The Solutions Network

Rochester, New York

An Introduction to Technology Pathways Used in the Production of Transportation Biofuels

Andrew Helminger

RTI International

August 10, 2004

Presentation Overview

- Background on transportation biofuel work performed by RTI for the Environmental Protection Agency (EPA)
- Description of selected resources and conversion technologies required to produce these biofuels
- Benefits/potential issues that may influence how transportation biofuels compete with fossil fuels

Background on EPA Work

"Development of Input Data for Analyses of Potential Biofuels for Transportation"

Project for EPA's Air Pollution Prevention and Control Division

- **Stage 1**: RTI identified biofuel technology pathways (other than hydrogen production) for EPA

Technology Pathway Defined

- **Input Resource** (e.g., energy crops such as corn)
- **Conversion Technology** (e.g., fermentation to ethanol using microbes)
- **Energy Carrier** (e.g., ethanol)
- **Demand Technology** (e.g., spark-ignition internal combustion engine)

Biofuel Pathways Explored for EPA

Input Resources	Conversion Technology	Products	
		Fuel (Energy Carrier)	**Potential Coproducts**
Energy Crops → OR Residues →	Fermentation →	Ethanol	Distillers Dried Grain w/Solubles Electricity
Energy Crops (Oil-Seed Crops) → OR Animal Fats/Grease →	Transesterification (Chemical Conversion) →	Biodiesel	Glycerin Oil-Seed Meal
Energy Crops (Woody Crops) →	Fisher-Tropsch (w/ Gasification) →	Green Diesel	Electricity
Energy Crops (Woody Crops) →	Thermochemical Conversion (w/ Gasification) →	Methanol	Electricity

Background on EPA Work

"Development of Input Data for Analyses of Potential Biofuels for Transportation"

Project for EPA's Air Pollution Prevention and Control Division

- **Stage 1**: RTI identified biofuel technology pathways (other than hydrogen production) for EPA
- **Stage 2**: RTI collected data on pathways for EPA to use in modeling applications

Data Collected for EPA

Conversion Technologies:

- Investment costs
- Operating and maintenance costs
- Process efficiency
- Start year
- Technology lifetime

Input Resources:

- Market prices
- Production costs
- Transportation costs

EPA's Modeling Efforts — MARKAL

- Data from literature will be fed into the MARKAL (Market Allocation) model
- The model analyzes energy, economic, and environmental data for various technology pathways
- The model allows for assessment of pathways when key parameters are changed (e.g., resource availability, regulations, technology stage of development)
- MARKAL will help evaluate how alternative fuel technology pathways can compete over the long term (50 years) with fossil fuel production

Pathway #1: Ethanol via Fermentation

- Commercially well-established—in practice since the late 1970s
- Most common automotive biofuel conversion technology in the United States
- 7% of the U.S. corn crop used to produce ~1%–2% of the total automotive fuel supply
- ~2 billion gallons of ethanol produced annually from corn starch in the United States (3.2 B gal/yr produced from sugarcane in Brazil)
- Typically blended with gasoline (e.g., E85)
- Approximately 150 stations in 23 U.S. states

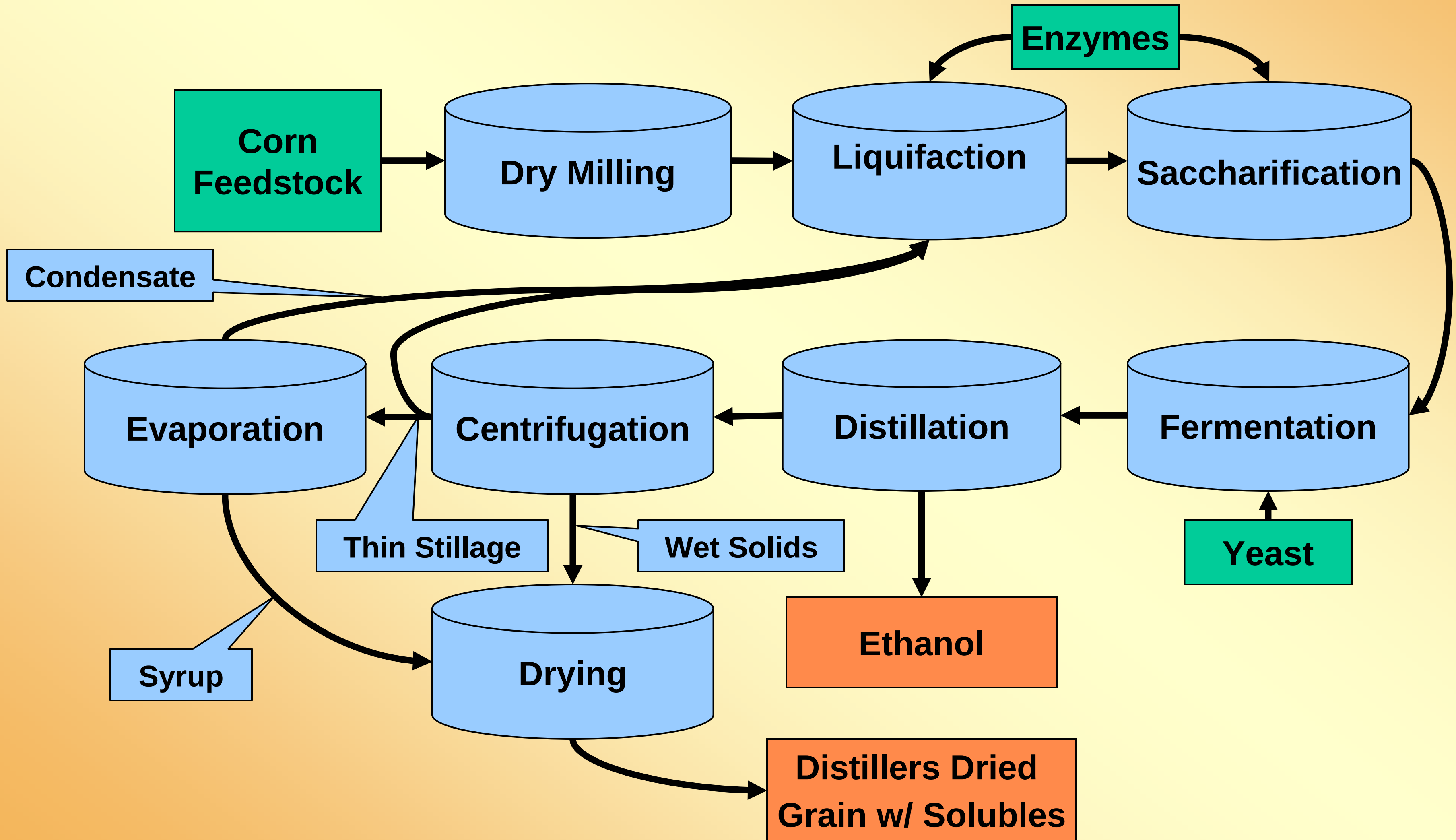
Ethanol via Fermentation – Resource Inputs

Starch Crops
- Corn
- Barley
- Wheat

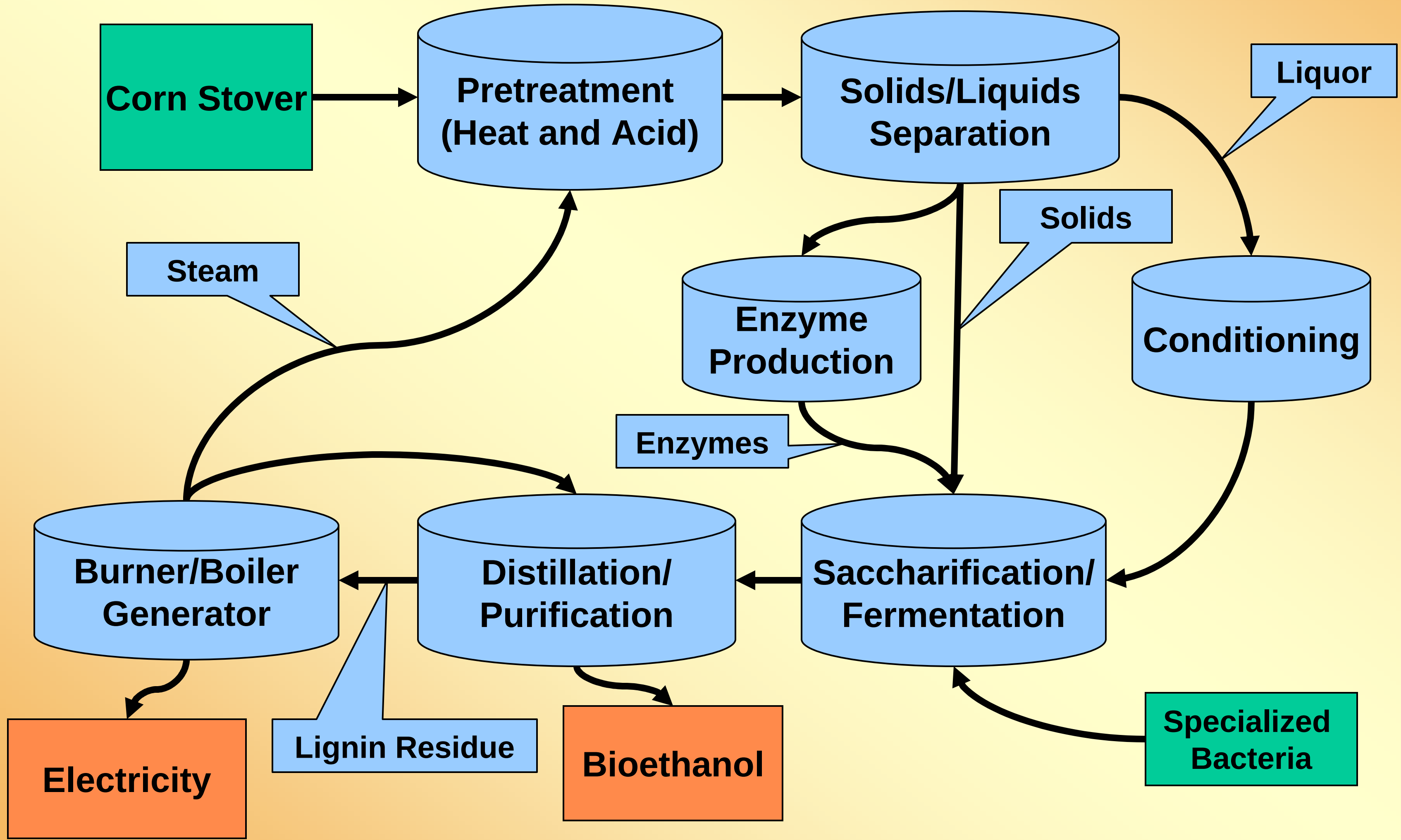
Cellulosic Crops
- Grasses
- Trees

Crop Residues
- Corn stover

Ethanol via Fermentation with Dry-Milled Corn



Ethanol via Fermentation with Corn Stover



Ethanol via Fermentation Investment Costs

Facility Type	Capacity (gal/yr)	Investment Cost	Normalized Cost (per M-gal of capacity)	Source
Corn to Ethanol	25 M	$27.9 M	$1.1 M	McAloon et al., 2000
Corn Stover to Ethanol	25 M	$136.1 M	$5.4 M	McAloon et al., 2000
Corn Stover to Ethanol	295 M	$268.4 M	$0.9 M	Lynd, 1996

Ethanol via Fermentation Production Costs

Pathway Type*	Feedstock Costs	Other Production Costs	Coproduct Credits	Total
Corn to Ethanol	$17.0 M/yr	$12.1 M/yr	–$7.1 M/yr (DDGS)	$22.0 M/yr
Corn Stover to Ethanol	$12.1 M/yr	$28 M/yr	– $2.8 M/yr (Electricity)	$37.3 M/yr
*Assumes a capacity of 25 M gal/yr of ethanol. Source: McAloon et al. (2000)				

Ethanol via Fermentation Benefits

- Coproduct credits can help offset costs
- Potential use of waste products as resource input
- Ethanol use can reduce air pollution (ozone)
- Ethanol use can reduce dependence on toxic octane boosters such as benzene, toluene, and xylene
- Ethanol is less explosive than gasoline during an accident

Ethanol via Fermentation Potential Issues

- Food crops are currently used as a resource input (ethical issue)
- Question of whether input crops could ever sustain pathway as a primary fuel provider
- Conventional gasoline engines can only operate on gasoline/ethanol blends up to 10% ethanol (E10)

Pathway #2: Biodiesel via Transesterification

- Used at the commercial scale in Europe since the late 1980s
- 60M–80M-gallon dedicated capacity in United States
- 22 U.S. states have public biodiesel stations
- Stand-alone vs. vertically integrated facilities

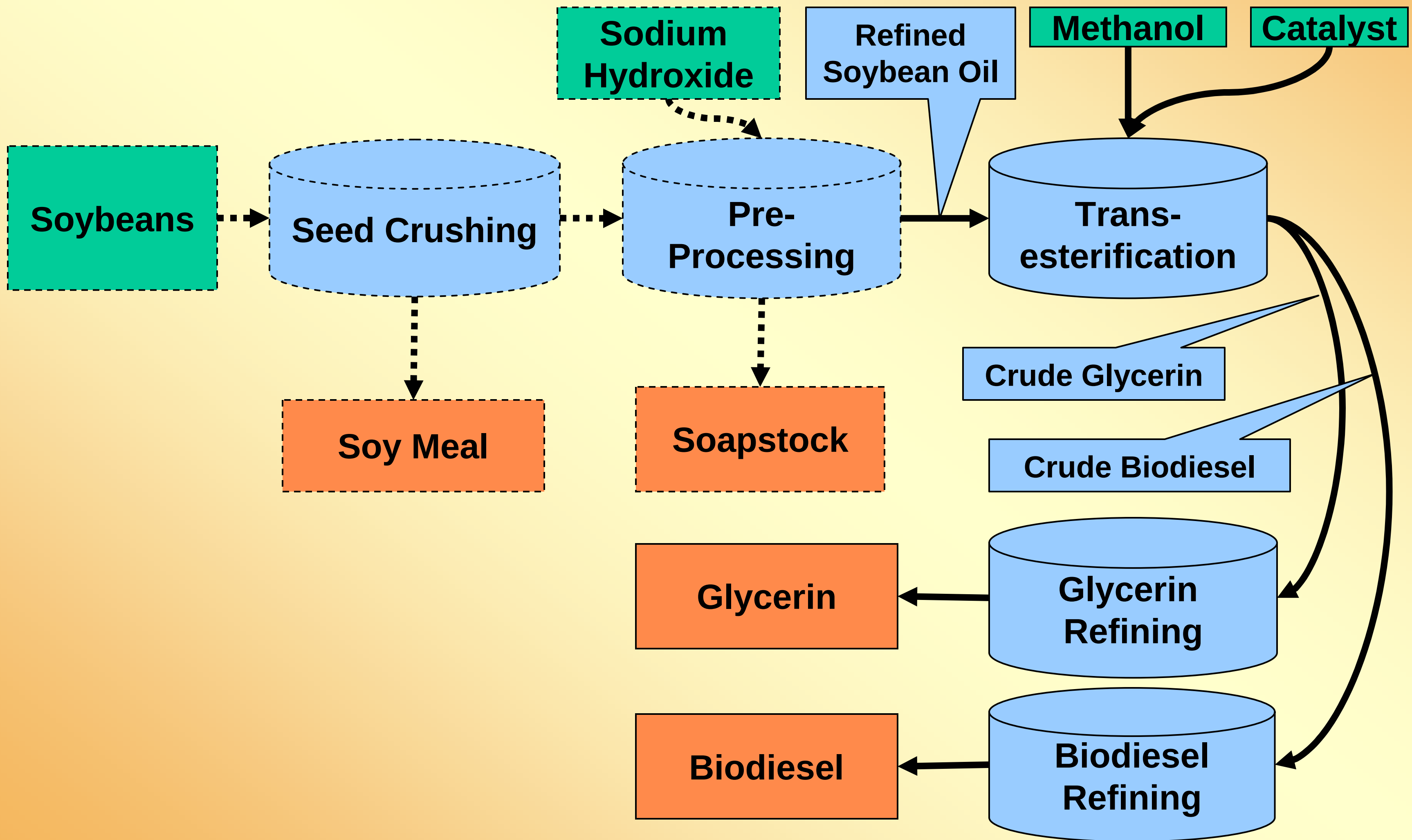
Biodiesel via Transesterification Resource Inputs

Vegetable Oils
- Soybean
- Rapeseed
- Canola

Waste Oils
- Yellow grease

Animal Fats
- Tallow
- Lard
- Poultry fat

Biodiesel via Transesterification with Soybeans



Biodiesel via Transesterification Investment Costs

Facility Type	Capacity (gal/yr)	Investment Cost	Normalized Cost (per M-gal of capacity)	Source
Stand-Alone Facility for Soybeans	13 M	$ 18.8 M	$1.4 M	AIM-AG et al., No date
Vertically Integrated Facility for Soybeans	13 M	$ 37.6 M	$2.9 M	AIM-AG et al., No date
Stand-Alone Facility for Vegetable Oil (Europe)	16.5 M	$35 M	$2.1 M	USDA, 2003b

Biodiesel via Transesterification Production Costs

- Stand-alone (13 M gal/yr): $14.2 M in feedstock costs (soybeans oil) + $5.7 M in other processing costs = ~$19.9 M/yr in production costs
- Stand-alone coproduct credit for glycerine of $7.4 M, so adjusted production costs are $12.5 M
- Vertically integrated facilities have higher operating costs than stand-alone because of added costs associated with seed crushing unit
- Vertically integrated facilities have additional coproduct credits (for meal and soapstock)
- One source indicated that production costs are potentially higher in Europe

Biodiesel via Transesterification Benefits

- Coproduct credits can offset costs
- Potential use of waste products as resource input
- Biodiesel is generally compatible with current storage and handling infrastructure
- Safer to handle—less combustible and less toxic than petro-diesel
- Reductions in most air pollutants

Biodiesel via Transesterification Potential Issues

- Use of biodiesel blends (B20), and especially pure biodiesel (B100), may require some engine modification to prevent performance and maintenance issues
- Increases in nitrogen oxide emissions

Pathway #3: Green Diesel via Fischer-Tropsch (F-T)

- Green diesel vs. biodiesel
- F-T process is used commercially to produce petroleum diesel from gasified coal or natural gas
- No commercial applications currently exist that use biosyngas
- The Netherlands is actively pursuing research in this area

Green Diesel via F-T Resource Inputs

Woody Crops

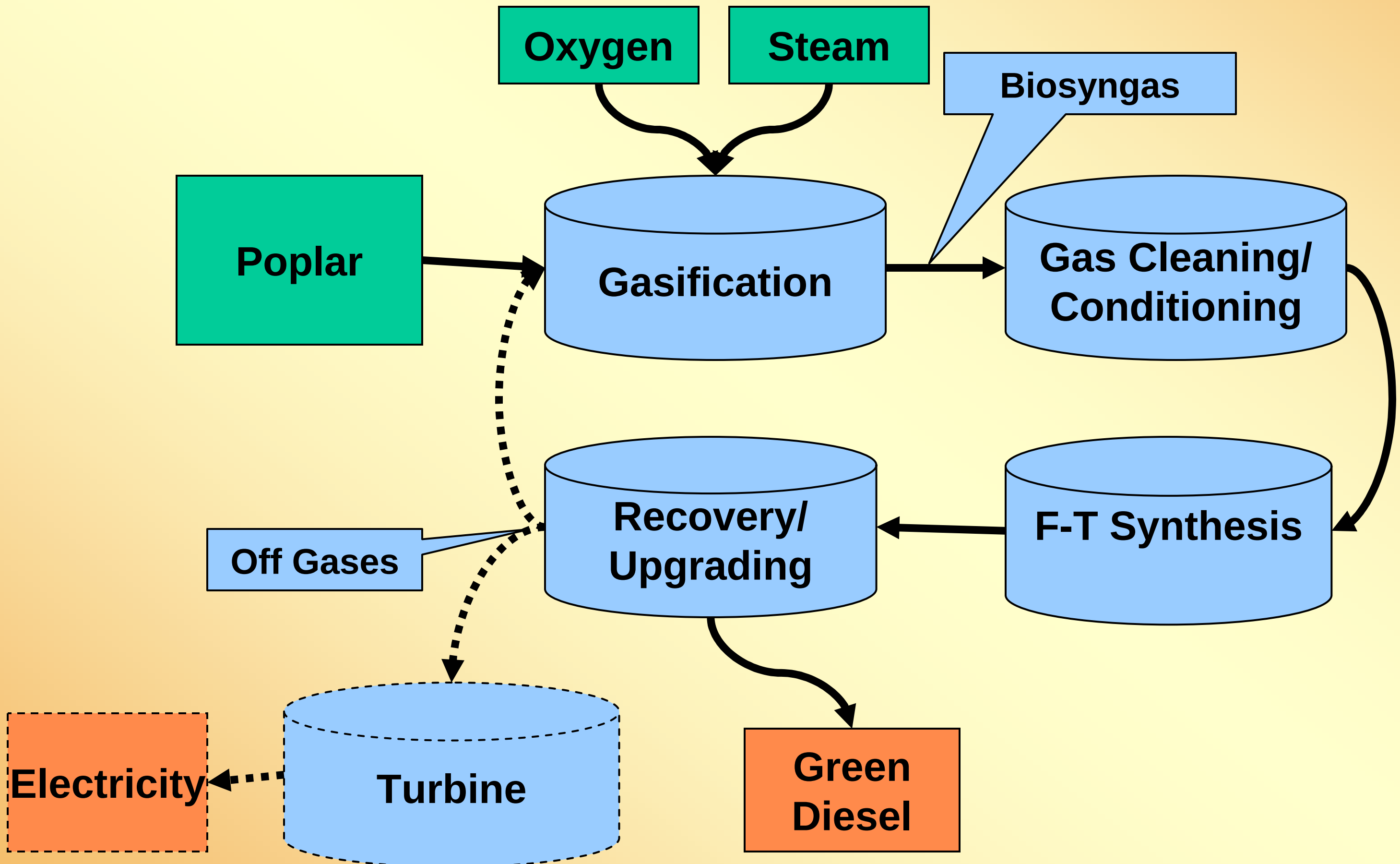
- Poplar
- Willow

Wood Wastes/Residues

Fossil Inputs (F-T Diesel)

- Natural gas
- Coal

Green Diesel via F-T with Poplar



Green Diesel via F-T Investment/Production Costs

- Investment costs of $335 M for a ~29M-gal/yr plant
- Pretreatment, gasification, and gas-cleaning stages account for ~75% of total investment costs for an F-T plant with biomass gasification
- Feedstock costs (for poplar) of >$42 M/yr for a ~29M-gal/yr plant
- Other production costs of $22.2 M/yr to $23.9 M/yr for a ~29M-gal/yr plant
- Electricity credits could offset production costs
- Over the short term, production costs for green diesel appear to be about four times the cost of petroleum diesel

Green Diesel via F-T Benefits

- Electricity as a coproduct
- Potential use of waste products as resource input
- Generally compatible with current storage and handling infrastructure
- Safer to handle—less combustible and less toxic than petro-diesel
- Reductions in most air pollutants

Green Diesel via F-T Potential Issues

- Removing tar is currently the most critical step of the F-T pathway when using biosyngas
- Unproven commercially (stage-of-development issues)
- F-T green diesel may prove to be more expensive than methanol or hydrogen

Pathway #4: Methanol via Thermochemical Conversion

- Methanol (wood alcohol) as a chemical commodity vs. fuel
- Natural-gas-to-methanol (i.e., fossil fuel) plants well-established commercially
- 90 natural-gas-to-methanol plants worldwide (annual capacity of more than 11 B gallons)
- 18 methanol production facilities in the United States, with an annual capacity of up to 2.6 B gallons
- Biomass-to-methanol plants not yet commercial
- One source predicts commercial-scale biomass plants online by 2010

Methanol via Thermochemical Conversion

Woody Crops

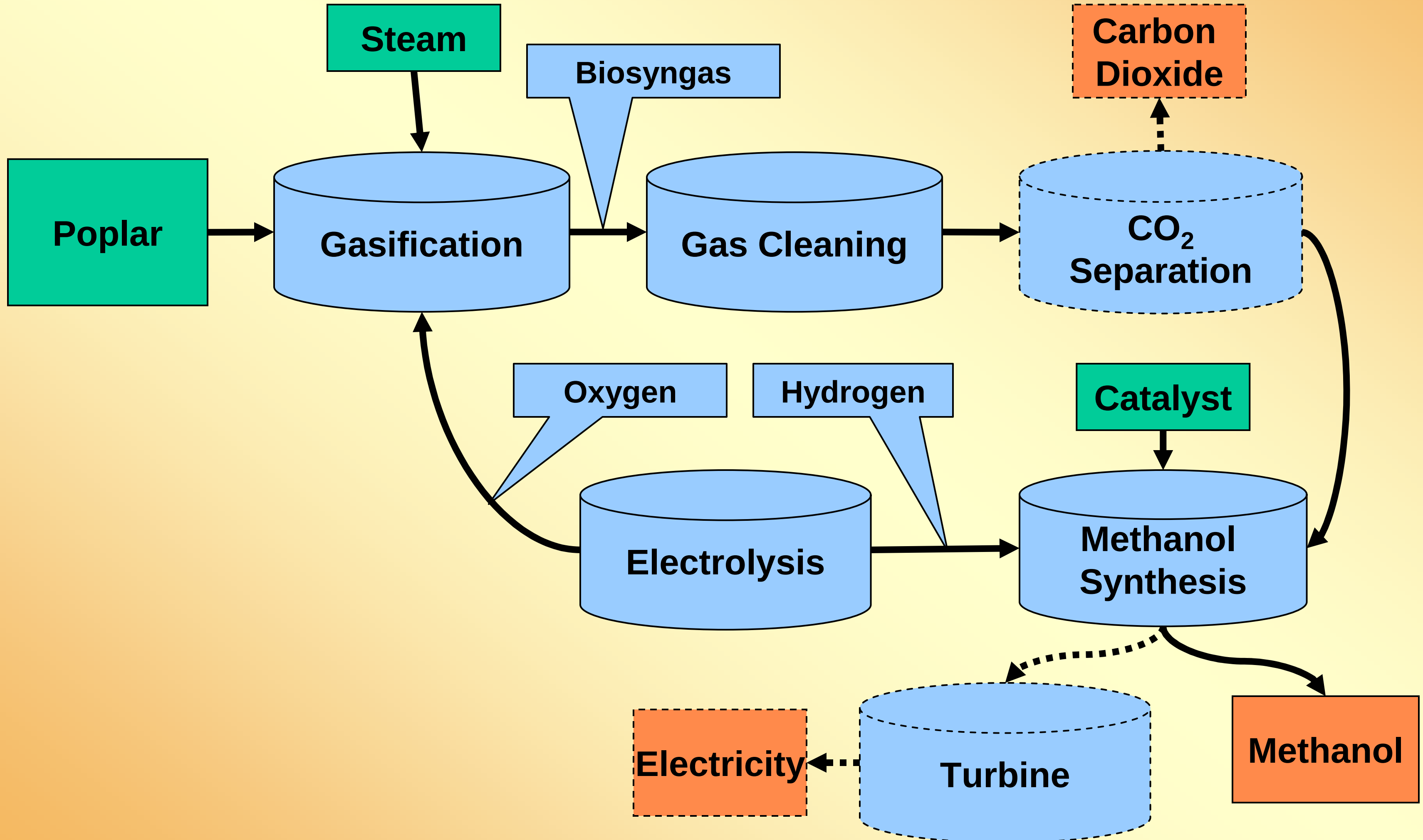
- Poplar
- Willow

Wood Wastes/Residues

Fossil Inputs

- Natural gas
- Coal

Methanol via Thermochemical Conversion with Poplar



Methanol via Thermochemical Conv. – Investment/Prod. Costs

- Little cost data on biomass-to-methanol plants
- One source indicated capital costs of $15.4 M to $24 M for a plant with a capacity of 25–50 tons of methanol per day (depending on plant configuration)
- Capital costs are approximately 3 to 7 times higher than for natural-gas-to-methanol plants
- No data found for production costs

Methanol via Thermochemical Conversion – Benefits

- Electricity as a coproduct
- Potential use of waste products as resource input
- M85 vehicles produce 40% less CO and NOx vs. vehicles running on reformulated gasoline
- Methanol is less explosive than gasoline during an accident

Methanol via Thermochemical Conversion – Potential Issues

- Biomass-to-methanol process is unproven commercially (stage-of-development issues)
- Methanol fuel is not currently in widespread use
- Expense associated with retrofitting refueling stations for methanol
- High levels of formaldehyde in emissions

Acknowledgments

Carol Shay and Julian Jones
from EPA's Air Pollution
Prevention and Control Division

Mark Bahner, Camille Heaton, Keith Weitz, Bill White, and Alexandra Zapata
from RTI who contributed to this work