Exploring Secondary Markets to Improve Circularity: A comparative case study of photovoltaics and hard-disk drives

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Background – Problem statement

- **Problem:** Currently 1.5 million photovoltaic (PV) solar panels and 50 million hard-disk drives (HDDs) reach product end-of-life (EOL) annually (IRENA-IEA 2016, iNEMI 2017).

- **A solution?** The circular economy (CE) can utilize EOL products to reduce amount of landfilled material
  - In 2040 projected PV waste = 2-4 million tonnes
  - CE could reduce PV waste through recycling and reuse, lowering raw material demand and GHG emissions

- Techno-economic solutions are necessary but not sufficient to improve the circularity of the PV life cycle (Salim et al., 2019)
1. Contribute to the CE research by collecting data on primary and secondary PV and HDD markets

2. Identify the shortcomings of the secondhand PV market through comparison with the secondary HDD market to improve available knowledge about secondhand modules

- Existing PV secondhand market information on module pricing is conflicting:
  - Tao and colleagues state 50% of new module price (Tao et al., 2020)
  - Unpublished IEA PVPS Task 12 estimates 40%
  - IRENA-IEA 2016 report estimates 70% (IRENA-IEA 2016)
Overview:

**Step 1:** Literature review to find existing PV and HDDs studies and data

**Step 2:** Review websites and collect data on used PV module and HDDs for sale

**Step 3:** Compile and organize data (e.g., year produced, manufacturing country, price, capacity)

**Step 4:** Analysis and data visualization; comparatively analyze both PV module and HDDs markets’ data

Collection Process:

- Various available methods for collecting market data: literature, market reports, interviews, or web-scraping
  - **literature review** to identify any similar studies
  - **market reports** for collecting any historic data related to new or secondhand PV and HDD data
  - **interviews** for identifying the types of data available on certain PV and HDD websites
  - **web-scraping** for collecting any current PV and HDD available data
PV and HDD Collection – Steps 1 and 2

Details:

-New PV market prices (price per watt) collected from Wood Mackenzie 2019 report
-New HDD market prices (price per terabyte) collected from Coughlin 2020

-Secondhand PV market prices were scraped from 2 websites and manually collected from 1 (20 websites were assessed for viability)
-Secondhand HDD market prices were scraped from diskprices.com

Sample of Python bs4 scraping code for 1 of the 3 websites
PV and HDD Collection—Step 3

Tools:
- Web scraping was conducted using Beautiful Soup
- Data was compiled and organized using pandas
- Graphics were generated using seaborn and Matplotlib
PV and HDD Markets – Results

• Notable Findings:
  • The useful life of PV modules are 5x longer than HDDs
  • Secondhand PV market represents 0.05% of total annual sales in comparison to 4.2% by the secondhand HDD market
  • Secondhand PV market absorbs 1% of PV waste, while the secondhand HDD market absorbs 6% of HDD waste
  • The oldest PV module for sale was from 2000 with the average being from 2013
  • The oldest HDD for sale was from 2012 with the average being from 2017

|                | PV                                      | HDDs                                   |
|----------------|-----------------------------------------|----------------------------------------|
| Average lifetime | 30 years (IRENA & IEA, 2016)            | 6 years (iNEMI, 2019)                  |
| Annual installed capacity (units) | 32.4 million (IRENA & IEA, 2016) | 70 million (Shehabi et al., 2016) |
| Annual EOL product (units)          | 1.5 million (IRENA & IEA, 2016)       | 50 million (iNEMI, 2017)              |
| Annual used sales (estimated units) | 10-25 thousand                        | 1.5-3 million                          |

|                | PV                                      | HDDs                                   |
|----------------|-----------------------------------------|----------------------------------------|
| Capacity (Wp/TB) | Mean 264  Std 48  Min 75  Max 370   | Mean 4.4  Std 3.6  Min 0.32  Max 16   |
| Year produced   | 2013 3.77  2000  2019                   | 2017 2  2012  2020                     |
| Used PPW/PPT ($) | Mean 0.23  Std 0.13  Min 0.1  Max 0.6 | Mean 33.7  Std 16.2  Min 13.7  Max 81.4 |
| New PPW/PPT ($)  | Mean 0.72  Std 0.17  Min 0.4  Max 1.26 | Mean 38.7  Std 13.5  Min 5  Max 100   |
| Used/new price ratio | Mean 0.31  Std 0.21  Min 0.11  Max 1.14 | Mean 0.92  Std 0.47  Min 0.19  Max 2.34 |
Key takeaways:

- There is a small trend of secondhand/new price ratios in PVs with time, but variability also increases.
- Website pricing structure is unrelated to the other websites.
- No relationship between average secondhand PPW (blue line) and average new PPW (orange line).
- Average price ratio for PV is more erratic than average price ratio for HDDs over time.
PV and HDD Markets—Results Cont.

**Expanded Data:**

- Secondhand PV modules are typically sold at less than the new module price while HDDs have more price variability

**PPW**

- Secondhand PPW for PV modules has greater variability

**HDD**

- Secondhand PPT for HDDs have higher density below $50 with decreasing density with price increase
Key takeaways & further steps

• The secondhand PV market is extremely underdeveloped, and no correlations were drawn between PPW and any descriptive characteristic (e.g., year produced, manufacturer, cell type, country etc.)

• The comparison of the PV and HDD market help show what correlations exist in further developed secondhand markets.

• Next steps:
  • Further research would lead to better estimations regarding the secondary markets’ sizes as new data is available
  • Compare other emerging secondary markets to see what similarities exist to help contribute to the ABM
Thank you!

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