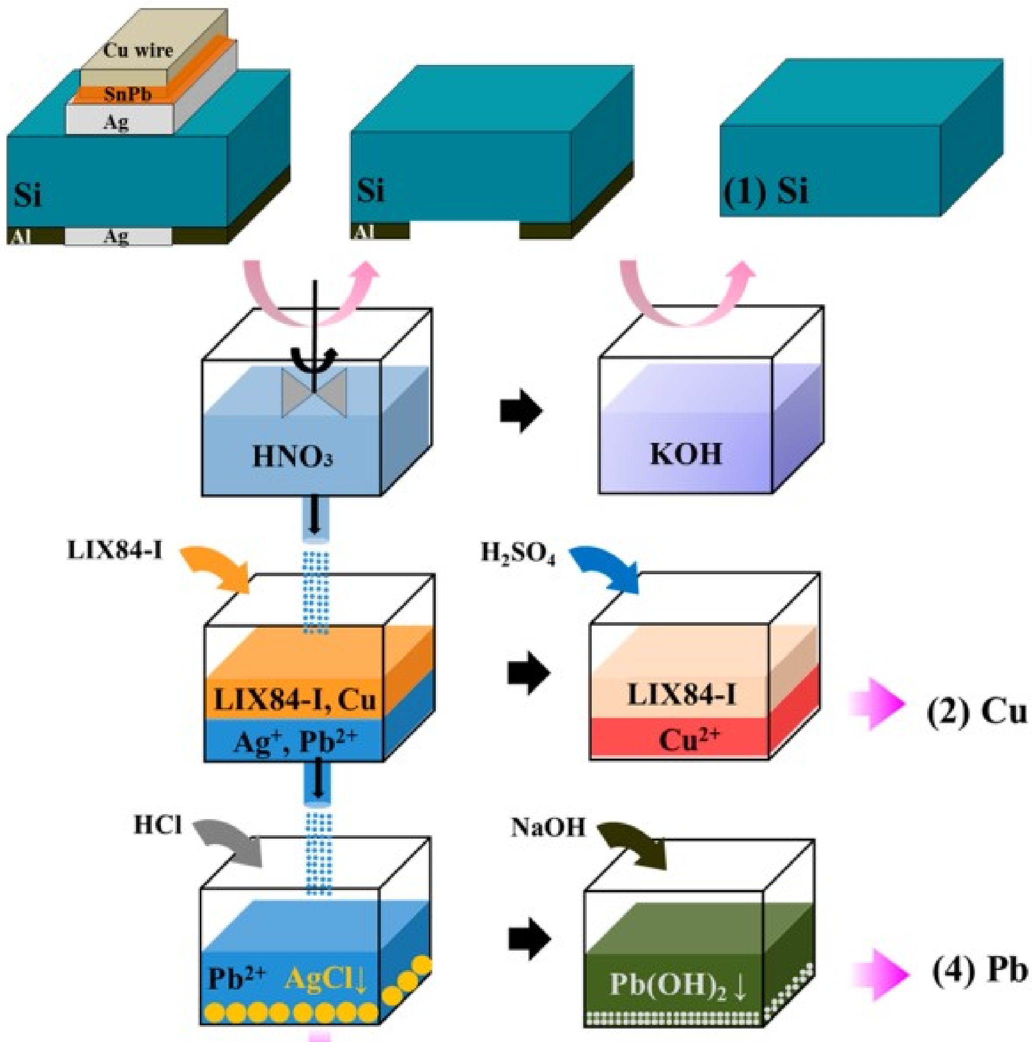
| METALS | Roles(or use) In solar panel | Percentage of Panel's Weight |
|---|---|---|
| Silicon (Si) | Primary semiconductor material in crystalline silicon solar panels | 90% |
| Aluminum(Al) | Used for the panel's frame, providing structural support and protection | 5-10% |
| Silver(Ag) | Used for electrical contacts and busbars to efficiently collect and conduct electricity | 0.3-0.5 % |
| Copper(Cu) | Used in electrical contacts and wiring within the solar cells and junction box | 0.1-0.3% |
| Trace metals(Tin,lead,) | Used in components like soldering materials | <0.1% |

- Silver and copper are some of the most valuable components found in Crystalline Silicon Solar Panels.
- Lead is one of the most hazardous elements present in solar panels, hence its removal before disposal is necessary.

Let's now focus on the extraction process of silver and copper, as well as the removal of lead:

- Pre-processing- This includes the measurement of the initial content of metal in the given solar panel.We can achieve this using the above given information about the composition of solar panels.
- Milling and Sieving- Using different instruments it is divided into smaller pieces.
- Heating- In this process we heat the solar panels using heating machines to remove glasses and to remove the organics from the waste PV module.
- Leaching- Then we leached the entire composition with the help of 64% nitric acid.
- Extraction of Silver- For this purpose we used 99% of NaCl to precipitate the silver in the form of AgCl. Then using the filtration process we removed it from solution. Then we used some reducing agents to obtain Ag from AgCl.
- Extraction of Copper- (1) Cu extraction from the leaching solution involved using 20% LIX84-I to separate Cu ions from an HNO3 solution containing Ag and Pb. The resulting solutions were divided into two parts: one with LIX84-I and Cu and the other with the HNO3 solution.
  (2) Stripping Cu from the LIX84-I fraction was achieved by adding a 150 g/L H2SO4 solution, causing Cu to move to the H2SO4 solution as CuSO4, using a 4:1 Organic/Aqueous solution ratio.
  (3) A 24-hour electrowinning method was applied to recover Cu metal. This involved using 200 L of H2SO4 solution containing 50 g/L Cu at 50 °C, with a current density of 0.5 A/dm2. Titanium and Cu plates served as the anode and cathode, respectively, with an 11.5 cm distance between them.

- Removal of Lead- (1) Pb2+ ions in a leaching solution was treated with 5 M NaOH at room temperature, resulting in the formation of lead II hydroxide (Pb(OH)2) precipitate. The precipitate was then separated through filtration.
  (2) The obtained Pb(OH)2 was subjected to heating at 500 °C for 1 hour, yielding lead oxide (PbO).
  (3) To eliminate any remaining Pb in the HNO3 solution, 5 M sodium sulfide (Na2S) was added, causing the precipitation of lead sulfide (PbS). The lead sulfide was subsequently removed through filtration.




## CHAPTER-4

## Results and Discussion

### A). <u>Co-Gasification</u>

For 75% feed stock and 25% saw dust, grate movement interval of 10 min and equivalence ratio approx 0.3 ; the values of

- Cold gas efficiency(CGE)=59.24%.
- Lower Heating Value (LHV)= 4.34 MJ/Nm3
- Tar content = 13.6g/Nm3 - 8.8g/Nm3

### B.) <u>Extraction and Removal of Metals</u>

- In the first method(without heating), the silver concentration yield was 94%.
- In the second method,subjected to pyrolysis at 500 C the silver concentration yield was 92%.
- We achieved a Cu recovery rate of 79% .
- We were able to achieve a removal rate of 93% for Pb through neutralization and sulfurization.

# CHAPTER-5

## Challenges and Solutions

### A). <u>Co-Gasification</u>

One of the biggest challenges was to increase the efficiency of the process. For that we made some changes in the feedstock content, burner design etc.

## Change In Feedstock Content:

Here we changed the feedstock content to plastic(low density polythene) and garden waste .
We performed a Co-gasification process on this feedstock as mentioned in previous chapters.
The results we obtained:

- Cold gas efficiency(CGE)= 61.8%.
- Lower Heating Value (LHV)= 4.7 MJ/Nm3
- Tar content = 8.1g/Nm3 - 5.7g/Nm3

It is evident from above results in an overall efficient process.

## Change in Burner Design:

We changed the design of the existing conventional burner to a premix burner. It has a dual swirl vane with angle(32 and 45) which helps in the mixing of air-fuel (producer gas and air) more efficiently. Resulting overall increase in the process efficiency.

Premix Burner

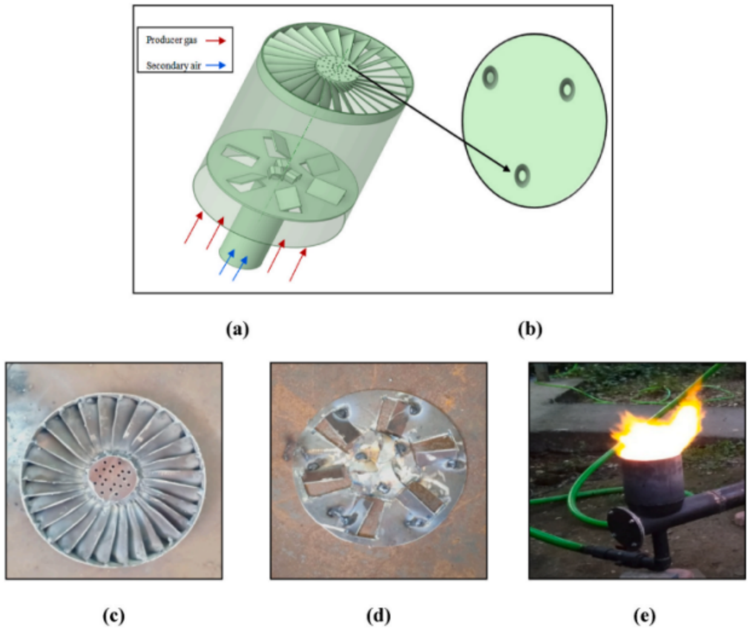



**Fig. 3.** a) 3D model of premix burner, b) Mini divergent cone punch hole for stable pilot flame, c) Photographic view of bluff body, d) Photographic view of dual slit swirler (swirl vane), e) Photographic view of producer gas fired premix burner.

Conventional Burner

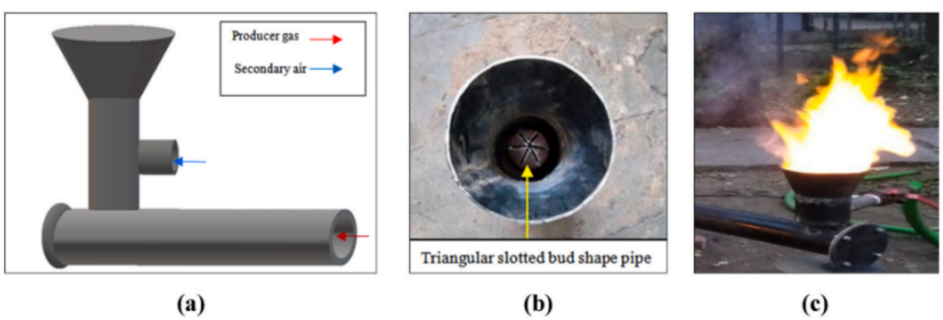



**Fig. 2.** a) 3D model of conventional burner, b) Top view of conventional burner (traingular shape cutting on bud shape pipe for fuel distribution), c) Photographic view of a conventional burner.

## B.) <u>Extraction and Removal of Metals</u>

- The extraction of metals using the above methods provide us with good results proving it to be efficient.

- But the acids used during the leaching process are also hazardous as they can cause severe effects on the person using it and also it is only one use leading to the secondary pollution.
- To overcome this we used the Deep-Eutectic Solvents System (DES).
- They are organic solvents which are almost as efficient as nitric acid in the leaching process.
- Also, if we can use the same leaching solution for more than one time.

C. Zhang et al. Waste Management 150 (2022) 280–289

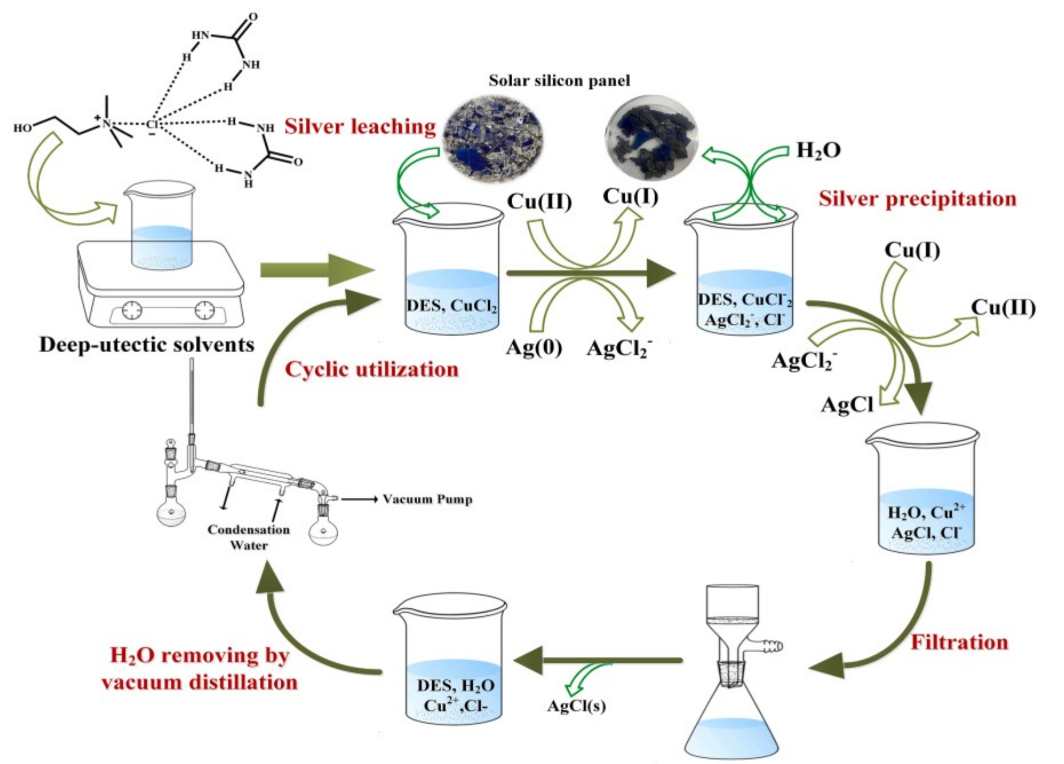



Fig. 1. General flow chart for recycling silver from photovoltaic panel.

# CHAPTER-6

## Conclusion

We have successfully acquired the knowledge to undertake waste valorization through two distinct methods i.e. Co-gasification and Extraction of metals. We also learned about the different aspects on which their efficiency depends and how.

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