DOE Bioenergy Technologies Office (BETO) 2021 Project Peer Review

Small Scale Decentralized Fuel Production Facilities via Advanced Heat Exchanger-Enabled Biorefineries
DOE Award EE0007964

- March 25, 2021
- Systems Development and Integration

- Ravi Chandran
- TRI

Project Overview

- *DE-FOA-0001232 – 2016 Project Development for Pilot Scale manufacturing of Biofuels*

- *Project Goals:*
  - *Design and develop a 2nd generation integrated biorefinery capable of*
    - *Distributed small scale biofuel production based on process intensification*
    - *Enhanced biofuel yield per ton of cellulosic biomass*
    - *Lower Capex and Opex, and*
    - *Wide deployment*
  - *Meet DOE/EERE/BETO objectives*
    - *Dramatically reduce dependence on imported oil*
    - *Spur the creation of domestic bio-industry*
  - *Target drop-in cellulosic biofuel cost < $2/GGE*

- *Risks:*
  - *Brownfield installation – integration of new components with existing TRI Process Demo. Unit*
  - *Contingency reserve requirement*

1 – Management

- *Management approach:*
  - *Stage Gate method with a Steering Committee (one Executive from each team member) review at the first level and the DOE (and the Independent Engineers) review at the second level for Go/No Go decision*
  - *Critical success criteria or key technical achievements formulated for each stage so that the project meets or exceeds a minimum hurdle rate to proceed forward*
  - *Task based milestones to monitor progress*
- *Project structure:*
  - *Team comprising TRI, RTI, Velocys, Susteon and InnoSepra*
  - *TRI technical & Admin POCs for the DOE, Steering Committee, team member leads*
  - *<u>Task Areas:</u>*

TRI: Steam reforming, advanced heater, PDU Integration – testing, validation, design, CFD, CPFD & ASPEN Plus simulations, FEA, scaleup, 3D Modeling, IP management plan

RTI, InnoSepra: CO_2 removal & regeneration - testing, validation, design

Susteon: H_2S/COS and HCN/NH_3 removal - validation, design

Velocys: Microchannel F-T synthesis – testing, validation

Velocys, RTI: FTL upgrading - testing, validation

1 – Management (continued)

- *Risk Mitigation:*
  - *Risk Registry table included in the additional slides which identifies risk and indicates the mitigation strategy and the status*

2 – Approach

- *Overall technical approach: Design, test and validate the high impact process intensification improvements to “first generation” IBR*
  - *Experimental validation of individual, new unit ops*
  - *Run simulations to validate model, scaleup and confirm performance improvement*
  - *Design, fabricate, install, commission and test the integrated Process Demonstration Unit (PDU) to demonstrate improvements*

- *Challenges:*
  - *Design and integration of Advanced Heater to replace existing electrical heaters in the steam reformer*
  - *Installation and integration of the new components with the existing TRI PDU*
  - *Biomass preparation for PDU testing*

- *Go/No Go Decision points:*
  - *Initial Process and Data Validation for proof of performance – successfully completed*
  - *Syngas production improvement – successfully completed*
  - *Phase 1 project review - pending*

2 – Approach (continued)

- *Metrics used to measure progress:*
  - *Improvement in heat flux and heat transfer coefficient for the TRI advanced heat exchanger – TRI testing and CFD simulations*
  - *Increase in usable syngas (H_2 + CO) per unit mass of dry feedstock – TRI testing and CPFD simulations*
  - *Syngas CO_2 capture efficiency – testing at RTI and InnoSepra*
  - *Velocys' Microchannel Fischer-Tropsch (F-T) single pass CO conversion - Integrated testing by TRI and Velocys*
  - *F-T liquids upgrading catalyst integrity and performance – testing at RTI*
  - *Structural integrity of TRI advanced heat exchanger – detailed finite element analyses*
  - *Readiness for brownfield installation of new process components at the TRI Process Demonstration Unit – component design and 3D modeling*

TRI Integrated BioRefinery
Process Demonstration Unit
Durham, NC

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3 – Impact

- *Small scale IBRs with process intensification decrease biomass conversion costs and directly support BETO MYPP goals:*
  - *Enable sustainable, nationwide production of biofuels compatible with today’s transportation infrastructure, reduce greenhouse gas emissions relative to petroleum-derived fuels, and displace a share of petroleum-derived fuels to reduce U.S. dependence on foreign oil*
  - *Plant size commensurate with economical biomass transportation and distributed biofuel (diesel and naphtha) production*
  - *Encourage the creation of a new domestic bioenergy and bioproduct industry*
- *Addresses BETO’s 2017 target of <$2/GGE biofuel cost*
- *Targets BETO’s goal to validate biofuel production at pilot scale (>1 ton/day) by 2022*
- *Plan to present at domestic and international conferences upon the successful completion of Phase 2 trial as this plant scale can cater to the more common albeit smaller feedstock supply sources and leverage feedstock transportation economics*

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4 – Progress and Outcomes

- *Status of project:*

    - *TRI advanced heater – validation, mechanical design, CFD modeling, Finite Element Analyses and 3D modeling for PDU steam reformer integration – all completed*
    - *CO_2 removal and regeneration – validation and design - completed*
    - *Velocys' Microchannel F-T unit - integration with the TRI PDU and validation - completed*
    - *NEPA documentation and permitting - completed*
    - *TRI 2nd gen steam reforming – validation, CPFD modeling – completed*
    - *IP management plan – completed*
    - *Budget for Phase 2* – pending*
    - *Project review and approval to proceed to BP3* - pending*
    - *9 milestones and the performance metric go/no go criterion have been met*
    - *Budget milestone and BP3 go/no go decision are pending*

***** *Proposed combining this project and the feeder project (WBS 3.4.1.201) for Phase 2*

4 – Progress and Outcomes (continued)

- *Accomplishments:*
  - *Significant improvement in both heat flux and heat transfer coefficient for the TRI advanced heat exchanger in comparison to both the TRI first generation pulsed heater and the conventional fire-tube – TRI testing and CFD simulations*
  - *> 25% increase in usable syngas (H_2 + CO) per unit mass of dry feedstock – TRI testing and CPFD simulations*
  - *> 90% syngas CO_2 capture efficiency – testing at RTI and InnoSepra*
  - *> 60% Velocys' Microchannel Fischer-Tropsch (F-T) single pass CO conversion - Integrated testing by TRI and Velocys*
  - *No adverse effect on catalyst integrity and performance while upgrading Velocys' F-T liquids to drop-in fuels – testing at RTI*
  - *TRI advanced heat exchanger satisfies structural integrity criteria – detailed finite element analyses*
  - *3D integration of TRI advanced heat exchanger with the existing TRI steam reformer – 3D modeling*
  - *Configuration and location of new process components at the TRI Process Demonstration Unit for brownfield installation – component design and 3D modeling*
  - *Potential to meet the project goals via preliminary technoeconomic analysis*

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Summary

1. Overview: *Second generation IBR for improved economics and wide scale deployment*
2. Approach*: Design, test and validate the high impact process intensification improvements to "first generation" IBR;*

    Critical success factors:

    > 25% increase in usable syngas (H_2 + CO) per unit mass of dry feedstock

    > 35% decrease in overall Capex of the IBR

    < $2/GGE Opex of IBR

3. Technical Accomplishments/Progress/Results: *Successful validation of 5 unit ops in BP1; successful completion of component design, simulations and analyses in BP2; exceeded the syngas yield improvement go/no go criterion*
4. Relevance: *Directly supports BETO's MYPP, 2017 & 2022 goals*
5. Future work: *Construction, PDU Integration and demonstration*

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Quad Chart Overview

Timeline

- *Project start date 1/15/2017*
- *Project end date 12/15/2023*

	FY20 Costed	Total Award
DOE Funding	(10/01/2019 – 9/30/2020) *$96,367*	(negotiated total federal share) *$807,984*
Project Cost Share	$92,853	$808,999

Project Partners

- *Velocys, RTI, Susteon, InnoSepra*

Project Goal

Design and develop a 2nd generation IBR for distributed biofuel production with enhanced yield at lower Capex & Opex to accelerate IBR deployment

End of Project Milestone

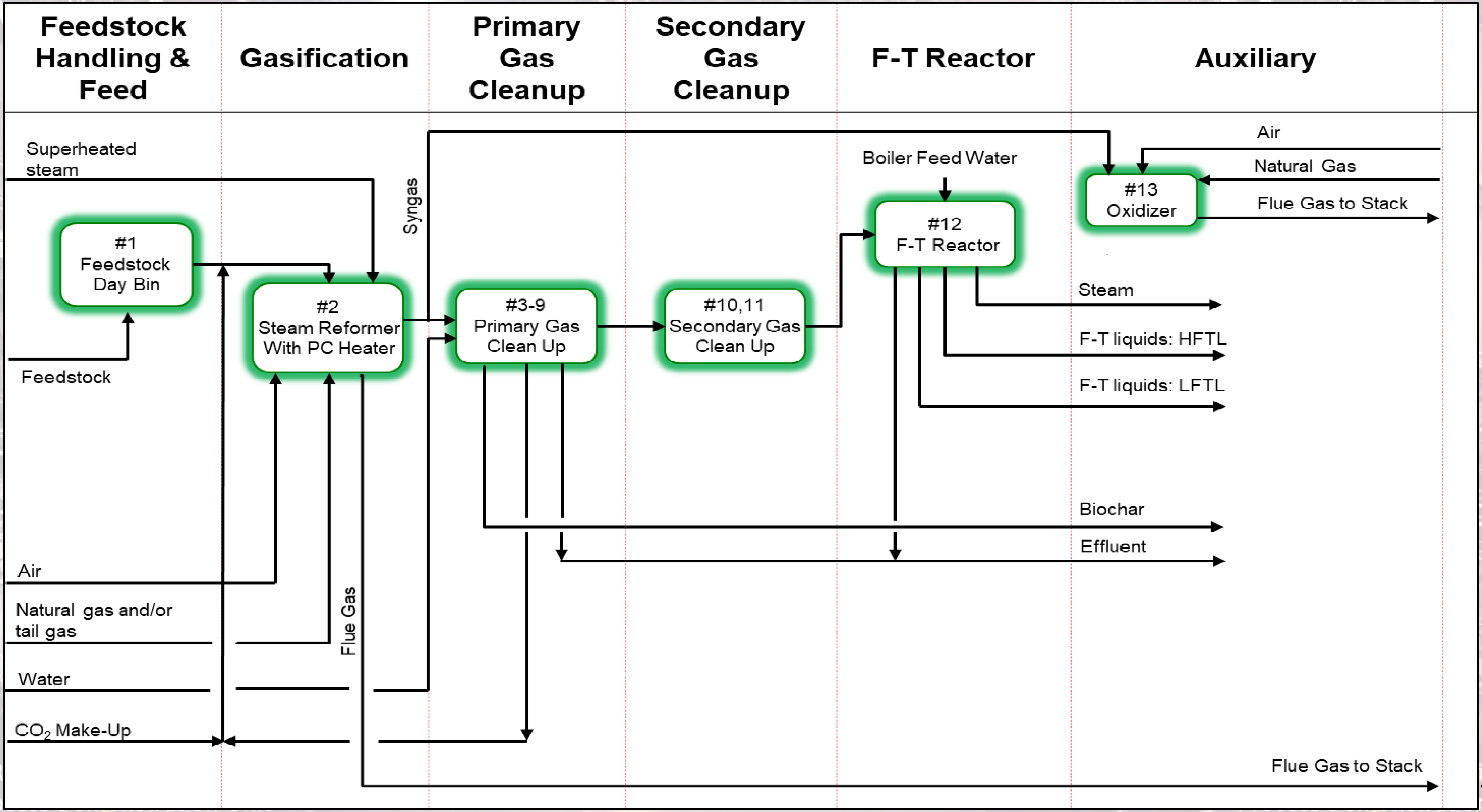
- *> 25% increase in usable syngas (H_2 + CO) per unit mass of dry feedstock*
- *> 35% decrease in overall Capex of the IBR*
- *< $2/GGE Opex of IBR*

Funding Mechanism

FOA No. DE-FOA-0001232 Project Development for Pilot and Demonstration Scale Manufacturing of Biofuels, Bioproducts, and Biopower - 2016

Additional Slides

Process Operations Block Diagram



Risk Registry Table

	Risk Identified			Mitigation Strategy		Current Status
Risk ID	**Process Step**	**Risk Description**	**Severity (High/ Med/Low)**	**Mitigation Response**	**Action Date**	**Active/ Closed**
TRI Indirectly heated steam reforming						
1	Modified steam reforming process	Syngas (H_2+CO) yield increase	High	Validation trial	10/2017	Closed
2	Advanced heater	Heat transfer effectiveness	High	Validation trial	10/2017	Closed
3	Scale-up of 1 Scale-up of 2	Performance	Medium High	CPFD simulation CFD simulation	1/2019 10/2019	Closed Closed
4	PDU Integration	Brownfield installation	Medium	3D Modeling	2/2019	Closed
RTI/InnoSepra CO_2 capture and regeneration						
1	From syngas	> 90% capture	High	Validation trial	10/2017	Closed
2	PDU Integration	Brownfield installation	Medium	3D Modeling	10/2019	Closed

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Risk Registry Table (continued)

	Risk Identified			Mitigation Strategy		Current Status
Risk ID	**Process Step**	**Risk Description**	**Severity (High/ Med/Low)**	**Mitigation Response**	**Planned Action Date**	**Active/ Closed**
Velocys Microchannel F-T						
1	FT synthesis	Performance	Medium	Validation trial	3/2018	Closed
2	PDU Integration	Brownfield installation	Medium	Installed and operated	3/2018	Closed
F-T upgrading						
1	Diesel and Naphtha	Catalyst integrity and performance	Medium	Validation trial	3/2018	Closed

Responses to Previous Reviewers' Comments

- This project was peer reviewed in 2019 and the reviewers' comments were all positive and complimentary

Publications, Patents, Presentations, Awards, and Commercialization

- No publications, patents, awards, and presentations have resulted from work on this project
- Commercialization of this technology will benefit from the maturation of large scale IBRs

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