SOLAR EWASTE SOLUTIONS
VALUE RECOVERY EXPERTS

DERISK YOUR DOWNSTREAM:
STEPS TO QUALIFY YOUR SOLAR EWASTE RECYCLING PARTNERS

DWIGHT CLARK, CHMM – SOLAR EWASTE SOLUTIONS, INC.

WHO IS DWIGHT CLARK?

- Environmental Engineer and Certified Hazardous Materials Manager(CHMM) with over 30 years of experience in EHS Management and a specialty in Environmental Compliance
- Experience in EHS compliance ranging from ISO 14001 and 45001 auditing to being an EHS Manager on several RCRA Part B permitted Facilities
- Having Permitted Three Part B Facilities for various operations and closed another Four Part B Facilities
- Developed Recycling Facility operations plans under several regulatory schemes ranging from scrap metal exclusions to Universal Waste Destination Facilities
- Developed operating structure under Hazardous Secondary Materials exclusions for Solar Recycling
- Key Participant in helping develop the solar recycling portions of the R2 standard, detailing processing and treatment requirements, which was just approved 2/1/2024

OVERVIEW OF RECYCLING SYSTEMS

This presentation aims to provide an overview of a comprehensive solar module recycling system specifically tailored for utility-scale applications.

The key initial questions include:

- Does size matter?
- What is Utility Scale?
- Are Solar Modules Hazardous Waste?
- What is an appropriate level of Due Diligence?

TYPICAL RECYCLING PROCESS FOR SOLAR MODULES

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•There are several **“package unit”** processing systems for the recycling of solar modules in the market today - Mostly manufactured in China

•These units offer a treatment process for **“typical single glass silicon solar modules”** but can not (currently) treat bifacial modules or thin film modules

•These units have significant drawbacks in throughput, with some **best-case production rates advertised at 60-80 solar modules per hour** of operation

•This **a key problem at Utility Scale** when the plant can only ”treat” approximately 176,000 solar modules per shift annually, if there is no downtime for maintenance

•We have seen **projects in excess of 100,000 modules for recycling** on severaloccasions

TYPICAL RECYCLING PROCESS FOR SOLAR MODULES

The current technology in the plants does some separation, though some of the critical materials in our experience are not “clean” enough to be of value.

- **Silicon typically has little to no value below 95% purity** and does not become “valuable” until > 99.5%. Our testing indicates typical purity of the Silicon stream from these package units are approximately 40-50% with the balance being glass, adhesives, and other metals
- Approximately **25% of the glass will be contaminated** to the point it may not be directly used in a glass furnace to make new glass

WASTE CLASSIFICATION OF SOLAR MODULES

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No specific classification for solar modules is currently in federal regulation.

- The methods for collection of a representative sample are not defined but there is an **ASTM standard (E3325-21)** specific to collecting this sample
- California has specifically included Solar modules in **Universal Waste**, though as we all know they must be first hazardous
- **Often Solar modules that are classified as Hazardous Waste** typically fail for the Characteristics of Hazardous Waste for leachable lead, silver, cadmium, and sometimes selenium
  - Most common is leachable lead on federal regulation from **solder joints**
- California solar modules almost always are **Hazardous for TTLC copper**
  - The modules contain ~1% copper by mass and the regulatory level is 2500 mg/kg in California

POTENTIAL PITFALLS & ENVIRONMENTAL CHALLENGES IN SOLAR RECYCLING

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- **Speculative Accumulation**
  - Some recyclers stockpile panels without proper processing—must process 75% of materials yearly
- **Auto Shredders**
  - Some recyclers only recover the aluminum frame and landfill the rest
- **Lack of Pollution Liability Insurance**
  - Cleanups cost millions—ensure recyclers have financial safeguards
- **Illegal Exporting of Waste**
  - Some recyclers ship hazardous materials to unregulated countries—violating international law
- **Transportation**
  - The logistics issues are a huge aspect in carbon emissions from solar recycling as trucking distances can be significant
- **The Potential Release of Hazardous Materials**
  - As with many waste materials in transportation or storage, the packaging will be key in preventing releases
  - The universal waste regulation requires that modules with broken glass be “contained”

LONG TERM LIABILITY ISSUES

RCRA and CERCLA are two different statutes that govern the federal management and cleanup of hazardous waste facilities (RCRA) and response to abandoned, uncontrolled hazardous waste sites (CERCLA).

- CERCLA implications
  - Can easily create legal issues by the concept of **“joint and several liability”**
- RCRA Implications
  - Improper use of recycling exemptions could easily create a RCRA related issue such as **disposal without a permit**, **unpermitted hazardous waste treatment, or speculative accumulation**

AVOIDING RCRA/CERCLA RELATED ISSUES

- RCRA issues related to solar module recycling are best avoided by using the **Hazardous Secondary Materials** exclusions
- A key piece of legislation on the federal level that will aid in defense of CERCLA related issues is the **Superfund Recycling Equity Act (SREA)**
- Both of these methods are **based on the generator** (the firm calling the solar module a waste the first time) doing a level of Due Diligence
- There are other methods to use as an exclusion from RCRA but I have yet to see a good argument for any, I know from experience **scrap metal exemptions will not work in many states**

WHAT IS APPROPRIATE DUE DILIGENCE?

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The **RCRA Hazardous Secondary Materials** rule and the SREA call out some specific items such as:

- **Is the recycling process viable and does it recycle a valuable commodity?**
  - The Aluminum frames are certainly of value but are only ~15% of the mass of a solar module
- **Is the recycler treating the solar modules as a valuable commodity?**
  - Storage conditions, security, etc.
- **Does the recycler have adequate pollution insurance to reduce risk from release or accident at the operation?**
  - As Environmental Professionals, we understand that $1 million or $2 million is not much of a cleanup
- **Can your recycler easily demonstrate they do not meet speculative accumulation? e.g., processing at least 75% off previous annual receipts?**
  - Inspection of receipt and processing records should demonstrate this
  - This is the EPAs method to prevent “sham recycling”

WHAT IS APPROPRIATE DUE DILIGENCE?

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- **Is the recycling activity meeting the local regulations in addition to federal?**
  - Some states have not adopted **Hazardous Secondary Materials** exclusions, some require universal waste to go to specifically permitted facilities
  - California has very specific requirements for activities within the state and permitting for most recycling activities
- **Has the facility notified the EPA of the recycling activity?**
  - Not just an EPA ID number but a notification documenting the activity
  - As a note: an EPA ID number is not a permit. Recycling activities are not typically permitted activities but work based on notification and often self-certification. **This makes the need to review a facility even more imperative**
- **Does the facility have a closure plan and current cost estimate?**
  - Should be written to manage the maximum volume of materials possible at the facility, if you see more than listed likely an issue

MORE DUE DILIGENCE CONSIDERATIONS

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Additional questions that will help in deciding where to recycle your used solar modules include:

- **How is the closure cost assured?**
  - The money set aside for closure typically should be set aside in a manner prescribed by rule. In general, it is a manner that the facility can not access the money except for closure activities with the EPA somewhat involved
- **Are the secondary wastes analyzed for hazardous characteristics?**
  - Process documentation should show the generation and sampling report for the materials of concern
- **Does the secondary material contain contaminants that are not found in the analogous product they are replacing**
  - Glass culet typically does not contain more than a few hundred parts per million metals

MORE DUE DILIGENCE CONSIDERATIONS

Additional questions that will help in deciding where to recycle your used solar modules include:

- **Where are and how are secondary materials processed at next facilities (aka downstream)?**
  - Can your recycler tell you where everything goes and why it is a legal transfer?
  - Remember that glass is often too contaminated to be reused for glass or the metals mixed with silicon
  - The secondary materials should provide a useful contribution to the new product and be well documented
- **What is the safety record of your recycler?**
  - A quick check of the experience modifier ratio (EMR) is a simple method using workers comp data and an EMR greater than 1.10 indicates a significant safety issue. **The good ones are all < 1.00.** You can get an official copy of the letter or worksheets from the recycler as objective evidence

MORE DUE DILIGENCE CONSIDERATIONS

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- **Does your recycler export any of the secondary materials?**
  - If so, are they adequately sampled to determine regulatory status, not only in U.S. but receiving countries?
  - If they are hazardous then U.S. EPA must be notified and a formal consent process conducted
- **Some operations mix the contaminated glass with other materials and send to smelters for metals recovery**
  - The silicon and glass are then lost to the slag layer and not beneficially reused

DUE DILIGENCE CHECKLIST FOR HIRING A PV RECYCLER

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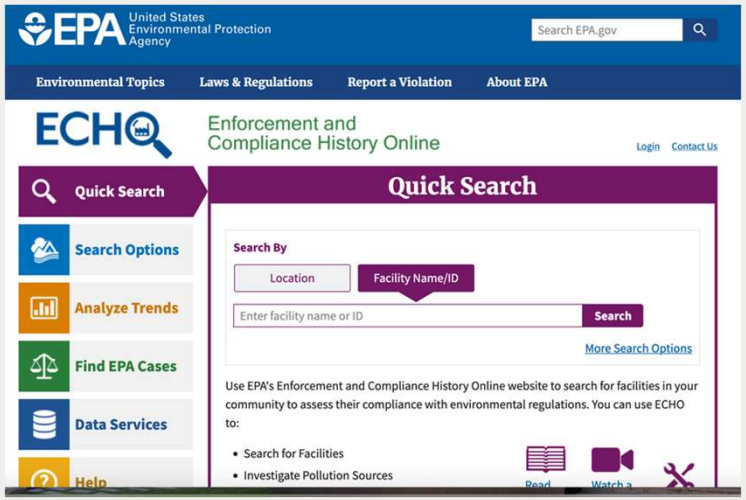
1. **Verify Certifications**
   - Look for **R2, ISO 14001, or state-issued hazardous waste compliance standards**.
2. **Request Transparency**
   - Ask for documentation on processing methods and recovery rates.
3. **Check Compliance History**
   - Use **EPA's ECHO database** to review compliance records.
4. **Assess End Markets**
   - Ensure recyclers have buyers for recovered materials—not just landfilling waste.
5. **Understand Liability Protections**
   - Confirm that **SREA standards** are met to reduce liability risks.



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DOWNLOAD THE CHECKLIST
FOR QUALIFYING YOUR PV RECYCLER

solarewastesolutions.com

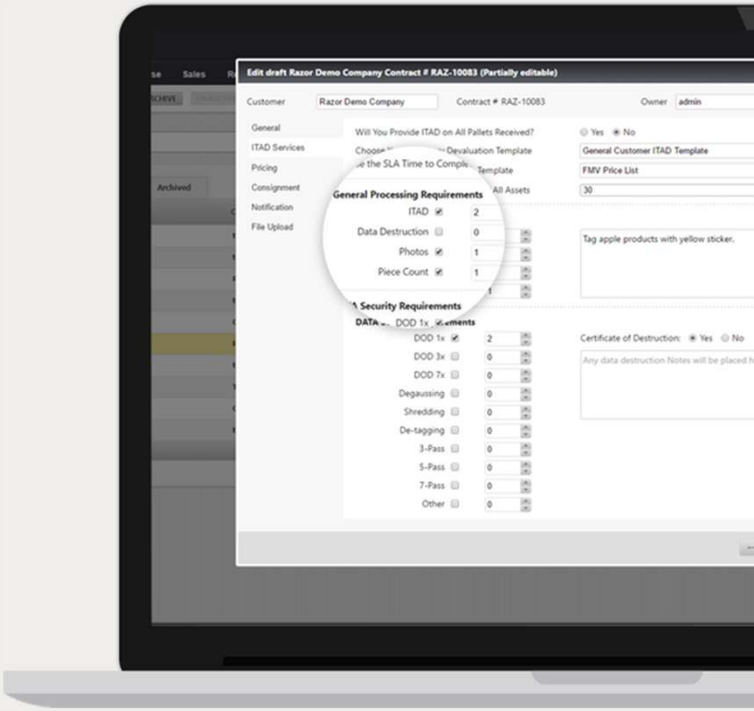
WHAT A RESPONSIBLE RECYCLER SHOULD PROVIDE

- **Material verification** – Clear reporting on material flows.
- **Pollution liability insurance** – At least $5M coverage.
- **End-market accountability** – Documentation on material resale.
- **EPA notifications & proper closure plans** – Ensuring facility stability.

WHAT'S AT STAKE FOR SOLAR OWNERS?

Choosing the wrong recycler can lead to:

- Fines and lawsuits under RCRA and CERCLA.
- Reputation damage for poor ESG performance.
- Increased industry-wide scrutiny on improper solar waste management.



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THREE FAQS

Q: Isn't the end-of-life panel problem an issue for the future?
A: The solar waste problem is not a tomorrow issue. Current generation rates.

Q: Where can I find the best guidance on the Hazardous Secondary Materials rule?
A: North Carolina has the best guidance I have seen on application of Hazardous Secondary Materials rule and how to document the generators responsibilities. https://www.deq.nc.gov/about/divisions/waste-management/hazardous- waste-section/technical-assistance-and-guidance-documents#HazardousSecondaryMaterialHSM-2201

Q: How is PV glass valued?
A: Glass is infinitely recyclable if clean and negative value if contaminated.

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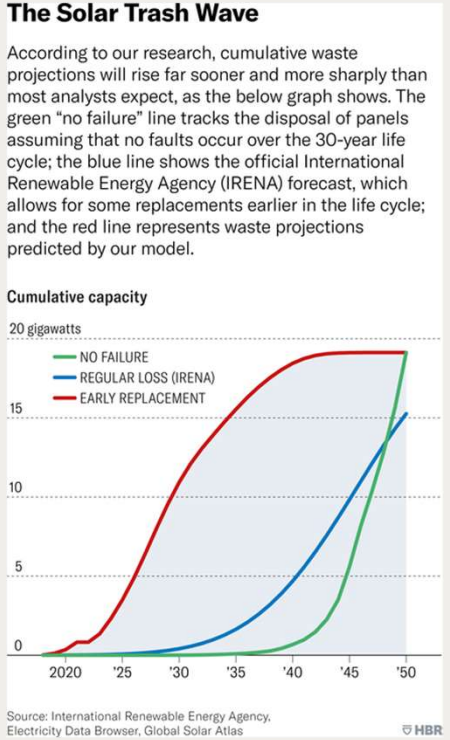

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CONTACT

Dwight Clark

928-224-9239

602-376-6232

dwight@solarewastesolutions.com

LinkedIn: Dwight Clark

solarewastesolutions.com