

Submarine Cables in the New England Region

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Activity Overview

Scope of this document

Cables for both electricity and data transmission crisscross the seabed of the world's oceans and the area offshore New England is no exception. The purpose of this document is to provide an overview of current and potential future submarine cable activities in the New England region. This document also summarizes the potential positive and negative effects of cable installation and operations on the species of fish and shellfish managed by the New England Fishery Management Council (NEFMC) and their habitats. While there is the potential for effects on protected resources, these are not discussed here, since their management is beyond the Council's area of authority and particular expertise. Finally, this document identifies ways in which other human activities, including fishing, could interact with cables.

Various primary literature sources, white papers, and experts were consulted to support the preparation of this document. As of fall 2020, a report on offshore wind submarine cabling is currently in preparation by Tetra Tech in consultation with NYSERDA's Fisheries Technical Working Group. Once published, this report will serve as a more detailed source of information on electrical cables, particularly in an offshore wind context. Some of the experts involved in preparation of this report provided background information for this document. Carter et al. (2009) and OSPAR (2008) provide general overviews of modern telecommunications cable technology, and were the primary sources relied on to describe the use and installation of fiber optic cables.

This document is specific to cables installed on or in the seabed. Floating renewable energy is a possible future activity in the region in waters deeper than approximately 100 meters. For such projects where generators (i.e. wind turbines) are floating in the water column and not fixed to the seabed, portions of the cables would not be buried at all, but would be hanging in a lazy wave shape from the turbine to the seabed close to the turbine location. Such suspended cables associated with floating arrays are beyond the scope of this document, in part because their configuration is presently uncertain. The main portion of the cables between generators within the array would be buried, however (**Figure 1**), and the effects are expected to be similar to electrical cables described herein.

Pipelines have some similarities to cables in terms of installation approaches and environmental effects, but are beyond the scope of this document. A common type of pipeline used in the coastal zone are outfalls for the discharge of combined sewer overflow or treated sewage. One notable example here is the Massachusetts Water Resource Authority's outfall in Massachusetts Bay which discharges effluent from the Deer Island Wastewater Treatment Plant. The NPDES permit for the outfall has standards for discharge of different contaminants, and monitoring is conducted under the advice of three [advisory panels](#) with expertise in science, public interest, and inter-agency issues. One type of marine pipeline that is not currently used or planned for use in New England is oil pipelines connecting offshore rigs to shore. In the event that the Bureau of Ocean Energy Management (BOEM) included the North Atlantic region in a future 5-year oil and gas leasing plan, resource exploration, leasing, drilling, and transport of oil and natural gas could occur in the region, potentially requiring installation of pipelines. Some

additional information about oil pipelines is provided in the background document prepared by the Mid-Atlantic Fishery Management Council ([link](#)).



Figure 1. Schematic of a floating wind array showing the suspended and buried portions of the inter array cables.

Types of cables used in ocean environments

Power transmission cables can be alternating or direct current (AC or DC). Direct current cables have fewer losses and can be used to transmit power over long distances; however conversion of electricity that is both generated and used in alternating current is required, and converters can be costly. Thus, over shorter distances, AC cables avoid the need for converters, which in some applications is a reasonable tradeoff for power losses. As such, AC power cables are generally more common at transmission distances of approximately 100 km or less, which means AC cables are typically used for offshore wind, a growing activity in the region that will rely on networks of cables to transmit electricity within the arrays and to shore. Because the wind turbines generate power in AC, inter array cables are always AC, traditionally 33 kV but moving to 66 kV. In terms of export cables, high voltage AC (HVAC) submarine cables can typically transmit about 400 MW of power, up to distances of about 100-125 km. High voltage DC (HVDC) cables can transmit several times the power (up to about 2 GW) and are theoretically unlimited with regard to length.

For each type of cable (AC or DC), there is an array of different configurations employed depending on the situation. These configurations have implications for magnetic fields. Older cables may present different environmental concerns from modern styles. For example, monopolar HVDC cables used seawater to carry the return current, whereas modern bipolar HVDC cables pair conductors to achieve two-way transmission. Monopolar cables with electrodes are no longer standard because of the environmental concerns they pose (Stehmeier 2006, from OSPAR 2008), such that while older cables may remain, this configuration is not relevant to the potential effects of new installations.

A major use of cables is for carrying data: nearly all transoceanic communications occur via cables, not with satellites. Coaxial telecommunication cables were installed from the 1950s until the late 1980s; modern versions employ fiber optic technology. At present, globally, there are over a million kilometers of fiber optic telecommunication cables on and in the seabed. The [North American Submarine Cable](#)

Association (NASCA) cable catalog represents a comprehensive look at the trans-oceanic systems, and is available on the Marine Cadastre: <https://marinecadastre.gov/nationalviewer/>. Other NOAA charted cables are also indicated on the Marine Cadastre.

Many cables have both fiber optic and power elements. Fiber optics are bundled with power cables to allow for data transmission related to cable monitoring systems, and potentially for internet traffic. These are integrated within the electrical cable sheathing for AC, and run alongside for HVDC. In turn, fiber optic cables are generally powered as they require repeaters to transmit signals over longer distances (at distances less than around 100 km, repeaters are not required). Typical cable and repeater specifications for long distance data transmission cables are summarized by Carter et al. (2009) and OSPAR (2008).

Armoring is the strength element that accommodates the pulling forces experienced during the installation of the cable (depending on the cable design, the weight in the water can reach 100 kilograms per meter). Once installed, armoring protects both telecommunication and power cables from external damage. Power cable armor is generally galvanized steel wire that is wrapped around the cable during manufacture. The armor is bedded on polypropylene yarns and is also covered by an external layer of polypropylene yarns that provide integrity to the cable bundle and protect it from abrasion during installation. In special cases, armoring can be made from stainless steel or aluminum to reduce the electrical losses within the cable. Burial, the primary means of cable protection, is discussed further below.

Cable insulation is used in power cables to keep the electricity within the conductor, rather than dissipating into the surrounding seabed. For some older types of marine cables, insulation was achieved with fluid. The potential environmental concern was that this fluid could leak out if the cable is damaged. Currently, power cables are insulated with cross-linked polyethylene (XLPE), or for some types of HVDC cables, paper impregnated with high viscosity oil, neither of which present threats of leaks.

Route selection and pre-construction surveys

The first step in cable or pipeline installation is route selection and survey. Initially, there is a desktop study (DTS), generally done by marine geologists considering available hydrographic and geologic data as well as examining other uses of the route, including fishing and the presence of other cables. The results of the DTS are used to design in-depth surveys along the potential route. Data gathered during these surveys includes water depth and seabed topography, sediment type and thickness, biological communities, natural and human-made hazards, and measures of currents, tides and waves to estimate stability of the seafloor. The term 'geophysical' is used to refer to remote-sensing-based surveys, including side scan sonar, multibeam sonar, magnetometer, and ship- and air-based LIDAR, while the term 'geotechnical' refers to physical sampling, including core penetration testing (commonly required), benthic grabs, and vibrocores. Image-based assessments may also be used to characterize seabed geology and fauna.

Installation

A variety of techniques are used for cable installation, and different approaches may be used adjacent to the shoreline (the shore landing) vs. in deeper waters (the main lay). The major installation methods include burial tools that trench or plow the seabed and horizontal directional drilling (HDD).

Cables are typically buried in the seabed, which protects the cable from damage. Various methods are used to bury cables depending on the location and the sediment type, and projects may employ multiple techniques. Burial tools are remotely operated devices that trench and lay both small and large diameter cables simultaneously. They can be self-propelled or towed. Examples include remotely operated vehicles, tracked trenchers, towed jetting sleds/plows, including vertical injector tools, and mass flow excavators. Trenches are created using either a plow blade or nozzles that hydraulically disperse the sediment. Cables can be buried to depths of 8 m, depending on sediment conditions at the site and the tool used.

Depth of burial depends on the sediment type as well as the operational needs of the project. **Table 1** provides some local examples. A Cable Burial Risk Assessment (CBRA) assesses both regulatory requirements, for example minimum burial depths within shipping channels, as well as expected risks to the cable. Specifically, in an area where bottom contact activities like fishing or dredging are likely, deeper depths may be preferred as a precautionary measure to protect the integrity of the cable. Bedform movement, specifically the expected migration of sand waves, will require burial in stable seabed below the bedforms to avoid exposure. This can be an issue both along the coastline and further offshore, and requires bathymetric profiling during site assessment.

Burial may not be possible in areas with rock ledges or other hard substrates, or where it is necessary to cross over an existing cable. In very deep waters where interactions with fishing gear or anchors are not anticipated, burial may not be required. Such situations are unlikely to arise with electrical cables, but may occur with transoceanic telecommunications cables. When burial is not possible and the cable is located such that it could be damaged by activities including fishing, cables may be covered with mechanical protection external to the cable, in addition to any armoring that is part of the cable's sheathing. Protection methods include dumped rocks, cast iron shells, steel or plastic conduits/half shell pipes, steel plates, or articulated concrete mattresses (Taormina et al. 2018).

Horizontal Directional Drilling can be used where marine cables make landfall. HDD employs a land-based drilling machine, producing a bore hole underneath an area where disturbance is being avoided. A mixture of water and bentonite clay is injected into the bore hole to reduce friction and emulsify the sediment. The exit point of the bore hole is underwater. A duct is then installed in the bore hole, and a messenger wire is then installed in the duct. The cable is installed in the duct later, using the messenger wire. Cofferdams with gravity cells are temporary structures that may be used in the intertidal/shallow water if a dry work area is needed, most likely at HDD duct exits.

Cable laying may precede or coincide with burial, and is either done from a barge (in shallow water) or more typically from a specialized Cable Laying Vessel (CLV). In shallow areas, the cable is paid out and suspended via floats, which are then deflated and the cable is guided towards the seabed by remotely

Submarine cables and their potential effects in the New England region

operated vehicles, avoiding marine vegetation and other features to be conserved. This approach is only used in nearshore sites where the CLV cannot approach. In some cases, divers may be used, although this carries Health, Safety, and Environmental risks relative to ROVs.

Table 1. Existing and proposed power cable burial specifications. Depth achieved column refers to cable sections where burial was possible, does not include cable crossings

Cable	Type	Target Burial Depth	Length	Installation Method/s	Depth Achieved
Sea2shore: The Renewable Link (Block Island Transmission System)	AC (30 MW at 34.5 kV)	4-6 ft	~39 km	Jet plow, horizontal directional drill	2-4 ft with some areas exposed and matted
Vineyard Wind Export Cables (Proposed, combining VW1 and Park City Wind projects)	AC (220-275 kV export, 66 kv inter-array)	5-8 ft	~48 miles, includes ~14 miles inside lease area for PCW	Jet plow or other methods depending on bottom conditions, water depth, and contractor preferences; HDD at landfall	NA
South Fork Wind Farm Export Cable (Proposed)	AC (130 MW of electricity at 138 kV)	4-6 ft	30.6 km	Mechanical cutter, mechanical plow, and/or jet-plow	NA
Cross Sound Cable	HVDC (330 MW electricity at 300 kV)	6 ft	40 km	Jet plow	1.9-5.7 ft
Neptune Regional Transmission System	HVDC (660 MW of electricity at 500 kV)	4-6 ft	105 km	Jet plow	3.8-8.6 ft

Monitoring

Monitoring is important during cable laying in order to know the vessel's position and speed, as well as seafloor conditions, which are assessed using precision echo-sounders. Wind and currents may need to be measured and corrected for during the installation. Once the cable touches down on the seabed, laying speed can reach as much as 6-8 knots, or 11-15 km/hr for telecommunication cables, slower for electrical cables. Deployment may be followed by an inspection using divers (very shallow water), remotely operated vehicles equipped with cameras, remote sensing technology, or some combination of these.

Monitoring of the cable during operation is necessary to ensure continued burial to the specified depths, thereby avoiding interactions between the cable and other activities that could lead to damage, or pose risks to other mariners such as fishermen. Burial status can be assessed via continuous, remote, temperature monitoring, where changes in temperature may indicate changes in burial depth. Such monitoring relies on sensors bundled into the cable sheathing,

A specific type of monitoring, referred to as cable burial surveys, can be planned for specified intervals; for example Vineyard Wind anticipates annual monitoring for the first three years, and then monitoring every three years thereafter. Such geophysical surveys compare multiple bathymetry data sets to indicate changes in the seafloor. Cable burial surveys may also be indicated after significant storm events where migration of seabed sediments is likely, thus potentially exposing the cable.

Repair and decommissioning

Cable damage severe enough to affect transmission is referred to as a fault. Faults are typically detected by monitoring equipment onshore, although they may be reported at the site where the impact occurred. If faults occur, the cable must be repaired. This involves removing the damaged section followed by splicing of the replacement. Modern, specialized, fiber-optic cables may require a week for repair, and cable repair authorities must have on-hand the specific cable type to splice into the damaged site (Carter et al. 2009). Maintenance Agreements, with costs shared by cable owners, provide for ongoing vessel, equipment, and personnel staging in strategic locations in order to expedite repairs of fiber-optic cables (Wagner 1995). Power cables can take much longer to repair, on the order of weeks.

Cable recovery, whether for replacement, repair, or removal, requires location of the cable and identification of the damaged area, retrieval with grapnels or ROVs, and haul up. Haul up considers similar factors to those monitored during cable deployment, i.e. depth, currents, waves, vessel speed, potential hangs, and cable drag.

At the end of their lifecycle, cables can be left in place or removed, based on the findings of an environmental impact assessment. Removal may be stipulated as a condition of the permit.

Permitting, environmental review, and operating standards

This section provides an overview of the federal and state permitting and authorization process for laying cables in the New England region, highlighting places in the permitting process where opportunities exist for input on concerns related to adverse effects to NEFMC managed species and habitats. The permitting and environmental review for a cable or pipeline project may be led by various federal agencies, depending on the type of cable or pipeline. Since the purpose of cables is to move a commodity, i.e. electricity or data, from one place to another, by definition cable projects will make landfall within a state coastal zone. Depending on the project, portions of the cable may also be installed in federal waters.

Involved agencies and entities

Multiple agencies are involved with permitting and environmental review for cable and pipeline projects, working with other groups to establish operational standards. The exact entities involved and which agency takes the lead during the permitting process depends on the type of cable or pipeline being installed.

Regardless of the type of installation, a permit from the **US Army Corps of Engineers (USACE)** is likely to be required. USACE requires that any person, firm, or agency (including Federal, state, and local government agencies) planning to work in navigable waters of the United States, or discharge (dump, place, deposit) dredged or fill material in waters of the United States, including wetlands, must first obtain a permit. Minor projects may be covered under regional or nationwide general permits but major projects will require their own application.

The **Bureau of Ocean Energy Management (BOEM)** is the lead agency responsible for leasing areas of the outer continental shelf for both renewable and oil/gas energy development projects. For renewable energy projects, BOEM formally approves a construction and operations plan (COP) via an agency record of decision on the National Environmental Policy Act document. The COP includes plans for the export and inter-array cables.

The **Federal Energy Regulatory Commission (FERC)** is an independent agency that regulates interstate transmission of natural gas, oil, and electricity. Other entities are also involved in the design and reliability of the electrical transmission system. The **North American Electric Reliability Corporation (NERC)** is a not-for-profit regulatory authority charged with ensuring the reliability and safety of the bulk electric system. Cable owners are registered with NERC and must adhere to their reliability standards. The **Northeast Power Coordinating Council (NPCC)** promotes and enhances the reliability of the interconnected bulk electric system in the Northeast.

The International Bureau of the **Federal Communications Commission (FCC)** administers international telecommunications and satellite programs and policies, including licensing and regulatory functions, including issuance of permits.

Environmental Protection Agency (EPA) permits are required for projects that involve intake of seawater (i.e. for cooling). An example of this is the Neptune natural gas terminal. EPA is also involved in new outfalls or modified outfalls; however many legacy outfalls can be maintained without the need for further consultation if changes are minimal (de minimis).

NOAA's Office of National Marine Sanctuaries authorizes installation permits for cable projects, and requires special use permits which allow continued operation and placement of cables in a sanctuary. ONMS also assesses a fair market value fee for the ongoing use of Sanctuary resources, based on established guidance (see this [policy document](#) for more information).

Cable installers work with the **US Coast Guard (USCG)** to issue Notices to Mariners when installations are planned (Wagner 1995). Once the cable is installed, hydrographic offices are advised of the final route so that the cable may be added to nautical charts (Wagner 1995). The **Naval Seafloor Cable Protection Office (NSCPO)** provides the single point of contact and management of a world-wide Geographic Information System (GIS) database of commercial and government submarine cable systems. In order to ensure that new commercial or Government cable projects are routed clear of any Department of Defense cable systems, the NSCPO requests system planners and installation contractors to contact NSCPO early in the planning process. To create additional awareness, these formal notifications are often supplemented by chart products developed by the cable owners (Wagner 1995).

Applicable laws

A variety of federal laws have bearing on the installation of submarine cables and pipelines. Federal permitting agencies coordinate compliance with federal laws as part of the review and authorization process. If a federal permitting agency determines a proposed project may have an adverse effect on certain public interests as outlined by federal law, they are required to consult with the federal agencies responsible for the implementation of those laws prior to issuing permits. In addition to coordination with federal and state agencies, federal permitting agencies also are responsible for coordinating opportunities for public comment on permitting actions. Due to the need for federal permits and authorizations for projects proposed in the Coastal Zone and the EEZ, and the nexus between federal permitting actions and consultation with NMFS under the MSA, it is during the federal permitting and authorization process where formal opportunities for input from the NEFMC and fishing communities/stakeholders on potential impacts to NEFMC species and habitats primarily occur.

The **National Environmental Policy Act (NEPA)** lays out specific requirements for permitting agencies when they anticipate that an action could significantly affect the quality of the human environment. If a determination of significance is made, the agency must document its consideration of those impacts in an environmental impact statement (EIS). If the impacts are uncertain, an agency may prepare an environmental assessment (EA) to determine whether a finding of no significant impact could be made or whether an EIS is necessary. In some cases, federal agencies can determine the level of analysis they will be required to undertake based on how the activities compare to past agency actions or during pre-permitting discussions with partner federal agencies. In other cases, the determination is made after an application is submitted based on considerations raised during the project review process by the permitting agency, the public, and/or consulting agencies.

Under the **Magnuson Stevens Fishery Conservation and Management Act (MSA)** if a proposed project may result in adverse effects to EFH, the lead federal agency must prepare a written EFH Assessment describing the effects of the activities on EFH (50 CFR 600.920(e)(1)). The level of detail required in an EFH Assessment is commensurate with the complexity and magnitude of the potential adverse effects of the action, 50 CFR 600.920 (e)(2). Actions that may pose a more serious threat to EFH, or that involve a more complex range of potential adverse effects, justify a correspondingly more detailed EFH Assessment that includes information, such as an analysis of alternatives, the results of on-site inspections, literature reviews and the views of recognized experts. NOAA Fisheries biologists (GARFO in this region) review the EFH assessment and provide conservation recommendations to federal agencies on means to avoid, reduce, or offset these adverse effects. These conservation recommendations are intended to be included on federal agency permits as special conditions or integrated into the project plans, as appropriate. Action agencies are not required to comply with conservation recommendations that are included in an EFH consultation, but they are required to respond to NMFS, in writing, explaining the reasons why they are not adopting the recommendations.

Various additional laws have provisions for living marine resource protection. Section 7(a)(2) of the **Endangered Species Act (ESA)** requires federal agencies to consult with the NOAA Fisheries, the U.S. Fish and Wildlife Service, or both, before taking any action that may affect an endangered or threatened

species or their critical habitat to insure their actions are not likely to jeopardize any listed species or result in the destruction or adverse modification of designated critical habitat. The **Fish and Wildlife Coordination Act** requires any federal agency issuing permits to consult with the U.S. Fish and Wildlife Service and NOAA Fisheries if the proposed activities could potentially harm fish and/or wildlife resources. These consultations may result in project modification and/or the incorporation of measures to reduce these effects. The **Marine Mammal Protection Act (MMPA)** prohibits take, including the harassment, hunting, capturing, or killing of marine mammals, except under certain circumstances. The NOAA Fisheries Office of Protected Resources authorizes the incidental take of marine mammals under the MMPA to U.S. citizens and U.S.-based entities, if they find that the taking would be of small numbers; have no more than a "negligible impact" on those marine mammal species or stocks; and not have an "unmitigable adverse impact" on the availability of the species or stock for subsistence uses. Most incidental take authorizations have been issued for activities that produce underwater sound, which would include different cable installation projects related to oil and gas production, renewable energy production, and other types of construction projects.

Other laws protect specific sites and associated features. Section 106 of the **National Historic Preservation Act (36 CFR Part 800)** requires any federal agency issuing a permit to account for potential effects of the proposed activity on historic properties, e.g., shipwrecks, prehistoric sites, cultural resources. If a proposed activity has the potential to affect historic properties, these details must be provided by the applicant as part of the application package. Section 304(d) of the **National Marine Sanctuaries Act (NMSA)** requires any federal agency issuing permits to consult with NOAA's National Marine Sanctuary Program (NMSP) if the proposed activity is likely to destroy or injure sanctuary resources. As part of the consultation process, the NMSP can recommend reasonable and prudent alternatives. While such recommendations may be voluntary, if they are not followed and sanctuary resources are destroyed or injured in the course of the action, the NMSA requires the federal action agency(ies) issuing the permit(s) to restore or replace the damaged resources.

Current and potential extent of activity in New England

Long distance electrical transmission: Long distance electrical transmission refers to regional-scale projects that move power over hundreds of miles using HVDC cables. For example, Emera's Atlantic Link project would have used a 1000 MW HVDC cable to carry renewable energy from New Brunswick, Canada to Plymouth, Massachusetts. Two routes were proposed, both largely in federal waters, one somewhat inshore and one quite far offshore. This project was not selected by MA during a competitive bid process that concluded in 2018.

Shorter distance electrical transmission from offshore wind projects: Offshore wind farms transmit electricity to shore via submarine export cables, which are typically HVAC. Offshore wind projects also include inter-array cables that connect the turbines within the array. The export cables can either be developed and permitted in conjunction with the power generation parts of the project (point-to-point), or can be developed by a separate company in a parallel process (coordinated). The offshore endpoint of these export cables will be within a leased wind energy area, and the possible onshore endpoints are governed by capacity in New England's electrical grid, considering existing system capacity, planned

upgrades (e.g. new 345kV interconnections), and planned retirements (e.g. existing power plants going offline). Various developers including Vineyard Wind, Equinor, and Ørsted are planning for project-specific export cables. In terms of coordinated transmission, Anbaric's proposed Southern New England OceanGrid projects would bring electricity generated from offshore wind into Everett, MA, Somerset, MA, and Bridgeport, CT. Anbaric has filed grid interconnection requests into these locations, and has applied with BOEM for non-exclusive rights of way to offshore corridors; they are interested in developing coordinated transmission off NJ and NY as well. Atlantic Wind Connection was an earlier, similar project considered in the Mid-Atlantic region.

Existing and planned projects have highlighted various questions around siting, installation, monitoring, and decommissioning. As an example of burial considerations, high energy forces in the Crescent Beach area are requiring a second HDD effort to more deeply bury the sea2shore cable serving the Block Island Wind Farm. As another example, burial below the base of offshore sand waves will be required for the Vineyard Wind export cables. As an example of monitoring approaches, for the Block Island Wind Farm sea2shore cable, RIDEM required Deepwater Wind/National Grid to submit a long-term monitoring and operations and maintenance plan that included post-construction inspection using multi-beam survey and shallow sub-bottom profilers to measure burial depth and verify reconstitution of the trench. Cable burial depth along the route must be inspected using a sub-bottom profiler at least once every five years following installation. An EMF survey was also required upon completion and within the first five years of operation to determine potential effects on the composition, life cycle functions, uses, processes and activities of fish and wildlife (RIDEM WQC # 12-039; DP-12-120). In terms of removal, RI DEM permits allow the BIWF transmission cable (sea2shore) to be left in place at decommissioning for any sections buried 36 inches or deeper to avoid disruption to habitats above the cable.

Other shorter distance electrical transmission: In addition to cables that transport electricity from a power plant to the grid, marine cables may be a part of the electrical transmission system. For example, the Cross Sound Cable is a 40 km combined telecommunication and HVDC power cable running from New Haven, CT to Shoreham, NY. It has been in operation since 2003 and generally transfers electricity from the New England grid to the New York grid, but works in both directions.

Telecommunications: The Hibernia cable (currently owned by GTT) extends from Ireland to the United States. It was installed in 2000 and 12 miles are within Stellwagen Bank National Marine Sanctuary. The Sanctuary's special use permit stipulated that a survey would be done at the end of the cable's lifespan (~25 years) to evaluate removal or decommissioning in situ, payments for monitoring and education/outreach, and payment of annual permit fees. The Grace Hopper cable project (Google) is under development as of fall 2020. The cable is planned to run from Long Island across the Atlantic to Europe, splitting to make landfall in both England and Spain.

Potential impacts to habitat and managed species

Generally the effects of cables, considering both installation and operations, include underwater noise, heat dissipation to the surrounding water or sediment, electromagnetic fields, contamination, and mechanical disturbance of seabed sediments and organisms. Cable type, installation methods,

underlying habitat and ecological conditions, spatial extent, and operational time scale are important to consider when determining the severity of potential impacts. Some effects are associated with installation, repair, and removal, while others persist during the operational period (**Table 2**).

Table 2. Types of environmental impacts associated with submarine cables. Reproduced from OSPAR 2008.

Cable type	Installation, maintenance, and removal phases	Operational phase
Telecommunication	Disturbance, contamination, noise	Electromagnetic fields
Power	Disturbance, contamination, noise	Heat dissipation, electromagnetic fields, vibration noise

Various reviews in the grey and primary literature summarize the range of effects cables may have on marine environments and species. Those consulted during preparation of this report include Meißner et al. 2006, OSPAR et al. 2008, Carter et al. 2009, RGI 2015, and Taormina et al. 2018. Other studies referenced below examined in-situ effects of specific cable installations, or evaluated factors such as heat dissipation and electromagnetic fields and their implications for the marine environment in laboratory settings. Overall, the effects of cables on the marine environment are generally considered to be relatively minimal in comparison to other human activities, but this does not mean that there are no negative effects. Understanding the mechanisms behind these effects is important, since many can be mitigated by adjusting the path of the cable, the configuration of the cable, the depth of the cable in the seabed, or the installation method. Cumulative effects across multiple cable projects, as well as the potential for coordination across projects to minimize effects, should be considered.

Mechanical disturbance, sedimentation, and reef effects

Mechanical disturbance of seabed sediments, plants, and animals varies by installation technique. At the time of installation, embedment has the largest impact, laying on the seabed an intermediate impact, and directional drilling the lowest impact. The area of the seabed affected will depend on the equipment used, with wider corridors impacted by embedment vs. laying a cable on the surface. For example, the trench width for the embedded portion of the Vineyard Wind export cable is estimated to be 3.5 ft. For directional drilling, the impacted seafloor area will be limited to where the cable enters the seabed. Mechanical disturbance near the cable corridor may also result from ship anchoring during the installation process (Taormina et al. 2018).

With embedment, the trench is filled with displaced and suspended material following installation, allowing for recovery of the seafloor over time, although the potential for recovery will vary across different areas based on the organisms present, sediment type, and disturbance regime. While cable corridors are fairly narrow, such that they may only damage a small percentage of a patch of habitat, if conditions are not suitable, recovery and recolonization could be delayed. One example in Puget Sound

required blending anoxic sediment in the trench with beach sand and transplanting *Z. marina* to achieve connectivity of the fragmented eelgrass bed (Austin et al. 2004). Ecological effects may depend on community composition, specifically abundance, biomass, and richness of species in the corridor in comparison with the surrounding area (Taormina et al. 2018). Cable installation could have negligible effects in more homogeneous settings, but more substantial impacts if rarer taxa are affected.

Mechanical impacts to the seabed may be most biologically significant during periods when spawning is occurring, or when juveniles are present in the area. This effect is not limited to commercially-important species, but such species are likely to be of greater concern to resource managers. Because these behaviors are seasonal, time of year restrictions on cable installation can be used to mitigate impacts. Sediment resuspension and resettlement during installation will generally be short-term (hours to days). However, sediment suspension could be problematic in cases where an organism is vulnerable to burial with deposited sediments (e.g. burial of eggs laid on the seabed) or susceptible to physical injury (e.g. gill damage in larval fish) (Taormina et al. 2018). In addition, lower light conditions associated with turbidity could decrease primary production or impact feeding behaviors, including visual detection of prey or filter feeding (Taormina et al. 2018).

For installations directly on the seafloor, cables and cable armoring structures introduce artificial hard substrate into areas that may not have previously had this type of habitat. This is sometimes referred to as habitat conversion. Cables or cable armoring devices can thus provide new substrates for benthic organisms that may not have existed previously at the site, similar to an artificial reef. In vegetated habitats, algae or other organisms growing on the cable could cause shading of adjacent seagrass plants. Different types of armoring will vary in terms of surface area and texture, and may support different attached organisms and attract different types of mobile invertebrates and fishes. From an ecological perspective, such habitat conversion may or may not be a net negative (mobile fishing gear interactions with armoring structures are a separate issue).

Unburied cables that are not anchored or armored can cause damage to seabed habitats. Cables on the seabed surface could move during tidal cycles or storms, causing scouring of adjacent seabed and removal of organisms. When cables cannot be buried because they are being installed over rocky substrates, especially where free spans occur, they can cause incisions in the rock over time due to vibration and chafing (Taormina et al. 2018).

Noise

Noise impacts could occur during construction, operation, or repair. Determination of impacts related to noise should consider both level, commonly expressed in decibels (dB) relative to a reference unit (which is 1 microPascal or μPa for water), and frequency, or rate of oscillation of the sound pressure wave moving through a medium, measured in Hertz (Hz). Different species perceive noise differently, and may be physiologically or behaviorally affected by sounds. The species hearing threshold or dB_{ht} scale (developed by Nedwell et al. 1998) estimates whether a particular noise level can be perceived by a species, based on frequency-dependent filters, where 0 dB_{ht} is at the species' hearing threshold (Nedwell et al. 2001).

Relative to other human activities, the level of noise associated with cable installation and operations is low, and installation activities are temporally and spatially localized, such that overall impacts on managed fishes and invertebrates are likely minimal (Taormina et al. 2018). However, there is uncertainty in the threshold levels of noise that cause physiological damage in fishes and invertebrates, making the assessment of minimal impacts difficult to estimate (Taormina et al. 2018). Compared to installation sound levels from vessels and embedment machines, operational noise levels due to cable vibration are generally much lower, but occur over a much longer period, and the impacts of these operational noises are uncertain (Taormina et al. 2018).

Electromagnetic fields

OSPAR (2008) provides succinct technical background on electric and magnetic fields produced by power transmission cables. Electric fields (volts per meter, $V\ m^{-1}$) are produced by voltage and increase as voltage increases, while magnetic fields (microtesla, μT) are produced by current, and increase as current increases. The magnetic field generates an induced electric field. It is possible to effectively shield the directly generated electric fields, and the strength of the magnetic (and thus induced electric) fields can be managed via conductor/cable placement patterns and configuration geometry. Burial does not dampen the magnetic and induced electric fields (assuming the sediment does not have magnetic properties), but does increase the distance between animals living on the surface of the seabed and the cable. Since the magnetic and induced electric fields attenuate rapidly with distance from the cable, burial can reduce exposure.

Numerous studies have investigated whether electromagnetic fields affect the behavior of marine animals and therefore their fitness at the individual level, which could scale up to population-level effects. Many species, including elasmobranchs, finfish, mammals, turtles, mollusks, and crustaceans, are sensitive to electromagnetic fields, while others, in particular elasmobranchs, are sensitive to electric fields. Electric field detection can be used for sensing prey, and electric and electromagnetic fields can be used for orientation and migration. Responses appear to be species-specific, such that it is difficult to generalize based on studies of taxa that do not occur in New England, and inferring population-level effects from observations of individual responses is also challenging.

Hutchinson et al. (2020) studied little skate and American lobster behavioral responses to electromagnetic fields, specifically the position of each animal within an enclosure and the direction of movement. Skates exposed to EMF travelled further, made more large turns, and stayed closer to the seabed as compared to control skates, and lobsters exposed to EMF stayed closer to the seabed than control lobsters. They interpreted the behavior of EMF-exposed skates as indicating increased exploratory or area restricted foraging behavior, which could have an energetic loss and thus negative impacts on skate fitness. Lobster behavior changes were more subtle. Taormina et al. (2020) investigated the response of juvenile European lobsters to an artificial magnetic field of realistic intensity for a single power transmission cable, and did not see differences in behavior as compared to control lobsters. However they noted that investigation of responses for additional lifestages would be useful. Both Hutchinson et al. (2020) and Taormina et al. (2020) suggested that increased knowledge of

the magneto-sensory ability/sensitivity of the target organisms would be useful in terms of estimating effects.

Chemical contamination

Chemical contamination may occur during installation when pollutants such as heavy metals or hydrocarbons are released from the seabed during trenching and burial operations (Taormina et al. 2018). The potential for such effects to occur will relate to the existence of contaminants along the cable route, such that a sediment toxicity assessment should factor into route selection.

Certain types of cables can also be a source of chemical pollution. Monopolar HVDC cables use sea electrodes for return of the current, which release toxic electrolysis products, e.g. chloride and bromide. This issue is solved through the use of bipolar systems with a main and return cable, which is the current standard, but monopolar HVDC remain in service use (30% of HVDC according to Sutton et al. 2017). Fluids and heavy metals can also leak from the cable if it is damaged, until the cable is able to be repaired. Hydrocarbon insulation is associated with older cables and stopped being used in the 1990s (Carter et al 2013), but metal sheathing (e.g. lead) continues to be used in new installations. Metals could dissolve and spread into the surrounding seabed, but given the quantities involved, impacts are probably not significant (Taormina 2018). Overall, newer cable technologies minimize many contamination risks, but older styles of cables remain in service.

Heat dissipation

For electrical transmission cables, heat is dissipated from the cable surface during operation, with AC cables losing more heat than DC cables. This thermal energy dissipates rapidly for cables installed on the seabed, but for those buried in the sediment, warming of the surrounding area results. Effects are dependent on the surface temperature of the cable and on sediment permeability. Laboratory experiments showed that both conductive and convective heat transfer occurs, depending on the conditions, with low permeability (coarse silt) sediments showing temperature increases in a smaller radius around the cable, primarily due to conductive heat transfer, and high permeability (coarse sand) sediments showing temperature increases at greater distances from the cable, primarily due to convective heat transfer (Emeana et al. 2016). Temperature distributions were not necessarily symmetrical, depending on the conditions. These changes in thermal regimes can have impacts on chemical and physical sediment properties, and on biological activity of micro and macro infaunal organisms (Emeana et al. 2016).

Potential Interactions with Other Coastal/Marine Activities

The majority of cable faults are the result of human activities. Cables in waters shallower than 1,500 m are typically buried in order to avoid damage associated with bottom tending fishing gears and anchoring of fishing and other types of vessels. Combined, fishing gear and anchors are the greatest source of cable faults, contributing to 65-70% of faults in waters shallower than 200 m. Modern telecommunications cables are buried to depths of at least 60 cm. This is generally sufficient to ensure

that contact is unlikely even if fishing gear passes over the cable, given the typical penetration depth of gear components. Fixed fishing gears are thought to cause fewer faults, particularly in shallow waters, but their impacts may be greater at deeper depths, where static gears are heavier and telecommunications cables are generally less heavily armored and buried more shallowly. Dredging (for mineral mining or channel deepening purposes, vs. fishing) and drilling are other less frequent sources of human-caused impacts.

Natural disturbances can affect cables as well. In waters beyond 1,500 m, cables are generally installed on the surface of the seabed. In these locations, natural hazards such as submarine landslides caused by earthquakes, tsunamis, or severe storms can cause cable failures. Even on the abyssal plain, ocean currents scour and transport sediment to depths of at least 6,000 m. In deep waters, natural hazards are the largest source of faults (31%), although they only account for 10% of faults at all depths. In coastal areas, climate change may increase the risk of erosion, exposing cables nearshore, as well as increasing the flood risk of cable facilities.

References

Austin S, Wyllie-Echeverria S, Groom MJ (2004). A Comparative Analysis of Submarine Cable Installation Methods in Northern Puget Sound, Washington. *J. of Marine Env. Engg.* 7: 173–83.

Carter L, Burnett D, Drew S, Marle G, Hagadorn L, Bartlett-McNeil D, Irvine N (2009). *Submarine Cables and Oceans -- Connecting the World*. UNEP-WCMC Biodiversity Series No. 31. ICPC/UNEP/UNEP-WCMC. 64p.

Carter L, Burnett D, Davenport T. The relationship between submarine cables and the marine environment. Pages 179-212 in: Burnett D, Beckman R, Davenport T, editors. Submarine cables: the handbook of law and policy. Martinus Nijhoff Publishers.

Emeana, CJ, Hughes TJ, Dix JK, Gernon TM, Henstock TJ, Thompson CEL, Pilgrim JA (2016). The Thermal Regime around Buried Submarine High-Voltage Cables. *Geophysical Journal International* 206(2): 1051–1064.

Hutchison ZL, Gill AB, Sigray P, He H, King JW (2020). Anthropogenic Electromagnetic Fields (EMF) Influence the Behaviour of Bottom-Dwelling Marine Species. *Scientific Reports* 10 (1): 4219.

Meißner K, Schabelon H, Bellebaum J, Sordyl H (2006). *Impacts of Submarine Cables on the Marine Environment: A Literature Review*. Institute of Applied Ecology, Ltd.

Nedwell JR, Needham K, Gordon J, Rogers C, Gordon T (2001). The effects of underwater blast during wellhead severance in the North Sea. Report No. 469 R 0202 by Subacoustech Ltd, funded by CSOL on behalf of consortium.

[http://www.subacoustech.com/downloads/469R0202\(current\)/report/dbha_theory.html](http://www.subacoustech.com/downloads/469R0202(current)/report/dbha_theory.html)

Submarine cables and their potential effects in the New England region

Nedwell JR, Turnpenny AWH, Lambert D (1998). Guiding fish with sound, the acoustics of fish behavioural barrier design. 128th Annual Meeting of the American Fisheries Society Conference, Baltimore, USA August 1998.

NOAA ONMS (2011). Final Policy and Permit Guidance for Submarine Cable Projects. National Oceanic and Atmospheric Administration Office of National Marine Sanctuaries. 24p.

OSPAR Commission (2008). Background Document on Potential Problems Associated with Power Cables Other than Those for Oil and Gas Activities. 50p.

Renewables Grid Initiative (2015). Subsea Cable Interactions with the Marine Environment: Expert Review and Recommendations Report. 58p.

Sutton SJ, Lewin PL, Swingler SG (2017). Electrical power and energy systems review of global HVDC subsea cable projects and the application of sea electrodes. *International Journal of Electrical Power & Energy Systems* 87: 121–135.

Taormina B, Bald J, Want A, Thouzeau G, Lejart M, Desroy N, Calier A (2018). A review of the potential impacts of submarine power cables on the marine environment: Knowledge gaps, recommendations, and future directions. *Renewable and Sustainable Energy Reviews* 96: 380-391.

Taormina B, Di Poi C, Agnalt A-L, Carlier A, Desroy N, Escobar-Lux RH, D'eu JF, Freytet F, Durif CMF (2020). Impact of Magnetic Fields Generated by AC/DC Submarine Power Cables on the Behavior of Juvenile European Lobster (*Homarus Gammarus*). *Aquatic Toxicology* 220: 105401.

Tetra Tech, Inc. and NYSERDA Fisheries Technical Working Group (in preparation, July 2020). Offshore Wind Submarine Cabling Overview. Prepared for NYSERDA, Albany, NY.

Wagner E (1995). Submarine Cables and Protections Provided by the Law of the Sea. *Marine Policy* 19 (2): 127–136.