Potential integration between residual biogenic process resources and green hydrogen

Presenter: Abhijit Dutta, NREL, USA

Location: IEA Bioenergy Task 42 (biorefining in a circular economy) webinar on:

Novel opportunities for the development of biorefineries: bio-carbon to chemicals and fuels by integration of biorefineries and green hydrogen

Date: May 16, 2024

My Background

Chemical Engineer, focused on process modeling and control, with >30 years experience

- Principal Investigator for biomass thermo-catalytic conversion modeling project at **NREL** since 2008
- Prior employment:
  - **Bloom Energy**
  - **Aspen Technology Inc.**

Abhijit Dutta – Senior Research Engineer, NREL

Presentation Overview

Process Focus: Biomass pyrolysis and steam reforming for H_2

Why: Inefficiencies towards target products need to be exploited wisely

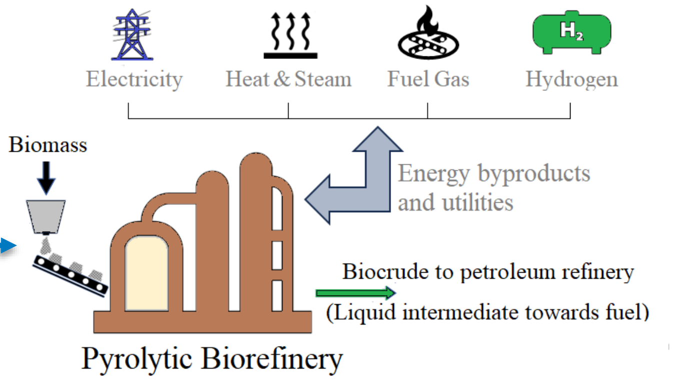
Process Resource: Off-gases from fast pyrolysis (FP) and catalytic fast pyrolysis (CFP)

Additional Relevance: Applicable to biogenic off-gases from other processes

Methods: Conceptual process modeling with heat integration

Key References

Sustainable Energy Fuels, 2023,7, 4955-4966.
https://doi.org/10.1039/D3SE00745F



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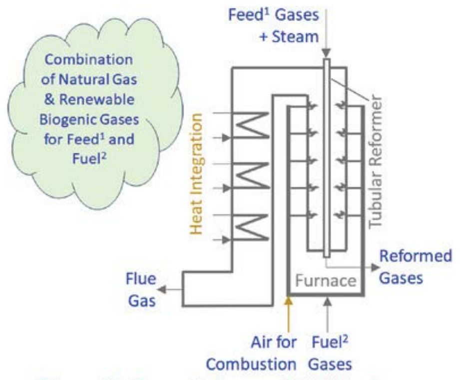
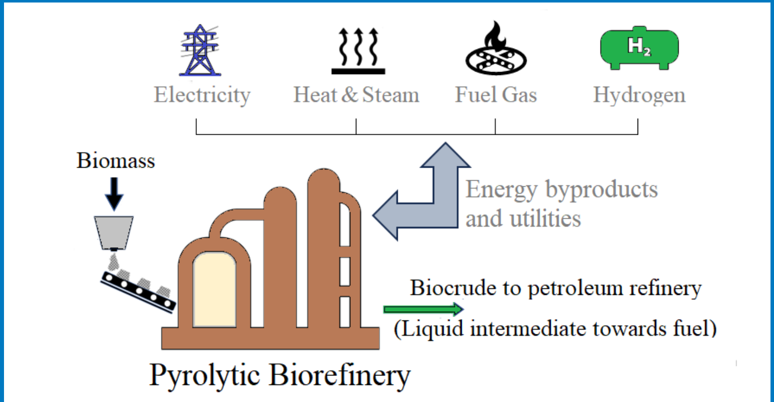


Steam Methane Reformer (SMR) System

Location and Infrastructure for Decision-Making

Impacts of choices based on locational feasibility



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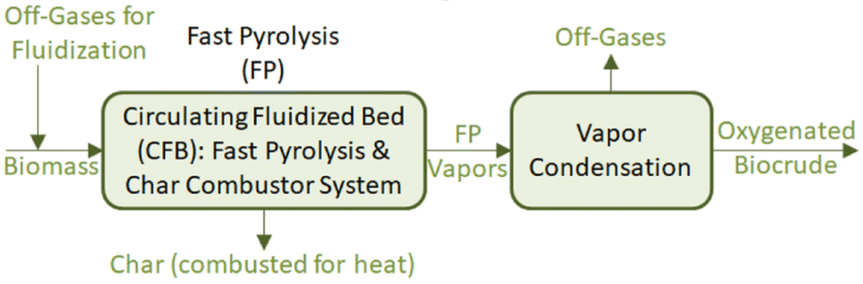
Example Pyrolysis Process Designs

FP Configuration

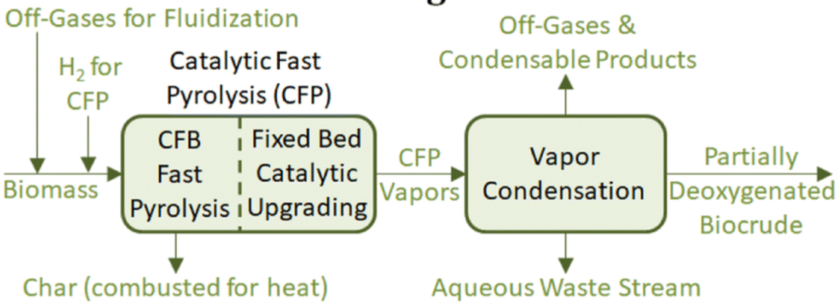


Major Inputs
- Woody biomass
- Electricity
- Other utilities

Major Outputs
- FP Biocrude
- Heat and steam
- Off-gases

Utility Integration Options
- Electricity
- Steam
- Fuel Gas

CFP Configuration



Major Inputs
- Woody biomass
- Hydrogen
- Electricity
- Other utilities

Major Outputs
- CFP Biocrude
- Heat and steam
- Off-gases
- Chemical coproducts

Utility Integration Options
- Hydrogen
- Electricity
- Steam
- Fuel Gas

Abbreviations: FP = Fast Pyrolysis, CFP = Catalytic Fast Pyrolysis

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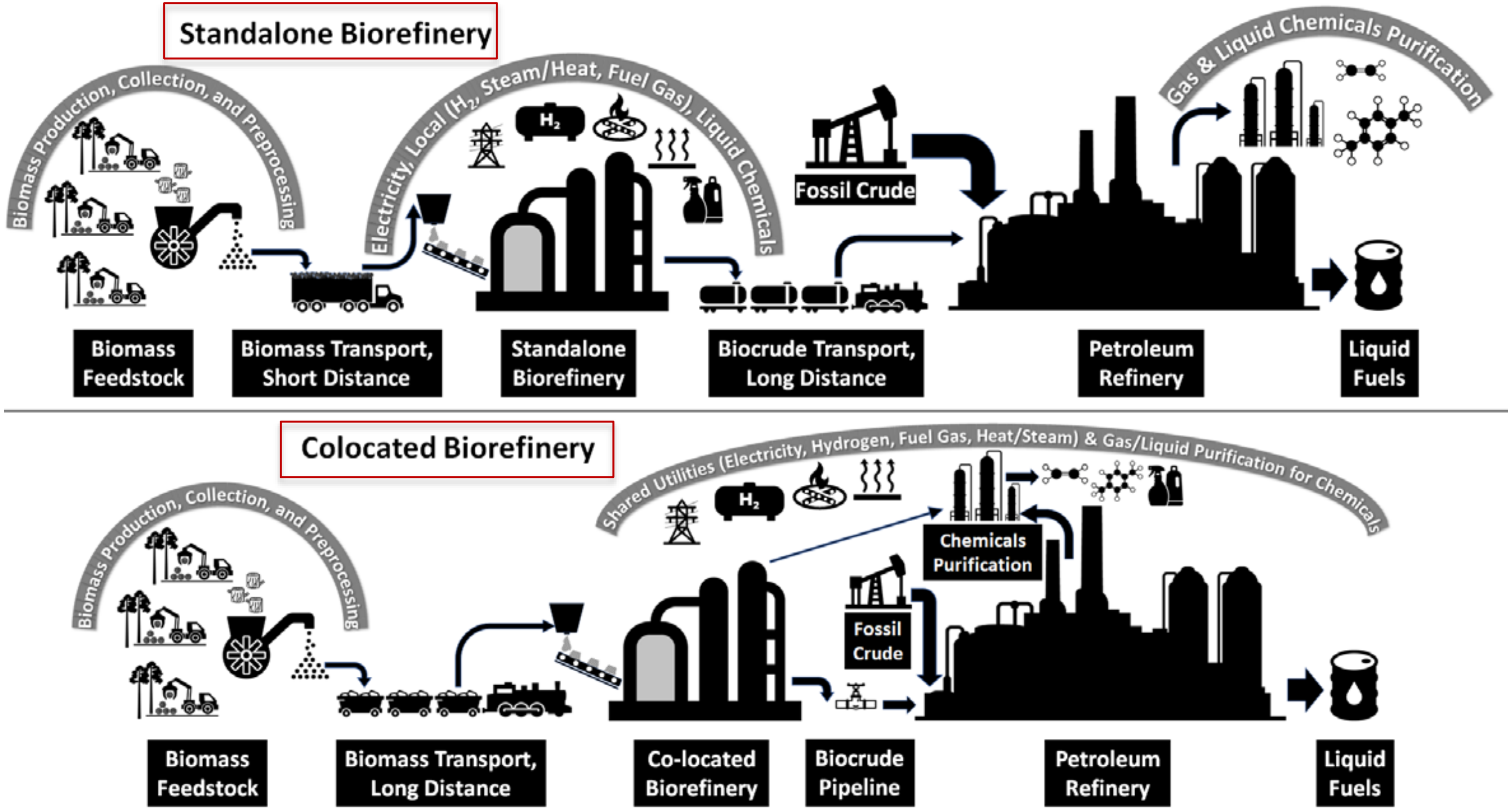
Location/Infrastructure for Utilization



Limitations

- H_2 export
- Heat export
- Steam export
- Fuel gas
- Gaseous products

Electricity export is flexible

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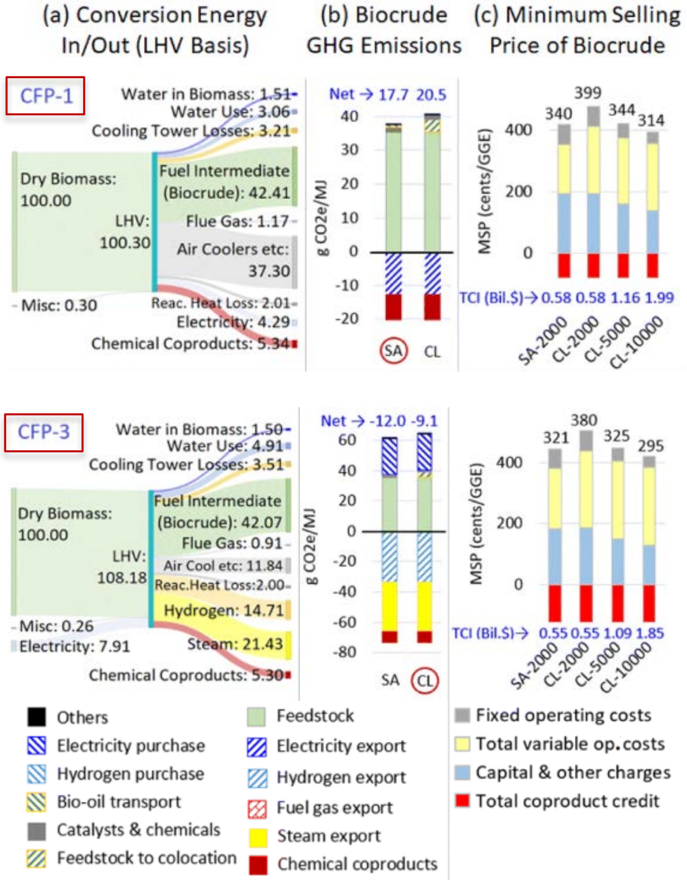
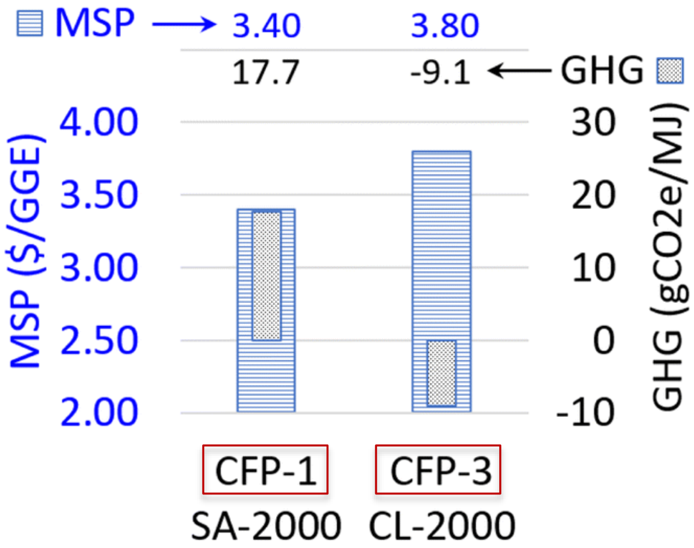
Making the Right Location-Specific Choices

(CFP Example)

Standalone with only electricity export feasible

Colocated with complete flexibility for utilization of resources





Displacement method used for assessing GHG impacts of energy resources

Abbreviations: SA = Standalone, CL = Colocated, MSP = Minimum Selling Price

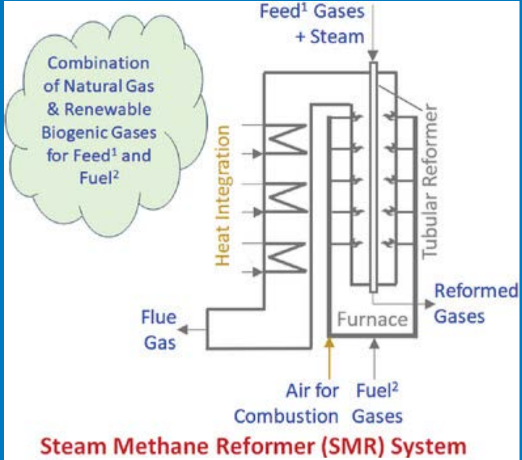
SA-2000 = SA 2000 tonnes/day, CL-2000 = CL 2000 tonnes/day

Impacts of making other additional choices are presented in:

Sustainable Energy Fuels, 2023,7, 4955-4966. https://doi.org/10.1039/D3SE00745F

Steam-Reforming for Hydrogen Production from Biogenic Gases

Impacts on existing steam-reforming processes; conceptual assessment via process modeling



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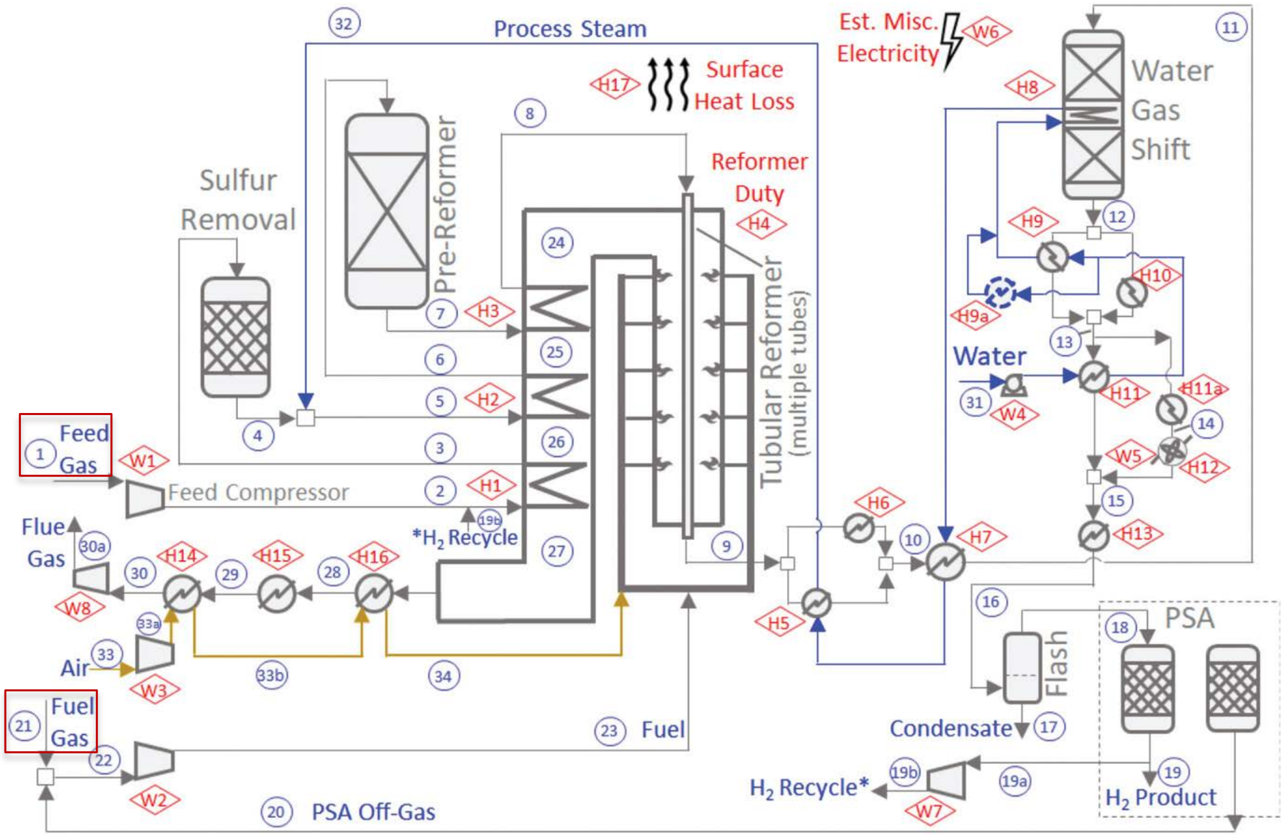
Process Configuration for Impact Assessment



Assessment using heat-integrated model.

Validation of base case using natural gas with a scenario in IEAGHG Report (https://ieaghg.org/exco_docs/2017-02.pdf)

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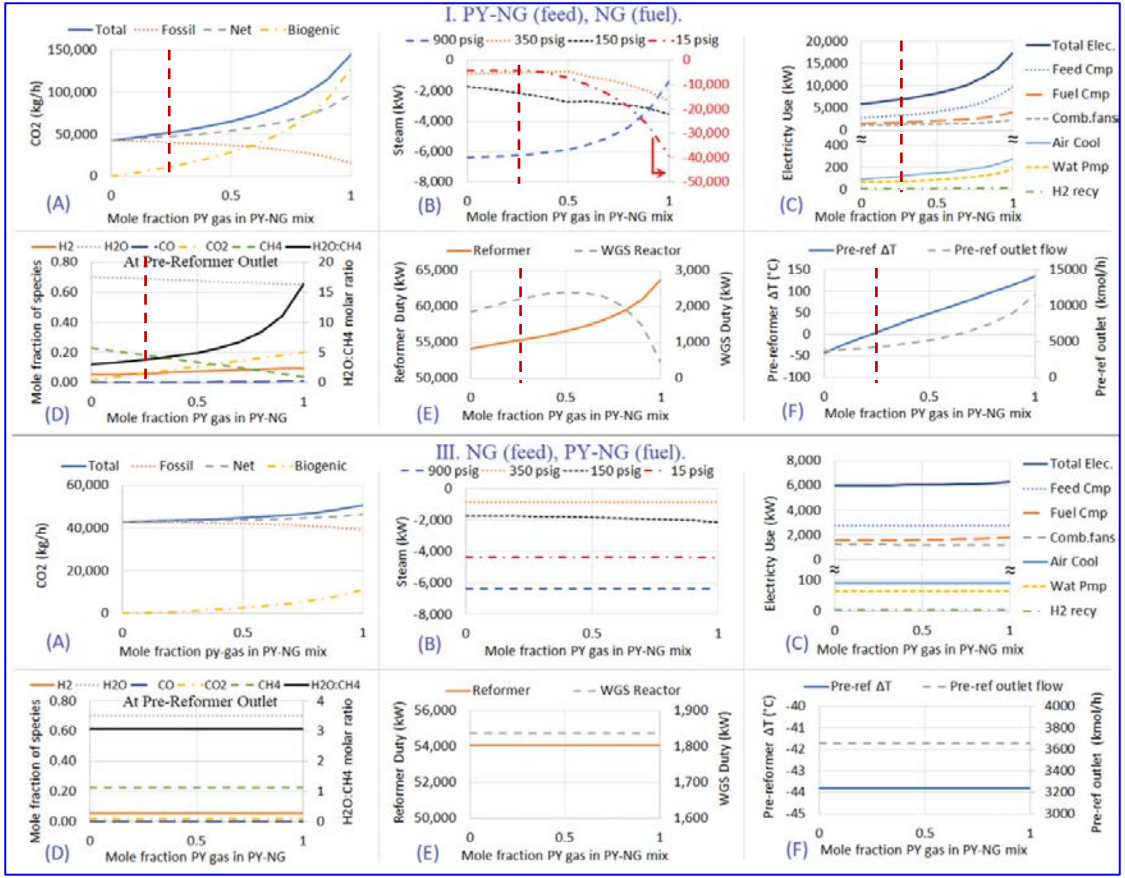
Sample of Results – Tracking Substitution of Natural Gas (NG) with Pyrolysis Off-Gases

Plant Capacity
5000 kg/h H_2

Feed Side Impact



Fuel Side Impact

As expected, substitution of *fuel side* natural gas is easier with minimal process impacts.

Other key sensitivities included: steam:carbon ratio and CO_2 in off-gases

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Key Conclusions from Steam-Reforming Analysis

- Besides fuel side substitution of NG with off-gases, feed replacement up to 25% (depending on off-gas) composition may be possible within design tolerances (often ~15%)
- Enabling CO_2 use with partial dry-reforming can increase efficiency
    - By reducing steam consumption concurrently (with syngas output composition richer in CO)
- Pre-reformers will play a critical role
    – Handle compositional variations & shield main reformer
- **Caveat:** These are process model results
    – Industrial implementation will have other considerations
        - E.g., corrosion, safety, supplier design guarantees etc.
- Analysis method can be applied to other biogenic gases

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Thank you for your attention

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