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Offshore wind farms' decommissioning: a semi quantitative Multi-Criteria Decision Aid framework

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ABSTRACT

In this paper a framework for identifying an appropriate decommissioning method for offshore wind farms is developed and applied. The whole approach is based on Multi-Criteria Decision Aid techniques that perform an integrated evaluation of three available wind farms' decommissioning methods. A number of evaluation criteria are established and assessed on a semi quantitative basis. The preference of a diverse audience of pertinent stakeholders can be also incorporated in the overall analysis. The framework is applied in a case-study in the Netherlands. Even though the stakeholders included were hypothetical and their preferences only assumed the proposed overall approach, methodology and application could be useful for practitioners in the field.

Introduction

In recent years, offshore wind power has grown extensively. Global offshore cumulative installed wind capacity was 4117 MW in year 2011 representing 1.73% of total capacity and it reached 8759 MW in 2014 representing 2.37% of total capacity [1]. Projections show that by 2020, offshore wind will account for about 10% of global installed capacity. At present, more than 90% of all offshore wind installations can be found in European waters in the North, Baltic and Irish Seas, and the English Channel. The advantages of offshore wind energy compared to onshore wind energy are that the winds are typically stronger and more stable which results in higher and more reliable production. Furthermore, the turbines have the potential to be larger offshore than onshore, since it is expected that there will be less resistance from citizens and other stakeholders.

With an expected life time of 20 years, most of the existing offshore wind farms have not been in operation long enough to be decommissioned. As a result, the majority of available research has focused so far on the construction and production phases of offshore wind energy, with limited research devoted to the decommissioning phase. However, given that the demand for decommissioning will increase in the near future, the impacts and costs need to be evaluated in order to find the preferred decommissioning method based on a number of sustainability criteria.

As a means of identifying an appropriate offshore wind farm decommissioning method, this paper introduces a methodological framework to guide decision makers. The framework is based on Multi-Criteria Decision aid (MCDA) techniques which can be used to provide for an integrated evaluation on a number of economic, social, environmental and technical criteria, of the currently readily available wind farm decommissioning methods. Then, the preference of a diverse audience of stakeholders can complement the analysis. The methodological framework is tested in a case study in the Netherlands. Even though the stakeholders included were hypothetical and their preferences only assumed, the proposed overall approach, specific methodology and application could be useful for practitioners in the field like for example the industry, regulators and environmental bodies.

The paper unfolds as follows: In Chapter 2 the relevant literature is presented; in Chapter 3 the methodological framework is introduced; in Chapter 4 an application of the framework is presented; Chapter 5 includes results and discussion and Chapter 6 the conclusions.

Literature review

Process of decommissioning a wind farm

In most cases, the decommissioning process of a turbine is expected to be the reversal of the commissioning process. It is, therefore, expected that the process would be subjected to similar

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constraints as those experienced when commissioning an offshore wind turbine [2].

The first step in decommissioning a wind turbine is to disconnect the wind turbine from the grid and de-energize it. Then, deconstruction proceeds in the following order: blades, nacelle and tower [3]. At this point, two wind turbine decommissioning methods can be identified, that differ in the way the foundation is treated; these are the partial removal of the foundation method and the total removal of the foundation method. The difference between the partial removal method and the total removal method is that with the partial removal method some parts can be left in situ. In most cases, this would be the scour protection[1] and/or parts of the foundation. With the partial removal method the area does not have to be brought back to the pre-wind farm state [4].

The total removal method is based on the generally accepted idea that the site should be returned to the state it had before the wind farm. This would mean a revocation of all restrictions for shipping, fishing and navigation. Based on this idea, there should be nothing left in situ and therefore everything, including all of the below seabed components should be removed. The common method to completely remove a foundation is to use explosives which are placed below the mudline. Once the foundation is removed, the state of the area should be restored mechanically to the original physical characteristics [5].

There are several methods available to partially remove a foundation. The methods can be external cutting of the foundation, internal cutting of the foundation or using explosives. Of these, the external and internal cutting without using explosives will be preferred [6]. In order to cut a monopile[2] several steps must be taken. For external cutting, first mud has to be dredged to create an excavation pit. When this is done, it is possible to cut the monopile and to remove the pile. Following on from this, the pit should be filled with mud again on a natural way. For internal cutting, mud has to be first pumped away. When this phase is done, it is possible to cut the foundation and remove it (Fig. 1).

It seems, therefore, that there are at least three different methods to decommission an offshore wind turbine (total removal of foundation, partial removal of foundation – external cut and partial removal of foundation – internal cut) and each one of them may include advantages and disadvantages. Nevertheless, the complex nature of decommissioning decisions, the extensive and varied nature of criteria involved and the trade-offs between criteria given, often by the competing objectives of stakeholders, are required to frame this decision problem. This can lead to the conclusion that, in order to identify a 'preferred' decommission method, Multi-Criteria Decision Aid (MCDA) techniques may be employed.

An integrated environmental and socio-economic impact assessment of the various options of future use or demolition of the oilfield platforms in the North Sea has been initially presented in [7] and more recently a MCDA approach to decommissioning of offshore oil and gas infrastructures has been developed in [8]. Subsequently, a cohesive examination of decommissioning options for the offshore wind power industry in particular has been offered in [4]. Finally, a specific participatory MCDA approach (Multicriteria Approval) has been proposed for decommissioning of offshore wind farms [9] and other authors also agree that MCDA is a suitable tool for such complex decisions problems and acknowledge the need to a further usage of MCDA in such highly subjective decision processes [10].

[1] Scour refers to the removal of sediment from the area around the base of a support structure. Scour protection includes dumping rock of different grade and placing concrete mattresses around the foundation of an off shore wind turbine [6].

[2] A monopile is a simple design which support the tower of the wind turbine either directly or by a transition piece. The monopile is made of steel tubular and is drilled into the seabed [6].

Multi Criteria Decision Aid

Multi-Criteria Decision Aid tools have been developed to help decision-makers in taking decisions for complex problems where a number of usually diverse decision parameters are involved and are particularly helpful in environmental decision making [11]. Nonetheless, MCDA methods can be useful for a wide range of topics. For example, they have been used in natural resource management [12], urban road planning [13], selection of alternative-fuel vehicles [14], fishery management [15], wind power planning [16,17] and decommissioning of offshore gas- and oil infrastructure [8], among others. A descriptive multi-criteria approach for analyzing available options for the repowering of wind farms' is developed in [18].

Several MCDA tools or methods have been created and are available to guide decision makers through a decision-making process. A few examples are the PROMETHEE and the ELECTRE families of techniques and the AHP [19–21]. The PROMETHEE family of techniques is widely used in energy and environmental planning mainly due to simplicity, clear meaning of the parameters used and straightforward application [22–24]. There is, however, not a single best MCDA method, only suitable methods for certain cases [25–27].

Methodological framework

The methodological framework presented in Fig. 2 proposes that when the wind farm is reaching the end of its lifetime or when the decision maker is investigating the decommissioning method, the first thing to be done is to identify the readily available decommissioning methods. This should be done carefully, because decommissioning is most likely an extremely controversial subject. Furthermore, there exist country-specific regulations which should be taken into account.

At this moment, the regulation in most countries allows for both the partial and total removal of the foundation methods. It should be noted that there could be differences per country if for instance the cables can be left in situ or not[3]. Lastly, it should be said that more decommissioning options could be possible in the future if regulation changes.

The next step could be to collect data and select the relevant stakeholders. The data collected can be for example the costs of the different decommissioning methods, the impact on the environment and the possible benefits for recreational and commercial industries. The stakeholders should also be selected at this moment. In fact, the whole process of wind energy planning is an extremely controversial subject whereby stakeholders with contradicting opinions are involved [28].

The next step in the framework is to select the evaluation criteria. This is an important feature, because the criteria naturally define what the decision is based on. In the case of decommissioning an offshore wind farm, a wide range of criteria could be selected. The list of criteria can include economic, environmental, social and technical criteria among others. When the criteria are selected, assessed and ranked according to stakeholders' preferences, they can be put into a MCDA tool and the result of the process should represent the preferred compromise outcome, which would be supported by most of the stakeholders. It is expected that, if this process is followed, it should reduce conflicts and enhance transparency.

In the next chapter an application of the proposed methodological framework is presented for a case-study in the Netherlands.

[3] Cables in the seabed are necessary to export electricity from a wind turbine to the substation and from the substation to the shore.