# E Social, planning and environmental impact

## E 1 PUBLIC ACCEPTABILITY



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### E 1.1 Introduction

The objectives of this work package have been to identify potential barriers and benefits regarding social acceptance in relation to the expected development of wave energy, and to present recommendations concerning this subject based on experience from the wave energy devices that are currently being deployed, and from other renewable energy technologies.

For this purpose, developers of wave energy and tidal schemes have been approached and information gathered. However, as the experience regarding social acceptance and wave energy is sparse (see Section E 1.4), experiences from wind energy have been included in this report, and recommendations and conclusions are primarily based on these. Given the low level of practical experience with wave power, methods developed for wind energy, described below, may be utilised as guidelines for securing fruitful involvement of the public in the project planning phase and thereby avoiding adverse public reactions.

**Appendix 6** includes conclusions by Pat Mc Cullen (ESB International) regarding ways to improve the public interest for wave power in Ireland. These conclusions are not only valid on a local scale, i.e. for Ireland, but for all countries with a potential for wave energy.

In **Appendix 7** selected conclusions from a UK qualitative public attitude research study on cumulative effects of wind turbines are presented. These conclusions are regarded as being highly relevant in the development of wave energy projects.

### E 1.2 Background

Wave and tidal energy are both essentially benign activities. Despite this, as has been shown for wind power, a lack of public acceptance could prevent the development of wave and other renewable energy projects. It is therefore crucial that developers should not presume on public acceptance. Furthermore, from a more pragmatic, economic point of view, it is currently of vital importance for renewables that they are supported by the political system. As long as externalities are not internalised in the price of fossil fuels and nuclear energy[34] the development of wave and tidal energy is dependent of some sort of subsidies which will be very difficult to receive, if not impossible, if the energy source is not publicly acceptable.

The preconditions for achieving a broad acceptance from a large majority of the public exist. Opinion polls from e.g. Denmark show that renewable energy in general (in this case wind and solar energy) are the preferred energy sources, if people could choose themselves[35]. We cannot however presume local acceptance based solely on national surveys.

Public acceptability is however sometimes seen as an increasing constraint on the exploitation of renewable energy. Despite what seems to be a high level of national support for the development of renewable energy, attitudes towards specific projects among authorities and the public can be negative, and often conflicts appear within the process of planning and approval. Experiences from studies made of the public opinion of wind energy show that attitudes can be highly variable, dynamic and sometimes contradictory. It is important to note that public opinion can be divided between representative national views, usually considering issues in a more abstract and remote way, and local views based upon the potential or actual experience of particular developments.

Experience shows that the perceived environmental impacts are of special importance to the public, in particular the local public. As wave energy is currently characterised by a number of different technologies (onshore, near-shore and offshore) and as each device will have specific impacts, it is only possible to give a general presentation of the subject of public acceptability. It can however be expected that onshore and near-shore projects—especially due to visual concerns—make extra demands on developers regarding providing information to and gaining the involvement of the local public, in order to secure the highest possible level of acceptance. The information about the use of technology must present the desired effects in ways that are acceptable to the public.

Social acceptance of renewable energy has often been characterized by a NIMBY (not in my backyard) syndrome. The NIMBY-explanation is, however, a too simplistic way of explaining all the variables involved when determining the general and local public acceptance of a specific project. This means that the question of social acceptance really has many components, e.g.—

- the general attitude towards renewable energy in the population as a whole,
- the acceptance within the subpopulation that will experience the local impacts,
- the legal framework for public consultation and involvement, and
- the management strategies for public (and economic) involvement.

### E 1.2.1 Legal frameworks

The legal frameworks for public consultation and participation in future large-scale wave energy projects are national directives fulfilling the requirements of the EU Environmental Impact Assessment (EIA) directives[36] (See Section E 5 on ‘

Environmental impact'), as private and public projects that are likely to have significant effects on the environment must be subject to an EIA before they can be allowed to proceed.

Furthermore, the public should in future be consulted (earlier than currently is the practice) in the project planning phase regarding the effects of certain plans and programmes on the environment, according to the European Directive 2001/42/EC, the so-called SEA Directive, which must be incorporated to national laws by July 2004.

### Environmental Impact Assessment (EIA)

The main purpose of the EIA is to examine in detail, the impacts of the project, and this also includes a requirement for a running public consultation.

The public that is likely to be most concerned about a project must be informed and consulted, but each EU member state defines individually the details of these arrangements, resulting in numerous potential approaches. Often the public experiences no realistic opportunity to have an effect on the scale and layout of the project.

Although national relevant authorities have the responsibility to safeguard that these consultations are carried out in an appropriate and thorough way, the process of information and consultation is often carried out by the developer without any involvement from the responsible authority and with no knowledge about the sometimes dramatic consequences of an inadequate dialogue with the public.

In the EIA also the true potential of the project lies hidden. Hence, the relevant issues of an EIA will prove to be relevant also to the decisions made during the planning phase of a project. If the scope of an EIA also covers social impacts of a development, this will prove to be an important foundation for a dialogue with the concerned population. Even better, there will be an understanding of how the population perceive themselves as affected and what their concerns are when it comes to specific wave energy projects. It should therefore be known whom to address, when to address and how to address. If there is no understanding of the local social contexts and important issues for the concerned population, this cannot be determined. In addition, there will be no opportunity to follow up on the mitigation measures taken or to document experienced effects as opposed to perceived ones. This is something that may prove essential to coming projects and company good will.

An EIA might prove to be the foundation needed for the appropriate adjustment of the project to the prevailing circumstances. Hence, it is not only supposed to be a document (Environmental Impact Statement—EIS) presented to the authorities, but a dynamic process, a framework and tool for the project development. An EIA involves a flexible procedure where amendments to the original proposal are constantly weighed against all different aspects of the project. Mitigation is discussed in order to arrive at the most acceptable form of development. It is impossible to understand, which mitigation measures are relevant, if there is no open dialogue between different concerned parties.

### The Strategic Environmental Assessment (SEA) directive

The EIA Directive has recently been supplemented by the European Directive 2001/42/EC 'on the assessment of the effects of certain plans and programmes on the environment', known as the 'strategic environmental assessment' or SEA Directive. The

SEA Directive must be transposed into national laws by July 2004 and is expected to apply to plans for offshore renewable energy developments.

Where a SEA is required, the authority responsible for the plan or programme will need to—

- prepare an environmental report on the likely significant effects of the proposed plan or programme, including reasonable alternatives. In deciding on the content and level of detail, the authority will need to consult environmental authorities defined by Member States
- give the environmental authority and the wider public 'an early and effective opportunity within appropriate time frames to express their opinion on the draft plan or programme and accompanying environmental report before the adoption of the plan'[37]
- take into account the environmental report, the opinions expressed by the relevant authorities *and the public* and the results of any cross-border consultations, during the preparation of the plan or programme and before it is adopted [*ibid.*].

The following information must be made available to the public—

- the adopted plan or programme
- a summary of how environmental considerations have been integrated to the plan/programme and how the SEA report and consultations have been taken into account
- the reasons for choosing the plan/programme adopted, over of the other reasonable alternatives
- arrangements for monitoring environmental impacts.

In the UK the government has decided to carry out formal SEAs already before the Directive is in force. The SEA is seen as a useful in supporting the development and refinement of plans for expansion of the offshore wind farm industry. The first phase of SEA work, focussing on three strategic offshore wind regions, has already been commissioned. For further details refer to the DTI 'Future Offshore' report[38].

As the UK government wishes to provide an appropriate planning framework not only for offshore wind but also for other offshore technologies, and to ensure that the development of such a framework is properly integrated to the SEA process, the provisions under the SEA directive are expected, in general, to apply to tidal stream and wave power projects [*ibid.*].

### E 1.2.2 Strategies for public acceptance

There are many different forms of public participation, but basically the public can be involved in a project in three important ways see [37], [39] and [40]—

- through information about ongoing development (information)
- through involvement in the decision making process (planning participation)
- through financial involvement in the project (financial participation)

#### Information strategy

The most common approach is to only passively inform people and carry out the minimum requirements regarding consultation. The public in such cases are almost never offered a direct influence on the decision.

This is due to imagined disadvantages and misconceptions, including[36]—

- public participation may worsen the situation,
- public participation might be inefficient,
- it is impossible to satisfy all interests so you might as well not try,
- public participation may expand the scope of any conflict.

Often this strategy is based on the assumption that the local public opposition can be overcome by rational decisions made by experts, and that people will eventually get used to change. However, infra-structural development is no longer automatically looked upon as a common good as we move deeper in to the post-industrial society.

### Planning participation

Another strategy is to directly involve the local public early in the planning phase, and incorporate the recommendations into the project at an early stage. The purpose of this strategy is to give the local population a motivation to accept change by, for example, giving them a say in the planning of the project, which will generate an interest and also eliminate misconceived threats. The 'risk' of this strategy is that the public debate generates so much awareness that it delays the whole planning procedure. A delay, which on the other hand is unavoidable when permits are appealed against and projects face the threat of never being realised.

However, if the channels for a dialogue are kept open and looked after, potential threats can be mitigated before a more general disruptive protest is formed. There will be a sense of control over the development of the project and the dialogue with the concerned public will not be handed over to misinformation by media.

If a sense of public control is created through an open and dynamic dialogue, the confidence of the public can be achieved. This is a very efficient way to navigate towards not only a successful outcome of a project but also future confidence in renewable energy developments.

The advantages of public participation in the planning process may therefore include—

- an essential improvement of planning decisions and balancing of different aspects,
- increased awareness of public concerns,
- an increased understanding of possible cooperation between opposing parties,
- elimination of misinformation and misconception of threats,
- future confidence and acceptance.

For an example of specific experiences with the planning participation management strategy, please see Sections E 1.3.1 and E 1.3.2.

### Financial participation

In some offshore wind projects the public has been involved as owners of (part of) the farms e.g. when buying shares, and thereby sharing potential economic risks and profits from the project. This is the case for instance at the Middelgrunden and the planned German Butendiek offshore projects.

One obvious advantage from public financial involvement is the fact that the specific project and the specific energy source in each shareholder will have a (mostly well-informed) advocate who can disseminate information to relatives, friends and colleagues, thereby increasing public interest and acceptance.

As described in Section E 1.3.1, it is believed that the strong public participation, including the public financial participation in the Middelgrunden offshore wind project, was an important prerequisite for the success of the project. The public resistance has been surprisingly small despite the obvious visibility of the twenty 2 MW turbines from many recreational areas in Copenhagen.

### E 1.2.3 Conclusions

If many parties are involved in the decision making, the social and environmental impacts can be properly addressed and the conflicts reduced. Conflicting interests can be illuminated in a pedagogic way early in the process. This improves the possibilities to compare facts such as the pros and cons of renewable energy in relation to the effects of other energy sources. The risk of public involvement is relatively small due to the experience that people who tend to accept the process also tend to accept its outcome[41].

## E 1.3 Experiences from wind energy

In general, opinion polls in countries like the Netherlands, Germany, Denmark and the UK show that more than 70 % of the population are in favour of using more wind energy.[42], [43], [44], [45]. In the UK, a summary of opinion surveys indicates that 8 out of 10 people support local wind projects[46].

Regarding tourism[a], a German study on effects from on- and offshore wind farms indicated that offshore wind farms would generally be accepted by tourists as long as the farms were not situated too near the coastline[47]. A recent study (September 2002) of the effects from onshore wind farms on tourists, a study commissioned jointly by the British Wind Energy Association and the Scottish Renewables Forum, found that 91 % said the presence of wind farms in the specific area made no difference[48].

The surveys show that wind farms in general are much more popular than one would be led to believe from reading letters to the editors in various newspapers, for example, and may indeed become tourist attractions instead of ‘scaring off’ tourists, as is often claimed by wind power opponents.

In Sweden, however preliminary results from a study on public acceptance from 1988 to 2002 show the opposite. The tourists are in general more negative to wind turbines, because they want to enjoy the unspoiled nature, whereas the reaction to planned offshore projects among the local public is often more positive[49].

There is every reason to believe that wave energy may become equally accepted, or even become more popular—in general, a particular advantage of offshore renewables is regarded to be their potential for greater public acceptability, because of lower visual impact[38].

The acceptability of wave and tidal energy does however depend on e.g. the degree of environmental impacts, the strategies chosen regarding public information and involvement, and the ability of the wave energy community to get good press coverage.

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[a] Tourists are of course very important to the local public, due to the potential income, or loss of income if the tourists stay away.

One important lesson to learn from the field of wind energy is that one as an advocate must avoid a polarisation of the dialogue with the public. In such cases a debate results in which one must defend and rather than engage in useful dialogue in which you can discuss and explain.

Although the experiences from offshore wind do not give any certain conclusions, the following general hypotheses, which are also broadly valid for wave power, can be derived—

- public acceptance in general is high but falls when it comes to our own living surroundings,
- coastal areas are more sensitive to change because of great recreational values,
- local acceptance seems to increase after the installation, provided that no disturbances are experienced[a],[50],
- public acceptance increases with the level of information and economic involvement.

In the following sections specific examples of different strategies for public involvement in wind energy projects are presented[b],[51]. The purpose is to give wave energy developers and relevant authorities some ideas on how to secure public acceptance, regardless of the choice of management strategy/public participation strategy.

### E 1.3.1 Experience from Denmark

In Denmark many people are involved in wind energy projects, approximately 150,000 families, either with environmental concerns and/or the possibility of receiving some financial benefits from them.

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[a] This is clearly illustrated in the experience from the Danish Tunø Knob offshore wind farm that was the focus of massive protests before and during the installation in 1995, but now, after it has been proved that the turbines do not disturb birds, fish, seals or humans, is broadly accepted.

[b] The Danish and Swedish experiences were first published in [51].

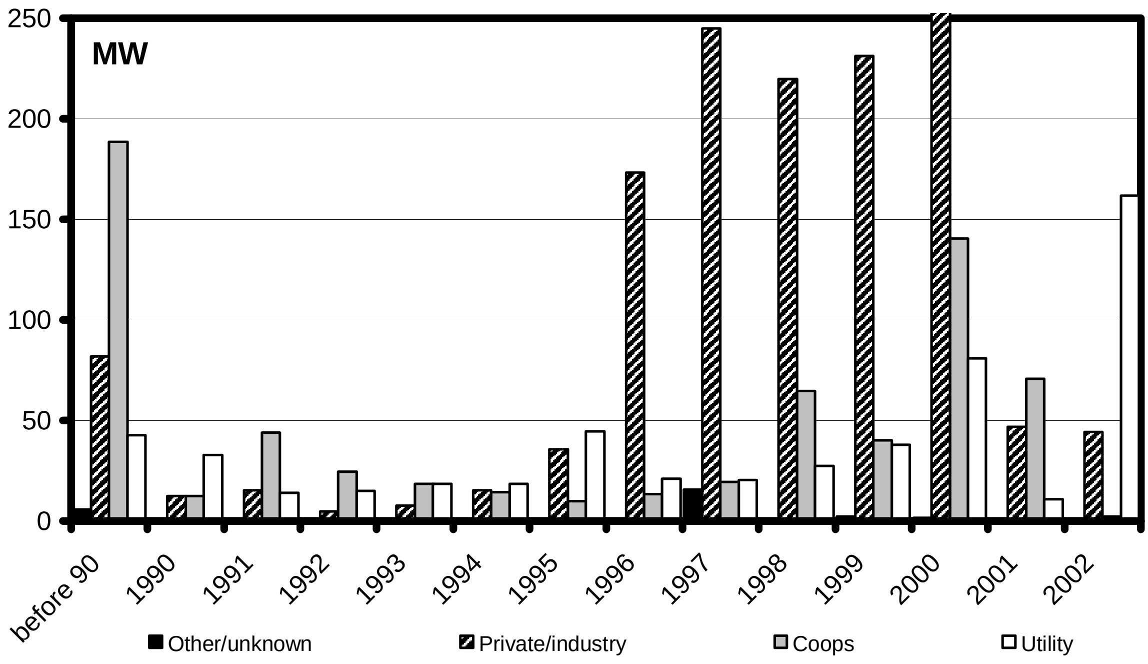


**Figure E-1 Development in ownership of wind farms in Denmark MW installed power each year**[52]

The cooperatives, where mainly local people share expenses and income from a wind turbine, have played an important role, especially in delivering project acceptance at a local level, where the possibility of resistance is otherwise high due to visual or noise concerns. In general there is a broad acceptance of wind energy in Denmark—opinion surveys result in at least 70 % being in favour of wind energy, whilst only about 5 % are against[35].

### The Middelgrunden project

The project consists of twenty 2 MW Bonus turbines, half of them owned by the local utility and the other half by Middelgrunden Wind Turbine Cooperative. Around 8,500 people, primarily in the local area, have joined the cooperative, which makes it the world's largest wind turbine cooperative. Each invests typically €2,850, corresponding to the production of 5,000 kWh/year.

In 1996, the Copenhagen Environment and Energy Office (CEEO) took the initiative to organise the project, after the location of Middelgrunden, 3 km from Copenhagen harbour, had been identified as a potential site in the Danish Action Plan for Offshore Wind[53]. Together with CEEO a group of local people formed the Middelgrunden Wind Turbine Cooperative and cooperation with Copenhagen Energy was established. As the Municipality of Copenhagen owns Copenhagen Energy, a close link to politicians was thereby also established. The locally based commitment, along with cooperation between the cooperative, the local utilities, and the municipality of Copenhagen, constituted a significant precondition for the development of the project.

The original project dating back to 1997 consisted of 27 turbines placed in three rows. After the public hearing in 1997, where this layout was criticised, the farm layout was changed to a slightly curved line and the number of turbines had to be decreased to 20.

The authorities raised a number of questions that were answered during the publicly funded preliminary investigations. During the hearing in 1997, 24 positive and 8 critical answers were received.

These figures mask the complexities of the issue, both in relation to relevant authorities and NGO's and in relation to the many future shareholders in the cooperative. For instance, local people were worried about potential noise impact from the farm, but after a demonstration tour to a modern on-shore wind turbine, the locals were convinced that there would be no noise impact from the Middelgrunden turbines.

Information to the potential shareholders was initially undertaken to secure a sufficient number of pre-subscriptions. This turned out to be a success, and the interest of more than 10,000 local people was proof of a strong local support, which could be useful in the approval phase.

A part of the shareholders got involved in the democratic hearing process, which was intended to create the foundation for authorities' approvals.

As an example the Danish Society for the Conservation of Nature at first decided to reject the proposed location, but through involvement of and information directed to the local committees of the society, this decision was later changed.

At the final hearing a large number of local groups and committees, not mentioning the several thousand shareholders, recommended and supported the project—only a relatively small group of yachtsmen, fishermen, individuals and politicians remained in opposition.

During and after the construction there has been surprisingly little resistance to the project, considering the visual dominance of the turbines, located just 3 km away from, for instance, a very popular recreational area—a beach—near Copenhagen. The reason for this lack of protest is believed to be the strong public involvement, both financially and in the planning phase.

#### *Lessons learned*

During the approval process, authorities raised a number of questions that were answered through the carefully planned preliminary investigations.

Through dialogue with many kinds of interest groups, CEEO and the Middelgrunden Cooperative, with its 8,500 members, generated a widespread understanding for and social acceptance of the chosen location and layout of the farm.

Locally based commitment and cooperation between the cooperative, the local utility and the municipality of Copenhagen have been significant preconditions for the successful development of the project.

This cooperation provided credibility to the project in relation to politicians, press and public.

### Conclusions from Denmark of relevance for wave energy

In Denmark most wind turbines are owned by locally established cooperatives and private persons and this appears to improve the social acceptance, as it is, generally speaking, the same people who experience the impacts also receive a share of the financial benefits.

Most of the coming offshore wind power projects will be owned by the utilities, but it is still a political priority to encourage the formation of cooperatively owned offshore wind power farms as well. This also applies for wave power, where public involvement was specifically mentioned in the Danish wave energy work programme.

This ‘Danish model’ is, however, rather unique, and for most other countries the offshore wind farms are either owned by utilities or private consortia, thus enabling only indirect financial benefits and influence to the local citizens. This is also likely to be the case for wave power in Europe to a significant extent, as the sheer scale of current renewable energy projects calls for an amount of funding, which can be very difficult for a cooperative to raise.

### E 1.3.2 Experience from Sweden

A broad-based participation in the implementation and decision process was used in a Swedish offshore project in Kalmarsund conducted by Vattenfall, the largest utility in Sweden. This is a form of ‘conflict management’, which extends the group of actors involved in the decision-making process, increases transparency and promotes negotiations and discussions.

Special focus for this project is to investigate, which parties should be involved in the decision process and how these different parties can participate and represent their interests in the planning process.

The result of this approach is that so far the project has conducted a management of dissent instead of putting trust in a fictitious consent. The importance of this type of conflict management seems to correlate with the amount of realised and planned projects in a demarcated and clearly defined geographical area suitable for offshore wind power.

This experience supports the view that one cannot assume that the local public opposition can be overcome by rational decisions made by experts, and that people will eventually get used to change, and more importantly that there are other more inclusive methods to use. Indeed it is feared that an exclusive attitude may prove fatal to the project. The strategy of the Karlskrona Offshore project has instead been to directly involve the local public early in the planning phase, and incorporate the recommendations into the project planning and decision-making. The purpose of this strategy is to give the local population a motivation to accept change by for example giving them a say in the planning of the project.

Another lesson learned is that the presentation of a wind power plan requires a sense of timing. In some cases, depending on the size of the project, it might be worthwhile to allow a certain period of adjustment. A large wind farm can be developed sequentially which makes adjustments easier if people express misgivings. Such adjustments manifest the flexibility and reversible quality of wind power developments. Just because a wind farm can be erected quickly, does not mean it should be.

### Public dialogue—use of information communication technology

In the Karlskrona offshore project different ways of promoting a dynamic dialogue has been developed. In this context information communication technology (ICT) plays an important role. The use of a website for communication on project updates has been the main tool[52]. An important task has been to make sure that this site is updated regularly and maintains a high standard of information in order to promote confidence in the developer. Regular information has also been sent out to complement and draw attention to the website.

Phone calls and e-mails have also been important tools for a direct personal response to concerned people. It has been of a high priority in the project to answer all questions as expediently as possible. It has also been important to direct questions from the public directly to the project management. This communication strategy has emanated in a thorough report on information, communication and reactions from the public in the EIS.

On top of this the Karlskrona Offshore project has distributed two inquiries along the coast in order to identify in which geographical area the public feel concerned, and *what* they are concerned about. The replies to these enquiries, and subsequent interviews, have been very useful for guidance concerning what topics are of central importance to emphasise in the EIA and how to mitigate in order to arrive at an acceptable EIS. Also, enquiries and interviews have made it possible to prepare and address the issues of central importance to the public at public meetings. This has been a very effective way to create confidence in the project and the developer, Vattenfall.

## E 1.3.3 Conclusions

An open public dialogue from the very beginning of a planning phase is important for achieving social acceptance—and the social acceptance on the other hand may influence political decisions.

Direct public involvement, e.g. the cooperative ownership model, is an important means for social and political acceptance, but may influence strongly decisions taken during the planning phase, which must be accounted for in the pre-planning phase as even minor deviations in the work at sea have a disproportionately large effect on the time schedule.

According to experiences from the offshore wind farms already established it can be said that—

- the degree of involvement of the local population in the planning phase influences public acceptance.
- the procedures for public involvement, hearings etc., vary considerably between countries and may even vary among regions within the same country.
- there is as yet no clear overview on the results of different strategies for public involvement and conflict management.

The issue of public acceptance deserves to be studied in more detail, e.g. through a monitoring programme focussing on public acceptance before and after the installation of a farm consisting of e.g. wave energy converters in relation to the degree of public involvement and active conflict management.

## E 1.4 Wave energy

The experience with public acceptability in relation to wave and tidal energy is so far very limited. Legitimacy is strongly connected to usefulness, and usefulness is an essential quality for rational technology. However, techniques have to be known in order to be useful. Techniques with a high degree of utility are seen as rational. A technique must produce the wanted effects in ways that are acceptable to the users. These facts are important to know in order to successfully introduce and promote wave energy technologies.

The test devices that have already been deployed, or will be deployed within the foreseeable future, seem generally to have had the same information strategy: To keep the public well-informed, e.g. through websites and newsletters, but there has been no direct involvement of the public in the projects. As the demonstration projects do not have to carry out an EIA, it has not been necessary to consult the public or inform the local public directly.

Only in relation to the planning and construction of the Orkney Test Centre public meetings have been held concerning the whole centre, and not concerning one specific device/project.

The projects have been discussed in the local press, and in some cases objections especially concerning visual and noise impact have been expressed, but there has been no organised dialogue with the public.

In order to promote public acceptability of wave energy, it is therefore essential that

- the public knowledge about wave energy is increased, e.g. through information campaigns directed at press, public and politicians each time new devices are successfully deployed
- each project developer aims at the highest positive level of openness and information, and considers the benefits of direct public involvement, for instance when the development of specific projects have resulted in a production price that makes public financial participation relevant.
- legislation/politicians encourages dialogue with and involvement of the local public

## E 1.5 General conclusions

### E 1.5.1 Identification of problem areas

The biggest challenge, currently, is the low public knowledge in most EU countries concerning wave energy. Before it becomes relevant to discuss and practice specific strategies for public involvement on a larger scale, it is necessary that the energy becomes known to the public as a huge, important and reliable source of energy.

### E 1.5.2 General recommendations

Developers and authorities should remember to promote openness and local involvement, also at this early stage of development—if mistakes are made at this point, before large-scale deployment takes place, it may prove very difficult to make wave energy acceptable to a the majority of the population.

### E 1.5.3 Recommendations for RTD programmes

Evaluation of experience of the effects of different ownership models and local ownership of wave power plants in relation to social acceptance.

Evaluation of experienced effects after deployment in relation to perceived effects in the planning phase.

# E 2 SOCIO-ECONOMIC BENEFITS OF WAVE ENERGY



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## E 2.1 Introduction

Detailed evaluation of the socio-economic benefits of renewables is a difficult, technology- and country-specific task. In order to present an outline of the likely benefits, a study has been carried out on the likely implications of one renewable (wave energy) for one country (Scotland).

## E 2.2 Background

It is relatively straightforward to calculate the number of direct jobs created by the manufacturing of on particular item of equipment. These depend on the technology, the processes and so on. Associated with these jobs are those created by the demand for components and in turn sub-components. Each job created is then serviced by a range of other jobs from other sectors. For example, the manufacturing employee buys bread from the baker and keeps that baker employed and so on.

Each employee at each stage creates earnings that are passed on to other sectors of industry by the so-called multiplying effect. The same one Euro earned in the manufacture of an item is spent several times over. The limits to this multiplying effect depend on each individual in the chain’s propensity to save. Typical multipliers are around 1.5-2.

The true effects of manufacturing an item can be assessed using a range of techniques such as input-output analyses. Each component and process in the manufacture, transport and installation can be identified and the value in terms of money and jobs evaluated. Since some components will be manufactured in-house and some brought from further afield or abroad it is important to decide where the boundary should be drawn.

In a very large industry with plenty of capabilities in all areas there is no input or output. All the components are manufactured within the boundary. Europe could be considered to be such an industry. In terms of wave energy Europe has all of the skills, expertise and facilities to manufacture any of the systems currently being investigated around the world.

Input-output analyses are more suited to local areas such as regions or countries. Below is an example looking at Scotland. There remain some further difficulties. There are many different wave energy concepts being considered. Each is of a different size, design and each works in a different way. It is difficult to give a meaningful breakdown of the jobs created with each aspect of the device manufacture, deployment and operation since these vary so widely.

An input-output analysis also requires estimates of the amount of skills and components that must be brought in from outside the boundary. Without a clear understanding of which components are required and from where these are likely to be sourced a reliable analysis is difficult.

Given these difficulties in demonstrating a believable estimate of job creation we will consider an example area—Scotland.

## E 2.3 Background to the opportunities in Scotland

Whilst Scotland currently enjoys overcapacity in electricity generation (exporting its surplus to England), it will loose about 50 % of its generating capacity within the next 20 years. This capacity will have to be replaced. There are many benefits (other than environmental) from replacing at least part of this capacity with offshore renewables.

Many of the components of wave energy devices could be sourced in Scotland and all of the construction could be undertaken in Scotland. Indeed, this calls upon the same types of skill and resources currently employed in shipbuilding and offshore oilrig fabrication. It could also account for similar levels of employment. For example, 15 years ago there was no commercial wind energy; now it is a €2,200,000,000 per year industry, employing about 40,000 people world-wide with growth rates of 10 % per annum. Denmark, whose Government sought to establish its country as an early world leader in wind, now employs over 12,000 people in wind energy[54]. In comparison, the Scottish offshore industry employs about 30,000. In many ways, constructing offshore renewable energy schemes could be seen as the natural area for fabrication yards to move into as orders for North Sea oil and gas rigs gradually decrease—'In the 21st Century, offshore renewables could be to Scotland what shipyards were in the 19th Century and offshore oil rigs in the 20th'[55].

## E 2.4 Job opportunities in Scotland's home market

This section analyses the job creation potential for marine energy in Scotland. The method used makes only a limited number of assumptions on the job creation potential. It assumes that over the period to 2015 wave power will be deployed steadily to achieve a proportion of Scotland's energy demand. This section does not discuss the likelihood of this development happening but does give an indication of the likely job potential of wave energy.

### E 2.4.1 Methodology

The number of concepts being considered and the huge range of different ideas proposed makes it difficult to assess which of the concepts will be successful. Additionally it is difficult to determine which of the development groups have the strongest commercial skills and which will bring their concepts to market first. This analysis therefore uses a simplification that the number of jobs created is related to the capacity of the plant installed. The manufacture of certain types of devices may employ more people than others, and so the estimates here are purely indicative.

The potential job market is estimated assuming—

- All outstanding R&D is completed and is successful
- The devices can be made economically

- The market for the devices is sufficient to allow for reasonably rapid increase in production

### Job creation

An estimate of the number of jobs per megawatt installed capacity can be made. This is based on 4-4.5 fulltime jobs per megawatt for offshore wind (CA-OWEE, 2001). Whilst there is no robust direct comparison with marine energy this figure is considered reasonable since there are many common activities associated with installing an offshore wave energy device or marine current device such as laying cables, installing foundations or anchors, etc. In addition, if wave energy is to compete with wind energy (and other energy technologies) then it is unlikely to be significantly more labour-intensive. Further, given the complexity of the technology in comparison to wind energy it is unlikely to be less labour-intensive. The up-front costs of wave energy, given the zero fuel costs, form a significant proportion of the costs.

It is possible that during the early development of wave energy, more effort will be required and there will be more jobs per MW. To account for this during the period 2002-2015 the full-time jobs reduce from 10 jobs/MW to 4.6 jobs/MW.

The product of the number of devices built, their installed capacity and the number of jobs per unit installed capacity gives an estimate of the number of full-time jobs associated with that production schedule.

### Development profile

This method considers the effect of introducing a market mechanism that encourages a certain proportion of electricity supply in Scotland from indigenous marine energy devices. This method is designed to place the estimates of jobs into context. It does not look at the export market, which could be significant and (as in the case of Denmark's wind industry) could be several times larger than the home market.

This approach expresses the market size as a share of the current Scottish electricity consumption (which was 32,027 GWh in 1999/2000 according to the Scottish Executive). Scottish consumption comprises approximately 9 % of the UK consumption (which was 338,500 GWh in 2000 according to the DTI UK Energy in Brief). This analysis assumes that there is no change in the demand for electricity in Scotland or the UK during the period 2000-2015.

It is important to assume a reasonable development profile for the technology, since the rate of installation of the devices will drive the jobs created. It is assumed that the proportion of energy supplied by marine energy in Scotland increases from zero in 2007 to the target value in 2015 according to a parabolic profile. This results in a linear rate of installation. Figure E-2 shows the assumed development profile. This shows how the proportion of Scottish electricity supplied by marine energy is essentially zero until 2008 after which it increases to the target by 2015. The profile is assumed to have the same shape regardless of the end target.

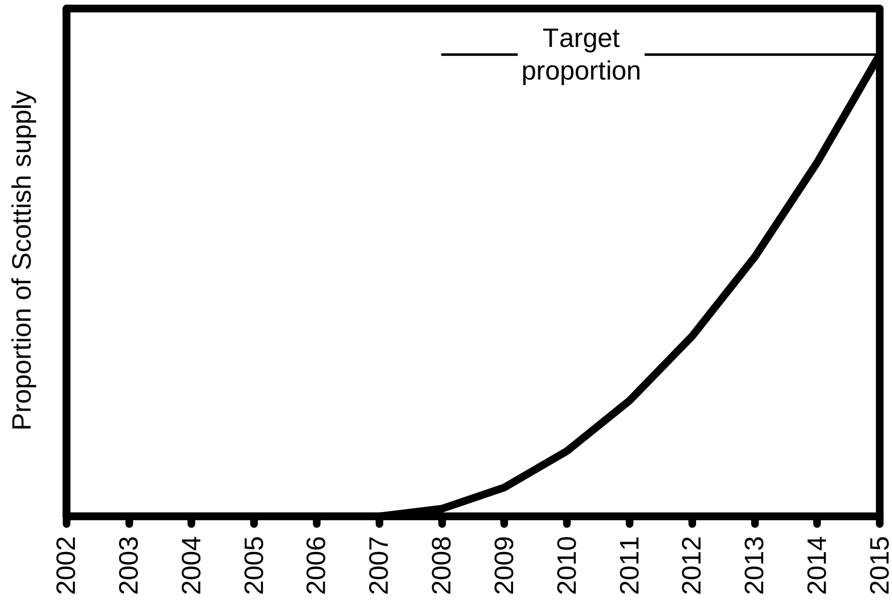


**Figure E-2 Assumed profile of contribution to Scottish electricity supply from marine energy**

The assumption that no installations take place before 2008 is a somewhat pessimistic view of the market. However, such a view gives an optimistic estimate of the number of jobs in 2015.

The energy consumption was converted to an installed capacity figure based on an average load factor of 25 %. This approximation is not completely reliable but does give a rough indication. It is not known what the load factor of a wave energy plant will be or how they would be sized (quoting installed capacity may be misleading for example).

Estimates of jobs for each target market size and by year are then calculated.

This analysis assumes that this development is reasonable and possible. It does not consider how much the development of the market would cost and assumes that achieving the target would be technically and commercially possible.

### E 2.4.2 Analysis

Figure E-3 shows the results of the analysis. For simplicity it is assumed that essentially no jobs are created until 2008. The figures can be interpreted as follows—

Considering only one case—that 10 % of Scotland's electricity demand is supplied by Scottish-manufactured marine energy by 2015—there would be around 1,600 people employed full-time in manufacturing and installing the devices in 2015 to deliver this. If Scotland were also to supply the market then the associated jobs would be very much higher.

Ten percent of Scotland's electricity consumption would represent around 1 % of UK energy supply. This would be a challenging target to achieve and given marine energy's current status of development perhaps a costly one—large quantities of untried technology would need to be installed rapidly with sufficiently high market value for the electricity to justify the risks.

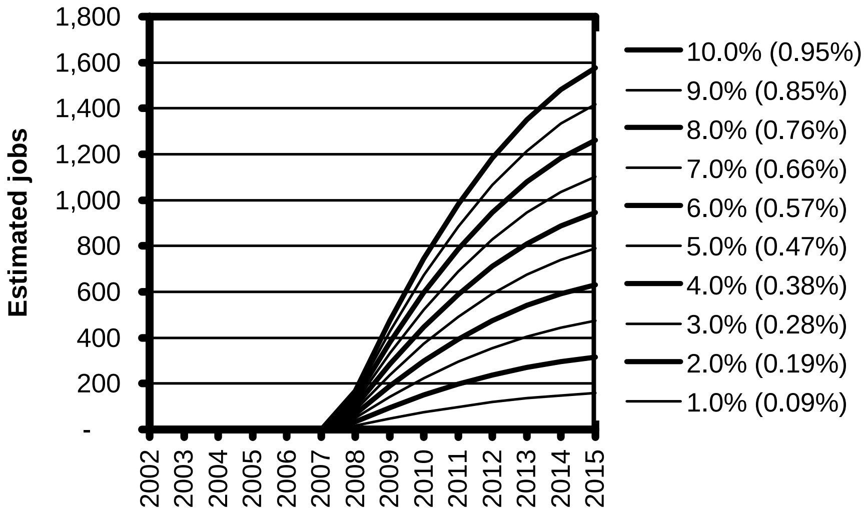


**Figure E-3 Estimated jobs created for a given proportion of electricity demand in Scotland supplied from marine energy (figures in parenthesis show proportion of UK electricity demand)**

During the period to 2008 the profile would be somewhat erratic because prototypes are likely to be deployed sporadically and tested for periods of 1–2 years before any further prototypes or indeed commercial systems are deployed. Also, during this period the sustainability of the jobs is highly questionable and it is possible that whilst new companies may appear rapidly others may fold completely or refocus the energies elsewhere. To put this into context the two Scottish Companies, Ocean Power Delivery and Wavegen employ around 20 people and to meet their expected growth targets will need to increase this number substantially in these early years—possibly through subcontracts as well as permanent staff.

Whilst in principle there is little reason why all of these jobs cannot appear in Scotland there is no certainty that this will happen. There are many barriers to such job creation. These include—

- Lack of a strong market pull for the technology
- Limited public finance
- High perceived risks in the new technology and market leading to low availability of private funds
- High employments costs, particularly in activities such as shipbuilding, compared to elsewhere in Europe and the rest of the world

Of primary importance is the need for a strong market for the technology but another significant barrier is the cost of employment. Whilst the companies may base themselves in Scotland to make use of the skills and specialist equipment manufacture some of the more labour intensive activities may be undertaken abroad where the cost of labour is lower. For example the Dutch-designed Archimedes Wave Swing wave device was manufactured in a Romanian shipyard where the costs were low and deployed in Portugal where the market for wave energy and the planning regime favourable.

Additionally, many of the jobs are associated with deployment. If the devices are not deployed in Scotland then it is possible that these jobs will accrue in the country of deployment for example. The wind industry has seen much of the civil construction undertaken by local contractors, whilst the turbine erection and commissioning is completed by specialists from the manufacturing country. It is likely that a similar situation might occur in Scotland. This does not affect the estimates for supplying Scotland's home market but it demonstrates that the benefits in terms of jobs of supplying a foreign market are slightly reduced in comparison.

There may be some challenges to attracting investment in wave energy devices to Scotland. These challenges include—

- Over-investment in this technology within a single manufacturing base and region may well carry unacceptable investment risks. Investment is more likely to be spread among a number of countries.
- Device teams and concepts are born in many different countries. The native country of each is more likely to be its home for development. Although Scotland might attract developers from the rest of Europe, it is unlikely that Scotland could attract all developers from all countries.
- The market for deployment of the technology may be stronger in other countries thereby making them more attractive as manufacturing bases.
- Competing incentive mechanisms in other countries may attract wave energy developers there drawing them away from Scotland.

### E 2.4.3 Operation and maintenance

Another real opportunity is in providing operation and maintenance services to the installed devices. Whilst the effort required in the manufacture goes with the rate of installation, the jobs associated with operations and maintenance goes with the total installed capacity in a region.

An estimate of the amount of effort required to service this can be taken from the offshore wind industry (CAOWE, 2001). It is predicted that 0.06 full-time jobs per MW would be created to service the offshore wind industry. It is assumed that marine energy is likely to require a similar amount 0.03-0.1 jobs/MW.

If ten percent of Scotland's electricity were supplied by marine energy in 2015 then around 1,500 MW of installed capacity would need to be serviced that year. This would support around 40-150 jobs in Scotland.

## E 2.5 Employment multipliers

All of the jobs discussed in the above sections are direct jobs. They are based on the numbers of people in full-time employment in manufacturing and deployment of the technology. The economic effects of such jobs can be estimated by considering employment multipliers.

The employment multipliers estimate the number of jobs associated with support to the direct jobs. For, example, the numbers of bakers making bread to feed the manufacturers. A rigorous approach to this analysis is a full input-output analysis. However, to give an idea of the scope we can consider some published multipliers. The Scottish Executive publishes employment multipliers in two forms (Scottish Executive (1998)), these are summarised in Table E-1. The first method considers only indirect jobs, those that are required to support the main workers. The second method estimates the induced jobs. New jobs can bring increased economic prosperity and the new employees increase their consumption of other services, such as in entertainment. These jobs are termed induced jobs.

| | Type I | Type II |
|---|---|---|
| **Sector** | **Direct + Indirect** | **Direct + Indirect + Induced** |
| Agricultural Machinery | 1.617 | 1.823 |
| Articles of Concrete etc | 1.601 | 1.822 |
| Construction | 1.844 | 2.087 |
| Cutlery and Tools | 1.376 | 1.561 |
| Electric Motors and Generators | 1.322 | 1.476 |
| Electrical Equipment nes | 1.301 | 1.441 |
| Electronic Components | 1.520 | 1.799 |
| General Purpose Machinery | 1.594 | 1.828 |
| Insulated Wire and Cable | 1.268 | 1.400 |
| Iron and Steel | 1.703 | 1.983 |
| Machine Tools | 1.430 | 1.655 |
| Mech Power Transmission Equipment | 1.557 | 1.796 |
| Metal Castings | 1.275 | 1.433 |
| Metal Containers, etc | 1.519 | 1.785 |
| Metal Forging, Pressing, etc | 1.286 | 1.453 |
| Metal Goods nes | 1.304 | 1.491 |
| Non-ferrous Metals | 1.904 | 2.190 |
| Shipbuilding and Repair | 1.687 | 1.971 |
| Special Purpose Machinery | 1.537 | 1.774 |
| Structural Metal Products | 1.540 | 1.814 |

**Table E-1 Employment multipliers for wave energy comparable industries in Scotland (Scottish Executive, 1998)**

Table E-1 shows some comparable industries. The most appropriate multipliers to use would depend on the mix of technologies used in wave energy devices in the future. Given the uncertainty in the types of design that are likely to be seen in the market it would be misleading to make too precise judgements about the effects of an expanding wave energy market on employment.

It is clear however that the number of jobs created for each direct job in wave energy is in the range 1.3-1.9 when considering only indirect jobs and 1.4-2.2 when considering other jobs resulting from increasing economic prosperity. Hence, the total number of jobs in Scotland related to supplying the marine energy could be more than double the figures estimated in Section E 2.4.

## E 2.6 Comparison with wind energy

It is instructive to compare the predictions of marine energy development against the historic development of wind energy. Figure E-4 shows the historic worldwide wind energy development trends. The estimates of jobs created are based on a figure of 10 jobs per MW in 1983, which linearly reduces to 4.5 jobs per MW (it is noted that this method is not rigorous).

During 1983-1987 there was a boom in wind turbine deployment. This was fuelled by tax incentives in the USA. These incentives encouraged the deployment of very large numbers of wind turbines on single sites. This situation was short-lived and the boom collapsed after the incentives were removed. Accounting for the boom, it can be seen that broadly the development has been exponential with relatively low levels of deployment to 1993.

By 1993 the number of jobs in wind energy worldwide was around 3,200, which is equivalent to the number estimated in this analysis by 2015. This would put wave energy approximately 15-years behind wind energy, if the deployment profile was assumed to be similar.

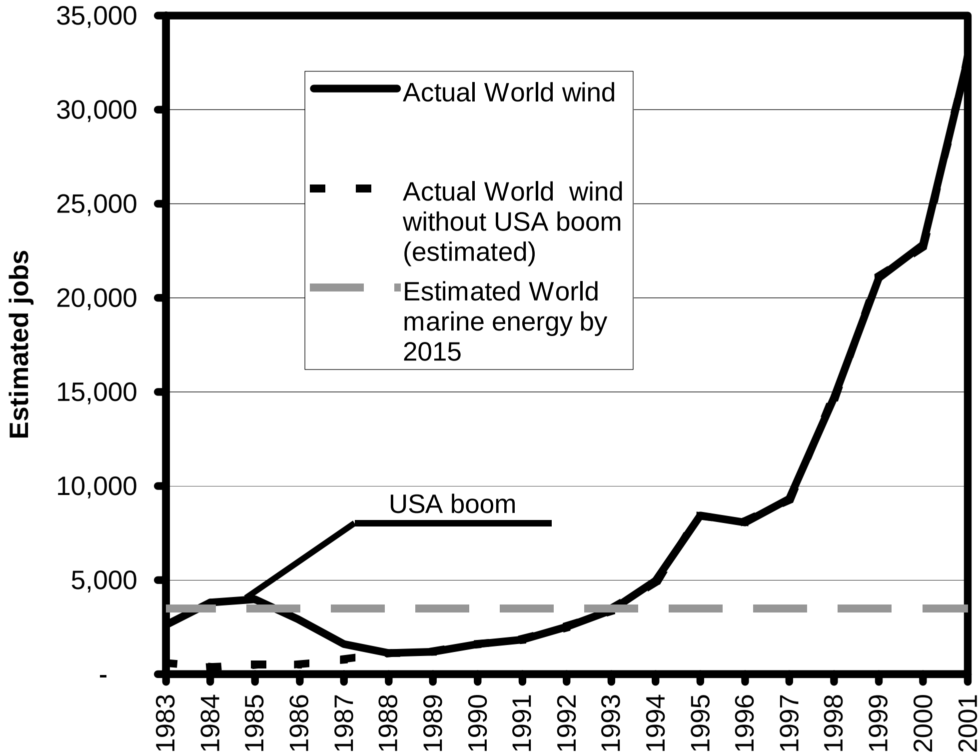


**Figure E-4 Estimated jobs in wind energy 1983-2001 based on 10 jobs per MW in 1983 reducing linearly to 4.5 jobs per MW by 2001**

By comparison prior to 1983 the number of wind turbines in commercial production was very small and large-scale production did not occur until around the time of the USA boom in 1984. Wave energy has no concepts in commercial production now, but by 2004 reasonable quantities could be in production by some early players. This implies that in two to three years time wave energy could be in a position to benefit from a wave energy boom as wind did in the USA in 1983–1987.

## E 2.7 Technology competitiveness

Scotland's long association with wave energy and the potential synergy between the expertise required for development of offshore oil and offshore renewables gives Scotland an edge in developing these renewables[56,57].

## E 2.8 Diversification of rural economies

Much of the offshore resource is situated in rural parts, which have traditionally been dependent on a few industries (e.g. fishing and tourism). Operation of offshore renewable energy schemes will entail **long-term** employment, with much of the economic benefit being retained within the local community.

## E 2.9 Conclusions

The situation in Scotland could be repeated elsewhere in Europe, but until wave energy becomes established and the industrial demands for building the designs in the quantities required are known any estimate of job creation would be very uncertain. It is fair to conclude however that when wave energy moves on from the prototype to volume or mass production that jobs will be created and primary and secondary economies will grow too.

# E 3 CONFLICTS OF INTEREST


| | |
|---|---|
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## E 3.1 Introduction

According to the work program of the Wave Energy Network, the purpose of this work package is to collate information on barriers to large-scale development of wave energy basically arising from competing uses of the resources, such as areas required for shipping, military exercises, existing subsea pipelines and cables, fishing grounds, etc.

As the presence of such barriers is heavily dependent on the specific location, it is only possible to give a general overview presentation of the subject in this report. Potential barriers for specific sites will be discovered during the SEA[a] and EIA[b] process of individual, larger wave energy projects, and detailed information about these barriers will then be available in the SEA Statement and the EIS[c,60,61]. For further details concerning EIA and EIS, refer to Section E 5.2 on 'Environmental impact'.

The information on barriers basically arising from competing uses of the resources has been collated through interactions with device teams (e.g. through responses to questionnaires, see **Appendix 1**) and studies of selected references. As can be seen from the list of references useful information has been found from studies of offshore *wind* energy, and the information in this draft report is in many cases based on a similar study from the EU Concerted Action on Wind Energy in Europe[58].

The information obtained from the relatively few device teams in the responses to the questionnaires show that barriers resulting from 'conflicts of interest', as defined here, are not at present expected to constitute major barriers for the large-scale development of wave energy.

## E 3.2 Barriers arising from competing uses

As an initial step in the planning process, the mapping of areas reserved for other uses must be carried out, and an alternative location of deployment will have to be analysed before deployment.

Areas with competing uses generally fall into two categories—areas with restricted or prohibited access and areas with conflicting uses.

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[a] Strategic Impact Assessment, EC Directive to be transposed into national laws by 2004 (European Directive 2001/42/EC). SEA process to be carried out by authorities.

[b] Environmental Impact Assessment. (Council Directive 85/337/EEC, amended by Council Directive 97/11/EC (1997)). EIA process usually carried out by developer.

[c] Environmental Impact Study, the final document of the EIA process

Areas with restricted or prohibited access include—

- Major shipping routes
- Military exercise grounds
- Areas near other major coastal or offshore structures (bridges, harbours, oilrigs, wind turbines, etc.)
- Areas near sub-sea cables or pipelines
- Natural reserves

Areas with conflicting uses are typically—

- Fishing grounds
- Resource extraction areas (aggregate extraction, etc.)
- Recreational areas
- Areas of archaeological interest

As most European countries have procedures for hearing the views of interest groups, potential conflicts of interest are mostly well known, and should be identified during the SEA and EIA process [59,60,61]. Apart from various lobbying organisations, primary conflicts of interest concern ship traffic, defence and fishing interests.

Some areas may be excluded from consideration for use for wave energy projects even at the pre-feasibility assessment phase. These are major ship lanes, oil and gas pipelines, cable routes, raw material deposits, military restricted areas and areas of importance in relation to flora and especially fauna, e.g. Special Areas of Conservation. However, most other suitable sites will be subject to potential conflicts of interests with other uses and users of the locations.

In order to present an idea of the number and types of users and uses, a list of consultees who should be involved in the EIA process regarding Orkney Marine Energy Test Centre[62] has been attached at **Appendix 2**.

## E 3.3 Areas with restricted or prohibited access

Regarding the restricted areas these are plotted in naval maps, and updates are frequently published in notices for fisheries and notices for mariners.

This type of barrier was in general considered to be of medium importance by the network members, although restricted areas exclude significant potential locations for wave energy production, but such restrictions are generally of local nature and do not concern major sea areas.

### E 3.3.1 Ships

According to international shipping conventions all ships have the right of innocent passage through territorial waters, and beyond this 12 nautical-mile limit shipping enjoys freedom of navigation. Where required for safety reasons sea-lanes and traffic separation schemes are designated or prescribed for the regulation and passage of ships. International shipping activities are regulated within the IMO (International Maritime Organisation), a specialised organisation of the United Nations[63].

According to international law countries have the right to construct renewable offshore projects within a 200-mile renewable energy production zone. It is possible to establish safety zones up to a distance of 500 m around such installations, however offshore renewable installations and safety zones are not permissible if they interfere with recognised sea-lanes[64].

Shipping is likely to be an important source of conflicts of interest. The reasons for this seem to be the following—

- ship lanes represent a siting limitation factor, as certain areas will be prohibited for use for wave power where established shipping lanes demand it. Furthermore, locations where ships may lay anchor to enter harbours, must be avoided.
- even where careful planning is carried out, and the farm is not placed near major navigation routes, or routes have been altered in order to minimise collision risk, there will still exist a risk of significant environmental damage in case of ship collisions with wave energy converters, e.g. an oil carrier collision. In Danish EIA risk analyses applied for the Middelgrunden and Nysted/Rødsand offshore wind farms, a calculated risk in the order of 1 collision every 10 years has been accepted by the authorities, as the risk frequency was not higher than at baseline conditions[65]. For wave energy converters deployed in deep waters, the frequency of collision is likely to be lower, but nevertheless likely to be higher than the baseline conditions.
- wave energy farms must be marked properly and effectively in accordance with national or international guidelines (IALA 1984, IALA 2000[66]), even though painting and illumination/signal lights may have a negative visual impact, which could lead to increased public resistance.
- there is a need for proven reliability of anchor/mooring systems of wave energy converters to avoid hazard of drifting converters in e.g. shipping lanes.

As collision risk analyses for all offshore construction projects will be a mandatory part of the EIA, valuable information will be available from these studies, as can be seen in offshore wind energy EIAs, see for instance background reports to the offshore wind farms at Horns Rev and Nysted/Rødsand [67,68].

Due to the significant environmental risks associated with ship collisions, this issue may pose a significant barrier for some wave energy technologies. Methods for assessing ship collision risks are available from other industries and must be applied. However, at the current state of development it is unclear which collision frequency might be acceptable. The risk assessment will have to assess the additional risk associated with the wave power plant compared to baseline conditions before deployment.

In order to minimise the risk of collision with naval traffic, the wave energy converters must be painted and lit according to the requirements of the safety authorities. The lighting requirements may be expected to vary according to the classification of the different device types. Furthermore, lighting requirements will probably also depend on the conclusions from the ship collision risk assessment, which might introduce additional marking requirements.

### E 3.3.2 Military exercise grounds

Military area restrictions disqualify a number of feasible sites from being developed. In many countries coastal areas owned by the military cover a significant part of the sea potentially usable for wave power. Practical solutions for co-existence between military and wave power are called for, but a solution must come through the political system.

In the UK, the Ministry of Defence have raised objections concerning the siting of several offshore wind farms, as these—according to the MOD—are supposed to disturb vital radar systems and constitute a risk for low-flying aircrafts[a],[69]. As long as wave energy schemes do not reach the height of today's offshore wind turbines or consist of moving blades like the wind turbines[70], barriers due to disturbance of radar or radio links or collision risks with low-flying aircrafts are not to be expected.

### E 3.3.3 Areas near other major coastal or offshore structures

Areas near other coastal or offshore structures constitute a limitation regarding potential locations of wind energy schemes.

For some regions, the shallow water locations may already be reserved for offshore wind power. This might develop into a barrier for some device types, which are only applicable for water depths of less than 15 m, but if the reliability of anchoring/mooring systems of wave energy converters has been proven, a fruitful co-existence between e.g. offshore wind and wave energy could be possible.

When the mooring problem has been solved, and different wave energy technologies have proven to be reliable and safe, the limitations due to neighbouring coastal or offshore structures should be minimised, thereby for instance lowering cable costs if wave energy converters can be located near existing offshore wind farms.

### E 3.3.4 Sub-sea cables, pipelines and raw material deposits

Corridors around electricity and telecommunications cables, oil and gas pipelines and oil and gas production sites prohibit renewables developments in these areas and thereby constitute a site-limiting factor[70].

This is however not seen as major barriers for the development of wave energy, as these sites and corridors are already well known and should therefore not lead to any significant conflict of interests.

Moreover, there is no reason why the oil and gas industry and offshore renewables should not be able to work closely with each other in the future—indeed, there are plans to generate electricity from a combination of gas and e.g. offshore wind power, and a close cooperation would further enable the potential sharing of facilities, thereby minimising the costs and impact from the establishment of offshore renewables project[70].

### E 3.3.5 Natural reserves

Protected areas such as *Special Protection Areas* and *Special Areas of Conservation* (**Appendix 3**) limit the number of potential locations for wave energy. In cases where these areas are well known, conflicts should be easily avoidable, as long as the deployment site is not within a restricted area. In many countries (e.g. the UK) such areas

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[a] See for instance The Guardian, May 31, 2001. An ongoing and continuing dialogue between the MOD and the British Wind Energy Association has however been established and common interim guidelines published, in: ETSU (DTI, MOD and BWEA) 2002: Wind Energy and Aviation Interest.

have until now however only been defined within the territorial waters (the 12 nautical-mile zone).

It should be noted that even though future wave energy devices are not located within the borders of a restricted area, it is not unlikely that the sub-sea cables from the wave energy converters to shore must be placed in a restricted area. This cabling problem is actually seen as a serious barrier for the development of large-scale offshore wind projects in the German part of the North Sea, as the authorities, due to environmental concerns, until now have been reluctant to accept that cables are laid in protected areas near-shore. A (political) solution is called for, and one possible solution could be the approval of cable-laying under very strict rules, in order to minimise impact on environment during construction; one minimum requirement would be only to allow cable laying work at times that are not important or sensible for the surrounding wildlife, which would often result in work at winter time.

Furthermore, areas that at a first glance do not seem to be protected areas (on official maps) must in some cases be regarded as protected areas, because in the EU different unclassified sites that deserve EU classification should be treated as classified sites.

For example—*Important Bird Areas* (a *BirdLife* term) that have not been officially declared as a *Special Protection Area* (SPA, the official EU term covering areas that deserve protection due to their importance for birds), must be treated as an SPA until a decision has been made[71].

The choice of location for the Danish Energy Authority's wave energy test centre in Limfjorden (Nissum Bredning), in the middle of an SPA, can be seen as an indication that wave energy is not expected to have negative impact on birds, and that natural reserves' restrictions may not constitute a serious limitation of wave energy, if it proves that wave energy does not imply negative impacts on the surrounding nature.

For the Wave Dragon project, where a model will be tested at the Danish Wave Energy Test Centre from Spring 2003, and later on a few kilometres away, still within the borders of the SPA, an analysis has been carried out leading to the conclusions, that disturbance of the birds would only be temporary, during deployment and maintenance work. When/if wave and tidal energy devices are equipped with wind turbines there will be a new situation, but research from offshore wind farm monitoring studies may then have lead to solutions concerning this subject.

Ornithological associations are a very strong lobby in most European countries, and negotiations are often carried out to define whether or not an area can be used for wind power. Due to the low height of wave energy converters, this conflict should however be less severe than is the case for offshore wind energy projects.

## E 3.4 Areas with conflicting uses

### E 3.4.1 Fishing

Restrictions to fishing rights from wave power are bound to be an area of conflicting interests as the fishermen will lose trawling ground and in some cases also areas for pot fisheries.

Experiences from offshore wind indicates that up to now this conflict has not excluded any projects from being carried through, but often financial compensation must be given to the fishermen even without much evidence that fishing is actually reduced.

This conflict appears to be especially problematic for France where the fishing lobby is very strong and does not hesitate to block harbours if they feel their interests are threatened, but such problems may also occur elsewhere since the fishermen are generally well organised all over Europe.

In the UK, the DTI has established a liaison group to encourage open dialogue between the fishing industry and the offshore renewables sector, and best practice guidelines on consultation between developers and fishing interests are being prepared[72].

Some of the device developers responding to the questionnaire stated that their device would probably be beneficial for fish populations, but there is no reason to believe that this will mean that financial compensation to fishermen need not be paid.

In order to minimise impacts on fish, and thereby reduce the risk of conflicts with fishermen, it is recommended to—

- avoid construction of wave energy farms in sensitive spawning areas, areas with species of commercial or conservation importance and areas with a very high value for fisheries
- avoid construction during important breeding, nursery or feeding periods
- carry out site-specific and species-specific monitoring studies in order to investigate the (positive and negative) effects of the wave energy farm on fish, including the consequences on fish population/fishing possibilities when fishing is restricted within and in the vicinity of the wave energy devices.

### E 3.4.2 Resource extraction areas (aggregate extraction, etc.)

Resource extraction areas generally concern small and localised areas, and as most wave energy converter types can be applied for quite a wide span of locations, the significance of this will not be major.

### E 3.4.3 Recreational areas

The coast and the sea is a primary holiday and leisure location and is a significant asset in a nation’s recreational resource[73]. Recreational areas and values are often a significant barrier to major on- or near-shore construction projects, and for instance in the UK over a third of its coastline is designated for its scenic or natural beauty[74].

Apart from natural reserves, the conflict basically concerns the visual intrusion of the technology into the landscape/seascape. In general, conflicts and opposition lessen when the plant is deployed ‘out of sight.’ In [73] it is suggested that a distance of 15 km may be the maximum limit of visual significance regarding offshore wind turbines along the coast. In many cases wave power converters should be ‘out of sight’ at much shorter distances.

Compared to wind power, where significant local opposition to large-scale farms is found in several countries, the conflict is likely to be less severe for wave energy. First of all, wave energy converters do not extend far above sea level, making them hardly visible from a distance. Even the shore-based devices like the LIMPET are barely visible from a distance. For near-shore and offshore devices, this might be a problem in itself, as naval standards will require visibility from quite some distance, which means installation of buoys, lanterns or radar reflectors. This might be a subject of public concern for really large farms, but cannot be expected to pose a serious barrier for wave energy in the short and medium term.

### E 3.4.4 Marine archaeology

Areas of archaeological interest are not often identifiable solely from maps—as an example there are thousands of historic shipwrecks along the British coast, however only fifty-two of them have so far been selected for protection under the UK Protections of Wrecks Act[74]. Seismic site surveys and historical records investigation during the planning phase prior to the decision of the exact siting should however avoid possible conflicts of interest.

Specific areas of archaeological interest should be avoided. However, if for instance a wreck is found during installation, this may lead to a partial or total relocation to avoid serious delay to the whole project. In some cases the public approval may be granted on the condition that the contractor funds archaeological investigations of the specific site. All solutions—relocations, delay and funding—may incur considerable costs

In general, areas of archaeological interest are found near-shore. The issue is not to be considered as a barrier to large-scale exploitation of wave energy, but as a risk factor to be considered in the planning process, and measures can easily be taken to avoid such incidents by carrying out the investigations necessary in the SEA and EIA.

### E 3.4.5 Others

For some countries the coastal region is covered by very strict rules of land (and sea) use, effectively hindering the deployment of near shore devices. In Denmark construction works are generally prohibited in the coastal region up to 8 km from the shore, unless located near to an industrial area, and in Ireland the same applies for areas within 5 km distance from shore.

It should be repeated that in many countries the rules governing renewable energy devices deployed outside the territorial borders are not currently defined. To what extent this will pose a significant barrier to offshore wave energy is hard to assess. In any case, it seems likely that this issue will be handled by offshore wind power, before it is relevant for offshore wave energy[a,64].

## E 3.5 Conflicts of interest—general conclusions

The general conclusion is that most conflicts of interest are restricted to areas already identified in the planning phase, thus severe conflicts of interest which could stop a project can theoretically be avoided through careful, open planning.

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[a] As an example the UK government has stated that new legislation is needed to allow development of offshore renewables outside territorial waters and has subsequently proposed a legislative basis for such developments in the ‘Future Offshore’ consultation report.

Conflicts with fishermen are almost bound to occur, but within other marine construction works such conflicts have been solved to date through agreed financial compensation. Some commentators note that conflict with fishermen is likely to occur regardless of the expected positive and negative effects on fish stocks.

Ship collision risks are to be carefully assessed in the project-planning phase. Whereas deployment of wave and tidal energy schemes in shallow water may in some cases decrease ship collision risks, due to markings lights and thereby improved 'visibility' of reefs and bank. The acceptable level of risk associated with offshore wave power is currently undefined, but relevant experiences may become available from the developing offshore wind industry.

It will be very important to collect information from different studies in order to cover the whole area, as different 'narrow' site-specific studies are carried out at the different projects. Baseline and impact studies from individual projects are to be disseminated and jointly appraised. Conclusions from local projects should be translated and all relevant existing material placed on a publicly accessible web-site.

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# E 4 PLANNING

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|---|---|

## E 4.1 Introduction

The objectives of this work package are to assess national and international rules and regulations concerning wave and tidal energy, highlight key-problem areas such as planning and legal barriers and create recommendations regarding methods for overcoming such problems. Furthermore, lessons learned in relevant industries should be included.

This report covers these objectives based on studies of selected references and on responses from network members and international colleagues.

The responses to the questionnaires have been attached to this report at **Appendix 8**, and they do not only present national examples of planning issues, but also present some of the different wave energy pilot projects that are currently being developed.

As can be seen from the list of references much information and many recommendations have been be found from studies of offshore *wind* energy, and the information in this draft report is in many cases based on a similar study from the EU Concerted Action on Wind Energy in Europe[75], dealing with planning issues and national and international policies.

Furthermore, the study of Ecofys on policies and regulations concerning offshore wind[76] and especially the so-called 'Sealegal' document[77], that contains comprehensive information regarding offshore wind planning issues in selected European countries, have contributed with much valuable information.

The reasons for using information from wind energy is the fact that planning rules concerning wave energy generally have not been prepared yet, and it may be expected that rules and regulations regarding offshore wind energy will in many cases also apply to wave and tidal energy.

### E 4.1.1 Policies

On the political and public levels, the profile of wave power appears to be relatively low, with significant differences across Europe. Especially in the UK and Portugal there is a high political awareness of the possibilities of wave power, because of its potential as a renewable energy and because it is seen as a potential new market for the declining offshore industry, which is of specific importance in the UK.

Some spin-off effects from the wind energy industry can be utilised by the wave and tidal energy community, but it is not likely that wave power will receive a generally high level of public and political awareness before it has been established as a viable renewable energy technology through deployment of a significant number of commercial plants. In popular terms: 'as long as wave power does not appear in energy statistics, it is unlikely to receive a high public and political profile'.

What is called for is therefore the successful demonstration of several devices, followed by large-scale commercial penetration. Furthermore, information campaigns directed at politicians, press and public will also be necessary.

As the successful offshore demonstration on a larger scale has yet to be achieved, wave energy is generally not specifically included in national renewable energy policies, rules and regulations, with the exceptions of United Kingdom and Portugal[a].

### E 4.1.2 Planning rules

During the planning and pre-planning process of wave (and tidal) energy projects, developers are confronted with a number of specific rules and regulations, but may in some cases also experience that the legal planning framework has not been fully developed yet, forcing the authorities to create such a legal framework during the development of the project, which may lead to a delay of the specific project.

In general, planning rules and regulation concerning offshore renewable energy projects within and beyond the 12-mile-zone (see below) do not exist in all countries, but can be foreseen in the coming years, especially for offshore wind energy. It may be expected that rules and regulations laid out for offshore wind energy schemes may in many cases also apply to wave energy projects.

Not only are the legal frameworks still under construction and unclear in many countries, which may become a major limiting factor to the development of wave energy, but national planning rules may vary significantly within the EU, and even on the national level, different and confusing legal frameworks exist within individual countries.

For example, different regulations regarding the same subject exist in some countries, depending on whether a proposed project is located inside the 12 nautical-mile zone (often referred to as ‘territorial sea’) or outside (‘exclusive economic zone’, EEZ, extending from the 12 nM zone seawards to a maximum of 200 nM from the shoreline).

In a recently published British report on ‘Future Offshore’[78] it is concluded that current UK legislation fails to provide a firm basis for development beyond territorial waters, and that new legislation is therefore urgently needed.

Below an overview of the most relevant international and national policies and legal frameworks is presented. For a more detailed analysis of policies and regulations concerning offshore renewable energy, in particular wind, in Northern Europe, please refer to the so-called Sealegal document[77]. This report contains comprehensive information regarding international, EU and national frameworks of relevance for offshore wind (and wave) energy in Europe, with national analyses from: Belgium, Denmark, Germany, France, Ireland, The Netherlands, Sweden and UK. The sections below are in many cases based on information from this document.

[a] The Danish programme for wave energy has not been continued after 2002.

## E 4.2 International and EU policies, rules and regulations

### E 4.2.1 Delineation of the sea

The United Nations Convention on the Law of the Sea, UNCLOS[a],[79], sets out the rights of a coastal state over its territorial sea and over the seas beyond this limit.

The maritime zones, of relevance for wave energy, defined by this Convention, are[77]—

- The territorial sea (up to a limit not exceeding 12 nautical miles)
- The contiguous zone (the zone adjacent to the territorial sea up to 24 nM)
- The continental shelf (the sea-bed and subsoil of the submarine areas that extend beyond the territorial sea of a coastal state throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nM from the baselines)
- The EEZ (the Exclusive Economic Zone is an area beyond and adjacent to the territorial sea, extending up to, but not beyond 200 nM, and includes, besides the sea-bed and subsoil, the waters superjacent to the seabed)
- The high seas (All parts of the sea that are not included in the EEZ or in the territorial sea).

Whilst a coastal state has full sovereignty over its territorial sea, its rights beyond the 12 nM-boundary are more limited.

A coastal state has sovereign rights for the purpose of exploiting the natural resources—resources of the seabed and subsoil, such as oil and gas—of its continental shelf. But the production of energy from water, currents and wind will only be possible according to international legislation if the state has established an EEZ around its territory, or a special renewable energy production zone, which the individual coastal state has the right to do, according to the UNCLOS.

In order to protect offshore installations, and to ensure safe navigation, a state may establish safety zones around such installations and structure for a distance of up to 500 m, but still the state must not interfere with international laws, such as the right of freedom of navigation (see Section E 3 on ‘

[a] UNCLOS came into force in 1994 and contains a legal framework covering navigation, maritime boundaries, fisheries, the marine environment and marine scientific research. To date 138 states are members.

Conflicts of interest‘).

The UK is an example of a state that has not declared an EEZ yet (2002). So far, only an Exclusive Fisheries Zone and a pollution zone have been established, but the government is planning to declare a Renewable Energy Production Zone that will extend up to 200 nM from the baseline of the territorial sea, in accordance with UNCLOS. Before the UK can exercise EEZ rights conferred by UNCLOS, there has to be legislation at a national level which defines e.g. the limits of the Renewable Energy Production Zone[80].

## E 4.2.2 Environmental issues

### Kyoto agreement, EC renewables objectives

In general, all EU states have adopted national legislation and established targets for reducing greenhouse gas emissions and promoting the use of renewable energies, in order to meet the objectives of—

- the Kyoto Protocol (1997) regarding reduction of greenhouse gas emissions
- the EC White Paper (1997[81]) on doubling the share of renewables in gross domestic energy consumption in the EU from 6 % in 1995 to 12 % in 2010, and
- the EC Directive on the promotion of electricity produced from renewables energy sources (2001[82]) with the aim of increasing the share of electricity produced from renewables in total gross electricity consumption in the EU from 13,9 % in 1997 to 22,1 % in 2010.

In most cases, as stated above, wave energy is not even mentioned in the national plans and policy programmes that aim at fulfilling these targets, whereas the potentials of wind energy is proposed as a partial solution.

### EIA and SEA directives

Regarding the EC Environmental Impact Assessment Directive (1985, amended 1997[83]) and Strategic Environmental Assessment Directive (2001[84]) detailed information can be found in Section E 5 on ‘

Environmental impact‘.

For future larger-scale wave and tidal energy projects an EIA must be carried out (usually by the project developer) and in many cases an SEA is expected to be carried out by the authorities prior to the EIA. The SEA Directive must be transposed into national laws by July 2004.

### Protected species and habitats

The following conventions and directives are relevant regarding the development of wave and tidal energy—

- the Ramsar Convention (on wetlands and waterfowl habitat of international importance[85])
- the Bern Convention (on the conservation of European wildlife and natural habitats[86])
- the Bonn Convention (on the conservation of migratory species[87])
- the EC Birds Directive (on the conservation of wild birds[88]), and
- the EC Habitats Directive (on the conservation of natural habitats and of wild fauna and flora[89])

Designated areas, according to the conventions and directives mentioned above, often overlap partially or wholly. If a specific project is expected to have an impact on such areas, an assessment must be carried out either as part of the EIA or as an individual assessment. Possibilities for derogation depend on the proposed projects, its specific size, location and assessed impacts, and the specific statements in the conventions and/or directives in question.

For a more detailed presentation of these conventions and directives, please refer to the Section E 3 on ‘

Conflicts of interest and the Sealegal report[77].

**International conventions and declarations**

- ESPOO Convention (on Environmental Impact Assessment in a Transboundary Context[90]). The objective of the convention is to promote international cooperation on EIA, especially in a cross-border (transboundary) context: Countries are obliged to assess, at an early stage of planning, the environmental impacts of certain projects with possible cross-border impacts, and to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact on a cross-border level. The EC SEA Directive will in many cases ensure that the information and consultation requirements of the ESPOO Convention are fulfilled.
- OSPAR Convention (on the Protection of the Marine Environment of the North-East Atlantic[91]). The convention stipulates that contracting parties must take necessary measures to protect the maritime area against the adverse effects of human activities in order to safeguard human health and conserve marine ecosystems.
- Barcelona Convention (on the protection of the marine environment and the coastal region of the Mediterranean[92]). Within this framework an Action Plan, covering e.g. coastal zone management, protection of ecosystems and preservation of bio-diversity, is serving as the basis for sustainable development in the area.
- Helsinki Convention (on the Protection of the Marine Environment of the Baltic Sea Area[93]). The convention applies to the marine environment of the Baltic Sea and internal waters, comprising the water-body and the seabed, including their living resources and other forms of marine life. Each year the Helsinki Commission meets, and unanimous decisions taken by this commission are to be incorporated into the national legislation of the member countries.
- Bergen Declaration (Fifth North Sea Declaration, March 2002, on the Protection of the North Sea[94]). The participating ministers made a number of commitments, e.g. regarding the development of renewable energy technology, *inter alia*, offshore *wind* energy, agreeing upon the necessity of and benefits from taking action in order to exploit the potential of offshore wind energy fully and safely (while applying the precautionary principle), for instance by encouraging authorities to develop guidance on areas suitable for the development of offshore wind and to exchange information and experience.

  The ministers invited OPSAR, in co-operation with the EU, to—
  - develop a comprehensive set of criteria regarding the decision-making on applications for the development of offshore wind energy installations, and
  - develop best-practice guides regarding location, construction, operation and removal of offshore wind farms in order to facilitate their development and to protect the marine environment.

The results of this process may prove to be highly relevant also to the development of wave and tidal energy.

## E 4.3 National rules and regulations

During the project lifetime of a wave or tidal energy project, the following issues must be considered in accordance with national rules and regulations—

- Location of project
- Environmental Impact Assessment (see Section E 5 on ‘Environmental Impact’ and Section E 3 on ‘Conflicts of Interest’)
- Consultation (see Section E 3 on Conflicts of Interest, and Section E 1 ‘Public Acceptability’)
- Grid connection, sea cables and power production
- Marking requirements (see Section E 5 on ‘Environmental Impact’ and Section E 3 on ‘Conflicts of Interest’)
- Insurance
- Sea lease
- Decommissioning (see Section E 5 on ‘Environmental Impact’)

Table E-2 presents national planning rules and regulations relevant to wave and tidal energy. It has been based partly on responses from members of the Concerted Action on Offshore *Wind* Energy in Europe and the Sealegal study [77], as the response form Wave Net members was very limited, possibly due to the fact that wave energy has generally not been adopted in national planning rules and regulations.

Table E-2 is by no means thought of as an exhaustive presentation of all relevant aspects concerning national planning rules and regulations for development of wave and tidal energy projects. Firstly, such a presentation is currently not possible, because of the lack of national legal frameworks regarding wave energy, and secondly it has not been within the scope of this Network to make such an analysis.

The Table E-2 should merely be seen as an introduction to national legislation issues, serving as background information for the recommendations in Section E 4.4.

As no firm legal frameworks covering wave and tidal energy exist, and as the existing general legal frameworks regarding development of onshore, near-shore and offshore renewable energy projects (especially wind) in many countries are under consideration, developers must seek relevant detailed information themselves for each individual project.

For detailed information (2002) from Denmark, France, Ireland, The Netherlands, Sweden and UK regarding (offshore wind) policies, rules and regulations, please refer to[77]. This Sealegal study also contains information from Germany and Belgium. An overview of relevant national policies and planning issues concerning offshore wind, taken from the Sealegal document, can be found in Table E-2. For specific cases from Portugal, UK and Denmark, see **Appendix 9**.

**Table E-2 National Planning Rules and Regulations**

| | |
|---|---|
| DK | **Onshore/Near-shore—**<br>The coastal zone in Denmark has very strict and rather complicated legal rules with a number of different regulations, depending on the actual site (e.g. distance to recreational areas, proximity to industrial area) and the general distance to shore[95]<br>**Offshore—**<br>Permit regarding grid connection required from local utility<br>Permit regarding sea cables and power production required from Danish Energy Authority<br>Permit regarding localisation (of test site) required from The Danish Coastal Authority, including permissions from local, regional and archaeological etc. authorities.<br>It is expected that an insurance covering damage on third person is required, as is the case with ships.<br>Marking requirements are set by The Royal Danish Administration of Navigation and Hydrography.<br>EIA is currently not required for test devices because of limited size and temporal deployment.<br>In line with its tradition the Danish authorities put a lot of attention on the consultation of the public. |
| FR | No specific rules.<br>In France, the question of a specific legislation regarding offshore renewables is very new and there is no specific legislation for instance concerning offshore wind exploitation and no lease procedure.<br>**Onshore/Near-shore—**<br>Implementations of projects within the territorial sea generally follows the same process as for general building works, with additional requirements related to the use of the marine public domain and the generation of electricity.<br>**Offshore—**<br>Outside the territorial waters there is as yet no fixed regulation for offshore renewables development[77]. |
| GR | Legislation for renewable energy sources applies also to large-scale offshore wind energy—<br>Law governing energy production-distribution incl. RES<br>Greek legislation for environment<br>Environmental legislation for shoreline<br>Catalogue of natural protected areas in Greece |
| IR | **Onshore/Near-shore—** |

**Table E-2 National Planning Rules and Regulations**

| | |
|---|---|
| | The development of National Coastal Management Planning has shown little recognition of the potential wave power resource and is dominated by fisheries, tourism, heritage and landscape/seascape considerations. In a draft policy plan for coastal zone management in Ireland (1997) the consultants make only a passing mention of the wave resource[96]. The recognition and incorporation of such documents into the county development planning process adds to the potential difficulties of shoreline or near shore wave power developments.<br>**Offshore—**<br>The Irish republic has issued a coherent set of rules[97]. It has for example been made clear that offshore wind parks are eligible everywhere in Irish waters unless it is forbidden in specific locations. Licenses are approved in two phases. Phase 1, 'the Site Investigation License', allows consortia to investigate whether the targeted site is suitable and economically viable. The licensing authority is the Department of Marine and Natural Resources. Under Phase 2 a full license can be granted in case all approvals have been obtained. Environmental and safety prescriptions are in place although it is still allowed that the Minister may include additional requirements. The Irish government urges the developers to obtain public acceptance before inserting the application.<br>Offshore *wind* farms will not, as a general rule, be allowed within 5 km of shore. Certain areas are identified as prohibited to ensure safety at sea, protection of established shipping lanes, air navigation, telecommunication needs and defence requirements.<br>Planning permission required from relevant local authority for onshore infrastructure associated with offshore wind farms. |
| IT | **Wind energy—**<br>The Italian Navigation Code (INC) and the Application Guide of INC (AGINC) are the reference legislation for offshore wind farms installation in the Italian national waters; specifically art.36 and following of INC and art.5 and following of AGINC (for the type and format of application documents).<br>Special permits should be considered for offshore wind farms, because of the long time limitation related to their presence for the activity of navigation, fishing, marine sport, and others.<br>Many other Administrations are involved in processing the installation permits: Ministry of Transport, of Defence, of Environment, of Industry, of Civil Works, of Sea and Terrestrial Resources (General Direction of Maritime Fishing) and others.<br>The Environmental Impact Evaluation should be considered necessary, even though no clear policy is applied today.<br>At the end of the procedure the Permits are issued by the Compartment of Maritime Transport and shown to public office of interested Municipality and Province for public information and possible opposition. |

**Table E-2 National Planning Rules and Regulations**

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|---|---|
| | The installation of Offshore Wind Farm and Permit applications is under the control of the local Harbour Authorities by their presence in the Coastal Guard.<br><br>Safety features for navigation and aviation are requested in the Permit. Information on the offshore plants is due to Marigrafico office for its inclusion on the nautical charts. |
| NL | **Onshore/Near-shore: Rules for Wind Energy Projects—**<br><br>Within the 12-mile-zone, apart from a near shore wind farm pilot project (NSW), no wind farms will be allowed.<br><br>**Offshore: Rules for Wind Energy Projects—**<br><br>There are practically no Dutch regulations and rules existing for large-scale offshore wind energy outside the 12-mile-zone. This could be positive or negative depending on political will. However, there are several laws and regulations that have to be considered when licenses in the Dutch Exclusive Economical Zone of the North Sea must be gained.<br><br>These regulations are—<br><br>Sea Water Pollution Law (Wet Verontreiniging Zeewater)<br><br>Environmental Administration Law (Wet Milieubeheer)<br><br>Spatial Arrangement Law (Wet Ruimtelijke Ordening)<br><br>Environmental Protection Law (Natuurbeschermingswet)<br><br>Governmental Water Works Administration Law (Wet Beheer Rijkswaterstaatswerken)<br><br>Wreckage Law (Wrakkenwet)<br><br>Monuments Law (Monumentenwet)<br><br>Excavation Works Law (Ontgrondingenwet)<br><br>North Sea Installations Law (Wet Installaties Noordzee)<br><br>(Sea) Bottom Protection Law (Wet Bodembescherming)<br><br>Mining Laws 1810, 1903 & EEZ (Mijnwetten 1810, 1903 & NCP buiten 12 mijl—From recent studies, it seems that this law has no implications for offshore wind farms)<br><br>Route Law (Tracéwet—This law is important for the seaways to be chosen) |
| PT | **National Incentives to promote Wave Energy**<br><br>The comprehensive programme *Programa E4 –Eficiencia Energética e Energias Renováveis* (Energy Efficiency and Endogenous Energies) supporting the penetration of renewable energies in Portugal, namely Wave Energy, was established since late 2001.<br><br>**Main Legislation—**<br><br>*Programa E4—Resolução do Conselho de Ministros,* Number 154/2001, |

**Table E-2 National Planning Rules and Regulations**

| | |
|---|---|
| | October 19, Its objectives include the facilitation of access and the development of production of electrical energy by cleaner technologies namely wave energy, as well as the management of the grid connection points for independent producers.<br><br>Decree-Law nº 33-C/2001, December 29, establishes the tariff to be paid by the national grid to the independent producers of electrical energy from ocean waves. The tariff is around 0.225 Euro/kWh, up to 20 MW installed capacity in national territory. The grid is obliged to purchase all the energy produced<br><br>The Ministry of Economy—through Direcção Geral de Energia (General Direction for Energy) provides information at www.dge.pt.<br><br>As a consequence of this national legislation, Portuguese authorities show much good-will and have in many cases been very flexible during planning and construction of test devices. |
| SE | There is no dedicated legal basis regarding offshore wind energy generation—and none at all regarding wave/tidal energy—and the planning procedures have not yet been carried out in all relevant municipalities.<br><br>In a study carried out by the Swedish Energy Agency[98], and initiated by the government with aims to make standards for the future offshore wind power, it is proposed that 3,300 MW of offshore *wind* power is to be developed within the next 10 to 15 years. Seven offshore areas have been suggested as locations of special interest, first of all in the Southern part of Sweden. There are no specific plans for wave energy.<br><br>In current rules and regulations (2001) the administrative procedures and competent authorities depend on project size (below 1 MW, 1-10 MW, above 10 MW) and location (distance to shore)—<br><br>**Onshore/Near-shore (territorial sea)—**<br><br>Building Permit required from local authorities' (municipality) building and planning committee, according to the Planning and Building Act.<br><br>Permit required from local County Administrative Board concerning environmental issues (according to the Environmental Code). For projects larger than 10 MW, permits are issued by the Environmental Court concerned.<br><br>Application for water operation permits shall be considered by the Environmental Court<br><br>The government shall assess the permissibility of wind farms inside territorial waters if they are consisting of clusters of three or more wind turbines with a total output of not less than 10 MW.<br><br>**Offshore (outside territorial waters)—**<br><br>Construction of wind farms outside territorial waters requires permission from the government.<br><br>The Swedish Energy Agency issues permits regarding cabling |

**Table E-2 National Planning Rules and Regulations**

| | |
|---|---|
| | For further information, see [77] |
| UK | The legislation regarding offshore wind energy developments is diverse.<br><br>As for other countries developers have to obtain approvals from various governmental authorities, although the Department of Trade and Industry (DTI) provide 'one-stop' consenting assistance. The 'Offshore Renewable Consents Unit' does not, however, affect the statutory roles of other departments, agencies and authorities involved in the consent process.<br><br>**Onshore/near-shore (territorial sea)—**<br><br>There are two main legislative consent routes for onshore projects and projects located in territorial waters, and it is up to the developer to choose which is the most appropriate—<br><br>Section 36 of the Electricity Act 1989 and Section 34 of the Coastal Protection Act 1949, or<br><br>an order under the Transport and Works Act 1992 (not available in Scotland)<br><br>Regardless of consent route, applications must be in accordance with e.g. the following planning rules and regulations—<br><br>Procedure for obtaining offshore wind energy site lease from Crown Estates (who is the 'landowner' of most areas within the 12 nautical mile limit).<br><br>Environmental Impact Assessment and consultation leading to EIS<br><br>Food and Environmental Protection Act 1985, Section 5<br><br>Town and Country Planning Act 1990, Section 57 or 90<br><br>**Offshore (beyond 12nm-zone)—**<br><br>No firm legal basis for development beyond territorial waters. The UK Government is therefore preparing new legislation to allow developments outside territorial waters.<br><br>**In general,** the UK Government is aware of the fact that the consent procedure regarding offshore renewable projects needs to be streamlined and it is currently (2002/2003) undertaking a regulatory review with the objective of reducing the complexity of the regime governing development in coastal and marine waters. Additionally, DTI will work with other Departments to streamline further the administration of offshore consents process and explore the feasibility of having one main point of contact for applicants and consultees.<br><br>For further information, see [79] and, especially, [80].<br><br>**Wave Energy—**<br><br>The planned streamlining of consent procedures focuses in particular on offshore wind, but the UK Government wishes equally to provide an appropriate planning framework for other offshore technologies, such as wave and tidal energy. As part of the 'Future Offshore Consultation Process', views have been invited on whether separate provision will be needed for offshore technologies other than wind, and if so on what |

**Table E-2 National Planning Rules and Regulations**

| | |
|---|---|
| | timescale, [80]. Deadline: 18 February 2003. |

| Procedures | DK | FR | GER | IR | NL | SE | UK |
|---|---|---|---|---|---|---|---|
| **Fixed procedure** | *under review* | not clear | yes | yes | *under review* | yes | yes |
| **One-stop shopping** | probable | no | no | no | uncertain | | yes |
| **Pre-selected sites** | yes (by previous Govt.- but under review by new Govt.) | no | Provisions for specially suited areas for establish-ing offshore wind install-ations | no (but certain areas prohibite d) | uncertain | no | no |
| **Economics: costs** | *under transition* | | | *to be reviewed after con-clusion of current tendering scheme* | | | |
| **Lease fee** | *under review* | fixed by Tax authority (no known rule) | no | commercial rents (3800 €/MW/yr or 2.5 % gross revenue, whichever higher) | *under review* | annual fee of app. 150 €/year and per wind turbine | commercial rents (2 % gross revenue) |
| **Priority grid access** | *under review* | yes | yes | predeter-mined capacity | grid con-nection not guaranteed | guaranteed access for <1.5 MW | no |
| **Grid connection costs** | Developer pays up to onshore junction pt. (for sites in ex-govt's plan, all costs paid by grid operator) | new users-no grid connection cost for electricity producer | Developer pays grid connection & transmission, but grid operator obliged to reinforce grid, if required, at his own cost | integrated into bid price for tender | paid by developer | paid by developer | paid by developer |
| **Decom-missioning fund** | uncertain | possible prerequisite | possible prerequisite | yes (case by case—bond agreed as part of lease negotiations —reviewed every 5 yrs) | yes (developer to provide security for (non-negotiable) sum, deter-mined by authorities) | yes conditions & funds related to decom-missioning agreed (case by case) at granting environ-mental permit (no advance payment required) | yes (fund or bond—case by case basis—established as a condition to granting Lease) |

**Table E-3, Overview of basic characteristics of offshore wind policies in selected countries (August 2002, source [77])**

## E 4.4 Conclusions and recommendations

Regarding national planning rules and regulations it can be concluded that the legal framework has not been fully clarified yet, which may become a barrier for future development of large-scale wave energy.

The recommendations below, found in [76] and [77], will all be highly relevant for politicians and authorities to bear in mind when policies, planning rules and regulations for wave and tidal energy are being developed—

- one-desk policy/one-stop-shop procedure for all necessary licenses
- definition of exclusion areas
- selection of preferable areas for which SEAs are carried out—this should not exclude other potential areas than the ones already having been excluded
- preparation of the infrastructure such as grid connections in the area(s) selected
- burden sharing for grid connection—the grid connections to major offshore renewable sites can be considered as an enhancement of the overall supply system and should therefore be financed partially or completely by the grid operator
- transparency in financial burden for the project developer, such as royalties, lease fees, administrative handling costs, cost charged for research required by authorities, cost related to increased availability of emergency teams
- anti-speculation clauses—legislation should prevent early wave and tidal energy developments being hindered by speculative concessions
- risk-hedging schemes—most project developers will confront significant barriers with respect to obtaining full insurances, e.g. due to a lack of references. The public sector could play an important role by initiating risk-hedging schemes in association with insurance companies.

# E 5 ENVIRONMENTAL IMPACT

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|---|---|
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## E 5.1 Introduction

### E 5.1.1 Environmental impacts

The objectives of this work package have been to identify the environmental impact from the expanded development of wave and tidal energy schemes and to create recommendations for their development. Furthermore, the objectives have been to collate information regarding the potential impact that the environment could have on wave energy devices (e.g. growth of mussels, corrosion). Finally, environmental benefits in terms of reduced emissions of pollutants should be determined.

The current draft report covers these objectives based on responses from network members and studies of selected references.

As can be seen from the list of references much information has been be found from studies of offshore *wind* energy, and the information in this draft report is in many cases based on a similar study from the EU Concerted Action on Wave Energy in Europe, dealing with 'Environmental Impacts'[99].

In addition, Tom Thorpe's work on 'Environmental economics' in Section D 2.6 and on this work package have been very useful and many passages have been included, and Pat McCullen (ESB International) has improved the report with his comments that have been included in this final edition.

Finally, results from the environmental scoping study for the Marine Energy Test Centre on Orkney have been included as **Appendix 9**, presenting a valuable overview of potential impacts during construction and operation of the test centre.

### E 5.1.2 Background

In November 2000, a questionnaire was distributed to the network members, but only four members responded. These responses are attached to this report in **Appendix 4**.

As to why the response was so limited, some features of wave energy might give a partial explanation.

Firstly, it is not really meaningful to speak of wave energy in singular, as wave energy is currently pursuing a vast number of widely different technology trails, which means that the assessment of environmental impact, apart from being location dependent, to a large degree can be expected to be technology dependent as well. This can be seen from the responses received and is also illustrated in the Environmental Scoping for the Orkney Marine Energy Test Centre, where it is emphasised that 'the full EIA required to support licence applications for the establishment of the test facilities will not necessarily be able to predict all the specific impacts relating to each separate device that may be tested. It is therefore recommended that an 'environmental approval procedure' be developed, which will ensure that prior to deployment of each device, an assessment of device specific environmental impacts be undertaken and management or mitigation measures implemented where necessary'[100].

Secondly, there are only very limited practical deployment experiences available. Even within offshore wind power, a similar study[99] concluded that the available knowledge on a number of environmental impacts was sparse. For wave power it appears to be almost non-existent, and estimations of the environmental and social perceptions will largely have to be based on experiences from comparable industries.

Given this background this report utilises the experiences from offshore wind power. Obviously the environmental impacts may in some cases be quite different for wave power compared to wind power, and therefore inputs from other network members have been included with reference to specific device types. Nevertheless, this report may shed some light on the issues involved, and also prove as a good recommendation for the potential environmental barriers facing wave and tidal energy in the future.

Wave energy is here defined as multi-unit applications of a size rendering the projects within the scope of the EC Council Directive 85/337/EEC[101] amended in Directive 97/11/EC[102], which state the minimum requirements for Environmental Impact Assessment for large construction projects. In the near future wave power appears to be bound to single-unit plants, which are likely to be too small for EIA requirements to apply. Nevertheless, excepting island applications, the future of wave power must be in projects of a size comparable to offshore wind if large-scale commercial penetration is to be achieved, and for these projects an EIA will be required.

Finally, this study is limited in the sense that only direct potential impacts from wave energy schemes offshore, near-shore and onshore have been included in this report. This means that additional expected impacts from e.g. necessary reinforcement of the grid onshore, like overhead power lines, are not presented.

## E 5.2 Environmental impact

### E 5.2.1 Environmental Impact Assessment

In theory, the siting of wave energy schemes can potentially avoid many of the perceived environmental impacts that have arisen with the rapid expansion of some on- and offshore technologies. However, with only a few schemes having been built to date, there is little evidence to substantiate this view, and offshore developments do generate additional impacts associated with the marine environment. If wave energy is to fulfil its potential as part of an integrated energy system, then a full and accurate assessment of its environmental benefits and burdens needs to be undertaken.

Within the EU, an Environmental Impact Assessment[a] (EIA) must be carried out before public approval for larger projects can be granted. The minimum requirements of the EIA

[a] The term 'Environmental Impact Assessment' (EIA) covers the procedure that fulfils the assessment requirements of Directive 97/11/EC. In many countries, e.g. in the UK, the environmental information

are specified in the EC Council Directive 85/337/EEC[101] amended in Directive 97/11/EC[102].

The directives require that private and public projects, which are likely to have significant effects on the environment, must be subject to an assessment of their potential effects on the environment before they can be allowed to proceed.

An EIA shall identify, describe and assess the direct and indirect effects of a project on the following factors—

- human beings, fauna and flora
- soil, water, air, climate and the landscape
- material assets and the cultural heritage
- the interaction between these factors mentioned

The directives lay down rules for the EIA procedure, which includes a requirement for public participation—the results are to be made public, and the views of the public taken into consideration in the consenting procedure (for more information regarding this subject see Section E 1 ‘Public acceptability‘).

As is the case for wind energy, the individual member states shall determine, either through a case-by-case examination or through thresholds or criteria set by the member state, whether wave power projects shall be made subject to an assessment. In this way, member states may exempt a specific project from the provisions in the directives.

### E 5.2.2 Strategic Environmental Assessment

The SEA Directive (2001/42/EC 1[103]), which must be transposed to national laws by July 2004, and which has already been used by the UK government regarding three strategic offshore wind development sites[104], supplements the environmental impact assessment system on the assessment of the effects of certain plans and programmes on the environment.

As this Directive is quite new and as the SEA report and statement will assist developers to prepare cost-effective EIAs for individual offshore renewable projects, it is presented in detail below—

The objective of the Directive is to help integrate the environment into the preparation and adoption of plans and programmes liable to have significant effects on the environment, by subjecting them to a prior environmental assessment at the planning stage.

The Directive applies to plans and programmes prepared and adopted by a competent authority or prepared by a competent authority; it also applies to amendments to such plans and programmes. Other plans and programmes which set the framework for future development consent of projects will be subject to environmental assessment if an examination shows that they are liable to have significant effects on the environment.

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provided by the developer is presented in the form of an Environmental Impact Statement (EIS), which may then be described as the final product of an EIA. In this report only the term EIA will be used.

Before the adoption of a plan or programme or its submission to the legislative process, the competent authority of the relevant Member State is required to carry out an environmental assessment and, after consulting the competent environmental authorities, to prepare an environmental report setting out—

- the contents of the plan or programme and its main objectives,
- the environmental characteristics of any area likely to be significantly affected by the plan or programme,
- any existing environmental problems which are relevant to the plan or programme,
- the national, Community or international environmental protection objectives which are relevant to the plan or programme in question,
- the likely environmental effects of implementing the plan or programme,
- the measures envisaged to prevent, reduce and offset any significant adverse effects on the environment,
- the envisaged monitoring measures.

The report must also include a non-technical summary of this information.

The draft plan or programme and the environmental report must then be made available to the authorities responsible for the environment and to the public, who should be able to express their views before the plan or programme is adopted or submitted to the legislative process. Furthermore, neighbour countries must be informed and consulted if it is considered that the plan or programme is liable to have cross-border environmental effects.

The environmental report, the opinions expressed by the relevant authorities and the public and the results of any cross-border consultations must be taken into account by the competent authority during the preparation of the plan or programme and before it is adopted.

When a plan or programme is adopted, the Member State responsible will inform all of the parties concerned regarding the plan or programme as adopted including a statement summarising how environmental considerations have been integrated, the environmental report, the opinions and the results of consultations, the reasons for choosing the plan or programme as adopted and the planned monitoring measures[105] (for more information regarding the adoption of the SEA Directive in UK, see [104])

### General conclusions

Developers of wave power farms must carry out an EIA on the specific project, with the purpose of providing information about the possible impacts on the environment from the time of installation until the dismantling of the farm.

The EIAs from individual wave energy projects will contain much valuable information regarding the effects from wave energy on the environment, but due to the fact that the experiences with wave power are currently very small, the literature on environmental impacts is lacking. However, the experiences from offshore wind can be expected to produce relevant references for a number of the potentially significant impacts, which also apply to some of the wave power plants.

The SEA directive, requiring strategic environmental assessments and consultations at an early stage of certain plans and programmes, may assist ocean energy developers in carrying out the EIA.

### E 5.2.3 Biological impacts

Responses from a questionnaire distributed in the Network indicate that visual and noise impacts from shore-based devices are likely to be the most likely potential environmental impact. A number of other potential impacts were identified, but in general, they were concluded to be technically solvable, simply adding to the costs of the projects. Whether or not the above conclusion is the result of the main operational experiences with shore-bound devices is hard to judge, but it appears to be a fact that a precise evaluation of the environmental impacts associated with different types of wave energy converters cannot be performed with the current low level of operational experiences available. However, the lessons from offshore wind power clearly indicate that the documentation of environmental impacts will be an important issue for wave power as well, when the technologies reach large-scale commercial development.

In 'The Concerted Action on Offshore Wind Energy in Europe'[99] the following biological issues were indicated as being potentially problematic—

- Collision of birds with turbines
- Ousting off birds from their traditional feeding/roosting grounds
- Unknown effect of low frequency noise emissions on fish life and sea mammals
- Impacts on fish larvae
- Disturbances of seabed and fauna during construction and operation.

While bird life impacts are undoubtedly considered the most important for wind power, fish, sea mammals, and potential pollution associated with ship collisions are probably the impacts that will attract the most interest for wave power.

Only a few case studies of the impact on fish, birds, sea mammals and flora have been carried out in connection with the offshore wind farms already established, either as part of the Environmental Impact Assessments or as individual studies. This knowledge has not yet been compiled in a systematic manner, which results in the fact that the biological impacts and mechanisms involved are still associated with significant uncertainties.

The experience from studies on environmental aspects of offshore wind farms in Denmark and UK are collated on a national level—

- in Denmark the monitoring studies are being closely followed by an international expert group, and reports in English from these studies can be found on the internet, e.g. www.hornsrev.dk and www.nystedhavmoellepark.dk
- the British studies are administered by a steering group known as COWRIE (Collaborative Offshore Wind Research into the Environment), including members from the industry, authorities and NGOs. The group is chained by the Crown Estate and reports will be available from: www.offshorewind farms.co.uk.

#### Sea mammals

The effect from wave energy converters on sea mammals is considered relevant but not prohibitive by the WaveNet respondents.

An assessment of the local mammal population, e.g. seals, whales and dolphins, is however needed in the EIA, and if the specific site is situated in the vicinity of colonies (e.g. grey-seal) this question may become crucial in relation to the approval of the project. This was the case for the Swedish Bockstigen offshore wind power project, where a Before-After-Impact-Study was carried out before construction, during construction and two years after the start of operation, showing that wind turbines did not affect the seals in any respect[106].

At the moment a Danish project is underway by SEAS, where the movements of radio-tagged seals are followed as part of a larger seal surveillance program in relation to the construction of the Nysted/Rødsand wind farm where the population of seals is significant. One of the preliminary conclusions from this study is that seals are very mobile, and move over great distances in their ordinary lives[107]. This means that disturbances during the construction phase can be expected to be only temporary, as seals will move back when their habitat is restored to normal conditions.

An issue which was deemed important for offshore wind power, and is likely to be so for wave energy as well, is low frequency underwater sound or electromagnetic field effects on cetaceans and seals.

*Expected impacts*

- loss of habitat due to disturbance through noise emission from wave energy devices and from construction and maintenance vessels (or helicopters). The disturbance during the construction phase is expected to be only temporary, whereas disturbance from wave energy devices and maintenance vessels might have long-term effects. Although some disturbance of feeding patterns and social behaviour is possible, overall, these effects are likely to be insignificant; evidence from drilling activity for a geological survey at a offshore wind farm site in Sweden did not appear to disturb seal colonies 2 km away[108].

  For the Nysted/Rødsand Offshore Wind Farm it has been estimated, based on measurements from the Vindeby and Bockstigen offshore farms, that the submarine noise will at most be audible to marine mammals at a distance of up to 20 metres from the foundations[109].

  The noise impact can be expected to vary considerably between different wave energy device types.
- vibrations in the infra sound area that could affect the animals' sonar system, making it more difficult to retrieve food. (On the other hand, when fishery—with trawling equipment—is restricted in the vicinity of the wave power plants, feeding possibilities might improve.)
- potential influence from low-frequency sound emission and electromagnetic fields in cables. (However, calculations of magnetic fields from submarine cables dug down one metre under the seabed show that the magnetic field on the seabed above the cable will be smaller than the geomagnetic field[a]. Therefore, no impacts are expected if the cables are buried properly.)
- Finally, there may be some risks to marine mammals arising from impacts from the operation of some schemes (e.g. hitting the blades of a turbine). However,

[a] The geomagnetic field is the constant magnetic field surrounding the earth.

most mammals do avoid dangerous moving underwater objects (e.g. ship hulls and propellers).

*General conclusions*

- More studies are needed to evaluate the effect from noise and magnetic fields, and the visual impact on mammals.
- Before-After-Impact-Studies, including seismic surveys and monitoring of underwater noise levels, and studies on noise reception of sea mammals must be carried out where large projects are contemplated.
- When planning commercial wave energy projects, specific protection areas for sea mammals must be avoided[a], and duration and quantity of noise must be minimised during construction (especially at sensitive time periods) and operation. Submarine cables must be properly buried or shielded.

*Fish*

Only a few studies deal with the subject of the impact from offshore wind farms on fish, as the existing wind farms are erected in areas with no or very few fish. No studies have, to our knowledge, yet been performed in relation to wave power.

A Swedish study of the first offshore wind power project in the world outside Nogersund, Blekinge (Sweden), showed that there was no negative impact on fish from the 220 kW turbine—the fish population within 400 m from the turbine increased, however the fishermen caught less fish when the turbine was in operation, leading to a conflict of interest[110].

**Expected impacts**

- Some positive effects on fish stocks can be expected to the extent that wave energy farms prohibit fishing with trawling equipment while improving habitat as breeding and resting grounds for fishery species. The exclusion of fishing will in some cases lead to conflicts, expectedly short term, with the fishing industry, see Section E 3 on ‘

[a] For further information, please see Section E 3 on ‘
Conflicts of interest‘.

Conflicts of interest‘.

- Foundations tend to serve as artificial reefs within the local ecosystem. Evidence indicates that this reefing effect does not produce a significant increase in fish production but serves to aggregate fish more densely[111]. This is backed up by operational experience—studies at the Tunø Knob wind-farm have shown codfish numbers have increased around foundations[112].

*Potentially negative effects are*

- effects of noise emission and vibrations on fish life both in the construction phase and after installation, which may lead to loss of habitat. Maintenance vessels may also have a negative impact, but compared to the ‘usual’ impact from fishing boats and other ships this can be considered as a minor impact.
- Changes in sedimentation and turbidity[a] of water may impact on fish and fish larvae. This is predominantly a temporary effect during construction. Evidence from fish surveys before and after construction for Danish offshore wind farms have not shown any reduction in fish species[112]. However, these effects may be more important in fish breeding areas or shallow areas, which juvenile fish tend to inhabit and some care may be needed in these areas, such as avoiding breeding seasons. For cables, some guide to the potential level of impact can be taken from the laying of natural gas pipelines. Laying of such pipelines causes a disturbance corridor of around 5 metres[113], with effects from suspended sediment levels affecting organisms of to 50 metres away. However, this is regarded as a temporary impact as the area rapidly re-colonises following completion. (It should be borne in mind that at some locations the effect of naturally occurring storm events may routinely outweigh these temporary impacts).
- electric and magnetic fields around the cables may influence fish and fish breeding, but no research results have yet been found published on these issues, although seabed cables have existed during the last 80 years. This may be seen as an indication of the fact that sea cables have only little or no impact on marine life, but information on the impacts, if measurable, from the many existing seabed cables can be gained from monitoring studies. The cables connecting wave energy converters, substations and the grid will tend to be buried to avoid potential damage, for example from anchors or fishing activity.

*General conclusions*

As the effect of noise, vibrations and magnetic fields on fish is relatively unknown, studies and surveys may be needed before, during and after construction. Projects should seek to minimise the effect of structures and cabling on existing stocks, their food sources and spawning activity, e.g. by shielding and burying cables appropriately in order to minimise electro-magnetic impacts on fish.

### Seabed and benthos

In general the disturbance of seabed, and thereby of benthic communities[b], will primarily take place during the construction (and dismantling) phase, but for most types of wave and tidal energy converters this will be limited in scope and period, e.g. deployment of

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[a] Turbidity is the degree of cloudiness or opacity of the seawater due to disturbed sediment.

[b] benthic communities: communities living on the sea bed, also known as ‘Benthos’. (‘Benthos’ originally means ‘seabed’ in Greek)

mooring systems, sinking or submersion of bottom-mounted plant if used, cable laying etc. This means that for most devices the potential impacts seem likely to be significantly less than for an offshore wind power farm of similar size.

All offshore construction activity will affect the transparency of water and the local bottom sediment. Drilling, trenching, pile-driving or dredging operations during foundation placement and cable-laying will lead to increased loading of suspended solids, which can affect benthic organisms. Similarly, the reinstatement of the trench around the cable or foundation base results in burial of existing habitats for a few metres either side of the structure. Benthic organisms are particularly vulnerable, though impacts are small.

*Expected impacts*

- loss of habitat and individuals due to construction activities. However, the disturbance of the seabed from sedimentation during the construction phase only seems to be temporary.
- footprint of cables, maintenance vessels, electromagnetic radiation and noise may reduce abundance and diversity of seabed life somewhat.
- bottom-mounted structures tend to act as natural reefs and introduce fauna, however these artificial hard substrates may cause some changes to the biotope structure with consequences regarding benthos and subsequent food chain that are as yet unclear.
- the absence of fishing and shipping (except for maintenance vessels) will have a positive local effect on fauna and seabed

*General conclusions*

The quality and quantity of possible impacts on seabed and benthos are not well known, calling for monitoring of specific project sites, both as part of the EIA and as generic studies. When designing large wave power projects, maintaining or improving habitat for local species of importance should be considered.

In general, the subject of cables needs to be further investigated in relation to impacts due to physical size and electromagnetism, and the area around the cables may be included in the fishery exclusion zone. Existing seabed cables in position for some years between mainland and islands may serve as useful models.

### Hydrography and coastal processes

Wave energy converters may have a variety of effects on the wave climate, patterns of vertical mixing, tidal propagation and residual drift currents. The most pronounced effect is likely to be on the wave regime. A decrease in incident wave energy could influence the nature of the shore and shallow sub-tidal area and the communities of plants and animals they support.

Impacts on sea currents and hydrography may occur for large wave energy projects, where a significant portion of the wave energy is captured or reflected. Obviously, this impact is largely dependent of the area covered and draught of the wave energy converters and distance to shore. Fixed structures such as the OSPREY are more likely to alter the wave climate than floating devices.

Impacts may be positive as well as negative, depending on project lay-out and location.

Positive impacts may occur in the form of reduced coastal erosion levels from wave energy capture and reflections from large-scale wave energy schemes. Such impacts are however expected to be localised.

### *Expected impacts*

- permanent changes in sediment structure may rise from changed water flow behind the wave energy converter, as it captures or reflects significant amounts of the wave energy
- changes to the wave regime along the shoreline could change the composition of the shoreline. Detailed modelling may be necessary depending on size of project, proximity to shore, shallowness of water and general sensitivity of local hydrography or sea currents.

### *General conclusions*

For some wave energy schemes potentially significant impacts on sea currents can be expected. Hydrological modelling and before-after studies are therefore likely to be included in the EIA for large projects.

## Birds

Whereas birds are one of the most significant issues within wind power this is less likely to be so for wave power. As wave energy converters generally do not elevate much above sea level, and have no rotors moving in the air, actual and publicly perceived impacts are expected to be rather low. It is advisable to avoid placing large wave energy projects in the vicinity of important bird areas[a]. As important bird areas are often located in shallow water with low wave heights, many of these areas will not be of interest for the development of wave energy.

### *Potential impacts*

- ousting birds from their traditional feeding/roosting grounds due to physical changes of habitat

The possible impacts will depend on the following parameters—

- construction work: the impacts on birds during the construction phase are only expected to be temporary and limited. However, the choice and timing of construction method may be of importance as high noise levels can potentially disturb both breeding and staging birds.
- feeding conditions: as the sub-surface part of the wave energy converter may prove to be a good living environment for small fish, mussels etc, this tends to attract bird colonies, feeding from this new fauna. If fishing, as expected, is to be forbidden within the wave power farms, the farm area may serve as feeding ground for birds, thereby improving feeding conditions and minimizing the ousting of birds from their traditional feeding/roosting grounds. It is for the same reason important that the wave energy device is designed in a way where no physical damage to animals will occur. It is also likely that birds may use converters for roosting and preening if the structural configuration allows this.

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[a] See Section E 3 on ‘
Conflicts of interest‘.

- noise/movements during operation: Noise may influence the impact on birds through ousting from the vicinity of the converter.

### E 5.2.4 Effects from accidents

The effects on the environment due to accidents are to be taken seriously, as for instance a collision with an oil tanker may in worst-case cause severe damage regarding fauna and flora, water quality, coastline etc. It should however also be noted that it some cases wave and tidal energy farms may prevent accidents from happening, if the offshore renewable energy converters are located in waters where the collision risk is already high, e.g. due to reefs. Properly marked wave energy converters will then more clearly warn ships against the risk of collision than was the case before the devices were installed.

Collision risk analyses will be carried out as part of the EIA, but so far it seems to be quite difficult to develop reliable risk models—as can be expected, taking the lack of experience with collisions of this kind into consideration[a]. Moreover, the effects of potential oil pollution for example birds have not been estimated in the Danish EIAs for offshore wind farms.

#### Expected impacts

Accidental impacts on the environment may originate from collisions between ships (e.g. maintenance vessel) or, theoretically, a low-flying aircraft (e.g. maintenance helicopter) and structure or substation, or from damage to submarine cable caused by anchoring, colliding or sinking ship, by trawling equipment or during construction[b].

The effect of such accidents may be a pollution of the environment caused by substances from the offshore installation (converter/cable) or substances from the colliding ship or aircraft. The exact consequences of a collision are dependent on many parameters, such as type of ship/helicopter, collision angle, speed of colliding vehicle and the type of wave energy converter.

If larger ships, such as oil tankers, collide with a wave energy converter (WEC), in many cases it is to be expected that only the WEC will be seriously damaged. In other words, a ship collision does not necessarily mean leakage of huge amounts of harmful substances.

Moreover, if a leakage of polluting substance is actually the result of the collision, the degree of impact on the environment will vary in relation to weather (temperature, wind speed) and of course the nature of the polluting substances.

The most likely polluting substance in these cases is thought to be oil—

- oil spillage deriving from the WEC is not an issue of major concern, as the WECs will often contain only small amounts of oil, if any.

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[a] For instance, the risk analyses regarding the Nysted/Rødsand and Horns Rev offshore wind projects were not immediately accepted by the developers, as the figures were based on the assumption that a ship entering the farm area would unavoidably cause a collision. A revised risk analysis has therefore been carried out for the two projects.

[b] During the construction of the Middelgrunden Offshore Wind Farm, the submarine cables were damaged three times, however without environmental impacts as the cables did not contain oil as an insulating medium.

- the diesel oil inside a potential substation is neither regarded as being a major source of risk, as the oil amount is limited and the diesel oil will relatively easily evaporate. However, to minimise risks of leakage, substations should be constructed with double walls.
- damage to submarine cables may cause a release of mineral oil isolating the cable, if this type of cable is chosen. In a worst-case-scenario at Horns Rev[114], the maximum oil leakage amount would be 4,200 l. Although this is a relatively small amount, and although the risk of such accidents has been calculated to be very low (one every 32,000 years), mitigation measures such as protection of the cable (by trenching if possible) and prohibition against fishing within the area of the farm and around the cable are therefore highly recommended. Moreover, the pressure inside the cable is to be monitored continuously in order to take immediate action in case of leakage.
- the most critical impact on environment regarding oil pollution would be caused by oil from ships. Diesel oil from fishing boats and maintenance vessels is not regarded as serious as oil from larger ships, because diesel oil will evaporate to a relatively high degree compared to bunker oil. According to [114] the most critical event would be the pollution resulting from a collision with an oil tanker, as this collision could result in the leakage of considerable amounts of light oil or bunker oil. The bunker oil is the more destructive due to its low evaporation rate. The consequences of such a collision call for development of special emergency procedures with a short reaction time for each large offshore farm.

#### General conclusions

As the consequences of collisions may be very serious, mitigating measures are called for in order to minimise collision risks, such as: proper marking of farm/WECs, protection of cables and development of special emergency procedures. However, it should be noted that the collision frequency is relatively low and that a collision would not necessarily result in severe environmental damage[a].

### E 5.2.5 Visual effect

The visual impact will depend on, among other things—

- the distance offshore
- the height of the device above sea level
- the weather conditions, and
- the height above sea level of the viewpoint

Wave energy converters are not expected to have a visual impact comparable to wind turbines due to their limited height. Nevertheless, coastal areas are often considered important for recreational purposes, making visual intrusion a potentially high-profile political issue, especially for on-shore and near-shore wave energy schemes.

In the UK, for example, over a third of the coastline is designated for its scenic or natural beauty, and as one in three people in the UK lives within a distance of 10 km from the coastline[115], and as public opposition and concerns are generally related to visual effects[116], the visual aspects are of very high importance.

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[a] For Horns Rev, the revised calculations resulted in a ship collision risk of 1 collision every 641 years.

In a UK/Irish Guide to Best Practice in Seascape Assessment[117] a distance of 15 km is suggested as the maximum limit of visual significance along the coast in relation to offshore wind turbines.

Given the limited number of wave energy converters currently deployed, it is hard to quantify the magnitude of visual impacts from wave and tidal energy devices, but it is expected to be very location dependent and only becoming an issue of increasing importance when devices are deployed in larger numbers.

The visibility from shore will also depend on the requirements regarding marking lights and painting—marking lights will be mandatory in order to avoid ship collision. Therefore marking requirements (such as those of IALA[118]) and their effects regarding visual impacts should be known as early as possible in the planning phase. For shore-based devices the siting and design is of utmost importance. A good example of how this can be done is given by the LIMPET project, which is practically invisible until one is relatively close to the device.

As the visual impact is a matter of the viewer's taste, it must be expected that there will always be some public resistance, especially for near-coast projects, but even the visual impact from offshore projects invisible from the shore may experience resistance when intrusively visible from ships, boats and ferry lines. An open and careful planning process with detailed visualisations and intensive dialogue with the local public may result in less public resistance.

### Experience from wind power visualizations

In the case of wind power, Swedish investigations indicate that visualizations can cause problems with acceptance because pictures do not present the true visual impact of wind turbines on a landscape[116]. Neither do they present their functional contribution. People construe the depicted wind turbines not as a source of renewable energy but as a new element in the landscape that will diminish its scenic value. On the other hand, visualizations undeniably have some value in accelerating social adjustment by providing an idea of what planned developments will look like. Inevitably, however, these pictures never truly depict the experience of an active wind turbine, although they are a great aid.

The benefits of using visualizations are connected to a person's professional training and their previous experience with wind turbines. If people can understand the rationale behind certain designs or if they can recognize some benefits in relation to other wave power locations, visualisations can work well to create a positive dialogue. In this context, it is important to understand that a 'picture' can both suppress the benefits of wave energy devices and camouflage some of the visual effects. Hence, visualizations must always be accompanied by detailed explanations. Furthermore, wave energy converters are not only experienced by seeing them, but also through hearing and feeling their presence, and the use of 'virtual reality' should be useful in this regard.

### General conclusions

The general conclusion is that visual impact of energy plants has a very high profile in the public awareness, and that this high awareness might apply for wave energy projects as well—especially shore-based and near-shore plants. At the current level of commercial impact from wave energy, visual impacts do not appear to possess a significant barrier, but the issue might pose a barrier for specific locations, especially when large-scale future wave power farms are envisaged. The experience with offshore wind power clearly indicates that there is strong public concern over this issue, even concerning offshore wind power farms, which are barely visible to the naked eye from the shore.

Experience from existing offshore wind farms indicates that the following recommendations of relevance for wave power can lead to reduced public resistance—

- The devices should in general be placed as far away from the coast as possible, and in particular proximity to recreational areas and/or areas of great scenic value should be avoided
- the planning process must be very open and careful, and if the farm is visible from land, the effect on the environment and economy (e.g. tourism) of the coastal area must be assessed
- farm formation, number and size of wave energy converters and cumulative effects should be thoroughly and openly analysed and discussed before a decision is taken
- early local involvement in the planning phase is essential and community involvement in ownership of the wave farm will be beneficial when the technology has been proven.

### E 5.2.6 Noise and vibration effects

Noise from wave energy converters arises from e.g. the movement of mechanical parts (aerodynamic noise), and the transmission of power and momentum in the conversion system (mechanical noise from gearboxes). Furthermore, mechanical noise may arise from some control equipment.

The degree of noise effects is primarily dependent upon the level and character of the noise emitted, the distance from the plants to potential sensitive receivers, wind directions and background noise levels. For wave energy converters the noise emission levels can in general be expected to increase in parallel with the background noise level (breaking waves). Nevertheless, noise may be a significant issue, especially for shore-based devices.

#### Airborne noise

It is expected that airborne noise could have the following impacts—

- ousting of birds
- loss of habitat for marine mammals
- decrease in public acceptance if noise from the wave energy converter is audible to humans from the shore

Concerning noise it appears that wind power has received a reputation for being noisy, which, together with the fact that noise propagates much easier over the sea than over land, is reflected in the public attitude towards wind power, including offshore wind. This reputation is somewhat unjustified, as current wind turbines are not very noisy. The reputation therefore seems to be a public perception based on experiences with early turbines, which could be noisy. The lesson to be learned for wave power therefore appears to be that noise effects are to be handled carefully for early prototypes as the public perception of the noise impact may not change significantly when mature technologies with lowered noise emissions are available.

During construction, airborne noise from construction work (vessels, blasting etc.) is expected to affect birds and marine mammals (ousting), but as the effects are of limited duration, the impacts are expected only to be temporary. However, sensitive time periods like breeding or nursery periods should be avoided if the construction site is placed near important biological areas—this may be in conflict with the intentions of the developers to establish wave power plants when stormy weather is least probable.

#### Underwater noise and vibrations

During construction, underwater noise may have a detrimental effect on marine mammals, fish and benthos. However, the effect is temporary, but sensitive time periods should be avoided—in the case of fish larvae, construction work at sensitive periods may result in a very high fish mortality rate.

During operation, noise from wave energy converters can be transmitted into the water in two ways: the noise either enters the water via the air as airborne sound, or the noise is transmitted into the water as structural noise. The frequency and level of underwater noise is thereby determined to a certain degree by the way the wave energy converter is constructed.

Underwater noise from wave energy converters must of course exceed the level of underwater background noise (ambient noise, especially from ships) in order to have any impacts on marine fauna.

The effects on marine life from vibrations of the turbines are rather unknown. Noise frequencies and magnitudes are likely to show considerable variations among different technologies, but noise measurement data on wave energy converters are currently not publicly available.

Only measurements and post construction impact studies will reveal if underwater noise will really affect marine mammals.

#### General conclusions

The general conclusion is that for *wind* turbines airborne noise impact has a high profile where public awareness is concerned, but that this is derived from previous generations of wind turbines and not to the technical realities of today. This perception may however become associated with *wave* energy converters also, especially if the early generation plants have significant noise impacts. Demonstrating that noise from wave energy converters is insignificant is therefore important for the future of wave power. It must be remembered that noise may travel large distances over open water surfaces.

Regarding underwater noise and vibrations, the effects on marine animals, fish and benthos need assessment in generic studies and in a site-specific manner, because the extent of these effects is relatively unknown. The experience gained from small pilot projects will be important in this regard.

### E 5.2.7 Decommissioning

The issue of decommissioning is a potentially great problem for offshore developments.

National (see for instance [104]) and international laws of the sea require total removal of offshore structures (installed after February 1999) when they reach the end of their operating lifetimes. Partial removal will not be allowed for such installations.

Not only will the requirements regarding decommissioning increase costs, the removal of offshore installations will also cause marine disturbance, and consequently decommissioning work should not take place during sensitive periods in order to minimize impacts on environment due to e.g. noise, vibrations, and sediment disturbance.

However, the effects are expected to be temporary, as the environment will return to its pre-development status with time.

### E 5.2.8 Emissions

Unlike conventional fossil fuel technologies, wave energy produces no greenhouse gases or other atmospheric pollutants whilst generating electricity. However, emissions do arise from other stages in its life cycle (i.e. during the chain of processes required to manufacture, transport, construct and install the wave energy plant and transmission equipment).

For wave energy technologies, the typical stages of the life cycle are—

- Resource extraction
- Resource transportation
- Materials processing
- Component manufacture
- Component transportation
- Plant construction
- Plant operation
- Decommissioning
- Product disposal

Ideally, each of the life cycle stages listed above should be considered, in order to evaluate the total emissions from the life cycle of the technology. However, an exact analysis of every stage is neither possible nor necessary. The emissions of most of the major air pollutants (particularly carbon dioxide, sulphur dioxide, oxides of nitrogen and particulates) are expected to be broadly proportional to energy use. Therefore, the most important life cycle stages for atmospheric emissions are those with the highest energy use. Detailed studies of the main renewable energy technologies have been carried out using this approach within the ExternE study (e.g. [119]) and elsewhere in the literature. This has shown that, for most renewables—

- The emissions released during the manufacture of the materials are the most important;
- Energy use in all of the transportation stages is likely to be negligible; energy use in freight transport is typically only 1 mJ/t/km for rail[120] and in road transport is typically 3 mJ/t/km;
- Energy use in the extraction of the primary materials used in construction (e.g. limestone and aggregates) or in components (e.g. iron ore and copper ore) is typically an order of magnitude lower than energy use in their primary processing;
- Energy use in the construction, decommissioning and disposal processes is also likely to be at least an order of magnitude lower than for material manufacturing.

In assessing the energy use and emissions for technologies, data relating to realistic sites and technologies should be used, in recognition of the fact that these factors are important in determining the magnitude of some emissions. Emissions associated with the manufacture of materials and components are dependent (to some extent) on industrial practices, the generation mix and pollution control regime in the country of manufacture.

The above evaluation has been carried out for a range of technologies[121], [122], and the results for some renewables and wave energy are shown in Table E-4, where the resulting emissions from typical examples of offshore renewable energy technologies are compared with the emissions arising from the average mix of generating technologies in the UK[123].

It is evident that wave energy (and the other renewables) can offer significant reductions in the omissions of gaseous pollutants when compared to fossil-fuel based[a].

Although power produced in the UK 2002 involves less greenhouse emissions, especially because there has been a major shift from coal to gas powered generation since the early 1990 s[124], the result, that wave energy produced power emissions are negligible compared to the UK mix, will still be valid.

| Pollutant | Tidal Current (g/kWh) | Wave (g/kWh) | Wind (g/kWh) | Average UK Mix (g/kWh) (1993) |
|---|---|---|---|---|
| $CO_2$ | 12 | 14 - 22 | 12 | 654 |
| $SO_2$ | 0.08 | 0.12 – 0.19 | 0.09 | 7.8 |
| $NO_x$ | 0.03 | .05 - .08 | 0.03 | 2.2 |

**Table E-4 Life-Cycle Emissions from Offshore Renewables**

### General conclusions

The general conclusion is therefore that although emissions arise from different stages of a wave energy device's life cycle, this amount is negligible and more than outweighed by the saved emissions from power production, stressing the fact that wave energy is an environment friendly energy (see Section E 5.4 below).

## E 5.3 Impacts from environment on wave energy converters

The potential impact from environment on wave energy schemes will be highly dependent on the type of WEC and its location—onshore, near-shore or offshore.

Below the most important expected potential impacts are presented, based on responses from Network members to a questionnaire that was sent out concerning this topic (see **Appendix 4**).

### Sensitivity to sea currents

For offshore systems currents should not be a problem, providing the survivability is good, which of course is an essential precondition. Shoreline devices may be sensitive to orthogonal currents which break up wave patterns.

[a] T.W Thorpe is the true author of this whole section on 'Emissions'.

### Sensitivity to wind

This subject should not become a barrier, as aerodynamic behaviour of floating structures can be considered during design. However the subject of wind needs consideration at all stages where site investigation, construction operation, maintenance, human access and risk analysis is concerned.

### Sensitivity to marine growth

The subject of marine growth is an important area for research, both regarding marine growth inside the turbines and regarding marine growth in general. The systems will have to be treated and maintained in order to avoid the expected reduced efficiency over time.

Evasion technologies, which are available e.g. within the ship industry, must be neutral to environment (marine fauna and flora, quality of water) according to the International Convention on the Control of Harmful Anti-Fouling Systems, developed by IMO's (International Maritime Organization's) Marine Environment Committee[125].

As offshore oil and gas installations provide attachment surfaces for a variety of algae and invertebrates, so wave energy converters would be colonised by fouling organisms. The species recruited to these sites would depend on the species communities within the vicinity of the device, distance offshore, water depth and clarity, prevailing weather conditions and position relative to coastal currents and the speed of those currents[126]. There would be a seasonal factor involved in the build up of this community with the main build up of fouling extending from about April to November.

It is inevitable that anti-fouling measures would be necessary where, for instance, attached organisms cause changes in corrosion and fatigue behaviour, hinder inspection and maintenance, etc. Fouling prevention measures specific to wave energy converters have yet to be developed, but could include the use of anti-fouling paints or direct injection of biocides. Fouling of seawater conduits at coastal power stations has been controlled by injection or electrolytic generation of chlorine. Due to the effects of dilution, it is not clear if the use of this measure at a more open sea location might be environmentally harmful. Certainly chronic impacts may result if the chlorine was allowed to react to form chlorinated organics which tend to bio accumulate and persist in the environment, although this would appear to be unlikely in open waters. There are numerous options for the removal of marine fouling, each of which has its relative merits. None of these pose any significant environmental problem although some (e.g. high-pressure jets) could be hazardous to the user.

### Sensitivity to material deposits (soil, debris)

As intrusion of material deposits between moving parts, into turbines (air- or water), flow channels etc. might cause malfunction/destruction of a device, the sensitivity of a WEC to material deposits is an important issue.

For instance, shoreline devices could be vulnerable to floating seaweed, jellyfish, trash and may be partly blocked by storm movement of deposits. Offshore and near shore devices are expected to be less affected, however this is to a high degree depending on the individual design.

For example concerning the floating offshore WEC, Wave Dragon, the device may be expected to collect considerable amounts of garbage in the reservoir with its wide gap between two wave reflectors. Although cleaning technologies are available from hydro power plants, special precautions need to be taken in order to avoid reduced efficiency e.g. if access to turbines is blocked by debris (or, in theory: marine mammals) in the grid trash rack serving as protection in front of the turbines.

### Risk of corrosion problems

By using standard offshore technology, risks and effects can be calculated, and if the devices are built according to offshore norms corrosion problems can be avoided. Corrosion problems are not regarded as a technical barrier as problems can be solved—prevention measures will simply add to costs.

### General conclusions

It is not expected that impact from environment on wave energy devices will constitute a barrier for the large-scale development of wave energy, providing survivability aspects have been solved. However, as the experience is limited, information regarding this subject gained from studies of individual demonstration projects in the near future should be collated and made available for the wave energy community. It must however be remember that this type of experience will to a very high degree be both location and device specific.

## E 5.4 Environmental benefits of wave energy

The most important environmental benefits of wave energy are similar to other renewables—

- the avoidance of pollutant gasses, and
- the preservations of raw materials like gas and coal

Secondary benefits of wave energy such as lowered risk of pollution due to accidents with e.g. oil tankers—because less oil needs to be transported—have not been included and will not be important before the use of wave energy in particular (and renewable energy sources in general) has reached higher levels than today[a],[127].

Environmental benefits should be clearly stated in the Environmental Impact Assessment and the emphasizing of these *positive* environmental impacts is crucial in relation to the public and political acceptance of wave energy.

### E 5.4.1 Avoided emissions

The benefits to the environment from using wave power are mainly by reducing atmospheric pollution. As well as a significant reduction in $CO_2$, other pollutants are also reduced; $SO_2$, $NO_X$, CO, Methane and Particulates.

In Denmark it is estimated that for each produced kWh wind power, the following emissions are avoided from an ordinary coal fired power plant—

$CO_2$ 810 g/kWh

[a] The share total EU energy consumption provided by renewables was around 6% in 1999, and the renewable share of EU electricity consumption 13%. The EU indicative targets for 2010 are 12% respectively 22.1%

| | |
|---|---|
| $SO_2$ | 1.5 g/kWh |
| $NO_X$ | 1.4 g/kWh |

**Table E-5 Avoided emissions from wind power plant**

The actual saving in emissions depends to a large extent on the mix of types of power generation for an individual country or region and the type of plant replaced. It is apparent that any calculations on emissions savings must look realistically at the type of power generation likely to be replaced, and not just assume that the most polluting will be shut down[99].

For the UK, evaluations regarding avoided emissions have been carried out for a range of technologies[121],[122] and the results for some renewables and wave energy are shown in Figure E-5-Figure E-7 below.

In order to compare with the range of possible fossil fuel stations, three different fossil fuel technologies were chosen—

- Combined cycle gas turbines (CCGT).
- Modern coal plant (i.e. pulverised fuel with flue gas desulphurisation—PF+FGD).
- The UK generating mix 1993[122].

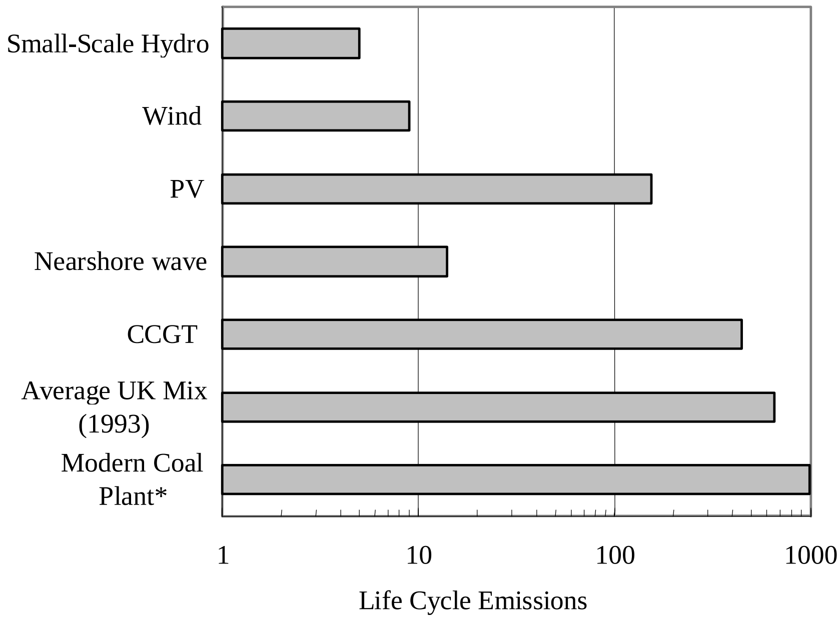


**Figure E-5 Comparison of Life Cycle Emissions of $CO_2$**

Key. * = coal plant with flue gas desulphurisation and low $NO_x$ burners.

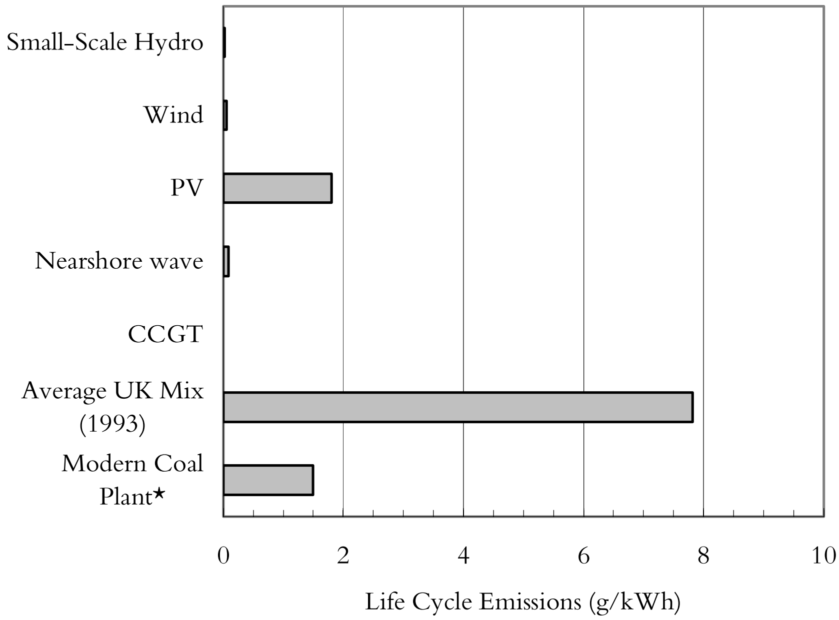


**Figure E-6 Comparison of Life Cycle Emissions of $SO_2$**

Key. * = coal plant with flue gas desulphurisation and low $NO_x$ burners.

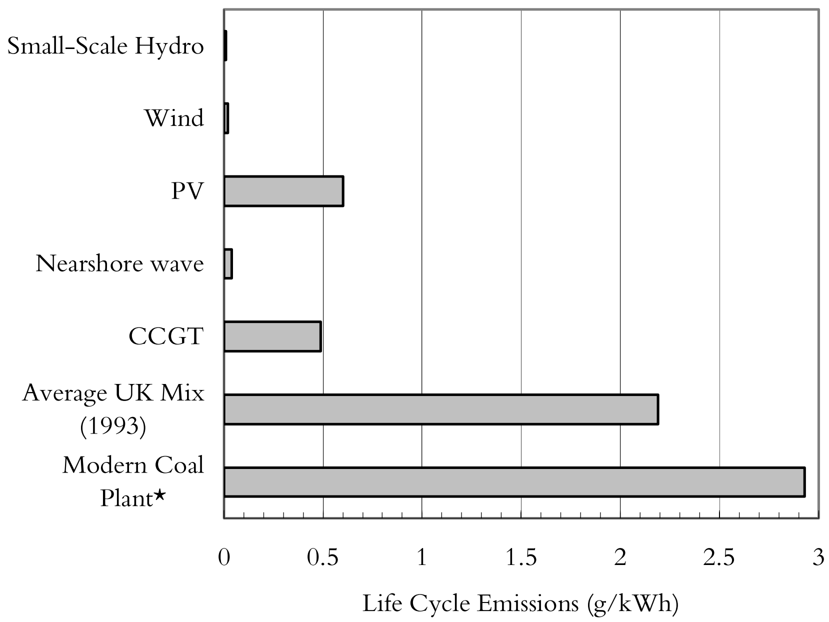


**Figure E-7 Comparison of Life Cycle Emissions of $NO_X$**

Key. * = coal plant with flue gas desulphurisation and low $NO_x$ burners.

It can clearly be seen that wave energy (and other renewables) can offer significant reductions in the omissions of gaseous pollutants when compared to fossil-fuel based generation. The only exception to this is for CCGT, whose emissions of $SO_2$ are effectively zero.

### General conclusions

As Wave Energy is a renewable energy that produces no greenhouse gases or other atmospheric pollutants while generating electricity, environmental benefits will arise from the avoidance of pollutant gasses and the preservations of raw materials like gas and coal.

The actual saving in emissions and preservations of raw materials will of course depend on the ability of wave energy to penetrate the energy market, and on the type of energy that is replaced by wave energy.

## E 5.5 General conclusions

In summary, the environmental burdens of offshore energy schemes are likely to be low, provided developers show sensitivities with appropriate site selection and planning authorities control deployment in sensitive locations. Although the potential impact appears to be low, the lack of operational schemes means that further research into likely practicable impacts and mitigation strategies might be required.

The following conclusions and recommendations concerning future RTD-activities in most cases imply the construction of large-scale wave energy projects, as monitoring programs and Before-After-Impact-Studies carried out at specific sites often represent the only possible way to achieve exact knowledge or at least an improved understanding of the impacts from wave power, particularly on the environment.

However, the lessons learned within offshore wind power in the coming years will probably yield significant new insights, especially concerning the impacts on marine environment, social acceptance management and conflicts of interest, which can provide more guidance for the wave energy environment.

As the assessment of environmental impacts associated with wave power is made extremely difficult due to the lack of reference cases and impact studies, it is important that relevant information is systematically collected and disseminated early in the market penetration phase, in order to allow the non-important factors to be ruled out. It is therefore strongly recommended that a European working group is established securing effective transfer of practical experiences gained, when a representative number of devices have been installed.

### E 5.5.1 Identification of problem areas

Potentially negative environmental impacts

**Mammals**

- loss of habitat due to
    - noise emissions
    - accidents
    - food chain changes
    - electromagnetic fields and vibrations, e.g. affecting the sonar system

**Fish**

- impacts on fish and fish larvae from sedimentation/turbidity, underwater noise, vibrations and electromagnetic fields
- effects from unnatural reef (if any)

**Fauna and seabed**

- changes in sediment structure
- direct loss from foundation and cable footprints
- impact on biotope from foundations/hard substrates and electromagnetic fields

**Coastline**

- impact on coastline due to current/sediment changes arising impacts on local currents/waves

**Visual impact**

- man-made intrusions in an otherwise structureless seascape, or—for onshore converters—in the coastal landscape.

**Noise impact**

- noise impacts from shore-based and near shore devices
- impact on birds, sea mammals and fish from underwater noise

**Leakages**

- Primarily associated with risk of ship collisions

### E 5.5.2 Recommendations for RTD programmes

In general, it will be very important to collect information from different studies in order to cover the whole area, as different 'narrow' site specific studies are carried out at the different projects: Baseline and impact studies from individual projects are to be disseminated and jointly appraised. Conclusions from local projects should be translated and all relevant existing material placed on a publicly accessible web-site

**Environmental impacts**

*Mammals*

- More studies are needed to evaluate the effect from noise and magnetic fields, and the visual impact on mammals. Before-After-Impact-Studies, including seismic surveys and monitoring of underwater noise levels, and generic studies on noise reception of sea mammals are called for.

*Fish*

- As the effect of noise, vibrations and magnetic fields on fish is relatively unknown, studies and surveys must be carried out before, during and after construction: Site-specific and species-specific monitoring studies are necessary in order to investigate the effect on fish, e.g. investigate if marine structures may indeed serve as natural reefs, as indicated from previous studies of offshore wind power, the consequences thereof, and investigate the consequences on fish population/fishing possibilities when fishing (with net) is restricted within and in the vicinity of the wave energy converter(s).

*Seabed*

- The quality and quantity of possible impacts on seabed and benthos is not well known, calling for surveys of specific project sites, both as part of the EIA and as generic studies. How will the hard substrates and cable footprints/electromagnetic fields influence the base-line biotope? Investigations should seek to enhance habitat, e.g. by use of appropriate foundation design where seabed mounted devices are concerned.

*Visual impact*

- Research of computer simulation possibilities to test different farm layouts seen from different angles, levels and at different weather conditions in order to make

visualisations comparable to real-life conditions, is recommended for large-scale shore based and near-shore projects. Buoys and lanterns might be expected to be the most significant visual impact.
- Clear definitions of marking requirements

### E 5.5.3 General recommendations

It is very important that mitigation strategies are developed for each wave energy project in order to avoid/minimise negative impacts on environment.

**Fish, birds and mammals**
- Identification and avoidance of sensitive areas
  - Avoidance of site works during sensitive time periods
  - Minimisation of noise levels during construction, operation and dismantling
  - Minimise effect of structures and cabling on fish stocks

**Seabed, benthos**
- Minimize artificially induced sedimentations and turbidity

**Hydrography, currents and coastal processes**
- Analysis of local impacts on currents and wave climate. Potentially positive and negative effects on coastal erosion rates, if any, should also be carefully modelled in the pre-planning phase

**Water quality**
- Avoid use of pollutant chemicals when wave energy devices are protected against marine environment

**Noise**
- Secure low noise levels

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