

# Feedstocks for Scale-up and Build-out in the Cellulosic Biofuels and Bioproducts Industry

Jim Dooley, PhD, PE  
Forest Concepts, LLC

Scale-up From 10 to 100 to 1,000 tons per day of biomass per facility

Build-out From 5 to 50 to 500 to 1,000 biomass consuming facilities

The math gets scary in a hurry!

An overview of the needs and benefits for the advanced feedstock supply system to mobilize biomass from an industry perspective

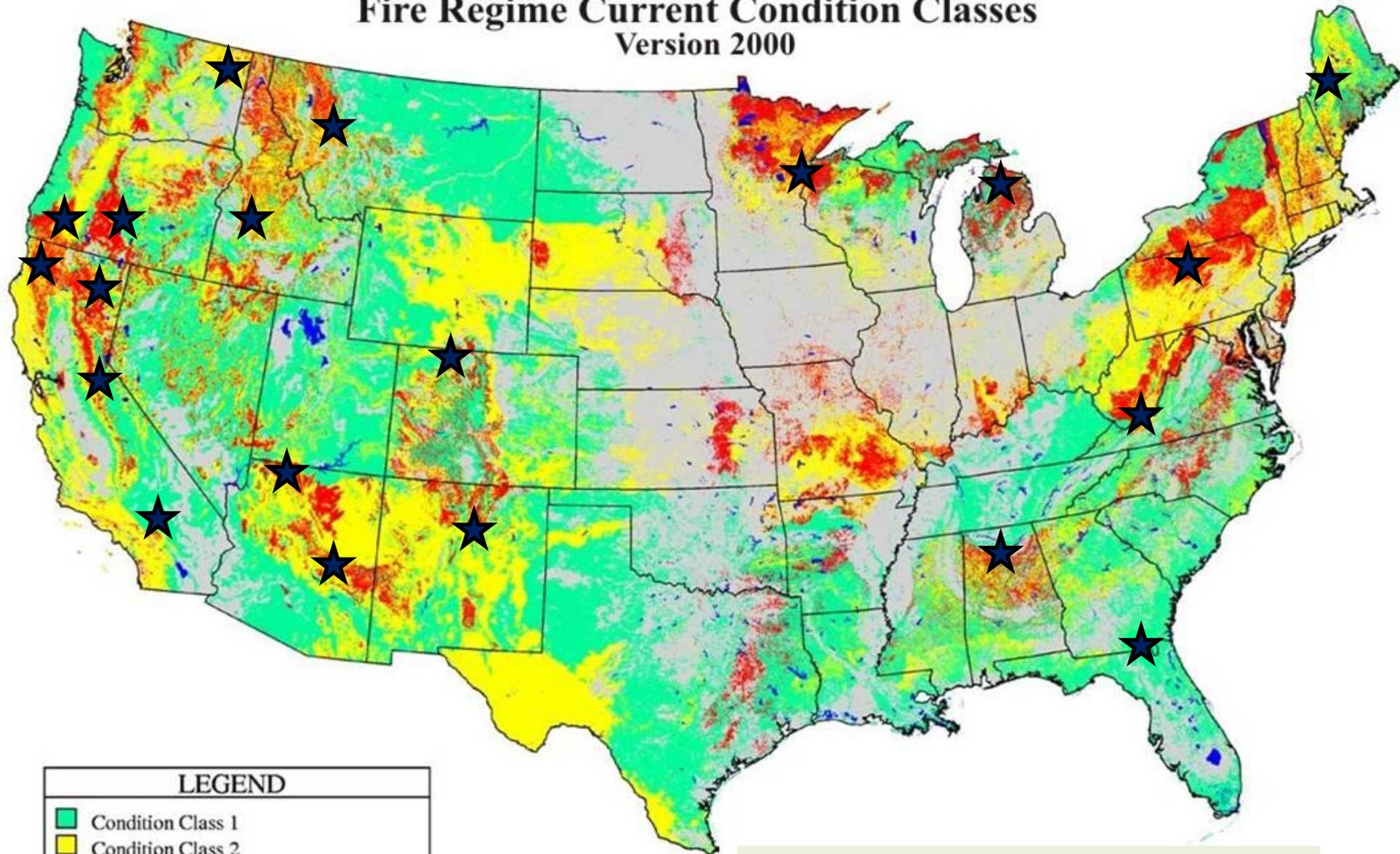
# Core Business Questions

- How many facilities constitute critical mass?
- Site refinery or bioproducts facility near to biomass resource or next to customers?
- Biorefinery specialist vs vertical integration?
- Make from raw biomass or buy feedstocks?
- Proprietary vs commodity feedstocks?
- Single species vs feedstock agnostic?
- Low cost vs optimized feedstocks?

# Scale – Number of Locations

- Pulp & Paper Mills ~ 120
- Ethanol biorefineries - 200+ in US (RFA)
- Home Depot – 2,200 stores in US (2016)
- John Deere – nearly 5,000 dealers worldwide
- Grain Elevators & Warehouses ~ 8,800 (USDA)
- McDonalds – 14,157 stores in US (2012)

# Fire Regime Current Condition Classes Version 2000

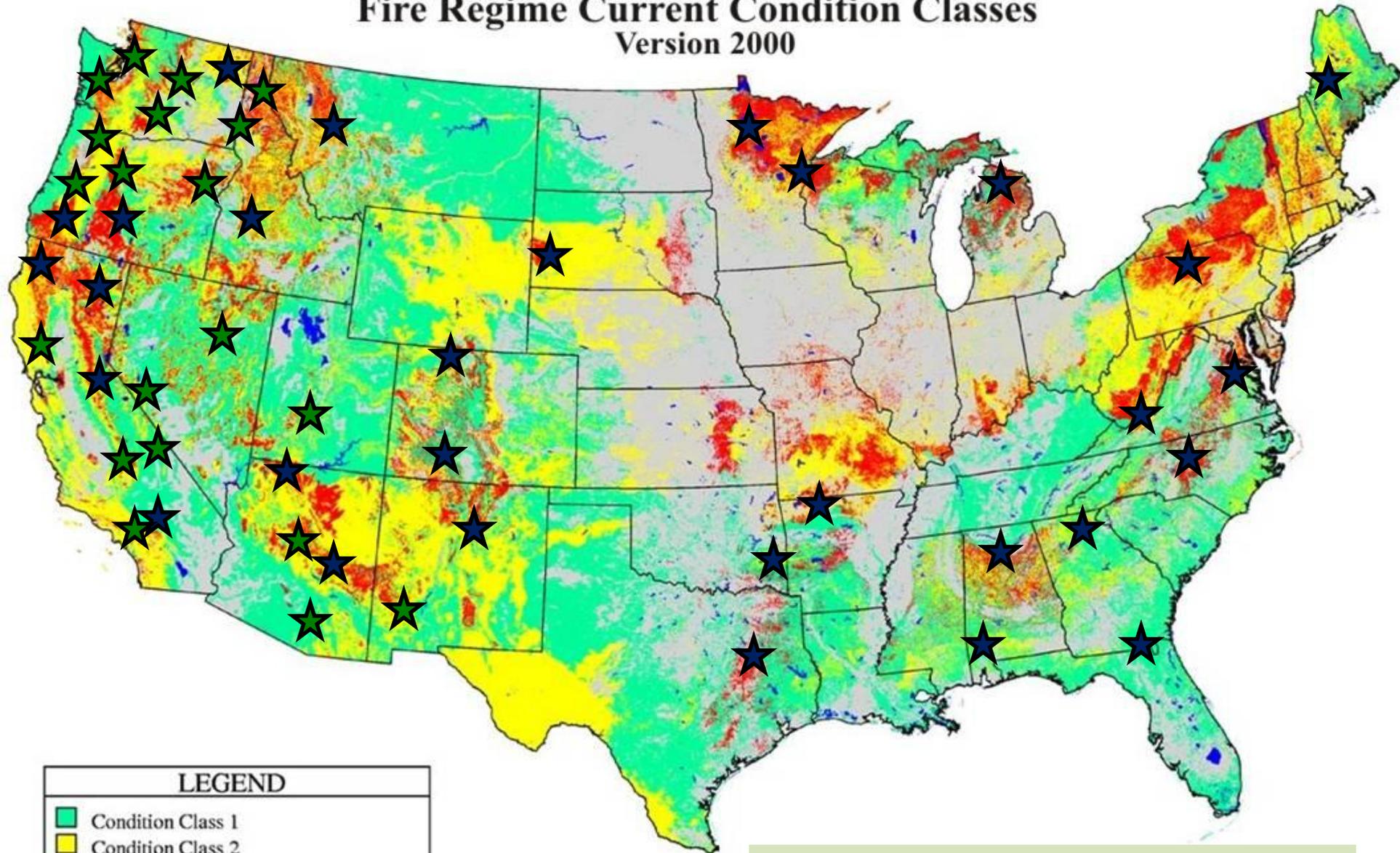


## LEGEND

- Condition Class 1
- Condition Class 2
- Condition Class 3
- Water
- Agriculture & Non-Vegetated Areas

Ideal Locations for First 20  
Woody Biomass Biorefineries

# Fire Regime Current Condition Classes Version 2000

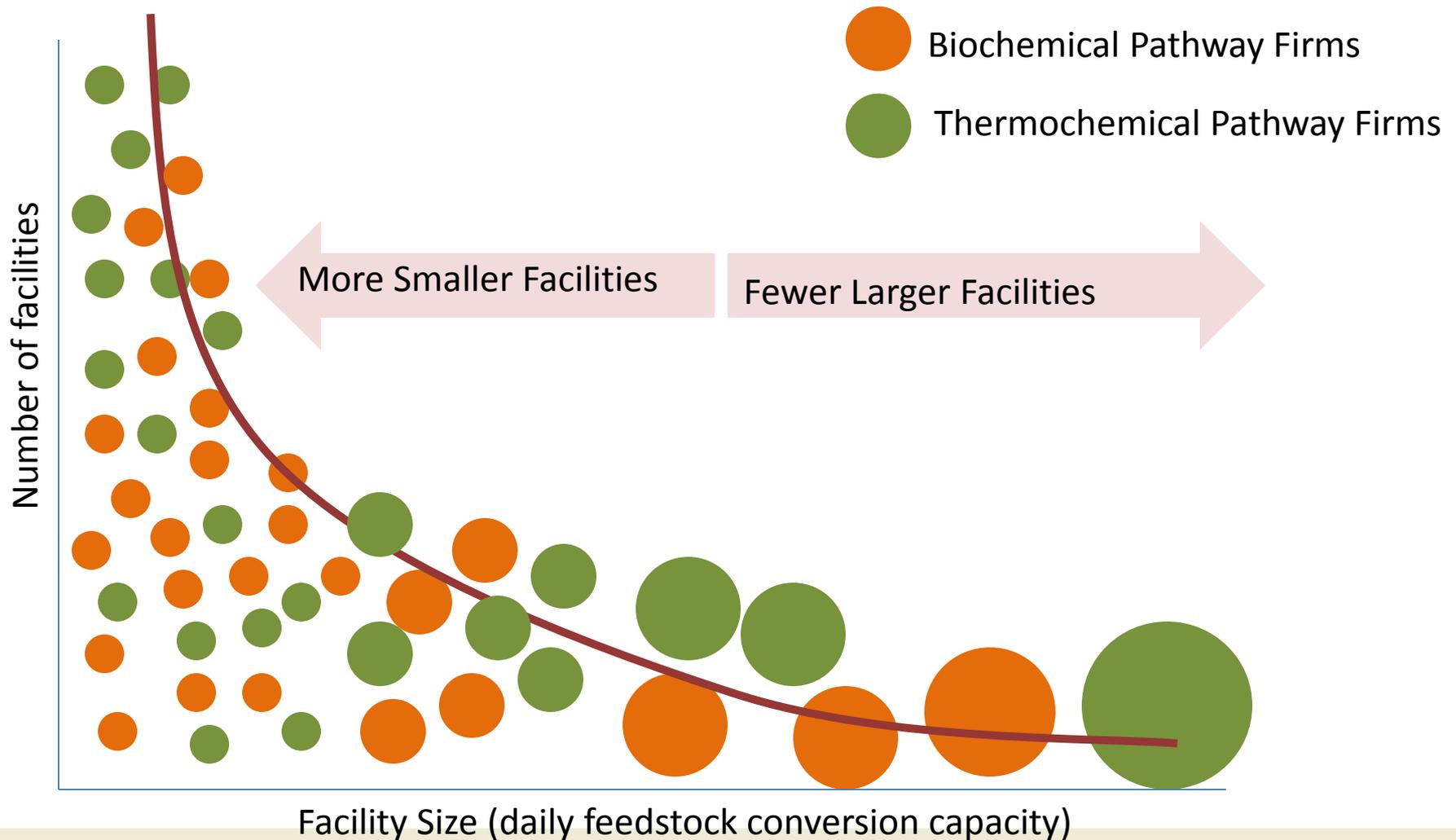


## LEGEND

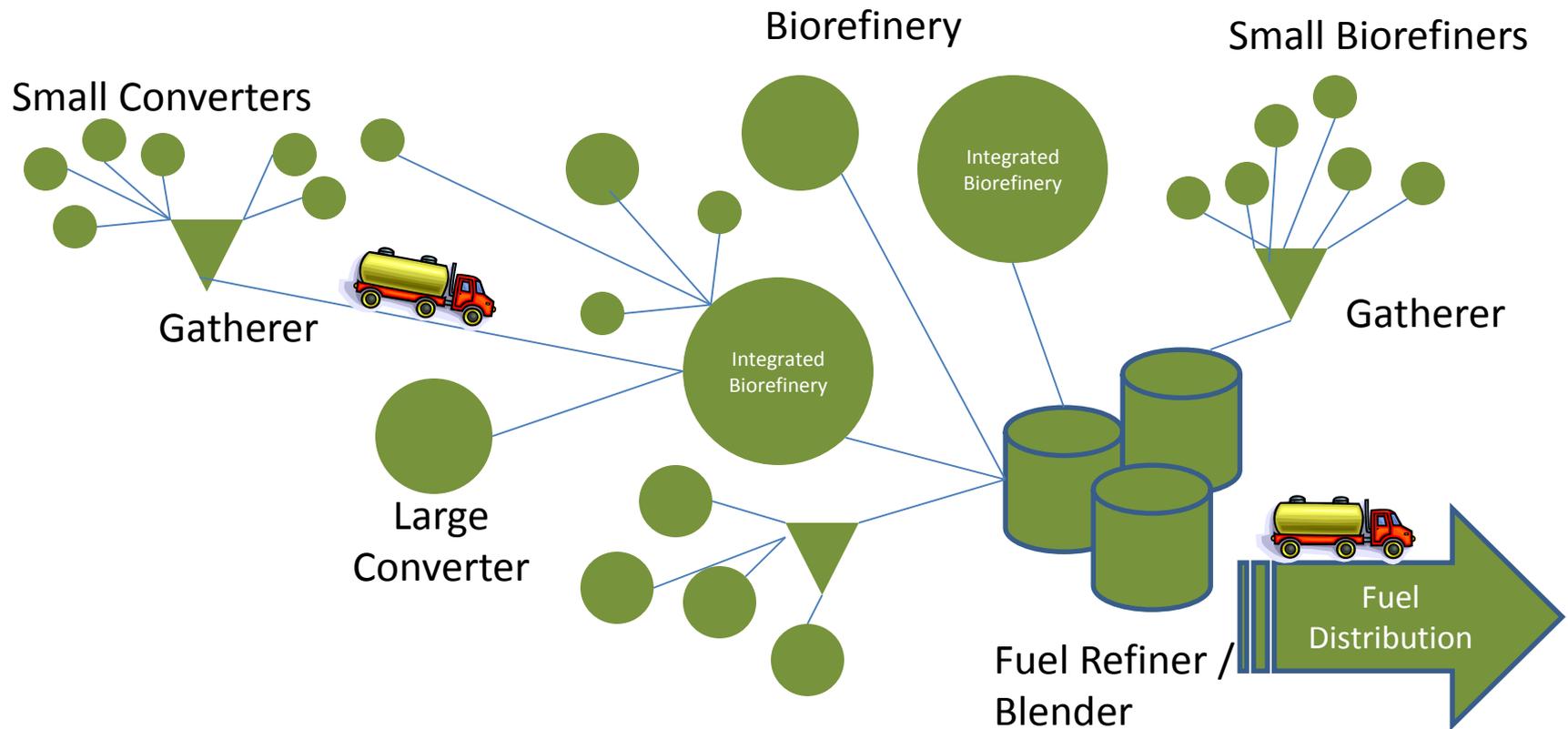
- Condition Class 1
- Condition Class 2
- Condition Class 3
- Water
- Agriculture & Non-Vegetated Areas

Ideal Locations for First 20 +25 more  
Woody Biomass Biorefineries

# Concept of Power Function Distribution



# Distributed Production of Biofuels and Bioproducts



# Core Business Questions

- How many facilities constitute critical mass?
- Site refinery or bioproducts facility near to biomass resource or next to customers?
- Biorefinery specialist vs vertical integration?
- Make from raw biomass or buy feedstocks?
- Proprietary vs commodity feedstocks?
- Single species vs feedstock agnostic?
- Low cost vs optimized feedstocks?

# Biomass



# Feedstock



# A Different Paradigm

## Industrial Biomass Feedstock Supply Industry

- Separate dirty and clean end of facilities
- Based on well defined commodity feedstocks
- Packaged appropriately for users
- Transported via conventional rail, barge, truck



# Why the Interest?

## Biorefinery

- Shift capital off-site (CAPEX)
- Reduce biorefinery footprint (acres)
- Reduce staffing
- Reduce truck traffic and receiving
- Reduce fire risks from onsite storage
- Reduce waste & soil disposal issues/cost
  
- Make variability someone else's problem

## Biomass Feedstock Producer

- Increase revenue and gross margins
- Return screenings, leachates, etc. to the landscape as nutrients/amendments
- Increase jobs in supplier communities
  
- Profit by simplifying biorefinery operations and management

# Biorefinery Implications

- **Particle Size & Shape**
  - Comminution, steam explosion, digestion
  - Flowability, bridging, plugging
- **Moisture Content – Storage and Drying**
  - High moisture processes – “never-dried” feedstocks
  - Dry feedstock processes
- **Environmental Ash Components**
  - Abrasive grit, catalyst poisons, bad catalysts, waste disposal
- **Biogenic Ash Components**
  - Catalyze char and unwanted chemical species content
  - catalyst poisons, acid consumers, waste disposal
- **Upstream Chemical Preprocessing**
  - AFEX™, torrefaction, hydrothermal, liquid intermediates, leaching, ...

# More Questions than Answers!

- **Where to make reactor ready feedstocks?**
  - At producer, aggregator (woodyard), depot, ...
- **What are best processes and equipment?**
  - Comminution, sorting, cleaning, washing...
- **What are mass, energy, and LCA balances?**
  - How are energy and LCA inventories allocated?
- **What are economic benefits?**
  - Rural economic development
  - Economies of scale of distributed processing
- **What is the willingness to pay for reactor ready feedstocks?**
  - How are benefits priced through the supply chain?

# Low Cost vs Equitable Cost

Quality is like buying oats -if you want nice, clean oats, you must pay a fair price;

However,

if you're satisfied with oats that have already been through the horse - such oats can be had a little cheaper!!

Anonymous (oats were domesticated ~ 2000 BC)

# Core Business Questions

- How many facilities constitute critical mass?
- Site refinery or bioproducts facility near to biomass resource or next to customers?
- Biorefinery specialist vs vertical integration?
- Make from raw biomass or buy feedstocks?
- Proprietary vs commodity feedstocks?
- Single species vs feedstock agnostic?
- Low cost vs optimized feedstocks?



Jim Dooley

[jdooley@forestconcepts.com](mailto:jdooley@forestconcepts.com)

Thank You

---

[www.forestconcepts.com](http://www.forestconcepts.com)

Development was supported in-part by the CSREES Small Business Innovation Research program of the U.S. Department of Agriculture, grants 2005-33610-15483 and 2006-33610-17595. Development was supported by US Department of Energy SBIR contracts DE-SC0010122 and DE-SC0003489.

**Contact:**

**Forest Concepts, LLC  
3320 W. Valley Hwy. N., Ste D110  
Auburn, WA 98001  
Ph: 253.333.9663**

# Potential Feedstock Products?

- Mechanically processed biomass
- Chemically enhanced & refined biomass
- Pellets, pucks, cubes, briquettes...
- Torrefied or thermally modified
- Partially digested – AFEX,  $\text{SO}_2$ , Steam treated...
- Hydrolysate, liquid mixed sugars, purified sugars
- Pyrolysis oil (bio-oil, bio-crude, Pyoil...)
- Syngas and purified/filtered gas

# Forest Feedstock Situation

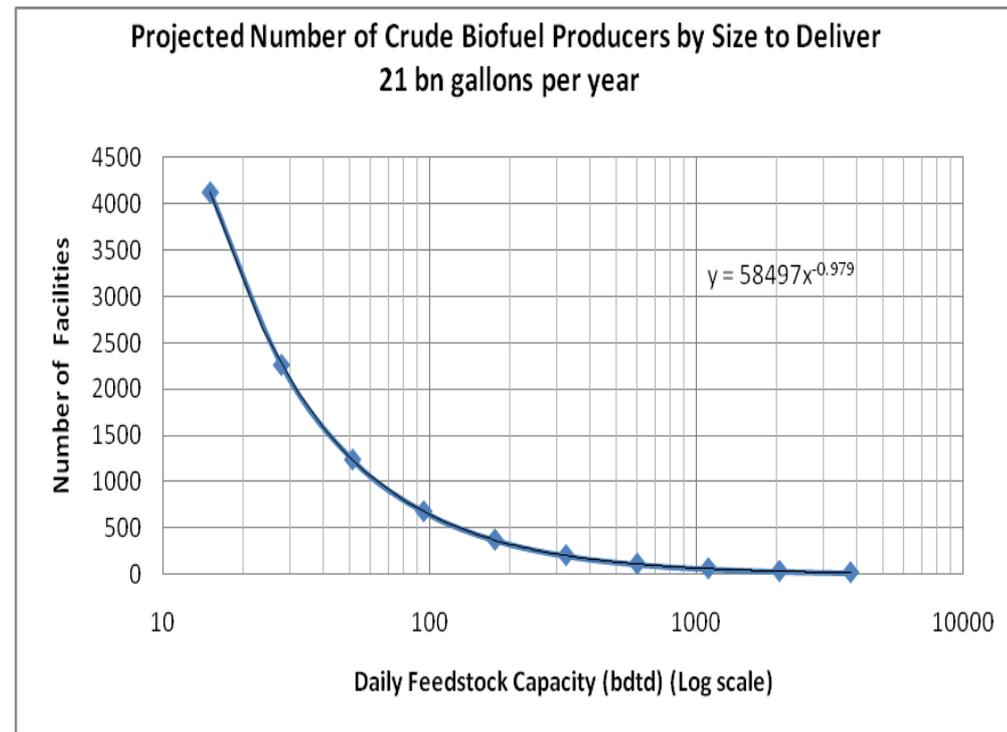
- Supply is abundant, BUT....
- No such thing as free wood – costs are real
- Competing uses set market value
- Environmental implications are still under study
- Public and interest groups have not bought in



# What will be the Distribution of Biomass Converters by Size?

## Power Curve Distribution (aka Axtel Distribution) of Firms by Size

- Most industries in the developed world are comprised of a mix of very small to very large facilities.
- In the dairy industry there are more than 50,000 of dairies with less than 100 cows and a only about 500 dairies with more than 2,000 cows according to USDA.
- In the sawmill industry there are more than 2,000 sawmills with less than 10 employees and only 27 with more than 500 employees according to the US Census Bureau.
- Sawmills and dairies are somewhat analogous to the emerging second generation biofuels industry.



# This biomass stuff is harder than it seems!

- Mt. Shasta News – Oct. 10, 2007
  - “Biomass expectations unrealized, Opportunity Center project halted”
    - *“The biomass electrical generation machine is being returned to its manufacturer after not living up to what may have been unrealistic expectations...”*
- Nevada Appeal – March 2, 2008
  - “Prison biomass plant choked by supply costs”
    - *“The plant has not run more than three days straight since it opened six months ago.”*
    - *“Wood continues to be an issue for us. We do not have an adequate and appropriate supply.”*

**DICK'S**  
**THRIFTWAY**

**SAVE OUR TREES \$2.99**  
**PURCHASE YOUR**  
**RECYCLABLE BAGS**  
**INSIDE**



# “Bambi lives in the forest”



# Toilet Paper vs Fuel



# Attitude (Framing)



## Scavenged Forest and Crop Residuals vs. Market-driven Products

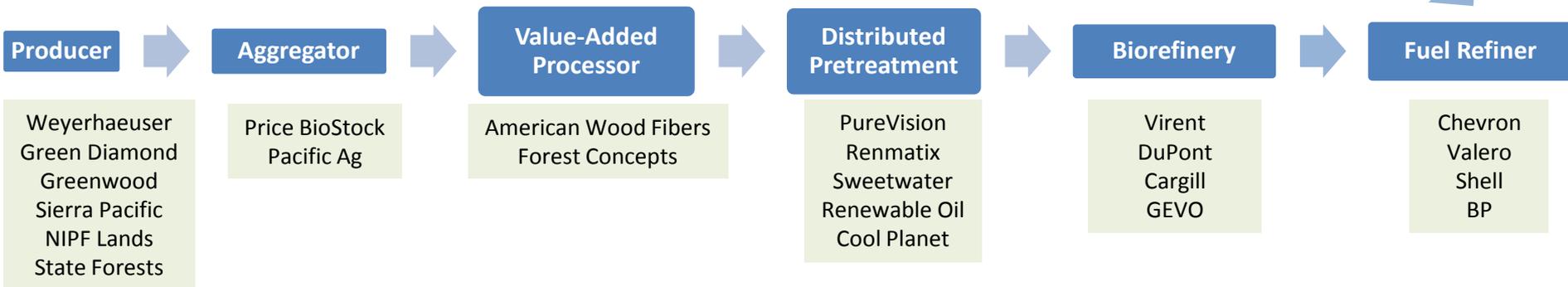


# Biofuel Supply Chain

- **Integrated Biorefinery**

- Receives pellets, logs, bales, land clearing debris, etc.
- Ships biofuel blend-stock to petroleum distributors

- **Fully Decoupled Supply Chain**



- “A lot of companies spent all their money trying to build a single facility — to just get one running.” But that was the easy part. The hard part comes after the plant is built: It’s figuring out what to do when farmers don’t want to buy the equipment to bale up their cornstalks, or when a pile of biomass bursts into flames, or when that biomass comes in caked with mud, or when a central pump jams, or soil microorganisms wipe out your specially engineered fermentation bacteria.
  - Chris Somerville, director of the Energy Biosciences Institute at the University of California, Berkeley

# Reactor-ready

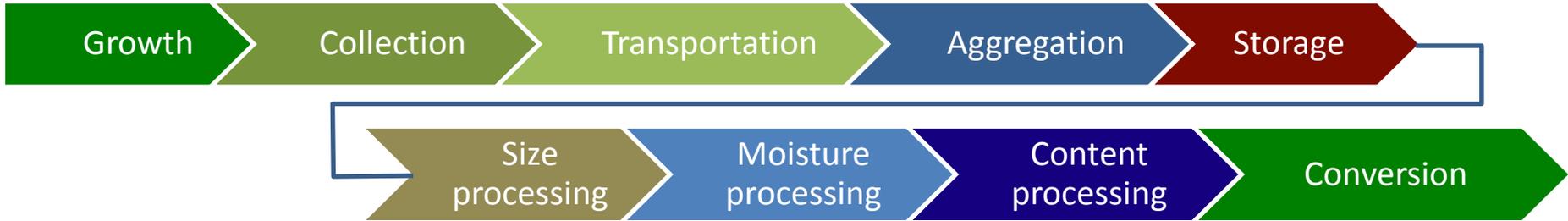
Characteristic	Reactor A	Reactor B
Right particle size	Pass 4mm, No-Pass 1mm	Pass 25mm
Right particle shape	Aspect ratio: 0.8 – 2.5	Aspect ratio: 0.5 - 20.0
Right moisture content	10 – 12 % wb	40 – 70 % wb
Acceptable anatomical content	< 1% bark	N/A
Acceptable mineral and chemical content	Dilute acid washed	N/A
Total ash content	0.2%	12%
Upstream chemical preprocessing	N/A	AFEX – Ammonia treated

# Supply Chain Pre-Processing Ops

- **Beneficiation** – cleaning and separation
  - Environmental ash – soil, silt, dust, salt
  - Contaminants – sand, rock, metal, plastic
  - Anatomical Fractionation – wood, bark, leaves
  - Washing – leaching catalysts and catalyst poisons
- **Comminution** – Size reduction
  - Size and shape creation
- **Moisture Control**
  - Drying, blending wet with dry, or preserving high moisture
- **Homogenization**
  - Blending across sources, species, ...

Adapted from INL Uniform Format Feedstocks program

# Forest Concepts Technologies through the Supply Chain



## Related Forest Concepts' technologies

### Baling Biomass



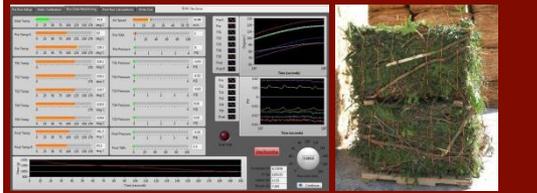
### Crumbles® Particles



### Advanced Drying



### Managed Drying / Handling



### Beneficiation

