the Energy to Lead

Exploring the Optimum Role of Natural Gas in Biofuels Production

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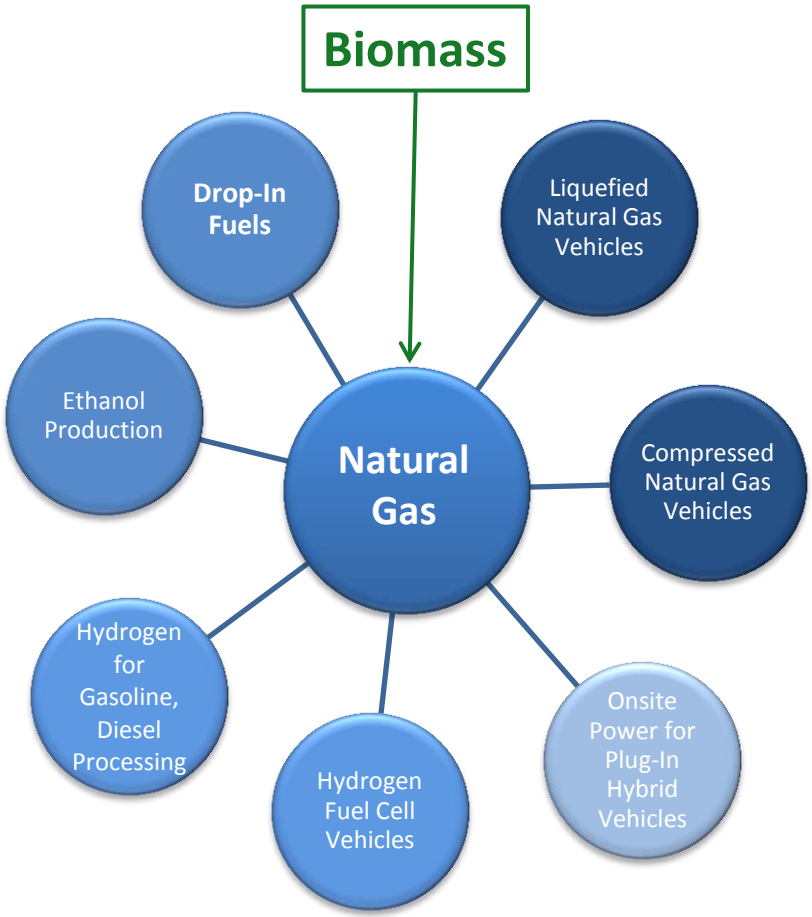
Natural Gas Uses in the Transportation Sector



Natural gas use for vehicles is multi-faceted, with about 1.3 Tcf (mostly indirect fuels production).

> Indirect
  - Hydrogen for petroleum refining
  - Ethanol, biofuel production

> Direct: NGVs
  - CNG, LNG (about 40 bcf)

> New paths:
  - H_2 vehicles, GTL, PHEV power
  - SNG to feed all routes

Why Incorporate Natural Gas in Biofuels Production?

- Increase process scale to lower CAPEX per unit production
- Increase process efficiency to lower OPEX per unit production
- Stabilize OPEX and production costs with dual feed
- Supply hydrogen to make higher quality products
- Supply heat to permit maximum renewable content in liquids

Methane – A Useful Reactant for Drop-In Hydrocarbon Production

$$CH_{1.6}O_{0.6} \longrightarrow (CH_2)_n + H_2O + CO_2$$

- Need to remove oxygen
- Need to add hydrogen

$$xCH_{1.6}O_{0.6} + yCH_4 \longrightarrow (CH_2)_n + H_2O + CO_2$$

Technical Options to Incorporate Natural Gas for Biofuels Production

Where is the best place to incorporate natural gas in these processes?

- Does combustion for heat provide the best value from natural gas?
- Should natural gas be used as an external hydrogen source?
- Should natural gas be incorporated as a hydrogen carrier to be internally reformed?
- Should natural gas be specifically used to reform the biomass conversion products?

To what extent are these answers sensitive to feedstock prices?

To what extent are these answers specific to the final product?

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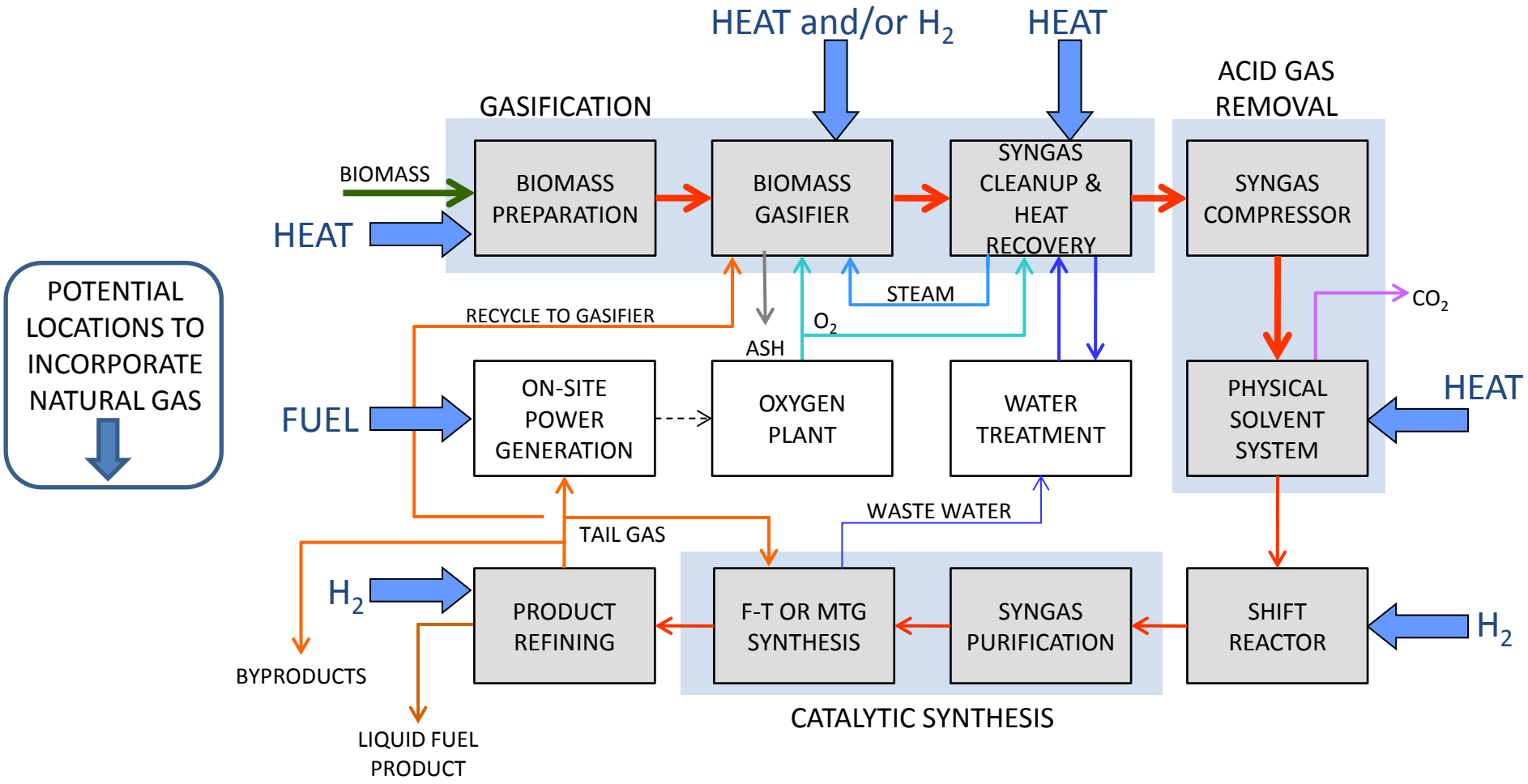
Example for Natural Gas Options in Biomass-to-Liquids Production



Exploring Optimum Ways to Incorporate Natural Gas in Biofuels

Process simulations – necessary, but not sufficient

Techno-economic sensitivity analyses – always

Experimental confirmation – essential for validation

There are many paths and novel configurations to exploit the chemistry and economy of natural gas for biofuels.

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