



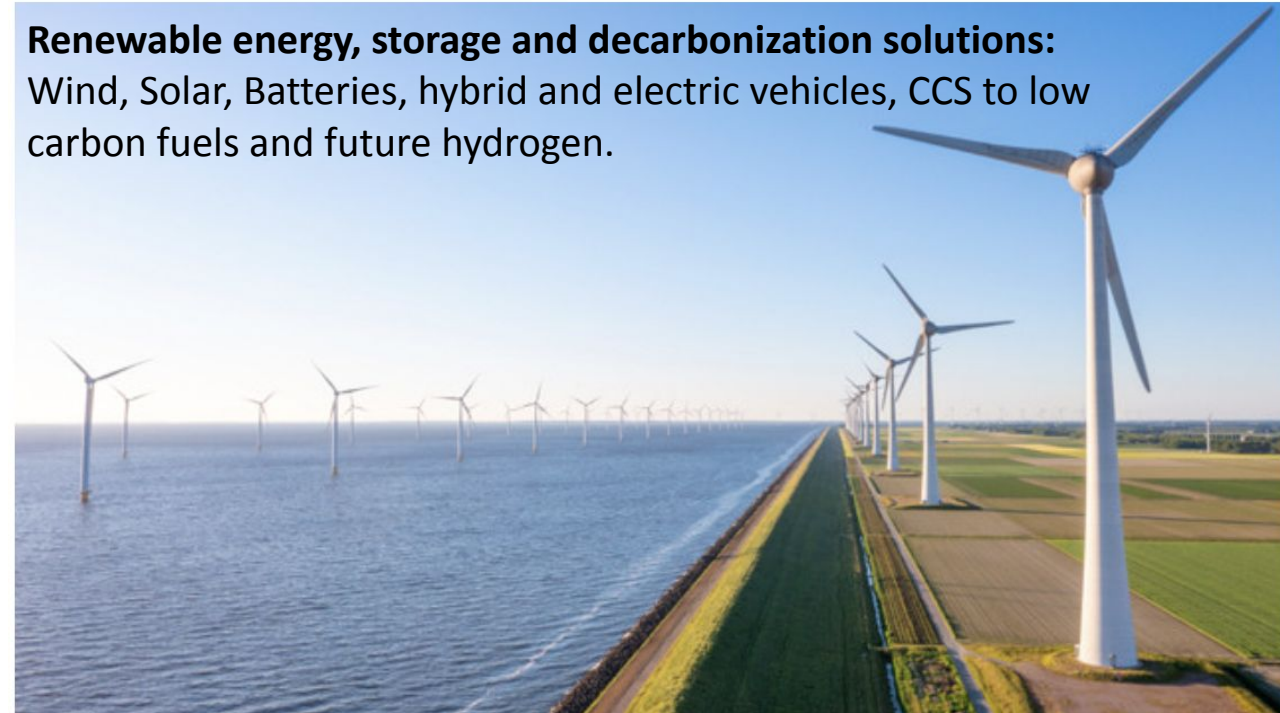
Circular Solar

Circular Solar Wind

Improving lifecycle and potentially reaching 100% wind blade, nacelle repurposing and recycling rates:

1. Reducing corrosion.
2. Circular Solar Nanorocks placed below turbines protect farmland: soil, groundwater and wildlife.
3. With solar-battery farms; generating 15% extra solar yield.
4. Innovations for sustainable concrete.
5. OCTOPUS drones.
6. REEs critical mineral streams from generators.

Circular Solar Wind: What if the problems with wind are solutions for: solar-battery projects, pollution control infrastructure, innovative circular concrete and drones (UAVs)?



Problems:

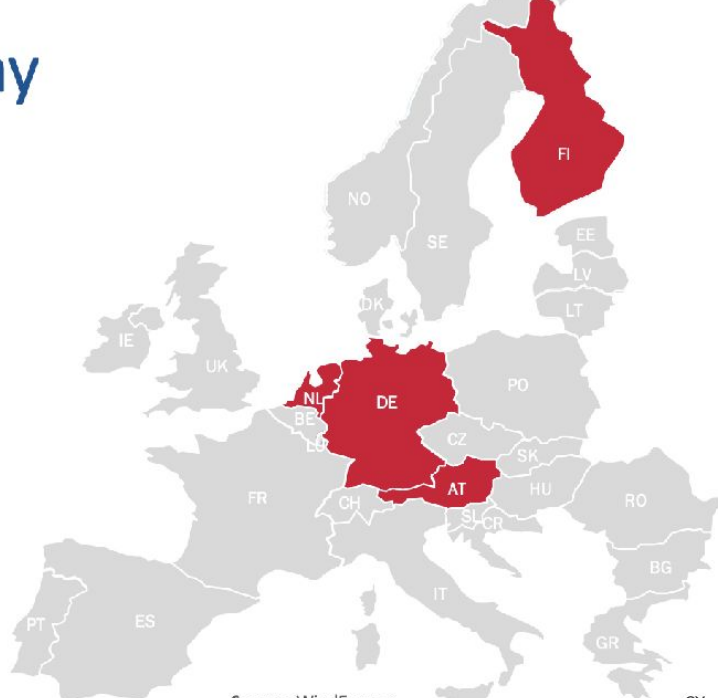
- Recycling rates of blades average at around 90%.
- Those opposing wind point to their impact on landfills.
- Failures include from corrosion, oil leaks and lightening strikes causing fires, composite plastic debris polluting land or water to foreign adversary cyber attacks causing problems (ex. Russian attack on Enercon Wind in Germany, same day invasion of Ukraine, February 2022).
- PFAS contamination is of major concern for its impact on soil, plants, wildlife, waterways, drinking water.
- Wind Europe called for a landfill by 2025.

Current Solutions:

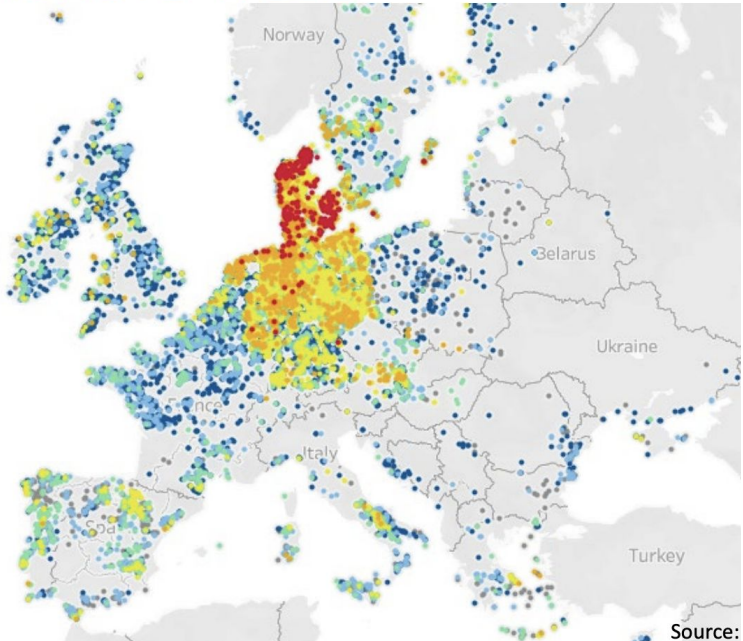
- Downcycled as a SCM for concrete, where it competes with lower cost virgin material.
- Used as WtE fuel; which emits plastic, toxic emissions and its a low BTU value at a cement kiln versus other alt fuels (Ag waste – tyres).
- Recycling, including chemicals, are available but at a high cost.
- Repurposing, into bridges to e-bike infrastructure are useful and effective.



Landfill ban today



An ageing onshore fleet



Our 600+ members make wind energy work

Wind Turbine manufacturers	
Wind farm developers	
Power utilities	
Component manufacturers	
Digital solutions & service providers	
EPC, installation and logistics	
Financial & legal services	
Research institutes	
Energy buyers	

+ NATIONAL WIND ENERGY ASSOCIATIONS

USA, California Wind Recycling Policy:



Wind turbine recycling is under further review. Where currently materials are exported out of state: such as Wyoming, Iowa, Texas. California often follows EU policy.

Building a circular economy can fill product and material gaps such as:

- High-value materials with increasing volumes (e.g., food waste, emerging energy transition technologies such as batteries, solar panels)
- Materials with limited value as a resource (e.g., single-use plastics, multi-layer packaging)
- Other materials with service gaps (e.g., non-standard organic waste, urban wood waste, appliances, tires, small electronics such as vaping devices)
- Materials with solution gaps (e.g., disaster debris, recreational vehicle and temporary encampment materials, wind turbines, medical waste, litter and illegal dumping, residuals)

Not all materials and products in California have clear recycling or composting solutions. The Zero Waste Plan offers a path for managing these hard-to-recycle materials through source reduction, while continuing to improve and develop new solutions for recycling.

Figure 2: Circular Economy

Circular Economy

To value: Take, make, return, remake



Download PDF ►

Policy and Regulation

- A. Review and refine existing policies, programs, regulations and statutes to align incentives and requirements with materials' highest and best use
1. Review and update key materials management targets, definitions and rules across state agencies and policies to align on definitions that drive materials to be used for highest and best use at each decision point.
 2. Review existing statutes, regulations, and policies across state agencies to identify and address gaps / overlaps where policies are misaligned with optimal, circular behavior (e.g., policies that prevent reuse due to building code, food safety, etc.)
- B. Adopt a California circular materials management framework to develop and implement policies that prioritize source reduction, waste prevention, and proactive circular materials management
1. Prioritize source reduction by using a circular-first lens in policy design and implementation and materials management within CalRecycle
 2. Adopt state-wide strategy and associated policies to address influx of sources of high volume and/or valuable waste, or materials of concern
 3. Incorporate circular considerations into design of policies influencing material consumption / generation

Project Circular Solar focuses on research, innovation and products for current recycled, new potential products, supporting and scalable globally for the UN Zero Waste Initiative, Renewable Energy, CDR (carbon dioxide removal) targets:

Materials:

Recycled glass, to support [SB1013](#) Bottle Bill and for SB54 this project ensures higher rates of overall glass recycling eliminating “single use” in glass packaging.

Wind turbines composite fiberglass blades, nacelles which can fall under this bill that just passed, [SB235](#) (“other similar valuable materials within products”). This bill includes requesting CalRecycle to take under consideration the opportunity CA has with EoL materials from energy which contain critical minerals, metals, such as REE (rare earth elements), and other materials, that are exported out of state for their recycling, businesses. Circular Solar takes it next level, with the ability to reuse, repurpose whole EoL wind blades, nacelles into negative emissions solar-battery power plants. Pitch deck with live tests [available here](#)

Concrete, certain construction waste: [SB596](#) which is for low carbon cement, this may include circular concrete materials.

Certain single-use plastic packaging: [Sb54](#)

Nanotechnology for environmental remediation, carbon removal: which supports and should qualify for [SB285](#)

Circular Solar’s first concrete, glass example in a road installed in Fairfield in 2008 which was an early real-life example supporting: SB1013, SB596, SB285:
<https://youtu.be/I7ydpFWBpGo>

To increase consumer participation of recycling, innovation is required where consumers feel moved to make additional effort. By seeing recycled glass materials cooling surfaces reflecting sunlight, heat back up into the atmosphere or into solar panels, simulating high albedo value fresh snow, this both cools the ground and surface (such as rooftops which means energy efficiency in the home; less A/C use) and produces higher solar efficiency. By adding these cooling, recycled products around roads, highways, ports or waterways (solar canals for example) along with carbon management nanotechnology, to break down exhaust emissions to toxic tire dust (6PPD-Q fatal to Coho Salmon, Trout), knowing it offers various climate, environmental, energy benefits; consumers will try harder to recycle. Additionally, Circular Solar is patent-pending for this technology added to Wind turbines in use, as carbon removal wind energy and negative carbon solar farms.

Cyber threats impact Wind adding to additional EoL materials:

Nov 7, 2022

Meg Egan
Control Systems Cybersecurity Analyst
Megan.egan@inl.gov

Cyber Threats to Renewable and Distributed Energy Technologies

INL is managed by Battelle Energy Alliance
for the US Department of Energy

INL Idaho National Laboratory

INL/CON-22-69152

Renewable Energy Cyber Incidents

- 2014: **SolarWorld AG**: Chinese cyber espionage for economic advantage
- March 5, 2019: **sPower**: Denial-of-service attack
- Feb. – April 2020: **Azerbaijani wind turbines**: PoetRAT malware
- April 18, 2020: **EDP Renewables**: Ransomware
- June 2021: **Invenergy**: REvil ransomware
- August 2021: **ERG**: LockBit 2.0 ransomware
- Sep. 2021: **Swedish renewable manager**: LockBit 2.0 ransomware
- Nov 19, 2021: **Vestas**: LockBit 2.0 ransomware
- Feb. 24, 2022: **Enercon**: Russian state-sponsored SATCOM attack
- March 31, 2022: **Nordex Group**: Conti ransomware
- April 11, 2022: **Deutsche Windtechnik**: Ransomware
- April – June 2022: **South China Sea wind turbines**: Chinese ScanBox malware
- August 28, 2022: **GSA**: BlackCat ransomware

IDAHO NATIONAL LABORATORY

February 24, 2022, around 30,000 satellite communication (SATCOM) terminals were hit by a Russian cyber-attack, causing them to stop working. This included SATCOM modems in 5800 wind turbines across 1217 wind farms operated by ENERCON.

This DOE report is cited at the bottom of site page :“albedo effect, environment ”

Current Adversary Capabilities

- **Russia:**
 - “Particularly focused on improving its ability to target critical infrastructure including ICS”
 - Utilizing cyber as a foreign policy lever, including as deterrence and as a military tactic
- **China:**
 - “Almost certainly capable of launching cyber attacks to disrupt critical infrastructure services”
 - Broad, persistent espionage threat



IDAHO NATIONAL LABORATORY

Current Adversary Capabilities

- **Iran:**
 - “Opportunistic approach to cyber attacks makes critical infrastructure owners susceptible to being targeted”
 - Successful targeting in Israel reflects growing willingness to take risks
- **Criminal Actors:**
 - “Innovating targeting to focus on victims whose business operations lack resilience or whose customers cannot sustain service disruptions, driving ransomware payouts up”

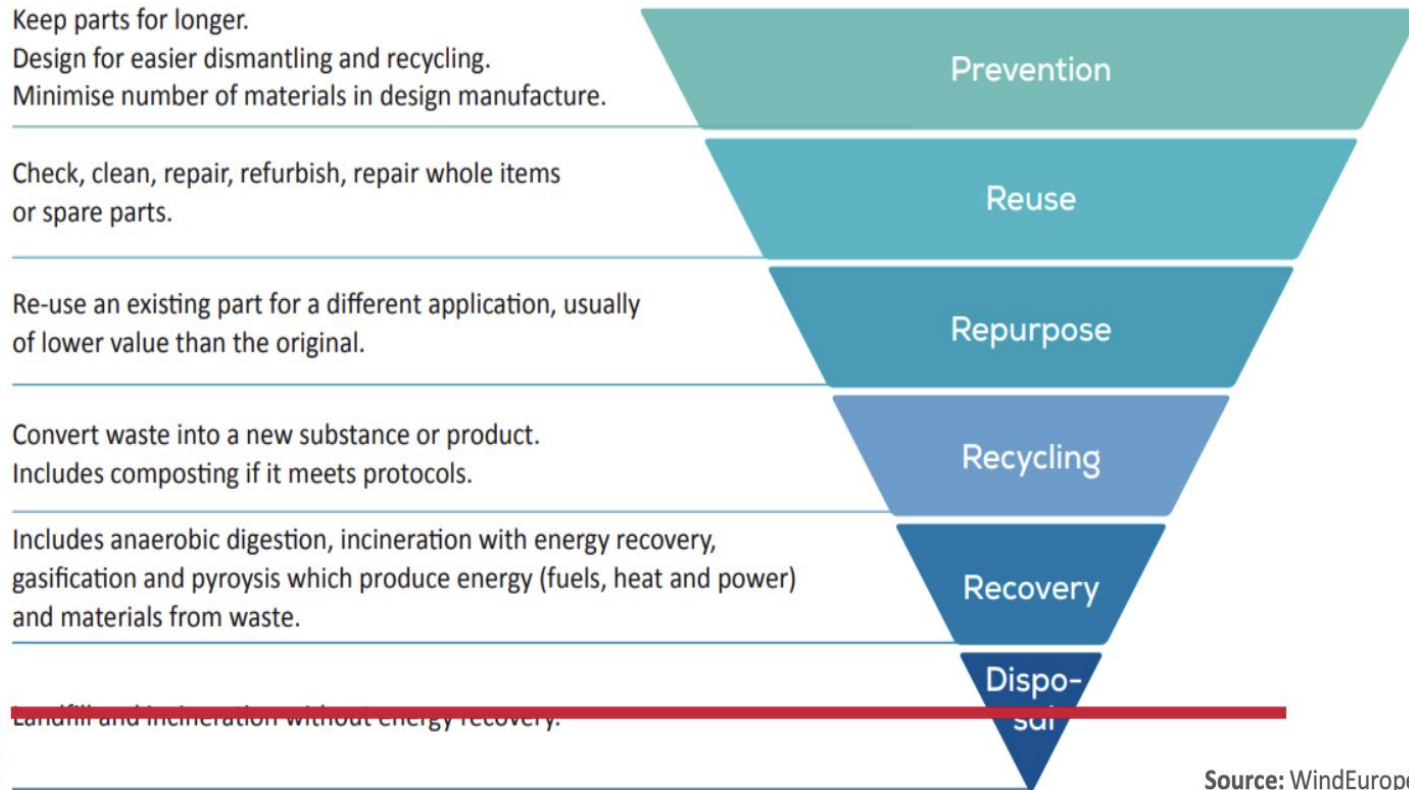


IDAHO NATIONAL LABORATORY

[Link to Cherise’s letter to the U.S. Department of Commerce for sec. 232 Wind investigation](#), where only two letters addressed cybersecurity (GE is the other). Included are recommendations from this presentation, including drones for care and maintenance, potential defense drones to protect assets

Will the Wind industry achieve 90% or 100% recycling rate?

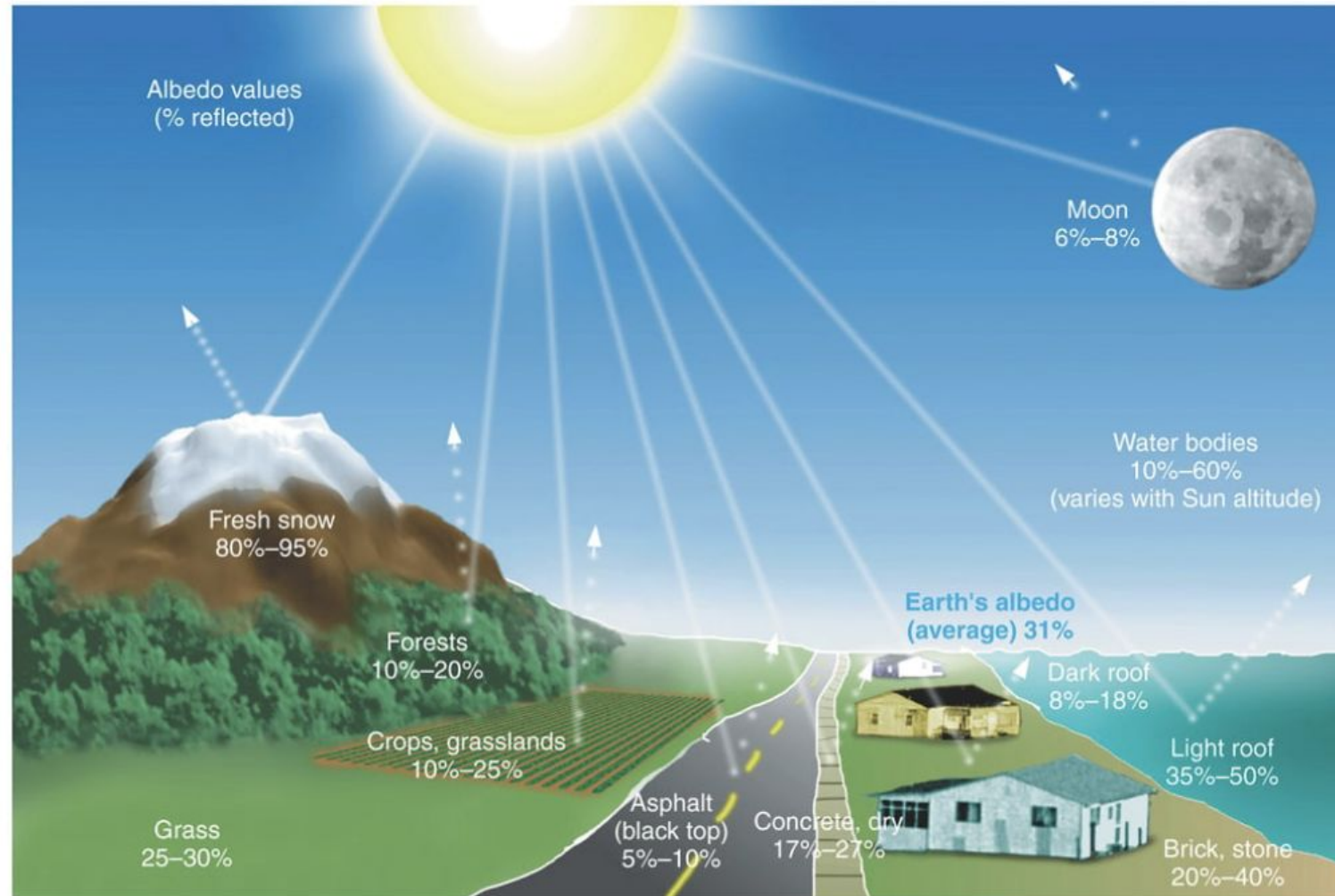
How to treat end-of-life turbines ?



Circular Solar closes the loop on Wind – to 100%!

1. Reducing corrosion.
2. Circular Solar Nanorocks placed below turbines protect farmland: soil, groundwater and wildlife.
3. Solar-battery farms, safe cattle shade - Agrivoltaic.
4. Innovations for recycled concrete.
5. OCTOPUS drones
6. REEs critical mineral streams from generators.

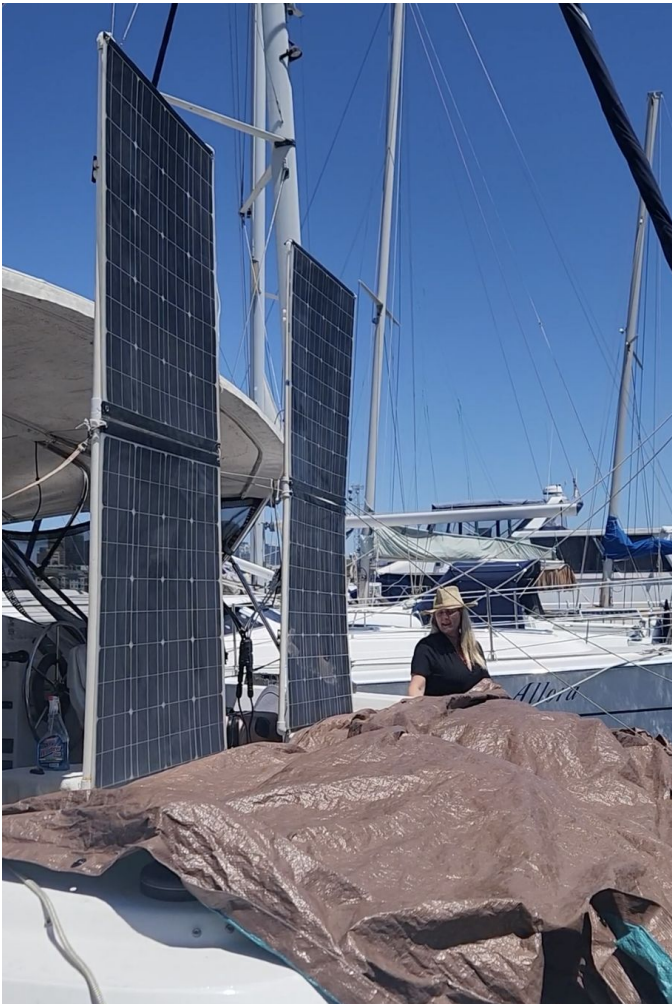
Science and physics behind Circular Solar from albedo values and albedo effect: Wind composites can become reflective, high albedo value fresh snow and repurposed below solar panels or downcycled into concrete. Where 3-dimensional solar power generation – unlocks the full potential of bifacial solar panels with albedo effect products by Circular Solar.



Copyright © 2006 Pearson Prentice Hall, Inc.

Albedo, the percentage of available sunlight reflected back into space, varies from surface to surface. Photo: Pearson Prentice Hall Inc.

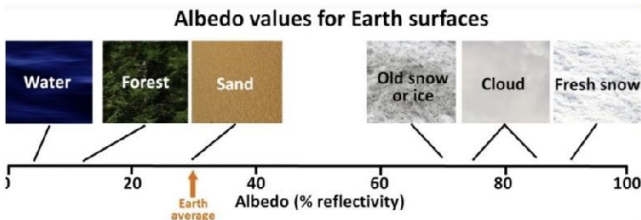
Near Summer Solstice, sun is directly over-top, panels facing North and South, albedo effect changes:



Brown 43 watts



White composite, glass
53 watts, 24% increase
Live video





Solar Tests, September 26th 2022 nearly 5pm, sun off to the side, backside tests

Asphalt output
is 40 Watts:



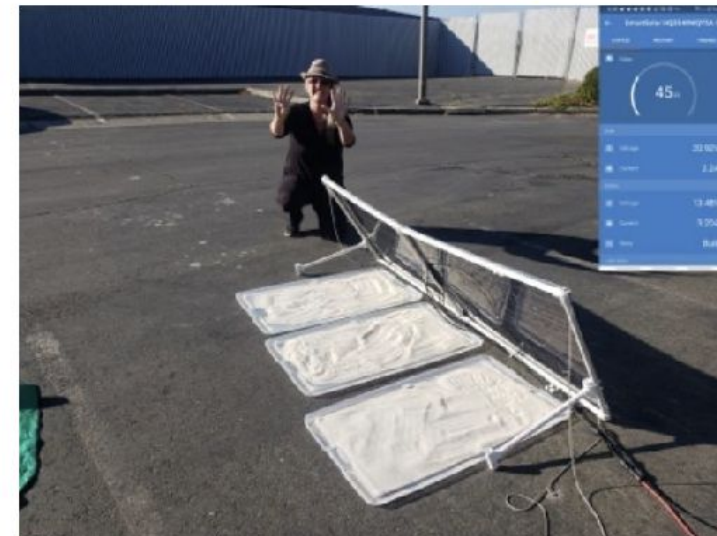
Recycled Glass
Mulch 45W



White Quartz
Sand 45W



Brown Tarp
41W, Green
42W



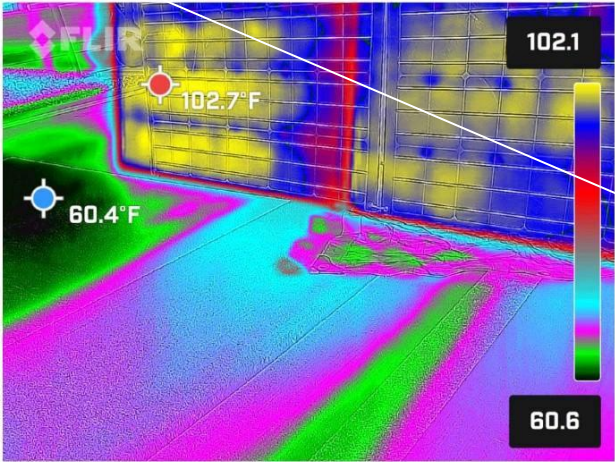
[Short video of materials/test setup](#)

[Then video tested/metered on floating minigrid](#)

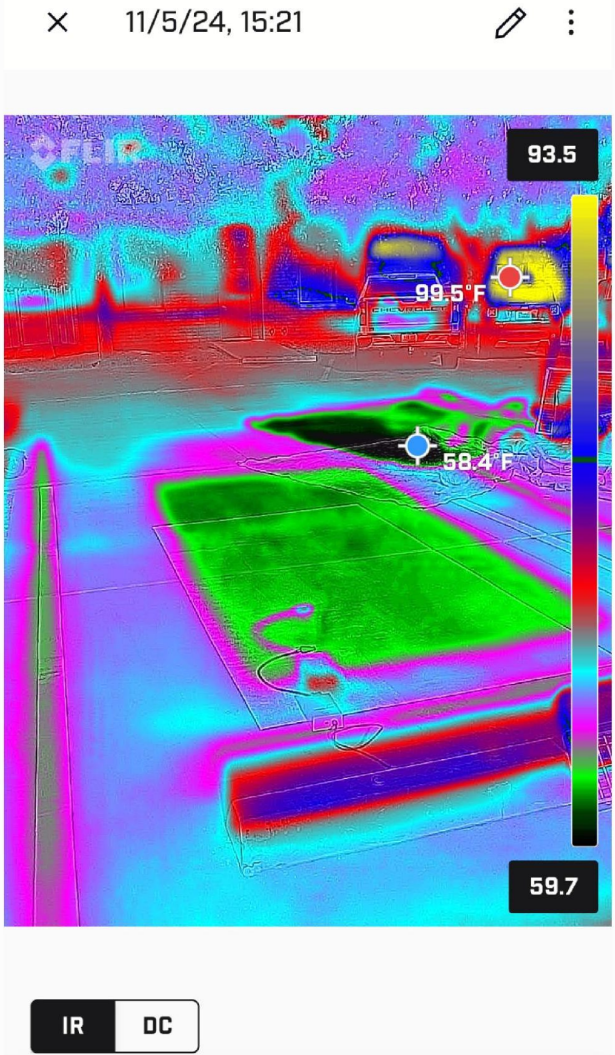
CDR cooling sustainable concrete: for solar or autonomous EV wireless vehicle BESS to AI data-centers:

Hot concrete in Arizona (location below) will stay cooler when EVs, park or charge over the space. Both wired but especially future wireless induction charging remains cooler, thus improving charging efficiency and component, battery lifecycle, due to less heat losses as the product is reflective and has a cooler UHI (urban heat island effect).

Circular Solar is also a data-center rooftop, reflective, circular, CO2 removal product, as seen here over concrete, it is almost as cool as the plastic tarp



Wireless induction pad over concrete



AI Data-centers: Circular Solar is an an Epri-Open Ai Consortium Member: as a potential “use-case” pilot with utilities and hyperscalers with four use-cases: 1. as a CDR project. 2. as a PPA with the highest possible daily solar yields. 3. Our product for data-center infrastructure, especially cooler rooftops by reducing airborne dust buildup, retaining high albedo effect to reduce interior water use for cooling as seen in previous slide. 4. Which can breakdown PFAS in the event of leak within the data-center or as pollution outside the building; see side five for pollution breakdown which includes PFAS water and airborne pollution from Radius Recycling (automobile shredder residue ASR PFAS).

1. Coolest, CDR carbon removal rooftop (less water required for interior cooling).
2. Cooler EV charging spaces for employees or autonomous fleets (slide 12) which doubles as higher efficiency, faster charging vehicle to data-center).
3. Circular Solar Wind: EoL wind blades repurposed below solar panels, with CDR (slides 7-10). Texas and California have wind blades being decommissioned now ideal this project.



The Lancium Clean Tech data center campus is being constructed by contractor DPR Construction in Abilene, Texas, with Crusoe Energy as its developer.

Circular Solar CDR Wind: blades and nacelle's repurposed solar-battery microgrids:

Left: Dual axis circular CSP (concentrated solar power) where fresh snow albedo may offer <50% higher daily solar yields vs fixed horizontal. Solar efficiency records are expected (which may already have been achieved in 2023 for a fixed mount panel; see slide 6).

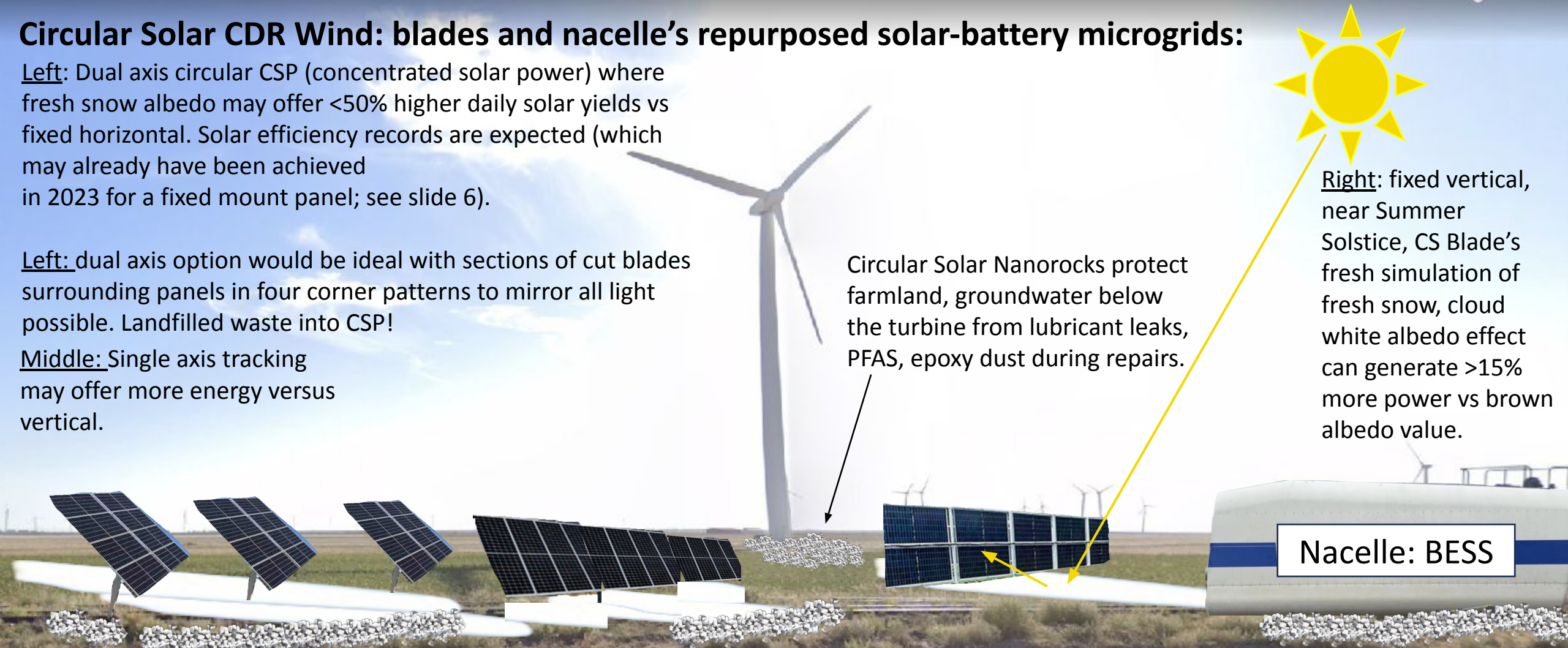
Left: dual axis option would be ideal with sections of cut blades surrounding panels in four corner patterns to mirror all light possible. Landfilled waste into CSP!

Middle: Single axis tracking may offer more energy versus vertical.

Circular Solar Nanorocks protect farmland, groundwater below the turbine from lubricant leaks, PFAS, epoxy dust during repairs.



Right: fixed vertical, near Summer Solstice, CS Blade's fresh simulation of fresh snow, cloud white albedo effect can generate >15% more power vs brown albedo value.



Dual-axis

Tracking

Fixed vertical

Battery Storage

Nacelle: BESS

Microgrids Powering: AI Data-Centers, Agriculture Equipment, Barns, Highway Charging Stations, Rail Depots, Mine Sites and more.

Business case for a .25 MW Circular Solar Hybrid Wind Farm produces 15% additional solar yields:



1. JV on the new PPA project, Wind operator and CS takes a portion of the revenue on the new PPA.
 2. 70% of wind decommissioning costs are used onsite (5% to land-owner, 25% Circular Solar IP fee).
 3. On average these are smaller .25 MW solar farm: \$50–\$60/MWh (2025 US average with credits).
 4. 15% higher yield: (levelized cost) LCOE drops ~13% (to \$43–\$52/MWh).
 5. For a 1 MW farm over 25 years (total ~50,000 MWh base): Annual savings ~\$14,000–\$16,000
- In effective cost per MWh. A .25 MW: \$3,500 - \$4,000/annual savings OR approx. 13 – 15% less solar panels are required for the farm, OR additional power feeds EV charging station. This is the highest value/ lowest cost Wind blade, nacelle repurposing project. Circular Solar could retain 30% of EoL recycling market, which is projected to have \$1B market value by 2030, Circular Solar could capture \$300M. Watch the measured micro test generate 18% higher yield, plus pollution control.

Circular Solar is seeking \$2.5M seed, \$1M FOAK funding (which includes a .25MW - .5MW pv-bess CS farm).

New Gaza or Ukraine: reconstruction of highway, Circular Solar Farm and ERW(enhanced rock weathering) soil restoration:

1. Recycled rubble generating additional solar energy, EoL Wind materials for BESS storage meeting 2026 EU Circular Economy Act.
2. All with Pollution Management for cleaner groundwater runoff,
3. Enhanced Rock Weathering (ERW) for soil restoration and durable CDR project.

Recycled rubble, treated to remove highway pollution from vehicles, tire wear from roads buildup for cleaner stormwater runoff.

ERW for soil health, 1,000 year durability

For Ukraine, reusing EoL Wind nacelle's shipped from Germany for BESS and Inverter storage increasing efficiency.

Additionally, sections of EoL wind blades for Circular Solar Wind Farms can be shipped on rail with nacelle BESS and secured over the gravel for >.85% albedo value.

Nanorocks .65 albedo boost solar efficiency, cooler solar panels and provide fire mitigation,

UAV/Drone charging, launch section for Agriculture work or provide video footage to first responders in vehicle accidents.

Circular Solar pollution management to reduce corrosion, failure and CDR nanorocks; Lifecycle extension:

Airborne vehicle exhaust, brake, tire dust, freight truck ,rail emissions build-up in the sky onto Wind energy and their EoL materials placed below, generating higher solar yields, efficiency



Demo video of exhaust emissions onto the materials, improving solar efficiency.

CS OAE growth from wind turbine runoff, and shoreline



< **Shipping CDR**, here is Port of Rotterdam, NL. Circular Solar would love to pilot here because we've already proven the technologies working, removing any wind pollution buildup and emissions buildup by as demonstrated by Port of Oakland. Improving plant, soil health (2008 example in a road) and now ocean alkalinity restoration; 12-month example of algae bloom and restoration and here and visual of ship emissions

Rotterdam is a bunker hub for fossil fuels – high emitter.
4/2025: IMO agrees to a global carbon pricing: \$100 or \$380.

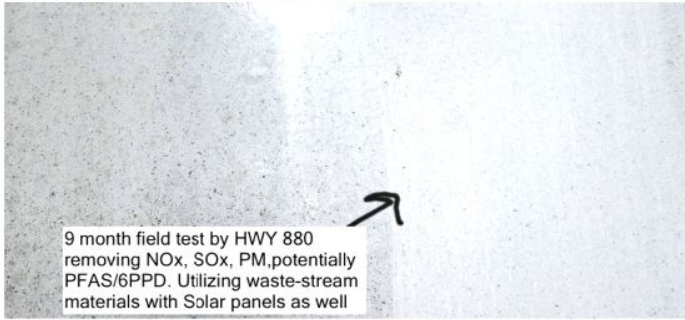
Circular Solar's CDR, pollution management product, method for Regenerative Agriculture, protecting soil health:



9 – 21 months pollution buildup and runoff



Circular Solar Nanorocks: Pollution control to improve soil health and water quality



Polluted runoff: Algae bloom marine growth, toxic seaweed.

Cleaner stormwater runoff: Less pollution, toxins and calcium nitrate byproduct grows healthy carbon capture seaweed.



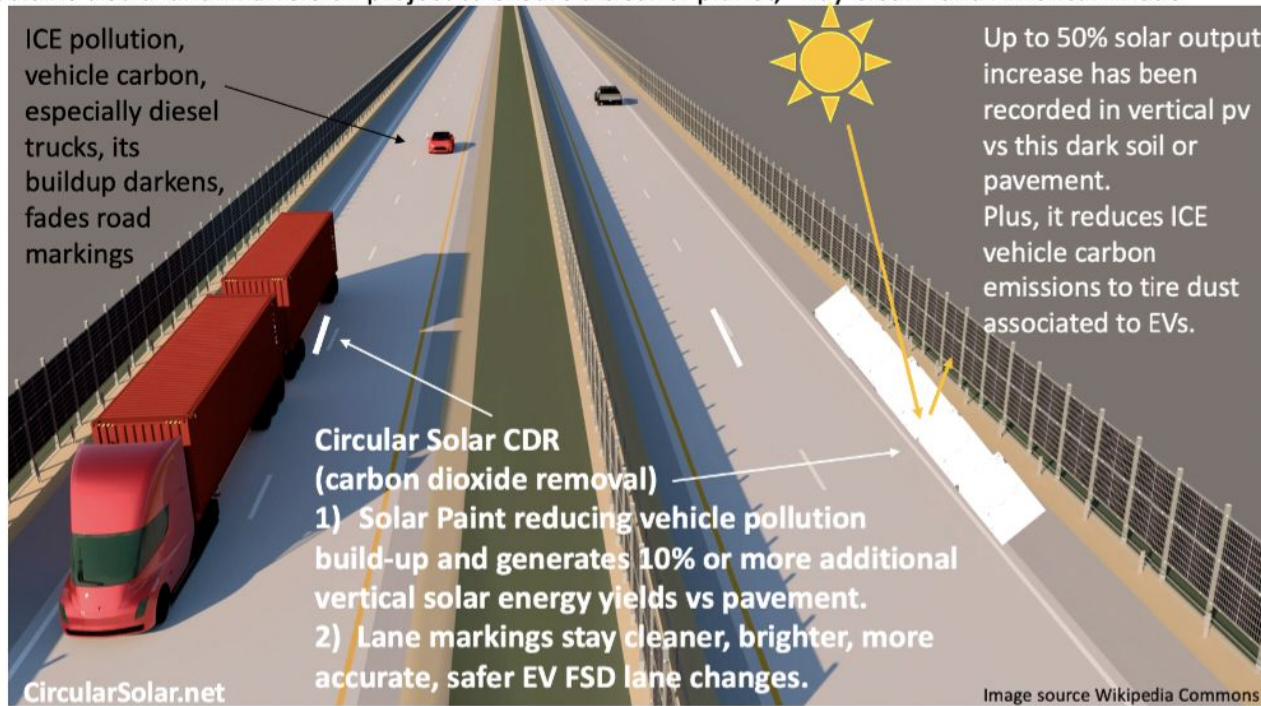
Two months pollution wiped off, note the water is now brown. Pollution sources: Port, 880 freeway, Recycler automobile metal shredder residue. Environmental protection to support Mining & AI's SPEED Act (NEPA permit reform).



Updated field test R&D for Circular Solar CDR Highway applications:

For road safety, brighter, cleaner more reflective road markings for road safety, especially at night, including for improving autonomous vehicle, FSD, accuracy thus safety. For CS Highway PV, cooler AI DC wireless EV charging

Circular Solar CDR Highways: Increasing canopy or vertical solar efficiency and vehicle safety with brighter, cleaner road markings. This helps keep EVs, such as Tesla FSD safer when using "Auto Lane Change" because the reflective markings stay cleaner, brighter in low light, dirty when high carbon pollution events, or something covering the pavement. Circular Solar's vertical efficiency record is 50% higher output vs dark albedo when the sun is directly over top vertical pv. Circular Solar is also a landfill diversion project to ensure a cleaner planet, "Buy Clean" and American Made



With the real-life multi-month pollution control results in mind, Scale to road markings and highway PV verify it works and provides environmental protection. These roads can include recycled Wind composites as an SCM.



Road marking field test (on OCTOPUS, by a road, not on it). We see the normal pollution buildup is darker, making lines less reflective during the day but especially at night. Circular Solar treated road markings will improve safety for all vehicles and drivers, However, this can improve autonomous vehicle accuracy. Also note the road is cooler with Circular Solar, by about 5F+.

Heat stress on cattle is a growing problem:

In Kansas during the 2022 heatwaves, there were 2,000 cattle deaths.

In Europe, due to heat stress, dairy cows milk yield may decrease by about 2.8% and farmers may expect financial losses in the Summer season of about 5.4% of their monthly income.

Circular Solar Wind Canals or Cattle Shade can mitigate this problem. And in-use Wind could add the carbon, dust, toxin, heavy metal removal coating for healthier water runoff sequestered in the soil, farm, creek below.



Kansas officials say weather conditions made it hard for cows to cool down in an intense heat wave. Here, cattle graze near wind turbines in Hays, Kansas, in 2017.

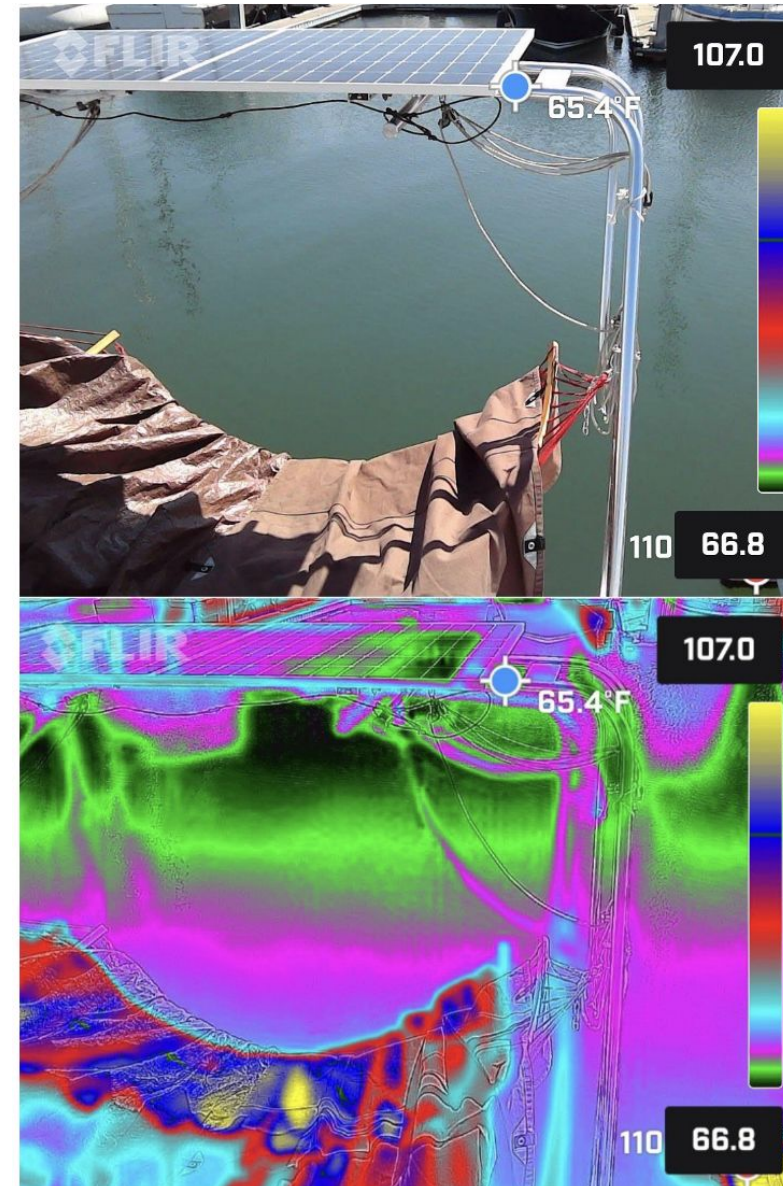
Daniel Acker/Bloomberg via Getty Images

Circular Solar Wind Agrivoltaic: the shade will reduce cowhide temperatures by up to 30F. This may be the only safe Agrivoltaic for cattle, with no concern of cattle leaning against, breaking solar panels.

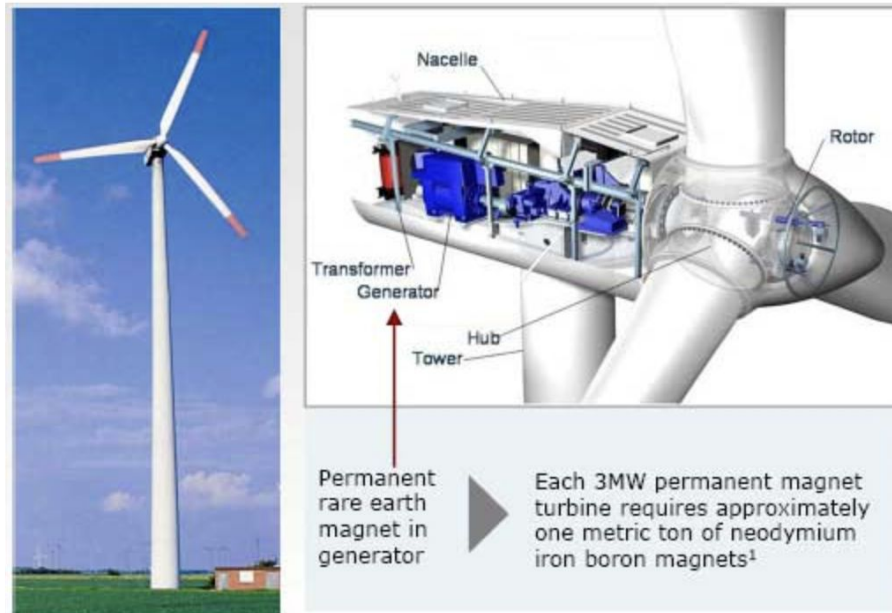
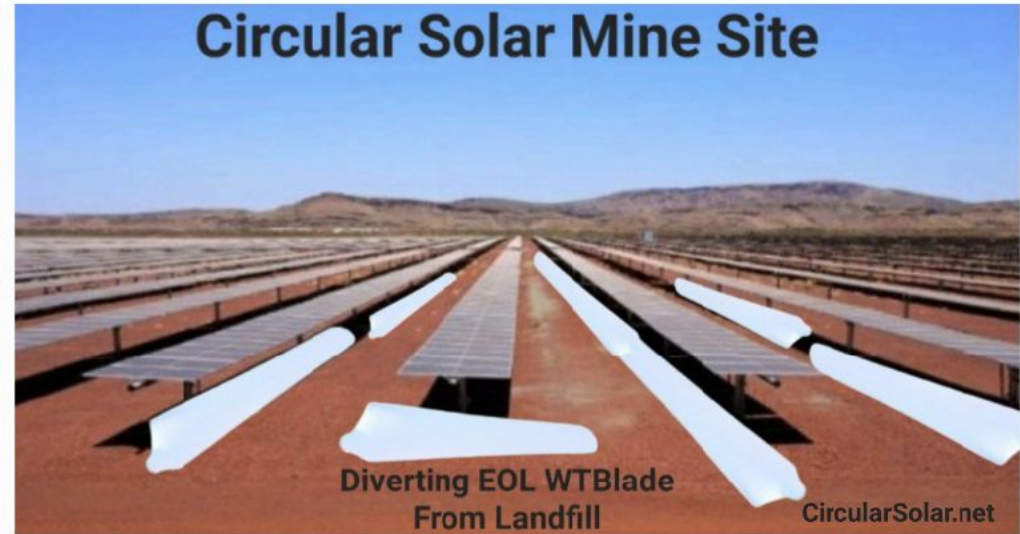


Our prototype and thermal up to 30F cooler surfaces temperatures from wind, solar canal shade:

The shade cools off cattle, farm equipment, drones and water (providing colder water and less water evaporation), healthier marine ecosystem. CDR ERW (enhanced rock weathering) with limestone, recycled concrete can be added.

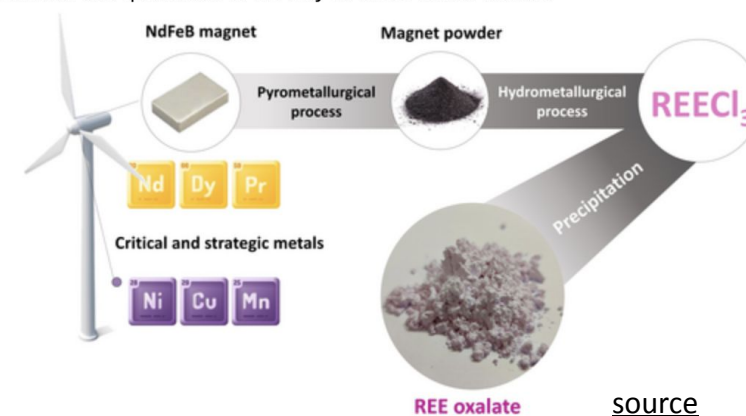


Mine sites, landfill diversion can accept hazardous EoL composite waste and recycling, process e-waste streams; such as REE magnets from nacelle generators (and first pitched to a mine site in 2010), manufacture drones onsite; with using DPA (defense production act funding).

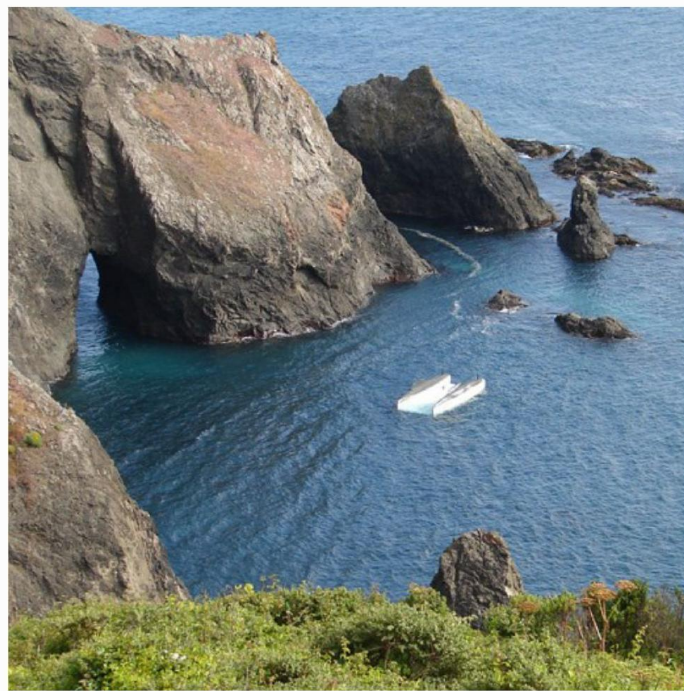


Graphical Abstract

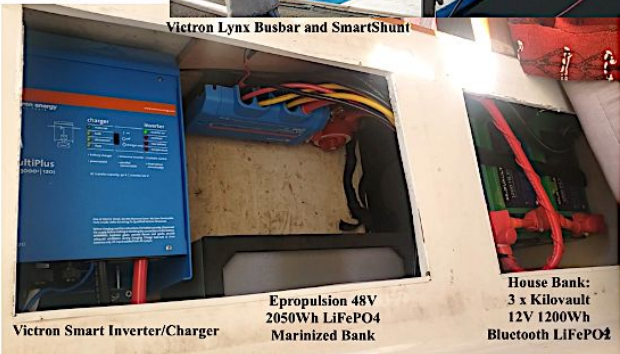
This work outlines a process for the recovery of rare earth elements from permanent magnets from wind turbines. Pyrometallurgical and hydrometallurgical methods are employed to produce a concentrated rare earth solution. Finally, these elements are selectively precipitated yielding a mixed rare earth oxalate. This process demonstrates the efficient and quantitative recovery of these critical metals.



2010 offshore composite vessel simulating offshore wind failure – into floating remote minigrid testbed OCTOPUS



OCTOPUS Testbed: 1 kW of solar: 3.6kW BESS, 3.3kW BESS
for motor, components, Starlink stored in nacelle or blades.
Scale-up to 80' length floating solar-blade powerplants:
20kW solar – 60kW BESS charging station for E-vessels



Large
decommissioned
wind blades.

Floating
solar-battery
charging stations



Smart city example by Siemens and arrows are locations well suited to Circular Solar CDR project, products:



Circular Solar is an Epri OPAI Consortium Member: as a potential technology provider to big tech and utilities, globally.

Update: Epri is considering Circular Solar as a use-case to test/pilot with the Micro Data Center 5 pilots with NVIDIA, Prologis, InfraPartners and select utilities (please see the comment section).

OPAI Participants

AI and Energy Technology Partners



AIDASH, Articul3, ATOMIC CANYON, AWS, Baringa, BURNS & MCDONNELL, CEN, Cisco, DATA GLANCE, Databricks, Distill Energy, DNV, Efficiency Signal, Energy Exemplar, GE Vernova, GE, HITACHI, itg, LopezAI, Microsoft, NETSIA, nexbe, NOKIA, ORACLE, pebble, Palantir, POWER ENGINEERS, QUALUS, Photometrics.ai, Sandia National Laboratories, PRATEXO, SAP, Schneider Electric, SHI, Silurian AI, simple, thread, SMR, TACIT, TRC, Utilidata, UTILITYAPI, Xtensible, Westinghouse, World Wide Technology, Inc.

Academia & Other Strategic Partners

BETTERGRIDS.ORG, Centre for Net Zero, DCCM, GALVANIZE, IIS, Innovate UK, KAUST, KHALIFA UNIVERSITY, NRECA, pwc, RSM, scottmadden, smart KPX, Structural Associates, Inc., VIRGINIA TECH

Energy Partners

ACWA POWER, aeci, Ameren, AMERICAN ELECTRIC POWER, aps, Alliant Energy, Arkansas Electric Cooperative Corporation, ATC, Avangrid, CENTRAL ELECTRIC POWER COOPERATIVE, INC., CHUBU Electric Power, conEdison, Constellation, CPS, DAIRYLAND POWER COOPERATIVE, EAST KENTUCKY POWER COOPERATIVE, East River Electric, EDF, EDISON, ENEL, ENOWA, NEOM, entergy, ENEC, ENERGY NORTHWEST, ESB, evergy, EWEC, EXELON, FORTIS, GEORGIA TRANSMISSION, GREAT RIVER ENERGY, HOOSIER ENERGY, ICHNP, ICRA, LES, LINCOLN ELECTRIC SYSTEM, LIPA, MISO, nationalgrid, NC Electric Cooperatives, Nebraska Public Power District, NEW YORK STATE, NY Power Authority, Oglethorpe Power, OHIO'S ELECTRIC COOPERATIVES, OPPD, PGE, PJM, POWER SOUTH ENERGY COOPERATIVE, PPL, PSEG, PSC&E, Rte, Rappahannock Electric Cooperative, Santee Cooper, Scottish & Southern Electricity Networks, Saudi Electricity Company, SMUD, TAIWAN POWER COMPANY, T&A, TEPCO, Transener, Transba, TVA, UK Power Networks, WEC Energy Group

© 2025 Electric Power Research Institute, Inc. All rights reserved.

- Team Circular Solar LLC, at CircularSolar.net is a small team under 5 people.

- Recycling solution to improve Wind, concrete/construction waste recycling rates by at least 5% to 95%, goal 100%.

- Next steps, pilots in Europe, USA, Middle East.



Cherise Petker, Founder, Circular Solar LLC
CircularSolar.net CircularSolar@outlook.com

