

# Task 4A

## Co-Production Analysis

Mark Laser (Co-Leader)  
Thayer School of Engineering  
Dartmouth College

*The Role of Biomass in America's Energy Future*

Public Meeting  
Washington, D.C.  
February 23, 2004



# Objectives

1. Evaluate potential economic and resource efficiency/environmental benefits for several combinations of co-products
2. Determine the extent to which economic and environmental benefits converge
3. Analyze the impact of maturing technology on co-production

*Consider co-production in the context of :*

- *Processing (this presentation)*
- *The field (Bruce Dale)*

# Potential Co-Products from Cellulosic Biomass

## Gaseous Fuels, e.g.:

- Hydrogen
- Methane

## Liquid Fuels, e.g.:

- Ethanol
- Methanol
- Fischer-Tropsch Liquids
- Dimethyl Ether
- Pyrolysis Oils
- Plant Oils/Biodiesel

## Solid Fuels, e.g.:

Charcoal



→ Electricity

→ Steam

→ Organic Chemicals, e.g.:

- Lactic Acid
- Succinic Acid
- Adhesives
- Phenol

→ Animal Feed Protein

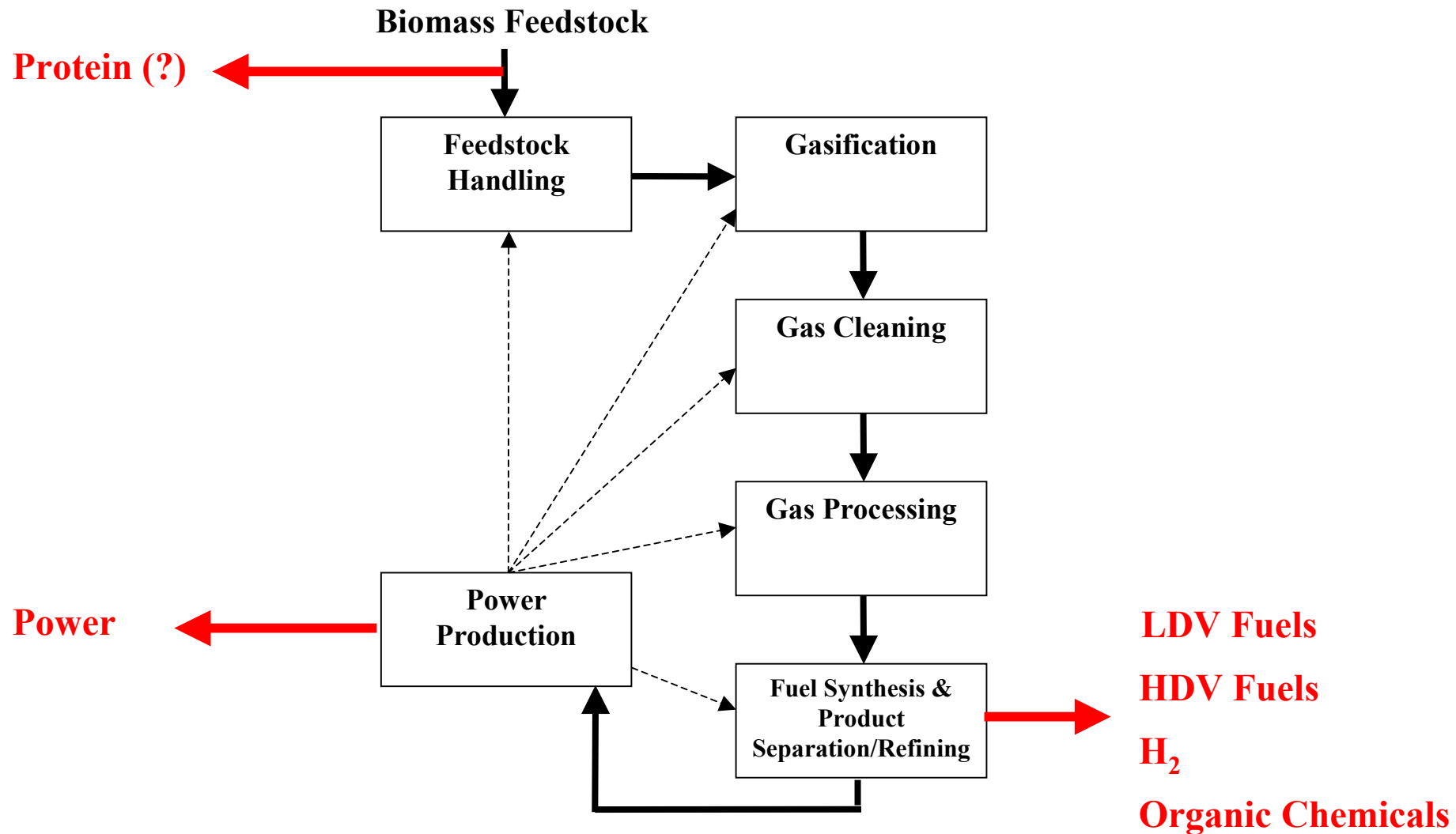
Lubricants

Biomaterials, e.g.:

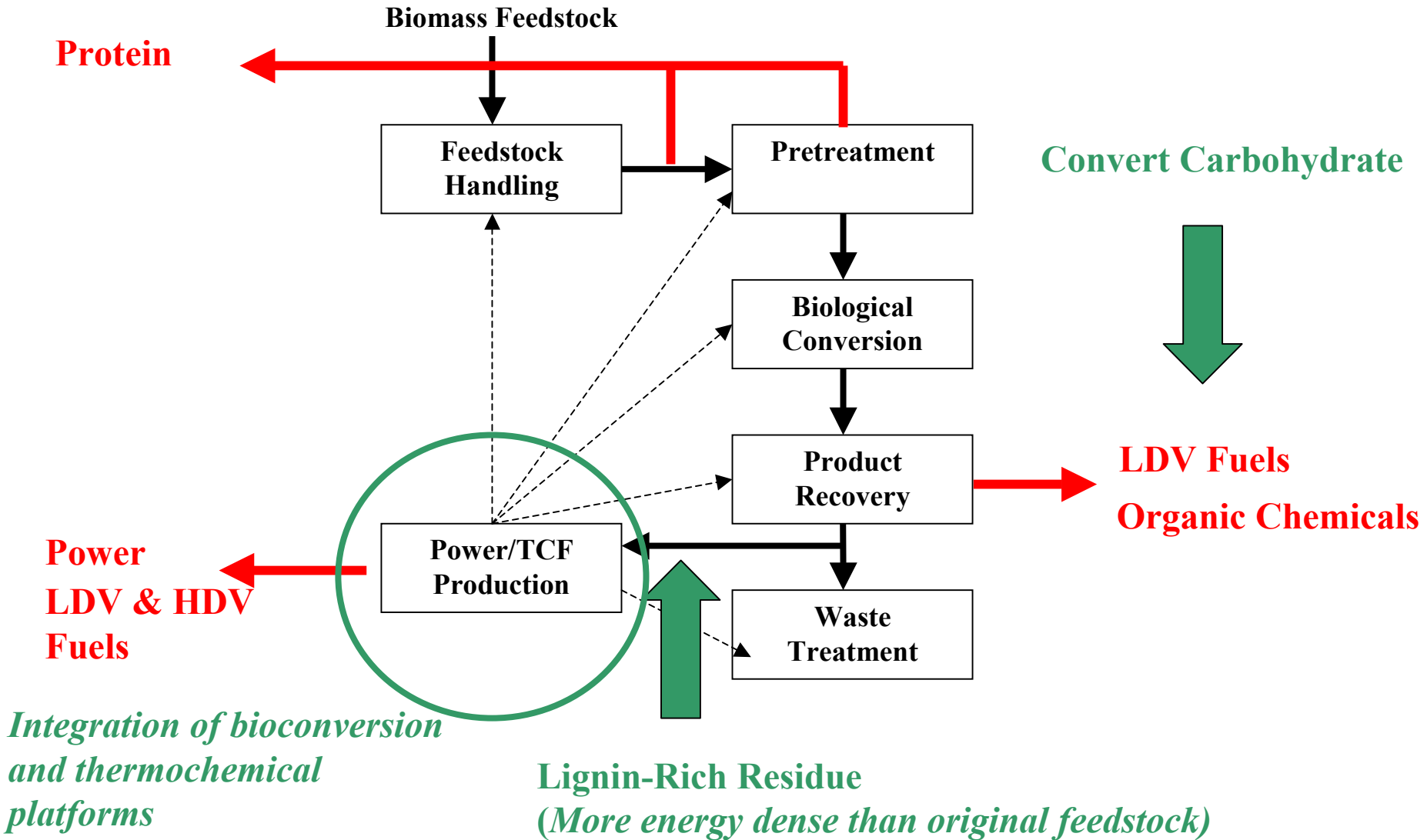
- Insulation
- Composites

Fertilizer

# Thermochemical Conversion Platform



# Bioconversion Platform



# Co-Production Scenarios

SCENARIO	Biopower	Bioethanol	H <sub>2</sub>	TCF	Organic Chemicals	Protein
1	X		X			
2	X	X				
3	X	X	X			
4	X	X	X		X	
5	X	X				X
6	X	X			X	
7	X	X			X	X
8	X		X			X
9	X			X		
10	X	X		X		
11	X	X		X	X	
12	X			X		X

*By no means comprehensive...*

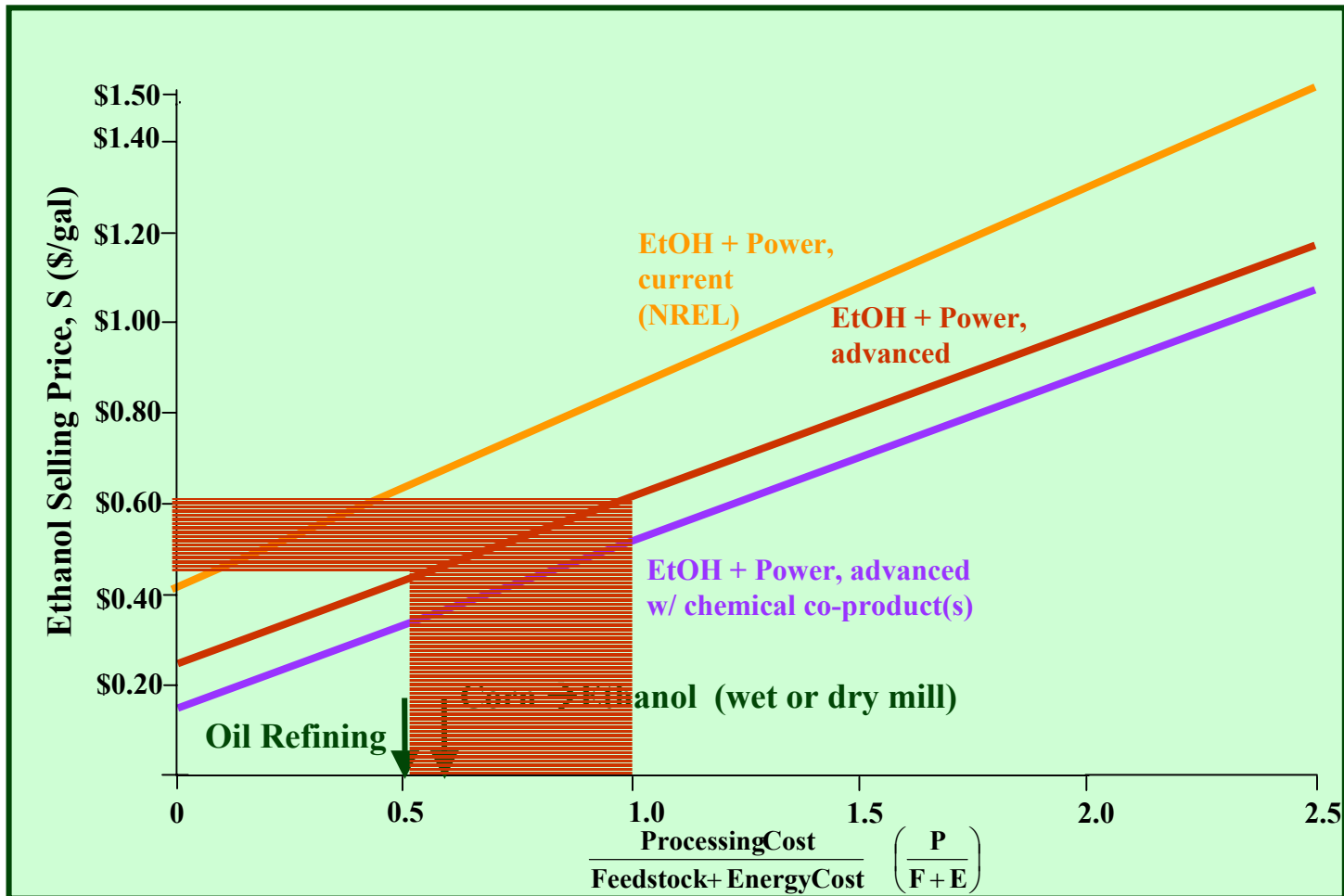
*But, provides a broad range of product categories that have potential for enabling a large-scale transition to biomass-based energy use in the U.S.*

# Potential Co-Production Benefits

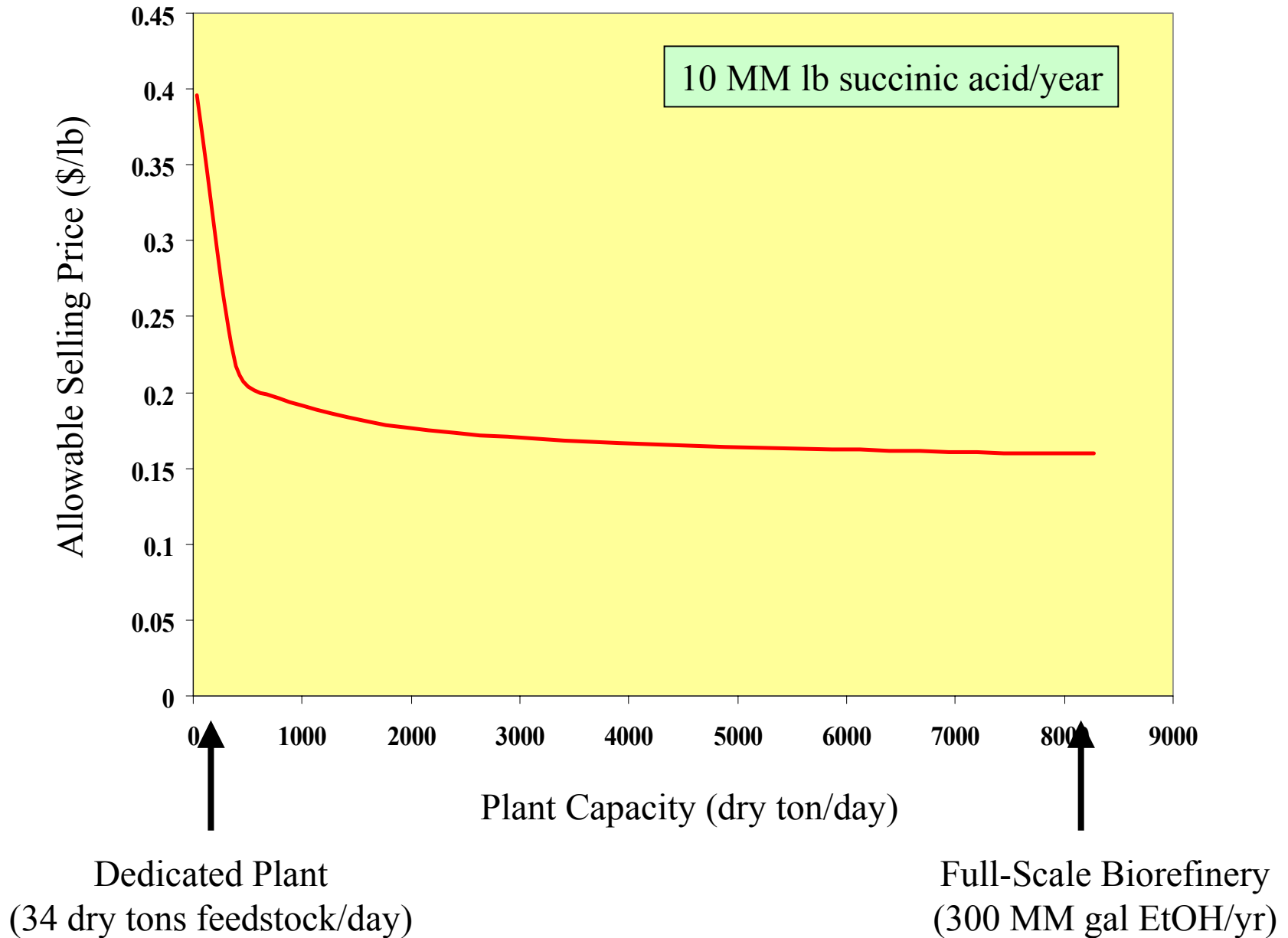
- Revenues from high-value co-products reduce the selling price of primary product
- Economies of scale provided by full-size biorefinery lowers processing costs of low-volume, high-value co-products
- Process yield increases due to:
  - 1) Use of all component fractions of biomass feedstock
  - 2) Process integration synergies

**which enhances both economic and environmental benefits**

# Potential Benefit to Primary Product Price



# Potential Benefit to Co-product Price

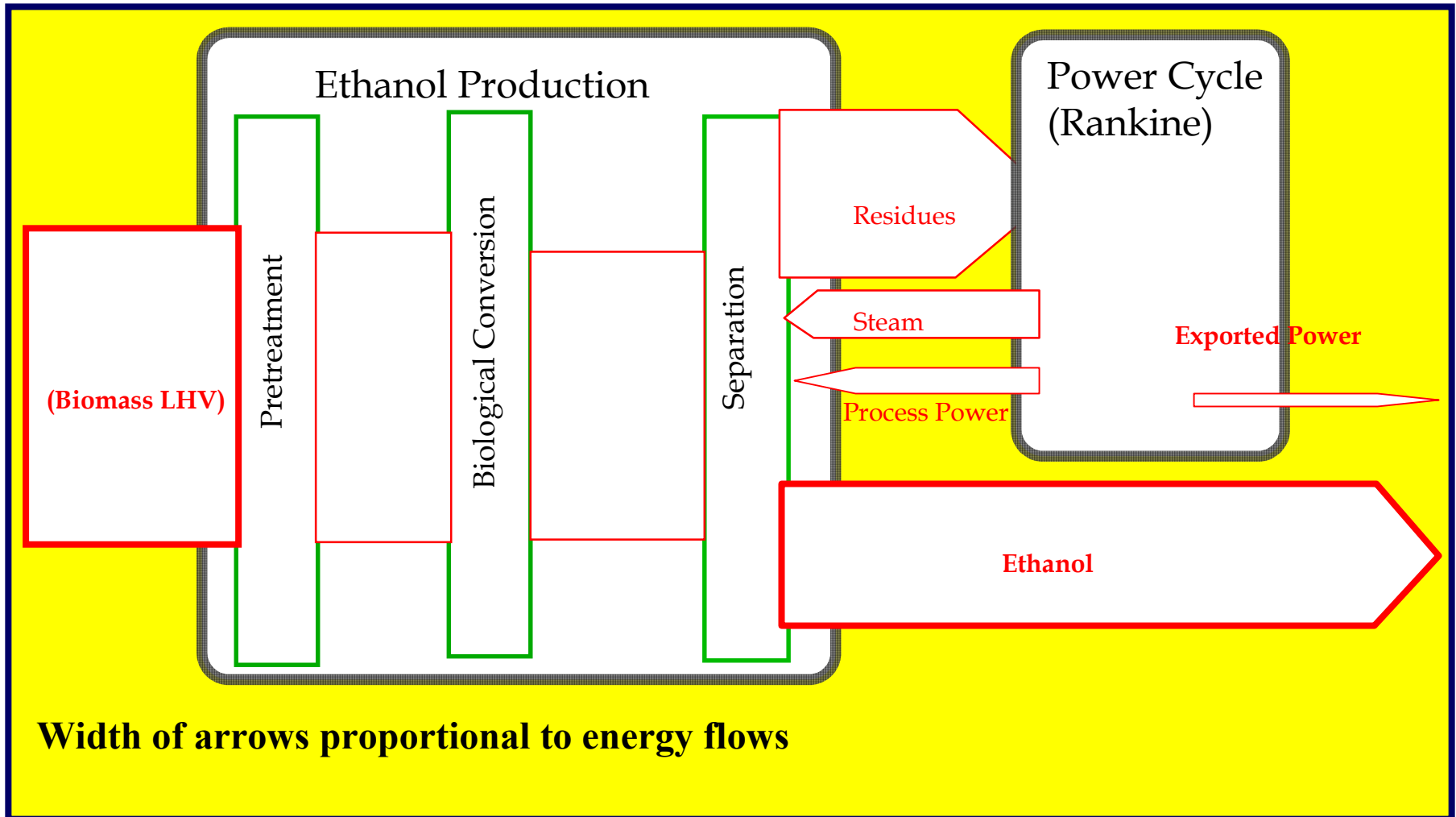


# Benefits of Technology Maturation: Power Generation

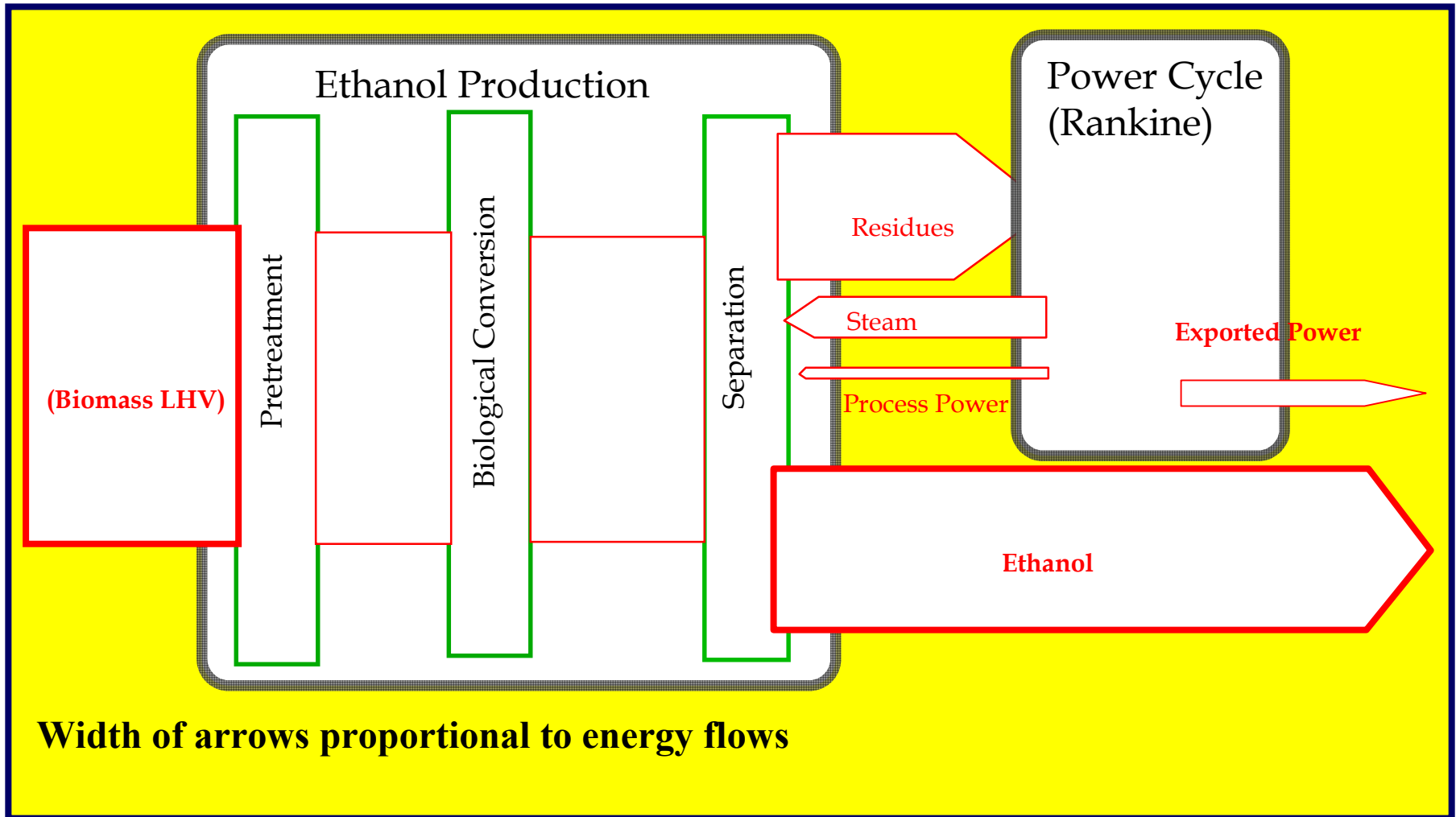
<b>Technology</b>	<b>Net Electric Efficiency (LHV Basis)</b>
Rankine	33%
Gas Turbine Combined Cycle (GTCC)	50%
Solid Oxide Fuel Cell (SOFC)	57%

*Now consider potential thermodynamic benefit of  
technology maturation in the context of co-production...*

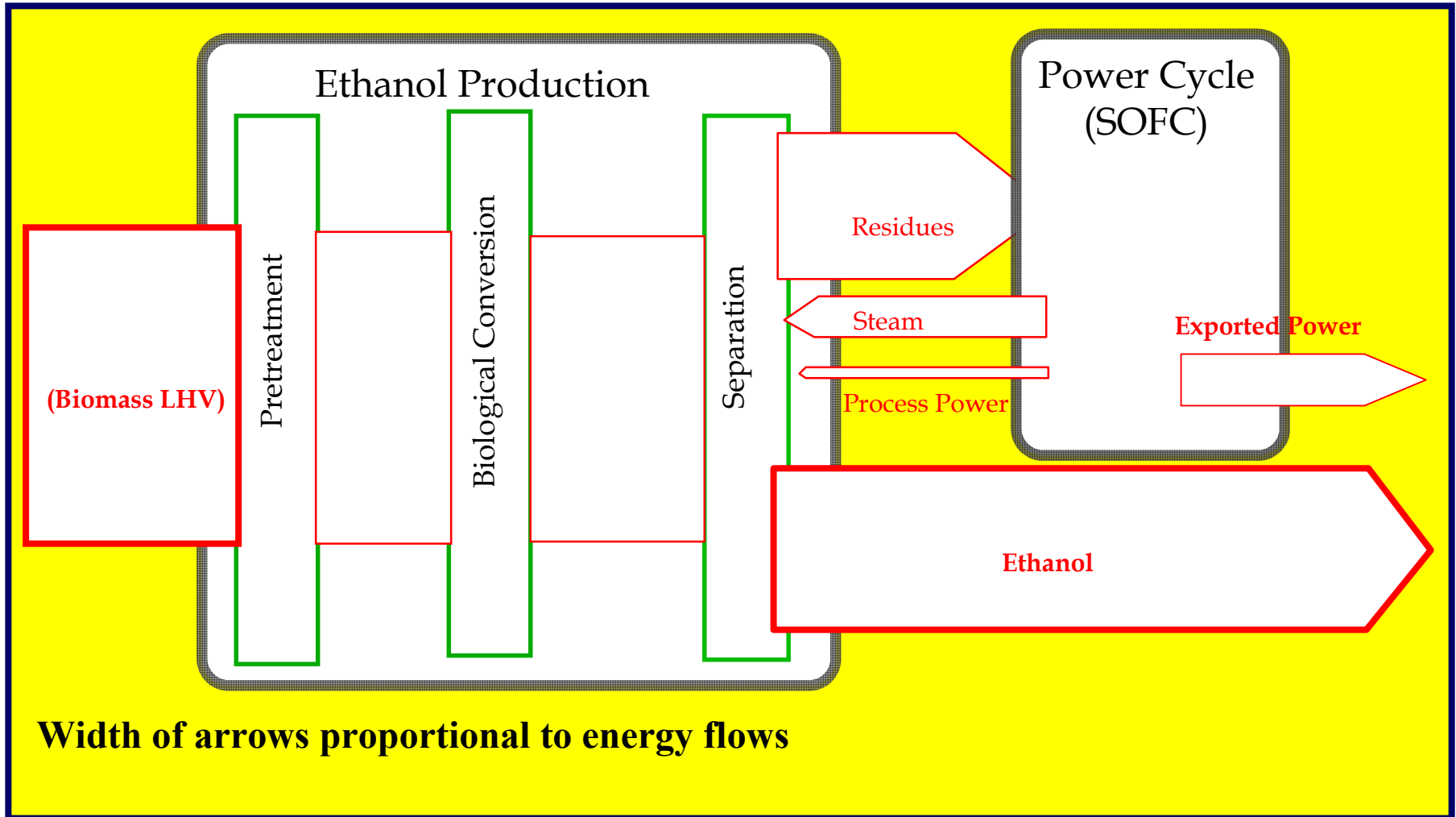
# “Near-Term” Technology EtOH/Rankine Power



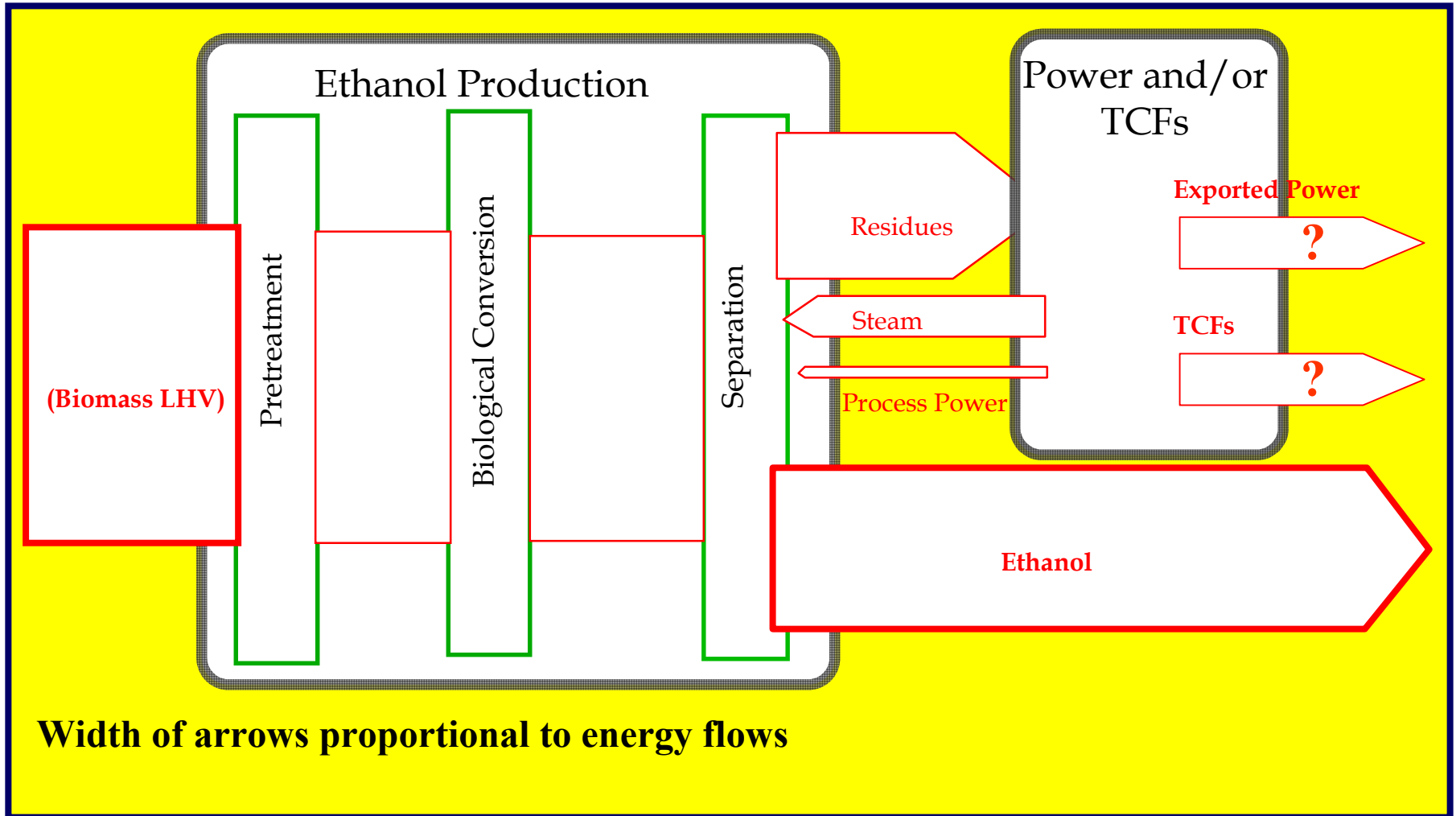
# Advanced Technology EtOH/Rankine Power



# Advanced Technology EtOH/Advanced Power



# Advanced Technology EtOH/Power/ Thermochemical Fuels



## Conclusions and Next Steps

- To our knowledge, this is the first study that considers co-production in the context of mature technology—could lead to unforeseen, favorable results
- Process synergies between biological and thermochemical conversion have the potential to significantly increase process yields—of particular interest is the potential to efficiently co-produce ethanol and HDV fuels
- We will continue our in-progress co-production analysis—including economics—of ethanol/TCFs and examine co-production scenarios involving organic chemicals and protein