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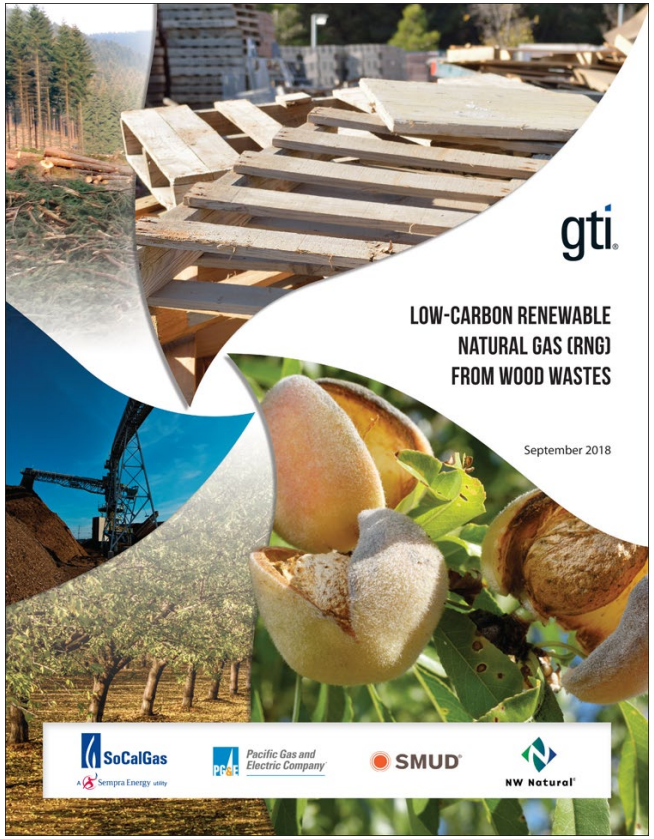
Low Carbon Renewable Natural Gas (RNG) from Wood Wastes

Context and Site Specific Engineering Design Study



What is Renewable Natural Gas (RNG)?

- RNG from Biogas: decomposition gases processed to remove carbon dioxide and other trace constituents, resulting gas is typically >90% methane
  - From anaerobic digesters
    - Animal manure (dairy cows, swine)
    - Waste water treatment facilities
    - Food processing plants
  - From landfills

Wood residue

- **RNG from Syngas: produced from thermochemical processes like gasification utilizing renewable feedstocks including forest residues and agricultural wastes**

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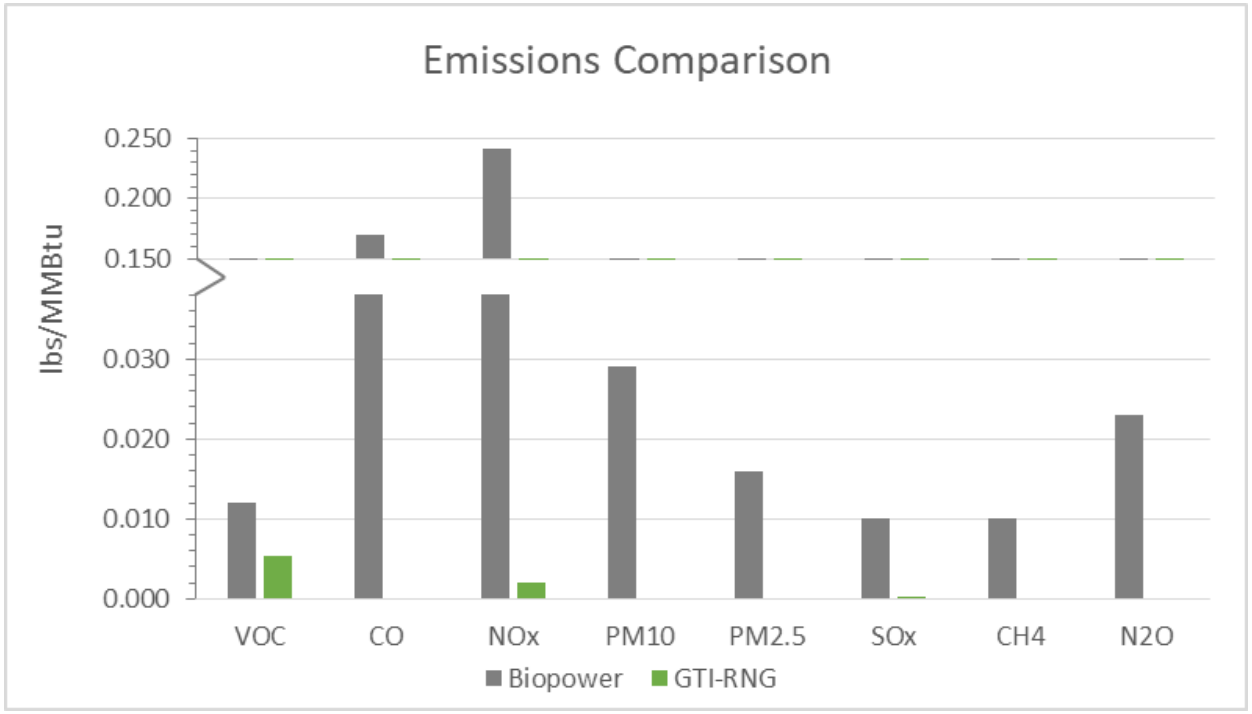
Benefits of RNG

- Decarbonization (pipelines, transportation, power generation)
- Reduction in GHG emissions
- Improved air quality
- Diversity in energy supply
- Highly efficient use of waste biomass



Source of biopower data: Assessment of the Emissions and Energy Impacts of Biomass and Biogas Use in California, January 14, 2015

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Project Description

Drivers

- **Biomass power plants** that process wood wastes to produce electricity **continue to close**, there is now more wood wastes in California than places to have it processed, thus, leading to open burning of agricultural wastes in the San Joaquin valley and rampant forest fires throughout the State every year.
- **Aggressive mandates for GHG emission reductions** in all energy sectors is creating an expanded need for low- and zero-carbon fuel for transportation as well as for residential, commercial and industrial energy consumers

The Project

- The Low Carbon RNG from Wood Wastes Engineering Design Study leveraged millions of dollars of previous pilot-scale testing funded by GTI, UPM, Andritz, USDOE, Haldor Topsoe, Pall Corporation, and design work sponsored by European Commission and E.ON.
- RNG technology team members are experts in gasification, gas clean-up, and conversion technologies. RNG technology suite is commercially available, with performance guarantees.
- The goal of the site-specific engineering design (Stockton Biomass Power Plant) is to lead to the building of a commercial facility.

***Funders**:*
SoCalGas
PG&E
Northwest Natural
SMUD
CARB

Partners:
Black & Veatch
ANDRITZ
Haldor Topsoe
DTE Energy Services

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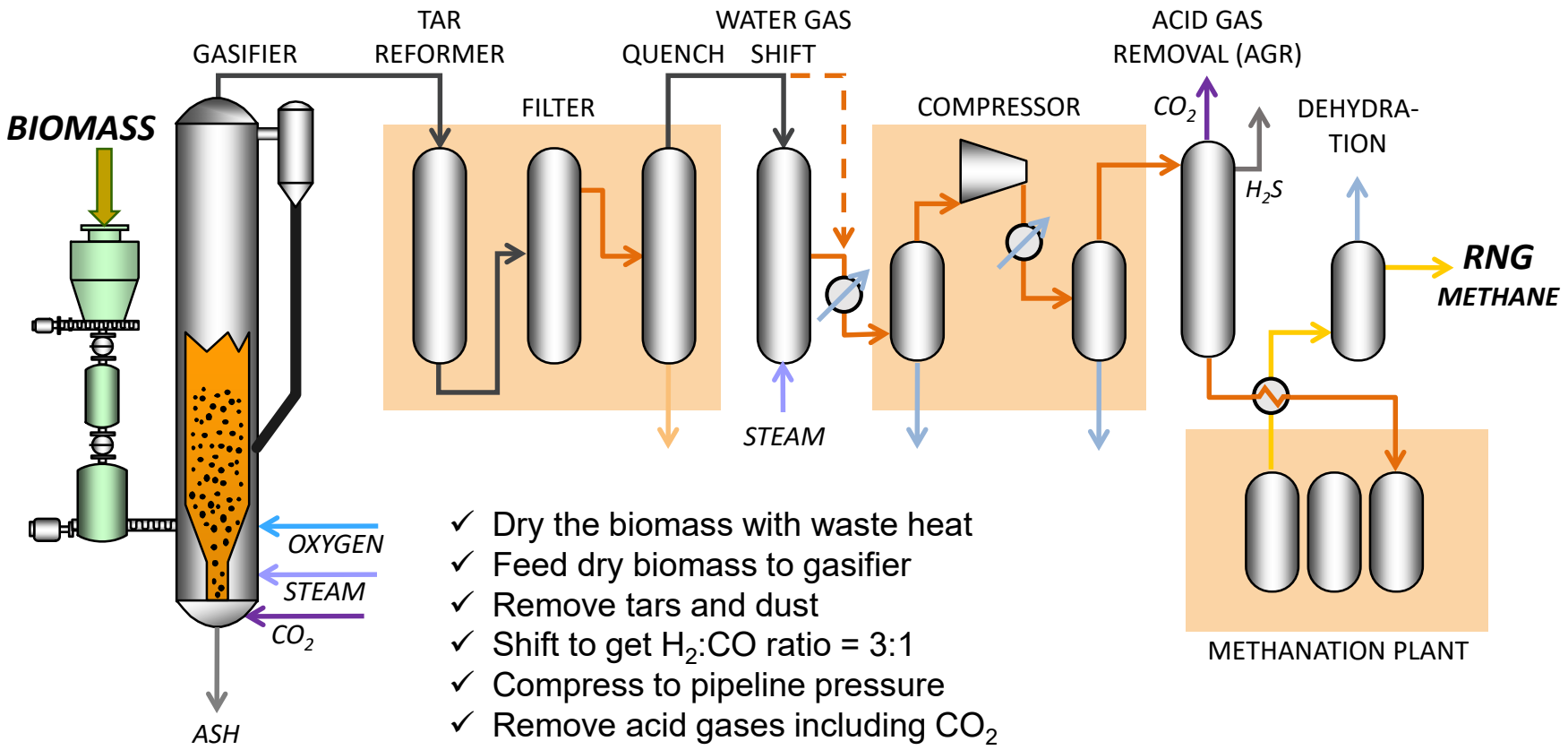
The RNG Production Process



- ✓ Dry the biomass with waste heat
- ✓ Feed dry biomass to gasifier
- ✓ Remove tars and dust
- ✓ Shift to get H_2:CO ratio = 3:1
- ✓ Compress to pipeline pressure
- ✓ Remove acid gases including CO_2
- ✓ Convert syngas to methane
- ✓ Remove remaining moisture

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GTI created a subsidiary SunGas Renewables in 2019 to deploy near-zero or below-zero carbon intensity (CI) pipeline-ready RNG plants based on commercially-proven hardware.

Site Specific FEL-2 Engineering Study (Stockton, CA)

- Rationale for choosing this Biomass Power Facility as a host site:
  - Wood biomass supply access (contracts in place)
  - Existing fuel processing and handling
  - Transportation (rail and road) and water access
  - Re-use some existing systems for RNG production facility (Cooling tower, demin water, instrument air, fire water, biomass handling, electrical distribution, plant control system)
  - Integrate with existing biomass power plant to reduce deployment costs

    >Feedstock handling
    >Thermal integration
    >Utilities
    >O&M expertise

DTE Energy, Stockton, CA

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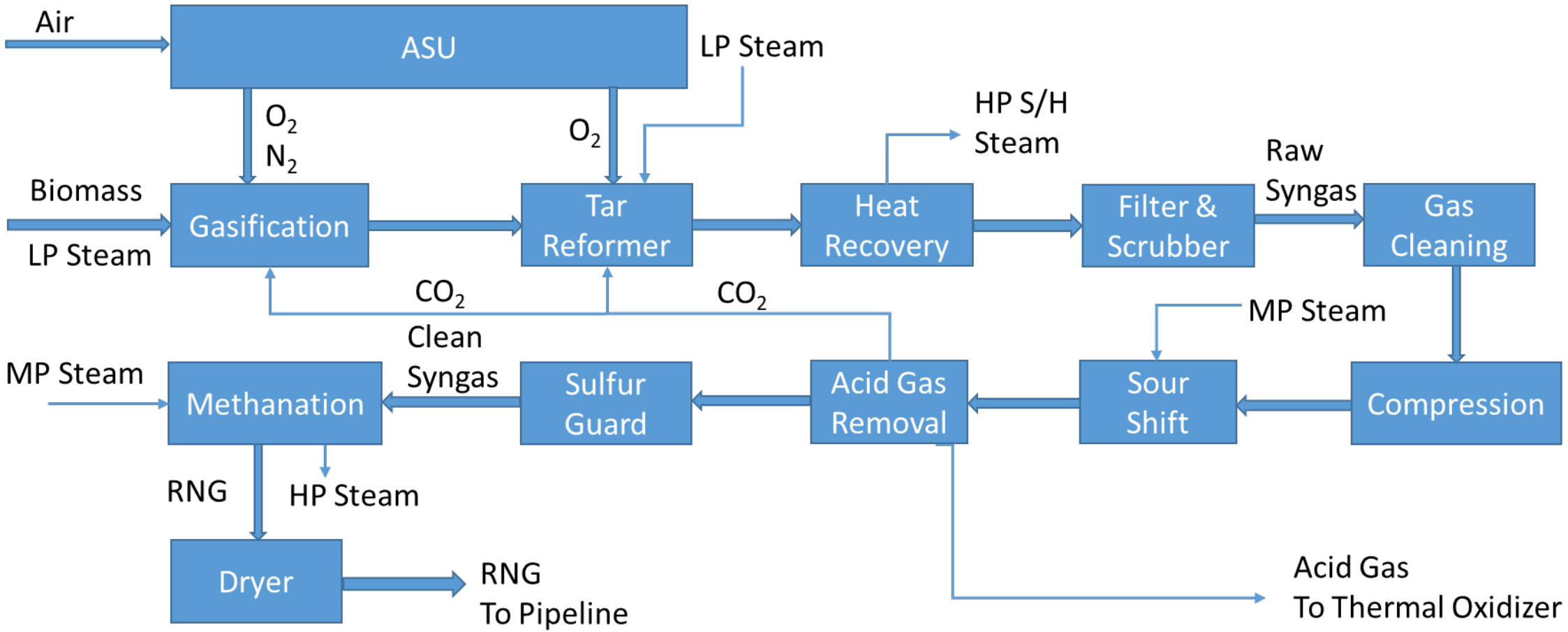
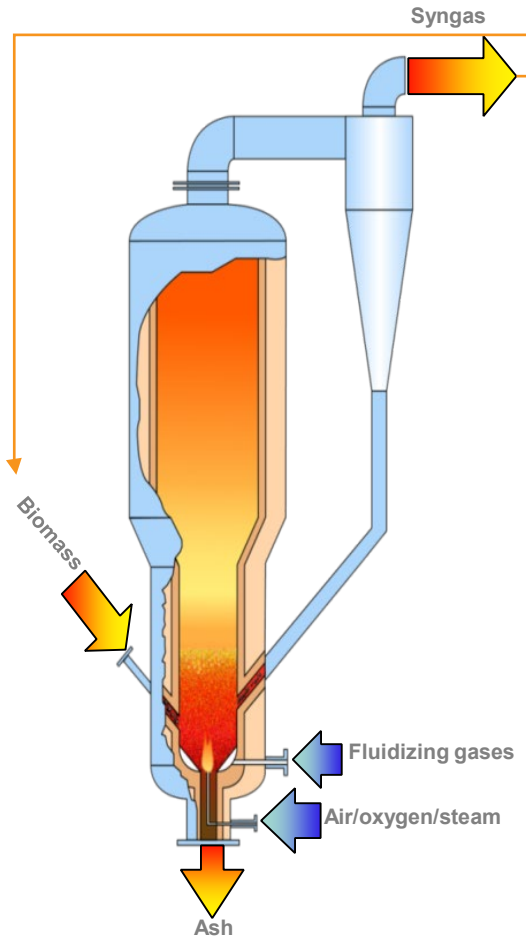
RNG Block Flow Diagram for Stockton Plant Revamp



U-Gas® Gasifier Performance

*Agricultural waste, forest wood waste, urban wood waste



	Biomass Proximate Analysis*
Moisture Content, wt% (AR)	37
Ash Content, wt% (dry)	3.71
Fixed Carbon, wt% (dry)	49.75
Moisture Content, wt% (AF)	17
HHV, MJ/kg (DAF)	21

	Syngas**
$CO+H_2$, mol%	56
CO_2, mol%	33
CH_4, mol%	9
NH_3, mol%	0.9
Tar, mol%	0.6

**On N_2, S, Ar and moisture free basis

Feedstock rate: **945** tons/day, or **310,000** tons/year

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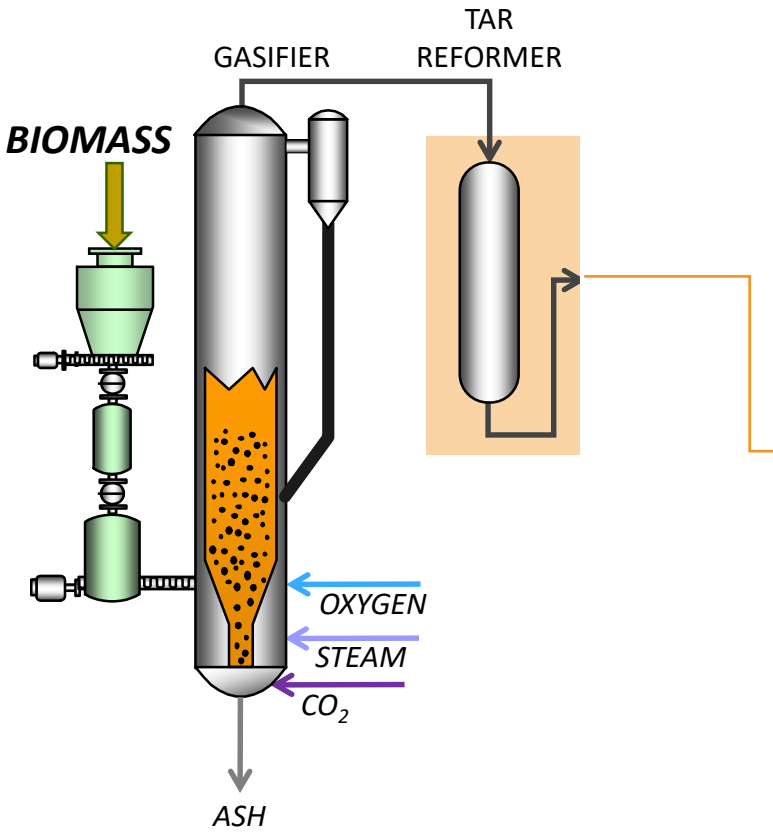
+ Tar Reformer



- Developed by Haldor-Topsoe A/S
- Convert tar and unsaturated HC to CO and H_2 (~85% Conversion)
- Residual tar is removed in scrubber

	Reformed Syngas*
$CO+H_2$, mol%	67
CO_2, mol%	27
CH_4, mol%	5
NH_3, mol%	0.4
Tar, mol%	0.1

*On N_2, S, Ar and moisture free basis

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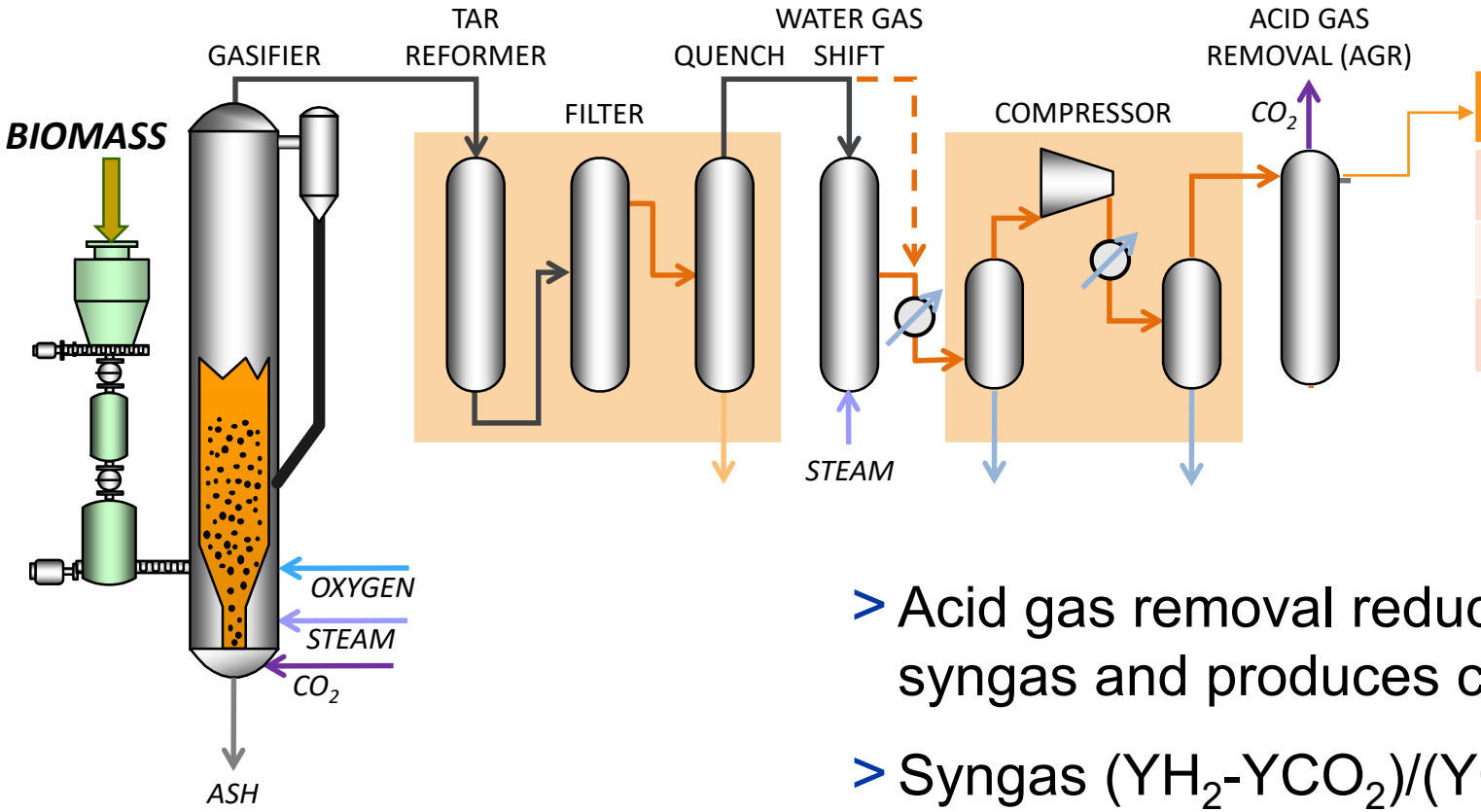
+ Syngas Clean-up



	Clean Syngas*
$CO+H_2$, mol%	86
CO_2, mol%	7
CH_4, mol%	7

*On N_2, S, Ar and moisture free basis

> Acid gas removal reduces H_2S to <1 ppm in the syngas and produces concentrated CO_2

> Syngas $(YH_2-YCO_2)/(YCO+YCO_2) \sim 3$ is fed to Methanation reactor along with steam

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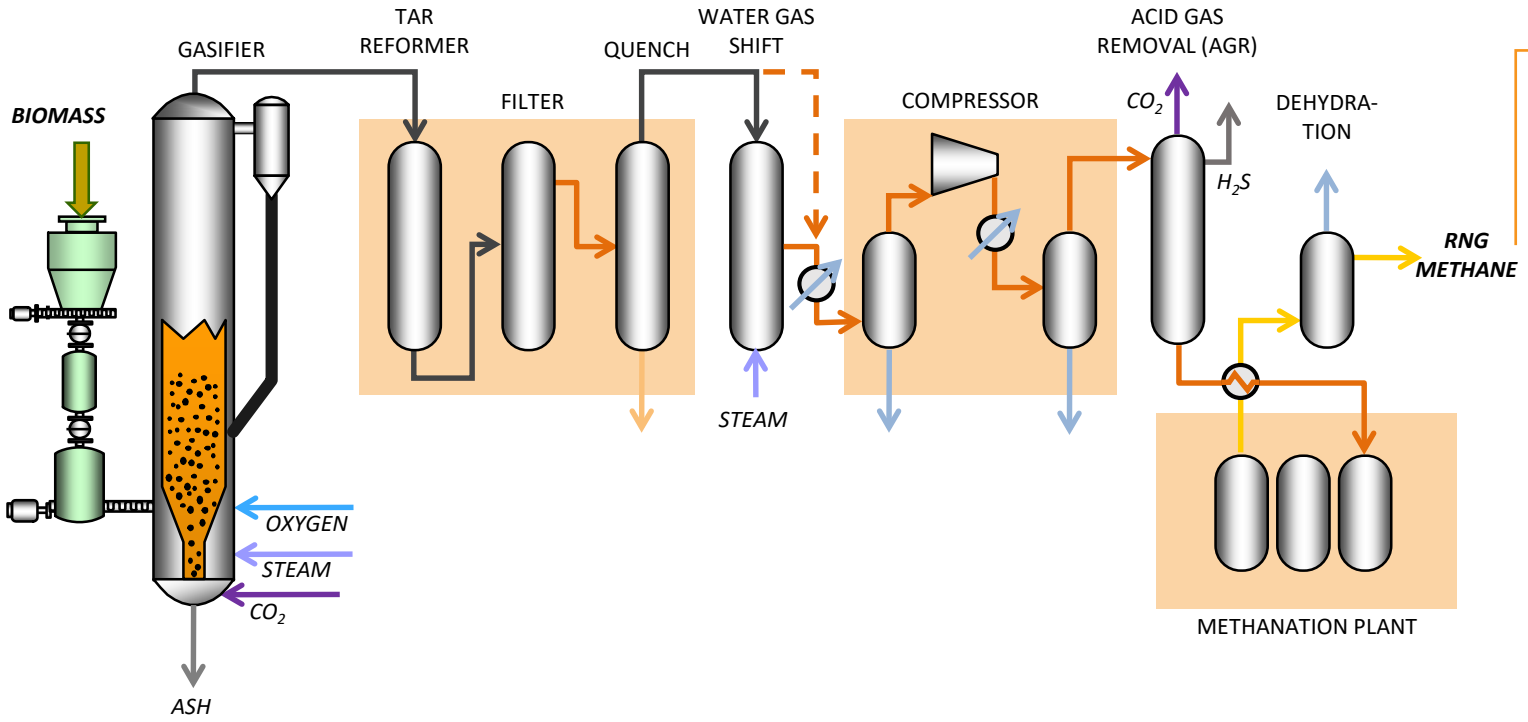
+ RNG Production Island



	RNG
CH_4, mol%	96.5
N_2, mol%	1.34
H_2, mol%	1.17
Ar, mol%	0.78
CO, mol%	0.20
CO_2, ppm	22
H_2O, ppm	17
LHV MJ/m^3	33
HHV MJ/m^3	36

> Two-pass methanation reactor (Haldor-Topsoe A/S)

> Dehydration to achieve gas pipeline spec

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Summary of Site-Specific Study

What We Learned

- Plant would convert 945 tons/day of wood wastes
- Study basis to produce approximately 85 MM m^3/yr of pipeline-ready RNG
- Base case carbon intensity (CI) is 16.8 gCO2e/MJ
- To lower CI on base case – 1st commercial plant likely to produce all its own electricity (~ 3-7 gCO2e/MJ)

Next Steps

- Explore power-to-gas options
- SunGas Renewables to deploy technology

This plant alone could displace approximately 170,000 tons of CO_2 vehicle emissions each year. (equal to offsetting the emissions from 400 million vehicle miles, or consuming 15 million gallons of gasoline)

*Assuming there are 148 million dead and dying trees in CA, there would be 258 million bone dry tons of wood available. That would feed 832 plants of the size of the Stockton RNG plant design for a year, or 27 of those plants for 30 years of operation.**

*Dead Tree Utilization Assessment. Project report May 2017, prepared for CALFIRE & California Tree Mortality Task Force.

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