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Environmental effects of marine renewable energy

What do we know?

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Marine renewable energy (MRE):

- Tidal power
- Wave power
- Early stage of development but tidal is further ahead

Driver:

reliable production of low carbon energy (large parks or local solutions)

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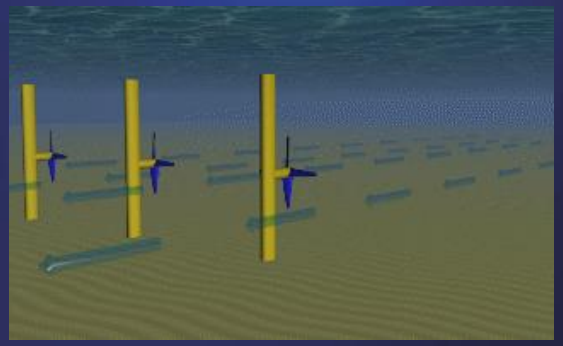
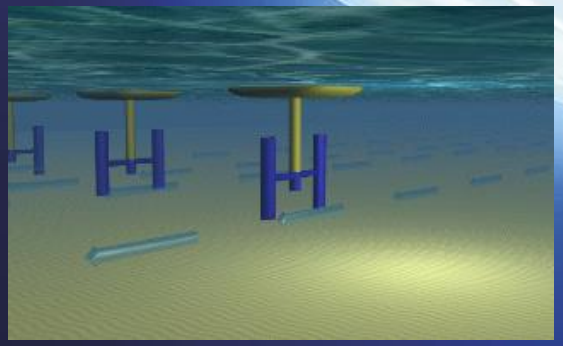
Tidal energy devices

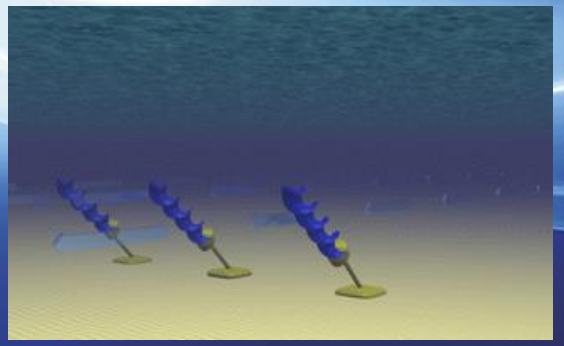
Horizontal axis



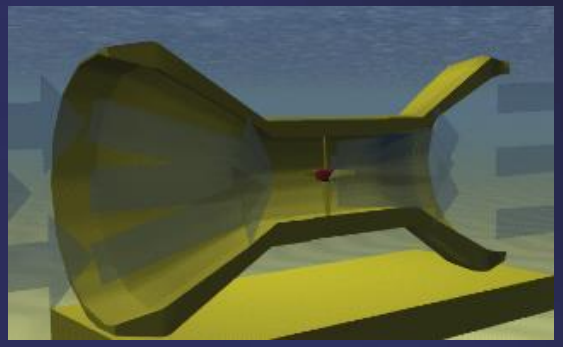
Vertical axis



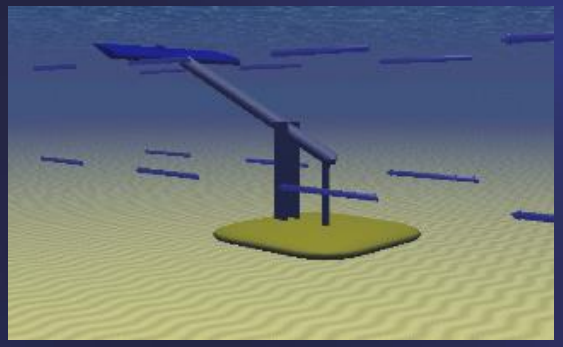
Archimedes screw



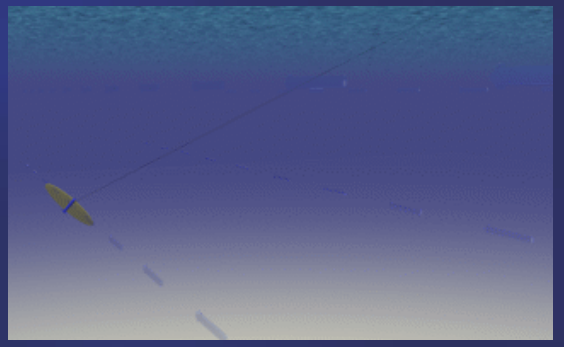
Venturi effect



Oscillating hydrofoil

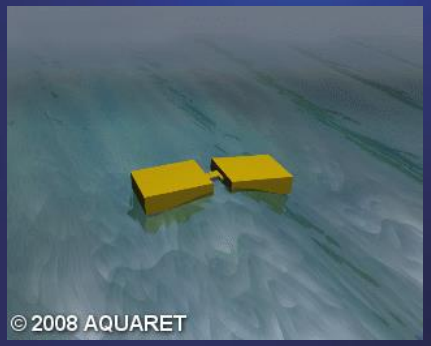


Tidal kite



Wave energy devices

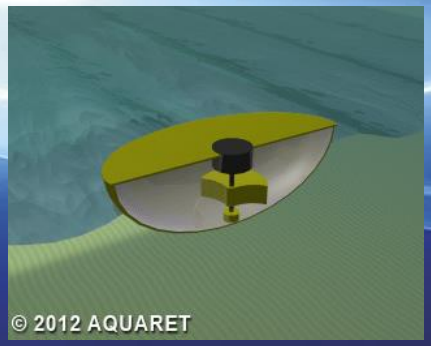
Attenuator



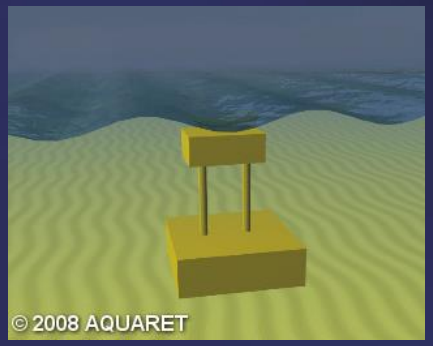
Point absorber

Oscillating wave surge

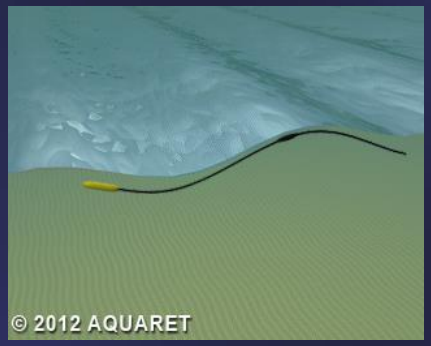
Rotating mass



Pressure differential



Bulge



Oscillating water column

Overtopping

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- MRE = new technologies: unknown potential of harm to wildlife
- Insufficient knowledge of ocean environment in high energy areas
- Concerns about marine species already under stress
- Regulatory/consenting processes are not yet well established

Challenge:

foster MRE development while observing the precautionary principle

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Key potential issues of MRE

1. Collision & encounter risk
2. Underwater noise
3. Electromagnetic fields
4. Habitat changes
5. Spread of non-natives
6. Marine space use
7. Circulation/flushing patterns

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1. Collision & encounter risk

- 3 Scenarios:
  - Natural movement
  - Attraction (curiosity, shelter, feeding)
  - Inability to go against current
- 2 potential outcomes:
  - Injury
  - Death
  - Distraction from other activities
  - Decrease survivability of species already at risk (human activities & climate change)

Marine mammals, fish & sea birds

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Collision & encounter risk-what we know

- No reported collision yet (few devices in the water & little means of monitoring)
- Equipment to observe animal/turbine interactions under development
- Challenges of getting images or sound in high-flow environments (tidal)
- Fish: Lab results show fish are unlikely to get harmed by passing through a turbine
- Mammals: even if hit by a turbine, the animal is likely to recover

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Collision & encounter risk-what we know

- For other spp. we rely on modelling studies but
  - Lack of data species' movement in tidal areas (chance of encounter)
  - Models on single device, not arrays
  - Models often do not account for animal behaviour
    1. change direction
    2. detect and avoid underwater structures
    3. evade the structure at close range

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2. Underwater noise

- Potential behaviour change
  - Attraction
  - Avoidance
  - Interference with communication, navigation, and detection of prey
- Potential physical harm
  - Temporary or permanent reduction in hearing ability
  - Damage to non-auditory tissues
  - Irregular gas bubble formation in fish & marine mammals tissues & nerve damage

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2. Underwater noise – what we know

- No reported damage from operational noise of MRE devices yet
- Lack of knowledge on animal behaviour near MRE devices
  - Human observations
  - Automated observations (optic & acoustic)
- Noise scape of area where device is sited must be understood
- Models made to estimate underwater sound propagation
- Construction noises seem to be more impacting than operational noise (single device)
- More dose/response relationship studies needed with amplitude, frequencies and propagation studies necessary (prob. lab-based)
- More noise measurement at all phases (construction, operations & decommissioning)

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3. Electromagnetic fields

- Sources of EMF
  - power cables
  - moving parts of devices
  - underwater substations or transformers
- Potential effect on spp. using earth's EMF for
  - Hunting
  - Orientation
  - Navigation

  }
  - Elasmobranchs
  - Marine mammals
  - Crustaceans
  - Sea turtles
  - Some fish spp.
- Possible impact on
  - Survival
  - Reproductive success
  - Migratory patterns

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3. Electromagnetic fields – what we know

- Avoidance or attraction
- No information on
  - Long term consequences
  - Impact at population levels
  - Effect of MRE's device additional contribution to EMF
  - Effect most likely on eggs, larvae, benthic or demersal species
  - Only available data: European Commission MaRVEN project (Environmental Impacts of Noise, Vibration and Electromagnetic Emissions from Marine Renewable Energy)

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4. Habitat changes

- MRE devices may induce physical changes
  - Movement of anchor lines or cables
  - Spp. may disappear, appear or the community composition may shift
- Flow and sedimentation changes
- Introduction of new habitat through anchoring structures, device itself
- Attraction (displacement or recruitment?) through artificial reef effect may affect population
  - Movement
  - Structure
  - Success

} Fish, benthic organisms

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4. Habitat changes – what we know

- Tidal
  - Sea Gen (Strangford Lough, Northern Ireland) – loss of habitat directly under the turbine
  - OpenHydro's open-center turbine at the European Marine Energy Centre (EMEC), Orkney, Scotland – benthic and fish attracted
  - High natural variability make other effects difficult to assess
- Wave
  - Lysekil wave test park on the west coast of Sweden - Higher biomass, diversity, and species numbers of benthic organisms & fish

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5. Spread of marine non-natives

- If no new habitat (i.e. soft vs hard) introduced, maybe no "stepping stone effect"
- Aggressive competitors
- Colonise new surfaces quickly
- Compete with native species once established
- Risk of non-natives going from device to the natural habitat

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6. Marine space use

- MRE device presence may exclude other users
- Benefits (*de facto* no-take zone) or loss (e.g. fishing, boating access)

6. Marine space use – what we know

- Low on the agenda in nations where marine space is less coveted
- Developers, regulators, and stakeholders interested in good practices examples

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7. Circulation/flushing patterns

- Tidal circulation and flushing
- Freshwater input from rivers and streams
- Heating at the air-surface interface
- Mixing & exchange of sediments, nutrients, and contaminants
- MRE devices and export cables effect on flow patterns locally & regionally (arrays)
    - Slowing down of flow
    - Speeding up of water in channels

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7. Circulation/flushing patterns – what we know

- Environment for MRE are not well researched - too dynamic & difficult to survey
- Lack of knowledge about the natural variability & the effects of global changes
- Models used for: resource assessment, device survivability, & array siting
- Current non-validated models of array predict little effect of arrays unless they are very large but more field data need to validate numerical models
- Flow change may have food chain, indirect effects, difficult to measure
- Needed: field data, turbulence data, near/far-field effects, cumulative effects within MRE and other effects

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In short

- Consenting process too long
- Risks not yet fully known
- Concerted effort necessary
- Administrative path and jurisdiction need clarification

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OES OCEAN ENERGY SYSTEMS
An IEA Technology Initiative

ANNEX IV

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Annex IV is a collaborative initiative of the Ocean Energy Systems (OES), under the International Energy Agency (IEA) Technology Network.

http://tethys.pnnl.gov/publications/state-of-the-science-2016

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