EVOLUTION OF MARINE BLACK CARBON EMISSIONS

in European seas from 2012 to 2050 | Jan Hulskotte

TNO innovation for life

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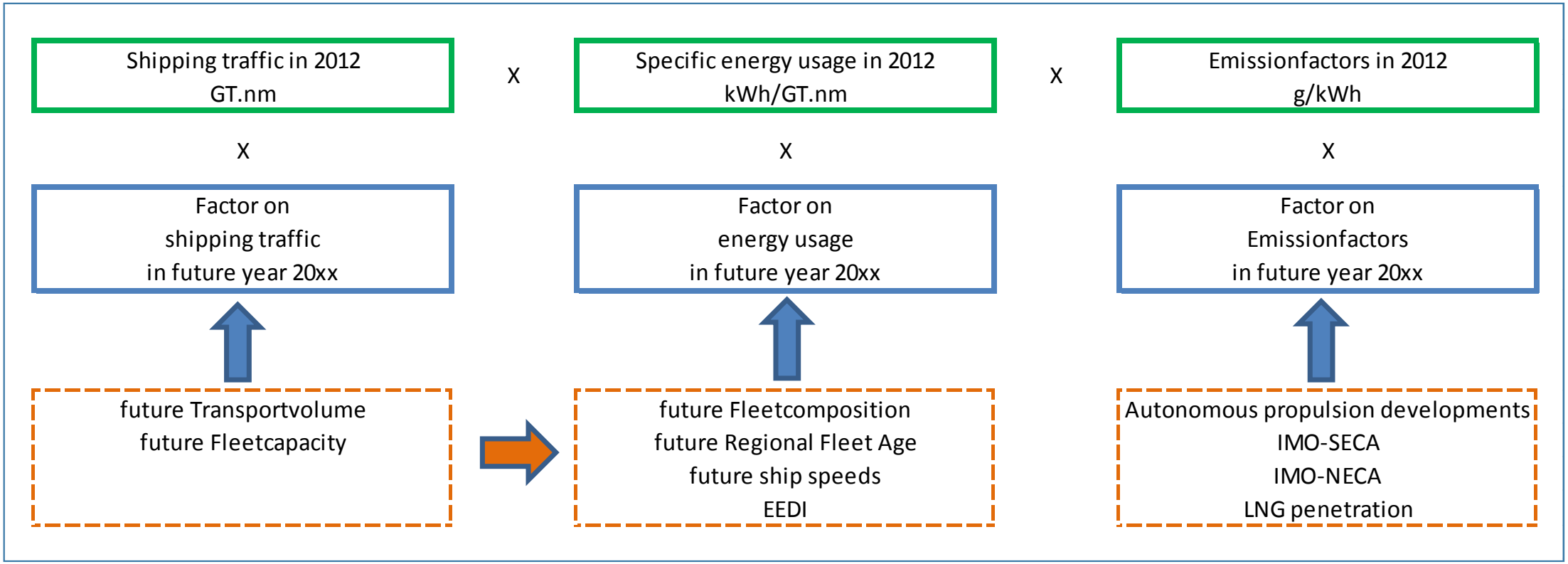
POSEIDON MODELLING TOOL



POSEIDON DETAILS

Shiptypes
Oil tanker
Chemical/LNG/LPG tanker
Bulk carrier
Container ship
General Dry Cargo
RoRo Cargo / Vehicle
Reefer
Passenger
Miscellaneous
Tug/Supply
Fishing
Non Merchant

Shipvolumes (GT)
100 - 1,600
1,600 - 3,000
3,000 - 5,000
5,000 - 10,000
10,000 - 30,000
30,000 - 60,000
60,000 -100,000
> 100,000

Enginetypes
Slow-speed
Medium/High speed
Steamturbines
Gasturbines

Fuels
HFO
MDO
MGO
LNG

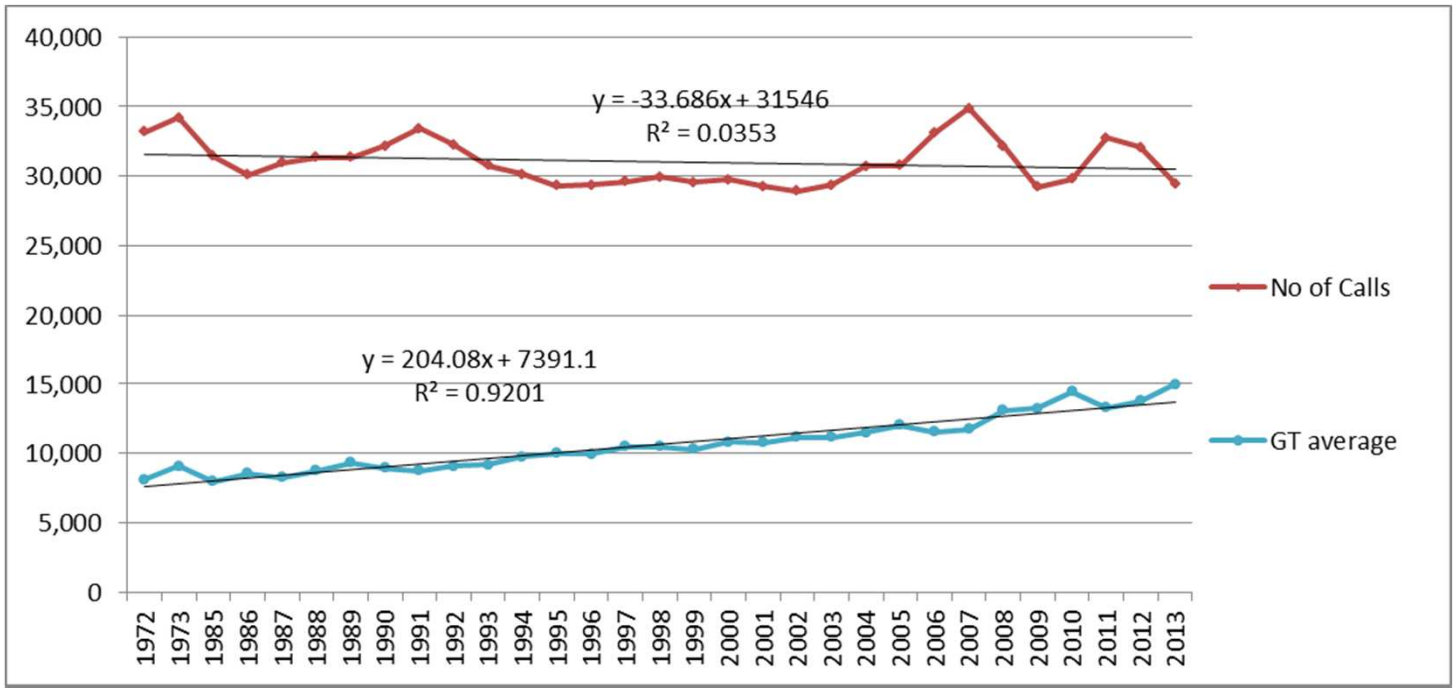
Substances
CO2
SO2
NOx
CO
NMVOC
Methane
PM10
PM2.5
(Black Carbon)

Areas
Dutch Continental Shelf
Rotterdam area
Amsterdam area
Scheldt area
Ems area
Den Helder area
Harlingen area

Ref.:Hulskotte. J.H.J., POSEIDON user manual (in Dutch), TNO-2014-R211208 dd 2014/08/27

Commissioned by PBL Netherlands Environmental Assessment Agency

EVOLUTION OF SHIP SIZE IN ROTTERDAM

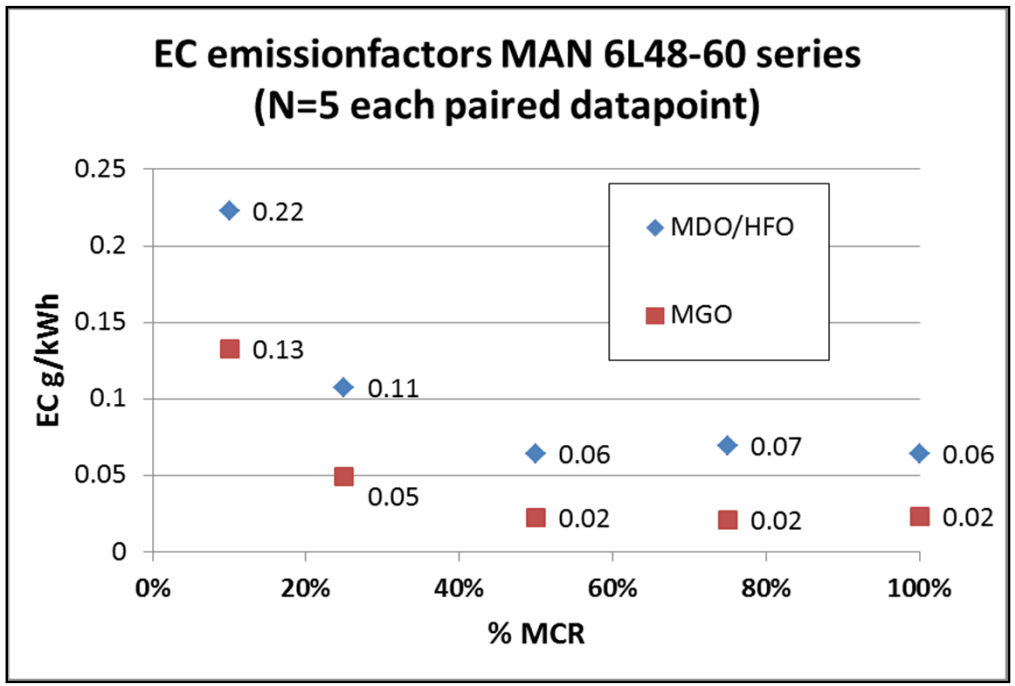


Harbour has grown 1.6% p/a , energy efficiency by ships volume growth compensates ca. 0.5% p/a

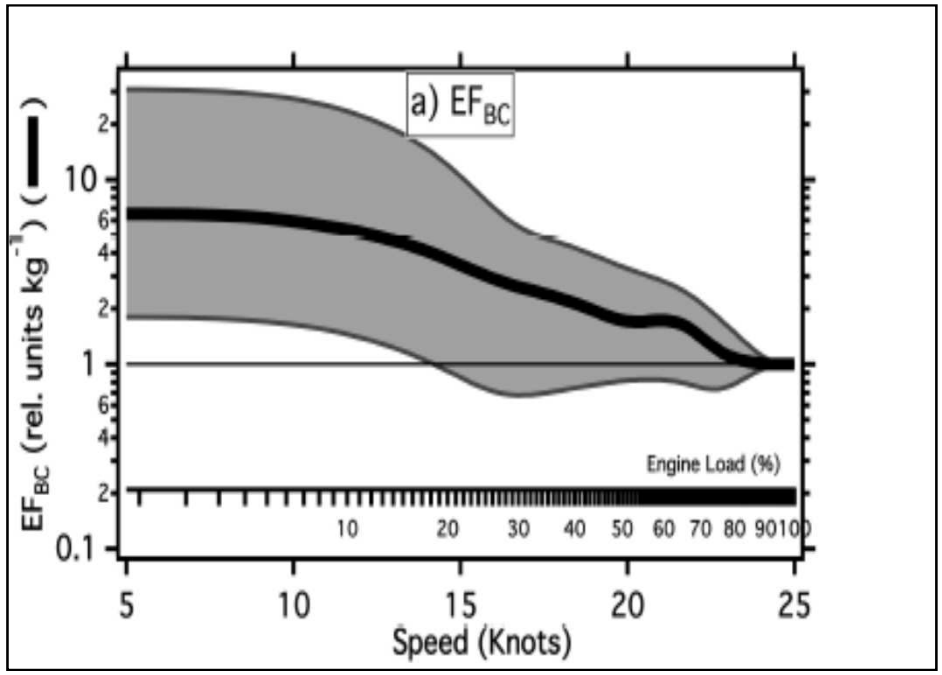
BLACK CARBON EMISSION FACTORS

- Until now no differentation between Fuels, Engine Type, Engine Age
- J.P. Jalkanen et al., 2012 (STEAM-model): BC = 0.08 g/kWh
- J. Moldanova. 2010 (TRANSPHORM-project): BC = 0.05 – 0.06 g/kWh
- M. Winther et al., 2014 (Polar-study): BC = 0.35 g/kg fuel
- Very poor support for studies on future emission scenarios

EMISSION FACTORS SEARCH FOR DIFFERENTIATION (1)



Elaborated data taken from: Lauer presented at ETH conference 2007-08-13



Source: D. Lack and J. Corbett, Atmos. Chem. Phys., 12, 3985–4000, 2012

Conclusions: With identical engines there is an influence of fuel type (1) and %MCR (2), However the extent of influence of %MCR at medium loads is not very clear (3)

EMISSION FACTORS SEARCH FOR DIFFERENTIATION (2)

	TexAQS (Lack et al., 2009)		Lower Elbe (Diesch et al., 2013)		Calnex (Buffaloe et al., 2014)	
Engine-type	gBC/kWh	S%*)	gBC/kWh	S%	gBC/kWh	S%
HSD	**0.07**	0.98	**0.04**	0.20%	**0.06**	0.03%
MSD	**0.14**	1.46	**0.03**	0.46%	**0.07**	0.09%
SSD	**0.06**	2.87	**0.02**	0.55%	**0.05**	0.40%

Conclusions: Fuel quality is important but Sulphur% is not the ultimate indicator (1), Slow-speed (SSD) engines tend to have lower emission factors independent on fuel quality (2)

BASIC BC EMISSION FACTORS APPLIED IN POSEIDON

Engine year of build	Slow speed (g BC/kWh)		Medium/High speed (g BC/kWh)	
	MDO/MGO	HFO	MDO/MGO	HFO
< 1974	0.06	0.08	0.06	0.12
1975-1979	0.06	0.08	0.06	0.12
1980-1984	0.06	0.08	0.06	0.12
1985-1989	0.06	0.08	0.06	0.12
1990-1994	0.06	0.08	0.05	0.12
1995-1999	0.04	0.06	0.04	0.1
2000-2010 (IMO 1)	0.04	0.06	0.04	0.1
2011-2019 (IMO 2)	0.04	0.04	0.04	0.1
2020- ? (IMO 3)	0.03	0.04	0.03	0.07

Simple approach applied here: Take 20% of the part of PM that is not caused by Sulphur

CONCLUSIONS ON EMISSION FACTORS

- BC emissionfactors are dependent on:
  - **Fuel Quality**

    (= not directly the same as Sulphur content, MGO shows approx. half of emission of HFO and MDO)
  - **Engine type**

    (Slow Speed engine emit little less than Medium Speed engines)
  - **Engine year of build**

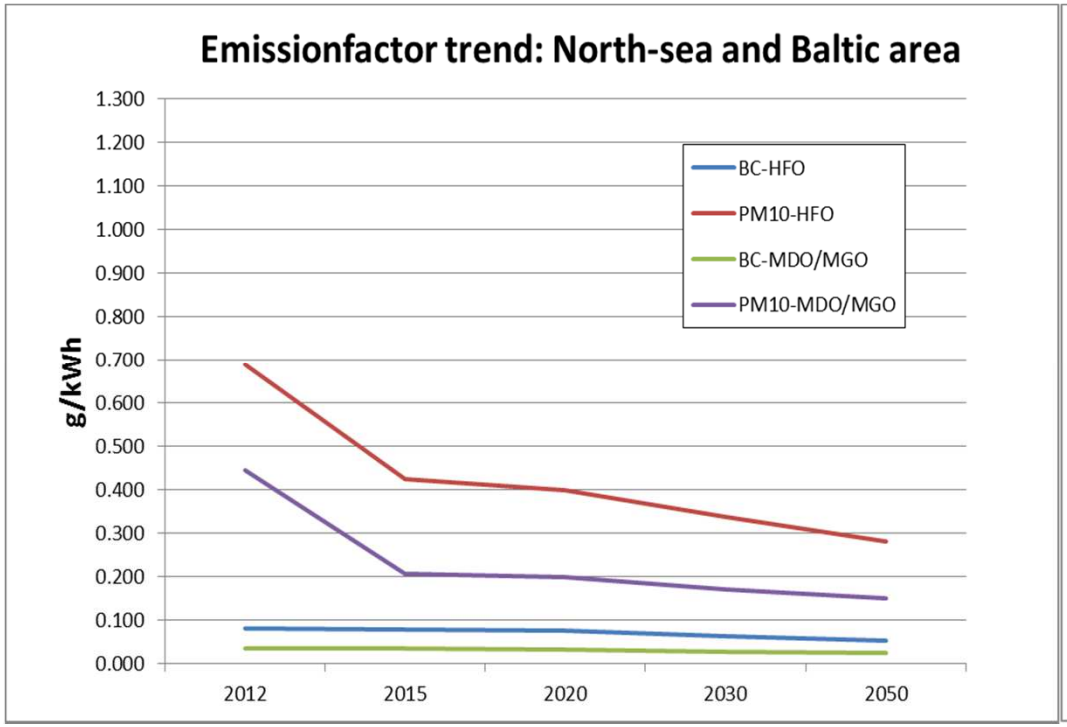
    (older engines can have much higher emission factors)
  - **%MCR**

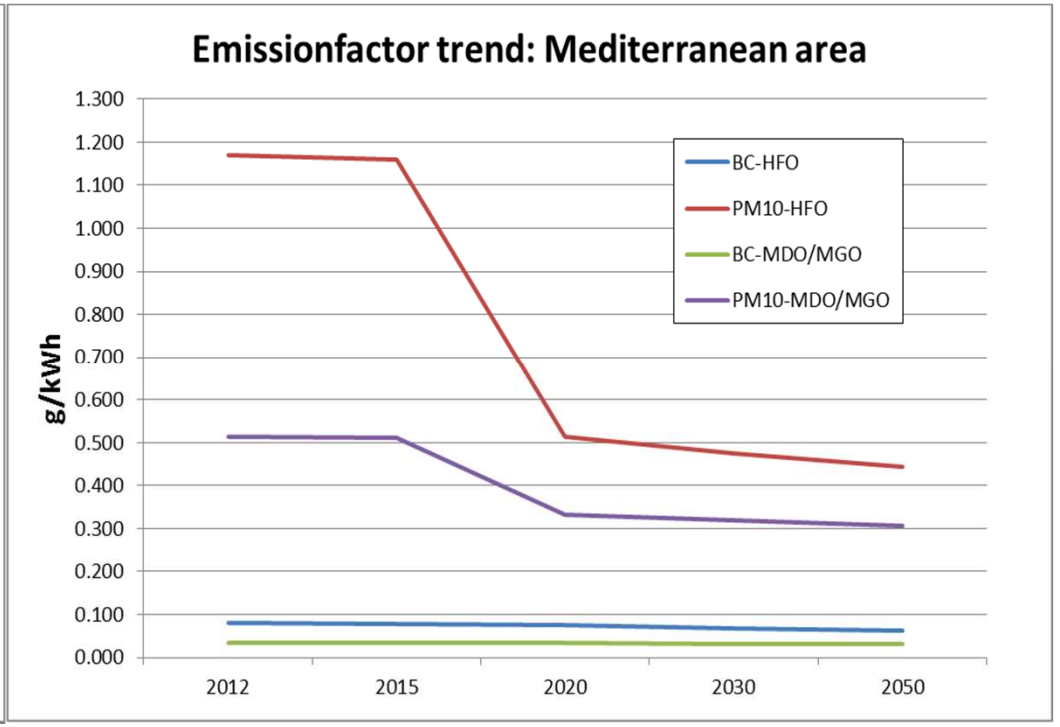
    (especially very low loads show much higher emissions, the resulting effect of slow-steaming on emission is still unclear)

SEA SPECIFIC SCENARIOS

Sea area	North Sea, Baltic Sea	Mediterranean Sea, Black Sea, Atlantic Ocean
2.7% transport growth/year	✓	✓
SECA in 2015: 0.1% S	✓	X
IMO worldwide 2020: 0.5% S	-	✓
NECA in 2020	✓	X
8% LNG in 2050 (scenario I)	✓	✓
30% LNG in 2050 (scenario II)	✓	✓

MODELLED TRENDS IN EMISSION FACTORS BC AND PM

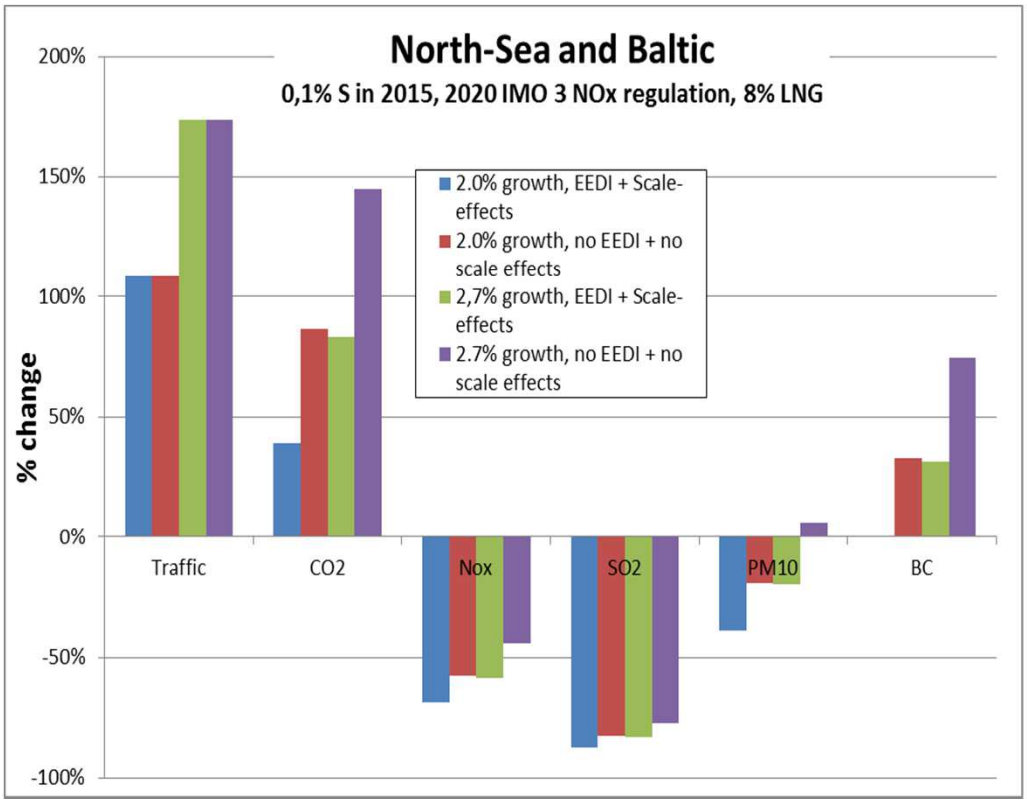


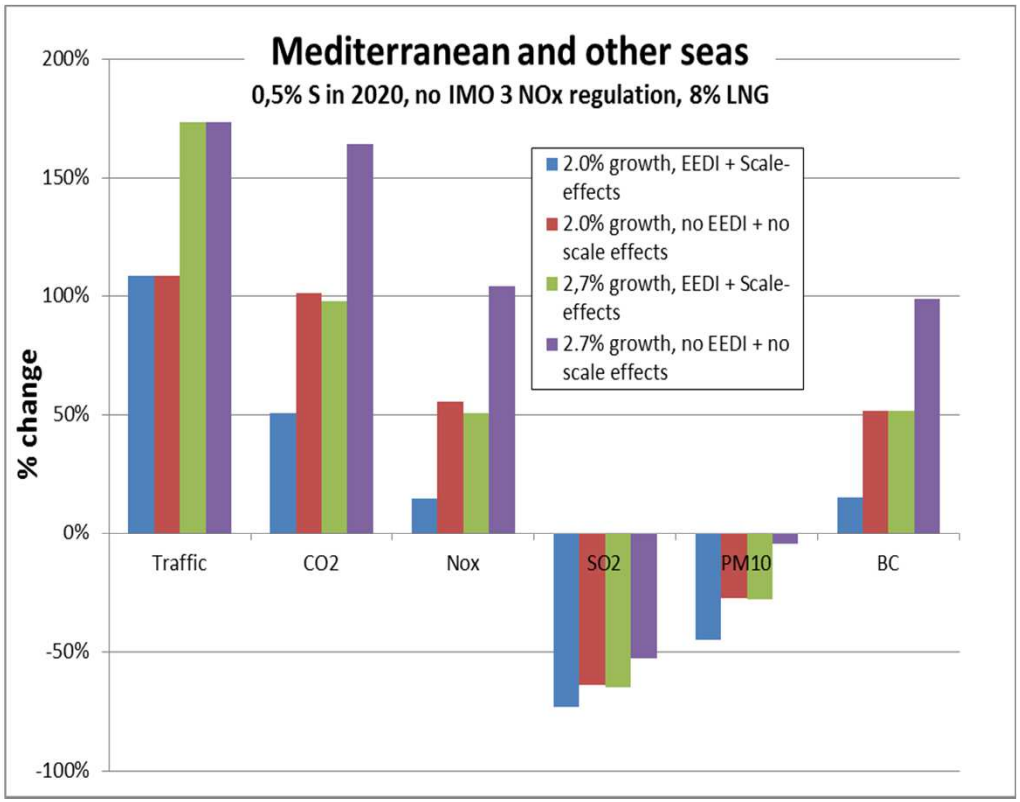


Conclusions: PM-emission factors show strong reduction caused by IMO-SECA and IMO global regulation (1), BC-emission factors show much less reduction (2),
Reduction of BC-emission factors in SECA are slightly stronger than non-SECA reduction (3)

Possible evolution of BC emissions in European seas

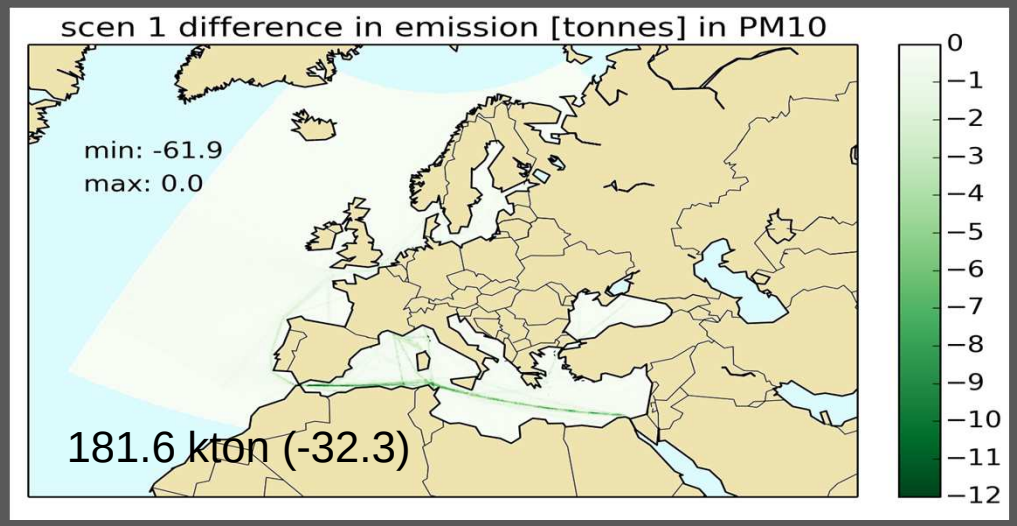
CHANGE OF EMISSIONS 2050/2012 WITH EXISTING POLICIES

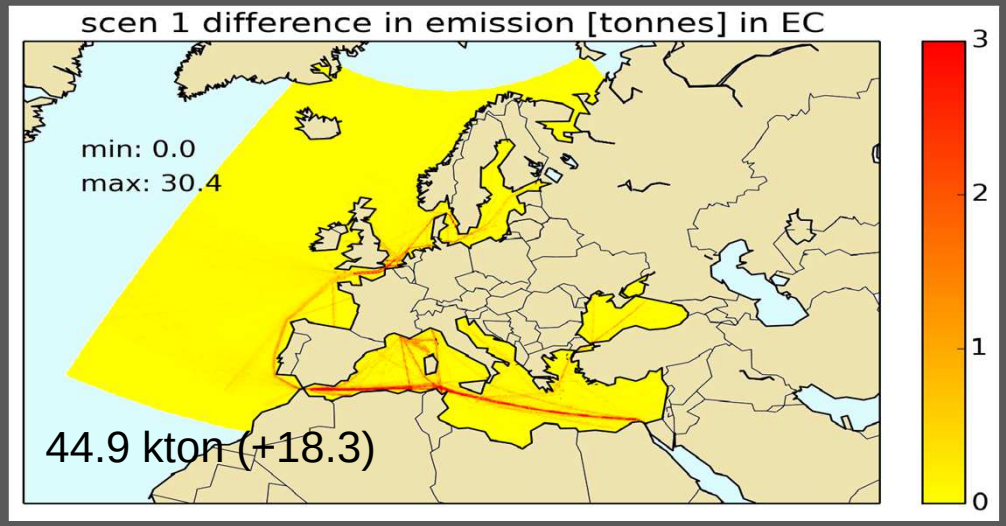


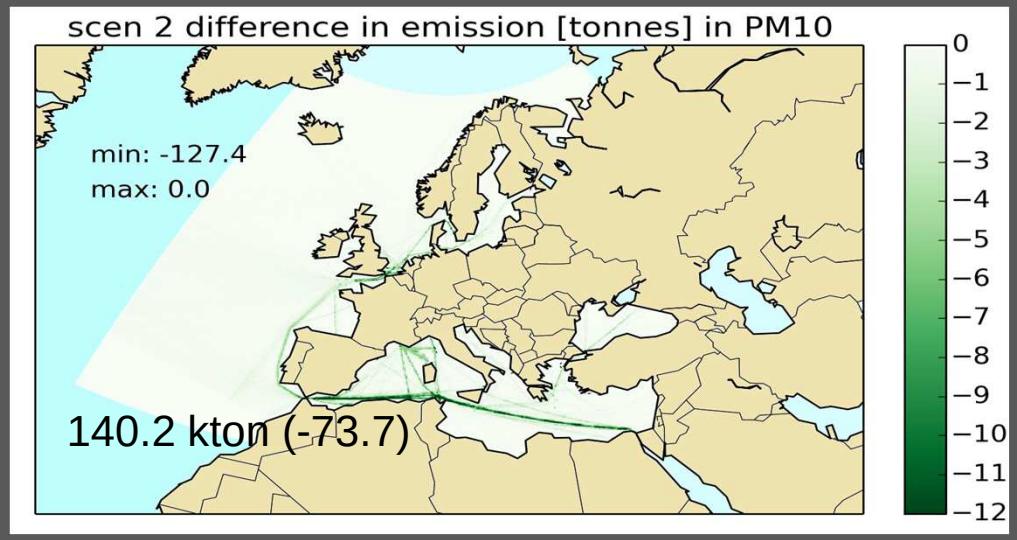


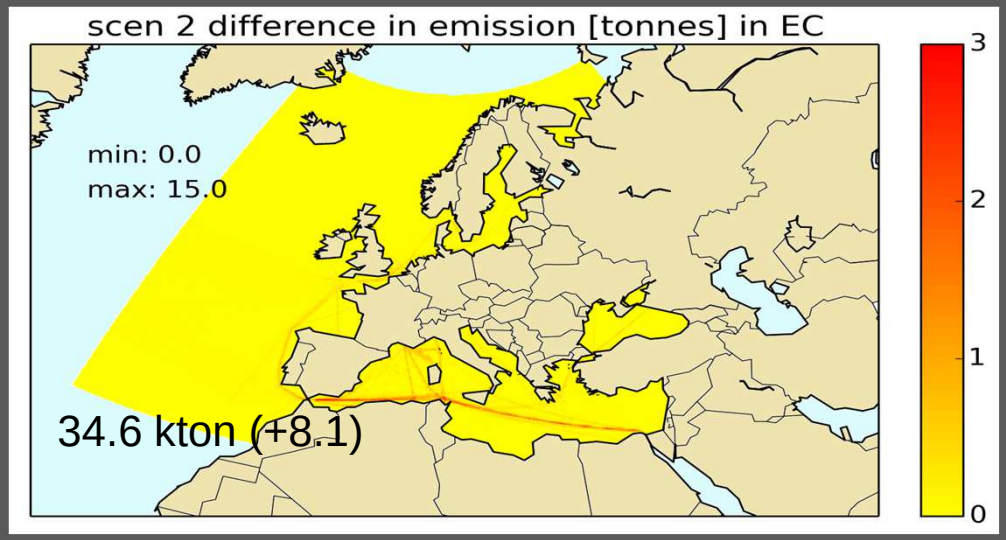
Possible evolution of BC emissions in European seas

MACC shipping emission change grids of PM10 and EC 2050/2012 for NW-Europe









CONCLUSIONS

- Black Carbon emission factors are dependent on:
  - **Fuel Quality**

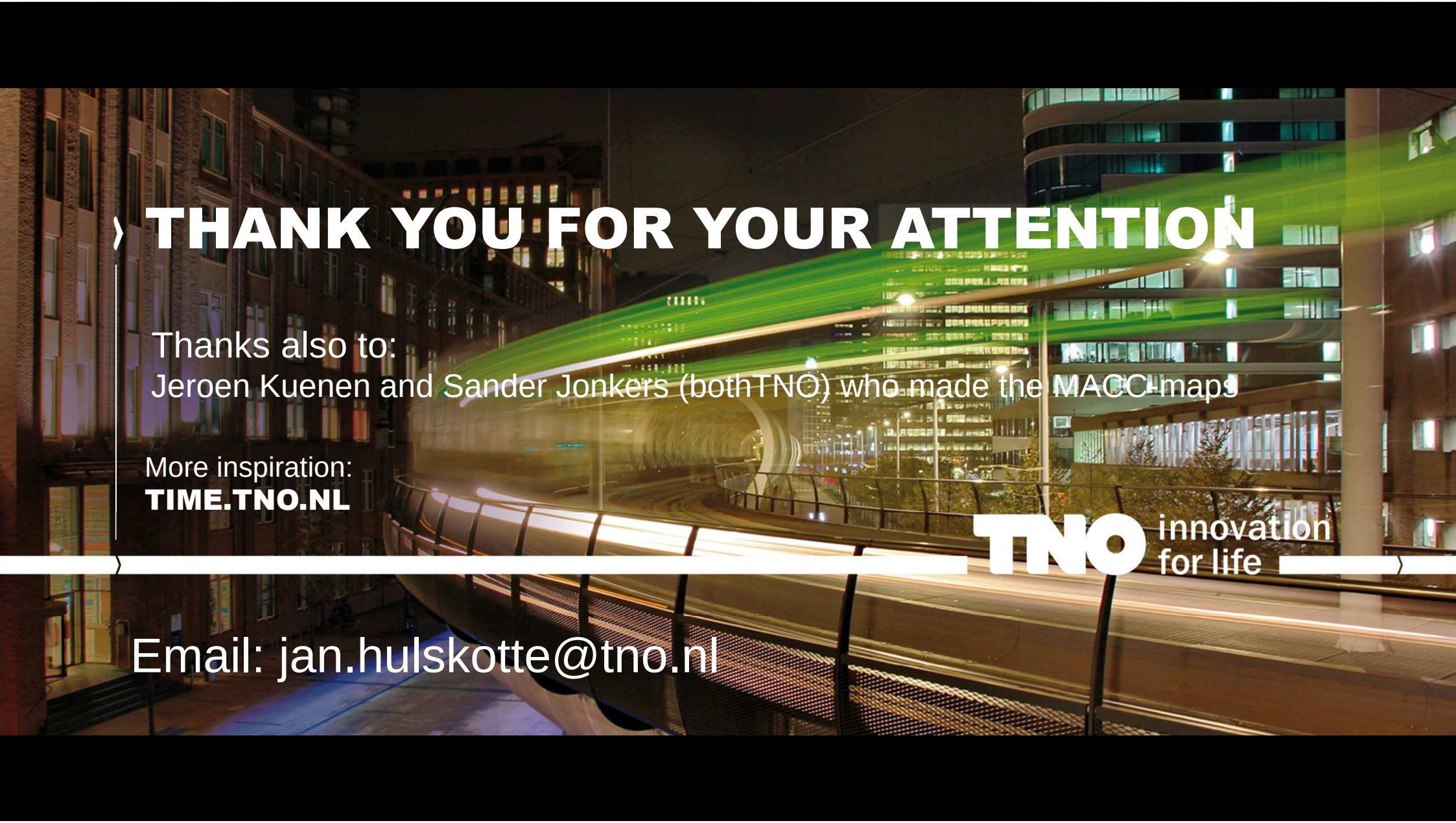
    (= not directly the same as Sulphur content, MGO shows approx. half of Black Carbon emission of HFO and MDO)
  - **Engine type**

    (Slow Speed engines tend to emit less Black Carbon than Medium Speed engines)
  - **Engine year of build**

    (older engines can have much higher Black Carbon emission factors)
  - **%MCR**

    (especially very low loads show much higher black carbon emissions, the resulting effect of slow-steaming on emission however is still unclear)

- Current IMO-policies on Sulphur and NOx have very little influence on future Black Carbon emissions:
  - Exemption is **IMO EEDI** that deminishes future Black Carbon emissions little
  - **LNG** and other **alternative marine fuels** show strong potence of deminishing of future emissions
  - Dedicated **research** is adviced **on fuel parameters (i.e. aromatic HC-content)** that specifically deminish BC emissions


THANK YOU FOR YOUR ATTENTION
Thanks also to:
Jeroen Kuenen and Sander Jonkers (bothTNO) who made the MACC maps
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