Decarbonising Shipping: **SETTING SHELL'S COURSE**

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INTRODUCTION

When the Shell and Deloitte *Decarbonising Shipping: All Hands on Deck* report was published in July 2020 I wrote that we must all get to work on moving from "deadlock to decarbonisation". The rich reflections of the many customers, partners and stakeholders who generously gave us their time in developing that report, have helped us to refine our own thinking on how we can best help to accelerate progress to a net-zero emissions shipping sector.

With this follow up, *Decarbonising Shipping: Setting Shell's Course*, we are sharing some of the thinking and actions we are taking to make our contribution. We know there is no single silver bullet to this complex challenge. There will likely be multiple solutions across sub-sectors of shipping. Changes in industrial and other transport sectors will also likely influence the outcome for shipping. Even with all hands on deck the scope of the challenge will likely remain a multi-decade journey, and for that we will need determination and stamina. Shell's own ambition to be a net-zero energy business by 2050 or sooner, in step with society, gives us that long term focus.

The *Decarbonising Shipping: All Hands on Deck* report received a positive response from many across the shipping industry, even during the inherent uncertainties of COVID-19. But the barriers that it highlighted and the actions to 'unlock' them are going to require a full suite of solutions deployed in all corners of our industry – and deployed with urgency by all participants. At Shell, we have many touch points into the sector – as a fuel and lubricants supplier, as a ship charterer and manager – to name a few. We want to use that knowledge to best effect to help accelerate the change needed.

We do not yet have all the answers, but I hope in reading this you will find some positive steps that we are taking towards developing a cleaner more efficient industry. I look forward to continuing the conversation and working together with our many highly valued customers and partners.

Grahaeme Henderson
Vice President,
Shell Shipping & Maritime

Context

CONTEXT

THE JOURNEY TO DECARBONISING SHIPPING

In April 2020, Shell set out an ambition to become a net-zero emissions energy business by 2050, or sooner, in step with society and our customers. A key pillar to making this happen is partnering with our customers to help them decarbonise.

In the recently published Shell and Deloitte report, *Decarbonising Shipping: All Hands on Deck* (henceforth "*All Hands on Deck*"), over 90% of respondents from across the shipping industry highlighted that decarbonisation is an important or top priority for their organisations, and 80% noted that its importance has increased significantly over the past 18 months.

We have listened to this call for action and have been encouraged by the commitment to change in the sector. But the report also highlighted a number of considerable barriers to change. These are termed "The Deadlock", characterised by long lifecycles of ships, a lack of incentive for owners and operators to change, and limited end-customer demand for lower-emission shipping. In addition, as one participant noted, there are "too many alternatives and not one viable solution" when it comes to how to power shipping in the future.

So, using the deep expertise of our own scientists, engineers, and analysts and the feedback we received from our customers, we are setting out to help co-create a lower carbon future for shipping. We will do this together with our customers, working closely with those at the forefront of this transition, and we aim to lead within our own operations. *We strongly believe that shipping, which today transports around 80% of the world's traded goods, and which is responsible for 2.9%[1] of global CO_2, can choose a pathway, supported by regulation, which is a credible and lowest cost means to reach a net-zero emissions future by 2050.* To achieve this aim we must collectively do more to accelerate change.

The *All Hands on Deck* interviewees coalesced around 12 solutions to overcome the barriers to decarbonisation. These were:

1. Scale-up customer demand
2. Global regulatory alignment
3. Cross sector research and development
4. Scale-up controlled pilot projects
5. Coordinated industry commitments
6. Flexible and modular designs
7. Port coalitions
8. Investor pressure
9. Green finance
10. Scale-up fuel production
11. Scale-up bunkering infrastructure
12. Operational efficiency

Five of these were seen as being needed to unlock change in the next several years: scaling up customer demand, global regulatory alignment, cross sector research and development, scaling controlled pilot projects and coordinated industry commitments. In addition, operational efficiency was a foundational imperative. What we outline in our response is how we will set our course to play a constructive role in achieving these aims.

The International Maritime Organization's (IMO) Initial Strategy focuses on the reduction of the CO_2 intensity of the ship through energy efficiency design requirements; and lowering the CO_2 intensity per transport work as an average across international shipping (by at least 40% by 2030 and pursuing efforts towards 70% by 2050 compared with 2008). It sets out to achieve peak greenhouse gas (GHG) emissions from international shipping as soon as possible and to reduce the total annual GHG emissions by at least 50% by 2050 compared with 2008 while pursuing efforts towards phasing them out on a pathway to CO_2 emissions reductions consistent with the Paris Agreement temperature goals.

In developing Shell's approach to achieve a net-zero emissions energy business by 2050 or sooner, in step with society and our customers, and in line with the IMO's strategy, we have used three questions as a framework.

Three questions to drive our approach:

1. **How can we innovate to help phase out emissions from shipping as soon as possible?**[2]

2. **How can we work with customers and within our own operations to reduce emissions and help reach peak emissions from shipping, as soon as possible?**[3]

3. **How can we partner within shipping and across sectors to lower barriers to success and achieve decarbonisation through an ecosystem approach?**

In the shipping industry, as in other 'hard-to-abate' sectors, it is helpful to adopt an approach of "avoid, reduce, then offset" to decarbonisation.

As the sector focuses on how to eliminate emissions as soon as possible, it must lean its efforts into the advance of fuel and technology offerings which avoid emissions altogether – 'thinking big, starting small and scaling fast' in areas such as hydrogen research and development. These new fuels will require significant changes to ships, ports and operations. We will look to lead and participate in like-minded collaborations and coalitions to advance these technologies, with the aim of seeing commercially operating ships on the water in the 2030s.

As the sector seeks to reach to peak emissions as soon as possible, Shell will focus on what we can do to reduce emissions through energy efficiency measures, and through expanding the availability of lower carbon fuels, such as liquified natural gas (LNG), and biofuels that are available to us today. The sector can also look to emerging options for high quality offsets to balance the remaining hard-to-abate emissions. In all of this we see the role of end-consumers and buying behaviours driving change.

The interdependencies in the sector and with other sectors developing transport fuels and infrastructure means that it is imperative the whole industry employs an ecosystem approach – partnership is a critical enabler, and we must all play our part.

Shell's view on future pathways

SHELL'S VIEW ON FUTURE PATHWAYS

PATHWAYS TO DECARBONISATION

As a matter of urgency, the shipping sector must accelerate the pace of change.

Future fuels and technologies

Shipping's future will involve different parts of the sector using different fuels, in what is sometimes called a "poly-fuel" scenario. For example, electrification may work on vessels used for short voyages, but heavy deep-sea freight ships need more range than a reasonably sized battery could provide before needing to be recharged.

As yet, there are no commercially viable zero-emissions technologies, (those that avoid adding to the overall amount of greenhouse gases in the atmosphere). A number of contenders may serve deep-sea shipping in the future and will take considerable development in the meantime.

There are many factors which will ultimately influence which technological pathway succeeds. From our initial analysis, Shell believes it can best play a role by focusing its development on the technologies, infrastructure and production of the fuels it has most confidence in today.

For this reason we're looking at hydrogen – a fuel that 65% of the participants in the *All Hands on Deck* report report believed would feature in the future fuel mix used by shipping. We will continue to explore this as we test and learn.

Hydrogen

We believe liquid hydrogen to be advantaged over other potential zero-emissions fuels for shipping, therefore giving a higher likelihood of success.

Clean hydrogen, produced either from renewable electricity or using carbon capture and storage, can be expensive to produce today. But it is also attracting interest as a potential fuel for power and land-based transport and as a possible feedstock for industry.

These other sectors could help develop and pay for some of the production and distribution infrastructure needed for hydrogen's use as a shipping fuel. The shipping sector should stand ready to capitalise on that development.

The properties of hydrogen are well understood and although there is much work to do, Shell considers that safe designs can be developed

for marine use. As a fuel, it can be switched in to use with 'fuel-agnostic' fuel cells which have been developed using LNG first.

Processes with the fewest transformations in delivering the energy to ships are likely to be the most efficient, and ultimately have the lowest cost – a key factor for the sector. Therefore, hydrogen appears likely to be competitive over the long-term cost of ownership versus other zero-emissions fuels that may be available.

Ammonia

Ammonia is already used in fertilisers, so some supply and distribution networks exist, and it could offer a pathway to zero-emissions shipping. Whether ammonia plays a significant role will depend on whether it will be used at scale in other industries, and like other future fuels, whether the costs associated with its production, transport and use are competitive.

Ammonia's higher energy density means it could free up more cargo space than hydrogen, if that becomes a significant factor. However, toxicity, emissions, and high ignition energy also present challenges.

Biofuels

Biofuels can play a valuable role in reducing CO_2 emissions from the marine sector over the decades ahead. Because biofuels can be blended with existing fuels such as gasoline and diesel and used in today's vessels and existing infrastructure, they offer practical and cost-efficient solutions for reducing emissions. *In this way biofuels can be used in the engines of today's ships during the years it will take for these vessels to be fully phased out.* To play their full role biofuels must be produced using sustainable feedstocks and processes while also meeting energy security and local development needs.

Biofuels are considered unlikely to be the dominant future fuel for shipping. This is because the sector would need huge volumes, and other sectors such as aviation and road transport are likely to be more able to pay the cost.

Methanol, electric batteries, nuclear

All Hands on Deck found little support for these three options, with potential problems including long sea voyages requiring large scale battery units, methanol's pathway to zero emissions is considered less efficient than other zero-emissions fuel options that may be available, and social anxiety about nuclear power.

The potential value of fuel cells

A key technology to unlock the use of future fuels is fuel cells. Fuel cells, used to convert fuel into electricity, and a proven technology for land-based power, could replace internal combustion engine technology. This is because they can improve energy conversion efficiency to over 60%, and if waste heat is harnessed they can achieve around 80% efficiency[4]. This efficiency means a reduced need for significant auxiliary power plant which in our view could lead to improved ship design with additional space for cargo. They also have the advantage of being able to work using a range of fuel types, including hydrogen or

ammonia, which, if produced from renewable energy would result in zero-emissions shipping.

Today fuel cells are more expensive than internal combustions engines (ICE) on a $/KW basis. However, this does not deter us. We have experience of new technology development and how costs can improve with uptake and standardisation. For example, Ballard, demonstrates cost reduction for fuel cells in the order 70–80% for land-based vehicles[5].

Fuel cells have competitive operating costs once installed, as they have very few moving parts, and thus the maintenance requirements are very low compared to ICE's. The solid state nature of fuel cell technology lends itself to lower operating costs, less need for intervention from crew and high reliability[6].

While the available scale and global supply infrastructure for hydrogen and ammonia is being developed, LNG could be used in fuel cells – the only fuel available today to help advance this critical technology. In this way, *shipping could lay the foundations for future fuels while securing immediate emissions reductions.*

Fuels and technologies available today

Shipping cannot simply wait for its zero-emissions fuel to emerge given the uncertainties around how long it will take for them to scale and the fact that cumulative emissions are a critical factor for climate outcomes.

The critical role of efficiency

Shell's analysis of publicly available industry data suggests encouraging CO_2 intensity improvement in the global fleet between 2008 and 2018 – in the range of 20% to 40%. The IMO's Fourth Greenhouse Gas Study (2020) reports an industry improved carbon intensity of 30% on an energy efficiency operational indicator (EEOI) basis since 2008. This has been achieved by the introduction of larger ships; improved hull and onboard mechanical design; the introduction of digital technologies that allow for better trim and improved

management of operations such as ship speed and port scheduling; and the retirement of older less efficient vessels.

But with society focusing on achieving net-zero emissions there is still much more to do. Shell's research found that *if used more widely, existing energy efficiency technologies, such as air lubrication, Shell's JAWS technology (hydrodynamic optimisation), wind technologies and improved hull coatings, could further reduce emissions by up to 25% compared to today's leading designs*[7]. These can be partnered with lubricants that can considerably improve engine efficiency. Marine lubricants reduce friction and consequently wear and tear, therefore extending the life of engines and vessels, and reducing a ship's environmental impact.

Using existing technologies to get closer to net zero must be a priority for the industry today.

LNG – lowering towards zero

LNG can help lower greenhouse gas emissions now. Compared to heavy fuel oil, from extraction to combustion LNG reduces greenhouse gas emissions by up to 21% for 2-stroke slow speed engines and up to 15% for 4-stroke medium speed engines. LNG significantly reduces pollution from nitrogen oxides and particulate matter compared to conventional marine fuels, while cutting emissions of sulphur oxides by more than 90%[8].

LNG is the cleanest fuel currently available to shipping in meaningful volumes. There are more than 75 ports with LNG refuelling infrastructure worldwide, and Shell aims to double its own LNG fuelling network by the mid-2020s.

Shell modelling shows that a ship using a high-efficiency LNG fuel cell and adopting other energy-efficient technologies could potentially reduce greenhouse gas emissions by up to 80% versus the 2008 baseline[9]. This means tangible emissions reductions during the time it takes for deep decarbonisation solutions to emerge, and the ability to switch from LNG to zero-carbon fuels through 'fuel-agnostic' fuel cells.

The methane emissions that can occur during the production and use of LNG can and are being reduced. This will further improve its

environmental footprint. For example, Wärtsilä reports that "[m]ethane slip from Wärtsilä dual-fuel engines has been slashed by 75% over the past 25 years and further advances will drastically reduce methane slip again over the next three years"[10]. Shell worked with others to develop the Methane Guiding Principles for reducing emissions across the natural gas supply chain[11], and we support well-to-wake measurement of emissions for all fuel types.

Bio and synthetic LNG development offer a pathway for getting to even lower carbon LNG using existing ship design and infrastructure. Shell will continue to look for ways to make this feasible and available for the shipping sector.

Regulation

Regulations need to provide a strong and stable incentive for the industry to decarbonise. Shipping is an international market that is highly competitive and plays a significant role in the economy. A global comprehensive policy regime will be the most effective in driving change while maintaining a level playing field.

Shell supports putting a price on carbon emissions from the shipping sector to provide the additional economic incentive to develop new technologies. Such a pricing mechanism will need to consider how best to direct its revenue towards in-sector research and development.

Shell would like to see the IMO adopt more ambitious targets for 2050, 2040 and 2030. *We would like the IMO to use its 2023 strategy review to set the trajectory for the sector to move to net-zero emissions by 2050.*

Carbon offsetting

The scope of the climate challenge is immense. All possible levers to reduce the environmental impact should be considered.

While the industry invests its resources in developing technological solutions to avoid and reduce emissions, the use of high-quality carbon credits from nature-based projects, such as planting and protecting trees, should be considered as the sector transitions to net-zero emissions. Robust rules and criteria on the use of carbon offsets should be integrated into national and global policy regimes, and ensure that the incentive to invest in efficiency measures and lower-carbon technologies is maintained.

The course to plot

The shipping sector as a whole must find fuels for the long-term future, but also act today.

While researching future fuels, technologies and fuel cells, the sector can immediately adopt energy efficient technologies more widely. More use of LNG as a fuel would also assist progress towards decarbonisation.

Climate change is one of the greatest global challenges of our times. *Inaction is not an option.*

Shell's role in shipping decarbonisation

SHELL'S ROLE IN SHIPPING DECARBONISATION

SETTING SHELL'S COURSE

Shell's purpose is clear – we want to power progress together by providing more and cleaner energy solutions to our customers.

Driven by that purpose we can play an active role in realising a lower carbon, more efficient shipping future. Transition of the sector will not be an overnight journey, but we can act with urgency in close partnership with our customers to be part of accelerating change. As outlined on page 6, we are shaping our response to three questions which focus our attention on innovating for new zero-emissions fuels, emissions reductions today and partnership.

The following pages highlight some of our key decarbonisation work today, and our plans to help the sector accelerate progress. These examples, which focus on our decarbonisation efforts, are selected from our wider shipping programme.

This is an evolving picture, and we are continuing to define our role. As such, the below examples are in some cases pre-cursors to more in-depth work that we intend to undertake later (for example, in measuring the emissions across our shipping operations so that we can better track and reduce them over time). In other cases, the examples involve really moving into new research domains such as fuel cells in a marine environment. *We are critically aware that we can only do this with others, so we hope that this publication triggers new conversations, leading to tangible action in the sector.*

How can we innovate to help phase out emissions from shipping as soon as possible?

Shell is increasing its shipping decarbonisation research and development capability in order to develop the zero-emissions fuels of the future.

What we are already doing:

Developing future technologies

- We are growing our academic research and development programme focusing on decarbonisation of the shipping sector, including trebling our research resources working on future fuels for shipping.
- Shell sponsors the Southampton University Centre for Maritime Futures including several PhD positions assigned to decarbonisation technologies and future fuels development.
- Shell as a consortium partner, worked with Kawasaki Heavy Industries on the design and construction of the hydrogen containment and handling systems for the CO_2-free Hydrogen Energy Supply-chain Technology Research Association (HySTRA) vessel, launched in 2020. Shell will be the technical manager of the vessel in the operations phase and it will be on the Shell fleet when it sails away in 2021, allowing us to develop the proof case for large-scale distribution of hydrogen.
- Shell is testing hydrogen as a fuel for the marine environment with DNV GL at the Spadeadam Facility, UK. We aim to develop a detailed understanding of its properties. The research is a key enabler for future ship designs.
- In 2020 Shell joined the DNV GL-led Maritime Hydrogen Safety Joint Development Project (MarHySafe) consortium which aims to develop the knowledge required for safe and reliable onboard hydrogen storage, bunkering and use of hydrogen in shipping, with the aim of removing regulatory barriers to hydrogen fuel use.
- Shell, in collaboration with industry and academic partners from around the world, is leading research into ammonia, methanol, synthetic fuels and other technologies such as carbon capture and storage to ensure these can develop at pace as market conditions emerge.

Accelerating change:

Fuel cells

- Shell is working to establish a consortium to develop a fuel cell trial on a commercial deep-sea vessel, pulling in partners from across the value chain (owners, classification societies, fuel cell vendors, and ports). The purpose of the consortium, launching later in 2020, is to demonstrate the maritime suitability of fuel cells and how these might shape future ship design.

Hydrogen

- Shell is working to deliver world-leading hydrogen production and delivery projects to show the viability of large-scale hydrogen production. For example, in the Port of Rotterdam, Shell is supporting H-vision, a consortium of 10 companies looking to decarbonise energy by replacing natural gas and coal with blue hydrogen.
- Also in the Port of Rotterdam, Shell is working on large-scale electrolysis for provision of hydrogen to its Pernis refinery. Fuel infrastructure linked to ports will be a critical enabler in the transition to zero-emissions fuels for the sector.
- Shell, together with its consortium partners, Gasunie and Groningen Seaports, announced one of the largest green hydrogen projects in Europe, the NortH2 project, in February 2020. Located in the Netherlands, the project envisages the construction of wind farms in the North Sea, up to a capacity of about 10 gigawatts by 2040. The first turbines could be ready in 2027 and will be used for green hydrogen production. The plan provides for a large electrolyser in the Eemshaven (a seaport located in the north of the Netherlands), where wind energy will be used to produce green hydrogen – up to 800,000 tonnes per year by 2040.

Innovation

- Shell is assessing opportunities to partner with others to explore new marine technologies and clean fuels. For example, Shell joined MarRI-UK to develop UK-based innovation projects in clean technologies.

How can we work with customers and within our own operations to reduce emissions and help reach peak emissions from shipping, as soon as possible?

We will help our customers avoid, reduce and offset their carbon emissions today, and we will take action on our own fleet.

EFFICIENCY

What we are already doing:

Reducing emissions through efficiency:

- Shell's patented draft and trim optimisation software, Just Add Water System (JAWS) has been deployed on 62 Shell-operated vessels, each delivering up to 7% reductions in fuel consumption and associated emissions. This has been licensed to Kongsberg Maritime, now making it available to the wider industry.
- Air lubrication is being deployed for the first time on Shell's in-service LNG ships with the first vessel setting sail in October 2020. This technology delivers in the region of 5–8% reduction in fuel consumption and associated emissions, and will be included on all eight of Shell's LNG fleet currently under construction.
- Shell partnered with Norsepower Oy Ltd., Maersk Tankers and the Energy Technologies Institute (ETI) to deploy Flettner rotors on the LR Tanker, Maersk Pelican as proof of concept, delivering around 8% fuel savings.
- Shell provides lubricants and technical services for over 10,000 vessels in over 700 ports across 61 countries, helping customers make their voyage more predictable, efficient and cleaner through a suite of solutions.

Within our operations, we look to further reduce our carbon intensity by introducing more sustainable packaging solutions for our cylinder oils, supplying more in bulk, and using solar energy at our lubricant plants.

- We work closely with original equipment manufacturers (OEMs) to allow the introduction of more fuel-efficient engines. We also worked with OEMs to develop our Shell Naturelle range of environmentally acceptable lubricants.
- Shell LubeMonitor helps customers lower their emissions by reducing consumption of lubricants through operational efficiency measures and technical services. Shell Accuport is a digital service that helps ship owners and fleet managers track their lubricant use and manage liftings, optimising delivery and minimising movements.

Accelerating change:

- Shell has an ambition to be a net-zero energy business by 2050 or sooner, in step with society and our customers. We also have an ambition and to reduce the net carbon footprint of the energy products we sell by 30% by 2035 and by 65% by 2050 – this includes transportation, and as such this drives our efforts more keenly on decarbonising shipping operations.
- Shell welcomes challenging performance standards from the IMO to make improvements in the global fleet as it lowers towards net zero. We are developing efficiency standards to apply to our chartered fleet in line with this aspiration, with an initial implementation on 60 of our long-term LNG charters.
- We are also developing a set of performance standards for application on future new-build vessels for all ship types with the aim to deliver up to 25% emissions savings.
- Effective measurement of emissions is a critical step towards being able to manage them downwards. We are committing to implement a programme of high quality emissions data collection for our time- and voyage-charter fleet across LNG, crude and products vessels. We will be working on a data collection platform and adding a clause for data collection for our voyage charter contracts. Following this step we will use this data to define the reduction trajectory to meet our net-zero emissions energy business ambition. It is our intent to publish annual carbon intensity data from our internationally-traded shipping fleet. The specific scope and methodology will be determined in the coming months.
- Shell will further build the commercial case for our unique industry offering of carbon-neutral lubricants through development of our nature-based solutions portfolio.
- Shell is working with Norsepower to consider deployment opportunities for Flettner rotors and also BAR Technologies and Smart Green Shipping to investigate wind sails.

How can we work with customers and within our own operations to reduce emissions and help reach peak emissions from shipping, as soon as possible?

FUELS AND CARBON COMPENSATION

What we are already doing:

Reducing emissions through biofuels:

- Shell is one of the largest biofuel blenders and distributors in the world, and is now also involved in more sustainable biofuels production. As we build out the capability onshore we learn more about its applicability for the marine sector today. Shell adopts international sustainability standards and is committed to biofuels that are produced in an environmentally and socially responsible way, across the whole supply chain.
- Shell was the first fuel supplier to provide certified second-generation sustainable biofuel to some of the world's leading shipping companies, in the Netherlands.

Reducing emissions through LNG:

- Shell has developed the world's largest LNG fuelling network of ports and bunker vessels on key trading routes, enabling more customers to choose LNG and save up to 21% CO_2 emissions versus high-sulphur fuel oil.
- Shell has significantly invested in LNG for its oil and products long-term charter fleet. Shell expects to take delivery of 10 LNG dual-fuel Aframax crude oil tankers, and four new LNG dual-fuel oil products tankers from 2021.
- Shell's own fleet rejuvenation programme has improved emissions of its commissioned LNG vessels by up to 60% emissions versus a 2008 baseline.
- Shell is undertaking a large assessment of processes onboard its LNG carriers, LNG-fuelled ships and in its plants to eliminate fugitive emissions in line with the Methane Guiding Principles. Shell is also working closely with engine manufacturers to eliminate methane slip and thus unlock the full environmental potential of LNG.
- Shell has built two bio-LNG plants in Europe to support decarbonisation of the heavy-duty road transport sector from which we can transfer lessons to the maritime sector.

Balancing emissions through nature-based solutions:

- Shell has developed a portfolio of high-quality carbon credits, offering a route to carbon compensation as a complementary measure to emissions reduction efforts.
- Shell offers nature-based voluntary carbon credits bundled with some of our products to help customers meet their own sustainability goals. For example, Shell has partnered with GS Energy, Tokyo Gas, CPC Corporation, and CNOOC Gas & Power Group Co., Ltd to deliver carbon-neutral LNG to customers in Asia. The carbon offsetting means that all emissions – from exploring for and producing the natural gas, to the use by the final consumers – are offset by credits from a variety of nature-based projects.
- We are now offering all of our customers the possibility to offset their lubricants emissions through nature-based solutions, providing carbon-neutral lubricants to the market for the first time. Our customer GasLog is the first to offset the carbon emissions from its marine lubricants purchased from Shell.

Accelerating change:

Biofuels

- Shell is growing its sustainable biofuel offer to ship operators across new markets and shipping sub-sectors.

LNG

- Shell will double its existing LNG bunkering infrastructure on key international trade routes by the mid-2020s, including the Q-LNG Articulated Tug and Barge bunker vessel expected in the 4th quarter of 2020.
- Shell has initiated a methane slip measurement campaign on our own fleet. This will entail the deployment of monitoring equipment on four of Shell's operated LNG vessels in order to advance our knowledge of this issue with real operating data, and inform the work we are undertaking on solutions.
- Shell will lead advocacy on methane slip through industry bodies, with the aim to ensure that appropriate policy development at the IMO is put in place to tackle this issue across the industry.
- Shell will focus investment into research to look at pathways for bio-LNG and synthetic LNG, building on our experience with our European plants and in close partnership with engine manufacturers.

Balancing emissions

- Shell is helping to shape the understanding of the responsible and appropriate use of carbon credits across shipping. For example, Shell is part of the World Economic Forum Natural Climate Solutions Alliance which is developing guidelines for buyers in identifying "high-quality credits".

Case Study: The World's First Cruise Ship Powered by LNG

Shell LNG worked with the Carnival Corporation plc to run achieve reduced emissions, quieter engines and no visible emissions from the funnel. The AIDAnova, the world's first cruise ship powered by LNG delivers a 95–100% reduction in sulphur oxides (SOx), up to 85% reduction in particulate matter and nitrogen oxides and up to 22% tank to wake greenhouse gas emissions reduction versus marine diesel oil. Tom Strang, Senior Vice President Maritime Affairs at Carnival said: "LNG is currently the most cost-effective solution that offers emission reductions today. What we can achieve today with fossil LNG plus an increasing introduction in the percentage of renewable liquefied methane – either from bio or synthetic sources – could see ships being effectively carbon neutral in the future."

How can we partner within shipping and across sectors to lower barriers to success and achieve decarbonisation through an ecosystem approach?

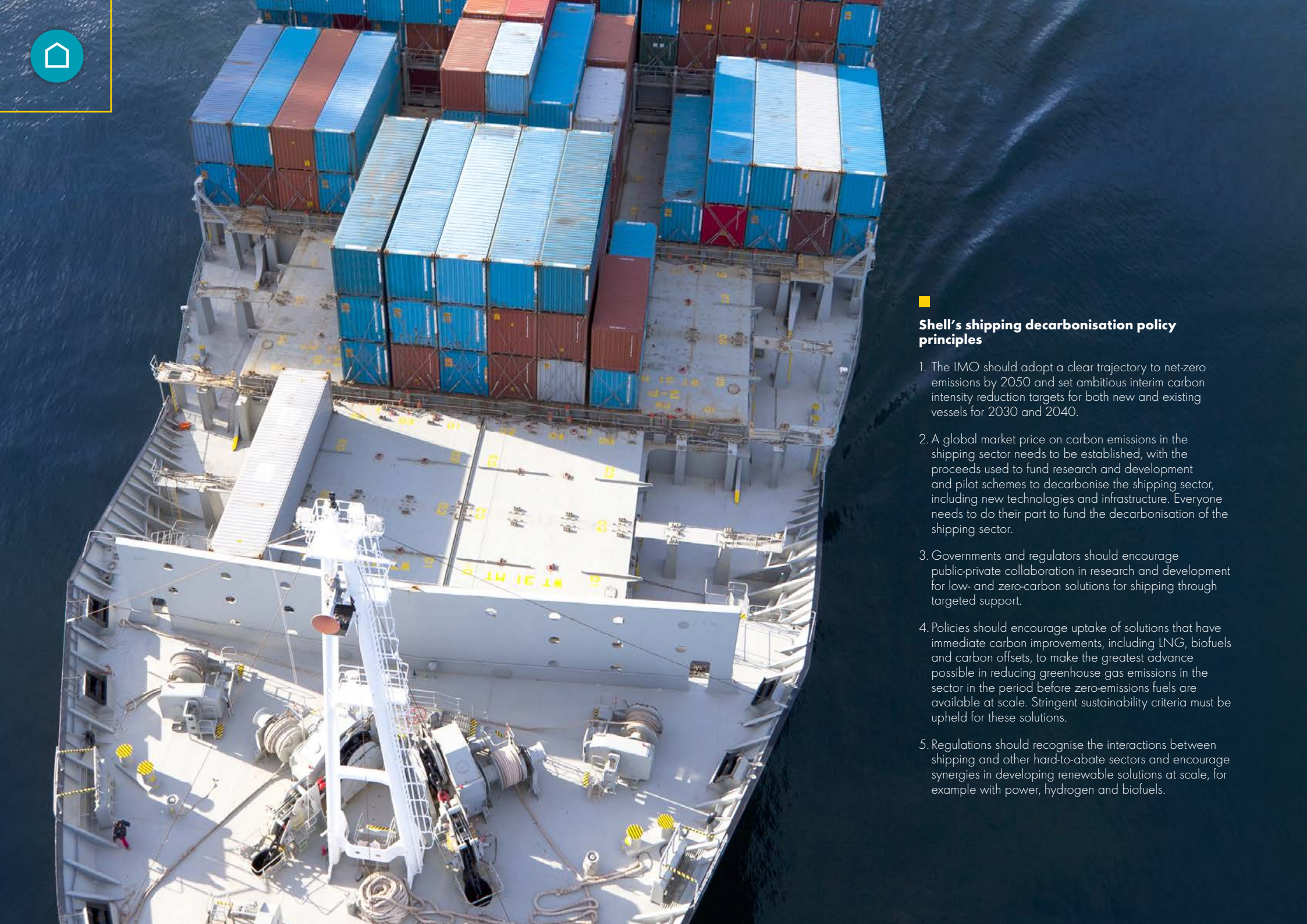
We will partner with our customers, suppliers and the wider shipping ecosystem to catalyse and lead change in the sector.

What we are already doing:

- Published *Decarbonising Shipping: All Hands on Deck* with Deloitte to continue to inform and progress industry conversation.
- Shell argues in favour of the IMO and member states taking measures to accelerate the pathway to decarbonising the shipping sector. In this report, Shell publishes a set of high-level principles which shape our advocacy.
- Shell is a founding member of the Getting to Zero coalition and an active participant in the First Movers group within the Global Maritime Forum.
- We aim to partner across the shipping sector in nearly all our research and development work to ensure we are leveraging the expertise of our customers and partners. We share our technical know-how where commercially possible.
- Shell is a founding member of the IMO Global Industry Alliance (Low Carbon) working towards lower-carbon opportunities in the sector today.
- Shell holds a number of positions in the Oil & Gas Climate Initiative (OGCI) including: member of the OGCI's Transport Working Group looking at options such as carbon capture and storage in a maritime environment; and member of the OCGI's Investment Fund looking for opportunities to invest in low-carbon technologies.
- Shell has membership of a broad range of industry associations such as IPIECA, The Society for Gas as a Marine Fuel, and the Oil Companies International Marine Forum where we work to further discussion and find solutions to barriers to decarbonisation.
- Shell and the University of Southampton Centre of Maritime Futures are collaborating to model and simulate different carbon policy scenarios for the sector based on real voyage data, and to advise on effective changes that can be undertaken to reduce the industry's carbon footprint.

Accelerating change:

- Shell will step up its engagements directly with governments and industry groups to further the decarbonisation agenda across the sector ahead of the IMO's revised 2023 strategy – arguing strongly for our advocacy principles including a net-zero emissions industry in 2050.
- We will enhance the transparency of Shell's advocacy positions on shipping decarbonisation by publishing them on shell.com.
- Shell will increase its partnership across the value and technology chain to drive the decarbonisation agenda. For example, in North America we are leading the development of an industry-based coalition covering the entire value chain for US and Canadian cabotage shipping operations, with the aim to accelerate pathways to decarbonisation.
- Decarbonisation of shipping will require a suite of solutions which have interdependencies in other sectors. Shell will leverage its customer base across multiple sectors to help identify opportunities for co-creation, for example around industrial and port hubs.



Shell's shipping decarbonisation policy principles

1. The IMO should adopt a clear trajectory to net-zero emissions by 2050 and set ambitious interim carbon intensity reduction targets for both new and existing vessels for 2030 and 2040.

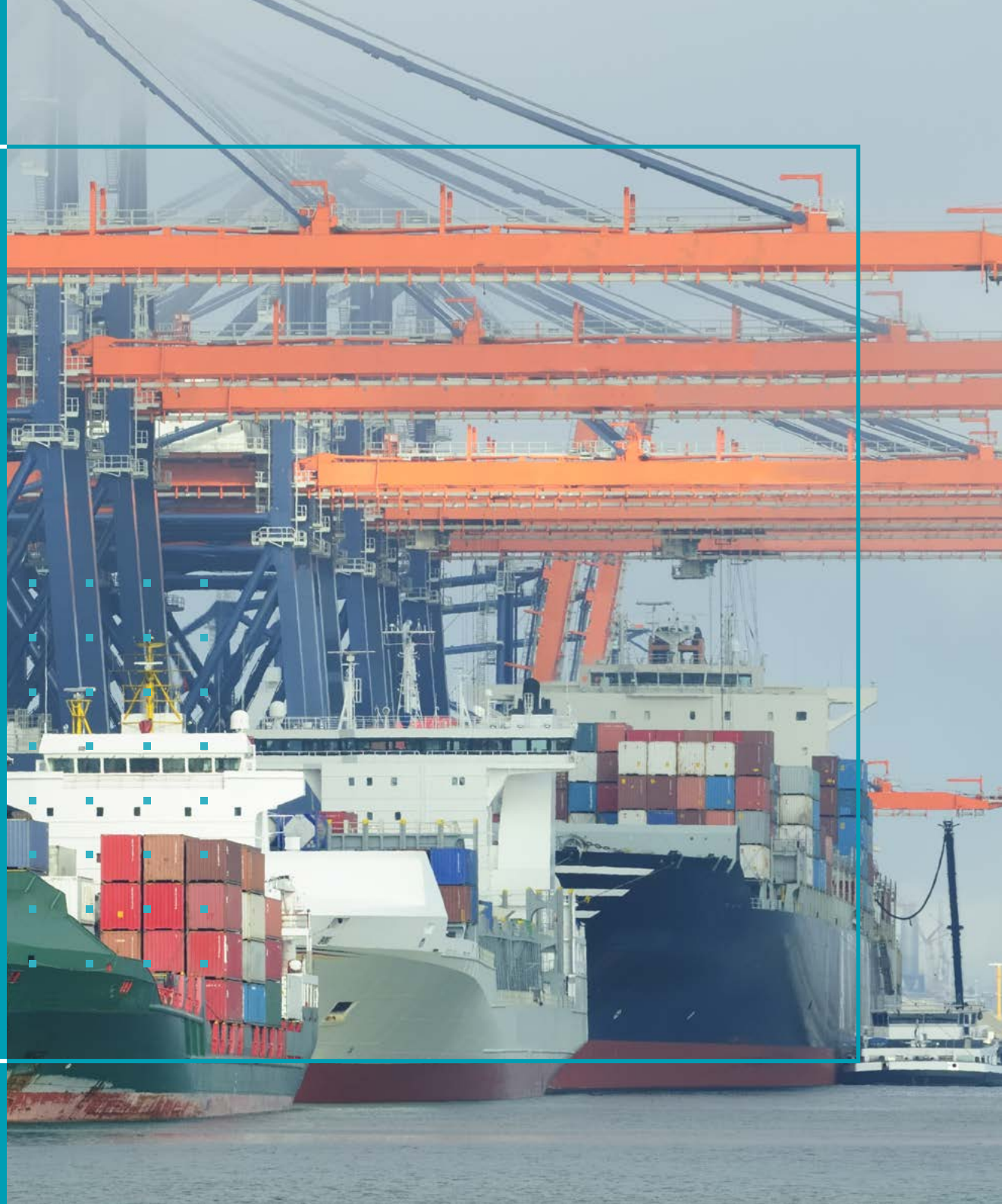
2. A global market price on carbon emissions in the shipping sector needs to be established, with the proceeds used to fund research and development and pilot schemes to decarbonise the shipping sector, including new technologies and infrastructure. Everyone needs to do their part to fund the decarbonisation of the shipping sector.

3. Governments and regulators should encourage public-private collaboration in research and development for low- and zero-carbon solutions for shipping through targeted support.

4. Policies should encourage uptake of solutions that have immediate carbon improvements, including LNG, biofuels and carbon offsets, to make the greatest advance possible in reducing greenhouse gas emissions in the sector in the period before zero-emissions fuels are available at scale. Stringent sustainability criteria must be upheld for these solutions.

5. Regulations should recognise the interactions between shipping and other hard-to-abate sectors and encourage synergies in developing renewable solutions at scale, for example with power, hydrogen and biofuels.

Conclusion



CONCLUSION

ACCELERATING CHANGE

The optimism that shone out of the *All Hands on Deck* report, the fast-changing pace of societal expectation and associated changing demand patterns, and the opportunities for regulatory changes at the IMO lend an air of expectancy to the sector. *Shell is working to meet that challenge, and while we are certainly still developing our own efforts, we hope to be a catalyst for change through our research, our advocacy, our chartering operations and our fuel and lubricants supply positions.*

We will step up our efforts on hydrogen research and development and drive new understanding of the role fuel cells can play. We are growing our LNG, biofuels and offsets offers, and developing lubricants which help our customers achieve improved engine efficiency and performance. We are taking action on methane slip, and we are working towards quality emissions data collection and publication to aid transparency.

Strong regulatory signals in the 2023 IMO's revised strategy will be fundamental to the success of shipping decarbonisation in meeting the Paris goals. In this paper, we have set out some of the principles we believe will help to unlock the change that is needed.

What is abundantly clear is that all players in the industry need to address this challenge together. Co-operation across the entire industry will be needed to develop robust solutions – from those funding first movers to ports galvanising their infrastructure eco-systems, and shippers creating demand for lower emission voyages. Shell will work closely with our customers and partners who are leading the way in the energy transition to achieve this ambition.

Shell is setting its course to help decarbonise shipping and we look forward to working together with others in the sector on a net-zero emissions future.

SOURCES

1. International Maritime Organization's Fourth Greenhouse Gas Study, 2020
2. "to phase out emissions as soon as possible" is taken from the aims of the IMO's Initial Strategy
3. "peak emissions as soon as possible" is taken from the aims of the IMO's Initial Strategy
4. Fuel Cell Fundamentals, Third Edition, 2016, page 284
5. Ballard – Fuel Cell Price to Drop 70-80% as Production Volume Scales
6. Environmental and Energy Study Institute – Fact Shell – Fuel Cells, 2015
   Hydrogenics – Fuel Cells
7. Emissions reduction potential offered by energy efficiency technologies is based on pilot projects and actual deployments of the technologies; Air Lubrication – Quoted emissions reduction based on existing applications of the technology. JAWS, deployed on 62 ships, emissions reduction of up to 7% achieved; wind technologies, quoted emissions reduction based on the Norse Power Maersk Pelican research; hull coatings, Shell monitoring fleet performance.
8. ThinkStep, Life Cycle GHG Emission Study on the Use of LNG as Marine Fuel, 2019
9. Shell modelling based on up to 40% emissions from efficiency gains versus the 2008 baseline, and cumulative emissions savings of 25% from additional application of energy efficient technologies, 21% CO_2 emissions reductions from the use of LNG as a fuel (well-to-wake), and 42% fuel cell contribution. UNCTAD 2008 Global Shipping Review, page 9, 30, 46; ICCT, Greenhouse Gas emissions from Global Shipping 2013-15,. 2017, page iv DNV GL Energy Transition Outlook 2019, page 24; Fuel Cell Fundamentals, Third Edition, 2016, page 284; Thinkstep Report, 2019
10. Wärtsilä – 'Cutting greenhouse gas emissions from LNG engines', 2020
11. Shell has set a target to maintain a methane emissions intensity below 0.2% by 2025. This target covers all oil and gas assets for which Shell is the operator.

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