Technology opportunities and barriers
The Thermochemical Biorefinery – Technical Status and Need for Innovation

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September 20, 2005 – Atlanta, GA

Opportunities For Innovation That Will Make A Difference

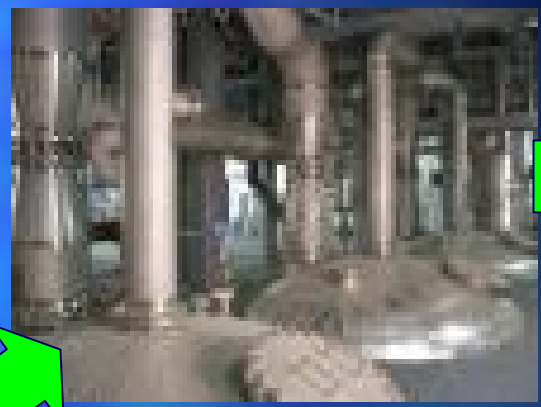
- Multiple value streams from *Forest* BioRefineries
- Sustainable process technology
- Industrial symbiosis

Multiple Value Streams

Biomass

Fiber

Power



Ethanol

Hemicellulose

Syngas

Fuels

Multiple Value Streams

Ethanol

Hemicellulose

Pharmaceuticals
Flavorings
Polymers
Chemicals
Solvents
Etc…

Fuels

Syngas

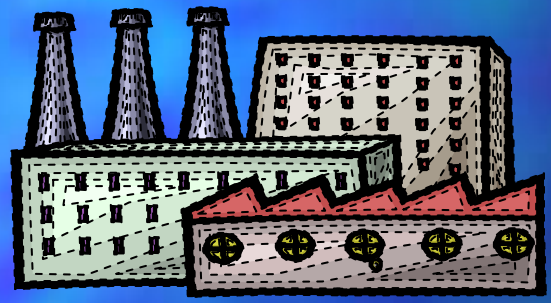
Biomass

Fiber

Power

Industrial Complexes: Advantages of Process and Energy Integration

Biomass
4446 MT/d
(1148 MW_t)



Kraft Pulp Mill

Fiber
2000 MT/d

Power
71 MW_e

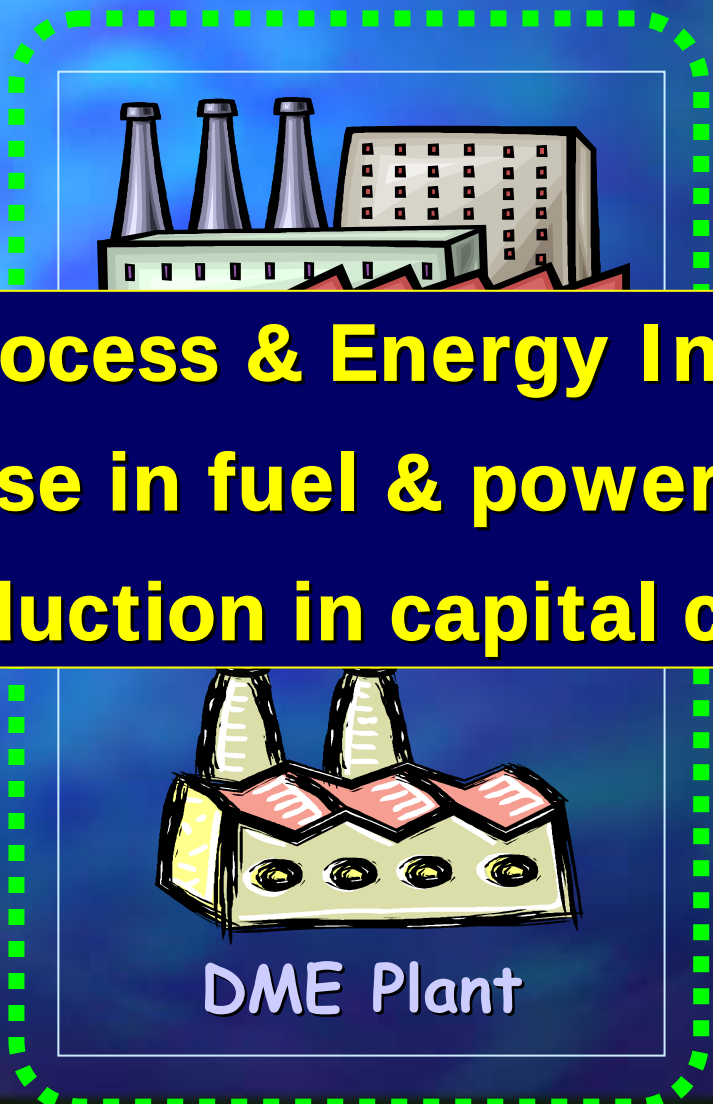
Biomass
525 MT/d
(117 MW_t)

DME Plant

DME
35 MW_e

Energy at low availability

Industrial Complexes: Advantages of Process and Energy Integration



Benefits of Process & Energy Integration:

- 29% increase in fuel & power production
- 20-30% reduction in capital cost

Demonstration of Technology

- Biomass gasifier and IGCC power plant in Värnamo, Sweden
- Fluidized bed gasifier, 18 bar, 950°C
- 18 MW fuel consumption
- 6 MW_e to grid and 9 MW_{th} to district heating
- Facility is being converted to a biofuels demonstration plant

Demonstration of Technology

- Commercial black liquor gasifiers are operating
- Pressurized BL gasifier under development
- Not yet directly coupled with power or fuels plants

Norampac (Trenton, ON)

Weyerhaeuser (New Bern, NC)

Demonstration of Technology

- **Gasification of mixed fuels**
  - ✓ ***Possible feedstocks: wood residue, black liquor, biosludges, agricultural wastes, sorted municipal refuse, etc.***
  - ✓ ***Could eliminate biomass supply limitations***
  - ✓ ***Technical issues***
    - **Mixed feedstocks or separate?**
    - **Control of problematic contaminants**
    - **Recovery of pulping chemicals (black liquor)**

Industrial Symbiosis

Symbiosis:

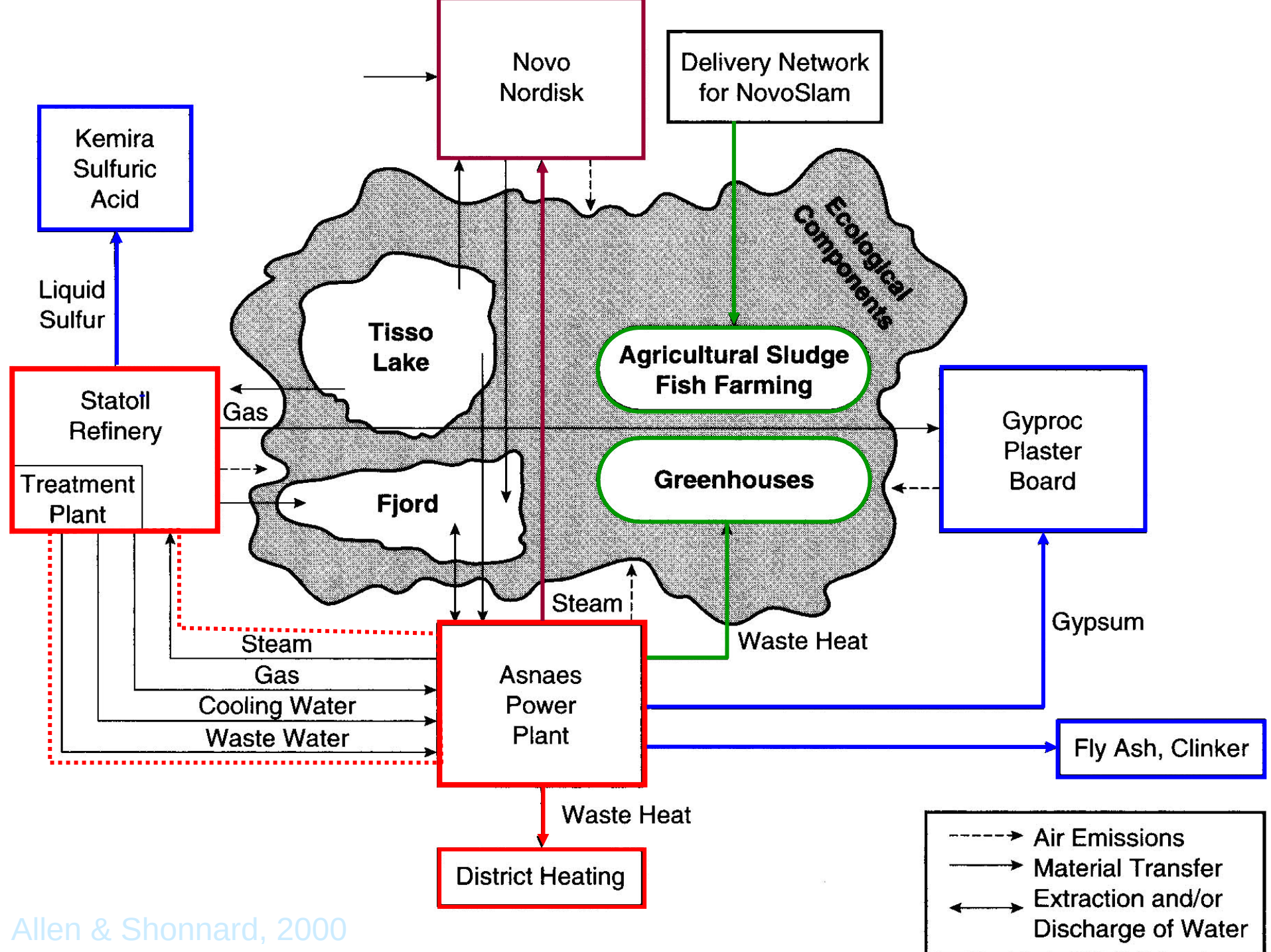
co-existence between diverse organisms in which each may benefit from the other.

Industrial Symbiosis:

industrial co-operation taking place between a number of companies, all of which exploit each other's residual or by-products mutually.

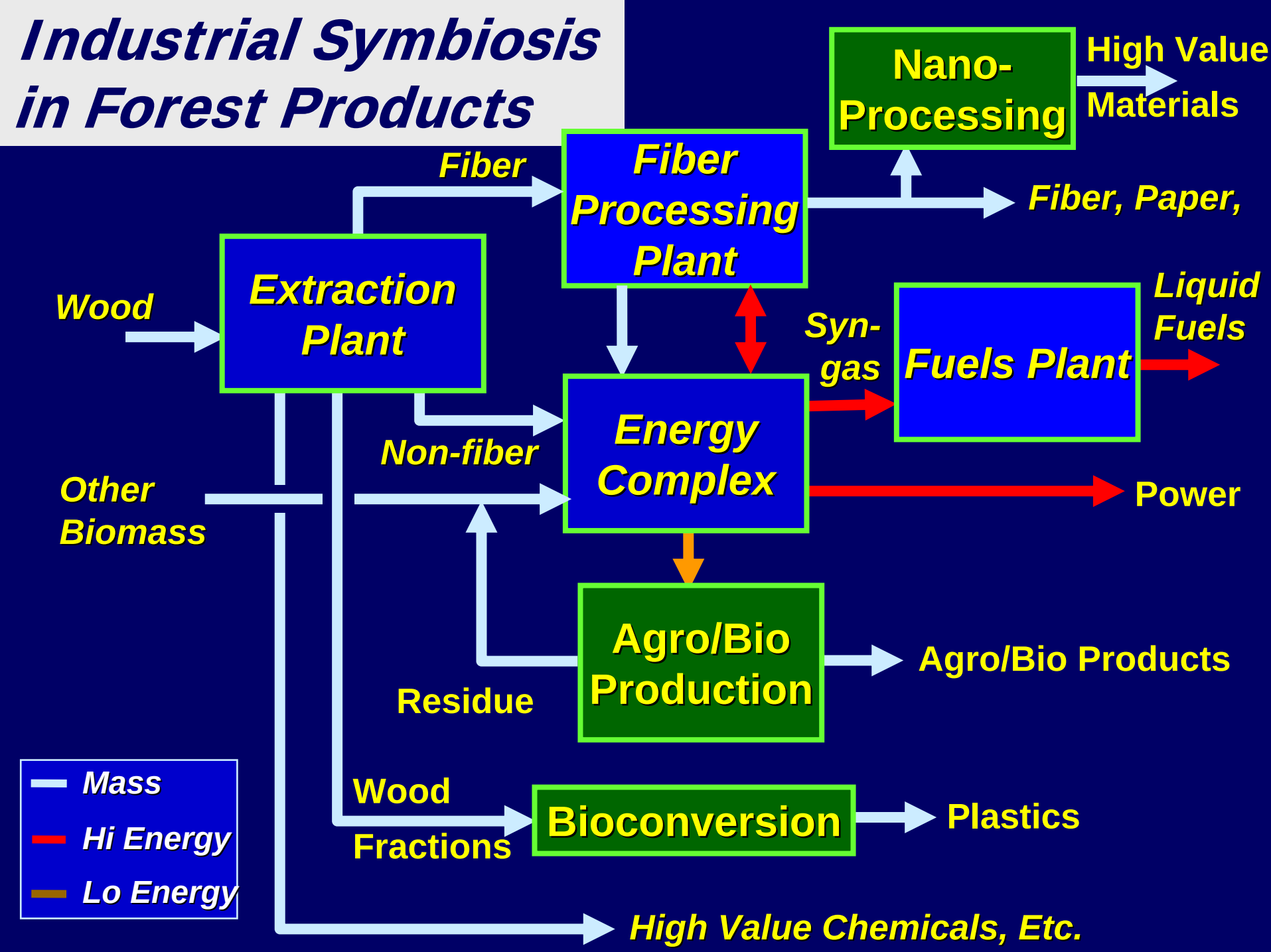
Industrial Symbiosis

- **Objectives**
  - ✓ ***Cross-integration of manufacturing facilities to exchange residuals and energy***
    - **Utilize completely raw materials**
    - **Produce no wastes**
    - **Discharge energy only at near zero availability**
- **Status**
  - ✓ ***Kalundborg, Denmark***
  - ✓ ***A few others in early stages world-wide***
  - ✓ ***none in FP***



Allen & Shonnard, 2000

Industrial Symbiosis in Forest Products



Concluding Remarks

- **Unique opportunities to increase profitability by broadening product spectrum of FP industry**
  - ✓ ***Increasing energy prices put FP industry/resources in a strong position***
  - ✓ ***Take advantage of need for "green" fuels, chemicals, materials***
  - ✓ ***Utilize mass and energy integration***
  - ✓ ***Some capital investment will be required***
    - **Order of $10 billion for all U.S. P&P mills in addition to recovery boiler replacement cost**