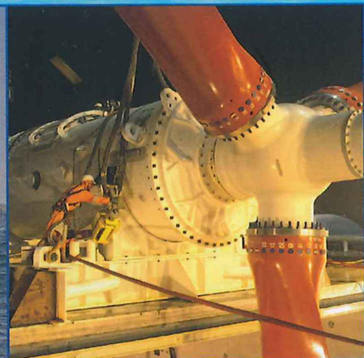
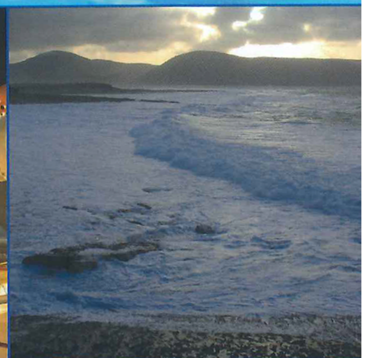
Earthscan Oceans

Ocean Energy

Governance Challenges for Wave and Tidal Stream Technologies





Edited by Glen Wright,
Sandy Kerr and Kate Johnson

earthscan
from Routledge

Ocean energy at the edge

Laura Watts and Brit Ross Winthereik

How do we change perceptions
of 'the edge'
and marine energy.

There is needed
a quite new attitude
about (marine) energy.

Is it surprising to people from Orkney
that Danish people (or anyone else)
are unaware of the value of marine energy –

What you know in daily experience,
that makes you understand degrees
of importance. I suggest that by linking
the two places, and providing an 'edge'
for Denmark (as was suggested) and
a European centre for Orkney
both places will benefit.

1 Introduction

The preceding inscriptions on Post-it® notes were written by marine energy industry representatives from Denmark and Orkney, Scotland, to Marine Renewable Energy at Futures Edge: Connecting Denmark and Orkney, Scotland, a workshop held in Copenhagen in September 2011. This group of industry, policy and academic practitioners were brought together in an interdisciplinary workshop to explore what the *futures' edge* might be for marine energy in these two places.

The word 'edge' in the title for the workshop was chosen with deliberate care. We both work as ethnographers of ocean energy (OE), and as such we hear 'edge' over and over. The word permeates conversations, presentations and documentation in our ethnographic collaborations with people, places and organizations. For example, marine energy is often talked about as though positioned at the edge of a larger energy industry, with fossil fuel power stations at the centre. Secondly, marine energy is an environmental resource located at the geographic periphery. Those who work in the industry live, or at least must work, where these high-energy seas are to be found: literally at the geographic edge. In both these examples, marine energy is conceptualised as marginal compared to some other central power.

The workshop in 2011 was the beginning of a research project to explore this edgy quality that suffuses marine renewable energy, their people and places. Since then, we have continued the exploration as part of a research project entitled Marine Renewable Energy as Alien: Social Studies of an Emerging Industry. We have spent time with people in Denmark and in Orkney and have talked with them about what it means to work in an energy sector that is both 'in the making' and marginalised.

This chapter will take up the call made by participants in the workshop and do two things. First, we will explore the many different versions of the edge in ocean energy we have encountered during our four-year research project. Second, we will draw on resources in the social studies of science and technology and the ethnographic studies of infrastructure in order to reconceptualise or 'reconfigure'[1] the ocean energy edge not as marginal but as powerful and with tactical advantages that may be relevant to other ocean energy edges and communities throughout the world.

2 Ethnography at/of the edge

Over the next four years after the workshop, we spent considerable time in conversation, sometimes immersed, in the organizations and places around wave and tide energy in Denmark and in Orkney, Scotland. We gathered extensive transcripts and notes from interviews and meetings we participated in, took thousands of photographs, read and annotated hundreds of related documents. As ethnographers, we attended to the social and material infrastructure of wave and tide energy.[2] Brit Ross Winthereik worked with people around the Danish wave energy industry; Laura Watts worked in Orkney with those working in and around the marine energy industry there.

We were interested, first, in how these new energy infrastructures were developing in social, cultural, technical and environmental relations – in policy and practice, for example. In this, we draw on work in science and technology studies (STS) that understands infrastructure as not just a material system of transportation, nor just as a technical object, but also as embedding social, cultural and political decisions and agencies that have to hold together and endure over long periods of time.[3] In the context of marine energy, attending to infrastructures as social and technical meant attending to how, in our fieldsites, political decisions (whether local, industry or national politics) hindered or enabled OE to be transformed and transmitted onto the electricity grid. Second, we were exploring how local communities, which often included the marine energy industry community itself, were developing a relationship to these 'alien' and 'other' infrastructures for marine energy in their seascape – from the devices to the onshore buildings – and, conversely, how the devices themselves moved through different environments making relations with business investors, politicians, actual and potential subcontractors, and industry partners. In short, how was tide and wave energy being enacted at the edge, and how was it being done differently in Orkney, Scotland, compared to Denmark?

3 Edge histories

Orkney and Denmark already had an existing relationship prior to our research, of course, and interestingly each has a very different role in the overall global marine energy industry.

Orkney, the islands off the far northeast coast of Scotland, is a place of very high energy waves and strong tides; waves may be 14 m high and the tide perhaps 8 knots. This is the location for the European Marine Energy Centre (EMEC), the world's first and longest running grid-connected test site for wave and tide energy generators. It has had large and full-scale prototypes in the water and on the grid since 2004, when the Pelamis 'sea snake' became the first wave energy machine in the world to generate on-grid electricity. Since then, EMEC has expanded to provide 14 berths for wave and tide energy generators to plug in and test in the open sea. At our last count, in 2012, there have been 45 device developers testing at EMEC, with well known energy and engineering companies involved, from Kawasaki to Voith, from Alstom to E.ON. Around 300 people work in or around the test site in Orkney, an ecosystem of support companies and facilities that is almost unique in the industry. Although there are perhaps 40 open sea marine energy test sites around the world, none have comparable experience; the number of device developers testing across all of the United States test sites put together is under 20, at the time of writing. This is why EMEC and Orkney are regarded by many as the industry beacon. The European Marine Energy *Centre* is often taken as just that, the global *centre* for the marine energy industry.

In comparison, the waves surrounding Denmark are much smaller than those near Orkney. Still, in 1998 the combination of more than 8,000 km of coastline, a history of renewable energy production and a group of inventive marine energy enthusiasts led to the design of the Danish Wave Energy Program. In its first years, the programme allocated small amounts of state funding to around 50 marine energy projects. Roughly ten of these received additional funding to conduct further development and testing. Over the years, testing activity flourished, creating a need to further expand the testing infrastructure. At first, this infrastructure was set up by a group of committed wave energy inventors (The Wave Energy Association). This was a grassroots movement, and its main objective was to select and lay down cabling for a test site. In 2008, two new state-led funding programmes were initiated, and a handful of new devices were designed, along with an increasing need to perform offshore tests. In 2009, the company Wavestar began testing its 1:2-scale device in the North Sea just outside the port of Hanstholm. This led to considerable publicity for the emerging wave energy sector. A year later, in 2009, as a result of collaboration between the port of Hanstholm, the local municipality, the local business association and Aalborg University, the Danish Wave Energy Center (DanWEC) was officially announced right where the Wavestar was also based. In 2012, a national wave energy strategy was published, but in 2016 Wavestar went bankrupt. Several other companies are testing in the North Sea and in other places around Denmark, but none of them are grid connected. With DanWEC not managing to establish itself as *the* centre for marine energy testing in Denmark, and with Wavestar gone, there is no one place where Danish marine energy is happening but many.

In 2011, the Danish marine energy inventors explicitly looked to EMEC and Orkney as their centre, as our Post-it notes showed. And with the situation today, it would appear that the relationship between Danish and Scottish marine renewable energy industries has EMEC and Orkney at the centre, with DanWEC and Denmark located more at the periphery.

However, this comparison belies some crucial histories that relocate this relationship and the histories of renewable energy more generally. On 9 July 2015, Denmark generated over 140% of its electricity from wind energy. This was a day when the entire country ran on nothing but air and also generated considerable revenue by exporting its excess wind energy to Norway, Sweden and Germany. Denmark could therefore be said to be synonymous with wind energy: it has some of the world's largest wind energy companies (e.g. Vestas) and massive national support for the industry. Wind energy is celebrated and entangled in Danish pride for their world-leading energy technology industry. The Danish Government has invested in and remained committed to the development of this renewable energy industry since the 1980s. Wind energy dominates the energy landscape, both in policy and practice, with the Danish Wind Energy Association, a partnership of over 240 companies, providing considerable political and commercial leverage. In Denmark, wind energy is the energy source at the *centre*, with wave, solar and biomass more in the *periphery*. Compared to solar and biomass, marine energy is marginal, but it is at least 'on the map' of this renewable energy-led national policy.

Back in Orkney and in the UK more generally, the political geography for renewable energy is somewhat muddier. Orkney was the location for the UK's largest experimental wind turbine in the 1980s (300 kW), but the Government failed to commit to wind energy and research stalled. Although tariffing schemes that privilege renewable energy have been in place, such as the Renewable Obligation Certificates (ROCs), it could not be said that wind energy or any other renewable energy lies at the centre of UK energy policy. Marine energy is not just marginal to wind energy, the entire renewable energy industry is somewhat peripheral to an energy policy that favours centralised power sources (nuclear, gas and 'clean' coal) and is moving towards importing electricity and interconnector grid networks.[4]

Comparing these histories and political geographies of renewable energy, then, suggests that Denmark, with its long heritage of wind energy, lies very much at the global centre of renewable energy, with the UK a poor peripheral figure. It is into this wider political geography, which has differing national positions, that the marine energy industry must locate itself. How centres and peripheries are constructed and can be constructed differently in the marine energy industry are what we will now explore.

4 Centre–periphery

There is an extensive literature across sociology, anthropology and geography that reflects on how the centre–periphery dichotomy is made and how it might be unmade, or at least represented and read otherwise. These largely derive from discussions of marginalisation, how places and peoples are made marginal to some central power through colonisation or other political histories of 'othering' – which makes both 'us' and 'other'.[5] Two particularly important threads in that discussion, which seem important for centre–periphery in marine energy, are (1) the effects of physical geography and its mapping; and (2) the discourse of urban nodes versus rural edges perpetuated in notions of globalisation and models like the Network Society.[6]

First, in the mentioned literature maps are technologies that represent space but also politics. When the Flemish geographer Mercator presented his map of the world in the sixteenth century, his projection was intended to aid seafarers' voyages across the Atlantic by representing lines of constant course. The prime meridian line runs straight through London and down through Spain and Algeria on this map, placing the European colonial powers at the centre. But by supporting colonial sea navigation, landforms are completely misrepresented: Northern Europe is massively over-proportioned compared to the African continent. It makes Europe and North America look much more dominant on the planet than they actually are. It is this outdated and misleading map of the world that remains more or less the standard, since its politics of centre–periphery privileges current political world powers.[7] Moreover, such politics of maps reproducing a central power happens at the national scale. Maps of the UK are centred on London as the capital, and the choice of viewing angle or projection distorts the landmass so that Scotland is foreshortened, and the northern islands such as Orkney and Shetland are squeezed into obscurity (if they are not cut off entirely). In summary, centres and edges are made and reproduced through maps – choose the centre of your map differently, and a different world with a different politics is made. It therefore makes an enormous difference where marine energy environmental resources are located on the map, for with that mapped location comes particular politics and power.

Our second version of the centre–periphery dichotomy revolves around the urban metropolis with rural areas reduced to peripheries that must play catchup.

This model is most notably perpetuated through Manuel Castells' account of the modern Network Society.[8] This model rests upon a technological map of how information (email, Internet, bitcoin) moves around the world through communication infrastructures. It is reproduced through endless, dramatic visualisations of the networked world, with cities as hubs reaching out to other urban centres and to those of us who live elsewhere either in the dark or simply invisible. This discourse is pervasive: rural places and people are assumed to be lacking technological progress, as though technology development is a single smooth line on which we can all be located, and urban places and people are considered ahead on that same line of technological development. Many researchers have troubled this dichotomy. For example, Anna Tsing's work on *friction* shows the generative tension between urban centres and rural sites of production necessary to create globalisation.[9] Tsing's work shows how much is happening in the places described by others as "the end of the world"; such places are where global connections are established; for example, science and technology studies scholar Nicole Starosielski has conducted a study of the undersea cable networks that carry telephone and Internet data around the world.[10] She notes how its physical geography in no way correlates to the public imaginaries of this global network. For example, large data centres are not located in cities but are more often located close to water-cooling resources and renewable energy that, as we have already discussed, are more often found in high-energy, stormy edge places. So, if information is power, such power is at the geographical edge.[11]

From this initial foray into centres and peripheries, it would seem that both EMEC in the Orkney islands and DanWEC in north-western Jutland, share a similar geography and challenge. First, DanWEC in north-western Denmark and EMEC in northern Scotland are both located at the edges of their national maps. And this geography is repeated for many marine energy test sites around the world. Marine energy would appear to be located at the periphery of the map and far from powerful centres, where parliamentary political decisions are made. Second, wave and tide energy devices are, without doubt, advanced technology. Yet they are to be found, installed within their environmental resource, in stormy coastal locations that are often distant from the calm, un-weathered urban centres. If we were to follow the rigid binary of centre versus periphery, it would appear that marine energy technology, located at the weathered edge of the land, has to work against the grain of the 'technologically backwards' rural periphery.

But seen through a more careful and critical lens, marine energy devices and their infrastructures are at odds with this standard version of the centre–periphery relation. This is where ethnographic fieldwork and attention can provide a richer and more complex empirical account.

5 From periphery to edge

We stand at what some think of as the end of the world. We are in Orkney, at the geographic periphery of Europe, an archipelago of 20 or so inhabited islands, a wild mix of farmland and Atlantic wind and waves. We stand at the periphery, yet if we drove half an hour to the other side of the main island we would be at the centre of the islands, in the main cathedral town of Kirkwall, and there is much grumbling about centralisation of the islands' administration in the town.

We stand on a beach with fossil-filled sandstone rising around us, the Sun low and cool across a winter-green sea. If we squint, we can just see four red lights blinking in and out of the waves. These are the marker buoys for the European Marine Energy Centre wave energy test site. Out there, floating on the rolling horizon, we might be lucky enough to see bright yellow generators, such as the gyroscope system that is Well Oy's Penguin. Out there, in those green waves, was where the Pelamis became the world's first grid-connected wave energy machine. Behind us, under a grass-covered mound and half buried in the cliff side are the substation and equipment housing for the European Marine Energy Centre wave energy test site.

The former first minister of Scotland called this pounding of green sea and waves, 'the Saudi Arabia of marine power'. This place, this beach, is central to stories of both political and electrical power. So we stand at both the centre and the periphery; centre and periphery are fractal. You might look at a map of the UK and see London as the innovation centre, and Orkney as the technological backwater. But zoom in to Orkney, and you see the EMEC wave energy test site as the innovation centre and the outer islands in the archipelago with their limited broadband connection as the periphery. So if it is centres and peripheries' all the way down, how to consider this dichotomy otherwise? We were often told how hard the islanders have to work to resist a very real experience of being marginalised. As one environmental consultant said: "[I]t's like hyperthermia, all the blood goes to the centre. . . [W]e have to look after ourselves". Orkney is distant from London in so many ways that matter. How to keep the empirical evidence of fractal centres and peripheries in view, all at once? Where to locate ourselves?

We are now standing on a beach outside the port of Hanstholm. From here we have a perfect view to the alien construction that makes experiments in wave energy – the massive white block and four pillars that raise the Wavestar prototype out of the sea. Here, wind and waves are strong, and technologies for marine renewables that may help ensure fossil-free futures can be tested. We may say that it is an innovation centre, but it is not a place that most people would think of as a place for future making. This is definitely not Silicon Valley. But is it the periphery?

Jens Ole Bæhrenholdt and Brynhild Granås have argued against and sought to deconstruct the notion of the periphery.[12] Undoing the centre–periphery dichotomy is important, but it is also very difficult since people living in places regarded as remote often understand themselves as precisely that – peripheral. Young people, for example, when negotiating their identities, do so through binaries like future–past and centre–periphery. Should we take such binaries seriously? Are there limits to the intellectual project of deconstructing peripherality? Moving away from the binary vocabulary is one way of seeing what else is happening here at the edge, apart from repetition of what is considered centre and what periphery.

In Hanstholm, being at the 'periphery' is certainly an issue. At the bus station, you'll encounter a painted signpost with 'World's End' written on it. A manager at the Fishermen's Association spoke to us about Hanstholm as a remote area, completely invisible to Copenhagen and with limited possibilities for development. A teacher also involved in DanWEC said, memorably, that the distance from Copenhagen to Hanstholm is twice the distance from Hanstholm to Copenhagen. In the national context, Hanstholm is regarded as part of *udkanstdanmark* ('outland Denmark'), an area of limited prospects, especially for young people, around the western and southern margins of Denmark; an area also sometimes referred to as 'the rotten banana' (*den rådne banan*) – as though this periphery were a rotting skin around a more robust and healthy country.[13]

But a flyer from the region also says, 'Welcome to World's End – *a place of new beginnings*', and a popular musician, Simon Kwamm, has turned Hanstholm's historical light house into a recording studio. So being at the edge is also mobilised as a resource: peripherality is part of the branding efforts of Hanstholm. Yet framing peripheral Hanstholm as a technological cutting-edge akin to Silicon Valley, stating that this peripheral place really is a global innovation centre, does not empirically ring true. It leaves the people living in peripheral places, as well as the scholars trying to take seriously their lives and practices, at an irresolvable dead end. We must hold together both the empirical evidence of the periphery as both problem and resource and our need to move beyond the centre–periphery conceptualisation, which is so prevalent.

One way of doing this is by opening up our understanding of places at the edge. The edge marks a place of transformation, in our case where sea power is transformed into power on land. It is a boundary place where you encounter difference and mixture. But the edge is not a line on a map. It is an indication of places that share a particular experience – there is something shared between Hanstholm and Orkney, for example. Being located at the edge, in this sense of an edge experience, highlights how innovation in marine energy differs from innovation happening in other places that are more usually associated with tech industries (such as Silicon Valley).

6 Connecting the edges

There is much we can say about innovation 'at the edge' in marine energy. To do so, we must first constitute the edge analytically, drawing on our empirical evidence. We must develop the concept of an edge that is not simply one side of a centre–periphery.

Anthropologist Anna Tsing argues that edges are often zones of unpredictability on the margins of stability,[14] whether that be unstable coastline or unstable as a concept. She also argues that 'edges' are good to think with: they generate questions that counter the assumption that the margin and the marginal are in opposition to progress and development.[15] We follow Tsing in thinking through edge as a way to counter a simplistic understanding of marine energy as marginal.

What follows are three different analytic versions of the edge that can reconceptualise marine energy innovation.

6.1 Resilient edge

Peripheries are often considered as places that are vulnerable and at risk. Seen through the concept of edge, as we will show, the risky places of marine energy emerge as advantageous.

Thy, the municipality in which Hanstholm is located, has more than 200 wind turbines, Denmark's first power plant based on geothermal energy, a national test centre for large-scale wind turbines, a centre for research and development of energy technologies, and a centre for wave energy technology. Also, it is the home of (a part of) Denmark's first national park reaching across the dunes and the coastal landscape stretching inland towards the fjords. Thy brands itself as a 'climate municipality', highlighting in its branding efforts that 100% of the electricity and 80% of the heating there come from renewable sources. By this framing, it seeks to position itself as an example for national attempts at moving from a society based on fossil fuels to one independent of oil and gas.[16]

Thy municipality works to tell a counter-story to its marginalisation. Its story is one of *new beginnings*, that the municipality has a long history of being on the renewable energy front line, of being a landscape for research and development – a place where the future arrives first and is tested. The testing of wave energy is positioned as a continuation of this ongoing story. Wave energy is tamed, made familiar and enrolled in the regional story of being a 'climate municipality'.

Over the North Sea, in Orkney, this move to retell the edge as a place of new beginnings is also ongoing. Orkney calls itself a Living Laboratory, with a long history of testing energy futures. This history begins in the 1950s with the testing of an early wind turbine, through to the UK's large-scale wind energy test site in the 1980s, and on to the country's first smart grid, 700 or so micro wind turbines, and a test site for electric cars. The European Marine Energy Centre is just one more test site, the continuation of a well established trend.

In both places, marine energy is entangled in histories of an edge that is a site of technical experimentation and ongoing energy future making. The marine energy test sites are not located just due to the local environmental resource, the energetic sea. They are also entangled in wider relations: regional commitments to renewable energy development and a cultural history that emphasises the locale as a 'natural' site for technical experimentation, very different from stories about the edge told elsewhere.

We do not hear this as the edge claiming centrality. As we argued previously, marginalisation (marked by young people leaving the area due to limited job prospects) remains a serious problem. We hear this as a clear articulation that being at the edge is not *ipso facto* a negative; rather, there are well established advantages to being at the edge for scientific and technical development, and this has long been the case.

This should not be surprising. For those who live and work at similar edges, it will resonate. Island studies, along with anthropology and geography, have long argued against remoteness as a universal negative, that creativity and improvisation thrive at the edge.[17] Empirical evidence continues to show how islands, for example, are the harbingers of the future: their fine-tuned ecosystems and fragile socio-economics make them global barometers for planetary change.[18] It was the Alliance of Small Island States who began the climate change mitigation campaign, 1.5 to Stay Alive. Many of these low-lying island nations are on the front line of human-induced climate change. These edges are prophetic for the rest of the world. Rather than being behind, they are ahead – already living in the future. And it is important to remember that geographic understandings of islands are not limited to isolation by the sea but include wider forms of isolation; edges are not always wholly maritime.

In a reflection on a climate-changed future, the UK Government wrote, "[A] high-carbon world is one with more extreme weather, where we and our children are faced with the costs of adapting the way we live and the infrastructure and systems that support us".[19] Extreme weather is a given in many sites for OE. The high-energy sea, which makes these sites suitable for high-energy wave and tide generation, means serious weather and storms. Ocean energy edges are by definition often located in places where the weather can be ferocious: in Orkney, waves can be coming over cliffs in great booming explosions of salt and sea spray. Orkney and Hanstholm both face the Atlantic and its wrath.

Aside from being a sensitive barometer, the high-energy seas and weather can also lead to another edge effect. This relates to the UK Government's correlation between weather and infrastructure. Whether it is transport, telecommunications or electricity networks, infrastructure is often vulnerable in high-energy environments. In Orkney, the so-called lifeline ferry can stop for several days during winter storms, meaning that fresh food runs out at the supermarket. The electricity cables strung up on poles over the islands can be downed due to fierce winds, and the lights and phones can go out.

This has two implications. First, infrastructure has been regarded as an indicator of modernity, and its loss synonymous with a sudden and threatening loss of modern civilisation.[20] However, in high-energy places where infrastructure is unreliable, their breakdown does not lead to panic, social media meltdown or any perceived loss of civilisation. Rather, the breakdown of infrastructure networks such as food transportation or electricity is taken as business-as-usual in a modern world. In Orkney, locals reach into the chest freezer or into the bag of potatoes, and oil stoves and petrol generators are common. Such edge places are resilient to modern infrastructure breakdowns.

Second, as has been well discussed in infrastructure studies, when infrastructure breaks down, it becomes visible.[21] Thus, in high-energy edge locations, modern infrastructures, such as electricity, are visible networks and well known to those who live with and without them. Electricity does not come out of the electricity socket in the wall in Orkney or Hanstholm. It comes from the hundreds of local wind turbines or from the nearby geothermal plant (the case in Hanstholm).

Marine energy is thus being tested in places where it is visible as an extended part of the electricity infrastructure. It should be no surprise that regular tours around Wavestar were offered to the public (initiated as part of COP15 events) – and it became a known tourist attraction. In Orkney, there is a well established marine energy public: islanders have an informed opinion about wave and tide energy, made through extended reporting in the local newspaper and radio, ongoing since EMEC began ten years ago.[22]

Overall, marine energy is entangled in edge places that are resilient. We mean that in two ways. Following our argument, we mean that high-energy environments are resilient to infrastructure breakdown, leading to both mitigation experience and visible public participation in infrastructure – and thus public awareness and participation in marine energy. But we also want to draw on our prior comments about the potential for technical experimentation, which is another long held quality of the edge – our sites in Denmark and Scotland have long histories of technical experimentation. This enduring experimentation is also a form of resilience.

In Hanstholm, the teacher involved in DanWEC quoted previously told us about a local saying: "[I]s it possible? No? So we do it anyway!" We heard the history of this harbour town told as one of self-determination. The harbour walls, a huge concrete installation, were regarded as an engineering impossibility during previous centuries. Yet the people persevered and made the technically impossible happen. The Nazi occupation forced locals to leave; those who returned to these windblown sand dunes were "Klondike types . . . who took chances".

It is a similar story in Orkney. The islands' smart grid is under massive strain due to increasing production of local renewable energy. The local energy operator has issued a moratorium on further renewable energy generation, which would seem to make more wind or wave energy generation impossible. In response, the islanders have gone ahead and bought electric cars to increase capacity and are developing their own hydrogen fuel network to transform the renewable energy into another form. They persevere and make the technically impossible happen.

Resilience is an empirical experience for us as ethnographers. It is less a measure or prediction and more an ongoing, observable and mundane practice associated with living at the edge. Here, at the oceanic edge, the energy future is alive and kicking back.

6.2 Innovation edge

There are many different models for innovation at the edge. Indeed, innovation metaphors often include the edge: cutting edge, bleeding edge. However, rather than review the literature on innovation, we are interested in how innovation is done and discussed in practice in our OE generation sites and in what conclusions we might draw.

To learn about different attempts to move Danish wave energy forward and stabilize it as an industry, Winthereik participated in work to develop an interest organization for wave energy. The group refers to itself as the partnership, and under this partnership framework, wave energy device developers, municipality politicians, energy company representatives, suppliers of technology and materials, university-employed physicists and energy consultants meet to create a voice for Danish wave energy. This partnership is therefore one innovation practice for Danish wave energy.

The partners assemble around a five-step innovation model. The model is a classic phase model describing technological innovation as linear. It presents the development of wave energy technology as an incremental process where the technology is first small-scale and undergoing testing in a test basin; then in the second phase, it is tested in a slightly bigger scale, still in a lab. In the third phase, small prototypes are tested in inner Danish waters, for example in fjords. In the fourth phase, a device is tested in the sea at Hanstholm, and, finally, in the fifth phase, the wave energy goes commercial, and devices operate in offshore wave energy parks consisting of several units. During meetings, the model featured as a road map towards a future, where a small and vaguely defined community could go commercial and acquire the characteristics of an industry.

The model is both universalizing and very specific with regard to the places of wave energy innovation. The model both embeds geographical edge (Hanstholm) and the cutting edge (future). In the model, there is convergence between the two. The seascape at the edge is enrolled into the innovation model. In essence, innovation and the energy future are a matter of the wave energy generator physically moving to the edge. There is a doubling of the edge as both future and geography in the innovation model.

There is another important aspect to this partnership model: the underlying histories of renewable energy innovation and its edges in Denmark.

At one meeting, they invited one of wind power's 'grand old men' to speak and inspire them. In a spotless white shirt, he was living proof of wind's commercial success. He told how the capacity of windmills went from 30 kW to 6 MW in only 30 years. He narrated this rapid sectorial development as a combination of "small steps" and a willingness among a small group of pioneers to experiment and team up. The proposition is that the wave energy inventors should experiment together and become "Wave", which would allow them to replicate the success of "Wind".

The origins of wind energy (at the centre of Danish energy policy) are entangled in the same north-western region as the Danish Wave Energy Center; down the coast is where Vestas began, started by a local blacksmith. The origin myth and success of Wind, a story located here at the edge of Denmark, provide the model for innovation in Danish wave energy and underpins their five-step strategy. The steps assume a singular technological development path and that developers should cooperate to constitute a singular organization, akin to the politically powerful Danish Wind Energy Association. It could be said that Wind's approach is to centralise wave energy – to make it look (at least, politically) like them, as a central national energy industry. The fact that wind managed to make the move from the peripheral Atlantic west coast to central Copenhagen is part of the lure.

This is, indeed, the approach that the Danish Government has taken: with support for the creation of the partnership as the interest organization for the wave energy sector. So, in Denmark, we have an approach that assumes relocating from edge to centre as an innovation model.

In Orkney, understanding OE innovation by comparison with other tech industries is also a tactic. Neil Kermode, director of the European Marine Energy Centre, has often likened the development of marine energy to the beginnings of flight. In 2008 he said, "We are where the Wright brothers were after their first flight. We have proven we can do this, but we have not yet mastered our art. . . [It's like the first planes] are for sale but it's a long way from a commercial airline industry". This analogy reminds us that the development of OE is not just a matter of scaling up a single generator. You need more than just an iconic flying machine to go from the Wright brother's first flight to a Jumbo Jet on the runway at an airport. You also need the OE equivalent of passenger terminals, air traffic control, airline fuel and much else. In short, you also need infrastructure. This is not unsurprising given that EMEC is a test site that specialises in developing this infrastructure, somewhat differently from the inventors and engineers of wave energy generators involved in the Danish partnership. But what Neil Kermode at EMEC emphasises is an innovation model that is more than machine orientated, scaling up from basin to open sea, but that includes the end-to-end industry value chain. It is a reminder that OE innovation, to become the equivalent of a commercial airline industry, must include the whole environment and associated infrastructural support *at sea*. As with the partnership model, this innovation ends with salty, sea-cracked commercialisation. As Neil Kermode commented at another time, what they do is practical and inseparable from the sheer physicality of the sea: "You want to know how to anchor your device in eight knots of tide? It's practical. You try this, try that . . ."

The argument we are making is that innovation in marine energy is at the edge, not through some cutting-edge hubris but because OE at the geographic edge, the sea, must be inside innovation for it to be possible. In the case of the Danish partnership, the sea flows in one stage at a time through the innovation model. The surrounding water for the wave energy device gets ever more salty as they get closer to commercialisation, from a basin in the lab, to brackish water in a fjord, to the open Atlantic Ocean. At EMEC, they are committed to open sea testing for the whole end-to-end infrastructure of the prototype, from anchoring to cabling to support vessels.

This may seem something of an obvious point: commercial marine energy must include the sea. The sea edge must be inside OE for it to reach commercialisation. We make this point clear for two reasons. First, because we believe that the 'innovation edge' in OE should not be regarded as a flippant repetition of 'cutting edge' and 'bleeding edge' often used in technology development. The salty sea is a powerful force that alters what innovation is possible (and we will explore that in more detail in our final section). Second, this troubles the assumption that OE needs to become more central as a sector. As this book has emphasised, the resource for wave and tide energy is highly located and not general over the ocean. We have already discussed how high-energy seas are often a prerequisite for OE testing and deployment – which is not every coastline around the world. Indeed, there is much debate about where good environmental resources are to be found. To be blunt, the possible sites for profitable OE are much more limited compared to wind energy. The appropriate coastal edge is a limited resource compared to the breezy land it contains. The strength of OE is that it lies at the edge and will always do so. No market remodelling or tariff shift can alter the movement of the sea or the orbit of the Moon – wave and tide energy are immovable. Moreover, as we were often reminded, "[Y]ou can't just send a person out with a pot of paint and a spanner" to maintain an OE device in the sea, as you would a wind turbine. Instead, it involves the overhead costs of a boat, crew, divers and undersea equipment. Thus, we wonder if an innovation model that attempts to replicate wind energy or other mature land-based renewable energy industry is appropriate. We remain unconvinced that centralisation is an approach that will be effective. OE will always be innovation at the edge.

6.3 Edge of the wave

Our final version of the edge as analytic tool for marine energy returns to our description of Wintherik standing on the beach at Hanstholm looking towards Wavestar and of Watts standing on the beach in Orkney looking out over the EMEC wave energy test site. As we stand at our respective edges and watch the sea, we both reflect on so-called wave capture in marine energy – the very material process by which wave energy is transduced into electrical energy.

Wintherik says:

> I once tried to capture a wave. As part of my participation in a workshop, I had been assigned the task of bringing an object from my fieldwork site to the workshop. I decided to capture a wave to mimic the practices of 'wave capture'. With studied naivety and a jam jar I waded into the ocean and waited for a wave to let itself be captured. Once a wave had rolled into the glass, I screwed the lit back on, waded back in and put the wave in my backpack. Compared to the stories of 'wave capture' I had heard, this was too easy. Before walking back to the summerhouse I tried to prolong the event and sat for a while watching the waves . . . When I arrived at the workshop I realized that indeed I had not been able to capture a wave, far less wave energy. I had stopped the movement of water and hence its energies.

Looking out towards the same Atlantic but from the Orkney coast, Watts is beachcombing, looking for pieces of flotsam and jetsam that the waves have caught and thrown to shore. She finds a large pale, spherical float – perhaps it once hung over the side of a boat. Its pale glow in the Sun is marred by grey patches and a pitted surface, making it look like a full Moon rising over the beach. She places it on a

stone on the beach and takes a photograph to capture the momentary installation. She names it: Found Full Moon. Today the waves lap at her feet. Tomorrow the waves might be 10 m high, making the beach impassable but leaving other pieces of floating detritus to be found another day.

The sea that OE operates in is hard to characterise and 'capture'. Indeed, hydrodynamic modelling of the sea and its waves and tides is a calculated craft. Our two moments may seem outliers in the material experience of OE, but we include them to emphasise that our two accounts are also, quite literally, accounts of OE – the power in the sea. We tell them to make present the sea as material agency that cannot be wholly modelled or reproduced by any empirical account or calculation. The sea cannot be tamed. It can only be approximated, and only in some small part. As those working in the industry have repeatedly told us, freak waves, unexpected and unpredictable waves, are potentially lethal to OE generators, whose design parameters must always be bounded and limited to operation in only certain kinds of seas.

Neil Kermode at EMEC once said that "the sea is a biologically active electrolyte filled with grit". Despite this attention to the grit and critters that are the sea, OE is awash in hydrodynamic models of the sea as water. These may give initial purchase on this slippery, wet environment, but we want to argue for the importance of retaining all the grit and biological critters that can never be contained in such models. We want to keep in view the materiality of the edge as essential to the power of OE. We tell our two unusual accounts of the edge to emphasise the flotsam and stones that will be hammering down upon a generator, just as they hammer down and land on a beach; to emphasise that, to completely capture a wave and cut it out of the sea, as in a jar, is to remove all its energy and power. To lose the materiality of OE, to lose a gritty understanding of the sea is to write out all the practical work needed to make any device operate and thus to write out its future and existence.

We want to show how this overflowing, turbulent and gritty sea is not a problem but an edge that can be ridden forward into the future. To do that work, we want to call attention to what happens in OE here at the edge; we want to call attention to that energy transformative process, transduction.

Transduction is when energy changes form. For example, when the kinetic energy in the movement of the waves or tides is transduced through a mechanism (such as underwater turbine blades) into electrical energy. Transduction makes an edge; it makes a boundary between two different types of energy. But transduction requires a transducer, some kind of agency and mechanism, and that means transduction is inherently lossy. You can never perfectly transduce all the energy in a wave or in the tide. OE is lossy, partial – it can take only part of the energy from the sea.[23] Transduction reminds us that edges are not where things end. Rather, edges are where things change form: land to sea, Moon to moving water, OE to water in a jar. Transduction as not just an engineering phenomena but can also be an analytic approach that gives us a way to float in the seas of OE, without trying to capture them whole.

Debates in OE have sometimes focused on which device should 'win out' over the others. We have seen elegant spreadsheets that compare the cost per kilowatt-hour of different generators. This is a universalising question, since it attempts to take one device modelled for one sea, as though the ocean were the same the planet over. The spreadsheet is akin to capturing a wave in a jar. Instead, the seas in which OE operates are edges all the way up and down, and so the practical experience of the actual sea involved, which cannot be known in advance, remains essential to the OE as a sector. Rather than trying to write this out as a problem to be solved, we are interested in celebrating and riding along on the overflowing, unpredictable and rock-strewn sea. The sea is an edge, where things change form, rise and fall, in ways that will always overflow our capacity to know in advance. OE may never be wholly predictable, but it will always be experiential – a gritty edge the industry can ride and transduce into electricity.

7 Conclusion

We began this account by pointing to how our industry colleagues in marine energy were already bringing together various geographical edges during our initial workshop. We interpreted their efforts as a call for remaking the old dichotomy of centre and periphery. In this chapter, we have emphasised how the usual approach to centres and peripheries as a dichotomy is problematic. Centres and peripheries are both highly contingent (they are not always the same for everyone), and, despite being mobilised in the industry, they do not serve marine energy innovation well: our two test sites and national industries are both technologically advanced cutting-edge practices and located on geographical edges.

To reflect on the serious issues of marginalisation in OE but to not be limited by that understanding, we have instead focused on the concept and experience of edge. Through our ethnographic fieldwork around the Danish wave energy industry and the European Marine Energy Centre in Orkney, we developed three different approaches to the edge specific to OE.

First, we named one edge 'the resilient edge' and described how OE seems to be located in places with long histories of technical experimentation and with highly visible electricity infrastructure – either through infrastructure breakdown or ongoing commitments to local renewable energy generation. The resilient edge appears to be living in the future for low-carbon infrastructure, which could be a tactical advantage for OE.

Second, we explored the marine energy innovation models discussed at our field sites. We noted how both marine and wind energy is entangled in these models of how OE could be harnessed in the future. We discussed how the sea, an edge essential to OE, cannot be written out of the innovation process, thus making notions of centralising OE, as land-based wind has been centralised, deeply problematic.

Finally, we explored the irrepressible materiality of the sea as an edge. We discussed how struggles to model or to capture in a computer the sea with all the flotsam and jetsam it contains does not need to be only a problem for OE. Instead, we suggest that the overflowing, physical quality of the sea is both the environmental resource that OE depends on and the physical differentiator that makes testing in local sea conditions intrinsic to the sector: marine energy innovation will always be located at the edge, and will always overflow predictions. OE is, in essence, uncontainable and demands constant adaptation to new seas where it is deployed. In essence, we see OE on an ever moving wave of innovation.

Our chapter has attempted to consider marine energy 'edges' laterally, slantwise and against the grain. We have considered the edge as both a located experience and as a concept. We do not regard these as tangential. Rather, this chapter is about how the edge is always both material and semiotic, both raging sea and raw model.

In the marine energy sector, we understand this multifaceted edge as a way to open up how we understand the industry. We find that our three versions of the edge provide a more accurate account and grasp on marine energy and its processes and sites of innovation. Rather than the edge as a lack and limitation to be overcome, we regard the edge as an inseparable part of what makes wave and tide energy devices work, now and into the future – a defining characteristic that is built-in. If we understand wave and tide energy generation as more than a technical endeavour and instead as the development of a social, cultural, environmental, political and technical infrastructure (as we have argued), then the edge becomes an important part of OE infrastructure.

To conclude, the edge is not the end of the world but is where things (whether waves or innovative ideas) transform – a zone of unpredictability that always overflows. As they glint and undulate in the always shifting waves, OE devices, along with all the people, places and work needed to make and maintain them, are not located at an edge that is falling off the map but on an edge that is always connecting, transducing, innovating, never still or powerless.

Notes

1 'Reconfigure' is more than reconceptualise. The latter assumes that a concept is semiotic and 'in the mind' (so to speak), whereas the former, reconfigure, includes the way a concept is made through practice and heterogeneous relations, and so it is both semiotic and material, not just 'in the mind'. For a discussion, see Haraway, D. (1994) A Game of Cat's Cradle: Science Studies, Feminist Theory, Cultural Studies. *Configurations*, 2(1), pp. 59–71.

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