NARA

Economic Impacts of Forest Residue Feedstocks Preparation for Biofuels

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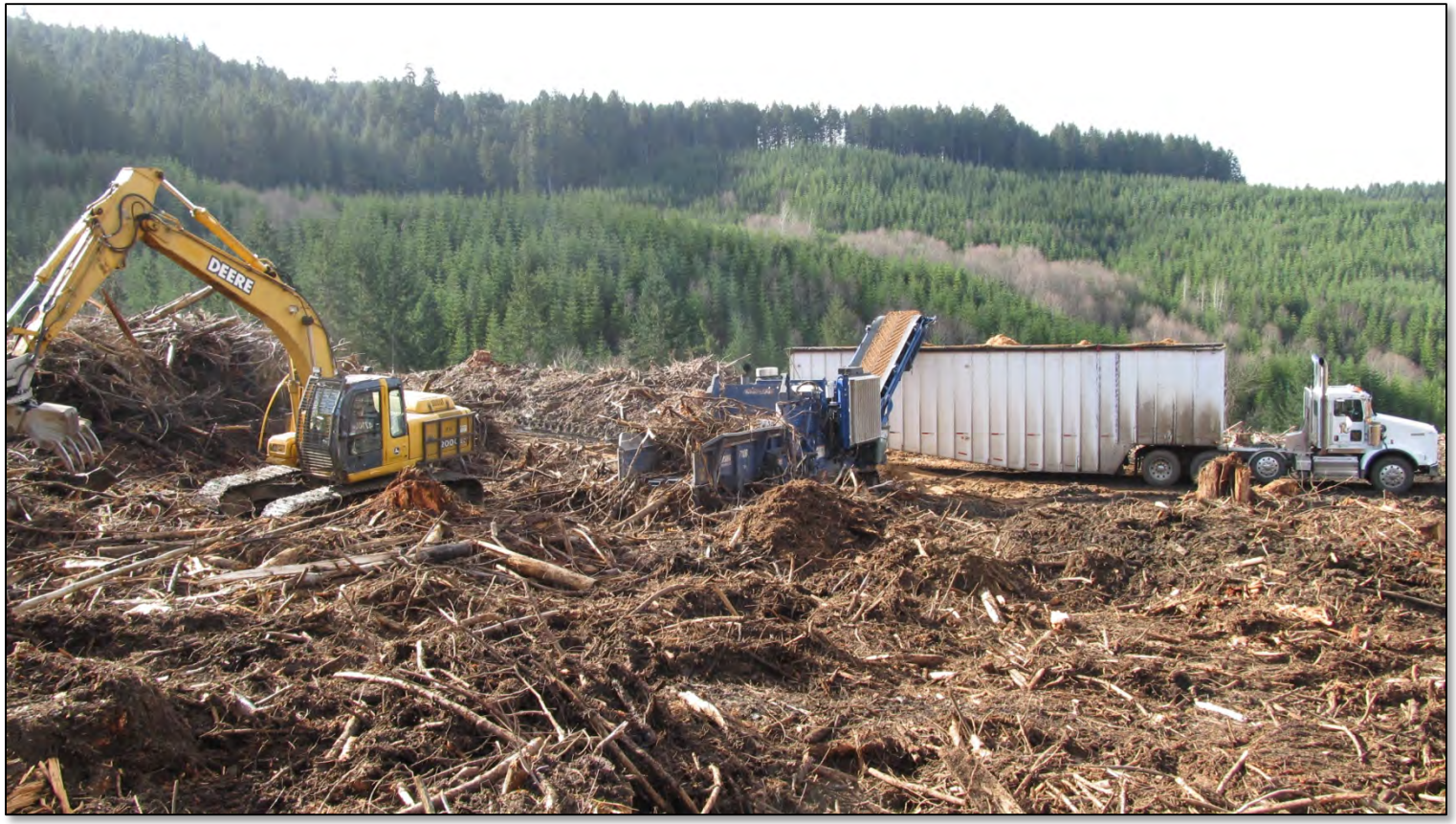
Forest Residue Comminution

- NARA Base case: PNW Douglas-fir forest harvest residuals comminuted in a horizontal drum grinder, screened for oversize and fines at mill-site to get pulp-chip size distribution to bio-fuels conversion mouth.

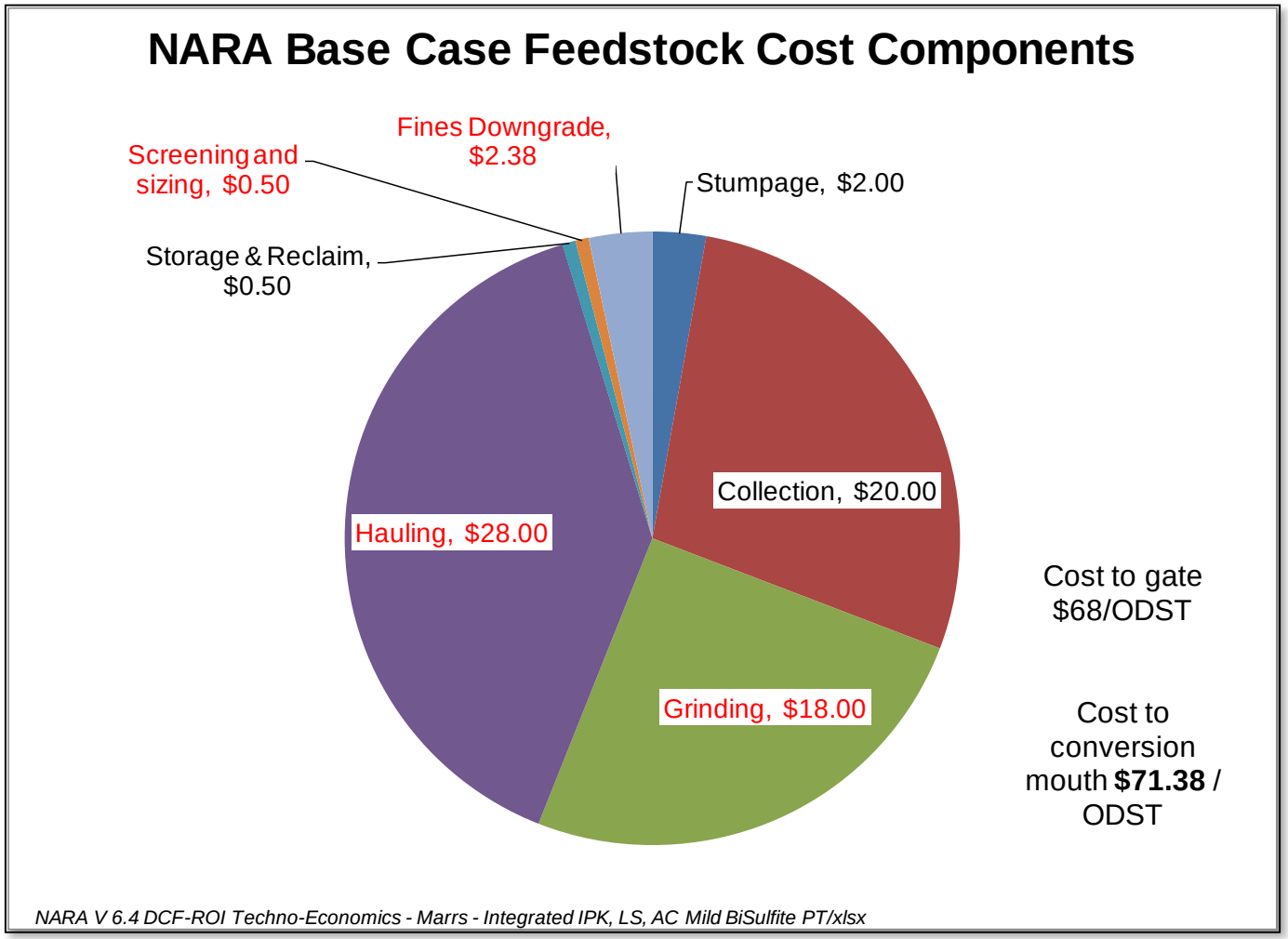


Feedstock Cost

- NARA Base Case (850k ODST / year) Techno-Economic Analysis shows feedstock is the largest single cost component of the NARA conversion process operating costs.
- For Base Case 850k ODST/year facility, feedstock cost is about $75 million per year.
- Feedstock annual expenses are about 17% of the total manufacturing costs.
- Reducing feedstock costs can measurably improve project return.

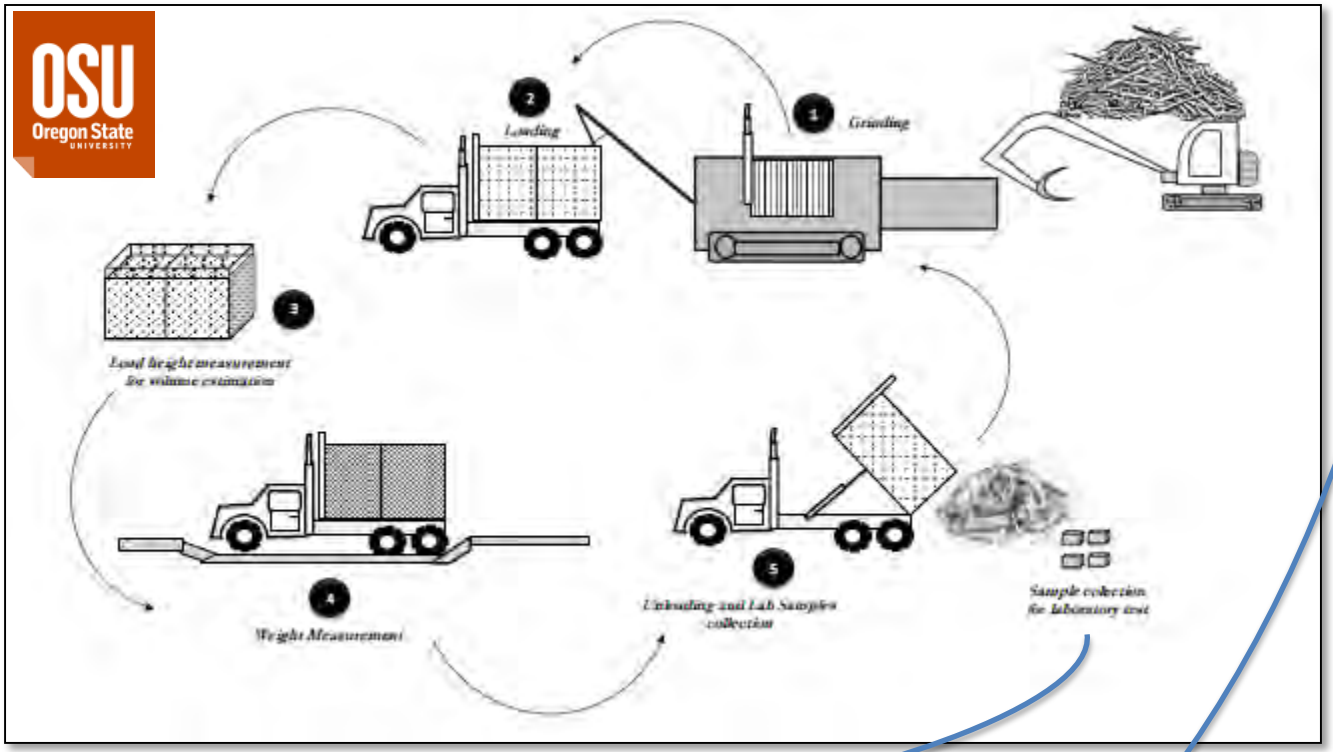
NARA Feedstock Cost Components

- Grinding and Sizing trials focused on four elements of feedstock cost (red text below).

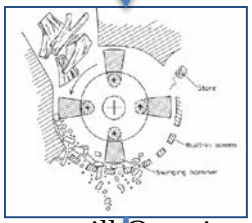


Grinding and Sizing Trials

- Equipment and processing



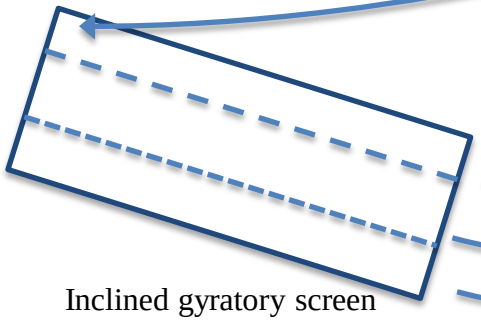
+ 1.75 inch gyratory Oversize



Hammer-mill Oversize to –1.5”

Gyratory Accepts

- 1/8 inch Gyratory Fines



Inclined gyratory screen

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2013 “Grinding Trials”

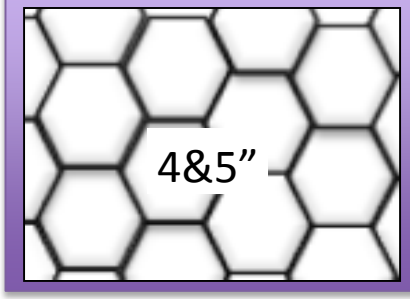
Douglas-fir Forest Harvest Residuals Sorted into 3 Piece Classes

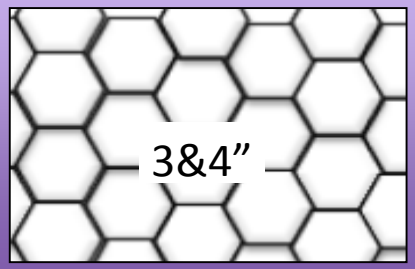
Feed Class 1
Tops & Limbs

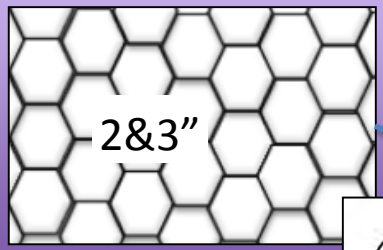
Feed Class 2
Pulpwood Logs

Feed Class 3
Chunks

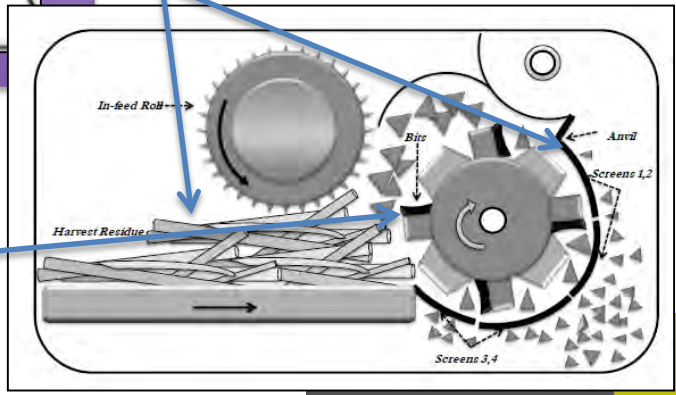
Three Grinder Screen Size Sets







Two Grinder Bit types



Key Trial Responses and Cost

1. **Fuel usage** for grinding -> power -> **grinding cost**
2. **Bulk density** -> dry weight per truckload -> **hauling cost**
3. **Oversize** chip production -> **resizing cost**
4. **Fines** production -> cost of value **downgrade to hog fuel**

5. The four factors above are not independent, sometime off-setting, and thus there is a **total cost impact** of all combined for each treatment.

- Approach: Translate each response change into $ impact, index as +/- difference from NARA base case
  - Base case used here is Hammer-carbide bits, 3&4-inch screens, on Pulplogs Feed Piece Size class.

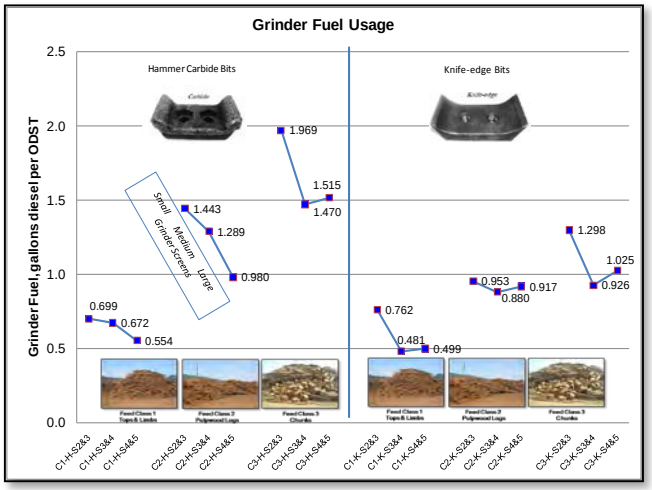
Treatment Codes and Visuals

- Pairs of charts for:

Treatment plotting codes

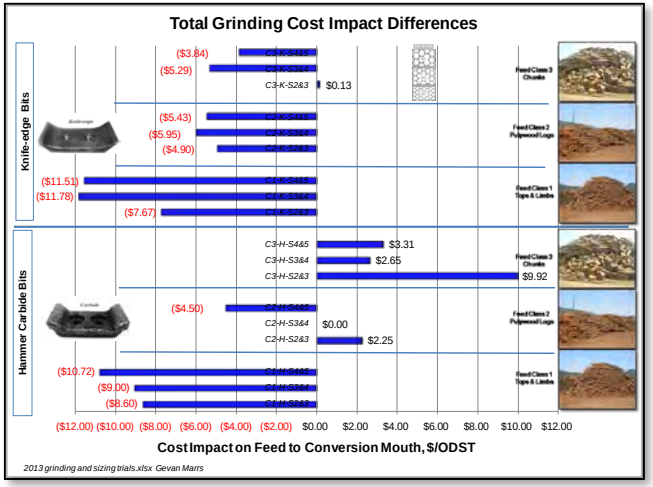
Piece Size Type	Piece Size class	Code	Knife or Hammer bits	Code	Screen size	Code	Plot Code
Tops and Limbs	*Class 1*	*C1*	*Hammer*	*H*	*2 & 3*	*S2&3*	*C1-H-S2&3*
Tops and Limbs	*Class 1*	*C1*	*Hammer*	*H*	*3 & 4*	*S3&4*	*C1-H-S3&4*
Tops and Limbs	*Class 1*	*C1*	*Hammer*	*H*	*4 & 5*	*S4&5*	*C1-H-S4&5*
Pulp Logs	*Class 2*	*C2*	*Hammer*	*H*	*2 & 3*	*S2&3*	*C2-H-S2&3*
Pulp Logs	*Class 2*	*C2*	*Hammer*	*H*	*3 & 4*	*S3&4*	*C2-H-S3&4*
Pulp Logs	*Class 2*	*C2*	*Hammer*	*H*	*4 & 5*	*S4&5*	*C2-H-S4&5*
Log Chunks	*Class 3*	*C3*	*Hammer*	*H*	*2 & 3*	*S2&3*	*C3-H-S2&3*
Log Chunks	*Class 3*	*C3*	*Hammer*	*H*	*3 & 4*	*S3&4*	*C3-H-S3&4*
Log Chunks	*Class 3*	*C3*	*Hammer*	*H*	*4 & 5*	*S4&5*	*C3-H-S4&5*
Tops and Limbs	*Class 1*	*C1*	*Knife*	*K*	*2 & 3*	*S2&3*	*C1-K-S2&3*
Tops and Limbs	*Class 1*	*C1*	*Knife*	*K*	*3 & 4*	*S3&4*	*C1-K-S3&4*
Tops and Limbs	*Class 1*	*C1*	*Knife*	*K*	*4 & 5*	*S4&5*	*C1-K-S4&5*
Pulp Logs	*Class 2*	*C2*	*Knife*	*K*	*2 & 3*	*S2&3*	*C2-K-S2&3*
Pulp Logs	*Class 2*	*C2*	*Knife*	*K*	*3 & 4*	*S3&4*	*C2-K-S3&4*
Pulp Logs	*Class 2*	*C2*	*Knife*	*K*	*4 & 5*	*S4&5*	*C2-K-S4&5*
Log Chunks	*Class 3*	*C3*	*Knife*	*K*	*2 & 3*	*S2&3*	*C3-K-S2&3*
Log Chunks	*Class 3*	*C3*	*Knife*	*K*	*3 & 4*	*S3&4*	*C3-K-S3&4*
Log Chunks	*Class 3*	*C3*	*Knife*	*K*	*4 & 5*	*S4&5*	*C3-K-S4&5*

a) treatment response



b) economic impact

<- reduced $ increased->



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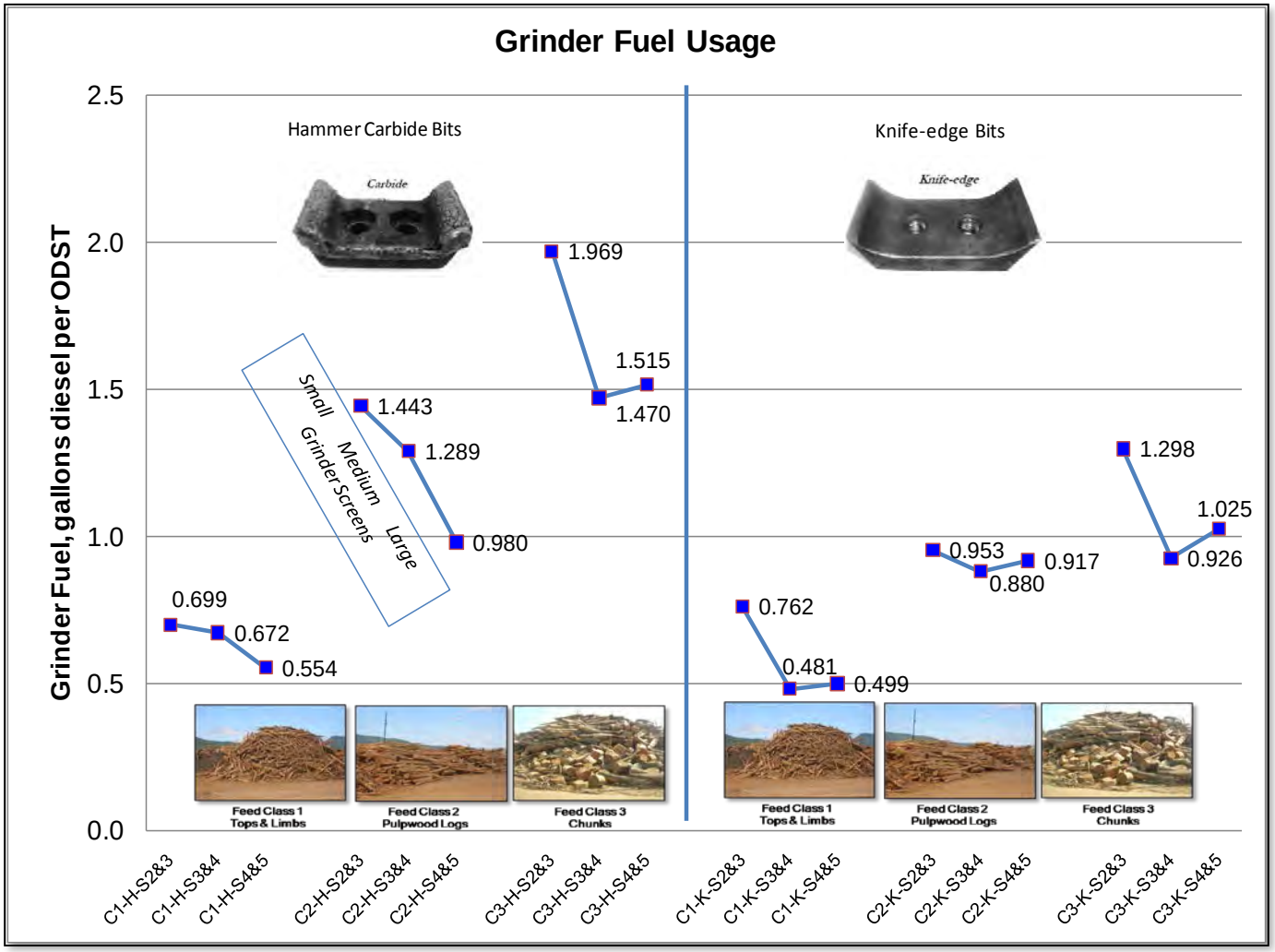
Grinding Power and Total Cost

- Lowest fuel usage per ton achieved with largest grates, smallest feed pieces, knife bits.
  - But, this produces more oversize, higher bulk density.



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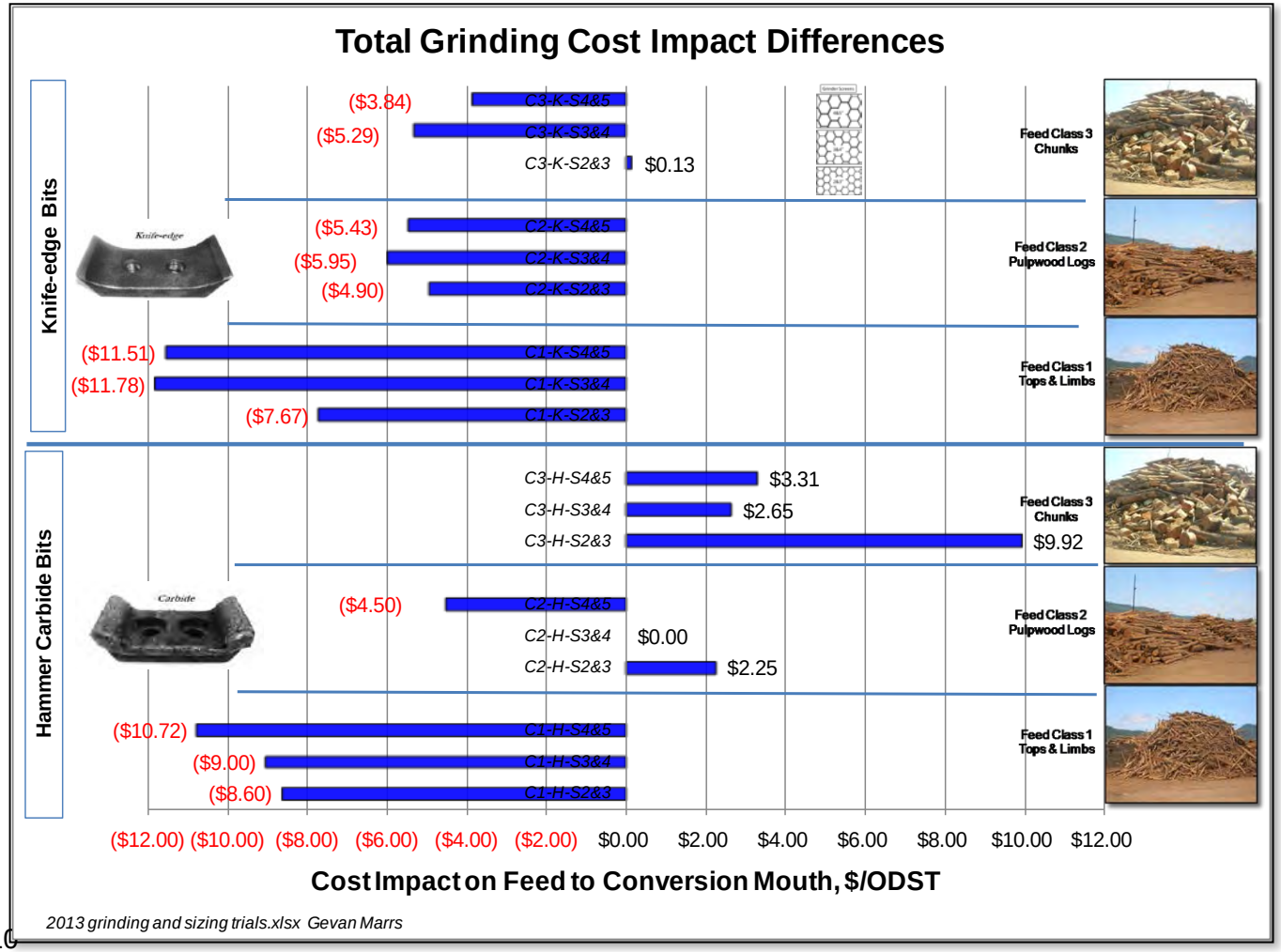
Total Grinding Cost Differences

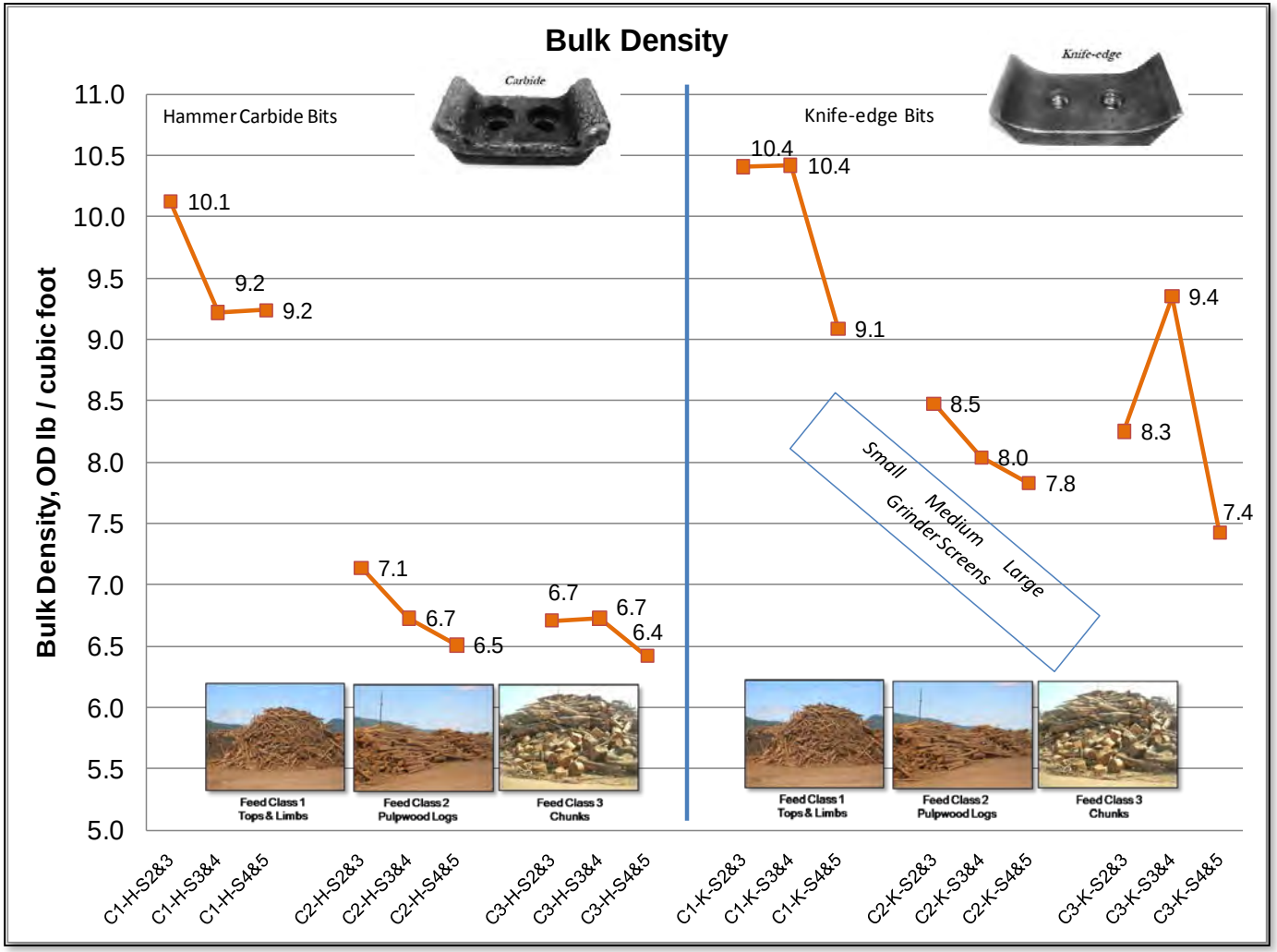
- Assume grinder cost is $216/hour without fuel cost, loader is $102/hour.
- Grinder is kept running at 75% of full power all the time, using 26.5 gal/hour, which equals $93/hour.
- Total loading and grinding cost is $411 / hour.
  - Varying gal/ODST translated to varying ODST/hour, and thus varying $/ODST total cost



Range of treatments impacts production cost total range of $21.70/ODST

Bulk Density Impacts

- The tops and limbs gave significantly higher bulk density – likely because they higher wood density *and* had more bark *and* were drier thus produced more fine particles.
- On larger pieces, knife bits gave somewhat higher bulk density.



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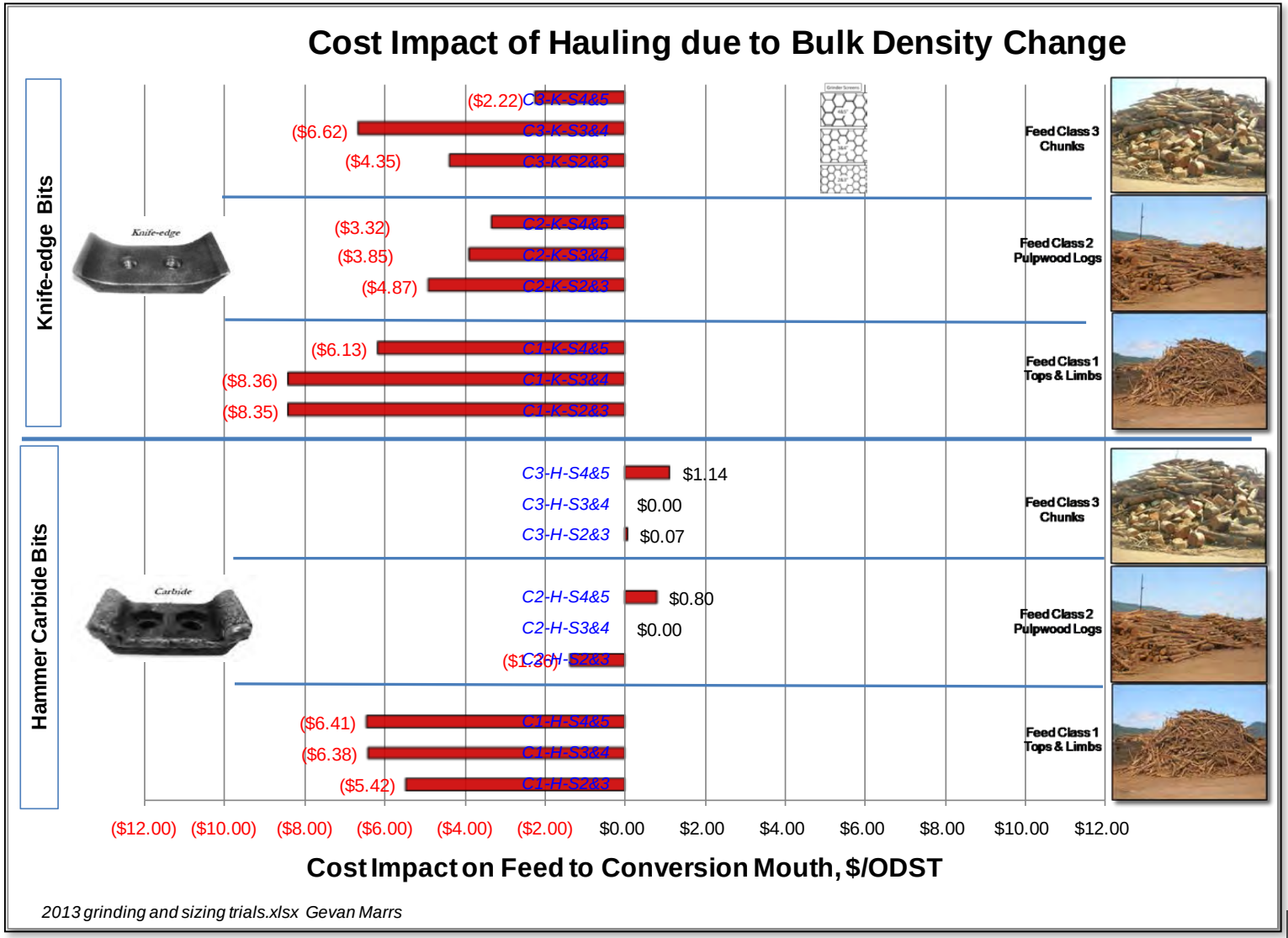
Hauling Cost Impact – Bulk Density

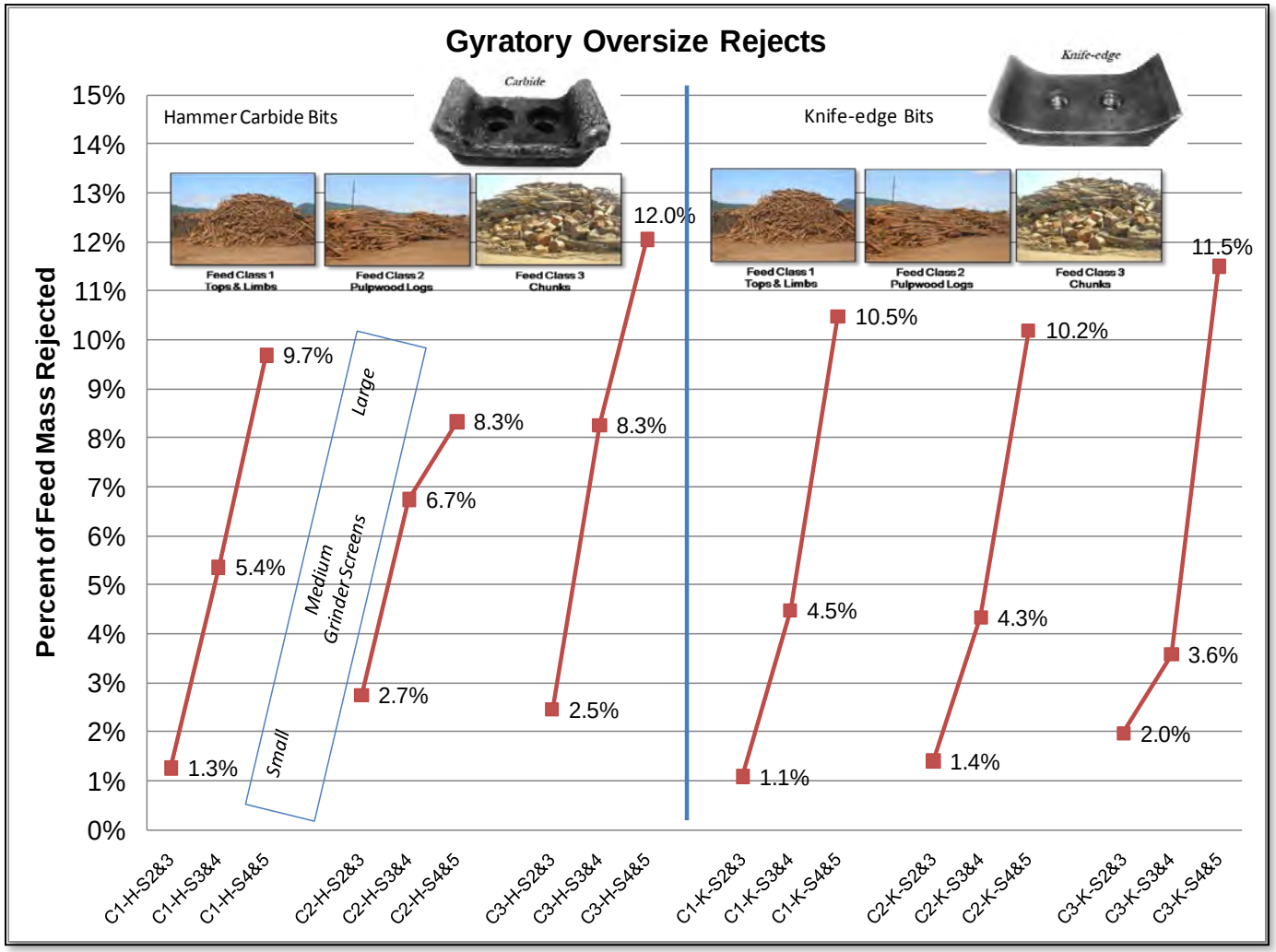
- Assuming moisture is low enough to keep truck under GVW limits, this factor is quite powerful on hauling costs.



Bulk density range of impact on hauling cost is $9.50 / ODST.

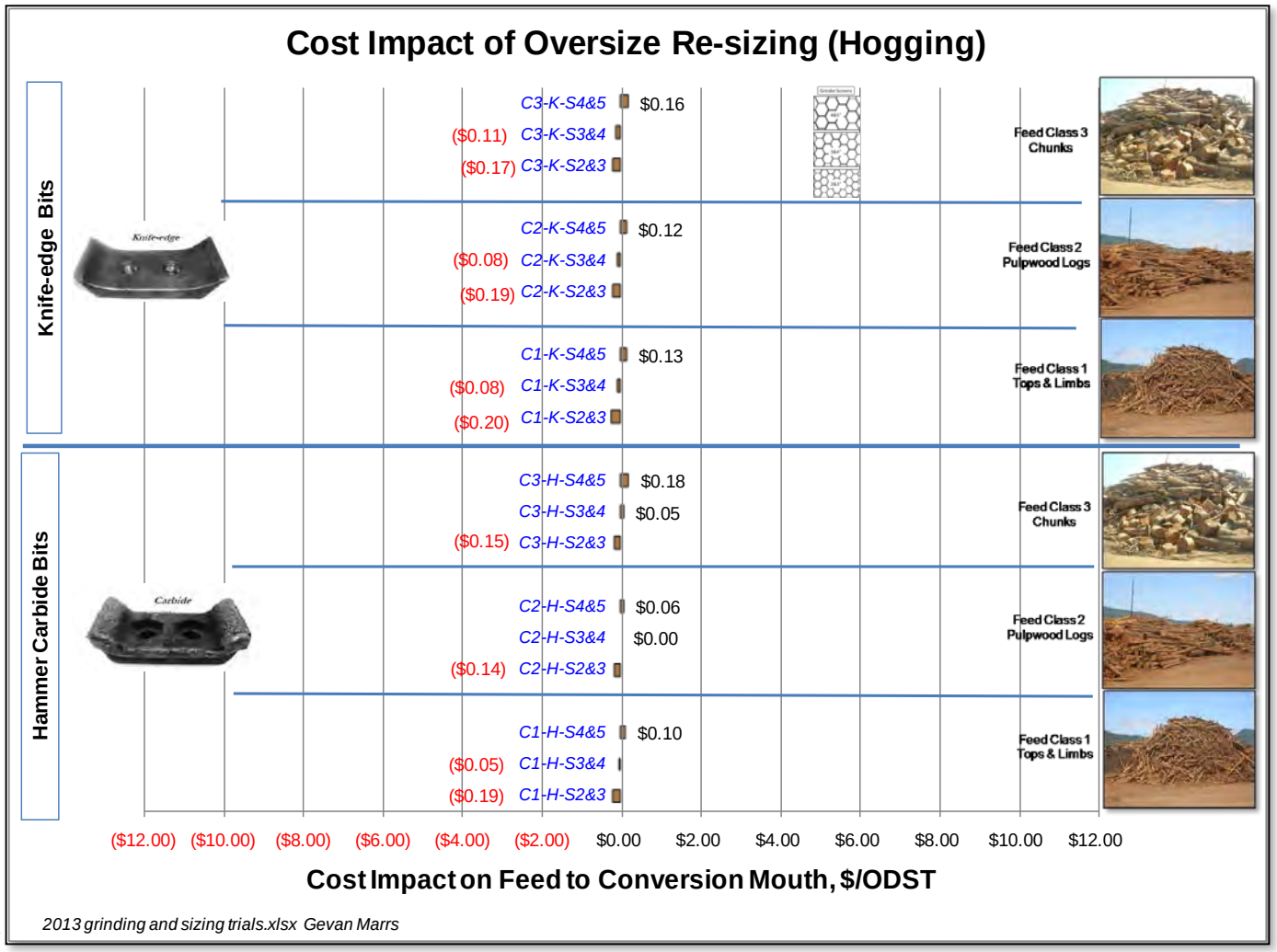
Oversize material production

- Amount of oversize material (>1.75 inch) screened out at “millsite” much higher for large grates, so re-sizing costs are higher
  - Screening oversize amount varies significantly - from 1.1% to 11.5%



Cost Impact – Oversize Resizing

- Total re-sizing cost, including machine capital, power, labor, maintenance assumed $3.47 / ODST **of oversize**
  - But, when this is expressed on feed basis, not very large.

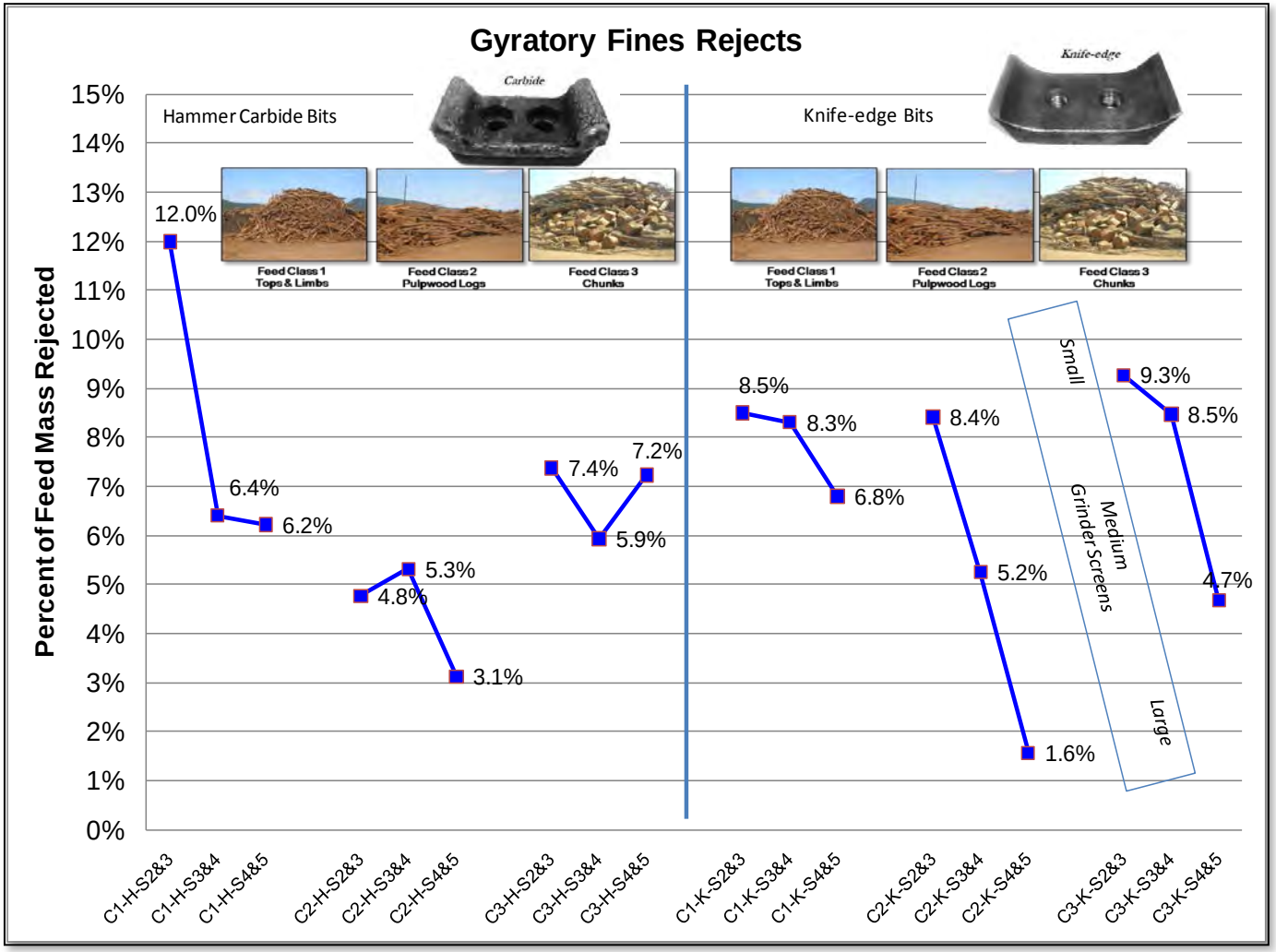


But total resizing cost relatively small – only impacts range $0.38/ODST

trivial…

Millsite Screen Fines

- Significantly reduced < 1/8th inch fines using larger grinder grate sizes and with larger piece sizes.
  - Fines reject rates vary significantly – from 1.6% to 12.0%



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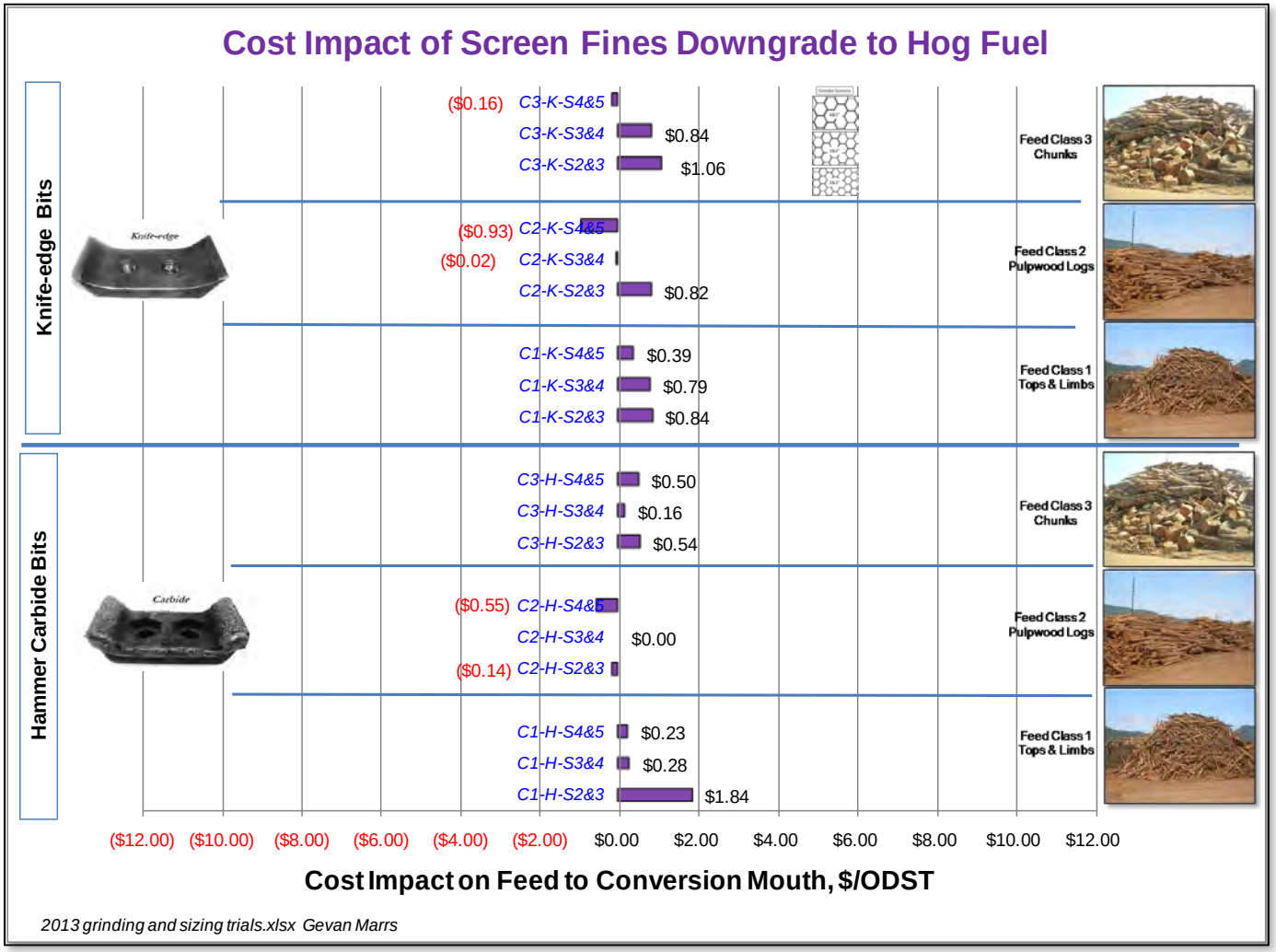
Cost Impact of Fines Downgrade

- Assume fines go to hog fuel at $45/ODST value
- Spread reduction from gate price to hog fuel over remaining feed to conversion.



Feedstock cost to conversion impact range is $ 2.77/ODST

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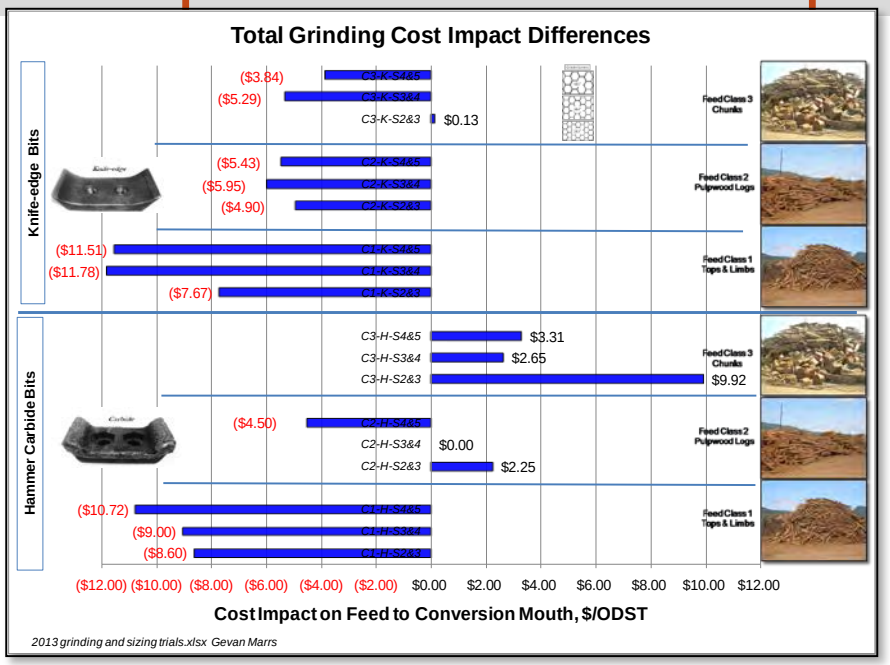
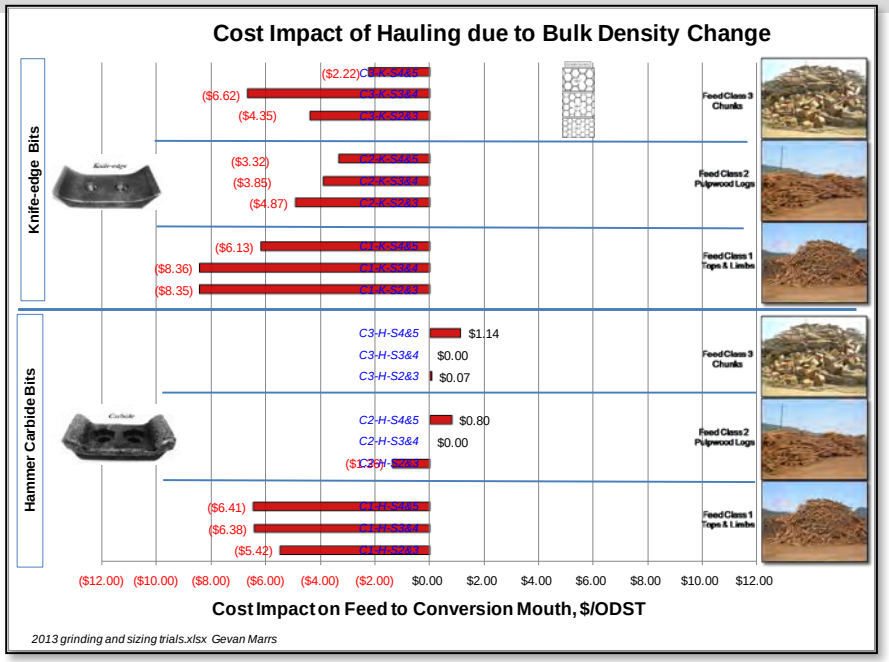
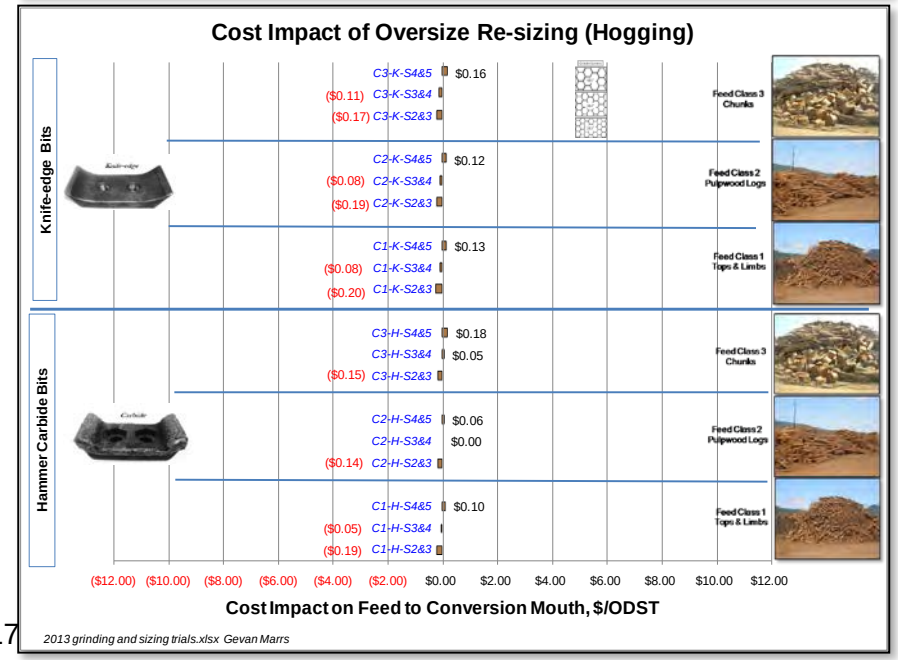
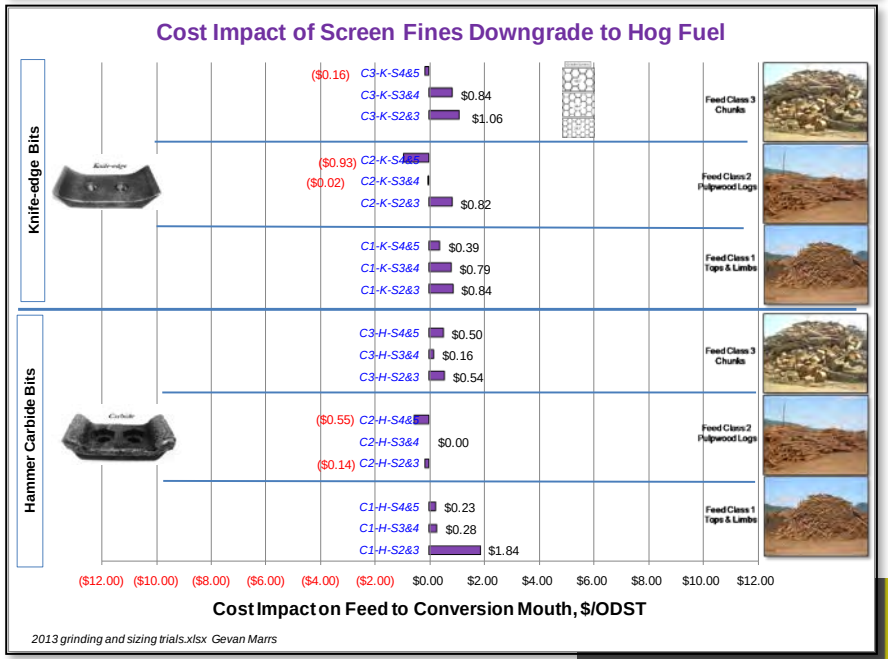
Comparison of Cost Impacts



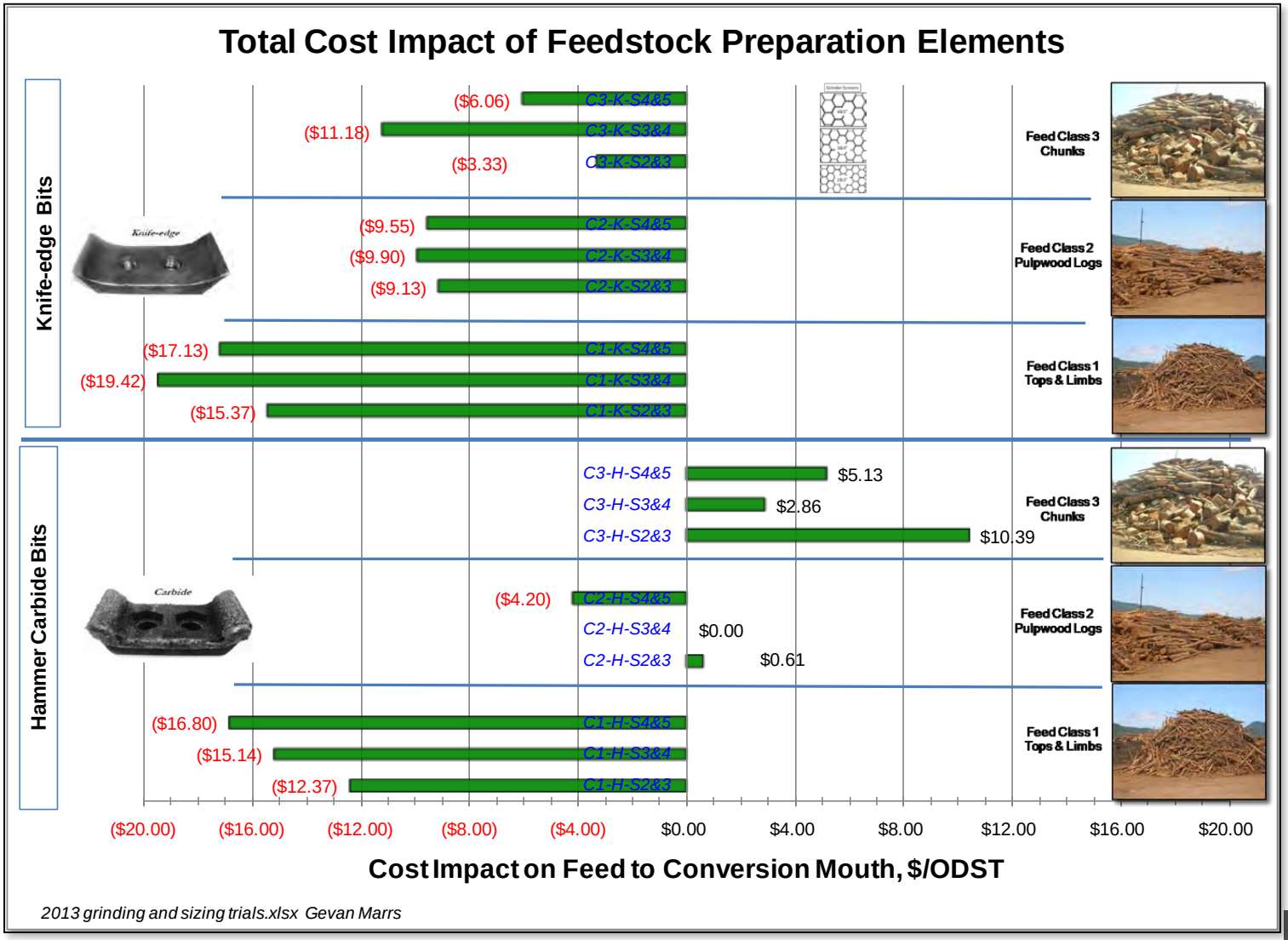






Total Cost Impact of 4 elements

- Most of the 4 cost impacts are inter-related
- Total effect is sum of the 4 difference from same base case.



Range of total effect impact is **$29.81 / ODST**

Conclusions

1. Lowest grinding power was achieved by: a)Starting with smaller piece sizes, b) grinding to larger final sizes, and c) using (sharp) knife bits instead of (blunt) hammer bits.
2. Under the assumptions used here, **total grinding costs** are the largest impact factor, in the directions noted above, to the tune of $22 / ODST impact range.
3. Highest bulk density was obtained with: a) Smaller feed piece size class – tops & limbs, otherwise, with b) knife bits compared to hammer.
   – The reason for higher bulk density with tops and limbs is probably due to some combination of higher wood density, greater fines content due to drier wood and higher bark content.
4. Higher bulk density (as long as moisture low enough) reduces **hauling cost** and is the second most powerful economic effect, having an impact range of $11 / ODST.
5. Oversize material production is, logically, almost totally controlled by grinder screen size.
   – The economic impact of **resizing oversize** is very small – impact range of <$0.40 / ODST.
6. Fines downgrade to hog fuel is mostly related to grinder screen size, particularly for tops and limbs with hammer bits.
   – The economic impact of **fines downgrade** is relatively small – impact range of <$3 / ODST.

Conclusions continued

7. Overall, the **total net impact** of variable assess here can be quite large – the impact range is $30 / ODST.
   - Because both lower total grinding costs and higher bulk density were achieved consistently with Tops and Limbs, this Feed Piece Size class was consistently economically favored for both bit types.
   - For other Feed Class piece sizes (pulp logs and chunks), knife bits were economically favorable to hammer bits, mostly due to lower grinding costs and higher bulk density for knife bits.

Caveats:

1. Knife bits are somewhat more expensive and likely have higher maintenance costs and those were not tested in this trial.
2. It is probably not economically realistic to sort material sizes classes in practice. That is, avoiding grinding material after one is already set up at the harvesting site is not logical, even if slightly more expensive on a unit cost.
3. Some of the bulk density benefit of Tops and Limbs is probably due to higher bark content creating more fines- but these have lower conversion yield and is not (yet) accounted for here.
   - *(A rough estimate was made for Tops & Limbs – about $4.30 lower value)*

Recommendations

- A major negotiable, controllable specification for feedstock is particle size average and distribution through the gate.
- **It appears to be in the best interest of the feedstock producer and consumer jointly to allow (relatively) larger sizes to come through the gate, reducing production costs significantly and lowering fines downgrade costs.**
- Oversize in the range of 10 to 15% can be re-sized at very low costs in fixed, electrically-powered hammer hogs, netting an overall significant cost advantage that can be shared in some manner between producer and consumer.
- Producers should carefully consider any increased maintenance costs for knife-type bits and determine if the advantages (grinding and hauling cost) will far more than offset these.