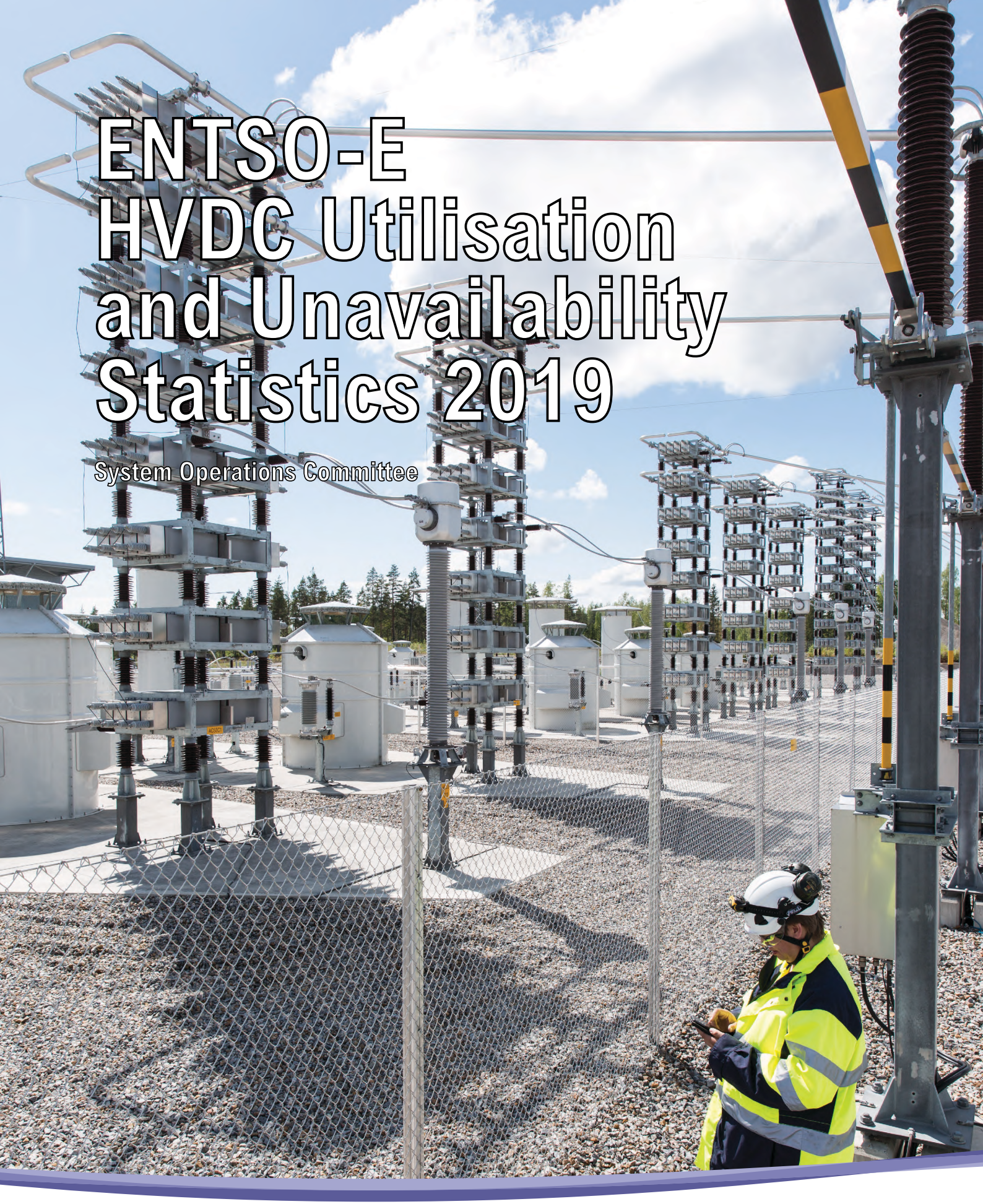
ENTSO-E HVDC Utilisation and Unavailability Statistics 2019

System Operations Committee



European Network of
Transmission System Operators
for Electricity

entsoe

ENTSO-E HVDC Utilisation and Unavailability Statistics 2019

Report rendered June 12, 2020

Executive Summary

The HVDC links are important components for a stable operation of the Nordic and Baltic power system while supporting the commercial power trade in the European energy markets. Furthermore, the HVDC links can provide other important functions like voltage and emergency power support to the HVAC grid. Hence, the advantages of keeping the HVDC links in operation as much as possible are indisputable. The ENTSO-E HVDC Utilisation and Unavailability Statistics 2019 report aims to provide an overview of the Nordic and Baltic HVDC links as well as a detailed view of each individual link. The executive summary concludes the most important parts of the report into one chapter.

Overview

In 2019, 52.9 TWh of electric energy was transmitted through the Nordic and Baltic HVDC links. This is approximately 58 % of the total technical capacity (E_{max}) and correlates well with the percentage utilisation from previous years. Nevertheless, the transmitted energy and unavailable technical capacity is showing a slight increasing trend after a significant drop in 2012, as shown in Figure E.1.

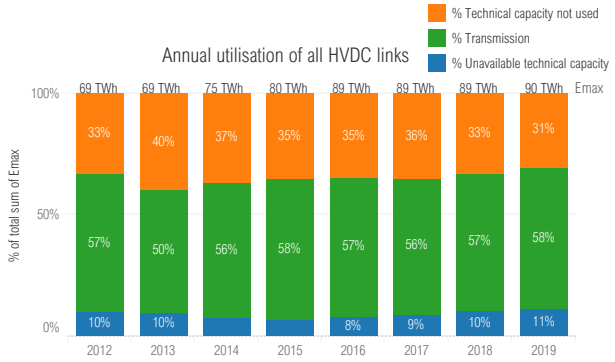


Figure E.1: The annual utilisation of all HVDC links since 2012. Technical capacity not used is the amount of energy that has neither been transmitted nor been unavailable due to limitations or outages.

The total number of disturbance outages registered was 63, preventing 2.8 TWh of potential energy transmission, or 3.1 % of the total technical capacity (E_{max}). Maintenance outages amounted to 3.5 TWh, or 3.8 % of the total technical capacity (E_{max}), and limitations reduced the transmission capacity by 3.8 TWh (4.2 % of the total technical HVDC transmission capacity). The total amount of unavailable technical capacity compared to the total technical capacity (E_{max}) has increased by 1 % per year since 2015 and was in 2019 at its highest point since 2012, as can be seen from Figure E.1. The change is mostly due to increasing planned and unplanned maintenance outages as well as limitations. The unavailable technical capacity includes disturbance outages, limitations, unplanned and planned maintenance outages and other outages.

The most significant unavailabilities in 2019 occurred for Baltic Cable, EstLink 2, Konti-Skan 1–2, NorNed, Skagerrak 1–4 and SwePol. Baltic Cable limitations were mainly due to wind and solar energy feeds and EstLink 2 had 3 more severe disturbances caused by a cooling water leakage, another by a faulty capacitor and faulty thyristors in the valve hall and the last by a faulty DC voltage divider. Konti-Skan 1–2 had their HVDC conductor lines (in Denmark) and their control systems replaced. NorNed had a faulty bushing in February, filter problems in March–April and maintenances in the Eemshaven region in Q4. Skagerrak 3 had a major planned maintenance for installation and testing of the new control system on the Norwegian side. Skagerrak 4 had cable faults that limited the usage of Skagerrak 1, 2, 3 and 4 due to restrictions on the maximum allowed electrode currents. SwePol had 1 unplanned maintenance outage due to an oil leakage and 1 disturbance outage due to a valve cooling system failure. The effect of these incidents can be seen in Figure E.2.

Individual HVDC links

Baltic Cable

Baltic Cable continued to have its transmitted energy at about 30–46 % of the maximum technical capacity (E_{max}) without a noteworthy change to previous years. The transmitted energy was 36 % of the technical capacity (E_{max}) in 2019. However, the amount limited capacity was the highest of all HVDC links during 2019 and was the all-time second highest of the annual values since 2012 when only considering Baltic Cable. Limited capacity amounted to nearly 24 % of the total technical capacity (E_{max}) and was mostly due to wind and solar energy feeds.

Estlink 1 and 2

The use of EstLink 1 continued to be small in 2019, about 22 % of the technical capacity (E_{max}), yet it was utilised twice as much compared to 2018 (11 %). EstLink 1 has previously been utilised more than 22 % of the technical capacity in 2015, when it was utilised by approximately 29 %. The percentage of unavailable hours in 2019 was approximately 0 % for EstLink 1 and 3 % for EstLink 2. The percentage values of unavailable hours in 2019 were positive, considering that the number of disturbances in 2019 were above the average for both EstLink 1 and 2.

Fenno-Skan 1 and 2

The use of Fenno-Skan 1 continued to be very high in 2019 with 95 % of the technical capacity (E_{max}) being used for transmission. For Fenno-Skan 2, 74 % of the technical capacity (E_{max}) was used for transmission leaving approximately 21 % of the technical capacity unused. However, the percentage of technical capacity used for transmission was still approximately 14 percentage units higher than in 2018. Almost all of the transmitted energy of Fenno-Skan 1 and 2 was imported to Finland. The percentage of unavailable annual hours continued to be insignificant for Fenno-Skan 1. However, the percentage of hours limited during 2019 increased by 5 % compared to 2018, when it was 1 %. The number of disturbances for Fenno-Skan 1 and Fenno-Skan 2 were lower than the 5-year average.

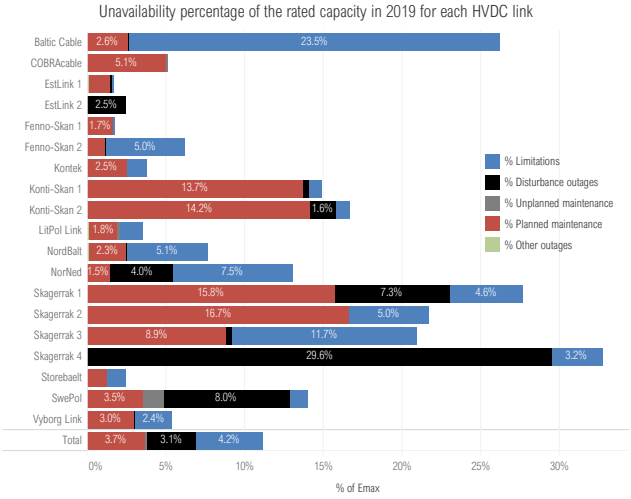


Figure E.2: Percentage distribution of unavailable technical capacity due to limitations, disturbance outages, unplanned and planned maintenance and other outages for each link in 2019.

Kontek

Kontek is reaching its past annual utilisation values of approximately 68 %–73 % of the technical capacity (E_{max}). In 2019, 69 % of the technical capacity was used for transmission. A significant reason for this may be that Kontek had closely to no outages nor limitations that affected its availability, and was therefore readily available to the markets without risk factors.

Konti-Skan 1 and 2

The utilisation of Konti-Skan 1 and 2 has not changed significantly since 2017 and is at about 51 % and 49 % of the technical capacity (E_{max}). However, the unavailable technical capacity was higher than usual due a considerable amount of planned maintenance. Konti-Skan 1 and 2 had extensive planned maintenances due to replacements their of conductor lines in Denmark in May. Furthermore, Konti-Skan 1 control system was replaced in October and November and Konti-Skan 2 control system was replaced in September.

LitPol Link

LitPol Link is continuing in showing an increasing trend in transmitted energy. While the transmitted energy was 34 % of the technical capacity (E_{max}) in 2016, it was nearly 62 % in 2019. Additionally, the unavailable technical capacity has decreased annually since 2016 and was below 4 % of the technical capacity (E_{max}) in 2019.

NordBalt

NordBalt had its best year of transmission so far since 2016, with 63 % of the technical capacity (E_{max}) being transmitted through it. Furthermore, outages and limitations caused an all-time low of unavailable technical capacity since 2016, being about 8 % of the technical capacity (E_{max}) in 2019. However, the unused technical capacity remained the same, at about 29 %, compared to previous years. This could be interpreted as NordBalt's utilisation being very planned and regularly with each outage or limitation affecting greatly on its transmission capabilities.

NorNed

The utilisation of NorNed during 2019 was approximately 61 % of the maximum technical capacity. NorNed had 8 disturbances and 4 planned maintenances during 2019. In February, the outage was due to a fault on a bushing in Feda, and filter problems limited the transmission capacity in March–April. The unavailable energy in Q4 was due to maintenance in the Eemshaven region. Furthermore, the unavailable technical capacity is showing an increasing trend since 2015 even though it was lower in 2019 than in 2018.

Skagerrak 1, 2, 3 and 4

Skagerrak 1, 2, 3 and 4 have had a notable part of their technical capacity afflicted by disturbance outages and unplanned and planned maintenance outages since 2017, and 2019 was no exception. In 2019, Skagerrak 4 had 3 major disturbance outages due to faults on the Danish land cable, which also resulted in limitations for Skagerrak 1, 2 and 3 and all the cables being operated in "careful operation" as of December 2019. Last, Skagerrak 1 and 2 had each an annual maintenance lasting approximately 57 days, and Skagerrak 3 had a major planned maintenance for installation and testing of the new control system on the Norwegian side.

Storebaelt

Storebaelt available capacity is continuing to be high at approximately 98 % of the technical capacity (E_{max}). However, its utilisation percentage is showing a slight decrease since 2015, when it was 69 % of the technical capacity. In 2019,

54 % of the technical capacity was transmitted through the link.

SwePol

SwePol transmitted 62 % of its technical capacity (E_{max}), which is slightly less than in 2018 but still higher than the average utilisation since 2012. The available capacity was lower than normally due to an unplanned maintenance outage and a disturbance outage. The unplanned maintenance outage was caused by an oil leakage and the disturbance outage was caused by a valve cooling system failure.

Vyborg Link

The annual utilisation of Vyborg Link did not increase in 2019 compared to the previous year, as it has done every year since 2014. 61 % of the technical capacity (E_{max}) was transmitted in 2019, 67 % in 2018 and 25 % in 2014. Nevertheless, the transmitted energy was at its all-time second highest value in 2019. The annual maintenance of Vyborg Link lasted 31 days in July. Normally, maintenance work on Vyborg Link causes only limitations because the 350 MW units are not worked on simultaneously.

COBRAcable

COBRAcable was commissioned in late 2019, and the DISTAC group is eager to see future results from it as the current amount of data is not yet ready for extensive analysis.

Table of contents

List of figures

List of tables

1 Introduction and background

This report presents the availability and utilisation of HVDC links connected to the Nordic and Baltic power system in 2019, with an emphasis on disturbance outages. This includes an overview of availability and utilisation for the HVDC links, information about disturbances and unavailability and individual presentations of the performance of each HVDC link.

The first version of the HVDC statistics for utilisation and unavailability was published in 2011 as an addition to the Nordic Grid Disturbance and Fault Statistics 2010 [1]. At that time, the report covered only the Nordic power systems and presented 8 HVDC links. For the statistical year 2012, the HVAC Grid Disturbance Report and HVDC statistics were separated into two reports, which is the format of the reports today. In present time, this report includes 19 HVDC links connected to the Nordic and Baltic countries.

The total HVDC transmission capacity connected to the Nordic and Baltic power systems in 2019 is 10.9 GW, which makes the annual transmission capacity 91.1 TWh. Most of the HVDC links connect the Nordic synchronous system to other systems. Each HVDC link has a predefined export direction only to distinguish a direction of power flow. These are presented in Figure 1.1.

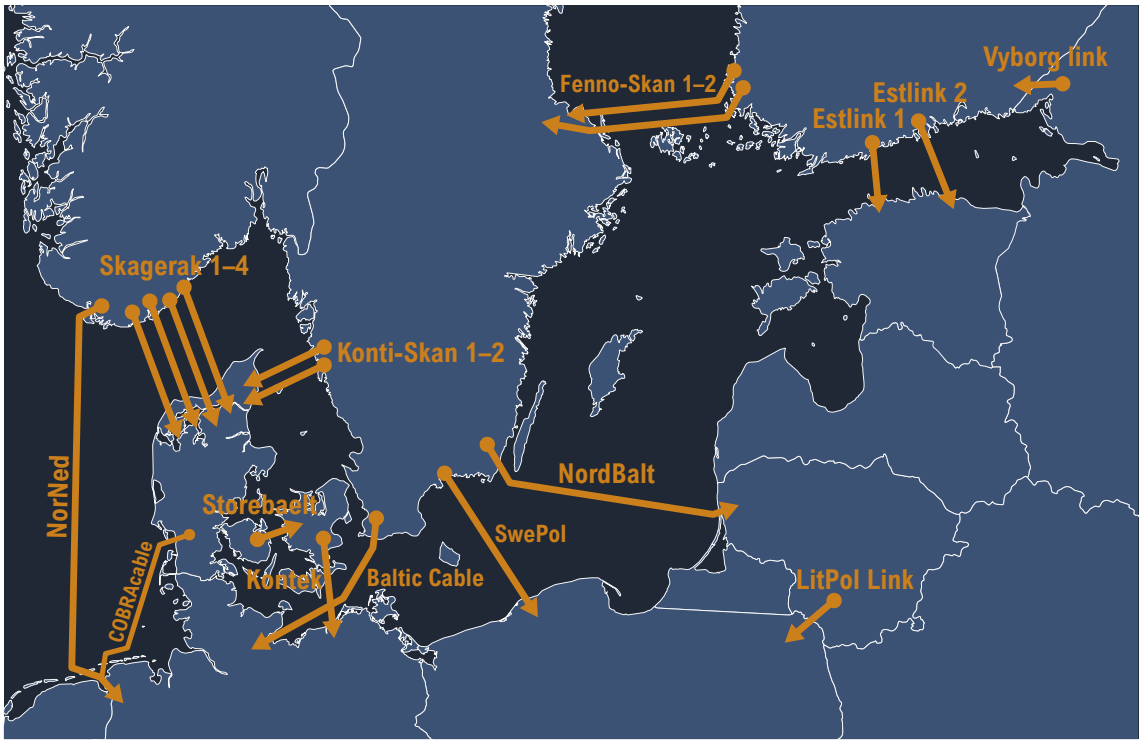


Figure 1.1: A map of the 19 HVDC links included in this report. To distinguish the direction of power flow, each link has a predefined export direction. This direction is indicated by the arrows.

The HVDC links are important components for a stable operation of the Nordic and Baltic power system while supporting the commercial power trade in the European energy markets. Furthermore, the HVDC links can provide other important functions like voltage and emergency power support to the HVAC grid. Hence, the advantages of keeping the HVDC links in operation as much as possible are indisputable.

To achieve as much uptime as possible, the number and length of disturbance outages must be kept at minimum. This requires high-quality hardware components, thorough installation routines, and efficient fault analysis combined with preventive maintenance. However, planned outages and limitations due to maintenance work are necessary but should be planned and conducted as efficiently as possible.

Therefore, mapping the available capacity, including the reasons for unavailability, is of vital interest for the utilisation of this infrastructure. Furthermore, the utilisation of the links directly correlates with the commercial value of the energy trade.

2 Scope

The ENTSO-E HVDC Utilisation and Unavailability Statistics 2019 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 transfer of an HVDC connection. Furthermore, disturbance outages are more thoroughly examined than other events.

The scope of the ENTSO-E HVDC Utilisation and Unavailability Statistics 2019 is different from the CIGRE HVDC statistics, which focuses more on outages, faults and disturbances of the HVDC links. This means that CIGRE is more detailed regarding what happens at the HVDC station, and includes transients, commutation failures, thyristor failures and so on. In general, DISTAC has the macro view and CIGRE has the micro view. But most of the data is the same for both reports.

2.1 Contact persons

Each country is represented by at least one contact person, responsible for the statistical information of the corresponding country. The contact person can provide additional information concerning the HVDC availability and utilisation statistics. The relevant contact information is given in Appendix B.

3 Methods, definitions and calculations

To compare the utilisation and availability between HVDC links, different ways of using them must be discerned and understood. This chapter explains the availability and utilisation categories used to differentiate between means of utilising HVDC links. The hierarchy of the categories is illustrated in Figure 3.1.

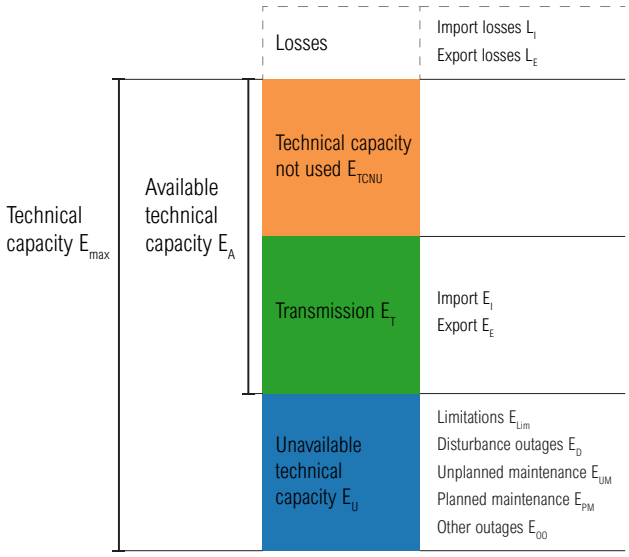


Figure 3.1: The hierarchy of the availability and utilisation categories used in the HVDC statistics.

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)*.

The *available technical capacity (E_A)* is further divided into technical capacity that has been *transmitted (E_T)*, that is, *imported energy (E_I)* and *exported energy (E_E)*, and into technical capacity that could have been utilised, that is, *technical capacity not used (E_{TCNU})*.

- *Exported energy (E_I)* is the energy transferred from the HVDC link to the exporting AC side. The direction of export is defined for each HVDC link and can be viewed in Table 4.2 or in the respective subchapter in Section 5.3. It does not include *export losses (L_I)*, that is, the energy losses in any of the HVDC link components during export. It should be noted that these values are measurements and therefore considered factual.
- *Imported energy (E_E)* and *import losses (L_E)* is defined like the exported energy, but with an opposite point of view.
- *Technical capacity not used (E_{TCNU})* is the amount of energy that has not been imported or exported or been unavailable due to limitations or outages.

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 of the HVDC link.
- *Disturbance outages (E_D)* is technical capacity lost due to a fault on the HVDC link or in the AC grid causing a total outage of the link. This could be a forced outage or an automatic trip.
- *Unplanned maintenance outages (E_{UM})* occurs when the HVDC link is not in service because of urgent maintenance, inspection, fault tracing or repairing after disturbances or other faults that cannot wait until a maintenance outage can be planned and (re-)scheduled. Unplanned implies that the outage is to be taken as soon as possible due to increased risk of re-trip or further damage.
- *Planned maintenance outages (E_{PM})* is technical capacity lost due to maintenance work on the HVDC link. The work must be done to retain an entity's ability to perform its required function. Examples for planned maintenance are annual and preventive maintenance, replacement and updating of components.
- *Other outages (E_{OO})* is technical capacity lost due to any other reason except those mentioned above. This could be, for example, when the markets do not need the transmission capacity of the link and the link is disconnected.

4 Technical details of the HVDC links

Table 4.1 presents the main properties of the HVDC links while Table 4.2 presents the technical properties of the HVDC lines. The predefined export directions are also presented in Figure 1.1.

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 4.1: Main properties of the HVDC links.

Link	Commissioning year	Market connection	Type of HVDC converter	Rated power, mono-polar (MW)	Parallel monopolar capacity (MW)	Bipolar capacity (MW)	Export direction
Baltic Cable	1994	Yes	LCC	600			South
COBRAcable	2019	Yes	VSC	700			West
EstLink 1	2006	Yes	VSC	350	1000		South
EstLink 2	2014	Yes	LCC	650			South
Fenno-Skan 1	1989	Yes	LCC	400	1200	1200	West
Fenno-Skan 2	2011	Yes	LCC	800			West
Kontek	1995	Yes	LCC	600			South
Konti-Skan 1[2]	2008	Yes	LCC	370	680/740		West
Konti-Skan 2[2]	1988	Yes	LCC	370			West
LitPol Link	2015	Yes	LCC	500			West
NordBalt	2016	Yes	VSC	700			South
NorNed	2008	Yes	LCC	700			South
Skagerrak 1	1976–	Yes	LCC	236			South
Skagerrak 2	1977	Yes	LCC	236	1000	1000	South
Skagerrak 3	1993	Yes	LCC	478			South
Skagerrak 4	2014	Yes	VSC	682			South
Storebaelt	2010	Yes	LCC	600			East
SwePol	2000	Yes	LCC	600			South
Vyborg Link[1]	1981, 1982, 1984, 2000	Partly	LCC	1400			West
Total				10972	3940	2200	

[1] Each commissioning increased capacity by 350 MW. However, the total commercial capacity of Vyborg Link is 1300 MW. Fingrid Oyj, the Finnish transmission system operator, allocates 100 MW for reserves.

[2] Konti-Skan 1 and 2 are rated differently depending of direction of flow. They are rated towards east (import) at 740 MW (370+370) and towards west (export) at 680 MW (340+340). The capacity has been asymmetric due to historical limitations and reserve requirements, along with transmission measurements only being done in DK1. As a step towards correcting this, the rated capacity at the receiving end of DK1 was changed from 680 MW to 715 MW on 1 October 2019. As the final step towards correcting the asymmetrical NTC capacities, measurements will be done on receiving ends of the cables as of 1 February 2020.

Table 4.2: Technical details of the HVDC links

Link	Total length of the link (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 km)	0	
EstLink 1	105		210 (2 × 105 km)		
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		
NorNed	580	580			
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			
Storebaelt	57	57			
SwePol	254	254			
Vyborg Link	< 1				< 1

5 Results

This chapter presents the utilisation and unavailability of all the HVDC links as well as individual presentations of each HVDC link connected to the Nordic and Baltic power system.

Section 5.1 provides an overview of the HVDC links for the year 2019 and Section 5.2 provides an overview of the years 2012–2019. Section 5.3 presents the availability and utilisation of each HVDC link for the year 2019 as well as an annual overview of the utilisation and a trend of the utilisation and the number of outages for the years 2012–2019.

5.1 Overview of 2019

In 2019, 52.9 TWh of electric energy was transmitted through the Nordic and Baltic HVDC links. The total number of disturbance outages registered was 63, preventing 2.8 TWh of potential energy transmission, or 3.1 % of the total technical capacity (E_{max}).

Maintenance outages amounted to 3.5 TWh, or 3.8 % of the total technical capacity (E_{max}), and limitations reduced the transmission capacity by 3.8 TWh (4.2 % of the total technical HVDC transmission capacity).

Figure 5.1 presents the overview of the availability and utilisation of HVDC statistics at an aggregated level, thus allowing to compare links with each other. It should be noted that the usages of the links show big variations. Most links are market dependent, some are mostly used only in one direction, and some are used for technical reasons to control power flow for system stability according to agreements. Appendix C shows the overviews of the HVDC links using the same values as Figure 5.1 but ranked according to the highest unavailable technical capacity, according to the highest transmission, and according to the highest technical capacity not used.

Figure 5.2 compares the availability and utilisation of the HVDC links between bidding zones. That is, it measures the utilisation of the energy transfer capacity between the bidding zones ignoring the performance of individual links. However, the number of HVDC links connecting different bidding zones varies. A map portraying the HVDC links is presented in Figure 5.9.

Figure 5.3 presents the percentage unavailable technical capacity (E_U) of the annual technical capacity (E_{max}) due to the disturbance outages. Figure 5.4 presents the number of all disturbance, maintenance and other outages. The explanations for the most notable unavailability in 2019 are listed below. Further details are presented in Section 5.3.

- Baltic Cable limitations were mainly due to wind and solar energy feeds.
- EstLink 2 had 3 more severe disturbance outages. The first was caused by a cooling water leakage, the second by a faulty capacitor and faulty thyristors in the valve hall and the last by a faulty DC voltage divider.
- Konti-Skan 1 and 2 had a considerable amount of planned maintenance due to replacements of conductor lines in Denmark in May. Furthermore, Konti-Skan 1 control system was replaced in October and November and Konti-Skan 2 control system was replaced in September.
- NorNed had 8 disturbances and 4 planned maintenances during 2019. In February, the outage was due to a fault on a bushing in Feda, and filter problems limited the transmission capacity in March–April. The unavailable energy in Q4 was due to maintenance in the Eemshaven region.
- Skagerrak 1 had 1 major disturbance during 2019 due to a failure on the pole transformer on the Norwegian side.
- Skagerrak 4 had 3 more severe disturbances due to faults on the Danish land cable.
- The planned maintenances on Skagerrak 1 and 2 were annual maintenance lasting approximately 57 days each.
- Skagerrak 3 had 1 major planned maintenance for installation and testing of the new control system on the Norwegian side.
- The limitations on Skagerrak 1, 2, 3 and 4 were due to maintenances and restrictions on the maximum allowed electrode currents, which were put in place because of the Skagerrak 4 cable faults.
- SwePol had 1 unplanned maintenance outage due to an oil leakage and 1 disturbance outage due to a valve cooling system failure lasting 29 days.

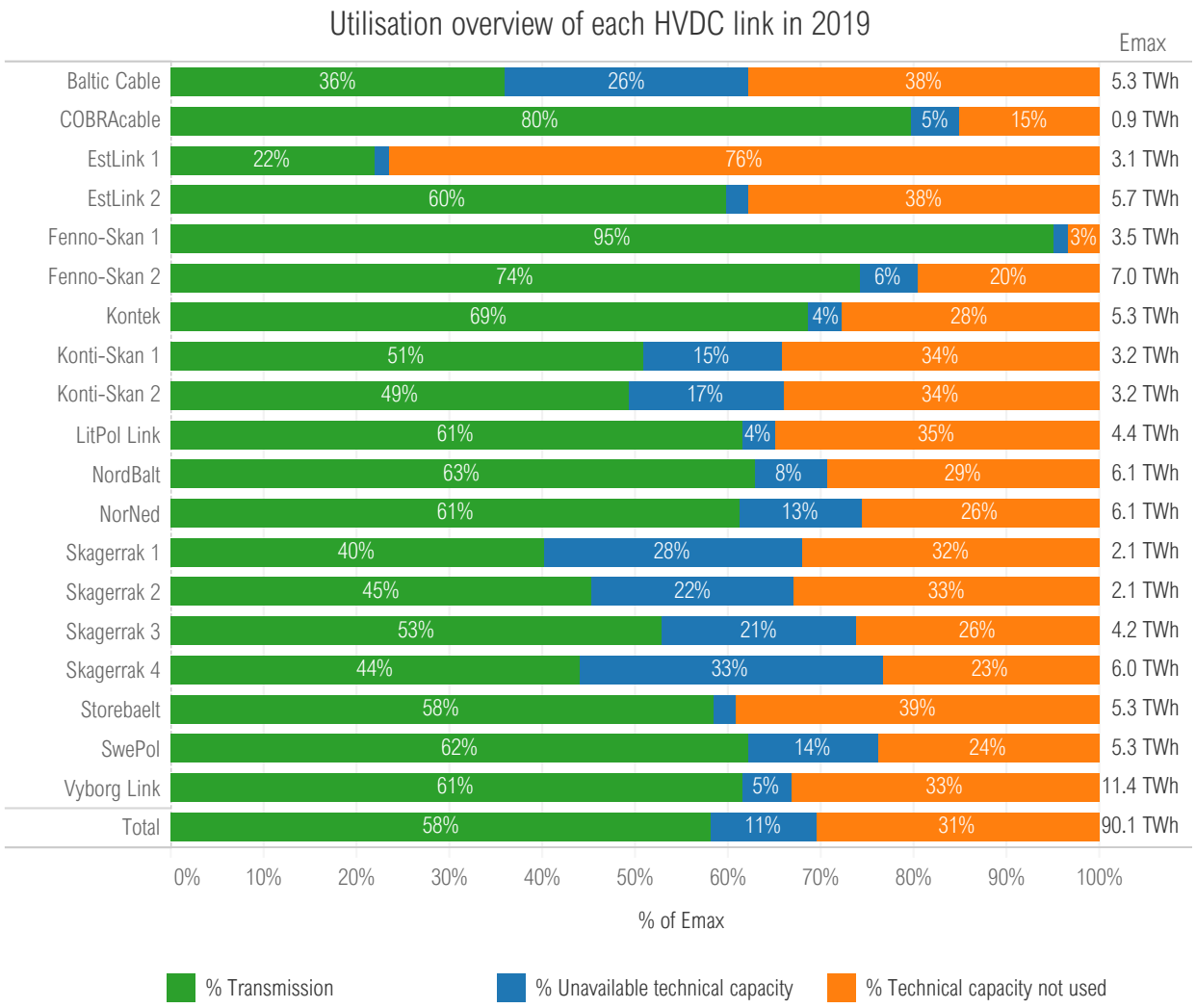


Figure 5.1: Overview of the availability and utilisation of each HVDC link in 2019. The unavailable technical capacity (E_U) is the amount of technical capacity (E_{max}) not available due to limitations or outages. Transmission (E_T) is the amount of technical capacity (E_{max}) imported and exported through the HVDC link. Technical capacity not used (E_{TCNU}) is the amount of energy that has not been imported or exported or been unavailable due to limitations or outages. More detailed explanations can be read in Chapter 3. Appendix C shows the overviews of the HVDC links using the same values as Figure 5.1 but ranked according to the highest unavailable technical capacity, according to the highest transmission, and according to the highest technical capacity not used.

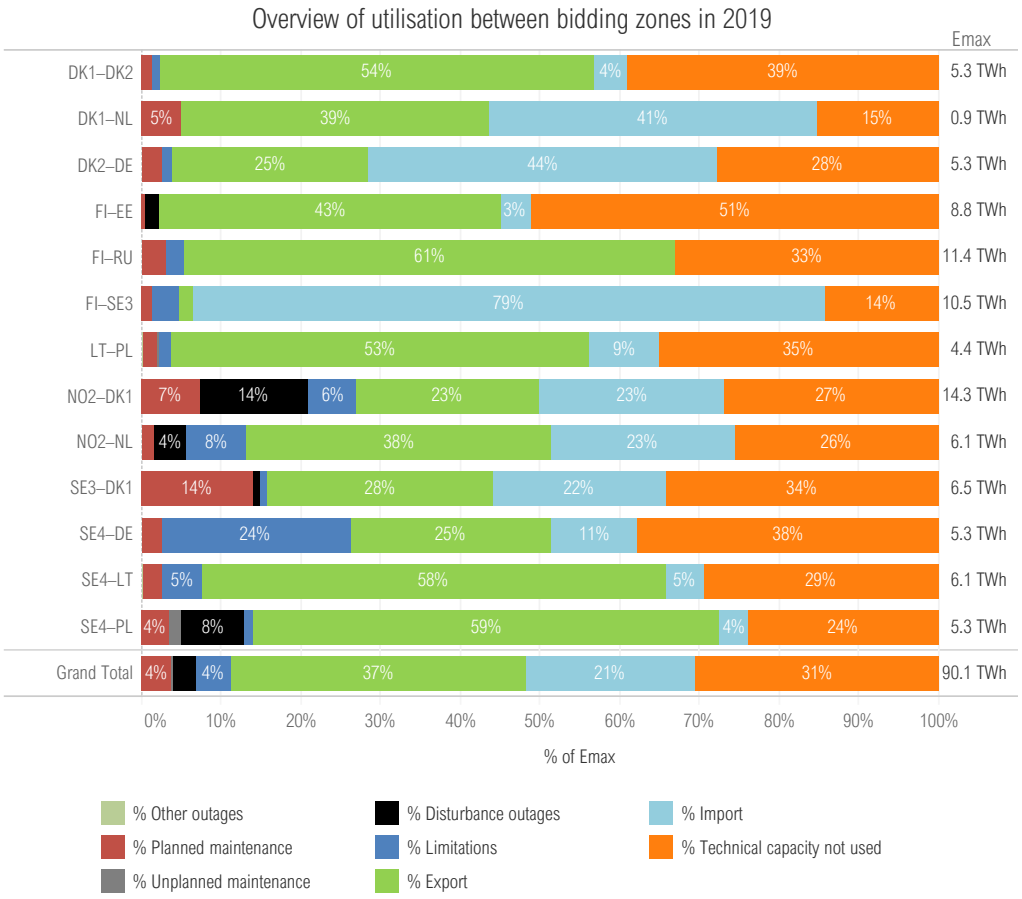


Figure 5.2: Overview of the availability and utilisation of each HVDC link in 2019. More detailed explanations about each utilisation category can be read in Chapter 3.

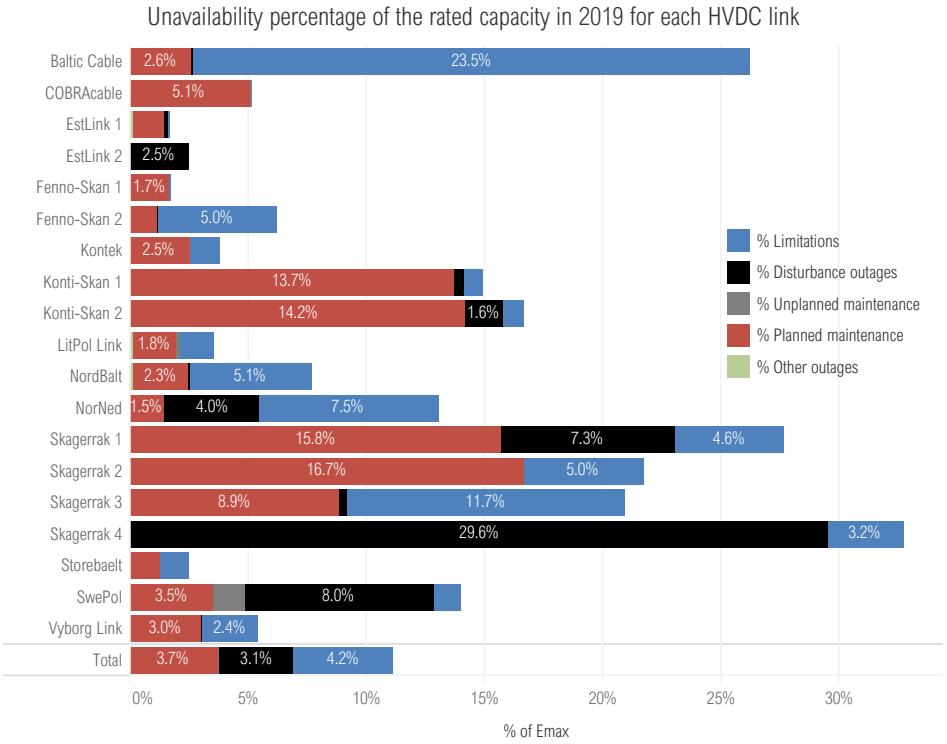


Figure 5.3: Percentage distribution of unavailable technical capacity (E_U) due to limitations, disturbance outages, unplanned and planned maintenance and other outages for each link in 2019.

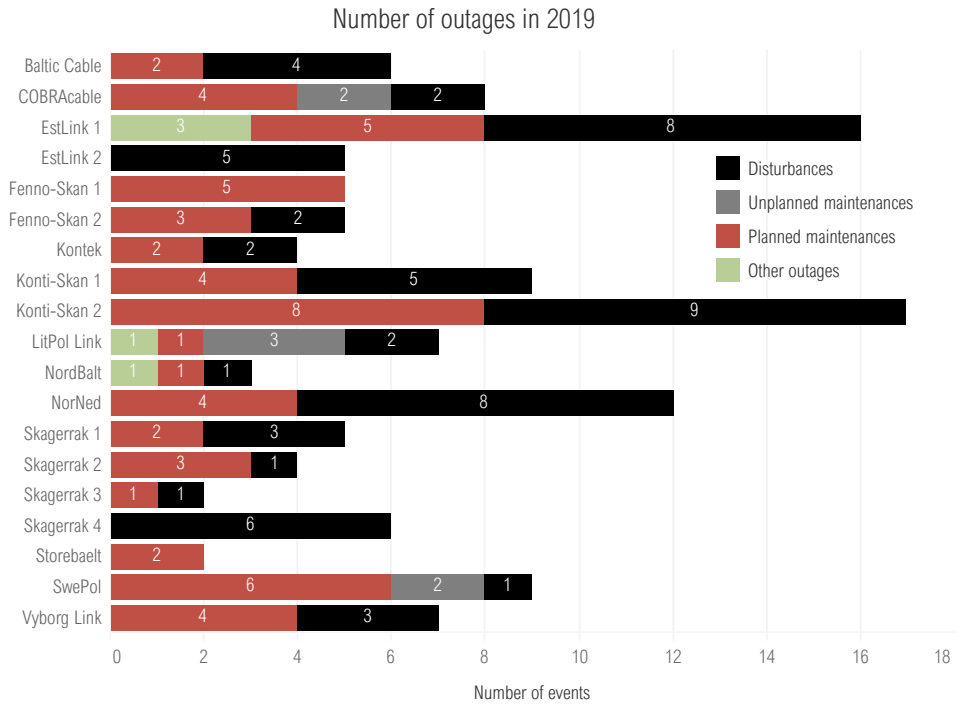


Figure 5.4: The number of disturbance outages, unplanned maintenance and planned maintenance outages and other outages for each link in 2019.

5.2 Overview of years 2012–2019

Because the HVDC links are an important component in the Nordic and Baltic power systems, it is also very interesting to see how the links have been utilised during the past years. Figure 5.5 presents the annual utilisation (%) of all HVDC links and Figure 5.6 presents the annual utilisation with all utilisation categories.

As can be seen, the percentage distribution of transmission (E_T) and unavailable technical capacity (E_U) is showing a slight increasing trend after a significant drop in 2012. However, the total technical capacity (E_{max}) of all HVDC links has increased, as can be seen in Figure 5.6.

Figure 5.7 presents the combined annual hourly utilisation rate for all HVDC links. Figure 5.8 presents the percentage of hours a link has been affected by either a limitation, unplanned or planned maintenance or disturbance or other outages.

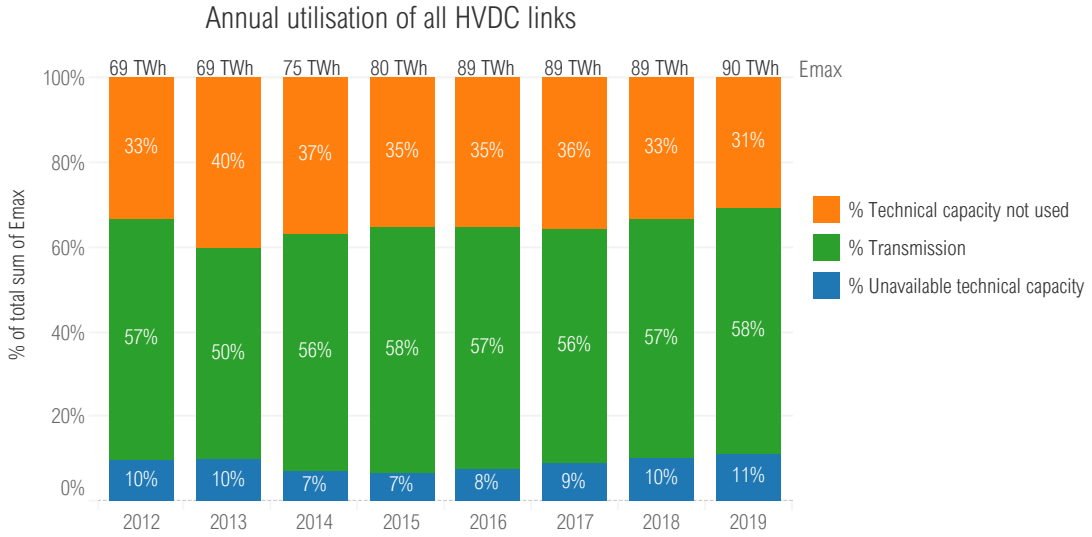


Figure 5.5: The annual utilisation of all HVDC links since 2012. The unavailable technical capacity (E_U) is the amount of technical capacity (E_{max}) not available due to limitations or outages. Transmission (E_T) is the amount of technical capacity (E_{max}) imported and exported through the HVDC links. Technical capacity not used (E_{TCNU}) is the residual energy that has neither been transmitted nor been unavailable due to limitations or outages. More detailed explanations can be read in Chapter 3.

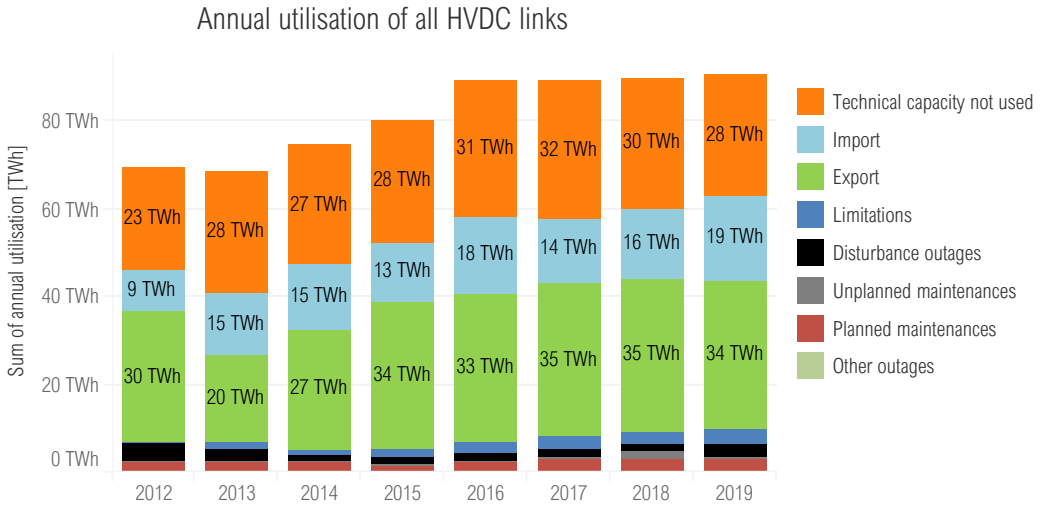


Figure 5.6: Annual utilisation of all HVDC links presented in megawatt hours (MWh). Technical capacity not used (E_{TCNU}) is the residual energy that has neither been transmitted nor been unavailable due to limitations or outages. Transmission (E_T) is the amount of technical capacity (E_{max}) imported and exported through the HVDC links. Limitations, disturbance outages, unplanned and planned maintenance outages and other outages form together the unavailable technical capacity (E_U). More detailed explanations can be read in Chapter 3. From 2012, there are 14 HVDC links included. As of 2014, EstLink 2 and Skagerrak 4 were added. In 2016, LitPol Link and NordBalt were added. In 2019, COBRAcable was added. The maximum technical capacity (E_{max}) is marginally higher in 2012 and 2016 because they are leap years.

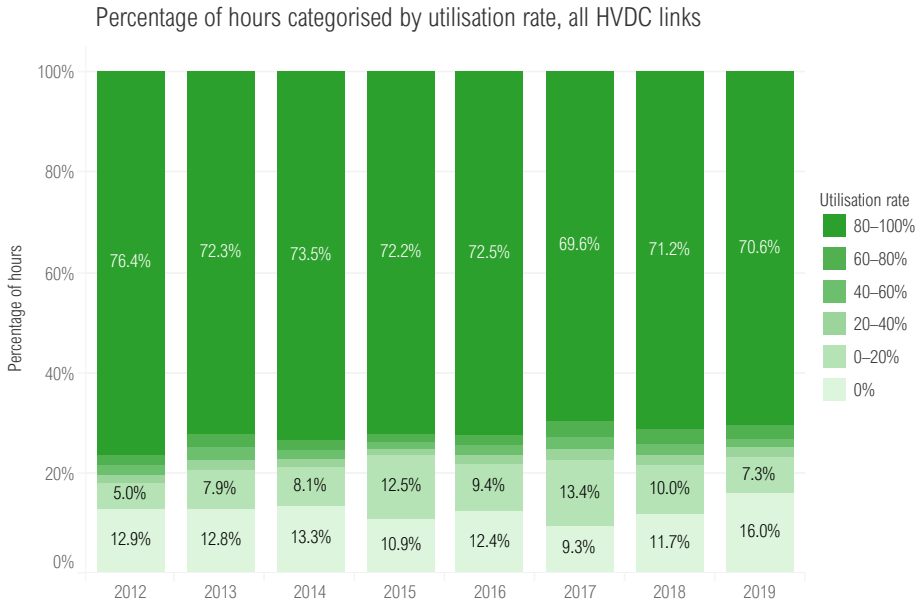


Figure 5.7: Combined annual hourly utilisation rate for all HVDC link. The HVDC links were utilised by more than 80 % of their respective maximum technical capacity 70.9 % of the time during 2019.

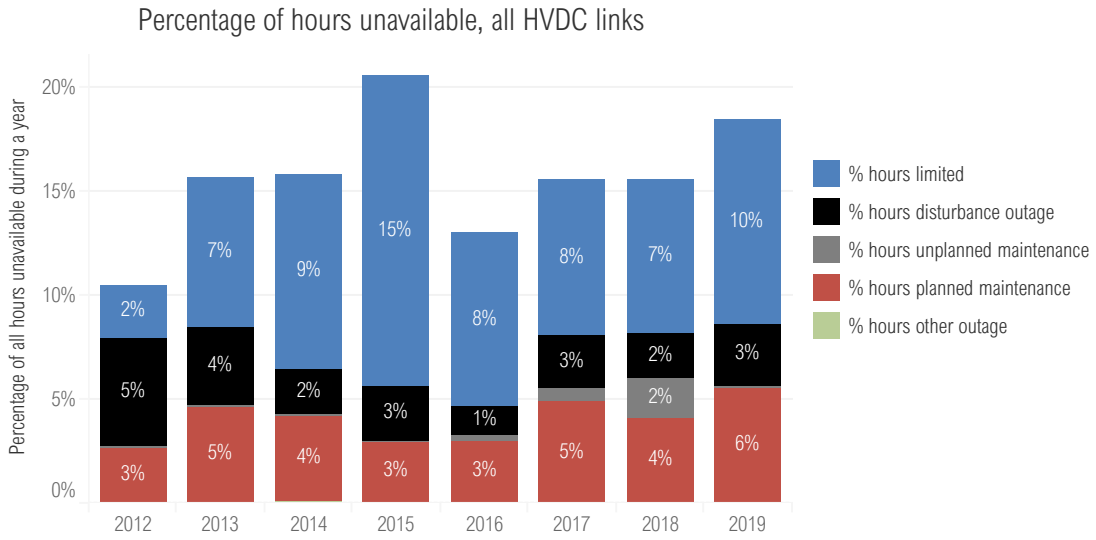


Figure 5.8: The percentage of hours all HVDC links have been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

5.3 Individual presentations of each HVDC link

This section presents the performance of each HVDC link. Figure 5.9 presents the geographical location of each HVDC link along with their predefined export direction. The categories used in the following presentations of each separate HVDC link are presented and defined in Chapter 3.

Note that the sums in the tables for each link 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 rated technical capacity of the links. 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".

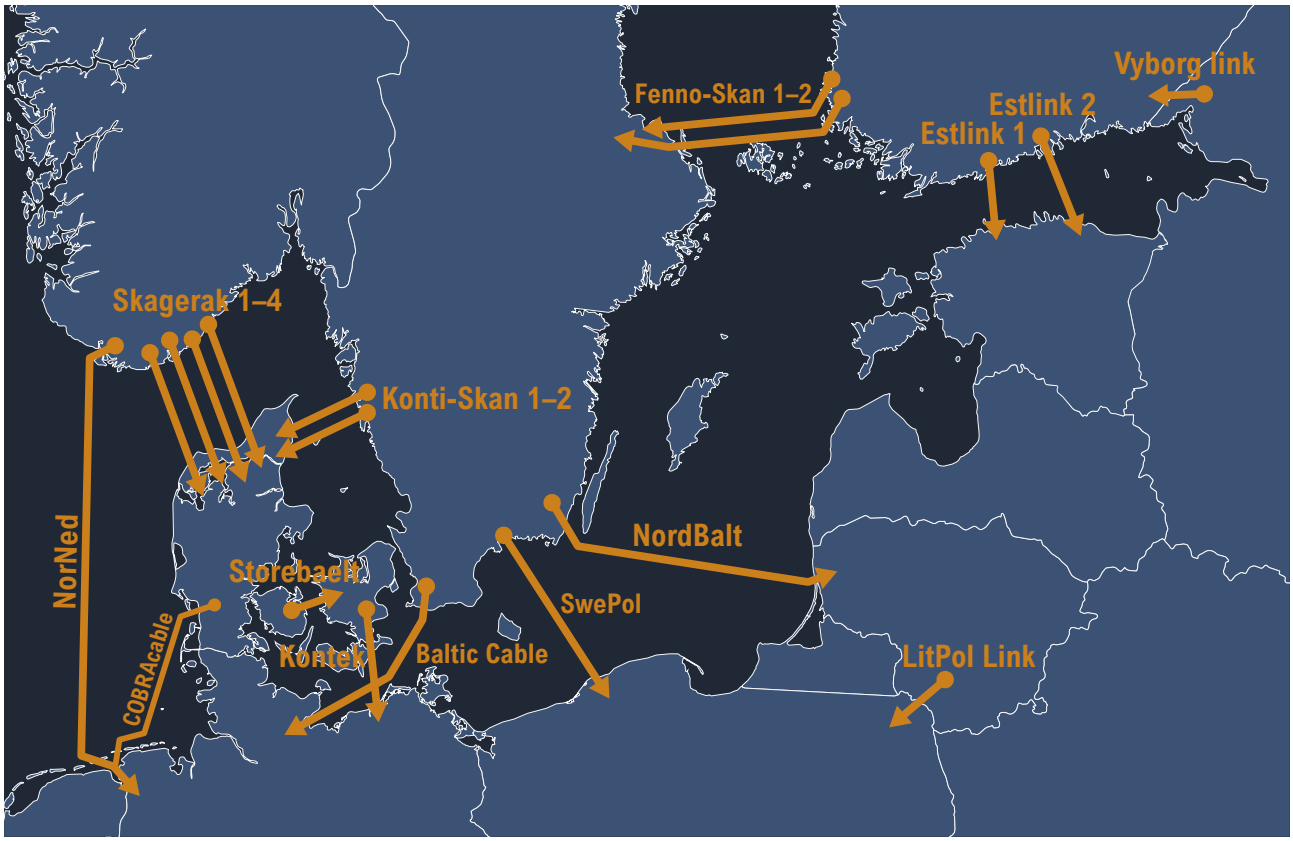


Figure 5.9: A map of the 19 HVDC links included in this report. To distinguish the direction of power flow, each link has a predefined export direction. This direction is indicated by the arrows.

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5.3.1 Baltic Cable

Figure 5.10 presents the availability and utilisation of Baltic Cable for 2019 and Table 5.1 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 2019, Baltic Cable had an available technical capacity of 74 %. The technical capacity not used was 38 %. Totally, 1.3 TWh (25 % of the technical capacity) was exported from Sweden to Germany and 0.6 TWh (11 % of the technical capacity) was imported to Sweden.

The annual maintenance of Baltic Cable lasted from late September to early October. Additionally, Baltic Cable had 4 disturbance outages with only minor impact.

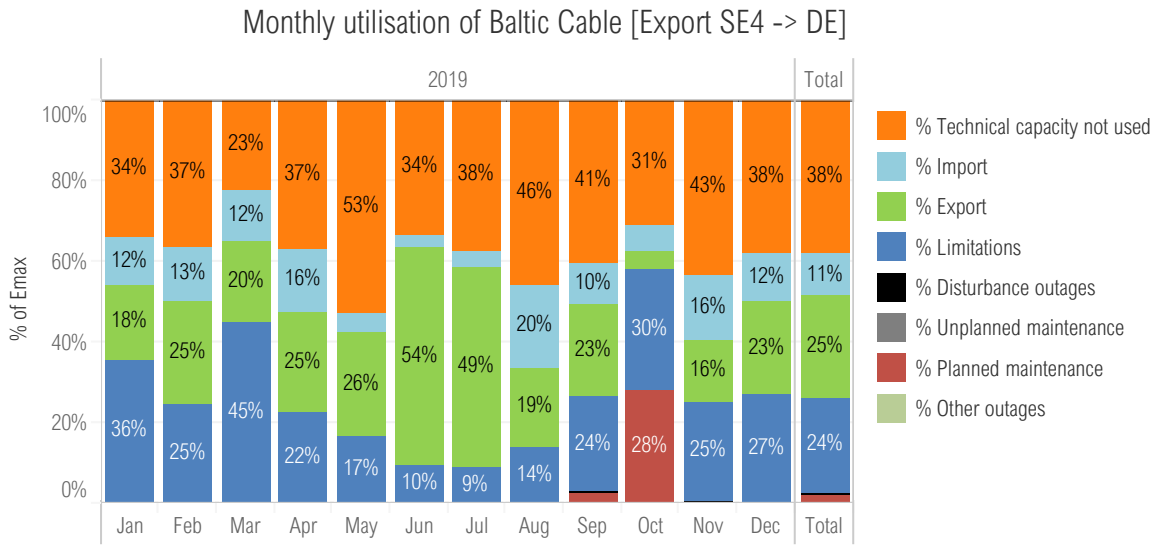

Figure 5.10: Percentage distribution of the availability and utilisation per category according to month for Baltic Cable in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.1: Monthly distribution of the technical capacity (E_{max}) for The Baltic Cable in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Baltic Cable [Export SE4 -> DE]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	151.9	147.7	101.0	159.4	236.2	145.0	168.2	206.5	175.7	139.5	187.9	169.0	1988.1	37.8%
Import, GWh	53.5	53.9	54.8	67.1	21.0	12.8	18.5	91.0	43.1	28.5	69.1	53.5	566.8	10.8%
Export, GWh	81.7	102.2	89.0	109.4	115.3	233.2	220.5	87.1	98.4	20.0	67.3	103.6	1327.7	25.2%
Limitations, GWh	159.6	99.3	201.6	96.6	74.0	41.8	40.5	62.1	102.9	133.2	106.5	120.6	1238.6	23.5%
Disturbance outages, GWh	-	0.6	-	-	-	-	-	-	1.2	-	1.3	-	3.1	0.1%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	-	-	-	-	-	10.8	125.8	-	-	136.6	2.6%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	1.2	1.3	1.2	1.4	0.4	0.3	0.4	2.1	1.0	2.1	1.7	1.1	14.1	0.3%
Export losses, GWh	3.3	3.3	2.9	3.4	4.2	6.0	6.6	4.0	4.1	6.3	3.4	3.9	51.4	1.0%
Total, GWh	446.7	403.7	446.3	432.5	446.6	432.8	447.7	446.7	432.0	447.0	432.1	446.7	5260.8	100.0%

Figure 5.11 presents the annual utilisation of Baltic Cable per utilisation and unavailability category for the years 2012–2019.

Figure 5.12 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 2012–2019. Figure 5.13 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

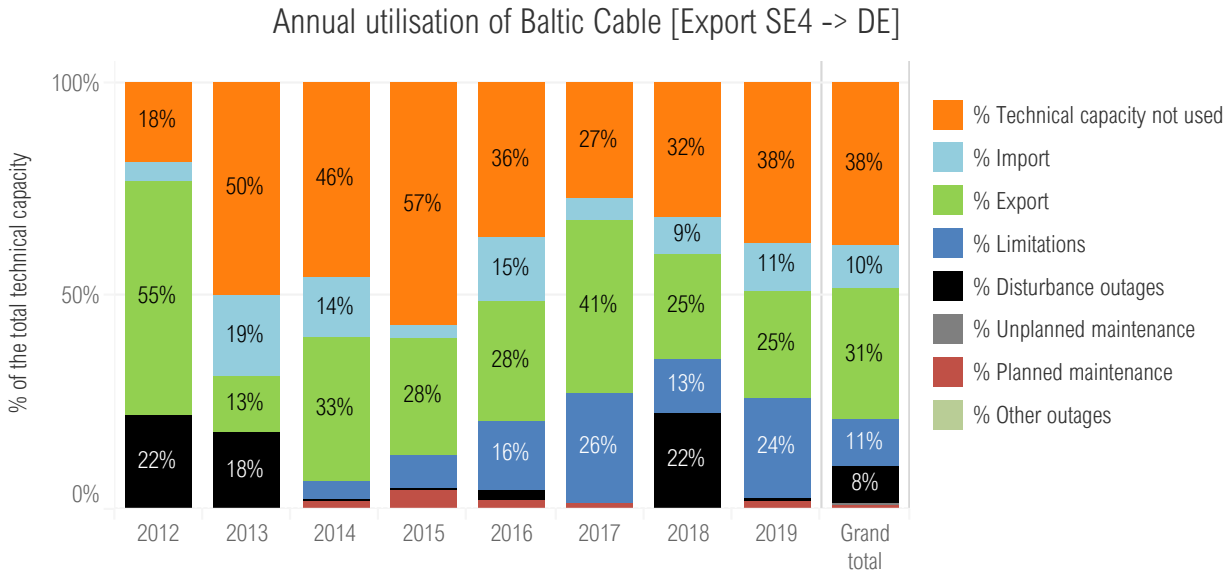

Figure 5.11: Annual utilisation of Baltic Cable according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

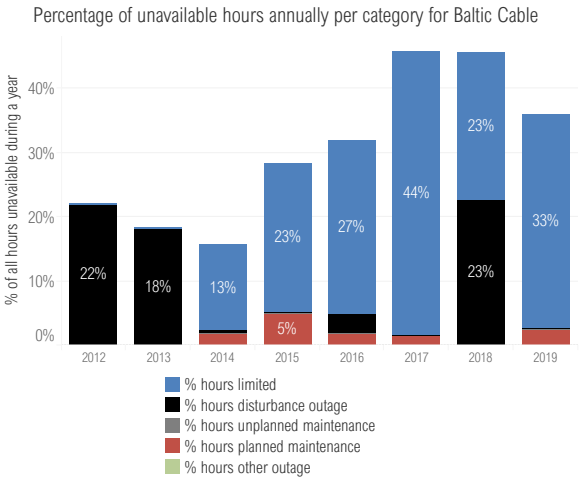

Figure 5.12: Percentage of hours Baltic Cable has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

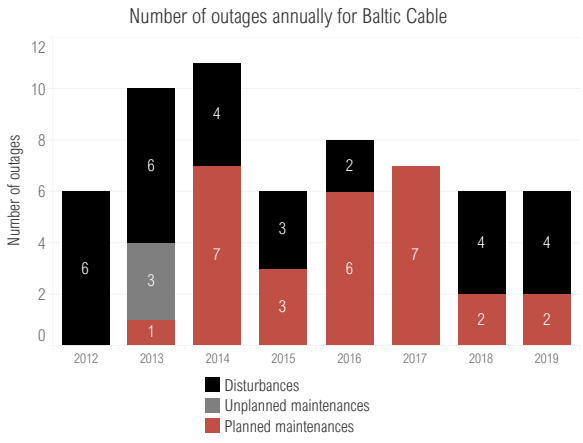

Figure 5.13: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Baltic Cable for the years 2012–2019. Baltic cable has not had any other outages during the years 2012–2019.

5.3.2 COBRAcable

Figure 5.14 presents the availability and utilisation of COBRAcable for 2019 and Table 5.2 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). The transmission capacity of COBRAcable is 700 MW.

In 2019, COBRAcable had had an available technical capacity of 95 %. The technical capacity not used was 15 %. Totally, 0.6 TWh (39 % of the technical capacity) was exported from Denmark to the Netherlands and 0.7 TWh (41 % of the technical capacity) was imported to Denmark.

In 2019, COBRAcable was already used in trial mode and was available to the market as of 11 September, even though it was officially commissioned 5 November. Therefore, there is no unused technical capacity (E_{TCNU}) before 5 November, as can be seen in Figure 5.14.

COBRAcable had two disturbance outages, which were most likely teething troubles. Additionally, scheduled maintenance (lasting 3 days) was performed in late November before the final handover to operation in November.

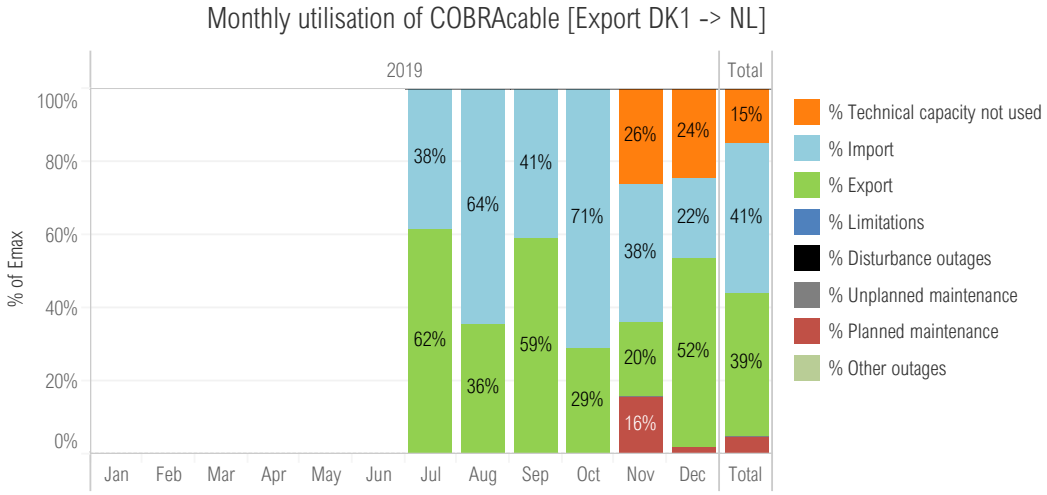

Figure 5.14: Percentage distribution of the availability and utilisation per category according to month for COBRAcable in 2019. The availability and utilisation categories are defined in detail in Chapter 3. There is no unused technical capacity (E_{TCNU}) during July–November because COBRAcable was commissioned 5 November. Technical capacity not used is ignored during the testing period before commissioning.

Table 5.2: Monthly distribution of the technical capacity (E_{max}) for COBRAcable in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of COBRAcable [Export DK1 -> NL]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	-	-	-	-	-	-	-	-	-	-	115.8	127.4	243.2	15.2%
Import, GWh	-	-	-	-	-	-	1.9	14.8	102.0	250.7	171.1	114.9	655.5	41.0%
Export, GWh	-	-	-	-	-	-	3.0	8.2	145.9	101.6	91.4	268.5	618.5	38.7%
Limitations, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	0.1	-	0.1	0.0%
Planned maintenance, GWh	-	-	-	-	-	-	-	-	-	-	70.7	10.0	80.7	5.1%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	-	-	-	-	-	-	0.1	0.4	2.4	6.1	4.0	2.7	15.8	1.0%
Export losses, GWh	-	-	-	-	-	-	0.1	0.2	4.1	2.8	2.5	7.6	17.4	1.1%
Total, GWh	-	-	-	-	-	-	4.9	23.0	247.9	352.3	449.1	520.8	1598.0	100.0%

This page intentionally left blank because COBRAcable has no historical data past 2019.

5.3.3 EstLink 1

Figure 5.15 presents the availability and utilisation of EstLink 1 for 2019 and Table 5.3 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 2019, EstLink 1 had an available technical capacity of 98 %. The technical capacity not used was 76 % due to that EstLink 2 is prioritised because of its lower transmission losses and because EstLink 1 is often used in Automatic Frequency Control Mode. Totally, 0.6 TWh (20 % of the technical capacity) was exported from Finland to Estonia and 0.1 TWh (2 % of the technical capacity) was imported to Finland.

The annual maintenance of EstLink 1 lasted four days in June 2019. Additionally, EstLink 1 had 8 short disturbance outages with only minor impact Most of them had the same reoccurring (and externally originated) cause.

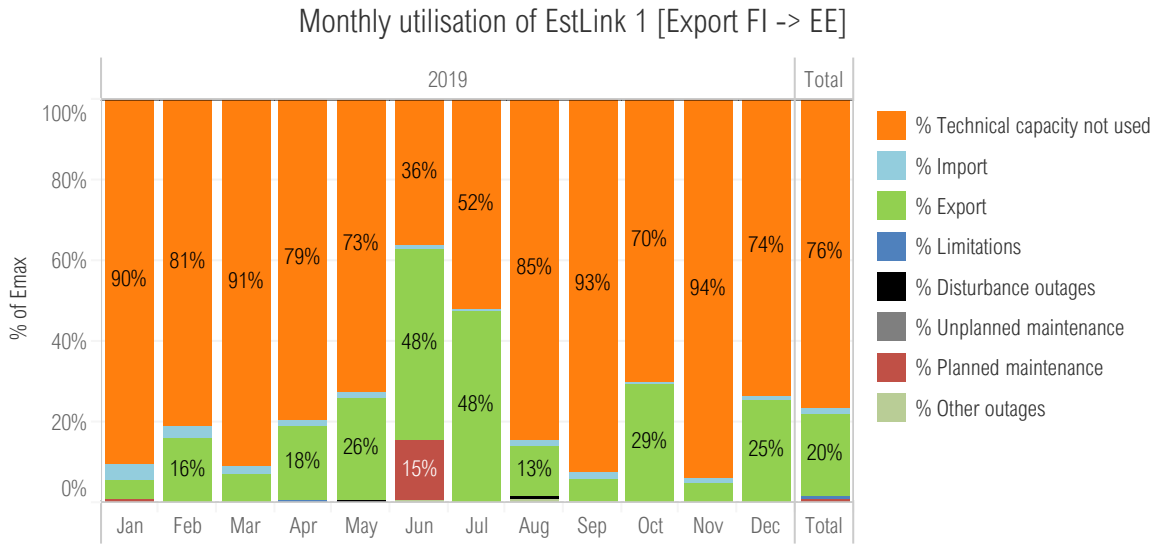

Figure 5.15: Percentage distribution of the availability and utilisation per category according to month for EstLink 1 in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.3: Monthly distribution of the technical capacity (E_{max}) for EstLink 1 in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of EstLink 1 [Export FI -> EE]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	235.0	190.6	236.7	200.3	188.8	90.3	135.0	220.2	233.4	182.0	236.3	192.0	2340.6	76.3%
Import, GWh	10.9	7.3	5.4	4.0	4.1	2.4	1.4	3.7	3.4	2.4	3.1	2.3	50.4	1.6%
Export, GWh	12.5	37.3	17.7	45.9	66.6	119.9	124.0	32.9	14.4	76.4	12.5	66.1	626.3	20.4%
Limitations, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0%
Disturbance outages, GWh	-	-	-	1.8	0.9	-	-	0.2	-	-	-	-	2.9	0.1%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	2.0	-	0.2	-	-	38.7	-	-	-	-	-	-	40.9	1.3%
Other outages, GWh	-	-	-	-	-	0.8	-	3.4	0.8	-	-	-	5.0	0.2%
Import losses, GWh	1.7	2.8	2.0	3.3	4.3	6.6	7.1	2.9	2.0	4.8	1.9	4.5	44.0	1.4%
Export losses, GWh	1.7	1.3	1.5	1.2	1.1	0.4	0.5	1.5	1.5	1.0	1.5	1.1	14.3	0.5%
Total, GWh	260.4	235.2	260.1	252.0	260.4	252.0	260.4	260.4	252.0	260.8	252.0	260.4	3066.0	100.0%

Figure 5.16 presents the annual utilisation of EstLink 1 per utilisation and unavailability category for the years 2012–2019.

Figure 5.17 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 2012–2019. Figure 5.18 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

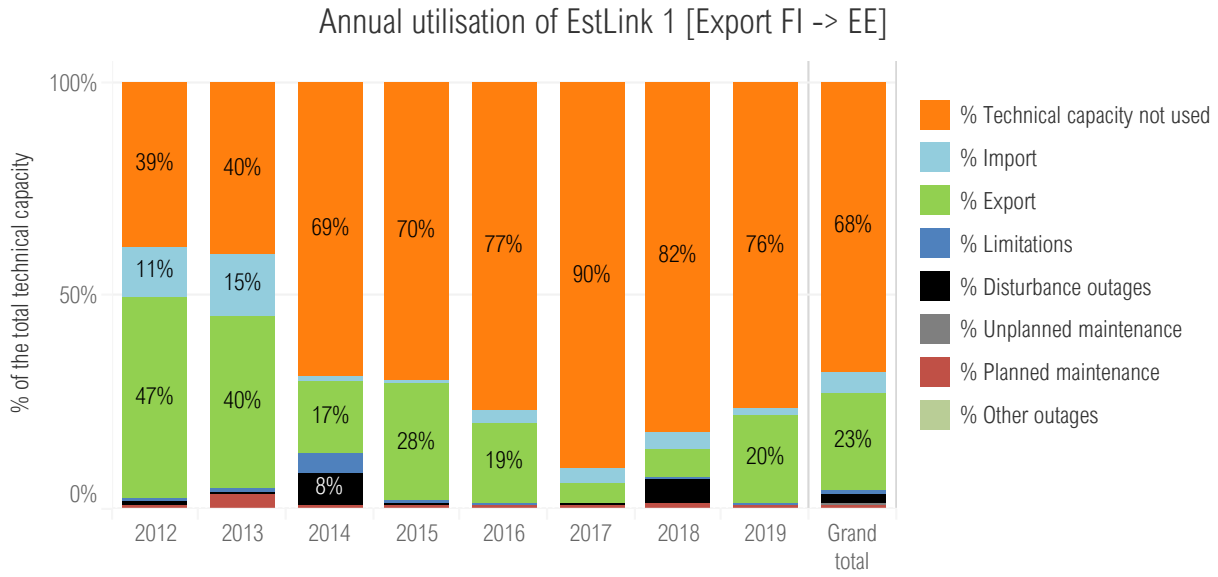

Figure 5.16: Annual utilisation of EstLink 1 according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

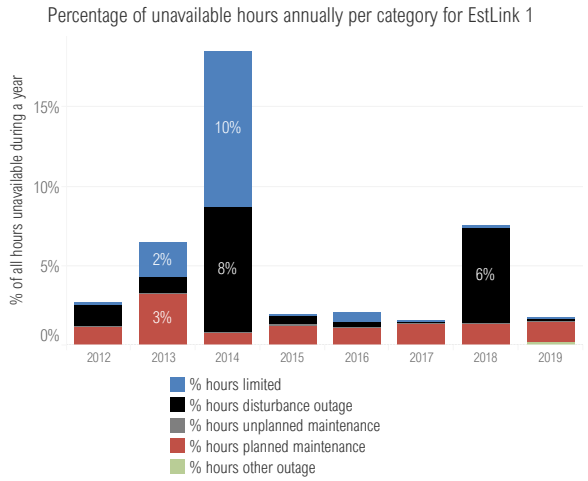

Figure 5.17: Percentage of hours EstLink 1 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

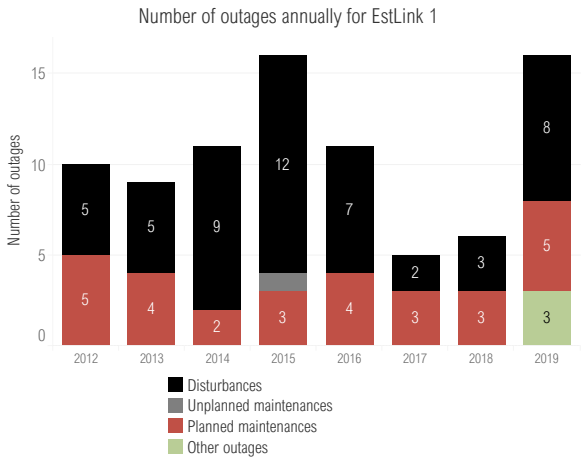

Figure 5.18: The annual number of disturbances, unplanned and planned maintenance outages and other outages for EstLink 1 for the years 2012–2019.

5.3.4 EstLink 2

Figure 5.19 presents the availability and utilisation of EstLink 2 for 2019 and Table 5.4 presents the numerical values behind it. EstLink 2 was commissioned in Feb 2014 and is the second HVDC connection between Finland and Estonia. In Finland, it is connected to Anttila substation (bidding zone FI) and in Estonia, it is connected to Püssi substation (bidding zone EE). The transmission capacity of EstLink 2 is 650 MW.

In 2019, EstLink 2 had an available technical capacity of 97 %. The technical capacity not used was 38 %. Totally, 3.2 TWh (55 % of the technical capacity) was exported from Finland to Estonia and 0.3 TWh (4 % of the technical capacity) was imported to Finland.

No annual maintenance for EstLink 2 was held in 2019. Normally, there is annual maintenance for HVDC links but for EstLink 2 the maintenance happens every second year. Additionally, there were 5 disturbances during 2019, of which 3 had a more severe impact. The disturbance outage in April was caused by a cooling water leakage, the disturbance outage in June by a faulty capacitor and faulty thyristors in the valve hall and the last one in December was caused by a faulty DC voltage divider.

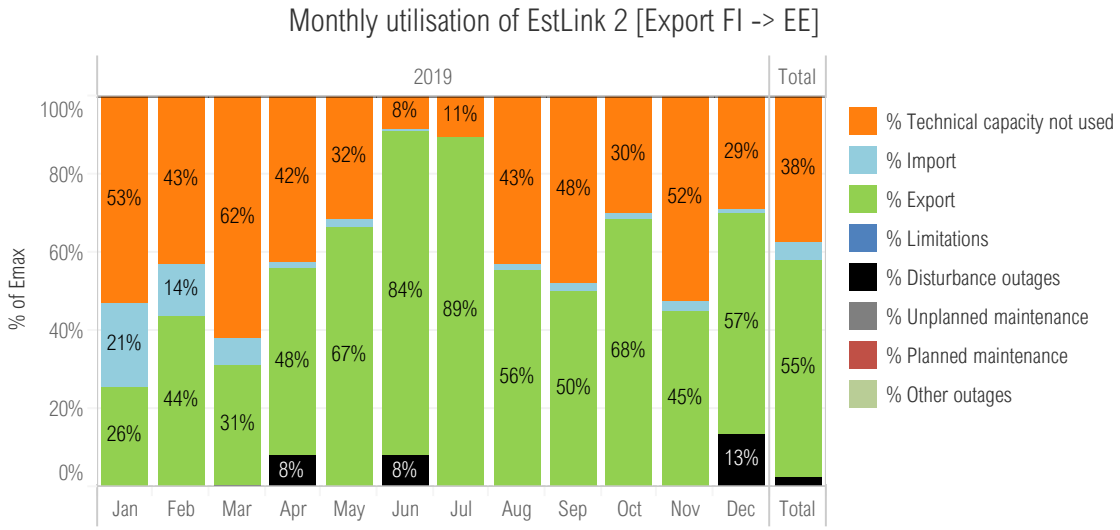

Figure 5.19: Percentage distribution of the availability and utilisation per category according to month for EstLink 2 in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.4: Monthly distribution of the technical capacity (E_{max}) for EstLink 2 in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of EstLink 2 [Export FI -> EE]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	255.2	187.2	298.7	198.4	152.9	39.3	51.8	207.9	225.1	145.5	245.0	141.3	2148.2	37.7%
Import, GWh	103.9	59.2	33.5	7.3	8.3	0.2	-	6.2	9.9	7.5	13.4	3.3	252.8	4.4%
Export, GWh	124.5	190.4	148.0	225.3	322.3	391.7	431.8	269.6	233.0	331.3	209.6	274.0	3151.4	55.3%
Limitations, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Disturbance outages, GWh	-	-	2.8	36.9	0.2	36.9	-	-	-	-	-	65.0	141.7	2.5%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	2.5	4.0	2.9	4.4	6.8	8.7	9.5	5.5	4.6	7.1	4.1	5.6	65.6	1.2%
Export losses, GWh	2.0	1.1	0.7	0.2	0.2	-	-	0.1	0.2	0.2	0.3	0.1	4.9	0.1%
Total, GWh	483.6	436.8	483.0	468.0	483.6	468.1	483.6	483.6	468.0	484.3	468.0	483.6	5694.2	100.0%

Figure 5.20 presents the annual utilisation of EstLink 2 per utilisation and unavailability category for the years 2014–2019.

Figure 5.21 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 2014–2019. Figure 5.22 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2014–2019.

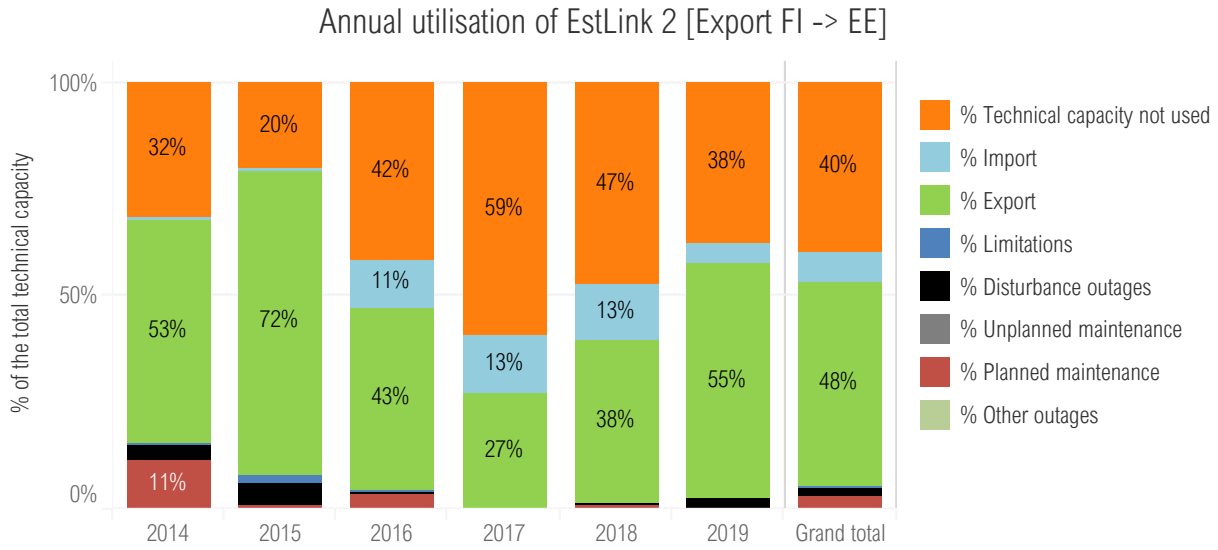

Figure 5.20: Annual utilisation of EstLink 2 according to the utilisation and unavailability categories for the years 2014–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

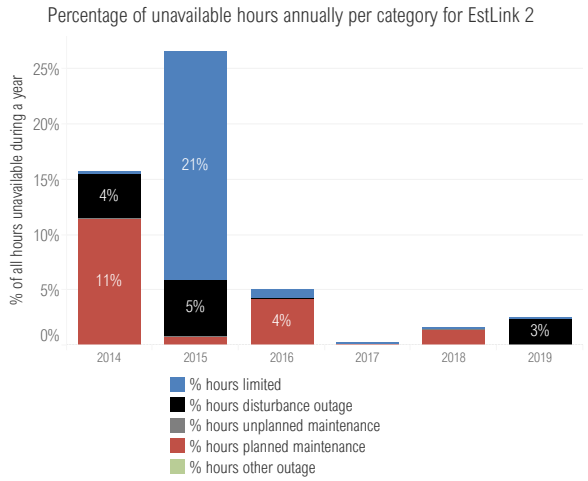

Figure 5.21: Percentage of hours EstLink 2 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2014–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

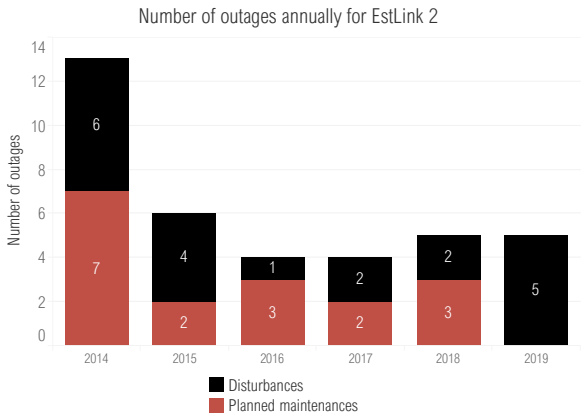

Figure 5.22: The annual number of disturbances, unplanned and planned maintenance outages and other outages for EstLink 2 for the years 2014–2019. EstLink 2 had neither unplanned maintenance nor other outages during this period.

5.3.5 Fenno-Skan 1

Figure 5.23 presents the availability and utilisation of Fenno-Skan 1 for 2019 and Table 5.5 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 used to be 500 MW during summer and 550 MW during winter but was permanently decreased to 400 MW on 1 July 2014 after detailed DC cable investigations were completed. The investigations were started after a cable fault 12 February 2013.

In 2019, Fenno-Skan 1 had an available technical capacity of 98 %. The technical capacity not used was 3 %. Totally, 0.7 GWh (0.2 % of the technical capacity) was exported from Finland to Sweden and 3.2 TWh (95 % of the technical capacity) was imported to Finland.

The annual maintenance of Fenno-Skan 1 lasted five days from late September to early October. Fenno-Skan 1 had no disturbance outages during 2019.

It should be noted, that Fenno-Skan 1 and 2 is sometimes operated at equivalent transmission levels but with reversed directions to keep the temperature of Fenno-Skan 1 at adequate levels. The utilisation is still regarded as import and export even though the resulting net exchange between Finland and Sweden is zero.

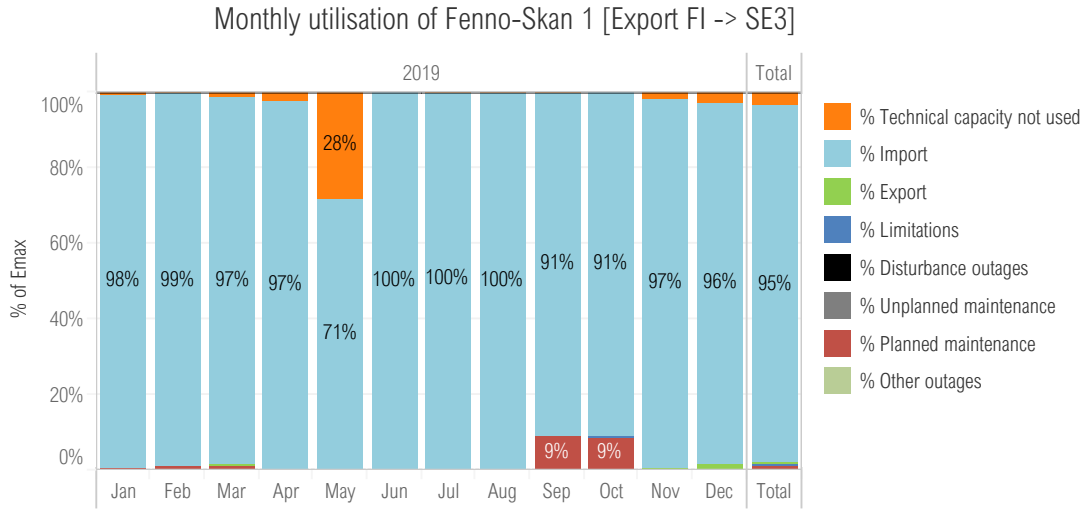

Figure 5.23: Percentage distribution of the availability and utilisation per category according to month for Fenno-Skan 1 in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.5: Monthly distribution of the technical capacity (E_{max}) for Fenno-Skan 1 in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Fenno-Skan 1 [Export FI -> SE3]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	3.6	1.2	4.5	7.7	84.7	-	0.2	0.2	0.5	-	5.3	8.4	116.2	3.3%
Import, GWh	293.7	266.1	289.0	280.6	213.1	288.6	297.2	298.0	262.0	272.3	281.5	285.2	3327.4	94.8%
Export, GWh	-	-	1.2	0.1	-	-	-	-	-	-	1.9	4.9	8.1	0.2%
Limitations, GWh	-	-	-	-	0.4	-	0.7	-	-	-	0.2	-	1.2	0.0%
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	1.2	2.0	2.9	-	-	-	-	-	26.0	26.2	-	-	58.3	1.7%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	7.9	7.2	7.7	7.4	6.0	7.8	7.5	7.6	6.7	7.0	7.3	7.5	87.8	2.5%
Export losses, GWh	-	-	-	-	-	-	-	-	-	-	0.1	0.1	0.3	0.0%
Total, GWh	298.5	269.3	297.6	288.4	298.2	288.6	298.1	298.2	288.5	298.4	288.8	298.5	3511.2	100.0%

Figure 5.24 presents the annual utilisation of Fenno-Skan 1 per utilisation and unavailability category for the years 2012–2019.

Figure 5.25 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 2012–2019. Figure 5.26 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

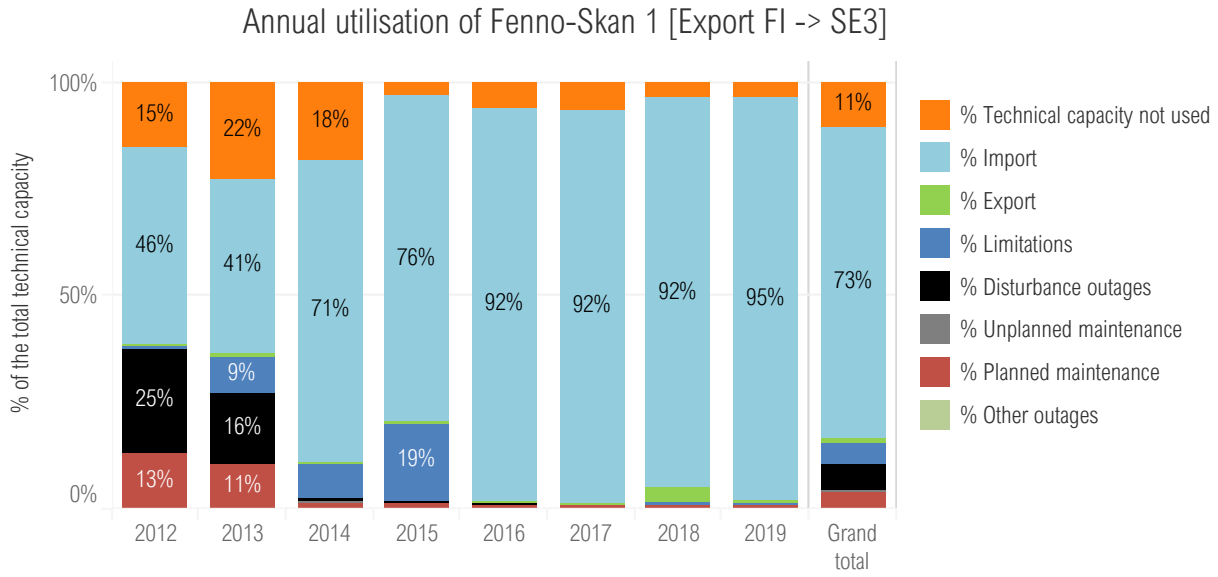

Figure 5.24: Annual utilisation of Fenno-Skan 1 according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

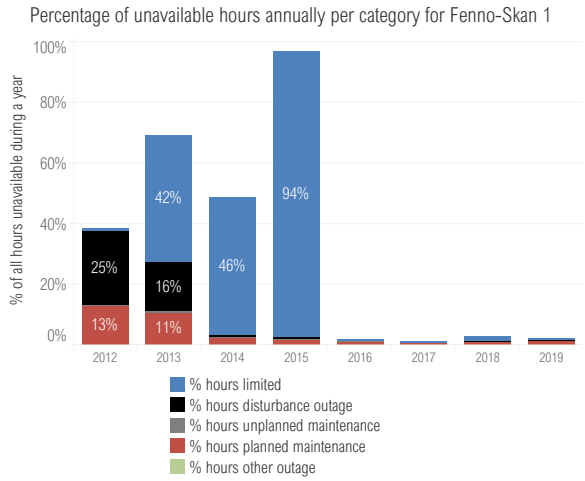

Figure 5.25: Percentage of hours Fenno-Skan 1 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

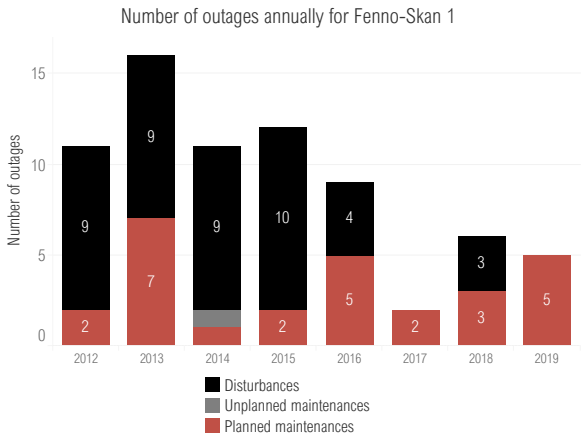

Figure 5.26: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Fenno-Skan 1 during 2012–2019. Fenno-Skan 1 had no other outages during the years 2012–2019.

5.3.6 Fenno-Skan 2

Figure 5.27 presents the availability and utilisation of Fenno-Skan 2 for 2019 and Table 5.6 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 2019, Fenno-Skan 2 had an available technical capacity of 95 %. The technical capacity not used was 21 %. Totally, 0.2 TWh (3 % of the technical capacity) was exported from Finland to Sweden and 5.0 TWh (72 % of the technical capacity) was imported to Finland.

The annual maintenance of Fenno-Skan 2 lasted four days in September. Additionally, Fenno-Skan 2 had 2 disturbance outages with only minor impact during 2019.

It should be noted, that Fenno-Skan 1 and 2 is sometimes operated at equivalent transmission levels but with reversed directions to keep the temperature of Fenno-Skan 1 at adequate levels. The utilisation is still regarded as import and export even though the resulting net exchange between Finland and Sweden is zero.

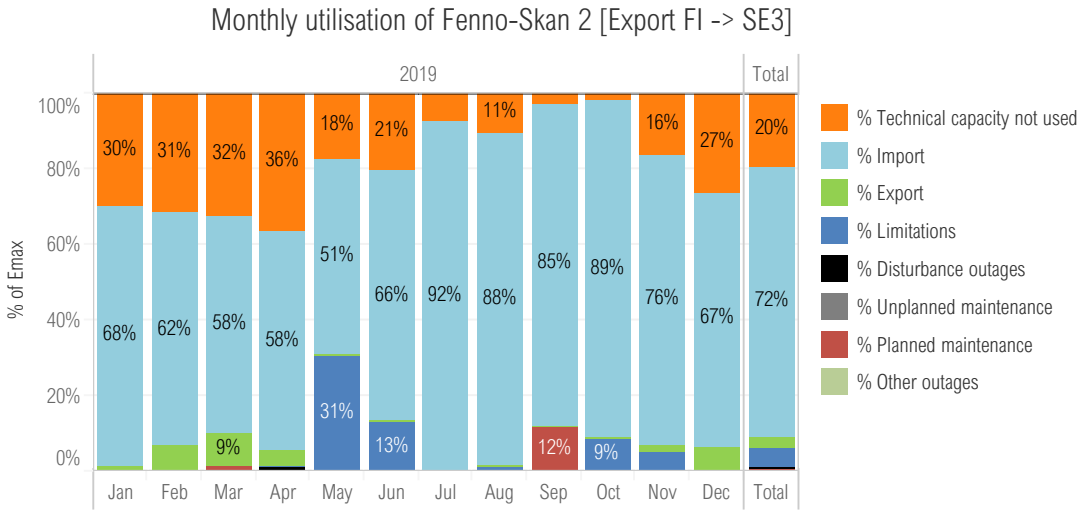

Figure 5.27: Percentage distribution of the availability and utilisation per category according to month for Fenno-Skan 2 in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.6: Monthly distribution of the technical capacity (E_{max}) for Fenno-Skan 2 in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Fenno-Skan 2 [Export FI -> SE3]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	179.6	168.9	192.7	210.0	105.5	119.2	45.0	62.8	18.3	10.9	95.1	159.2	1367.1	19.5%
Import, GWh	406.7	332.5	341.9	333.4	303.8	379.9	549.1	524.9	488.3	532.1	440.6	396.4	5029.9	71.7%
Export, GWh	8.2	36.3	50.8	24.2	3.1	2.2	1.2	1.3	-	0.1	12.7	39.7	179.7	2.6%
Limitations, GWh	-	-	-	3.0	182.9	74.9	0.2	6.5	-	53.2	27.9	-	348.6	5.0%
Disturbance outages, GWh	0.9	-	-	5.6	-	-	-	-	-	-	-	-	6.5	0.1%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	9.1	-	-	-	-	-	69.7	-	-	-	78.8	1.1%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	8.7	7.0	6.7	7.0	5.8	7.8	12.7	11.9	11.3	12.0	9.5	8.3	108.7	1.6%
Export losses, GWh	0.1	0.7	1.2	0.4	0.1	-	-	-	-	-	0.2	0.8	3.5	0.1%
Total, GWh	595.4	537.7	594.5	576.2	595.3	576.2	595.5	595.5	576.3	596.4	576.3	595.3	7010.5	100.0%

Figure 5.28 presents the annual utilisation of Fenno-Skan 2 per utilisation and unavailability category for the years 2012–2019.

Figure 5.29 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 2012–2019. Figure 5.30 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

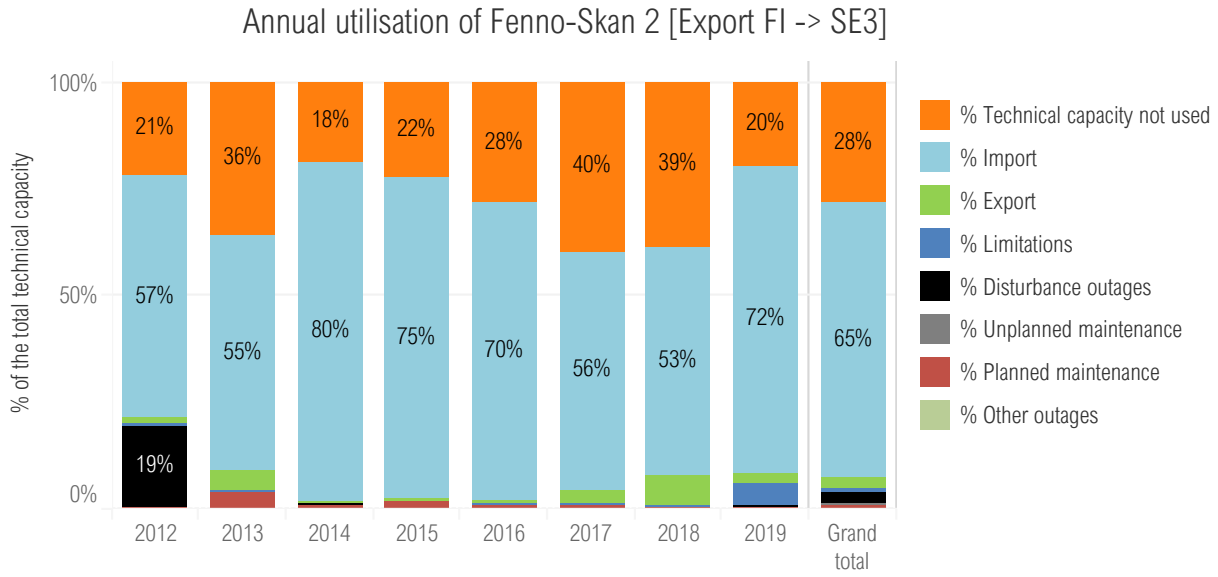

Figure 5.28: Annual utilisation of Fenno-Skan 2 according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

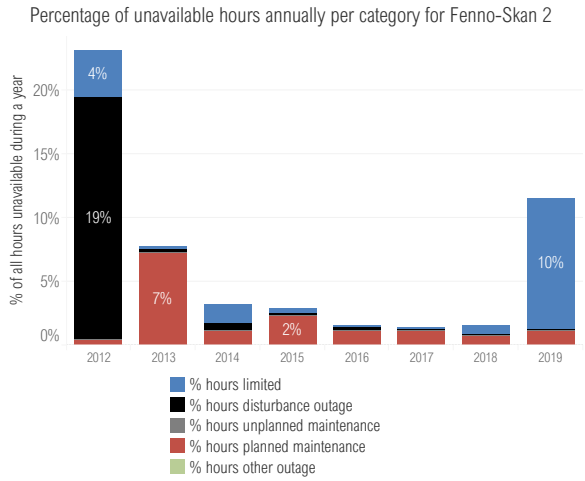

Figure 5.29: Percentage of hours Fenno-Skan 2 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

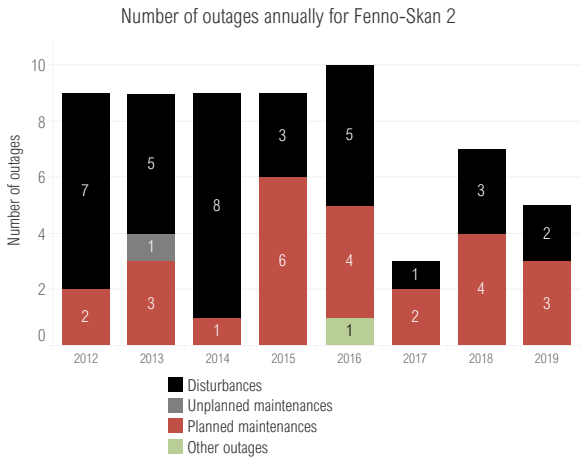

Figure 5.30: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Fenno-Skan 2 for the years 2012–2019.

5.3.7 Kontek

Figure 5.31 presents the availability and utilisation of Kontek for 2019 and Table 5.7 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 2019, Kontek had an available technical capacity of 97 %. The technical capacity not used was 28 %. Totally, 1.3 TWh (25 % of the technical capacity) was exported from Denmark to Germany and 2.3 TWh (44 % of the technical capacity) was imported to Denmark.

The annual maintenance of Kontek was done in two parts (one in April and the second in August), with each of them lasting approximately 4.5 days. Additionally, Kontek had two minor disturbance outages. The first was due to a breaker fault on a line connecting the connected busbar of Kontek, and the second was due to an operational fault during maintenance.

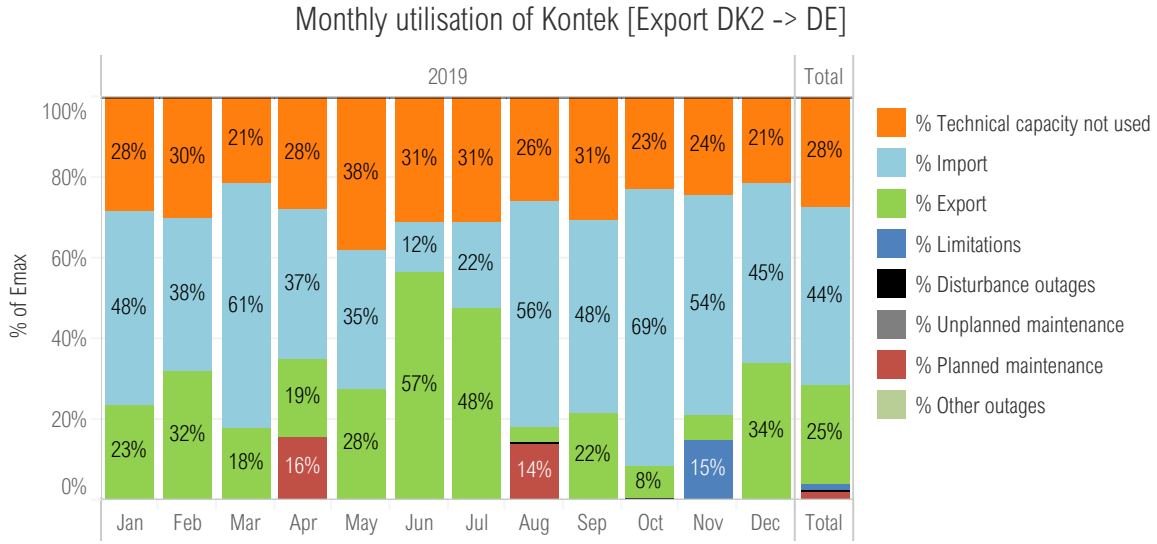

Figure 5.31: Percentage distribution of the availability and utilisation per category according to month for Kontek in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.7: Monthly distribution of the technical capacity (E_{max}) for Kontek in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Kontek [Export DK2 -> DE]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	126.4	121.3	95.2	120.3	169.0	133.8	137.6	116.7	131.9	101.7	105.5	95.2	1454.6	27.7%
Import, GWh	215.2	152.8	271.0	160.4	154.1	53.7	96.5	248.6	206.6	308.0	235.2	200.3	2302.5	43.8%
Export, GWh	104.8	129.1	79.6	83.3	123.3	244.5	212.2	17.3	93.5	36.0	26.2	150.9	1300.7	24.7%
Limitations, GWh	-	-	-	-	-	-	-	-	-	-	65.1	-	65.1	1.2%
Disturbance outages, GWh	-	-	-	-	-	-	-	0.3	-	1.3	-	-	1.5	0.0%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	68.0	-	-	-	63.5	-	-	-	-	131.5	2.5%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	4.4	3.1	5.7	3.3	3.1	1.1	2.0	5.3	4.4	6.6	4.8	4.1	47.8	0.9%
Export losses, GWh	2.1	2.6	1.6	1.6	2.4	5.1	4.5	0.3	1.9	0.7	0.5	3.3	26.7	0.5%
Total, GWh	446.4	403.2	445.8	432.0	446.4	432.0	446.4	446.4	432.0	447.0	432.0	446.4	5256.0	100.0%

Figure 5.32 presents the annual utilisation of Kontek per utilisation and unavailability category for the years 2012–2019.

Figure 5.33 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 2012–2019. Figure 5.34 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

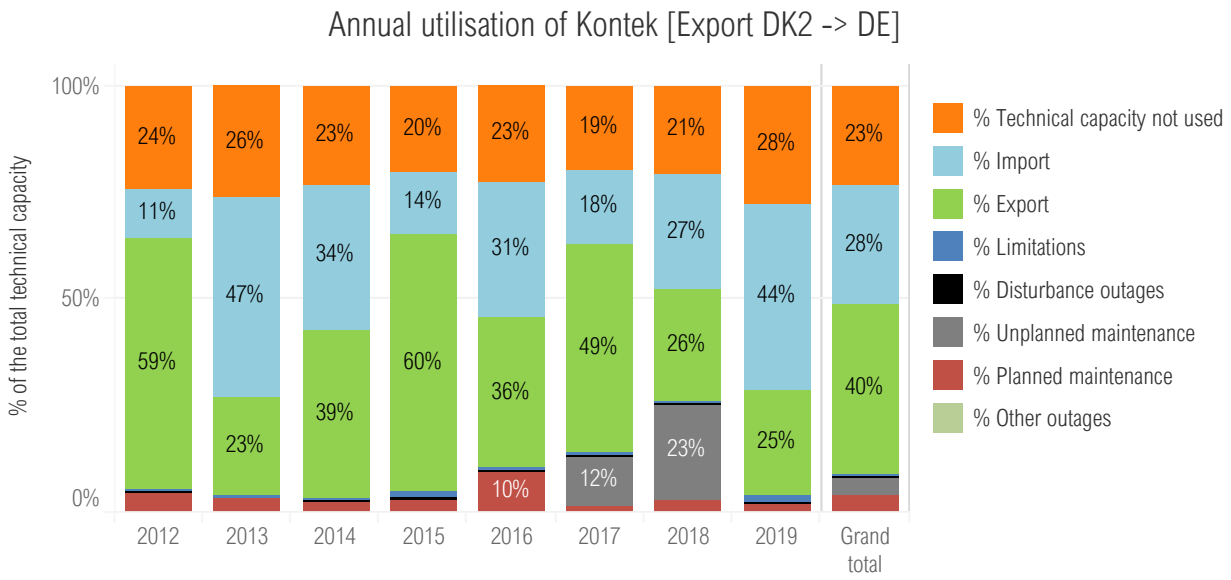

Figure 5.32: Annual utilisation of Kontek according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

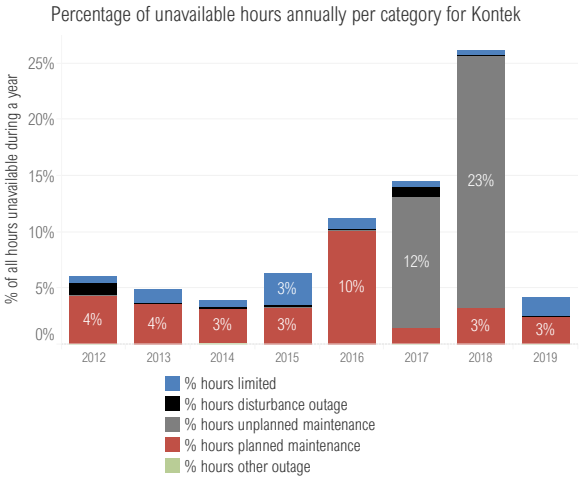

Figure 5.33: Percentage of hours Kontek has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

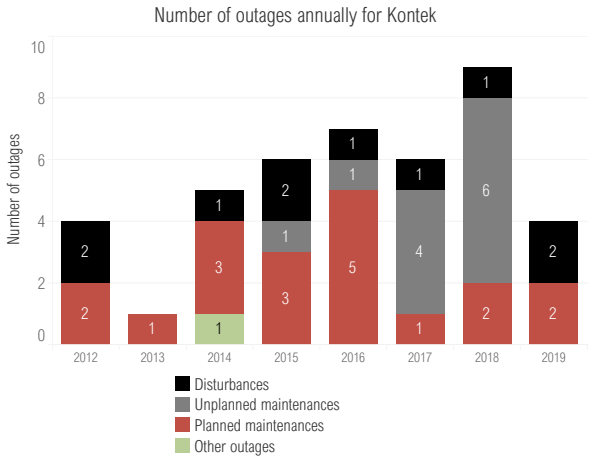

Figure 5.34: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Kontek for the years 2012–2019.

5.3.8 Konti-Skan 1

Figure 5.35 presents the availability and utilisation of Konti-Skan 1 for 2019 and Table 5.8 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). It has a transmission capacity of 370 MW towards east and 340 MW towards west.

The capacity has been asymmetric due to historical limitations and reserve requirements, along with transmission measurements only being done in DK1. As a step towards correcting this, the rated capacity at the receiving end of DK1 was changed from 680 MW to 715 MW on 1 October 2019. As the final step towards correcting the asymmetrical NTC capacities, measurements will be done on receiving ends of the cables as of 1 February 2020.

In 2019, Konti-Skan 1 had an available technical capacity of 85 % and the technical capacity not used was 34 %. Totally, 0.7 TWh (22 % of the technical capacity) was exported from Sweden to Denmark and 0.9 TWh (28 % of the technical capacity) was imported to Sweden.

Konti-Skan 1 and 2 had large amounts of planned maintenance due to replacements of conductor lines in Denmark in May and Konti-Skan 1 control system replacement in October and November. Additionally, Konti-Skan 1 had 5 disturbance outages during 2019 of which some were due to installation errors of previously mentioned planned maintenances.

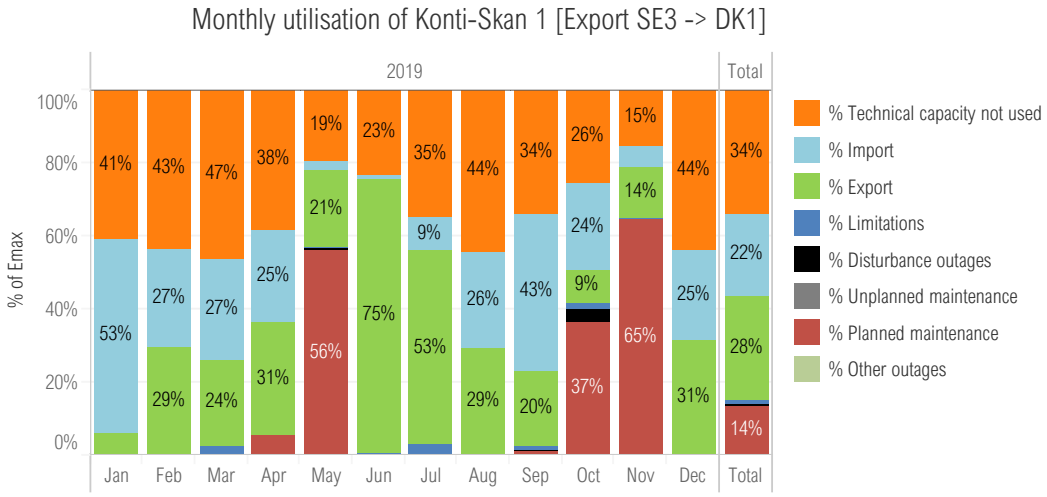

Figure 5.35: Percentage distribution of the availability and utilisation per category according to month for Konti-Skan 1 in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.8: Monthly distribution of the technical capacity (E_{max}) for Konti-Skan 1 in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Konti-Skan 1 [Export SE3 -> DK1]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	113.5	107.8	128.1	102.4	53.2	62.4	96.3	121.9	91.2	70.9	40.7	121.7	1110.0	34.2%
Import, GWh	144.7	68.0	75.1	66.7	7.7	3.5	24.6	72.2	113.6	66.0	14.8	67.5	724.4	22.3%
Export, GWh	17.1	72.8	65.2	83.0	57.4	199.0	146.5	80.7	54.5	23.9	37.1	85.9	923.1	28.5%
Limitations, GWh	-	-	6.6	-	1.3	1.6	7.9	0.6	2.7	4.4	0.3	-	25.3	0.8%
Disturbance outages, GWh	-	-	-	-	2.0	-	-	-	1.1	9.5	-	0.2	12.8	0.4%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	14.3	153.7	-	-	-	3.3	100.8	173.4	-	445.5	13.7%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	3.9	1.8	2.0	1.8	0.2	0.1	0.7	2.0	4.0	1.8	0.2	1.6	20.1	0.6%
Export losses, GWh	-	1.1	0.7	1.3	1.0	3.7	2.5	1.0	0.5	0.1	0.5	1.6	14.0	0.4%
Total, GWh	275.3	248.6	274.9	266.4	275.3	266.4	275.3	275.3	266.4	275.7	266.4	275.3	3241.2	100.0%

Figure 5.36 presents the annual utilisation of Konti-Skan 1 per utilisation and unavailability category for the years 2012–2019.

Figure 5.37 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 2012–2019. Figure 5.38 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

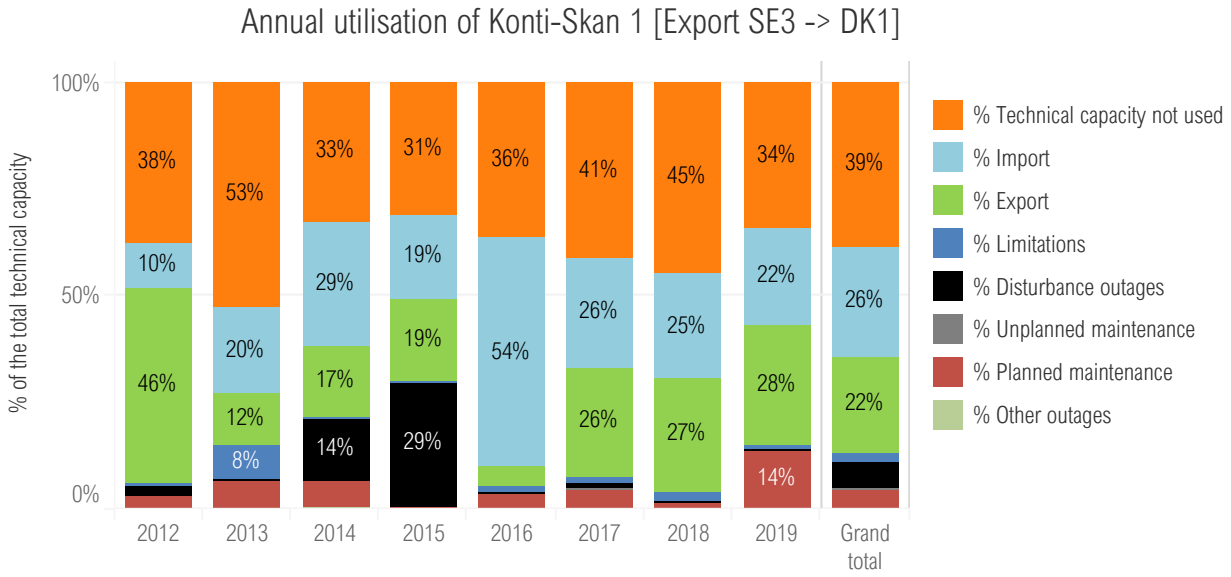

Figure 5.36: Annual utilisation of Konti-Skan 1 according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

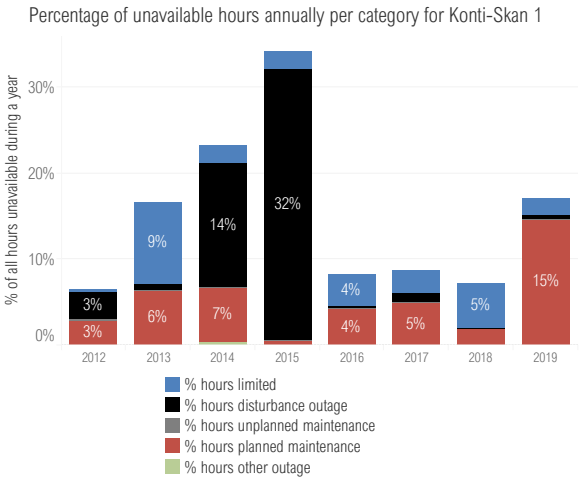

Figure 5.37: Percentage of hours Konti-Skan 1 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

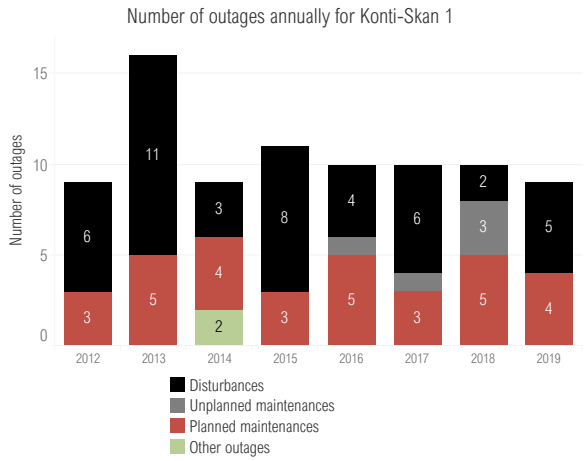

Figure 5.38: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Konti-Skan 1 for the years 2012–2019.

5.3.9 Konti-Skan 2

Figure 5.39 presents the availability and utilisation of Konti-Skan 2 for 2019 and Table 5.9 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. It has a transmission capacity of 370 MW from west to east and 340 MW from east to west. The capacity has been asymmetric due to historical limitations and reserve requirements, along with transmission measurements only being done in DK1. As a step towards correcting this, the rated capacity at the receiving end of DK1 was changed from 680 MW to 715 MW on 1 October 2019. As the final step towards correcting the asymmetrical NTC capacities, measurements will be done on receiving ends of the cables as of 1 February 2020.

In 2019, Konti-Skan 2 had an available technical capacity of 83 % and the technical capacity not used was 34 %. Totally, 0.9 TWh (28 % of the technical capacity) was exported from Sweden to Denmark and 0.8 TWh (21 % of the technical capacity) was imported to Sweden.

Konti-Skan 1 and 2 had large amounts of planned maintenance due to replacements of conductor lines in Denmark in May and Konti-Skan 2 control system replacement in September. Additionally, Konti-Skan 2 had 5 disturbance outages during 2019 of which some were due to installation errors of previously mentioned planned maintenances.

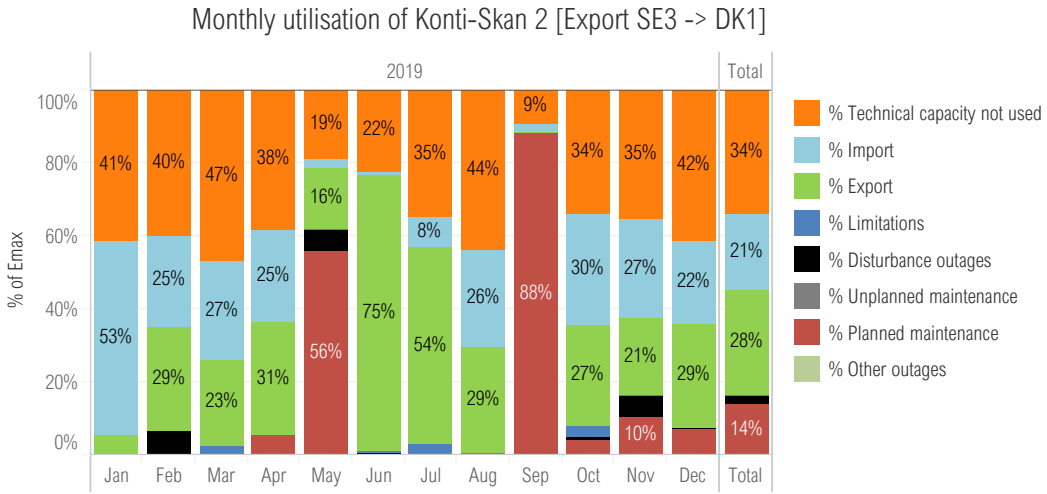

Figure 5.39: Percentage distribution of the availability and utilisation per category according to month for Konti-Skan 2 in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.9: Monthly distribution of the technical capacity (E_{max}) for Konti-Skan 2 in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Konti-Skan 2 [Export SE3 -> DK1]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	114.1	100.0	128.9	102.5	52.3	59.5	95.8	121.1	24.9	94.4	94.1	114.3	1101.8	34.0%
Import, GWh	145.7	61.4	75.1	66.5	7.4	3.4	23.0	72.3	5.9	83.9	72.5	61.7	679.0	20.9%
Export, GWh	15.5	71.4	64.1	83.1	45.4	200.9	148.6	80.7	1.7	75.0	55.5	78.6	920.5	28.4%
Limitations, GWh	-	-	6.8	-	1.5	1.5	7.9	1.1	-	8.5	1.1	-	28.4	0.9%
Disturbance outages, GWh	-	15.9	-	-	15.0	1.1	-	-	-	2.8	15.8	0.8	51.3	1.6%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	14.3	153.7	-	-	-	233.8	10.9	27.4	20.0	460.1	14.2%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	3.8	1.5	1.7	1.6	0.2	0.1	0.6	1.9	0.2	2.3	2.1	1.4	17.3	0.5%
Export losses, GWh	0.3	1.6	1.5	1.9	1.0	4.9	3.5	1.6	-	2.0	1.3	1.8	21.4	0.7%
Total, GWh	275.3	248.6	274.9	266.4	275.3	266.4	275.3	275.3	266.4	275.7	266.4	275.3	3241.2	100.0%

Figure 5.40 presents the annual utilisation of Konti-Skan 2 per utilisation and unavailability category for the years 2012–2019.

Figure 5.41 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 2012–2019. Figure 5.42 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

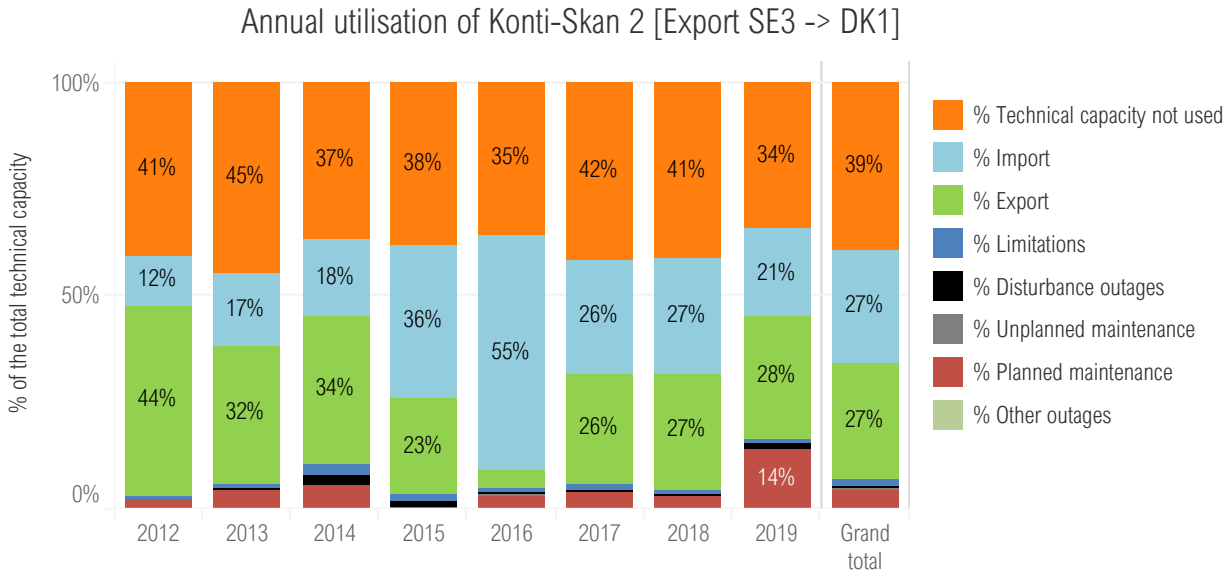

Figure 5.40: Annual utilisation of Konti-Skan 2 according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

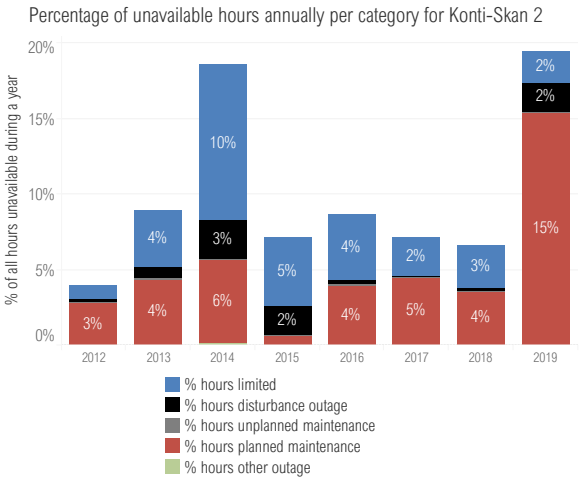

Figure 5.41: Percentage of hours Konti-Skan 2 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

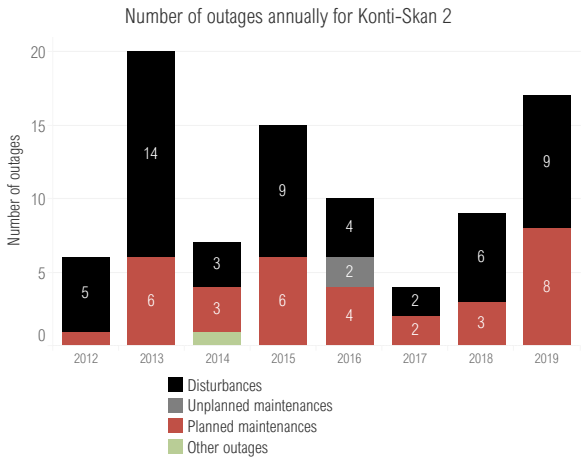

Figure 5.42: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Konti-Skan 2 for the years 2012–2019.

5.3.10 LitPol Link

Figure 5.43 presents the availability and utilisation of LitPol Link for 2019 and Table 4.1 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 2019, LitPol Link had had an available technical capacity of 96 %. The technical capacity not used was 35 %. Totally, 2.3 TWh (53 % of the technical capacity) as exported from Lithuania to Poland and 0.4 TWh (9 % of the technical capacity) was imported to Lithuania.

The annual maintenance of LitPol Link lasted six days in May. Additionally, LitPol Link had 2 disturbance outages with only minor impact in 2019.

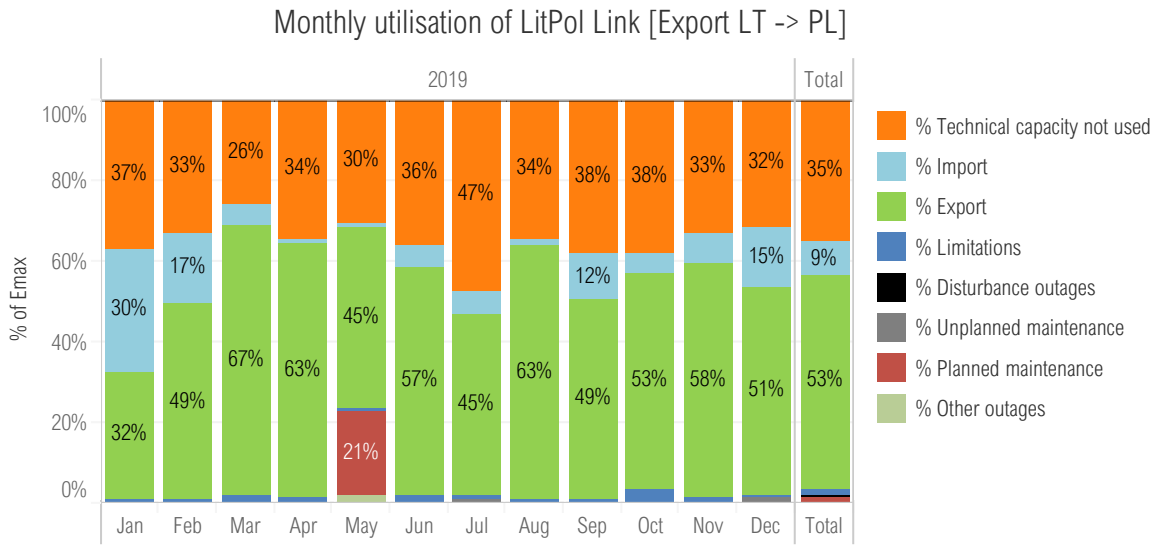

Figure 5.43: Percentage distribution of the availability and utilisation per category according to month for LitPol Link in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.10: Monthly distribution of the technical capacity (E_{max}) for LitPol Link in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of LitPol Link [Export LT -> PL]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	137.9	111.5	97.1	123.7	113.0	129.8	175.8	128.0	135.9	142.0	118.9	117.2	1530.7	34.9%
Import, GWh	112.8	57.4	18.2	3.8	4.0	19.3	21.5	5.1	42.8	18.2	26.1	55.4	384.7	8.8%
Export, GWh	117.8	164.5	248.1	227.5	167.5	203.8	167.5	234.8	177.1	198.9	210.3	191.2	2308.9	52.7%
Limitations, GWh	3.5	2.6	8.1	5.0	2.8	7.1	3.7	3.5	4.1	13.4	4.7	3.2	61.7	1.4%
Disturbance outages, GWh	-	-	-	-	-	-	-	0.7	-	-	-	-	0.7	0.0%
Unplanned maintenance., GWh	-	-	-	-	-	-	3.5	-	-	-	-	5.0	8.5	0.2%
Planned maintenance, GWh	-	-	-	-	77.5	-	-	-	-	-	-	-	77.5	1.8%
Other outages, GWh	-	-	-	-	7.2	-	-	-	-	-	-	-	7.2	0.2%
Import losses, GWh	1.8	0.9	0.3	0.1	0.1	0.4	0.4	0.1	0.7	0.4	0.5	0.9	6.6	0.2%
Export losses, GWh	1.9	2.5	3.7	3.4	2.6	3.1	2.7	3.6	2.8	2.9	3.2	2.9	35.2	0.8%
Total, GWh	372.0	336.0	371.5	360.0	372.0	360.0	372.0	372.0	360.0	372.5	360.0	372.0	4380.0	100.0%

Figure 5.44 presents the annual utilisation of LitPol Link per utilisation and unavailability category for the years 2016–2019.

Figure 5.45 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 2016–2019. Figure 5.46 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2016–2019.

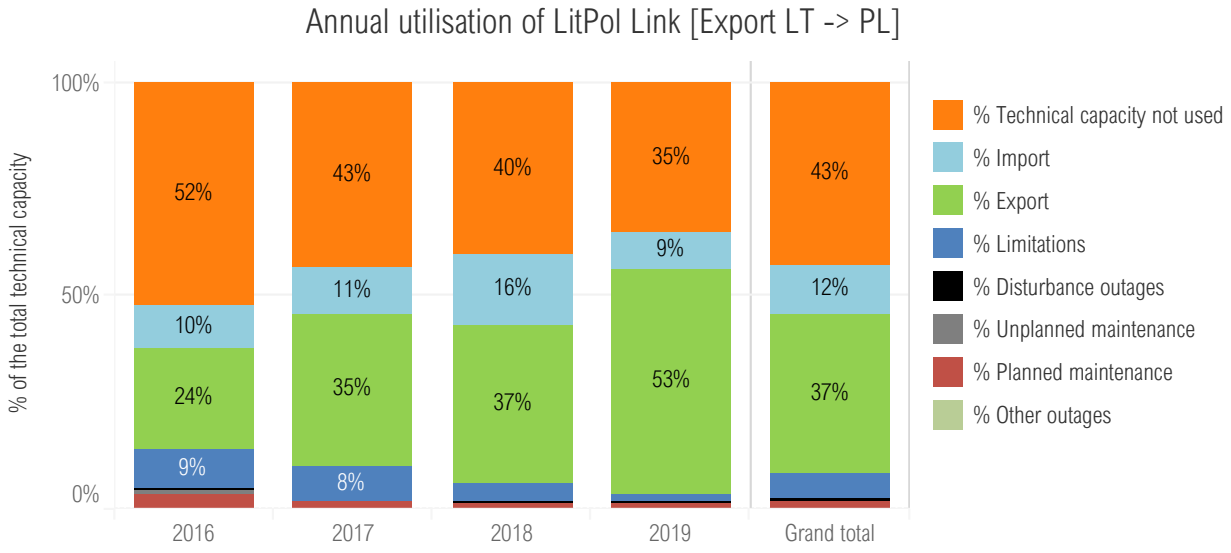

Figure 5.44: Annual utilisation of LitPol Link according to the utilisation and unavailability categories for the years 2016–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

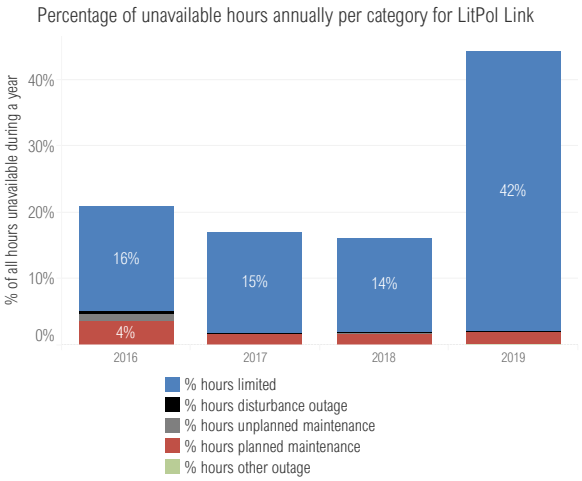

Figure 5.45: Percentage of hours LitPol Link has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2016–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

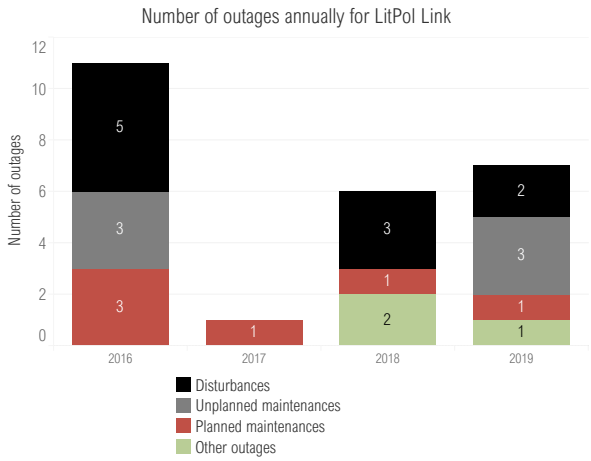

Figure 5.46: The annual number of disturbances, unplanned and planned maintenance outages and other outages for LitPol Link for the years 2016–2019.

5.3.11 NordBalt

Figure 5.47 presents the availability and utilisation of NordBalt for 2019 and Table 5.11 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.

In 2019, NordBalt had had an available technical capacity of 92 %. The technical capacity not used was 29 %. Totally, 3.6 TWh (58 % of the technical capacity) was exported from Sweden to Lithuania and 0.3 TWh (5 % of the technical capacity) was imported to Sweden.

The annual maintenance of NordBalt lasted eight days in September. Additionally, NordBalt had 1 disturbance outage with only minor impact during 2019.

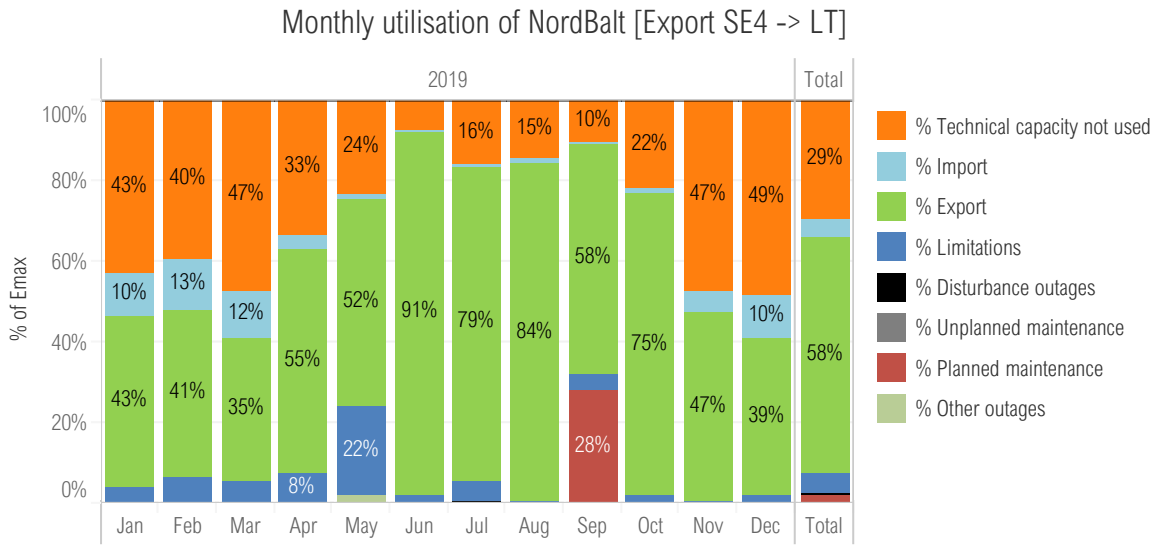

Figure 5.47: Percentage distribution of the availability and utilisation per category according to month for NordBalt in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.11: Monthly distribution of the technical capacity (E_{max}) for NordBalt in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of NordBalt [Export SE4 -> LT]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	224.6	185.9	246.0	168.7	123.4	37.8	82.6	76.7	52.3	114.5	239.2	253.4	1805.1	29.4%
Import, GWh	54.0	58.9	60.9	18.5	4.6	0.2	0.4	3.1	0.4	5.1	25.6	53.6	285.3	4.7%
Export, GWh	222.5	194.8	183.7	278.0	268.5	456.4	409.7	437.8	289.9	392.5	236.5	202.8	3573.2	58.3%
Limitations, GWh	19.7	30.8	29.5	38.8	114.5	9.6	25.0	3.2	19.0	9.5	2.7	11.0	313.3	5.1%
Disturbance outages, GWh	-	-	-	-	-	-	3.0	-	-	-	-	-	3.0	0.0%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	-	-	-	-	-	142.3	-	-	-	142.3	2.3%
Other outages, GWh	-	-	-	-	9.8	-	-	-	-	-	-	-	9.8	0.2%
Import losses, GWh	9.7	8.3	8.1	12.2	11.8	20.8	18.7	20.0	13.2	17.5	10.2	8.9	159.3	2.6%
Export losses, GWh	1.9	2.0	2.1	0.7	0.2	-	-	0.1	-	0.2	0.9	1.8	10.0	0.2%
Total, GWh	520.8	470.4	520.1	504.0	520.8	504.0	520.8	520.8	504.0	521.5	504.0	520.8	6132.0	100.0%

Figure 5.48 presents the annual utilisation of NordBalt per utilisation and unavailability category for the years 2016–2019.

Figure 5.49 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 2016–2019. Figure 5.50 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2016–2019.

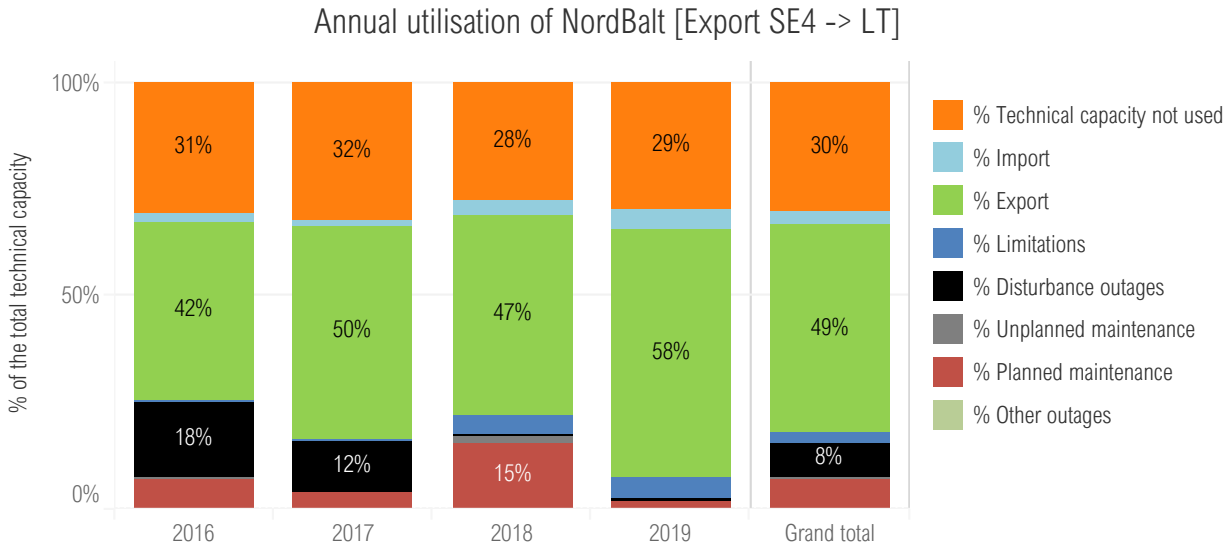

Figure 5.48: Annual utilisation of NordBalt according to the utilisation and unavailability categories for the years 2016–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

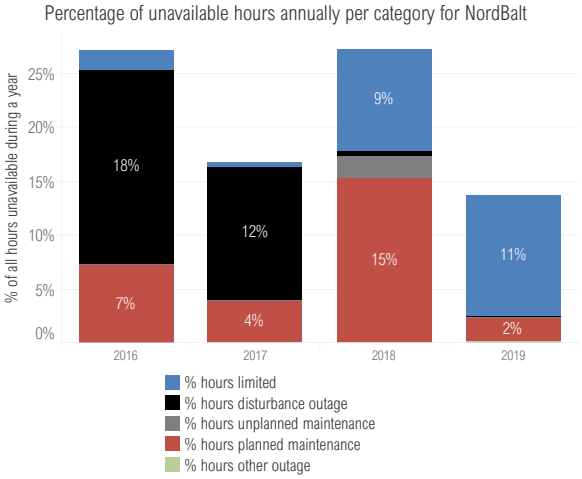

Figure 5.49: Percentage of hours NordBalt has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2016–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

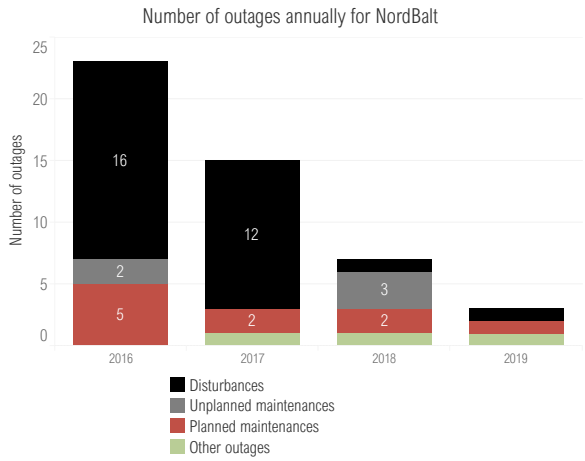

Figure 5.50: The annual number of disturbances, unplanned and planned maintenance outages and other outages for NordBalt for the years 2016–2019.

5.3.12 NorNed

Figure 5.51 presents the availability and utilisation of NorNed for 2019 and Table 5.12 presents the numerical values behind it. NorNed has been in operation since 2008, and is, with a length of 580 km, the longest HVDC link connected to the Nordic power system. 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). The transmission capacity of NorNed is 700 MW.

In 2019, NorNed had had an available technical capacity of 82 %. The technical capacity not used was 11 %. Totally, 2.4 TWh (38 % of the technical capacity) was exported from Norway to the Netherlands and 1.4 TWh (23 % of the technical capacity) was imported to Norway.

NorNed had 8 disturbances and 4 planned maintenances during 2019. In February, the outage was due to a fault on a bushing in Feda. Furthermore, filter problems in Eemshaven caused maintenance outages and limitations in March–April. The unavailable energy in Q4 was due to maintenance in the Eemshaven region.

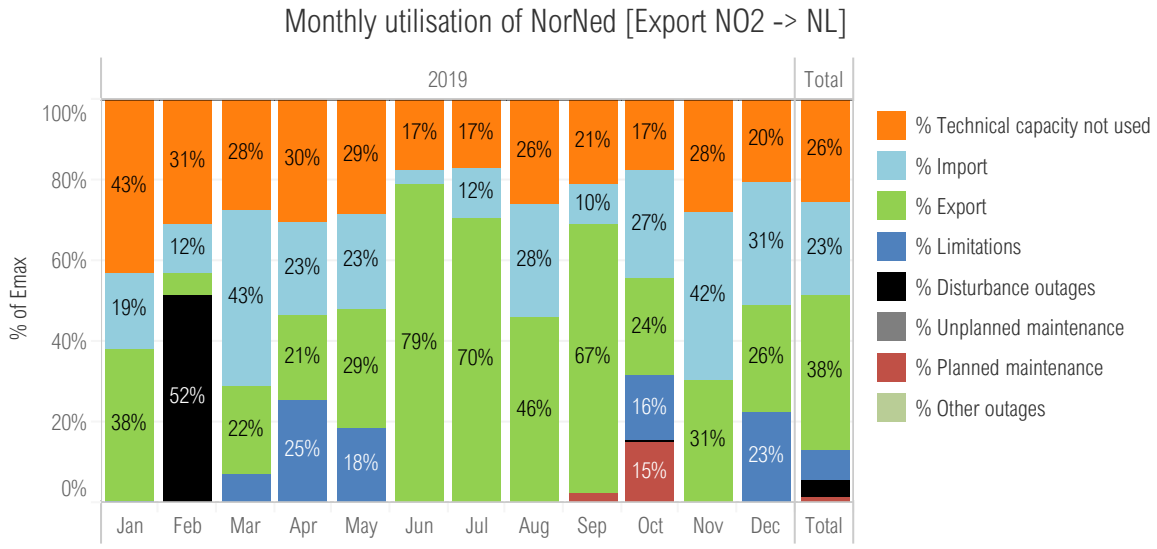

Figure 5.51: Percentage distribution of the availability and utilisation per category according to month for NorNed in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.12: Monthly distribution of the technical capacity (E_{max}) for NorNed in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of NorNed [Export NO2 -> NL]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	224.9	145.4	144.3	152.9	149.0	87.3	89.6	135.4	106.8	90.1	139.9	106.7	1572.6	25.6%
Import, GWh	97.7	56.8	225.7	117.2	122.2	18.9	65.1	147.1	50.5	140.8	209.6	159.7	1411.3	23.0%
Export, GWh	195.7	24.8	115.0	106.3	153.5	399.3	366.8	238.6	335.8	126.1	154.0	136.1	2352.0	38.3%
Limitations, GWh	0.6	-	35.1	127.5	96.2	-	-	-	-	84.6	0.7	118.3	463.0	7.5%
Disturbance outages, GWh	2.1	243.4	0.1	-	-	-	-	-	-	2.6	-	-	248.2	4.0%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	-	-	-	-	-	11.8	77.5	-	-	89.3	1.5%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	3.4	2.2	8.4	3.5	4.0	0.7	2.5	5.7	1.9	4.9	8.3	5.3	50.7	0.8%
Export losses, GWh	6.9	0.9	4.0	2.9	4.8	15.1	14.0	9.0	13.0	4.1	5.7	4.3	84.6	1.4%
Total, GWh	521.0	470.4	520.2	504.0	520.9	505.5	521.5	521.1	504.8	521.7	504.2	520.9	6136.5	100.0%

Figure 5.52 presents the annual utilisation of NorNed per utilisation and unavailability category for the years 2012–2019.

Figure 5.53 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 2012–2019. Figure 5.54 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

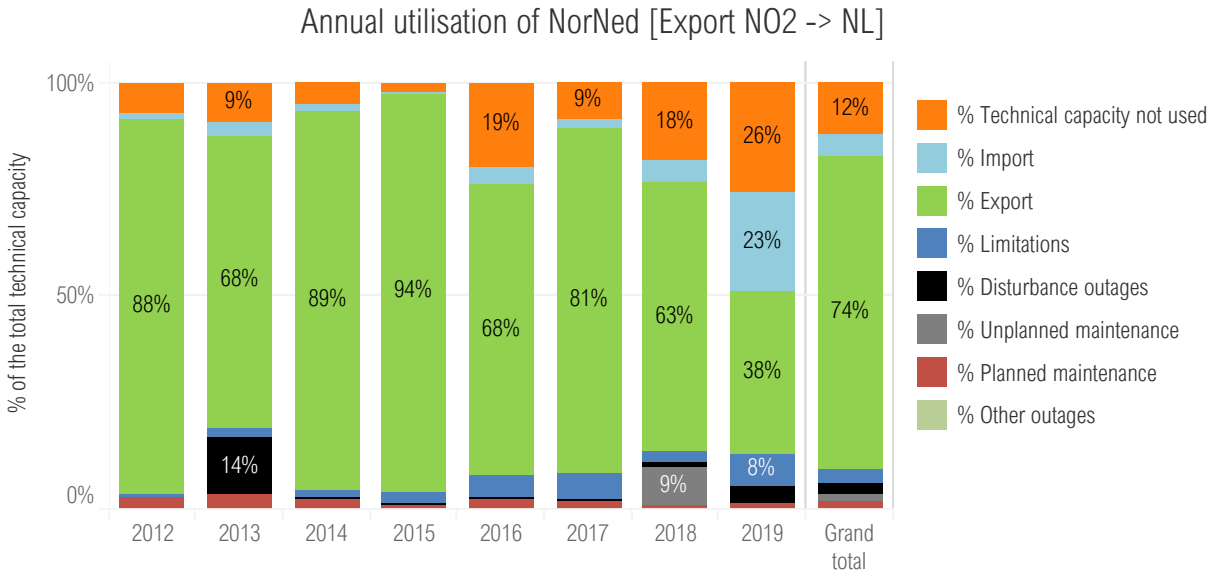

Figure 5.52: Annual utilisation of NorNed according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

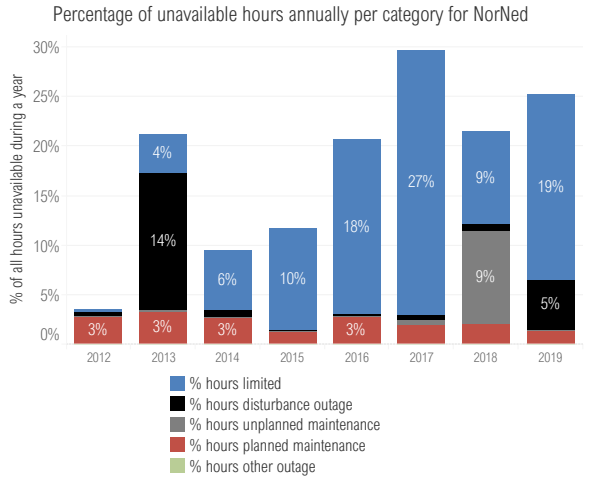

Figure 5.53: Percentage of hours NorNed has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

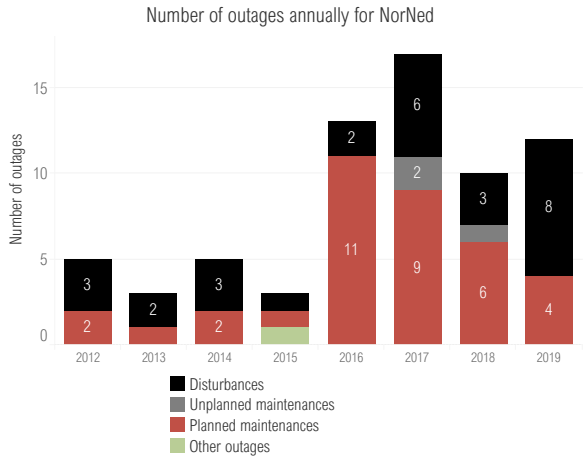

Figure 5.54: The annual number of disturbances, unplanned and planned maintenance outages and other outages for NorNed for the years 2012–2019.

5.3.13 Skagerrak 1

Figure 5.55 presents the availability and utilisation of Skagerrak 1 for 2019 and Table 5.13 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), approximately 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 2019, Skagerrak 1 had an available technical capacity of 72 %. The technical capacity not used was 32 %. Totally, 0.5 TWh (22 % of the technical capacity) was exported from Norway to the Denmark and 0.4 TWh (18 % of the technical capacity) was imported to Norway.

Skagerak 1, 2, 3 and 4 have been operated in "careful operation" since December 2019 due to the cable faults on Skagerak 4, which in turn caused limitations due to restrictions on the maximum allowed electrode currents. The annual maintenance was done during refurbishment of Skagerak 1 AC equipment on the Danish side and lasted 58 days from late September to late November. Additionally, Skagerrak 1 had 1 major disturbance during 2019 due to a failure on the pole transformer on the Norwegian side.

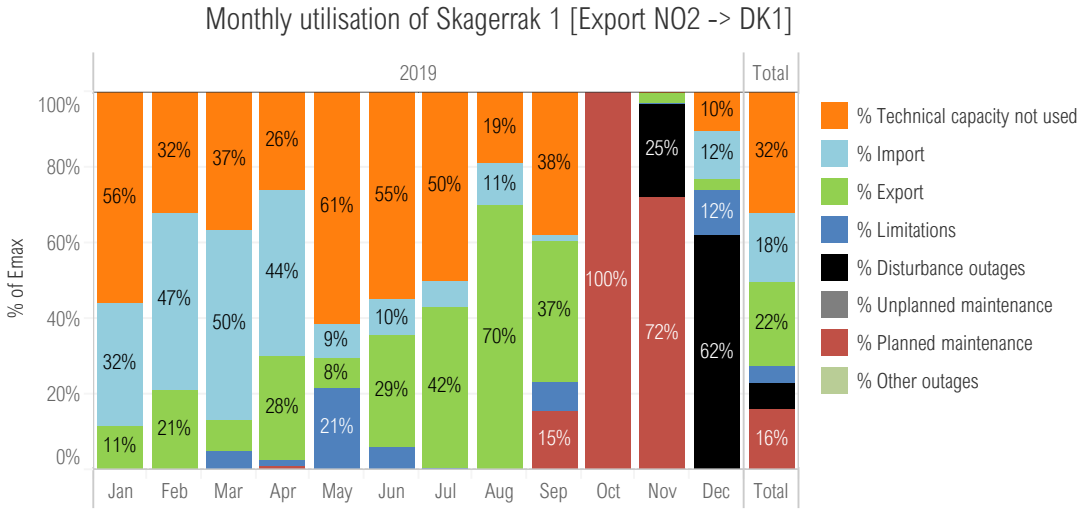

Figure 5.55: Percentage distribution of the availability and utilisation per category according to month for Skagerrak 1 in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.13: Monthly distribution of the technical capacity (E_{max}) for Skagerrak 1 in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Skagerrak 1 [Export NO2 -> DK1]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	98.4	50.9	64.3	43.8	107.9	93.3	88.2	33.4	64.9	-	0.2	18.4	663.8	32.1%
Import, GWh	57.0	74.1	88.2	74.9	15.5	16.6	11.7	19.3	2.0	-	0.3	21.8	381.3	18.4%
Export, GWh	20.2	33.6	13.9	47.0	14.5	50.0	74.5	122.9	63.5	-	4.2	5.6	450.0	21.8%
Limitations, GWh	-	-	9.1	2.6	37.7	10.0	1.3	-	13.4	-	0.2	20.7	95.0	4.6%
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	42.8	109.1	151.9	7.3%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	1.7	-	-	-	-	26.1	175.8	122.1	-	325.7	15.8%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	2.8	3.5	4.4	4.0	0.6	0.8	0.6	0.9	0.1	-	-	0.9	18.5	0.9%
Export losses, GWh	0.9	1.6	0.6	2.2	0.6	2.6	3.7	5.9	2.9	-	0.2	0.3	21.4	1.0%
Total, GWh	175.6	158.6	175.4	170.1	175.6	169.9	175.6	175.6	169.9	175.8	169.9	175.6	2067.7	100.0%

Figure 5.56 presents the annual utilisation of Skagerrak 1 per utilisation and unavailability category for the years 2012–2019.

Figure 5.57 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 2012–2019. Figure 5.58 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

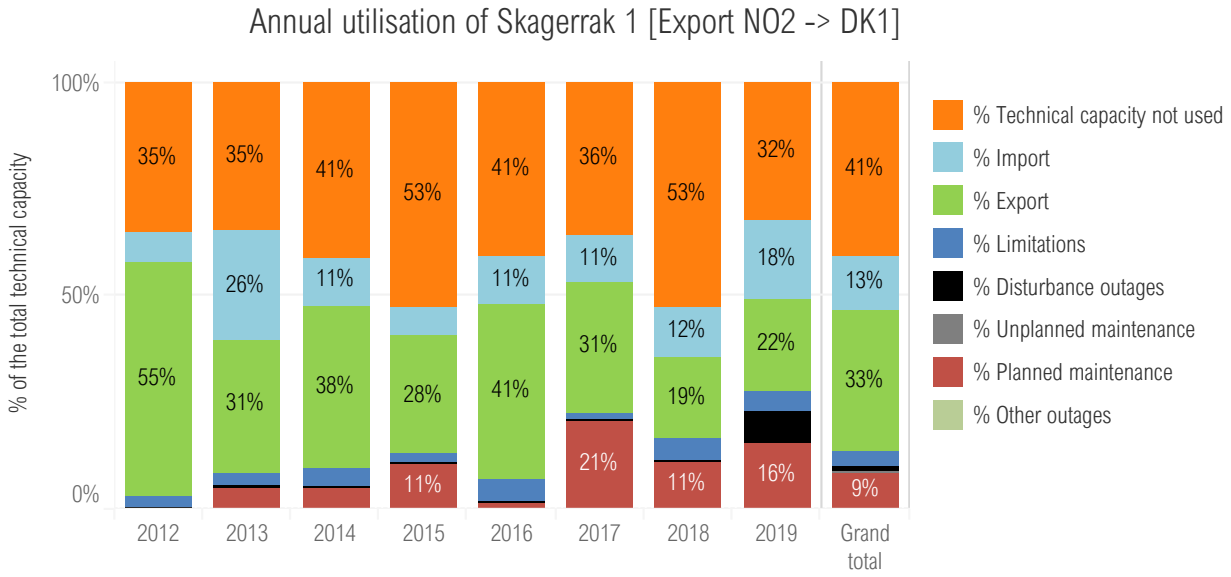

Figure 5.56: Annual utilisation of Skagerrak 1 according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

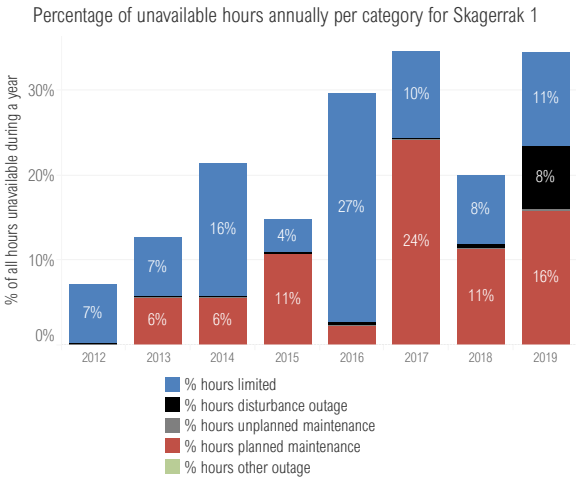

Figure 5.57: Percentage of hours Skagerrak 1 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

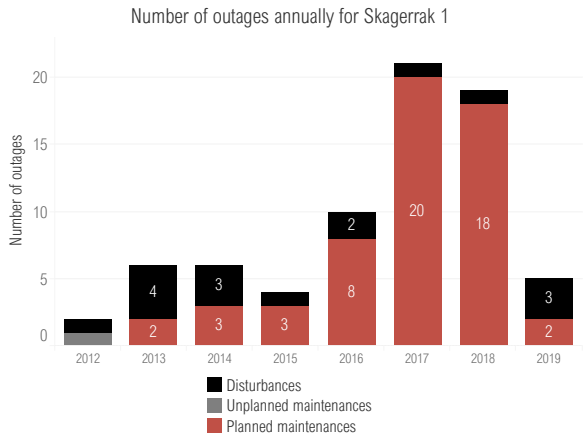

Figure 5.58: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Skagerrak 1 for the years 2012–2019. Skagerrak 1 had no other outages during the years 2012–2019.

5.3.14 Skagerrak 2

Figure 5.59 presents the availability and utilisation of Skagerrak 2 for 2019 and Table 5.14 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), approximately 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 2019, Skagerrak 2 had an available technical capacity of 78 %. The technical capacity not used was 33 %. Totally, 0.5 TWh (22 % of the technical capacity) was exported from Norway to the Denmark and 0.5 TWh (23 % of the technical capacity) was imported to Norway.

Skagerrak 1, 2, 3 and 4 have been operated in "careful operation" since December 2019 due to the cable faults on Skagerrak 4, which in turn caused limitations due to restrictions on the maximum allowed electrode currents. The annual maintenance of Skagerrak 2 was done during replacement of the new control system on the Norwegian side and lasted 57 days from late May to July. Additionally, Skagerrak 2 had one minor disturbance during 2019.

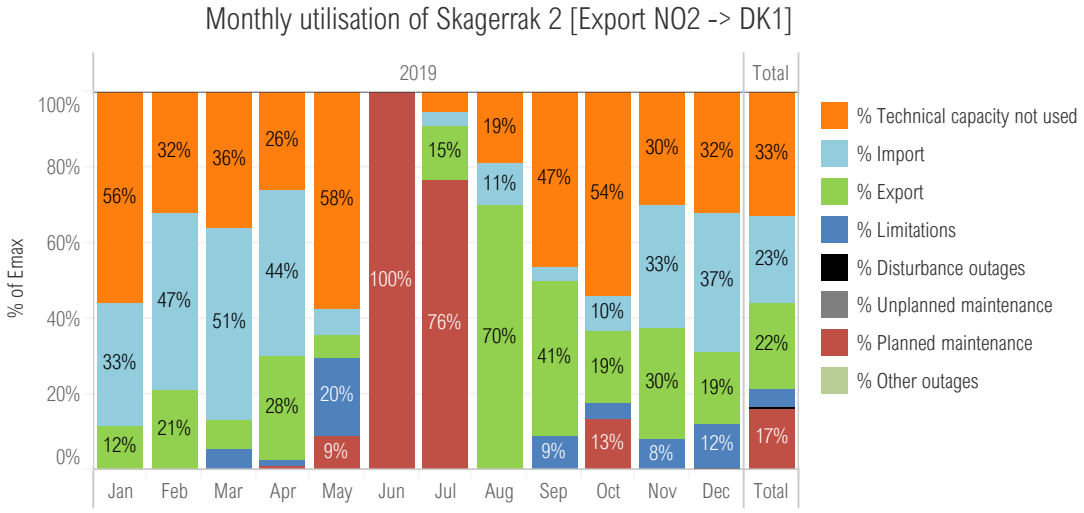

Figure 5.59: Percentage distribution of the availability and utilisation per category according to month for Skagerrak 2 in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.14: Monthly distribution of the technical capacity (E_{max}) for Skagerrak 2 in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Skagerrak 2 [Export NO2 -> DK1]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	98.2	50.7	63.3	43.9	101.3	-	9.9	33.2	79.4	94.8	50.9	56.4	682.1	33.0%
Import, GWh	57.1	74.2	88.9	74.9	12.2	-	5.9	19.4	5.6	17.1	55.5	64.5	475.4	23.0%
Export, GWh	20.3	33.7	13.9	47.0	10.7	-	25.8	123.1	69.9	33.4	50.2	33.5	461.5	22.3%
Limitations, GWh	-	-	9.3	2.6	35.9	-	-	-	15.0	7.0	13.4	20.6	103.8	5.0%
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	-	0.6	0.6	0.0%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	1.7	15.5	169.9	134.0	-	-	23.5	-	-	344.6	16.7%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	2.9	4.0	4.5	3.6	0.4	-	0.3	1.1	0.3	0.9	2.9	3.4	24.2	1.2%
Export losses, GWh	0.9	1.7	0.7	2.4	0.3	-	1.3	6.4	3.2	1.7	2.2	1.6	22.4	1.1%
Total, GWh	175.6	158.6	175.5	170.2	175.6	169.9	175.6	175.6	169.9	175.8	170.0	175.6	2068.0	100.0%

Figure 5.60 presents the annual utilisation of Skagerrak 2 per utilisation and unavailability category for the years 2012–2019.

Figure 5.61 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 2012–2019. Figure 5.62 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

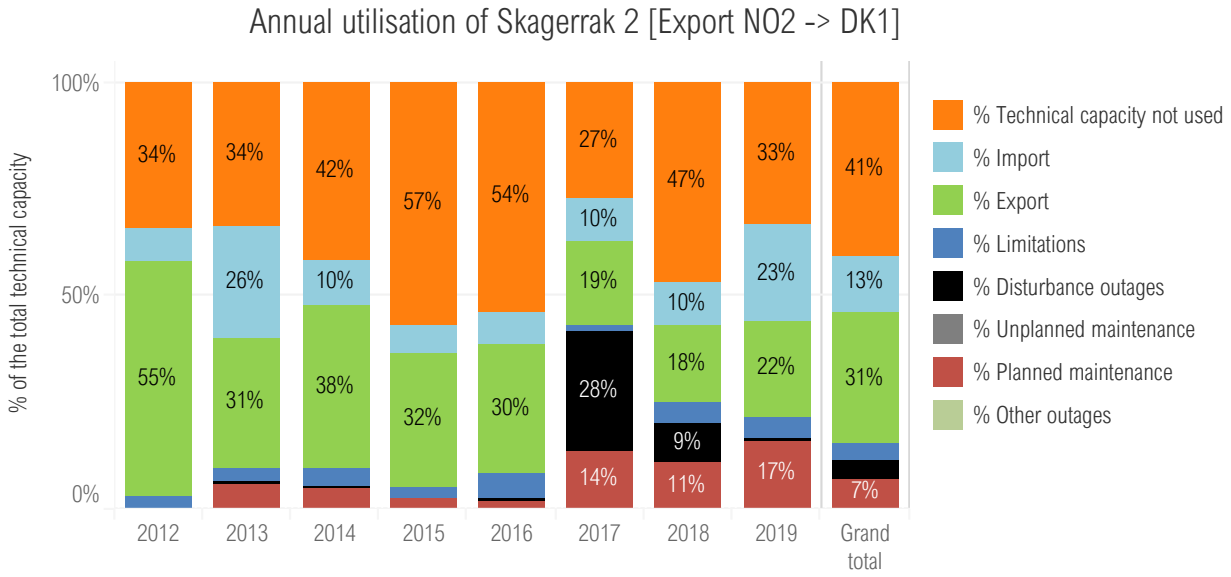

Figure 5.60: Annual utilisation of Skagerrak 2 according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

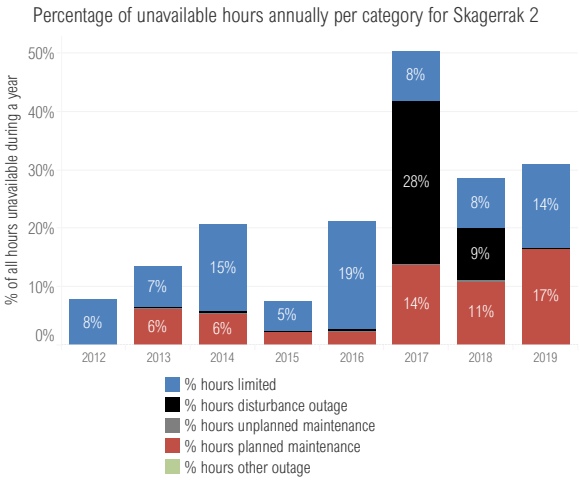

Figure 5.61: Percentage of hours Skagerrak 2 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

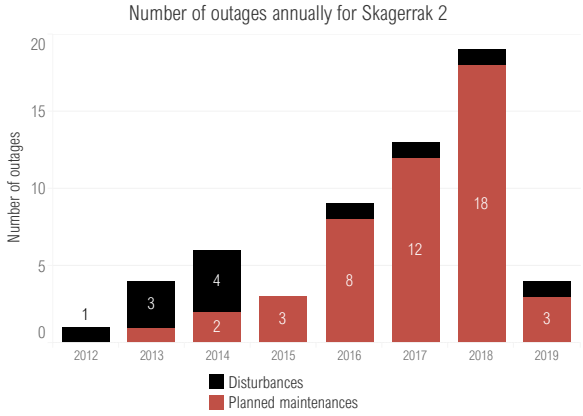

Figure 5.62: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Skagerrak 2 for the years 2012–2019. Skagerrak 2 had no other outages during the years 2012–2019.

5.3.15 Skagerrak 3

Figure 5.63 presents the availability and utilisation of Skagerrak 3 for 2019 and Table 5.15 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 2019, Skagerrak 3 had an available technical capacity of 78 %. The technical capacity not used was 26 %. Totally, 1.1 TWh (26 % of the technical capacity) was exported from Norway to Denmark and 1.1 TWh (26 % of the technical capacity) was imported to Norway.

Skagerrak 1, 2, 3 and 4 have been operated in "careful operation" since December 2019 due to the cable faults on Skagerrak 4, which in turn caused limitations due to restrictions on the maximum allowed electrode currents. There was no annual maintenance done on Skagerrak 3 in 2019. Instead, there was 1 major planned maintenance for installation and testing of the new control system on the Norwegian side, which lasted from late March to April. Additionally, Skagerrak 3 had 1 minor disturbance.

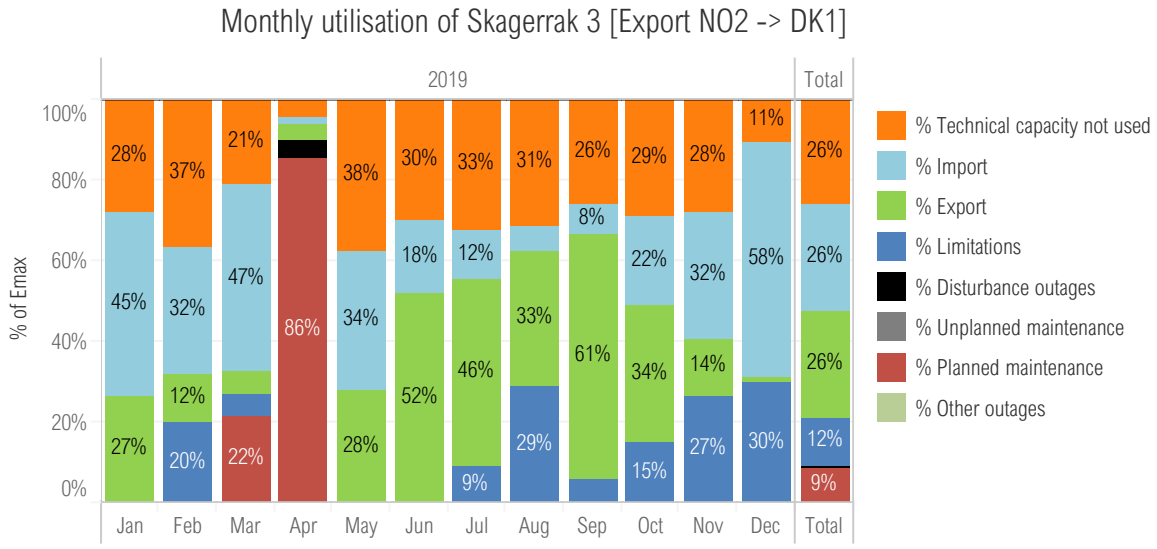

Figure 5.63: Percentage distribution of the availability and utilisation per category according to month for Skagerrak 3 in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.15: Monthly distribution of the technical capacity (E_{max}) for Skagerrak 3 in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Skagerrak 3 [Export NO2 -> DK1]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	99.6	117.7	73.9	14.8	133.9	103.2	115.6	112.0	89.5	104.1	95.9	37.7	1097.8	26.2%
Import, GWh	161.5	101.3	166.1	5.8	121.3	62.8	42.8	21.5	26.2	78.0	109.2	207.3	1103.8	26.4%
Export, GWh	94.6	38.8	19.8	14.2	100.5	178.1	164.8	119.0	208.3	120.3	47.0	4.0	1109.5	26.5%
Limitations, GWh	-	63.4	18.9	-	-	-	32.5	103.2	20.2	53.8	92.0	106.6	490.6	11.7%
Disturbance outages, GWh	-	-	-	15.0	-	-	-	-	-	-	-	-	15.0	0.4%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	76.5	294.4	-	-	-	-	-	-	-	-	370.9	8.9%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	4.3	2.6	4.4	0.1	3.2	1.6	1.1	0.5	0.6	2.0	2.8	5.1	28.3	0.7%
Export losses, GWh	2.2	0.8	0.4	0.3	2.3	3.8	3.6	2.6	5.0	2.9	1.2	0.3	25.4	0.6%
Total, GWh	355.7	321.2	355.2	344.2	355.7	344.2	355.7	355.6	344.2	356.1	344.2	355.6	4187.5	100.0%

Figure 5.64 presents the annual utilisation of Skagerrak 3 per utilisation and unavailability category for the years 2012–2019.

Figure 5.65 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 2012–2019. Figure 5.66 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

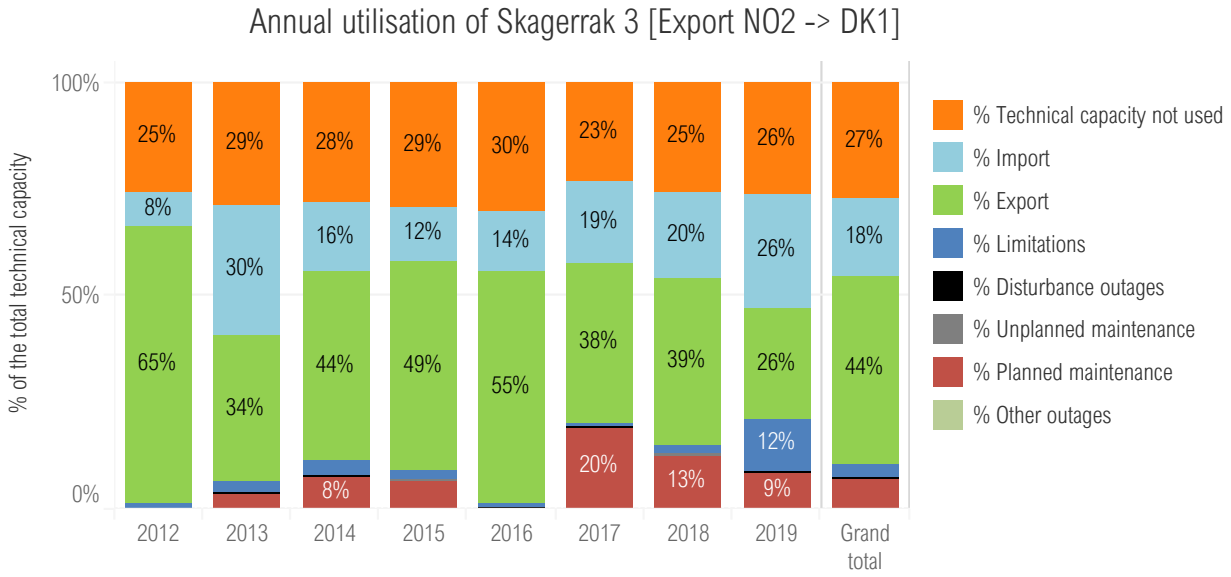

Figure 5.64: Annual utilisation of Skagerrak 3 according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

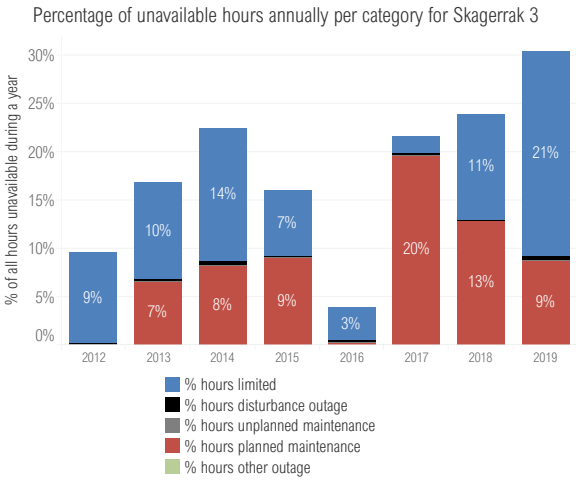

Figure 5.65: Percentage of hours Skagerrak 3 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

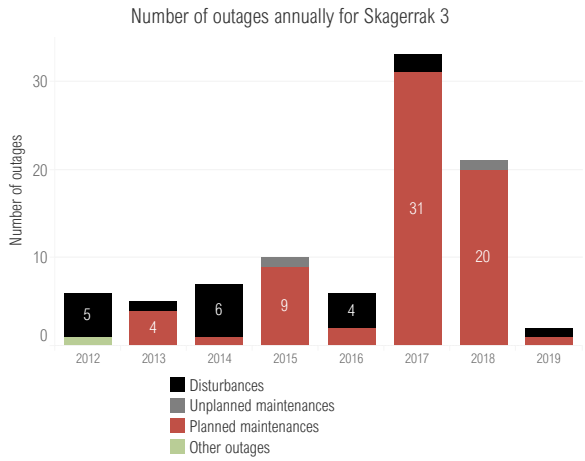

Figure 5.66: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Skagerrak 3 for the years 2012–2019.

5.3.16 Skagerrak 4

Figure 5.67 presents the availability and utilisation of Skagerrak 4 for 2019 and Table 5.16 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 2019, Skagerrak 4 had an available technical capacity of 67 %. The technical capacity not used was 23 %. Totally, 1.3 TWh (21 % of the technical capacity) was exported from Norway to the Denmark and 1.3 TWh (23 % of the technical capacity) was imported to Norway.

Skagerrak 1, 2, 3 and 4 have been operated in "careful operation" since December 2019 due to the cable faults on Skagerrak 4, which in turn caused limitations due to restrictions on the maximum allowed electrode currents. There was no annual maintenance done on Skagerrak 4 in 2019. Additionally, Skagerrak 4 had 6 disturbance outages of which 3 were major due to faults on the Danish land cable. The cable faults occurred in February, July and October.

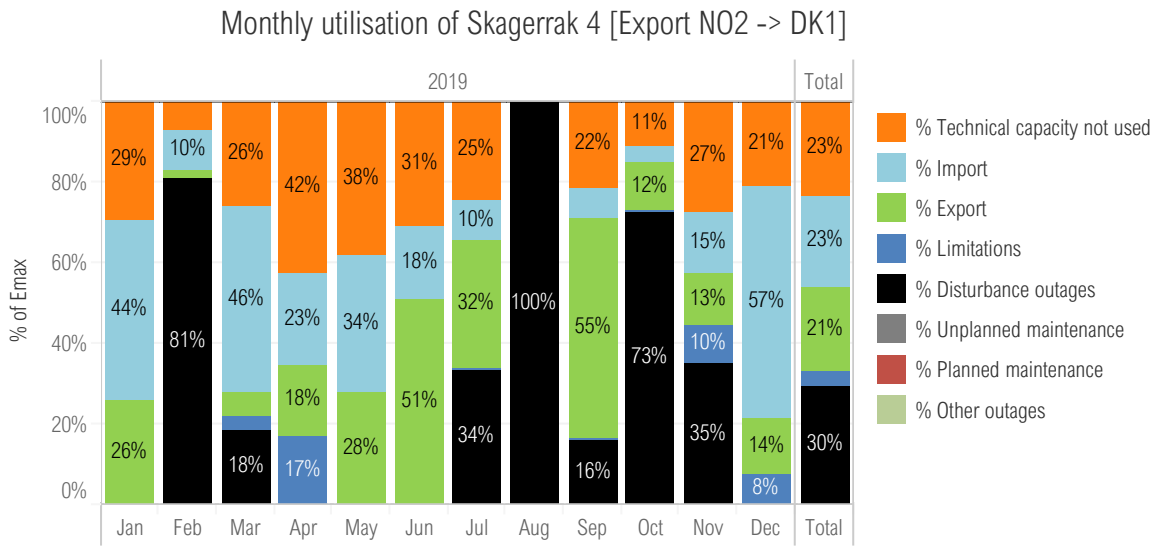

Figure 5.67: Percentage distribution of the availability and utilisation per category according to month for Skagerrak 4 in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.16: Monthly distribution of the technical capacity (E_{max}) for Skagerrak 4 in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Skagerrak 4 [Export NO2 -> DK1]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	149.4	32.0	131.2	208.1	192.9	152.0	124.4	-	106.2	54.7	134.8	107.0	1392.9	23.3%
Import, GWh	225.1	44.8	234.4	113.4	172.7	87.9	49.6	-	35.2	21.4	73.4	290.4	1348.3	22.6%
Export, GWh	132.9	9.2	28.4	86.6	141.6	251.1	160.7	-	268.1	61.8	63.7	71.0	1275.1	21.3%
Limitations, GWh	-	-	19.5	82.8	0.2	-	0.1	-	1.9	0.7	47.1	39.0	191.4	3.2%
Disturbance outages, GWh	-	372.3	93.1	-	-	-	172.5	507.4	79.7	369.6	171.9	-	1766.6	29.6%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	5.5	1.1	5.5	2.7	4.1	2.2	1.2	-	0.8	0.5	1.8	7.8	33.2	0.6%
Export losses, GWh	2.5	0.2	0.5	1.7	2.7	5.1	3.3	-	5.0	1.1	1.1	1.1	24.2	0.4%
Total, GWh	507.4	458.3	506.7	491.0	507.4	491.0	507.4	507.4	491.0	508.1	491.0	507.4	5974.4	100.0%

Figure 5.68 presents the annual utilisation of Skagerrak 4 per utilisation and unavailability category for the years 2015–2019.

Figure 5.69 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 2015–2019. Figure 5.70 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2015–2019.

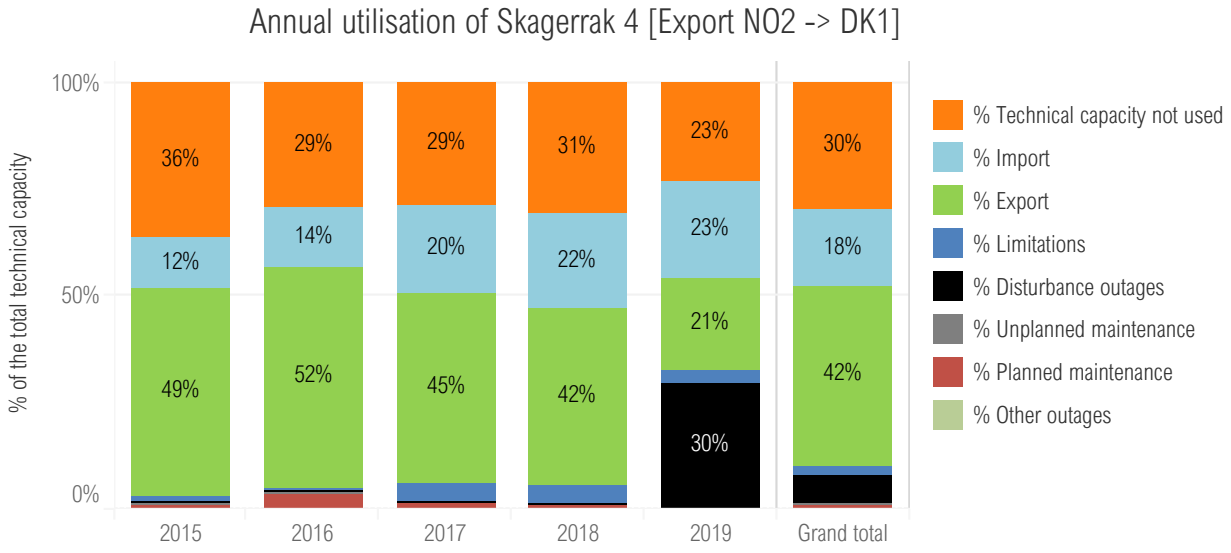

Figure 5.68: Annual utilisation of Skagerrak 4 according to the utilisation and unavailability categories for the years 2015–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

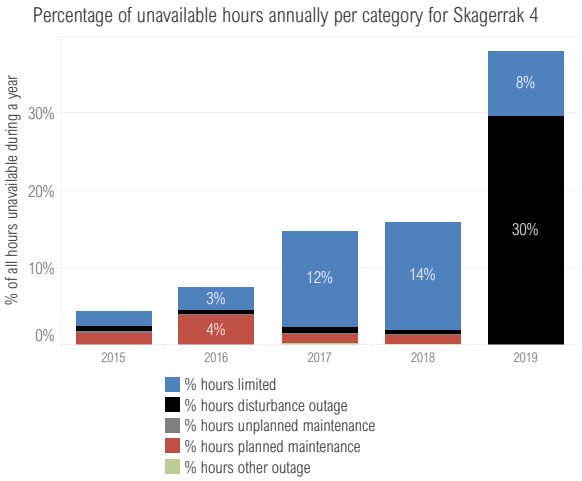

Figure 5.69: Percentage of hours Skagerrak 4 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2015–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

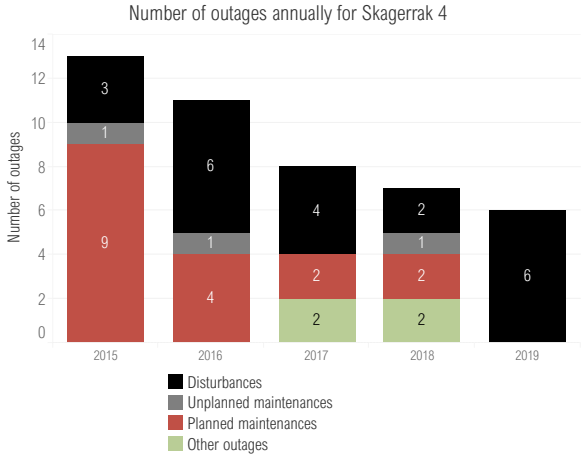

Figure 5.70: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Skagerrak 4 for the years 2015–2019.

5.3.17 Storebaelt

Figure 5.71 presents the availability and utilisation of Storebaelt for 2019 and Table 5.17 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 2019, Storebaelt had an available technical capacity of 97 %. The technical capacity not used was 39 %. Totally, 2.9 TWh (54 % of the technical capacity) was exported from Jutland to Zealand and 0.2 TWh (4 % of the technical capacity) was imported to Jutland.

The annual maintenance of Storebaelt lasted 4 days in October. Additionally, Storebaelt had no disturbance outages.

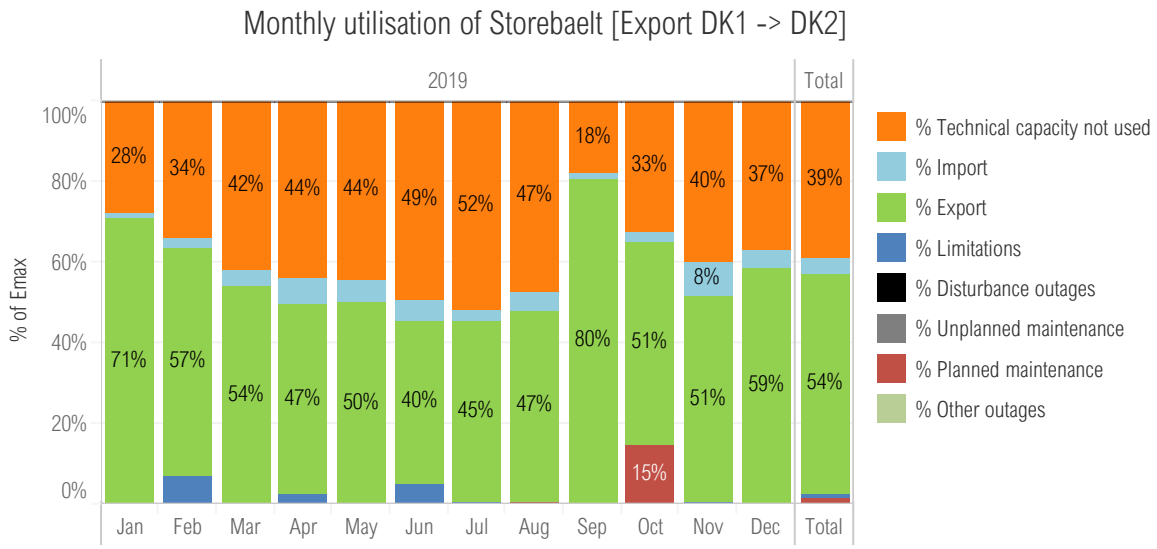

Figure 5.71: Percentage distribution of the availability and utilisation per category according to month for Storebaelt in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.17: Monthly distribution of the technical capacity (E_{max}) for Storebaelt in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Storebaelt [Export DK1 -> DK2]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	125.6	136.3	187.8	190.9	197.6	213.7	232.1	211.7	78.7	146.0	173.3	166.1	2060.0	39.2%
Import, GWh	3.8	10.9	17.0	27.6	25.9	22.3	11.3	21.4	6.1	9.7	36.0	18.0	210.0	4.0%
Export, GWh	317.0	228.8	240.0	203.6	222.9	174.3	201.9	211.6	347.3	226.1	221.1	262.2	2856.7	54.4%
Limitations, GWh	-	27.2	0.9	9.9	-	21.7	1.2	-	-	-	1.5	-	62.4	1.2%
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	-	-	-	-	1.7	-	65.1	-	-	66.8	1.3%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	0.1	0.2	0.3	0.4	0.4	0.4	0.2	0.4	0.1	0.2	0.6	0.3	3.4	0.1%
Export losses, GWh	5.4	3.8	4.1	3.4	3.8	2.8	3.3	3.6	6.1	3.8	3.7	4.4	48.3	0.9%
Total, GWh	446.4	403.2	445.8	432.0	446.4	432.0	446.4	446.4	432.0	447.0	432.0	446.4	5256.0	100.0%

Figure 5.72 presents the annual utilisation of Storebaelt per utilisation and unavailability category for the years 2012–2019.

Figure 5.73 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 2012–2019. Figure 5.74 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

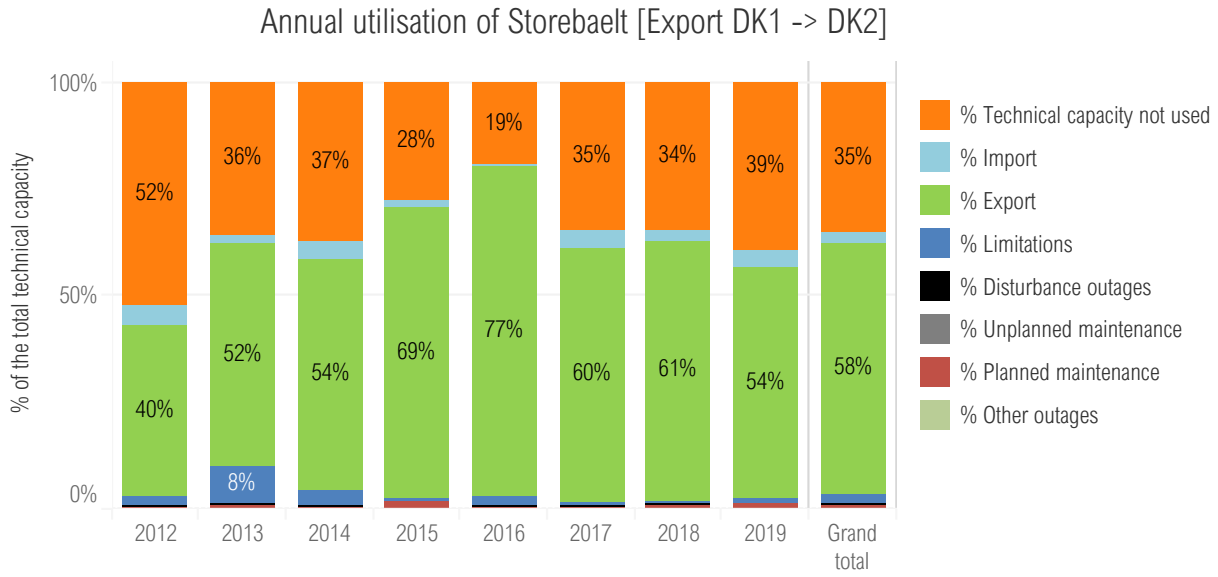

Figure 5.72: Annual utilisation of Storebaelt according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

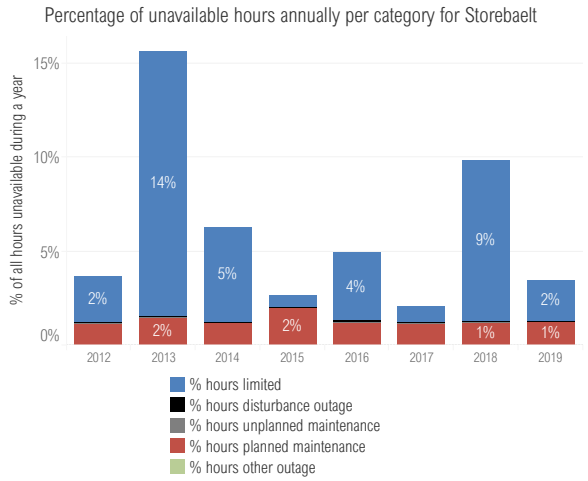

Figure 5.73: Percentage of hours Storebaelt has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

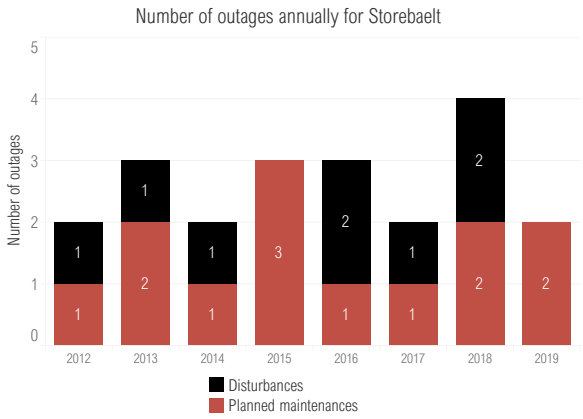

Figure 5.74: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Storebaelt for the years 2012–2019. Storebaelt had no other outages during the years 2012–2019.

5.3.18 SwePol

Figure 5.75 presents the availability and utilisation of SwePol for 2019 and Table 5.18 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.

In 2019, SwePol had an available technical capacity of 86 %. The technical capacity not used was 24 %. Totally, 3.1 TWh (59 % of the technical capacity) was exported from Sweden to Poland and 0.2 TWh (4 % of the technical capacity) was imported to Sweden.

The annual maintenance of SwePol lasted 11 days in September 2019. Additionally, SwePol had one more severe unplanned maintenance outage due to an oil leakage and 6 minor planned maintenance outages. Last, SwePol had 1 major disturbance outage due to a valve cooling system failure in August. The disturbance outage lasted for 29 days.

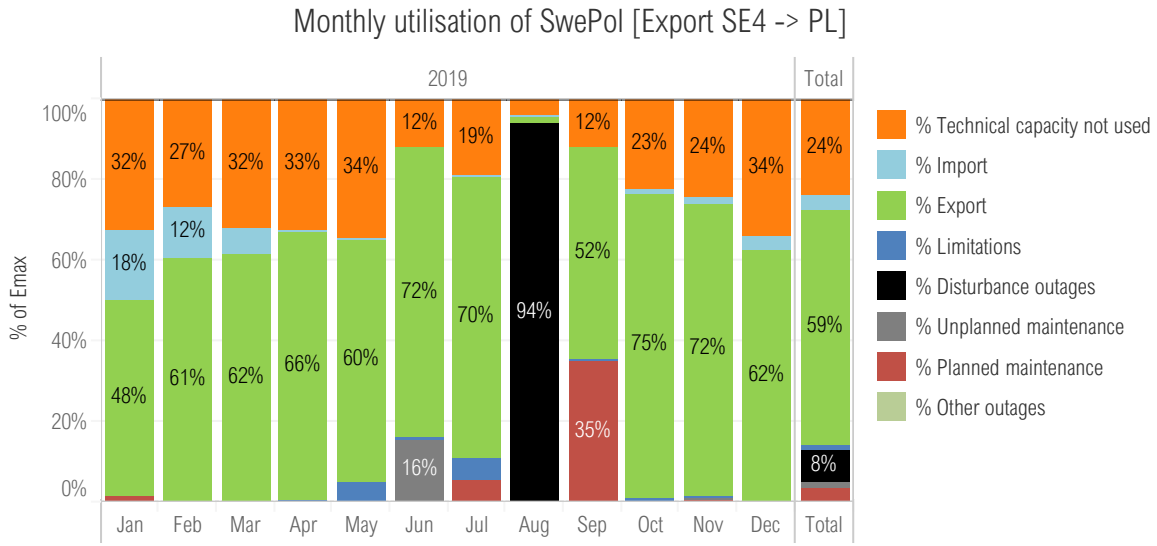

Figure 5.75: Percentage distribution of the availability and utilisation per category according to month for SwePol in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.18: Monthly distribution of the technical capacity (E_{max}) for SwePol in 2019. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of SwePol [Export SE4 -> PL]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	144.0	109.5	141.6	141.0	152.9	52.3	85.0	17.4	52.6	101.3	105.1	151.1	1254.0	23.9%
Import, GWh	78.8	49.2	29.6	1.7	0.5	-	0.5	-	-	2.9	8.3	17.0	188.4	3.6%
Export, GWh	216.5	244.5	274.5	287.0	269.9	310.6	312.8	9.9	225.3	337.4	311.2	277.5	3077.2	58.5%
Limitations, GWh	-	-	-	2.2	23.1	0.6	23.4	-	2.3	5.3	3.3	0.8	61.0	1.2%
Disturbance outages, GWh	-	-	-	-	-	-	-	419.0	-	-	-	-	419.0	8.0%
Unplanned maintenance., GWh	-	-	-	-	-	68.5	-	-	-	-	1.8	-	70.3	1.3%
Planned maintenance, GWh	7.1	-	-	-	-	-	24.8	-	151.8	-	2.3	-	186.1	3.5%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Import losses, GWh	1.9	1.2	0.7	-	-	-	-	-	-	0.1	0.2	0.4	4.5	0.1%
Export losses, GWh	6.2	7.1	7.9	8.2	7.6	9.0	8.9	0.4	6.6	9.7	9.1	8.0	88.6	1.7%
Total, GWh	446.4	403.2	445.8	432.0	446.4	432.0	446.4	446.4	432.0	447.0	432.0	446.4	5256.0	100.0%

Figure 5.76 presents the annual utilisation of SwePol per utilisation and unavailability category for the years 2012–2019.

Figure 5.77 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 2012–2019. Figure 5.78 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

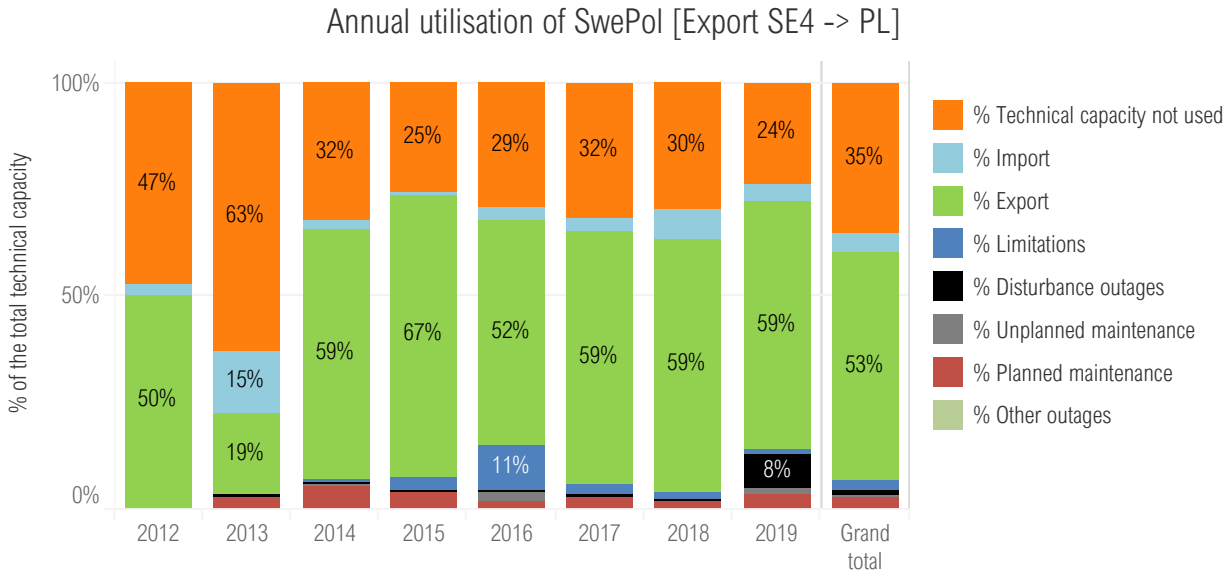

Figure 5.76: Annual utilisation of SwePol according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

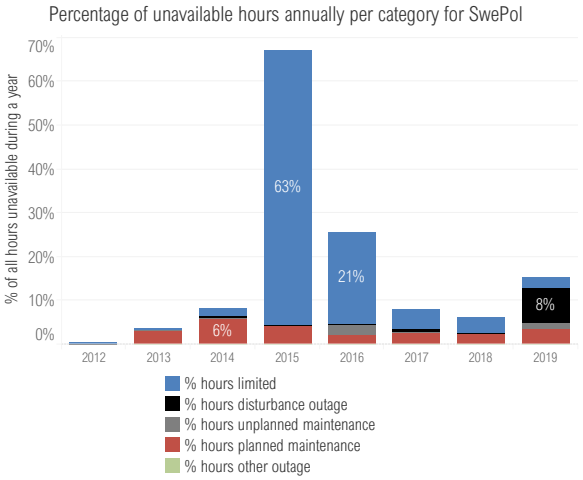

Figure 5.77: Percentage of hours SwePol has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

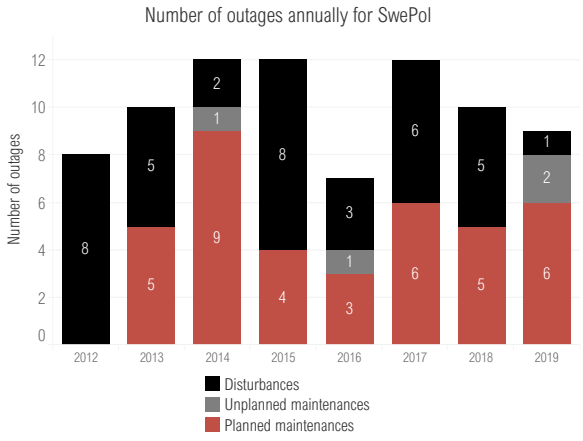

Figure 5.78: The annual number of disturbances, unplanned and planned maintenance outages and other outages for SwePol for the years 2012–2019. SwePol had no other outages during the years 2012–2019.

5.3.19 Vyborg Link

Figure 5.79 presents the monthly availability and utilisation of the Vyborg Link for 2019 and Table 5.19 presents the numerical values behind it. The Vyborg Link is a back-to-back HVDC connection between Russia and Finland. The HVDC substation is situated in Vyborg, Russia. The 400 kV lines from Vyborg are connected to substations Yllikkälä and Kymi in southern Finland.

Vyborg link has been commissioned four times. It was first commissioned in year 1981, and further in 1982, 1984, and 2000. Each commissioning increased the transmission capacity by 350 MW. Today, the total technical capacity is 4 × 350 MW and the commercial transmission capacity is 1.3 GW. Fingrid Oyj, the Finnish transmission system operator, allocates 100 MW for reserves. Earlier, the direction of transmission has been only to Finland but during September 2014, one 350 MW unit was successfully tested to be able to export electricity to Russia. The possibility of commercial trade from Finland to Russia started on 1 December 2014.

In 2019, the Vyborg Link had an available technical capacity of 95 %. The technical capacity not used was 33 %. Totally, 7.0 TWh (62 % of the technical capacity) was exported from Russia to Finland and none was imported to Russia.

The annual maintenance of Vyborg Link lasted 31 days in July. Normally, maintenance work on Vyborg Link causes only limitations because the 350 MW units are not worked on simultaneously. Furthermore, additional (corrective) planned maintenance work lasting 25 days was held from the end of October to the middle of November. Last, Vyborg Link had 3 disturbance outages with only minor impact during 2019.

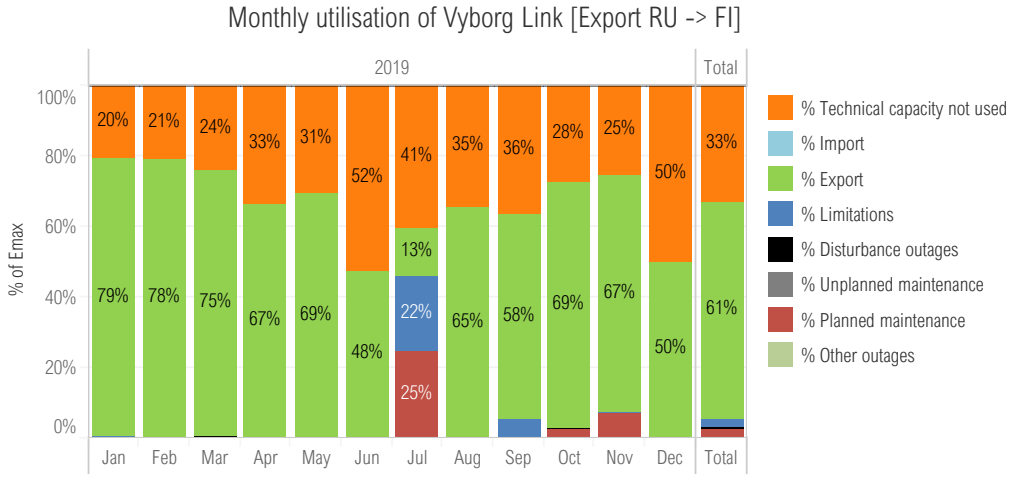

Figure 5.79: Percentage distribution of the availability and utilisation per category according to month for Vyborg Link in 2019. The availability and utilisation categories are defined in detail in Chapter 3.

Table 5.19: Monthly distribution of the technical capacity (E_{max}) for Vyborg Link in 2019. Measurements from the other side of the Vyborg Link is unknown and therefore losses are based on assumptions. Therefore, transmission losses have been omitted from this table.

Monthly utilisation of Vyborg Link [Export RU -> FI]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	% total
Technical capacity not used, GWh	197.2	184.4	231.9	311.5	296.8	490.3	391.9	334.6	341.4	267.9	238.3	484.6	3771.0	33.1%
Import, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Export, GWh	765.9	683.6	726.9	624.5	670.4	444.7	128.7	633.6	542.5	672.5	626.1	480.8	7000.0	61.5%
Limitations, GWh	4.1	1.6	-	-	-	0.7	208.8	-	52.1	-	1.8	-	269.1	2.4%
Disturbance outages, GWh	-	-	3.6	-	-	-	-	-	-	2.5	-	1.8	7.9	0.1%
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	4.0	3.5	-	-	0.3	237.8	-	-	25.5	69.8	-	341.0	3.0%
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	967.2	873.6	965.9	936.0	967.2	936.0	967.2	968.2	936.0	968.5	936.0	967.2	11389.0	100.0%

Figure 5.80 presents the annual utilisation of Vyborg Link per utilisation and unavailability category for the years 2012–2019.

Figure 5.81 presents the percentage of hours of a year Vyborg Link has been affected by either a limitation, a disturbance outage, an unplanned or planned maintenance outage or other outage annually during the years 2012–2019. Figure 5.82 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2019.

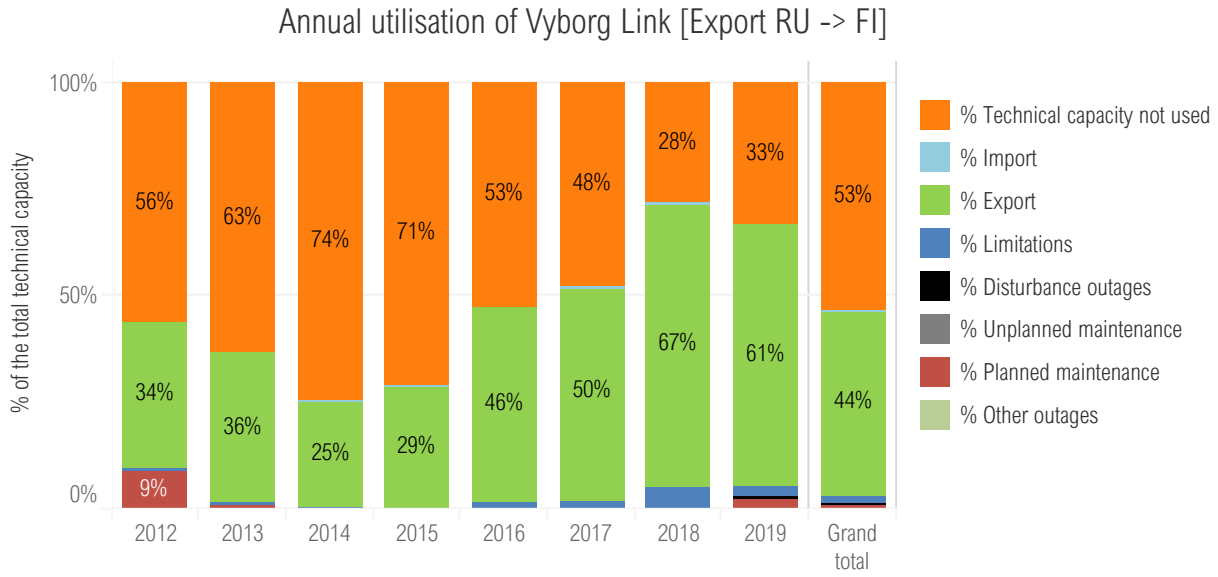

Figure 5.80: Annual utilisation of Vyborg Link according to the utilisation and unavailability categories for the years 2012–2019. The utilisation and unavailability categories are described in more detail in Chapter 3.

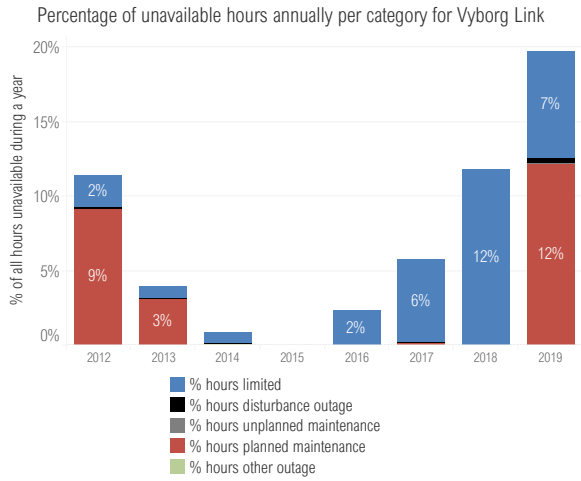

Figure 5.81: Percentage of hours Vyborg Link has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2019. The percentage is calculated by counting the number of hours with a limitation or outage and dividing it by the total number of hours in a year. It should be noted, that any single hour can be affected by both an outage and a limitation.

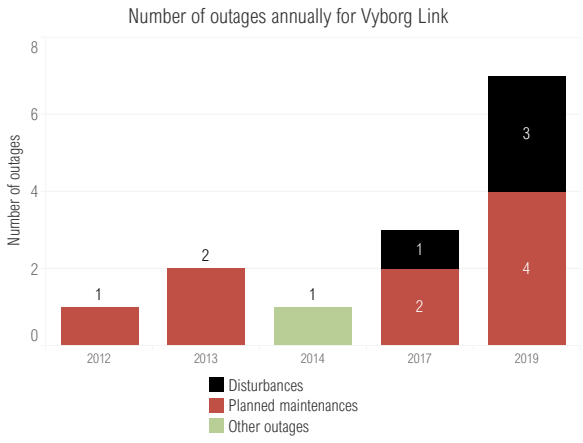

Figure 5.82: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Vyborg Link for the years 2012–2019.

References

[1] DISTAC, "Nordic Grid Disturbance Statistics 2010." https://www.fingrid.fi/contentassets/03690e21eae3449f8fe5d8d96b746e12/pohjoismainen-vika-ja-hairiotilasto-2010-2.pdf, August 2010.

Appendices

A Schematic presentation of HVDC links

Figure A.1 and Figure A.2 show the schematic presentations of a HVDC converter station having line-commutated converters (LCC) and voltage-source converters (VSC), respectively. All the figures also show definitions for the origin of an event. The origin of each event is used for categorizing 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.

It should be noted, that these figures are only show an example of a possible LCC or VSC converter station as there are multiple different ways to construct one.

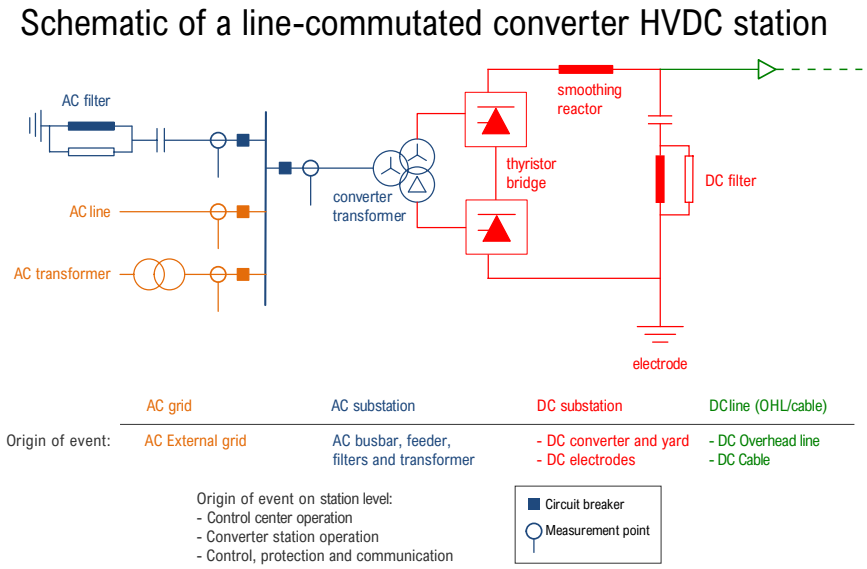

Figure A.1: An example of a line-commutated converter (LCC) station schematic with the connection to the AC grid. The other (remote) side of the HVDC link has a similar albeit mirrored version of the converter station.

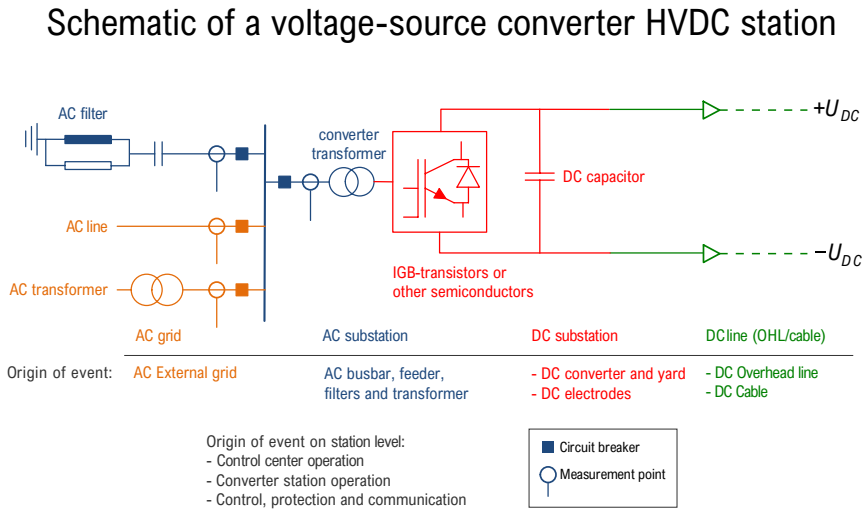

Figure A.2: An example of a voltage-source converter (VSC) station schematic with the connection to the AC grid. The other (remote) side of the HVDC link has a similar albeit mirrored version of the converter station.

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C Sorted overview of utilisation and unavailability for all HVDC links

This chapter contains sorted versions of Figure 5.1 Availability and utilisation overview of each HVDC link in 2019.

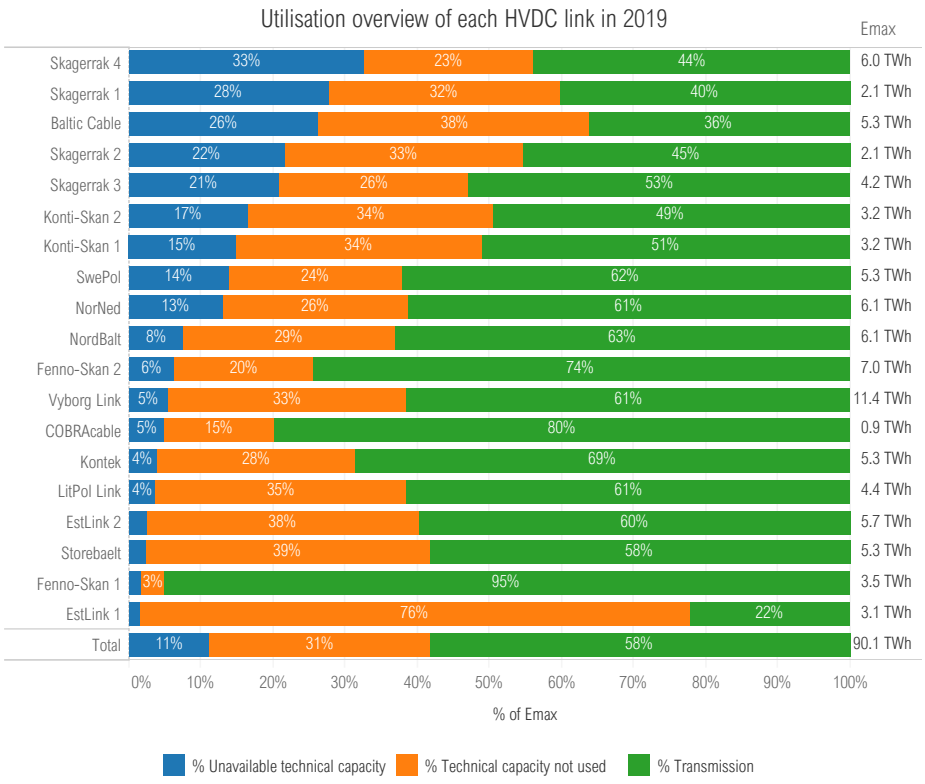

Figure C.1: Overview of each HVDC link sorted by descending unavailable technical capacity (E_U) in 2019.

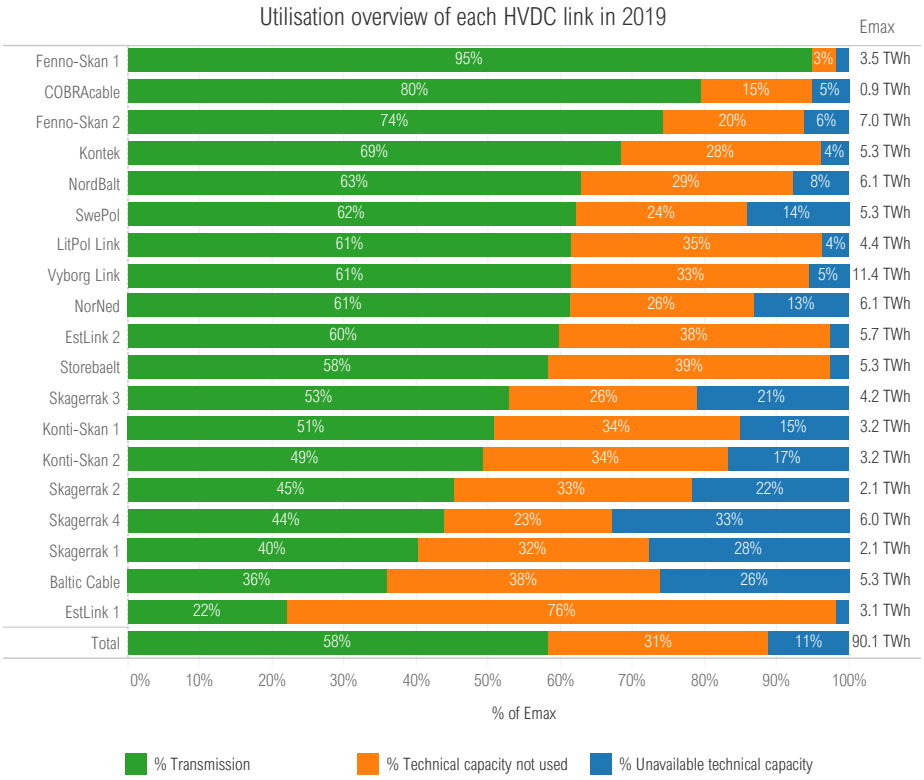

Figure C.2: Overview of each HVDC link sorted by descending transmission (E_T) in 2019.

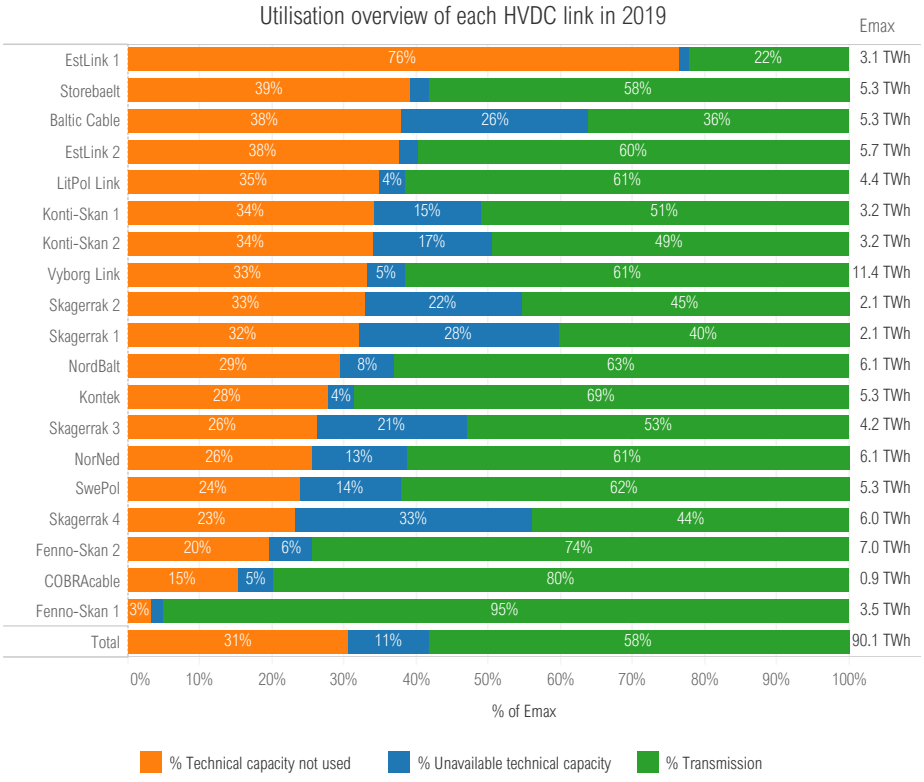

Figure C.3: Overview of each HVDC link sorted by descending technical capacity not used (E_{TCNU}) in 2019.

D 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.

D.1 Annual utilisation per type of HVDC converter

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

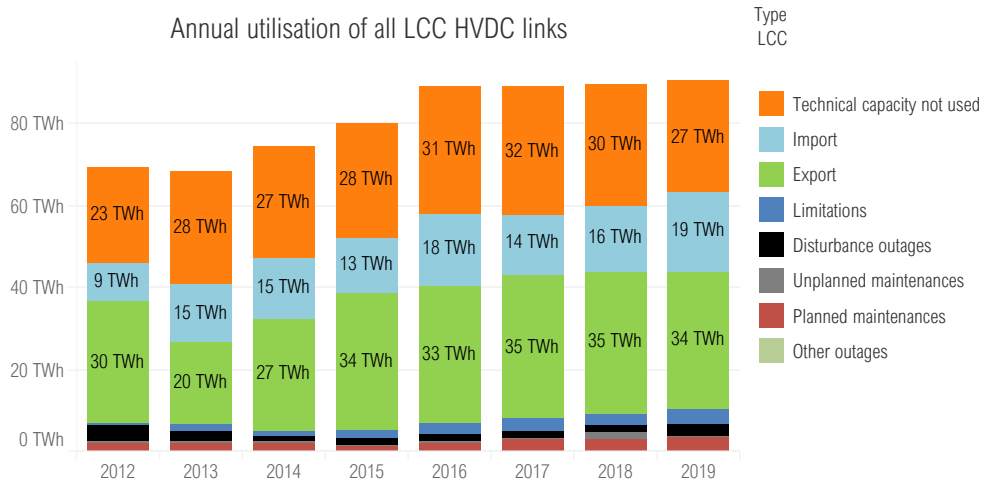

Figure D.1: Annual utilisation of all HVDC links using line-commutated converters (LCC) together presented in megawatt hours (MWh).

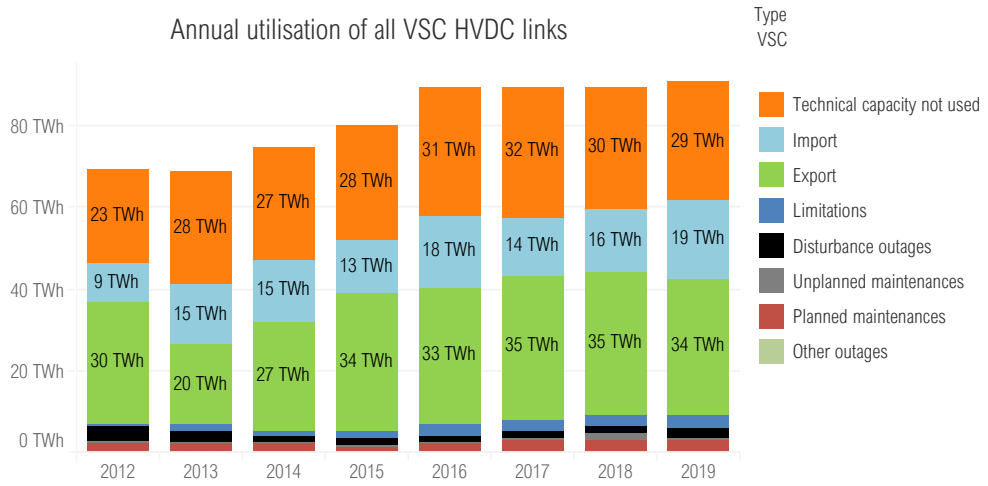

Figure D.2: Annual utilisation of all HVDC links using voltage-source converters (VSC) together presented in megawatt hours (MWh).

D.2 Additional figures with unavailability hours due to different causes

This section presents additional figures with a more detailed categorisation of unavailability. The figures presenting the percentage of hours unavailable may be interesting when one considers how often any size of unavailability is affecting an HVDC link.

Figure D.3 presents the percentage of hours all the Nordic and Baltic HVDC links have been affected by a limitation due to seasonal causes during a year. Figure D.4 presents the percentage of hours all the Nordic and Baltic HVDC links have been limited, distributed per type of limitation. The limitation types are AC limiting and DC limiting. Figure D.5 presents the percentage of hours the HVDC connection between each bidding zone has been limited due to an AC limiting condition during 2019.

Figure D.6 presents the percentage of hours each HVDC link has been available due to planned maintenance, distributed per cause, during 2019. Figure D.7 presents the same but for all links during 2019.

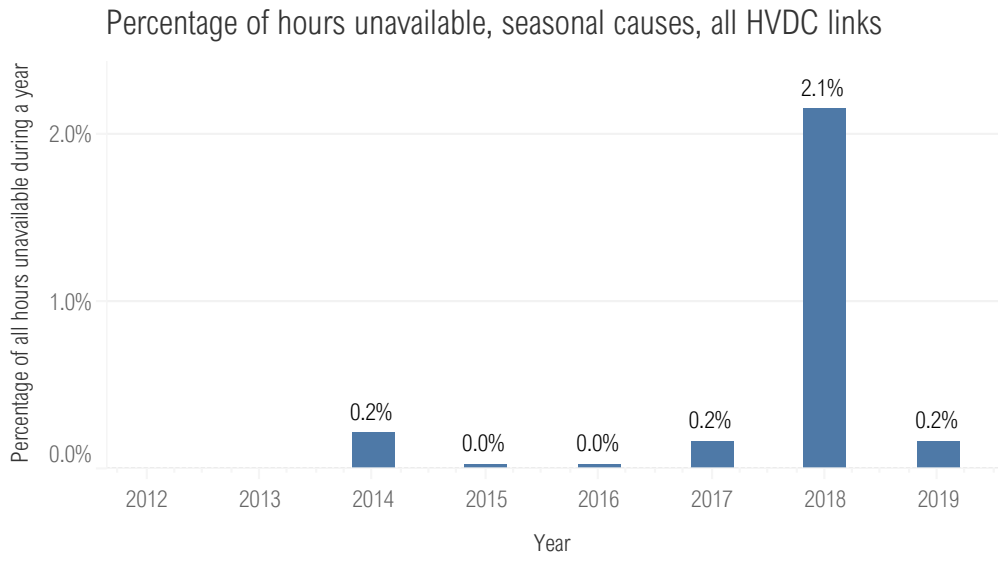

Figure D.3: Percentage of hours all HVDC links have been affected by a limitation due to seasonal causes. The percentage is calculated by counting the number of hours with a limitation due to a seasonal cause and dividing it by the total number of hours in a year.

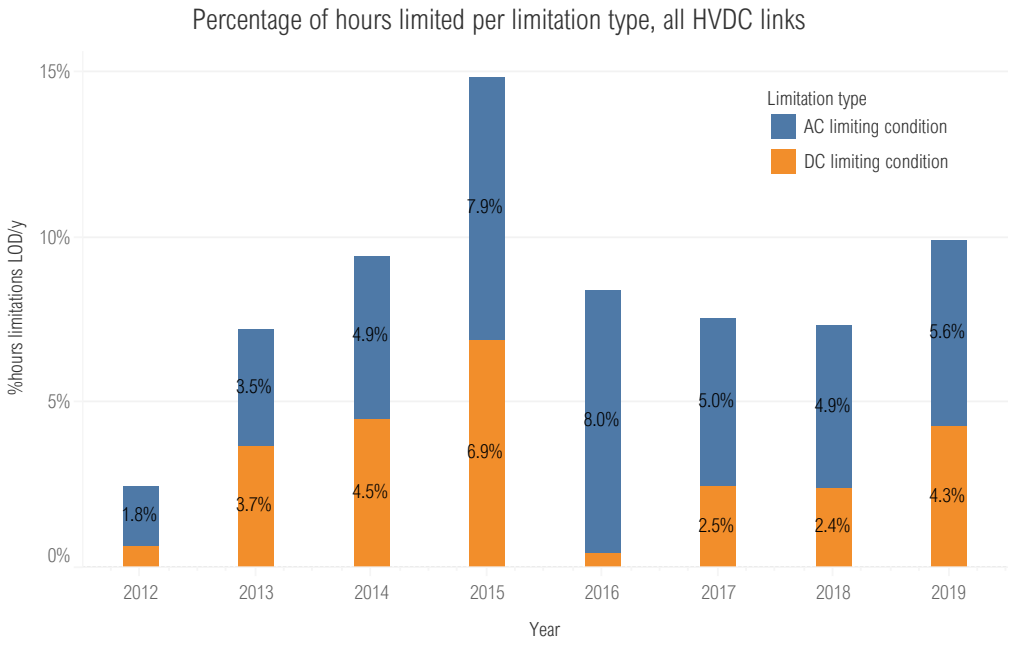

Figure D.4: Annual percentage of hours all HVDC links have been affected by a limitation per limitation type. The limitation types are AC limiting and DC limiting. The percentage is calculated by counting the number of hours with a limitation and dividing it by the total number of hours in a year.

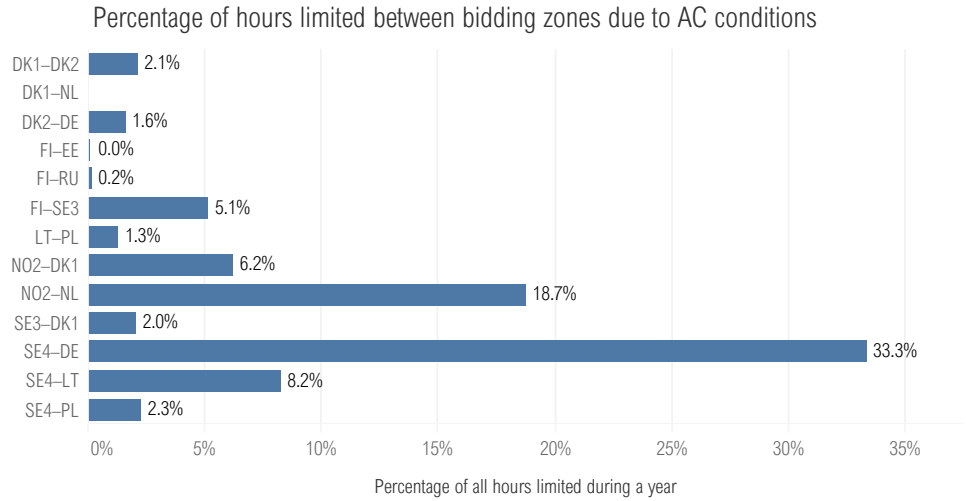

Figure D.5: Percentage of hours the connection between each bidding zones has been limited due to AC conditions in 2019. The percentage is calculated by counting the number of hours with an AC limiting condition and dividing it by the total number of hours in a year.

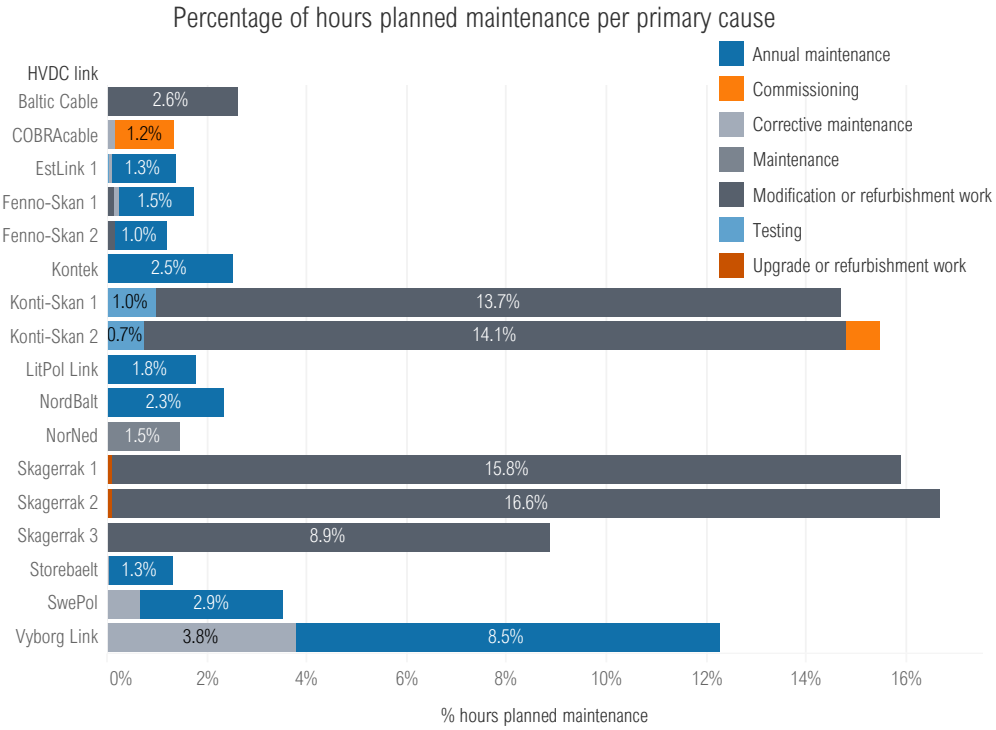

Figure D.6: Percentage of hours each HVDC link has been unavailable due to planned maintenance, distributed per cause, in 2019. The percentage is calculated by counting the number of hours with a planned maintenance and dividing it by the total number of hours in a year.

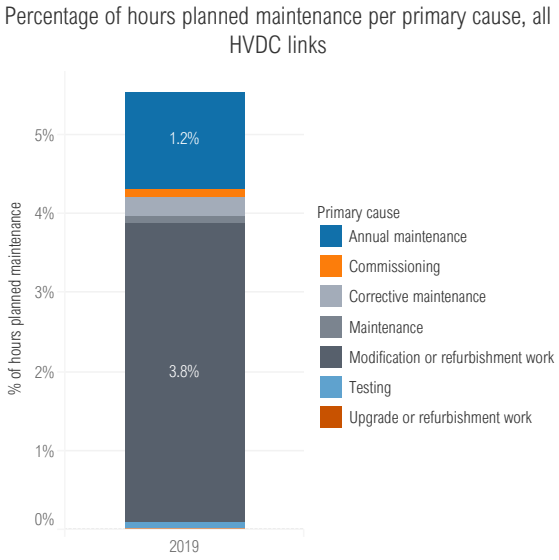

Figure D.7: Percentage of hours all HVDC has been unavailable due to planned maintenance, distributed per cause, in 2019. The percentage is calculated by counting the number of hours with a planned maintenance and dividing it by the total number of hours in a year.

D.3 Average utilisation and unavailability per month per HVDC link

The figures in this section present average monthly utilisation starting from 2012 or the year the HVDC link was added into the ENTSO-E HVDC Utilisation and Unavailability Statistics.

COBRAcable is not included in this figure because it was commissioned in late 2019.

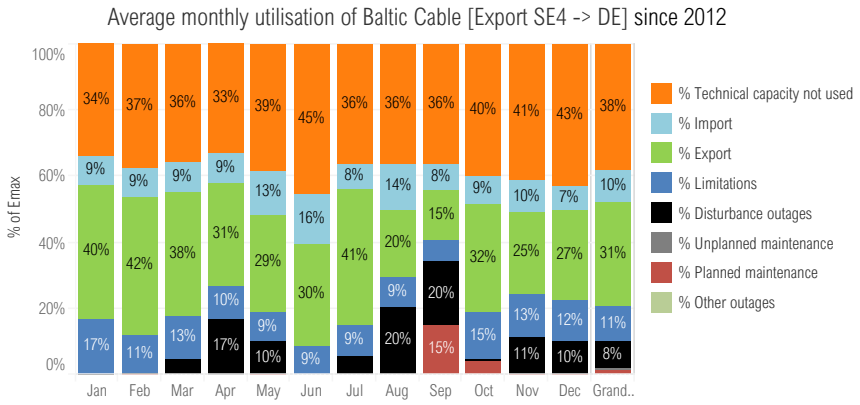

Figure D.8: Average percentage distribution of the availability and utilisation per category according to month for Baltic Cable during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

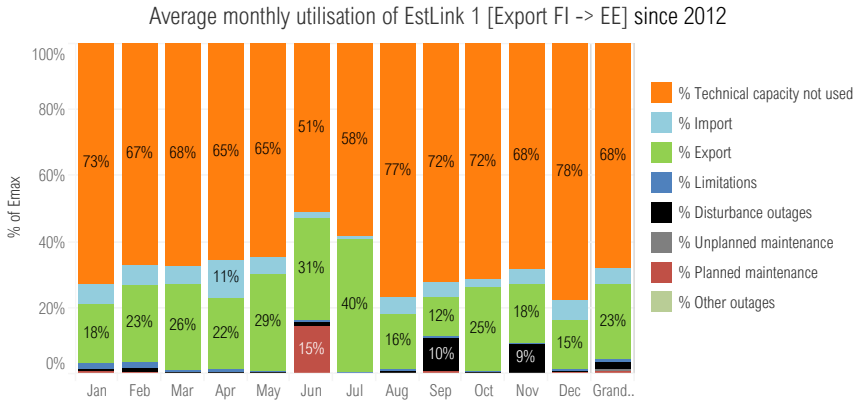

Figure D.9: Average percentage distribution of the availability and utilisation per category according to month for EstLink 1 during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

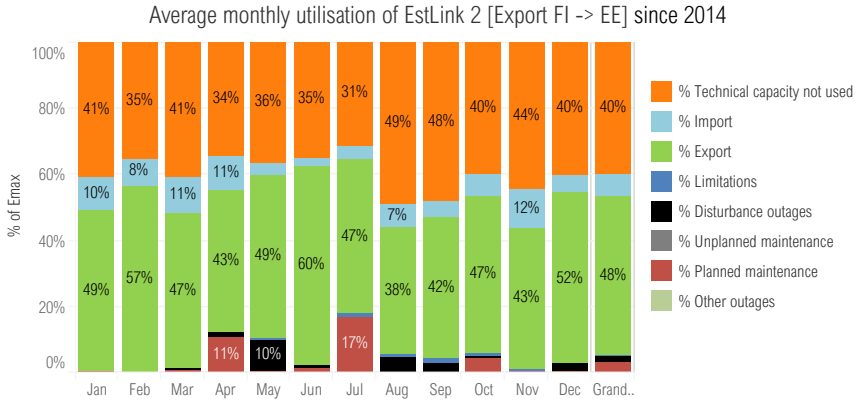

Figure D.10: Average percentage distribution of the availability and utilisation per category according to month for EstLink 2 during 2014–2019. The availability and utilisation categories are defined in detail in Chapter 3.

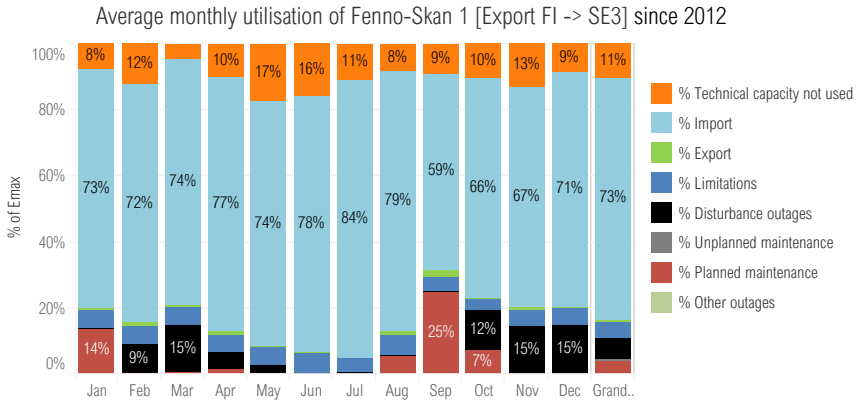

Figure D.11: Average percentage distribution of the availability and utilisation per category according to month for Fenno-Skan 1 during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

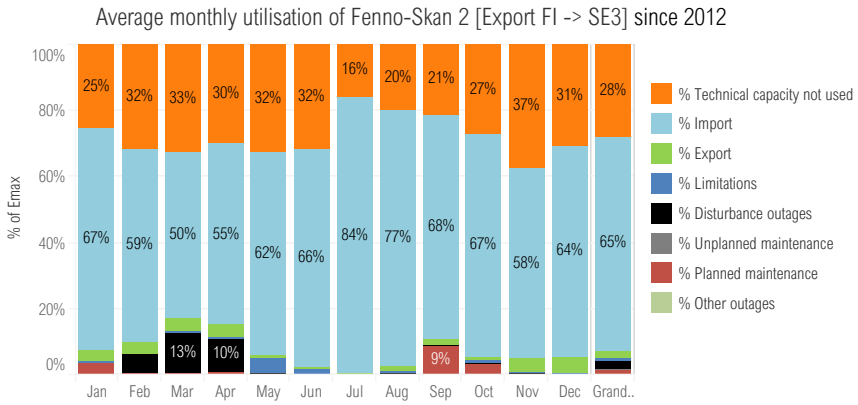

Figure D.12: Average percentage distribution of the availability and utilisation per category according to month for Fenno-Skan 2 during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

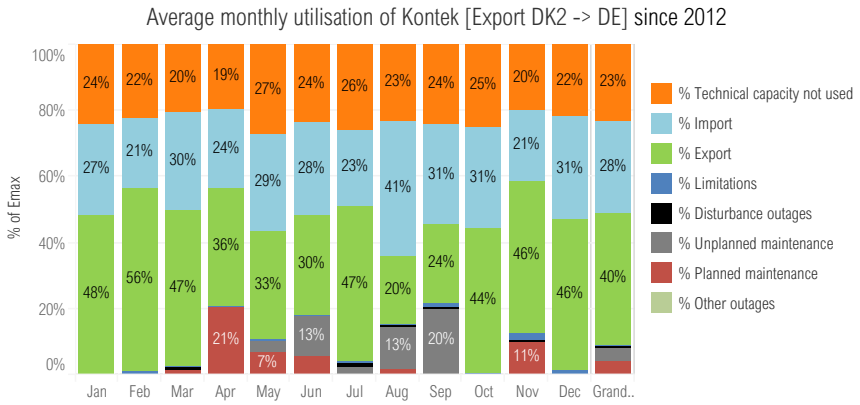

Figure D.13: Average percentage distribution of the availability and utilisation per category according to month for Kontek during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

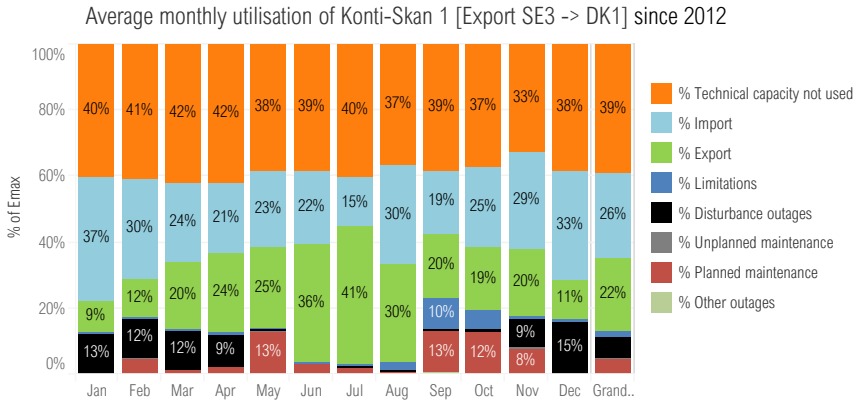

Figure D.14: Average percentage distribution of the availability and utilisation per category according to month for Konti-Skan 1 during 2016–2019. The availability and utilisation categories are defined in detail in Chapter 3.

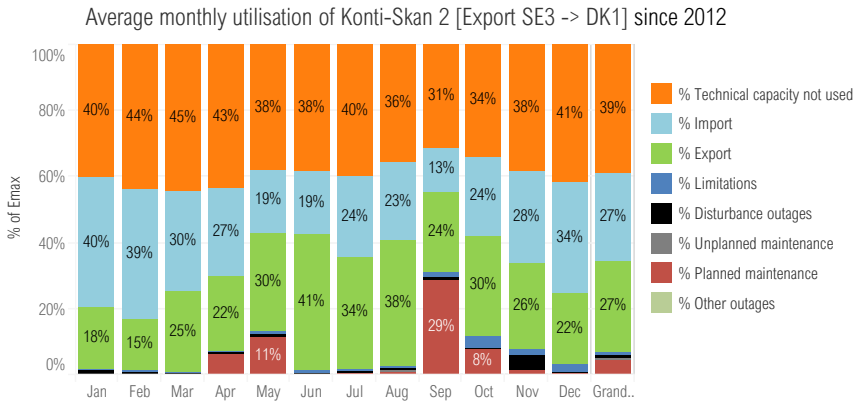

Figure D.15: Average percentage distribution of the availability and utilisation per category according to month for Konti-Skan 2 during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

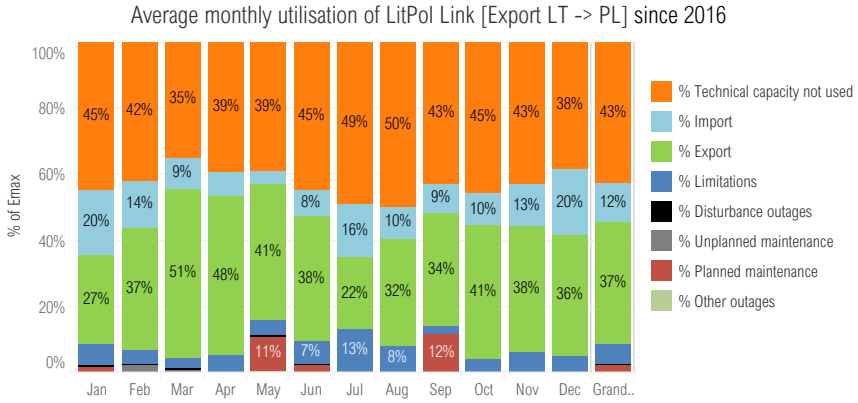

Figure D.16: Average percentage distribution of the availability and utilisation per category according to month for LitPol Link during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

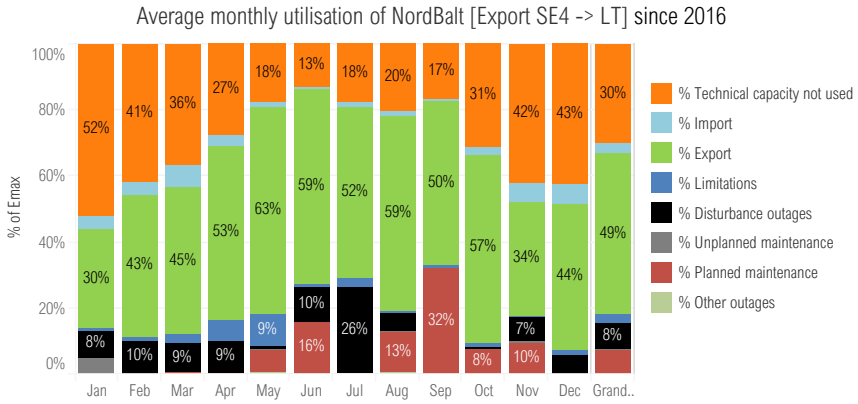

Figure D.17: Average percentage distribution of the availability and utilisation per category according to month for NordBalt during 2016–2019. The availability and utilisation categories are defined in detail in Chapter 3.

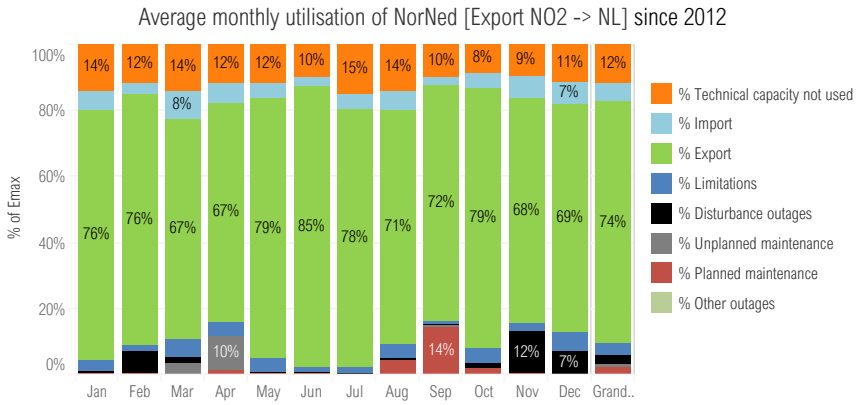

Figure D.18: Average percentage distribution of the availability and utilisation per category according to month for NorNed during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

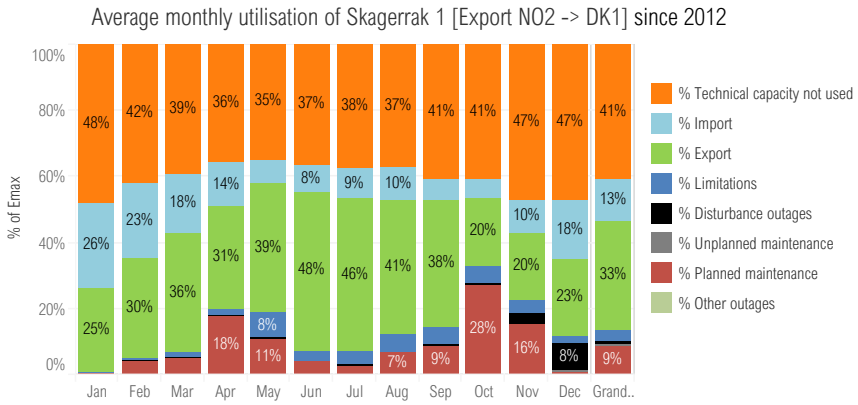

Figure D.19: Average percentage distribution of the availability and utilisation per category according to month for Skagerrak 1 during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

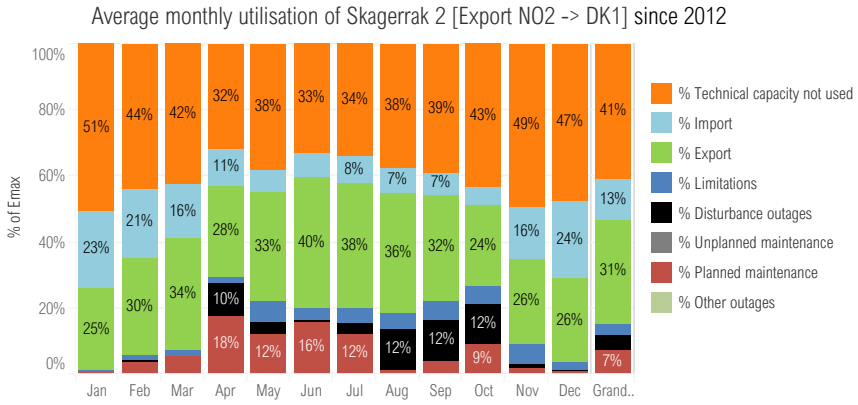

Figure D.20: Average percentage distribution of the availability and utilisation per category according to month for Skagerrak 2 during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

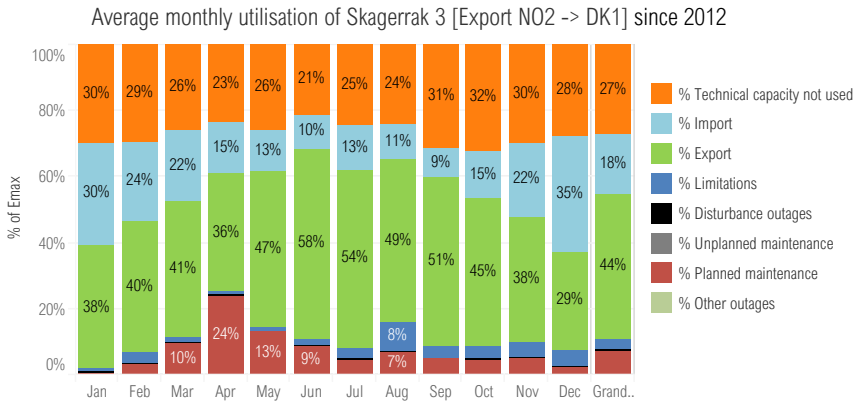

Figure D.21: Average percentage distribution of the availability and utilisation per category according to month for Skagerrak 3 during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

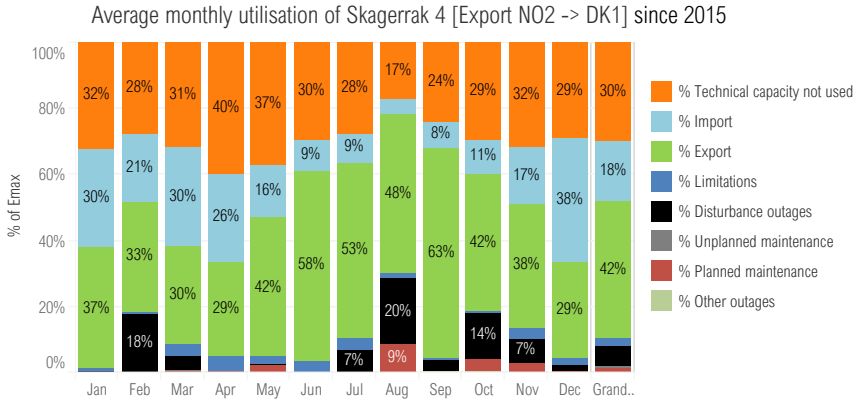

Figure D.22: Average percentage distribution of the availability and utilisation per category according to month for Skagerrak 4 during 2015–2019. The availability and utilisation categories are defined in detail in Chapter 3.

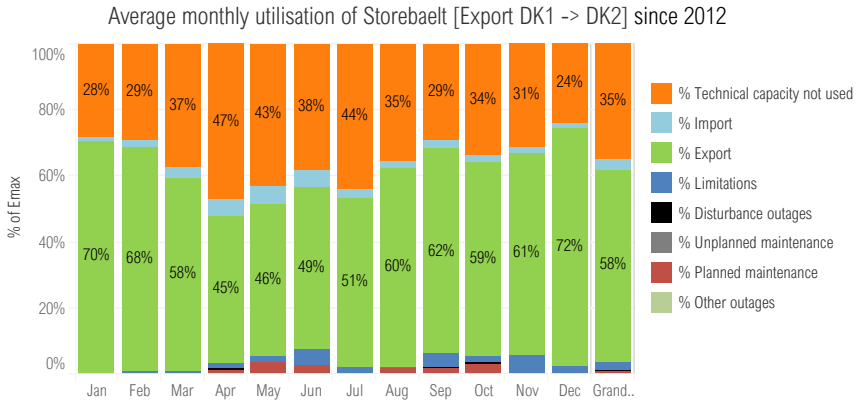

Figure D.23: Average percentage distribution of the availability and utilisation per category according to month for Storebaelt during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

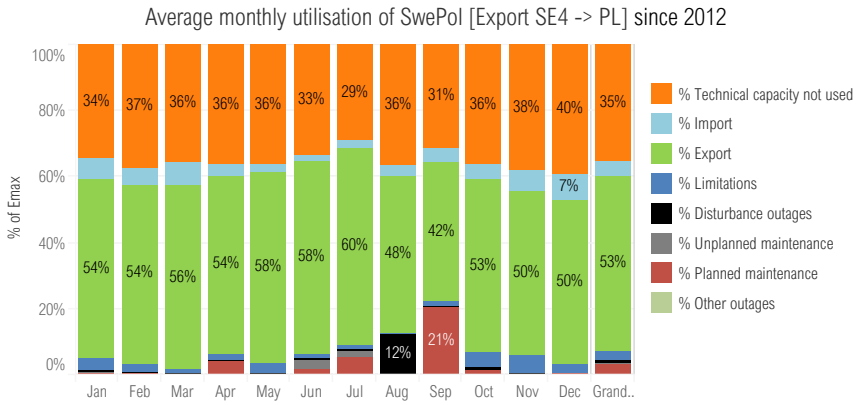

Figure D.24: Average percentage distribution of the availability and utilisation per category according to month for SwePol during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.

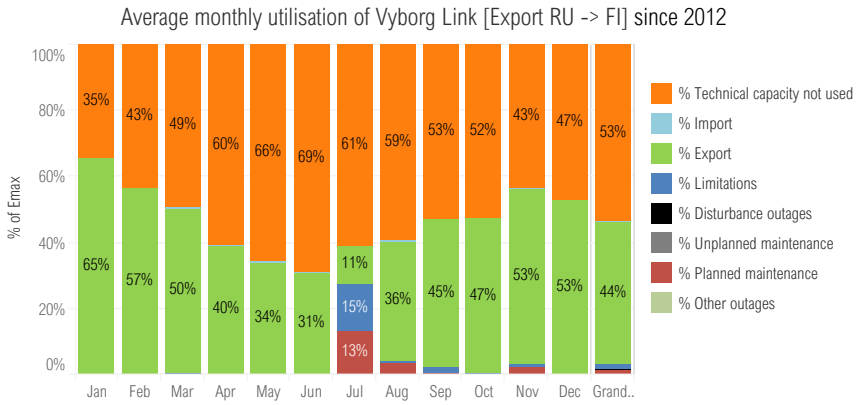

Figure D.25: Average percentage distribution of the availability and utilisation per category according to month for Vyborg Link during 2012–2019. The availability and utilisation categories are defined in detail in Chapter 3.