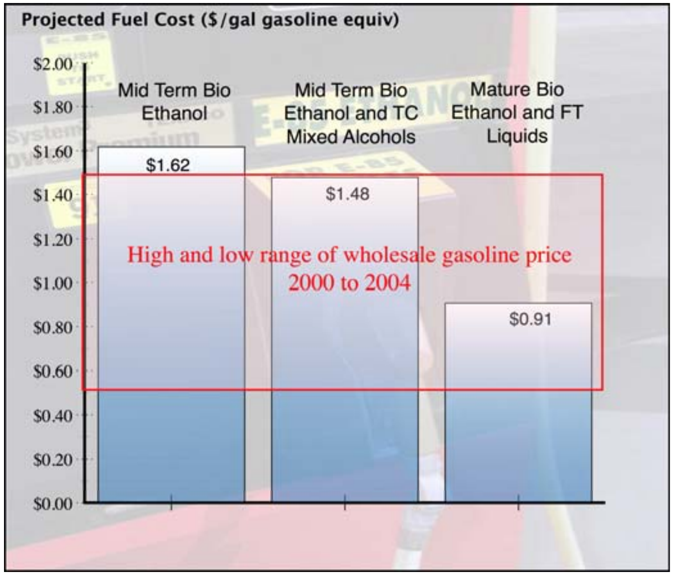
열적변환의 플랫폼 경제 분석

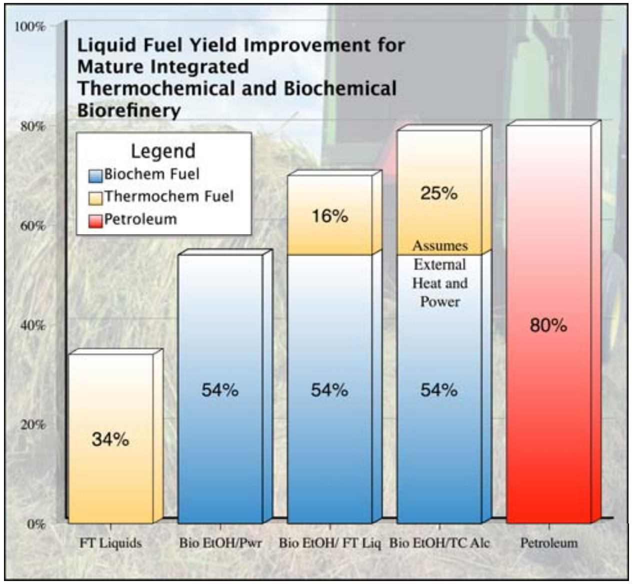
Economics of Thermal Conversion

Examining economics of syngas in an integrated process & biorefinery design

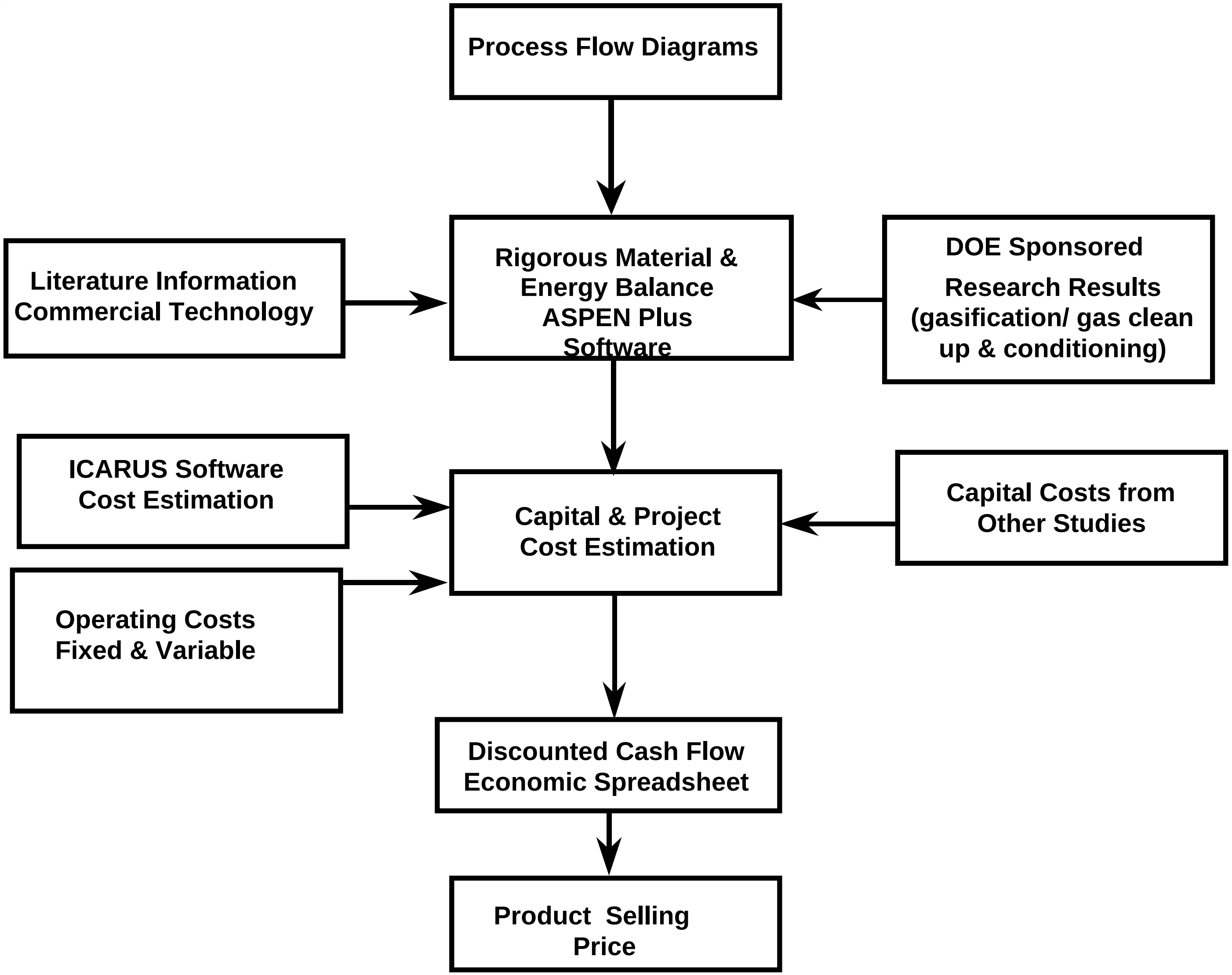
Examples of specific thermochemical products for which detailed designs exist:

- **Biomass syngas to hydrogen (complete)**
- **Biomass syngas to mixed alcohols with separation of ethanol (on-going)**



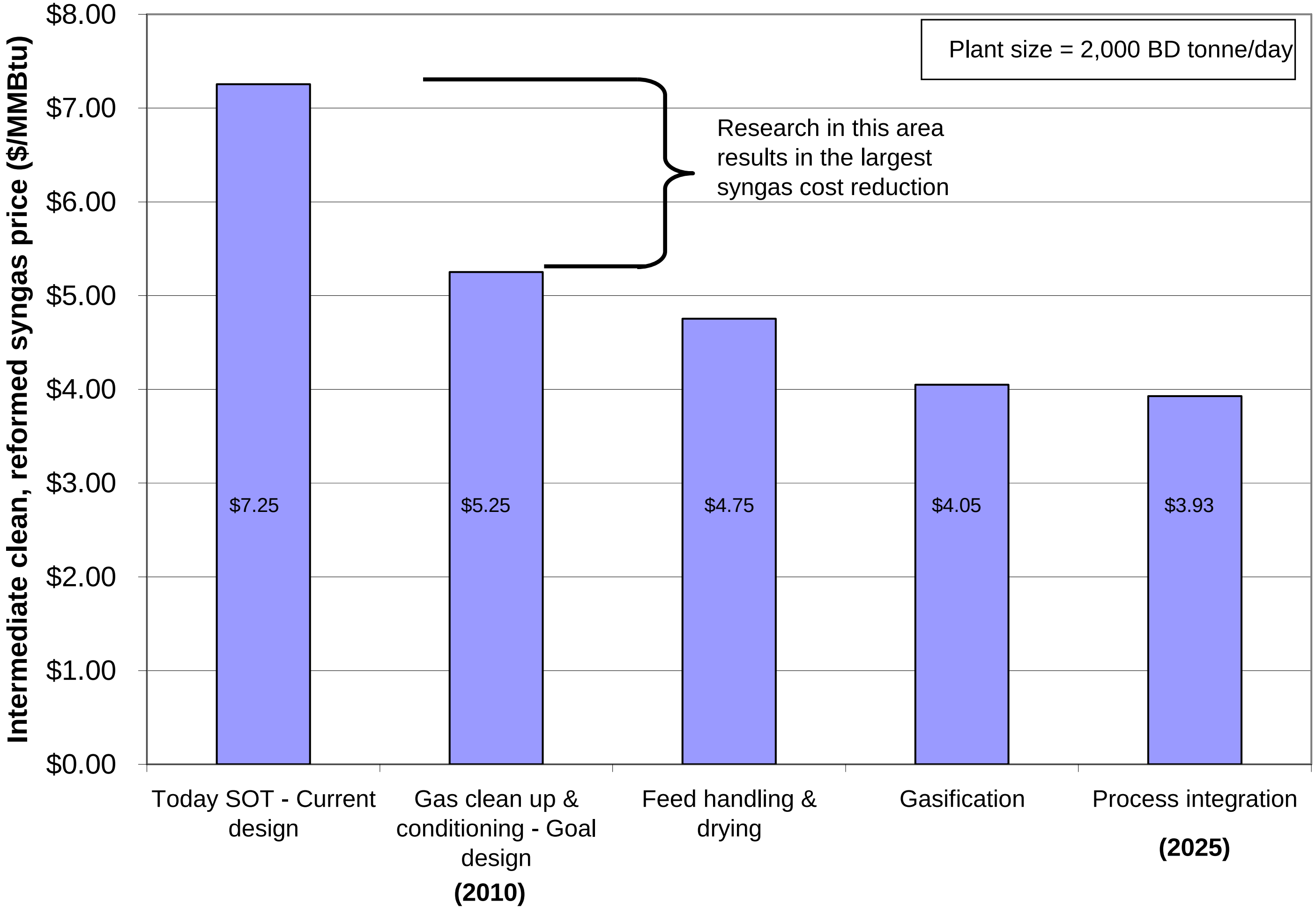


Performing A Detailed Design



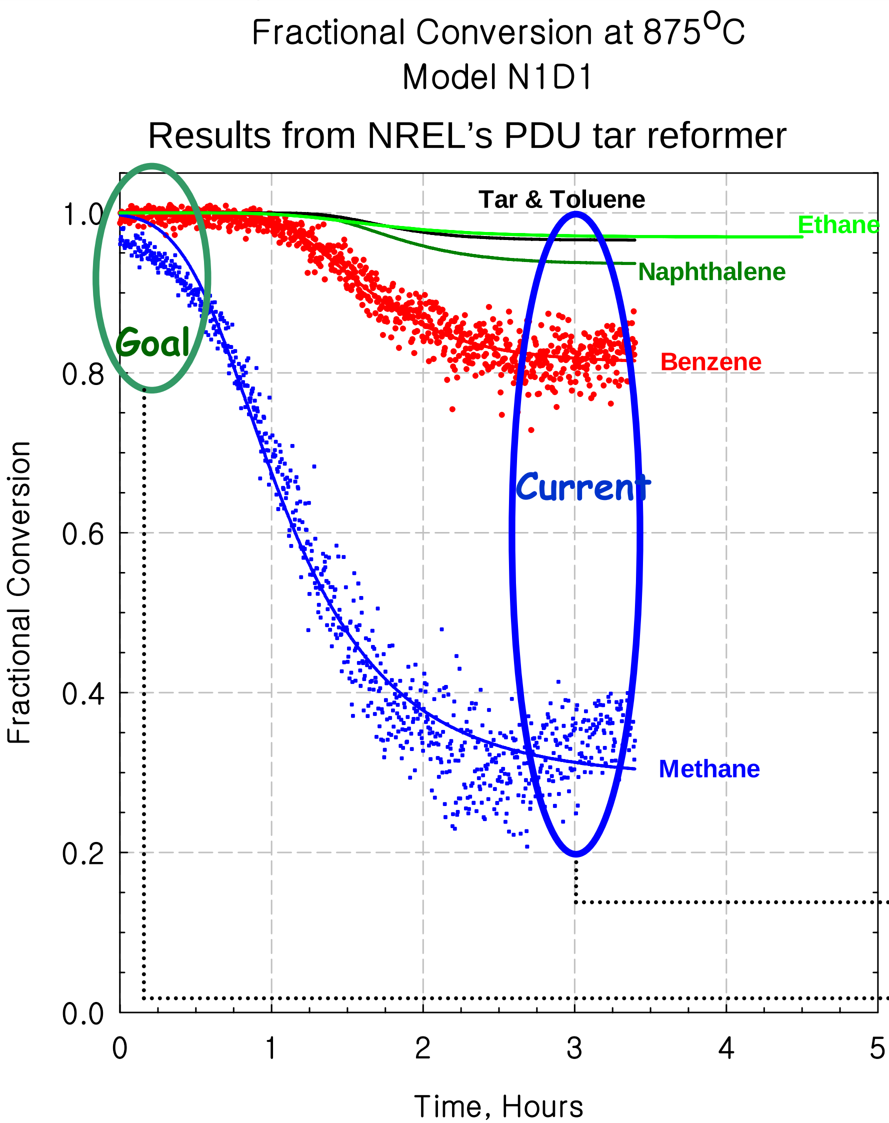
Intermediate Syngas Price – Targets & Barriers

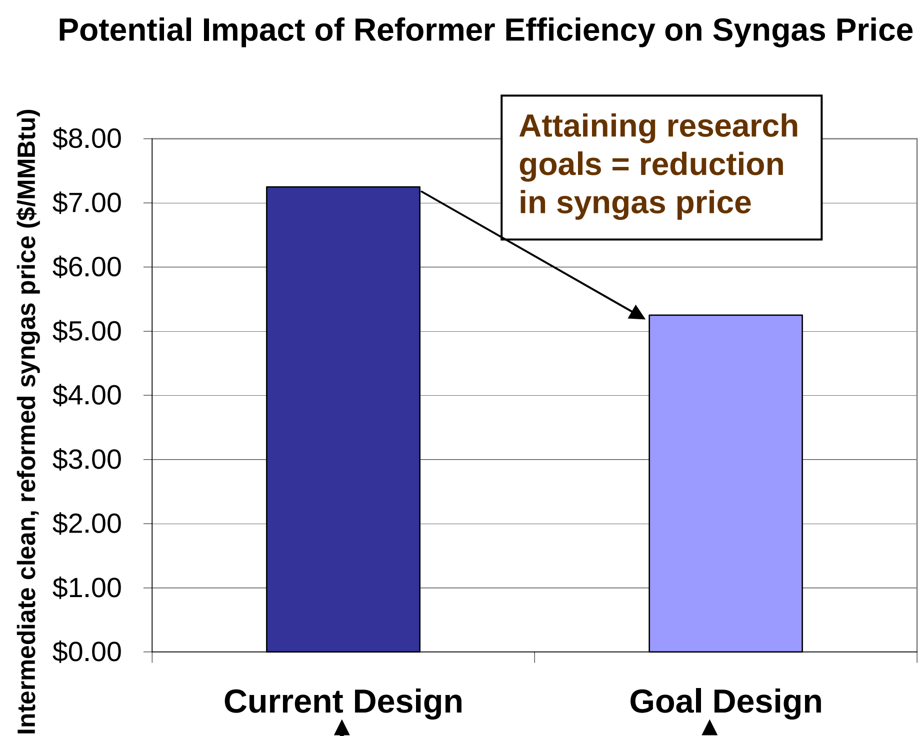
- DOE program targets based on intermediate syngas price to track progress toward reducing technical barriers



Decrease in syngas price due to increased yields, decreased capital costs, & efficiency gains

Tie in With Research



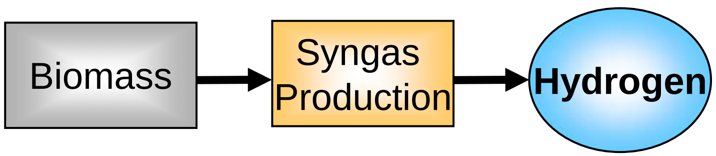


- **Goal case yield is increased & capital cost is less**

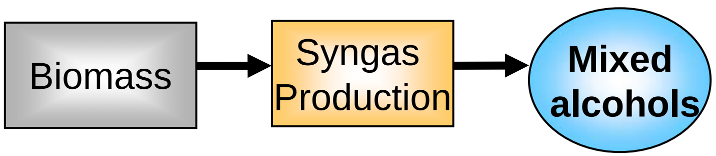
Progression of Analysis

Progression of analysis toward integrated biochemical/thermochemical biorefinery design

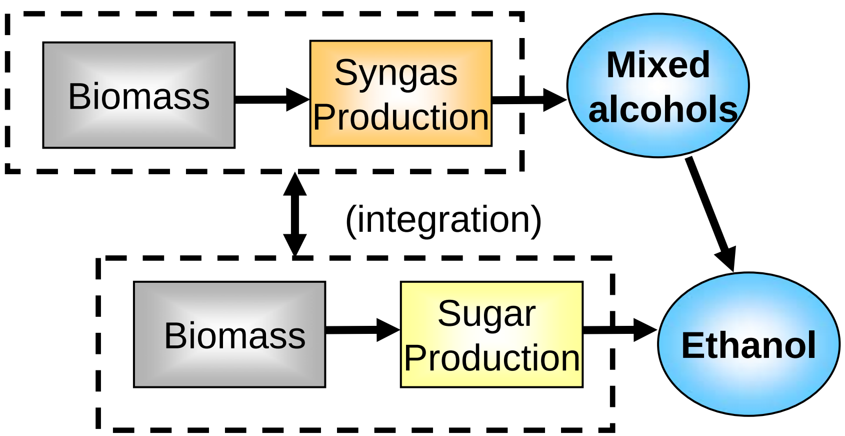
- **Using results of biomass to H_2 detailed design to move forward for mixed alcohol detailed design**



- **Begin by building stand-alone mixed alcohol design**

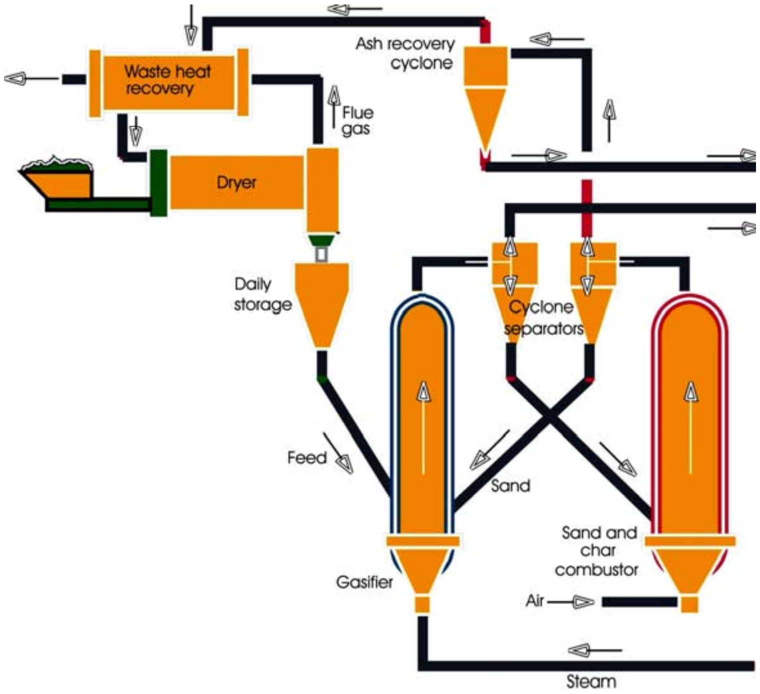


- **Build off of stand-alone mixed alcohol analysis and stand-alone ethanol analysis to create a biochemical/thermochemical integrated biorefinery design**



Biomass Gasification – Syngas to Products

- FY 2003 NREL's preliminary screening study showed H_2 to be technically and economically feasible product from biomass gasification
- H_2 was picked as a model product to show effect of process integration & economics of a final product from biomass gasification
- Performed detailed process design and modeling using Battelle Columbus Laboratory (BCL) low pressure, indirectly-heated gasifier



Gas composition	mol% (dry)
H_2	23.85
CO_2	12.79
CO	42.18
CH_4	15.36
C_2H_2	0.41
C_2H_4	4.35
C_2H_6	0.29
C_6H_6	0.13
tar ($C_{10}H_8$)	0.23
NH_3	0.32
H_2S	0.07
H_2:CO molar ratio	0.57
Gasifier efficiency	72.1% HHV basis 71.8% LHV basis

Syngas Clean Up & Gas Conditioning

Two designs examined based on catalytic tar destruction and heteroatom removal work at NREL:

- current design – defines today's state of the technology
- goal design – shows the effect of overcoming R&D technical barrier

Tar reformer conversion #'s

Compound	Current	Goal
Methane (CH_4)	20%	80%
Ethane (C_2H_6)	90%	99%
Ethylene (C_2H_4)	50%	90%
Tars (C_{10+})	95%	99.9%
Benzene (C_6H_6)	70%	99%
Ammonia (NH_3)	70%	90%

Higher conversions for goal case; notably methane.

Biomass Gasification - Detailed Design

Both designs broadly consist of:

- feed handling, drying, gasification, gas clean up and conditioning, shift conversion, and purification integrated with a steam and power generation cycle

Main design differences:

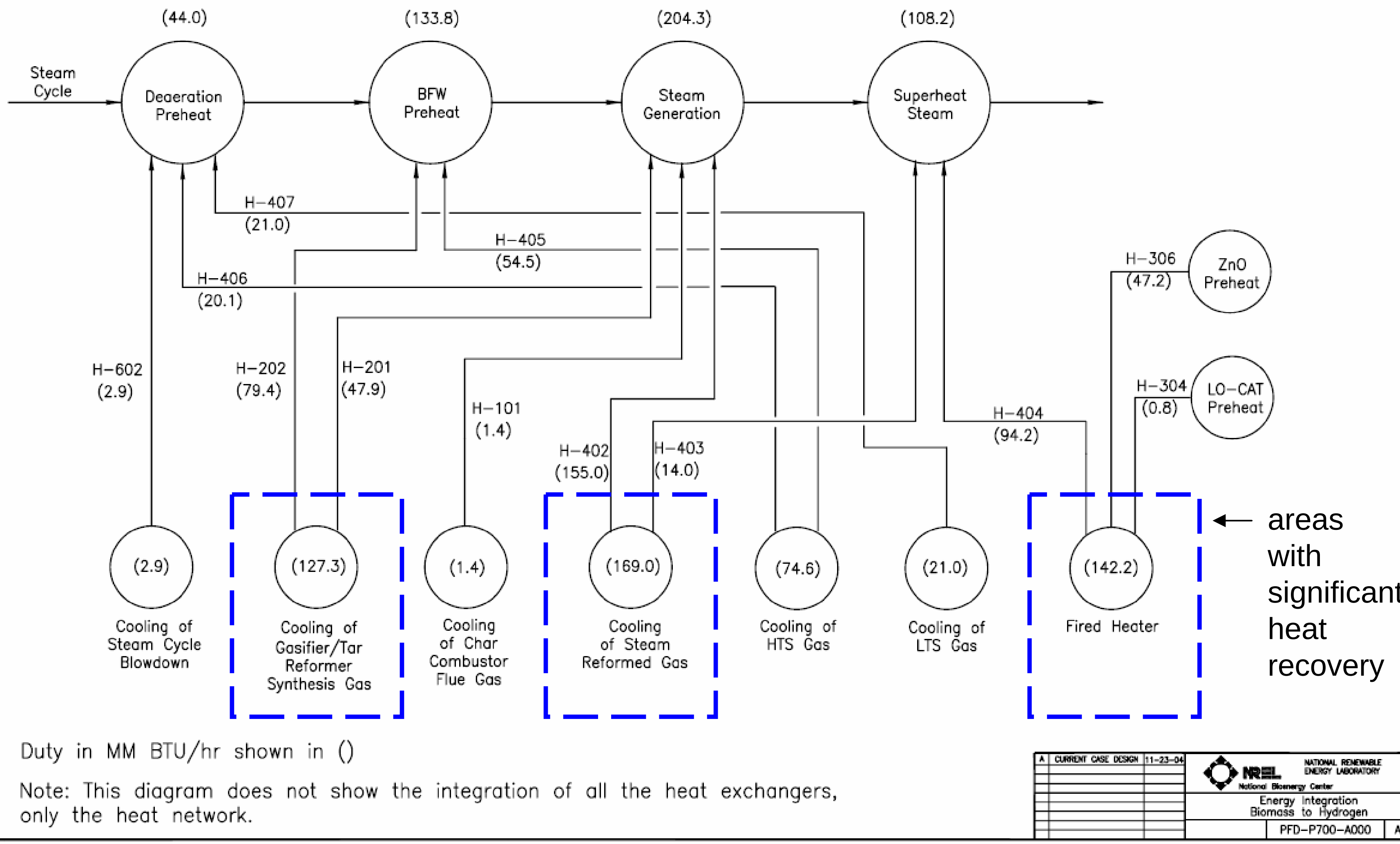
	Current	Goal
Tar reformer	Bubbling fluidized bed with 1% per day catalyst replacement	Reactor vessel & catalyst regeneration vessel operating isothermally
Steam methane reformer (SMR)	SMR downstream of sulfur removal	None (SMR eliminated)

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Integration is Important

biomass program

- **FT & mixed alcohols will have large amount of heat available in synthesis step due to exothermic reactions**



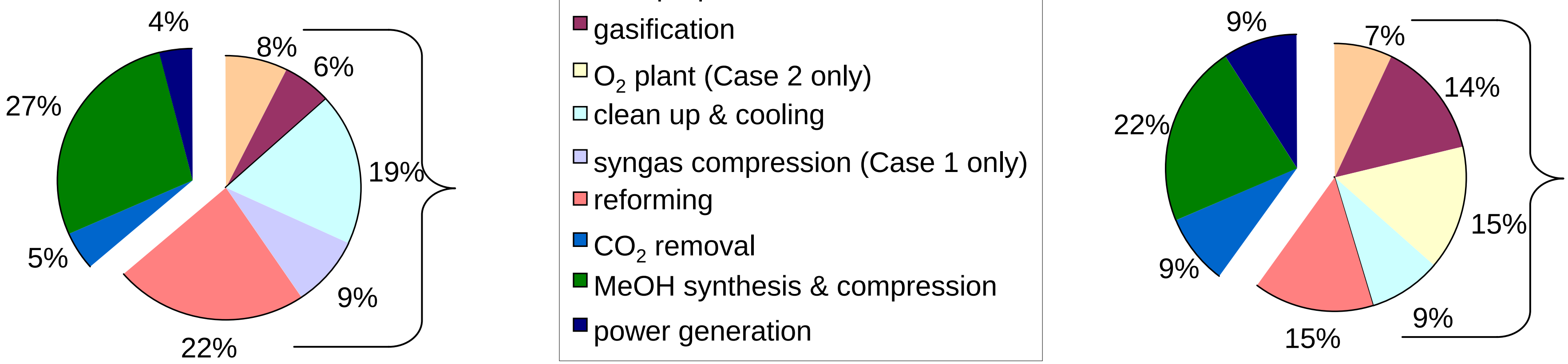
Syngas Production is Large Contribution to Product Price

- **This is true of other products, not just H_2**
- **An estimation of the syngas cost can be made and used as a benchmark……………however, it doesn't make sense to look at just stand-alone syngas production because integration is important and a key to economical process designs**

From FY 2003 preliminary screening study

Case 1 - Indirect: BCL, scrubbing, stm reformer, shift, conv MeOH, stm turbine

Case 2 - Direct: GTI, HGCU, ATR, shift, conv MeOH, stm turbine



Clean, reformed syngas generation = 60-64% of total capital in thermochmeical conversion

Syngas Price – Integration Results & Lower Price

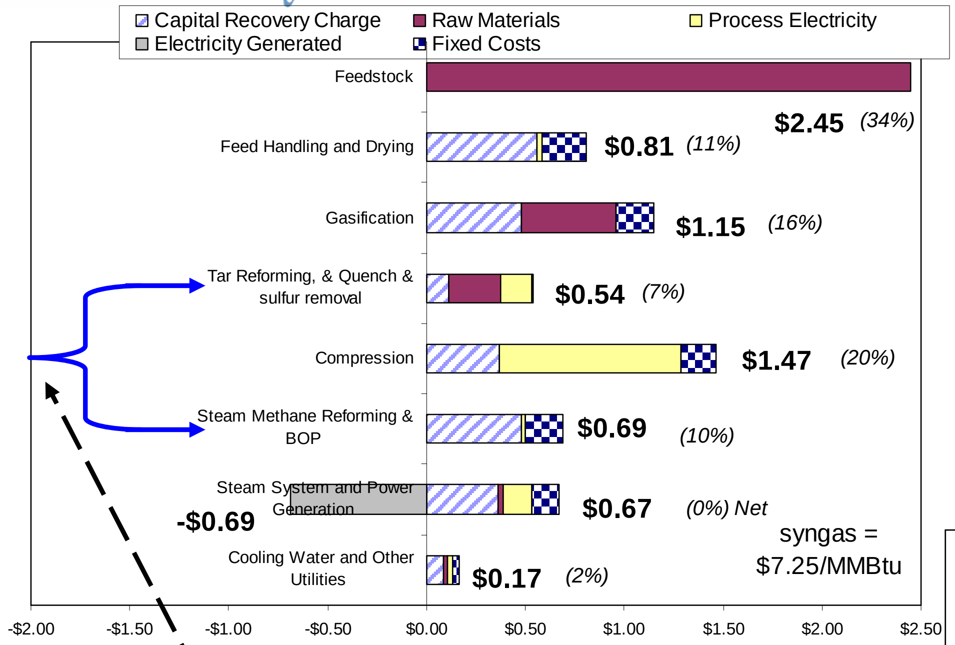
- **Intermediate –** Price of clean, reformed syngas in an integrated process.
- **Stand-alone –** Price of syngas with synthesis steps downstream of gas clean up & conditioning removed, natural gas used as fuel, and heat balance is reconfigured.

	($/MMBtu, LHV)	
	Current	**Goal**
Intermediate syngas price	**7.25**	**5.25**
Stand-alone syngas price	**8.67** (20% higher)	**7.10** (35% higher)

- More economical to build entire syngas generation to fuels production plant than to purchase syngas due to process integration advantages
- Completed analysis; NREL technical report available at *www.nrel.gov/docs/fy05psti/37408.pdf*

Intermediate Syngas Cost Contribution – Current & Goal Design

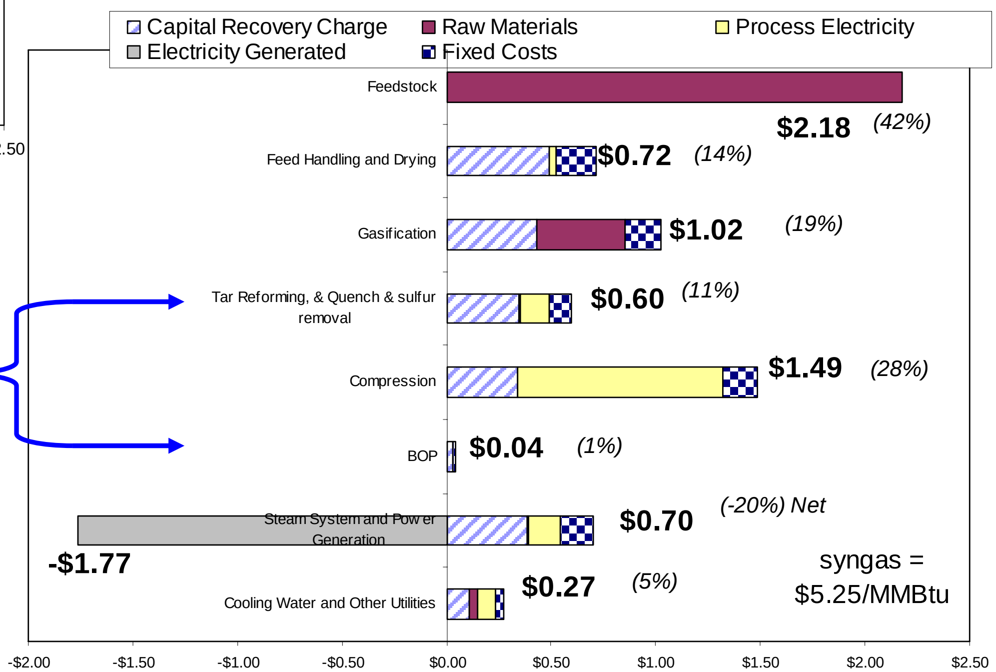
Current Design



Reforming cost is reduced and shifted to a different plant section

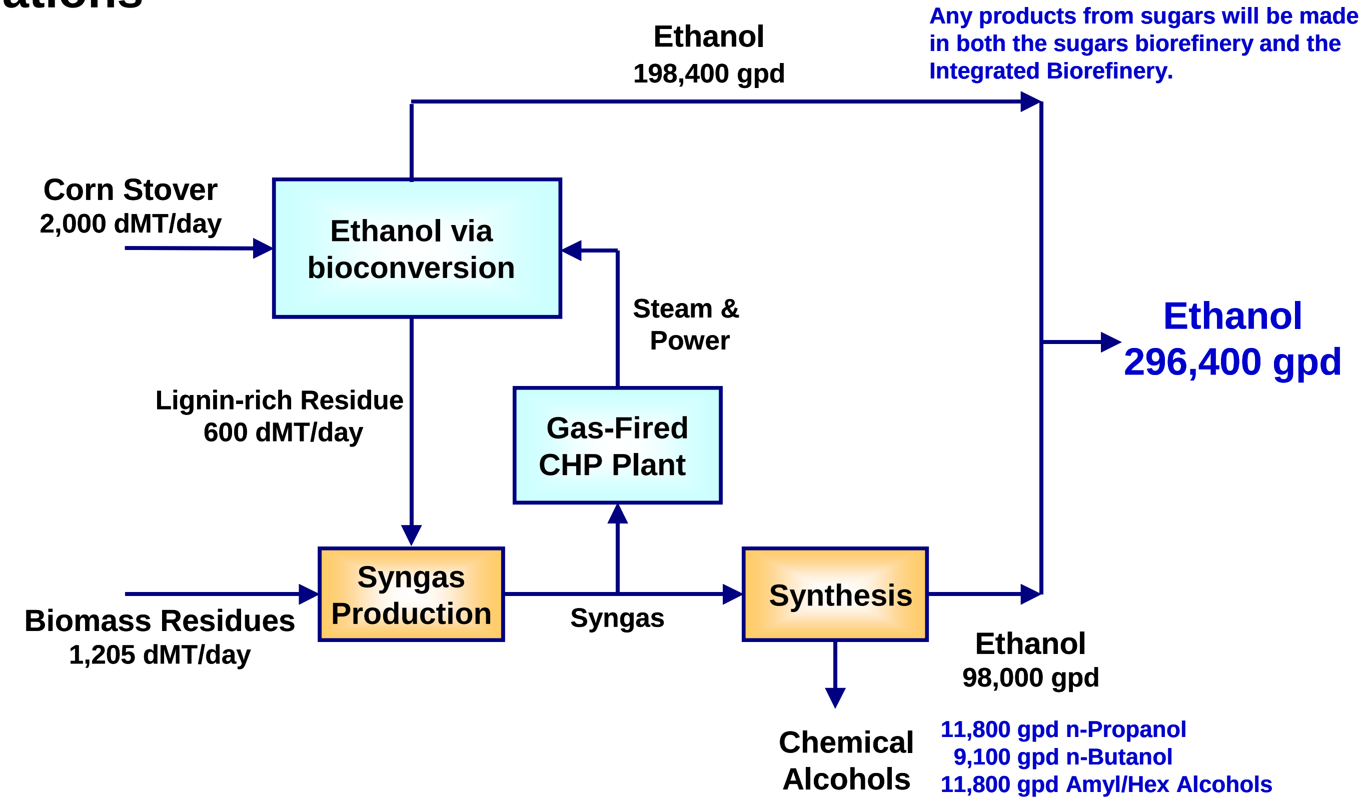
($0.64 vs $1.23/MMBtu contribution to syngas price)

Goal Design

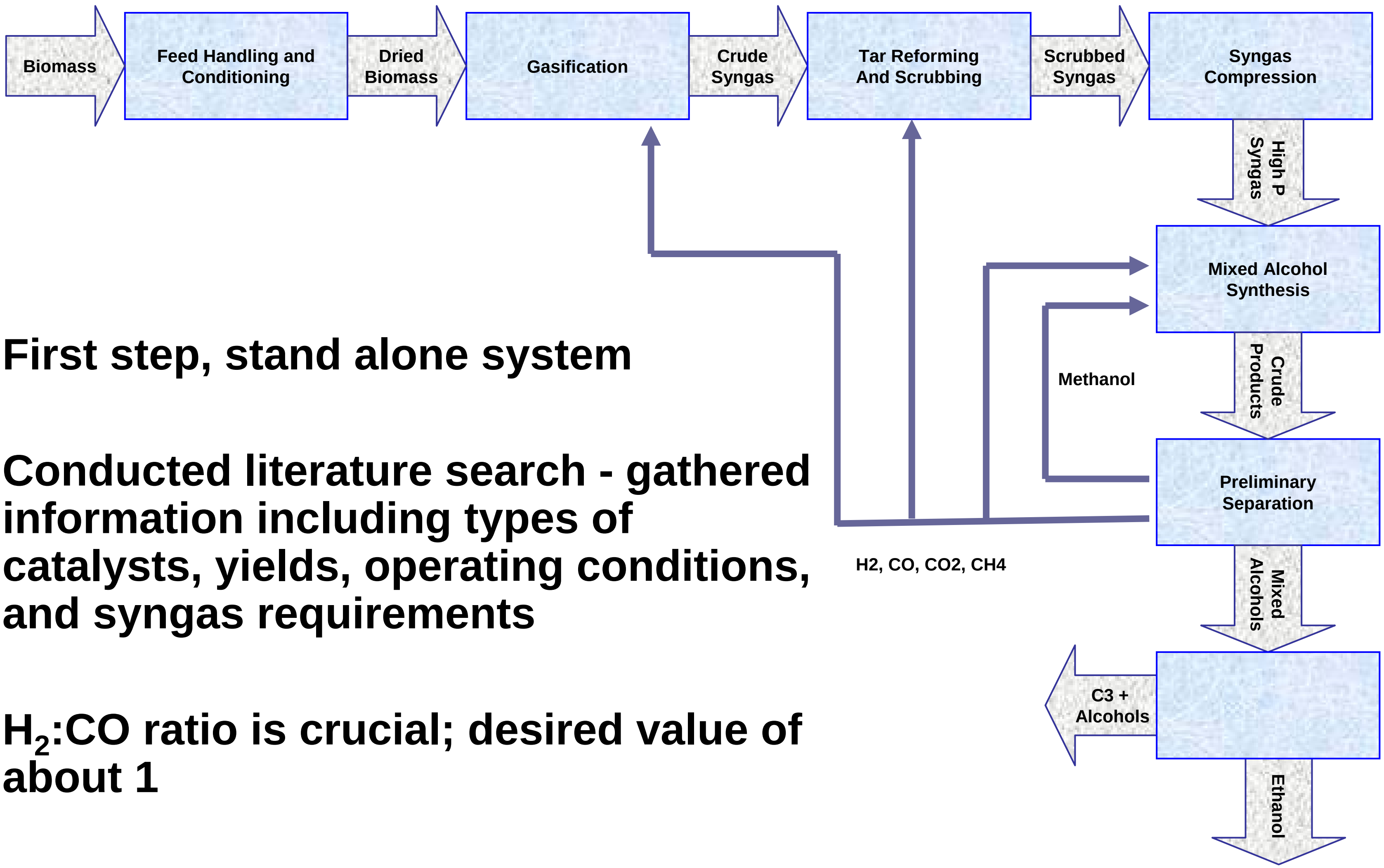


Mixed Alcohols Analysis

- **Dec 2004 refocused thermochemical conversion to examine synergies & integration into a sugars biorefinery**
- **Mixed alcohols detailed design is a follow on to the biomass to H_2 study and validates initial December spreadsheet material balance & cost calculations**



Stand Alone Mixed Alcohols

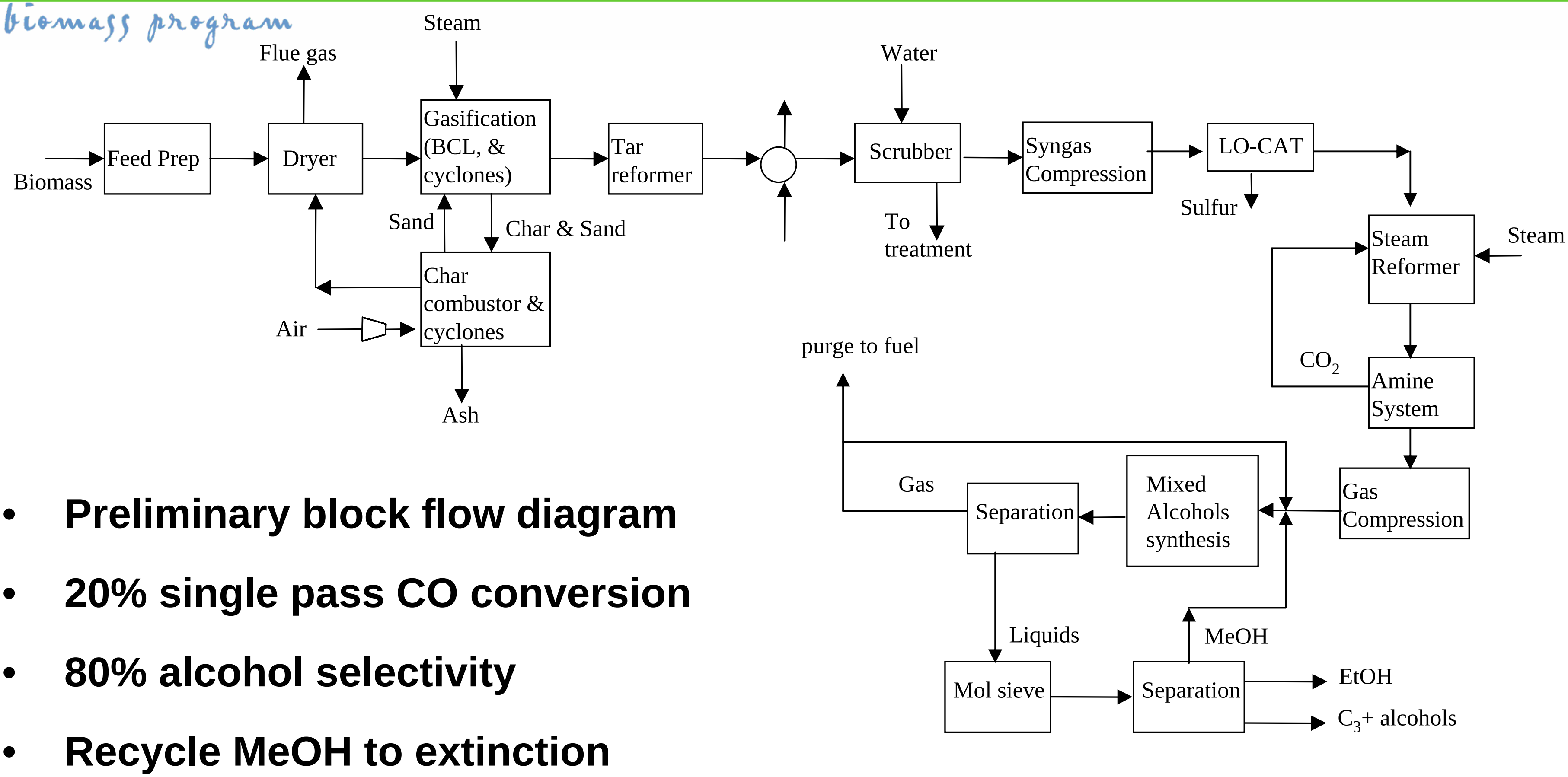


- First step, stand alone system
- Conducted literature search - gathered information including types of catalysts, yields, operating conditions, and syngas requirements
- H_2:CO ratio is crucial; desired value of about 1

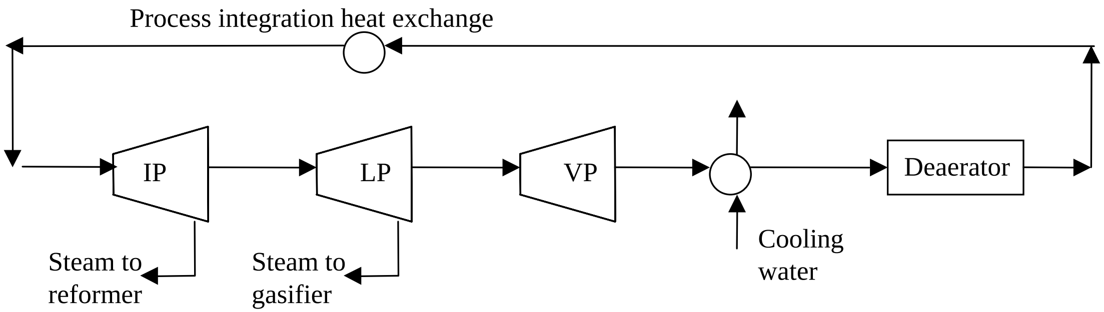
Stand Alone Mixed Alcohols

- **Maximum hydrocarbon conversion in conjunction with optimal/most economical gas clean up and conditioning steps is challenging**
- **Selected modified FT catalyst (MoS_2-variation) based on its ability to produce linear alcohols & higher sulfur tolerance**
- **Working on modifying biomass to H_2 model for mixed alcohols production using BCL gasifier**
- **Milestone report due 7/18/05**

Stand Alone Mixed Alcohols - Simulation

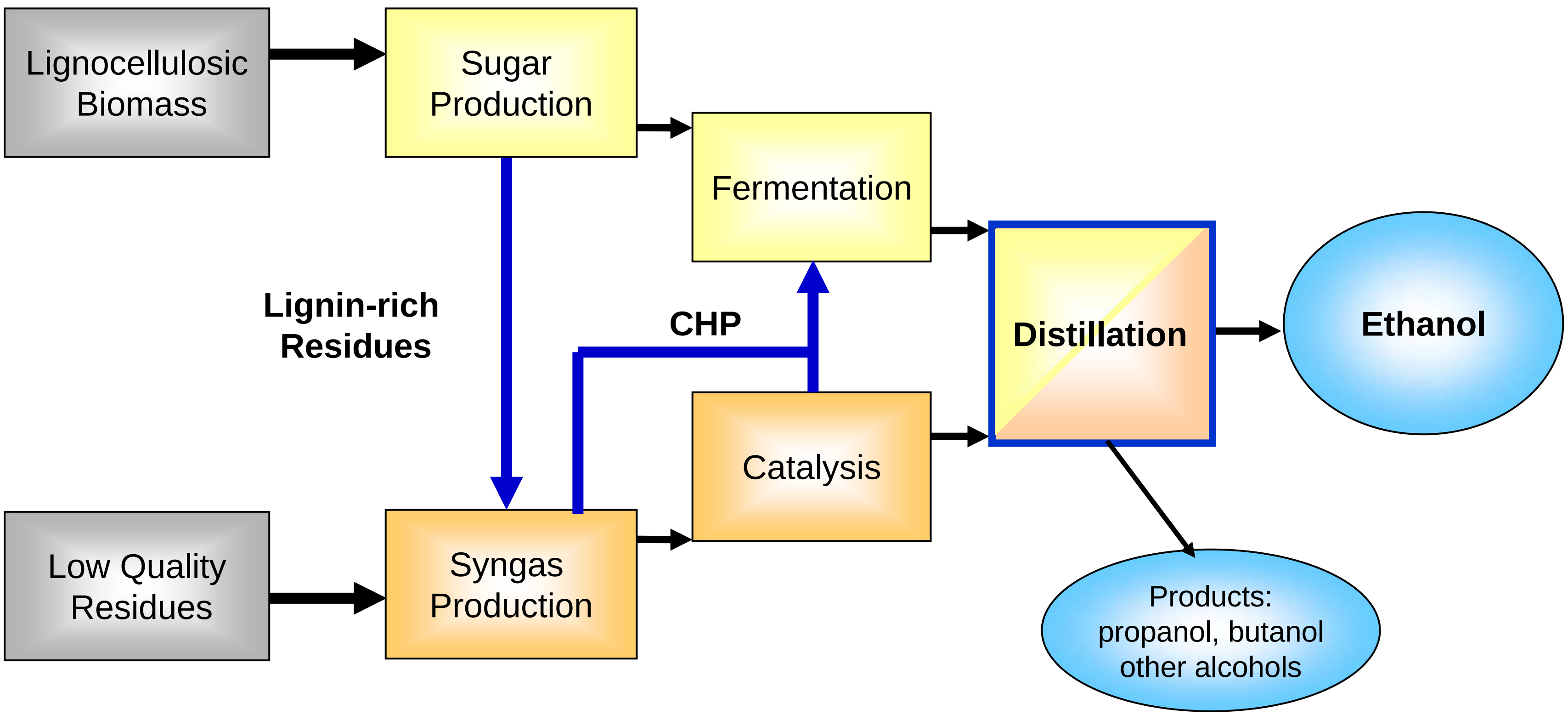


- **Preliminary block flow diagram**
- **20% single pass CO conversion**
- **80% alcohol selectivity**
- **Recycle MeOH to extinction**



Integrated Sugars/Thermochemical Biorefinery

- **Next step, in FY 2006 will combine mixed alcohols and ethanol stand alone systems to create an optimized biochemical/thermochemical biorefinery**



Acknowledgements

Additional analysts:

Andy Aden

Tim Eggeman

Matt Ringer

Bob Wallace

John Jechura

Kelly Ibsen