Marine Navigation - Sample Calculation for Emission

Marine Emission from Macau Ferry (Cotai Water Jet) (Arrival)

Total Emission = Emission of Fairway Cruising Mode + Emission of Slow Cruising Mode + Emission of Maneuvering Mode + Emission of Hotelling Mode

Emission = Engine Power (kW) x Loading Factor x Time-in-mode (hr) X Emission Factor (g/kWh)

Engine Type	Engine Type	Engine Power [1] (kW)	Loading Factor [2]			
			Fairway Cruise	Slow Cruise	Maneuvering	Hotelling
Propulsion Engine	Diesel	9280	0.35	0.28	0.19	0.00
Auxiliary Engine	Diesel	326	0.45	0.45	0.45	0.45

According to the site survey, the fairway within the 500m boundary is about 1200m.

Mode	Speed (knots)	Speed (m/s)	Time-in-mode (hr)	Distance Travelled (m)
Maneuvering [3]	8.0	4.1	0.015	222.2
Slow Cruise [3]	12.0	6.2	0.020	444.4
Fairway Cruise [3]	15.0	7.7	0.019	533.3
Total	NA	NA	0.067	1200

Time = 533.3/7.7*60*60

Engine Type	Time-in-mode (hr) [3]			
	Fairway Cruise	Slow Cruise	Maneuvering	Hotelling
Propulsion Engine	0.019	0.020	0.015	0.500
Auxiliary Engine	0.019	0.020	0.015	0.500

Engine Type	Emission Factor (g/kWh) [4]						
	CO	HC [5]	VOC [5]	NO_x	SO_2	RSP	FSP
Propulsion Engine	1.10	0.47	0.49	13.20	2.08	0.31	0.29
Auxiliary Engine	1.50	0.26	0.27	10.00	2.12	0.31	0.29

Note:

[1] Engine Power for the Propulsion Engine - Referenced from Table 4-8 of the Study on Marine Vessels Emissions Inventory, February 2012;
Engine Power for the Auxiliary Engine - According to Section 4.2.12 of the Study on Marine Vessels Emissions Inventory, February 2012;
For Macau Ferry (Turbojet), there are three types of vessels with different engine power involved, the final emission are the weighted average of the emission of these three vessels types;

[2] Loading Factor for the Propulsion Engine - Details of load factor refer to Appendix 5.3.12-3 Marine Navigation - Engine Power, Load Factor and Emission Factors;
Loading Factor for the Auxiliary Engine - Referenced from Table 4-10 of the Study on Marine Vessels Emissions Inventory, February 2012;

[3] Time-in-Mode refer to the travel time within 500m of the airport boundary- Referenced from Table 3-24, Table 4-14 and 4-15 of the Study on Marine Vessels Emissions Inventory, February 2012; and site survey result;

[4] Emission Factor for the Propulsion Engine - Referenced from Table 4-17 of the Study on Marine Vessels Emissions Inventory, February 2012 ; and

[5] An adjustment factor 1.053 is applied to HC outputs to calculate the VOC emission - Reference from Section 3.3.1 of the Study on Marine Vessels Emissions Inventory.

Emission (Fairway Cruise)

Engine Type	Emission (kg)					
	CO	VOC	NO_x	SO_2	RSP	FSP
Propulsion Engine	0.0692	0.0311	0.8301	0.1308	0.0195	0.0182
Auxiliary Engine	0.0070	0.0013	0.0465	0.0099	0.0014	0.0013

Emission (Slow Cruise)

Engine Type	Emission (kg)					
	CO	VOC	NO_x	SO_2	RSP	FSP
Propulsion Engine	0.0576	0.0259	0.6917	0.1090	0.0162	0.0152
Auxiliary Engine	0.0044	0.0008	0.0293	0.0062	0.0009	0.0009

Emission (Maneuvering)

Engine Type	Emission (kg)					
	CO	VOC	NO_x	SO_2	RSP	FSP
Propulsion Engine	0.0288	0.0130	0.3459	0.0545	0.0081	0.0076
Auxiliary Engine	0.0033	0.0006	0.0220	0.0047	0.0007	0.0006

Emission (Hotelling)

Engine Type	Emission (kg)					
	CO	VOC	NO_x	SO_2	RSP	FSP
Propulsion Engine	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Auxiliary Engine	0.1100	0.0201	0.7335	0.1555	0.0227	0.0213

Emission (Total per trip with 500m of the airport boundary)

Engine Type	Emission (kg)					
	CO	VOC	NO_x	SO_2	RSP	FSP
Propulsion Engine	0.16	0.07	1.87	0.29	0.04	0.04
Auxiliary Engine	0.12	0.02	0.83	0.18	0.03	0.02
Total	0.28	0.09	2.70	0.47	0.07	0.07

Estimation of Year 2031 Emission

Daily and Total Emission of Year 2011 Marine Traffic Activities at Skypier

Daily Sailing Schedule			Emission (kg)					
Company	From	To	CO	VOC	NO_x	SO_2	RSP	FSP
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Shekou	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
Turbojet	Macau	Hong Kong	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Shenzhen Airport Fuyong Terminal	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Macau Outer Harbour Ferry Terminal	Hong Kong	0.28	0.09	2.68	0.47	0.07	0.06
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Shekou	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
CKS	Dongguan Humen	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Zhongshan	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Hong Kong	Macau	0.06	0.02	1.11	0.50	0.06	0.06
Turbojet	Macau	Hong Kong	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Macau Taipa	Hong Kong	0.28	0.09	2.68	0.47	0.07	0.06
CKS	Hong Kong	Shenzhen Airport Fuyong Terminal	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Jiuzhou Port Zhuhai	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Guangzhou (Nansha)	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
Turbojet	Shekou	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
CKS	Hong Kong	Dongguan Humen	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Hong Kong	Macau	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Macau Taipa	Hong Kong	0.28	0.09	2.68	0.47	0.07	0.06
Turbojet	Macau	Hong Kong	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Dongguan Humen	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Zhongshan	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Shekou	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
CKS	Shenzhen Airport Fuyong Terminal	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Jiuzhou Port Zhuhai	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Dongguan Humen	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Macau Taipa	Hong Kong	0.28	0.09	2.68	0.47	0.07	0.06
Turbojet	Shekou	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
Turbojet	Hong Kong	Macau	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Dongguan Humen	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Macau Taipa	0.28	0.09	2.68	0.47	0.07	0.06
Turbojet	Macau	Hong Kong	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Jiuzhou Port Zhuhai	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Shekou	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
CKS	Hong Kong	Dongguan Humen	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Jiuzhou Port Zhuhai	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Shenzhen Airport Fuyong Terminal	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Hong Kong	Macau	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Macau Taipa	Hong Kong	0.28	0.09	2.68	0.47	0.07	0.06
Turbojet	Macau	Hong Kong	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Shekou	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Hong Kong	Macau	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Dongguan Humen	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Macau	Hong Kong	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Zhongshan	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Shekou	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
CKS	Hong Kong	Dongguan Humen	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Shekou	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
CKS	Shenzhen Airport Fuyong Terminal	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Jiuzhou Port Zhuhai	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Macau	Hong Kong	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Hong Kong	Macau	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Shekou	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
CKS	Hong Kong	Jiuzhou Port Zhuhai	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Shenzhen Airport Fuyong Terminal	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Zhongshan	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Shekou	Hong Kong	0.11	0.03	0.99	0.18	0.03	0.02
Turbojet	Macau	Hong Kong	0.06	0.02	1.11	0.50	0.06	0.06
CKS	Shenzhen Shekou	Hong Kong	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
CKS	Hong Kong	Shenzhen Shekou	0.13	0.04	1.25	0.22	0.03	0.03
Turbojet	Hong Kong	Macau	0.06	0.02	1.11	0.50	0.06	0.06
Daily Emission (kg)			12.12	4.09	126.20	27.23	3.81	3.54
Year 2011 Emission (kg)[6]			4424	1492	46062	9940	1389	1292

[6] Annual Emission = Daily Emission x 365 days

According to the "Engineering Feasibility and Environmental Assessment Study for Airport Master Plan 2030 - Marine Traffic Impact Assessment Final Report" Appendix A, the average growth rate of Cross Boundary Passenger Vessels at Skypier is about 3.0% between Years 2016 to 2035. Therefore, an annual growth rate of 3.0% is assumed for marine traffic activities at Skypier between Years 2011 to 2031 for conservative approach. Therefore, a total increase of 60% of marine traffic activities from Year 2011 to Year 2031 is assumed for marine traffic activities at Skypier.

Total Emission of Year 2031 Marine Traffic Activities at Skypier

	Emission (kg)					
	CO	VOC	NO_x	SO_2	RSP	FSP
Emission at Year 2011 at Skypier	4424	1492	46062	9940	1389	1292
Emission at Year 2031 at Skypier	7079	2386	73700	15904	2223	2068

CO Emission at 2031 = 4424kg x 160% = 7079 kg

Daily and Total Emission of Year 2011 Marine Traffic Activities at CKS (Rivertrade Vessels)

Daily Emission in Year 2011	Emission (kg)						Total Operation Day in 2011
	CO	VOC	NO_x	SO_2	RSP	FSP	
101TEU	2.25	0.40	14.69	2.44	0.46	0.36	293
101TEU	2.25	0.40	14.69	2.44	0.46	0.36	293
16TEU	1.43	0.25	9.29	1.55	0.30	0.23	281
16TEU	1.43	0.25	9.29	1.55	0.30	0.23	281

Year 2011 Total Emission[7]	Emission (kg)					
	CO	VOC	NO_x	SO_2	RSP	FSP
101TEU	659	116	4304	716	136	105
101TEU	659	116	4304	716	136	105
16TEU	403	70	2611	434	84	65
16TEU	403	70	2611	434	84	65
Total (kg)	2124	373	13830	2301	440	341

[7] Annual Emission = Daily Emission x Operation Day of Year 2011

According to the "Engineering Feasibility and Environmental Assessment Study for Airport Master Plan 2030 - Marine Traffic Impact Assessment Final Report" Appendix A Table A.4, there is 39% increase in the number of forecast cargo vessel arrivals at Hong Kong from Year 2009 to 2031. Assume that the annual growth rate is the same between Year 2009 to Year 2031 is the same, an average annual growth rate of 1.8% will be resulted.
Based on the above assumption, the rivertrade vessels activities of Year 2011 and Year 2031 are 104% and 139% compared with Year 2009, respectively. Therefore, there is about 34% increase of rivertrade activities from Year 2011 to Year 2031.

Let X be the rivertrade activities at Year 2009, the river trade activities at Year 2011 is 1.04X and at Year 2031 is 1.39X, respectively.
Therefore, the scaling factor of activities from Year 2011 to Year 2031 = 1.39X / 1.04x = 1.34.

Total Emission of Year 2031 Marine Traffic Activities at CKS (Rivertrade Vessels)

	Emission (kg)					
	CO	VOC	NO_x	SO_2	RSP	FSP
Emission at Year 2011 at CKS	2124	373	13830	2301	440	341
Emission at Year 2031 at CKS	2851	501	18566	3089	590	457

CO Emission at 2031 = 2124kg x 134% = 2851kg