Evaluating Opportunities for a Circular Economy

An investigation of economic and decision-making factors underlying recycling, reusing and remanufacturing habits in U.S. consumers and manufacturers

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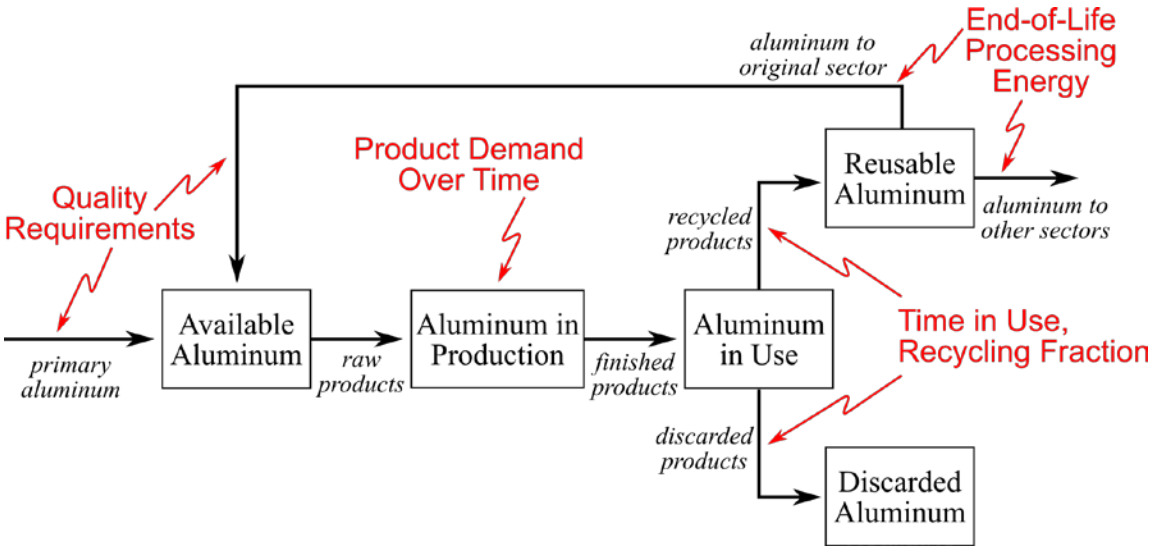
Summary of Previous Work

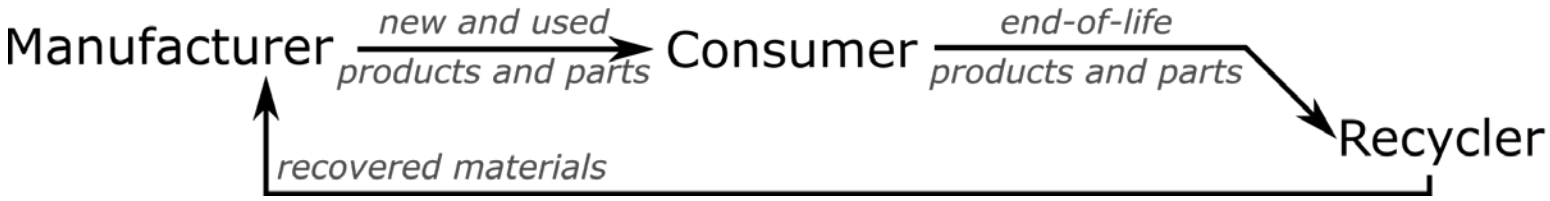
System dynamics (SD) analysis of strategies to reduce energy use in aluminum-intensive sectors

- SD modeling used to quantify **technical potential** of various strategies to reduce the energy impacts of aluminum use and re-use
- Accounted for distinct aluminum use types, reusability limitations imposed by alloying elements, delays from time aluminum spends in use



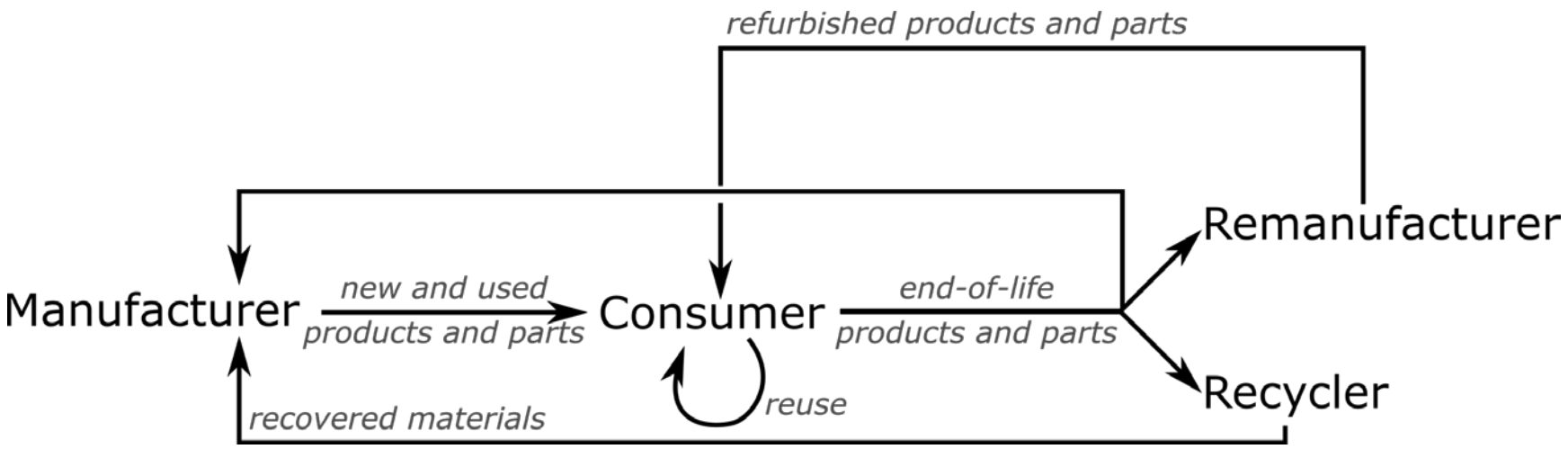
General conclusion: Increasing the amount of recirculating (secondary) aluminum is the only way to decouple energy consumption from aluminum use

Achieving Circular Material Flows



- Previous work focused on simple end-of-life recycling system
- Recycling can get cumbersome as more products are recycled

Achieving Circular Material Flows



- Previous work focused on simple end-of-life recycling system
- Recycling can get cumbersome as more products are recycled
- This work expands the focus to include a more complete recycling and reuse system
- Energy, effort required for recycling can be (relatively) high
- Remanufacturing and similar efforts can require less energy
  - But: Shifts in consumer purchasing habits and manufacturing practices may be required

Objectives

Within a U.S. context …

Assess current product systems with varying degrees of circularity

- Vehicles
- Consumer electronics

Investigate *barriers* and *drivers* for circular economy methods

- Recycling
- Reusing
- Remanufacturing
- Refurbishing

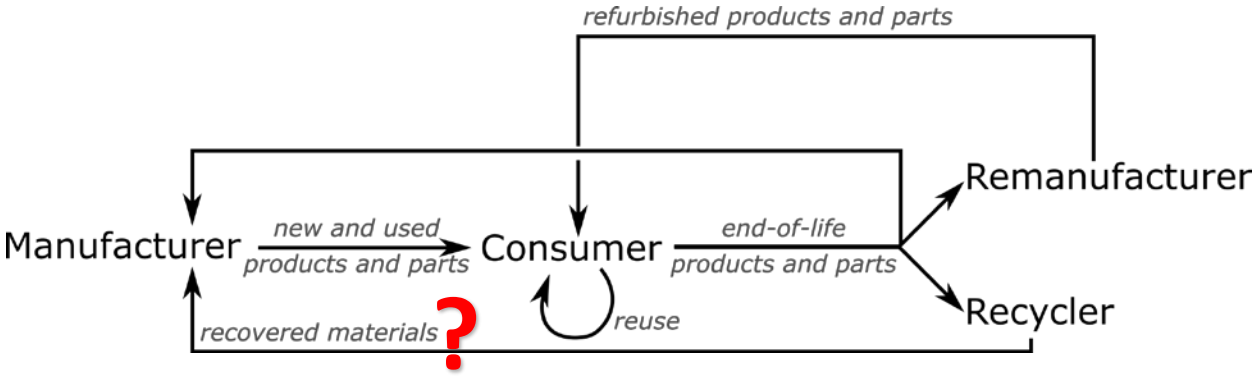
Construct "blue sky" circular economy scenarios and gauge their attainability relative to current status

Future work

Presentation Overview

- Learn by example: Assess a highly circular product system, a moderately circular system and a mostly linear system
  - Which aspects of each product system promote circularity?
  - Which aspects hinder circularity?
  - How are the product systems different, and how might these differences be influencing circularity?
  - Do the highly circular and less circular systems have anything in common?
- Draw some conclusions around how each product system might improve in circularity
- Future work: Moving towards quantitative blue sky scenarios

Circular System Overview: Vehicles



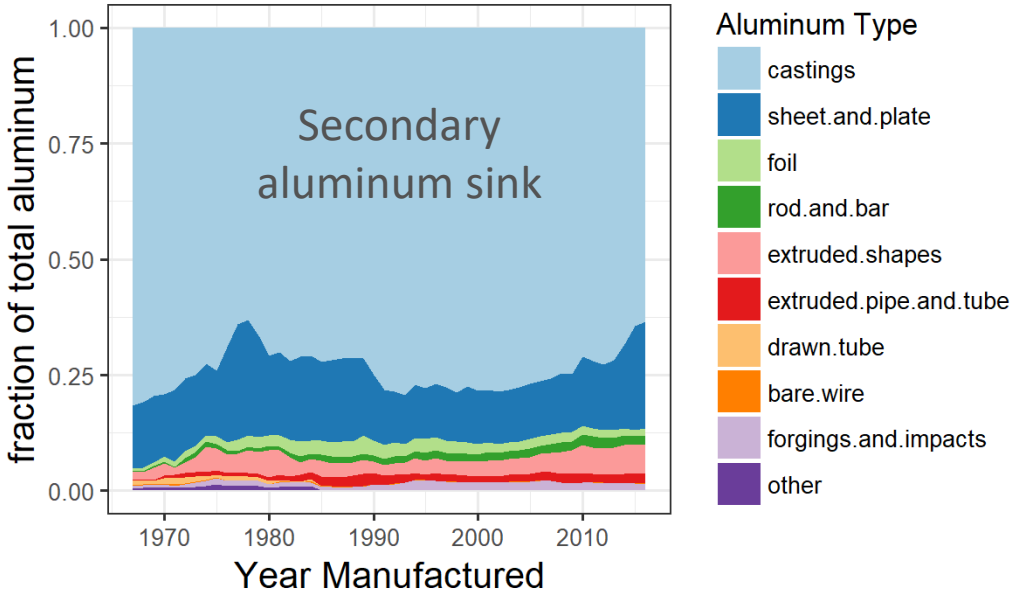
- 95+% of end-of-life vehicles are re-sold as used, stripped for useful parts and/or sent to scrapping (Jody et al., 2011)
- Recovery rates vary by material; can be as high as 90% (Kelly and Apelian, 2016)
- No information on how recovered materials are used (Wang, 2018)
- Extensive market for used vehicles
- Replacement parts are a mix of new and used or refurbished

Circular System Overview: Vehicles

- Shifts in materials used for new vehicles will complicate future use of secondary materials (Modaresi and Muller, 2012)

<u>Summary of Barriers:</u>

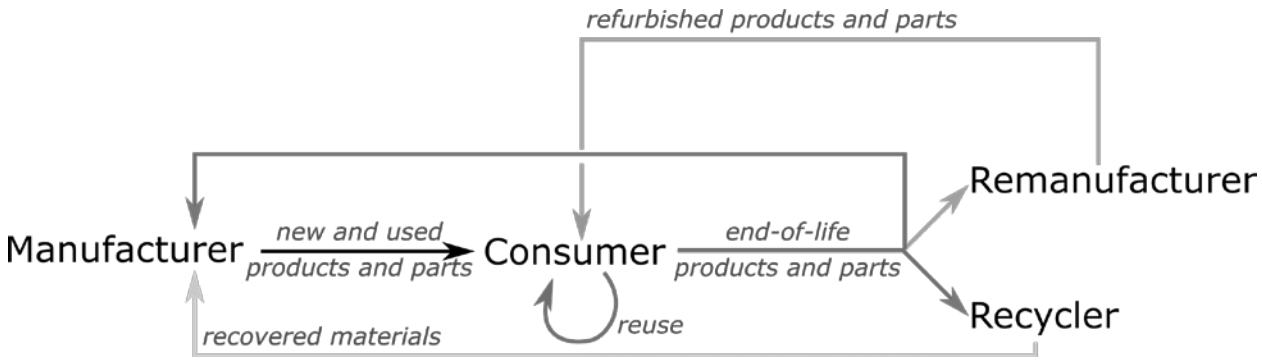
- Secondary materials identification and sorting technologies (Li et al., 2011)
- Product design: Maintain structural requirements when using secondary raw materials (Noshadravan et al., 2017)



Aluminum Association (2018)

- EOL return rate is unlikely to reach 100% (Lakhan, 2016), but is already high

Circular System Overview: Consumer Electronics



- Manufacturer and retailer take-back programs are moderately widespread but not as widely used by consumers (Saphores et al., 2006; Electronics Takeback Coalition, 2016; Fang and Rau, 2017)
- Circularity is slowly increasing, possibly driven by demand for rare earth elements and other valuable materials (Tansel, 2017)
- Used market is also growing

Circular System Overview: Consumer Electronics

- Electronics recycling processes require economies of scale to achieve profitability (Rahman and Subramanian, 2012)
  - Improved technologies for secondary material sorting and identification will also promote profitability
- Refurbishment and similar processes will likely be more economical for manufacturers, considering the short product lifetimes (Parjuly and Wenzel, 2017)
  - Products are sometimes designed to prevent non-manufacturer upgrading or resale
- Relatively little buy-in from consumers on electronics recycling
  - Increased effort compared to vehicles
  - Low or no monetary incentive

Why the differences?

Convenience and Practicality

- Product size: Excess electronics products can be stored easily
- Integration of recycling/refurbishing with purchase: Vehicle trade-ins are normalized and widely used

Monetary Incentive

- Retailers and manufacturers: Amount of material in each product; ease of recovery and separation
- Consumers: Potentially large benefit from returning EOL vehicles; uncertain, possibly non-monetary benefit for returning EOL electronics
- Consumer perceptions of value and quality

Culture

- Strong culture around keeping and maintaining cars in the U.S.
- Less so for consumer electronics

Summary and Next Steps

- This work investigated barriers and drivers for the circular economy by assessing the current status of several product systems with various degrees of circularity.
- Currently: Have a qualitative understanding of how circularity can be promoted across several product systems
- Next fiscal year: We'll be working on developing relationships and collaborations with industrial stakeholders to continue this project with more detailed, quantitative information

Thank you

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