

Processing Recalcitrant Feedstocks in a Biorefinery

Johnway Gao

Dwight Anderson

Benjamin Levie

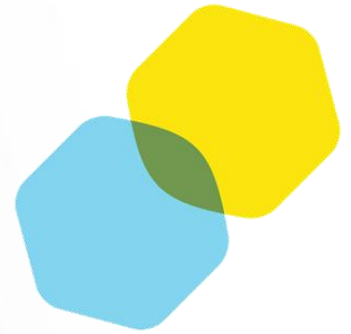
Paul Spindler

October 10–12, 2012

*For Bio Pacific Rim Summit on Industrial
Biotechnology and Bioenergy
Vancouver BC, Canada*

Catchlight
Energy™

A Chevron | Weyerhaeuser
Joint Venture



Outline

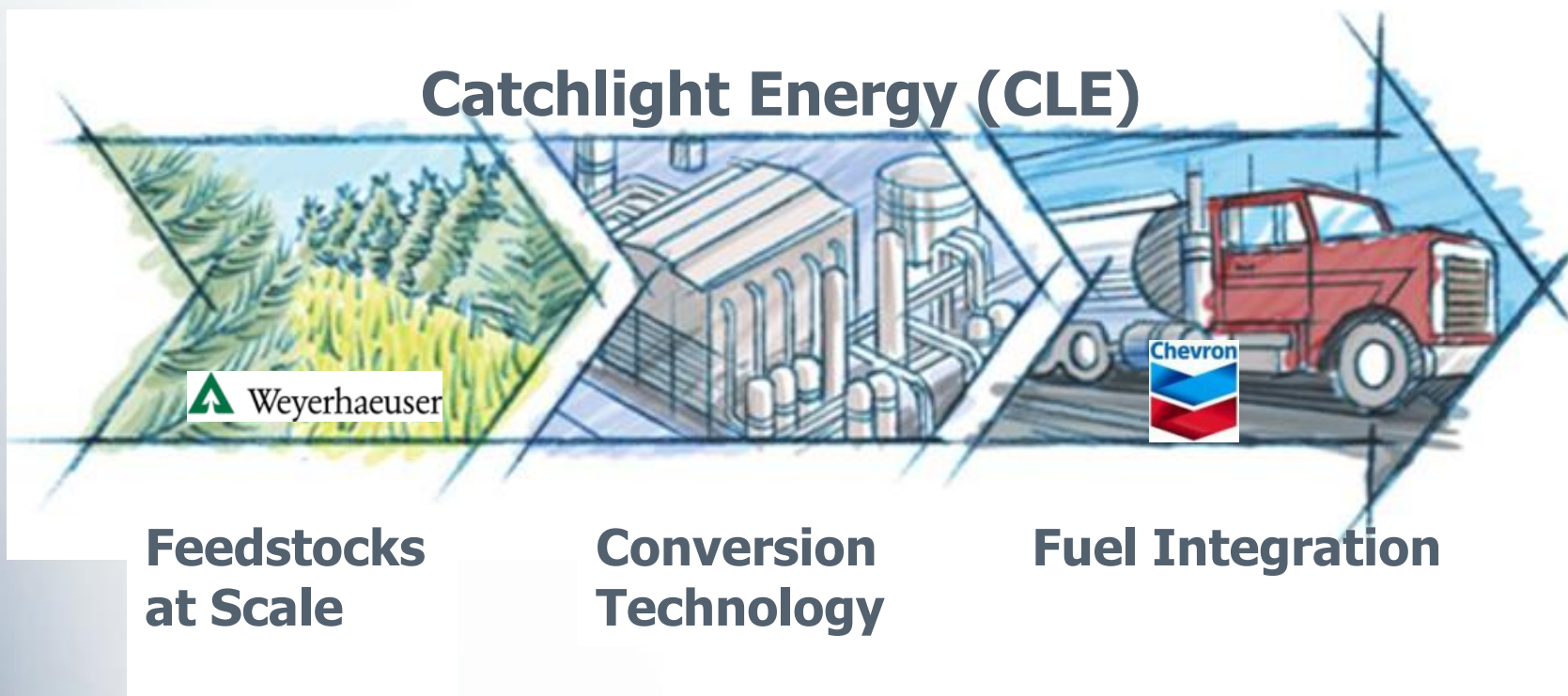


- **Catchlight Energy’s mission**
- **Biomass management**
 - Forestry sustainability
 - Cellulosic feedstock supply
- **Cellulosic fuel off-taking from third parties**
- **CLE Developments**
 - Sugar technology
 - Bio-oil to “drop-in” hydrocarbon fuels.
- **Summary**

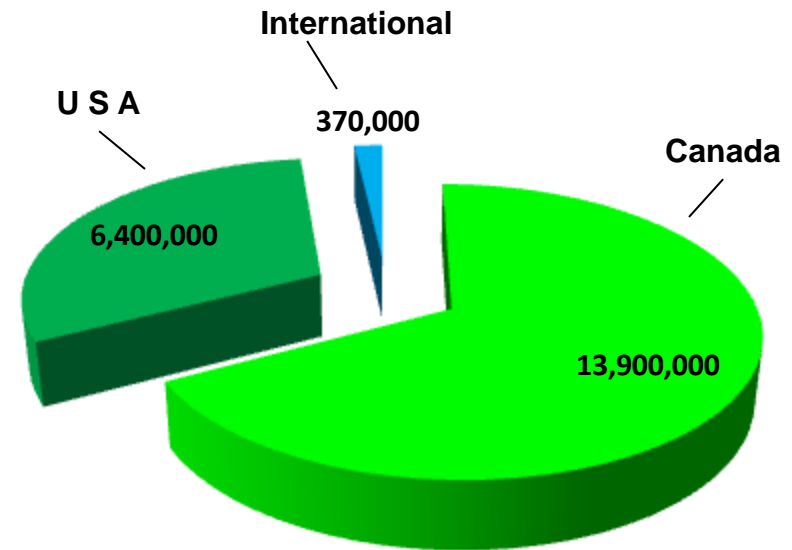
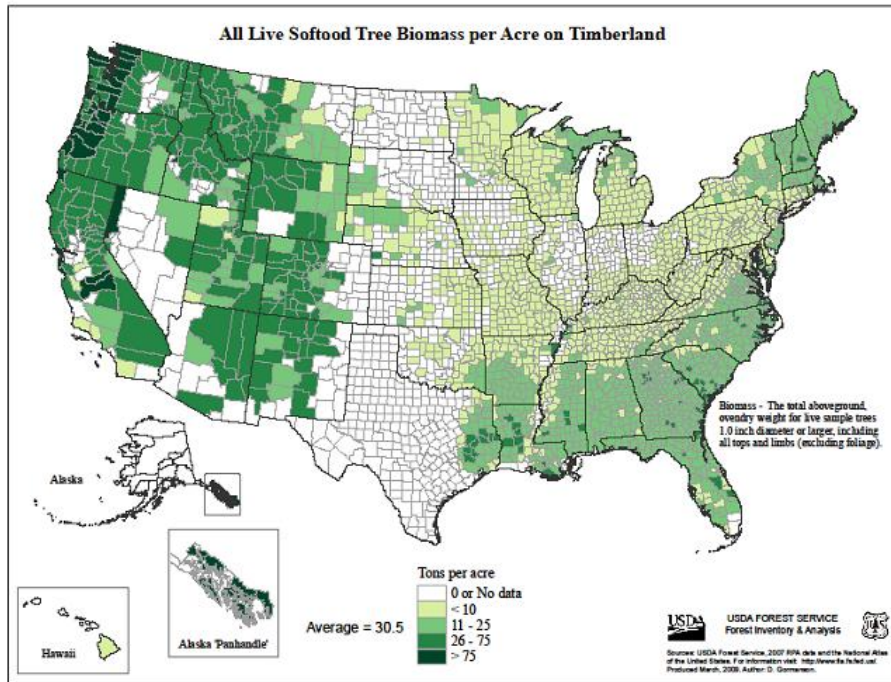
Mission: Commercializing Sustainable Forest Biomass to Fuels



End-to-End Value Chain Solution Leverages the Strengths of Two Natural Resource Leaders



Softwood – High Availability/High Recalcitrance



Weyerhaeuser-Managed Acres

Weyerhaeuser Annual Report 2011

The use of softwood is of high value to the biofuel industry, but it remains a difficult feedstock for most pure bio-conversion processes.

Catchlight Energy (CLE) – What we do



Feedstock supply and product off-take for biofuel facilities (Wrap services)

- CLE to provide woody feedstock & fuel integration for KiOR's 1st plant

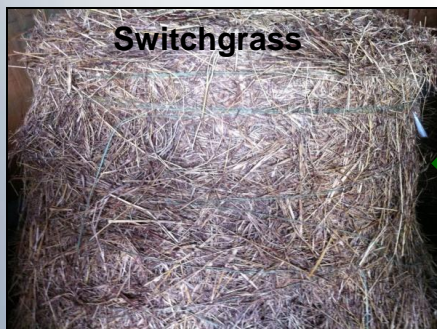
Unparalleled sustainability science

- Large-scale studies (1200 acres)
- Identify ecosystem effects
 - Soils/nutrients
 - Water quality/quantity
 - Wildlife/biodiversity
 - Carbon life cycle analysis



CLE Sugar Technology

- Adaptable to existing infrastructure – modify or retrofit
- Scalable from pilot operations
- Feedstock flexible – softwood, hardwood, and herbaceous biomass
- Cellulosic sugar options



Pretreatment



Hydrolysis
and Sugar
Production

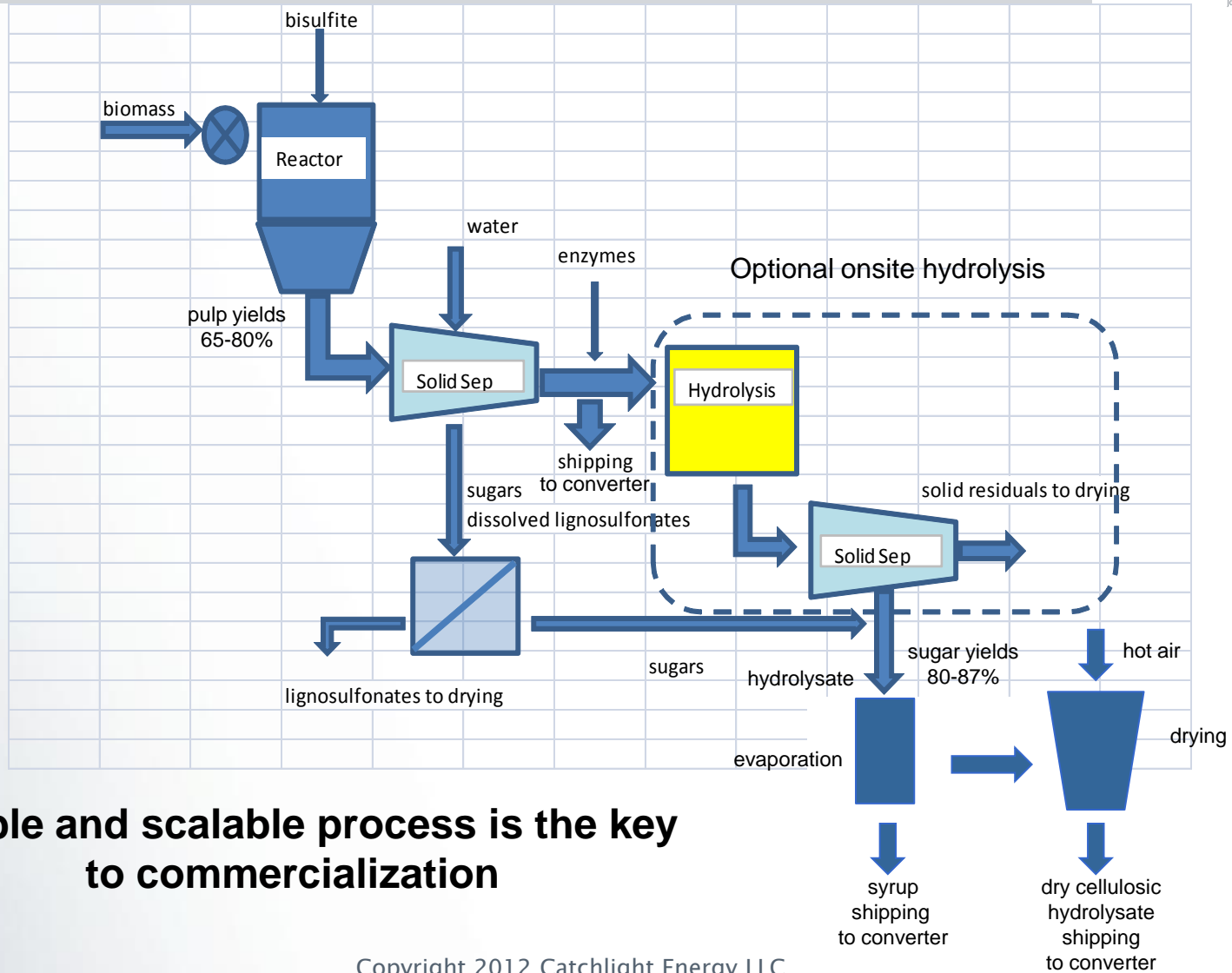


Cellulosic Sugar Syrup



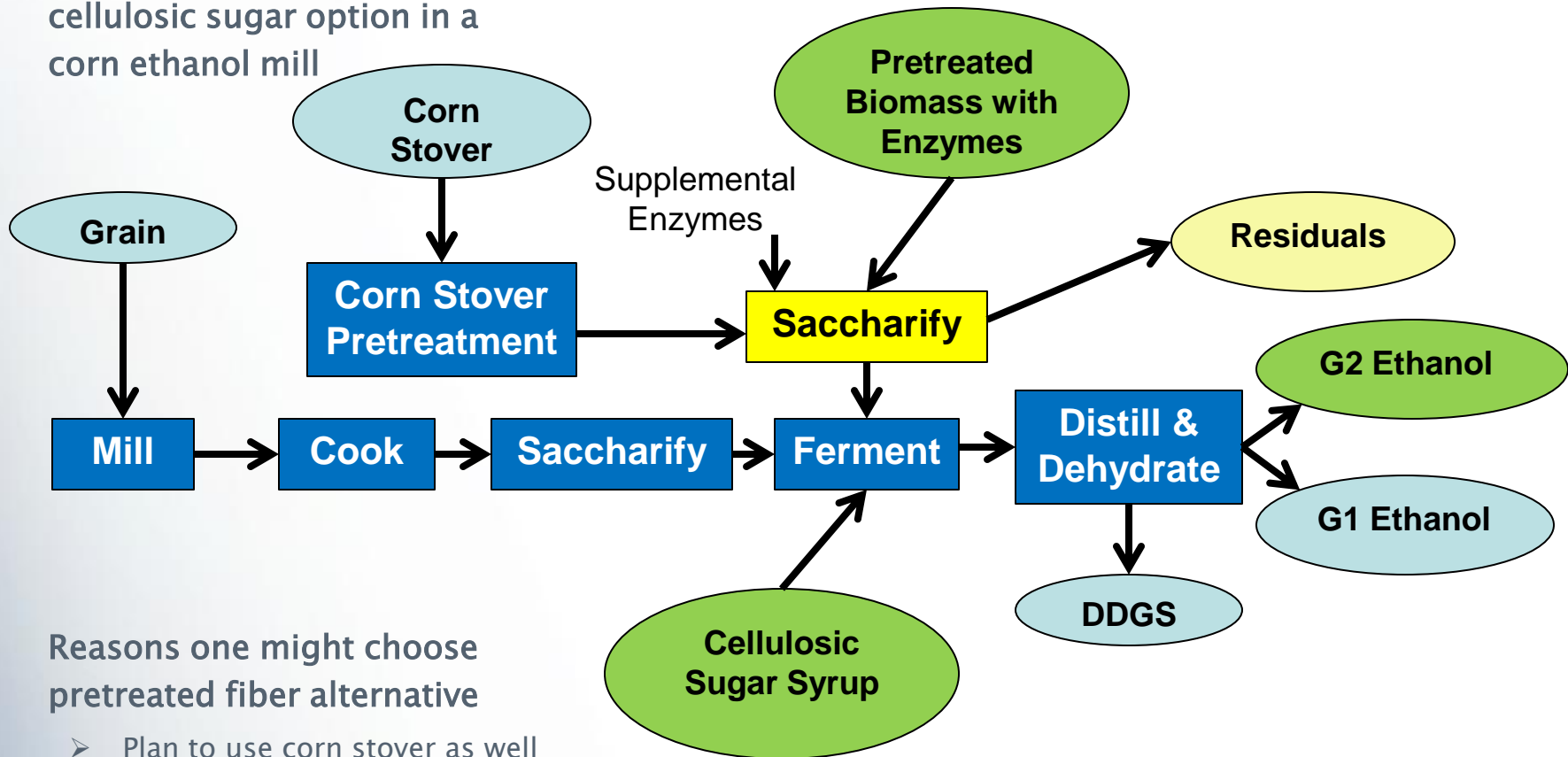
Cellulosic Sugar Solid

Process Flow Diagram



Cellulosic Biomass Addition

- Pretreated fiber option and cellulosic sugar option in a corn ethanol mill



- Reasons one might choose pretreated fiber alternative
 - Plan to use corn stover as well
 - Residuals available for a boiler
 - Increase hexose content

Feedstock Intermediate Options

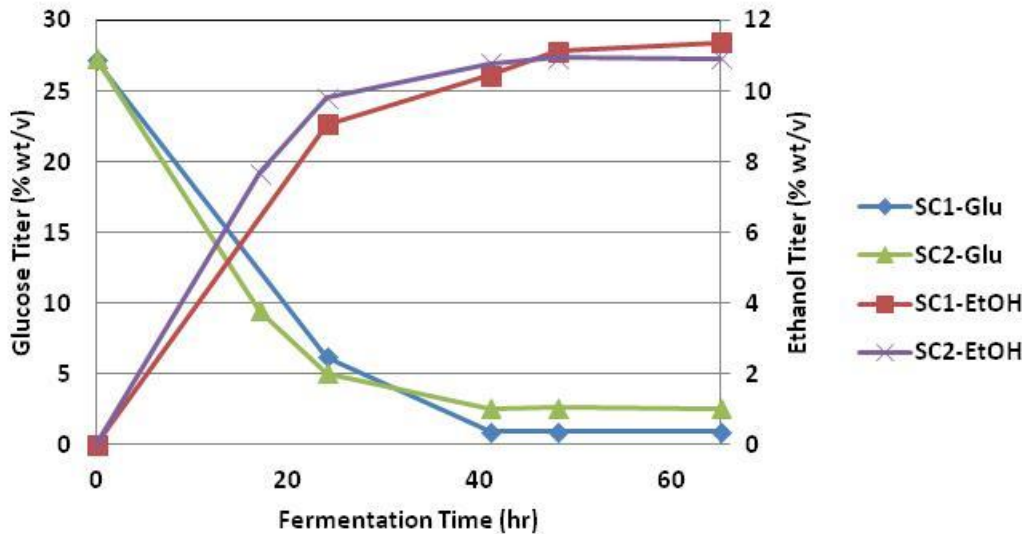


- Implications of cellulosic feedstock choices: corn stover vs. CLE softwood options

| | Corn Stover | CLE Pretreated Biomass | CLE Cellulosic Sugar Syrup | CLE Solid Sugar |
|------------------------------------|----------------|---------------------------------|----------------------------|-----------------|
| Storage | Keep dry | Keep wrapped | Need tank | Keep wrapped |
| Availability | November–April | Year-round | | |
| Enzyme Use | Add in plant | Can be included | Not needed | |
| Sugar Conc. | 12% | | Up to ~75% | 80–95% |
| % C6 sugars (balance is C5) | 60% | 93% due to softwood composition | | |

CLE pretreated biomass or sugar options are convenient and easy to use

Cellulosic Sugar Syrup Ferments Easily



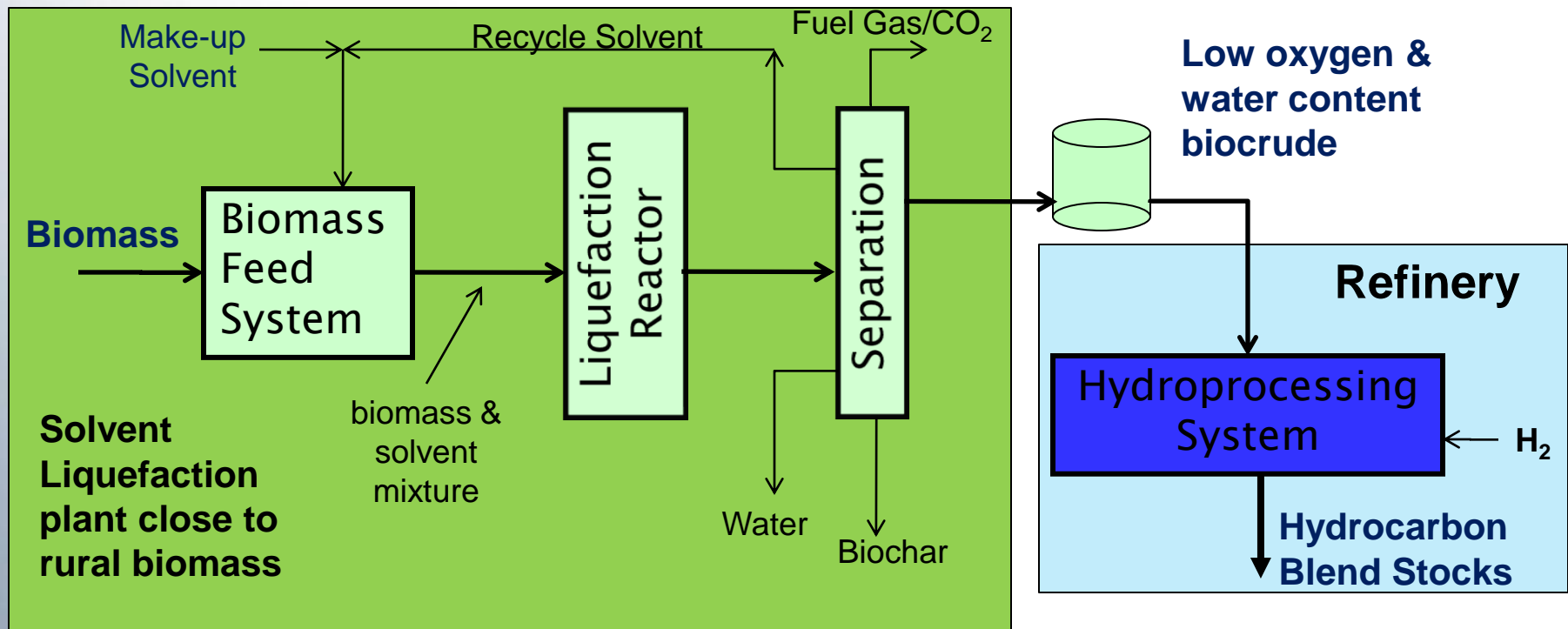
**Light Fermentation Broth
Color**

- Softwood sugar syrup is highly fermentable
 - Ethanol titer can be 11.0% (wt/v) in 48 hrs
 - Optimization may increase ethanol titer further
 - Syrup titer can be adjusted to optimize energy costs

CLE Solvent Liquefaction (SL) Process

Main Process Steps

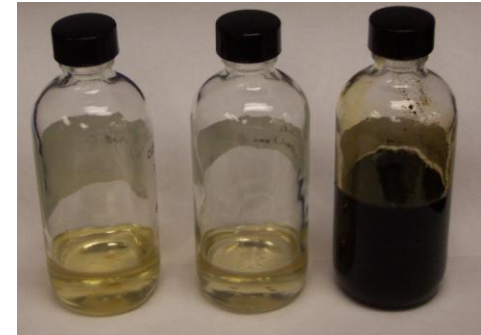
- Biomass Feed System (raise biomass pressure & temperature for reaction)
- Convert biomass in the presence of organic solvent & partially remove oxygen
- Hydroprocess liquefied-biomass to remove remaining oxygen in refinery



CLE Solvent Liquefaction Process

Key process advantages:

- Very high yields (> 100 gal of finished HC products/BDT)
 - 70% carbon conversion to the organic phase
 - Low carbon loss (<3%) to the aqueous phase
 - Low char yield (~5 wt%)
- Favorable biocrude properties
 - Lower oxygen content (~20 wt%)
 - Very low water content
- Low complexity process
 - Moderate pressure operation, no catalyst
 - A practical, effective and low-cost solvent system
 - Processes a wide variety of whole biomass
- Greater than 60% GHG reduction ➡ renewable cellulosic fuel



Summary



- CLE is selectively offering feedstock supply and product off-take for cellulosic biofuels producers in North America (“wrap” agreements)
- CLE’s technologies are advantageous for difficult to hydrolyze feedstocks, such as softwood residuals which are available today at commercial scale
- The underlying components of CLE’s Sugar technology are proven, scalable, and cost effective
- Solvent Liquefaction is a high-yield process and is undergoing additional development
- CLE is open to technology collaboration as well as “wrap” agreements



Catchlight Energy is uniquely
positioned for commercial
success



"The power of Human Energy to
find newer, cleaner ways to
power the world"



"Releasing the potential in trees
to solve important problems for
people and the planet"