Biofuels – An Overview

RMDZ Zone Works Training Workshop

Sacramento, CA

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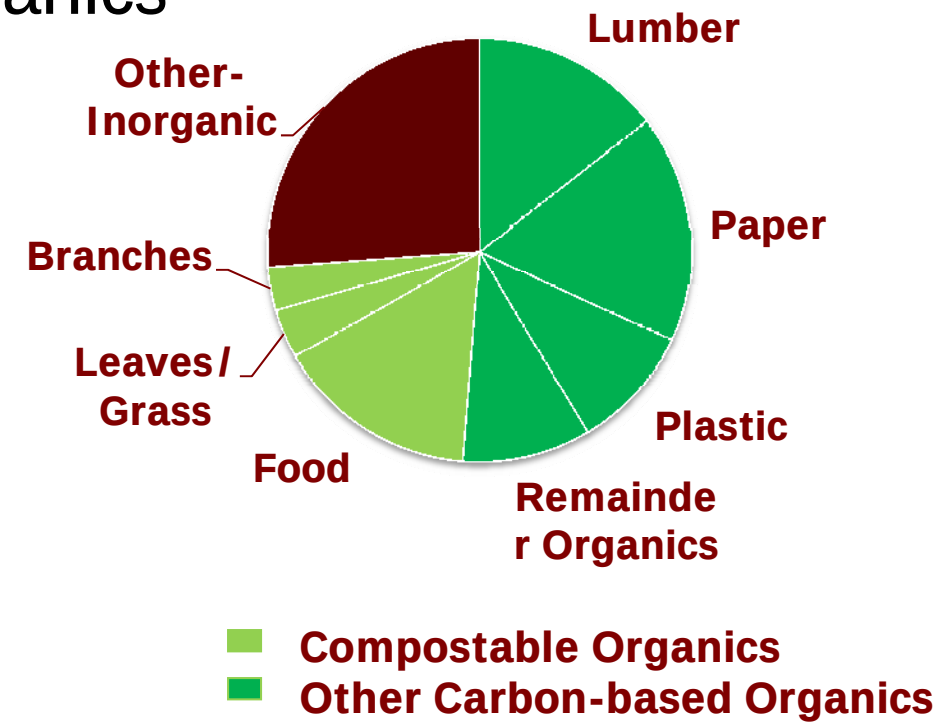
California Integrated Waste Management Board

Current State of California Landfills

- 36 Million tons disposed annually
  - 70% Carbon-based organics
  - 25% is compostable organics
    - 15% is food
  - 17% is paper



Executive Order S-06-06

- Increase production and use of bioenergy, and biofuels from renewable resources
- In-state Production
  - 20 percent - 2010
  - 40 percent - 2020
  - 75 percent - 2050
- 20 percent renewable electricity from biomass

Low Carbon Fuel Standard

- Executive Order S-01-07
- LCFS as Early Action Measure for AB 32
- Reduce fuel carbon intensity – 10% by 2020

Federal Renewable Fuel Standard 2

- Modify National RFS Program
- Increase volume of renewable fuel required blended in gasoline
  - 13 billion gallons in 2010
  - 36 billion gallons by 2022
- LCA of GHG emissions being utilized
- Urban Waste
  - Only yard waste and food waste eligible feedstock
- Final Rule - 2010

RFS2: 4 Separate Stds

Year	Advanced Biofuel			Total Renewable Fuel
	Biomass-Based Diesel	Cellulosic Biofuel	Total Advanced Biofuel	
2006				4.0
2007				4.7
2008				9.0
2009	0.5		0.6	11.1
2010	0.65	0.1	0.95	12.95
2011	0.80	0.25	1.35	13.95
2012	1.0	0.5	2.0	15.2
2013	1.0	1.0	2.75	16.55
2014	1.0	1.75	3.75	18.15
2015	1.0	3.0	5.5	20.5
2016	1.0	4.25	7.25	22.25
2017	1.0	5.5	9.0	24.0
2018	1.0	7.0	11.0	26.0
2019	1.0	8.5	13.0	28.0
2020	1.0	10.5	15.0	30.0
2021	1.0	13.5	18.0	33.0
2022	1.0	16.0	21.0	36.0

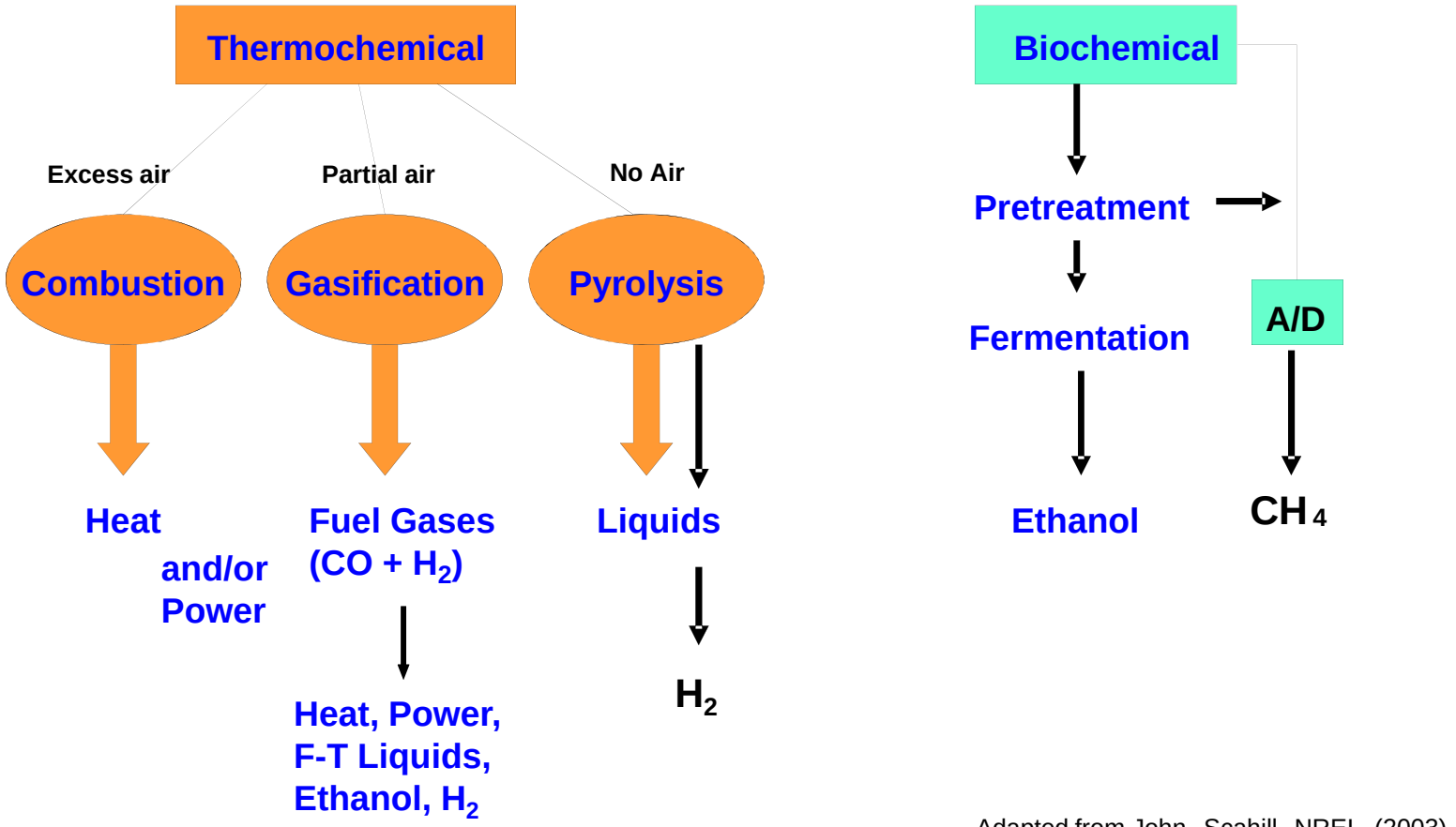
What Are Biofuels

Biofuels

Renewable fuels produced from biomass resources to make *liquid or gas fuel*

- *Ethanol*
- *Biodiesel*
- *Compressed or Liquid Natural Gas*
- *Hydrogen*
- *Dimethyl Ether (diesel-like fuel)*
- *Biobutanol*

Biomass Conversion Pathways and Primary Products



Adapted from John Scahill, NREL. (2003)

CT Major Categories

Biochemical Processes

- Anaerobic Digestion
  - Bacteria breaks down feedstock
  - No oxygen
  - Temp Range: 20^{o} C to 70^{o} C
- Acid or Enzymatic Hydrolysis/Fermentation
  - Also anaerobic process
  - Microbes used to produce ethanol

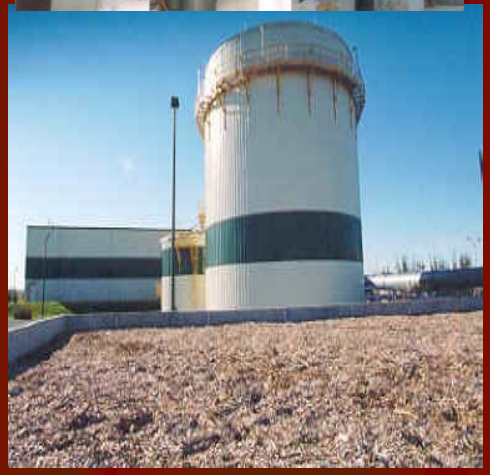
Technology	Primary Product	Secondary Product	Residue
Anaerobic Digestion	Biogas	Heat, Electricity, Fuels, Soil Amendment	Lignin, inorganics
Fermentation	Ethanol	Gypsum	Lignin, inorganics

Biogenic Feedstocks

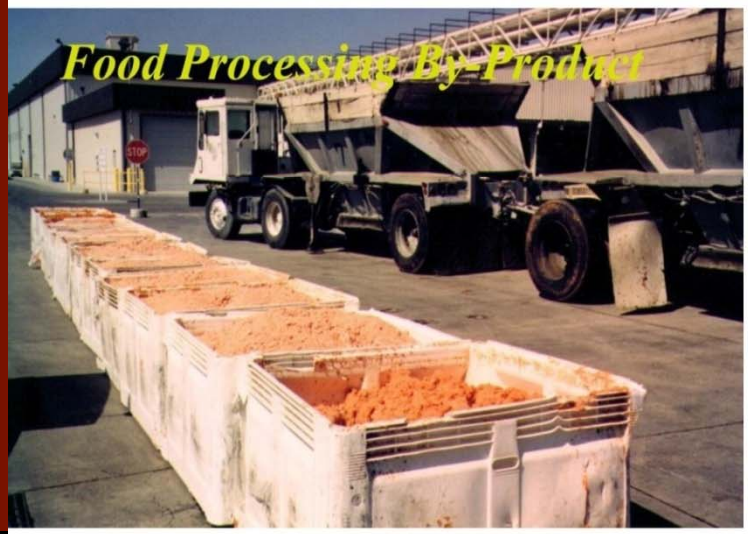
- Plant-derived material
- Cellulose (glucose sugar polymer)
- Hemicellulose (5-carbon sugars)
- Lignin

ANAEROBIC DIGESTION

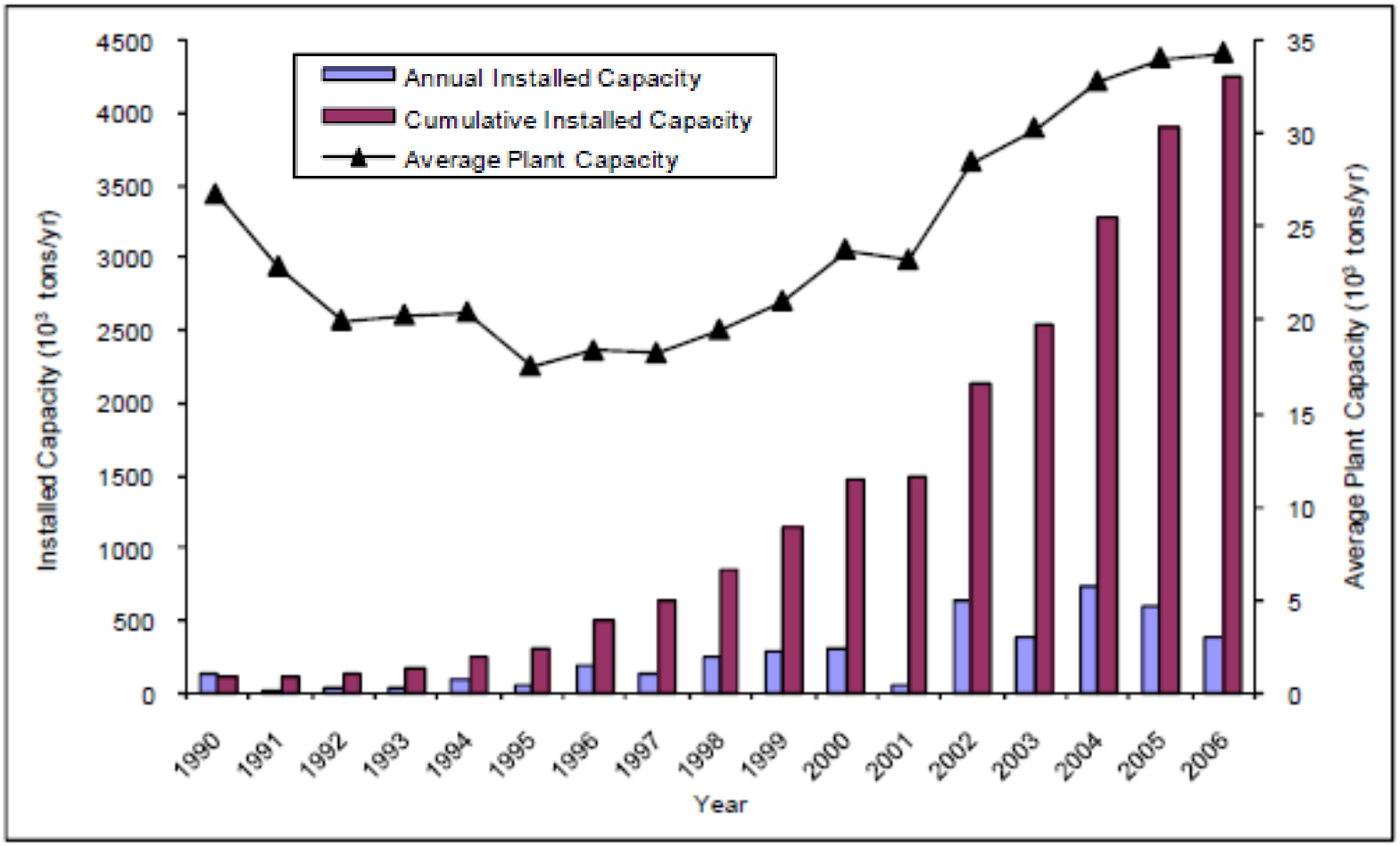
- Bacteria “digest” feedstocks
- Mesophilic or Thermophilic temperatures
- Yields gases and residues
- Gases into electricity
- Residues into fertilizer



Typical Feedstock



AD Capacity in Europe



Source: Contractor Report to the CIWMB: *Current Anaerobic Digestion Technologies Used for Treatment of Municipal Organic Solid Waste*; Zang, et.al. UC Davis, March 2008

California Integrated Waste
Management Board

March 2008

Contractor's Report
To The Board

Current Anaerobic Digestion Technologies Used for Treatment of Municipal Organic Solid Waste

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California Environmental Protection Agency

Hydrolysis/Fermentation

- Breaks cellulosic feedstocks into sugars, then "brews" products
- Uses acid or enzyme pre-treatment
- Yields ethanol, citric acid, other products

Enzymatic Hydrolysis

- Uses fungal enzymes to convert cellulose to simple sugars
- Enzymes can process 6-carbon sugars or 5-carbon sugars but not both
- Sugars fermented by yeast (like making WINE!!!)

The Original Hybrid Car??

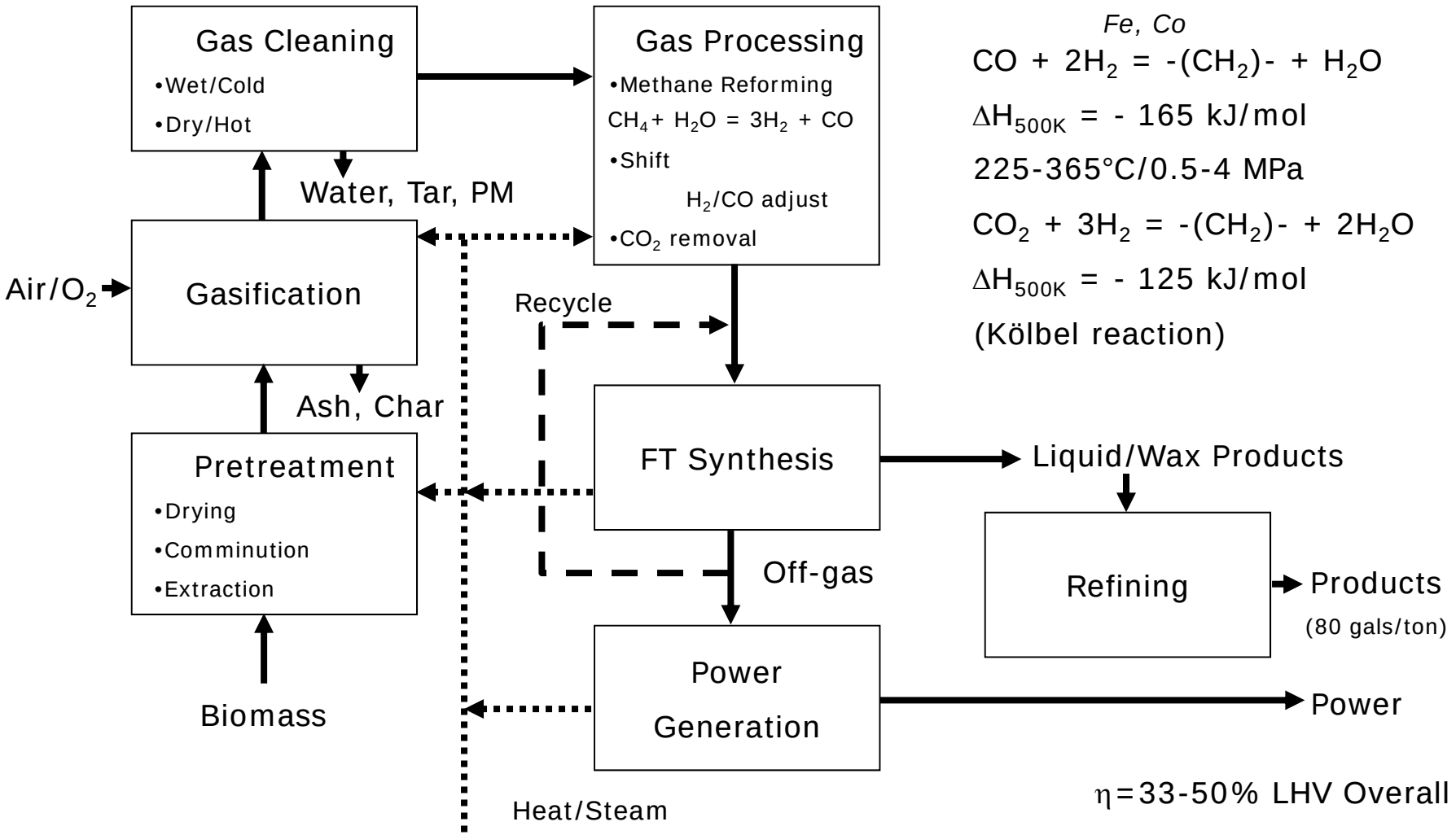
Biofuels/Bioenergy Production

Thermochemical Processes

- Pyrolysis
  - Very little air/oxygen added or none at all
  - 750^{o} F to 1500^{o} F
- Gasification
  - Some air/oxygen used but less than for incineration
  - Begins at 1300^{o} F

Technology	Primary Product	Secondary Product	Residue
Gasification	Fuel Gas Synthesis Gas	Fuels, Chemicals, Power	Char, Ash
Pyrolysis	Fuel Gas Synthesis Gas Pyrolytic oils	Fuels, Chemicals, Power	Char, Ash

BTL: Biomass To Liquids



Fischer-Tropsch Synthesis

Fe, Co

$CO + 2H_2 = -(CH_2)- + H_2O$

$\Delta H_{500K} = -165$ kJ/mol

225-365°C/0.5-4 MPa

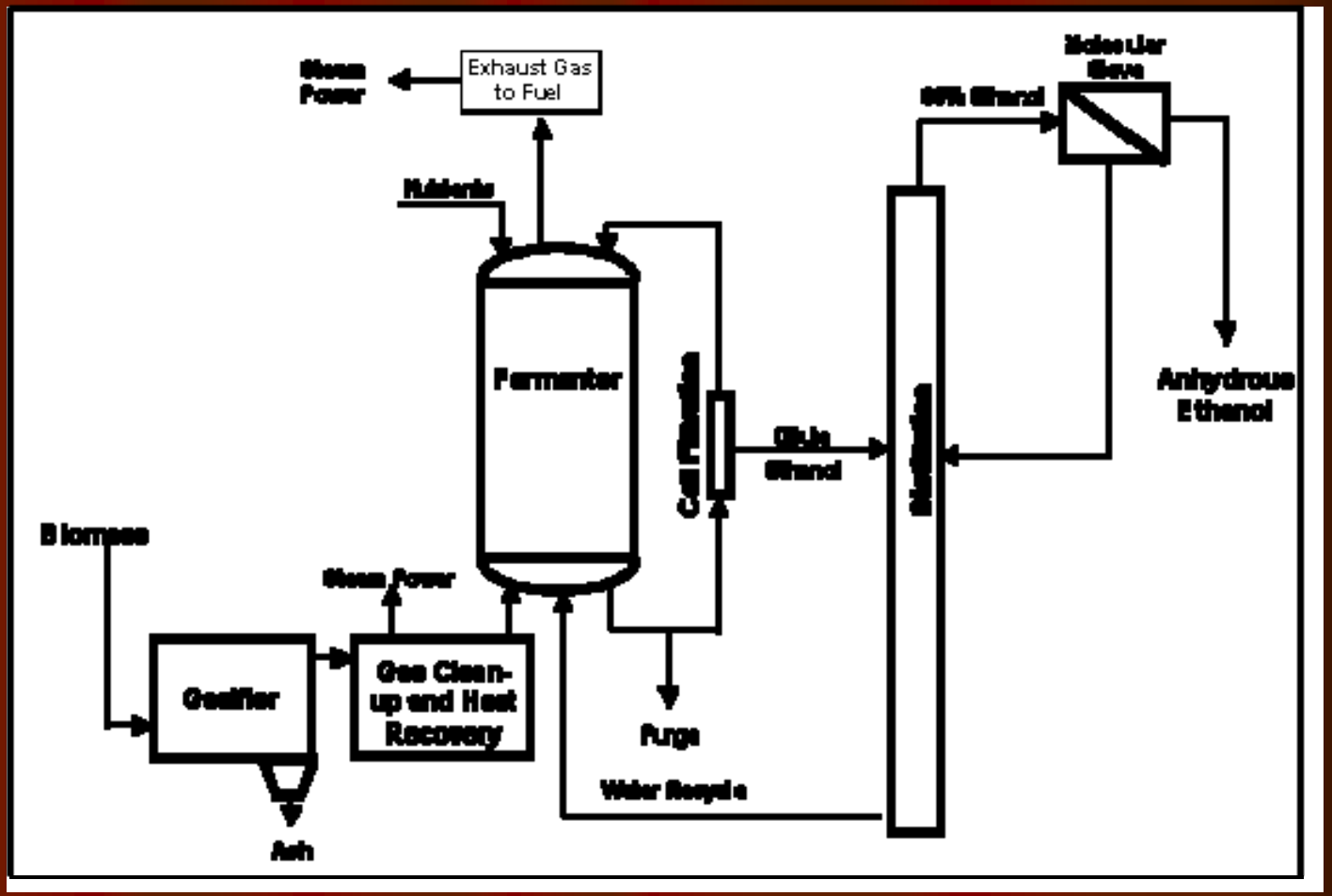
$CO_2 + 3H_2 = -(CH_2)- + 2H_2O$

$\Delta H_{500K} = -125$ kJ/mol

(Kölbel reaction)

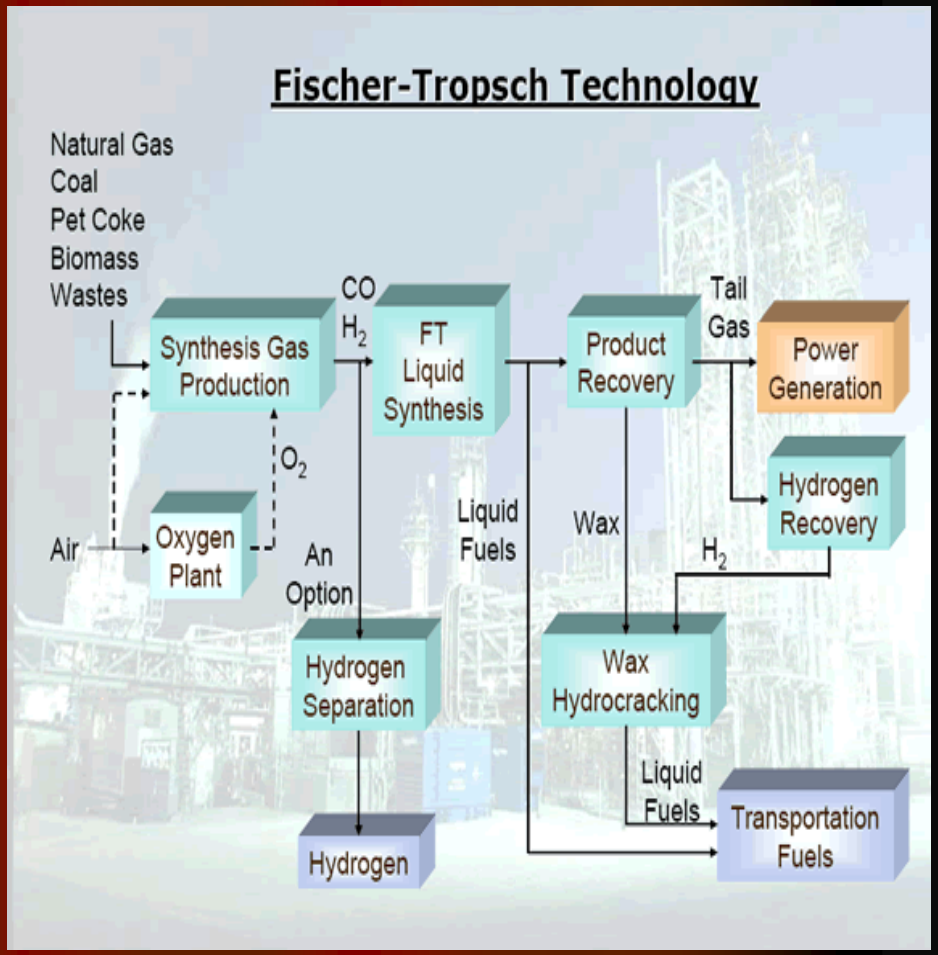
η=33-50% LHV Overall

Hybrid Gasification System



Fischer-Tropsch Synthesis

- Catalyst reaction
  - Iron or cobalt
  - Iron preferred for biomass-derived syngas
- Temp range: 300-570^{o} F
- Used to produce biofuels



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