sustainability

MDPI

Article

Different Shades of Green: An Analysis of the Occupational Health and Safety Risks Faced by Wind Farm Workers

Liliana Cunha [1,2,*], Daniel Silva [1] and Mariana Macedo [1]

[1] Faculty of Psychology and Educational Sciences, University of Porto, 4200-135 Porto, Portugal; danielsilva@fpce.up.pt (D.S.); up201405206@fpce.up.pt (M.M.)
[2] Centre for Psychology, University of Porto, 4200-135 Porto, Portugal
* Correspondence: lcunha@fpce.up.pt

Abstract: The growth of the wind power sector has been marked by environmental, economic, and political drivers. Its starring role is also visible in the emergence of the so-called "green jobs". Notwithstanding, its evolution ought not to compromise issues related to occupational risks. This exploratory study examines psychosocial risks in the operation and maintenance of onshore wind turbines in a leading Portuguese company. We conducted interviews with main stakeholders (human resources, OHS professionals, and team leaders); developed an "activity diary" for the operation and maintenance technicians to describe their activity and perceived impacts on health, complemented with collective interviews; and applied the Work and Health Survey. The results revealed the following particular risks and health impacts: working under adverse weather conditions, working at heights and in confined spaces, spending long work hours inside of the nacelles to achieve an optimum balance between favourable wind slots to intervene and avoiding additional trips up and down the wind turbines without lifts (70–120 m), and the feeling of early ageing. At a time when these workers are striving for recognition of their profession as a "rapid wear profession", it is a pivotal moment to discuss these results to guarantee sustainable conditions for future generations of workers.

Keywords: green jobs; wind turbines; psychosocial risks; health-related risks; work sustainability

Citation: Cunha, L.; Silva, D.; Macedo, M. Different Shades of Green: An Analysis of the Occupational Health and Safety Risks Faced by Wind Farm Workers. *Sustainability* **2024**, *16*, 3012. https://doi.org/10.3390/su16073012

Academic Editors: Lucian-Ionel Cioca and Simone De Sio

Received: 15 January 2024
Revised: 22 March 2024
Accepted: 29 March 2024
Published: 4 April 2024

1. Introduction

1.1. Green and Sustainable Purposes for the Environment, but What about the Workers?

Combating climate change and investing in renewable energy is a societal challenge and one of the Sustainable Development Goals (SDG 7), as envisaged by the United Nations [1]. Nevertheless, according to our scientific tradition of work psychology and activity ergonomics [2,3], work activity cannot be a forgotten component in the framework of projects aimed at reconciling economic development and environmental sustainability.

The work activity of operation and maintenance (O&M) technicians In the wind power sector is the privileged focus of our analysis. The vast expansion of the wind sector in both the international and national contexts has been marked by environmental, economic, and political factors, which pursue a new paradigm regarding energy production [4]. Such a paradigm is reinforced by (i) the European Climate Law—Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 [5]—and national strategic plans, in the case of Portugal, as reflected in the Integrated National Energy and Climate Plan 2021–2030 [6]; (ii) the consolidation of economic confidence in the face of the inexhaustible nature and reduced environmental impact of these energies [7,8]; and (iii) the introduction of technological innovation in the sector (e.g., turbines with more efficient technological solutions) [9].

The evolution of the wind sector has been reflected in the growth of its employment rate. According to the International Renewable Energy Agency, the wind energy sector

employs 1.4 million workers worldwide, with 29% of these jobs in Europe [10]. In Portugal, between 2014 and 2018, among the renewable energy sources, the wind sector was the main driver for job creation (48%, corresponding to about 22,426 jobs), with the projection that, between 2020 and 2030, there will be an increase of over 15,500 jobs [9].

These jobs are known in the literature as "green jobs" in the sense that they contribute to the preservation of the environment and the transition to the "bioeconomy" [11,12]. Following one of the first definitions of "green jobs" provided by the United Nations Environment Programme [13], it deals with work that contributes substantially to preserving or restoring environmental quality. Although these jobs are linked with "a green purpose", this is not synonymous with having working conditions that safeguard the health and safety of its protagonists. That is to say, the commitment between different sustainable development goals is not self-evident. Therefore, how is it ensured that investment in renewable energies (SDG 7) also creates sustainable working conditions (SDG 8) for those involved in their production and maintenance, throughout their professional paths? A recent special report from the European Trade Union Institute (ETUI) has brought to the fore the need to look into the working conditions of those workers who, today, guarantee a transition to clean energy [14]. As for the case of wind energy industries (both onshore and offshore) and taking the example of the United Kingdom, the report flagged up a paradoxical reality surrounding the so-called "green jobs". On one side, workers and trade unions are often faced with institutional and organizational guidelines addressing "a great game on green job creation", but, on the other side, they do not provide "the structure or detail of how we can achieve this for the workers of today and the future" [14] (p. 31).

As stated by some authors, the working conditions under which these jobs are performed require further analysis and an understanding of the risks to which workers are exposed, focusing on primary prevention [15,16]. According to the EU-OSHA [4], it is legitimate to speak of "emerging risks", which are both "new" and "increasing" (even a long-standing occupational issue is considered a new risk due to the change in social or public perceptions) [17], associated with the activity in this sector; even knowing that some risks are not specific (e.g., working at height and in limited spaces), the environment and the situations under which they occur (e.g., extreme weather conditions, isolated areas) make them necessarily unique [18]. Considering that there are grey areas with regard to knowledge of the risks of work activity in these types of situations, the health effects are at risk of being underreported. For instance, early in 2014, the EU-OSHA [19] flagged the possibility of perpetuating a lack of research on workers' exposure to risks, while "most research focusing on the safety of third parties [e.g., the effects on population surrounding the wind farms]" (p. 4, free translation). Since then, more attention has been devoted to this work activity in the wind energy sector and, in particular, to its occupational risks among onshore and offshore workers, highlighting the association between wind turbine noise and sleep problems [15,20,21], or the high frequency of going up and down ladders (in the case of wind turbines without a lift) and musculoskeletal problems, especially in the knees [18,22,23], and the inhalation or absorption of hazardous agents (e.g., volatile compounds, vapours, or dust) during maintenance operations [18]. Also, it has been reported in the literature that there is an emerging association between these risks and possible impacts on mental health, namely, nervousness, extreme fatigue, sleep problems and insomnia, and headaches [21].

Despite the contribution of such analyses, mainly quantitative in nature, for a better understanding of the risks associated with the operation and maintenance of wind turbines, these approaches tend to be based on cross-sectional surveys without an articulation with the workers' point of view regarding their specific expression in that context, that is, without differentiating those same risks in other sectors (it is the dialogue with these workers that allows understanding of the risk of "working at height", knowing that such a risk, in the case of the wind sector, often implies working in suspension and carrying loads at the same time, for example). Therefore, the invisibility of less tangible (or measurable) risk factors,

such as psychosocial risk factors, is reinforced, considering its assessment is necessarily based on self-reporting approaches [24–26].

Against this backdrop, multipronged approaches are needed instead of statistical analysis alone. This is precisely the specificity of the case study presented herein. It is based on the assumption of developing an approach from the activity level, and, in dialogue with the workers, it considers their perceptions and complaints [26] and also their power to act, which is developed through worker experience [27,28]. In work psychology, workers' power to act is one of the main touchstones of health, development, and efficiency at work. It has to do with the subjects' ability to broaden the field of their actions in performing work activity and mobilizing their own capacities and subjectivity to address the conflicts of goals [29]. It is due to the power to act that these conflicts are "overcome by workers and their collectives [when] confronted with the singularity of each work situation" [28] (p. 47). This approach aims to create conditions to track the less visible risks and contribute to both the improvement of their working conditions and the sustainability of their professional paths, which are still under development.

1.2. Research Questions and Objectives

Following a request addressed by a leading company in the Portuguese market to assess the psychosocial risk factors in the operation and maintenance (O&M) of onshore wind turbines, an action-research project was designed. This request follows a keen and growing interest among companies' decision makers in the wind sector about the need to expand the predominant probabilistic risk assessment models beyond ergonomic factors (e.g., see [30,31]) and come to grips with psychosocial factors, from an individual and collective experience. To do so, we followed an activity-centered approach [2,32,33] by assuming work activity as the unit of analysis and, at the same time, as an object of potential action through the possible development of psychological and social resources in order to change it [34]. Falling into the scientific tradition shared by work psychology and activity ergonomics (e.g., [2,3]), this stance is deeply committed to taking action on working conditions (and not on individuals) based on the analysis of work activity, which in turn could become a resource to support a collective experience of debating and designing possible changes in work by those who do it [35]. Otherwise, when a perspective of intervention on real work is removed, risk assessment processes tend to prescribe measures to "repair" workers (i.e., an exclusive intervention on an individual level), while overlooking the concrete problems of work and its organization. For example, as a consequence of obfuscating the real work activity (i.e., as it is performed by workers), Lhuilier [35] refers to prevention strategies that invest in the "modification" of workers through "health instructions", "good practices" guides, or training intended to "increase the workers' stress tolerance threshold". In the work psychology field, different authors confirmed this tendency, particularly in the assessment and management of psychosocial risks [34–36]. This is particularly visible when health at work and, consequently, workers' complaints are treated based on "an individualization of these issues by reducing them to personal and private characteristics, taken as a result of personality attributes or to issues of life outside work" [35] (p. 263, free translation).

In this context, the aim of our research was to address the perceived health impacts of exposure to work risks in the activity of O&M technicians and to identify intervention proposals in line with the diagnosis developed. By using a predominantly qualitative methodology, we explored workers' discourse to understand the extent to which what they say about their work and their perceived state of health is a more collective representation.

Taking into account that this is a pilot case study conducted in a national context, the study aimed to explore the following research questions: (i) What are the psychosocial risks associated with maintaining wind turbines? And which factors increase these risks? (ii) What impacts on health are perceived by workers? And what are their perspectives regarding the sustainability of the activity throughout their professional career?

2. Materials and Methods

This case study followed a heuristic and inductive methodological approach [32], adjusted to the singularities of the context under analysis. As there are still few studies regarding the professional risks associated with the work activity developed in this sector, the methodology adopted in this study was essentially qualitative, crossing the use of different methods over the course of seven months, and followed the principles of an "extended case study" [37].

Reconciling different levels of analysis (a macro-analysis of the sector and the company and a micro-analysis of the work activity), data were collected using the following, complementary methods: individual and collective interviews with the company's main stakeholders (HR, human resources; OHS, occupational health and safety; quality management; team coordinators); the design of an "activity diary" to be filled in by the O&M technicians over the course of a work week; collective interviews with these workers (organized in team pairs in each wind farm); and the application of the INSAT, health and work survey [38], as explained below. Table 1 provides an overview of the methods applied.

Table 1. Methods and instruments to collect data.

	Methods and Instruments	*n*	Objective
Stage 1	Document analysis	---	Review of the company's internal documents on occupational risks and health safety: - Annual Activity Report of the OHS Service - Risk Assessment Matrix - Safety and Environment Manual
	Interviews with the company's key interlocutors (HR; OHS Service; Ergonomics; Quality Management)	$n = 5$	Map the company's main historical milestones, which impacted the forms of work organization, the constitution of work teams, and the evolution of risks to which workers are exposed.
Stage 2	Observations at wind farms (12 h)	$n = 10$	Free observations of the work activity of five pairs of O&M technicians at four wind farms (including the work performed inside the wind turbines and in the corresponding control rooms)
	Activity diary	$n = 6$	Collect self-reported data (once a day for one working week) on the relation between the work done each day, its conditions and organization, and perceived health.
	Collective interviews with pairs of O&M technicians	$n = 17$	Seven interviews with pairs of O&M technicians (7×2) and one interview with three technicians. These moments were dedicated to exploring (i) the experience of working in the wind sector; (ii) the ways of developing and preserving a collective experience within each pair of technicians; (iii) the variability of operating modes; (iv) the difficulties and risks of the work and their perceived impact on health; and (v) the main strategies for preserving oneself and the pair.
	INSAT Survey	$n = 8$	Extend the analysis regarding the relationship between the perceived work risk factors and the health impacts.

Table 1. *Cont.*

	Methods and Instruments	*n*	Objective
Stage 3	Collective restitution and validation sessions (two sessions, lasting on average 1 h)	$n = 13$	Final sessions to present the results of the analysis and its validation with the O&M technicians, focusing on the most demanding tasks, physical and psychosocial risk factors identified, health impacts, and conditions pointed out by the workers as favouring the preservation of their health. Prior to these sessions, an infographic synthesizing these results was prepared and sent to all the workers and team coordinators.

Data were collected between September 2020 and April 2021. At the beginning of our research, the company concerned employed 34 O&M technicians, whose average age was 33.9 years (range 29–38), and their average seniority in the company was 4.1 years (range 4.2 months–14 years).

Observations were conducted of the O&M technicians' activity in a real work context, with ascent and permanence in the wind turbines. Nevertheless, the difficulties in collecting data related to the day-to-day activity, under these conditions (imperative to climb up/down the wind turbine towers and stay in a limited space), justified the proposal to design another mediating instrument to gain access to what is experienced in the real work context, an "activity diary" as a daily diary methodology [39]. This "activity diary", as we conceived it, consists of self-reported data, based on what is performed in the real context (even if the report is not carried out in real-time) and on what is experienced in that specific context, including successive records throughout a week, i.e., with a temporal breadth that allows measuring intra- and inter-individual variability. Six workers filled this diary (see Table 1) throughout a working week, taking into account the dimensions which follow:

- "Background to my working day" (including the wind farm where the work was being performed; weather conditions; characterization of the wind turbines; type of intervention to be done; tasks performed; co-workers; and the conditions that affected the work plan).
- Work schedule (including the expected and actual schedule, time travelling to and from the wind farm; time spent inside the machine (wind turbine); and the work pace determined by the need to attain the goals).
- "My day in review" (including "what gave me the most pleasure at work"; "what went worst"; unforeseen or critical situations; what required more expertise; and what made the work easier).
- "My health and wellbeing" (including the identification of pain and affected body areas, relating them to tasks that were performed; situations of incidents/accidents; health issues that were aggravated by the work).
- "My working week in review (including the most painful day in the working week; "what went best" and why).

The "activity diary" also included an illustrative representation of a wind turbine in which the workers were requested to pinpoint the most critical points/areas of the wind turbines to work on.

Collective interviews were then carried out with the O&M technicians ($n = 17$) of four of the wind farms considered, supported by records shared anonymously in the "activity diary". In this context, while exploring the critical aspects of their work activity, the workers were asked to signal these points in a graphical representation of a wind tower, created by themselves. Figure 1 shows one of these representations, which was used as a mediating tool to analyse the workers' point of view about their activity exigencies.

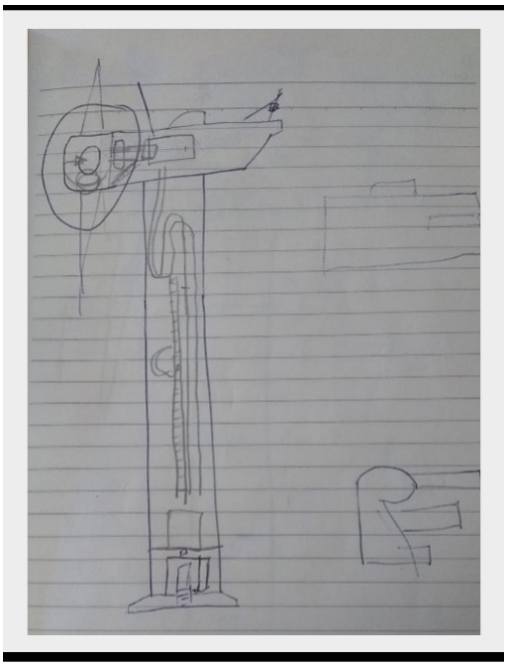

Figure 1. Graphic representation of a wind turbine with "critical points" drawn by the O&M technicians in the context of the collective interviews.

Beyond the "activity diary", the exploration of the drawings as a data collection technique in this context underpinned a heuristic approach in conducting this case study. The purpose of using the graphic representation of a wind turbine developed by workers themselves was to constitute it as a "common place" for dialogue within the workers' collective on dimensions of the activity that could not be observed continuously over time (the analysis of risks in situ), nor would they be spontaneously verbalized in the absence of this symbolic reference to their work situation [40]. Furthermore, the request for the representation of a wind turbine was not intended to be a faithful representation of their workspace but rather to serve as a mediating tool to explain the details concerning critical points of the work activity, namely, local specificities to be considered in the risk evaluation, reinforcing the centrality of certain areas to how those risks are expressed [40,41]. The identification of risk factors using this graphic representation was, firstly, based on the workers' point of view, which was then complemented with other dimensions of analysis, stemming from the data collected.

Figure 1 illustrates a graphic representation of a wind turbine with "critical points" drawn by the O&M technicians in the context of the collective interviews.

Finally, in order to explore the relationship between the perceived risk factors, namely the psychosocial risks and the health impacts, the INSAT, health and work survey, was used, which is validated for the Portuguese population [38]. Eight O&M technicians responded to the survey during working hours and at a time when the company was undergoing a merger and acquisition process by an international economic group, which justified the reduced number of participants, compared to the participants in the previous phase of the interviews. The survey application was important for identifying and contextualizing the risks to which these workers are exposed, which constitutes an added value compared to what is recommended by the normative framework for the assessment of psychosocial risks and was oriented more towards the identification of risk and not their understanding (e.g., "being exposed to an intense pace of work" and not necessarily the identification of concrete work situations in which this happens).

All workers participated voluntarily, upon consenting and signing an informed consent form. The data collected were, finally, analysed in an integrated way, for both complementarity and triangulation.

3. Results and Discussion

3.1. Activity Content: Interventions on Onshore Wind Turbines

The analysis in a real context and the dialogue with the O&M technicians and the team leaders supported the identification of the principal risk factors and their impacts on health, in relation to the type of intervention the workers could perform in the wind farms. Here, there are three main operations: preventive maintenance, "curative" maintenance (troubleshooting), and the substitution of major components (in the wind turbines).

Preventive maintenance operations involve monitoring and controlling the operation of the wind turbines, whose purpose is preventive in nature (e.g., technical checks, lubrification, and a set of actions to prevent breakdowns). Each wind farm has a biannual plan of preventive maintenance, which implies that these operations are programmed and planned. The following is according to the O&M technicians: "[The preventive] *maintenance tasks are routine, it's like the car revision. These operations have to be done at predefined intervals, it's always the same thing for all [wind turbines], there aren't significant differences* [between the operations carried out from wind turbine to wind turbine]".

Operations of "curative" maintenance refer to solving breakdowns and malfunctions that occur unpredictably in the wind turbines. Taking into account that these breakdowns interrupt wind energy production, solving them as fast as possible is, thus, crucial, which gains priority over regular and planned operations of preventive maintenance. Operations of "curative" maintenance are also conducted during the weekend, with three teams (three pairs) assigned on-call: "*When we're on call at the weekend, there's one team working in the north* [of the country], *another one in the south, and a backup team, six workers in total, so*".

As for the operations involving the substitution of major turbine components, a team is specifically devoted to carrying out these operations. It is made up of five or six workers, depending on the type of component to be substituted (e.g., wind turbine blades, generator). These operations are programmed in advance as they require longer periods of intervention in the wind turbines due to the size of the components.

3.2. A Not-So-Green Shade: The Exposure to Physical and Psychosocial Risk Factors

The analysis of the O&W technicians' activity enabled the identification of specific aspects of this work that the workers perceived as being critical. To visually illustrate these aspects, Figure 2 summarizes different points/components and areas of a wind turbine where these critical aspects were identified in light of the O&M technicians' point of view.

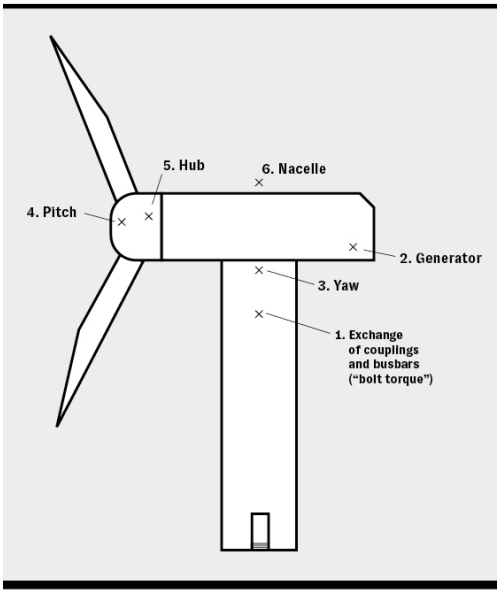

Figure 2. Representation of a wind turbine with all the "critical points" collectively identified by the O&M technicians.

One of the main critical operations regards the exchange of couplings and busbars (see Figure 2: 1–3). For example, these operations imply working through the internal ladder of the tower (at height and in suspension), requiring the adoption of awkward and painful postures (principally, in those moments which make demands for torso rotation): "*The most critical task is to change couplings and busbars, we're on the ladder in a strained and awkward posture, we have to work in that position, in very unfavourable and unstable positions*". Also, the bolt torque and tensioning were highlighted by the workers. Broadly speaking, this operation entails manually handling the tension heads used to test and tighten bolts (bolted joints). This operation is performed mainly in limited spaces (e.g., in the hub or the internal ladder of the tower), leading to the adoption of various awkward and painful postures (whilst standing, kneeling, or seated depending on the dimension of the workspace). For example, as regards the position adopted on the ladder, one O&M worker stated: "*On the ladder, our body is twisted while the torque tightening, and we have to pass from one side of the ladder to the other and lag one foot*". In a previous study, Milligan et al. [42] reported that bolt torque and tensioning are "whole body tasks" (p. 542), with fatigue accumulating in the shoulders, wrists, torso, and back.

The need to climb extensive ladders several times a day (in wind turbine towers without lifts) is also mentioned by the O&M workers, mainly due to the impact that is progressively felt on the knees: "*The worst is even when we're going down, we felt it in our knees*".

Tasks related to substituting major components are also perceived as being "critical" and even more dangerous due to the increased risks (e.g., having to handle heavier loads). Lastly, the workers highlighted a few areas in the wind turbines that, given their characteristics (in terms of access, space available, the weight of the loads handled, or the height), the tasks become more difficult, along with the exposure to different risks. Examples of these areas and components are as follows: the generator area (see Figure 2: 2), the yaw deck (see Figure 2: 3), the pitch (see Figure 2: 4), the hub (see Figure 2: 5), and outside the nacelle (see Figure 2: 6).

Figure 3 provides an integrative overview of physical and psychosocial risk factors (see [24] regarding the dimensions of psychosocial risk factors) that were reported by the workers. To this end, we crossed the data obtained from the interviews (n = 17) with the data collected via the INSAT survey (n = 8), and then we complemented this analysis with the control measures and other intervention proposals that are inscribed in ISSO/DIS 45003 on the management of psychosocial risks at work [43].

As far as the psychosocial risk factors are concerned, in the literature, there is a scarce body of knowledge on this topic, as the EU-OSHA [4] called attention to reinforcing the need to look at work organization options in this sector. However, in 2013, the EU-OSHA [4] already affirmed that issues such as working long hours, working alone, or working remotely for extended periods should be considered when addressing psychosocial specificities in this work. We could observe these issues from the workers' answers (see Figure 3), mainly in regard to the work intensification and emotional demands. On the intensification, the workers pointed out situations of long hours: "*Just the day before yesterday we went a bit over the normal schedule (. . .). At the end of the day, we got the information that we had to go to another breakdown, and it wasn't exactly next door, we were able to get home by 8.30 pm*".

In our study, the findings related to emotional demands seem to confirm the first clues put forward by the EU-OSHA in 2013. In fact, the O&M technicians brought to the debate factors like having to work alone (in a team of two technicians), in what the workers perceive as being apart from the world: "*We're cut off from the world, what if we need help*"? In the past, Chaumel et al. [44] looked specifically at the consequences of working alone (a pair of O&M technicians) for long periods in a wind turbine in forested areas, far from a main road, in the case of an accident. In Quebec, they revealed a series of difficulties in providing help to these workers, who were placed in remote areas and had weak communication signals. This issue permeates the thought of the workers participating in our study as they

are working, and, insofar in the case of an accident or injury, it is up to the other colleague of the pair to be responsible to face the situation, for example. This is a real concern for the workers, as they revealed.

Finally, an issue that needs to be addressed is related to access to a toilet. In most cases, toilets are placed next to the control room of the wind farm. However, these workers spend long periods in the nacelle without access to the toilet. This fact is associated with the lack of lifts in most wind turbine towers, and the workers try to avoid descending (and then climbing the ladder again) due to the physical effort required.

PHYSICAL RISK FACTORS			
DIMENSIONS	**VERBATIM EXCERPTS FROM INTERVIEWS**	**INSAT ANSWERS**	**CONTROL MEASURES (ISO/DIS 45003)**
Exposure to adverse weather conditions	*"The weather conditions are adverse, very windy, rainy, cold* (...) *we have to work on maintenance with 6 °C".*	8/8 O&M technicians are exposed to "thermal variations (e.g., heat, cold, wind, humidity)"	Improve equipment and the work environment by avoiding or protecting exposure to physical risk factors Provide and encourage the use of personal protective equipment (PPE)
Working at height and in suspension	*"Working at height is already a big con. And it's an activity where one mistake can be fatal".* *"When changing the bars on the stairs (...) we have to be hanging all the time, 1h, 1h30, 2h".*	7/8 work "at height"	
Working in limited spaces	*"The space is very restricted, and we are in painful positions, or twisted* (...) *we have to walk on all fours when we take the batteries to the hub".*	8/8 work in a "context/place whose space is poorly adapted to the type of tasks performed (ex: restricted, poorly accessible, poorly organized space)"	
Frequent walking up and down stairs	*"They are machines with 70 metres and more, if there's no lift, we have to go up and down everything by hand".* *"The worst bit is even climbing down, you feel it in your knees".*	7/8 have to "going up and down very often (e.g., stairs, ramps)"	
Manual load handling	*"During pitch motor replacements* (...) *I get a bad back, because of the positions we hold it in, it's 80 kilos heavy".* *"Carry heavy weights to change batteries".*	8/8 have to "make intense physical efforts (e.g., heavy loads handled or moved)"	
Adoption of painful postures	*"In pitch motors replacements* (...) *every time I change one, my back hurts because of the positions we hold it in, it's 80 kilos, we have to walk with it on our knees, we have to bend down with it".* *"We have to make very abrupt movements, we have to be in positions that sometimes are not comfortable for us, for our body, for our back".*	8/8 "adopt painful postures (painful, costly, uncomfortable body positions)", "make repetitive gestures", "make precise and meticulous gestures"	
Contacting with moving parts of the machine	*"In both the yaw and the hub, all it takes is one slip and we can get stuck"*		
Machine vibrations	*"With the wind, it wobbles a lot* (...) *it wobbles when you're up there (...) it interferes a bit with our meticulous work".* *"The busbar joints in the middle of the tower can come loose with the vibration".*	6/8 are exposed "vibrations (oscillations or tremors in the body, or in the limbs)"	
Exposure to dangerous products and components	*"Chemical risks, associated with the handling of products used for cleaning".* *"Inhalation of dust particles coming out from the generators".*	8/8 work with "electrical equipment susceptible to electrocution" and "chemical products"; and are exposed to "dust or gases" 4/8 are exposed to "nanoparticles (e.g., industrial cleaning)"	

Figure 3. *Cont.*

PSYCHOSOCIAL RISK FACTORS			
DIMENSIONS	**VERBATIM EXCERPTS FROM INTERVIEWS**	**INSAT ANSWERS**	**CONTROL MEASURES (ISO/DIS 45003)**
Work intensification	*"Customers are demanding because of the wind. If we're in the machine for too long, customers immediately start asking why the machine is stopped".* *"We left the machine until 11 pm, since noon. That was a really hard day for us. We had lunch before going up there and that was all. Besides that, it was water, air and wind because that was the only thing we had up there."* *"Just the day before yesterday we went a bit over the normal schedule (...) at the end of the day, we got the information that we had to go to another breakdown, and it wasn't exactly next door, we were only able to get home by 8.30 pm."* *"We know at what time we start work, but we may not know the time we finish it, which sometimes impacts the management we do of our personal life".*	8/8 revealed having "to work at an intense pace", "to depend on colleagues to be able to carry out my work", "to comply with strict rules and/or deadlines", "to exceed normal working hours" and "to take work home, in addition to my schedule" 7/8 revealed "significant estrangement that interferes with family or social routine" and "make frequent work trips (absence or significant absence that interferes with family or social routine)" 6/8 have to "skip" or shorten a meal, or not even take a break because of work 5/8 "having to depend on direct orders from customers" and "hyper-requesting"	Prioritize tasks and flexible deadlines for their completion Limit worker contact to work beyond hours (email and phone) Provide support in times of greater overload (more experienced workers)
Emotional demands	*"We have two hours left and we could finish the job, but the client won't let us [due to wanting to put the machine at work because of the favourable wind speed]".* *"At most, we contact one person throughout the day. So, imagine if I have my meal in the nacelle, I don't see anyone else during the whole day."* *"Doing 7 hours of travelling alone, because we are on call with a colleague who lives 350 km away from us, ends up being a little bit painful".* *"We're cut off from the world, what if we need help?"* *"In emergency and accident situations, it is difficult to get rescue teams in there".* *"At wind farm or in the machine, when we spend all day in the nacelle, the toilet is... improvised".*		Minimize isolated work as much as possible, promoting access to support and social support
Insufficient autonomy	*"The operator doesn't let the machines stop [because the wind speed is more advantageous for energy production]".* *"Customer contracts define wind/power thresholds (...) above 1KJ you can no longer stop".*		Making workers more flexible and autonomous in managing the pace, schedule, and division of work (flexible hours)
Ethical and values conflicts	*"Sometimes we do things we don't agree with (...) for example, changing all the air filter sleeves because the temperature rises and causes the machine stop"* [at present, with the company fusion].	4/8 have to do things they disapprove of	Consult workers on work-related issues (work practices, possible changes to be introduced)
Poor quality of working social relations [mainly due to the acquisition of the company by another with a different organisational culture]	*"People are getting demotivated by this work..., it's the pressure, and the lack of recognition".* *"We, at xxxxx* [the worker was referring to the former company] *used to have autonomy, because they trusted us. Not here, there is a lot of pressure from the leadership".* *"They command us to take photos of everything that has been done, they don't trust us".* *"Lack of recognition and personal valorization".*	3/8 assumed: "I am little recognized by my colleagues" 2/8 revealed: "I spend many hours in a space where I feel uncomfortable", "I often need help from colleagues and do not have it" and "I am not treated fairly and with respect by supervisors"	Promote effective supervision and constructive feedback to workers Promote management attitudes and encourage reporting of psychosocial risks (harassment, intimidation) Recognize and reward workers
Work and employment insecurity	*"The xxxxxx* [the worker was referring to the new company] *pays less. What will happen to our wages* [with the company fusion]?" *"If something better comes along, I'll leave, I'm fed up".*	4/8 indicated "there is a threat of job loss" and "career development is almost impossible" 2/8 assumed that "the pay does not allow me to have a satisfactory standard of living" and "there are conditions that undermine my dignity"	Develop support measures for workers exposed to psychosocial risks Avoid exposure or protect workers exposed to psychosocial risk factors

Figure 3. Physical and psychosocial risk factors.

3.3. The Perceived Impacts of Work on Health

The word "green" is often associated with the preservation and protection of the environment, but what is good for the environment may not necessarily be good for the safety and health of workers, as illustrated in Figure 3. In the context of collective interviews, it was possible to explore the perceived health effects that stem from these working conditions and the characteristics of this work. One of the main impacts regards the musculoskeletal pain mainly associated with the fact that these workers have to climb ladders several times a day, as well as the handling of heavy loads and the performance of operations in awkward and uncomfortable positions: "*I feel it [the health impact] in my knees and back, we have to ascend and descend several times, carry tools, and expend physical efforts in positions that are not very comfortable for us*". As stressed in the literature on this matter (e.g., [18,22,42]), these requirements place the O&M technicians at risk of musculoskeletal injuries. What is more, the workers mentioned that, on occasion, accidents during these operations occur, involving injuries such as cuts, abrasions, and, at times, fractures. In spite of the relatively "emerging" nature of this sector and even though these workers are young (most of them are in their 30 s), they are already aware that this work activity could lead to premature ageing. Such a perception is expressed when the workers reveal they do not feel be able to perform this activity until retirement age. This assessment is based mainly on the effects they already feel in their bodies, a "professional wear" that involves the loss of muscular endurance and physical abilities and also from the testimony of older colleagues: "*I can't imagine working here till retirement, because of the physical impact*"; "*I've got a colleague who is 54 years old, and he no longer does some tasks*".

Not only health impacts but this work activity also impacts the difficulties associated with work–family balance. As there are breakdowns in the turbine towers that require exceeding the work schedule (e.g., to avoid a return to the wind turbine concerned the next day, mainly when it does not have a lift to ascend), this will also have further implications on their perceived well-being: "*A breakdown requiring more time than the 8 h interferes with the planning of our life outside of work*"; "*Sometimes, there're operations that require from us a further effort. Look, we don't have a regular schedule, from Monday to Friday, from time to time, there're weekends in which we are on-call. And some operations on the weekends could take several hours into the night*".

3.4. Study Limitations

As a limitation of this study, we point out the lack of peer-reviewed scientific literature on occupational risks and health impacts in the wind farm sector, especially those following a participatory and worker-centered approach. This issue further limited the insights into how occupational health in a relatively recent industry can impact workers' professional paths. Moreover, the analysis of a small sample of workers in this study and the lack of comparative data in the literature covering a more extended period seems to reinforce the knowledge gap concerning the health impacts of this work activity and the employment sustainability in this industry.

Even though this is a pilot case study, its results have the potential, on the one hand, to highlight critical issues that require a broader and sectoral analysis and, on the other hand, to contribute to an "analytical generalization" [45], that is, to contribute to the generalization of the methodological device described so that it can be used in future studies developed in this sector.

4. Conclusions: A "Rapid Wear Profession" vs. a 'Green Job'

The missive of sustainable development, with renewable energies, boosted the increase of wind farms and the so-called "green" jobs. However, what is debated in the concrete work activity are the risks that are inherent to it, and the sustainability of the conditions in which it is developed have not had the same awareness. Recently, in Portugal, these workers have organised themselves to start a process of recognition of their profession as a "rapid wear profession". As one of the interviewed workers said, "*We're the first ones, the*

first generation of this profession. I don't believe we can do this activity for many years. . . going up and down the machines, with weight [work equipment]. . . *Even if we don't know others* [the professional history of older colleagues], *we already know it from the impact we feel today*".

Although these workers are still considered young, there is the perception that the risk factors to which they are exposed are likely to potentiate early ageing, with the expectation that they will not be able to exert their activity until retirement age [46].

At a time when psychosocial risk factors and their impact on health have become subject to more debate, reflecting on the sustainability of career paths in painful conditions is essential for affirming the right to decent work. This is, therefore, also a pertinent moment to discuss the sustainability principles according to what the activity analysis reveals so as to guarantee the preservation of decent working conditions for future generations of workers. In fact, being labelled "green" does not mean that the safe and healthy working conditions are de facto forms of this work; that is to say, it is not as if the "green" feature of this work exempts all occupational risks. In the case of Portugal and taking into account the growing number of workers in the "green jobs" sector, the country faces a double challenge, as reinforced by Moreira et al. [47]. On the one side, there is the challenge of guaranteeing OHS control measures for the existing and future generations of workers in green jobs so as to promote healthy work environments, and, on the other side, OHS issues related to these green jobs should be inscribed as an "indispensable reference and indicator of sustainability" [47] (p. 205) and, consequently, an essential driver to sustainable development. Our research has the potential to contribute to widening the present debate on the conflicts between environmental priorities and social commitments for the future [48], namely, by introducing the work point of view. Work psychology and activity ergonomics together have long contributed to this, pointing out that work cannot be perpetuated as a second-order component within the ongoing environmental, technological, and organisational transitions. It is precisely from this perspective that this research fits in and seeks to ensure that the debate on environmental sustainability is also woven from the point of view of the sustainability of these workers' activities. Otherwise, there is a risk that these transitions, in seeking to achieve environmental sustainability, could lead to future configurations that could not be sustainable in terms of safety and occupational health.

In terms of future research, we support the expansion of the analysis to a wider sectoral level, as well as the increase of long-term follow-up data. In this way, the debates on combating climate change can also integrate and address the professional risks and impacts on health of those who carry out activities within the so-called "Green jobs". The "just transition" vision [14,49] cannot neglect issues of safety and health at work.

Author Contributions: Conceptualization, L.C.; Methodology, L.C., D.S. and M.M.; Investigation: L.C., D.S. and M.M.; Data curation, Formal analysis, Visualization, and Writing—original draft preparation, L.C., D.S. and M.M.; Supervision: L.C. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by national funding from the Portuguese Foundation for Science and Technology (UIDB/00050/2020).

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and the methodological plan for the analysis of the impacts of work on health, through the application of the INSAT survey, and was approved by the Ethics Committee of the Faculty of Psychology and Educational Sciences of the University of Porto (protocol code 2015/04–1, Approval Date: 21 April 2015).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in the study have been included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. UNCTAD—United Nations Conference on Trade and Development. *Structural Transformation, Industry 4.0 and Inequality: Science, Technology and Innovation Policy Challenges*; UNCTAD: Geneve, Switzerland, 2019.
2. Daniellou, F. The French-speaking ergonomists' approach to work activity: Cross-influences of field intervention and conceptual models. *Theor. Issues Ergon. Sci.* **2005**, *6*, 409–427. [CrossRef]
3. Lacomblez, M.; Bellemare, M.; Chatigny, C.; Delgoulet, C.; Re, A.; Trudel, L.; Vasconcelos, R. Ergonomic analysis of work activity and training: Basic paradigm, evolutions and challenges. In *Meeting Diversity in Ergonomics*; Pikaar, R., Koningsveld, E., Settels, P., Eds.; Elsevier: Oxford, UK, 2007; pp. 129–142. [CrossRef]
4. EU-OSHA—European Agency for Safety and Health at Work. *Occupational Safety and Health in the Wind Energy Sector*; EU-OSHA: Bilbao, Spain, 2013. [CrossRef]
5. Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021. Available online: https://ec.europa.eu/clima/policies/eu-climate-action/law_pt (accessed on 30 July 2021).
6. Portugal Energia. Plano Nacional Energia e Clima 2021–2030. In *Resolução do Conselho de Ministros n.º 53/2020, de 10 de Julho*; Presidência do Conselho de Ministros: Lisboa, Portugal, 2020.
7. APREN—Associação Portuguesa de Energias Renováveis. Novo Máximo Histórico de Energia Eólica na União Europeia. 2017. Available online: https://www.apren.pt/pt/novo-maximo-historico-de-energia-eolica-na-uniao-europeia (accessed on 7 May 2021).
8. APREN—Associação Portuguesa de Energias Renováveis. Anuário APREN. 2023. Available online: https://www.apren.pt/contents/documents/a-card-280723-02-final.pdf (accessed on 26 December 2023).
9. APREN—Associação Portuguesa de Energias Renováveis and Deloitte. Impacto da Eletricidade de Origem Renovável. 2019. Available online: https://www.apren.pt/pt/deloitte-lanca-estudo-sobre-o-impacto-da-eletricidade-de-origem-renovavel-em-portugal (accessed on 20 May 2021).
10. International Renewable Energy Agency (IREA) and International Labour Organization (ILO). *Renewable Energy and Jobs: Annual Review 2023*; IRENA: Abu Dhabi, United Arab Emirates, 2023. Available online: https://www.irena.org/Publications/2023/Sep/Renewable-energy-and-jobs-Annual-review-2023 (accessed on 3 March 2024).
11. European Commission. Exploiting the Employment Potential of Green Growth. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Towards a Job-Rich Recovery. Strasbourg, 2012. Available online: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SWD:2012:0092:FIN:EN:PDF (accessed on 24 April 2022).
12. ILO—International Labour Office. *Green Jobs. Progress Report 2014-2015*; ILO: Geneva, Switzerland, 2016. Available online: https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_502730.pdf (accessed on 20 January 2018).
13. UNEP—United Nations Environment Programme. *Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World*; UNEP/ILO/IOE/ITUC: Nairobi, Kenya, 2008. Available online: https://www.unep.org/resources/report/green-jobs-towards-sustainable-work-low-carbon-world (accessed on 4 March 2024).
14. Lynch, M. Workers and the Climate Challenge. *Hesamag* **2023**, *38*, 31–33. Available online: https://www.etui.org/publications/workers-and-climate-challenge (accessed on 3 March 2024).
15. Freiberg, A.; Schefter, C.; Girbig, M.; Murta, C.; Seidler, A. Health effects of wind turbines in working environments—A scoping review. *Scand. J. Work. Environ. Health* **2018**, *44*, 351–369. [CrossRef] [PubMed]
16. Jia, N.; Li, T.; Hu, S.; Zhu, X.; Sun, K.; Yi, L.; Zhang, Q.; Luo, G.; Li, Y.; Zhang, X.; et al. Prevalence and its risk factors for low back pain among operation and maintenance personnel in wind farms. *BMC Musculoskelet. Disord.* **2016**, *17*, 314. [CrossRef]
17. Wandzich, D.; Plaza, G. New and emerging risks associated with green workplaces. *Workplace Health Saf.* **2017**, *65*, 493–500. [CrossRef] [PubMed]
18. Karanikas, N.; Steele, S.; Bruschi, K.; Robertson, C.; Kass, J.; Popovich, A.; MacFadyen, C. Occupational health hazards and risks in the wind industry. *Energy Rep.* **2021**, *7*, 3750–3759. [CrossRef]
19. EU-OSHA—European Agency for Safety and Health at Work. Questões de Segurança e Saúde no Trabalho Associados à Construção Ecológica. 2014. Available online: https://osha.europa.eu/pt/publications/e-fact-79-occupational-safety-and-health-wind-energy-sector (accessed on 10 March 2024).
20. Mette, J.; Velasco Garrido, M.; Harth, V.; Preisser, A.; Mache, S. Healthy offshore workforce? A qualitative study on offshore wind employees' occupational strain, health, and coping. *BMC Public Health* **2018**, *18*, 172. [CrossRef] [PubMed]
21. Sgourou, E.; Katsakioril, P.; Kavvathas, A. Occupational health and safety in wind turbines' maintenance: An investigation of maintenance technicians' perceptions. *Ecol. Saf.* **2021**, *15*, 43–55.
22. Fischer, S.; Koltun, S.; Lee, J. A cross-sectional survey of musculoskeletal disorder hazard exposures and self-reported discomfort among onshore wind turbine service technicians. *Ergonomics* **2021**, *64*, 383–395. [CrossRef]
23. Cooper, K.; Stewart, A.; Kirkpatrick, P. Health effects associated with working in the wind power generation industry: A comprehensive systematic review. *JBI Database Syst. Rev. Implement. Rep.* **2014**, *12*, 327–373. [CrossRef]

24. Gollac, M.; Bodier, M. Mesurer les Facteurs Psychosociaux de Risque au Travail Pour les Maîtriser. Rapport du Collège D'expertise sur le Suivi des Risques Psychosociaux au Travail, Faisant Suite à la Demande. Ministre du travail, de l'emploi et de la santé: Paris, 2011. Available online: http://travail-emploi.gouv.fr/IMG/pdf/rapport_SRPST_definitif_rectifie_11_05_10.pdf (accessed on 12 June 2016).
25. Cunha, L.; Barros, C. The evaluation of psychosocial risks: An emerging issue? And its prevention. . . a postponed issue? *J. Spat. Organ. Dyn.* **2018**, *6*, 19–28.
26. Barros, C.; Baylina, P.; Cunha, L. Impact of Psychosocial Risk Factors on Workers' Health: Contributions of a Subjective Health Indicator. In *Occupational and Environmental Safety and Health II*; Arezes, P.M., Baptista, J.S., Barroso, M.P., Carneiro, P., Cordeiro, P., Costa, N., Melo, R.B., Miguel, A.S., Perestrelo, G., Eds.; Springer: Berlin/Heidelberg, Germany, 2020; Volume 277, pp. 557–566. [CrossRef]
27. Clot, Y. *Travail et Pouvoir d'agir*; Presses Universitaires de France: Paris, France, 2008.
28. Clot, Y.; Simonet, P. Power to act and operational leeway. *Le Trav. Hum.* **2015**, *78*, 31–52. [CrossRef]
29. Van Belleghem, L.; De Gasparo, S.; Gaillard, I. The development of the psychosocial dimension of work. In *Constructive Ergonomics*; Falzon, P., Ed.; CRC Press: New York, NY, USA, 2014; pp. 33–47. [CrossRef]
30. Aneziris, O.; Papazoglou, I.; Psinias, A. Occupational risk for an onshore wind farm. *Saf. Sci.* **2016**, *88*, 188–198. [CrossRef]
31. Bepary, B.; Kabir, G. Occupational risk assessment of wind turbines in Bangladesh. *Appl. Syst. Innov.* **2022**, *5*, 34. [CrossRef]
32. Guérin, F.; Laville, A.; Daniellou, F.; Duraffourg, J.; Kerguelen, A. *Understanding and Transforming Work: The Practice of Ergonomics*; Anact: Lyon, France, 2007.
33. St-Vincent, M.; Vézina, N.; Bellemare, M.; Denis, D.; Ledoux, E.; Imbeau, D. *Ergonomic Intervention*; IRSST: Montréal, QC, Canada, 2014.
34. Clot, Y. *Le Travail à Cœur: Pour en Finir Avec Les Risques Psychosociaux*; La Découverte: Paris, France, 2010.
35. Lhuilier, D. La santé mentale au travail. In *Un Monde Commun: Les Savoirs des Sciences Humaines et Sociales*; Gefen, A., Ed.; CNRS Éditions: Paris, France, 2023; pp. 262–265.
36. Lhuilier, D.; Litim, M. Le rapport santé-travail en psychologie du travail. *Mouvements* **2009**, *2*, 85–96. [CrossRef]
37. Burawoy, M. *Ethnography Unbound. Power and Resistance in Modern Metropolis*; University of California Press: Berkeley, CA, USA, 1991.
38. Barros, C.; Cunha, L.; Baylina, P.; Oliveira, A.; Rocha, Á. Development and Validation of a Health and Work Survey Based on the Rasch Model among Portuguese Workers. *J. Med. Syst.* **2017**, *41*, 79. [CrossRef] [PubMed]
39. Gunthert, K.; Wenze, S. Daily diary methods. In *Handbook of Research Methods for Studying Daily Life*; Mehl, M.R., Conner, T.S., Eds.; Guildford: New York, NY, USA, 2012; pp. 144–159.
40. Andéol, M. Le «cadastre du risque avéré». *Rives Méditerranéennes* **2020**, *61*, 179–204. [CrossRef]
41. Vermersch, P. Expliciter l'expérience. *Éducation Perm.* **1989**, *100*, 123–131.
42. Milligan, G.; O'Halloran, J.; Tipton, M. A job task analysis for technicians in the offshore wind industry. *Work: A J. Prev. Assess. Rehabil.* **2019**, *63*, 537–545. [CrossRef]
43. *ISO/DIS 45003*; Occupational Health and Safety Management—Psychological Health and Safety at Work: Managing Psychosocial Risks—Guidelines. ISO—International Organization for Standardization: Geneva, Switzerland, 2020.
44. Chaumel, J.-L.; Giraud, L.; Ilinca, A. *Secteur éolien—Risques en Santé et en Sécurité au Travail et Stratégies de Prévention*; Institut de Recherche Robert-Sauvé en Santé et en Sécurité du Travail: Montréal, QC, Canada, 2014.
45. Leplat, J. De l'étude de cas à l'analyse de l'activité. *Perspect. Interdiscip. Trav. Santé* **2002**, *4*, 3658. [CrossRef]
46. Barros-Duarte, C.; Carnide, F.; Cunha, L.; Santos, M.; Silva, C. Will I be able to do my work at 60? An analysis of working conditions that hinder active ageing. *Work: A J. Prev. Assess. Rehabil.* **2015**, *51*, 579–590. [CrossRef]
47. Moreira, S.; Vasconcelos, L.; Silva Santos, C. Occupational health indicators: Exploring the social and decent work dimensions of green jobs in Portugal. *Work: A J. Prev. Assess. Rehabil.* **2018**, *61*, 189–209. [CrossRef]
48. Taylor, J.; Klenk, N. The politics of evidence: Conflicting social commitments and environmental priorities in the debate over wind energy and public health. *Energy Res. Soc. Sci.* **2019**, *47*, 102–112. [CrossRef]
49. European Commission. *Report on a Toolkit for National and Regional Decision-Makers. Supporting Sustainability Transitions under the European Green Deal with Cohesion Policy*; Publications Office of the European Union: Luxembourg, 2021.