European Network of
Transmission System Operators
for Electricity

entsoe

ENTSO-E HVDC UTILISATION AND AVAILABILITY STATISTICS 2024

30 June 2025

From: DISTAC Subgroup under Regional Group Nordic

ENTSO-E HVDC Utilisation and Availability Statistics 2024

Report rendered 30 June 2025

ENTSO-E Mission Statement

Who we are

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the association for the cooperation of the European transmission system operators (TSOs). The 40 member TSOs, representing 35 countries, are responsible for the secure and coordinated operation of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs.

ENTSO-E brings together the unique expertise of TSOs for the benefit of European citizens by keeping the lights on, enabling the energy transition, and promoting the completion and optimal functioning of the internal electricity market, including via the fulfilment of the mandates given to ENTSO-E based on EU legislation.

Our mission

ENTSO-E and its members, as the European TSO community, fulfil a common mission: Ensuring the security of the interconnected power system in all time frames at pan-European level and the optimal functioning and development of the European interconnected electricity markets, while enabling the integration of electricity generated from renewable energy sources and of emerging technologies.

Our vision

ENTSO-E plays a central role in enabling Europe to become the first climate-neutral continent by 2050 by creating a system that is secure, sustainable and affordable, and that integrates the expected amount of renewable energy, thereby offering an essential contribution to the European Green Deal. This endeavour requires sector integration and close cooperation among all actors.

Europe is moving towards a sustainable, digitalised, integrated and electrified energy system with a combination of centralised and distributed resources. ENTSO-E acts to ensure that this energy system keeps consumers at its centre and is operated and developed with climate objectives and social welfare in mind.

ENTSO-E is committed to use its unique expertise and system-wide view – supported by a responsibility to maintain the system's security – to deliver a comprehensive roadmap of how a climate-neutral Europe looks.

Our values

ENTSO-E acts in solidarity as a community of TSOs united by a shared responsibility.

As the professional association of independent and neutral regulated entities acting under a clear legal mandate, ENTSO-E serves the interests of society by optimising social welfare in its dimensions of safety, economy, environment, and performance.

ENTSO-E is committed to working with the highest technical rigour as well as developing sustainable and innovative responses to prepare for the future and overcoming the challenges of keeping the power system secure in a climate-neutral Europe. In all its activities, ENTSO-E acts with transparency and in a trustworthy dialogue with legislative and regulatory decision makers and stakeholders.

Our contributions

ENTSO-E supports the cooperation among its members at European and regional levels. Over the past decades, TSOs have undertaken initiatives to increase their cooperation in network planning, operation and market integration, thereby successfully contributing to meeting EU climate and energy targets.

To carry out its legally mandated tasks, ENTSO-E's key responsibilities include the following:

› Development and implementation of standards, network codes, platforms and tools to ensure secure system and market operation as well as integration of renewable energy; › Assessment of the adequacy of the system in different timeframes;

› Coordination of the planning and development of infrastructures at the European level (Ten-Year Network Development Plans, TYNDPs);

› Coordination of research, development and innovation activities of TSOs;

› Development of platforms to enable the transparent sharing of data with market participants.

ENTSO-E supports its members in the implementation and monitoring of the agreed common rules.

ENTSO-E is the common voice of European TSOs and provides expert contributions and a constructive view to energy debates to support policymakers in making informed decisions.

Executive Summary

The ENTSO-E HVDC Utilisation and Availability Statistics 2024 report provides an overview of the Nordic and Baltic HVDC links as well as a detailed view of transmission, limitations, and outages of each individual link.

With the introduction of Viking Link 1 and 2 in 2024, the Nordic and Baltic links now has a total technical capacity E_{max} of 131,6 TWh. 85.1 TWh (65 % of the total technical capacity, E_{max}) of electric energy was transmitted through the Nordic and Baltic HVDC links, as seen in Figure 1. The total capacity not used was 32.9 TWh (25 % of the total technical capacity, E_{max}).

The HVDC links with most available technical capacity were North Sea Link 1 (99 %), Storebælt (99 %), and NordLink 2 (98 %). These were closely followed by North Sea Link 2 and Skagerrak 4, each with 98 % availability.

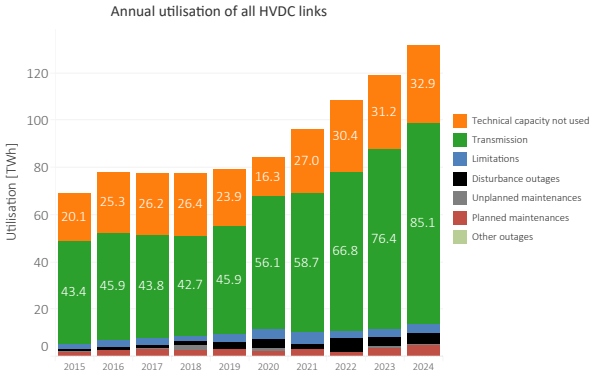

Figure 1: Annual utilisation of all HVDC links.

The percentage of unavailable technical capacity (E_U) of all links in 2024 was 11 %. The total number of disturbance outages was 120, preventing 4.7 TWh (3.6 % of the total technical capacity, (E_U)) of potential energy transmission. The total number of maintenance outages (planned and unplanned) were 169 in 2024, preventing 5.1 TWh (3.9 % of the total technical capacity, E_{max}) of potential energy transmission. Limitations represent 3.8 TWh (2.9 %) of the total technical capacity (E_U) in 2024.

The HVDC links with most unavailable technical capacity due to outages and limitations were EstLink 2 (62 %), SwePol (22 %), Viking Link 1 (20 %) and Viking Link 2 (20 %). EstLink 2 seacable was mechanically damaged near the Estonian shoreline in January. The repair took 7 months. SwePol annual maintenance was quite long, almost two and a half months. Viking Link 1 and 2 was limited throughout most of the year due to delayed grid reinforcements in the AC grid in Denmark.

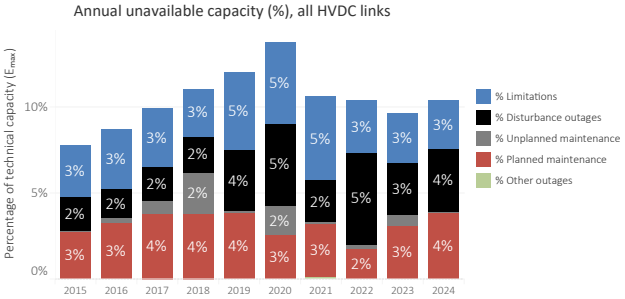

Figure 2: Annual unavailability (%), all HVDC links.

The most utilized market connections in 2024 were SE4-LT (83 %), NO2-GB (83 %) and DK2-DE (78 %) as shown in Table 1. Nine other market connections reached a utilisation rate of 60–70 %, two market connections were utilized between 50–60 % of the maximum technical capacity. Lowest utilisation had FI–EE (48 %) and DK2–DK1 (48 %).

Table 1: The annual utilisation (%) of HVDC links per market connection.

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
DK1–GB										52%
DK1–NL					80%	51%	63%	65%	69%	66%
DK2–DE	75%	67%	66%	53%	69%	47%	71%	65%	45%	78%
DK2–DK1	70%	78%	64%	63%	58%	71%	57%	50%	50%	48%
FI–EE	57%	42%	29%	37%	47%	75%	77%	78%	80%	48%
FI–SE3	76%	78%	70%	72%	81%	85%	68%	72%	60%	62%
LT–PL		34%	47%	54%	61%	58%	55%	61%	58%	53%
NO2–DE							44%	58%	64%	67%
NO2–DK1	54%	61%	54%	53%	46%	62%	67%	55%	59%	68%
NO2–GB								51%	76%	83%
NO2–NL	94%	72%	83%	68%	61%	77%	63%	35%	57%	64%
SE3–DK1	49%	59%	52%	53%	50%	57%	49%	66%	68%	66%
SE3–SE4									50%	65%
SE4–DE	31%	43%	46%	33%	36%	55%	48%	62%	65%	61%
SE4–LT		44%	51%	50%	63%	76%	60%	80%	77%	83%
SE4–PL	67%	56%	62%	66%	62%	72%	69%	76%	82%	65%
Grand Total	63%	59%	56%	55%	58%	67%	61%	62%	64%	65%

The most utilized HVDC links were Nordbalt (83 %) North Sea Link 1 (83 %) and North Sea Link 2 (83 %).

Table of contents

List of Figures

List of Tables

This page is intentionally left blank.

1 Introduction and background

The ENTSO-E HVDC statistics 2024 presents the utilisation and availability and of all 26 HVDC links connected to the Nordic and Baltic power system in 2024. The statistics shows transmission, outages, limitatations and technical capacity not used of each HVDC link and summaries for all links combined. The report is made following the ENTSO-E Nordic and Baltic Guidelines for HVDC Statistics 2020 [1].

1.1 Scope

The ENTSO-E HVDC Utilisation and Availability Statistics 2024 presents a macro view of the availability and utilisation of each HVDC link, including disturbance, maintenance and other outage events as well as limitations. Limitations originating from maintenance work done in the AC grid are also included if they affect the power transmission of an HVDC connection. Furthermore, disturbance outages are examined more closely than other events.

The scope of the report is different from the CIGRE performance survey data [2], which focuses mainly on outages, faults and disturbances of the HVDC systems. CIGRE statistics gives more details about the condition and performance of the HVDC assets themselves, including forced and scheduled outages, thyristor and transistor failure rates, commutation failures, and so on. On the other hand, ENTSO-E HVDC statistics covers more divergent performance and availability data and goes deeper into classification, consequences and outage reasons.

HVDC task force of NordAM (Nordic Asset Management Forum) and the ENTSO-E DISTAC (Disturbance Statistics) group have together developed the ENTSO-E HVDC outage and utilisation data collection so that more detailed performance analysis of HVDC links is possible.

1.2 Contact persons

Each country is represented by at least one contact person who is responsible for the statistical information of the corresponding country. Contact persons can provide additional information concerning the HVDC utilisation and unavailability and statistics. The relevant contact information is given in Appendix C.

[0]The five Nordic Transmission System Operators (TSOs) founded a Nordic Asset Management Forum (NordAM) in 2009 with the main goal to increase cooperation, jointly influence, build up knowledge, create networks as well as carry out agreed surveys and development tasks within the field of Asset Management. The HVDC working group was established after a very successful task force work done in 2017.

2 Methods and definitions

The statistics is made according to the ENTSO-E HVDC Guidelines [1]. To compare the utilisation and availability between HVDC links, different ways of using them must understood. This chapter explains the utilisation and availability categories used in the report. The categories are illustrated in Figure 2.1.

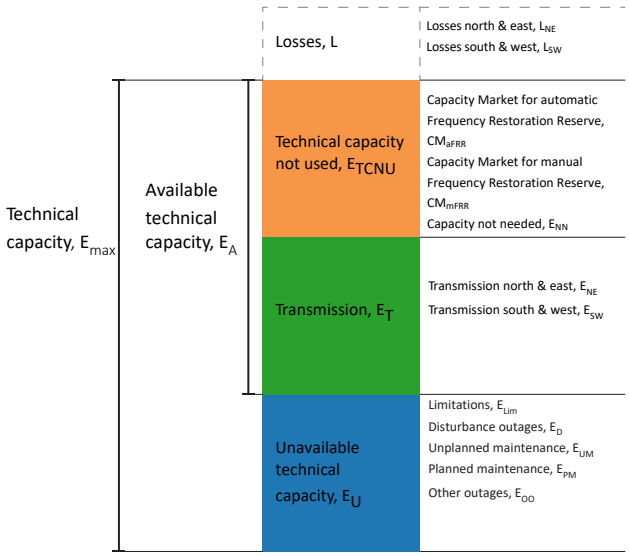

Figure 2.1: The hierarchy of the availability and utilisation categories used in the HVDC statistics.

The technical capacity (E_{max}) of an HVDC link is the maximum energy that can be physically received through the HVDC link to the converter station, excluding all HVDC link losses, during a year. The technical capacity is divided into two categories: *available technical capacity (E_A)* and *unavailable technical capacity (E_U)*.

Transmitted energy (E_T) is the sum of transmitted energy in both directions of the HVDC link. Energy transferred to the north or east side of the HVDC link is called *transmission north and east (E_{NE})*, and energy transferred to the south or west side of the HVDC link is called *transmission south and west (E_{SW})*. It does not include *losses (L)* that is, the energy losses in any of the HVDC link components during transmission. It should be noted that these values are measurements and therefore considered factual.

The technical capacity not used (E_{TCNU}) is the residual energy after transmission, outages and limitations. This includes the capacity reserved in the capacity markets, both aFRR (CM_{aFRR}) and mFRR (CM_{mFRR}), but not activated, and the Capacity not needed (E_{NN}) by the electricity markets.

The *unavailable technical capacity (E_U)* is the part of the *technical capacity (E_{max})* that could not be utilised. It has five subcategories: *limitations (E_{Lim}), disturbance outages (E_D), unplanned maintenance (E_{UM}), planned maintenance (E_{PM})* and *other outages (E_{OO})*. An outage occurs when the HVDC link is fully disconnected from the system and the transfer capacity is reduced to zero. A limitation occurs when the capacity of the link has been reduced by between 0–100 %. Limitations and the outages are described in more detail below.

A *limitation (E_{Lim})* is a condition when the transmission capacity of an HVDC link is limited that is, the power transmission capacity of the link is less than the rated power. The limitation is always motivated from a technical perspective, but not always concerning the link itself. The most common causes of limitations are:

- faults on any HVDC link component that do not cause a total outage;
- faults, congestions or outages in the AC grid causing a limitation in the transmission capacity of the link;
- seasonal variations on the transmission capacity.

Note that a limitation is counted for an hour only if there was transmission in the direction of the limitation and the sum of transmission and unavailable technical capacity is more than 90 % of the rated capacity. The reason to this is to only include limitations that have truly impacted the transmission of a HVDC link. Limitations that do not meet this requirement become *technical capacity not used (E_{TCNU})* instead.

Disturbance outages (E_D) are total outages due to a fault on the HVDC link or in the AC-grid causing a total outage of the link. A disturbance outage occurs when the protection trips the link or, in rare cases, disconnected manually. Manual disconnection is usually categorised as unplanned maintenance.

Unplanned maintenance outages (E_{UM}) occurs when the link is manually disconnected for emergency or urgent repair. In general, unplanned maintenance are outages that cannot wait until the next scheduled maintenance.

Planned maintenance outages (E_{PM}) are total outages due to all technically motivated actions on the HVDC link or in the AC grid intended to retain an entity in, or restore it to, a state where it can perform its required function.

Other outages (E_{OO}) are outages due to any other reason. This could be, for example, black start or other tests or when the markets do not need the transmission capacity of the link and the link is disconnected.

3 Technical details of the HVDC links

Table 3.1 presents the main properties of the HVDC links while Table 3.2 presents the technical properties of the HVDC lines.

Schematic presentations of the HVDC links and their converter stations, both for line-commutated converters (LCC) and voltage-source converters (VSC) are presented in Appendix A.

Table 3.1: Main properties of the HVDC links.

Link	Commissioning year	Market connection	HVDC converter type	Rated power, monopolar (MW)	Parallel monopolar capacity (MW)	Bipolar capacity
Baltic Cable	1994	Yes	LCC	600		
COBRAcable	2019	Yes	VSC	700		
EstLink 1	2006	Yes	VSC	350	1000	
EstLink 2	2014	Yes	LCC	650		
Fenno-Skan 1	1989	Yes	LCC	400	1200	1200
Fenno-Skan 2	2011	Yes	LCC	800		
Kontek	1995	Yes	LCC	600		
Konti-Skan 1[1]	2008	Yes	LCC	357.5		715
Konti-Skan 2[1]	1988	Yes	LCC	357.5		
LitPol Link	2015	Yes	LCC	500		
NordBalt	2016	Yes	VSC	700		
NordLink 1	2020	Yes	VSC	700	1400	1400
NordLink 2	2020	Yes	VSC	700		
NorNed	2008	Yes	LCC	700		
North Sea Link 1	2022	Yes	VSC	700	1400	1400
North Sea Link 2	2022	Yes	VSC	700		
Skagerrak 1	1977	Yes	LCC	236	1000	1000
Skagerrak 2	1977	Yes	LCC	236		
Skagerrak 3	1993	Yes	LCC	478		
Skagerrak 4	2014	Yes	VSC	682		
South West Link 1	2021	Yes	VSC	600	1200	1200
South West Link 2	2021	Yes	VSC	600		
Storebaelt	2010	Yes	LCC	600		
SwePol	2000	Yes	LCC	600		
Viking Link 1	2023	Yes	VSC	700	1400	1400
Viking Link 2	2023	Yes	VSC	700		

[1] Konti-Skan bipole can export 740 MW and the import capacity is 715 MW. This counts in both directions since the reference-point is now on the importing side.

Table 3.2: Technical details of the HVDC links

Link	Physical length (km)	Length of mass cable (km)	Length of PEX cable (km)	Length of DC overhead line (km)	Length of DC back-to-back connection (km)
Baltic Cable	262	250		12	
COBRAcable	325	325	650 (2×325)		
EstLink 1	105		210 (2×105)		
EstLink 2	171	157		14	
Fenno-Skan 1	233	200		33	
Fenno-Skan 2	299	196		103	
Kontek	160		160		
Konti-Skan 1	150	89		61	
Konti-Skan 2	150	89		61	
LitPol Link	< 1				< 1
NordBalt	450		2×450		
NordLink 1	623			53	
NordLink 2	623			53	
NorNed	580	580			
North Sea Link 1	720	720			
North Sea Link 2	720	720			
Skagerrak 1	212.5	133.6		78.5	
Skagerrak 2	211.4	132.9		78.5	
Skagerrak 3	212.9	134.4		78.5	
Skagerrak 4	226	226			
South West Link 1	252	192		60	
South West Link 2	252	192		60	
Storebaelt	57	57			
SwePol	254	254			
Viking Link 1	767.5	767.5			
Viking Link 2	767.5	767.5			

4 Results

This chapter presents the utilisation and availability of all the HVDC links as well as individual presentations of each HVDC link connected to the Nordic and Baltic power systems. Section 4.1 provides an overview for each HVDC link in 2024 and Section 4.2 provides an overview of all links for the years 2015–2024. Section 4.3 presents an overview of all electricity market connections for 2015–2024. Section 4.4 presents the utilisation and availability of each HVDC link for the year 2024 as well as an annual overview of the utilisation and a trend of the utilisation and the number of outages for the years 2015–2024.

4.1 Overview for each HVDC link in 2024

Figure 4.1 presents the transmission and unavailability (%) of each HVDC link in 2024. Sorted views of Figure 4.1 are shown in Appendix D.

In 2024, 85.1 TWh of electric energy was transmitted through the Nordic and Baltic HVDC links, as seen in Figure 4.5. The total number of disturbance outages was 120, preventing 4.7 TWh of potential energy transmission, and 3.6 % of the total technical capacity (E_{max}). Maintenance outages amounted to 5.1 TWh, (3.9 % of the total technical capacity) (E_{max}), and limitations reduced the transmission capacity by 3.8 TWh (2.9 % of the transmission capacity).

Figure 4.2 presents the percentage unavailable technical capacity (E_U) of the annual technical capacity (E_{max}) due to the outages and limitations. Figure 4.3 presents the number of all disturbance, maintenance and other outages. The explanations for the most notable unavailabilitys in 2024 are listed below. Further details are presented in Section 4.4.

Since November 2024, when flow-based was introduced, all limitations due to constraints in the AC grid have yet not been included in the report because all these limitations cannot be identified for the moment. It is assessed that the impact is less significant. The DISTAC group is exploring which options are available for including these limitations in future reports.

Review of notable unavailable technical capacity 2024

The HVDC links with most unavailable technical capacity due to outages and limitations are Estlink2 (62 %), SwePol (22 %), Viking Link 1 (20 %), Viking Link 2 (20 %) and Fenno-Skan 1 (15 %). EstLink 2 DC seacable was mechanically damaged on the landside near the Estonian shoreline in January. The cable was unavailable for 7 months of the year 2024. In late December, the DC seacable was again mechanically damaged, now by an anchor of a ship. This damage reduces mostly availability for year 2025. SwePol annual maintenance was quite long, almost two and a half months. Viking Link 1 and 2 was limited throughout most of the year due to delayed grid reinforcements in the AC grid in Denmark. Fenno-Skan 1 was out of service for 6.5 weeks in August - September for refurbishment of the 400 kV AC stations, renewal of station control and monitoring systems at both ends and annual maintenance.

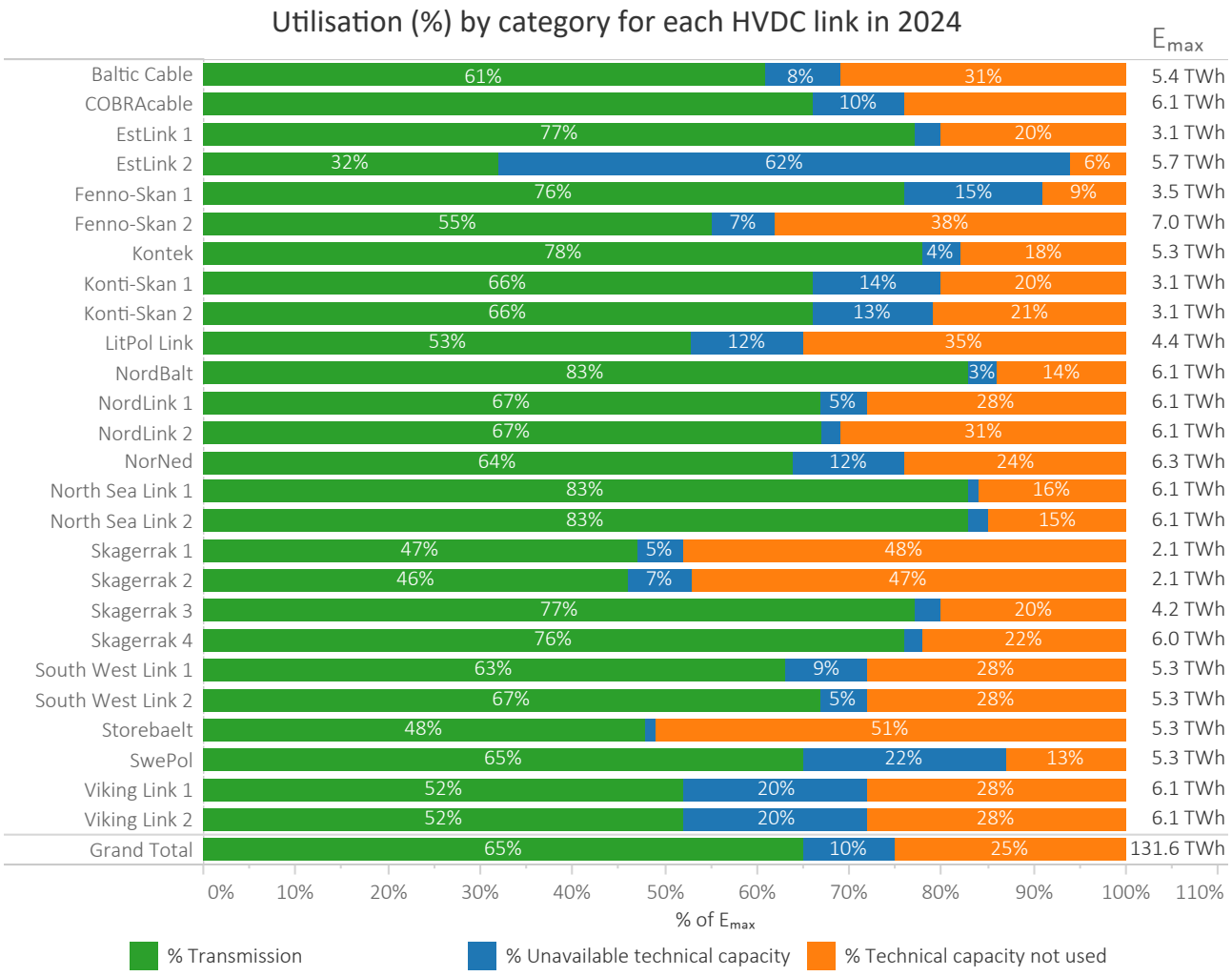

Figure 4.1: Utilisation (%) by category for each HVDC link in 2024. The unavailable technical capacity (E_U) is the amount of technical capacity (E_{max}) not available due to limitations or outages. Transmission (E_T) is the amount of technical capacity (E_{max}) transmitted through the HVDC link. Technical capacity not used (E_{TCNU}) is the amount of energy that has not been transmitted or been unavailable due to limitations or outages.

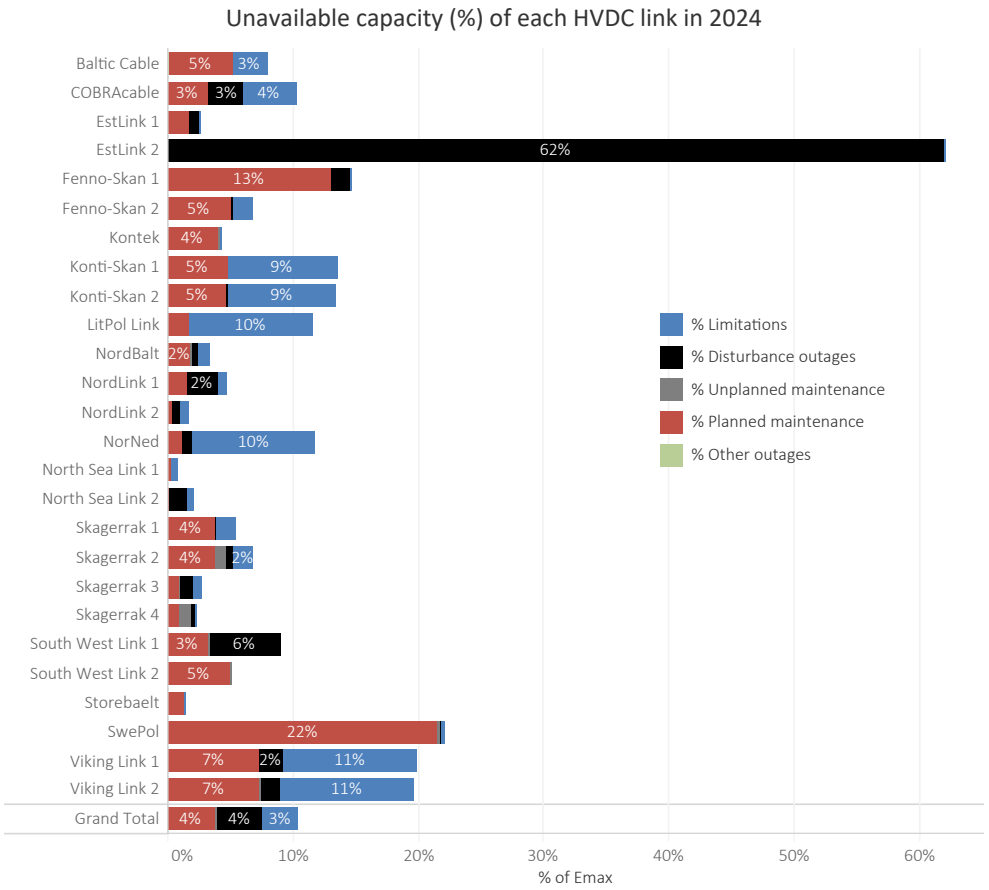

Figure 4.2: Unavailable technical capacity (%) for each HVDC link in 2024. The used unavailability categories are limitations, disturbance outages, unplanned and planned maintenances and other outages.

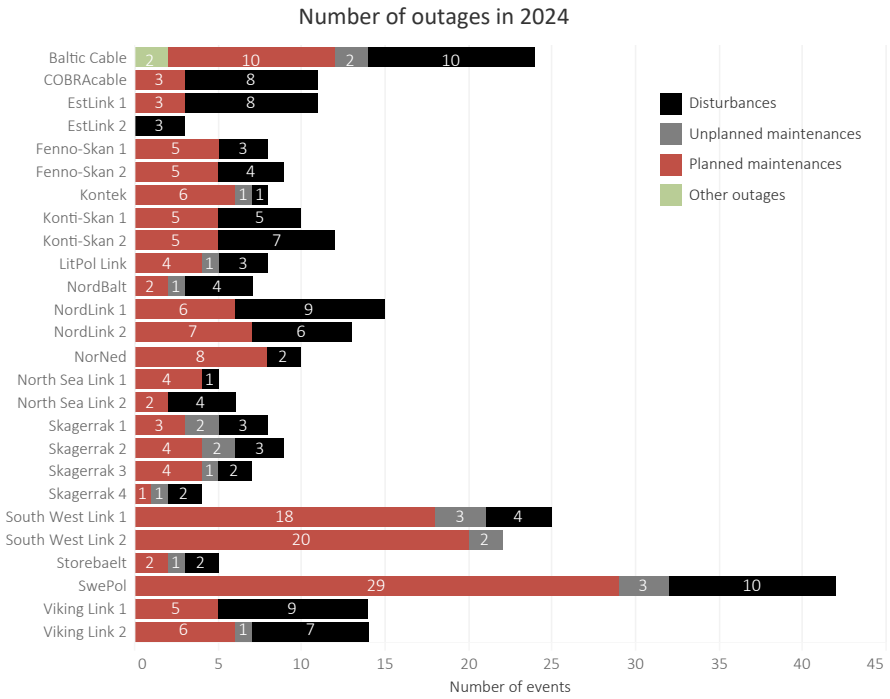

Figure 4.3: The number of disturbance outages, unplanned maintenance and planned maintenance outages and other outages for each link in 2024.

4.2 An overview of HVDC links during 2015–2024.

Figure 4.4 presents the annual utilisation (%) of all HVDC links and Figure 4.5 presents the annual utilisation (TWh) with all utilisation categories.

The percentage of unavailable technical capacity (E_U) in 2024 was on the normal 10-year average 10 %. The percentage of transmission (E_T) was 65 % which is above the 10 -year average (61 %).

Figure 4.5 shows annual utilisation of all HVDC links in TWhs. More HVDC links have been commissioned during the previous years such as South West Links, Viking Links and North Sea Links. Figure 4.6 presents the annual utilisation rate grouped by utilisation percentage for all HVDC links. Figure 4.7 presents the annual unavailable technical capacity (%) by unavailability category. Figure 4.8 presents the annual unavailability hours (%) for all HVDC links.

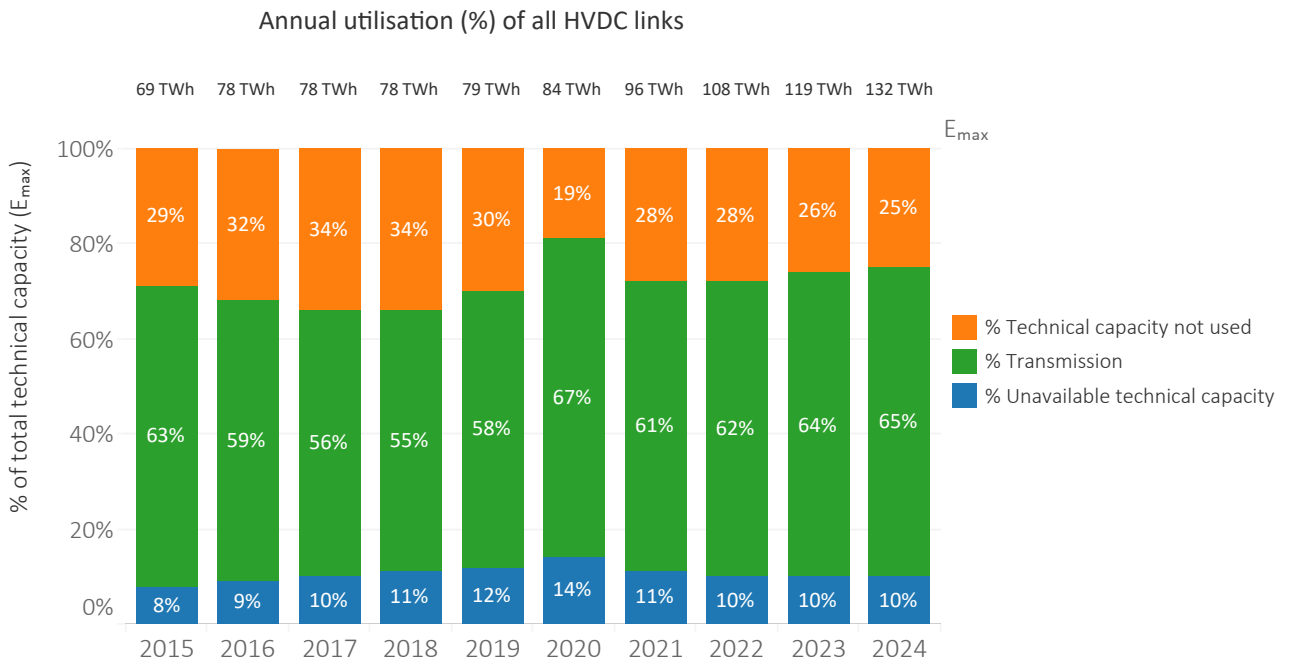

Figure 4.4: The annual utilisation percentage of all HVDC links since 2015. The unavailable technical capacity (E_U) is the amount of technical capacity (E_{max}) not available due to limitations or outages. Transmission (E_T) is the amount of technical capacity (E_{max}) transmitted through the HVDC links. Technical capacity not used (E_{TCNU}) is the residual energy that has neither been transmitted nor been unavailable due to limitations or outages.

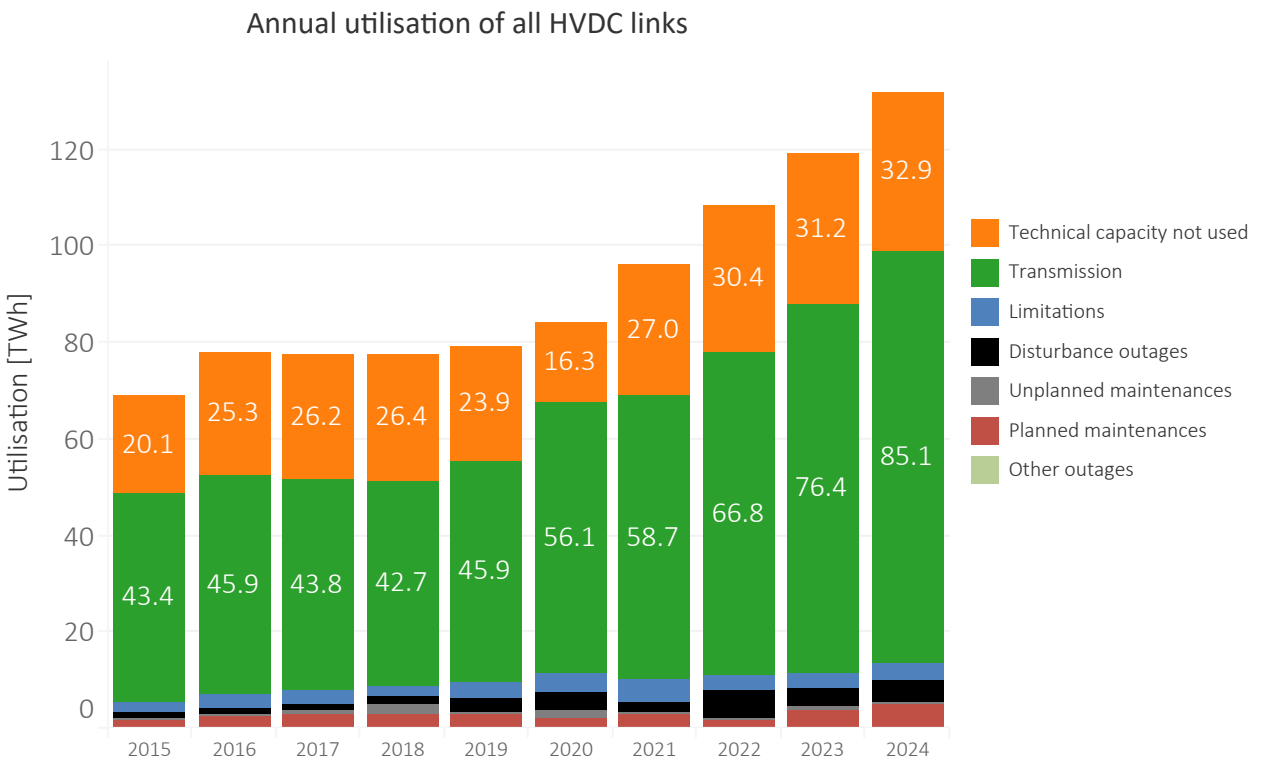

Figure 4.5: Annual utilisation (TWh) of all HVDC links. Transmission (E_T) is the amount of technical capacity (E_{max}) transmitted through the HVDC links. Limitations, disturbance outages, unplanned and planned maintenance outages and other outages form together the unavailable technical capacity (E_U). Technical capacity not used (E_{TCNU}) is the residual energy that has neither been transmitted nor been unavailable due to limitations or outages. The larger capacity increases in some years is due to new links being introduced to the report. The maximum technical capacity (E_{max}) is marginally higher on leap years due to one extra day of operation.

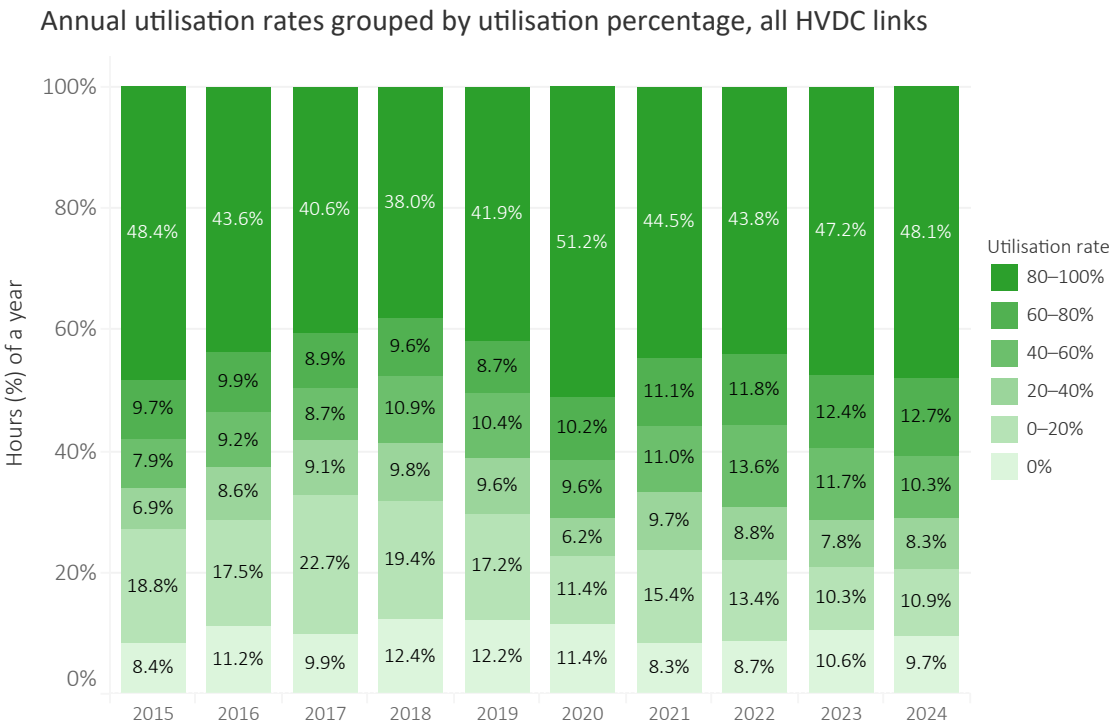

Figure 4.6: Annual utilisation rate grouped by utilisation percentage for all HVDC links. The HVDC links were utilised by more than 80 % of their respective maximum technical capacity 47.2 % of the time in 2024.

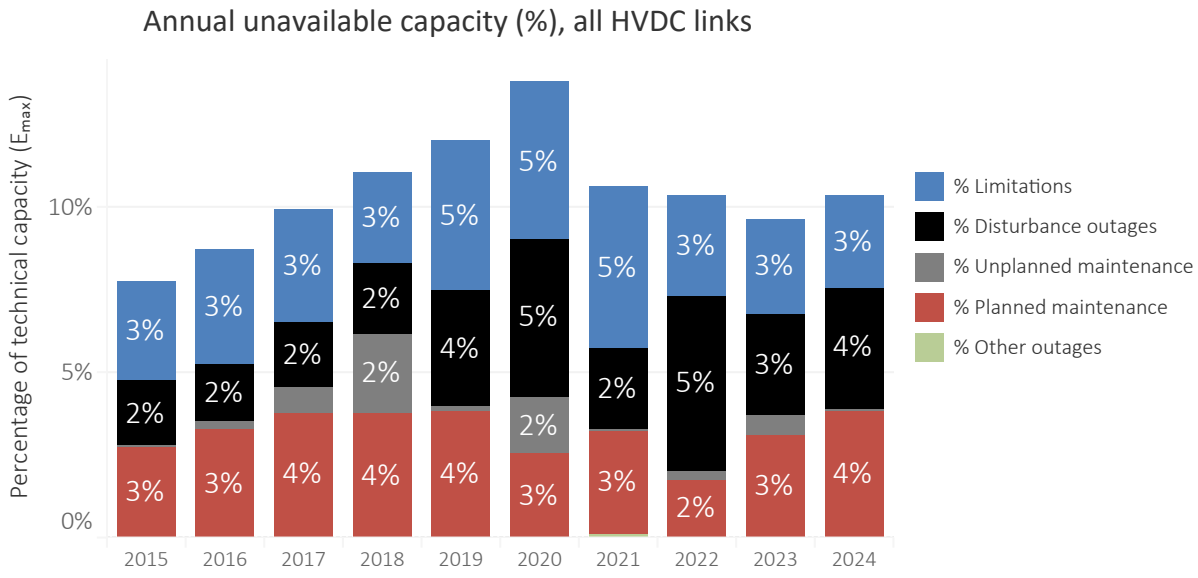

Figure 4.7: Unavailable technical capacity (%) by unavailability category for all HVDC links combined. The unavailability categories are limitations, disturbance outages, unplanned and planned maintenances and other outages.

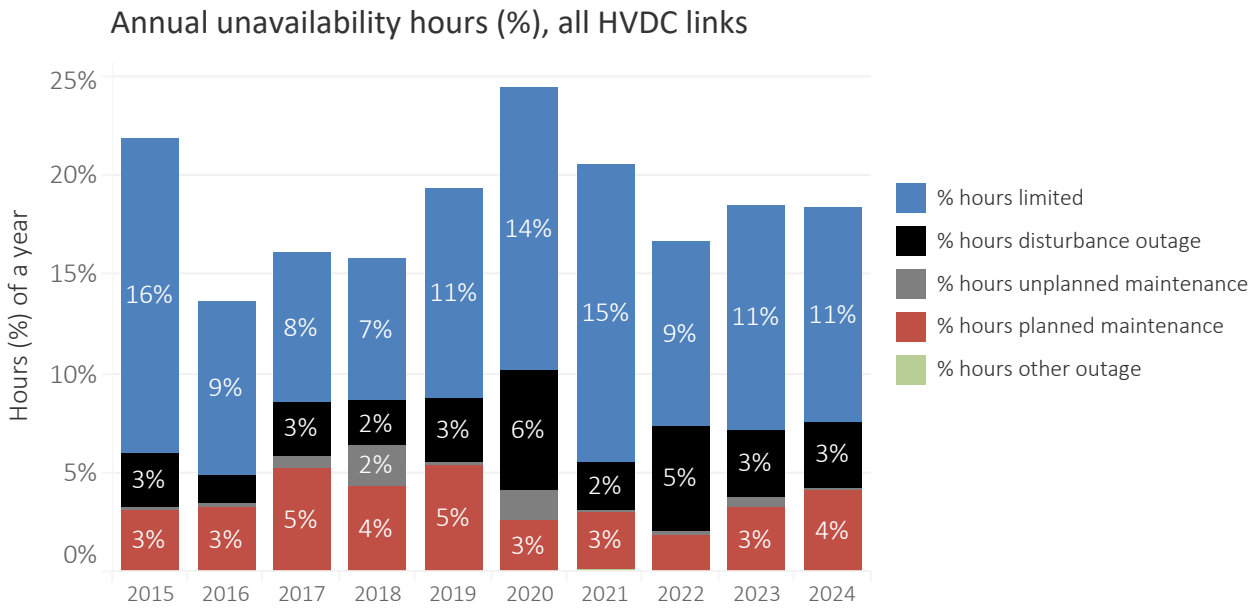

Figure 4.8: Annual unavailability hours (%) by unavailability category. The categories are limitation, unplanned or planned maintenance or a disturbance or other outage. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation. A higher value in the percentage of hours may indicate that the corresponding type of event has not fully disconnected the affected HVDC link from the system. A lower value may instead indicate that the corresponding event type has affected an HVDC link with a high rated capacity.

4.3 An overview of electricity market connections 2015–2024.

Figure 4.9 shows utilisation (%) by category for each electricity market connection in 2024.

The most utilised market connections in 2024 were SE4-LT (83 %), NO2-GB (83 %) and DK2-DE (78 %) as shown in Table 4.1. Nine other market connections reached a utilisation rate of 60–70 % and two market connections were utilised between 50–60 % of the maximum technical capacity. Lowest utilisation had FI–EE (48 %) and DK2–DE (48 %). Annual utilisation (%), annual unavailability (%) and annual technical capacity not used (%) are presented in Table 4.1, Table 4.2, and Table 4.3 for different market connections.

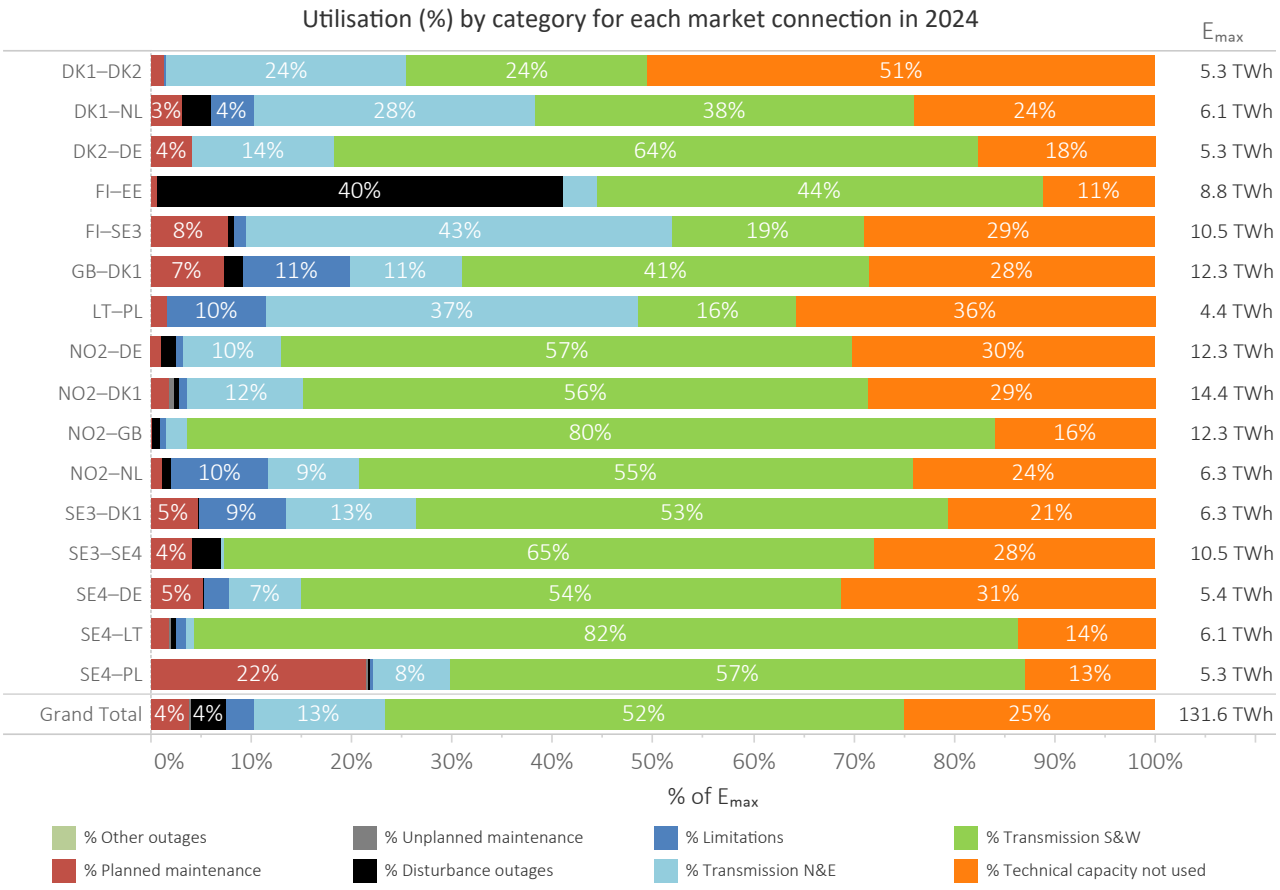

Figure 4.9: Utilisation (%) by category for each market connection in 2024.

Table 4.1: The annual utilisation (%) per market connection.

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
DK1–GB										51.9%
DK1–NL					79.7%	50.6%	63.0%	65.1%	69.4%	65.7%
DK2–DE	74.8%	66.8%	66.3%	53.3%	68.6%	47.4%	71.4%	64.6%	44.9%	78.1%
DK2–DK1	70.1%	78.0%	63.7%	63.4%	58.3%	70.7%	57.2%	50.2%	50.1%	48.0%
FI–EE	56.8%	42.3%	29.2%	37.0%	46.6%	75.3%	76.9%	77.7%	80.4%	47.7%
FI–SE3	75.8%	77.7%	70.2%	71.8%	81.2%	84.6%	68.0%	71.9%	60.5%	61.7%
LT–PL		33.5%	46.7%	53.5%	61.5%	58.4%	54.8%	61.5%	58.0%	52.7%
NO2–DE							44.0%	57.5%	63.5%	66.8%
NO2–DK1	54.0%	60.6%	54.1%	52.7%	46.2%	62.3%	67.0%	55.2%	58.8%	67.8%
NO2–GB								50.8%	76.0%	82.6%
NO2–NL	93.9%	72.5%	82.8%	68.3%	61.3%	76.7%	62.7%	35.0%	56.5%	64.2%
SE3–DK1	48.7%	58.8%	51.8%	52.7%	50.1%	57.3%	49.0%	65.8%	68.3%	65.9%
SE3–SE4									50.4%	65.1%
SE4–DE	30.5%	43.3%	45.6%	33.2%	36.0%	54.9%	47.9%	61.8%	65.1%	60.8%
SE4–LT		43.6%	51.5%	50.5%	62.9%	76.2%	60.4%	79.9%	77.0%	82.8%
SE4–PL	67.2%	55.8%	62.3%	66.1%	62.1%	72.1%	69.3%	76.3%	81.8%	64.9%
Grand Total	63.0%	58.9%	56.4%	55.0%	57.9%	66.9%	61.2%	61.6%	64.2%	64.6%

Table 4.2: The annual unavailability (%) per market connection.

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
DK1–GB										19.8%
DK1–NL					5.1%	29.3%	10.8%	10.6%	2.8%	10.3%
DK2–DE	5.2%	10.4%	14.3%	25.9%	3.8%	30.0%	5.0%	11.5%	42.9%	4.2%
DK2–DK1	2.4%	2.8%	1.6%	2.2%	2.5%	0.3%	1.4%	4.4%	1.3%	1.5%
FI–EE	5.8%	3.6%	0.6%	3.6%	2.2%	2.7%	1.5%	3.4%	2.9%	41.1%
FI–SE3	9.5%	1.5%	1.2%	1.1%	4.7%	0.9%	13.1%	1.3%	5.3%	9.4%
LT–PL		14.0%	10.1%	6.1%	3.6%	8.6%	13.4%	3.2%	14.3%	11.5%
NO2–DE							9.8%	4.5%	3.5%	3.2%
NO2–DK1	6.5%	4.8%	18.0%	12.7%	27.0%	23.6%	8.2%	13.9%	12.1%	3.6%
NO2–GB								11.9%	6.6%	1.4%
NO2–NL	4.2%	8.1%	8.4%	13.8%	13.5%	16.9%	27.1%	49.2%	15.6%	11.7%
SE3–DK1	16.7%	5.5%	6.7%	4.3%	15.8%	16.7%	27.7%	12.7%	8.4%	13.5%
SE3–SE4									20.9%	6.9%
SE4–DE	12.5%	20.4%	27.1%	36.3%	26.2%	18.7%	9.8%	3.8%	2.9%	7.9%
SE4–LT		25.7%	16.5%	22.0%	7.6%	5.5%	5.8%	6.5%	7.5%	3.4%
SE4–PL	7.3%	15.3%	5.9%	4.2%	14.0%	12.8%	8.9%	12.6%	4.8%	22.2%
Grand Total	7.8%	8.7%	9.9%	11.0%	12.0%	13.8%	10.6%	10.4%	9.6%	10.4%

Table 4.3: The annual technical capacity not used (%) per market connection.

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
DK1–GB										28.4%
DK1–NL					15.2%	20.1%	26.3%	24.3%	27.8%	24.0%
DK2–DE	20.1%	22.8%	19.4%	20.7%	27.7%	22.6%	23.6%	23.9%	12.2%	17.7%
DK2–DK1	27.5%	19.3%	34.7%	34.5%	39.2%	29.1%	41.3%	45.4%	48.5%	50.6%
FI–EE	37.3%	54.1%	70.2%	59.3%	51.2%	22.0%	21.6%	18.8%	16.7%	11.2%
FI–SE3	14.8%	20.7%	28.6%	27.1%	14.1%	14.6%	18.8%	26.8%	34.2%	28.9%
LT–PL		52.5%	43.2%	40.3%	34.9%	33.0%	31.8%	35.4%	27.7%	35.8%
NO2–DE							46.2%	37.9%	33.0%	30.1%
NO2–DK1	39.5%	34.6%	27.9%	34.6%	26.8%	14.2%	24.7%	30.8%	29.1%	28.6%
NO2–GB								37.3%	17.4%	16.0%
NO2–NL	1.9%	19.4%	8.8%	17.9%	25.2%	6.4%	10.2%	15.8%	27.8%	24.1%
SE3–DK1	34.6%	35.8%	41.4%	43.0%	34.1%	26.0%	23.3%	21.5%	23.3%	20.6%
SE3–SE4									28.8%	28.0%
SE4–DE	57.0%	36.3%	27.4%	30.6%	37.8%	26.4%	42.3%	34.4%	32.0%	31.3%
SE4–LT		30.7%	32.1%	27.6%	29.4%	18.3%	33.8%	13.6%	15.5%	13.7%
SE4–PL	25.5%	28.9%	31.8%	29.7%	23.9%	15.1%	21.8%	11.0%	13.5%	12.9%
Grand Total	29.2%	32.4%	33.7%	34.0%	30.1%	19.4%	28.2%	28.0%	26.2%	25.0%

4.4 Individual presentations of each HVDC link

This section presents the performance of each HVDC link. Figure 4.10 presents the geographical location of the links. The categories used in the following presentations of are defined in Chapter 2.

The sums in the tables may show a technical capacity E_{max} higher than the E_{max} stated in the diagram. This is due to power flows that may momentarily be higher than the rated technical capacity of the link. Other times, when power flow is below the rated technical capacity (and there is no limitation reported), the difference is registered in the category "technical capacity not used".

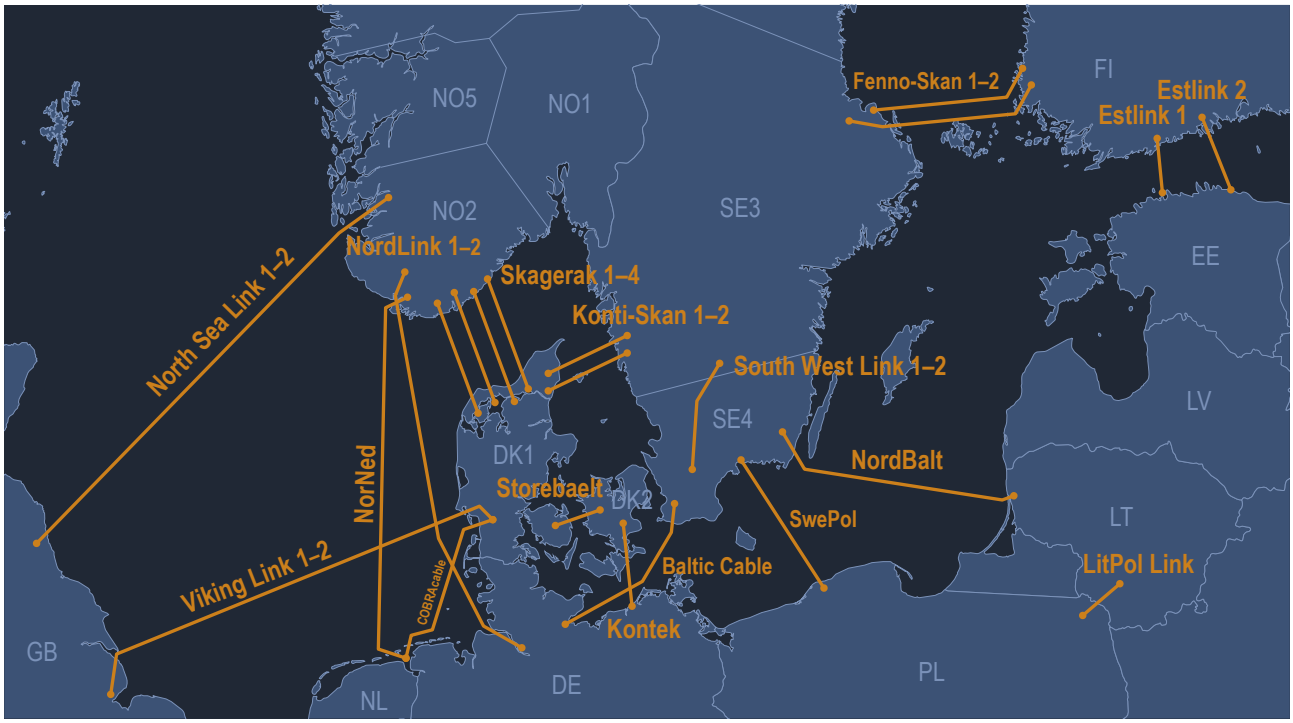

Figure 4.10: A map of the bidding zones and the 26 HVDC links included in this report.

4.4.1 Baltic Cable

Figure 4.11 presents the availability and utilisation of Baltic Cable for 2024 and Table 4.4 presents the numerical values behind it. Baltic Cable is connected between southern Sweden (bidding zone SE4) and Germany (bidding zone DE-TenneT). The operations started in 1994 and the transmission capacity is 600 MW.

In 2024, Baltic Cable had an available technical capacity of 92 %, and 31 % technical capacity not used. During the year, ten shorter disturbance outages occurred, most due to the external AC grid. Two system related disturbance outages did also take place. Despite this, the total disturbance outage time over the year remained very low due to the very short outage time. The annual maintenance for the Baltic Cable took place between the 9th and 27th of September, making up the main portion of the links unavailability during 2024.

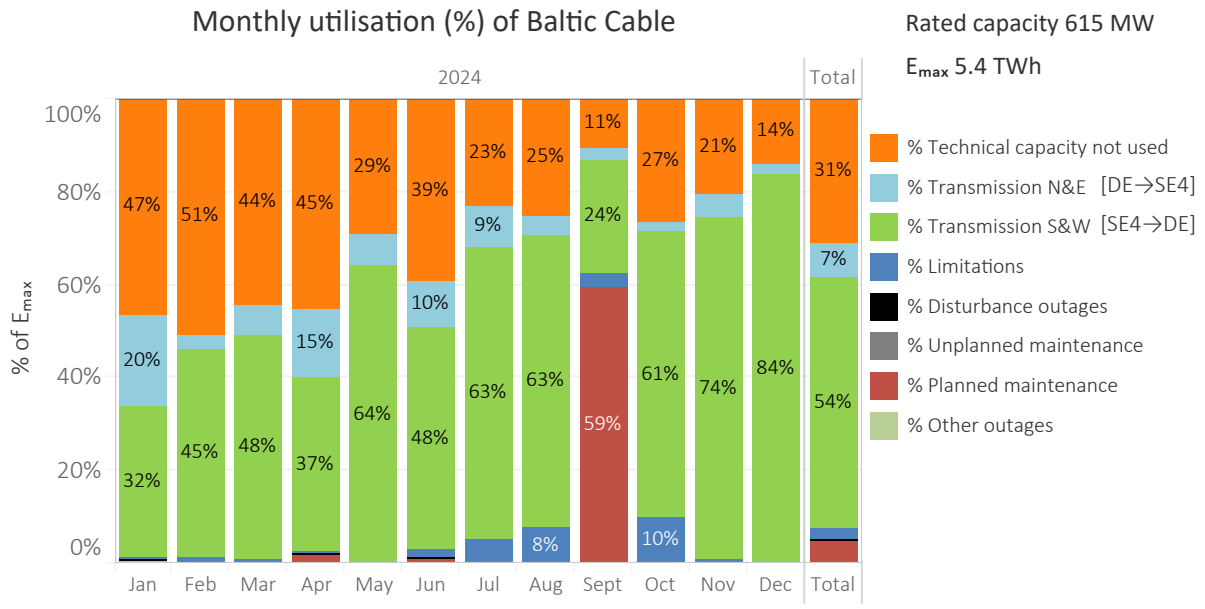

Figure 4.11: Monthly utilisation (%) by category for Baltic Cable in 2024.

Table 4.4: Monthly allocation (GWh) of technical capacity (E_{max}) for The Baltic Cable in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Baltic Cable (South & West direction SE4→DE)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	214.0	217.4	202.5	201.2	133.4	173.5	106.4	114.7	47.6	122.3	91.0	65.0	1688.9	31.3%
Transmission N&E, GWh	89.3	13.6	29.6	64.3	30.4	43.6	39.8	20.3	11.0	9.8	22.8	9.1	383.5	7.1%
Transmission S&W, GWh	148.6	191.5	220.4	165.7	293.3	211.8	287.0	286.8	107.4	281.6	325.5	383.5	2903.1	53.7%
Limitations, GWh	1.1	5.6	3.7	1.9	-	9.2	23.8	35.8	13.4	44.4	3.6	-	142.6	2.6%
Disturbance outages, GWh	0.3	-	-	0.3	0.5	1.8	0.5	-	-	-	-	-	3.4	0.1%
Unplanned maintenance., GWh	-	-	0.8	-	-	-	-	-	-	-	-	-	0.8	0.0%
Planned maintenance, GWh	-	-	-	9.5	-	3.0	-	-	263.3	-	-	-	275.8	5.1%
Other outages, GWh	4.2	-	-	-	-	-	-	-	-	-	-	-	4.2	0.1%
Total, GWh	457.6	428.0	456.9	442.8	457.6	442.8	457.6	457.6	442.8	458.2	442.8	457.6	5402.2	100.0%
Losses SW, GWh	5.6	5.7	7.8	7.8	32.3	5.5	7.0	7.0	3.7	6.2	19.4	9.7	117.7	2.2%
Losses NE, GWh	4.3	2.2	3.2	2.9	12.9	1.8	1.3	0.9	1.5	0.5	3.5	0.9	35.9	0.7%

Figure 4.12 presents the annual utilisation of Baltic Cable per utilisation and unavailability category for the years 2015–2024.

Figure 4.13 presents the percentage of hours of a year Baltic Cable has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.14 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

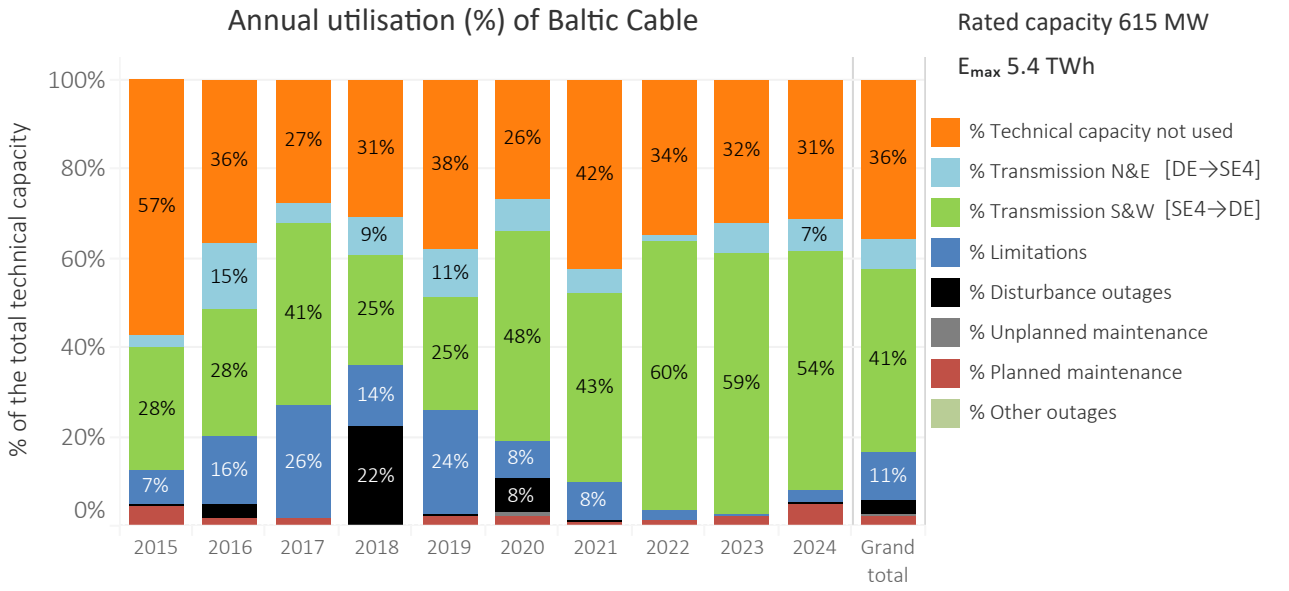

Figure 4.12: Annual utilisation (%) of Baltic Cable by category for 2015–2024.

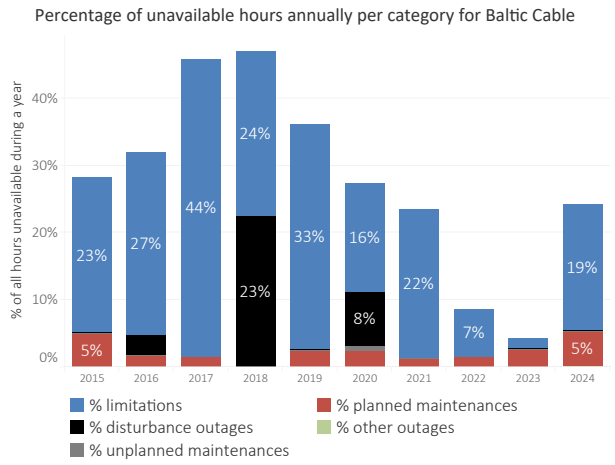

Figure 4.13: Percentage of hours Baltic Cable has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

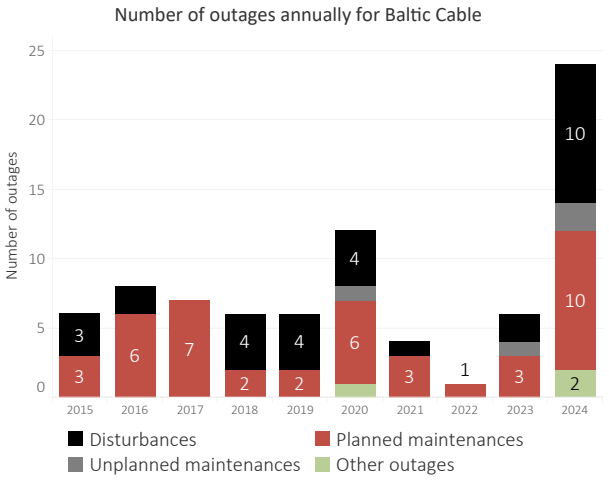

Figure 4.14: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Baltic Cable for the years 2015–2024. Baltic cable has not had any other outages during the years 2015–2024.

4.4.2 COBRAcable

Figure 4.15 presents the availability and utilisation of COBRAcable for 2024 and Table 4.5 presents the numerical values behind it. COBRAcable has been in operation since 2019. In Denmark (bidding zone DK1) it is connected to Endrup substation and in Netherlands to Eemshaven (bidding zone APX NL). COBRAcable was commissioned 5 November and has a transmission capacity of 700 MW.

In 2024, COBRAcable had an available technical capacity of 90 %. The technical capacity not used was 24 %. Totally, 2.3 TWh (38 % of the technical capacity) was transmitted south to the Netherlands (DK1→APX NL) and 1.7 TWh (28 % of the technical capacity) was transmitted north to Denmark (APX NL→DK1).

COBRAcable annual maintenance lasted five days in October and November. Furthermore, there were two minor maintenance outages in 2024. Both were due to x-rays of cable transition joints. There were eight minor disturbances outages lasting from a few hours to a few days, four of these was caused due to faults in the cooling system in Eemshaven.

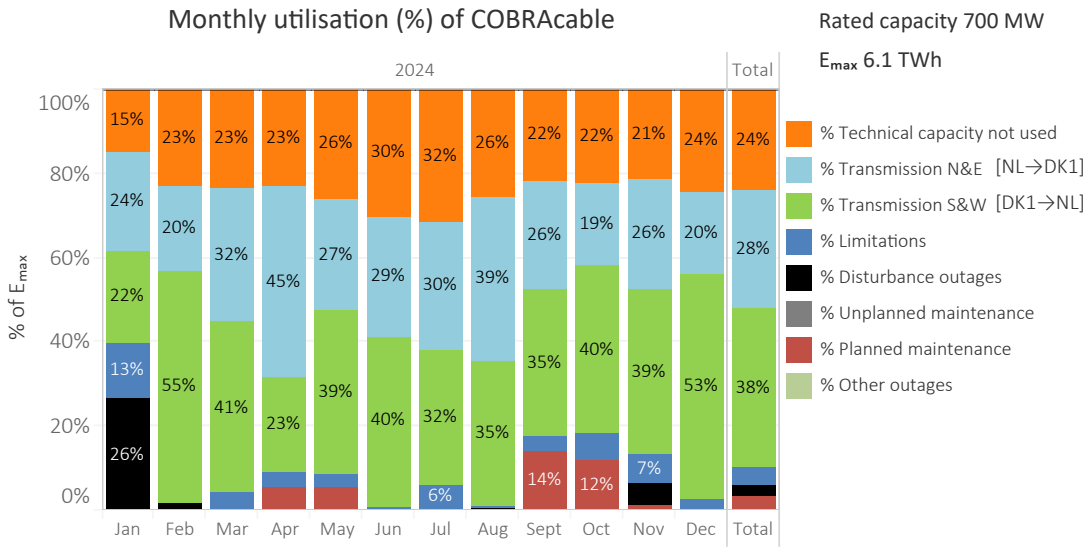

Figure 4.15: Monthly utilisation (%) by category for COBRAcable in 2024.

Table 4.5: Monthly allocation (GWh) of technical (E_{max}) for COBRAcable in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of COBRAcable (South & West direction DK1→NL)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	78.0	111.9	122.0	116.5	135.8	153.6	164.3	133.9	110.5	116.5	107.7	127.5	1478.3	24.0%
Transmission N&E, GWh	123.1	98.9	164.1	228.8	138.5	144.7	158.1	201.4	129.6	101.4	131.4	102.7	1722.7	28.0%
Transmission S&W, GWh	113.2	268.5	212.7	113.8	202.1	200.7	167.2	181.3	176.2	208.8	198.8	276.9	2319.9	37.7%
Limitations, GWh	69.0	-	21.6	16.4	16.8	5.3	31.4	2.6	15.9	32.0	34.8	14.2	259.9	4.2%
Disturbance outages, GWh	137.7	8.4	-	-	-	-	-	1.9	-	-	24.9	-	172.9	2.8%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	28.7	28.1	-	-	-	72.0	63.0	6.8	-	198.5	3.2%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	521.0	487.6	520.4	504.2	521.2	504.3	520.9	521.2	504.2	521.7	504.3	521.2	6152.2	100.0%
Losses SW, GWh	3.4	7.4	5.6	3.1	5.6	5.5	4.2	5.0	4.7	5.5	5.3	7.7	63.1	1.0%
Losses NE, GWh	2.7	2.3	3.9	5.3	3.1	3.4	3.6	4.7	3.1	2.4	3.1	2.3	39.9	0.6%

Figure 4.16 presents the annual utilisation of COBRAcable per utilisation and unavailability category for the years 2019–2024.

Figure 4.17 presents the percentage of hours of a year COBRAcable has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2019–2024. Figure 4.18 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2019–2024.

Data for 2019 does not cover the whole year because COBRAcable was commissioned in September 2019.

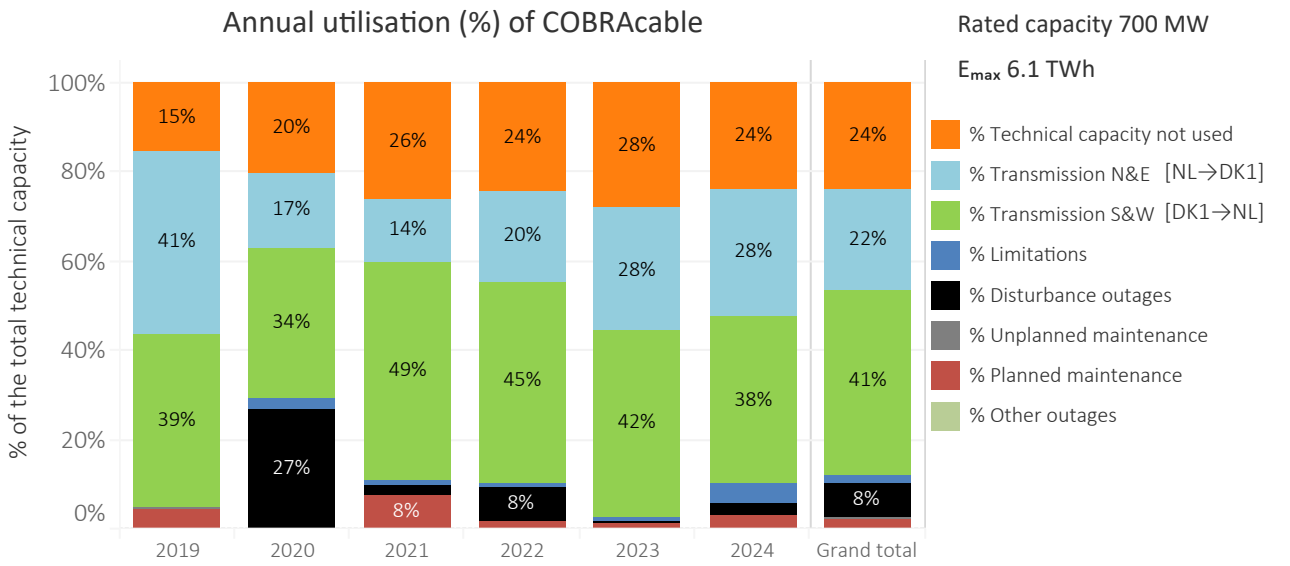

Figure 4.16: Annual utilisation (%) of COBRAcable by category for 2019–2024.

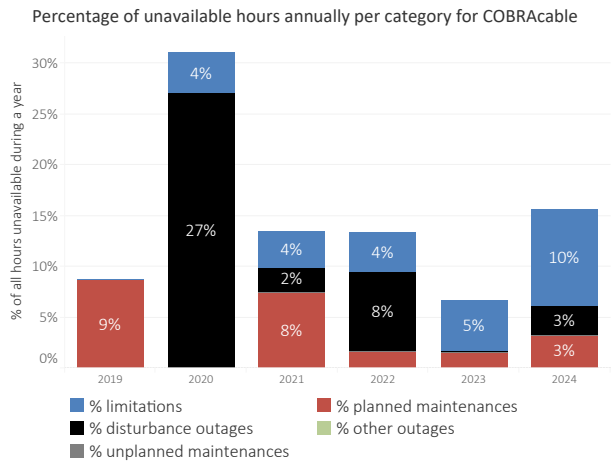

Figure 4.17: Percentage of hours COBRAcable has been affected by either a limitation or an outage annually since 2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

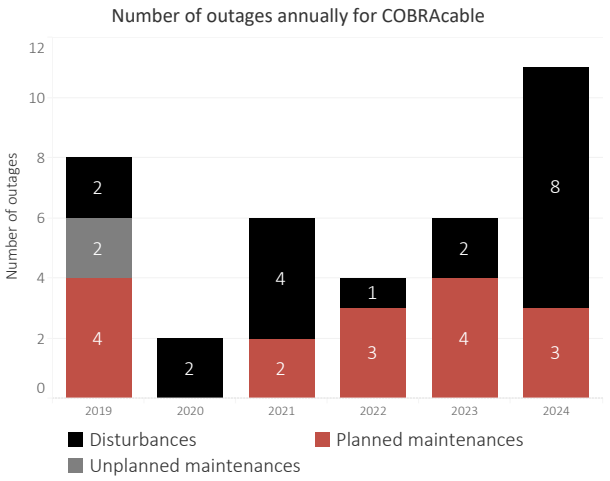

Figure 4.18: The annual number of disturbances, unplanned and planned maintenance outages and other outages for COBRAcable for the years 2019–2024.

4.4.3 EstLink 1

Figure 4.19 presents the availability and utilisation of EstLink 1 for 2024 and Table 4.6 presents the numerical values behind it. EstLink 1 has been in operation since 2006 and is the first HVDC connection between Finland and Estonia. In Finland, it is connected to Espoo substation (bidding zone FI) and in Estonia, it is connected to Harku substation (bidding zone EE). The transmission capacity of EstLink 1 is 350 MW.

In 2024, EstLink 1 had an available technical capacity of 97.5 %. The technical capacity not used was 20 %. Note: EstLink 2 is prioritised due to its lower transmission losses and because EstLink 1 is often used in Automatic Frequency Control Mode. However, EstLink 2 was long out of operation in 2024. Totally, 2.2 TWh (71 % of the technical capacity) was transmitted south (FI→EE) and less than 0.2 TWh (6 % of the technical capacity) was transmitted north (EE→FI).

EstLink 1 had three planned outages in 2024. 4.5 days for annual maintenance, 2 days for cable end termination repair in Espoo and another 1.5 days for IGBT replacements in Harku. EstLink 1 tripped five times due to different faults and mis-operations of AC and DC protection in Espoo. Once due to fault in auxiliary power systems in Harku, once due to a fault in valve cooling in Espoo and once due to 400kV AC CT fault in Espoo (outage 1.5 days for replacement). All other faults were cleared within some hours.

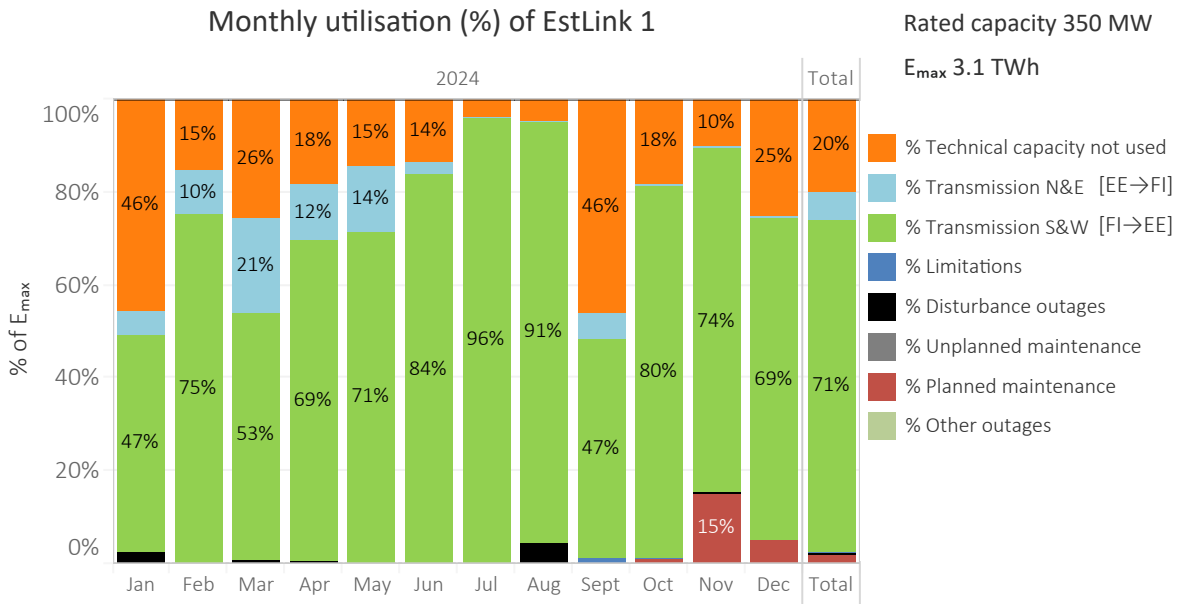

Figure 4.19: Monthly utilisation (%) by category for EstLink 1 in 2024.

Table 4.6: Monthly allocation (GWh) of technical capacity (E_{max}) for EstLink 1 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of EstLink 1 (South & West direction FI→EE)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	119.4	37.5	67.0	46.5	38.3	34.7	9.8	12.4	116.3	48.1	26.4	66.5	622.8	20.1%
Transmission N&E, GWh	13.6	24.0	54.4	30.8	37.4	6.4	-	0.2	14.0	0.5	0.2	0.8	182.4	5.9%
Transmission S&W, GWh	122.1	184.7	137.9	175.2	187.3	213.4	254.0	239.8	119.2	211.6	188.9	182.2	2216.3	71.4%
Limitations, GWh	-	-	-	-	-	-	-	-	3.1	0.3	-	-	3.5	0.1%
Disturbance outages, GWh	6.7	-	2.6	1.3	-	-	-	11.5	-	-	0.9	-	23.0	0.7%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	-	-	-	-	-	-	2.6	38.0	13.5	54.1	1.7%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	261.7	246.2	261.8	253.8	263.0	254.6	263.8	263.9	252.7	263.2	254.4	262.9	3102.0	100.0%
Losses SW, GWh	6.0	9.0	6.7	8.5	9.1	10.4	12.4	11.7	5.8	10.3	9.2	8.9	108.2	3.5%
Losses NE, GWh	0.7	1.3	3.0	1.7	2.1	0.4	-	-	0.8	-	-	-	10.1	0.3%

Figure 4.20 presents the annual utilisation of EstLink 1 per utilisation and unavailability category for the years 2015–2024.

Figure 4.21 presents the percentage of hours of a year EstLink 1 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.22 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

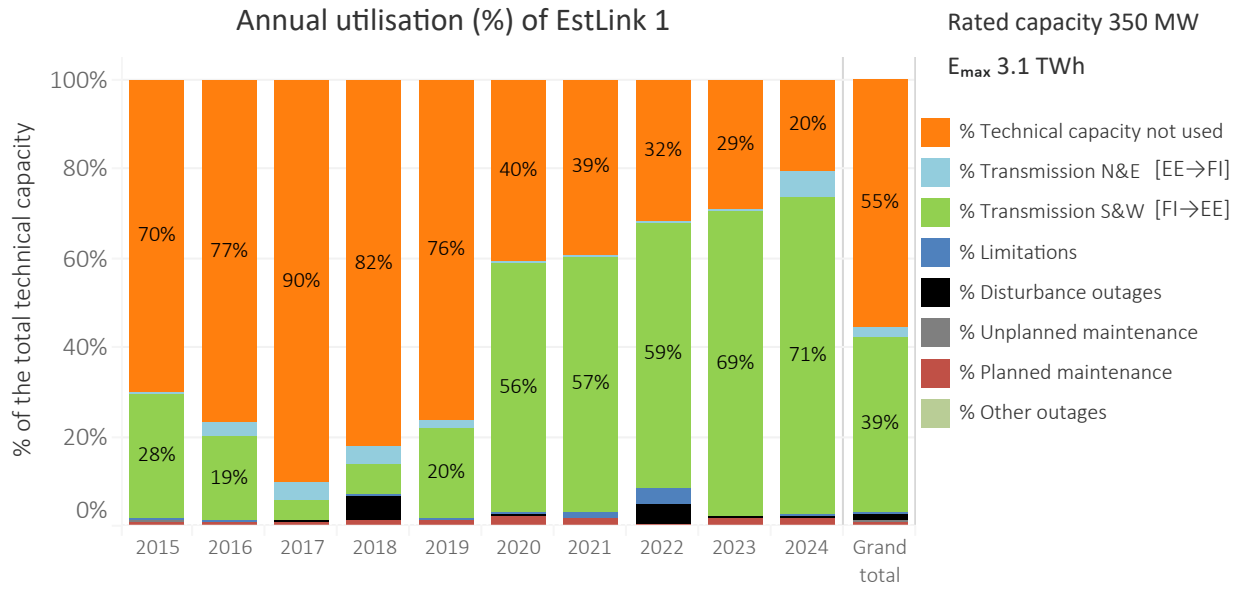

Figure 4.20: Annual utilisation (%) of EstLink 1 by category for 2015–2024.

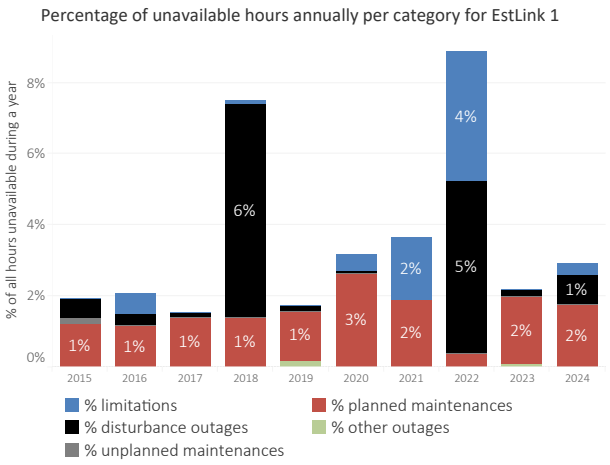

Figure 4.21: Percentage of hours EstLink 1 has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

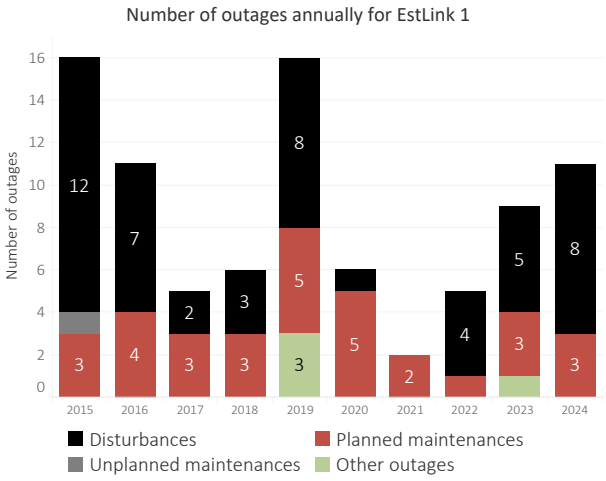

Figure 4.22: The annual number of disturbances, unplanned and planned maintenance outages and other outages for EstLink 1 for the years 2015–2024.

4.4.4 EstLink 2

Figure 4.23 presents the availability and utilisation of EstLink 2 for 2024 and Table 4.7 presents the numerical values. EstLink 2 was commissioned in February 2014 and is the second HVDC connection between Finland and Estonia. It is connected in Finland to Anttila substation (bidding zone FI) and in Estonia to Püssi substation (bidding zone EE). The transmission capacity of EstLink 2 is 650 MW.

In 2024, EstLink 2 had an available technical capacity of 38 %. The technical capacity not used was 6 %. Totally, 1.7 TWh (30 % of the technical capacity) was transmitted south (FI→EE) and only 0.1 TWh (2 % of the technical capacity) north (EE→FI). EstLink 2 had no planned outages in 2024. All maintenance activities were performed during the DC cable repair outage.

EstLink 2 tripped twice due to DC cable faults. In January, the DC seacable was mechanically damaged on the land-side near the Estonian shoreline. The repair took 7 months, as it was difficult to find the fault location and to perform the repairs in special topological and cable laying conditions

In late December, the DC seacable was again mechanically damaged, now by an anchor of a ship. This causes long unavailability in 2025 statistics. There was also one trip due to AC grid undervoltage during black start testing in Estonia, which was quickly cleared.

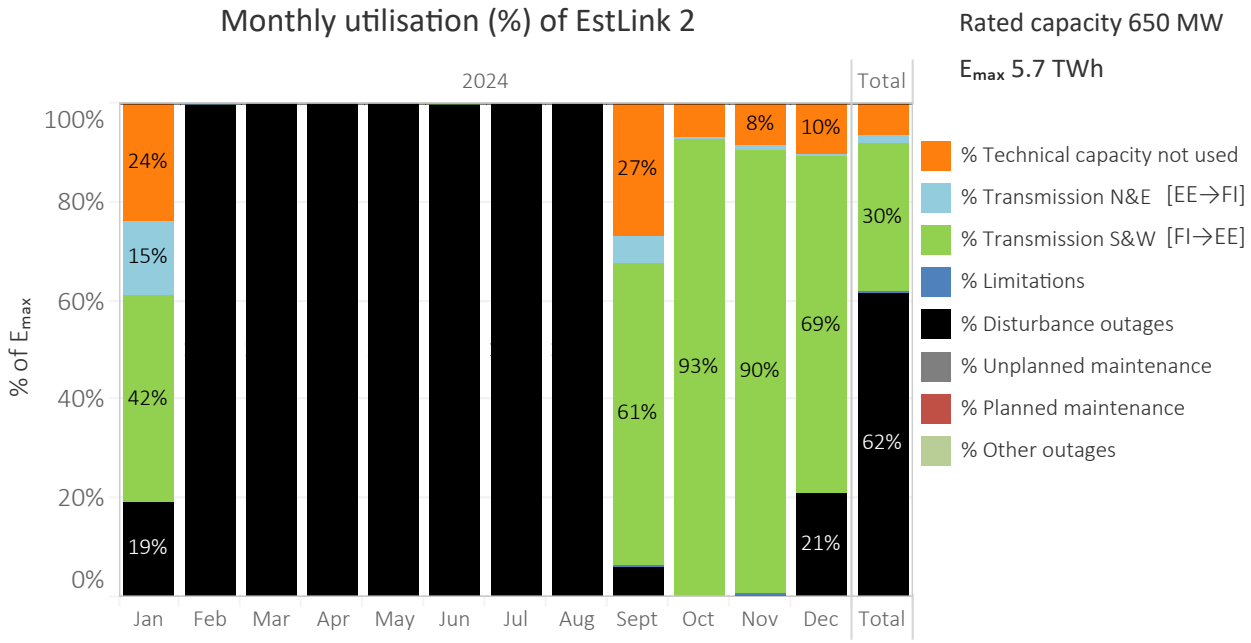

Figure 4.23: Monthly utilisation (%) by category for EstLink 2 in 2024.

Table 4.7: Monthly allocation (GWh) of technical capacity (E_{max}) for EstLink 2 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of EstLink 2 (South & West direction FI→EE)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	115.9	-	-	-	-	-	-	-	125.7	32.9	39.4	50.5	364.3	6.4%
Transmission N&E, GWh	73.4	-	-	-	-	-	-	-	26.7	0.7	4.0	1.0	105.8	1.8%
Transmission S&W, GWh	202.4	-	-	-	-	-	-	-	287.6	454.7	424.6	334.1	1703.4	29.8%
Limitations, GWh	-	-	-	-	-	-	-	-	0.1	-	2.3	-	2.3	0.0%
Disturbance outages, GWh	93.5	452.4	483.0	468.0	483.6	468.0	483.6	483.6	30.3	-	1.8	101.1	3548.8	62.0%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	485.2	452.4	483.0	468.0	483.6	468.0	483.6	483.6	470.2	488.3	472.1	486.7	5724.7	100.0%
Losses SW, GWh	4.5	-	-	-	-	-	-	-	6.4	10.0	9.4	7.4	37.6	0.7%
Losses NE, GWh	1.4	-	-	-	-	-	-	-	0.5	-	0.1	-	2.0	0.0%

Figure 4.24 presents the annual utilisation of EstLink 2 per utilisation and unavailability category for the years 2015–2024.

Figure 4.25 presents the percentage of hours of a year EstLink 2 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.26 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

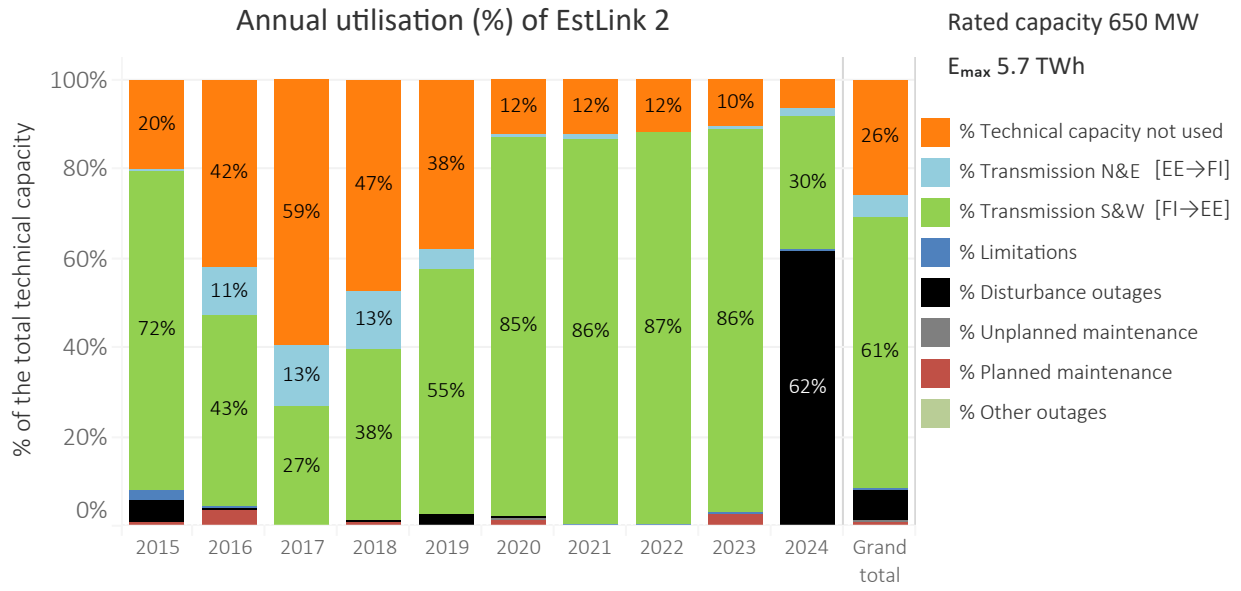

Figure 4.24: Annual utilisation (%) of EstLink 2 by category for 2015–2024.

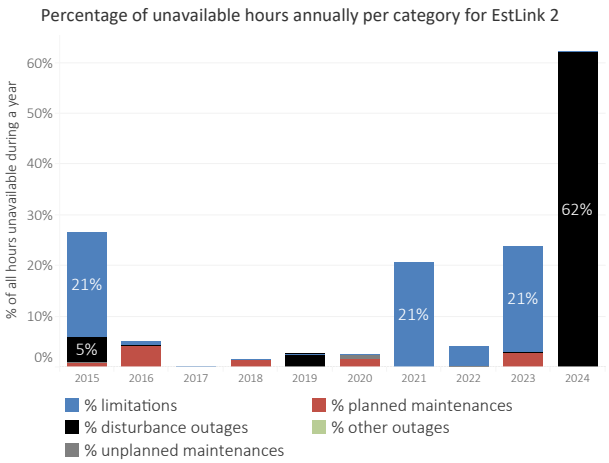

Figure 4.25: Percentage of hours EstLink 2 has been affected by either a limitation or an outage annually since 2014. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

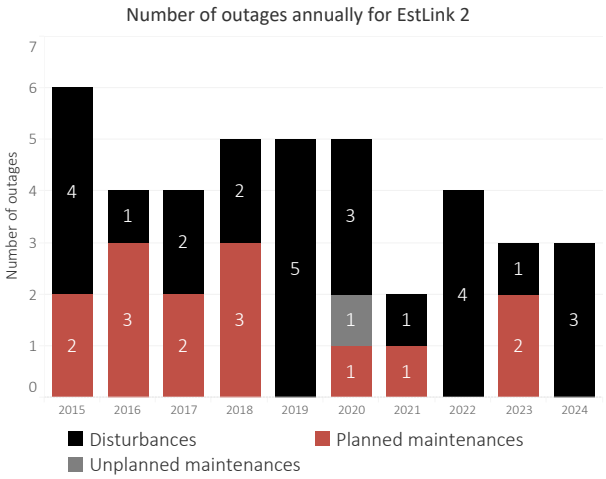

Figure 4.26: The annual number of disturbances, unplanned and planned maintenance outages and other outages for EstLink 2 for the years 2015–2024. EstLink 2 had neither unplanned maintenance nor other outages during this period.

4.4.5 Fenno-Skan 1

Figure 4.27 presents the availability and utilisation of Fenno-Skan 1 for 2024 and Table 4.8 presents the numerical values behind it. Fenno-Skan 1 has been in operation since 1989 and is the first HVDC connection between Finland and Sweden. In Finland (bidding zone FI), Fenno-Skan 1 is connected to Rauma and in Sweden to Dannebo (bidding zone SE3). The transmission capacity of Fenno Skan 1 is 400 MW.

In 2024, Fenno-Skan 1 had an available technical capacity of 85 %. The technical capacity not used was 9.5 %. Totally, 2.2 TWh (63 % of the technical capacity) was transmitted east (SE3→FI) and 0.5 TWh (13 % of the technical capacity) was transmitted west (FI→SE3). Fenno-Skan 1 was out of service for 6.5 weeks in August - September for refurbishment of the 400 kV AC stations, renewal of station control and monitoring systems at both ends and annual maintenance. DC electrode and current transformer faults in Rauma caused some shorter bi-pole outages for repairs and limitations for risk management.

Fenno-Skan 1 had three trips, one from valve hall transformer bushing oil leakage in Rauma and two due to misoperation of reactive power control.

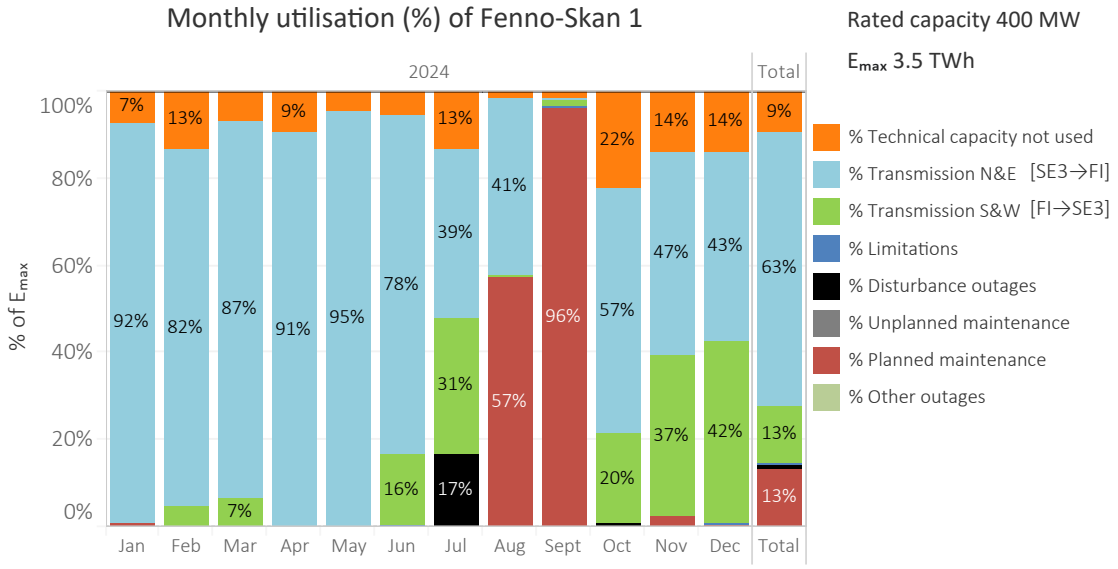

Figure 4.27: Monthly utilisation (%) by category for Fenno-Skan 1 in 2024.

Table 4.8: Monthly allocation (GWh) of technical capacity (E_{max}) for Fenno-Skan 1 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Fenno-Skan 1 (South & West direction FI→SE3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	21.7	36.7	19.8	26.7	13.5	16.4	39.0	4.6	4.9	65.7	40.9	42.4	332.4	9.5%
Transmission N&E, GWh	273.4	228.7	258.1	261.5	284.2	223.9	116.2	121.3	1.7	169.3	134.3	127.9	2200.5	62.6%
Transmission S&W, GWh	-	13.2	19.6	0.1	-	47.0	92.6	1.8	2.8	60.9	105.6	124.9	468.3	13.3%
Limitations, GWh	-	-	-	-	-	0.9	-	-	1.3	-	-	0.2	2.4	0.1%
Disturbance outages, GWh	-	-	-	-	0.3	-	50.0	-	-	2.4	-	-	52.6	1.5%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	2.8	-	-	-	-	-	-	169.9	277.2	-	7.4	2.3	459.7	13.1%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	297.9	278.6	297.5	288.3	298.0	288.2	297.7	297.6	288.0	298.2	288.1	297.7	3515.9	100.0%
Losses SW, GWh	-	0.4	0.6	-	-	1.5	3.0	0.1	0.1	1.9	3.4	4.0	15.0	0.4%
Losses NE, GWh	5.7	4.8	5.4	5.5	6.0	4.7	2.4	2.5	-	3.6	2.8	2.7	46.2	1.3%

Figure 4.28 presents the annual utilisation of Fenno-Skan 1 per utilisation and unavailability category for the years 2015–2024.

Figure 4.29 presents the percentage of hours of a year Fenno-Skan 1 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.30 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

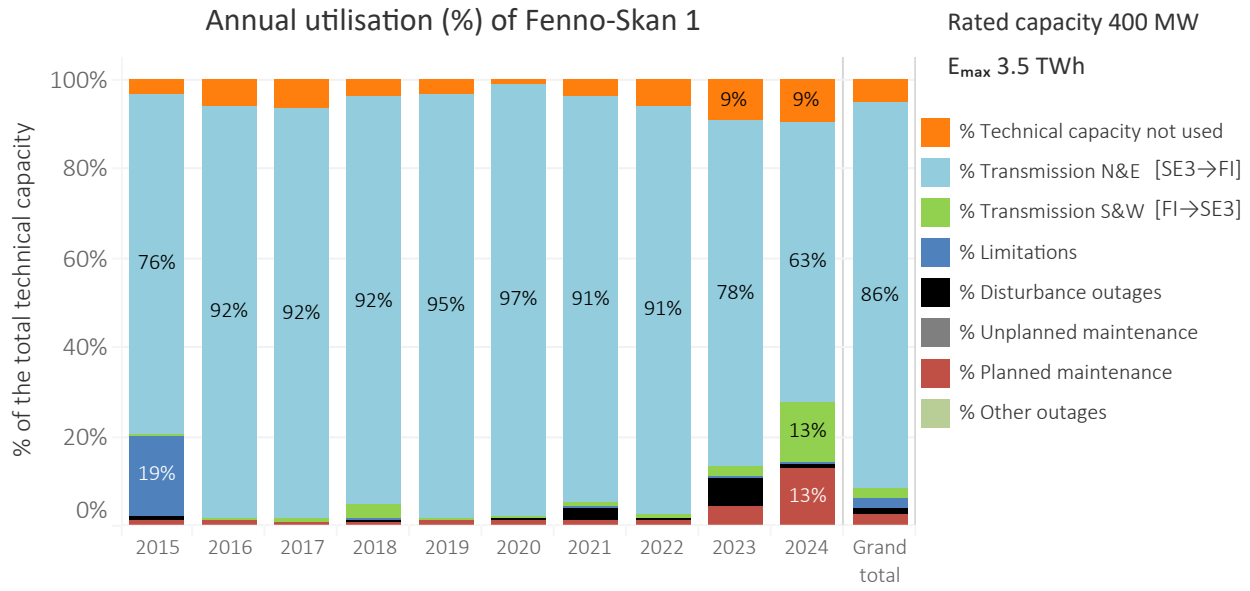

Figure 4.28: Annual utilisation (%) of Fenno-Skan 1 by category for 2015–2024.

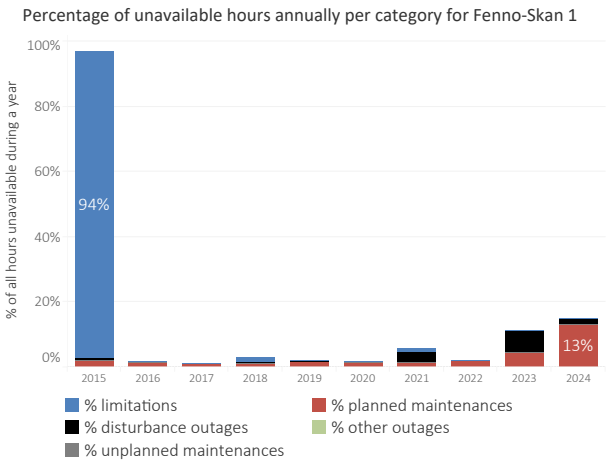

Figure 4.29: Percentage of hours Fenno-Skan 1 has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

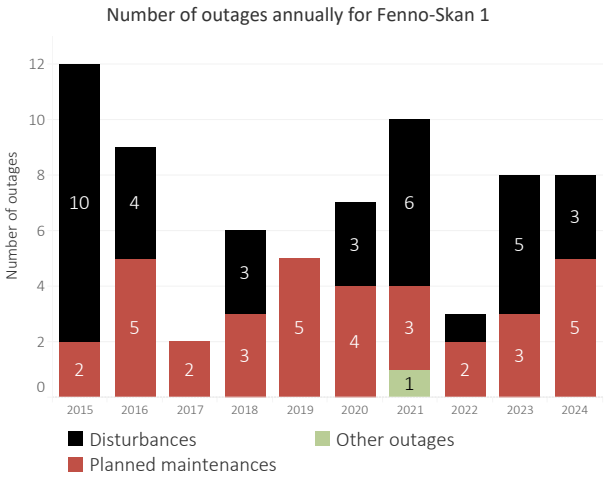

Figure 4.30: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Fenno-Skan 1 during 2015–2024. Fenno-Skan 1 had no other outages during the years 2015–2024.

4.4.6 Fenno-Skan 2

Figure 4.31 presents the availability and utilisation of Fenno-Skan 2 for 2024 and Table 4.9 presents the numerical values behind it. Fenno-Skan 2 has been in operation since 2011 and is the second HVDC connection between Finland and Sweden. In Finland (bidding zone FI) Fenno-Skan 2 is connected to Rauma and in Sweden to Finnböle (bidding zone SE3). The transmission capacity of Fenno-Skan 2 is 800 MW.

In 2024, Fenno-Skan 2 had an available technical capacity of 93 %. The technical capacity not used was 39 %. Totally, 2.3 TWh (33 % of the technical capacity) was transmitted east (SE3→FI) and 1.6 TWh (22 % of the technical capacity) was transmitted west (FI→SE3). Fenno-Skan 2 was out of service for 2.5 weeks in September - October for renewal of station control and monitoring systems and biennial maintenance at both ends. DC electrode and current transformer faults in Rauma caused some shorter bi-pole outages for repairs and limitations for risk management.

Fenno-Skan 2 had four trips from Finnböle. Three due to auxiliary power supply circuit-breaker malfunctioning and one due to hardware fault in control and protection.

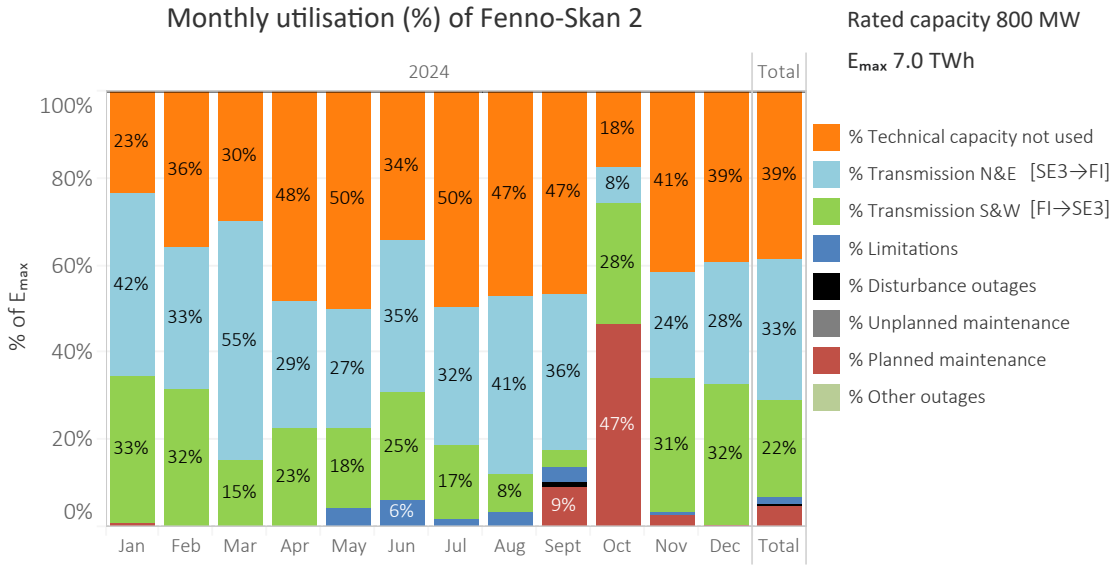

Figure 4.31: Monthly utilisation (%) by category for Fenno-Skan 2 in 2024.

Table 4.9: Monthly allocation (GWh) of technical capacity (E_{max}) for Fenno-Skan 2 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Fenno-Skan 2 (South & West direction FI→SE3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	139.0	198.8	177.4	277.7	298.8	197.0	295.5	280.3	268.0	105.4	237.9	235.0	2710.7	38.6%
Transmission N&E, GWh	251.5	181.3	325.4	168.4	162.4	202.6	188.1	244.8	207.8	47.3	140.7	164.6	2284.8	32.5%
Transmission S&W, GWh	199.3	176.7	91.8	130.0	109.0	141.9	101.1	48.8	22.5	165.0	177.1	192.4	1555.7	22.1%
Limitations, GWh	-	-	-	-	25.0	34.7	10.6	21.3	17.7	-	5.6	-	114.9	1.6%
Disturbance outages, GWh	-	-	-	-	-	-	-	-	8.0	-	-	-	8.0	0.1%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	5.5	-	-	-	-	-	-	-	52.0	278.4	14.7	3.2	353.9	5.0%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	595.3	556.9	594.5	576.1	595.2	576.1	595.3	595.3	576.0	596.0	576.0	595.2	7028.1	100.0%
Losses SW, GWh	4.0	3.5	1.8	2.6	2.2	2.8	2.0	1.0	0.5	3.3	3.5	3.8	31.1	0.4%
Losses NE, GWh	4.5	3.3	5.9	3.0	2.9	3.6	3.4	4.4	3.7	0.9	2.5	3.0	41.1	0.6%

Figure 4.32 presents the annual utilisation of Fenno-Skan 2 per utilisation and unavailability category for the years 2015–2024.

Figure 4.33 presents the percentage of hours of a year Fenno-Skan 2 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.34 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

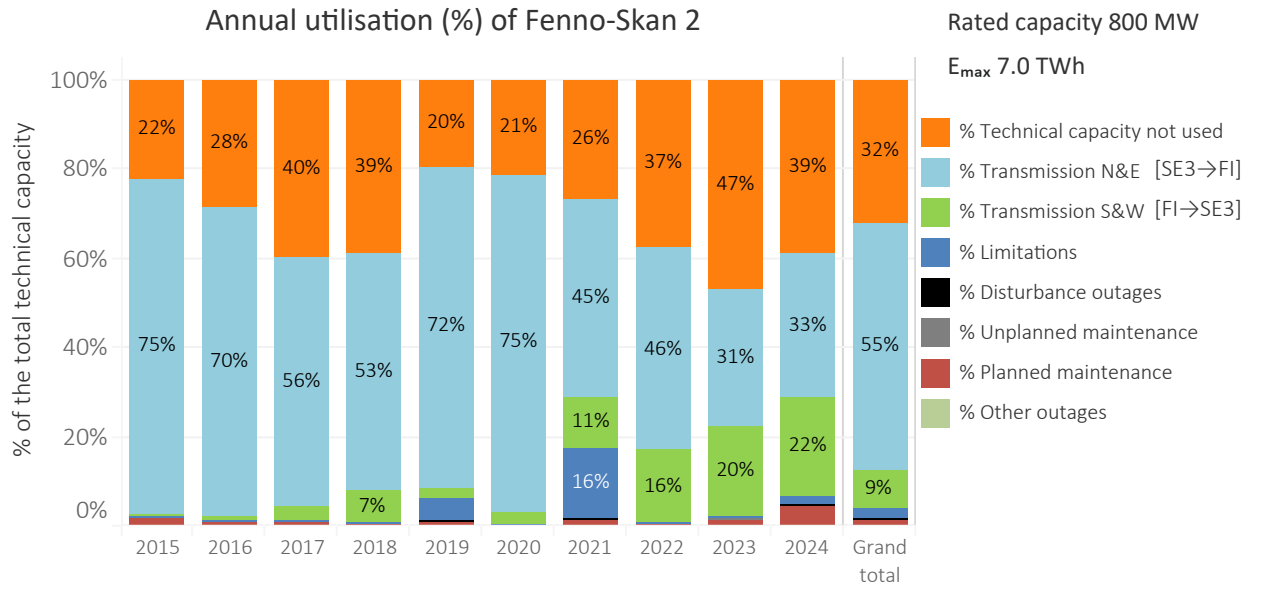

Figure 4.32: Annual utilisation (%) of Fenno-Skan 2 by category for 2015–2024.

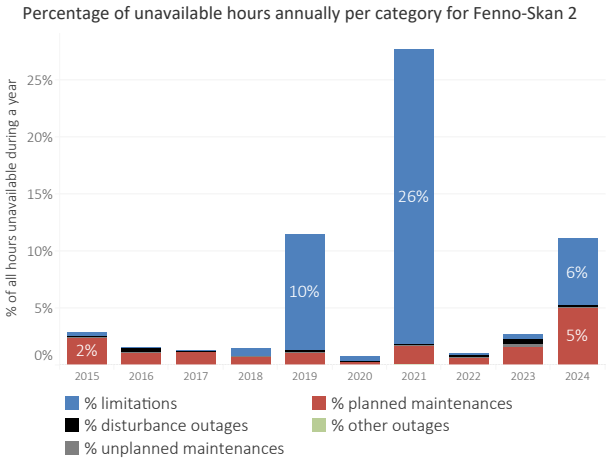

Figure 4.33: Percentage of hours Fenno-Skan 2 has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

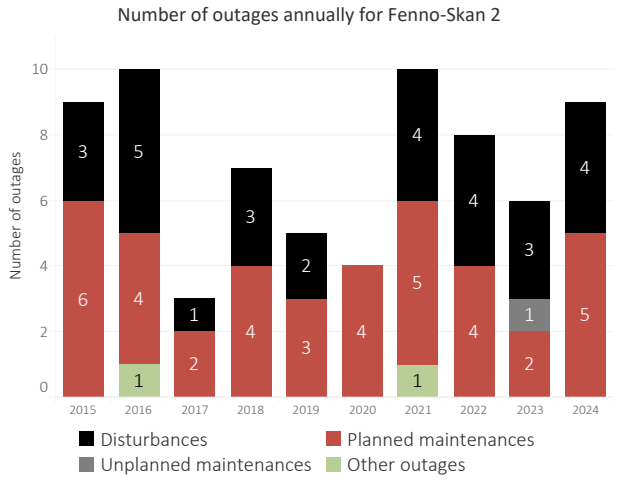

Figure 4.34: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Fenno-Skan 2 for the years 2015–2024.

4.4.7 Kontek

Figure 4.35 presents the availability and utilisation of Kontek for 2024 and Table 4.10 presents the numerical values behind it. Kontek has been in operation since 1995. In Denmark it is connected to Bjaeverskov (bidding zone DK2) and in Germany to Bentwisch (bidding zone DE-50Hertz). The transmission capacity of Kontek is 600 MW.

In 2024, Kontek had an available technical capacity of 96 %. The technical capacity not used was 18 %. Totally, 3.4 TWh (64 % of the technical capacity) was transmitted south to Germany (DK2→DE) and 0.7 TWh (14 % of the technical capacity) was transmitted north to Denmark (DE→DK2). Kontek annual maintenance lasted 12 days in April. Furthermore, there were five planned and one unplanned maintenance outages, one was repair of a cable sealing in Bentwisch, one was exchange of fire safety equipment in the valve hall, one was cleaning of postinsulators, and the last three due to reallocation of a reactor in Bentwisch.

There were one disturbance outages, which was caused by a fault in the auxiliary power for the valve cooling.

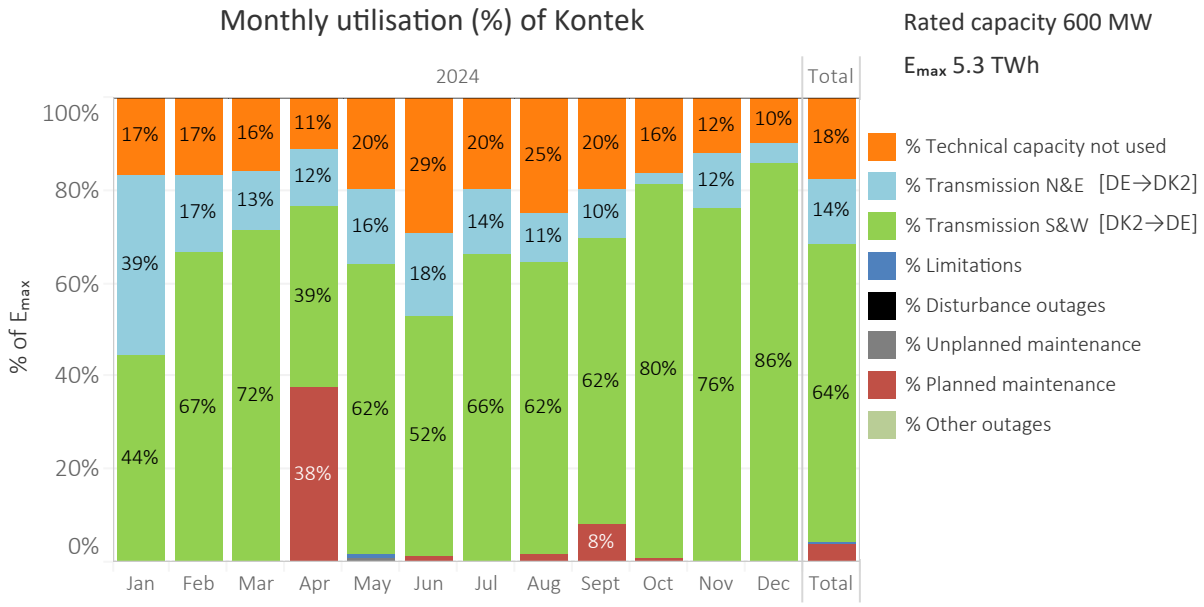

Figure 4.35: Monthly utilisation (%) by category for Kontek in 2024.

Table 4.10: Monthly allocation (GWh) of technical capacity (E_{max}) for Kontek in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Kontek (South & West direction DK2→DE)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	74.7	70.1	69.6	48.5	88.3	126.3	87.2	111.6	85.7	72.7	52.1	44.1	931.0	17.7%
Transmission N&E, GWh	173.4	69.5	57.4	52.4	71.9	76.9	64.4	47.6	44.9	12.2	51.5	18.3	740.3	14.0%
Transmission S&W, GWh	198.4	278.1	318.9	167.9	278.6	224.1	294.9	279.0	266.7	358.0	327.9	384.3	3376.6	64.1%
Limitations, GWh	-	-	-	-	4.7	-	-	-	-	-	-	-	4.7	0.1%
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	0.7	-	0.7	0.0%
Unplanned maintenance., GWh	-	-	-	-	3.0	-	-	-	-	-	-	-	3.0	0.1%
Planned maintenance, GWh	-	-	-	163.1	-	4.7	-	8.3	34.8	4.1	-	-	215.0	4.1%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	446.4	417.6	445.8	432.0	446.4	432.0	446.4	446.4	432.1	447.1	432.2	446.7	5271.2	100.0%
Losses SW, GWh	4.6	6.5	7.5	3.9	6.5	5.4	7.3	6.9	6.5	8.9	8.2	9.5	81.7	1.5%
Losses NE, GWh	3.1	1.2	1.0	0.9	1.2	1.3	1.1	0.8	0.7	0.2	0.9	0.3	12.7	0.2%

Figure 4.36 presents the annual utilisation of Kontek per utilisation and unavailability category for the years 2015–2024.

Figure 4.37 presents the percentage of hours of a year Kontek has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.38 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

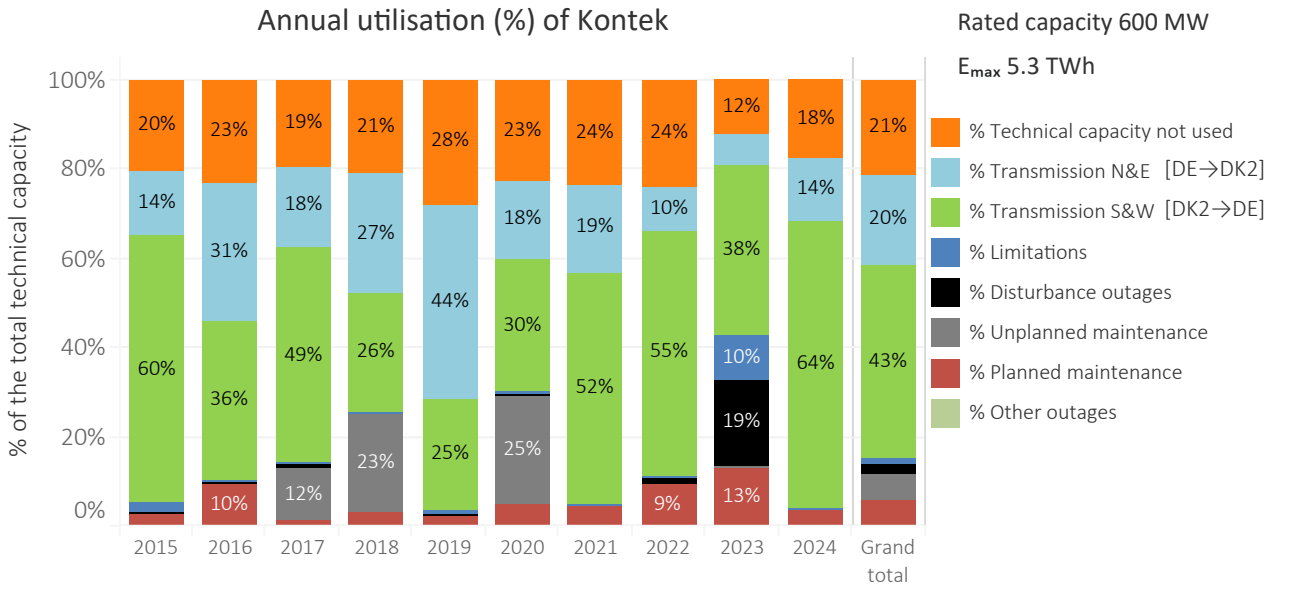

Figure 4.36: Annual utilisation (%) of Kontek by category for 2015–2024.

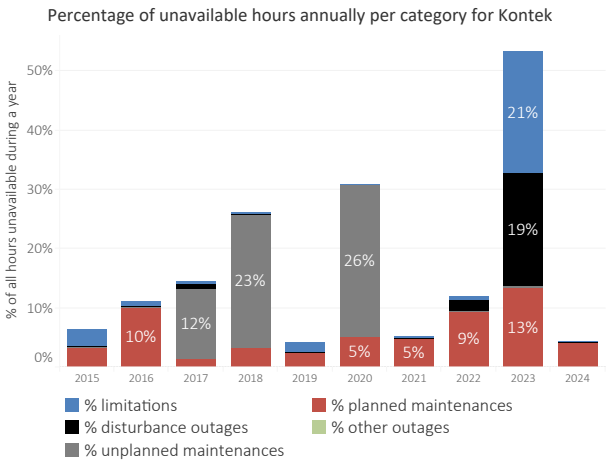

Figure 4.37: Percentage of hours Kontek has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

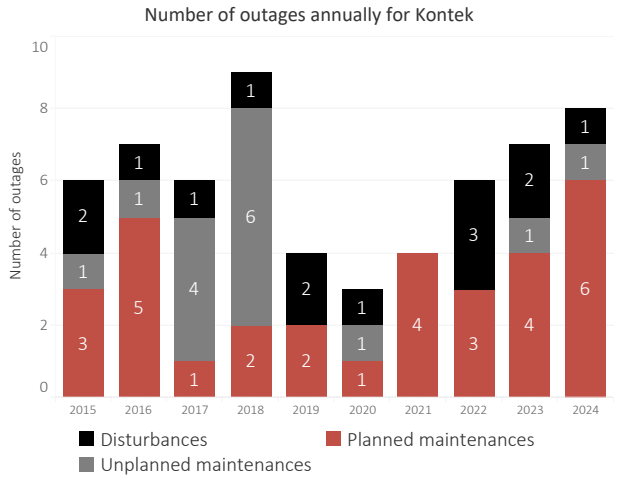

Figure 4.38: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Kontek for the years 2015–2024.

4.4.8 Konti-Skan 1

Figure 4.39 presents the availability and utilisation of Konti-Skan 1 for 2024 and Table 4.11 presents the numerical values behind it. Konti-Skan 1 has been in operation since 1965 and it is connected in south-western Sweden to Lindome (bidding zone SE3) and in Denmark to Vester Hassing (bidding zone DK1).

The rated capacity of Konti-Skan 1 and 2 was updated to 715 MW in both directions on 1 February 2020 (357.5 MW per link). The rated capacity was previously asymmetric depending on the flow direction: 740 MW towards east (370+370) and 680 MW towards west (340+340). The reason of the asymmetric rated capacity was due to historical limitations and reserve requirements, along with transmission measurements only being done in DK1.

In 2024, Konti-Skan 1 had an available technical capacity of 87 % and the technical capacity not used was 21 %. Totally, 1.7 TWh (53 % of the technical capacity) was transmitted west to Denmark (SE3→DK1) and 0.4 TWh (13 % of the technical capacity) was transmitted east to Sweden (DK1→SE3).

Konti-Skan 1 annual maintenance lasted seven days in September. Furthermore, there were four planned maintenance outages, where the change of a filter in Lindome lasted seven days in June, and warranty work on the smoothing reactor lasted four days in October. Additionally there were two minor maintenance outages. There were seven disturbance outages, all of which were of short duration and had a total impact of 0,1 %. Konti-Skan 1 was limited during severel months of the year due to maintenance work in the grid of northern Jutland.

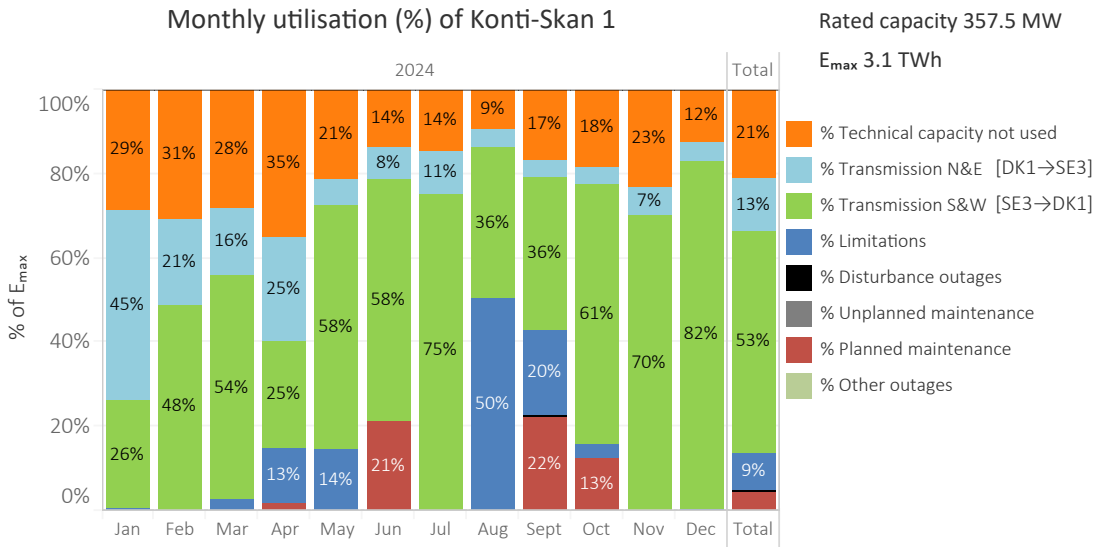

Figure 4.39: Monthly utilisation (%) by category for Konti-Skan 1 in 2024.

Table 4.11: Monthly allocation (GWh) of technical capacity (E_{max}) for Konti-Skan 1 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Konti-Skan 1 (South & West direction SE3→DK1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	76.7	76.5	74.8	89.8	56.6	35.0	38.3	24.6	42.6	48.8	59.5	32.7	655.8	20.9%
Transmission N&E, GWh	120.8	51.8	41.9	64.3	16.2	19.8	28.2	11.4	11.4	11.8	17.6	12.6	407.7	13.0%
Transmission S&W, GWh	69.0	120.7	142.7	65.4	155.1	148.2	199.3	95.9	93.9	163.8	180.4	219.4	1653.6	52.6%
Limitations, GWh	0.6	-	6.4	33.2	38.3	-	0.5	134.1	51.6	8.4	-	-	273.0	8.7%
Disturbance outages, GWh	-	0.2	-	-	-	-	-	-	0.7	-	-	1.5	2.4	0.1%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	4.9	-	54.6	-	-	57.2	33.5	-	-	150.2	4.8%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	267.1	249.2	265.6	257.6	266.0	257.5	266.2	266.0	257.4	266.4	257.5	266.2	3142.7	100.0%
Losses SW, GWh	1.7	2.8	3.3	1.6	3.7	3.6	5.0	1.9	2.1	4.0	4.3	5.2	39.3	1.3%
Losses NE, GWh	2.9	1.4	1.1	1.7	0.6	0.6	0.9	0.3	0.4	0.4	0.5	0.4	11.0	0.4%

Figure 4.40 presents the annual utilisation of Konti-Skan 1 per utilisation and unavailability category for the years 2015–2024.

Figure 4.41 presents the percentage of hours of a year Konti-Skan 1 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.42 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

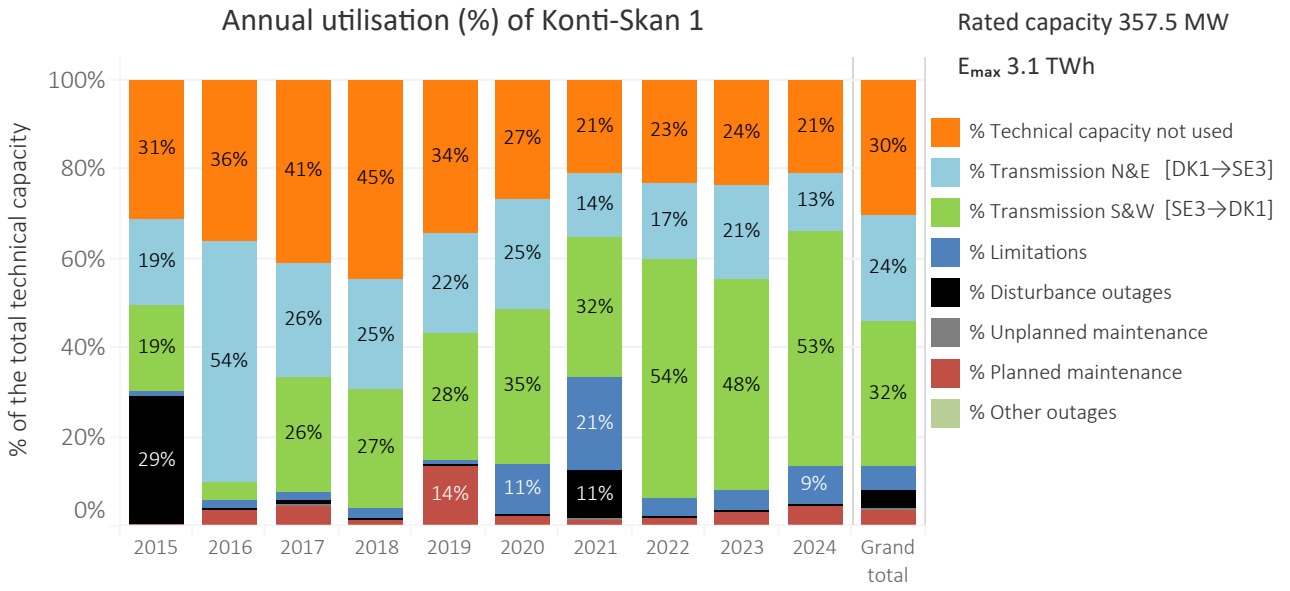

Figure 4.40: Annual utilisation (%) of Konti-Skan 1 by category for 2015–2024.

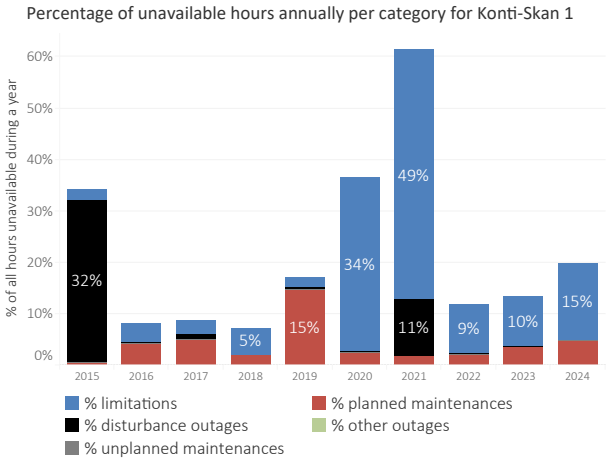

Figure 4.41: Percentage of hours Konti-Skan 1 has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

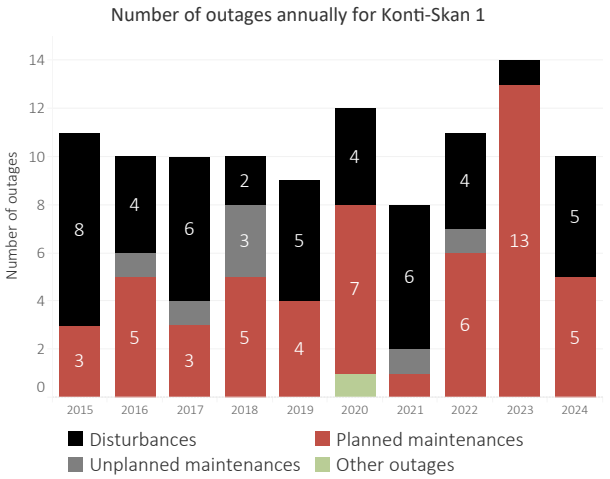

Figure 4.42: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Konti-Skan 1 for the years 2015–2024.

4.4.9 Konti-Skan 2

Figure 4.43 presents the availability and utilisation of Konti-Skan 2 for 2024 and Table 4.12 presents the numerical values behind it. Konti-Skan 2 is connected between Sweden and Denmark in parallel to Konti-Skan 1 and has been in operation since 1988.

The rated capacity of Konti-Skan 1 and 2 was updated to 715 MW in both directions on 1 February 2020 (357.5 MW per link). The rated capacity was previously asymmetric depending on the flow direction: 740 MW towards east (370+370) and 680 MW towards west (340+340). The reason of the asymmetric rated capacity was due to historical limitations and reserve requirements, along with transmission measurements only being done in DK1.

In 2024, Konti-Skan 2 had an available technical capacity of 87 % and the technical capacity not used was 20 %. Totally, 1.7 TWh (53 % of the technical capacity) was transmitted west to Denmark (SE3→DK1) and 0.4 TWh (13 % of the technical capacity) was transmitted east to Sweden (DK1→SE3).

Konti-Skan 2 annual maintenance lasted eight days in September and October. Furthermore, there were four planned maintenance outages, where the change of a filter in Lindome lasted seven days in June, and warranty work on the smoothing reactor lasted four days in October. Additionally there were two minor maintenance outages. There were five disturbance outages, all of which were of short duration and had a total impact of 0,1 %. Konti-Skan 1 was limited during severel months of the year due to maintenance work in the grid of northern Jutland.

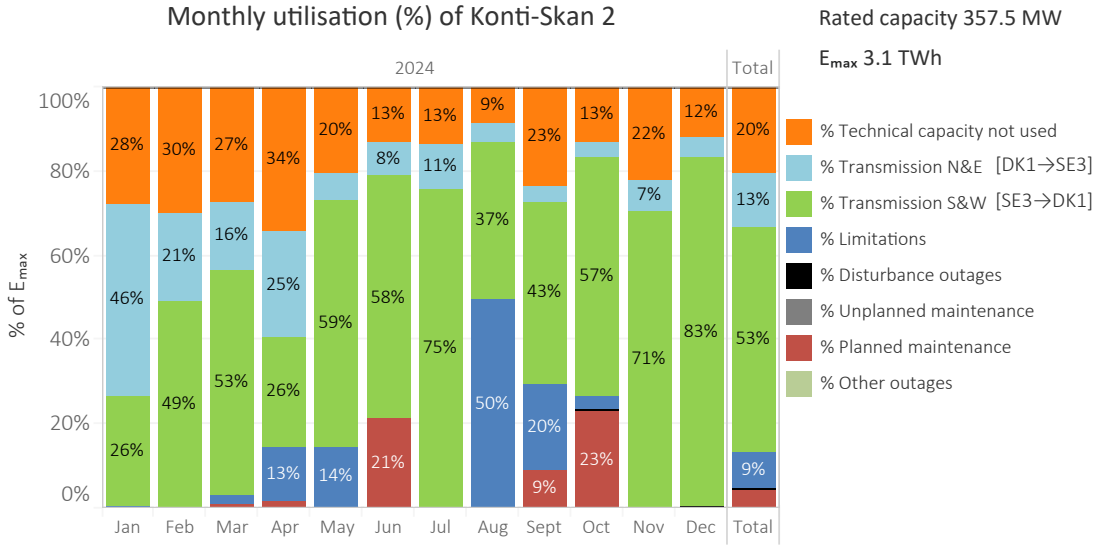

Figure 4.43: Monthly utilisation (%) by category for Konti-Skan 2 in 2024.

Table 4.12: Monthly allocation (GWh) of technical capacity (E_{max}) for Konti-Skan 2 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Konti-Skan 2 (South & West direction SE3→DK1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	74.5	74.6	72.9	87.7	54.5	33.8	36.0	23.2	60.4	35.1	57.7	31.7	642.2	20.4%
Transmission N&E, GWh	122.1	52.5	42.5	65.6	17.0	20.1	29.1	12.0	9.6	9.0	18.1	13.0	410.6	13.0%
Transmission S&W, GWh	70.1	121.9	142.0	66.7	156.5	149.6	201.6	99.2	111.3	151.7	182.2	220.8	1673.8	53.2%
Limitations, GWh	0.6	-	6.2	32.7	38.1	-	0.5	132.4	52.5	8.4	-	-	271.4	8.6%
Disturbance outages, GWh	-	0.3	-	-	0.4	-	-	-	-	0.6	-	1.5	2.8	0.1%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	2.1	4.9	-	54.6	-	-	23.5	62.1	-	-	147.2	4.7%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	267.3	249.4	265.8	257.6	266.5	258.0	267.2	266.9	257.4	266.9	258.1	267.0	3148.0	100.0%
Losses SW, GWh	3.0	1.2	1.0	1.5	0.4	0.5	0.7	0.2	0.2	0.2	0.4	0.3	9.6	0.3%
Losses NE, GWh	1.7	2.9	3.3	1.5	3.8	3.8	5.3	2.2	2.6	3.8	4.6	5.7	41.1	1.3%

Figure 4.44 presents the annual utilisation of Konti-Skan 2 per utilisation and unavailability category for the years 2015–2024.

Figure 4.45 presents the percentage of hours of a year Konti-Skan 2 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.46 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

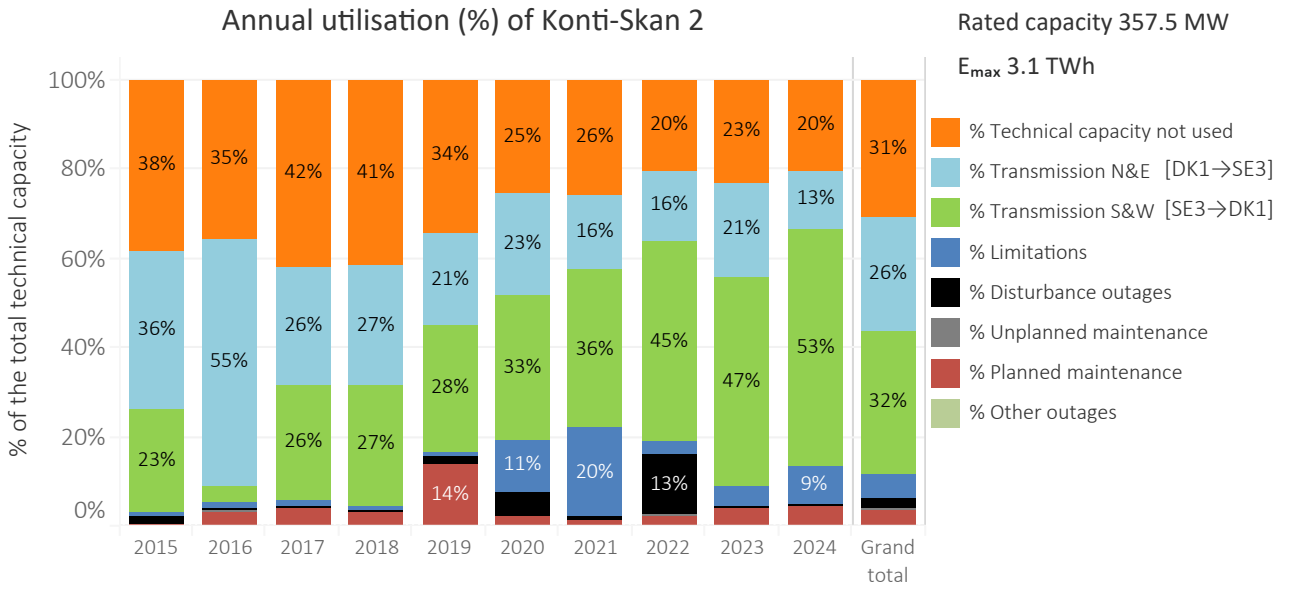

Figure 4.44: Annual utilisation (%) of Konti-Skan 2 by category for 2015–2024.

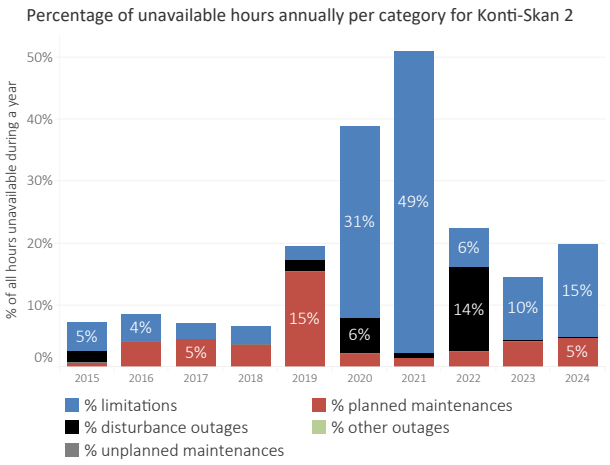

Figure 4.45: Percentage of hours Konti-Skan 2 has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

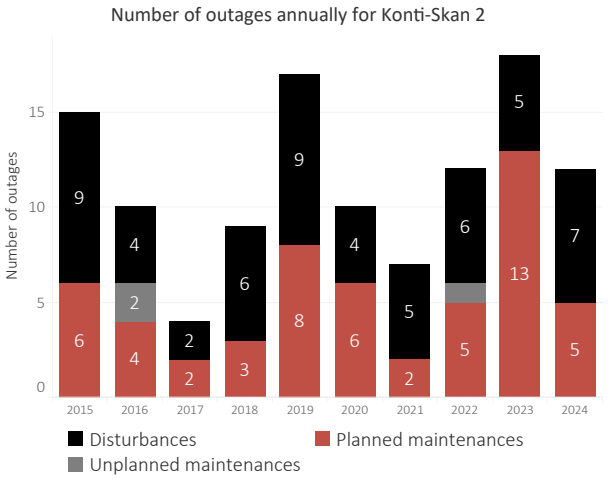

Figure 4.46: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Konti-Skan 2 for the years 2015–2024.

4.4.10 LitPol Link

Figure 4.47 presents the availability and utilisation of LitPol Link for 2024 and Table 3.1 presents the numerical values behind it. LitPol Link has been in operation since the end of 2015. In Lithuania, it is connected to Alytus (bidding zone LT) and in Poland to Ełk (bidding zone PL). The transmission capacity of LitPol Link is 500 MW.

In 2024, LitPol Link had an available technical capacity of 89 %. The technical capacity not used was 36 %. Totally, 1,6 TWh (37 % of the technical capacity) was transmitted east (PL->LT) and 0,7 TWh (16 % of the technical capacity) was transmitted west (LT->PL).

The annual maintenance of LitPol Link lasted 5 days in January. LitPol Link had in addition 3 corrective maintenances in October and December.

There were three minor disturbances outages lasting few hours caused due to faults in AC filters protection, cooling system and probably geomagnetic storm which activated the saturation protection of the converter transformer on 330 kV side.

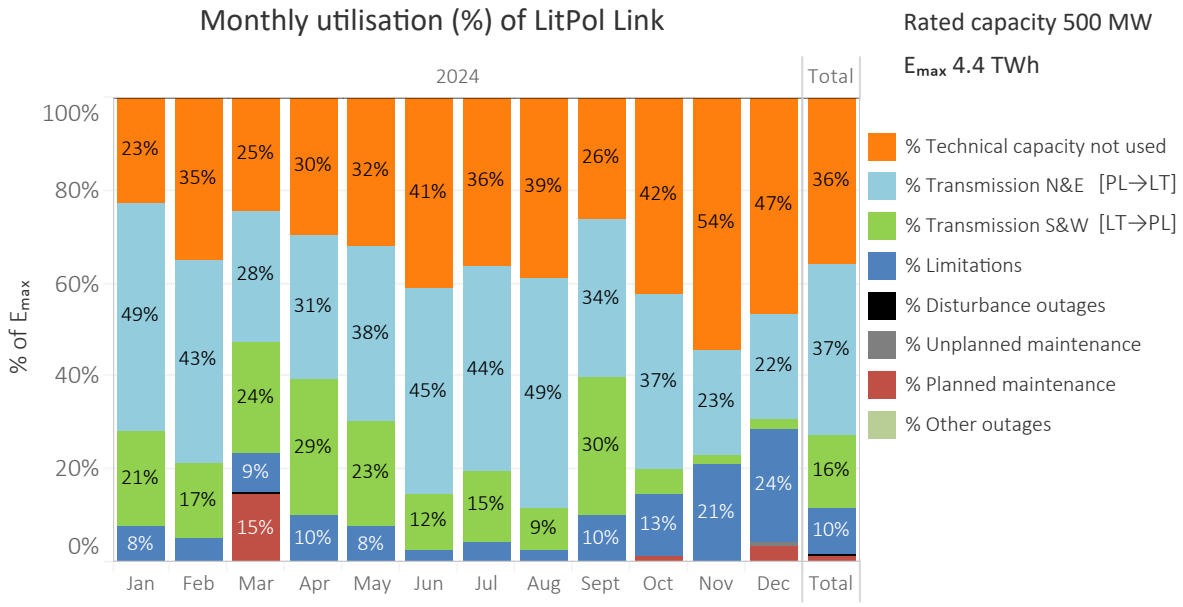

Figure 4.47: Monthly utilisation (%) by category for LitPol Link in 2024.

Table 4.13: Monthly allocation (GWh) of technical capacity (E_{max}) for LitPol Link in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of LitPol Link (South & West direction LT→PL)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	81.3	122.5	91.1	106.6	119.1	147.1	134.6	144.6	93.5	157.8	195.4	173.8	1567.5	35.8%
Transmission N&E, GWh	177.6	150.6	103.8	111.6	139.8	161.2	164.8	183.6	122.9	139.5	81.2	83.3	1619.8	37.0%
Transmission S&W, GWh	73.8	57.7	89.5	105.7	83.8	41.8	56.2	33.0	106.9	21.5	7.8	8.9	686.5	15.7%
Limitations, GWh	27.3	17.2	32.0	36.2	28.8	9.8	16.4	10.3	36.5	49.2	75.6	90.3	429.6	9.8%
Disturbance outages, GWh	-	-	1.1	-	0.5	-	-	-	0.3	-	-	-	1.9	0.0%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	2.2	2.2	0.1%
Planned maintenance, GWh	-	-	54.0	-	-	-	-	-	-	4.4	-	13.4	71.9	1.6%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	360.0	348.0	371.5	360.0	372.0	360.0	372.0	371.5	360.0	372.5	360.0	372.0	4379.5	100.0%
Losses SW, GWh	1.2	1.1	1.5	1.8	1.5	0.9	1.1	0.7	1.8	0.6	0.5	0.6	13.3	0.3%
Losses NE, GWh	2.7	2.4	1.7	1.8	2.1	2.5	2.6	2.9	1.9	2.3	1.5	1.6	26.1	0.6%

Figure 4.48 presents the annual utilisation of LitPol Link per utilisation and unavailability category for the years 2016–2024.

Figure 4.49 presents the percentage of hours of a year LitPol Link has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2016–2024. Figure 4.50 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2016–2024.

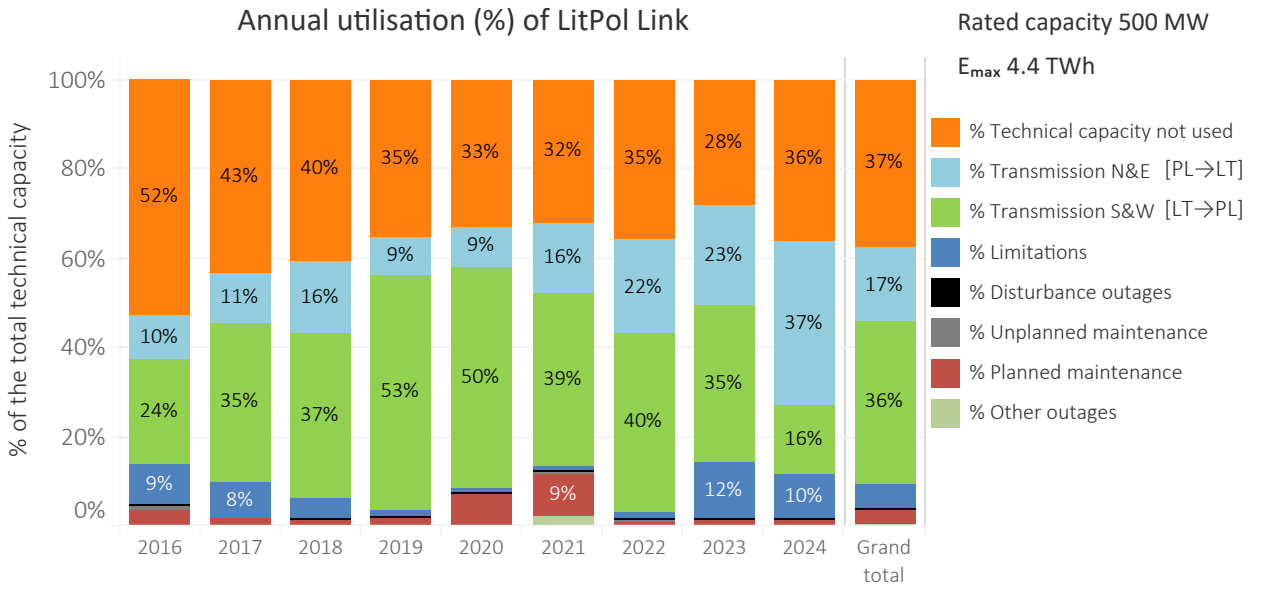

Figure 4.48: Annual utilisation (%) of LitPol Link by category for 2016–2024.

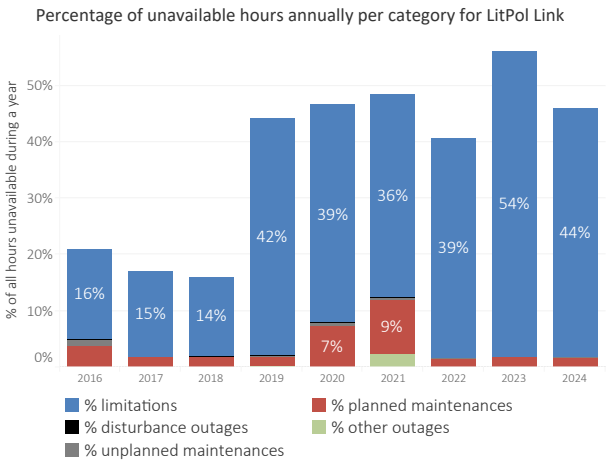

Figure 4.49: Percentage of hours LitPol Link has been affected by either a limitation or an outage annually since 2016. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

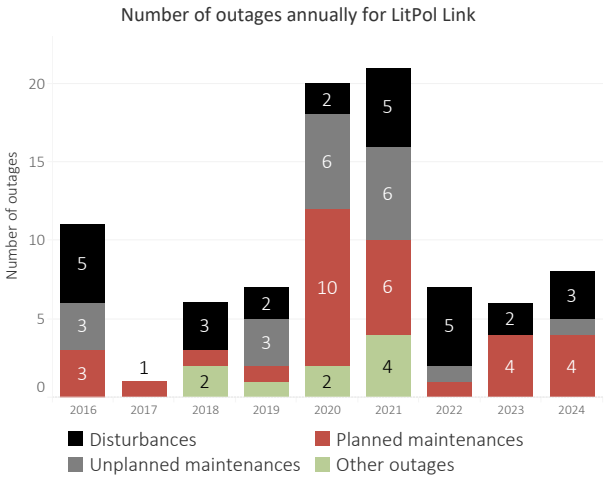

Figure 4.50: The annual number of disturbances, unplanned and planned maintenance outages and other outages for LitPol Link for the years 2016–2024.

4.4.11 NordBalt

Figure 4.51 presents the availability and utilisation of NordBalt for 2024 and Table 4.14 presents the numerical values behind it. NordBalt has been in operation since 2016. In Sweden, it is connected to Nybro (bidding zone SE4) and in Lithuania to Klaipeda (bidding zone LT). The transmission capacity of NordBalt is 700 MW at the receiving end.

Nordbalt had an available technical capacity of about 97 % in 2024. Four disturbance outages occurred, two that were technical faults and two that were of operational origin. The longest technical fault lasted for about a day and was due to a cable fault for the auxiliary power. The annual maintenance was conducted from October 21st to October 27th. Additionally, there was one planned and one unplanned maintenance outage over the course of the year. The unplanned maintenance involved a converter transformer and was completed within two days.

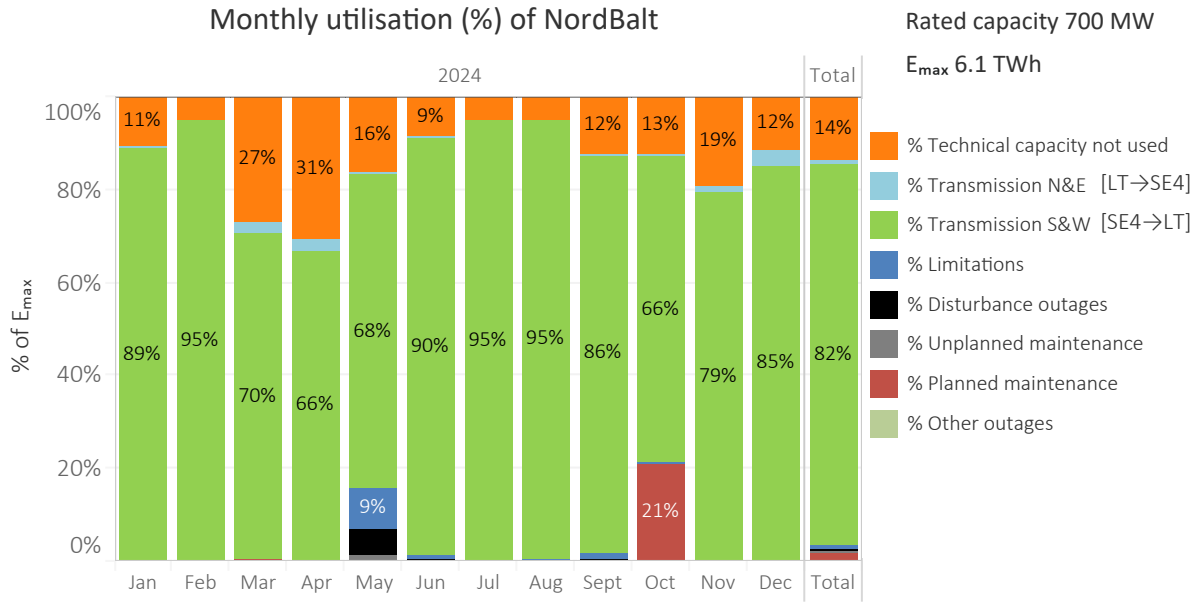

Figure 4.51: Monthly utilisation (%) by category for NordBalt in 2024.

Table 4.14: Monthly allocation (GWh) of technical capacity (E_{max}) for NordBalt in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of NordBalt (South & West direction SE4→LT)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	55.2	24.2	139.5	156.1	84.3	44.1	26.0	26.9	62.5	65.7	97.9	60.2	842.7	13.7%
Transmission N&E, GWh	2.6	-	13.6	12.9	3.0	0.3	-	-	0.2	1.2	5.6	17.6	57.1	0.9%
Transmission S&W, GWh	462.9	463.0	364.2	334.5	352.0	452.8	494.8	492.4	433.1	344.1	400.5	443.3	5037.6	81.9%
Limitations, GWh	-	-	-	0.6	44.9	5.6	-	1.4	6.2	0.6	-	-	59.3	1.0%
Disturbance outages, GWh	-	-	-	-	29.1	1.3	-	-	2.0	-	-	-	32.3	0.5%
Unplanned maintenance., GWh	-	-	-	-	7.5	-	-	-	-	-	-	-	7.5	0.1%
Planned maintenance, GWh	-	-	2.9	-	-	-	-	-	-	109.9	-	-	112.8	1.8%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	520.8	487.2	520.2	504.1	520.8	504.0	520.9	520.8	504.0	521.5	504.0	521.1	6149.4	100.0%
Losses SW, GWh	21.4	21.8	16.1	14.4	14.4	20.8	23.2	23.1	19.1	15.5	18.2	20.7	228.6	3.7%
Losses NE, GWh	0.1	-	0.5	0.5	0.1	-	-	-	-	-	0.2	0.7	2.0	0.0%

Figure 4.52 presents the annual utilisation of NordBalt per utilisation and unavailability category for the years 2016–2024.

Figure 4.53 presents the percentage of hours of a year NordBalt has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2016–2024. Figure 4.54 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2016–2024.

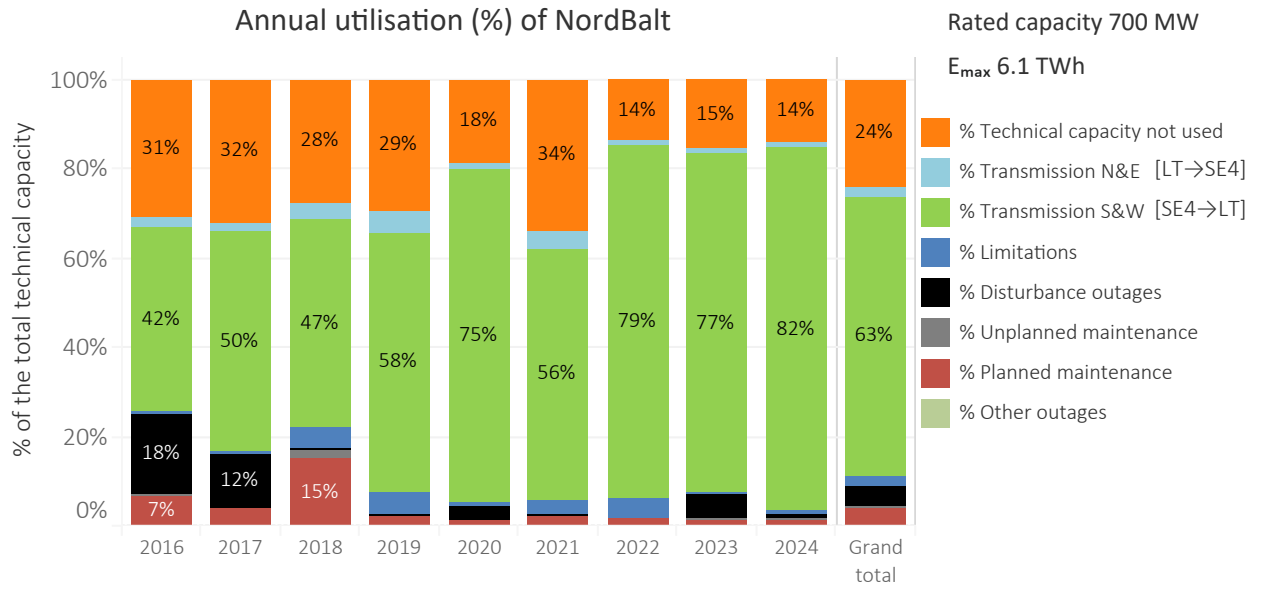

Figure 4.52: Annual utilisation (%) of NordBalt by category for 2016–2024.

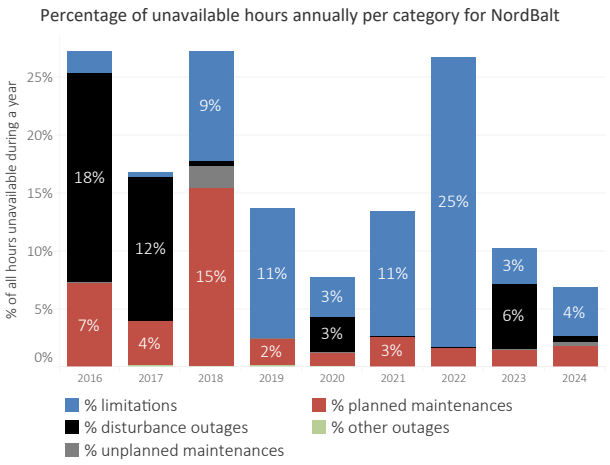

Figure 4.53: Percentage of hours NordBalt has been affected by either a limitation or an outage annually since 2016. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

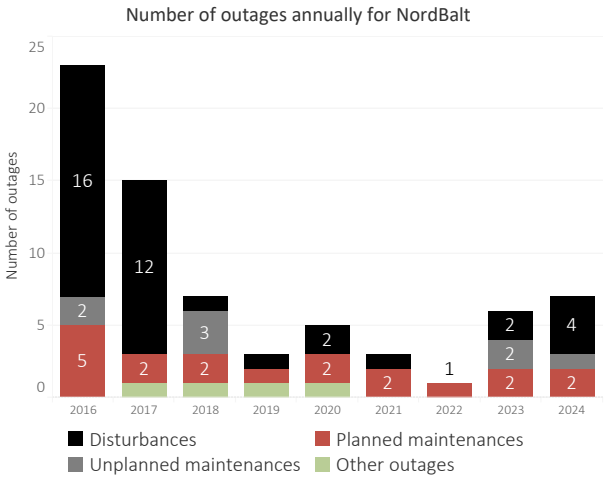

Figure 4.54: The annual number of disturbances, unplanned and planned maintenance outages and other outages for NordBalt for the years 2016–2024.

4.4.12 NordLink 1

Figure 4.55 presents the availability and utilisation of NordLink 1 for 2024 and Table 4.15 presents the numerical values behind it. NordLink 1 is the HVDC link located between Tonstad/Ertsmyra in Sirdal municipality in Norway (bidding zone NO2) and Wilster in Schleswig-Holstein in Germany (bidding zone DE). The parallel NordLink 1 and 2 links were commissioned on December 2020 and have each a transmission capacity of 700 MW (1400 MW in total) to the receiving end.

In 2024, NordLink 1 had an available technical capacity of 96,1 %. The technical capacity not used was 29,4 % Totally, 3.5 TWh (56,9 % of the technical capacity) was transmitted south to Germany (NO2→DE) and 0.6 TWh (9.8 % of the technical capacity) was transmitted north to Norway (DE→NO2).

NordLink has a 51 km overhead line from Ertsmyra to Vollesfjord where the cable starts. This part is vulnerable to disturbances due to weather (lightning and storms). These are normally not permanent faults, so the system is equipped with auto-reclosing functionality. Thus, there are several faults with short duration.

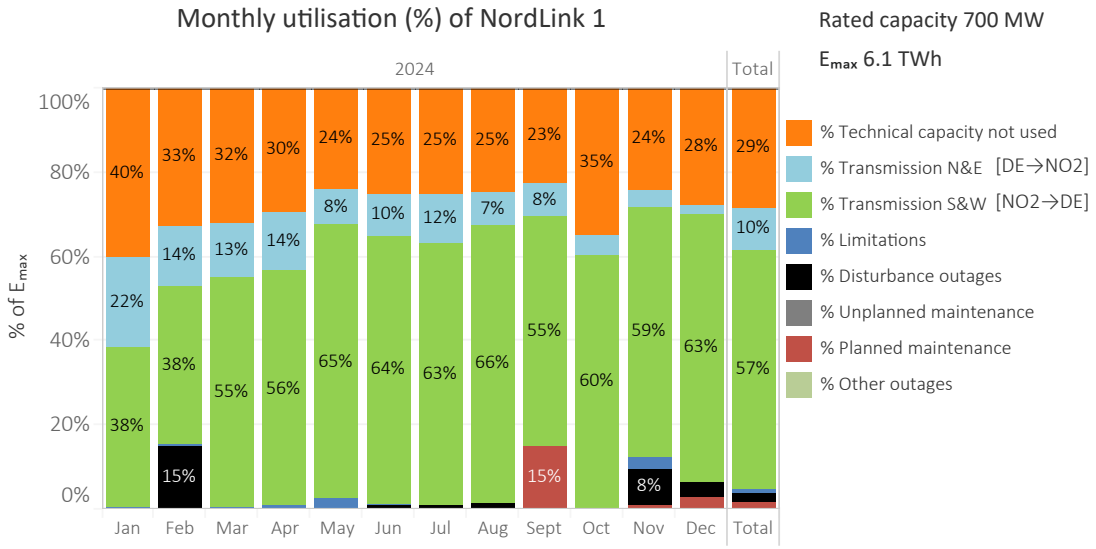

Figure 4.55: Percentage distribution of the availability and utilisation per category according to month for NordLink 1 in 2024.

Table 4.15: Monthly distribution of the technical capacity (E_{max}) for NordLink 1 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of NordLink 1 (South & West direction NO2→DE)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	209.2	159.9	166.3	149.3	125.8	126.5	131.2	129.9	114.4	183.7	123.1	144.4	1763.6	28.7%
Transmission N&E, GWh	112.3	68.6	67.3	68.1	43.5	50.6	60.6	39.1	38.1	23.8	19.6	12.3	604.0	9.8%
Transmission S&W, GWh	197.5	183.0	284.1	283.8	339.1	320.5	326.1	346.7	277.5	314.5	298.4	330.1	3501.3	56.9%
Limitations, GWh	2.2	0.5	2.7	3.3	13.3	0.5	-	-	-	-	16.8	-	39.1	0.6%
Disturbance outages, GWh	-	75.5	-	-	-	5.9	3.7	6.2	-	-	41.6	19.0	151.9	2.5%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	-	-	0.7	-	-	74.4	-	4.9	15.4	95.4	1.5%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	521.1	487.4	520.4	504.5	521.7	504.6	521.6	521.9	504.5	522.0	504.4	521.2	6155.3	100.0%
Losses SW, GWh	5.5	5.1	8.1	8.4	10.1	9.9	9.8	10.7	9.3	9.0	8.5	10.4	104.8	1.7%
Losses NE, GWh	3.4	2.2	2.1	2.0	1.3	1.6	1.9	1.2	1.1	0.7	0.6	0.4	18.3	0.3%

Figure 4.56 presents the annual utilisation of NordLink 1 per utilisation and unavailability category for the years 2021–2024.

Figure 4.57 presents the percentage of hours of a year NordLink 1 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2021–2024. Figure 4.58 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2021–2024.

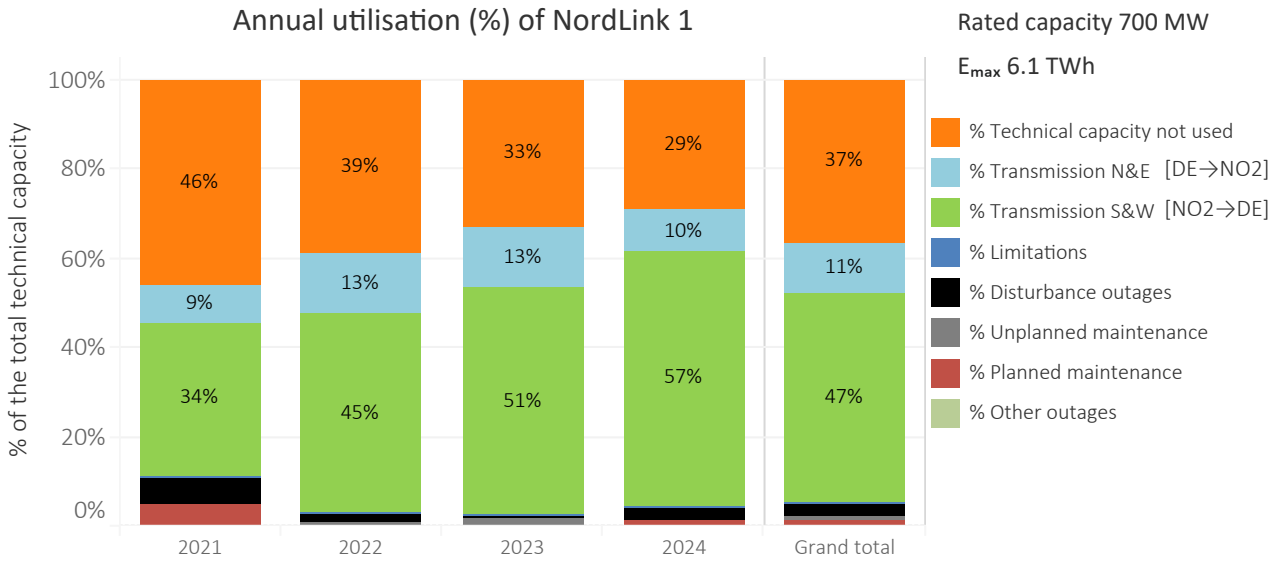

Figure 4.56: Annual utilisation (%) of NordLink 1 by category for 2021–2024.

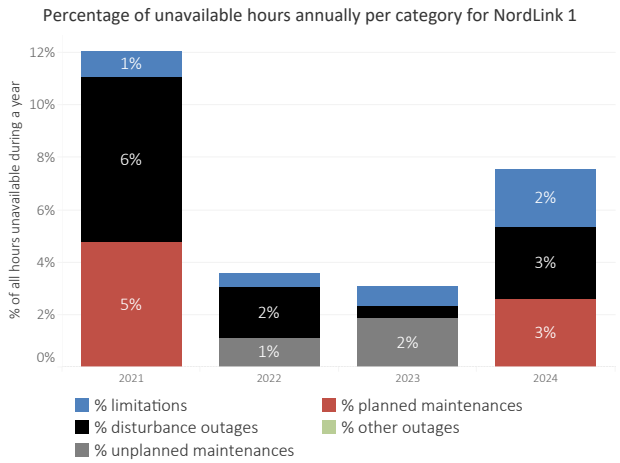

Figure 4.57: Percentage of hours NordLink 1 has been affected by either a limitation or an outage annually since 2021. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

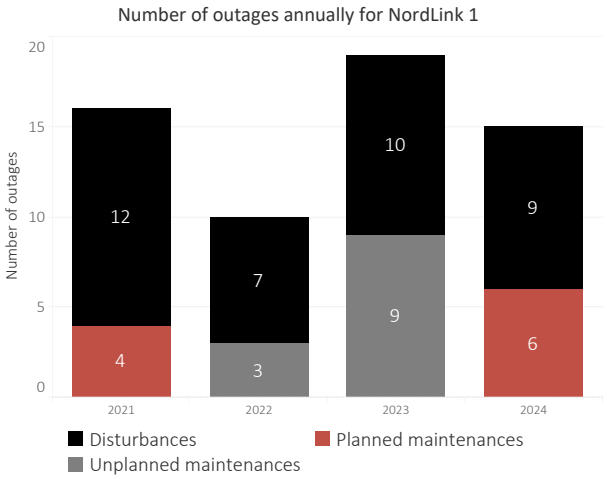

Figure 4.58: The annual number of disturbances, unplanned and planned maintenance outages and other outages for NordLink 1 for the years 2021–2024.

4.4.13 NordLink 2

Figure 4.59 presents the availability and utilisation of NordLink 2 for 2024 and Table 4.16 presents the numerical values behind it. NordLink 2 is the HVDC link located between Tonstad/Ertsmyra in Sirdal municipality in Norway (bidding zone NO2) and Wilster in Schleswig-Holstein in Germany (bidding zone DE). The parallel NordLink 1 and 2 links were commissioned on December 2020 and have each a transmission capacity of 700 MW (1400 MW in total) to the receiving end.

In 2024, NordLink 2 had an available technical capacity of 95.4 %. The technical capacity not used was 31.5 %. Totally, 3.5 TWh (56.9 % of the technical capacity) was transmitted south to Germany (NO2→DE) and 0.6 TWh (10 % of the technical capacity) was transmitted north to Norway (DE→NO2).

NordLink has a 51 km overhead line from Ertsmyra to Vollesfjord where the cable starts. This part is vulnerable to disturbances due to weather (lightning and storms). These are normally not permanent faults, so the system is equipped with auto-reclosing functionality. Thus there are several faults with short duration.

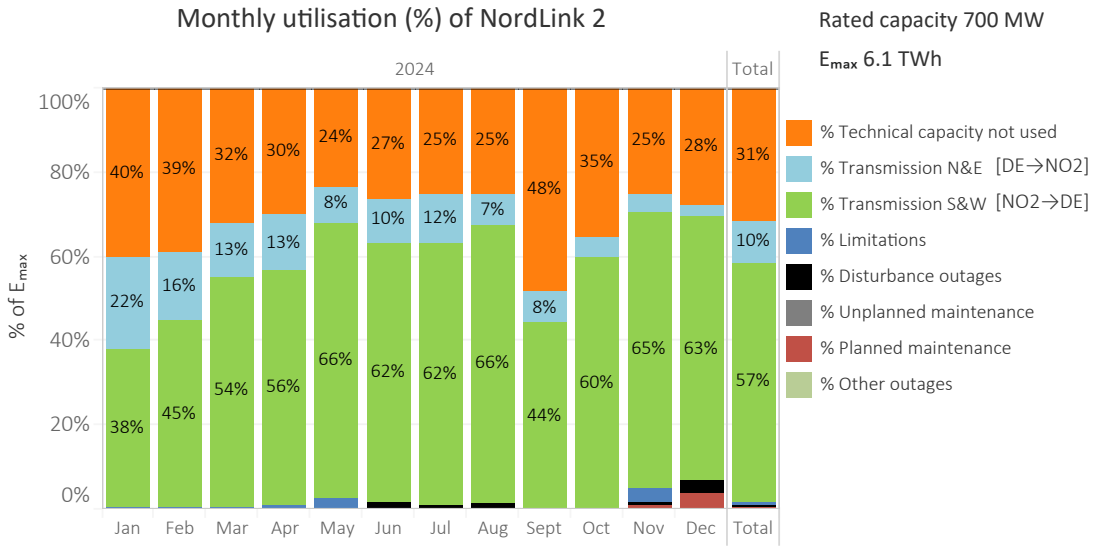

Figure 4.59: Percentage distribution of the availability and utilisation per category according to month for NordLink 2 in 2024.

Table 4.16: Monthly distribution of the technical capacity (E_{max}) for NordLink 2 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of NordLink 2 (South & West direction NO2→DE)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	210.0	189.8	167.2	150.0	122.9	134.2	131.9	130.5	242.7	184.7	128.1	144.7	1936.8	31.5%
Transmission N&E, GWh	112.0	79.1	67.2	68.0	43.4	50.5	60.5	39.0	38.1	23.7	21.2	12.2	614.8	10.0%
Transmission S&W, GWh	196.6	216.9	283.1	282.8	341.5	310.4	325.0	345.4	223.4	313.1	329.9	328.6	3496.8	56.9%
Limitations, GWh	2.2	0.2	2.7	3.3	13.4	-	-	-	-	-	16.9	-	38.7	0.6%
Disturbance outages, GWh	-	-	-	-	-	8.4	3.7	6.2	-	-	3.0	15.4	36.8	0.6%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	1.4	-	-	-	0.7	-	-	-	-	4.9	19.9	26.9	0.4%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	520.8	487.2	520.2	504.1	521.2	504.2	521.1	521.2	504.1	521.6	504.1	520.9	6150.7	100.0%
Losses SW, GWh	5.6	6.8	8.1	8.5	10.4	9.5	9.9	10.7	6.6	9.1	10.2	10.0	105.3	1.7%
Losses NE, GWh	3.3	2.7	2.1	2.0	1.3	1.5	1.9	1.2	1.1	0.7	0.7	0.5	18.9	0.3%

Figure 4.60 presents the annual utilisation of NordLink 2 per utilisation and unavailability category for the years 2021–2024.

Figure 4.61 presents the percentage of hours of a year NordLink 2 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2021–2024. Figure 4.62 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2021–2024.

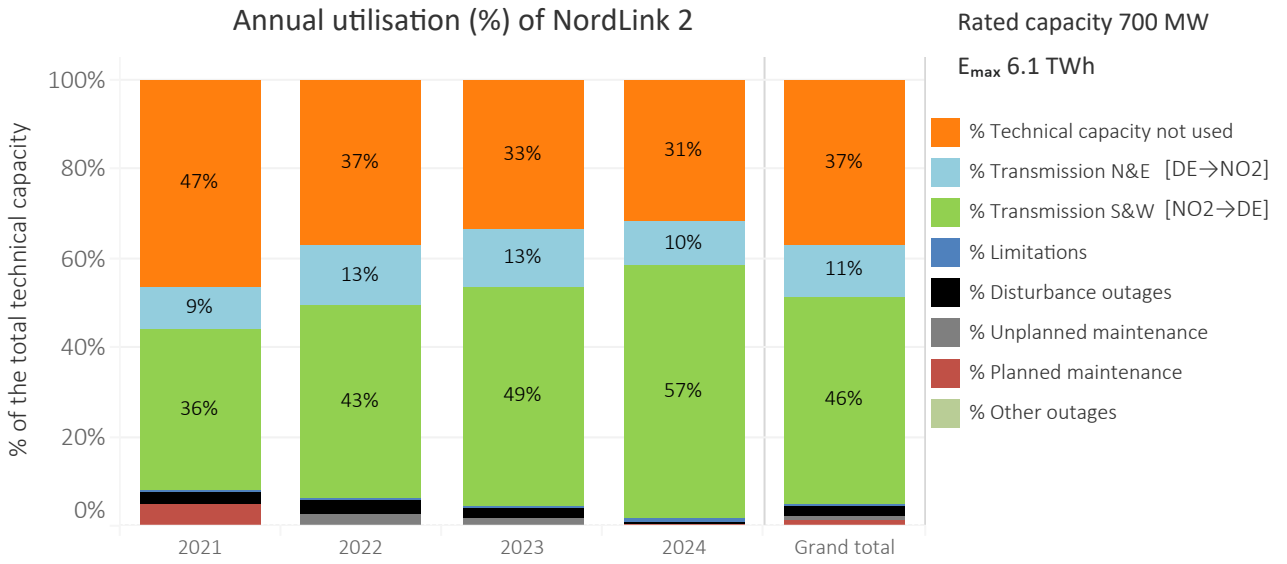

Figure 4.60: Annual utilisation (%) of NordLink 2 by category for 2021–2024.

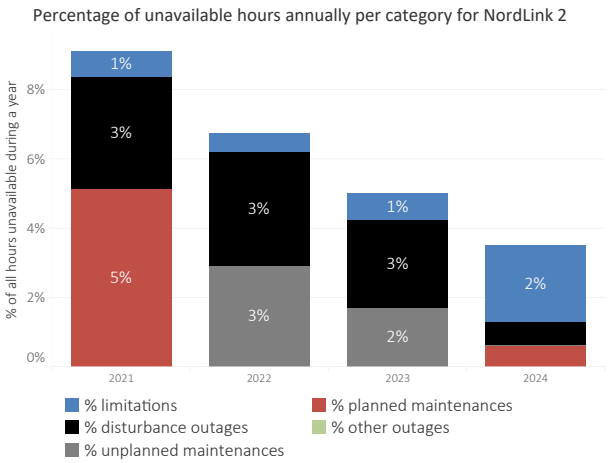

Figure 4.61: Percentage of hours NordLink 2 has been affected by either a limitation or an outage annually since 2021. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

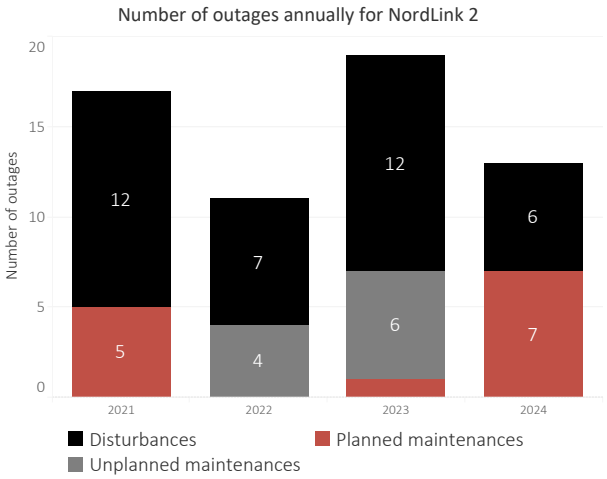

Figure 4.62: The annual number of disturbances, unplanned and planned maintenance outages and other outages for NordLink 2 for the years 2021–2024.

4.4.14 NorNed

Figure 4.63 presents the availability and utilisation of NorNed for 2024 and Table 4.17 presents the numerical values behind it. In Norway on the south-western coast (bidding zone NO2) it is connected to Feda substation and in Netherlands to Eemshaven (bidding zone APX NL). NorNed has been in operation since 2008 and its transmission capacity is 700 MW.

NorNed had a major cable fault on the Dutch side in 2022. Following the repair of this fault it has been decided to reduce the DC operation voltage to 400 kV to protect the cable. This has reduced the capacity to 640/620 MW export/import. This will be held until that part of the cable is renewed. It is also some restrictions regarded to change of flow directions since the voltage change is quite stressful to the cable.

In 2024, NorNed had an available technical capacity of 88.8 %. The technical capacity not used was 24.7 %. Totally, 3.5 TWh (55,1 % of the technical capacity) was transmitted south to Netherlands (NO2→NL) and 0.57 TWh (9.0 % of the technical capacity) was transmitted north to Norway (NL→NO2).

There were several situations with limitations due to problems with filter on the Dutch side. Also, maintenance work in the AC transmission system on the Dutch side had an impact on the capacity.

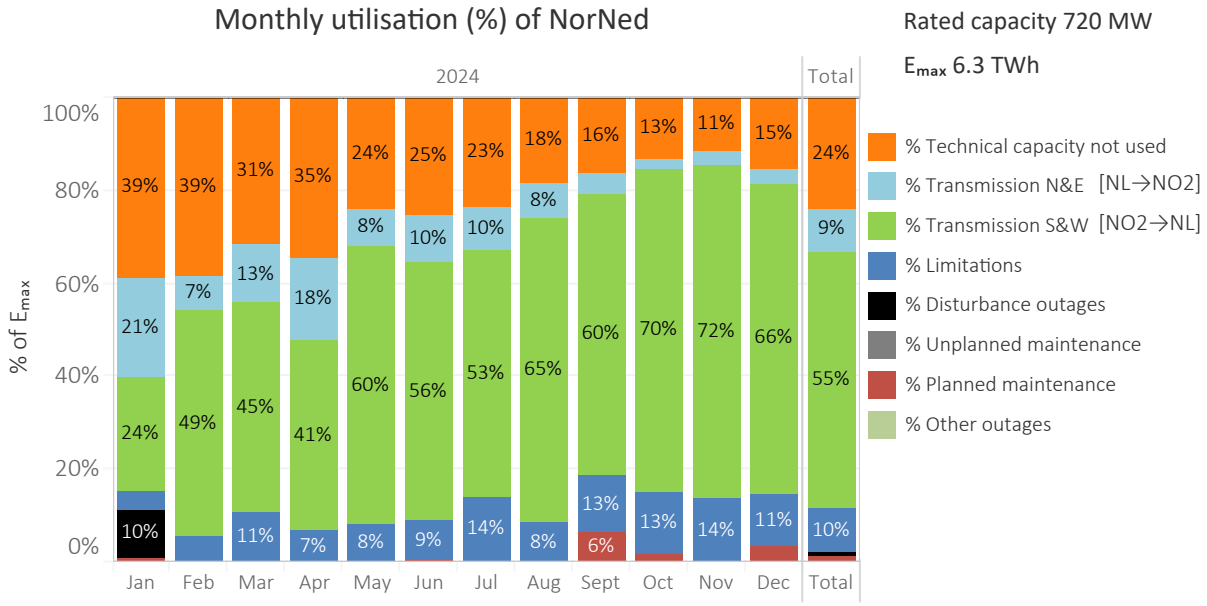

Figure 4.63: Monthly utilisation (%) by category for NorNed in 2024.

Table 4.17: Monthly allocation (GWh) of technical capacity (E_{max}) for NorNed in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of NorNed (South & West direction NO2→NL)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	208.0	193.2	168.0	179.3	127.3	131.2	125.7	97.6	83.2	71.4	59.2	82.6	1526.7	24.1%
Transmission N&E, GWh	114.7	36.0	68.6	91.8	43.2	52.3	51.4	42.5	24.8	10.2	16.1	19.0	570.7	9.0%
Transmission S&W, GWh	130.8	244.7	241.8	212.6	320.9	287.8	283.0	350.8	312.2	374.7	372.5	355.2	3487.0	55.1%
Limitations, GWh	22.9	27.2	56.5	34.7	44.3	44.4	75.6	44.9	65.7	69.8	70.5	59.9	616.3	9.7%
Disturbance outages, GWh	53.6	-	-	-	-	-	-	-	-	-	-	-	53.6	0.8%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	5.7	-	-	-	-	2.6	-	-	32.6	10.3	-	19.0	70.1	1.1%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	535.7	501.1	535.0	518.4	535.7	518.4	535.7	535.7	518.4	536.4	518.4	535.7	6324.5	100.0%
Losses SW, GWh	5.2	9.7	9.2	8.3	12.8	11.5	10.5	14.7	12.6	15.2	15.2	14.4	139.2	2.2%
Losses NE, GWh	4.9	1.5	2.9	3.8	1.8	2.1	2.1	1.7	1.0	0.4	0.7	0.7	23.5	0.4%

Figure 4.64 presents the annual utilisation of NorNed per utilisation and unavailability category for the years 2015–2024.

Figure 4.65 presents the percentage of hours of a year NorNed has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.66 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

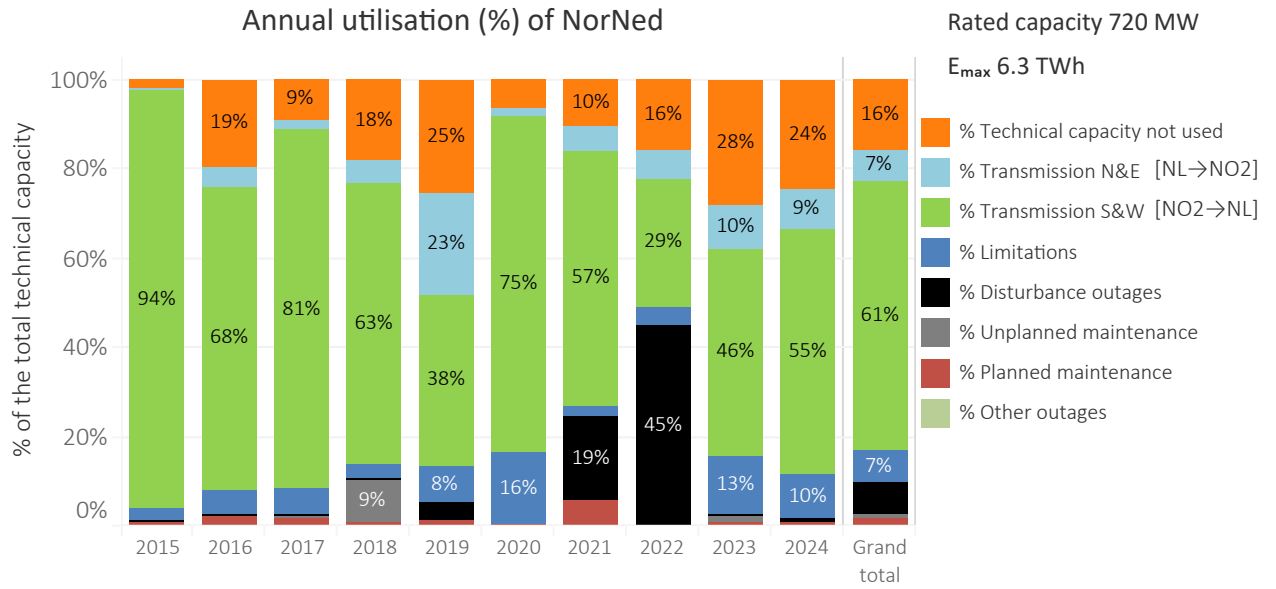

Figure 4.64: Annual utilisation (%) of NorNed by category for 2015–2024.

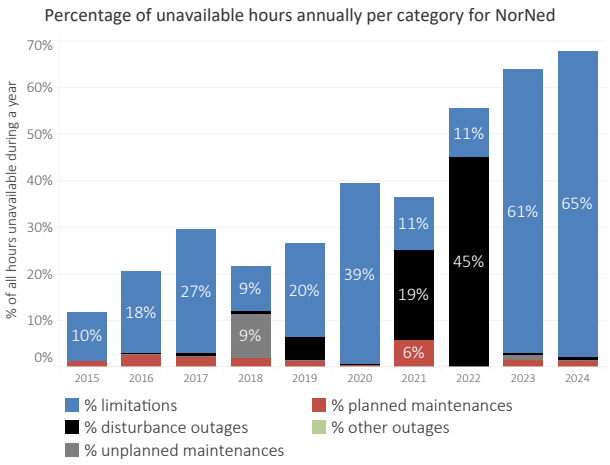

Figure 4.65: Percentage of hours NorNed has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

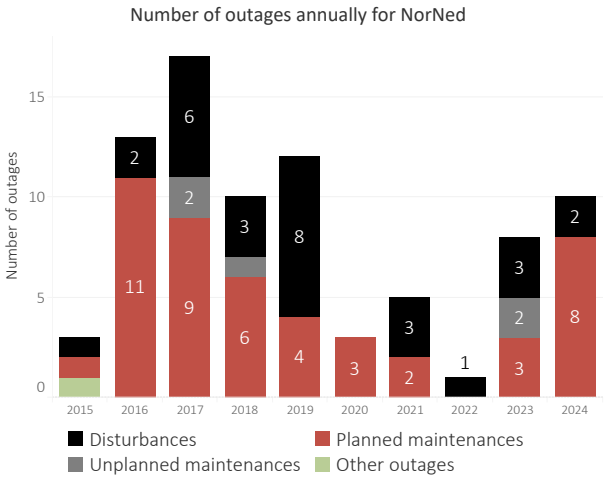

Figure 4.66: The annual number of disturbances, unplanned and planned maintenance outages and other outages for NorNed for the years 2015–2024.

4.4.15 North Sea Link 1

Figure 4.67 presents the availability and utilisation of North Sea Link 1 for 2024 and Table 4.18 presents the numerical values behind it. North Sea Link 1 where put into operation 1. October 2021 so this is the second year with data for this link. With a cable length of 720 km the cable is the longest in this publication.

In 2024, North Sea Link 1 had an available technical capacity of 99.3 %. The technical capacity not used was16.8 %. Totally, 4.9 TWh (80.3 % of the technical capacity) was transmitted west to Great Britain (NO2→UK) and 0.13 TWh (2.2 % of the technical capacity) was transmitted north to Norway (UK→NO2). During the year there have been no long outages for North Sea Link 1, just some short interruptions.

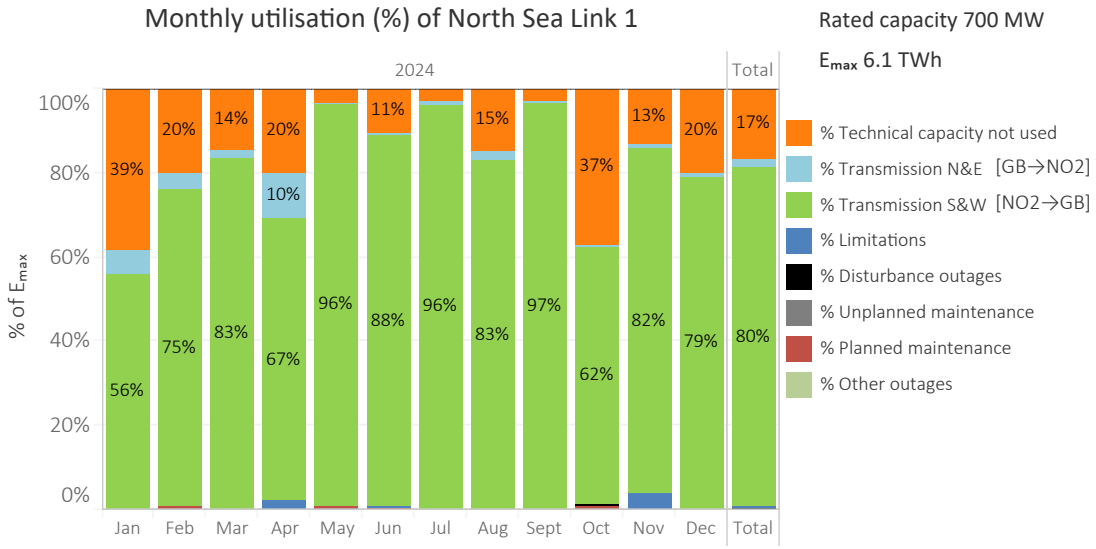

Figure 4.67: Monthly utilisation (%) by category for North Sea Link 1 in 2024.

Table 4.18: Monthly allocation (GWh) of technical capacity (E_{max}) for North Sea Link 1 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

North Sea Link 1

Monthly utilisation of North Sea Link 1 (South & West direction NO2→GB)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	201.3	98.8	74.7	102.1	17.7	54.6	16.1	78.4	15.8	193.0	67.1	104.7	1024.3	16.7%
Transmission N&E, GWh	28.0	17.9	12.5	52.2	-	2.3	4.9	11.6	0.5	-	3.6	3.4	136.9	2.2%
Transmission S&W, GWh	291.5	366.7	432.9	339.5	498.9	443.4	499.8	430.8	487.7	322.2	414.0	412.7	4940.2	80.3%
Limitations, GWh	-	-	-	10.2	-	-	-	-	-	-	19.3	-	29.5	0.5%
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	0.7	-	-	0.7	0.0%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	3.7	-	-	4.2	3.6	-	-	-	5.6	-	-	17.2	0.3%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	520.8	487.2	520.1	504.0	520.8	504.0	520.8	520.8	504.0	521.5	504.0	520.8	6148.8	100.0%
Losses SW, GWh	10.6	13.6	16.3	12.6	19.3	17.8	19.5	16.4	18.9	12.5	16.7	16.2	190.3	3.1%
Losses NE, GWh	1.1	0.6	0.3	1.7	-	0.1	0.1	0.4	-	-	0.1	0.1	4.6	0.1%

Figure 4.68 presents the annual utilisation of North Sea Link 1 per utilisation and unavailability category for the years 2021–2024.

Figure 4.69 presents the percentage of hours of a year North Sea Link 1 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2022–2024. Figure 4.70 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2022–2024.

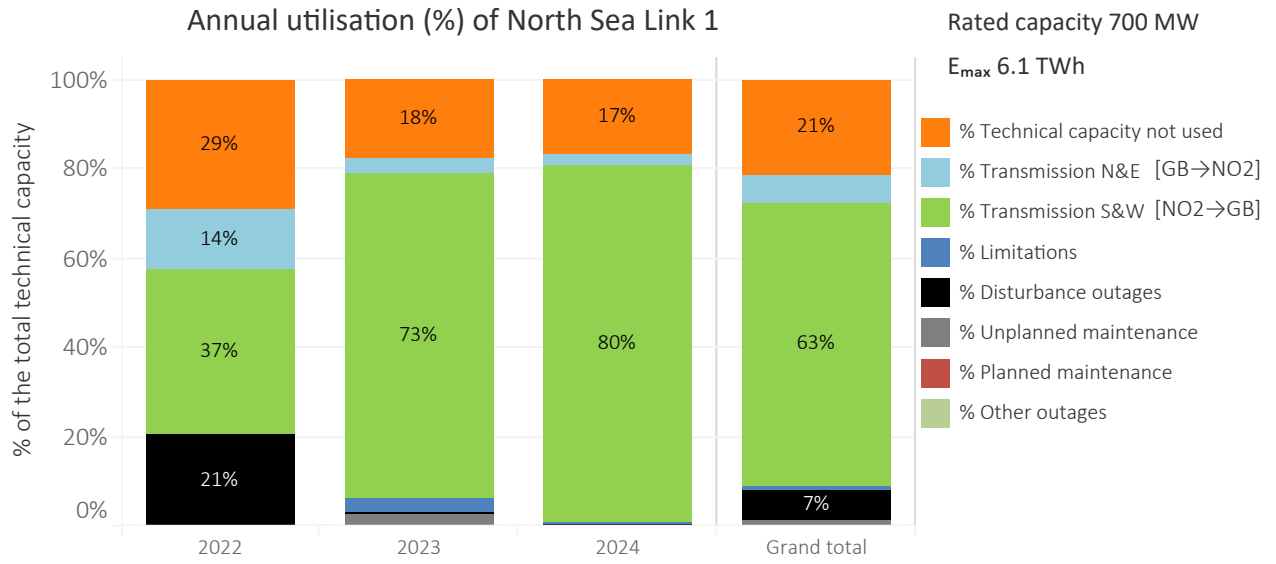

Figure 4.68: Annual utilisation (%) of North Sea Link 1 by category for 2021–2024.

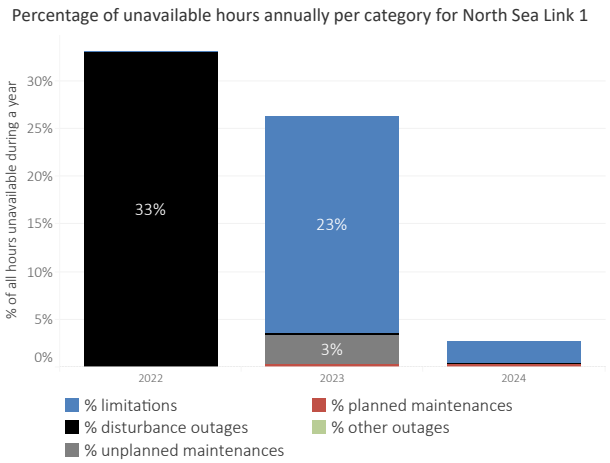

Figure 4.69: Percentage of hours North Sea Link 1 has been affected by either a limitation or an outage annually since 2021. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

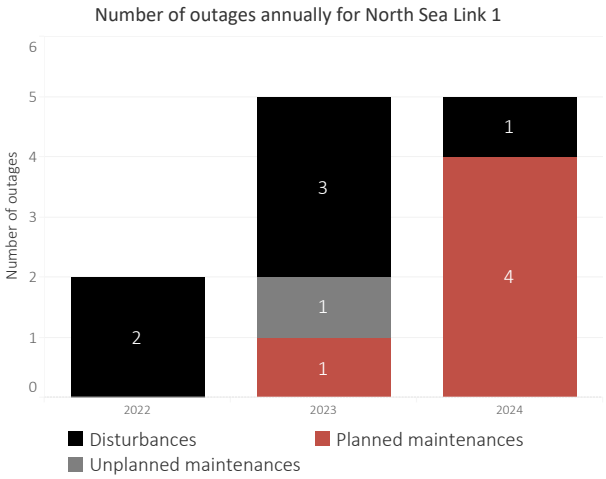

Figure 4.70: The annual number of disturbances, unplanned and planned maintenance outages and other outages for North Sea Link 1 for the years 2021–2024.

4.4.16 North Sea Link 2

Figure 4.71 presents the availability and utilisation of North Sea Link 2 for 2024 and Table 4.19 presents the numerical values behind it. North Sea Link 2 where put into operation 1 October 1, 2021 so this is the second year with data for this link. With a cable length of 720 km the cable is the longest in this publication.

In 2024, North Sea Link 2 had an available technical capacity of 97.9 %. The technical capacity not used was 15.4 %. Totally, 4.9 TWh (73 % of the technical capacity) was transmitted west to Great Britain (NO2→UK) and 0.13 TWh (2.2 % of the technical capacity) was transmitted north to Norway (UK→NO2). During the year there have been two longer disturbance outages for North Sea Link 2 lasting for in total 10 days due to technical problems.

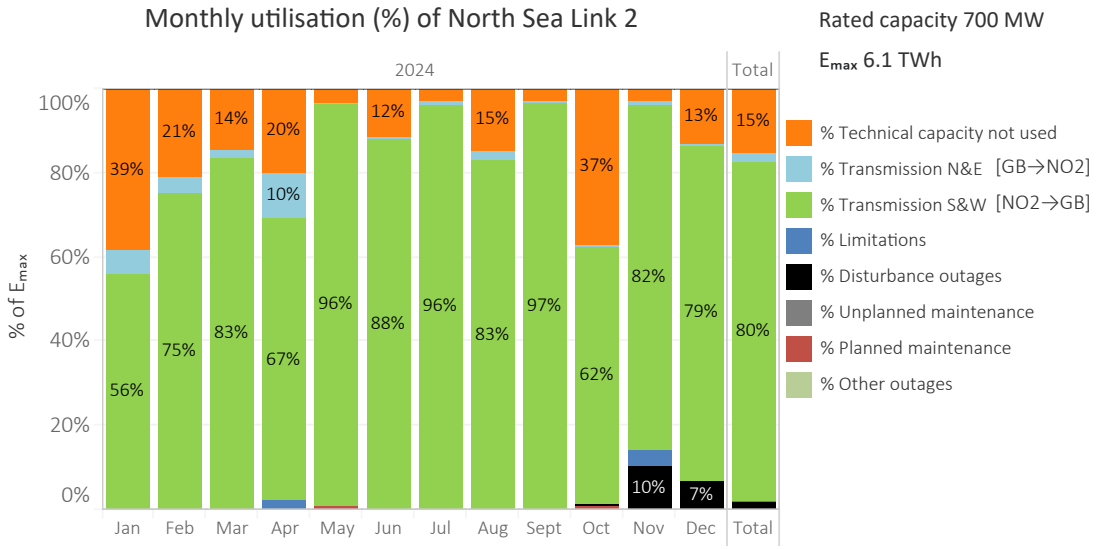

Figure 4.71: Monthly utilisation (%) by category for North Sea Link 2 in 2024.

Table 4.19: Monthly allocation (GWh) of technical capacity (E_{max}) for North Sea Link 2 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of North Sea Link 2 (South & West direction NO2→GB)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	201.3	102.6	74.7	102.1	17.7	58.3	16.1	78.4	15.8	193.0	15.2	68.6	943.6	15.3%
Transmission N&E, GWh	28.0	17.9	12.5	52.2	-	2.3	4.9	11.6	0.5	-	3.6	3.4	136.9	2.2%
Transmission S&W, GWh	291.5	366.7	432.9	339.5	498.9	443.4	499.8	430.8	487.7	322.2	414.0	412.7	4940.2	80.3%
Limitations, GWh	-	-	-	10.2	-	-	-	-	-	-	19.3	-	29.5	0.5%
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	0.7	51.9	36.2	88.8	1.4%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	-	4.2	-	-	-	-	5.6	-	-	9.8	0.2%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	520.8	487.2	520.1	504.0	520.8	504.0	520.8	520.8	504.0	521.5	504.0	520.8	6148.8	100.0%
Losses SW, GWh	10.6	13.6	16.3	12.6	19.3	17.8	19.5	16.4	18.9	12.5	16.7	16.2	190.3	3.1%
Losses NE, GWh	1.1	0.6	0.3	1.7	-	0.1	0.1	0.4	-	-	0.1	0.1	4.6	0.1%

Figure 4.72 presents the annual utilisation of North Sea Link 2 per utilisation and unavailability category for the years 2021–2024.

Figure 4.73 presents the percentage of hours of a year North Sea Link 2 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2022–2024. Figure 4.74 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2022–2024.

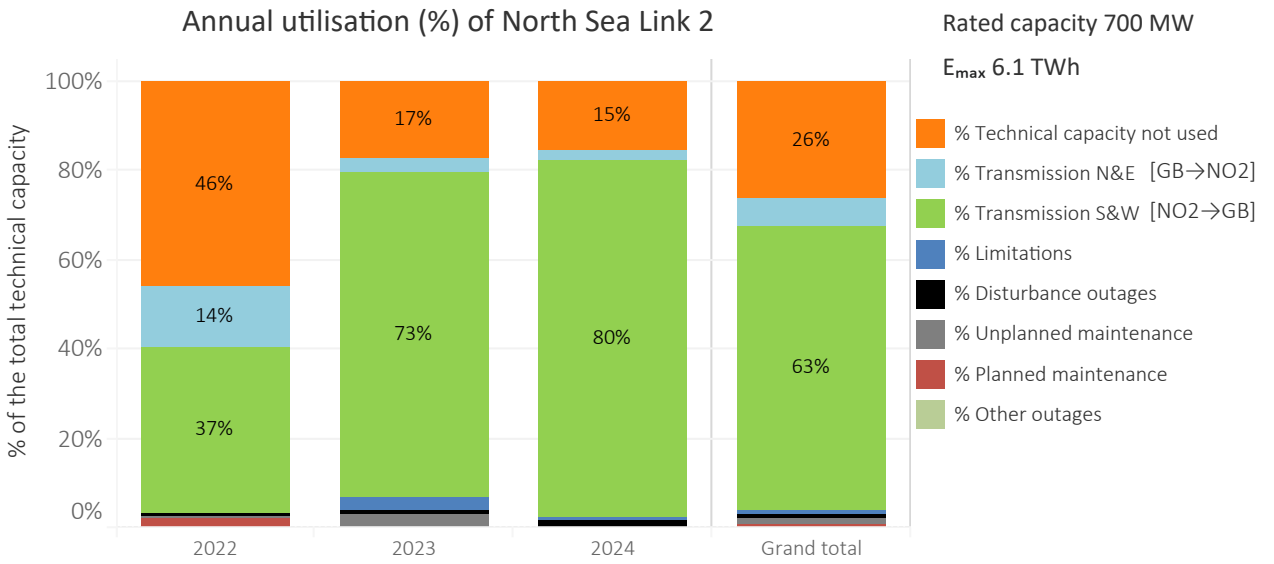

Figure 4.72: Annual utilisation (%) of North Sea Link 2 by category for 2021–2024.

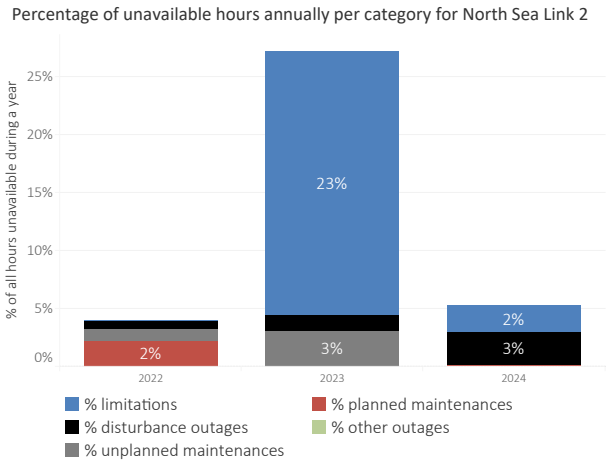

Figure 4.73: Percentage of hours North Sea Link 2 has been affected by either a limitation or an outage annually since 2021. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

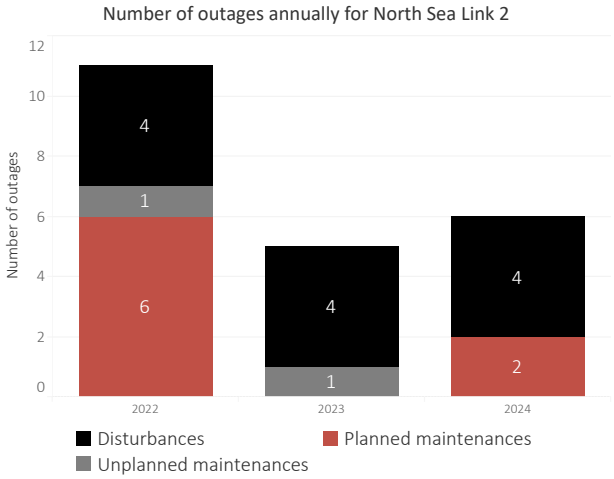

Figure 4.74: The annual number of disturbances, unplanned and planned maintenance outages and other outages for North Sea Link 2 for the years 2021–2024.

4.4.17 Skagerrak 1

Figure 4.75 presents the availability and utilisation of Skagerrak 1 for 2024 and Table 4.20 presents the numerical values behind it. Skagerrak 1 and Skagerrak 2 have been in operation since 1976 and are the oldest HVDC links in operation in the Nordic countries. In Norway, the links are connected to Kristiansand on the southern coast (bidding zone NO2) and in Denmark to Tjele (bidding zone DK1), 15 km east of the town of Viborg in the northern part of Jutland. The transmission capacity is 236 MW at the receiving end.

In 2024, Skagerrak 1 had an available technical capacity of 95 %. The technical capacity not used was 48 %. Totally, 0.9 TWh (41 % of the technical capacity) was transmitted south to Denmark (NO2→DK1) and 0.1 TWh (6 % of the technical capacity) was transmitted north to Norway (DK1→NO2). Annual maintenance for Skagerrak 1 lasted 10 days in April. Additionally, there were four maintenance outages, three minor and one which was necessary maintenance of oil system in the smoothing reactor that lasted four days. Furthermore, there were three minor disturbance outages.

Untill June 2023, Skagerrak 1, 2, 3 and 4 have been limited due to "careful operation" since the Skagerrak 4 cable faults in December 2019. The careful operation of the Skagerrak links has impacted each of the links differently based on the transmission direction and which links are in operation. For example, if all links are available and the transmission goes from Denmark to Norway (i.e., north), Skagerrak 2 is limited to 0 MW and Skagerrak 3 is limited to 200 MW to maintain acceptable electrode current levels.

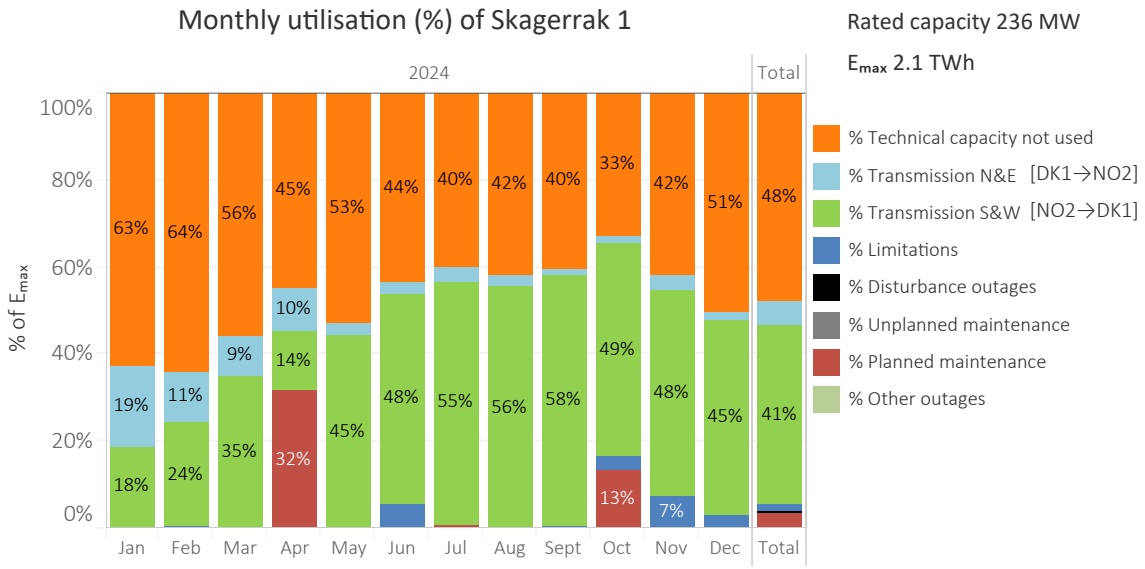

Figure 4.75: Monthly utilisation (%) by category for Skagerrak 1 in 2024.

Table 4.20: Monthly allocation (GWh) of technical capacity (E_{max}) for Skagerrak 1 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Skagerrak 1 (South & West direction NO2→DK1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	111.0	106.5	97.9	76.2	93.1	74.0	70.6	73.8	68.7	57.5	71.2	88.7	989.4	47.7%
Transmission N&E, GWh	32.9	18.8	15.7	17.0	4.2	4.3	6.2	4.2	2.3	3.1	5.6	3.1	117.5	5.7%
Transmission S&W, GWh	32.3	40.2	61.8	23.1	78.3	82.1	97.1	97.6	98.0	85.7	80.9	78.8	855.8	41.2%
Limitations, GWh	-	0.2	-	-	-	9.5	-	-	0.6	6.2	12.2	5.0	33.6	1.6%
Disturbance outages, GWh	0.1	0.2	-	-	-	-	-	-	0.3	-	-	-	0.5	0.0%
Unplanned maintenance., GWh	0.9	-	-	-	-	-	-	-	-	-	-	-	0.9	0.0%
Planned maintenance, GWh	-	-	-	53.6	-	-	1.7	-	-	23.4	-	-	78.6	3.8%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	177.2	165.9	175.3	169.9	175.6	169.9	175.6	175.6	169.9	175.8	169.9	175.6	2076.3	100.0%
Losses SW, GWh	1.7	2.1	3.1	1.2	4.0	4.1	5.0	5.0	5.0	4.4	3.8	3.9	43.3	2.1%
Losses NE, GWh	1.7	1.0	0.8	0.8	0.3	0.3	0.3	0.2	0.1	0.2	0.3	0.2	6.2	0.3%

Figure 4.76 presents the annual utilisation of Skagerrak 1 per utilisation and unavailability category for the years 2015–2024.

Figure 4.77 presents the percentage of hours of a year Skagerrak 1 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.78 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

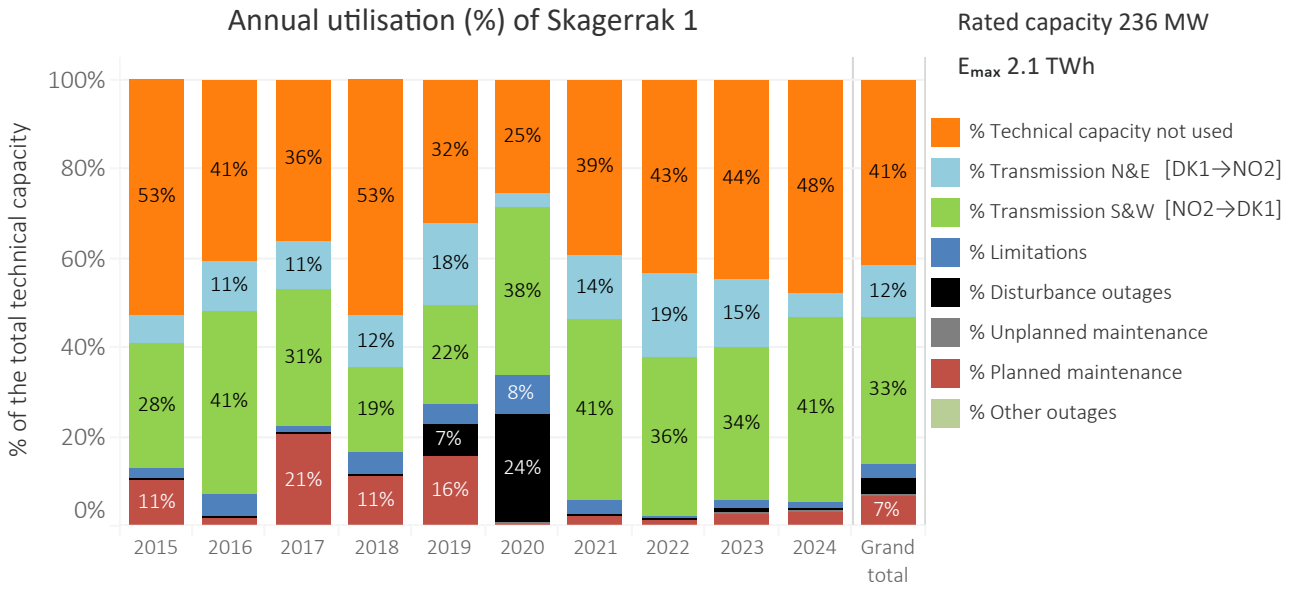

Figure 4.76: Annual utilisation (%) of Skagerrak 1 by category for 2015–2024.

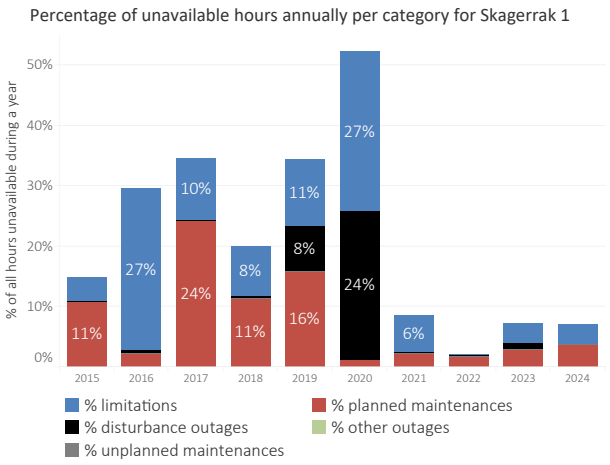

Figure 4.77: Percentage of hours Skagerrak 1 has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

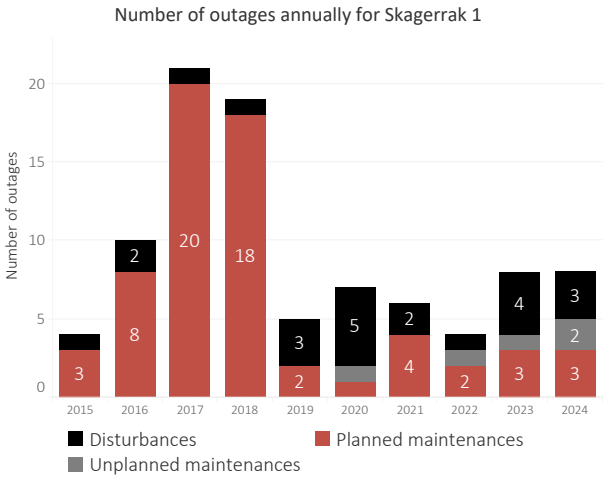

Figure 4.78: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Skagerrak 1 for the years 2015–2024. Skagerrak 1 had no other outages during the years 2015–2024.

4.4.18 Skagerrak 2

Figure 4.79 presents the availability and utilisation of Skagerrak 2 for 2024 and Table 4.21 presents the numerical values behind it. Skagerrak 1 and Skagerrak 2 have been in operation since 1976 and are the oldest HVDC links in operation in the Nordic countries. In Norway, the links are connected to Kristiansand on the southern coast (bidding zone NO2) and in Denmark to Tjele (bidding zone DK1), 15 km east of the town of Viborg in the northern part of Jutland. The transmission capacity of Skagerrak 2 is 236 MW at the receiving end.

In 2024, Skagerrak 2 had an available technical capacity of 93 %. The technical capacity not used was 47 %. Totally, 0.8 TWh (40 % of the technical capacity) was transmitted south to Denmark (NO2→DK1) and 0.1 TWh (6 % of the technical capacity) was transmitted north to Norway (DK1→NO2). Annual maintenance for Skagerrak 2 lasted 10 days in April. Additionally, there were five maintenance outages, three minor, one which was necessary maintenance of oil system in the smoothing reactor that lasted four days, and one where the cable was exposed on the beach that lasted 3 days. Furthermore, there were three minor disturbance outages.

Untill June 2023, Skagerrak 1, 2, 3 and 4 have been limited due to "careful operation" since the Skagerrak 4 cable faults in December 2019. The careful operation of the Skagerrak links has impacted each of the links differently based on the transmission direction and which links are in operation. For example, if all links are available and the transmission goes from Denmark to Norway (i.e., north), Skagerrak 2 is limited to 0 MW and Skagerrak 3 is limited to 200 MW to maintain acceptable electrode current levels.

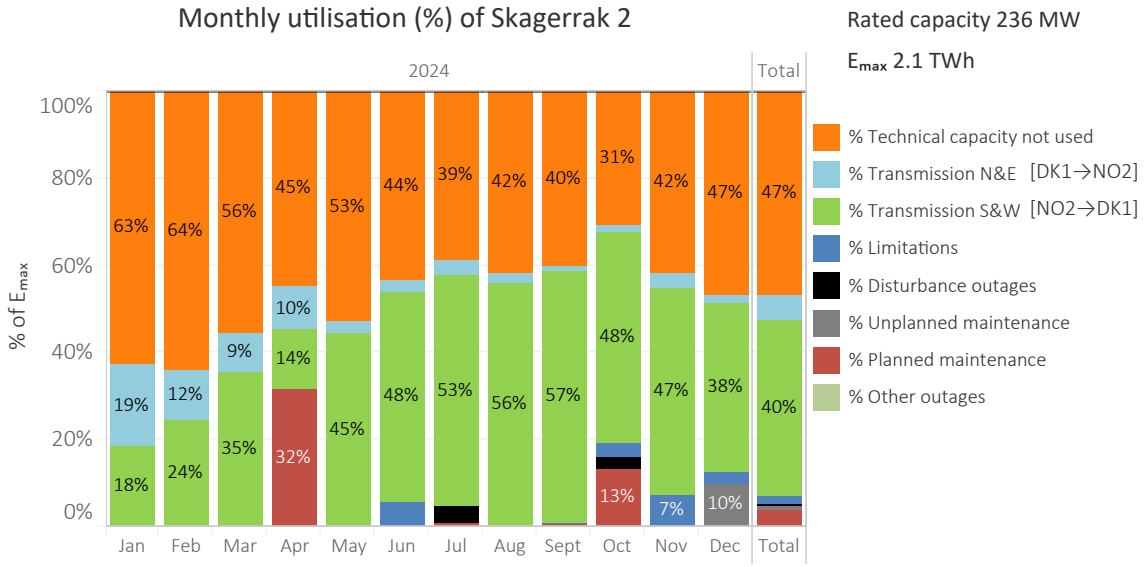

Figure 4.79: Monthly utilisation (%) by category for Skagerrak 2 in 2024.

Table 4.21: Monthly allocation (GWh) of technical capacity (E_{max}) for Skagerrak 2 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Skagerrak 2 (South & West direction NO2→DK1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	111.9	106.4	97.7	76.1	93.0	74.0	68.1	73.2	68.5	54.2	71.3	82.8	977.2	47.0%
Transmission N&E, GWh	33.4	19.3	15.8	17.1	4.2	4.3	6.2	4.3	2.3	2.8	5.6	3.1	118.5	5.7%
Transmission S&W, GWh	32.4	40.4	61.9	23.1	78.3	82.1	92.9	98.2	97.6	84.9	80.6	67.6	839.9	40.4%
Limitations, GWh	-	0.2	-	-	-	9.5	-	-	0.6	6.2	12.4	5.0	33.9	1.6%
Disturbance outages, GWh	-	-	-	-	-	-	6.6	-	-	4.7	-	-	11.4	0.5%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	17.1	17.1	0.8%
Planned maintenance, GWh	-	-	-	53.6	-	-	1.7	-	0.9	23.1	-	-	79.2	3.8%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	177.7	166.3	175.4	169.9	175.6	169.9	175.6	175.6	169.9	175.8	169.9	175.6	2077.2	100.0%
Losses SW, GWh	1.7	2.1	3.1	1.2	4.0	4.0	4.7	4.9	4.9	4.2	3.9	3.4	42.2	2.0%
Losses NE, GWh	1.8	1.1	0.8	0.9	0.3	0.3	0.3	0.3	0.1	0.2	0.3	0.2	6.5	0.3%

Figure 4.80 presents the annual utilisation of Skagerrak 2 per utilisation and unavailability category for the years 2015–2024.

Figure 4.81 presents the percentage of hours of a year Skagerrak 2 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.82 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

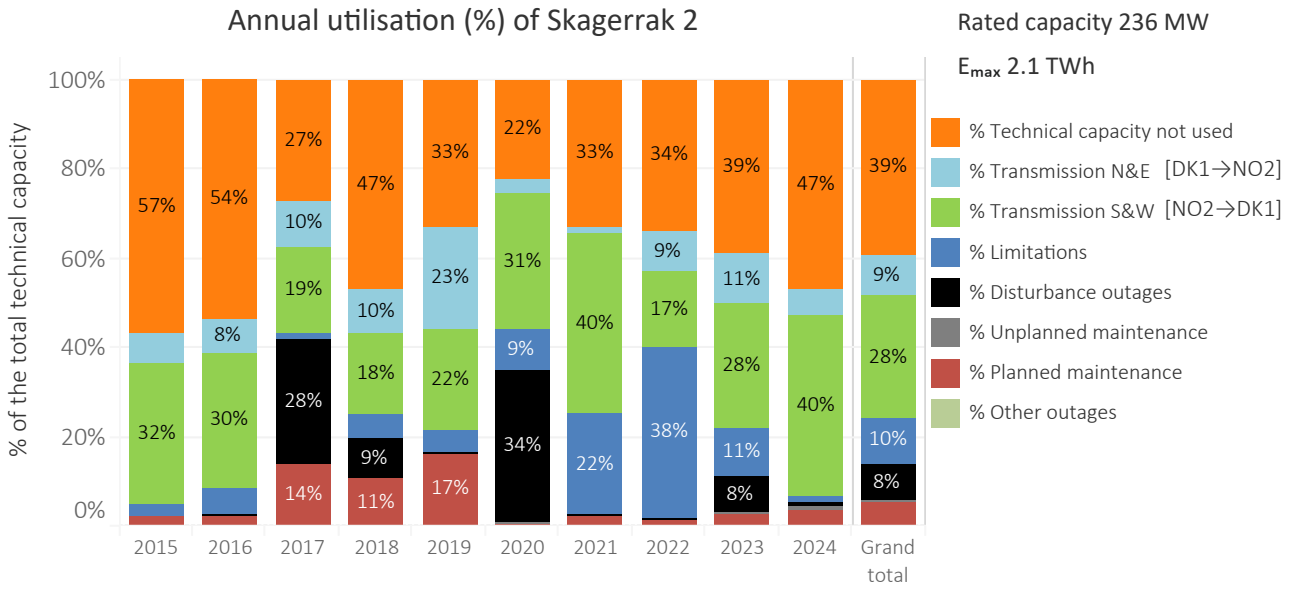

Figure 4.80: Annual utilisation (%) of Skagerrak 2 by category for 2015–2024.

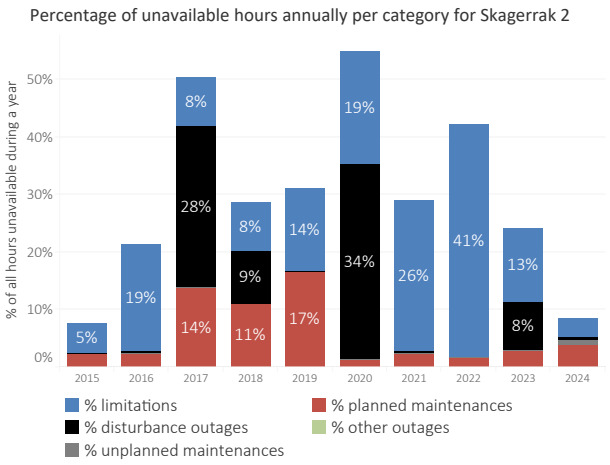

Figure 4.81: Percentage of hours Skagerrak 2 has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

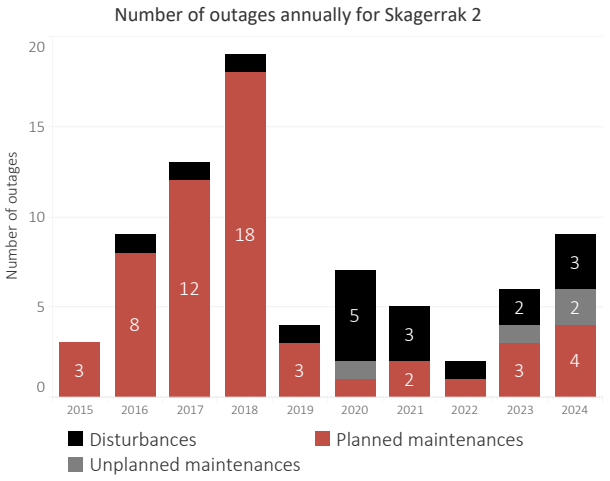

Figure 4.82: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Skagerrak 2 for the years 2015–2024. Skagerrak 2 had no other outages during the years 2015–2024.

4.4.19 Skagerrak 3

Figure 4.83 presents the availability and utilisation of Skagerrak 3 for 2024 and Table 4.22 presents the numerical values behind it. Skagerrak 3 has been in operation since 1993. In Norway, it is connected to Kristiansand (bidding zone NO2) and in Denmark to Tjele (bidding zone DK1). The transmission capacity of Skagerrak 3 is 478 MW at the receiving end.

In 2024, Skagerrak 3 had an available technical capacity of 97 %. The technical capacity not used was 20 %. Totally, 2.6 TWh (63 % of the technical capacity) was transmitted south to Denmark (NO2→DK1) and 0.6 TWh (14 % of the technical capacity) was transmitted north to Norway (DK1→NO2). Annual maintenance for Skagerrak 3 lasted two days in April. Additionally, there were four minor maintenance outages. Furthermore, there were two disturbance outages, one minor and one which was caused by a fault in the transformer cooling system.

Untill June 2023, Skagerrak 1, 2, 3 and 4 have been limited due to "careful operation" since the Skagerrak 4 cable faults in December 2019. The careful operation of the Skagerrak links has impacted each of the links differently based on the transmission direction and which links are in operation. For example, if all links are available and the transmission goes from Denmark to Norway (i.e., north), Skagerrak 2 is limited to 0 MW and Skagerrak 3 is limited to 200 MW to maintain acceptable electrode current levels.

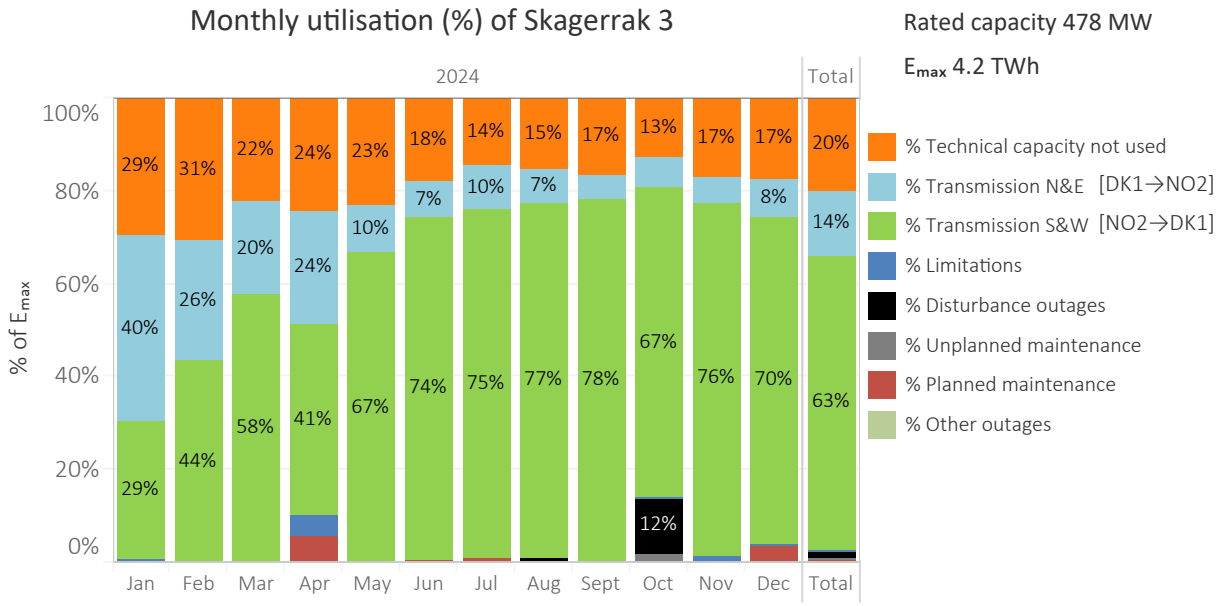

Figure 4.83: Monthly utilisation (%) by category for Skagerrak 3 in 2024.

Table 4.22: Monthly allocation (GWh) of technical capacity (E_{max}) for Skagerrak 3 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Skagerrak 3 (South & West direction NO2→DK1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	104.9	101.8	78.3	83.7	81.8	62.2	51.1	54.7	57.3	46.4	58.8	61.8	842.9	20.1%
Transmission N&E, GWh	142.8	85.6	72.4	83.4	37.1	25.8	34.0	26.3	17.8	21.7	19.4	29.0	595.4	14.2%
Transmission S&W, GWh	104.3	145.2	204.8	142.4	237.1	255.3	267.8	272.3	269.1	237.5	261.0	250.8	2647.8	63.0%
Limitations, GWh	3.7	0.4	-	16.1	-	-	-	-	-	0.3	5.0	0.1	25.5	0.6%
Disturbance outages, GWh	-	-	-	-	-	-	-	2.5	-	44.4	-	-	46.9	1.1%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	5.9	-	-	5.9	0.1%
Planned maintenance, GWh	-	-	-	18.6	-	1.1	3.1	-	-	-	-	14.1	36.9	0.9%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	355.7	333.0	355.5	344.3	356.0	344.4	356.0	355.9	344.3	356.1	344.2	355.8	4201.3	100.0%
Losses SW, GWh	2.5	3.5	5.1	3.4	6.0	6.6	7.0	7.1	7.0	6.0	6.6	6.2	67.0	1.6%
Losses NE, GWh	3.9	2.3	2.0	2.4	1.0	0.7	0.9	0.7	0.5	0.6	0.6	0.8	16.4	0.4%

Figure 4.84 presents the annual utilisation of Skagerrak 3 per utilisation and unavailability category for the years 2015–2024.

Figure 4.85 presents the percentage of hours of a year Skagerrak 3 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.86 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

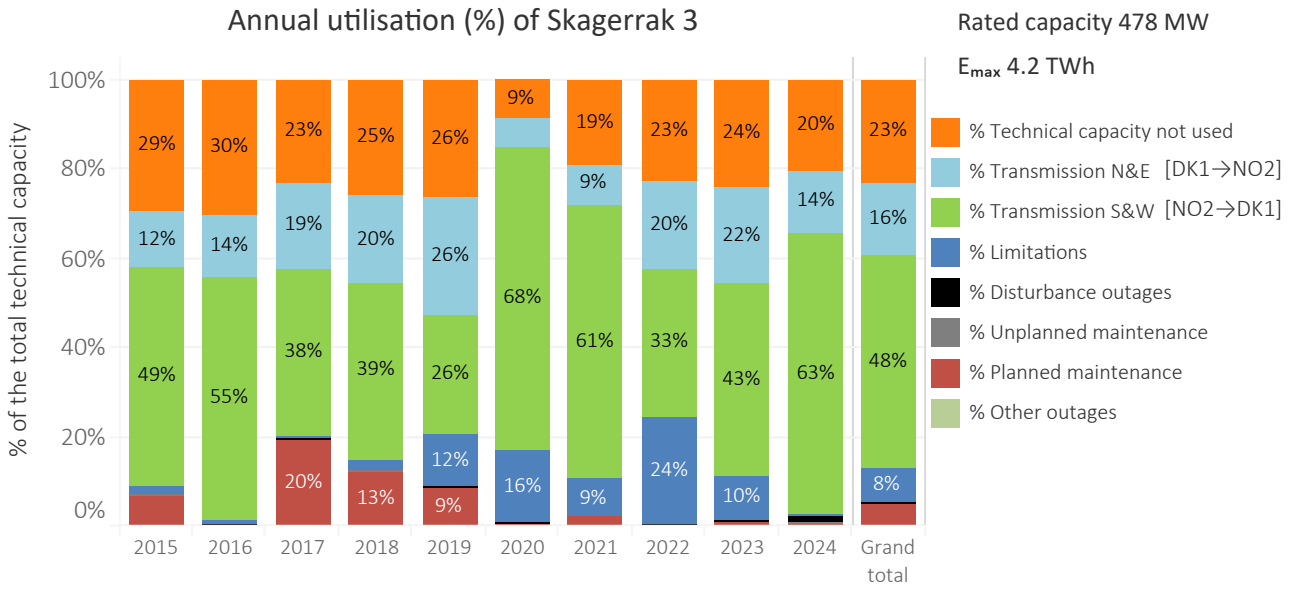

Figure 4.84: Annual utilisation (%) of Skagerrak 3 by category for 2015–2024.

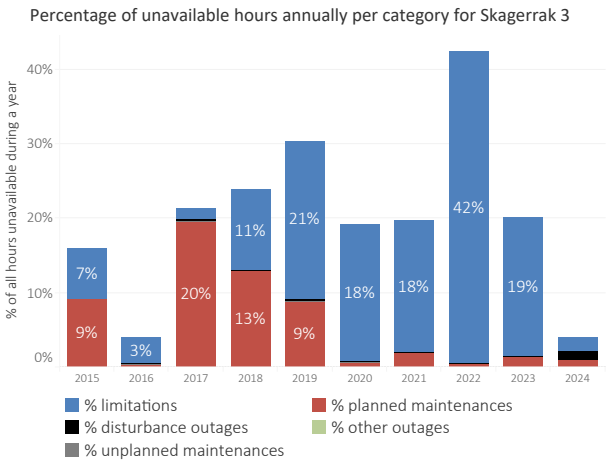

Figure 4.85: Percentage of hours Skagerrak 3 has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

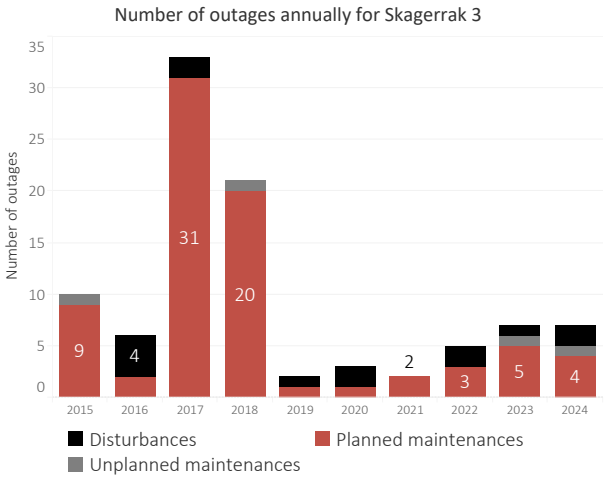

Figure 4.86: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Skagerrak 3 for the years 2015–2024.

4.4.20 Skagerrak 4

Figure 4.87 presents the availability and utilisation of Skagerrak 4 for 2024 and Table 4.23 presents the numerical values behind it. Skagerrak 4 has been in commercial operation since 29 December 2014. In Norway, it is connected to Kristiansand (bidding zone NO2) and in Denmark to Tjele (bidding zone DK1). The transmission capacity is 682 MW at the receiving end.

In 2024, Skagerrak 4 had an available technical capacity of 98 %. The technical capacity not used was 22 %. Totally, 3.7 TWh (62 % of the technical capacity) was transmitted south to Denmark (NO2→DK1) and 0.8 TWh (14 % of the technical capacity) was transmitted north to Norway (DK1→NO2). Annual maintenance for Skagerrak 4 lasted four days in April. Additionally, there were one unplanned maintenance outages due to loss of SF6 in a circuit breaker. Furthermore, there were two minor disturbance outages.

Untill June 2023, Skagerrak 1, 2, 3 and 4 have been limited due to "careful operation" since the Skagerrak 4 cable faults in December 2019. The careful operation of the Skagerrak links has impacted each of the links differently based on the transmission direction and which links are in operation. For example, if all links are available and the transmission goes from Denmark to Norway (i.e., north), Skagerrak 2 is limited to 0 MW and Skagerrak 3 is limited to 200 MW to maintain acceptable electrode current levels.

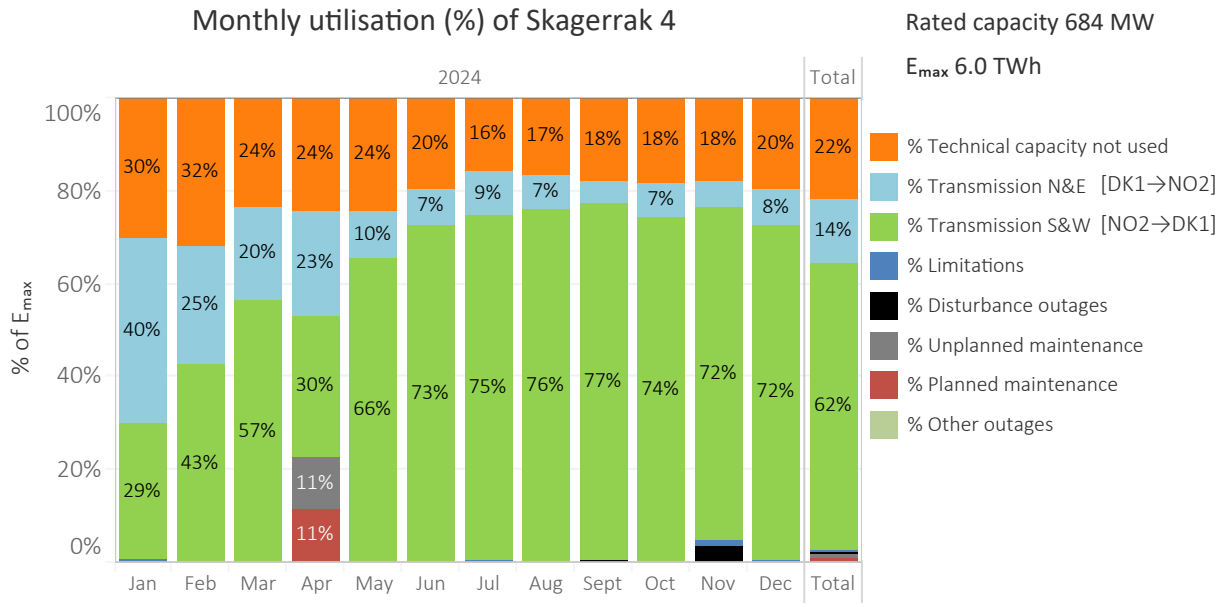

Figure 4.87: Monthly utilisation (%) by category for Skagerrak 4 in 2024.

Table 4.23: Monthly allocation (GWh) of technical capacity (E_{max}) for Skagerrak 4 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Skagerrak 4 (South & West direction NO2→DK1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	154.7	152.2	119.8	120.1	123.7	97.7	80.6	84.4	88.2	93.4	88.7	99.3	1302.8	21.7%
Transmission N&E, GWh	201.8	119.9	101.3	112.0	51.8	36.1	47.2	36.6	24.0	37.1	27.2	40.4	835.3	13.9%
Transmission S&W, GWh	147.3	203.3	287.2	149.3	333.7	358.7	380.1	388.2	378.7	378.7	353.6	368.1	3726.8	62.0%
Limitations, GWh	5.3	0.6	-	-	-	-	1.2	-	-	0.4	5.6	1.2	14.3	0.2%
Disturbance outages, GWh	-	-	-	-	-	-	-	-	1.5	-	17.4	-	18.9	0.3%
Unplanned maintenance., GWh	-	-	-	54.5	-	-	-	-	-	-	-	-	54.5	0.9%
Planned maintenance, GWh	-	-	-	56.6	-	-	-	-	-	-	-	-	56.6	0.9%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	509.1	476.1	508.2	492.5	509.2	492.5	509.1	509.2	492.5	509.6	492.5	508.9	6009.3	100.0%
Losses SW, GWh	2.9	4.0	5.7	2.9	6.6	7.2	7.7	7.8	7.7	7.8	7.1	7.4	74.8	1.2%
Losses NE, GWh	5.0	2.9	2.5	2.9	1.3	0.9	1.2	0.9	0.6	0.9	0.7	1.0	20.7	0.3%

Figure 4.88 presents the annual utilisation of Skagerrak 4 per utilisation and unavailability category for the years 2015–2024.

Figure 4.89 presents the percentage of hours of a year Skagerrak 4 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.90 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

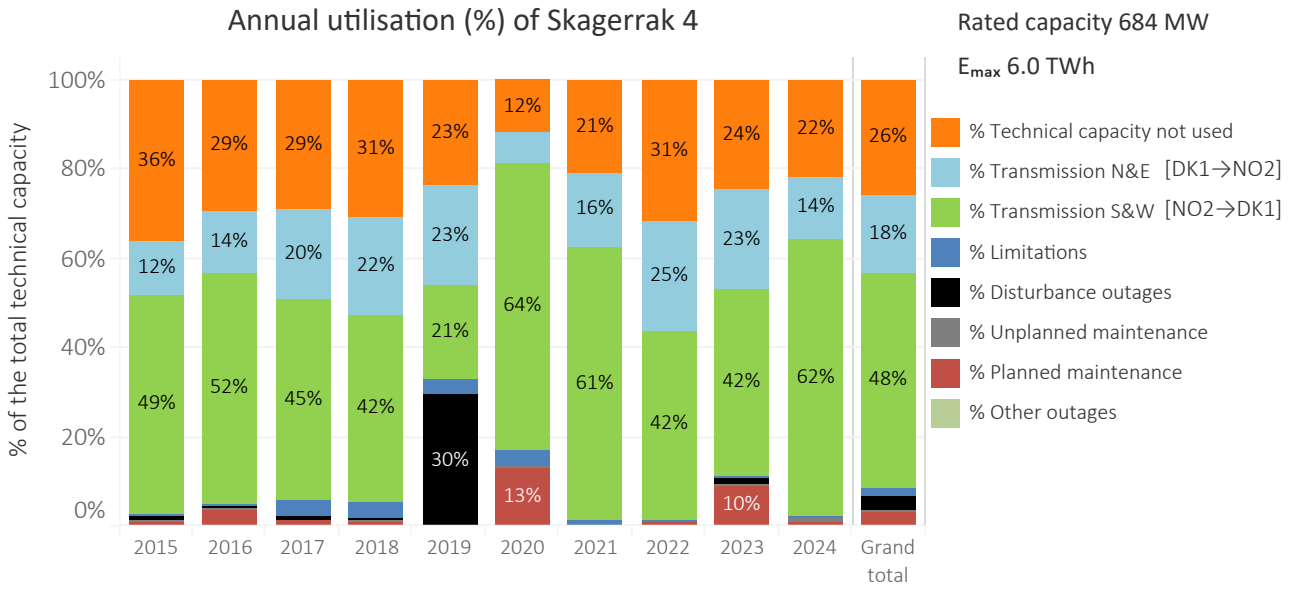

Figure 4.88: Annual utilisation (%) of Skagerrak 4 by category for 2015–2024.

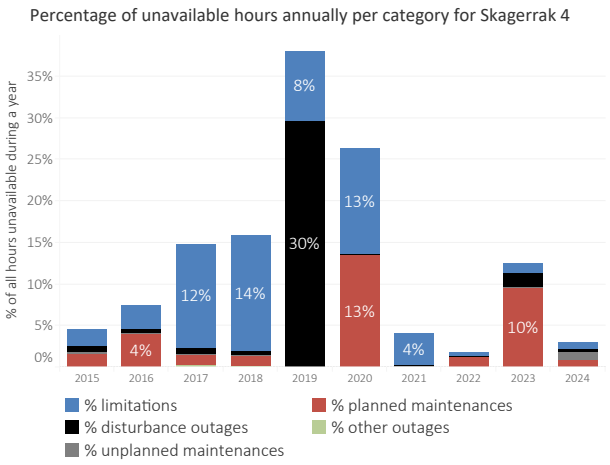

Figure 4.89: Percentage of hours Skagerrak 4 has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

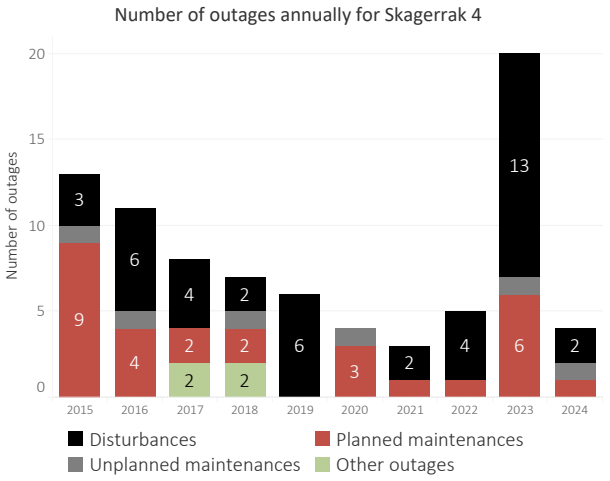

Figure 4.90: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Skagerrak 4 for the years 2015–2024.

4.4.21 South West Link 1

Figure 4.91 presents the availability and utilisation of South West Link 1 for 2024 and Table 4.24 presents the numerical values behind it. South West link 1 is connected between Barkeryd (SE3) and Hurva (SE4) in Sweden, and runs next to South West link 2. The parallel South West link 1 and 2 were commissioned on 2021 and have each a transmission capacity of 600 MW (1200 MW in total).

In 2024 the South West link 1 had an available technical capacity of 91 %. Of this, roughly 27 % was technical capacity not used. Several disturbance outages took place during the year, all within the DC converter and yard area. The longest disturbance outage lasted approximately ten days in October and likely occurred due to an earth fault, with some required repairs as a consequence. The annual maintenance for South West Link 1 lasted for approximately four days, between the 5th and the 9th of May. Additionally, many maintenance outages, some planned and some unplanned, also took place during the year. These outages consisted of corrective maintenance and testing outages to verify function of various station components. The main areas covered were control and protection, DC converter and yard and converter transformer maintenance.

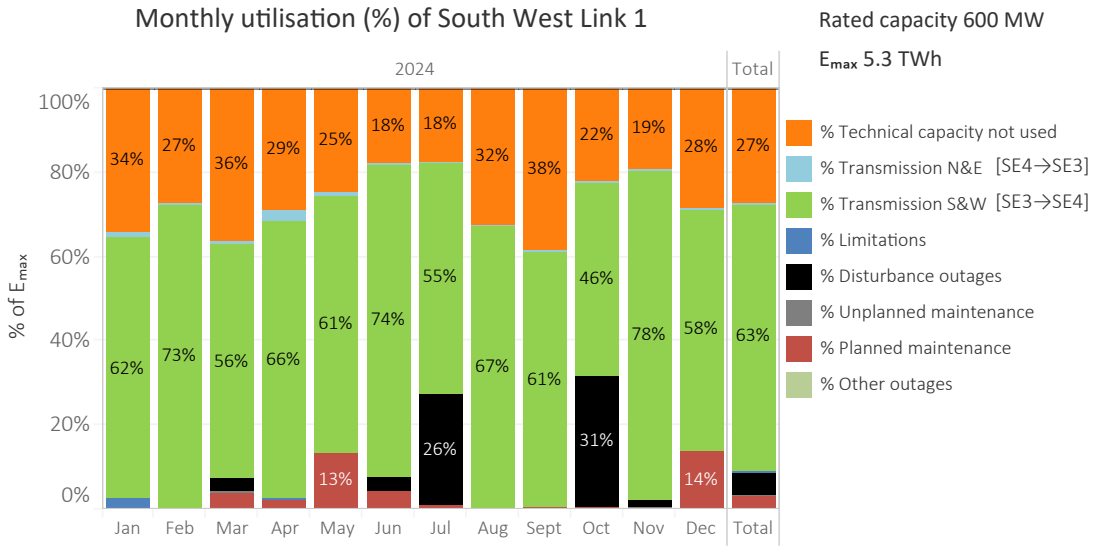

Figure 4.91: Monthly utilisation (%) by category for South West Link 1 in 2024.

Table 4.24: Monthly allocation (GWh) of technical capacity (E_{max}) for South West Link 1 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of South West Link 1 (South & West direction SE3→SE4)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	153.8	114.3	161.9	126.7	112.0	77.7	79.1	145.6	165.7	100.1	84.5	127.6	1448.9	27.4%
Transmission N&E, GWh	4.5	0.1	4.3	11.3	3.6	0.1	0.1	0.1	0.1	0.1	-	0.1	24.3	0.5%
Transmission S&W, GWh	279.0	305.2	248.3	285.3	273.5	323.1	246.4	302.4	266.1	205.9	341.0	258.2	3334.4	63.0%
Limitations, GWh	10.6	-	-	1.0	-	-	-	-	-	-	-	-	11.6	0.2%
Disturbance outages, GWh	-	-	13.4	-	-	15.2	118.5	-	-	139.7	8.3	-	295.1	5.6%
Unplanned maintenance., GWh	-	-	2.0	-	-	-	-	-	-	-	1.1	-	3.1	0.1%
Planned maintenance, GWh	0.1	-	17.0	9.6	59.7	18.9	4.1	-	1.1	1.5	-	61.9	173.9	3.3%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	447.9	419.5	446.9	433.9	448.8	435.0	448.1	448.1	433.0	447.5	434.9	447.7	5291.3	100.0%
Losses SW, GWh	6.7	7.4	5.8	7.0	7.0	8.2	6.1	6.9	5.9	4.6	8.2	5.8	79.7	1.5%
Losses NE, GWh	0.2	0.1	0.2	0.4	0.2	0.1	0.1	0.1	0.1	0.1	-	0.1	1.7	0.0%

Figure 4.92 presents the annual utilisation of South west link 1 per utilisation and unavailability category for the years 2021–2024.

Figure 4.93 presents the percentage of hours of a year South west link 1 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2022–2024. Figure 4.94 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2022–2024.

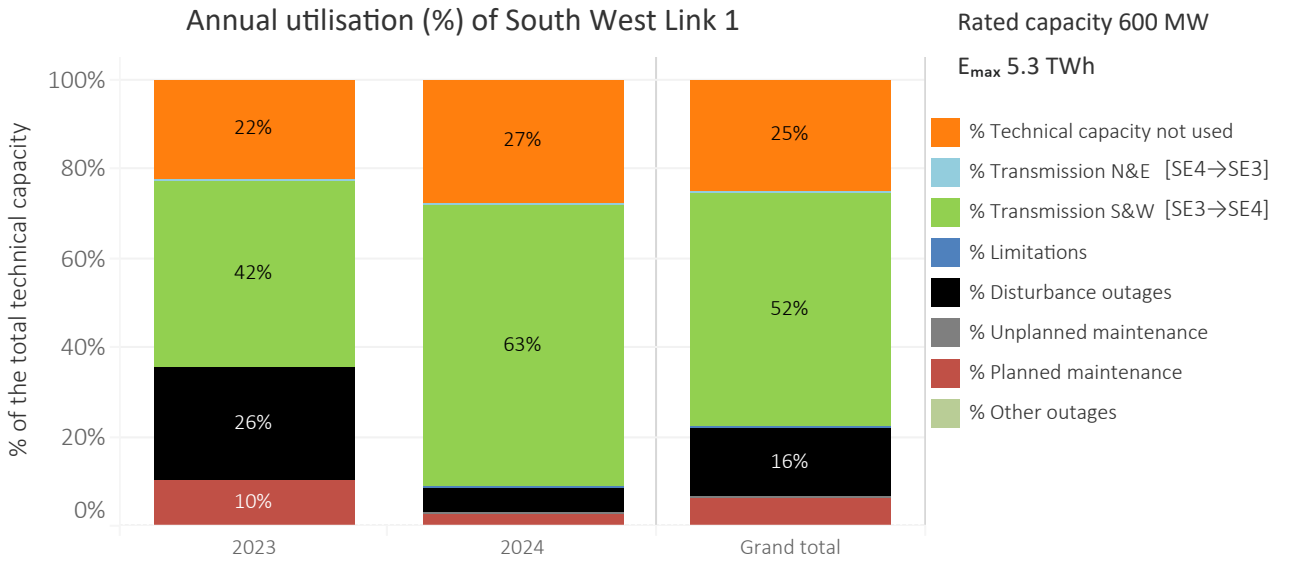

Figure 4.92: Annual utilisation (%) of South west link 1 by category for 2021–2024.

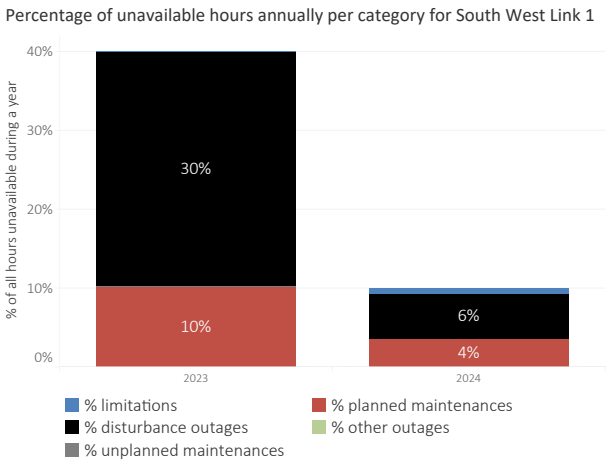

Figure 4.93: Percentage of hours South west link 1 has been affected by either a limitation or an outage annually since 2021. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

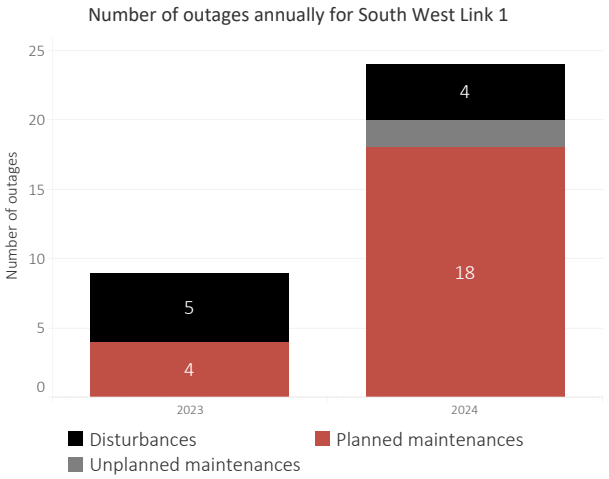

Figure 4.94: The annual number of disturbances, unplanned and planned maintenance outages and other outages for South west link 1 for the years 2021–2024.

4.4.22 South West Link 2

Figure 4.95 presents the availability and utilisation of South West Link 2 for 2024 and Table 4.25 presents the numerical values behind it. South West link 2 is connected between Barkeryd (SE3) and Hurva (SE4) in Sweden, and runs next to South West link 1. The parallel South West link 2 and 2 were commissioned on 2021 and have each a transmission capacity of 600 MW (1200 MW in total).

The South West link 2 had an available technical capacity of 95 % in 2024, with the technical capacity not used being 28 %. There were no disturbance outages during the year. The annual maintenance for South West Link 2 took place between the 11th and the 18th of May. There were also many maintenance outages for South West link 2 due to corrective maintenance and testing. The main areas covered were control and protection, DC converter and yard and converter transformer maintenance.

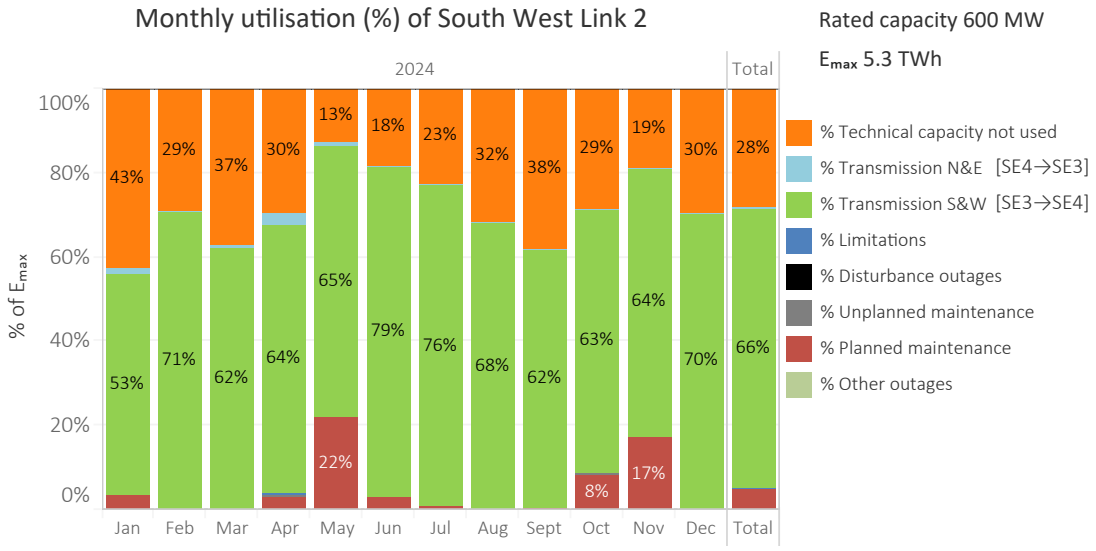

Figure 4.95: Monthly utilisation (%) by category for South West Link 2 in 2024.

Table 4.25: Monthly allocation (GWh) of technical capacity (E_{max}) for South West Link 2 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of South West Link 2 (South & West direction SE3→SE4)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	192.5	121.7	166.6	128.9	57.5	79.7	102.9	140.8	164.1	128.6	82.7	133.4	1499.5	28.3%
Transmission N&E, GWh	4.2	0.1	3.0	11.3	3.5	0.1	0.1	0.1	0.1	0.1	-	0.1	22.7	0.4%
Transmission S&W, GWh	235.5	298.7	278.3	276.8	291.3	343.7	343.0	306.0	266.4	281.4	278.4	316.4	3515.9	66.3%
Limitations, GWh	-	-	-	2.5	-	-	-	-	-	-	-	-	2.5	0.0%
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	
Unplanned maintenance., GWh	-	-	-	0.3	-	-	-	-	-	1.4	-	-	1.7	0.0%
Planned maintenance, GWh	16.2	-	-	14.8	97.8	13.2	4.2	-	1.6	37.1	74.7	-	259.6	4.9%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	448.5	420.5	447.8	434.6	450.2	436.7	450.2	446.9	432.3	448.6	435.8	449.8	5301.8	100.0%
Losses SW, GWh	5.8	7.3	6.6	6.8	7.5	9.0	8.9	7.5	6.4	6.4	6.8	7.6	86.7	1.6%
Losses NE, GWh	0.3	0.1	0.2	0.4	0.1	0.1	0.1	0.1	0.1	0.1	-	0.1	1.8	0.0%

Figure 4.96 presents the annual utilisation of South west link 2 per utilisation and unavailability category for the years 2021–2024.

Figure 4.97 presents the percentage of hours of a year South west link 2 has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2022–2024. Figure 4.98 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2022–2024.

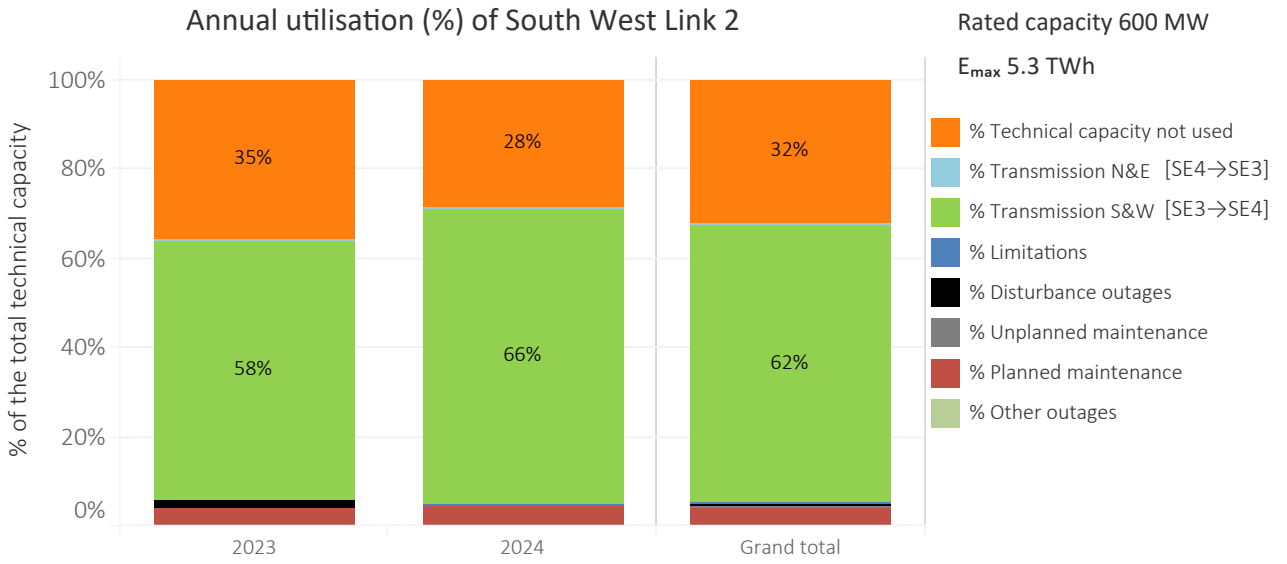

Figure 4.96: Annual utilisation (%) of South west link 2 by category for 2021–2024.

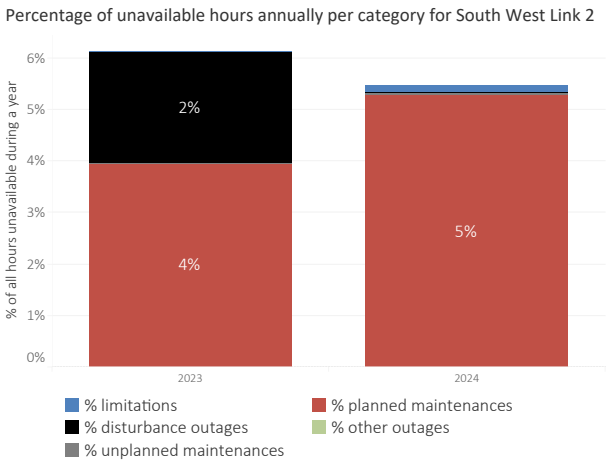

Figure 4.97: Percentage of hours South west link 2 has been affected by either a limitation or an outage annually since 2021. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

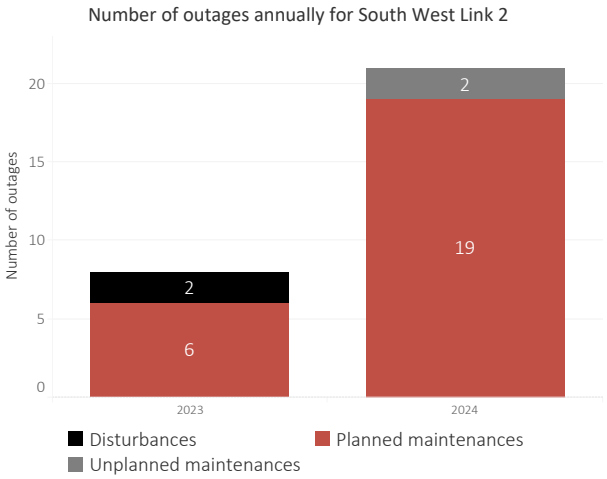

Figure 4.98: The annual number of disturbances, unplanned and planned maintenance outages and other outages for South west link 2 for the years 2021–2024.

4.4.23 Storebaelt

Figure 4.99 presents the availability and utilisation of Storebaelt for 2024 and Table 4.26 presents the numerical values behind it. Storebaelt has been in operation since 2010. It connects the western part of the Danish system, which belongs to the Continental European synchronous system (Jutland and the island of Fynen), with the eastern part, belonging to the Nordic synchronous system (Zealand). The link is connected to Fraugde on Fynen (bidding zone DK1) and to Herslev on Zealand (bidding zone DK2). The transmission capacity is 600 MW.

In 2024, Storebaelt had an available technical capacity of 99 %. The technical capacity not used was 51 %. Totally, 1.3 TWh (24 % of the technical capacity) was transmitted east to Zealand (DK1→DK2) and 1.3 TWh (24 % of the technical capacity) was transmitted west to Jutland (DK2→DK1).

Annual maintenance for Storebaelt lasted six days in August. Additionally, there were two minor maintenance outages. Furthermore, there were two minor disturbances, which both were due to other maintenance work in the substations.

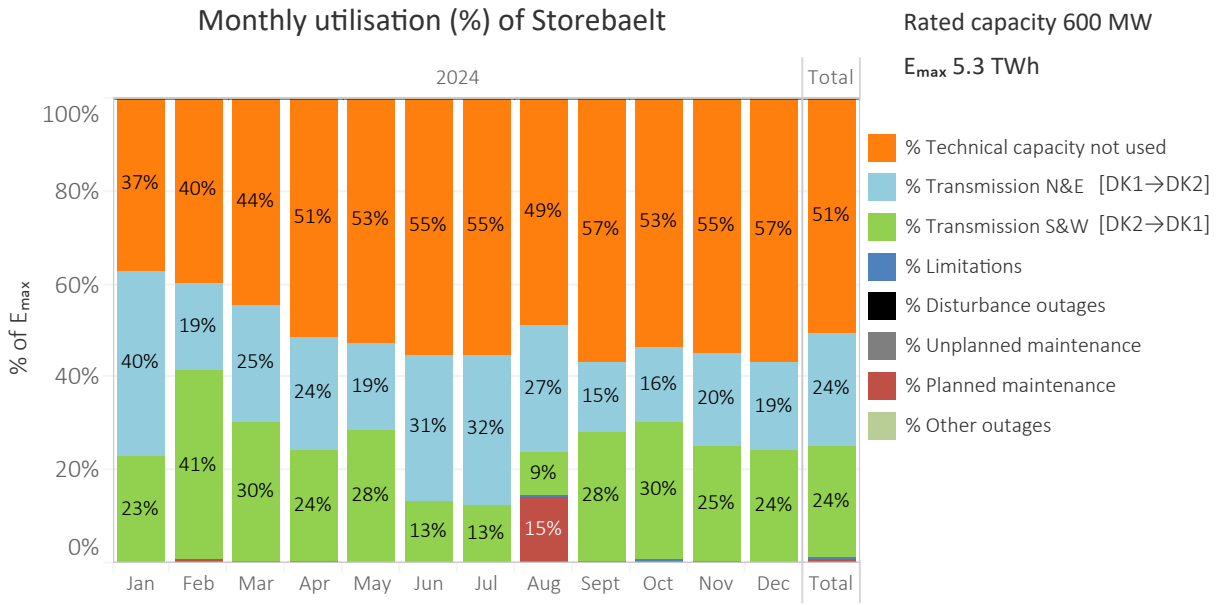

Figure 4.99: Monthly utilisation (%) by category for Storebaelt in 2024.

Table 4.26: Monthly allocation (GWh) of technical capacity (E_{max}) for Storebaelt in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Storebaelt (South & West direction DK2→DK1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	166.8	166.2	198.0	222.3	235.0	238.5	246.4	216.8	245.6	238.4	235.9	254.6	2664.4	50.6%
Transmission N&E, GWh	177.0	77.7	112.9	104.4	84.4	135.6	143.8	122.4	64.5	73.6	86.9	83.9	1267.2	24.0%
Transmission S&W, GWh	102.6	170.8	133.8	103.5	126.4	57.8	56.1	41.3	120.8	132.0	108.3	107.9	1261.5	23.9%
Limitations, GWh	-	-	-	1.7	0.6	-	-	1.1	0.5	2.9	0.9	-	7.8	0.1%
Disturbance outages, GWh	-	-	-	-	-	-	0.1	-	0.6	-	-	-	0.7	0.0%
Unplanned maintenance., GWh	-	-	1.2	-	-	-	-	-	-	-	-	-	1.2	0.0%
Planned maintenance, GWh	-	2.9	-	-	-	-	-	64.7	-	-	-	-	67.7	1.3%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	446.4	417.6	445.8	432.0	446.4	432.0	446.4	446.4	432.0	447.0	432.0	446.4	5270.4	100.0%
Losses SW, GWh	1.6	2.7	2.1	1.6	2.0	0.9	0.9	0.7	2.0	2.0	1.7	1.6	19.8	0.4%
Losses NE, GWh	2.9	1.2	1.8	1.7	1.4	2.2	2.3	2.0	1.1	1.2	1.4	1.4	20.6	0.4%

Figure 4.100 presents the annual utilisation of Storebaelt per utilisation and unavailability category for the years 2015–2024.

Figure 4.101 presents the percentage of hours of a year Storebaelt has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.102 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

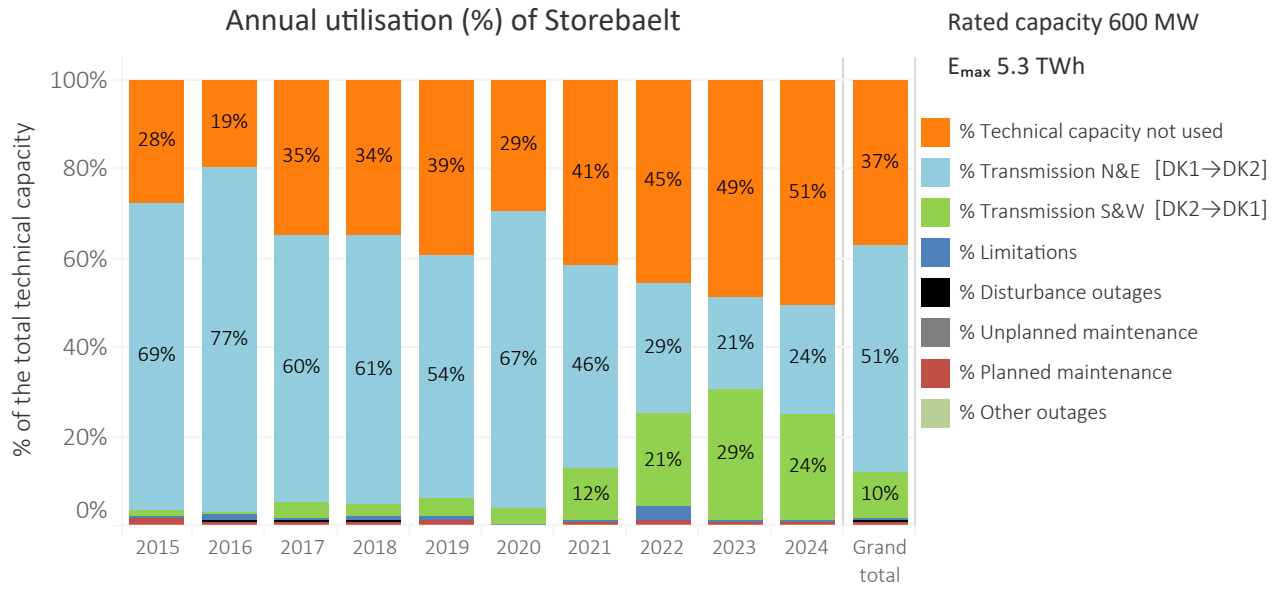

Figure 4.100: Annual utilisation (%) of Storebaelt by category for 2015–2024.

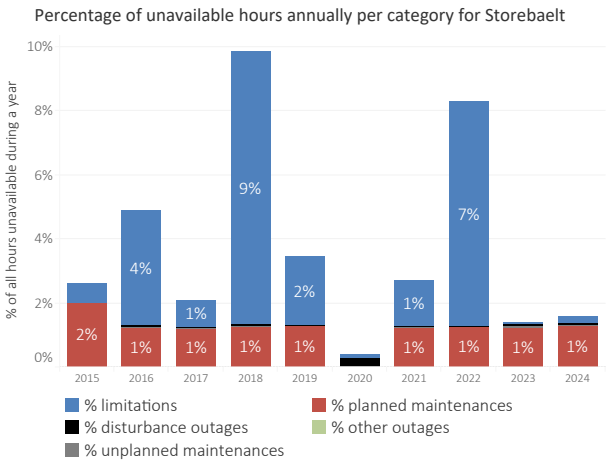

Figure 4.101: Percentage of hours Storebaelt has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

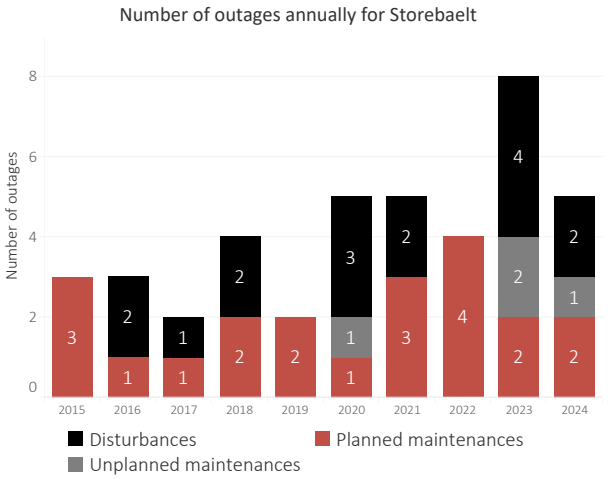

Figure 4.102: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Storebaelt for the years 2015–2024. Storebaelt had no other outages during the years 2015–2024.

4.4.24 SwePol

Figure 4.103 presents the availability and utilisation of SwePol for 2024 and Table 4.27 presents the numerical values behind it. SwePol Link has been in operation since 2000 and it connects the Swedish and Polish transmission grids. In south-eastern Sweden (bidding zone SE4) it is connected to Stärnö and in Poland (bidding zone PL) to Slupsk. The transmission capacity is 600 MW.

The SwePol link had an available technical capacity of 79 % in 2024. SwePol had a total of ten disturbance outages during the year, most due to technical equipment and specifically control and protection related faults. Another noteworthy disturbance originated in the external grid on the Polish side and was likely caused by a storm.

The annual maintenance for SwePol lasted between August 20th until October 24th and included replacement of system control componentshence the longer than usual outage time. Many smaller maintenance outages occurred during the year, often during low load periods. The exact cause of these outages is not well documented and at times also take place in the external AC grid.

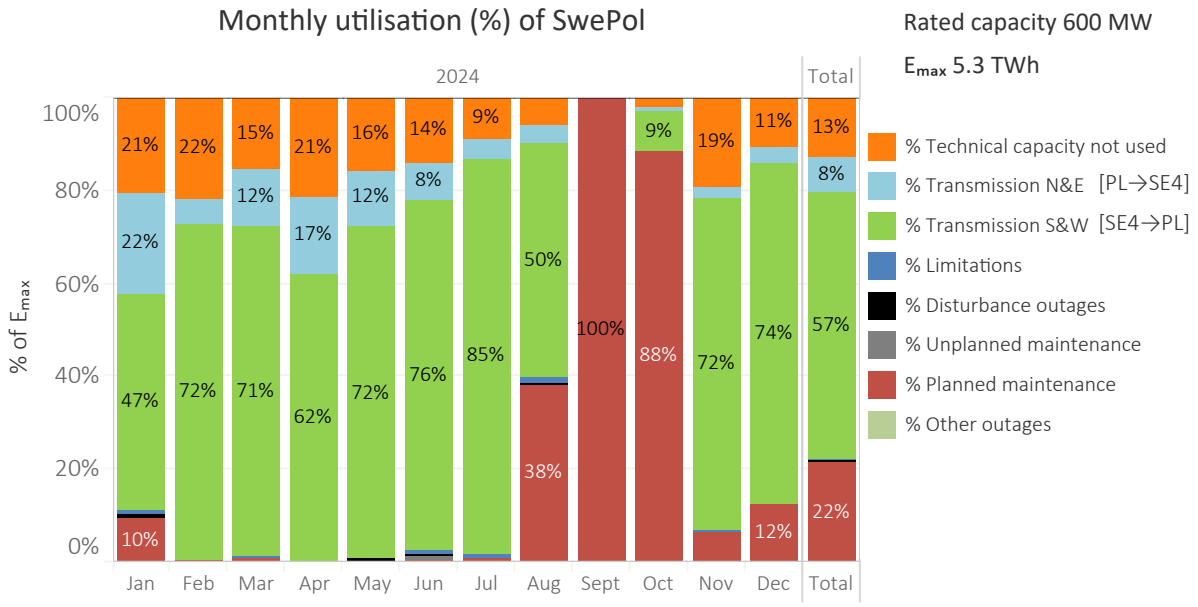

Figure 4.103: Monthly utilisation (%) by category for SwePol in 2024.

Table 4.27: Monthly allocation (GWh) of technical capacity (E_{max}) for SwePol in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of SwePol (South & West direction SE4→PL)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	92.7	90.3	69.1	91.9	71.1	60.2	39.4	25.8	-	8.9	83.7	48.2	681.4	12.9%
Transmission N&E, GWh	97.1	23.7	54.3	71.9	52.3	35.0	20.4	17.4	-	4.2	9.7	14.5	400.4	7.6%
Transmission S&W, GWh	208.2	301.3	316.3	268.9	320.6	326.9	378.3	225.4	-	38.6	309.3	328.4	3022.0	57.3%
Limitations, GWh	3.1	-	0.1	-	-	2.0	4.9	5.3	-	-	1.4	-	16.9	0.3%
Disturbance outages, GWh	3.9	-	1.2	-	2.3	1.0	-	1.2	-	-	-	-	9.6	0.2%
Unplanned maintenance., GWh	-	-	-	-	0.5	4.8	-	2.4	-	-	-	-	7.7	0.1%
Planned maintenance, GWh	42.6	2.4	5.4	-	-	2.5	3.6	169.1	432.0	395.4	28.0	55.4	1136.3	21.5%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	447.6	417.7	446.4	432.7	446.9	432.3	446.7	446.6	432.0	447.1	432.1	446.5	5274.4	100.0%
Losses SW, GWh	5.8	8.5	9.0	7.5	9.2	9.3	10.9	6.5	-	1.1	8.6	9.2	85.8	1.6%
Losses NE, GWh	3.0	0.7	1.7	2.1	1.5	1.0	0.6	0.5	-	0.1	0.3	0.4	11.9	0.2%

Figure 4.104 presents the annual utilisation of SwePol per utilisation and unavailability category for the years 2015–2024.

Figure 4.105 presents the percentage of hours of a year SwePol has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2015–2024. Figure 4.106 presents the annual number of disturbance outages, unplanned and planned maintenances and other outages during the years 2015–2024.

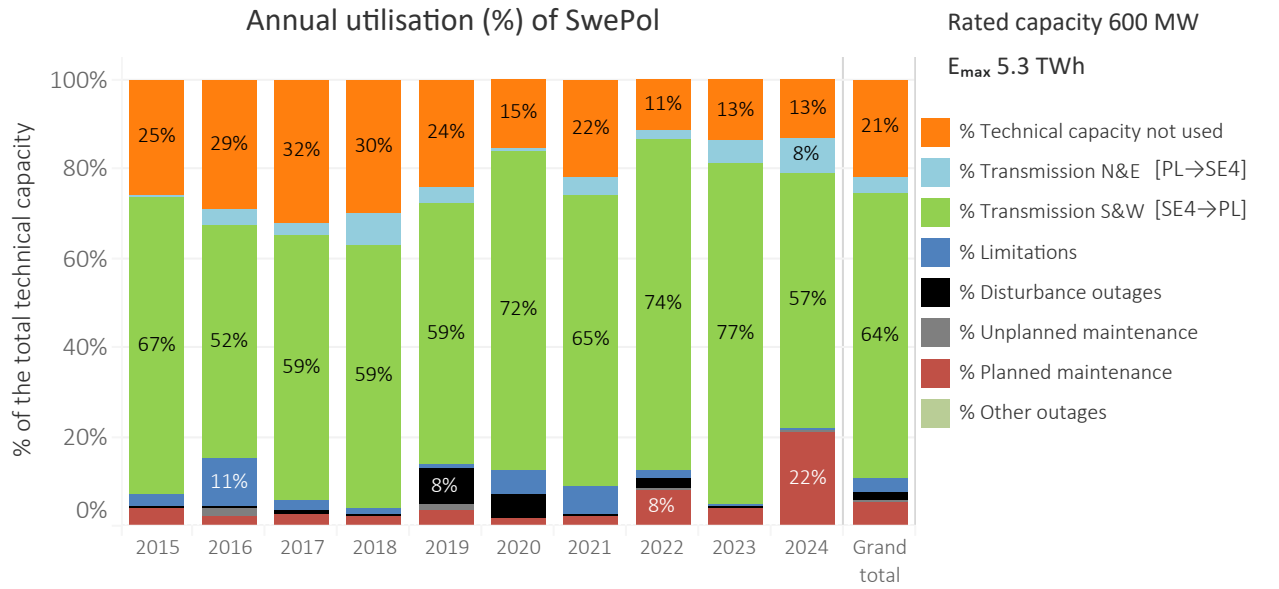

Figure 4.104: Annual utilisation (%) of SwePol by category for 2015–2024.

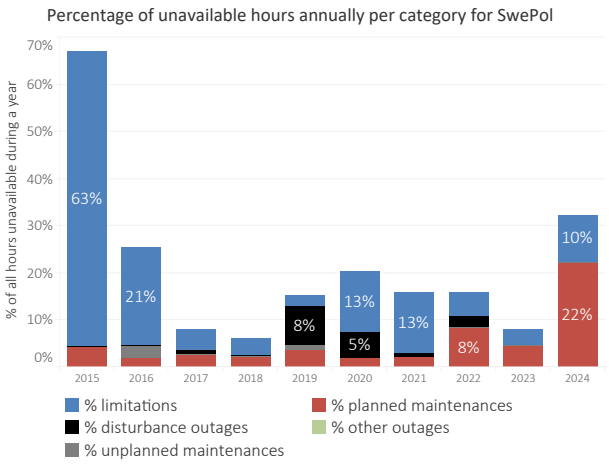

Figure 4.105: Percentage of hours SwePol has been affected by either a limitation or an outage annually since 2015. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. Any single hour can be affected by both an outage and a limitation.

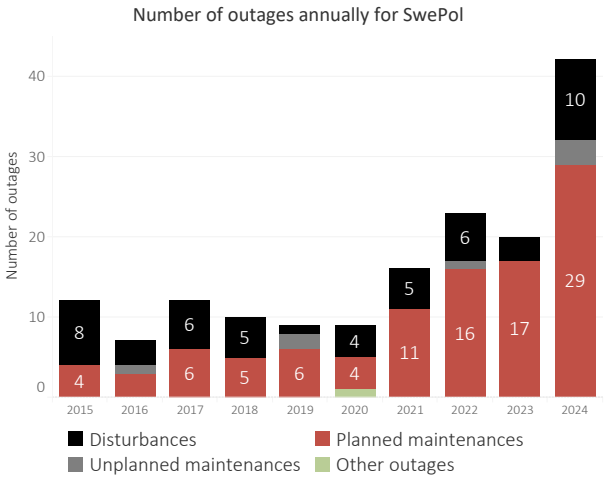

Figure 4.106: The annual number of disturbances, unplanned and planned maintenance outages and other outages for SwePol for the years 2015–2024. SwePol had no other outages during the years 2015–2024.

4.4.25 Viking Link 1

Figure 4.107 presents the availability and utilisation of Viking Link 1 for 2024 and Table 4.28 presents the numerical values behind it.

Viking Link has been in commercial operation since December 2023. In Great Britain, it is connected to Bicker Fen (bidding zone GB) and in Denmark to Revsing (bidding zone DK1). The transmission capacity is 700 MW at the receiving end.

In 2024, Viking Link 1 had an available technical capacity of 80 %. The technical capacity not used was 28 %. Totally, 0.7 TWh (11 % of the technical capacity) was transmitted east to Denmark (GB→DK1) and 2.5 TWh (41 % of the technical capacity) was transmitted west to Great Britain (DK1→GB).

Annual maintenance for Viking Link 1 lasted 14 days in August. Additionally, there were four planned maintenance outages, three was warranty work and one was due to testing of zero current. Furthermore, there were nine disturbance outages, eight minor disturbances and one which was caused by a fire in the ventilation system for the cable sealing where the outage lasted four days.

Viking Link has been limited due to the delay of the expansion of the grid in the western part of Jutland. When Viking Link went to operation the limitation for both poles were 800 MW for both directions. Currently the limitation are 1000/1100 MW (east/west) with the possibility to raise the capacity to 1400 MW when the operational conditions allow it.

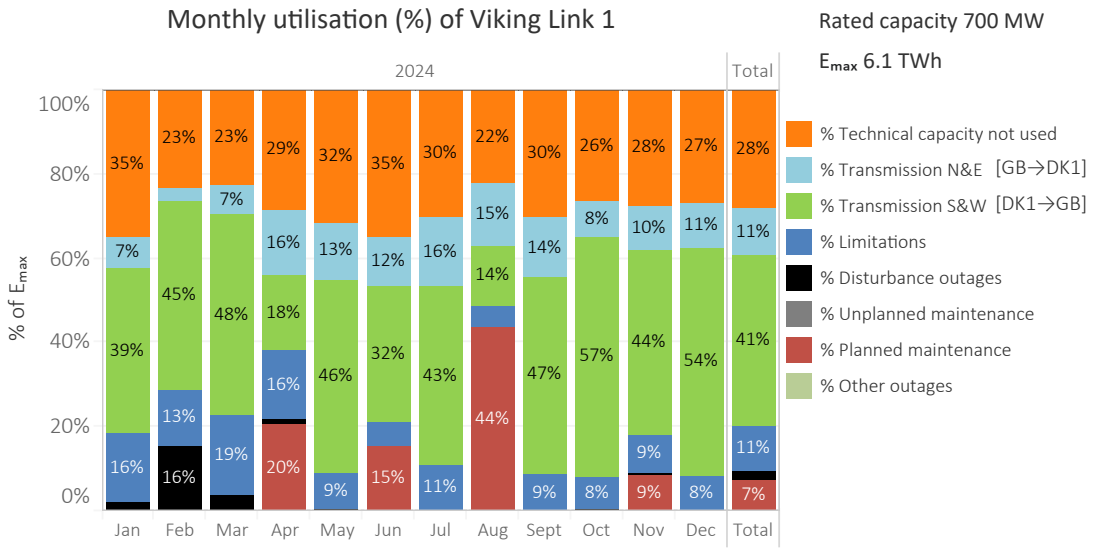

Figure 4.107: Monthly utilisation (%) by category for Viking Link 1 in 2024.

Table 4.28: Monthly allocation (GWh) of technical capacity (E_{max}) for Viking Link 1 in 2024.

Monthly utilisation of Viking Link 1 (South & West direction DK1→GB)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	183.1	114.3	118.7	144.5	165.6	176.5	157.2	116.4	152.1	138.3	139.7	141.0	1747.5	28.4%
Transmission N&E, GWh	37.6	15.6	35.4	78.4	69.8	58.3	85.5	77.9	72.8	43.9	52.3	55.6	683.0	11.1%
Transmission S&W, GWh	204.1	218.7	248.1	90.3	239.5	163.2	223.4	73.5	235.3	297.0	222.9	281.8	2497.8	40.6%
Limitations, GWh	85.2	63.1	97.3	81.8	44.8	29.2	54.8	26.3	44.1	39.9	45.4	43.2	655.2	10.6%
Disturbance outages, GWh	10.8	76.0	21.0	6.2	1.7	-	-	-	-	3.0	0.1	-	118.8	1.9%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	102.8	-	76.9	-	226.8	-	-	44.1	-	450.6	7.3%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	520.9	487.6	520.4	504.1	521.4	504.1	521.0	520.9	504.4	522.1	504.5	521.5	6152.9	100.0%
Losses SW, GWh	5.4	6.4	7.2	2.3	6.5	4.1	5.9	1.9	6.3	8.3	6.2	8.0	68.4	1.1%
Losses NE, GWh	0.7	0.3	0.5	1.8	1.9	1.6	2.4	2.2	2.1	1.2	1.4	1.4	17.3	0.3%

4.4.26 Viking Link 2

Figure 4.108 presents the availability and utilisation of Viking Link 2 for 2024 and Table 4.29 presents the numerical values behind it.

Viking Link has been in commercial operation since December 2023. In Great Britain, it is connected to Bicker Fen (bidding zone GB) and in Denmark to Revsing (bidding zone DK1). The transmission capacity is 700 MW at the receiving end.

In 2024, Viking Link 2 had an available technical capacity of 80 %. The technical capacity not used was 28 %. Totally, 0.7 TWh (11 % of the technical capacity) was transmitted east to Denmark (GB→DK1) and 2.5 TWh (41 % of the technical capacity) was transmitted west to Great Britain (DK1→GB).

Annual maintenance for Viking Link 2 lasted 14 days in August. There were four planned maintenance outages, three was warranty work and one was due to testing of zero current. Furthermore, there were nine disturbance outages, eight minor disturbances and one which was caused by a fire in the ventilation system for the cable sealing where the outage lasted four days.

Viking Link has been limited due to the delay of the expansion of the grid in the western part of Jutland. When Viking Link went to operation the limitation for both poles were 800 MW for both directions. Currently the limitation are 1000/1100 MW (east/west) with the possibility to raise the capacity to 1400 MW when the operational conditions allow it.

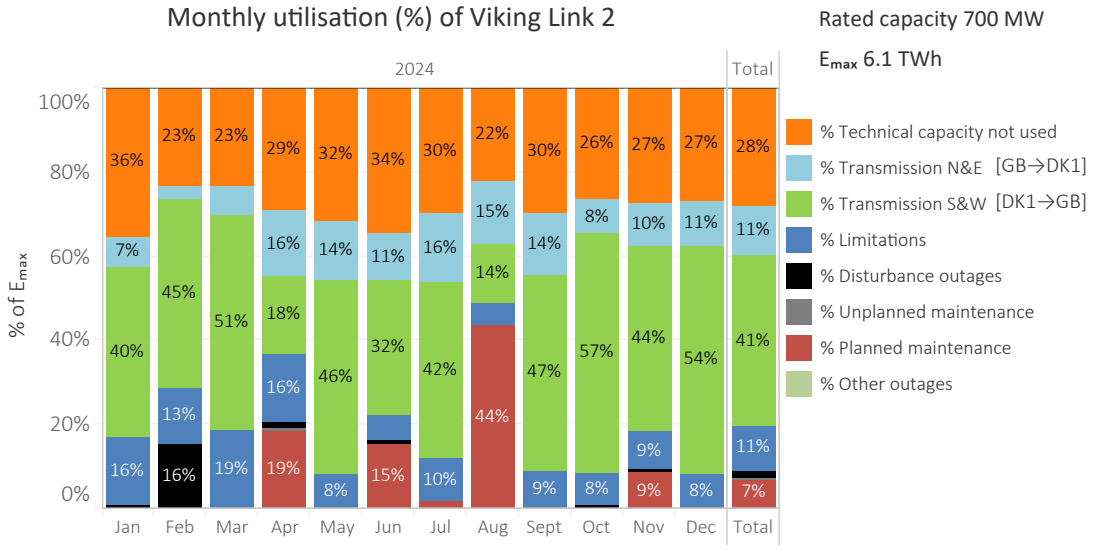

Figure 4.108: Monthly utilisation (%) by category for Viking Link 2 in 2024.

Table 4.29: Monthly allocation (GWh) of technical capacity (E_{max}) for Viking Link 2 in 2024. Losses are not included in the technical capacity (E_{max}), as is shown in Figure 2.1.

Monthly utilisation of Viking Link 2 (South & West direction DK1→GB)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	185.0	113.8	121.4	146.3	165.3	173.6	155.5	116.3	151.8	137.3	137.1	140.7	1744.1	28.3%
Transmission N&E, GWh	37.6	15.6	36.1	80.8	74.2	56.8	85.5	77.9	72.9	43.9	52.2	55.6	689.1	11.2%
Transmission S&W, GWh	209.7	218.8	265.7	91.8	239.7	160.7	217.6	73.6	235.6	295.4	221.8	282.1	2512.4	40.8%
Limitations, GWh	85.3	63.3	97.3	82.6	42.3	30.7	52.7	26.3	44.2	40.2	46.8	43.3	655.0	10.6%
Disturbance outages, GWh	3.4	76.0	-	6.2	-	5.5	-	-	-	5.4	2.7	-	99.2	1.6%
Unplanned maintenance., GWh	-	-	-	2.8	-	-	-	-	-	-	-	-	2.8	0.0%
Planned maintenance, GWh	-	-	-	93.7	-	76.9	9.7	226.7	-	-	44.1	-	451.1	7.3%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	521.0	487.6	520.5	504.1	521.5	504.1	521.0	520.9	504.5	522.2	504.6	521.7	6153.6	100.0%
Losses SW, GWh	5.7	6.1	7.8	2.2	6.1	3.8	5.2	1.7	5.8	7.6	5.6	7.4	65.1	1.1%
Losses NE, GWh	0.8	0.3	0.8	1.9	2.2	1.5	2.3	1.9	2.1	1.2	1.3	1.4	17.5	0.3%

References

[1] ENTSO-E, “NORDIC AND BALTIC GUIDELINES FOR HVDC STATISTICS.” https://eepublicdownloads.entsoe.eu/clean-documents/SOC%20documents/Nordic/Nordic_and_Baltic_Guidelines_for_HVDC_Statistics_17.11.2020.pdf, November 2020.

[2] CIGRE Technical Brochure, “Protocol for reporting the operational performance of HVDC Transmission Systems,” technical brochure, CIGRE, 2014.

Glossary

DISTAC Disturbance Statistics and Classification. Working group DISTAC reports to Regional Group Nordic (RGN) in ENTSO-E.

ENTSO-E European Network of Transmission System Operators for Electricity.

HVDC High Voltage Direct Current.

LCC Line-commutated converter.

NordAM Nordic Asset Management Forum.

PEX Cross-linked polyethylene.

RGN Regional Group Nordic.

TSO Transmission System Operator.

VSC Voltage-source converter.

Appendices

A Schematic presentations of HVDC links

Figure A.1 shows the schematic presentation of a line-commutated converter station (LCC) and Figure A.2 voltage-source converter station (VSC). Both figures show also the origin of an event which is used for categorising a disturbance or a limitation for statistical purposes. The figures also show the locations of the circuit breakers and measurement points for transferred energy on a link. These figures are showing an example of a possible (LCC) or (VSC) converter station but there are multiple different ways to construct one.

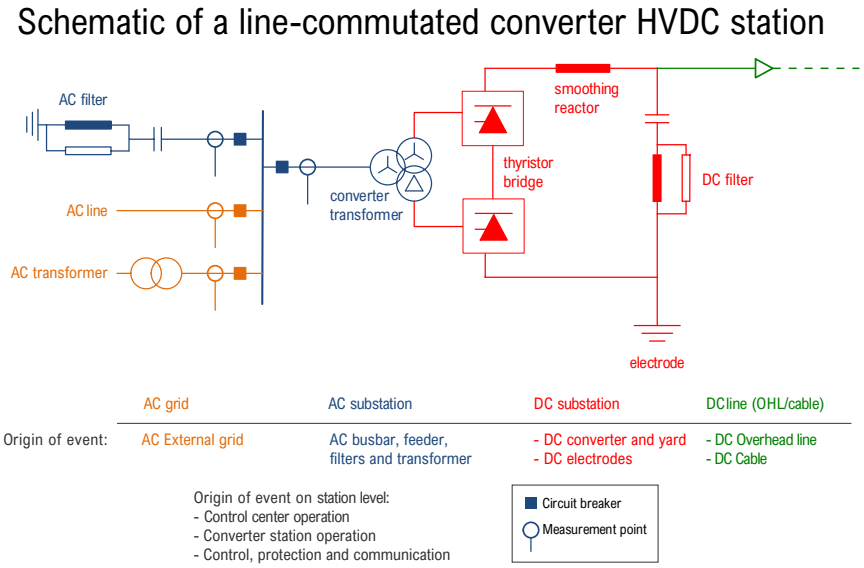

Figure A.1: An example of a line-commutated converter (LCC) station schematic with the connection to the AC grid. The other remote side of the HVDC link has a similar albeit mirrored version of the converter station.

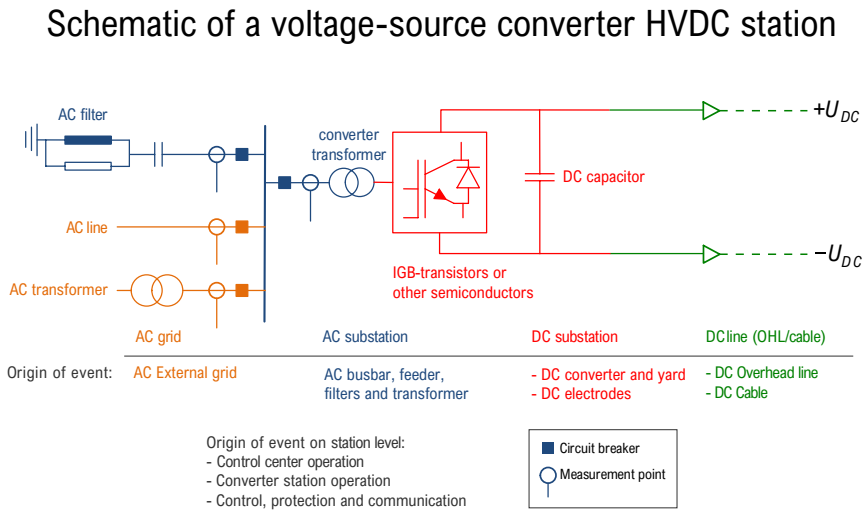

Figure A.2: An example of a voltage-source converter (VSC) station schematic with the connection to the AC grid. The other remote side of the HVDC link has a similar albeit mirrored version of the converter station.

B Origin of event classification in DISTAC and in CIGRE

Table B.1 shows the classification in DISTAC and the corresponding CIGRE outage codes [2]. The full compatibility is not achieved in control and protection areas. The schematics in Appendix A can be helpful in visualising the different categories.

Table B.1: The origin of event categories and subcategories in DISTAC and the corresponding CIGRE outage codes.

DISTAC Origin of event	DISTAC / CIGRE Subcategory / Outage Code	Comment
Multiple places	-	Used primarily for annual maintenance in DISTAC.
Control centre operation[1]	C-P.L – Local HVDC Control & Protection[1]	Control, protection or monitoring equipment of the local HVDC station, for example, converter firing control, current and voltage regulators, converter and dc yard protections, valve control and protection, and local control sequences.
	C-P.M – Master HVDC Control & Protection[1]	Equipment used for inter-station coordination of current and voltage orders, inter-station sequences, auxiliary controls such as damping controls or higher level controls such as run-back/run-up power control or frequency control.
	C-P.T – Control & Protection and Telecommunication[1]	Equipment for coding of control and indication information to be sent over a telecommunication circuit including the telecommunication circuit itself (microwave, PLC or optical).
Converter station operation[1]	Same as for “Control centre operation” above	
Control, protection and communication[1]	Same as for “Control centre operation” above	
AC External grid	EXT – External AC System	
AC and auxiliary equipment	AC-E.F – AC Filter and Shunt Bank	Including AC filter CTs, arresters as well as PLC/RI, SVC, STATCOM, series capacitor at HVDC station.
	AC-E.SW – Other AC Switchyard Equipment	For example, switches, surge arresters, busbars, insulators.
	AC-E.CP – AC Control and Protection	AC C&P including CTs, VTs, also for auxiliary power and valve cooling.
	AC-E.TX – Converter Transformer	Including interface transformers.
	AC-E.SC – Synchronous Compensator	Including SC cooling system and exciter.
	AC-E.AX – Auxiliary Equipment and Auxiliary Power	For example, auxiliary transformers, pumps, battery chargers, heat exchangers, cooling system instrumentation, LV switchgear, motor control centres, fire protection, civil works.
DC converter and yard	V.E – Valve Electrical	
	V.VC – Valve Cooling	Valve Cooling pipes and parts in valve hall.
	V.C – Valve Capacitor	
	DC-E.F – DC Filters	
	DC-E.SR – DC Smoothing Reactor	
	DC-E.SW – DC Switching Equipment	
	DC-E.ME – DC Measuring Equipment	
	DC-E.O – Other DC Yard and Valve Hall Equipment	
DC Electrodes	DC-E.GE – DC Ground Electrode	
	DC-E.EL – DC Ground Electrode Line	
DC Overhead line	TL-OH – DC Overhead Transmission Line	
DC Cable	TL-C – DC Underground / submarine Cable	
Other or unknown	O – Other	

[1] There is no direct one-to-one compatibility between DISTAC and CIGRE for these definitions.

C Contact persons

Denmark	Energinet Tonne Kjærsvej 65 DK-7000 Fredericia, Denmark Anders Bratløv Tel. +45 51 38 01 31 E-mail: anv@energinet.dk Jakob Cordes Nørskov Tel. +45 26 36 40 50 E-mail: JNV@energinet.dk
Estonia	Elering AS Kadaka tee 42 Tallinn, Estonia Irene Puusaar Tel. +372 508 4372 E-mail: irene.puusaar@elering.ee Kaur Krusell Tel. +372 564 86011 E-mail: kaur.krusell@elering.ee
Finland	Fingrid Oyj Läkkisepäntie 21, P.O. Box 530 FI-00101 Helsinki, Finland Markku Piironen Tel. +358 30 395 4172 Mobile +358 40 351 1718 E-mail: markku.piironen@fingrid.fi
Lithuania	Litgrid AB Karlo Gustavo Emilio Manerheimo st. 8 LT-05131, Vilnius Valdas Tarvydas Tel. +370 686 77626 E-mail: valdas.tarvydas@litgrid.eu
Norway	Statnett SF Nydalen allé 33, PB 4904 Nydalen NO-0423 Oslo Olve Mogstad Tel. +47 997 12 068 E-mail: Olve.Mogstad@Statnett.no
Sweden	Svenska kraftnät Sturegatan 1, P.O. Box 1200 SE-172 24 Sundbyberg Jonathan Kristensson Tel: +46 10 475 81 69 Mobile: +46 72 512 22 80 E-mail: Jonathan.Kristensson@svk.se Tsega Muzollo Mobile: +46 72 444 50 62 E-mail: tsega.muzollo@svk.se
Publisher	ENTSO-E AISBL Rue de Spa 8 1000 Brussels, Belgium Tel. +32 2 741 09 50 info@entsoe.eu www.entsoe.eu

D Sorted overview of utilisation and unavailability for all HVDC links

This chapter presents sorted versions of Figure 4.1 Utilisation (%) by category for each HVDC link in 2024.

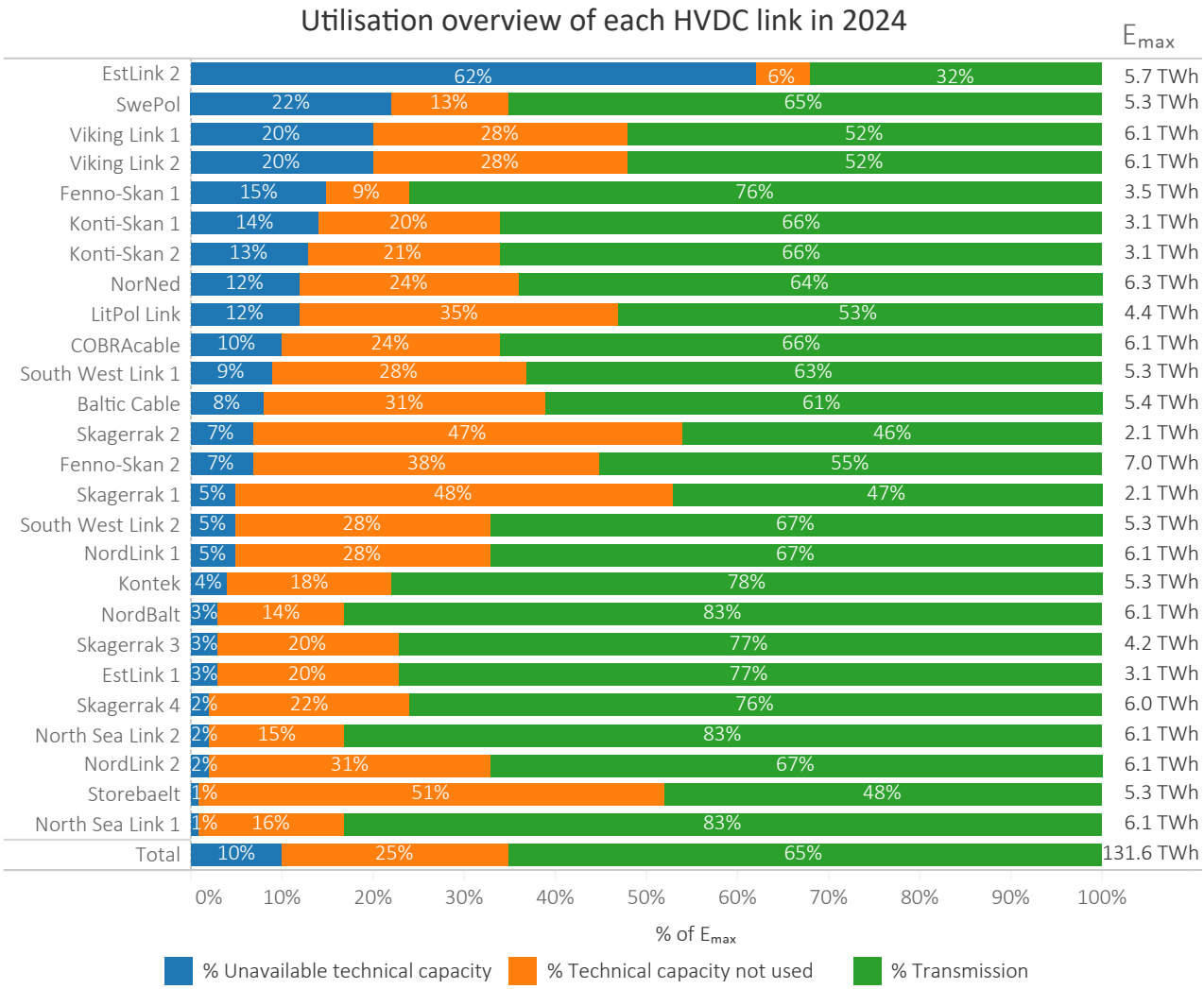

Figure D.1: Overview of each HVDC link sorted by descending unavailable technical capacity (E_U) in 2024.

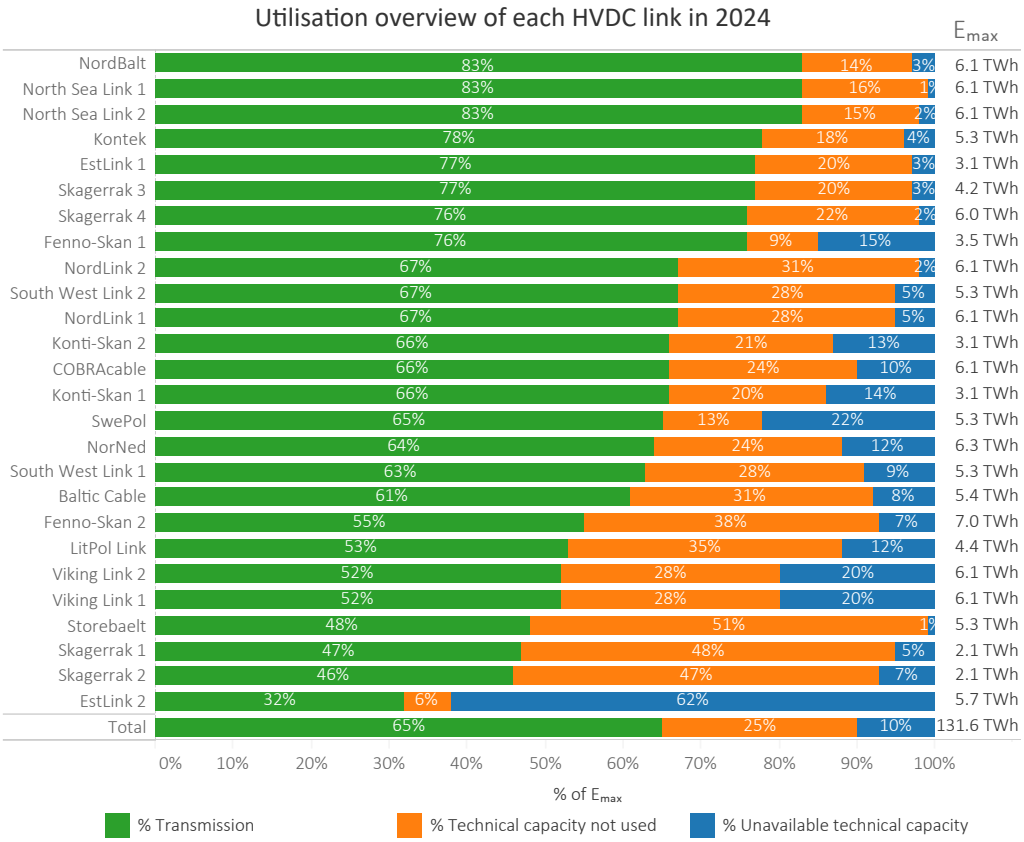

Figure D.2: Overview of each HVDC link sorted by descending transmission (E_T) in 2024.

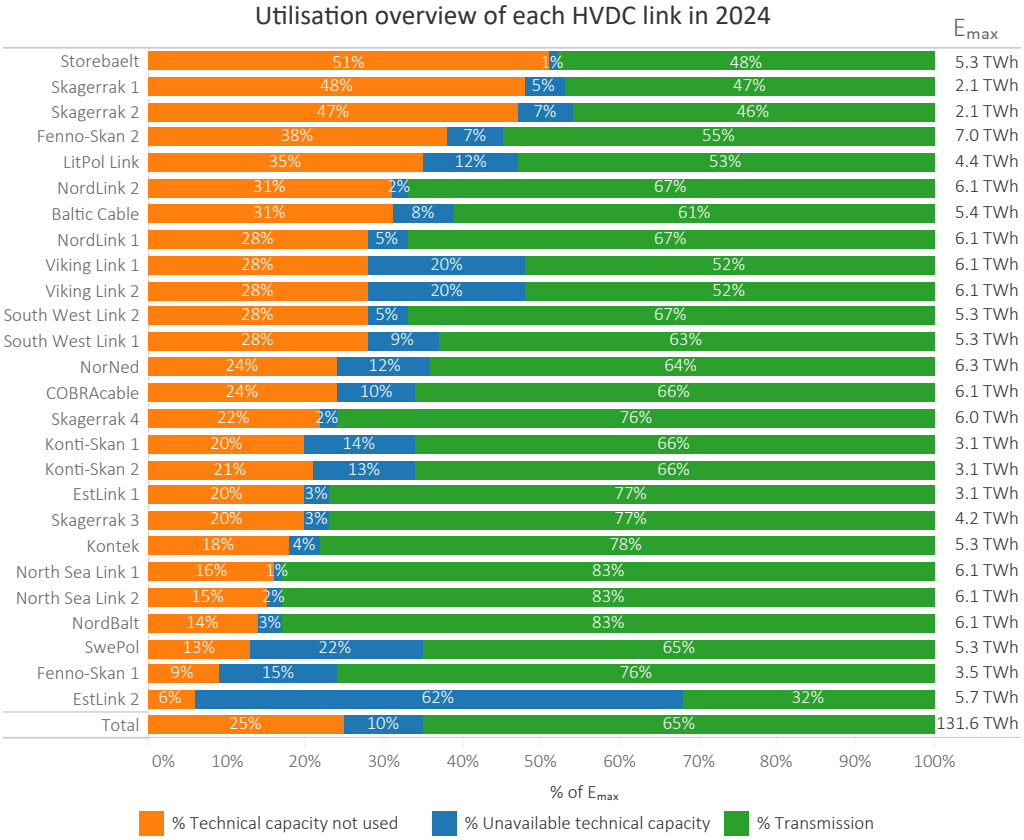

Figure D.3: Overview of each HVDC link sorted by descending technical capacity not used (E_{TCNUEM}) in 2024.

E Additional figures

This appendix was introduced to allow experimenting with new kinds of figures without affecting the rest of the report. Furthermore, it shows what kind of statistical data can be derived from the data collected by the DISTAC group.

E.1 Annual utilisation per type of HVDC converter

Figure E.1 presents the annual utilisation of all HVDC links using line-commutated converters (LCC) and Figure E.2 all HVDC links using voltage-source converters (VSC).

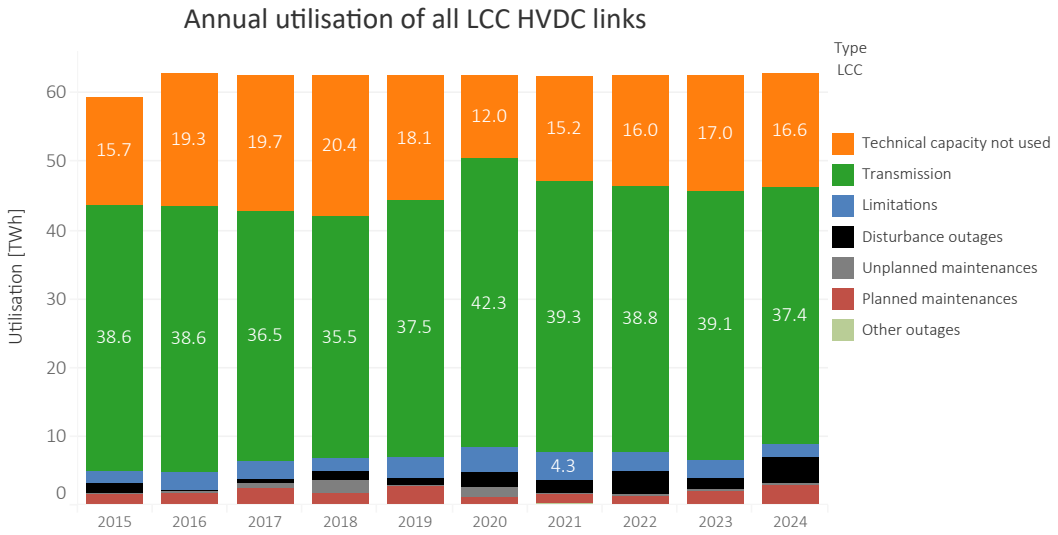

Figure E.1: Annual utilisation of all HVDC links using line-commutated converters (LCC)(TWh).

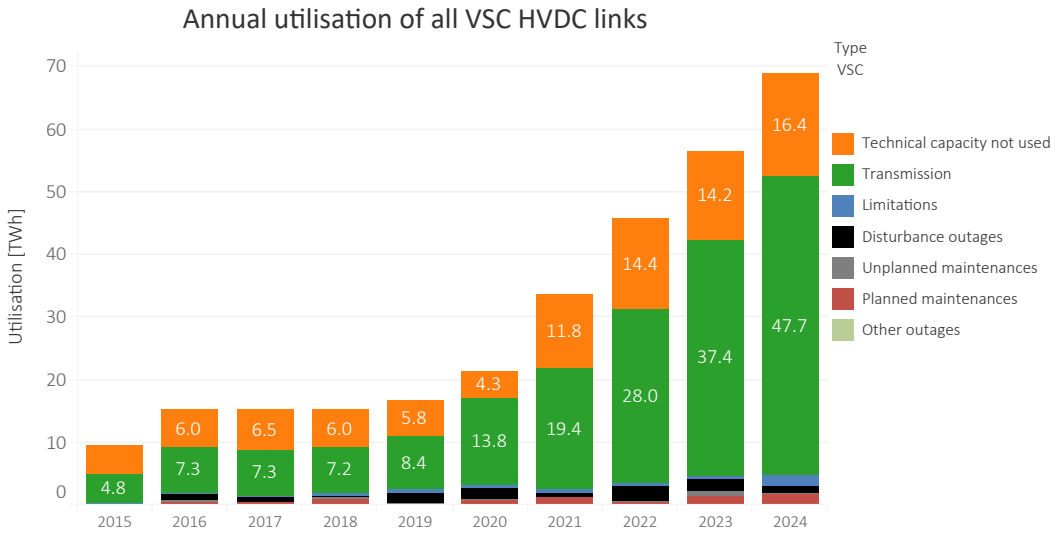

Figure E.2: Annual utilisation of all HVDC links using voltage-source converters (VSC)(TWh).

E.2 Additional figures with percentages of hours unavailable

This section presents additional figures with a more detailed categorisation of unavailability. Figure E.3 presents the hours (%) limited due to seasonal causes annually for all HVDC links. Figure E.4 presents the hours (%) limited by limitation origin and type annually for all HVDC links. The limitation origins are AC and DC limiting conditions, and the types are planned or unplanned.

Figure E.5 presents the hours (%) limited by limitation origin and type in 2024 for each HVDC link. Figure E.6 presents the same but for each market connection.

Figure E.7 presents hours (%) unavailable due to planned maintenance by primary cause in 2024 for each HVDC link and the corresponding annual values for all HVDC links combined.

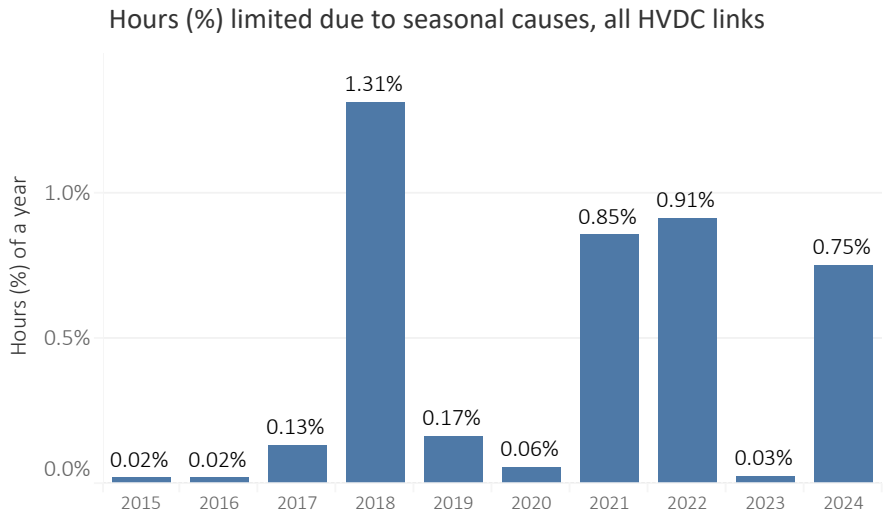

Figure E.3: Hours (%) limited due seasonal causes for all HVDC links. The percentage is calculated by counting the number of hours with a limitation due to seasonal causes and dividing it by the total number of hours in a year.

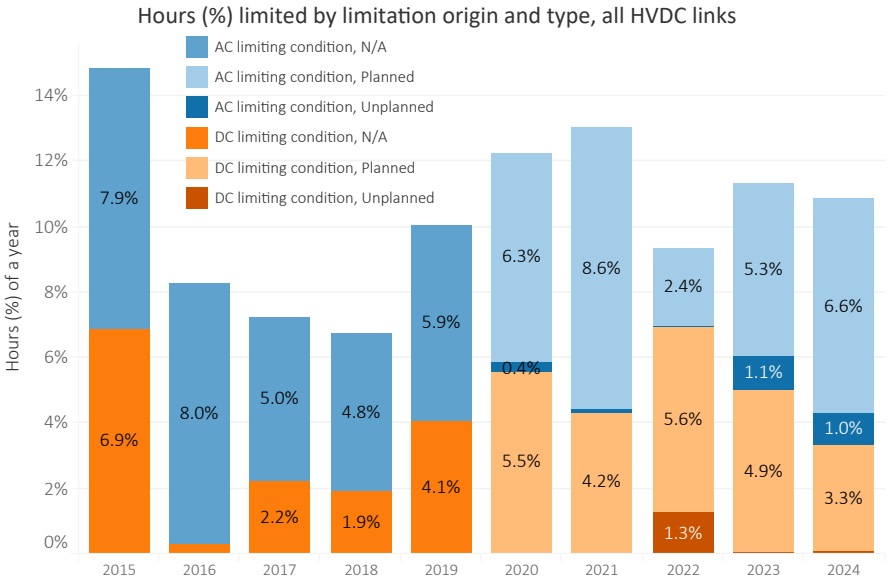

Figure E.4: Hours (%) by limitation origin and type annually for all HVDC links. The limitation origins are AC limiting and DC limiting and the types are planned and unplanned. The percentage is calculated by counting the number of hours with the specific limitation origin and type and dividing it by the total number of hours in a year. Limitation type was not recorded prior to 2020.

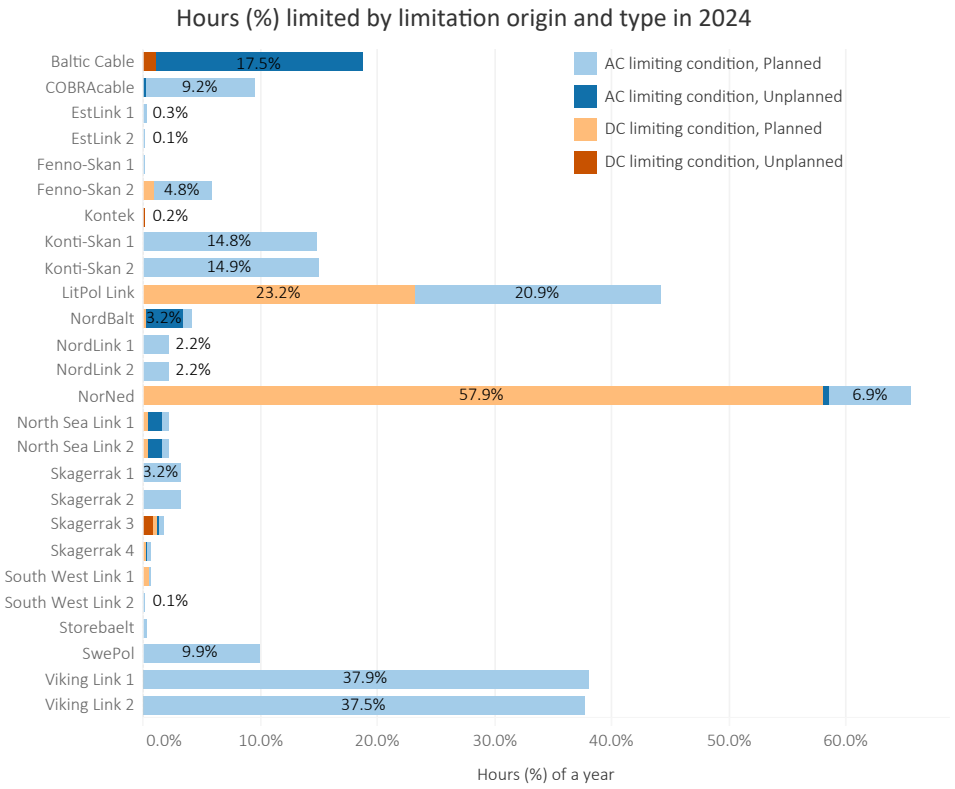

Figure E.5: Hours (%) limited by limitation origin and type in 2024 for each HVDC link. The percentage is calculated by counting the number of hours with the specific limitation origin and type and dividing it by the total number of hours in a year.

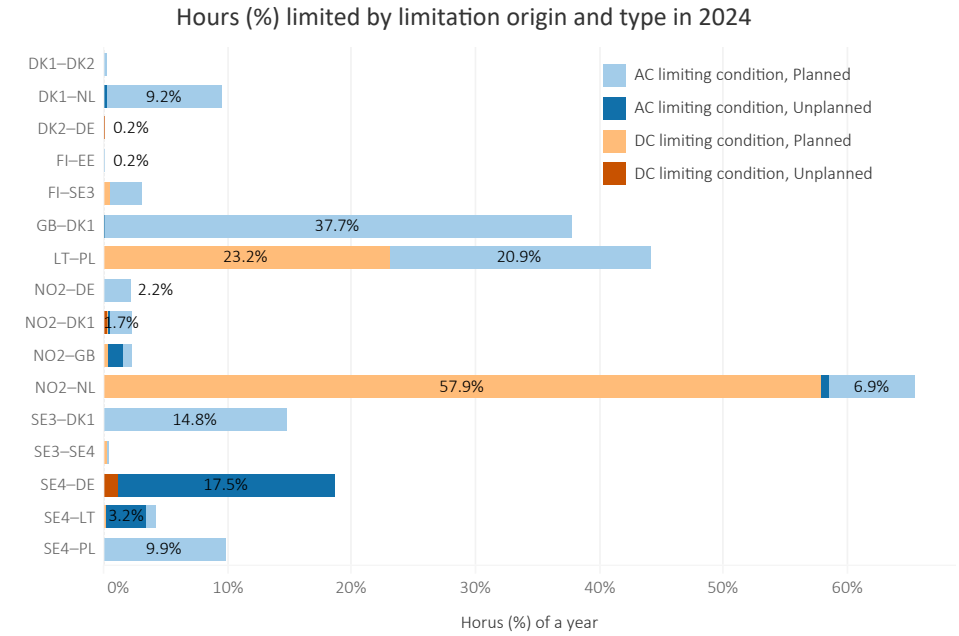

Figure E.6: Hours (%) limited by limitation origin and type for each market connection in 2024. The percentage is calculated by counting the number of hours with the specific limitation origin and type and dividing it by the total number of hours in a year.

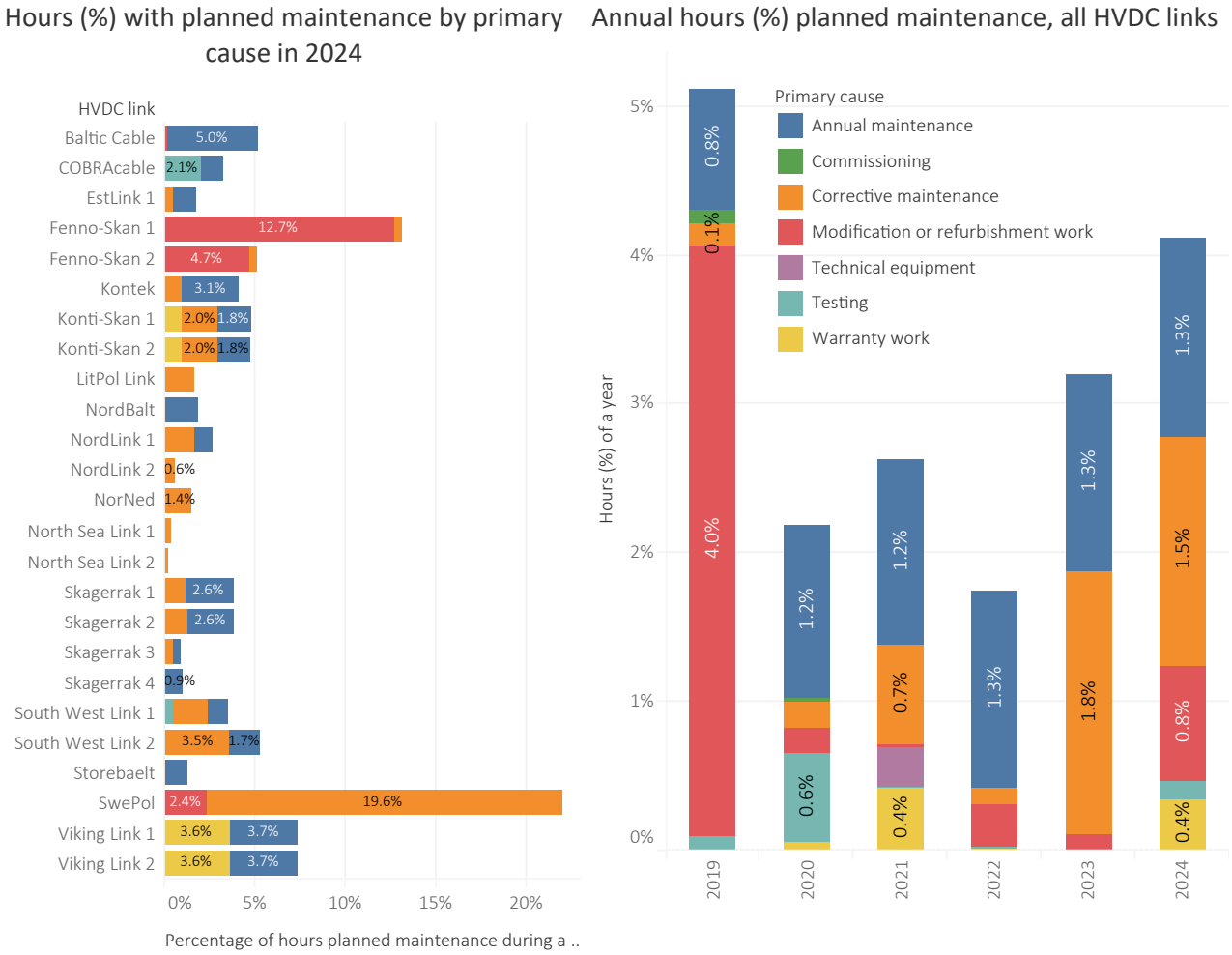

Figure E.7: On the left: hours (%) with planned maintenance by primary cause for each HVDC link in 2024. On the right: hours (%) with planned maintenance by primary cause annually for all HVDC links combined. The percentage is calculated by counting the number of hours with a planned maintenance and dividing it by the total number of hours in a year.

E.3 Additional figures with origin of event

This section presents additional figures about disturbance and maintenance outages, with a focus on their origin of the event. Origin of event corresponds to the location on the HVDC link that the event originated from. The origin of event categories and subcategories are presented in Appendix B. The HVDC link schematics in Appendix A can be helpful in visualising the categories.

Figure E.8 presents the number of disturbance outages divided by the number of HVDC links annually grouped by origin. Figure E.9 presents the annual unavailable capacity due to disturbance outages by origin of event for all HVDC links combined. Last, Table E.1 presents the numerical values behind Figure E.9 with further subcategorisation of the origin.

Figure E.10 presents the annual unavailable capacity due to maintenance outages by primary cause. Figure E.11 presents the annual unavailable capacity due to corrective maintenances by origin of event for all HVDC links, and the number of corrective maintenances divided by the number of HVDC links annually grouped by origin of event. Primary cause of outages has not been recorded prior to the year 2019.

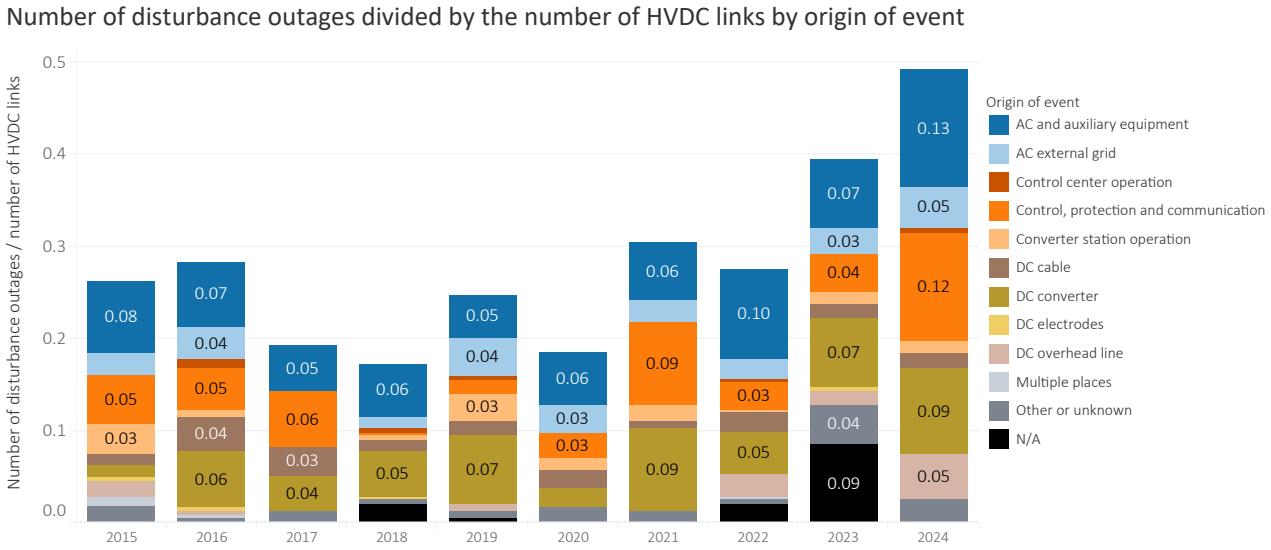

Figure E.8: Number of disturbance outages divided by the number of HVDC links, grouped by origin of event.

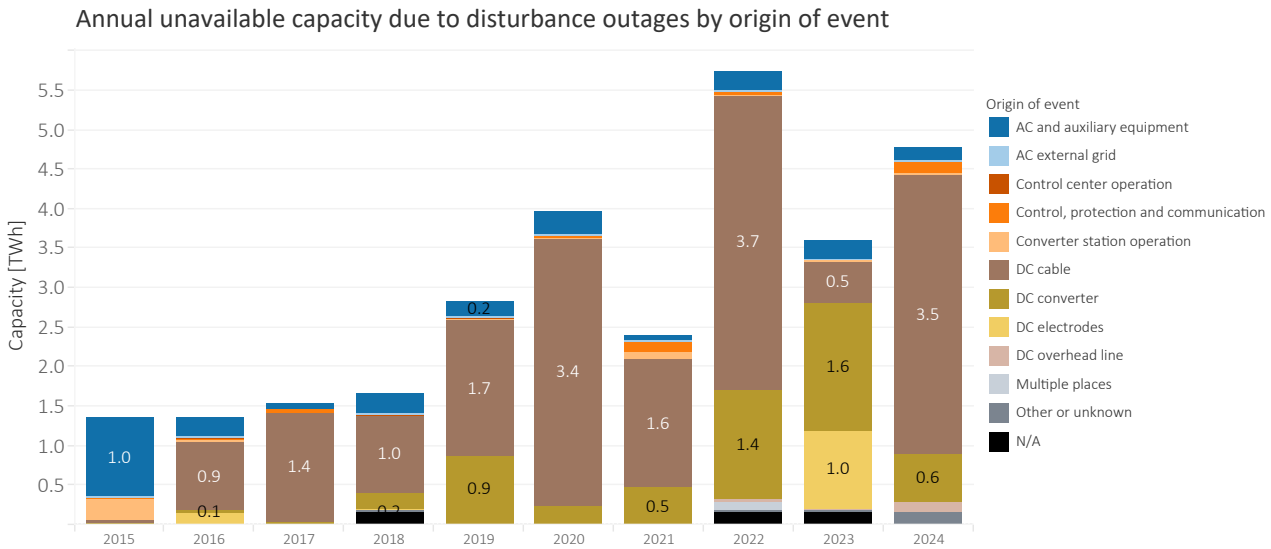

Figure E.9: Annual unavailable capacity due to disturbances outages by origin of event for all HVDC links.

Table E.1: Annual unavailable capacity due to disturbances outages by origin of event and subcategory for all. N/A means not available. Note that the level of detail in the data collection has increased since 2019.

Annual utilisation of all HVDC links

		GWh									
Origin	Subcategory	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
AC and auxiliary equipment	AC-E.AX - Auxiliary Equipment and Auxiliary Power	-	-	-	-	1.5	280.1	12.9	97.2	6.5	8.6
	AC-E.CP - AC Control and Protection	-	-	-	-	15.0	3.6	6.7	1.7	2.5	41.8
	AC-E.F - AC Filter and Shunt Bank	-	-	-	-	0.1	0.6	0.1	112.5	-	0.4
	AC-E.SW - Other AC Switchyard Equipment	-	-	-	-	0.2	1.1	18.6	-	-	2.4
	AC-E.TX - Convertor Transformer	-	-	-	-	168.7	0.2	3.3	13.2	226.6	106.1
	N/A	1005.9	228.9	65.2	260.5	0.8	1.3	1.1	9.8	-	3.1
AC external grid	EXT - External AC System	-	-	-	-	8.0	9.2	4.9	5.3	9.7	4.2
	N/A	6.2	13.6	-	2.2	-	-	4.2	-	0.4	3.1
Control center operation	C-P.L - Local HVDC Control & Protection	-	-	-	-	-	-	-	-	-	1.4
	C-P.M - Master HVDC Control & Protection	-	-	-	-	-	-	-	0.0	-	-
	N/A	-	9.6	-	0.2	0.0	-	-	-	-	-
Control, protection and communication	C-P.L - Local HVDC Control & Protection	-	-	-	-	6.8	10.3	106.2	7.8	21.0	156.5
	C-P.M - Master HVDC Control & Protection	-	-	-	-	-	6.6	37.3	-	-	1.7
	C-P.T - Control & Protection and Telecommunicati..	-	-	-	-	-	0.7	-	-	0.7	1.2
	N/A	12.6	26.3	63.5	0.6	2.7	-	1.3	0.2	1.6	7.1
	C-P.L - Local HVDC Control & Protection	-	-	-	-	-	-	-	46.1	-	-
Converter station operation	C-P.L - Local HVDC Control & Protection	-	-	-	-	21.1	0.8	84.2	-	3.2	14.3
	C-P.M - Master HVDC Control & Protection	-	-	-	-	8.2	0.6	-	-	3.7	-
	N/A	290.4	20.1	-	1.5	-	-	-	-	-	-
	C-P.L - Local HVDC Control & Protection	-	-	-	-	-	-	-	1.8	-	-
DC cable	TL-C - DC Underground / submarine Cable	-	-	-	-	1729.1	3410.9	1623.7	3748.9	178.9	3548.4
	N/A	32.2	876.0	1361.8	996.5	-	-	-	-	341.8	-
DC converter	DC-E.F - DC Filters	-	-	-	-	-	-	0.1	-	-	50.7
	DC-E.ME - DC Measuring Equipment	-	-	-	-	65.2	3.6	148.3	-	61.5	-
	DC-E.O - Other DC Yard and Valve Hall Equipment	-	-	-	-	2.8	-	18.6	30.2	1435.1	238.5
	DC-E.SR - DC Smoothing Reactor	-	-	-	-	245.3	174.5	-	-	26.7	4.7
	V.C - valve capacitor	-	-	-	-	36.5	-	-	-	-	-
	V.E - Valve Electrical	-	-	-	-	36.9	33.6	217.0	7.1	-	156.7
	V.VC - Valve Cooling	-	-	-	-	52.8	13.5	91.4	3.6	2.4	132.7
	N/A	3.3	37.2	33.8	210.6	419.0	-	0.9	-	-	-
	DC filter	-	-	-	-	-	-	-	339.1	-	-
	DC-E.SW - DC Switching Equipment	-	-	-	-	-	-	-	-	-	14.9
	V.C - Valve Capacitor	-	-	-	-	-	-	-	994.1	91.3	-
DC electrodes	N/A	9.0	136.3	-	4.6	-	-	-	-	-	-
	DC-E.EL - DC Ground Electrode Line	-	-	-	-	-	-	-	-	988.6	-
DC overhead line	TL-OH - DC Overhead Transmission Line	-	-	-	-	3.1	-	-	28.5	16.6	128.0
	N/A	3.0	2.3	-	-	-	-	-	-	-	-
Multiple places	N/A	0.2	0.7	-	-	-	-	-	106.8	-	-
N/A	TL-C - DC Underground / submarine Cable	-	-	-	-	-	-	-	34.8	-	-
	N/A	-	-	-	186.5	0.7	-	-	147.0	154.5	-
Other or unknown	O - Other	-	-	-	-	0.0	4.5	1.2	0.2	27.8	155.1
	N/A	1.4	0.7	8.4	0.7	0.5	-	-	-	6.5	0.2

Table dist.out. GWh lookup without zeros broken down by GWh (Parameters) and Datetime Year vs. Origin and Subcategory. The data is filtered on HVDC link, which excludes Null, Vyborg Link, Vyborg Link FI→RU and Vyborg Link RU→FI. The view is filtered on Datetime Year, which excludes Null, 2012, 2013 and 2014.

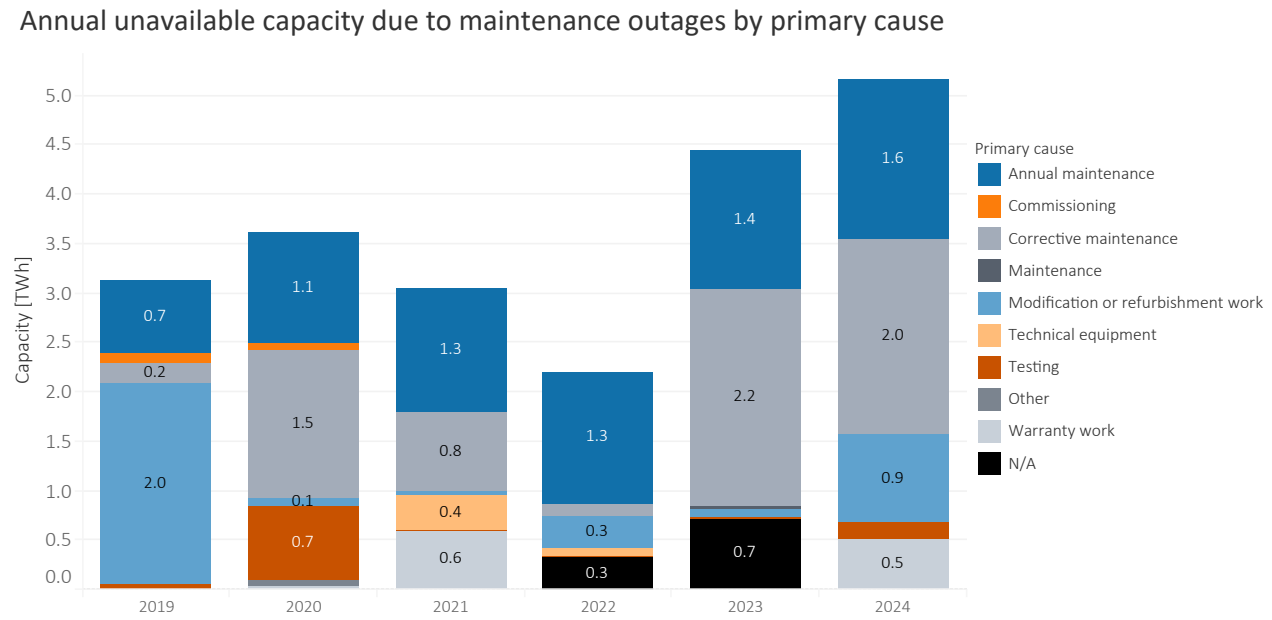

Figure E.10: Annual unavailable capacity due to maintenance outages by primary cause for all HVDC links. Primary cause of outages has not been recorded prior to 2019.

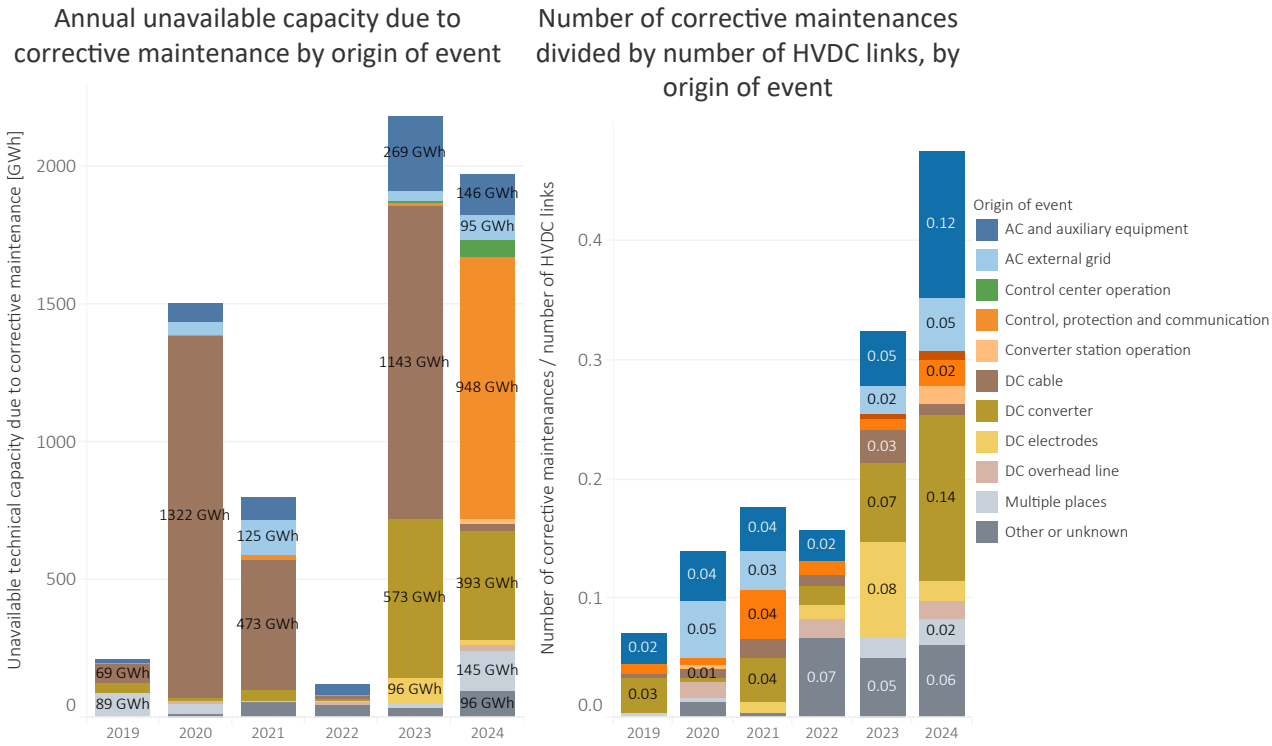

Figure E.11: On the left: annual unavailable capacity due to corrective maintenance outages by origin of event for all HVDC links. On the right: number of corrective maintenance outages divided by the number of HVDC links annually grouped by origin of event. Primary cause of outages has not been recorded prior to the year 2019.