ENVIRONMENTAL EFFECTS METADATA SURVEY FORM

Name	Date submitted
Jan Sundberg	October 3, 2014

Project name: Lysekil Wave Energy Test Site

☐ Planned ☒ In Operation ☐Completed

Project description:

Project Developer: Uppsala University

Technology Developer: Uppsala University

Technology type: Linear generators, floating point absorbers (buoys)

Resource (wave, tidal): Wave

Project scale (test and research site, prototypes and array testing): Test site of array of maximum 10 wave power devices, plus related equipment – new permit will allow use of 0.5 km^2 and make possible for external use of test site area.

Installed capacity (MW): Pending on current research program: 30 kW to 500 kW – new permit will allow operation of 20 units, simultaneously.

Project Website: http://www.el.angstrom.uu.se/forskningsprojekt/WavePower/Lysekilsprojektet_E.html

Launch Date:
Project start in 2004, first generator/WEC deployed March 2006, plus land cable.

Additional Description: The project was started in 2004 and old permissions / consents run until the end of 2013. A new round for permanent permits, and for an extended test site, is currently under analysis by the Environmental court – decision expected during late 2014.

During the first 10 years of the project a maximum of 10 generators were allowed to be deployed simultaneously, plus two submarine substations. Additionally, the project were allowed to use 30 smaller buoys, with foundations, for studies on environmental impact, and a surveillance tower for monitoring the interaction between waves and converters was installed on a nearby islet. To date the research area also holds one sea cable connected to a measuring station on shore and a Wave RiderTM buoy for wave measurements. The wave energy converters are based on a linear synchronous generator which are placed on the sea bed and driven by a heaving point absorber at the ocean surface. The converter is directly driven, i.e. it has no gearbox or other mechanical or hydraulic conversion system. This results in a simple and robust mechanical system and a sophisticated electrical system.

Location: The Lysekil research site is situated on the Swedish West coast, about 100 km North of Gothenburg, near the municipality of Lysekil. The site is located 2 km offshore, between a northern (58º 11' 85" N, 11º 22' 46" E) and a southern navigational marker (58º 11' 63" N, 11º 22' 46" E) signaling the research area to avoid interference with shipping.

Process status: The establishment of the research test site has been done in several steps. The launch of the first wave power generator, including the sea cable to shore, was made in the beginning of March 2006. Over the years several different contractors has been working within the project during commissioning and decommissioning phases of equipment.

Licensing information (brief description): During 2004–2011 the County Administration gave a number of necessary permission for ten wave energy converters, along with an additional 30 buoys for environmental impact studies. A special permit was needed for the sea cable from the project area to the mainland grid at the nearby island of Gullholmen. All old consents/permits run until the end of 2013. During the end of 2013 a full scale application was filed to the Environmental Court which was proceeded by a number of consultations and full scale Environmental Impact Assessment. Consultations involved, e.g. local inhabitants, fishing organizations, local governments and the National Maritime Administration were necessary in order to obtain the permits referred above and thereby the use of the area.

Key Environmental issues: The environmental studies has so far focused on marine organisms living in the seabed (the infauna), organisms involved in biofouling and on vertebrates, mainly fish. Reef effects of the devices foundations have been investigated with significant difference between foundations with and without holes are one of the findings. Over the last years focus has been set on measuring under water noise with extensive development of hydrophone equipment. Also, a PhD-program where sonars are developed and adapted for passive or remotely controlled under water monitoring is under progress. Sonars are anticipated to help in monitoring presence and behaviour of fish and marine mammals in the vicinity of wave energy (and other marine energy) installations.

Environmental webpage:
http://www.el.angstrom.uu.se/forskningsprojekt/WavePower/Lysekilsprojektet_E.html

Baseline studies and project effects studies: Lysekil Wave Energy Research Project				
General description				
Receptor	**Study description including question and/or objective**	**Design and methods** (brief description)	**Results** (brief description)	**Status** (planned, underway, completed, with dates)
Physical Environment	Time series of wave elevations at the Lysekil research site continuously since April 2004.	Datawell Waverider buoy - the measured spectrum has been used for numerical studies of the power	The average energy flux during 2007, excluding August, was 3.4 kW/m. While the most frequent sea state has a value for TE around 4 sec and HS less than 0.5 m, the main energy contribution comes	Underway

	Wave climate.	capture capability of a cylindrical buoy. It has also been used to calculate the wave climate of the site.	from the more energetic sea states. Due to its relatively low energy flux, the wave climate at the Lysekil test site would not be ideal for commercial wave power production.	
Benthos	Infauna characterization: analysis of species composition.	Sediment sample collection inside the test area and in control areas. A hap-score with a diameter of 14 cm was used. The sediment sample was filtered using a 1mm sieve and animals were removed and preserved in formalin. Diversity data (number of individuals, number of species and Shannon Wiener diversity) were compared with a one-way ANOVA.	The sediment samples contain in total 309 individuals of 68 different species. There is significantly higher species abundance in the buoy area compared to the control area. This can be explained by the variety of sediment substrate: sediments in the test area contains both silt, sand and shell gravel whereas the control area contains silt and shell gravel. The biodiversity in sandy sediments with medium grain size is most often higher than in other soft bottom. For wave power devices anchored on soft sediments the type of sediment and infauna the area contains should be an important issue. Polychaete worms were the most abundant species in the sediment and very small, juvenile organisms were found. There were no red listed species in those areas and thus no concern about extinction of sensitive local species arose from this study.	Completed (sediment samples taken bw 2004-2008)
Reports or papers	• Leijon, M., Boström, Danielsson, C. O., Gustafsson, S., Haikonen, K., Langhamer, O., Strömstedt, E., Stalberg, M., Sundberg, J., Svensson, O., Tyrberg, S., Waters, R., 2008. Wave Energy from the North Sea: Experiences from the Lysekil Research Site. Surv Geophys (2008) 29:221–240 • Langhamer, O., Wilhelmsson, D., Engstrom, J. 2009. Artificial reef effect and fouling impacts on offshore wave power foundations and buoys – a pilot study. Estuarine, Coastal and Shelf Science. 82:426-432. • Olivia Langhamer, "Wave energy conversion and the marine environment: Colonization patterns and habitat dynamics"**,** Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology, Uppsala University, ISSN 1651-6214; 663. • http://www.el.angstrom.uu.se/Meny/mpub.html			
Research projects	N/A			

Monitoring and adaptive management: Lysekil Wave Energy Research Project				
General description				
Receptor	**Monitoring program description including question and/or objective**	**Design and methods** (brief description)	**Results** (brief description)	**Status** (planned, underway, completed, with dates)
Benthos and fish	Investigation of the effects of wave energy converters on macrofaunal species abundance in surrounding soft bottoms.	The succession of colonization patterns in different organisms was investigated. A reference site was selected and used for comparison. 9 core samples were taken both at the reference and the deployment site using a Hapscore sampler. Macrofaunal species were identified to the lowest possible taxon.	Differences in biomass, number of individuals, species and diversity were most probably due to sediment transportation and hydrodynamic processes rather than biological processes. The deployment of WEC's in the Lysekil site would rather have minor direct ecological impacts beyond the level of natural variances.	Completed in 2009 but to be continued
Marine Ecology	Investigation of the succession of colonization patterns in different organisms.	In the spring of 2005, 4 biology cylindrical buoys with a diameter of 1.8 m and a height of 0.8 were installed at 25 m depth on a seabed consisting of firm shell gravel and silt. They were moored with stiff lines to 10-tonne concrete foundations having a diameter of 2.8 m. The distance between the buoys were 100 m to 300 m. An additional bigger buoy, with a diameter of 3 m, moored to a 40 tonne concrete foundation was also installed. In the Spring of 2007, 21 additional buoys (ten of them without holes and eleven of them with various holes) were put in place with a distance of 15-20 m between each other. The succession of	Vertical structures were more colonized than horizontal ones but there was no significant difference between foundations with and without holes. The low light penetration was identified as the most probable cause of low biomass at the location.	Completed

		colonization patterns in different organisms has been investigated.		
Underwater Noise	Investigation of eventual effects by wave energy converter generated noise.	Recordings over long periods by multiple hydrophone systems positioned on seabed.	Noise is generated, especially during higher wave states. Noise not regarded as a severe impact mainly as back ground noise is far loader.	Completed in 2014 - to be continued
Reports or papers	• Leijon, M., Boström, Danielsson, C. O., Gustafsson, S., Haikonen, K., Langhamer, O., Strömstedt, E., Stalberg, M., Sundberg, J., Svensson, O., Tyrberg, S., Waters, R., 2008. Wave Energy from the North Sea: Experiences from the Lysekil Research Site. Surv Geophys, 29:221–240. • Langhamer, O., Wilhelmsson, D., Engstrom, J. 2009. Artificial reef effect and fouling impacts on offshore wave power foundations and buoys – a pilot study. Estuarine, Coastal and Shelf Science. 82:426-432. • Langhamer, O., Wilhelmsson, D. 2009. Colonisation of fish and crabs of wave energy foundations and the effects of manufactured holes – a field experiment. Marine Environmental Research. 68:151-157 • Olivia Langhamer, "Wave energy conversion and the marine environment: Colonization patterns and habitat dynamics"**,** Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology, Uppsala University, ISSN 1651-6214; 663. • Haikonen, K. Sundberg, J. & Leijon, M. "Characteristics of the Operational Noise from Full Scale Wave Energy Converters in the Lysekil Project: Estimation of Potential Environmental Impacts", *Energies*. 2013; 6(5):2562-2582, doi:10.3390/en6052562 • http://www.el.angstrom.uu.se/Meny/mpub.html			
Research projects	N/A			