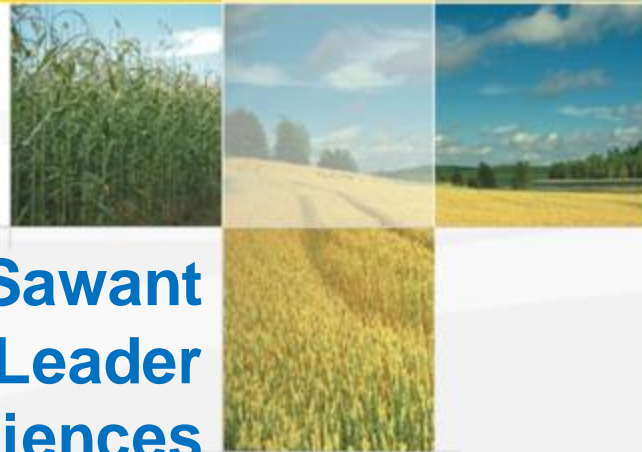




CARBOHYDRATES TO PLATFORM CHEMICALS

Challenges & Opportunities in developing Sustainable Green Technologies



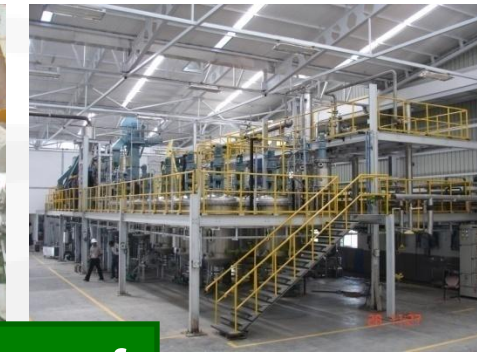
Jayant Sawant
Program Leader
COE Chemical Sciences

- ❑ Established in 1984
 - 1st Company to avail VC funding in India
 - Listed on Indian Stock Exchanges
- ❑ Business Lines
 - BioEthanol
 - Breweries
 - Water and Wastewater
 - Inputs and Chemicals
 - Energy Crops Services
 - Customized Engineering and Manufacturing
- ❑ Over 450 references in 60 countries
- ❑ Over 275,000 sq ft of world class manufacturing facilities meeting global standards.



Largest Resource Base for Bio Ethanol Industry
Diverse Global Feedstock Experience

- ❑ US\$ 20+ Mn investment
 - 80,000 sq ft of Labs, PP, and Offices
- ❑ 14 Well Equipped Labs
- ❑ 125 technologists and growing
 - 30 PhDs, 80 Masters
- ❑ Pilot Plants
 - 2 TPD Cellulosic Ethanol pilot plant
 - Two 750 kg/d Chemical pilot plants
 - 500 sq ft Open Raceway Pond for Algal Cultivation
- ❑ IP - 11 granted patents



Bench and Pilot scale facilities to enable validation of scientific assumptions and rapid commercialization

Praj Matrix – Centers of Excellence

Intellectual
Property and
Business
Analytics

Molecular
Biology, Genetic
Engineering &
Biochemistry

Ethanol
Fermentation &
Microbiology

Analytical &
Instrumentation
Services

Scientists,
Engineers &
Technologists

Chemical
Fermentation &
Microbiology

Chemical
Sciences

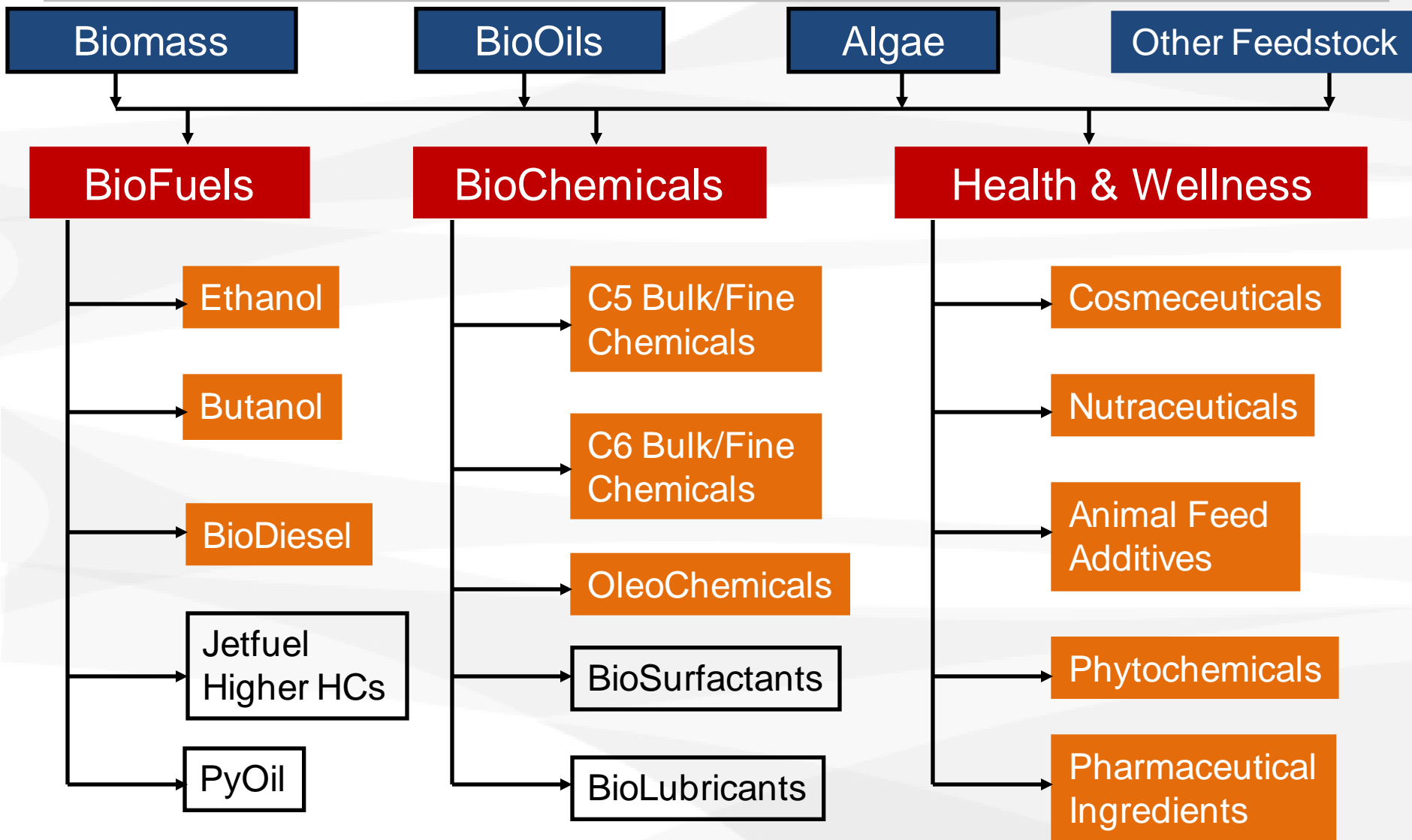
Algal
Sciences

Chemical
Engineering

Process & Systems
Engineering

Our Focus – BioFuels, BioChemicals, Environment, Health & Wellness

Praj Matrix – Focus Areas

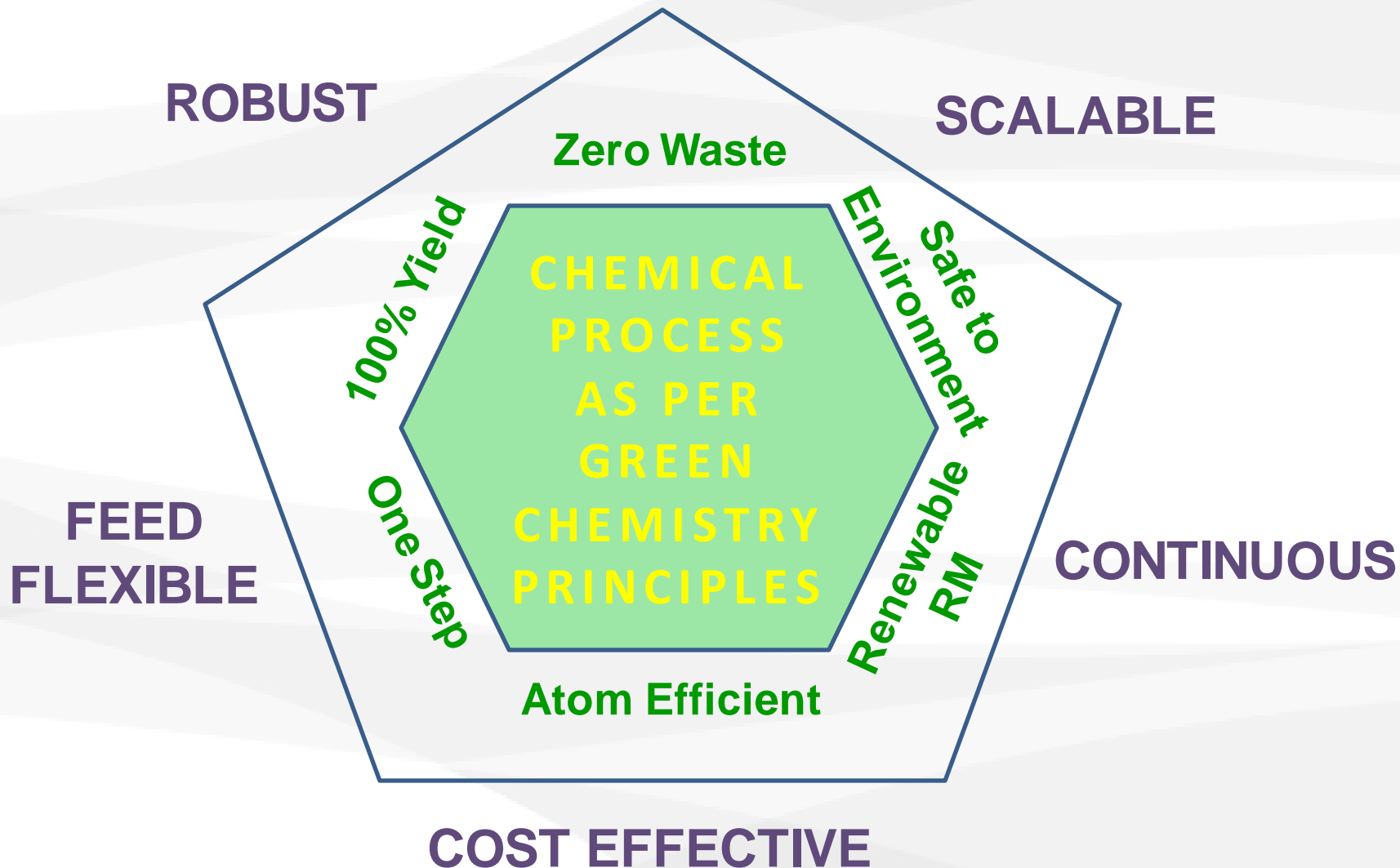


Renewable feedstock to platform chemicals

Industry	Production (tons/year)	E-factor
Oil Refining	10^6-10^8	0.1
Bulk Chemicals	10^4-10^6	1-5
Fine Chemicals	10^2-10^4	5-50
Pharmaceuticals	10^1-10^3	25-100

R. A. Sheldon; "Atom Economy and Catalysis"; Chem. Rev, May 2000, pp10 – 13.

- E factor for bulk chemicals is lower as compared to fine chemicals
- High Production volumes
- 80% contribution from starting product
- Renewable starting product will make a huge impact



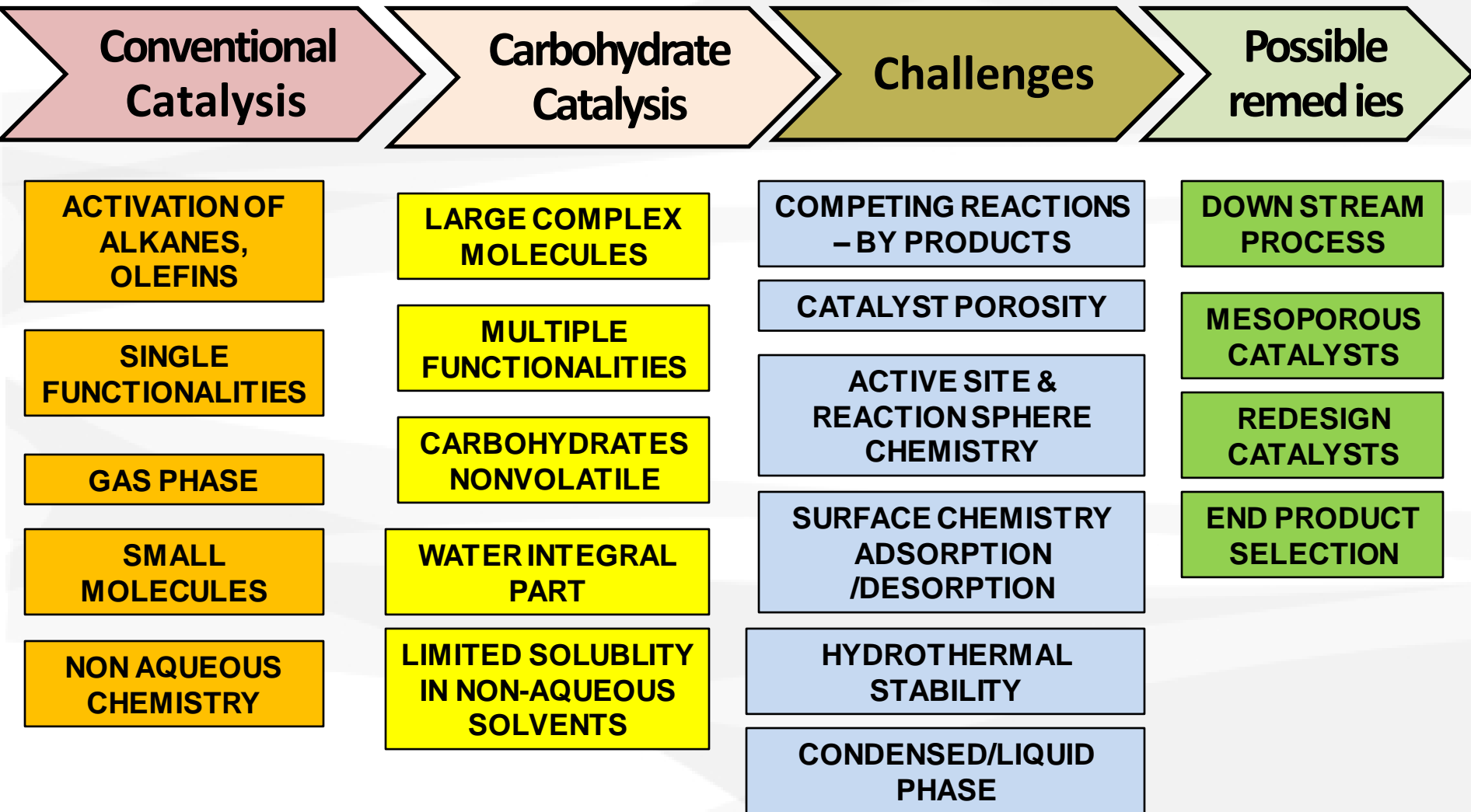
Heterogeneous Catalysis

– A Green option

- ✓ Adaptability to feedstock
 - ✓ Minimum/zero pretreatment
 - ✓ Catalyst poisoning
- ✓ Multiple functionalities
 - ✓ Selectivity
 - ✓ Downstream processing
- ✓ Solubility
 - ✓ Non aqueous solvents
- ✓ Non volatility
- ✓ Charring
- ✓ Humins formation

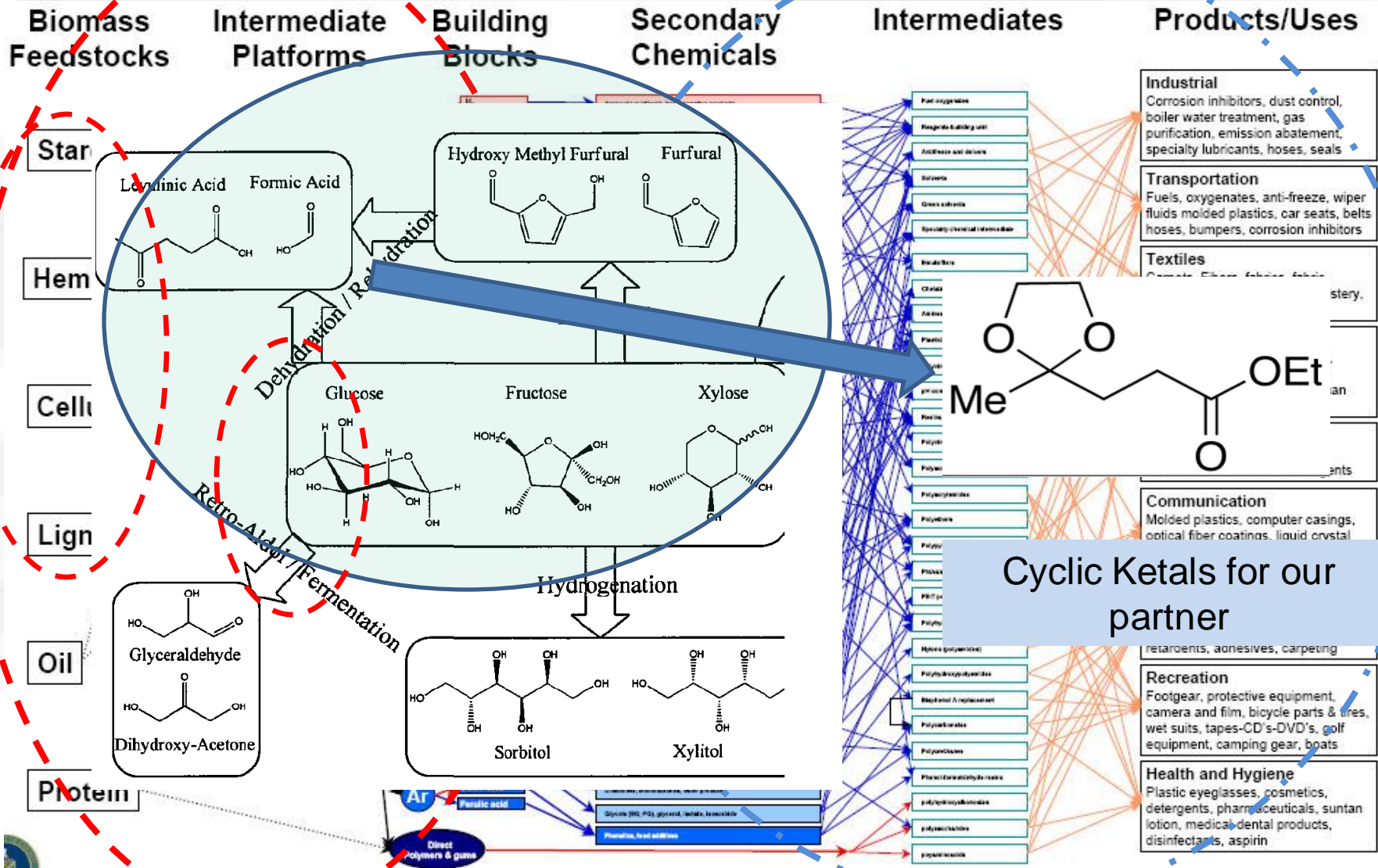


Challenges with respect to carbohydrate chemistry for Catalysis

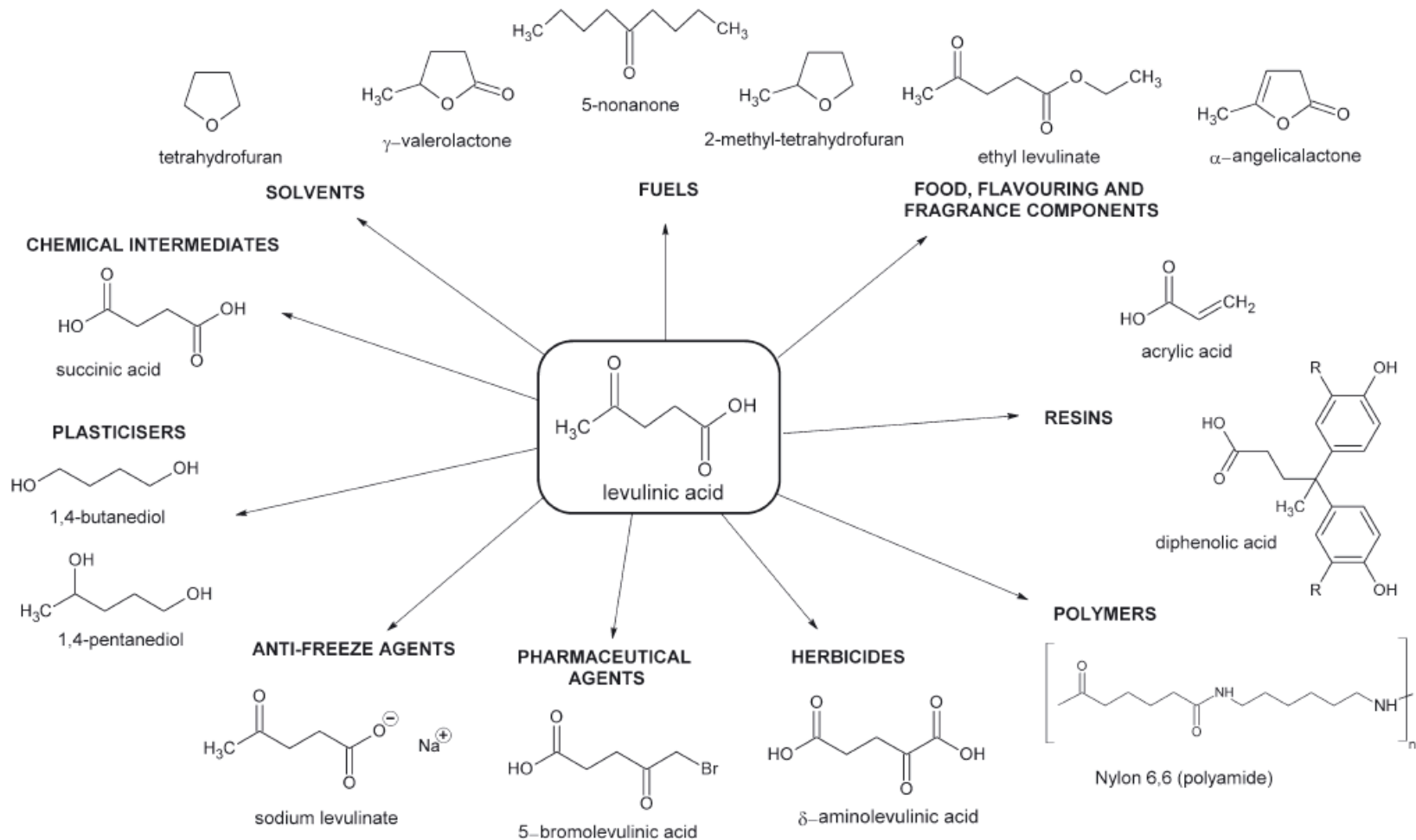


- Applications well reported and commercialized
 - Reduction of glucose to sorbitol
 - Glucose oxidation to gluconic acid
 - Alkylation of sugars to yield non ionic surfactants
 - Glucose acetylation
- Recent reports:
 - Dehydration to yield furan ring compounds
 - Glucose to HMF
 - Xylose to furfural

Focus chemicals

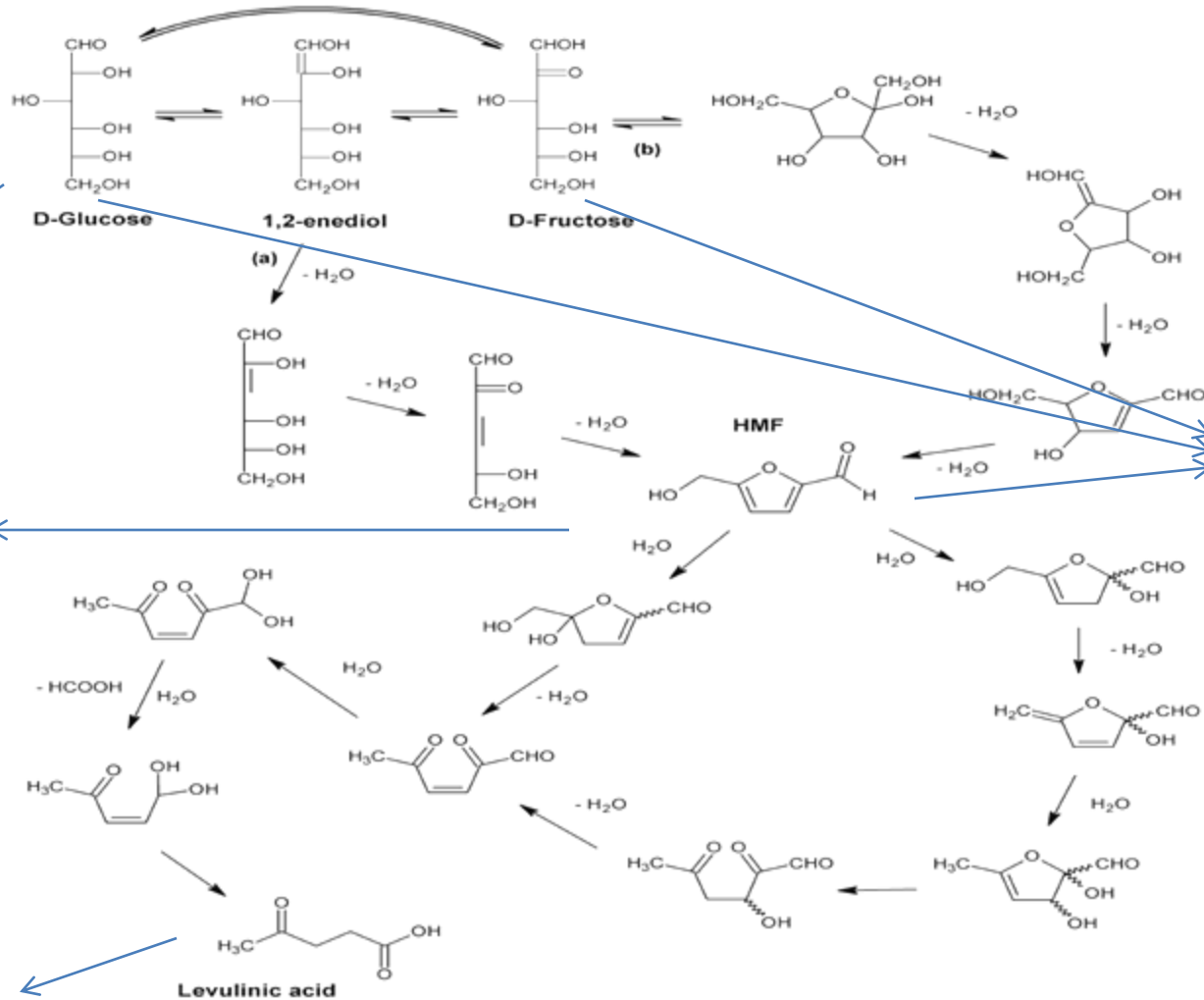


Levulinic acid: A Green platform chemical



**ROUGH ESTIMATES SHOW A REPLACEMENT POTENTIAL OF
50 MTPA @ 1USD/KG**

Conversion of Glucose to Levulinic acid



HUMINS

Etherification

Polymerization

Ref.: Rackeman D. W. , Doherty W.O.S, Biofpr. 5:198-214(2011)

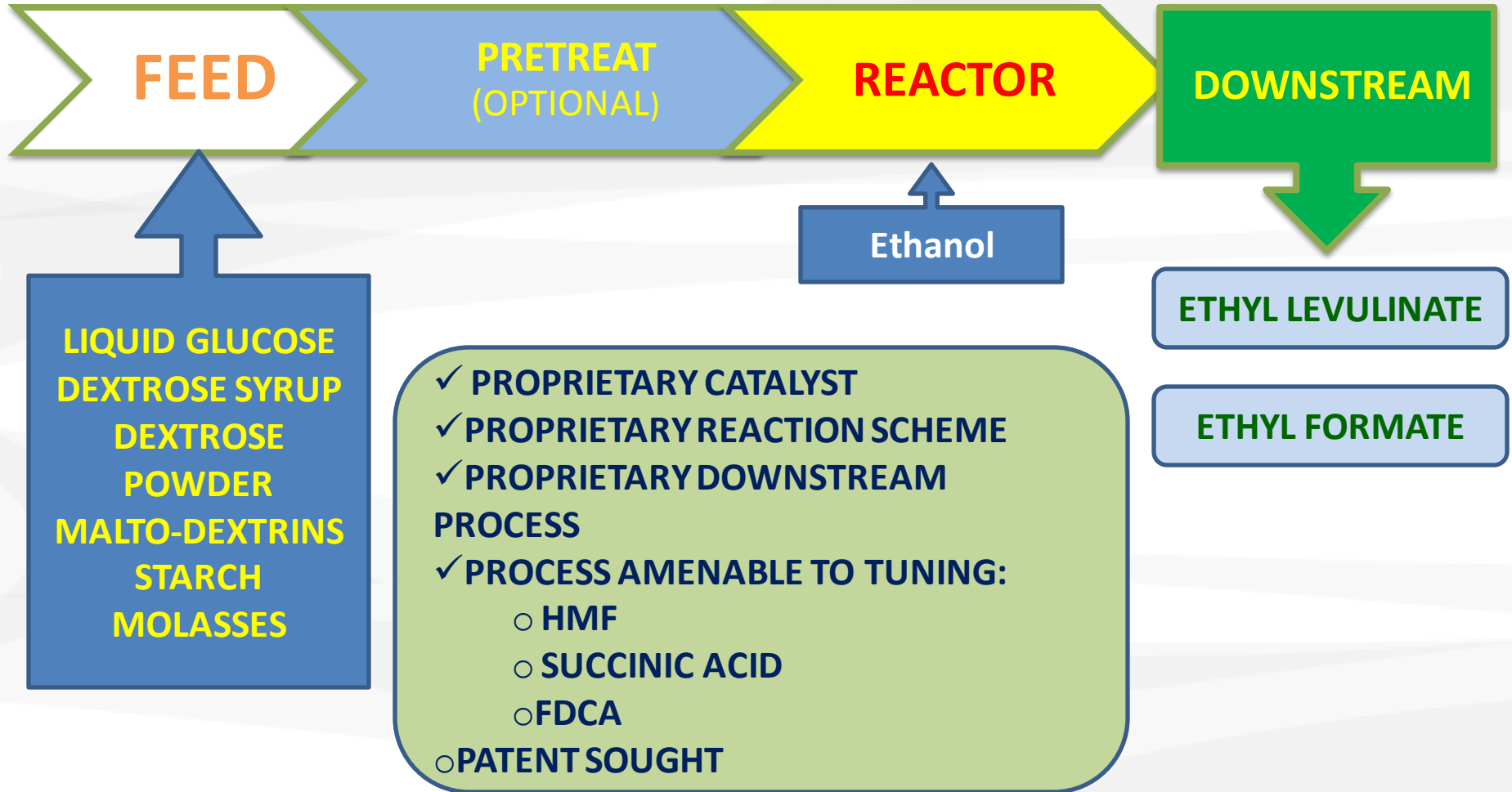
TECHNOLOGIES BASED ON SOLID CATALYSTS

Feed	Catalyst	Conc (wt%)	Process conditions		Yield (mol%)
			Temp. (°C)	Time (h)	
Fructose	Amberlite IR-120	19	25	27	23.5
	LZY-zeolite	50	140	15	43.2
Glucose	Amberlite IR-120	19	25	124	5.8
	Clay-catalyst	3	150	24	12
	HY-zeolite	3	150	24	6
Sucrose	Amberlite IR-120	19	25	41	15.6
	Resin-Dowex	6.25	100	24	24
Cellulose	Nafion SAC-13	3	190	24	9
HMF	ZSM-5	5	116	2	70.0
	Bagasse	42	4.5% HCl	220	82.7
	Water hyacinth	26.3	10% H ₂ SO ₄	175	53

^a Based on theoretical yield of the conversion of cellulose/hexose sugars.

Ref.: Rackeman D. W. , Doherty W.O.S, Biofpr. 5:198-214(2011)

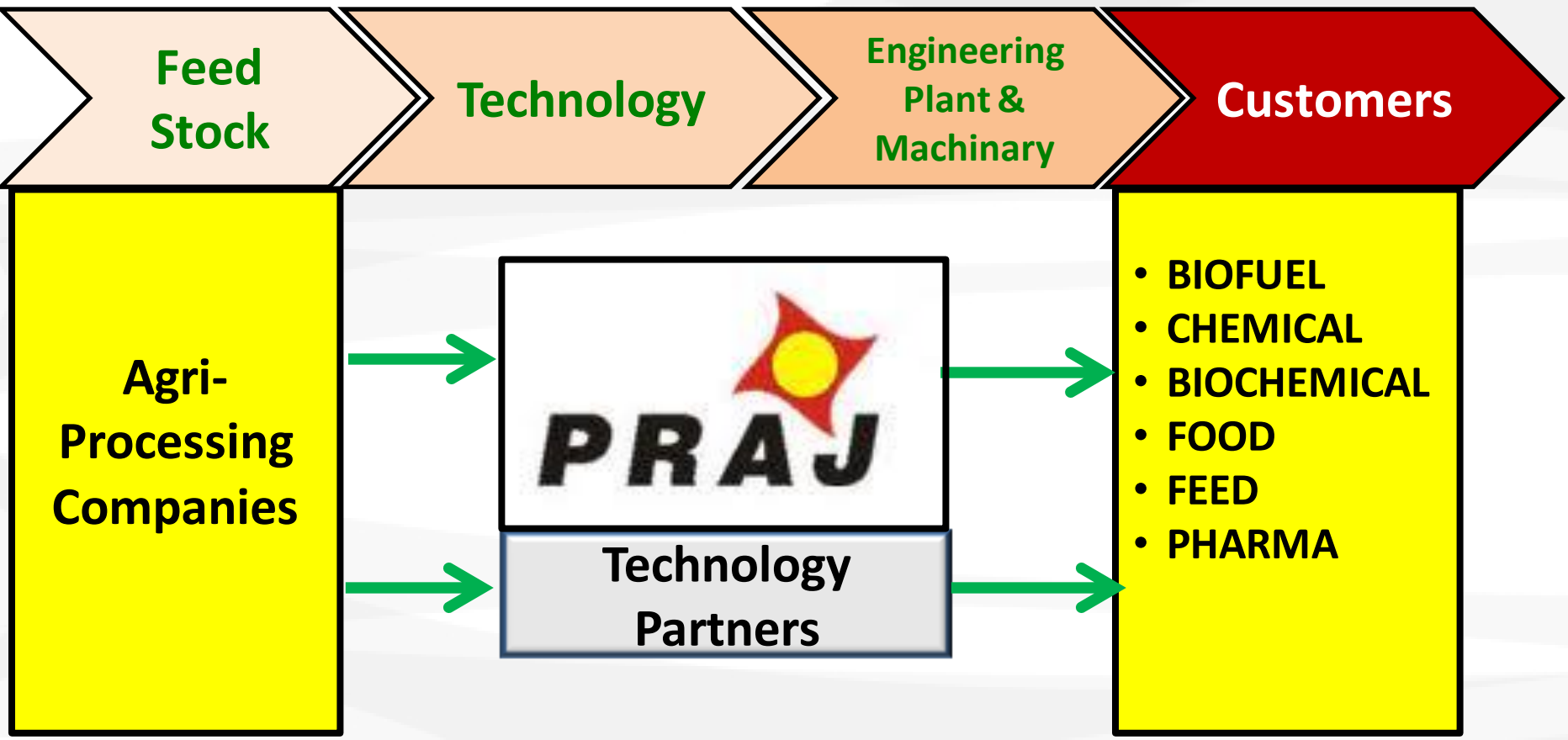
PRAJ PROCESS FOR ETHYL LEVULINATE



SALIENT FEATURES OF PROCESS

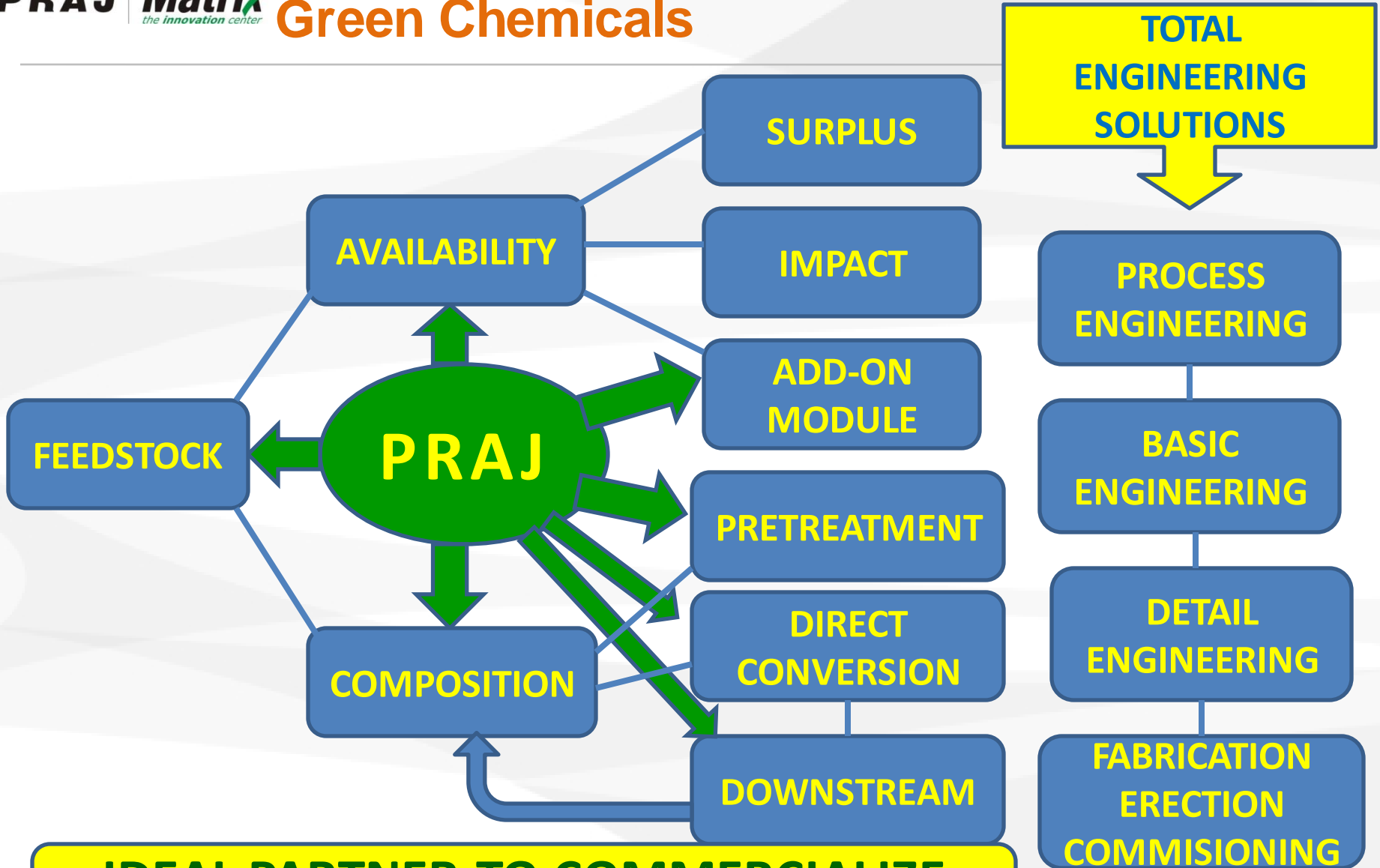
- ✓ ZERO DISCHARGE
- ✓ GREEN PROCESS
- ✓ FEED FLEXIBILITY
- ✓ HIGH SELECTIVITY
- ✓ PRODUCT FLEXIBILITY
- ✓ MINIMUM HUMIN FORMATION
- ✓ MORE THAN 80% CARBON CONVERTED TO VALUE ADDED PRODUCTS

Emerging Value Chain



Partnerships Across Value Chain

Praj role in commercialization of Renewable Green Chemicals



**IDEAL PARTNER TO COMMERCIALIZE
BIORENEWABLE GREEN CHEMISTRY**

Collaborations – Value Proposition

What We Bring To the Table

- ✓ Core expertise in Process Technology and Process Engineering
- ✓ Solid understanding of Feed Stock Diversity and its utilization
- ✓ More than 25 years of expertise In concept to Commercialization
- ✓ Unmatched competencies in Scale up Heat and Energy integration
- ✓ World class R&D Set up backed with State of the art Pilot plants,
- ✓ Interdisciplinary technical expertise
- ✓ Understanding of Local markets

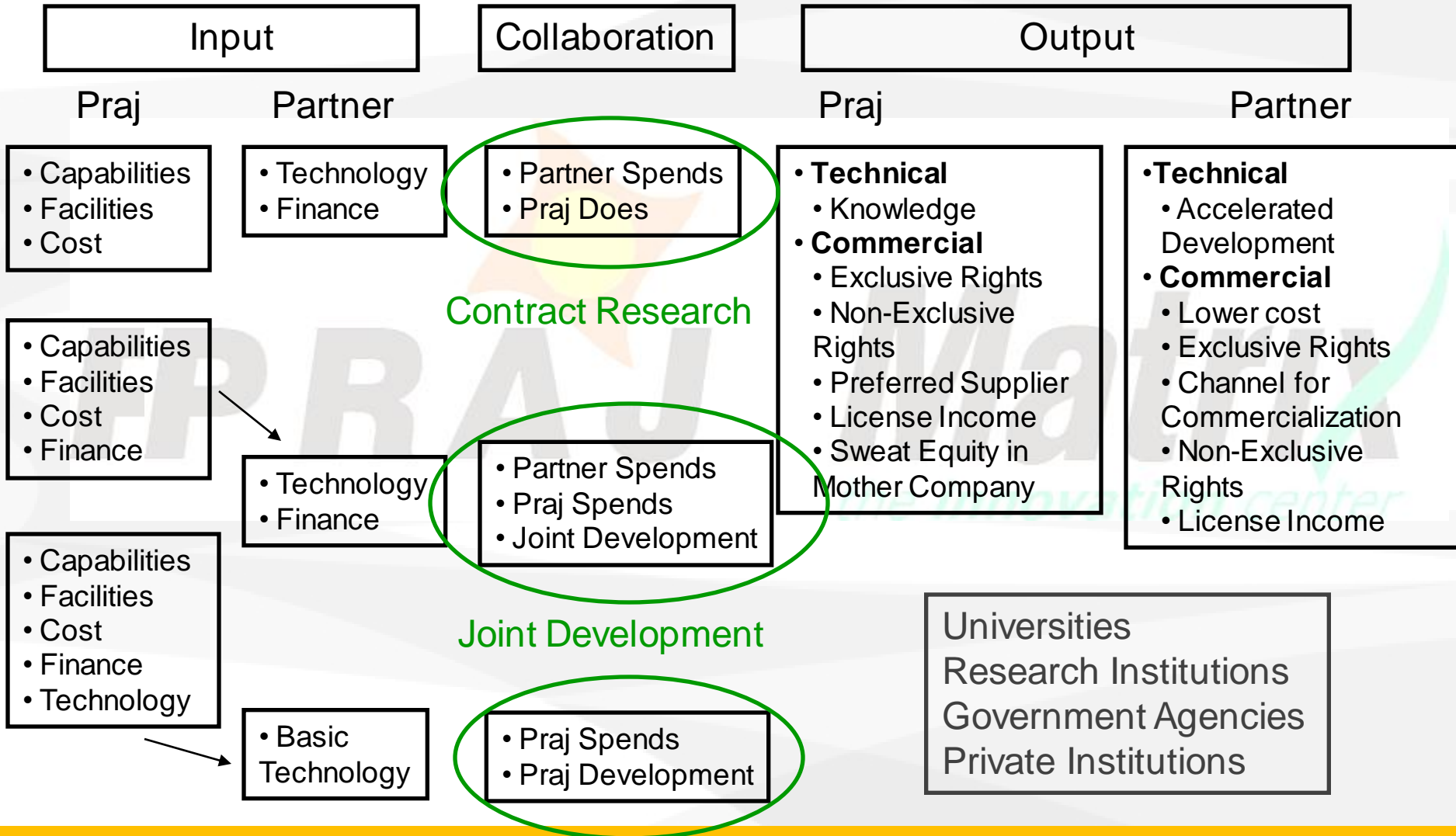


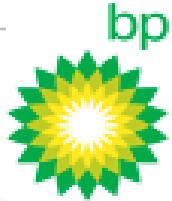
What are We Seeking

- Complementary partners with Global Outlook in Renewable Green Chemistry
- Sustainable Access to Feed stock streams (Carbohydrates/Oil/ Biomass)
- Technology and Commercial Risk Sharing Ability in the bargain of long term Economic Gains
- Transparent Long Term Relationships for whom we can develop Processes & Technology Packages
- Willingness to scale-up in INDIA & SE ASIA region

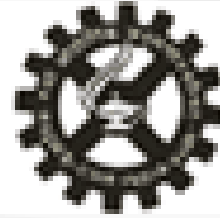
Build Partnerships Across Value Chain

External Collaborations





The miracles of science™



Ingenio Mayagüez

