TITLE: Sustainability transitions in shipping and the role of LNG as a ship fuel- A comparative analysis of the Netherlands and eastern Baltic (FIRST DRAFT)

ABSTRACT
LNG has been used as a marine fuel in the LNG carrier industry for decades, but over the past 20 years it has been used in the wider maritime industry as well. This process has started in Norway in 2000 in the shortsea ferry industry, and has since most prominently spread within the ferry and shortsea industries in the Baltic and North Sea areas, driven primarily by financial support and emissions regulations. However, the unique set of local drivers that has affected the pace of LNG developments in different parts of northern and western Europe have not been studied in specific detail. This study uses a combination of interviews with key stakeholders in the east Baltic and Netherlands, in combination with documentary content analysis to shed new light on the historical development of LNG as a ship fuel in these two distinct regions. A comparative case study analysis is applied to understand the difference in local circumstances that have supported/inhibited the spread of LNG. The analysis shows that beyond regulatory and price incentives, agency of small local ship-owners and unique local environmental concerns played a key role in the spread of LNG as a ship fuel. The differences and similarity between eastern Baltic (Estonia and Finland) and the Netherlands in use and adoption of LNG in their respective fleets, helps to inform the wider role that localities can play in sustainability transitions in shipping.

Keywords: LNG as a ship fuel, Finland, Estonia, Netherlands, 'technology advocates', protective spaces, niches, sustainability transitions

List of abbreviations:
BOG-Boil-Off Gas
DF- Dual Fuel
ECA- Emission Control Area
IMO- International Maritime Organization
HFO- Heavy Fuel Oil
LNG- Liquefied Natural Gas
MARPOL- International Convention for the Prevention of Pollution from Ships
NOx-Nitrogen Oxides
PSV-Platform Supply Vessel
SOx-Sulphur Oxides

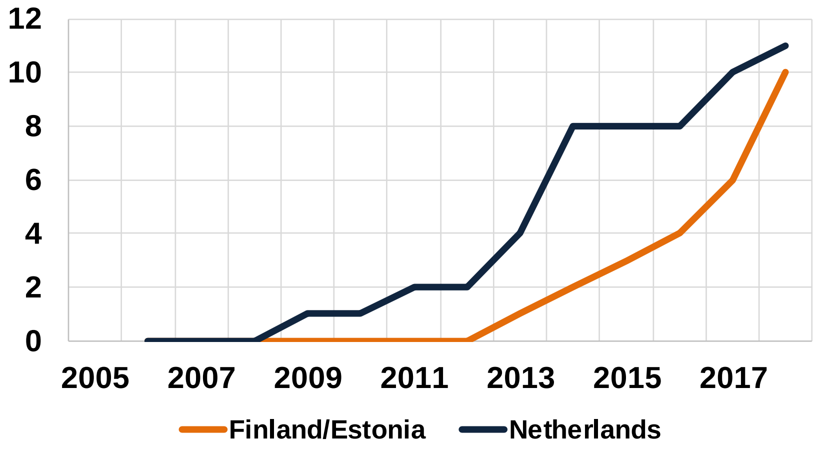
1. INTRODUCTION

Liquefied Natural Gas (LNG) has been used as a marine fuel for decades within the LNG carrier industry in the form of boil-of gas (BOG) in steam turbine engines (MAN, 2013). A significant change happened in the 1990s and 2000s with technological advances by companies such as Wartsila in DF engine technologies, that have, due to their higher energy efficiency almost completely phased out steam turbines in the LNG carrier industry (Wartsila, 2012). With growing concerns over coastal pollution from air emissions in northern Europe in the 1990s, and growing price of crude oil derivatives (distillate fuels and HFO), LNG was proposed as a potential alternative for the maritime transport industry outside of the LNG carrier sector (Burel et al, 2013). LNG, even though a fossil fuel, reduces harmful emissions of SOx and NOx by 95% and 85-90% respectively, compared to heavy fuel oil (HFO) (Herdzik, 2011).

This process initiated in Norway, but later spread through northern and western Europe. The Netherland and Finland/Estonia, both experienced part of this trend with the development of LNG import terminals, small scale bunkering infrastructure and take up of LNG by some LNG fuelled vessels (DNV GL, 2015). The late 2000s and early 2010s saw a rapid growth in the discussion of LNG, development of different legislation concerning marine and inland shipping applications of LNG and the first front-runners started appearing in both countries. Marine LNG continued to develop as a fuel option in both the Netherlands and Estonia/Finland, this development divergent in the two countries, with most of LNG fuelled ships in the Netherlands being LNG bunker barges and smalls scale LPG/LNG carriers whereas Finland/Estonia have seen a large diversification of LNG into large ferries, patrol vessels, ice-breakers and first containerships (DNV GL, 2015).

It seems that regulations on their own are not sufficient to explain these differences as both countries are part of ECA areas with the same regulatory incentives in place for SOx and NOx emissions. In addition, in both cases the main source of funding available for marine LNG projects seems to be EU finding through TEN-T and later CEF projects (Wang and Noteboom, 2014). There seems to be unique local geographical, and potentially unique local networks of technology advocates that have supported this divergent technology evolution (Kern et al, 2014). However, this is something that has not been researched in more detail, and questions remain around explaining how LNG actors shaped local spaces for technology deployment between these two separate regions.

Figure 1Total LNG flagged ships



**Based on documentary research, excludes conventional LNG carriers*

To be able to answer these questions, Strategic Niche Management (SNM) literature in the context of wider socio-technical transitions (Kern and Schot, 1998) is explored for a methodological framework to study the story of marine LNG development in the two relevant geographical areas (Netherlands vs Finland/Estonia). The relevant literature deals with the role of niches (or protective spaces) within wider sustainability transitions of complex systems (Raven, 2007; Schot and Geels, 2008; Smith et al.,2010). Niches are considered as 'protective spaces' shielded from the broader market where experimentation and development of new technologies can take place until they mature (Kemp et al, 1998). In this process, the role of technological advocacy (Raven, 2007) in shaping the development of the 'protective spaces' for technological developments and how these are shaped by wider socio-technical configurations plays an important role (Schot and Geels, 2008). Kern et al (2014) use the concepts developed by (Smith and Raven 2012) to further develop a conceptual framework to study the historical development of 'protective spaces' for offshore wind development (OSW) in the UK, in the context of 'technological advocacy' within this wider socio-technical context (Kern et al, 2014).

The methodological framework developed by Kern et al (2014) is used in this paper to answer the following two questions:

1. How did the creation and evolution of 'protective spaces' for marine LNG differ between Netherlands and Finland/Estonia?
2. How did these 'protective spaces' contribute to the observed difference in development of marine LNG between the Netherlands and Finland/Estonia?

In addition, to the role that different 'technology advocates' play in the development and maintenance of 'protective spaces' (Raven, 2007), an area of interest in this specific paper is the role of localities in shaping the development of protective spaces (Coenen et al, 2012). Some studies on development of technological niches do take a comparative analysis of protective space developments (between two nations (Bergek et al, 2003),(Mazur et al, 2014), this study tries to follow such a comparative approach in considering issues of unique local circumstances when analysing the two cases.

In addition, it must be stated that sustainability transitions in maritime transport are complex processes taking place at multiple levels of the industry (IMO, EU regulators, ship-owners, ship-charters, engine producers, fuel suppliers etc.) and in this process several different technological and operational approaches to making the industry more sustainable are taking place simultaneously

(Stopford, 2008). These include, but are not limited to, increasing ship energy efficiency, slow-steaming, other alternative fuels such as biofuels, battery-electric, hydrogen, improving ship operational efficiency and developing substitute power sources (Stopford, 2008). LNG is in many ways a transitional fuel, which tackles some of these issues such as SOx, and NOx emissions, but as a fossil fuel, still only marginally addresses the issue of GHG emissions from ships (Herdzik, 2011).

2. METHODOLOGY – STRATEGIC NICHE MANAGEMENT

2.1 NICHE AS A 'PROTECTED SPACE' – THE ANALYTICAL FRAMEWORK

The analytical framework this study is anchored in is the sustainability transitions literature, that deals with the reconfigurations of socio-technical systems towards more sustainable arrangements (Raven 2007, Smith et al, 2010). In this process, the idea of a niche of 'protected space' is fundamental, it is a place where a new technology can be shielded from the selective pressures present in the wider socio-technical regime, until the technology matures enough to become competitive or the regime itself is reconfigured (Raven, 2007). In this sense the 'protective space' allows time for the technology to mature, but also can contribute to wider changes in the wider 'socio technical regime' (Kemp et al 1998). The 'protected space' can be viewed as a specific niche that allows the new technology to grow, but also to develop new rules and ways of doing things that are separate from the wider socio-technical regime (Geels and Schot, 2007; Kemp et al., 1998) In this sense the regime can be defined as the stable configurations of certain relationships between different industry, regulatory, policy and technological actors, that are united together by certain views and visions (Schot and Geels 2008).

Expanding on sustainability transitions theory and drawing on work from Strategic Niche Management scholars (SNM) and amongst others the work by Rip and Kemp, 1998; Geels, 2002; Smith et al., 2010; a framework for the studying of 'protective spaces' or niches in their role in shielding path breaking innovations (Kemp et al 1998), was developed by Smith and Raven (2012). In their paper, Smith and Raven (2012) outline a framework in which 'protective space dynamics' or the creation and development of niches requires three functional properties with the context of socio-technical transitions, these being: shielding, nurturing and empowerment. These three processes are considered necessary for the development of healthy niches (Kern et al 2014) and have the following properties:

1. Shielding - defined as 'those processes that hold at bay certain selection pressures from mainstream selection environments' (Smith and Raven 2012). Shielding can be passive where technology promoters mobilize financial support from generic funding schemes, find customers willing to pay higher prices due to their environmental beliefs, mobilizing support from other groups and finding other pontifical customers. On the other hand, active shielding would involve specific schemes in place for the technology. Such as specific funding available for the niche technology, creation of technology incubator units within mother firms and specific lobbying for the technology in white papers or political forums.

2. Nurturing - niche nurturing per Smith and Raven (2012) and expanded from strategic niche management literature includes the development and assisting in learning processes, articulation of expectations and building of network processes. Learning processes are considered as helping in niche reinforcement and development when they cover many issues and include not only first order learning (accumulation of data), but also higher order learning (changes in cognitive frame and expectations) (Hoogma et al 2002). Expectations are considered to help niche development when they are robust, and of high quality and social networks are considered as being most successful when they have broad memberships and substantial commitment and resources (Schot and Geels 2008)

3. Empowering - is a process per Raven et al (2014) where niche representing actors mobilise resources in the wider social world for the purposes of building and expanding the niche. The empowering process can lead to the new socio-technical configuration of which the niche is part of- becoming more competitive under existing market rules (i.e. selective environment) (so called 'fit and conform') or where this technology selection environment is modified by the actors to be better able to accommodate the new niche with its associated socio-technical configuration ('stretch and transform').

2.2 METHDOOLOGY

In order to be able to study the processes outlined in the analytical framework, a case study approach is taken as being appropriate, it is an approach suggested for empirical research of sustainability transitions (Geels, 2011) and is of great use in describing complex and contemporary social phenomena that cannot be attributed to a single cause (Yin 1994). In this research paper the empirical approach developed by Kern et al (2014) to study offshore wind developments in the UK is taken as a methodological starting point. The work follows the analytical framework developed by Smith and Raven (2012) that was already used previously in the study of PV developments in the Netherlands (Verhees et al 2013) and UK (Smith et al, 2014). The same framework is applied to the case of LNG in the Netherlands and Finland/Estonia. The analysis is based on an analysis of relevant literature to LNG developments in the two regions (academic, policy papers, industry articles, shipowner association publications, media articles, policy documents). The analysis uses a process tracing approach to outline the main causal mechanisms relevant to the research questions (George and Bennet 2005). The documentary data was used to develop a picture of LNG developments in Netherlands and Finland/Estonia, this data was triangulated with data obtained from 11 stakeholder interviews conducted between May and July 2017 that further explores how different LNG processes and protective spaces developed over time. The interviews were transcribed and coded using a set of codes adapted from Kern et al (2014). The methodology was adapted to include a comparative case study approach as two unique cases were studied and the difference between them being the most important part of the research problem.

3. NETHERLANDS AND EASTERN BALTIC MARINE LNG DEVELOPMENTS – A SHORT HISTORY

3.1 NETHERLANDS

3.1(a) 1990s-2000s: Increased prominence of environmental issues and changing energy landscape

Environmental awareness in the Netherlands markedly increased over the 1990s. In 1988, the Dutch parliament adopted the National Environmental Policy Plan (NEPP), this processes seemed to stem from the growing concerns of increasing environmental degradation in the 1980s, the result was a ‘social contract’ that created a system of problem solving, based on collaborative effort between multiple stakeholders (de Jongh P.E., 1996). In 1987, at the North Sea Ministers Conference, driven by growing concerns of growing nutrient concentrations and their adverse effects on wildlife, agreed at a 50% reduction of emissions of nitrogen and phosphorus compared to 1985, a similar agreement was concluded for inland waterways through the plan of the International Commission for the Protection of the Rhine (Erisman et al, 2005).

At the same time, partially motivated by these developments, during, the 1990s, the Dutch shipping industry considerably changed with the growing need for fleet modernization (Peeters et al., 1994). During this period, Dutch shipping policy was becoming specifically concentrated around the Dutch maritime clusters (Chu-Hwan, 2006). The Netherlands has a sophisticated maritime cluster including shipbuilders, shipowners, operators, port authorities, equipment suppliers and other important stakeholders brought together around the Dutch Maritime Network. The network was created in 1997 to promote the maritime cluster and with the aim of creating an innovative and forward looking Dutch maritime industry (Janssens, 2006). The cluster is well known for its unique regionalization with a couple specifically strong sub-clusters, the largest of which is around the Port of Rotterdam (Langen, 2002).

3.1(b)2000s-2010s: Gate LNG import terminal opens and first movers use it in shipping

At the global level, air pollution from ships became more and more discussed from the late 1990s onwards. In 1997 MARPOL Annex 6 dealing with emissions of SOx, and NOx from ships was agreed upon. In 2005, it entered into force, and was later revised to include progressive reductions of SOx, NOx and particulate matter emissions in specific emission control areas, including the North Sea (IMO, 2015) thus providing an extra regulatory incentive for low sulphur fuels such as LNG in marine usage (Lloyd’s Register, 2012).

Within the Netherlands, the growth in natural gas prices and decreasing production of domestic gas led to the decision to build the Rotterdam Gate Terminal in 2005, originally built as an import terminal for LNG (Gate Terminal, 2007). In 2005, plans were announced for the planned construction of a second LNG terminal in Rotterdam by 4GAS, called the LionGas terminal, which were later cancelled in 2010, even though by 2006 a land use agreement was signed with the Port of Rotterdam (Ligteringen et al 2014).These early discussions about constructing LNG import terminals were taking place in 2005-2006 when the Ukraine-Russia gas supply dispute was leading to increased policy awareness within the European Commission about security of energy supply (EC, 2006). In 2009, the EC Renewable Energy Directive (2009/18/EC) was passed, whose targets the Dutch government promoted could also be reached through production of biofuels (Netherlands Enterprise Agency, 2015). In 2008, Neste Oil and the Port Authority of Rotterdam agreed to start construction of a biofuels plant for which the Port Authority agreed to facilitate a sea jetty; with the refinery completed in 2011. The refinery also opened the option for future production of liquefied bioLNG (Neste, 2015). In 2006 the development of the 'Coral Methane' was innitiated by the Dutch shipowner Anthony Veder, for Gasnor, a Norwegian natural gas company. The project was completed by 2010. The 'Coral Methane' in 2008 won the 'Innovation Award of the Royal Association of Dutch Shipowners' (KVNR), it was the world's first combined LNG/LPG/LEG Carrier (Anthony Veder, 2010). At this same time, inland shipping saw the development of 'Argonon' the first inland barge with DF engines, powered by LNG. The ship-owners Deen Shipping decided to develop the barge and in the process secured additional funding through Agentschap NL and the European Regional Development Fund (Deen Shipping, 2012).

3.1(c) 2010s-2015: Building of small scale bunkering and spread to inland shipping

In 2011, the Gate Terminal was completed in Rotterdam (Port of Rotterdam, 2015), over the next five years the terminal was transformed from an LNG import terminal into an 'LNG Hub' through the construction of an EUR 76 million LNG break bulk facility commissioned in 2014, and financed by the European Investment bank (EIB). The new facilities allow for the small-scale bunkering of LNG to bunker vessels and smaller tanker allowing for inland and short sea shipping (Port of Rotterdam, 2015). During this same time, with growing support from multiple stakeholders, including the Port of Rotterdam, the Dutch National LNG Platform was established in close conjunction with the 'Rhine and Wadden Green Deal', a private-public multi-stakeholder partnership created to decrease transport emissions (The Dutch National LNG Platform, 2015). At the same time, interest in the use of LNG for inland shipping continued to grow with the establishment of the 'LNG Masterplan for Rhine-Main-Danube' EUR 40 million, funded EU project, with the overall interest in developing LNG as a fuel for inland navigation (EC, 2012). In 2013, Shell funded the first 100% LNG fuelled inland barge in the Netherlands built to transport liquid fuels on European inland waterways, the 'Greenstream'. The following year a sister ship, the Greenrhine was also launched (Shell, 2014).

With respect to short sea shipping, during this period Anthony Veder completed a vessel commissioned by the Norwegian/Finnish natural gas company Skangas in 2012. The 'Coral Energy' was the world's first direct driven dual-fuel ice-class 1A LNG carrier (Anthony Veder, 2012). Anthony Veder continued developing innovations in the Dutch LNG industry in the joint development with Sirius Shipping of the 'Coralius', the first 'EU-built' LNG bunker vessel. The ship was built at the Royal Bodewes shipyard in the Netherlands, for Skangas and is fuelled with Wartsila DF engines (Skangas, 2016). During this time Anthoyn Veder, also developed two DF LPG carriers, the 'Coral Star' and 'Coral Stico' (Anthony Veder, 2016).

3.2 EASTERN BALTIC – FINLAND AND ESTONIA

3.1(a) 1990s-2000s: Development of domestic DF engines

One of the world largest engine manufacturers Wartsila is based in Finland. In the 1990s with growing prices of crude oil and increasing environmental concerns from land based emissions, Wartsila seized the market by developing its first dual-fuel DF engines (i.e., 20 DF, 46 DF, 50 DF, two stroke and four stroke) for uses in land-based power plants (Watsilla, 2012) (Woodyard, 2009:41-51). This was happening at a time when Wartsila was still recovering from the financial changes and bankruptcy it experienced in the late 1980s and early 1990s (Kaukiainen, 2008b). During this same time, Finnish shipping, heavily dependent on short-sea transport of goods to the rest of Europe, was affected by the shipping crisis and could not adjust to low freight rates, some companies changed strategies and specialized to niche markets, such as wood products and the passenger transport industry. Over the 1990s passenger traffic between Finland, Estonia and Sweden grew considerably. In the 1970s-passenger traffic between Finland and Sweden accounted for just 10% of total Finnish shipping income, this grew to 40% by the 2000s (Tenold and Iversen, 2012:147-153). One significant contributing factor to the rise of economic activity and passenger transport between Finland and Estonia was the break-up of the Soviet Union and the independence of Estonia in 1991 which led over the decade to increased economic cooperation, knowledge sharing and workforce migration between Finland and Estonia (Feldmann, 2017). The 1990s also saw increased interest in the environmental concerns of the Baltic Sea, especially due to fragile nature of the closed sea, and its eutrophication, leading to the signing of the Joint Comprehensive Environmental Action Programme (JPC) in 1992 to tackle land based pollution from the Baltic Sea (Auer and Nilenders, 2001). Over 1993-1997, Finland was heavily involved in negotiations at HELCOM to designate the Baltic Sea as an Emission Control Area (ECA), which was submitted for adoption by the IMO in 1997 (HELCOM, 2000).

3.1(b) 2000s-2010s: Marine LNG innovation hub grows further

The beginning of the 2000s saw continued innovation and development of new DF engine designs by Wartsila. In 2003, a new breakthrough was made with the development of the world's first LNG fuelled, PSV for the Norwegian Owner Eidesvik Shipping AS, for the Charterer Statoil (Hetland et al, 2006). This project saw the successful implementation of the Wartsila 32DF engine, developed in 2000 specifically for marine applications (Wartsila, 2001). In 2006, Wartsila entered a new period of DF engine manufacturing with the delivery of several 50DF engines for a new generation of LNG carriers, the 50DF engine was initially developed in 2002 in Finland (Wartsila, 2003). In 2003, DNV GL initiated the FellowSHIP project, brining on board Wartsila and Ediesvik to develop fuel cell technology for vessel propulsion, the result was the Viking Lady which was delivered in 2009, which resulted in significant political attention when it was promoted at COP15, in 2009 in Copenhagen (Holmen and Fosse, 2017).

During this same time period, growing concerns in Finland and Estonia about energy security of Russian gas supply, led to increased discussions about the need to develop alternative forms of energy supply in the form of an LNG import terminal (Prontera, 2017:154-157). Over this same period, Finnish shipping went through considerable changes, in 2002, Finland issued a law on tonnage taxation, preceded by a wide political debate on the issue (Poulsen et al, 2011). The changes in Finnish shipping that started in the 1990s continued over the 2000s. In 2006, the Estonian passenger operator Tallink acquired Finnish SiljaLine, forming a strong cross border ferry operator (Tallink, 2006).

3.1(c) 2010s-2015: Marine LNG adaption gowns and diversifies

In 2011 Wartisla completed the first LNG conversion of the 'Bit Viking' product tanker for the Norwegian owner Tarbit Shipping, the project was eligible for support under the Norwegian Business Sector NOx Fund (Wartsila, 2011). This project formed an integral part of the development of Wartsila from an engine suppler to and full LNG fuel handling system supplier (Wartsila, 2011). In 2011, the 'Make a Difference' EU TEN-T project with EUR 2.5 million was initiated between Sweden and Finland to minimize the barriers when operating an LNG fuelled vessel (EC, 2011). In addition, in 2014 further cross border cooperation between Helsinki and Tallinn resulted in EUR 29 million funding for the 'Twin-Port 2' funded project by CEF-Transport for construction of additional port level infrastructure in the ports of Tallinn and Helsinki which also contributed funding or the development of a new LNG fuelled Ro-Pax vessel (EC, 2014). The LNG supply to Finland also became more readily available with the completion of the LNG import terminal in Pori, which concluded its first LNG ship bunkering operation in 2016 (Gasum, 2016). At the same time the development of LNG fuelled vessels for domestic use in Finland continued with the development of the 'Turva' a coast guard vessel at Rauma Shipyard for the Finnish Border Guard (Wartsila Encyclopedia, 2017). In 2013, Wartsila supplied the propulsion system for the world's largest Ro-Pax ferry fuelled by LNG at the time, the 'Viking Grace', the vessel operates between Finland and Sweden (Wartsila, 2017). The development by Viking Line was followed in 2017 with the completion of the 'Megastar', the first LNG fuelled large passenger vessel by Tallink. The vessel was constructed in Finland at the Meyer Turku shipyard, powered by Wartsila DF engines and was partially funded through the EU CEF facility (Tallink, 2017).

4. PROTECTIVE SPACES FOR MARINE LNG AND THEIR IMPACTS

4.1 THE ACTOR-NETWORKS

The development of LNG as a marine fuel in the Netherlands and Finland/Estonia involved complex relationships between different actors. In the Netherlands, the story of LNG was firstly initiated through the development of the Rotterdam Gate terminal: "*It started all with the Gate import terminal, the Gate access to Europe, so the import terminal*" (Interviewee 6). The port of Rotterdam played an important role in the creation of LNG networks in the Netherlands (Interviewee 1,2,3,4,5,6), this seems to be driven by a change in attitude towards the LNG terminal, from an 'LNG import terminal' to an LNG bunkering "hub" (Interviewee 6). Later on, the Port of Rotterdam played an important role in knowledge sharing and development of regulatory standards for LNG for Port Bunkering and for the development of safety standards in the 'LNG Rhine-Maine-Danube Masterplan' (Interviewee 6) (SGMF, 2017).

Anthony Veder, was the first ship-owner to develop LNG fuelled vessels, primarily driven by demand from Norway: *"… it was driven by demand from Norway, so Norway was the very first ones that were looking in ways to reduce emissions, reduce carbon footprint, but also NOx, SOx and small particles*" (Interviewee 3). Anthony Veder's development of LNG fuelled vessels was funded by Norwegian natural gas companies Gasnor and Skangas (Interviewee 3, 4,11)(Anthony Veder, 2017). Inland shipping in the Netherlands is dominated by "Captain-Owner" ship-owners where usually a family owned business runs a couple of ships for generations (Interviewee 1,2,3,4,5), here individual agency of ship-owners such as Deen Shipping deciding to be first movers, played an important role in the initial uptake of LNG (Interviewee 5). Later, Shell continued to play an important role, by funding the development of first inland and then short-sea bunkering barges to be used in the Netherlands (Interviewee 2,3).

In Finland and Estonia, the story of marine LNG applications was started by Wartsila, the large ship-engine manufacturer responding to market demand to construct dual fuelled engines for land-based use such as power plants and later for LNG carriers (Interviewee 7). The company initially seemed to view DF engines as just another part of its portfolio, but with the development of emission control areas and growth in the potential of LNG for other uses, Wartsila started moving toward the development of a fuel LNG fuel handling system, expanding its expertise base (Interviewee 7). Senior members of the company became involved in the development of SEA LNG, the market organisation for the promotion of LNG (Wartsila, 2016). In the early 2000s several smaller flagships project by Wartsila for the development of LNG fuelled vessels (Ediesvik Shipping, Simon Monkster) further supported this development (Interviewee 7,9).

The Port of Helsinki first became involved in discussions about marine LNG applications through participation in the BPO led consortium that researched the potential for development of LNG bunkering infrastructure in Baltic Sea Ports in 2011 (BPO, 2017)(Interviewee 9).Later on, as the need for the first LNG bunkering at the port became necessary, for the LNG fuelled border guard vessel Turva in 2014, the process of organizing the bunkering was led by Skangas (Interviewee 9) and the same story was repeated for other vessels such as the development of LNG bunkering for the Megastar by Tallink: "*but it was led by Gasum (Skangas), they had the best knowledge, they did all the risk analysis, together with Tallink and port of Helsinki and so on. Which mean they were key for the cooperation*" (Interviewee 9). Skangas was also integral in the construction and developed of the LNG import terminal in Pori (Interviewee 9, 10. The Finnish Maritime Transport Agency, Finnish Border Guard both played an important role in deciding to use LNG as a fuel option in the development of the Turva patrol vessel and Polaris icebreaker respectively (Interviewee 9,10).

4.2 SHIELDING MARINE LNG

In the Netherlands, a couple processes were identified that shielded marine LNG from wider selection pressures that helped in it development. In the early years, there was no specific funding available for marine LNG developments within the Netherlands. Anthony Veder, a front-runner in applying new DF engines for its vessels, was indirectly shielded in its development by being commissioned to develop vessels for Skanags and Gasnor, both of which were intended to operate off the coast of Norway and for the Gasnor project was eligible for additional funding under the Norwegian Business Sector NOx fund (Interviewee 3). In later projects that were commissioned for Norwegian-based operations Anthony Veder also benefited from indirect shielding, due to the rising demand for an LNG bunker vessel in the North Sea area because of increased numbers of local LNG fuelled vessels being build due to Norwegian regulations (i.e. NOx fund) (Interviewee 3). Similarly, in Finland, many vessels that Wartsila developed were intended for the Norwegian market, and others such as the conversion of the 'Bit Viking' ship received support from the Norwegian Business Sector NOx fund (Interviewee 7, Wartsila 2012)

Other sources of shielding that were available in the Netherlands were from Agentschap NL (Dutch national funding for sustainable projects) and the European Regional Development Fund which were both utilized by the 'Argonon' the first inland barge powered by LNG (Bestfact, 2012). There has been no specific mention of relevant national funding projects for marine LNG developments in Finland and Estonia. However, the decision by the Finnish Border Guard and Finnish Maritime Transport Agency to use public funds to develop their new vessels (Turva and Polaris) respectively with DF LNG engines, seems to be driven partially by the intention to promote 'green technologies' (Interviewee 9,10). Later, additional funding sources in both Finland and the Netherlands became available through EU TEN-T projects, and after 2014 replaced by CEF (Connecting Europe facility), envisioned through the 2014 EU Alternative Fuels Directive, considered paramount to shielding LNG developments, especially for inland shipping in the Netherlands (Interviewee 5,6).Similar importance to EU funding sources was emphasised in Finland (Interviewee 7,8,9,10), especially for the development of LNG bunkering infrastructure through the BPO EU funded 'LNG Bunkering in Baltic Sea Ports' project in 2011 (Interviewee 9).The Port of Rotterdam has more recently created a number of initiatives aimed at shielding LNG developments and creating an Environmental Ship Index, LNG Bunkering Incentive that give discounts of 20% and 10% respectively on port fees for LNG fuelled vessels (Port of Rotterdam, 2017): "The port of Rotterdam has encouragement for LNG bunkering, … incentives for most sustainable and clean ships, called the environmental ship index" (Interviewee 3).

4.3 NURTING MARINE LNG

The main difference in the learning processes between the Netherlands and Finland/Estonia was the lack of a domestic engine manufacturer in the Netherlands which could be called upon for local advice and that could mobilize local learning processes (Interviewee 4). A lot of the learning in Netherlands was initially done through learning from first movers on trial and error such as Anthony Veder who gathered significant experience from working with Norwegian partners (Interviewee 3). The Netherlands also benefited from having a large domestic population of natural gas expert due to the countries long history of being a gas producer in the North Sea, who could advise on safety issues and certain engineering issues concerning gas handling (Interviewee 4). The Netherlands inland shipping learned a lot through the first movers such as 'Argonon' and the Argos Energies inland LNG bunkering vessel. These projects helped in the development of knowledge on the types of regulations that needed to be development for LNG transport on inland waterways*:" oh yeah for example the first company was, the first company that ran on LNG which was Deen Shipping, it was the first ship to run on LNG, and it gave precedent for other projects, to convince the authorities that it was technically possible to get assumption from the Dutch government to run on LNG*" (Interviewee 5).

In addition, in the Netherlands the creation of the National LNG Platform, seems to have significantly contributed to knowledge sharing between different actor s (Interviewee 1,2,3,4). However, COP21 and the rising concerns over GHG emission from shipping and new studies on Methane slip changed the expectation of LNG from being a potential long term shipping fuel to that of a transitional fuel (Interviewee 1,2,3,4,5,6,7). A specific turning point for this change in opinion seems to have happened with COP21:" *I think the perception of LNG changes dramatically due to COP 21… about CO2 and LNG has an advantage depending on the methane slip discussion… but given now the pressure on CO2, I think the perception on LNG is slipping and now it is being looked at much more as a transitional fuel instead of the fuel of the future*". Several actors counteracted these concerns by promoting LNG as a first step toward bioLNG (Interviewee 2,3,4). In Finland, a lot of technical learning happened at Wartsila through the development of a few flagship LNG filled vessels (Interviewee 7,8). Significant knowledge was gathered by the company through acquisition of smaller equipment producers and design companies such as Vik Sandvik (Interviewee 7). Within the LNG fuel systems development of Wartsila, a lot of higher level learning seemed to take place in understanding the operational measured, financial contracts and ways of doing business (Interviewee 7,8). However, some of the more recent operators of LNG fuelled vessels in Finland and Estonia did not seem to show any higher-level learning taking place, implying that what they used was a mature technology (Interviewee 8,9).

4.4 EMPOWERING MARINE LNG

Empowering is a process where network of actors considered 'technology champions' try mobilizing resources for niche development in the wider world (Kern et al 2014). Part of this process of network formation and resource mobilization through technology champions is covered in section 4.1. The main aim of this section is to discussion examples of actors positively representing LNG to gather additional resource. There were several ways that actors in both the Netherlands and Finland/Estonia tried working to convince consumers of the benefits of LNG as a marine fuel compared to standard fuels. In the Netherlands, the most significant of these was the introduction of common inland LNG bunkering guidelines to provide clarity, and a few interviewees mentioned this as an issue (Interviewees 2,3,4). In June 2015, CCRN, after working closely and taking input from the Netherlands national LNG Platform and Port of Rotterdam amongst others adopted LNG bunkering guidelines that followed closely IAPH guidelines (CCNR, 2015). In comparison, in Finland and Estonia no such type of empowering processes has been observed (Interviewee 6,7,8).

5. CONCLUSIONS

The development of LNG as a ship fuel in the Netherlands and Finland/Estonia has benefited from the existence and development of protected spaces that allowed for specific maritime transport niches and funding opportunities. In both cases these niches did not provide much in terms of local regulatory financial incentives for direct funding of LNG as a ship fuel, that would be like the NOx fund in Norway (Interviewee 1,2,3,4,5,6,7,8,9,10,11). In both regions protected spaces were partially the result of environmental concerns of sea eutrophication and pollution that led to the development of ECA areas which contributed to LNG becoming discussed as a potential alternative to HFOs in the 2000s (Interviewee 2,5,6,7,8,11). Some protection was provided by the Norwegian NOx fund due to shipping's international nature and some Dutch operators and Wartsila in Finland being awarded contracts to work on LNG fuelled vessels that would later operate in Norway. In addition, most interviewees (1,2,3,5,6,7,9,10,11) identified the role of EU funding projects TEN-T and CEF as being a significant technology neutral measures that provided additional resources for niche nurturing. Here the 2011 EU Alternative Fuels Directive has been an instrumental guideline due to its specific mention of LNG bunkering targets for TEN-T core ports (Directive 2014/94/EU). At a local level, some technology neutral funding at a national level for LNG fuelled projects from Agentschap NL existed in the Netherlands that seemed to go beyond any similar types of measures in place in either Finland or Estonia (Interviewee 3,9). However, this measure was aimed at innovative technologies and with the change in perception of LNG over the past 6 years in the Netherlands amongst some stakeholders, arguments have been made that currently the same types of funding sources would be more difficult to obtain by LNG projects (Interviewee 5).

The main difference between the two regions was that, in the Netherlands the role of 'technology champions' was visibly taken by the Port of Rotterdam which through the existence of the Gate Terminal had a vested interest in promoting the technology and was also pressured to deal with local air pollution problems by local citizens' groups (Interviewee 3,4,5), for which LNG could be presented as a valid solution due to its low particulate matter and SOx emissions. The Port of Rotterdam, together with fuel and equipment suppliers contributed strongly to the development of the national LNG platform in the Netherlands that was further able to organize resources for funding of inland LNG projects, and became a strong network in lobbying to the development of inland bunkering regulations (Interviewee 3,4). On the other hand, in Estonia, LNG was viewed as a mature technology used to promote an operator's environmental image (Interviewee 10), whereas in Finland the main technology champion was Wartsila. Due to the company's worldwide reach, its main aims were not as much in creating a local national LNG network, but promoting the technology globally (Interviewee 7).

Some support for technology development came from Skangas, the main LNG supplier in Finland, which strongly supported the growth of the niche through simplifying the LNG bunkering process, and providing all the necessary knowledge on site to interested parties (Interviewee 9,10,11). The main projects for LNG in the Netherlands were primarily driven by the requirements of providing LNG bunkering to marine and non-marine customers (in Norway or in Rotterdam from outside of the Netherlands) and by individual agency of small-ship-owners (Interviewee 2,3,5,6). In Finland and Estonia, ferry operators such as Tallink and Viking Line saw LNG as a potentially new fuel that would help in building their 'green' public image, and in this process, they received the full support of the strong local maritime cluster. Most of the other marine LNG vessels developed in Finland were supported through state-owned agencies, exhibiting a combination of a desire to experiment with a cleaner fuel and to promote the local maritime cluster (Interviewee 7,8)

REFERENCES

Anthony Veder (2010) 'Coral Methane'
https://www.anthonyveder.com/activities/innovations/coralmethane/

Anthony Veder (2017); The Coral Methane and Coral Energy
https://www.anthonyveder.com/activities/innovations/coralmethane/

Antohony Veder (2015) FIRST LNG BUNKERING OF CORAL STAR AND CORAL STICHO IN UK Posted on September 16th, 2015 https://www.anthonyveder.com/first-lng-bunkering-of-coral-star-and-coral-sticho-in-uk-2/

Athony Veder (2012) Anthony Veder 'Coral Energy'
https://www.anthonyveder.com/activities/innovations/coral-energy/

Bergek, A., Jacobsson, S., (2003). The emergence of a growth industry: a comparative analysis of the German, Dutch and Swedish wind turbine industries. In: Metcalfe, J.S., Cantner, U. (Eds.), Change, Transformation and Development. Physica-Verlag (Springer), Heidelberg, pp. 197–228.

CCNR (2015) Publication by the CCNR of edition 1.0 of the standard for a Liquefied Natural Gas (LNG) Bunker Checklist (Truck-To-Ship), CCNR PRESS RELEASE | Strasbourg, 24th November 2015

Chul-Hwan Han, (2006) Comparative Analysis on World's Major Maritime Clusters Professor, Department of International Logistics, Division of International Relations, Dongseo University, Busan, Korea, The Journal of Maritime Business, No.81, pp. 89-114 Dec 2006

Coenen, L., Benneworth, P., Truffer, B., (2012). Toward a spatial perspective on sustainability transitions. Res. Policy 41, 968–979.

de Jongh P. E. (1996). The Netherlands' approach to environmental policy integration, Centre for Strategic and International Studies, Washington D.C.

Deen Shipping (2012) ARGONON, SUSTAINABLE SHIP FIRST INLAND BARGE ON DUAL FUEL, http://www.deenshipping.com/files/documents/Argonon%20PressMap_LRES.pdf

DNV GL (2015). In focus –LNG as ship fuel, No. 01 2015, DNV GL AS. All rights reserved. ©DNV GL 05/2015 Design: Maritime Communications ID: 837974

Dutch National LNG Platform (2015) Introducing LNG as a new, cleaner and quieter fuel for road transport and marine navigation. G.J. van Tongeren, http://www.nationaallngplatform.nl/wp-content/uploads/2016/04/Folder-Engelstalig-2015.pdf

EC (2006) COMMISSION OF THE EUROPEAN COMMUNITIES Brussels, 8.3.2006 COM(2006) 105 final GREEN PAPER A European Strategy for Sustainable, Competitive and Secure Energy {SEC(2006) 317}

EC (2011) European Commission, Make a Difference, https://ec.europa.eu/inea/en/ten-t/ten-t-projects/projects-by-country/multi-country/2011-eu-92079-s

EC (2014) European Commission, Twin-Port 2 https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport/projects-by-country/multi-country/2014-eu-tm-0087-m

Erisman, J.W., Domburg, N, de Vries, W., Kros,H.,de Haan, B.,Sanders, K. (2005) The Dutch N-cascade in the European perspective, Science in China Series C: Life Sciences, September 2005, Volume 48, Supplement 2, pp 827–842

Feldmann, M. (2017). Crisis and opportunity: varieties of capitalism and varieties of crisis responses in Estonia and Slovenia. European Journal of Industrial Relations, 23(1), 33-46. DOI: 10.1177/0959680116672280 (Auer and Nilenders, 2001) Baltic sea seca, neca

Florian Kern, Adrian Smith, Chris Shaw, Rob Raven, Bram Verhees (2014) From laggard to leader: Explaining offshore wind developments in the UK, Energy Policy 69 (2014) 635–646

Gasum (2016) Gasum: First LNG bunkering operation completed at Pori terminal in Finland https://www.gasum.com/en/About-gasum/for-the-media/News/2016/First-LNG-bunkering-operation-completed-at-Pori-terminal-in-Finland/

Gate Terminal (2007) Investment Decision Gate Terminal, http://gate.nl/en/media/news/newsdetail/investment-decision-gate-terminal.html

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms, Environmental Innovation and Societal Transitions 1 (2011) 24–40

George, A.L., Bennett, A., 2005. Case Studies and Theory Development in the Social Sciences. MIT Press, Cambridge, London.

Herdzik, J(2011) LNG as a marine fuel-Possibilities and problems, Journal of KONES Powertrain and Transport, Vol. 18, No. 2 2011

HELCOM (2000) Guidelines on Ensuring Successful Convictions of Offendersof Anti-pollution Regulations At Sea Baltic Sea Environ. Proc. No. 78

Hetland et al, (2006) Security of Natural Gas Supply through Transit Countries, Nato Science Series II, ISBN 978-1-4020-2078-0, Editors: Hetland, Jens, Gochitashvili, Teimuraz (Eds.)

Holmen and Fosse, (2017) Regional agency and constitution of new paths: a study of agency in early formation of new paths on the west coast of Norway, AKT Holmen, JK Fosse - European Planning Studies, 2017 - Taylor & Francis

Hoogma, R., Kemp, R., Schot, J., Truffer, B., 2002. Experimenting for Sustainable Transport: The Approach of Strategic Niche Management. Spon Press, London

IMO (2015) MARPOL Annex 6, http://www.imo.org/en/OurWork/environment/pollutionprevention/airpollution/pages/air-pollution.aspx

Janssens, H. (2006). The Dutch Maritime Cluster. In N. Wijnolst (Ed.), Dynamic European Maritime Clusters. Amsterdam: IOS Press BV.

Kaukiainen Yrjö (2008), Ulos maailmaan! Suomalaisen merenkulun historia. SKS, Helsinki.

Kemp, R., Schot, J., et al., 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. Technol. Anal. Strateg. Manag. 10 (2), 175–198.

Langen, P. W. de (2002). Clustering and performance: the case of maritime clustering in The Netherlands. Maritime Policy and Management, 29(3): 209-221.

Ligteringen, H., Velsink, H, (2012) Ports and Terminals, Publisher, VSSD, 2012. ISBN, 9065623043, 9789065623041.

Lloyds Register (2012) LNG-fuelled deep sea shipping The outlook for LNG bunker and LNG-fuelled newbuild demand up to 2025 August 2012, Jesper Aagesen, Latifat Ajala, Stuart Nicoll

MAN Diesel and Turbo (2013) Propulsion trends in LNG carriers, Aug 2013 Printed in Denmark

Mazur,C., Contestabile, M., Offer, G.J., Brandon, N.P. (2014) Assessing and comparing German and UK transition policies for electric mobility, Environmental Innovation and Societal Transitions, Available online 9 May 2014, ISSN 2210-4224, http://dx.doi.org/10.1016/j.eist.2014.04.005.

Neste (2015) Neste breaks ground of world's first bio LPG facility in Rotterdam, https://www.neste.com/en/neste-breaks-ground-worlds-first-bio-lpg-facility-rotterdam

Netherlands Enterprise Agency (2015) Sustainable biomass and bioenergy in the Netherlands, Netherlands Programmes Sustainable Biomass, Copernicus Institute, Utrecht University Authors Chun Sheng Goh, Thuy Mai-Moulin, Martin Junginger

Peeters, C., K. Debisschop, P. Vandendriessche and N. Wijnolst (1994). De toekomst van de Nederlandse zeevaartsector: Economische Impact Studie en beleidsanalyse. Delft: Delft University Press.

Port of Rotterdam (2015) Gate terminal starts construction of LNG break bulk facility at the port of Rotterdam, https://www.portofrotterdam.com/en/news-and-press-releases/gate-terminal-starts-construction-of-lng-break-bulk-facility-at-the-port-of

Port of Rotterdam LNG as a fuel for vessels and trucks, https://www.portofrotterdam.com/en/cargo-industry/lng-liquefied-natural-gas/lng-as-a-fuel-for-vessels-and-trucks

Poulsen, R. – Sjögren, H. – Lennerfors, T. (2011) The Two Declines of Swedish Shipping. In: Global Shipping in Small Nations: Nordic Experiences after 1960. Eds: S. Tenold, M. Iversen, and E. Lange. Palgrave Macmillan.

Prontera, A., (2017) The new politics of energy security and the rise of the catalytic state in southern Europe, Cambridge University Press, 2017:154-157, DOI:

Raven, R., 2007. Niche accumulation and hybridisation strategies in transition processes towards a sustainable energy system: an assessment of differences and pitfalls. Energy Policy 35 (4), 2390–2400.

S Wang, T Notteboom (2014) The adoption of liquefied natural gas as a ship fuel: A systematic review of perspectives and challenges - Transport Reviews, 2014 - Taylor & Francis

Schot, J., Geels, F.W., 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. Technol. Anal. Strateg. Manag. 20 (5), 537–554.

SGMF (2017) Gas as a Marine Fuel, Safety Guidelines, Version 2.0., the society for gas as a marine fuel, ISBN: 978-0-9933164-4-9

Shell (2014) Shell to build innovative bunker vessel to deliver LNG fuel, http://www.shell.com/business-customers/trading-and-supply/trading/news-and-media-releases/innovative-bunker-vessel.html

Skangas (2016) Coralius is the first state-of-the-art LNG bunker and feeder vessel to be built in Europe. http://www.skangas.com/en/our-portfolio/our-ships/coralius/

Smith, A., 2007. Translating sustainabilities between green niches and sociotechnical regimes. Technol. Anal. Strateg. Manag. 19 (4), 427–450.

Smith, A., Raven, R.P.J.M., 2012. What is protective space? Reconsidering niches in transitions to sustainability. Res. Policy 41 (6), 1025–1036.

Smith, A., Voß, J.-P., et al., 2010. Innovation studies and sustainability transitions: the allure of the multi-level perspective and its challenges. Res. Policy 39 (4), 435–448.

Stopford, M. (2008) Maritime Economic, 3rd Edition, Routledge, Paperback, ISBN-10: 041527558X, ISBN-13: 978-0415275583

Tallink (2017) Tallink: Megastar Intro http://megastar.tallink.com/about-megastar/intro/

Tallink, (2006) AS Tallink Group Annual Report 2006/2007, AS Vaba Maa

Verhees, B., Raven, R., et al., 2013. The development of solar PV in The Netherlands: a case of survival in unfriendly contexts. Renew. Sustain. Energy Rev. 19, 275–289.

Wartsila (2016) Wartsila in coalllition to promote LNG as a marine fuel https://www.wartsila.com/media/news/13-07-2016-wartsila-in-coalition-to-promote-lng-as-a-marine-fuel

Wartsila (2017) Wartsila, Viking Grace https://www.wartsila.com/resources/customer-references/view/viking-grace

Wartsila Encyclopedia (2017) Coast Guard Vessel Turva - https://www.wartsila.com/encyclopedia/term/coastguard-vessel-k-v-turva

Wartsila, (2001) Wärtsilä LNG-fuelled engines for offshore vessels Wärtsilä Corporation Trade press release 30 October 2001 at 2:00 PM E. Europe Standard Time, https://www.wartsila.com/media/news/30-10-2001-wartsila-lng-fuelled-engines-for-offshore-vessels

Wartsila, (2003) Wärtsilä tests first Wärtsilä 50DF dual-fuel engine Wärtsilä Corporation Trade press release 20 January 2003 at 10:00 AM E. Europe Standard Time https://www.wartsila.com/media/news/20-01-2003-wartsila-tests-first-wartsila-50df-dual-fuel-engine

Wartsilla (2012) Case: tanker ship Bit Viking LNG conversion for environmental sustainability, 2012 Wärtsilä Corporation.

Wartsilla (2012) Wartsilla dual-fuel technology now the choice of 100 LNG carriers, http://www.wartsila.com/media/news/31-05-2012-wartsila-dual-fuel-technology-now-the-choice-of-100-lng-carriers

Watsilla, 2012 DUAL-FUEL ENGINES – WÄRTSILÄ 20DF, 34DF, 46DF AND 50DF https://cdn.wartsila.com/docs/default-source/product-files/engines/df-engine/brochure-o-e-df-engines-2015.pdf?sfvrsn=6

Woodyard, D. 2009. Pounder’s marine diesel engines and gas turbines, ninth edition. London: Butterworth-Heinemann.:41-51

Burell, F., Tccani,R., Zuilani, N. (2013) Improving sustainability of maritime transport through utilization of Liquefied Natural Gas (LNG) for propulsion, Energy, Volume 57, 1 August 2013, Pages 412-420 https://doi.org/10.1016/j.energy.2013.05.002