**Green Chemistry Project**

**Recommended End-of-Life Options for Silicon Solar Panels**

Rahul Barwani, Wesley Chen, Ryo Wakabayashi, Jack Wang

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### Recommendations

**EXTEND + RECYCLE**

- Eliminate solar cell disposal
- Hazardous chemicals kept to a minimum
- Technology to recycle already exists
- Extended use feasible for 5 additional years beyond expected life-span.

1989 Photovoltaic effect discovered.

1954 Modern silicon cell developed.

2000 Silicon solar cells made largely commercially available.

2020 Predicted year for need of a silicon cell recycling system.

**IMPROVED COLLECTION SYSTEMS**

- Reallocate government subsidies for solar cell manufacturers for
- Pick-up options for end-of-life panels
- Uninstallation performed by professionals
- Decentralized facilities to pre-process and treat solar cells (puts initial responsibility on manufacturer).
- Centralized facilities to recover material and send them back to manufacturers (apply national standards).
- Design for easy uninstallation in the future to eliminate need for professional involvement (reduce costs).

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### Financial Analysis

#### Recycling

- Few solar cell companies choose to offer recycling programs.
- Limiting economic factor: small size of waste stream
- Raw material costs: $1.50/W
- Disposal costs (classified as hazard waste): $0.09-0.11/W
- Assuming a waste stream of 150,000 x Si cells per company with a 90% materials recovery rate:
  - Recycled material costs: $0.13/W
  - Collection and recycle costs: $0.08-0.11/W
  - Technology for recycling polysilicon cells already exists.
  - In 2008, approximately 30 million cells were sold worldwide.

#### Extended Use

- Key takeaways:
  - Recycling is feasible at no additional cost.
  - Recycled materials are cheaper to obtain.

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### Environment Impacts

- Parts of solar sells like indium tin oxide, lead, cadmium, chromium (VI), brominated fire retardants are toxic and harmful to the environment.
- Recycling is more environmentally friendly, even considering energy input for the processes.
- It is also more energy efficient, and cells with recycled Si shows no difference in performance.

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### References


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### Limitations

**ONLY SILICON**

- 95% Si PV before 2005. Mostly Si PV waste this decade.

**NO REUSE**

- Requires extra infrastructure, delivery then retake cost analysis, and retrofitting.

**TIME SCOPE**

- PV production in 2010 is still above 50% silicon PV.

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**Introduction**

- Increasing PV market: average annual growth rate of over 30% in the recent 10 years
- Up to 95% of PV market up to 2005 is silicon PV
- Production today, waste stream tomorrow
- Two End-of-Life options:
  1. Decommission and Recycle
  2. Extended use past recommended decommission age
- Extended use past recommended decommission age

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**Extended Use**

<table>
<thead>
<tr>
<th>Year</th>
<th>Efficiency</th>
<th>Energy Usage (kWh)</th>
<th>Average Efficiency</th>
<th>Average U.S. Household Energy Usage (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>15%</td>
<td>12,000</td>
<td>12%</td>
<td>1,100</td>
</tr>
<tr>
<td>1985</td>
<td>20%</td>
<td>10,000</td>
<td>20%</td>
<td>1,000</td>
</tr>
<tr>
<td>1995</td>
<td>25%</td>
<td>8,000</td>
<td>25%</td>
<td>900</td>
</tr>
<tr>
<td>2010</td>
<td>30%</td>
<td>6,000</td>
<td>30%</td>
<td>800</td>
</tr>
</tbody>
</table>

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