



## Appendix:

1. Distances and times between port area border and berths in Faxaflóahafnir
2. Emission factors
3. Environmental Ship Index (ESI)



## Appendix 1. Distances and times between port area border and berths in Faxaflóahafnir.

Berth number	Name	Distance (NM)	Estimated time from port area border to at berth position (h)			Type	Port
			0_10 GRT	10_20 GRT	>20 GRT		
110	NORÐURGARÐUR - ISPS	3.20	0.50			Berth	Old harbour
111	NORÐURGARÐUR-111	3.20	0.50			Berth	Old harbour
112	NORÐURGARÐUR-112	3.20	0.50			Berth	Old harbour
113	NORÐURGARÐUR-113	3.20	0.50			Berth	Old harbour
114	NORÐURGARÐUR-114	3.20	0.50			Berth	Old harbour
121	SÍLDARBRYGGJA-121	3.20	0.50			Berth	Old harbour
122	SÍLDARBRYGGJA-122	3.20	0.50			Berth	Old harbour
123	OLÍUBRYGGJA-123	3.20	0.50			Berth	Old harbour
124	OLÍUBRYGGJA-124	3.20	0.50			Berth	Old harbour
131	Grandabryggja-Stubbur	3.20	0.50			Berth	Old harbour
141	GRANDABRYGGJA-141	3.20	0.50			Berth	Old harbour
142	GRANDABRYGGJA-142	3.20	0.50			Berth	Old harbour
143	GRANDABRYGGJA-143	3.20	0.50			Berth	Old harbour
144	GRANDABRYGGJA-144	3.20	0.50			Berth	Old harbour
145	GRANDABRYGGJA-145	3.20	0.50			Berth	Old harbour
151	GRANDABAKKI-151	3.20	0.50			Berth	Old harbour
152	GRANDABAKKI-152	3.20	0.50			Berth	Old harbour
153	Bótarbryggja -153	3.20	0.50			Berth	Old harbour
154	Bótarbryggja -154	3.20	0.50			Berth	Old harbour
155	Bótarbryggja -155	3.20	0.50			Berth	Old harbour
161	VERBÚÐARBRYGGJUR-161	3.20	0.50			Berth	Old harbour
162	VERBÚÐARBRYGGJUR-162	3.20	0.50			Berth	Old harbour
163	VERBÚÐARBRYGGJUR-163	3.20	0.50			Berth	Old harbour
164	VERBÚÐARBRYGGJUR-164	3.20	0.50			Berth	Old harbour
165	VERBÚÐARBRYGGJUR-165	3.20	0.50			Berth	Old harbour
166	VERBÚÐARBRYGGJUR-166	3.20	0.50			Berth	Old harbour
171	EYJARGARÐUR-171	2.50	0.42			Berth	Old harbour
181	DANÍELSSLIPPUR-181	3.20	1.00			Shipyard	Old harbour
182	VESTARI SLIPPUR-182	3.20	1.00			Shipyard	Old harbour
183	STÓRI SLIPPUR-183	3.20	1.00			Shipyard	Old harbour
184	EYSTRÍ SLIPPUR-184	3.20	1.00			Shipyard	Old harbour
191	EYJARGARÐUR-191	2.50	0.50	1.00		Berth	Old harbour
211	ÆGISGARÐUR-211	3.20	0.50	0.75		Berth	Old harbour
212	ÆGISGARÐUR-212	3.20	0.50	0.75		Berth	Old harbour
213	ÆGISGARÐUR-213	3.20	0.50	0.75		Berth	Old harbour
214	ÆGISGARÐUR-214	3.20	0.50	0.75		Berth	Old harbour



215	ÆGISGARÐUR-215	3.20	0.50	0.75		Berth	Old harbour
216	ÆGISGARÐUR-216	3.20	0.50	0.75		Berth	Old harbour
217	ÆGISGARÐUR-217	3.20	0.50	0.75		Berth	Old harbour
221	GRÓFARBRYGGJA-221	3.20	0.50			Berth	Old harbour
222	GRÓFARBRYGGJA-222	3.20	0.50			Berth	Old harbour
231	MÍÐBAKKI-231	3.20	0.50	0.75		Berth	Old harbour
232	MÍÐBAKKI-232	3.20	0.50	0.75		Berth	Old harbour
233	MÍÐBAKKI-233	3.20	0.50	0.75		Berth	Old harbour
234	MÍÐBAKKI-234	3.20	0.50	0.75		Berth	Old harbour
251	FAXAGARÐUR-251	3.20	0.50	0.75		Berth	Old harbour
252	FAXAGARÐUR-252	3.20	0.50	0.75		Berth	Old harbour
253	FAXAGARÐUR-253	3.20	0.50	0.75		Berth	Old harbour
254	FAXAGARÐUR-254	3.20	0.50	0.75		Berth	Old harbour
261	INGÓLFSGARÐUR-261	3.20	0.50			Berth	Old harbour
262	INGÓLFSGARÐUR-262	3.20	0.50			Berth	Old harbour
263	INGÓLFSGARÐUR-263	3.20	0.50			Berth	Old harbour
291	SUÐURBUGT	3.20	0.33			Berth	Old harbour
311	SKARFABAKKI-311	4.00	0.50		1.50	Berth	Sunda harbour
312	SKARFABAKKI-312	4.00	0.75	1.00	1.50	Berth	Sunda harbour
313	SKARFABAKKI-313	4.00	0.75	1.00	1.50	Berth	Sunda harbour
314	SKARFABAKKI-314	4.00	0.75	1.00	1.50	Berth	Sunda harbour
315	SKARFABAKKI-315	4.00	0.75	1.00	1.50	Berth	Sunda harbour
411	KORNGARÐUR-411	4.00	0.75	1.25	1.50	Berth	Sunda harbour
412	KORNGARÐUR-412	4.00	0.75	1.25	1.50	Berth	Sunda harbour
420	SUNDABAKKI - ISPS	4.00	0.75	1.25	1.50	Berth	Sunda harbour
421	SUNDABAKKI-421	4.00	0.75	1.25	1.50	Berth	Sunda harbour
422	SUNDABAKKI-422	4.00	0.75	1.25	1.50	Berth	Sunda harbour
423	SUNDABAKKI-423	4.00	0.75	1.25	1.50	Berth	Sunda harbour
430	KLEPPSBAKKI - ISPS	4.00	0.75	1.25	1.50	Berth	Sunda harbour
431	KLEPPSBAKKI-431	4.00	0.75	1.00	1.50	Berth	Sunda harbour
432	KLEPPSBAKKI-432	4.00	0.75	1.00	1.50	Berth	Sunda harbour
433	KLEPPSBAKKI-433	4.00	0.75	1.00	1.50	Berth	Sunda harbour
434	KLEPPSBAKKI-434	4.00	0.75	1.00	1.50	Berth	Sunda harbour
451	SUNDABAKKI - 451	4.00	0.75	1.00	1.50	Berth	Sunda harbour



452	SUNDABAKKI - 452	4.00	0.75	1.00	1.50	Berth	Sunda harbour
529	VOGABAKKI-529	5.10	1.00	1.25	1.67	Berth	Sunda harbour
530	VOGABAKKI - ISPS	5.10	1.00	1.25	1.67	Berth	Sunda harbour
531	VOGABAKKI-531	5.10	1.00	1.25	1.67	Berth	Sunda harbour
532	VOGABAKKI-532	5.10	1.00	1.25	1.67	Berth	Sunda harbour
533	VOGABAKKI-533	5.10	1.00	1.25	1.67	Berth	Sunda harbour
534	VOGABAKKI-534	5.10	1.00	1.25	1.67	Berth	Sunda harbour
535	VOGABAKKI-535	5.10	1.00	1.25	1.67	Berth	Sunda harbour
610	Ártúnshöfði -610	5.20	1.50			Berth	Sunda harbour
611	Ártúnshöfði -611	5.20	1.50			Berth	Sunda harbour
612	Ártúnshöfði -612	5.20	1.50			Berth	Sunda harbour
711	GRUNDARTANGI-AUSTURKANTUR-711	1.20	0.50	0.75	1.67	Berth	Grundartangi Harbour
721	GRUNDARTANGI-TANGABAKKI	1.20	0.50	1.00	1.67	Berth	Grundartangi Harbour
722	GRUNDARTANGI-TANGABAKKI	1.20	0.50	1.00	1.67	Berth	Grundartangi Harbour
723	GRUNDARTANGI-TANGABAKKI	1.20	0.50	1.00	1.67	Berth	Grundartangi Harbour
724	GRUNDARTANGI-TANGABAKKI	1.20	0.50	1.00	1.67	Berth	Grundartangi Harbour
811	AKRANES-ADALHAFNARGARÐUR	1.20	0.50	1.00		Berth	Akranes Harbour
812	AKRANES-ADALHAFNARGARÐUR	1.20	0.50	1.00		Berth	Akranes Harbour
813	AKRANES-ADALHAFNARGARÐUR	1.20	0.50	1.00		Berth	Akranes Harbour
814	AKRANES-ADALHAFNARGARÐUR	1.20	0.50	1.12		Berth	Akranes Harbour
821	AKRANES-BÁTABRYGGJA	1.20	0.50			Berth	Akranes Harbour
822	AKRANES-BÁTABRYGGJA	1.20	0.50			Berth	Akranes Harbour
823	AKRANES-BÁTABRYGGJA	1.20	0.50			Berth	Akranes Harbour
824	AKRANES-BÁTABRYGGJA	1.20	0.50			Berth	Akranes Harbour
831	AKRANES-FAXABRYGGJA	1.20	0.50			Berth	Akranes Harbour
832	AKRANES-FAXABRYGGJA	1.20	0.50			Berth	Akranes Harbour



841	AKRANES-FERJUBRYGGJA	1.20	0.50			Berth	Akranes Harbour
861	AKRANES-ADSTADA HAFNSÖGUB.	1.20	0.50			Berth	Akranes Harbour
871	AKRANES-Viðgerðarbryggja	1.50	0.80			Berth	Akranes Harbour
881	AKRANES-Skipalyfta	1.50	0.80			Shipyard	Akranes Harbour
951	KOLLAFJÖRDUR	2.20	0.50	0.75	0.75	Anchor	Reykjavik
961	Ytri höfn innan Engeyjar	3.00	0.50	0.75	0.75	Anchor	Old harbour
971	Viðeyjarsund	2.70	0.50	0.75	0.75	Anchor	Sunda harbour
972	Grundartangi-Biðsvæði	1.20	0.75	0.75	1.50	Anchor	Grundartangi Harbour
U7B	7-BAUJA					Pilot	Pilot
1001	Whale 1	3.20	1.83	1.83		Berth	Whale
1002	Whale 2	6.00	3.44	3.44		Berth	Whale



## Appendix 2. Emission factors

**Emission factors** (g/kWh) for the main engine in the port basin and during manoeuvring.

Engine type	Fuel type	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	TIER o NO <sub>x</sub>	HC	Ref.
HSD	MD	717	0.008	0.031	9.6	0.4	Cooper and Gustavsson, 2004
MSD	MD	717	0.008	0.031	10.6	0.4	Cooper and Gustavsson, 2004
SSD	MD	647	0.012	0.031	13.6	0.6	Cooper and Gustavsson, 2004
HSD	RO	752	0.008	0.031	10.2	0.4	Cooper and Gustavsson, 2004
MSD	RO	752	0.008	0.031	11.2	0.4	Cooper and Gustavsson, 2004
SSD	RO	682	0.012	0.031	14.5	0.6	Cooper and Gustavsson, 2004

**Emission factors** (g/kWh) for aux engines in all operational modes.

Engine type	Fuel type	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	TIER o NO <sub>x</sub>	HC	Ref.
HSD	MD	690	0.01	0.031	11.8	0.5	Cooper and Gustavsson, 2004

Abbreviations used:

SSD – "Slow Speed Diesel" (Engines with revolutions <300 rpm)

MSD – "Medium Speed Diesel" (Engines with revolutions 300-1000 rpm)

HSD – "High Speed Diesel" (Engines with revolutions > 1000 rpm)

MD – Marine distillate oil

RO – Residual oil

The carbon in 1 kg fuel cause 3,179 kg **CO<sub>2</sub>** (Cooper och Gustafsson, 2004).

**NO<sub>x</sub>-emission** factors for engines on ships constructed between 2001 and 2011 calculated according to IMO's NO<sub>x</sub> Tier-I standards and from 2011 and onwards according to IMO's Tier II standards:

Engine speed (RPM)	Emission factor (g/kWh)	
	Tier I	Tier II
<130	17	14.4
130 – 2000	45*RPM <sup>(-0.2)</sup>	44*RPM <sup>(-0.23)</sup>
>2000	9.8	7.7

**SO<sub>2</sub> emissions** are calculated from fuel consumption and the sulphur content of the fuel. Assumed 0.1 % S in MD, and 2.7 % in RO.

**Particle emissions** are determined based on the used fuel type and its sulphur content from a statistical analysis of multiple references:

Particle emission factors, at fuels with sulphur content >0.5%:

4-stroke engines:  $y = 37.624x + 0.2714$

2-stroke engines:  $84.509x - 0.2531$

$y$  gives the emission factor for PM10 in g/kWh,  $x$  is the sulphur content of fuel



Particle emission factors, at fuels with sulphur content <0.5%:

HSD/MSD/SSD: 0.2 g/kWh

Used references for calculating particle mass emission factors:

- Kasper, A et al., 2007. Particulate Emissions from a Low-Speed Marine Diesel Engine. *Aerosol Science and Technology*, 41(1), pp. 24-32.;
- Cooper, D., 2001. Exhaust emissions from high speed passenger ferries. *Atmospheric Environment*, Volume 35, p. 4189–4200;
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- Fridell, E. et al., 2008. Primary particles in ship emissions. *Atmospheric Environment*, Volume 42, p. 1160–1168;
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- Winnes H and Fridell, E, 2009. Particle Emissions from Ships: Dependence on Fuel Type. *Journal of the Air & Waste Management Association*, Volume 59, p. 1391–1398;
- Winnes H et al., 2016. On-board measurements of particle. *Journal of Engineering for the Maritime Environment*, 230(1), p. 45–54; ICCT, 2016. Black Carbon Measurement Methods and Emission Factors from Ships
- Moldanová J et al., 2013. Physical and chemical characterisation of PM emissions from two ships operating in European Emission Control Areas. *Atmospheric Measurement Techniques*, Volume 6, p. 3577–3596.;
- Moldanova J., et al., 2009. Characterisation of particulate matter and gaseous emissions from a large ship diesel engine. *Atmospheric Environment*, Volume 43, p. 2632–2641;
- Murphy S.M. et al., 2009. Comprehensive Simultaneous Shipboard and Airborne Characterization of Exhaust from a Modern Container Ship at Sea. *Environmental Science & Technology*, 43(13), pp. 4626-4640; U.S.
- Environmental Protection Agency, 2009. Proposal to Designate an Emission Control Area for Nitrogen Oxides, Sulfur Oxides and Particulate Matter
- Zetterdahl, M., 2016. Particle Emissions from Ships

Emission factors for **boilers** in g/tonne fuel:

Fuel	NO <sub>x</sub>	PM	HC	CH <sub>4</sub>	N <sub>2</sub> O
MD	2 900	290	36	7.4	37

Ref: USEPA, 1999, AP42, 5th ed, Vol1 Ch1 External Combustion Sources, sections 1.3 and 1.4.



## Appendix 3. Environmental Ship Index (ESI)

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### Description of methodology for estimating sulphur content in fuel from ESI score:

According to the Environmental Ship Index (ESI) the ESI score is calculated with the following model:

$$ESI\ SO_x = x \cdot 30 + y \cdot 35 + z \cdot 35$$

Where:

x: the relative reduction of the average sulphur content of Heavy Fuel Oil (HFO). The sulphur content is greater than 0.50% S but do not exceeding 3.50% S

y: the relative reduction of the average sulphur content of Marine Diesel Oil (MD). The sulphur content is equal or less than 0.50%, but greater than 0.1%

z: the relative reduction of the average sulphur content of MD. The Marine Diesel Oil has a sulphur content equal to or less than 0.10% S

Since Iceland has a 0.1% restriction at berth we assume that the MDO are 0.1 % or lower for ships entering Icelandic waters. We therefore exclude all boats having a lower ESI than 35 since:

$$ESI\ SO_x = x \cdot 30 + y \cdot 35 + z \cdot 35 \rightarrow ESI\ SO_x = 0 \cdot 30 + \frac{0.50\% - 0.1\%}{0.50\% - 0.1\%} \cdot 35 + 0 \cdot 35 = 35$$

Furthermore, for ships having an ESI SO<sub>x</sub> score between 30 and 65, we assume that the sulfur content in the Heavy Fuel Oil is reduced. The following equation describes how the sulfur content from RO is extracted for ships where 30 < ESI score < 65:

$$S\ content\ in\ HFO = 3.5\% - \frac{ESI\ SO_x - 35}{30} \cdot 3\%$$

If instead ESI score > 65:

$$S\ content\ in\ HFO = 0.05\%$$

$$S\ content\ in\ MDO = 0.1\% - \frac{ESI\ SO_x - 65}{35} \cdot 0.1\%$$



**Description of methodology for estimating NO<sub>x</sub> emission factor from ESI score:**

The emission factors for NO<sub>x</sub> are estimated from the scores given in the ESI register by resolving  $EF_{NOX\ rated}$  from equation (2).

$$ESI_{NOX} = \frac{100 * (EF_{NOX\ Tier\ I\ limit} - EF_{NOX\ rated})}{EF_{NOX\ Tier\ I\ limit}} \quad (2)$$

Where  $ESI_{NOX}$  is the NO<sub>x</sub> score calculated by ESI,  $EF_{NOX\ Tier\ I\ limit}$  the emission factor corresponding to Tier I-limits for the engine in g/kWh, and  $EF_{NOX\ rated}$  is the measured emission factor of the engine in g/kWh.

The NO<sub>x</sub> and SO<sub>x</sub> scores for the ships in Faxaflóahafnir 2019 that were registered with the ESI are shown in the table (should not be disclosed):

IMO_No	NO <sub>x</sub> score	SO <sub>x</sub> score
9371426	3.675	0
9370018	8.1	0
9490040	2.35	16.93
9641314	21.3	0
9158109	0	22.74
9243667	4.05	28.95
9141065	0	33.99
9367217	6	29.82
8822636	0	36.97
9375850	0	38.5
8913485	0	41.82
9177894	0	44.02
9261114	0	44.04
9491757	0	46
9234305	0	47.54
9116022	0	48.525
9017393	0	48.79
9440265	7.8	41.64
9156113	0	51.9
8918485	0	51.93
9199696	0	52.695
9313709	2.75	50.14
9595321	2.1	52.17
9192612	0	55
9461661	11.7	43.57
9064906	0	55.43
9431018	0	55.83
9491745	0	56.45



9177882	0	56.79
9056040	0	57
9017434	0	57.12
9753193	13.8	43.54
9064891	0	57.675
9313735	0	57.9
8918461	0	58.515
9430973	6.75	52.14
9325609	1.35	57.705
9173290	0	59.19
7926095	0	59.37
9506459	0	59.66
9178458	0	59.7
9430961	6.75	52.98
9491769	0	59.84
9440241	7.8	52.21
9509487	5.2	55.32
9507374	8.4	52.46
7810222	0	61.245
9507362	8.4	53.09
9177868	0	61.695
9163582	0	62.88
9641730	19.85	43.4
9050137	0	63.32
7382495	0	63.525
9156101	0	64.29
9431006	0	64.41
9491733	0	64.85
9118006	0	64.94
9760512	19.8	45.675
9219331	8.4	57.15
9017379	0	65.76
7810210	0	65.8
9313747	8.4	57.765
9017381	0	67.47
9467574	9.9	58.08
9315068	8.55	59.66
9426867	2.1	66.45
9320099	4.2	64.575
9451094	4.8	64.18
9714795	34.35	34.695
9440253	7.8	61.57
9358931	0	69.825



9333175	3.375	66.93
9106924	0	70.33
9371610	0	70.965
9307798	21.9	49.27
9195664	0	71.24
9224104	0	71.75
9241061	4.8	67
9195676	0	71.85
9534274	17.55	55.245
9333187	0	73.02
9430959	17.55	55.92
9199256	0	73.71
9430985	20.85	52.94
9005730	0	74.1
9156199	0	74.39
9005742	0	74.745
9477438	7.05	67.93
9150236	0	75.3
9211078	0	75.98
9237345	12.45	63.69
9697820	17.25	60.07
9195690	0	77.48
9430997	20.85	60.14
9708083	19.75	61.83
9448279	30.9	51.78
9696589	26.55	56.925
9320556	16.35	67.2
9190183	0	84.36
9678408	20.1	65.04
9266425	5.7	86.385
9226906	24.9	67.74
9771456	72.85	87.62