2024 NORTH AMERICAN BIOCHAR CONFERENCE — USBI — CALIFORNIA, USA

forestconcepts™

# Biochar Production Facility Design Process and Tools

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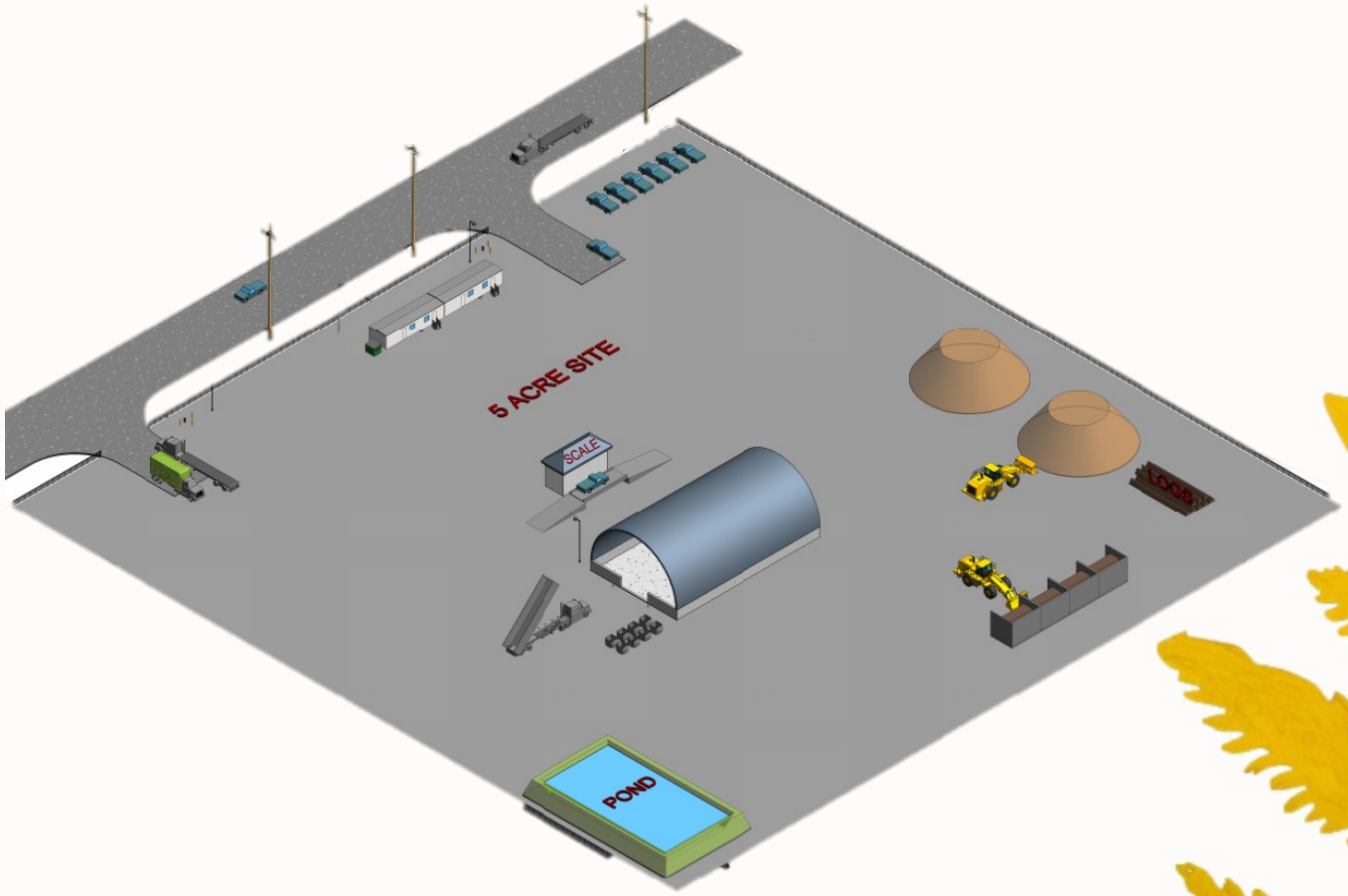
Cooperators:
US Dept of Energy
C6 Forest to Farm
By Design Engineering

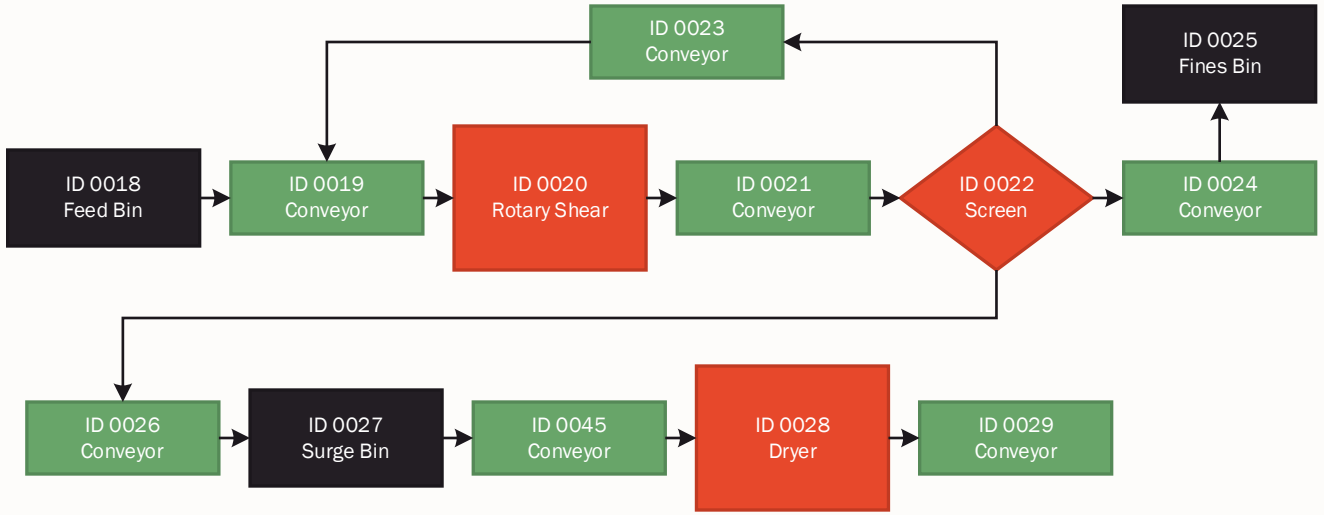
# Agenda

- 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)

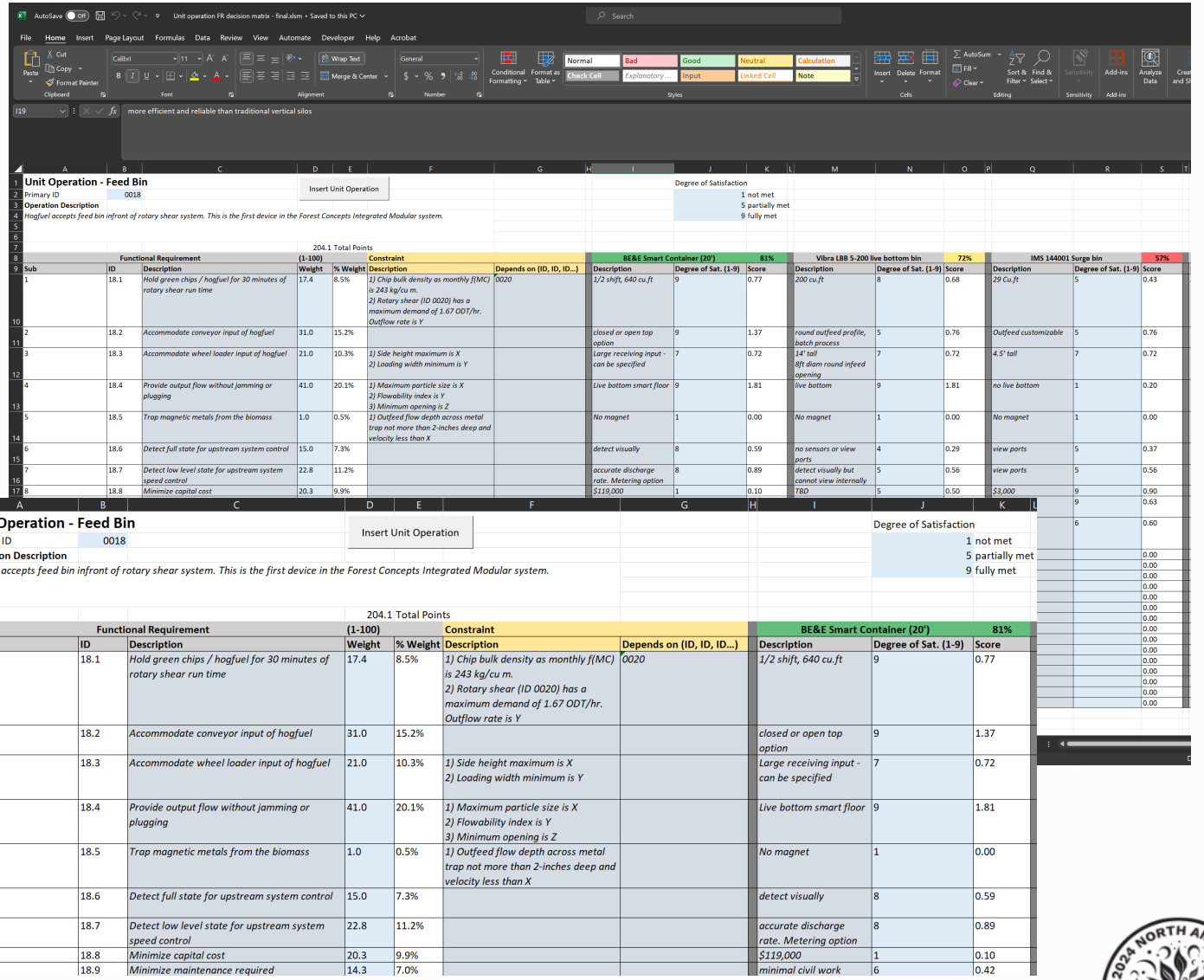
# Appreciative Design (2)

## 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 | | | | | Constraint | | BE&E Smart Container (20') 81% | | | Vibra LBB 5-200 live bottom bin 72% | | | IMS 144001 Surge bin 57% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sub | ID | Description | Weight | % Weight | Description | Depends on (ID, ID, ID...) | Description | Degree of Sat. (1-9) | Score | Description | Degree of Sat. (1-9) | Score | 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 | *200 cu.ft* | 8 | 0.68 | *29 Cu.ft* | 5 | 0.43 |
| 2 | 18.2 | *Accommodate conveyor input of hogfuel* | 31.0 | 15.2% | | | *closed or open top option* | 9 | 1.37 | *round outfeed profile, batch process* | 5 | 0.76 | *Outfeed customizable* | 5 | 0.76 |
| 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 | *14' tall 8ft diam round infeed opening* | 7 | 0.72 | *4.5' tall* | 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 | *live bottom* | 9 | 1.81 | *no live bottom* | 1 | 0.20 |
| 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 | *No magnet* | 1 | 0.00 | *No magnet* | 1 | 0.00 |
| 6 | 18.6 | *Detect full state for upstream system control* | 15.0 | 7.3% | | | *detect visually* | 8 | 0.59 | *no sensors or view ports* | 4 | 0.29 | *view ports* | 5 | 0.37 |
| 7 | 18.7 | *Detect low level state for upstream system speed control* | 22.8 | 11.2% | | | *accurate discharge rate. Metering option* | 8 | 0.89 | *detect visually but cannot view internally* | 5 | 0.56 | *view ports* | 5 | 0.56 |
| 8 | 18.8 | *Minimize capital cost* | 20.3 | 9.9% | | | *$119,000* | 1 | 0.10 | *TBD* | 5 | 0.50 | *$3,000* | 9 | 0.90 |
| 9 | 18.9 | *Minimize maintenance required* | 14.3 | 7.0% | | | *minimal civil work* | 6 | 0.42 | | | | | 9 | 0.63 |
| | | | | | | | | | | | | | | 6 | 0.60 |
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# SiPS TEA Software - Overview

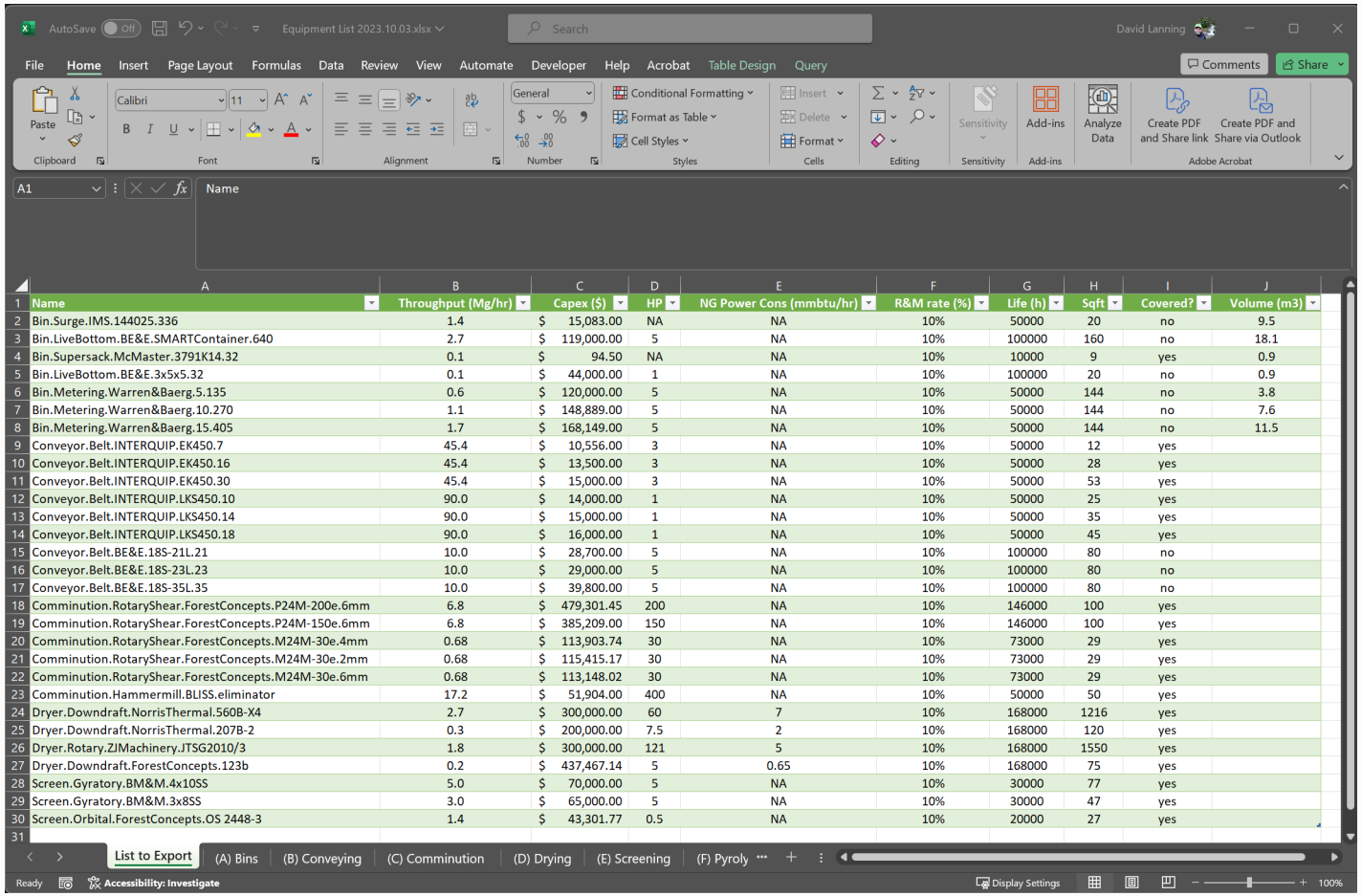
## Simulation of Processing Systems for Techno-Economic Analysis

- 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

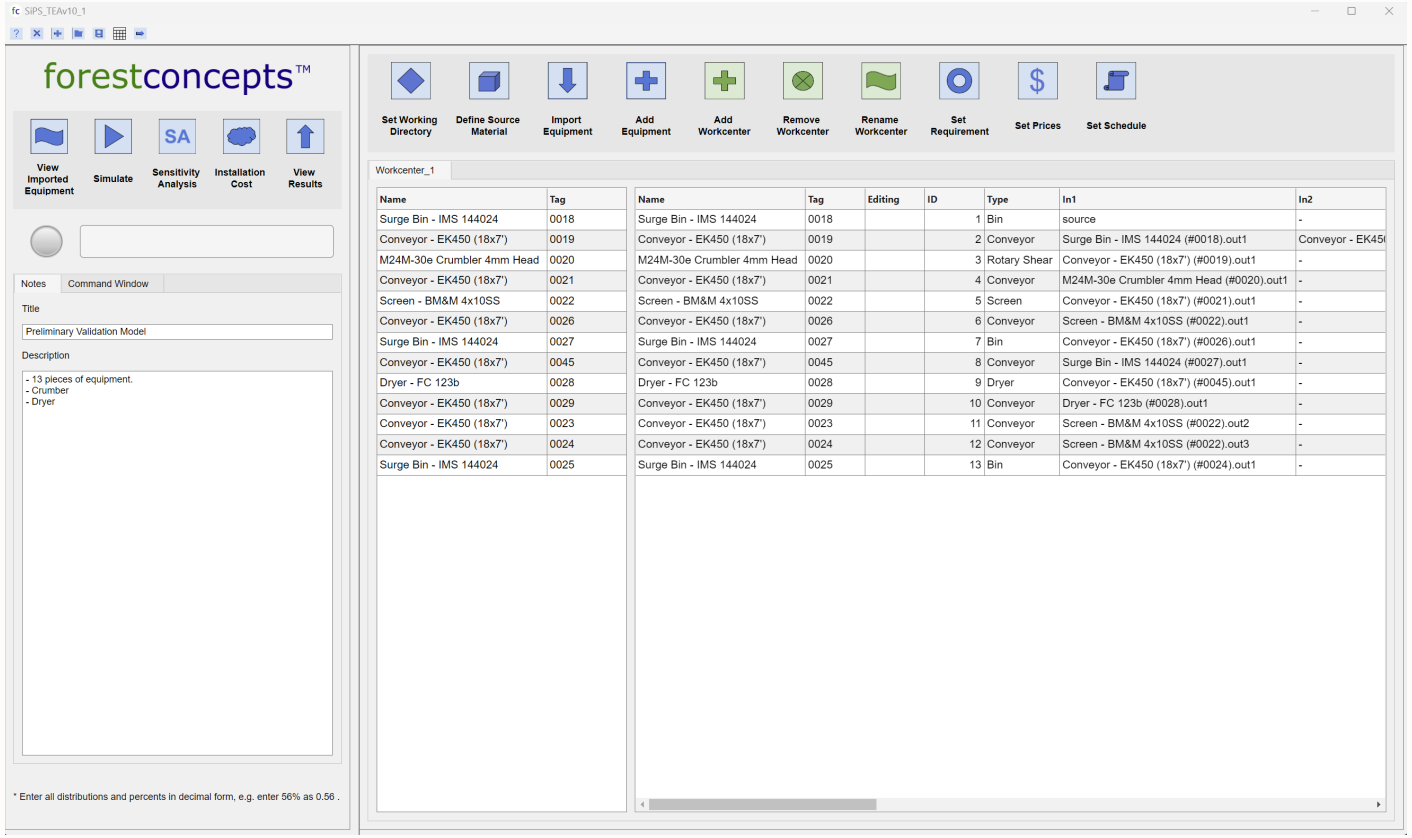


| Name | Throughput (Mg/hr) | Capex ($) | HP | NG Power Cons (mmbtu/hr) | R&M rate (%) | Life (h) | Sqft | Covered? | Volume (m3) |
|---|---|---|---|---|---|---|---|---|---|
| Bin.Surge.IMS.144025.336 | 1.4 | $ 15,083.00 | NA | NA | 10% | 50000 | 20 | no | 9.5 |
| Bin.LiveBottom.BE&E.SMARTContainer.640 | 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

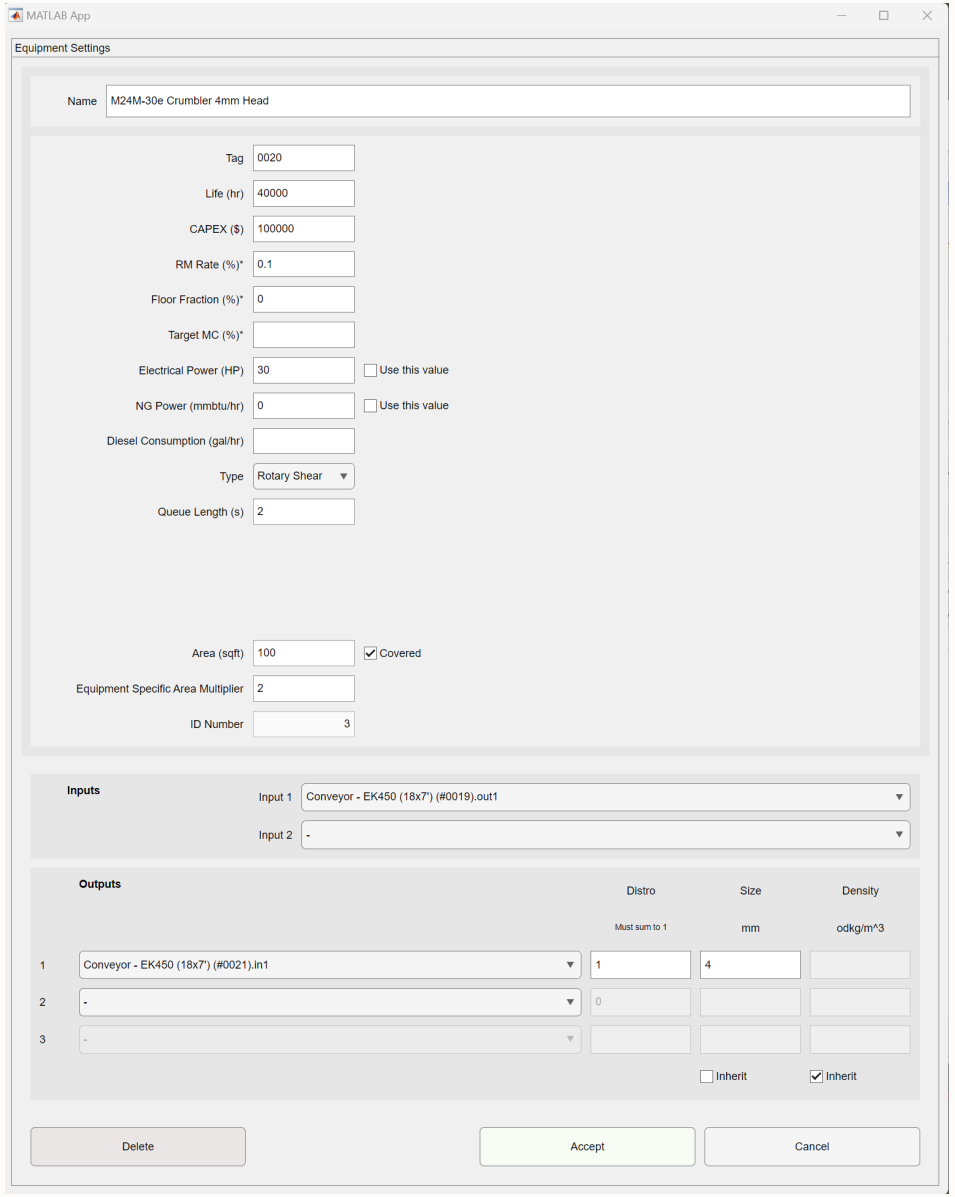



| Name | Tag |
|---|---|
| Surge Bin - IMS 144024 | 0018 |
| Conveyor - EK450 (18x7') | 0019 |
| M24M-30e Crumbler 4mm Head | 0020 |
| Conveyor - EK450 (18x7') | 0021 |
| Screen - BM&M 4x10SS | 0022 |
| Conveyor - EK450 (18x7') | 0026 |
| Surge Bin - IMS 144024 | 0027 |
| Conveyor - EK450 (18x7') | 0045 |
| 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 | - |

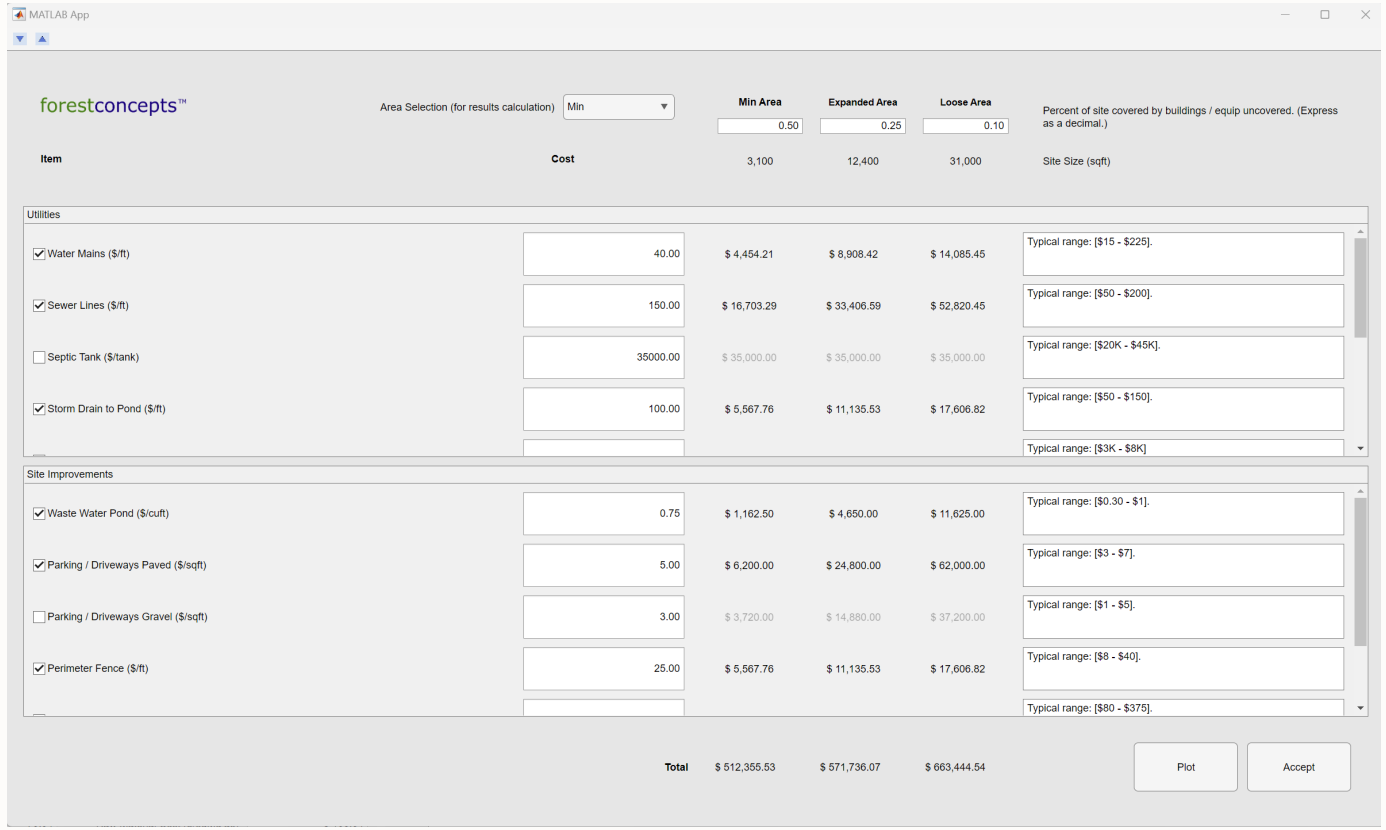
# SiPS TEA – Equipment Details

- 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



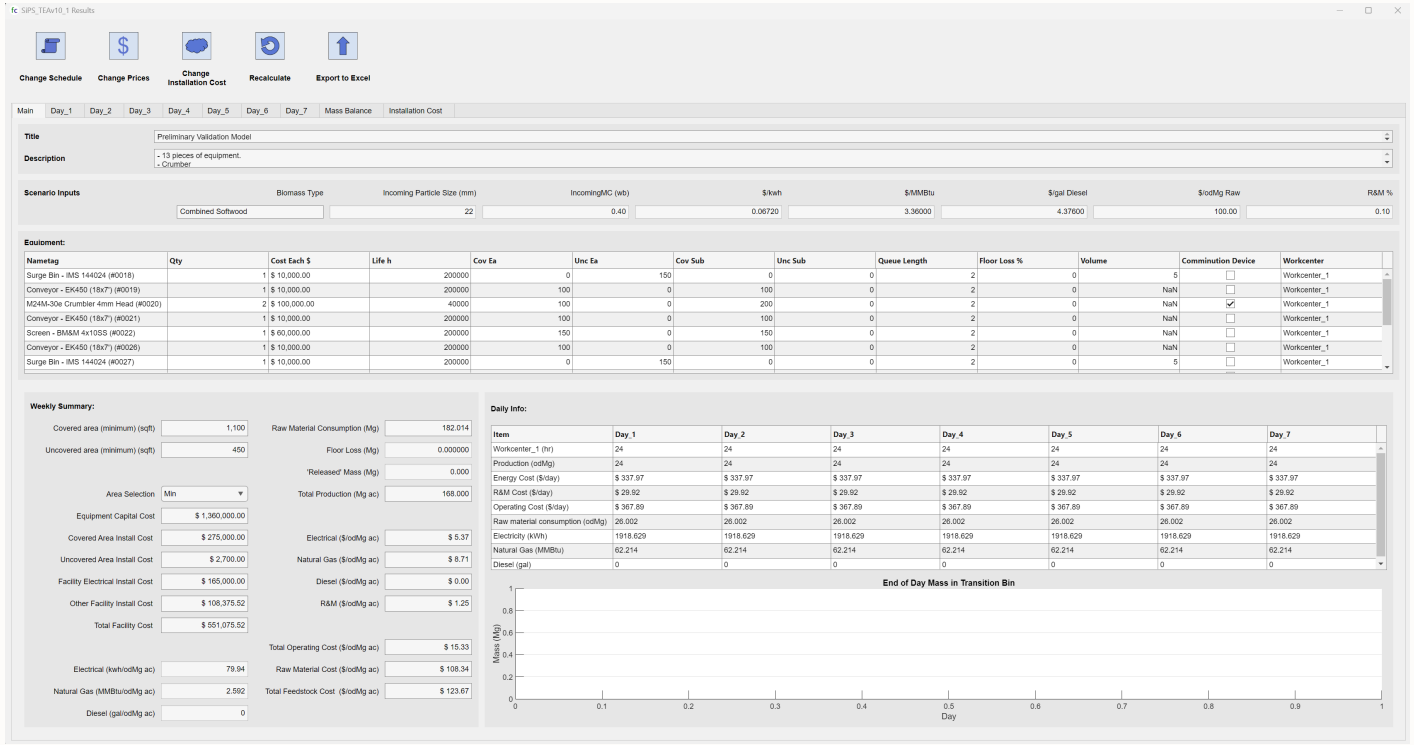
# SiPS TEA – Facility Installation Cost

- 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

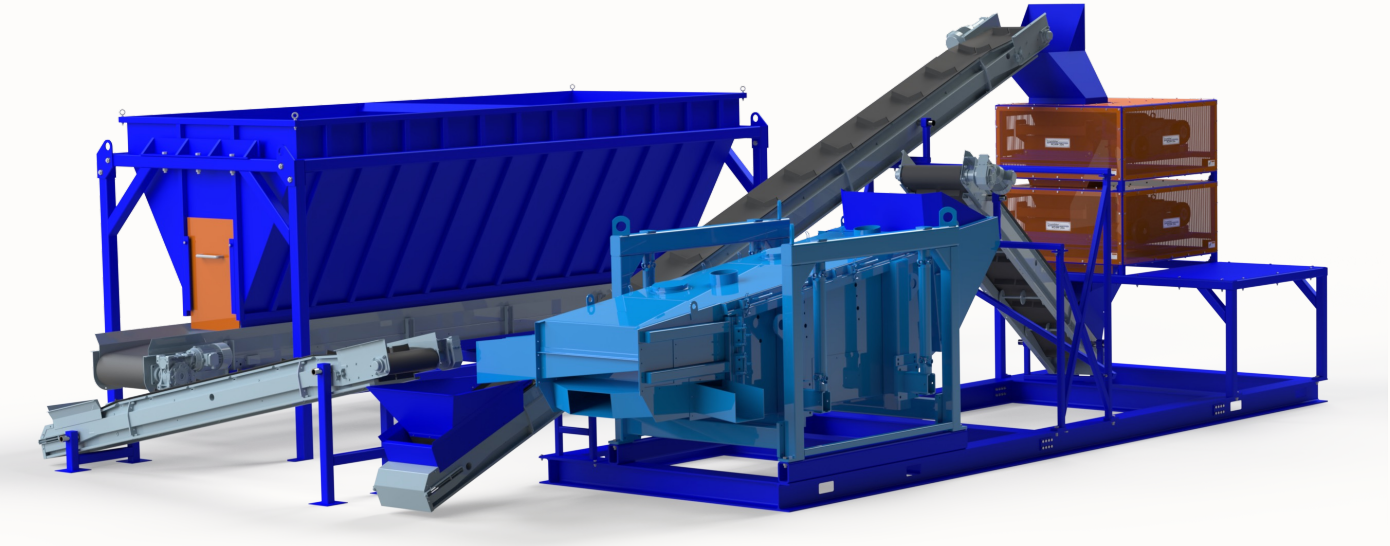


# Results

- 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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