DanWEC study
Port of Hanstholm

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Disclaimer:
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Introduction and scope
This publication concerns the establishment of Danish Wave Energy Center “DanWEC” as the Danish test site for Wave Power Converters at the Port of Hanstholm figure 1. The local impact and possible transnational impact related to the North Sea Region in terms of jobs created related to the development of Wave Energy Converters is described.

Some of the benefits from research and development of marine renewables in the local community will be presented such as the near term opportunities for locale service companies, maritime handling services and port facilities that can support the typical needs of the WEC companies testing in the area.

A review of the existing plans for extending the Port of Hanstholm is given and it includes visions for maintaining and developing activities around off-shore renewables.

Finally elements of a hypothetical production facility for wave energy systems at the Port of Hanstholm is described in terms of allocation of space for fabrication, deployment and O&M in relation to support a large wave energy power plant in the North Sea.

Figure 1 Map showing the Port of Hanstholm year 2015 [w1]
Opportunities and transnational impact of the DANWEC test site

DanWEC was established as a not-for-profit corporate fond by the port of Hanstholm, Thisted Municipality, Thy Erhvervsforum (Local Business Organization) and Aalborg University in 2010 in connection with the testing of the wave energy converter Wavestar shown on figure 2. WaveStar was tested in the period 2009–2013 and also the converter DexaWave was tested further offshore during the period 2010-2011.

In 2012 DanWEC applied for GreenLab funding of 1.5M€ under the Danish Energy Agency to prepare DanWEC for additional need for WEC test activities in Denmark. The development of Danish Wave Energy Converters slowly approached Technology Level 4, (see annex 1) that would justify real sea testing of smaller prototypes. The development history of the major Danish Wave energy projects are indicated in figure 3. Projections are made under the assumption that funding and co-finance can be obtained.

The basic structure of DanWEC as a “Greenlab” was prepared based on interviews with WEC developers and companies concerning their needs with regard to marine services test and data support [2].
DanWEC
DanWEC at the Port of Hanstholm has its distinctive nature given characteristics that are unique compared to other test centres worldwide. However typical marine services that can be provided are common to other Ports in the North Sea region. Thus experience from the development of a test site at one location can be used at another location with transnational impact.

The off-shore wave energy resource at DanWEC, Hanstholm, is 6kW/m, which is lower than EMEC [3] having 20kW/m. DanWEC is thus suited to for the testing of smaller prototypes compared to EMEC. However it is still a severe challenge to test a wave energy converter off-shore at DanWEC with up to 12 meter high waves. DanWEC can therefore in addition offer test facilities in the sheltered site at Nissum Bredning close to Hanstholm suited for quarter scale prototype tests prior to testing in Hanstholm.

Location characteristics
Hanstholm is a small city with a relatively short distance (1½ hour drive) to (Aalborg) Airport. Offshore test locations at 25-30 meter depth are 2-4 km from the Port of Hanstholm. For researchers DanWEC can provide a list of houses for periodic rent.

Legal support and maritime advice
- Support to easy obtainable periodic permits for testing periods from months to more years
- Support to address insurance and certification bodies
- Health, safety and environmental management advice and counselling

Test site Design data (provided before testing)
- Test location at water depths from 15-25 m
- Mooring specifications
- Wave conditions
  - Resource power level annual average: 5-6kW/m
  - Dominating Significant wave heights: 0,5m- 6m
  - Max heights: 12m
- Seabed characteristics and general bathymetry of the test site berths
Data and Data acquisition (during testing)
DanWEC can offer online wave and current data as reference for the measured energy production.

Seabed characteristics: General bathymetry of the test site berths
- Comprehensive near real time time-series of hindcast weather (wind, temp. etc.), water, wave and current (height, direction, frequency etc.) Data, from wave buoys and other offshore instrumentation.
- Scatter diagram

Daily Weather forecasts
- Independent validation and verification of testing data by e.g. AAU or third party
- WiFi and fiber data acquisition and transmission to server with back-up

Hanstholm Port Facilities (deployment, operation and maintenance)
- Day-to-day marine operational support and GPS surveillance
- Large designated power and fiber supplied wharf area for assembling, maintenance, and repairs. incl. e.g. placement of mobile container-workshop.
- Docks and Wharves area with berths for deployment and mooring of WEC
- Availability to storage/ware house facility

Vessel support:
- Experienced WEC deployment vessels at order
- Safe seagoing transit/transport and inspection vessels

Availability to 24/7 marine specialist
- Technical, craftsman, workshop and engineering support.
- Dry dock
- Welding, assembling, coating
- Fiberglass workshop
- Electronics and electrical support.

Dive support available

DanWEC services at NBTS
Nissum Bredning suited for downscaled prototype tests prior to testing in Hanstholm can offer

Wave conditions Hs : 0.1 meter – to 1.0 meter
- 200 meter shore connected pier and platform with 2 meter water depth
- Floating platform with outboard engine and Small Rubber dinghy
- 350 kg and 600 kg Crane at platform
- Secured/locked weather stable container-workshop at platform
- Acclimated electronics cabinet and power connection

Estimated charges of the test site services
The charges of the services provided to the developers testing at DanWEC at Hanstholm have been estimated as shown in table below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Legal support and maritime advice</td>
<td>50.000 DKK</td>
</tr>
<tr>
<td>Test site Design data basis (provided before testing)</td>
<td>200.000 DKK</td>
</tr>
<tr>
<td>Data and Data acquisition (during testing)</td>
<td>500.000 DKK/Year</td>
</tr>
<tr>
<td>Hanstholm Port Facilities (deployment, operation and maintenance)</td>
<td>Ad hoc</td>
</tr>
<tr>
<td>Estimated rental fees for NBTS</td>
<td>10.000 DKK/month</td>
</tr>
</tbody>
</table>
**Instrumentation**

DanWEC aims at having at least two wave rider buoys deployed at the site. Initial testing can often be carried out without grid connection just to verify the function of the WEC, using energy dump for the wave power absorption and monitoring its mooring system.

To accommodate a future common the grid connection for multiple WEC’s DanWEC has proposed building a mono-pile to which several wave energy converters can connect. From the mono-pole a secured subsea grid connection will connect to shore. The cost is estimated to about 10 mio. DKK.

DanWEC plans to participate as partner in specific development projects.

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**Location of wave measurement buoys:**

- Buoy 1: 57.153586, 8.619226, water depth ~26 m, Model: Datawell Mark IV (directional wave, currents)
- Buoy 2: 57.117119, 8.517387, water depth ~25 m, Model: Datawell Mark IV (directional wave, currents)
- Port Buoy: 57.131500, 8.582100, water depth ~17.5 m, Model: Datawell Mark II (non-directional)
Transnational impact
The open sea test site environment supports the WEC developers in tests demonstrating R&D results and innovations towards commercial viable products. The goal and transnational element concerning test sites are described in the annual report 2010 [w2] of the Implementing agreement of Ocean Energy Systems IEA-OES which states:

Future Research and Development priorities must include collation and analysis of data, and verification of device performance based on sea trials of full-scale grid-connected and partial-scale non-grid connected prototypes. There is still insufficient data in the public domain and research work being undertaken on costs for marine energy and cost reduction strategies. Test facilities should be better focused as incubators where technology developers and utilities are catalysing a phased development of power development projects as the prototype “power plants” for this sector.

The need for traditional marine service requested by the developers deploying Wave Energy systems during preparation, construction, deployment and operation have been found in the local marine infrastructure of the Port of Hanstholm. This infrastructure is similar to many other Ports in the North Sea area. The map below shows the location of Ports in the North Sea Area and experience from testing at one location can be transferred to another. Testing at multiple locations will be required in order to validate principles of transferring performance results from one to another location – taking into consideration the environmental differences. Guidelines and standards for performance assessment for a second location based on measured data at a primary Location is being drafted as Part of IEC TC 114 62600-102 [w3].

![Figure 6 SI Ocean Project North Sea Region Interactive map produced by DHI group.](image)

The dark orange collared sea area shows potential locations for wave energy power plants, described in the SI Ocean project [w4]. Major sailing routes are also indicated on the map.
Existing Plans for the extension and development of the Port Hansholm

A local plan for development of the Port of Hanstholm [4] was prepared in 2009 to ensure that the port also in the future will be attractive as a commercial port. This includes an extension plan of the harbour to a size 3 times bigger than its current size, figure 2 as well as the establishment of wind turbines at the new outer piers. The local plan is prepared to enable:

- Extension of the harbour on territorial waters to ensure an application for area
- Port-related purposes, including modification of the use of previously planned areas

**Purpose of port expansion**

The planned port expansion allows for the reception of larger ships than today, better navigation conditions regardless of weather conditions and opens up new business areas, which are crucial for the whole region's positive development. Among the objectives of port expansion is:

- Maintain and expand the port's status as one of Europe's largest fishing ports
- Open up new business opportunities in relation to offshore activities in the North Sea
- Expand the port's position as a freight port – both nationally and internationally
- Open the option for fixed routes to the Faroe Islands, Iceland, Norway and Scotland
- Make a positive contribution in relation to the development and exploitation of renewable energy within, wind and wave energy
- Construction of wind turbines on Harbour wall
**Future opportunities of the planned port extension**

Hanstholms position as one of the largest fishing ports in Europe is achieved via, a large and wide network, services 24 hours a day, as well as an efficient transportation, which means that the fish can come to the European market as soon as possible.

The concentration of jobs in the relatively small geographical area, of Hanstholm Harbour is considered one of the most important driving forces and the engine of growth in the local area in business development in the municipality and Region Nordjylland.

Since the fishing industry does not necessarily result in increased employment, the plan also includes the growth of business by developing the cargo area and develop off-shore and renewable energy-activities.

On the cargo area the aim is to develop traditional activities such as ferry goods (Ro/Ro), landing, stocking and resale of materials from the sea. In addition it is expected that more fishing boats than today, could result in the establishment of additional dock facilities and fish processing companies.

In the offshore area, a share of the market in offshore repairs and recovery it is expected.

In the area of renewable energy, Hanstholm extension including wind turbines on the harbour walls will provide and income give status as a “plus-energy port”.

The port has a unique location in relation to several wind projects in the North Sea, which makes both the establishment and the service can be performed from the port (e.g. casting of foundations, collection of m, indog shipping, etc.)

In the sea area around the Port of Hanstholm wave energy converters has been tested and testing facilities are being developed. The unique position in the wave energy development which Hanstholm has is expected to be retained in the future.

The continued development of the port in the above mentioned areas are based on a number of synergies, in which the individual activities complement each other, and at the same time has a number of common requirements for the port’s future physical forming, as follows:

- Increased water depth
- Better entry conditions
- More berth
- Large areas in and around the port
Production facilities for large scale Wave Energy Parks

The Port of Hanstholm has the potential to introduce the concept of mass production, deployment and implementation of offshore Wave Energy Parks. This opportunity has not been touched on in the local development plan for the Port, the plan only mentions maintenance of off-shore oil and gas platforms, wind energy projects – and wave energy projects.

In 1993 the first wave energy project was built in the Port of Hanstholm and tested just outside the Port on 30 meter deep water. This development activity was carried by a consortium Danish Wave Power (DWP) composed of four large Danish companies: Højgaard & Schultz, Nordisk Kabel & Tråd, Flygt Pumper and Højlund Rasmussen [5].

The vision of DWP was to deploy a 300 MW wave power plant in the North Sea. In order to realize this plan DWP investigated how and where in Denmark such a production could be established in connection with existing Ports. The Port of Hanstholm turned out to be the Port with the most suitable infrastructure and navigation conditions close to the final deployment location at sea. The production factory in the Port of Hansholm for the wave energy converters was proposed – using a production technique similar to what Højgaard and Schultz used to produce the bridge and foundations elements of the Great Belt Bridge.

![Figure 8 Production of the seabed foundation and pump for the DWP wave power converter in the Port of Hansholm 1993](image)
Production area and facilities
The production area required was estimated in the order of 1500 meter by 500 meter, including 6 parallel production lines of which a 260 meter was crane operated area production area, where the caissons would be casted in moulds at the top and sliding on skid beams toward the terminal from which they would be loaded on a ship and sailed to deployment.

This would include:
- Office buildings
- Storage
- Production buildings
- Production area

Figure 9 Layout of the Danish Wave Power production plant in connection with the Port of Hanstholm (1994)

Production speed and duration
The speed of production of an Offshore Energy Plant has an impact on the local activity level in terms of job creation and energy production. The sooner and the faster the Energy plant is built and deployed – the sooner it will be able to produce Power and generate income. As an example the deployment of the
Anholt Wind farm of 500 MW was deployed over a period of 2 years creating about 2000 temporary jobs [w5].

Longer or perhaps a permanent production facility of Wave Power converters – could be more attractive seen from a local community point of view – this would lead to activity and co-operation on a transnational level – exporting structures to not only Danish sites but to also to other North sea locations over time.

The DWP plant for the North Sea was planned at 300 MW – to be deployed over a 150 km long front in the central part of the North Sea. It consisted of 2640 modules of 120 kW. A weekly production of 12 modules would lead to the estimated building time of 5 years (5200 m$^3$ concrete per week).

**Storage and deployment**
The lower part of the production lines is storage of converters – so that deployment could be executed within suitable to weather conditions. In the present case the storage area was large enough to store 9 month of production. The speed of installation and storage can be adjusted to the weather windows – related to the operational conditions of the installation vessel and the distance to installation point from the production site.

In the Roadmap produced by the Danish Partnership for Wave Power [6], the need for a plan for deployment for wave energy converters as shown in the figure below as shown below is presented.
The Wave Dragon constructions methods
MT Højgaard carried out a feasibility study of possible production methods of one 37,000 tonnes WaveDragon wave power unit in the area of Milford Haven. WaveDragon was in 2005 at a concept stage in the development where no detailed drawings or final specifications were available [7]. Two different construction methods were considered:

- Casting the structure in a dry dock (75m long x 100m wide x 4m depth)
- Casting the structure on a semi-submersible barge

Both methods require a site location with access to the sea and with water depths to allow the structure/barges to be towed to the final installation position and an infrastructure that allow easy delivery of construction material to site.

A sketch of the two production methods are shown below.

Figure 11 Production methods for Wave Dragon.
The Femarn Belt tunnel production principle
Wave Energy Converters such as the KNSwing [w6] are ship like structure that absorbs wave power along its length i.e. with submerged openings to the sides. The WEC is floating structure and can be towed to its deployment positions where it is moored in such a way that it always meet the incoming waves head-on.

![Figure 12 Photo of the ship like wave energy converter KNSwing [w6]](image)

Each structure is likely to be somewhere between 150 - 240 meter long and suitable for production in concrete. Thus a production facility similar to the planned Fehmarn belt [w7] figure 12 could be modified to suit the local conditions at the Port of Hanstholm.

![Figure 13 Production of long tunnel concrete structures Femarn Belt [w7]](image)
Annex 1 Danish Wave Energy Converters

In Denmark, developers have since the eighties and nineties initiated ideas, designed, developed, innovated and tested several Wave Energy Converters (WEC). The tests have been performed on different levels and scales, and following the DWP project the first dedicated Danish Wave Energy Development Programme was established 1998 - 2002, during which more than 20 WEC ideas, concepts went through early technology tests and technology assessments [8]. Today several of the concepts initiated during the Wave energy programme have developed further such as WaveStar, FFP WaveDragon, WavePlane and new WEC ideas and concepts appeared. Their technology and economic performance is assessed using common principles and experience from the development process integrated under the Partnership for Wave Power – in order to further improve the economic performance.

Technology Levels

A five step Technology Level (TL) can help characterize the WEC developers need for test facilities over the typical development stages.

- TL 1: initial assessment of ideas and concepts on basic models;
- TL 2: Development and Test in R&D Tanks. (scales 1:25-1:100);
- TL 3: Pilot concepts and downscaled sea based tests (scales 1:5-1:10, e.g. at NBTS);
- TL 4: Larger scale power producing sea based demonstration (scales 1:4 -1:2 e.g. at Hanstholm);
- TL 5: Full scale commercial demonstration units. (Model scales 1:2 -1:1)

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<th>Expected ¾-½ scaled sea based testing (e.g. Hanstholm)</th>
<th>Expected downscaled sea based testing (e.g. NBTS)</th>
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<tr>
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<td>Crestwing</td>
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<td>2014</td>
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<tr>
<td>WavePiston</td>
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<td>2015</td>
<td>?</td>
</tr>
<tr>
<td>WavePlane</td>
<td>2</td>
<td>2015</td>
<td>?</td>
</tr>
<tr>
<td>Leancon</td>
<td>2</td>
<td>2015</td>
<td>?</td>
</tr>
<tr>
<td>Weptos</td>
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<td>2016</td>
<td>?</td>
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<td>Dexa wave</td>
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<td>2010-2011</td>
<td>2008-2009</td>
</tr>
</tbody>
</table>
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[4] Hanstholm Havn, Lokalplan nr. 3-002, April 2013


[8] Bølgekraftudvalgets Sekretariat, Bølgekraftprogram, Afsluttende rapport fra Energistyrelsens, Rådgivende Bølgekraftudvalg, August 2002

Web references:


**BEPPo (Blue Energy Production in Ports)**

The BEPPo project focuses on Blue Energy (wave/tidal) and its complementarity with traditional (gas/oil/coal) & new (wind/biomass) sources of power, building on the innovation capacity of ports to become bases for the production of integrated sustainable renewables, thus ensuring reliable & affordable supplies of clean, green energy. It provides a unique opportunity to understand how to develop marine energy platforms in ports and promote local business opportunities to accelerate economic growth in port regions.

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