2024 NORTH AMERICAN BIOCHAR CONFERENCE — USBI — CALIFORNIA, USA

forestconcepts™

Biochar Production Facility Design Process and Tools

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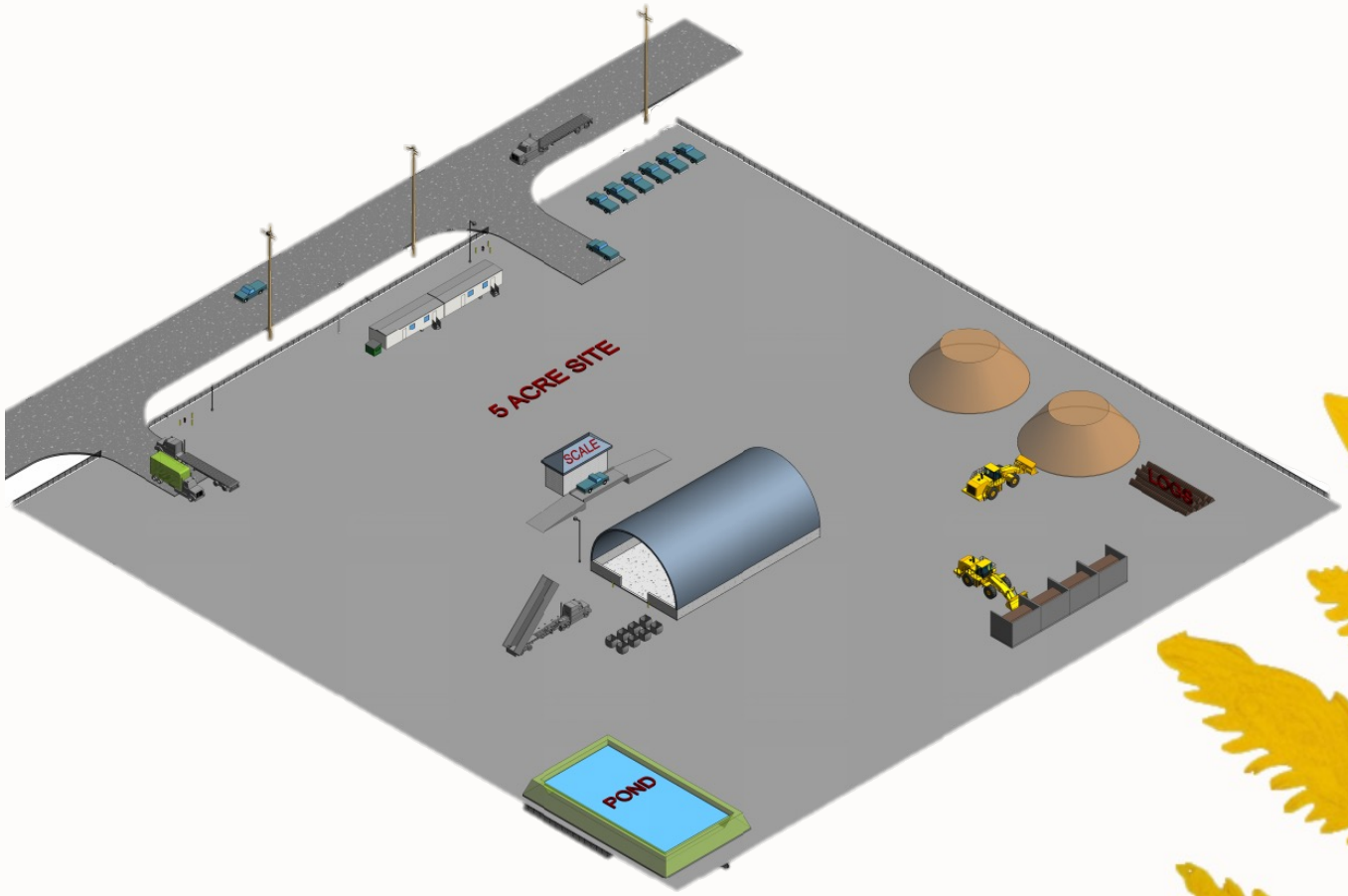
Cooperators:
US Dept of Energy
C6 Forest to Farm
By Design Engineering

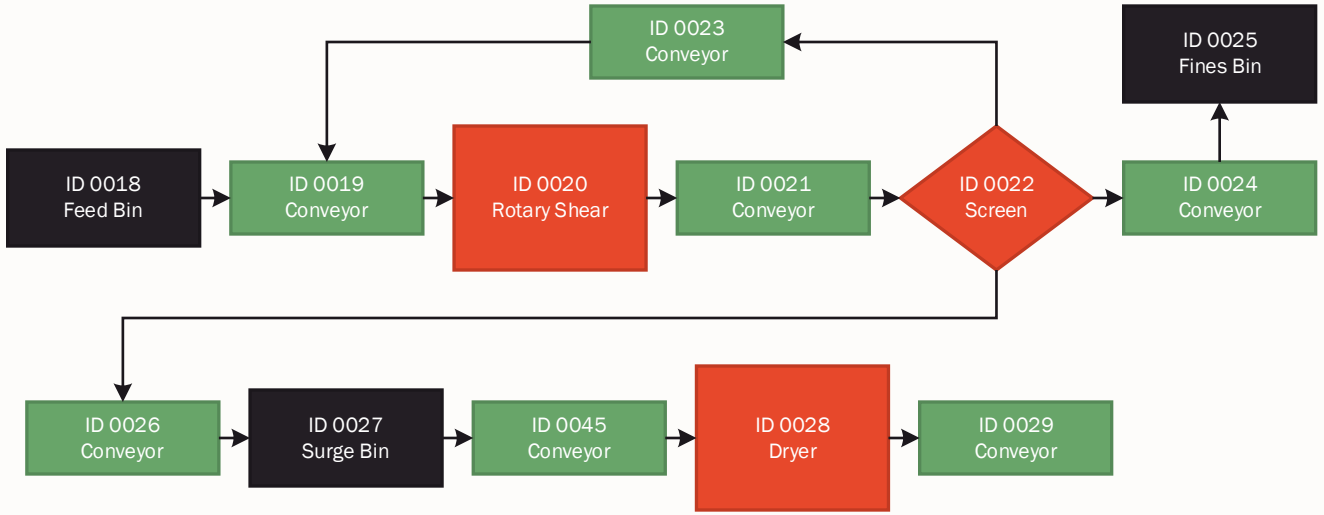
Agenda

- Background
- Appreciative Design Process
- SiPS TEA Software
- Wrap up



Background

- Biochar production facility
- C6 Forest to Farm siting facility in North-Central Washington
- Community scale (1 odt/hr equivalent)



Appreciative Design

- Appreciate beliefs, values, and needs of individuals and institutions (Soft Systems Methodology)
- Treat beliefs, values and other “externalities” just like hard constraints (Policy Analysis)
- Follow accepted design methodology (Suh’s Axiomatic Design)

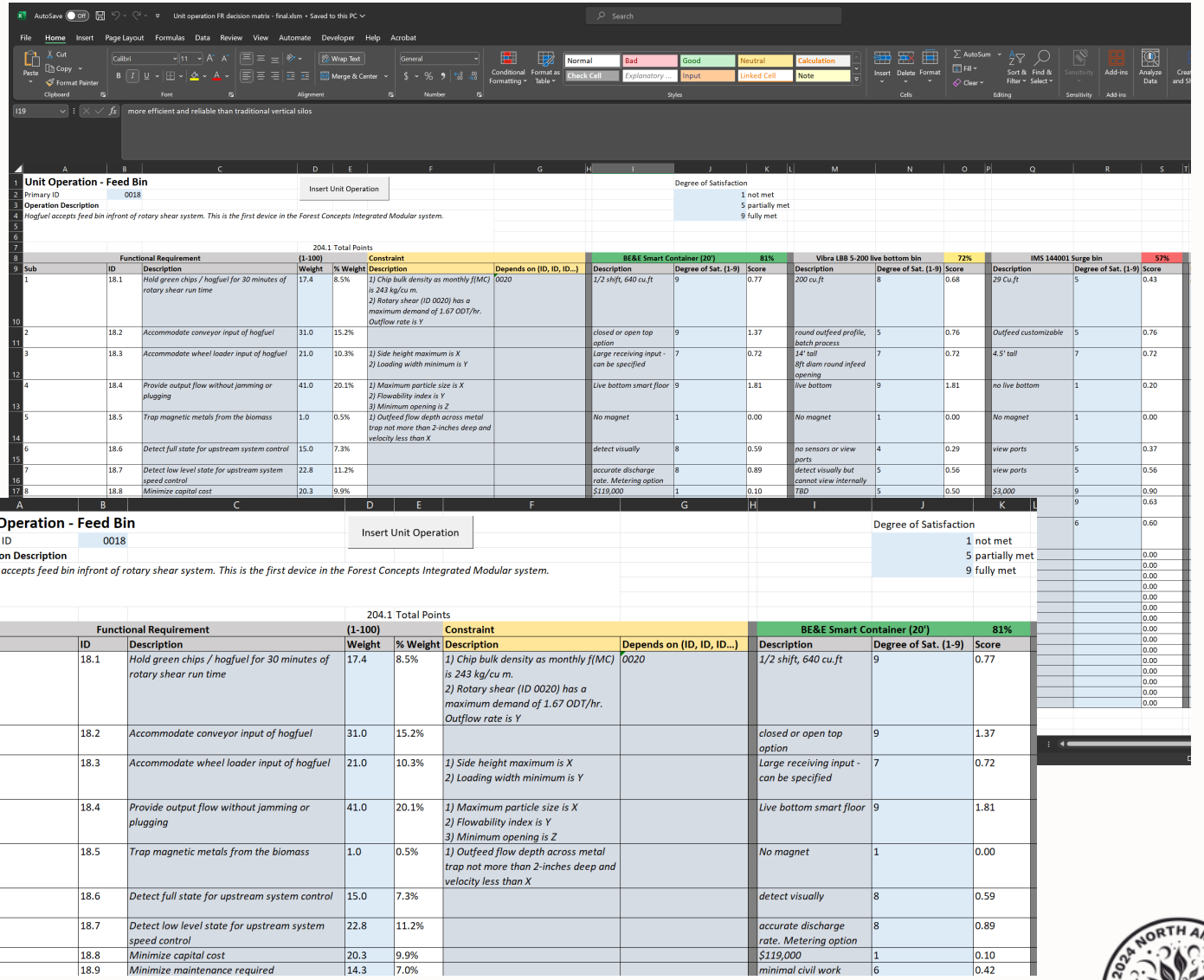
Appreciative Design (2)

Community Engagement

- Stakeholder identification and surveys
  - Weight stakeholder groups as needed
    - Regulatory
    - Owner
    - Operator
    - Neighbor

Axiomatic Design (Nam Suh)

- Three components
  1. Functional Requirements (FRs) (objectives)
  2. Constraints (Cs)
  3. Design Parameters (DPs) (solutions)
- Two Axioms
  1. Independence among Functional Requirements
  2. Best DPs have least information content



Unit Operation - Feed Bin — Insert Unit Operation

Primary ID: 0018

Operation Description

Hogfuel accepts feed bin infront of rotary shear system. This is the first device in the Forest Concepts Integrated Modular system.

Degree of Satisfaction: 1 not met; 5 partially met; 9 fully met

204.1 Total Points

	Functional Requirement			(1-100)		Constraint		BE&E Smart Container (20')		81%
Sub	ID	Description	Weight	% Weight	Description	Depends on (ID, ID, ID...)	Description	Degree of Sat. (1-9)	Score
1	18.1	*Hold green chips / hogfuel for 30 minutes of rotary shear run time*	17.4	8.5%	*1) Chip bulk density as monthly f(MC) is 243 kg/cu m. 2) Rotary shear (ID 0020) has a maximum demand of 1.67 ODT/hr. Outflow rate is Y*	*0020*	*1/2 shift, 640 cu.ft*	9	0.77
2	18.2	*Accommodate conveyor input of hogfuel*	31.0	15.2%			*closed or open top option*	9	1.37
3	18.3	*Accommodate wheel loader input of hogfuel*	21.0	10.3%	*1) Side height maximum is X 2) Loading width minimum is Y*		*Large receiving input - can be specified*	7	0.72
4	18.4	*Provide output flow without jamming or plugging*	41.0	20.1%	*1) Maximum particle size is X 2) Flowability index is Y 3) Minimum opening is Z*		*Live bottom smart floor*	9	1.81
5	18.5	*Trap magnetic metals from the biomass*	1.0	0.5%	*1) Outfeed flow depth across metal trap not more than 2-inches deep and velocity less than X*		*No magnet*	1	0.00
6	18.6	*Detect full state for upstream system control*	15.0	7.3%			*detect visually*	8	0.59
7	18.7	*Detect low level state for upstream system speed control*	22.8	11.2%			*accurate discharge rate. Metering option*	8	0.89
8	18.8	*Minimize capital cost*	20.3	9.9%			*$119,000*	1	0.10
9	18.9	*Minimize maintenance required*	14.3	7.0%			*minimal civil work*	6	0.42

Vibra LBB 5-200 live bottom bin		72%	IMS 144001 Surge bin		57%
Description	Degree of Sat. (1-9)	Score	Description	Degree of Sat. (1-9)	Score
200 cu.ft	8	0.68	*29 Cu.ft*	5	0.43
round outfeed profile, batch process	5	0.76	*Outfeed customizable*	5	0.76
14' tall 8ft diam round infeed opening	7	0.72	*4.5' tall*	7	0.72
live bottom	9	1.81	*no live bottom*	1	0.20
No magnet	1	0.00	*No magnet*	1	0.00
no sensors or view ports	4	0.29	*view ports*	5	0.37
detect visually but cannot view internally	5	0.56	*view ports*	5	0.56
TBD	5	0.50	*$3,000*	9	0.90
				9	0.63
				6	0.60

SiPS TEA Software - Overview

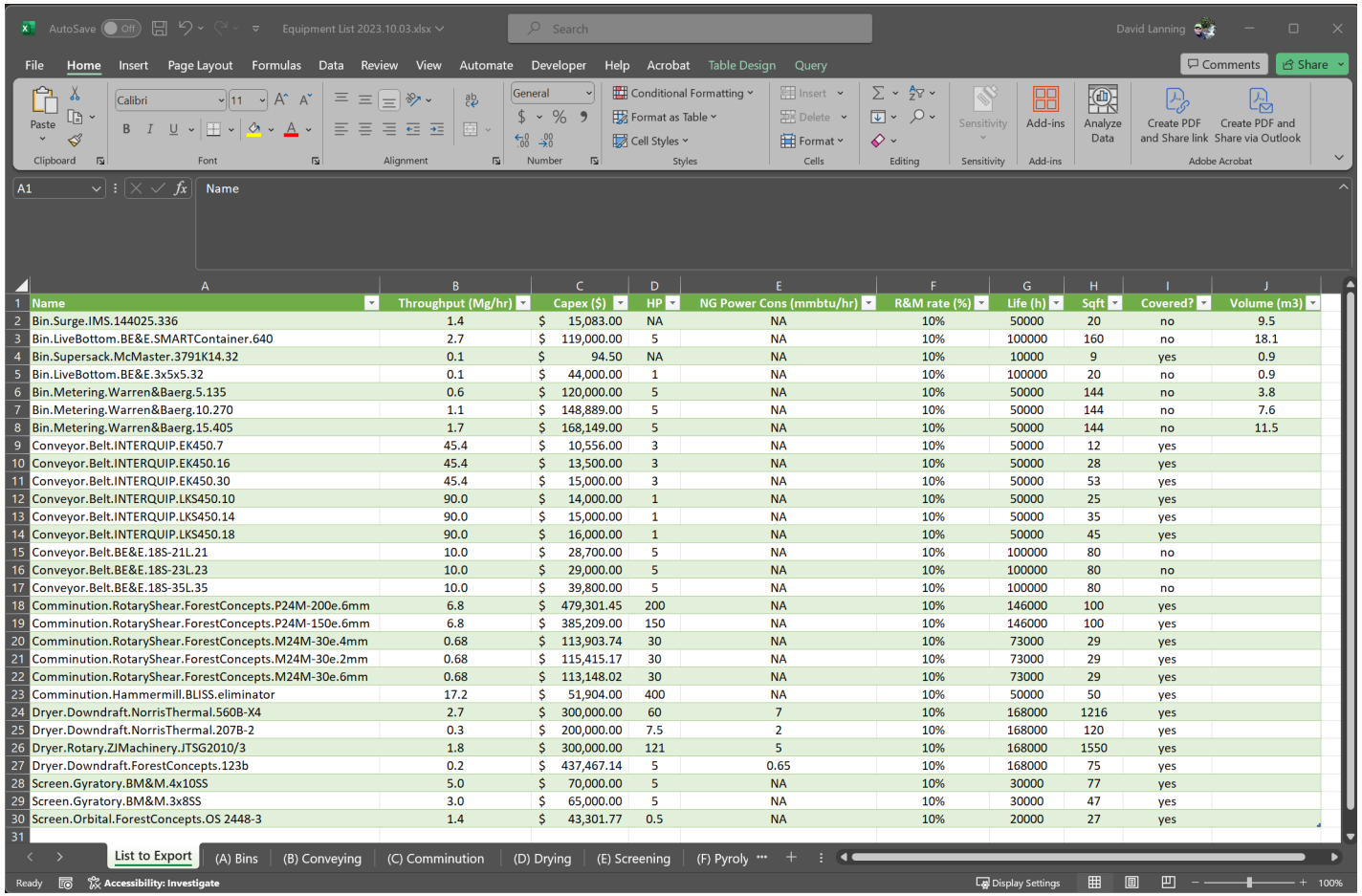
Simulation of Processing Systems for Techno-Economic Analysis

- Enables developers to quickly analyze design alternatives for community scale biomass processing centers
- Enable rapid creation of flexible TEA simulations
- Model multiple lines of biomass flow (split, combine, recirculate)
- Add / reorder equipment connections automatically
- Model non-steady state conditions and sensitivities
- Track biomass properties through the system
  - Size
  - Density
  - Moisture content

SiPS TEA – Equipment

Excel Based Equipment List

- Equipment Name
- Capacity (Mg/hr)
- CAPEX ($)
- Electrical Power (HP)
- Natural Gas Consumption (MMBtu/hr)
- R&M Rate (% of CAPEX)
- Life (h)
- Footprint (ft^2)
- Covered (Y/N)
- Volume (m^3)
- Expandable to other parameters

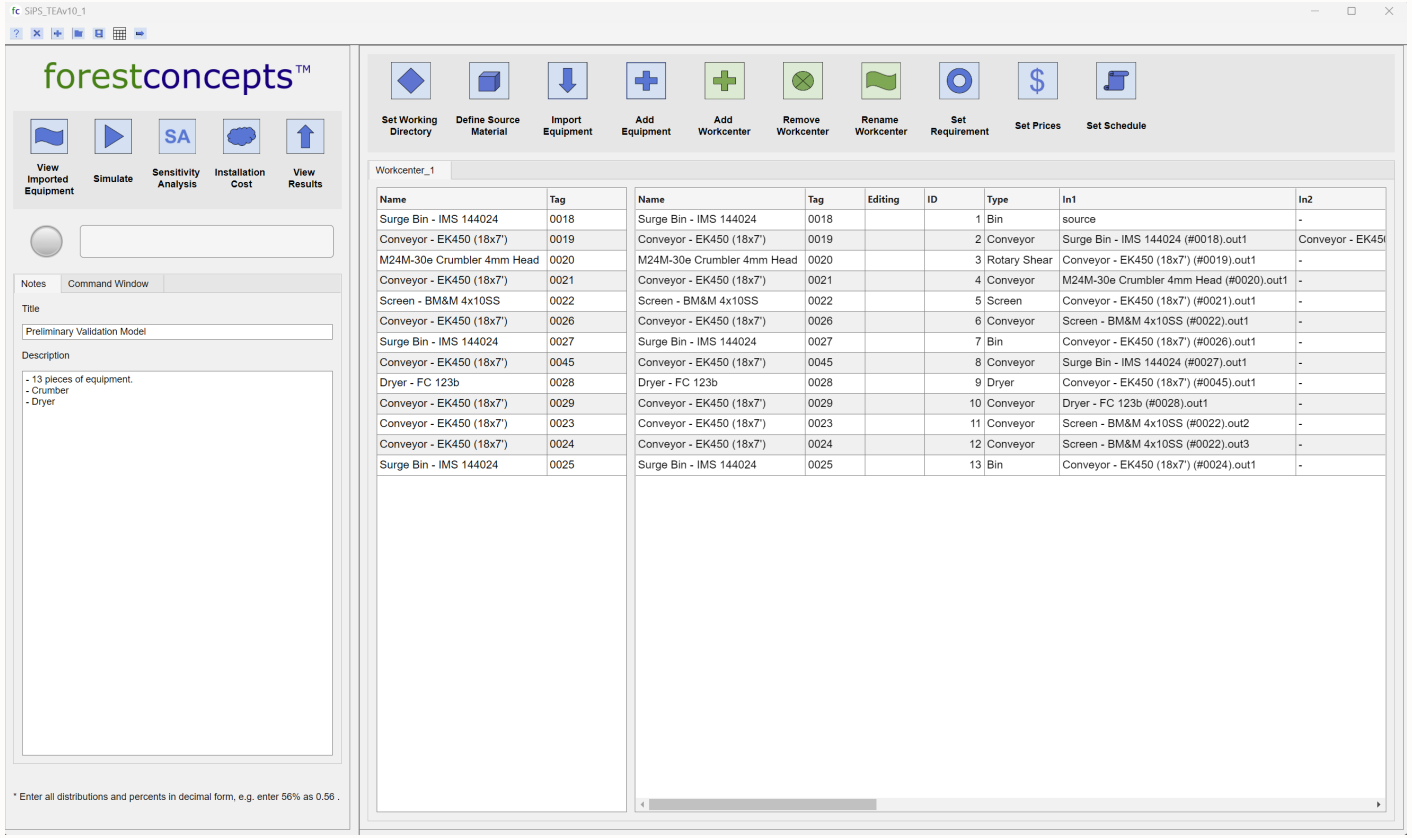


Name	Throughput (Mg/hr)	Capex ($)	HP	NG Power Cons (mmbtu/hr)	R&M rate (%)	Life (h)	Sqft	Covered?	Volume (m3)
Bin.Surge.IMS.144025.336	1.4	$ 15,083.00	NA	NA	10%	50000	20	no	9.5
Bin.LiveBottom.BE&E.SMARTContainer.640	2.7	$ 119,000.00	5	NA	10%	100000	160	no	18.1
Bin.Supersack.McMaster.3791K14.32	0.1	$ 94.50	NA	NA	10%	10000	9	yes	0.9
Bin.LiveBottom.BE&E.3x5x5.32	0.1	$ 44,000.00	1	NA	10%	100000	20	no	0.9
Bin.Metering.Warren&Baerg.5.135	0.6	$ 120,000.00	5	NA	10%	50000	144	no	3.8
Bin.Metering.Warren&Baerg.10.270	1.1	$ 148,889.00	5	NA	10%	50000	144	no	7.6
Bin.Metering.Warren&Baerg.15.405	1.7	$ 168,149.00	5	NA	10%	50000	144	no	11.5
Conveyor.Belt.INTERQUIP.EK450.7	45.4	$ 10,556.00	3	NA	10%	50000	12	yes	
Conveyor.Belt.INTERQUIP.EK450.16	45.4	$ 13,500.00	3	NA	10%	50000	28	yes	
Conveyor.Belt.INTERQUIP.EK450.30	45.4	$ 15,000.00	3	NA	10%	50000	53	yes	
Conveyor.Belt.INTERQUIP.LKS450.10	90.0	$ 14,000.00	1	NA	10%	50000	25	yes	
Conveyor.Belt.INTERQUIP.LKS450.14	90.0	$ 15,000.00	1	NA	10%	50000	35	yes	
Conveyor.Belt.INTERQUIP.LKS450.18	90.0	$ 16,000.00	1	NA	10%	50000	45	yes	
Conveyor.Belt.BE&E.18S-21L.21	10.0	$ 28,700.00	5	NA	10%	100000	80	no	
Conveyor.Belt.BE&E.18S-23L.23	10.0	$ 29,000.00	5	NA	10%	100000	80	no	
Conveyor.Belt.BE&E.18S-35L.35	10.0	$ 39,800.00	5	NA	10%	100000	80	no	
Comminution.RotaryShear.ForestConcepts.P24M-200e.6mm	6.8	$ 479,301.45	200	NA	10%	146000	100	yes	
Comminution.RotaryShear.ForestConcepts.P24M-150e.6mm	6.8	$ 385,209.00	150	NA	10%	146000	100	yes	
Comminution.RotaryShear.ForestConcepts.M24M-30e.4mm	0.68	$ 113,903.74	30	NA	10%	73000	29	yes	
Comminution.RotaryShear.ForestConcepts.M24M-30e.2mm	0.68	$ 115,415.17	30	NA	10%	73000	29	yes	
Comminution.RotaryShear.ForestConcepts.M24M-30e.6mm	0.68	$ 113,148.02	30	NA	10%	73000	29	yes	
Comminution.Hammermill.BLISS.eliminator	17.2	$ 51,904.00	400	NA	10%	50000	50	yes	
Dryer.Downdraft.NorrisThermal.560B-X4	2.7	$ 300,000.00	60	7	10%	168000	1216	yes	
Dryer.Downdraft.NorrisThermal.207B-2	0.3	$ 200,000.00	7.5	2	10%	168000	120	yes	
Dryer.Rotary.ZJMachinery.JTSG2010/3	1.8	$ 300,000.00	121	5	10%	168000	1550	yes	
Dryer.Downdraft.ForestConcepts.123b	0.2	$ 437,467.14	5	0.65	10%	168000	75	yes	
Screen.Gyratory.BM&M.4x10SS	5.0	$ 70,000.00	5	NA	10%	30000	77	yes	
Screen.Gyratory.BM&M.3x8SS	3.0	$ 65,000.00	5	NA	10%	30000	47	yes	
Screen.Orbital.ForestConcepts.OS 2448-3	1.4	$ 43,301.77	0.5	NA	10%	20000	27	yes	

Equipment list currently includes 167 pieces of equipment from 32 manufacturers

SiPS TEA - Main

- Import and link equipment
  - Multiple work centers with different operating schedules possible
- Set throughput requirements
- Set standard prices
  - Electricity, natural gas, diesel, raw material, etc
- Set facility installation cost, if including

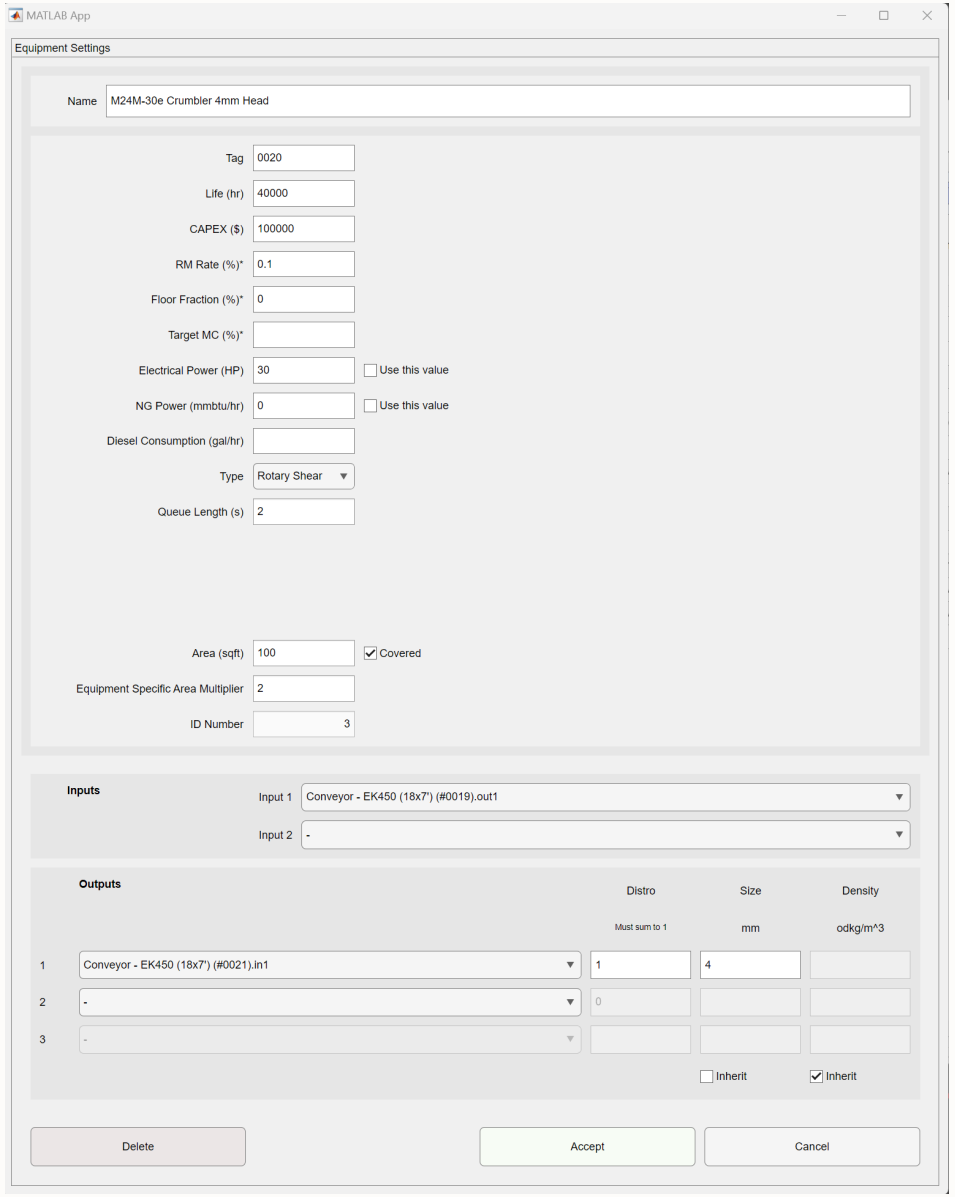


Name	Tag
Surge Bin - IMS 144024	0018
Conveyor - EK450 (18x7')	0019
M24M-30e Crumbler 4mm Head	0020
Conveyor - EK450 (18x7')	0021
Screen - BM&M 4x10SS	0022
Conveyor - EK450 (18x7')	0026
Surge Bin - IMS 144024	0027
Conveyor - EK450 (18x7')	0045
Dryer - FC 123b	0028
Conveyor - EK450 (18x7')	0029
Conveyor - EK450 (18x7')	0023
Conveyor - EK450 (18x7')	0024
Surge Bin - IMS 144024	0025

Name	Tag	Editing	ID	Type	In1	In2
Surge Bin - IMS 144024	0018		1	Bin	source	-
Conveyor - EK450 (18x7')	0019		2	Conveyor	Surge Bin - IMS 144024 (#0018).out1	Conveyor - EK45
M24M-30e Crumbler 4mm Head	0020		3	Rotary Shear	Conveyor - EK450 (18x7') (#0019).out1	-
Conveyor - EK450 (18x7')	0021		4	Conveyor	M24M-30e Crumbler 4mm Head (#0020).out1	-
Screen - BM&M 4x10SS	0022		5	Screen	Conveyor - EK450 (18x7') (#0021).out1	-
Conveyor - EK450 (18x7')	0026		6	Conveyor	Screen - BM&M 4x10SS (#0022).out1	-
Surge Bin - IMS 144024	0027		7	Bin	Conveyor - EK450 (18x7') (#0026).out1	-
Conveyor - EK450 (18x7')	0045		8	Conveyor	Surge Bin - IMS 144024 (#0027).out1	-
Dryer - FC 123b	0028		9	Dryer	Conveyor - EK450 (18x7') (#0045).out1	-
Conveyor - EK450 (18x7')	0029		10	Conveyor	Dryer - FC 123b (#0028).out1	-
Conveyor - EK450 (18x7')	0023		11	Conveyor	Screen - BM&M 4x10SS (#0022).out2	-
Conveyor - EK450 (18x7')	0024		12	Conveyor	Screen - BM&M 4x10SS (#0022).out3	-
Surge Bin - IMS 144024	0025		13	Bin	Conveyor - EK450 (18x7') (#0024).out1	-

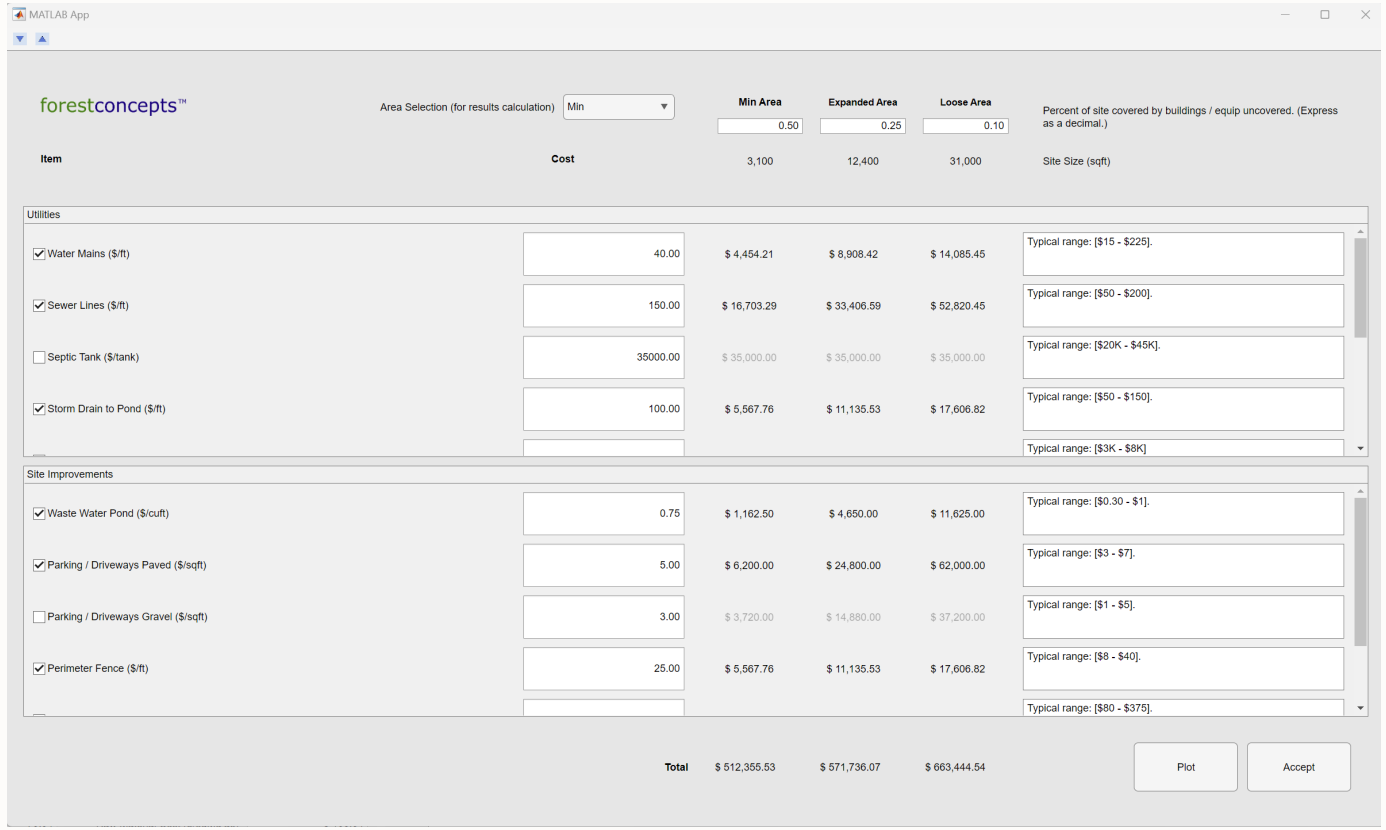
SiPS TEA – Equipment Details

- Tag/ID
- Life
- CAPEX
- Repair and Maintenance rate
- Electrical Power Consumption
  - User specified or calculated based on particle size change, material type, and size reduction type
- Natural Gas Consumption
  - User specified or calculated based on moisture change, particle size, material type
- Footprint
- Connections to other equipment



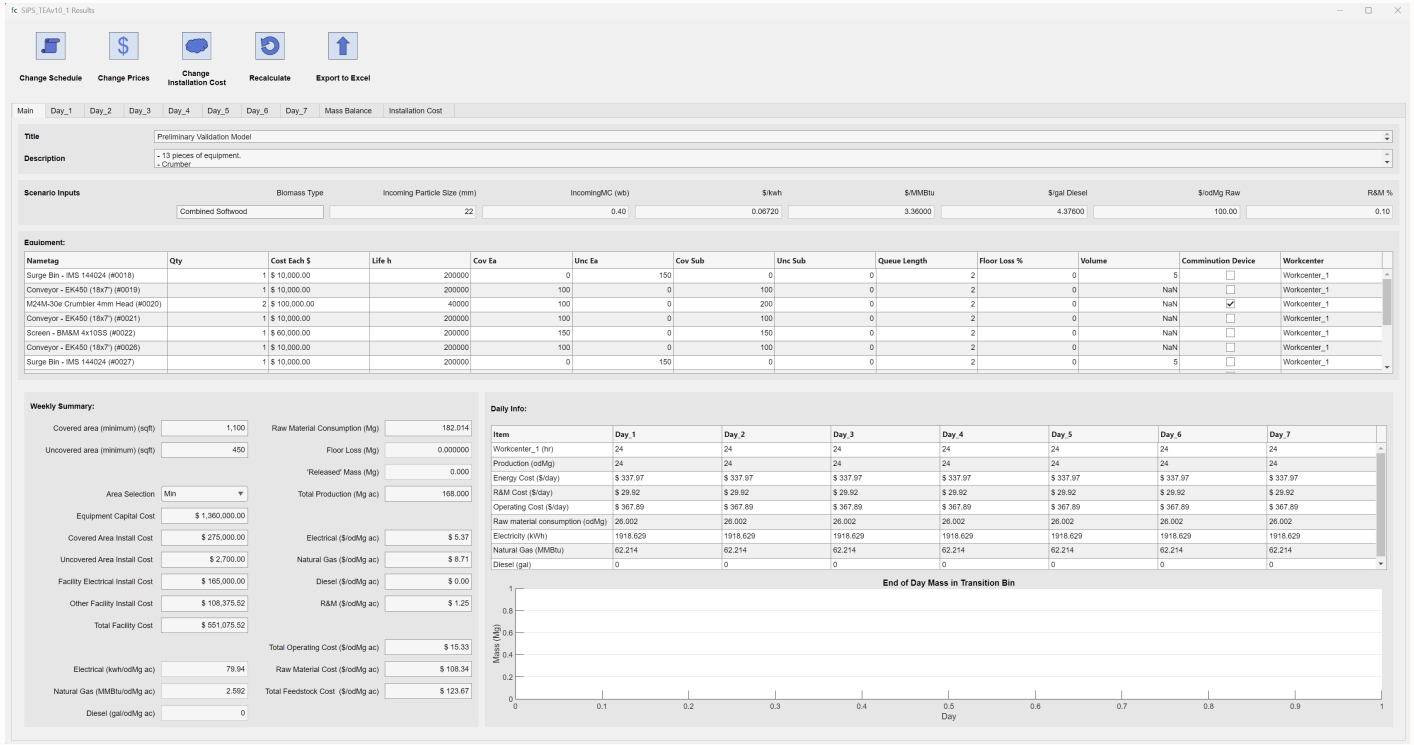
SiPS TEA – Facility Installation Cost

- Site upgrade costs
  - Electrical lines
  - Sewer lines
  - Fencing
  - Lighting
  - Paving
  - Catch basin
  - And more
- Building size multipliers of equipment footprint
- Site size based on building, uncovered area, catch basin ratios
- General costs ranges for each category
- Select only desired categories for inclusion



SiPS TEA - Results

- Mass and energy balances for each week
- Daily (with work center scheduling) mass and energy balances
- Calculation of quantities of equipment pieces based on inputs
- Total CAPEX
- Total OPEX
- Export to MS Excel

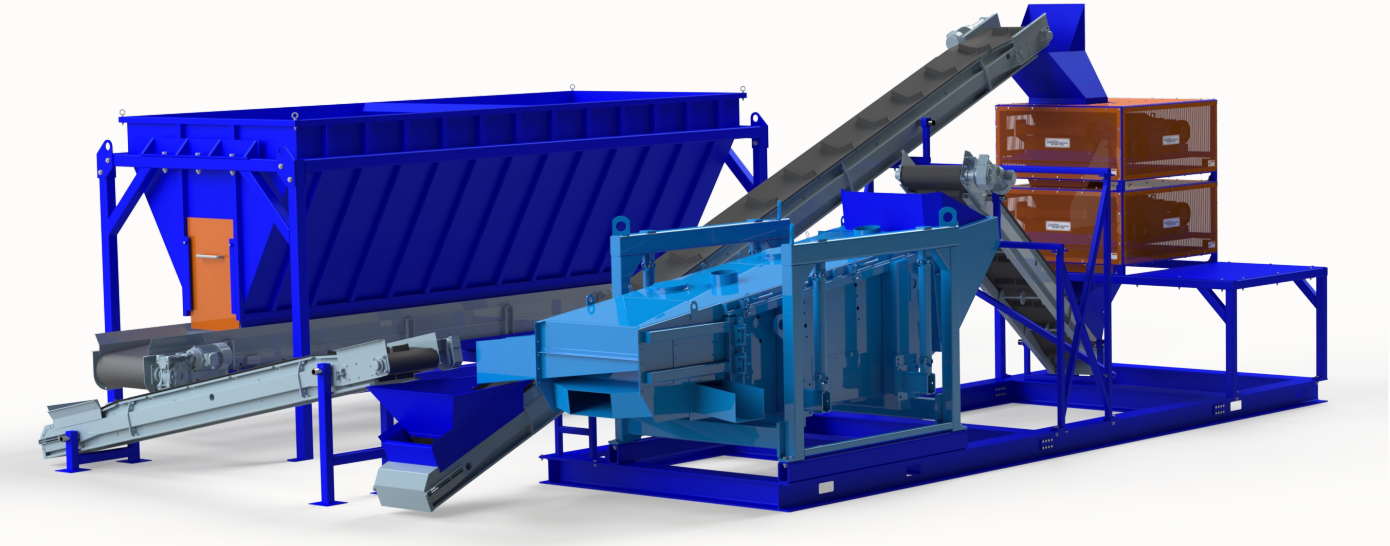


Results

- Appreciative design reduces project failures and “yeah, but” delays
- Project planners can have good mass and energy balances early in the planning phase to prevent “gotchas”
- TEA parameter adjustments are relatively easy
- Result is lower technical, operational, and financial risk

Results (2)

- Modular preprocessing equipment to “plug and play” will speed facility installation and planning



Where We Go From Here

- Work with additional developers to continue process validation
- Model additional work centers beyond feedstock preprocessing (conversion, etc)
- Add equipment and manufacturers to the equipment list
- Place Feed/Comminution module with partner for validation testing

Acknowledgements

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Thank You!

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