Double Greening of Photovoltaics: Optimizing the PV Recycling Network in the United States

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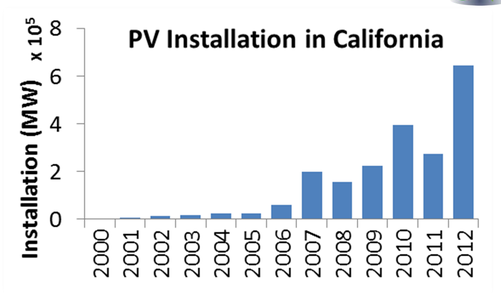
Motivation

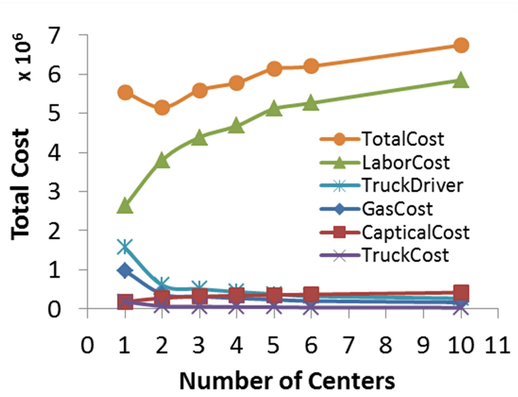
- Photovoltaics (Solar Panel) include materials: 1) Energy intensive (i.e. silicon, aluminum, copper); 2) high value (i.e. indium, tellurium); 3) Toxic (i.e. cadmium, selenium, mercury)
- PV market has been growing exponentially in recent years.



- Lifetime of PV module is 25+ and large portion of end-of-life PV modules started to retire in the U.S.

- Proper planning for managing End-of-life PV modules are necessary.
- Following data/tools are used to solve the proposed problem: Open PV, ArcGIS, mathematical modeling

Cost Benefit Analysis



- The figure shows variation of each cost as the number of PVTBC increases.
- The Total Cost is the summation of all costs.
- The Minimum Total Cost is located between the two and three centers scenario.
- The two recycling center scenario has the lowest total project cost.
- The three recycling center scenario is the most environmentally friendly.

Mathematical Modeling

- The objective of this optimization is to minimize the total travel cost between Reverse Logistics Companies, PV installations, and the PV Recycling Centers.
- The capacity limitations of each Reverse Logistics Company and PV Recycling Center are considered constraints.

Objective Function:

Minimize:

$$\sum_{i\in I}\sum_{j\in J}\sum_{k\in K}\left\{\left[fC_j + mC_j \times (D_{ij} + D_{ik}) + wC_j \times W_i\right] \times X_{ijk}\right\}$$

Subject to:

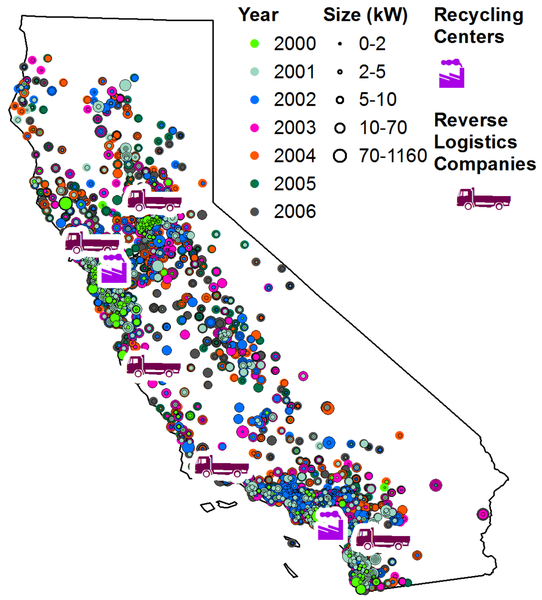
$$\sum_{j\in J}\sum_{k\in K} X_{ijk} = 1$$

$$\sum_{i\in I}\sum_{k\in K} (W_i X_{ijk}) \le W_j$$

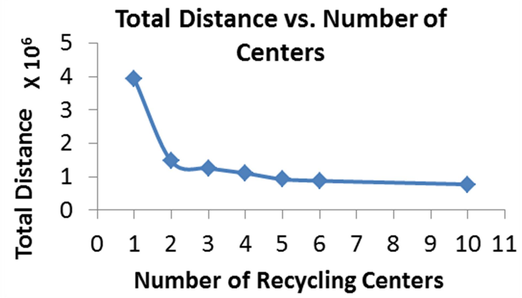
$$\sum_{i\in I}\sum_{j\in J} (W_i X_{ijk}) \le W_k$$

California Case

- Finding the locations of Recycling Centers.
- Finding the locations of Reverse Logistics Companies.

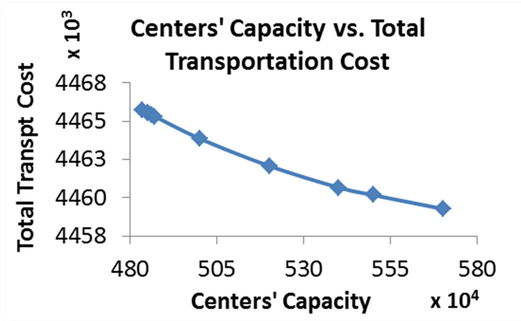


Results



* Based on 2000-2006 Data

- A decentralized scenario will decrease the total travel distance and cost.



* Based on 2006 Data, two Recycling Centers

- Total transportation cost decreases as the capacity of PVTBC increases.

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Reference

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