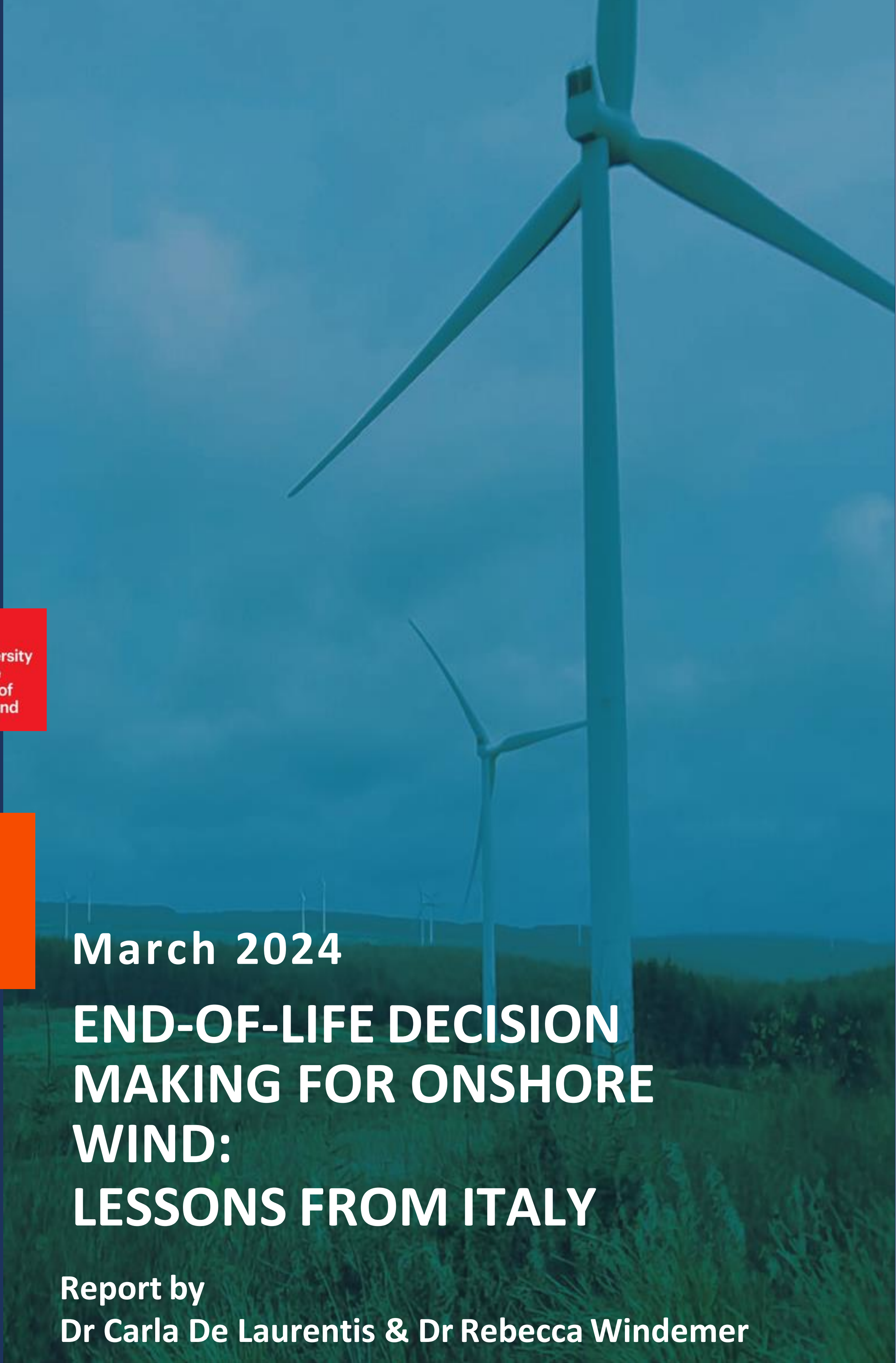

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END-OF-LIFE DECISION MAKING FOR ONSHORE WIND: LESSONS FROM ITALY

Report by
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Royal Geographical Society with IBG

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End-of-life decision making for onshore wind, Lessons from Italy Research Findings

Part of the project 'Is there an afterlife for wind installations in Italy?'

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EXECUTIVE SUMMARY

This report investigates one of the biggest emerging environmental sustainability issues facing the world. That is, the question of what to do with ageing onshore wind infrastructure. This has waste management and economic implications as well as impacting decarbonisation goals. This matters now because over 570 GW of new onshore wind capacity is forecast to become operational over the 2022-27 period (IEA, 2022). With an increase in installations also comes the rise in the number of wind farms reaching end-of-life (hereafter, EoL). There are numerous benefits globally from the growth in wind generation. However, as an environmental policy matter, the consideration of the EoL of low carbon infrastructure has so far received little attention.

What is particularly pressing for industry and policy makers alike is not only to identify the scale of the potential environmental problem but also to understand when a turbine has reached the end of its productive lifetime and to consider the moments in the life of a wind turbine (WT) in which this waste stream will materialise. Drawing on pioneering research in Italy, the findings within this report provide a rounded understanding of EoL decision making and emerging solutions for ageing wind infrastructure.

This report identifies how end-of-life decisions for onshore wind farms in Italy are being made and what influences them. The research highlights a number of key technical, economic and regulatory factors that influence EoL decision making. This is valuable as it suggests there is a need to distinguish between the end of technical life and the operational and economic life of wind turbines – it is the latter that can also influence the waste stream.

1. INTRODUCTION

The technical and/or economic lifecycle of energy infrastructure is predetermined by the lifetime of certain components. At the end of their life expectancy, this infrastructure is expected to contribute to a dramatic increase in waste generation. With an installed capacity of 837 gigawatts onshore wind worldwide in 2022, considering the decision making around EoL of wind infrastructure and waste management strategies becomes vitally important. Exploring ways to tap into the resource potential of the waste generated whilst minimising waste management challenges is what is at stake here.

While the standard design lifetime of a wind turbine (WT) is traditionally 20-25 years, the timescale under which wind turbines approach the end of their operational lifetime is not uniform. The 'age' of the wind farm - and its degrading performance - will be determined by a number of factors. Decisions made about the future of wind infrastructure will also influence their waste impacts and what to do with existing turbines is a particular concern here. Project owners, operators and policymakers face the dual need to reconcile the demands of ageing infrastructure alongside environmental sustainability issues. Very few onshore wind turbines have been decommissioned to date. This means there is a significant lack of guidance and best practice (Invernizzi et al, 2020).

With the aim of understanding when and why end of life decisions for onshore wind farms are being made, we discuss the example of Italy in this report. Given its geographical location and a strong wind resource base, Italy has an installed wind capacity of 11 764 MW and a total of 7360 wind turbines in 2022, with 50% of the country's wind capacity expected to reach EoL by 2030.

This report sets out the research aims and methods, it then discusses the results before providing some recommendations for policy makers, renewable energy developers and operators.

2. THE ITALIAN CONTEXT

The challenge of what to do with an ageing onshore renewable energy infrastructure is particularly acute in Italy, an early leader in wind farm development. At the end of 2000, Italy was among the five countries with the biggest installed windfarm capacity. The Italian Association of Wind Energy (ANEV) estimates that approximately 1.5GW of capacity could be decommissioned by 2025, a figure that is expected to be five times higher by 2032.

In the past decade there has been a rapid development of the wind sector in Italy supported by financial incentives. Nevertheless, wind farms that have been supported by incentives (from CIP6/92, Green Certificates and Feed-in premium) are approaching the end of the incentive period, which is also becoming an issue of growing concern. Projects reaching the end of the funding period are challenged to identify alternative profitable end-of-funding strategies and decommissioning options. Between 2023-2028 about 447 plants (6.1 GW) will see their incentives expire, while the figure for 2017-2019 was about 103 plants with a total of 1.4 GW expiring.

Despite strong interest in energy decarbonisation efforts, Italy is seeing a gap between actual and desired renewable energy installations. The country could fall short in achieving the targets in the final 2030 National Energy and Climate Plan (MASE, 2023) of 44 GW of renewables by 2030. The desired Italian contribution to the RePower EU targets is 40% of energy demand from renewables and over 70 GW of power from renewables by 2030 (with 72% of electricity produced by renewables). Achieving these targets would require a steep increase in installed wind power capacity (approximately 19,000 MW of installed wind capacity by 2030, according to ANEV). To attain such increases, the National Energy and Climate Plan (MASE, 2023) indicates repowering of existing wind farms (with more efficient turbines) is key to increasing wind power capacity.

3. HOW DID WE CONDUCT OUR RESEARCH?

As outlined in figure 1, in order to explore the EoL of Italian wind farms, we firstly conducted a review of academic and industry literature. This literature review provided an overview of the different EoL options and challenges for onshore wind farms.

Energy transition policies and the legislative/regulatory regime play an important role in influencing decision-making for EoL management of wind infrastructure, we therefore reviewed national level policies in Italy for onshore wind development, particularly on 'repowering' (including revamping'), 'life-extension', and ‘decommissioning’. Italian policies on the circular economy, particularly around composite materials and onshore WTs, were also reviewed. Interviews were then conducted with 14 expert stakeholders involved in EoL decision-making. These included wind farm owners, developers and operators of Italian wind farms as well as relevant policymakers, consultants, and industry organisations.

Figure 1: Research stages

4. EXAMINING END-OF-LIFE (EOL) DECISION MAKING

EoL options and the decision-making process associated with the choices operators can make for the future of wind infrastructure are driven by a number of issues including technical, economic and regulatory aspects. Before analysing these, we turn our attention to the EoL options for wind turbines.

4.1 END OF LIFE OPTIONS

WTs (like most technologies) will be exposed to two forms of ageing, firstly loss of performance, from physical wear and tear. Secondly, the relative age of the turbines when compared to advancement in technological innovation in the market that can affect the profitability of a project. Increased performance and energy output are some of the key benefits of new turbine technology that might influence return on investment (ROI) for a wind farm (Jensen, 2019). Towards the end of the operational life of a wind farm, operators must decide on whether to seek to maximise ROI by extending operations via lifetime-extension and repowering, or to decommission the site.

4.2 LIFETIME-EXTENSION, REPOWERING AND DECOMMISSIONING

4.2.1 Lifetime-extension

Lifetime-extension means extending the operation of wind farms beyond their technical design life.

During lifetime extensions, some components of the existing wind turbines may be replaced, but the overall height and layout of the site remain the same. For lifetime-extension, WTs must have sufficient life remaining without any compromise in safety levels. Technical assessments are often needed to determine the suitability of any lifetime-extensions. This can include site evaluation to investigate environmental (e.g. wind speed) and operational conditions.

While operational data is relevant, decisions on life-extension will also vary depending on the type of operators (e.g. small operators with few assets will approach EoL in different ways from large operators), the operational costs (e.g. maintenance contracts and repair expenses), subsidy schemes (e.g. tariffs and support schemes and their duration) and legal requirements (e.g. certification and guarantees required for the WT that exceed their design lifetime).

Operators might develop a life-extension strategy based on individual component analysis, inspection requirements and recommendations, aided by industry association reports and decision support tools.

4.2.2 Repowering

Repowering is a way to increase a wind farm's performance and energy output by replacing old WTs with newer, more efficient technologies. This can also involve improved electrical connections that contribute to the stability of the power system. Repowering can be partial which involves the replacement of certain components to increase the units' lifespan and/or power output, this is sometimes referred to as revamping. Full repowering will involve full replacement often with a larger and more productive turbine model. Repowering as an EoL option can reduce maintenance and operation costs, reducing WT failure rates. However, it also requires a specific and stable financial framework to justify the investments. Repowering will require new planning / permitting approval. Such permitting processes are currently often similar to those of new projects in terms of the detail of documentation required. This includes environmental impact assessment, legal and public consent. Advantages of repowering relate to:

i) increasing specific energy production and improved performance;
ii) deeper knowledge of the wind resource, including historical records of wind

conditions;

iii) better exploitation of the resource in the most windy sites (in many, but not all cases, these coincide with first-generation wind plants)

iv) reduction of the overall capital costs for the installation of a wind plant in comparison to a new plant (through reusing infrastructure); v) reduced maintenance and operation costs; vi) availability of grid connection.

4.2.3 Decommissioning

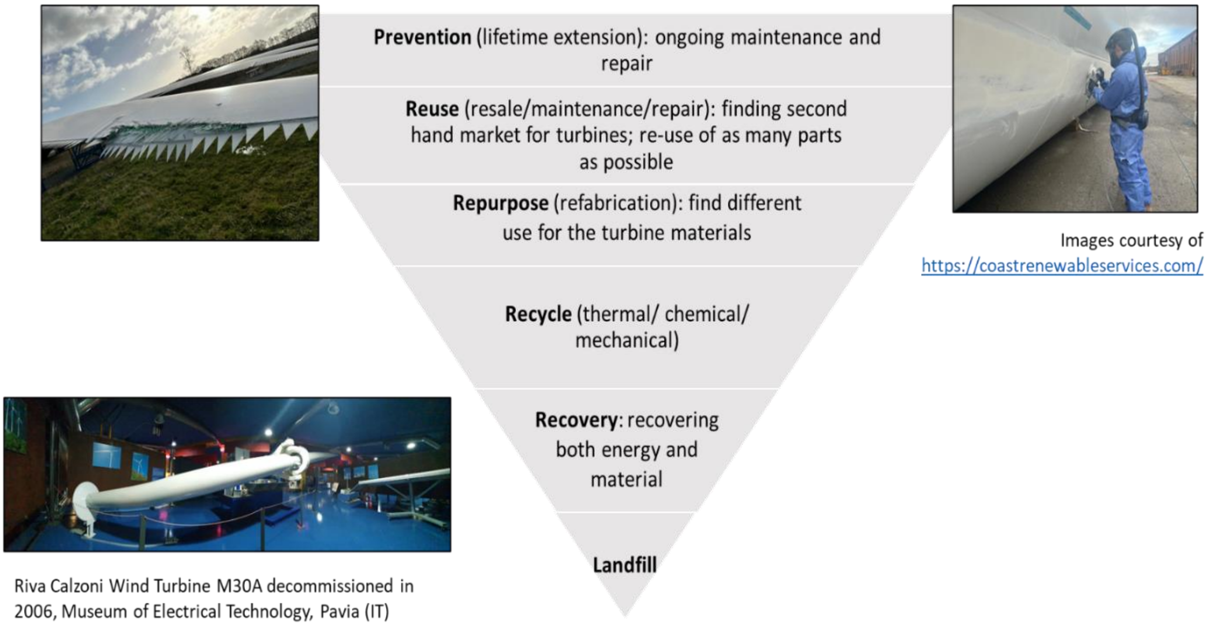
Decommissioning involves the removal of WTs altogether along with their foundations, often returning the land to its previous condition. Full decommissioning will usually be subject to specific legal agreements being in place. Decommissioning may be unavoidable in some circumstances, for example, due to permitting restrictions or changes in land designation. Nevertheless, removing capacity is often seen as the option of last resort compared to life-extension and repowering.

4.3 WASTE MANAGEMENT IMPLICATIONS OF EOL OPTIONS

While the quantity of waste expected from decommissioning will usually be high, it is also important to consider that decommissioned components will also result from lifetime-extensions and repowering (both partial and full). How these decommissioned components are treated may vary. For instance, some discarded components might be directly reused in other wind farms or redeployed after being refurbished and/or re-manufactured. While others might be repurposed for use in different applications or recycled to recover materials. Some of these options for waste management are highlighted in the figure below.

Although turbine design and models might differ in terms of technology choice and other product parameters, materials generally include steel, iron, aluminum, copper, some rare elements (e.g. neodymium), fiberglass and resin. It could be argued that most components of a WT – the foundation, tower, and components in the nacelle – have long established recycling practices, with around 85 to 90% of WTs' total mass being 'in principle' recycled (Mendoza et al., 2022). Yet despite these high recycling potentials, in reality, decommissioned WTs are not always recycled at such a rate due to inefficiencies in recycling, the lack of a recycling 'supply chain' and metal dissipation.

Figure 2: Circular economy options following a waste hierarchy for WTs



Images courtesy of https://coastrenewableservices.com/

Riva Calzoni Wind Turbine M30A decommissioned in 2006, Museum of Electrical Technology, Pavia (IT)

5. FACTORS INFLUENCING DECISION-MAKING FOR EOL

There are a range of technical, economic and regulatory aspects influencing EoL decisions. These, undoubtedly, will also determine some of the potential challenges associated with waste management and resource recovery. Determining EoL options will undoubtedly be a decision unique to each project. Nonetheless, there will be a number of factors that will also influence EoL decision making and EoL moments, we list the main factors in Table 1.

Table 1 Factors influencing decision making for EoL

Technical/ design life	**Economic/ business model**
Legislative/ regulatory	**Business environment**

The remainder of the report investigates how these factors have influenced EoL choices in the Italian context. [Participant insights are quoted in this report anonymously with the abbreviation WO for wind operators and GOV for governmental organisations].

5.1 TECHNICAL / DESIGN LIFE ISSUES

The design life of a WT- along with its components – can undoubtedly impact when EoL decisions are taken. The standard design lifetime of a WT is 20-25 years, although this can be extended to 35 years with a good level of ongoing maintenance, and with renovation and repair. A total of 1625 MW of onshore wind has been installed in Italy between 1991-2005, corresponding to 133 plants and 2083 turbines, which are considered reaching their end of technical design life. The standard design life of these plants, however, is not the only technical factor affecting EoL decisions. The timescale under which WTs approach the end of their operational lifetime is not uniform. Real data on site performance will determine the 'age' of the turbine. Performance and age will depend on the wind conditions in the specific sites as different wind speeds and patterns can impact the performance of turbine components. Parts will wear out more quickly in sites with stronger wind speeds. Lightning strikes are a good example of what can damage parts. EoL decisions will need to be taken earlier if WTs become damaged during the operation life. Such damage can render them unsafe, requiring replacement.

Ongoing maintenance can impact the 'age' / lifespan of components. Some developers report how one strategy to keep their wind farms working for as long as possible was through high quality maintenance. This could be provided by turbine manufactures upon agreement or via dedicated maintenance teams. Maintenance plans including parts replacement are often supported by detailed site assessment and monitoring. Replacements to WT components have to be on a like-for-like basis, as the wind farm planning authorisation will permit the generation of a certain amount of power. To actually change the type of components would require new permission. A challenge to such replacement is the availability of replacement parts, particularly for older turbines, therefore affecting life-extension opportunities. In terms of waste management, some operators are stockpiling older turbines on site to guarantee a supply of spare parts to prolong WT's life.

The certification / guarantee on the equipment can also influence the timing of EoL decisions. For example, many older WT components in Italy have a 20-year guarantee, requiring parts to be replaced after this point. A strategic approach used from some developers is to seek the extension of the service life of the asset and de-risk life-time extension by working with suppliers to guarantee life certificate extensions and re-certify the assets. Where this cannot be provided by suppliers, some organisations work with professional bodies that provide lifetime extension certification and related verification and inspection tasks. This life-extension certification process involves providing the certification organisation with detailed data on the performance of the wind farm and allowing them to conduct a detailed inspection of the site.

Common agreement on EoL decisions is that they need to be considered as early as the 15th year of the WT. Alternatively, some operators are considering ad-hoc EoL strategies for their wind assets, such as reblading, '*for the partial and full replacement of some WTs that are only 8-9 years old and 12 years old*.'

5.2 ECONOMIC AND INDUSTRY FACTORS

There are many economic factors that can affect EoL management and decision making such as operation costs, electricity markets, subsidies, incentive schemes and power purchase agreements. Lifetime decisions will differ depending on the economic evaluation of the sites and their performance. These economic evaluations are in turn influenced not only by the site wind conditions but also by the business model associated with the original wind farm's business case. Italian wind farm operators point to the discrepancy whereby some original business models are designed for 15 years, even though turbines may last for up to 30 years. Also, sometimes, developers acquire wind farms from other companies, then develop their own strategies regarding EoL options.

There have been some instances where companies have chosen to acquire older sites, rather than developing on greenfield sites, as their business model. This can be down to being able to harness the best anemological conditions. Key, in the decision-making process, is the real-time information on wind and the experience and data availability at existing sites. Decisions, therefore, can be affected by how well the site is performing and whether the increase in energy production (e.g from repowering) is sufficient for the economic sustainability of the investments. Re-blading options, such as changes in the type of blades and increasing the rotor size, offer an opportunity, without modifying the installed capacity to '*increase production in sites with medium-to-low wind conditions'*. Moreover, repowering is currently considered by many wind energy developers as the 'smartest solution' due to the location of many existing wind farms in 'favourable areas'. Albeit the challenges of potentially upgrading the grid infrastructure will also need to be considered.

Critically, EoL decision making may be different when financial incentives affect existing sites:

> *'While we have a life-time guarantee on the assets for 20-30 years, our decisions on EOL will be driven by the incentives: one of our wind farms, built in 2012, will benefit from incentives for another 4 years and we have considered the re-blading of the site to cover the cost sooner' (WO 5).*
>
> *'A wind plant will have a life duration of about 20 years as operators and developers will associate the durability of the plant not with technological obsolescence of the turbines but rather with the termination of the incentives' (GOV 1b).*

Given their lifespans, many windfarm operators will be faced with EoL decision-making challenges in the very near future. The strike price that the wind farm operators have secured through auctions and power purchase agreements will also have a similar impact on the economic and financial sustainability of EoL options. The possibility for repowering projects in Italy to participate in auctions represents another opportunity for the economic and financial sustainability of sites.

The decisions around EoL will also be influenced by waste management options and the cost of waste collection and landfill policies related to the discarded blade/s:

> *'In the EoL projects we have been involved with we have kept three blades for spare; we have re-sold some of the blades to the manufacturers to enter second markets (especially the newer ones- some were only 10 years old) and some have been kept disused on-site awaiting decision on waste treatment' (WO 5).*

There is not currently a legislative ban for disused wind blades in Italy. However, operators have been seeking options to minimise blade waste disposal. This is because there are both environmental costs and financial implications. You cannot just dispose of blades:

> *'You are required to find a solution (...) So we are trying also avoiding the costs because we expect to dismantle many first-generation WTs' (WO 6).*

Moreover, developers have to contribute towards a guarantee fund for the decommissioning of the wind farm to the municipalities:

> *'Developers need to contribute a fixed-cost of surety to guarantee the municipality for the disposal of the plant (..) the decommissioning requires developers to restore the area, removing the WTs and foundations (up to 10 mt)' (GOV 1b).*

When it comes to dealing with older turbines re-selling them is the most economically viable approach. If a wind farm is being repowered early, then selling turbines on the second-hand market (or re-selling to manufacturers) provides a viable approach. This is not without its challenges as there are uncertainties on where the responsibility lies in terms of performance, technical assistance, and after-sale services. Similarly, the cost of partial repowering (revamping) which can keep the same project operational for a lot longer, can include high costs. Changing the rotor, for example, improves production, but it is very expensive. Likewise, re-blading is considered expensive. Thus, these approaches may have a significant impact on waste reduction but may be prohibitively costly.

5.3 LEGISLATIVE AND REGULATORY FACTORS (INCLUDING PERMITTING)

The end of financial support mechanisms makes EoL options for existing wind farms very pertinent. Government policy can influence choices regarding the future of existing windfarms. Here we refer to:

I. changes in policy and financial support and how they might lead to EoL decisions being taken earlier than the operational life of a site; and

II. to the way in which EoL decisions are also affected by the current authorisation granted to the site.

The first point refers to the way in which re-powering and life-extensions can be explicitly supported from governments. In Italy, for instance, the National Energy and Climate Plan (NECP) states that repowering existing wind farms offers a key opportunity to increase power capacity and contribute towards achieving 2030 targets:

> *'In order to attain the targets on renewables identified for 2030, it will not only be necessary to stimulate new production, but also to preserve existing production and, if possible, actually increase it, by promoting the revamping and repowering of installations. In particular, the opportunity to promote investments in the revamping and repowering of existing wind power plants with more developed and efficient machines, by exploiting the excellent wind conditions at well-known sites that are already being used, will also help to limit the impact on soil consumption' (MISE, 2019: 68)*

Despite the support for repowering in the NECP, repowering has not had, for some time, any specific support measures. Repowering projects, in terms of authorisation procedures and environmental impact assessments, were treated as completely new plants. However, projects with 'no-relevant modification defined by law' can take advantage of a simplified administrative procedure, although there is no definition of what comprises a 'no-relevant modification'. This, to a certain extent, has had the effect of discouraging operators to undertake repowering interventions. One of the main barriers being the time waiting for the authorisation procedure to be granted:

> *'The time for the authorisation procedures for repowering is too long and too onerous' (WO 5).*

Nevertheless, more recently, some simplifications in the authorisation procedures have been put in place to support the repowering of existing wind sites:

> *'There are a number of decrees, published in the past three years that are basically trying to sustain these types of EoL options that are helping to clarify and define what can be considered as a no-relevant modification and can be considered as a substantial change - this simplification can also apply to sites that have been granted authorisation but they have not yet been built and can be modified - via simplified authorisations - to increase the installed capacity' (GOV 1b).*

Changes in these authorisations (permitting regulations for modifications, simplification of authorisations and permitting timing) have started to positively influence repowering of some sites. Introduced in early 2023, it is the changes in the environmental impact analysis, to be undertaken on a differential basis from existing plants, that are expected to contribute to an increase in repowering projects. The adopted principle is that:

> '…for environmental assessments, the intention is to favour an approach that evaluates only the impact of the changes with respect to the situation prior to the revamping or repowering intervention' (MASE, 2023: 180).

Following the intervention, repowering projects of existing wind farms, that do not include changes to the occupied area and total power of less than 50 MW, are exempt until 30 June 2024 from the environmental impact assessment. This, coupled with repowering projects and green field projects being considered in the same auctions, yet with some tariff reductions, has led some commentators to suggest that Italy is becoming de-facto a *fertile* ground for the development of repowering. Moreover, as early wind farm development was mainly located in the windier southern regions (Campania, Apulia, Sicily, Molise and Sardinia), some regions are looking at opportunities for some EoL solutions so as to maintain their role in contributing to national wind energy production targets. For instance, Apulia, in 2020, adopted a regional law to regulate EoL so as to identify ways in which current wind sites could be renewed, via further simplification and in respect of national legislation.

Permitting / operational licences and land use agreements are important for EoL. While developers have to pay a guarantee for decommissioning to the municipalities, for example, in Apulia this is fixed at £100 Euro per Kw. The cost is defined at the time of the authorisation of the wind farm. However, developers are pushing regions, such as Apulia, to consider revising this fixed cost by identifying alternative EoL options. For instance, in the authorisation phase, developers could present an EoL plan for the decommissioning of the WTs which can include the options for WTs to be re-sold (in their entirety or as components) to reduce the fixed costs of surety.

Another factor influencing EoL decision-making is permits, in terms of planning / operational licences and land use agreements. In some instances, in Italy, operating licences have been issued for 20 years. In these cases, if there are no terms for an extension of the licence, then decommissioning might be the only option. Importantly this will also depend on the type of rights the wind farm operators have on the land on which they operate: for instance, the EoL will be determined by the end of land use contracts and whether they can be extended. Such restrictions can bring forward the date at which the future use of the materials has to be decided upon.

> *'… in some cases, you have a 20 year authorization to operate that wind farm in other cases, we have 30 years in some other cases you do not have a time limit to operate'* (WO 4).

'If, at national level, the government introduces a way to extend the incentives already assigned to projects of revamping, operators and developers might apply for an extension of the planning permits and operational license.' (GOV 1a)

A further issue that is having an impact on EoL decision-making processes relates to changes that have been introduced in land designation, since early developments in wind energy. In the Italian context, national guidelines provide the criteria for identifying areas to be excluded from wind energy production. The national guidelines were only published in 2012 yet for several plants that are reaching EoL, the new criteria means that their locations fall in unsuitable areas.

There are also, at the time of writing, a number of reforms currently under consideration from the Italian Government, such as the regional burden sharing targets to 2030 and the identification of suitable areas for renewable energy developments which will indeed affect some of the decision-making and opportunities for end-of-life management.

5.4 BUSINESS ENVIRONMENT

There is widespread recognition amongst wind farm developers that repowering is often the ‘smartest solution’ in terms of enabling increased energy generation from existing sites. Wind farm developers are pushing for an easier and quicker consenting process for repowering. This translates into learning opportunities. A task force was created for EoL, including operators, developers, wind and renewable energy associations and industry association for composite material. This task force promoted the publication of a *Charter of Sustainable Wind Energy* (ANEV et al., 2019) aimed at promoting the:

> *‘…reconstruction and modernization projects of existing plants as well as of those already authorised, but not yet built’ (ANEV et al., 2019: 3).*

The wind sector in Italy has been collaborating on providing potential responses to the challenge of WT waste materials – in particular the question of what to do with the blades that currently cannot be recycled. Those representing the sector include Elettricità Futura, the main renewable energy association, ANEV, the wind energy association, and Assocompositi, the industry association for composite material. These organisations have published a position paper (ANEV et al., 2021) to discuss and ensure the sustainable and circular management of EoL WTs. The position paper resulted from a working group in which over forty companies in the sector participated. This was coordinated by leading companies in the Italian and global markets – Enel, ERG, Vestas and Enercon – as pioneers in the adoption of EoL strategies. This supported collaborative learning and sharing of best practice. One key take away is the recognition that re-use and repurposing are unlikely to be large scale solutions given the expected volumes of wind farms that will reach EoL. There is also a recognition that blade waste is an increasing problem e.g. in 5-7 years there could be a significant amount of waste fiberglass.

The Italian wind farm industry has been at the forefront of the movement to address waste materials. What emerged from the interview data was that many developers saw addressing the challenge of ‘*what to do with old blades and moving the wind sector to a circular economy as their responsibility*’ (WO 1). As such the wind industry has been leading the way, both in terms of raising the issue and working to provide potential responses.

Industry efforts have successfully influenced policy change for repowering, such as simplification of authorisation and shortening the time allocated for a decision on planning applications and permits. However, industry actors highlight that there is a key gap in national level policy / activities in Italy regarding waste treatment. This relates particularly to fiberglass. Industry figures and associations have identified the need to understand the costs and opportunities for this material. Legislation is needed on wind farm waste in Italy[1]. In the meantime, industry is working towards addressing this gap by:

1. Identifying the supply chain challenge related to waste management of fiberglass, working in collaboration with other sectors. For example, an emerging technology under consideration is the grinding of blades, that could be used in the construction industry such as for road surfacing. As things stand, a value chain to provide proof of concept that grinding blades would be suitable for this purpose does not yet exist. However, industry is working to develop a pilot project to create a treatment facility to explore these challenges.

2. Seeking collaboration with national government and the General Directorate for the Circular Economy of Government. This is by proposing the involvement of the wind sector in the working group for the End of Waste decrees on composite materials (ANEV et al., 2021).

It is also important to recognise that recently the industry has suffered from a number of challenges, including inflation in commodity prices and other input costs that have given raise to the price of wind turbines. These challenges might have had the effect of slowing down progress in addressing the sustainability challenge of the industry, despite industry commitment.

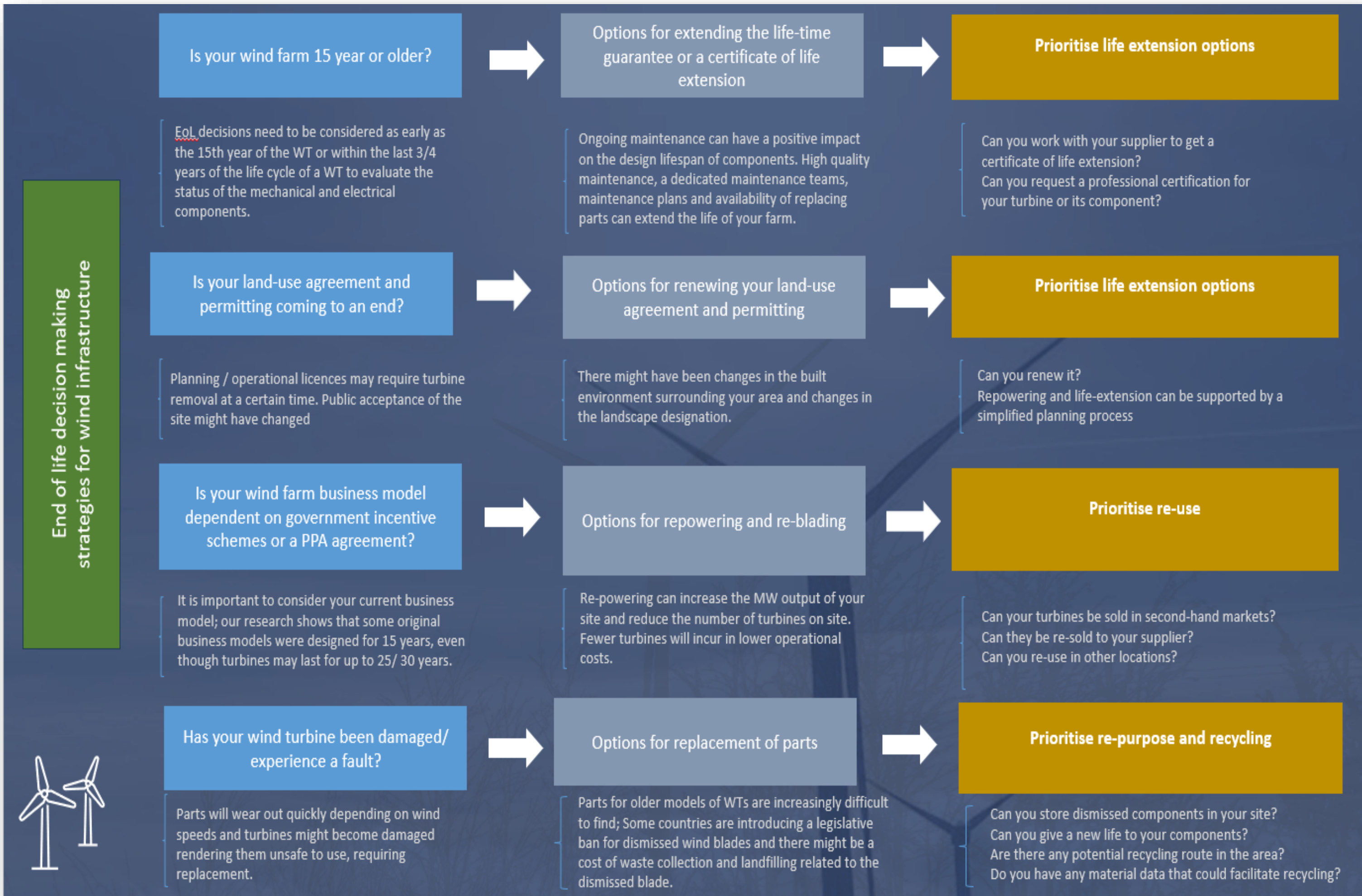
5.5 SUMMARY

In summary, the identified factors are influencing decision making around EoL while also affecting options and opportunities around what can be done with the emerging waste. The next table summarises the discussion and provides a suggested decision-making process that support the identification and the linkages between EoL decisions and waste management options.

[1] There is a need to address a legislative vacuum in Italy on wind farm waste through pushing for a policy decision (ASS 2).

5.6 END OF LIFE DECISION MAKING STRATEGIES FOR WIND INFRASTRUCTURE: A SUMMARY

Here we summarise the decision-making process and the EoL options for wind operators.



6. CONCLUSIONS

This report has provided some key insights on how EoL decisions for onshore wind farms and associated waste considerations are being undertaken in Italy. It provides new information on the scale of the challenge including when EoL decisions are being made and how waste is being considered, from undertaking primary data collection in Italy.

As the report shows, decisions on EoL involve technical aspects as well as analytical and political considerations. This report examines the technical, economic and legislative issues, including the policy context and business environment, that are influencing EoL options for onshore wind in Italy. Furthermore, deciding on the future of existing turbine materials brings waste management opportunities and questions over what to do with decommissioned components.

There are a number of lessons from the research. Wind infrastructure EoL represents both an opportunity and a challenge for industry and government departments. Wind industry operators are keen to showcase the environmental credentials of the technology. While Government departments are interested in regulating the way in which long-term, EoL impacts are governed.

The Italian case study shows that policy considerations for EoL issues for onshore wind resides in the opportunities life-extension and repowering offer to reach decarbonisation of the energy sector targets. In particular, managing EoL of renewable energy projects represents many cross-sectoral challenges, that require the sharing of best practices and active engagement from the main players from the renewable energy sector and beyond (including building and construction, electrical and electronics, waste). There is an important role for industry in promoting collaboration between the various actors involved. Successful collaborative platforms are starting to emerge in Italy to share best practice that can support the management and decommissioning challenges of onshore wind infrastructure. Additionally, there is alignment between government's awareness of the opportunities EoL management brings (to reach ambitious decarbonisation targets) and industry's interest in the economic opportunities. Industry needs to grasp the advancement in technological innovation in the market, which favours life-extension and repowering opportunities.

Industry and governments alike need to focus more on the management and decommissioning challenges that European and international contexts face. Identifying EoL decision making and assessing consequent waste issues is not straightforward. When considering waste there are a number of key technical, economic and regulatory questions that must be asked before deciding on the most appropriate EoL option. This is an important message and outcome from the research.

The findings of this research provide valuable insights and lessons to be learned for countries around the world seeking to address this emerging environmental sustainability issue, as the industry matures. EoL management for onshore wind is a relatively new concern and there are many lessons yet to be learned.

7. RECOMMENDATIONS FOR POLICY

In light of the research conducted, we suggest that the Government bodies consider the following:

- Further simplification in respect of national legislation should reflect regional best practices across the territory. This could include the identification of areas that are most suited for life-extension and re-powering. There is a need to accelerate planning and authorisation processes particularly for repowering applications.

- Provide a clear blueprint for 'no-relevant modification' and substantial change in order to support developers in decision making for their sites. There should be a clear identification and examples of modification included in the simplified application and permitting procedures.

- Implement a guarantee fund that actively supports EoL management options at the time of the authorisation of the wind farm, for decommissioning. The guarantee fund will be linked to EoL options and support developers in the later stages of end-of-life management. The fund will help municipalities in mitigating waste management challenges (e.g. logistics).

- Decommissioning of wind turbines needs to be considered at the outset of the permitting and application process. Tender specification – in particular for re-powering projects- should highlight a clear decommissioning pathway and an EoL plan for components, including targets for a certain % of WT and its component that prioritise re-use and recycle.

- Accelerate the introduction of a landfill ban.

8. RECOMMENDATIONS FOR WIND OPERATORS AND DEVELOPERS

In light of the research conducted, we suggest that wind operators and developers consider the following:

- High-quality maintenance is key to extending the operational life span. Develop an end-of-life plan that includes a step-by-step process towards life-extension. This should form part of business model of the site.

- Work with suppliers or professional bodies to guarantee life certificate extensions and re-certify WT assets. Ensure that you work with your supplier to build in a guaranteed life certificate extension and re-certify the assets.

- Information exchange on second-hand market opportunities and sellers of used blades and other components, ensuring that information about the components is made available to customers.

- Contribute to the creation of a repository of type and size of wind turbines including material components that can facilitate waste management opportunities, including recycling.

- Accelerate the development of a value chain for recycling working collaboratively with recycling companies and be open to develop opportunities for testing material recovery innovations.

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APPENDIX 1

Visual Summary of the research: Factors influencing Decision making at end of life

Visual Summary of the research: Afterlife options for wind installations