GASIFICATION WORKSHOP

Gasification Technology Status and Pathways for Net-zero Carbon Economy

April 24, 2024

Summary

Workshop Theme: Clean Hydrogen Production from Gasification of Alternative Feedstocks

Alternative feedstocks *are defined as biomass or biomass wastes, municipal solid waste (MSW), industrial wastes, carbonaceous waste materials (e.g., plastics wastes), or any combination of the above.*

Workshop Objectives

- Discuss and exchange ideas for utilization of alternative feedstocks for future energy systems
- Identify near-term research and development (R&D) needed to enable market-competitive decarbonized hydrogen from smaller/distributed gasification systems
- Increase understanding of constraints/bottlenecks on waste/biomass usage in gasification-based clean hydrogen production opportunities
- Inform the Department of Energy (DOE) of industrial and academic advancements relevant to gasification-based clean hydrogen production
- Visualize the current and near-term energy marketplace for hydrogen generation as context for focused development efforts

Workshop Technical Areas

Workshop participants considered three major technical areas in which further R&D of gasification of alternative feedstocks for clean hydrogen production may be needed, with the workshop objectives (to the left) in mind:

A. Components (unit operations of gasification-based systems)
B. Supply chains (of alternative gasification feedstocks)
C. Markets and products (from process systems gasifying alternative feedstocks).

Workshop groups provided individual discussion notes from which the following summary R&D needs/recommendations were extracted, consolidated, and summarized.

Workshop Summary R&D Needs/Recommendations

A. Components

1. Better gasifier/reactor controls capable of handling variations in mixed feedstocks, i.e., reliable feed forward control of the gasifier.
2. Alternative feedstocks gasifier reaction kinetics R&D (lacking compared to well-understood coal gasifier kinetics).

3. Alternative feedstocks preparation, sorting and size reduction specific to gasifier type/technology to be used: more investigation is needed in this area.
4. Solids feeding across increasingly high-pressure boundaries of alternative feedstock gasifiers and feed injection design are critical; more determination of physical flow properties of alterative feedstocks (especially biomass), bridging phenomena, penalties on torrefaction vs. not-intensive pretreatment is needed.
5. Plastics feeding issues and plastic melting problems in feeders need further investigation.
6. Relationship between feedstock preprocessing and gasifier selection; inform by known database of experience of pretreatment/preprocessing of biomass and waste feedstocks in various gasifier systems.
7. Understanding of complexities of effects of higher-pressure gasification in costs, system performance, operational challenges, and scales.
8. Tradeoff between costs of pre-processing feedstock vs. downstream adjustments (e.g., syngas cleanup).
9. Tar management issue as a function of gasifier type (fixed/moving bed and fluidized bed gasifiers all of concern but bubbling fluidized bed may have advantage); downstream tar management options (e.g., plasma) and tradeoffs.
10. Ash melting from biomass utilization (biomass containing high phosphorus and potassium amounts) causing ash fouling and slag formation are concerning. Experience with catalytic gasification is troubled by ash/slagging issues and caution is urged about pursuit of this technology.
11. Soiling of biomass from harvesting and handling. In general, more precise characterization/quantification of the complete spectrum of different contaminants in biomass/MSW is needed, along with holistic thinking of contaminated feedstocks' impacts on the environment.
12. Deterioration of biomass stored at the plant is a concern (rotting/bacterial growth) along with biomass storage area prompt use of stored biomass within time limits.
13. Lifecycle of biomass, possible use of residual products to return to the land needs consideration.
14. Non-tested agricultural residuals need better characterization.
15. Complications of biomass fines. Raw biomass fines utilization, avoid use of fines (mainly in fluidized beds).
16. Variability of plastic feedstocks: measures to accommodate (tolerant feed systems vs. pretreatment, etc.) inherent variability of plastics (some contains ash-forming calcium, polyvinyl chloride/chlorine) and issues emerging with high proportions of plastics in mixed feedstocks. All these plastics feedstock variabilities and measures need better understanding, and understanding of how plastics can be used in an economical and efficient manner.
17. Variability of biomass sourced from different locations and at different times of the

year is significant, with impacts at scale. Feedstock characterization studies referenced to gasification options and sources would be invaluable. Large differences in various species content fed to the same system can lead to catastrophic results; these fundamental biomass variability impacts need to be better understood.

18. Biomass preprocessing requirements (e.g., biorefineries have failed because of lack of understanding of preprocessing needs or unfavorable energetics).
19. Plastics preprocessing (e.g., to pyrolysis liquids) to enable facile use in entrained flow gasifiers and fluidized bed gasifiers: continued investigation in this area is warranted.
20. Quantitative understanding of clean energy security/climate security driving hydrogen production/economics
21. Alternative feedstock-based syngas cleanup: differences from well-studied coal syngas experience such as high amounts of alkali metals, unusual contaminants, complications of tar presence, inevitable presence of chlorine/halogens to address.
22. Oxygen production is still a concern (over-the-fence not generally viable), more emphasis on pressure swing adsorption (PSA) improvements needed.
23. More rigorous understanding of hydrogen separations—one focus should be on hydrogen PSA in particular (especially for high-purity hydrogen), or any technologies that could compete at high-purity levels.
24. Refractory challenges remain in alternative feedstock gasification.
25. Institutional experience from companies/organizations in the waste/biomass gasification field should be gathered/shared with cooperative research and development agreements; a repository of this information would be invaluable. Prime areas of experience of interest would be syngas cleanup from unusual feedstocks, the complications of fluidized bed gasifiers, assemblages of unit operations offering synergisms for gasification of alternative feedstocks, etc.
26. Standard models for gasifiers would be helpful (e.g., specifications for unusual feedstock components integrated into models). In general, more development is needed for computational tools/digital twins in weaker areas such as feedstock processing/handling.
27. Pilot scale: 1–2 MW is commonly mentioned, and 1 MW may be a lower limit, with better heat balance at 2.5 MW and up (to about 5 MW). Difficulty increases above 5 MW. Note that 5 MW = ~44 tonnes dry woody biomass per day.
28. Demonstration scale: 10 MW is a good starting point for these projects (industrial standpoint) with valid demo scales of ~25 MW being common, scalable to 100 MW (essentially commercial); 1,000 TPD feedstock is also characteristic of commercial scale. Gasifiers generally require these larger scales, more so than some unit ops like syngas cleanup.
29. The lack of demonstrations at industrial scale (20–50 TPD) needed to validate processes and prove operability/viability, and lack of utilization of MSW or mixtures thereof at such scale, equates with significant need for more demos.
30. Project duration: longer periods needed at larger technology readiness levels

(compounded by supplying construction materials). Typically, a 2–2.5-year timeframe is suitable for a defined process technology where the inputs are known and if there are no permitting issues (engineering, procurement, and construction/industry). Three years is a typical timeframe, as it allows projects to be more flexible (academia). Five years overall for an academic research scale integrated with a commercial test campaign.

31. Rigorous techno-economic analyses (TEAs) and life cycle analyses (LCAs), for both costs and carbon footprint and including policy factors as practicable. Economics and economies of scale are a large driver in gasification projects and must be thoroughly understood and accurately estimated. Tracking of carbon in analyses for varied alternative fuels with complicated fossil vs. biogenic constituents also goes into LCAs including rigorous quantification of carbon emissions of the processes.
32. Carbon capture is critical factor for these systems (needs to be scaled and modular), yet transport and storage lends itself to larger scales.
33. Community acceptance of gasification is a concern. Coherent regional policies/permitting will factor into gasification projects. Possibility of carbon credits emerging exists and would also be factored.

B. Supply Chains

1. Agricultural biomass is important. Corn/soy rotation represents a huge amount of biomass in the U.S. However, transportation for biomass (and waste for that matter) is prohibitive. Biochar return to the farms is important ($20 in phosphorus value per ton of biochar). Location of plant within 10 miles of source is favorable.
2. Forestry lands have lots of woody biomass, but projects need to be in 60-mile proximity and will be limited in size (<200 MW) per the material available within that radius. Forest fuels production could help with amelioration of forest fire danger (associated carbon emissions from fires). Woody biomass is already highly compatible with current technologies. Logging infrastructure is there, and the industry is suffering due to the closing of various paper mills.
3. MSW-based plants could access smaller municipalities by decrease of cost and size/modularity; there is a barrier to this right now with conventional MSW-based energy plants. MSW-based plants in areas of heavy industry may be suited based on transportation and other factors; more analysis required. In general, MSW and landfill waste would ideally be more readily used, and technology to advance that is much needed.
4. In general, a viable plant needs 20 years of feed availability to justify the business case; multiple feed options may need to be utilized depending on the location. Definitions/quantifications of biomass and MSW are critical in specifying the plant.
5. Energy crops supply development requires market demand first: investigate ways/methods to spin up biomass supply for new gasification industry. Energy crops can be useful for land reclamation efforts. Choosing energy crops that can revitalize the soil and rotating crops throughout the year is important. In general, good land

management is important.

6. Better understanding of the tradeoffs in transportation of alternative feedstocks vs. transportation of products, driven by complex combinations of variables including variety of feedstocks available, pre-treatment impacts, and cost factors.
7. Development of a live database/map in the U.S. of what alternative feedstocks are available in different states would be invaluable (e.g., to inform feasibility studies).

C. Markets and Products

1. Market/product focus from the viewpoint of the National Energy Technology Laboratory (NETL) is net-zero performance/decarbonized energy. Hydrogen is the best vehicle to accomplish this but does not have the energy content to compete with traditional liquid fuels. This tradeoff should be kept in mind in future technology development.
2. Understanding is needed of the limitations of modularization given the powerful cost benefits of economies of scale. Better understanding of the benefit of hydrogen storage in the context of larger hydrogen generation process systems is needed. System integration essential.
3. Understanding is needed of role of Fischer-Tropsch (FT) for liquids/fuels/hydrocarbons vs. decarbonized hydrogen production in alternative feedstocks gasification context. There is possible strength in gasification over renewable power-driven electrolysis for clean hydrogen production for FT given the very high cost of electrolysis—do not discount gasification in this role.
4. Syngas vs. hydrogen tradeoff: question of whether hydrogen is a useful product in many locales. In that case, limited hydrogen injection in natural gas pipelines might be possible. If not, synthetic natural gas could be injected into pipeline networks whereas hydrogen may not be. Consider which downstream products are really needed/practicable to produce in modular systems using these feedstocks.
5. Understanding of requirements for hydrogen/syngas purity as a function of intended specific uses/products (allowable amounts of carbon monoxide, contaminants).
6. High tar content from gasification/pyrolysis may favor synthesis of certain higher-value products (aromatic chemicals)—market driver complications such as this should be understood as they could have significant impact on gasification processes and technology choices.
7. Capital costs are a large obstacle, especially at small scales, for gasification systems. Market drivers must be understood as technology development is pursued.
8. Location issues can be overlooked and need more attention, e.g., proximity to available resources (landfills, pipelines, etc.)
9. Market sectors such as data centers, replacing gray hydrogen for petroleum production, hydrogen for fuels cells are likely targets.