

# Humboldt County Biomass Utilization Analysis



REDWOOD COAST  
**Energy**Authority



ENGINEERING 492

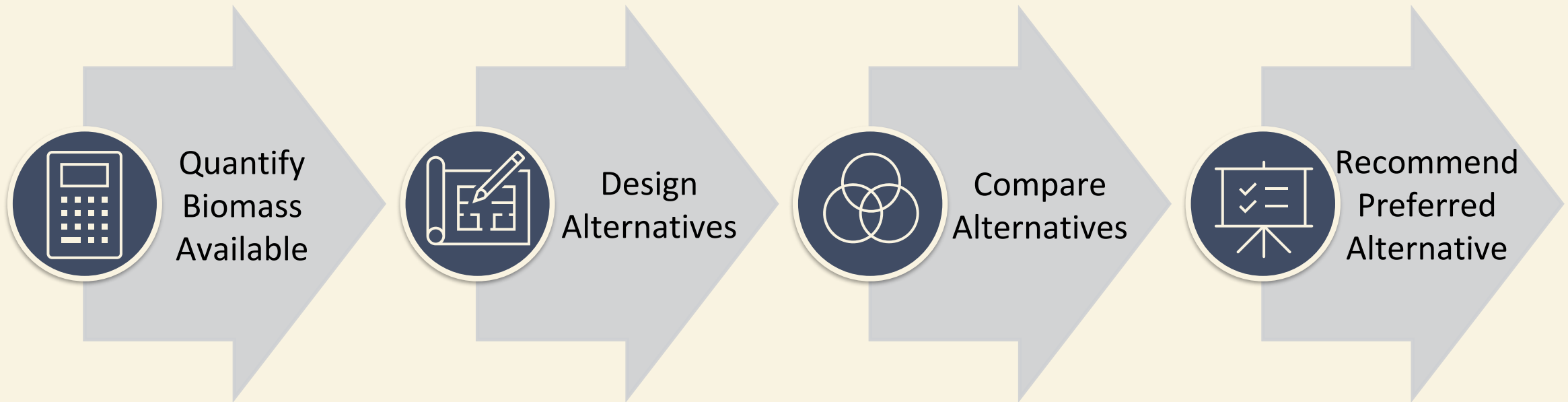
SPRING 2020

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# Project Scope

Project Overview  
Initial Alternatives  
Decision Analysis

Scope  
Constraints  
Criteria



# Constraints

- **Biomass** – Must use at least 80% by mass of the woody biomass material that is going to the power plants annually.
- **Local** - Geographical location must be in Humboldt County due to the transportation costs and emissions.
- **Regulations** – Must abide by all local, state, and federal regulations and standards.

# Criteria

Project Overview  
Initial Alternatives  
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Scope  
Constraints  
Criteria

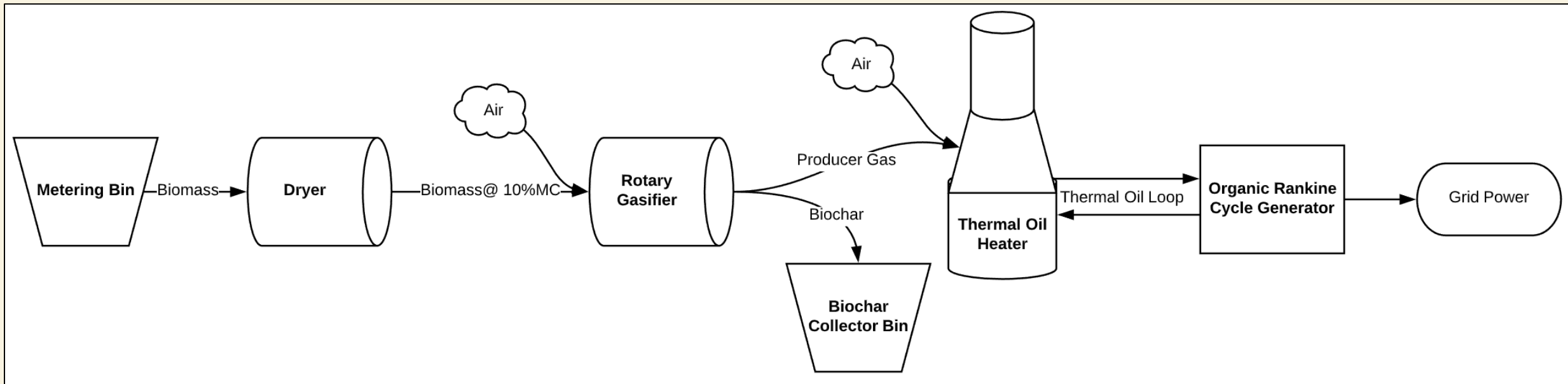
| Criteria                    | Descriptor of Quantification  |
|-----------------------------|---|
| <b><i>Social</i></b>        |   |
| Community Satisfaction      | Number of frequently asked questions addressed  |
| Aesthetics                  | Height of facility  |
|                             | Population impacted   |
| <b><i>Economic</i></b>      |   |
| Cost                        | Minimize payback period to offset capital and O&M costs (Years)                                       |
| Local Employment            | Number of jobs supported by implementation of alternative   |
| Ease of Implementation      | Number of permits required to execute   |
| <b><i>Environmental</i></b> |   |
| Air Quality                 | Minimize GHG emissions and local air quality impacts (tons/yr)  |
|                             | Minimize mass of criteria pollutants discharged (tons/yr)   |
| Carbon Sequestration        | Maximize sequestration of carbon through proposed alternative (tons/yr sequestered CO <sub>2</sub> e) |
| Excess Biomass              | Maximize percentage of available biomass used   |

# Gasification

Project Overview  
Initial Alternatives  
Decision Analysis

Gasification  
Biochar  
Compost/WWTP  
OSB

- 9 Units, 27 MW Power Generation
- Substantial Carbon Sequestration
- Significant Reduction in Criteria Pollutant Emissions, Increase in GHG
- High Cost



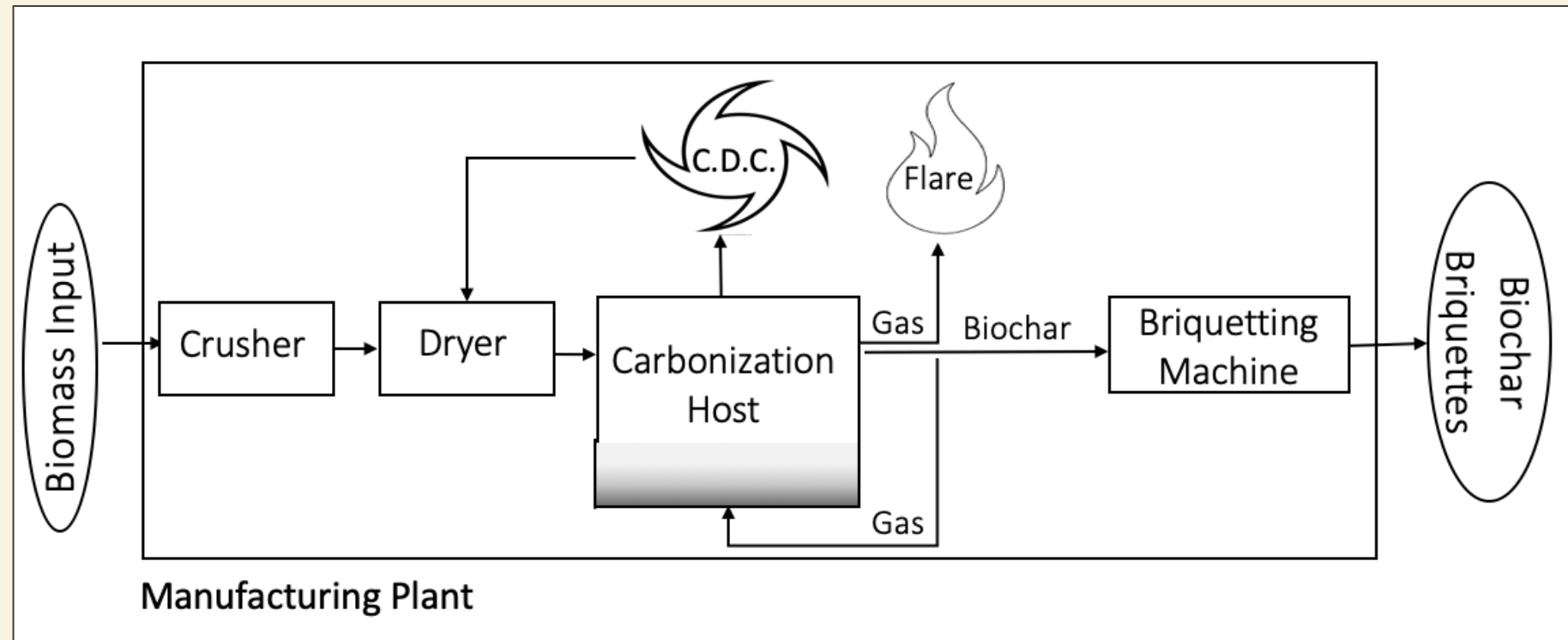
# Biochar Production

Project Overview  
Initial Alternatives  
Decision Analysis

Gasification  
Biochar  
Compost/WWTP  
OSB

## Biomass to Biochar Conversion

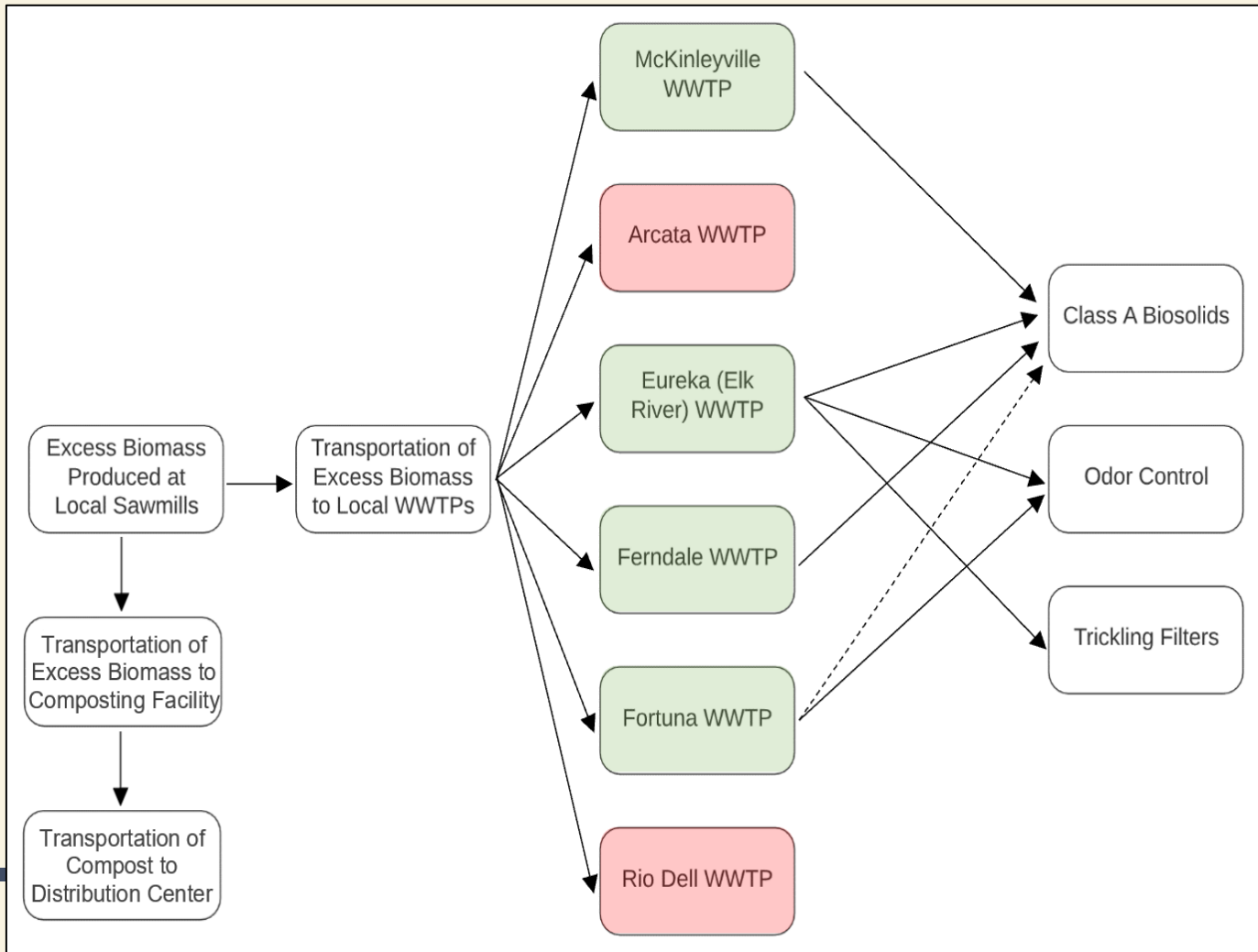
- Lowered Emissions
  - GHG Reduced by 60%
  - Criteria Pollutants Reduced by Over 99%
- High Carbon Sequestration Potential



# Compost with Local WWTP Utilization

Project Overview  
Initial Alternatives  
Decision Analysis

Gasification  
Biochar  
Compost/WWTP  
OSB



- Utilization of excess biomass at local WWTPs
  - Production of Class A Biosolids
  - Odor Control Media
  - Trickling Filter Media
- Trickling filter and odor control media replaced every 4 months then composted
- Excess is composted in windrow piles

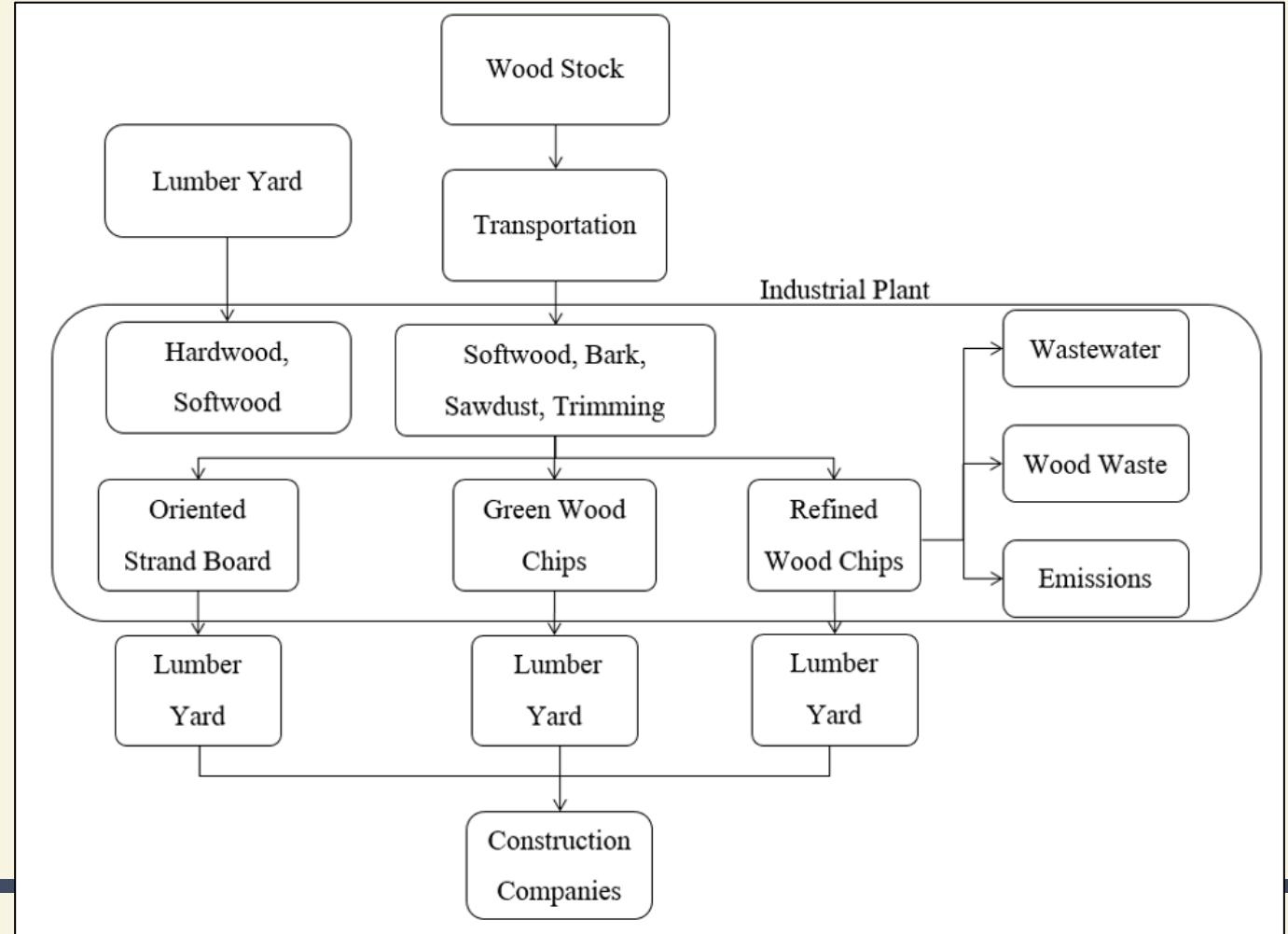
# OSB: Oriented Strand Board Production

Project Overview  
Initial Alternatives  
Decision Analysis

Gasification  
Biochar  
Compost/WWTP  
OSB

Biomass used to produce OSB

- High Employment
  - 169 employees
- Carbon Sequestration
  - Net: ~ 450,000 tons CO<sub>2</sub>e
- High Capital Cost
  - 17.3 years payback
- 80 acres of land required





# Criteria Scoring

Project Overview  
Initial Alternatives  
Decision Analysis

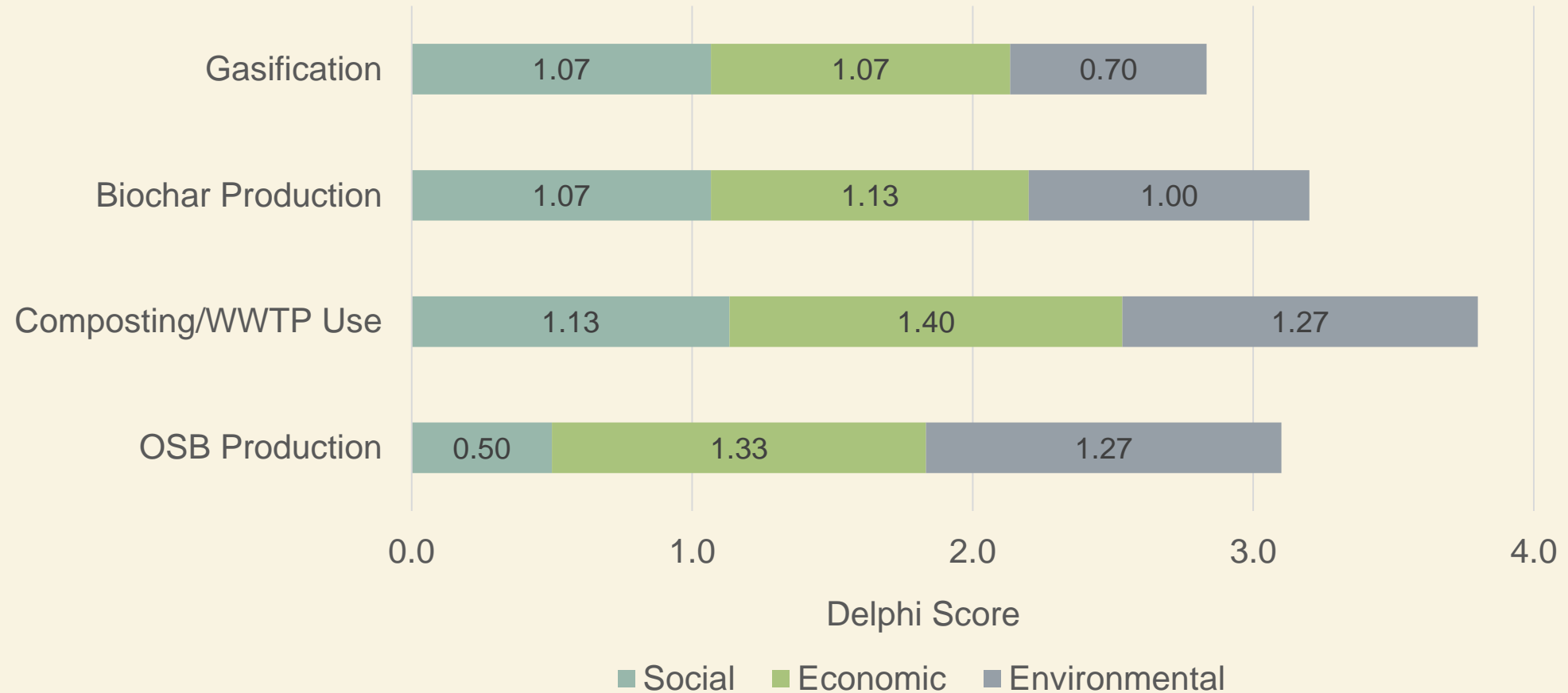
Criteria Scoring  
Decision Matrix  
Preferred Alternative  
Sensitivity Analysis  
Recommendations

|                        |   | Score | 1          | 2               | 3               | 4               | 5           |
|------------------------|---|-------|------------|-----------------|-----------------|-----------------|-------------|
| Criteria               | Descriptor of Quantification  |       | Poor       | Below Average   | Average         | Fair            | Exceptional |
| <b>Social</b>          |   |       |            |                 |                 |                 |             |
| Community Satisfaction | Number of frequently asked questions addressed  |       | ≤1         | 2               | 3               | 4               | ≥5          |
| Aesthetics             | Height of facility  |       | >48'       | 36-48'          | 24-35'          | 12-23'          | <12'        |
|                        | Population impacted   |       | >8,000     | 6,000-7,999     | 4,000-5,999     | 2,000-3,999     | <2,000      |
| <b>Economic</b>        |   |       |            |                 |                 |                 |             |
| Cost                   | Minimize payback period to offset capital and O&M costs (Years)                                       |       | >20        | 16-20           | 11-15           | 6-10            | 0-5         |
| Local Employment       | Number of jobs supported by implementation of alternative   |       | <5         | 5-9             | 10-20           | 21-50           | >50         |
| Ease of Implementation | Number of permits required to execute   |       | >10        | 8-10            | 5-7             | 1-4             | 0           |
| <b>Environmental</b>   |   |       |            |                 |                 |                 |             |
| Air Quality            | Minimize GHG emissions and local air quality impacts (tons/yr)  |       | >1,000,000 | 700,000-999,999 | 400,000-699,999 | 200,000-399,999 | <200,000    |
|                        | Minimize mass of criteria pollutants discharged (tons/yr)   |       | >25,000    | 25,000-10,000   | 10,000-5,000    | 5,000-1,000     | <1,000      |
| Carbon Sequestration   | Maximize sequestration of carbon through proposed alternative (tons/yr sequestered CO <sub>2</sub> e) |       | <200,000   | 200,000-300,000 | 300,000-400,000 | 400,000-500,000 | >500,000    |
| Excess Biomass         | Maximize percentage of available biomass used   |       | <85%       | 85-89.9%        | 90-92.5%        | 92.6-95%        | >95%        |

# Decision Matrix

Project Overview  
Initial Alternatives  
Decision Analysis

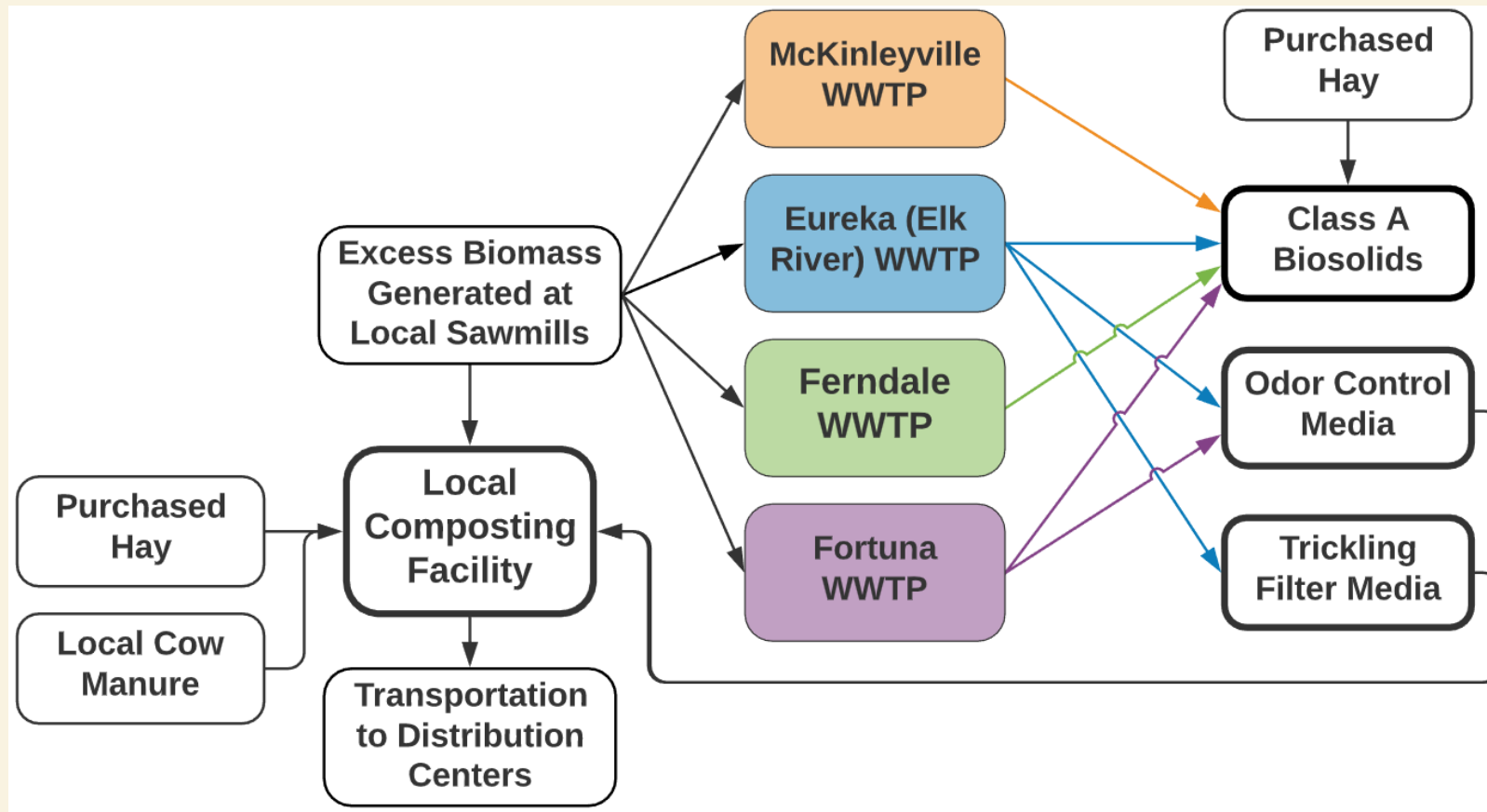
Criteria Scoring  
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Recommendations



# Preferred Alternative: Composting with Local WWTP Utilization

Project Overview  
Initial Alternatives  
Decision Analysis

Criteria Scoring  
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Recommendations



# Preferred Alternative: Composting with Local WWTP Utilization

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Decision Analysis

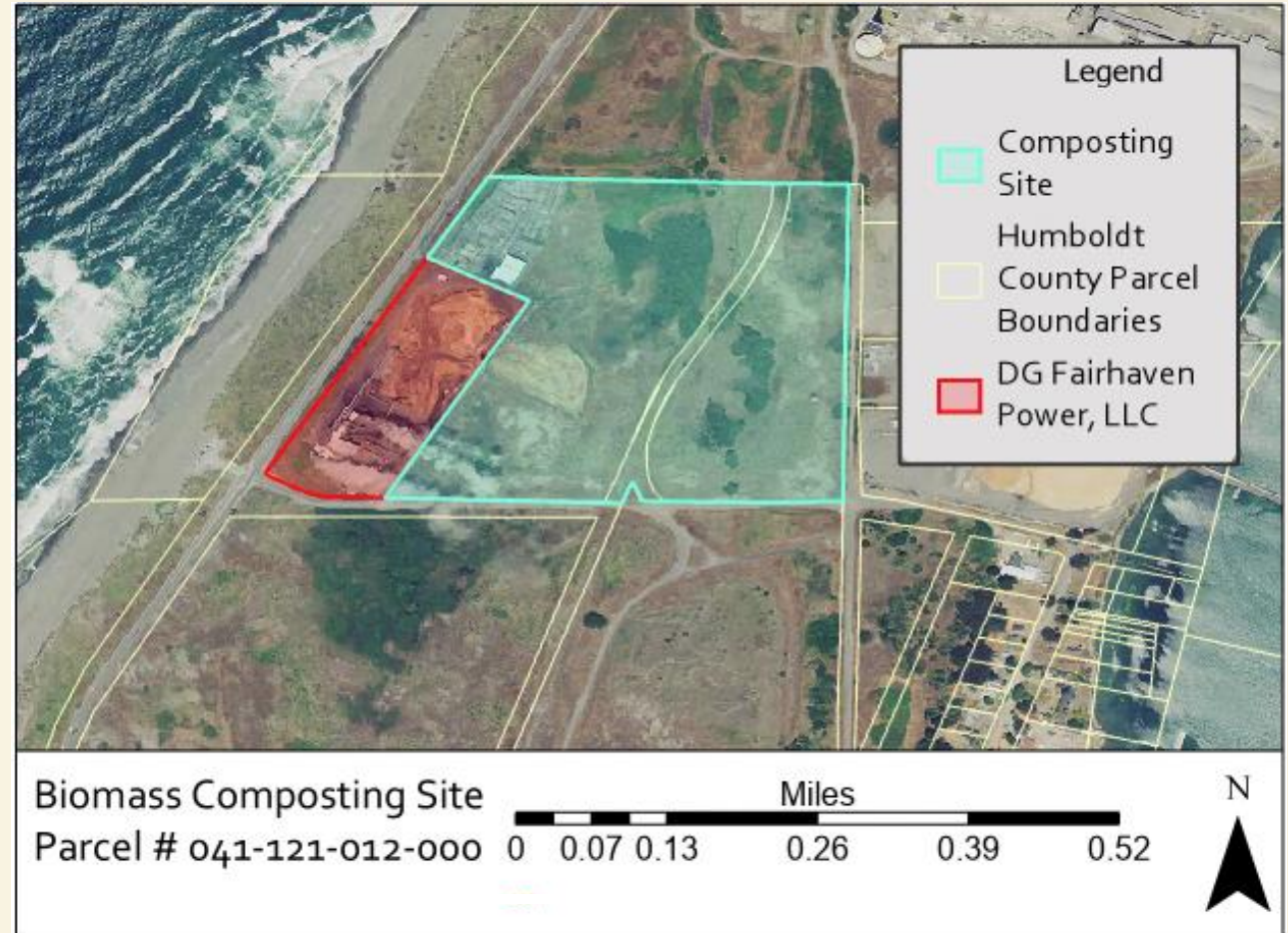
Criteria Scoring  
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## Area

- 36-acres required for composting facility

## Demand

- Half transported to Santa Rosa area distributors
- Half sold locally



# Preferred Alternative: Composting with Local WWTP Utilization

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Recommendations

## Emissions

- Negative net CO<sub>2</sub>e emissions: -353,000 tons/yr

## Compost Mix

- Compost meets optimal chemical composition requirements for:
  - Moisture
  - Density
  - C:N ratio

| Compost Mx | Mass (tons/yr) |
|------------|----------------|
| Hay        | 608,984        |
| Biomass    | 619,027        |
| Manure     | 373,169        |

# Sensitivity Analysis: Optimal Mix

Project Overview  
Initial Alternatives  
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Preferred Alternative  
Sensitivity Analysis  
Recommendations

- Changed biomass moisture content from 0 to 100%
- Due to hay, the change in biomass moisture continued to be within the requirements.

| Recipe Parameters            | Values |
|------------------------------|--------|
| Density (kg/m <sup>3</sup> ) | 262    |
| Moisture Content (%)         | 40     |
| C:N                          | 35:1   |

# Sensitivity Analysis: Emissions and Quantity of Biomass Utilized

Project Overview  
Initial Alternatives  
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Criteria Scoring  
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Preferred Alternative  
Sensitivity Analysis  
Recommendations

- Linear trend, direct correlation
- Analysis is representative of both GHG and criteria pollutants
- Assumes compost mix remains optimal with increase in biomass

| Pollutant   | Compost/WWTP Alternative | Power Plants         | % Reduction |
|---|--------------------------|----------------------|-------------|
| CO <sub>2</sub> , tons yr <sup>-1</sup>                         | 554,655 <sup>1</sup>     | 474,035 <sup>4</sup> | -17         |
| N <sub>2</sub> O, tons yr <sup>-1</sup>                         | 422 <sup>1</sup>         | 21 <sup>4</sup>      | -1,909      |
| CH <sub>4</sub> , tons yr <sup>-1</sup>                         | 4,650 <sup>1</sup>       | 155 <sup>4</sup>     | -2,900      |
| CO, tons yr <sup>-1</sup>                                       | 0 <sup>2</sup>           | 2,217 <sup>4</sup>   | 100         |
| SO <sub>2</sub> , tons yr <sup>-1</sup>                         | 0 <sup>2</sup>           | 60 <sup>4</sup>      | 100         |
| NO <sub>x</sub> , tons yr <sup>-1</sup>                         | 0 <sup>2</sup>           | 329 <sup>4</sup>     | 100         |
| TVOC, tons yr <sup>-1</sup><br>as C <sub>3</sub> H <sub>8</sub> | 11 <sup>3</sup>          | 48 <sup>4</sup>      | 78          |
| PM <sub>TOTAL</sub> , tons yr <sup>-1</sup>                     | 90 <sup>2</sup>          | 130 <sup>4</sup>     | 24          |

<sup>1</sup>(Williams et al. 2019), <sup>2</sup>(BioMRF Technologies Inc. 2020), <sup>3</sup>(Clements et al. 2010), <sup>4</sup>(CARB 2020)



# Cost Analysis:

## Capital and Annual Cash Flow

Project Overview  
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|                             | Cost                         | Item Description                                      |
|-----------------------------|------------------------------|---|
| <b>Capital Costs</b>        | \$2,700,000 <sup>1</sup>     | Cost of land, Samoa Peninsula CDI zone                |
|                             | \$1,540,000 <sup>2</sup>     | Equipment (bucket loaders, shredder)                  |
|                             | \$692,000 <sup>2</sup>       | Construction (Excavation, paving, fencing, buildings) |
|                             | \$288,000 <sup>2</sup>       | Engineering   |
|                             | \$237,000 <sup>2</sup>       | Utility Hookup  |
| <b>Annual O&amp;M</b>       | \$3,251,000 <sup>3</sup>     | Employee Salary                                       |
|                             | \$40,534,000 <sup>4</sup>    | Transportation Expenses                               |
|                             | \$121,557,000 <sup>5</sup>   | Hay for Compost Mix                                   |
|                             | \$3,301,000 <sup>6</sup>     | Trickling Filter Operation and Maintenance            |
|                             | \$1,517,000 <sup>2</sup>     | Composting Operation and Maintenance                  |
| <b>Annual Income</b>        | \$172,126,000 <sup>7,8</sup> | Compost Sales   |
| <b>Payback Period (Yrs)</b> | <b>2.8 years</b>             |   |

<sup>1</sup>(Humboldt County MLS 2020), <sup>2</sup>(Tchobanoglous and Kreith 2002), <sup>3</sup>(IWMC 2019), <sup>4</sup>(C.H. Robinson 2020), <sup>5</sup>(USDA 2020), <sup>6</sup>(EPA 2000), <sup>7</sup>(Wes Green Landscape Materials 2020), <sup>8</sup>(Sonoma Compost 2020)



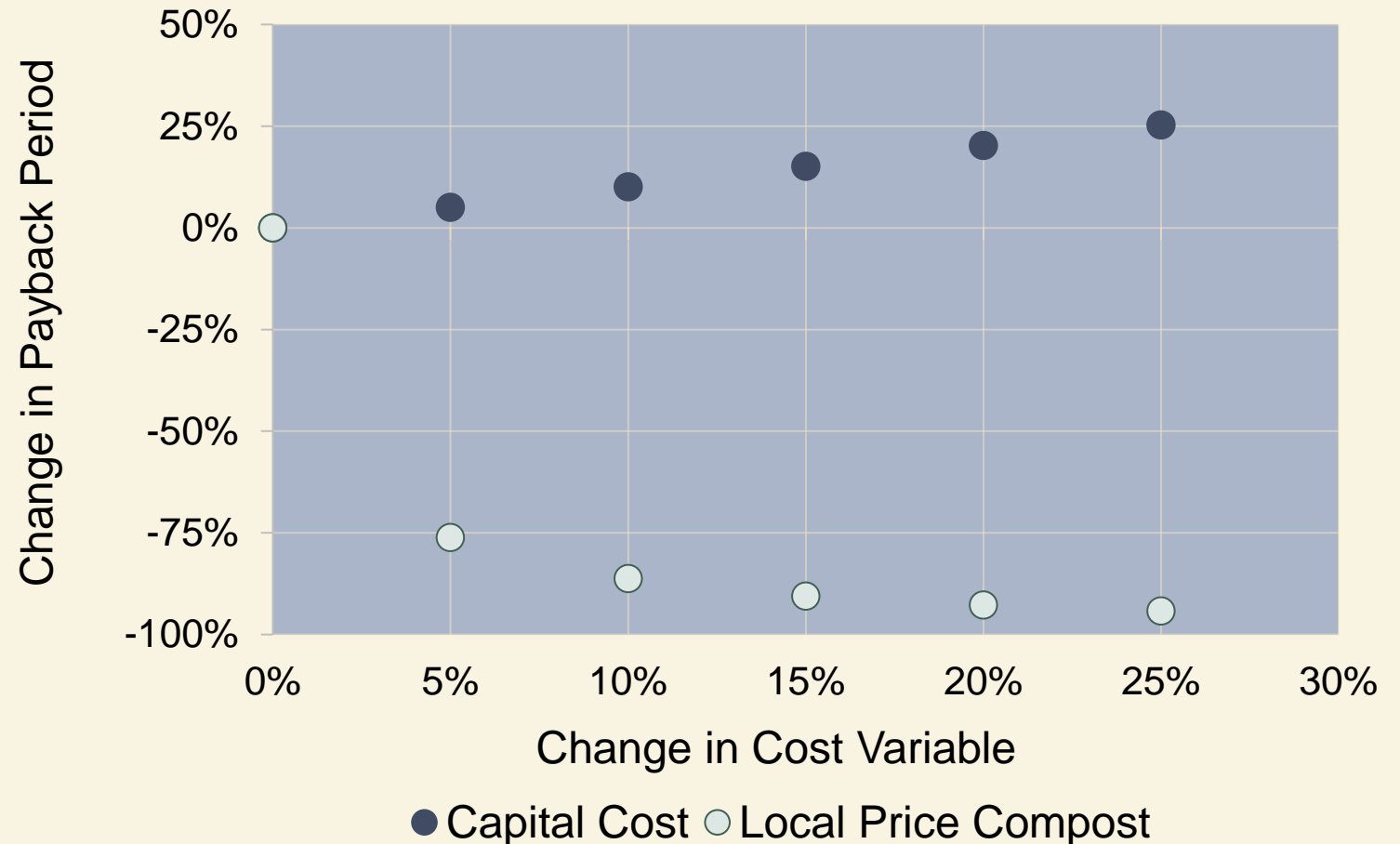
# Cost Analysis: Sensitivity of Payback Period

Project Overview  
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Recommendations

## Payback Period Sensitivity

- Capital Costs
- Local Price of Compost  
\$38/yd<sup>3</sup> minimum



# Limitations & Recommendations

Project Overview  
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Criteria Scoring  
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Recommendations

- Cow manure availability
  - Requires manure from 1/5 of Humboldt County's cows
- True compost demand
  - Income reliance
- 20% of biomass not utilized



# Acknowledgements

- Dr. Sintana Vergara, Humboldt State University
- Dr. Tesfayohanes Yacob, Humboldt State University
- Anamika Singh, Redwood Coast Energy Authority
- Richard Engel, Redwood Coast Energy Authority
- Bob Marino, DG Fairhaven
- Capstone Class of Spring 2020

# Questions?



# References

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# CO<sub>2</sub> Equivalent Emissions

| Alternative  | CO <sub>2</sub> e | Net<br>(tons/year) | % Reduction<br>From Current <sup>1</sup> | CO <sub>2</sub> e Sequestered<br>(tons/year) |
|--------------|-------------------|--------------------|--|--|
| Gasification |                   | 158,344            | 36                                       | 121,700                                      |
| Biochar      |                   | -332,624           | 227                                      | 521,505                                      |
| WWTP/Compost |                   | -352,640           | 235                                      | 1,149,301                                    |
| OSB          |                   | -416,817           | 260                                      | 534,299                                      |

1. Compared with CO<sub>2</sub>e emissions reported by CARB for DG Fairhaven and Humboldt Sawmill Company for 2017, the most recent year on record.



# Alternative Criteria Quantification

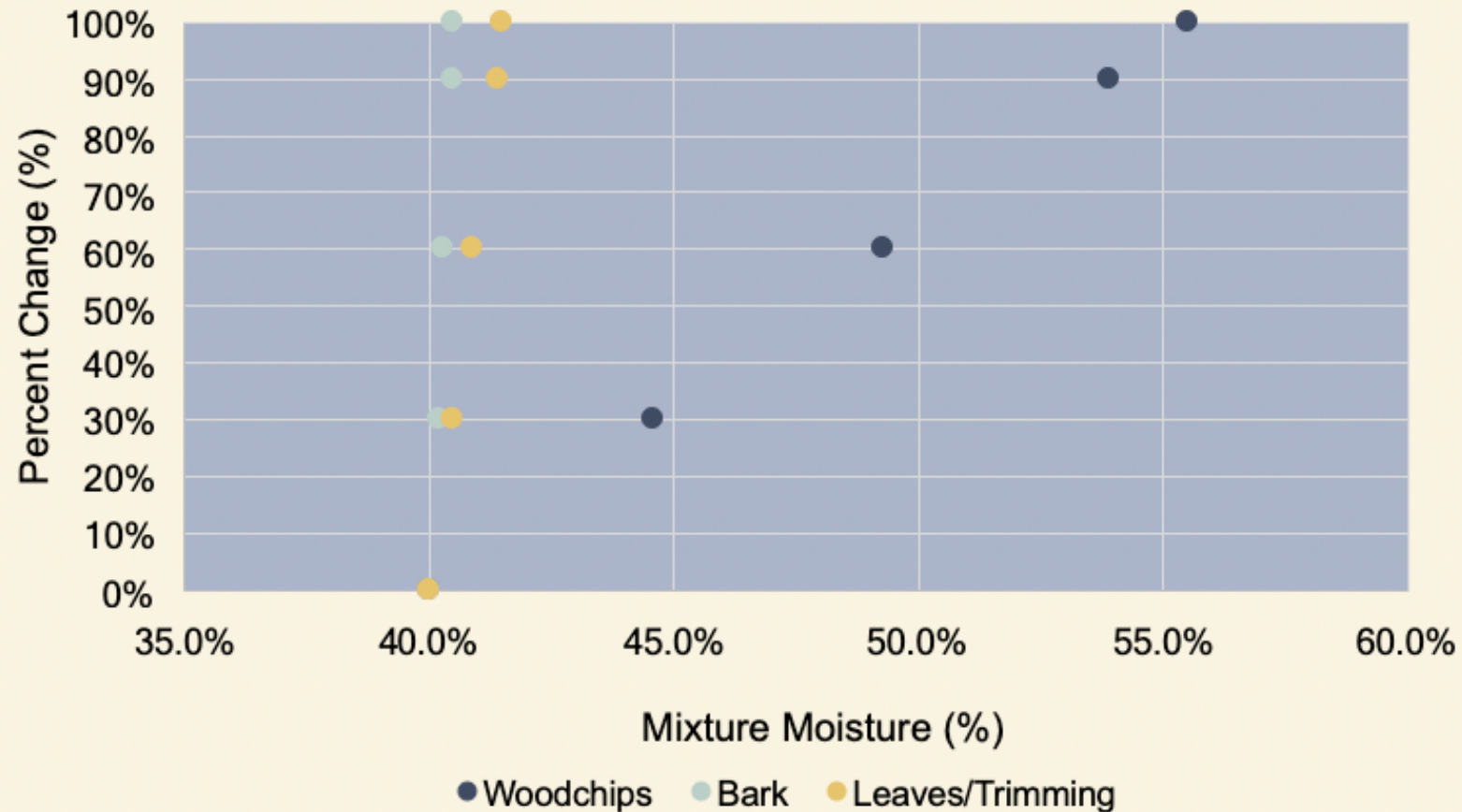
|                                  | Gasification | OSB     | Compost | Biochar |
|----------------------------------|--------------|---------|---------|---------|
| Social                           |              |         |         |         |
| Community Satisfaction           | 2.5          | 1       | 3       | 3       |
| Aesthetics: Height               | 30           | 40      | 6       | 24      |
| Aesthetics: Population Impacted  | 1,000        | 1,000   | 1,000   | 1,000   |
| Economic                         |              |         |         |         |
| Cost, Payback Period             | 8.5          | 17.2    | 2.8     | 2.5     |
| Local Employment                 | 8            | 169     | 386     | 8.5     |
| Ease of Implementation           | 4            | 3       | 5       | 3       |
| Environmental                    |              |         |         |         |
| Air Quality, GHGs                | 281,417      | 60,657  | 559,305 | 188,881 |
| Air Quality, Criteria Pollutants | 10,601       | 730     | 101     | 0.05    |
| Carbon Sequestration             | 121,723      | 534,299 | 582,764 | 142,315 |
| Biomass Use                      | 80%          | 80%     | 80%     | 80%     |



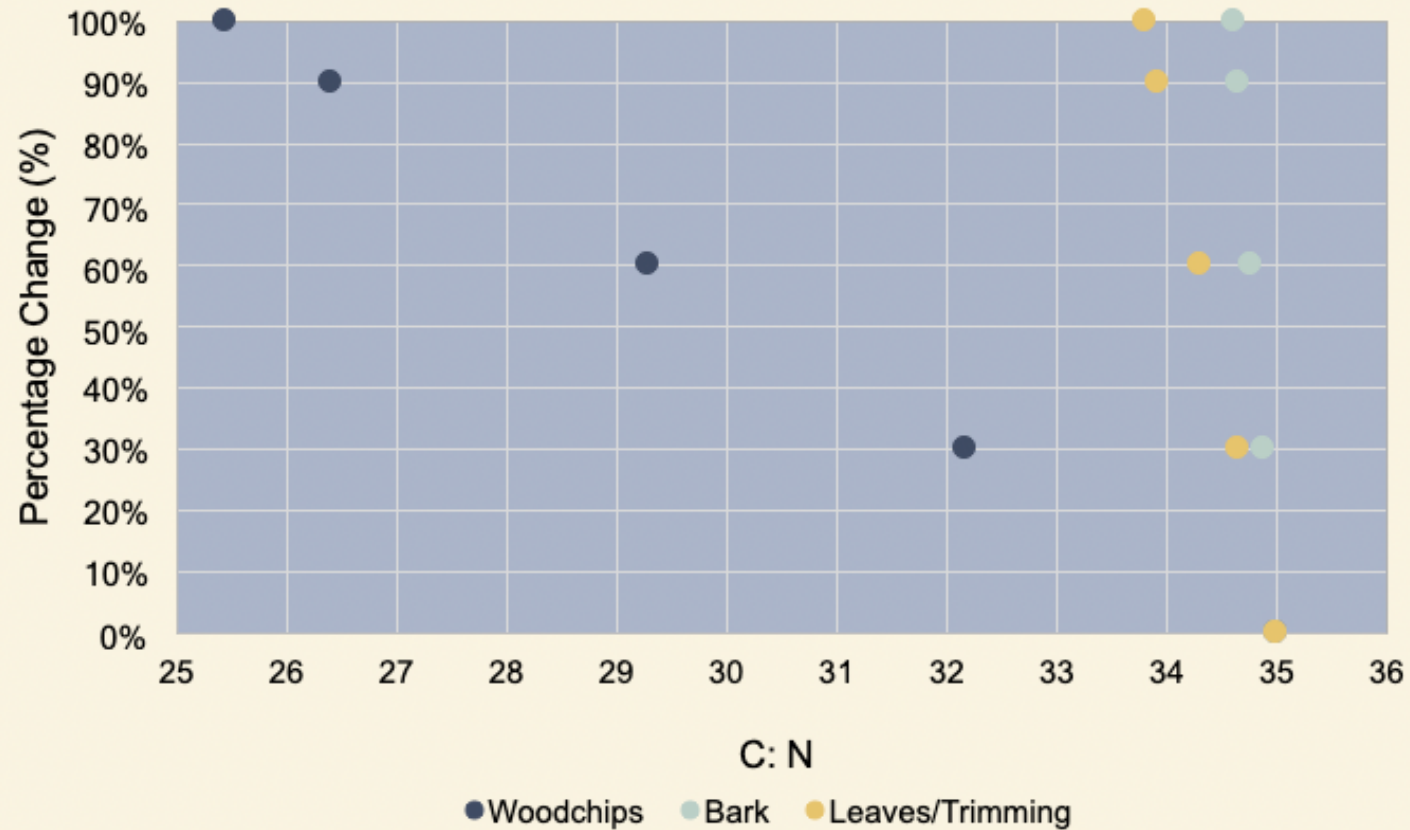
# Decision Matrix

|                                  |       |                     | Alternative:<br>Gasification |                   | Alternative:<br>Biochar Production |                   | Alternative:<br>Compost/WWTP |                   | Alternative:<br>OSB |                   |
|----------------------------------|-------|---------------------|------------------------------|-------------------|------------------------------------|-------------------|------------------------------|-------------------|---------------------|-------------------|
| <b><i>Social</i></b>             | Score | Normalized<br>Score | Score                        | Weighted<br>Score | Score                              | Weighted<br>Score | Score                        | Weighted<br>Score | Score               | Weighted<br>Score |
| Community Satisfaction           | 8     | 0.27                | 3                            | 0.80              | 3                                  | 0.80              | 3                            | 0.80              | 1                   | 0.27              |
| Aesthetics: Height               | 1     | 0.03                | 3                            | 0.10              | 3                                  | 0.10              | 5                            | 0.17              | 2                   | 0.07              |
| Aesthetics: Population Impacted  | 1     | 0.03                | 5                            | 0.17              | 5                                  | 0.17              | 5                            | 0.17              | 5                   | 0.17              |
| <b><i>Economic</i></b>           |       |                     |                              |                   |                                    |                   |                              |                   |                     |                   |
| Cost, Payback Period             | 2     | 0.07                | 4                            | 0.27              | 5                                  | 0.33              | 5                            | 0.33              | 2                   | 0.13              |
| Local Employment                 | 4     | 0.13                | 2                            | 0.27              | 2                                  | 0.27              | 5                            | 0.67              | 5                   | 0.67              |
| Ease of Implementation           | 4     | 0.13                | 4                            | 0.53              | 4                                  | 0.53              | 3                            | 0.40              | 4                   | 0.53              |
| <b><i>Environmental</i></b>      |       |                     |                              |                   |                                    |                   |                              |                   |                     |                   |
| Air Quality, GHGs                | 3     | 0.10                | 4                            | 0.40              | 5                                  | 0.50              | 5                            | 0.50              | 5                   | 0.50              |
| Air Quality, Criteria Pollutants | 2     | 0.07                | 2                            | 0.13              | 5                                  | 0.33              | 5                            | 0.33              | 5                   | 0.33              |
| Carbon Sequestration             | 2     | 0.07                | 1                            | 0.07              | 1                                  | 0.07              | 5                            | 0.33              | 5                   | 0.33              |
| Biomass Use                      | 3     | 0.10                | 1                            | 0.10              | 1                                  | 0.10              | 1                            | 0.10              | 1                   | 0.10              |
| <b>Total</b>                     |       |                     |                              | <b>2.83</b>       |                                    | <b>3.20</b>       |                              | <b>3.80</b>       |                     | <b>3.10</b>       |

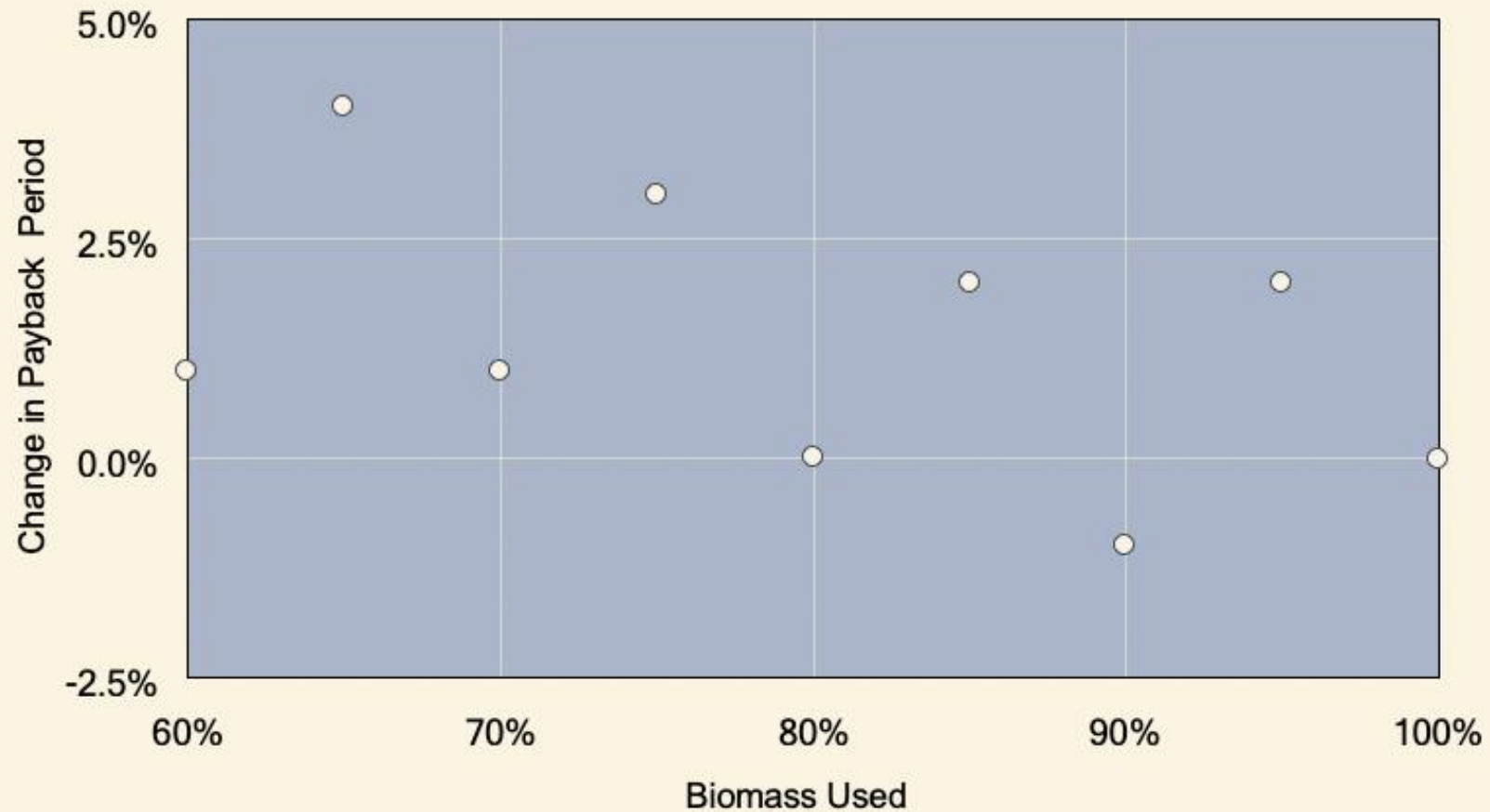
# Sensitivity Analysis: Biomass vs. Moisture Content



# Sensitivity Analysis: Biomass vs. Moisture Content

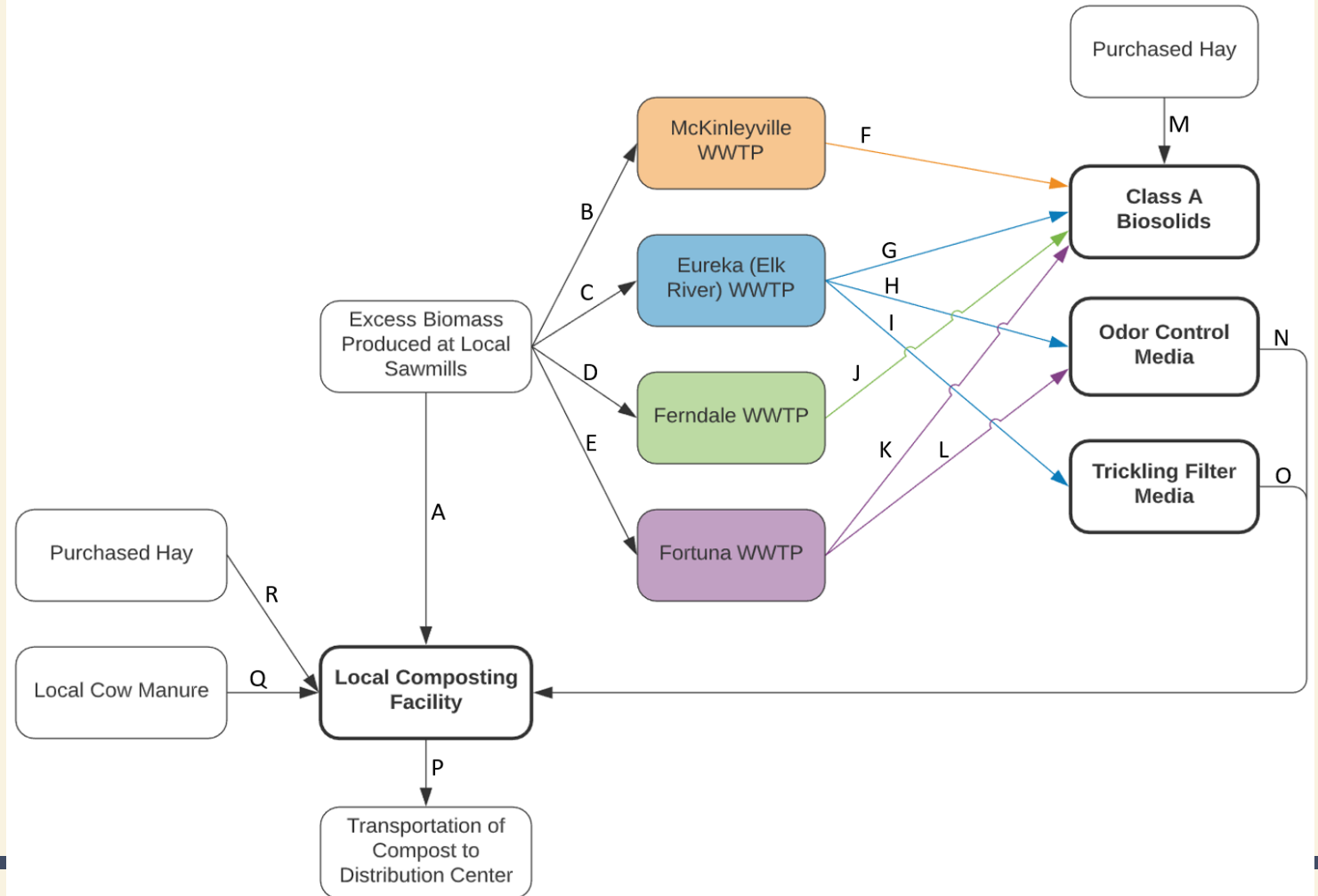


# Economic Sensitivity: Biomass Used



# Design Optimization

| Path | Amount (ft <sup>3</sup> /yr) | Product        |
|------|------------------------------|----------------|
| A    | 80,293,256                   | Excess Biomass |
| B    | 193                          | Excess Biomass |
| C    | 1,417,845                    | Excess Biomass |
| D    | 77                           | Excess Biomass |
| E    | 3,331                        | Excess Biomass |
| F    | 193                          | Excess Biomass |
| G    | 738                          | Excess Biomass |
| H    | 3,393                        | Excess Biomass |
| I    | 1,413,714                    | Excess Biomass |
| J    | 77                           | Excess Biomass |
| K    | 211                          | Excess Biomass |
| L    | 3,120                        | Excess Biomass |
| M    | 1,707                        | Hay            |
| N    | 6,513                        | Used Biomass   |
| O    | 1,413,714                    | Used Biomass   |
| P    | 89,373,822                   | Compost        |
| Q    | 6,369,297                    | Manure         |
| R    | 92,085,090                   | Hay            |



# Optimal Compost Mixture Requirements

| Compost Mixture | C:N Ratio | Density (kg/m <sup>3</sup> ) | Moisture Content (%) |
|-----------------|-----------|------------------------------|----------------------|
| Optimal         | 20-40:1   | < 600                        | 40-60                |
| Achieved        | 35:1      | 262                          | 40                   |