Future emissions from Global Shipping: a critical analysis using the MUSE Integrated Assessment Model

Daniel Crow*, Sara Giarola, Paul Balcombe, Jamie Speirs and Adam Hawkes

*dco8@ic.ac.uk

Overview:

- Use MUSE to generate commodity price pathways consistent with a 2˚C scenario
- Focus on decarbonisation options for global shipping in this 2˚C scenario which target sector-specific emissions reductions by 2050

Emissions from International Shipping[1]:

- Inherently efficient (slow and big).

Rail freight transport (MJ/tkm)	0.35
Road freight transport (MJ/tkm)	1.31
Air freight (MJ/tkm)	10.46
Oceanfreight (MJ/tkm)	0.11

- Traditionally neglected in international climate policy. 3% of emissions but could rise to 20% by 2050[2].

	2007	2008	2009	2010	2011	2012
Global	31,959	32,133	31,822	33,661	34,726	34,968
Shipping (% of Global)	1,100 3.5%	1,135 3.5%	977 3.1%	914 2.7%	1,021 2.9%	942 2.6%

- Predicted growth of 70 – 100% by 2050 compared to 2015.

IMO Targets and EEDI[2,3]:

- IMO adopted "initial strategy" to clean up international shipping in April 2018.
- GHG emissions should "peak as soon as possible", ***reduce by 50% compared to 2008 by 2050***.
- *Energy efficiency design index* (EEDI) mandates:

  Drastic SOx reductions on new-build after 2020. Eliminate HFO.

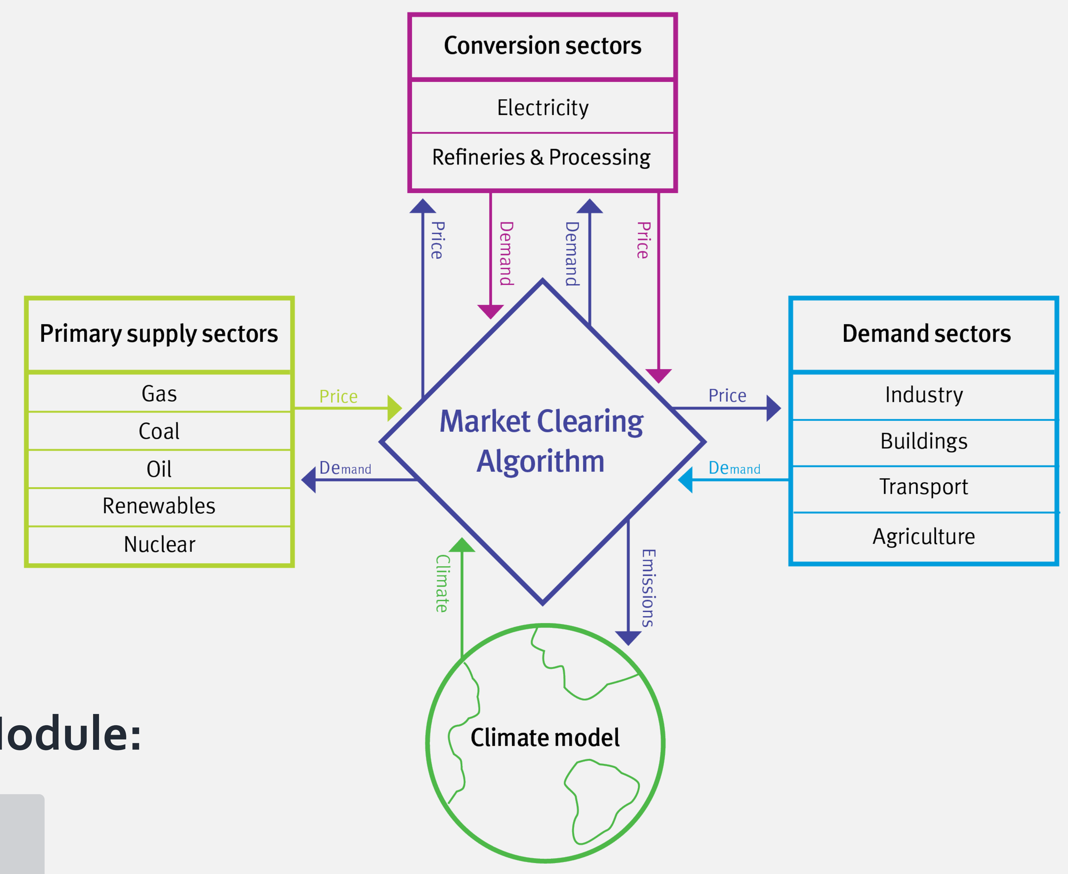
  20% CO_2 reduction on new-build after 2020, 30% reduction after 2025.

  ."..technological innovation and the global introduction of alternative fuels and/or energy sources for international shipping will be integral to achieve the overall ambition."

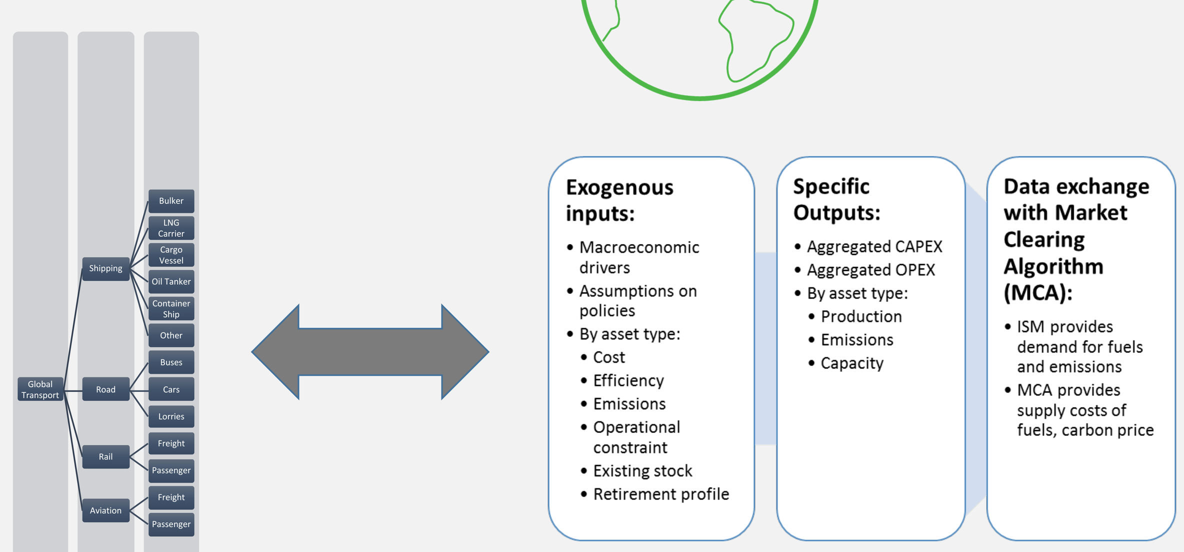
MUSE: a new IAM:

MUSE framework:

- Covers all the sectors in the energy system (highly disaggregated)
- Global scale with regional disaggregation
- Simulation with time horizon 2010 to 2100
- Modular: each sector is modelled in a way that is appropriate for that sector
- Engineering-led and technology-rich with a bottom-up technoeconomic characterization
- Microeconomic foundations: all sectors agree on price and quantity for each energy commodity
- Partial equilibrium on the energy system (models supply and demand)
- Policy instruments modelled (e.g. carbon price, subsidies)



MUSE Transport Module:

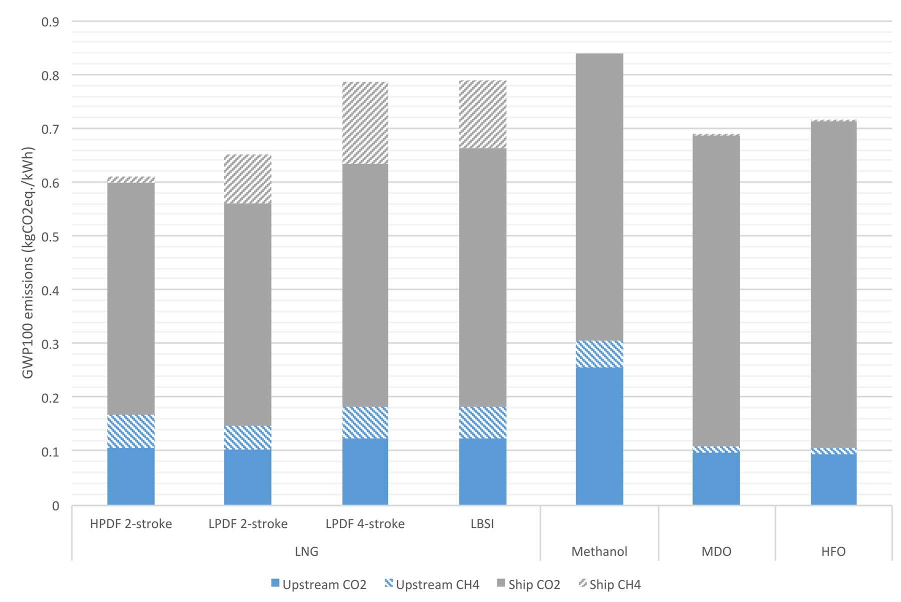


International shipping model:

- Model builds new ships based on levelised cost of delivering a tonne-km of supply
- Levelised cost includes capital, operating (variable & fixed), fuel and emissions costs
- Consider a range of new engine options of different TRLs

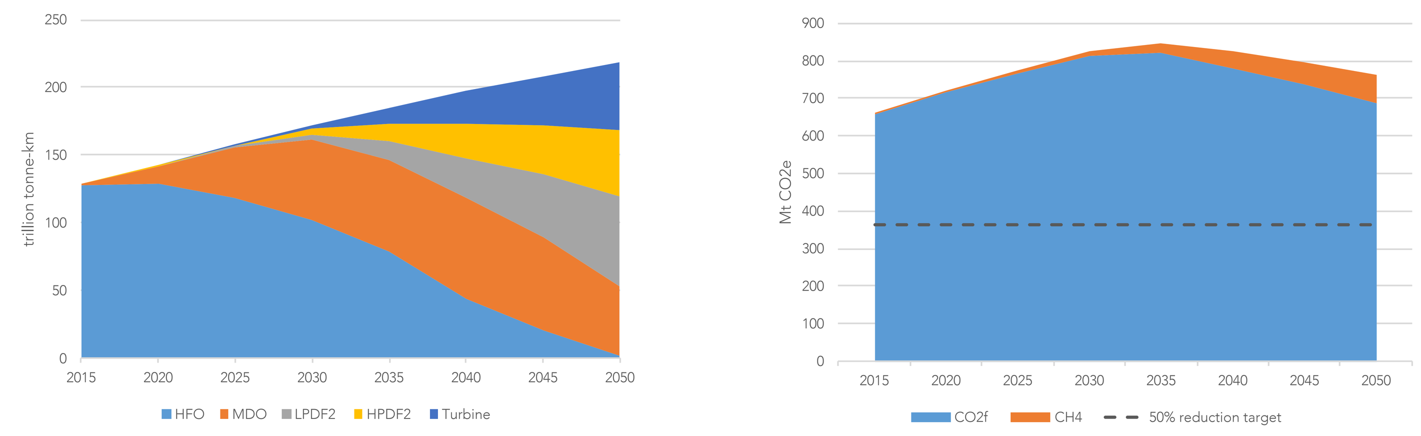
	Cost (MUSD/kWh)	CO2 (g/kWh)	CH4 (g/kWh)
HFO (conventional heavy oil - benchmark)	465	579.4	0.01
MDO (conventional marine diesel oil)	465	557.5	0.01
LPDF4 (LPDF 4 stroke)	674	433	7
LPDF2 (LPDF 2 stroke)	674	411.6	3.2
Turbine (Gas Turbine)	943	437.9	0
HFC (H2 Fuel Cell)	3720	0	0

- Consider lifecycle emissions. Emissions costs commensurate with endogenous global carbon price 2°C scenario

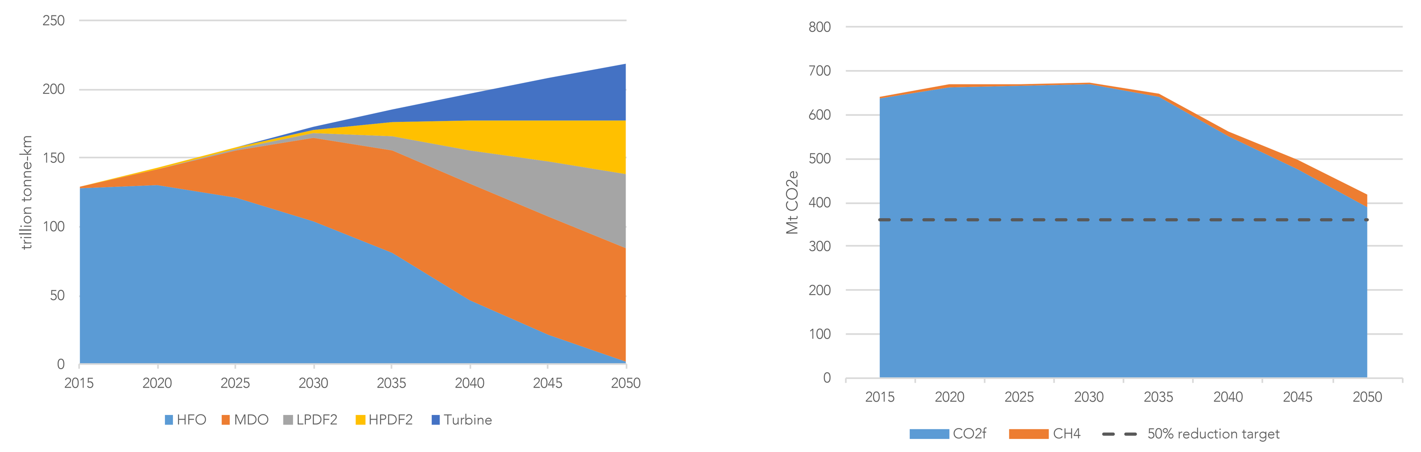


Results:

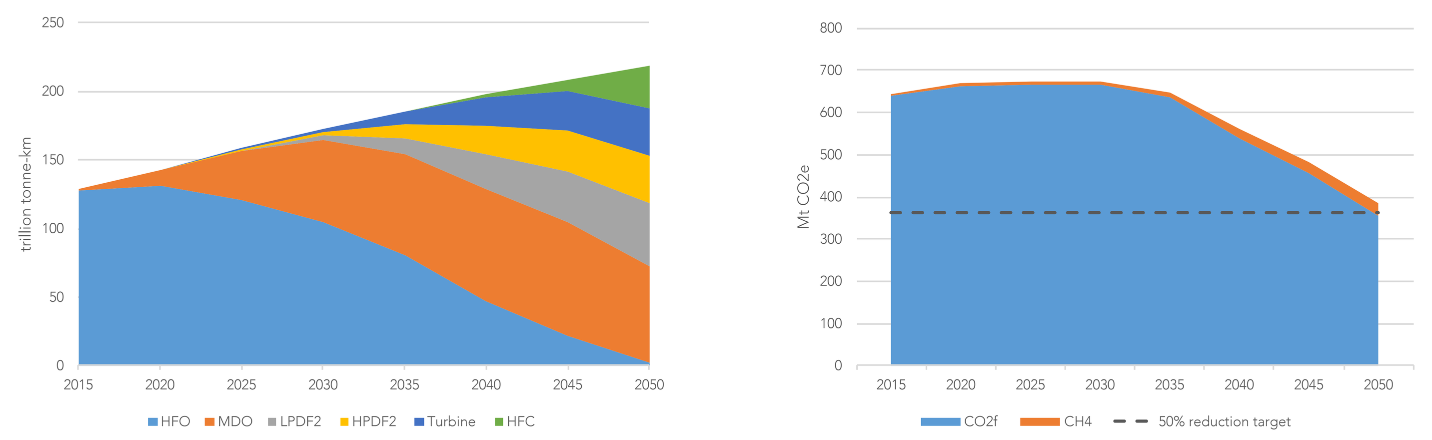
- No EEDI current policies; all efficiency improvements engine-related



- EEDI current policy



- EEDI enhanced policy with 40% reduction in CO_2 after 2030 plus H_2 fuel cell option



Conclusions:

- **50% reduction in GHG emissions by 2050 very challenging with existing policies and 70% demand growth.**
- **EEDI would be more effective if methane emissions included in targets.**
- **An enhanced EEDI policy including non-engine efficiency improvements and a zero-emissions option needed.**

References:

[1] *IEA (2017). Energy Technology Perspectives, [Online]. Available: https://www.iea.org/etp2017/ [Accessed 19/12/2017].*

[2] *Olmer, N., B. Comer, B. Roy, X. Mao, and D. Rutherford, Greenhouse Gas Emissions From Global Shipping, 2013-2015, ICCT, Editor. 2017, The International Council on Clean Transportation. p. 1-38*

[3] *IMO, MARPOL Annex 6; http://www.imo.org/en/MediaCentre/HotTopics/GHG/Pages/default.aspx*

Sustainable Gas Institute
Website: www.sustainablegasinstitute.org
Twitter: @SGI_London
Email: sgi@imperial.ac.uk