CHAPTER 10

KEY ISSUES FOR SEA IN THE TIDAL ENERGY SUB-SECTOR

10.1 WHY SEA IS IMPORTANT TO THE TIDAL ENERGY SUB-SECTOR

SEA can provide critical information to support better decision-making for tidal energy planning and development, including identifying where there may be implications for a PPP to adequately address significant environmental and/or socio-economic risks and impacts. This information can be particularly important to identify and assess the scale and significance of possible cumulative impacts of of multiple tidal energy schemes/developments whether alone or in combination with other renewable energy technologies (e.g. offshore wind energy).

The SEA process will:

- Identify and focus on key environmental and socio-economic issues and the concerns of likely affected stakeholders, including local communities, marginalised groups and indigenous peoples. Major issues are discussed in detail in section 10.5 and are summarised in Table 10.2.
- Identify/recommend if there are areas that should be avoided for tidal energy development ('no go' areas) because of particularly high risk to the environment, habitats/biodiversity and/or people.
- Identify what changes or additions are required to PPPs governing tidal energy development to address these risks.
- Make subsequent project-level EIAs more efficient and cheaper by addressing the big picture and upstream, downstream and cumulative potential impacts, identifying the particular issues that individual project EIAs should focus on in more (site-specific) detail. This may also include spatial planning recommendations for optimal siting of tidal energy projects to minimise these risks and impacts.
- Engage stakeholders (particularly in areas where tidal energy potential has been identified) including communities, marginalised groups and indigenous peoples which can be particularly affected by tidal energy developments - to be informed of proposed or possible policy options or plans and enable them to provide their perspectives and present their concerns. This will enable key issues to be identified and verified, help build understanding and support for tidal energy development, and avoid future misunderstanding and possible conflicts.

The steps and methodologies available for use in SEA are common to all SEAs, whatever they are focused on, and reflect internationally accepted standards of good practice. They are discussed in detail in Chapters 1 and 3 and are therefore not repeated in this chapter.

10.2 EXISTING SEA GUIDANCE/GUIDELINES FOR THE TIDAL ENERGY SUB-SECTOR

An international survey of existing SEA guidelines conducted for the IAIA was unable to identify any that are specifically focused on the tidal energy sub-sector. Similarly, there appear to be very a few guidelines specific to EIA for tidal energy development projects. One example is from the UK[1].

Various sources discuss the environmental impacts of tidal energy[2].

[1] Environment Agency (2011)
[2] e.g., Choose Clean Power (2022); Burrows *et al*. (2009)

10.3 TIDAL ENERGY INSTALLED CAPACITY

Compared to other renewable energy technologies, tidal energy is still in development. In 2021, global installed marine/tidal energy capacity was 524 MW. The main producing regions were Asia (dominated by South Korea) and Europe (dominated by France and the UK) (Table 10.1).

Table 10.1: Marine (tidal) energy installed capacity, 2021
Source: IRENA (2022b)

Region	Installed capacity (MW)
World	524
Asia	260
South Korea	*256*
China	*5*
Eurasia	2
Russia	*2*
Europe	241
France	*212*
UK	*22*
European Union	219
North America	20
Canada	*20*
Oceania	1
South America	0
Australia	1

10.4 BACKGROUND TO TIDAL ENERGY GENERATION

Tidal power is a form of energy generation that utilizes either the tide or marine currents to generate electricity. Although not yet widely used, tidal energy has the potential for future electricity generation. Tides are more predictable than the wind and the sun.

Historically, tide mills have been used both in Europe and on the Atlantic coast of North America. The incoming water was contained in large storage ponds, and as the tide goes out, it turns waterwheels that use the mechanical power to mill grain. The earliest occurrences date from the Middle Ages, or even from Roman times. The process of using falling water and spinning turbines to create electricity was introduced in the U.S. and Europe in the 19th century.

Tidal energy is still not widely used and has had limited commercial rollout to date, partly due to:

- The high costs of development (tidal energy can be almost 10 times more expensive than other renewable technologies[3]) and the technical challenges created by the harsh nature of the marine environment and the sensitivities of estuarine areas;
- Limited availability of sites with sufficiently high tidal ranges or flow velocities;
- The potential environmental impacts and the site-specific topographical changes needed to locate and establish such schemes in environments sensitive to change.

However, many recent technological developments and improvements, both in design (e.g. dynamic tidal power, tidal lagoons) and turbine technology (e.g. new axial turbines, cross flow turbines), have helped to address some of these issues and indicate that the total availability of tidal power may be much higher than previously assumed and that economic and environmental costs may be brought down to more economically competitive levels.

Globally, there has been a tenfold increase in tidal energy production in the past decade[4].

[3] www.statista.com
[4] Largue (2020)

The world's first large-scale tidal power plant was France's Rance Tidal Power Station, which became operational in 1966. It was the largest tidal power station in terms of output until Sihwa Lake Tidal Power Station opened in South Korea in August 2011. The Sihwa station uses sea wall defense barriers complete with 10 turbines generating 254 MW.

Tidal power can be split into two subsets: tidal stream and tidal range.

10.4.1 Tidal stream power generation

Tidal stream power generation utilizes the flow of currents through a turbine. This is akin to wind turbines and converts kinetic energy in the water into electricity. The turbines are located below the surface and are generally less visible as limited surface infrastructure is required.

Tidal stream infrastructure requires placement of turbines in areas where there are high velocity marine currents. Turbines can be located individually or in an array configuration and can be either suspended on the sea surface or fixed to the seabed. Electricity is transported to an onshore substation via an undersea cable and is then exported to the electricity grid.

Some examples of tidal stream projects are provided in Box .

10.4.2 Tidal range power generation

Tidal range energy generation uses a form of barrage to impound the water at high tide, so that at low tide a difference in head is created and used to drive a turbine. This is a "reaction" type turbine that converts pressure into electricity and is based on low head hydropower technology. It is possible to generate electricity on both the ebb and flood tides.

Tidal range turbines are placed at estuarine or coastal locations and require a barrage with a low-sitting profile.

There are two types of tidal range arrangements:

- A barrage arrangement is typically located across an estuary and impounds water in the estuary;
- A lagoon arrangement is a form of barrage that encloses a body of water, either connected to the coastline or placed entirely out to sea.

In both cases, turbines are in a linear powerhouse arrangement forming part of the barrage body.

Tidal range infrastructure with barrages that incorporate turbines usually consist of:

- Embankments, constructed where there are gaps along an estuary, and to enable access;
- The barrage structure;
- Turbines, located along the barrage structure;
- Openings, fitted with control gates to enable flow at a particular time; and
- Locks - one or more to enable boat traffic (if required).

Box **10.2**10.2 provides examples of existing barrage projects. No lagoon-type projects have been taken beyond the planning stage anywhere in the world. Therefore, a lot of currently unknown risks and factors need to be expected in these environments. Planning for the Tidal Lagoon Swansea Bay in southwest Wales is well advanced and will be the world's first purpose built tidal energy lagoon. The generating station will have a capacity of 320 MW. To deliver the project, a U-shaped 9.5 km long seawall is required, encompassing 11.5 km^2 of the seabed, foreshore, and intertidal area of Swansea Bay.

Box 10.1: Examples of Tidal Stream Projects

(A) Current projects

The MeyGen tidal energy project is located at an offshore site between Scotland's northernmost coast and the island of Stroma. Here, multiple turbines installed on sub-surface gravity turbine support structures operate in a high flow and medium water depth environment. When fully developed, it will be the world's largest tidal energy project with the option to develop a tidal stream project of up to 398MW.

Figure 10.1: MeyGen tidal energy project's sub-surface turbine during transportation prior to commissioning

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Orbital Marine Power's O2 turbine went into operation in July 2021 in the waters off Orkney in Scotland. The floating 74-meter-long turbine is anchored in the Fall of Warness, where a subsea cable connects the offshore unit to the local onshore electricity network.

Figure 10.2: A turbine at Orbital Power's 'O2' turbine in operation

Figure redacted pending securing copyright permission to use. If you have an image showing this spatial distribution that you can provide (with permission to use – please indicate the credit to cite) we would be delighted if you can send it.

(B) Emerging tidal stream projects in Southeast Asia

Zambales, Sorsogon, Northern Samar, and Surigao del Norte provinces, Philippines. Multiple sites are at pre-development and development contract stage for projects with the capacity to generate between 5–10 megawatts (MW). These projects are being undertaken by a number of different companies[5].

Larantuka Strait, Indonesia. Nova Innovation's FLITE (Feasibility of Larantuka and Indonesian Tidal Energy) project is currently underway. It will deliver a feasibility study for Larantuka Strait which lies between the islands of Flores and Adonara and has one of the strongest tidal currents in Indonesia.

Larantuka and Boleng Straits, Indonesia. In early 2022, the UK-based energy developer SBS International Limited signed a memorandum of understanding with the state-owned Indonesia Power for the development of tidal energy projects for both the Larantuha and Boleng Straits.

Source: OES | Ocean Energy Systems - an IEA Technology Collabouration Programme (ocean-energy-systems.org).

[5] awarded_ocean_2020-12-31.pdf (doe.gov.ph)

Box 10.2: Examples of barrage projects

(A) Operational Projects

***Shiwa Lake, Gyenggi Province, South Korea*.** Construction of the 12.7 kilometer (km) tidal barrier in 1994 at Sihwa lake (c.20 km SW of Seoul) subsequently became an opportunity to commission a 260 megawatt (MW) capacity hydro project in 2010.

La Rance Tidal Power Station, France is located on the estuary of the Rance River, in Brittany. It was the world's first tidal power station, opening November 1966. The Rance Barrage is 750 meters (m) long and 13 m high, enabling a peak capacity of 240 MW to be generated by its 24 turbines.

Figure 10.2: La Rance Tidal range barrage, France

Figure redacted pending securing copyright permission to use. If you have an image showing this spatial distribution that you can provide (with permission to use – please indicate the credit to cite) we would be delighted if you can send it.

***Bay of Fundy, Annapolis Royal, Nova Scotia, Canada*.** This is the only barrage project in North America. The Annapolis tidal plant was commissioned in 1984 and had a generating capacity of 20 MW using a single 7.6m diameter turbine. It was decommissioned in 2019 due to equipment failure that was considered uneconomical to repair.

Each of these sites used traditional hydropower technology adapted for marine conditions. Due to the wide head range associated with the tides, these projects cannot fully exploit the potential energy available due to the limitations in operation ranges and poor efficiency at extremes of operation. A report by Sidgwick and Macrae (2016) suggested that recent developments in variable speed converter and turbine technology at the time made it possible to generate efficiently across a much wider range of heads.

An example of using this technology is the ***New Bong Escape Hydropower Project in Pakistan***. This is a low head 84MW hydro power scheme located on Bong Canal/Jhelum River basin in Azad Kashmir. Construction commenced in 2009 with commissioning in 2013, It generates power through four 21 MW low head high efficiency Kaplan turbines.

(B) Emerging Barrage Projects

***River Wyre, Fleetwood, England*.** The project is located at the mouth of the River Wyre, requiring a 600 m barrage between Fleetwood and Knott End on the Lancashire Coast. Natural Energy Wyre (NEW) has been planning the project that seeks to generate 160 MW, providing electricity for an estimated 50,000 homes.

***Derby, Western Australia, Australia*.** Tidal Energy Australia is the proponent securing approvals for the Derby Tidal Energy Project. The project proposes to generate 40 MW of electricity, with potential to supply enough to power 10,000 to 15,000 homes.

10.5 IMPACTS OF TIDAL ENERGY DEVELOPMENT

During scoping for a SEA, key issues regarding tidal energy development should be identified. They will be used to focus the SEA on the most important issues and to help develop environmental and social quality objectives (ESQOs) – that address these issues - to be used during the main assessment stage. The key issues will be identified by reviewing relevant documents (e.g., EIA and special subject reports, environmental/social profiles, sector and inter-sector strategies, donor documents, academic papers, other tidal energy development applications, interviews with key informants and during stakeholder consultations at national to local levels. Many of the issues will be well known as a result of implementing other tidal energty development projects.

At the individual project-level these issues will be the focus of an EIA which should recommend how to manage or mitigate project impacts associated with these issues that might be likely to arise. Ideally, before individual tidal energy projects are approved, the implementation of a policy, plan or programme (PPP) for tidal the sub-sector should be completed. This will involve the assessment of multiple likely projects, schemes and activities, some directly concerned with the construction and operation of sites and facilities; and others linked to associated infrastructure (e.g cables). Thus, there is a risk that the impacts of individual developments/projects may become highly significant as they become cumulative. A SEA should focus on the potential for such cumulative impacts and make recommendations for addressing them. This may include recommending thresholds for particular factors that should not be breached by an individual project (and which should be addressed by a project-level EIA). Where the risks of cumulative impacts are extremely high, this might provide the basis for the SEA report to recommend an alternative to the PPP or components of it. Often, the timing of individual tidal energy applications and overarching SEA planning is not synchronized, and SEA may have to “catch-up” to the pace of individual projects rather than providing upstream (pre-project) guidance as to how they should proceed.

Table 10.2 summarises the key environmental and socio-concerns concerns likely to be associated with tidal energy development.

Table 10.2: List of key environmental and socioeconomic issues for tidal power (tidal stream and tidal range generation)

ISSUE	COMMENT
Environmental	
Physical changes (e.g. to estuaries and river channels)	• Modified tidal and residual flows -scouring around structures • Reduced vertical mixing, leading to increase in density stratification • Reduced levels of suspended particulate matter, leading to increased light penetration • Reduced saline penetration within the basin leading to freshening (i.e., more brackish water)
Air quality	• Emissions from vehicles, barges, dust (during construction)
Water quality	• Build-up of physical and chemical contaminants due to reduced flushing rates. • For tidal range projects that include barrage infrastructure, the amount of natural vertical mixing of sea water will be reduced due to the reduced tidal flows; and there will be less re-suspension of particulate matter, leading to decreased light penetration; and reduced saline penetration within the basin leading to freshening i.e., more brackish water. • In areas of increased flows, there may be potential re-suspension of contaminated sediments—with net reduction in water quality • Toxic paints, lubricants and antifouling coatings used on offshore tidal infrastructure can affect sea water and sediment quality
Greenhouse gases	• Tidal energy can reduce GHG emissions where it displaces coal as a fuel source
Impaired land drainage	• Impaired drainage due to increase in average water level inside the basin, which could lead to a decrease in ground water flows
Loss of habitats and biodiversity	• Especially intertidal mudflats and salt marshes—important for some species of birds and can be nationally and internationally protected areas. • Benthic habitats may change due to bottom stress as a result of modified waves and currents • Migratory fish may be impeded although fish passes can be constructed • Fish and marine mammals may suffer damage by collision with the barrage and turbines. • Some estuaries may provide nurseries for breeding fish and conditions for these may no longer be suitable • An increase in primary productivity may enhance the population of filter feeders • Tidal stream infrastructure can have negative impacts on biodiversity, including disturbance and displacement, collision, and entanglement and introduction of nonnative species, and can also modify or create new habitats
Noise	• During construction and operation • Changes to ambient noise in aquatic environments can affect many types of aquatic life, including marine mammals, fish, and birds—changing their responsiveness to other stimuli, masking, temporary threshold suppression and injury, as well as interfering with communication, echolocation for navigation, spawning and shoaling behavior
Land or marine use change	• Some coastal land used for agricultural grazing or crops may be lost or more gained. • Change in access to tidal areas • Potential to impact on localized fisheries
Visual and aesthetic impacts	• Tidal infrastructure may impact on the aesthetic view and landscape of the host community • Possible impact on recreation and tourism (may deter or possibly attract tourists) • Temporary disruption or permanent loss of port, commercial, and recreational shipping activities
Marine and ecosystem restoration	• Tidal energy systems are inherently age resistant and have long lifespans. The average estimate for most tidal systems is 75-100 years of working use. After this, some components might be decommissioned and restoration of the local marine ecosystem will be

ISSUE	COMMENT
	required. Other structures might be left in situ to conserve changed (since prior to construction) ecosystems that are likely to become established.
Socioeconomic	
Local economy and livelihoods	• Diminished income of fisherfolk due to restrictions on access to mudflats • Restricted or denied access for shellfish gatherers • Disruption to fisherfolks' pier and landing areas and potential damage to fishing gear from contact with turbines • Price of land and housing near the project area may decrease • Displacement of people when land acquired for access roads and transmission lines
Gender and vulnerability	• Vulnerable groups (e.g., the poor, women, persons with disabilities, children, the elderly, and indigenous communities) may be disadvantaged and at particular risk where coastal communities are dependent on fishing. • Employment opportunities within new projects. • Opportunities for vulnerable groups to acquire new skills and learn new technologies
Cultural heritage	• Loss of religious, historical and archaeological sites and properties • Destroyed or damaged due to transmission lines and access roads • Limited access to cultural heritage sites
Employment and labour conditions	• Employment in the construction and operation phases of projects • Employment in relation to projects' associated activities • Substandard working conditions • Worker safety • Opportunities for workers to acquire or learn new skills
Health and safety	• Noise from the tidal structures can disturb beach users or nearby communities • Electricity transmission lines from the tidal power plants may be a safety issue for nearby communities during construction and operation (e.g., electric shocks from touching live cables)
Transportation	• Marine transport and navigation may be disrupted but a barrage also gives potential for road and rail crossings • Access to shoreline may be impeded
Public services and infrastructure	• Infrastructure (e.g., roads and bridges, schools, health centers, and administrative buildings) may be improved due to community investment by tidal power companies • Pressure on public services and infrastructure will increase as a result of immigration • Heavy vehicles and transportation can damage existing roads and bridges • Increased vehicle traffic during construction

10.5.1 Environmental issues and impacts

Physical changes to estuaries, river channels, terrestrial and benthic environments

Benthic habitats (those on the sea or ocean floor) can be altered, or instead can be created, by offshore tidal stream infrastructure. They are modified due to direct disturbance (e.g., seabed clearance) caused by new infrastructure introduced to either tether surface turbines, house sub-surface alternatives or deliver power back to the shore via cables[6] . Depending on the sensitivity of the local environment, structures can cause changes to bathymetry, including tidal flows, waves and currents which can have negative impacts on marine and estuarine habitats, flora, and fauna.

By retaining sea water for part of the tidal cycle, there will inevitably be some changes in an estuary basin and its channels. The tidal and residual flows will be modified, possibly leading to some local scouring around the new structures (specifically in the outflow regions of the turbines and sluices) and siltation in the basin. An increase in average water level inside the basin would lead to a decrease in ground water flows which may have impacts on land drainage[7] . The extent of these effects is dependent upon how the barrage structure is operated and will be specific to each site and each local environment.

All types of tidal power infrastructure also have the potential to have negative impacts on terrestrial environments. Where sites with strong tidal flows are in locations that do not already have access to the power transmission network, then clearing of vegetation will be required for transformers and transmission lines, and for access roads to enable construction and maintenance. This can lead to the fragmentation or loss of habitats and biodiversity, and disturbance or relocation of fauna (see discussion in section on habitats and biodiversity in Chapter 9 (section 9.3.1) for further information as the effects are similar).

A key principle of SEA is to address the cumulative impacts of multiple projects, schemes and developments that may arise when a PPP is implemented. However, it is unlikely that many tidal projects will be developed in any individual country. Assessing their cumulative impacts in an estuary will be difficult. At present, there are only a handful of commercially-operating tidal power plants worldwide. However, many new projects have been proposed or are in development with the potential environmental and social impacts of these not yet fully understood. So, given the lack of existing experience of the impacts of tidal power schemes, a precautionary approach to impact assessment is warranted. But there will be cumulative impacts arising from the combination of developing tidal power schemes and other renewable energy projects (e.g. from the construction of transmission lines), as well as from projects in other sectors and from other land uses in an estuary.

Air quality

During operation, tidal power does not normally have significant impacts on air quality. There will be impacts during construction, e.g., emissions from machinery and vehicles (trucks, workers' vehicles, generators, etc.) and dust from land clearing to construct terrestrial infrastructure (barrages, access roads, substations and transmission lines). The severity of such impacts will depend on the proximity of sensitive receivers. Once operational, the quality of the air around tidal power infrastructure will likely return to pre-construction levels since there will be only a low number of vehicle movements and few sources of dust.

Water quality

Modified flow rates or changes in mixing and settlement of particulate matter caused by tidal power turbine infrastructure (for both tidal stream and tidal range) have the potential to change the water quality and sediments. This includes mixing (both physical and chemical) of built-up contaminants in

[6] Orbital Marine Power (2021)
[7] Wolf *et al.* (2009)

areas where flows are increased. Contaminated sediments can also become re-suspended reducing water quality. This impact, coupled with increased turbidity, has the potential to affect the health of marine and estuarine life in the local area.

Toxic paints, lubricants and antifouling coatings used on offshore tidal infrastructure can also contribute to reducing sea water and sediment quality. Depending on the tidal energy technology, hazardous chemicals could be accidentally released to the marine environment during installation, operation, maintenance, and removal. This can occur due to an unplanned acute release of fluids and contaminants, or a spill of large amounts of lubricants, hydraulic fluids, vessel fuel or other petroleum-based products and gradual releases of toxic contaminants over time from antifouling coatings used on tidal devices.

Further complications could result if the contaminants bioaccumulate in the food chain, potentially affecting public health if the aquatic organisms are consumed by humans[8].

For tidal range projects that include barrage infrastructure, the amount of natural vertical mixing of sea water will be decreased due to the reduced tidal flows; and there will be less re-suspension of particulate matter, leading to increased light penetration. The reduction in mixing will also lead to an increase in density stratification. There will be reduced saline penetration within the basin, leading to freshening (i.e., more brackish water). There may be a build-up of contaminants (both physical and chemical) due to the reduced flushing rates. In areas of increased flows, there may be potential for the re-suspension of contaminated sediments which could cause a net reduction in sea water quality. An abundance of nutrients combined with increased light penetration may cause increased primary production, potentially leading to eutrophication[9] . The extent of these effects is dependent upon the how the barrage structure is operated and will be specific to the local environment.

Habitats and biodiversity

Estuarine and lagoon environments are important habitats for invertebrates, fish, and some species of birds and marine mammals, and all are susceptible to local environmental change. The uniqueness, and often remoteness, of these sites is recognized. They are often listed as nationally and internationally protected areas.

Tidal power infrastructure can lead to localized environmental changes that occur due to housing, installing, and operating the turbines. These changes are most notable with tidal range projects where water regimes (flow and depth) are affected by infrastructure installation and operating methodologies. They can result in a direct loss of habitat and biodiversity (including birdlife), particularly in estuaries and lagoons with intertidal mudflats and salt-marsh habitats that are susceptible to change. These habitats are often nurseries for breeding fish and are particularly vulnerable to the changes that would occur during construction and operation. As a result, the introduction of new infrastructure has the potential to impact on local fisheries, resulting in a reduction of local fish populations and diversity in the area and reduced access for migratory bird species. Intertidal mudflats habitats are also susceptible to change because of altered tidal flows.

Tidal barrages can impede migratory fish paths and breeding cycles. However, depending on the species of fish, the risk can be mitigated to some extent by fish ladders.

There is some understanding of the interaction between marine wildlife and tidal turbines and the potential for collision[10]. There is a low risk of marine animals colliding with underwater turbines constructed for offshore tidal steam projects. There have been only rare and isolated instances of such collisions with tidal range infrastructure involving barrages. The Annapolis Tidal Station (operating from 1984 to 2019 in the Bay of Fundy in Canada) saw two incidents involving humpback whales. In the last decade, there have been advances in methods to prevent fish and marine life

[8] Polagye *et al*. (2010)
[9] Wolf *et al*. (2009).
[10] Carlson *et al*. (2013).

mortality when passing through turbines, and deterrent devices for marine mammals are available for new infrastructure[11].

Tidal stream infrastructure can have negative impacts on biodiversity, including disturbance and displacement, collision and entanglement and introduction of non-native species, and can also modify or create new habitats[12].

Electromagnetic fields (EMF) associated with tidal power generators and underwater power cables can affect aquatic wildlife in the near-field of the device, array, or cable[13] , although the effects may be location-specific. The EMFs can be potentially sensed by fish and evoke avoidance or attraction behaviours. Some species of fish, such as sturgeon and eels, appear to be particularly sensitive to EMF, and others, such as salmon, do not appear to be as sensitive. Sharks, skates, rays, ratfishes, and other elasmobranchs can detect faint electric fields[14].

The effects of tidal power infrastructure (including cables) on fish behaviour are not clear. In situ studies of EMF effects are challenging to conduct and, often, inconclusive.

Surface structures in estuaries and at sea that require lighting for safety and navigation have the potential to affect seabirds and aquatic species, including fish.

Noise

Various activities and processes, both natural and human made, combine to form the sound profile (ambient noise) at and below the surface in estuaries, lagoons, and the open sea. Changes to ambient noise in aquatic environments can affect many types of aquatic life, primarily invertebrates, fish, but also marine mammals.

Tidal power noise sources that change existing ambient noise vary during construction and operation. The nature of these impacts will vary according to the receiving environment (whether onshore—estuaries and lagoons, or offshore—marine) and to the sensitivities of the species living on land, in intertidal areas and in the water near the tidal infrastructure.

For fish and marine mammals in particular, the observed effects of changes in ambient noise include changes in their responsiveness to other stimuli, masking temporary threshold suppression and injury, as well as interfering with communication between members of particular species, echolocation for navigation, spawning, and shoaling behaviour[15].

Short-term changes to ambient noise occur during construction for both tidal stream (during installation of rock anchors and cables) and tidal range (during barrage construction). Temporary increases in vehicle traffic, construction equipment, vessel engines, propellers, drilling, and piling contributes to the changes in noise levels.[16]

Noise from the operation of machinery and turbines housed in sub-surface structures has potential to change the ambient underwater noise (sound pressure and particle motion) for extended durations over a longer term, and this can affect marine life.

Land and marine use change

All tidal power infrastructure has the potential to change land and marine uses, both at the site of the infrastructure and along the transmission lines and access roads. Some coastal land used for agriculture and/or livestock grazing may be lost or, potentially, gained with land reclamation for

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[11] Neill *et al*. (2018).
[12] Orbital Marine Power (2021)
[13] Bochert and Zettler (2006)
[14] Öhman *et al*. (2007)
[15] Michel *et al*. (2007)
[16] Gill *et al.* (2005)

infrastructure. Shellfish fisheries relying on the intertidal zone (e.g., cockles and mussels) are most susceptible to being affected by changes in water volumes. If these changes are significant, these livelihoods, and similar fisheries reliant on the existing intertidal environment may be affected if there is a change (including restriction) in access for local communities.

The development of shore-based infrastructure can cause a change in land use (and loss of livelihood for some people) and may lead to conflicts over land use and access to areas and resources—making co-location problematic or impossible.

There have been advances in the industry over the last 10–15 years in structure, design, and turbine technology that minimize the footprint extent of projects, and evolution will be ongoing as the technology develops further.

Tidal area habitats are often nurseries for breeding fish, and the introduction of new infrastructure can cause a reduction of local fish stocks. This has the potential to make fishing in the local area unviable, or force fisher folk to turn to other uses of marine and estuarine environments.

If existing access to the power network is not available for either tidal stream or tidal range infrastructure, then there will be land clearing for onshore transformers, transmission lines, substations, and access roads. This may change local access to agricultural land and conservation areas along the routes.

Visual and aesthetic impacts

The visual and aesthetic impacts of tidal power projects will depend on location. Both tidal stream and tidal range power infrastructure can result in changes to the visual appearance and aesthetics of the receiving local environment. These changes can occur at the site of the infrastructure, particularly for tidal range infrastructure and along onshore transmission lines. Subject to the local tidal environment and siting methodology, tidal stream projects are often less visible and have less aesthetic impact.

The character of an area and the landscape may be drastically changed if a tidal barrage (for tidal range sites) is constructed, but there may be pros and cons. Some people may find the visual intrusion of tidal power schemes objectionable and feel they undermine the scenic appeal of coastal areas, particularly barrage schemes. But others find tidal schemes of considerable interest[17]. The change in the speed and rise of tides resulting from tidal power schemes can be dramatic, particularly in estuarine areas, detracting markedly from the aesthetics of more inland areas of estuaries[18].

Generally, a tidal lagoon has a surface barrier marking the area. Control centres may be built into the water or on the land.

Figure 10.3 shows how a tidal project can look in open water where the visual impact is limited[19].

Figure 10.3: Tidal energy depiction in open water

Figure redacted pending securing copyright permission to use. If you have an image showing this spatial distribution that you can provide (with permission to use – please indicate the credit to cite) we would be delighted if you can send it.

[17] Tidal Power - Disadvantages of Tidal Power.
[18] Tidalpower (undated)
[19] https://education.nationalgeograophic.org/resource/tidal-energy

Marine and ecosystem restoration

As discussed above, there are significant risks associated with tidal power development with regard to potential environmental harm and degradation, e.g. loss of habitats and biodiversity and ecosystem services, coastal land and marine use change, unnecessary or excessive deforestation when constructing new on-shore access roads and transmission lines, This will particularly arise where mitigation measures proposed by a SEA (and subsequent project-level EIAs) are inadequate, ineffective or not undertaken. The significance and seriousness of such degradation can be compounded where the impacts are cumulative and extensive. Such cumulative impacts will be highly likely to occur where there are multiple tidal power developments across areas of sea in combination with other coastal development projects and activities.

The need and nature for land/marine and ecosystem restoration is discussed in Box 3.9. For most renewable energy developments, this need will also arise at sites of projects that have come to the end of their useful operational life. However, tidal energy systems are inherently age resistant and have long lifespans. The average estimate for most tidal systems is 75-100 years of working use. After this, some components (e.g., turbines and housings) might be decommissioned (see Box 10.2) and restoration of the local marine ecosystem will be required. Other structures (e.g., barrage walls) might be left in situ to conserve changed (since prior to construction) ecosystems that are likely to have become established.

Box 10.2: Decommisioning of Strangford Lough tidal turbine, Norther Ireland

A tidal energy turbine installed in Strangford Lough, County Down, Northern Ireland is to be removed. The SeaGen turbine was lowered into place in 2008 and generates electricity from tidal currents.Two horizontal axis turbines are anchored to the seabed and are driven by the powerful currents resulting from the tide moving in and out. The topsides and crossbeam were taken August 2018, while the remaining tower and subsea structure were removed thereafter. SeaGen's foundation structure was taken to a dry-dock in Swansea for where all recyclable materials were recycled (mainly steel) and the concrete sections were then ground down as far as possible[20].

An EIA for the decommissioning recommended mitigation for the potential environmental impacts:

- Short-term and temporary impacts upon benthic communities in Strangford Lough via loss or damage of seabed habitat through use of moored barge or jack-up vessel;
- No adverse effect on site integrity of Strangford Lough SAC and less than 0.01% will experience short-term temporary impacts via loss or damage of designated seabed habitat through use of a moored barge or jack-up vessel;
- Short-term and temporary impacts upon fish, including basking shark, pinnipeds and cetaceans, due to noise disturbance through use of DWCT or AWJ;
- Impacts on all other receptors are considered to be negligible;
- No cumulative impacts with commercial fisheries, shipping and the Minesto tidal device were expected; and
- Decommissioning of the SeaGen device is not predicted to result in any medium to long-term environmental impacts.

The EIA concluded that that, following mitigation, there would be no major adverse residual impacts either from the project alone or cumulatively with other projects on any environmental receptors within Strangford Lough[21].

[20] Pioneering SeaGen tidal power turbine decommissioned | Recharge (rechargenews.com)
[21] Decommissioning of the SeaGen Tidal Turbine in Strangford Lough, Northern Ireland: Environmental Statement | Tethys (pnnl.gov)

10.5.2 Socio-economic issues and impacts

Local economy and livelihoods

As indicated in section 10.3, there are few existing tidal power projects and so there is little direct evidence yet of their impacts on local communities. The most significant livelihood impacts from tidal energy are related to fishing and transportation.

Pollution from vessel discharges and accidental leakage of contaminants caused by tidal power projects can have a negative impact on fishing and collecting shellfish. It is reported that fish stocks in the oceans of Southeast Asia are already declining rapidly following a major expansion of regional fisheries, putting the livelihoods of up to 100 million people at risk[22] . Any additional potential impacts from tidal power development on local fisheries need careful consideration.

The rapid increase in fishing in Southeast Asia has been stimulated by increased demand for and consumption of fish due to population growth and has been accompanied by the adoption of modern fishing and aquaculture technologies, burgeoning domestic and international markets, flexible and rapidly adapting fish-supply chains, and investments in fish processing. Fishing communities' ability to access fisheries resources is critical to being able to sustain their livelihoods. Where the fish resources are depleted, larger operators continue to prosper while small-scale fishers seem to do poorly[23].

The potential effects of tidal energy generation projects on natural fish and shellfish populations (i.e., not farmed under aquaculture), which in turn could impact the livelihoods of fishermen, include:

- Release of fluid waste/contaminants;
- Light pollution;
- Excess noise and vibration;
- Increase in suspended sediments;
- Loss of spawning/nursery grounds;
- Removal/alteration of habitats;
- Barriers to fish movement; and
- Electromagnetic fields.

These effects can occur to varying degrees throughout the life cycle of a tidal power project. There could be associated impacts on shellfish gatherers if access to shellfish gathering areas is restricted or denied. Similarly, there could be a disruption to fisherfolks' pier, mooring and landing areas. There may be some short-term disruption to fishing activity during device deployment and recovery operations. However, due to the small amount of ocean energy devices, the impact from this on fishing would generally be negligible[24] . In the long term, there could be habitat changes that could create new economic activities such as new fisheries.

The supply chain supporting the development of tidal and wave energy production provides energy devices and subsystems, foundations and mooring systems, cables, installation ports, and vessels (both small and large)[25]. Expanded supply chains may provide opportunities for increased turbine production and provision of other materials. If countries are to develop tidal lagoons on a large scale, this would stimulate a supply chain. Depending on the scale, individual projects may lead to the creation of dedicated manufacturing facilities to produce turbine generator sets or other components.

The prices of land and housing near new large infrastructure may change, but for tidal projects this impact is expected to be negligible. As with all energy projects, associated infrastructure could entail some physical and or economic displacement where land needs to be acquired for access roads and transmission lines.

Some tidal projects contribute to local economic development through tourism (Box 10.3).

[22] Williams (2007)
[23] Bene (2003)
[24] Tethys. Galway Bay Test Site. https://tethys.pnnl.gov/project-sites/galway-bay-test-site
[25] Hundleby *et al.* (2015)

Box 10.3: Positive impacts of tidal energy projects on tourism and employment in the United Kingdom and France

It is suggested that 100,000 tourist visitors per year could be attracted by the proposed Swansea tidal lagoon project (320 megawatt installed capacity), which could generate new indirect employment opportunities, with associated training. The project would involve constructing a breakwater to enclose 11.5 km^2 of sea and create 2,232 construction and manufacturing jobs.

The Rance power station in France has a tidal barrage and has become a significant tourist attraction, with 70,000 visitors a year. The improvement of roads and associated infrastructure along the coastal area facilitate the access of tourists to where the tidal projects are located. In addition, some of the visitors are interested in visiting the site to understand how energy is generated. There is potential for many types of renewable energy to be more open to developing programs for such spin-off economic benefits.

Sources:
Key Statistics - Tidal Lagoon (tidallagoonpower.com); Key Statistics - Tidal Lagoon (tidallagoonpower.com);
http://www.tidallagoonpower.com/projects/swansea-bay/key-statistics/;
France - Tidal Lagoon (tidallagoonpower.com).

Employment and labour conditions

With little existing expertise globally in tidal energy project implementation, local expertise is unlikely to be available at new project sites. As the case of Tidal Lagoon Power in Wales, UK, shows (see Box 10.3), tidal energy projects can provide opportunities for training, both in terms of income-generating activities per se and for upskilling workers and increasing their chances of better paid employment going forward.

Health and safety

Renewable UK[26] has produced a health and safety guide for mitigating and avoiding OHS risks associated with wind and tidal power[27] . It identifies the risks of working near water, noting that the construction of tidal projects involves large numbers of people and vessels, working in small groups, in multiple locations. It may include vessels and offshore structures and working on a remote site for an extended period. These activities present OHS risks for the workers and marine navigation. The guide also identifies the need to address issues such as:

- Providing clear policies defining weather limits supported by effective forecasting;
- Safe practices for line handling when towing;
- Effective diver competency standards; and
- Proper equipment for recompression (when diving).

The main community health and safety risk relates to collisions and navigational safety[28] . As with other renewables, there will be a range of community and OHS issues during construction.

Indigenous communities

Tidal energy projects could have negative impacts on indigenous communities whose lives and livelihoods are primarily marine based, e.g., in Australia and the islands and coastal area throughout Indonesia and the Philippines. Indonesia has a particularly large number of indigenous communities.

[26] A membership organization involved in wind and marine renewables
[27] Renewable UK (2014)
[28] Howell and Drake (2012)

Such communities may claim traditional or customary ownership or use of coastal regions for their cultural traditions which could require BCS or FPIC for tidal power development. FPIC is usually a requirement under "lenders" (e.g., MDBs) safeguard standards to obtain financing and before a project can proceed. ''The UN Declaration on the Rights of Indigenous Peoples (UNDRIP)[29] recognizes the rights of indigenous peoples in marine environments. As tidal energy projects scale up in future, the need for inclusive consultation and engagement of indigenous peoples will gain further importance.

Gender and vulnerability

The is little analysis in the literature of the impacts of tidal energy on women or vulnerable groups. As with other renewable technologies, tidal projects need to identify and manage any risks and negative impacts on women and vulnerable groups that may arise. Discussions of gender and vulnerability in sections on hydropower and offshore wind indicate that impacts could include exposure to risks of sexual exploitation and abuse and sexual harassment, pressures on social amenities from the temporary presence of construction workers from outside the local area, and disruption to travel routes.

As noted in the previous section, tidal projects can have adverse impacts on remote and/or indigenous communities in coastal areas, including potential displacement of and disruption to marine-based livelihoods. Without sufficient planning and consultation that includes women and vulnerable groups, there is a risk that projects will be rejected by the affected community. The involvement of communities in decision-making processes can ensure that any benefits derived from the project are shared equitably among community members, local governments, project developers and other private sector investors e.g., through benefit-sharing schemes and favourable project contract mechanisms that allow for the scaling-up of renewable technologies in local communities.

Cultural heritage

Many communities have an intimate cultural relationship with local aquatic and coastal environments. Land/sea acquisition for project development may affect cultural heritage sites in coastal zones, including areas with potential shipwrecks and other marine archaeological sites. It may restrict local communities' and indigenous peoples' access to sites of cultural and spiritual significance.

Some tidal energy projects can act as tourist attractions (
Box10.3). In addition to informing tourists about the technology, visitors can be made aware of local culture. In Nova Scotia, Canada, a 'visitors' centre is attached to the Fundy Ocean Research Centre for Energy (FORCE). The approximately 3,000-square foot facility houses interpretive exhibits, interactive displays, a small theatre/community room, as well as space for on-site meetings and research work[30].

Transportation

In general, shipping lanes and navigation requirements will have to be considered during the planning and design of tidal energy projects. The installation of facilities on rivers may require the installation of locks to facilitate shipping up rivers. Tidal projects may disrupt access to ports, sailing routes, navigation aids, and transportation routes in estuarine areas. Modifications may affect sea conditions, bathymetry, fishing grounds and fishing activities[31] which then influence the need for riverine transportation.

[29] See United Nations Declaration of Rights of Indigenous Peoples (www.un.org)
[30] FORCE. fundyforce.ca.
[31] https://tethys.pnnl.gov/project-sites/galway-bay-test-site

Public services and infrastructure

As with other large projects, tidal power projects can be expected to provide on-site health services during the construction phase. Construction will require the use of heavy machinery and transportation of large parts which may require changes to roads and bridges (e.g., improvements, widening), or repair work if there is damage. Increased vehicle traffic during construction may have a negative impact on existing settlements, causing accidents and air, noise, and dust pollution. It may also restrict people's movement since terrestrial access to coastal communities can be limited to the landward side. Boats and vessels are needed to support installation and their presence may affect coastal access by others.
Tidal project developers may provide financial support to improve local public facilities and infrastructure, such as schools, roads, clinics, transportation services, etc. This support is mostly included in the developers' social and EMPs or their CSR or investment.

For instance, Tidal Lagoon power (in the UK) built access roads that the public can use to access the coastal areas[32].

[32] There is a Tide? - Tidal Lagoon (tidallagoonpower.com).