Biomass Gasification

Ready to Meet Needed Bioenergy Market Growth?

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LEE ENTERPRISES CONSULTING, INC.

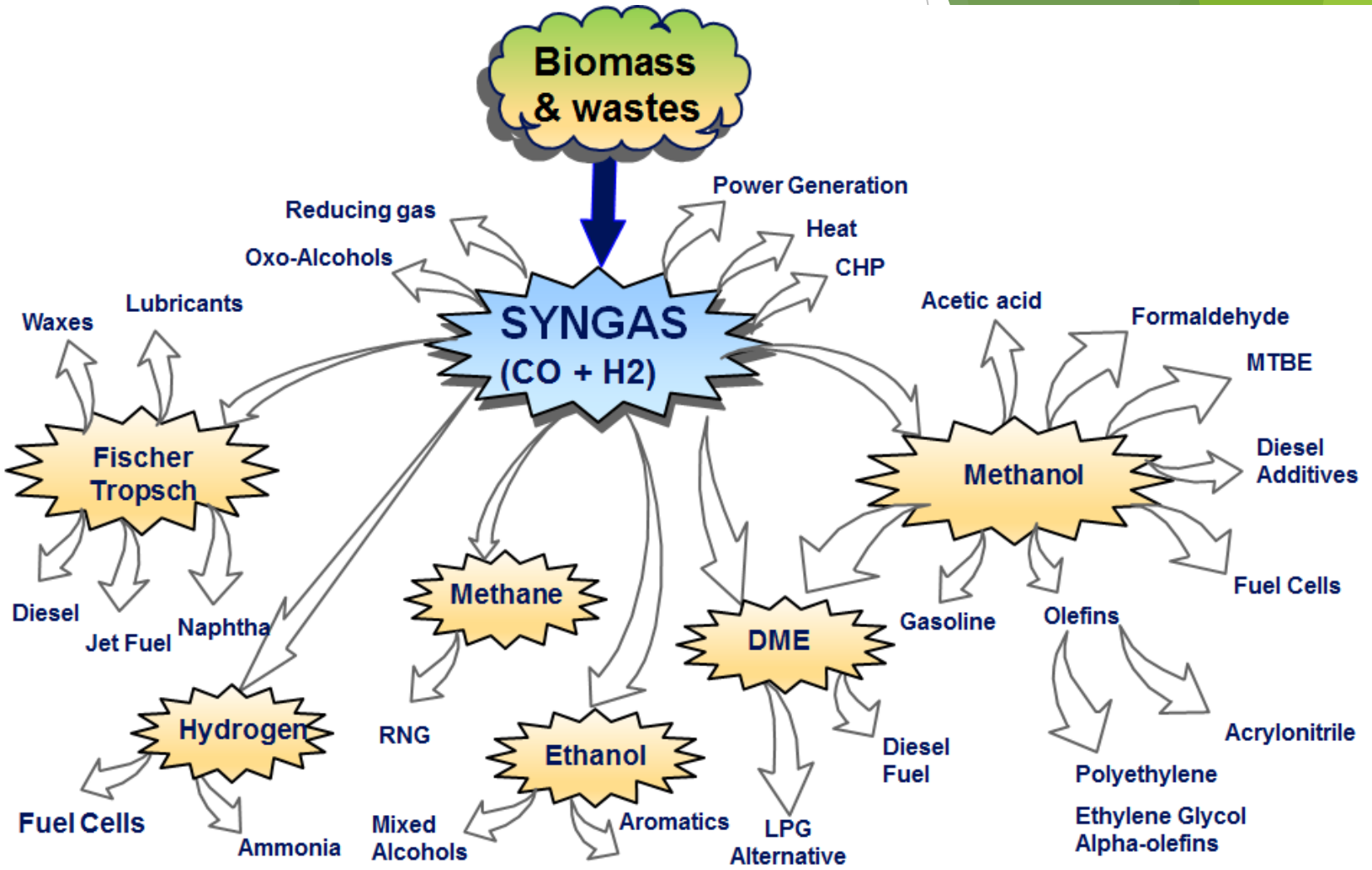
About Lee Enterprises Consulting

◆ *SEASONED, INDEPENDENT, PROFESSIONAL EXPERTISE* ◆

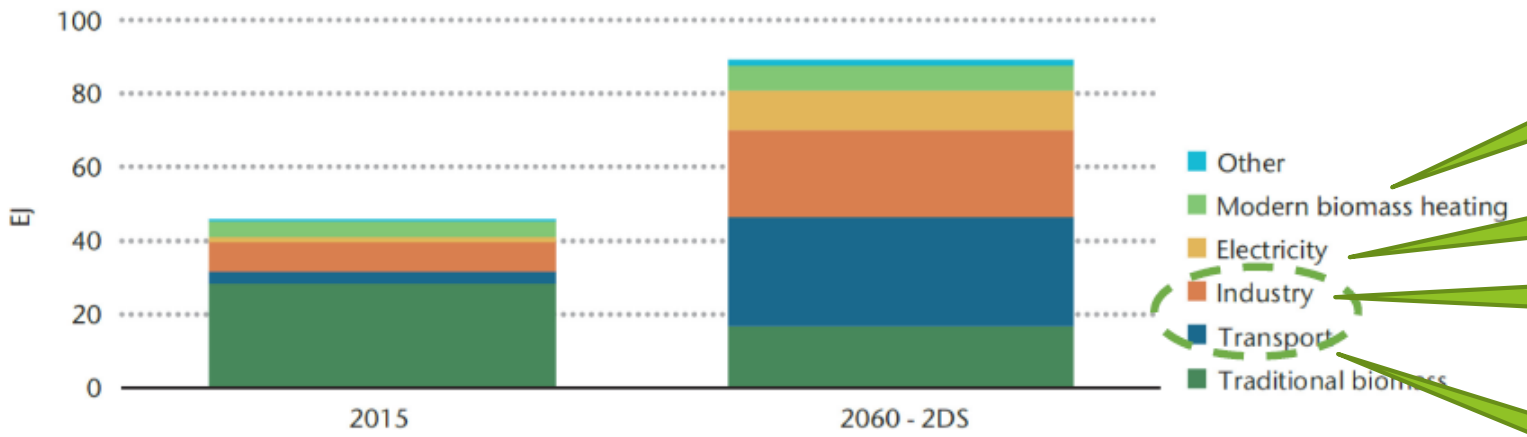
- **OUR TEAM:** We are the world's largest bio consulting group with over 100 subject matter experts.
- **OUR PROJECTS:** Our members have completed thousands of projects in anaerobic digestion, biofuels, biomaterials, chemicals, DSP, feedstocks, fermentation, gasification, pyrolysis, synthetic biology, and water/ wastewater treatment.
- **OUR ADVANTAGE:** We provide independent third party expertise that provides cost-effective, interdisciplinary teams with a single point of client contact without hiring additional full-time employees.
- **OUR CLIENTS:** Our clients include biofuels companies, biochemical companies, investors, banks, entrepreneurs, plant owners, law firms, biotechnology providers, energy companies, and engineering firms.

Biomass Gasification

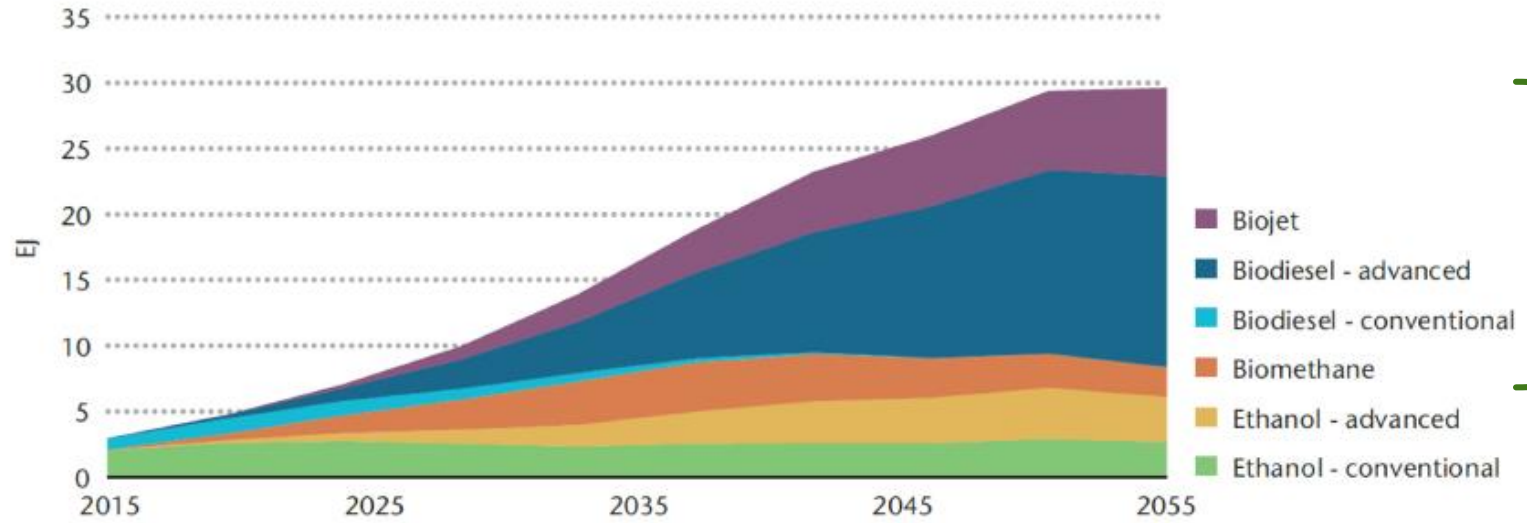
A thermochemical process in which a renewable solid carbonaceous feedstock is reacted with air, oxygen, CO_2 and/or steam to produce a gaseous product stream containing hydrogen and carbon monoxide (synthesis gas).



Global Potential for Biomass Gasification



Bioenergy Use for Final Energy in the IEA Bioenergy Roadmap[1].



Biofuels for Transport in the IEA Bioenergy Roadmap[1].

District heating, CHP, RNG

Biomass Power, CHP, BIGCC, WtE, repowering, fuel cells.

Syngas refueling, hydrogen and chemicals

Liquid biofuels, RNG for transport

Potential biofuels generated via Gasification. Only a 10% share of a 20 EJ biofuel market (in 2050) is approx. 1700 x 50 MW_{th} Gasifiers!!

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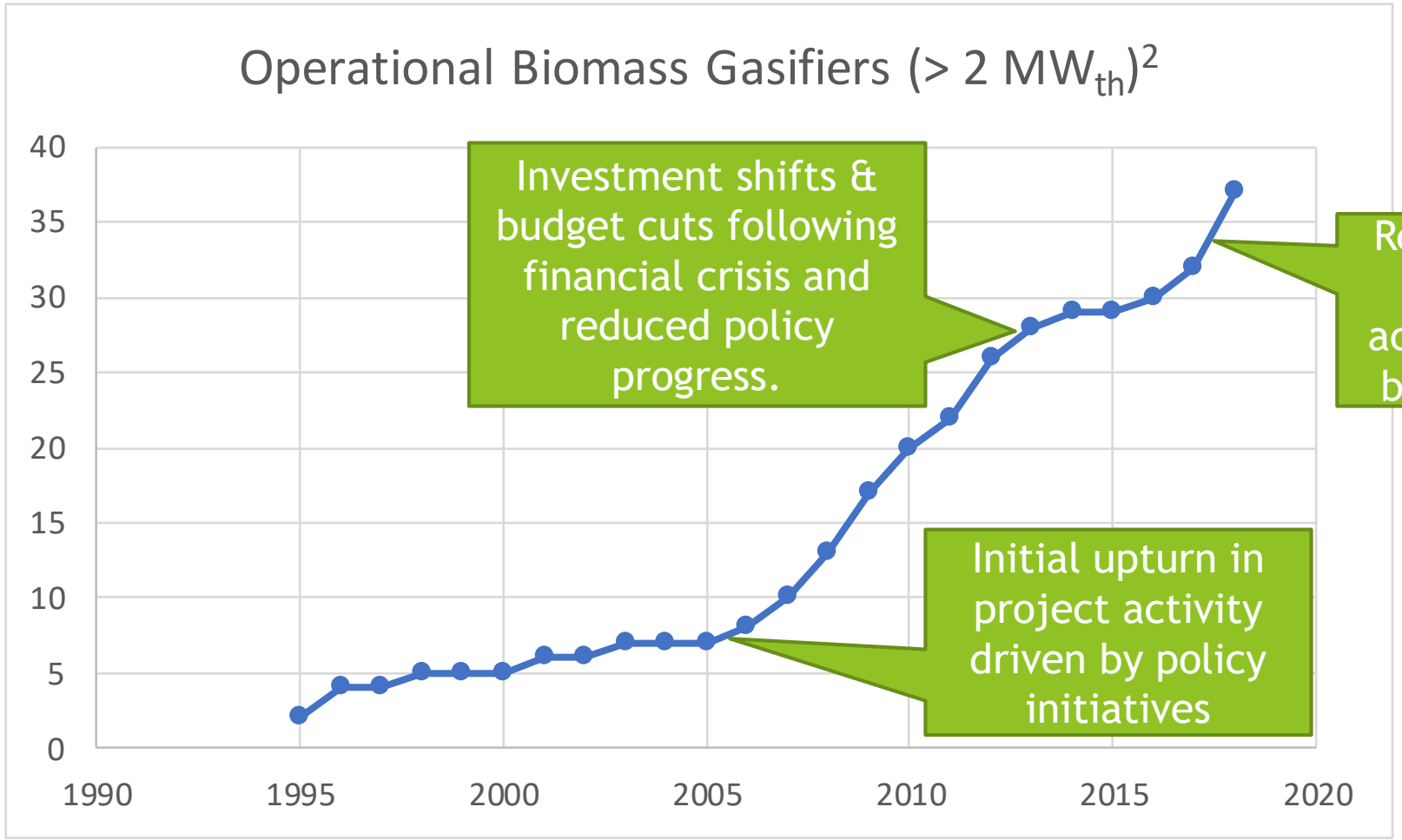
1. IEA Technology Roadmap: Delivering Sustainable Bioenergy (2017).

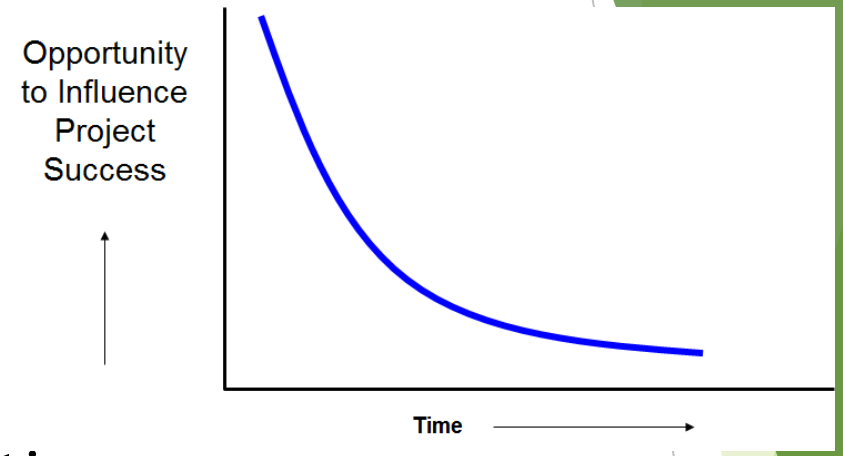
Current Biomass Gasification Status

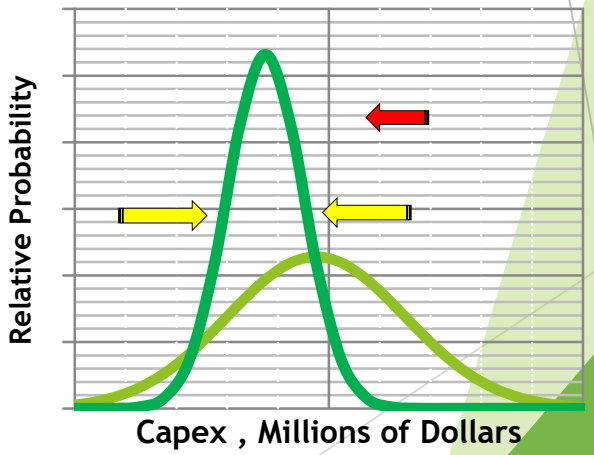


2. IEA Bioenergy Task 33 Database.

Industry Best Practice

- Technology development
- Risk management
- Value Engineering
- Engineering – Front End Loading
- Technology and site evaluation and selection
- Scaleup
- Pilot Plant design
- Design of Experiments (DoE)
- Thermochemistry and reactor modeling
- Feedstock supply & material handling





Biomass Gasification Technologies

Informal survey results: 250+ Biomass Gasifier Technology Companies

- General Categories and Features:
  - Dual Fluidized Bed (DFB)
  - Circulating Fluidized Bed (CFB)
  - Bubbling Fluidized Bed (BFB)
  - Entrained Flow (EF)
  - Moving/Fixed Bed: Updraft, Crossdraft and Downdraft
  - Cyclonic
  - Plasma
  - Indirectly Heated
  - Electric Arc
  - Molten metal
- Induction Heated
- Stoker/Fixed Grate
- Rotary Drum
- Air/Enriched Air/Oxygen/Steam Blown
- Slagging/non-slagging
- Bubbling/Turbulent/Fast/Circulating/Spouted Fluid Bed
- Low Pressure / High Pressure
- Low Temperature/ High Temperature
- Feed Pretreatment / Gas Cleanup Requirements

Biomass Gasification Technology Selection

Technology Screening:

- Project Scale
- Project Location
- Feedstock(s)
- End Product(s)
- Technology Readiness Level (TRL)
- Commercial

Number of Potential Technologies reduced from 250+ to a few, based on only a few simple criteria

Technology Evaluation:

- Technoeconomic Analysis (TEA)
- Environmental incl. LCA and waste management
- Reliability/Availability
- Hazard & Risk Analysis
- Technical & Commercial Due Diligence
- Pilot/Demo testing

Gasification technology selection, if done right, has a positive impact on subsequent project activities (e.g. engineering & construction) and will improve overall project outcomes

Technology Selection

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Technology Screening - Project Scale

- Fundamental (single train) scale limitations for a gasification technology.
- Practical (single train) scale limitations for a gasification technology, including vessel fabrication costs and transportation size limitations.
- Scaleup limitations for a piloted/demonstrated gasification technology.
- A large number of (identical) gasification trains, is usually not going to be an economic alternative.

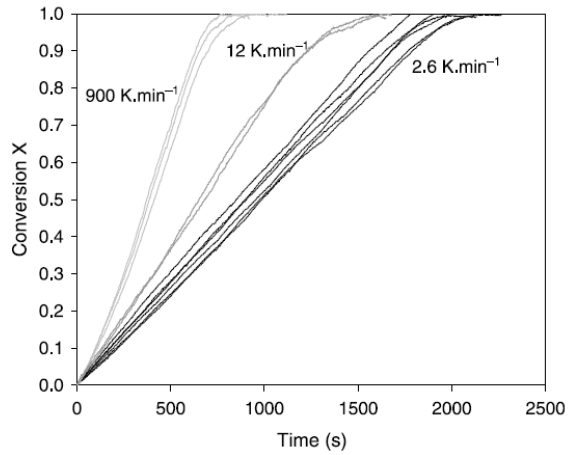
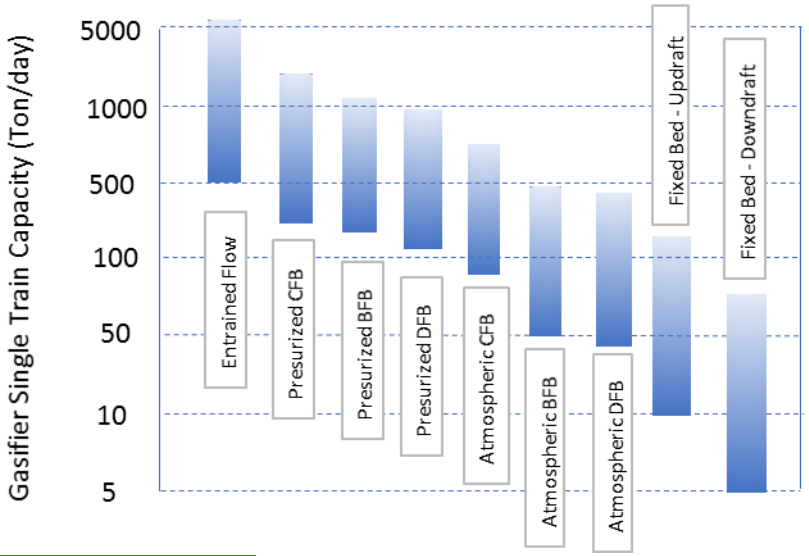


Fig. 6. Gasification progress under 20% H_2O at 1200 K of charcoal particles pyrolysed at 2.6, 12 and 900 K min^{-1}.

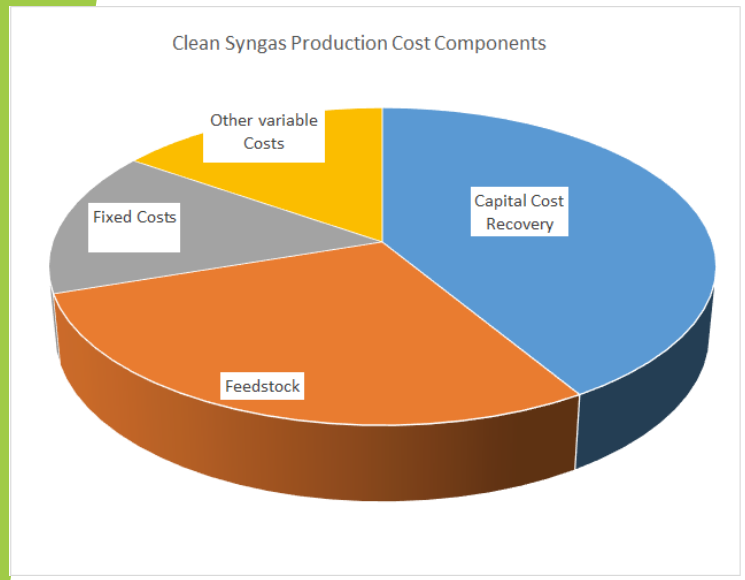


http://www.alternrg.com/waste_to_energy/projects/

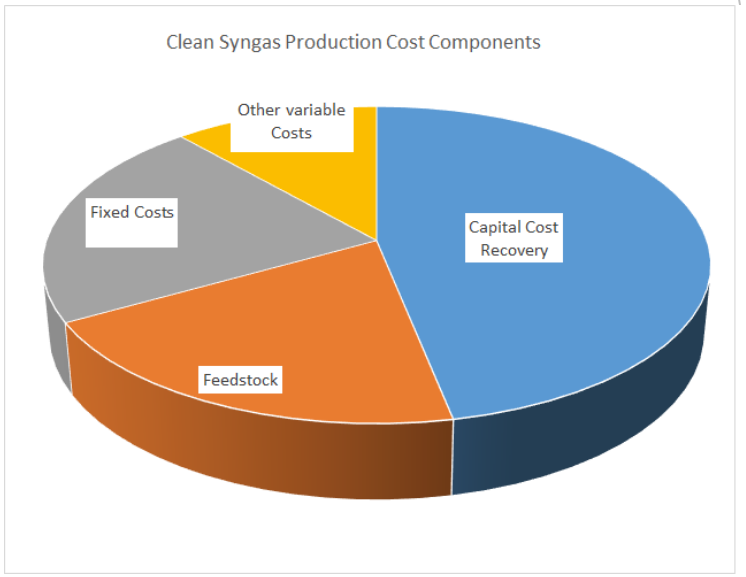
Influence of the pyrolysis heating rate on the steam gasification rate of large wood char particles
F. Mermoud a,*, S. Salvador b, L. Van de Steene a, F. Golfier c

Technology Screening - Project Scale

- Typical “economies of scale” (e.g. cost of oxygen ($/ton) versus O_2 plant size (tons/day)).



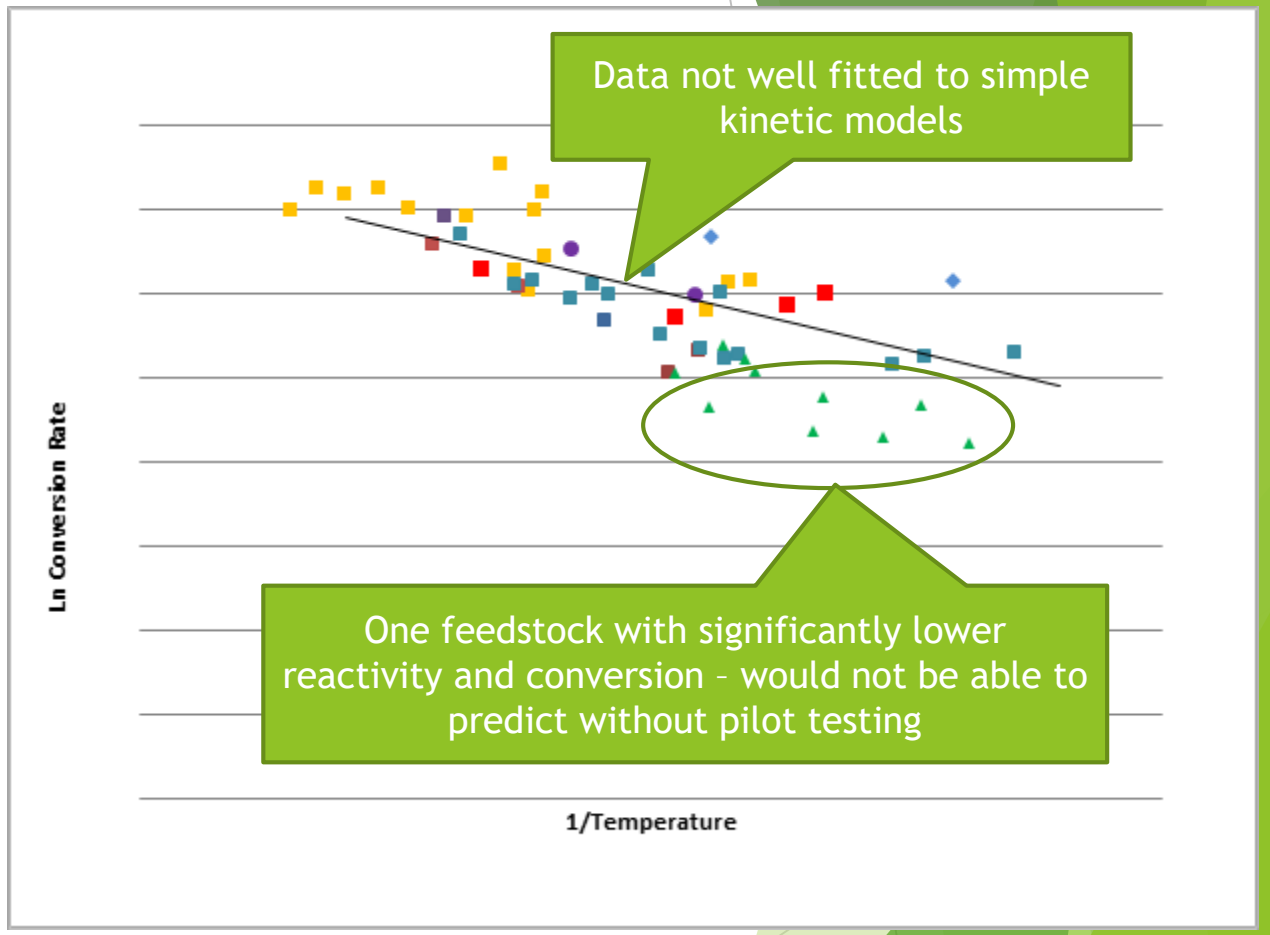
Smaller Scale



- Increased emphasis on capital costs and fixed costs (labor) for smaller plants generally results in simpler feed handling & processing equipment and less feedstock flexibility.
- For smaller projects the costs of “one-off” engineering and FOAK engineering development can be prohibitive, so look for “off-the-shelf” (modular) solutions with minimal custom engineering.

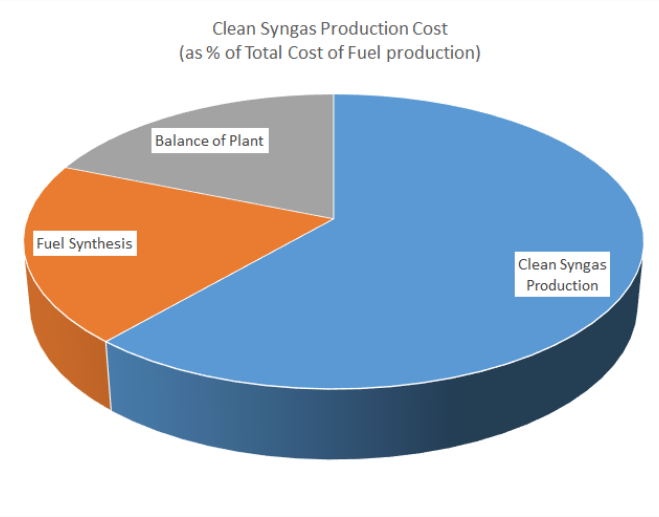
Technology Screening - Feedstock

- Compare gasifier feed requirements with available (as delivered) biomass quality with and without feedstock processing.
- Biomass gasification is inherently complex and not well suited to extrapolation outside of the envelope of previous experience. What feedstocks have previously been gasified, for how long and what was the performance and operating experience?
- New feedstocks need to be run on a pilot or demonstration unit for a suitable length of time. What facilities are available, what will it cost to run the necessary tests and how will that impact the project schedule?
- Early feedstock sampling and analysis, including contaminants, trace elements and potential feedstock variability is always warranted.



Technology Screening - End product(s)

- Match gasifier composition (after cleanup) with downstream synthesis or end use quality requirements.
- Gas cleanup costs are significant. Need to compare cost of supplying cleaned, on spec, synthesis gas on a equivalent basis (e.g. $/'000 SCF H_2+CO contained in syngas).
- High pressure end-use for syngas doesn't necessarily mean high pressure gasification technologies are preferred.



Syngas Use	Syngas Production Costs
Fuel/Chemical Synthesis	$/'000 SCF ($H_2$+CO) contained in syngas
Biomass-to-Heat and/or Power	$/MMBtu contained in syngas
Renewable Nat Gas	$/'000 SCF ($H_2$+CO+4x$CH_4$) contained in syngas

Technology Screening – Technology Readiness

- Evaluation of Technology Readiness Level (TRL)

TRL Level	DOE Definition
9	Actual system operated over the full range of expected conditions
8	Actual system completed and qualified through test and demonstration
7	Full-scale, similar (prototypical) system demonstrated in relevant environment
6	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment
5	Laboratory scale, similar system validation in relevant environment
4	Component and/or system validation in laboratory environment
3	Analytical and experimental critical function and/or characteristic proof of concept
2	Technology concept and/or application formulated
1	Basic principles observed and reported

Technology Screening – Location & Commercial

Note: For early stage project development, it may not be possible to obtain the following information definitively, but gather what qualitative information you can:

- License fees, royalties and fees incl. cost of Process Design Package and timing.
- Proprietary equipment or consumables purchases. Location of approved fabricators or suppliers?
- Intellectual property (IP) protections and/or license restrictions or exclusivity at project location.
- Process guarantees typically provided.
- If applicable, how to share First-of-a-Kind (FOAK) risks?
- Existing (regional) relationships or partnerships between the gasifier supplier and engineering and construction companies that operate in the region.

Gasifier Technology Screening (Examples)

Large Scale (5000 BPSD) Woody Biomass to Liquids (BtL) Plant:

- High pressure gasifier
- High specific O_2 consumption
- Entrained flow or high pressure oxygen blown fluidized bed gasifier
- Extensive biomass pretreatment (e.g. torrefaction, pyrolysis, pelletization, etc)
- Centralized BtL plant and distributed biomass collection & pretreatment

Medium Scale (5 MMSCFD) Woody Biomass to Renewable Natural Gas (RNG) Plant:

- Low to Medium pressure gasifier
- Nil to medium specific O_2 consumption
- Dual Fluidized Bed or low/medium pressure steam/oxygen blown fluidized bed gasifier
- Minimal biomass pretreatment (typically drying & size reduction)
- Co-located pretreatment & gasifier plant

Technology Evaluation

Take the technology selections that successfully made it through the screening process and apply the following analyses:

- Technoeconomic Analysis (TEA)
- Environmental incl. LCA and waste management review
- Reliability/Availability
- Hazard & Risk Analysis
- Technical & Commercial Due Diligence
- Pilot/Demo testing (if required)

Technology Selection

Common Gasification Technical Challenges

Pro-actively manage the inherent (technical) risks and challenges associated with biomass gasification:

- Biomass feedstock non-homogeneity
- Biomass Tars
- Fouling & alkali deposition
- Ash agglomeration and slagging
- Solid fuel feeding
- Syngas impurities and downstream impacts
- Air, water & solid emissions and byproducts
- Refractory and metal erosion & chemical attack
- Transient syngas quality and flow
- Reliability & availability
- High specific capital and operating costs and need for scalable designs, modularization, automation and design standardization.
- Efficiency losses at small/medium scale.
- High parasitic power demand and water usage.

Other Biomass Gasification & Bioenergy Project Challenges

Just like the technical risks, the common gasification related project and commercial risks should be identified and managed Pro-actively:

- Feedstock(s) sustainable supply volumes, long term contracts, data availability, accessibility, competition, quality, seasonality, collection, transportation and delivered costs.
- Low forecast natural gas and oil prices.
- Competition from other renewables including solar, wind and biogas.
- Product market access barriers and uncertainty.
- Project risk due to lack of commercial deployment and non-standardized first-of-a-kind(FOAK) plant designs.
- Regulatory/policy uncertainty, risks and barriers.
- Project financing barriers and costs
- Burdensome permitting and project approvals for small and medium scale projects.

Biomass Gasification Opportunities

<u>But, with risk comes significant opportunity:</u>

- Large scale of the potential (future) market, especially for transportation fuels (jet/diesel/RNG), renewable chemicals and industrial applications.
- Potential to utilize plentiful low cost feedstocks such as MSW and other industrial, forestry and agricultural wastes and residues.
- Increasing number of semi-commercial (demonstration) and commercial plants and subsequent technology licensing options.
- Revenue generation from byproduct sales (e.g. biochar and waste heat).
- Geographic “hot spots” with favorable feedstock supply, markets and policies.
- Remains to be seen where bioenergy regulatory supports, economic supports and carbon pricing trend. In specific geographies trends seem hopeful (e.g. Canadian Federal & Provincial carbon pricing).

Biomass Gasification Outlook

- Current period of increased project activity. Will it be sustained?
- Multiple near-commercial or commercial biomass gasification technologies available.
- Rigorous accepted industry practices, including technology and project selection required. Use technology screening to narrow the technology field initially.
- Need to identify common technical problems, manage risks appropriately and not remake the mistakes of the past.
- Although there are significant challenges, opportunities do exist in specific geographic locations and product markets.
- Very large market opportunity IF technologies can get over FOAK, technical & financial hurdles.

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