# CO-ORDINATED ACTION ON OCEAN ENERGY

# WORKSHOP 5 – EXPERIENCE OF THE SEAFLOW PROJECT

IT POWER LIMITED

## 1 INTRODUCTION

IT Power, a UK-based sustainable energy consultancy, has been at the forefront of the worldwide development and application of clean renewable energy technologies for more than 25 years. Today, IT Power is leading the commercialisation of ocean energy conversion systems through innovation and technology incubation, research and development, consulting, testing, resource assessment and site surveys and other services in support of this emerging industry and energy policy.

This paper summarises IT Power's experience from a range of RTD projects, particularly the Seaflow project, developing the world's first pile-mounted prototype tidal stream turbine.

## 2 Theme 1 : Environmental Impact and Mitigation

### 2.1 Site selection

The search for a site began with a study of available tidal information, such as UK Admiralty Tidal Atlases & Charts and ships' pilots. Various other studies were consulted, such as the CENEX study from EC CENEX project and the UK Tidal Stream Energy Review . Advice was sought from marine consultants, marine construction companies, harbour authorities, universities with marine or oceanographic departments, and marine sports groups.

#### 2.1.1 Site selection criteria

The key criteria for selecting sites were:

- 2-3m/s maximum spring peak current (4-6 knots), in order to achieve an economic size of rotor;
- Uniform flow with strong currents for long periods to maximise power available;
- Minimum depth 15m to chart datum or lowest astronomical tide (LAT), to provide adequate space for a rotor;
- Maximum depth 25m, to remain within capability of Seacore's largest available jack-up barge at the time;
- Close to the coast (preferably < 1km);
- Reasonably close to Seacore's base (to keep mobilisation overhead costs down), and to be accessible from IT Power;
- Not too exposed to open sea waves and wind, to reduce the risk of weather-induced delays and to maximise time available for installation and servicing;
- No major conflicts with other sea users;
- Avoiding sensitive environmental sites.

This preliminary study led to a shortlist of possible sites around the coast of England and Wales. Many other good tidal sites were identified off Scotland, Ireland, and the Channel Islands, but were not pursued as they were too distant from where the partners were based.

#### 2.1.1.1 General site selection criteria

Some general principles for tidal current turbine site selection were noted. The Mean Spring Tide current over most of the continental shelf is quite low, less than 1 knot (0.5m/s). Higher currents are only found around certain features, such as:

- Channels or constrictions between islands - these provide some of the best sites, as the flow is fast and rectilinear;
- Headlands in the path of moderate flows - these are best when the headlands are large and do not protrude too sharply into the flow, otherwise the flows are fast but turbulent, and the high currents may be in different places on ebb and flood;
- Estuaries or other resonant water volumes - good sites with rectilinear flow, but combined with high tidal ranges;
- Narrow entrances to enclosed tidal lakes – these can have very high currents, but only over a small area.

Using these observations, large-scale maps can be used to predict possible sites, but in many places there is insufficient published data to verify whether an actual site is suitable. As marine current exploitation develops, there will be a need for a detailed inventory of potential sites.

On small-scale maps, areas that do have high currents appear very small, though in reality each one may be several kilometres long in the direction of flow, and have space for many turbines, potentially generating tens or even hundreds of megawatts. Many suitable areas are several kilometres from the shore, and would be suitable for development as tidal “farms”, though they would be prohibitively expensive for a single, isolated turbine. In this respect, the search for a site for Seaflow was unusual, and it will be easier to find sites for larger developments where overhead costs can be more easily absorbed.

#### 2.1.1.2 Seaflow Site

The outcome of the above work was a shortlist of four areas. These were: the Bristol Channel off North Devon, the north coast of Anglesey in North Wales, the West Solent between the Isle of Wight and the mainland in the south of England, and the Kent coast just north of Dover in south-east England. Consultations with various official bodies indicated that it would be difficult to obtain permissions for the Solent and Dover sites. Preliminary survey work showed that the Bristol Channel was much more favourable than Anglesey, so North Devon was chosen as the preferred site.

The Bristol Channel acts to constrict the tidal wave coming off the continental shelf, giving both large tidal ranges and high currents. These currents are faster further up the Channel, but the depths decrease. A survey site was chosen off Foreland Point, near Lynmouth, which is the northernmost tip of the Devon coastline (see Figure 1). Being about halfway along the Channel, it has high currents in depths of 20-30m.

A detailed survey was made of the bathymetry, seabed type, and current regime, confirming that it was a suitable location.

### 2.1.2 Site Permissions

The regulatory framework governing construction at sea off the coast of England is complex. There are several relevant pieces of legislation and EC Directives that cover coastal waters, and these are administered by different government departments. When applications were made for licences for Seaflow, even the departments themselves were unclear as to which legal Acts applied, and how areas of apparent overlap were to be resolved. The situation has improved somewhat during the project, partly due to the Seaflow project itself, but primarily because of the advent of offshore wind farms. The various government departments have now created a single point of contact for marine licensing, but this was not the case when the Seaflow applications were made.

The consents to be obtained for a marine current turbine fall into four broad categories:

- Lease arrangements for the seabed;
- Navigation and shipping interests;
- Marine environment and usage;
- Cable and electrical connections on land.

Lease arrangements for the seabed are relatively straightforward, and are handled by The Crown Estate, which owns nearly all the seabed around the UK within the 12 nautical mile limit.

Navigation and shipping in UK coastal waters are the responsibility of the Department for Transport. (The government department responsible for transport was initially DETR, then became DLTR, and then DfT during the project.) There were two possible legislative routes to obtaining permission: one was the Coastal Protection Act 1949, Section 34 (CPA), and the other was the Transport and Works Act 1992 (TWA). In consultation with officials it was felt that the CPA was more appropriate for a single experimental turbine than the wide-ranging procedures of the TWA. Obtaining permission under the Coastal Protection Act requires advertising the proposal and consultation, the scope of which is limited to issues of obstruction of navigation routes and safety. The project was also advised that the installation came within the scope of the Harbour Works (Environmental Impact Assessment) Regulations 1999, which meant that the department responsible for transport required an Environmental Impact Assessment.

The legislation covering the marine environment and usage is the responsibility of the Department for Environment, Food and Rural Affairs, DEFRA (which was called MAFF at the beginning of the project). Permission needs to be obtained under the Food and Environmental Protection Act, 1985 (FEPA). EC Directives on Environmental Impact Assessments (Directives 85/337/EEC and 97/11/EC) are also implemented through FEPA. The FEPA process involves widespread consultation with environmental groups, fishermen and other sea-users, so the process can be lengthy and involved if objections are raised.

The land-based consents for bringing a cable ashore and erecting switchgear are the responsibility of the local planning authority and the landowners. The project applied for planning permission for laying a cable across the beach at Lynmouth to a substation just on the seafront, and this was granted by the Exmoor National Park Authority on 7 March 2000. In the event, the turbine was not connected to the grid, and this permission was not used.

Consultation was carried out with all the official bodies who have a statutory input to the consents process, in advance of submitting formal applications. Discussions were also held with many other local organisations which potentially had an interest in the project. There was general enthusiasm for the tidal turbine concept, and the responses were nearly all positive.

Official applications for permission to install were made in 2001. A FEPA licence was granted by DEFRA on 20 March 2002. This had to be renewed in 2003 as the installation began just outside the twelve month licence period. Permission was granted by DfT under the Coastal Protection Act on 5 April 2002. A rental agreement was made with The Crown Estate dated 8 May 2003, after the other permissions were received, as this was conditional upon the granting of all other licences.

The Crown Estate required that the turbine should have third party insurance covering third-party liability to other sea users, and that the consortium should provide guarantees that the turbine would be removed at the end of the project. This guarantee was made by Seacore, which was considered to have sufficient financial stability to make the commitment. The insurance proved more of a difficulty, as the world-wide insurance market became unstable after the 11 September attacks in USA in 2001. Eventually, a special agreement with Seacore's normal insurance brokers allowed the consortium to obtain insurance, though at a rate above previous estimates.

### 2.1.3 Environmental Impact

One of the pre-requisites for the FEPA licence was that the project produce an Environmental Statement, ES. Since an ES was also required for the Harbours Act, MAFF and DETR joined together to produce a scoping document for an Environmental Impact Assessment, EIA. An independent consultant was contracted to undertake the study.

The EIA and licence applications for Seaflow were groundbreaking, requiring the various authorities to think though the implications of marine current energy exploitation.

#### 2.1.3.1 Possible Impacts

The EIA scoping document required that the following impacts be evaluated:

- The impact on benthos;
- The physical/chemical characteristics of material arising from the installation of the turbine and the effects of their deposition;
- Effects on water flows;
- Impacts of construction on fish resources and invertebrates;
- Impacts on marine flora and fauna in terms of scouring of the sea bed and physical contact with fish, sea birds and mammals;
- The visual impact of the turbine structure above the water;
- The noise disturbance implications of the development;
- Possible effects on tourism;
- Highway access implications.

#### 2.1.3.2 Objections & Concerns Raised

Concerns raised during the consultations were relatively few, and all were addressed within the Environmental Statement.

There was some concern that lobster potting conducted out of Lynmouth could be disturbed both by the turbine and the construction work. However, the turbine is well offshore of any lobster pot locations, and both the North Devon Sea Fisheries Committee and the local MAFF fisheries officer agreed that any disruption was unlikely to be serious. There were only two fishing boats operating out of Lynmouth, both engaged in lobster potting, and one of the fishermen moved out of the area before the turbine was installed.

A number of ecological concerns were raised by English Nature and the Devon Wildlife Trust. English Nature was concerned that certain rare corals had been found in nearby areas, and could be present near the Seaflow site. It recommended that the turbine should avoid rocky habitat. The Devon Wildlife Trust requested that certain issues be addressed in the EIA: the disturbance to the seabed during construction, the risk of harm to sea mammals and fish from collision with the rotor, and the risk of leakage of pollutants. The Exmoor National Park Authority were concerned at the possible effects of scour on benthos, and the Lynton and Lynmouth Town Council (LLTC) wanted assurance that the turbine would not affect the sandbanks in the bay.

More general concerns were expressed by LLTC and in a public meeting held in Lynmouth about the visual impact, and the audibility of the turbine foghorn.

#### 2.1.3.3 EIA Survey Results

A field survey into the possible impacts of the Seaflow turbine on the environment was carried out in July - November 2001, and all the areas of concern raised in the scoping document. It had a major section on the visual impact and landscape, a photomontage from which is shown in Figure 2.

| | **Scale** | | | | **Duration** | | | **Residuals** | | **Significance** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Local | Regional | National | International | Short term | Medium term | Long term | No residuals | Residuals | Major | Moderate | Minor |
| **Physical environment** | | | | | | | | | | | | |
| Wave climate | ✓ | | | | | ✓ | | ✓ | | | | ✓ |
| Flow | ✓ | | | | | ✓ | | ✓ | | | | ✓ |
| Sea bed / sediments | ✓ | | | | | ✓ | | ✓ | | | | ✓ |
| Water quality | ✓ | | | | ✓ | | | ✓ | | | | ✓ |
| **Biological environment** | | | | | | | | | | | | |
| Habitats/benthos | ✓ | | | | | ✓ | | ✓ | | | | ✓ |
| Marine species | ✓ | | | | | ✓ | | ✓ | | | | ✓ |
| Birds | ✓ | | | | | ✓ | | ✓ | | | | ✓ |
| **Landscape** | | | | | | | | | | | | |
| >3km | ✓ | | | | | ✓ | | ✓ | | | | ✓ |
| 2-3km | ✓ | | | | | ✓ | | ✓ | | | | ✓ |
| 1.5-2km | ✓ | | | | | ✓ | | ✓ | | | ✓ | |
| 1-1.5km | ✓ | | | | | ✓ | | ✓ | | ✓ | | |
| **Fisheries** | ✓ | | | | | ✓ | | ✓ | | | | ✓ |
| **Navigation** | ✓ | | | | | ✓ | | ✓ | | | | ✓ |
| **Noise** | ✓ | | | | | ✓ | | ✓ | | | | ✓ |

Table 1: Summary of impacts from the Seaflow Environmental Statement

In general the conclusion of the ES was that the environmental impacts of the scheme were "minor" or "insignificant", with the exception of the visual impact from the coast very close to the turbine.

#### 2.1.3.4 Environmental Impact Observed During Operation

Compared with a wind turbine, Seaflow stands very low in the water. Nevertheless, it is clearly visible even from 3-4km away, and when seen from sea level it is quite noticeable. Photographs taken of the installed turbine are very similar to the photomontages in the ES (see Figure 2). However, the visual impact is perhaps slightly greater than photographs suggest, as the eye is drawn to the turbine in an otherwise featureless sea. Very little adverse comment has been received about the effect of the turbine on the view, with most visitors apparently being interested in what the machine is. The only complaint was received from a resident of Lynton concerning the navigation light. While the local people in and around Lynmouth have remained generally very supportive of the project, the only reservations expressed about developing from Seaflow to a farm of turbines on the site have been that the visual impact could be unacceptable.

The Seaflow turbine has two disadvantages in respect of visual impact. Firstly, not being grid connected it has considerably more equipment in the pod than would be required normally, making the pod disproportionately large. Secondly, the tidal range of around 10m at that point in the Bristol Channel means that the turbine stands 15-20m above the water at low tide, which is higher than would be the case for most other sites. Nevertheless, it is clear that future machines must be made as unobtrusive as possible.

Other effects of the turbine are, as expected from the ES, relatively small, and therefore rather difficult to evaluate. There has been no rotor damage, which indicates that there have been no collisions with fish or sea mammals (or any other debris). Dolphins and diving birds are regularly seen around the turbine, but always at some distance.

As expected, ADCP data shows that the current speed is reduced downstream of the rotor, and the flow is more turbulent, as would be expected. However, these effects only last for a limited distance downstream, and the flow does recover.

#### 2.1.3.5 Future EIA Recommendations

Future environmental studies for MCTs will need to address basically the same issues as those covered by the Seaflow ES. Particular local environmental sensitivities may require more detailed work in certain areas.

When arrays of turbines come to be installed, the effect of energy extraction on wider tidal flows, and therefore on coastal processes such as sediment transport, will become more important. It should be noted, though, that the power generated by marine current turbines is very sensitive to current. If the current is reduced by even a small amount, the power drops noticeably. Therefore, if tidal farms began to significantly reduce the flow in their area, this would have a detrimental effect on the energy output of the farm, something developers will wish to avoid.

Many of the potential environmental impacts of tidal turbines are generic, and would require detailed, long-term monitoring and analysis to address with any certainty. It would be prohibitively expensive for the first commercial tidal farm to provide definitive answers to every possible question. To this end, there is a need for a generic environmental study, and a scoping document for such work has already been commissioned by the DTI. This work could then feed into the Strategic Environmental Assessments being conducted by DTI.

## 3 Theme 2 : RTD barriers and technology development

### 3.1 Partnership & Complementary Projects

Seaflow has been a co-operative effort of multiple partners and multiple funding agencies. The work originally started with the EC project on 1 September 1998. The UK Department of

Trade and Industry, DTI, project to support Seaflow, was initiated on 1 June 2001: *Development, Installation and Testing of a Large-Scale Tidal Current Turbine*. The work also benefited from a German government project, *Control and management of variable speed marine current turbines on variable-speed powertrains for tidal turbines*.

This led to a consortium of seven organisations working on Seaflow, with a wide and complementary range of experience and skills. Both the EC and DTI projects were co-ordinated by IT Power, but only IT Power and Seacore were in both projects. The structure is summarised in Figure 3.

The rather complex interlinking of the projects reflected the complexity of the work, and the need to raise a considerable amount of finance. The overall budget was around £3.2 million, of which £1.3m was grant from the DTI and £600k was from the EC. Some assistance was received in hardware from the BMWi project, to the value of around £60k. The remainder was financed by the partners.

It was agreed that Marine Current Turbines Ltd., one of the partners in the DTI project, would be the ultimate owners of the Intellectual Property Rights arising from the project, as it will be developing the subsequent commercial technology.

### 3.2 Intellectual Property Rights (IPR), Patents

MCT has a policy of seeking to gain patent protection for key ideas stemming from its research programme. To this end it has secured eight UK patents so far (with several more applications in process) and several of the UK patents have been internationalised with versions granted in a number of foreign countries. The main topics covered by our patents are as follows:-

- A floating near neutral buoyancy device mounted under a moored floating raft with a mechanism for raising the turbine to the surface for maintenance (based on work carried out originally by IT Power in partnership with Scottish Nuclear and NEL on Loch Linnhe in 1994-5).
- A series of arrangements in which a turbine (or several turbines arranged side by side), generally with axial flow rotors, can be mounted on a monopile such that it/they can be raised above the surface for maintenance or repairs
- The use of full span active pitch control to permit a fixed axial flow rotor to operate efficiently in a bi-directional flow (using the flow from either direction) plus other methods of addressing bi-directional flow such as pitching the rotors either around a vertical axis or around a horizontal axis

### 3.3 Follow-on work

Marine Current Turbines Ltd (MCT) was originally set up by IT Power to take over the commercial development of the Seaflow technology at the end of the project. MCT is now an independent company, and has raised investment capital to take forward the work. Among its shareholders are two utilities, EdF Energy and Guernsey Electricity, the Danish venture capital group BankInvest, and the Seaflow partners Seacore and Bendalls Engineering.

#### 3.3.1 Technology Development

MCT is already working on the design of a twin-rotor 1MW turbine. A potential site within the UK has been identified, and work is underway to obtain the permissions necessary to install the turbine. The DTI is supporting the preliminary work for this project. This turbine is to be the precursor of commercial machines.

Following on from the twin-rotor prototype, MCT plans to install a commercial demonstration tidal farm, with multiple turbines and a total power output of between 10-15MW. This will give some economies of scale, but also allow for field testing of the effects of an array on interaction between turbines, and the larger scale effects of arrays.

The first farm will be followed by others, initially in the range 10-30MW, developed between 2007 and 2010. These will ideally be on sites that are capable of further development.

### 3.3.2 Installation Development

Seaflow has proved that a jack-up barge provides an excellent platform for the installation of a tidal turbine. The ability to sit on site, fixed to the seabed, can potentially make operations independent of the weather, allowing quick progress.

However, the development of installation methods and equipment will need to be run in parallel with the development of the technology. Seaflow was restricted by the limited depth and current capabilities of existing jack-up barges. Larger vessels are becoming available, but the marine construction industry currently lacks equipment for the depths, tides and exposed locations that will need to be tackled for the longer term deployment of MCTs.

Most existing work for marine construction is in ports or near-shore coastal waters. It is unusual to work in strong tides, and there is never the need to work in both strong currents and large depths. The work also varies from project to project, so the machinery has to be general purpose, adaptable to a wide range of operations and situations. This makes it less suitable, slower, and therefore more expensive than dedicated tidal turbine installation equipment would be.

Installation development needs to pursue two main tracks: the creation of design tools and the development of equipment.

Working in deep, fast-moving currents challenges both the stability of a jack-up and the strength of its structure. Special studies had to be undertaken for Seaflow to ascertain that there was sufficient safety margin against slippage, bending of legs, or resonant vibration of the structure due to vortex shedding. There are no directly applicable design guidelines for these cases, and new methods had to be developed.

This is not simply a case of giving the installer confidence that the machinery is safe. The need to obtain liability insurance for operations means that there have to be accepted design tools and criteria against which jack-ups can be certified.

Larger jack-up barges will definitely be necessary. Existing equipment can only work in depths of up to ~30m in still water. Development will also be needed for pile handling and assembly so that components can be worked with even in poor weather conditions and with fewer tidal and spring-neap cycle limitations.

Some equipment is becoming available for offshore wind construction, such as Seacore's barge Excalibur and the Mayflower Resolution. These go part of the way towards meeting the needs of tidal turbine, and begin to extend the range of conditions into which MCTs can be installed, but they are not ideal. In order to reduce the time and cost of installing piles and assembling turbines, dedicated jack-ups will be required.

A difficulty here is that equipment development is expensive, and there needs to be a definite volume of work before construction companies can invest in it. At present there are only prospects for a small number of MCTs to be installed in the next few years, not sufficient to merit spending millions on new barges. A combination of the use of equipment built for offshore wind, grant funded development, and investment associated with individual developments will be required to see installation methodology develop at a pace to match MCT's installation requirements.

## 3.4 Experience of barriers to RTD

Since undertaking the Seaflow project, IT Power has led a range of RTD projects:

1) “Construction of an Offshore Wave Energy Converter”, supported by the Carbon Trust, through the company Offshore Wave Energy Limited, in which a 15 tonne test specimen was designed, constructed and installed at NaREC’s wave testing facility in Blyth, in the northeast of England (completed in 2005);
2) “Development, Test and Demonstration of High Efficiency Shallow Tidal Flow Device”, supported by the UK Department of Trade and Industry Technology Programme, in which a 100kW prototype tandem oscillating foil tidal stream energy converter is being designed, constructed and installed in the Humber estuary in north England (started in 2006 and ongoing);
3) “Wave DyVaR : An innovative Wave Energy Converter for use in the Renewable Energy market”, supported by the UK Department of Trade and Industry through a Grant for Research and Development, in which a desk study into the technical and commercial viability of a novel wave energy converter is being undertaken (started in 2006 and ongoing).

These three projects have given IT Power considerable recent experience in the early to mid stages of ocean energy technology development. Experience of initiating, applying for and running these projects, along with the earlier Seaflow project, suggest the following observations on the barriers to RTD in the ocean energy sector:

1) The long timescale from initial application to obtaining a grant presents a substantial barrier to rapid development of ocean energy technology. This is particularly problematic for early stage technologies which, being less developed than the market leaders, need to develop rapidly. IT Power’s experience is that, in the case of large national grants (such as the DTI Technology Programme), this process can take close to a year. Large European grants can take a similar amount of time. Smaller grants, appropriate to earlier stages of development, take less time.
2) The amount of time which has to be devoted to management and reporting is considerable, often occupying one member of staff full time. To an extent, this is unavoidable, but is often underestimated by technology developers. Time committed to project management and reporting can significantly reduce the resource available for technical work, leading to delays and overruns.
3) There is often a discontinuity between competitions. Recently a major funding body has decided to fund only a small part of a project. However, the applicant then has to go through whole application process again, causing substantial delays to the overall development programme. This approach does not allow for the building of relationship, knowledge and trust between the technology developer and the funding body. Long projects, with review points could give more confidence and stability to developers.
4) Consenting – the UK Crown Estate is often reluctant to grant leases longer than 5 years in length. This acts as a disincentive for developers of pre-commercial scale machines, which require revenue to improve viability.
5) There is often a long communication chain between the technology developer and the funding body, partly due to the fund being administered by a third party. This situation can be exacerbated in a review period, as review is undertaken by independent assessors, adding a further link to the chain.
6) IP does know barriers, so national grant awarding bodies will often not allow overseas organisations to be full partners in their projects as that would involve part of developed IP going abroad.
7) Funding often requires direct cash contributions into the project from the technology developers. This may be acceptable to large organisations with R&D budgets, but is particularly difficult for small, cash-starved start-up companies.

## 4 Theme 3 : Preferred incentive system to bring technology to market

IT Power has, to date, concentrated on early stage developments. Hence its experience has been mainly of the earlier developmental stages of ocean energy technology development. The technology underling the Seaflow tidal stream turbine is currently being taken to commercial maturity by Marine Current Turbines Limited, a company set up by IT Power as a technology development vehicle. IT Power has therefore no direct experience of the later stages of development.

IT Power can, however, make the observation that the preferred incentive system is entirely dependent on stage of development. In the early experimental stages, grant funding is appropriate. As the technology develops towards commercial maturity and can reliably produce energy at near-commercial costs, a combination of capital grant and revenue support becomes appropriate.

It goes without saying that whatever support system is put in place, it should address the barriers identified in paragraph 3.4 above.

1)

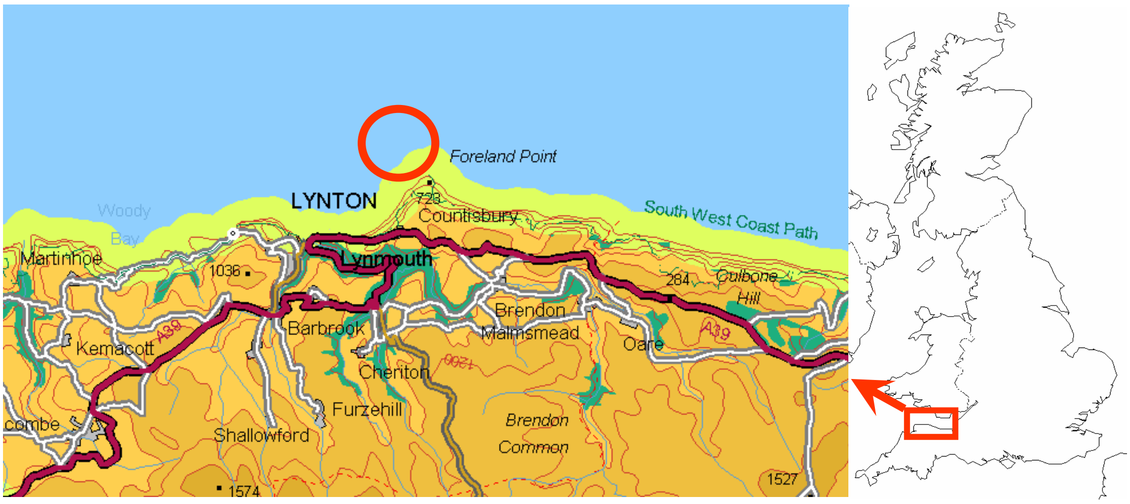


Figure 1: Location of the Seaflow site.

Figure 2: Photomontage of the Seaflow turbine prepared for the Environmental Statement.

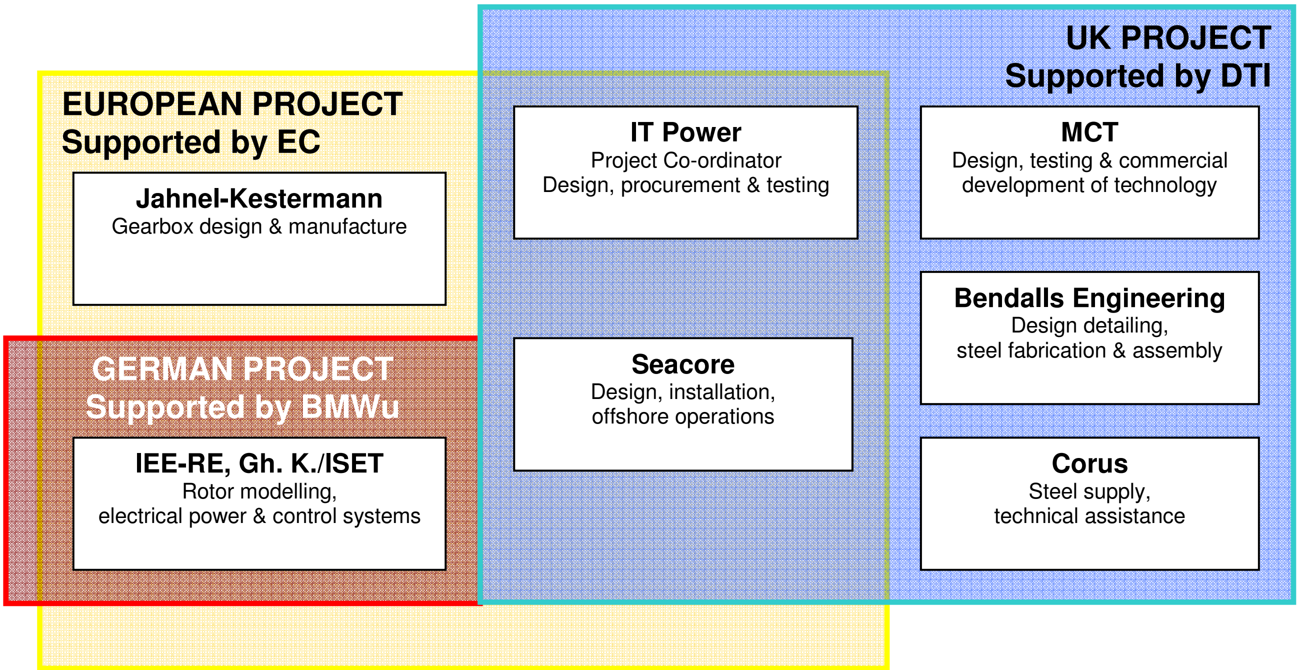


Figure 3: The relationship of the various projects and partners behind Seaflow.