APPENDIX

TECHNOLOGY OPTIONS, MEASURES, APPLICABILITY AND OTHER CONSIDERATIONS FOR BLACK CARBON EMISSION REDUCTION FOR EXISTING SHIPS[1]

Possibility to apply:

✓ possible
(✓) possible with constraints and associated with high costs/efforts
X virtually impossible, would require efforts like conversion to new

Effectiveness related to its BC reduction potential:

+++ to +: very high to good 0: neutral n/a: not applicable

Detailed technology	**Estimated BC reduction potential in relation to HFO**	**Possibility to apply the technology to ships**		**Effectiveness of the detailed technology** ATTENTION: Effectiveness related to its BC reduction potential		**Comments / constraints**
		Re-fit	*Existing*	*Re-fit*	*Existing*	*"Re-fit" means that a measure can be applied to an "existing" ship after modifications; "existing" means a ship as it is, with no (technical) changes.*
***Technology:* Exhaust after treatment**						
DPF *(Diesel Particulate Filter)*	80 – 99%	(✓)	X	+++	n/a	Only in combination with appropriately controlled sulphur / ash content fuels.
ESP *(ElectroStatic Precipitator)*	70%	(✓)	X	+	n/a	Safety aspects yet unsolved, may hinder the application of ESP on board ships.
Wet EGCS *(Exhaust Gas Cleaning System, "scrubber")*	0 - 25%	(✓)	X	0	n/a	There may be local restrictions to the discharge of discharge water from EGCS.
SCR *Selective Catalytic Reduction)*	0-35%	(✓)	X	+	n/a	SCR is a technology to reduce NO_x. In combination with fuel injection timing, the engine can be tuned to reduce PM and BC emissions by increasing NO_x emissions abated by the SCR
DOC *(Diesel oxidation catalyst)*	0	(✓)	X	0	n/a	DOC is a technology to reduce CO and HC but has no effect on BC[2]

[1] Annotation: BC reduction potential depends on engine load, type and working principle (2- or 4-stroke, mean engine speed) and deviations of fuel properties.

[2] DOC was often mentioned and listed as a technology to reduce exhaust emissions in the BC discussion.

Detailed technology	**Estimated BC reduction potential in relation to HFO**	**Possibility to apply the technology to ships**		**Effectiveness of the detailed technology** ATTENTION: Effectiveness related to its BC reduction potential		**Comments / constraints**
		Re-fit	*Existing*	*Re-fit*	*Existing*	*"Re-fit" means that a measure can be applied to an "existing" ship after modifications; "existing" means a ship as it is, with no (technical) changes.*
Technology: Cleaner fuels						
Distillates	30-45%	✓	✓	+	+	30% with a low aromatic content (high H/C ratio). A lower H/C ratio means an increase in unsaturated hydrocarbons which indicates an increase in aromatic content which results in higher BC emissions.
LNG *(Liquified Natural Gas)*	>85%	(✓)	X	++	n/a	
LPG *(Liquified Petroleum Gas)*	>85%	(✓)	X	++	n/a	
Methanol	>85%	(✓)	X	++	n/a	
OME *(Oxymethylene ethers)*	>85%	(✓)	(✓) *(up to 15% mixing ratio)*	+++	+	OMEs contain oxygen and their combustion is similar to LNG. However, not commercially available, yet. Can be used as drop-in fuel. BC reduction potential relates to mixing ratio.
Biofuels						BC emission reduction. potential largely varies and depends on the fuel production pathway, its property and quality.
Sustainable synthetic fuels, PtX *(Power to Gas or Liquid)*	20 – 80%	✓	✓	++	++	Since these are sulphur and ash free fuels, they would provide the necessary basis for allowing possible DPF application.
Fuels with high H/C ratio	10 – 60%	✓	✓	+	+	The H/C ratio provides information on the aromaticity of a fuel, decreased ratio means higher aromatic content and higher BC emissions (H/C ratio is not provided in ISO 8217).