Construction delivering transition -Danish and Swedish offshore wind farms

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Abstract

Construction activities are part of present societal transition towards a zero carbon society through several clean technologies' implementation and the construction sector is thereby possible either constraing and or enabling this current transition. Offshore wind turbine farms in Denmark and Sweden are one example of this. These projects encompass a high public profile, and might involve time delay, cost overruns and underperformance of their operations. The paper views offshore wind farms as socio technical undertakings of construction and draw on a combination of internal and external perspectives i.e. complex engineering projects and megaproject concepts and operation strategy and management. The aim of the paper is to investigate the phenomenon at Danish and Swedish offshore farms for strategic misrepresentation, overruns and underperformance or the opposite. Such projects tend to enact strategic misrepresentation understood as a combined practice of underestimating time and cost and overestimating the benefits of use of the completed product. The paper review other scholar's comments and criticism to strategic misrepresentation. The internal perspective focus on operation strategy is condensed into looking at contracts, planning, equipment and competences.

The results building on public accessible material show both successful and less successful projects, the less successful involving budget and time overrun, as well as under performance at a sample of 7 Danish and Swedish offshore wind farms. The paper discusses the particular elements of possible strategic misrepresentation but finds a contradictory pattern. Also experientally based competences are not clearly developing as later wind farms perform less than earlier. The insights provided offers alternative interpretations of overruns, relying on operations strategy elements.

Keywords: Transition, offshore wind farm, Denmark, Sweden, strategic misrepresentation

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1. Introduction

In the present contradictory societal situation strong forces push for transition towards a zero carbon society issuing demands for clean technology, yet the austere financial environment hampers the very same development. In these waters the wind industry continues to grow in terms of employment, conditioned by an uneven global development i.e. the light stagnation of number of new installed offshore wind turbines in Europe 2011 compared to 2010 (EWEA 2012), and the growth globally on markets like China, Asia and Latin America. And the impressive offshore wind plans presented in the EU members States energy renewal plans for 2020 alone represents investments in around 43 GW offshore (EWEA 2012). The installation of offshore wind farms, encompassing large power plants of wind turbines, as well as nearshore smaller farms are complex endeavours and the growth in demand for installations have generated a similar growth in operating companies, manufacturers, clients and interested citizens (BTM, 2010). Therefore the term “off shore wind farm” is used not only to denote the installations, but also the community of social players around them, adopting a sociotechnical viewpoint (Koch 2007). The technology involved encompasses installations from 5 MW and upward, usually consisting of a number of MW turbines, with an internal grid, a substation for transforming power, and an export cable connecting to a national grid (Gerdes et al., 2005; IEA, 2005; Snyder & Kaiser, 2009, Zhixin et al., 2009).

The aim of this paper is first to develop a combined social constructivist internal and external conceptualisation of the process of realising offshore wind farms; second, to investigate costs, time, delays and operational performance results of offshore wind farm power plant projects in Denmark and Sweden with a view to possible strategic misrepresentation.

The overarching theoretical perspective is thouroughgoing interpretivism (Grint and Woolgar 1997) appreciating the dynamic renegotiation of a sociotechnical community like offshore wind farms. This overarching perspective in turn features an external and internal perspective on offshore wind farms. The external perspective mobilised is Flyvbjergs constructs such as strategic misrepresentation as a combined practice that underestimates time and cost and overestimates the benefits from using the completed product (Flyvbjerg 2009).

The internal perspective builds on operations strategy (Slack And Lewis 2008), operations strategy (Slack et al 2007) and project management (Liu and Napier 2010, Love 2011). It focuses on contracts, planning, equipment and competences.

The empirical material encompasses data on seven offshore wind farms, six Danish and one Swedish, realised between 2001 and 2010. The farms are Horns Rev I, Horns Rev II, Lillgrund (SE), Middelgrunden, Nysted, Rødsand II, Samsø. Both the external and internal perspective is mobilised to scrutinize the process of realising those farms.

The paper is structured in a classical manner. Opening with a method, followed by theory, case description, discussion and conclusion.

2. Method

The research design behind this paper matches the two main aims of the paper. The first research question, the theoretical framework, is composed by combining an external and internal perspective. The external perspective contributions are critical studies of megaprojects (Flyvbjerg 2009, 2011)), complex engineering project management contributions (Davies and Hobday 2005, Miller and Lessard 2008) The internal perspective is covered by using operation strategy and operation management perspectices (Slack & Lewis 2008, Slack et al 2007). Finally Science, Technology, and Society (STS) approaches (Hughes 1983, Latour 1987, 2005, Grint and Woolgar 1997), acts as overall framework understanding of offshore wind farms as essentially being thoroughly negotiated and renegotiated, with inseparable social and technical aspects, operating in a semi-public environment, and involving a substantial amount of public performance. The second research question, the empirical, is answered by first investigating the external aspects of costs, time, delay and operational performance in relation to strategic misrepresentation, second the internal aspect of operational strategy. Both is done in an exploratory investigation manner with focus on a core data set from a selection of Danish and Swedish offshore wind farms. The selection of offshore wind farms has been done taking the largest in this geographical area, which also encompasses operational experience. These criteria lead to a sample of seven farms, six Danish and one Swedish; Horns Rev I, Horns Rev II, Lillgrund (SE), Middelgrunden, Nysted, Rødsand II, and Samsø. These farms also constitute a considerable basis of experience for a recurrent group of companies. The selection implies that some smaller Danish and Swedish wind farms have been disregarded, such as Frederikshavn (DK), Sprogø (DK), Vindeby (DK) and Yttre Stengrund (SE). The central tool for the first empirical work has been a desk study using internet sources. The analysis thus relies on publicly accessible sources, which is justified by the characteristics of engineering construction described above. Most of this material is not referenced as it is in Scandinavian language. It ranges from short newspaper announcements, articles in the business press and websites to reports and articles based on research from public wind industry associations and universities. For each of the figures and information given below, triangulation is used (Bryman and Bell, 2007), relying on several independent sources. The available public information has its strengths and weaknesses. Two examples of issues are currency conversion and difficulties in measuring the start and finish of a construction phase. The study is clearly limited in that it uses only desk research. If combined more systematically with other methods, it would be possible to detect internal phenomena, such as transfers of resources between projects, and capture details on labour and material costs.

3. Theory

The theoretical framework adopts an social constructivist approach drawing on STS (Latour 2005, Woolgar & Grint 1997). Within this frame two different perspective the external and the internal is combined. The external view draws on critical studies of megaprojects by Flyvbjerg and colleagues (Flyvbjerg 2009, 2011), and complex engineering approaches (Davies and Hobday 2005, Miller and Lessard 2008). The internal perspective combines operations strategy and management (Slack and Lewis 2008) project management contributions (Love 2011, Liu and Napier 2010). The social constructivist approach used here, the thoroughgoing interpretive perspective (Grint & Woolgar 1997), appreciates the indeterminate features of cost, time, service provision, contracts and enterprise organisation and strategy, and viewing offshore wind farms as “texts” in an anti-essentialist manner (Grint & Woolgar 1997, Sismondo 2010). Throughout the project life time the figures and features characterising it are renegotiated over and over again both in the public sphere but also internally in the contributing companies. For example fixed sum contracts generate “backwards” controlling of expenses and/or attempts through various types of claims to enlarge the fixed sum. And project based accounting involves controlling hours spent using the portfolio of projects and activities rather than just one project, meaning the project costs are not necessarily allocated to the accounts where they belong. Texts on budget, time and cost figures thereby are renegotiated. Moreover the social constructivist approach implies that offshore wind farms should be understood as a socio-technical undertaking (Hughes 1983, Latour 1987, 2005) that operates in a semi-public environment (Hughes 1983). Hughes (1983) suggests ‘system’ as term, distinguishing between vertical systems, when the technical content varies between the different components, and horizontal when the same elements are repeated. Hughes (1983) views technical content and social aspects as inseperable, similar to Latour (2005). This is here taken to mean, that down to the detailed components of the technological constellation, they would encompass social issues such as cost, design approaches etc. Offshore wind farms can be understood as such socio-technical projects, which can be further defined using a complex engineering project definition: “high cost, technology intensive, customized capital goods, systems, networks, control units, software packages, constructs and services” (Davies and Hobday 2005). The strength of this definition is that it merges a business approach (capital goods) with a technical approach, underlining the scope and bundles of technologies associated with the product and appreciating the interconnection with the customer and the service aspect. The downside is however that the technology side tends to be described on a too abstract level and with too little appreciation of the intertwinedness of the technical and social. With a sociotechnical conceptualisation a cautious contextualisation in time and space of a study of socio technical phenomena is appreciated (Latour 2005). This approach emphasises an understanding of less stabilisation of the technology over time. Complex projects are often carried out under conditions of great risk and uncertainty, with a number of unforeseen aspects emerging as they develop (Davies and Hobday 2005, Hughes 1983, Millar and Lessard 2008). Decision-making regarding such aspects as budgeting and planning must thus cope with these conditions (Kahneman 1994). Offshore wind farms are essentially thoroughly negotiated and involve a substantial amount of public performance, and the project players are involved with the outer world.

Flyvbjerg (2009, 2011) represents a different, externalist approach, claiming that especially projects operating in a public-private interface would tend to be hampered by political mechanisms leading to a far more complex task for project management. The studies by Flyvbjerg (2009, 2011) on cost and time overruns within transport infrastructure (tunnels, roads, railroads, bridges) describe and document a long series of examples of heavy overruns. Also in later studies, Flyvbjerg and others have documented similar patterns (Flyvbjerg 2009). Flyvbjerg et al (2003) show that cost underestimation is a global and long-term phenomenon that does not diminish over time. Moreover, they document that cost underestimation cannot be explained by error, but rather by optimism bias and strategic misrepresentation. Optimism bias occurs when planners of complex projects underestimate or are not fully aware of the time and costs necessary to realise the project. Estimations are often based on assumptions (Kahneman 1994). Strategic misrepresentation occurs when planners and other players who are active in preparing a project purposely reduce the required cost and time and increase the project's positive impacts in order to make the project attractive (Flyvbjerg 2011). Public and private players who join in alliance to launch a project often practice strategic misrepresentation. Project promoters may possess knowledge about how much a client for a complex engineering product can afford to pay, or at least the budgetary constraints that might exist (Flyvbjerg et al. 2003). Such knowledge can be used to fit budgets and schedules to these constraints rather than to present a realistic calculation of the project risks. Also, on a public-private arena, a "point of no return" is likely to exist; once a project is initiated, it cannot be stopped even if it runs out of funding (Flyvbjerg et al. 2003). The concept of strategic misrepresentation involves argumentation that combines underestimating time and cost and overestimating the value of the completed product to the customer (the benefit side, Flyvbjerg 2009). In relation to wind farm power plants, this would be equivalent to overestimating the actual power production based on unrealistically high expectations to production time and availability and underestimation of maintenance time and service costs. Flyvbjerg et al. (2009, 2011) argue that technical explanation cannot be found, whereas psychological and political-economic explanations are prevalent, which is contrary to the project management literature (see also Vanston and Vanston 2004). Political-economic explanations, however, explain inaccuracy in terms of strategic misrepresentation. Strategic misrepresentation is more likely to occur in wind farm projects than optimism bias, since these projects involve a series of reciprocal actions with public authorities, the press and the public. Flyvbjerg's critics, such as Love (2011), point out that the delimitation of Flyvbjerg's approach and concepts leaves a "chronological lacuna" between the initial event and the final outcome (Love 2011: 1202) since "intermediary conditions and events that lead to project overruns occurring are not examined or explained" (Love 2011: 1202). Moreover, Love (2011) characterises the reasoning of strategic misrepresentation and optimism bias as counterfactual causation (Love et al. 2011). Importantly, it can be added that Flyvbjerg, by adopting a focus on input and outcome measured in time and costs, overlooks the content of the project, which is rarely fixed as the project develops. Liu and Napier (2010) claim that optimism bias can be found widely within the construction industry. They contend that "it has been recognized that in preparing estimates, estimators are likely to make 'self-protective predictions', influenced by self-interest in securing contracts" (Liu and Napier 2010). Similarly, contractor's tender prices are often not only a product of the estimating department, but also managers may intervene reducing prices to lower levels in an attempt to win the contract (Liu and Napier 2010). Finally, clients may strategically underestimate costs to ensure that the project is launched and to obtain funding. Therefore there is a need for a more internal perspective.

3.1 The Internal perspective, operation strategy

Operation Strategy as a discipline and practice deals with "the total pattern of decisions which shape the long term capabilities of any type of operation and their contribution to overall strategy, through the reconciliation of market requirements with operations resources" (Slack & Lewis 2008:18)

The main element of operations strategy according to Slack and Lewis (2008) are:

- Capacity Strategy
- Supply Network Strategy including purchasing and logistics
- Process Technology Strategy
- Development and Organisation

Capacity Strategy is concerned with how Capacity and facilities in general should be configured. In an offshore wind farm context contracts with windturbine manufacturers and a range of other suppliers is central. Windturbine manufacturer's capacity and quality of delivery are important and they normally do not directly do the installation, which is contracted. *Supply Network Strategy* including purchasing and logistics i s concerned with how operations relate to suppliers and customers. This is in the context of wind farms understood as the configuration of contracts with suppliers of products and processes for erecting the offshore wind farms, allowing the description and analysis to disregard the relation to the clients and customers. *Process Technology Strategy* concerns the choice and development of systems machines and processes. This is here simplified into looking at the equipment used. *Development and Organisation* is concerned with how the long term decision governing how the operations are run on a continuing basis. In the offshore wind farm context this occurs across projects and is here viewed as an issue of how project organisation is conceptualised as well as how competences develop. Competences as seen as a measure whether operational strategy are developing across projects. Also project management encompasses project planning. Literature on project management, often portray making time, cost and quality balance as a question of project management skills and tools (Atkinson 1999, Olewale and Sun 2010, Reichelt and Lyneis 1999) involving various budgeting, cost estimation and forecasting and planning techniques; however, the project management literature also explains how phenomena like 'scope creep' (increase in the number of project tasks) complicate this task. Love (2011) identifies a series of possible internal explanations for project overrun, which encompass practice, tasks, circumstances, organisation, system, industry and tools (including design errors and coordination problems). Similarly, Kaming et al. (1997), looking at high-rise projects, find "internal project" explanatory factors – such as inflationary increases in material costs, inaccurate material estimations and project complexity – to be the main causes of cost overruns. For time overruns, the main causes of delay are design changes, poor labour productivity and inadequate planning (Kaming et al. 1997).

Summarising the social constructivist framework, by combining an external and internal sociotechnical understanding of offshore wind farms provides an appropriate framework for evaluating both the external strategic misrepresentation and the internal operations strategy for offshore wind parks here condensed into looking at contracts, planning, equipment and competences.

4. Cases: Selected Danish and Swedish offshore wind farms

The seven offshore wind farms investigated in this study are the following: Horns rev I, Horns Rev II, Lillgrund, Middelgrunden, Nysted, Rødsand II and Samsø. Lillgrund is the only placed in Swedish waters whereas the rest are placed in Danish waters. Middelgrunden is the oldest and was in operation in 2001. The youngest Rødsand II was operational in 2010.

Table 1 Technical features (M= monopole, G= Gravitation)

Wind farms	Power capacity	Turbine MW	Foun-dation	Water depth	Infield Cable kv/km	Export Cable kv/km	Offshore Sub-stations
Horns rev I	160	2	M	6-11	30/63	150/21	1
Horns rev II	209	2,3	M	9-17	33/70	150/42	1
Lillgrund SE	110	2,3	G	4-8	33/24	130/7	1
Middelgrunden	40	2	G	3-6	30/5	30/3.5	0
Nysted	166	2,3	G	6-10	33/48	132/11	1
Rødsand II	207	2,3	G	6-12	33/75	132/80	1
Samsø	23	2,3	M	10-13	30/3,5	30/4	0

Table 2 Cost

Wind farms	Power capacity	Initial Budget Mio. Euro	Actual Cost Mio Euro	Cost overrun %	Cost per MW Mio Eur
Horns rev I	160	229	278	21,4	1,74
Horns rev II	209	470	470	0	2,25
Lillgrund SE	110	167	197	18,0	1,79
Middelgrunden	40	46	49	6,5	1,23
Nysted	166	269	269	0	1,62
Rødsand II	207	450	446	-0.90	2,15
Samsø	23	33	32	-3,0	1,39

Table 2 shows that three out of seven wind farms exhibit a cost overrun. Two farms are completed using exactly the budget, whereas two farms have used less than budget (up to 10 %). Four can cautiously be considered as exhibiting acceptable performance for clients and contractors, also considering uncertainty connected with the calculation.

Table 3 Time

Wind farms	Power capacity	Initial time Month	Actual time Month	Time overrun %
Horns rev I	160	10	16	60

Horns rev II	209	21	17	-19,0
Lillgrund SE	110	20	23	15
Middelgrunden	40	4	6	50
Nysted	166	19	18	-5,3
Rødsand II	207	20	17	15
Samsø	23	7	9	28,6

Table 3 shows that four farms exhibit time overruns compared to the initial schedule, and that these overruns exceed 10 percent. Conversely three farm are completed before time even up to twenty percent. It derives that the small farms; Middelgrunden and Samsø will relatively short initial schedules are more vulnerable to unplanned events. Horns Rev 1 experienced very extensive problems with the turbine technology. The discussion presents an analysis of the reasons for compliance and overperformance respective underperformance and overrun.

4.1 Power production performance during operation

The planned production of wind farm power plants is often stated by an expected capacity factor, expressing the MW-hours one would expect out of the MW-capacity provided (Feng et al. 2010:4).The factor is around 35% for offshore (BWEA, 2008, Levitt et al 2011). Danish experiential figures show a “lifetime” capacity average of 37% for 12 long-term operational offshore farms (DEA, 2011) (lifetime meaning from installation some 20 years back to present date) including those examined here, see table 4. Four wind farms, have actual capacity factors lying above the average (BWEA 2008, Levitt et al 2011) and three wind farms, have actual capacity factors lying below. Only one, Middelgrunden is significantly lower (25,2% compares to 35%). The operational offshore wind farm power plants exhibit higher levels of maintenance time than planned. All offshore wind farms have scheduled service and maintenance, but there are many examples of unplanned extraordinary issues lowering the availability of the wind farm. These include unplanned replacement of generators, gearboxes, cabling, shafts and more. The owners of Samsø, had to carry out repair of the export cable in 2004. Vattenfall, owner of Horns Rev, announced in April 2010 that repair of transition pieces (between the monopile and the tower). Such extraordinary repair rounds affected British wind farms as well (Koch 2012).

Table 4 Actual Capacity factor (Source DEA 2011, LORC 2012)

Wind farms	Power capacity	Year In operation	Actual Capacity Factor %
Horns rev I	160	2003	39,9
Horns rev II	209	2009	46,7
Lillgrund SE	110	2008	33,79
Middelgrunden	40	2001	25,2
Nysted	166	2004	36,1
Rødsand II	207	2010	42,1
Samsø	23	2003	38,9

5. Discussion

The Danish and Swedish cases show an interesting mixture of some projects exhibiting compliance with articulated time and cost budgets and others with cost and time overrun. There is no difference between small and large projects in this small sample. Judged by budgets and schedule there is therefore not a clear picture of strategic misrepresentation. Lönker (2005)'s findings on the Nysted farm even indicates elements of proactive project scheduling, using two summers rather than one winter, and compliance with budget that can be said to demonstrate the opposite; a well exercised project management. Strategic misrepresentation also involves overestimating the benefits of the projects (Flyvbjerg 2009). By wind farms, this involves overestimating the power production based on unrealistically high expectations to production time, availability and underestimating maintenance and service costs. The present sample does not exhibit important deviances from planned capacity, with the exception of one, Middelgrunden. Two farms are even significantly higher than Danish average (DEA 2011). What the cases along with the UK cases demonstrate is, that the involved companies are involved in an developing the operations strategy gradually. This encompasses planning for the weather, using onshore assembly of either Siemens or Vestas turbines and barges and jack-up vessels as central equipment. And that competences develops as the projects are carried out, yet in a sometimes disruptive manner hampering experiential knowledge to be translated and carried on as the companies grow.

5.1 Contracts

It is clear that project management has to operate a complex set of contracts- Forexample Horns Rev 1, realised in 2003 had 69 contracts (4Coffshore 2012), and Horns Rev 2 had 91 (4Coffshore 2012). It is occasionally reported that contracts also involve the main contracting unit involve directly in the manufacturing at the wind turbine manufacturer and (for example) steel pipe manufacturers (Lönker 2005). It is equally clear that Danish, Swedish and UK wind farms built between 2000 and 2012 all encompasses a small group of recurrent firms. Siemens and Vestas share the installations between them and only in Holland and Germany one find other turbine suppliers present (Nordtank and RE power, 4coffshore 2012)

5.2 Planning

There is both examples of well exercised planning and less so. As Lönker (2005) finds Nysted appear to have benefitted from project manager recurrent from Horns rev I, and the planning works well here. The two small farms in the sample Middelgrunden and Samsø are different in terms on compliance with time, even they both feature short tight schedules, one complies with schedule and the other don't.

5.3 Equipment

Where the early farms tended to be erected using ad hoc equipment from the oil and gass offshore industry or from bridge building, the later uses a more and more advanced set of specially designed vessels. This also reflect the central placing of the A2SEA company both in Danish, Swedish and UK windfarms (Koch 2012). Another important feature is the appropriation of harbour facilities such as the nearby harbour for Rødsand 2, also involving the possibility of onshore assembly of turbines

5.4 Competences

If one juxtaposes the development of Danish and Swedish windfarms with the UK ones developed over the same period (Koch 2012) it is less clear that the centrally placed and recurrent companies are learning and becoming more competent. There is even a tendency that some later wind farms involve more overrun and lower performance. It appears like the windturbine manufacturers have considerable problems with quality and defects when it comes to the UK deliveries, both impacting on the installation and operation phase. The worst example in a Danish context occurs at Horns rev I, which receives a heavy overrun because of quality problems at Vestas windturbines.

6. Conclusion

The aim of this paper was first to develop a combined social constructivist internal and external conceptualisation of the process of realising offshore wind farms; second, to investigate costs, time, delays and operational performance results of offshore wind farm power plant projects in Denmark and Sweden with a view to possible strategic misrepresentation. The results shows that combining the internal and external perspective gives a more precise understanding of why complex offshore wind farms come to operate well or less so. The investigated wind farm does not exhibit a clear pattern of strategic misrepresentation. Rather there are examples of project management that emerges into being successful even if the process is disruptive and full of complications. Even if there is a strong concentration of a few players on the Danish, Swedish and UK markets in the period investigated, learning effects and developed competences are less clear as late installed farms actually perform worse than earlier installed. The construction sector thus seem to contribute in an ambigious manner to societal transition towards zero carbon.

References

4Coffshore (2012): Wind farm data accessed at 4Coffshore.com during 2012.

Atkinson R. (1999) Project management: cost, time and quality, two best guesses and a phenomenon, it's time to accept other success criteria, International Journal of Project Management, 17 (6), 337-342.

Bryman A. and Bell E. (2007) Business research methods, Second edition. Oxford University Press, Oxford.

BTM (2010) World Market Update 2010, BTM Consulting. Accessed February 2011 at http://www.btm.dk.

BWEA (2008) Annual Review 2008. British wind Energy Association, London.

Davies A. and Hobday M. (2005) The Business of Projects. Managing Innovation in Complex Products and Systems. Cambridge University Press, Cambridge.

DEA (2011) Register of wind turbines. Danish Energy Agency website www.ens.dk retrieved February 2011.

De Bruijn H. and Leijten M. (2008) Megaprojects and contested information. Chapter 5 in H. Priemus, B. Flyvbjerg and B. van Wee (eds.) Decision-Making on Mega-Projects' Cost–benefit Analysis, Planning and Innovation. Edward Elgar, Cheltenham.

EWEA (2012) Green Growth -The impact of wind energy on jobs and the economy. The European Wind Energy Association - April 2012- accessed at www.ewea.org Nov. 2012.

Flyvbjerg B. (2009) Survival of the Unfittest: Why the Worst Infrastructure Gets Built—and What We Can Do about It. Oxford Review of Economic Policy, 25 (3), 344-367.

Flyvbjerg B. (2011) Over budget, over time, over and over again—managing major projects. P. Morris, J. Pinto and J. Söderlund (eds.) The Oxford Handbook of Project Management, pp. 321-344. Oxford University Press, Oxford.

Flyvbjerg B., Bruzelius N. and Rothengatter W. (2003) Megaprojects and Risk: An anatomy of Ambition. Cambridge University Press, Cambridge.

Gerdes G., Tiedemann A and Zeelenberg S. (2005) Case Study: European Offshore Wind Farms - A Survey for the Analysis of the Experiences and Lessons Learnt by Developers of Offshore Wind Farms. Deutsche WindGuard GmbH, Deutsche Energie-Agentur GmbH, University of Groningen.

Grint K. and Woolgar S. (1997) The Machine at Work. Polity Press, Cambridge.

Hughes T.P. (1983) Networks of Power: Electrification in Western Society, 1880-1930. John Hopkins University Press, Baltimore.

IEA (2005) Offshore Wind Experiences. International Energy Association, IEA Publications, Paris.

Kahneman D. (1994) New challenges to the rationality assumption. Journal of Institutionaland Theoretical Economics, 150, 18-36.

Kaming P.F., Olomolaiye P.O., Holt G.D. and Harris F.C. (1997) Factors influencing construction time and cost overruns on high-rise projects in Indonesia. Construction Management and Economics, 15 (1), 83-94.

Koch C. (2012) Contested overruns and performance of offshore wind power plants. Construction Management and Economics. 30(8). 609- 622.

Latour B. (1987) Science in Action: How to Follow Scientists and Engineers through Society. Harvard University Press.Cambridge.

Latour B. (2005) Reassembling the Social. Oxford University Press, Oxford.

Levitt A.C., Kempton W., Smith A.P., Musial W. and Firestone J. (2011) Pricing offshore wind power. Energy Policy, 39 (10), 6408-6421.

Liu L. and Napier Z. (2010) The accuracy of risk-based cost estimation for water infrastructure projects: preliminary evidence from Australian projects. Construction Management and Economics, 28 (1), 89-100.

Love P.E.D. (2011) ‘Plugging the gaps’ between optimum bias and strategic misrepresentation and infrastructure cost overruns. Procedia Engineering, 14, 1197-1204.

Lönker O. (2005) Operation Offshore. Neue Energie, 2005-1, accessed at http://www.neueenergie.net/index.php?id=731, November 2011.

Miller R. and Hobbs B. (2005) Governance regimes for large complex projects. Project Management Journal, 36 (3), 42-50.

Miller R. and D. R. Lessard (2008) Evolving strategy: Risk management and the shaping of mega-projects. Chapter 8 in H. Priemus, B. Flyvbjerg, B. van Wee (eds.) Decision-Making On Mega-Projects’ Cost–benefit Analysis, Planning and Innovation. Edward Elgar, Cheltenham.

Olawale Y.A. and Sun M. (2010) Cost and time control of construction projects: inhibiting factors and mitigating measures in practice. Construction Management and Economics, 28 (5), 509-526.

ONS (2011) Statistics. Accessed November 2011at http://www.statistics.gov.uk

Reichelt K. and Lyneis J. (1999)The dynamics of project performance: Benchmarking the drivers of cost and schedule overrun. European Management Journal, 17 (2), 135-150.

Renewable U.K. (2010) Annual Review 2010. Inspiring Excellence. London.

Slack, N. and Lewis, M. (2008) Operations Strategy, 2nd Ed., Prentice-Hall, Harlow.

Slack, N., Chambers, S. and Johnston, R. (2007) Operations Management, 5th ed., Pearson, London.

Snyder B. and Kaiser M.J. (2009) A comparison of offshore wind power development in Europe and the U.S.: Patterns and drivers of development. Applied Energy, 86 (10), 1845-1856.

Zhixin W., Chuanwen J., Qian A. and Chengmin W. (2009) The key technology of offshore wind farms and its new development in China. Renewable and Sustainable Energy Reviews, 13 (1), 216-222.