A Sustainable Circular Economy for Wind: The Bigger Picture

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My background

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Transforming Foundation Industries Research and Innnovation Hub

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Circular economy for energy infrastructure – incl. wind energy lifecycle sustainability group

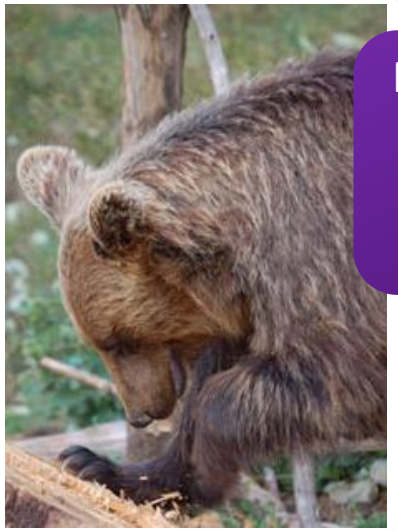
Regional circular economy – head of Yorkshire Circular Lab

Yorkshire Circular Lab

RESOURCE RECOVERY FROM WASTE

Resource Recovery from Waste

Facilitating circular economy transition in the UK



PhD Coevolution of industrial symbiosis networks, governance systems & markets

Sustainable consumption

Participation process management

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UEA
University of East Anglia

AOC Terra

Zookeeper

BSc Wildlife management

MSc Applied Ecology & Conservation

Integrated biodiversity management

van hall larenstein
university of applied sciences

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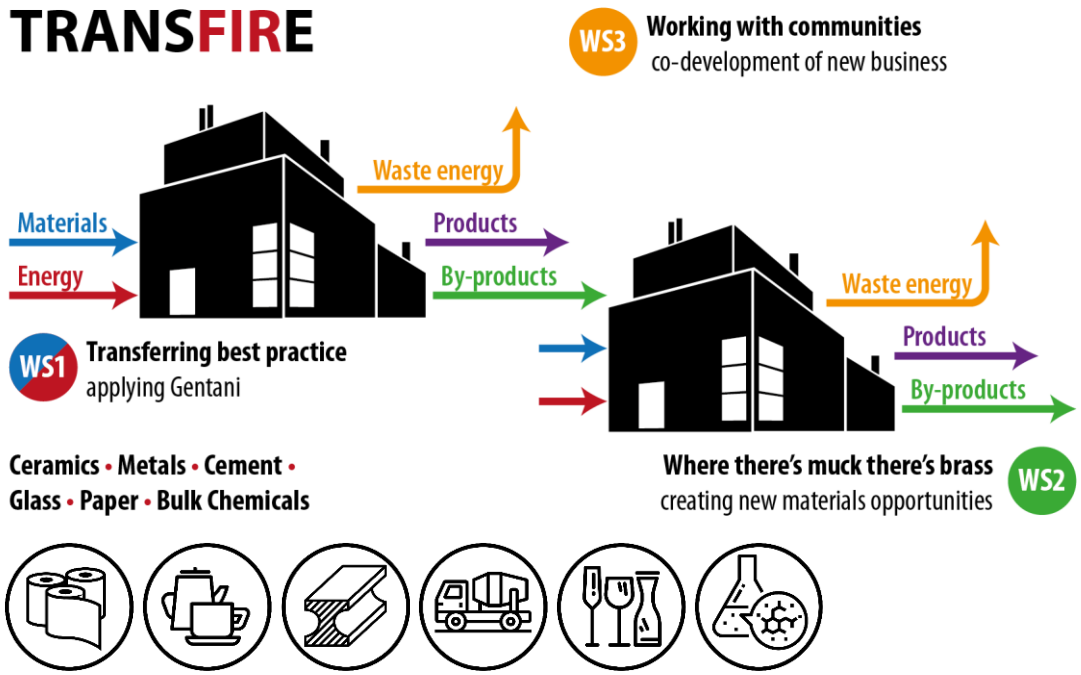
75% of materials in the economy, value of £52 Bn
but also create 10% of CO_2 emissions



A proactive, interdisciplinary, inclusive research and practice driven hub that:

- Optimises flows of all resources within and between Foundation Industries
- Improves competitiveness
- Works with communities
- Assists UK in achieving GHG Net Zero 2050 targets
- Develops an ED&I strategy for the FIs

Further reading:
www.transfire-hub.org

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Today

1. Circular wind strategies
2. Sustainable circular economy
3. Sustainability transitions
4. Circular renewables challenges
5. Business case for innovation

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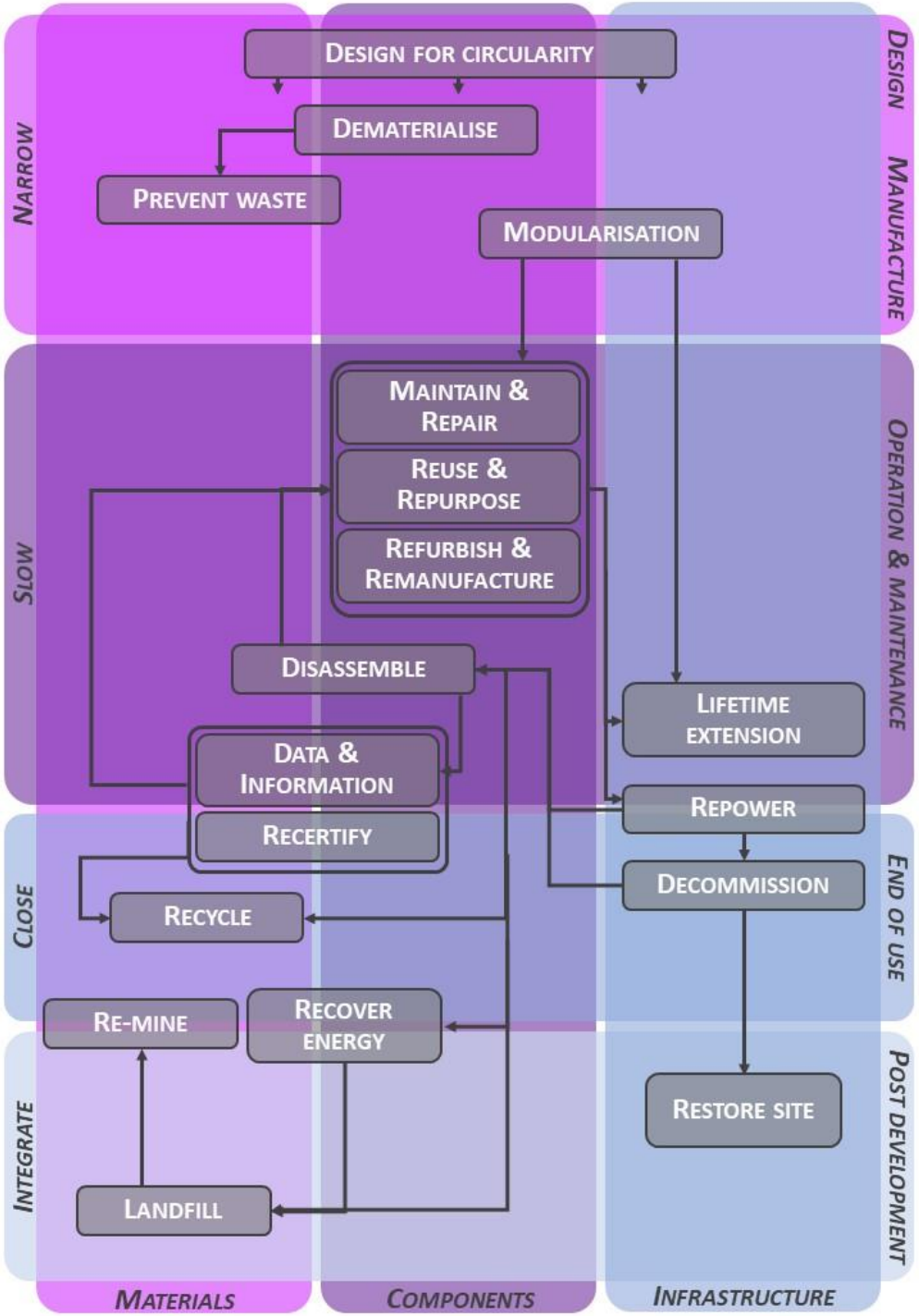
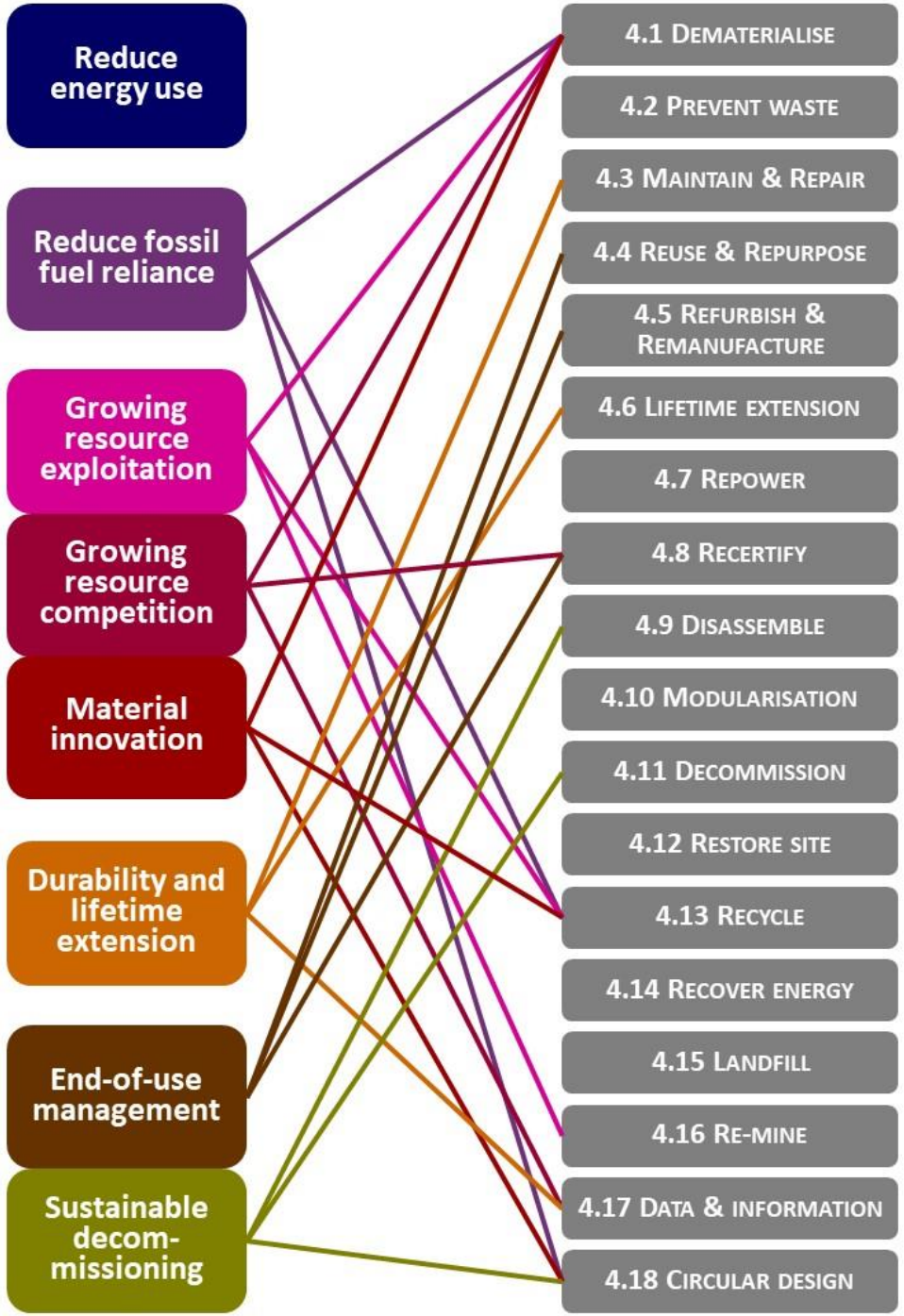
1. Circular wind strategies

Circular economy for wind



Further reading: Velenturf (2021) A Framework and Baseline for the Integration of a Sustainable Circular Economy in Offshore Wind

Mitigate sustainability challenges with circular economy strategies



Further reading on wind sustainability: Velenturf (2020) Challenges and opportunities for sustainable offshore wind development: Preliminary findings from a literature review and expert survey

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Resource use in UK offshore wind

Table 1
Selected UK offshore wind component and material inventory.

Pertinent Metrics and Cumulative Figures for Installed and Under Construction Offshore Wind Farms in the United Kingdom (as of Autumn 2019)		
Capacity (MW)	13,403.5	Based on all WTGs *currently* in or being installed in UK waters
Number of Turbines	2555	As above, i.e. does not include decommissioned Blyth or Triton Knoll
Number of Blades	7655	
Blade Length (km)	476.6	i.e. combined length of the 7655 blades
Blade Mass (kt)	***151.6***	
Blade Fibre/Resin Mass (kt)	128.9	i.e. based on 85% of blade mass consisting of composites
Nacelle Mass (kt)	549.9	
Proportion of PMG WTGs (%)	42	
Proportion of DD WTGs (%)	32	
Nacelles Cu Mass (kt)[1]	12.7	
Nd Mass in PMG WTGs (kt)[1]	***1.0–1.3***	i.e. DDPMG = 165.6 – 216.2 kg/MW; MSPMG = 37.4 – 46 kg/MW
Dy Mass in PMG WTGs (kt)	0.15–0.20	i.e. based on 4% of NdFeB magnet being Dy
Distance to Shore (km)	734	N.B. distance to shore is 'as the crow flies'
Length of Subsea Export Cable (km)	3113	–
Cu Mass of Subsea Export Cable (kt)	***23***	N.B. 55.5 kt if Hornsea 1 and 2 use Cu, rather than Al, export cables
Length of Array Cable (km)	3123	–
Cu Mass of Array Cable (kt)[2]	***22.8***	Based on the average of known cables specifications
Conservative Estimate of Pertinent Additions to Total UK OSW Inventory by 2030		
Capacity (MW)	16,600	–
Number of Turbines	2075	Based on 8 MW turbines, i.e. ~8 MW turbines are the current norm.
Number of Blades	5532	–
Blade Length (km)	498	i.e. based on (at least) 80 m blades
Blade Mass (kt)	***186.8***	i.e. based on (at least) 80 m blades weighing (at least) 30 t
Blade Fibre/Resin Mass (kt)	158.7	i.e. based on 85% of blade mass consisting of composites
PMG WTG NdFeB Mass (kt)	***8.3 – 10.8***	i.e. based on range of NdFeB content range for MSG/DD WTGs
PMG WTG Nd Mass (kt)	***2.2–2.9***	i.e. based on a conservative 27% Nd NdFeB content

Further reading: Jensen et al. (2020) Highlighting the need to embed circular economy in low carbon infrastructure decommissioning: the case of offshore wind

Long-term resource use forecasts in UK offshore wind

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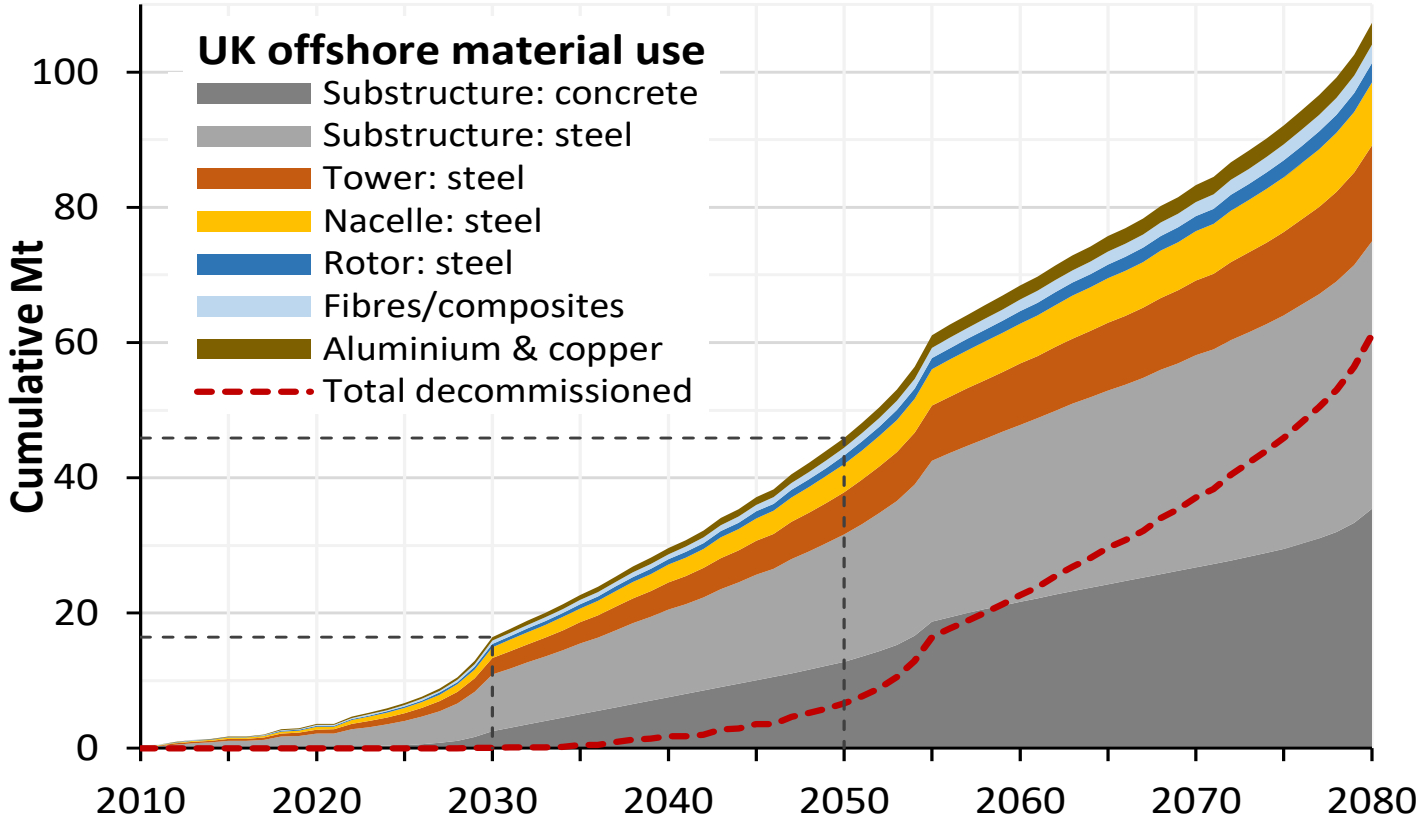

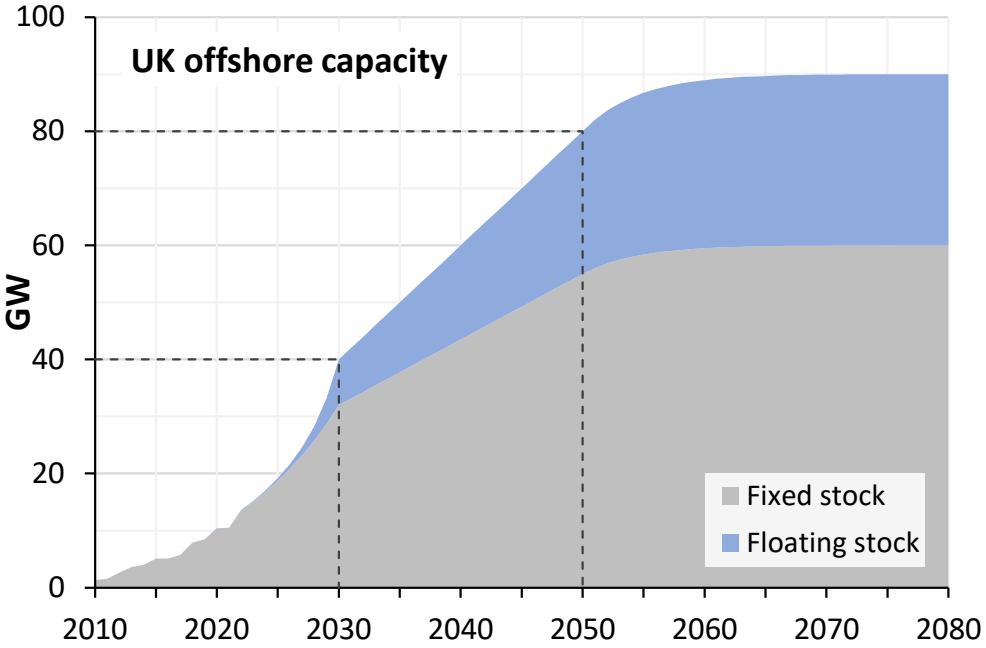

Unpublished results exclusive to University of Leeds (2022)

Narrow lifecycle perspective & carbon blindness

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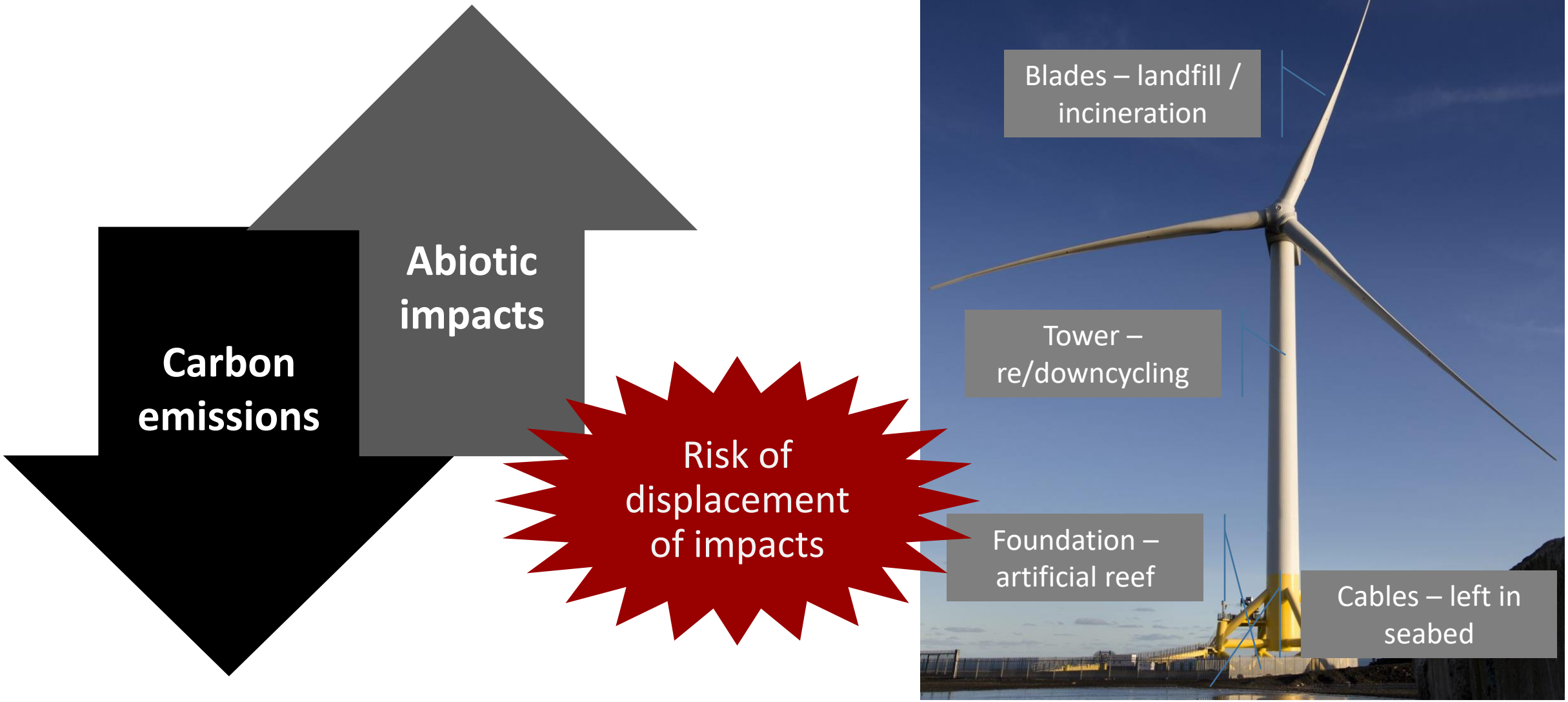

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2. Sustainable circular economy

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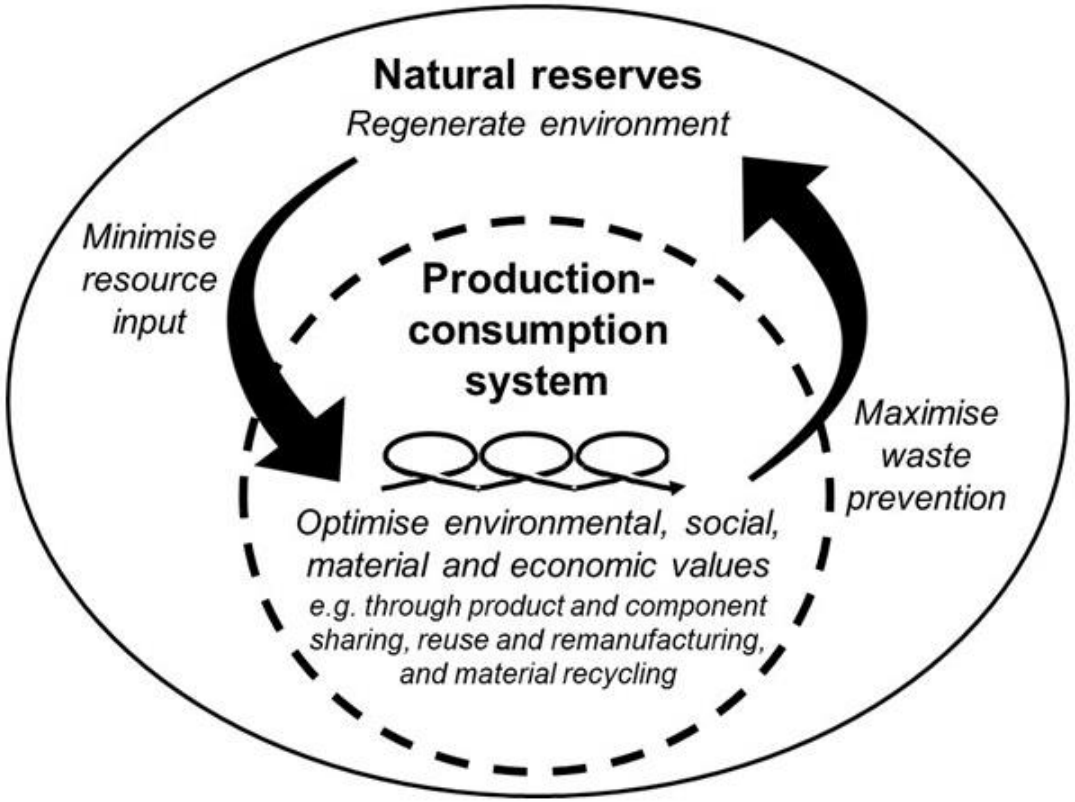
Sustainable circular economy



- Opposite of the linear take-make-use-dispose economy
- Make better use of materials, components and products
- Optimise economic, technical, social and environmental values of materials and products
- Whole lifecycle approach

Further reading: Velenturf and Purnell (2021) Principles for a Sustainable Circular Economy

Value framework

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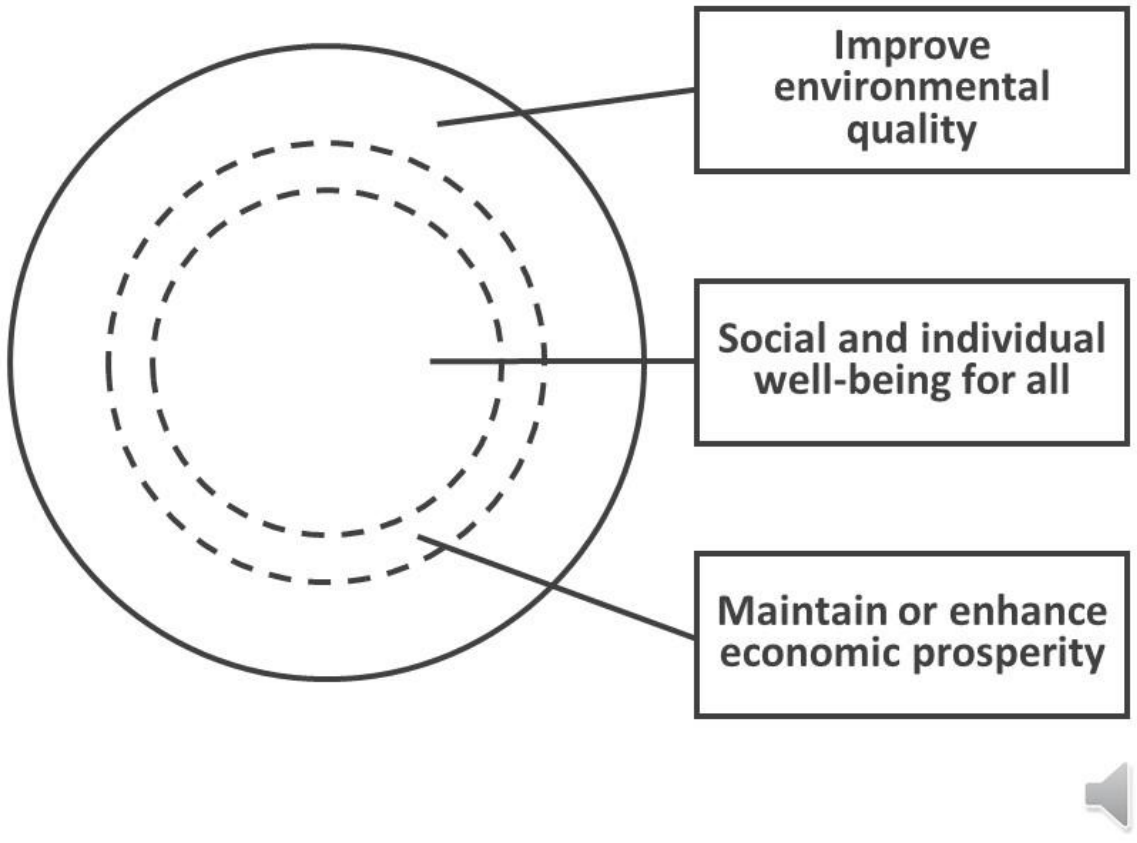
Optimise material and product use for the core values of a:

Sustainable circular society

An equitable society that improves environmental quality and maintains or enhances economic prosperity for current and future generations



Video: Value framework for a sustainable circular economy https://youtu.be/qvmISgjIlgs

Recycling “circular” economy

Production and consumption patterns largely unchanged

Reformative

Technology will save us

Resource efficiency

Progress = Green growth

Weak sustainability

Sustainable circularity

Average material use per person halved

Transformative

Behaviour change

Resource efficiency + sufficiency

Progress = Well-being and environmental quality with economic prosperity

Strong sustainability

Recycling ≠ Circular economy

Depending on where we are in the world, the resource economy has to grow or shrink

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3. Sustainability transitions

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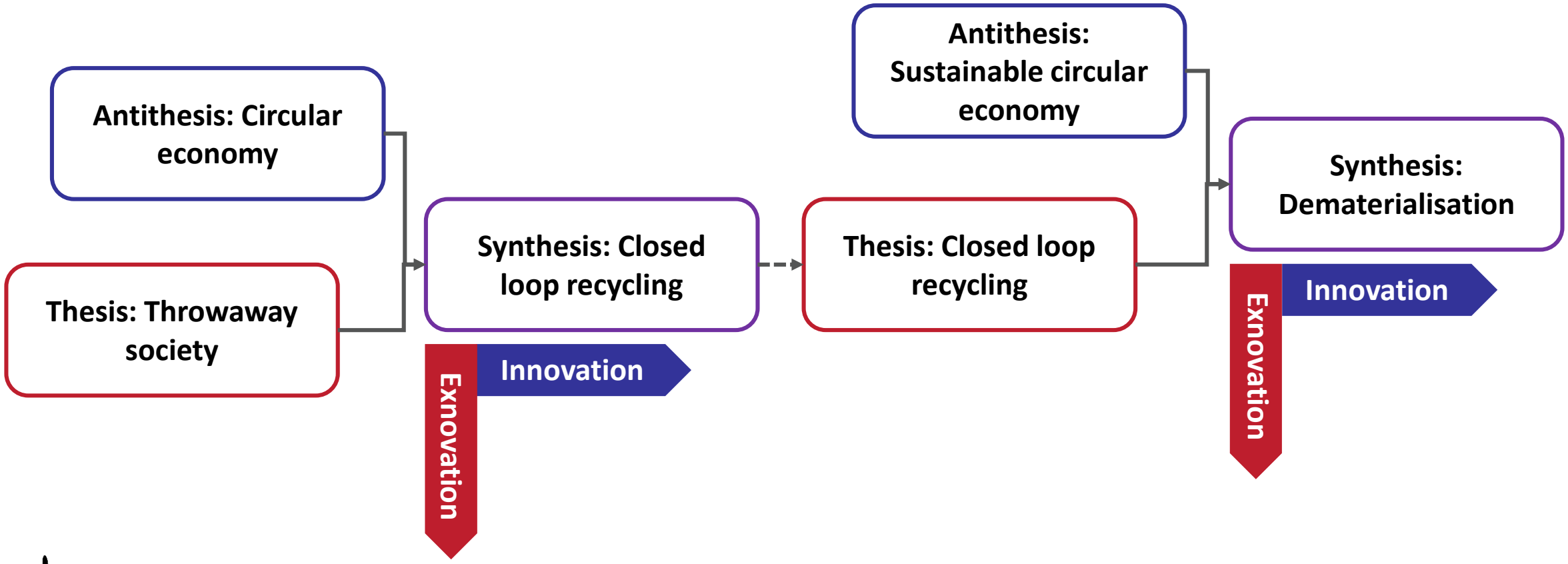
Societal transition



Further reading: Velenturf and Purnell (2021) Principles for a Sustainable Circular Economy

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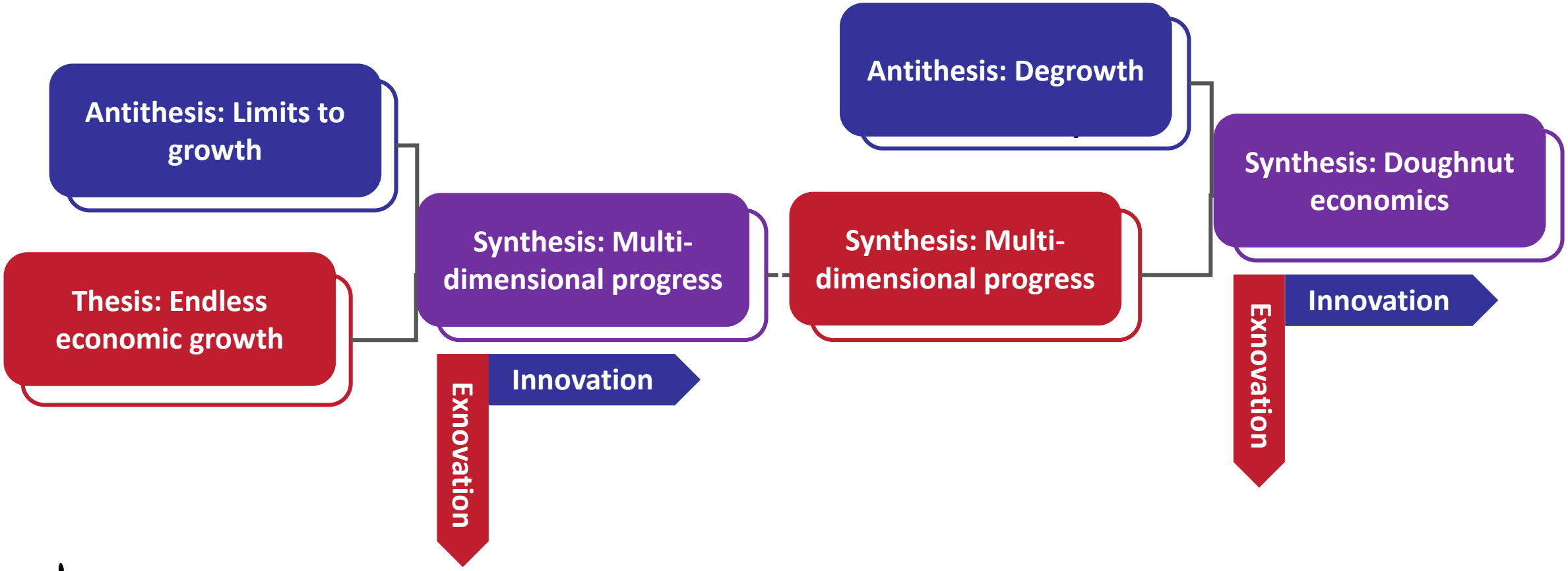
Societal transition



Further reading: Velenturf and Purnell (2021) Principles for a Sustainable Circular Economy

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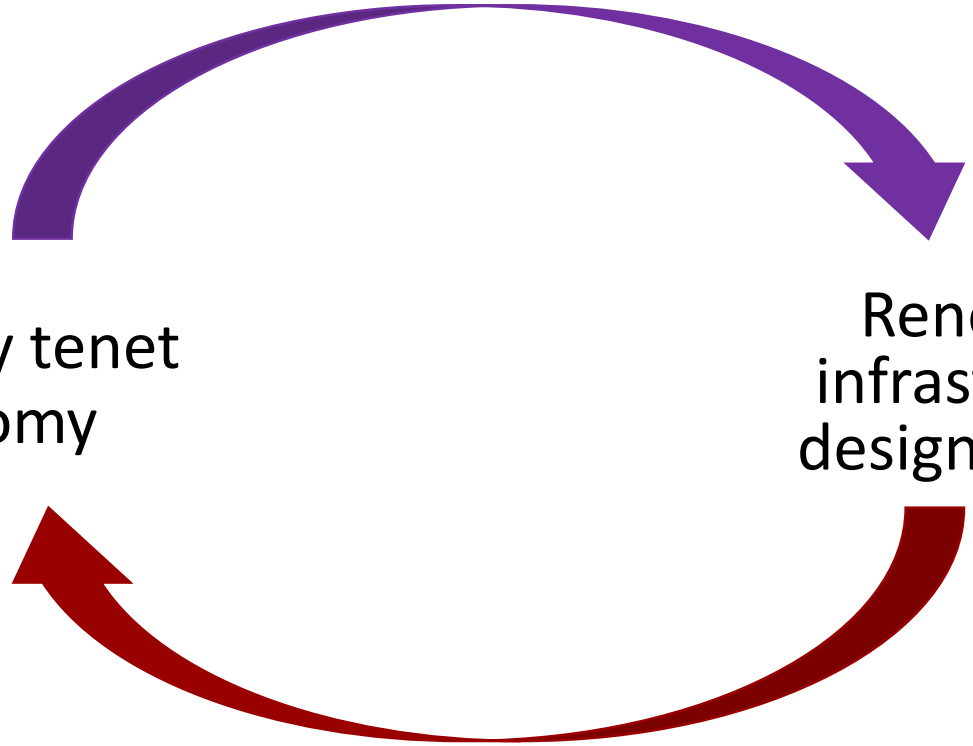
Renewable energy



Interdependency renewables and fossil fuels

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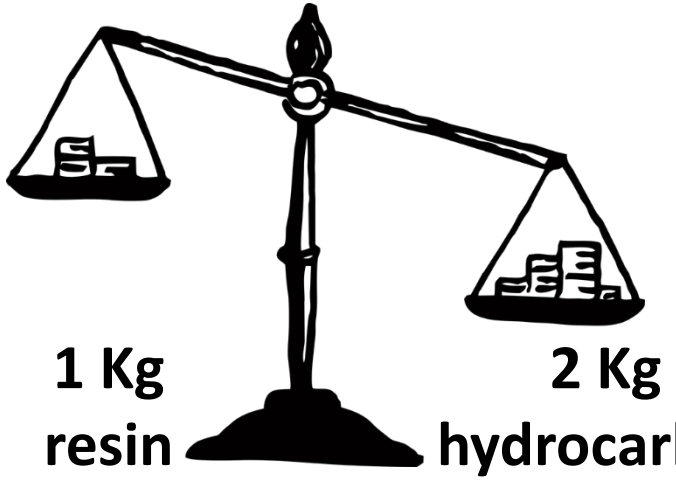
Materials

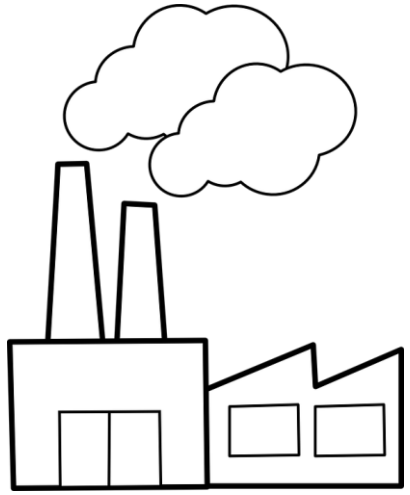


1 Kg resin

2 Kg hydrocarbon

Glass fibre reinforced with resins

Energy



Machinery
High temperature processes

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4. Circular economy challenges in renewables

Scope of Challenges and Opportunities

1. Material value, durability and criticality
2. Inventory – lifecycle data system
3. Whole system analysis
4. Reuse, remanufacturing, decommissioning and resource recovery infrastructure
5. Skills and expertise
6. Policy, regulation, legislation
7. Economics and business models

Further reading: Purnell et al (2018) Developing Technology, Approaches and Business Models for Decommissioning of Low-Carbon Infrastructure

Leeds involvement in circular wind research and innovation projects

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A Sustainable Circular Economy for Offshore Wind

Opportunities for Wind Turbine Blade Recycling in the UK

Energy Transition Alliance stage 1 – blade recycling baseline

ELM Wind – resources inventory

CISTE – circular business models for wind

IEA Wind Task 45 – blade recycling

And many others!

The Circular Wind Hub

The Circular Wind Guide

Internal capacity building project

- Mapping the funding landscape from UKRI and EU on wind energy lifecycle sustainability

wind + sustainab

Funded research & innovation on sustainable wind

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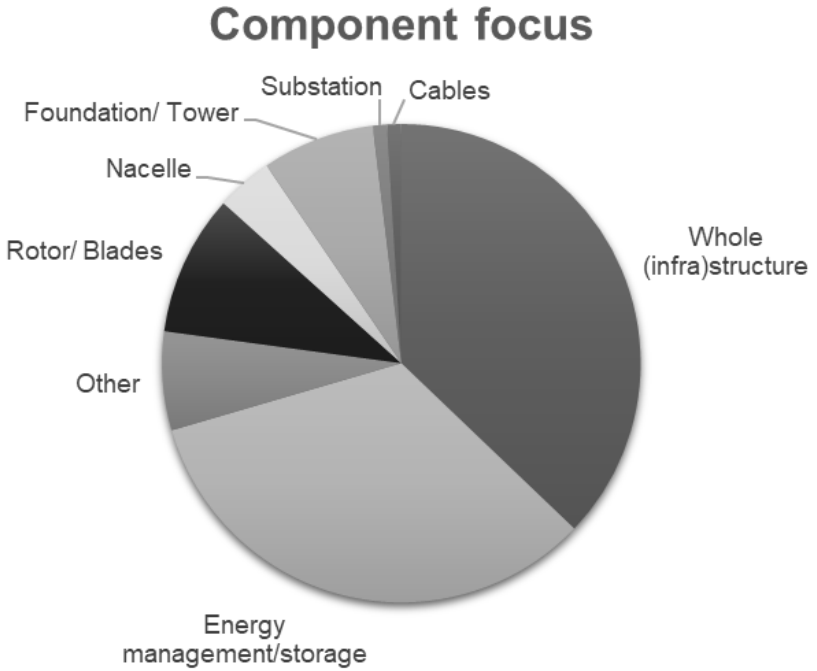
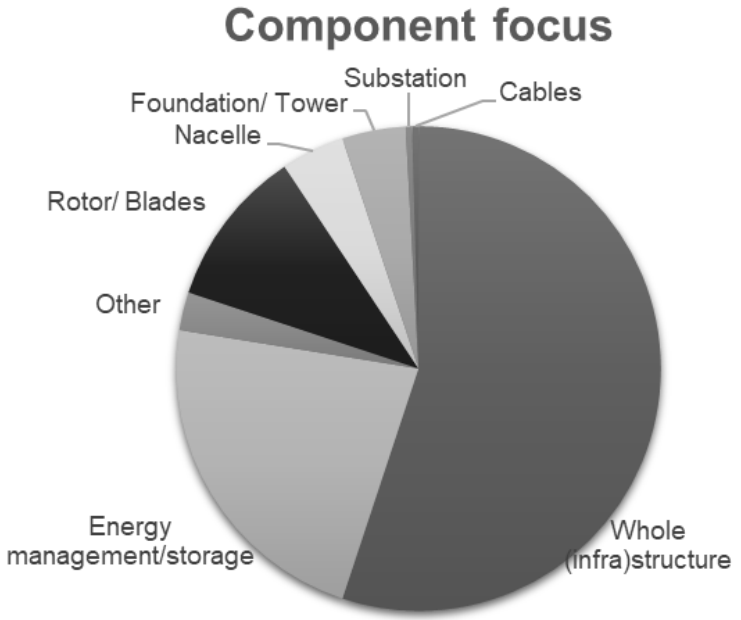
UK

- 105 projects since 2006, some until 2027
- £85.7M
- Engineering 58% of projects, 85% by value
- Relatively much focus on energy storage and training/ doctorate programmes.



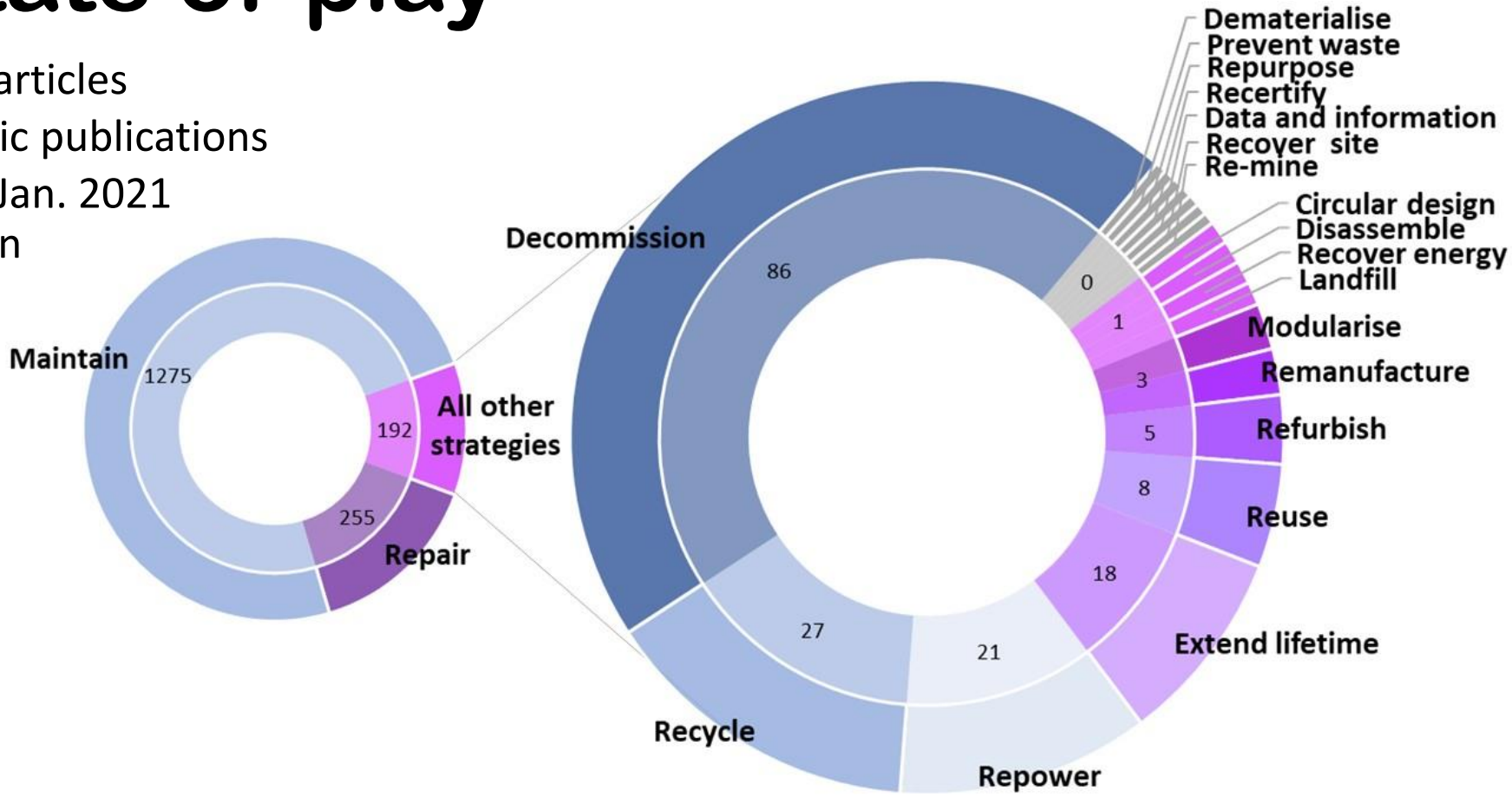
EU

- 237 projects since 1992, some until 2026
- Ca. €1.1Bn, of which €677M EU funded
- Engineering 72% of projects, 80% by value
- Relatively much on energy management, weather forecasting and social impacts.



Offshore wind – circular state of play

- Scanned thousands of articles
- Reviewed >350 scientific publications
- Practitioner workshop Jan. 2021 reflected similar pattern



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5. Business case for innovation

Circular economy can deliver multi-dimensional value

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Job creation, increase local supply chain contents
Reputational benefits
License to operate

Reduce cost and supply risk
New business opportunities
Capital costs

Reduce energy and carbon footprints
Lower environmental impacts

Material flow analysis

Further reading: Millward Hopkins et al (2018) Fully integrated modelling for sustainability assessment of resource recovery from waste

Multi-dimensional value dynamics for circular offshore wind

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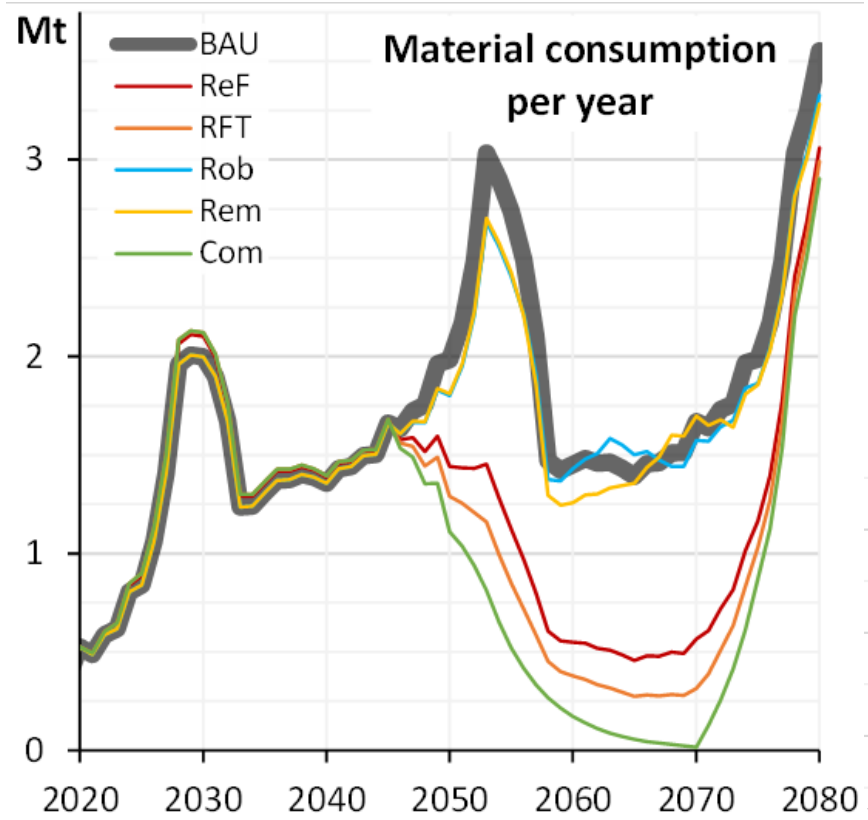
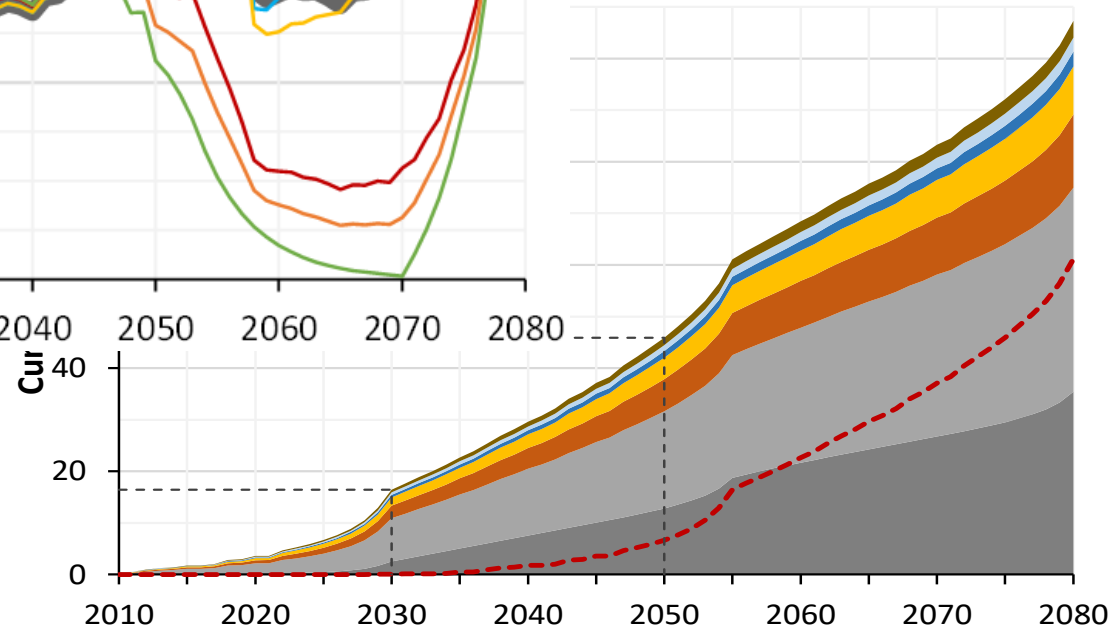
- Business as usual
- Repower, extend life of foundation
- Report, extend life foundation + tower
- Extend life with robotics
- Remanufacture parts
- All scenarios combined





Reduced material use is associated with:

- Lower capital costs
- Lower embodied energy and vastly reduced embodied carbon
- Reduces jobs in wind industry, except for remanufacturing. Does not include jobs in recycling, reuse and repurpose.

Unpublished results exclusive to University of Leeds (2022)

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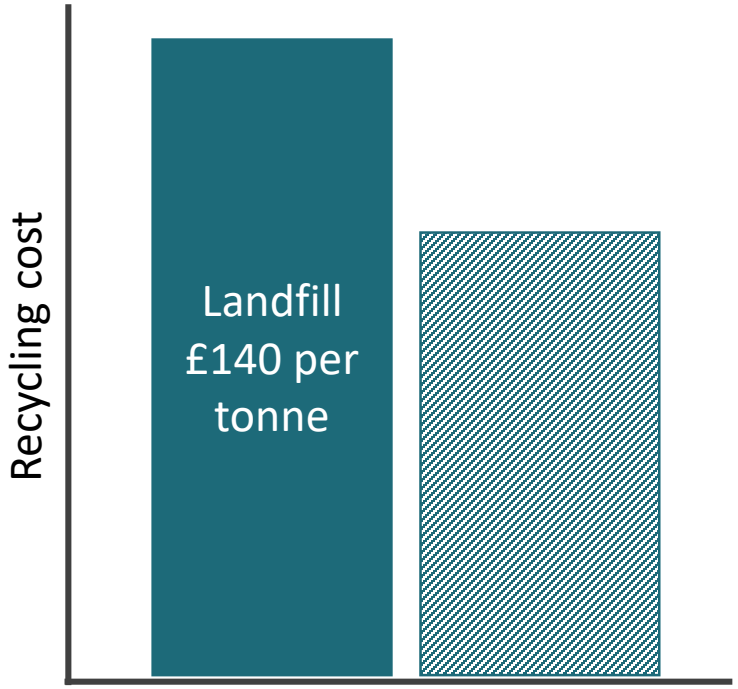
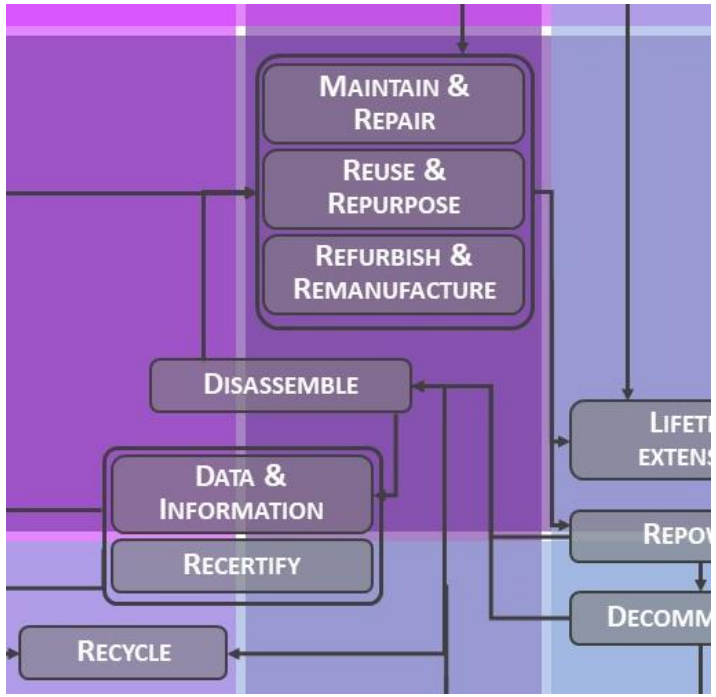
Novel integrated circular business models

Along the wind lifecycle



Along the circular economy chain



Whole turbine turn key model

- Similar to Oil and gas Engineer Procure Remove Dispose model
- Components with critical materials (if recoverable) and copper likely positive value.
- Steel low scrap value but lots of it.
- Balance out negative cost of resource recovery from blades?

Systematic review: Mendoza et al (2022) Circular economy business models and technology management strategies in the wind industry: Sustainability potential, industrial challenges and opportunities

Energy infrastructure decommissioning

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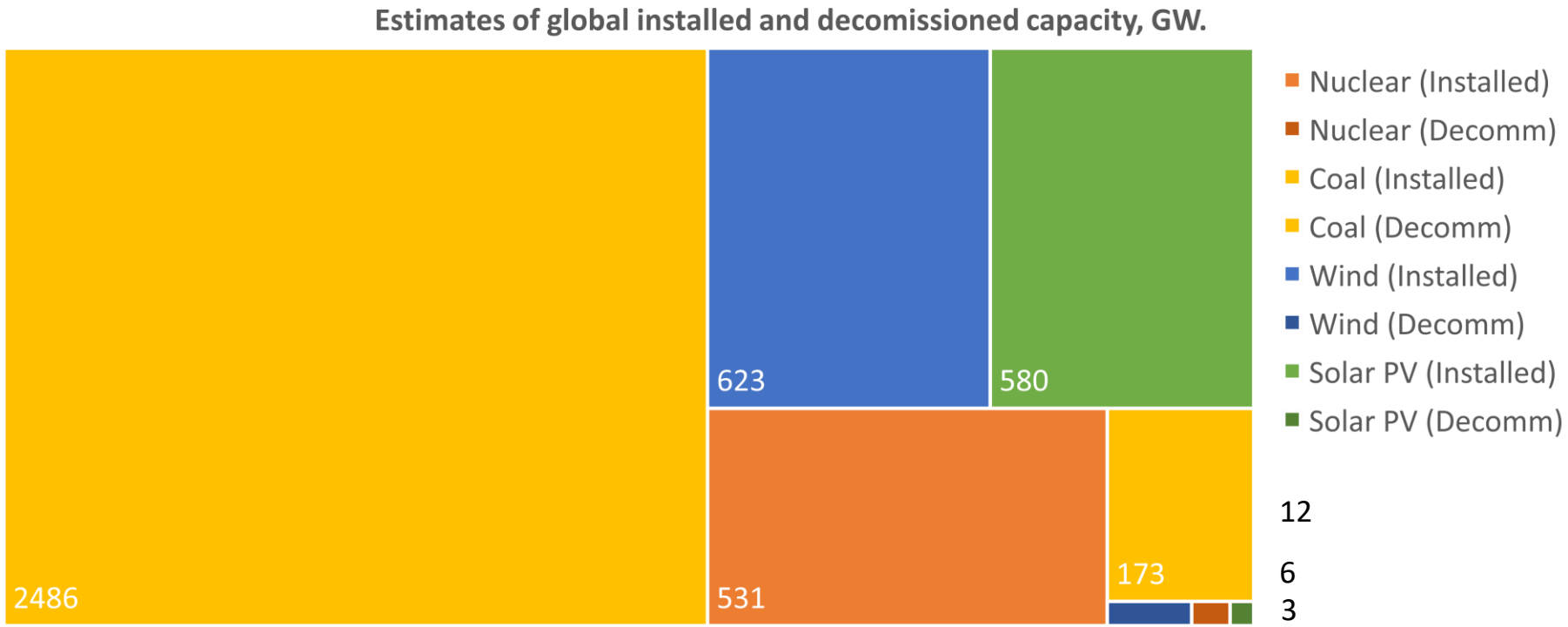
- ✓ Energy infrastructure decommissioning huge global growth market
- ✓ High potential for sustainability wins with circular economy approach



Further reading: Invernizzi et al. (2020) Developing policies for the end-of-life of energy infrastructure: Coming to terms with the challenges of decommissioning

Image source: https://image.shutterstock.com/image-photo/spanish-windmills-like-those-described-260nw-1153466737.jpg

Thank you!

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