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Project Title: Development of a novel gasification technology for distributed power generation from solid wastes

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## MILESTONE REPORT

Executive Summary: Unlike biomass combustion to electricity technology which directly burns biomass to supply steam for steam-electric generators, gasification to electricity technology converts solid feedstock to a combustible gas that can then fuel steam generators or gas turbines. Compared with direct combustion, gasification has higher conversion efficiency; its gas products are easier to handle; it has less emission problems; it has less solid residue left in the equipment; and last but not the least, gas product can be used in a greater variety of power plant configurations, either internal – combustion engines, gas turbines or CHP units. Gasification is considered by most the “Clean Biomass Technology”, the equivalent of Clean Coal Technology. In addition, gasification technology can be operated in scales suitable for distributed/ decentralized power generation, and hence compatible with the distributed nature of biomass feedstock production.

The University of Minnesota (University) will conduct a three year research project to develop a fast gasification-based electricity generation technology. The University will investigate and fabricate a gasification method based on microwave heating to raise the process temperature and increase heating rate. This will improve biomass conversion efficiency and syngas quality and cleanness. A fast microwave assisted gasification (fMAG) system and electricity generator will be designed and demonstrated as a prototype to evaluate techno-economic and other benefits of the proposed technology. Incorporated into the prototype system developed will be microwave susceptors (MWS) which are effective at raising temperatures to a very high level at extremely fast rates.

The technology to be developed is scalable and portable which will enable distributed and decentralized electricity generation from biomass and other solid wastes that are intrinsically widely distributed in loose form. Unlike biomass combustion to electricity technology which directly burns biomass to supply steam for steam electric generations, gasification to electricity technology converts solid feedstock to a combustible gas that can then fuel steam generators or gas turbines.

The goal of this milestone period was to prepare experiment materials, set up equipment, develop protocols, and conduct initial screening of microwave susceptors (MWS). In the three months of this milestone period, we have acquired and examined a number of biomass feedstocks and microwave susceptors (absorbents). Basic experimental protocols have been set up. Preliminary tests on the acquired microwave absorbents were carried out and preliminary data were obtained. As a result, we are ready to conduct a full study of MWS, which is the primary task of Milestone 2. In summary, the current milestone has been completed and the outcome meets the expectation

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Technical Progress: We collected a wide range of potential feedstocks for gasification including corn stover, corncobs, switchgrass, and sludge from municipal wastewater treatment plant, used tire pallets, and wood sawdust. Proximate and elemental analyses were carried out to determine their chemical composition. We collected a wide range of potential feedstocks for gasification including switchgrass, corncob, corn stover, sawdust, lignin, microalgae, sludge, scum, plastic (LDPE), waste tire. Proximate and elemental analyses were carried out to determine the moisture, ash, volatile matter, fixed carbon, hydrogen, carbon, nitrogen, oxygen, and heating value. The plant-origin feedstocks (biomass) generally have higher moisture, oxygen, and nitrogen content but lower carbon, hydrogen, and heating value than the municipal solid wastes. In gasification, hydrogen to carbon ratio or H/C is an important factor affecting gasification process and products. It would be interesting to investigate co-gasification of biomass with municipal solid wastes with different ratios. We also believe the high carbon content of municipal solid wastes may also improve microwave absorption. Binary or even ternary systems may be considered. Activated carbons (AC), SiC, and char from pyrolysis (CH) were also acquired. The catalysts including Fe/Al<sub>2</sub>O<sub>3</sub>, Co/Al<sub>2</sub>O<sub>3</sub>, and Ni/Al<sub>2</sub>O<sub>3</sub> were prepared. A bench scale microwave assisted gasification device was designed and fabricated. A very mild vacuum is applied to draw the vapors and gas out of the flask to a series of refrigerated water-cooled condensers. The vacuum may be varied to adjust the gas/vapor residence time. For safety purpose, a microwave leakage detector is used to monitor if there is any leakage.

A baseline protocol for fast microwave assisted gasification (fMAG) has been formulated. The protocol employs a modified reaction microwave oven with the power of 750 W at a frequency of 2,450 MHz (The schematic diagram of experimental apparatus is shown in Fig. 1 in the Appendix). The protocol also includes procedures to load microwave absorbents and catalysts, control heating, load biomass, apply vacuum, remove condensables, and collect syngas product. Mass balance procedure is also in place to calculate the yields of individual fractions (gas, liquid, solid residue). The recovered fractions will be analyzed for composition and energy contents.

We conducted preliminary tests on the acquired microwave absorbents in different microwave heating settings. Preliminary data such as heating curves were obtained. We have identified following experimental parameters as candidates for the screening of microwave absorbents: type of materials, dielectric constant, shape and size, ratio of microwave absorbents to biomass, and methods of loading and recovery. Experimental data were collected for a preliminary evaluation of the heating rate, maximum temperature attainable, energy efficiency, and conversion efficiency.

Additional Milestones: N/A

Project Status: The project is on schedule and within budget.

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## Appendix:

### A. Experimental setup

The experimental device consists of: (1) biomass feeder; (2) inlet quartz connector; (3) microwave oven; (4) quartz reactor; (5) microwave absorbent bed; (6) thermocouple (K-type) to measure the temperature of cavity; (7) thermocouple (K-type) to measure the temperature of bed particles; (8) outlet quartz connectors; (9) liquid fraction collectors; (10) condensers; (11) connection for vacuum pump, (12) insulation.

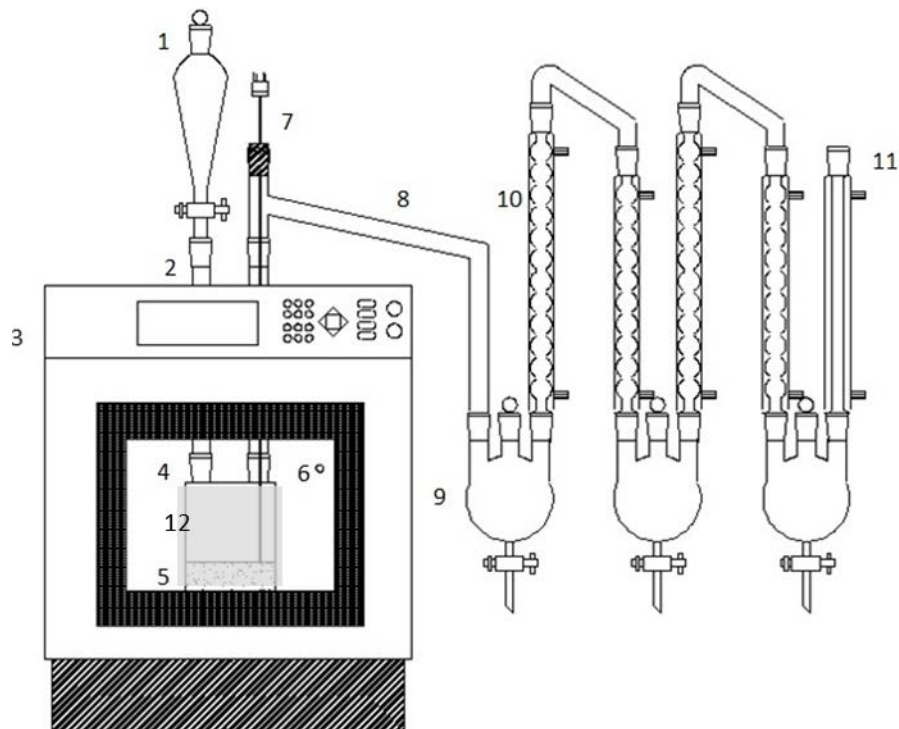


Figure 1-1. Schematic diagram of fast microwave-assisted pyrolysis and gasification system.



Figure 1-2. Photo of the experimental set up