Tidal Energy

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Ocean Energy

- What is Ocean Energy?
- Wave Energy
- Tidal and Ocean Currents
- Salinity Gradients - Osmotic Power
- Ocean Thermal Energy Conversion - OTEC
- Off-shore wind - not considered further in this presentation

Sources of Information

- IPCC report: Renewable Energy Sources and Climate Change Mitigation, 2012
- http://srren.ipcc-wg3.de/report/IPCC_SRREN_Full_Report.pdf
- TETHYS Knowledge Base (US) (http://tethys.pnnl.gov/knowledge-base)
- Elsevier Journal: Renewable and Sustainable Energy Reviews
- ENOVA report on Ocean Energy (2007) (www.enova.no)
- National Strategy: ENERGI21
- http://www.energi21.no/prognett-energi21/Home_page/1253955410599
- www.tidalenergytoday.com

Tidal and Ocean Currents

- Ocean currents - low speed
- Tidal currents - stronger
- Tidal range - potential energy
- Conversion to kinetic energy and electricity
- Today: speeds over 2 m/s necessary
- Potential in UK approx. 50 Twh/year
- Selected inlets and throughflows - as they are
- Robust ocean energy converters a challenge

Tidal Energy in Norway

- Tidal range - low
- Tidal currents - strong
- 2007 assessment tidal energy - 1 Twh per year
- 2009 paper on tidal energy - 17 Twh per year
- Selected inlets and throughflows - as they are
- Robust ocean energy converters a challenge
- Small companies with many ideas

Kinetic energy fluxes

- Flux $\sim 0.5\rho AU^3$
- A is cross-sectional area of a tidal inlet/throughflow
- U is current speed
- ρ is density of sea water
- Assume constant volume flux
- Flux $\rightarrow \infty$ as $A \rightarrow 0$
- Hydropower is large because of dams and pipelines into turbines
- We can optimize the energyfluxes through tidal passages

Tidal Energy - Globally

Estimate of global potential tidal resources

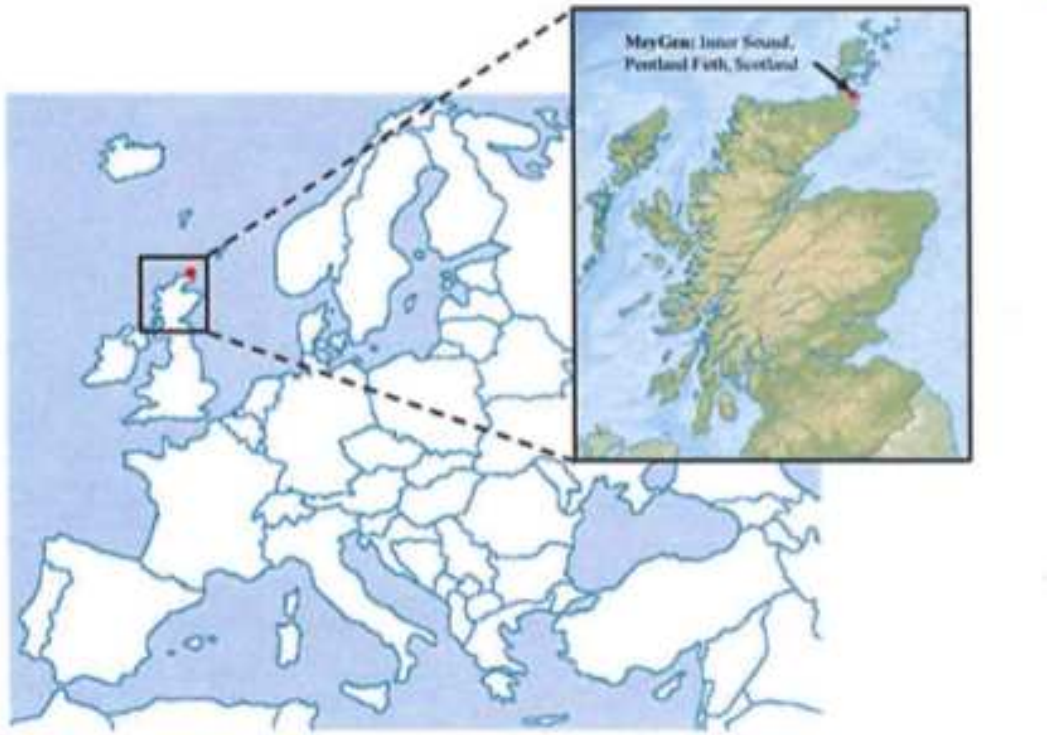
The estimates of global potential of tidal energy generation vary, but it is widely agreed that tidal stream energy capacity could exceed 120 GW globally.

The MeyGen Tidal Stream Project

- Tidal current turbine farm north of Scotland
- 400 Mw to the grid by early 2020
- Atlantis Resources Corporation
- Andritz Hydro Hammerfest

Map - MeyGen

Inner Sound



Map supplied by Black and Veatch

The dimension of the turbine

Andritz Hydro Hammerfest

See www.hammerfeststrom.com

The Open Hydro turbine - Irish Company

Status today on MeyGen

Third MeyGen turbine in place

Image: Atlantis Resources/ Fraser Johnson, Dave Rigg (cropped)

The third Andritz Hydro Hammerfest 1.5MW tidal turbine was installed at the MeyGen site on Saturday, according to Atlantis Resources' social media.

The installation at the project site in the Pentland Firth, Scotland, was done overnight from Olympic Ares, a multipurpose vessel supplied by subsea services provider Bibby Offshore, which has been also used to carry out the commissioning work.

The vessel transported the first turbine to the MeyGen project site on November 6, and another one on November 10.

The first Andritz tidal turbine started producing power on November 15, 2016, after it was installed a week earlier.

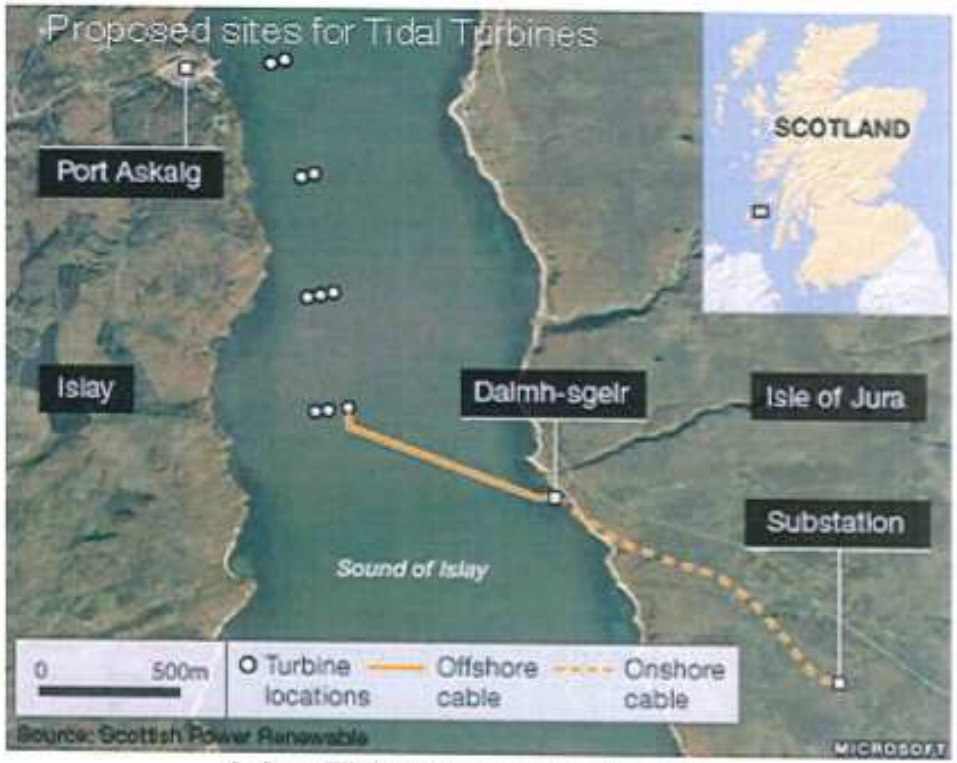
With the third turbine now in place, MeyGen Phase 1A has one more turbine left to be installed.

MeyGen Phase 1A will comprise four tidal turbines with the combined output of 6MW. The MeyGen project is planned to have a total capacity of almost 400MW.

Construction for the next 6MW phase, MeyGen 1B – supported by a €17 million grant from the EC's NER300 fund – is due to begin this year.

Islay tidal installation

Islay Tidal Energy Scheme

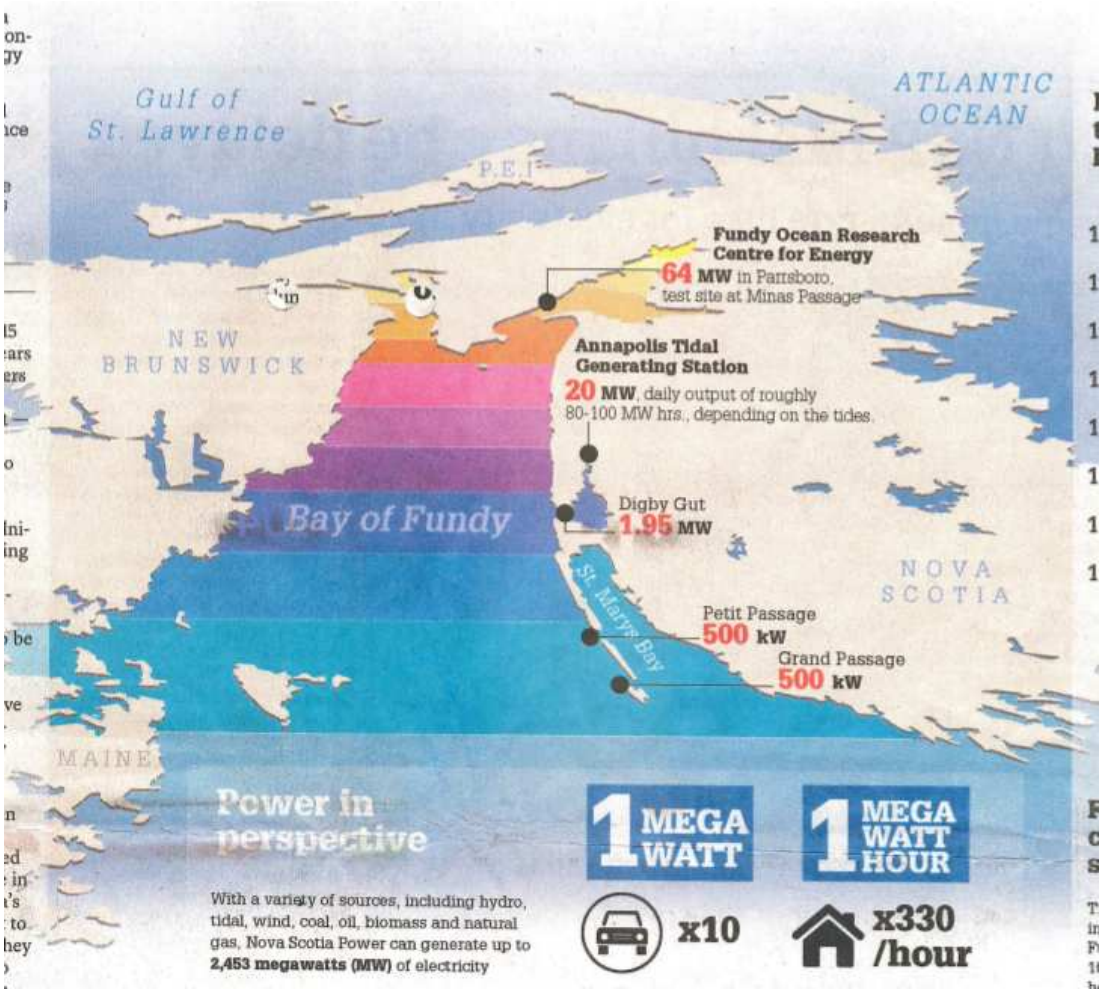


Islay Tidal Energy Scheme

The Scottish government has approved the Islay tidal energy project to build a 10-megawatt array of 10 tidal turbines. It will be the world's largest tidal power array and will generate enough electricity to power more than 5,000 homes, trebling the current capacity of marine energy projects in the UK. There is currently 3.4MW of marine energy installed capacity installed in the UK.

Scottish Power Renewables is to invest £40m to install

The Bay of Fundy tidal energy farm



ICOE 2014- International Conference on Ocean Energy

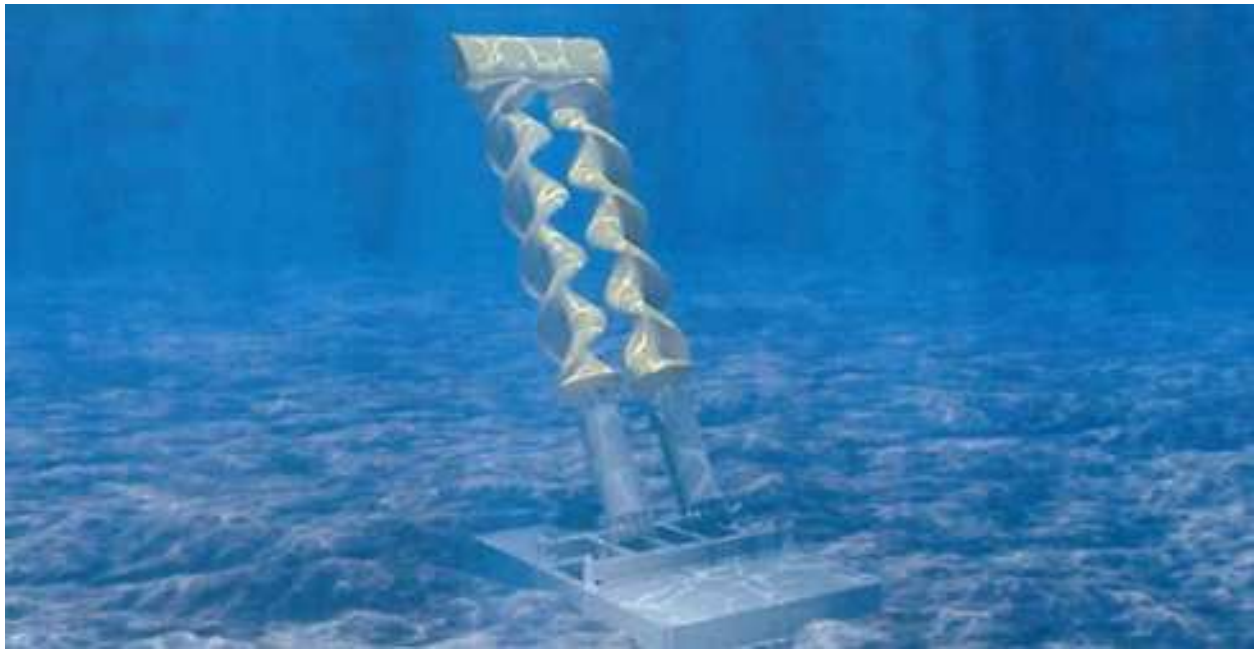
- Halifax, Canada - 700 participants
- Industry, Business, Research centers, Academia
- They ask for convergence?
- Small Companies versus large Companies?
- Long term committment from the governments
- A long list of 'failures'
- Why are ocean energy devices 'destroyed'?
- 3/4 of the costs outside the energy converters.
- It is necessary to bring down costs.

Tidal Sails - To be implemented 2014

See www.tidalsails.com

Flumill - To be implemented 2014

See www.flumill.com



TideTec - Bridges and barrages

See www.tidetec.com

The Lofoten Throughflows

From Gjevik, Moe, and Ommundsen 1997, Nature

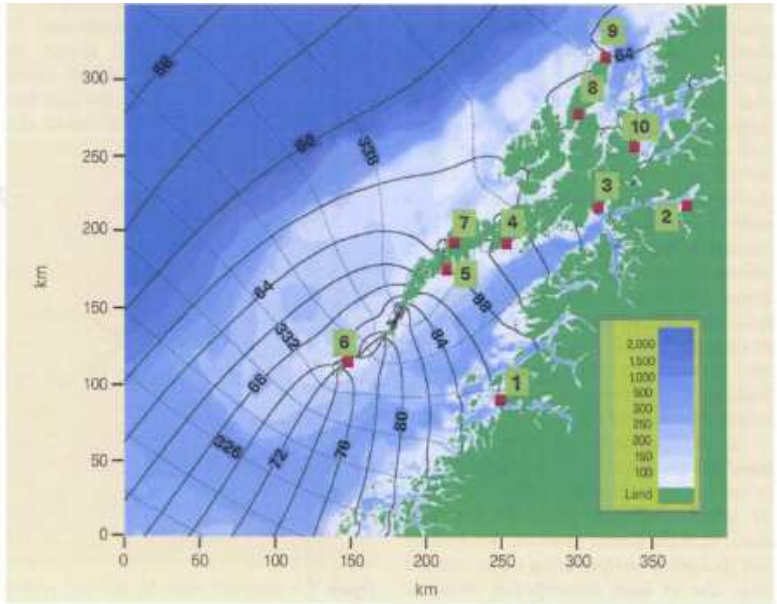


Figure 1 Modelled sea-level amplitude and phase for the dominant semi-diurnal tidal component (M_2). The Lofoten islands extend northeast from Røst (6), to Ladingen (3). Vestfjorden between Lofoten and Bodø (1), Narvik (2), Andenes (9) and Harstad (10). Colour depth-scale is in metres. Solid contour lines show amplitude (in cm) with 2-cm separation. Dotted contour lines indicate phase (deg, GMT) with 2 deg separation. A decrease of 2 deg in phase corresponds to a time delay of the tide of 4 min. Observed/modelled amplitude (in cm) for the stations 1-10: 87/86, 99/100, 93/96, 93/92, 88/89, 78/76, 62/63, 68/66, 65/63 and 69/66, respectively.

around Lofotodden and through the narrow channels between the islands further east. The sea-level variation, with contour lines converging on Lofotodden (Fig. 1) is due to the change in shelf width from a relatively broad shelf south of Lofoten to a narrow shelf further north, and the scatter-

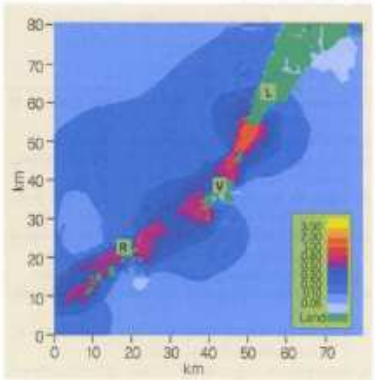
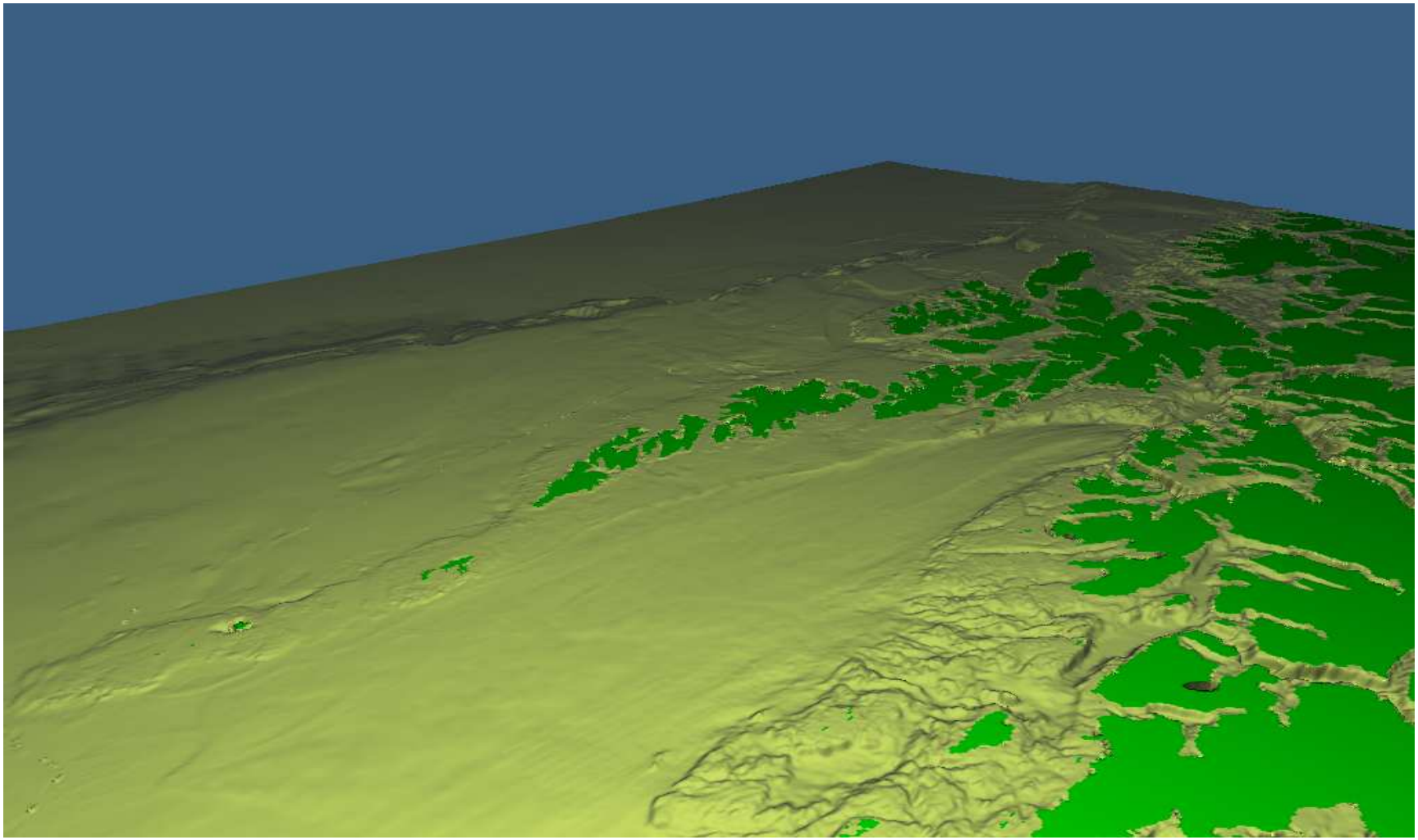


Figure 2 Maximum depth mean current for M_2 in the area southwest of Lofotodden (L) with Værøy (V) and Røst (R). Mosken is midway between L and V. Colour scale is in m s^{-1}. Volume flux through the sections between L and V and between V and R are 0.35×10^6 m^3 s^{-1} and 0.55×10^6 m^3 s^{-1}, respectively, at the peak of the tide. Volume fluxes at spring tide are 1.8 times larger.

NATURE | VOL 388 | 28 AUGUST 1997

3D view of Lofoten



Produced with SUBSEAVIZ (Aase, Grotle and Dombestein 2014)

Tidal energy from the Lofoten throughflows

- Master thesis Johannes Dugstad 2014
- Conversion from potential energy to kinetic energy in the throughflows and inlets
- Tidal energy converters will give blocking effects
- The Lofoten Wall blocks the flows
- Further blocking from energy converters has small effect on tidal range
- $\sim$ 1MW tidal energy potential overall
- May be increased by optimal focusing of the currents
- Environmental effects?

Lofoten-Eco-system perspective

- Historically the cod fisheries is the main source of income in Norway
- Lofoten is the main spawning ground for cod
- Fish, fish eggs and larvae swim/flow trough the troughflows
- Moskstraumen at the tip is especially important
- The throughflows also important for marine mammals and shipping
- Maybe shift focus from throughflows to the shallow areas outside Røst

European Vision Document on Marine Energy- 2010

- European Science Foundation
- Marine Board
- Vision: By 2050 Europe could source up to 50% of its electricity needs from Marine Renewable Energy
- They include offshore wind and marine biomass
- Coordinated action from the research, industry and policy sectors
- Environmental challenges and opportunities
- Marine Spatial Planning

Discussion-Overall

- At present: Ocean energy costs too much
- The large companies are in oil/gas and hydropower
- Low support from the government to push ocean energy
- Several smaller companies try to develop ocean energy converters
- Very good on engineering and technology
- The challenges in a free flowing ocean are neglected
- Many set-backs in early installations
- Still a challenge to build ocean energy converters that are robust and cost-efficient

The role of UiB-Bergen-The West Coast

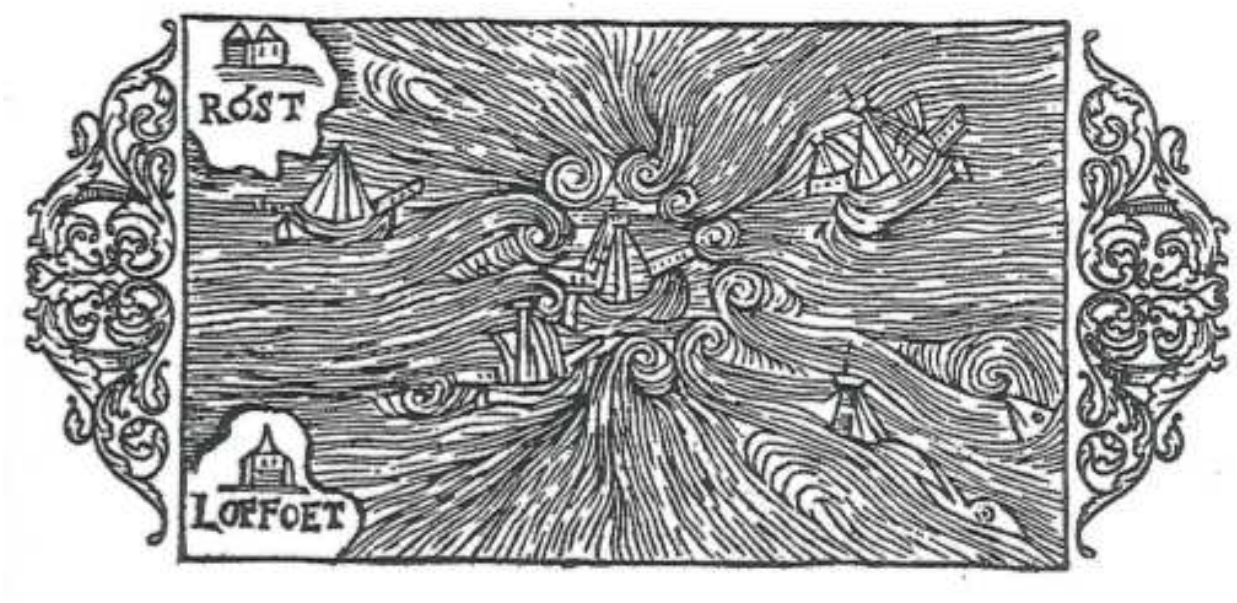
- Marine and Maritime Centers
- Off-Shore industry
- NCE SUBSEA
- Tekno Vest
- World leading on Marine Research
- Education, Research, Technology and Experience

The Energy Transition

- SERC
- Sustainable Energy Research Centre
- Cross-disciplinary
- UiB-board 2015
- We need to fill SERC with activities

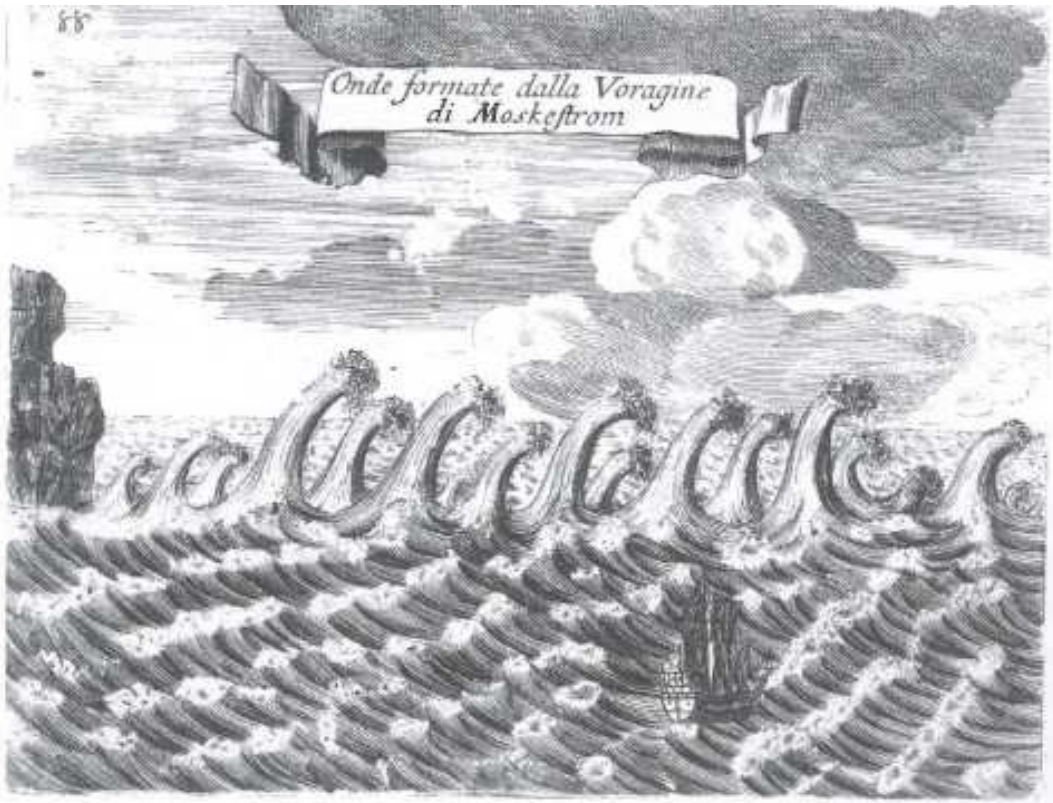
The Moskstraum eddy by Olaus Magnus -1555

From Gjevik 2009 - Olaus Magnus was a Swedish Bishop - Connects the Moskstraum to Odyssev



Wave - Current interactions

From Gjevik 2009 - From Coronelli (1650-1718)



Figur 12.3: To grafiske blad fra Moskstraumen av den berømte italienske karttegneren Vincenzo M. Coronelli (1650–1718). Virvelen i sundet mellom Lofotodden og øya Mosken øverst. Strømsjø og styrtbrenninger nordøst for øya Mosken nederst.