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Sustainable fuels and chemicals from biomass

The ABS Process

Deriving value from biomass

- Developed as a pretreatment for pulping / pelletization
  - Hot Water Extraction (HWE) as biomass pre-treatment
  - Separations technology for recovering value
- Improves biomass for downstream processing
  - **Improves pellet quality / lowers production costs**
  - Increases pulping capacity & improves quality
  - Decreases shrink/swell in fiber composites

The ABS Process

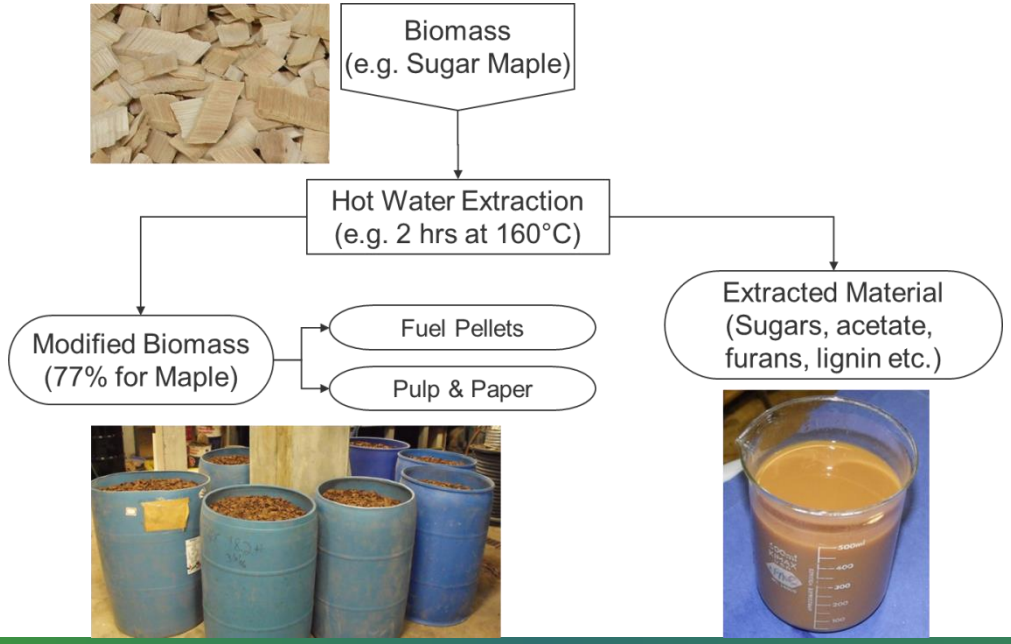
Deriving value from biomass

- HWE processing returns a suite of co-products:
  - Fermentable sugars
    - Ethanol of other products
  - Renewable chemicals
    - Acetic acid, furans, methanol
  - Lignin based resins
    - Replacement for phenol-formaldehyde glues
  - Alternatively: cattle feed molasses
    - High C5 content may allow higher usage
    - Organic certification likely

ABS Process: Hot Water Extraction

Pretreating biomass for pulping, pelletization, etc.

- Processing of biomass in water at elevated temperatures
- 16-45% mass removal, condition and biomass dependent
  - Primarily hemicelluloses & lignin extracted
- Equipment similar to pulping digesters

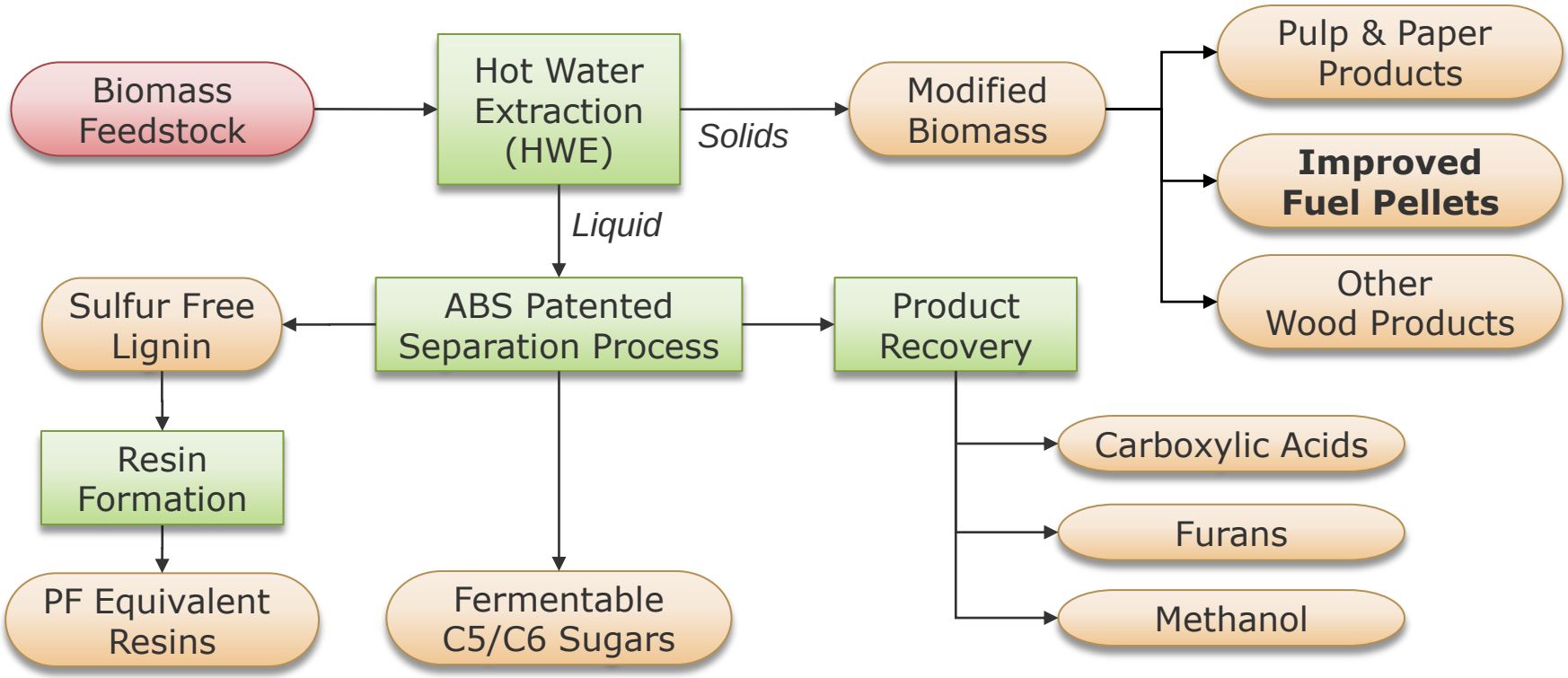


Pilot Extraction System, SUNY ESF

ABS Process: Separations & Recovery

Making value from extracted components

- Separations result in a range of industrially valuable chemical and material products



Advantages of HWE for Fuel Pellets

Improved pellet quality, reduced production cost

- Massively improved water resistance & durability
- Up to 10% increase in energy content
- **Ability to utilize low cost, barky/high ash, feedstock**
  - Due to de-ashing effect of HWE: ~60% ash reduction
  - Potential to use non-woody raw materials
- Reduction in pre-pelletizer milling energy
  - 64-82% reduction demonstrated
- Expected reduction in pelletizer energy consumption
  - 10-25% reduction expected from anecdotal data
  - Third party testing data expected soon

Advantages of HWE for Fuel Pellets

Highly moisture resistant pellets

Extracted Pellet | Standard Pellet

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Fuel Pellets and Opportunities for West Coast Biomass

Current Market Situation

Large volumes, rapid growth

- Fuel pellets are a large and growing market
  - World production of >28.6MM MT in 2016
  - Historical growth of 9-14%/year (FAO / IEA)
- Largest import demand currently is Western Europe
  - UK, Denmark, Italy major importers
  - 5.8MM MT flowed from NA to the EU in 2015
  - Infrastructure for handling white pellets in place
  - Demand growth expected to slow

Opportunities For California's Biomass

Korea and Japan Are an Opportunity

- Japan and Korea are new growth markets
  - ~4.4MM MT in 2018
  - Potential to reach >20MM MT/year by mid 2020's
- West coast producers are advantaged for export to Asia
- Japan desires water resistant "black" pellets
  - Would save need for new infrastructure
- Japanese buyers are long term contract focused
- Korea has been primarily active in spot markets
  - Recent events suggest transition to long term contracts

Opportunities For California's Biomass

Potential For Upgrading Low Grade Forest Biomass

- Estimates of potential supply: 4-51MM MT/year
  - Primarily from "mechanical fuel reduction"*
- HWE could enable utilization of this material
  - Upgrade forest biomass for pelletization via ash reduction
  - Provide 3-40MM MT/year pellets
  - Could co-produce 80-1000 MMgal/year of ethanol
  - Generate other co-products (acetic acid, etc.)

*As per USDA Forest Service RMRS-GTR-149 (2005)

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Paths To Commercial Application

Direct To Commercial Project

Simplified technology & equipment re-use

- Opportunity provided by shuttered site near Redding
  - Estimated capacity: 175-200 kton/year pellets
- Simplified technology to reduce technology risk
  - Extraction for pellets (for export to Japan / Korea)
  - Evaporation for cattle feed molasses
    - Potential for high value organic molasses
- Provides opportunity to scale technology
  - Expected to enable full deployments (e.g. ethanol)

Direct To Commercial Project

Significant potential, solid returns

- Project would include dedicated pellet mill
  - Investment including pellet mill : $60-75MM
- Approximate revenue: $40-50MM/year
- EBITDA: $14-18MM/year
- Base case (all cash) return on investment: ~20%
- W/debt return on investment: ~80%

Direct To Commercial Project

Current Next Steps

- Currently looking for $1-2MM in project seed funding
  - Conduct demonstration runs with representative biomass
  - Provide large product samples to potential customers
  - Conduct site survey / initial engineering
  - Looking for grant / VC / strategic partner support
- Looking for state support in accessing site

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Complete Deployment Business Case

ABS Business Case (Pellet Mill Case)

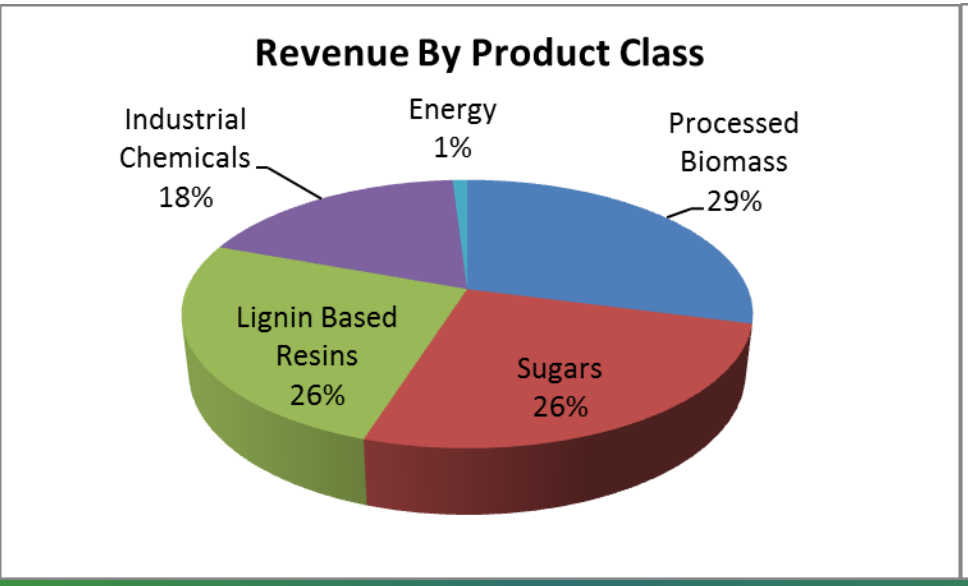
Broadly applicable, capital intensive, solid returns

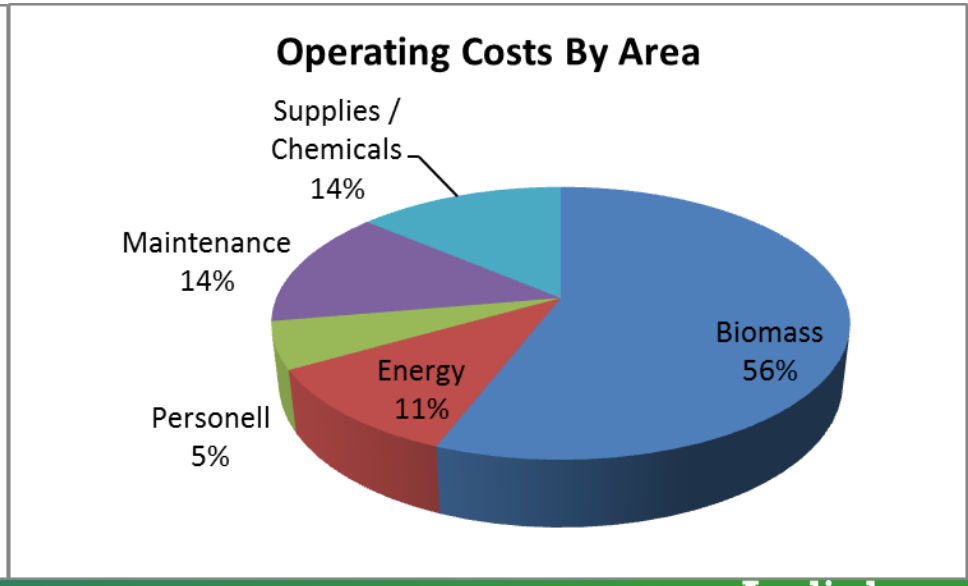
- Technology applied as pretreatment for existing pellet mill
  - Currently 57 plants in North America of appropriate scale
  - Market growth of 14%/year since 2011
- Target capacity (wood side): 240kton/year
- Approximate investment: $90-95MM
- Approximate revenue: $45-50MM/year
- EBITDA: $20-25MM/year
- Base case (all cash) return on investment: ~22%
- W/debt return on investment: ~85-90%

ABS Business Case (Pellet Mill Case)

Diverse products, potential for further improvement

- Revenue from a diverse range of products
  - Provides protection from shocks in one product
- Expected technology improvements improve ROI
  - Reduce capital investment, increase revenue
  - Improves base ROI to 33%





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