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Developing Biorefineries to Produce Energy, Ethanol and Other Industrial Products

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Definition of a PureVision Biorefinery

An industrial complex that will convert renewable, lignocellulosic biomass into fiber, chemicals, fuels, power and/or products with minimal or no negative environmental impacts.

PureVision Technology, Inc.

A technology development company with critical IP and processes to make biorefineries economical

- **PureVision was formed in 1992**
- **Privately held**
- **Based in Fort Lupton, CO**
- **Virtual company**
- **Mission: To commercialize biorefineries for the conversion of biomass into transportation fuel, industrial raw materials, energy and consumer products.**

The PureVision Biorefining Platform

-Fractionates diverse lignocellulose biomass feedstocks into its three primary components - cellulose, hemicellulose and lignin.

-Cellulose and hemicellulose can be converted into 6 and 5-carbon sugars - the building blocks for producing fuel, fiber and industrial chemicals.

-Cellulose can be used to make pulp and paper products.

-Lignin, a high-BTU biomass component, can generate process steam and electricity for the biorefinery or become higher-value products.

Lignocellulosic Biomass is the non-fruit or woody portion of plants.

Lignocellulose is composed of:

1. Cellulose, a biopolymer composed primarily of 6-carbon sugars (~40%)
2. Hemicellulose, a biopolymer composed primarily of 5-carbon sugars (~30%)
3. Lignin, a biopolymer composed of phenolic derivatives (~25%)
4. Extractives, including resins and proteins (~5%)

Biorefineries of the future will integrate:

Plant Science
– Genomics
– Enzymes
– Metabolism
– Composition

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Production
– Wood, trees
– Grasses
– Energy crops
– Agricultural Residues
– MSW

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Processing
- Acid/enzymatic hydrolysis
- Fermentation
- Bioconversion
- Chemical Conversion
- Gasification
- Combustion
- Pulping

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End-Uses

Products
– Fuels
– Plastics
– Solvents
– Chemical Intermediates
– Phenolics
– Adhesives
– Hydraulic Fluids
– Fatty acids
– Carbon black
– Paints
– Dyes, Pigments, and Ink
– Detergents
– Pulp & Paper products
– Horticultural products
– Fiber boards
– Solvents
– Adhesives
– Plastic filler
– Abrasives

Fuel
Power

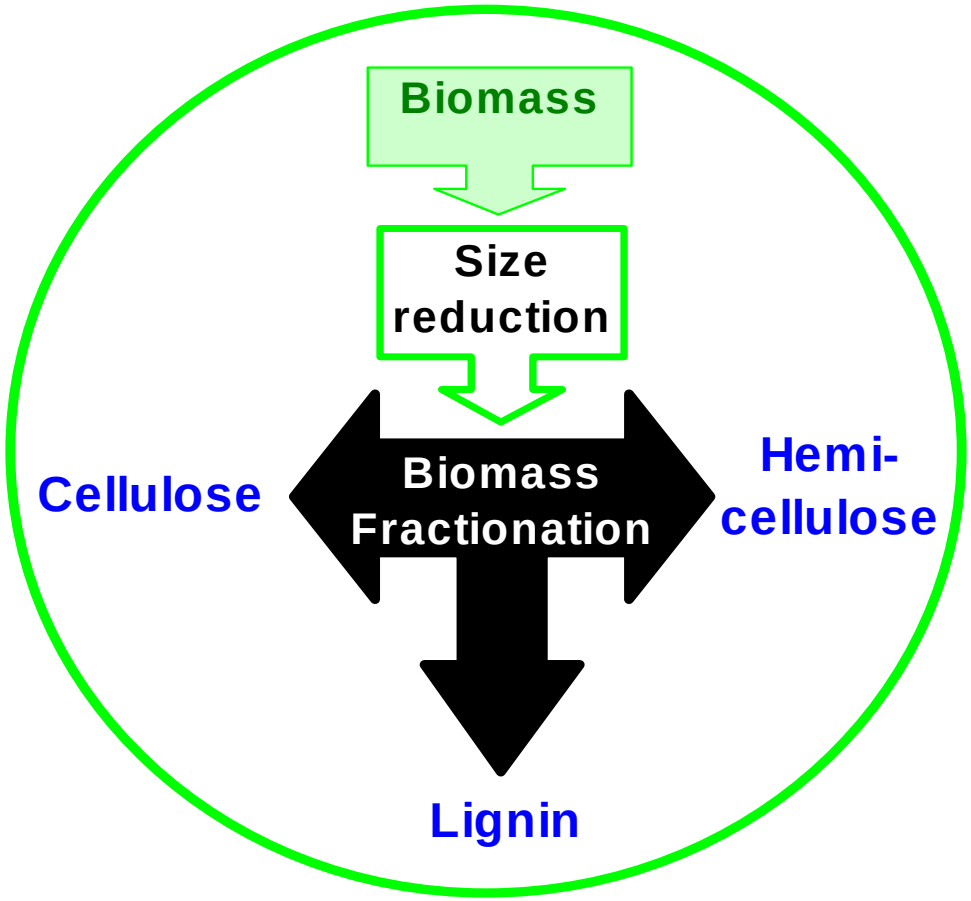
PureVision plans to supply the operating system to the <u>emerging biorefinery industry</u>

The renewable resource base of the U.S. is currently underutilized. Feedstocks that can be used as biomass inputs to the PureVision process include, but are not limited to the following:

Potential Biorefinery Feedstocks	**Tons (dry) millions per year**
Agricultural crop residues (Straw, corn stover, bagasse, etc.)	**150**
Wastes including organics and paper from municipal solid waste, commercial waste wood and urban tree residues.	**150**
Energy crops (Switch grass, hybrid poplar, willow, etc.)	**120**
Forest and pulp mill residues (Small diameter trees, cleanings, waste streams, etc.)	**80**
Total	**500**

The Reactive Fractionation Process

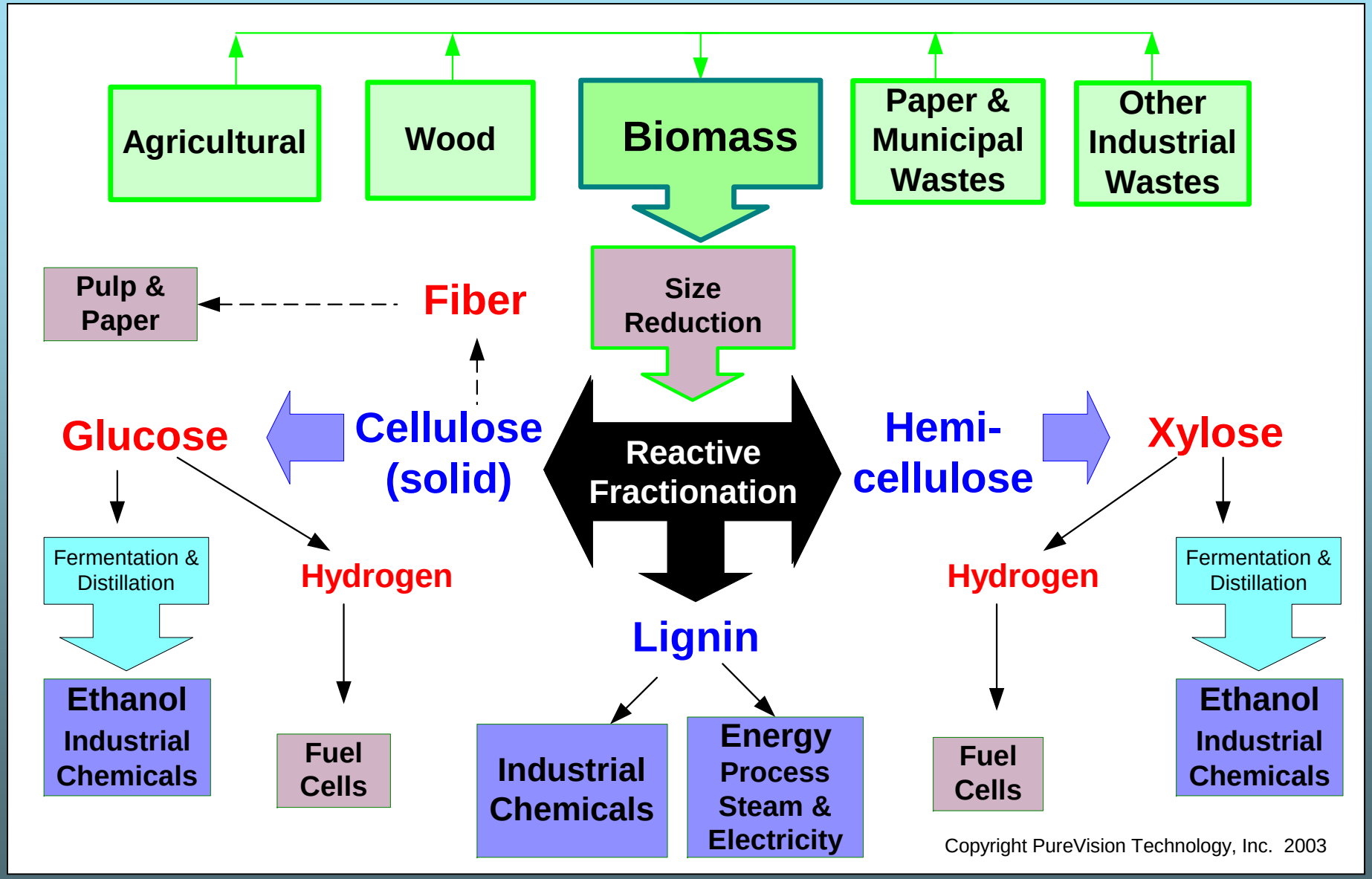
- PureVision's Core biorefinery technology
- Separates the hemicellulose and lignin from the cellulose
- Patented in U.S. with foreign patents pending



PureVision's reactive fractionation process consists of the following steps

1. Mechanical preparation of biomass.
2. Continuous counterflow washing at elevated temperature followed by steam explosion to yield liquid fractions (with dissolved lignin, hemicellulose and extractives) and a solid fraction of pure cellulose.
3. Separation, recovery and utilization of hemi-sugars and lignin in liquid fractions.
4. Enzymatic hydrolysis or pulp production of solid cellulose fraction.
5. Fermentation of C-5 and C-6 sugars to produce fuel ethanol and/or other industrial chemicals.
6. Processing, recycle, and utilization of feedstocks resulting in products and co-products from biomass.

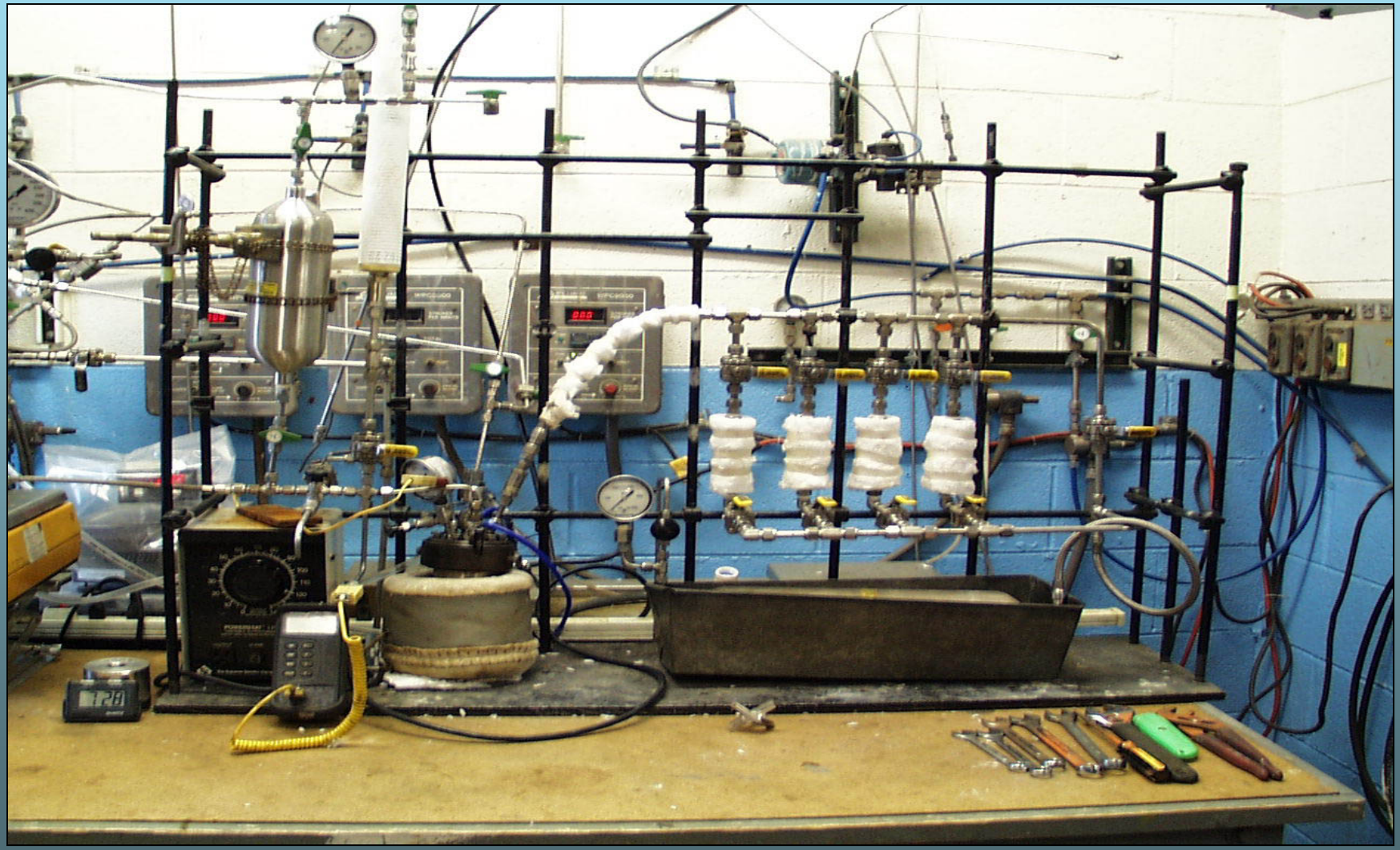
PureVision Biorefinery Schematic



Distinguished in Marketplace

- Total utilization of biomass
- Produces purified cellulose
- Reduces enzyme use
- Closed loop operating system that relies on water, caustic & steam
- Scaleable for large industrial and smaller rural applications
- Relies on off-the-shelf equipment

Bench-Scale Proof-of-Concept Testing at Hazen Research Inc. in 1999



Third Generation Batch Reactor at Western Research Institute 2002-2003

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Reactive Fractionation
Bench-Scale Results

- Bench-scale studies using wheat straw resulted in fractionated cellulose with greater than 99% of the hemicellulose hydrolyzed into sugars.
- Greater than 97% of the lignin removed.
- Subsequent hydrolysis studies showed a 3-fold reduction in enzymes used to hydrolyze the fractionated cellulose.
- Fractionated wheat straw is suitable as a substitute for hardwood market pulp.

Continuous Pilot-Scale Testing confirming counterflow processing of biomass in January of 2003

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Process Development Unit Undergoing Shakedown in January 2004

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US DOE / USDA Farm Bill Grant:
Demonstration of the PureVision Biorefinery

- Corn stover will be the primary feedstock.
- PureVision will optimize fractionation operating parameters using 10 kg/hr PDU.
- Genencor to supply cellulase enzyme system.
- NREL and MTR to characterize, separate and recover lignin and hemicellulose components.
- Harris Group and PureVision to perform Aspen Plus modeling.
- PureVision, Harris and Entek to develop the design for a prototype (4 dry t/d).

PureVision's Three Biorefinery Platforms

- **Sugar Platform**-Auto hydrolysis of hemicellulosic sugars. Enzymatic hydrolysis of cellulose to produce C-6 sugars (glucose). Lignin utilization.
- **Pulp and Paper Platform**-Conversion of cellulose fibers into pulp and paper products. Fermentation and/or distillation of C-5 sugars. Lignin utilization.
- **Hydrogen Platform**-Conversion of glucose, xylose and/or ethanol into hydrogen. Lignin utilization.

Reactive Fractionation Technology Major Challenges:

- **Shakedown underway, technology needs to be perfected using continuous process.**
- **Mass and energy balance closure needed.**
- **Technology must be demonstrated at a commercial scale.**
- **Substantial funding is needed to scale up the reactive fractionation process for commercial operations.**
- **Economics must be proven to be economical.**

PureVision's Commercialization Timeline

1992-2003:
Developed biorefining technologies. Designed and built continuous Process Development Unit.

2004-2005:
Process biomass at PDU- scale. Develop design criteria for prototype.

2006- Ongoing:
Build prototype. Process biomass at PDU and prototype-scale. Begin planning to develop and build biorefineries.

2007- Ongoing:
Establish the design criteria for a 75-t/d commercial demonstration. Continue planning to develop and build biorefineries.

2008-2009:
Build and test commercial demonstration. Finalize plans to begin building first biorefinery.

2009- Ongoing:
Commercialization of PureVision's technology. Begin world-wide implementation of biorefineries.

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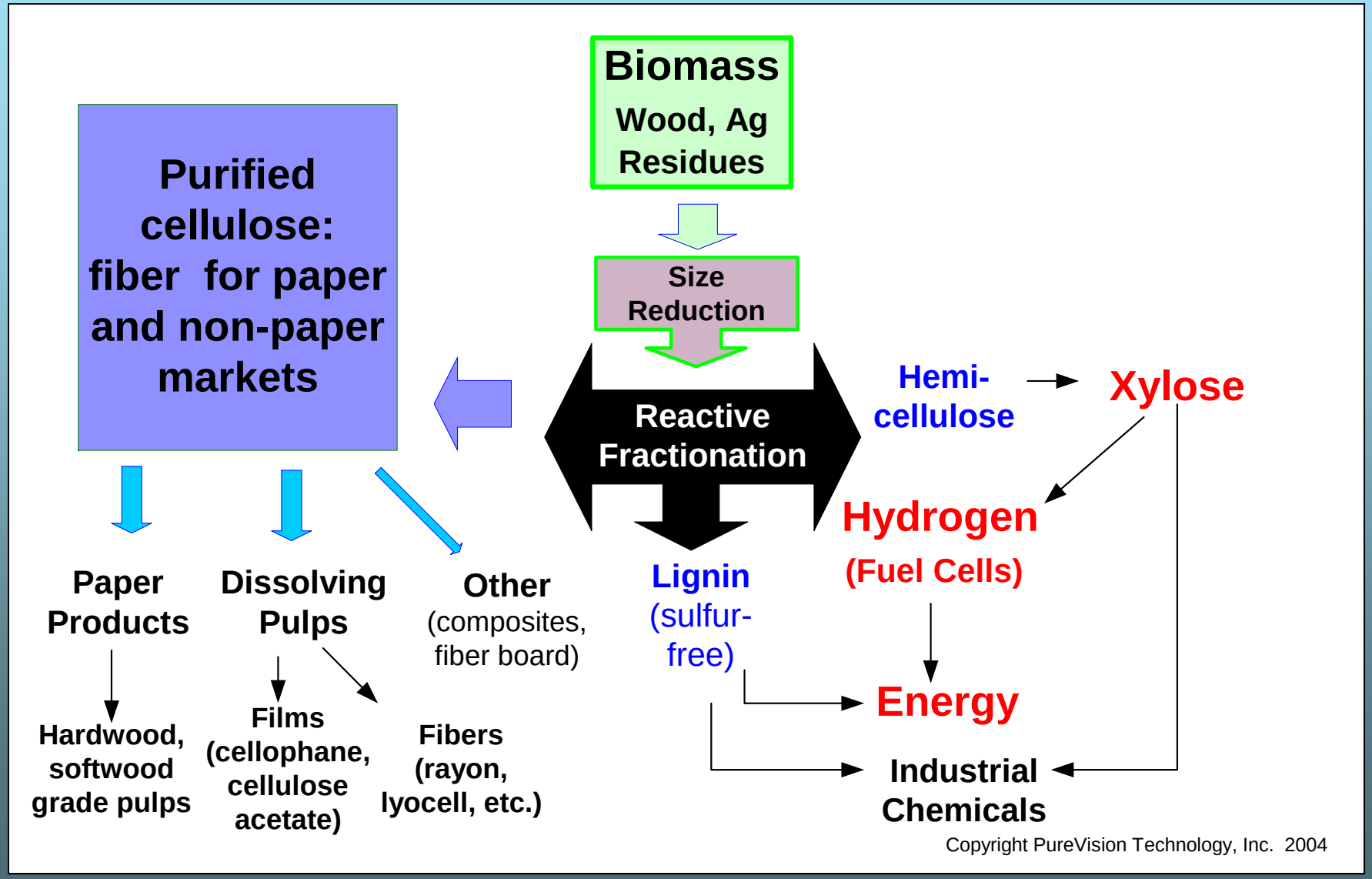
Opportunities of Building a PureVision Biorefinery in Louisiana

-LA has approx. 900,000 dry t/y of bagasse
-Co-locate next to existing sugar plants
-Develop mini pulp mills to process 100 t/d
-Pulp & paper, ethanol and energy products
-Promote rural economic development
-Promote carbon neutral industry
-Reduce dependency on importing oil

Fiber Recovery and Utilization Biorefinery



Challenges to Build a PureVision Biorefinery in Louisiana

-Technology must be perfected
-Bagasse biorefinery has to be profitable,
  i.e. utilize cellulose, hemicellulose & lignin
-Nov. through Jan. bagasse harvest equates
  to at least one additional feedstock
-Partnerships must be formed
-Public acceptance of biorefinery in LA
-Ability to finance a biorefinery in LA
-Local & State permitting and incentives

Biorefinery Development Program

The PureVision team has developed a four-phased program to evaluate and develop biorefineries.

- **PHASE I** - Preliminary feasibility study, location study, feedstock assessment and economic modeling.
- **PHASE II** - Comprehensive feasibility study, feedstock testing at prototype-scale and process & economic modeling.
- **PHASE III** - Demonstration-scale testing, comprehensive modeling, finalize plans to development targeted biorefinery including: Complete approval process, arrange financing and begin bidding process.
- **PHASE IV** - Finalize financing, negotiate bids for procurement, construction, shakedown and operation.

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