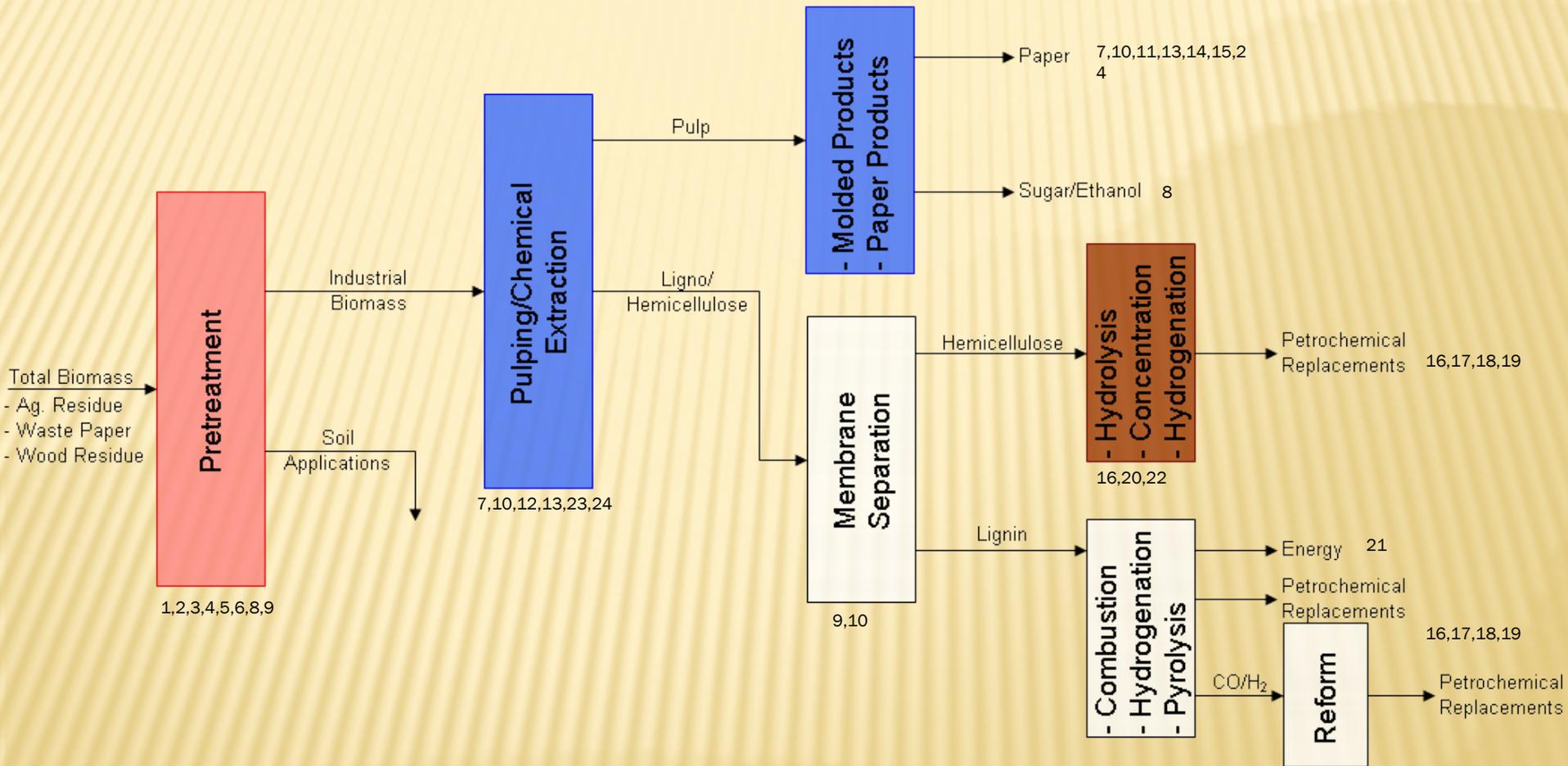


Mark Lewis University of Washington
William Pan Washington State
William McKean University of Washington
William Johnston Washington State
Kristi Lewis Lewis Engineering Consultants

PAPER AND CHEMICAL PRODUCTION FROM AG RESIDUE

POTENTIAL WASHINGTON AGRO-INDUSTRY MANUFACTURING CONFIGURATION



- █ - In development stage
- █ - Nearly commercial (2009), needs some optimization
- █ - Process presently commercial/needs R/D for bio-sugar feed and glycerin
- Research/Development

Biorefinery Sustainable??? - environmental

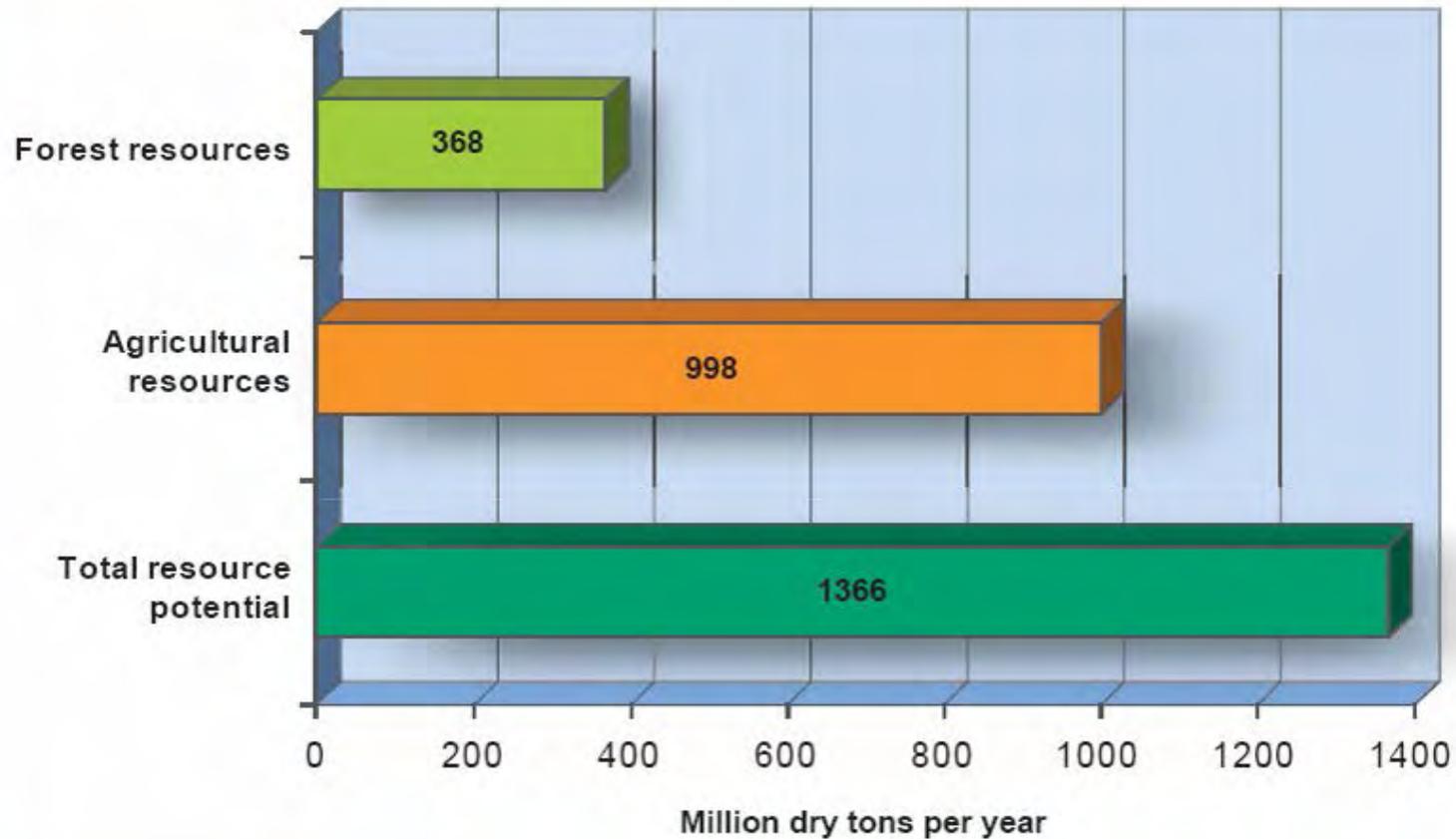


Figure 1: Annual biomass resource potential from forest and agricultural resources

REVIEW OF PREVIOUS GRANT WORK

- ✘ Production of Glycols from Wheat Straw
- ✘ Production of Market Pulp from Alfalfa and Wheat Straw
- ✘ Separation of Sugars and Lignin from Wheat and Alfalfa straw
- ✘ Feasibility Study for Pulpmill in Columbia County

PRODUCTION OF GLYCOLS

- ✘ A mixed stream of glycols was produced on a continuous basis from wheat straw
 - + 75% Ethylene and Propylene Glycols
 - + 16% mixed diols produced
- ✘ A mixed stream of glycols was produced on a batch basis from alfalfa straw
 - + Lower production rate on a batch basis

PRODUCTION OF MARKET PULPS

- ✘ Bleaching Study completed on both wheat and seed alfalfa straw
- ✘ Unbleached wheat straw and three bleached levels of seed alfalfa straw were produced
- ✘ Bleached and Unbleached market pulp was evaluated by outside customer.
- ✘ Natural wheat straw was used to produce copy paper by outside customer

SEPARATION OF WASTE LIQUOR

- ✘ Wheat Straw waste liquor was used to evaluate VSEP separation technology
- ✘ Lignin was successfully removed from the waste liquor
- ✘ A mixed sugar stream was condensed to a higher percentage sugar stream
 - + This stream was used to produce glycols

FEASIBILITY OF PULPMILL

- ✘ Market Evaluation
- ✘ Equipment List
- ✘ Raw Material Analysis

OVERVIEW OF TASKS FOR 2011-13

- ✘ Production of Grade Book for Customers
- ✘ Separation of Waste Liquor Streams
- ✘ Production of Glycols
- ✘ Field Application of Waste Liquor

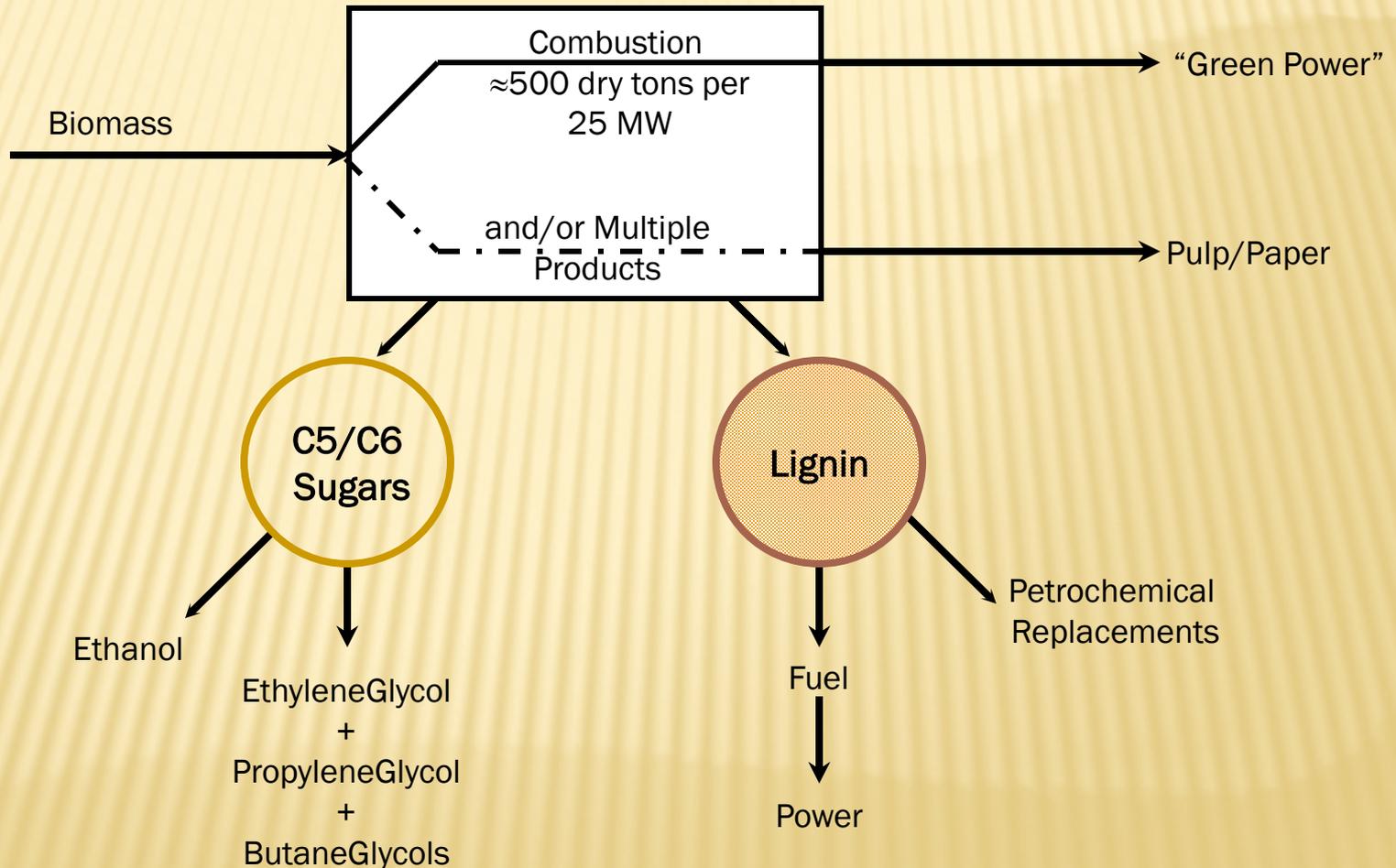
PAPER PRODUCTION

- ✘ Production of Packaging Grades
- ✘ Production of Printing and Writing Grades
- ✘ Book Grades
- ✘ Coated Grades for Magazine Production

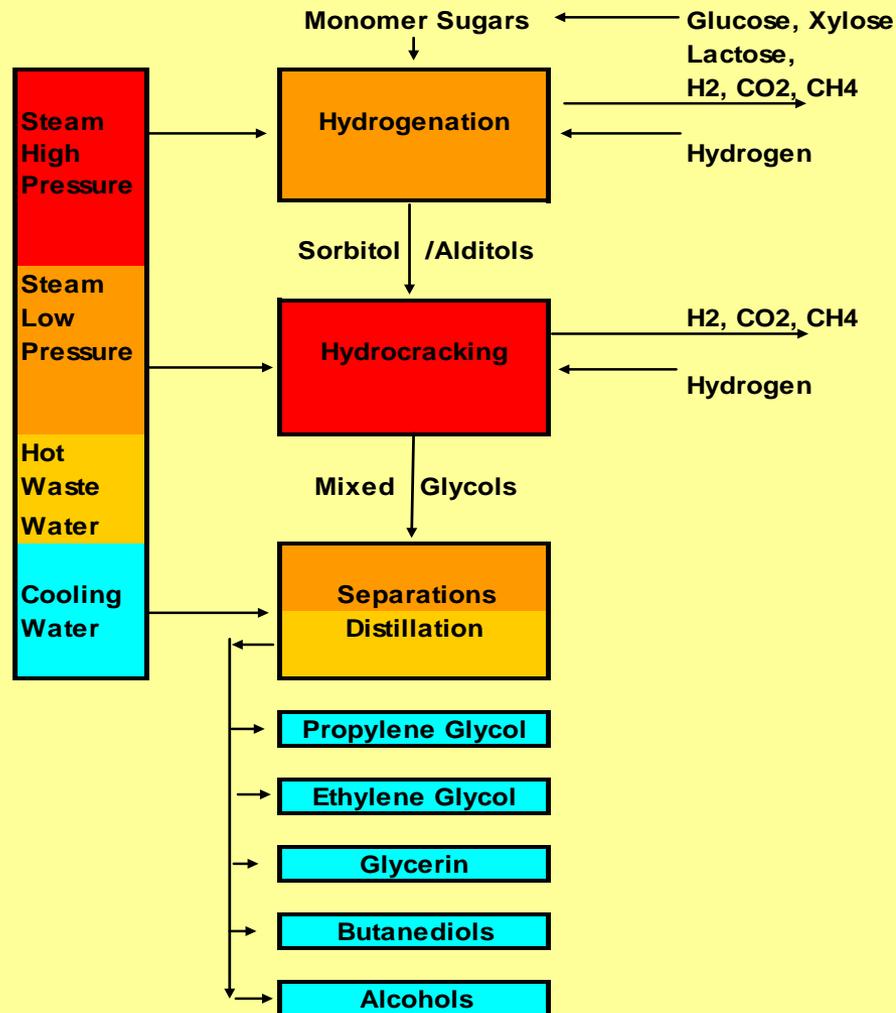
SEPARATION OF WASTE LIQUOR

- ✘ Separation of Lignin from Waste Liquor
 - + Removal of 95+% Lignin
- ✘ Separation of Hemicelluloses from Permeate
 - + Hydrolyzed Sugars and Separate
 - + Separate and Condense Sugar Stream
- ✘ Separation of Sugars
 - + Separate Monomer and Oligimer Sugar Streams into two Streams

“GREEN POWER” AND/OR MULTIPLE PRODUCTS FROM BIOMASS

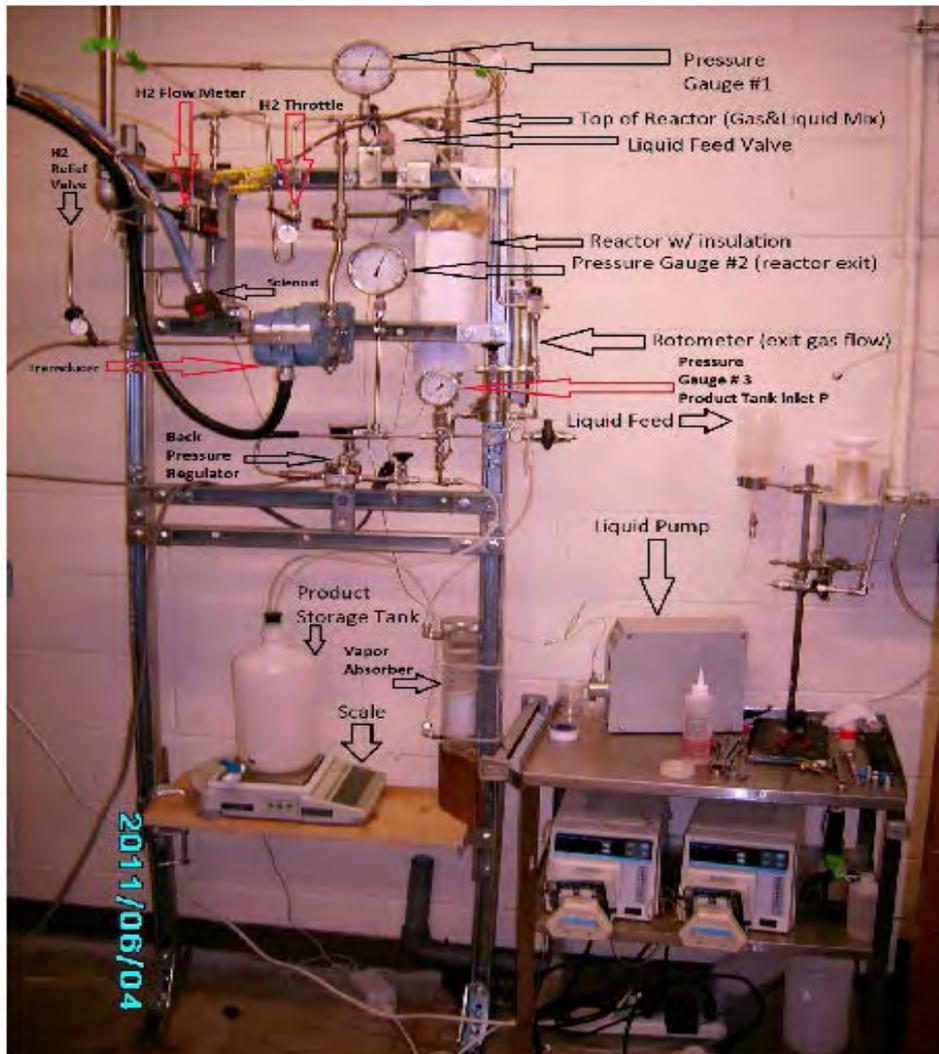


FIVE AND SIX CARBON SUGAR TO GLYCOL BLOCK FLOW DIAGRAM



HYDROGENATION OF SUGARS TO GLYCOLS

- ✘ Evaluation of Catalysts
 - + All New Research for C5 and C6 Sugars
- ✘ Optimization of Hydrogenation of Process Conditions
 - + Various Experimental Designs are Required
 - + Temperature, Pressure, Flow Rate and Catalysts
- ✘ Separation of Mixed Glycol Stream
 - + PG, EG, Butane Diols, and Ethanol need to be Separated into Individual Streams



FIELD APPLICATION OF WASTE LIQUOR (WSU)

- ✘ Concern Over Minerals Being Removed
- ✘ Production of Lignin Rich Stream
 - + Addition of Carbon and Minerals to be Applied to the Field
- ✘ Apply in Statistical Design
- ✘ Soil Evaluation Pre and Post Application
 - + pH and Mineral Analysis over 20 months
- ✘ Add to grass seed application
 - + Fertilizer vs. Hydromulch

COLUMBIA PULP

- ✘ Working with Government Entities
- ✘ Working with Farmers
- ✘ Relationships with IPCI for Integrated Biorefinery
- ✘ Continuous Development of Strategic Relationships with Paper Companies