The Circular Wind Hub

How to facilitate the wind industry to become circular

The Circular Wind Hub

How to facilitate the wind industry to become circular

The project and results described in this report are written by ECHT regie in transitie. The project has been partly funded by the Ministry of Economic Affairs and Climate Policy and the Netherlands Enterprise Agency (RVO). This report has been made publicly available by ECHT regie in transitie to support and stimulate the stakeholders in wind industry to work together towards even more sustainable and circular wind industry.

February 2022

Authors:
Nina Vielen-Kallio
Erik van Diest
Joren Room
Erik Knol

Citation suggestion: N. Vielen-Kallio, E. van Diest, J. Room & E. Knol (2022) The Circular Wind Hub – How to facilitate the wind industry to become circular

Executive summary

The wind industry has proven its capabilities in accelerating innovations in order to provide economically viable and sustainable energy in large scale. However, the stakeholders of wind industry are highly motivated in increasing the circularity and sustainability of wind farms even further. This is important as the resources of our planet are limited and therefore, we need to apply circular strategies not only at End-of-Life (EoL) stage of wind farms, but already at design phase.

The stakeholders across the value chain and member states of European Union were first gathered in 2020 in Moonshot project[1] to evaluate together the most important topics to be considered when increasing the circularity and sustainability. This phase 1 provided nine action agendas ((1) circular permit and tender criteria. Knowledge Hub included action agendas: (2) The modular design, (3) Collaboration in design, (4) Responsibility of materials, and (5) Platform for European wide circular collaboration. The Industrial Hub focused on action agendas: (6) Environmental-specific foundation design and multi-use, (7) retaining data for optimal decommissioning and EoL strategies, (8) Refinery and recycling plant(s), as well as (9) Circular clusters of companies around ports), which were further worked on at phase 2: the Circular Wind Hub.

In 2021 the Circular Wind Hub acted through 3 different working groups, so called "hubs": Policy Hub (PH), Knowledge Hub (KH) and Industry Hub (IH). The PH was further divided to Policy Hub International (PHI) and National Policy Hub (NPH) due to the practical differences in tenders in offshore wind (objective in PHI) and onshore wind (objective in NPH).

Any transition in society requires a balanced developments in the 5 different aspects, social (acceptance), technological (readiness), environmental (impact), economic (viability), and regulative (support), which together are named *STEER aspects.* Interventions and changes related to these aspects are important and required, but it can be argued that regulations have a major role in either hindering or stimulating transitions. Therefore, this report highlights the outcomes of the PH as the objective of the PH was to recognise the needs in policy change, which would increase the circularity and sustainability of the whole industry according to its industrial stakeholders.

The objective of KH was to provide information about current knowledge gaps which still exists and provide suggestions for further research objectives, which would support the implementation of policy changes. The IH was established to build collaborations between industrial partners with target to initiate demonstration projects. Total of almost 200 stakeholders across the value chain worked together to meet the Circular Wind Hub targets.

In PHI the industry stakeholders suggested minimum requirements to include:

A) Landfill and incineration ban for waste

B) Material Passport/Life Cycle Assessment/Environmental Product Declaration

and circular tender criterial to include:

C) Innovative circular design

[1] The ideation process focused on circular strategies in the wind industry (Lobregt et al., 2021)

D) Circular (de)commissioning plan
E) Reduction of greenhouse gas emissions

These suggestions were assessed by KH, which made further assessment on the viability and related uncertainties especially related to digital solutions, which minimum requirement B holds. The uncertainties according to KH are whether information is open and accessible; if manufacturers and operators are willing to share data; how to value future technology; whether standardization of certificates etc. hamper innovation; to which level of detail does the passport need to cover (product info of tech info, lifetime or economical value info, indexation).

In NPH a matrix of actors and their main responsibilities during different phases of the wind farm's lifetime was established in order to understand better the complexity and to assure that correct decision makers are part of any policy changes. Here so-called "buyers group" was initiated, which has the long-term goal to set out a market vision for circular wind turbines, a procurement strategy for private parties, and a coherent set of policy instruments that are implemented by all levels of government nationwide in the Netherlands.

Based on the work done in the Circular Wind Hub the recommendations are: (1) Expand the scope from "circularity" to "sustainability" in policy changes; (2) Implement the suggested policy changes through different policy levels (European, permitting and tender criteria); (3) To keep level playing field and space for new innovations, start with qualitative scoring in tender criteria; (4) Establish Buyer Group for Dutch onshore wind farms; (5) Improve the communication between stakeholders regarding circularity and EoL strategies; (6) Increase data sharing through digitalization; (7) Continue cross-national collaboration for harmonized solutions.

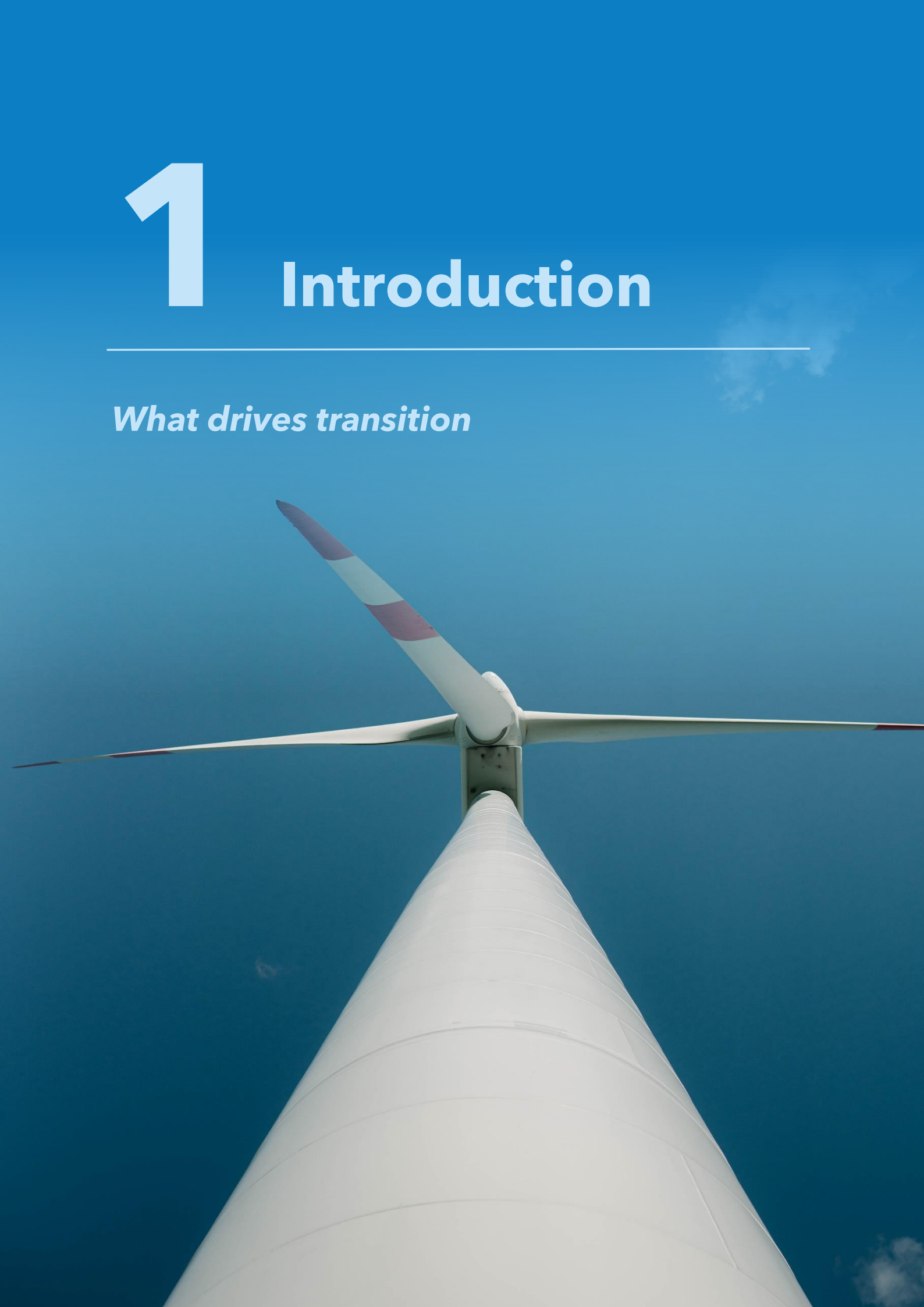
For 2022 and onwards, several projects and initiatives have been started as Phase 3. Consortiums are being built for Horizon Europe calls related to (1) composite recycling demonstration and (2) digitalization. In Rotterdam, DecomCockpit has been established by ECHT, Jansen Recycling Group and CRC to recycle decommissioned wind turbines. Additionally, the Circular Wind Guide was initiated by the University of Leeds and ECHT to increase the knowledge related to circular strategies in wind industry. To increase the resilience in supply chain, an initiative by Circular Industries for Rare Earth Element recycling plant has also been taken. The ecological aspects of the offshore wind farms are further assessed in De Rijke Noordzee project, which aims to find new opportunities to combine nature enhancements and wind energy generation.

When reflecting on the STEER aspects, which facilitate any transition in our society, the largest impact can be made through the recommended policy changes. This reduces the risk of EoL service providers and accelerates the development and implementation of new solutions such as digitalization.

Table of Contents

1 Introduction

What drives transition



1. Introduction

When a transition is needed in a society, it always causes challenges and hurdles. The initiator of the change can differ from for example public to industry, or science, but it can be confirmed that in order to establish new mainstream systems, the policy makers have a major role to play. A multitude of aspects needs to be developed in a balanced way in order to convert any large-scale system, such as our current energy system. These aspects can be clustered in five aspects areas: social (acceptance), technological (readiness), environmental (impact), economic (viability), and regulative (support), which together are named *STEER aspects*. Interventions and changes related to these aspects are important and required, but it can be argued that regulations have a major role in either hindering or stimulating transitions, which is illustrated in Figure 1.

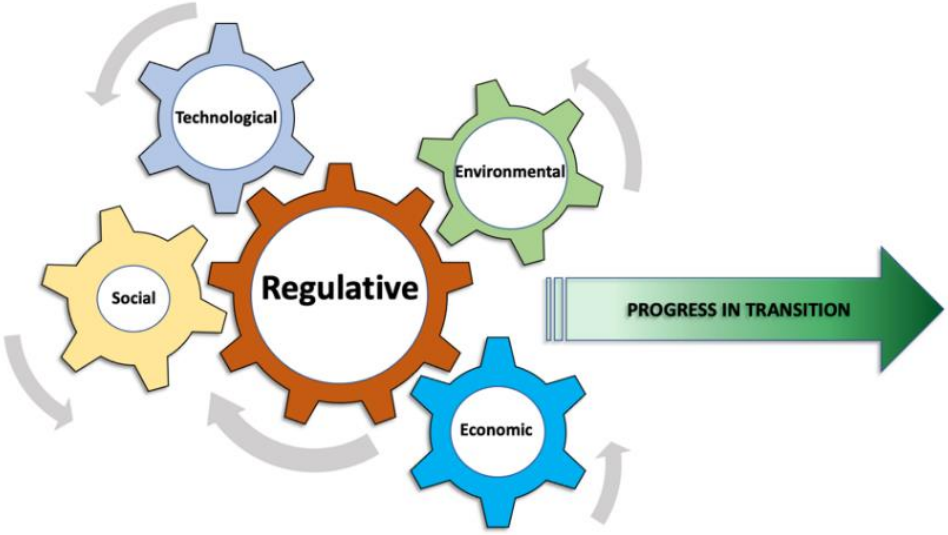


Figure 1 STEER aspects as parts of progress in transition

This same challenge of stimulating appropriate changes regarding all five aspects can be seen in the wind energy industry, which is facing a challenge of increasing the wind energy capacity[2] with historical speed and at the same time the industry is required to meet the latest circularity targets[3] with the lowest cost of energy. When adding the trading tensions between the European Union and China[4], the challenge for the European wind energy industry is massive.

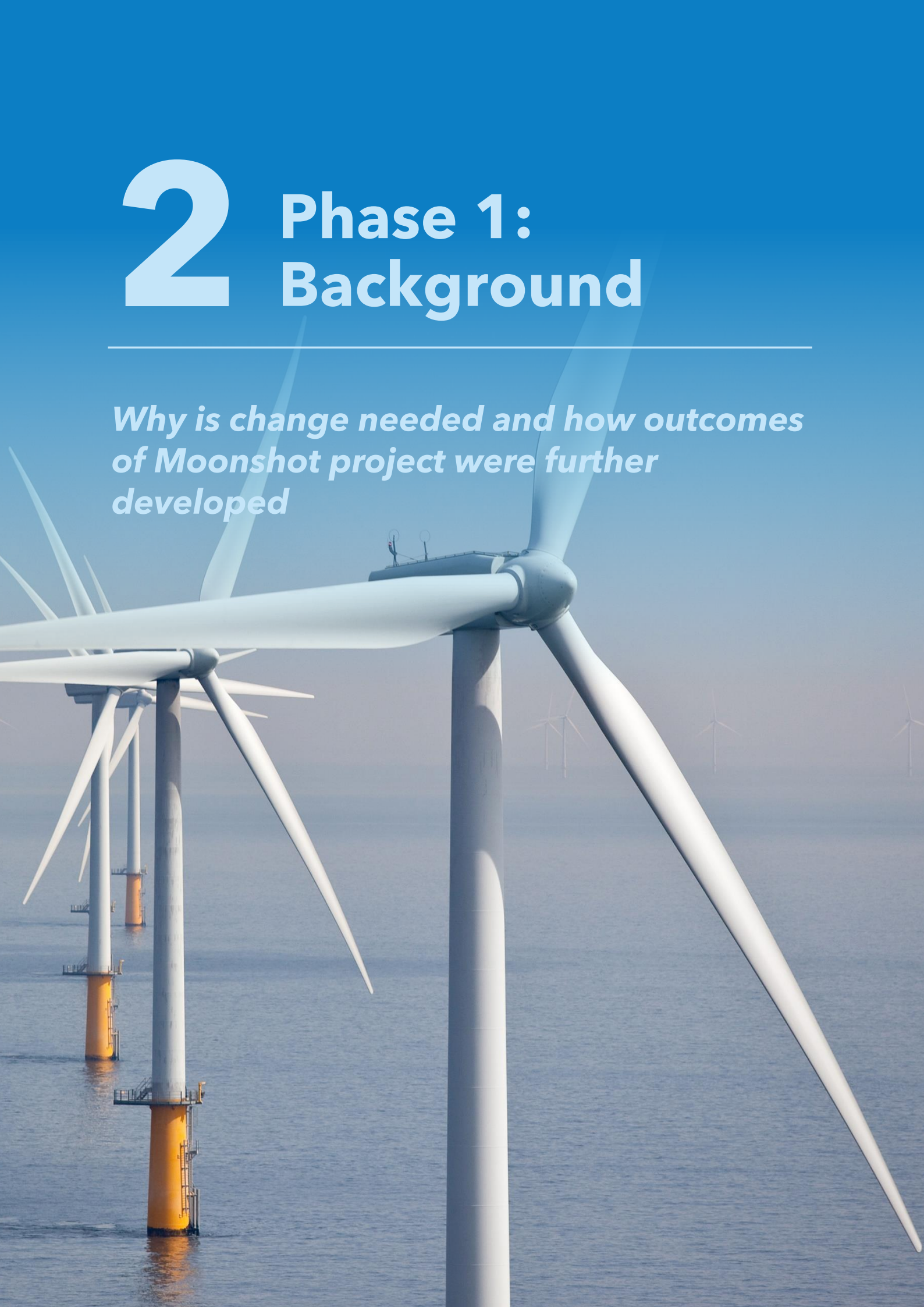
However, the wind energy industry has shown its willingness and drive to expand sustainability and circularity targets even further than the current common targets, which was first proven in Moonshot project[5] in 2020 (Phase 1) and now in the continuation-

[2] An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future (European Commission, 2020)
[3] The European Green Deal (European Commission, 2019), Circular Economy Action Plan (European Commission, 2020)
[4] Action Plan on Critical Raw Materials (European Commission, 2020)
[5] The ideation process focused on circular strategies in the wind industry (Lobregt et al., 2021)

project of the Circular Wind Hub (CWH) in 2021 (Phase 2). The CHW-project organised the stakeholder elaborations on establishing a circular wind industry. This report is focused on the results of CWH. The Chapter 1 provides background information about the Circular Wind Hub (CWH) project and its goal. The Chapter 2 presents the structure and objectives of the working groups in the CWH. In the Chapter 3 the main outcomes are presented. In Chapter 4 recommendations are given related deployment (Phase 3) of increasing the circularity and sustainability of wind industry.

2 Phase 1: Background

Why is change needed and how outcomes of Moonshot project were further developed



2. Background

The current recycling rate of wind turbines is high, close to 90%[6], but there is much more to be improved than the recycling rate alone. To further embed circularity – which includes more than recycling - in the wind energy industry, the complete value chain should be further improved by implementing new policies, new technologies, and new collaborations. Even though the discussion is often focused on the wind *industry*, it is crucial to recognize that valuable input from policy makers and academia is fundamental.

In order to design and develop viable processes and solutions in circularity (and other targets, such as capacity increase of wind energy), they need to fit the targets of different level policies (EU, national, regional etc) or there needs to be a policy change in some of these levels, which facilitate the joint target better. Practical example of an EU target, which should be considered by the wind industry, is the aim to keep critical raw materials in Europe[7]. At the same time, the academia has research capabilities, which are out of reach especially for SMEs in the industry. By disseminating the valuable information gathered and developed in academia, to the other stakeholders, the knowledge level in the wind energy sector can be improved and further developments are easier to implement. Additionally, the whole value chain of the industry needs to work together towards circularity.

Therefore, the joined goal of the stakeholders in circular wind industry, is to establish several physical End-of-Life (EoL) hubs for the decommissioned wind farms across the Europe. As important as the viable circular EoL solutions are to be established for the decommissioned turbines, it is also crucial to integrate smart circular strategies to wind industry, where the complete lifecycle of materials is taken into account. This means that the responsibility for circularity is not only at the stakeholders providing EoL services, but even more at the designers and manufacturers. Here again, the regulators have a major influence, because through policy measures, it is possible to improve or hinder the transition towards circular economy or introduce very strict responsibility shifts such as extended producer responsibility (EPR)[8].

[6] How wind is going circular: blade recycling (ETIP wind, 2019)

[7] Action Plan on Critical Raw Materials (European Commission, 2020)

[8] Extended Producer Responsibility: Design, Functioning and Effects (PBL Netherlands Environmental Assessment Agency and CPB Netherlands Bureau for Economic Policy Analysis, 2021)

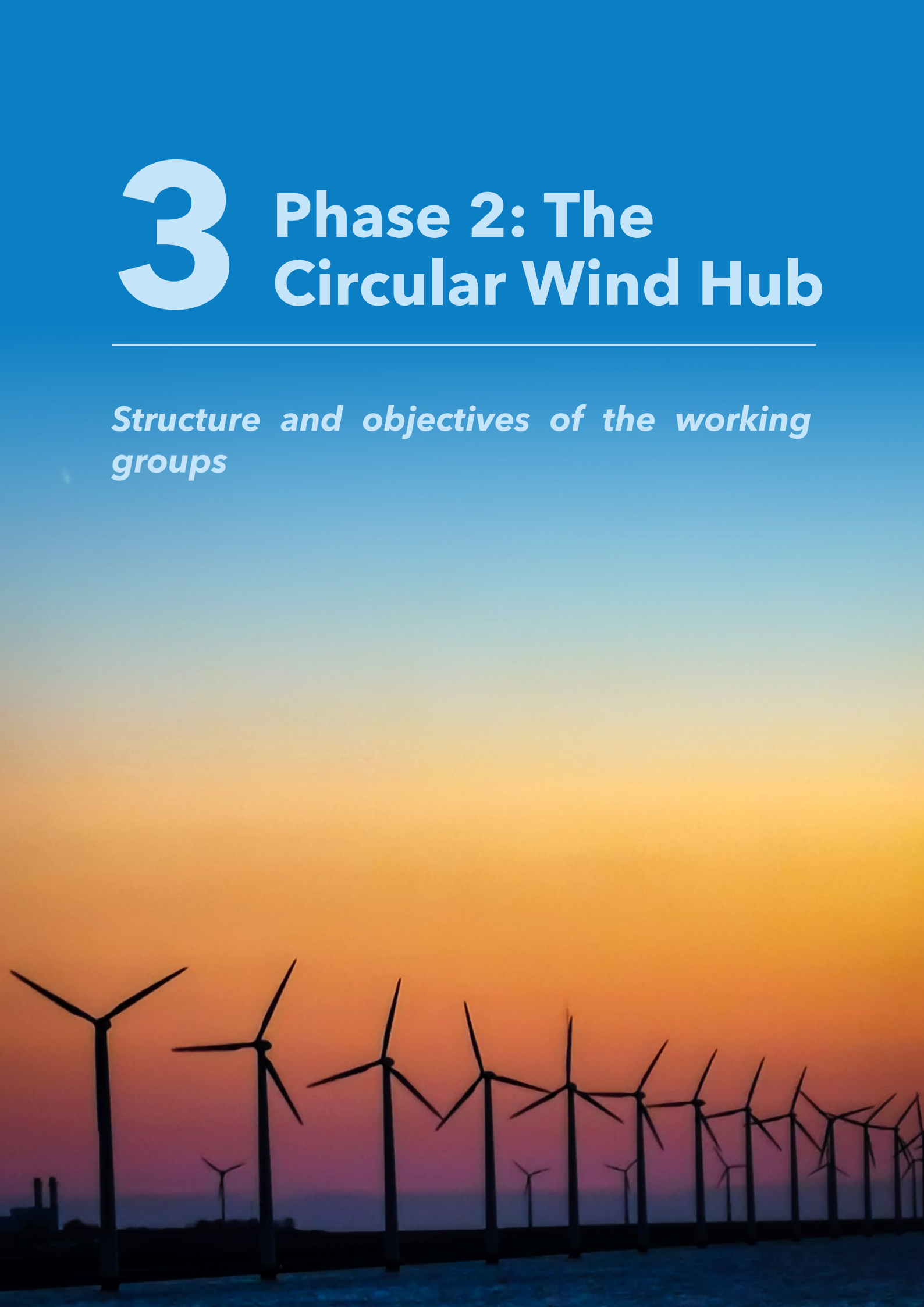
To assess viable approaches towards a circular wind industry and actually implement these approaches, a 3-phase strategy was designed. The Phase 1 was the so-called Moonshot project, which started in 2020 and gathered over 150 stakeholders from the industry to recognize the different challenges, which should be taken into account when aiming for a circular economy in the wind energy industry. The outcome of the Moonshot project[9] was 9 industry-recommended circular action agendas.

These 9 recommendations became the starting point of Phase 2: the Circular Wind Hub, which included 3 different working groups, called hubs: Policy Hub (PH), Knowledge Hub (KH), and Industry Hub (IH). Goal of phase 2 was to work out action agendas; and initiate circular business cases and pilot projects. This report is focused on the outcomes of this Phase 2.

[9] The ideation process focused on circular strategies in the wind industry (Lobregt et al., 2021)

3 Phase 2: The Circular Wind Hub

Structure and objectives of the working groups



3. Circular Wind Hub

The Circular Wind Hub comprises the Policy Hub (PH), the Knowledge Hub (KH), and the Industry Hub (IH), and is the central community where a select group of stakeholders (from companies, NGOs, knowledge institutes, and governmental organizations) have collaborated towards a common goal: a circular wind industry. The CWH-project focused on the local, national as well as on the European level and facilitated interconnected collaboration and synergies. The process included stakeholder inventory, problem-identification, input and collaboration on challenges and opportunities, knowledge sharing, ideation for a circular wind industry as well as solution-finding and creating synergies.

The 9 circular action agendas identified in phase 1[10] were addressed in the three working groups (so-called "hubs"). The Policy Hub, which was further divided between a National Policy Hub (NPH; focussing on the Dutch policy domain) and a Policy Hub International (PHI), addressed (1) Circular permit and tender criteria. The Knowledge Hub included the following action agendas: (2) Modular design, (3) Collaboration in design, (4) Responsibility of materials, and (5) Platform for European wide circular collaboration. The Industrial Hub focused mainly on the following action agendas: (6) Environmental-specific foundation design and multi-use, (7) Retaining data for optimal decommissioning and EoL strategies, (8) Refinery and recycling plant(s), as well as (9) Circular clusters of companies around ports.

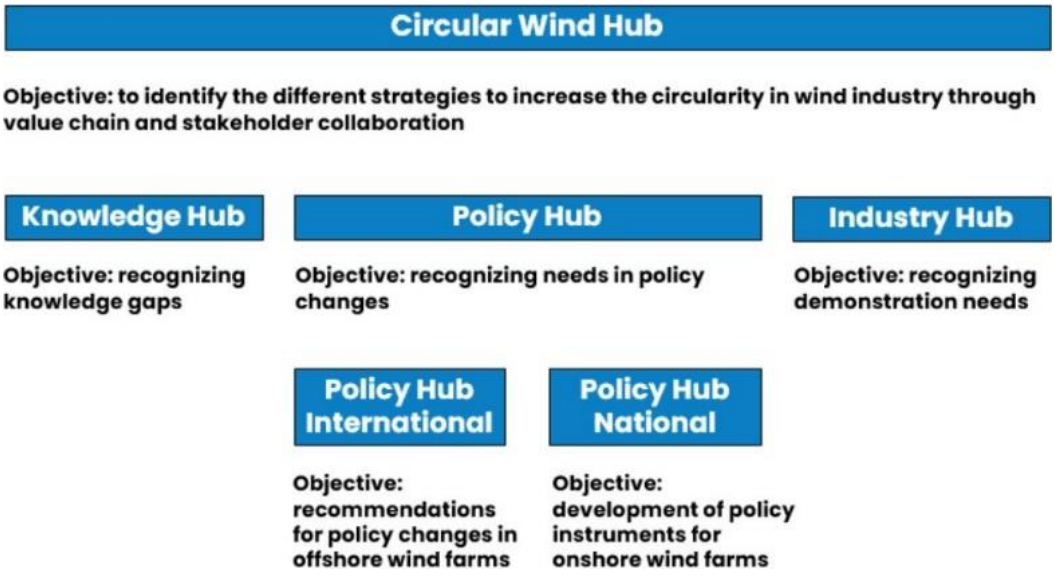


Figure 2 the Circular Wind Hub and its working groups and objectives

[10] The ideation process focused on circular strategies in the wind industry (Lobregt et al., 2021)

The objectives of the working groups are presented in Figure 2. One important overarching objective was to recognize which knowledge and industry- related developments are needed in order to apply the suggested policy changes originating from the policy hub. Here KH and IH had an important role of giving views on the policy-related suggestions and validate them.

The objective of the PH is to assess the possibilities to improve policies, which have an impact on sustainability and circularity of wind farms. The PH recognised the differences between onshore wind farms and offshore wind farms in terms of for example project scale, involved (national and international) stakeholders, and permitting and tender procedures. This is the reason why the PH was split in two groups: National Policy Hub (NPH) and Policy Hub International (PHI). The NPH mainly addressed the circular challenges related to local onshore wind farm initiatives in the Netherlands. The PHI dealt with the circular policy aspects of Dutch offshore wind farm initiatives and related international (European) aspects.

In NPH, the involved governmental organisations, companies, and NGOs all shared the need to make a transition in the onshore wind industry towards circularity. However, the individual stakeholders in onshore wind energy do not have the power or the means to change the industry. They either have knowledge, experience, capabilities, and/or the power to force change through policies, but neither of them have all the circular transition pieces in their hand. In the NPH working group delegates from the national, regional, and municipal governments have been gathered to identify their respective roles in the transition process to a more circular onshore wind sector. NPH stakeholders have identified 4 areas that require further investigation: 1) Uncertainty regarding the division of roles between parties, and the power of governmental organisations when it comes to implementation of new policies; 2) Definition for circularity in general; 3) overview of obstacles and bottlenecks regarding a transition towards circular onshore wind farms; and 4) State of play on circularity in the onshore wind industry.

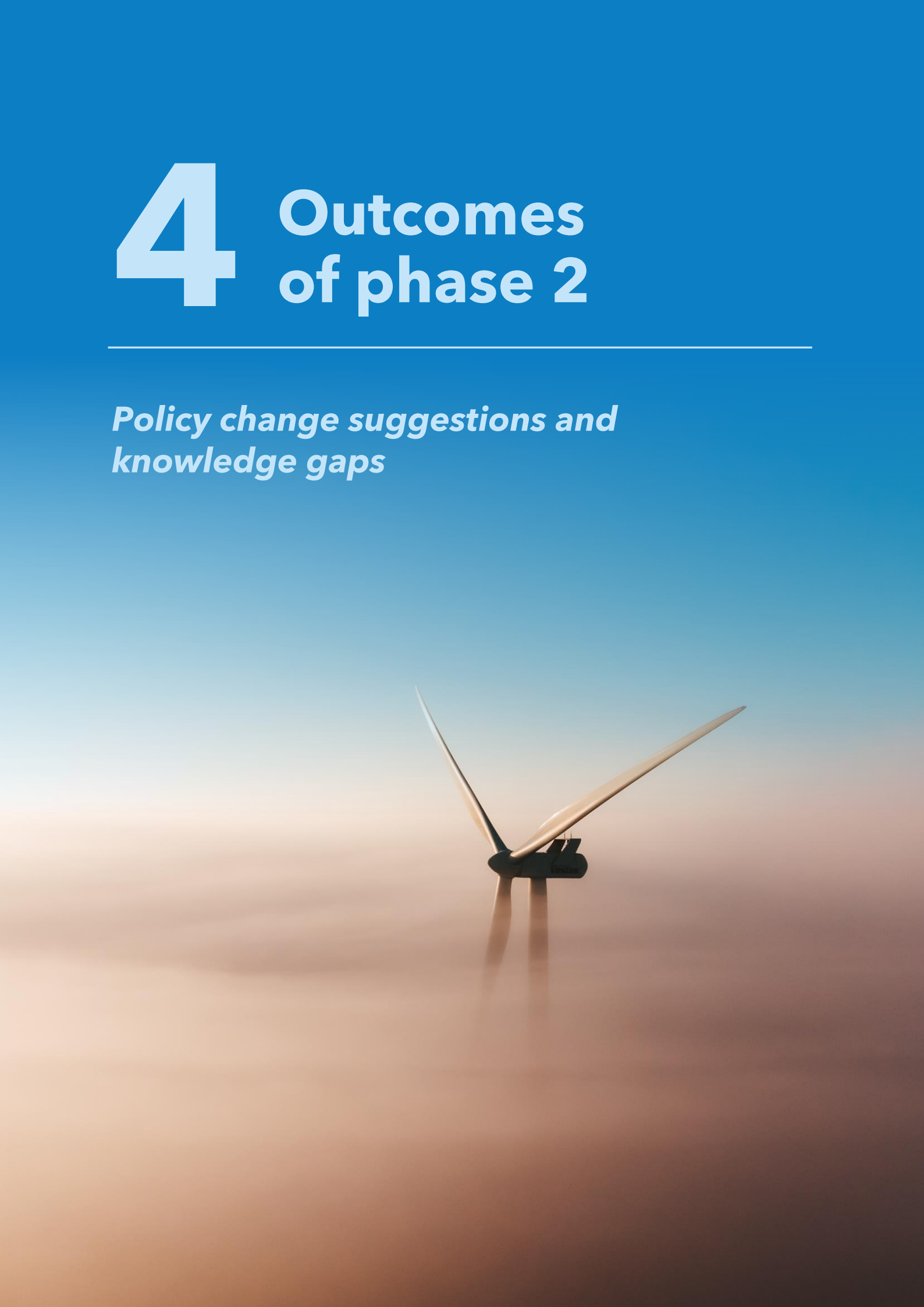
The PHI was established to recognize the (industrial) needs for policy changes in the field of circularity in the offshore wind industry. The objectives were: 1) Present the view of industrial stakeholders on preferred enhancements in policy areas to stimulate circularity and sustainability in the Dutch offshore wind industry; 2) Provide a framework of suggested changes in policy measures; and 3) Give concrete suggestions to the Dutch policy makers on which policy changes would improve the circularity and sustainability of offshore wind farms, including special attention for tender criteria.

KH has been instrumental in the collaborations with developments of PHI and IH. Here, cross-sector and cross-country collaboration concerning knowledge and expertise took place. Experts involved in the wind energy industry addressed European wide standards, impacts, and projects in wind energy sector. The objective of the KH was to facilitate and share knowledge. Furthermore, the hub aims for 'knowledge preparations' in order to fuel and start circular wind demonstration projects particularly related to 'design for circularity' and knowledge sharing.

To implement circular strategies in the wind energy industry, the IH aimed to facilitate 1) the start of demonstration projects and 2) the building of relevant infrastructures for circularity as a basis for circular refinery and recycling plants that will serve the European wind energy industry. Such plants will extract, (re)design, (re)manufacture, and recycle materials and parts. Hereby ideas and initiatives from other hubs come together to explore the start of demonstration projects. The main objective of the IH was to bring together wind energy stakeholders who have a common interest on demonstration projects in the field of circularity. Due to the current knowledge gaps, uncertainties in future policy drivers, and the price-driven market structure, especially smaller actors have difficulties to bear the financial risks included in larger demonstrations. This is the reason why the IH also facilitated information sharing about funding and other financial opportunities relevant for demonstration initiatives. Due to the current knowledge gaps, uncertainties in future policy drivers and price-driven market structure, especially smaller actors have difficulties to bear the economic risks included in larger demonstrations.

4 Outcomes of phase 2

Policy change suggestions and knowledge gaps



4. Outcomes

This chapter presents the most relevant outcomes from the CWH, which are further transformed into practical recommendations in the next chapter. Topics that will be addressed are: 1) circular permitting and tender criteria regarding offshore wind; 2) (potential) roles of governmental organisations (local, regional, national) to stimulate circularity in onshore wind; 3) buyer groups to trigger circular innovation among suppliers in the supply chain; 4) suggestions for knowledge development and sharing, and 5) demonstration projects to gain experiences.

4.1 Circular permitting requirements and tender criteria regarding offshore wind

The PHI recognized 11 topics which are related to enhancing policies with respect to circularity and sustainability in offshore wind. These topics are organized by ECHT based on their impact locations during the wind farm's lifetime (See Figure 3).

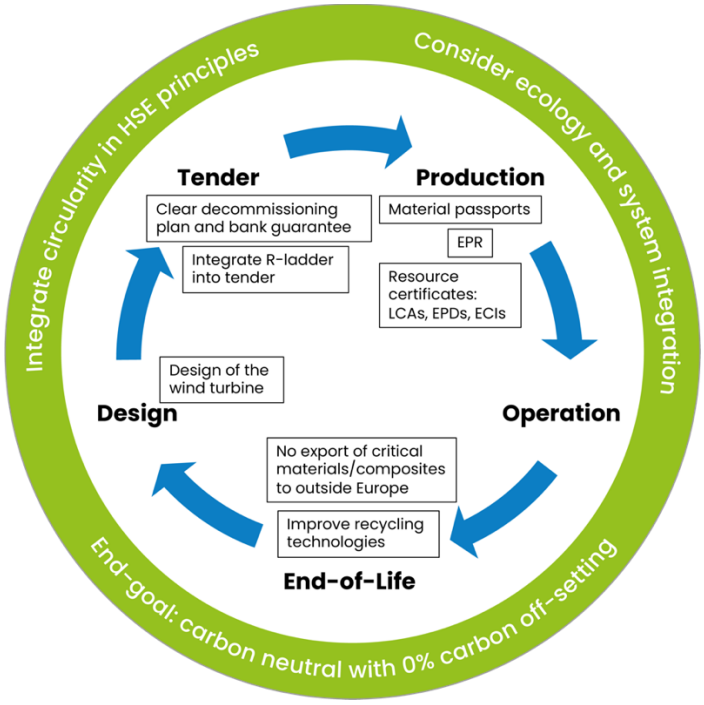


Figure 3 Policy enhancing topics in circularity and sustainability in wind farm's lifetime

From these topics two were chosen by the industrial stakeholders as minimum requirements regarding circularity in offshore wind farm initiatives and three as tender criteria. These are further introduced below.

Two suggestions for minimum requirements on circularity and sustainability:

a. **Landfill and incineration ban**
   Landfill ban (mostly relevant for wind turbine blades) is already part of national policies in several European countries. There are several industrial stakeholders who are either committed to following it voluntarily or actively already promote that a landfill ban should become a European policy. As there are already options available beyond landfill and incineration even at commercial scale, banning landfilling and incineration of waste should be implemented.

b. **MP, LCA, and/or EPD**
   There is also a clear recognition of need for information sharing and transparency on the circularity characteristics of materials and components used in offshore wind farms through certificates and/or assessments methods like Material Passports (MP), Life Cycle Analysis (LCA) and/or Environmental Product Declarations (EPD). Digital services are perceived as essential when implementing requirements to provide MPs, LCAs and/or EPDs. Further work would be needed in the development of such digital services, but in general the support from the industry is existing.

Three tender criteria regarding circularity and sustainability

The industrial stakeholders see the need for offshore wind tender criteria dealing with circularity and sustainability. The tender criteria should be organized in such a way that it will facilitate innovation and it will keep the level playing field for all actors. Therefore, industrial stakeholders prefer qualitative tender criteria as starting point. The involved industrial stakeholders also recognized the need of pushing tender criteria of circularity and sustainability from the national level(s) to the European level.

In general, implementation of circularity and sustainability to tender criteria were seen as positive, because it gives a correct sign to and push for the industry. In order to utilize an already globally existing framework, it was seen beneficial to implement the United Nations Sustainable Development Goals (SDGs) to the tender criteria.[11] The specific tender criteria put forward by the industrial stakeholders are:

a. **Circular innovative design**
   Circular innovative design would provide the industry the opportunity to implement a variety of strategies related to material (and components) circularity. These include for example the use of biobased raw materials or more effective recycling of the materials after the operational phase of the wind farm.

b. **Circular (de)commissioning plan**
   The circular (de)commissioning plan refers to strategies used in the logistic processes and is focused to ease the decommissioning phase already during the commissioning phase of the offshore wind energy project. Through long-term orientated decisions related to decommissioning strategies during the design and

[11] SDG 12: Responsible consumption and production

commissioning phases, it is possible to lower the total environmental impact of the offshore wind farm.

c. **Reduction of GHG emissions**
As several sustainability targets are currently linked to CO_2 emissions, the industry partners would like to see consistency which keeps the level playing field and supports different innovations strategies. Therefore, it is also suggested to not only focus on the reduction of CO_2 emissions, but on the reduction of GHG emissions.

The full descriptions of the three tender criteria are presented in Appendix A.

When assessing the circularity and sustainability (policy) measure suggestions of the industry of PHI within the setting of the CWH-project and reflecting them on the current policy frameworks and domains, a three level approach can be identified: 1) the landfill and incineration ban should be implemented through European wide policy; 2) the certificates and/or assessments methods (MP, LCA, and EPD) should be part of the offshore wind project permitting process wind farm site decision; and 3) the remaining suggestions should be implemented as tender criteria. In order to provide a clear taxonomy of the policy levels and a division between circularity and sustainability measures, the suggested measures are positioned in a framework (Figure 4).

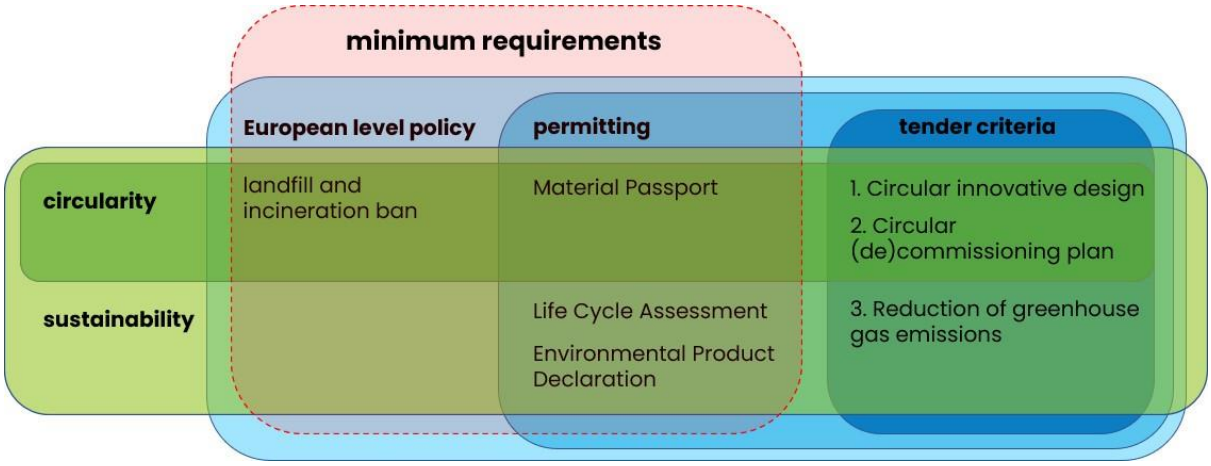


Figure 4 Framework of policy changes in different domains

4.2 Roles of governmental organisations to stimulate circularity in onshore wind

The NPH came up with outcomes relevant for governmental organisations involved in onshore wind. To gain insight on the current knowledge and possibilities for governmental organisations mostly involved in during the lifetime of Dutch onshore wind farms, a matrix was developed. This included the different phases of an onshore wind farm are set out against the different domains on which an involved governmental organisation acts.

The domains are 1) legal framework & instruments, 2) the authority of the government body, 3) action perspectives to stimulate circularity as government body, 4) Perceived risks that might slow down the process towards circularity, and 5) Current activities employed by government bodies. This matrix is presented in Appendix B.

The options for governmental organisations to give a push on circularity were mostly identified in the development phase of onshore wind farms. During this phase governments work out anterior agreements with developers including attention for the building regulations for a wind farm site. There might be opportunities for the governmental organisations to add extra demands above the basic legal requirements, for example on circularity. Other options that were identified included a bonus on top of subsidy awards for the (additional) circularity measures a developer implements (for example due to additional regulations in permits).

4.3 Buyer groups to trigger circular innovation among suppliers in the supply chain

In 2050, every sector in the Netherlands has to be fully circular, so the Dutch government has started a national program in 2016 to make this transition happen. One of the program's instruments is 'Buyer group'. The idea behind these groups is that suppliers prefer to have a robust forecast of incoming projects (short-term and mid-term) in order to better weigh the feasibility of investing in innovative (e.g. circular) products and services for clients. As a single supplier (especially for smaller companies) it is not easy to have a good view on its project's pipeline in order to make strategic innovation decisions. However, by combining the purchasing forecasts of a group of (smaller) buyers and share these insights in supply chains, suppliers can be better triggered to consider and develop innovations that will have specifications that are above the current standards, for example on circularity. The main purpose of these buyer groups is to active innovation and market development in supplier networks. It is not the goal to combine purchasing power.

The long-term goal of the buyer group-approach is 1) to set out a market vision for circular wind energy, 2) to offer a (collective) procurement strategy that enables suppliers to innovate, and 3) to have a more coherent set of policy measures to enhance circularity in the wind energy industry in the Netherlands.

4.4 Suggestions for knowledge development and sharing on circularity

In order to implement new policies related circularity and sustainability in wind energy industry, it is important to reflect on the current state of the knowledge and possible knowledge gaps. Based on research[12] the focus in academic literature is still mainly on maintenance of offshore wind farms. Other strategies related to circularity are in minor role as shown in the Figure 5.

[12] A framework and baseline for the integration of a sustainable circular economy in offshore wind. Velenturf, A.P.M., *Energies*, 14, 2021

The clear conclusion is, that (scientific) knowledge development regarding circular strategies is still very much orientated on the operational phase in the wind farm's lifetime and more knowledge gathering and exchange should be focussed on other circular strategies, especially to those which higher positions in the so-called 'R-ladder, which are presented more in detail in Appendix C.

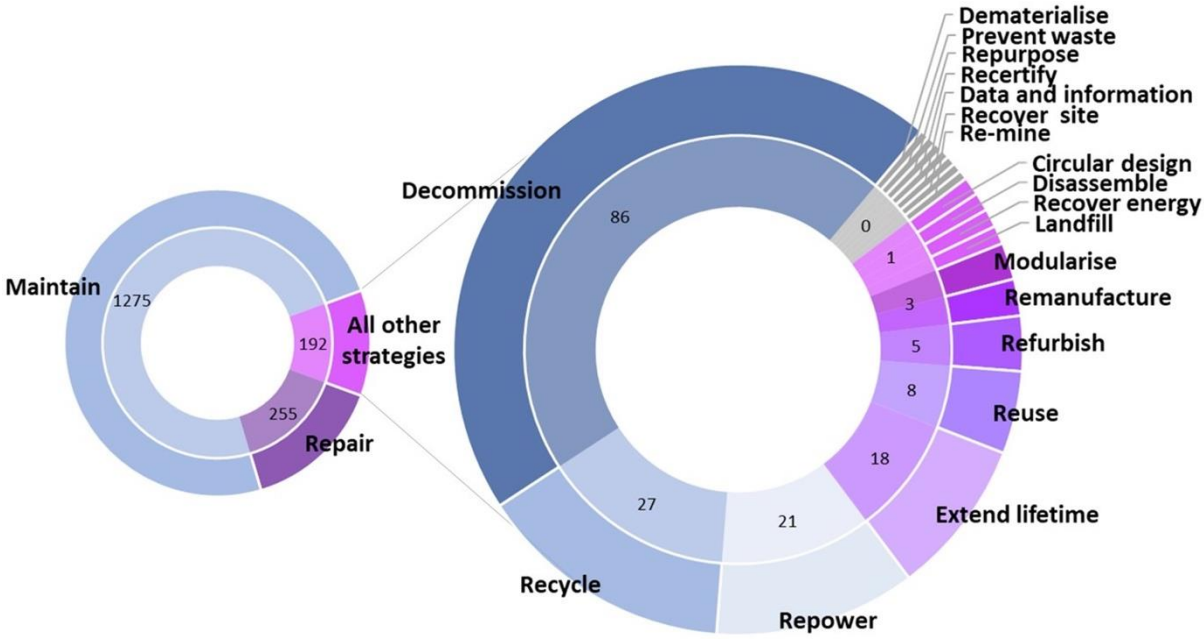


Figure 5 Scientific knowledge development on circularity in offshore wind in perspective. Based on research of Velenturf (2021)

It is expected that the coming years the wind energy industry will focus stronger on knowledge development and sharing regarding circular solutions positioned higher in the 'R-ladder'.

Also, this project gives sound directions for knowledge development and sharing, for example in the field of "data and information on circularity". This topic is hardly represented in the academic literature (see Figure 5) although the PHI stakeholders strongly showed their interest and willingness to make structured information sharing (MP, LCA, and/or EPD) part of minimum requirements for the industry (see section 'Circular permitting requirements and tender criteria regarding offshore wind' earlier in this chapter). Similar conclusions were drawn also regarding funded project in UK and EU. The result of this gap analysis is more detailed presented in Appendix D. Here further analysis should be performed to include different national level and regional level projects.

Also, the KH stakeholders gave relevant directions for knowledge development and sharing related to circularity in the wind energy industry. The KH pointed the (most) relevant topics for knowledge development: 1) MP (in general); 2) LCA embedded in tender and evaluation criteria; 3) LCA integrated in the waste hierarchy; 4) R-strategies; and 5) modular design of wind turbine generators (WTG).

These topics are not only interesting from the academic perspective, but directly connected to the suggestions of PHI stakeholders and the IH stakeholders.

Additionally, the KH advised the PHI the following: 1) embed (elements of) the waste hierarchy in the (checklists of) decommissioning guidance (used in the industry); 2) work with the industry to create so-called 'Circular Economy Guidelines'; 3) implement Environmental Cost Indicator (ECI) scores; and 4) clarify the extended producer responsibility due to current unclarities in responsibility at EoL (OEMs versus developers/operators).

The KH stakeholders also acknowledged knowledge sharing opportunities related to 'data transparency and intellectual property'. As indicated earlier in this report, structured data sharing via data services (with the aid of e.g. MP, LCA, and/or EPD) contributes to enhancing circularity, especially in the EoL phase of the wind farms. However, there is a delicate balance between data transparency in the value chain and protecting the intellectual property (IP) of manufacturers (OEMs) and operators. The KH pointed out various (research) topics that has to be addressed with the stakeholders: 1) degree of openness and accessibility of information; 2) willingness of manufacturers and owners/operators to share data; 3) how to value future technology; 4) whether standardization of certificates and/or assessments methods (like MP and EPD) could hamper innovations in circularity; and 5) level of detail of data recorded in MPs (and alike methods).

4.5 Demonstration projects to gain experiences and to limit (existing) uncertainties

The IH stakeholders have made strong elaborations on the relevance of demonstration projects to proceed with circular strategies and innovations. More field experiences are needed how the industry should deal with for example EoL material streams. It was recognized that there are uncertainties who the 'problem owner' is regarding the actual processing of EoL materials and what the best strategies are to implement higher levels of circularity (looking at the R-strategies in the so-called R-ladder). Most of the time, the industry's uncertainties lie on the economic risk. For example: when landfilling and incineration are (still) allowed, the costs of new circular solutions should be able to compete with the current (and future) prices of landfilling and incineration. This is a challenging setting especially with materials (such as composites) which could have a (very) low or negative value at the EoL market. Financial incentives are needed to start experimenting with these (technical and economic) challenges.

Additional to financial incentives, the implementation of new demonstrations requires the alignment of these demonstration projects with relevant initiatives across Europe. For instance, across Europe several initiatives are active in composite recycling and REE (rare earth elements) recycling[13]. A systematic and open tracking of relevant initiatives for a circular wind industry is currently lacking.

[13] Rare earth elements (REEs) are essential for most wind turbine generators. New recycling techniques need to be developed and implemented to keep the scare elements in the value chain

Alignment inside the industrial sector, across the value chain and inside geographical region of the potential demonstration location would improve transparency and increase opportunities for balanced development of circularity in wind energy sector.

There are several projects initiated as spin-offs from this CWH project. They target on increasing circularity, rely on new types of business models, and aim to increase the resilience of the value chains in Europe. These projects are further described in the next chapter.

This chapter has given an overview of the main outcomes of the stakeholder elaborations within the various workings groups ('hubs') of the Circular Wind Hub project. Close to 200 stakeholders (mostly companies active in or for the wind energy industry) have participated through multiple webinars and discussion sessions. The perspectives received from these stakeholders has led to various recommendations (for policy makers, industry, and researchers) and concrete suggestions for follow-up initiatives - being part of phase 3 of the transition towards a circular wind energy industry. The next chapter highlights the recommendations and gives an overview of the most relevant initiatives that could be linked to phase 3.

5 Recommendations and phase 3 outlook

How to continue improving circularity of wind industry in 2022 onwards

5. Recommendations and phase 3 outlook

The recommendations provided in this chapter rely on the combined outcomes of the different working groups, with emphasis on the policy change suggestions.

5.1 Landfill and incineration ban as European level policy for wind industry

The willingness of the industrial stakeholders to implement a landfill and incineration ban related to residual streams of decommissioned offshore wind energy farms speaks for the trust the stakeholders have regarding upcoming solutions. In summer of 2021 also Wind Europe has called for a European wide landfill ban of wind turbine blades by 2025[14].

Currently, only some European countries have a national level landfill ban in place for wind turbine blades and for example some wind farm operators have already committed to recycle all the wind turbine blades by 2030[15]. The first steps have been taken, but these actions can be further supported through policy measures on European level.

By implementing a landfill and incineration ban regarding residual streams of decommissioned offshore wind energy farms, a clear and concrete signal is given to the industry and other stakeholders that other end-of-life strategies are needed and supported.

5.2 Starting with qualitative tender criteria regarding circularity and sustainability

To keep a levelled playing field and opportunities for new innovations to emerge, the industrial partners have a strong preference of keeping the scoring of tender criteria related to circularity and sustainability qualitative instead of quantitative in the coming period. Before there is a systematic process and/or widely accepted standard for quantitative measuring of circularity and sustainability aspects of offshore wind energy, keeping the scoring of tender criteria qualitative would enhance the industry's willingness to accept the changes faster. At later stage, when more experience is gained with certain circular tender criteria and a baseline has been recognized, it is possible to (gradually) implement quantitative scoring on circularity in tenders. This is illustrated in Figure 6.

[14] How to build a circular economy for wind turbine blades through policy and partnerships (Wind Europe, 2020)

[15] Vattenfall commits to landfill ban and to recycle all wind turbine blades by 2030 (Vattenfall press release, 2021)

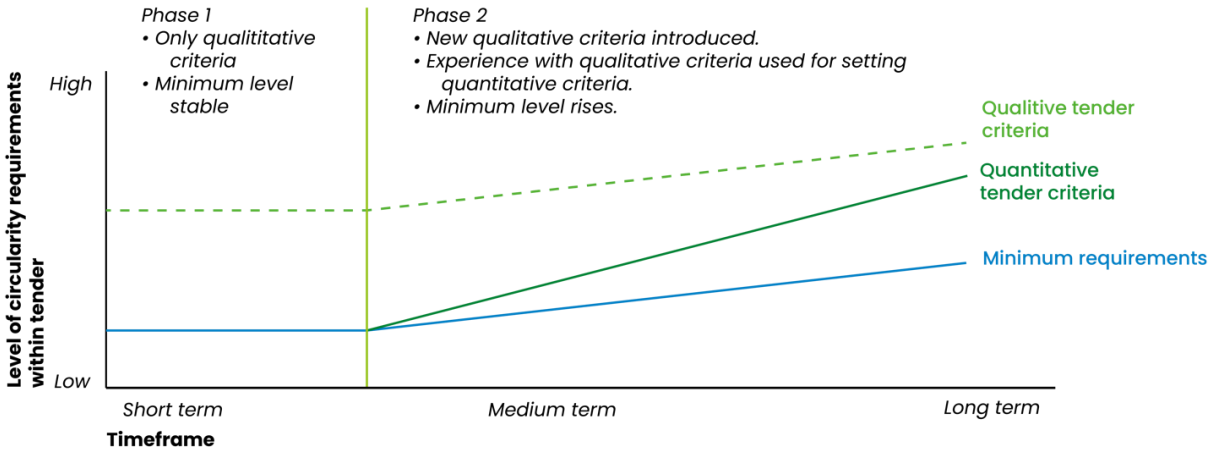


Figure 6 Phases in applying minimum requirements, qualitative tender criteria and quantitative criteria regarding offshore wind farms permits and tenders

During the phase of gaining experiences and searching for a baseline approach, the government could stimulate the learning curve on circularity and sustainability strategies related to the phases of a wind farm. For example, the government could obligate the wind farm owners/operators (and related stakeholders) to report on circularity and sustainability efforts and results with respect to the operational phase of wind farms (GHG emissions of maintenance activities, material flows and recycling activities related to repairs etc.). These reporting obligations will increase the transparency and will provide double benefit:

1. Better understanding of the governmental organisations on relevant aspects of a baseline approach, and better decision making of these organisations on minimum criteria and (qualitative and quantitative) tender criteria;
2. Industry partners becoming more knowledgeable about their own environmental impact which gives them more opportunities to track and improve it in a systematic way, and to be better prepared for future minimum requirements and tender criteria regarding circularity and sustainability.

At later stage - when the baseline is found and better understood - the bidders can decide which quantitative values and to what extend they are willing to share in a systematic and transparent way in tender biddings. With the results of the first qualitative tender, a baseline can be set for next offshore wind farms. During this incremental process the design of each following offshore wind farm will be more sustainable.

5.3 Create buyer groups that could trigger circular innovation in the supply chain

It is recommended to establish buyer groups related to the development of Dutch (onshore) wind farms. As indicated in this report, a buyer group will combine purchasing forecasts (related to the development and operations of wind farms) and share these insights in supply chains. These insights could trigger suppliers to consider and develop innovations, including innovations in the field of circularity.

Included in such a buyer group should be developers, owners/operators, and representatives of governmental organisations (national, regional and local). It is advisable to (initially) support the buyer group by an experienced external party.

5.4 Expansion of scope from "circularity" to "sustainability" in policy changes

The original scope of the Policy Hub International project was to assess the preferred and recommended measures for policy changes by the industry related to *circularity*. However, during the various stakeholder meetings and the principals a strong base of evidence has been gathered to support the industry's drive to expand this scope more towards *sustainability.*

Such a more holistic and broader scope is better aligned with the Dutch and European ambitions to be as society climate neutral[8], fossil free, and circular-based around 2050[9]. The broadening of the scope from circularity to sustainability opens more policy steering opportunities for governmental bodies regarding the offshore wind industry and increases the opportunities for this industry to optimize its footprints (material usage, GHG emissions, environmental impacts etc.).

5.5 Increasing data sharing through digitalization

Digital services provide new opportunities in data storage and sharing. By developing an industry wide digital service where data related to Material Passports (MP), Life Cycle Assessments (LCA), and/or Environmental Product Declarations (EPD) could be stored and shared in a controlled way, it is possible to utilize data that becomes important during the development phase, the installation phase, the operational phase (which includes maintenance and repair), and the EoL phase of offshore wind energy farms.

By storing data systematically (considering the intellectual property of OEMs and operators) and providing access to it when needed, it is possible for industrial actors to make new circularity and sustainability assessments, when necessary, also regarding new innovations to be developed and implemented. By increasing the possibilities for data sharing, circular and sustainability strategies can be optimized by the offshore wind industry in such a way that the industry fully supports the objectives of the European Commission's Circular Economy Action Plan.

Development of such a data storage and sharing tool can be done in phases, by first implementing it only for one components of the wind turbine (such as blade), next for a complete wind turbine generator (WTG) and eventually for a whole wind farm (including for example supportive structures and balance-of-plant infrastructures).

5.6 Improve the communication between stakeholders regarding EoL strategies

By establishing more clear knowledge baseline of circular strategies, the communication between stakeholders can be improved with the aid of a guideline. Such a guideline would also support the industry to recognize opportunities of sustainable business models and create new synergies between stakeholders.

5.7 Continuation of cross-national collaboration

Further collaboration is needed (1) between stakeholders in the value chain, (2) between industry and policy makers, and (3) across the member states.
The European Commission, individual member states, and the offshore wind industry share mutual interest on increasing the circularity in and sustainability of the wind industry, but a holistic, transparent, and systematic approach of sharing these interests is missing. This has been recognized not only by the partners of PHI of the Circular Wind Hub, but also by the Knowledge Hub and Industry Hub partners.

By initiating a European level collaboration focused on multi-level and interdisciplinary topics regarding circularity and sustainability in the offshore wind industry, there is an opportunity for multi-direction knowledge sharing and learning which enables the energy transition based on the most circular and sustainable principles. This type of collaboration could be utilized through Public Private Partnerships or as an additional taskforce working together with North Seas Energy Cooperation.

Additionally, harmonization of policies in (at least) European level compared to each country having their national ones, could bring benefits for the involved stakeholders. The industrial actors are most of the time operating internationally and find it challenging to accommodate to the various national policies and requirements across Europe and the periodic changes of these national policies and requirements. By increasing harmonization on European level harmonization as much as possible, it would accelerate tender procedures and processes due to more rapid learning processes of all involved stakeholders.

As the target of the European Commission is to increase the offshore wind capacity from 25 GW to 60 GW by 2030, and to 300 GW by 2050[12], all possible improvements regarding governmental procedures and processes are required in order to meet these targets. Even though the industry is pushing hard to enhance the capacities of individual turbines and offshore wind energy farms, the governmental permitting process is often seen by the industry as one of the major bottlenecks for speeding-up the upscaling ambitions of the offshore wind industry. Harmonization of (at least some part of) the wind energy related policies would be one solution that eases the process for all the stakeholders involved.

5.8 Initiated projects for Phase 3 of the transition towards a circular wind industry

This sector will give an overview of the most relevant initiatives that could be linked to Phase 3 of the transition towards a circular wind industry.

5.8.1 The Circular Wind Guide

To increase the understanding of different circular strategies in wind industry, this initiative aims to translate valuable academic findings related to circular business models into industry-friendly information package labelled as 'Circular Wind Guide'. This guide will present 18 different circular strategies, which go beyond traditional "recycling". By introducing the strategies systematically and giving practical examples of already utilized strategies, it is possible to increase the circular opportunity recognition of stakeholders in the industry and in the policy domains. This guide will be designed to be utilized through partnerships between the University of Leeds, ECHT, and industrial partners.

5.8.2 Consortium focusing on composite recycling

To address the challenges of composite recycling, an international consortium has been formed to apply a grant from Horizon Europe call. The proposal of the consortium will include 3 recycling location across the Europe with a target of recycling wind turbine blades, which are coming to decommissioning in the next couple of years and to develop a design of EoL strategies for future blades.

5.8.3 Consortium building regarding digital solutions for value chain transparency

Digitalization provides new opportunities for information sharing on circularity in the value chain, which supports the circularity and sustainability ambitions of the industry. Therefore, Circular Wind Hub is inviting industrial partners to build a consortium that will focus on digital solutions for value chain transparency. One of the steps of this consortium is to apply for EU funding.[16]

5.8.4. Consortium to recycle decommissioned wind turbines in the Rotterdam area

Stakeholders active in wind turbine inspections, metal recycling, and composite recycling have indicated the interest for the development of a consortium (work name: DecomCockpit) with objective to recycle decommissioned wind turbines in the Rotterdam area. Industrial partners Jansen Group Recycling and CRC collaborate with ECHT to set-up the consortium.

5.8.5 Investigating opportunities in REE recycling

European Commission has indicated the importance and urgency to increase the resilience of critical raw materials supply chains by supporting initiatives through EIT Raw Materials and ERMA (European Raw Materials Alliance). Therefore, further investigation for opportunities in REE recycling will be executed together with partners from the wind energy value chain.

[16] Horizon Europe call "Circular and low emission value chains through digitalisation."

5.8.6 De Rijke Noordzee

The ecological aspects of offshore wind farms and especially the opportunities of multiuse of the offshore wind farm areas were recognized as important topics related to sustainability in the offshore wind energy industry during Phase 1 ('Moonshot project'). As a result, De Rijke Noordzee[17] project started in 2021 and continues to focus on ecology and multiuse in relation with offshore wind farms.

5.9 Schematic overview of presented recommendation and phase 3 initiatives

This chapter has given the recommendations and an overview of phase 3 initiatives. These are summarised in a schematic overview (Figure 7) and per item categorised according to the STEER aspects (see Chapter 1). Interventions and changes related to these aspects are important and required to make the transition towards a circular wind industry.

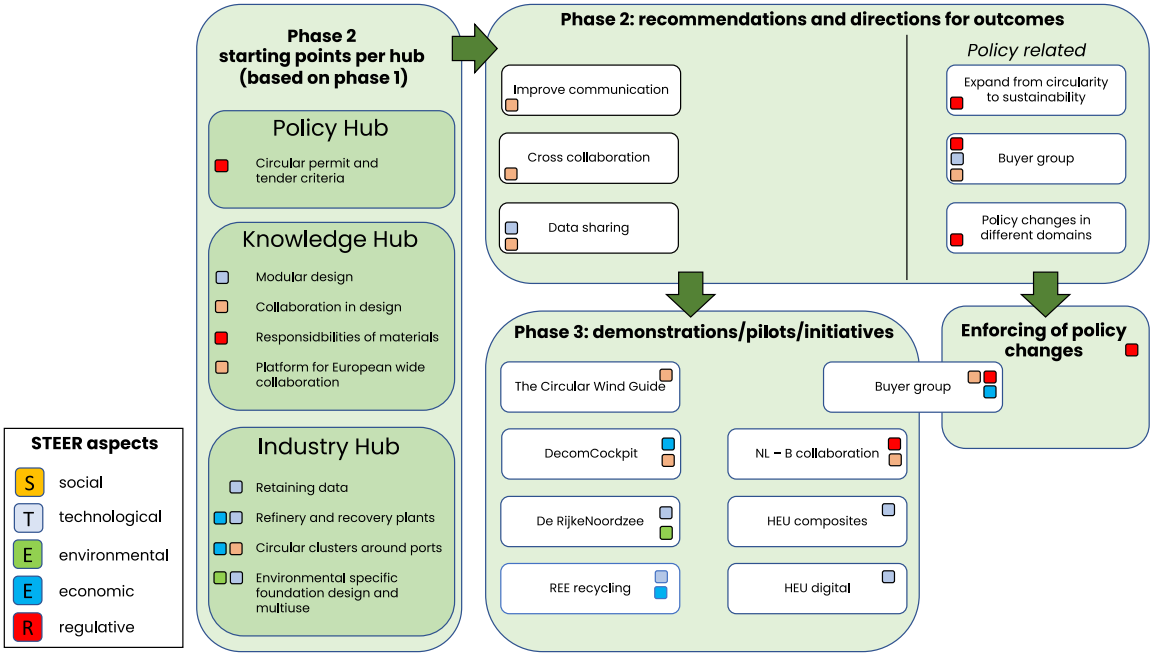


Figure 7 Schematic overview of the phases

[17] The Rich North Sea

Appendices

Appendix A

c. Circular innovative design

Circular innovative design would provide the industry the opportunity to implement a variety of strategies related to material circularity. These include for example the use of biobased raw materials or more effective recycling of the materials after the operational phase of the wind farm.

Criterium: Circular innovative design		
Suggested objective	**Suggested qualitative criteria**	**Qualitative scoring criteria suggestions according to the Policy Hub International**
The stimulation of circularity for the benefit of a resilient, sustainable, and innovative European wind industry, SDG12, the EU Circular Action Plan, and our planet.	*The demonstration of a sustainable innovative design of the wind farm (WTG + BoP) that contributes to overall circularity of the wind farm. This can be reached by:* • *Design for 'reducing' the overall resource usage by smarter designs and hereby 'reducing' the waste generated by factories, during operations and after decommissioning* *and/or* • *'Replacing' high-impact virgin materials (rare earth elements[8]) in favour of low-impact ones.* *and/or* • *Use of 'recycled' or 'recyclable' materials* *and/or* • *Design that facilitates easy replaceability or easy decommissioning.* *And/or* • *'Designed for second life' where materials/components are developed for either life-extension or other circular end-of-life strategies in order of the r-ladder[9]* *For every demonstration there must be a prototype in an operating environment (TRL7) in the form of a pilot at the time of the demonstration.*	*The extent to which the design is a sustainable design, regarding the effect on reduced greenhouse gas emissions* *The extent of using materials that may be harmful or even toxic.* *The extent to which the dissemination and communication plan is usable for subsequent parties in the value chain that will use the materials in a later stage.*

d. Circular (de)commissioning plan

The circular (de)commissioning plan refers to strategies used in the logistic processes and is focused to ease the decommissioning phase already during the commissioning phase of the offshore wind energy project. Through long-term orientated decisions related to decommissioning strategies during the design and commissioning phases, it is possible to lower the total environmental impact of the offshore wind farm.

<table>
<tr><th colspan="3">Criterium: Circular (de)commissioning plan</th></tr>
<tr><th>Suggested objective</th><th>Suggested qualitative criteria</th><th>Qualitative scoring criteria suggestions according to the Policy Hub International</th></tr>
<tr><td rowspan="3">The stimulation of circularity for the benefit of a resilient, sustainable, and innovative European wind industry, SDG12, the EU Circular Action Plan, and our planet.</td><td rowspan="3">Providing an adaptive circular decommissioning process (minimum requirement) of the wind farm (WTG + BoP) that must:
• Clearly describe how the wind farm is commissioned to be easily repaired or decommissioned.
and/or
• Describe how materials/components are handled during decommissioning, aiming to retain its value so they can be used for either life-extension or other end-of-life solutions.
and/or
• Describe how least ecological impact during decommissioning is safeguarded. This includes the handling on site but also the transportation of materials to shore as well as the handling onshore.
and/or
• Cover how the decommissioning plan is updated during operation until the actual execution of decommissioning.
and/or
• Describe the disassembled components/materials end-of-life strategy. Extra priority: When keeping components in tighter circularity loops (reuse/repair) rather than recycling. Also detailing if the components lose structural integrity.</td><td>The plan of approach is adaptive to an extent it is workable at the time of decommissioning</td></tr>
<tr><td>The extent of resource management, where the least impact of CO_2 emissions by vessels and machinery is achieved during executions of the decommissioning and end-of-life strategy.</td></tr>
<tr><td>The extent to which the dissemination and communication plan is usable for subsequent parties in the value chain that will use the materials in a later stage.</td></tr>
</table>

e. Reduction of GHG emissions

As several sustainability targets are currently linked to CO_2 emissions, the industry partners would like to see consistency which keeps the level playing field and supports different innovations strategies. Therefore, it is also suggested to not only focus on the reduction of CO_2 emissions, but the reduction of GHG emissions.

<table>
<tr><th colspan="3">Criterium: Reduction of GHG emissions</th></tr>
<tr><th>Suggested objective</th><th>Suggested qualitative criteria</th><th>Qualitative scoring criteria suggestions according to the Policy Hub International</th></tr>
<tr><td rowspan="3">The stimulation of circularity for the benefit of a resilient, sustainable, and innovative European wind industry, SDG12, the EU Circular Action Plan, and our planet.</td><td rowspan="3">The demonstration of innovation to reduce greenhouse gas emissions (for instance using non-virgin materials/refurbished components)

and

a long-term action plan towards (almost) zero emissions.

For every demonstration there must be a prototype in an operating environment (TRL7) in the form of a pilot at the time of the demonstration.</td><td>The extent to which the evaluation of the calculation is transparent,
so an independent review of the calculation can be performed.</td></tr>
<tr><td>The extent to which innovations could improve also future projects and are really innovative.</td></tr>
<tr><td>Gradual steps towards the zero-emission target are rewarded with additional scoring points (current: value: 6 g/kWh, target in 2050: 0 g/kWh).</td></tr>
</table>

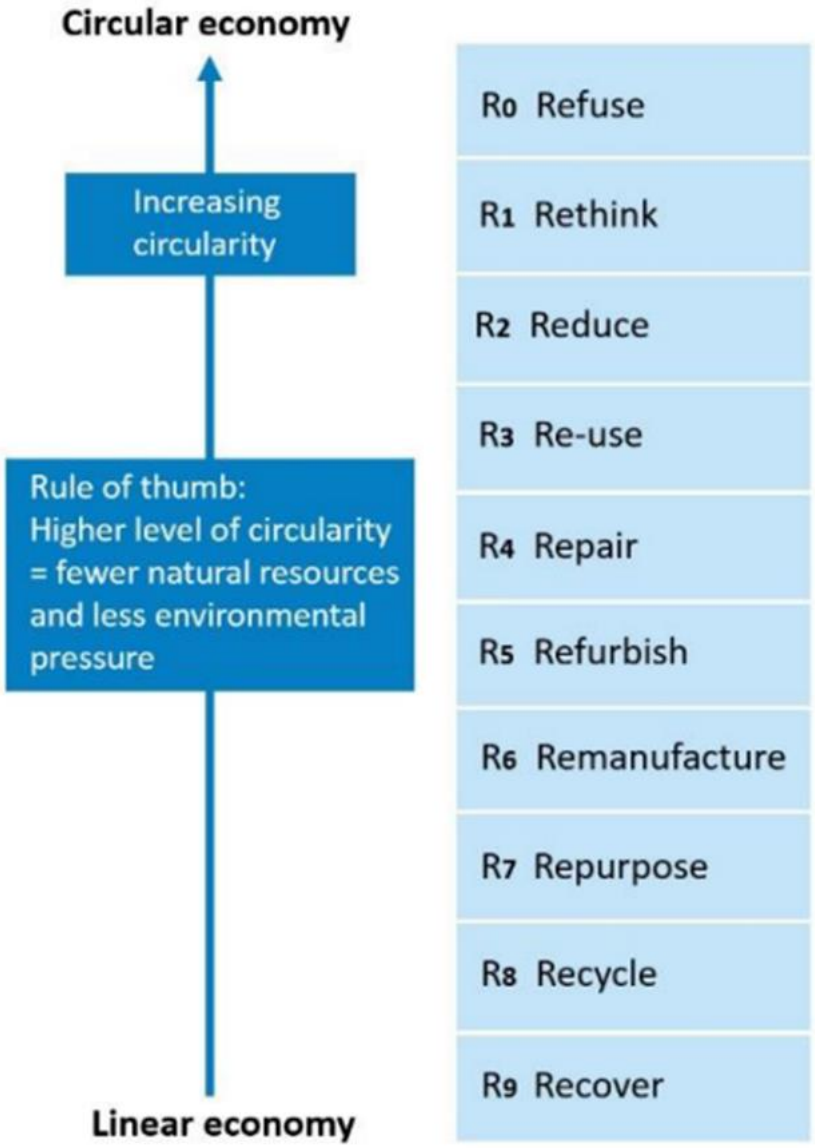
The normal scoring related to “innovativeness” and “impact” are not presented. The scope of the project on determining the tender criteria was more on the side of the content instead of scoring method. Therefore, the balance between innovativeness and impact can be determined by the tenderer (like RVO in the Netherlands) similar to previous tenders.

Appendix B

Phase / Domain	Development		Financing	Permit	Exploitation	Decommission-ing	Re-use
Legal framework/ instruments	Possible demands circularity: Anterior agreement as a me-dium of exchange in which the government agrees to change the zoning plan in such a way that turbines are possible at a location in exchange for the initiator's promise to comply with government wishes that exceed the statutory requirements	No legal framework Producer responsibility Input	Input	Onshore turbines double term to 40 years	Which hooks refer to circularity in legislation and regulations Occupational health and safety legislation Are there any existing regulations that are currently relevant?	Input Input	Input
Authority of government body	Province: Unclear with regard to the legal basis for material use (composition, reuse, etc.). Also potential opportunity for influence: anterior agreement, pre-negotiated between initiators, governments and landowners.	Input	SDE-subsidy (till 2025). Priority/extra money for cir-cular demands. Currently no demands for circularity.	National Government (Ministry of Economic Affairs & Climate): Supervising Authority >100 MW Province: Supervising Authority 5 < 100 MW Municipality: Supervising Authority <5 MW	Input	Input Input Municipality: Authority regarding building permits in addition to government	Building permit: Municipality can influence re-use products, materials?
Action perspectives to stimulate circularity as government body	Input	Input	Input	Input	Life time planning Lifetime extension through management & maintenance Safety legislation	Input	Input
Perceived risks that might slow down the process towards circularity	Input	Input	Input	Review: Inspectors and environmental services	Input	Input	Review: Inspectors and environmental services Input Input
Current activities employed by government bodies	Input	Input	Input	Input	Input	Input	Input

Appendix C

Levels of Circularity ("R-ladder")



PBL, 2017

Appendix D

UK and EU funded projects in the domain of wind energy and circularity

Cables UK 1/ EU 1	**Gap analysis** UNIVERSITY OF LEEDS			**Whole (infra)structure** UK 39/ EU 130
Substation UK 1/ EU 1	**Foundation/ tower** UK 8/ EU 10	**Nacelle** UK 4/ EU 10	**Rotor/ blades** UK 10/ EU 25	**Energy management/ storage** UK 35/ EU 53
Design UK 51/ EU 95	**Maintain & repair** UK 14/ EU 15	**Circular economy** UK 1/ EU 5	**Data system** UK 0/ EU 3	**Recertify** UK 0/ EU 0 *Certify UK 2/ EU 7*
Dematerialise UK 0/ EU 0	**Reuse & repurpose** UK 1/ EU 3		**Lifetime extension** UK 1/ EU 1	**Repower** UK 1/ EU 1
Prevent waste UK 0/ EU 1	**Refurbish & remanufacture** UK 0/ EU 3	**Recycle** UK 8/ EU 12	**Recover energy** UK 0/ EU 0	**Decommission** UK 6/ EU 3
Modular UK 8/ EU 14	**Disassemble** UK 0/ EU 0 *Dismantle UK 0/ EU 1*	**Remine** UK 0/ EU 0	**Landfill** UK 0/ EU 2	**Restore site*** UK 0 / EU 0 **and variations*

A. Velenturf presentation, University of Leeds, 2021