Task 4A
Co-Production Analysis

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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

Solid Fuels, e.g.:
- Charcoal

→ Electricity

Gaseous Fuels, e.g.:
- → Hydrogen
- Methane

→ Steam

→ Organic Chemicals, e.g.:
- Lactic Acid
- Succinic Acid
- Adhesives
- Phenol

Liquid Fuels, e.g.:
- → Ethanol
- → Methanol
- → Fischer-Tropsch Liquids
- → Dimethyl Ether
- Pyrolysis Oils
- Plant Oils/Biodiesel

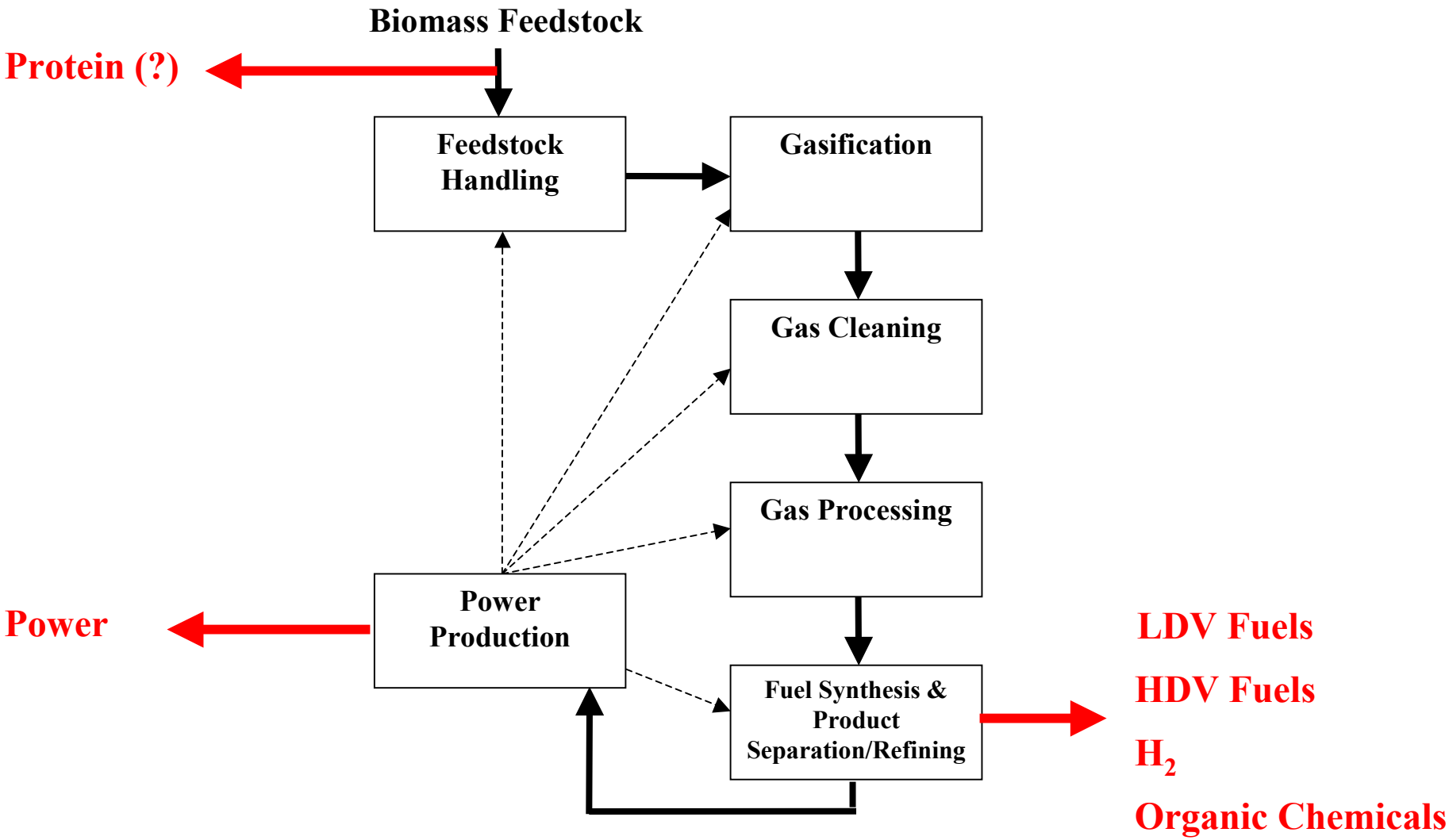
→ Animal Feed Protein

Lubricants

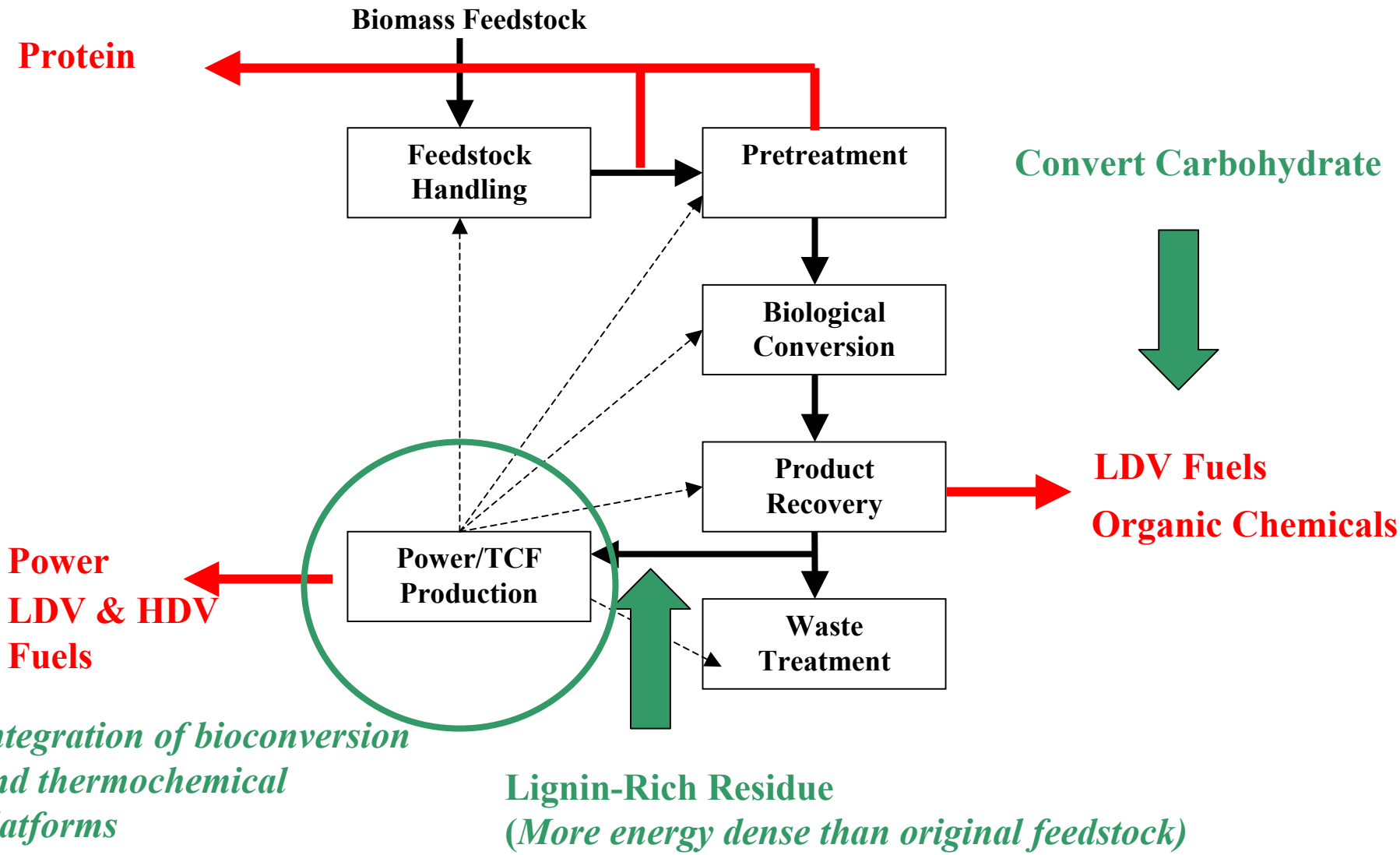
Fertilizer

Biomaterials, e.g.:
- Insulation
- Composites

Thermochemical Conversion Platform



Bioconversion Platform



Co-Production Scenarios

SCENARIO	Biopower	Bioethanol	H_2	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

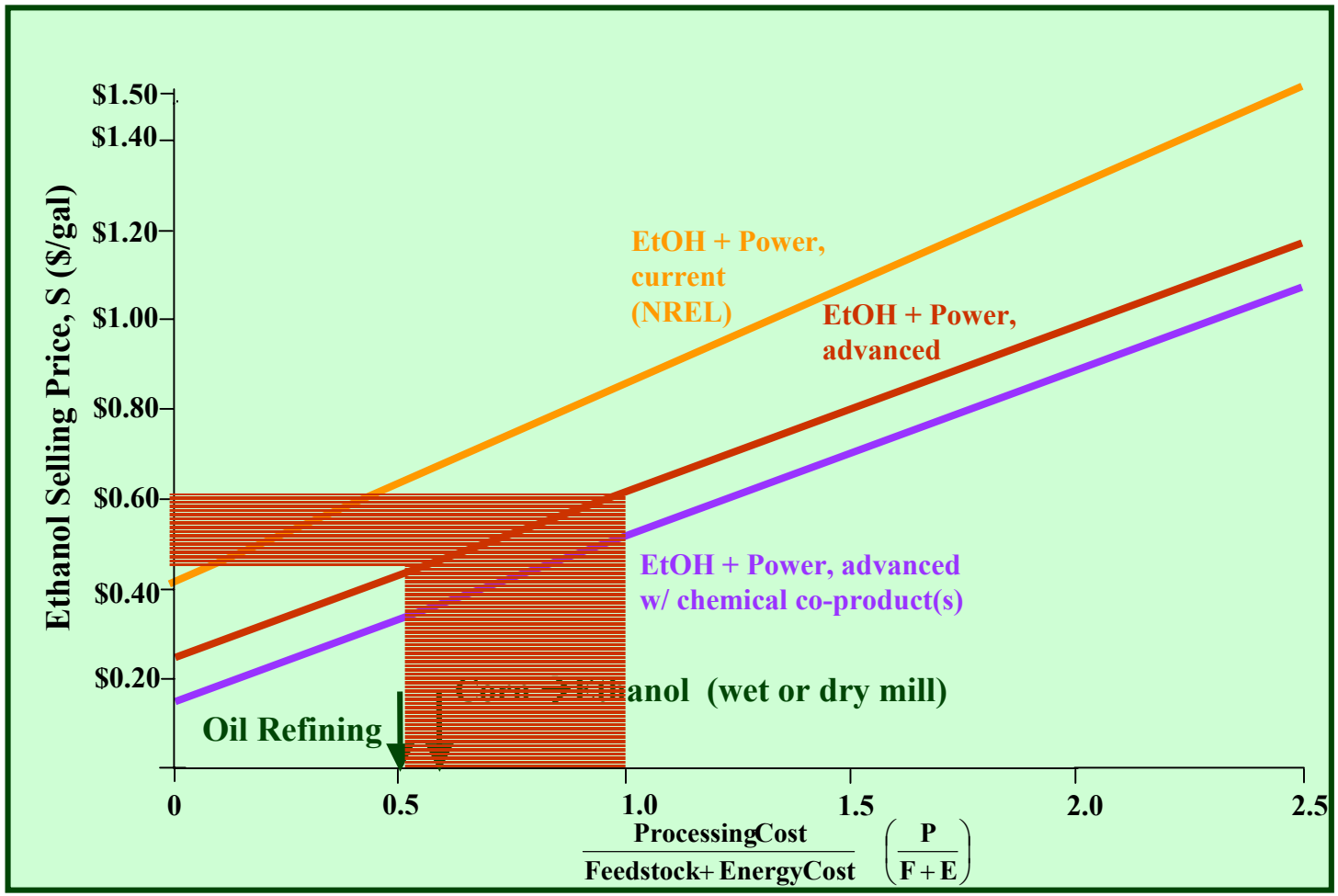
- Economies of scale provided by full-size biorefinery lowers processing costs of low-volume, high-value co-products

- Process yield increases due to:

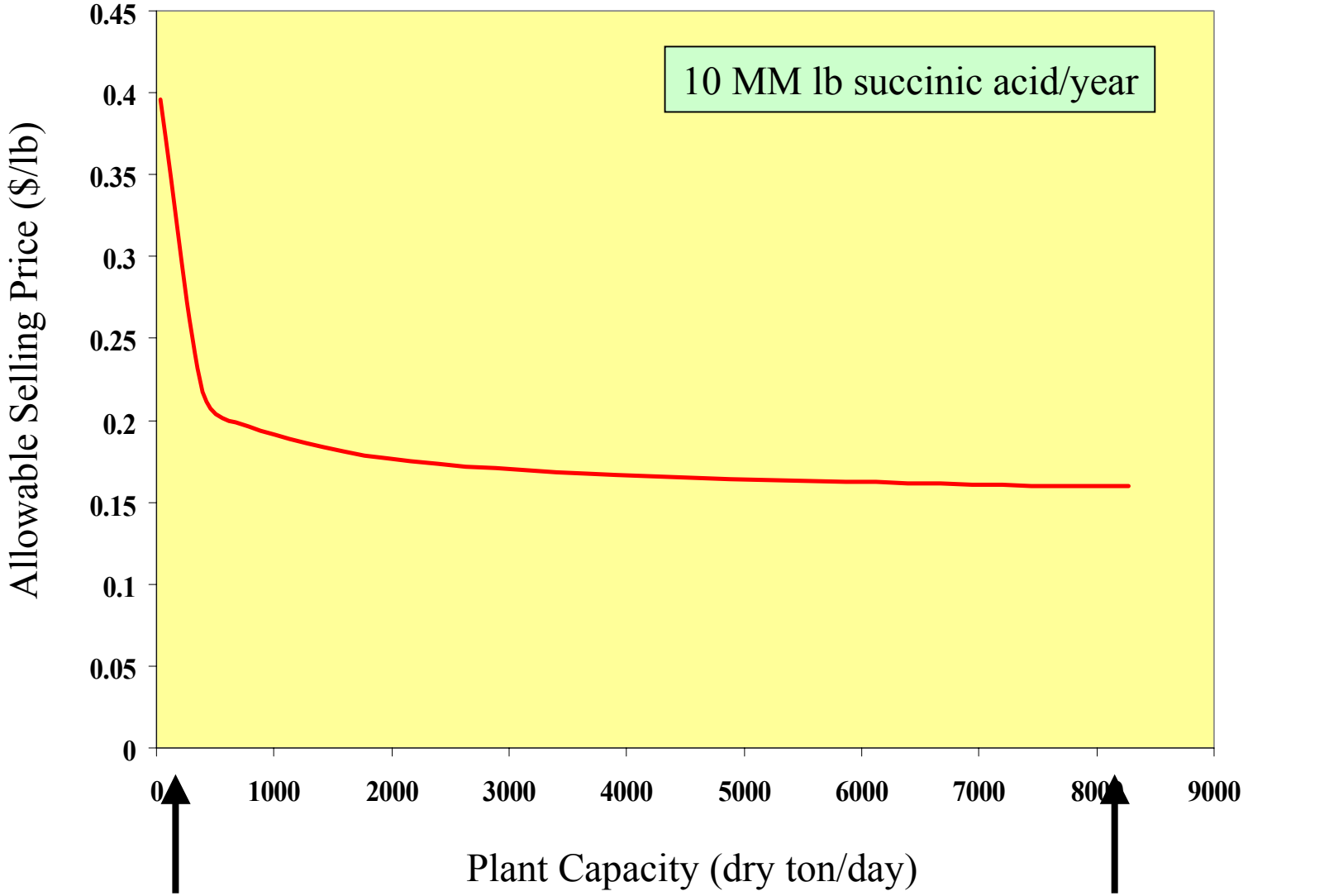
    1) Use of all component fractions of biomass feedstock
    2) Process integration synergies

which enhances <u>both</u> economic and environmental benefits

Potential Benefit to Primary Product Price



Potential Benefit to Co-product Price

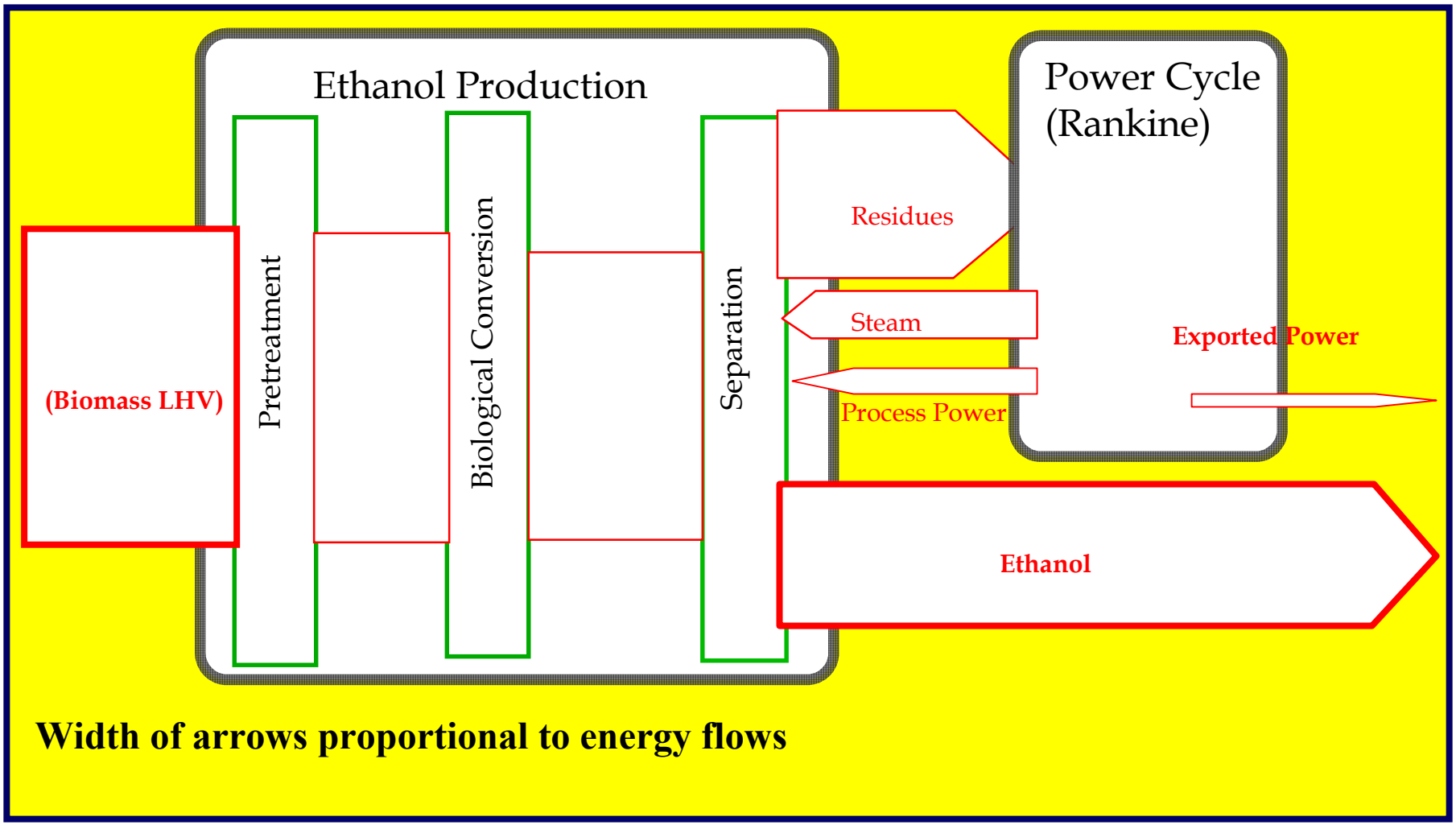


Benefits of Technology Maturation: Power Generation

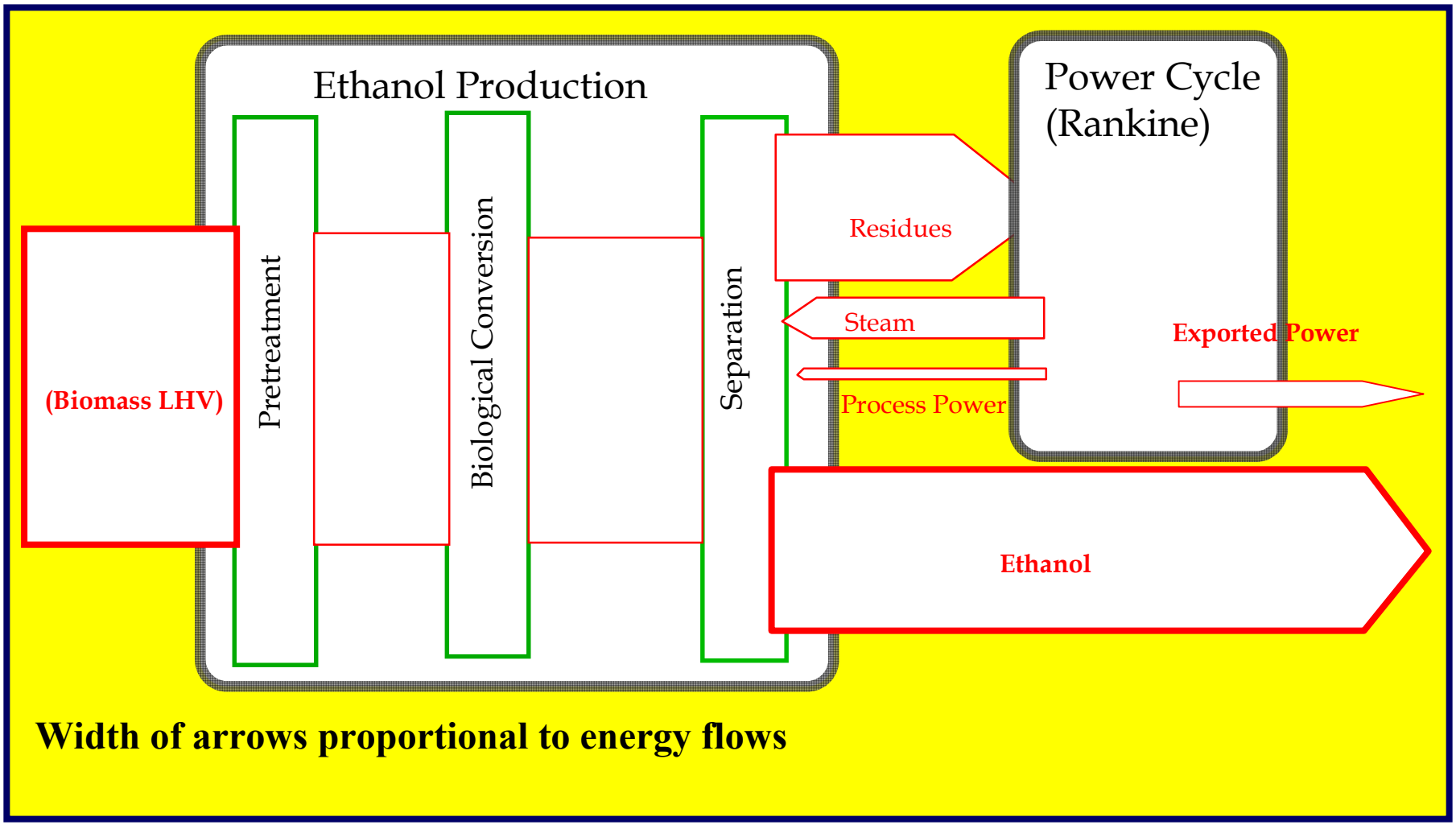
Technology	Net Electric Efficiency (LHV Basis)
Rankine	33%
Gas Turbine Combined Cycle (GTCC)	50%
Solid Oxide Fuel Cell (SOFC)	57%

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

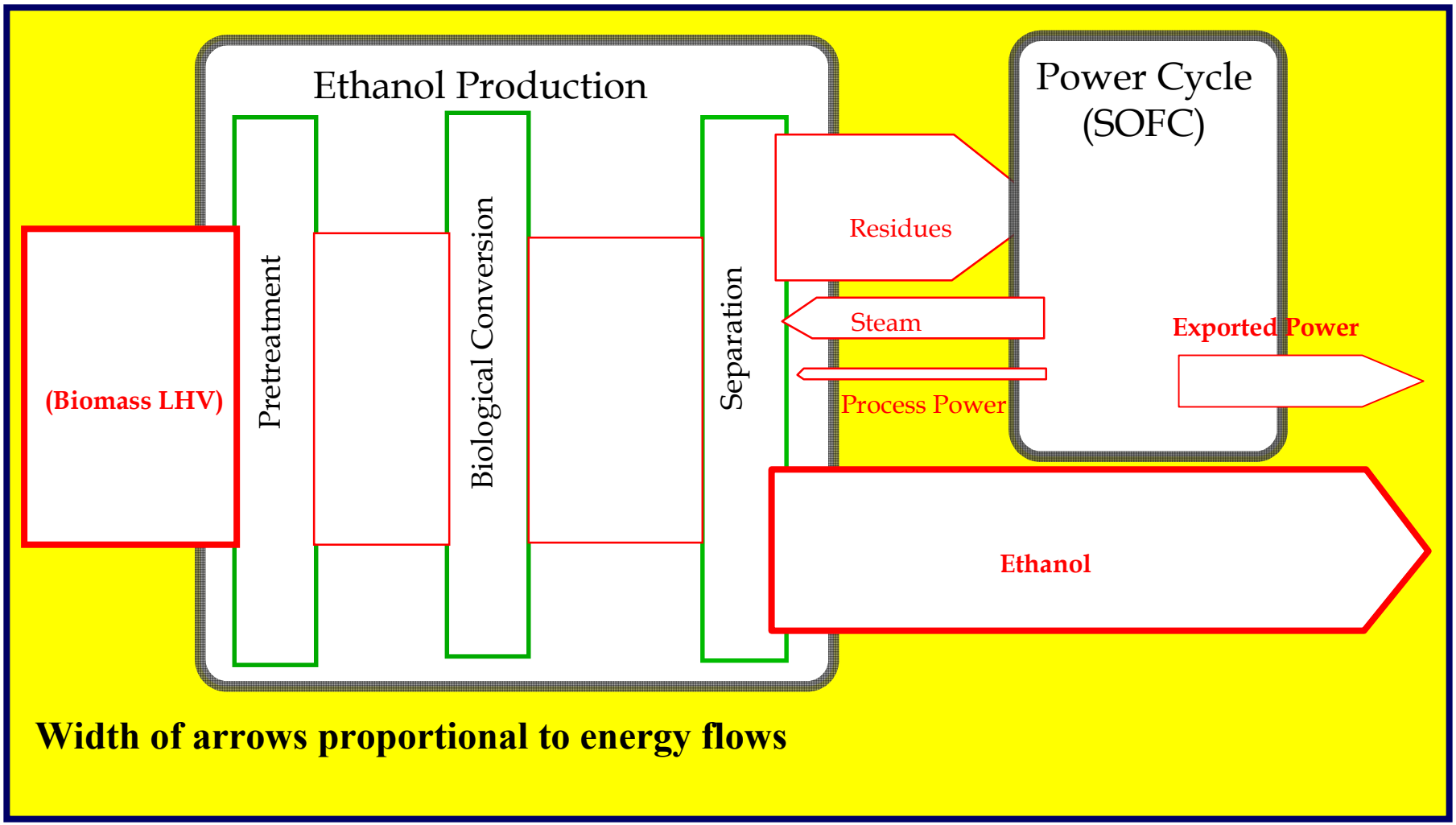
"Near-Term" Technology EtOH/Rankine Power



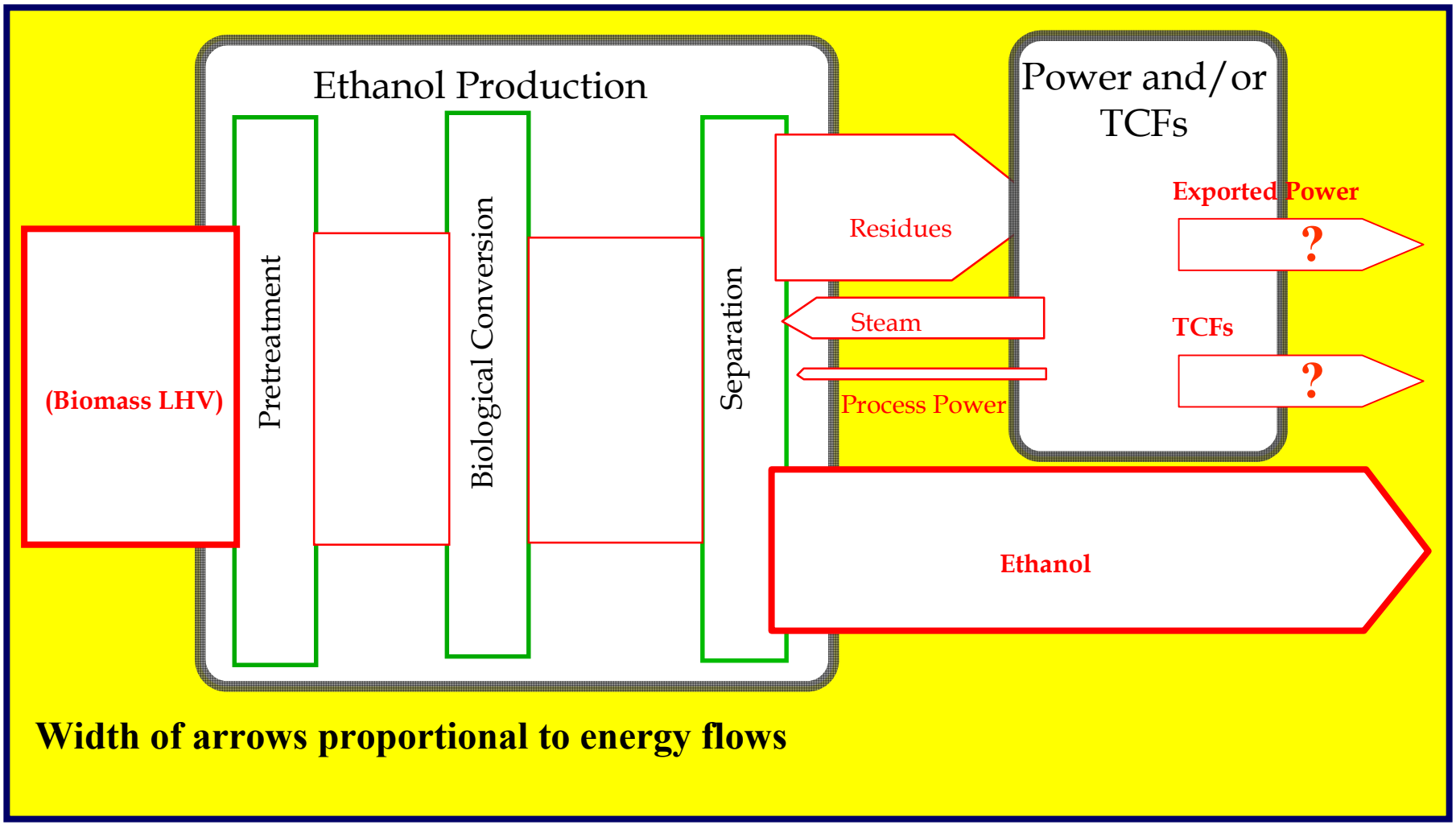
Advanced Technology EtOH/Rankine Power



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