WESTBIOFUELS

Co-Production of Mixed Alcohols and Renewable Natural Gas from Forest Biomass

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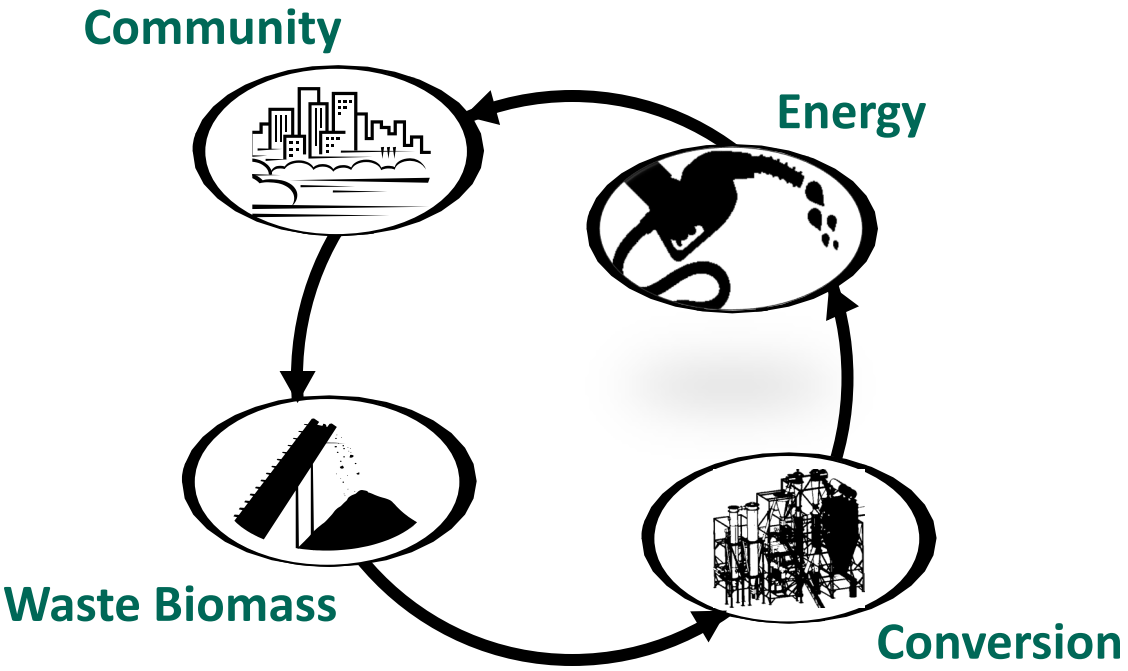
West Biofuels Mission

To reinvent energy production in ways that help us become energy independent, lower our carbon footprint, create local green jobs and foster economic growth.



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Who we are at West Biofuels, LLC

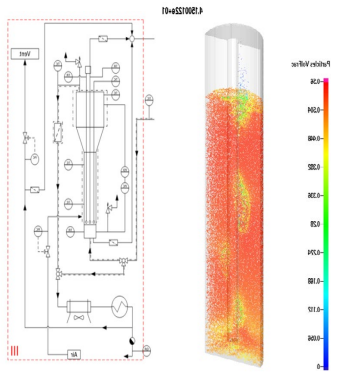
- Technology developer and EPC for thermochemical biomass systems since 2007
- Construction and operation of commercial community-scale bioenergy facilities
- Low-carbon renewable pathways with diesel, aviation fuels, alcohols, renewable natural gas, biomass-based hydrogen, and biocarbon products
- Collaborations with public/private and national/international partners
- Gasification company at heart.

Biomass to Power

Biomass to Fuels and Chemicals

Diesel & aviation fuels

Alcohols



RNG &H2

Biocarbon Products

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Introduction – Mixed Alcohols and Renewable Natural Gas Project (MARG)

Motivation:

- Reducing greenhouse gas emissions to meet CA/US climate goals.
- Utilize existing natural gas infrastructure with renewable alternatives.
- Leveraging biomass resources to reduce reliance on fossil fuels.
- Reduce impacts of devastating forest fires and open burning.

Summary of Presentation:

- Introduction of MARG project
- Project Goals
- Project Team
- Overview of the Dual Fluidized Bed Gasifier and Bio-syngas Results
- Overview of the Mixed Alcohol Synthesis System and Results
- Overview of Renewable Natural Gas (RNG) Purification System
- Conclusions and Future Work

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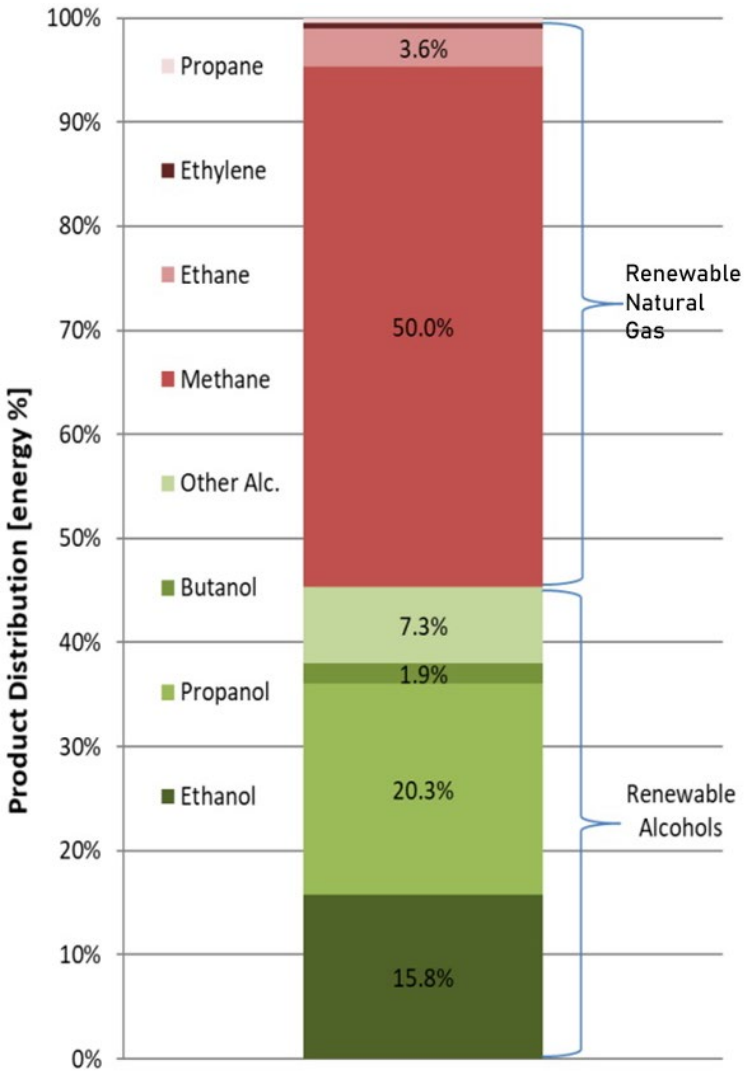
Project Goals

- Convert woody biomass residue to a multiple products including mixed alcohols and pipeline quality renewable natural gas (RNG)
- Develop and validate the integrated process steps demonstrating the production of gas grid-quality RNG



(Source: West Biofuels/UCSD)

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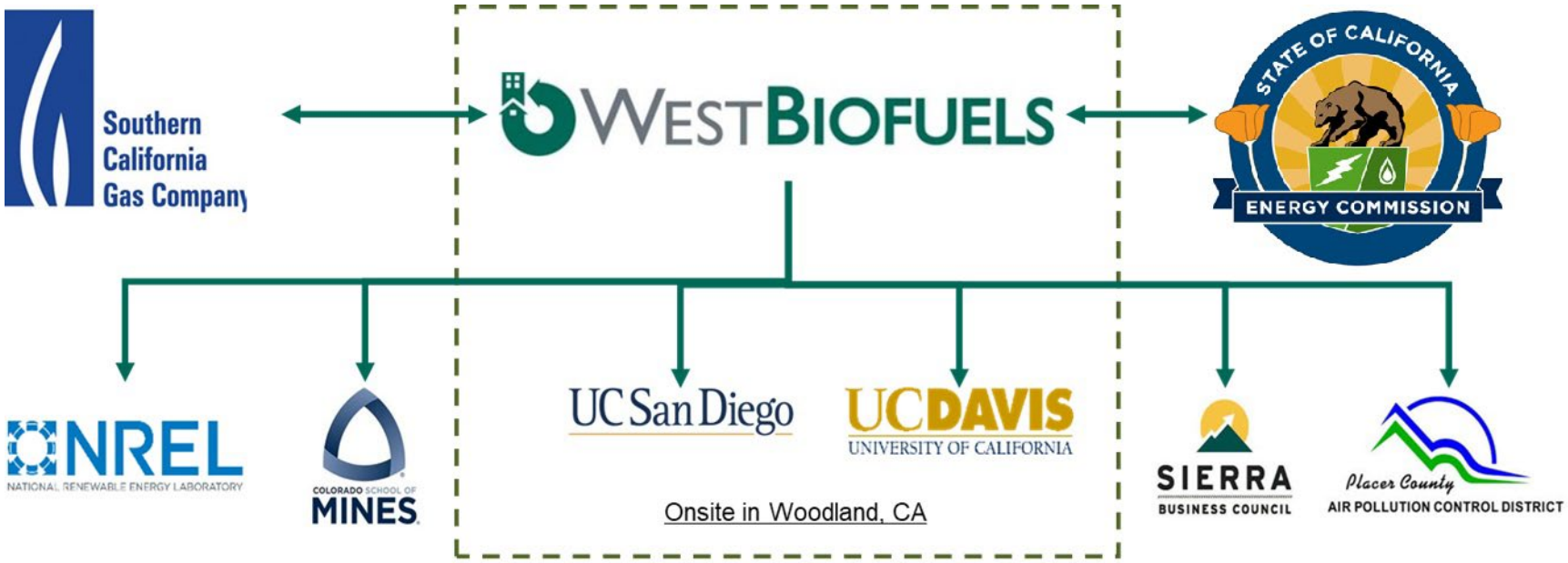
Project Team



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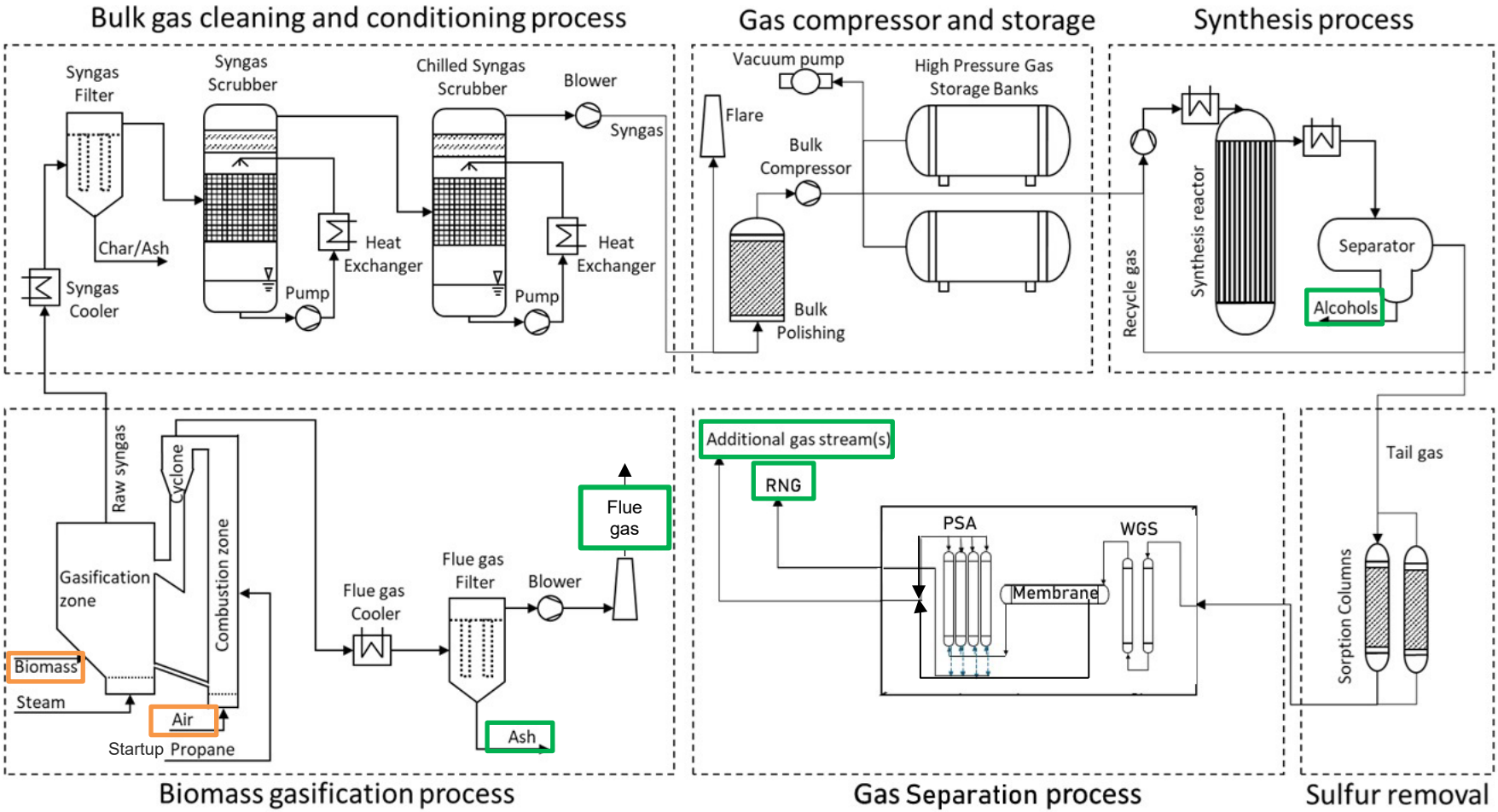
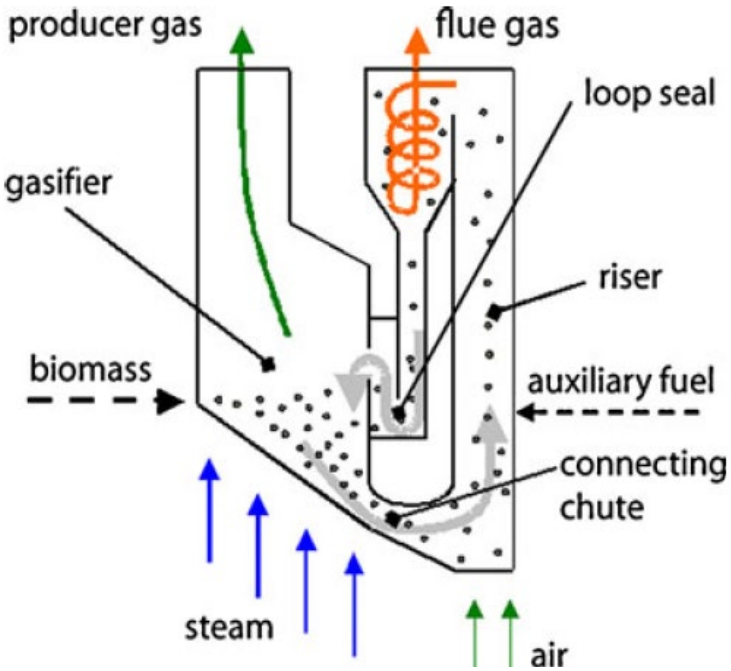
Process Flow Diagram of the MARG Process



Fast Internally Circulating Fluidized Bed (FICFB) -Biomass Gasifier System

1MWth, 5 tons of dry biomass per day



Syngas Composition, %	
H2	35-45
CO	22-25
CH4	~10
CO2	20-25
C2H4	2-3
C2H6	~0.5
C3H4	~0.4
O2	< 0.1
N2	1-3

Potential Poison	Concentration	Unit
H2S	~200	mgS/Nm³
COS	~5	mgS/Nm³
Mercaptans	~30	mgS/Nm³
Thiophens	~7	mgS/Nm³
HCl	~3	ppm
NH3	500-1000	ppm
HCN	~100	ppm
Dust	< 20	mg/Nm³

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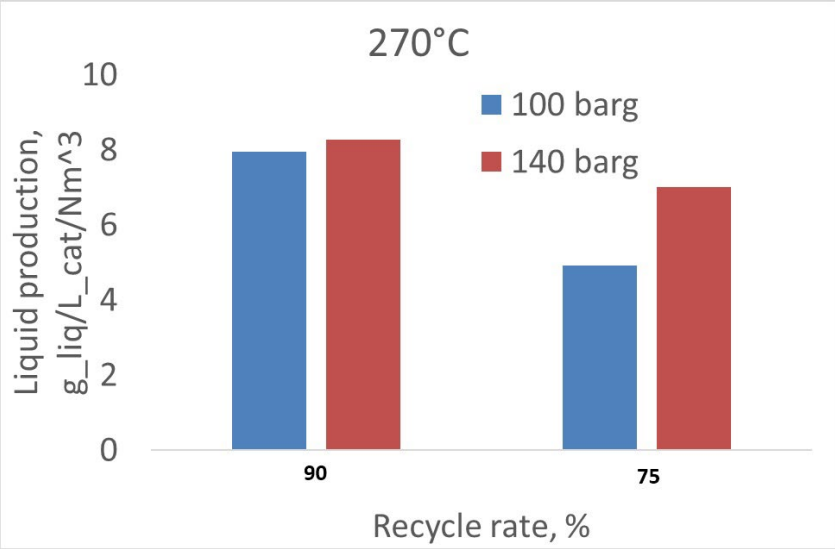
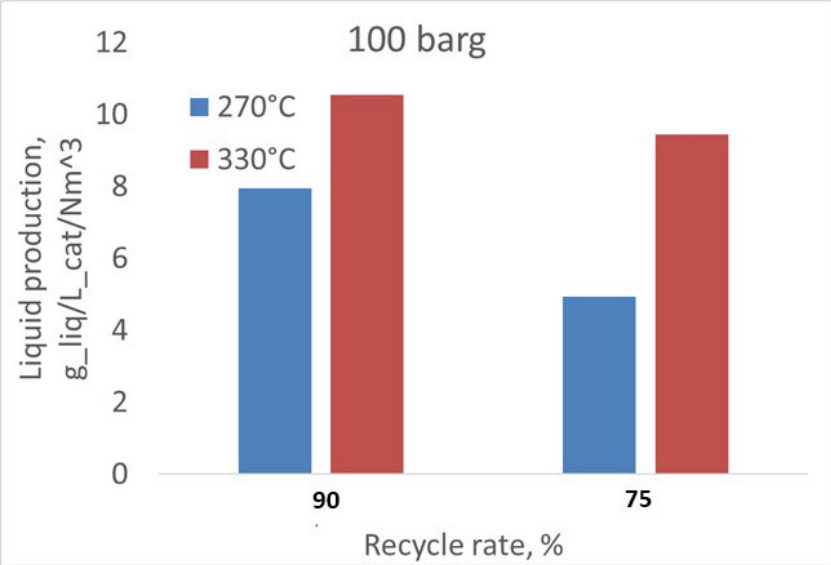
Mixed Alcohol Synthesis (MAS) System





Tailgas composition	
H2	17-30%
N2	2-5%
CH4	14-18%
CO	16-32%
CO2	16-30%
C2H4	0-1%
C2H6	0-1%

Alcohol types	Composition range, %
1-propanol	20-35
Methanol	20-30
Ethanol	10-25
IPA	0.4-14
n-butanol	0.9-4.1
n-pentanol	0-1.3
n-hexanol	0-0.2

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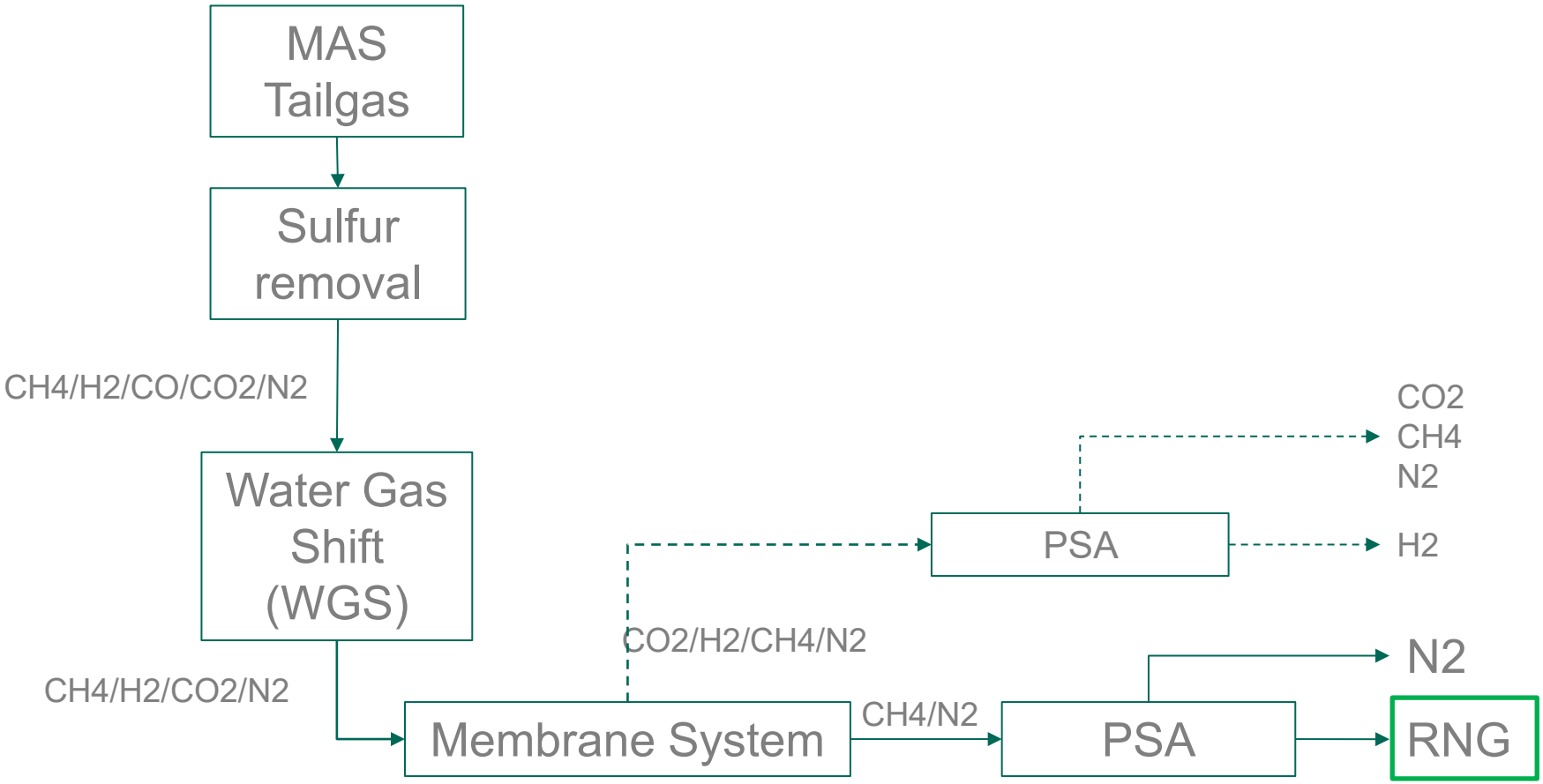
RNG Purification System



PSA = Pressure Swing Adsorption

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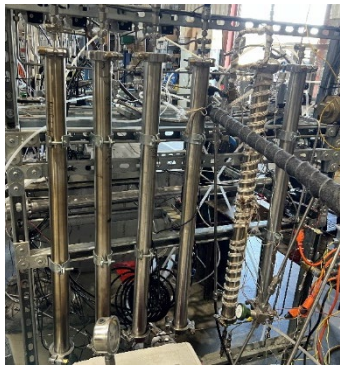
Develop Integrated Gas Separation System



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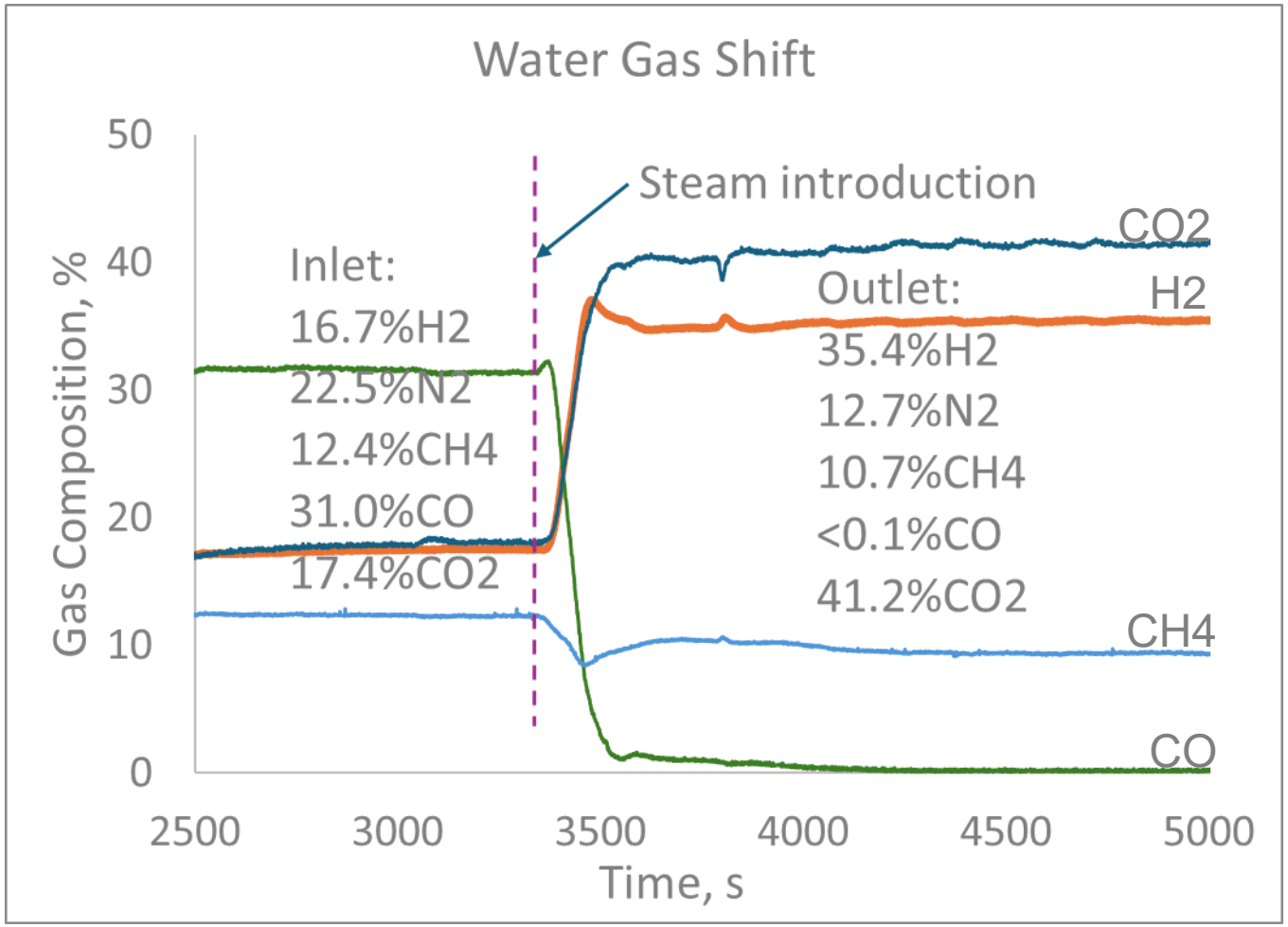
Gas Separation Results – Water Gas Shift



After WGS, nearly all of the carbon monoxide (CO) was removed, leaving less than 0.1% CO in the tail gas.

$$CO + H_2O \leftrightarrow H_2 + CO_2$$

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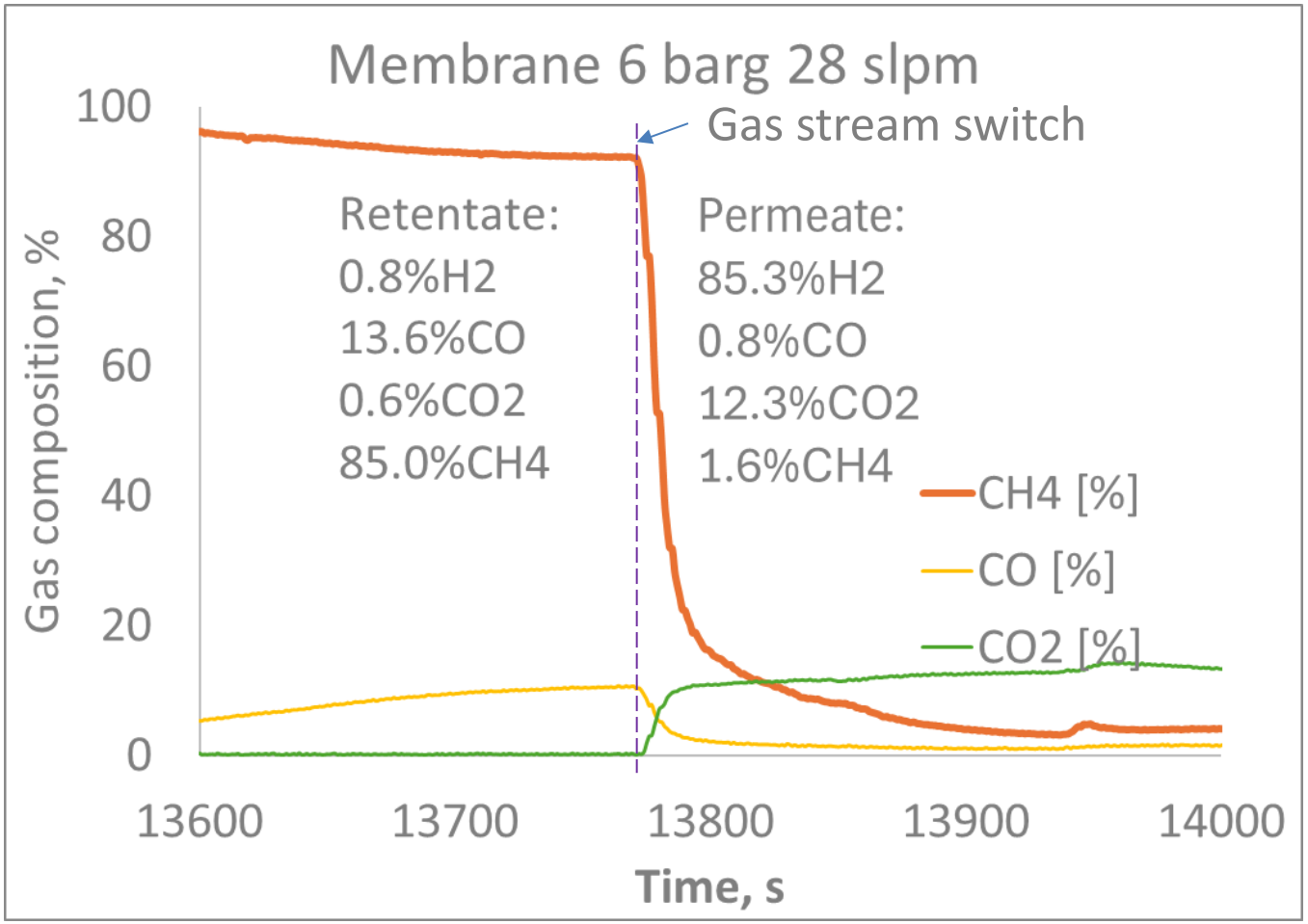
Gas Separation Results – Membrane



Feed gas composition:80.9%H2, 6%CH4,1.4%CO, 11.7%CO2

CH4 was enriched in retentate stream.

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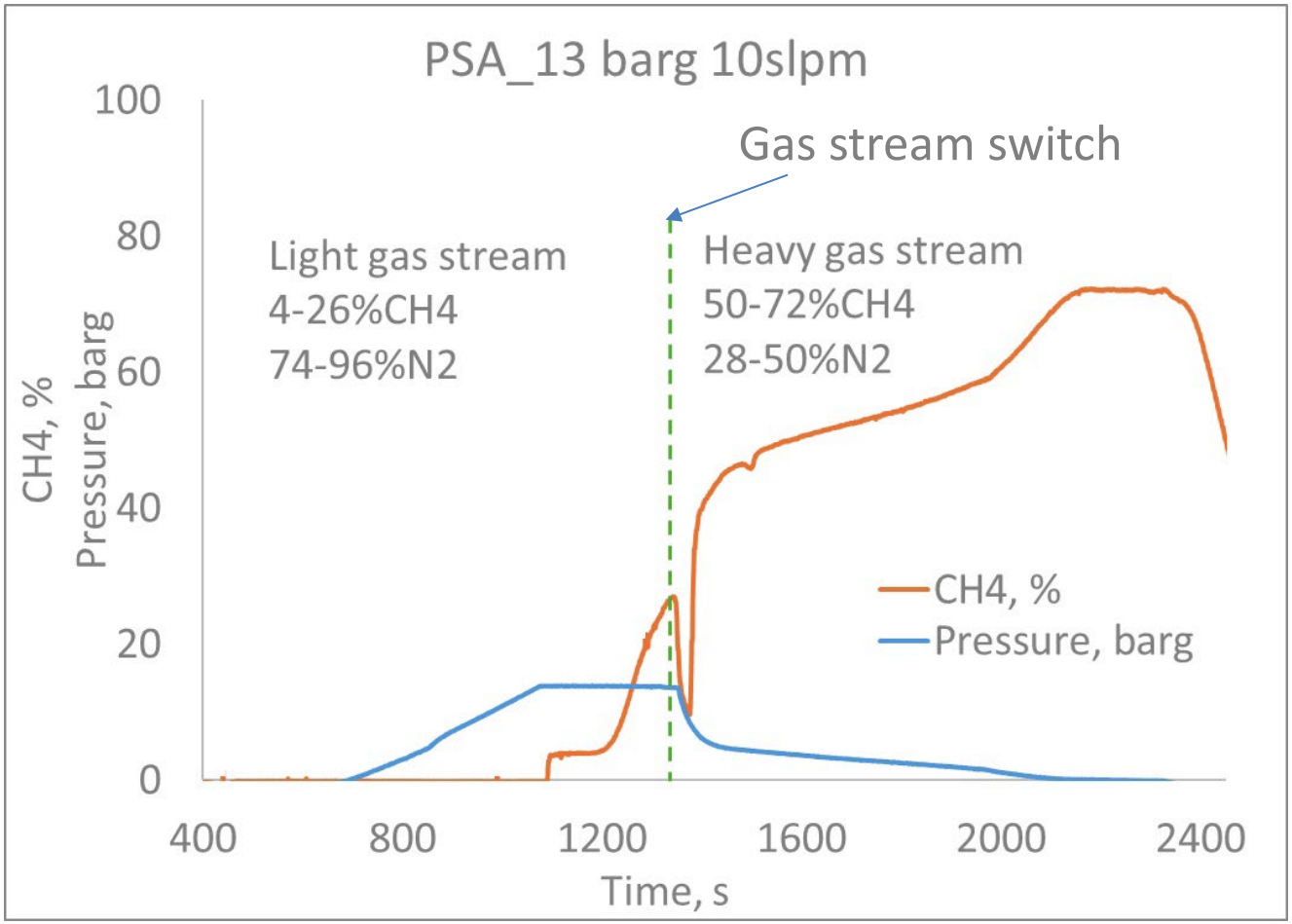
Gas Separation Results – Pressure Swing Adsorption



Feeding gas was comprised of 70% N2 & 30% CH4.
After PSA, CH4 was enriched to 70% in the heavy gas stream.

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Conclusions

- Alcohol production is achieved by converting compressed syngas into mixed alcohols using a catalytic MAS reactor.
- The methane content in the tail gas of the MAS system has increased from ~10% to 14-18%.
- CO levels were reduced to <0.1% after the WGS process.
- Membrane system could achieve nearly complete separation of H2 and CO2 from the tail gas.
- PSA loaded with a specialized activated carbon could enrich CH4 in a mixture of CH4 and N2.

Future Work

- Integrate and tune the gas purification process steps.
- Use the gas purification system to produce pipeline quality renewable natural gas from the MAS tail gas.
- Identify the optimal parameters for maximizing CH4 recovery rates.
- Conduct LCA and TEA analyses for the final system configuration.

Task Level Acknowledgements

Task	Lead	Primary Support
1: General Project Tasks	West Biofuels	
2: Parameter Testing and Optimization	UCSD,CSMs	WB, UC Davis, NREL
3: Design and Construct Integrated Pilot System	West Biofuels	UCSD, NREL, CSMs
4: Test Pilot System	West Biofuels	UCSD, UC Davis
5: Long-term Pilot Testing	West Biofuels	UCSD, UC Davis, NREL, CSMs
6: Renewable Gas Testing	West Biofuels	UCSD, SoCalGas
7: Evaluation of Project Benefits	West Biofuels	Placer County APCD
8: Technology/Knowledge Transfer Activities	West Biofuels	Grant Farm / Momentum
9: Production Readiness Plan	NREL	Sierra Business Council, WB

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THANK YOU!

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