

The instrumental use of technical doubts: Technological controversies, investment decisions and air pollution controls in the global shipping industry

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In principle, the installation of emissions abatement technology (otherwise known as scrubbers) on ships would reduce air pollution and premature deaths from disease and allow vessels to save costs by continuing to burn cheap high-sulphur residual fuel oil. But very few scrubbers have been installed. A recent House of Commons Select Committee Inquiry was unable to decide between the competing technical claims of scrubber manufacturers and ship operators, over whether scrubber technology was sufficiently 'mature' for present installation. From the perspective of science and technology studies, this paper draws on interviews with stakeholders and written and oral evidence to the committee to argue that this was a dispute, which foregrounded technical arguments for investment decisions that were actually being taken on economic grounds. Where scientific/technical closure is a matter of communal understanding rather than technical demonstration, technical doubt can be used instrumentally for economic reasons to delay closure.

Keywords: science and technology studies; scientific closure; ship emissions; technology implementation.

1. Introduction

The starting point for this paper is a report from the Transport Select Committee of the UK's House of Commons on 'Sulphur emissions by ships' (House of Commons Transport Committee 2012). The committee's Inquiry had been occasioned by shipping industry concerns that that new international regulations restricting the sulphur levels in marine fuels, and additional proposed restrictions by the European Commission on the sulphur levels of fuels used in passenger ships, were damaging the competitiveness of the shipping industry and threatening to cause a modal shift from low-carbon maritime transport to high-carbon road transport. The relevant regulations exempted vessels from burning much more expensive

low-sulphur fuels where those vessels had fitted abatement technology (known as scrubbers) to remove sulphur oxides (SO_x), nitrogenous oxides (NO_x) and harmful particulate matter (PM) from the vessels' exhaust gases. The committee considered that scrubber technologies had the potential to deliver population health benefits through decreased air pollution while continuing to allow ship operators to burn low-cost, high-sulphur, fuel oil and was concerned that so little progress had been made in the installation of scrubbers. It identified a clear disagreement between ship operators and scrubber manufacturers about whether or not scrubber technology had reached sufficient 'maturity' for such installations to proceed, but the committee pronounced itself unable to judge between the competing scientific claims of the two industries in their written and

oral evidence. The UK Department for Transport, in its response to the committee's report ([House of Commons Transport Committee 2012](#)), similarly avoided pronouncing on those contested claims.

We will examine whether the debate over the fitting of scrubbers has an instrumental character, insofar as public debates about the fitness-for-purpose of existing scrubber technology have served to delay expensive investment decisions in the face of economic and regulatory uncertainty. The process we are seeking to describe here is analogous to Habermas's description of the 'scientization of politics' — the conversion of political disputes into technical disputes. Politicians refer to expert advice and potentially contentious decisions are then

... denuded of their ideologically transfigured and compelling character. ([Habermas 1970](#): 68)

Both the scrubber manufacturers and the ship owners/operators (and their respective industry associations) have sought to justify contentious economic decisions by recourse to technical data on the effectiveness and robustness of scrubber systems.

Near-parallels can be drawn between the scrubbers dispute and findings from various previous science and technology studies (STS) projects. The study by [Pinch et al. \(1984\)](#) of the development of the safety cycle (and the partial reworking of their original argument by [Bijker \(1995\)](#)) laid the groundwork for a number of studies which contested the implicit technological determinism of earlier studies of technological innovation. They argued that there is an important degree of 'interpretive flexibility' in the understanding of technology and that the adoption of a technology depends in some large part (but not entirely) upon the strength and size of the social group or collectivity that takes it up and promotes it. Interpretive flexibility means, in effect, that one person's efficient technical device is another person's questionable object. For example, Edwards' study of the growth of computing technology

... cast[s] technological change as technological choice, tying it to political choices and socially constituted values at every level. ([Edwards 1996](#): xiii)

Likewise, the work of [Gusterson \(2008\)](#) on the expert debates about whether to replace possibly unreliable stored nuclear weapons with the assumed-to-be reliable (but untested) Reliable Replacement Warhead. In these nuclear weapons disputes, technical and political judgments are indissoluble and evidence is constructed in different ways by opposing experts:

To its advocates, [the Reliable Replacement Warhead] is more reliable than existing warheads. To its opponents, it is less reliable. ([Gusterson 2008](#): 558)

Relatedly, actor-network theory, associated with the work of [Latour \(1988\)](#) and of [Callon \(1986\)](#), sees innovation as

the construction of an expanding network of actors, both advocates and opponents, with material interests that have to be accommodated. Within STS there are differences of viewpoint between different proponents (see [Callon and Latour \(1992\)](#) versus [Collins and Yearley \(1992\)](#)), but this is not our main concern here. Instead, this paper seeks to identify some of the most salient economic and regulatory uncertainties that may underlie interpretive flexibility over the fitness for maritime installation of scrubber technology, and to show how technical doubts raised through this interpretive flexibility may serve instrumentally the economic and political interests of participants in this technological controversy. Ship operators wish avoid any perception among charterers or the public that they are environmentally irresponsible, and so are likely to emphasise sincerely held technical doubts rather than economic difficulties as the reasons for delaying investment in technology with environmental benefits.

The shipping industry carries more than 80% of world trade by volume and cheap maritime freight rates have been one of the motors of globalisation, with the cost of shipping Chinese jeans to the UK working out at around £0.20 per pair. The industry itself is one of those most altered by globalising economic processes, now characterised by complex 'global value chains' ([Gereffi et al. 2005](#)) of different contractors. Typically, a vessel may be owned by a transnational corporation, managed by a specialist international ship management company, and crewed by the casualised employees of a specialist crewing agency. Ship owners and ship operators do not own the cargo, that is the property of the charterer. The industry displays a 'polycentric governance structure' ([Bloor et al. 2013](#)) that is complex, multi-level, overlapping, part interdependent and part fragmented. Governance roles are played by non-State actors (for example, the Oil Companies International Marine Forum, which inspects and vets vessels for the tanker trade), local actors (for example, port health authorities), global UN agencies (the International Maritime Organization (IMO) which sets ship standards, and the International Labour Organization (ILO) which sets ship labour standards), regional actors (for example, the European Commission, and regional associations of port-States which collaborate to enforce IMO and ILO standards on berthing ships of all nations), and national actors—the national maritime administrations which are represented at IMO and ILO, give effect to IMO/ILO standards in their national laws, enforce those laws on their own flagged ships ('flag-State control') and in their own ports ('port-State control'), and enact and enforce their own unique maritime regulations, for example, the Swedish 'fairway dues' which are levied on berthing ships to pay the costs of ice-breaking and navigation lights and are differentiated to reward 'greener' vessels.

Air pollution from ship emissions is a serious concern. Until recent IMO regulations came into force, most ocean-going ships burned a marine fuel which was, and still is, a cheap residual by-product of oil refineries—that which is not sold for marine fuel is used for road tar. The burning of this residual fuel releases large quantities of NO_x and SO_x gases (which harm crops, forests and oceans through acidification) and fine particulate matter (PM_{2.5}) which causes lung and coronary illness. A scientific review for IMO estimated that ship emissions were causing 64,000 premature deaths per year worldwide (27,000 deaths in Europe) in 2002 (Corbett et al. 2007), and ships are estimated to emit 150–300 times more SO₂ per ton km than lorries burning diesel with just 50 ppm sulphur (Hemmings 2010). The IMO regulations on sulphur content in fuel came into force in 2005 and were revised in 2010. The worldwide sulphur cap was initially set at 4.5%, reducing to 3.5% in 2012, with a projected further reduction to 0.5% in 2020. This last 2020 deadline is subject to a planned review and could be postponed until 2025. Additionally, IMO set up Emission Control Areas (ECAs) in the Baltic (from 2006), the North Sea/English Channel (from 2007) and North America (from 2012). Initially, the sulphur limit for the ECAs was set at 1.5%, reducing to 1.0% in 2010, and due to reduce further to 0.1% in 2015. The projected restriction to 0.1% sulphur in the ECAs in 2015 would, in effect, require all vessels in the ECAs (except those fitted with scrubbers) to switch from low-cost residual heavy fuel oil to high-cost distillate fuels. Additionally, the EU has introduced restrictions on sulphur levels for passenger ships in EU waters and restrictions on the sulphur levels of fuel that can be burned in EU ports and harbours. California also has restrictions on fuel sulphur levels in ports and coastal waters. It has been calculated that the projected IMO global 0.5% sulphur limit would reduce annual premature deaths by ~41,200 (Winebrake et al. 2009).

The shipping industry is notoriously subject to cyclical fluctuations in profitability and investment (Lane 1986). When freight rates are high the order books at shipyards rapidly fill up. However, by the time new vessels are launched, they often enter the market place in very changed economic circumstances. Typically in such circumstances, the increased carrying capacity represented by the new builds serves to further deflate falling freight rates and this reduces both the inclination and financial capacity of the industry to invest in new vessels in hard economic times. As a consequence, when world trade improves there is undercapacity in the industry, resulting in rising freight rates and overinvestment in new building, which renews the cycle once again. At present the industry is at the low point of the cycle: in early 2012 the Baltic Dry Index, which measures short-term freight rates for the bulk carrier sector, dropped to the lowest point in its 26-year history, with the international bulk carrier fleet due to expand by 14% in 2012, compared to an expected 3%

gain in the volume of seaborne trade (Norris 2012). Other industry sectors, such as the container and tanker trades, have been hit almost as hard. The shipping industry simply does not invest on any scale during economic recessions: the Council Working Party on Shipbuilding of the OECD announced in July 2009 that worldwide new orders had contracted by up to 90% in the last quarter of 2008 and the first quarter of 2009, compared to the third quarter of 2007 (OECD 2009). International regulations on ship emissions which ostensibly might incentivise ship operators to invest in the installation of scrubbers are coming into force at a time of greatly reduced industry investment.

Following a description of the study methods, this paper first examines the conflicting scientific evidence claims made to the House of Commons Transport Select Committee. Secondly, the paper reports on further contested claims on scrubbers made at interview by a range of industry stakeholders; and thirdly, on alternative accounts—non-technical reasons advanced by interviewees for the lack of investment in scrubbers. These non-technical reasons for non-investment were: the lack of advantage for ‘first movers’, regulatory uncertainty, uncertainty about the type of scrubber that should be installed, lack of investment funds, managerial short-termism, and uncertainty about the future availability of high-sulphur fuel oil for scrubbers. The paper concludes by relating these empirical data to STS analyses of counterfeit scientific/technical disputes.

2. Methods

The data reported here were collected as part of an Economic & Social Research Council-funded study which compared the UK and Sweden on issues in the enforcement of the new international regulations on ships’ sulphur emissions. Although enforcement practices in respect of the operation of scrubbers might have formed an important part of the study, in the event this proved not to be the case. The monitoring of scrubber operations (by flag-State inspections or by port-State inspections) will not be an important issue in the short-term because very few vessels are being fitted with scrubbers. A very few new builds are currently being fitted with scrubbers on a trial basis (see below), additional to a small number of trial installations already in operation, but retrofitting of scrubbers onto current vessels is hardly occurring. Enquiries with dry-dock managers in early 2012 did not turn up any current retrofits of scrubbers taking place¹ and we know of only one such retrofit currently being planned before 2015: a vessel belonging to Maersk (the largest shipping company in the world), and in this case the scrubber will only be retrofitted to a single auxiliary engine, not a main engine. So scrubber installations, although only forming a limited fraction of our dataset,

excited our curiosity as the ‘dog that didn’t bark in the night’.

The dataset for the study comprised the observation of 16 ship inspections (involving visits to seven different port-State control offices in the UK and Sweden) and 50 qualitative interviews with a range of different industry stakeholders, again in both the UK and Sweden. None of the ship observations involved vessels with scrubbers. The range of interviewees embraced port-State inspectors, national and international regulators, managers within shipping companies, industry associations, classification societies, bunkerers, marine fuel experts, trade unionists and environmental non-governmental organisations (NGOs). All the interviews involved questions on scrubbers, although not all interviewees felt sufficiently qualified or experienced to offer opinions. Four interviews were not taped at the request of the interviewees. Transcripts were made of the remainder and those transcripts, field notes and interview notes were all coded and systematically analysed using analytic induction (Bloor 1978). The written and oral evidence to the House of Commons Transport Select Committee, the committee’s report, and the government’s response are all available from the Parliament website (House of Commons Transport Committee 2012).

3. The Transport Committee Inquiry

The committee, as is usual with House of Commons Select Committees, advertised a request for written evidence and also requested a number of individuals to give oral evidence and to submit to questions from the members. A report was issued and published along with the response of the government. The committee’s report contained a number of statements on abatement (i.e. scrubbers) technology which were careful to avoid a judgement on the present robustness of the technology, such as:

It is not yet clear whether this technology will be available in the near future. (House of Commons Transport Committee 2012: 2)

and

We are not in a position to judge the maturity of abatement technology. (House of Commons Transport Committee 2012: 3)

An interviewee sought to explain the committee’s position:

...it’s not that unusual to get a situation where one side says one thing and the other side say another. But both of them backed it up with credible-looking evidence [...]. That’s why it was impossible, you know, we put the evidence to both sides and they both gave credible points-of-view back [...]. That’s quite unusual – normally somebody collapses because they can’t back up their view at all [...]. I have to say it was a mystery why the two sides were so far apart. (interview: parliamentary advisor)

Both the written and the oral evidence to the committee on scrubbers were peppered with assertions of fact that were sharply conflicting. On the one hand we have these statements from ship operators:

...it is not feasible to retro-fit these [scrubbers] to most existing vessels because the equipment is bulky and heavy and would therefore sacrifice capacity. They also create stability issues, are expensive and, even though high efficiency can be demonstrated on some pilot installations, MARPOL [i.e. the IMO international air pollution regulations] requires 100% compliance. There is no room for temporary disruptions. Scrubbers can, of course, be incorporated in any new ship design provided the technology becomes more reliable... (written evidence: Brittany Ferries)

...while scrubbers have been demonstrated to work well in shore installations such as power stations, manufacturers have yet to be able to ‘marinise’ their equipments sufficiently [...] much more time is required to make it functional, reliable and able to meet the compliance requirements. (written evidence: Maritime UK, an umbrella group representing UK ports and ship operators)

The technology is not there. I do not think anybody who fits a scrubber will have absolute confidence that that scrubber will work in a compliance regime. That is what you need because, if you cannot guarantee the scrubber will work in a compliance regime, you have to have all the additional back up plans, such as additional piping and tankage, to cope when the scrubber is not in operation. (oral evidence: Robert Ashdown, European Cruise Council)

And, on the other hand, there were conflicting statements from the Exhaust Gases Cleaning Suppliers Association (EGCSA), the European Commission, and an environmental NGO:

EGCSA members currently have exhaust gas cleaning systems installed and operational on eight vessels and have orders for installations on a further ten vessels. [...] The position senior leadership in the Marine Industry has taken so far, is to avoid or delay any strategic planning and or attempt to delay entry into force [of the impending regulations] with various claims of modal shift, increased cost of fuel, lack of impact assessment etc. [...] EGCSA members have been attempting to introduce their technology on board ship for over three years, they have been frustrated by the unwillingness of ship-owners to take up the technology. Comments by Maritime UK such as ‘unproven’ [...] are simply incorrect and misleading. They perpetuate a myth which has no foundation and which provides ship-owners with a reason not to take action... (written evidence: EGCSA)

When the 2005 [Commission] Directive was introduced [...] the Directive was foreseeing trials of scrubbers. [...] The Commission had to be notified [...] of the results. Such trials have been carried out on several ships, with the result that the conclusions drawn by the operator of the ship were fundamentally different from the conclusions drawn by the supplier who installed the scrubber. [...] the Commission is of the view that scrubbers are ready for purpose but most likely they will still undergo further development, just as the cellular phone was

very different 20 years ago from what we have now. (oral evidence: Christian Wimmer, Policy Officer, European Commission)

Flue gas cleaning of sulphur (scrubbing) is a technology that has proven to be very effective with industrial plants. Tests on ships have demonstrated at least 90% SO₂ removal efficiency... (written evidence: the Air Pollution & Climate Secretariat, an environmental NGO)

Two of those called to give oral evidence were Mr Gregory of EGCSA (and previously of the scrubber manufacturer BP Krystallon) and Mr Garner of P&O Ferries, who had both been closely involved in the trial of a BP Krystallon scrubber retrofitted onto one of the generators (rather than a main engine) on the P&O ferry, the *Pride of Kent*, in 2005. They drew very different conclusions from the same trial evidence, just as Mr Wimmer of the European Commission described. Parallels with the adversarial court evidence of expert witnesses, as analysed by [Jasanoff \(1995\)](#), are very clear. P&O Ferries chose not to invest in scrubbers on their two new ferries, the *Spirit of Britain* and the *Spirit of France*, which came into service in 2011 and 2012, respectively.

As further evidence of this mismatch of perspectives, we can cite the fact that scrubber manufacturers can point to the certification (by the respected classification societies Det Norske Veritas and Germanischer Lloyd) of a Wartsila–Metso-manufactured scrubber as meeting IMO standards for scrubbers and to the sale by Wartsila of scrubbers for a fleet of six vessels to the Canadian shipping company Algoma Central ([Wartsila 2012](#)). Whereas, on the other hand, a shipping industry association representative could baldly state at interview:

...the scrubbers as they exist today are not a possibility, neither technically nor economically.

Public debate over the effectiveness of scrubber technology is, of course, still continuing (see, for example, the report commissioned by the [UK Chamber of Shipping \(2013\)](#)). However, all the main reasons for non-investment, both technical and non-technical can be traced within the Inquiry evidence and (more clearly) within the study interview transcripts. We list these non-technical reasons separately in the next section.

4. Non-technological reasons for non-investment

4.1 No incentives for early investors/no first-mover advantage

Scrubber-less ships trading within the ECAs will not be obliged to switch from residual fuel to much more expensive distillate until 2015. Early, pre-2015 investors would be seriously disadvantaged initially compared to their non-investing competitors because of the cost of the

installation, the loss of vessel earnings in dry dock, and the extra running costs of the installation. Similarly, in respect of vessels trading outside the ECAs, owners who chose to invest in scrubbers prior to the current 2020 deadline for switching to 0.5% sulphur fuel could find themselves seriously disadvantaged against their non-investing competitors if, after review, IMO decided to postpone that deadline until 2025. As one interviewee put it:

...if you can run on heavy fuel oil for five years more while your competitor has bought a scrubber, you will have a huge advantage compared to your competitor. (shipping company manager)

The only compensating advantage for early investors appears to lie in being first in what could be a lengthy queue for dry-dock facilities. More than one interviewee pointed to the need for a global governance structure for the industry which rewarded early investors, such as the Norwegian NO_x Fund which taxes vessels and then compensates investors in ship propulsion systems which reduce NO_x emissions.

4.2 Regulatory uncertainty

In respect of ship sulphur emissions, regulatory uncertainty takes several forms. First, there is uncertainty over the deadline for a global (non-ECA) sulphur cap of 0.5%—as mentioned above, IMO left open the option of postponing that deadline until 2025, depending on a review (taking into account projected future global fuel availability) to be completed by 2018. Secondly, there is the possibility that energetic lobbying by shipping interests (at IMO and at national government level) could ensure a postponement or a modification of the regulations, as they relate to both the global and the ECA sulphur caps:

As an industry we have not been passive; we have been meeting with every shipping Minister since 2008 on this issue. We have been lobbying heavily and raising the concerns that we raise today. (oral evidence: Lars Ollsson, Stena Line and Vice Chairman of Maritime UK)

The very creation of the Transport Select Committee Inquiry was itself, in part, a result of such political activity by the industry. Opponents, of course, allege that such political lobbying itself generates an atmosphere of regulatory uncertainty which inhibits investment decisions:

There were discussions and discussions and discussions for 20 years until you arrived at this solution [IMO regulations]. Then, after the decision was taken, it was questioned for several years instead of just getting on with it. It is uncertainty about the deadline of 2015. Who is causing that uncertainty? It is not the people who work with legislation or environmental protection. It is the industry itself. (oral evidence: Christer Agren, environmental NGO)

And it is also alleged that lobbyists purposely overstate the technical and economic difficulties of meeting new environmental regulations:

When it comes to producing environmental standards, what you observe, for example, for cars is that it was always claimed until the last day before a provision came into force that the technology was not available, and all of a sudden, overnight, it was available and it was typically, in the case of cars, cheaper than predicted by a factor of 10. (oral evidence: (Christian Wimmer, policy officer, European Commission)

A third and important source of regulatory uncertainty lies in the possibility of regulatory diversity between jurisdictions, in the possibility of future additional regional, national or local regulations on sulphur emissions being framed which are at variance with the IMO regulations and which may not allow the use of scrubbers, or the use of certain types of scrubbers. This relates back to the aforementioned polycentric governance structure of the industry. There is a danger that vessels fitted with scrubbers to IMO standards may nevertheless find themselves non-compliant with local regulations in certain ports, with the consequent possibility of a fine for contravention of local pollution laws and/or detention of the vessel. Thus, the European Commission has proposed a revised directive on ships' sulphur emissions, which would set down requirements for scrubber systems additional to IMO standards. So-called 'wet scrubbers', which involve the discharge of wash-water overboard, must meet IMO requirements on those discharges, but EGCSA claim that the proposed Commission directive would additionally require:

... each and every ship to be able to demonstrate that their discharge is not causing an impact to the marine and aquatic environment. (oral evidence: Donald Gregory, EGCSA)

There are also fears that in future Baltic States may ban wash-water discharges from wet scrubbers because of concerns that these discharges may contribute to the acidification of the Baltic. The pH level of discharge water from the DFDS ferry *Tor Ficaria*, fitted with what is claimed to be the world's largest vessel scrubber, is in the range 3–5 (freshwater pH = 7), depending on exhaust gas and water flow (Knudsen, 2010). It should be noted that the *Tor Ficaria* wash-water discharges do not meet the IMO guidelines (pH = 6.5) and Denmark has accordingly proposed a revision in those guidelines. So some regulatory uncertainty exists even in respect of the IMO regime. Additionally, there are fears that certain ports may ban wash-water discharges and may not recognise derogation from the IMO low-sulphur regulations for vessels with scrubbers. The *Tor Ficaria* is actually fitted with a hybrid (seawater/freshwater) scrubber with the capacity to store discharge in sensitive areas like ports and estuaries, but future regulations may not differentiate between types of scrubbers when it comes to derogations.

Ship operators (at least those operating in European and North American waters) have adopted a 'culture of compliance', associated with an assumption that non-compliance will be detected and sanctioned (Bloor et al. 2013). This culture of compliance persists despite the regulatory uncertainty that comes from a fragmented, polycentric governance structure. This regulatory uncertainty poses three different types of risk for potential scrubber investors: first, the risk of fines/detentions (with a consequent blow to market reputation and a resultant diminution in the freight rates a vessel can command); secondly, the risk of investing in the wrong type of scrubbers; and thirdly, the associated risk that operators on scrubber vessels may need to 'cover' themselves against regulatory uncertainty by making dual provision—investing in scrubbers but also carrying a strategic reserve of compliant low-sulphur fuel as well as the residual fuel oil for scrubbing. The latter risk adds considerably to overall installation costs through extra piping, storage and settlement tanks, consequent loss of payload space, and increasing overall fuel costs:

... where you solely rely on the scrubber to meet your environmental objectives and do not carry the supplies of compliant fuel instead [...] it is very important, especially in the cruise industry where we may visit 27 or 30 different ports in a season, to know that we can use that scrubber in every port that the ship visits [...]. Without that absolute regulatory certainty that that scrubber can be used in every port in the area in which the ship is operating, it becomes a much more difficult investment decision to make. (oral evidence: Robert Ashdown, European Cruise Council)

4.3 The wrong scrubbers

As already implied, a range of scrubber systems is available: dry scrubbers (using calcium hydroxide granulate and producing calcium sulphate waste, used in gypsum industries), wet scrubbers on an open loop (i.e. with wash-water discharge), wet scrubbers on a closed loop (potentially suitable for ferries on short voyages), and hybrids like that used for the *Tor Ficaria*. A range of different scrubbers are also fitted to different power plants. Although the first scrubbers were fitted to power plants back in the 1930s, no one-size-fits-all technical fix has emerged. Rather, different fuels and different sized plants require different cost-efficient scrubber designs (Kaminski 2003). The choice of maritime scrubber has implications for the vessel's future trading patterns:

... we have got rather lax [...] in our approach to marine operations in the sense that one size goes everywhere. But [...] we are going to have to start thinking as to what option do I adopt? Do I adopt an option that has a high capital or a high operating cost? (marine fuel expert)

Critics and advocates of marine scrubbers alike agree that it is a developing technology. The industry includes

companies such as Aalborg Industries, with 40 years experience of systems for dealing with inert gases venting from oil tankers, and Wartsila, the marine engine and power plant manufacturer with previous experience of manufacturing power station scrubbers. A Singaporean company, Ecospec, is even (very controversially) claiming to have developed a scrubbing system that will scrub CO₂ as well as SO_x and NO_x (Lloyds List 2011). It is possible that future developments could deliver quicker investment paybacks and could be cheaper in terms of capital and/or operating costs than the present generation of scrubbers. There is therefore an argument that can be made for delayed investment:

... gigantic amounts of investments to be made [in vessels] that have to work for 20-to-30 years, that's the perspective, and they don't want to lock themselves into a technology that will be out-of-date the day after tomorrow. (shipping association representative)

It has also been suggested that wet scrubbers, as a technology, are effective in meeting the current 1% sulphur limit in the ECAs but may find it difficult to meet future requirements to operate with 0.5% or 0.1% sulphur:

Some scrubbers use sea water to wash the fumes and the water flow that is needed [...] down to 1% [sulphur] is no problem, but then at 0.5% or 0.1% it takes so much water that it is nearly impossible to achieve a functioning system on board. (marine fuel expert)

Wet scrubbers may be relatively inefficient in Baltic waters because of the lower alkalinity of Baltic Sea water. And vessels with dry scrubbers will need regular port access to substantial amounts of calcium hydroxide granulate and port facilities to dispose of the spent granulate.

4.4 Lack of investment funds

The written evidence to the committee supplied by the cruise company, Carnival UK, suggested that the installation costs of a scrubber on a large cruise ship would be US\$13–20 million, with annual running costs in the region of US\$150,000–900,000, depending on the type of scrubber. The cost of the scrubber retrofitted onto the (single engine) *Tor Ficaria* ferry was US\$2.9 million, with an additional US\$3 million installation costs (if it had been a new build it would have been US\$1.5 million) and with estimated annual running costs of US\$181,440 (Knudsen 2010). Payback times on this investment may be short or longer: the estimated payback time for the *Tor Ficaria* was 1.35 years (Knudsen 2010), but the written evidence from Stena Line suggested a much longer period. But, in any case, US\$13 million for a cruise ship installation or US\$6 million for a ferry installation is still a lot of money to find upfront. Some of the larger scrubber manufacturers have been prepared to part-fund trial installations (the *Tor Ficaria* and *Pride of Kent* installations were

both part-funded in this way), but clearly this is not going to be an important source of future funding for ship owners.

Investments (in new builds or in new installations) may be financed by bank loans, ship mortgages or from profits. The cyclical nature of the industry has already been described above—profitability has fallen in most sectors of shipping since 2008. And the ‘credit crunch’ has reduced bank lending and mortgage activity, particularly where operational and maintenance costs are uncertain. Thus:

These [scrubbers] are essentially prototype technologies. There are very few of them operating in the world, very few operating on main engines and even fewer operating as part of a compliance regime. The level of experience is low and, of course, these may have high operating costs. To try and take that business model to a bank or lender and say, ‘We want you to lend for a product which is unproven and which may or may not work’, poses significant difficulties for companies. (oral evidence: Robert Ashdown, European Cruise Council)

And similarly:

... I think because it is a huge capital investment not many ship owners have the money to do these kind of things right now. And then there has been the regulatory uncertainty that has just made it easier to kind of close our eyes and say let's just postpone the whole thing. (shipping company manager)

Note that the above interviewee is positing an additive relationship between the different non-technical arguments against scrubber investment, but interactive relationships may also be occurring, as where lack of first-mover advantage is exacerbated by current regulatory uncertainty, which will naturally diminish over time.

The shipping industry is not alone reducing investment levels: business investment has fallen substantially in most industrial sectors across the globe since 2008. This is sometimes described as an ‘investment strike’ (Burke 2012), not a wholly accurate term when businesses find themselves both under pressure from banks to reduce their borrowings and with surplus capacity due to falling demand. Several of the submissions to the committee from ship operators requested government funding to defray the costs of scrubber investment, but the committee's report did not support this and neither did the UK government's response to the report.²

4.5 Short-termism

Closely related to a lack of investment funds is managerial short-termism, defined by the *Financial Times* lexicon (2012) as:

... an excessive focus on short-term results at the expense of long-term interests.

Corporate leaders are said to be driven by accountancy-driven metrics like earnings per share (EPS) to restrict

spending on research and development; companies which have large development budgets but low EPS are very vulnerable to take-over bids. Only privately-owned companies are immune to these pressures. The need to control corporate expenditures in order to maintain EPS leads to the concentration of investment decision-making in the hands of a few senior persons who may not always be fully informed on technical aspects of the investment, a situation that is exacerbated where shipping forms only part of a transnational corporation's activities. Thus:

I think the industry has changed quite a bit in the way it operates and who holds the purse strings and who are the decision-makers. [...] most of that discretionary expenditure or decisions all sits with the chief executive [...]. So getting it to board level, and I think this is where it needs to be, and getting the board to understand that this is a strategic decision, that if they don't get it correct could be they'll go out of business, is the challenge. (expert on scrubbers)

4.6 Future availability of residual fuel

As mentioned previously, high-sulphur fuel oil is by-product of refinery distillation processes: supply is thus unresponsive to demand. Moreover, improvements in refinery technology are gradually reducing the proportion of residual fuel that is being produced. Industry experts predict that a future generation of refineries will no longer produce residual fuel:

...if you develop the sort-of sophistication of a refinery [...] you end up with mostly higher fractions, no residual fuel oil, and just petroleum coke at the bottom which [...] has no sort of hydro carbon value. (bunker industry expert)

This diminution in supply will be very gradual because refinery plant has a long operating life. But vessels also have a long operating life (say 20/25 years), so that the future availability of residual oil for scrubbers is an additional source of uncertainty for investors in new-build vessels.

There is also an additional question mark over future fuel availability that relates, not to the refineries, but to the bunker suppliers. Namely, that if very few ship owners opt to retrofit scrubbers onto their vessels by 2015, then bunker suppliers may no longer consider that it is economically viable to store and supply high-sulphur fuel oil. Early investors in scrubber installations may then find that they cannot source high-sulphur fuel for their new scrubbers—a wasted investment. Thus:

The danger is that, certainly within the Baltic Sea in 2015, if the market penetration of scrubbers remains very low, then the ships will be using distillate fuels to remain in compliance. If all the ships are using distillate fuels, that means the bunker supply industry may no longer supply residual fuel oils into the Baltic Sea area. So [...] there will not be the higher sulphur residual fuel to purchase to scrub down [...] which is the rationale for the business case. (oral evidence: Robert Ashdown, European Cruise council)

4.7 Industry structure

Finally, the vertical disaggregation of the industry may be thought to militate against investment in scrubbers. For many vessels, the owner is not the operator: specialist ship management companies contract with an owner to manage a vessel or a fleet of vessels. And the operator does not always pay for the fuel: that responsibility may lie with the charterer. Charterers may, in turn, re-let a vessel to another charterer, who then may be liable for the fuel costs. Thus, the vessel owner who is taking the decision on whether or not to invest in scrubber installations often experiences no direct benefits from the charterer's lower fuel costs, only the possibility that such an installation may make the vessel more attractive to charterers. This may be thought to dilute the investment incentive for owners. The same point was made in relation to ship owners' investment in carbon abatement technologies in a recent House of Commons Committee Report on climate change policies (House of Commons Climate Change Committee 2008). The opportunities for scrubber sales may therefore be largely confined to that fraction of the industry where owner-operators predominate (in the ferry and cruise sectors) and to blue riband owner-operators elsewhere such as Maersk Line (container sector) and BP Shipping (tankers).

5. Conclusions

In describing scientific and technological disputes, STS researchers have described the notion of rhetorical 'closure'. Thus, writing of the contest between environmentalists and road transport interests over the plan for a Trans-Israel Highway, Garb describes the moment when:

...the winning project (or theory) comes to occupy the full space of possibility, alternatives become unthinkable, and all 'serious' argument is now conducted inside the project's 'box'. (Garb 2005)

At the time of writing this paper, the point of closure has not been reached in the contest over scrubbing technology, but arguably it is looming. In 2015 all ships in the ECAs will be required to burn 0.1% sulphur fuel. A dry-dock manager interviewed in November 2011 did not know of any competitor dockyard in Europe that might have an order for retrofitting scrubbers. Thirty million euros of Finnish state aid for retrofitting scrubbers, approved in January 2013, has created a recent mini-boom for Finnish scrubber manufacturer, Wartsila, with orders for 27 vessels by March 2013. But elsewhere and to date, the Canadian Algoma Central Corporation remains the only shipping company that has placed a multi-vessel order for new-build scrubber installations. As one interviewee put it, nearly all the shipping companies are still 'dancing round their handbags'. Unless decisions on investments in scrubbers are made almost immediately, ship operators will have

no choice but to switch to 0.1% sulphur fuel (distillate) in the ECAs from 2015. It is perhaps significant that the same dry-dock manager reported a boom in the retrofitting of 'split' service tanks, especially in the last couple of years: splitting a ship's service tank (a relatively cheap and straightforward procedure) enables the vessel to readily and economically switch between distillate and high-sulphur fuel when moving in and out of the ECAs. Additionally, as has already been stated, if only a very few vessels in the ECAs operate with scrubbers, then this may well cause at least some of the bunker suppliers in the ECAs to stop supplying high-sulphur fuel, prejudicing future scrubber operations.

To be clear, our argument here is not that shipping companies' technical claims about the lack of maturity of scrubber technologies are false. In pointing to the extreme environmental conditions in which ships operate and the serious consequences of even infrequent equipment failures, it could be said that shipping companies are drawing on the same valid 'local knowledge' that Cumbrian sheep farmers drew on to contest scientific advice on the radioactive contamination of sheep pastures (Wynne 1992), and that the farmworkers union drew on to contest the 'decontextualized' advice of the UK Advisory Committee on Pesticides on the safety of the pesticide 2,4,5-T (Irwin 1995). Instead, our argument is that these technical claims are specious: they are analogous to what Habermas called the 'scientization of politics' (Habermas 1970). The manufacturers wish to sell their scrubbers and the shipping companies wish to delay their investment decisions, but these conflicting commercial interests are represented, or misrepresented, as a contest between different technical claims.

Similarly, there should be no disputing the right of enterprises and industry associations to lobby governments and in the course of that lobbying technical arguments may play a legitimate part. This is an old song. A celebrated earlier example was the strong opposition of US car manufacturers to the 1970 Clean Air Act and their associated scepticism that catalytic converter technology, if installed in their vehicles, could achieve the standards set by the act. In a memo sent to Congress by the Automobile Manufacturers Association it was stated that:

...it will simply not be possible for vehicle manufacturers to achieve the control levels specified in the bill. (Automobile Manufacturers Association 1970)

The projected health benefits of pollution controls were also disputed (Kovarik and Hermes n.d.). In the event, the new catalytic converters introduced in 1975 proved equal to the task.

Just as in the depiction of the interpretive flexibility that occurred in respect of the superiority of different bicycle technologies (Pinch et al. (1984), there are different social and economic interests influencing the different claims concerning the technical effectiveness and efficiency of

scrubbers. There is also a political dimension that lies indissolubly behind these different technical claims, in this case it is the dimension of environmental politics, where ship operators have identified a need to present themselves as environmentally responsible to charterers, shareholders, legislators and passengers (Bloor et al. 2013). The fitting of scrubbers would allow vessels to reduce sulphur emissions both inside and outside the ECAs, which would produce clear and immediate environmental benefits. However, the cost implications of such measures deter ship operators from investing in such equipment. An image of ship operators as more concerned with finance than with the environment would be unfortunate and damaging, so the operators' sincerely held technical reservations are placed in the foreground rather than their funding concerns. A potentially harmful dispute about environmental damage is defused and converted into a symbolic (in anthropological terms) technical argument.

There are many examples, within the history of science and technology, of scientific or technical disputes acting as epiphenomena for other struggles, be they economic or personal. To give one instance, in the 1930s J. S. Haldane (Oxford professor of physiology and honorary director of the Mining Research Laboratory) strongly contested claims about the pathogenic qualities of coal dust and thus delayed the recognition of pneumoconiosis as a compensatable industrial disease. Haldane had earlier identified the presence of silicosis among Cornish tin miners cutting their way through silica-rich rock. Despite accumulating epidemiological and X-ray evidence to the contrary, Haldane long claimed that the widespread pulmonary disease among coal miners was not due to the high levels of coal dust produced by mechanical cutters and conveyors, but was either due to the presence of silica in some pits or due to bronchitis. Meiklejohn (1952), in his history of pneumoconiosis states that:

There can be little dispute that, in relation to bronchitis, Haldane's intransigence beguiled him.

Haldane persisted in advancing specious scientific arguments in order to defend his personal prestige.

In writing of the struggles 80 years ago of the leaders of the South Wales miners to obtain compensation for miners suffering with pulmonary disease, Bloor (2000) has described how union officials *instrumentally* used scientific expertise in a variety of forms—they contributed epidemiological evidence, lobbied for government research funding, 'bought' experts, duped expert witnesses, and made sophisticated instrumental appeals to the supposed independence of favourable expert opinion. The present paper, in contrast, is about *the instrumental use of technical doubt*. Scientific or technical statements, be they about scrubbers or about global warming, are always both universal and provisional, potentially open to re-examination and subsequent qualification. Closure is a matter of taken-for-granted communal understanding, rather than simply

a matter of technical demonstration. Scientific/technical reasons for action or inaction are not simply shared (i.e. socially acceptable) ‘vocabularies of motive’ (Mills 1940), they are also a means of prolonging debate: further evidence may be called for, universal applicability and long-term durability may be questioned, and future suitability in changed circumstances may be uncertain. Studies of ‘market failures’ in implementing environmental or sustainable innovation (Foxon and Pearson 2008) may need to embrace the role of instrumental technical doubt in preventing the movement of early-stage technologies along the innovation chain.

The precautionary principle, a cornerstone of UN and EU environmental policy, states that the lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation (UN 1992; Commission of the European Communities 2000). However, as with tobacco companies funding sceptics about the harmful effects of tobacco, and energy companies funding climate change sceptics (Orestes and Conway 2010), the debate over the installation of scrubbers shows how technical doubt may be used instrumentally to justify delay in the implementation of social or economic change.

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Notes

1. Technically, it is possible for some types of scrubber to be retrofitted on some types of vessel without dry-docking, by a ‘riding crew’. However, we understand that the numbers of suitably qualified riding crews likely to be available for such work are quite limited.
2. Pleas for government assistance in making new technologies cost-effective do not always fall on deaf ears. This has long been advocated as a principle in the development of clean technologies (Foxon and Pearson 2008) and in January 2013 the European Commission approved a Finnish state scheme to provide €30 million to assist in the retrofitting of scrubbers (Finnish Ministry of Transport and Communications 2013).

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