IPRO 347

ILLINOIS INSTITUTE OF TECHNOLOGY

Design and Economic Evaluations of

BIO REFINERY OPERATIONS

Objective and Motivation

- 85% of total energy consumed by Americans comes from coal, crude oil, and natural gas.
- Non-renewable energy sources will eventually diminish.
- Coal, crude oil, and natural gas contribute to atmospheric pollution.

Alternative Energy Sources

- Solar – seasonal and inefficient
- Wind – unreliable and inefficient
- Biomass – readily available

Biomass Methods

- **Biological** – uses bacterium to break down biomass into the necessary components to form ethanol.
- **Thermochemical -** uses a gasifier in order to take the biomass and create a synthetic gas which is burned for electricity or converted to transportation fuel.

Project Breakdown

- Biomass Selection
- Gasification
- Syngas Purification
- Fisher-Tropsch (FT) Reactor

Biomass Selection

- Types of Biomass

  -Wood

  -Black liquor

  -Corn

  -Animal Waste

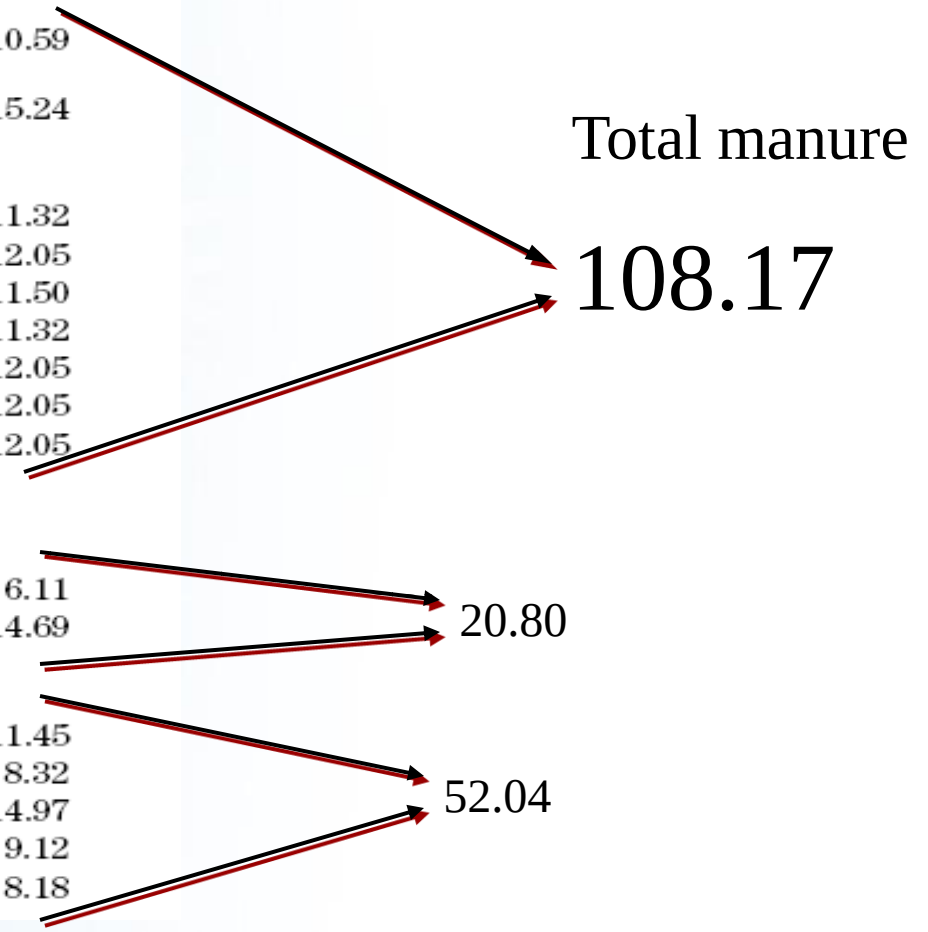
    -Swine

    -Poultry

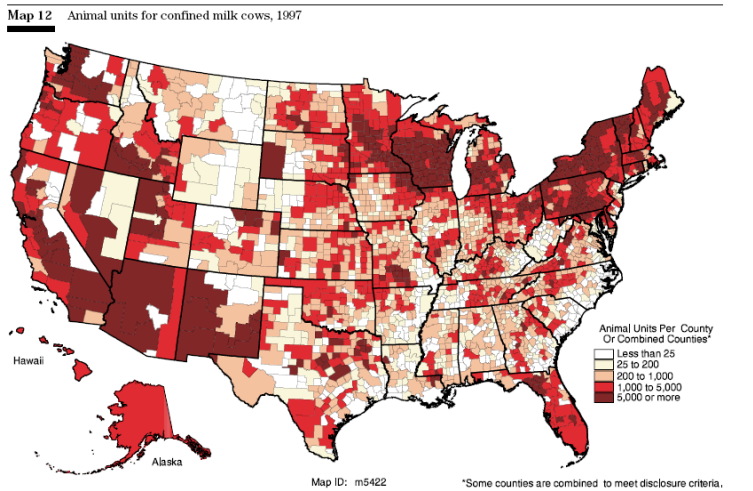
    -Cattle

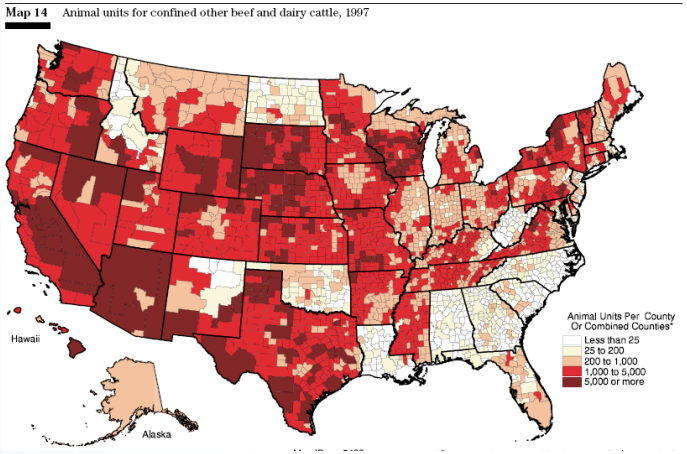
Biomass Quantities

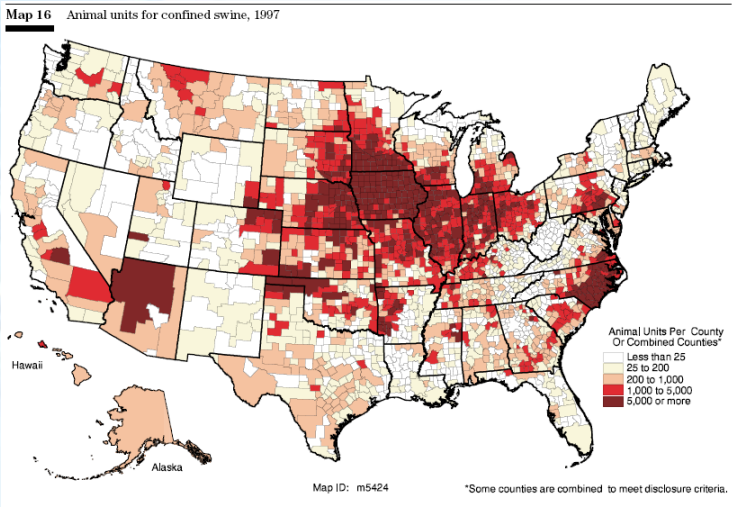
Livestock category	Tons of manure per animal unit per year as excreted
Fattened cattle	10.59
Milk cows	15.24
Other beef and dairy	
Beef calves, from calving to about 500 pounds	11.32
Beef heifers for replacement herds	12.05
Beef breeding herds (cows and bulls)	11.50
Beef stockers and grass fed beef	11.32
Dairy calves, from calving to about 500 pounds	12.05
Dairy heifers for replacement herds	12.05
Dairy stockers and grass fed animals marketed as beef	12.05
Swine	
Breeding hogs	6.11
Hogs for slaughter	14.69
Poultry	
Chickens, layers	11.45
Chickens, pullets	8.32
Chickens, broilers	14.97
Turkeys for breeding	9.12
Turkeys for slaughter	8.18



Biomass Location







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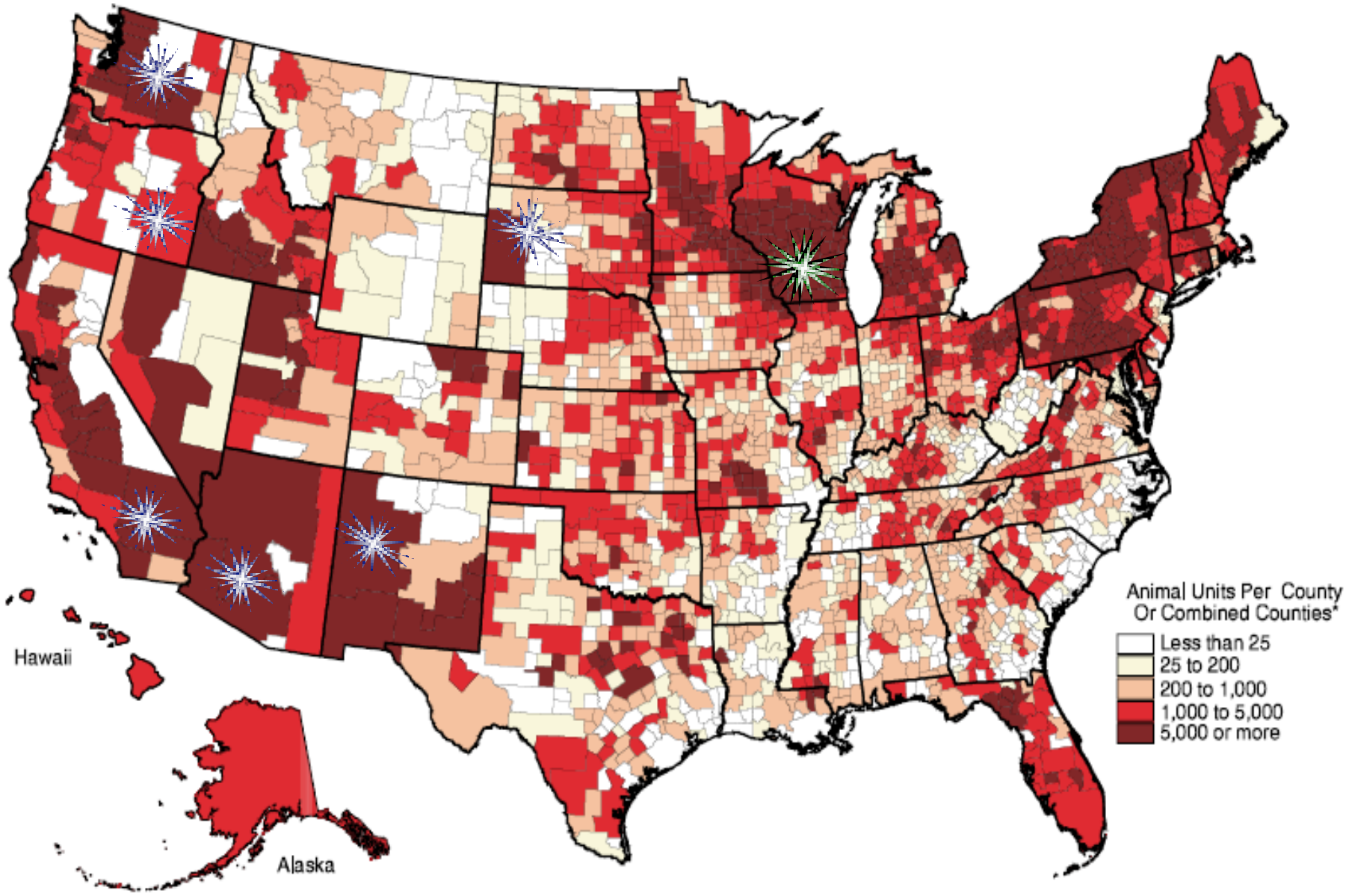
Biomass Location



Manure Availability

South Western Wisconsin					
CATTLE					
	animal units (AU) per county	**manure per AU**	**tons manure per county per year**	**dried manure per county per year**	**availability per day assuming 260 days**
Confined fattened cattle	5000	10.59	52950	6354	24.4
Confined milk cows	5000	15.24	76200	9144	35.2
Other Beef and dairy cattle	5000	11.5	57500	6900	26.5
Totals	15000	37.33	186650	22398	86.1

Gasification

- A process where a complex carbon based material is partially combusted with limited oxygen to create an energy rich gaseous fuel source.
- Syngas can be directly burned as a fuel source or can be further modified into liquid based transportation fuels.
- Types of Gasifiers
  - Steam Reforming
  - Fixed Bed
  - Fluidized Bed

Cow Manure Gasification

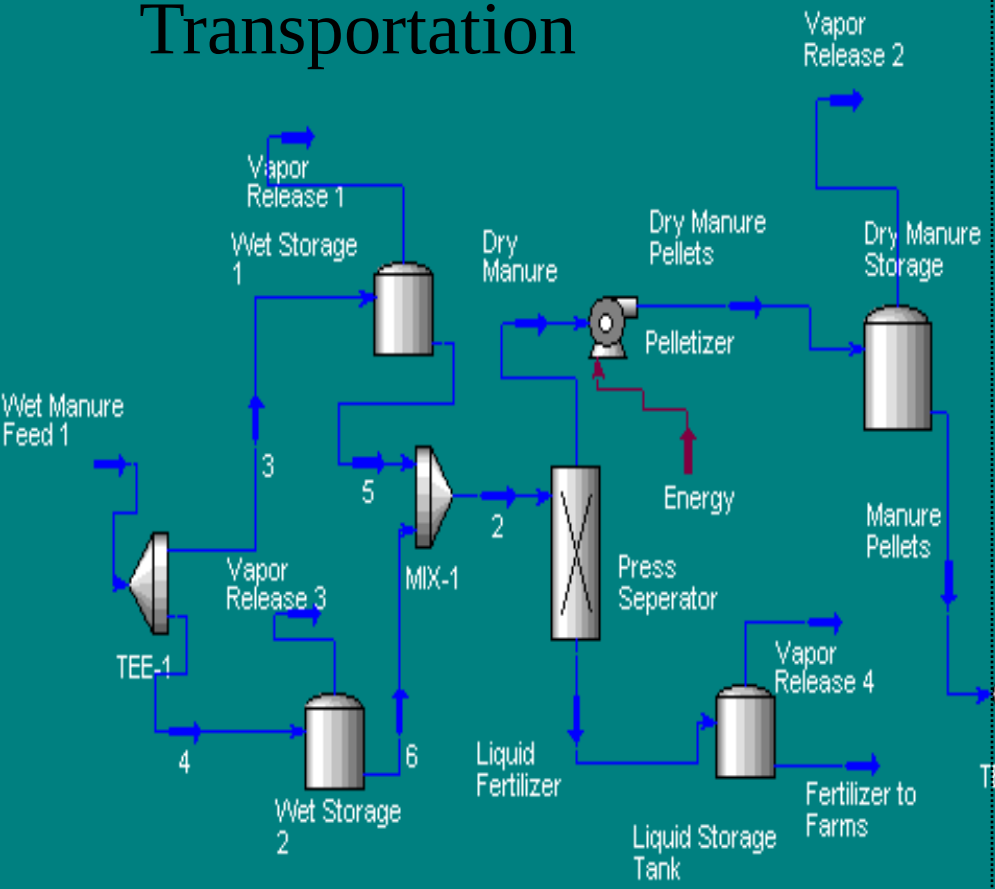
- Slagging:
  Temperature 1350-1400ºC
- Syngas:
  26.9% molar carbon monoxide
  6.1% carbon dioxide
  17.1% hydrogen
  49.9% nitrogen

- Non-slagging:
  Temperature 800-900ºC
- Syngas:
  30.2% molar carbon monoxide
  5.5% carbon dioxide
  25.7% hydrogen
  38.6% nitrogen

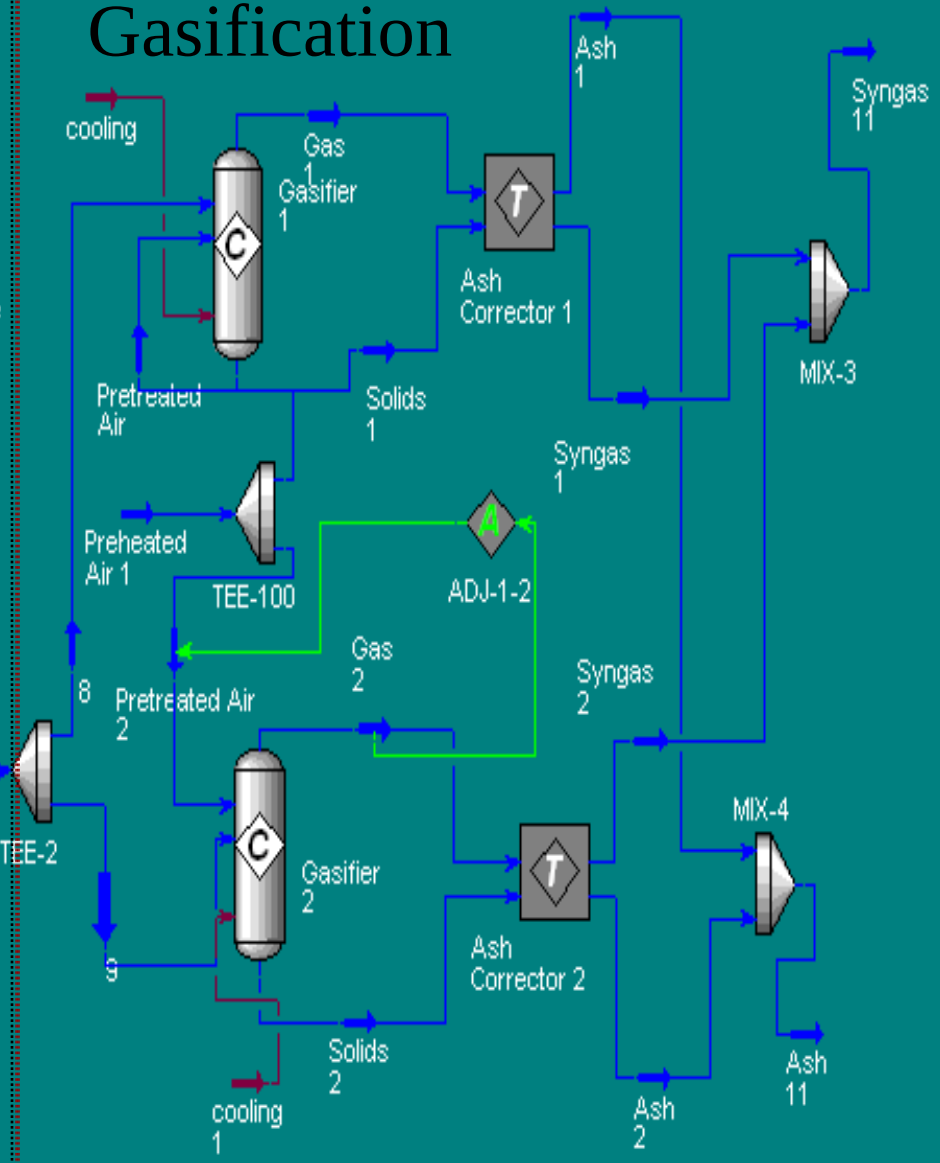
- Design – Fluidized Bed Single Throat Updraft Style

Gasification Design

Pretreatment and Transportation



Gasification

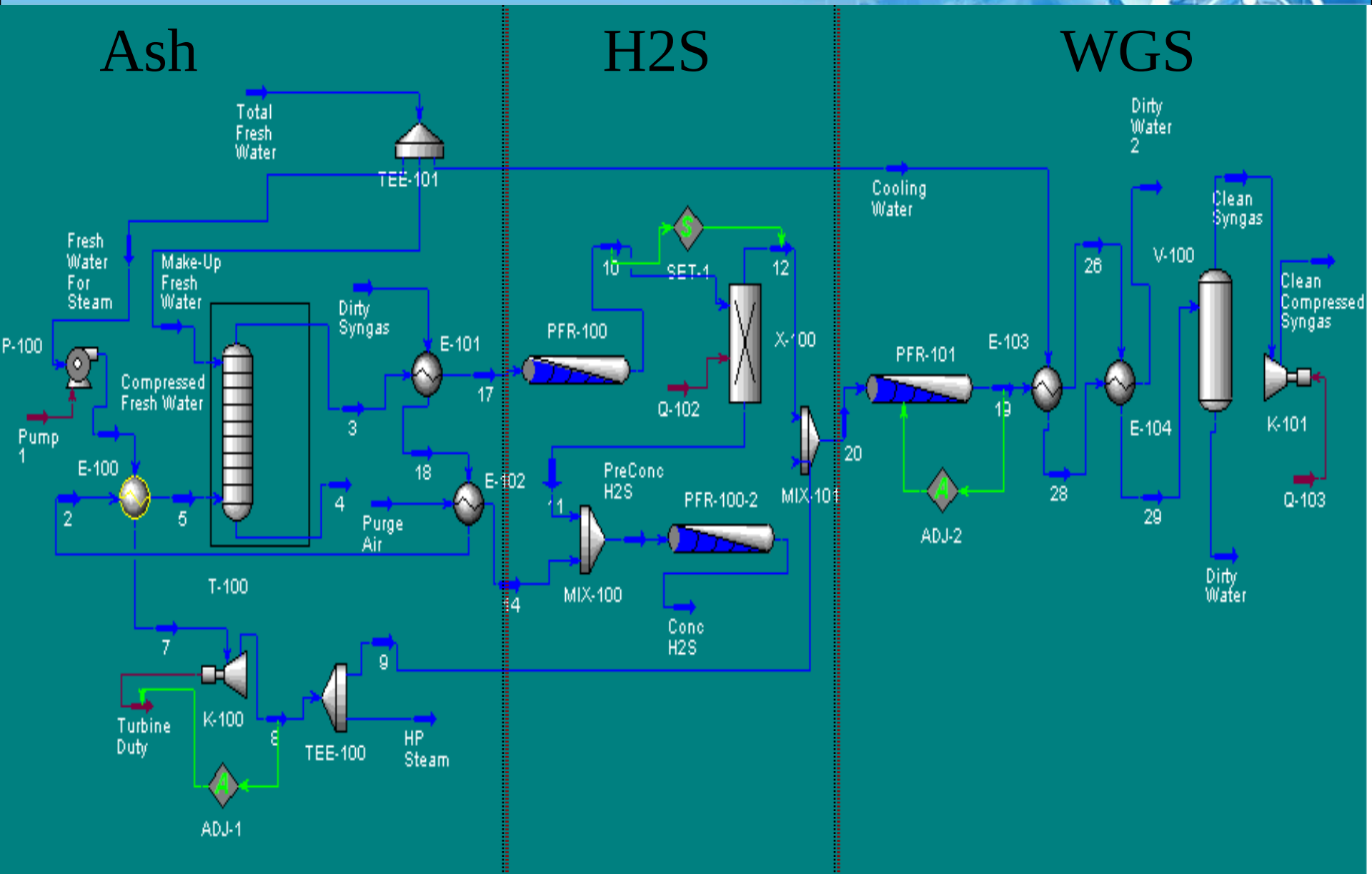


Syngas Purification

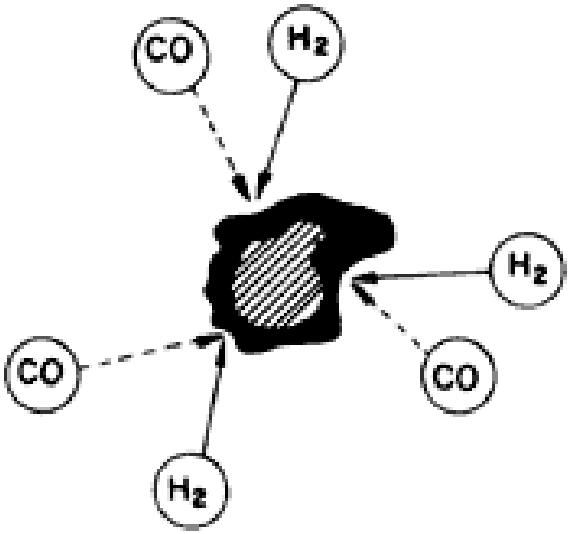
- Ash removal
- Hydrogen Sulfide (H2S) removal
- Water-Gas Shift (WGS) reaction:

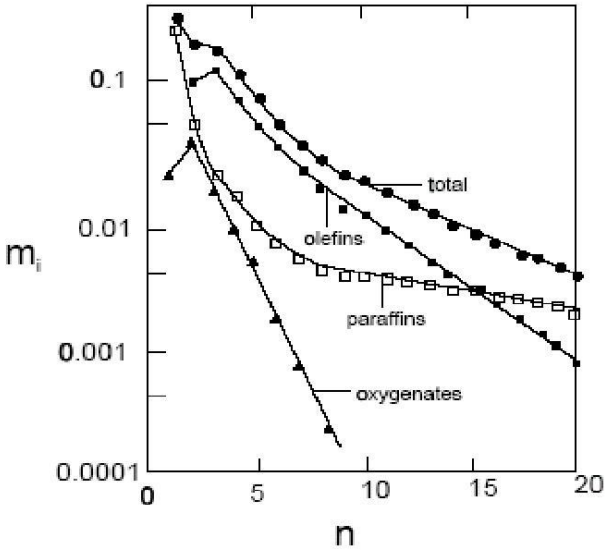
$$CO + H_2O \leftrightarrow CO_2 + H_2$$

Syngas Purification Design



FT Reactor





- In the FT Reactor Hydrogen and Carbon Monoxide combine to form a variety of Hydrocarbons ranging from C1 to C30.

1.Paraffins

$(2n+1)H_2+nCO \rightarrow C_nH_{2n+2}+nH_2O$

2. Olefins $2nH_2+nCO \rightarrow C_nH_{2n}+nH_2O$

3. Water-gas shift $CO+H_2O \rightarrow CO_2+H_2$

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Types of Reactors

- Different types of reactors

-There are currently four different types of FT reactors in commercial use:

-Sasol Circulating Fluidized Bed Reactor
-Sasol Advanced Synthol Reactor
-Tubular Fixed Bed reactor
-Sasol Slurry Phase Distillate Reactor.

-The first two reactors are operated at high temperatures (320^{o}C - 350^{o}C) and are thus called HTFT reactors.

-The latter two are operated at lower temperatures (220^{o}C - 250^{o}C) and are called LTFT reactors.

Basic FT Reactor Model

- For our model we assumed one overall reaction.

  The iron catalyst was chosen based on its low cost, low operating temperature, ability to perform WGS.
- The product distribution in mole percent was based on the carbon number and experimental data of the ratios of alkenes and alcohols to alkanes.

Preliminary Costing

Total Purchase Cost	$78,043,378.
Bare Module Cost for Equipment/Installation	$164,692,757
Direct Permanent Investment	$321,150,876
Total Permanent Investment	$481,726,314
Working Capital	$72,258,947
Total Capital Investment	$553,985,261

Total Capital Investment	$553,985,262
years	10
payment per day	$196,670
Biodiesel Production	8007.6
$ cost per gallon	$25

Conclusion

- Process is feasible
- Project needs further research to actually define the economic viability
- With the increase of cost of oil, the process will become more economically viable
- This process provides a very attractive approach to production of renewable fuels similar to existing oil, coal, and natural gas derivatives.

Future Research

- More accurate gasifier model.
- FT reactor section modeled in Hysys
- More in depth FT reactor model.
- A further refining of the specific type of fuel that will be produced
- More comprehensive cost analysis
  - Comparison to simply burning the syngas

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QUESTIONS

- Niekoo Abbasian (CHE 496)
- Daisy Agose (CHE 296)
- Susanna Arguijo (CHE 496)
- Anthony Ferrese (CHE 296)
- Brian Hogan (CHE 296)
- Minsuk Jung (CHE 296)
- Raisa Pelae (CHE 296)
- Ben Roberts (CHE 296)
- Tor Kyaagba (ECE 347)
- Chris MacDougall (CHE 496)
- Adam Malacina (CHE 496, Team Leader)
- Henry Michael (CHE 296)
- Daniel Demarah (CHE 296)
- Phil Newberg (CHE 496)
- Sarah Ocwieja (CHE 496)
- Julie Patti (MMAE 347)
- Adam Vann (MMAE 347)
- Andrew Keen (CHE 296)
- Hyun Woo (CHE 296)
- Nyah Zarate (CHE 296)