# Quarterly Interim Report on the Activities Conducted to Establish a Regulatory Program for the Management and Decommissioning of Renewable Energy Equipment

**Citation of Law or Resolution:** Section 2.(d) of S.L. 2019-132 (H329)
**Due Date:** Quarterly
**Submission Date:** March 1, 2020

**Receiving Entities:**
The Environmental Review Commission
The General Assembly

**Submitting Entity:**
Department of Environmental Quality

# Quarterly Interim Report of the Department of Environmental Quality

## Executive Summary and Transmittal

Pursuant to Section 2.(d) of S.L. 2019-132 (H329/Renewable Energy Amends), the North Carolina Department of Environmental Quality (Department or DEQ) and the Environmental Management Commission (Commission), must submit quarterly interim reports as to the activities conducted, including updates on the stakeholder process and the work to adopt rules governing the management of end-of-life (EOL) photovoltaic modules and energy storage battery systems and the decommissioning of utility-scale solar projects and wind energy facilities, to the Environmental Review Commission and the General Assembly. This is the second such quarterly report and covers the activities undertaken to implement this Section since the submission of the previous quarterly interim report, from December 1, 2019, through March 1, 2020.

## Quarterly Interim Report of Activities

In accordance with Section 2.(c) of S.L. 2019-132, the Department established a stakeholder process and convened three stakeholder meetings during this quarter on December 9, 2019, January 22, 2020, and February 10, 2020. The agendas for and presentations shared in association with these three stakeholder meetings are included as Appendix A to this report. To follow is a brief summary of the work undertaken by the Department and the stakeholders to implement this Section of the Act since the previous report was submitted. Thus far, the work to implement this Section of the Act has been conducted exclusively by DEQ and the stakeholders, without input or participation from the Commission.

### DEQ Resources

Due to the multi-disciplinary scope of the legislative directive to adopt rules governing the management of end-of-life (EOL) photovoltaic (PV) modules and energy storage battery systems and the decommissioning of utility-scale solar projects and wind energy facilities, staff from three DEQ units are assigned to support this effort. The Division of Waste Management, the Division of Environmental Assistance and Customer Service, and the State Energy Office are each represented and this team's work is coordinated by the Office of Governmental Affairs and Policy. Pursuant to Section 2.(d) of S.L. 2019-132, the Department will submit its recommendations regarding resources necessary to implement this Section in its April 1, 2020 interim report.

### Stakeholder Organizations[1]

The following public, private, and not-for-profit organizations have joined the stakeholder process since the last quarter. In addition to these entities, DEQ solicited stakeholder's feedback to broaden and include participation from all potentially interested Parties. A list of all participating stakeholders to-date is included in Appendix C of this report.

Solterra Partners
Electronic Recyclers International
Law Office of Robert W. Kaylor*
Smith Anderson
Capitol Advantage Associates
Energy Intelligence Partners*
Brooks Pierce & Recycling*
Southern Power Companies*
SunnKing*

### Matters Under Consideration

Pursuant to Section 2.(a), DEQ must consider nine matters in its development of the rules governing the management of EOL PV modules and energy storage battery systems and the decommissioning of utility-scale solar projects and wind energy facilities. The following table lists the matters DEQ, with assistance from stakeholders, has considered through the date on which this report was submitted. The shading in the table indicates matters that have been evaluated and are considered by DEQ to be complete.

[1] Organizations with an asterisk (*) have participated in the stakeholder meetings either in-person or by remote conference call.

| S.L. 2019-132 / HB 329 | Photovoltaic (PV) Modules | Wind Energy Facilities (WEF) | Energy Storage System Batteries | Status | Next Steps |
|---|---|---|---|---|---|
| **§2.(a)(1): Characteristics of hazardous waste identified** | • Presentations on classifications of solar waste<br>• TCLP methodology, results, and potential hazardous characteristics of modules has been thoroughly discussed<br>• DEQ drafted a literature review on the hazardous characteristics of modules and TCLP methodology[2] | DEQ initiated literature review of the potential hazardous characteristics of turbines and related facility equipment | DEQ presentation on hazardous characteristics in common types of energy storage system batteries | PV modules have been thoroughly researched and discussed | • DEQ to draft proposed rules for waste characteristics for EMC consideration<br>• Research will be conducted and presentations made in the next quarter on the potentially hazardous characteristics of wind energy equipment and energy storage system batteries |
| **§2.(a)(2): Preferred methods to responsibly manage end-of-life (EOL) products** | Presentations on methods to manage EOL PV modules. Reuse, refurbish, recycle, and landfill disposal options has been researched by DEQ | | DEQ presentation on different EOL management options for several energy storage system battery technologies | EOL for PV modules has been thoroughly researched and discussed | • Coordinate presentations and research on EOL management for wind energy equipment and energy storage system batteries<br>• DEQ drafting white paper on preferred methods to manage EOL renewable energy equipment, to be submitted with June 1, 2020 quarterly report |
| **§2.(a)(3): Economic and environmental costs and benefits** | • Stakeholder discussions on environmental costs/benefits<br>• EOL management methods for PV modules reviewed by DEQ | | • Stakeholder discussions on environmental costs/benefits<br>• EOL management methods for batteries reviewed by DEQ | Limited discussion of environmental costs/benefits information on recycling, reusing, and disposing of PV modules and energy storage system batteries | DEQ to conduct additional research and obtain information from stakeholders on the environmental and economic costs/benefits on different EOL management options for renewable energy equipment |
| **§2.(a)(4): Expected economically productive life** | • Stakeholders have submitted resources on the economically productive life cycle of PV modules<br>• Data on current NC PV module lifespan has been collected and presented[3] | Presentation on Amazon Wind, U.S. East, the State's only operational WEF, included this information | Stakeholders provided applicable resources for energy storage system batteries | • NC solar facility lifespan data obtained and presented[3]<br>• Limited data on energy storage system batteries received | DEQ to collect additional information, including NC site specific data, on the economically productive lifecycle of energy storage system batteries and the Amazon Wind facility |

[2] Executive Summary of the Literature Review of Hazardous Characteristics of Solar PV Equipment is included in Appendix B.

[3] Data on the number of modules, weight in tons, and estimated timeframes for decommissioning is included in the January 22, 2020 meeting materials in Appendix A2.

| S.L. 2019-132 / HB 329 | Photovoltaic (PV) Modules | Wind Energy Facilities (WEF) | Energy Storage System Batteries | Status | Next Steps |
|---|---|---|---|---|---|
| **§2.(a)(5): The volume of photovoltaic modules, wind turbines, and energy storage system batteries currently in use in the State, and projections** | • The volume of PV modules currently installed in NC facilities was compiled by DEQ and presented in graphs[3]<br>• DEQ compiled the capacity, panel type, and estimated volume of PV modules currently installed in NC solar facilities and the results were illustrated in graphs presented to the stakeholders in January 2020 | The volume of turbines currently installed in NC has been researched and presented[4] | | Based on the data collected:<br>• the bulk of the solar PV facilities/ modules will not be decommissioned until early-to-mid 2030<br>• the Amazon Wind facility's 104 turbines have an expected life of at least 20 years, estimated decommissioning in 2036, at the earliest | • DEQ will update PV module volume graphs with additional data<br>• DEQ evaluating impacts on landfill capacity if PV modules, wind turbines, and energy storage system batteries are disposed in landfills<br>• DEQ collecting information on energy storage system batteries in NC |
| **§2.(a)(6): A survey of federal and other states' and countries' regulatory requirements** | • Federal, state, county, and EU regulatory requirements, including financial assurance (FA) requirements, researched and presented to stakeholders<br>• Discussions of solar ordinances adopted in NC counties<br>• Stakeholders provided list of solar decommissioning requirements in other states<br>• DEQ completed summary of current decommissioning requirements in NC counties | • Federal and NC requirements for WEFs presented and discussed<br>• Stakeholders provided list of WEF decommissioning requirements in other states | Stakeholders provided list of battery decommissioning requirements in other states | Completed evaluation of regulatory requirements at federal-, state-, NC county-, and international-level for management of EOL PV modules | DEQ will research, work with stakeholders, and present energy storage system batteries' and WEF regulatory requirements at federal-, state-, and international-level |
| **§2.(a)(7): Financial assurance requirements** | • FA requirements for PV modules in NC counties (per ordinance) have been collected and presented to stakeholders<br>• Stakeholders have discussed the need for and implementation of FA for PV modules | *Not required per S.L. 2019-132* | *Not required per S.L. 2019-132* | A subgroup of stakeholders was formed to dive into the need for, approach, and implementation of FA for PV modules | Following completion of discussions, DEQ is collaborating with stakeholders to draft language for FA requirements for PV modules |
| **§2.(a)(8): Infrastructure that may be needed to collect and transport EOL products** | | | | Little work has been done to-date as the stakeholders have been focused on quantifying the universe of and expected timeline for decommissioned EOL renewable energy equipment | DEQ will work with stakeholders to research and evaluate the infrastructure that may be needed to develop practical, effective, and cost-efficient means to collect and transport EOL PV modules, energy storage systems, and WEFs |

[4] See February 10, 2020 presentation on WEF in North Carolina in Appendix A3

| S.L. 2019-132 / HB 329 | Photovoltaic (PV) Modules | Wind Energy Facilities (WEF) | Energy Storage System Batteries | Status | Next Steps |
|---|---|---|---|---|---|
| **§2.(a)(9): Manufacturer stewardship programs** | Examples of existing manufacturer stewardship programs for recycling PV modules have been presented and discussed | | | Limited information on manufacturer stewardship programs for EOL PV modules has been received again, as the stakeholders' focus has been on quantifying the universe of EOL renewable energy equipment and the timeline | DEQ will research and discuss with stakeholders the potential and feasibility for creating a manufacturer stewardship programs for recycling of EOL PV modules and energy storage system batteries |

Materials Received from Stakeholders

To support the completion of the scope of work directed by the Session Law, DEQ continues to solicit assistance from the stakeholders to fill knowledge and data gaps. DEQ has received the following information from stakeholders since the last quarterly interim report was submitted:

- Energy Intelligence Partners provided a report on $Li^+$ battery recycling and best practices for management of energy storage batteries.
- Both First Solar and the NC Clean Energy Technology Center submitted studies on PV module waste characteristics and issues with TCLP testing methodology.
- The National Renewable Energy Laboratory shared studies on managing EOL PV modules and human health risk assessment methods for PV.
- Southern Environmental Law Center provided examples of international decommissioning regulations and a list of decommissioning requirements for PV modules in other states.
- NC Sustainable Energy Association shared two decommissioning cost estimate studies performed by Duke Energy Progress and a list of the installed solar capacity in NC by county.
- Duke Energy shared results from two TCLP tests on PV modules.
- Dominion Energy provided a list of operational solar facilities that it owns in NC as of November 14, 2019, and a list of non-utility solar generators in DE Service Territory.
- The Solar Energy Industries Association submitted a manufacturer plan guidance for the PV module stewardship program.
- NC Electric Membership Cooperatives shared a list of the Co-op's utility-scale renewable energy projects.

Upcoming Activities

On March 4, 2020, staff from the Division of Waste Management will brief the EMC Groundwater and Waste Management Committee on the status of DEQ's work and the stakeholder efforts underway to implement this Act.

DEQ will convene the next stakeholder meeting on Thursday March 19, 2020, in Raleigh to discuss current deployment and management options for energy storage batteries and management options for EOL wind turbines.

DEQ anticipates convening monthly stakeholder meetings through 2020, as needed, to inform the Department's work to develop rules to govern the management of EOL PV modules and energy storage battery systems and the decommissioning of utility-scale solar projects and wind energy facilities.

The next report will be submitted on or before April 1, 2020, and will include recommendations regarding the resources necessary to implement the requirements of the Section 2 of the Act.

## APPENDIX A
## Stakeholder Meeting Agendas and Associated Presentations

**Monday, December 9, 2019**
1:00pm to 3:00pm
Ground Floor Hearing Room – Archdale Building
512 N. Salisbury Street, Raleigh NC

**AGENDA**

1. Welcome and introductions

2. Recycling PV Modules, Programs and Practices
    a. Recycling PV modules in the European Union
        Jessica Citrola, Environmental Specialist II
        DWM, DEQ

    b. Industry PV module recycling practices
        Ricky Sinha, Sr. Scientist, Sustainability Research
        First Solar, Inc.

        Evelyn Butler, Senior Director of Codes and Standards
        Solar Energy Industries Association

    c. Discussion

3. Additional knowledge gaps, review and assign homework

4. Adjourn and convene the Decommissioning/Financial Assurance (FA) Sub-stakeholder Group

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**Wednesday January 22, 2020**
1:00pm to 3:00pm
1st Floor Training Room, Green Square
217 West Jones Street, Raleigh NC 27603

**AGENDA**

1. Welcome and introductions

2. Presentations
    a. Assumptions, issues, and review of data collected for solar facilities in North Carolina
        Katie Wanka, Environmental Program Consultant
        DWM, DEQ

b. Financial assurance requirement for other energy generation resources and activities
Katie Wanka, Environmental Program Consultant
DWM, DEQ

3. Discussion and Action items
   a. Threshold for applicability of regulatory program to utility-scale solar facilities.
   b. Review understanding of hazardous content of crystalline silicon and thin film PV modules
   c. Proposed topics for February stakeholders meeting:
      i. Hazardous content of energy storage system batteries and wind energy facilities.
      ii. Preferred methods for managing end-of-life of batteries and wind energy facilities.
      iii. The volume of turbines and batteries currently in use and projected in the State.

4. Adjourn

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**Monday, February 10, 2020**
2:00 pm to 4:00 pm
1st Floor Training Room, Green Square
217 West Jones Street, Raleigh, NC 27603

**AGENDA**

1. Welcome and introductions

2. Presentations
   a. Wind Energy in NC
   Jennifer Mundt, Senior Policy Advisor, DEQ
   b. Hazardous Content and End-of-Life Management of Energy Storage System Batteries
   Jessica Citrola, Environmental Specialist II, DWM, DEQ
   c. Solid and Hazardous Waste Transportation
   Ellen Lorscheider, Deputy Director
   DWM, DEQ

3. Discussion
   a. Wind energy statute review
   b. How should decommissioning requirements, including financial assurance apply to utility scale
   facilities already installed vs future facilities?
   c. Review of changes to PV module hazardous characteristics paper

4. Discuss topics for next stakeholders meeting

5. Adjourn

# Appendix A1
# December 9, 2019 Meeting Presentations

## *End-of-Life Management of PV Modules in Europe*

Stakeholders Meeting
December 9, 2019

# *Recap*

- Few states have implemented statewide regulations for end-of-life management of PV modules.
  - California
  - New Jersey
  - Hawaii
  - Washington (Effective 1/21)
- Current PV module disposal volumes in the United States are not substantial enough for the establishment of widespread dedicated PV recycling facilities.
- The European Union has set an example for end-of-life management of PV modules by including collection and recycling requirements in the WEEE Directive 2012/19/EU.

# *Waste Electrical and Electronic Equipment (WEEE) Directive- Purpose*

- "The purpose of this Directive is, as a first priority, the prevention of waste electrical and electronic equipment (WEEE), and in addition, the reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste. It also seeks to improve the environmental performance of all operators involved in the life cycle of electrical and electronic equipment, e.g. producers, distributors and consumers and in particular those operators directly involved in the treatment of waste electrical and electronic equipment."

NORTH CAROLINA
Department of Environmental Quality

# *Waste Electrical and Electronic Equipment (WEEE) Directive*

- The European Commission revised the first Waste Electrical and Electronic Equipment (WEEE) Directive 2002/96/EC and a new WEEE Directive 2012/19/EU became effective on February 14, 2014.
- The WEEE Directive 2012/19/EU provides a legislative framework for extended producer responsibility of PV modules.
- It requires producers to establish take-back programs. It also regulates the collection, transport and recycling of PV panels.
- Producers are required to finance the costs associated with dismantling, transporting and recycling of PV modules, and to provide a financial guarantee for the management of end-of-life products.
- This directive prevents additional costs to consumers at the time of disposal.

# WEEE Recycling Process

- The recycling process depends on the type of module:
  - Silicon-based:
    - Aluminum frames and junction boxes are disassembled.
    - The module is crushed and the components are separated, which allows for as much as 80% recovery of the panel.
  - Non-silicon-based Cadmium telluride (CdTe) panels:
    - Modules are crushed into different fractions.
    - Chemical baths are used to separate the various semiconductor materials, allowing for the recovery of 95% these components.
    - Similar chemical bath treatments apply for copper indium selenide (CIS) and Copper indium gallium (di)selenide (CIGS) photovoltaic modules.

# Germany

- European countries incorporate this legislation into their national laws.
- In Germany, Das Elektro- und Elektronikgerätegesetz (ElektroG) regulates the putting on the market, recovery and recycling of electrical and electronic equipment.
  - Producers are responsible for the end of life management for the products they sell, and are required to take back and dispose of the waste at their own expense.
  - PV modules are classified as household waste in Germany.
  - Producers must register PV modules through Stiftung ElektroAltGeräte (EAR), the national register for waste electronic equipment.
  - Financial guarantees and a trusteeship need to be in place in case the producer is unable to finance the end-of-life process of their electronic waste.

# France

- French WEEE Law Le décret 2014-928 requires producers and importers of PV modules to plan and finance the collection and treatment of end-of-life PV modules.
- Under this law, all PV modules put on the market are classified as household waste and must apply a visible fee.
- The visible fee is issued on the invoice of every newly sold PV module and finances the collection, sorting and recycling of future PV waste.
- Producers must register with the National WEEE Register.
- Producers must register with an accredited take-back program or establish an individual system approved by the Ministry of Environment to put PV panels on the market.

# *Italy*

- In Italy, “Attuazione della direttiva 2012/19/UE sui rifiuti di apparecchiature elettriche ed elettronice (RAEE)” includes PV modules in the national WEEE law.
  - Producers are required to plan and finance the collection and recycling of PV modules.
  - Producers need to register all PV modules in the National WEEE Register.
  - Non-household PV module waste (installed with capacity greater than or equal to 10 Kw) placed on the market before Dec. 4, 2014 are financed by the producers when selling a replacement PV module. In all other cases, the financing responsibility falls on the users.
  - It is the producers’ responsibility to finance non-household PV module waste placed on the market after Dec. 4, 2014.

# PV Cycle

- Provides waste management and compliance services for companies and waste holders in the EU for a variety of products, including PV modules.
- Created a voluntary take back and recycling program for the solar industry.
- Manufacturers that complete successful evaluation obtain a PV Cycle membership.
- Membership annual fees range from 5,000-25,000 euros (approximately $5,400-$27,400 USD) depending on the producer's revenue in Europe the previous calendar year.
- Operational in all 28 EU states and 4 European Free Trade Association countries.

# PV Cycle

- PV module collection and processing is financed by fees from its members.
- PV modules are collected from PV Cycle permanent containers at collection points (wholesalers, retailers and installers), temporary containers at construction, renovation, and demolition sites, and are picked-up when more than 50 km away from the closest collection point. The modules are then brought to a recycling plant.
- Since the start of operations in 2010, there has been 27,195 metric tons of PV waste processed.
- Since the incorporation of PV modules in the WEEE Directive 2012/19/EU, PV Cycle has greatly invested in its organization, members and participants to become the best option for WEEE compliance and PV panel waste management.

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*Department of Environmental Quality*

# HIGH VALUE RECYCLING

Parikhit (Ricky) Sinha, Ph.D.
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First Solar®

LEADING THE WORLD'S SUSTAINABLE ENERGY FUTURE

# FIRST SOLAR PRODUCT LIFE CYCLE APPROACH

## Material Sourcing

Converting mining byproducts into a stable semiconductor

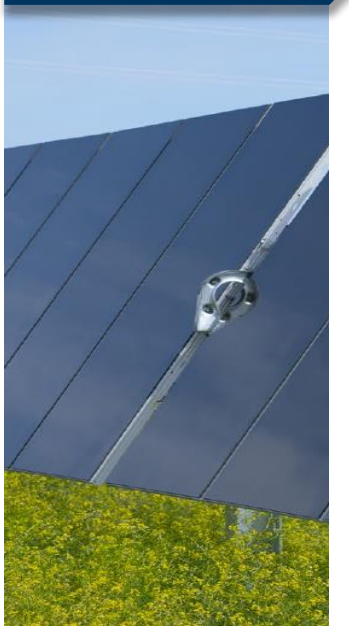
## Product Design

Designed for high-value recycling

## Manufacturing

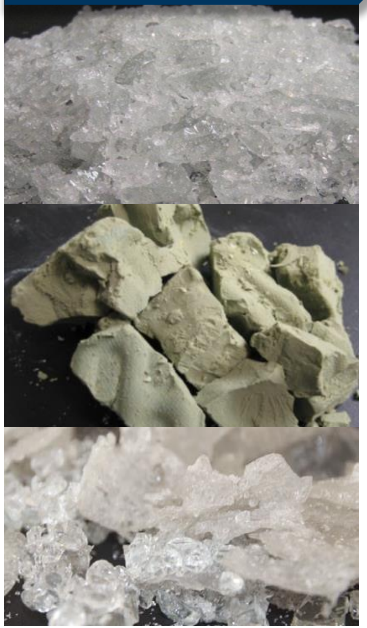
Manufacturing with less energy, water, and GHG emissions

## Product Use



Faster $CO_2$ reductions and greater return on energy invested

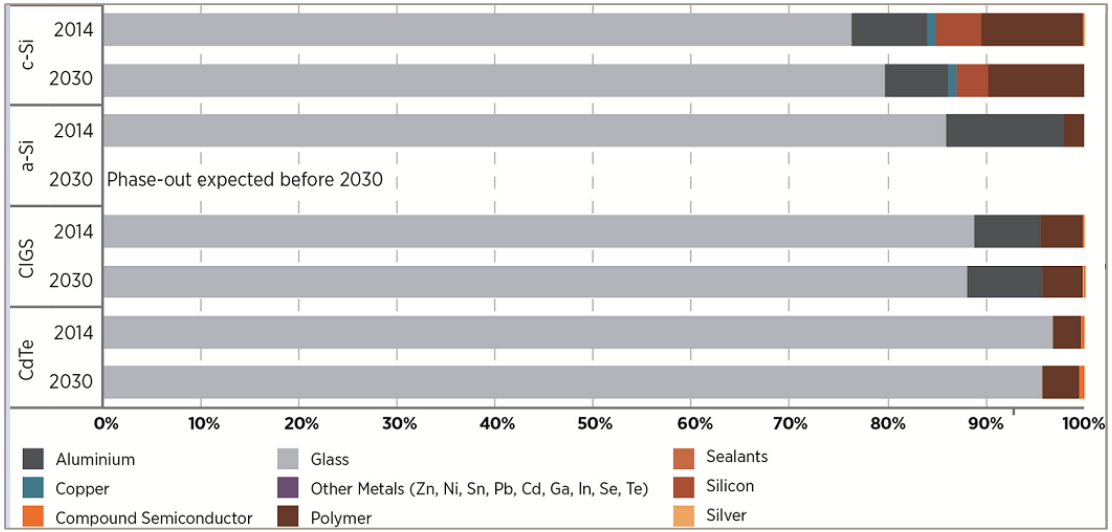
## High-Value Recycling



Recovering over 90% of materials at end-of-life for new PV modules

# COMPOSITION OF PV MODULES

- PV modules consist of glass, aluminum, semiconductor materials, and other metals that can be successfully recovered and reused
- By weight, more than 80% of a PV module is glass and aluminum
- High-value recycling also recovers environmentally sensitive, valuable and energy-intensive materials






IRENA and IEA-PVPS (2016), "End-of-Life Management: Solar Photovoltaic Panels," International Renewable Energy Agency and International Energy Agency Photovoltaic Power Systems.

# WHY DOES HIGH-VALUE PV RECYCLING MATTER?

**Crucial to managing large future PV waste volumes**

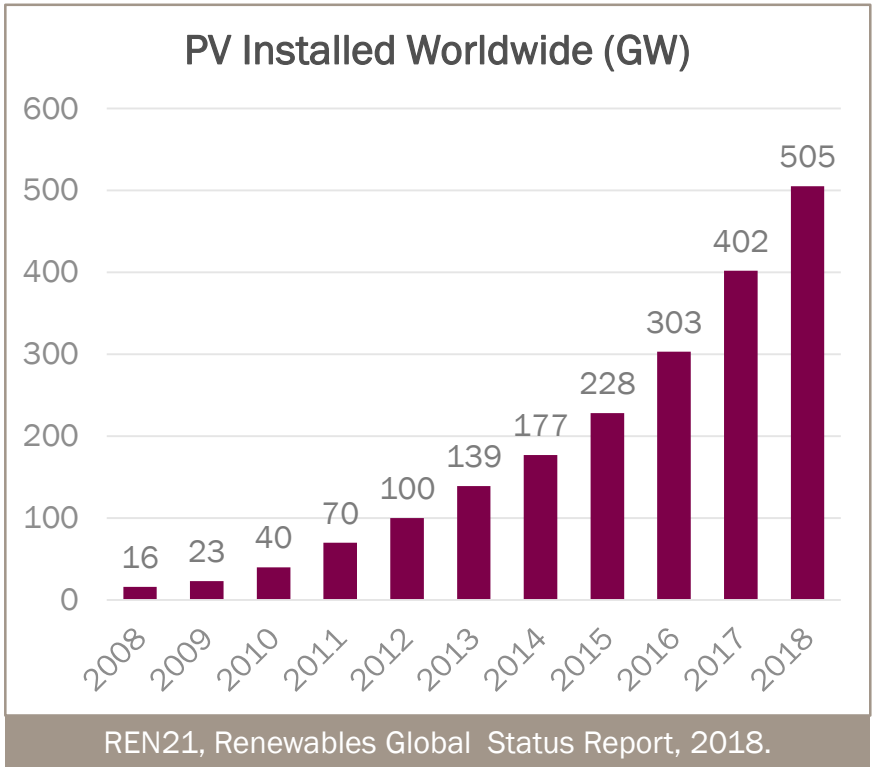
- Over 500 GW PV installed worldwide

**Recycling is important for all PV technologies**

- Environmentally sensitive materials are common in the industry (Pb, Cd, In, Se, Ag…)

**Provides socio-economic and environmental benefits**

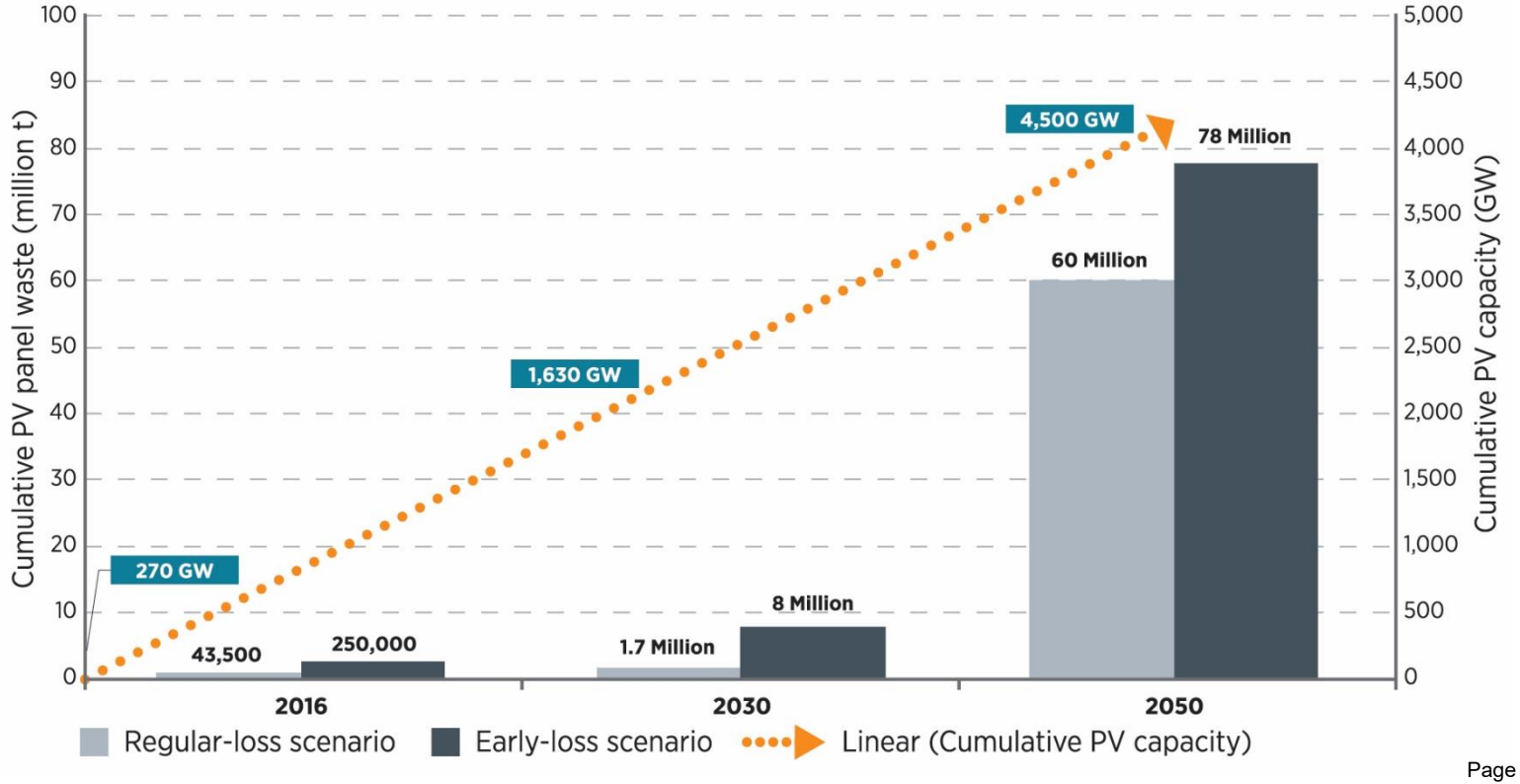
- Minimizes life cycle impacts
- Reclaims valuable and energy intensive materials
- Creates jobs and economic benefits
- Recoverable value could exceed $15bn by 2050 (IRENA & IEA PVPS, 2016)




REN21, Renewables Global Status Report, 2018.

**Recycling maximizes resource recovery and increases the sustainability of PV.**

# GLOBAL PV PANEL WASTE PROJECTIONS 2016-2050





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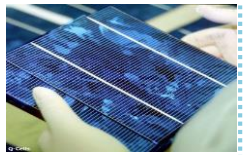
IRENA and IEA-PVPS (2016), "End-of-Life Management: Solar Photovoltaic Panels," International Renewable Energy Agency and International Energy Agency Photovoltaic Power Systems.

# A SHORT HISTORY OF PV RECYCLING

1st global PV recycling program in the industry

2005



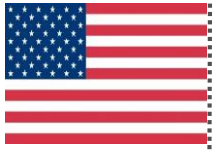
Ökopol Study

2007

PV Cycle Industry Initiative

EU WEEE Directive

2012



U.S. Industry Program

2016

PV Recycling Treatment Standard (EN 50625)

2017

Sustainability Leadership Standard

2019

First Solar

First Solar provides free of charge collection and environmentally responsible recycling of this solar module. Please do not dispose of this product in any manner before contacting First Solar via:

- the Web: **www.firstsolar.com/recycling**
- telephone: **1.866.456.8938** (North American Toll free) **+800.433.32.333*** (International Freephone)
  *For more details on dialing codes please visit First Solar's website.
- email: **recycling@firstsolar.com**

First Solar bietet für dieses Solarmodul die Möglichkeit zur kostenlosen Rücknahme und umweltgerechten Wiederverwertung. Bitte kontaktieren Sie First Solar, bevor Sie das Produkt entsorgen.

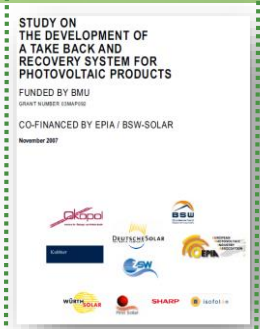
First Solar ofrece gratuitamente la recogida y el reciclaje responsable con el medio ambiente de este producto de módulo solar. Por favor, no elimine de cualquier modo los residuos de este producto antes de ponerse en contacto con First Solar.

La First Solar raccoglie gratuitamente questo modulo solare e lo ricicla nel rispetto dell'ambiente. Non gettí via questo prodotto prima di aver contattato la First Solar.

First Solar assure gratuitement la collecte et le recyclage de ce module solaire de manière écologique et responsable. Merci de ne pas vous débarrasser de ce produit de quelque façon que ce soit avant d'avoir contacté First Solar.

First Solar παρέχει δωρεάν συλλογή και περιβαλλοντολογικά υπεύθυνη ανακύκλωση της παρούσας ηλιακής μονάδας. Απορρίψτε την απόρριψη του προϊόντος με οποιονδήποτε τρόπο πριν επικοινωνήσετε με τη First Solar.

First Solar www.firstsolar.com




PV CYCLE

SEIA PV RECYCLING PROGRAM

CENELEC


NSF

epeat

# FIRST SOLAR'S HIGH VALUE PV MODULE RECYCLING PROCESS


Shredder

Hammermill

Crushed/ Milled Scrap Holding Bin

Metals Precipitation

Film Removal Solid/ Liquid Separation

Unrefined Semiconductor Material

Third-party Cd/Te Separation & Refining

EVA/Glass Separation

CdTe

FS PV modules

Clean Glass Cullet

Glass products

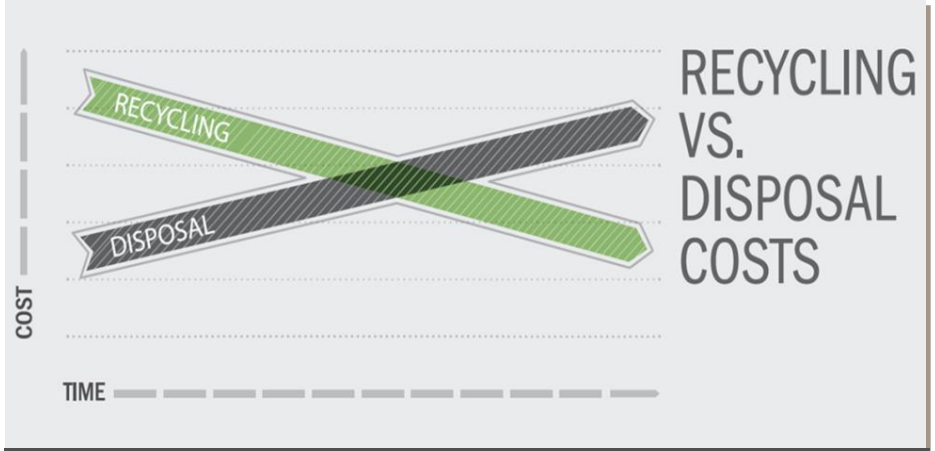
Laminate Material

Rubber products

+ 90% Recycling of Semiconductor Material and ~ 90% Recycling of Glass

# FINANCING PV RECYCLING: PRE-PAY VS. PAY-AS-YOU-GO

| Pre-Pay / Pre-fund | First Solar RSA |
|---|---|
| Customer pays for EOL collection and recycling at time of sale and funds are placed in an independent trust fund | Customer contractually commits to recycling through an RSA with 2-year termed renewable pricing. EOL recycling is funded with later year project cash flows |
| ✓ Convenient<br>✓ Effective for low volumes<br>✗ Inefficient use of customer cash flows<br>✗ Not cost-effective or scalable<br>✗ Not competitive | ✓ Globally available<br>✓ Cost effective and scalable<br>✓ Optimized use of cash flows<br>✓ Convenient and comprehensive<br>✓ Flexible pay-as-you-go service<br>✓ Allows prices to drop as recycling costs decrease |




Increased volumes of solar modules at end-of-life and greater experience in recycling, accompanied by rising disposal costs, will likely lead to recycling becoming more commercially attractive and result in higher volumes of collection and recycling.

# CENELEC HIGH VALUE RECYCLING STANDARDS

- EN50625-2-4 covers the waste fraction of end-of-life photovoltaic panels and aims to assist organizations in achieving effective and efficient treatment of waste photovoltaic panels in order to
  - prevent pollution and minimize emissions;
  - promote increased material recycling;
  - promote high quality recovery operations;
  - prevent the inappropriate disposal of photovoltaic panels and fractions thereof, assuring the protection of human health and safety, and the environment;
  - and prevent shipments of waste photovoltaic panels to operators whose operations fail to comply with this standard or a comparable set of requirements.
- The content of hazardous substances in output glass fractions shall not exceed the following defined limit values:
  - 1 mg/kg (dry matter) cadmium (Si-based PV) / 10 mg/kg (dry matter) cadmium (non-Si-based PV)
  - 1 mg/kg (dry matter) selenium (Si-based PV) / 10 mg/kg (dry matter) selenium (non-Si-based PV)
  - 100 mg/kg (dry matter) lead

European Committee for Electrotechnical Standardization (CENELEC): EN 50625-2-4, Collection, logistic & treatment requirements for WEEE - Part 2-4: Specific Requirements for the treatment of photovoltaic panels.
European Committee for Electrotechnical Standardization (CENELEC): TS 50625-3-5, Collection, logistic & treatment requirements for WEEE - Part 3-5: Technical Specification for de-pollution – Photovoltaic panels.

# EPEAT | NSF 457 SUSTAINABILITY LEADERSHIP STANDARD FOR PV MODULES

### 6.1.2 Recycled Content in product

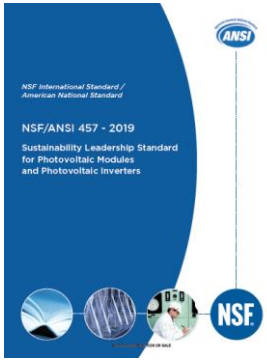
- Minimum percentage recycled content in product

### 9.1 End-of-life Management

- Required product take-back service
- Publicly available record of annual recycling and recovery achievement
- Material recovery targets

### 9.2 Design for Recycling

- Identification of materials for EOL management




| Minimum percentage recycled content | Points |
|---|---|
| ≥ 10% recycled semiconductor material | 1 |
| ≥ 10 % recycled glass material | 1 |
| Achieve 4 out of 8:<br>— ≥ 25 % recycled frame material<br>— ≥ 10% recycled transparent conductive layer<br>— ≥ 10 % recycled paste and contact material<br>— ≥ 10 % recycled ribbon material<br>— ≥ 10 % recycled solder material<br>— ≥ 10 % recycled encapsulant material<br>— ≥ 10 % recycled backsheet material<br>— Demonstrated conformity with a material traceability standard[7] | 1 |

| Recovery achievement thresholds | Points |
|---|---|
| — ≥80% glass; and<br>— ≥80% metals (not including semiconductor materials); and<br>— ≥30% semiconductor materials | 1 |
| — ≥90% glass; and<br>— ≥90% metals (not including semiconductor materials); and<br>— ≥60% semiconductor materials | 2 |

# CIRCULAR ECONOMY: BEYOND WASTE

## TYPICAL RECYCLING RATES

AUTOMOTIVE
~75%

INFORMATION TECHNOLOGY
~45%

FIRST SOLAR MODULES
~90%

## THE VALUE LOOP

SEMICONDUCTOR FROM MINING BY-PRODUCTS

THIN FILM PV MANUFACTURING

Resource-Efficient Manufacturing

DISPLACE GRID EMISSIONS

25+ Years of Deployment

FIRST SOLAR RECYCLING SERVICES

90% RECOVERY RATE

**GLASS:** Used to make glass products

**ENCAPSULANT:** Used to make rubber products

**SEMICONDUCTOR:** Reused to produce First Solar modules

| 1Kg | 40x | 1,230 years |
|---|---|---|
| Of CdTe Semiconductor | Times it can be recycled | Years it can generate electricity |

First Solar.

FIRSTSOLAR.COM/SUSTAINABILITY

# PV End-of-Life Management

Evelyn Butler

Sr. Director, Codes & Standards

December 9, 2019

# Who We Represent

SEIA Members represent every aspect and vertical within the solar industry (>1000 companies)

**Manufacturers**

**Installers**

**Project Developers**

...and many more!

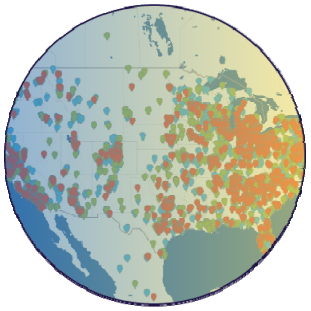
# Our Work

Industry Leadership

Government Affairs

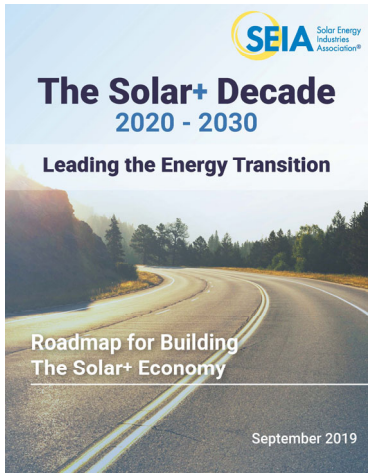
Events & Education

Communications



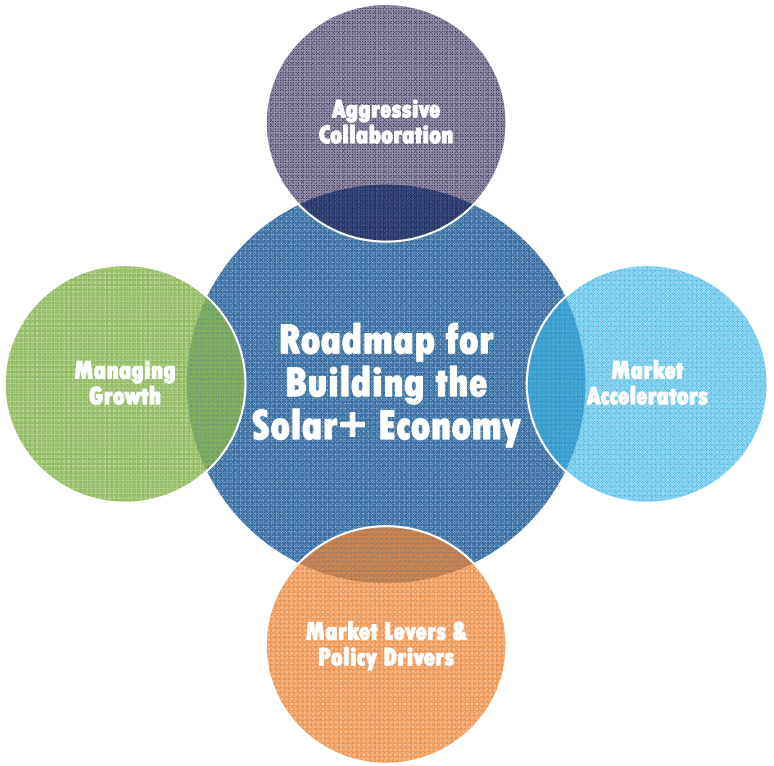
Market Research

# Roadmap for the Solar+ Decade



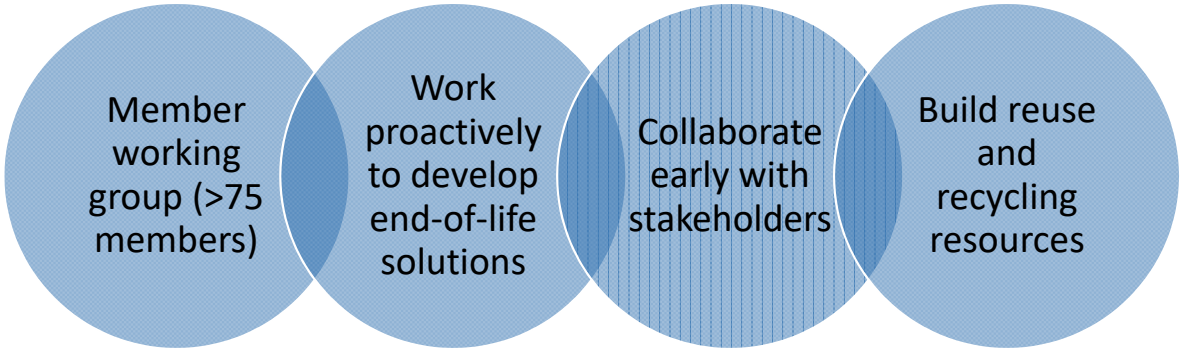

SEIA is 100% committed to leading the industry towards radical market transformation in the 2020s.

We will be taking on tough opponents, providing industry expertise and aggressively collaborating with partners that will push us all forward



# PV Systems, Storage and Solar Projects

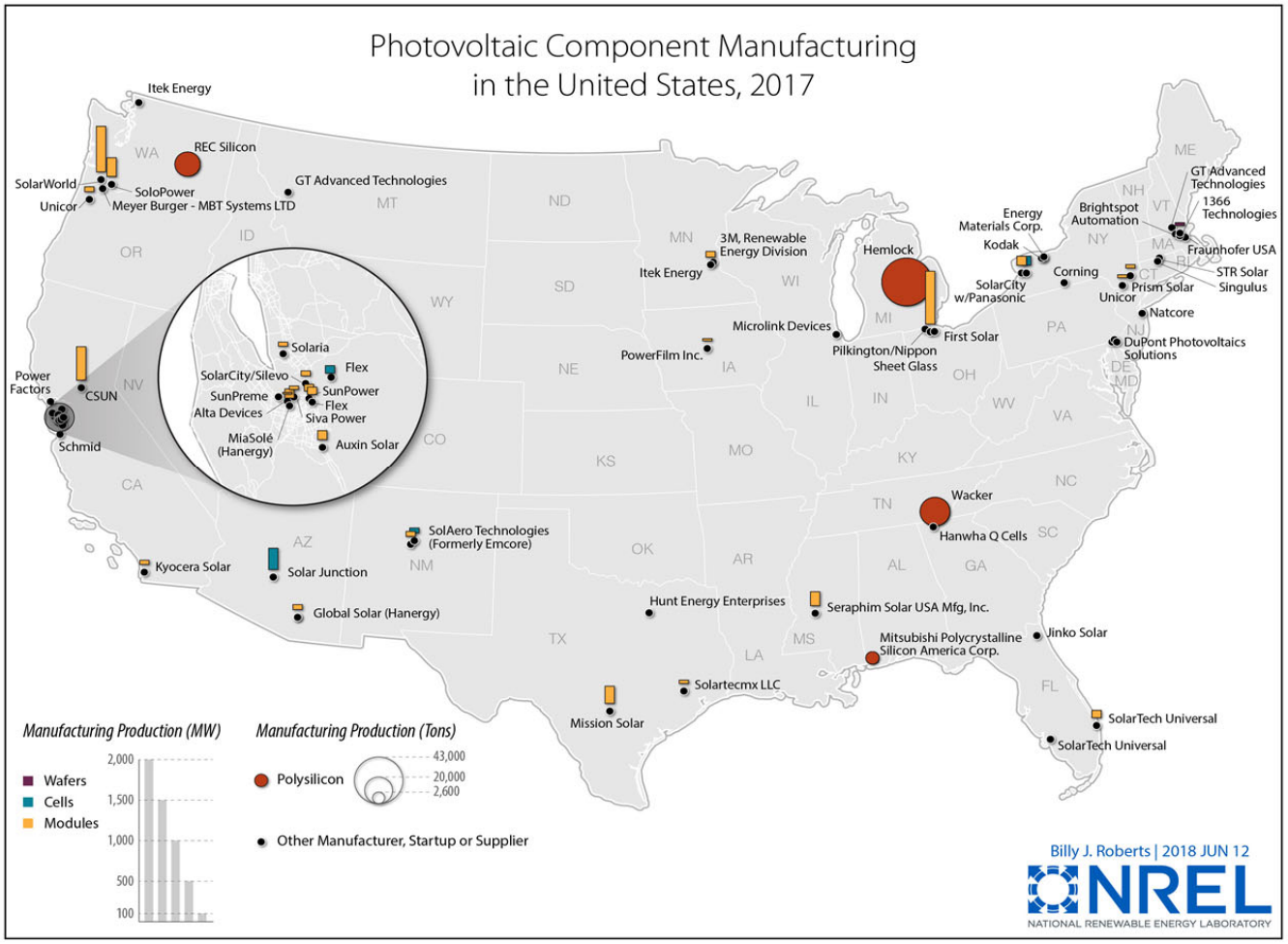
# SEIA's EOL Management / PV Recycling Initiative




# Products

- PV Modules (Silicon, Thin-Film)
- Inverters, energy storage
- Mounting / racking systems

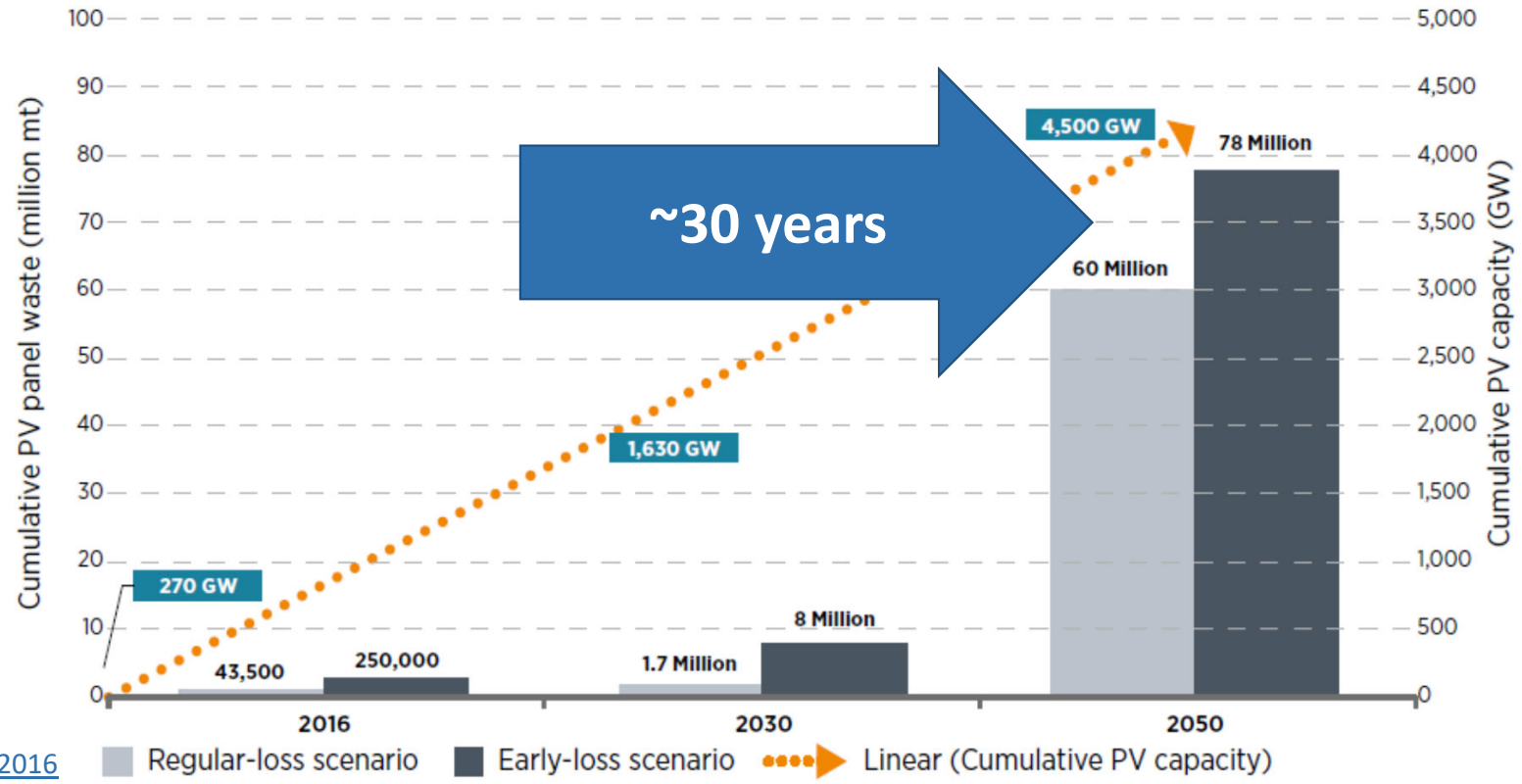

# From where is the waste coming?




- Manufacturing scrap
- Warranty-related returns
- Broken during logistics or handling
- Extreme weather events
- Technology upgrades

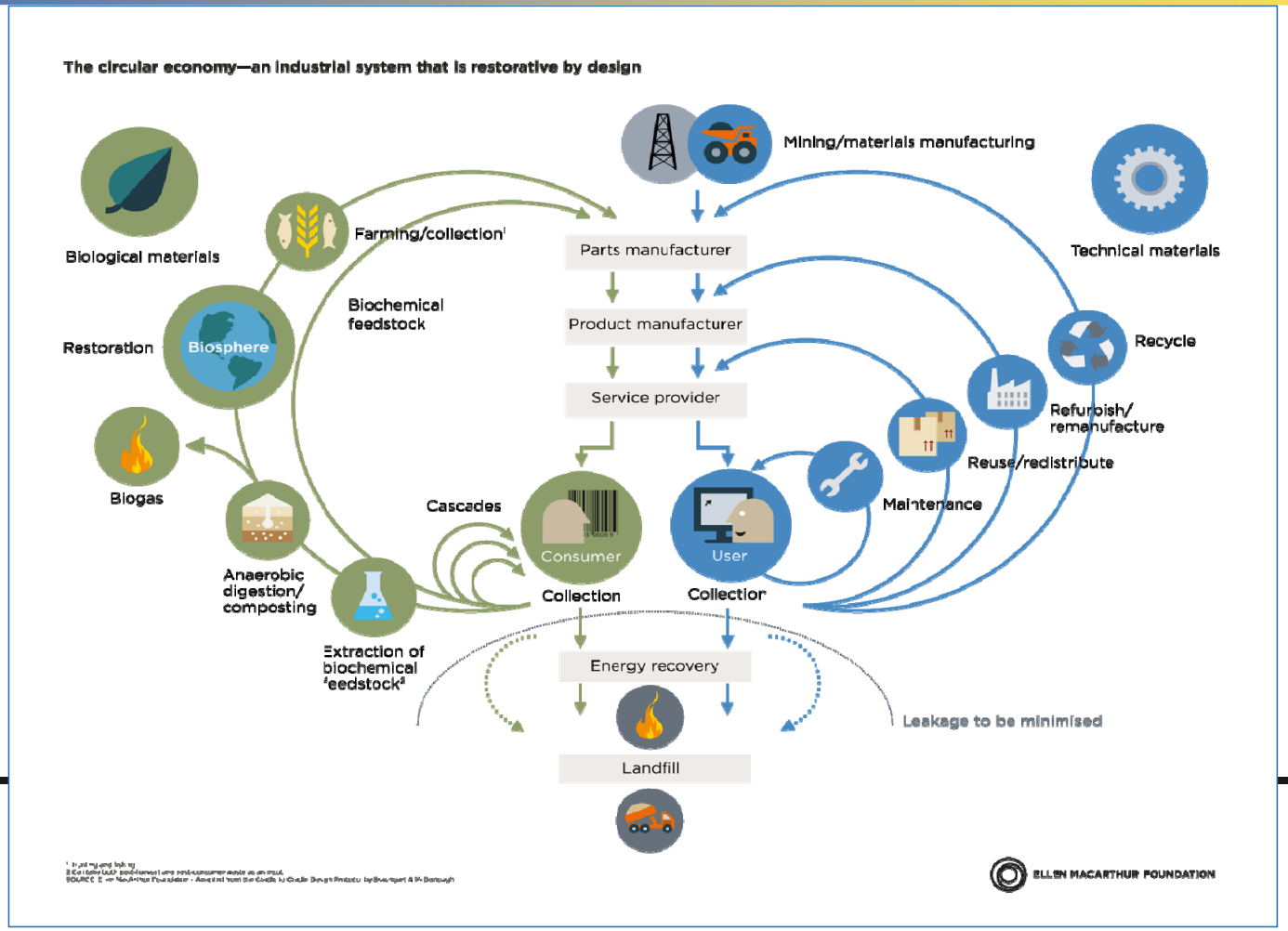
SEIA Solar Energy Industries Association

# Global volume forecast (cumulative)




Source: IEA/IRENA, 2016

# Circular Economy Approach



# EOL Factsheet and Preparation Checklist

- SEIA Website:

https://www.seia.org/initiatives/recycling-end-life-considerations-photovoltaics

- End-of-Life Considerations for PV
- PV End of Life Management: Prepare for recycling PV equipment

PV End-of-Life Management

Prepare for recycling PV equipment

End-of-Life Considerations for Solar Photovoltaics

Engaging the circular economy approach

Photovoltaic equipment and options for first end-of-life stages

The falling cost of solar has made renewable energy accessible to more people than ever before and has resulted in an exponential increase in solar adoption. With more than 400 gigawatts (GWdc) of photovoltaic (PV) modules installed globally (including 62 GWdc in the U.S. through 2018), end-of-life management is important for all PV technologies to ensure clean energy solutions are a sustainable component of the energy economy for future generations.

Like many other durable products and construction materials, solar equipment can last for decades, particularly with proper maintenance. In some cases, PV modules can be reused or refurbished to have a "second life" of generating electricity. The other components of solar systems can also be handled responsibly. Inverters can be recycled as e-Waste and racking equipment can be re-utilized with newer technology or recycled like other metals.

Reuse

PV systems may be decommissioned for several reasons. Repowering a solar system with newer technology that is more efficient or has a higher nameplate capacity can provide even more electricity from the same amount of space.

The replaced PV modules can be reused in other projects as they may still have plenty of useful life left. Often these modules can find new opportunities in charitable, off-grid or even grid-connected projects, provided they continue to meet the appropriate building codes and safety standards.

Refurbishment

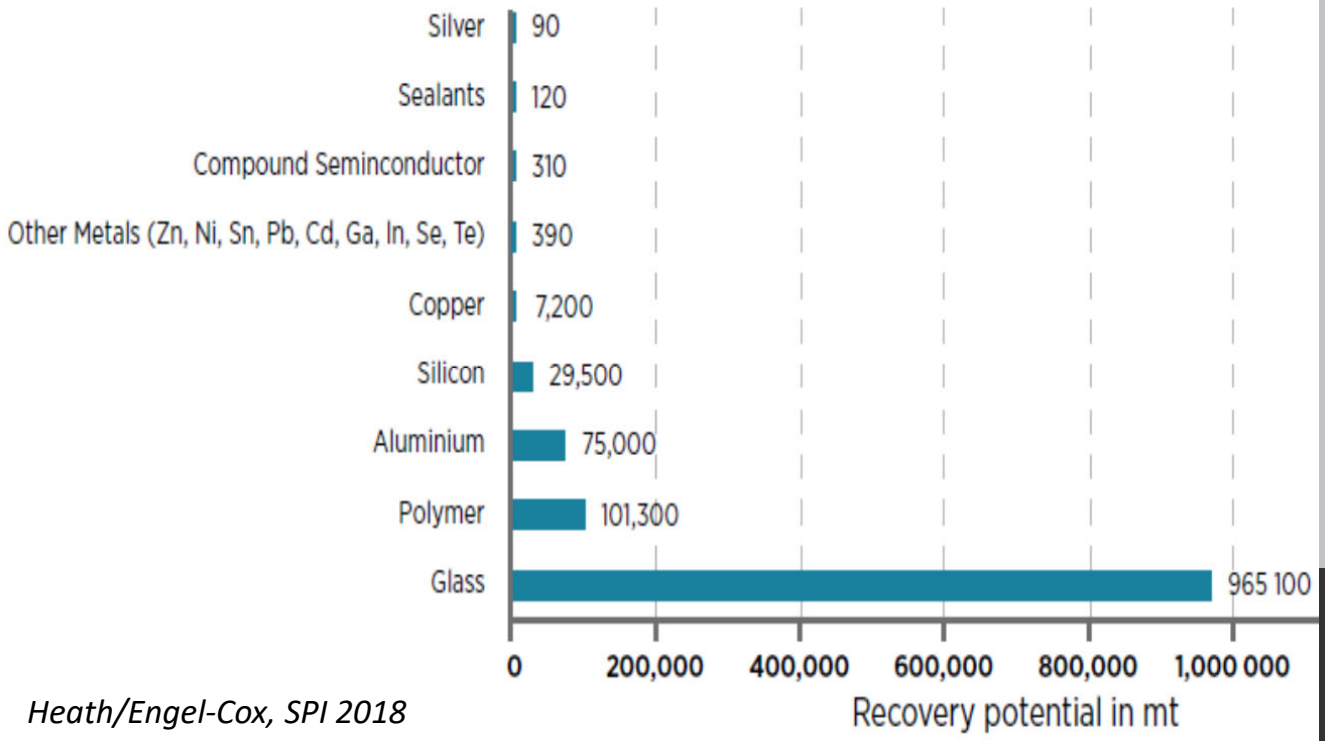
PV modules can be damaged during transit, installation or moving. Some of these modules can be repaired for minor issues and there are several new organizations pursuing this option. If the product is still under warranty, the installer or manufacturer should be contacted to determine if repair is an option. Many modules that are repaired today are often reused in off-grid or non-grid connected applications. While this channel is not as developed as other end-of-life options, SEIA is actively exploring the related options with our members and other stakeholder

September 2019

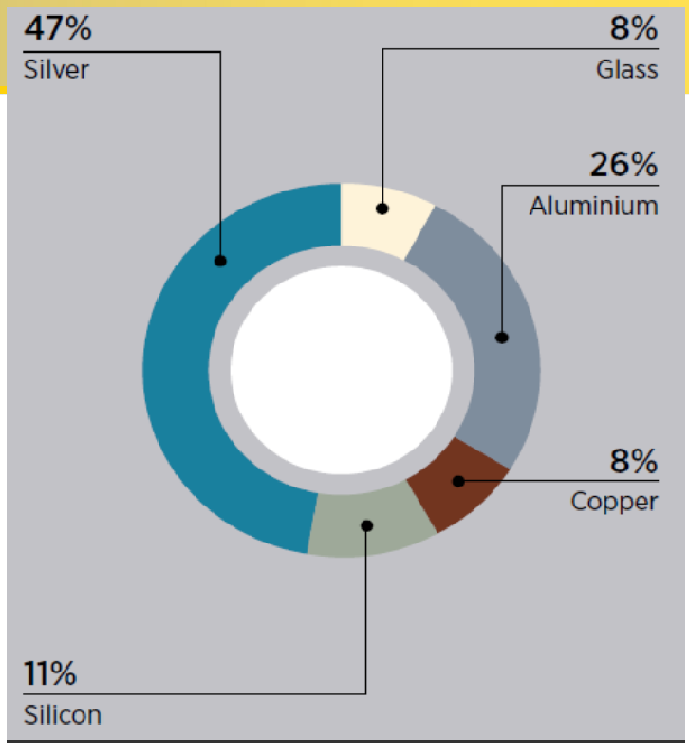
www.seia.org

May 2019

# Why recycle PV modules?




*Heath/Engel-Cox, SPI 2018*



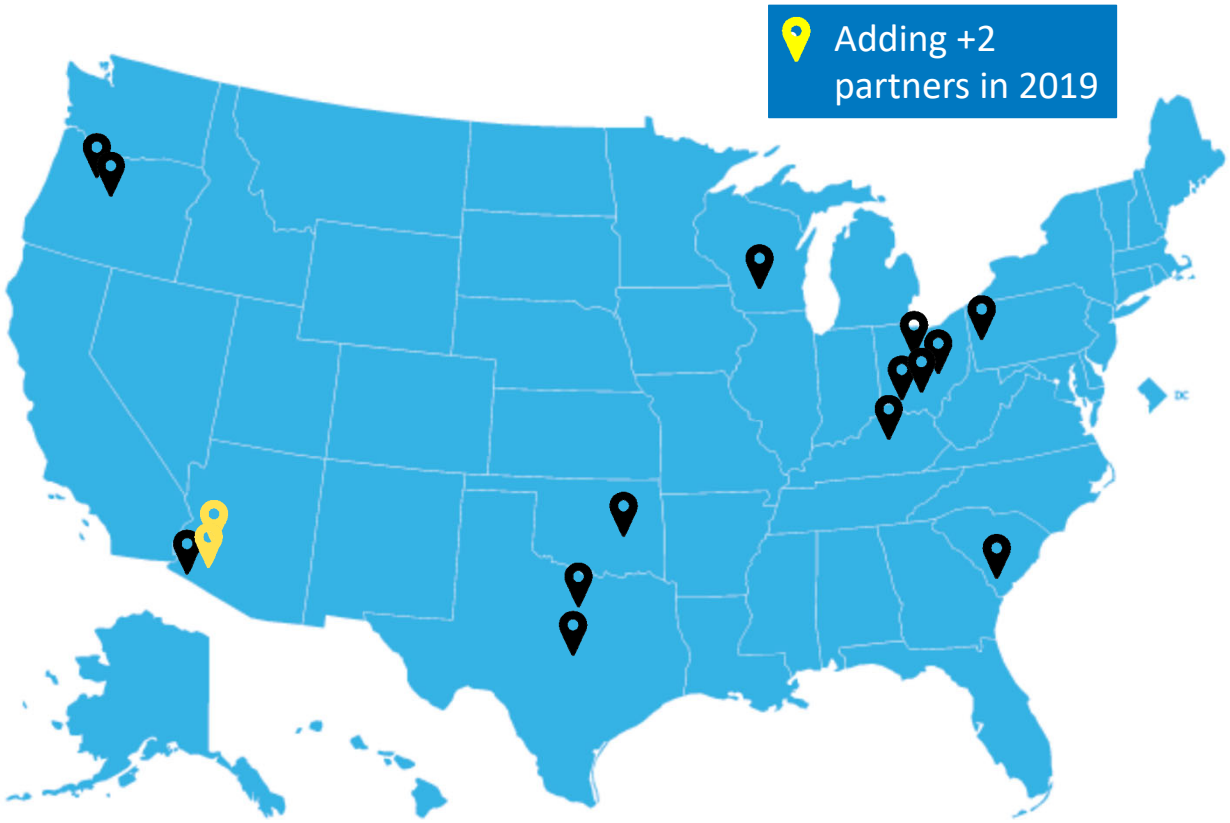

**Relative material value of a c-Si Panel**

Based on Raithel (2014)

# SEIA's PV Recycling Program

| Member-based program | Evaluate and develop recyclers | Collect data |
|---|---|---|
| • Evaluate service capabilities<br>• Downstream capabilities<br>• **Anyone** can use these recyclers | • Members help develop process<br>• Members help with technology<br>• Site visit, samples | • Weight and volume (est. annually)<br>• Recovered materials (modeled) |

# SEIA Recycling Partners




CEM
CASCADE ECO MINERALS

CLEANLITES
RECYCLING

DYNAMIC
LIFECYCLE INNOVATIONS

Echo
Environmental

First Solar

GREEN
CENTURY
RECYCLING

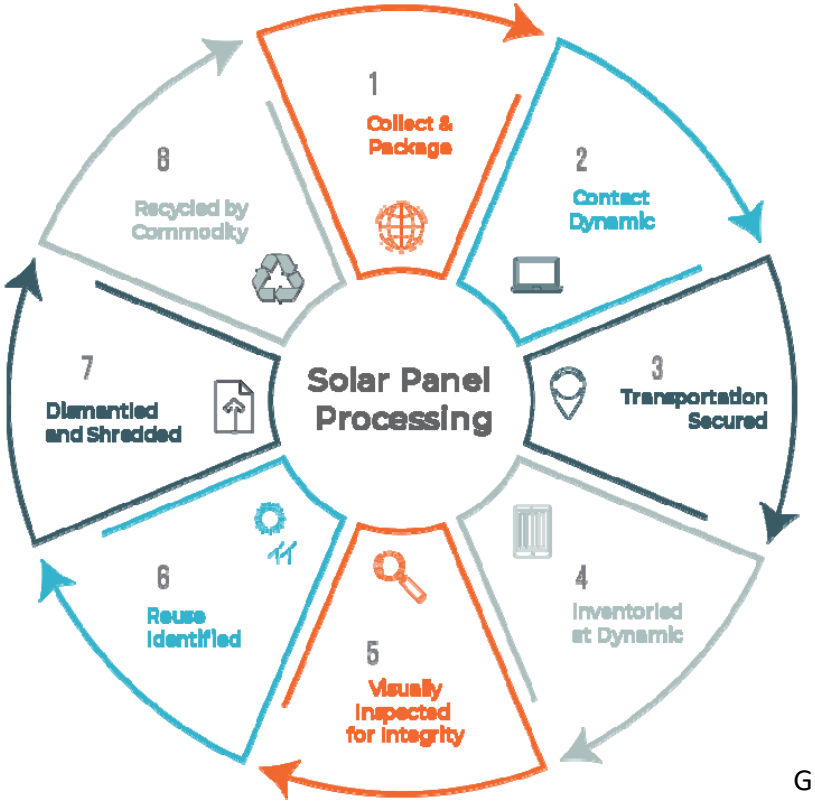
SEIA
Solar Energy
Industries
Association

www.seia.org

# Partner Qualifications

- Collect and process in the U.S.
  - no exporting
- Accredited
- Strive for maximum material recovery / second-life usage
- Specific benefits for SEIA members
- Work sustainably and promote sustainability

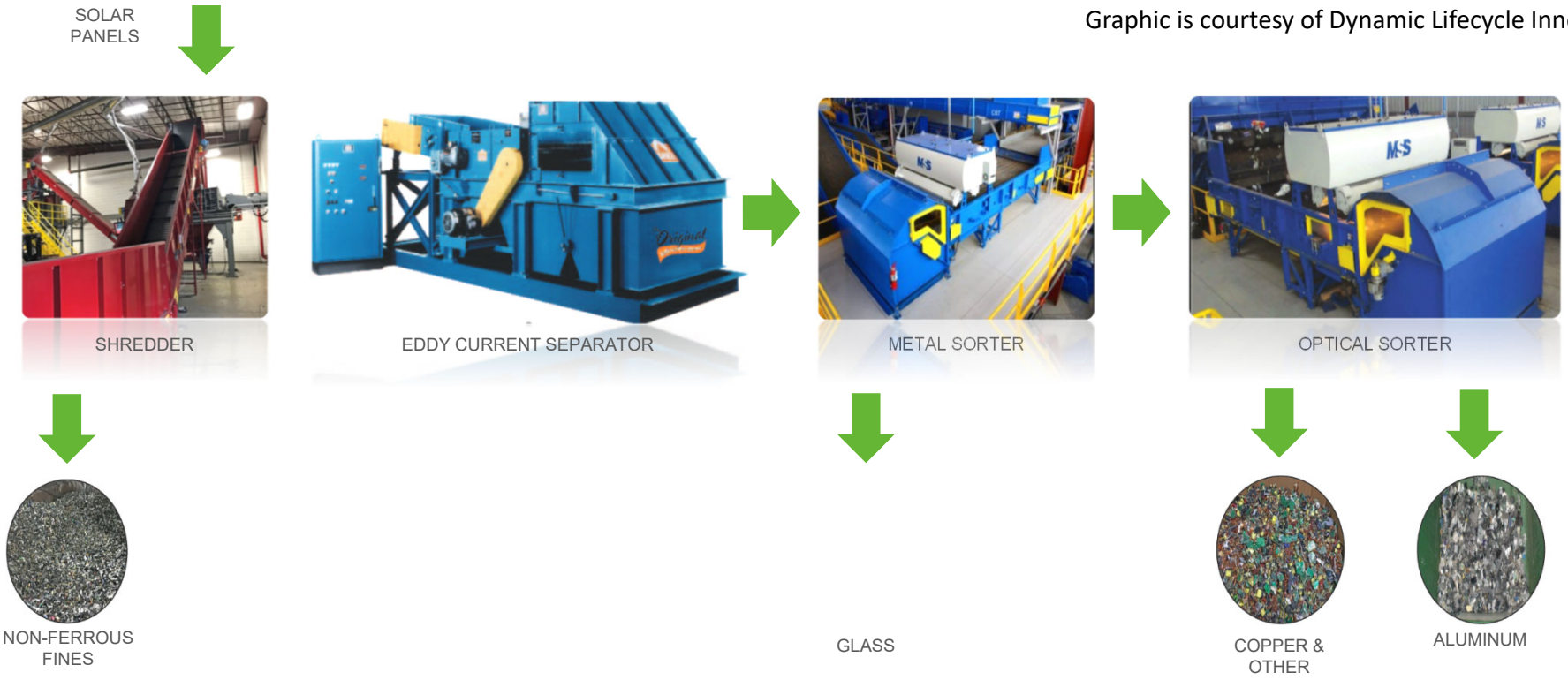
# Recycling Process (mechanical process)




Graphic is courtesy of Dynamic Lifecycle Innovations

# Example process (Dynamic Lifecycle)

Graphic is courtesy of Dynamic Lifecycle Innovations



# Challenges and Opportunities

## Manufacture

- Solutions for manufacturing scrap
- Design innovation for ease of reuse, refurbishment or recycling
- Work with suppliers Improve purity of recovered minerals

## Reuse

- Create and prioritize reuse above other channels to ensure viable product is utilized
- Expand beyond off-grid or charitable / second-market solutions
- Potential conflicts with state waste regulations

## Remanufacture or Refurbishment

- Identify treatments that don't affect module certification
- Minimize / eliminate expensive retesting
- Training, staffing
- Codes and standards

## Recycle

- Develop collection in key markets
- Minimize costs to encourage recycling
- R&D PV recycling equipment to maximize material recovery
- Maximize communication to minimize environmental impacts

# NASEW / SPI 2020

- Annual renewable energy/ solar conference and tradeshow
- Research, white papers, articles
- PV Recycling / End-of-Life sessions at regional solar events, webinars, meetings

SOLAR POWER INTERNATIONAL

SMART ENERGY MARKETPLACE + MICROGRID

ESI ENERGY STORAGE INTERNATIONAL

H2 fci Hydrogen+ Fuel Cells International

wind ENERGY INTERNATIONAL

# Thank you!

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# Appendix A2
# January 22, 2020 Meeting Presentations

## *Summary of Solar Facilities Currently Operational in North Carolina*

Stakeholders Meeting
January 22, 2020

NORTH CAROLINA
Department of Environmental Quality

# *Data Sources:*

- North Carolina Utilities Commission's (NCUC) Renewable Energy Facility Registration
  https://www.ncuc.net/Reps/reps.html
- North Carolina Renewable Energy Tracking System (NC-RETS)
  https://www.ncrets.org/public-reports/
- U.S. Energy Information Administration (EIA)
  https://www.eia.gov/electricity/data/eia860/
- Facility and Interconnection Data provided by Dominion, Duke, and NCEMC

# *How We Complied Our Data:*

- Only ground mounted facilities 1 MW or greater were included
- If multiple operation dates were listed, the most recent date was utilized
  - This same approach was used for panel counts
- If a range was provided for the projected lifespan, the lesser number was utilized
- If a facility was included on one or more of the following, then it is assumed to be in operation:
  - NC-RETS Project List
  - EIA-860 Facility List
  - Stakeholder Facility Data
  - Transmission Interconnection Data

# *Solar Facilities By the Numbers:*

- 530 Facilities were identified with a total of 4,065 MW
- Located across 75 counties
- Panel Counts were provided for 483 of the facilities
  - Ranged from 1,000 to 16,000 per MW (averaging 5,080 per MW)
- Panel Types were available for 499 of the facilities
  - 89% silicon-based (c-Si)
  - 10% cadmium telluride (CdTe)
  - 1% copper indium gallium selenide (CIGS)
- Reported Project Lifespans ranged from 20 to 40 years
- Reported PPAs ranged from 10 to 20 years

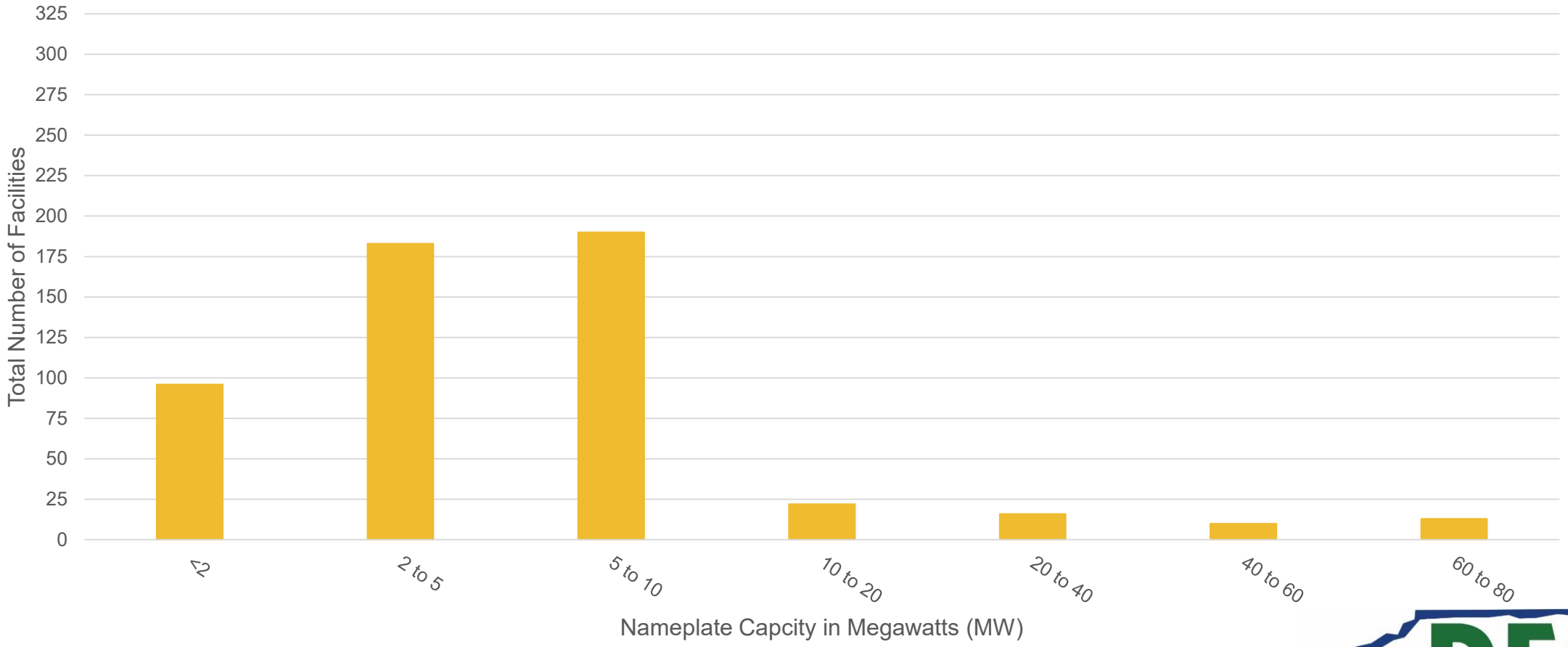
# *Assumptions for our Projections:*

- For the 47 Facilities without panel counts, an estimate was used based on the average panel per MW for the known facilities (5,080 per MW).

- For the 82 Facilities without lifespan data, 25 years was utilized since this is the most common reported length of manufacturer warranties.

- The estimated metric tons of panels is based off the average panel weighing 40 pounds.  This is based off the weight of specific panel types cited in our data as well as a literature review.

## Solar Facilities Currently Operational in NC by MW

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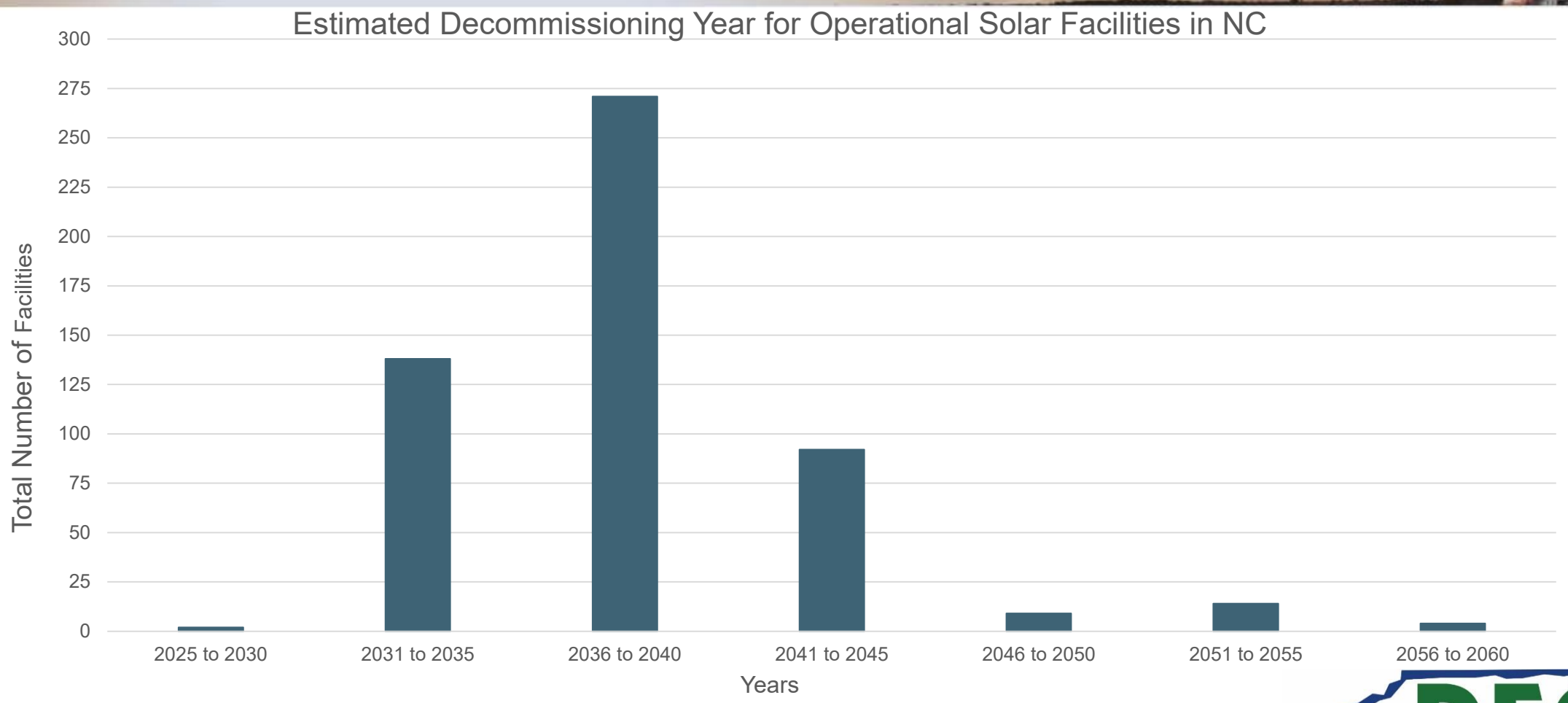


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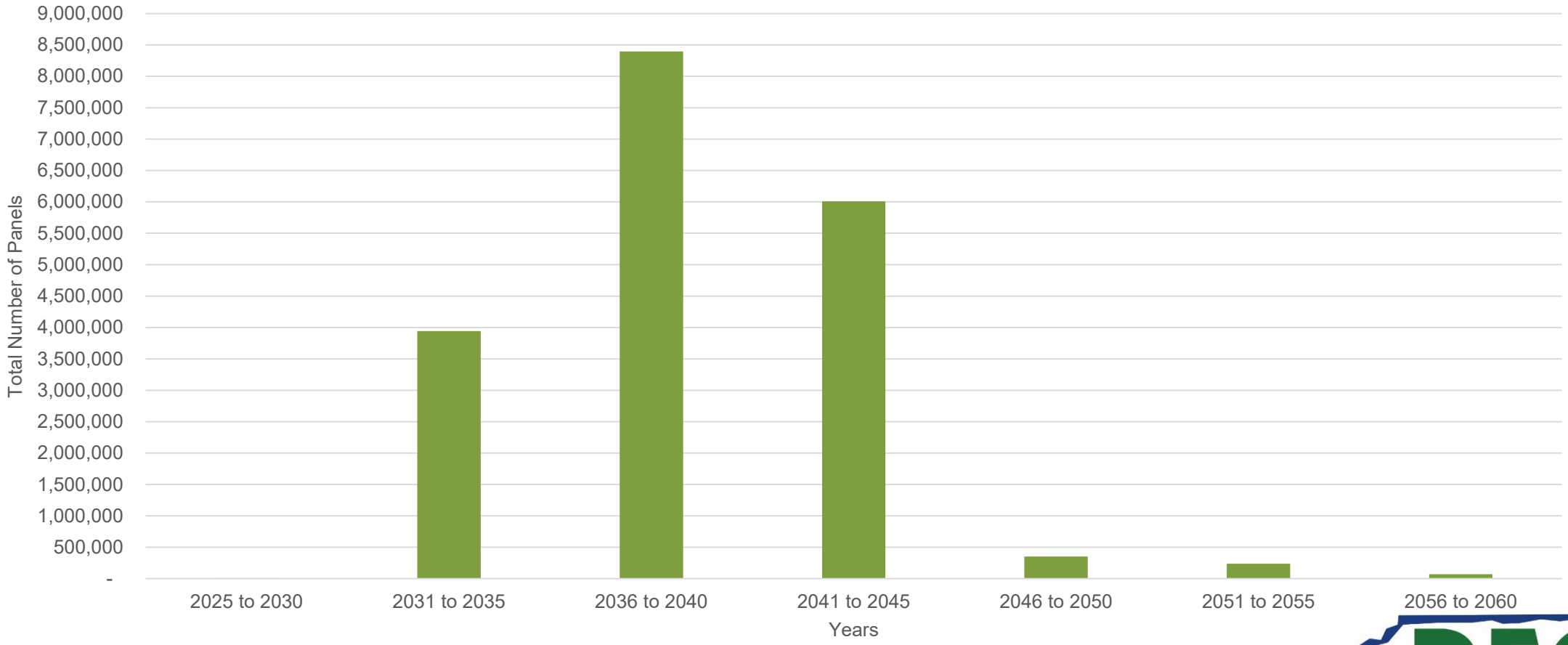
## Estimated Number of PV Panels to be Decommissioned by Year

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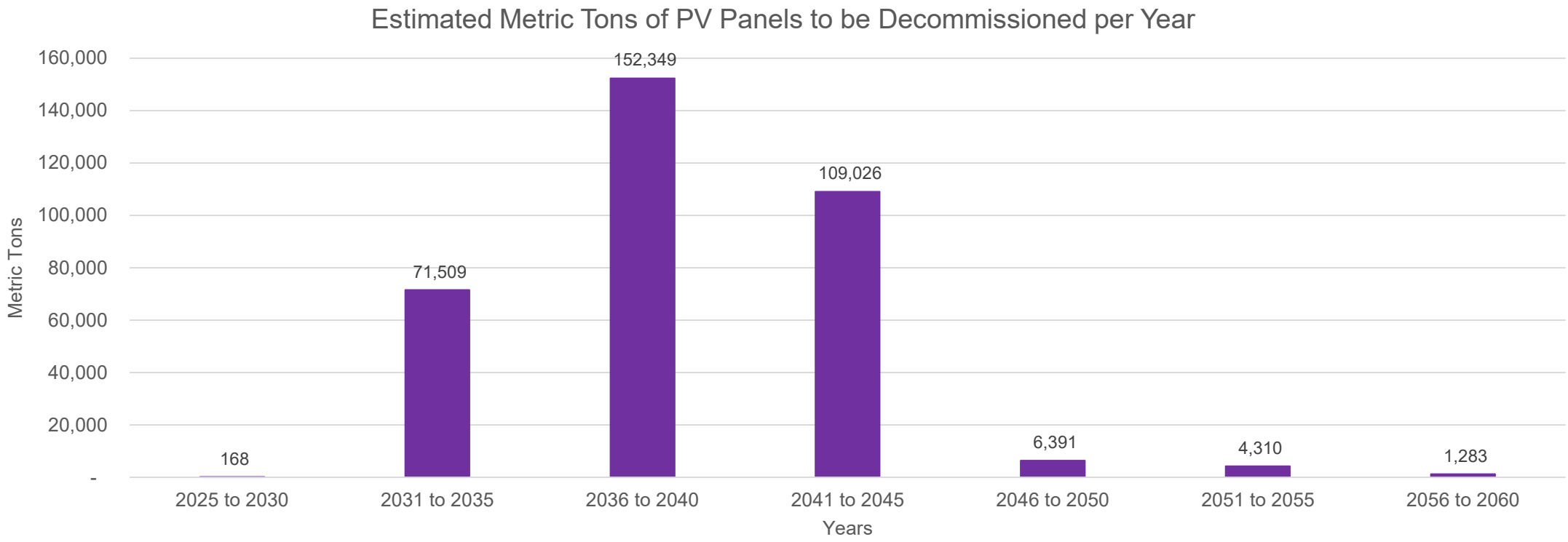


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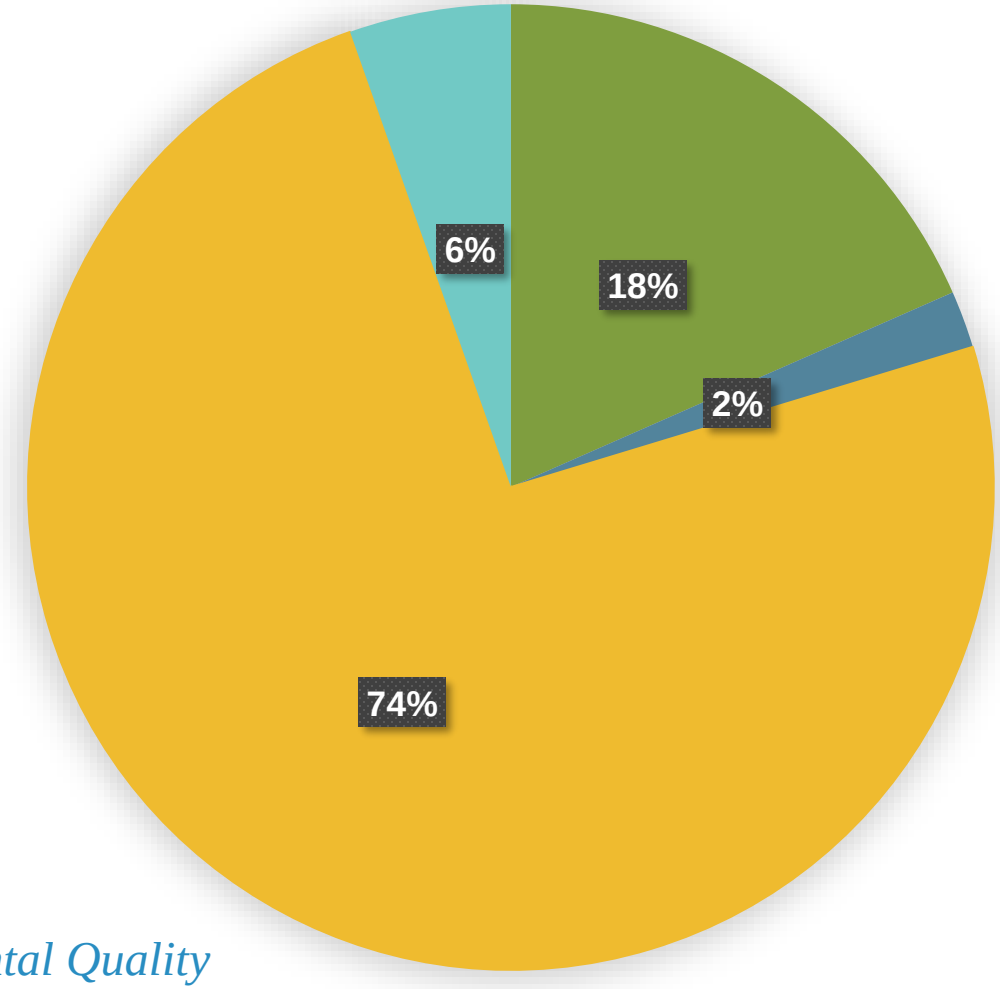
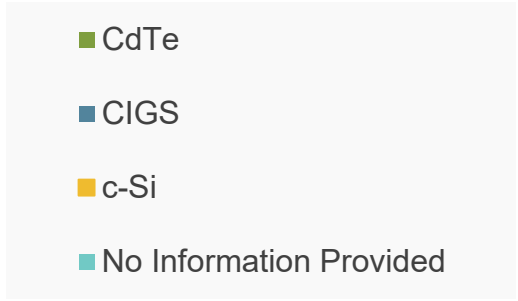
## Types of PV Panels Operational in NC

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# *Federal Financial Assurance Requirements for Other Energy Sources*

Stakeholders Meeting
January 22, 2020

NORTH CAROLINA
Department of Environmental Quality

# Nuclear Power Plant

- Before a nuclear power plant begins operation, the licensee must establish a financial mechanism to ensure there will be sufficient money to pay for the decommissioning of the facility.
- Each licensee must report to the Nuclear Regulatory Commission (NRC) every two years on the status of its decommissioning funding for each reactor that it owns. The report must estimate the minimum amount needed for decommissioning.
- Financial assurance must be provided via one of the following methods: prepayment, external sinking fund, surety method, insurance, any other mechanism, or combination of mechanisms.
  - The minimum financial assurance is between $105 and $135 million depending on the type and capacity of the reactor.
- Approximately 70% of licensees are authorized to accumulate decommissioning funds over the operating life of their plants. These owners are not required today to have all of the funds needed for decommissioning.

# Petroleum Underground Storage Tanks

- EPA designed the financial responsibility requirements to insure that the costs of cleaning leaks and compensating 3rd-parties for damage caused by leaking storage tanks are funded.
- The amount of financial responsibility coverage needed is determined by the type of business, the amount of throughput of the tank, and the number of tanks owned.

| Group Of UST Owners And Operators | Per Occurrence Coverage | Aggregate Coverage |
|---|---|---|
| **Group 1:** Petroleum producers, refiners, or marketers | **$1 million** | **$1 million** for 100 or fewer tanks *or* **$2 million** for more than 100 tanks |
| **Group 2:** Nonmarketers | **$500,000** if throughput is 10,000 gallons monthly or less *or* **$1 million** if throughput is more than 10,000 gallons monthly | |

- State financial assurance funds, insurance coverage, guarantee, surety bond, letter of credit, financial test, and trust fund are the mechanisms allowed in North Carolina.

# Onshore Oil and Gas Drilling

- U.S. Bureau of Land Management:
  - Prior to the commencement of surface disturbing activities related to drilling operations, the owner must submit a surety or a personal bond.
    - Minimum $25,000 covering all leases and operations in any one State.
    - Minimum $150,000 covering all leases and operations nationwide.
  - FA is used to ensure timely and complete plugging of wells, reclaim lease areas, and restore lands and/or surface waters adversely affected by lease operations after the abandonment or cessation of oil and gas operations.
- State requirements:
  - Financial assurance and bonding requirements for well plugging and abandonment, disturbed land, and environmental damage are set out in 15A NCAC 05H. 1400 et seq.

# Surface Coal Mining

- Minimum initial bond amount of $10,000 is required to ensure the completion of the reclamation plan.
- The total bond amount is determined by the regulatory authority.
- Amount is based on the estimated reclamation cost submitted by the applicant and is adjusted based off of the requirements of the approved permit and reclamation plan. The bond must also account for the possible difficulty of reclamation.

Jessica Citrola, Environmental Specialist II

Phone: (919) 707-8339

jessica.citrola@ncdenr.gov


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# Appendix A3
# February 10, 2020 Meeting Presentations

## Wind Energy and Equipment in North Carolina

*H329 Stakeholders*

February 10, 2020

*Department of Environmental Quality*

# *Wind Energy In North Carolina: Overview*

- N.C.G.S. Chapter 143, Article 21C
  - Permitting of Wind Energy Facilities
- On-shore: Amazon Wind Farm, U.S. East
- Offshore: Kitty Hawk, Avangrid Renewables and future outlook
- Questions to answer, *H329 information needs*

# *N.C.G.S. Chapter 143, Article 21C*

Permitting of Wind Energy Facilities (WEFs)

- Enacted in 2013, requires permits for WEFs and expansions with ≥ 1MW capacity
  - Pre-application and scoping meetings
  - Permit application
    - N.C.G.S. §143-215.119(a)(13): Decommissioning and removal of WEF
      - Estimated cost
      - Anticipated project life
      - Manner in which WEF will be decommissioned
      - Expected condition of the site following decommissioning and removal

# *N.C.G.S. Chapter 143, Article 21C (cont'd)*

Required Financial Assurance for WEFs

- N.C.G.S. §143-215.121 requires financial assurance:
  - Sufficient to decommission and reclaim property
    - Regardless of insolvency, or otherwise reside, conduct business in NC, etc.
  - May be in the form of:
    - Insurance
    - Financial tests
    - 3rd-party or corporate parent guarantees who can pass financial test
    - Irrevocable letters of credit
    - Trusts, surety bonds, or other/combination of financial device(s)

# *On Shore Wind in North Carolina*

Amazon Wind Farm, U.S. East

- Grandfathered: not subject to Article 21C permit requirements
  - On-line in 2017
  - 104-2MW Gamesa turbines, 208MW nameplate capacity
    - Hub height = 92m (301ft)
    - Rotor diameter = 114m (374ft)
  - Electricity wheeled into PJM/Dominion

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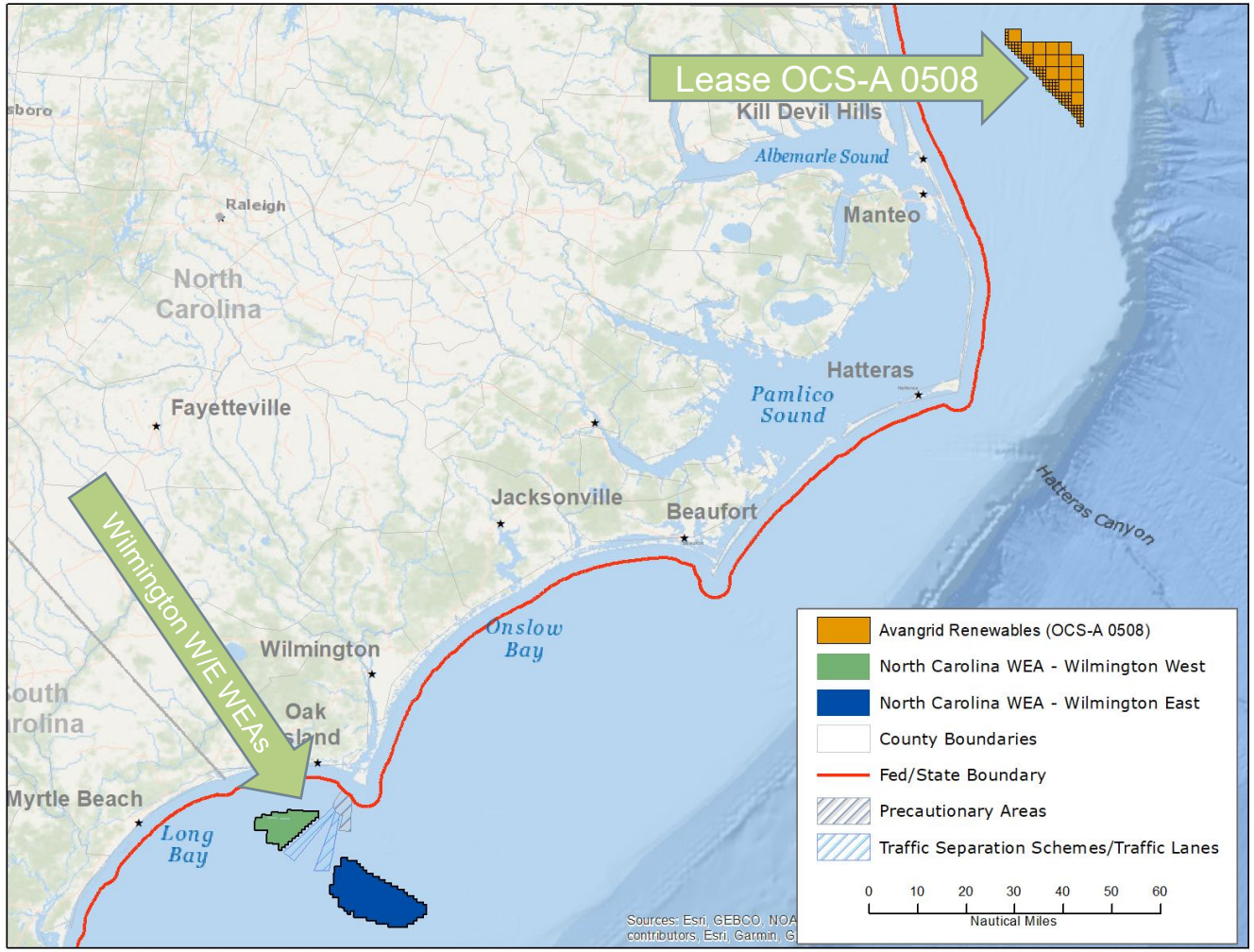
# North Carolina Offshore Wind

## Kitty Hawk/Avangrid Renewables, LLC




- Up to 2.5 GW in multiple phases, 40-year expected life
- Expect to complete and submit the COP in 2022, estimated construction timeline: 2025-2029
  - FA requirements:
    30 CFR 585, Subpart E
  - Decommissioning requirements:
    30 CFR 585, Subpart I

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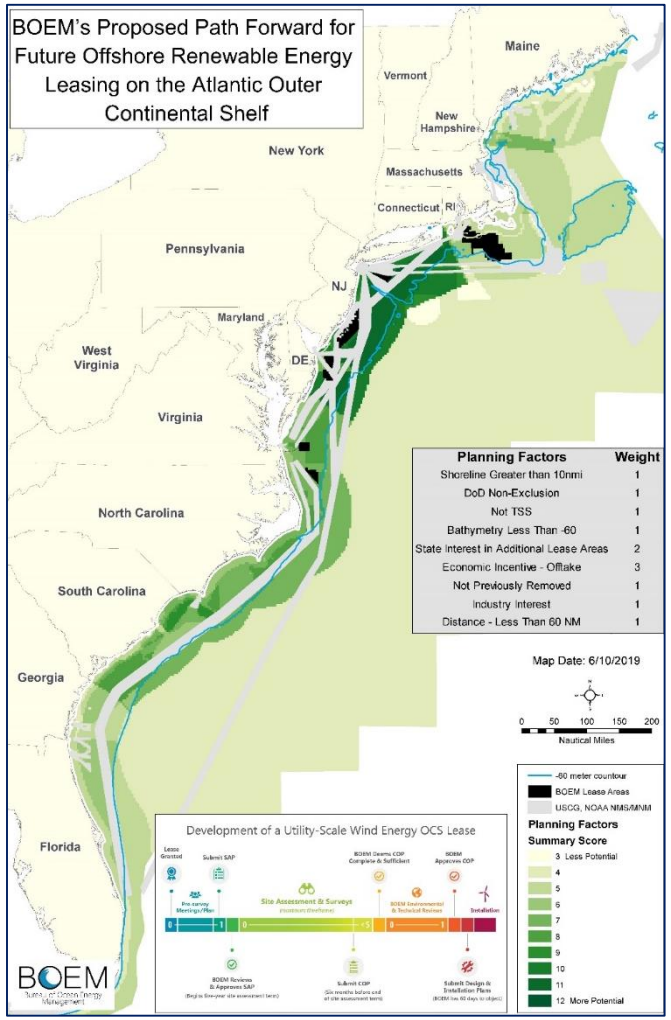
# *Future OSW Wind Energy Areas (WEAs)*

## Next Steps




- BOEM's *Path Forward*
  - Identify additional lease locations
    - Military
    - Tourism
    - Viewsheds
    - Shipping lanes
    - Fisheries
    - Environmental impacts
    - Etc.
  - NC regional task force participation
    - VANC
    - Carolina Long Bay

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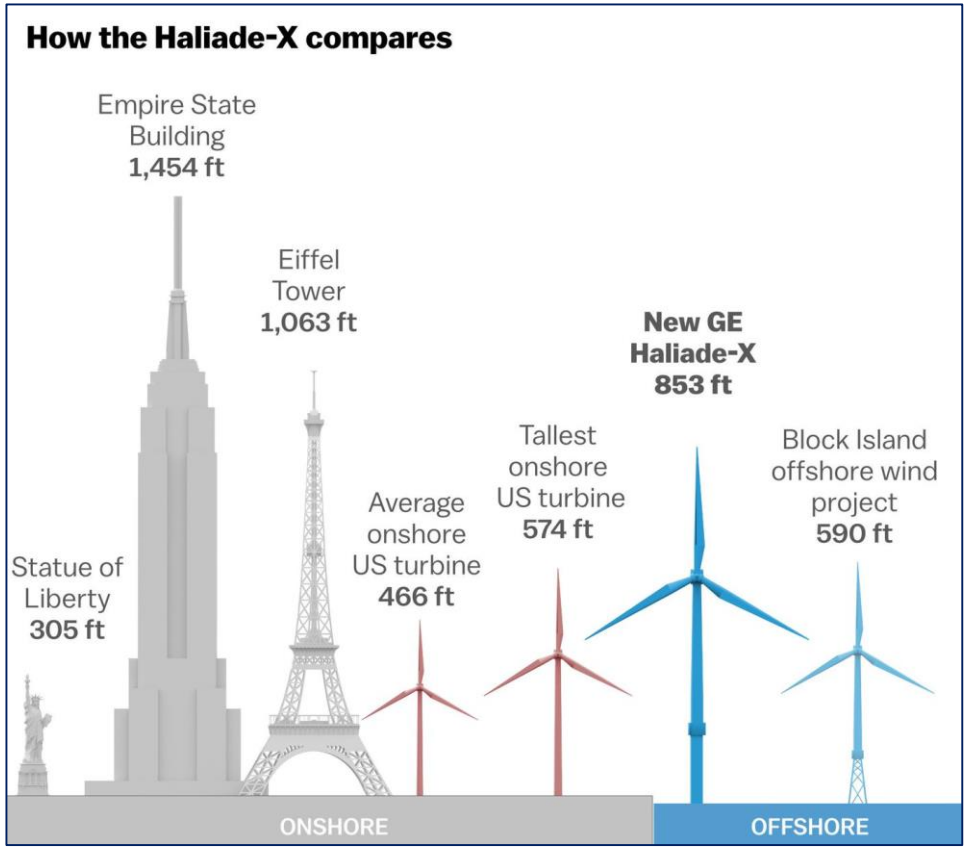
*BOEMs Proposed Path Forward, https://www.boem.gov/sites/default/files/uploadedImages/Renewable_Planning_Lease_Process_6_10_2019%20(1).jpg*

# Future Offshore Wind Development

## Technological advancements: power & size




- GE's 12MW Haliade-X turbine
  - 260m height
  - 220m rotor
  - 107m blade

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*https://www.vox.com/energy-and-environment/2018/3/8/17084158/wind-turbine-power-energy-blades, https://www.ge.com/renewableenergy/wind-energy/offshore-wind/haliade-x-offshore-turbine*

# *Questions that need to be addressed*

H329 Knowns and *Information Gaps*

- *? Clarify hazard characteristics of WEFs and equipment*
  - Generally understood to be non-hazardous (blades, towers, etc.)
- Methods to responsibly manage end-of-life WEF equipment
  - Landfill fiberglass blades
    - *? Available landfill capacity, technology trends (growing size of infrastructure)*
  - Repower/repurpose turbines
  - Reuse/recycle steel towers
  - *? Reusing or recycling fiberglass blades*
  - *? Infrastructure to support end-of-life management options*
- Life cycle = 1 project Amazon Wind, min. 20 years, 104 turbines + equipment
- *Federal and other state decommissioning and FA requirements*
- *? Additional FA requirements, beyond G.S. 143-215.121*

# *Thank You!*

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https://www.cleanenergywire.org/factsheets/german-offshore-wind-power-output-business-and-perspectives

# *Hazardous Content and End-of-Life Management of Energy Storage System Batteries*

Stakeholders Meeting
February 10, 2020

NORTH CAROLINA
Department of Environmental Quality

# *Battery Energy Storage Systems Overview*

- U.S. Energy Information Administration
  - Lithium-Ion batteries represent over 80% of energy capacity of battery storage systems greater than 1MW. Lithium-ion technology is the fastest growing in battery storage development.
  - Lead-acid batteries are one of the oldest storage technologies and estimated to represent about 3% of large scale battery storage capacity. However, it is commonly used for smaller energy storage.
  - Nickel based batteries are also an early form of large-scale storage system used.
  - Flow batteries are a relatively new technology and represent less than 1% of large scale battery storage.

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# Hazardous Characteristics of Lead-Acid Batteries

- Lead-acid batteries are characterized as hazardous waste.
- A typical lead-acid battery is composed of lead (metal or lead oxide paste), plastic, sulfuric acid, electrolyte, and other components such as antimony, arsenic, and cadmium.
  - These materials contain several toxic, corrosive, and flammable characteristics.
- Lead-acid batteries can pose serious harm to human health and the environment if improperly handled and/or disposed.
- Lead-acid batteries can leak hazardous materials, especially if the battery is damaged.

# *Hazardous Characteristics of Lithium-Ion Batteries*

- Classified as non-hazardous waste by federal government.
- A typical lithium-ion battery is composed of a cathode, an anode, an electrolyte separator, and an outer casing.
  - Common metal oxides used in the cathode include lithium cobalt oxide, lithium manganese oxide, lithium nickel manganese cobalt oxide, and lithium nickel cobalt aluminum oxide.
  - The separator contains a lithium salt electrolyte.
  - Common electrolytes used are lithium based compounds.
- These materials contain toxic and flammable characteristics.
- Lithium-ion batteries have the potential to release toxic elements into the environment if improperly disposed.

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# Hazardous Characteristics of Nickel-Cadmium Batteries

- Classified as hazardous waste by federal government.
- A Nickel-Cadmium battery is composed of positive and negative plates, separators, electrolyte, cell vent, and cell container.
  - These components contain nickel hydroxide, cobalt hydroxide, cadmium hydroxide, iron oxide, and potassium hydroxide.
  - Several of these substances are identified as toxic and corrosive.

# *Hazardous Characteristics of Redox Flow Batteries*

- A conventional flow battery contains liquid electrolyte solutions, electrolytic tanks, a cathode, an anode, and pumps.
  - The electrolyte contains sulfuric acid, however, it is less acidic than a lead-acid battery.
- Vanadium redox flow technology is the most developed flow battery.
  - Vanadium has a low toxicity.
- Redox flow batteries is a relatively new energy storage technology that has several advantages compared to lead-acid and lithium-ion batteries.
  - Considered to be less toxic, more sustainable, and easier recycled.

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# *End-of-life Management Energy Storage Systems*

- Decommissioning energy storage systems requires disassembly of battery packs and safe transportation.
  - Disassembly is done manually and requires a significant amount of time.
  - Companies will typically take back the systems at the end of life for recycling.
  - Utility can also pay for recycling service.

# *End-of-life Management Energy Storage System Components*

- Market for containers that house battery systems.
  - Containers also have insulation, lighting, flooring, and railings.
  - Containers can be used for multiple purposes, however, disassembling and recycling individual components is energy intensive. Therefore, reusing containers is an increasingly popular option.
- Computer components, cable connectors, switches, breakers, and fuses can be collected for recycling.
- The power conversion system can be sent to a metal recycler.
- System controls and communications can be reused or recycled.
- HVAC thermal management system can be recycled after removal of refrigerant by a certified technician.
- Fire suppression piping, tanks, and racks can be reused or recycled as scrap metal.
  - Fire suppression agents can be returned to the supplier for reuse.
- After batteries are disassembled, the battery components are transported and decommissioned in different manners, depending on the type of battery.

# *End-of-life Management of Lithium-Ion Batteries*

- MSW Landfills
  - Many will be discarded as municipal solid waste unless the batteries are banned in the jurisdiction.
    - New York, California, and Minnesota are the only states that have banned lithium-ion disposal in landfills.
- Recycling Facilities
  - Call2Recycle is the only lithium-ion battery processor in the U.S.
  - Voluntary recycling program.
  - Established collection infrastructure.
- Several other companies available to collect, treat, or recycle lithium-ion batteries in the U.S.

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# End-of-life Management of Lead-Acid Batteries

- Lead-acid batteries can be managed as universal waste or under the specific alternative standards of 40 CFR 266, Subpart G.
  - Subpart G exempts some lead-acid batteries from certain hazardous waste management requirements depending on the battery owner (generator, collector, transporter, importer, exporter) and if the lead-acid batteries will be reclaimed.
- Lead-acid batteries are typically crushed into small pieces and separated from plastic components.
  - Plastic is sent to processor to use in new plastic products.
  - Lead is repurposed by battery manufacturers and other industries.
- It is illegal to dispose of a lead-acid battery in a landfill in NC.
- In NC, retailers are required to accept lead-acid batteries for recycling.
- Lead is the most efficiently recycled commodity metal.
- 99% of lead batteries are recycled in the U.S.

# *End-of-life Management of Nickel-Cadmium Batteries*

- Universal Waste Rule regulates nickel-cadmium batteries.
  - Batteries can be recycled as a whole.
  - Battery material can be separated and nickel is recovered.
- Battery Act implements efficient recycling or proper disposal of nickel-cadmium batteries.

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# *End-of-life Management of Redox Flow Batteries*

- Currently, redox flow batteries are not as widely used and a recycling process is not well-established.
  - Vanadium can be easily reused.
  - Flow companies may pay customers for the value of the vanadium.

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*Department of Environmental Quality*

**NCGS 130A-290 (35) "Solid waste**" means any hazardous or nonhazardous garbage, refuse or sludge from a waste treatment plant, water supply treatment plant or air pollution control facility, domestic sewage and sludges generated by the treatment thereof in sanitary sewage collection, treatment and disposal systems, and other material that is either discarded or is being accumulated, stored or treated prior to being discarded, or has served its original intended use and is generally discarded, including solid, liquid, semisolid or contained gaseous material resulting from industrial, institutional, commercial and agricultural operations, and from community activities. Notwithstanding sub-sub-subdivision b.3. of this subdivision, the term includes coal combustion residuals. The term does not include:

a. Fecal waste from fowls and animals other than humans.

b. Solid or dissolved material in:

1. Domestic sewage and sludges generated by treatment thereof in sanitary sewage collection, treatment and disposal systems which are designed to discharge effluents to the surface waters.

2. Irrigation return flows.

3. Wastewater discharges and the sludges incidental to and generated by treatment which are point sources subject to permits granted under Section 402 of the Water Pollution Control Act, as amended (P.L. 92-500), and permits granted under G.S. 143-215.1 by the Commission, including coal combustion products. However, any sludges that meet the criteria for hazardous waste under RCRA shall also be a solid waste for the purposes of this Article.

c. Oils and other liquid hydrocarbons controlled under Article 21A of Chapter 143 of the General Statutes. However, any oils or other liquid hydrocarbons that meet the criteria for hazardous waste under RCRA shall also be a solid waste for the purposes of this Article.

d. Any source, special nuclear or byproduct material as defined by the Atomic Energy Act of 1954, as amended (42 U.S.C. § 2011).

e. Mining refuse covered by the North Carolina Mining Act, G.S. 74-46 through 74-68 and regulated by the North Carolina Mining Commission (as defined under G.S. 143B-293.1). However, any specific mining waste that meets the criteria for hazardous waste under RCRA shall also be a solid waste for the purposes of this Article.

f. Recovered material.

g. Steel slag that is a product of the electric arc furnace steelmaking process; provided, that such steel slag is sold and distributed in the stream of commerce for consumption, use, or further processing into another desired commodity and is managed as an item of commercial value in a controlled manner and not as a discarded material or in a manner constituting disposal.

**Hazardous waste** is waste that has substantial or potential threats to public health or the environment.

Characteristic hazardous wastes are materials that are known or tested to exhibit one or more of the following hazardous traits:

- Ignitability-something that can combust (burn) in air.
- Reactivity is when a substance or compound added to a system causes a chemical reaction,
- Corrosivity - one that will damage or destroy other substances with which it comes into contact by means of a chemical reaction.

- Toxicity substances that cause death, injury or harm to organs, usually by chemical reactions or other activity on the molecular scales, when an organism absorbs a sufficient quantity.

Listed hazardous wastes are materials specifically listed by regulatory authorities as hazardous wastes which are from non-specific sources, specific sources, or discarded chemical products.

**Universal waste** is a category of waste materials designated as "hazardous waste", but containing materials that are very common. It is defined in 40 C.F.R. 273.9, by the United States Environmental Protection Agency but states may also have corollary regulations regarding these materials.

Universal waste includes:

- Batteries; lithium, Silver ion, nickel cadmium (Ni-Cad), mercury-oxide, or sealed lead-acid. Spent Lead-Acid Batteries being reclaimed do not need to be managed as universal waste.
- Pesticides; Stocks of a suspended and canceled pesticide that are part of a voluntary or mandatory recall
- Mercury Containing Equipment; a device or part of a device (including thermostats) that contains elemental mercury integral to its function.
- Lamps; include, but are not limited to, fluorescent, high intensity discharge, neon, mercury vapor, high pressure sodium, and metal halide lamps.

Businesses and other generators of such waste are required to provide for their proper disposal.

**APPENDIX B**
**Executive Summary of Literature Review**
**Hazardous Characteristics of PV Modules and TCLP Methodology**

Crystalline silicon solar panels are the dominant technology and 90% of its mass is composed of glass, polymer, and aluminum. Crystalline silicon solar panels may contain traces of copper, zinc, silver, tin, and lead. Despite the presence of these heavy metals, crystalline silicon modules generally test below Toxicity Characteristic Leaching Procedure (TCLP) regulatory thresholds. Cadmium-telluride (CdTe) modules are the most common thin film module technology and approximately 98% of a CdTe panel is composed of glass, polymer, and aluminum. CdTe panels are considered hazardous waste if the modules meet or exceed the regulatory limits for Cd or other toxins in a TCLP test.

A literature review of TCLP methodology revealed several issues with regard to its accuracy for PV module waste characterization. The TCLP methodology requires a PV module to be reduced in size by crushing, cutting, or grinding to a maximum size of 9.5mm. Because the method does not require a minimum size, laboratories that perform TCLP tests may reduce the sample size to 9.5mm or grind the samples to micron levels. This discrepancy in sample size has resulted in significant variation in TCLP results for PV module characterization. In addition, the TCLP methodology often varies between laboratories, which could result in different waste characterizations for the same PV module. The location of the module from which samples are extracted may yield irregular results, as samples taken along the cell stringing ribbons typically show a higher toxicity level. Another study determined that waste characterization leaching tests, including TCLP, model aggressive PV module field breakage conditions, including sample size, solvent, and treatment method. In a field environment, PV modules tend to fracture rather than break into small pieces due to the industrial laminate that encapsulates the modules.

The literature review presents the results from several TCLP studies conducted on crystalline and thin film PV modules, however each study employed a different sample preparation method. Some samples that were reduced to very small pieces that tested above the regulatory thresholds for several heavy metals. Even though the TCLP results from two of the studies revealed concentrations of hazardous materials exceeding regulatory thresholds, it is possible that the discrepancies between testing methods and unrealistic leaching scenarios may have affected the TCLP findings. In comparison, the samples that were extracted using a consistent and proportional methodology and used the largest sample size allowed passed the TCLP test. In conclusion, DEQ finds that the hazard characterization of a PV module drastically depends the extraction and testing methodology. To that end, the Department is drafting rules for the EMC's consideration, on the preferred TCLP methodology for determining hazard characteristics of PV modules.

The full text of the literature review is available upon request.

## APPENDIX C
## List of Participating Stakeholders[5]

Duke Energy*
Dominion Energy*
NC Electric Membership Cooperatives*
NC Sustainable Energy Association*
First Solar*
Cypress Creek Renewables*
NC Clean Energy Business Alliance
NC Farm Bureau*
Energy & Environment Innovation Foundation
Ecoplexus
Smith Gardner Inc.
Sierra Club*
NC Conservation Network*
Southern Environmental Law Center*
Recycling Association of NC
NC Clean Energy Technology Center*
Dynamic Lifecycle Innovations
TT&E Iron and Metal
Foils Inc.
Regional Materials Recovery, Inc.
NC Utilities Commission-Public Staff
Advanced Energy*
NC State University Extension
Solar Energy Industries Association*
Electronic Recyclers International
Law Office of Robert W. Kaylor
Smith Anderson
Capitol Advantage Associates
Brooks Pierce & Recycling*
Southern Power Companies*
SunnKing*
Energy Intelligence Partners*
Synergy Recycling
Metech Recycling
GEEP Global (Global Electric Electronic Processing)
Powerhouse Recycling Inc.*
Institute of Scrap Recycling Industries, Inc.
Carolina Recycling Association
ecycleSecure
NC Department of Public Safety*
Synergy Recycling
NC Association of County Commissioners*
Alamance County
Solterra Partners

[5] Organizations with an asterisk (*) have participated in the stakeholder meetings either in-person or by remote conference call.