Agent-based modelling for scenario development of offshore wind energy

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Abstract

Within a PhD-research, scenarios will be developed as paths to the implementation of large-scale offshore wind energy in the Netherlands towards a target of 6000 MW in the Dutch EEZ in order to investigate opportunities and threats to the new industry. The uncertainties of the future and the consequences of decisions are taken into account, from several perspectives. This paper investigates whether agent-based modelling can be used to develop consistent scenarios. Therefore a simple model has been created, including the actors involved in the supply chain at a high aggregation level.

Keywords: *Offshore wind energy, scenarios, agent-based modelling*

1 Introduction

In the Energy report 2002 of the Ministry of Economical Affairs [1], the following targets are considered as ‘possible’ for the Netherlands: 1500 MW of installed onshore wind power by 2010 and 6000 MW installed wind power offshore by 2020. These targets are described as ‘a necessary step for the transition towards a sustainable energy household’. The first demonstration park, Egmond aan Zee Offshore Wind Farm, has been formally opened in April 2007. The construction of the first commercial park has started in the end of 2006 and is expecting commissioning in 2008. The target of 6000 MW by 2020 seems a very ambitious target; 2030 seems a more realistic target.

For new commercial parks, towards 6000 MW, many obstacles still have to be overcome. The project developers have an interest in building offshore wind farms[1], especially since the planning of onshore farms is getting harder due to opposition by local groups, lengthening procedures considerably [2]. Also, the Netherlands has a reputable offshore industry, which could gain employment and profit from offshore wind development. But many uncertainties surround this new use of the sea. The question is, when setting 6000 MW by 2030 as an objective, what are the challenges to overcome and what are the opportunities for the stakeholders? Or, in a more process minded manner: in what ways can this 6000 MW be achieved or what can stop or delay it?

To try to answer this question (at least partly) a study is done in the possible developments of offshore wind in the Netherlands. The approach in this study is to create scenarios as development paths towards 6000 MW by 2030. Porter [3] defined a scenario as “an internally consistent view of what the future might turn out to be - not a forecast but one possible future outcome’. The future cannot be predicted, but by creating several scenarios, the uncertainty over the future can be captured by these different views of what could be, a range of possibilities for the future.

For these scenarios, different perspectives on the central issues are taken; a social, political, technical and economical perspective. Offshore wind is a multi-disciplinary field, and many stakeholders are involved. To look at the possible development for offshore wind (here: in the Netherlands) therefore requires an integral approach. Despite a shared main target for the development of large-scale offshore wind energy, conflicts of interests may arise between the different actors involved because they can have different objectives.

As an example of the political perspective: three claims have been given now on new locations, but the subsidy for offshore wind, a premium price per kWh, has been set to zero, which will likely be the situation until May 2008 [4]. The government wants assurance of their expenditures on offshore wind and therefore the procedure for attaining the subsidy is under review. A new commercial park is therefore not expected to be commissioned before 2010. A significant technical and regulatory challenge is the grid connection: studies have been performed that look at different configurations of an offshore grid, and for connecting 6000 MW the existing grid will need to be strengthened. From a social view, other users have to be taken into account in setting a location for a farm.

Because of the many different stakeholders and options for development, a complex system arises when one wants to look at the possible developments in the form of scenarios. Therefore, a model will be built to develop these scenarios. The modelling technique used is Agent Based Modelling (ABM), which is a technique capable of simulating a complex system. In this paper, it is described how ABM can be used to create the scenarios and what the setup of the model is. First, a short introduction to ABM is given. Second, the model is described by stating the main assumptions and basic form. Third, it is discussed how the scenarios will be developed using this model.

[1] Already more than 80 initiatives have been placed for locations for offshore farms in the Netherlands since the moratorium was lifted in January 2005. Four of these have submitted a permit request.

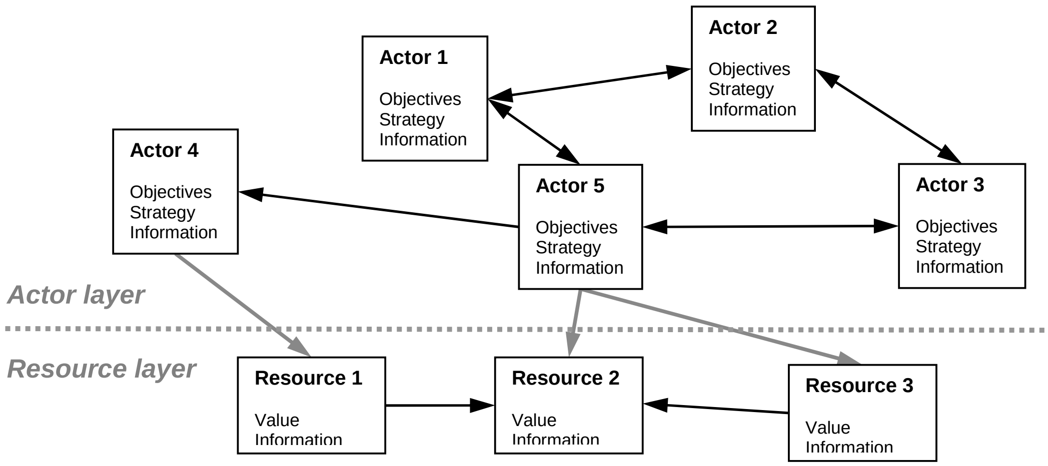

Figure 1: Elements in the model are actors, modelled as agents, and resources.

2 Short introduction to ABM

An agent can be described as a computer programme that models any one or any thing that you want to take action towards its own objectives, for instance a human looking for food or a company wanting to make a profit. An agent is therefore said to act *autonomously*, meaning it can act independently, without intervention, towards these objectives in goal-directed behaviour. It is placed in an environment, and from this environment it receives input to which it reacts to in a *reactive manner* as well as anticipates to in a *pro-active* manner. Jennings summarises this in his definition of an agent as 'an encapsulated computer system situated in some environment that is capable of flexible, autonomous action in that environment in order to meet its design objectives' [5].

An Agent Based Model (ABM) is basically a model consisting of several agents, as a computer representation of a complex system comprised of multiple, interacting actors (i.e. agents) [6]. By running an ABM, a complex system can therefore be simulated. The main advantages of ABM are the real-world modelling and the fast runs. By modelling a human, organisation or others, one can model as it is in the real world [5]. Because it is hard to predict the behaviour of a complex system, ABM gives the advantage of only having to model each agent in itself and then running the simulation where the interaction of the agent simulate the complex system. This will therefore give unexpected results, or *emergent behaviour*. This is also connected to a disadvantage of ABM; the uncertain origin of arising patterns. Therefore, great care has to be given to validating the programme by using known cases, to examine if that unpredictable, emergent behaviour is not a result of a programming error.

3 Description of model

3.1 Actors and resources

There are two important issues we want to be able to simulate with the model. First, the interaction between the different stakeholders will be simulated to see if this can form bottlenecks. The stakeholders are defined as organisations that can have a significant limiting or accelerating influence on the implementation. These will therefore include parties actively involved in implementation such as developers or installation companies, as well as condition setting groups such as environmental and interest groups and governmental agencies. These will compete and cooperate to attain their objectives, such as profit, market share or minimising environmental impact. The priority of their objectives and the instruments they have at hand will define their strategy. In this way, a simulation can show where conflicts of interests can jeopardise the 6000 MW target and where cooperation is needed.

The second issue is the availability of resources. In order to have a realistic view of the implementation in the model, the required resources have to be taken into account, as well as the time to change the availability of resources. Such resources are for instance vessels for installation; building a new vessel will take 2 to 3 years, so if an offshore company decides to build a vessel after the market has increased, the availability of vessels for installation can become a limiting factor. It also includes possible limiting resources such as harbour capacity, grid capacity, and human resources, since people might have to be educated to have enough personnel to install 6000 MW by 2030. The time-scale in which problems may arise and solutions can be implemented have to be taken into account for a realistic implementation rate.

3.2 Basic set-up

The two main issues were described above: the strategies and interaction of the relevant actors and availability of resources. To model the development of offshore wind in the Netherlands, the stakeholders will by modelled by agents in an ABM. These agents communicate with each other, and they own resources or can view the information on available resources. Therefore the model will consist of two layers; an *Actor layer* and a *Resource layer*, graphically depicted in Figure 1.

The actors will have objectives, and strategies to attain these objectives. Such strategies can for instance entail a risk-averse and risk-seeking behaviour. The objects in the resource layer will be non-acting Objects, which have values that can change and which have a list of agents that can see or change this information.

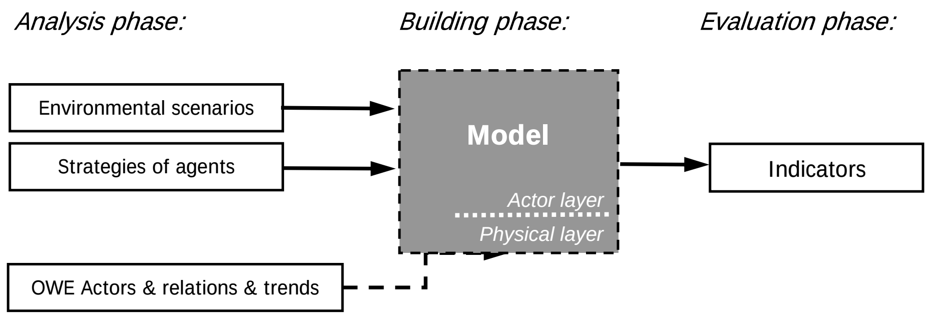

Figure 2: The input and output of the model.

3.3 Environment

The agents are situated in an environment, containing the information on the surroundings. This contains society is Renewables.
green-minded, meaning there is high environmental concern and therefore strong social support for information or factors of importance to the development of offshore wind, but external to the relevant actors; for example, market prices of oil and steel, or whether

3.4 Development of the model

To develop the model, first we want to determine which actors are relevant and which resources could possible pose a limiting factor for the development. The relevant actors have been defined by performing an actor analysis. The agents will not represent a specific company or organisation, but a more generic type is taken. Here the aggregation level is important; we want to model the (Dutch) offshore wind sector and stakeholders, and therefore to micro-analyse a company is of less importance; it is more important that all relevant actors are present. For instance, several *wind turbine manufacturing agents* will be incorporated, but not specifically Vestas or GE. In the actor analysis, the interests, instruments and relations between actors are analysed.

In the first design of the model, the following actors will be included:

List of relevant actors

- **Financial Actors**
  - Government
  - Insurance company
  - Investor
- **Environmental Actors**
  - Local environmental group
  - Global environmental group
  - Other users (Fishing, shipping, …)
  - Society
  - Coastal municipalities
- **Technical Actors**
  - Developer
  - Wind turbine Manufacturer
  - Operation and Maintenance company
  - Utility
  - Offshore installation contractor
  - Generator/ Gearbox sub-supplier
  - Cable contractor
  - Electrical contractor
  - Foundation contractor
  - Other sub-contractor
  - Monitoring and Evaluation company
  - Sea-bottom measurement company
- **Markets**
  - World market for raw materials
  - Wind Turbine Market
  - Electricity market
  -

Next the relevant resources are chosen. For the technological development of such resources, trends are researched. The size of a wind turbine can have an impact on the implementation speed, and it is not expected that the turbines will not evolve anymore; development is fast and trends (with possible limits) will be deduced to estimate wind turbine size for the future. In the first design of the model, the following resources will be taken along:

List of relevant resources

- National grid
- HV Stations
- Harbours
- Turbines
- Installation vessels
- WTM factory
- Projects
- Park location space

4 Developing scenarios

By running the AMB, different scenarios can be played out. These scenarios are first set up by forming environmental scenarios; scenarios that describe different possible environments. Together with the choices for the strategies for the different relevant actors, i.e. the agents, this forms the input of the model. By varying this input, different scenarios can be played out to see what is required to achieve 6000 MW in 2030.

This results in the determination of the *desirability indicators*; these are performance indicators which describe the desirability of the scenario that has been played out. These indicators are for instance required innovation (operationalised by R&D budgets), and the impact on the North Sea environment (operationalised by the used surface and time of activity on the sea). The different scenarios can then be evaluated and compared by looking at the desirability indicators.

In Figure 2, the planning for developing scenarios is given. First in the analysis phase the actor analysis and selection of relevant resources will form the basis for the model. The input of the model, the environmental scenarios and possible strategies for agents are chosen. Right now, the study is entering the building phase; a simple model has been implemented to test the possibilities. As a support, Repast Java [7] is used. Repast is an agent modelling toolkit, which supplies a graphical user interface as well as a library of graphical functions, and it runs the simulation by time steps.

5 Conclusions and future work

A simple model has been implemented, with only two types of agents communicating with each other; project developers and wind turbine manufacturers. In implementing the simple model, ABM showed itself a comprehensive way of modelling and Java as object-oriented language very suitable for programming such a model.

The next steps are the development of the model in Repast and translating the actor analysis, where the stakeholders and their different strategies, interests and relations are determined, into agents and their relations in the model. This model will include over 20 types of agents and several types of behaviour or strategies will be defined for them.

6 Acknowledgements

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7 References

1. Ministerie van Economische Zaken, Energierapport 2002, *Investeren in energie, Keuzes voor de toekomst*. Den Haag, 2002.
2. Wolsink M. Dutch wind power policy – stagnating implementation of renewables. *Energy Policy* 24, 1079-1088, 1996.
3. Porter ME. *Competitive advantage.* New York Free Press, 1985.
4. Brief aan de Tweede Kamer van Min. MJA van der Hoeven,, Voortgang MEP, ET/ED/7049573, 17 april 2007 (in Dutch).
5. Jennings NR. *On agent-based software engineering. Artificial Intelligence*, 117 (2) p. 227-296. 2000.
6. Brown DG. invited entry in H. Geist, Ed. *The earth's changing land: An encyclopedia of land-use and land-cover change*. Westport CT: Greenwood Publishing Group, 2000.
7. Repast website: http://repast.sourceforge.net (last visit April 2007)