Economics of Transportable Biomass Conversion Facilities for Producing Biochar, Briquettes, and Torrefied Wood Utilizing Forest Harvest Residues

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“Waste to Wisdom is an innovative biomass research project funded by a $5.88 million grant from the U.S. Department of Energy under the Biomass Research and Development Initiative program: Award Number DE-EE0006297. Led by Humboldt State University, has 15 regional partners extending research on the conversion of forest residues into bioenergy and other valuable bio-based products”

WEBINAR OUTLINE

- Project Question
- Background & Problem
- Literature Context
- Methods
- Applications
- Results
- Summary
- Lessons Learned
- Questions

PROJECT CONTEXT

THE PROBLEM

Forest harvest residues are a business/ operations byproduct. They are often currently burned in forests due to collection, transportation, and market constraints.

A SOLUTION

Project goal is to explore converting forest residues into valuable bioenergy and bio-based products using transportable conversion facilities.

Research Focus: Transportable Conversion Facilities

Broadly: Markets, Logistics, Conversion Technologies, Economic and Life Cycle Analyses

PROJECT QUESTION:

What are the economic and logistic implications of transportable biomass facilities and are they viable?

BACKGROUND & PROBLEM

What are Forest Harvest Residues?

What is a Transportable Biomass Conversion Facility?

BACKGROUND: FOREST HARVEST RESIDUES

- **WHAT ARE THEY?**

Forest harvest residues can include small diameter trees not meeting mill specifications, noncommercial species, small diameter logs (pulpwood), tree tops, branches, breakage, log defect, and short log sections (long butts) cut off to meet customer specifications

Depend on: Species, management objective, harvesting system, market

- **MARKETS**

Pulp

BACKGROUND: RESIDUE COMPOSITION

- **BRANCHES**

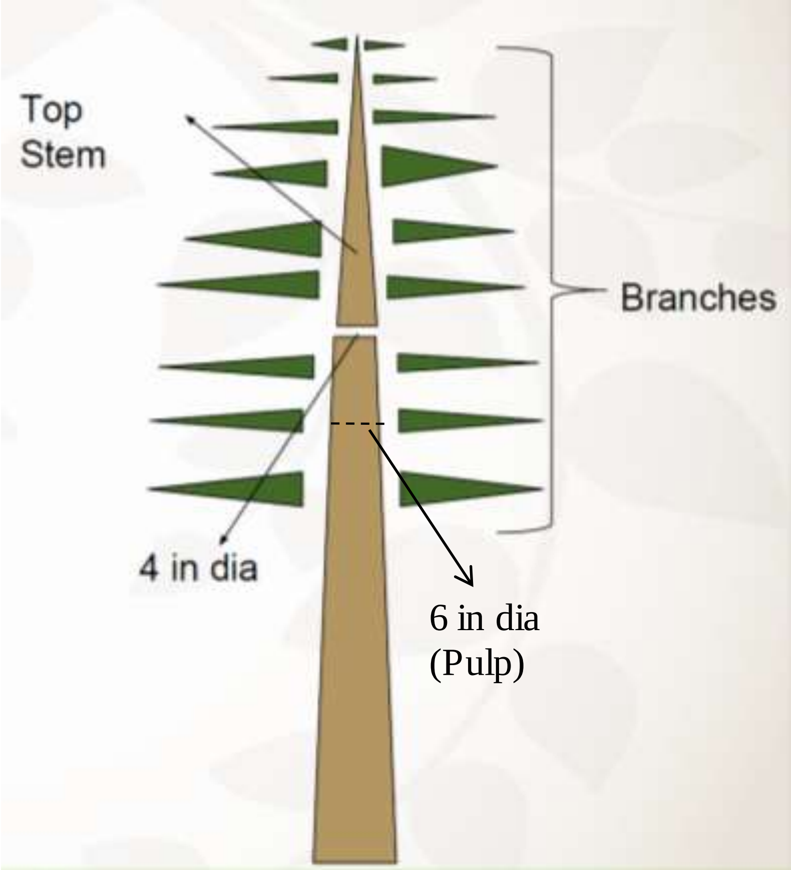
Branches, breakage, defects

- High dirt and ash content

- **LOG-LIKE MATERIAL**

Tops | Pulpwood

- Relatively Clean



BACKGROUND: PROBLEM

- POOR QUALITY
  - Composition
- HIGH LOGISTICS COST
  - Handling, Transportation, Processing
- MARKET
  - Low Value, Emerging

TYPICALLY BURNED ON SITE

SOLUTION CONCEPT: NEAR-WOODS CONVERSION

- PRODUCT CONVERSION
  - **Wood Products**

Converting material to ADD VALUE / REDUCE Transportation Costs

PRODUCTS & MARKETS

- BRIQUETTES
  - **Residential / Commercial Heating Fuel**
  - A briquette is a compressed block of other biomass material

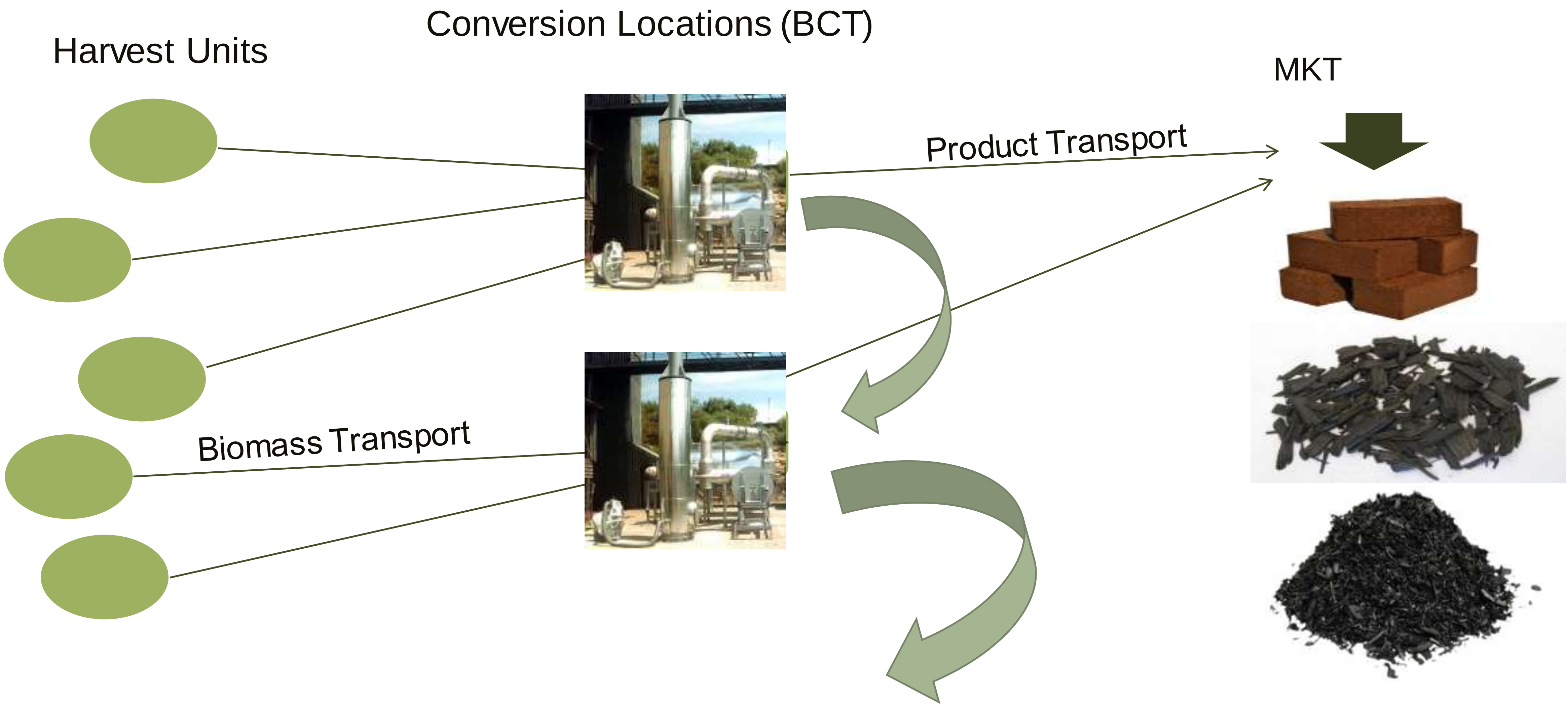
TORREFIED WOOD

- **Energy Product / Coal Substitute**
- Wood that has been heated in an oxygen limited environment to reduce moisture content and to transform it into a brittle, char-type material

- BIOCHAR
  - **Soil Amendment or Filtration Element**
  - Biochar is a solid material obtained from continued heating in an oxygen-limited environment producing a char-like material

TECHNOLOGIES SUITABLE FOR TRANSPORTABLE OPERATIONS

TRANSPORTABLE BIOMASS CONVERSION FACILITIES



TRANSPORTABLE FACILITY

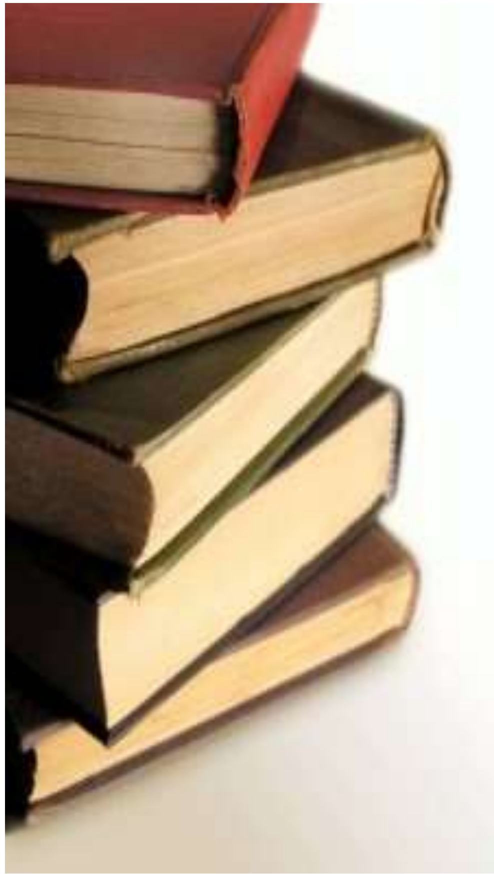
- **ADVANTAGES**
  - Reduction in transportation costs
  - Adaptable to evolving feedstock availability
  - Flexible/ modular production capacity

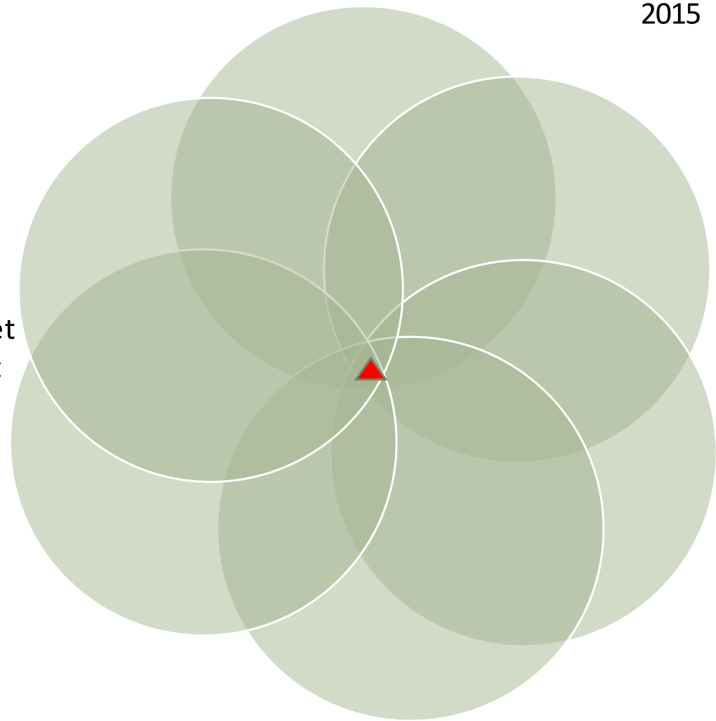
- **DISADVANTAGES**
  - Economies of scale
  - Energy costs compared with grid power
  - Downtime during moves >> loss of productive capacity
  - Potentially inefficient equipment selection / drying considerations

CONTEXT

How does this work fit into previous research and contribute to the literature?

LITERATURE





Biomass Supply Chain Pathways

Anderson et al. 2012, Johnson et al. 2013, Wolfsmayr and Rauch 2014. Rawlings et al., 2004, Harrill and Han, 2010, Kash and Dodson 2010, Bisson et al. 2015, Zamora-Cristales et al. 2013, Zamora-Cristales et al. 2015

Centralized Facilities & Depots

Lamers et al. 2015, Farahani et al. 2010, Jenkins 1997, Dornburg and Faaij, 2001, Han and Harrill 2010, Zamora-Cristales et al. 2015

Facility Design & Economies of Scale

Bowling et al. 2011, Mirkouei et al. 2015, Kumar et al. 2003, Larson & Marrison 1997, Kaznian et al. 2009, Asikainen et al. 2001, Cameron 2007, Caputo et al. 2005

Supply Chain & Landscape Optimization

Shabani et al. 2013, Sharma et al. 2012, Meyer et al. 2014, Van Dyken et al. 2010, Holo et al. 2015, Cambero et al. 2014, Tronoco et al. 2014

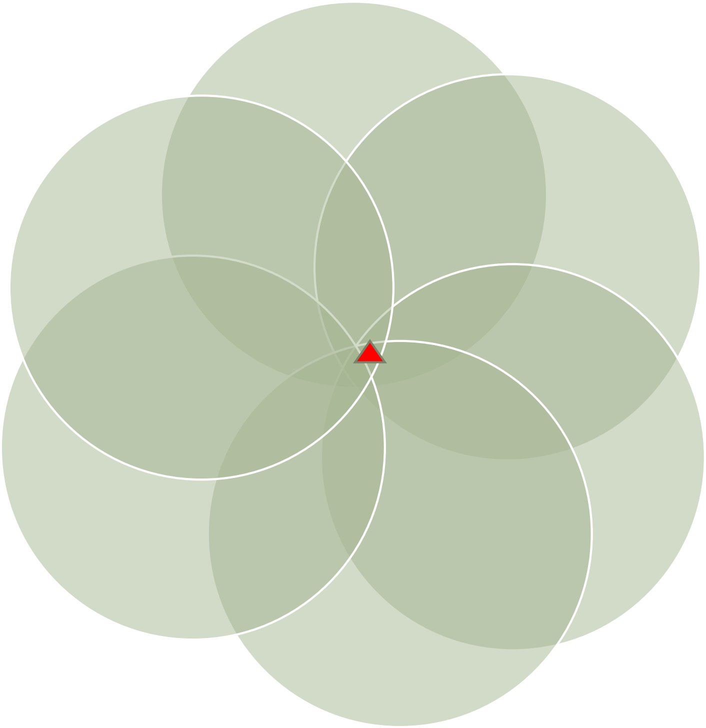
Emerging Technologies/ Wood Products

Loeffler et al. 2016, Bond 2008, Pirraglia et al. 2010, Sultana et al. 2010, Chai and Saffron 2016, Dumroese 2009, Sandberg et al. 2013

Mobile Conversion Facilities

Polagye et al. 2007, Brown 2013, Badger et al. 2010, Mirkouei et al. 2016, Mirkouei et al. 2015, Badger and Fransham 2006, Badger et al. 2011

SPECIFIC PROJECT OBJECTIVES



Develop and synthesize biomass supply chain economic model(s) to evaluate:

1) Scale & Mobility
2) Biomass Availability
3) Energy and Power Sensitivity
4) Logistics and Moisture Management
5) Product Assumptions (conversion, pricing and co-generation assumptions)
6) Regional Analysis (energy, fuel and transportation)

What are the economic and logistic implications of transportable biomass facilities and are they viable?

SPECIFIC PROJECT CONTRIBUTIONS

1) Transportable Biomass Facility Logic

- Economies of Scale, Move Frequency, Biomass Availability Impacts to Supply Chain Costs

2) Transportable Biomass Facility Economics

- Logistics, Multi-Product and Temporal Considerations, Economic Feasibility

3) Transportable Biomass Facility Regional Viability and Sensitivity

- Regional differences (logistics, biomass, energy rates, log markets) and sensitivity to fuel, energy and transportation distances

BROADER IMPACT

GENERALLY:

- ***Support modern efforts to sustainably use natural resources***
- ***Contribute to emerging field of biomass & bio-based products***

Help solve broader biomass market problem

- *Determine requisite conditions and success indicators*
- *Support the development of bio-based product markets*

Support Enabling Operational System Design Research

- *Considered main barrier to sustainable market development*
- *Improve feedstock collection, processing, conversion and transportation logistics*

Promote Positive Environmental, Economic and Social Impacts

- *Improve the economics of forest management activities*
- *Develop new jobs in forest & bio-energy sectors*
- *Promote economic development in rural areas*

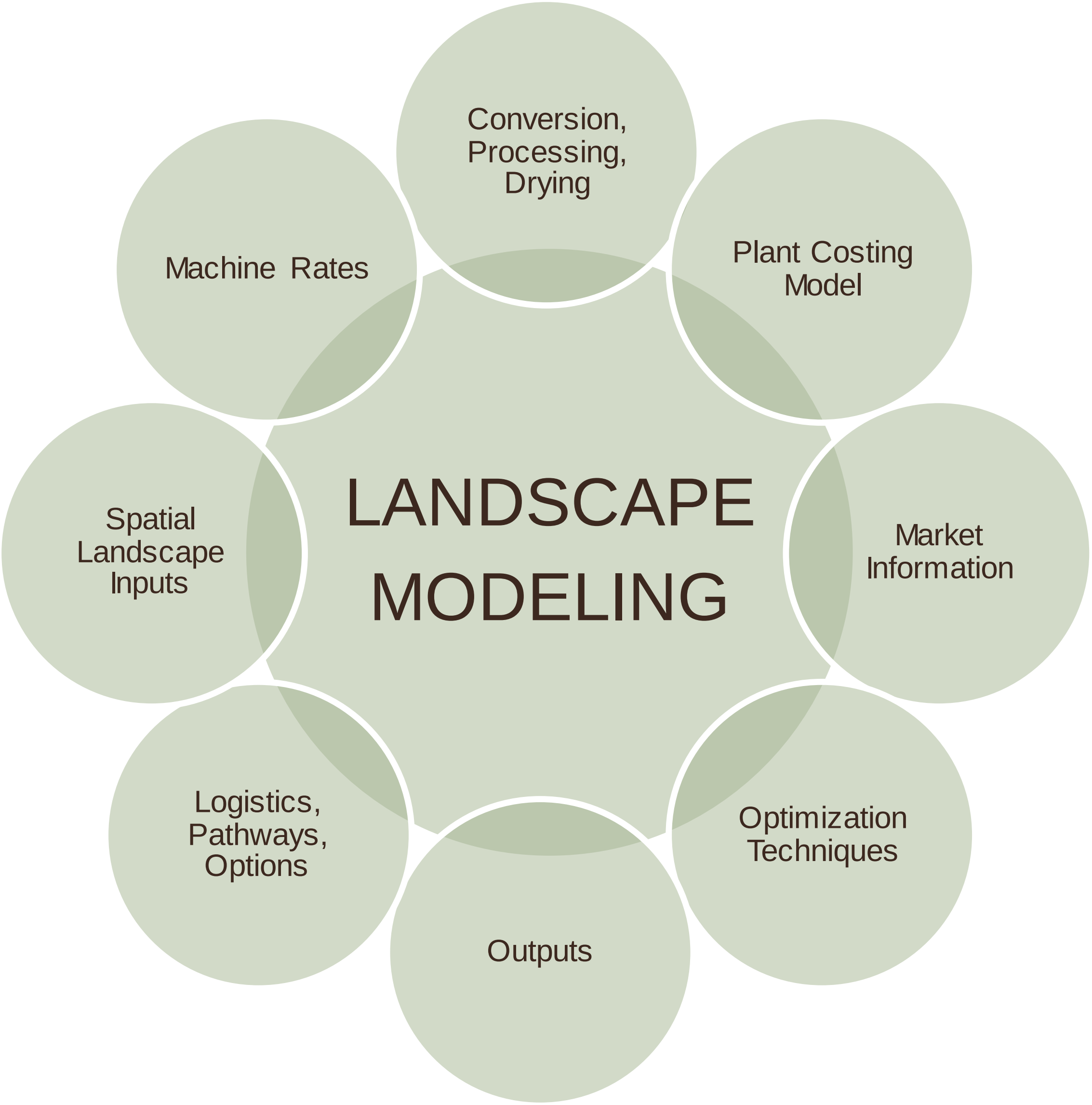
Helping to develop a marketplace for underutilized forest products to support local economies and promote energy independence

METHODS

How was the work done?

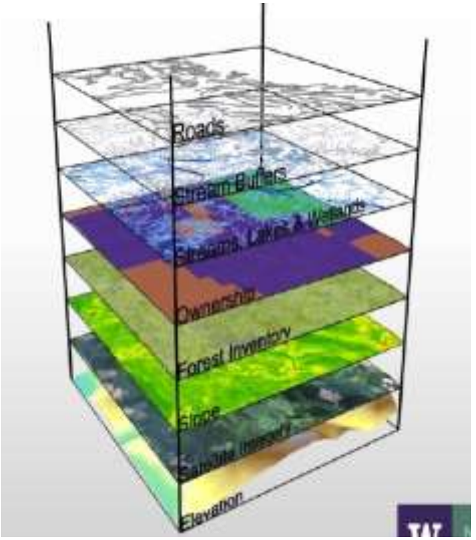
METHODS

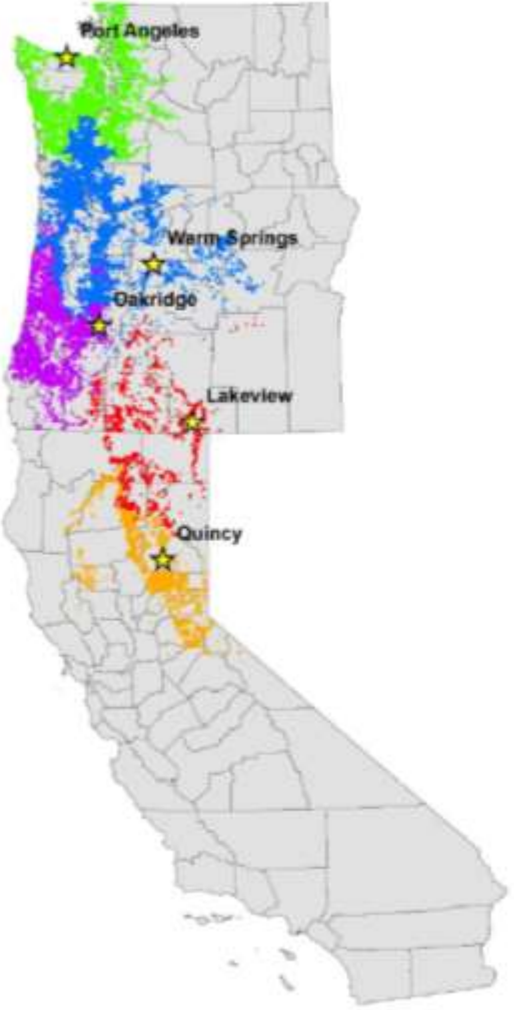
- Identify Biomass Availability
- Develop Supply Chain Pathways
- Identify Machine Costs & Productivity
- Identifying Facility Costs
- Identify Optimal Pathways with a Mathematical Model
- Case Study Application
- Sensitivity Analysis



SPATIAL INPUTS: BIOMASS

- 5 YEAR TIME HORIZON ESTIMATED BIOMASS AVAILABLITY
  - Markets
  - Harvesting System
  - Ownership Class
  - Management Objectives
  - Breakage/ Defects
  - Road Network

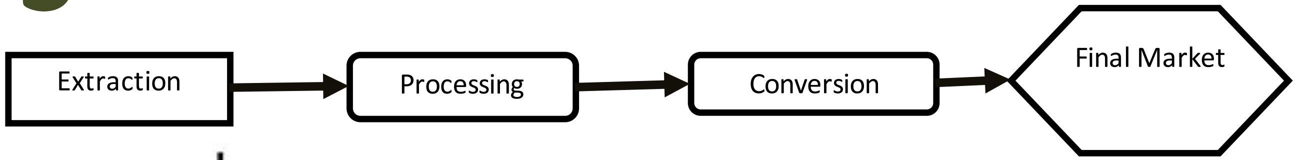


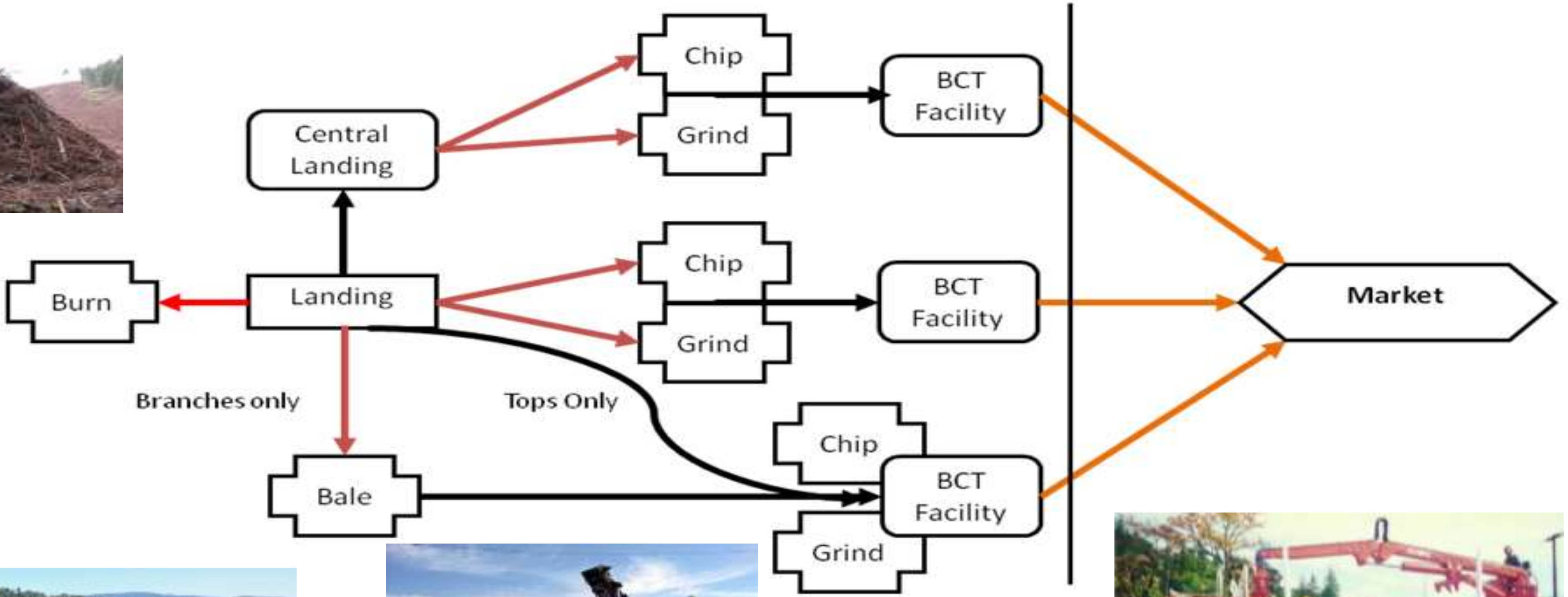


ROADSIDE AVAILABILITY
PACIFIC NORTHWEST
5 SUB-REGIONAL ZONES

University of Washington RTI

SUPPLY CHAIN PATHWAYS





Vary Depending on Commodity Class, Access, Availability

Biochar | Briquettes | Torrefied Wood

MATHEMATICAL FORMULATION

DECISION VARIABLE:
-X(a,i,j,k,m) –
BDT flow of residual *a*, front node *i*, to BCT *j*, along route *k*, to market *m*

GOAL: MINIMIZE SYSTEM COSTS

MIN:
$$\sum_a\sum_i\sum_j\sum_k\sum_m (C_{aijkm} * X_{aijkm}) + \sum_a\sum_i\sum_j\sum_k\sum_m (CONST_{ik} * XBIN_{aijkm}) + \sum_j (BCTmobe * JBIN_j)$$

KEY FACTORS:
- Variable Costs (Transportation)
- Fixed Costs (Mobilization)

Subject to:

$$C_{aijkm} = TRAW_{aij+}TCONV_{jm} + CC_j + SEC_{ak} + PRO_{ak} + PRE_{ak} + TLC_{ak} \quad \forall a \in A, \forall i \in I, \forall j \in J, \forall k \in K, \forall t \in T$$

Process Costs

$$M * XBIN_{aijkm} \geq x_{aijkm}, \forall a \in A, \forall i \in I, \forall j \in J, \forall k \in K, \forall m \in M \qquad XBIN(0,1)$$

Fixed Costs

$$M * JBIN_j \geq FLOWJ_j, \forall j \in J \qquad JBIN(0,1)$$

Notation:

SETS
A = Residual Class
I = Landing
J = BCT Location
K = Route
M = Market Location

PARAMETERS:
TRAW(*a,i,j*)- Raw/ Processed material transportation costs of residual *a* from node *i* to BCT *j* ($)
TCONV(*j,m*)- Converted material Transportation costs from BCT *j* to market *m* ($)
CONST(*i,k*)- Construction/Mobilization costs associated with node *i* taking route *k* ($)
BCTmobe(*j*)- Mobilization costs of setting up BCT *j* ($/EA)
PRO(*a,k*)- Processing cost (grind/chip) for each residual *a* along route *k* ($/BDMT)
SEC(*a,k*)-Supporting equipment cost (loader, etc.) associated with each residual *a* along route *k* ($/BDMT)
PRE(*a,k*)-Pre-Sorting/arranging cost associated with associated with each residual *a* along route k ($/BDMT)
TLC(*a,k*)- Transportation loading/waiting cost for residual *a* along route *k* ($/BDMT)
CC(*j*)- Conversion costs of producing material at BCT *j* ($)
M- Large number for logical trigger
material(*i*) – Material available at node *i* (BDMT)
XBIN(*a,i,j,k,m*)= Binary value – unique route
JBIN(*j*)= Binary value – conversion facility location

Mixed Integer Programming

MACHINE SPECIFICATIONS & RATES

- CONVERSION EQUIPMENT
  - Modular Product Production
- PROCESSING
  - Chipping/ Grinding
- TRANSPORTATION
  - Capacities, Unit Costs
- MARKET INFORMATION
  - Demand | Values

Throughputs, Ownership Costs, Operating Costs, Labor Costs, Product Prices

Schatz Energy Lab | HSU | USFS Forest Products Laboratory

FACILITY COSTING MODEL

- CAPITAL EXPENSES (CAPEX)
  - **Site, Technology, Utilities, Mechanical & Energy Installation**
- OPERATING EXPENSES (OPEX)
  - **Labor, Expenses**
- MOBILIZATION & SETUP
  - **Truckloads, Time, Labor, Supporting Equipment**

6 Facility Configurations

Biomass Enterprise Economic Model

Jump to: Overview | Instructions | Download

The Biomass Enterprise Economic Model is designed to help users rapidly evaluate and appropriately scale biomass utilization enterprises. Users can explore how woody biomass input volumes and the salable products mix influences capital establishment costs, annual operating costs, and annual revenue. The model is pre-loaded with cost and pricing data that automatically scales to the specific design scenario selected by the user. Many of the cost factors and product sales prices are also user-editable, to account for existing assets or different configurations and market conditions. The user can quickly see the impact of key variables on annual cash flow, capital investment, and simple payback. The details associated with attractive scenarios can be downloaded and saved.

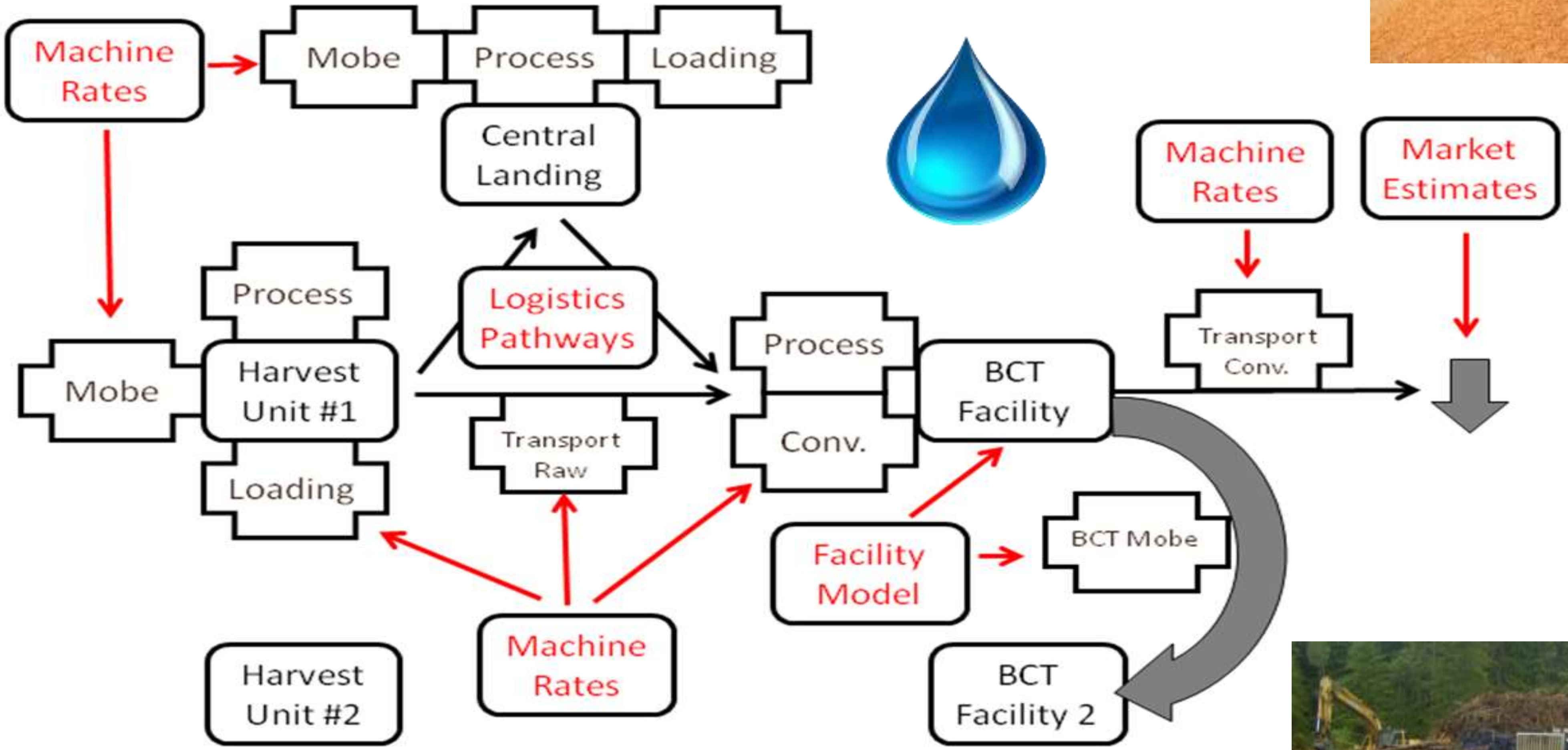
Step-by-step user instructions are downloadable and provided in full below.

Photos by Marcus Kauffman, Oregon Department of Forestry

A general overview:

Model users begin by specifying the scale of the enterprise to examine. Four basic size classes are available; Small, Medium, Large, and Major, and each is determined by the annual volume of woody biomass material available as raw material. The primary functional unit is the bone dry ton, or bdt. The user specifies the form the biomass will be in when delivered to the plant gate, and a desired product mix that is achievable with that raw material form. The kinds of enterprises supported by the model generally require starting with logs.

OPTIMIZATION MODULES



APPLICATIONS

LOCAL: Lakeview, Oregon, 1 location with 1 product
REGIONAL: 3 states, 5 locations, 3 products

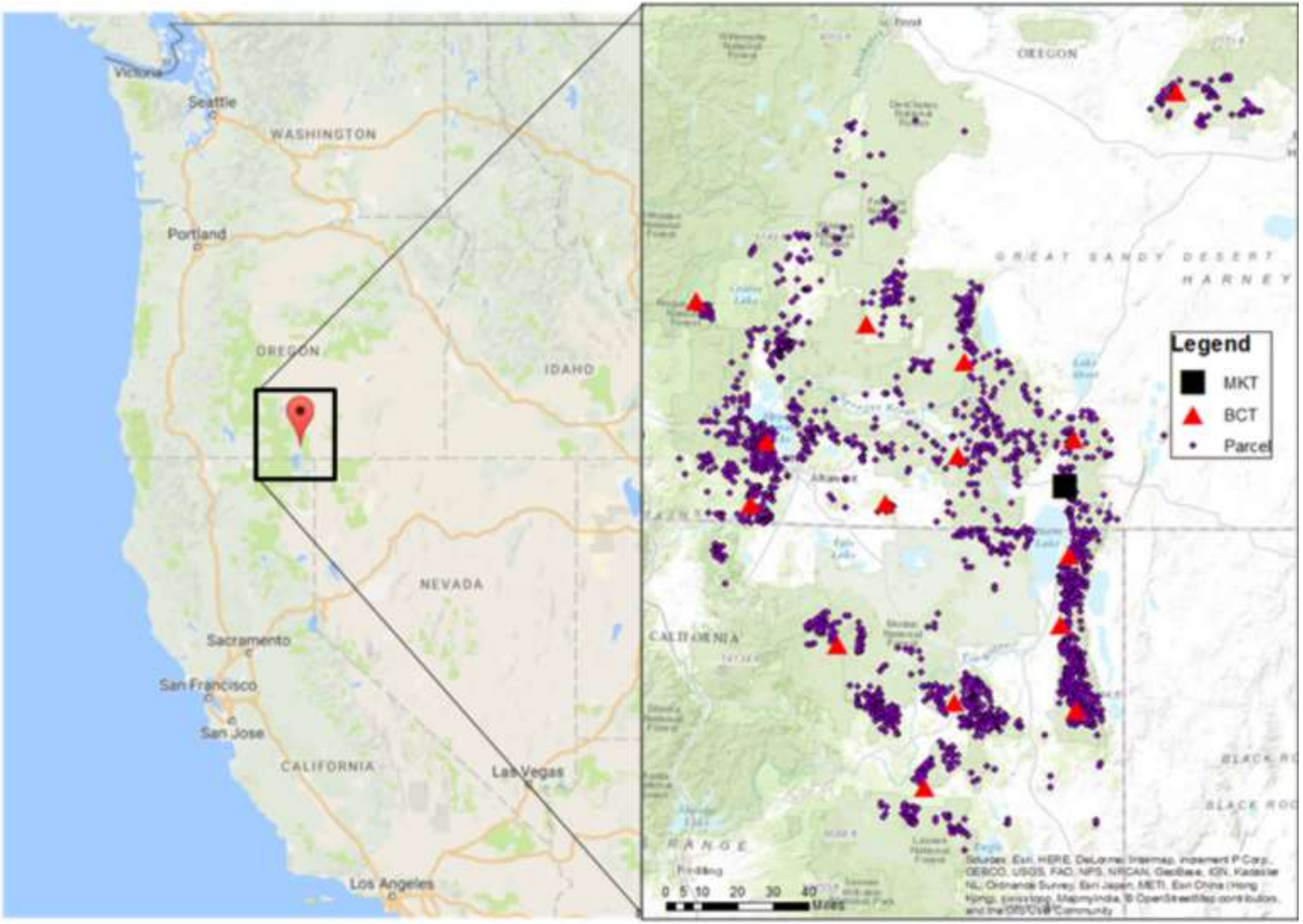
LAKEVIEW, OREGON

GOAL	• **MINIMIZE COSTS**
CONVERSION FACILITY TYPE	• Biochar
PLANT SCALE	• 15,000- 50,000 BDT/ Year
MATERIAL HANDELING	• SORTED: TOPS & BRANCHES
FEEDSTOCK AVAILALBITY	• 5 Year Time Horizon
PLANT PLACEMENT	• 15 Potential BCT sites • 1 Central Market Location
MOBILIZATION	• Varies $60,000-350,000/ Move

Other Key Comments

a) **Assume 30% Moisture Content**

b) **Parcels/ Volumes from UW – RTI Spatial Analysis**



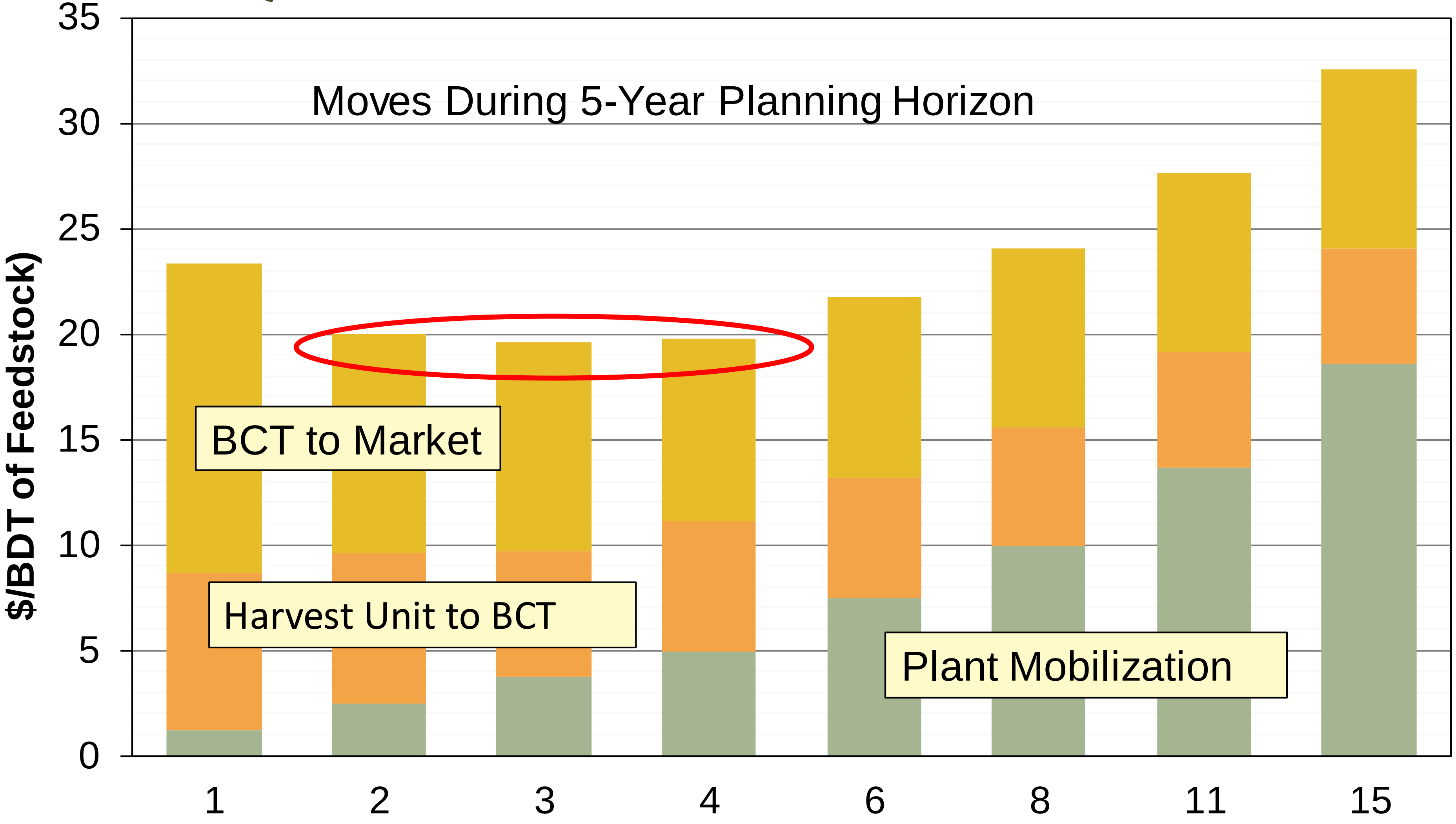
FEEDSTOCK AVAILABLITY

Commercial Harvest Left Site

Residues Left Behind

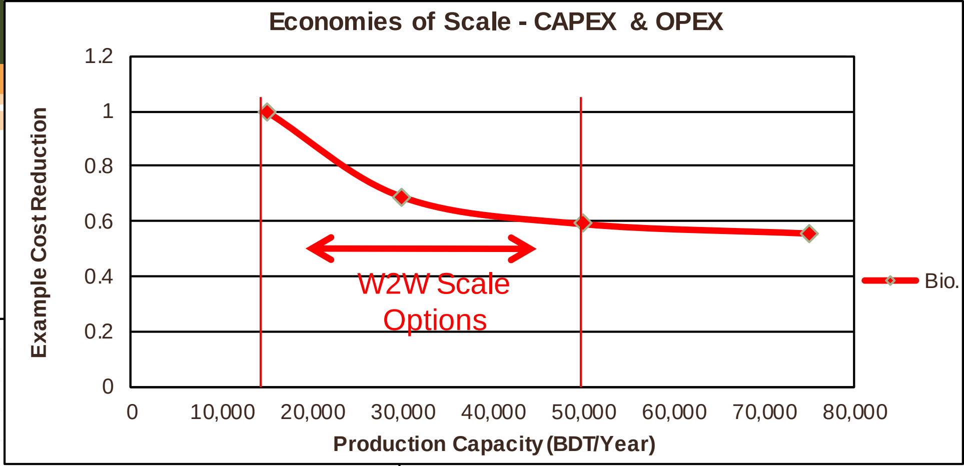
Bly Ranger District, Fremont National Forest

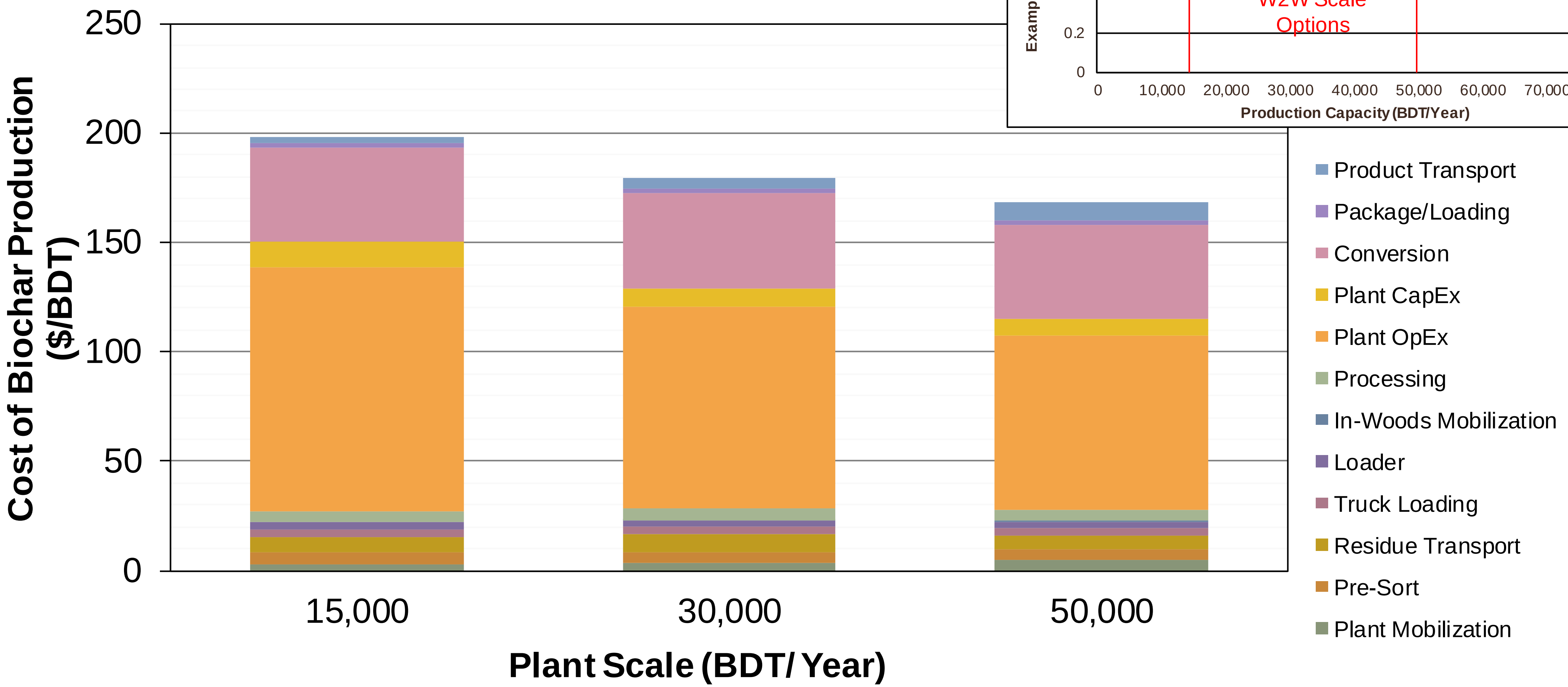
MOVE FREQUENCY



 # Moves: Tradeoff Transportation costs vs. Mobilization
Depends on the Region (Typically 2 - 4)

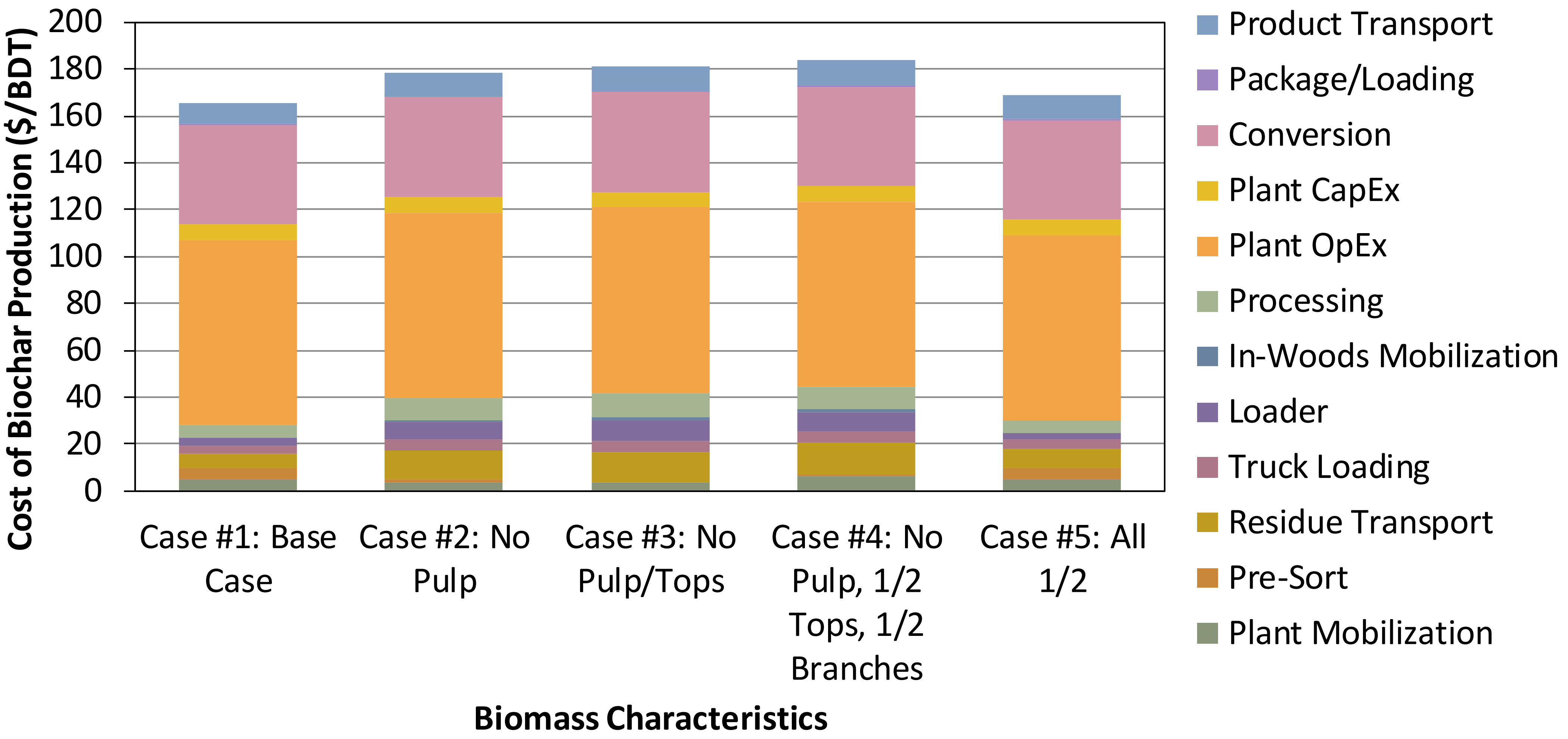
ECONOMIES OF SCALE





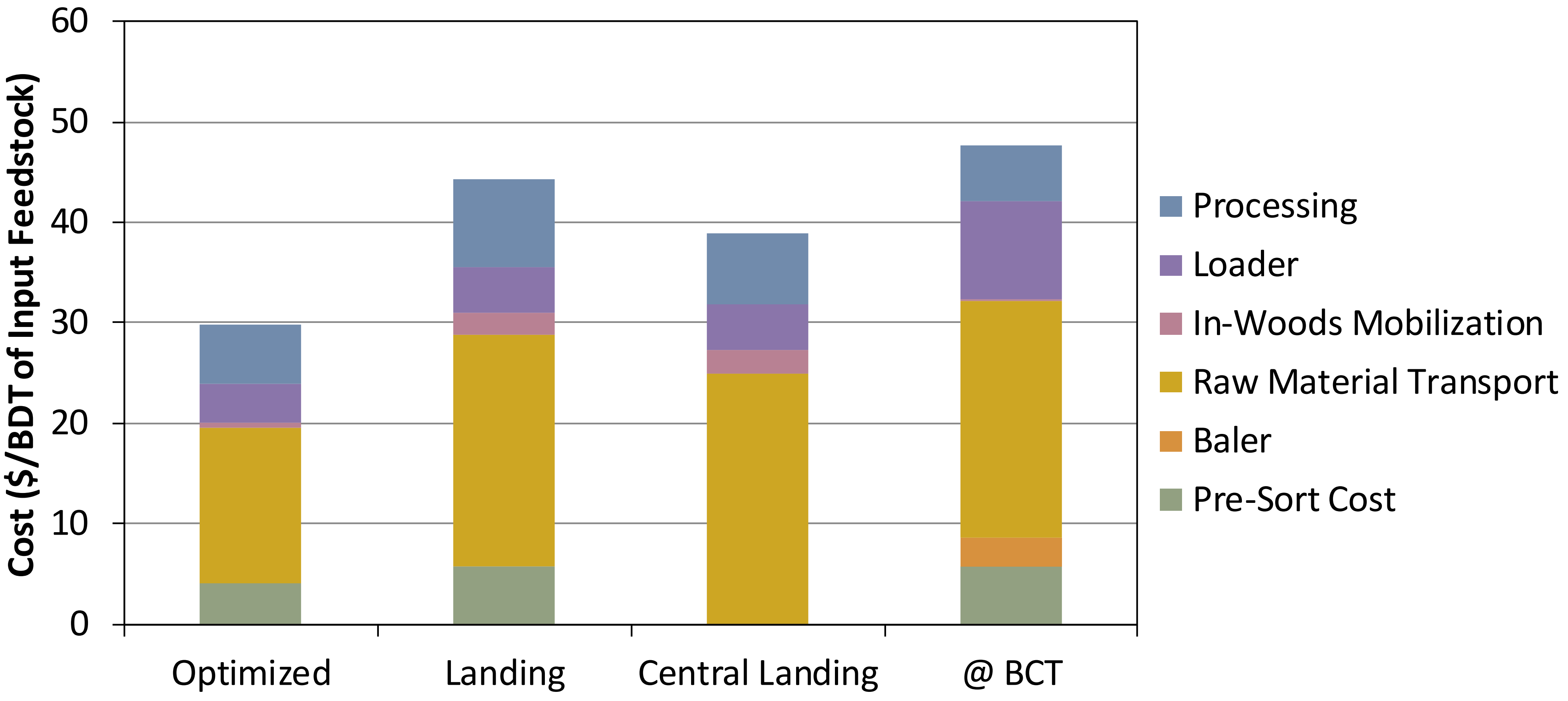
Economies of Scale are Significant
Moving from a small scale to a large scale can save $30/Ton

BIOMASS CHARACTERISTICS



Can increase costs up to ~ $20/Ton above base case

LOGISTIC COSTS



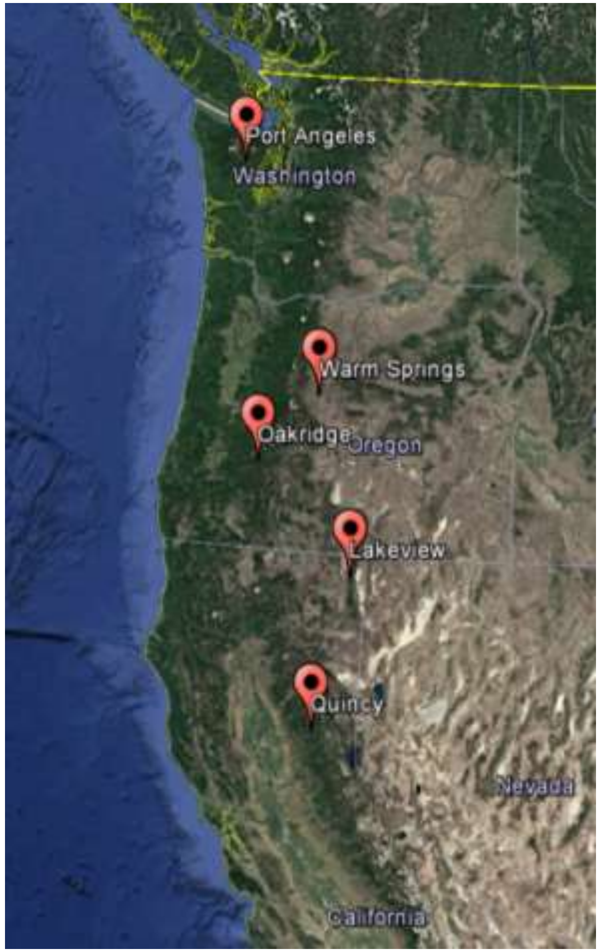
Sub-Optimal Solutions can increase costs ~$15/Ton above optimal solution

COST SENSITIVITY TO BASE CASE

This equates to ~5-20% of supply chain costs

Base Case: Large Scale Optimized Biochar Plant

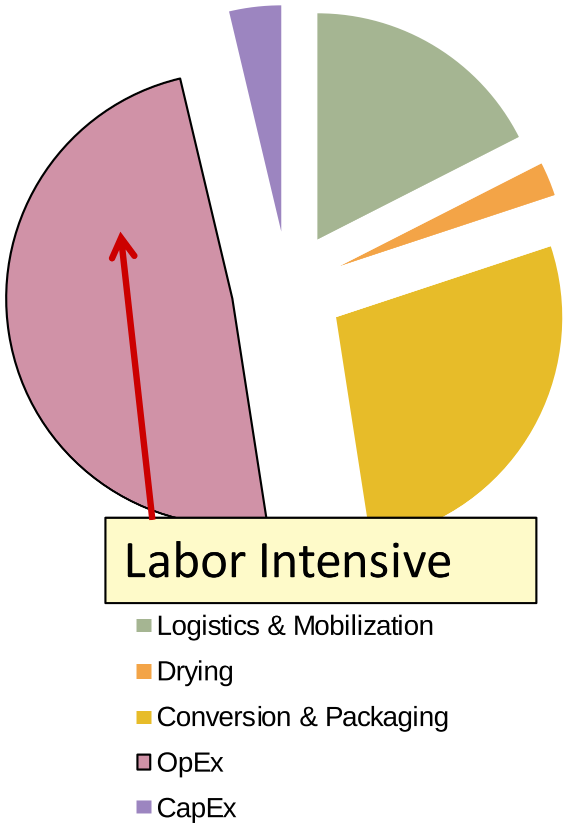
REGIONAL CASE STUDIES



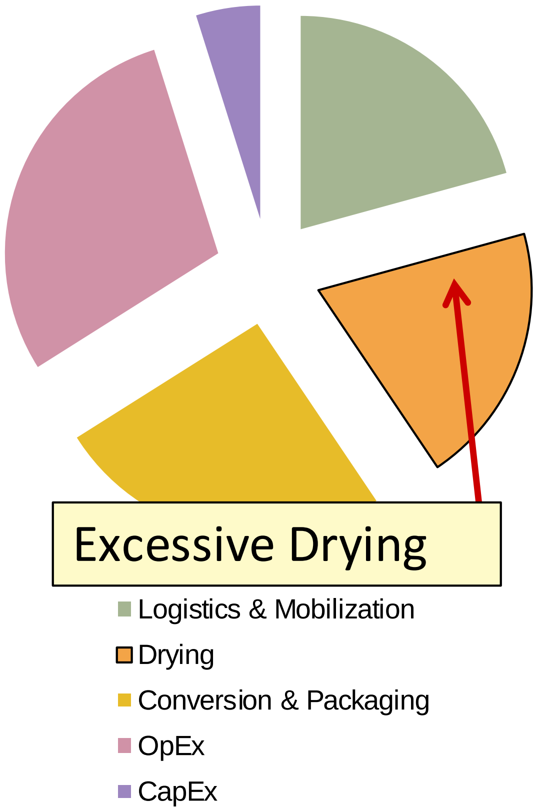
3 STATES | 3 PRODUCTS

PRODUCT DIFFERENCES & COST STRUCTURES

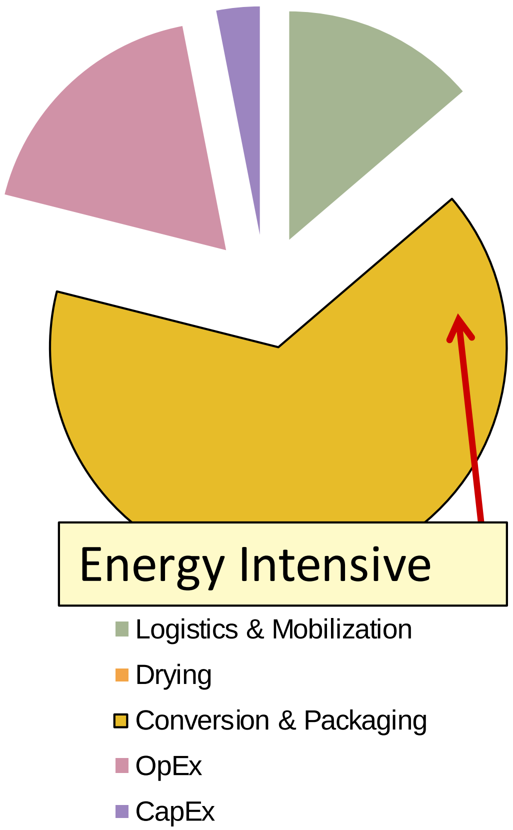
BioChar



Briquette



Torrefied Wood



Costs are Heavily Dependent on Conversion Technology

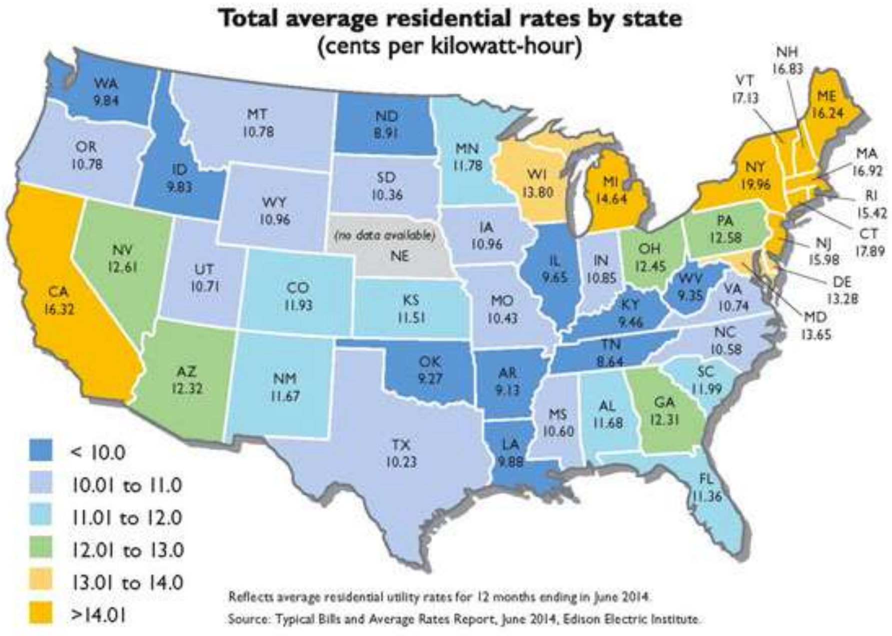
REGIONAL DIFFERENCES

1. Log Specifications and Utilization

2. Energy Rates

3. Truck Regulations

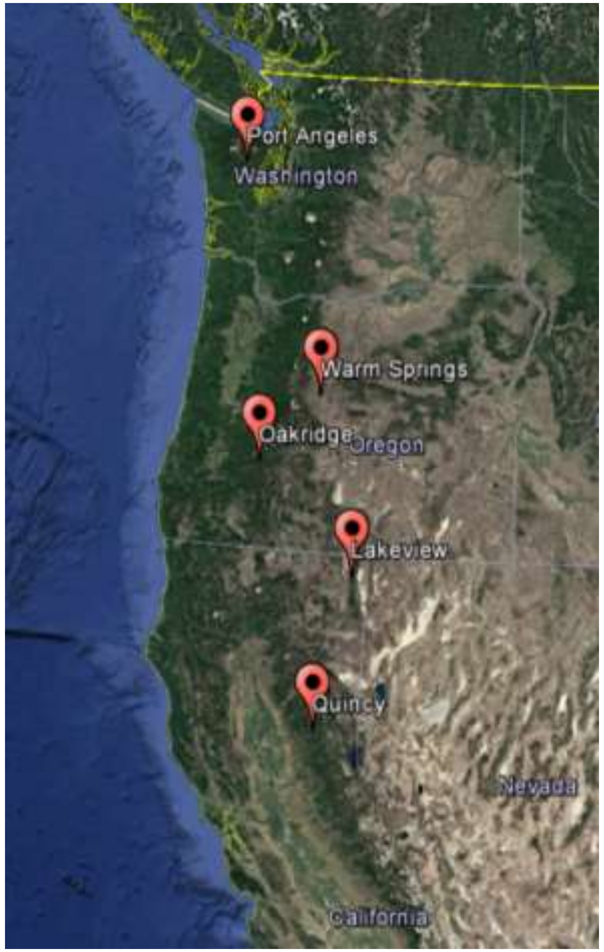
4. Silviculture / Regeneration / Disposal Costs



Question:
Does this facility concept make sense? Where?

REGIONAL CHARACTERISTICS

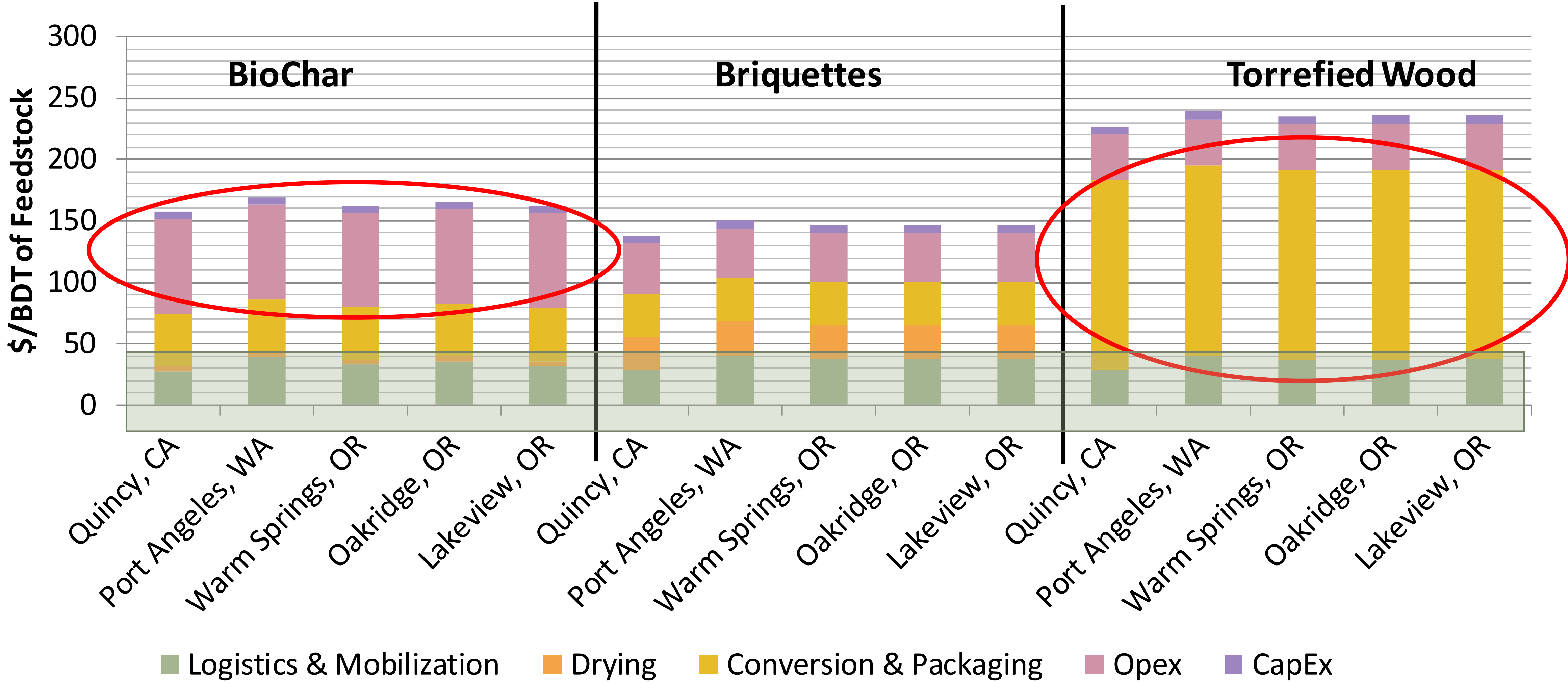
	Biomass Availability Parcel Level BDT/Ac	% Tops and Pulp Logs	Distance to Product Market	Biomass Density at Landscape Level BDT/Ac
Quincy, CA	35	51%	55	1.1
Lakeview, OR	21	53%	94	0.19
Oakridge, OR	**17**	**8%**	**31**	**0.47**
Warm Springs, OR	21	52%	56	0.44
Port Angeles, WA	**30**	**5%**	**53**	**0.83**



Note: 5 year Time Horizon

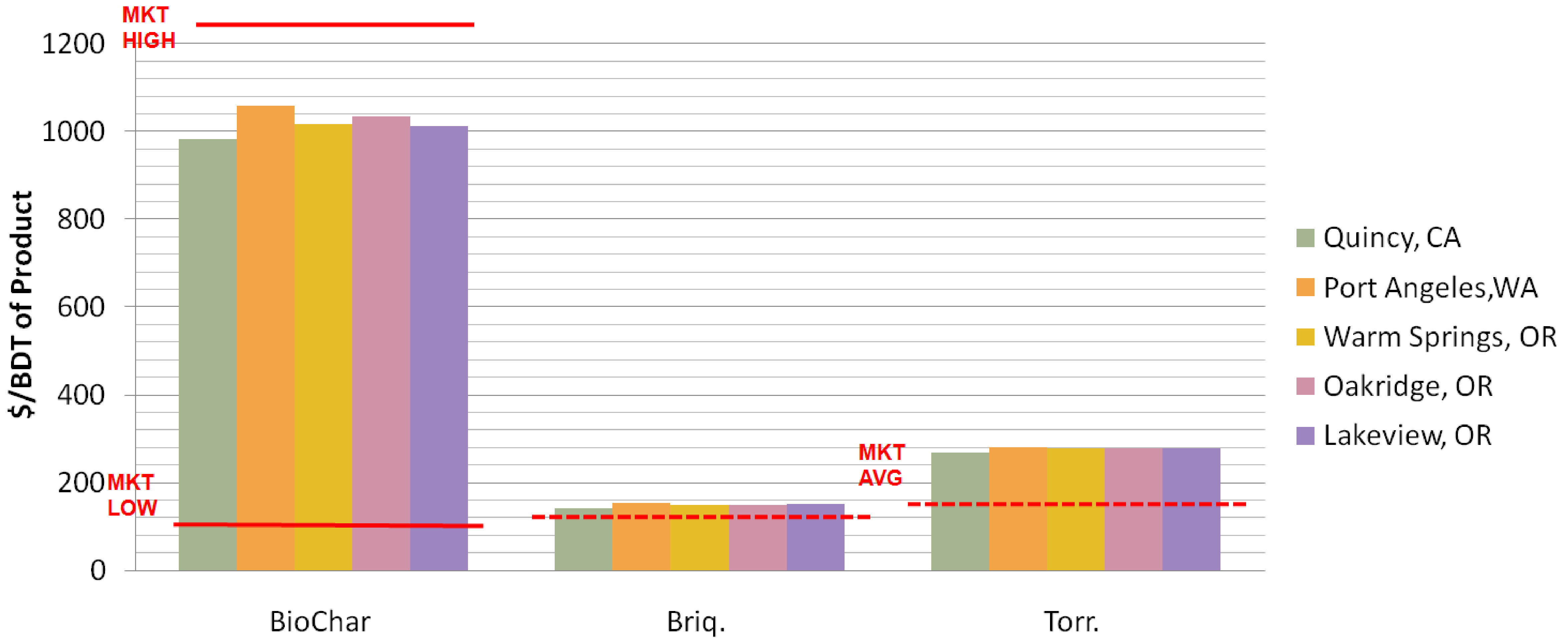
Varying Composition & Biomass Availability

WHAT ARE THE DIFFERENT SUPPLY CHAIN COSTS?



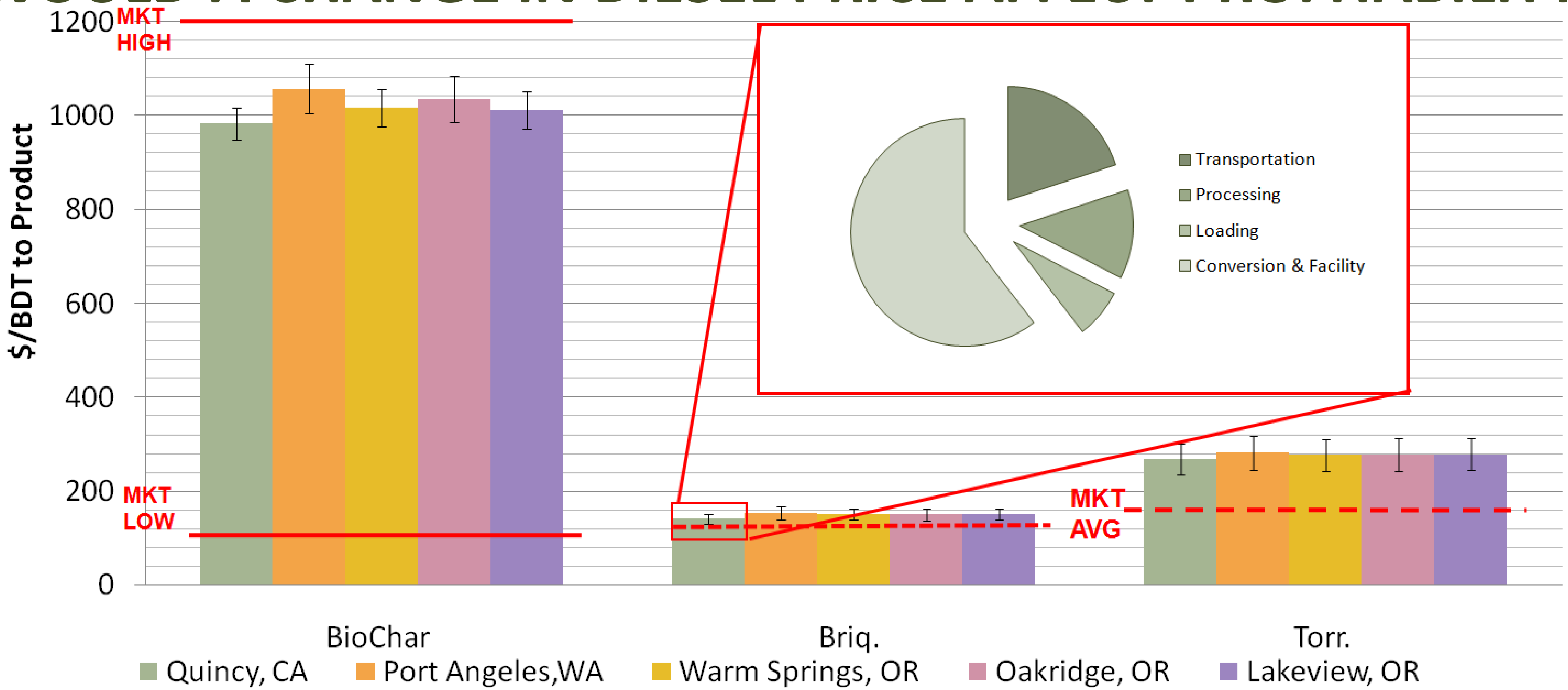
Regional Variation ~5-10%

WILL THE MARKET SUPPORT THE SUPPLY CHAIN COSTS?



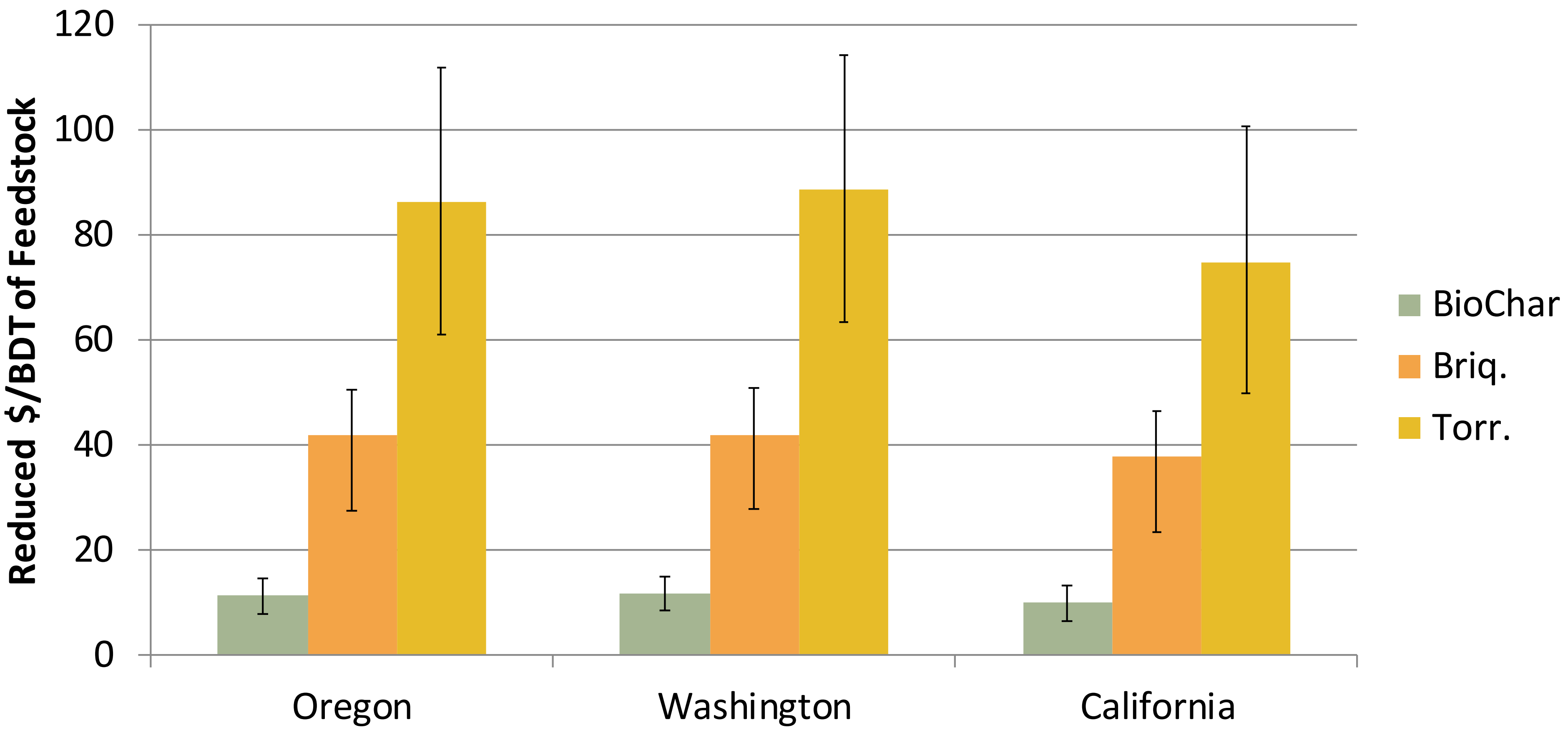
Biochar Likely Best Candidate
Depends on Local & Regional Market Conditions

WOULD A CHANGE IN DIESEL PRICE AFFECT PROFITABILITY?



Unlikely

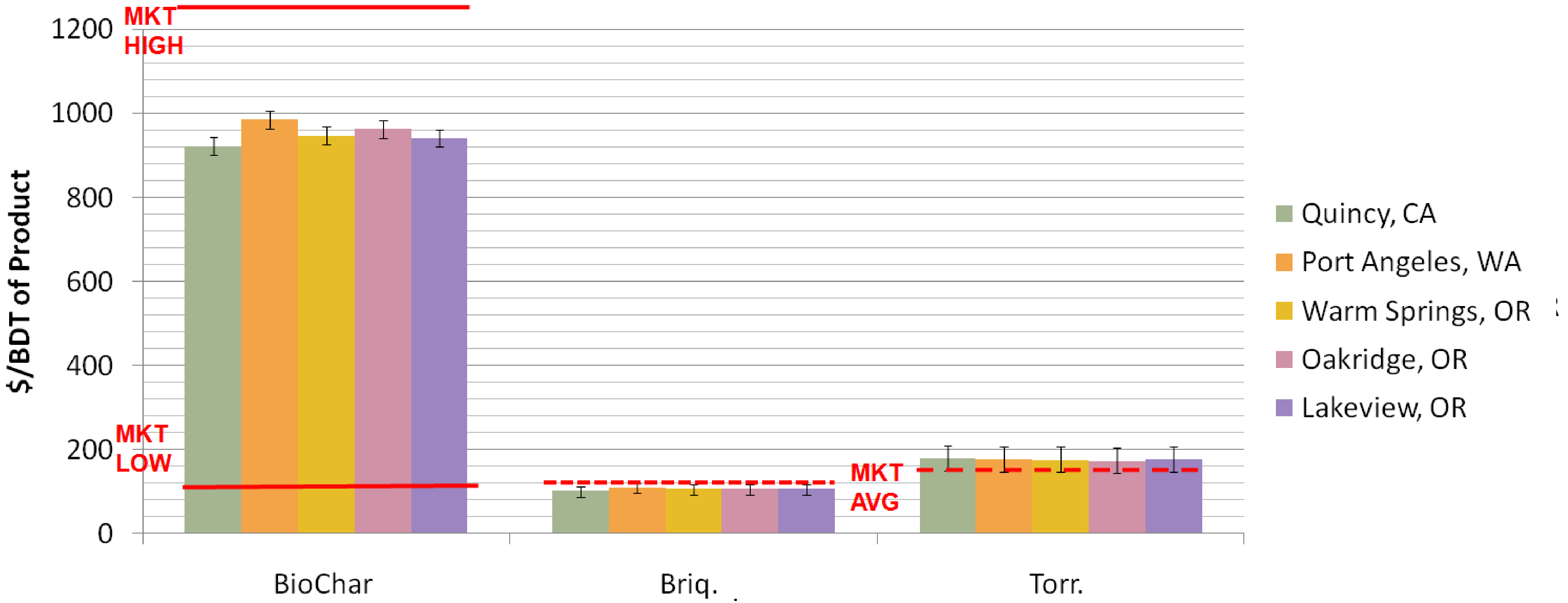
COST REDUCTION IF THE PLANT COULD BE GRID-CONNECTED?



ENERGY COST DIFFERENTIAL

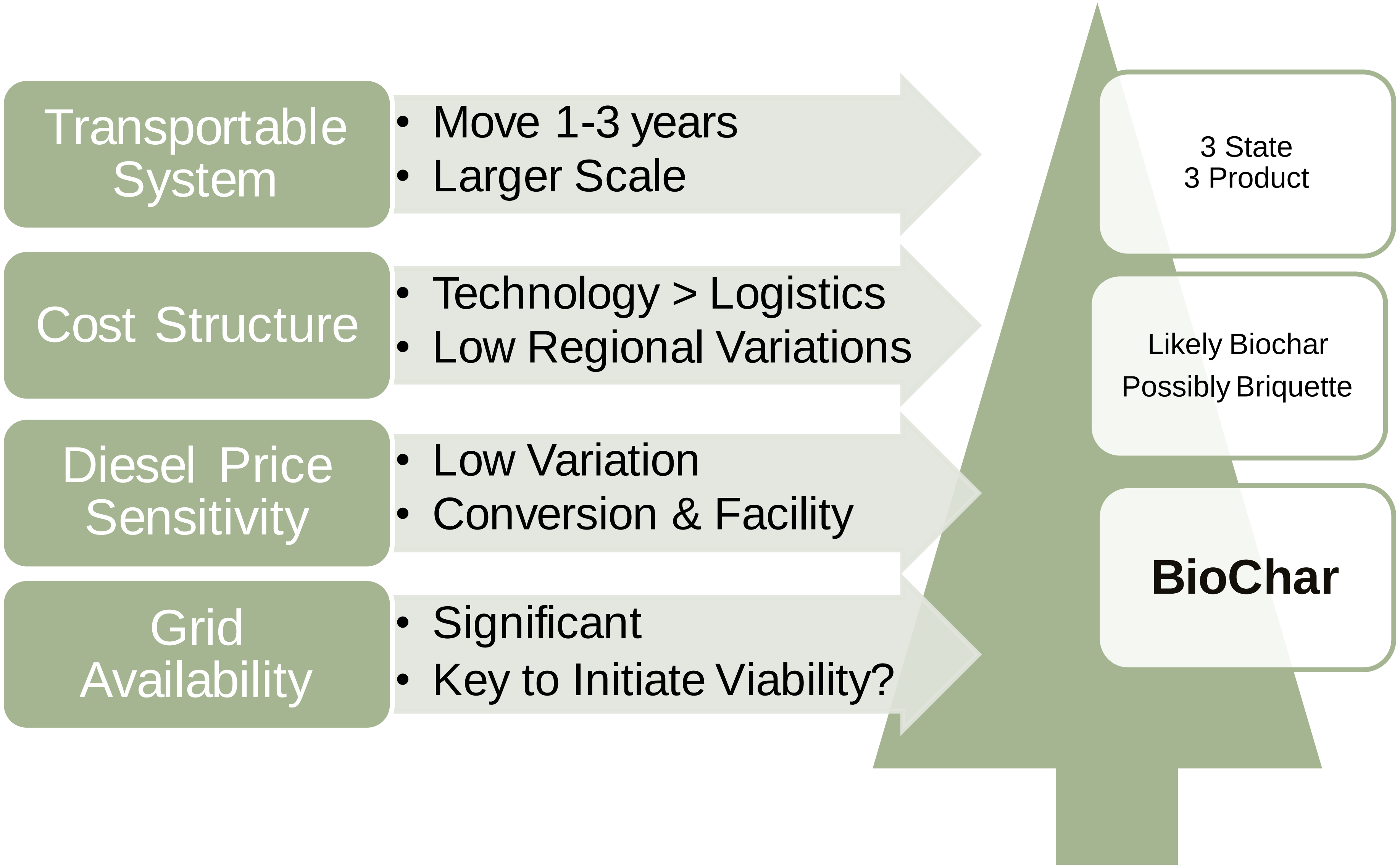
Of Supply Production Costs: Biochar: 6-7%, Briquette: 27-29%, Torrefied Wood: 33-38%

COSTS WITH A GRID-CONNECTED PLANT?



Biochar & Briquetting now could be viable
Torrefied Wood still likely too costly

SUMMARY


Transportable System
• Move 1-3 years
• Larger Scale
Cost Structure
• Technology > Logistics
• Low Regional Variations
Diesel Price Sensitivity
• Low Variation
• Conversion & Facility
Grid Availability
• Significant
• Key to Initiate Viability?
3 State
3 Product
Likely Biochar
Possibly Briquette
BioChar

LESSONS LEARNED

- SCALE:
  - Economies of Scale are a important consideration
- LOGISTICS:
  - Important but largely overshadowed by plant and operation expenses
- REGIONAL CONSIDERATIONS:
  - High quality & proximity of feedstock
- TECHNOLOGIES:
  - Conversion costs and yields are very important
- MARKETS
  - Product prices drive viability
- GRID-CONNECTION:
  - Maybe the key to cost-effective operations

Courtesy Colorado State Forest Service

For More Information

Special Issue of ASABE for the Waste to Wisdom Project (forthcoming)

- THE ECONOMICS OF BIOMASS LOGISTICS AND CONVERSION FACILITY MOBILITY: AN OREGON CASE STUDY
- A FOREST-TO-PRODUCT BIOMASS SUPPLY CHAIN IN THE PACIFIC NORTHWEST, USA: A MULTI-PRODUCT APPROACH
- SUBREGIONAL COMPARISON FOR FOREST-TO-PRODUCT BIOMASS SUPPLY CHAINS ON THE WEST COAST, USA

ACKNOWLEDGEMENTS

Collaborators:
Han-Sup Han (Humboldt State University)
Joel Bisson (Humboldt State University)
Mark Severy (Humboldt State University)
Jeff Comnick (University of Washington RTI)
Ted Bilek (USFS Forest Products Laboratory)
Diasuke Sasantani (University of Washington)
David Smith (Oregon State University)
Will Hollamon (Oregon State University)

QUESTIONS?

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Thank you for attending today's webinar. You can watch a recording of this webinar and other Waste to Wisdom webinars at :

wastetowisdom.com/webinars