

Governance of innovative cleantech retrofitting in the shipping industry? Experiences from a Danish case study

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Abstract

Air pollution from maritime transportation has become an important public health and environmental concern. As result, new international regulations seek to reduce the pollutants issuing from marine fuels combustion. Marine cleaner technology has been regarded as the key solution to comply with regulations and reduce operation costs. However, definitions of maritime cleantech differ and range from end-of-pipe pollution control equipment, more efficient engines, improved hull-design and alternate propulsion fuels (LNG, methanol). Different constellations of actors seem to follow different cleantech trajectories. It is therefore important to develop new forms of governance in order to create innovations, which are comparable with the state of art in other industries and new ways of building networks and partnerships. The paper aims to improve the understanding of cleaner technology as innovative retrofitting and forms of governance in the shipping sector by analyzing: How can governance promote clean tech innovation in the shipping industry? The Danish "Partnership for cleaner shipping" has been analyzed to answer this question. This partnership was initiated by the Danish Environmental Protection Agency in collaboration with the Danish Ship owners' Association. The partnership identifies innovative cleaner retrofitting as one of the key domains with the purpose to improve Danish shipping firms to create competitive advantage and comply with the new international regulations of air pollution avoidance at sea. The case shows that partnerships and networks create a protected space for development of maritime cleaner technology, which improves the environmental performance of the shipping industry by implementing cleaner retrofitting technologies.

Keywords

Clean tech, Governance, Innovation and Shipping industry

1 Introduction

This article defines the shipping industry as seaborne freight transportation. This industry has been a large player in globalization processes during several decades. In particular, containerization facilitates trade in a reliable and efficient way (Fremont and Soppe, 2005). Besides containers, shipping encompasses the transport of liquid and dry bulk, but also passengers. From an environmental planning perspective, seaborne transportation has environmental advantages over road and air transport. In particular, less greenhouse gas emissions per volume of transported goods (IMO 2009b). However, research also shows that some air pollutants are dispersed in coastal areas due to increased marine traffic. Main air pollutants are Sulphur Oxides (SO_x) and Nitrogenous Oxides (NO_x) (Agrawal et al., 2009; Matthias et al., 2010).

International conventions (e.g. International Convention for the Prevention of Pollution from Ships) are a traditional way to tackle these environmental impacts. Similarly, private actors increasingly participate in maritime environmental policy making processes (van Leeuwen, 2010). As result, shipping firms tend to adopt voluntary environmental programs—as complementary to environmental regulatory compliance (Wuisan et al., 2012). These combined approaches push forward green shipping practices within the sector. These practices challenge inefficient technology and push firms to retrofit fleets with cleaner technology (Lai et al., 2010). Cleaner technology retrofit is a wide concept that may cover incremental improvements to existing ships. Examples of retrofit are the inclusion of air pollution prevention equipment (e.g. scrubbers, selective catalytic reduction), the use of alternative fuels (e.g. Liquefied Natural Gas, Methanol, etc...) or improvements in the ship hull and propellers (Köhler, 2011).

Innovation and diffusion of cleaner technology in the shipping industry are complex process involving many actors and levels. The process is constrained by costs, learning, iterative improvements on the new technology and changes in the population of (potential) users. Kemp and Volpi (2008) classify these causes in endogenous and exogenous causes. Research on endogenous causes is dominated by management and organizational-oriented research. Exogenous aspects require a broader institutional and market analysis. In fact, a recent research review of cleaner technology makes an explicit call for research on exogenous aspects driving cleaner technology adoption (Montalvo and Kemp, 2008) (see also section 3.2).

Exogenous aspects are increasing focus of attention in the research field of sustainable transitions research agenda (STRN, 2010). Innovation and diffusion of the technology is according to this research tradition, not only the result of market dynamics, but also the influence of socio-technical systems and the governance systems (Grin et al., 2010). The socio-technical system implies different levels of governance and interaction of stakeholders; with a strong mediation by routines, formal and informal rules (Geels, 2011).

The multi-level perspective on socio-technological transitions (MLP) and governance forms are reflected in newer studies on global governance and studies of socio-technological system. This article combines both streams of research with a special emphasis on different analytical levels of aggregation: landscapes (macro), regimes (meso) and niches (micro). These levels evolve and interact over time and these interactions help to explain change of socio-technology and forms of governance (Geels, 2002). The use of the MLP framework opens up for understanding how different combinations of relations between the different forms of governance can create windows of opportunities for certain socio-technological transitions (Geels and Schot, 2007). Niches differentiate from the regime on the stability and the size of the networked actors involved. They are spaces of protection against selection pressures from the regime (Smith and Raven, 2012). From this definition, niches could be spaces of experimentation not only for cleaner technologies, but also for innovative ways of social organization and learning (Bulkeley and Castán Broto, 2012).

The aim of the paper is twofold: In the first place, it improves the understanding of how the shift from government to governance creates niches where actors create cleaner technologies. In the second place, it analyzes how niche governance functions as hubs for cleaner technologies in the shipping industry. The article analyzes innovative cleaner retrofitting technology and governance forms in the shipping industry. The article's contention is that partnerships (as experimental governance form) help to foster the niches creating innovative cleaner technologies. These partnerships create spaces for collaboration and synergies between the multiple actors in the shipping network, and in this way improve the number and variations of cleaner technology solutions.

The paper is structured in five sections. Section two discusses the methodological approach. Section three presents the analytical framework, which combines and integrates theories of governance and transitions to a new framework for understanding the role of governance in creating protected spaces for innovation and diffusion of cleaner technologies. Section four describes the context for innovation and diffusion of cleaner technologies with special focus on the global development in the maritime sector and the global regulation of environment. The fifth section analyses how different partnerships are established in the Danish shipping industry. Similarly, it analyses how these partnerships are formed by constellations of stakeholders with different roles and forms of governance. The analysis is based on a case study of the government initiated Danish partnership for cleaner technology", then it links to the partnership "Green Ship of the Future" which is dominated by private firms. The article concludes with a discussion of how different actors play an active role in establishing partnerships and networks for cleaner technologies. The discussion also highlights how these partnerships and their forms of governance create protected spaces for innovation and diffusion of cleaner technologies and how the influence the path creation of cleaner technology.

2 Methodological framework and materials

The analytical framework combines theories of global governance and socio-technological innovations. Its purpose being to explain how the shift in governance forms can support creation of protected spaces for innovation and diffusion of cleaner technology. The key concepts explain the shift from government to governance; the different forms of governance and the role of stakeholders and how the different forms of partnerships create protected spaces for innovation and diffusion.

The article focuses on a single case study: the Danish partnership for cleaner shipping. To select this case, the authors looked for a paradigmatic-case study (Flyvbjerg, 2006): one that could provide insights on how governance promotes cleantech innovations in the shipping industry. In addition, a geographical focus is on countries located around the Baltic Sea and the North Sea. The International Maritime Organization (IMO) designated these seas as Sulphur Emission Control Area (SECAs). The survey highlighted different national initiatives of maritime cleantech development. But these reduced to those incorporating both private and public partners. At the same time, the project should comprise cleaner technologies development and testing. A first assessment, shown that only two countries within the North Sea/ Baltic SECA do have projects of this type: Sweden (Effship) and Denmark. Denmark was chosen because the higher possibility to carry participant observation (with more regular meetings with project partners). The case study expands with statistics the shipping leading character of the Danish maritime industry. After narrowing the country, the authors carried an assessment of different critical niche initiatives of marine cleaner technology development and diffusion. The assessment shown that two other initiatives take place besides the Danish partnership for cleaner shipping: the Green Ship of the Future and the Retrofitting Project. These initiatives have also links with regulation induced cleaner technology diffusion.

Empirical evidence

Three qualitative methods used so far are: participant observation, document review and in-depth interviews. The contextual analysis (Sections 4.1 and 4.2) was informed by document review and participant observation. Appendix A presents a list of specialized documentation reviewed. Besides, the main author is participant observer in the Maritime Center for Operations and Development (Denmark)¹ and two European Union Interreg IVA/ IVB projects dealing with Cleaner Maritime Transportation in the North and Baltic Seas: the project MARKIS². All authors participate in the Interreg IVB project SAIL (Sustainable Approaches and Innovative Liaisons). The information in this section was triangulated with coded material from in-depth interviews with European maritime stakeholders at the government, research and private sectors (Appendix B.1).

Section 4.3 is work in progress and is mainly based in contrasting document review with in-depth interviews. By the submission date of this paper, the interviews were planned but not carried out. However, Appendix B.2 provides a list of the planned interviews to triangulate information in this section. Although the collection of empirical evidence started in December 2011, it is work in progress by the date of presenting this communication. Therefore, the results and the discussion thereon should be considered as "preliminary".

3 Governance and socio-technical systems.

The theoretical framework is based on the theories of government and governance inspired from the literature on environmental global governance. These are combined with the theories of socio-technological transformation and its focus on the importance of protected spaces as arenas for innovation and diffusion of cleaner technologies. The first part focuses on key concepts from theories of global governance. It firstly

¹ www.marcod.dk

² www.markis.eu

explains the shift from government to governance. It then explains the different forms of governance and how stakeholders integrate in the governance process.

The second part addresses the different forms for government. It then analyses how governance forms as partnerships and networks create space for innovation and experiments, which break with the existing routines and rules for development of cleaner technology. In this process, the concepts of niche and socio-technological regimes play an important role for understanding the dynamic role of protected innovations spaces.

3.1 Governance

The shift from government to governance plays an important role by reducing environmental effects of production and transport as well as by stimulating innovation and diffusion of cleaner technologies, business models and behavior. Governance can take many forms, which will have effects on the direction and the content of technological innovation. This analysis focuses on how different forms of governance create different paths of cleaner technology by studying the Danish partnership for clean shipping.

The Danish partnership for clean shipping is a strategic partnership with a potentially long term perspective and focus on efforts to reduce air pollution from shipping³. The concept of governance is elaborated in order to understand in order to understand the involvement and role of actors in the different forms of governance (partnership) and the way they interact.

Governance is a concept, which is widely used. Common for most understandings of the concept is a change in the role of the state as well as none state actors. Benz (2004: 25 in Treib et al. 2007) identifies the core meaning of governance as steering and coordination of interdependent actors based on institutionalized rule systems. Based on this definition, Treib et al. (2007, pp. 3-4) distinguish three understandings of the concept of governance depending on whether governance is seen as belonging to primarily the realms of politics, polity or policy. Governance relates to the politics dimension, if the focus is put on the actor constellation and power relation between political actors (Treib et al. 2007, 3). Rhodes (1997) uses the term governance to describe a process of policy formulation in which state actors share power with private actors (non-state actors) (Rhodes (1997) in Treib et al. 2007). Policy formulation takes place within inter-organizational networks characterized by interdependence and resource exchange. The relationship between public and private actors in the process of policy making is one crucial criterion to define governance (Treib et al. 2007: 3). Following Mayntz (2004), governance can be conceived of as a system of rules that shapes the actions of social actors. Different modes of governance are situated on a spectrum that is delineated by the two opposing ideal types of "market" and "hierarchy" (Treib et al. 2007). Between these two types, further modes of governance can be identified, such as "community", "associations" and "networks" (Schneider and Kenis (1996) in Treib et al. 2007). Finally, governance can also be regarded as a mode of political steering, i.e. by means of policy instruments. This is the policy dimension of governance (Treib et al., 2007). Figure 1 gives an overview of the different approaches to governance according to whether they highlight elements of politics, polity or policy dimensions.

Contrary to road transportation, environmental regulation is rather an international endeavor in the shipping industry. Rules to control pollution must be negotiated at the IMO by member states. The negotiations usually extend for many years, and the outcome should derive from agreements satisfying varying member states' expectations (Hjelle, 2010). Environmental protection under IMO is grouped in conventions. The two most important being the International Convention for the Prevention of Pollution From Ships (MARPOL) and the Ballast Water Management convention. MARPOL was originally ratified in 1973 and is currently into force. The Ballast Water Management convention has not yet entered into force. It will enter into force

³ http://www.ecoinnovation.dk/English/Topics/Public_private_partnerships/Shipping/

12 months after at least countries representing 30% of the world tonnage have signed and ratified the convention. As for July 2012 only states representing 27% of the world tonnage have done so.

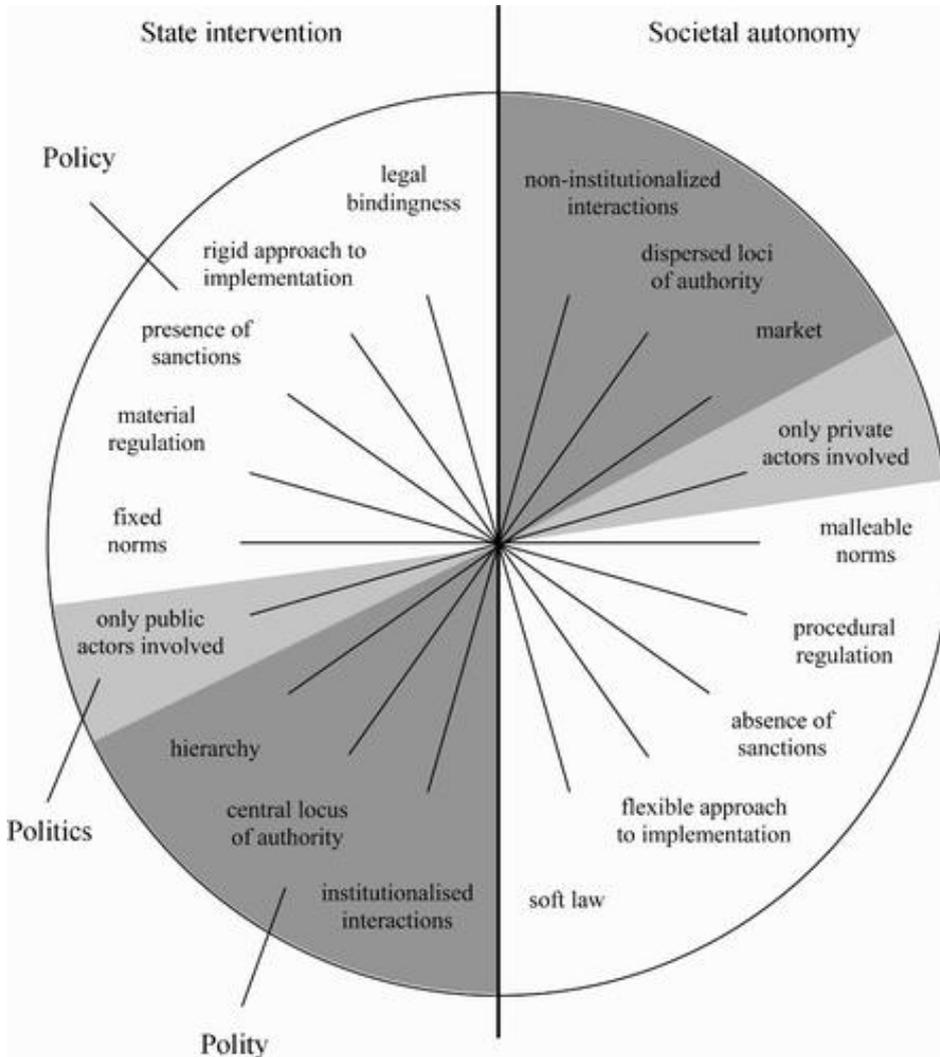


Figure 1. Existing conceptions of mode of governance. Source: Treib et al. 2007, 6

The different modes of governance determine the role of actors in partnerships and networks. This will influence both direction and content of cleaner technology innovations and possibilities for diffusion in the shipping sector. It is therefore important to analyze which actors get involved and how this affects the cleaner technology diffusion within the niche (or related networks and partnerships).

3.2 Governance as experimental spaces.

The different forms of governance influence how actors interact and the direction and the radicalness of cleaner technology solutions.

The different governance forms can be seen as arenas for change where the actors can experiment with new forms of technologies and ways of organizing. In these protected spaces actors collaborate and negotiate on designing solutions and technologies, which are not possible inside the dominating regime of production and regulation. The theory of socio-technological transitions explains the dynamics of creating protected spaces for new solutions.

The importance of protected arenas for experimenting with new technology is emphasized in the MLP framework of transitions. MLP integrates exogenous elements influencing cleaner technology diffusion (see also section 1). Montalvo and Kemp (2008) define exogenous elements as factors out of the control of an organization: market conditions, regulations, competition, technology push, etc. The levels represent two things: in the first place, the stability of formal and informal rules (herewith institutions on its normative, regulative and cognitive pillars). Second, they represent the extension of the network of stakeholders working in a particular direction (Geels and Kemp, 2007).

Niches are considered here as protection and empowerment “spaces” –in this case cleantech innovations- against the selection pressures of the regime. The selection pressures are: industry routines, technical standards, formalize research programs or research associations/ paradigms, user practices, market rules, media laws, etc. The “protection” can take place in different forms: subsidies, projects and strategic alliances between supply and demand (Smith and Raven, 2012). An important element of the niches are the actors participating as users or producers, these actors could behave in different ways as the regime actors – although some research claims that the regime and niche actors can be the same. In such cases, these actors are prone that technology to be developed/tested in the niche (Smith et al., 2010).

Cleaner technology innovations must face important barriers of introduction and subsequent diffusion (Kemp and Volpi, 2008). These barriers are partly set by routines and the selection aspects from the regime. Niches are unique spaces of interaction between incumbent and small innovative firms. In the environmental innovation literature, it is argued that small firms are important drivers of innovation and entrepreneurship (Hockerts and Wüstenhagen, 2010).

A regime can be understood as a larger network of actors than the niche, including incumbent actors that usually may not take part of a given niche- (Geels and Kemp, 2007). But a regime can also contain the codified formal and informal rules that actors at the regime and niche levels reproduce. This reproduction is at the same time reflected in certain socio technological trajectories that define path dependent socio-technological choices (Geels, 2011). The combination of actors and rules enhance the stability of the whole socio-technological system (Geels, 2002).

Landscape comprises societal values, macro-economic patters, demography and the like. In fact, recent research has modified this earlier understanding of landscapes as static elements. Instead, landscape dynamics can have an influence on the regime stability. Strategic decision making in certain socio-technological regimes can be influenced by market and regulatory signals originating at the landscape and creating windows of opportunities to certain cleantech (Berkhout et al., 2004). Cleaner technologies niche can exploit these windows of opportunities.

By combining the theory of governance with MLP it is possible to understand governance in form of partnerships and networks as key arenas for developing protected spaces. In these protected spaces, actors can collaborate on creating cleaner technologies outside dominating regimes of competition and regulation. These protected spaces take different forms depending on: which actors initiate the partnerships, what role have the partnership's actors, and how these different characteristics of governance forms influence the direction and the grade of innovation.

4 Results and discussion: Partnership for cleaner shipping

This section presents the case study. Firstly, it analyzes the context conditions affecting the shipping industry (Section 4.1). Part of this context involves increasing attention to environmental aspects of shipping, and as example air pollution regulation frames large part of these concerns (Section 4.2). The Danish partnership for cleaner shipping is later described, with a focus on stakeholders involved, actions and motivational drivers (Section 4.3).

4.1 Context of international and European shipping industry

As an economic activity, shipping keeps a steady growth in number of tonnage, volume and containers transported every year. Commodity trade volume increased in 5277 million loaded tons between 1970 and 2009 for three main shipment categories -oil, main bulks and dry cargo- (UNCTAD, 2010). Besides liquid and solid commodities, seaborne containerized transportation is one of the pillars of globalization. According to Fremont and Soppe (2005), between 1950 and 2002 the volume of maritime trade has growth on 4,5% per annum.

Despite such historical growth figures, financial crisis affect the maritime industry. The contemporary financial crisis entails various impacts to the sector. From the one side, the demand for shipping services has curved down due to decrease in consumption. Traditional liner curves –e.g. Asia- Europe have therefore redefined routes. An overcapacity of tonnage is also linked to the lowest demand in shipping services. Major liners have since 2008 opt to decrease their fleet capacity, with extreme cases being APL (-19,9%) or MISC (-27,2%). At the moment of the crisis broke-up in 2008, many shipping firms had already requested new buildings in shipyards. According to Slack's calculations in the following years, around 5000 TEUs will be added to the market every year (Slack, 2010).

Fuel prices increase as well, and the shipping firms operating costs add an extra burden to the market shrinking. In particular, most short and deep sea vessels have engines running with Heavy Fuel Oils (HFO). According to Notteboom and Vernimmen (2009), HFO prices have increased in all major ports, with some few extreme cases in European harbors (between 2001 and 2007): Rotterdam +335%, Genoa +297%. Increases in HFO prices, entails consequences on the market. Hitherto, the location of productions facilities was driven by the costs of the working force. Transport costs where the least important cost. However, with the increase of the transport costs, the tendency is to relocate production closer to the consumption heavens.

The third important aspect shaping the shipping industry is the societal awareness on environmental impacts from the industry. From the one side, a focus has traditionally be the impact of shipping at ports and harbors. Different publications compile different aspects of the activity into the environment. In particular: air, water and sediment pollution. Air pollutants results from the combustion of HFOs and other distillate fuels, while shore water receipts ballast and bilge discharges from stationary vessels (Gollasch et al., 2007, Ng and Song, 2010). Given that several harbors are located beneath, or even in the middle of urban areas, the shipping activity thus impacts the human health (Perez et al., 2009). Respiratory diseases result from Sulphate Oxides (SO_x), Particulate Matter (PM) or Volatile Organic Compounds (VOCs) originated from marine fuels (Bailey and Solomon, 2004). Yet, recent research has pointed out the extent of the pollution burden of the shipping activity to regional and –even global levels-. Matthias et al. (2010) concludes that routine vessel operations along the shores of the North Sea are the second cause of inorganic aerosol formation (SO₂ and NO₂). Stationary clouds of these particles move inland and entailing diverse impacts to the health and to the environment.

4.2 Air pollution regulation from maritime activities

Discussions within the IMO started in the late 1980s with the aim to include air pollution within MARPOL. The goal was to control SO_x and NO_x emissions that entailed health and environmental hazards in coastal areas with dense maritime traffic. By 2007, both pollutants were finally integrated into MARPOL annex VI (IMO, 2009). Annex VI sets limits to the sulphur content in marine fuels, and also set limits to the NO_x emissions by marine engines. A 2008 amendment also included alternative means of compliance to the sulphur content in fuels –e.g. end of pipe technology to capture sulphur from engine emissions. Concerning both pollutants: sulphur and NO_x, pollution limits are gradual and limited to the Emission Control Areas (ECAs). Two Sulphur ECAs (SECAS) are currently in place: since 2010 the North Sea, English Channel and Baltic Sea SECA. The second SECA starts in August 2012 around North America (200 nautical miles off the coast).

Inside SECAs, maximum Sulphur content is 1,0% by mass since July 1st 2010. This minimum will be decreased to 0,1 % on January 1st 2015. Outside SECAs, the minimum is decreased to 4,5 % until January 1st 2012, 3,5% until January 1st 2015 and below 0,5 % after 2020. In case of non-availability of low sulphur fuels, vessels can rely on alternative means of compliance. So far, these means of compliance are end of pipe technology like exhaust gas-cleaning systems. Similarly, other technological options prompt for the use of alternative fuels like Liquefied Natural Gas (LNG) (European Commission, 2011).

There are some differences between sulphur limits and NOx emissions limits. From the one side, NOx limits apply to engines in newly build vessels –and not to vessels in operation as the sulphur regulation. On the other hand NOx emissions are so far not controlled by ECAs –although negotiations are on the way to establish them. A three-tier approach mainly drives compliance to the limits set by IMO. The equations to calculate the NOx limits are set by IMO (2009). Campling et al. (2010) list the different technologies in development to comply with NOx requirements. These technologies can be grouped in three categories: first, engine modifications; second, alternative fuels and propulsion; and end of pipe technology. Engine modifications are rather a responsibility from the engine manufacturers.

National authorities have to enforce IMO regulations. At European level, the European Commission has the responsibility to homogenize the application of IMO rules among member states. The purpose being to avoid competition distortion: the proximity of ports makes it a requirement that fair conditions apply to the different EU member states. Directive 2005/33/EC (EU Sulphur Directive) replicates the provisions of MARPOL Annex VI into EU legislation. It stipulates the creation of a SECA in the Baltic Sea (August 2006) and the North Sea and English Channel SECA (August 2007). In addition to IMO rules, the Directive sets limits to the fuel's sulphur burnt at berth (maximum sulphur content of 0,1%) from the 01 January 2010. Directive 2005/33/EC is currently being amendment at the request of the EU Directorate General Environment. The purpose being to integrate the provisions of MARPOL Annex VI as modified in 2008. In particular, key elements of the amendments are: setting limits for the sulphur content of marine fuels –in the SECAs the same as MARPOL Annex VI. Agreement that member states shall provide aid for investment costs –to overcome competitiveness issues among shipping firms (European Council, 2012). The amendment process has been arena of fierce negotiations among European shipping stakeholders. Central stakeholders in this process were ship-owners associations, from the one side; environmentalist associations and the EU Commission on the other side. Ship-owners consider that the tighten regulations in the SECAs will increase shipping firms operating costs, and possibly part of the business will move to a land-based transportation. In the middle different marine equipment suppliers and shipyards foresee interesting business opportunities arising from the regulatory changes.

4.3 Danish Partnership for cleaner shipping

The Danish partnership for cleaner shipping is a partnership between the Danish Environmental Protection Agency and the Danish Ship owners' Association, which aims to reduce air pollution by shipping in Denmark and worldwide (Danish Ministry of the Environment, 2012). The Environmental Protection Agency and The Danish Ship owners Association wish to promote cleaner shipping though action aimed at (Danish Ministry of the Environment, 2012):

- Focusing attention on the importance of reducing air pollution from shipping by promoting awareness of the new regulations passed by the IMO
- Ensuring the visibility of these measures,
- Promoting innovative frameworks for environmental/technological development so that the requirements can be fulfilled and participants.

4.3.1 The blue Denmark: an overview of the Danish shipping industry

This section contextualizes the importance of the Danish shipping industry into a global/ European setting. Shipping stakeholders are a focus of attention, including their relations with external stakeholders.

As Figure 2 presents, the Danish shipping industry is part of a complex system in which the flow of products and services is not constrained to specific countries. The system connects a complex network of subsidiaries, suppliers and customers. Taking as basis Dicken's production circuit model (2011), the four stages highlight this sector: inputs, service provision, distribution and consumption. Freight transport is a goal of the service provided within this system. Shipping lines are service providers; while ship-owners may be sub-suppliers to these shipping lines or provide the service themselves. They both own or lease different kinds of vessels, which are subsequently used for the service. Vessels are main assets, which are constantly upgraded (either by maintenance or by having new additions to the fleet).

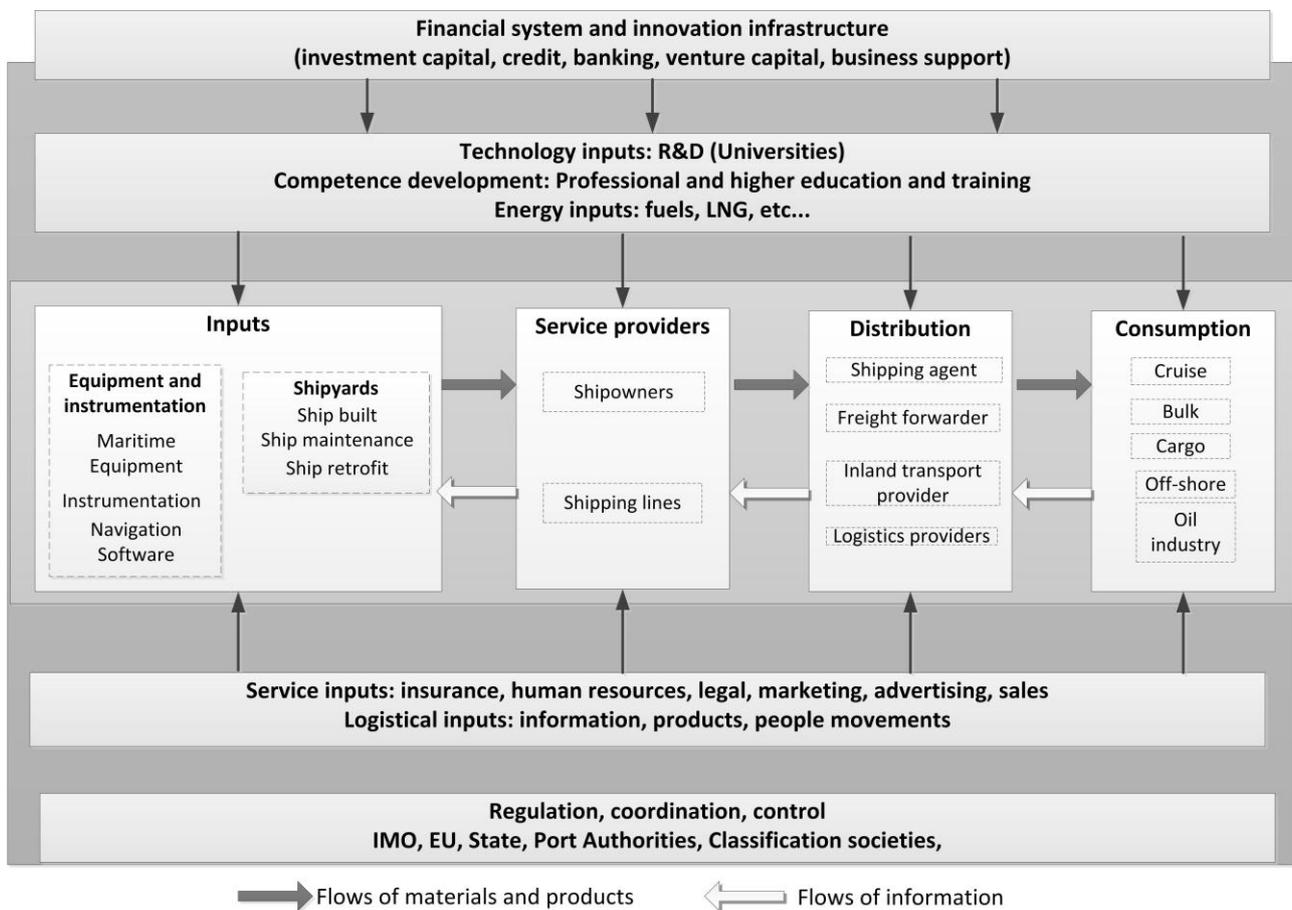


Figure 2- Circuits of materials, products and information in the Danish shipping industry. Adapted from: (Dicken, 2011, DMA, 2006, Fremont, 2009, Köhler, 2011)

In Denmark, Shipping lines have a strong influence in the dynamics of the local shipping system: as for July 2011, the Danish container fleet ranked first worldwide (22 006 GT out of 166 716 GT). Danish tankers' fleet ranked sixth (15 144 GT out of 319 742 GT), and the dry bulk fleet ranked 13th (6 473 GT out of 321 554 GT⁴). Roughly speaking, Danish shipping firms own 3% of the world tonnage, 5% of the world tonnage if chartered vessels are counted. In addition, Danish shipping companies transported 10% of the world trade. At EU level, Denmark ranks seventh in terms of merchant fleet tonnage with 11 319 thousand GT (out of 192 261 thousands GT) (Danish Shipowners' Association, 2011a).

⁴ These figures represent shall be multiplied by 1000 GT.

Shipping lines may require equipment to continuously improve the performance of their fleet. Maritime equipment manufacturers and shipyards provide ship-owners or shipping lines with different services. These services may range from retrofitting –upgrading existing vessels with new or improved equipment- to new builds. Alliances among these actors are at the core of the system: equipment manufacturers become suppliers of shipyards, while at the same time these are suppliers of shipping lines or ship-owners.

At the right of the figure, another set of stakeholders enter into the business: distribution agents. They are intermediary between customers requiring freight transport and service providers. Distribution agents can be different specialized companies: freight forwarders, inland transport providers, logistics providers. Similarly, some shipping firms increasingly take this role (Fremont, 2009). The demand side is composed by companies requiring transportation services. Almost any firm involved in commercial activities may be an user in any or other form. Generally speaking, users request services of transportations to a shipping agency.

The industry requires technology, competence and service inputs. R&D on marine equipment and freight optimization is performed by universities and specialized centers. Professional and higher education centers provide seafarers education and build competences on incoming technologies. A network of actors manages the infrastructure to bunker vessels at shores.

Regulation and control sets the standards for the different activities taking within the system. At an international level, this is done through the International Maritime Organization (IMO), or the European Union (for European Waters). These international agencies approve conventions and directives that each State is set to translate into national legislation. It is the task of port authorities to enforce the different conventions. Similarly, classification societies certify that any vessel complies with safety standards.

4.3.2 Interactions between maritime stakeholders: green ship of the future

Danish shipping stakeholders have launched common initiatives. These initiatives go further than merely market motivated interactions. One of these initiatives is the Green ship of the Future (GSF). Since 2008, the GSF is a public private partnership integrated by around 40 Danish marine equipment and service providers and major shipping firms. The partnership's most important aim is to reduce air pollutants from shipping. GSF targets the following reductions for new buildings –as compared to the 2007 average fleet (Schack, 2009):

- 30% reduction of CO₂ emissions
- 90% reduction of NO_x emissions
- 90% reduction SO_x emissions

Partners' interact through project development and external communication. Common business interest is the main driver for interactions among partners. Project partners joint together in topic-based groups, from there on, they prepare common projects (partner projects) which are subsequently presented as either prototypes or reports. So far, topic based groups are: novel ship design, on board systems/ systems integration and alternative fuels.

These topic based groups have organized 20 projects (13 related to machinery improvement, five related to operation and two for propulsion). Only three projects are still on-going. Most of the projects in machinery improvement seek to improve combustion process. In this way, such pollutants as NO_x can be reduced. Projects in the area of operation seek to reduce fuel consumption, and thus reduce the release of CO₂ and SO_x.

4.3.3 Shipping and the Danish action plan to promote eco-efficient technology

The Danish government has also prioritized the promotion of cleaner technology in the shipping industry in addition to private-driven programs, such as the GSF. At top policy level, this interest is expressed in the 2010 maritime strategy (DMA, 2010). Chapter 2 emphasizes the commitments to reduce greenhouse gas and air pollution from the Danish shipping industry. In particular, partnerships with stakeholders are considered as a top strategy to reduce air pollution:

The government will intensify the efforts made to reduce air pollution from shipping in close partnerships with the shipping industry and manufacturers of environmental engineering solutions, cf. the Action plan on cleaner shipping for 2010-2011 (DMA, 2010)

Besides the maritime strategy, another government action plan seeks to develop and diffuse cleaner technology in the shipping industry: the government's action plan for promoting eco-efficient technology. The plan create framework conditions for private firms developing and diffusing environmental technology. For this reason, the plan is not exclusive to marine technology. It is part of a broader government policy to prioritize green technology funding and research. The eco-efficient technology plan works in three areas (MST, 2010):

- Status of regulations that may create business opportunities for Danish green technology
- Strategic partnerships
- Public sector procurement policies

The plan was originally drafted by the Environmental Protection Agency in 2006. The first version was a green paper for politicians, describing the economic growth possibilities in the green technology domain. A first part of the action plan lasted between 2007 and 2009. The second version comprised two years: 2010 and 2011. The plan includes the "partnership for cleaner shipping". It is steered by the Danish Environmental Protection Agency and the Danish Ship owners' Association. The partnership's main objective is to develop and diffuse technology to comply with air pollution regulations by MARPOL and the EU.

Hitherto, the Partnership has funded five projects. Figure 4 summarizes the different projects funded hitherto.

Project name	Partners	Objective
NOx reduction/ Low NOx ventilation motor	MAN Diesel	10 to 20 % reduction in NOx emissions. 25-50% PM reduction
Reduction of SOx emissions/ development of a scrubber	Alfa-Laval Aalborg DFDS MAN Diesel	Development, installation and testing of a Scrubber on a DFDS Ro-Ro vessel
Selective Catalyst Reduction (SCR) system/ auxiliary engine	CATCON/ Haldor Topsøe/ Bornholmtrafikken	Adapting a SCR system to a vessel. Technical inspiration from the car industry
Development and standardization of a SCR system for vessels	RM Staal	
Development of PM filter for vessel engines	Teknologisk Institut Dinex A/S Ærøfærgerne A/S	

Figure 3 - Supported projects by the Danish partnership for cleaner shipping. *Source:* (Danish Shipowners' Association, 2011b)

5 Conclusions

The article departed with the research question: "How can governance promote cleaner technology innovation in the shipping industry?" To answer this question, the article presented a framework by combining theories of governance with theories of transition. This framework produced concepts as partnerships or protected spaces for experimental innovations. The concepts helped identify and evaluate the role of partnerships and networks in creation and direction of cleaner technologies in the Danish shipping industry with special focus on the Danish "partnership for cleaner shipping".

Governance is a widely used concept in the literature of environmental regulation and transition. However, only few articles have tried to integrate the concept of governance into a framework of innovation experiments (Bulkeley et al., 2012) Inspired by Bulkeley et al. we have identified partnerships and networks as protected spaces.

The Danish partnership for cleaner shipping was initiated by the Danish Environmental Protection Agency in collaboration with the Danish Ship owners' Association. It is a strategic public-private partnership with the aim – among other things – to influence international regulations (e.g. regulations for the emission of NO_x and SO_x particles from ships). This partnership is linked to other forms of private-driven partnerships as "The Green Ship of the Future". The cooperation intra and inter partnerships improves private firms and public authority's position in international negotiations on environmental aspects of shipping in the future.

Therefore, it can be concluded that the environmental governance is a complex process of interaction between state actors (the Danish Environmental Protection Agency) and non-state actors (the Danish Ship owners Association), where some partnerships are set up and organized by different modes of interaction between private and state actors. The analysis also indicates that the role of private actors is increasing, and private actors are more active in setting up and forming the modes of governance in partnerships and networks. Besides, it is expected that a number of other actors also will be included in the work, for example NGOs and relevant research institutions (MST, 2012). By this, governance will belong to the realm of polity as well: being in between "market" and "hierarchy".

Marine cleaner technology comprises both end-of pipe pollution reduction equipment and improved engines –with lower fuel consumption and pollutant release. In sectors as the maritime, end of pipe technologies play an important role in the development of cleaner technologies. It is important to develop protected spaces where actors have possibilities to experiment and collaborate with technologies, in this way it is possible to develop and diffuse new environmental technologies.

Changes in the economic and regulatory landscape create challenges and opportunities for innovation and diffusion of environmental technologies and solutions in the shipping industry. Partnerships and networks had been initiated by both public and private actors, which had created different forms of collaborative partnerships: "Partnerships for cleaner shipping" and the "Green ship of the future". The characteristics of these partnerships have consequences in the development and diffusion of marine cleaner technology. In particular, one important characteristic is the role of the different actors and the forms of governance. This adds to the debate of the initial interests and the end consequences when selecting a cleaner technology. In particular, the drives for adoption may be linked to the interest to yield a better fuel consumption performance, while disregarding secondary environmental improvement objectives.

The article argued that partnerships incorporating different actors: end-users, developers, suppliers and public institutions and authorities help to foster innovation and diffusion of cleaner technologies. The case study did not allow generalizing about the effects on the direction and grade of innovativeness. Further, the followed approach did not allow tracking the innovation and diffusion of a specific cleaner technology. Yet, it is possible to conclude that both private and public actors play an important role in building and governing niche-level partnerships, which can facilitate synergies between developers, suppliers and users, and in this way reduce some scale-up barriers for the technologies in question.

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7 Appendix A: Documents reviewed

Stakeholder	Document type
European Commission	Commissioned studies Directives Directive Amendments Green papers
International Maritime Organization	MARPOL Convention MEPC communications
Classification societies	Maritime environmental regulation databases Pollution prevention/control documentation
Danish Shipowners Association	Commissioned studies Position papers
OECD Two major European Shipping firms	Public presentations/ shipbuilding industry Environmental policies Public presentations/ cleaner shipping
NGO	Public presentations/ cleaner shipping Commissioned studies
Interreg projects (MARKIS, Clean North Sea, SKEMA) European Marine Equipment Council; European Shipyard association	Working papers Project description Catalogue Position papers

8 Appendix B: List of interviews

B.1 Interviews to build evidence on the contextual conditions

#	Date	Organization	Type	Name interviewee	Location
1	07-12-2011	Danish Environmental Protection Agency- Environmental technology		Mariane T. Hounum	Copenhagen
2	23-01-2012	Danish Environmental Protection Agency-Eco-innovation project shipping		Jesper Stubkjær	Copenhagen
3	23-01-2012		Shipowners' Association		Copenhagen
4	10-02-2012	Danish Maritime Authority			Copenhagen
5	02-03-2012		European Shipowners' Association		Brussels
6	29-02-2012	European Commission	Regulators		Brussels
7	29-02-2012	European Commission	Regulators		Brussels

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8	01-03-2012		National ship-owners association		Brussels
9	01-03-2012	EU Parliament	Envi-Commission	MEP Satu Hassi	Brussels

B.2 Planned interviews to expand case study

#	Date	Organization	Type	Name interviewee	Location
1	October 2012	MAN Diesel	Equipment manufacturer		Copenhagen
2	October 2012	Alfa Laval-Aalborg	Equipment manufacturer		Aalborg
3	October 2012	CATCON/ Haldor			
4	October 2012	DFDS	Ship-owner-demand side		Copenhagen
