Norway

Oslo, March 2021:

Update on Networks and Connectivity, Norway

Recent investments in subsea fiber infrastructure have radically improved Norway's connectivity.

Over the last few years, new subsea systems have been added to the Norwegian marketplace, strengthening the value proposition for Norway as a favorable location for cloud/content providers and enterprises to locate new data center builds. Norway is now on par, if not above, our neighboring countries in terms of offered connectivity, capacities and route diversity.

See the table below for a full overview of recent subsea cable systems in operation, systems under construction and planned systems:

In operation:

System Name	System Owner	From	To	Services
Havfrue	BULK	Kristiansand/N01	Wall Township, NJ, USA, Denmark (DK01), Ireland	Managed/raw spectrum
Skagerrak-4	Statnett/ Dansk Energinet	Kristiansand	Bulbjerg, Denmark	Dark Fiber
Tampnet Carrier*	Tampnet	Norway**	UK**	Dark Fiber, Waves, EoMPLS
Skagenfiber West	Altibox Carrier	Larvik	Hirtshals, Denmark	Waves, capacity, Dark Fiber

**Tampnet Offshore FOC Network*
***Multiple locations*

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Under construction:

System Name	System Owner	From	To	Services	RFS
NO-UK Cable System	Altibox Carrier	Stavanger	Newcastle,UK	Spectrum, waves	Q4 2021
Havsil	BULK	Kristiansand/N01	Hanstholm and Esbjerg, Denmark	Dark Fiber	Q4 2021

Planned:

System Name	System Owner	From	To	Services	RFS
Celtic-Norse	Celtic-Norse AS	Trondheim	Kilala, IRL	Dark Fiber, spectrum, waves	2022
Arctic Connect	Cinia OY	Kirkenes	Hokkaido, Japan	TBD	TBD
Leif Erikson	BULK	Husnes	Goose Bay, Canada	Dark Fiber, managed/raw spectrum	Q4 2023

The offered services per provider spans from EoMPLS, waves (10G/100G/400G), to managed/raw spectrum and dark fiber. IRU/lease terms and conditions apply and vary accordingly among the providers.

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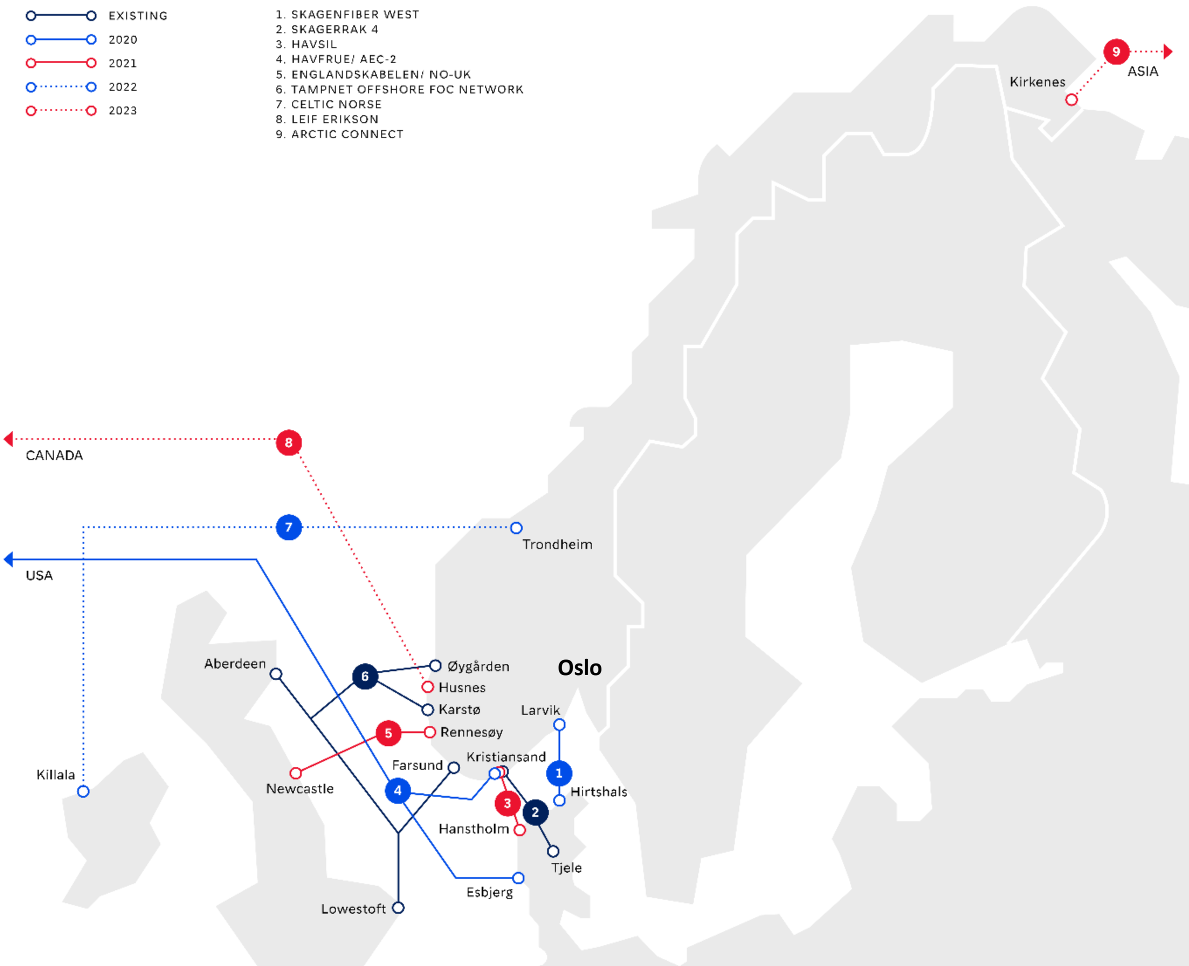
Subsea Network Map

The map below shows an overview of existing subsea networks, systems under construction and planned systems.



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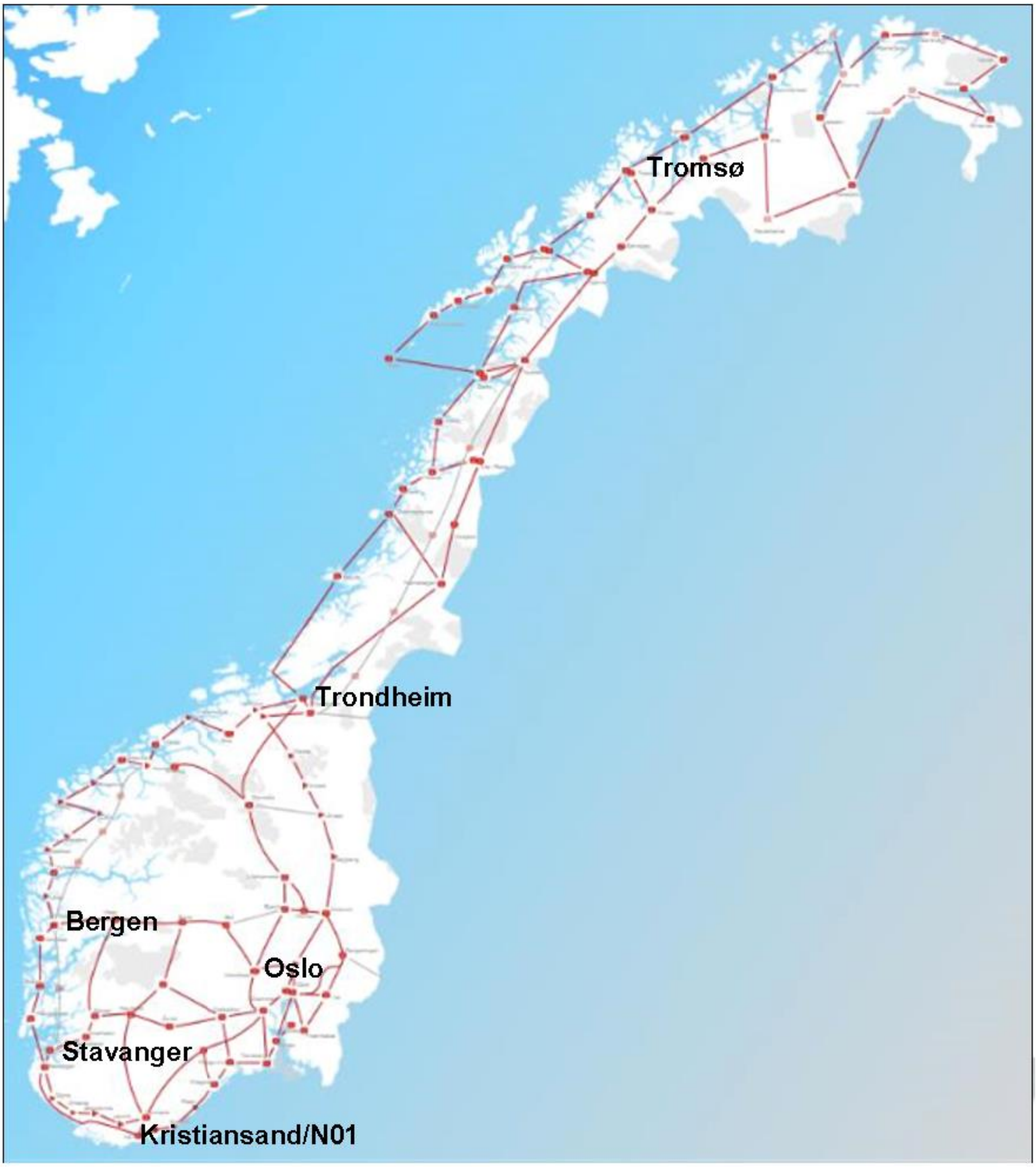
Domestic Terrestrial Fiber Infrastructure Overview

The map below shows an overview of domestic transport fiber infrastructure.



From each of the subsea cable landing sites, new terrestrial backhauls have been constructed to provide sufficient capacities and route diversity between PoPs in Norway and PoPs in Frankfurt, Amsterdam, London and other leading markets in Europe. Dark Fiber services are offered on selects routes over the domestic network.

Norway's capital Oslo has seen a vast improvement in connectivity as domestic and international fiber builds have come online recently, thus strengthening Oslo's position as the dominating ecosystem hub for the datacenter industry in Norway. But the construction of new terrestrial and subsea cable routes now also provides locations outside of Oslo with direct access to markets abroad.

Throughout the country there are five Internet exchange points serviced by NIX (Norwegian Internet Exchange), located in Oslo, Bergen, Trondheim, Tromsø and Stavanger, with international peering at NIX1 and NIX2 in Oslo. Most of the international carriers have their Points-of-Presence (PoP) for interconnecting to the data center ecosystems in Oslo.

Norwegian Internet Exchange – NIX

NIX NORWEGIAN INTERNET EXCHANGE

An Internet exchange point (IX or IXP) is the physical infrastructure through which Internet service providers (ISPs) and content delivery networks (CDNs) exchange regional Internet traffic between their respective networks.

In addition to the connectivity offered by national and international carriers in Norway, NIX (Norwegian Internet Exchange) provides connectivity across the country. NIX is present in Oslo, Stavanger, Bergen, Trondheim, Tromsø and Oslo. In addition, NIX is well connected to the Swedish IXP Netnod, operating the largest IXP in the Nordics and provides connectivity throughout the region.

NIX presents an opportunity to peer with (or connect to) some of the largest transit providers, telcos and CDNs in the region. Currently, the Oslo NIX nodes provides connectivity to 68 unique AS-es.

Latency to Northern Europe

The intuitive notion of Norway being a country very far north and "off-the-grid", implies that traffic between destinations in Europe or the USA, to Norway, entails intrinsically high latency – i.e. the time it takes for data traffic to reach a destination and get back again.

Until recently, Norway had a latency disadvantage versus other Nordic countries, as the lion's share of traffic from Norway to Northern Europe had to go east via Sweden before egressing to Europe. The influx of new subsea routes from Norway has effectively removed this disadvantage, and in some cases represents an advantage latency wise.

The metric for latency is RTD – Round Trip Delay – is the number of milliseconds it takes from traffic to transit between point of origin and destination and back.

The majority of traffic in high-capacity networks flows through fiber optic cables, and the latency will basically depend on the time it takes the photons in the cable to traverse the physical distance between the traffic endpoints. In order to calculate latency between two locations, $2*10^8$ m/s represents the speed of light when traveling through glass.

Ideally, fiber spans between two locations should be as short and straight as possible to keep distance and thereby latency low. But fiber routes are rarely deployed as perfectly straight lines, rather than following power lines, gas lines, roadside and rail side ducts and other viable infrastructure builds. Also, cable routes have to consider passing as many interconnection points as possible to optimize the route, factors that increase overall cable span lengths and adds extra latency to the traffic.

Assessing the roundtrip delay, or RTD, is done simply by looking at the time it takes for a data packet to be sent from an origin node to a destination node and back again. A usual way of measuring RTD is to “ping” a destination, which gives a good indication of RTD values for the specific destination.

Operators that operate their own fiber paths between destinations, will benefit from not having to route traffic via 3rd party networks to reach the destination, and will gain lower latency figures.

The table below indicates typical latency values between endpoints in Norway and leading markets in Europe:

Latency Figures, Primary Route

RTD in ms	Oslo	KRS/N01	Stavanger	Bergen	Trondheim	Tromsø	Stockholm	Copenhagen	Dublin	Frankfurt	London	Amsterdam	Paris
Oslo		3,8	5,4	4,5	4,9	22,8	6,8	9,6	18,2	14,4	14,9	12,6	19,9
KRS/N01			2,8	4,9	8,7	26,6	10,6	7,3	14,3	11.0	11,2	12,1	18,3
Stavanger				2,1	8,7	28,2	11,3	10,7	12,1	14,1	11,6	16,3	17,4
Bergen					9,4	27,3	11,3	12,8	14,2	19,0	13,7	18,4	19,5
Trondheim						17,9	11,7	13,9	24,8	20,2	24,3	21,1	23,3
Tromsø							29,6	32,4	41,0	37,2	37,7	35,4	40,2

As new subsea routes come online in the near future, some of the latency figures may improve. For more information on latency figures per provider, please see information on providers’ web pages.

Price Levels

As more subsea and terrestrial capacity has been injected into the Norwegian market, the general pricing level on WDM services in Norway is harmonized with the pricing levels in our Nordic neighbor countries. As in other markets, additional costs may apply for tail end connections.

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