ACMA
American Composites Manufacturers Association

RECOVER. TRANSFORM. INNOVATE.

Composites Recycling Conference 2020 | Online

May 19 – 21, 2020

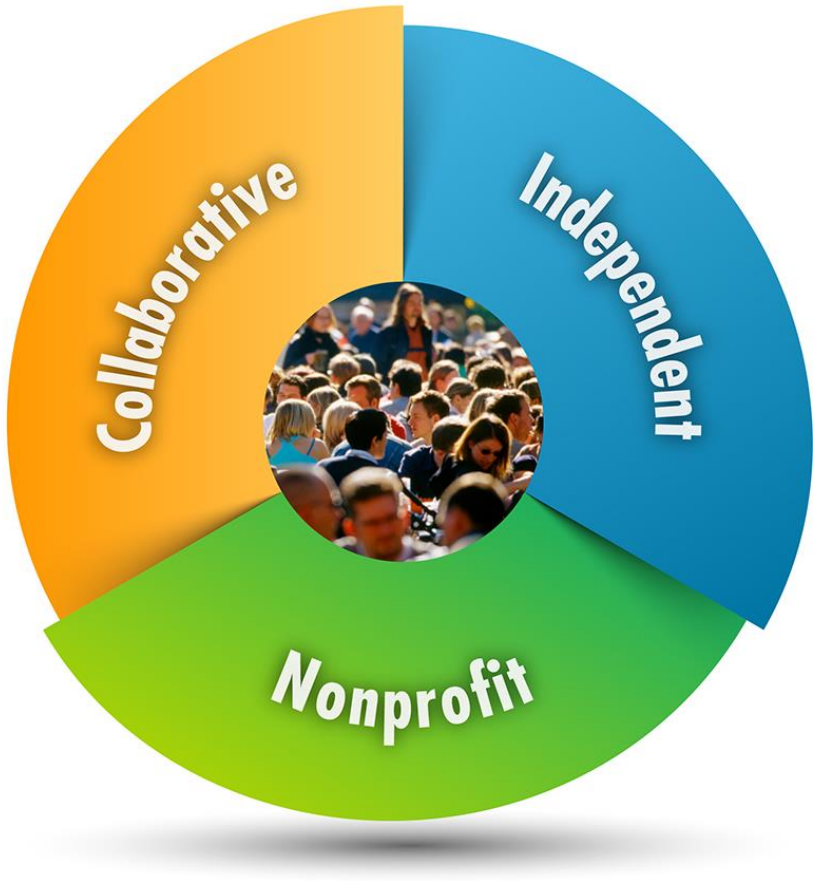
Wind Turbine Blade Recycling

Preliminary Assessment

Brandon Fitchett
Principal Project Manager
bfitchett@epri.com

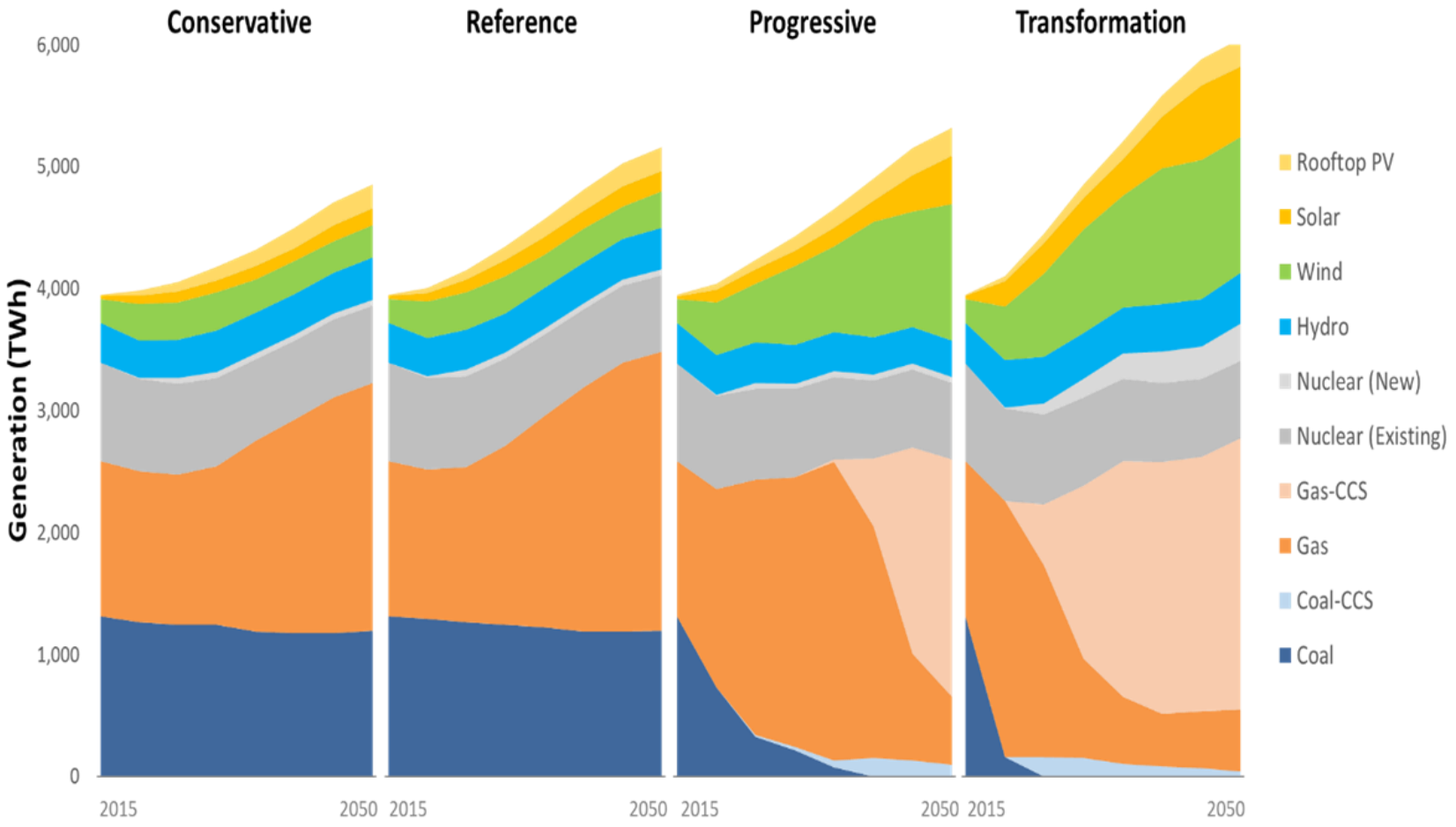
Ken Ladwig
Senior Technical Executive
keladwig@epri.com

EPRI Wind Turbine Blade End-of-Life Research



- Wind Power Program
- Environmental Aspects of Renewables
- End-of-Life Strategic Initiative

End of Life – An Emerging Issue



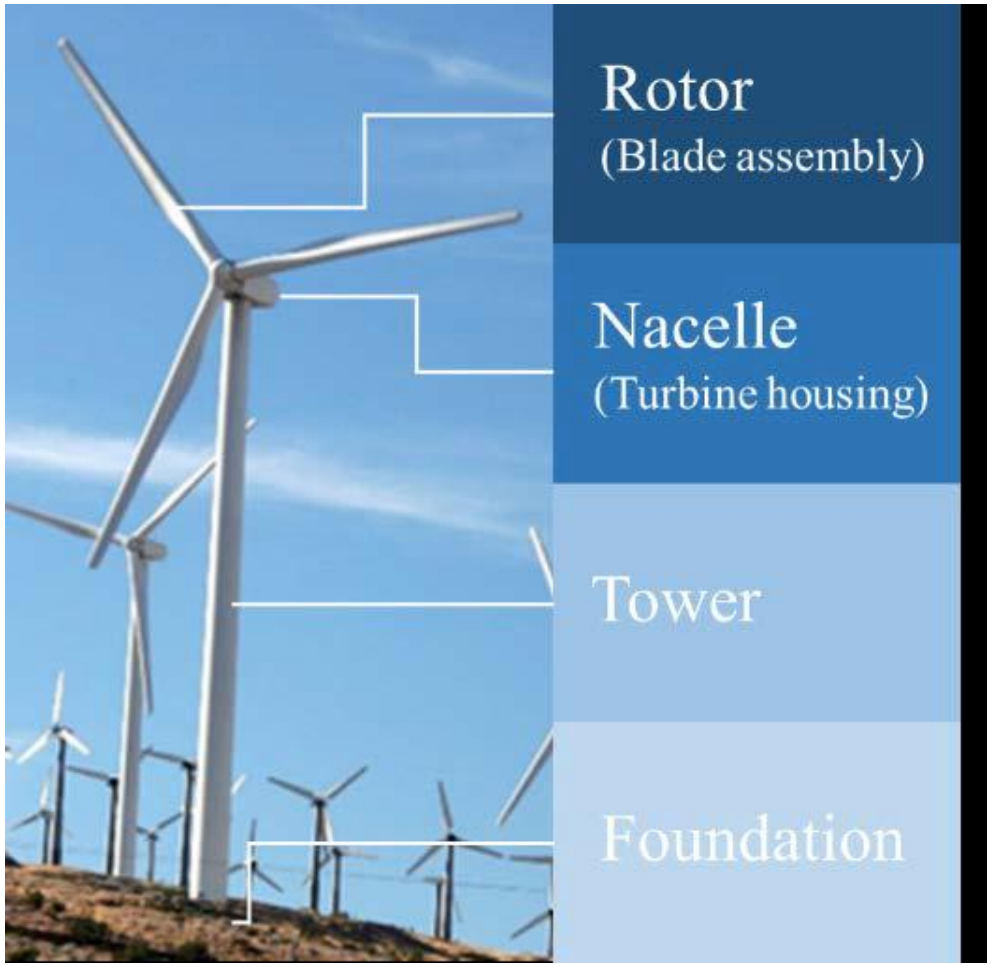
- Increasing volumes of PV modules, wind turbine blades, and battery systems
- What are the issues and risks?
- Public policy and regulation
- Sustainable management options
- Circular economy

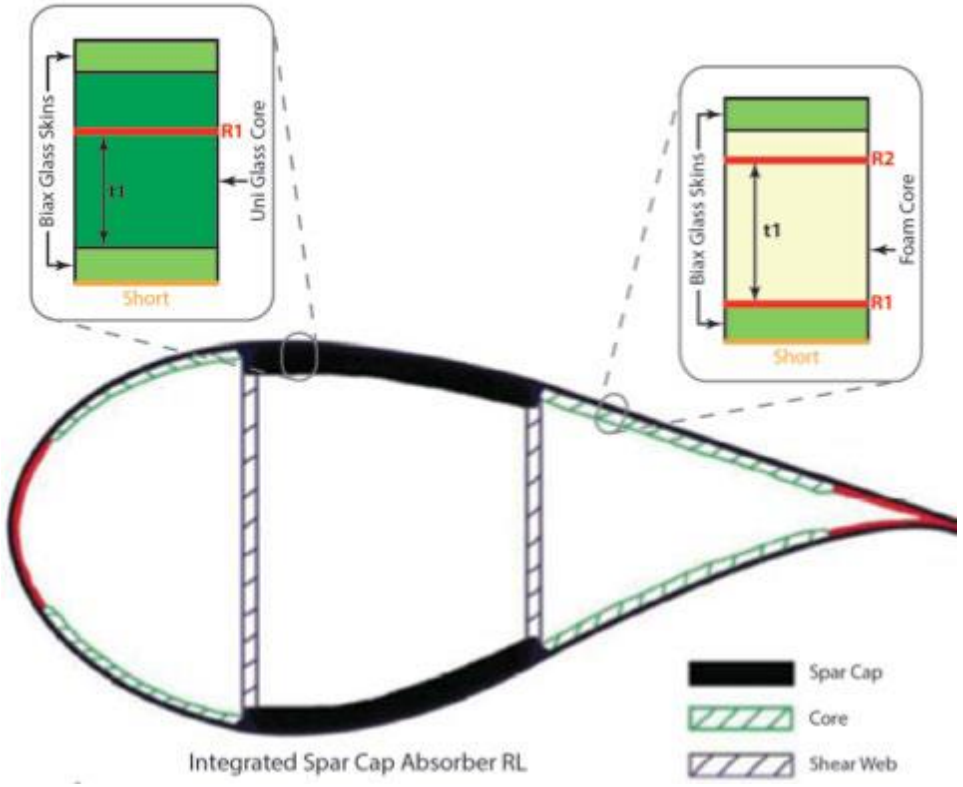
Source: EPRI

Wind Turbine Blade Recycling: Preliminary Assessment

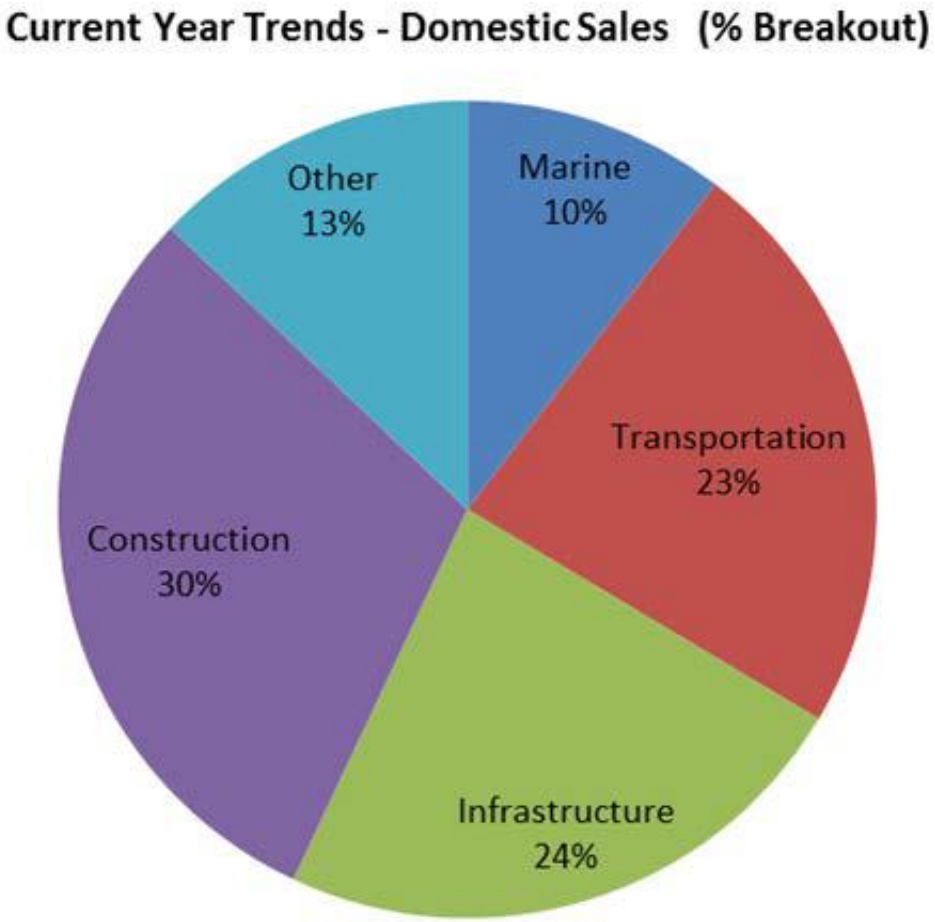
- Published as EPRI Report Number 3002017711 in April 2020
- Available for no cost at epri.com
- Authors
  - ACMA: Dan Coughlin
  - Urban Venture Group, Inc.: Paula Stevenson, Burr Zimmerman
- Scrap Resource Assessment
- Technology Assessment
- Site Location Considerations
- Existing Techno-Economic Assessment Models (TEA)

Wind Turbine Components



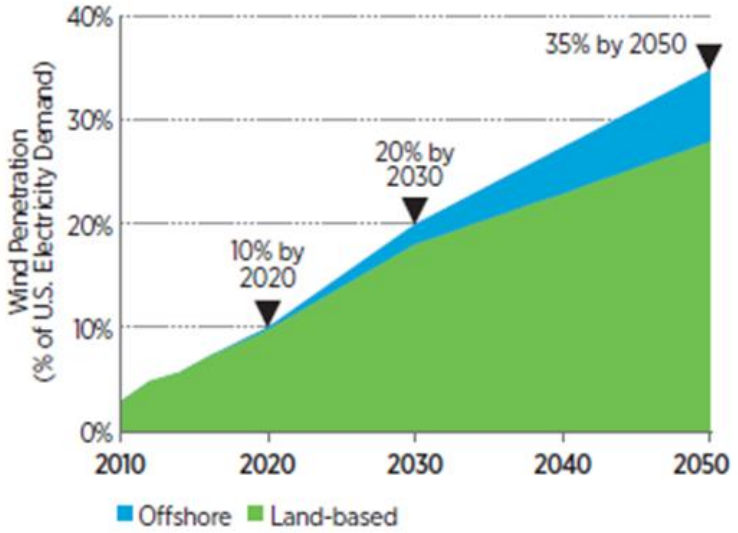


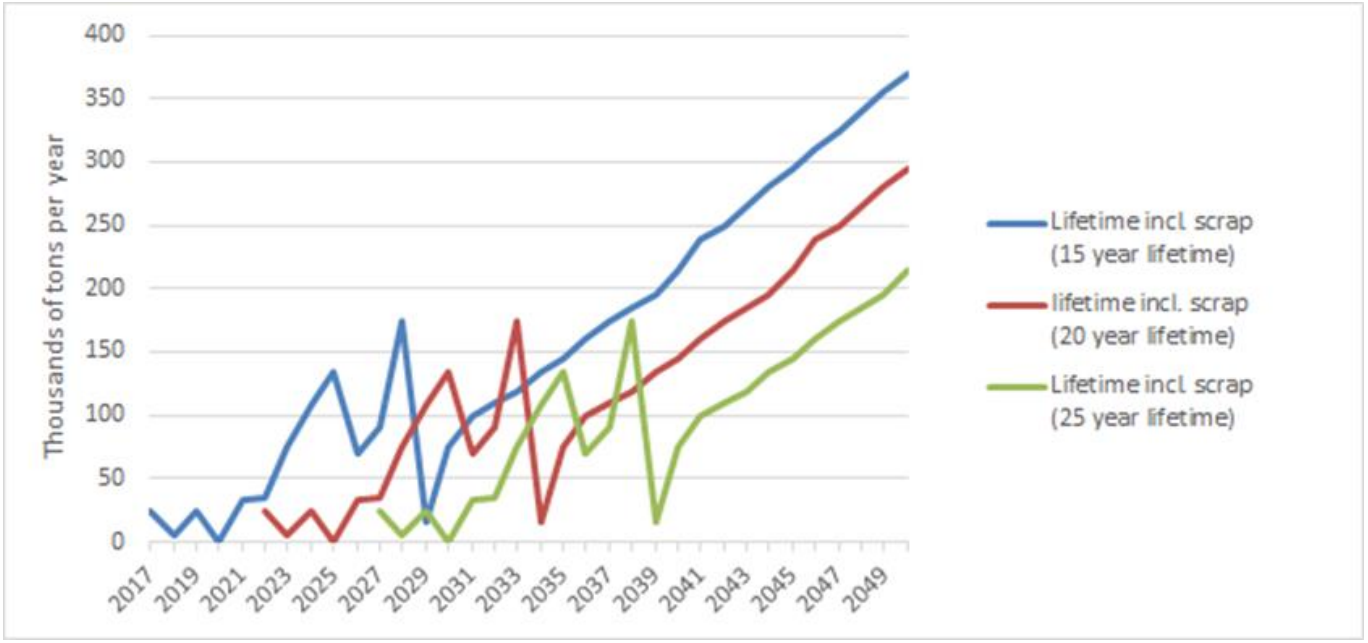
Wind Turbine Blades vs Other Composites



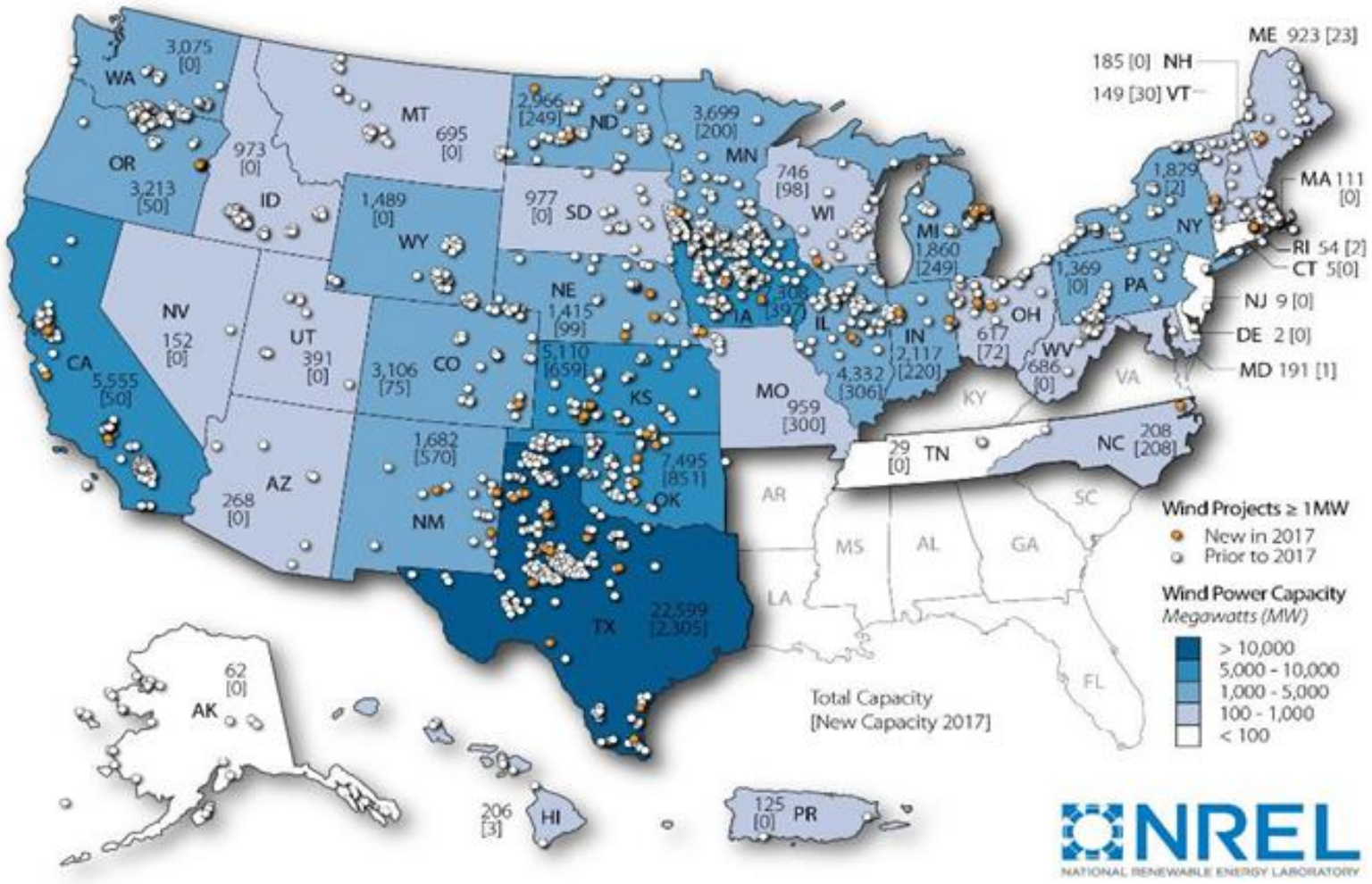
Wind Turbine Blades in US

- Wind could supply 1/3 of power by 2050, up to 400 GW
- Blade Lifetime: 15 – 25 years
- Blade EoL Volumes: 200-400 thousand tons per year by 2050
- Composites account for up to 80-90% of mass of wind turbine blades
  - Glass fiber reinforced polymer (GFRP)
  - Carbon fiber reinforced polymer (CFRP)
- Blade EoL Management: mostly landfill disposal due to low cost





Wind Farm Locations



Logistical Considerations

- Proximity to a high concentration of wind farms
- Potential to potential central processing location
  - Tribal lands
  - Decommissioned power plants
- Availability and proximity of other sources of composite for feedstock
  - Autos
  - Boats
- Proximity to a cement kilns
- Proximity to transportation networks (highways, railroads, and/or inland waterways);
- Availability of labor force, and availability of utilities such as electricity and water.

Management Technologies – Possible Hierarchy

Definitions: End-of-Life Technologies for Composite Materials

- **Lifetime Extension:** Return to same-as-new or upgraded condition and performance, for original application.
- **Pyrolysis:** A moderate-temperature process (450-700°C) to recover fiber, char, and gasses for energy.
- **Cement Kiln:** A high-temperature process (1000°C and upwards) to create cement and recover gasses for energy.
- **Re-Grind and Re-Use:** Mechanical processing into pellets, needles, etc. and combining with other materials to make new products.
- **Disposal:** Solid waste disposal (landfill)

Hierarchy of benefits: greatest (top) to least (bottom)

Management Technologies – Cement Kilns

- High Temperature Combustion
  - >1000°C
- Size reduction
- Products
  - Cement component
  - Energy offset
  - Reduced carbon emissions (16%)
- Considerations
  - Glass fiber only
  - 50-60K tons/yr/kiln needed
  - No fiber recovery
  - Halogens (PVC) questionable
- Commercial facility in Germany
- Veolia in US

Source: KERA News, Dallas

Management Technologies – Pyrolysis

- Lower temperature
  - 450 to 700°C
- Oxygen free
- Size reduction (1-2 inch size)
- Products
  - Fibers
  - Syngas
  - Char
- Carbon fibers (demonstrated)
  - Less common, higher value
- Glass fibers (in development)
  - More common, lower value
- ACMA/IACMA research on GF
  - CHZ Technologies (Thermolyzer™)

7 ton/day Pilot Thermolyzer (CHZ Technologies)

Carbon fiber blade

Glass fiber blade

Wind Turbine Blade Feedstock

Management Technologies – Regrind/Reuse & Other

Regrind/Reuse

- Size reduction
- Filler material
- Variety of products, e.g.
  - Pellets
  - Decking
  - Insulation
  - Panels
  - Road barriers
- Secondary waste stream
- Decrease in mechanical properties
- Commercial in US
- Global Fiberglass Solutions

Other (Early Development)

- Direct Use (Re-Wind)
  - Bridges, poles, etc.
- Chemical Solvolysis
- Vacuum Cracking
- Wet Chemical Breakdown
- Electrochemical
- High Voltage Fragmentation
- Fluidized Bed Pyrolysis
- Microwave Pyrolysis
- Ultra-High Temperature Gasification

Preliminary Techno-Economic Assessments

Processing Step	Solid Waste Disposal	Re-Use/ Recycle (Hoefer)	Re-Use/ Recycle (Wegman)	Cement Kiln (Wegman)	Pyrolysis/ Thermolyzer™ (Owens Corning)
Decommission/Lower Wind Turbine Blades	*	*	*	*	*
First-Pass Cutting or Shredding	$1,000-$2,000 per blade for 100 miles	$25/ton	**	**	$25-$50/ton
Transportation		**	$55/ton for 300 miles	$55/ton for 300 miles	~$40/ton for 300 miles
Grinding to 1-3 cm	N/A	$60/ton	$83-$110/ton	$90-$120/ton	Included in first-pass
Solid Waste Disposal Fee	$62/ton***	$71/ton	20%-40% waste: $$60-$250/ton (depending on country)	N/A	$61/ton
Processing to Recycle	N/A	N/A	$110-$150/ton for further grinding to fibers/powders	N/A	$230-$450/ton (variable and fixed costs)
Minimum Processing Volume	**	**	**	2500-3000 tons/day	100 tons/day
Recycled Material Value	N/A	$10/ton	$220-$275/ton	$0	$600-$5,200/ton for recovered GF and GF/CF

End of Life Management – Research Gaps

- Rigorous Techno Economic Assessment (TEA) comparing life extension, pyrolysis, cement kilns, and re-grind/re-use, in comparison with solid waste disposal.
- Front-end processing - wind turbine blade dismantling, transportation, storage and other processes
- Analysis of supply chain requirements for sustainable recycling.
- Applications for recycled glass fiber resulting from the controlled pyrolysis project.
- Other composites recycling technologies that are in development.



Take-Aways

- Emerging issue, will continue to grow in the future
- Time to get out in front of the issue
- Economically viable recycling technologies and processes do not currently exist
- Uncertainty on policy and regulations for EOL transport, recycling, and disposal
- Many stakeholders, opportunities for collaboration

PV Modules

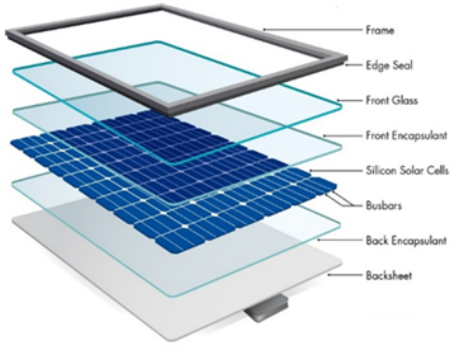
Batteries

Wind Turbine Blades

EPRI End-of-Life Management Strategic Initiative

Batteries

Solar PV Modules



Wind Turbine Blades

End-of-Life Strategic Initiative

Communications

Inform Public Policy

Technology Scouting

Stakeholder Engagement

Holistic, long-term strategy to proactively manage waste issues and mitigate risk

Together…Shaping the Future of Electricity

Composites Recycling Conference 2020 | Online

RECOVER. TRANSFORM. INNOVATE.

PRESENTED BY

ACMA

American Composites Manufacturers Association