Chapter 19. Submarine Cables and Pipelines

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1. Submarine communications cables

1.1 Introduction to submarine communications cables

In the last 25 years, submarine cables have become a dominant element in the world's economy. It is not too much to say that, without them, it is hard to see how the present world economy could function. The Internet is essential to nearly all forms of international trade: 95 per cent of intercontinental, and a large proportion of other international, internet traffic travels by means of submarine cables. This is particularly significant in the financial sphere: for example, the SWIFT (Society for Worldwide Interbank Financial Telecommunication) system was transmitting financial data between 208 countries via submarine cables in 2010. As long ago as 2004, up to 7.4 trillion United States dollars were transferred or traded on a daily basis by cables (Rauscher, 2010). The last segment of international internet traffic that depended mainly on satellite communications was along the East coast of Africa: that was transferred to submarine cable with the opening of three submarine cables along the East coast of Africa in 2009-2012 (Terabit, 2014). Submarine cables have advantages over satellite links in reliability, signal speed, capacity and cost: the average unit cost per Mb/s capacity based on 2008 prices was 740,000 dollars for satellite transmission, but only 14,500 dollars for submarine cable transmission (Detecon, 2013).

Submarine telegraph traffic by cable began between England and France in 1850-1851. The first long-term successful transatlantic cable was laid between Newfoundland, Canada, and Ireland in 1866. The early cables consisted of copper wire insulated by gutta percha, and protected by an armoured outer casing. The crucial development that enabled the modern systems was the development of fibre-optic cables: glass fibres conveying signals by light rather than electric current. The first submarine fibre-optic cable was laid in 1986 between England and Belgium; the first transatlantic fibre-optic cable was laid in 1988 between France, the United Kingdom and the United States. It was just at that time that the Internet was beginning to take shape, and the development of the global fibre-optic network and the Internet proceeded hand in hand. The modern Internet would not have been possible without the vastly greater communications possibilities offered by fibre-optic cables (Carter et al., 2009). Over the 25 years from 1988 to 2013, an average of 2,250 million dollars a year was invested in laying 50,000 kilometres of cable a year. However, this includes a great burst in the development of the global fibre-optic network that took place in 2000-2002, in conjunction with the massive interest in investment in companies based on the Internet: the so-called dot-com bubble. At the peak, in 2001, 12,000 million dollars were invested in submarine cables in one year. After the dot-com bubble burst in 2002, the cable-laying industry contracted severely, but by 2008 had recovered to what has since been a steady growth

(Terabit, 2014). Figures 1 and 2 show diagrammatically the transatlantic and transpacific submarine communications cables that exist. More detailed diagrammatic maps showing submarine cables in the Caribbean, the Mediterranean, North-West Europe, South and East Asia, and Sub-Saharan Africa can be found here: http://submarine-cable-map-2014.telegeography.com/.

Two Arctic submarine communications cables are reported to be planned, linking Tokyo and London: one will go around the north of the Eurasian continent, the other around the north of the American continent through the North-West passage; both would service Arctic communities *en route*. In 2012, both were planned to be in service by 2016. The link by the American route is said to be under construction but is not now expected to be complete until 2016. The link around the Eurasian route is reported to be stalled (Hecht, 2012; Arctic Fibre, 2014; Telegeography, 2013; APM, 2015).

Deployed international bandwidth (in other words, the total capacity of the world's international cables) increased at a compound annual growth rate of 57 per cent between 2007 and 2011. It reached 67 Terabits per second (Tbps) in 2011, which was six times the bandwidth in use in 2007 (11.1 Tbps). It has increased steadily since then and was estimated to be increasing to about 145 Tbps in 2014 (Detecon, 2013). Submarine cable bandwidth is somewhat lower, as shown in Table 1. The investment necessary to support this steady stream of investment is provided through consortia. The precise balance of the different interests varies from case to case, but the major players are nearly always national telecommunications operators, internet service providers and private-sector equity investors. Governments are rarely involved, except through government-owned national telecommunications operators (Terabit, 2014; Detecon, 2013).

Table 1. Activated Capacity on Major Undersea Routes (Tbps), 2007-2013

	2007	2008	2009	2010	2011	2012	2013	CAGR, 2007-2013
Transatlantic	6	8	11	13	15	19	23	25%
Transpacific	3	7	8	12	12	14	20	35%
Pan-East Asian	2	2	6	8	10	12	17	46%
South Asia & Middle East Inter-continental	1	2	3	3	4	8	12	42%
North America-South America	1	1	3	4	6	7	9	52%
Australia & New Zealand Intercontinental	1	1	2	2	2	3	5	40%
Sub-Saharan African Intercontinental	0	0	0	1	1	2	2	57%
Global Transoceanic Bandwidth (Tbps)	**14**	**22**	**33**	**43**	**51**	**65**	**87**	**36%**
Percent Change		57%	49%	32%	19%	26%	35%	

Source: Terabit, 2014.

1.2 Magnitude of the impact of submarine cables on the marine environment

In 2007, the total route length of submarine fibre-optic cables was about 1 million route kilometres (Carter et al., 2009). This has now extended to about 1.3 million route kilometres, given the extensions reported in the 2014 Submarine Cable Report (Terabit, 2014). Although these are great lengths, the breadth of the impact on the marine environment is much, much less: the diameter of the fibre-optic cables on the abyssal plain is about 17-20 millimetres – that is, the width of a typical garden hose. On the continental shelf, the width of the cable has to be greater – about 28-50 millimetres – to allow for the extra armour to protect it from impacts and abrasion in these more dynamic waters and the greater threats from shipping and bottom trawling (Carter et al., 2009).

The cable is normally buried in the seabed if the water depth is less than 1,000-1,500 metres and the seabed is not rocky or composed of highly mobile sand. This is to protect the cable against other users of the sea, such as bottom trawling. Known areas where mineral extraction or other uses are likely to disturb the seabed are avoided. In greater water depths, the cable is normally simply laid on the seabed (Carter et al., 2009). Where a cable is buried, this is normally done by a plough towed by the cable ship that cuts a furrow into which the cable is fed. In a soft to firm sedimentary seabed, the furrow will usually be about 300 millimetres wide and completely covered over after the plough has passed. On other substrates, the furrow may not completely refill. The plough is supported on skids, and the total width of the strip disturbed may be between two and eight metres, depending on the type of plough used. Various techniques have been used to minimise disturbance in specially sensitive areas: on the Frisian coast in Germany, a specially designed vibrating plough was used to bury a cable through salt marshes (recovery was monitored and the salt-marsh vegetation was re-established in one to two years and fully recovered within five years); in Australia, cables crossing seagrass beds were placed in narrow slit trenches (400 millimetres wide), which were later replanted with seagrass removed from the route prior to installation; in the Puget Sound in Washington State in the USA, cables were installed in conduits drilled under a seagrass bed. Mangroves are reported to have recovered within two to seven months, and physical disturbance of sandy coasts subject to high-energy wave and tide action is reported to be removed within days or weeks. Where burial has not been possible, it has sometimes been necessary to impose exclusion zones and to monitor such zones (as between the North and South Islands of New Zealand (Carter et al., 2009)).

Further disturbance will occur if a cable failure occurs. Areas of cable failure are likely to have already been disturbed by the activity that caused the cable failure. Normally, the cable will have to be brought to the surface for repair. This will involve the use of a grapnel dragged across the seabed, unless a remotely operated robot submarine can be used. Reburial of the cable may involve agitating the sediment in which it has been buried. This disturbance will mobilise the sediment over a strip up to 5 metres wide. Fibre-optic cables have a design life of 20-25 years, after which the cable will need to be lifted and replaced, with a recurrence of the disturbance, although there is also the possibility of leaving them in place for use for purposes of scientific research (Carter et al., 2009; Burnett et al., 2014).

Evaluating the impact on marine animals and plants of this disturbance is not easy, since the area affected, though long, is narrow. In general, the verdict is that the seabed around a buried cable will have returned to its normal situation within at most four years. In waters over 1,000-1,500 metres deep (where burial is unusual), no significant disturbance of the marine environment has been noted, although any repairs will disturb the plants and animals that may grow on the cable. Such growth is common on exposed cables in shallow calm water, but is limited in water depths greater than 2000 metres, where biodiversity and macrofaunal abundance are much reduced (Carter et al., 2009). Some noise disturbance may be caused by the process of laying cables, but this is not significantly more than would be caused by ordinary shipping (OSPAR, 2008).

1.3 Threats to communications cables from the marine environment

Soon after transoceanic communications cables were laid, problems were experienced from impacts of the marine environment on the cables: specifically, submarine earthquakes and landslides breaking the cables (Milne, 1897). However, around 70 per cent of all cable failures are associated with external impacts caused by fishing and shipping in water depths of less than 200 metres (Carter et al., 2009).

Nevertheless, the risks of damage through catastrophic geological events (including those triggered by storms) are real, and some aspects of such risks are probably growing (see the discussion of the effects of climate change on storms in Chapter 5). The most recent major events have been near the Taiwan Province of China. On 26 December 2006, an earthquake occurred at the south end of the island. This triggered multiple submarine landslides. The landslides and subsequent turbidity currents travelled over 330 kilometres and caused 19 breaks in seven cable systems. Damage was located in water depths to 4,000 metres. The cable repair works involved 11 repair vessels and took 49 days. The result was a major disruption of services in the whole region: the internet connections for China, Japan, Philippines, Singapore and Viet Nam were seriously impaired. Banking, airline bookings, email and other services were either stopped or delayed and financial markets and general commerce were disrupted (Detecon, 2013; Carter et al., 2014).

Three years later, Typhoon Morakot hit the island of Taiwan Province of China, on 7 August 2009. Three metres of rain fell on the central mountains, causing much erosion. The sediment carried into sea caused several submarine landslides which broke a number of cables. The level of disruption was shorter and less serious than in 2006. This case is particularly significant, however, because it was the result of an extreme weather event. Given the consensus that climate change is causing the poleward migration of storms, areas that have previously been spared this kind of event are more likely in future to suffer from such storms. This is likely to increase the chances of submarine landslides, since an instability will be introduced into areas where it has not previously been generated (Carter et al., 2012).

The seas off East Asia present a combination of a very dense network of submarine communications cables (see the diagrammatic map in http://submarine-cable-map-2014.telegeography.com/) and an area of unstable geology. The scale of disruption that might be caused, either by a geological incident or by a vessel, can be envisaged by considering the Straits of Malacca. Fourteen of the 37 main submarine cables in the Western Pacific run through this narrow strait. These cables represent virtually the entire data connection between Asia, India, the Middle East and Europe. In addition, it is one of the busiest shipping routes worldwide. This drastically increases the likelihood of disruptions by anchors and other manmade hazards. Such disruptions unfortunately do happen regularly (Detecon, 2013). This, and the situation on the Isthmus of Suez, is one of the main attractions in a submarine cable route from the Pacific to the Atlantic around the north of either the American or the Eurasian continent. There is further a risk from deliberate human interference, but statistically this is a rare event (Burnett et al., 2014).

The International Cable Protection Committee Ltd. (ICPC) is a non-profit organization that facilitates the exchange of technical, legal and environmental information concerning submarine cable installation, maintenance and protection. It has over 150 members representing telecommunication and power companies, government agencies and scientific organizations from more than 50 countries, and encourages cooperation with other users of the seabed. It is thus the main forum in which issues about the protection of these submarine cable connections, vital to global commerce, are being discussed.

1.4 Information and capacity-building gaps

A large body of knowledge already exists about the construction and operation of submarine communication cables, including how to survey environmentally acceptable routes and allow for the submarine geology. Coastal States need access to these skills to decide on safe locations and to take account of areas of potential geological change and disruption, or (at least) to negotiate successfully with commercial undertakings planning to install cables.

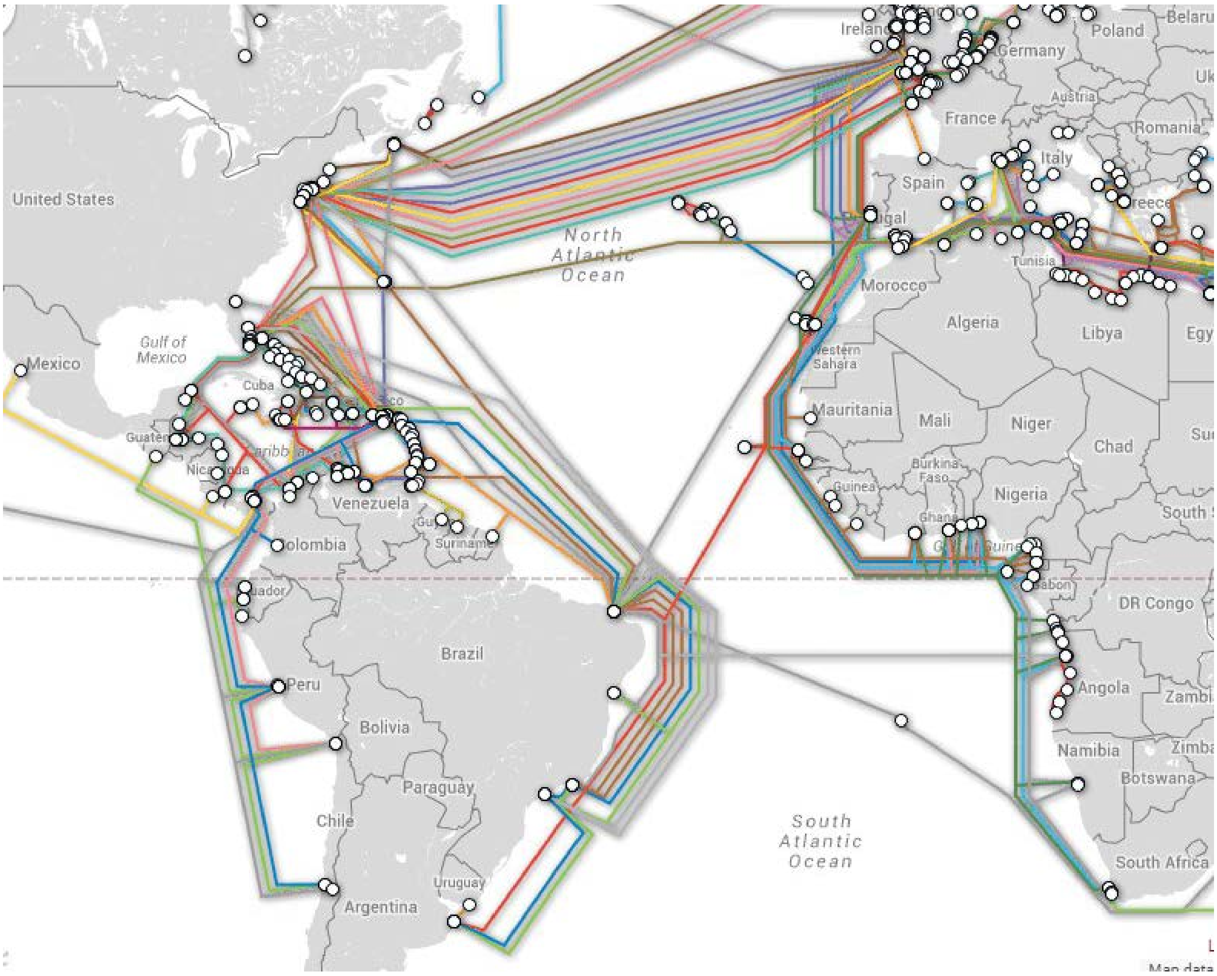
As with many other uses of the marine environment that involve uses of the seabed within their jurisdictions that may prevent or limit other legitimate uses of the sea, States need to have the capacities, in taking decisions on submarine cables, for resolving the conflicting demands of these uses with the other parties involved.

2. Submarine power cables

2.1 The nature and magnitude of submarine power cables

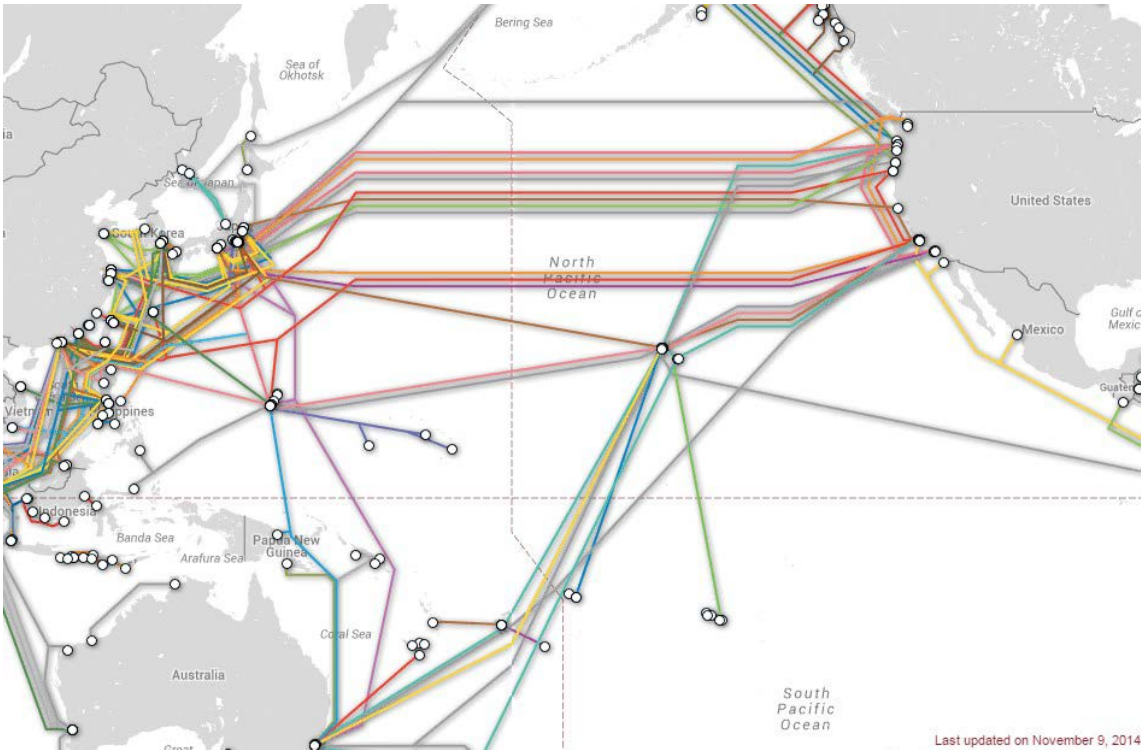
The number and extent of submarine cables carrying power rather than communications are much less significant, both in terms of their impact on the marine environment and in their importance to the world economy. They are essentially of only local interest.

Most of the world's submarine power cables are found in the waters around Europe. The cables fall into one of two classes, depending on whether the electricity is carried as direct current (DC) or alternating current (AC). The choice depends on several factors, including the length of the submarine cable and the transmission capacity needed: DC cables are preferred for longer distances and higher transmission capacities. DC cables can be either monopolar (when the current returns through the sea water) or bipolar (when the cable has two components with opposite polarities). Because monopolar DC cables tend to produce electrolysis, they are now rarely used for major projects.



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 1. Diagrammatic map of transatlantic submarine cables. Source: Telegeography, 2014.



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 2. Diagrammatic map of transpacific submarine cables. Source: Telegeography, 2014.

The AC cables include those between the mainland of Germany and its island of Heligoland, between Italy and its island of Sicily, between Spain and Morocco, between Sweden and the Danish island of Bornholm and, outside Europe, between the islands of Cebu, Negros and Panay in the Philippines. The DC cables include cables linking the Danish islands of Lolland, Falster and Zealand to Germany, Denmark to Norway, Denmark to Sweden, Estonia to Finland, Finland to Sweden, France to the United Kingdom, Germany to Sweden, the Italian mainland to its island of Sardinia and to the French island of Corsica, the Netherlands to Norway (at 580 kilometres, this is the longest submarine power cable in the world), the Netherlands to the United Kingdom, Northern Ireland to Scotland in the United Kingdom of Great Britain and Northern Ireland and the mainland of Sweden to its island of Gotland. Outside Europe, there are DC cables linking the mainland of Australia to its island of Tasmania, the mainland of Canada to its Vancouver Island, Honshu to Shikoku in Japan, the North Island to the South Island in New Zealand and Leyte to Luzon in the Philippines.[1] As can be seen, all these cables (with the exception of the Netherlands/Norway cable) cross fairly narrow stretches of water. They play a locally important part in managing electricity supply, enabling surpluses in one country or area to be transferred to another, or to enable an island to benefit from the economies of scale in power generation through a link to power stations serving

[1] This list has been compiled from a variety of sources.

a much bigger area. The links between Denmark, Norway and Sweden play an important role in the common power policy of those three States.

2.2 Environmental impacts of submarine power cables

The disturbance of the marine environment caused by the installation of a power cable will usually be larger than that for a communications cable, simply because the cable will be larger, in order to carry the current. However, neither the physical disturbance nor the associated noise is likely to have more than a temporary effect.

The other two aspects that have given rise to concern are heat and electromagnetic fields. There are few empirical studies of heat emitted from submarine power cables. AC cables are theoretically likely to emit more heat than DC cables. Calculations for the cable from the Australian mainland through the Bass Strait to Tasmania suggested that the external surface temperature of the cable would reach about 30°C-35°C. The seabed surface temperature directly overlying the cable was expected to rise by a few degrees Celsius at a burial depth of 1.2 metres. Readings taken at a Danish wind farm in 2005 showed that, for a 132 kV cable, the highest temperature recorded closest to the cable between March and September was 17.7°C. German authorities have set a precautionary standard for new cables such that the cables should not raise the temperature at a depth of 20 cm in the seabed by more than 2ºC. This can be achieved by burying the cables at an appropriate depth (OSPAR, 2008).

Concerns have been raised about the effects of the electromagnetic fields generated by the electric current flowing along submarine power cables, since some fish and marine mammals have been shown to be sensitive to either electric fields or magnetic fields. The World Health Organization, however, concluded in 2005 that "…none of the studies performed to date to assess the impact of undersea cables on migratory fish (e.g. salmon and eels) and [on] all the relatively immobile fauna inhabiting the sea floor (e.g. molluscs), have found any substantial behavioural or biological impact" (WHO, 2005). A literature survey in 2006 reached a similar conclusion (Acres, 2006), and nothing had emerged by the 2010 European Union report on the implementation of the EU Marine Strategy Directive to cast doubt on those conclusions (Tasker et al., 2010).

2.3 Knowledge and capacity-building gaps

As with communications cables, coastal States need to have access to the skills to locate submarine power cables in a safe and environmentally acceptable way, and to evaluate the economic and social benefits of introducing such links.

3. Submarine Pipelines

3.1 The nature and magnitude of submarine pipelines

Submarine pipelines are used for transporting three main substances: gas, oil and water. Submarine gas and oil pipelines fall into three groups: intra-field pipelines, which are used to bring the oil or gas from well-heads to a point within the operating field for collection, processing and onward transport; export pipelines, which transport the gas and oil to land; and transport pipelines, which have no necessary connection with the operating field, but transport gas or oil between two places on land. The last category is often included with the export pipelines. The intra-field and export pipelines are discussed in Chapter 21 as part of the processes of extracting the oil and gas. This section is concerned only with the transport pipelines. In general, what is said about submarine pipelines in Chapter 21 applies to gas and oil transport pipelines.

Submarine transport pipelines are used mainly for the transport of gas and are located predominantly around the Mediterranean and the Baltic and North Seas. Many have been created since 2000. In the Mediterranean, the earliest gas pipeline was the Trans-Mediterranean Pipeline, built in 1983 to link Algeria and the Italian mainland, via Sicily. This was followed in 1996 by the Maghreb-Europe Pipeline to link Morocco and Spain across the Strait of Gibraltar. Subsequent Mediterranean pipelines are: the Greenstream Pipeline, built in 2004 between Libya and Sicily, the interconnector built in 2007 between Greece and Turkey, the link completed in 2008 between Arish in Egypt and Ashkelon in Israel (which has been out of service since 2012), and the Medgaz Pipeline built in 2011 between Algeria and Spain. Further north, a link was built between Scotland and Northern Ireland in the United Kingdom in 1996. An interconnector was built between Belgium and the United Kingdom in 1998. The Balgazand/Bacton Line (BBL) connected the Netherlands and the United Kingdom in 2006. Finally, the Nord Stream Pipeline was completed in 2011 and 2012 through the Baltic, between Vyborg in the Russian Federation and Kiel in Germany. This is the longest gas transport pipeline in the world (1,222 kilometres in length). Issues about its environmental impact bulked large in the negotiations leading to its construction, and particular problems were encountered over munitions dumped in the Baltic at the end of the Second World War (see Chapter 24 (Solid waste disposal)).[2] There are also a number of gas pipelines linking Norwegian gas production to its export markets. The Norwegian upstream gas transportation system has been developed from the 1970s, and continues to develop, to cater for the transportation of natural gas produced on the Norwegian continental shelf. Norwegian domestic consumption of natural gas is limited. Almost all the gas produced is exported (101,000 million standard cubic metres) to European gas markets through landing terminals in Belgium, France, Germany and the United Kingdom. The pipeline network in 2014 forms a 7,980-kilometre integrated transportation system, transporting gas from nearly 60 offshore fields and three large gas processing plans on the Norwegian mainland, to European gas markets. The latest main addition to the system is the Langeled Pipeline, opened in 2007, which goes from the onshore processing plant in Norway for the Ormen Lange gas field to the United Kingdom, via a riser platform at the Sleipner field.

Outside Western Europe and the Mediterranean, there is a gas pipeline linking the Russian Federation and Turkey across the South-Eastern corner of the Black Sea, and

[2] This list has been compiled from a variety of sources.

one linking the island of Sakhalin to the mainland of the Russian Federation in the North-West Pacific. Oil transport pipelines exist between Indonesia and Singapore across the Strait of Malacca, and in China, linking the island of Hainan to Hong Kong.[3] Generally, these submarine transport pipelines have been built and financed by oil and gas operators (including national oil and gas companies), sometimes in consortiums with national gas distribution undertakings.

3.2 Environmental impacts of oil and gas pipelines

The environmental impacts of intra-field and export submarine pipelines are discussed in Chapter 21 (Offshore hydrocarbon industries). The impacts of oil and gas submarine transport pipelines are essentially the same.

3.3 Submarine water pipelines

Because of the high cost and maintenance difficulties, submarine pipelines are only used to supply small islands close to continents or larger islands where the natural water supplies of the islands are insufficient for their needs. The supply of water to Singapore from Malaysia is the only significant international example (PUB, 2014). Domestic examples include: China (where Xiamen Island receives some of its water from the mainland through 2.3 kilometres of submarine pipelines), Fiji (where several small islands with tourism resorts are supplied through submarine pipelines), Malaysia (where Penang receives some of its water supply from the Malaysian mainland through 3.5 kilometres of submarine pipelines), the Seychelles (where five small islands are supplied through submarine pipelines of up to 5 kilometres in length) and, most significantly, in Hong Kong, China (where water is supplied to some of the islands, including the densely populated Hong Kong Island, from the Chinese mainland, through 1.3 kilometres of submarine pipelines) (UNESCO, 1991).

3.4 Knowledge and capacity-building gaps

For oil and gas transport pipelines, the requirements are likely to arise from the overall planning of the exploitation of hydrocarbon reserves and the provision of gas services. The comments in Chapter 21 on this subject are therefore relevant.

For submarine water pipelines, the essential questions will be linked to the planning and implementation of freshwater supply services. Questions of access to information and the necessary skills need to be addressed in that context. As with the laying of submarine communication cables, in taking decisions on submarine water pipelines within their jurisdictions, States need to have the capacities for resolving the conflicting demands of these uses.

[3] This information has also been compiled from a variety of sources.

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