The Economics of an Integrated Offshore Wind Energy and Aquaculture Facility

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Introduction

This research evaluates the economic potential of an integrated offshore wind energy and aquaculture facility based in the North Sea. In countries with relatively limited marine areas, Germany for example, some novel ideas have emerged for conducting multiple economic activities in a given area. The pairing of wind farms with aquaculture offshore is one of these. Besides the immediate social advantage of concentrating more economic activity into the same area, this research establishes that private production complementarities may exist in the form of cost savings by pooling resources between firms.

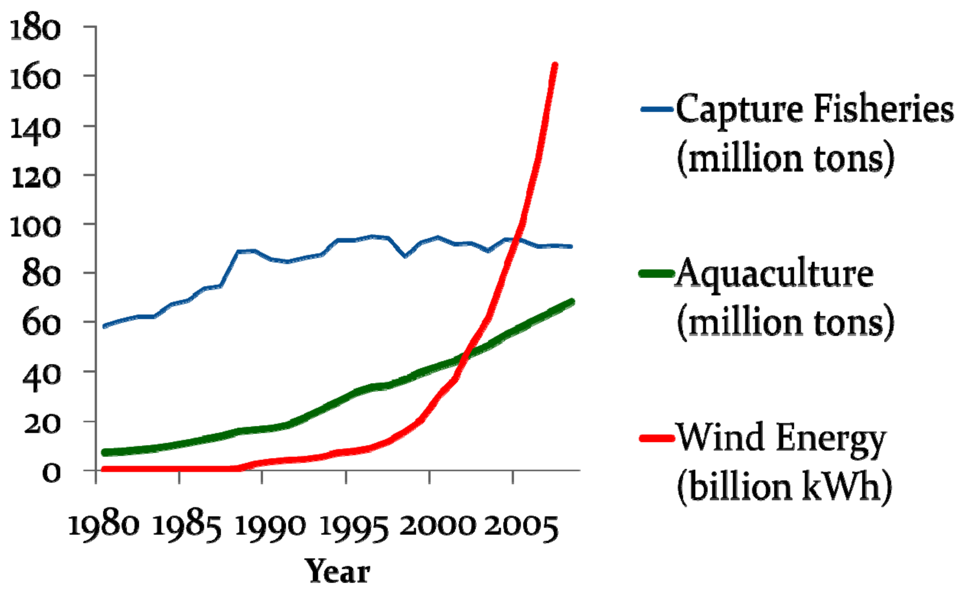

Figure 1. Motivation For Cooperation (Source EIA and FAO)

The progression of renewable energy worldwide recently has coincided with a similar increase in marine aquaculture. Figure 1 shows the worldwide stagnation of capture fisheries' harvest, coupled with the growth in aquaculture and wind energy over the last 30 years.

Recent research has looked at industry interest (Michler-Cieluch and Krause 2008) as well as engineering (Buck and Buchholz 2004) and biological (Buck and Buchholz 2005; Buck 2007) considerations of such a facility. A conceptual rendering of a hypothetical site plan using longline culturing is shown in Figure 2

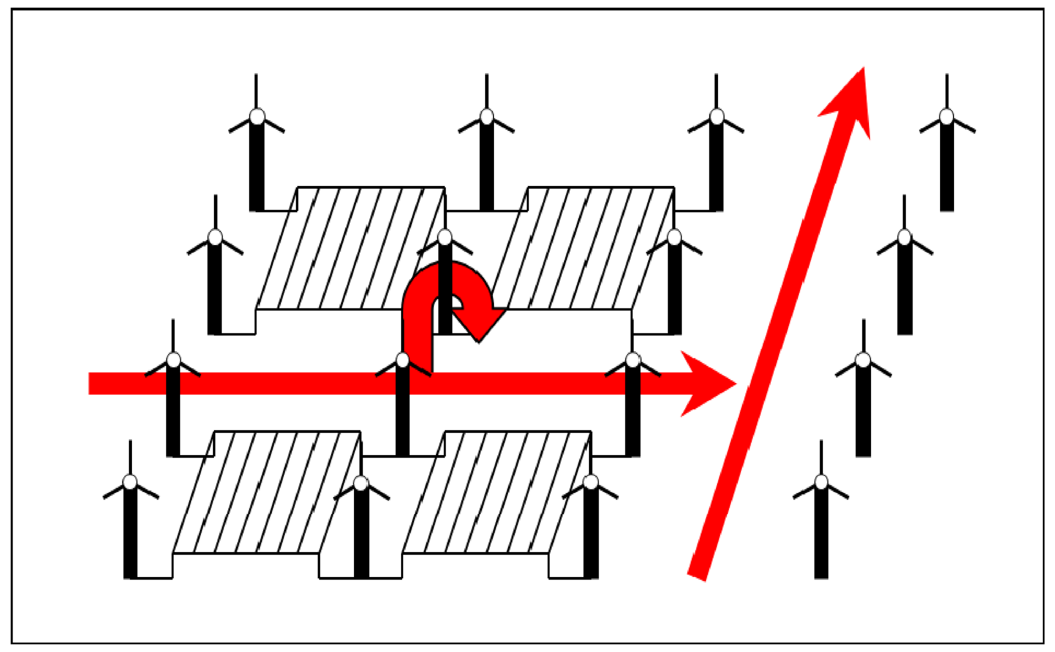

Figure 2. Conceptual Site Plan (Source Buck 2010)

An example integration concept employing longline culturing equipment, a tested method for growing North Sea native species such as Sugar Kelp (*saccharina latissima*) or Blue Mussels (*mytilus edulis*). The arrows indicate traffic paths for service vessels.

Newly acquired data on offshore wind energy and aquaculture costs finally allow for an economic feasibility assessment and a break-even analysis to assess the economic viability of merging aquaculture with offshore wind energy. The extent to which this is a viable idea will depend on how the integration of these activities impacts the costs and subsequently the profits of each firm. If there is a disparity in private benefits or no benefits at all from integration, a project like this will not emerge in the private sector. In that case, government intervention may be required if integration projects like this are deemed socially beneficial. This study provides insight to the private incentives for cooperation at a stylized facility at the site of an offshore wind park currently under construction in the North Sea.

Methods

This project uses the planned site of Nordergrunde in the German North Sea as a case study (Figure 3). Table 1 goes on to list the characteristics of the planned wind farm at Nordergrunde, and also details a potential larger wind farm at the same site which will be used for comparisons of scale.

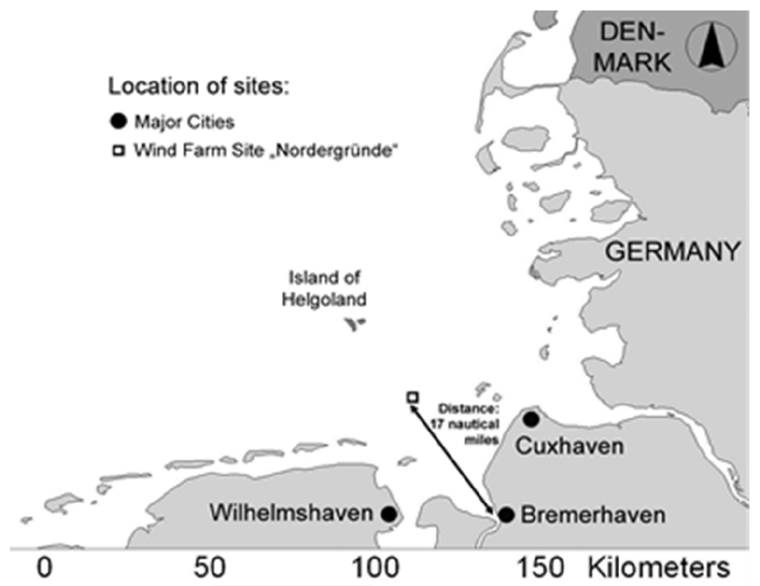

Figure 3. Case Study Nordergrunde

Making use of recent work to assess the costs of offshore Blue Mussel aquaculture (Buck et al. 2010), this research looks specifically at this type of aquaculture at the Nordergrunde site. Table 2 shows the relevant harvest parameters and site characteristics for Blue Mussel culture at this site. The harvest is rotational with half of the farm harvested every year, and the gear for aquaculture is longlines anchored to the monopile turbine foundations.

Table 1. Wind Farms - Site Detail

	Nordergrunde (90MW)	288MW
Turbines		
#	18	80
Manufacturer	REPower	Siemens
Rating(MW)	5.0	3.6
Foundations	Monopile	Monopile
Depth (m)	11	11
Distance to Land (km)	17.2	17.2
Energy Prod (per turbine)		
Wind Speed (m/s)	9.8	9.8
Max Annual Energy (MWh)	43,830	31,558
*Capacity Factor**	53.77%	53.82%
Annual Energy (MWh)	23,566	16,983
Availability	95%	95%
Losses	17%	17%
Net Energy (MWh)	**18,581**	**13,391**
Farmwide Energy (MWh)	278,722	1,071,294

Table 2. Nordergrunde Mussel Farm Details

	Small Facility	Large Facility
Project Lifetime (yrs)	20	20
Plots		
#	4	20
Longlines	284	1,420
Mussel Biomass per year		
Meter (kg)	12.5	12.5
Plot (tons)	1,487	1,487
Farm (tons)	5,946	29,731
Market Price (€/kg)	1	1
Costs (€)		
Per Plot Infrastructure	835,483	835,483
Vessels (#)	4,000,000 (1)	20,000,000 (5)
Land Facilities	2,000,000	10,000,000
License	1,000	1,000
O&M & Misc (per year)	367,116	1,835,578
Annual Revenues (€)	2,973,125	14,865,625

The economic analysis makes use of these parameters and discounted cash flow analysis to determine the net present value of both businesses under the financial terms listed in Table 3. An investment appraisal is also conducted. It is expected that these businesses will primarily be able to share costs for the purchase of vessels for transport and operating costs for vessels. As such, the focus is on the impact of this cost sharing on profits for both businesses.

Table 3. Other Financial Terms

Time	
Project Term	20 years
Discount Rate	6%
Debt	
Interest Rate on Debt	4.7%
Debt:Equity Ratio	65%:35%
Debt Term	15 years
Variable Costs	
O&M Costs	.056m€/MW/yr
Policy (Germany)	
Corporate Tax	30%
Initial Feed-In Tariff	.15€/kWh
Base Tariff	.035€/kWh

Results

Table 4 describes the results of this economic feasibility analysis for both wind park scale scenarios. Over the 20 year span, operating a mussel or wind farm offshore in Germany is a profitable endeavor at both scales of production. A mussel farmer could expect to earn from 8 to 44 million EUR in net present value in that time; a wind farm would generate between 120 to 426 million EUR dependent on scale. For a mussel farmer this is conditioned on the ability to use the turbine foundations as an anchor for culturing equipment. The would be unable to operate otherwise in the high-energy offshore environment of the North Sea.

Table 4 also considers the extent to which each firm may have activities and expenses which overlap with the other firm. In addition to the precondition of anchoring for the mussel farmer, each firm could also coordinate transportation of personnel for operations and management. The portion of total costs made up by each cost component is given, as well as the increase in net present value each firm would experience if these costs were shared equally. A 25% gain in net present value from collaboration could be expected for a mussel farmer, compared to only a 1-2% gain for the wind farm. While gains are positive for each, the disparity suggests that a wind farm would have a much lower incentive for cooperation, especially if these cost reductions are accompanied by higher production risk or coordination costs.

Table 4. Finances for a Multi-use at Nordergrunde Site

	Nordergrunde (90MW)	288MW
Net Present Value (m€)		
Wind Farm	119.8	426.0
Mussel Farm	8.7	44.2
Internal Rate of Return		
Wind Farm	25.6%	29.0%
Mussel Farm	16.9%	16.9%
Potential Shared Costs		
Wind Farm		
O&M (Vessel and Fuel)	1.5%	2.4%
Mussel Farm		
Anchoring	-	-
Vessel	11.7%	11.0%
Fuel	4.8%	4.9%
Total	16.5%	15.9%
50/50 Contract NPV (m€)		
Wind Farm	121.2	433
Mussel Farm	11.1	55.3
Total NPV Gain (Wind, Aqua)	**(1.2%, 27.6%)**	**(1.6%, 25.1%)**

Conclusion

The results here suggest that collaboration would mainly suit the mussel farmer and there is a very weak incentive for a wind farmer to cooperate from a balance sheet perspective. Increases in risk and transactions costs from collaboration may further erode the minimal incentive established here. As such, it is likely that this type of facility would not occur absent regulatory intervention. To the extent that spatial efficiency improves social welfare, the duty should fall on regulators to establish further incentives for cooperation.

References

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