Performance Testing of a Moving-Bed Gasifier Using Coal, Biomass, and Waste Plastic Blends to Generate White Hydrogen

FY22 FECM Spring R&D Project Review Mtg

Award Number: DE-FE0032044

George Booras
gbooras@epri.com
Technical Executive – Principal Investigator
Electric Power Research Institute, Inc (EPRI)

May 2, 2022

Project Objectives

- Qualify coal, biomass, and plastic waste blends based on performance testing of selected pellet recipes in a laboratory-scale updraft moving-bed gasifier
- Testing will provide relevant data to advance the commercial-scale design of the moving-bed gasifier to use these feedstocks to produce hydrogen
- Effects of the waste plastics on feedstock preparation (i.e., blending and pelletizing) and the resulting products (i.e., syngas compositions, organic condensate production, and ash characteristics) will be a focus

Funding: $625k ($500k gov't, $125k cost share)

Project Significance

- Hydrogen provides long-term energy storage for grid stability
  - Most hydrogen today is produced in carbon-intensive processes
- Co-gasification of coal, biomass, and plastic waste can provide hydrogen with net-negative CO_2 emissions
- Moving-bed gasification is a promising technology for successfully gasifying blended fuel pellets
- Learnings will accelerate commercialization of moving-bed gasifier technology
- Enables production of low-cost hydrogen from a range of locally available solid fuels in an environmentally beneficial way

Developing data for unique blends for an established gasifier

Major Project Tasks

- **Task 2 – Feedstock Procurement and Preparation:** Finalize feedstock selection and pellet formulations. Prepare and ship pellets.
- **Task 3 – Test Plan Development:** Specify test data to be reported, review facility instrumentation, and specify sampling procedures
- **Task 4 – Gasifier Testing:** Perform baseline coal gasification test, and tests for 9 different pellet formulations
- **Task 5 – Data Analysis and Reporting:** Correlate gasifier performance with pellet composition, assess overall prospects for gasification of mixed blends, and prepare the final report

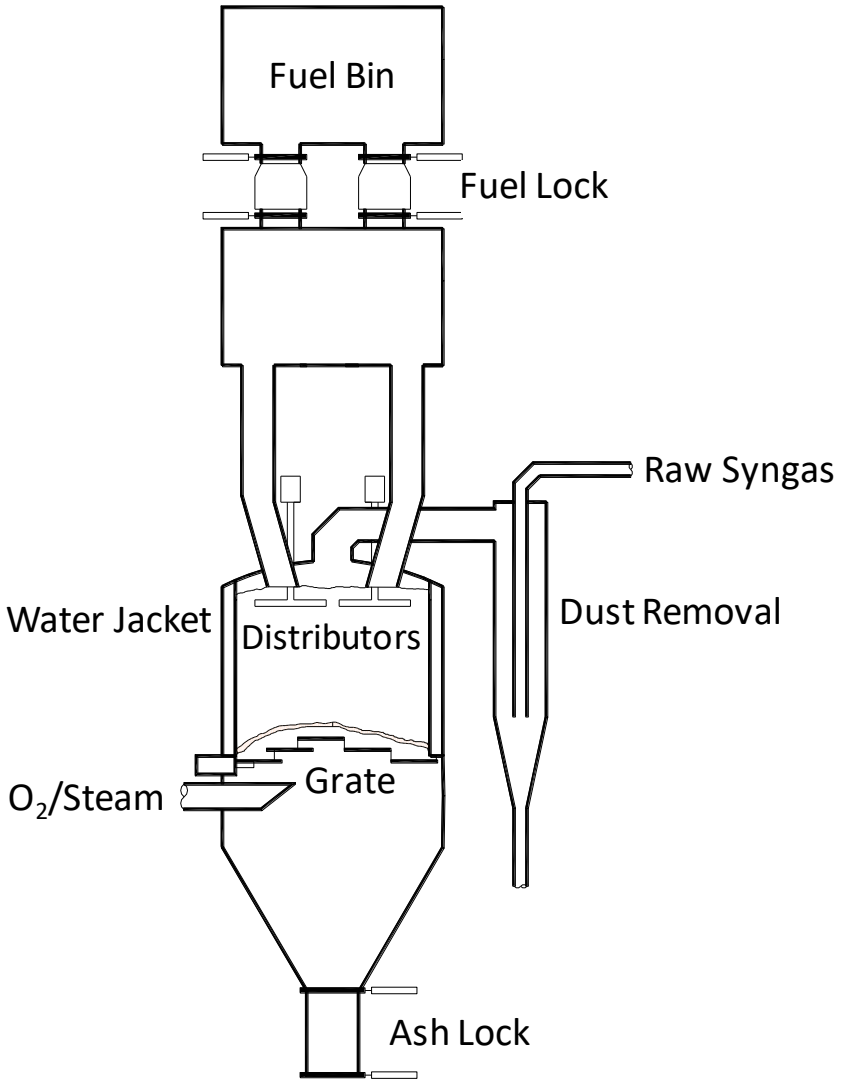
Overall project schedule is two years (7/1/21 to 6/30/23)

Project Team Organizations

EPRI	• Prime, lead organization, overall project management, and administration (Task 1) • Leading Test Plan Development (Task 3) • Key personnel – George Booras, Jose Marasigan, and Horst Hack
Hamilton Maurer International, Inc. (HMI)	• Gasification technology developer (sub-recipient) • Leading Feedstock Procurement and Preparation (Task 2) and Data Analysis and Reporting (Task 5) • Key personnel – Rolf Mauer and David Thimsen
Sotacarbo S.p.A	• R&D organization in Carbonia, Italy (sub-recipient) • Leading Gasifier Testing (Task 4) • Key personnel – Dr. Alberto Pettinau and Simone Meloni

HMI Moving Bed Gasifier

- Moving-bed gasification has demonstrated gasifying many coal ranks as well as biomass. Testing suggests that it should be well suited for blends of coal, biomass, and plastic waste.
- As the fuel descends, it is dried, devolatilized, and the resulting char is gasified. Ash is removed through a grate and collected in a lock hopper.
- CO_2 produced by combustion and the steam from the blast react with the char in the gasification zone to produce CO and H_2
- Streams leaving are ash out the bottom and dry gas/tar/water vapor/dust out the top

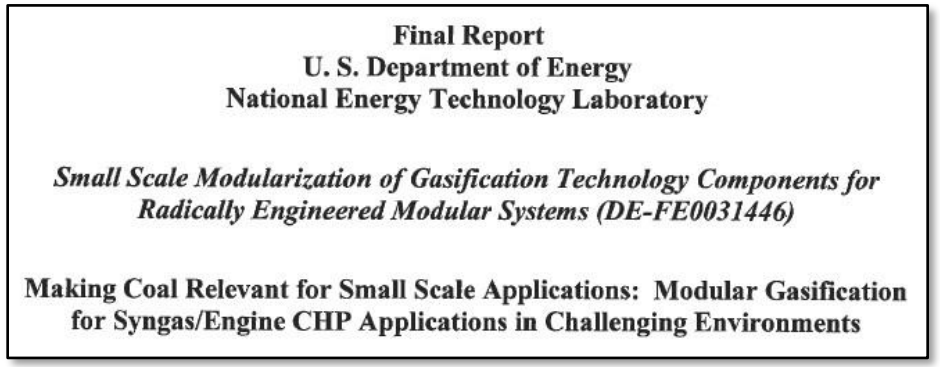


HMI Moving-Bed Gasifier

Hamilton Maurer International, Inc.

- Involved in U.S. Bureau of Mines MIFGA project that tested wide range of coal ranks and biomass materials
- Char with high compressive strength supports the fuel bed and allows even gas distribution
- HMI focusing on improved biomass and coal gasification efficiency: 81% with tar, 73% without tar
- Working with Sotacarbo, DOE, and University Alaska Fairbanks on small modular gasification for combined heat-and-power

MIFGA Coals Gasified	Rank
Jetson	hvBb
Rosebud	subB
Leucite Hills	subA
Stahlman Stocker	hvAb
Petroleum Coke	NA
Piney Tipple	hvAb
River King IL # 6	hvCb
Elkhorn	hvAb
Benton Lignite	lig
Peat Pellets	NA
Peat Sods	NA
Blind Canyon	hvBb
Kemmerer	subB
Absoluka	subC
SUFCO	hvBb
Indianhead	lig
Hiawatha	hvBb


Final Report
U. S. Department of Energy
National Energy Technology Laboratory

Small Scale Modularization of Gasification Technology Components for Radically Engineered Modular Systems (DE-FE0031446)

Making Coal Relevant for Small Scale Applications: Modular Gasification for Syngas/Engine CHP Applications in Challenging Environments

California Pellet Mill (CPM)

- In 1931, the company created its first pellet mill, the 30-hp flat bed with stationary flat die
- Will do the blended feedstock preparation in the form of pellets
- Has considerable experience creating fuel pellets including ones using biomass and waste and has worked with HMI and Sotacarbo on prior projects
  - Presented results of pilot gasifier test runs with coal/car fluff pellets at the 2007 Clean Coal Technology Conference in Sardinia

Sotacarbo R&D Facility

SOTACARBO SUSTAINABLE ENERGY RESEARCH CENTRE

- Sotacarbo and HMI have collaborated for 17 years on the installation, commissioning, operation, and automation for enhanced operation and control of updraft moving-bed gasifiers for industrial multi-fuel gasification processes
- HMI designed the lab-scale 12” inner diameter updraft moving-bed gasifier for coal/biomass installed at the Sotacarbo facility that will be used
- Significant testing has taken place on this test facility including the current project team members from both HMI and Sotacarbo

Sotacarbo Pilot Moving-Bed Gasifier

Task 2 Status

Task 2 – Feedstock Procurement and Preparation

- Finalized coal, biomass, and waste plastics selection
  - Coal is PRB subbituminous from Peabody's North Antelope Rochelle mine
  - Biomass is corn stover from a Nebraska farmer
  - Plastic waste is auto-shredder residue (ASR) a.k.a "car fluff"
- Finalized pellet formulations (total of 9 tri-fuel formulations)
  - Pellets with 100% PRB coal will be produced for baseline testing

Tri-Fuel Test Matrix Based on both Mass and Heat input

Approximately 150 kg of tri-fuel pellets are required for each test run

Feed fractions based on dry mass input

No.	Biomass	Coal	Plastic
1	0	100	0
2	31	69	0
3	31	53	15
4	32	36	32
5	47	53	0
6	48	41	12
7	49	27	24
8	67	33	0
9	67	25	7
10	68	17	15

Feed fractions based on heat input

No.	Biomass	Coal	Plastic
1	0	100	0
2	25	75	0
3	25	56	19
4	25	38	38
5	40	60	0
6	40	45	15
7	40	30	30
8	60	40	0
9	60	30	10
10	60	20	20

HHV, Btu/lb*	Biomass	PRB	Plastics
Dry	8,681	11,516	13,240
As-Rec	4,922	8,564	N/A

* Assumed Heating Values (to be confirmed)

Task 2 Status (cont.)

- OmniSource provided 2 tons of ASR from Indianapolis and 2 tons from Toledo
  - As-received ASR had much larger pieces than anticipated, and was shredded to -1/2” before delivery to CPM
- Corn stover supplier was identified in Nebraska
  - Stover was chopped to ½’ to 1” before delivery to CPM
- Peabody provided Powder River Basin (PRB) coal from their North Antelope Rochelle mine near Gillette, WY
  - Three supersacks of PRB coal were delivered to CPM

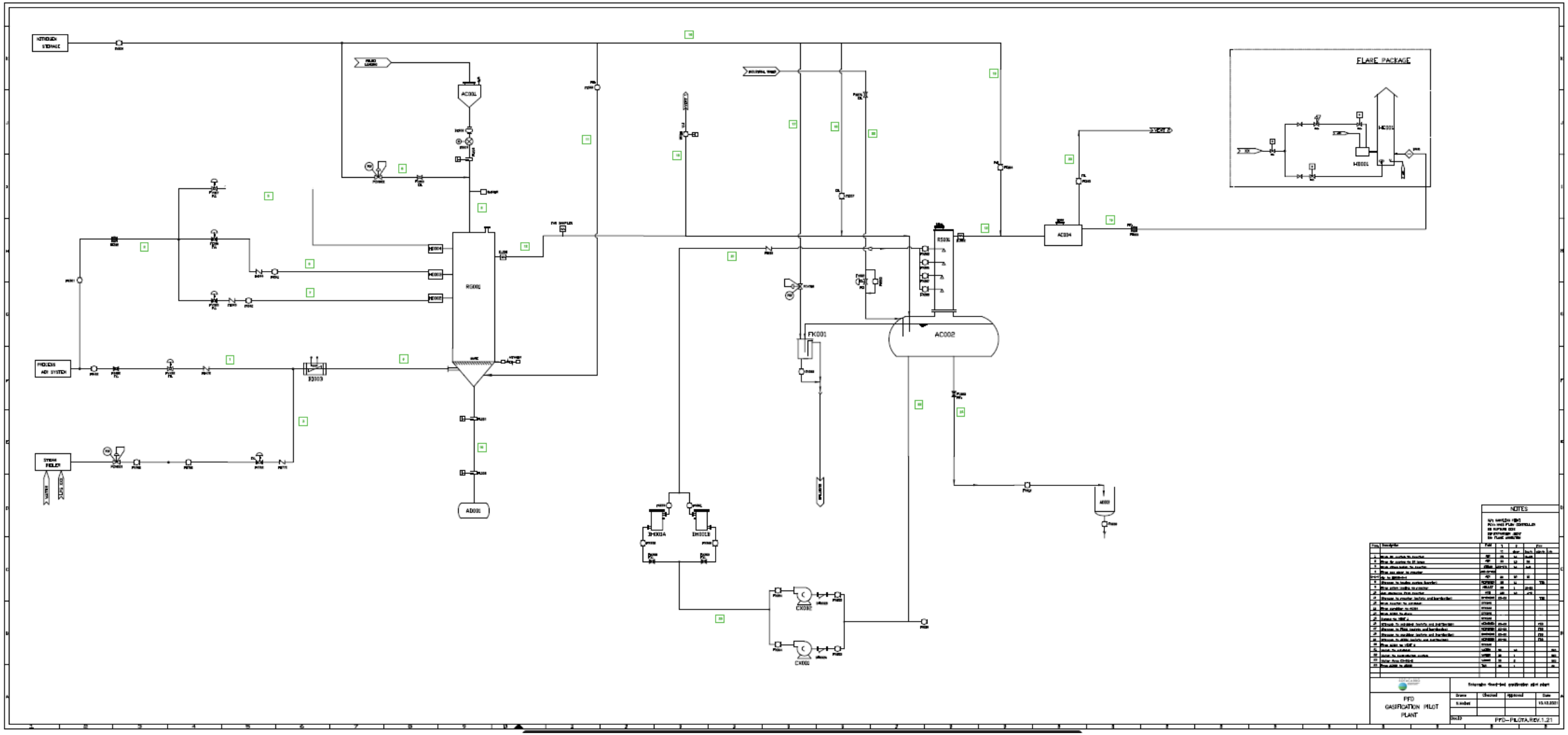
Pelletizing tests at CPM are scheduled for July 2022

Task 3 Status

Task 3 – Test Plan Development

- Sotacarbo's lab-scale gasifier process flow diagram (PFDs) and piping and instrumentation diagrams have been reviewed
- HMI is reviewing what instrumentation is, or will be, in place, and what other instrumentation may need to be procured
- Sampling and testing procedures are being reviewed
- Prior HMI gasifier test plans are being reviewed
- Gasifier startup procedure has been reviewed
- Each gasification test run will last one day, but Sotacarbo can only perform on average 1.5 runs per week due to cleanup of the gasifier and other equipment between runs

PFD for Sotacarbo 12” Inner Diameter (ID) Gasifier



Task 4 Status

Task 4 – Gasifier Testing

- Sotacarbo is implementing modifications to their 12” ID lab-scale moving bed gasifier
  - The gasifier is being refurbished, including new refractory wall
  - Piping will be reinstalled after the refractory is replaced
  - Other maintenance activities are being performed
- The gasification system should be available for initial shake-down tests in early fall 2022
  - Pelletized PRB coal will be used for the shake-down tests

Reactor removal and refractory layer before the reconstruction

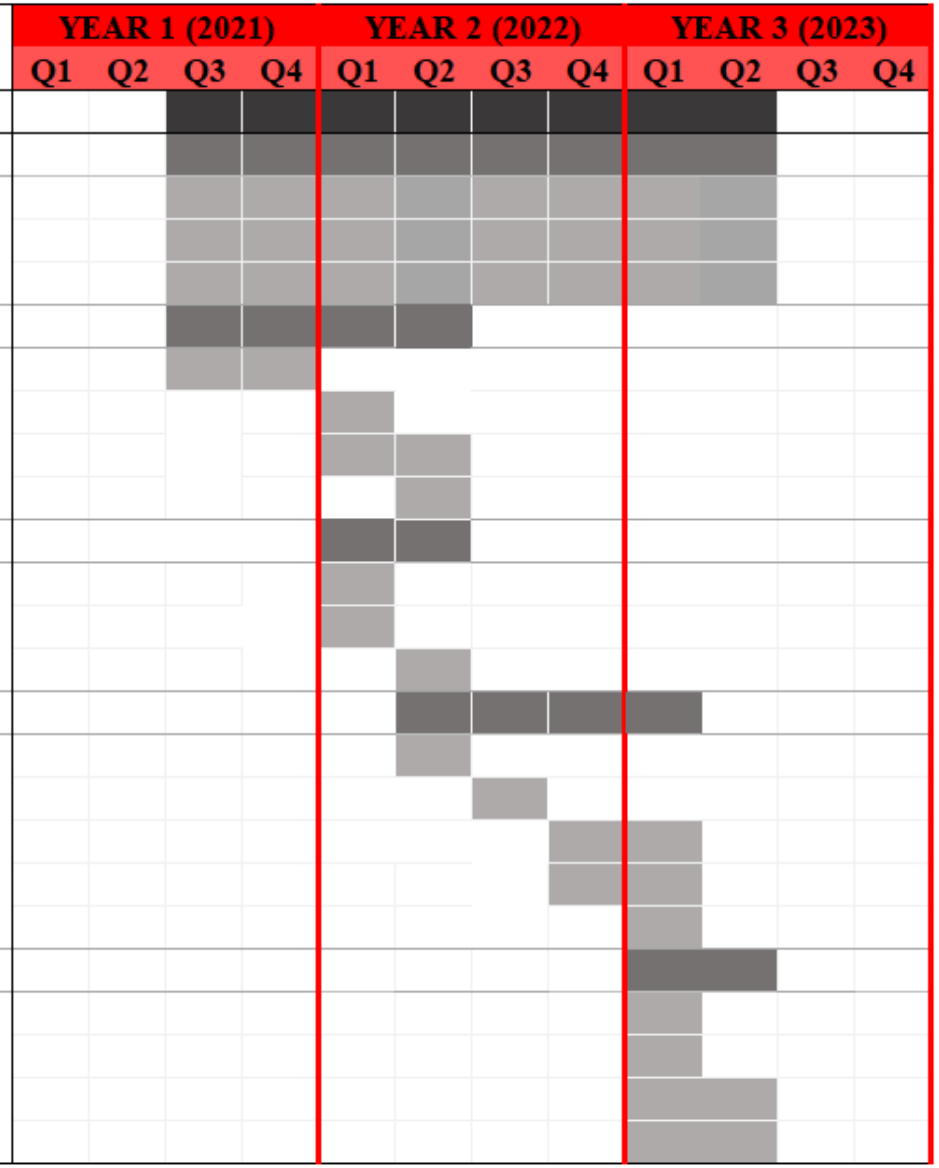
Next Steps

- Finalize the gasification test plan
  - Including an outline of the individual gasification test reports
- Complete the tri-fuel pelletizing tests
  - Obtain ultimate and proximate analyses for all tri-fuel pellet samples
  - Ship the tri-fuel pellets to Sotacarbo in sealed barrels
- Complete installation of the lab-scale gasifier
  - Begin shake-down testing of the gasifier and instrumentation systems

Gasification test runs are scheduled for 4Q 2022/1Q 2023

Project Schedule

Anticipated Start Date: 04/01/2021	Key Person	Duration (months)
BUDGET PERIOD 1 [8 Quarters]		**24**
Task 1.0: Project Management and Planning	**George Booras, EPRI**	**24**
1.1: Project Management Plan		**24**
1.2: Financial Reporting		**24**
1.3: Project Reporting		**24**
Task 2.0: Feedstock Procurement and Preparation	**Rolf Maurer, HMI**	**7**
2.1: Finalize Coal, Biomass, and Plastics Selection and Pellet Formulations		**2**
2.2: Acquire Coal, Biomass, and Plastics and Deliver to Preparation Site		**2**
2.3: Conduct Preliminary Pelletizing Tests and Prepare Gasification Test Pellets		**3**
2.4: Ship Gasification Test Pellets to Gasification Test Facility		**1**
Task 3.0: Test Plan Development	**George Booras, EPRI**	**5**
3.1: Specify Test Data to Be Reported		**2**
3.2: Specify Handling of Gasification Products		**2**
3.3: Review Test Facility Status and Instrumentation		**2**
Task 4.0: Gasifier Testing	**Alberto Pettinau, Sotacarbo**	**8**
4.1: Implementing Required Modifications to the Lab-scale Gasifier Test Facility		**3**
4.2: Preliminary Lab-scale Process and Instrumentation Testing		**1**
4.3: Conduct Gasification Test Runs		**3**
4.4: Assemble Raw Data Sets for Gasification Test Runs		**4**
4.5: Dispose of Solid and Liquid Co-products		**1**
Task 5.0: Data Analysis and Reporting	**David Thimsen, HMI**	**7**
5.1: Archiving Raw Data		**2**
5.2: Raw Data Reduction		**2**
5.3: Overall Assessment of Coal/Biomass/Waste Plastic Gasification Prospects		**2**
5.4: Final Report and Closeout Presentation		**4**



Acknowledgment and Disclaimer

- **Acknowledgment**: This material is based upon work supported by the Department of Energy under Award Number DE-FE0032044.
- **Disclaimer**: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Together...Shaping the Future of Energy®