Optimization of Rare Earth Recycling from End-of-Life Products

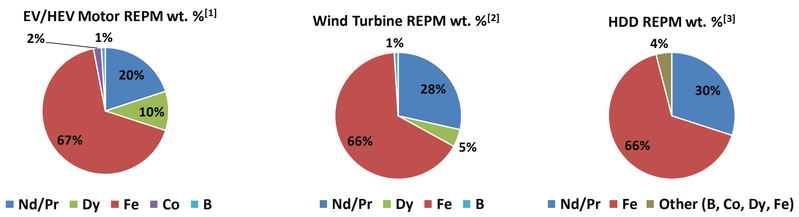
Chris Laliwala and Ana I. Torres (*)

Department of Chemical Engineering, Carnegie Mellon University

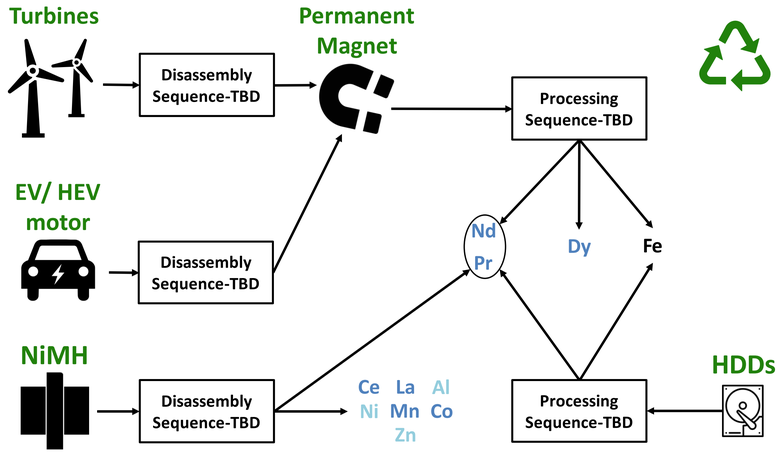
Motivation

REEs are essential to permanent magnets

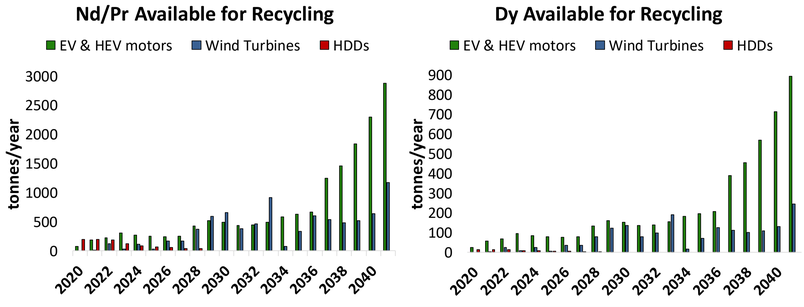
EV & HEV Motors | **Wind Turbines** | **HDDs**



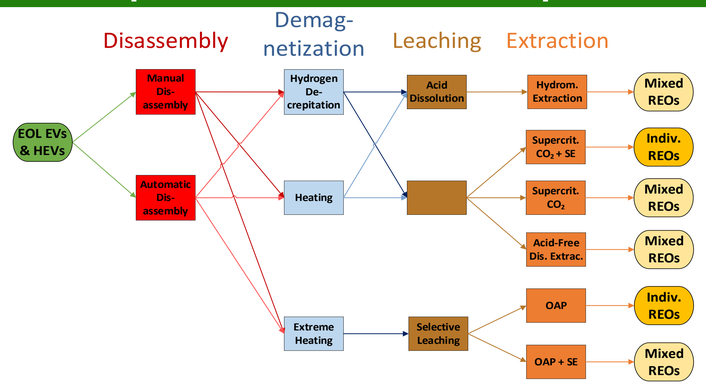
- Recovery of REE from end-of-life (EOL) products attractive as:
  - EOL products have high concentrations of valuable REEs:
  - Helps to solve the problem of disposal.
- Long term goal: design a feedstock agnostic process to recover rare earth oxides (REOs) from EOL products.



- Data: Quantification of feedstock potential[1][2][3][4][5]:



Superstructure and Assumptions



Simplified scheme of the superstructure[1][6][7][8][9][10]

Decision variables:

- Size and operations included in the process.

Main assumptions:

- The plant processes 10% of the available EOL feedstock in the U.S.
- The REO prices are known.

Model

$$\max \; z = NPV$$

s.t.

Mass Balance Constraints

$$\sum_{k=1}^{K^{in}} F_{i,j,k,c,t} = F_{i,j,c,t}^{in} \; \forall i \in I, j \in J_i, c \in C, t \in T$$

$$F_{i,j,c,t}^{out} = a_{i,j,c} * F_{i,j,c,t}^{in} \quad \forall i \in I, j \in J_i, c \in C, t \in T$$

$$F_{i,j,c,t}^{out} = \sum_{k=1}^{K^{out}} F_{i,j,k,c,t}^{out} \; \forall i \in I, j \in J_i, c \in C, t \in T$$

Logical Constraints

$$\sum_{j \in J_i} y_{i,j} = 1 \qquad \forall i \in I$$

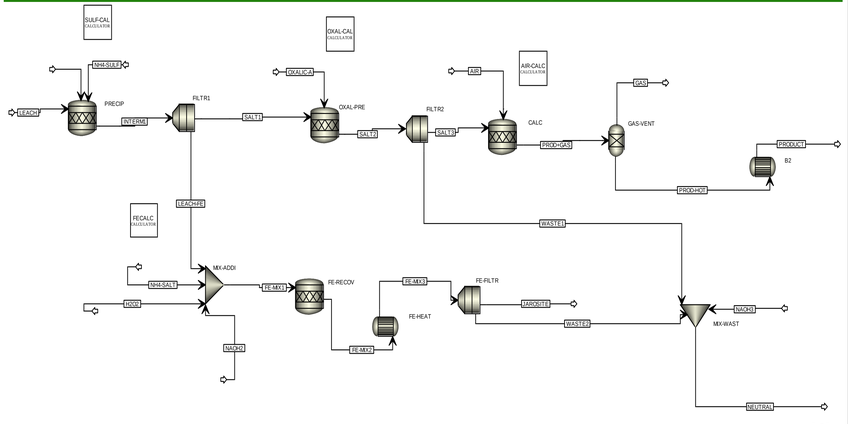
$$y_{3,1} = y_{4,1}$$

$$y_{2,3} = y_{3,3} = y_{4,5} + y_{4,6}$$

$$y_{3,2} = y_{4,2} + y_{4,3} + y_{4,4}$$

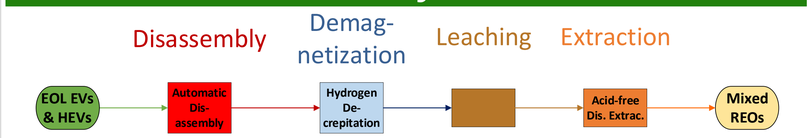
$$0 \le F_{i,j,c,t}^{in} \le y_{i,j} * M^{i,j} \quad \forall i \in I, j \in J_i, c \in C, t \in T$$

Aspen Modeling



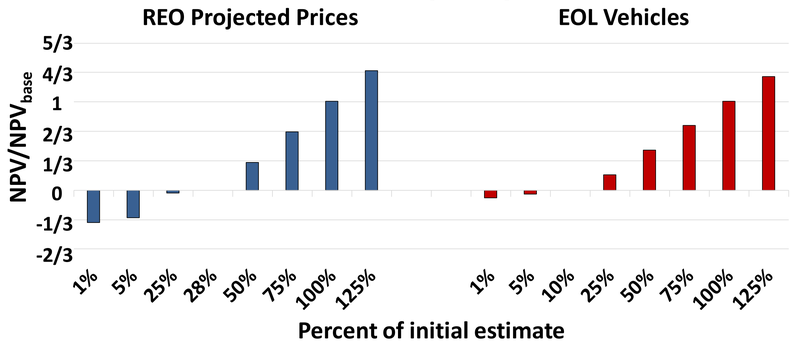
Aspen Plus model for the hydrometallurgical extraction process node[6]

Preliminary Results



Optimal pathway for REE recovery from EOL EV & HEV motors[1][8][9]

Sensitivity Analysis



- Optimal pathway: Automatic disassembly, hydrogen. decrepitation, and acid-free dissolution extraction to produce mixed REOs.
- Sensitivity analysis: Process structure remained unchanged.

Future Work

- Migrate Aspen Models to rigorous IDAES framework
- Generalize optimization code: analyze recovery of REEs from EOL HDDs.

Acknowledgements & Contact

Contact: Ana I. Torres, aitorres@cmu.edu

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