Introducing Small Scale Waste-to-Energy Technology in Microgrids

Cooperative Research and Development Final Report

CRADA Number: CRD-17-00703

NREL Technical Contact: Bill Kramer

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5B00-82332
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Suggested Citation
Kramer, Bill. 2022. *Introducing Small Scale Waste-to-Energy Technology in Microgrids: Cooperative Research and Development Final Report, CRADA Number CRD-17-00703.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-5B00-82332. https://www.nrel.gov/docs/fy22osti/82332.pdf.

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National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NOTICE

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Cooperative Research and Development Final Report

Report Date: March 2, 2022

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the CRADA final report, including a list of subject inventions, to be forwarded to the DOE Office of Scientific and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Cogent Energy System

CRADA Number: CRD-17-00703

CRADA Title: Introducing Small Scale Waste-to-Energy Technology in Microgrids

Responsible Technical Contact at Alliance/National Renewable Energy Laboratory (NREL):

Bill Kramer | bill.kramer@nrel.gov

Name and Email Address of POC at Company:

Abraham Haspel | ahaspel@cogentenergysystems.com

Sponsoring DOE Program Office(s): U.S. Department of Energy, National Renewable Energy Laboratory (NREL)

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
Year 1	$85,000.00
Year 2, Modification #1	$0.00
Year 3, Modification #2	$0.00
Year 4, Modification #3	$0.00
TOTALS	$85,000.00

Executive Summary of CRADA Work:

Cogent has developed an innovative, proprietary waste-to-energy (WTE) system, the HelioStorm^{TM} Gasifier, capable of efficiently operating on small amounts of heterogeneous municipal solid waste feedstocks, converting them into a clean syngas that can be used to fuel an electricity generator, all with rapid on/off cycle times. NREL will work with Cogent to complete a computer simulation of an integrated HelioStorm^{TM} plasma gasifier system and dual fuel diesel generator. Cogent will test the performance of an actual HelioStorm^{TM} WTE system and dual fuel diesel generator at their test facility using steady state electrical loads and provide a report describing the performance of the integrated system.

<u>Summary of Research Results</u>:

Purpose:

This project was selected to receive support from NREL (U.S. Department of Energy) to execute a high-impact project with researchers from NREL's Energy Systems Integration Facility (ESIF) on April 13, 2017. The purpose of the project was to demonstrate the use of biomass/municipal solid waste as an energy source at small scale. Cogent's HelioStorm^{TM} gasifier can transform such feedstocks into a synthesis gas of hydrogen and carbon monoxide, which can be used to generate electricity.

In order to successfully integrate WTE into a microgrid, NREL and Cogent needed to be able to better characterize the on-demand needs of a WTE gasifier and the balance of plant–in particular, the characteristics and parameters of the amount of uptime and downtime that the system can provide, the time gaps in between demands, any variability in the energy supplies and demands either between runtimes or during runtimes, and the requirements for personnel to operate and/or manage the system, including training and skill sets that would allow a better understanding of the types of operators that would be needed in the field.

As initial efforts to accomplishing the above purpose, the two main efforts under this CRADA were:

1. Complete a computer simulation of the syngas generation, control and simple combustion in an engine, to elucidate control methodologies and time constants of an end-to-end system.

2. Test an integrated WTE system at Cogent's test facility, using various feedstocks and evaluate the performance of both the gasifier and ability to generate electricity using steady state electrical loads.

Overview of Results:

The HelioStorm^{TM} gasifier developed by Cogent Energy Systems, Inc. transforms biomass and municipal solid waste (MSW) feedstocks into a synthesis gas (syngas) of hydrogen and carbon monoxide, which can be used to generate electricity. NREL worked with Cogent to develop a computer simulation of the HelioStorm^{TM} syngas production at the output of the gasifier's scrubber as a function of a single feedstock type and feedstock feed rate. The simulation included a simple dynamic model of appropriately prepared waste, conveying equipment, plasma gasifier and dual fuel diesel engine generator based on data collected on a HelioStorm^{TM} prototype system that is operating in Idaho Falls. The purpose of the computer simulation is to develop a simulated conveying control system and to estimate diesel fuel use. Together, NREL and Cogent worked to characterize the flexibility and ability of the computer simulated gasifier to produce electricity under various dynamic loads.

Task Descriptions per CRADA and Results:

The original CRADA include slightly different tasks, but the parties agreed to reduce the original goals, resulting in the tasks shown here:

Cogent Energy Systems Tasks	NREL Tasks	Results
Run HelioStormTM gasifier system in Idaho Falls to assist in the development of a dynamic model of syngas produced		Waste was gasified and the resulting syngas analyzed. Its Hydrogen and Carbon Monoxide composition was provided to NREL for use in the simulations as discussed below.
Assist in the development of dynamic model of HelioStormTM WTE syngas system	Complete development of dynamic model of HelioStormTM WTE syngas system production	See Dynamic Model section below
Conduct testing at Cogent's test facility under steady state electrical load conditions		See Testing section below
Final Report	Final Report	This document

Dynamic Model:

A simulation of the WTE and electrical generation using a diesel generator was developed. The simulation includes a conveyor of waste material and an "ionic gasification" plasma generator that produces a syngas made up of carbon monoxide (CO) and hydrogen. The syngas is fed into an accumulator and piping systems into the air intake of a diesel engine. The diesel engine turns a generator that produces a 3 phase 480V power that is feed to an electrical resistance load.

A schematic of the diesel generator and electrical system is shown in Figure 1. The blue box is a sub-model that includes the conveyor, WTE, Accumulator, piping, and diesel generator. The output of sub-model includes the mechanical shaft power that is fed into the green block which represents the generator. The generator outputs 3 phase power to a constant 50 kW load and a variable 50 kW load. The voltage is measured and fed into a control system to maintain a 480-volt setpoint.

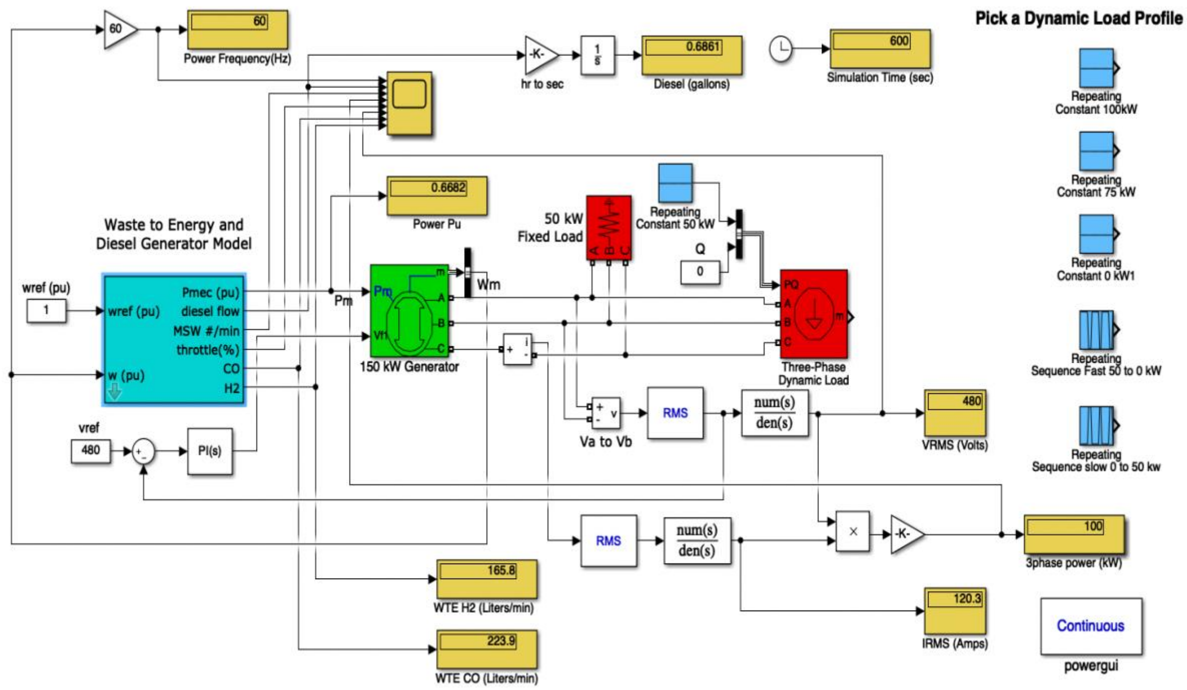

Figure 1: Schematic of the diesel generator and electrical system

Figure 2 is a model of the blue subsystem block shown in Figure 1. On the far left is a dark green block which represents the handling of the MSW feedstock including a variable speed conveying system. The output of the dark green block is the pounds/min of waste feedstock that is provided to the WTE system as represented by the orange block. Inside the orange block the number amount of CO and hydrogen is calculated based on tests provided by Cogent of the HelioStorm™ gasifier system.

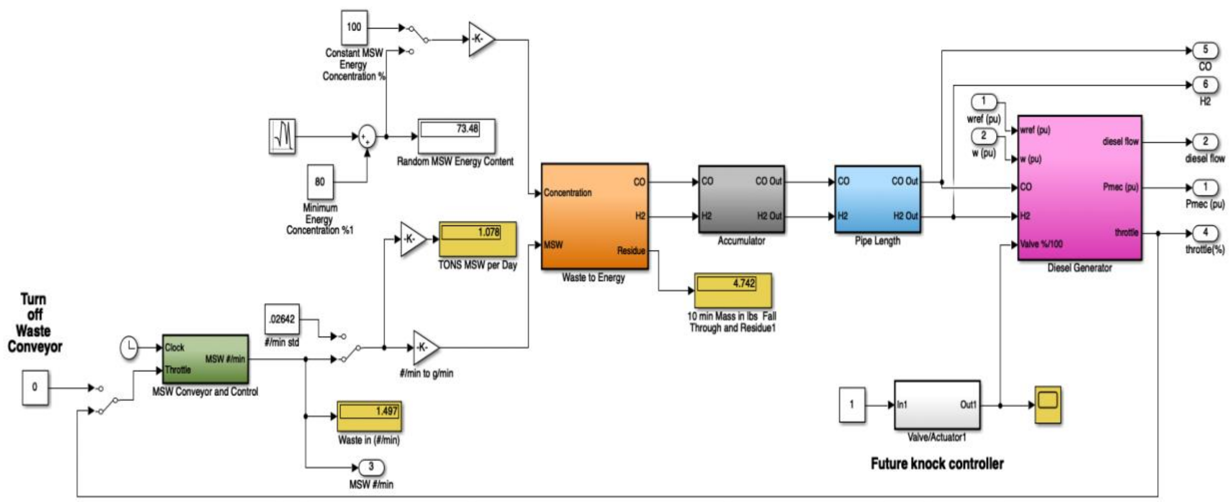

Figure 2: Model of the blue subsystem block shown in Figure 1

The CO and hydrogen are then feed to an accumulator as represented by the grey block, and then through a piping system which is represented in the light blue block. The CO and hydrogen are then feed into a diesel engine model that produces power based on both diesel and CO-hydrogen fuels. The diesel engine model controls the frequency of the shaft speed which is then output from this sub system.

Figure 3 shows a series of dynamic graphs for a 600 second simulation run with a constant 100 kW load. Both the conveyor and WTE system are maintained off for the first 30 seconds. After 30 seconds, the conveyor is started and the pounds/min of waste is increased until the diesel throttle position reaches 20%. The graphs predict how the system will perform in the future. Note that once the throttle position reaches 20%, the flow rate of the CO and hydrogen that is fed to the air intake of the engine stabilizes to a constant value.

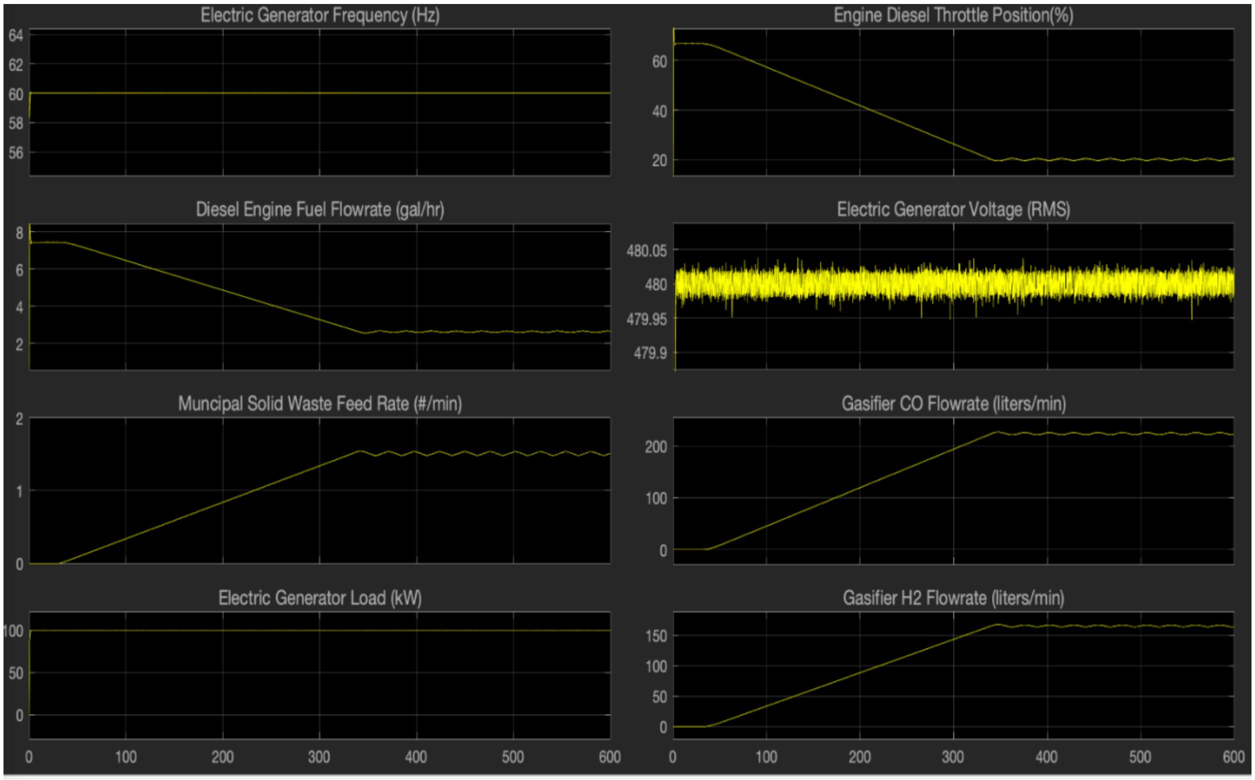

Figure 3: Constant 100 kW Load Profile at Startup

Figure 4 shows the predicted results for a time varying load from 50kW to 100 kW. The simulation can be used to evaluate changes to the plasma gasifier/generator designs based on test results and to predict how much diesel fuel will be used for various electrical load profiles. Note that the diesel controls respond more quickly than the conveyor controls during quick changes in electrical load.

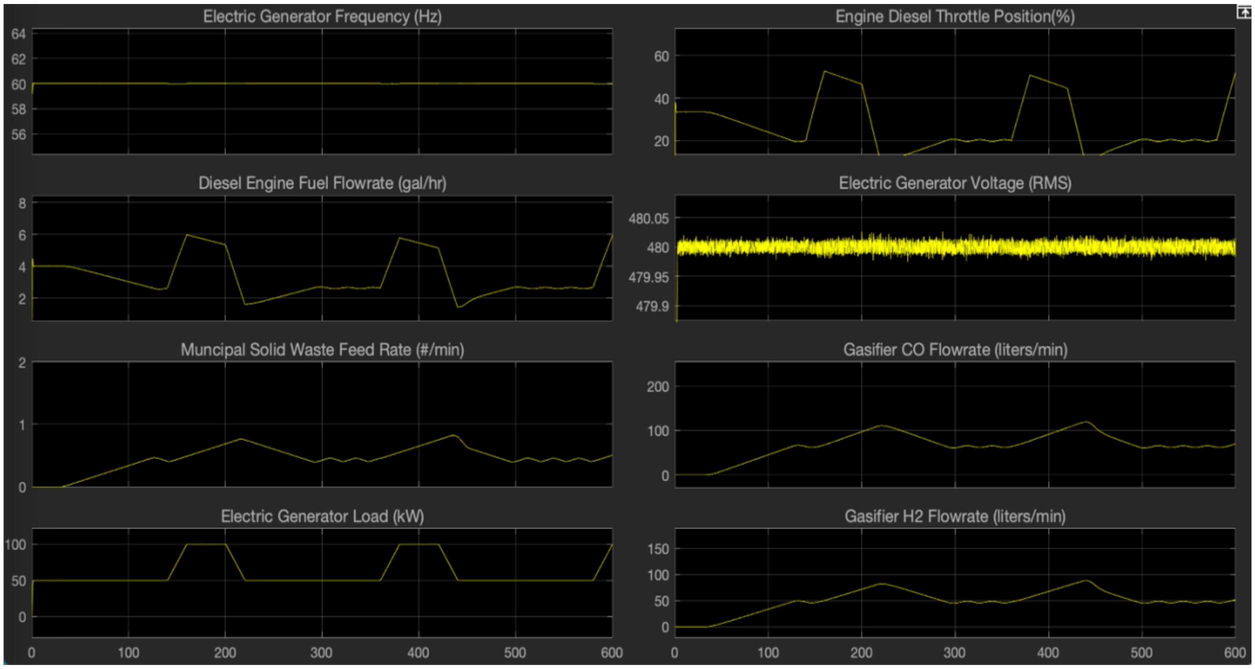

Figure 4: 50kW to 100 kW Load Profile at Startup

Testing:

Testing had mixed results. In short, the individual components of a system from feedstock preparation, gasification, accumulation, and generation were all successfully tested; unfortunately, an integrated system could not be tested. All the components of a full WTE system were available for testing at Cogent's facility in Idaho Falls, including an accumulator and a Woodward large engine control module (LECM) loaned from NREL to Cogent. While Cogent was able to gasify both biomass and WTE, the syngas production rate was limited – primarily for safety reasons and facility restriction limitations. In particular, Cogent's facility turned out to be not large enough to allow for storage and continuous operation with the amounts of feedstock necessary to generate enough syngas to operate the 150 kW genset and accumulator.

The individual components and elements of success were demonstrated by this project's first phase; unfortunately, integration of the elements and testing of an integrated system was not able to be undertaken. They await a location that can accommodate the feedstock stockpile necessary so that sufficient syngas can be produced for a generator to operate for a sufficiently long run time. Consequently, Cogent was partially successful but was unable to integrate and run the generator and controls available so that the performance, sequence of operations and safety aspects of the HelioStorm™ gasifier integrated with a dual fuel diesel engine could be verified. Integration into a microgrid was always envisioned as the second phase of this project.

Conclusions and Next Steps:

As described above, a dynamic simulation of a WTE system combined with a diesel engine generator was developed. The ionic gasification WTE system simulation sub-system was developed using actual HelioStorm™ gasifier generated test data that was collected using a waste feedstock in Idaho Falls. The simulation was used to develop a control system to control the amount of waste feedstock to be delivered to the ionic gasification WTE system. Testing of individual components was successful. Integration and testing of an integrated system were not undertaken.

Future work includes:

- Complete the installation and testing of the Woodward LECM including knock control algorithm on the diesel generator using commercial supplied CO and H_2 to simulate electricity generation
- Integrate diesel engine controls together with the conveying system based on simulation results.
- Complete the system assembly for cooling of the CO and hydrogen to be delivered to the diesel engine generator
- Complete testing of integrated system using sufficient batches of feedstock
- Analyze test results and modify system and simulation as needed.
- Site system where feedstock is readily available
- Conduct long-term testing
- Redesign components as required for commercial deployment

Subject Inventions Listing:

None

ROI #:

None