

Commercialization of Integrated Biorefineries via synergies between commodity and high value products

Presented by:

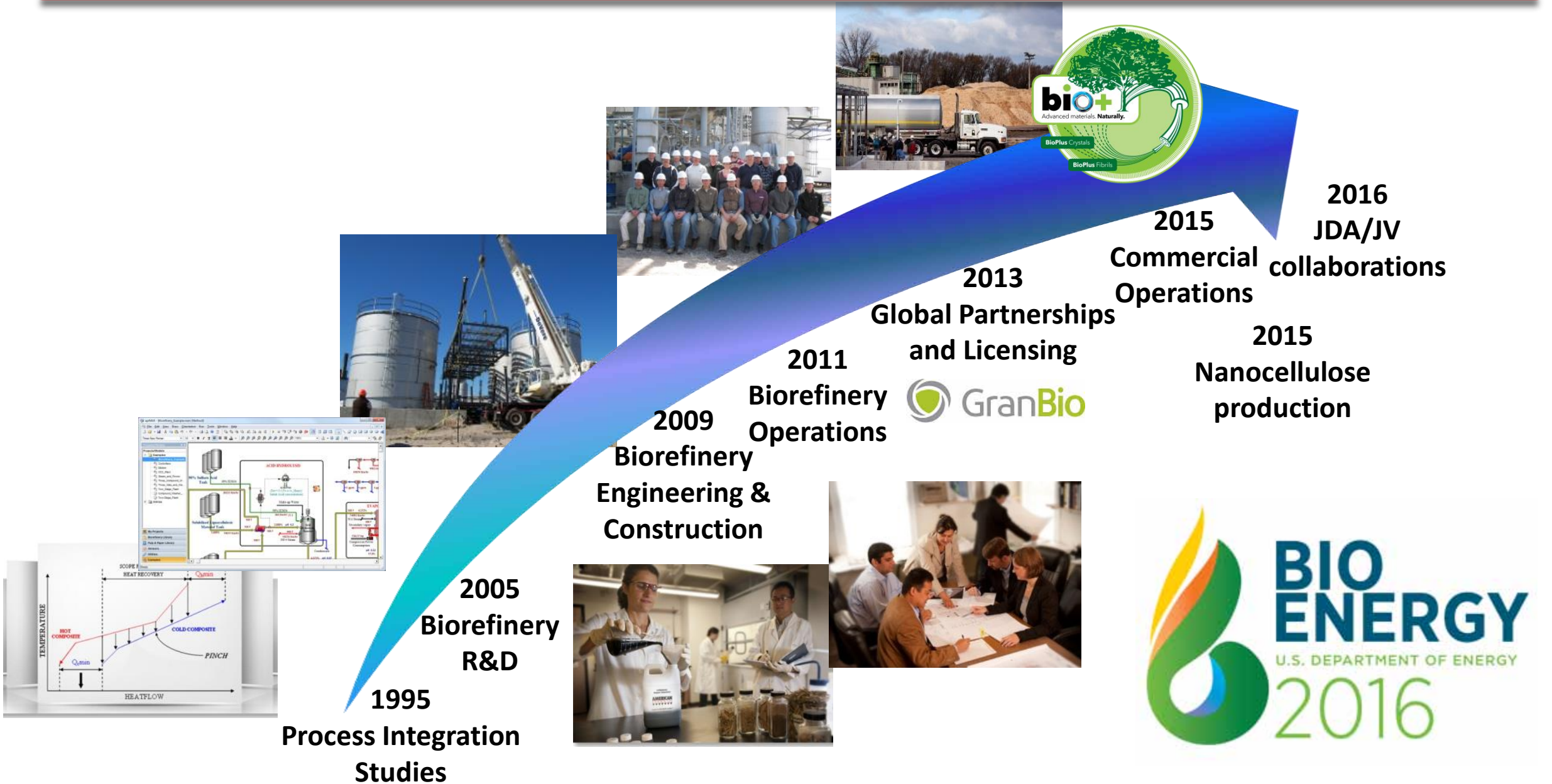
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American Process Inc. – a 20-year history



Route to Commercial Cellulosic Biorefineries

In the backdrop of today's realities, (oil prices and lackluster performance of the first 2G ethanol plants) - commercializing cellulosic biorefineries needs a different approach:

- Integrated biorefinery with *many synergistic products* to share market risk
- Build a *“barrel approach”* coalition of many partners cellulosic chemical producers, materials and biofuels producers
- Scale-up to *pre-commercial with profitability* by leveraging high value, small volume co-products
- Build commercial scale only *after derisking* - to mitigate real risk and perceived risk



Multiple technologies are demonstrated at the **Thomaston Biorefinery**

- Existing: 3.5 bd t/d feedstock pilots - over 8000 hours of operations
- To be scaled: to 50 bd t/d
- Products: lignocellulosic sugars, biofuels, biochemicals and nanocellulose

One Site – Multiple Technologies

AVAP[®] - Bulk sugar production & conversion

- ❑ Clean sugars from cellulose & hemicelluloses
- ❑ Feedstocks: Softwood, hardwood, ag residues
- ❑ Products: Butanol, Ethanol, lignin and refined sugars

BioPlus[™] – Nanocellulose production

- ❑ Pre commercial plant for market development
- ❑ Hydrophilic and Hydrophobic NanoCrystals and NanoFibrils

GreenPower+[®] Technologies - Simple process to alcohols

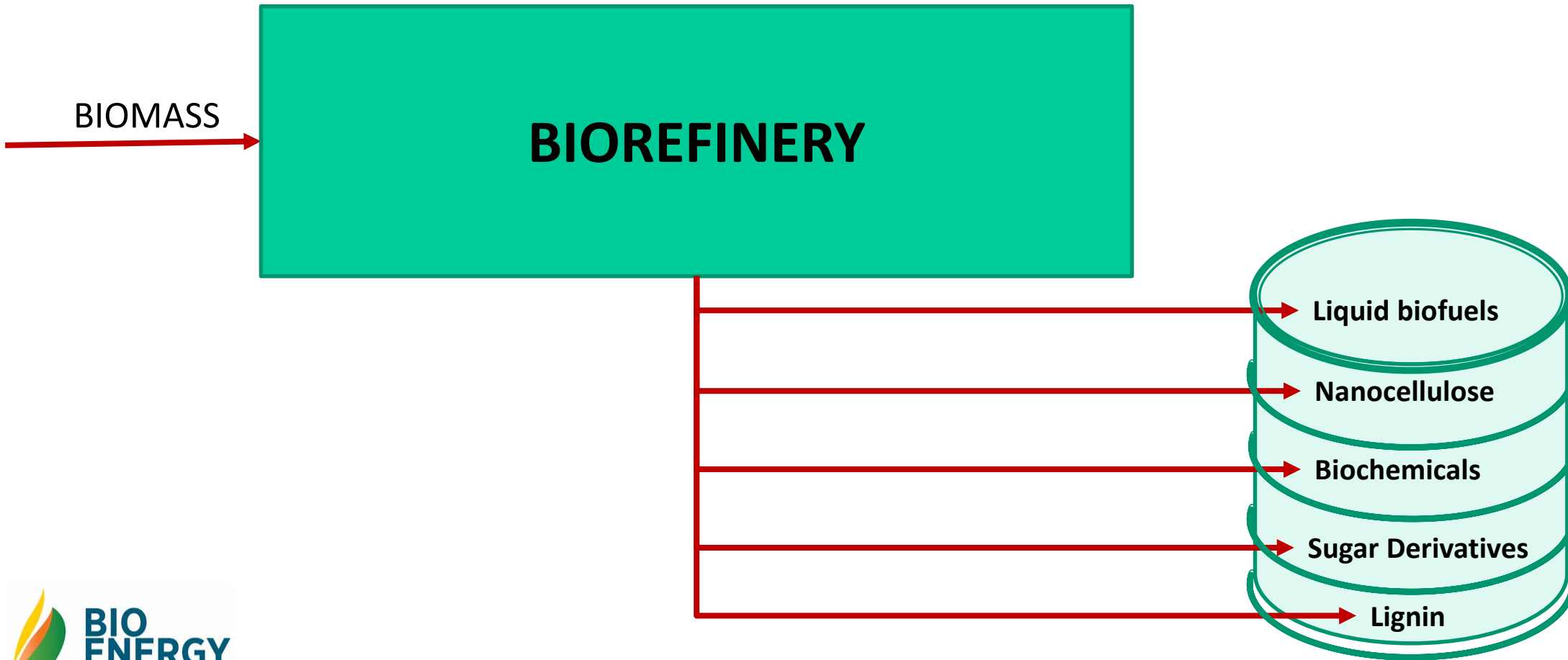
- ❑ Low cost alternative for bolt-on or standalone alcohol production

GreenBox+[®] Technologies - box board production

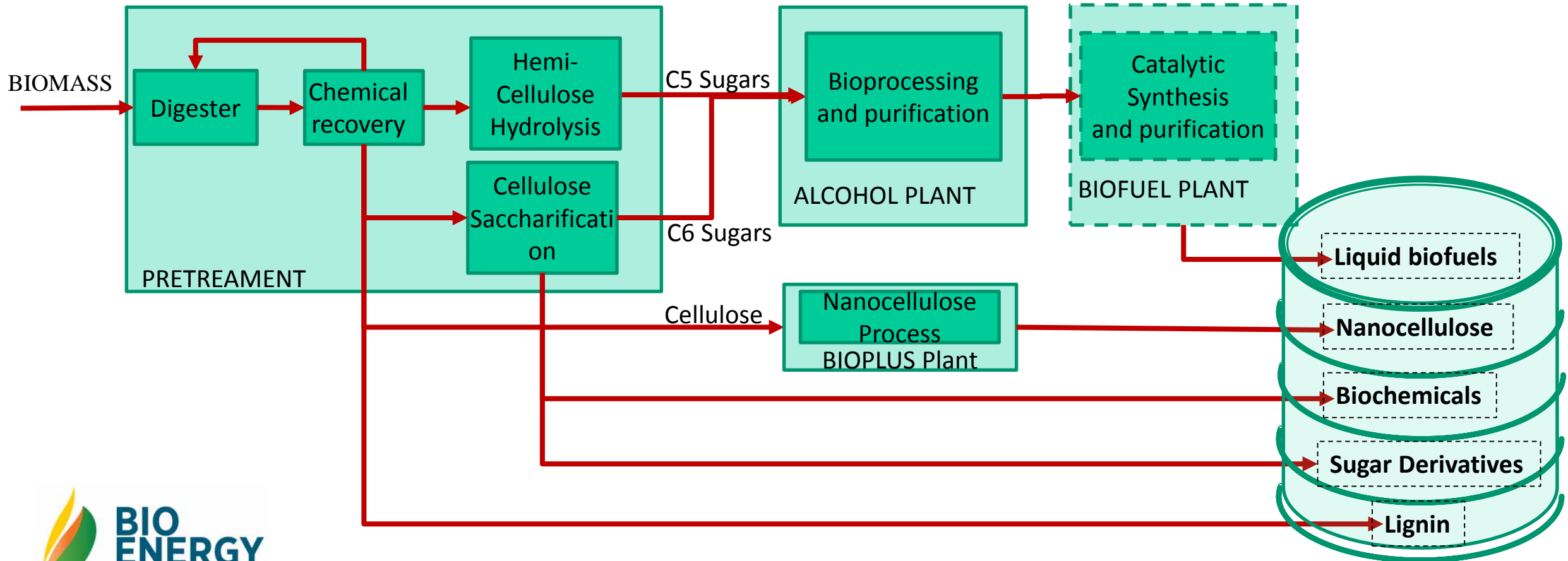
- ❑ Chemical free pulping process to yield hemicellulose byproduct
- ❑ Innovative integration of nanocellulose



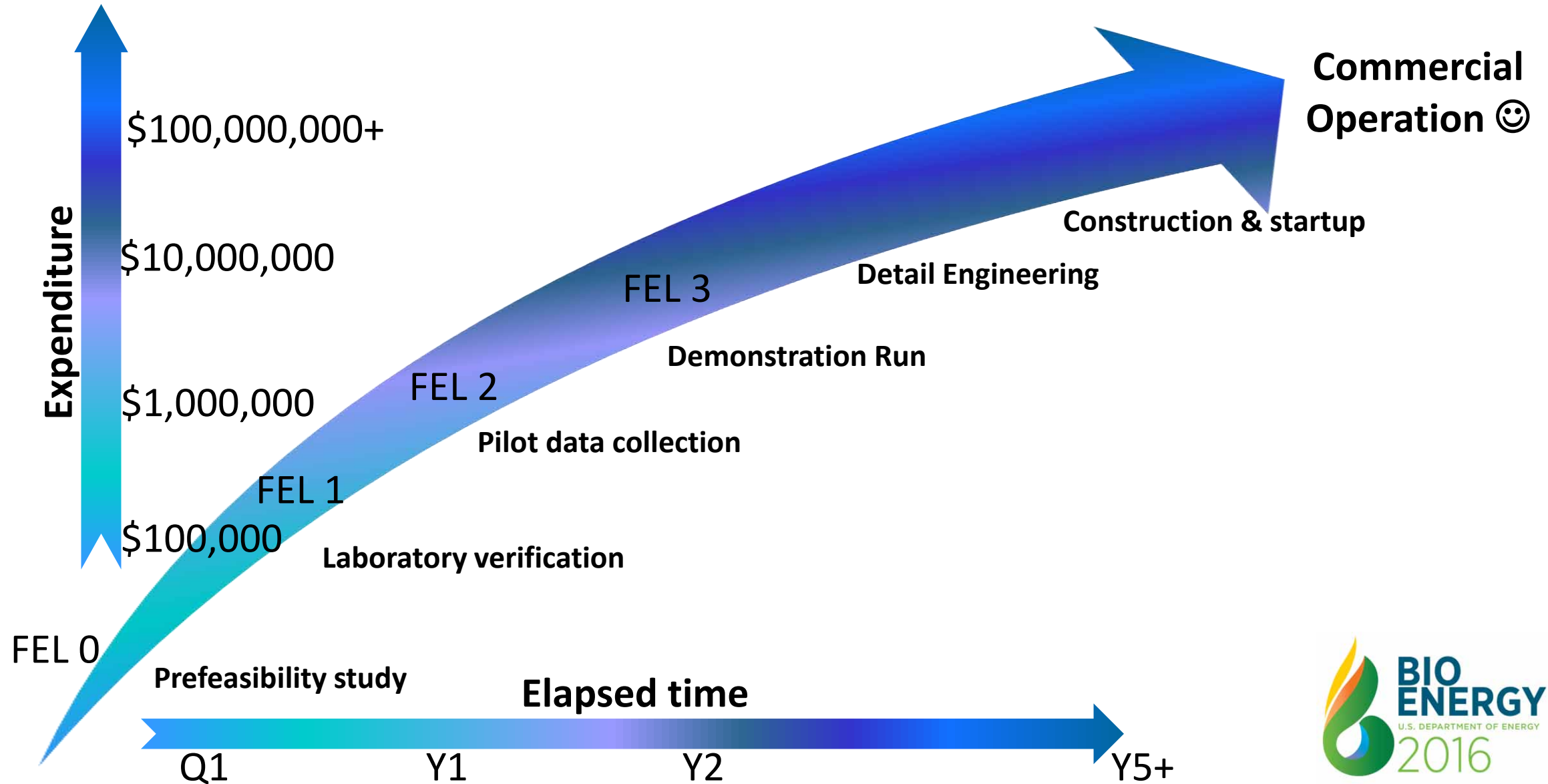
Lignocellulosic BioRefinery – “Barrel Approach”



Thomaston BioRefinery Scale-up – “Barrel Approach”



Bioindustry Project Development Cycle



Opportunities and Critical Pitfalls in Scale-up

Scale	Learning Opportunities	Pitfalls
Prefeasibility	Techno-economic analysis and optimization using process simulation	Optimistic projections
Laboratory	Accurate mass balance and optimization for reactions conditions	Unrealistic conditions
Pilot	Material handling, unit operation selection, corrosion prevention	Missing recycle streams
Demonstration	Workforce training, maintenance procedures, market development	Lack of integration with final product
Commercial	Continuous improvement	Extended startup Low product quality

Lessons Learned in the Journey

There are no shortcuts to a new process synthesis

- Realistic process design must be validated by technoeconomic analysis
 - Verification by laboratory test and process simulation
 - Fully Integrated demo – **A MUST**
- Process and market risks for feedstock and product(s) must be understood
- High value co-products allow riding over the economic cycles
- Final equipment selection should be used at intermediate scale
 - Delayed startup at commercial scale dramatically reduces return on invested capital
 - Workforce training is also best done at intermediate scale

Thank you!

Sisu..... Translation: (Irrational) Perseverance

Making Biorefineries a reality takes
Time, Money, and Perseverance!

