Material Recovery and Reprocessing Modeling

James Levis, PhD
Research Assistant Professor
Department of Civil, Construction, and Environmental Engineering

Morton Barlaz, PhD
Professor and Head
Department of Civil, Construction, and Environmental Engineering

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Significance of Recovery and Reprocessing

- Key place for savings in most LCA besides savings from energy production
- Important for recovery of scarce and environmentally "expensive" resources
- Complicated as it takes place outside the waste management system as well as global in scope

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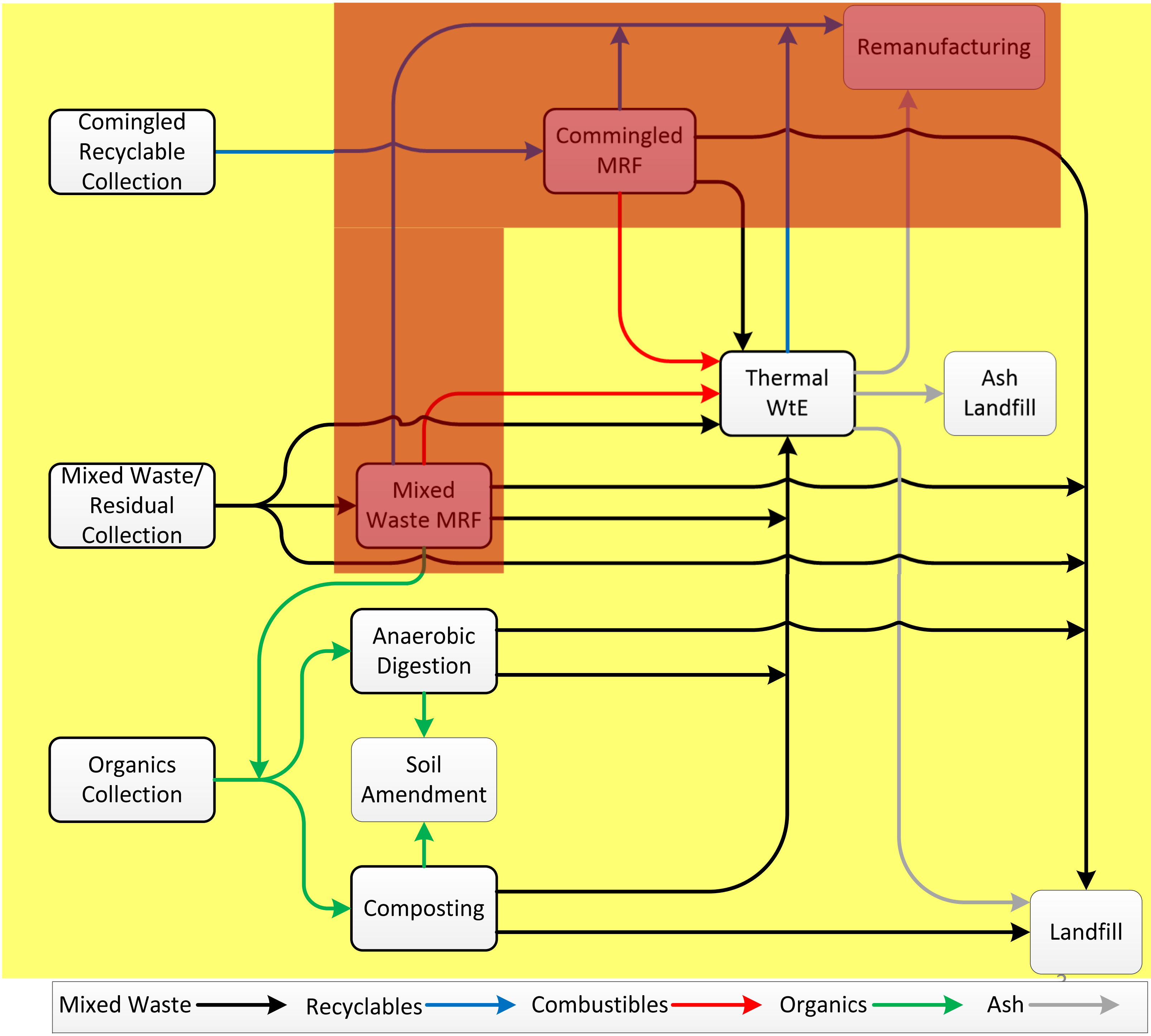
Solid Waste Systems



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MRF Types

- **Single-Stream**
  - Accept one stream of comingled recyclables
- **Dual-Stream**
  - Accept two waste streams (fiber, containers)
- **Pre-Sorted**
  - Accept many streams of source-separated recyclables
- **Mixed-Waste**
  - Accept one stream of mixed waste with no source separation

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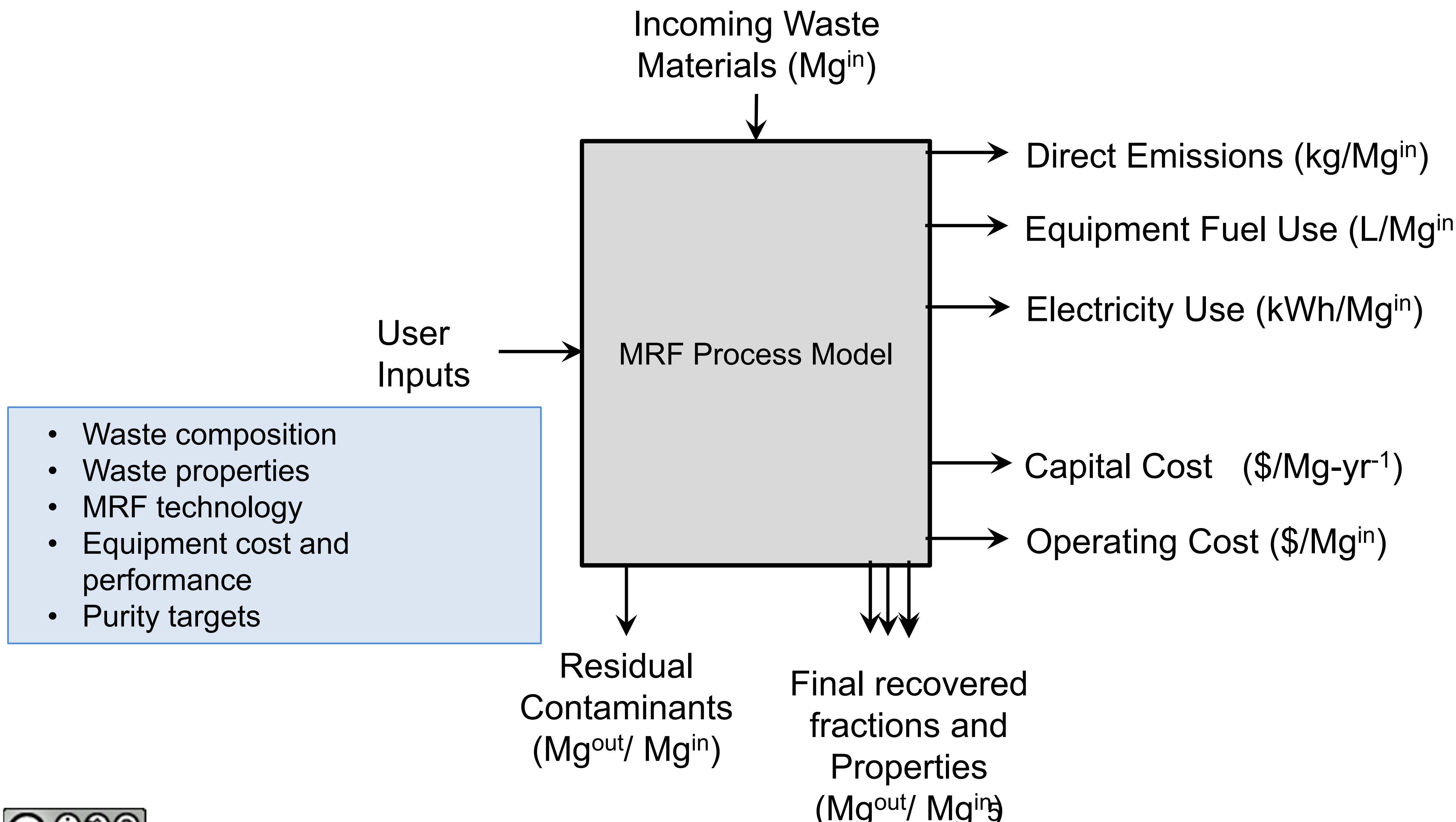
The MRF Process Model



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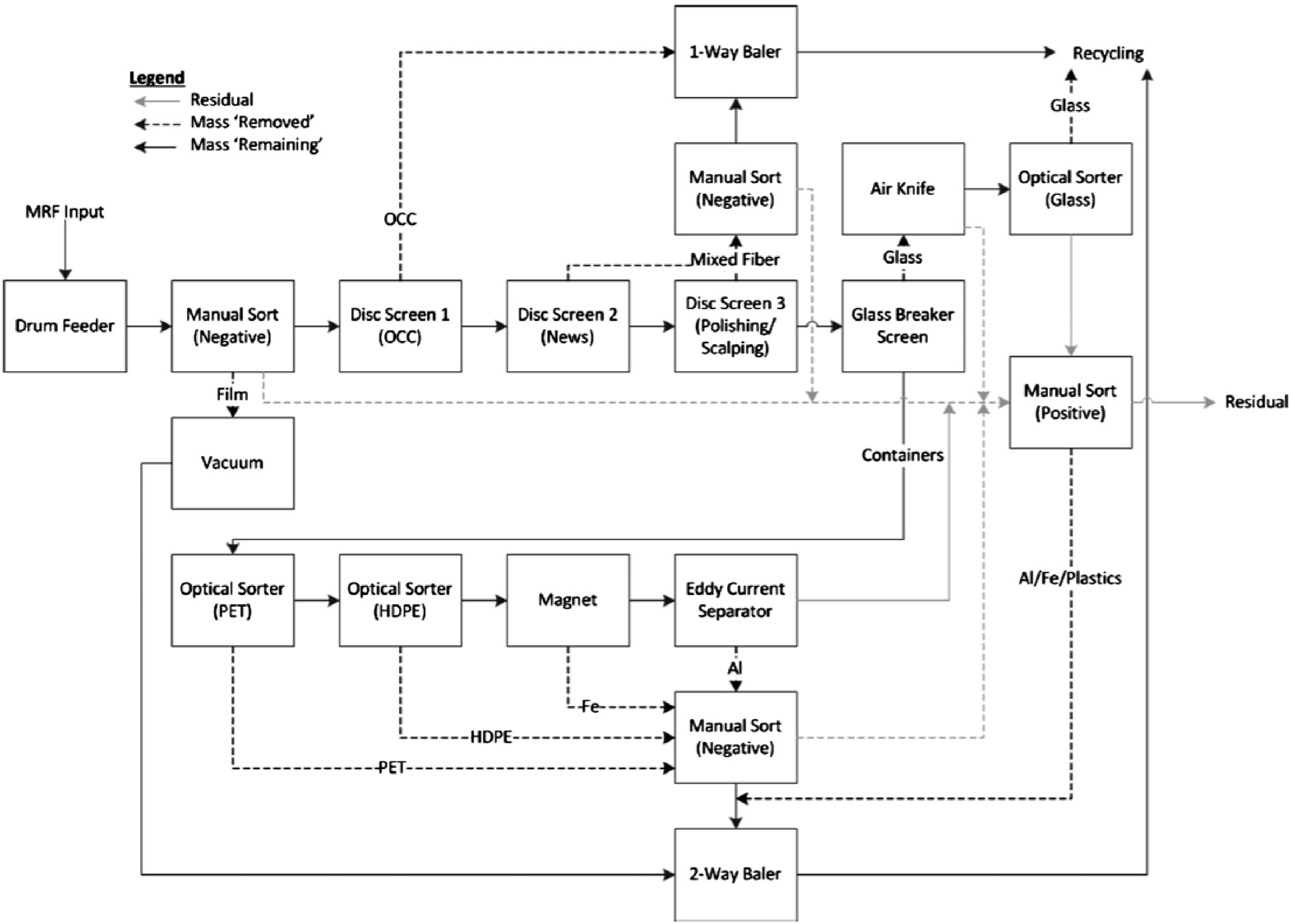
Example MRF Process Flow



Pressley, P.N., Levis, J. W. Damgaard, A. Barlaz, M. A., DeCarolis, J. D. (2014) Analysis of Material Recovery Facilities for Use in Life-Cycle Assess. *Waste Manag.*, 35: 307-317, DOI: 10.1016/j.wasman.2014.09.012.

MRF Models

- Empirical
  - Estimate outputs based on static inputs
  - Recovered fractions (and impurities) and properties set *a priori*
- Mechanistic
  - Estimate emissions, electricity/fuel use, mass and substance flows through each sub-process
  - Infinite combinations of equipment and hard to get real data
  - Variation in inlet waste stream(s)
  - Impurities

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Data Development

- Little MRF data publicly available
- Much of the data came from discussions with MRF operators, equipment vendors, and engineering judgment
- Example data types:
  - **Equipment**
    - Costs
    - Motor Size/Resource Use
    - Separation Efficiencies
    - Throughput
  - **Facility**
    - Costs
    - Sizing
    - Electricity Consumption

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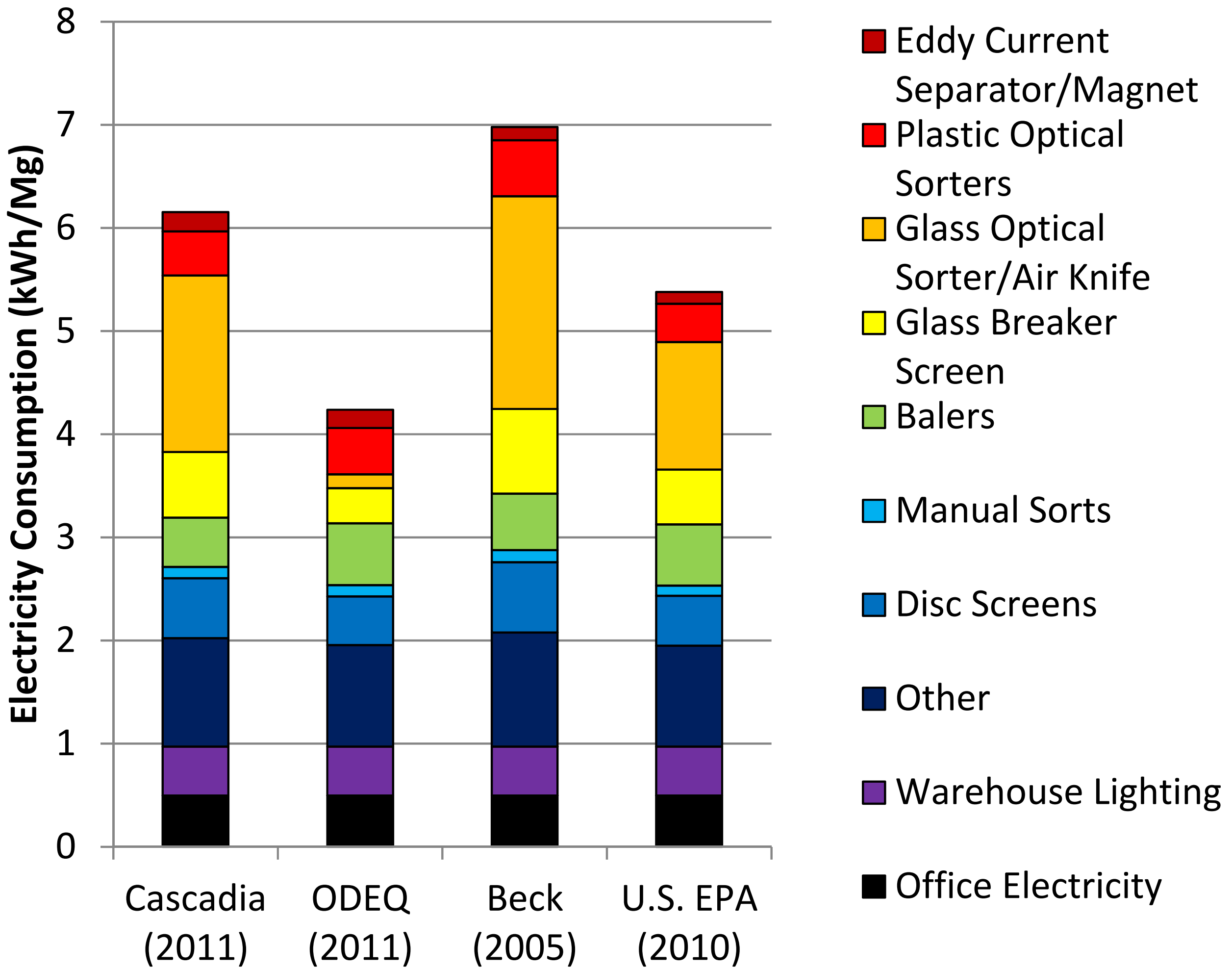
Single-Stream MRF Electricity Consumption by Waste Composition



- Input waste composition impacts electricity consumption for MRFs with identical equipment layouts
- Only glass separation equipment requires more than 10% of total consumption
- Office electricity and warehouse lighting each accounts for 8% of total electricity consumption

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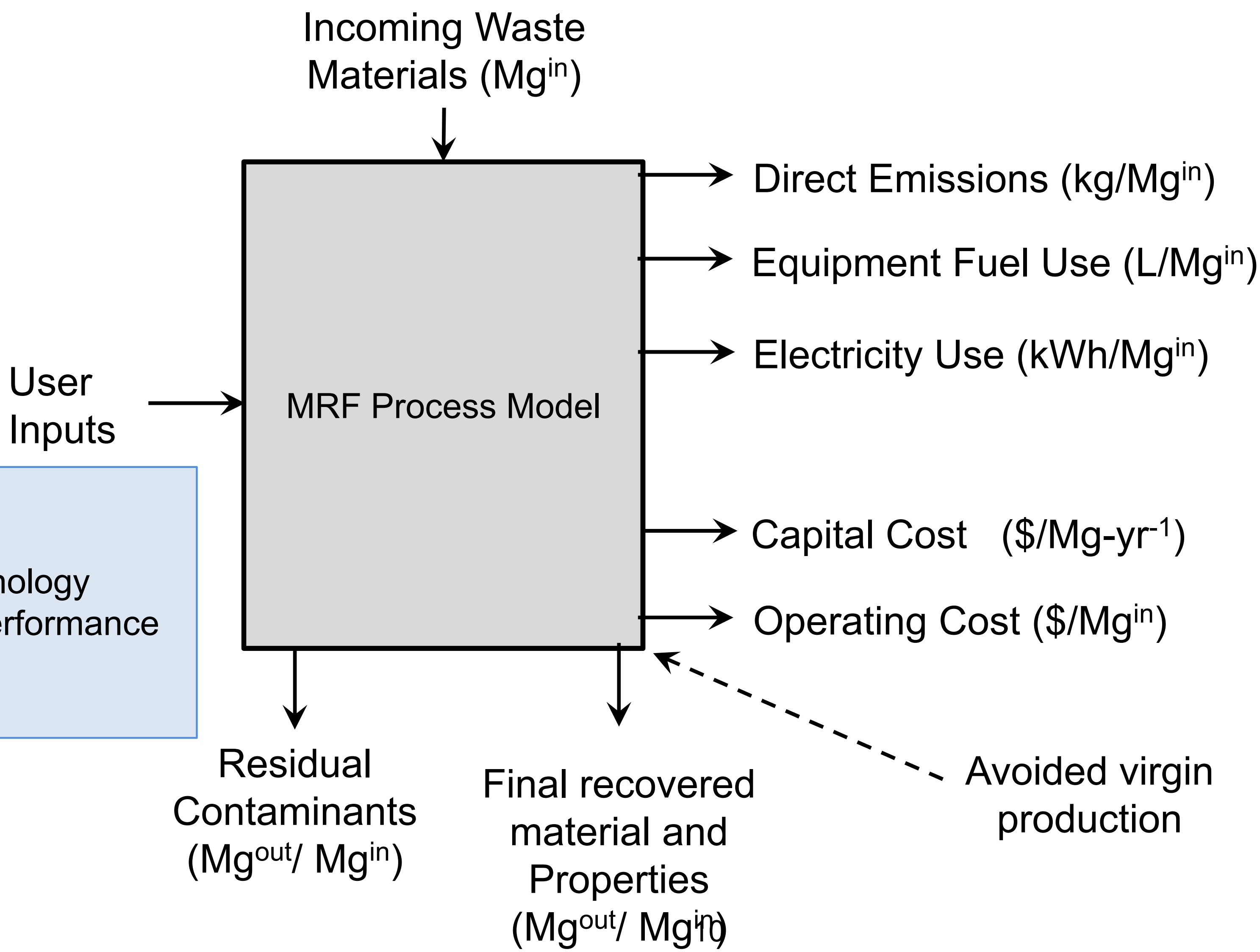
The Material Reprocessing Process Model



- Waste composition
- Impurities
- Remanufacturing technology
- Equipment cost and performance
- Purity targets
- End goal of material

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Material Recycling

- Material recycling: recovered materials are used for similar products (paper → paper; paper → cardboard)
  - The reprocessing has an environmental load that usually is less than the environmental load of virgin production, thus recycling may be environmental beneficial

recycling emissions = reprocessing emisisons - TSR·RVP·virgin emissions

- **TSR** is the **T**echnical **S**ubstitution **R**atio; 1 ton of waste paper produces 0.85 ton of paper product
- **RVP** is the **R**esponding **V**irgin **P**roduction at the market level; may be <1, never >1.
- **Reprocessing** is the process used to convert recyclable materials to a product with value (e.g., new OCC, Al ignot)
- **Virgin production** is the process for creating the virgin material typically taken from an external database.

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RVP – the responding virgin production

- How much is virgin production actually reduced due to 1 ton of material from reprocessing?
- May be less than 1 due to
  - Market reactions to perceived problems
  - Quality differences between products
    - Price differences due to non-problematic quality differences
  - Legal requirements

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Examples of values for remanufacturing processes -- Evaluated materials

- Office paper
- Newsprint
- Cardboard
- Corrugated board

} Fiber materials

- Glass
- Steel
- Aluminum
- High density polyethylene (HDPE)
- Low density polyethylene (LDPE)
- Linear low density polyethylene (LLDPE)
- Polyethylene terephthalate (PET)
- Polypropylene (PP)
- Polyvinylchloride (PVC)
- Polystyrene (PS)

} Plastics

Greenhouse gas (GHG) emissions from primary and secondary (recycled) material production were evaluated.

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Brogaard et al. 2014

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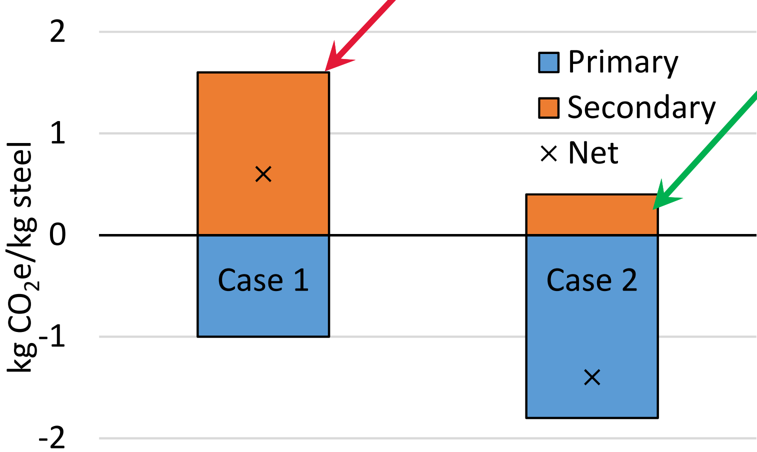
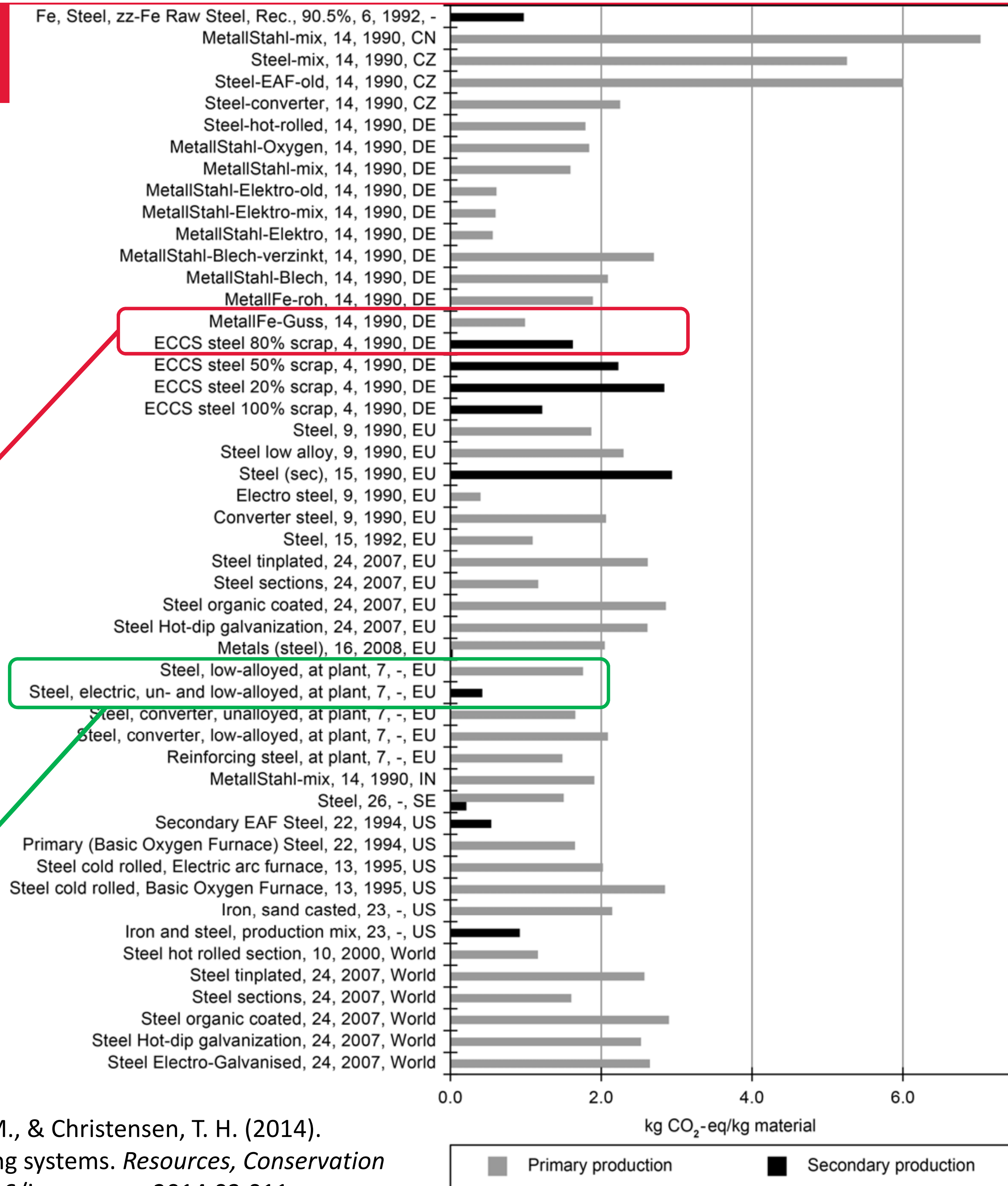
GHG Emissions from Production of Steel

- Benefits of recycling depend on choice of data





Brogaard, L. K., Damgaard, A., Jensen, M. B., Barlaz, M., & Christensen, T. H. (2014). Evaluation of life cycle inventory data for recycling systems. *Resources, Conservation and Recycling*, *87*, 30–45. https://doi.org/10.1016/j.resconrec.2014.03.011

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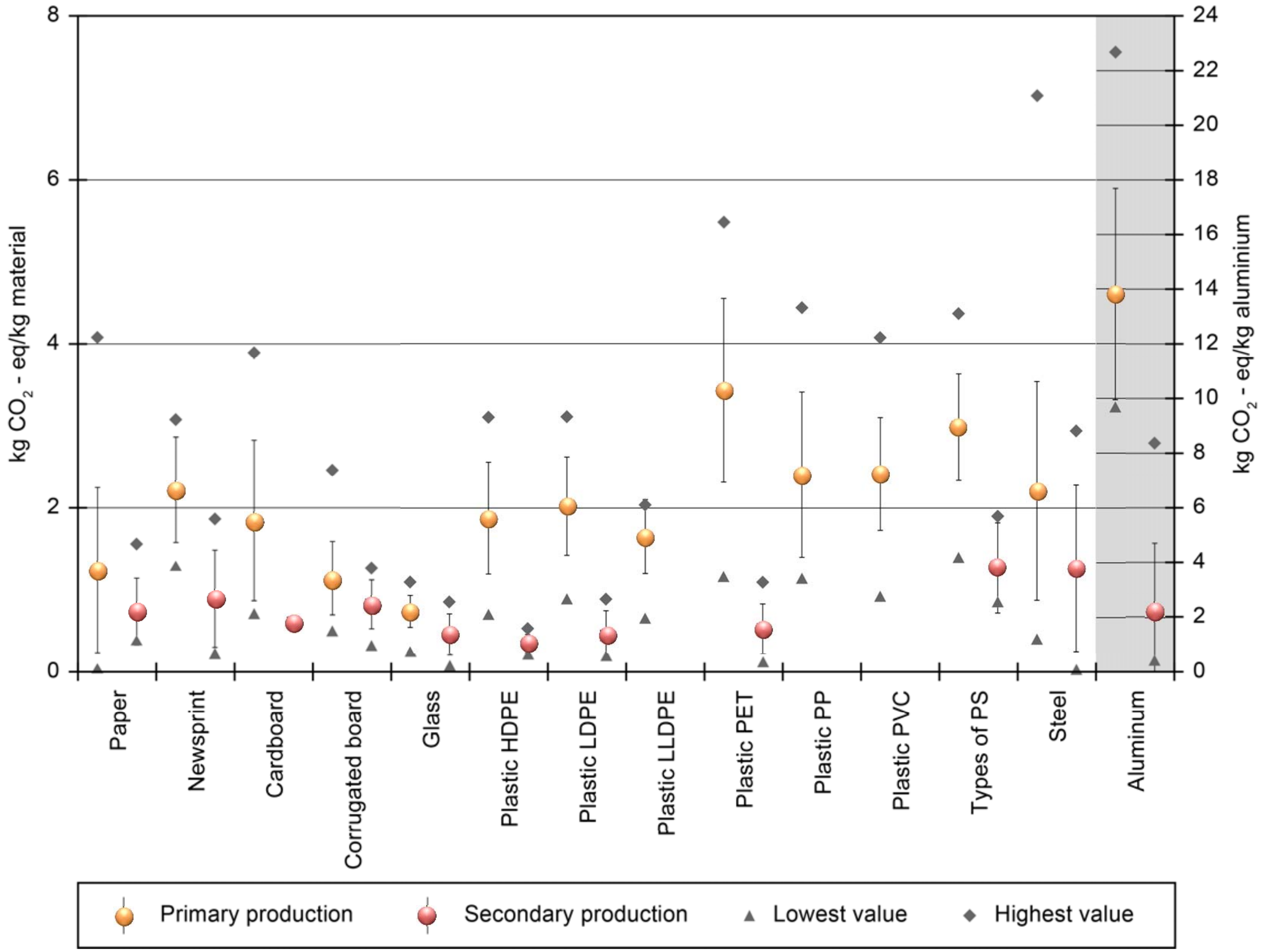
Uncertainty in All Datasets



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Research and Data Needs

- Data in general (very little exist)
  - Differences in product quality and contamination from different MRF types
  - Better description of input feedstock in remanufacturing processes
  - Disaggregated processes (energy inputs for forecasting)
- More understanding of how the “RVP” value for avoided virgin flow is found.
- Better knowledge on how the quality of input materials impact outputs
- Avoided production is dynamic (e.g., fiber markets in Asia or aluminum production in Iceland)

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Questions?

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Morton Barlaz
barlaz@ncsu.edu

Jim Levis
jwlevis@ncsu.edu

EREF Environmental Research & Education Foundation
Lighting a path to sustainable waste management practices

NSF National Science Foundation
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Additional Resources

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- Life Cycle Inventory Data Sets for Material Production of Aluminum, Glass, Paper, Plastic and Steel in North America; RTI International, Raleigh, NC, 2003.

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