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System dynamics analysis of strategies to reduce energy use in aluminum-intensive sectors

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Aluminum Recycling

- Aluminum use is increasing throughout the economy
- Aluminum is infinitely recyclable … in theory
- Amount, type of alloying elements in recycled streams difficult to predict and control
- Recycled alloys are generally not separated
- Alloying requirements limit the amount of secondary (recycled) aluminum that can be re-used in some applications

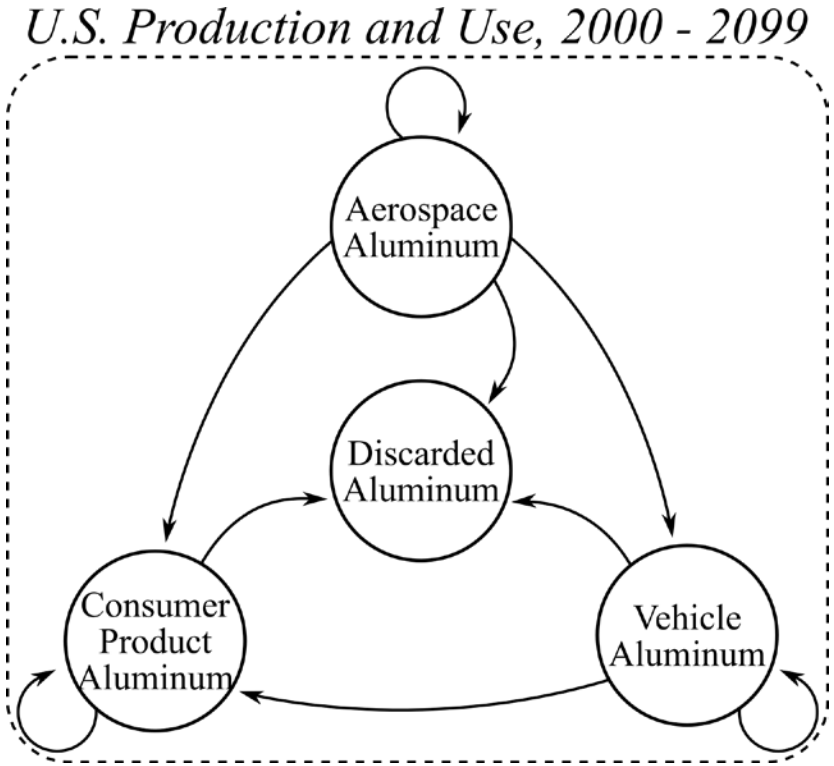
[1]

Objectives

- Use system dynamics modeling to quantify **technical potential** of strategies to reduce energy impacts of aluminum use and re-use
  - Future work: Evaluate strategy feasibility and non-energy impacts
- Account for …
  - Distinct aluminum use types
  - Reusability limitations caused by alloying elements
  - Delays from time aluminum spends in use

Is it possible to decouple aluminum use from energy consumption?

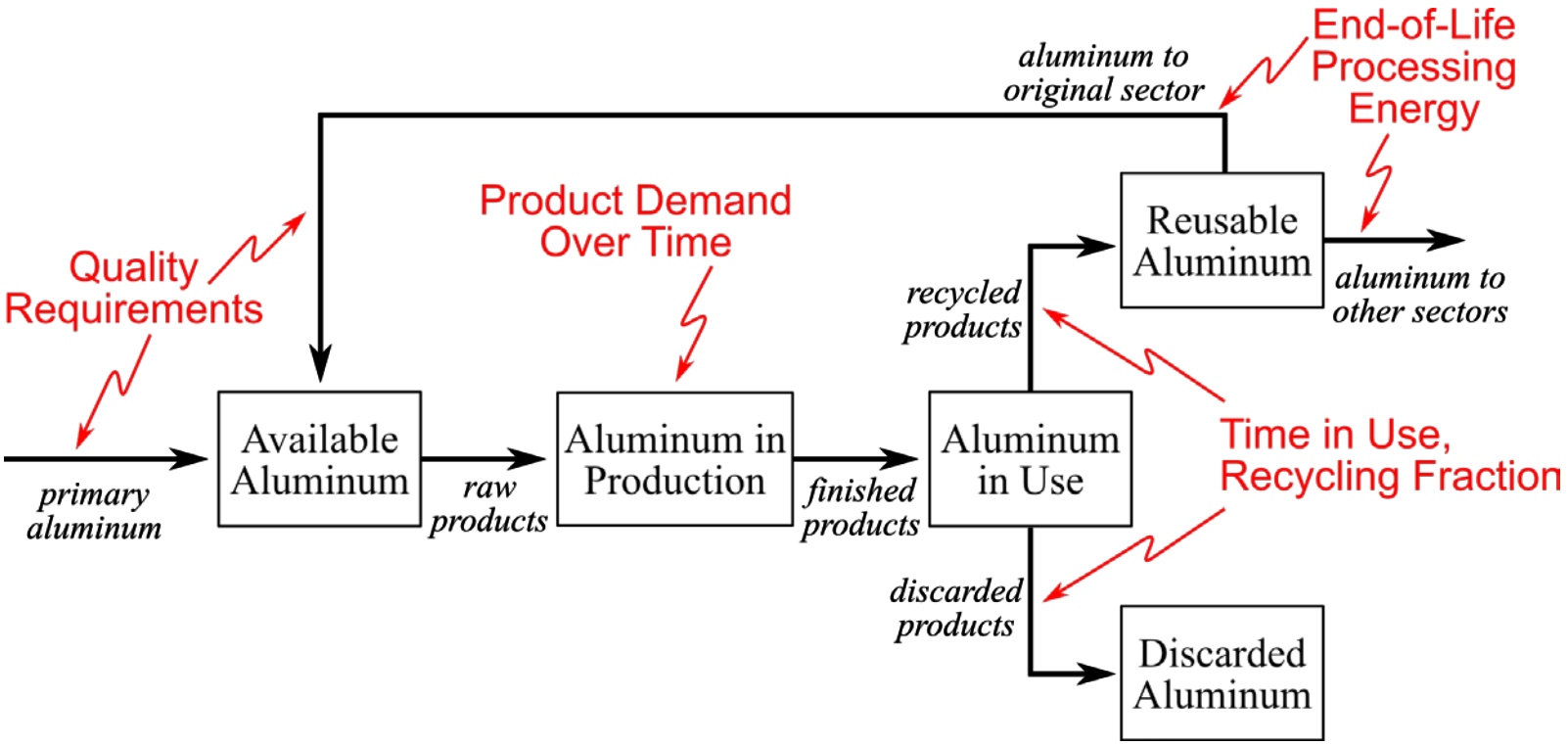
Model Structure



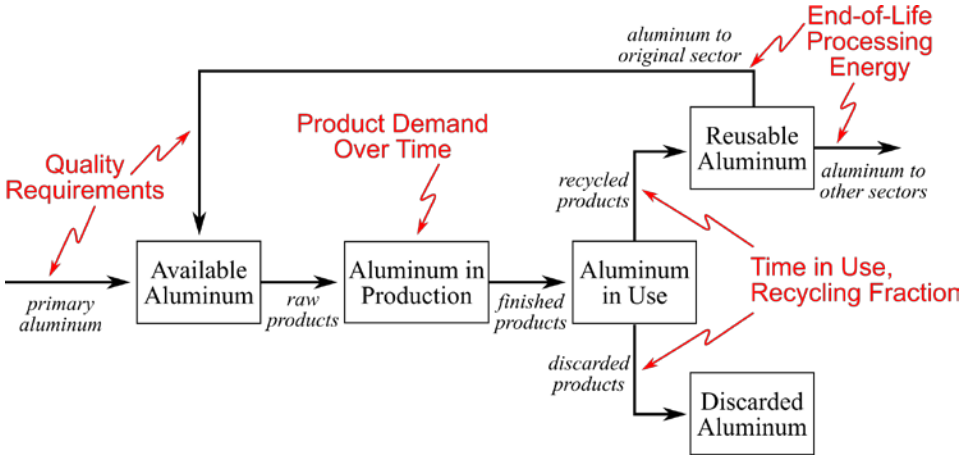
- Model scope is U.S. only
  - Exports, imports excluded
- 100 years time span
- Three aluminum intensive sectors
  - Buildings sector is excluded
- Recycling and “downcycling”, but no “upcycling”

Model Structure

- Five aluminum stocks per sector: Available, In Production, In Use, Reusable, and Discarded
- Exogenous data and endogenous parameters control aluminum flows between stocks



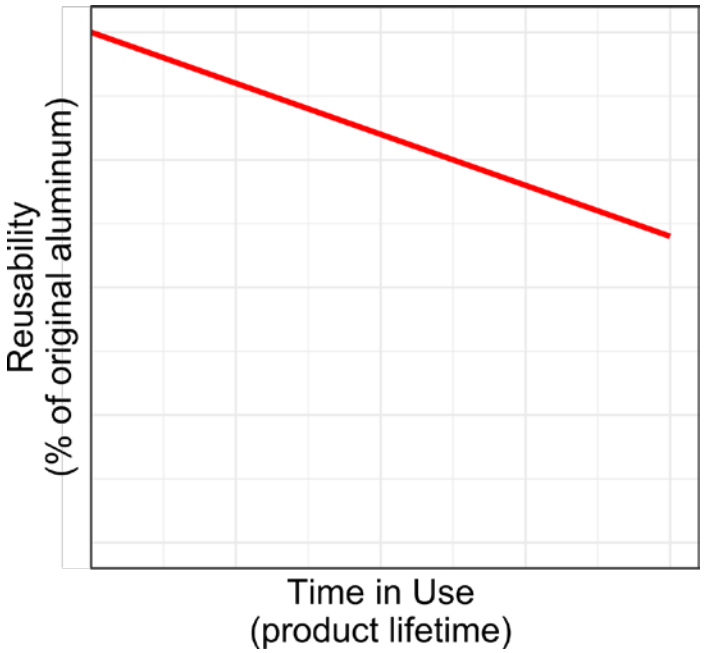
Assumptions



- Aluminum tends to be re-used within a sector before being sent to other sectors
- All secondary aluminum can be re-used somewhere
- Secondary aluminum processing remains static over time - no major technological advances
- Future demand growth in all sectors is assumed to be approximately the same as pre-recession growth

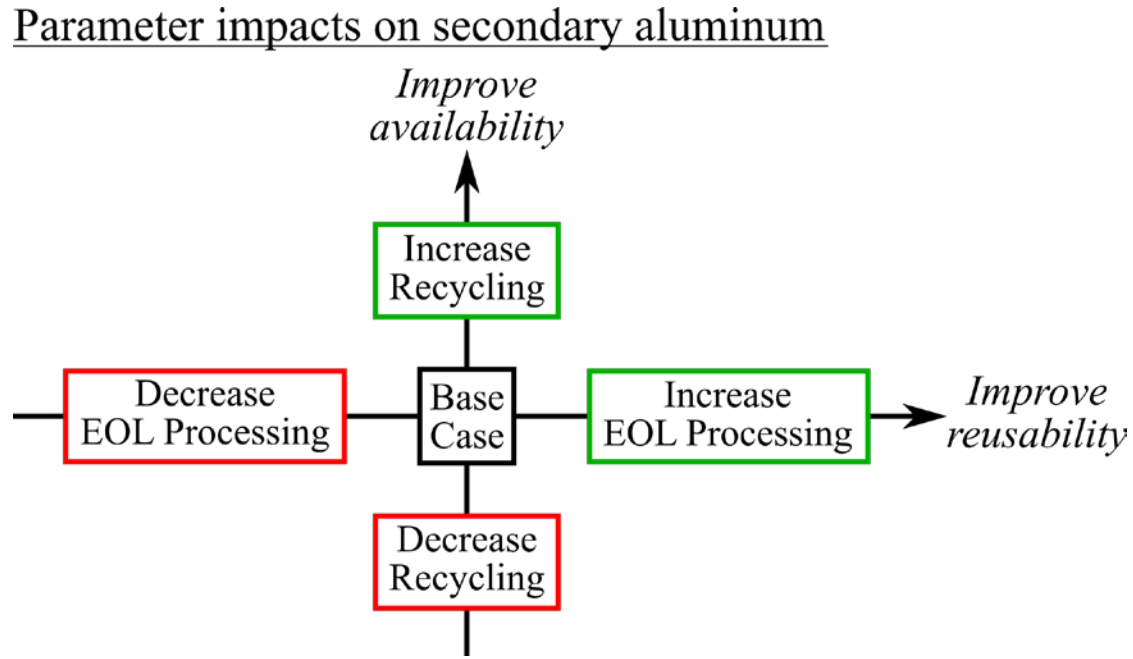
Challenges

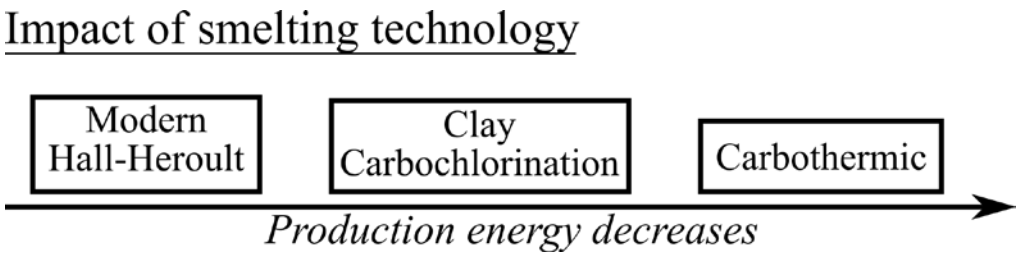
- Lack of detailed data on alloy types in use, how specific alloys change over time
- "Quality" parameters used to model qualitative trends in secondary aluminum re-use



- Products that are in use longer will contain older alloys at time of recycling
- Longer lifetime leads to …
  - Lower reusability in original sector
  - Fewer new products manufactured

Analysis Parameters and Scenarios





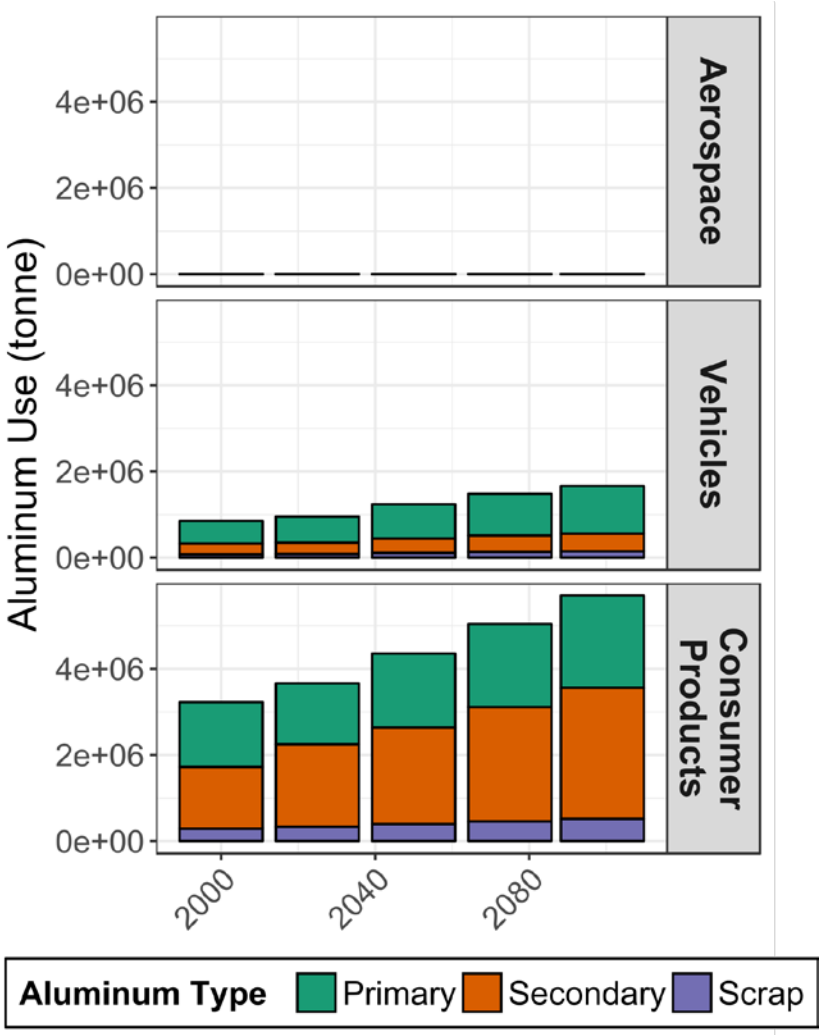
Scenarios cover …

- Improving secondary aluminum **reusability**
- Increasing secondary aluminum **availability**
- Reducing primary aluminum **production energy**
- Combinations of the above

Base Case Scenario: Results by Sector

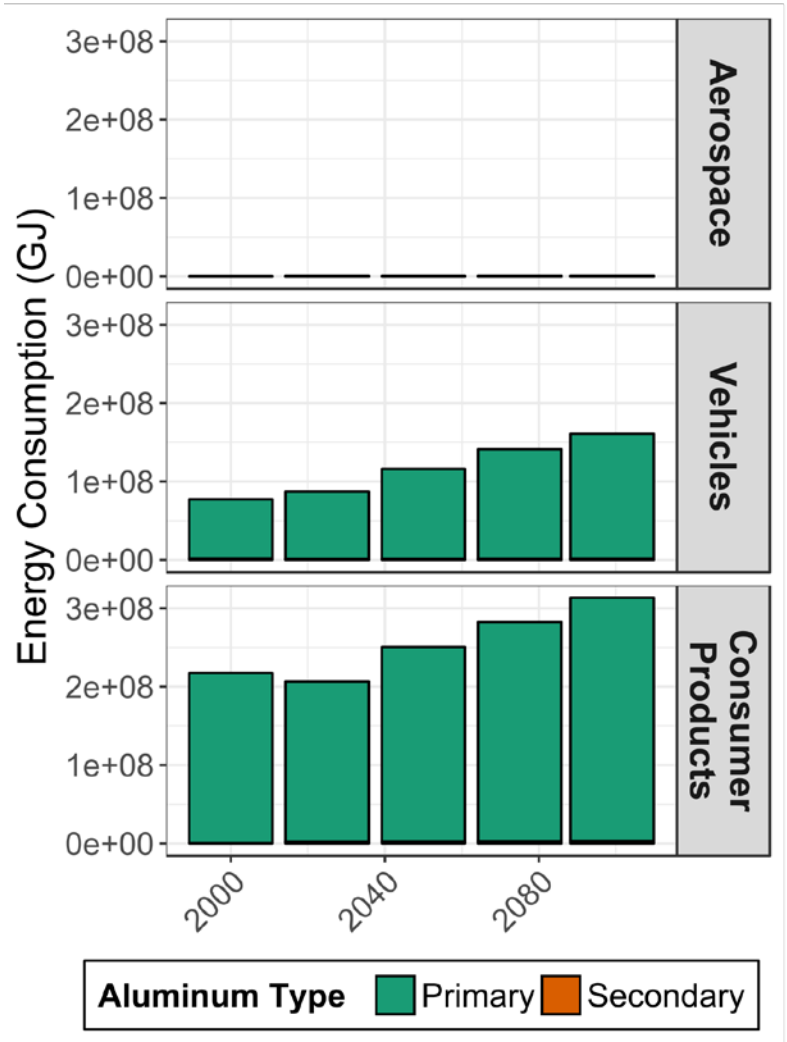
- Consumer products sector dominates consumption
- Consumption of all types of aluminum increases over time
- Aerospace sector requires highest fraction of primary aluminum, then vehicles, then consumer products

Annual Aluminum Use (tonne)



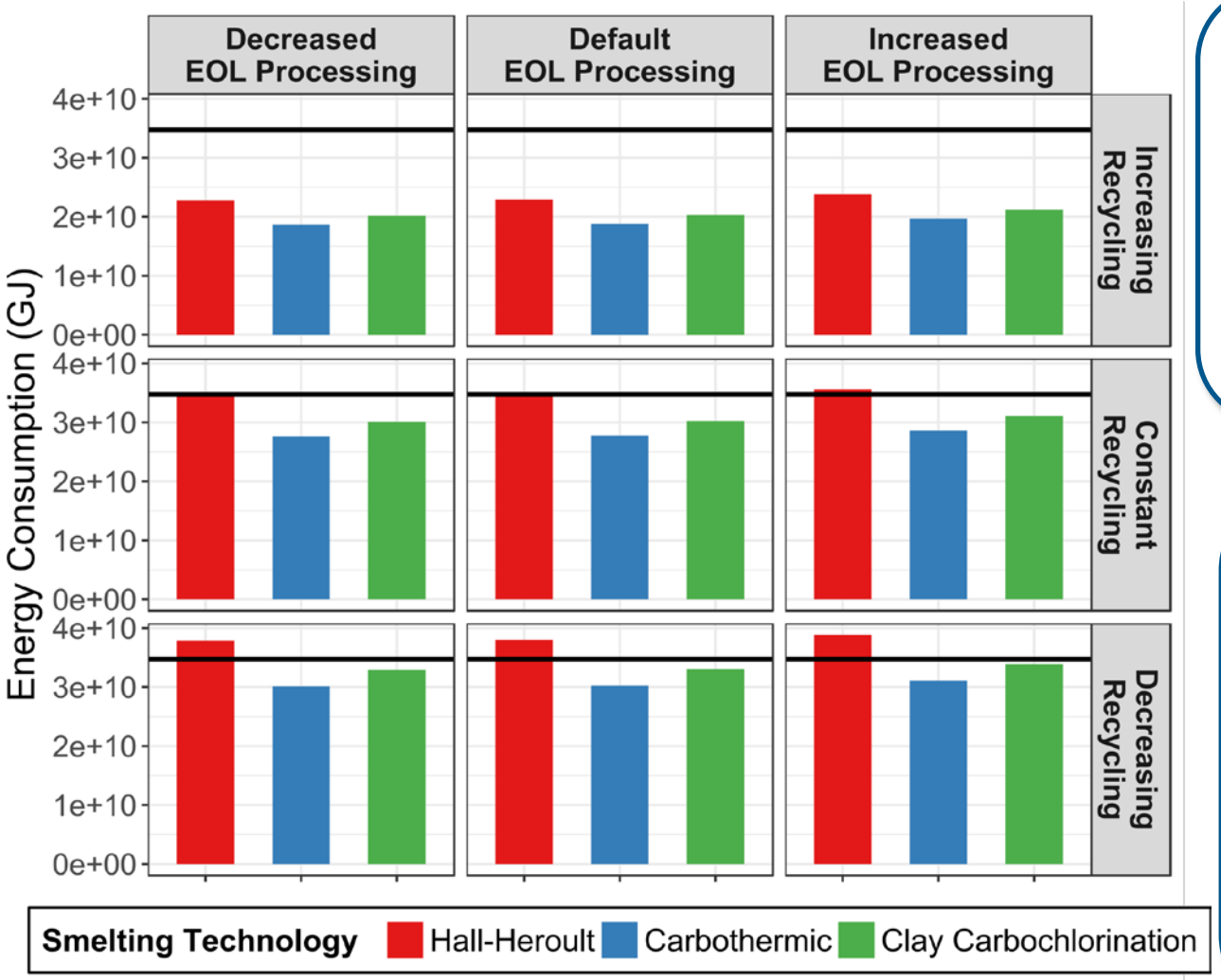
Base Case Scenario: Results by Sector

Annual Energy Consumption (GJ)



- Energy consumption also dominated by consumer products
- Energy for EOL processing and secondary aluminum is insignificant compared to primary aluminum energy
- Energy, aluminum use are heavily coupled

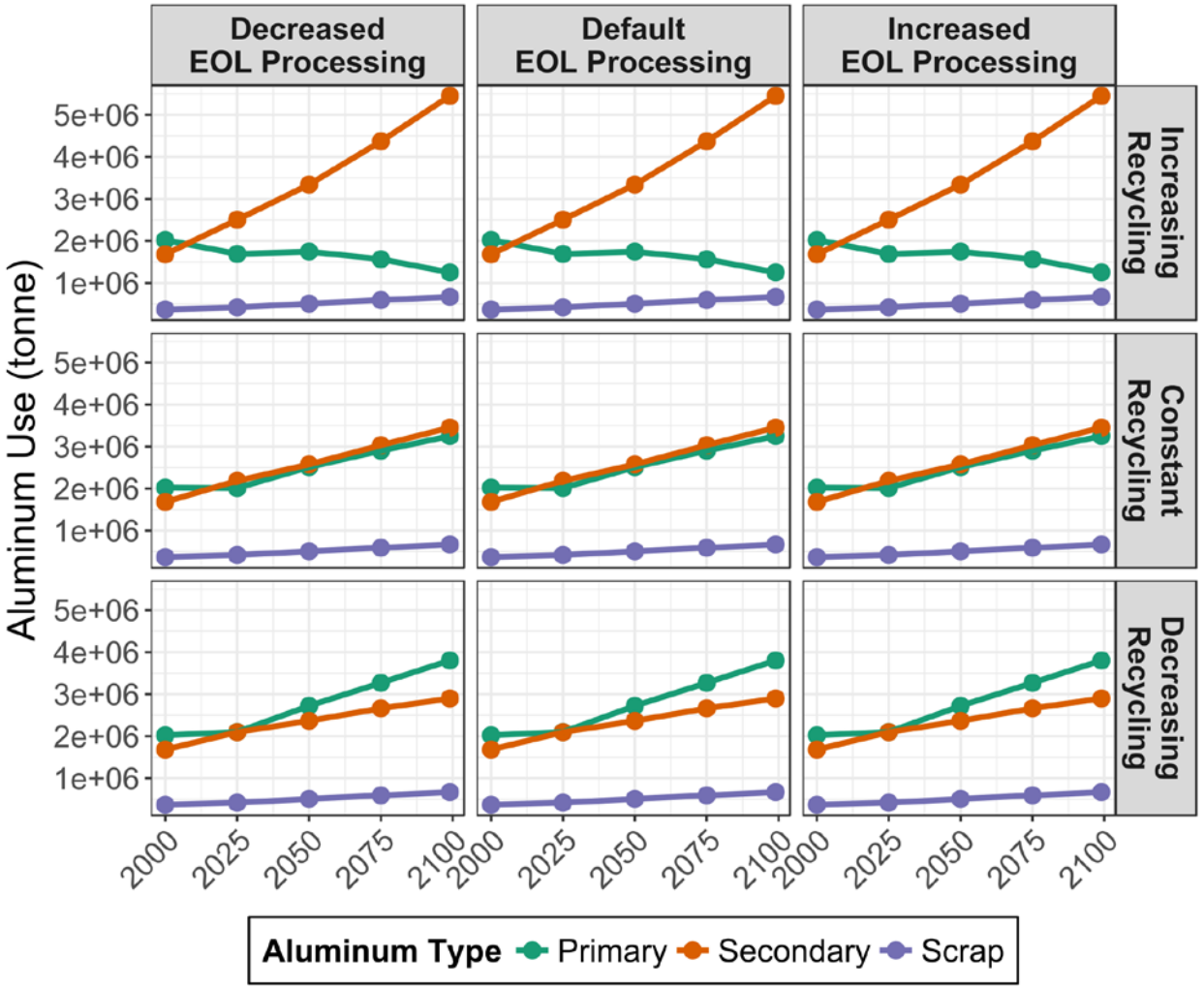
Cumulative Energy Consumption



EOL processing has minimal impact on cumulative energy consumption.

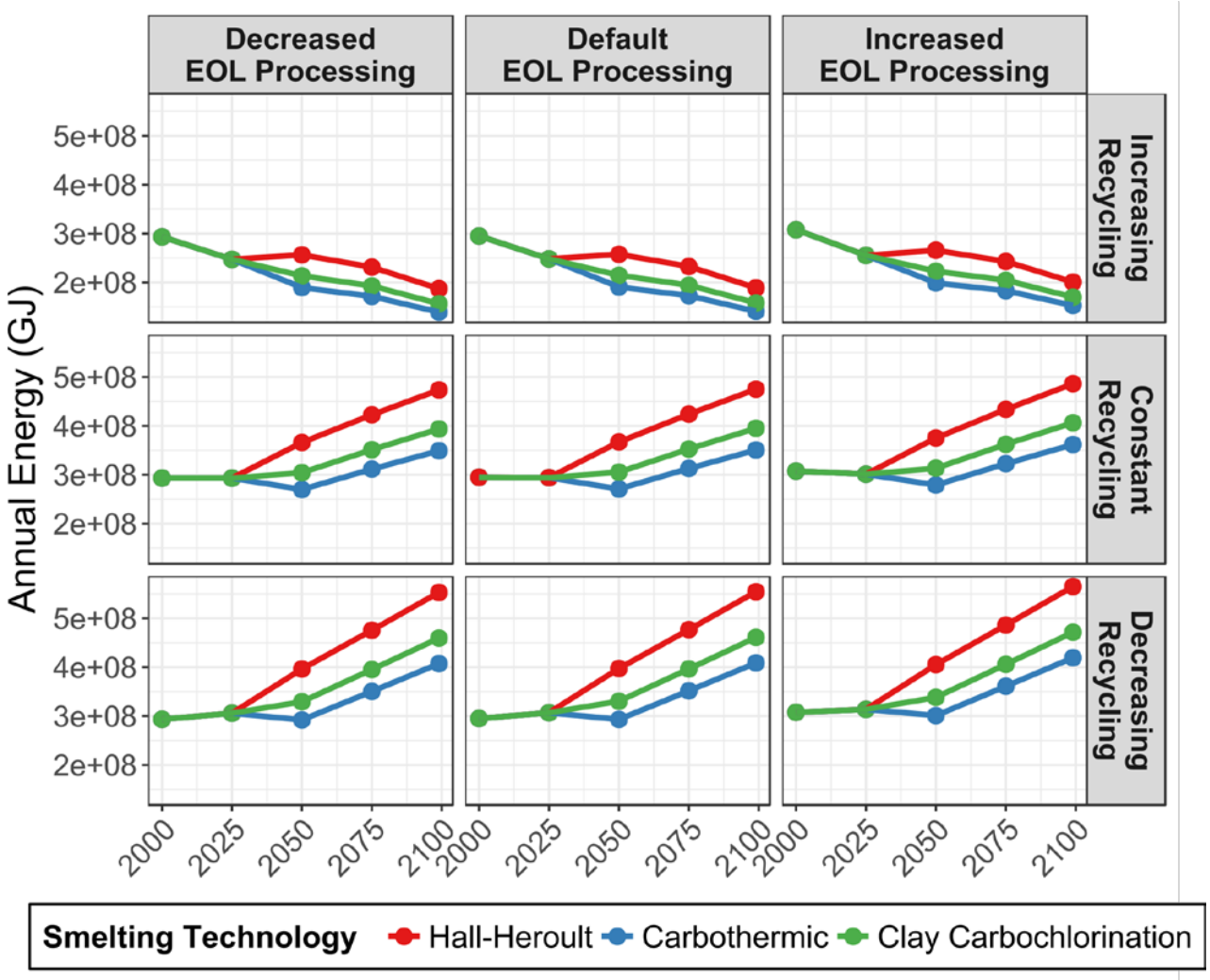
Increasing the recycling fraction and/or improving smelting process reduce energy significantly.

Aluminum Use Over Time (select points)



Primary aluminum consumption only decreases over time if the recycling fraction increases over time.

Energy Consumption Over Time (select points)



Recycling fraction must increase in order to decouple energy use from aluminum use.

Model Extensions and Future Work

- Economics, price impacts and purchaser behavior
  - Either as a new standalone model or as an extension to the existing model
- Expand scope to include imports, exports, international demand
- In-depth analysis of scenarios
  - How “easy” or “difficult” is improving smelting technology vs. increasing use of recycled aluminum?
  - What performance metrics are most relevant to scenario evaluation?
- Large-scale economic impacts
- Explicitly incorporate scrapping companies

Thank You

Questions?

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Image Credits

1. Kao et al, Soda Can Recycling and How it Affects the Environment. Accessed June 13, 2017.

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