

# Efficient, Safe Reduction of CO2 Emissions from Shipping

Jack Devanney

Center for Tankship Excellence, [djw1@c4tx.org](mailto:djw1@c4tx.org)

Sisyphus Beach

Tavernier, Florida

Version: 2.5

Date: 2010-09-05

In this version, CTX's critique of Energy Efficient Design Index (EEDI) has been moved to its own paper. Please see EEDI: A Case Study in Indirect Regulation of CO2 Pollution.

Copyright © 2010 Center for Tankship Excellence

Permission is granted to copy, distribute this document under the terms of the Gnu Free Documentation License (GFDL), Version 1.2 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the GFDL is available at [www.gnu.org](http://www.gnu.org).

# Contents

<b>1</b>	<b>The Mother of all Market Imperfections</b>	<b>2</b>
<b>2</b>	<b>Taxing Externalities</b>	<b>2</b>
2.1	A Tax is Efficient . . . . .	2
2.2	Slow-steaming and Inter-temporal Efficiency . . . . .	3
2.3	A Bunkers Tax and Newbuildings . . . . .	3
<b>3</b>	<b>Cap and Trade</b>	<b>4</b>
3.1	An Emissions Trading System for Shipping . . . . .	4
3.2	Big problems with inter-period transfers . . . . .	4
3.3	Uncertain Price Signals . . . . .	5
3.4	ETS is not comprehensive . . . . .	6
3.5	Administration costs much higher than a tax . . . . .	6
3.6	The Charterer Issue . . . . .	7
3.7	Enforcement Issues . . . . .	7
3.8	Bottomline . . . . .	8
3.9	Why is Cap and Trade so Popular? . . . . .	8
<b>4</b>	<b>Energy Efficiency Design Index</b>	<b>11</b>
4.1	Very Quick Overview of EEDI . . . . .	11
4.2	EEDI just plain ineffective, at least for VLCC's . . . . .	12
4.3	Market Based Measures render EEDI superfluous and counter-productive . . . . .	13
<b>5</b>	<b>The Ideal Tax System</b>	<b>13</b>
5.1	Conclusions . . . . .	13
5.2	Collect Tax at Point of Production/Importation . . . . .	13
5.3	The Rebate System . . . . .	13
<b>6</b>	<b>Imoland, a new country</b>	<b>14</b>

# 1 The Mother of all Market Imperfections

Mankind's use of the atmosphere as a dumping ground for CO<sub>2</sub> exhausted from the combustion of fossil fuels is a proto-typical case of an externality, using something without paying for the costs of that use. The atmosphere is a *public good*. It's not owned by anyone, and anyone can use it for free. As a result, CO<sub>2</sub> concentrations in the atmosphere are 40% higher than the highest the planet has experienced in at least the last 650,000 years. If we do nothing, these already unprecedented CO<sub>2</sub> levels will probably double by the end of the century.

The price for using the atmosphere to dump CO<sub>2</sub> is zero. But the cost to society of this use is not zero, and may be monstrously large. Unfortunately, nobody knows what the cost is. One can make a plausible case that Nature can handle current and higher CO<sub>2</sub> levels with reasonably mild, possibly even benign, changes. One can make an equally plausible argument that current and projected CO<sub>2</sub> levels will result in truly cataclysmic effects. The truth probably lies somewhere in between.

Given this enormous range of uncertainty, we desperately need insurance. Only the most imprudent would argue for doing nothing. The question is: what form should it take?

For shipping, three main alternatives have been proposed:

1. A carbon based bunkers tax.<sup>1</sup>
2. Cap and trade under the name, Emission Trading System (ETS) for International Shipping.<sup>2</sup>
3. Mandated reduction in installed power, called Energy Efficiency Design Index (EEDI).<sup>3</sup>

The IMO has separated its CO<sub>2</sub> reduction efforts into market based and non-market based (EEDI), and considers the two approaches complementary. This compartmentalization is not only artificial — these are three different ways of doing the same thing — but, as we shall see in Section 4.3, if an effective market based program is enacted, then an EEDI is both unnecessary and counter-productive.

This paper compares these three measures. It argues that the EEDI approach would not only be a horribly inefficient (high resource cost) means of reducing CO<sub>2</sub> emissions, but extremely dangerous in terms of safety and oil pollution. ***EEDI would be a major step in the wrong direction.*** While the ETS alternative is far superior to EEDI, a carbon based bunkers tax would be much more efficient, more effective, more comprehensive, and far easier to administer.

The paper then outlines an ideal carbon tax and what the IMO's role could be in implementing that tax. The paper suggests that the IMO could lead the way toward efficient reduction of CO<sub>2</sub> emissions.

## 2 Taxing Externalities

### 2.1 A Tax is Efficient

Economists have known for at least 100 years that the efficient way to handle externalities is a tax, in this case a tax on CO<sub>2</sub> emissions.<sup>4</sup> A tax on a public good re-establishes market forces. It is *efficient* in that, whatever level of emissions reduction is achieved by a properly administered tax, it will be achieved at least cost to society, that is, with a minimum wastage of resources. Those polluters for which it is costly in resources to cut back will cut back less than those for whom it is cheap to cut back. This will happen automatically without any regulator needing to know the cost of cutting back for the various polluters.

For shipping, there are essentially only two means of reducing CO<sub>2</sub> emissions:

1. In the short-run, slow-steaming.

---

<sup>1</sup> An International Fund for Greenhouse Gas Emissions from Ships, MEPC 60/4/8, 2009-12-18.

<sup>2</sup> A further outline of a Global Emission Trading System (ETS) for International Shipping, MEPC 60/4/22, 2010-01-15.

<sup>3</sup> Interim Guidelines on the Method of Calculation of the Energy Efficiency Design Index for new Ships, MEPC.1/Circ.681, 2009-08-17.

<sup>4</sup> The history of Pigovian taxes is summarized by Krugman, Paul, Building A Green Economy, New York Times, April 10, 2010. Normally, a pollution tax requires a direct measurement of the amount of emissions. But we can only economically monitor CO<sub>2</sub> emissions from large point sources. Fortunately, for CO<sub>2</sub> we have a very close proxy to emissions. Thanks to the fact that it is economic to remove and sequester CO<sub>2</sub> only for very large point sources (if then), the carbon content of the fuel is an excellent measure of the CO<sub>2</sub> emissions from the combustion of that fuel. This allows us to impose the "emissions" tax on the carbon content of the fuel. This applies to cap-and-trade as well.

2. In the long run, building a fleet which produces less CO<sub>2</sub> for a given transport capacity.

Consider how a carbon content bunkers tax, which for the purpose of this paper I will shorten to *bunkers tax*, handles these two measures.

## 2.2 Slow-steaming and Inter-temporal Efficiency

The cost of reducing emissions varies not only from polluter to polluter, but with time. In a cold winter or a period of high economic activity the cost of reducing emissions is higher than in a mild winter or slack times. Bulk transport offers an extreme example of this.

In the short run, by far the single most important emissions reduction measure in shipping is *slow-steaming*. Fuel consumption goes as something more than the cube of speed. Amount transported per period is roughly linear in speed. Thus, by reducing steaming speed ship owners can reduce emissions drastically per ton delivered. The issue is: what is the efficient level of slow-steaming?

The answer is: it depends on the market. When ships are scarce, the cost to society of reducing steaming speed is much higher than when ships are in surplus. This shows up most dramatically in the bulk markets. The tanker and dry bulk markets are examples of nearly textbook competition. These markets cycle between boom and bust. In boom, when ships are scarce the value of a marginal ton-mile to society is an order of magnitude or more higher than in slumps when ships are in surplus, and this is reflected in the spot rate. To be efficient, tanker and bulk carrier owners and charterers should reduce speed far more in a slump than in a boom.<sup>5</sup> The same thing is true, a little less dramatically, for container ships.<sup>6</sup>

With a bunkers tax, this will happen automatically.

## 2.3 A Bunkers Tax and Newbuildings

A tax filters through the system automatically sending the right signals at every level. Recently, the Japanese shipyards attempted to argue that very lightly built ships were an environmental good since they carried more cargo than a robust ship and thus less CO<sub>2</sub> would be produced for the same amount of cargo moved. Supporters of robust ships had to counter with a complicated analysis of the CO<sub>2</sub> generated by repair intensive, shorter lived versus longer lived ships.<sup>7</sup> This analysis tried to go back to the CO<sub>2</sub> produced not only by the newbuilding yard, but the steel mill as well. At this point, they stopped. They did not include CO<sub>2</sub> produced by the mining process, nor indirectly in any of these activities (eg CO<sub>2</sub> produced by yard workers commuting to work). If a bunkers tax, roughly representative of the societal cost of CO<sub>2</sub> emissions, had been in place, all such analyses become unnecessary.

Consider how a bunkers tax will effect newbuildings. Overall, a bunkers tax will slow the fleet down. This slow down will increase spot rates. In the bulk markets, the increase can be quite dramatic. Devanney argues that the 2004 tanker boom was almost entirely the result of bunker price increases.<sup>8</sup> These higher rates in turn will engender newbuilding. With a bunkers tax, the owners of these newbuildings know that they will be facing higher bunker prices. Thus, they will optimize their ships against a higher fuel price. It will pay them to install those fuel saving devices that are economic at the higher price, and not install those that are not. In some cases, such as LNG carriers, it may pay them to switch to a less carbon intensive fuel. In all cases, it will pay them to run their engines closer to the minimum Specific Fuel Consumption (SFC) point, which is about 70% of the Maximum Continuous Rating.<sup>9</sup> To do this, they will have to **increase** installed power for a given design speed.

---

<sup>5</sup> Perhaps surprisingly, oil/steel company owned or chartered in ships will operate at the same speed as spot ships in a given spot rate/bunker price situation. See The Impact of Bunker Prices on VLCC Rates

<sup>6</sup> With the demise of the conference system, there is little difference between a liner company's slow steaming decisions and an oil company's. In late 2008/early 2009, the spot box rate, Asia to Europe, dropped from around \$2000/TEU to near zero. Containership owners scrambled to install slow-steaming enhancements. If anything slow-steaming is more important for box ships than it is for tankers and bulk carriers given the much higher design speeds. Cariou estimates that since 2008 slow-steaming has reduced worldwide containership emissions by 17%. See The impact of speed reduction on liner CO<sub>2</sub> emissions

<sup>7</sup> Gratsos et al, "Life Cycle CO<sub>2</sub> Emissions of Bulk Carriers: A Comparative Study".

<sup>8</sup> Devanney, The Impact of Bunker Prices on VLCC Spot Rates, CTX, 2009.

<sup>9</sup> A important by-product of operating closer to the minimum SFC point will be an improvement in main engine reliability. Today's engines are very aggressively rated. At Max Continuous Rating (MCR), all the design margins have been pared down to the minimum. As a result, the failure rate is high. CTX estimates that the tanker fleet above 10,000 dwt is experiencing at least 10 complete losses of power per day. Operating at lower piston pressures and slightly lower temperatures should increase the Mean Time

The design speed will drop with increase in expected fuel cost, but the installed power will increase for a given design speed. Table 1 shows an actual example based on an 82,000 dwt bulkcarrier.<sup>10</sup>

Table 1: High powered vs Low powered Kamsarmax Bulk Carrier

	Low powered ship	High Powered ship
Main Engine	MAN 6S50 ME	MAN 6S60 MC
Installed power	10,680 KW @ 117 RPM	14,280 @ 105 RPM
Power at 14.5 kts	9,610 KW @ 113 RPM	9,050 @ 88 RPM
Full load speed	14.5 knots	14.5 knots
Consumption	38.4 TPD	35.0 TPD

The bigger engine can turn a larger propeller at lower RPM which improves propeller efficiency. That's the reason the ship on the right requires less power to do 14.5 knots than the ship on the left.

In the long run, the fleet will operate at a lower **average** speed due to the increased bunker costs, which means a larger fleet overall than without the tax.

All this happens automatically and at the efficient level with a bunkers tax.

## 3 Cap and Trade

### 3.1 An Emissions Trading System for Shipping

Despite the fact that there are no serious arguments against the efficiency of a pollution tax, it has not found favor politically. The main alternative is cap-and-trade. Like a tax, cap-and-trade attempts to put a price on pollution. In its purest form, some governmental body decrees how much pollution is going to be allowed in a particular time period. The rights to this amount of pollution are then auctioned off in the form of permits. In the CO<sub>2</sub> case, each permit gives the holder the right to emit a ton of carbon dioxide into the atmosphere. The permits are tradable and a market is established for executing these trades. The price established in this market is the signal to which all polluters will react in the same way they react to the tax. If the price is higher than the cost to the individual polluter of reduction, than that polluter will reduce his emissions rather than buy/use permits. If the price is lower than the cost to the polluter of reducing emissions, he will buy/use permits rather than reduce. At the end of the period, each polluter must surrender permits equal to his emissions to the governmental body.

The Emissions Trading System (ETS) proposed by Norway and others in MEPC 60/4/22 is a fairly stock example of a cap-and-trade system. But unlike any real world CO<sub>2</sub> cap-and-trade it would be fully auctioned.

In a static world with no uncertainty and forgetting about administrative costs and enforcement issues, it is theoretically possible to come up with a cap-and-trade system that approaches a tax in efficiency:

1. The system would have to allow inter-period transfers in an efficient manner.
  2. The system would have to be comprehensive, apply to all polluters.
  3. The permits must be bought and traded in a fully informed, honest market. No insider trading, no 'asymmetrical' information.
  4. The system would have to be administered as cheaply and as effectively as a tax.
- Merely listing the requirements shows the impossibility of meeting them.

### 3.2 Big problems with inter-period transfers

The real world is not static and it is rife with uncertainty. As we saw in Section 2.2 the cost to society of achieving a particular level of level of reduction varies sharply between periods of economic boom and slump. In a pure cap-and-trade system, this shows up in a fluctuating carbon price to maintain the mandated level of pollution. But the cost to

---

Between Failures markedly.

<sup>10</sup> Source: NTUA Laboratory for Maritime Transport.

society of a ton of CO2 in the atmosphere does not depend on the current level of economic activity. ***This means a fixed pollution level, cap-and-trade system cannot be resource efficient.***<sup>11</sup> This is critically important in highly cyclic industries such as ocean transportation. The solution is to allow inter-period transfers of permits.

A cap-and-trade system regulates by period. In the case of the Norwegian ETS the period is a year. Given that slow-steaming is the overwhelmingly important factor in the amount of ship emissions in the short-run, and the boom and bust nature of at least bulk shipping, any cap-and-trade system that does not correctly handle inter-period transfers of permits would be hopelessly inefficient. We'd have too much reduction in booms and far too little in slumps.

But for cap-and-trade, inter-period transfers are a problem. The best solution is *banking*, that is allowing permits purchased in the current period to be used in any period in the future.<sup>12</sup> If polluters expect the price of the permits to rise, they will purchase permits now and not surrender them at the end of the period. This will end up with more than the target reduction in the current period and less than the target in the future. The problem is that, for this to be efficient, the permit buyers have to out-guess the market; they have to be able to correctly predict what the market is going to do. Anyone who claims he can accurately predict the tanker or dry-bulk or spot container market is either a fool or a charlatan.

If the market unexpectedly (is there any other way?) goes into boom, the price of the permits will sky-rocket. In such a situation, the efficient solution would have ships producing more than the target reduction shifting the reductions elsewhere in the economy where for the moment the cost of reduction is far cheaper. Thus, an efficient ETS system must allow permits to be bought and sold across other ETS markets. In a boom, ship owners would find say EU ETS permits cheaper than shipping permits, and buy and surrender those rather than the shipping ETS. MEPC 60/4/22 proposes to allow this, but does not say how. At a minimum, this will generate a host of coordination, administration, and enforcement issues. When questioned at a recent IMO meeting, the promoters of ETS admitted they don't know how the cross-market transfers will be done.

Contrast this mess with a tax system in which the efficient slow-steaming response is completely automatic, without anyone having to predict the market. I can't over-emphasize how important this is. ***Any regulation system for CO2 emissions from shipping that does not get slow-steaming right will be hopelessly inefficient.***

### 3.3 Uncertain Price Signals

The whole point of both a bunkers tax and an ETS is to put a price on pollution, and then let shipowners react to that price. With a tax, an owner can be reasonably certain about the future pollution price; it's simply whatever the tax is. With cap-and-trade, he must predict the future price of permits through time. If he could do that, he would make a lot more money trading carbon than ship owning.

The uncertainty about future prices engendered by an ETS system relative to a bunkers tax can be a real problem especially with long lived investments such as ships. Investors tend to invest less money when they are uncertain about future prices than when they are confident about the prices they are facing. If IMO were to commit to a bunkers tax schedule, shipowners could be reasonably confident that their investments in carbon emissions reducing measures will be profitable. If IMO commits to an ETS, there will be all sorts of uncertainty about the future permit price, and shipowners, a conservative lot, will be slow to bet on high carbon prices. Current Emissions Trading Systems have engendered little investment in emissions reduction. One important reason is carbon price uncertainty. The draft Senate bill, the American Power Act, admits as much by imposing both a ceiling and a floor on permit price and then extolling the resulting "price certainty".

Proponents of cap-and-trade often make much of the "emissions reduction certainty" of an ETS (see below); but the flip side of that is pollution price uncertainty. Investors/operators react to price, not cap.

---

<sup>11</sup> A fundamental principle of efficient regulation of pollution is the polluter's price must be equal to the marginal social cost of his pollution.

<sup>12</sup> MEPC 60/4/22 sort of acknowledges this problem by allowing one period banking of permits,

### 3.4 ETS is not comprehensive

A real world cap-and-trade system cannot be as comprehensive as a tax system. All the existing cap-and-trade systems by necessity focus on the big, single point polluters. The problem is that the bulk of the planet's CO2 emissions is caused by little polluters. For example, the Waxman-Markey Bill goes after power plants and "energy intensive" industries. When you do the numbers, you find out that something like 60% of US emissions are outside the system. This generates an enormous inefficiency in which individually small polluters have no incentive to cut back.

The reason the individually small polluters are left out of cap-and-trade systems is the cost of administering cap-and-trade to these sources is prohibitive. MEPC 60/4/22 acknowledges this by proposing a lower limit on GRT. The actual lower limit is left blank. If this number is zero, then the system can't be administered. If the GRT number is large enough to get the ships down to a manageable number, then a very large number of polluters is left out of the system. The Norwegian Ministry of the Environment, an ardent ETS supporter, estimates that, if the low end GRT is 2,000 GRT, then the system will cover 30,000 ships and polluters representing 20% of the emissions will have no incentive to cut back. See Table 3.4. This is for international shipping only.

Table 2: % of International CO2 Emissions Covered as a function of low end GRT

GRT	Num ships	% coverage
400	60,000	91%
500	45,000	87%
2,000	30,000	80%
10,000	16,000	67%

And we can expect to see a great deal of magical GRT reduction in ships near the limit. If the low end GRT is say 2000 tons, then the number of 1999 GRT ships will skyrocket. This generates yet another inefficiency, as we will find two 1999 GRT ships doing what one 4000 GRT ship could at more cost and more emissions. For instructive examples of how far owners will go to to evade GRT limits, see Allen, *The Influence of Government Regulations on Vessel Efficiency*, 2009.

MEPC 60/4/22 applies only to international voyages. Domestic shipping is outside the system. According to the Norwegian Ministry of the Environment, domestic shipping and fishing emissions are about 22% that of international. Not only does this exemption leave these emissions unregulated, but it will generate reactionary inefficiencies and a host of enforcement problems. There will be an inefficient shift from international trade to domestic. Then there is a question of: what is an international voyage? Is a feeder container ship on an international voyage as it moves down the Malaysian coast picking up and dropping off containers? Does the whole voyage become an international voyage if the ship touches at Singapore? If so, all sorts of costly inefficiencies will be generated by ships avoiding "international" voyages. One way of doing this will be transshipping cargo to another ship as close as possible to the international destination. If only the "international leg" is an international voyage, then not only are we leaving out a great deal more pollution, but also we will see inefficient extra port calls whose only purpose is to shorten the international leg.

And then we have special interest exemptions which always seem to crop up in cap-and-trade systems. MEPC 60/4/22 explicitly allows for such exemptions: including "government" vessels, naval vessels, ships "usually" domestic, etc. Not only do these exemptions fly in the face of resource efficiency, they will be impossible to monitor. And they open the door for all sorts of additional exemptions. Perhaps the most debilitating exemption proposed by MEPC 60/4/22 is the exemption for trade to "small island developing states". Such an exemption would quickly produce large transshipment hubs on the exempted islands.

### 3.5 Administration costs much higher than a tax

MEPC 60/4/22 argues that there is little if any difference in administrative cost between a bunkers tax and the suggested cap-and-trade system. Even if the bunkers tax were collected at the ship level, this is not true. A bunkers tax collected at the ship level would have to

track bunker purchases and check that they matched what the ship claimed. But a cap-and-trade system has to do this **and much more**.<sup>13</sup> An ETS also has to check that the permits purchased matches the bunkers consumed, and determine how much of the voyage was international, and that the permits offered are real and not fraudulent. It will have to chase down any ship owner that does not come up with the right amount of permits (see below). It has to run an annual permit auction. It has to maintain a fair and honest, fraud-free market in the permits.<sup>14</sup> And it has to somehow coordinate with all the other ETS markets to ensure that any non-ship permits proffered are legit.<sup>15</sup>

### 3.6 The Charterer Issue

An administration problem specific to shipping is the bareboat or term charterer question. While a ship is on bareboat or term charter, the charterer is the effective owner as far as CO2 is concerned. He decides where the ship goes and at what speed. Legally, he is the *disponent* owner. This is recognized in the charter party which puts fuel expense to the charterer's account. If an ETS is going to impact the charterers' speed decision, it has to do the same. This means a shipping ETS not only has to do all of the above; but it also has to keep track of whether or not the ship was on charter and, if so, who the charterer was when the fuel was purchased.<sup>16</sup> And it gets worse. A chartered ship can be sub-chartered, and so on. Finally, when the ship goes on charter, the real owner sells the fuel on-board to the charterer and buys the fuel remaining on board at the end of the charter. The link between fuel purchaser and fuel consumer becomes very difficult to track down.

An ETS could simply ignore the ship's charter status and require permits from the owner for all the oil consumed on his ship regardless, looking to the owner to recover the permit cost from the charterer. This would put the owner in the untenable position of being responsible for emissions from bunkers which aren't his, and permit expenses over which he has no control, and which in many cases aren't known until well after the charter is complete. The choice is either a legal fiasco or an administrative mess.

All this is a non-issue for a tax system. A tax system could care less who purchases the fuel or how it changes hands on-board.

### 3.7 Enforcement Issues

In the ship focused, ETS proposed by MEPC 60/4/22, the prime enforcer is the flag state. Most of the largest flag states are known more for their marketing prowess than enforcement. The EU and Australia have not been able to enforce a workable cap-and-trade. MEPC 60/4/22 relies mainly on flags of convenience to enforce this complex system. Many of these countries can't even administer their own registry programs, hiring third parties to do the job. The prime enforcer of a bunkers tax is the country where the ship bunkers. However, I will refrain from comparing the Liberia's of the world with the Singapore's and just point out another massive enforcement hole in the proposed system.

MEPC 60/4/22 suggests each ship's permits will be surrendered annually. Think about that. A VLCC will burn about 100 tons of fuel per day. According to a recent Cambridge study,<sup>17</sup> the ship emissions price could easily go to \$3000 per ton of fuel. This means that

---

<sup>13</sup> By the way, MEPC 60/4/22's suggested checking method, comparing the ship's bunker claims with its steaming pattern is totally unworkable. Given the importance of slow-steaming and weather, you would need to track not only the miles traveled, but the ship's steaming speed and the ship's local weather on something like a daily basis. Lying about the weather is already an art on time chartered ships. A much more sensible approach would be to compare the ship's claimed bunker receipts with bunker supplier numbers, and then check the bunker supplier numbers with refiner/distributor numbers.

<sup>14</sup> For something as ethereal as carbon permits, this is a daunting task, as the EU has discovered. Europol estimates that the carbon permit carousel fraud has cost European tax payers at least 5 billion euros so far. Another problem is the totally inelastic nature of the permit supply. Not only will this produce a great deal of price volatility in general but it sets up an almost automatic bear squeeze. As the permit surrender date approaches, some polluters will be caught short. Canny market operators will be sitting on their permits. The price will skyrocket, and the unfortunate polluter — probably a small guy — will lose his shirt. This is quite different from real commodities markets where anyone who is short the future has the alternative of delivering the physical commodity.

<sup>15</sup> If the world were to adopt a carbon tax, MEPC 60/4/22's tax system is a straw man. The best way to enforce a tax is to collect it as far upstream as possible. Ideally this is at the point of production or importation. If this is done properly a self-enforcing mechanism is set up in which there is no way bunker supplier and ship owner can profitably collude. This is outlined in Sections 5 and 6.

<sup>16</sup> The CTX thanks George Gratsos for pointing out this issue.

<sup>17</sup> University of Cambridge et al, International Shipping and Market Based Instruments 2009.

the owner of a VLCC would need to surrender 90 million dollars worth of permits. An elderly VLCC might have a market value of 15 million, a lot less in a slump. Do the authors of this document really believe they are going to get the owner to surrender this money by sending him a bill?

More basically, any system that puts a massive amount of the public's money in the hands of private individuals spread all around the world, and expects to collect all that money easily is deluded.

In a tax system, the polluter pays up front.

### 3.8 Bottomline

In the real world, a cap-and-trade system that is any where near as efficient, as effective, as comprehensive, as feasible to administer and enforce as a tax system is simply impossible.

There has been only one clearly successful attempt at reducing CO2 emissions. Sweden imposed a carbon tax in 1991. It since has risen in fits and starts to about \$150/ton CO2. Figure 1 shows Swedish real GDP and GHG emissions for the period 1990 thru 2007. After about a 4 to 5 year lag, GDP and GHG went in opposite directions. In 2007, Sweden emitted about 8% less GHG than in 1990 with a 44% higher GDP.

There are reasons to believe other countries could do still better.

1. The Swedish carbon tax is far from perfect. In fact, it's a bit of a hodgepodge, in part because the Swedes were hamstrung by the EU ETS. Major polluting industries are exempted or pay only 50% of the tax.
2. There has been some vacillation in the implementation. At one point, some big polluters only had to pay 25% of the tax.
3. Sweden started out with a much lower carbon intensity than most countries. Almost all electric power was nuclear or hydro. There was little use of coal anywhere in the economy. For Sweden, there was very little low hanging fruit.

### 3.9 Why is Cap and Trade so Popular?

The obvious question then is: why would anybody favor cap-and-trade over a tax system. There are four basic reasons for the political popularity of cap-and-trade:

**Efficiency is not a priority** Politicians as a whole could care less about efficient allocation of resources. Politicians rarely worry about the cost to society of whatever they are proposing. The fact that one emissions reductions scheme costs society three or four times as much as another for the same level reduction is simply not an important factor in their thinking. The important thing is to get something done, take credit for it, and get re-elected. In 2008, the Congressional Budget Office suggested that the cost of a USA cap system would be "roughly 5 times" that of a tax system.<sup>18</sup> The US Congress ignored their own analysts and passed the Waxman-Markey cap-and-trade bill.

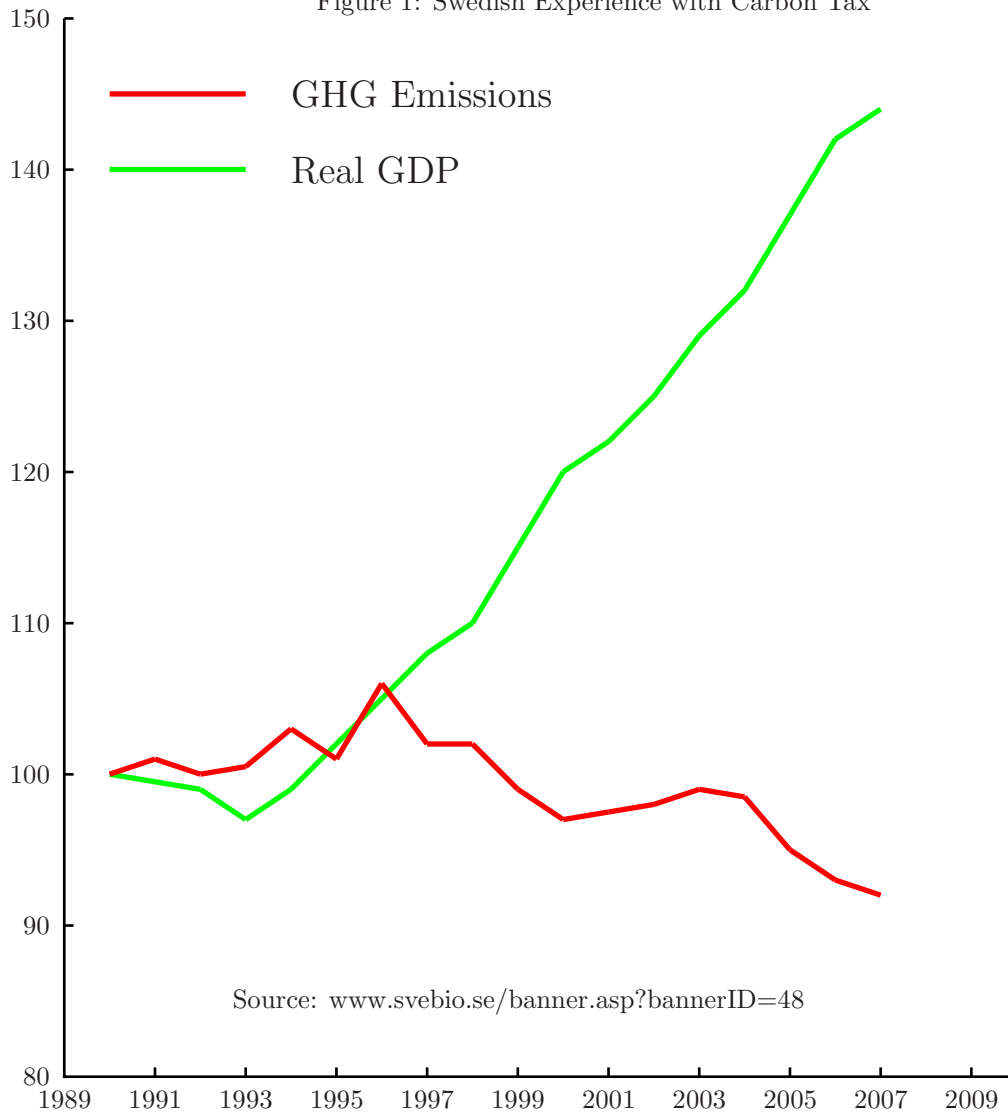
**Permit allocation offers opportunities to buy votes and trade favors** All CO2 cap-and-trade systems start out as an auction system, but to my knowledge pure auctioning has never survived. Waxman-Markey started off with a 100% auction. By the time it got out of committee, this was down to 57%. By the time it passed the House, only 15% would be auctioned. This 15% would had to have been further reduced to pass the Senate. For EU ETS Phase I, 21 member states ended up giving away all their allowances.<sup>19</sup> In the real world, the quotas awards are based on a huge surge of lobbying. The larger the polluter the more money he can afford to spend. An allocation of permits is a windfall for the permittee, found money stolen from the public. He can easily afford to give back a bit of this to lobbyists and incumbent campaign funds. Cap-and-trade ends up enriching some of the slimiest creeps on the planet while ensuring suborned incumbents will stay in office indefinitely. No wonder politicians love cap-and-trade.

**Promoters expect to benefit** In the case of the shipping ETS, playing games with permit allocation has not been an issue so far. But behind the scenes, the classification

<sup>18</sup> CBO, Policy Options for Reducing CO2 emissions, February, 2008, page ix.

<sup>19</sup> Some European power producers promptly passed on the "cost" of these permits to their consumers.

Figure 1: Swedish Experience with Carbon Tax



societies, IMO employees, and flag state registry services have been actively promoting ETS. ETS will require all sorts of audits and inspections and checks. The classification societies and related regulatory bodies see this as an immense expansion in their business, as it indeed will be. Some of the classification societies are already in the carbon auditing business. In fact, DNV has already been suspended by the EU as a carbon auditor for irregularities. All the usual regulatee-picks-and-pays-regulator problems will emerge in this system.

**Precise Emissions Reduction** With cap-and-trade, the benefit is out front and the cost is hidden. A cap-and-trade system can claim to guarantee a specific level of reduction while a tax based system cannot. With a cap-and-trade system, the headline is “ETS will reduce carbon emissions 23.5%”. Nobody knows what the costs will be, and they often go unmentioned. MEPC 60/4/22 calls this *precise emissions reduction* although in fact there is nothing precise about it.

A tax system is just the opposite. The cost is out front and the benefits opaque. Everybody knows what a tax is, and it is not nice. If the tax is \$50 per ton CO<sub>2</sub>, it is quite obvious that somebody will have to pay this, and that that somebody will attempt to pass this cost on to everybody else. And we can’t even say what the benefit will be.

Human nature being what it is the only thing we can do about the first two factors is hold our elected representatives accountable for their malfeasance. In short, vote the bastards out. A distressing feature of the Norwegian shipping ETS is that there is essentially no relationship between the people who will vote the system in and the people who will pay the cost: the planet’s producers and consumers. The shipping ETS will be voted on by IMO rules. Under IMO rules, the voting is by flag state, with each flag state’s voting power based on the size of its fleet. In other words, the people who vote the system in will be predominately flag of convenience politicians: Panamanians, Liberians, Marshall Islanders, etc, some elected, some not. In either case, they are totally out of the control of the people who will pay for the inefficiencies.

There are three points to be made about “precise emissions reduction”.

1. ***The quid pro quo for emissions reduction certainty is pollution price uncertainty.*** Investors/operators react to price, not cap. See Section 3.3.
2. ***There is no value in being precise if you pick the wrong target reduction.***

The correct level of reduction is the level at which the costs of further reduction are larger than the benefits of that additional reduction. Unfortunately, no one knows what that level is.

We don’t have a model of the earth’s climate that even qualitatively replicates past CO<sub>2</sub> spikes. We are not sure how much of the earth’s current warming is due to man-made CO<sub>2</sub>. We don’t know why the warming has flattened out for the last ten years. Thanks in part to some politicized data massaging, we are not even sure exactly how much warming has taken place.

We have almost no idea of what the impact of an x% reduction in man-made CO<sub>2</sub> emissions would be on the climate. Even if we knew all these things, we have only the foggiest idea of what the value of the resulting externalities are. We can’t even be positive of the net direction. In the 1970’s, the alarmists argued that cooling was bad. In the 1980’s, warming became bad. Apparently, the optimal temperature for mankind was achieved for a short period in the late 1960’s.

We don’t know the costs of cutting back CO<sub>2</sub> emissions nor how they are distributed among the multitude of polluters.

The only thing we can be sure of is that, whatever the values of all these unknowns are, they will be different tomorrow.

In short, picking the correct target reduction is impossible. In fact, MEPC 60/4/22 despite lauding “precise emission control” explicitly declines to even suggest a number. Given all our uncertainties, whether we start with a guess at the right level of tax or a guess at the right level of emissions reduction, it is a stab in the dark. Either way all we can do is try to pick something semi-reasonable, see what happens, and then adjust.<sup>20</sup> And a tax is much easier to change after we decide we’ve been too aggressive or not aggressive enough.

---

<sup>20</sup> Actually, a tax handles one important source of uncertainty efficiently while cap-and-trade does not. If the cost of cutting back is more than expected when the target reduction was set, then we should cut back

3. **For shipping we do have a rough idea of the relationship between a tax and the level of emission reduction.** DNV in a series of impressive studies called Pathways to Low Carbon Shipping has produced a set of *Marginal abatement cost curves (MACC)*, which relate the price of a ton of CO<sub>2</sub> averted to the amount of emissions reduction which take place at that price.<sup>21</sup> The outlook is long-run. The curves do not handle short-run slow-steaming which in any event will (or at least should) bounce around with the spot markets. However, with CO<sub>2</sub> the long-run is the key. Anyone can go into DNV's Marginal Abatement Cost Curves with a long-run target reduction, and get a pretty good idea of the corresponding CO<sub>2</sub> tax rate. For example, if you like the idea of a 40% reduction in CO<sub>2</sub> emissions by 2030, DNV estimates you will need to price CO<sub>2</sub> into the atmosphere at about \$60 per ton CO<sub>2</sub> or roughly \$180 per ton fuel for an average IFO 380 bunker fuel oil. With shipping, when we make our first stab on a tax, we do have an idea of the amount of reduction we can expect in the long run.

The reasons why cap-and-trade is politically popular are, to put it politely, not edifying. In fact, they are arguments for everybody other than special interests, lobbyists, auditors, and election obsessed politicians favoring a tax system over an ETS.

As the problems with the cap-and-trade have become clear, more and more people, spanning the political spectrum, have become carbon tax supporters. Initially, carbon tax supporters were mainly right leaning economists. But now they have been joined by not only a range of liberal economists such as Joseph Stiglitz, but also out and out environmental activists such as Al Gore and Dr. James Hansen, the man who originally raised the global warming alarm.<sup>22</sup>

Those on the alarmist side aren't that worried about the inefficiencies associated with cap-and-trade. Mainly, they have become convinced it is ineffective. Dr. James Lovelock, inventor of the Gaia Hypothesis, perhaps best expresses this frustration: "Most of the green stuff is verging on a gigantic scam. Carbon trading with its huge government subsidies, is just what finance and industry wanted. It is not going to do a damn thing about climate change, but it will make a lot of money for a lot of people, and postpone the moment of reckoning."

## 4 Energy Efficiency Design Index

### 4.1 Very Quick Overview of EEDI

For reasons which have nothing to do with resource efficiency and everything to do with bureaucratic inefficiency, the IMO has decided to compartmentalize its CO<sub>2</sub> reduction efforts into

1. Market based instruments
2. Non-market based instruments

The former has correctly focused on bunkers tax vs cap-and-trade. The latter has come up with something called the *Energy Efficiency Design Index (EEDI)*. EEDI is such a convoluted concept that it cannot be explained in a few paragraphs. CTX's own 20 page critique of EEDI can be found at [EEDI: A Case Study in Indirect Regulation of CO<sub>2</sub> Pollution](#). We urge anyone truly interested in ship safety and the environment to check out this document.

Here's a brief summary;

1. EEDI does not attempt to regulate CO<sub>2</sub> emissions directly. EEDI at its core is a mandated reduction in installed power.
2. EEDI will not result in a cost efficient reduction of emissions. Some low carbon intensity ships for which it is very costly to cut back further will be forced to cut back further. Some high carbon intensity ships for which it is cheap to reduce emissions will be forced to do little or nothing. The societal cost of reducing emissions shows up no where in the EEDI calculus.
3. It is not clear how much CO<sub>2</sub> reduction EEDI will result in. What is clear is that EEDI will result in ships that have **increased** CO<sub>2</sub> emissions at any given speed. See

---

less than the target. If the cost of cutting back is less than expected when the target reduction was set, then we should cut back more than the target. With a tax this happens automatically, with cap-and-trade it does not. Slow-steaming in a fluctuating market is a special case of this.

<sup>21</sup> Det Norske Veritas, Pathways to Low Carbon Shipping, 2009-12-15.

<sup>22</sup> Yarra Valley Action Group site has a long list of quotes.

Table 1. The ship on the left has a much “better” EEDI than the ship on the right. It also has 10% higher fuel consumption.

4. EEDI offers no incentive to slow-steam.
5. EEDI will not cover ships less than about 5000 GRT.
6. Despite effectively mandating more, shorter-lived ships, EEDI ignores Build/Repair/Scrap emissions
7. EEDI will mandate low quality, dangerous ships. EEDI will effectively prevent prudent owners from specing more than Class minimum steel, or more than than Class minimum generator power. It will force owners to reduce installed power thereby guaranteeing that already aggressively rated, unreliable engines will be pushed even harder.
8. EEDI will effectively outlaw twin screw.
9. EEDI will get rid of all the good owners. EEDI will either
  - a. force the good owners out of the industry, or
  - b. force the good owners to build under-powered, Class minimum ships. Any owner who builds such a ship is a bad owner.

There are several proposals to extend the EEDI concept to the operating life of the ships. Being built on EEDI, they cannot be resource efficient. In some cases, they set up perverse incentives. Please see EEDI: A Case Study in the Indirect Regulation of CO<sub>2</sub> Pollution, Sections 4 and 5. The principle features of one such proposal, Ship Efficiency Credit Trading (SECT) are outlined in Table 3.

## 4.2 EEDI just plain ineffective, at least for VLCC’s

Since the above sub-section was written, CTX undertook a study on how EEDI would impact the design of Very Large Crude Carriers (VLCC’s), and the resulting effect of CO<sub>2</sub> emissions from these large tankers.<sup>23</sup> The study concluded:

Our figures indicate that, under reasonable assumptions, ***the imposition of EEDI will result in slight increase in VLCC operational CO<sub>2</sub> emissions***, while imposing a heavy burden on society in market cost and safety. Even under an unrealistically optimistic set of assumptions, the Phase 2 CO<sub>2</sub> reduction is less than 3%.

Why is EEDI is so ineffective in reducing VLCC CO<sub>2</sub> emissions?

The answer is two fold:

1. EEDI does not limit CO<sub>2</sub> emissions. EEDI limits installed power. But at current and expected bunker prices, a non-EEDI VLCC owner/term charterer uses all his installed power only in a full boom, or about 10% of the ship’s life. So for the great bulk of her life, a non-EEDI ship uses little or no more power than an EEDI compliant ship
2. In limiting installed power, EEDI induces owners to use smaller bore, higher RPM engines which means that the EEDI-compliant VLCC will consume more fuel than the non-EEDI ship when the market is not in boom, which is most of the time.

In contrast, we find that VLCC owners will respond to a \$50 per ton CO<sub>2</sub> bunkers tax by reducing speed in all but booms and thereby reducing VLCC CO<sub>2</sub> emissions by about 7% over a market cycle. Unlike EEDI, a tax (or an equivalently priced cap-and-trade) will apply to all VLCC’s, including those already trading.

There is good reason to believe that the same analyzes applied to smaller tankers and bulk carriers will arrive at very similar conclusions. With the demise of the conference system, the same thing is true of containerships, with the important caveat that liner owners will be limited to a discrete set of slow steaming speeds if they wish to main schedule frequency. Certainly, such analyzes should be performed before a final decision is made on EEDI.

CTX urges anybody truly interested in shipborne CO<sub>2</sub> emissions to check out this study, and draw your own conclusions.

---

<sup>23</sup> The Impact of EEDI on VLCC Design and CO<sub>2</sub> Emissions

### 4.3 Market Based Measures render EEDI superfluous and counter-productive

If we adopt a market based emissions reduction program, then design constraints such as EEDI are both unnecessary and counter-productive. Once we have internalized the cost to society of emitting CO<sub>2</sub> by imposing a bunkers tax (or an equivalently priced cap-and-trade), our job is to sit back and let the market go to work. Mandatory design features that happen to be efficient will have no effect since the shipowners will adopt them automatically. Any inefficient design features won't be adopted which is exactly what we want.

In particular, forcing shipowners to install less power than they otherwise would is about as counter-productive as you can get. It will increase fuel consumption at whatever speeds they actually operate at while at the same time reducing already unsafe power plant reliability.

## 5 The Ideal Tax System

### 5.1 Conclusions

Table 3 shows an overall comparison of the three alternatives. The tax vs ETS vs EEDI conclusions are no-brainers.

1. EEDI and any other mandated design rules should be scrapped in favor of a market based instrument. There is no fixing such an unsafe, misguided approach, however well-intentioned.
2. By far the most attractive market based measure is a bunkers tax based on carbon content.

The only open question should be: exactly what form should this tax take?

Anything that the IMO does needs to be synched with the rest of the world. So before we talk about the IMO specifically, we need to step back and ask ourselves what would an ideal carbon tax look like for the world as whole. And then see how the IMO fits into that system. Surprisingly, we will find that the IMO need not wait for the rest of world before acting on its own.

### 5.2 Collect Tax at Point of Production/Importation

In the ideal system, each country's tax would be collected as far upstream as possible. For domestic production, this will be at the well-head or the mine mouth. For imports, it will be at the point of entry. The tax would be charged on the carbon content of **all** fossil fuel produced/imported without exception. This is sometimes called a Hansen fee, after one its foremost proponents.

Taxing at the point of production or importation is administratively very attractive. The number of producing entities is manageable, and far, far smaller than the number of consumers. Most producers already pay some sort of royalty or production based tax. For example, in the USA, coal producers pay an excise tax that is used to fund the Black Lung Trust Fund. A full system for tracking imports is already in place.

### 5.3 The Rebate System

However, taxing this far upstream requires a system of rebates to handle non-fuel use, carbon sequestration and removal, and exports.

**Non-fuel use** Chemical plants and other non-fuel consumers will have to apply for rebates by documenting that the fuel they bought were used for non-fuel purposes. This system allows the possibility of distinguishing between non-fuel uses. Some non-fuels put their carbon into the atmosphere pretty quickly. Two-stroke engine lube oil is an extreme example.

**Carbon Sequestration** To be efficient we must not tax those fossil fuel users who do not put the fuel's carbon into the atmosphere. Otherwise there would be no incentive for sequestration. Fuel consumers who are large enough to remove and sequester CO<sub>2</sub> will be large enough to document the amount of carbon sequestered, and then would apply

for rebates. Plants that produce hydrogen from fossil fuel and sequester the carbon, would also apply for rebates on the basis of the amount of carbon sequestered.

**Carbon Removal from the Atmosphere** To be efficient, the tax scheme must also encourage carbon removal where it becomes economic given the tax. Any operation which removes and sequesters atmospheric CO<sub>2</sub> should receive the same “rebate” as any other sequestration operation. It will probably never be economic to cut down trees simply to bury them,<sup>24</sup> but growing algae and burying the algae may well become economic in the future. Even a small tax may make carbon removing concrete economic.

**Exports** The tax would be rebated to exported fossil fuel. This perhaps surprising rebate has two purposes.

1. Avoid double taxation in the highly desirable event that the importing country adopts a similar system.
2. Keep the revenues from the tax inside the country that actually consumes the fuel. This allows the tax to be revenue neutral. ***This is extremely important for it allows a country to impose the tax unilaterally.*** There is no need for any international agreements. However, in order to counter carbon leakage, it will be necessary to impose carbon content import duties on the imports of countries which do not impose a similar tax.

Entrepot transfers would be taxed upon import and rebated on re-export.

Essentially, what this rebate does is make each country responsible for the fossil fuel consumed within its borders.<sup>25</sup>

***For the purpose of the ideal tax, international bunkers would be treated as exports.*** Otherwise, owners would preferentially bunker in non-carbon tax countries.

This rebate system has two important characteristics:

1. It puts the burden of proof on the claimant of an exceptional case to make that case.
2. The number of rebate requesters is manageable. There aren't that many chemical plants, or fuel consumers large enough to economically sequester carbon. The system for tracking exports is already in place.

## 6 Imoland, a new country

We are finally ready to a talk about the IMO's role in the ideal system.

If international bunkers are exports, then we have created a new “country”, call it Imoland. This country imports bunkers and consumes them. This country should act just like any other country: tax the fuel when it is imported and rebate the tax upon export.

A very important feature of the ideal tax is that each country can implement it independently. Imoland need not wait for other countries.

The issue is: at what point is the fuel imported to Imoland? If the exporting country has also enacted an ideal tax, it almost doesn't matter. Let's say the fuel is imported when it is loaded on to the ship. Notice the conflict that has been set up. The bunker supplier will want to claim as high a rebate as possible. The importing shipowner will want to pay as small an import tax as possible. There is no way they can mutually benefit by understating the amount loaded. The system is almost self-enforcing. Imoland can have faith in the Delivery Ticket.

---

<sup>24</sup> Unharvested forests/crops/weeds/etc do **not** remove CO<sub>2</sub> from of the atmosphere. Once a forest or other bunch of plants reaches maturity, the carbon fixed by the growing portion of the system is matched by the carbon liberated by rotting and respiration. Despite this payments to the Third World for promises to reduce deforestation (not to log) are a central feature of both the European and Australian carbon trading schemes. Even Swift and Carroll could not parody a system in which some people are paid not to grow and others (eg corn and sugar) are paid to grow, and in both cases we claim to be reducing carbon emissions.

<sup>25</sup> The requirement for an export rebate generates the most serious enforcement problem with the ideal system: phony exports. Small tanker claims it is exporting fuel, and tax is rebated. Small tanker then unloads domestically (or elsewhere) in a way that escapes the import tax. The check is exports have to match imports, but setting up a system that does this reliably will not be trivial. If two trading partners enact the same tax, the rebate can be paid directly from the exporting country to the importing country making this form of smuggling much more difficult. In any case, the rebate should not be paid until the claimant produces checkable documentation showing that the fuel was imported by another country.

Also the bunker supplier has no motivation to claim to be selling to domestic shipping when in fact he is not. That would cost him his rebate. In fact, his motivation is just the opposite, to falsely claim that he is exporting when in fact the fuel will be used domestically. But that's not Imoland's problem.

If the exporting country has not enacted an ideal tax, then Imoland's bunker tax is playing the role of a carbon content import duty. Imoland faces the same problems in enforcing this duty, as any other importing country would. Now collusion between the shipowner and the supplier becomes possible. By understating the amount bunkered, the owner can avoid a portion of the Imoland tax and pay a portion of that to the supplier.

Of course, to do that, both parties would have to keep two sets of books. If Imoland's inspectors have access to the bunker supplier's books, and access to the bunker supplier's books, and so on back to the refinery, then such collusion can be made difficult. At a minimum gross understatement of imports can be prevented by comparing the stated fuel consumption with the ship's trading pattern.

As more and more countries adopt the ideal tax, Imoland's job becomes easier and easier. In fact, if all countries adopt the tax, they can all agree to not treat international bunkers as exports, and Imoland can disappear.

But if that happens, Imoland will have done its job. It will have shown the world the ideal way to reduce carbon emissions. It will have led the way.

---

<sup>28</sup> 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 inducement will generate further inefficiencies. It incurs all the administrative costs of a tax plus much of the administrative costs of EEDI trading.

<sup>28</sup> 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.

<sup>28</sup> Efficiency here is defined to be achieving the emissions reduction with the least cost to society.

Table 3: Main Features of Cap-and-Trade, Carbon Content Bunkers Tax, EEDI Trading

Criterion	Cap-and-Trade	Bunkers Tax <sup>26</sup>	EEDI + Trading(SECT) <sup>27</sup>
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 <sup>28</sup> 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 <i>more</i> 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 Enforcement	By using auction proceeds could be. Flag state + new bureaucracy	By using tax proceeds could be. Bunker state	No. 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.