CO2 Emissions from Ships: the Case for Taking our Time

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1 Introduction

In a recent position paper, Efficient Safe Reduction of CO2 Emissions from Shipping the Center for Tankship Excellence (CTX) compared the three main proposals for reducing CO2 emissions from ships: a carbon content bunkers tax, an Emissions Trading System (ETS), and a mandated Energy Efficiency Design Index (EEDI). The results are summarized in Table 1. The CTX argued that

1. Market based measures are far superior to mandated technical requirements in achieving emissions reductions at least cost to society. In particular, EEDI which at its core is a mandated reduction in installed power would not only be ineffective but also unsafe.
2. A carbon content bunkers tax would be more effective than a cap and trade program. A tax has three major advantages over emissions permit trading:
   (a) Substantially less administrative costs.
   (b) No inter-period transfer problems. This is essential to inducing the right amount of slow-steaming in the short run.
   (c) Far less carbon price uncertainty. This is essential to inducing the right amount of investment in CO2 reducing measures in the long run.

This position paper addresses the question of: what is the right amount of tax (or cap if we go ETS). It comes up with the perhaps surprising suggestion that the right level of tax for the next few years is zero. Or to put it another way, a cap and trade based on Kyoto goals will result in a permit price of zero.

The combination of the massive increase in bunkers prices over the last few years together with shipping's sensitivity to bunker prices has resulted in around 600 million tons per year of CO2 reductions with negative abatement costs. ***These reductions will occur over the next 20 years even if we do nothing***.

This is important because it says ***we have time***. The major procedural disadvantage of either a tax or an ETS is that it will require a new IMO Convention in part to handle the funds generated. EEDI, on the other hand, despite its importance and its critical safety implications, procedurally is merely an admendment to an annex of MARPOL. As such it can be adopted by a handful of people (the MEPC) behind close doors and deemed accepted without a vote. The new convention process will probably take around 7 years. The adopt and deemed accepted admendment process takes less than a year.

The fact that shipping will beat the Kyoto goals over the next few years even if we do nothing, gives us the time to put the tax (or ETS) convention in place, leaving the level of the tax (cap) to be decided when the convention comes into force. With the convention in place, we check the situation and decide on the level of the tax (cap). If real bunker prices keep rising, as they probably will, then it is quite possible that the right move will still be: wait and watch.[1]

Finally, even if we were in a hurry, this would not be an argument in favor of EEDI. Quite the contrary. EEDI applies only to newbuildings. The first phase a 10% reduction in EEDI (not to be confused with a reduction in CO2 emissions which will be much smaller), will apply only to ships delivered between 2013 and 2017. Phase 2, a 25% reduction in EEDI, will apply to ships delivered between 2018 and 2022. Phase 3, a 35% reduction in EEDI, will apply to ship delivered in 2023 and later.

A tax which came into force in 2017 would immediately apply to every ship afloat. At that point, a 10% reduction in EEDI would apply to only a very small proportion of the trading fleet.

2 Bunker Prices since 1998

Figure 1 shows bunker prices for the last 12 years. In 1998, BFO was as low as \$50 per ton. In mid/late 1999, bunker prices rose to about \$150 per ton and stayed in the \$120 to \$180 range until 2005. In 2005, bunker prices started a precipitous climb to a peak of nearly \$800 per ton in mid-2008. With the late 2008 financial crisis, BFO prices fell steeply to a low of about \$225 per ton in early 2009, but recovered quickly to the current price of about \$450

[1] Theoretically, the level of tax (permit price) should be set to the marginal social cost of CO2 pollution, which is only very weakly dependent on oil prices. However, if shipping is way ahead of other sectors in cutting back, one can make a practical argument for deferring actually imposing the tax (cap) and avoiding the administrative costs.

per ton. A very rough rule of thumb is that heavy BFO price in tons is about five or six times the crude price in barrels.

When an owner buys a ton of BFO, he buys just over three tons of CO2 emissions. ***For a shipowner, the cost of a ton of CO2 emissions is about one-third his fuel price.*** Figure 2 converts bunker price, Figure 1, to the owner's cost of emissions. In 1998, this cost was a little over \$20 per ton of CO2. In 1999, this cost rose to about \$50 per ton.

During this period, the last of the turbine ships disappeared. A turbine ship burns about 75% more fuel than a diesel ship of the same size and speed. At least in tankers and bulk carriers, we also saw a substantial drop in speed capability. The typical turbine tanker built in the 1970's had a loaded, calm water full speed of about 16 knots. Most of the motor ships that replaced them are hard pressed to do more than 14 knots in calm but realistic conditions. In the long run, dropping average fleet speed by 2 knots drops individual ship fuel consumption by more than one-third while requiring about 15% more ships. Since ships only use full-power during a portion of their lives, the relationship between maximum speed and average operating speed is not clear cut as it might seem. Still is it clear that over the last ten years, the average steaming speed of the bulk fleet has declined. Between retiring the turbine ships, and reducing average operating speed plus a bunch of more minor improvements, most importantly, the adoption of the slow speed, super long stroke diesel, a ball park figure for the reduction in carbon intensity of the international tanker fleet over the last 20 years might be a factor of two. There are few major sectors that can claim this sort of improvement.[2]

Despite the 1990 to 2005 improvements, international shipping remains almost uniquely sensitive to fuel price. Currently the fuel bill accounts for around 50-60% of a large containership's total operating expense.[3] For tankers and bulk carriers, this percentage can be as high as 80%.

3 Negative Abatement Costs

In 2005 the owner's cost of CO2 emissions started climbing steeply. Since mid-2007, it has averaged about \$150 per ton, which also happens to be the current level. This post-2005 increase in owner's emissions cost of roughly \$100 per ton CO2 has engendered a massive increase in slow-steaming. For example, for a VLCC in a Worldscale 70 market (about RFR) increasing bunker prices from \$200 per ton to \$400 per ton will reduce steaming speed from 14 knots to 12 knots, which will reduce CO2 emissions by at last 25%.[4] Cariou estimates that since 2008 slow-steaming by containerships has reduced worldwide liner CO2 emissions by 17%.[5] This reduction is above the proposed IMO target for 2018.[6] However, the post-2005 bunker price rise has happened so recently that we cannot expect to start seeing the long-run effects on ship design for a few more years.

This lag shows up in *negative abatement costs*. Several recent studies of the cost of reducing CO2 emissions from ships have come up with the perhaps unexpected result that many measures that owner's could implement have negative cost, that is, if they were implemented the ship owner's profits would increase.[7]

Are we to assume that owner's are voluntarily reducing their earnings in order to put more CO2 into the air? Of course not. Owners are not stupid; owners are avaricious. They are always searching for ways to improve their profits, Ships have (or should have) an economic life of 20 or more years. Many of the measures studied by DNV and others can only be economically installed when the ship is built. The obvious example is building more ships. Still others can only be installed economically when the ship is already in the dry-dock for other reasons, usually a 5 year, Special Survey. Even where the abatement costs actually are negative, it will take a decade or more before these measures show up in the bulk of the fleet. But show up they will, ***even if IMO does nothing***.

[2] According to the Second IMO GHG Study 2009, page 55 average tanker emissions went from about 45 g C02/ton-m in 1960 to about 18 g CO2/ton-m in 2000.

[3] Notteboom T, Cariou P, Are Bunker Adjustment Factors aimed at revenue making or cost recovery? Handbook of Maritime Economics and Business

[4] Devanney,The Effect of Bunker Prices on VLCC Rates.

[5] Cariou,The impact of speed reduction on liner shipping CO2 emissions

[6] MEPC60/4/36.

[7] DNV, Pathways to Low Carbon Shipping, June 2010.
Sames, CO2 Marginal Abatement Cost Curves for Container Vessels, Germanisher Lloyd. 2010-06-03.
The Second IMO GHG Study 2009

Figure 1: BFO prices 1998 - 2010

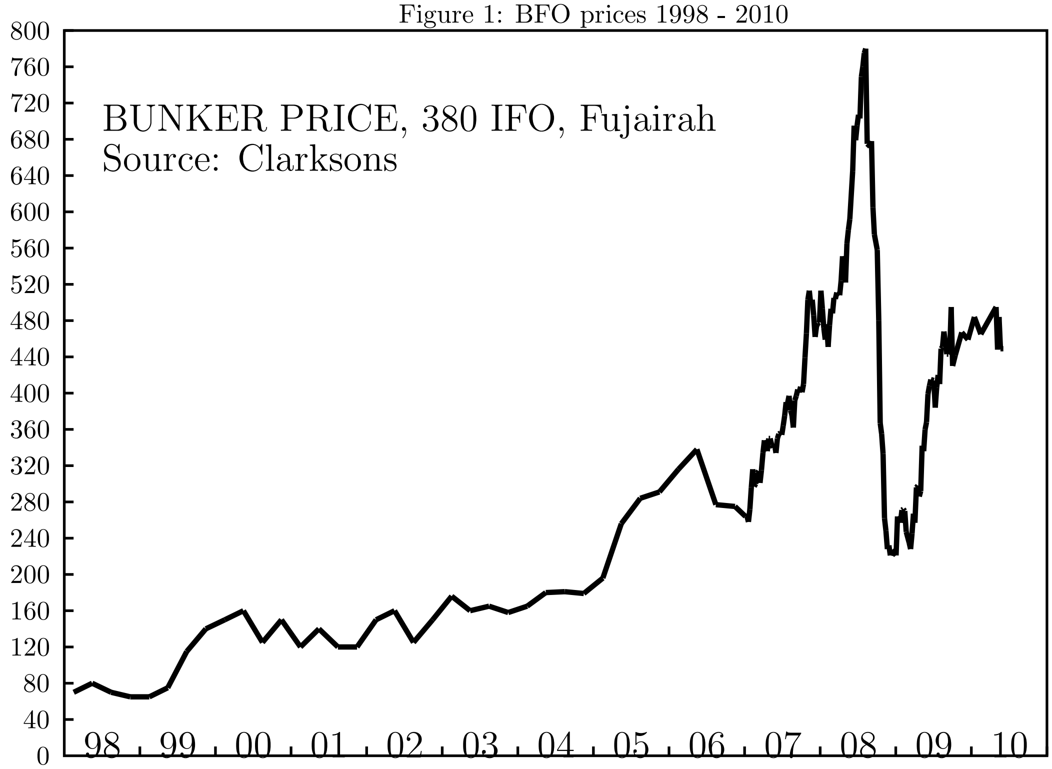


Figure 2: Owner cost of a ton of CO2 emissions

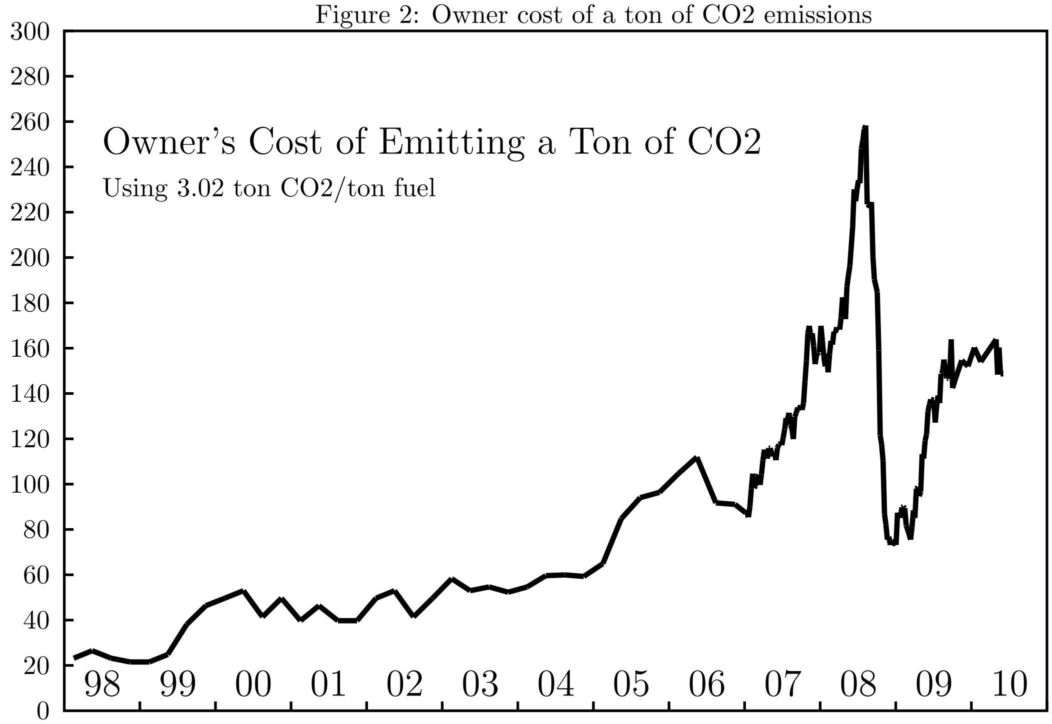
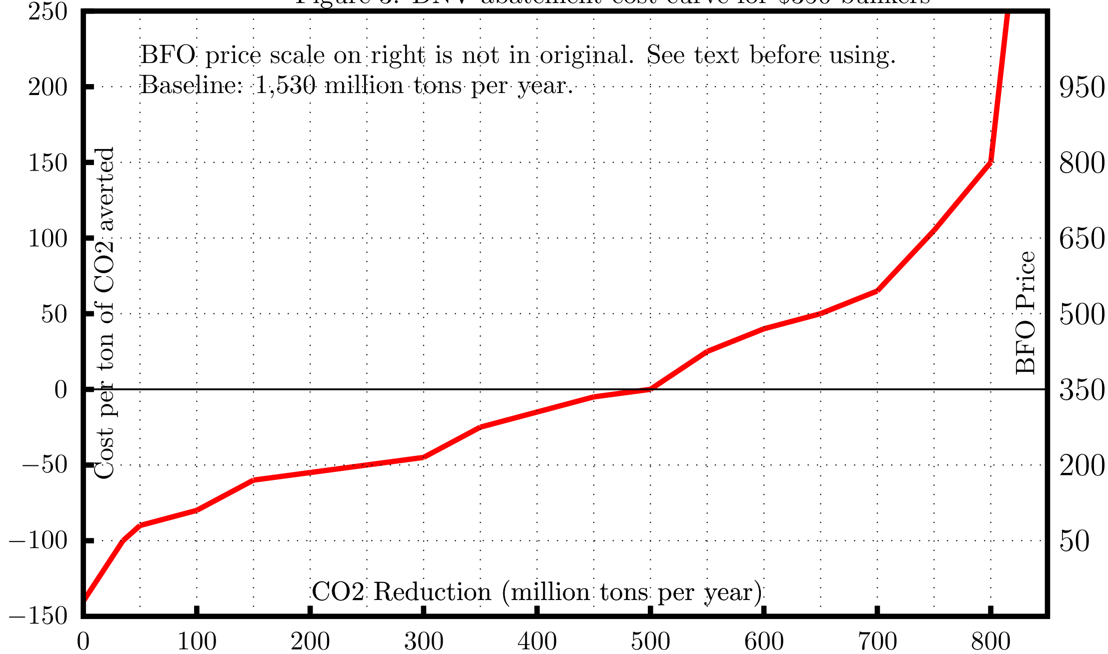


Figure 3: DNV abatement cost curve for $350 bunkers



We can get an idea of the eventual impact of these measures from abatement cost curves. By far the most comprehensive of the abatement cost studies is that by DNV, Pathways to Low Carbon Shipping. I have very roughly reproduced the key DNV results in Figure 3.

The vertical scale on the right showing BFO price is mine. ***It is not in the original DNV study, and must be used with some judgement.*** Assuming semi-incorrectly that fuel carbon content is fixed at say 3.02 ton CO2/ton fuel, as it effectively is for most owners, the net cost to the owner of reducing CO2 emissions by x tons is

$$C(x) - p_{BFO}x/3.02$$

where $C(x)$ is the cost of implementing the measures he chooses to employ. The second term is savings in fuel due to these reductions.

Now suppose society decrees that we will operate at a particular point on the MAC curve, y, either directly by imposing a tax or indirectly via a cap-and-trade.[8] In the long run, all owners will adjust to this by setting their marginal cost to y or

$$y = \frac{\partial C(x)}{\partial x} - \frac{p_{BFO}}{3.02}$$

If and only if the cost of implementing the CO2 reduction measures is independent of bunker prices, then y and p_{BFO} are linearly related, and we get the scale on the right hand side of Figure 3. Note this scale is anchored at a bunker price of $350/ton, not zero.

In reality, the cost of implementing almost any measure will depend on the price of energy and hence be correlated with BFO price. A propeller boss fin will cost more in a $150 per barrel crude world than in a $50 per barrel world. And for some measures, e.g. switching to gas as fuel, the cost of implementing the measure will probably be much more expensive when crude is at $150/bbl than at $50. But for most important measures the assumption of independence is correct to first order and to that extent the right hand side scale is meaningful.[9] Anyway under the assumption of independence and constant fuel carbon content, each $150 increase in fuel price is equivalent to moving the zero abatement

[8] In a world where there is no uncertainty, there is no real difference. In the real world where there are tremendous uncertainties, there is a tremendous difference. With a tax, the owners know the cost they are facing and can react to it with some confidence. With an ETS, the carbon price is both variable and unpredictable.

[9] Of course, if we had the DNV cost model, we could do much better by computing a family of curves, one for each BFO price. The right hand scale would go away. These constant BFO curves would shift rightward as BFO prices increased. It is extremely unfortunate that DNV has not made public the innards of such an important study. Right now the study is unauditable and unreproducable. In strict scientific terms, it is unusable.

And we can't build on it. It appears that DNV left out many possible emissions reduction meansures, including perhaps the most important development of the last five years: the common rail diesel. Prior to cost up \$50 per ton CO2. Whether or not these assumptions are correct, ***every time bunker prices rise the net cost of more abatement measures turns negative***.

According to DNV's numbers, over time a fuel price of \$350/t would result in about a 500 million ton per year reduction in CO2 versus the baseline of 1,530 million tons or about 33% reduction. But currently BFO prices are a lot closer to \$500 per ton than \$350 per ton. According to DNV, if BFO price averages \$500 per ton real over the next 20 years, we will see an 650 million ton per year reduction from the baseline or about 42%.

But the world is running out of cheap oil. There is good reason to believe that the real price of oil (and gas) will increase, quite possibly dramatically, over the next 20 years. Real BFO prices could easily go to \$1000 per ton in that period, possibly more. According to DNV, the cost abatement curve turns sharply upward at about \$150 per ton CO2, which under our somewhat suspect assumptions is about \$800 per ton BFO. Whether this is accurate remains to be seen. The cost abatement curve is surely subject to increasing marginal cost, but the near verticality at about 825 million tons is dubious. If it is true, then it is telling us that once we reduce ship CO2 emissions by about 52%, which will happen automatically if bunkers prices average around \$800, it will be cheaper for society to obtain further reductions from some other sector.

4 A Possible Plan

The post 2005 increase of roughly \$100 per ton CO2 in the owner's cost of emissions due to bunker price increase is much larger than that projected by both bunkers tax proponents and ETS promoters. Discussions at IMO have assumed a tax/carbon price in the range of \$10 to \$30 per ton CO2. Compared with the change in bunker price over the last ten years, this is almost in the noise.

Estimates of the unit social cost of CO2 range from \$7 per ton (Norhaus) to \$85 per ton (Stern). Eide et al after reviewing IPCC projections recommend using a cost of \$50 per ton CO2 in accepting/rejecting reduction measures.[10] This number is primarily based on meeting the Tier I Kyoto levels under the IPCC B1 scenario, which Eide et al estimate will require a 34% reduction in emissions from shipping in 2030. They point out that, under some of the other IPCC scenarios, this break-even level could rise to as high as \$100 per ton CO2.

In short, the post-2005 increase in owner's emissions cost is already at or above the high end estimates of the social cost of CO2 pollution, and the high end estimates of the price required to meet the Kyoto goals. And there is a very good chance real BFO prices will rise sharply in the next decade.

To put it another way, the BAU emissions in the DNV study from which Figure 3 was taken is 1530 million tons per year. So if we do nothing and even if real bunker prices don't rise, we will get at least a 40% reduction in CO2 emissions from shipping, which is in excess of the Kyoto goals.

In short, we have time.

- There is no need to hurridly implement ineffective, unsafe measures such as EEDI, which won't have any real impact on the trading fleet for another ten years.
- We have time to decide on a tax vs ETS.
- We have time to bring a tax or cap-and-trade convention into force.
- Five or so years down the road, we should have a better idea of the social cost of CO2 pollution, and with the convention in place, we can impose a tax (permit price) based on that cost.

5 Postscript: Minor Market Imperfections

As we have argued, recent bunker price increases will almost certainly allow shipping to do its share and more in reducing CO2 emissions, in the period between now and the coming into

the common rail it was effectively impossible to run a low speed diesel below 50% power for long periods. 50% power represents only a 20% reduction in speed. With the common rail, owners can now go down to 20% power and below without difficultly.

There is reason to believe that DNV numbers are conservative with respect to measures with negative abatement costs; but, until we see the model, we can't say.

[10] Eide et al, Cost Effectivness Assessment of CO2 Reducing Measures in Shipping, Mar. Policy & Mgmt, Apr 2009. Of course, the efficient way of doing this is to impose a bunkers tax of \$150 per ton.

force of a tax/ETS convention. However, during that period, there may be a few things we can do to smooth the process. There are three relatively minor, but still important, market imperfections which could noticeably slow the implementation of negative abatement cost reduction measures.

The yards resistance to change. When my company asked the Korean yards for rounded accommodations corners in our VLCC and ULCC newbuilding program in 1999 which we thought were economic with BFO at less than \$100/t, all three major yards refused to even give us a price claiming the corner of the yard where the accommodations blocks were built was not set up to do this.[11] The yards can be particularly intransigent when they are busy, which of course is the time when most ships are ordered.

The owners resistance to change. When I replaced the bridge wings with closed circuit TV on our ULCC's which clearly made economic sense in 1999 with BFO at less than \$100/t and at the same time got rid of two nearly impossible to maintain, vibration ridden hunks of steel, my masters went ballistic threatening hunger strikes, suicide, and the end of the world.[12] After they got used to the TV's, they were bragging to others that it was their idea.

The rules resistance to change Getting rid of the bridge wings violated SOLAS. Replacing lifeboats with liferafts as the primary means of escape would not only result in an increase in safety but reduce air drag as well. But the rules don't allow this. Another example is the bow visibility rules which forces the bridge up as much as 10 m on a big tanker/bulk carrier, yet still leaves an enormous blind spot. Both problems could be solved by intelligent use of TV/radar/infrared.

Perhaps it makes sense to set up some sort of board to hear complaints and prod owners/yards/rule makers when they get in the way of a safe measure that has negative abatement cost. This board could start out with nothing more than a name-and-shame power, and then be given more weapons, if that turns out to be necessary.

[11] It's interesting that truly streamlining the superstructure is still not in the DNV list. See 1960 Greek tankers for how it should be done.

[12] Also not in the DNV list of measures, perhaps because it is illegal.

[15] Japanese Leverage Incentive Scheme (LIS) is EEDI plus a bunkers tax plus funnelling a portion of proceeds back to low EEDI ships. It is saddled with all the EEDI design and safety problems It will induce slow-steaming but with the wrong ships. And to the extent that owners react to the EEDI enducement will generate further inefficiencies. It incurs all the administrative costs of a tax plus much of the adminstrative costs of EEDI trading.

[15] VES is an EEDI based system in which ships above the required EEDI would pay a penalty based on the ratio between the actual and required EEDI and the amount of fuel consumed. Built on EEDI, it is not resource efficient. Like LIS, it must verify both EEDI and bunkers consumed. But unlike SECT does not induce extra miles from low EEDI ships.

[15] Efficiency here is defined to be achieving the emissions reduction with the least cost to society.

Table 1: Main Features of Cap-and-Trade, Carbon Content Bunkers Tax, EEDI Trading

Criterion	Cap-and-Trade	Bunkers Tax[13]	EEDI + Trading(SECT)[14]
CO2 reduction certainty	Yes, but target reduction arbitrary	No, but abatement cost curves give estimate	No, does not attempt to regulate CO2 emissions directly.
CO2 price certainty	Very low	High	Does not put price on CO2.
Reduction cost certainty	No	Yes	No
Inter-period transfer problems	Yes	No	Yes
Efficient[15] amount of slow-steaming	In theory, but carbon price uncertainty, inter-period transfers big problems	Yes, see economics theory on externalities since Pigou	No, incentivizes ***more*** speed from low EEDI ships, might even steam in circles
Efficient amount of newbuilding	In theory, but price uncertainty a big problem	Yes, right amount of slow-steaming means right amount of newbuilding	No, inter alia, ignores building, repair, scrapping emissions
Efficient design features	In theory, but price uncertainty a problem	Yes, any feature whose cost is less than tax will be implemented	No, focus on installed power forces small prop, high SFC.
Ease of adjustment	Hard, existing permit holders affected	Easy, but lose some carbon price certainty	Tricky, might end up with too few credits.
Comprehensive	Only $GRT > x$. End up with two $x-1$ ships instead of one $2x$	No, but practical GRT limit can be lower than ETS x	Low end GRT much higher than ETS x due to EEDI scatter at small size.
Administrative Costs	Must verify bunkers purchases. Must auction permits. Must run permit market. Must collect permits. Likely income transfers from owners to speculators.	Must verify bunker purchases.	Must periodically verify EEDI. Must verify "activity". Must maintain EEDI credit market. Cant gtee enough EEDI credits unless lenient standards.
Opportunity for Fraud	Lots. Owners can end up with permits worth more than ship.	Limited to evasion	Lots, but AIS might help.
Handling proceeds	Assuming tax and carbon price the same, will generate same funds as tax less extra admin costs.	Problems same as ETS. Same opportunities for corruption and waste.	Much easier. Funds stay in sector.
UNFCCC Compliant	By using auction proceeds could be.	By using tax proceeds could be.	No.
Enforcement	Flag state + new bureaucracy	Bunker state	Flag + Class (Owner hires both). Ship's log.
Sync with non-shipping regulation.	Hard. Must get reduction level right. Must handle exchanging permits correctly	Easy. Carbon price for shipping same as carbon price elsewhere.	Impossible, doesn't even try
Safety	Neutral.	Neutral.	Limits installed power. Limits lightweight. No twin screw.