Methanol Production from Biosyngas Using Water-Gas Shift (WGS) to Improve the H_2/CO Ratio

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Project Overview

Saudi Arabia generates over 30 million tons of agricultural waste annually, including 1.6 million tons of palm waste that is burned or landfilled. Biomass gasification converts this waste into biosyngas (CO + H_2 + CO_2), which can be used to produce methanol. However, raw biosyngas has an insufficient H_2/CO ratio (SN < 2.0) for efficient methanol synthesis.

This project integrates a Water-Gas Shift (WGS) reactor to raise the SN to 2.008, enabling Grade-AA methanol production at 1.23 million tons/year with 99.85% purity. Waste heat from the exothermic methanol reactor (173.6 MW) is recovered via a Rankine cycle, generating 24.72 MW of electricity. The project achieves a 5-year payback and 18.4% ROI, confirming environmental and economic viability aligned with Vision 2030.

Background and Motivation

Biosyngas vs. Natural Gas Syngas:

Natural gas syngas has H_2/CO ≈ 3, sufficient for methanol synthesis. Biosyngas from agricultural waste has H_2/CO < 1.5 — below the required SN of 2.0. Without correction, methanol yield drops significantly.

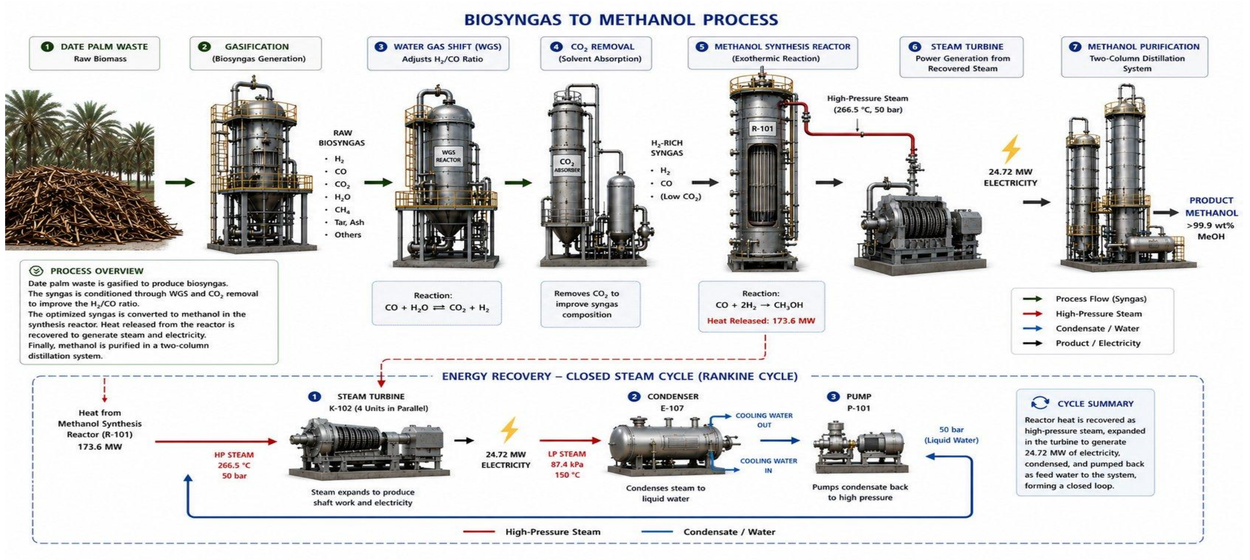
Why this matters:

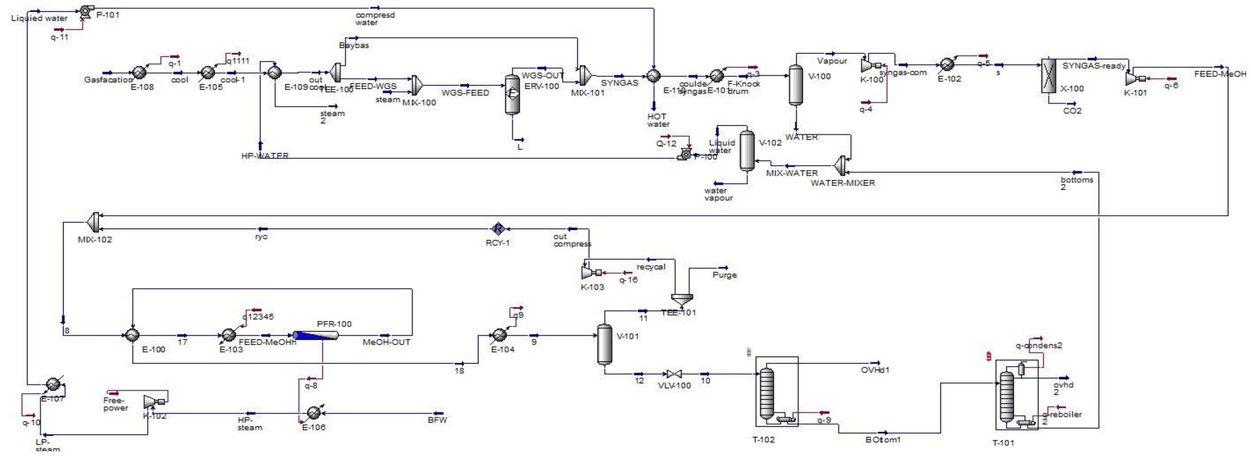
- 30M t/yr biomass waste in Saudi Arabia goes unutilized
- Global methanol price: $520/ton — growing demand
- WGS selectively converts excess CO → H_2, correcting the ratio and enabling clean methanol from a renewable local feedstock

Project Objectives

Design	a WGS-integrated methanol plant using Saudi biomass as feedstock.
Optimize	the H_2/CO ratio to achieve SN ≥ 2.0 via WGS bypass control.
Recover	reactor waste heat (173.6 MW) via Rankine cycle to reduce utility cost.
Evaluate	full economic viability: CAPEX, OPEX, NPV, IRR, and payback period.
Validate	environmental benefits vs. fossil-based methanol production routes.

Design Methodology and Process Simulation





Biosyngas to Methanol — Full Process & Energy Recovery

Key Performance Indicators

Methanol Production **1.23M t/yr**	Product Purity (Grade-AA) **99.85%**
WGS CO Conversion **83.2%**	Stoichiometric Number **SN = 2.008**
Turbine Power Output **24.72 MW**	Simple Payback Period **5 Years**

Key Conclusions

1 H_2/CO Ratio Successfully Corrected

WGS reactor raised SN from < 2.0 to 2.008, enabling Grade-AA methanol synthesis from biosyngas — proving local biomass can replace fossil feedstock.

2 High-Purity Product Achieved

Plant produces 1.23M t/yr at 99.85% purity with 83.2% CO conversion — meeting international Grade-AA commercial methanol specifications.

3 Energy Self-Sufficiency

Rankine cycle recovers 173.6 MW of reactor waste heat, generating 24.72 MW — reducing grid dependency and saving $8.2M/yr in electricity cost.

4 Economically Viable

TCI of $399M recovered in 5 years. NPV = $276M over 20 years at 10% WACC, ROI = 18.4%, annual net profit = $62M.

5 Vision 2030 Aligned

Converts agricultural waste into high-value methanol and clean electricity —Saudi Arabia's circular carbon economy goals. supporting

Sustainability Assessment

This project:	**~0.79 t CO_2/t MeOH**
Natural gas:	0.8–1.2 t CO_2/t MeOH
Coal-based:	3.5–4.5 t CO_2/t MeOH
Grid CO_2 saved:	**98,880 t/yr (turbine)**

Software and tools

Aspen HYSYS V12	Process simulation & optimization
Excel	Economic analysis & cost estimation
Polymath ODE	WGS reactor design & kinetic modelling
Microsoft Visio	P&ID diagrams