



More Power from Less Materials: Towards a Circular Economy in the Wind Industry for the UK

The Government must integrate a circular economy into wind energy to ensure timely access to all materials and components to build wind farms and achieve the UK's ambitions to double onshore and triple offshore wind by 2030, that are essential to stay on course for our national climate targets. This briefing calls to make circular economy a key pillar of the UK Government's clean energy superpower mission, to generate more power from less materials with durability and recycled content targets that drive circular supply chains.

Circularity in wind will enable innovative companies wanting to grow, which will increase supply chain resilience, domestic manufacturing and jobs while reducing resource security risks, costs and environmental impacts. This briefing introduces circular wind strategies, a roadmap for policy and regulatory change, a call to commit to circular economy as part of the clean energy superpower mission and outlines regulatory guidance.

A Circular Economy for Wind

What is a circular economy for wind energy?

The wind industry can benefit from circular economy strategies that apply along the wind turbine and wind farm lifecycle – from design to end-of-use – and to materials, component, turbines and whole portfolios of wind infrastructure. This section offers a brief overview of the strategies^[7].



Foreword

The UK has committed to double onshore wind and triple offshore wind installed capacity by 2030. More wind energy will reduce fossil fuel dependence, continue to reduce power prices and costs of living, and benefit our health and environment.^[1,2]

But building wind farms will require millions of tonnes of materials such as steel, concrete, copper, rare earths and composites^[3,4]. With demand stretching well beyond domestic material processing and wind turbine manufacturing capacity, the UK heavily relies on imports to fulfil wind growth ambitions. This makes us vulnerable, especially under geopolitical destabilisation. Moreover, with climate action heavily relying on the expansion of wind^[5], our carbon reduction targets are at risk.

At the same time, the first generation of wind turbines is reaching the end of use, with more than half of onshore wind capacity set to be repowered or decommissioned by 2035^[6]. This opens new valuable business opportunities such as reuse and refurbishment of wind turbines and parts.

A circular economy is essential both for building new wind turbines and to benefit from end-of-use business opportunities. Effective resource management through resilient supply chains depends on circular economy practices throughout the lifecycles of wind turbines^[7].

The UK is rich in innovative companies wanting to offer more circular economy solutions to the wind industry. Supporting these companies to grow gives the UK another chance to create a domestic wind manufacturing base^[8]. This will create skilled jobs up and down the country. For example, wind remanufacturing alone could create 5,000 jobs^[9]. Using wind turbines for longer will reduce capital costs, carbon emissions and waste^[5,9-11].

Research by the RESCUE project showed that companies and government bodies alike are finding it difficult to navigate the complex policy and regulatory landscape. While it is important that a critical sector such as energy is regulated well, more guidance is necessary.

Building on broad consensus among the RESCUE project stakeholders, this briefing presents a roadmap to embed a circular economy for onshore wind through policy and regulatory change, a vision to generate more power from less materials, and a guideline to support navigation of the regulatory landscape by industry and government bodies.

Design for Circularity

Materials

CIRCULAR DESIGN

Support sustainability with strategies that reduce material use, extend lifetimes of turbines and components, and recycle or reintegrate materials at end-of-use, including modular design (e.g. use common components across turbine models to ease reuse/repair; avoid irreversible joints between parts) and dematerialisation^[12] (minimising resource use e.g. shape optimisation, durability).

SUSTAINABLE MATERIAL SOURCING

Environmentally and socially responsible supplies that minimise impact of materials and products on environment and people. One under-explored supply route is urban mining, to extract materials for renewables from industrial and mining landfills^[13].

Ionic Technologies in Northern Ireland is scaling up solutions to recover critical materials from turbine magnets^[14].

LEAN MANUFACTURING

Minimising resource use and waste, well-aligned to waste prevention topping the waste hierarchy; reducing or avoiding waste by, for example, designing wastes out of manufacturing processes.

RECYCLE

In the UK specified as “Turning waste into a new substance or product”^[18], which includes material recovery and processing into new products. It does not include energy recovery or preparing materials for fuels/backfilling.



EMR has opened a dedicated wind turbine processing centre in Scotland, offering an integrated, full-turbine, end-of-use solution to wind operators for reusing, repurposing and recycling metal and composite wind turbine parts and ancillary equipment and infrastructure^[19].

TRANSPARENCY THROUGH DATA SHARING

Enable circular solutions with insights in volumes, technical characteristics and environmental, social and economic values. Supported by traceability systems for data collection (building on e.g. SCADA and CMS systems) and sharing. Lifecycle and sustainability assessments are commonly used to convert data into decisions, e.g. by governments (policy effectiveness), and investors and companies (commercial viability).

Components

MAINTENANCE AND REPAIR

Repair and maintenance increase the lifetime of wind turbines and their components. Maintenance and repairs can be preventative, planned or ad hoc in response to faults. Maintenance includes inspecting and servicing turbines at regular intervals to retain a product's functional capabilities. Repair can be part of maintenance and involves the restoring of products to a good condition.

REUSE, REFURBISH AND REMANUFACTURE

Many turbines and components are reused in entirety or for parts^[15] for the same function. Refurbishment and remanufacturing are closely aligned. The former keeps structures of turbines / major components intact, while parts may be replaced or repaired (incl. upgrades). The latter follows standardised industrial processes (sort, select, disassemble, inspect, repair/replace, reassemble), fully documented and certified by remanufacturers.

Business in Wind sources used turbines that are technically suitable for continued operation, undertaking detailed inspection and refurbishment of components (e.g. hubs, generators, gearboxes) in their workshop, before redeploying them across Europe^[16].

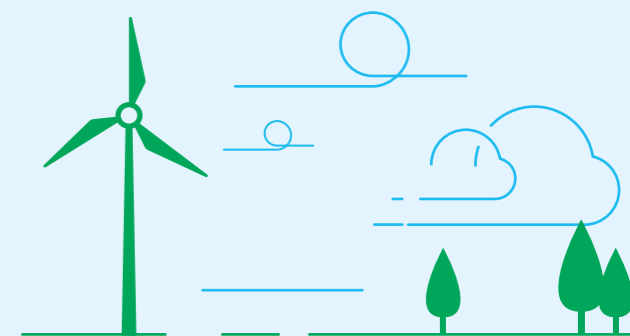
REPURPOSE

Structural reuse of entire or partial components for a different function than their original use. For example, turbine foundations can become water storage units on farms and blades can be turned into bridges, bus shelters and playparks^[17].

DISASSEMBLY

Important specialised enabling strategy for other solutions. Partial or full disassembly may be required, depending on whether components and parts will be repaired, reused, refurbished, remanufactured or recycled.

Infrastructure



LIFETIME EXTENSION

Wind farms are usually built to run for 20–25 years but, on average, onshore wind turbines operate for 33 years^[11]. Lifetime extension means that wind turbines and assets are kept in use beyond the designed service life.

REPOWER

Repowering extends the service life of wind farms, while replacing turbines on site. Partial repowering uses some components for longer (e.g. foundations, towers) but other parts are replaced (e.g. nacelle, rotor). Full repowering replaces whole turbines, usually with larger models of which fewer are needed.

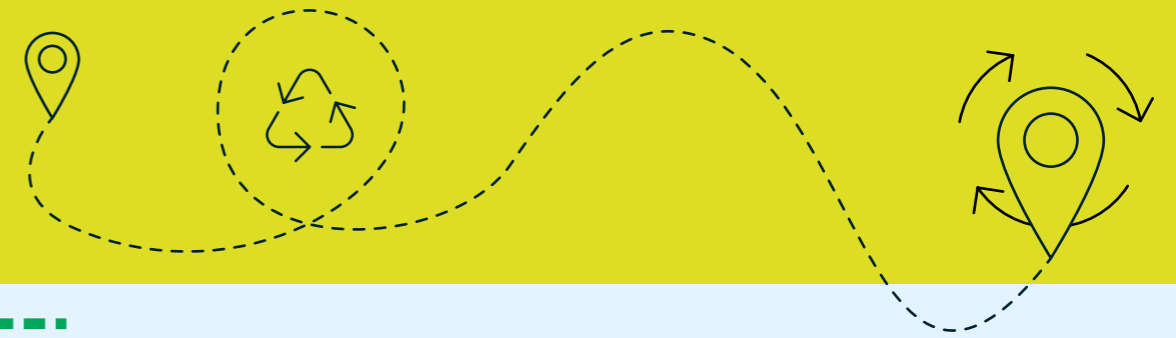
The Scottish Hagshaw Energy Cluster includes seven wind farms, with a further four consented including repowering, expected to total 584MW capacity while integrating community benefits and circular hubs for wind^[20].



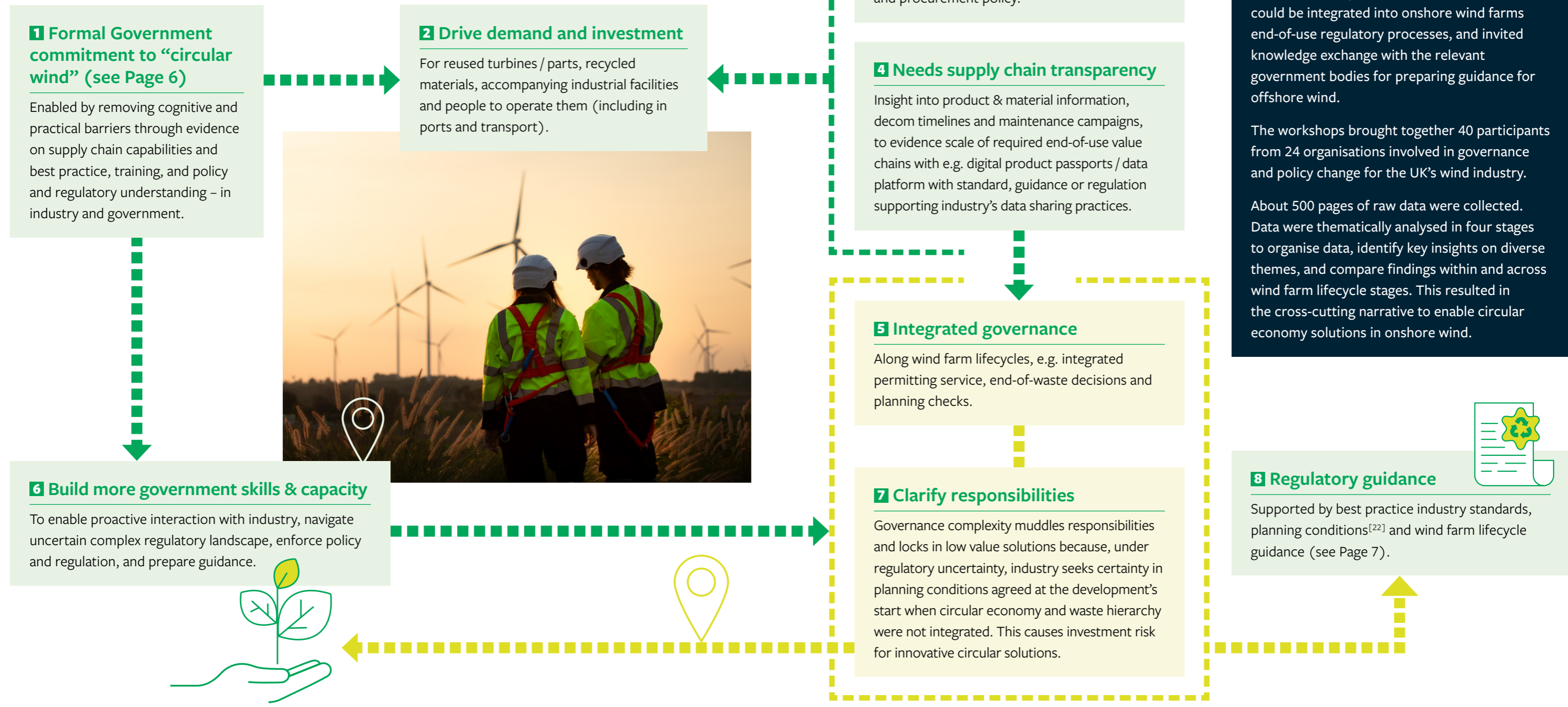
DECOMMISSION

Decommissioning involves^[21] preparing detailed plans and permits, disconnecting turbines from power transmission, removing turbines, foundations and other assets, and restoring and monitoring wind farm sites.

A roadmap towards a circular economy for wind



RESCUE’s governance stakeholders contributed to the preparation of pathways for the integration of a circular economy into onshore wind farms regulatory processes through policy and regulatory change (see Methods inset). This resulted in a set of eight interdependent challenge and solution areas presented in this roadmap.



More power from less materials



Circular economy as a pillar for the Government's clean energy superpower mission

The roadmap identified that a clear Government commitment to a circular economy in wind is the foundation for resolving policy and regulatory challenges. Moreover, access to sufficient, timely and affordable materials and components to double onshore wind and triple offshore wind is not guaranteed for the UK. This causes strategic risks to the UK's wind ambitions and climate targets.

Making circular economy for wind a key pillar of the Government's clean energy superpower mission^[23] will give a clear signal to generate more power from less materials.

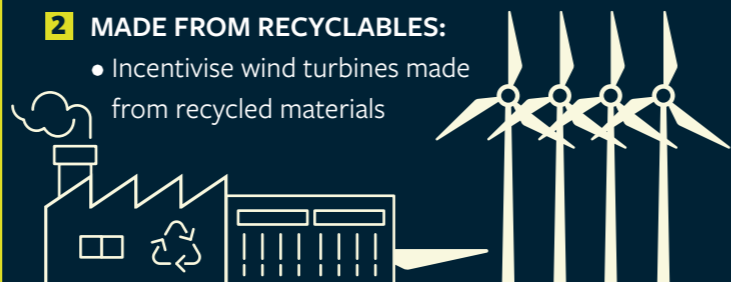
Two targets should underpin the mission.

1 PROMOTE DURABILITY:

- Use wind turbines that are made to last longer and easy to reuse, repair and refurbish
- Build wind farms to operate for 40-50 years, doubling current lifetimes of 20-25 years

2 MADE FROM RECYCLABLES:

- Incentivise wind turbines made from recycled materials

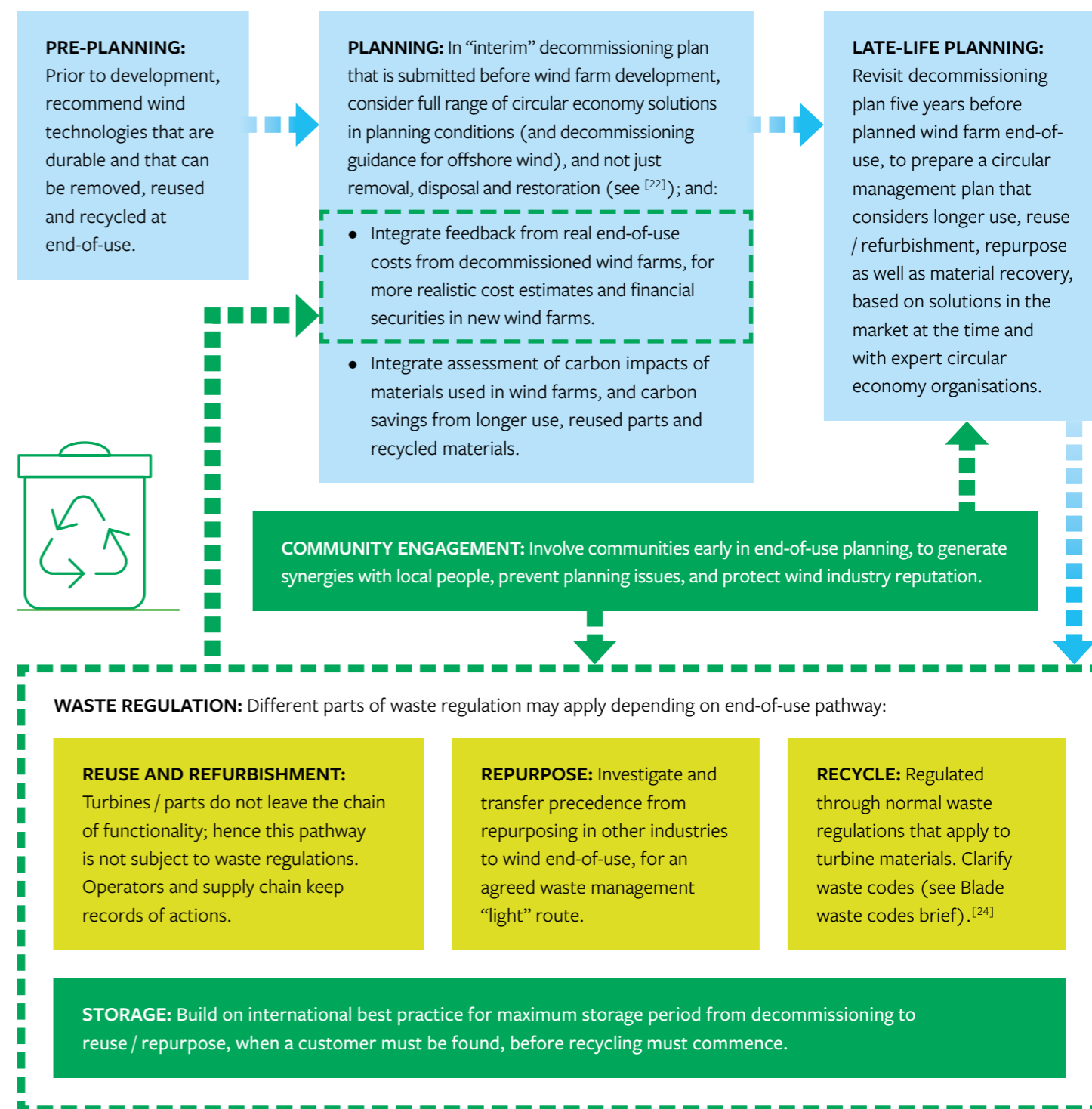


We need to build wind farms that can last for at least 40-50 years, with wind turbines that are made for durability, repair and reuse. This can double resource productivity, reduce costs and limit resource security risks to the UK under growing geopolitical instability.

Moreover, new wind farms should be built with recycled materials. This is the fastest way to further reduce already low environmental impacts from wind, create markets for recovered materials from our aging wind fleet, and strengthen our resource security.

A regulatory guideline to enable circular economy practices

A regulatory guideline is necessary to ease navigation of the governance landscape. Different regulators are involved along the lifecycle of wind farms, from planning authorities to dedicated wind/energy governance bodies and environmental regulators. Their actions impact on each other and can either limit or enable circular economy solutions later on. We present an initial outline for a regulatory guideline which needs to be developed further, including consultation with the respective regulators and industry stakeholders.



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RESCUE project: Regulations to Ensure Sustainable Circular Use at End-of-life

This project was funded by UK Research and Innovation's 'UK Regulatory Science and Innovation Networks' programme. RESCUE established a network exploring regulatory drivers and barriers impacting on innovation in circular supply chains for the wind industry in the UK.

The project's discovery phase (2024) identified and prioritised regulatory issues, followed by the implementation phase (2025-26) to collaboratively resolve regulatory challenges. Research and engagement focused on resources, waste and planning regulation, navigating the regulatory landscape, industrial standards, and capacity building. About 270 stakeholders from over a hundred organisations were involved in the implementation phase.

The RESCUE project was led by ORE Catapult, in partnership with the Universities of Leeds, West of England and Birmingham, with industry partners EMR and Ionic Technologies, and subcontractor Green Alliance.