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: June 1st, 2020 Quarterly

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 third such quarterly report and covers the activities undertaken to implement this Section since the submission of the previous quarterly interim report, from March 1, 2020, through May 31, 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 one stakeholder meeting during this quarter, on April 14, 2020. DEQ staff met with the North Carolina Utilities Commission public staff on March 18, 2020. Finally, DEQ presented initial findings to the Groundwater and Waste Management Committee of the Environmental Management Commission (Commission) and provided responses to Committee members' queries on March 4, 2020 and May 6, 2020, respectively. The agendas for, presentations to, and materials shared in association with these 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.

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 submitted 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 B of this report.

EQ Research
Umicore
Invenergy
Minnesota Pollution Control Agency

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 • TCLP methodology, results, and potential hazardous characteristics of modules has been thoroughly discussed • 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 recommendations for PV module waste classification for EMC consideration • DEQ coordinating with ASTM for publication of a TCLP guidance for PV modules • DEQ to present 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 initiated literature review on the preferred methods to manage EOL wind turbines	DEQ and stakeholder presentations on different EOL management options for several energy storage system battery technologies. Reuse, refurbish, recycle, and landfill disposal options has been researched by DEQ	EOL for PV modules and energy storage system batteries has been thoroughly researched and discussed	• DEQ to draft proposed recommendations for EOL management of energy storage system batteries • Coordinate presentations and research on EOL management for wind energy equipment • DEQ to draft white paper on preferred methods to manage EOL renewable energy equipment.
§2.(a)(3): Economic and environmental costs and benefits	• Stakeholder discussions on environmental costs/benefits • EOL management methods for PV modules reviewed by DEQ		• Stakeholder discussions on environmental costs/benefits • 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 • 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] • 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

[2] Executive Summary of the Literature Review of Hazardous Characteristics of Solar PV Equipment is included in Appendix B of the Quarterly Report submitted on March 1, 2020.

[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 of the Quarterly Report submitted on March 1, 2020.

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] • 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: • the bulk of the solar PV facilities/ modules will not be decommissioned until early-to-mid 2030 • the Amazon Wind facility's 104 turbines have an expected life of at least 20 years, estimated decommissioning in 2036, at the earliest	• DEQ to map the solar facilities in NC that are currently installed and identify which facilities that submitted NCUC applications were not constructed. • DEQ will update PV module volume graphs with additional data provided by facility mapping • DEQ evaluating impacts on landfill capacity if PV modules, wind turbines, and energy storage system batteries are disposed in landfills • 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 • Discussions of solar ordinances adopted in NC counties • Stakeholders provided list of solar decommissioning requirements in other states • DEQ completed summary of current decommissioning requirements in NC counties	• Stakeholders provided list of WEF decommissioning requirements in other states • Federal and NC requirements for WEFs presented and discussed[5]	• Stakeholders provided list of battery decommissioning requirements in other states • Federal and state regulatory requirements for energy storage system batteries has been collected	Completed evaluation of regulatory requirements at federal-, state-, NC county-, and international-level for management of EOL PV modules and WEFs	DEQ will research, work with stakeholders, and present energy storage system batteries' 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 • 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	DEQ is collaborating with stakeholders to draft language for FA requirements for PV modules

[4] See February 10, 2020 presentation on WEF in North Carolina in Appendix A3 of the Quarterly Report submitted on March 1, 2020.
[5] See April 14, 2020 presentation on States with WEF Regulations in Appendix A of this Quarterly Report.

S.L. 2019-132 / HB 329	Photovoltaic (PV) Modules	Wind Energy Facilities (WEF)	Energy Storage System Batteries	Status	Next Steps
§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
§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:

- The North Carolina Clean Technology Energy Center forwarded two reports titled, End-of-Life Management of Lithium-Ion Energy Storage Systems and How Does Wind Project Performance Change with Age in the United States? A short list of NC county government contacts was also provided.
- The Minnesota Pollution Control Agency submitted the presentations from their wind and solar decommissioning stakeholder meetings, a report with proposed recommendations to the Commission, and a solar panel recycling white paper.
- The Photovoltaic Reliability Laboratory at Arizona State University sent several research studies on TCLP testing of PV modules.
- A group of stakeholders provided a draft of proposed financial assurance requirements for PV modules.

Upcoming Activities

On July 8, 2020, staff from the Division of Waste Management will again 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 Wednesday, June 3, 2020, to discuss plans to classify PV modules as Universal Waste and financial assurance requirements.

DEQ has a tentative plan to reconvene with NCUC public staff depending on future discussions with stakeholders and the pathways identified to comply with the remaining subparts of HB329.

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.

APPENDIX A
Stakeholders, NCUC Public Staff, and GWWM Committee Meeting Agendas and Associated Presentations

GROUNDWATER AND WASTE MANAGEMENT COMMITTEE

512 N. Salisbury Street
Archdale Building - Ground Floor Hearing Room
Raleigh, North Carolina

March 4, 2020
11:30 a.m – 12:30 p.m.
Yvonne Bailey, Chairman, Presiding

In the event the previously scheduled committee meeting adjourns prior to the estimated adjournment time, the other committee meeting may be called to order, by the Chairman, fifteen minutes after the previous meeting adjourned.

I. Preliminary Matters:

1. **Call to Order and Notice of NCGS § 138A-15** ……..……...Chairman Bailey
General Statute § 138A-15 mandates that the Chairman inquire as to whether any member knows of any known conflict of interest or appearance of conflict with respect to matters before the Commission. If any member knows of a conflict of interest or appearance of a conflict, please so state at this time.

2. Approval of minutes from Groundwater and Waste Management Committee (GWWMC) meeting January 8, 2020(attached).

II. Information Item

1. **Update on the "Decommissioning Renewable Energy Equipment Stakeholder Process" Ellen Lorscheider (DWM)**

Explanation: Update on the stakeholder process required by Session Law 2019-132 entitled Renewable Energy Amendments which requires the EMC to establish a regulatory program no later that Jan 2022 which manages end-of-life photovoltaic modules and energy storage system batteries, and to decommission utility-scale solar projects and wind energy.

Attachments: There will be by Feb 13

IV. Closing:

Closing Remarks……..……...…Chairman Bailey

Adjournment 3-4-20

NCUC Public Staff and DEQ Meeting
Related to S.L. 2019-132 (HB 329)
Wednesday March 18, 2020
3:30pm to 5:30pm
AGENDA

1. Welcome and introductions

2. Review of Section 2 Requirements (timetable, deliverables, responsible parties)

3. Update on Progress to Date

    a. Stakeholder process
    b. Quarterly report key messages
    c. Current state of knowledge related to:
        - PV modules (Decommissioning and financial assurance requirements, End-of-life management practices, Hazardous characteristics of PV modules, Solar facility data specific to NC)
        - Energy storage batteries (hazardous characteristics)
        - Wind energy facilities
    d. Knowledge and data gaps
        - Discussion on potential areas of Public Staff assistance in fulfilling the data gaps

4. Strategy discussion to fulfill HB329 regulatory requirements
    a. Are certain items better suited to be implemented through the commission?
    b. What legislative authority and/or commission orders are needed?
    c. Should the requirements be different for existing projects vs. new/to be built projects?
    d. Which requirements are better suited through DEQ rules.

5. Schedule follow-up meeting

6. Adjourn

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Decommissioning Renewable Energy Equipment Stakeholders (Per §2 of S.L. 2019-132/H329)
Tuesday April 14, 2020
2:00 pm to 4:00 pm
Virtual Meeting
Remote Dial-In Number: (919) 850-2823

AGENDA

1. Welcome and introductions

2. Presentations

    a. Overview of Energy Storage Options for NC

Joseph DeCarolis, Associate Professor in the Department of Civil, Construction, and Environmental Engineering at NC State

b. Energy Storage System Battery Recycling
Mark Caffarey, President
Umicore

c. Overview of States with Wind Energy Decommissioning Regulations
Jessica Citrola, Environmental Specialist II
DWM, DEQ

3. Discussion
   a. Proposed language for PV module decommissioning and financial assurance requirements
      i. Discussion lead by- Daniel Brookshire (NCSEA) and John Morrison (Ecoplexus)

4. Discuss topics for next stakeholders meeting

5. Adjourn

Next Meeting: Date to be determined

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GROUNDWATER AND WASTE MANAGEMENT COMMITTEE

512 N. Salisbury Street
Archdale Building - Ground Floor Hearing Room
Raleigh, North Carolina

May 6, 2020
10:00 a.m-11:30 a.m
Yvonne Bailey, Chairman, Presiding

I. Preliminary Matters

1. Call to Order

General Statute § 138A-15 mandates that the Chairman inquires as to whether any member knows of any known conflict of interest or appearance of conflict with respect to matters before the Commission. If any member knows of a conflict of interest or appearance of a conflict, please so state at this time.

2. Approval of minutes from Groundwater and Waste Management Committee (GWWMC) meeting on March 4, 2020 (attached).

II. Action Items

1. Request Approval to Proceed to the EMC to Request Public Comment and Hearing on 15A NCAC 02N "Underground Storage Tanks" and 15A NCAC 02O "Financial Responsibility Requirements for Owners and Operators of Underground Storage Tanks."

(DWM) Ruth Strauss

Explanation: The Division of Waste Management requests approval to proceed to the Environmental Management Commission for public hearing for proposed amendments to 15A NCAC 02N "Underground Storage Tanks" and 15A NCAC 02O "Financial Responsibility Requirements for Owners and Operators of Underground Storage Tanks." The rules are proposed for readoption pursuant to G.S. 150B-21.3A.

Recommendation: The Division recommends that the GWWMC approve the proposed amendments and readoption of 15A NCAC 02N "Underground Storage Tanks" and 15A NCAC 02O "Financial Responsibility Requirements for Owners and Operators of Underground Storage Tanks" to proceed to the EMC for public comment and hearing.

2. Request Approval to Proceed to the EMC for Public Notice and Hearing on Readoption of 15A NCAC 13B Sections .0100 through .0700 (except .0531 - .0547) and .1300 Solid Waste Management
(DWM) Jessica Montie and Ed Mussler

Explanation: The Division of Waste Management requests approval to proceed to the Environmental Management Commission for public notice and hearing for proposed amendments to 15A NCAC 13B Sections .0100 through .0700 (except .0531 - .0547) and .1300 Solid Waste Management. These rules are proposed for readoption pursuant to G.S. 150B-21.3A.

Recommendation: The Division recommends that the GWWMC approve 15A NCAC 13B Sections .0100 through .0700 (except .0531 - .0547) and .1300 Solid Waste Management to proceed to the EMC for public hearing.

III. Information Items

1. Update on the "Decommissioning Renewable Energy Equipment Stakeholder Process"
(DWM) Ellen Lorscheider

Explanation: Update on the stakeholder process required by Session Law 2019-132 entitled Renewable Energy Amendments which requires the EMC to establish a regulatory program no later that January 2022 which manages end-of-life photovoltaic modules and energy storage system batteries, and to decommission utility-scale solar projects and wind energy.

2. Amendments to 15A NCAC 02L .0202 Groundwater Quality Standards: Part 1
(DWR) Bridget Flaherty Shelton

IV. Closing Remarks

By Chair Yvonne Bailey

Adjournment 5-6-20

Wind Energy and Equipment in North Carolina

February 10, 2020 Stakeholder Meeting

March 4, 2020 GWWMC Meeting

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)

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*

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Thank You!

Jennifer Mundt / Jennifer.Mundt@ncdenr.gov / 919-707-8406

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

Summary of Solar Facilities Currently Operational in North Carolina

January 22, 2020 Stakeholders Meeting
March 4, 2020 GWWMC Meeting

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

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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:

- 577 Facilities were identified with a total of 4,192 MW
- Located across 76 counties
- Panel Counts were provided for 530 of the facilities
  - Ranged from 2,868 to 14,288 per MW (averaging 5,068 per MW)
- Panel Types were available for 518 of the facilities
  - 89% silicon-based (c-Si) 460
  - 9% cadmium telluride (CdTe) 48
  - 2% copper indium gallium selenide (CIGS) 10
- Reported Project Lifespans ranged from 20 to 40 years
- Reported PPAs ranged from 10 to 20 years

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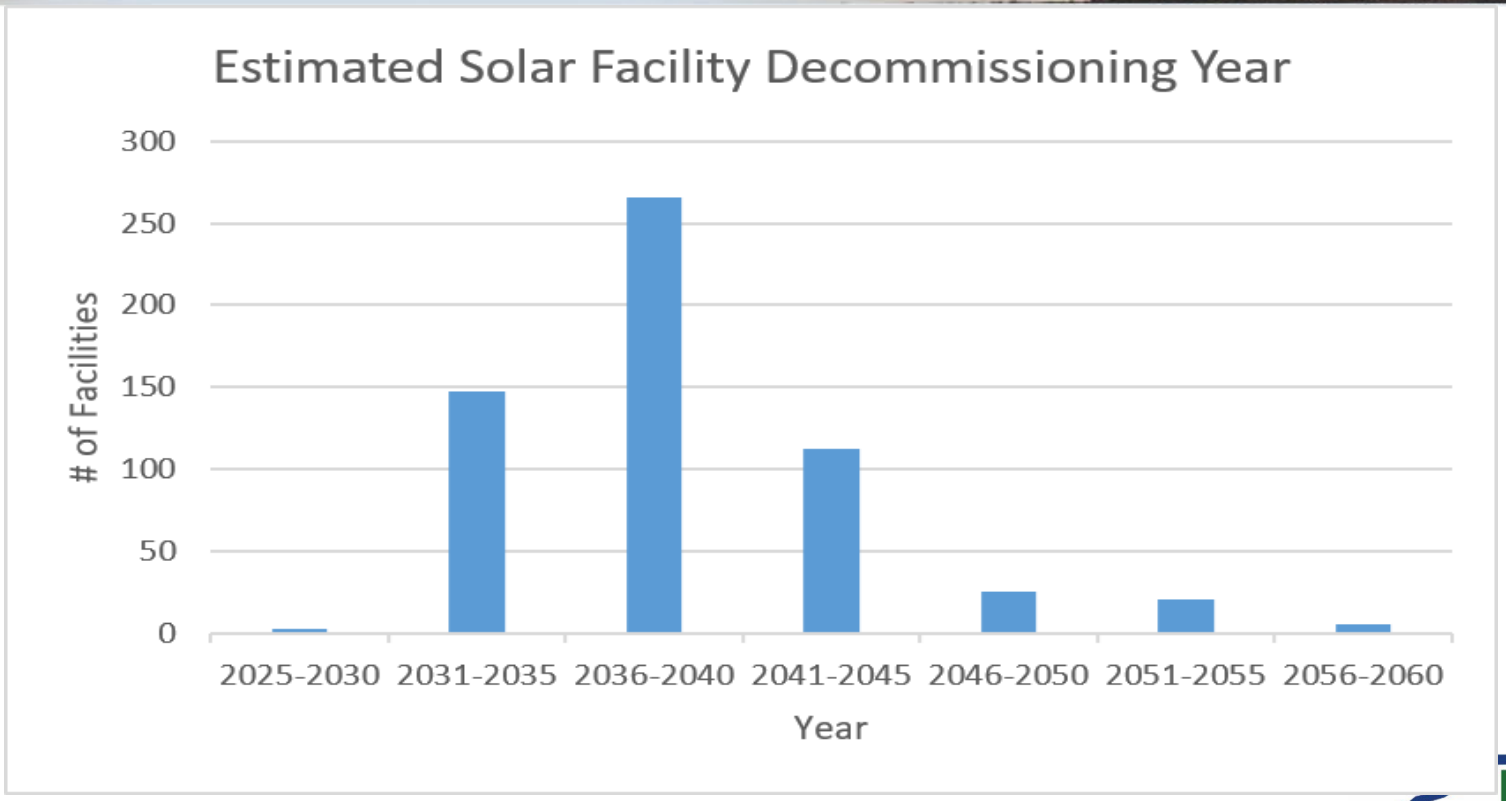
How We Complied Our Data:

- For the 41 Facilities without panel counts, an estimate was used based on the average panel per MW for the known facilities (5,068 per MW)

- For the 54 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 weight in the NC facility data, 50 pounds. This is based off the weight listed on manufacturer websites of specific panel types cited in our data. Any facility that did not list panel type was given an average weight value based off of the site capacity.



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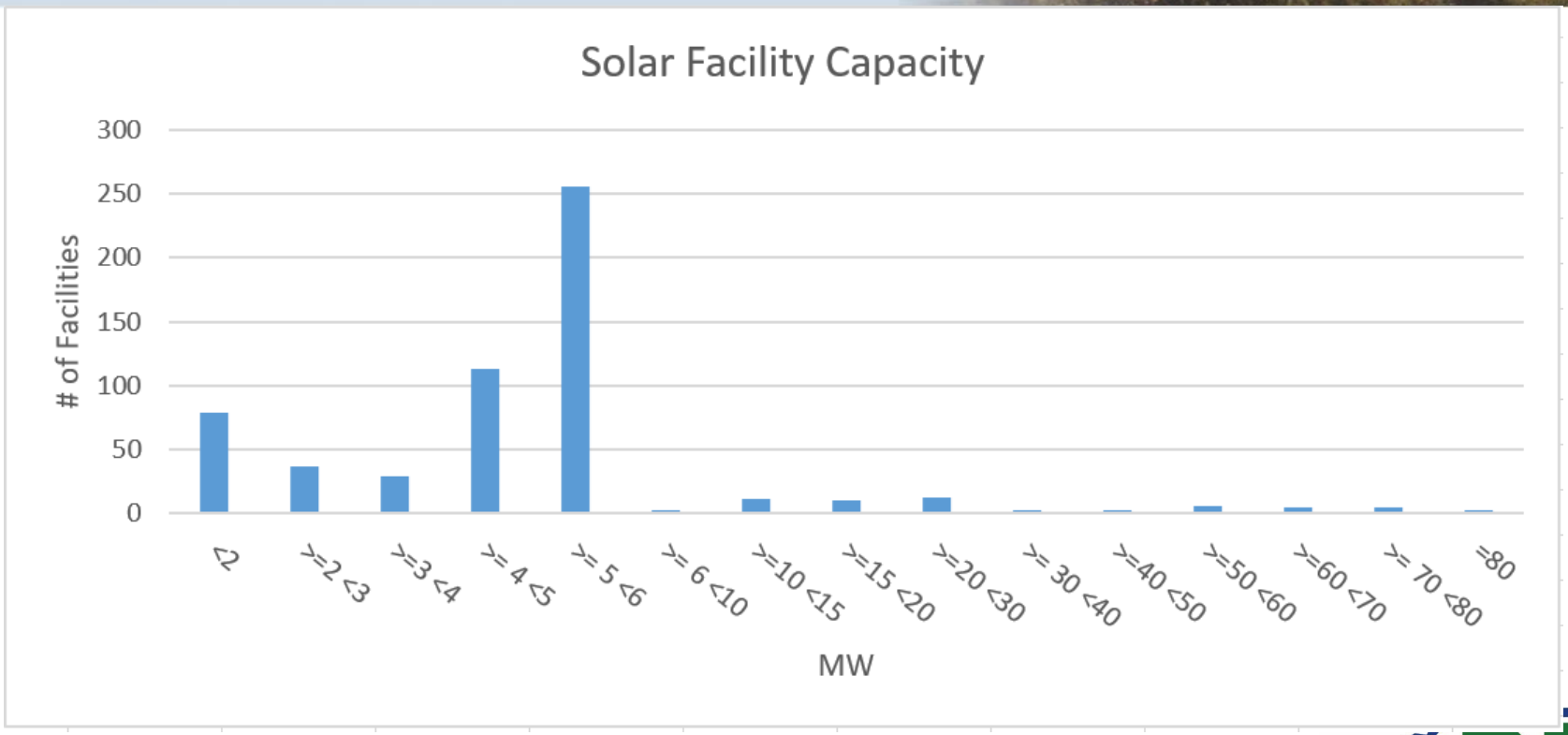

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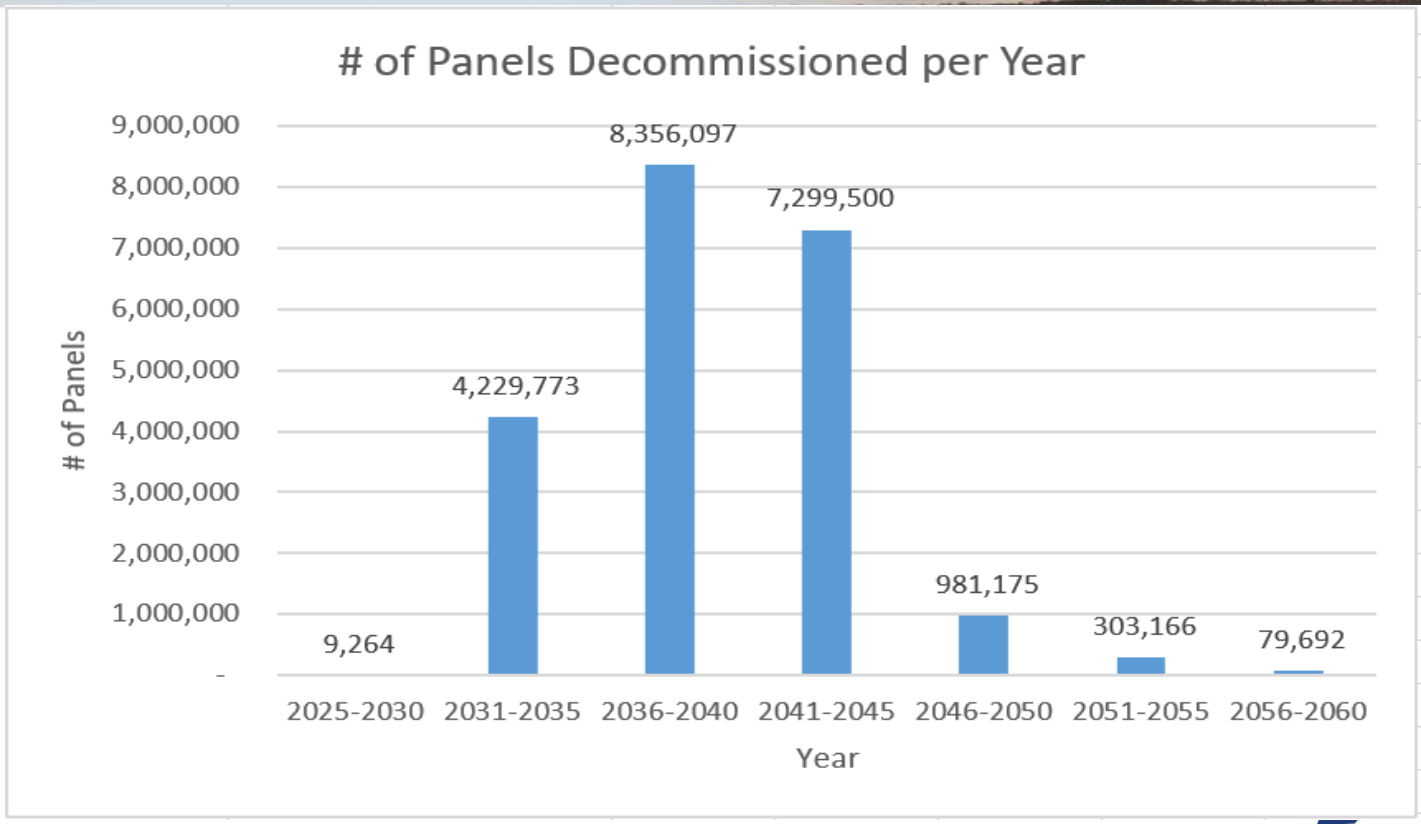

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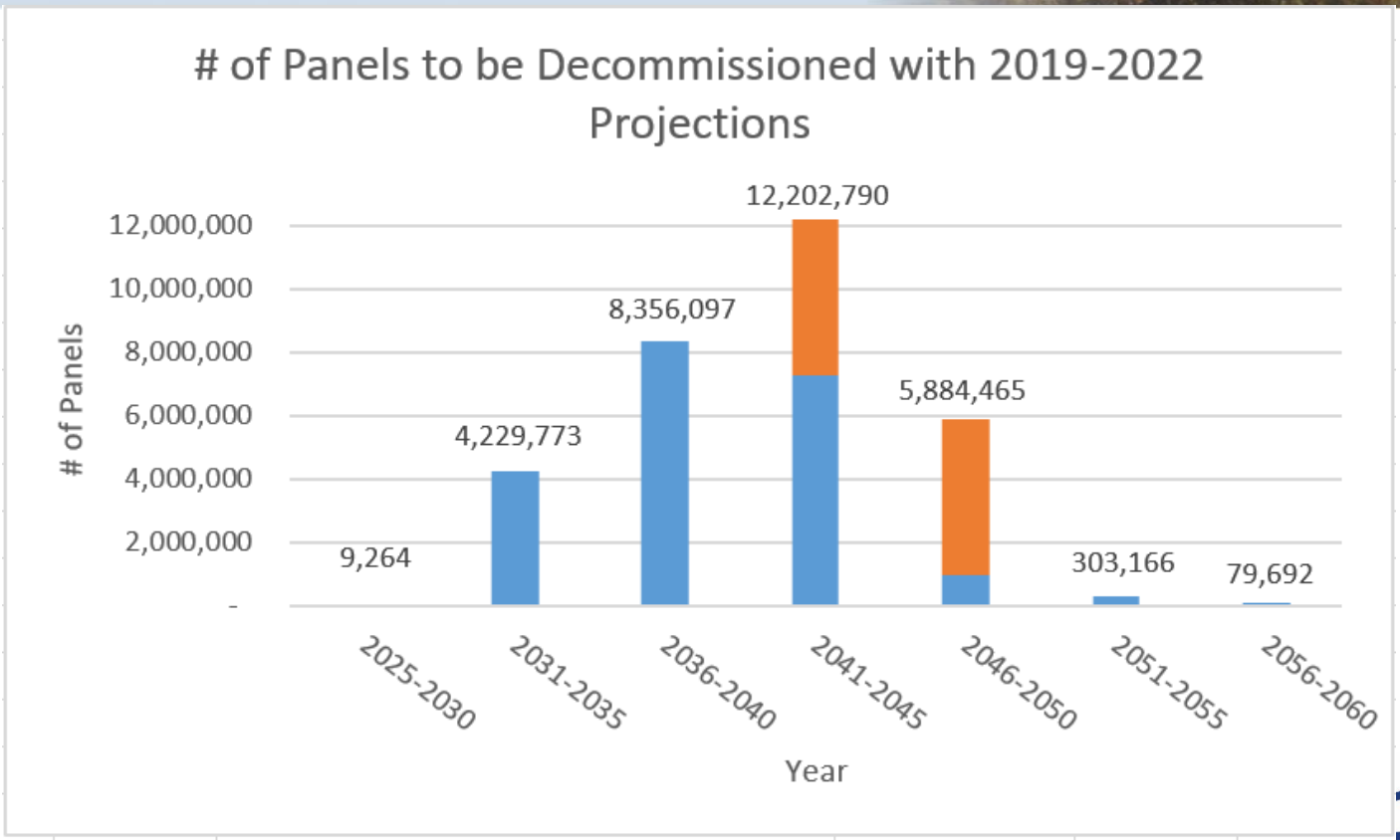

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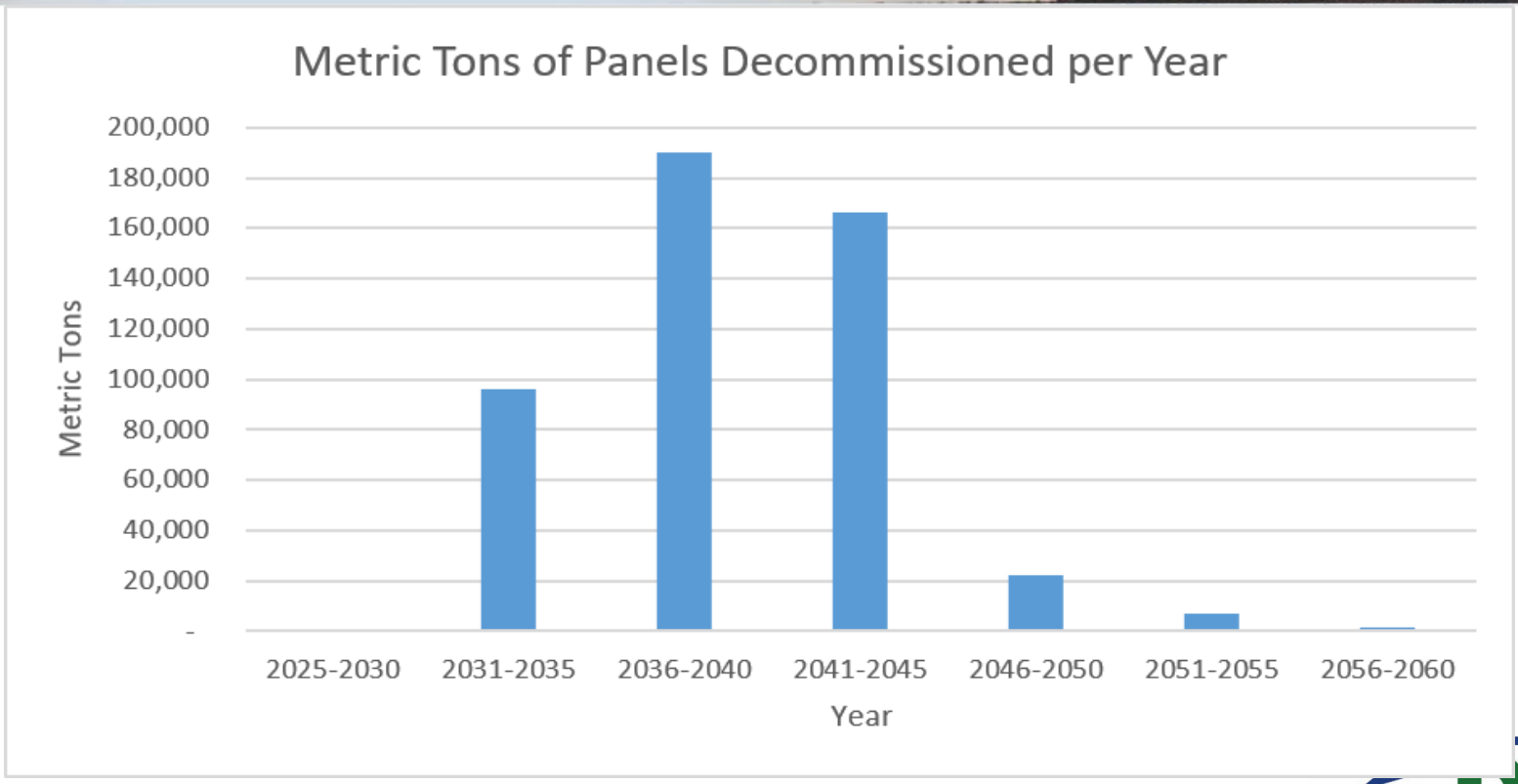

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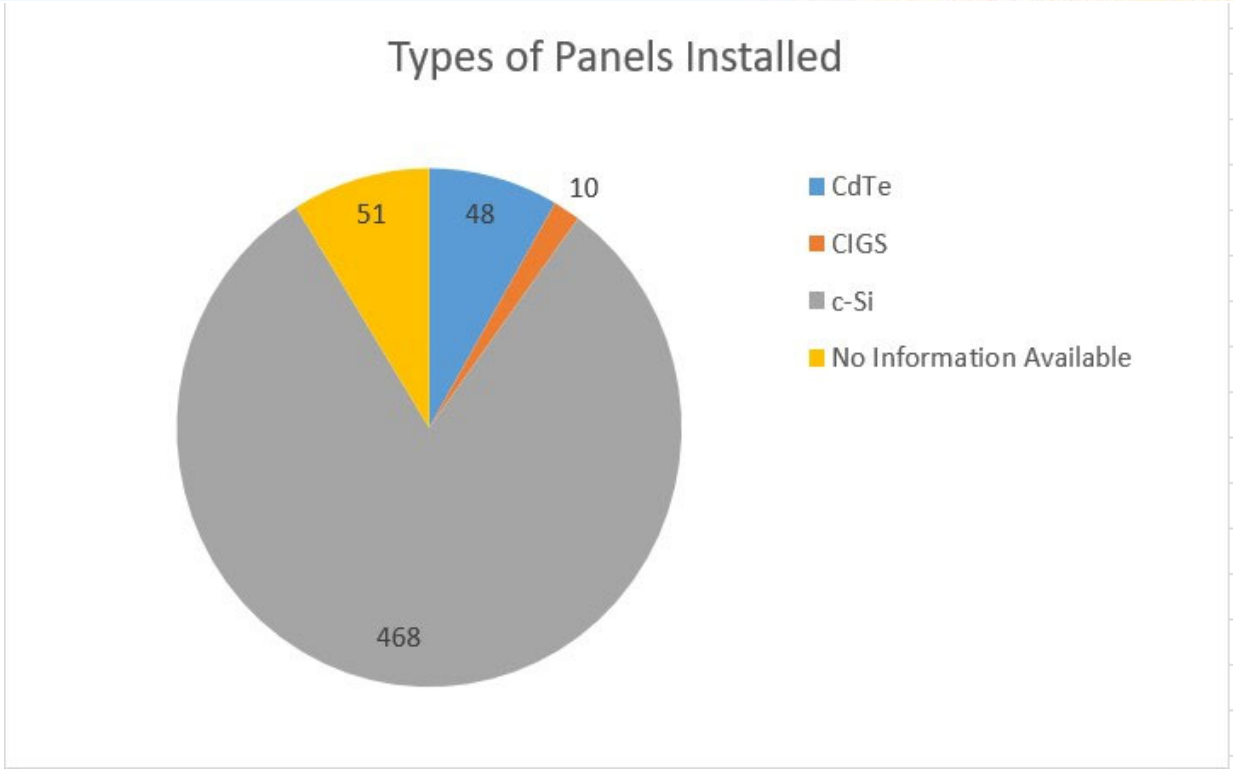

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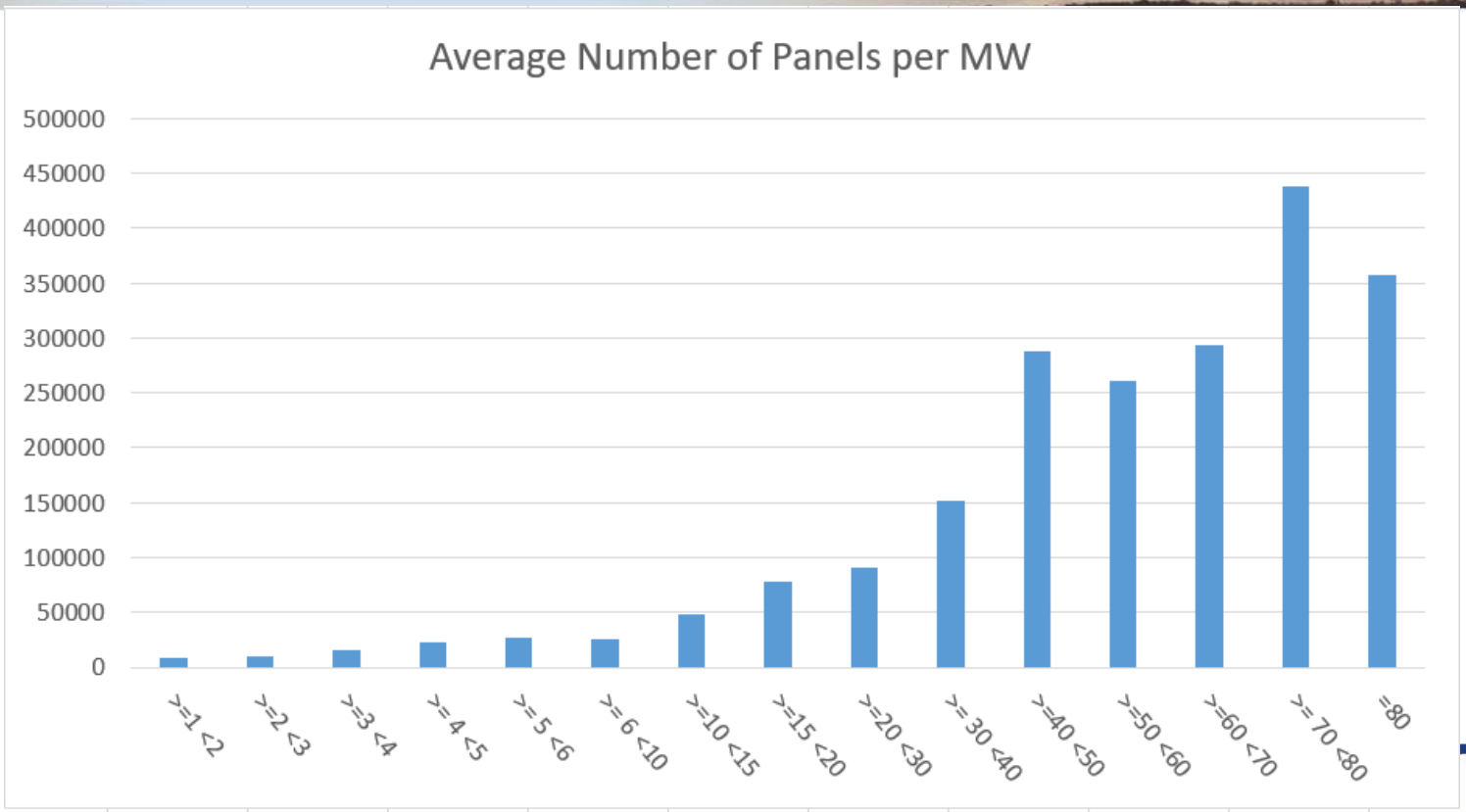

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Hazardous Content and End-of-Life Management of Energy Storage System Batteries

February 10, 2020 Stakeholder Meeting
March 4, 2020 GWWMC Meeting

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 is 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.
- Lithium-ion technology is the fastest growing in battery storage development.

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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.
  - Also encourages collection and recycling 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

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S.L. 2019-132 (HB-329)

NCUC Public Staff and DEQ Meeting
March 18, 2020

Today's Agenda

1. **Introductions**
2. **Review of Section 2 Requirements**
3. **Update on Progress to Date**
   a. Stakeholder process
   b. Current state of knowledge related to PV modules
      - Decommissioning and financial assurance requirements
      - End-of-life management practices
      - Hazardous characteristics of PV modules
      - Solar facility data specific to NC
   c. Knowledge and data gaps
4. **Open Discussion**
5. **Schedule follow-up meeting**

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Overview

- The Environmental Management Commission (EMC) has been given the responsibility to establish a regulatory program as per HB 329, to govern the management of end-of-life photovoltaic modules and energy storage system batteries, and decommissioning of utility-scale solar projects and wind energy facilities.
- DEQ has been tasked with establishing a stakeholder process to support the development of these rules.
- Staff from DEQ's Division of Waste Management, Division of Environmental Assistance and Customer Service, and the State Energy Office have been assigned to support this legislative directive.

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Timeline

- DEQ and EMC Reporting:
  - April 1, 2020 Interim Report – include recommendations on resources needed to implement the act
  - January 1, 2021 Final Report – include findings through stakeholder input

- EMC to adopt rules that establish a regulatory program no later than January 1, 2022 covering the following:
  - (i) the management of end-of-life photovoltaic modules and energy storage system batteries and
  - (ii) decommissioning of utility-scale solar projects and wind energy facilities.

S.L. 2019-132 (HB 329) §2.

Requirements to be Considered in Developing Rules	
(a)(1): **Characteristics of hazardous waste or solid waste identified**	• Hazardous waster per 40 CFR Part 261 or state rules under G.S. 130A-294(c) • Solid waste definition under State and Federal Law
(a)(2): **Preferred methods to responsibly manage end-of life (EOL) products**	• Reuse, Refurbish, Recycle • Dispose in C&D or MSW landfills • Dispose hazardous waste materials per State and Federal Law
(a)(3): **Economic and environmental costs and benefits**	• For each preferred method in (a)(2)
(a)(4): **Expected economically productive life**	• Data on systems currently in use
(a)(5): **The volume of photovoltaic modules, wind turbines, and energy storage system batteries currently in use in the State, and projections**	• Impacts to State's landfill capacity
(a)(6): **A survey of federal and other states' and countries' regulatory requirements**	• Management of EOL products • Decommissioning • Financial assurance by owners or operators
(a)(7): **Financial assurance Requirements**	• Determination if needed to ensure proper decommissioning of solar projects
(a)(8): **Infrastructure that may be needed to collect and transport EOL Products**	• For reuse, refurbishment, recycling, or disposal
(a)(9): **Manufacturer stewardship programs**	• For recycling of EOL products • Whether fees should be charged to manufacturers to support such programs

Key Definitions

- "**End-of-life**" means photovoltaic modules, energy storage system batteries, and other equipment used in utility-scale solar and wind energy projects that are removed and taken out of service, that will not be reused.
- "**Utility-scale solar project**" means a ground-mounted photovoltaic (PV), concentrating photovoltaic (CPV), or concentrating solar power (CSP or solar thermal) project directly connected to the electrical grid that generates electricity for sale. The term includes the solar arrays, accessory buildings, transmission facilities, and any other infrastructure necessary for the operation of the project. The term does not include renewable energy facilities owned or leased by a retail electric customer intended primarily for the customer's own use to offset the customer's own retail electrical energy consumption at the premises.
- "**Photovoltaic module**" means the smallest nondivisible, environmentally protected assembly of photovoltaic cells or other photovoltaic collector technology and ancillary parts intended to generate electrical power under sunlight, except that "photovoltaic module" does not include a photovoltaic cell that is part of a consumer electronic device for which it provides electricity needed to make the consumer electronic device function. "Photovoltaic module" includes interconnections, terminals, and protective devices such as diodes that: (i) are installed on, connected to, or integral with buildings or (ii) are used as components of freestanding, off-grid, power generation systems, such as for powering water pumping stations, electric vehicle charging stations, fencing, street and signage lights, and other commercial or agricultural purposes.

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Information Gathering Phase

- DEQ- Presentations, Graphs, and Reports
  - End-of-life management of PV modules
  - Overview of utility-scale solar PV project decommissioning requirements in NC and other jurisdictions
  - Recycling of PV modules in the European Union
  - Solar facility data in NC
  - Financial assurance requirements for other energy generation sources
  - Wind energy in NC
  - Hazardous content and end-of-life management of energy storage system batteries
  - Solid and hazardous waste transportation
  - Review of hazardous characteristics of PV modules and TCLP white paper

- Stakeholder Presentations
  - NC Clean Energy Technology Center- characteristics of solid and hazardous waste used in utility scale solar and energy storage system batteries
  - First Solar- PV module recycling practices
  - Solar Energy Industries Association- PV module recycling practices

Stakeholders

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

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

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DEQ's Current State of Knowledge

§2.(a)(1)- Characteristics of hazardous waste identified

- Topics researched, discussed, and presented:
  - Potential hazardous characteristics of PV modules
  - TCLP and issues with applicability to modules
  - Hazardous characteristics in common types of energy storage system batteries
- Successive steps:
  - Research will be conducted on the potentially hazardous characteristics of wind energy equipment
  - Proposed rules will be drafted for waste characteristics for EMC consideration

§2.(a)(2)- Preferred methods to responsibly manage end-of life (EOL) products

- Topics researched, discussed, and presented:
  - Reuse, refurbish, recycle, and landfill disposal options for PV modules
  - Reuse and recycle options for different energy storage system battery technology and related equipment
- Successive steps:
  - Research will be conducted on end-of-life management for wind energy equipment

§2.(a)(3)- Economic and environmental costs and benefits

- Topics researched and discussed:
  - Environmental costs and benefits of end-of-life management options for PV modules and energy storage system batteries

- Successive steps:
  - DEQ to conduct research on economic costs and benefits on different end-of-life management options for renewable energy equipment
  - Research will be completed on economic and environmental costs and benefits of end-of-life options for wind energy.

§2.(a)(4)- Expected economically productive life

- Topics researched, discussed, and presented:
  - Data on lifespans of PV modules currently installed in NC
  - Information on typical lifespan of wind facility equipment
- Successive steps:
  - Research will be conducted on the economically productive lifecycle of energy storage system batteries
  - Research to be completed on the lifecycle of wind turbines installed at NC's only wind farm, Amazon Wind.
- Assumptions:
  - 54 of 577 NC solar facilities we collected data from did not list lifespan data
    - 25 years was utilized for these facilities as it is the most common reported length by manufacturers

§2.(a)(5)- The volume of photovoltaic modules, wind turbines, and energy storage system batteries currently in use in the State, and projections

- Topics researched, discussed, and presented:
  - Capacities, panel types, and estimated volumes of PV modules currently installed at NC solar facilities
  - Volume of turbines currently installed at Amazon Wind
- Successive steps:
  - Collecting information on energy storage system batteries currently installed in NC
  - Information on PV module and wind turbine volumes will be used to evaluate the impacts on landfill capacity if these equipment are disposed in landfills
- NC solar facility data assumptions:
  - For the 41 Facilities without panel counts, an estimate was used based on the average panel per MW for the known facilities (5,068 per MW)

§2.(a)(5)- NC facility data assumptions cont.

- Assumptions:
  - Solar panel weights were collected from manufacturer information available for some facilities and averaged based off of capacity. Panels were categorized into four different weight classes:
    - 0 - 199w: 27.2 lbs
    - 200 - 299w: 48.3 lbs
    - 300 – 399w: 52.4 lbs
    - >400w: 67.8 lbs
  - Any facility that did not have a panel capacity listed to designate a weight, we classified as 52.4 pounds, as 300-399w was the most common capacity range for installed panels in NC facilities.

§2.(a)(6)- A survey of federal and other states' and countries' regulatory requirements

- Topics researched, discussed, and presented:
  - Federal, state, county, and EU solar and wind decommissioning regulations, including financial assurance (FA) requirements
  - Solar ordinances adopted in NC counties

- Successive steps:
  - DEQ to research on energy storage system battery decommissioning requirements in other states

§2.(a)(7)- Financial assurance requirements

- Topics researched, discussed, and presented:
  - Financial assurance requirements for PV modules in NC counties
  - Subgroup of stakeholders formed to discuss the need for, approach, and implementation of financial assurance for PV modules in NC

- Successive steps:
  - DEQ is collaborating with stakeholders to draft language for financial assurance requirements for PV modules in NC

§2.(a)(8)- Infrastructure that may be needed to collect and transport EOL products

- Topics researched, discussed, and presented:
  - Minimal work has been completed to-date as the stakeholders have been focused on other items of HB 329

- Successive steps:
  - DEQ to research and evaluate the infrastructure that may be needed to develop practical, effective, and cost effective means to collect and transport EOL PV modules, energy storage system batteries, and wind energy equipment.

§2.(a)(9)-Manufacturer stewardship programs

- Topics researched, discussed, and presented:
  - Existing manufacturer stewardship programs for recycling PV modules

- Successive steps:
  - DEQ will discuss with stakeholders the potential and feasibility for creating a manufacture stewardship program for recycling end-of-life PV modules and energy storage system batteries

Q&A

Data Gaps

1. What project size threshold should we consider in defining “utility scale solar project”?
2. Which of the following information is currently collected or readily available for existing solar projects going through the Utilities Commission?
   a. Project size (MW capacity), location info
   b. Owner/Operator info.
   c. Number and size of panels
   d. Panel material characteristics, including type of hazardous components and their properties, TCLP data
   e. Type of ancillary equipment
   f. Anticipated life of project
   g. Indication of whether the project was ever constructed
   h. Other relevant info. that may be useful to our analysis
3. How is the available information stored? (electronic, paper copies, multiple entities, etc.)
4. Is any of the information we are seeking confidential or proprietary that would restrict access?
5. Are decommissioning requirements addressed through the Utilities Commission? If so, please explain.
6. Is financial assurance requirement addressed through the Utilities Commission? If so, please explain.
7. What ongoing monitoring or reporting is done for these projects if any?
8. For future projects, if our organizations determine that additional data needs to be collected up front, what would be the best mechanism to do that?

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Rulemaking

1. Are certain project information items better suited to be required/tracked by the commission?
2. What legislative authority and/or commission orders are needed to accomplish this?
3. Should the requirements be different for existing projects vs. future projects?
4. Which requirements are better suited through DEQ rules?

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Department of Environmental Quality

Energy Storage Options for North Carolina

Joe DeCarolis
Associate Professor
Civil, Construction, and Environmental Engineering
NC State University

Presentation to DEQ
April 14, 2020

Legislative Language

PART XII. ENERGY STORAGE STUDY

SECTION 12. The North Carolina Policy Collaboratory (Collaboratory) at the University of North Carolina at Chapel Hill shall conduct a study on energy storage technology. The study shall address how energy storage technologies may or may not provide value to North Carolina consumers based on factors that may include capital investment, value to the electric grid, net utility savings, net job creation, impact on consumer rates and service quality, or any other factors related to deploying one or more of these technologies. The study shall also address the feasibility of energy storage in North Carolina, including services energy storage can provide that are not being performed currently, the economic potential or impact of energy storage deployment in North Carolina, and the identification of existing policies and recommended policy changes that may be considered to address a statewide coordinated energy storage policy. The Collaboratory shall provide the results of this study no later than December 1, 2018, to the Energy Policy Council and the Joint Legislative Commission on Energy Policy.

Faculty and Staff Team Members

- **Joe DeCarolis**, Civil, Construction & Environmental Engineering
- **Jeremiah Johnson**, Civil, Construction & Environmental Eng.
- **Christopher Galik**, Public Administration
- **Harrison Fell**, Agricultural and Resource Economics
- **Ning Lu**, Electrical and Computer Engineering
- **David Lubkeman**, Electrical and Computer Engineering
- **Wenyuan Tang**, Electrical and Computer Engineering
- **Ken Dulaney**, FREEDM Center
- **Anderson Rodrigo de Queiroz**, NC Central
- **Steve Kalland**, NC Cleantech Center
- **Autumn Proudlove**, NC Cleantech Center
- **Isaac Panzarella**, NC Cleantech Center

Student Team Members

- **Shuchi Liu,** Electrical and Computer Engineering
- **Yao Meng,** Electrical and Computer Engineering
- **Asmaa Alrushoud,** Electrical and Computer Engineering
- **David Mulcahy**, Electrical and Computer Engineering
- **Catie McEntee**, Electrical and Computer Engineering
- **Zachary Small**, Agricultural and Resource Economics
- **Danny Sodano,** Civil, Construction, and Environmental Engineering
- **Dustin Soutendijk,** Civil, Construction, and Environmental Engineering
- **Lisha Sun**, Electrical and Computer Engineering
- **Chris Gambino**, Public Administration

Stakeholder Engagement

Three public meetings:

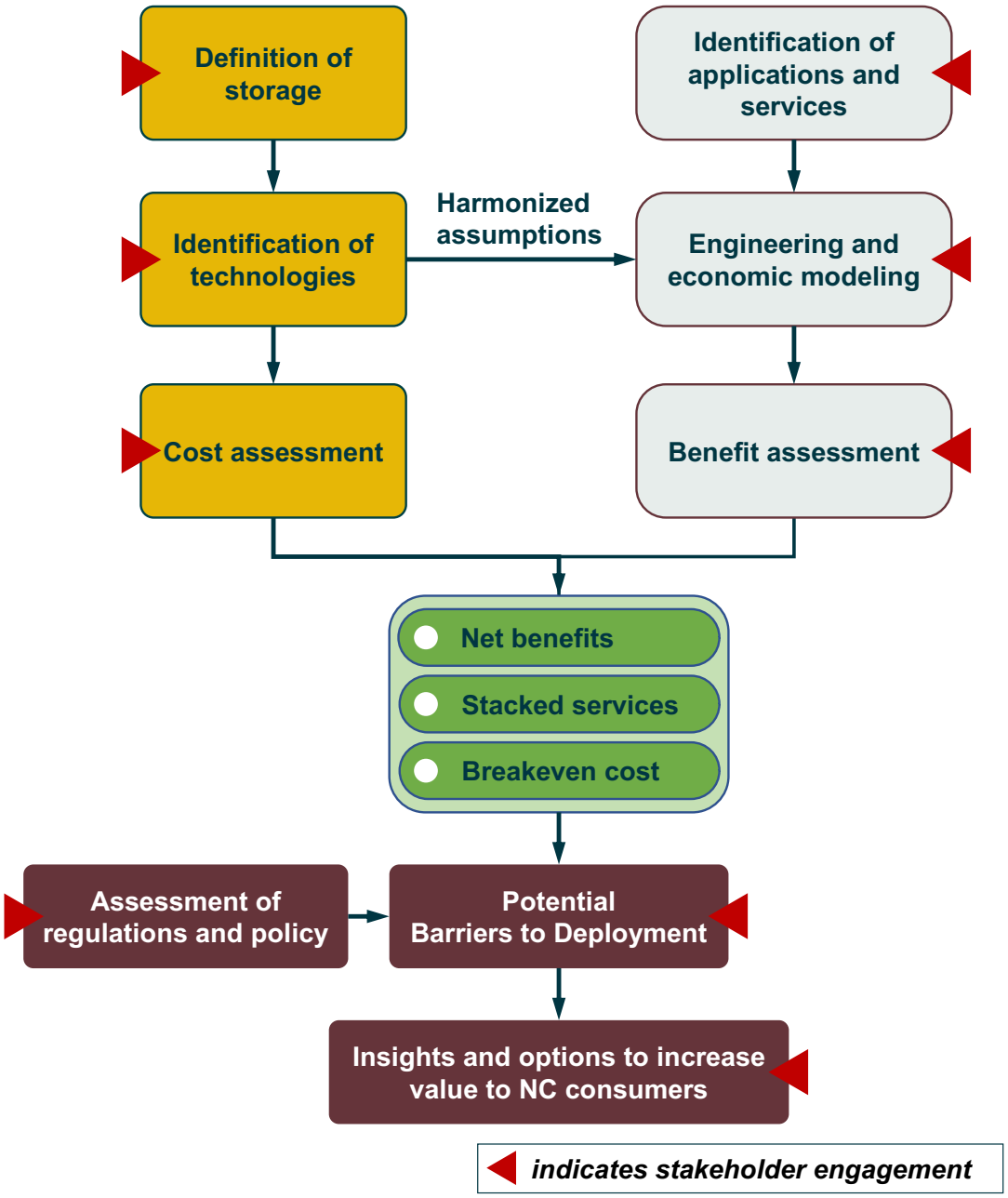
February 15, 2018

June 27, 2018

October 2, 2018

Plus a number of one-on-one meetings with different stakeholders.

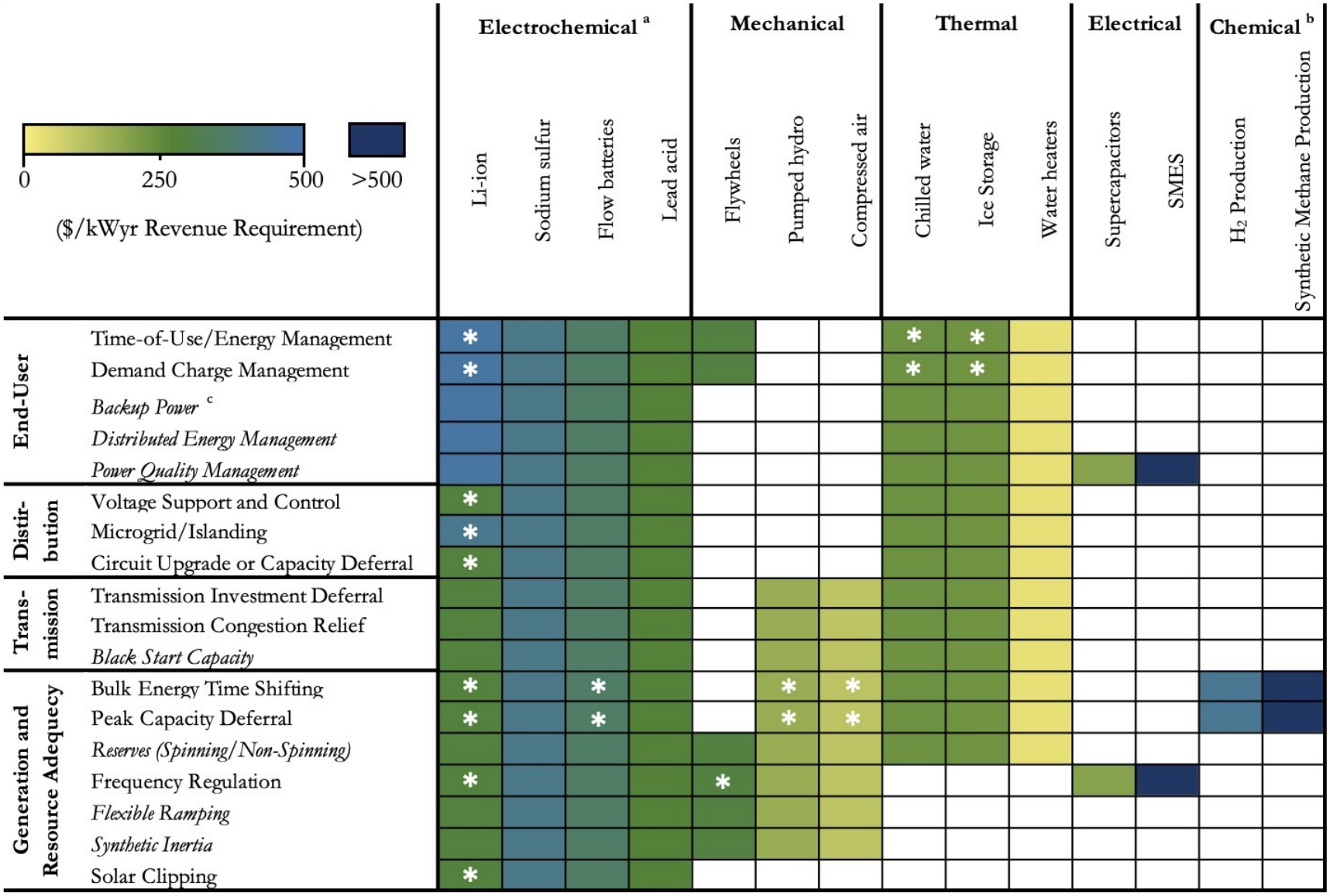
Workflow


Definition of storage
Identification of applications and services
Identification of technologies
Harmonized assumptions
Engineering and economic modeling
Cost assessment
Benefit assessment
Net benefits
Stacked services
Breakeven cost
Assessment of regulations and policy
Potential Barriers to Deployment
Insights and options to increase value to NC consumers
indicates stakeholder engagement

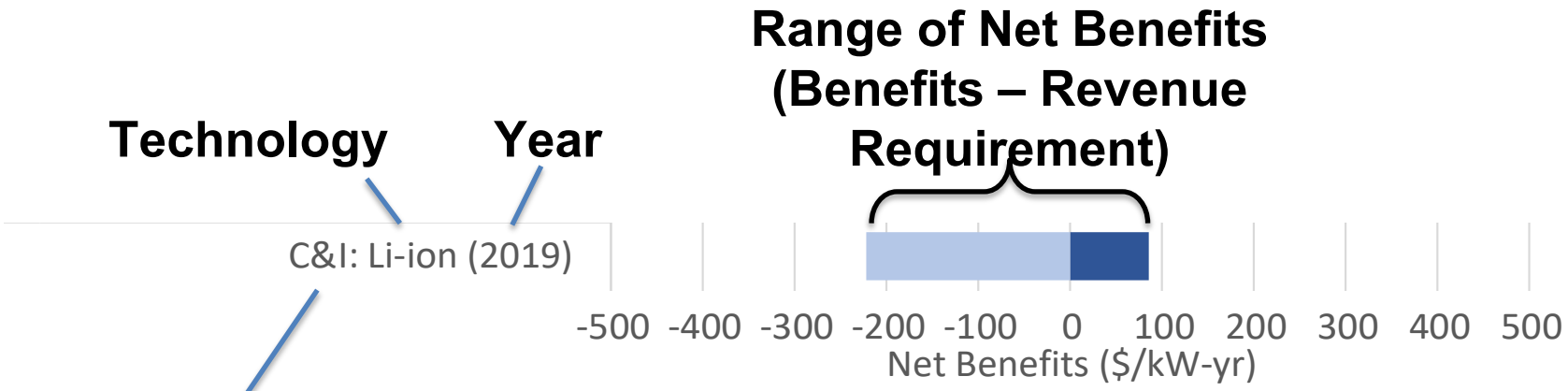
Definition of Storage

"a system used to store electrical, mechanical, chemical, or thermal energy that was once electrical energy, for use in a process that contributes to end-user demand management or grid operation and reliability."

Services and Technologies Analyzed



Summary: Net Benefits

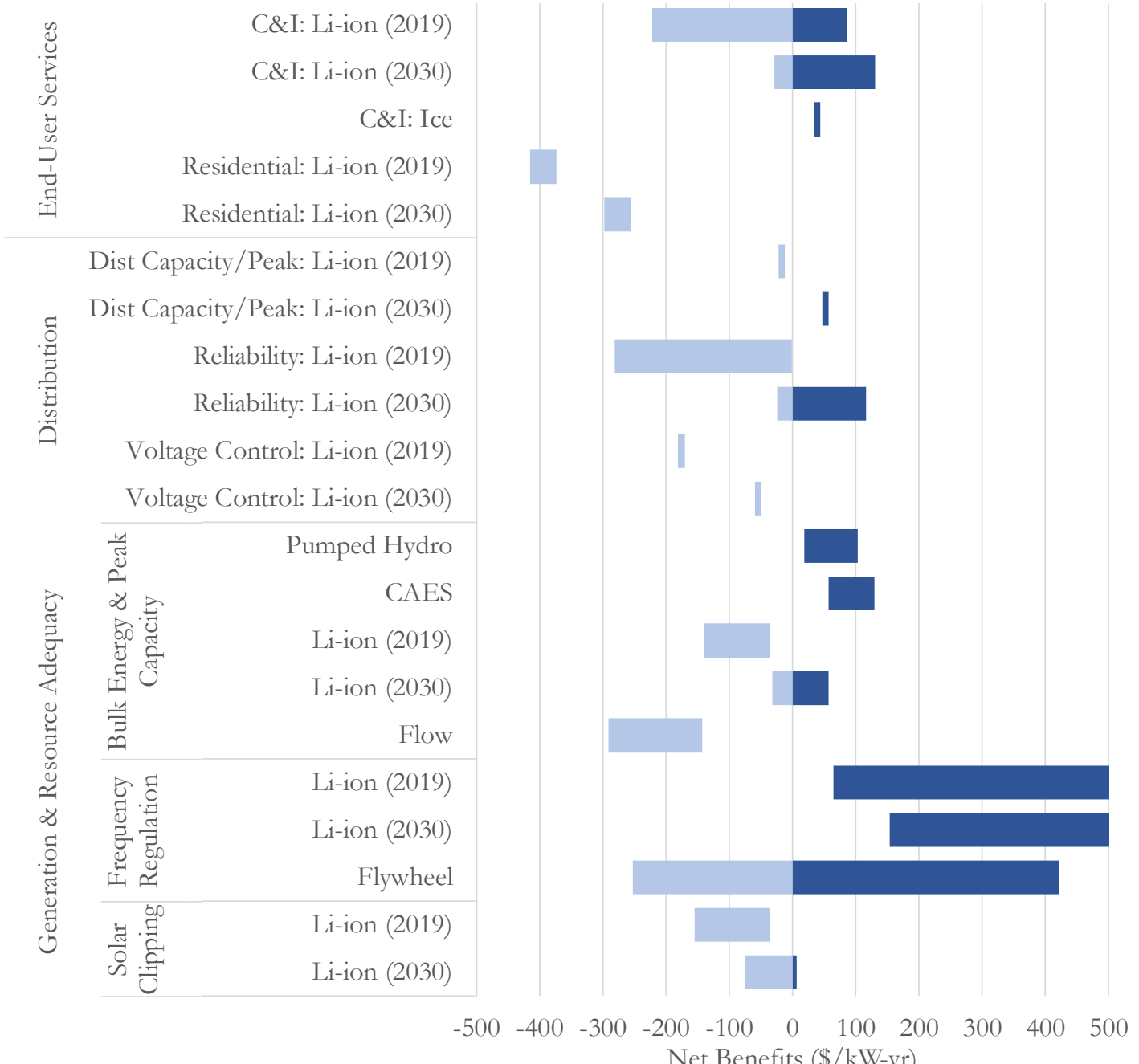


Application (commercial & industrial end-user services)

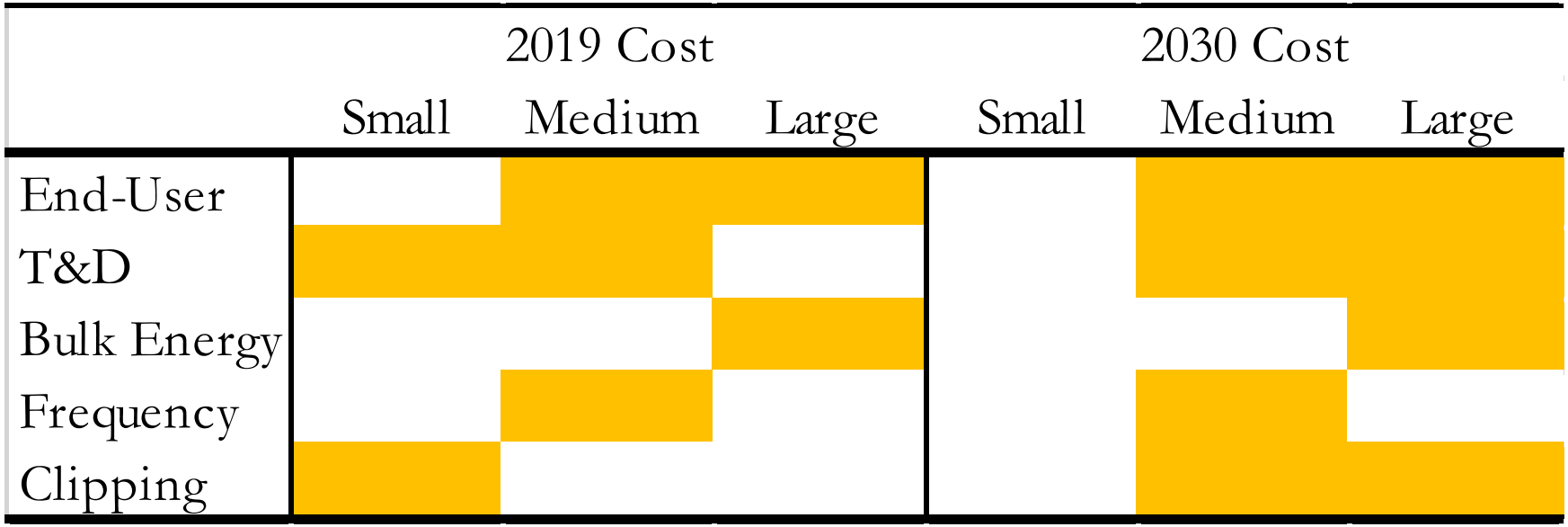
Light blue = not (yet) cost-effective

Dark blue = cost-effective

What Did We Find?



Deployment Levels



Small: 0-100 MW

Medium: 100-1,000 MW

Large: > 1,000 MW

Recommended Policy Options

The menu of recommendations we provide should be seen as a **starting point for further deliberations** between stakeholders and decision-makers in the development of a statewide coordinated energy storage policy.

Our recommendations can be categorized into three separate categories roughly corresponding to the magnitude of intervention: **Prepare, Facilitate, and Accelerate**.

Eventual policy should be informed by a broader set of strategic policy priorities.

Recommended Policy Options

Prepare

Address potential gaps or areas of uncertainty that might otherwise hinder the deployment of cost-effective energy storage.

- Update and clarify planning provisions
- Update and clarify definition and ownership of storage
- Evaluate net metering rules in relation to the utilization of storage
- Update interconnection rules
- Provide guidance for the updating and adoption of local codes and permitting standards

Recommended Policy Options

Facilitate

Consider interventions that might help to either increase the value or decrease the cost of energy storage in the near-term.

- Develop competitive procurement process to monetize storage services
- Develop a standard offer program to monetize services provided by smaller projects
- Develop new tariff structures
- Create an expedited or streamlined interconnection process for behind-the-meter systems
- Promote data access and transparency
- Develop targeted or expanded REPS cost-recovery funding stream
- Establish a procurement goal

Recommended Policy Options

Accelerate

Increase the pace of energy storage deployment.

- Develop storage-specific incentives
- Incorporate storage within the North Carolina REPS
- Develop a clean peak standard
- Establish a procurement requirement

Deliverables (https://energy.ncsu.edu/storage/)

Energy Storage Options for North Carolina

PREPARED BY
NC State Energy Storage Team

PREPARED FOR
Energy Policy Council
Joint Legislative Commission on Energy Policy

NC STATE UNIVERSITY

NCCentral UNIVERSITY

NC Policy Collaboratory

Deliverables

Our final report is now available for public download. Here is the associated press release.

Benefit-cost spreadsheet. This spreadsheet contains the benefit and cost information cited in the study. The 'B-C summary' tab contains the benefit ($/kWyr), cost ($/kWyr), and break-even cost ($/kWh) for all 432 scenarios we ran. The remaining worksheets contain the technology-specific cost and performance information we used to derive the revenue requirement for each technology. For more information on the cost calculations, see Section 4.6 of our study.

End User Services (Behind-the-Meter). These spreadsheets calculate the energy storage benefit for a customer site (large, medium, small, residential). The storage is located behind the electric meter and controlled to limit a customer's peak demand or coincident peak demand each month. In the case of solar PV plus storage, the battery is charged from the solar PV and in the case of storage only, it is charged from the grid. Each scenario is compared to a base case load profile, taken from NREL's System Adviser Module software, which represents a typical customer load. In this way, the net benefits from storage are comparable across the scenarios, regardless of the tariff used.

Distribution Services. This VBA-enabled Excel tool was used for the distribution system analysis. This analysis covers three cases where storage could provide value on the distribution system: capacity deferral and peak shaving, reliability enhancement, and voltage control for high penetrations of solar PV.

Frequency Regulation. This download includes the PJM regulation signal and prices, in addition to the NY-ISO regulation signal. The NY-ISO price data is posted by day and can be downloaded from their website here. The model used to perform frequency regulation is undergoing development as part of a PhD thesis. The full algebraic formulation of the model is given in Section 6.6 of the report.

Bulk Energy Time Shifting and Peak Capacity Deferral. The analysis was conducted with an open source energy system model called Tools for Energy Model Optimization and Analysis (Temoa), developed at NC State University. The link points to a zenodo archive that contains exact copies of the model code and data used to conduct the analysis. Additional information on how to run the model is available on the Temoa website.

Battery Chemistry

- Lithium-Ion (Li-ion, vary by manufacturer)
  - High energy density, high cost, better for low depth of discharge (DoD), dominates current stationary storage market
- Lead acid (PbA)
  - Seen mainly at residential and not commercial scale, low energy density, low cost, contains toxic lead, high recycling rate
- Nickel-based (Ni-Cd, Ni-MH)
  - Some contain cadmium (toxic), high cost, high self-discharge rate, higher energy density than lead acid, early adoption that has faded
- Sodium-based (NaS)
  - Higher energy density, high operation temperature present risk operation complications, good DoD, non toxic, reactive and explosive with air

Hazardous Classification

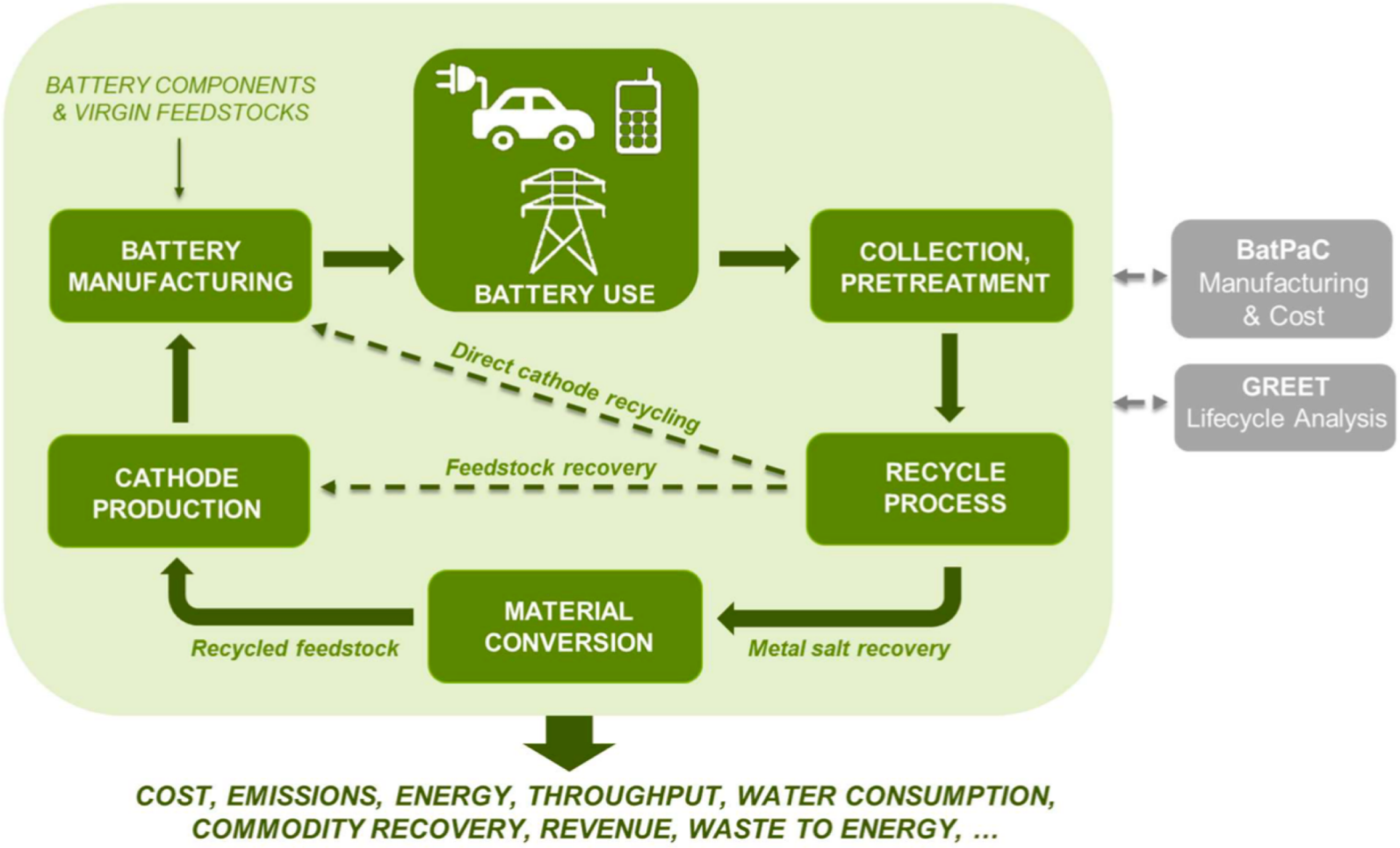
- Batteries could fall under any of the four hazardous classifiers
- Lead acid batteries are Universal Waste (hazardous with special regulations to allow for recycling)
- Most other batteries are not specifically called out as hazardous waste, but many could qualify given their constituent chemicals, reactivity, corrosive components, or even ignitability
  - If classified as universal waste, could be recycled more easily through collection and storage of large quantities

Relevant Questions to Battery Recycling

- How could battery recycling affect the material supply availability and price risk?– Globally?– In the U.S.?
- How does battery chemistry affect the economics of battery recycling over time?
- How much battery recycling is needed to enable *X*% EV deployment?
- How will R&D success in battery recycling affect material supply vulnerabilities?
- How will regional policies affect battery availability and clean energy manufacturing?
- How could the different energy storage markets affect EV deployment goals?

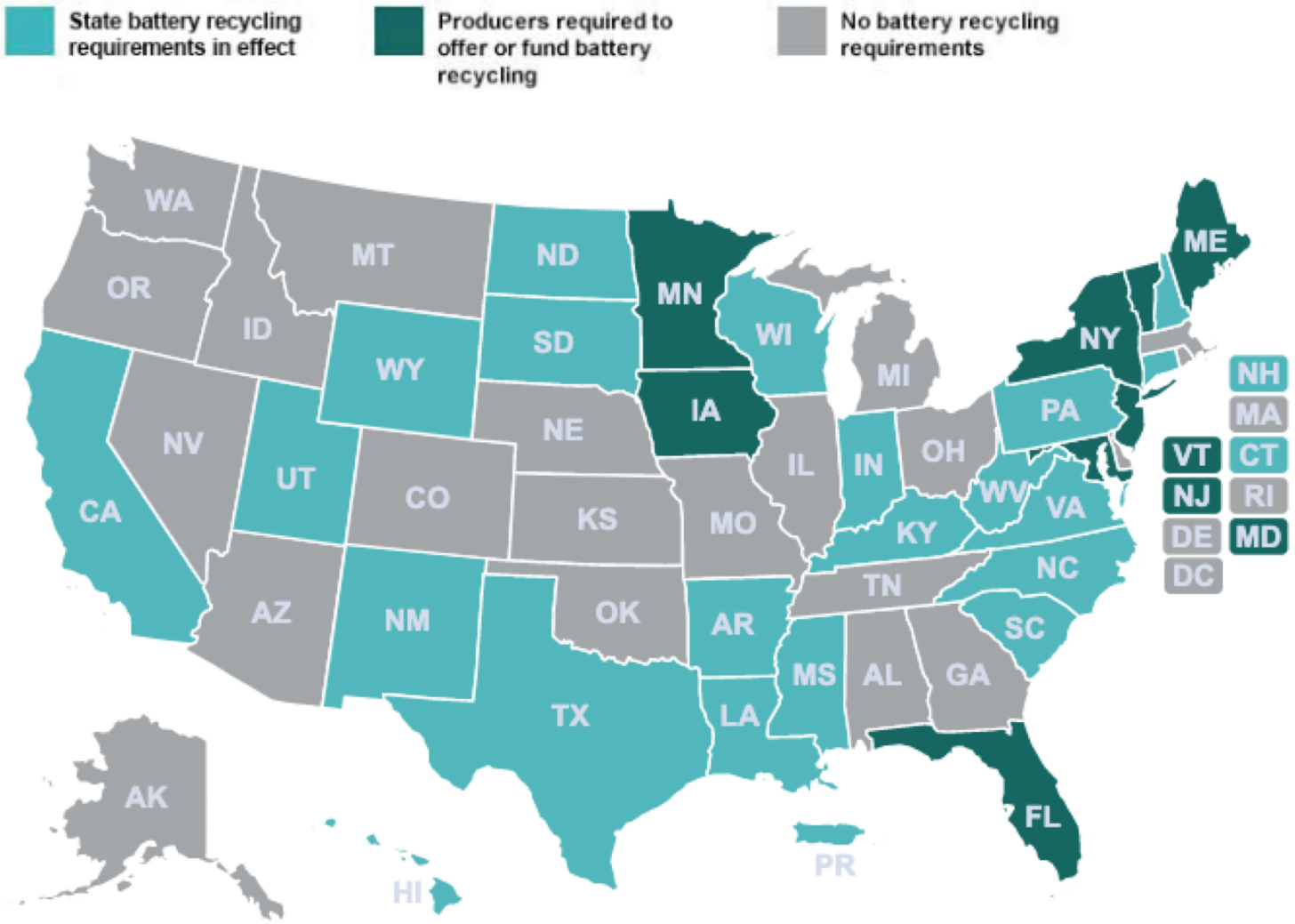
Source: NREL Battery Recycling Supply Chain Analysis, June 2019, https://www.nrel.gov/docs/fy19osti/74229.pdf

Example Closed-Loop Battery Recycling Model



Source: Argonne National Lab, EverBatt, https://www.anl.gov/egs/everbatt

Regulations



Source: Call2Recycle

Other Researchers

Annick Anctil, Michigan State University
https://www.egr.msu.edu/people/profile/anctilan

Callie Babbitt, Rochester Institute of Technology
https://www.rit.edu/directory/cwbgis-callie-babbitt

Parikhit Sinha, First Solar
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umicore

materials for a better life

Introducing Umicore

2020

Who we are

A global materials technology and recycling group

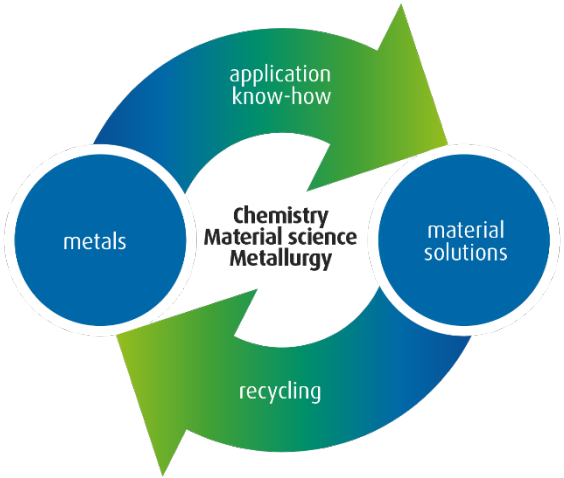
One of three global leaders in emission control catalysts for light-duty and heavy-duty vehicles and for all fuel types

A leading supplier of key materials for rechargeable batteries used in electrified transportation and portable electronics

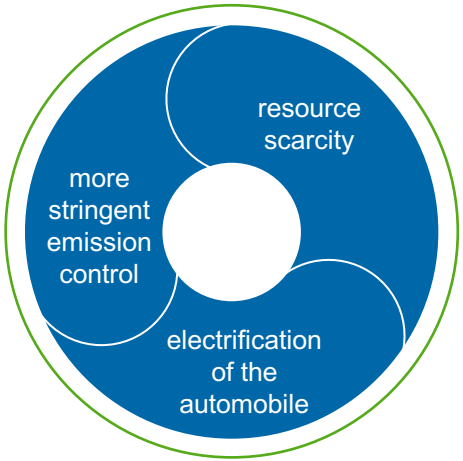
The world's leading recycler of complex waste streams containing precious and other valuable metals

Our foundations

Unique business model



Supportive megatrends



Industry leader in sustainability

Our strategy

horizon 2020

By 2020 we have…

clear leadership in clean mobility materials and recycling

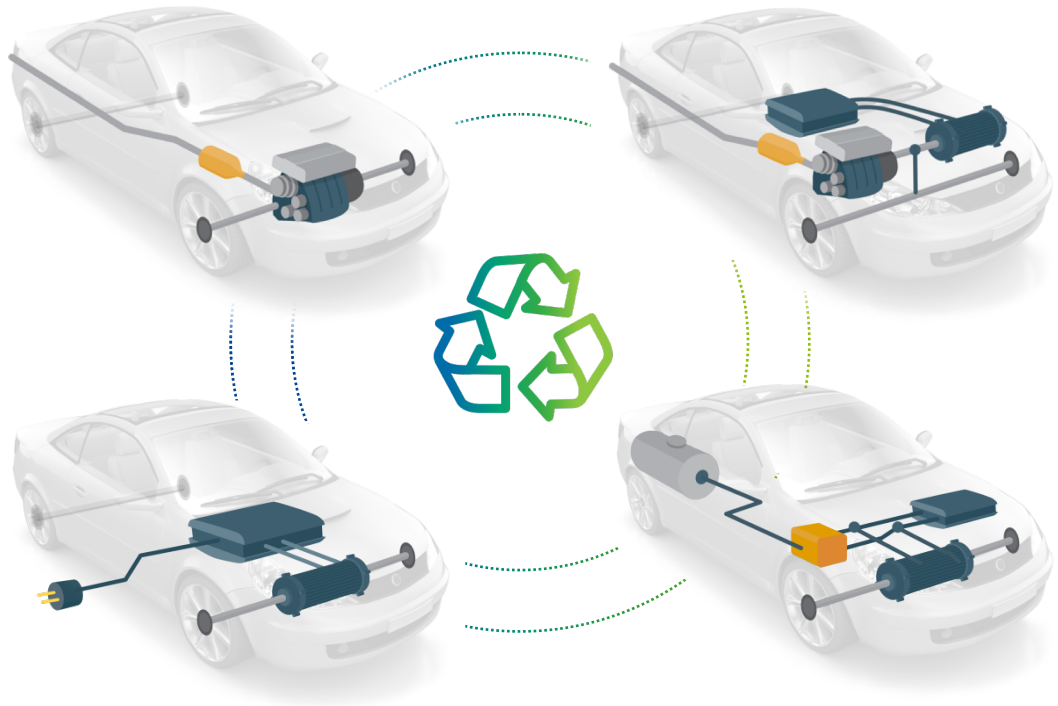
turned sustainability into a greater competitive edge

Unique position

in clean mobility materials

ICE
Emission control catalysts

BEV
Battery materials

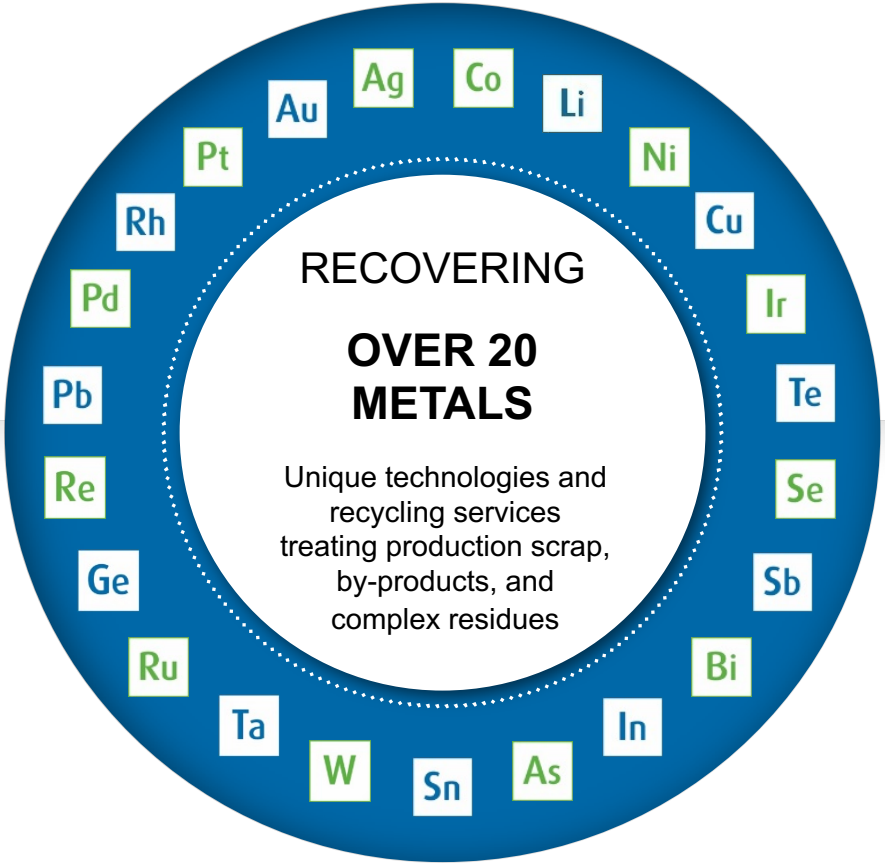


(p)HEV
Battery materials and emission control catalysts

Fuel cells
Electro-catalyst and battery materials

Unique position

in recycling

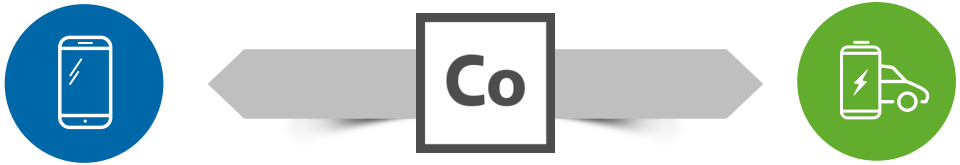


Turning sustainability

into a greater competitive edge

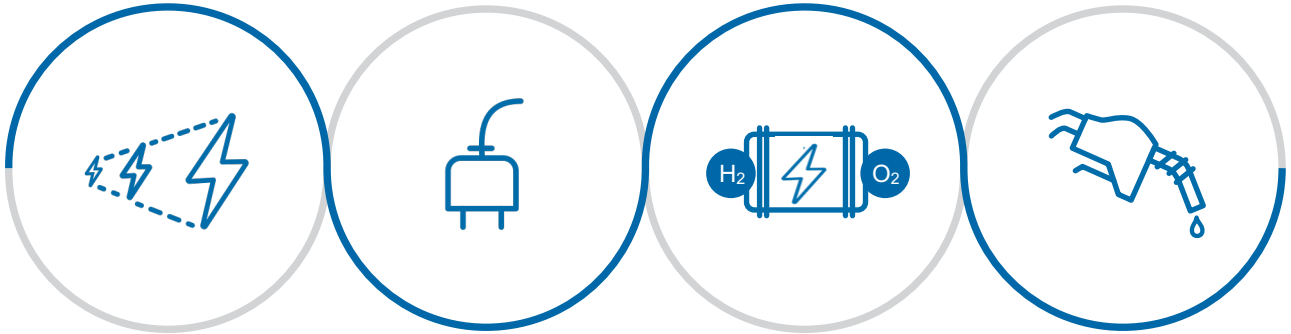
We have transformed Umicore into a sustainability leader over the past 15 years

The purpose is to generate more concrete benefits from our sustainability efforts eg:



Preparing the ground for further growth

Clean Mobility innovation roadmap spanning the next 20 years



Full electric

Plug-in hybrid

Fuel cells

Cleaner combustion engines

Battery Recycling gaining traction

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Recent developments for Umicore

Milestones 2019-2020 (1)

- 18 February 2019: Umicore partners with ABB FIA Formula E Championship to implement battery recycling program
- 29 May 2019: Umicore and Glencore develop partnership for sustainable cobalt supply in battery materials
- 23 September 2019: Umicore announces partnership with LG Chem for the supply of NMC cathode materials
- 25 September 2019: Energy Department Announces Phase 1 Winners of Battery Recycling Prize
- 24 October 2019: Umicore announces strategic supply agreement with Samsung SDI for NMC cathode materials
- 2 December 2019: Umicore completes acquisition of cobalt refining and cathode precursor activities in Finland

Milestones 2019-2020 (2)

- 20 December 2019: Umicore confirms its commitment to ethical and sustainable cobalt
- January 2020: Umicore has been ranked 14th in the 2020 top 100 of the world's most sustainable companies published by Corporate Knights
- 23 January 2020: Sustainable Growth award
- 24 January 2020: Umicore is one of the 42 global organizations agreeing to 10 principles for a sustainable battery value chain
- 29 January 2020: Umicore wins the fifth Febeliec Energy Award with their implementation of a Battery Storage installation in Olen, Belgium.

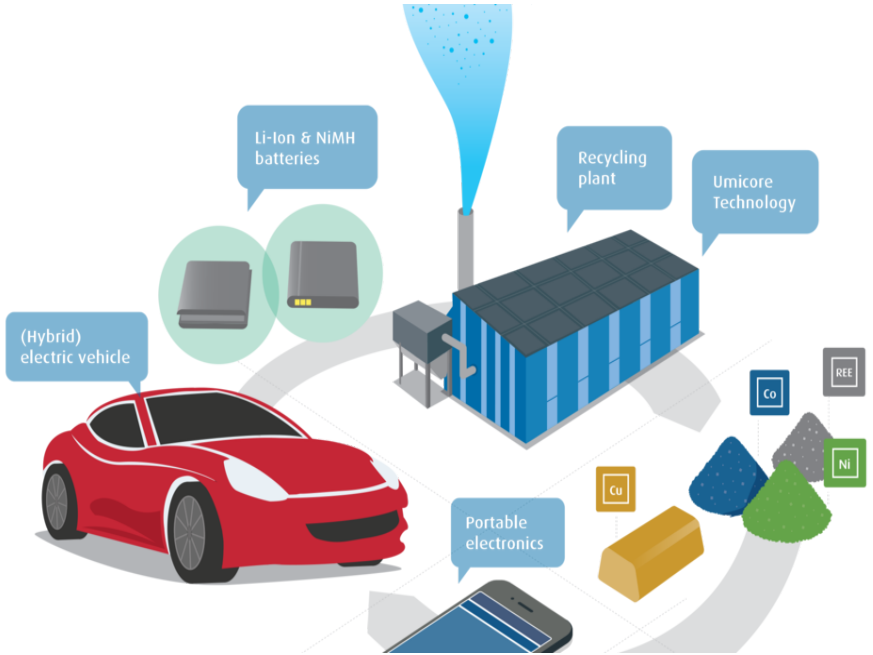
Battery recycling at Umicore

A dedicated process for recycling rechargeable batteries

- Umicore is able to treat all types of Lithium ion batteries as well as Nickel Metal Hydride batteries

- Capacity: 7,000 mt/y
  - ± 250M mobile phone batteries
  - ± 200,000 HEV's
  - ± 35,000 EV's

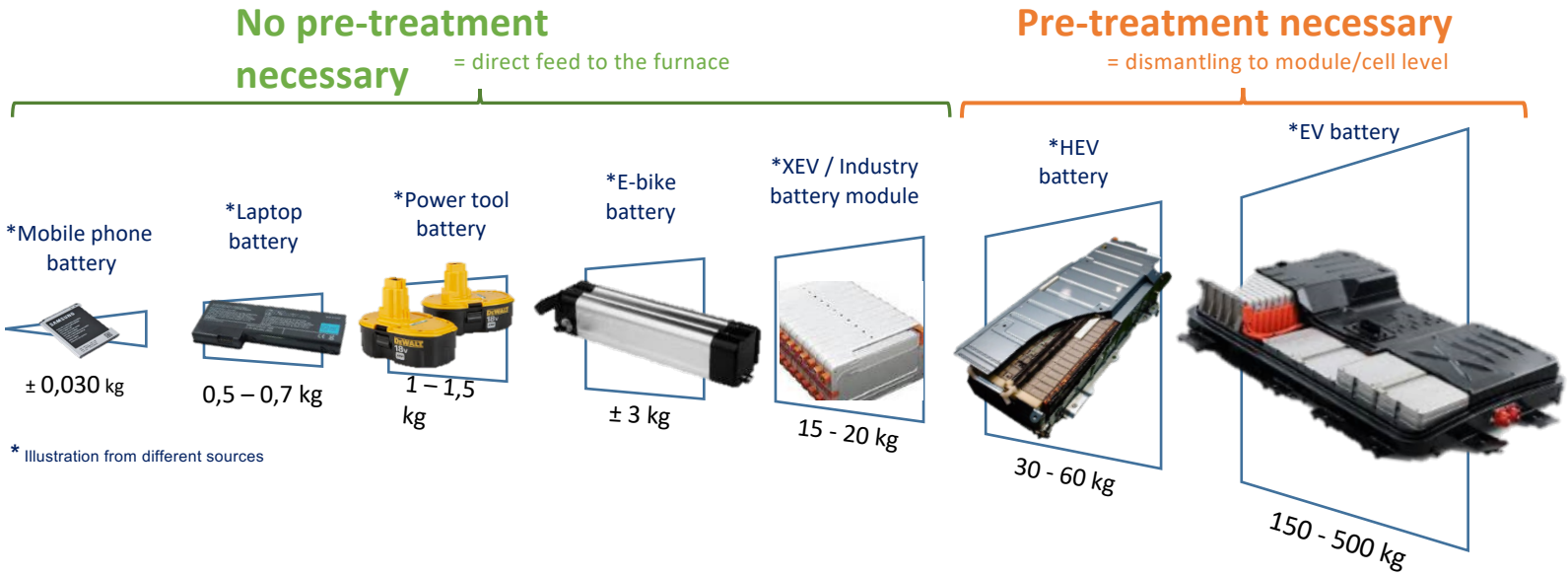
- Today only a small fraction of the Li-ion batteries of mobile devices is recycled



Variable feed size for Umicore process

Flexible on Size

- Medium sizes → directly to furnace
- Larger sizes after (partial) dismantling



U.S. Department of Energy
LITHIUM-ION BATTERY RECYCLING PRIZE

Store Packs Umicore

- Four US Collection & Storage Sites for EV LIBs

Presented at NAATBatt Annual Conference

Mark Caffarey
President Umicore USA Inc.

Team Introduction

Store Packs Umicore

With four collection & storage sites for EV LIBs aimed toward scrap yards we hope to provide a safe collection, storage, handling and transportation option. Scrap yards are not properly equipped to handle automotive Lithium ion battery packs and are coming to the industry looking for guidance on how to handle these packs.

Team Members:

- Mark Caffarey: President, Umicore USA
- Erika Warner: North American Battery Recycling Coordinator, Umicore USA
- Casey Westhoff: US Government Affairs Manager, Umicore USA

Phoenix Group Metals

- Nathan Laughlin: Operations Manager
- Matthew Steger: Regional General Manager

Spiers New Technologies

- Kylah McNabb: Director of Business Innovation
- Bryan Schultz, Director of Engineering

Project Overview

- Umicore is working with Phoenix Group Metals (PGM) and Spiers New Technologies (SNT) to establish automotive Lithium ion battery pack drop off sites that serve the U.S. scrap yard community.

- With three locations; Phoenix, Houston, and Atlanta are being established with PGM for handling and storage of large li-ion battery packs. With assistance of Umicore, PGM is working to become compliant with EPA, NFPA, DOT, and IMDG codes in order to properly handle, store, package, and transport lithium-ion battery packs.

- Spiers New Technologies will be the fourth location collection point located in Oklahoma City, OK.

- Packs will make their way to SNT for an evaluation of second life capabilities. Any packs that's are determined not to have a second life capability will be shipped for recycling for mineral value through Umicore.

Project Update

- Currently the Phoenix Group Metals sites, (Phoenix, AZ; Houston, TX and Atlanta, GA), are in the process of obtaining EPA identification numbers for all their locations.

- The next step, we are making sure that all locations are following NFPA protocols and reaching out to all local fire marshals to make sure that the sites are up to date. SNT will play a crucial role in training PGM personnel in the proper handling and storage of large Li ion battery packs.

- Additionally we are thinking about the transportation of packs from scrap yards to storage locations. Looking for solutions cross country shipping solutions that are trained, knowledgeable, and certified to ship hazardous materials.

- Based on the success of Phase I, we are looking to partner with companies similar to Phoenix Group Metals located in different US States.

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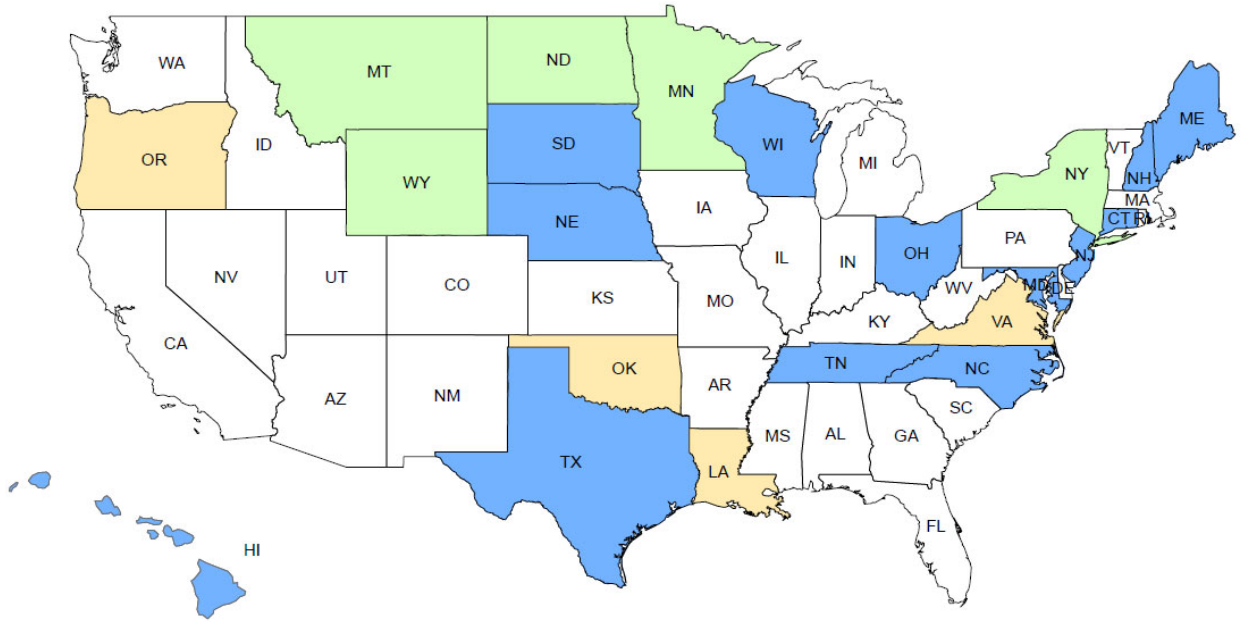
Overview of States with Wind Energy Decommissioning Regulations

Stakeholders Meeting
April 14, 2020

States with Decommissioning Requirements

- 22 states have wind decommissioning requirements.
- Decommissioning includes removal of wind turbines, facility equipment, restoring disturbed earth, projected lifespan, and method of decommissioning.
- Owner is responsible for decommissioning and all costs.
- Several require decommissioning within a certain timeframe.
- Some require the decommissioning plan to be re-evaluated every 5-years.

States with Decommissioning Requirements



Legend

- States with wind decommissioning requirements, without financial assurance
- States with wind decomissioning requirements, including decommissioning cost estimate or decommissioning funding method
- States with wind decomissioning requirements, including financial assurance

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States with Decommissioning Requirements

- Of the states with decommissioning requirements,13 include financial assurance
  - Different types of financial assurance allowed, including surety bond, performance bond, collateral bond, parent guaranty, letter of credit, etc.
  - Amount of financial assurance varies.
    - Equal to the estimated total cost of decommissioning minus the salvage value or equal to the estimated total cost of decommissioning.
    - Adequate financial capacity to decommission.
  - Several states require that estimated decommissioning costs are prepared by a professional engineer.

States with Decommissioning Requirements

- Of the states with wind decommissioning requirements, 5 include financial considerations.
  - Decommissioning plans must include decommissioning cost estimate or method for ensuring funds will be available.
  - No actual financial guarantee requirements

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States with Decommissioning Requirements

- Of the states with wind decommissioning requirements, 4 do not include financial assurance requirements.

Countries with Decommissioning Requirements

- France
  - To obtain the initial construction permit, the owner must commit to dismantle the turbines and complete site restoration.
  - Subject to financial guarantees in the event of bankruptcy, failure to decommission, etc.
  - €50,000 per turbine (approximately $56,000), in the form of a bank security, deposit, private guarantee fund, or bond.

Countries with Decommissioning Requirements

- Germany
  - Similar decommissioning requirements as France, with exception of site restoration.
  - Financial guarantee amount differs from one state to another.
  - Financial guarantees are authorized in the form of a bond, deposit account, collateral and pledge.

Countries with Decommissioning Requirements

- UK (Offshore)
  - Secretary of State may require the owner to prepare a decommissioning program.
    - Measures that will be taken for decommissioning
    - Decommissioning cost estimate
    - Provisions on restoring the site
  - The Secretary of State can approve, modify, or reject a program, including any financial security provisions.

NORTH CAROLINA
Department of Environmental Quality

Jessica Citrola, Environmental Specialist II
Phone: (919) 707-8339
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Department of Environmental Quality

Are batteries capable of producing air pollution?

Our research show batteries decompose and undergo a photochemical reaction which can also cause emissions. However, the potential air emissions from battery incineration or decomposition is not considered as much of a concern as water and soil contamination. Possibly, air pollution from batteries is a bigger concern during the manufacturing process. There is a lack of studies available that demonstrate significant air pollution from batteries.

What is the estimated size of a 1 MW storage system?

DEQ looked into several U.S. battery storage sites to estimate a size of a 1 MW energy storage system. Depending on the battery storage technology, one standard sized container can contain maximum capacities of half a MW to 3 MW. In addition, several websites cite different container capacities, as it depends on the battery manufacturer. One website stated a 40 foot container can produce one MW, while another manufacturer had a 20' container producing 3 MW. Another site has a larger container of 53' producing 1 MW. We also looked into Tesla battery storage packs, which do not utilize storage containers. Based off of other larger installations, we estimated that a one MW energy storage facility comprised of Tesla powerpacks will weigh about 4,800 lbs.

Are there secondary lead smelters in NC?

To the best of our knowledge, there are no secondary lead smelters in North Carolina.

What is the estimated volume of PV modules currently installed in NC?

DEQ has obtained data for 577 facilities, with a total estimate of 21,258,667 panels and 462,089 metric tons (509,365 tons) of panels currently installed.

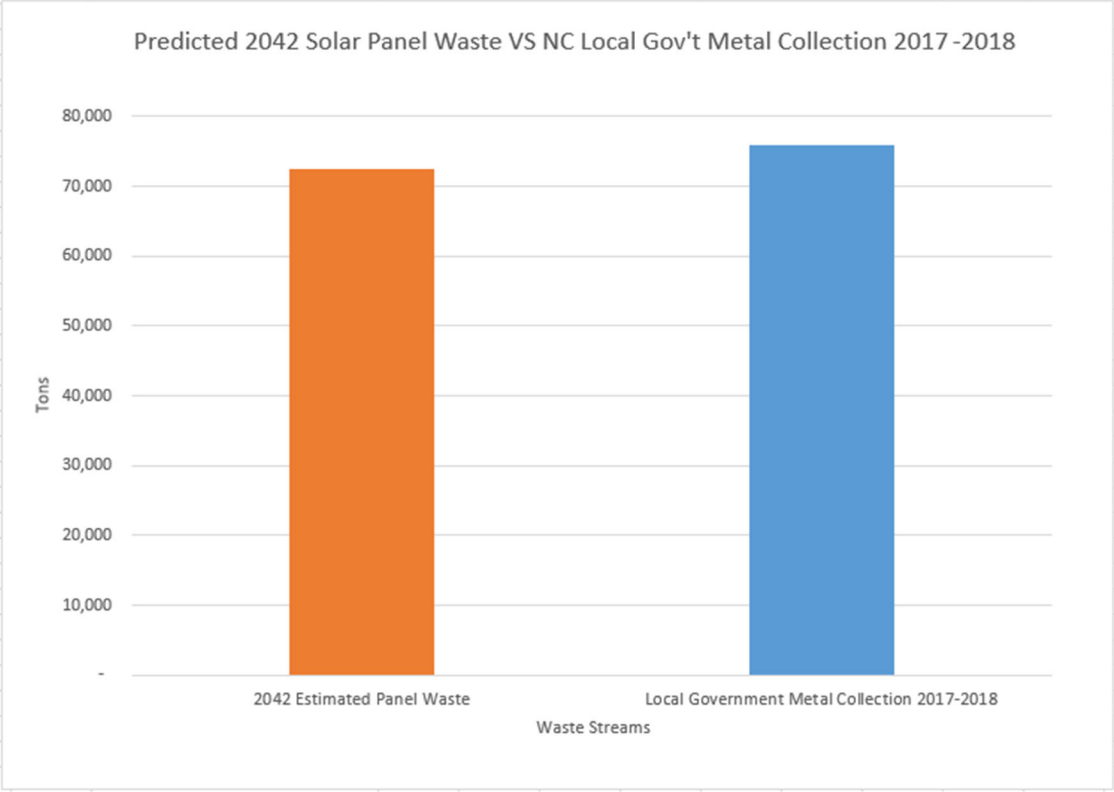
- In order to develop a comprehensive list and quantify volumes, we had to make several assumptions in the facility data to work around the data gaps. Solar panel counts were not reported for approximately 40 facilities. As a result, we divided the number of solar panels at each facility by the capacity in MW to determine the number of panels per megawatt, which was calculated to be 5,068. For all facilities that did not report the number of panels installed, we multiplied 5,068 by the capacity installed at the site to estimate a total number of panels installed.
- In order to understand the total volume of solar panels currently installed in NC and expected potential waste tonnage, we needed to determine a method for designating panel weights to facilities as this information was not reported. Since we had the panel manufacturer and model information for a small portion of NC solar facilities, we researched and compiled the weights for the panel types from manufacturers listed on our facility data. Then, we averaged the weight data based off of capacity and created four different weight classes. Facilities with panels under 200w averaged 27.2 pounds, 200-299w panels averaged 48.3 pounds, 300-399w panels averaged 52.4 pounds, and panels over 400w averaged 67.8 pounds. Most of the facilities in the data we collected listed a capacity for each panel and we designated one of the four weights above depending on the capacity provided. If a facility did not list a capacity for the panels used, we designated the weight as 52.4 pounds since the majority of the facilities' panels on our NC

solar facilities list fell between the 300-399w range. Lastly, we multiplied the weight by the number of panels at the facility to find the volume of modules currently installed.

How do other NC waste streams compare to future estimated solar panel waste volumes?

Waste Stream	Tonnage in 2017-2018
Public and Private C&D	1,620,487
Plastic Recovery Collected by Local Government	38,388
Recycling of Televisions (manufacturer + local government programs)	13,591
Total Metal, including White Goods, Aluminum Cans, Steel Cans Collected by Local Government	75,889
Total Glass Collected by Local Government	117,237
Tons of Yard Waste Landfilled	124,613
Tires Disposed of in Tire Mono-Landfill	65,806
Disposal of Coal Combustion Residuals	643,808
Hazardous Waste Generated in NC by Facilities	80,235

Tonnage Annual report to the NC general Assembly DWM Info from 2017-2018 report (not available yet for 2018-2019)



*2042 is the year projected to have the greatest tonnage of solar panels requiring decommissioning

What volume of silicon panels will be disposed of in a landfill?

The estimated volume of silicon solar panels currently installed in NC is 2.2 million panels and 360,051 metric tons. The quantity depends on the feasibility of the preferred methods to reuse, refurbish, and recycle panels in NC and results from toxicity leaching tests. If solar panels are disposed of in a landfill they must first be deemed nonhazardous.

What are the current recycling options for PV modules in NC?

The majority of solar panel materials are reusable and re-furbished panels can be resold. Some manufacturers have established take-back programs for decommissioning PV modules. However, there is currently no established recycling infrastructure in the U.S. for solar panels. There are 21 certified e-recyclers in North Carolina, and there are many uncertified recyclers in the state as well. As the end-of-life market for PV modules increases in the future, existing e-recyclers in North Carolina may expand their services to include PV modules.

What is the likelihood of restoration of soil for farm use or long term impacts on the land?

Studies have shown that leaching of hazardous materials from modules is unlikely due to the encapsulated layer of the installed panels. According to the Department of Energy, land can be reverted back to agricultural uses at the end of the operational life for solar installations. The NC Clean Energy Technology Center stated that the long-term impact of solar panels on farmland is small and manageable. Reclamation plans can help ensure that decommissioning is completed appropriately.

Are there any counties in particular concerned about financial assurance, and what is the typical financial assurance range implemented by county governments? Is financial assurance usually less than or greater than a landfill insurance?

Fifty-six of the counties in North Carolina have created ordinances relating to decommissioning and/or financial assurance measures for solar facilities. In addition, twenty-three counties have established specific financial assurance requirements for solar facility decommissioning. The majority of these counties require a type of financial guarantee greater than or equal to the estimated decommissioning costs, with the estimated decommissioning costs to be re-evaluated on a regular basis. The highest financial assurance requirement in North Carolina county is 125% of the estimated decommissioning cost of a solar facility.

Will financial assurance requirements be in further detail in the rule?

There are existing state rules for wind facilities. Decision on rule necessity is what we are working towards for PV modules and batteries. Given the abundance of ordinances controlling FA which are already in place. The stakeholders have discussed options such as no state rule on FA or a rule or law which requires minimum FA standards with requirements for local government approval.

I. Blue represents counties that have financial assurance requirements in addition to solar decommissioning requirements
II. Red represents counties that have solar decommissioning requirements without financial assurance

How does capacity factor affect the useful life of the PV panel/facility?

The useful life of PV systems is not related to the capacity factor. The useful life is determined by how long the technology will last and produce power as intended. The PV facility equipment will age and degrade over time regardless of how much the equipment is used.

Are there any members of county governments in the stakeholder group?

A representative from the Association of County Commissioners has attended several stakeholder meetings. Throughout the stakeholder process, DEQ has invited participation to members of county governments through contact with the Association of County Commissioners. However, DEQ will begin to expand outreach efforts by contacting county government offices directly about HB 329 and the stakeholder process.

Is California classifying PV modules as hazardous waste?

California created proposed amendments to title 22, Division 4.5, Chapter 11, Article 1, section 66261.9 of the Code of Regulations to include listing PV modules as universal waste. PV modules that do not exhibit a characteristic of hazardous waste, are not yet wastes, or are destined for recycling would not be subject to California's proposed universal waste regulations. Until the new regulations are adopted, solar panels that exhibit characteristics of hazardous waste must be currently managed as hazardous wastes and not as universal wastes in California.

Clarify what is covered by NC rules regarding for TCLP testing.

- Solid wastes are defined by regulation as hazardous wastes in two ways. First, solid wastes are hazardous wastes if EPA lists them as hazardous wastes. The lists of hazardous wastes are found in 40 CFR Part 261, Subpart D. Second, EPA identifies the characteristics of a hazardous waste based on criteria in 40 CFR § 261.10. Accordingly, solid wastes are hazardous if they exhibit any of the following four characteristics of a hazardous waste: ignitability, corrosivity, reactivity, or toxicity (based on the results of the Toxicity Characteristic Leaching Procedure, or TCLP). Descriptions of the hazardous waste characteristics are found in 40 CFR Part 261, Subpart C.

- Universal waste regulations include only hazardous waste batteries, mercury-containing equipment, pesticides, and lamps. To be covered under the universal waste program, these items must first be identified as hazardous waste. [Note: PV modules are unable to be managed as Universal Waste]

- When a facility conducts testing to determine if the waste exhibits any of the four characteristics of a hazardous waste, he or she must obtain a representative sample (within the meaning of a representative sample given at § 260.10)

- 40 CFR 260.10 definition of what a representative sample means-a sample of a universe or whole (e.g., waste pile, lagoon, ground water) which can be expected to exhibit the average properties of the universe or whole.

- EPA guidance on sampling procedures can be found in EPA's "Test Methods for Evaluating Solid Waste: Physical/Chemical Methods (EPA Publication SW-846)." In Chapter nine of SW-846, EPA's "Test Methods for Evaluating Solid Waste" gives guidance on how to develop a sampling plan to obtain a representative sample of wastes. Chapter nine states that representative samples of waste be collected and defines representative samples as exhibiting average properties of the whole waste. The HWS requires that 10% of the waste being disposed of be sampled (ie. If there are 300 panels then 30 should be test).

Summary Table of HB 329 DEQ Meetings

Meeting	Summary
Stakeholder Meeting September 13, 2019	DEQ introduced its interagency role and legislative charge under HB 329.
Stakeholder Meeting November 15, 2019	DEQ provided an overview of PV module end-of-life management in North Carolina and other states. NC Clean Energy Technology Center presented information on solid and hazardous waste characteristics of solar panels and energy storage system batteries.

Stakeholder Meeting December 9, 2019	DEQ presented on the recycling of PV modules in the EU. First Solar and Solar Energy Industries Association presented on industry PV module recycling practices. Discussions with stakeholders took place on decommissioning and financial assurance for PV modules.
DEQ/EMC 1st Quarterly Report to NCGA	Quarterly Interim Report on the Activities Conducted to Establish a Regulatory Program for the Management and Decommissioning of Renewable Energy Equipment
Stakeholder Meeting January 22, 2020	DEQ presented on assumptions, issues, and review on data collected for solar facilities in NC as well as financial assurance requirements for other energy generation sources in NC. Discussions with stakeholders took place on thresholds for applicability of regulatory programs to utility-scale solar facilities. A draft white paper on TCLP applicability to PV modules was also reviewed.
Stakeholder Meeting February 10, 2020	DEQ presented on wind energy in NC as well as hazardous content of energy storage system batteries. DEQ also provided an overview of solid and hazardous waste transportation. DEQ and stakeholders discussed TCLP testing and applicability to PV modules and edits made to corresponding white paper.
DEQ/EMC 2nd Quarterly Report to NCGA	Quarterly Interim Report on the Activities Conducted to Establish a Regulatory Program for the Management and Decommissioning of Renewable Energy Equipment
GWWMC March 4, 2020	Update on the stakeholder process required by Session Law 2019-132 entitled Renewable Energy Amendments which requires the EMC to establish a regulatory program no later than January 2022 which manages end-of-life photovoltaic modules and energy storage system batteries, and to decommission utility-scale solar projects and wind energy.
	POWERPOINT PRESENTATION - Wind Energy in North Carolina – Condensed March 4, 2020
	POWERPOINT PRESENTATION - NC Solar Facility Data March 4, 2020
	POWERPOINT PRESENTATION - GWWMC Energy System Batteries March 4, 2020

NCUC Public Staff and DEQ Meeting March 18, 2020	DEQ discussed with NCUC about the stakeholder process, quarterly report key messages, and current state of knowledge pertaining to PV modules, energy storage systems, and wind energy facilities. NCUC explained which requirements might be better suited to be implemented through the commission.
Stakeholder Meeting April 15, 2020	DEQ presented an overview of different states' and countries' wind energy decommissioning regulations. NC State Clean Energy Technology Center provided an overview of energy storage options for NC and Umicore presented on energy storage system battery recycling. NCSEA and Ecoplexus lead a discussion on proposed language for PV module decommissioning and financial assurance.
MN Stakeholder Meeting June 2020	Staff collaboration at Minnesota Photo Voltaic Stakeholder Meeting

Rulemaking Schedule for the EMC to approve rule by 2022*	
January 1, 2021	Submit Fiscal Note and Rule Text to OSBM for approval
GWWMC May 5, 2021	GWWMC Meeting: 1 Action item - Approval of text and fiscal note to proceed to EMC.
EMC July 7, 2021	EMC Meeting: 1 Action item - Approval of text and fiscal note to proceed to public hearing.
Publication, Public Comment Starts August 10, 2021	Rule published in NC Register; Comment Period Begins.
Public Hearing August 24 , 2021	Earliest date for Public Hearing
Public Comment Ends October 11, 2021	Comment Period Ends.
EMC November 11, 2021	EMC Meeting: 1 Action item - Adoption of rule, approve Hearing Officer's Report and Fiscal Note.
RRC December 12, 2021	RRC Meeting - Approval of text
Effective January 1, 2022	Proposed Effective Date

* Please note that all dates for 2021 are approximate

APPENDIX B
LIST OF PARTICIPATING STAKEHOLDERS[6]

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*
EQ Research*
Umicore*
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
Invenergy*
Minnesota Pollution Control Agency

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