WASTE TO WISDOM

Development and Optimization of a Northern California Biomass Supply Chain Model

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For more information please visit WasteToWisdom.com

PROJECT: WASTE TO WISDOM

THE PROBLEM

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

A SOLUTION

Waste to Wisdom goal is to help find a way to turn that forest residues into valuable bioenergy and bio-based products.

RESEARCH QUESTION

What is the optimal biomass supply chain system that will maximize net system profit?

OUTLINE

1. Project Overview – TASK 2.6
2. Problem Description & Supply Chain Elements
3. Project Integration
4. Model Formulation
5. Model Methodology
6. Key Model Considerations | Constraints
7. Example Model Outputs
8. Next Steps

Subtask: 2.6: Integration of Biomass Conversion Technologies (BCTs) with landscape level planning and transportation logistics

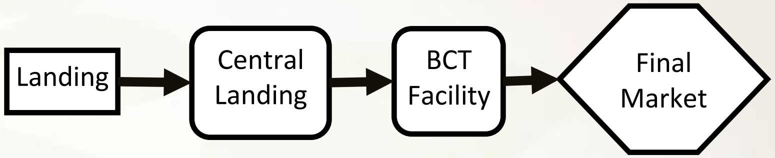
1. **DEVELOP** landscape prototype model suitable for planning and evaluating biomass conversion pathways.

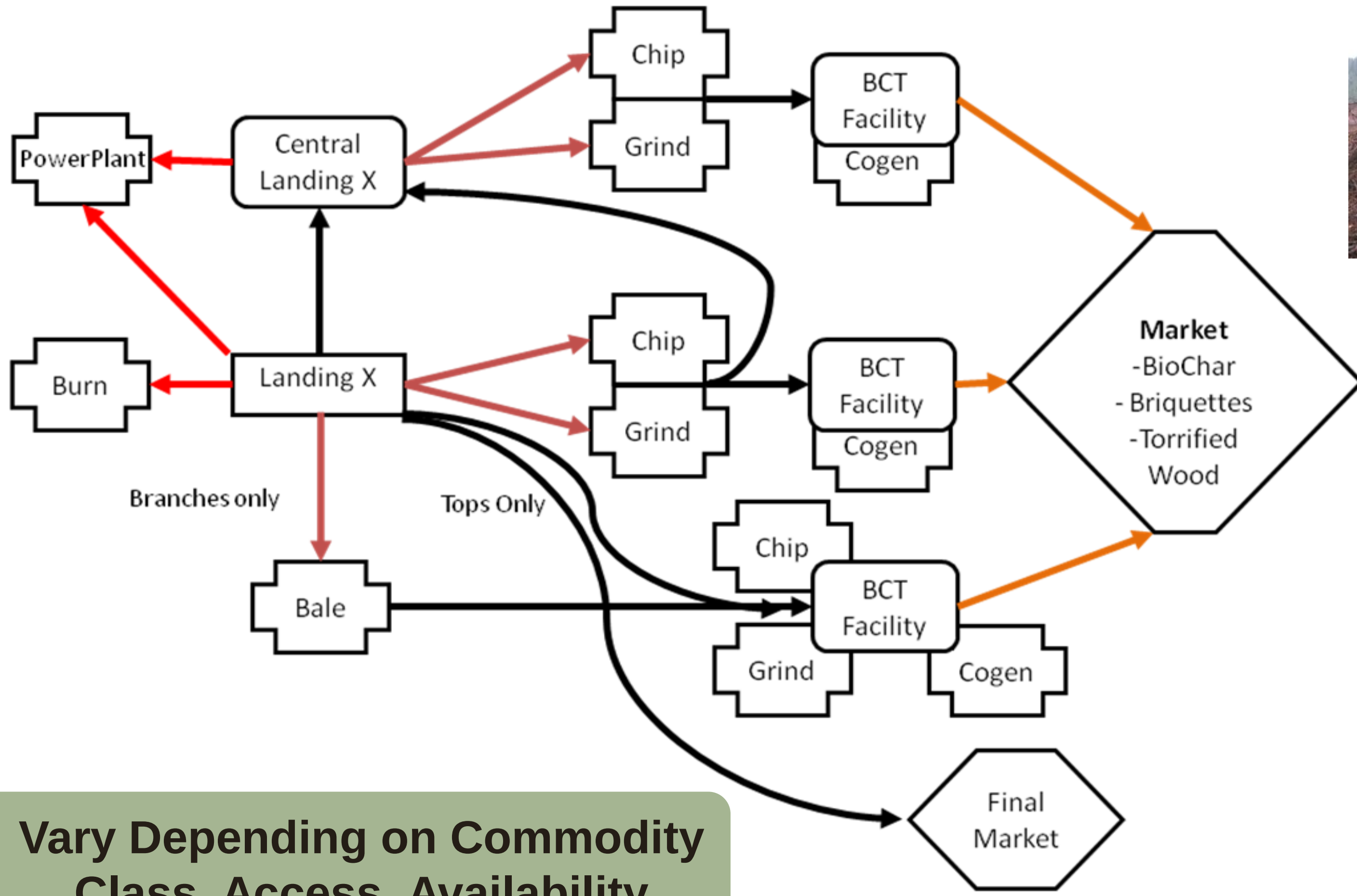
2. **INTEGRATE** research and models developed by Task Groups 2,3,4.

3. **TEST** sensitivity of landscape inputs and market assumptions to profit.

LANDSCAPE LEVEL | INVESTOR PERSPECTIVE | DATA INTEGRATION

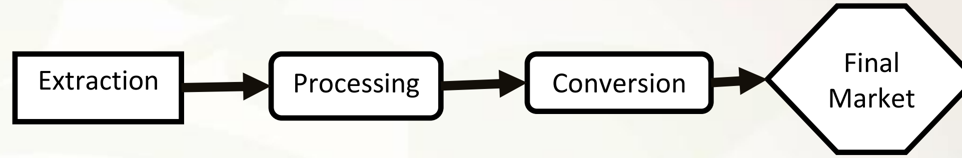
OVERVIEW:
SUPPLY CHAIN PATHWAYS





Vary Depending on Commodity Class, Access, Availability

OVERVIEW: MAIN MODEL INPUTS



HARVEST SCHEDULE

Main Inputs
- Biomass Availability (Quantity/Timing)
- Road Network
- Extraction Limitations
- Machine Data
- Moisture Content

LOGISTICS & CONFIGURATIONS

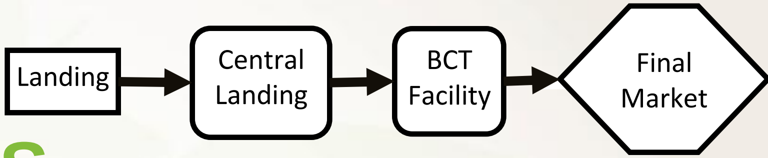
Key Variables
- Pathways per LX, CLX, BCT
- Trucking Options/Access
- Logical Triggers
- Powerplant Availability
- Facility Type & Scale
- Operating Conditions & Rules

REVENUES & RATES

Major Costs Drivers
- Product Market Prices
- Conversion
- Plant Variable & Capital Cost
- Processing & Utilization
- Mobilization & Transportation
- Supporting Equipment

TASK: BUILD & OPTIMIZE A LANDSCAPE MODEL

PROBLEM DESCRIPTION : KEY DESIGN CONSIDERATIONS



Pathways	• Landings (Raw Material) -> Central Landing (Collection Ports) -> • BCT (Conversion/ Processing Facility) -> Final Markets
Multi-Commodity	• Tops | Branches | Combination
Multi-Period	• 60 Monthly Periods (5 Year Planning Horizon)
Inventory Management	• Inventory potential @ CLX & BCT Facilities (Dynamic Flow – Multi-Echelon)
Processing Options	• Chip | Grind | Sort | Bale
Transportation Options	• Truck Types/ Capacities Vary
Moisture Content Feedback	• Variable with time – affects transportation/ production capabilities
Plant Scale & Configurations	• Tonnage Capacity | Product Suites (6 Configurations Identified)
Final Markets	• Biochar | Briquette | Torrified Wood | Tops – Post/Fence

PROJECT INTEGRATION

MODEL: Multi-Commodity, Multi-Period, Multi-Echelon

TA1

Moisture Management

Inventory Management

2.1

WT • Vary Material Specifications

P • Placement, Screening Mix

2.2, 2.3, 2.4

2.5

TA3

Main Inputs
- Site Characteristics
- Pathways per LX, CLX, BCT
- Road Network
- Trucking Options/Access
- Machine Data
- Logical Triggers

Timeline (Monthly) → Landing (LX) → Component (B/T) → Centralized Yard (CLx) → Comminution Option → BCT Facility

YR • Year

QTR • Seasonality

Lx • Characteristics, Material Available

S • Sorting

B • Branches

T • Tops

BT • Branches & Tops

CY_x • Variable Central Landing

EQ • Equipment Available

G • Grinding

C • Chipping

BCTx • Facility – Location, Capacity, Product Suite

COGEN • Facility Location/ Options

MKT • Biochar, Torrified Briquette

TA4

Major Costs Drivers
- Conversion
- Processing
- Transportation
- Mobilization
- Supporting Equipment
- Utilization

Trucking Option(s)

SA • Site Access

GOAL: MAXIMIZE NPV FOR INVESTOR

TASK AREAS

TA 1: Project Management
TA 2: Feedstock Development
TA 3: Conversion Technologies
TA 4: Sustainability Analysis

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MODEL DEVELOPMENT

THEME: Adaptable to Meet Project Needs, Inputs and Proposed Variations

1. **Key Concept: Pathways**
   a) Arc Vs. Route Approaches

2. **Data Assimilation**
   a) Group Coordination & Data Integration

3. **Decision Variables**
   a) Material Flow (Landing, BCT, Route, Time Period, Product)

ADAPTABLE | LOGICAL | ACCURATE

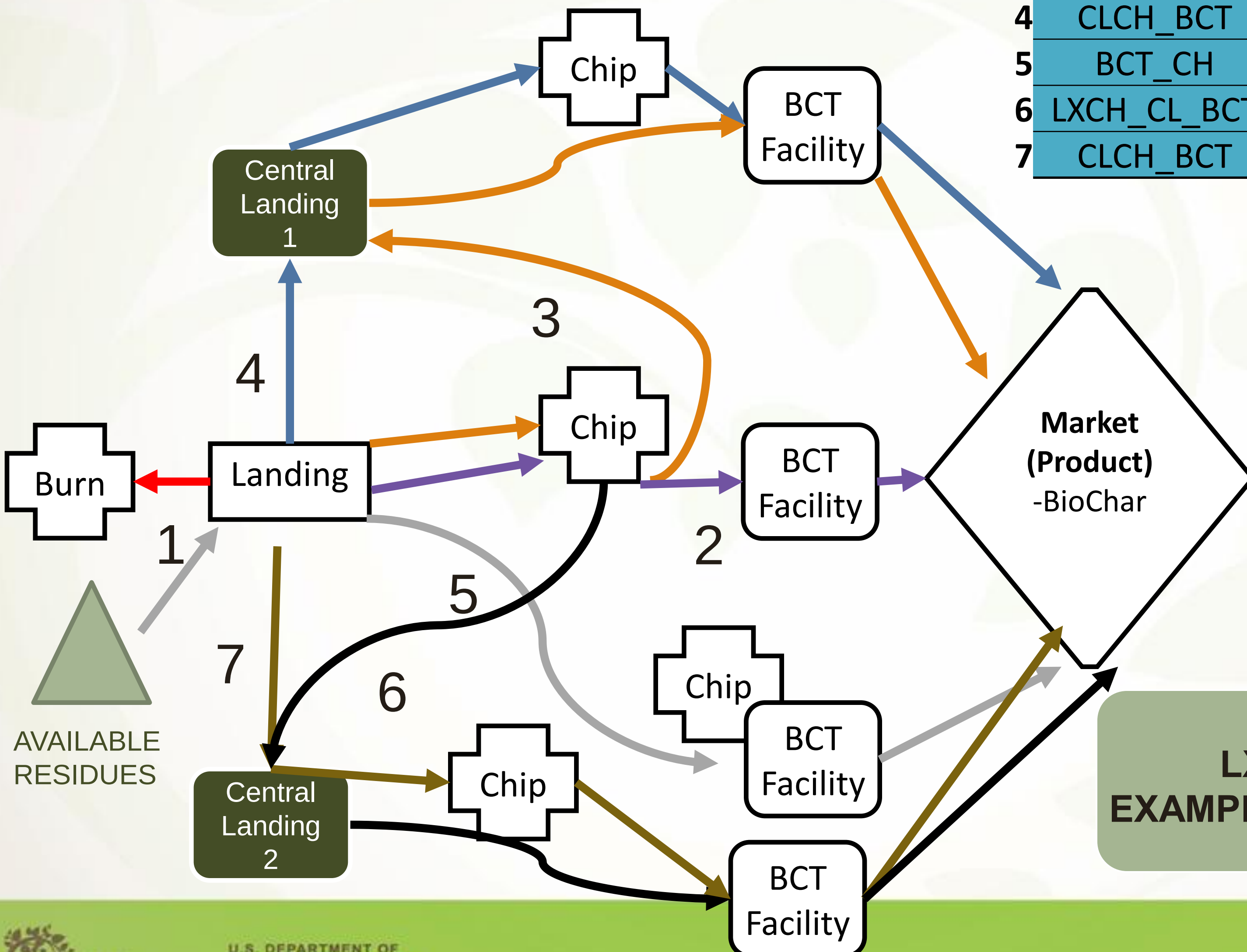
MODEL DEVELOPMENT – ROUTES

TOPS Material Route EXAMPLE

	Route
1	BURN
2	LXCH_BCT
3	LXCH_CL_BCT
4	CLCH_BCT
5	BCT_CH
6	LXCH_CL_BCT
7	CLCH_BCT

1

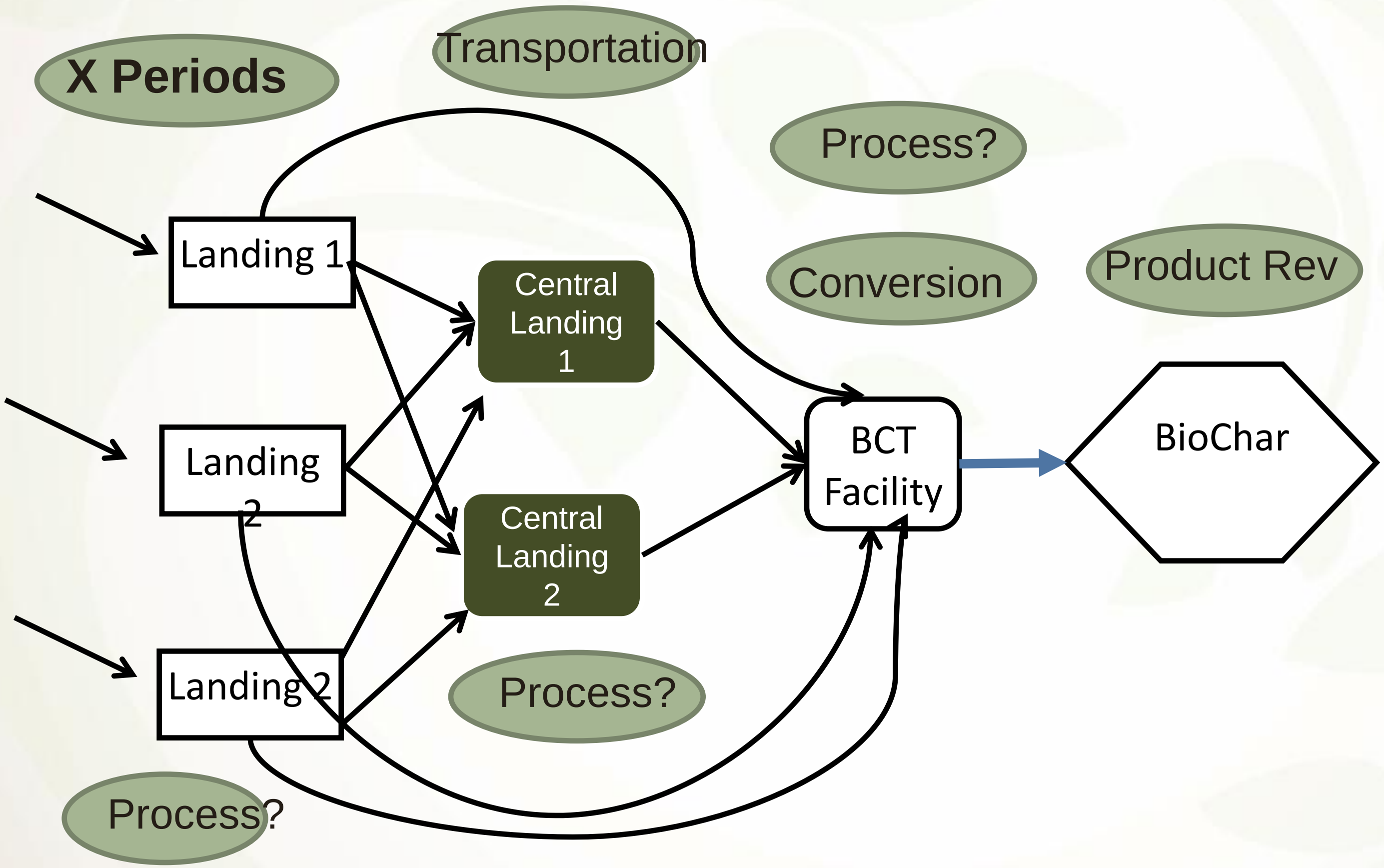
2



LXX→ ROUTE(S)
EXAMPLE: TOPS LXX → BCT

MODEL FORMULATION : NETWORK APPROACH

ROUTE SPECIFIC COSTS



MATHMATICAL FORMULATION - NOTATION

Notation:

SETS

A = Residuals
I= Node
J= BCT
K= Route Taken (Option)
T= Time Period
P= Product Produced

DECISION VARIABLES:

-X(a,i,j,k,t) –

BDT flow of residual a, from LXX i, to BCT j, using route k, in time period t

-Y(a,p,j,t)-

BDT of residual a, into product p, from BCT j, in period t

PARAMETERS:

available(i) – Material Available at node i, BDT
mci(i)- initial moisture content
pvalue(p) – value of product p produced per incoming BDT
mcfactor(i,t) – moisture content of material from node i if extracted in period t
pdsctfactor(p,t)- time value discount of product p in time period t
pbctfactor(p,j)- value discount factor from each bct (proxy for distance to mkt)
pinvestment(p,j)= infrastructure investment to make product p at bct j
routeinvestment(k,t) = investments to make route k in time t
TC(i,k)- Transportation costs from node i taking route k to bct ($/BDT)
CONST(a,p)- Construction costs from node i taking route k ($/EA)
CC(a,p)- Conversion Costs of residual a into product p ($/BDT)
Mobilization(i,k)- Mobilization costs from node i taking route k to bct ($/EA)
PC(i,k)- Processing costs from node i taking route k to bct ($/BDT)
Q(j,t)=bctcapacity(j,t) – Capacity of bct in period t (BDT)
Qt=bctcapacity2= Total Capacity of bct during time horizon (BDT)
pvalue=value of product, p ($/BDT)

KEY FACTORS:

- ***Inventory***
- ***Costs (Mobilization, Process, Conversion)***
- ***Moisture Content***
- ***Investments (Plant, Route)***
- ***Plant Estimates***

OTHER VALUES:

W(a,p,j,t)- value of residual a, into product p, from bct j, at time period t (function of pvalue,pbctfactor,pdsctfactor)
Inv(a,j,t) – inventory levels of residual a, at bct j, in time period t.
PIN(p,j)= Binary Value – investment in product p at bct j?
KIN (k,t)= Binary Value – investment in route k, in period t?

MATHMATICAL FORMULATION

GOAL: MAX NET PRESENT VALUE (NPV)

MAX:
$$\sum_a \sum_p \sum_j \sum_t (W_{apjt} * Y_{apjt}) - \sum_a \sum_i \sum_j \sum_k \sum_t (C_{aijkt} * X_{aijkt}) - \sum_k \sum_t (KIN_{kt} * RI_{kt}) - \sum_p \sum_j (PIN_{pj} * PI_{pj})$$

Subject to:

Inventory levels
$$INV_{ajt} = INV_{ajt-1} + \sum_i \sum_k X_{aijkt} - \sum_p Y_{apj}, \forall t \in T, \forall j \in J, \forall a \in A$$

Investments
$$M * PIN_{pj} \geq \sum_a \sum_t Y_{apjt}, \forall p \in P, \forall j \in J \qquad PIN(0,1)$$
$$M * KIN_{kt} \geq \sum_i \sum_i \sum_j X_{aijkt}, \forall k \in K, \forall t \in T \qquad KIN(0,1)$$

Capacity Considerations
$$\sum_a \sum_p Y_{apjt} \leq Q_{jt} \qquad \forall j \in J, \forall t \in T$$

Main Cost Drivers
$$C_{aijkt} = CONST_{ik} + TC_{ik} + PC_{ik} + MOBE_{ik} \qquad \forall a \in A, \forall i \in I, \forall j \in J, \forall k \in K, \forall t \in T$$
$$W_{apjt} = pvalue_p * pdiscountfactor_{pj} * pbctfactor_{pj} \qquad \forall a \in A, \forall p \in P, \forall j \in J, \forall t \in T$$

SOLUTION (OPTIMIZATION)

1. FULL MODEL:
   a) Customizable Metaheuristic-Based Model Formulation
   b) Genetic Algorithm (GA)

2. MODEL VALIDATION:
   a) Small Scale Exact Solution Confirmation - Validation
   b) Mixed Integer Programming (MIP)

ADAPTABLE | LOGICAL | ACCURATE

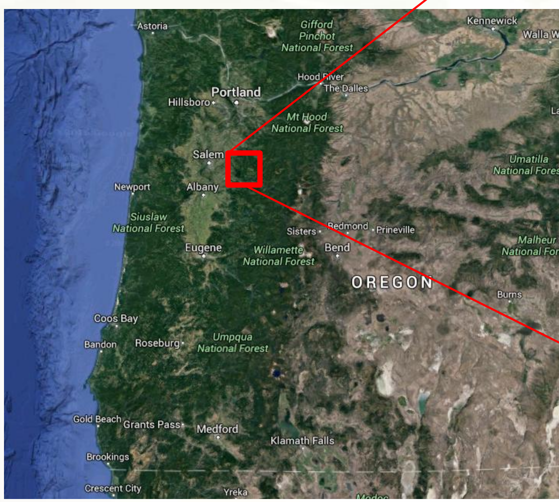
GOAL AND CONSTRAINTS

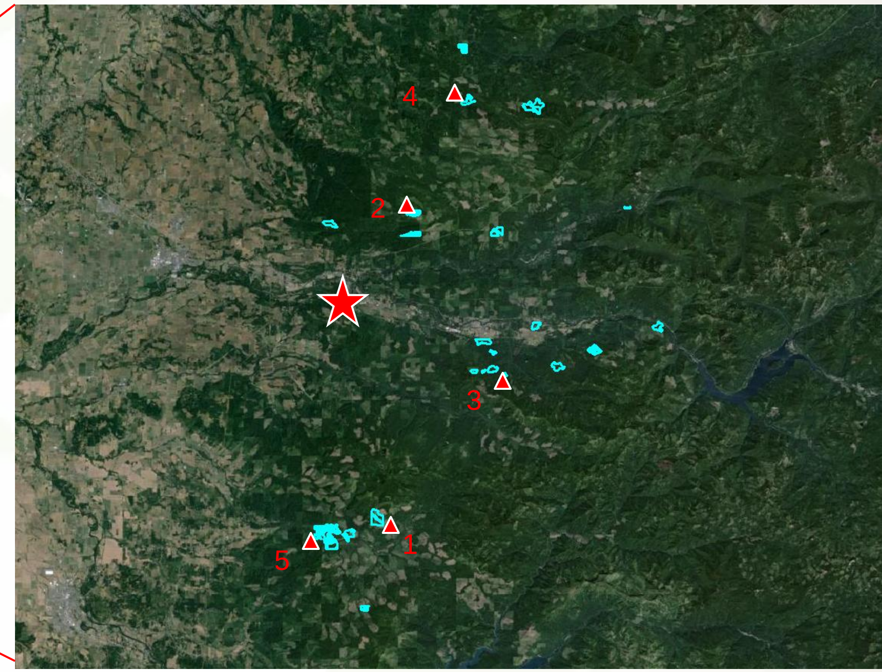
OPTIMIZATION GOAL	• **MAX NET PRESENT VALUE**
CONVERSION FACILITY CONFIGURATION	• (6 EA) Biochar | Torrified Wood | Briquette | BR+ BC | BR + TW | TWBR
PLANT SCALE	• (3 EA) 6K-15KBDT/ Year, 15K-30K BDT/ Year, 30K-50K BDT/Year
MATERIAL HANDLING	• Sorted, Routes Available
EXTRACTION TIMING	• Months/Year Available
MIN | MAX MATERIAL FLOW	• Biomass Extraction & Conversion Rates

EXAMPLE MODEL RESULTS

BCT SITE: LYONS, OR

a) Harvest Schedule Available
b) Road Network
c) Existing Cogen Facility





★ Lyons, OR ▲ Central Landing

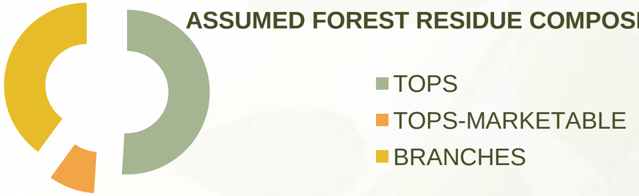
50 LXX | 5 CLX | 12 PERIOD | 2 COMMODITY

THIS IS AN EXAMPLE

EXAMPLE MODEL – KEY INPUTS | CONSTRAINTS

OPTIMIZATION GOAL	• **MAX NET PRESENT VALUE**
CONVERSION FACILITY TYPE	• Biochar & Briquettes
PLANT SCALE	• 30K-50K BDT/Year
MATERIAL HANDELING	• SORTED: TOPS= Chip/Burn, BRANCHES = Grind/Burn
EXTRACTION TIMING	• 12 Periods: 6 Months Extraction
MIN | MAX MATERIAL FLOW	• MAX Extraction = 10k BDT/Mo • MIN Conversion = 1.5k BDT/Mo

ASSUMED FOREST RESIDUE COMPOSITION



Other Key 'Placeholders'

a) **Revenue: Biochar @ $1800/BDT, Briquette: $200/BDT, Top-Mkt @ $120/BDT (Assumed 15%)**

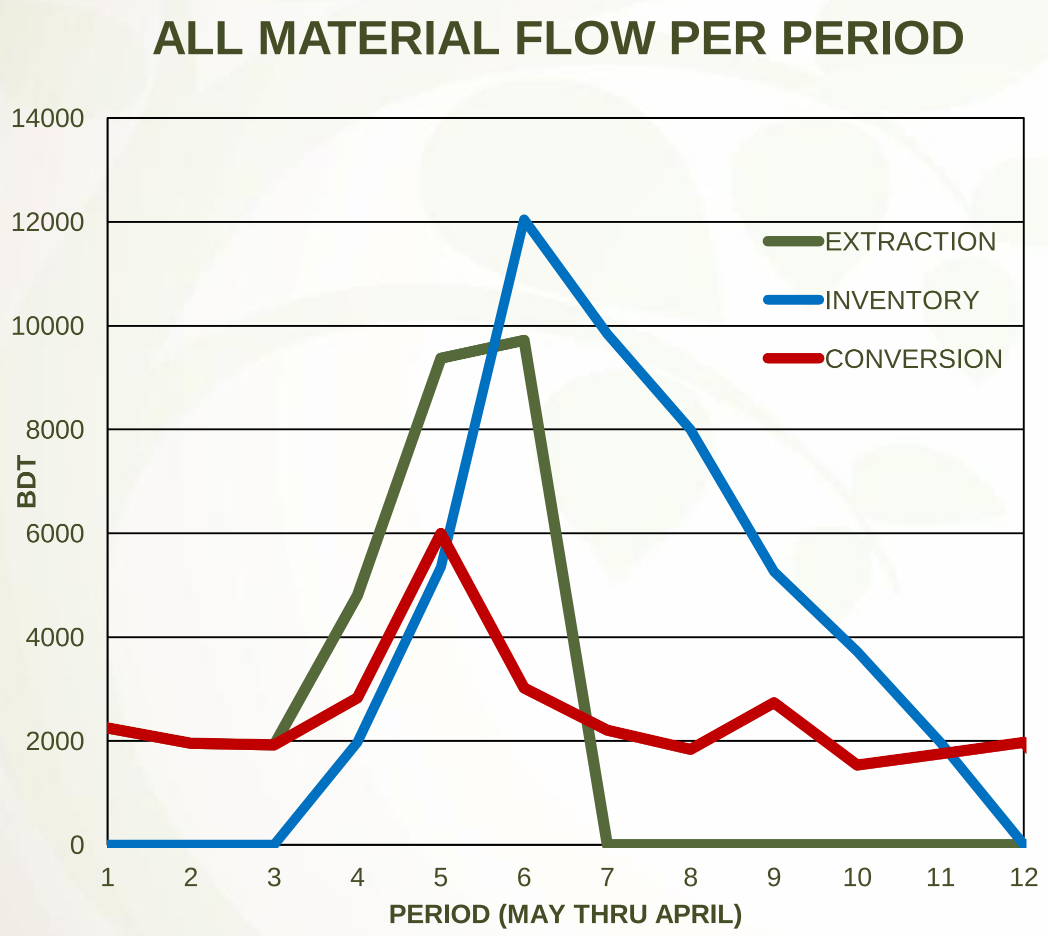
b) **Plant Cost = 7.5 Million**

Similar to a Hybrid Scenario '3'

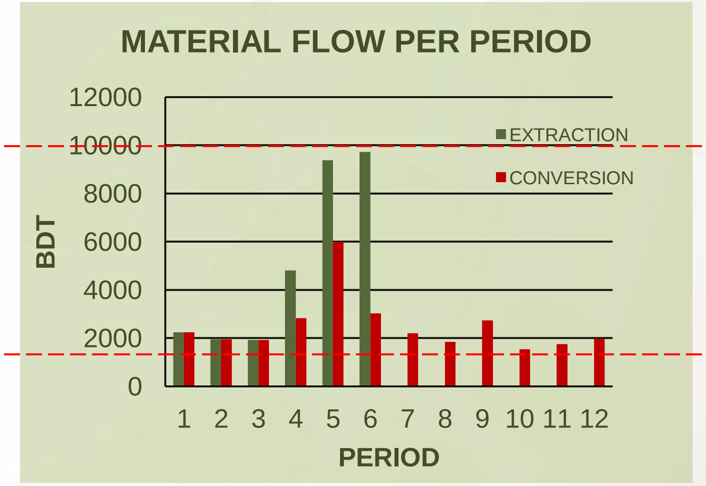
50 LXX | 5 CLX | 12 PERIOD | 2 COMMODITY

THIS IS AN EXAMPLE

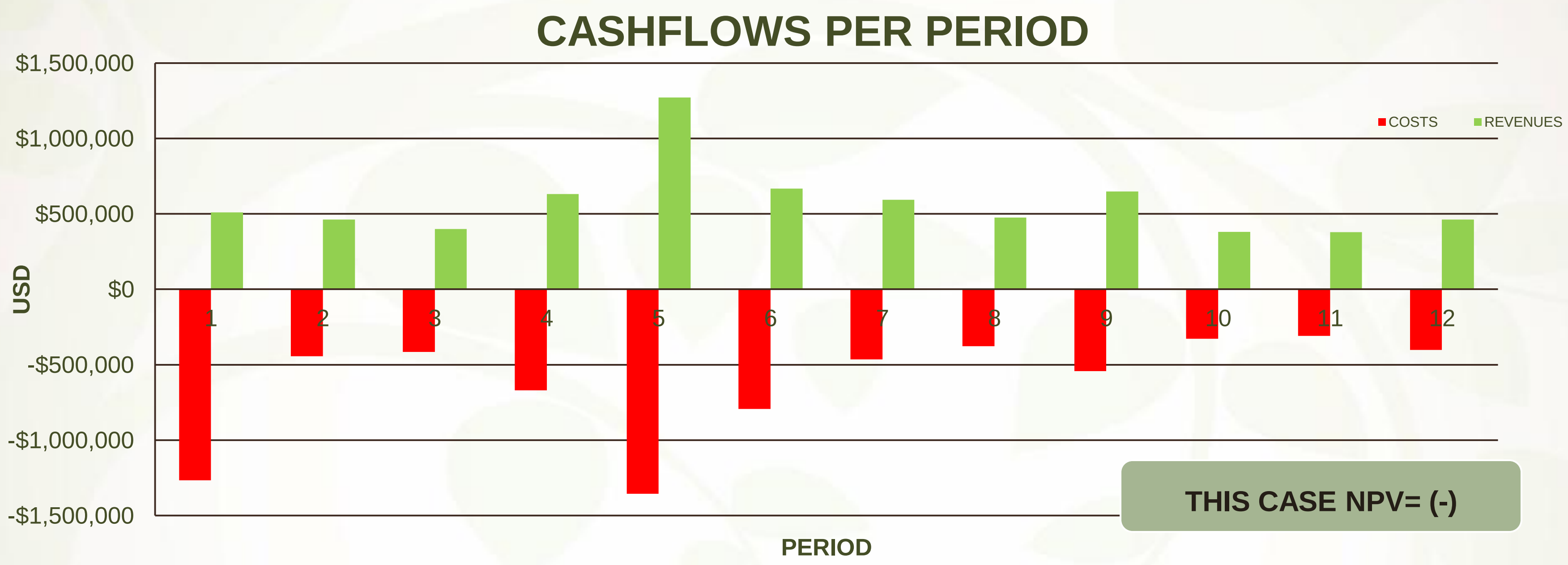
EXAMPLE MODEL OUTPUT : MATERIAL FLOW

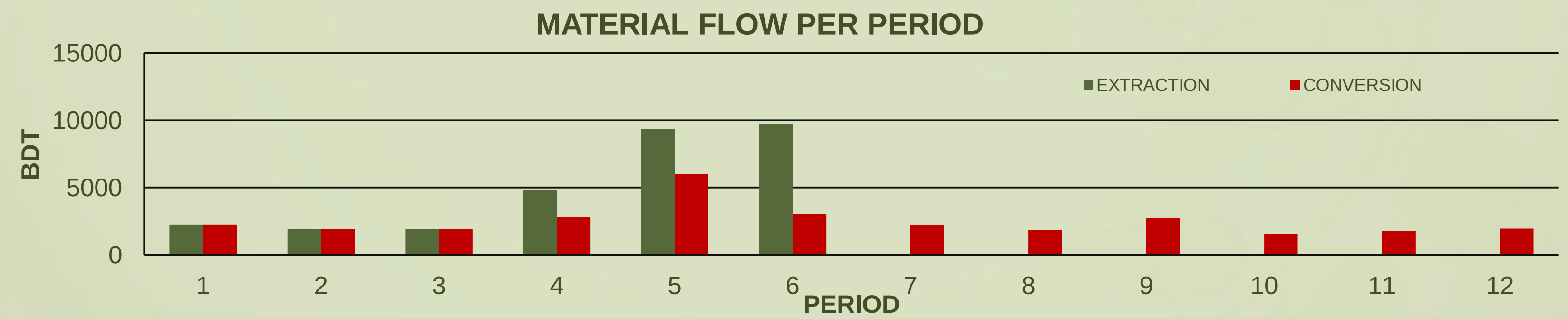


- **TOTALS:**
  - **30K BDT/YEAR CONVERSION**
- **Conservation of Flow**
- **Build Inventory – Late (MC)**
- **Maintain Production**

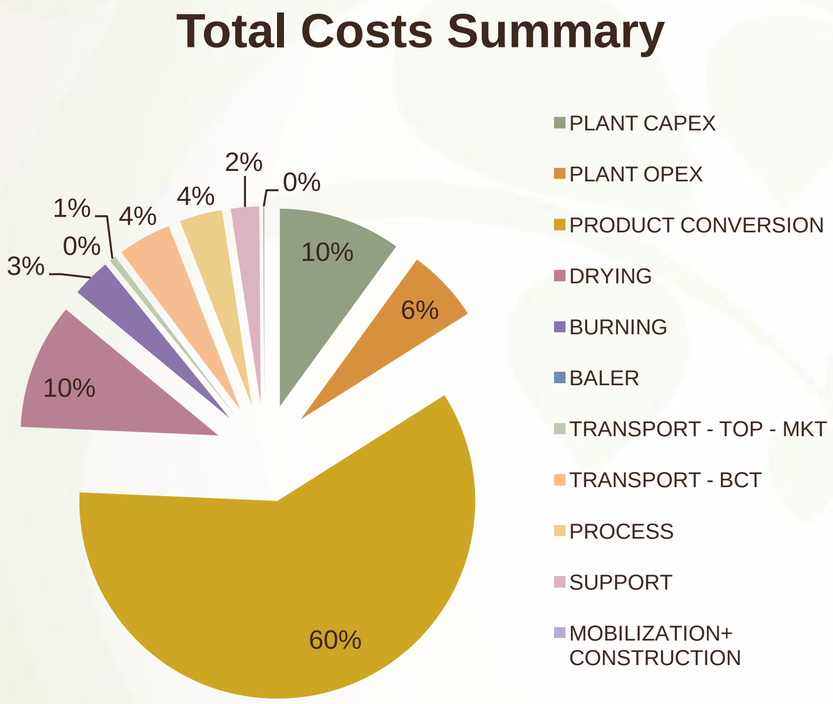


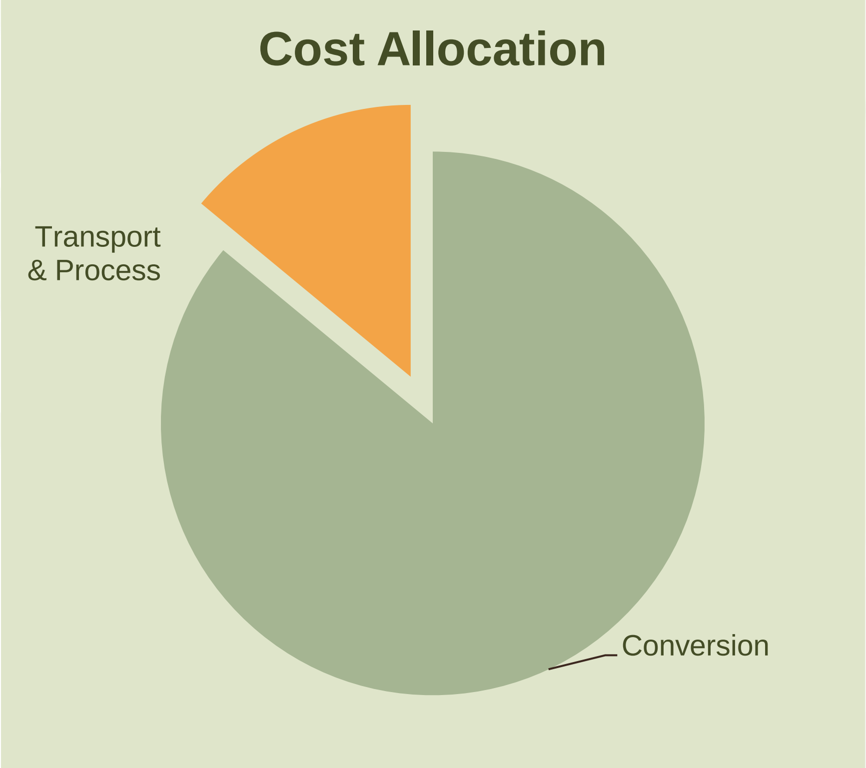
EXAMPLE MODEL OUTPUT : CASHFLOWS





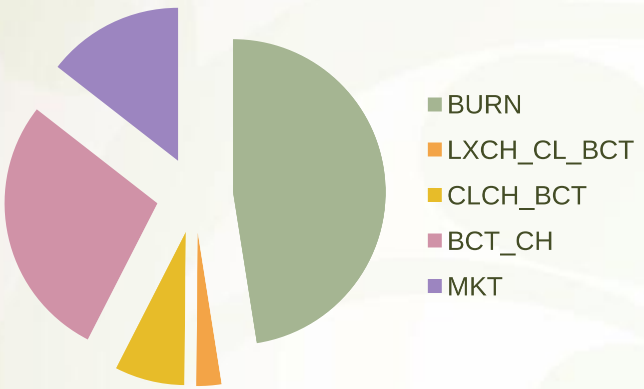
EXAMPLE MODEL OUTPUT : COST SUMMARY



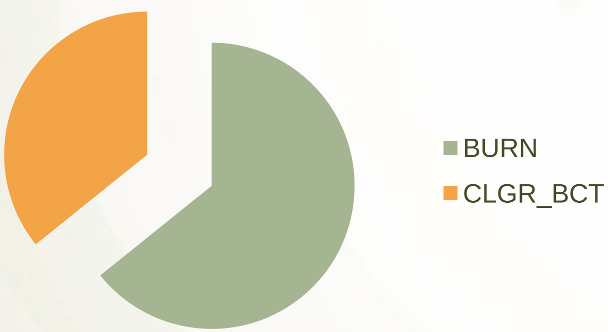


EXAMPLE MODEL OUTPUTS : PATHWAY SELECTION & REVENUES

Mass Flow Per Route

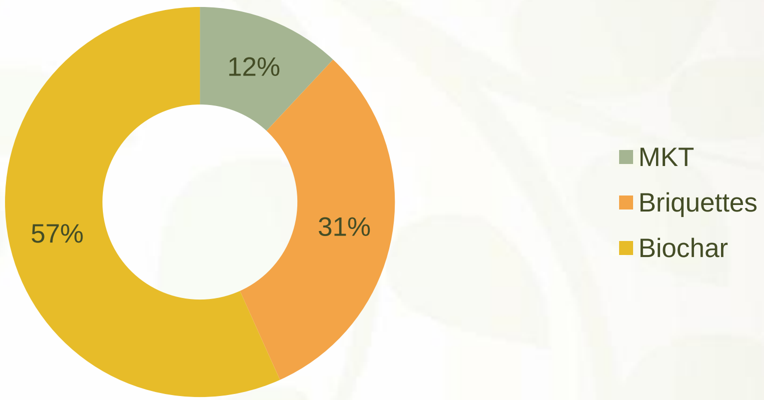


Tops

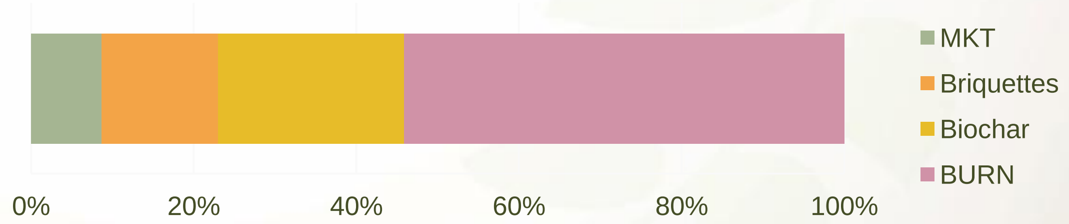


Branches

Total Revenue Summary



Final Product Mass Flow



EXAMPLE MODEL OUTPUTS : EXAMPLE SENSITIVITY ANALYSIS

BASELINE NPV= -6.9%

WHEN WOULD SYSTEM BECOME PROFITABLE?

- PLANT ASSUMPTIONS
- REVENUE ASSUMPTIONS
- CONVERSION
- PROCESSING
- TRANSPORTATION
- MATERIAL HANDLEING
- SCALE

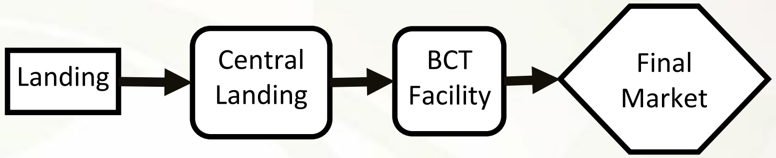
SCENERIO	CHANGE	NEW NPV
SCALE	30-50K TO 15-30K	-3.4%
PLANT COST	-66%	0.3%
CONV_COST	-17%	3.7%
BC_REV	22%	5.3%
BR_REV	25%	0.8%
NO_BURN	N/A	-3.5%

EXAMPLE: ECONOMIC SUMMARY

	PLANT CONFIGURATION					
PLANT SCALE	Biochar	Torrified Wood	Briquette	BR + BC	BR+TW	TWBR
6-15K BDT	SYSTEM NPV					
15-30K BDT						
30-50K BDT						

HIGHLIGHTS THE NEED FOR CONTINUED COLLABORATION

NEXT STEPS…



- Continue Model Development & Refinement
- Run W2W Group Scenarios
- Perform Sensitivity Analysis

CONTEXT: INVESTOR PERSPECTIVE

QUESTIONS?