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Report

Operational data from shipping in the Geirangerfjord, Nærøyfjord og Aurlandsfjord

Data collection from cruise ships and local traffic

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Report

Operational data from shipping in the Geirangerfjord, Nærøyfjord og Aurlandsfjord

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SUMMARY
A survey has been conducted among cruise ships operating in Norwegian fjords in order to map operational data and procedures related to discharges to sea and emissions to air. Based on the operational data, the operational profile in the fjords can be estimated, making it possible to estimate emissions to air.

Information has also been collected from local traffic operating in the fjords as well as from Hurtigruten that visits the Geirangerfjord in the summer season.

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Dag Stenersen	Ingebrigt Valberg	Anders Valland

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0.1	02/12/2016	For comments
1.0	14/12/2016	Final report
2.0	24/04/2017	Final report, security level set to 'unrestricted'

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ANNEXES/APPENDICES

1 Introduction

The Norwegian Maritime Authority (NMA), on assignment from the Ministry of Climate and Environment, has conducted a survey of emissions and discharges from ships sailing in the Geirangerfjord, Nærøyfjord and Aurlandsfjord. This involves a collection of data describing the technical aspects of the ships, along with their operational profile when visiting the fjords. The purpose of the project is to get a better overview of the environmental consequences of the calls at port when ships visit the Norwegian world heritage fjords.

The technical execution of the survey has been carried out by Rambøll AS and MARINTEK on assignment from the NMA. The assignment consisted of collecting data from ships that operate in the fjords by way of a questionnaire and developing a dispersion model for air pollution for the fjords in question. MARINTEK has been responsible for the data collection, and this report describes the structure and results from this work.

The questionnaire for the cruise ships that visited the fjords in question was distributed via their Norwegian agents:

- European Cruise services
- GAC
- Tyrholm & Farstad

Information was in addition collected from Hurtigruten, a passenger and freight shipping service that operates daily in the Geirangerfjord in the summer months, as well as from local traffic (ferries and passenger boats).

MARINTEK would like to thank everyone who has contributed to this survey.

This report presents the results from the survey on a general basis.

2 The survey on pollution

The survey on pollution was organised by MARINTEK, and data has been collected from ships visiting or operating in the three fjords in question in order to establish typical operational profiles during normal operation. Data was collected by contacting all ships that visited the respective fjords during the summer of 2016 (May to September). A web-based questionnaire was prepared and distributed to the ships via their Norwegian agents. Data was in addition collected from Hurtigruten and from local traffic such as ferries and passenger boats in regular scheduled service.

Complementary data was also collected from port authorities in Stranda and Aurland and from the Seaweb database. The survey includes only ships that has visited the Geirangerfjord, Nærøyfjord and/or Aurlandsfjord and local traffic in these fjords.

2.1 Questionnaire for the cruise ships

A comprehensive questionnaire was distributed to all the cruise ships that visited the fjords in question during the summer of 2016. The purpose was to map the technical information for the ships and their operational profile when sailing in the respective fjords.

The questionnaire is attached in Annex A.

2.2 Local fjord traffic

Local traffic in the fjords consists of small passenger boats, RHIBs, tenders and local ferry traffic.
The operators of these boats were contacted in order to map relevant data for technical specifications and operational profile.

2.3 Hurtigruten

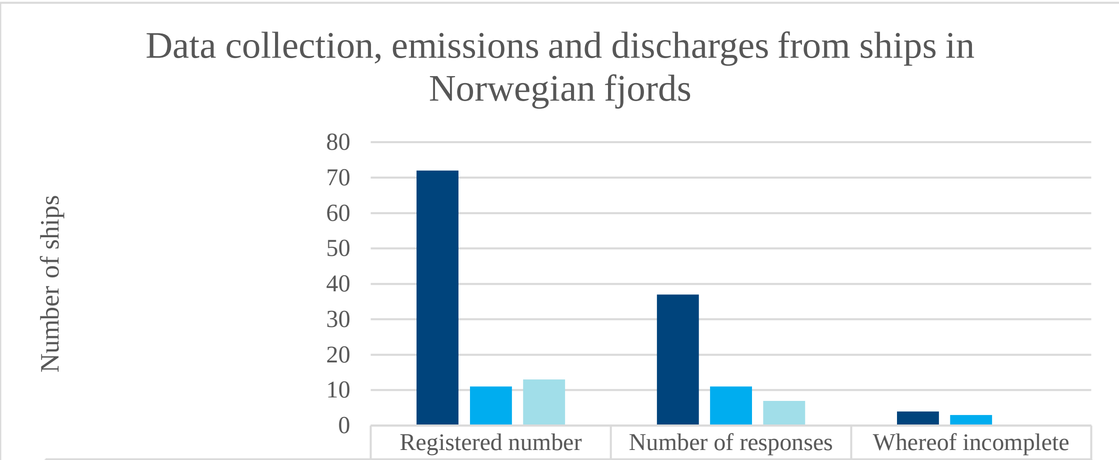
During the summer half of the year, Hurtigruten operates daily trips into the Geirangerfjord, and data for their sailing pattern has been of particular interest.

2.4 Background information, previous studies

Previous studies have estimated emissions to air from transport in the areas around Geiranger. In addition, air quality studies have been carried out by the Norwegian Institute for Air Research (NILU), and a new long-term project has been started in order to measure pollution and emissions to air in the Geirangerfjord.

2.5 Response rate

Feedback from the questionnaire for cruise ships and local traffic has been summed up in:



	Registered number	Number of responses	Whereof incomplete
Cruise ships	72	37	4
Hurtigruten	11	11	3
Local traffic, passenger ferries	13	7	0

Figure 2.1: Summary, data collection from ships

We received 37 responses from the cruise ships, whereof 4 were somewhat incomplete. In addition to data from the questionnaire, technical data have been complemented by information from Seaweb.

A total of 11 Hurtigruten ships visited Geiranger during the summer season as part of their ordinary route. We have received average estimates for the entire fleet as well as details for 8 of the ships. As regards local traffic, we received replies from ferries and passenger boats in regular scheduled service.

3 General emission factors

General emission factors are presented by IMO[1]. Stricter requirements for emissions to air from ships have reduced the emissions of NO_x and SO_x the last 15 years.

The emission factors for ships underway have been charted in several studies, some under IMO's auspices, and international requirements for emissions from ships are laid down by IMO in MARPOL Annex VI and the NO_x Technical Code. Ships underway shall comply with these requirements, and these factors are a good starting point for emission studies and estimating emissions from ships.

The goal of the survey was to chart ship-specific emission factors for ships visiting the Norwegian fjords, so that the general IMO factors could, if necessary, be corrected for further use in the dispersion analyses. In the questionnaire, the ships were asked to inform about level of NO_x certificate and other measures for reducing discharges to sea and emissions to air.

When evaluating the emission factors, it is natural to classify the ships according to year of construction, since emission requirements are defined as follows:

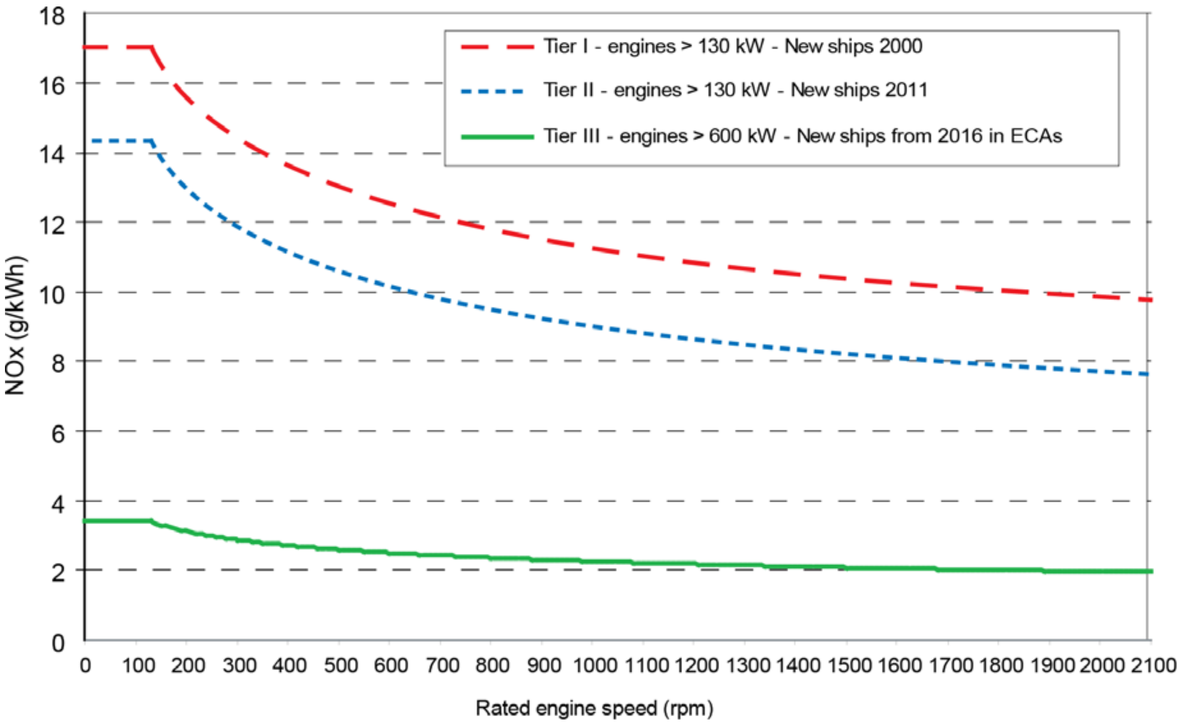


Figure 3.1: IMO NO_x requirements for ship engines (cf. IMO)

[1] Third IMO Greenhouse Gas Study 2014

4 Cruise ships in Norwegian fjords

In 2016, the Geirangerfjord had a total of 189 cruise calls (April-September) (ref:http://www.stranda-hamnevesen.no/), divided between 56 different cruise ships.

The Aurlandsfjord/Nærøyfjord had 163 ship arrivals divided between 56 different ships (http://aurlandhavn.no/). Altogether for both fjords, 72 different ships have been registered.

When evaluating the emission factors, it is natural to divide the ships by / classify the ships according to year of construction, based on IMO's emission requirements.

4.1 Ship data

4.1.1 Year of construction and technical information about the ships

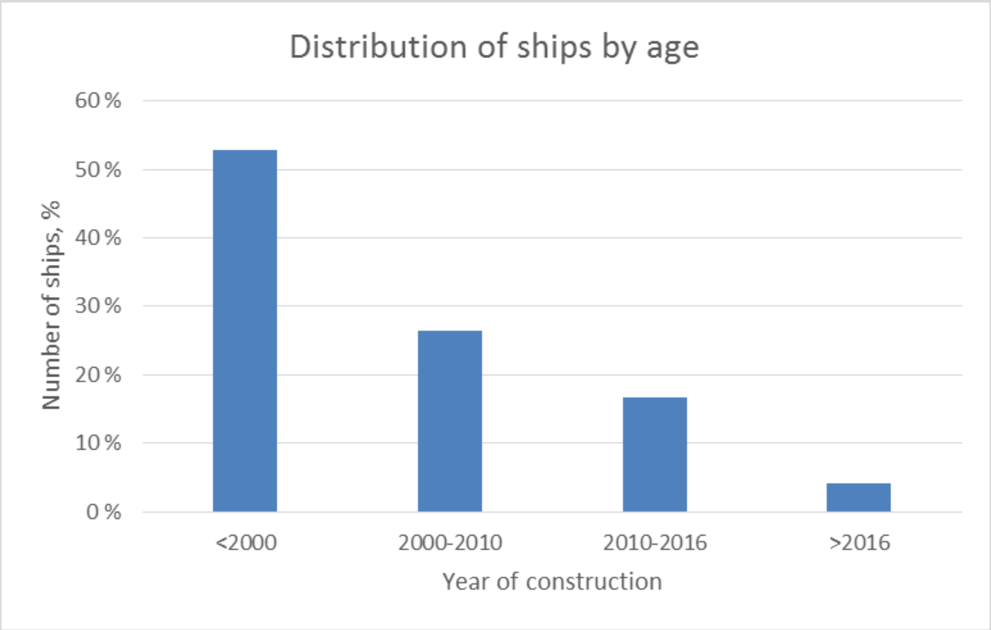


Figure 4.1: Distribution of cruise ships by year of construction (72 ships)

The average age for visiting ships is 20 years; the oldest ship was constructed in 1948 and the youngest in 2016.

We enquired about total engine power, and this information was additionally completed by information registered in Seaweb for all the 72 ships that visited the fjords in question. Presentation of data applies to main engines as defined in Seaweb.

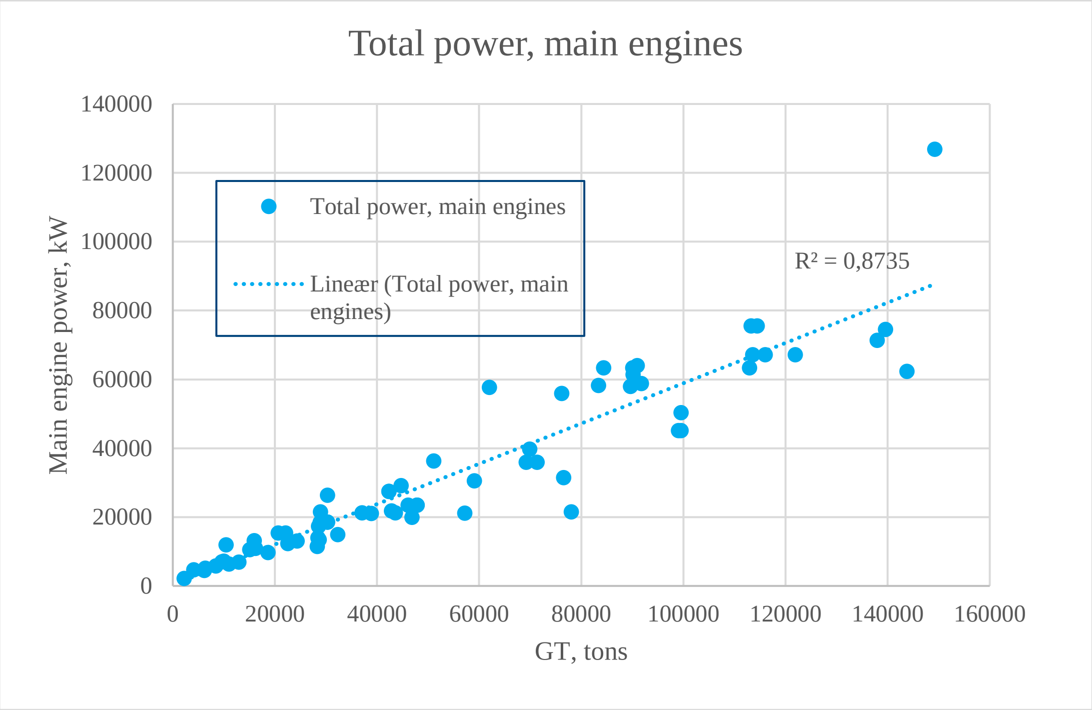


Figure 4.2: Main engine power (kW) vs ship size (GT) (72 ships)

Main engine power is approximately linear for the smallest ships. For larger ships (>40,000 GT) there is more dispersion. One ship stands out, however, with a main engine power of more than 120 MW.

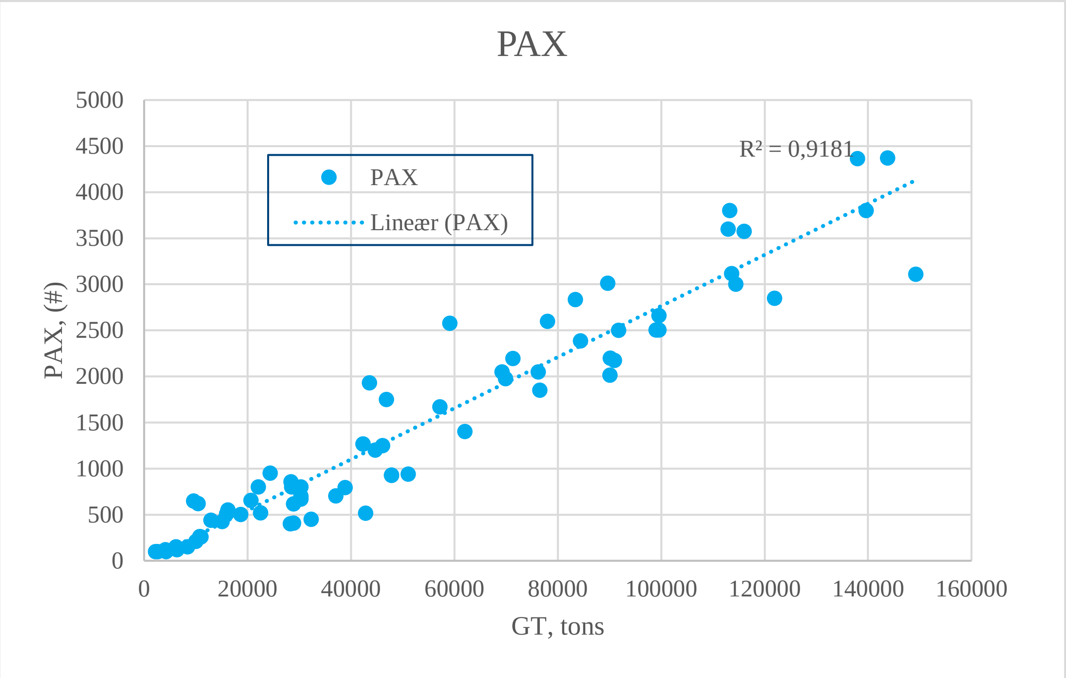


Figure 4.3: Number of passengers vs ship size (GT) (72 ships)

Passenger capacity is approximately linear compared to ship size in gross tonnage.

In our questionnaire, the ships were asked to specify propulsion power and auxiliary engine power. The results for our sample of ships is shown in Figure 4.4.

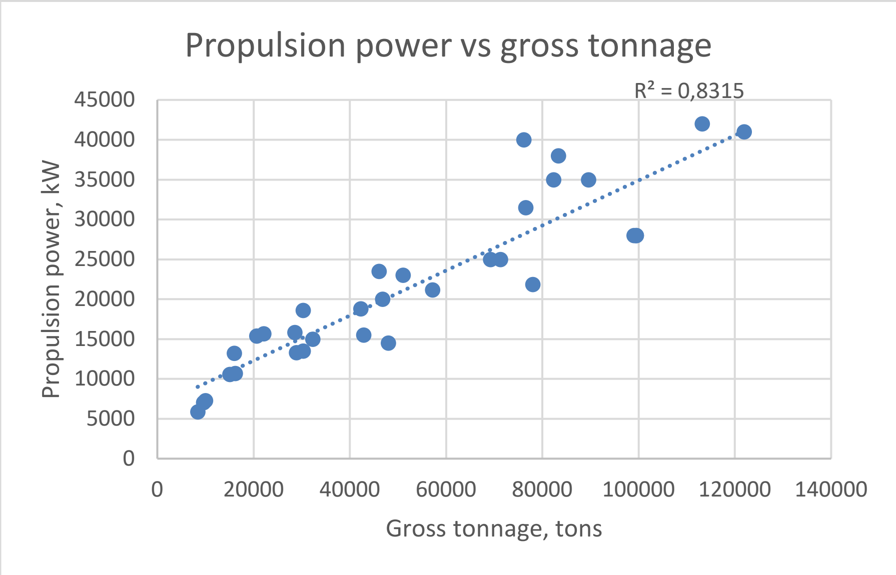


Figure 4.4: Auxiliary engine power (kW) vs ship size (GT) (34 responses)

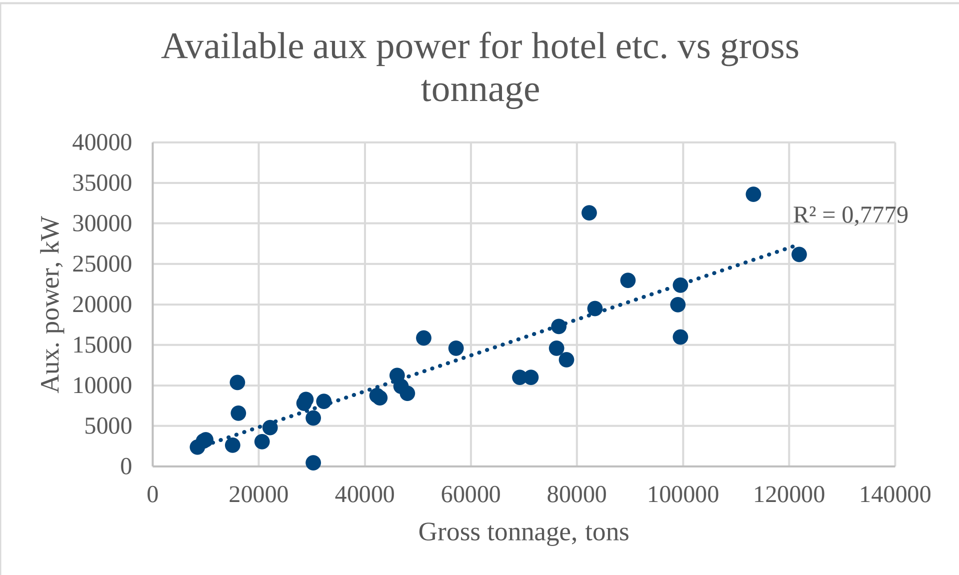


Figure 4.5: Available power for hotel etc. for ships in our survey (34 responses)

Figure 4.5 shows available power for hotel and other services on board at 100% loading of the propulsion engines. For diesel-electric installations, propulsion power will be defined as mechanical power of each propeller. Available power for hotel and other services will thus be the available auxiliary capacity as shown in Figure 4.5.

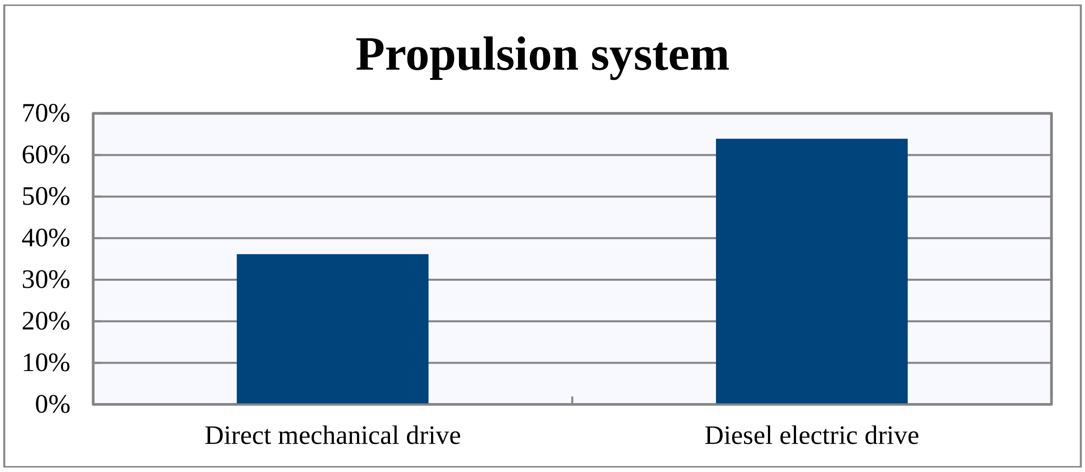


Figure 4.6: Distribution between direct mechanical drive and diesel-electric drive

36% of the ships have mechanical drive and 64% have diesel-electric drive.

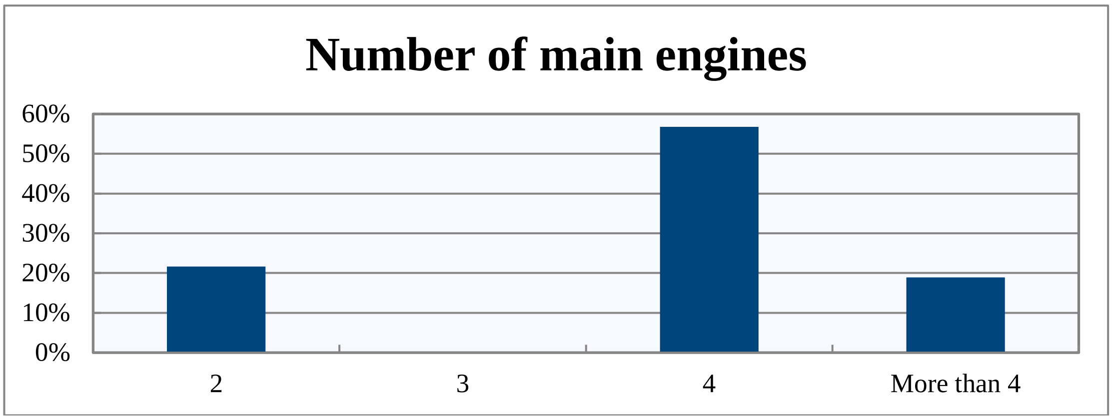


Figure 4.7: Number of main engines

Most ships have four or more main engines (ME). All ships having only two ME have mechanical drive.

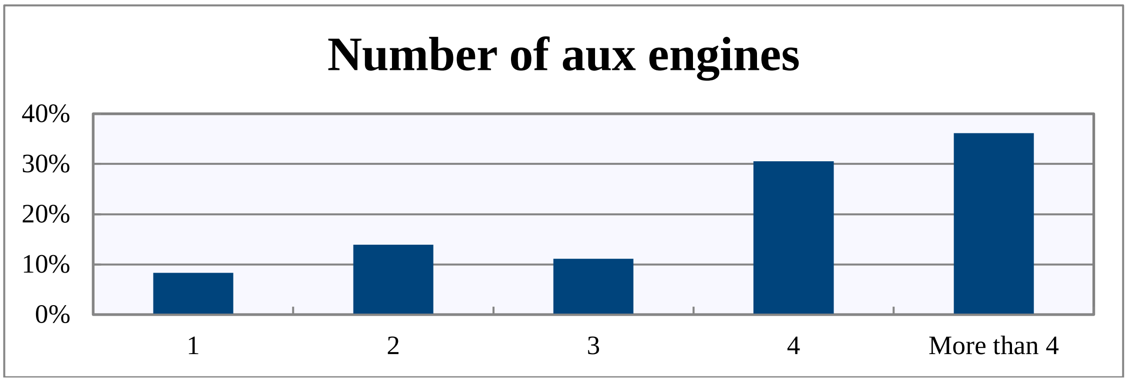


Figure 4.8: Number of auxiliary engines on board

Most ships have several auxiliary engines on board. For diesel-electric installations, some ships will define all their engines as auxiliary engines, whereas other ships will define these as main engines, so the definition of auxiliary engines for this ship category is not unambiguous. It is evident that all ships have

many engines on board, allowing flexible operation and power generation when the power requirement is low.
There are also ships using gas turbines for power generation.

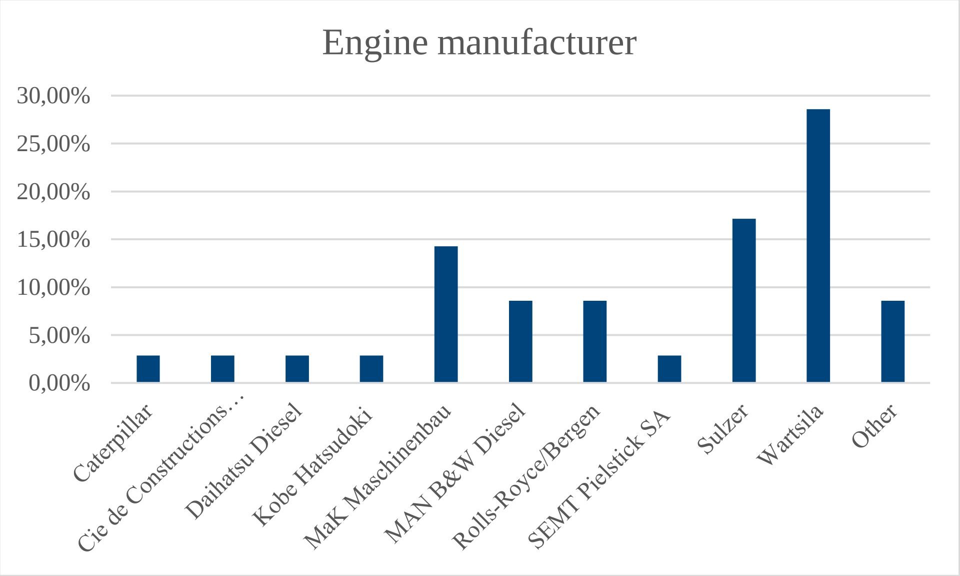


Figure 4.9: Distribution of main engine manufacturers

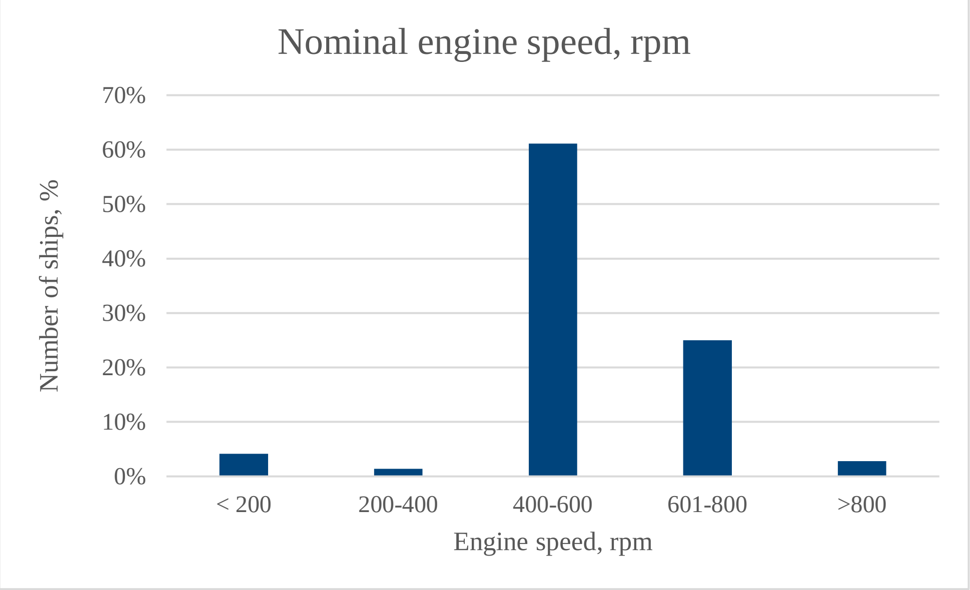


Figure 4.10: Main engine speed (rpm)

The vast majority of the ships (>85%) have medium speed main engines operating with an rpm between 400 and 800, which are delivered by recognised suppliers in the market.

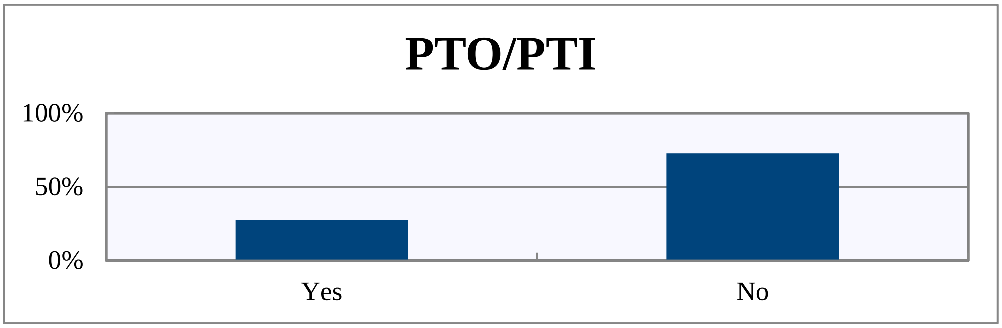


Figure 4.11: Number of ships with PTO/PTI

Approx. 30% of the ships have a PTO/PTI solution. This contributes to flexible power generation on board these ships. 50% of the ships with mechanical drive have a PTO/PTI solution.

4.1.2 Fuel

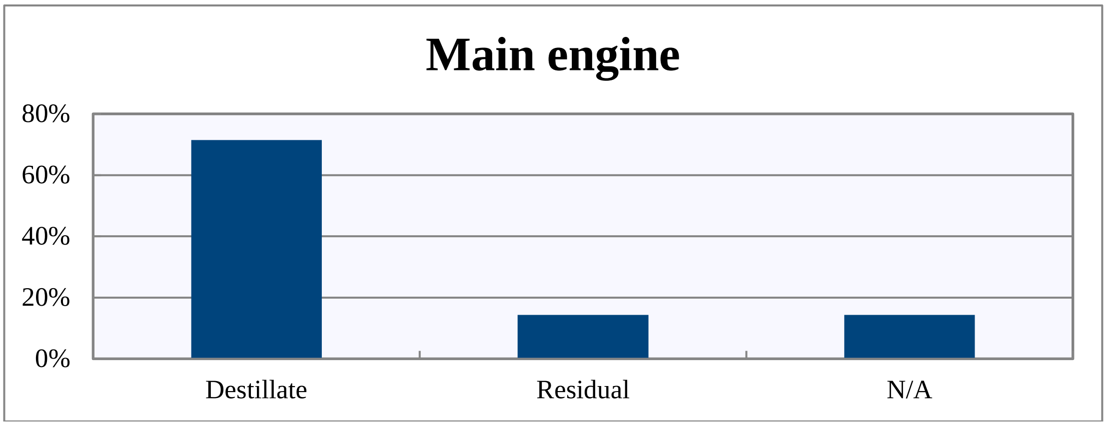


Figure 4.12: Fuel - main engines

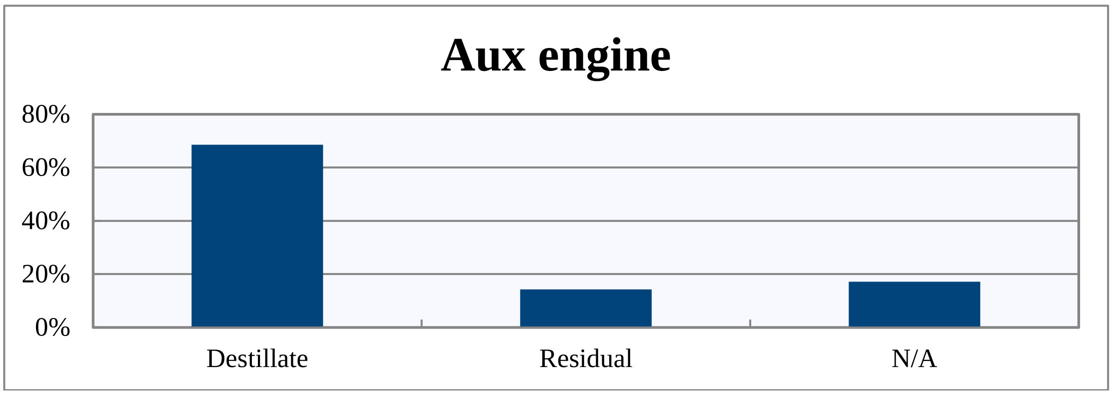


Figure 4.13: Fuel - auxiliary engines

Most ships (70%) use distillate (MGO) for main and auxiliary engines. Approx. 12% of the ships use heavy fuel oil (HFO 380 and HFO LS). The categorisation of main and auxiliary engines makes the question irrelevant for some ships (N/A).

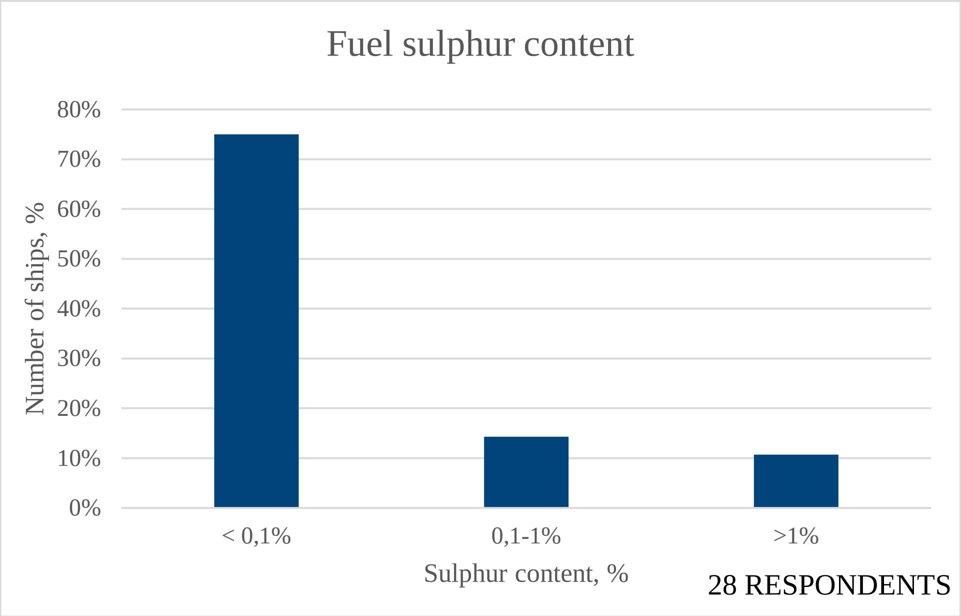


Figure 4.14: Sulphur content of bunker oil, main engine

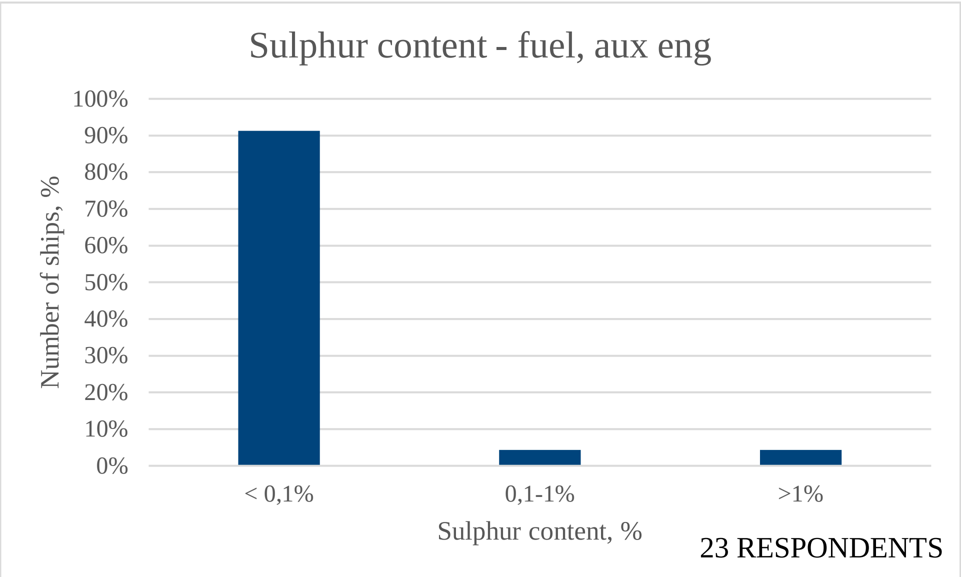


Figure 4.15: Sulphur content of bunker oil, aux engines

The vast majority of the ships use bunker oil with a low sulphur content. Most ships use MGO when operating in the fjords.

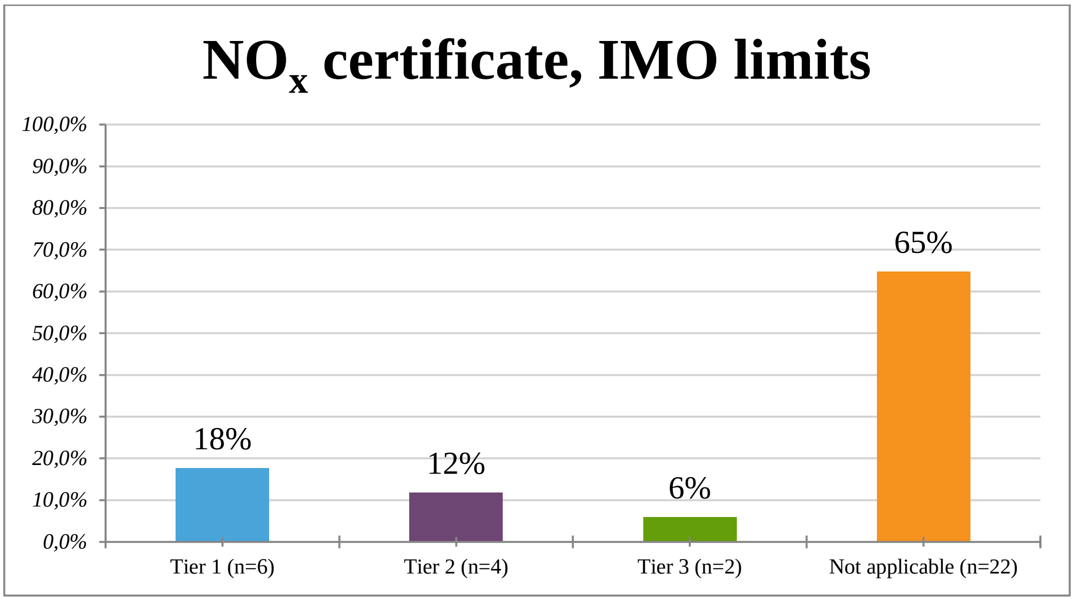


Figure 4.16: NO_x certificate, IMO limits

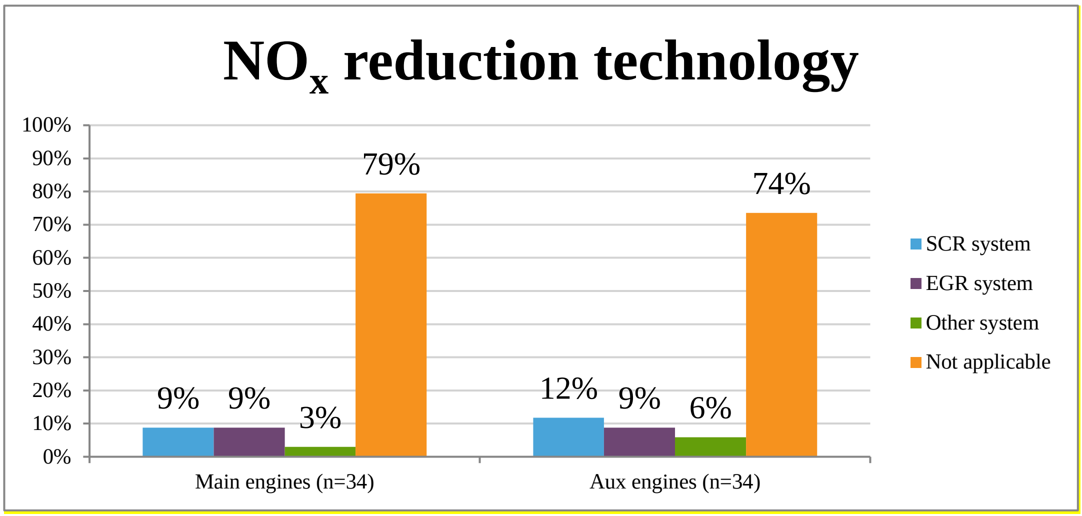


Figure 4.17: NO_x reduction technology, main and aux engines

NO_x emission level (Tier 1, 2, 3) is connected with the age of the ships (year of construction). Approx. 20-25% of the ships state that they have NO_x reduction technology installed.

SCR systems will reduce the NO_x emission factor by around 85-90% so that the engines satisfy the IMO Tier 3 requirements. EGR systems have less effect, but ships will satisfy IMO Tier 2 requirements by using such systems.

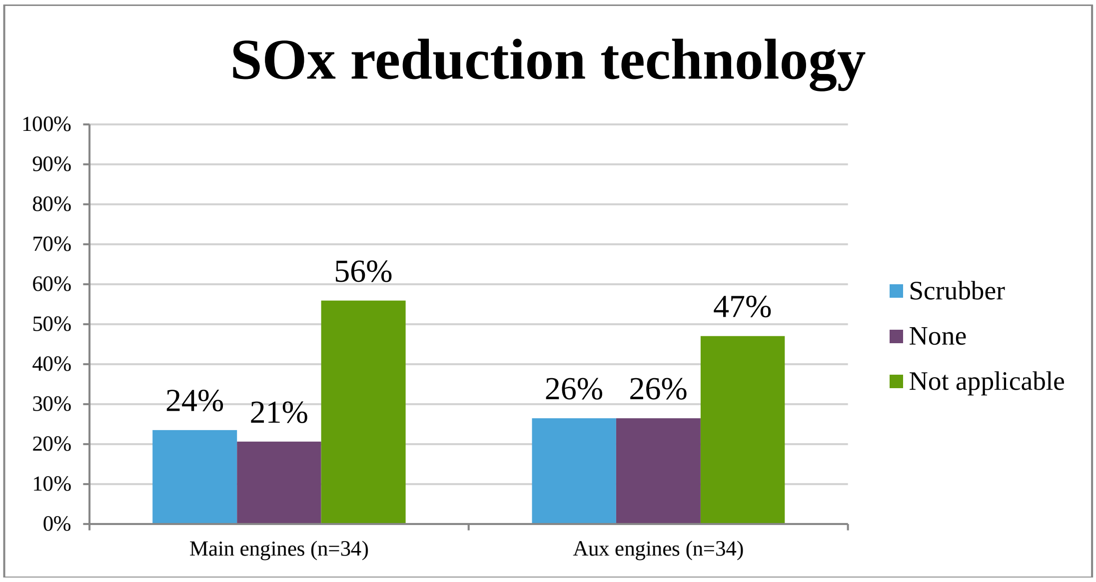


Figure 4.18: SO_x reduction technology installed on main and aux engines

Requirements for sulphur emissions can be met by using low sulphur fuel or by cleaning exhaust gases of sulphur to an equivalent low level if the fuel has a sulphur content that exceeds the required levels.

Approx. 25% state that they have scrubber systems installed in order to reduce SO_x emissions. Comments otherwise are that they use fuel with a sulphur content that complies with the current requirements, i.e. <0.1% S. The number of ships stating that they have scrubbers on board is slightly higher than the ones using heavy fuel oil. Comments to this question explain that the scrubber systems are under testing, and that the ships still use MGO in inner waters.

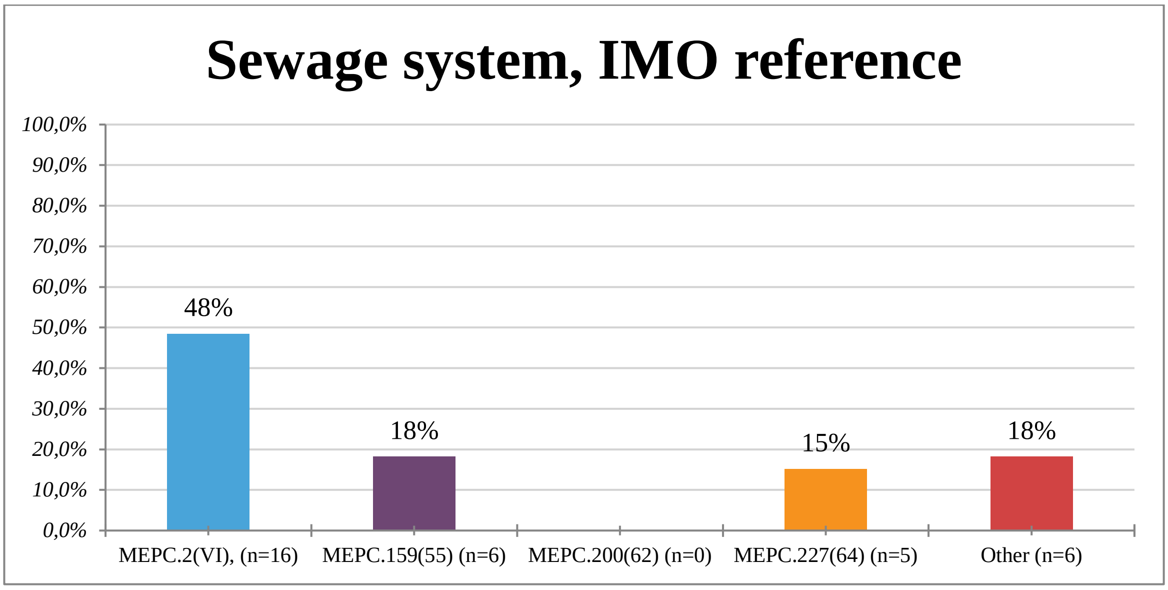


Figure 4.19: Sewage system, IMO approval reference

There are IMO requirements for sewage systems where they refer to various MEPC resolutions.

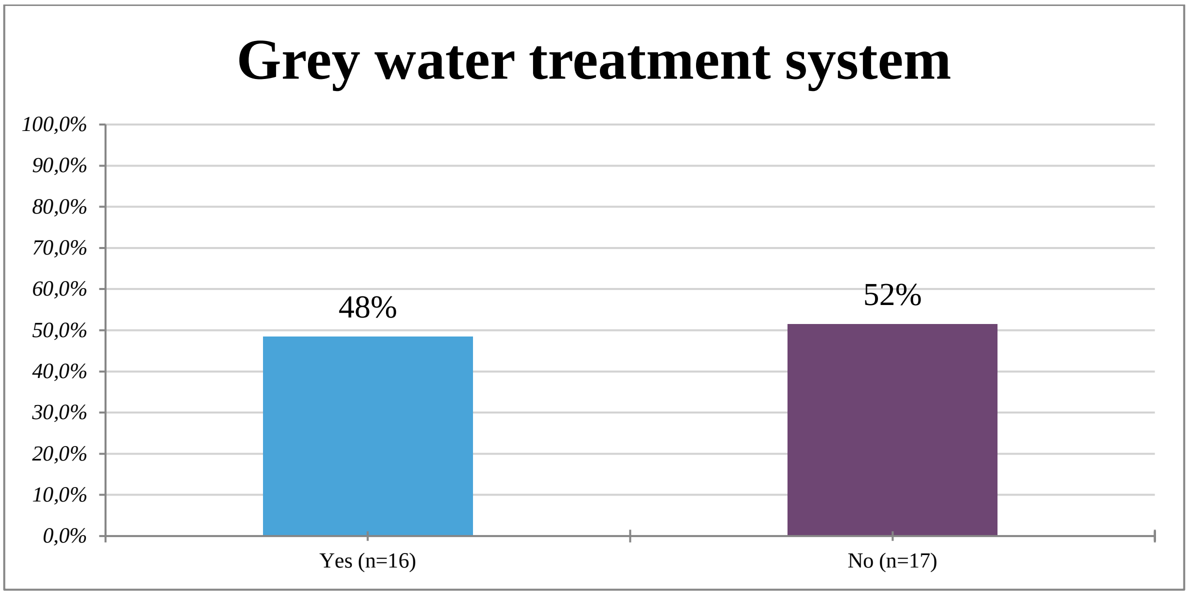


Figure 4.20: Ships with grey water treatment systems installed

Around half of the ships have special systems installed for treating grey water on board.

5 Operational data – the Geirangerfjord

One section of the survey was aimed at gathering operational data for the ships when they visit the Norwegian fjords.

This includes speed when entering the fjords and the power consumption when berthed or anchored. Based on their operational profile, it should thus be possible to estimate emissions to air.

We also requested information about procedures and systems for discharge into the sea.

5.1 Definition of emission zones, Geiranger

In the survey, four emission zones were defined for the Geirangerfjord. We also asked for data from the ships when they were at port.

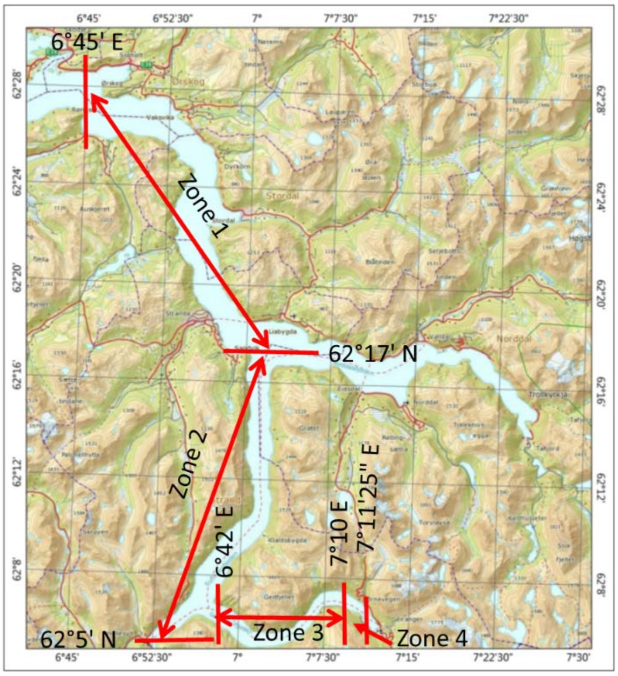


Figure 5.1: Definition of emission zones, entering the Geirangerfjord

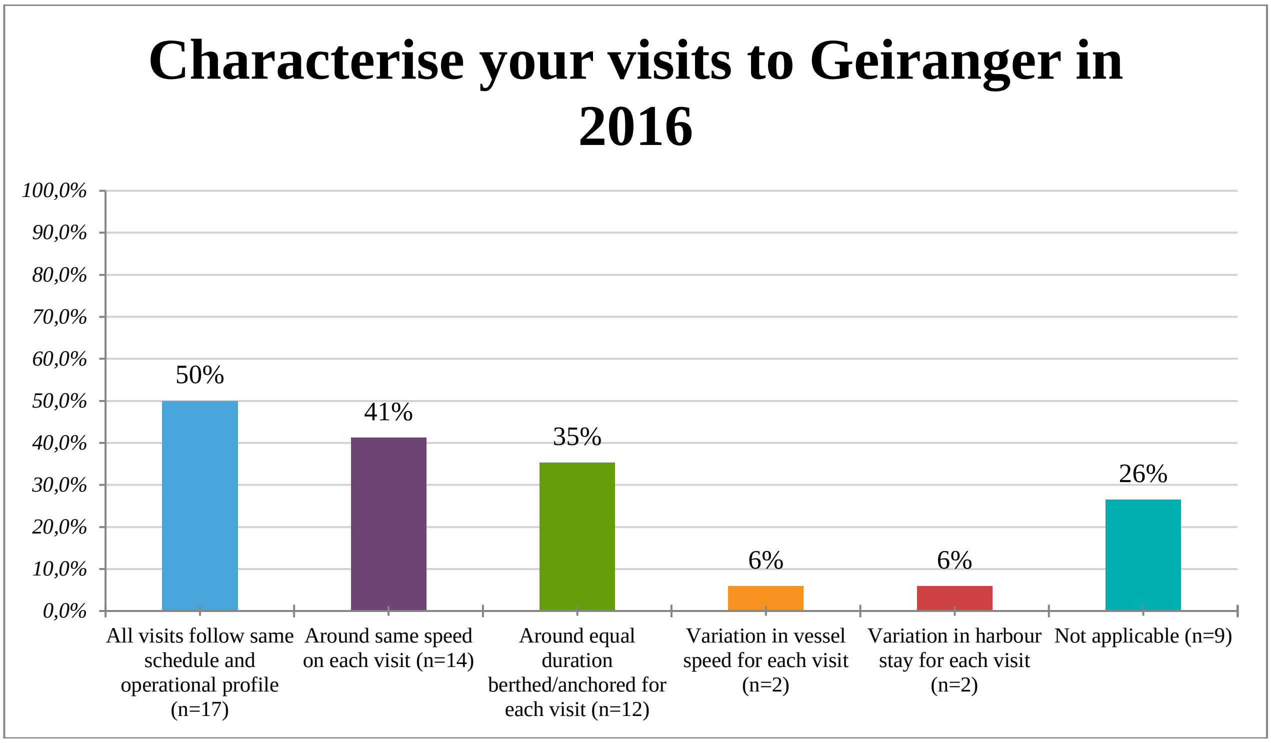


Figure 5.2: Description of voyage, Geirangerfjord

5.2 Discharges to sea, Geirangerfjord

Discharges into the sea include bilge water, sewage, grey water and discharges from the use of scrubbers on board, if any.

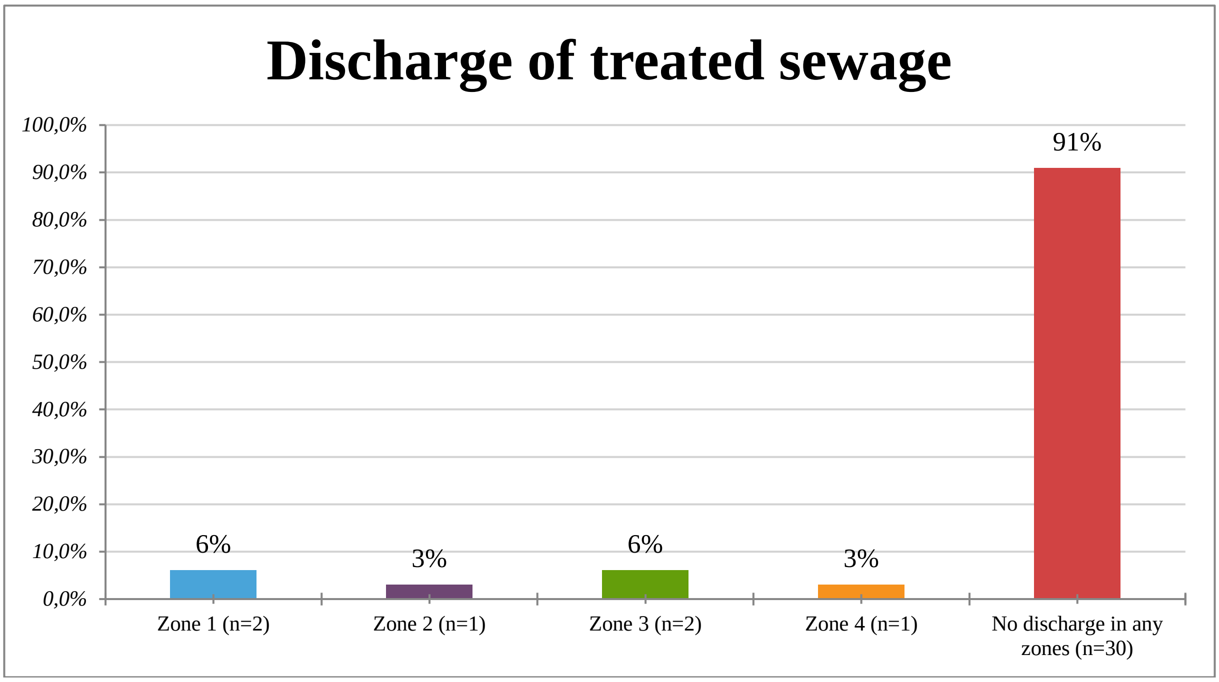


Figure 5.3: Discharge of treated sewage, Geirangerfjord

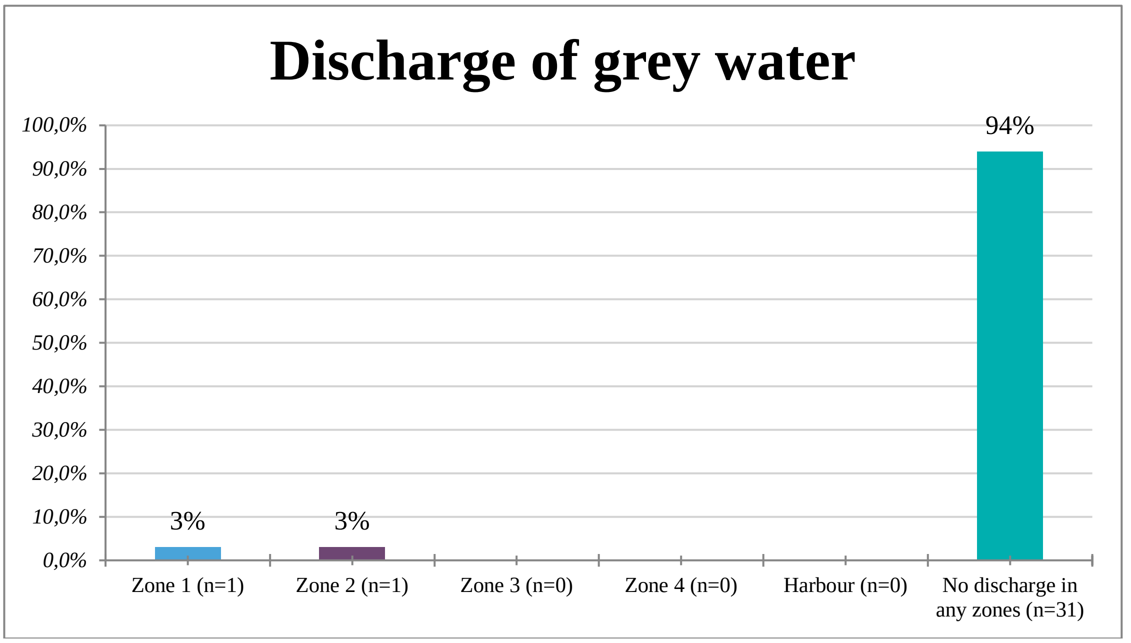


Figure 5.4: Discharge of grey water, Geirangerfjord

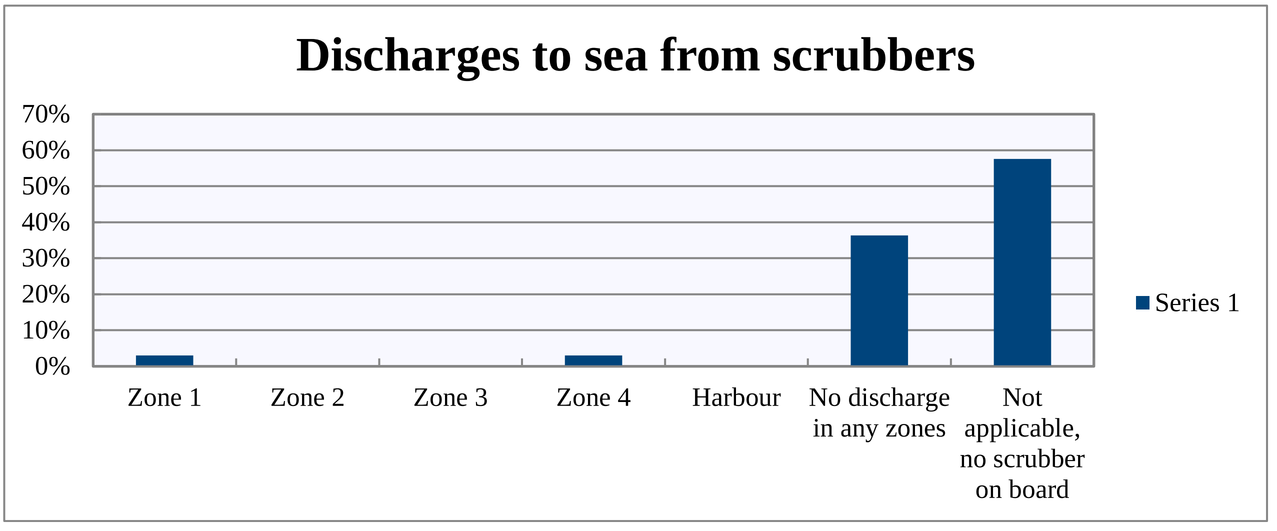


Figure 5.5: Discharges to sea from scrubbers

The responses to 'Discharges to sea from scrubbers' show that a low percentage of the ships have such systems installed or use this in the fjords, as most ships use MGO with a low sulphur content in these areas. Comments describe possibilities for running "closed loop" in port and sheltered waters with accumulation, and "open loop" with discharge to sea in other areas. Discharges to sea are treated in accordance with applicable requirements.

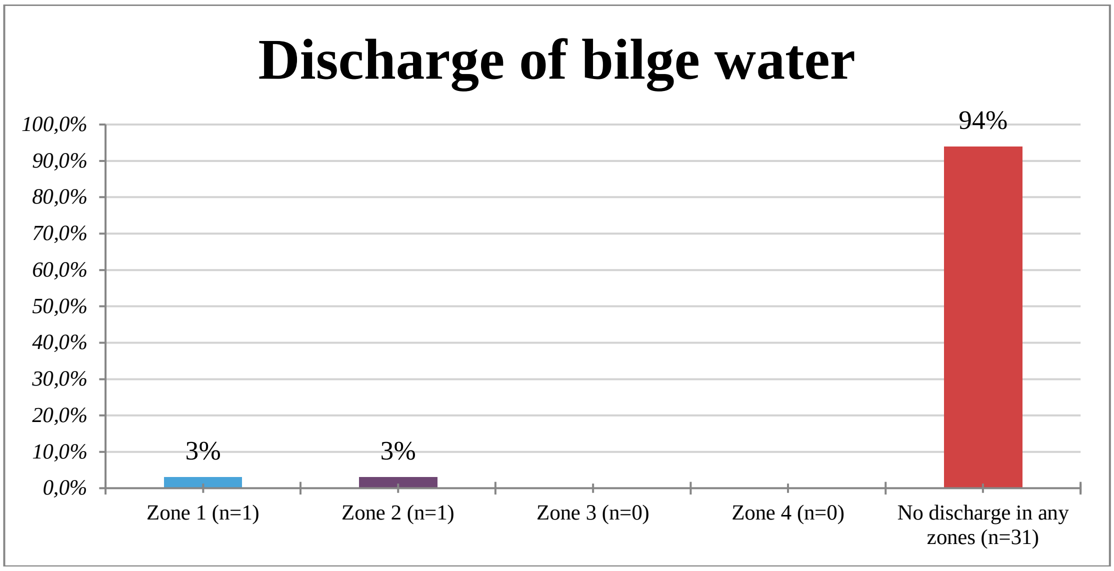


Figure 5.6: Discharge of bilge water, Geirangerfjord

Most ships do not discharge bilge water in the fjords.

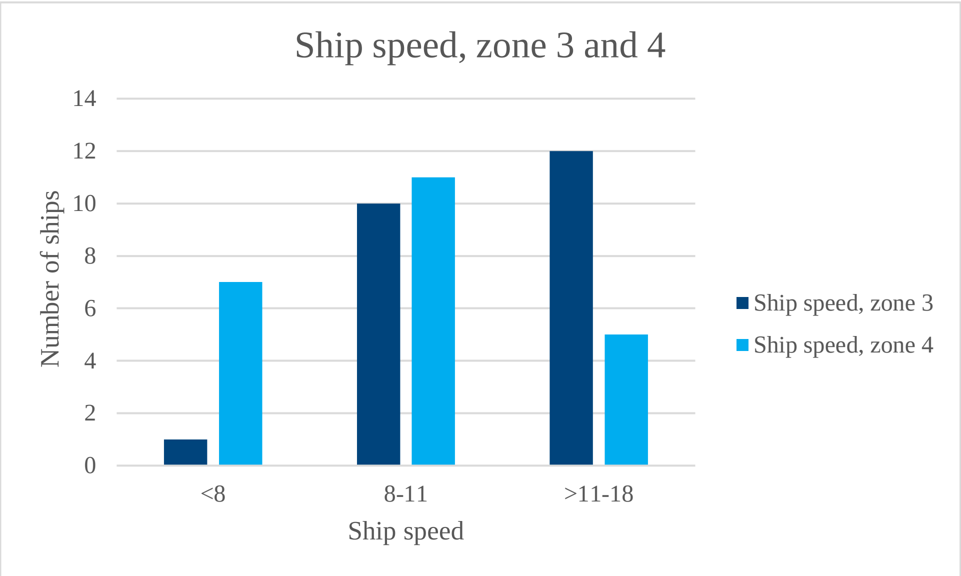


Figure 5.7: Ship speed in the Geirangerfjord, zone 3 and 4

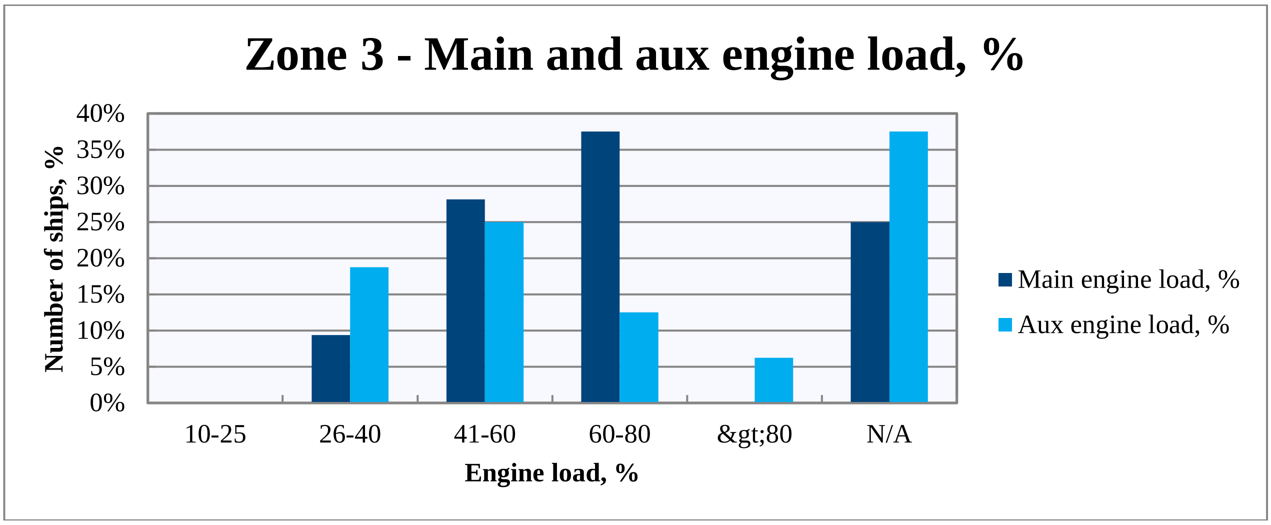


Figure 5.8: Engine load, zone 3, Geirangerfjord

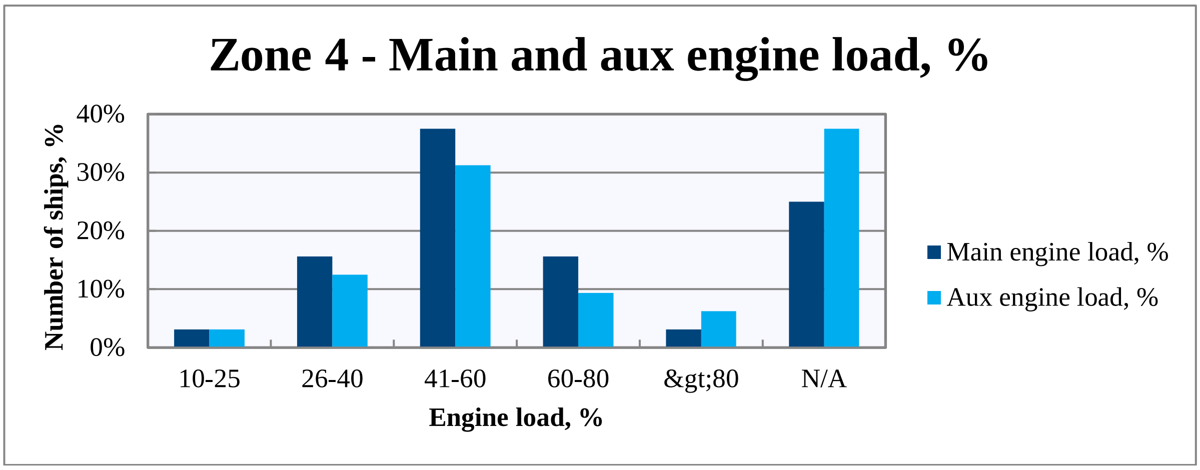


Figure 5.9: Engine load, zone 4, Geirangerfjord

In zone 3, the engine load is relatively high for the majority of the ships. In zone 4, the speed and engine load are reduced correspondingly.

Other engine-related questions related to operational pattern concerned exhaust temperatures and use of catalyst. A few ships have SCR systems, so that these questions become irrelevant and have not been reported.

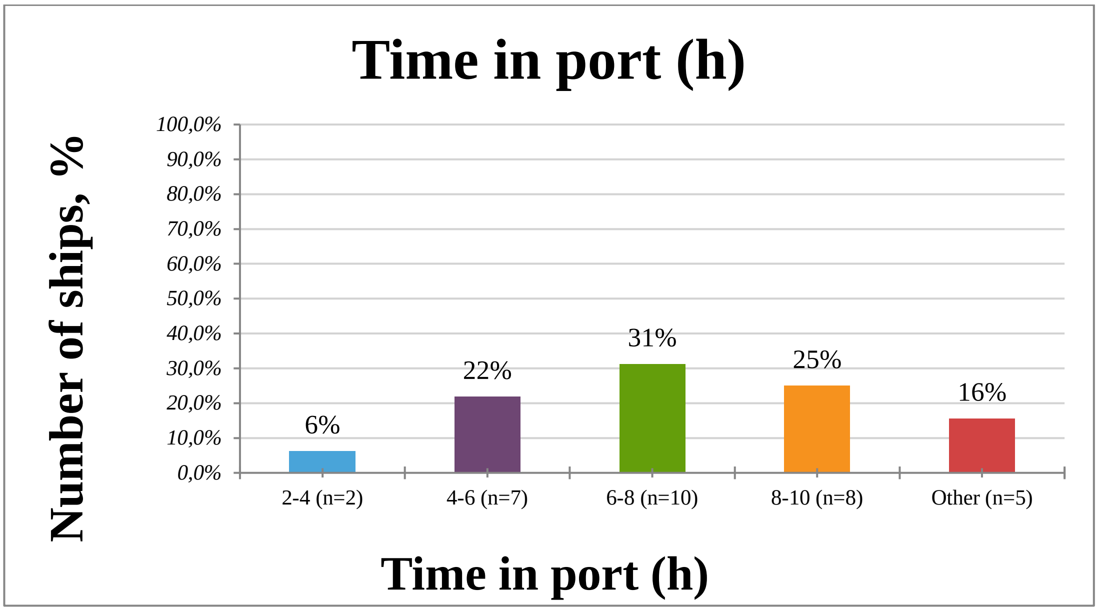


Figure 5.10: Time in port, Geiranger

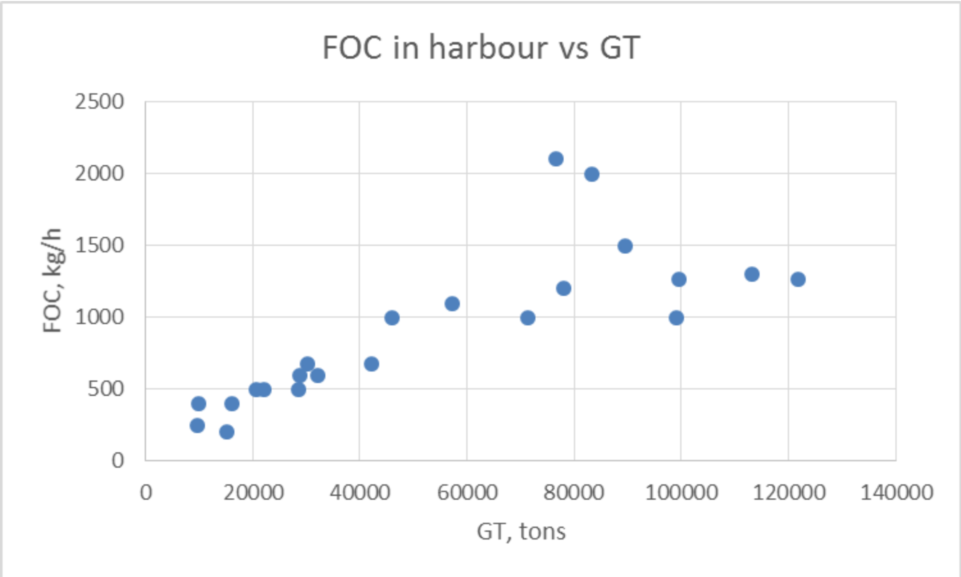


Figure 5.11: Fuel oil consumption in port by ship size, Geiranger

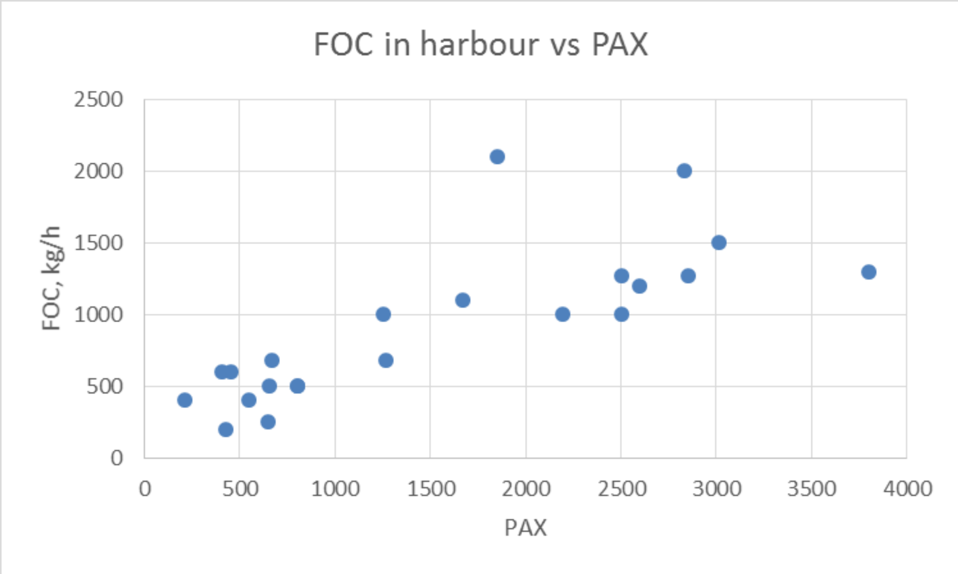


Figure 5.12: Fuel oil consumption in port by max number of passengers on board, Geiranger

There is a clear correlation between fuel consumption in port and size of ship and/or number of passengers on board.

The average power generation in port is fuel consumption in port for all the ships is calculated as:

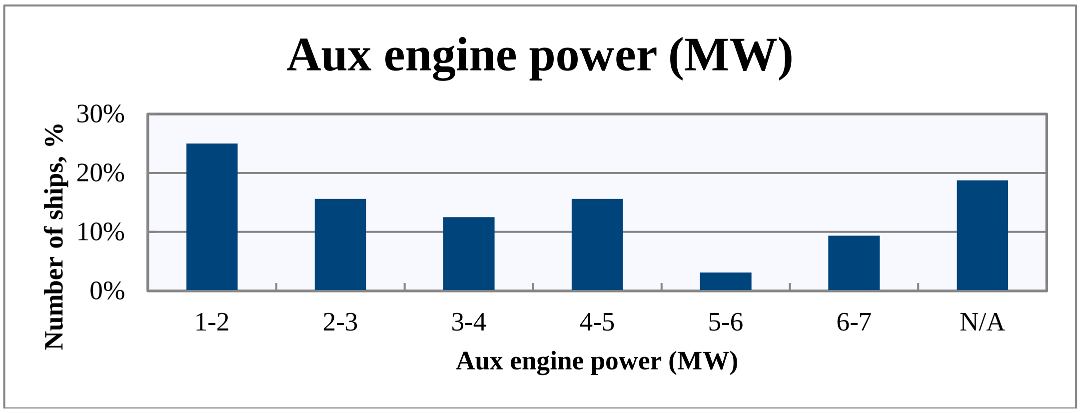


Figure 5.13: Power generation in port, Geiranger

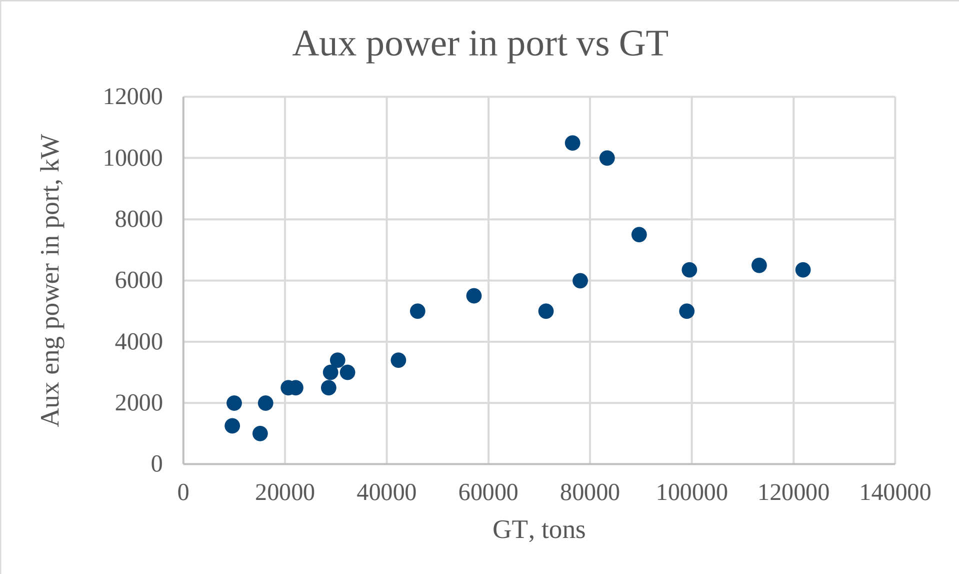


Figure 5.14: Aux engine power generation in port vs ship size, GT (ton)

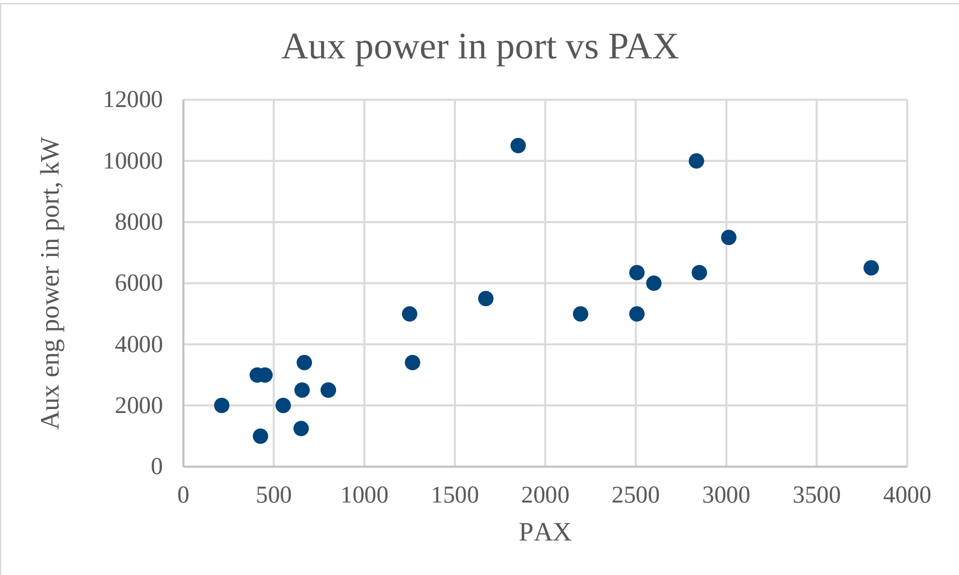


Figure 5.15: Power consumption in port by registered PAX capacity

Operational profile based on average data is summed up in Table 5.1.

Parameter	Zone 3	Zone 4	port
Ship speed, kn	13	10	0
Propulsion power, kW	11,113	8,611	0
Aux engine power, kW	5,636	5,594	4,557

Table 5.1: Operational profile, cruise ships in the Geirangerfjord zone 3, 4 and in port, based on average numbers

6 Operational data – the Aurlandsfjord and Nærøyfjord

6.1 Definition of emission zones, Aurlandsfjord and Nærøyfjord

In the survey, four emission zones were defined for the Aurlandsfjord and Nærøyfjord. We also asked for data from the ships when they were moored in port.

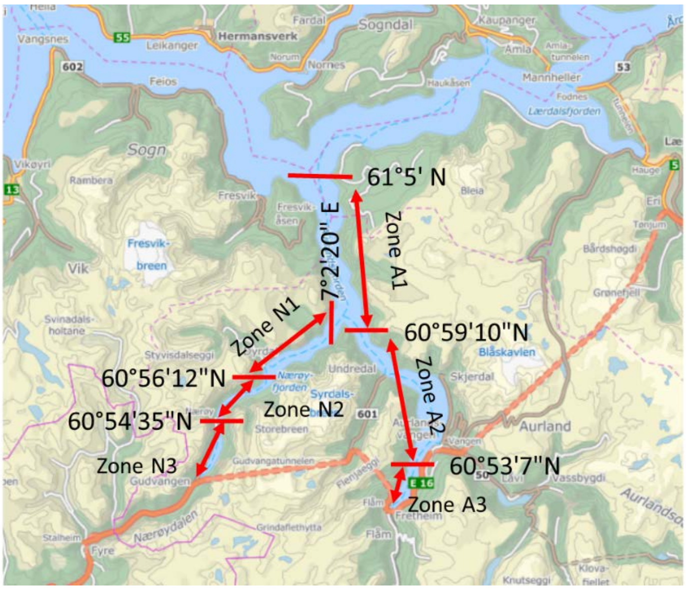


Figure 6.1: Emission zones – the Aurlandsfjord and Nærøyfjord

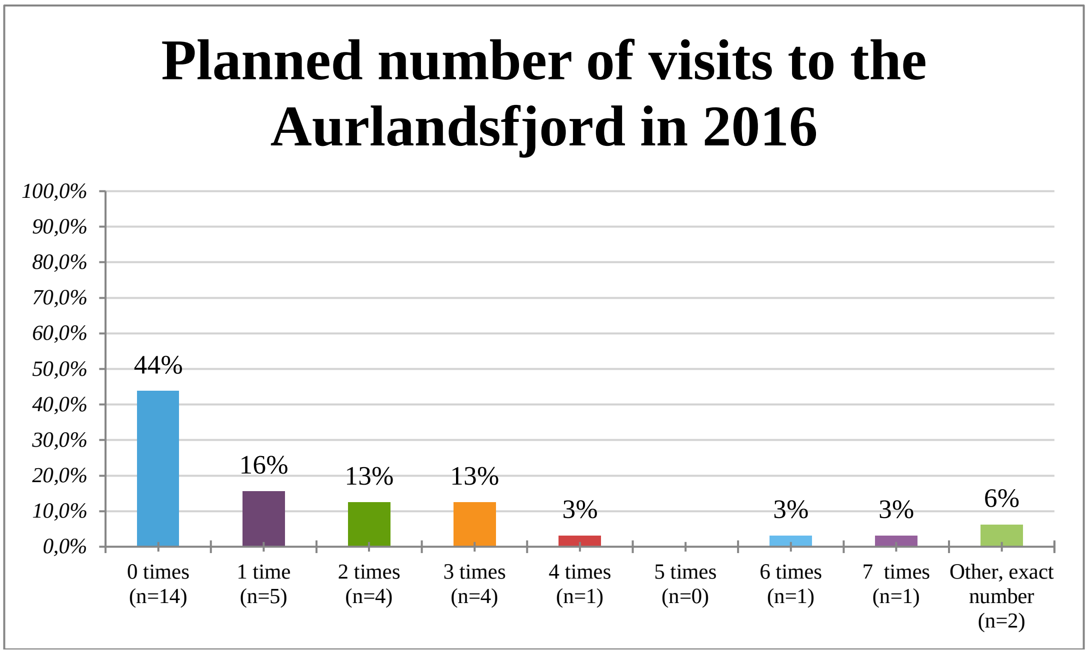


Figure 6.2: Planned number of visits to the Aurlandsfjord, 2016

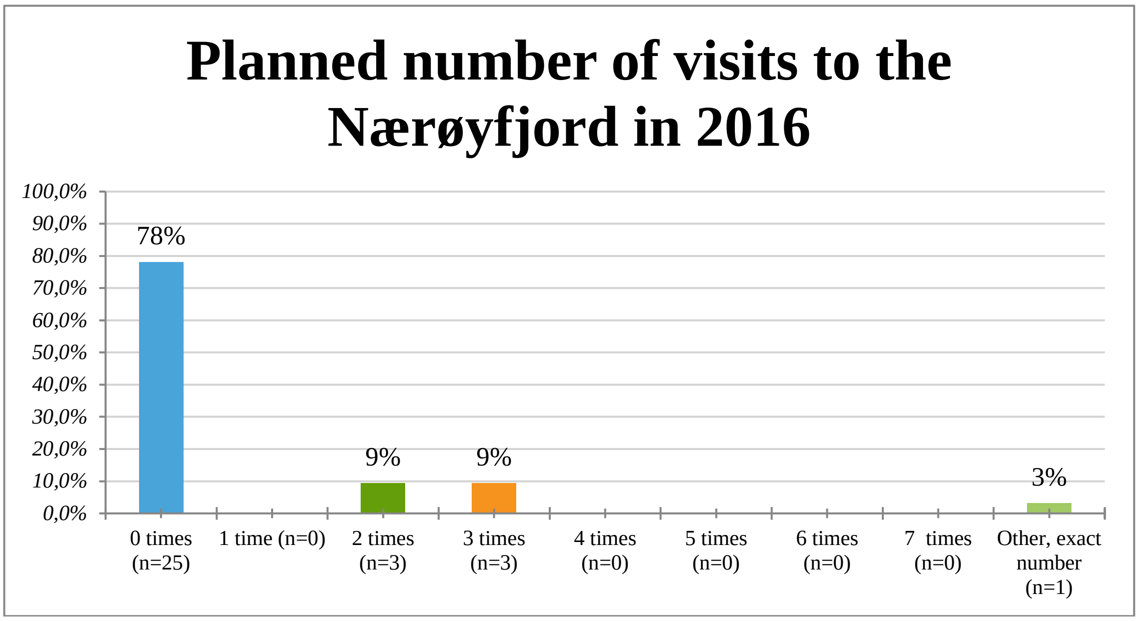


Figure 6.3: Planned number of visits to the Nærøyfjord, 2016

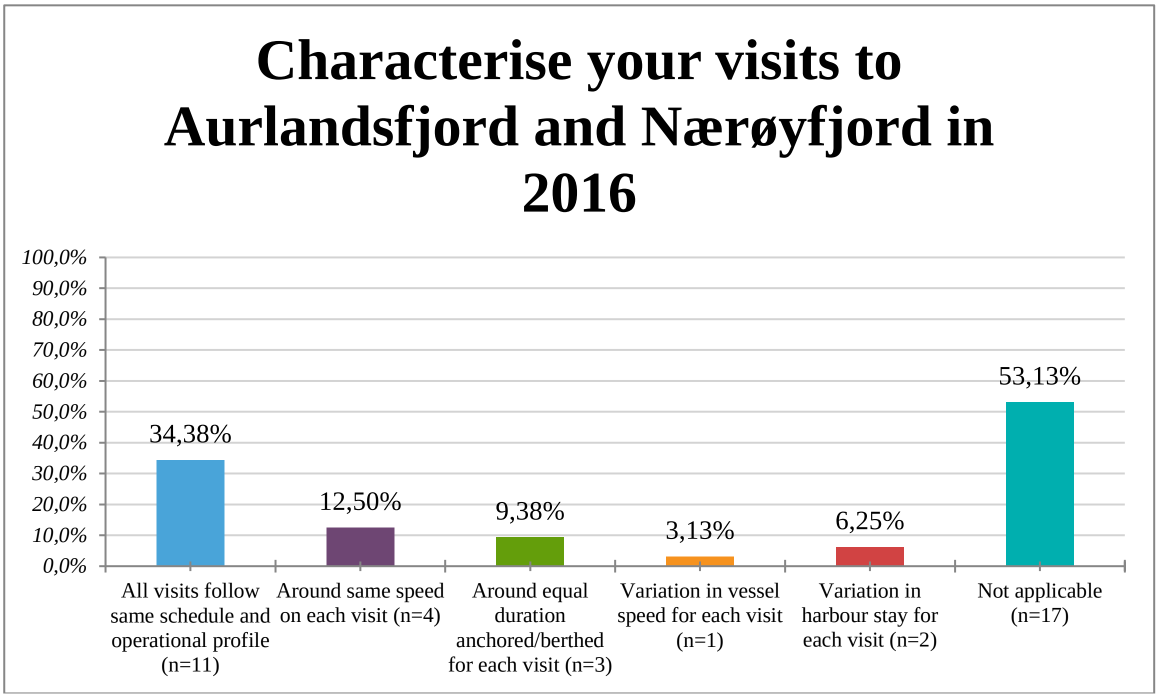


Figure 6.4: Description of sailing pattern

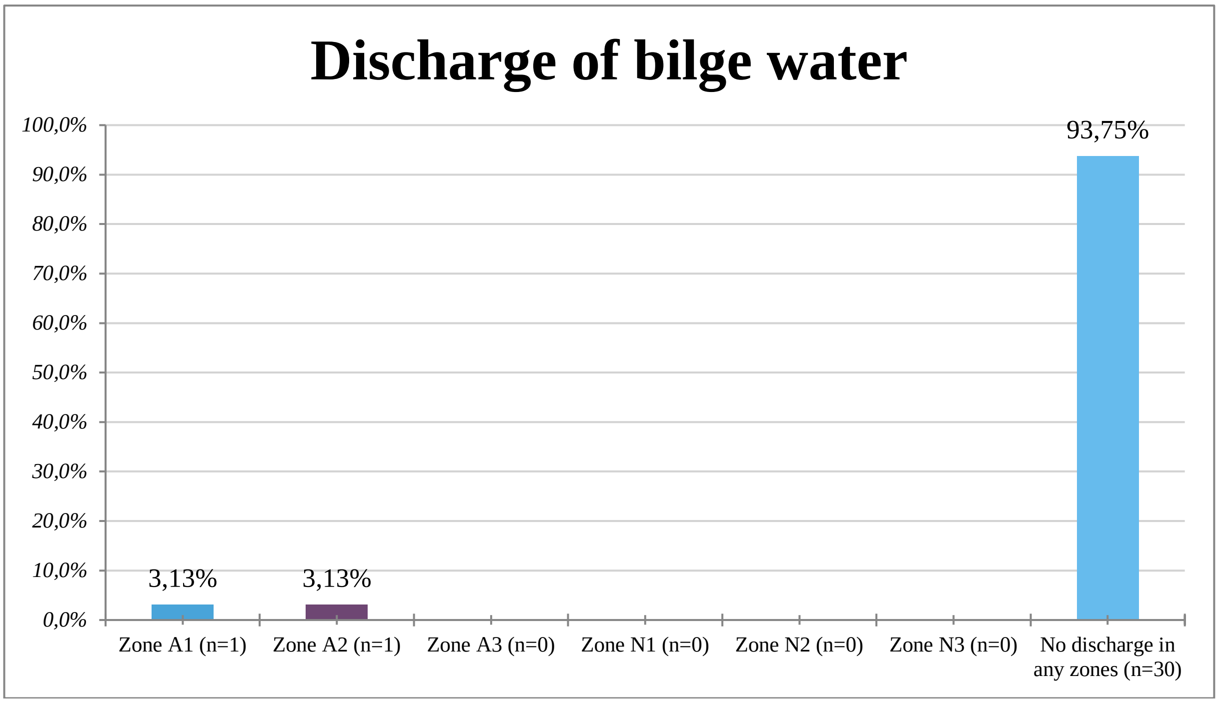


Figure 6.5: Discharge of bilge water, Aurlandsfjord and Nærøyfjord

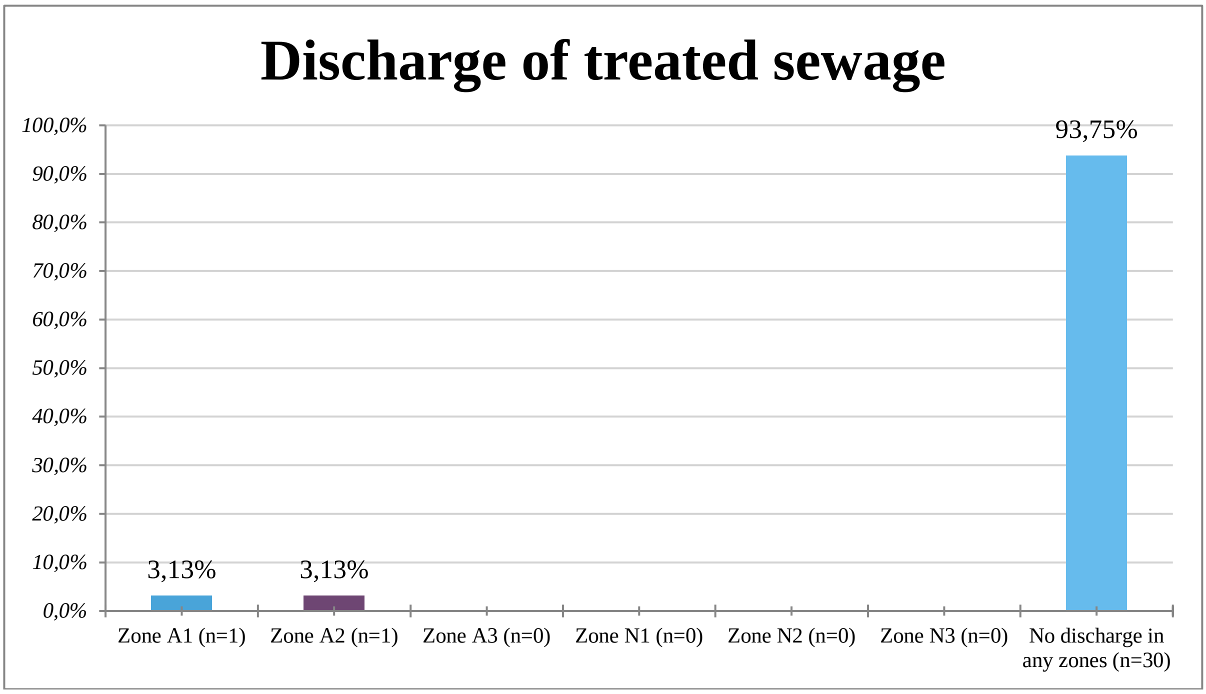


Figure 6.6: Discharge of sewage, Aurlandsfjord and Nærøyfjord

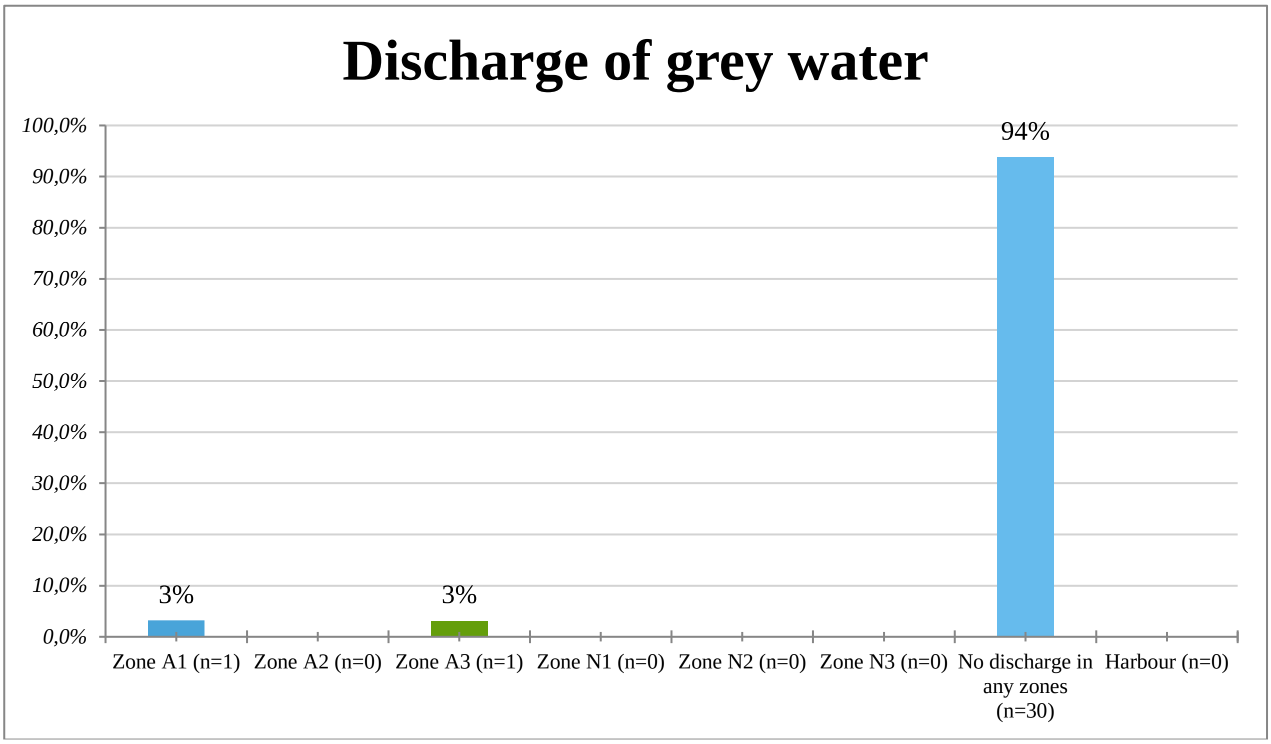


Figure 6.7: Discharge of grey water, Aurlandsfjord and Nærøyfjord

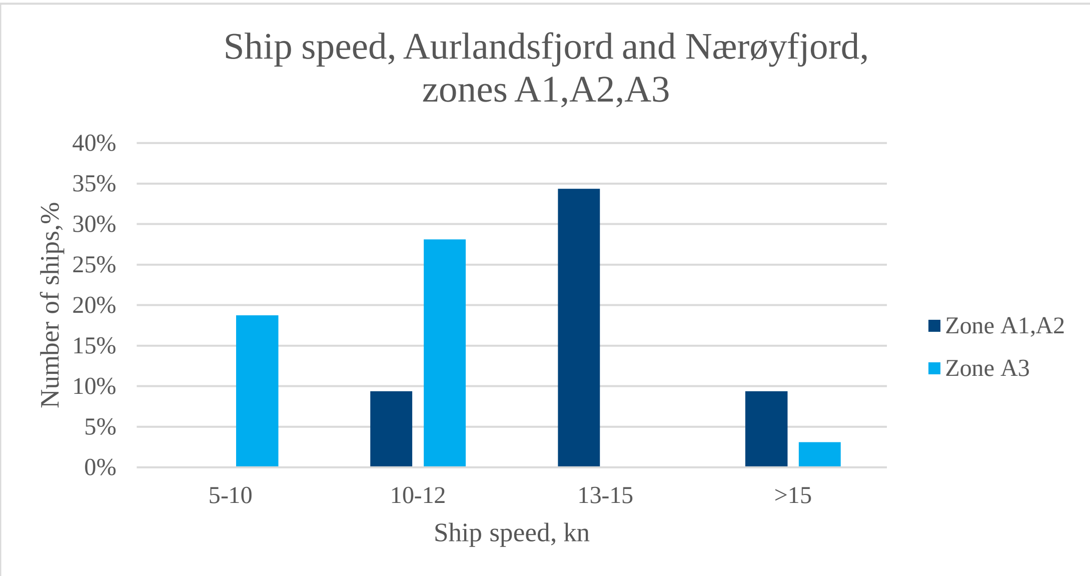


Figure 6.8: Speed, cruise ships in the Aurlandsfjord

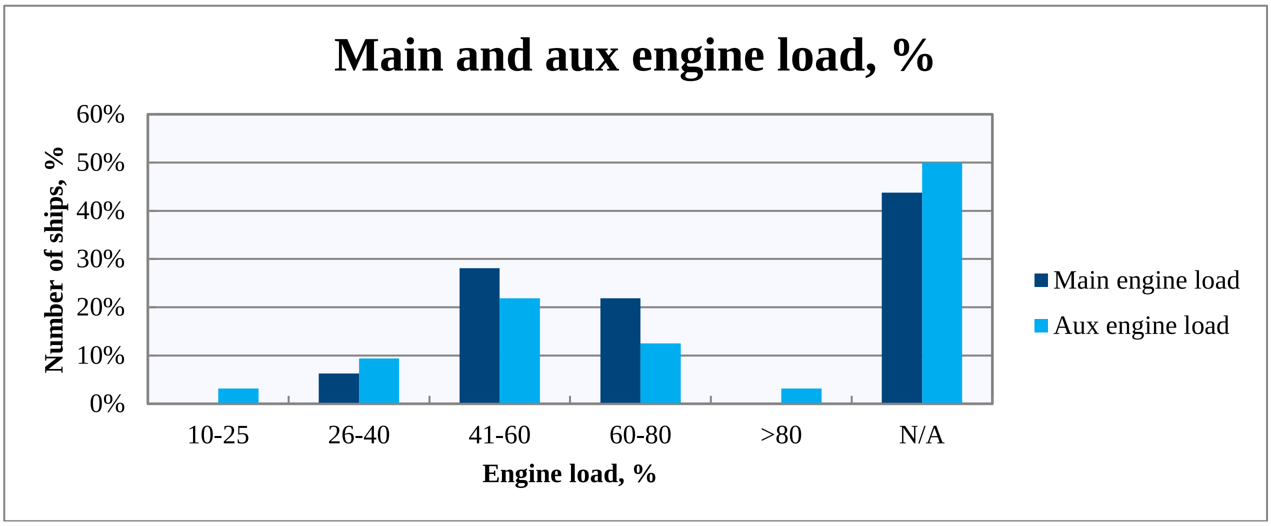


Figure 6.9: Main and aux engine load, zones A1 and A2

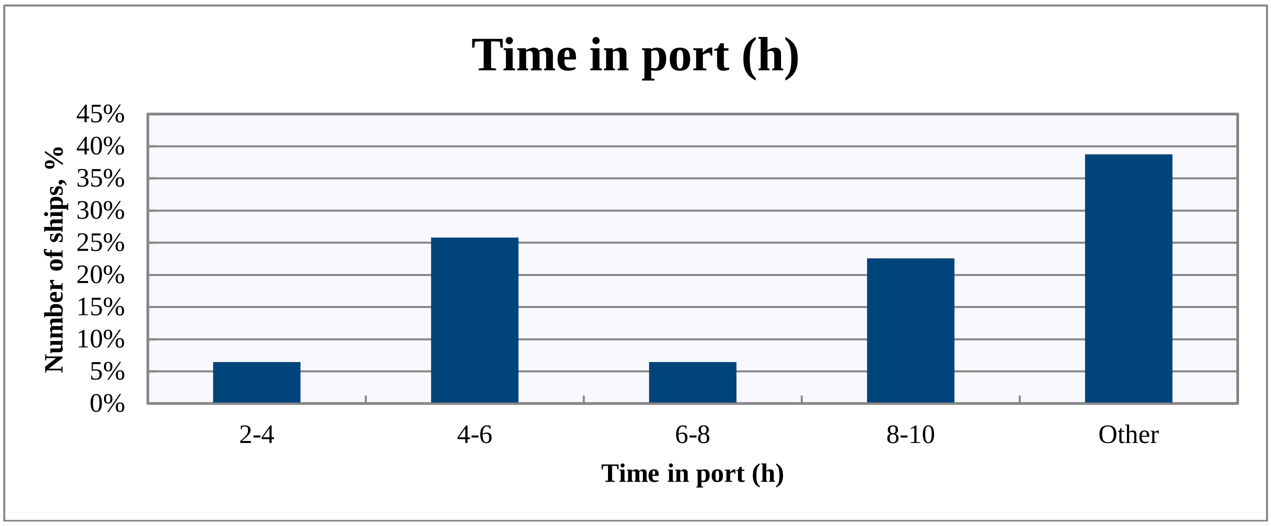


Figure 6.10: Time in port, Flåm

Consumption and power in port for Flåm will be equivalent to the numbers reported for Geiranger.

6.2 Nærøyfjord

Only eight ships state to have visited the Nærøyfjord, and incomplete answers were received from four of these.

Speed in zones N1, N2 and N3 is stated at between 10 and 12 knots, and engine load is equivalent to sailing in the Aurlandsfjord. Due to lack of source data, we have not provided further information from the Nærøyfjord in this report.

7 Local traffic

Data has been collected from local traffic from ferries and passenger boats by way of a questionnaire to relevant companies and operators. Local traffic consists of ferries and passenger boats as well as local charters, tenders and RHIBs. The survey respondents are vessels in regular scheduled service.

7.1 Technical information about the ships

Technical information about the ships is shown in Table 7.1.

Name	Year of constr.	No. ME	ME	Type	Model year	Rated output, kW	Engine rpm	No. AE	Manufacturer	Type	Rated output, kW
Bolsøy	1971	2	Wickmann	7ACAT	1971	2x770	400-600	2	Volvo	MD 120 AK	2x120
Veøy	1974	2	Wickmann	5AX	1974	2x920	400-600	2	Volvo	TAMD 122	2x120
Geirangerfjord	1981	2	Scania	DI16 42M	2007/2016	2x375	1200-1500	1	John Deere	4045 DF M50/TF 50	32
Fanaraaken	1973	1	Caterpillar	3512 BTA	2000	1119	1200-1500	2	Volvo/John Deere	MD70 / 6068	2x75
Hardingen Sr.	1966	2	Wickmann	4ACAT	1966	2x447.5	350	2	N/A	N/A	127
MF Skånevik	1967	2	Wickmann	4ACAT	1967	2x447.6	350	2	N/A	N/A	127
Skagastøl	1970	1	Wickmann	6ACAT	1970	661	375	2	Volvo	MD70	2x70

Table 7.1: Technical information, ships in local traffic. The Geirangerfjord, Aurlandsfjord and Nærøyfjord

Common for all ships is that they have not installed any particular NO_x reducing technology. NO_x emission factors may therefore be expected to be in accordance with the IMO curve, i.e. IMO before the year 2000 for all ships except *Geirangerfjord* that has newer engines that satisfy IMO Tier 1 requirements.

All boats use low sulphur fuel as specified.

Ship	Fuel	Sulphur, %	Area of op.
Bolsøy	MGO	0.038	Geiranger
Veøy	MGO	0.038	Geiranger
Geirangerfjord	Autodiesel	0.001	Geiranger
Fanaraaken	MGO	0.038	Aur/Nær
Hardingen Sr.	MGO	0.05	Aur/Nær
MF Skånevik	MGO	0.05	Aur/Nær
Skagastøl	MGO	0.038	Aur/Nær

Table 7.2: Fuel specification, local traffic in the Geirangerfjord, Aurlandsfjord and Nærøyfjord

Tenders are used in connection with transporting passengers to shore. Data for these have been previously collected in /1/. The typical engine installation is Volvo Penta D6-330 with rated output of approx. 250 kW.
Fuel consumption is estimated at around 2 tonnes MGO during a season in the Geirangerfjord (approx. 199 cruise calls).

RHIBs are used for fjord cruises, and we have not received operational data from these. Their consumption data is therefore taken from /1/, where it is stated that the RHIBs use approx. 1.5 l/nm and their overall consumption in a season in Geiranger is around 10,000 litres, equivalent to approx. 8.5 tonnes MGO.

Tenders and RHIBs are not discussed further in this report.

7.2 Geirangerfjord

Local traffic in the Geirangerfjord is well-known, and consists of ferries on regular scheduled voyages between Geiranger and Hellesylt, fjord cruises in accordance with set timetables for passenger boats, fjord cruises with RHIBs and operation of tenders to and from the cruise ships.

7.2.1 Ferries and fjord cruises

In the summer season, ferries run between Geiranger and Hellesylt in accordance with the timetable shown in Table 7. 3.

GEIRANGER FERRY 2016

Geiranger-Hellesylt

	01.05-31.05			
Dep. Geiranger	08:00	11:00	14:00	17:00
Arr. Hellesylt	09:05	12:05	15:05	18:05
	01.05-31.05			
Dep. Hellesylt	09:30	12:30	15:30	18:30
Arr. Geiranger	10:35	13:35	16:35	19:35

	01.06-31.08							
Dep. Geiranger	08:00	09:30	11:00	12:30	14:00	15:30	17:00	18:30
Arr. Hellesylt	09:05	10:35	12:05	13:35	15:05	16:35	18:05	19:35
	01.06-31.08							
Dep. Hellesylt	08:00	09:30	11:00	12:30	14:00	15:30	17:00	18:30
Arr. Geiranger	09:05	10:35	12:05	13:35	15:05	16:35	18:05	19:35

	01.09-30.09			
Dep. Geiranger	08:00	11:00	14:00	17:00
Arr. Hellesylt	09:05	12:05	15:05	18:05
	01.09-30.09			
Dep. Hellesylt	09:30	12:30	15:30	18:30
Arr. Geiranger	10:35	13:35	16:35	19:35

THE FJORDS

FLÅM

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Table 7.3: Timetable for ferry, Geiranger-Hellesylt

In 2016, the service was extended out October. A total of 552 round trips were therefore carried out in 2016. Average speed in order to run on time is 10 knots. The service is operated by two ferries; the *MF Bolsøy* and the *MF Veøy*.

In the Geirangerfjord, the *MF Geirangerfjord* also runs a regular service from April to November. In the peak season (15 May - 15 September) there are 4 round trips per day, which gives a total of 466 round trips in this period.

7.2.2 Discharges to sea, local traffic Geiranger

Discharges to the sea from the ferries are declared to be treated sewage and grey water discharged in zone 2, 0.5-2 m^3 per day.

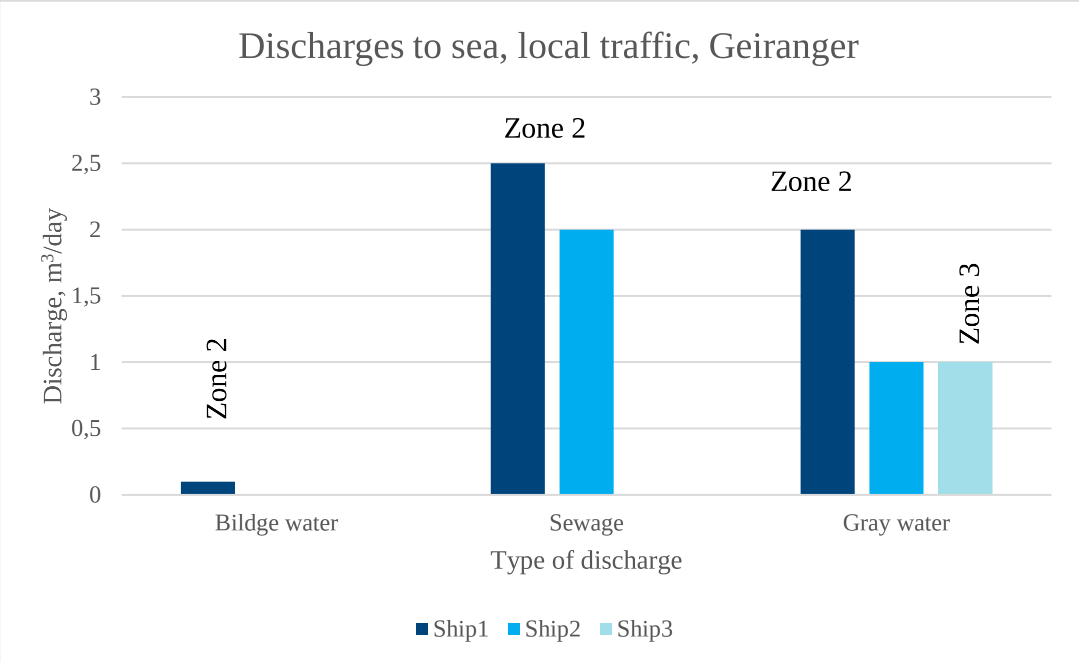

Figure 7.1: Discharges to sea, local traffic Geirangerfjord

One of the ferries also states that it discharges small amounts of bilge water in zone 2 (0.1 m^3).

7.2.3 Emissions to air, local traffic Geiranger

Emissions to air are directly related to operational profile and fuel consumption.
The ferries run on MGO with a sulphur content of 0.038%. The *MF Geirangerfjord* uses autodiesel with S < 0.001%.

The operators were asked to estimate fuel consumption per round trip. Estimated consumption is listed in Table 7.4.

Ship	Engine power	Spec. cons- umption	Cons. per hour	Cons. per trip	Cons. per round trip	No. of round trips	Annual cons.	Annual cons.	Daily cons.
	kW	g/kWh	kg	kg	kg/round trip		kg/year	tonnes/year	tonnes/day
Bolsøy	1,540	0.22	169.4	183.5	367.0	552	202,602	203	1.1
Veøy	1,840	0.22	202.4	219.3	438.5	552	242,070	242	1.3
Geirangerfjord	700	0.22	48		72.0	566	40,752	41	0.2

Table 7.4: Estimated fuel consumption in the 2016 season for local traffic in the Geirangerfjord

Estimated consumption for the ferries is based on an assumed specific consumption for the engines and an average engine load of 50%. For the *Geirangerfjord*, the annual fuel consumption is estimated based on the fuel consumption declared by the operator.

Special measures for reducing emissions from these ships have not been made, which means that the standard emission factors apply for these ships.

7.2.4 Hurtigruten

Hurtigruten has a regular service in the Geirangerfjord during the summer season, with daily port calls. A total of 11 vessels visited Geiranger in 2016, with 6-12 visits per ship. According to the timetable, a total of 97 trips to the Geirangerfjord were planned in the 2016 season.

Hurtigruten - ship and main engine						
Ship	**Main engine**	**Number**	**Model year**	**Individual engine power**	**Rated speed RPM**	**No. visits Geiranger acc. to timetable**
Lofoten	B&W - DM742VT2BF90	1	1964	2,447 kw		7
Vesterålen	Bergen Diesel KVM-16	2	1983	2,380 kw	750	8
Kong Harald	MaK 6M552C	2	1993	4,500 kw	500	8
Richard With	MaK 6M552C	2	1993	4,500 kw	500	8
Nordlys	MaK 6M552C	2	1994	4,500 kw	500	9
Nordkapp	MaK 6M552C	2	1996	4,500 kw	500	9
Nordnorge	MaK 6M552C	2	1997	4,500 kw	500	8
Polarlys	Ulstein Bergen BRM-9	2	1996	3,970 kw	750	9
Finnmarken	Wärtsilä W9L32	2	2003	4,120 kw	750	8
Trollfjord	Wärtsilä W9L32	2	2002	4,140 kw	750	8
Midnatsol	Wärtsilä W9L32	2	2003	4,140 kw	750	8
Spitsbergen	ABC	4	2009	2*3,000 2x 2,500	1,000	7

Table 7.5: Vessel data, Hurtigruten

AUXILIARY ENGINES					
Ship	**Auxiliary engine**	**Number**	**Model year**	**Individual engine power**	**Rated speed RPM**
Lofoten	Volvo Penta - D16C-A MG	2	2015	450 kw	1500
	Volvo Penta - D30 A MT	1	2007	640 kw	1500
Vesterålen	Bergen Diesel KRG-5	2	1983	650 kw	750
	Bergen Diesel KRG-3	1		385 kw	750
Kong Harald	Bergen Diesel KRG-8	2	1993	1,265 kw	750
Richard With	Bergen Diesel KRG-8	2	1993	1,265 kw	750
Nordlys	Bergen Diesel KRG-8	2	1994	1,265 kw	750
Nordkapp	Bergen Diesel KRG-8	2	1996	1,265 kw	750
Nordnorge	Bergen Diesel KRG-8	2	1997	1,265 kw	750
Polarlys	Ulstein Bergen KGR-9	2	1996	1,660 kw	750
Finnmarken	Wärtsilä W6L32	2	2003	2,760 kw	720

Trollfjord	Caterpillar 3516 BDITA	2	2002	1,901 kw	1,800
Midnatsol	Caterpillar 3516 BDITA	2	2003	1,901 kw	1,800

Table 7.6: Aux engines, Hurtigruten

Average NO_x emission factors for the fleet are listed in Table 7.7.

Model year	Engine speed RPM	**NO_x factor (kg NO_x/tonne fuel)**	Comments
< 2000	500	76.78	
< 2000	750	50.63	NO_x reduction conversion on one ship
>2000	750	53.68	NO_x reduction conversion on one ship

Table 7.7: Average NO_x emission factors for main engines on Hurtigruten's ships

Model year, engine	Engine speed, rpm	**NO_x factor (kg NO_x/tonne fuel)**
< 2000	750	54.7
>2000	720	51.9
>2000	1,800	37.1

Table 7.8: Average NO_xemission factors for aux engines on Hurtigruten's ships

Operational profile for Hurtigruten is provided by the company, and is summed up in Table 7.9.

No. of round trips	Main engine load, transit	Consumption, transit		Speed	Time in zone 1	Consumption, in port		Time in port
	% of MCR	kg/round trip	kg/h	kn	h	kg/h	kg/round trip	H
97	50-85	4,094	910	15	4.5	514	257	0.5

Table 7.9: Operational parametres, Hurtigruten, average values, 11 ships

7.2.5 Hurtigruten, discharges to sea

Relevant discharge parametres to sea from Hurtigruten are bilge water, sewage and grey water. Hurtigruten operates on marine special distillates (MSD) with a low sulphur content (0.04%). Therefore, none of Hurtigruten's ships have scrubbers on board.

As regards discharges to sea, there are slightly different practices when it comes to sewage and grey water. The company informs that a new practice for all ships is being considered; that they shall not discharge bilge water, black water or grey water in the Hjørundfjord, Storfjord/Geirangerfjord and Lyngenfjord. At present, no ships discharge bilge water in the mentioned fjords.

Average discharge numbers for individual ships are shown in Figure 7.2.

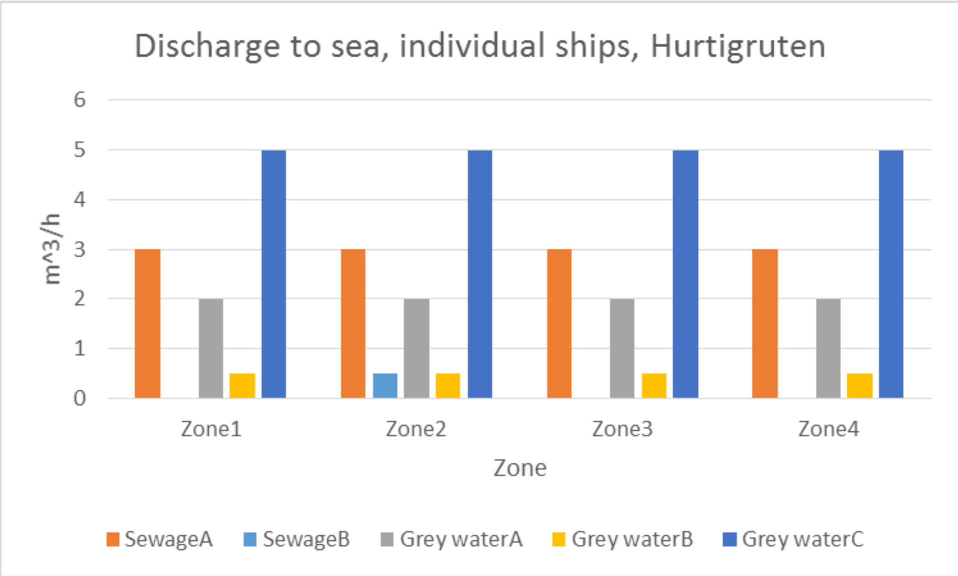

Figure 7.2: Discharges to sea from individual ships, Hurtigruten

Evidently, discharges to sea takes place in all the zones. The ships often have integrated sewage and bilge water systems, so that the distribution between these two has been estimated for some of the ships.

7.2.6 Hurtigruten, emissions to air

All Hurtigruten's ships appear to operate with approximately the same speed into the Geirangerfjord. We have received information about average fuel consumption for each round trip.

The transit speed is around 15 knots for all the vessels, and the average fuel consumption per hour has been estimated, see Table 7.9. This includes total consumption on board.

The above numbers can be used on in the dispersion analysis.

7.3 Local traffic, Aurlandsfjord and Nærøyfjord

Relevant ship data for local traffic in the Aurlandsfjord/Nærøyfjord is given in Table 7.10. A regular ferry service is operating between Flåm and Gudvangen and between Kaupangen and Gudvangen. Additionally, passenger boats are operating in connection with fjord cruises in the area. We have not received any data from this ships.

7.3.1 Schedule

The timetable for Kaupangen-Gudvangen is shown in Figure 7.3.

Departures from Kaupanger				* up to -40% discount
15. may - 31. may	09.00			
1. june - 30. june	09.00		15.00	
1. july - 20. aug	09.00	12.00	15.00	18.00*
21. aug - 31. aug	09.00		15.00	
1. sept - 14. sept	9.00			
Departures from Gudvangen				* up to -40% discount
15. may - 31. may		12.00		
1. june - 30. june		12.00		18.00*
1. july - 20. aug	09.00	12.00	15.00	18.00*
21. aug - 31. aug		12.00		18.00*
1. sept - 14. sept		12.00		

Figure 7.3: Timetable, Kaupanger-Gudvangen, 2016

The service between Flåm and Gudvangen is operated by two ferries, which in total make four round trips per day.

There are also several passenger boats operating in connection with fjord cruises in the area. Data have not been received from these boats.

7.3.2 Discharges to sea

None of these ships discharge bilge water. Two ships state that they discharge around 6 m^3 of sewage and grey water per day in zone A1.

7.3.3 Emissions to air

Emissions to air are estimated based on diesel consumption numbers provided by operators and set out in table 7.10.

Ship	Average consumption	No. round trips/day	No. round trips/total	Annual cons. for ferry service	Cons. in discharge zones	Average daily cons. in zones	Annual cons., zones	Zone
	kg/tround trip	trips/day	May - Sept	kg/year	kg/round trip	kg/day	kg/year	
Fanaraaken	600	2	300	180,000	600	1,200	180,000	A2-A3-N1-N2-N3
Skagastøl	500	2	300	150,000	500	1,000	150,000	A2-A3-N1-N2-N3
Hardingen Sr.	630	1,5	158	99,225	341	512	53,747	A1-N1-N2-N3

MF Skånevik	630	1,5	158	99225	341	512	53,747	A1-N1-N2-N4

Table 7.10: Fuel consumption, ferries, Aurlandsfjord and Nærøyfjord

8 References

/1/ Mikhail Shlopak, Svein Bråthen, Hilde Johanne Svendsen and Oddmund Oterhals, Møreforsking, REPORT NO. 1413 GRØNN FJORD, Volume II. Calculation of greenhouse gas emissions in Geiranger

A Annex A – Questionnaire for cruise ships

A Vedlegg A – Spørreskjema til cruiseskipene

The
Norwegian Maritime Authority (NMA), working for the Ministry of Climate and Environment, is conducting a survey of emissions to air and water from ships sailing in the Geirangerfjord, Nærøyfjord and the Aurlandfjord. It includes the collection of data describing the technical aspects of the ships as well as their operational profile when they are visiting the fjords. The purpose of the project is to better our understanding of the environmental impact of the ships, in order to have a sustainable development of the sector with respect to environment, safety and the cruise industry.

This survey is conducted by MARINTEK on behalf of NMA and will identify the real emission from the cruise fleet visiting Geirangerfjorden in 2016. Results will be used as input to emission dispersion models for the fjords in concern.

For any questions to this survey please contact MARINTEK on e-mail: dag.stenersen@marintek.sintef.no

1. Registration of ship data

First question is to register general data about your vessel

Vessel name

____
____
____
____
____

IMO number

____
____
____
____
____

Built year

____
____
____
____
____

Propulsion system

- ☐ Direct mechanical drive
- ☐ Diesel electric drive

Propulsion power installed, kW

____
____
____
____
____

Auxilliary power installed, kW

____
____
____
____
____

Comments, machinery plant arrangment and operation

____
____
____
____
____

2. Questions about your voyage

Information about last voyage to Geirangerfjorden

Planned number of visits to Geirangerfjorden in 2016

- ☐ 0 times
- ☐ 1-3 times
- ☐ 4-6 times
- ☐ 7 or more times

Date endtering the fjord last time (if any)

____
____
____
____
____

Characterise your visits to Geiranger in 2016

- ☐ All visits follows same schedule and operational profile
- ☐ About same speed on each visit
- ☐ About equal duration at anchore/in harbour for each visit
- ☐ Variation in vessel speed for each visit
- ☐ Variation in harbour stay for each visit

Comment to your scheduled visits to Geiranger

____
____
____
____
____

3. Machinery data

Number of main engines

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ More than 4, (give number) ________________________________

Number of aux engines

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ More than 4, (give number) ________________________________

4. Main engine data

Engine manufacturer

- ☐ Caterpillar
- ☐ Cie de Constructions Mecaniques (CCM)
- ☐ Daihatsu Diesel
- ☐ Deutz AG
- ☐ Fincantieri - Cantieri Navali Italiani SpA
- ☐ GE Marine Engines
- ☐ Grandi Motori Trieste
- ☐ Hanshin Diesel Works
- ☐ Hitachi Zosen Corp
- ☐ Hyundai Heavy Industries
- ☐ Kawasaki Heavy Industries
- ☐ Kobe Hatsudoki
- ☐ MaK Maschinenbau
- ☐ Makita Corp - Japan
- ☐ MAN
- ☐ MAN B&W Diesel
- ☐ Mitsubishi Heavy Industries
- ☐ Mitsui Engineering & Shipbuilding
- ☐ MTU Friedrichshafen
- ☐ New Sulzer Diesel France
- ☐ Niigata Engineering
- ☐ Nippon Kokan KK (NKK Corp)
- ☐ Rolls-Royce
- ☐ Ruston Paxman Diesel
- ☐ SACM Diesel SA
- ☐ SEMT Pielstick SA
- ☐ Ssangyong Heavy Industries
- ☐ Stork-Wartsila Diesel
- ☐ STX Engine
- ☐ Sulzer
- ☐ Sumitomo Heavy Industries
- ☐ Wartsila
- ☐ Yanmar Diesel Engine
- ☐ Zaklady Przemyslu Metalowego
- ☐ Zavod
- ☐ Other

Engine model

____
____
____
____
____

Built year

____
____
____
____
____

No of cylinders

- ☐ 6
- ☐ 8
- ☐ 9
- ☐ 10
- ☐ 12
- ☐ 16
- ☐ Other ________________________________

Cylinder configuration

- ☐ V
- ☐ L

Nominal power, MW

- ☐ 2-4
- ☐ 4-6
- ☐ 6-8
- ☐ 8-10
- ☐ 10-14
- ☐ 14-18
- ☐ Other ________________________________

Nominal engine speed, rpm

- ☐ < 200
- ☐ 201-400
- ☐ 401-600
- ☐ 601-800
- ☐ 801-1000
- ☐ Other ________________________________

PTO/PTI

- ☐ Yes
- ☐ No

If yes, Installed power on PTO/PTI (kW)

____
____
____
____
____

5. Aux engine data

Information/specification of aux engines

Engine Manufacturer

- ☐ Caterpillar
- ☐ Cie de Constructions Mecaniques (CCM)
- ☐ Daihatsu Diesel
- ☐ Deutz AG
- ☐ Fincantieri - Cantieri Navali Italiani SpA
- ☐ GE Marine Engines
- ☐ Grandi Motori Trieste
- ☐ Hanshin Diesel Works
- ☐ Hitachi Zosen Corp
- ☐ Hyundai Heavy Industries
- ☐ Kawasaki Heavy Industries
- ☐ Kobe Hatsudoki
- ☐ MaK Maschinenbau
- ☐ Makita Corp - Japan
- ☐ MAN
- ☐ MAN B&W Diesel
- ☐ Mitsubishi Heavy Industries
- ☐ Mitsui Engineering & Shipbuilding
- ☐ MTU Friedrichshafen
- ☐ New Sulzer Diesel France
- ☐ Niigata Engineering
- ☐ Nippon Kokan KK (NKK Corp)
- ☐ Rolls-Royce
- ☐ Ruston Paxman Diesel
- ☐ SACM Diesel SA
- ☐ SEMT Pielstick SA
- ☐ Ssangyong Heavy Industries
- ☐ Stork-Wartsila Diesel
- ☐ STX Engine
- ☐ Sulzer
- ☐ Sumitomo Heavy Industries
- ☐ Wartsila
- ☐ Yanmar Diesel Engine
- ☐ Zaklady Przemyslu Metalowego
- ☐ Zavod
- ☐ Other

If other, give manufacturer

____
____
____
____
____

Engine model

____
____
____
____
____

Built year

____
____
____
____
____

No. of cylinders

- ☐ 6
- ☐ 8
- ☐ 9
- ☐ 10
- ☐ 12
- ☐ 14
- ☐ 16
- ☐ Other ________________________________

Cylinder configuration, L or V

- ☐ L
- ☐ V

Nominal power, MW

- ☐ 1-2
- ☐ 2-4
- ☐ 4-6
- ☐ 6-8
- ☐ 8-10
- ☐ >10

Engine speed, rpm

- ☐ 400-600
- ☐ 601-800
- ☐ 801-1000
- ☐ 1001-1500
- ☐ Other ________________________________

Comments on aux eng, configuration, exact rating, MW

____
____
____
____
____

6. Fuel specification

Fuel used for main and aux engine during visit to Geiranger

Fuel used for main and aux engine

	Destillate	Residual	Other
Main engine	☐	☐	☐
Aux engine	☐	☐	☐

If other, please specify

____
____
____
____
____

Fuel viscocity, main engine, (cSt):

____
____
____
____
____

Fuel sulphur content, main engine, (%)

____
____
____
____
____

Fuel viscosity, aux engine, (cSt)

____
____
____
____
____

Fuel sulphur content, aux engine, (%)

____
____
____
____
____

Comments on fuel used on main and aux engines

____
____
____
____
____

7. Emission reduction technology on board

NOx and SOx reduction technology

NOx certificate, IMO limits

- ☐ Tier 1
- ☐ Tier 2
- ☐ Tier 3
- ☐ Not applicable

NOx reduction technology

	SCR system	EGR system	Other system
Main engines	☐	☐	☐
Aux engines	☐	☐	☐

If other system, please describe

____
____
____
____
____

SOx reduction technology

	Scrubber	None	Not applicable
Main engines	☐	☐	☐
Aux engines	☐	☐	☐

SOX and particle reduction from scrubber

	>90%	80-90%	70-80%	60-70%	50-60%	40-50%	< 40 %
SOx Reduction, %	☐	☐	☐	☐	☐	☐	☐
PM reduction, %	☐	☐	☐	☐	☐	☐	☐

Commments on scrubber/SOX reduction technology, SOx reduction, PM reduction

____
____
____
____
____

8. Emission to sea and air

Emission zone definitions

Zone 1: East of 6°45 E, North of 62°17' N

Zone 2: South of 62°17' N, North of 62°5' N

Zone 3: East of 6°42' E, West of 7°10 E

Zone 4: East of 7°10', West of 7°11'25" E

9. Emission to sea

Emission to sea: Zone, 1,2,3,4 and harbour operation

Discharge of bildge water

- ☐ Zone 1
- ☐ Zone 2
- ☐ Zone 3
- ☐ Zone 4
- ☐ No discharge in any zones

Quantity of discharged bildge water in zone 1,2,3,4, (m3)

____
____
____
____
____

Concentration of oil/chemicals in discharged bildge water, (Zone 1,2,3,4) (ppm)

____
____
____
____
____

Discharge of treated sewage

- ☐ Zone 1
- ☐ Zone 2
- ☐ Zone 3
- ☐ Zone 4
- ☐ No discharge in any zones

Quantity of discharged treated sewage in zone 1,2,3,4, (m3). Sewage treatment comments.

____
____
____
____
____

Sewage treatment plant IMO approval reference

- ☐ MEPC.2(VI),
- ☐ MEPC.159(55)
- ☐ MEPC.200(62)
- ☐ MEPC.227(64)
- ☐ Other ______________________________

Discharge of gray water

- ☐ Zone 1
- ☐ Zone 2
- ☐ Zone 3
- ☐ Zone 4
- ☐ Harbour
- ☐ No discharge in any zones

Quantity of discharged grey water in zone 1,2,3,4, and harbour(m3)

____
____
____
____
____

Gray water treatment system

- ☐ Yes
- ☐ No

Gray water treatment - comments

____
____
____
____
____

Discharge to sea from scrubber

- ☐ Zone 1
- ☐ Zone 2
- ☐ Zone 3
- ☐ Zone 4
- ☐ Harbour
- ☐ No discharge in any zones
- ☐ Not applicable, no scrubber on board

Quantity of dischard from scrubbers, (m3)

____
____
____
____
____

10. Operational data, Geiranger Fjord, Zone 3

Transit mode: East of longitude: 6°42' E

Ship speed, kn

____
____
____
____
____

Propulsion power, kW

____
____
____
____
____

Number of main engines in operation

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ Other ________________________________

Main engine load, %

- ☐ 10-25
- ☐ 26-40
- ☐ 41-60
- ☐ 60-80
- ☐ >80
- ☐ Other, exact load ________________________________

Exhaust temperatures

	< 250	250-269	270-299	300-330	> 330	Not applicable
Main engine exhaust temperature after turbocharger, (C)	☐	☐	☐	☐	☐	☐
SCR catalyst cut off temperature, (C)	☐	☐	☐	☐	☐	☐

Aux engine power, kW

____
____
____
____
____

Number of aux engines in operation

☐ 1
☐ 2
☐ 3
☐ 4
☐ Other ________________________________

Aux engine load, %

☐ 10-25
☐ 26-40
☐ 41-60
☐ 60-80
☐ >80
☐ Other, exact load ________________________________

Exhaust temperatures, aux engine, (C)

	< 250	250-269	270-299	300-330	> 330	Not applicable
Aux engine exhaust temperature after turbocharger, (C)	☐	☐	☐	☐	☐	☐
SCR catalyst cut off temperature, (C)	☐	☐	☐	☐	☐	☐

11. Operational data, Geiranger Fjord, Zone 4

Transit mode: East of longitude: 7°10' E

Ship speed, kn

____
____
____
____
____

Propulsion power, kW

____
____
____
____
____

Number of main engines in operation

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ Other ________________________________

Main engine load, %

- ☐ 10-25
- ☐ 26-40
- ☐ 41-60
- ☐ 60-80
- ☐ >80
- ☐ Other, exact load ________________________________

Exhaust temperatures, main engines, (C)

	< 250	250-269	270-299	300-330	> 330	Not applicable
Main engine exhaust temperature after turbocharger, (C)	☐	☐	☐	☐	☐	☐
SCR catalyst cut off temperature, (C)	☐	☐	☐	☐	☐	☐

Aux engine power, zone 4, kW

____
____
____
____
____

Aux engine load, %

- ☐ 10-25
- ☐ 26-40
- ☐ 41-60
- ☐ 60-80
- ☐ >80
- ☐ Other, exact load ________________________________

Number of aux engines in operation

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ Other ________________________________

Exhaust temperatures, aux engine, (C)

	< 250	250-269	270-299	300-330	> 330	Not applicable
Aux engine exhaust temperature after turbocharger, (C)	☐	☐	☐	☐	☐	☐
SCR catalyst cut off temperature, (C)	☐	☐	☐	☐	☐	☐

12. Operation data - Geiranger harbour

Data when moored in Gerianger harbour

Time in harbour, (h)

- ☐ 2-4
- ☐ 4-6
- ☐ 6-8
- ☐ 8-10
- ☐ Other ________________________________

Aux. engine power, kW

____
____
____
____
____

Number of engines in operation

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ Other ________________________________

NOx abatment system in operation

- ☐ Yes
- ☐ No
- ☐ Not applicable

Scrubber system in operation

- ☐ Yes
- ☐ No
- ☐ Not applicable

Thank you very much for your contribution to this survey.