This paper provides a quick-read summary of a webinar that was held in April 2024, as part of a series on circular economy in renewable energy infrastructure. To read more about the series visit our dedicated page [Circular renewables webinar series]

SESSION 4: RECYCLING: THE GOOD, THE MISSING AND THE IMAGINARY – APRIL 2024

The fourth session aimed to give a real insight into the current state of renewables recycling and what needs to happen to ensure renewables infrastructure can be recycled at end of use. Which components and materials are difficult to recycle? Which solutions are available / ready to be commercialised, and which are missing? What investment into recycling infrastructure is required and how can it be unlocked? The session was chaired by Deryth Wittek from the Department for Business and Trade with speakers Dr Charlotte Stamper, European Metals Recycling, and Dr Eleni Kastanaki, Technical University of Crete.

WIND TURBINE RECYCLING

Charlotte Stamper introduced European Metals Recycling, which currently handles around 10 million tonnes of metal globally each year. They have started to offer end-to-end decommissioning services for wind turbines and associated infrastructure that was first installed around 30 years ago. Forecasts show that strong growth in renewables will demand high volumes of materials, which partly can be supplied through reuse and recycling services.

1. **Current Practices and Challenges:**
    - In terms of recycling, solutions are well established for the metallic parts such as the drivetrain, towers and cables. Solutions for the composite materials in the blades and nacelle covers are still missing though. EMR has started commercial reuse and recycling of material from the decommissioning of early turbines. EMR has started practical recycling projects on small-scale decommissioning of early turbines.
    - The industry lacks scalable recycling technology for turbine blades, which often end up in landfills or are incinerated.
    - Recovery methods for rare earth elements used in offshore turbines are not yet scalable, and critical mass of feedstock for recycling is still some years away.
    - Policy and standards do not yet focus on recycling of this critical infrastructure. Industrial strategy, demand-side measures and design for disassembly need to be driven by policy and standards.

2. **Future Prospects:**
    - Significant investments are being made to develop better recycling technologies.
    - The industry anticipates substantial growth in renewable installations, which will eventually require decommissioning.

3. **Strategic Approaches:**
    - The establishment of a dedicated turbine reprocessing center in Glasgow aims to lead in repair, reuse, and recycling efforts.
    - A holistic view of renewables infrastructure as a material bank is necessary to align with industrial strategy and net zero aspirations.

- Collaboration between turbine owners and recycling companies can enhance circularity and result in better outcomes.
- 'Imaginary' solutions reside mostly within policy and standards. Industrial strategy, demand-side measures and design for disassembly must be driven by policy and standards.

4. **Design and Policy Considerations:**
    - Emphasis on design for disassembly to facilitate easier recycling of future turbines.
    - Greater focus on reducing energy demand to minimize the need for new infrastructure.

PHOTOVOLTAIC PANEL RECYCLING

Eleni Kastanaki focused on solar recycling. In Europe, flows of solar PV waste are still modest, being estimated at totals of 0.9-3 Mt by 2030, going up to 5.6-10 Mt by 2040 and 14.3-18.5 Mt by 2050. Annual flows go up from ca. 0.45 Mt in 2030 to 0.85 Mt in 2040. In general, the economic viability of a recycling plant depends on ca. 20kt of PV waste per year, which will likely be reached first in Germany, followed by Italy, France and Spain.

1. **Current practices and challenges:**
    - PV panels have a layered structure, typically consisting of tempered glass, EVA film, photovoltaic cells, and a back sheet. Different PV technologies (first to fourth generation) require varied recycling processes.
    - PV panels become waste after their operational lifespan ends, with degradation rates varying based on different statistical and physical methods. Recycling technologies are underdeveloped and result in downcycling.
    - Sufficient volumes to attract investment in specialised PV recycling sites can differ per country. A first investment in a specialised PV recycling site has materialised already in France. Due to modest waste forecasts in the next decades, most countries in the EU will likely rely on specialised recycling sites in a neighbouring country. From environmental perspective, and due to the wide geographic distribution of solar PVs which creates logistical challenges, local pretreatment combined with further processing in dedicated facilities is expected to be the most sustainable.
    - Geographic dispersion of installations and waste generates logistical challenges and high costs.
    - There is an undeveloped market for recovered materials from PV panels.
2. **Research and Data Gaps:**
    - Accurate estimation of future PV waste is crucial for planning treatment facilities.
    - Studies show different results due to varied assumptions, highlighting the need for detailed and realistic estimations.
    - Collaborative efforts are needed to enhance the reliability of waste assessments.

Policy and Strategic Approaches:

- Specialized treatment facilities should be established in countries with high PV installations, such as Germany, Italy, France, and Spain. A coordinated approach across Europe can help manage PV waste more effectively.
- Stockpiling until recycling becomes more widely available may be required. Investment into recycling has to happen in parallel with investment into manufacturing facilities that can use the recovered materials.
- The EU's regulatory framework can be strengthened by introducing a separate reporting category for solar PV waste and material passports, regulations on standards, safety controls and warranties for

reused and refurbished panels, and design for circularity including design for disassembly, minimise the use of hazardous materials and enabling repair.
- Due to the PV design of lamination and encapsulation, possibilities for repair, reuse and remanufacture of solar PVs and associated secondary materials currently depend on aggressive processing that leads to downcycling. As PV technologies advance rapidly, it is important to plan adaptable recycling infrastructure and focus on recovering high purity materials.

A note on artificial intelligence: This short paper was first drafted using artificial intelligence to summarise the recorded webinar. Prior to this publication it was then reviewed, and edited and corrected where necessary by Dr Anne Velenturf, Senior Researcher and project lead.