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Pre-Solicitation Workshop on Implementation Strategies for Production of Renewable Hydrogen in California

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Company Profile

- West Biofuels, LLC formed in 2007
- Primary Endeavors:
  - Commercialization of Gasification Systems
  - R&D Advancement for Syngas to Biofuels Conversion Technologies
- Strategic Technology Partnerships
  - UC Davis (US), UC San Diego (US)
  - Vienna University of Technology (AT), Paul Scherrer Institute (CH)
  - Bioenergy 2020+ (AT), INSER (IT), Albemarle (US)

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Feedstock

- Cellulosic Biomass
  - Forest Sourced Wood Residue
  - Agricultural Tree Removal & Pruning
  - Walnut Shell
  - Almond Shell
  - Cotton Stalk
  - Urban Construction & Demolition Wood

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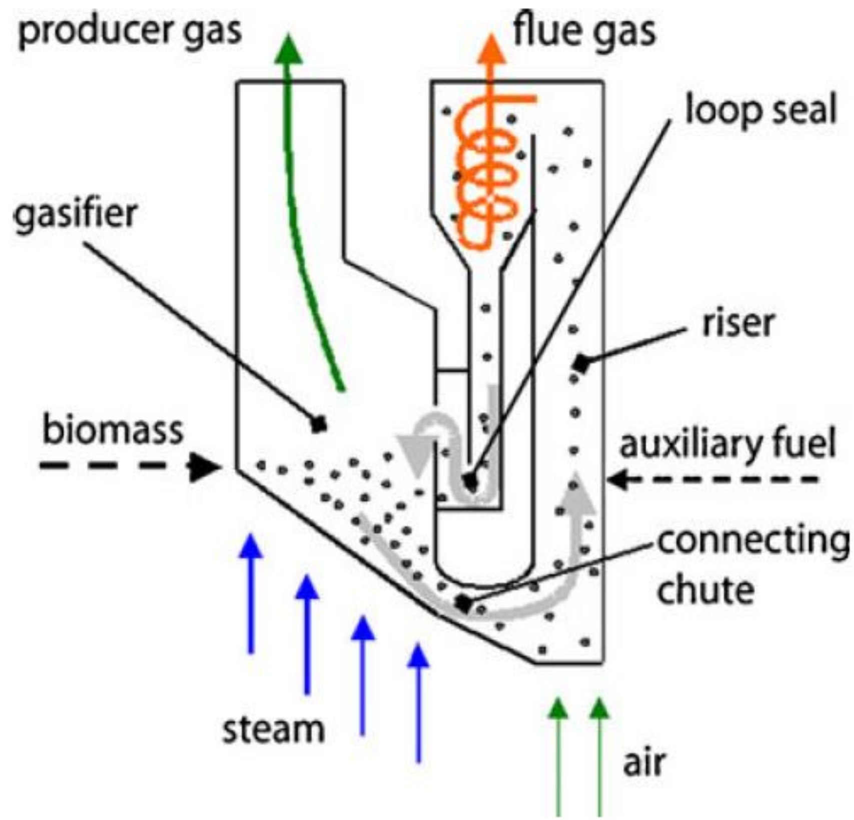
Technology Overview



Fast Internally Circulating Fluidized Bed (FICFB)
Gasification System at West Biofuels

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Technology Overview

Location	Usage / Product	Fuel / Product MW, MW	Start up	Status
Güssing, Austria	Gas engine	8.0_{fuel} / 2.0_{el}	2002	Operational
Oberwart, Austria	Gas engine/ ORC	8.5_{fuel} / 2.8_{el}	2008	Operational
Villach, Austria	Gas engine	15_{fuel} / 3.7_{el}	2010	Operational
Senden/Ulm, Germany	Gas engine/ ORC	14_{fuel} / 5_{el}	2012	Operational
Göteborg, Sweden	BioSNG	32_{fuel}/20_{BioSNG}	2013	Commissioning
Klagenfurt, Austria	Gas engine, BioSNG	25_{fuel} / 5.5_{el}	2016	Hold
Vienna, OMV Austria	Hydrogen	50_{fuel}/$30_{hydrogen}$	2016	Hold

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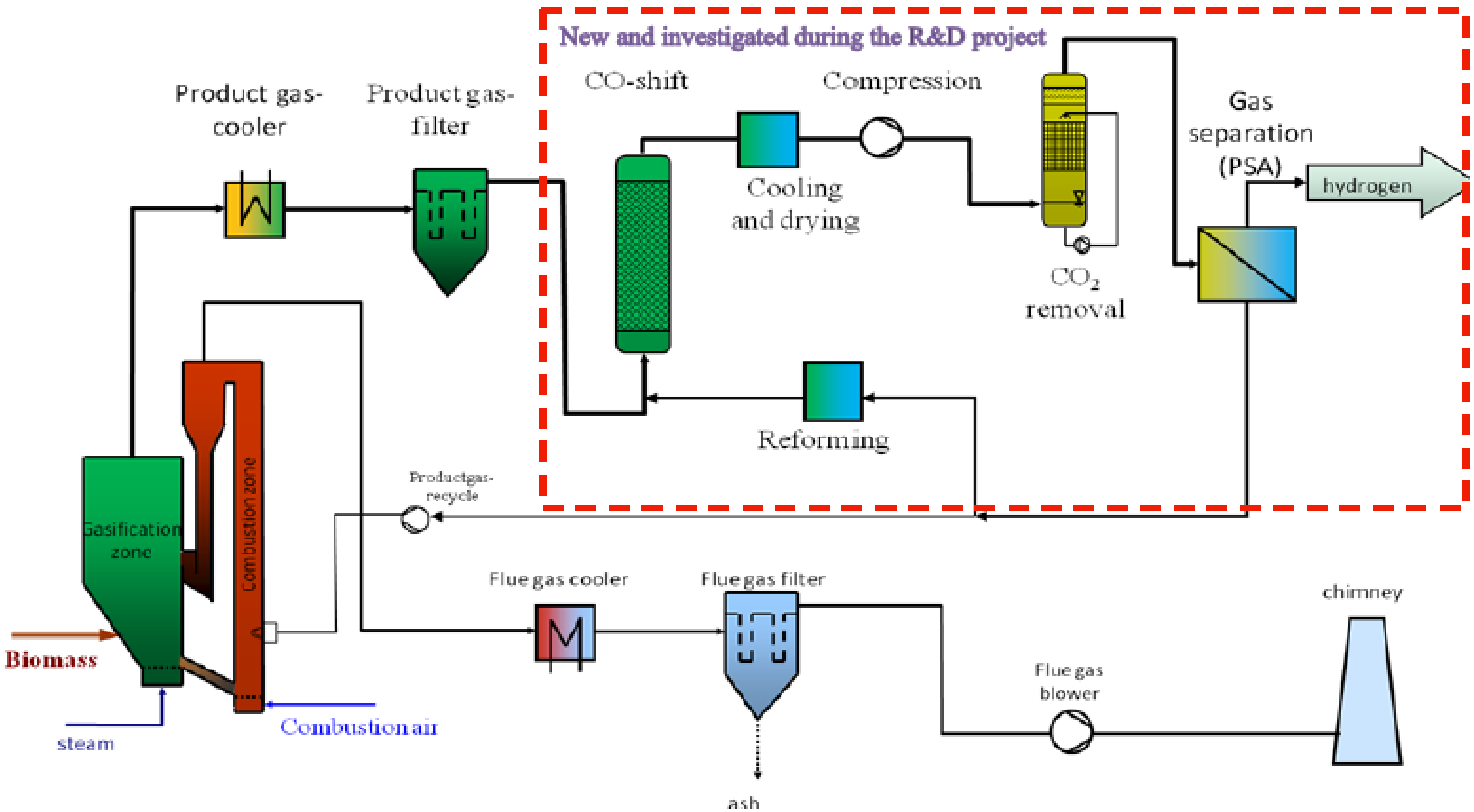
Hydrogen from Syngas

The most common approach:

- Step 1: Gasification
- Step 2: Water Gas Shift
  - $CO + H_2O$ + Catalyst → $H_2 + CO_2$ + heat
- Step 3: CO_2 Removal
- Step 4: H_2 Separation
  - Pressure Swing Adsorption (PSA)
- Step 5: Steam Reforming & Syngas Recycling
  - Convert high-hydrocarbon tail gas from PSA to CO, CO_2, H_2 for recycle into the water-gas shift reactor
  - Or send tail gas to onsite power generator

bioenergy2020+

Plant description



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Hydrogen from Syngas

- Step 1: Gasification
- Step 2: Water Gas Shift

Table I: Syngas composition after dust removal (wf) [5]

Component	Range	Dimension
hydrogen	35-45	Vol-%
carbon monoxide	20-30	Vol-%
carbon dioxide	15-25	Vol-%
methane	8-12	Vol-%
nitrogen	1-3	Vol-%
tar	2-5	g/Nm^3
hydrogen sulphide	150-300	ppm
H_2O	40-60	Vol-%

Table IV: composition of the syngas after the water gas shift

Component	composition [vol-%]	
hydrogen	47.35	± 2.53
carbon monoxide	6.16	± 2.07
carbon dioxide	32.17	± 2.41
methane	8.96	± 0.80
nitrogen	2.04	± 1.15
hydrocarbons (C_2, C_3)*	3.33	± 0.72

* minor gas components (C_2H_2, C_2H_4, C_2H_6, C_3H_6, C_3H_8)

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Hydrogen from Syngas

- Step 3: CO2 Removal
- Step 4: H2 Removal

Table V: composition of the syngas after CO_2 removal

Component	composition [vol-%]	
hydrogen	66.81	± 1.12
carbon monoxide	7.44	± 0.95
carbon dioxide	4.21	± 3.18
methane	12.21	± 2.12
nitrogen	3.10	± 1.78
hydrocarbons (C_2, C_3)	6.22	± 1.93

Table VI: quality of the produced hydrogen

Component	composition	Dimension
hydrogen	99,90	Vol-%
carbon monoxide	b.d.	ppm
carbon dioxide	500	ppm
methane	b.d.	ppm
nitrogen	520	ppm
hydrocarbons (C_2, C_3)	b.d.	ppm

b.d. … below detection limit

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Hydrogen from Syngas

- Step 5: Onsite Power Generation or Steam Reforming

Table VII: composition of the PSA tail gas

Component	composition [vol-%]	
hydrogen	22.95	± 2.64
carbon monoxide	16.89	± 2.79
carbon dioxide	11.34	± 3.55
methane	26.54	± 0.69
nitrogen	13.22	± 4.41
hydrocarbons (C_2, C_3)	9.06	± 3.03

Table VIII: composition of the syngas after the steam reformer

Component	composition [vol-%]	
hydrogen	60.30	± 3.06
carbon monoxide	15.49	± 1.76
carbon dioxide	12.52	± 0.08
methane	1.84	± 1.09
nitrogen	9.85	± 2.31
hydrocarbons (C_2, C_3)	b.d.	

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Hydrogen from Syngas

- Yield:
  - 60% of feedstock energy is recovered as H2
  - Requires approximately additional electricity, equal to approximately 10% of H2 production (by energy)
- Commercial System:
  - 500 TPD Biomass Plant (~50 MW of feedstock)
    - Comparable size to a 20MW biomass boiler (e.g. DTE Woodland)
  - 460,000 Nm3/day H2 (~30 MW of energy equivalent)
  - Uses 5.2 MW of electricity to operate
  - Produces 2.4 MW of recoverable heat (e.g. district heating)

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Hydrogen from Syngas

- Financial Criteria:
  - $86 million USD capital investment for a 30MW facility (500 TPD)
    - ($2.87/W of H2 production capacity)
- Critical Economic Drivers:
  - Cost of Natural Gas
  - Cost of Biomass
  - Cost of Electricity
  - Value of CO2 Offset
  - Opportunity for Heat Recovery

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Opportunities for Improvement

- Market Improvements
  - Renewable Gas Standard
  - High value for GHG reductions/LCFS
- Technical R&D Improvements:
  - Gasifier Improvements:
    - Prove with wide variety of California feedstock
    - Cost reductions in subsystems (e.g. syngas cleaning systems)
  - Conversion Improvements:
    - Long-term catalyst testing on syngas (resiliency, regeneration)
    - System integration and optimization (don't reinvent the PSA, look for innovative ways to integrate process steps)

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Thank You

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- Select papers from our European partners, Bioenergy 2020+:

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