# *The economic impact of small scale LNG*

May 2013

pwc

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# Nederlandstalige samenvatting

***Aanleiding***

*Doel van het onderzoek is een analyse van de economische impact van LNG in de transportsector*

Vloeibaar aardgas of "*liquefied natural gas"* (LNG) wordt gezien als een belangrijke potentiële nieuwe brandstof voor de transportsector. Op dit moment gebruikt de transportsector vrijwel uitsluitend olie gebaseerde brandstoffen zoals diesel en stookolie. Het gebruik van LNG zou in de toekomst sterk kunnen toenemen onder andere als gevolg van het aanscherpen van regelgeving op het gebied van emissies van schepen en een gunstige prijsontwikkeling van gas ten opzichte van olie. Op dit moment bevindt het gebruik van LNG zich echter nog in de "*development*" fase. Om daadwerkelijk de voordelen van LNG te kunnen plukken zijn de komende jaren substantiële investeringen nodig, met name door de scheep- en vrachtwageneigenaren en LNG leveranciers (infrastructuur).

Om inzicht te krijgen in de potentie van LNG is PwC ("wij") gevraagd door het Nederlandse ministerie van Economische Zaken om de verwachte economische impact op de transportsector in beeld te brengen. Het onderzoek is gericht op drie marktsegmenten van de transportsector: *short sea* schepen, de binnenvaart en het wegtransport. Wij analyseren de te verwachten ontwikkelingen in de periode tot en met 2030 voor Nederland en bespreken de relevantie van onze conclusies voor Duitsland.

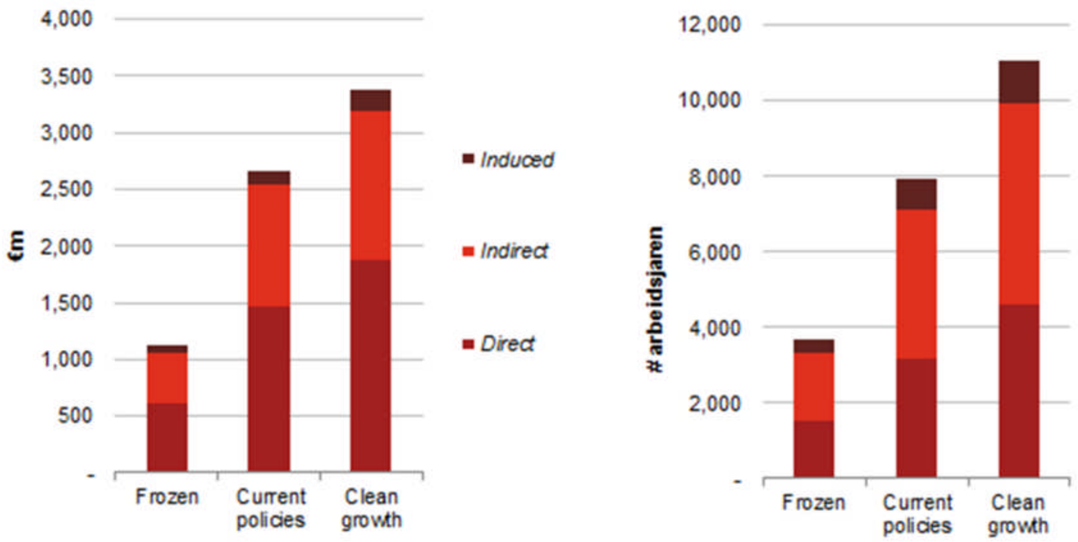
***Economische impact gebruik LNG***

*Het gebruik van LNG in de transportsector leidt tot significante groei- en werkgelegenheidseffecten*

Uit onze analyse blijkt dat het gebruik van LNG in de transportsector in de periode tot en met 2030 naar verwachting €2,7 miljard aan extra economische groei kan creëren evenals 8.000 extra arbeidsjaren. Dit is gelijk aan 0,4% van het huidige BBP en 0,1% van het huidige aantal arbeidsjaren. Hierbij gaan wij uit van een toekomstscenario dat in lijn is met onder andere de huidige beleidskaders en de huidige brandstofprijzen ("Current policies"). In een scenario met aangescherpte emissieregelgeving en gunstige brandstofprijsontwikkelingen ("Clean growth") kan de economische impact oplopen tot €3,4 miljard en 11.000 arbeidsjaren. In een toekomstscenario ("Frozen") waarin de drivers van de toepassing van LNG zich minder gunstig ontwikkelen bedraagt de impact €1,1 miljard en 3.700 arbeidsjaren. Op dit moment achten wij het "Current policies" scenario het meest reëel.

De economische impact die wij gekwantificeerd hebben valt uiteen in *"direct effects"* als gevolg van extra investeringen, "*indirect effects"* die optreden in sectoren buiten de direct geraakte sectoren (zoals de bouw), en "*induced effects*" als gevolg van extra vraag van eindafnemers zoals huishoudens. De werkgelegenheidseffecten zijn niet per definitie allemaal additionele banen voor de B.V. Nederland. Als zich tekorten van bepaalde typen personeel voordoen kan dit ook leiden tot een opwaarts effect op de lonen wat ook een positieve economische impact kan hebben.

## Impact op BBP en werkgelegenheid in Nederland in de periode tot en met 2030




*Bron: PwC analyse*

*Zes verschillende economische effecten*

Wij hebben zes economische effecten geïdentificeerd die een rol spelen bij het gebruik van LNG in de transportsector. De impact van de eerste drie effecten hebben wij gekwantificeerd, de overige drie bespreken wij kwalitatief in het rapport:

1. Investeringen in schepen en vrachtwagens die op LNG kunnen varen c.q. rijden

Scheep-en vrachtwageneigenaren zullen moeten besluiten om hun schepen en vrachtwagens op LNG te laten varen c.q. rijden. Het gaat hier zowel om nieuwe schepen en vrachtwagens, als om het geschikt maken van bestaande voertuigen voor het gebruik van LNG. Hun besluit om te switchen zal mede afhangen van de prijs van LNG motoren. Thans zijn deze nog substantieel duurder dan op olie gebaseerde motoren. Dit leidt ertoe dat de huidige business case relatief dun is voor de verschillende eindgebruikers. Echter bij stijgende vraag en verdere ontwikkeling en standaardisering van de technologie is de verwachting dat de extra kosten naar beneden gaan. Ook zal onze verwachting van een gunstige gas prijs ontwikkeling een positieve invloed hebben op de terugverdientijd in de komende jaren.

Uiteindelijk zal het besluit van scheep- en vrachtwageneigenaren om te investeren en om te schakelen naar LNG bepalen hoe snel de markt voor LNG als een brandstof voor de transportsector zich zal gaan ontwikkelingen. In het wegtransport hebben inmiddels al meerdere eigenaren een switch naar LNG gemaakt. De scheepsvaartsector loopt hier nog op achter, mede doordat binnenvaart en *short sea* shepen een veel langere afschrijvingstermijn hebben. Door strengere emissie-eisen vanaf 2015 verwachten wij echter dat de *short sea*, maar ook de binnenvaart sector zal volgen.

Voor zover de schepen en vrachtwagens in Nederland worden geproduceerd of aangepast leidt dit in ieder geval in de korte tot middellange termijn tot extra economische activiteit en werkgelegenheid in Nederland. Met name de Nederlandse scheepsbouwsector heeft een sterke positie en zal naar verwachting kunnen profiteren van de groei van LNG-transporttoepassingen.

*2.* Investeringen in LNG-infrastructuur

De fabrikanten van motoren en de eigenaren van schepen en vrachtwagens zullen pas hun investeringen doen als er zekerheid is dat de LNG-infrastructuur wordt aangelegd. Een groot voordeel in Nederland is dat er al een LNG-importterminal bestaat (i.e. GATE). Deze investering hoeft dus niet meer te worden gemaakt. Zoals wij hebben begrepen staan Vopak en Gasunie op het punt om te besluiten tot de bouw van een speciale *break bulk* terminal naast GATE, waarmee levering aan overslagstations en bunkerschepen mogelijk wordt. In de toekomst zal langs de binnenvaartroutes en in de belangrijkste zeehavens een aantal LNG-bunkerstations moeten worden geplaatst om binnenvaartschepen en kustvaartschepen te kunnen voorzien van LNG. Daarnaast moet het aantal tankstations waar vrachtwagens LNG kunnen tanken worden uitgebreid: de eerste LNG tankstations voor het wegtransport zijn reeds in bedrijf. In de komende jaren zal dat moeten worden uitgebreid tot circa 40 á 50 extra LNG-pompen, om gestaag door te groeien in lijn met de vraag. Al met al zijn de investeringen in infrastructuur – in vergelijking met andere energie investeringen - naar onze mening overzichtelijk. De verwachting is dan ook dat, indien aan de andere voorwaarden wordt voldaan, deze infrastructuur in de komende jaren zal worden aangelegd.

Om van het kleinschalig gebruik van LNG een succes te kunnen maken is een dergelijke infrastructuur niet alleen in Nederland, maar in heel Europa noodzakelijk. Alleen dan zullen de scheepsmotoren- en vrachtwagenfabrikanten de noodzakelijke investeringen doen om de technologie te standaardiseren en de eenheidsprijs naar beneden te brengen. De scheeps- en vrachtwagen eigenaren zullen dan bereid zijn om te switchen, en de infrastructuurbouwers om te investeren. Momenteel zijn voornamelijk Nederland en Scandinavië (focus op scheepsvaart) de kleinschalige LNG markt aan het ontwikkelen. De recente voorstellen van de Europese Commissie om een infrastructuurnetwerk voor alternatieve brandstoffen (waaronder LNG) uit te rollen leveren een belangrijke bijdrage aan de benodigde uitrol. De Nederlandse regering kan hier een voortrekkers rol in nemen.

*3.* Investeringen in bio-LNG

LNG kan niet alleen via de GATE terminal in Rotterdam beschikbaar worden gesteld voor transporttoepassingen. LNG kan ook worden gemaakt uit biogas. De Nederlandse overheid heeft berekend dat het totale potentieel voor biogas 56 Peta Joule (PJ) is (2020). Een van de belemmeringen op dit moment voor de realisatie van dit potentieel is dat het groen gas alleen tegen relatief hoge (opwerkings) kosten kan worden ingevoerd in het regionale of landelijke gastransportnet. Door het gebruik van LNG in de transportsector kan op termijn een attractief nieuw en rendabel afzetkanaal ontstaan van biogas. Hierdoor zullen biogas projecten uitgevoerd kunnen worden die anders niet van de grond waren gekomen. Over de effecten op het BBP en de werkgelegenheid van bio-LNG is relatief meer onzekerheid dan over de effecten van investeringen in schepen, vrachtwagens en infrastructuur. Dat komt omdat het thans nog zeer onzeker is hoeveel bio-LNG in Nederland geproduceerd gaat worden.

*4.* Diversificatie van de brandstofmix

Mede als gevolg van de relatief hoge olieprijzen sinds de midden jaren 2000 wordt er naarstig gezocht naar alternatieve brandstoffen voor de transport sector. Tot een paar jaar geleden lag de focus daarbij voornamelijk op de toevoeging van biobrandstoffen aan benzine en diesel, de ontwikkeling van elektrische personenauto's en waterstof als een nieuwe brandstof. Sinds kort is ook LNG als nieuwe brandstof geïntroduceerd. Door deze ontwikkelingen vergroot men enerzijds de hoeveelheid beschikbare brandstoffen om daarmee de prijs van olieproducten te verlagen dan wel minder te laten stijgen, en anderzijds de kansen op extra economische groei. Anderzijds hoopt men tot beduidend lagere emissies te komen. LNG in transport wordt thans zeer positief ingeschat; niet voor niets zijn de grootste oliemaatschappijen actief bezig om deze markten te ontwikkelen.

Het is echter nog niet duidelijk hoe aardgas precies zal worden geprijsd. Zoals het er nu naar laat uitzien zal het geprijsd worden ten opzichte van de dieselprijs. Het verschil zal worden bepaald door de betrokkenen in de LNG keten, wereld LNG prijzen, olie(product)prijzen en accijnzen. Het is ook mogelijk dat de detailprijs van LNG aan de pomp wordt bepaald door internationale LNG prijzen. Deze hoeven niet in lijn met olieprijzen te bewegen.

De gasprijs is relatief laag in verhouding tot de olieprijs, met name in Noord Amerika maar ook in Europa en China, al hoewel in mindere mate. Dit komt onder meer door nieuwe gasvoorraden die in de afgelopen jaren op de markt zijn gekomen, bijvoorbeeld door de winning van *shale gas* of *unconventional gas* in de Verenigde Staten en Canada. Mede gebaseerd op externe ramingen, zoals van het Internationaal Energie Agentschap (IEA), verwachten wij dat de gasprijs op de langere termijn op een relatief laag niveau blijft ten opzichte van de olieprijs.

5. Door vroegtijdige inzet op LNG kan de concurrentiepositie van Nederland verbeteren

Nederland is uitstekend gepositioneerd om LNG grootschalig toe te passen in de transportsector. Sterker, indien Nederland niet een investeringsklimaat creëert voor de ontwikkeling van LNG als een nieuwe alternatieve brandstof voor schepen en vrachtwagens, dan zal dit ook gevolg hebben voor de verdere ontwikkeling van deze nieuwe markt in continentaal noordwest Europa. Dit komt door de aanwezigheid van een LNG-terminal, de oriëntatie op gasgebruik in Nederland, en doordat Nederland bij uitstek een transportland is. Dat geldt zowel voor de scheepvaart - met de Rotterdamse haven en het grote aantal Nederlandse binnenvaartschepen - als het wegtransport. Spoor speelt ook een belangrijke rol maar laten we buiten beschouwing in dit onderzoek.

Nederland kan daardoor profiteren van schaal- en synergievoordelen bij het overstappen op LNG. Het Nederlandse bedrijfsleven kan daarvan profiteren door opgedane expertise en *know how* te exporteren. Hierbij is ook van belang dat kleinschalig LNG behoort tot één van de topsectoren waar het overheidsbeleid rondom innovaties zich op richt. Dit zal onderzoek en ontwikkeling in deze sector bevorderen, bijvoorbeeld op het gebied van veiligheid en emissies.

Het voordeel dat de Nederlandse economie kan behalen door de overstap naar LNG is naar verwachting echter tijdelijk van aard. Bij een positieve business case zullen andere landen (in navolging van Nederland, maar bijvoorbeeld ook Denemarken) overstappen op LNG waardoor de voorsprong van Nederland geleidelijk erodeert. Nederland zal desalniettemin een belangrijke importeur van LNG op het vaste land van Noordwest Europa blijven en daarmee een belangrijke rol spelen in de marketing en logistiek van LNG in de Benelux, Duitsland, en mogelijk Noord Frankrijk en de Alpen landen.

6. Gezondheidseffecten als gevolg van vermindering van emissies

Het gebruik van LNG in de transportsector levert naast directe economische voordelen ook aanzienlijke milieuvoordelen op ten opzichte van de huidige beschikbare technologieën. Ook op basis van de nieuwste beschikbare technologieën levert het gebruik van LNG nog milieuvoordelen op. Recent onderzoek van TNO, CE en ECN laat zien dat de milieueffecten het gunstigst zijn voor de uitstoot van fijnstof, $NO_x$ en $SO_x$. Wat de uitstoot van broeikasgassen betreft scoort LNG ook positief als het gaat om het wegtransport; in de scheepvaart is sprake van een lichte stijging van de uitstoot van broeikasgassen waarschijnlijk als gevolg van het vrijkomen van 'methaanslip'. De verwachting is echter dat LNG ook hier een positieve score zal laten zien door de voortschrijdende ontwikkeling van de motortechnologie. Wij hebben op basis van de gangbare kengetallen die door de overheid worden gebruikt de waarde van emissieverminderingen in euro's uitgedrukt. Dit kan worden beschouwd als de waardering die maatschappelijk wordt toegekend aan een betere gezondheid. De impact van broeikasgassen laten wij hier buiten beschouwing aangezien dit vooral gevolgen heeft voor de wereldwijde opwarming van de aarde en het effect op de gezondheid in Nederland niet direct meetbaar is. In het 'Current policies' scenario leveren de positieve gezondheidseffecten extra baten op van zo'n €214 miljoen per jaar (gebaseerd op 2030). Deze extra baten hebben een indicatief karakter en zijn niet meegenomen in de eerder genoemde cijfers.

*De economische impact in de omringende landen*

We hebben onze kwantitatieve analyse van de economische impact met name op Nederland gericht. Achterliggende aanname hierbij is echter dat Nederland weliswaar een voortrekkersrol kan vervullen maar dat op termijn LNG in de hele transportsector van Noordwest Europa zijn intrede zal doen.

Om een indruk te krijgen van de economische impact in andere Noordwest Europese landen kijken wij met name naar Duitsland. Op basis van door ons geanalyseerde gegevens over de omvang van de Duitse transportsector concluderen wij dat de economische impact in Duitsland ongeveer vergelijkbaar zal zijn met de impact in Nederland (relatief ten opzichte van de omvang van de economie). Het betreft hier de eerste drie door ons gekwantificeerde effecten (investeringen in schepen en vrachtwagens, investeringen in infrastructuur en investeringen bio-LNG).Mogelijk is het effect op de Duitse economie iets kleiner omdat er relatief minder vrachtwagens en binnenschepen zijn en Duitsland een kleinere scheepsbouwsector heeft. Natuurlijk heeft zij wel een belangrijke vrachtwagenbouwsector. Ook de effecten op de gezondheid door lagere emissies zullen in Duitsland naar verwachting beperkter zijn door de lagere bevolkingsdichtheid.

*De toepassing van LNG in de transportsector zal een S-vormig verloop kennen*

Het kleinschalige gebruik van LNG bevindt zich thans nog in de "*market development*" fase waarin nog relatief veel onzekerheden bestaan. Wij verwachten dat, na een geleidelijke groei waar *early adapters* een eerste stap zetten, er na 2020 een sterke groei zal zijn van het aantal schepen en vrachtwagens dat LNG voor aandrijving gebruikt. Afhankelijk van het relevante scenario kan de LNG-vraag in Nederland voor kleinschalige toepassingen in 2030 tussen 0,5 en 2,5 miljoen ton per jaar liggen in 2030. Dit komt overeen met circa 4-22 miljoen vaten olie ofwel 2-6%[1] van het totale brandstof verbruik door schepen en vrachtwagens in Nederland in 2030. Na een periode van sterke groei zal de groei geleidelijk aan afvlakken om zijn maximale potentieel te bereiken. Wanneer dit zal plaatsvinden is nu nog niet in te schatten.

*De snelheid waarmee LNG kan worden ingevoerd hangt af van vier hoofdrivers*

De belangrijkste drivers die het tempo bepalen waarmee LNG kan worden ingevoerd zijn de volgende:

1. Beleid

   De overheid kan met het regelgevend en fiscale kader voor LNG een belangrijke aanjagende of remmende rol vervullen. Zeker tijdens de "development" fase is het belangrijk dat het investeringsklimaat voor kleinschalig LNG gebruik niet negatief beïnvloed wordt door veranderingen in het belasting/ accijnzen stelsel. De Europese, nationale, regionale en lokale overheid kan op tal van manieren invloed uitoefenen op de relatieve aantrekkelijkheid van LNG ten opzichte van andere brandstoffen. Te denken valt aan de vaststelling van emissie-eisen, regelgeving ten aanzien van veiligheid en geluidsnormen, en het accijnzen, subsidie- en vergunningenregime. Wanneer de industrie eenmaal is uitgerold zullen stimuleringsmaatregelen niet meer nodig zijn, aangezien wij verwachten dat kleinschalig LNG een renderende industrie zal zijn.

[1] Gebaseerd op energetische waarde

## Key drivers van de groei van het gebruik van kleinschalig LNG

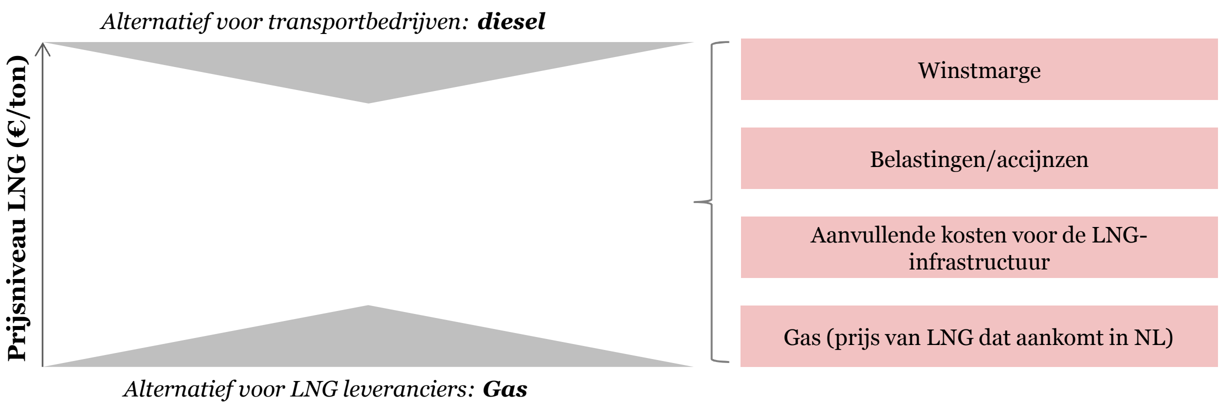

2 Beschikbaarheid van alternatieven

Een tweede driver is de mate waarin naast LNG alternatieven beschikbaar zijn die voldoen aan de milieueisen en die aantrekkelijk zijn gelet op de prijs-prestatieverhouding. Te denken valt aan de nieuwste schone dieseltechnologieën en “scrubbers” (rookgasreinigers voor olie-gebaseerde brandstoffen) voor de scheepvaart. De huidige benzine en dieselmotoren zullen naar verwachting nog een verdere ontwikkeling doorgaan wat betreft energieverbruik en uitstoot.

3 Verschil in brandstof prijs

Een derde driver is de relatieve prijs van LNG ten opzichte van de alternatieven die aan Noordwest Europese transportondernemingen ter beschikking staan. Onderstaande gestileerde figuur geeft aan dat een succesvolle uitrol van LNG vereist dat de prijs van LNG voor transportdoeleinden lager ligt dan de dieselprijs en maar naar verwachting hoger ligt dan LNG importprijs in Rotterdam. Het precieze prijsniveau dat tot stand zal komen zal mede afhangen van de winstmarge van aanbieders van LNG, het fiscale regime voor LNG, de additionele kosten die gemaakt moeten worden voor de infrastructuur om LNG aan te bieden en de LNG-prijs op de wereldmarkt. De dynamiek tussen deze drivers zal veranderen naar gelang de markt zich verder ontwikkeld, zowel mondiaal op de LNG markten, als regionaal in de LNG keten tot aan de pomp.

## De prijsdynamiek van LNG




*Source: PwC analysis*

4 Groei van de transportsector

Een laatste belangrijke driver is de algehele groei van de transportsector en de economische groei in Noordwest Europa. Een groeiende economie leidt in het algemeen tot een meer dan evenredige groei van het aantal transportbewegingen. Bij een hogere groei van de transportsector zal de bestaande vloot van schepen en vrachtwagens in het algemeen sneller worden afgeschreven en ontstaat er relatief gezien meer en sneller ruimte om te investeren in nieuwe voer- en vaartuigen. Indien dan ook aan de andere voorwaarden is voldaan, dan zullen de eigenaren / investeerders LNG meenemen in hun beslissingsproces als een geschikte brandstof.

*Belangrijke onzekerheden*

*O*p dit moment zijn er nog belangrijke onzekerheden over het exacte potentieel van LNG voor de transportsector, met name bepaald door de hier boven vier genoemde drivers. De eerste – "*Policies*" – wordt geheel bepaald door overheden; de tweede - "*Availability of alternatives*" – wordt bepaald door de industrie; de derde wordt bepaald door de wereld olie en gas markten; de vierde door een scala van actoren, waarbij de overheden en centrale banken een cruciale rol spelen. Wij verwachten dat het kip-ei probleem rondom de LNG infrastructuur de komende jaren wordt opgelost gelet op het grote aantal initiatieven die op dit moment reeds gaande zijn om voor LNG infrastructuur te zorgen. De kosten voor LNG schepen en vrachtwagens zijn op dit moment nog relatief hoog. De belangrijkste reden hiervoor is dat de technologie nog relatief nieuw is waardoor deze schepen en vrachtwagens nog niet massaal geproduceerd kunnen worden. Wij verwachten dat significante dalingen mogelijk zijn in de prijzen van LNG motoren en LNG aangedreven voer- en vaartuigen zodra meer ervaring is opgedaan met de technologie en massaproductie mogelijk wordt. Verder hebben de afgelopen jaren laten zien dat de prijsontwikkelingen op de olie- en gasmarkten moeilijk voorspelbaar blijven. Technologische ontwikkelingen en energiebeleid hebben grote invloed op de verdere evolutie van de energiemarkten. Ten slotte is het in deze pioniersfase van het gebruik van kleinschalig LNG van belang dat er duidelijkheid komt over het fiscale regime dat in de komende jaren van toepassing zal zijn zodat marktpartijen hiermee rekening kunnen houden bij het nemen van investeringsbeslissingen en het prijsvoordeel tussen detailprijzen voor LNG en diesel zodanig groot is dat de initiële investeringen in duurdere motoren en nieuwe infrastructuur kan worden terugverdiend.

# Summary


### *Background*

*Purpose of this study is to analyse the economic impact of the use of LNG in the transport sector*

Liquid natural gas (LNG) is seen as one of the key potential new fuels for the transport sector. At present, the transport sector mainly uses oil-based fuels such as diesel and oil. The use of LNG could significantly increase in future, driven by tougher emission regulations for ships and a positive price development of gas compared to oil. Yet, at this moment, the use of small scale LNG is still in the market development phase. In the coming years, shipowners and truck owners, and LNG (infrastructure) suppliers will need to invest substantially to be able to fully benefit from the advantages that LNG offers.

To get a clear insight into the potential of small scale LNG, PwC ("we") has been asked by the Dutch Ministry of Economic Affairs to analyse the expected economic impact on the transport sector. This study focuses on three transport segments: short sea shipping, inland shipping and road transport. We have analysed the developments that can be expected in the Netherlands in the period up to 2030. We have also discussed the relevance of our conclusions for Germany.

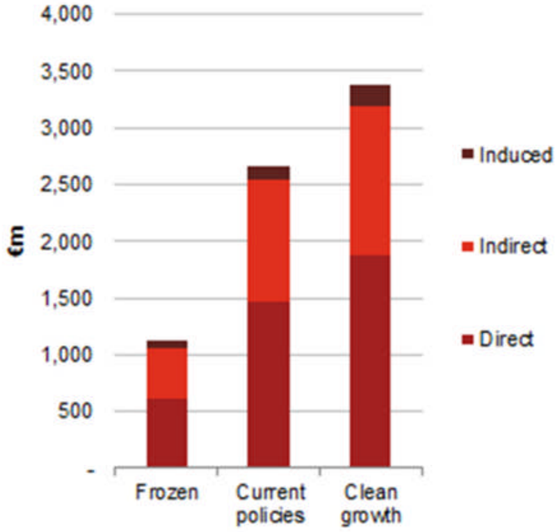
### *Economic impact of small scale LNG*

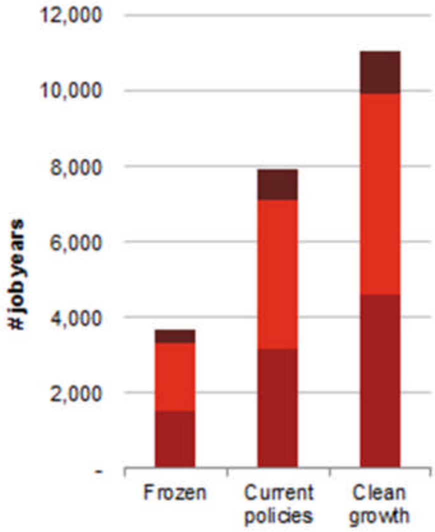
*The use of LNG in the transport sector leads to significant economic growth and employment*

Our analyses show that small scale LNG can lead to €2.7bn additional economic growth and 8,000 additional job years in the period up to 2030. This relates to 0.4% of current GDP and 0.1% of the current amount of job years. These results are based on a scenario which assumes Current policies and current fuel prices ("Current policies"). In a future scenario which assumes tougher emission regulations and positive price developments ("Clean growth"), the economic impact could increase to €3.4bn and 11,000 job years. In a future scenario ("Frozen") which assumes that underlying drivers will develop in a less positive manner, economic growth would be €1.1bn and 3,700 job years. We believe that the "Current policies" scenario is most realistic.

The economic impact that we quantified contains "direct effects" as a result of additional investments, "indirect effects" which take place in other (non-LNG-related) sectors, and "induced effects" as a result of additional household spend. The employment effects do not necessarily relate to additional jobs in the Netherlands. In case of personnel shortage in specific sectors, wages could be positively impacted.

## Impact on GDP and employment in the Netherlands in the period up to 2030




*Bron: PwC analysis*

*Six economic effects*

We identified six economic effects that play a role in the use of LNG in the transport sector. We quantified the impact of the first three effects. We have discussed the other effects qualitatively in the report:

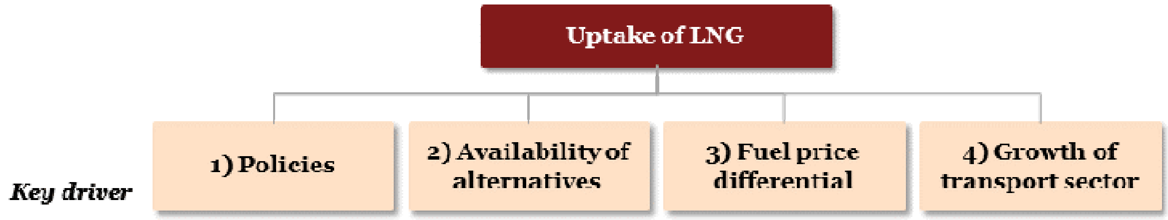
1. Investments in ships and trucks that operate on LNG

Shipowners and truck owners will need to decide to switch to LNG. In that case, they need to invest in new ships or trucks that are able to operate on LNG. They can also choose to adjust their existing ships or trucks. Their decision to start sailing or driving on LNG will partly depend on the price of LNG engines. Nowadays, these are relatively high compared to diesel-based engines. Consequently, the current business case is relatively thin for the different end-user segments. Yet it can be expected that prices will fall when LNG technology becomes more standardised. Also, our expectations of a favourable gas price development will positively impact the repayment period in the future.

End users' decision to switch to LNG determines how fast the small scale LNG market will develop. In the road transport segment, several owners already switched to LNG. The shipping sector lags behind, partly driven by the fact that inland and short sea ships face longer depreciation periods than trucks. Yet driven by stricter emission regulations as of 2015, we expect the short sea segment, but also the inland shipping segment, will follow.

If ships and trucks are produced and adjusted in the Netherlands, this will lead to additional economic activity and employment in the Netherlands, at least in the short to medium term. The strongly positioned Dutch ship-building sector is especially expected to benefit from the growth of the small scale LNG market.

## Key drivers of small scale LNG uptake




2. Investments in LNG infrastructure

Engine producers and shipowners and truck owners will only invest in LNG if they are confident that LNG infrastructure will be built. The Netherlands' big advantage is that it already has an LNG import terminal (i.e. GATE). This investment has already been made. We understand that Gasunie and Vopak are on the verge of making the final investment decision regarding the construction of a special break-bulk terminal next to GATE. This terminal will allow LNG supply to transport vehicles and bunker vessels. To supply inland and short sea ships, bunker stations will need to be built alongside the main inland shipping routes and in key sea harbours. The number of LNG refuelling stations also needs to be expanded: a few stations are already in use. Yet, 40 to 50 additional stations will need to be built to meet the expected increase in demand. We think the investments in infrastructure are achievable, compared to other energy investments. It can be expected that LNG infrastructure will be rolled out in the coming years, assuming key boundary conditions develop positively.

The rest of Europe also needs to have the infrastructure to help in the significant growth of small scale LNG. Only then, ship and truck producers will make the necessary investments to standardise engine technology, enabling reduction in unit prices, and they will be prepared to switch to LNG. If this happens, only then LNG suppliers will be prepared to make infrastructure investments. Now, mainly the Netherlands and Scandinavia (mainly shipping) are starting to develop the small scale LNG market. Recent proposals of the European Commission to roll out infrastructure for alternative fuels (LNG is among these) will play a key role in this. The Dutch government can choose to take a front runner's position.

3. Investments in bio-LNG

The GATE terminal in Rotterdam is not the only source of LNG. LNG can also be produced from biogas. The Dutch government has calculated that the potential for biogas is 56 Peta Joule (PJ) (2020). One of the current hurdles in realising this potential is the fact that green gas can only be injected into the regional or national grid against high costs. Due to the use of LNG in the transport sector, a new and cost-effective distribution channel comes into existence. This will allow rolling out green gas projects which would not have been realised otherwise. The uncertainty around the economic effects of bio-LNG is larger than around the effects related to the investments in ships, trucks and infrastructure. This is because it is still highly uncertain how much bio-LNG will be produced in the Netherlands.

4. Diversification of the fuel mix

The transport sector has been actively looking for alternative fuels being partly driven by relatively high oil prices since mid 2000. Till a few years ago, this mainly focused on adding biofuels to oils and diesel, developing electrical cars and using hydrogen as fuel. LNG has been introduced as a new (alternative) fuel only recently. First of all, this development increases the available amount of fuels, which can lead to oil prices increasing at a lower rate or declining oil prices. This will positively impact economic growth. Secondly, emissions can be reduced. The use of LNG in the transport sector is seen as an opportunity; this is reflected by leading oil and gas companies that are actively trying to develop these markets.

It is still uncertain how gas will be priced, but a price setting in relation to the price of diesel is most likely. The price difference will be determined by parties involved in the LNG chain, global LNG prices, oil (product) prices and excise taxes. It is also possible that retail prices at stations will be determined by international prices. These do not necessarily move in line with oil prices.

Gas price in relation to oil (product) price is currently at a historically low level, especially in North America, but also in Europe and China (although to a lesser extent). This is, among other factors, driven by an increased gas supply, for example, via winning of shale gas or unconventional gas in the US and Canada. We expect that gas price will remain on a relatively low level compared to oil price. This is also based on projections of the International Energy Agency.

5. The Netherlands' competitive position can be improved by early participation

The Netherlands is very well positioned to use LNG for transport purposes on large scale. If the Netherlands creates an investment climate for the development of small scale LNG, this will also impact further LNG market developments in the rest of north-west Europe. Its strong position is driven by the presence of an LNG import terminal, the focus on gas use in the Netherlands and the fact that the Netherlands is a transport-based country. This related to both the shipping sector — with the Rotterdam harbour and a large amount of inland ships — and to the trucking sector. Rail transport is also an important segment, but not in the scope of our research.

The Netherlands can benefit from scale and synergy advantages when switching to LNG. The Dutch trade and industry can benefit by exporting the know-how it has gained. Small scale LNG is one of the "top sectors" which receive government focus relating to innovation policy. This will stimulate research and developments in this sector, for example, in the field of safety and emissions.

Yet, the advantage that the Dutch economy will gain from switching to LNG is expected to be temporary. If the business case is positive, other countries will switch as well, implying that the Netherlands' advantage will gradually erode in the long term. But the Netherlands will remain an important importer of LNG in north-west Europe and, thus, continue to play an important role in the marketing and logistics of LNG in the Benelux, Germany and possibly France and the "Alps lands".

6. Health effects as result of emission reduction

Besides economic benefits, small scale LNG can lead to environmental benefits compared to currently available transport technologies. Also based on the latest (newest) technologies, LNG leads to substantial environmental benefits. Recent TNO, CE and ECN research shows that the environmental effects are largest for PM, $NO_x$, and $SO_x$ emissions. Concerning $CO_2$ emissions, LNG shows positive results for road transport; yet in the shipping sector, results show a small emission increase, probably caused by the "methane slip". But, it can be expected that in the future, LNG will also score positive in the field of $CO_2$ as engine technology is continuously being improved. We expressed the reduction of emission in EUR, based on parameters commonly used by government. This amount relates to the societal valuation of better health. We did not take the impact of $CO_2$ into account as this mainly relates to global warming and the exact effect on the health situation in the Netherlands is difficult to measure. In the "Current policies" scenario, positive health effects relate to additional benefits of €214m. Please note that these benefits have an indicative character and are not included in the numbers we discussed before.

*The economic impact in neighbouring countries*

Our quantitative analysis of economic impact is mainly focused on the Netherlands. This is because the Netherlands can take a front runner's role. Yet, in time, LNG will be introduced in the transport sectors of the whole of north-west Europe.

To get an impression of the economic impact in other north-west European countries, we looked at Germany. Based on analyses of the size of the German transport sector, we conclude that the impact in Germany will be largely comparable to the impact in the Netherlands (relatively compared to the size of the Dutch economy). The above relates to the first three economic effects that we identified (investments in ships and trucks, investment in infrastructure and investments in bio-LNG). Possibly the effect on the German economy is smaller; Germany has fewer trucks and inlands ships and a smaller shipbuilding sector. But it accommodates a large truck-building industry. Also, the health effects will be lower as Germany has lower population density.

*The development of small scale LNG market will follow an S-curve*

The use of small scale LNG is now in the market development phase, which is characterised by a relatively large amount of uncertainties. We expect that, after gradual growth via early industry adaptors, the market will grow substantially after 2020. Depending on the scenario, we expect annual demand for small scale LNG to be between 0.5 and 2.5m ton in 2030. This relates to c.4-22 million barrels of oil, implying 2-6%[2] of total fuel use by ships and trucks. After a period of significant growth, growth rates will diminish and reach its maximum potential. It is not yet possible to estimate when this will happen.

*The pace of LNG uptake is driven by four key factors*

The main factors determining the pace of small scale LNG uptake are as follows:

1. Policies

   The government plays a key role as it can either stimulate or discourage the use of LNG via regulations and fiscal schemes. Especially, during the market development phase, it is key that the use of LNG is not being negatively impacted by changing (excise) tax policies. European, national, regional and local governments have a variety of tools which they can use to impact relative attractiveness of LNG compared to other fuels. Examples are emission regulations, safety and noise regulations and, excise tax, subsidy and permit regimes. Once the industry has passed the development phase, stimulation measures will not be needed anymore. We expect that the small scale market will be a profitable industry.

2. Availability of alternatives

   A second driver is the availability of "clean" and cost-effective alternatives. These include, for example, increasingly clean diesel based technologies and scrubbers (cleaner for oil-based fuels) in the shipping industry. Current oil-based engines are expected to further improve in the field of energy use and emissions.

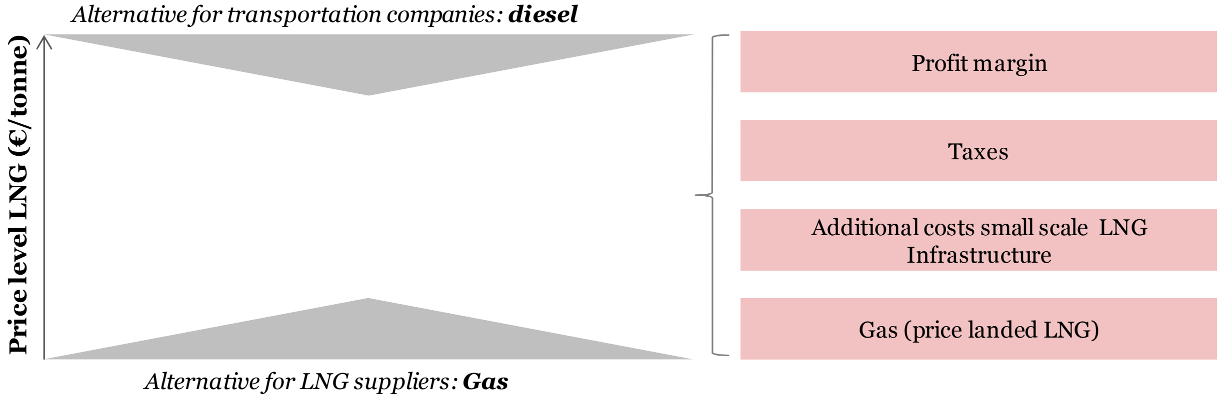
3. Fuel price differential

   A third driver is the relative price of LNG compared to alternative fuels which transport companies in north-west Europe can make use of. The figure below shows that for the market to be successful, the LNG price must be below the oil price and, that the small scale LNG price will lie above the LNG import price. The exact price level will depend on the profit margins of LNG suppliers, the fiscal regime, the additional costs that need to be made to roll out LNG infrastructure and the global LNG price. The dynamics between

[2] Based on energetic value

these drivers will change as the market develops further, both at a global LNG level and at a regional level (up to the refuelling stations).

## Price dynamics of LNG




*Source: PwC analysis*

4. Growth of the transport sector

A fourth key driver is the growth of the transport sector and the economic growth in north-west Europe. In general, a growing economy results in a more than proportionate growth of transport movements. High growth of the transport sector will, in general, also drive faster depreciation of ships and trucks, thereby implying relatively more flexibility to invest in new ones. In case the three factors above are positive, shipowners and truck owners will take an LNG-based vehicle into account.

*Main uncertainties*

Some important uncertainties exist around the exact potential of LNG in the transport sector. This is mainly driven by the four factors described above. The first, "policies", is fully determined by government bodies; the second, "availability of alternatives", is determined by the industry; the third is determined by the oil and gas markets; the fourth by a variety of participants in which the governments and central banks play a key role. We expect that the chicken-egg problem around the LNG infrastructure will be solved in the coming years, driven by the large number of initiatives that are currently being taken. At present, the investment in an LNG ship or truck is relatively high. This is mainly caused by the fact that the LNG technology is new, meaning LNG ships and trucks are not yet produced on large scale. We expect a significant decline in purchase prices should be possible as soon as experiences become larger and large scale production becomes possible. The recent years have proved that oil and gas prices are difficult to predict. Technological developments and energy policies will have a large impact on the further evolution of energy markets. Finally, clarity around the fiscal regime is key in the development phase of the small scale LNG market. This will enable market participants to take taxes into account when making investment decisions and, to evaluate whether the price advantage of LNG compared to diesel is large enough to compensate for the higher investment costs.

# 1. Introduction and background

*In the Netherlands, natural gas has traditionally been used for heating, power generation and industrial process purposes. Although gas is, to a limited extent, also being used as a transport fuel, LNG is new in the transport sector. LNG offers large benefits as it is a relatively clean fuel, which is able to reduce emissions that affect the environment and health. In this report, we will discuss the extent to which LNG could be adopted as a fuel in the transport sector and how this would impact the economy in the Netherlands.*

## 1.1. Gas as a transport fuel

*LNG as a fuel; a new market is coming into existence...*

In the Netherlands, natural gas has traditionally been used for heating purposes in houses and buildings, to fire power plants and to support industrial processes. Gas is also being used in the transport sector, but only to a limited extent. This is because gas has one major disadvantage compared to oil; its energy content is relatively low. This means the radius of action gas vehicles is limited (or that a huge tank is required).

Due to the shale gas revolution in North America, the *Energie Wende* in Germany, the recession in Europe, and consequential changes in the market with respect to price formation of natural gas, natural gas is now relatively cheaper than oil products in several regions around the world. In the last seven years, the world commercial gas reserves have grown tremendously. Unlike crude oil, gas reserves are plentiful and widely spread. This competitive advantage of natural gas over oil is expecting to stay in the foreseeable future. So, new technologies are rapidly being developed to capture the benefits of cheaper gas, notably in transportation sector, which is heavily dominated by oil products (e.g. diesel and gasoline). In the transportation sector, LNG (liquefied natural gas) is now entering the market for heavy trucking and shipping, while CNG (compressed natural gas) is used as a new fuel for passenger cars and light transport vehicles.

As the energy content of gas in its liquid form (LNG) is much higher, it is well suited for freight transport. Gas becomes liquid when it is cooled to a temperature of -162◦C. As LNG is very cold and a different type of fuel than oil, adoption in the transport sector requires the set-up of a new infrastructure and the development of LNG-based vehicles. Also, the (small scale) LNG price needs to be developed as infrastructure costs must be included. This new market is coming into existence and can impact our economy in several ways, as further described below.

In addition to the relative price advantage, the use of natural gas as a fuel has one other large advantage over oil. As the most clean fossil energy source, the growth in the share of natural gas and LNG in the energy mix will reduce emissions compared to the levels which would have been reached. This positively affects the health of the population and the environment, notably in densely populated regions and crowded cities.

*...to what extent will the Dutch economy benefit?*

In this report, we have analysed how the uptake of small scale LNG in the Netherlands can impact the economy till 2030. The small scale LNG market is still in the pioneering phase and it is uncertain how the market will develop in the next decades. The uptake depends on several factors such as government policies and LNG price spread development. The development of these factors is uncertain. Although the size of the economic impact might be difficult to predict, it is certain that the Netherlands will benefit from small scale LNG within a certain range.

## 1.2. The Green Deal between the industry and the Dutch government

*Via the Green Deal, the Dutch government aims to reach consensus on desired developments in small scale LNG and to support this development*

In 2011, the Dutch government launched a programme to improve cooperation between the industry and the government in reaching emission targets. In total, more than 150 so-called "Green Deals" were signed. One of these deals is the Green Deal Wadden and Rhine. In this deal, the industry, represented by Stichting LNG Technology, Research & Development, Deltalinqs and Energy Valley, commits to invest in the uptake of LNG and the realisation of pilot projects. According to the Green Deal, the pilot projects focus on the Rhine region, the main waterway in the region, and the Wadden sea region. In turn, the government commits to assist in developing a robust investment climate as well as to coordinate and to harmonise with other countries.

*Our report aims at understanding the potential impact of small scale LNG on Dutch economy*

This report, commissioned by the Ministry of Economic Affairs, is one of the elements of the Green Deal. In this report, we have discussed the potential effects that small scale LNG can have on Dutch economy. We have also indicated to what extent our findings are applicable to other countries, particularly to Germany, which is the number one destination for goods shipped from the Netherlands.

To support the analysis of the economic impact of small scale LNG, we have described the value chain, looked at the business case for LNG in terms of end users and have formulated scenarios to estimate the uptake of small scale LNG. In this report, we have analysed the potential of LNG in road and water transport. In theory, LNG can also be used in aviation and for passenger cars, but this was not part of our analysis.

## 1.3. Methodology

*Our report is mainly based on existing literature and feedback from the market*

We started this project with a review of the limited available literature on small scale LNG. Most of these have been written for the US market, some for the Chinese market and some for Europe, mainly for the Scandinavian countries. Between December 2012 and February 2013, we interviewed around 25 companies[3] and government bodies to get a better understanding of the market for small scale LNG in the Netherlands. In addition, we have used industry analyses and commodity research reports from a variety of firms.

In a meeting with the Dutch LNG platform on 28 January 2013, we shared our first findings on which we received feedback. Based on this feedback, we presented a draft report in March 2013, after which we again received comments. We would like to thank all the interviewees for their valuable input. We emphasise that all views expressed in this report are our own.

The methodology we used to analyse the uptake of LNG and its economic impact is described in Chapters 6 and 7 of this report.

## 1.4. Limitations of the analysis

We note that there is still considerable uncertainty around the uptake of small scale LNG, mainly driven by uncertainties in the business case such as investment costs, operational performance and LNG price. Our results should not be used as a basis for an investment decision, as this would require a detailed study of all the relevant costs and revenues of each individual investment. This is only expected, as the LNG proposition is new

[3] Please refer to "Appendix F. - List of interviewees" for an overview of interviewees.

and still in the development phase. Our analysis is meant to show what the most important drivers of the market are, how the industry can develop and how this can impact the Dutch economy.

## 1.5. Structure of the report

To provide an introduction to the LNG market, we start with a discussion around the LNG value chain. In order to use LNG for transportation purposes, a small scale LNG infrastructure is needed. In Chapter 3, we have explained what kind of infrastructure is needed in the Netherlands and what the expected developments are. The price differential between LNG and diesel products is an important driver of the business case for end users. In Chapter 4, we analyse developments in international oil and gas markets and describe the relationship between oil and gas prices and the price that end users have to pay for LNG.

Chapter 5 provides more detail on the business case for end users investing in LNG. We have made a distinction in the business case for trucks, inland vessels and short sea ships.

Chapters 1 to 5 provide the background for Chapter 6 where we have estimated how the uptake of LNG might look like. In Chapter 7, we have discussed how the potential uptake could positively impact the Dutch economy.

# 2. The LNG value chain

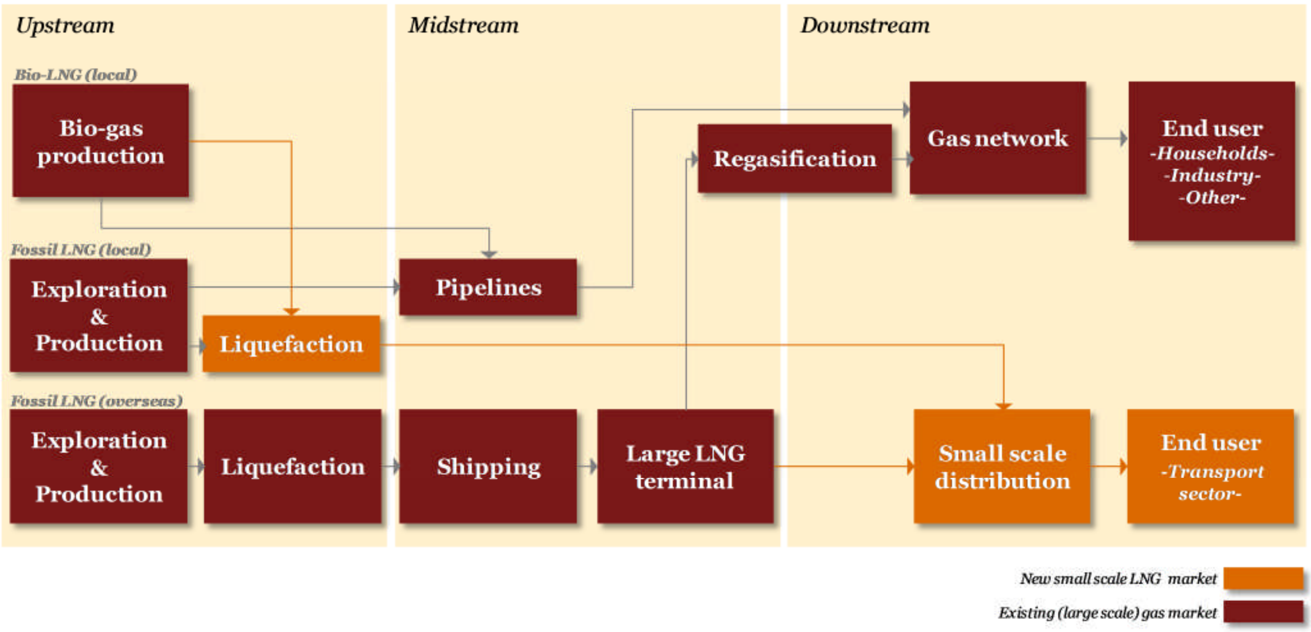
*The current natural gas value chain is based on the distribution of gas to households. Small scale LNG distribution will create a new value chain which attracts both new and established players. Currently, only some pioneers are involved (i.e. LNG supply, infrastructure, LNG vehicles). Yet, we believe that the small scale LNG market can offer opportunities to a large variety of companies. We expect that the LNG market landscape will be further established in the coming years, which could positively affect the financial business case for fleet owners.*

## 2.1. Introduction

By using LNG for transport purposes, a new market is developing, which must be seen separately from the existing gas market and which differs from the available oil-based transport fuel market. Small scale LNG has its own end users, requires a new infrastructure and has its own pricing mechanism. A new market attracts new market players, but also encourages players in the existing oil and gas markets to expand their services into this new area. The consequence of a new market is that there is a lot of uncertainty in the start-up phase and pioneers face various hurdles.

Figure 2.1 shows the LNG value chain, which encompasses the steps from gas exploration and liquefaction to the end user. In the following paragraphs, we have given an overview of the key market dynamics within the LNG value chain.

**Figure 2.1: LNG value chain**




*Source: Market feedback, PwC analysis*

## 2.2. Existing (large scale) LNG value chain

*The LNG value chain already exists for large scale distribution, with established players being actively involved*

The conventional natural gas reserves in the Netherlands and other north European countries are depleting, while demand is expected to increase again, once the economic recession is over. Historically, Europe's gas demand is met by indigenous production, mainly from the North Sea and by gas pipeline imports from Russia and North African countries. Since the 1990s, this has been supplemented by the import of LNG, again mostly from North Africa, Nigeria and Qatar, and smaller LNG import streams from Tobago/Trinidad and Australasia. Mainly in the 1990s and 2000s, the South European countries, France, Belgium and the UK built many LNG import terminals to diversify supply. Once it has arrived at the LNG import terminal, the liquid natural gas is re-gasified to normal natural gas and fed into the gas grids for delivery to end consumers in the stationary segment of the energy market (i.e. power generation, heating and cooling, and industrial use).

In 2008, infrastructure providers Vopak and Gasunie also built a large scale LNG import terminal in the Rotterdam port (i.e. GATE) to diversify the supply base for North Western continental Europe and to replace declining supply in the future from the Dutch gas fields and to meet expected growing demand. To justify the development of GATE, the company has signed long-term gas supply contracts with the energy companies Dong Energy, Econgas OMV International, RWE Supply & Trading, Eneco and E.ON Ruhrgas. The LNG producers deliver LNG from the gas-exporting countries mentioned above. The international oil companies (IOCs, e.g. Royal Dutch Shell, ExxonMobil, BP, Total) and the national oil companies (NOCs, e.g. Qatargas and Rasgas from Qatar and Sonatrach from Algeria) are the operators of these projects which produce natural gas and liquefy it to LNG. In addition to conventional natural gas, biogas is also a fuel which makes its inroad into the Dutch market, although on a much smaller scale. Schoteroog (located near Haarlem) is one such producer of biogas in the Netherlands.

The shipping of LNG is done by the same traditional oil and gas companies as mentioned above, but also by special transport companies (e.g. Anthony Veder, NYK). Most of the LNG ships costing over USD 100m each are built by the Japanese and South Korean ship yards[4].

The Port of Rotterdam (PoR) is not directly involved in the LNG infrastructure but leases the land/waterway, and facilitates and regulates the development and business. In addition, it plays an important role of an information-sharing platform for parties involved and interested in LNG and, so, is an important business and market developer for small scale LNG.

*The small scale LNG value chain is new but forms a link between the large scale LNG market and the oil-based transport market*

The currently available (downstream) natural gas infrastructure in the Netherlands is designed for distribution to the gas network via pipelines. Gas Transport Services, a subsidiary of Gasunie, is the owner of the high-pressure network and is responsible for system operation. Although the Netherlands shelters a large scale LNG terminal, small scale distribution is not yet possible as GATE has been designed for large scale distribution only.

Small scale LNG requires own infrastructure and has its own end users. The creation of this new market drives the set-up of a small scale LNG value chain. This new chain is partly linked to the existing natural gas chain via the supply of LNG[5], but it is also linked to the transport industry via its end users.

So, small scale distribution leads to new parties entering the market, and to existing parties entering a new market segment. For example, Vopak and Gasunie which have been engaged in large scale infrastructure so far, are now planning to build a break-bulk terminal to be completed in 2015 which will link GATE with the small scale market. *Please refer to Chapter 3 for details and an outline of small- scale LNG infrastructure requirements*.

With regard to LNG supply, traditional oil and gas companies (e.g. Shell, BP, Gazprom) are entering the new small scale LNG market to maximise sale of LNG and to deliver a new alternative fuel to their customers in the

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4 LNG must be transported in special cryogenic storage tanks, with double hulls to prevent damage and leakage, built in deep sea tankers where it can remain cool due to the creation of a vacuum in the tank.

5 Please note that natural gas from the Dutch gas reserves, or gas that is imported via pipes is not being liquefied in the process from exploration to import into the gas grid. Liquefaction would be needed to start using this gas for small scale purposes. Yet, market feedback confirms this is currently not a cost-effective option for the Dutch market, as LNG is readily available via overseas import. So we do not further elaborate on this option.

transport sector. They already have experience in the distribution of gas to the wholesale sector (notably utilities) and oil products to the transport sector. Given the advantages, they see major business opportunities in developing a market for LNG as a fuel in transportation. In addition, players currently engaged in large scale LNG distribution only (e.g. Linde, Ballast Nedam) are entering this field as well. New players fully focused on small scale distribution are also becoming engaged (e.g. LNG Europe, Rolande LNG). Besides these market and infrastructure developers, the truck manufacturers and engine manufacturers are now also developing new engines which could run on LNG.

At the end of 2012, energy company Essent and Gas Treatment Services (GTS) started with green gas production on the landfill site Schoteroog. Currently, bio-LNG production is tested in the Netherlands. If tests are successful, Schoteroog will have a capacity of about 500,000 kg bio-LNG per year, which can be used for small scale distribution[6].

As the small scale LNG market is new and full acceptance by the transport sector is still uncertain, many parties are still reluctant to become actively engaged and to make big investments. So there are limited LNG supply options for end users and the infrastructure is still in a development phase.

One peculiar aspect of LNG imports is that LNG's quality/product specification is variable and can be different from the natural gas produced in the Netherlands (i.e. lean Slochteren gas and rich gas from the offshore gas fields and imports). LNG could contain more longer or less longer carbon molecules and hence contain more liquid or less liquid. In the most liquid form, gas could be produced as natural gas liquids (NGLs). So LNG's quality (i.e. methane/energy level) varies based on its origin. As all supplied LNG from abroad is mixed during storage, quality levels can differ per period. For large scale distribution, quality levels are of less relevance and measurement tools or standards for the composition of LNG are not available. For small scale LNG use, the quality level of LNG is quite important though, as it can impact the efficiency of engines. Market feedback confirms that standards will be developed in the future. If the liquids levels are too high, these liquids could be stripped and sold separately to industrial users, leaving high-quality LNG for transportation purposes.

## 2.3. New end users

*The Netherlands has a large transport sector, meaning the potential for small scale LNG could be large*

The Netherlands is Europe's most important hub for freight transport. Much of the bulk and container cargoes are transported through the Netherlands to the hinterland, by truck, ship or train. Also, a relatively substantial part arrives into, or leaves the Netherlands by air. The share of inland shipping in transportation is, compared to other European countries, very high in the Netherlands (over 30%; c.60% for trucks[7]). In addition, trucks and ships are used for other purposes such as passenger transportation. Almost all heavy-duty trucks and ships use oil-based fuels. *Please refer to Appendix A for an overview of the Dutch transport fleet.*

For transport companies, LNG can offer opportunities to reduce emissions and/or to downsize variable costs. Details around the LNG business case for end users are discussed in more detail in Chapter 5. LNG is a suitable fuel for transport companies, as it can support long-distance travel on a constant base. Currently, LNG is only adopted on a limited scale, as shown in Figure 2.2.

[6] Bio-LNG has a low carbon footprint as $CO_2$ is separated during production. Bio-LNG is of better quality (>98% methane) than fossil LNG and can contribute to increased engine efficiency. It can also be used to mix with fossil LNG to increase quality, which can be important if LNG quality standards are set in the future (minimum methane requirements).
[7] Waardevol transport, 2010.

**Figure 2.2: Number of LNG vehicles in the Dutch fleet**

| Dutch fleet | Trucks | Inland ships | Short sea ships |
| --- | --- | --- | --- |
| # LNG-based | 70-100 (<1%) | 1 (<1%) | 1 (<1%) |
| Total | c.166,000 | c.10,000 | c.3,000 |

*Source: RAI, IVR, TNO, PwC analyses, PwC interviews*

*The Dutch shipping sector is relatively large, driven by developed waterways and a strong position of the Rotterdam harbour. LNG adaption has been limited so far, but this could gradually change*

The shipping industry consists of inland, short sea and deep sea shipping. The latter has a worldwide focus and is therefore considered as out of scope for the purpose of this study. Currently, ships mainly sail on heavy fuel oil (short sea) and marine gas oil (inland).

Ships for inland and short sea shipping are mostly used for freight-carrying purposes (i.e. >50% of the inland vessel fleet in the Netherlands is freight-carrying). They are operated by inland transport companies such as Interrijn Group, VanUden Maritime and by (short) sea transport companies such as Maersk. The ships sail on inland shipping routes (e.g. Rhine) and along the international coast (e.g. Baltic Sea). At present, the first LNG-based ship (i.e. the Argonon of Deen shipping) is sailing. Three LNG-based ships have received regulatory permission to sail but are not yet operational.

Ships are also used for passenger transportation (e.g. Rederij Doeksen, Stenaline), and for the transportation of LNG (and other fuels) itself. Rederij Doeksen is already investigating possibilities to use LNG. Currently, Anthony Veder operates an LNG/LPG/LEG tanker, which also uses LNG as a fuel (i.e. coral methane). Shell recently announced that it has signed a contract for the charter of two newly built LNG-powered tank barges, which will operate on the Rhine from 2013.

*Trucks are mainly used for freight transportation. The first LNG trucks are already in use*

The truck fleet in the Netherlands is mainly used for freight transportation, but also for special purposes such as cleaning and fire prevention. In 2012, the Netherlands registered a total of around 166,000 trucks[8] (please note that a truck is defined as > 3.5 tons).

Currently, over 98% of trucks use diesel as a fuel. Yet, the first LNG trucks are used in national distribution (e.g. by Simon Loos and Vos) and waste collection (e.g. Van Gansewinkel). Currently, around 70-100 LNG trucks are part of the Dutch truck fleet.

*LNG could also be adopted in other industries such as rail transport and manufacturing industries*

Potential end users of LNG in other forms of transportation could be railways, airplanes or other vehicles that have high energy demand on a frequent basis. Other potential end users of LNG are manufacturing industries (e.g. steel manufacturers). An analysis of these markets was not part of our research.

## 2.4. Suppliers (OEMs)

*A new fuel requires new vehicles; the first established (oil-based vehicle) suppliers have already moved to the LNG segment*

End users that want to switch to LNG need a vehicle which is able to run on the new fuel. This mainly refers to an engine which can operate on LNG and, a fuel tank which is suitable to store LNG. So the supplier/original equipment manufacturing industry plays a critical role in the development of the small scale LNG market.

The Netherlands has a large industry of shipyards, engaged in building high-quality ships (e.g. Damen shipyards, IHC Merwede, and some smaller specialised ones dedicated for Rhine cargo vessels and fishery vessels). All of these specialise in building complex vessels in the most efficient/standardised ways and are

[8] RAI

focused on innovation. Specialised companies such as Wärtsila provide ship engines. Mostly, ships are partly produced cross-border (e.g. China) and are finalised in the Netherlands. This means most of the value-added work takes placed in the country.

Established ship suppliers have already started to develop LNG engines (i.e. Wärtsila, Rolls Royce and Caterpillar). Trico, a shipyard that builds LNG ships, built the Argonon. Caterpillar provided the engine.

Trucks are largely produced by truck manufacturers outside the Netherlands, exceptions are Daf Trucks, a subsidiary of Paccard Trucks from the US and the production facilities of Scania in the Netherlands. Germany has a large truck manufacturing industry and is the place of origin for companies such as MAN and Mercedes, Europe's largest truck manufacturer.

Conventional truck producers provide LNG trucks. The ones currently developing and marketing LNG trucks are Volvo (Sweden), Scania (Sweden), Mercedes and Iveco (Italy). Besides the adoption of the engine, an important element is the LNG gas tank and the pumping system. Most of the LNG tanks are imported from countries where gas has historically been stored in liquid form, such as Spain. The Dutch companies Cryonorm and Cryovat also provide LNG tanks and related materials. None of the original equipment manufacturers, except the tank builders, have, as far we understood, set up dedicated LNG engine and truck building production lines that run full-time. In that sense, most are still "hand-made". Moreover, different truck manufacturers have chosen different types of technologies, such a mono-fuel, bi-fuel, and dual-fuel LNG engines, each with their own advantages and disadvantages. So the costs of such trucks/engines are still relatively high. But, with the roll-out of the infrastructure and the acceptance of LNG as a preferred fuel, it is expected that costs will come down over time and become competitive by the end of this decade.

# 3. LNG infrastructure in the Netherlands

*Small scale LNG requires setting up a new infrastructure. As LNG is a new transport fuel in the Netherlands, there is almost no infrastructure. LNG is currently supplied via the LNG terminal in Zeebrugge, Belgium, but local supply can be made relatively easy by building a new break-bulk terminal next to the existing LNG terminal GATE in Europoort, Rotterdam. In the road sector, the first LNG refuelling stations have been built, but in the maritime sector, there is still almost no infrastructure. We believe the LNG infrastructure will be further built up in the coming years, with key industry players having announced plans to roll out refuelling stations and bunker solutions. As only a limited number of stations is needed, investments are relatively low.*

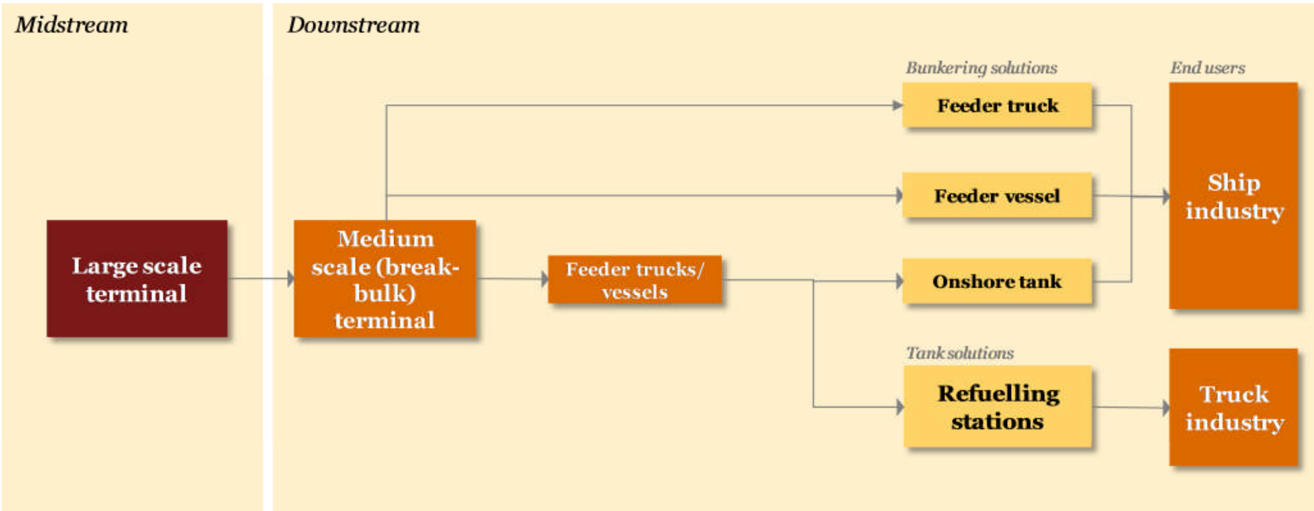
## 3.1. Background

The first prerequisite for successful penetration of LNG in the transport sector is building and rolling out a suitable LNG infrastructure throughout the Netherlands and the rest of northwest continental Europe at the main cargo transportation nodes. Without an adequate infrastructure, fleet owners are expected to be reluctant to invest in LNG trucks and ships. Exceptions might be those fleet owners who are forced by their customers to shift to LNG for sustainable development reasons and have enough scale to build a special LNG fuel station at their locations. Infrastructure operators can, in turn, be reluctant to invest in LNG infrastructure as few LNG vehicles ply. Their estimates of how fast markets will develop and the ramp-up will take place will define their commitment to investments. Over the previous year, the first infrastructure projects such as truck refuelling stations have been set up in the Netherlands. Key market players have now planned to further roll out the small scale LNG infrastructure throughout the country. Most importantly, the final investment decision on the break-bulk terminal by Vopak and Gasunie, planned for the coming months, is key for further infrastructure development. This means that the “chicken-egg” dilemma appears to come to an end.

In this chapter, we will discuss the infrastructure required for small scale LNG, the current status of the infrastructure both for road and water transport, and the projects expected to be rolled out. We will also discuss the related investments.

## *3.2. Required infrastructure for small scale distribution*

**Figure 3.1: Small scale LNG infrastructure**




*Source: PwC analysis, PwC interviews*

### *LNG supply*

Though existing large scale LNG terminals have been created for large scale distribution, these only have access quays for large ocean-going LNG carriers. To create a small scale infrastructure, a medium scale terminal (also referred to as break-bulk terminal) is needed to further distribute LNG. The medium scale terminal must have access stations and quays for LNG feeder trucks and feeder vessels. These are needed to further transport LNG to the small scale end users.

### *Tank solutions for trucks*

Drivers themselves refuel the trucks at refuelling stations built on the roadsides. The existing oil and gas refuelling stations are not suitable for LNG as LNG supply requires different safety restrictions, storage tanks and fuel systems. So, new or adjusted refuelling stations are needed. LNG refuelling stations are mainly supplied by feeder trucks which have been loaded at the medium scale terminal. LNG can also be transported via feeder vessels or trains.

### *Bunker solutions for ships*

Ships can be bunkered by ship-to-ship bunkering, truck-to-ship bunkering or shore-to-ship bunkering. During *ship-to-ship bunkering*, a ship is bunkered on the water by a feeder vessel. The feeder vessel sails and connects to the ship, which is either bunkered at anchor or during sailing. The latter is common for inland ships and is most efficient. (Short) sea vessels are often bunkered during (un)loading of freight at the harbour, which is also the most efficient. Another option is *truck to ship bunkering*. In this case, a ship sails to a location where it is bunkered from the shore by feeder trucks. The third option is *shore-to-ship bunkering*. A ship sails to an onshore tank location/small terminal, where it is bunkered by a connection to the tank. *Please refer to Appendix B for an overview.*

Existing bunkering infrastructures have been built for supplying of oil-based fuels, and are not suitable for LNG distribution. For LNG distribution, LNG feeder trucks and vessels are needed to distribute the LNG from the medium scale terminal to onshore stations or directly to end users.

## 3.3. Existing and planned infrastructure in the Netherlands

*Supplying LNG supply in the Netherlands can become relatively easy by building a break-bulk terminal at GATE*

In the Netherlands, Vopak and Gasunie built a large scale LNG terminal in the Rotterdam harbour (GATE), where gas companies can take the storage capacity on lease. The terminal consists of three storage tanks, two jetties and re-liquefaction facilities. It has an initial capacity of 12 BCM per year. Currently, only 10% of the capacity is being used as LNG demand is low in Europe and gas prices are less competitive than coal prices and subsidized renewable prices. The capacity can be expanded to 16 BCM per year.

Currently, GATE is connected to the Dutch /northwest European gas network, but the terminal is planned to be expanded with facilities which enable exporting LNG, and putting Rotterdam in the position of a key import and export merchant hub for Transatlantic LNG trade.

As GATE initially has been built to feed gas into the gas network, it does not contain any facilities for small scale distribution. Yet, Vopak and Gasunie are planning to expand the GATE terminal with a break-bulk terminal (medium scale terminal), which will enable small scale use. The break-bulk terminal, which is planned to be operational in 2015, will contain two loading bays to load LNG tank trucks and a dedicated jetty to load LNG vessels of 1,000 to 20,000 $m^3$ in size. The terminal will have an annual capacity for around 280 feeder ships, but can be expanded to 560 ships. It will have capacity for 1,500-2,000 feeder truck loadings per year but this can also be expanded. The break-bulk terminal is estimated to cost €60m.

The purpose of the break-bulk terminal is to enable small scale distribution, and is accessible only to LNG feeder trucks and vessels. In the second half of 2012, Shell has already signed an off-take agreement with Vopak and Gasunie as the launching customers of the break-bulk terminal. Please note that the final investment decision for building the break-bulk terminal was not yet taken at time of writing this report.

As it is not possible now to distribute LNG stored in GATE for small scale use, LNG is mainly sourced from Belgium. The large scale LNG terminal at the Zeebrugge harbour already has a break-bulk facility where feeder trucks and vessels can load LNG and distribute it in the Netherlands. Bio-LNG is now sourced from the UK (e.g. Gasrec, Chive fuels).

*The first refuelling stations have been built and further roll-out is expected*

As of now, five LNG refuelling stations in the Netherlands are accessible to the public. Two are operated by Rolande (please note that one is a mobile station) and supply bio-LNG, one by LNG24 (Ballast Nedam), one by LNG Europe (the first independent small scale LNG operator in northwest Europe) and one by GDF Suez. GDF Suez operates a mobile station, but this will be replaced by a fixed station in May 2013.

Please note that most of the existing LNG truck stations have been built in cooperation with fleet owners. For example, the refuelling station in Oss is a joint venture between Vos Logistics, Van Gansewinkel and LNG Europe. The advantage of such a venture is that the parties can offer each other security around demand and supply.[9]

In addition, LNG Europe operates two stations, built for private use. For example, the location in Zaandam is on the property of Albert Heijn, a leading supermarket chain in the Netherlands. This refuelling station supplies only to LNG trucks which distribute on behalf of Albert Heijn.

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[9] Please note that most current tank stations have been equipped with different tank connections as the different LNG truck brands do not operate a universal tank system (yet). Rolande stations, for example, are only assessable for Volvo and Iveco trucks. We expect that in the long term, a universal system will be developed, also driven by EC standards set in line with those mentioned above.

In 2012, a pilot bio-LNG station was opened in Heerenveen. The pilot is a cooperation between transport companies Portena, Van der Werff and Oenema, waste processor Omrin and Volvo Trucks. The project is being supported by the Province and several foundations. Bio-LNG is now being sourced from the UK, but local production by Omrin is expected in the near future.

### Figure 3.2 Current LNG refuelling stations in the Netherlands


*Source: Company websites, market feedback*

Although, the Dutch network of LNG refuelling stations is limited at the moment, key parties such as Shell, GDF Suez, LNG Europe, LNG24, Gazprom and Linde are planning to roll out a wider network (40 are planned) of stations across the country. For example, GDF Suez has committed to roll out 15 LNG stations in the next three to five years. This will increase the density of LNG tank stations and will provide a larger incentive to fleet owners to start using LNG. Please note that the number of planned LNG stations will only represent a very small part of the total number of existing stations (e.g. Shell owns around 600 refuelling stations in the Netherlands alone).

To build an LNG refuelling station, an estimated investment of €1,000,000-1,500,000 is needed (based on market feedback). A mobile station costs c.€500,000. Please note that market participants expect that station investment costs will fall after the first new builds (according to Energeia, Ballast Nedam expects the investment per station will decline by half if scale increases).[10] As of now, the "Truck van de toekomst" programme provides subsidies for building LNG stations. Investments will be made only if operators expect a positive return on their investments. If the end-user business case becomes unattractive, it is not likely that all stations will be rolled out.

Currently, there are no formal regulations, prescribing directives for the design, construction and operation of an LNG refuelling station in the Netherlands. The government is now finalising the draft version of specific guidelines (referred to as *Publicatiereeks Gevaarlijke Stoffen* (PGS) 33-1). These guidelines will connect to international guidelines prepared by the International Organization for Standardization (ISO) and include rules

[10] Cited in PwC interviews

of fuel station design, construction, operation, equipment, safety devices and maintenance (referred to as ISO/PC 252). As there are no guidelines, there is uncertainty at the level of local governments, which need to provide permits to allow for the building of LNG refilling stations. So, getting all the required approvals and permits still currently takes relatively long.

In the neighbouring countries, LNG infrastructure is not yet established, meaning international transport from the Netherlands is possible only to a limited extent (an LNG truck has an action radius of c.600-800km). In all of EU, only 38 LNG refuelling stations are currently in use (EC January 2013).

Recently, the European Commission (EC) announced an ambitious package of measures to ensure installing alternative fuel stations (among which are LNG stations) across Europe. These include common standards for design and use. EC targets that at every 400 km along the roads of the Trans European Core Network, LNG refuelling stations will be built by 2020 and 2025. According to the EU, member states will be able to implement these changes without necessary public spending, but by changing local regulations, which will encourage private sector investment and behaviour. Based on these EC policies, we expect that the possibilities for international transport will grow in the future. This scheme will provide an incentive for the truck manufacturers to further develop LNG trucks and engines. The Netherlands could lead the way in making this plan a reality.

*Bunkering solutions for ships are limited at the moment, but plans are drawn up for further roll-out*

Currently, the small scale infrastructure for LNG ships is very limited in the Netherlands, both for inland and the nearby sea shipping routes. The Argonon (Deen shipping), which is the only sailing LNG-based inland ship, is fuelled by truck-to-ship bunkering. The LNG is sourced from Zeebrugge as no small scale LNG is available in the Netherlands.

Also looking at a broader area, LNG bunker facilities are limited. In the EU, Sweden is now the only country with a small scale LNG bunkering facility for seagoing vessels. Just as with trucks, the EC recently announced a target for installing LNG refuelling stations in all 139 maritime and inland ports on the Trans European Core Network by 2020 and 2025 respectively. These include either fixed or mobile refuelling stations. We expect EC policies will stimulate setting up an international maritime LNG infrastructure, which will enable LNG-based international transport over water. The Scandinavian countries are particularly enthusiastic about developing a comprehensive LNG refuelling network in their countries

In the Netherlands, parties such as Shell, GDF Suez, LNG24 and Deen shipping are planning to set up a small scale infrastructure alongside the key shipping routes (i.e. Waddenzee, North Sea area and the Rijn). Most projects are planned to be established in 2015/2016 at the latest, when the new sulphur emission standards are implemented. Please note that LNG bunkering is an important aspect for quickly ramping up the LNG break-bulk terminal and better utilising LNG bunker feeder vessels. This is because of the volumes burn per vessel is much higher than in trucks. So the development of LNG in shipping is very important to make the overall business case a success.

Initially, ships are likely to be bunkered through the truck-to-ship method as limited investments are required (estimation DMA 2012: €800,000 for tank trucks (50m$^3$) including filling station). Yet, in the medium to long run, ship-to-ship bunkering is expected to be the established method. According to DMA 2012, the investment in a LNG bunker feeder vessel ranges between €20.3m (1,000m$^3$) and €56m (20,000m$^3$). A small land-based thermos tank (700m$^3$) is estimated to cost €7m. Possible locations for (onshore) bunker stations in the Netherlands include, for example, Harlingen, Den Helder and Eemshaven,and Antwerp in Belgium.

Currently, the IMO (International Maritime Organisation) is developing an international code for safety on gas-fuelled ships (referred to as IGF code; International Code of Safety for gas-fuelled ships). The code is expected to come into force at the end of 2014/2015 and will provide clear guidelines for bunkering procedures. These guidelines will provide more certainty in the market for building LNG ships (i.e. what standards they need to meet).

# 4. The price of LNG and its alternatives

*The spread between oil product and LNG prices is an important driver of small scale LNG uptake. The price of LNG is based on international supply and demand conditions and can differ from natural gas prices at the hub (TTF).We expect that the price of natural gas will remain relatively low in the long run compared to the price of oil products. We even believe that a further decrease in the price of natural gas is possible in the next decade, driven by increased gas supply.*

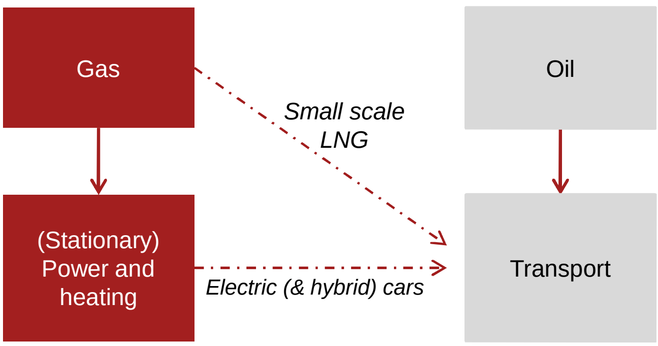
## 4.1. Introduction

Fuel costs are the largest share of the total cost of ownership of a truck or a ship and the oil-gas spread is an important driver for the uptake of small scale LNG. From an end user's perspective, it is not the level of the LNG price which is the most important driver but the price relative to alternatives, i.e. diesel for truck owners or marine gas oil (MGO) or (HFO) heavy fuel oil for ships. [11]

In this chapter, we first discuss the major developments in international oil and gas markets. We have to analyse both markets as small scale LNG connects two markets that have been increasingly delinked in recent times: the market for oil used mainly for transportation and petrochemicals, and the "stationary" market for natural gas including LNG which is used mainly for power production, heating and cooling, and as a feedstock for petrochemicals. After discussing the developments in international oil and gas markets, we discuss projections of the future development of the natural gas to oil price spread.

Developments in the oil and natural gas market are reflected in the price of MGO, HFO, diesel and LNG. So this chapter ends with an analysis of the price dynamics in the small scale LNG market.

**Figure 4.1: LNG connects natural gas and oil markets**




*Source: PwC analysis*

## 4.2. Development of the gas-oil spread

### 4.2.1. Oil market

Until the beginning of this millennium, oil was priced at a relatively low level of c.USD 20-40 per barrel. Since then, the price gradually increased and, in 2008, the oil price reached the milestone of USD 100 per barrel for the first time. At constant prices, that is at the same level it had during the oil crises in the 1970s.

[11] We use the term MGO for all low-sulphur fuels in this report.

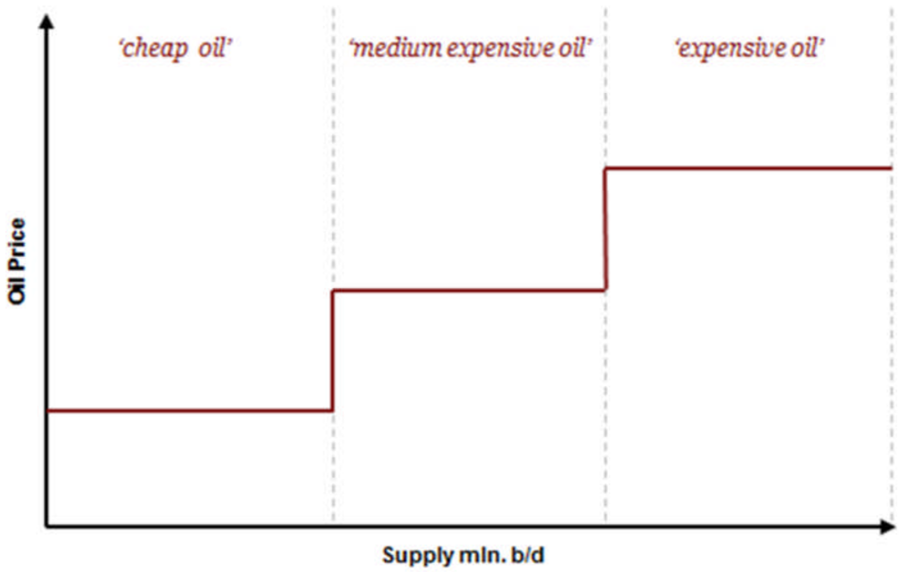
The oil price, like all commodities, is set by many drivers, each more or less influencing the price on a daily basis. The overarching driver of long-term oil and gas prices is the marginal cost of (new) oil production. This is the price of the most expensive barrel of oil which oil companies decided to bring to the market. One way to determine the oil price in the long term is to look at the futures market. Current Brent futures prices traded at the Intercontinental Exchange (ICE) point at c.USD 90-95 five years from now.[12]

In addition to the marginal costs, other drivers have a more short-term (cyclical) impact. The first set of cyclical drivers consists of worldwide oil inventories. Another key element driving oil prices is the level of spare capacity in OPEC, which is now available only in Saudi Arabia and perhaps in small quantities in the UAE and Kuwait. In the second half of the 1980s and throughout the 1990s, OPEC had ample spare capacity. But, since 2004, spare capacity is much tighter to being even non-existent. Between 2004 and 2008, spare capacity was tightened in OPEC, mainly due to the high economic growth, notably in the BRIC countries. The wars and boycotts in the Middle East and North Africa affected the tight situation since then.

In a market which has large drawings from the commercial oil inventories and where OPEC spare capacity is limited, oil prices are skewed to the upside. Geopolitical events and weather-driven events, but also increasingly more and longer planned maintenance on producing oil fields and unexpected outages due to mechanical breakdowns, put additional upward pressure on oil prices. The latter reasons caused the oil price in 2012 to be the highest since 1864, although most of the world faced the aftermath of the financial crisis.

Looking to the marginal cost curve (or oil supply curve, see Figure 4.2. for a schematic chart), during the mid-2000s the oil companies were forced to concentrate their exploration and development efforts increasingly at the most expensive part of the curve, i.e. oil sands, deep water, biofuels, and arctic, putting more pressure on oil prices. At that time, the oil companies had no access to the so-called cheap oil in the OPEC countries. At the time, Iraq had not yet granted licences to the international oil companies. Meanwhile, oil companies did not discover a lot of "medium expensive" oil. Thus, ultimately there was no other option than to go for the most expensive oil, which is exactly what happened, pushing prices higher as demand was growing faster than new supplies.

**Figure 4.2: The marginal cost curve of oil production (stylised)**




Today, the situation has changed dramatically due to technological innovation. The oil industry became able to tap well-known shale oil and gas reserves so far not economically viable to be produced. Higher prices and

[12] Source ICE (March 2013)

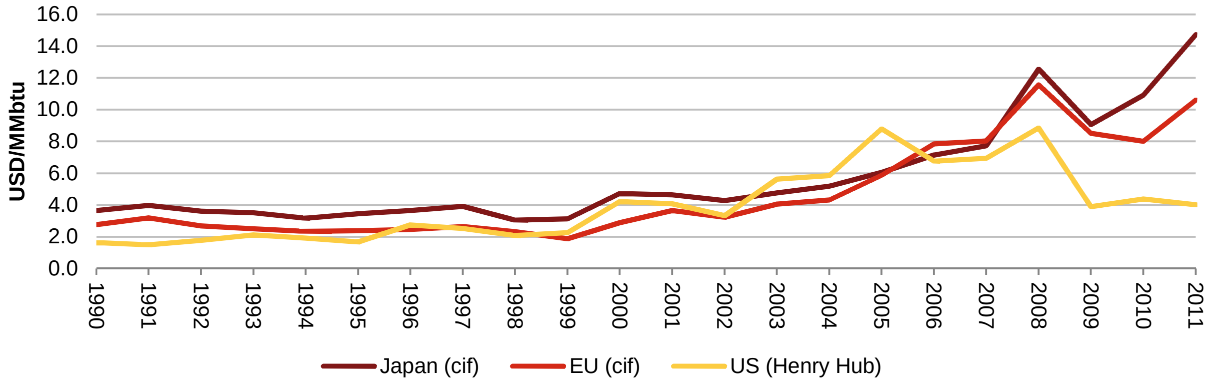
technical innovation led to a genuine revolution not foreseen only five years ago. This shale revolution started in the gas industry in the US in the first part of the last decade, with the oil sector now experiencing a similar phenomenon as Light Tight Oil is rapidly being developed in the US, causing the US to quickly become (close to) self-sufficient instead of being the largest crude oil importer in the world as it was in 2007/2008. This surge in new supplies is quickly improving the global oil supply demand picture, taking oil price pressure away. In addition, very large oil fields have been discovered in deep water offshore Brazil, also contributing to new supplies, which will replace depleting oil fields and ever growing demand for oil. Finally, Iraq is now an equally large contributor of oil to the world market. Thus, unlike 2008, there is now enough oil being developed in the "cheap oil" (Iraq), "medium-priced oil" (Brazil and other very large deep water developments, and shale oil in the US) and "expensive oil" (also the more marginal shale oil developments, deep water, arctic, complex fields, tar sands) segments.

We expect that this new era will at least continue till the end of this decade, assuming the absence of major geopolitical events or higher than expected economic growth in the major world economies. Given these assumptions, oil prices should remain close to current levels. But all market analysts do not agree with this view as some expect average oil prices to fall back to USD 85-90 per barrel (Brent), while others still expect oil prices to stay above USD 100 per barrel for the years to come. Hardly any analyst forecasts oil prices to further rise to a level structurally above USD 120 per barrel. But the surge in light tight oil in the US is projected to start flattening off by 2020 with no major new oil source being foreseen now to allow continuing the current supply surge, except Saudi Arabia and especially Iraq. Thus, there will be no new major source of supply other than from these two countries, which can replace falling production from declining oil fields. So, in the next decade, ongoing demand growth will be difficult to match by new supplies putting upward pressure on oil prices again. Introducing substitutes and higher efficiencies will be crucial to avoid the risk of price spike in the next decade if such scenario unfolds. LNG in transportation is one of the best examples of such a substitute in heavy trucking and shipping, replacing diesel, the oil product with the highest demand.

### *4.2.2. Natural gas markets*

Even more than oil, natural gas markets are going through a volatile time. In the "Golden Age of Natural Gas", as the IEA proclaimed, gas is expected to transform the global energy market. Most important is of course the shale gas revolution in the US. Gas production has increased rapidly here due to technical developments that made it possible to extract gas from tight shale formations that were earlier uneconomic for recovering. Due to this rapid development, gas prices in the US have plummeted from a peak of USD 12/MMBtu in 2008 to about USD 3/MMBtu now. But, like in crude oil, the shale revolution has resulted in very uneven oil and gas prices around the world. WTI prices in the US is now USD 15-20/bbl lower than Brent, the global benchmark for international oil prices, and natural gas traded at prices between USD 3 and close to USD 19/MMBtu for the most expensive LNG cargo sold recently.

## Figure 4.3: Gas prices around the world




*Source: BP Statistical Review of World Energy*

This wide price range is the result of several factors: Following the Fukishima nuclear crisis in 2011, the global LNG market has tightened as Japanese natural gas imports have surged. Global LNG markets tightened further recently with increased demand from South Korea and South America due to severe droughts resulting in less hydro power. Meanwhile, several LNG exporters have difficulties in maintaining their export supply for a variety of reasons such as steep productivity declines, political turmoil and terrorist attacks. Latest LNG spot prices for delivery in Asia have moved to the USD 15-19/ MMBtu range this year, the highest since 2008 and more than five times the price in the US. But this does not mean that all LNG imports in the Far East are priced at that level; large legacy volumes for which gas contracts were signed many years ago still have much lower prices, many below USD 10/MMBtu.

In Europe, the situation is different. Due to the economic crisis, gas demand has been very weak since 2009, the first year in which gas demand fell by 5%. European gas demand has declined further due to a shift from gas to coal in power production and the steep rise in renewables, notably in Germany.

How natural gas should be priced is a contentious issue. Natural gas prices have historically been relatively differentiated across the globe (compared to oil), largely due to various countries' pricing mechanisms and the significant expenses in transporting gas. Outside the US and the UK, gas prices were indexed to crude oil and petroleum products. But over the last couple of years, this pricing mechanism has come under increased pressure as high oil-linked gas prices no longer reflected gas supply-demand fundamentals. This has led to moving away from oil-linked prices to more hub-based prices. Also in Asia, rumblings are brewing for changing the crude oil-linked pricing mechanism, but the gas-oil spread is not as wide, as demand growth is still strong and cheap alternatives to LNG are scarce. Meanwhile in European gas markets, many gas supply contracts have been renegotiated. Many of the large wholesale buyers were able to secure gas price reductions, and, in some cases, a re-indexation of these contracts away from oil and oil products to hub gas. Here, the reason has been the material impact on risk, buying gas under an oil-indexed formula, while having to sell it at hub prices, which created a substantial basis risk that the utilities could not transfer or hedge. With hub prices having been at a discount over the last few years, mounting losses on gas trading pushed most European gas buying utilities to negotiations with their main gas suppliers to Europe. Moreover, LNG has become too expensive in many parts of Europe compared to pipeline gas.

Although the LNG market is linked to the market for natural gas, the LNG market has its own price dynamics. This is because prices are based on the international demand and supply of LNG in contrast to the natural gas market where the geographical market is limited due to the costs involved in transporting natural gas. LNG markets are currently tight; Asia absorbed most Qatari LNG surplus capacity that emerged from declining demand in Europe. The LNG markets at present look a lot like the oil markets in the mid 2000s with demand (outside Europe) surging, the global supply chain stretched, and geopolitics providing upward price pressure which resulted in the highest price (of USD 19/MMBtu) for LNG since the start of the financial crisis. This tightness of the LNG market is expected to last for the next three to four years. During this period, incremental LNG supply (in liquefaction) is low as no significant new LNG supply is foreseen, while widely dispersed demand growth will continue leaving not much room for lower prices.

Meanwhile, last year, Qatar started shipping more LNG cargoes to Asia and less to Europe. But, after 2015, a large number of new LNG liquefaction plants currently under construction will become operational. In Australia only, seven LNG projects are expected to start operations. Once taken in production, Australia will be as big as Qatar in exporting LNG. Strong supply growth is also expected from North America, where the government already has approved a licence for one LNG export facility while reviewing several others. If only a third of the plans are approved, that is about five to six LNG export schemes in the US and Canada, North America will join the super league of LNG and pipeline exporters (the Big 4: Russia, Qatar, Australia and North America). When realised, this LNG exports growth could well place additional pressure on oil-linked prices from elsewhere and price pressure in all major LNG consumer markets relative to oil markets by the end of this decade.

How markets will develop say five years from now is uncertain. The political debate concerning US LNG exports obviously poses a risk to the ultimate volumes of gas to be exported in the form of LNG to overseas markets. Also, the uncertainty of the timing of liquefaction projects currently under construction and of the development of gas fields and LNG projects in East Africa, Russia and Cyprus similarly pose a risk. Additional US builds could leave global markets in surplus beyond 2020, weighting on-spot LNG markets. But potential demand growth due to favourable prices in Asia, and also from conversion from oil to gas, could create the necessary conditions to accommodate some (but not all) of the large liquefaction projects currently proposed in North America and potentially developed in East Africa, Russia, Cyprus and elsewhere. Finally, the demand side is also uncertain, notably the level of demand growth in China, where potential exploration and development of shale gas poses a risk of reduced need for LNG imports in China.

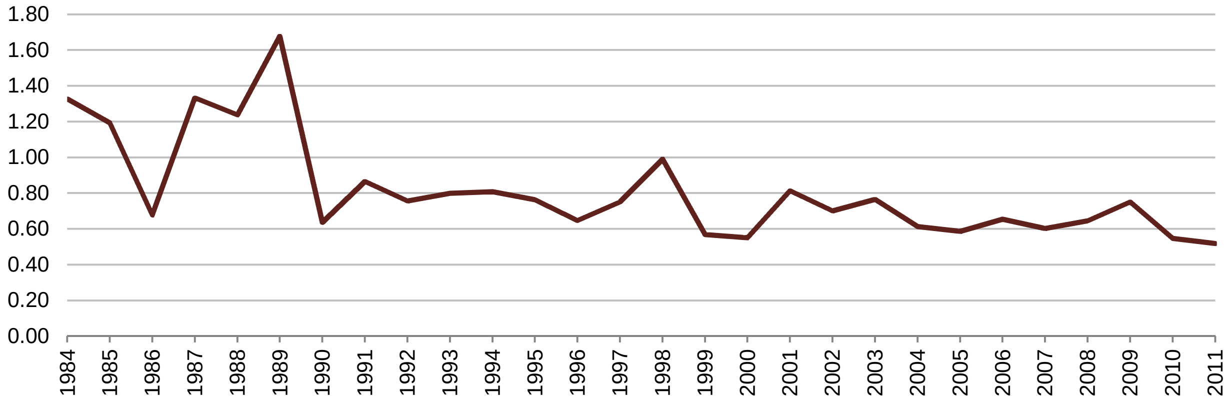
This said, it is important to note that LNG liquefaction and transportation costs are always high, especially compared with coal and certainly crude oil. Export costs for the US to Europe or Asia will add USD 5-6/MMBtu to US spot market prices, making a big difference for the Asian market given the recent prices been paid in the market, but much more limited for Europe. But, still it now appears that particularly the large pipeline suppliers to Europe, Russia and Norway have opted for a volume-driven strategy to keep pipeline gas competitive with LNG, narrowing the difference between spot markets and (discounted) oil-indexed pipeline flows, especially when economic activity in Europe picks up after 2013. Also, higher global LNG prices since late 2012 have helped in closing the gap. Thus, it is important to highlight that gas prices will continue to be substantially higher in Europe than in North America, and even more in Asia, irrespective of the number of LNG export projects to be approved.

In the future, markets are expected to gradually return to mid-cycle levels in the second half of this decade which should result in lower LNG prices, notably in Asia. This results from a number of factors: Additional LNG liquefaction capacity is brought online and Japanese demand declines as nuclear plants return to operations. Moreover, an expected increase in the total size of the LNG tanker fleet relative is likely to reduce the LNG freight rates, and consequently, delivery prices to markets.

### *4.2.3. Spread between natural gas and oil prices*

Figure 4.4 shows that the ratio of natural gas prices to crude oil prices in 2010 and 2011 is low from a historical perspective. This figure is based on natural gas prices in Europe. As natural gas prices today are much lower in the US, the increase in the natural gas to oil price spread is much more pronounced in the US. Figure 4.4.shows one of the major reasons for the increased interest in LNG as a transport fuel; from an economic point of view, natural gas has become more attractive.

**Figure 4.4: Natural gas price to crude oil price – calculated on an energy-equivalent basis**




*Source: BP Statistical review of world energy, PwC analysis*

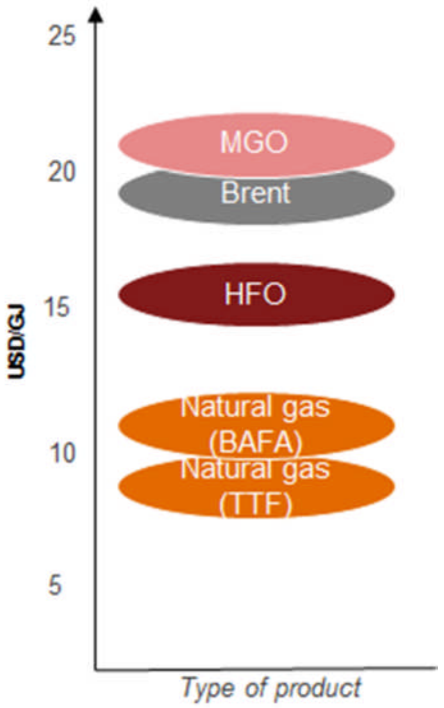
However, trucks and ships do not ride and sail on oil itself but on oil-based refinery products such as diesel. Although the prices of the oil-based refinery products and crude oil generally move in tandem, price developments may vary due to imbalances in demand and supply.

Oil product demand in northwest Europe has declined since 2006 and continues to show shifts in supply and demand for the individual oil products. As a result, the 57 refineries in Europe are not s utilised now. This could result in small unprofitable refineries throughout Europe closing down further. Product imbalances are expected to further widen, with growing surpluses of gasoline which will be exported to overseas markets, and growing shortages in diesel/ gasoil and naphtha, for which comparatively strong demand growth outpaces flattening supply.

Supply-demand balances in refineries can influence relative prices of oil-based products. Some analysts expect an increase in the price of low-sulphur diesel when new emission regulations in SECA areas are enforced and the demand for low-sulphur diesel increases. Given the wide range of changes expected in the refineries market, oil product prices might deviate temporarily from their long-term price spreads versus Brent, before finding a new equilibrium. This said, in the longer run, average diesel and heavy fuel prices and crude oil prices are closely connected. So product prices are projected to follow the crude oil price trend.

Figure 4.5 shows the price development of low-sulphur diesel (currently used for trucking and inland vessels) and diesel with higher sulphur content (currently used for short sea shipping) in 2011 and 2012.

**Figure 4.5: Prices of gas and petroleum products expressed in energetic value (USD/GJ)[13]**




*Source: Bunkerworld.com, Bloomberg, BAFA, PwC analysis*

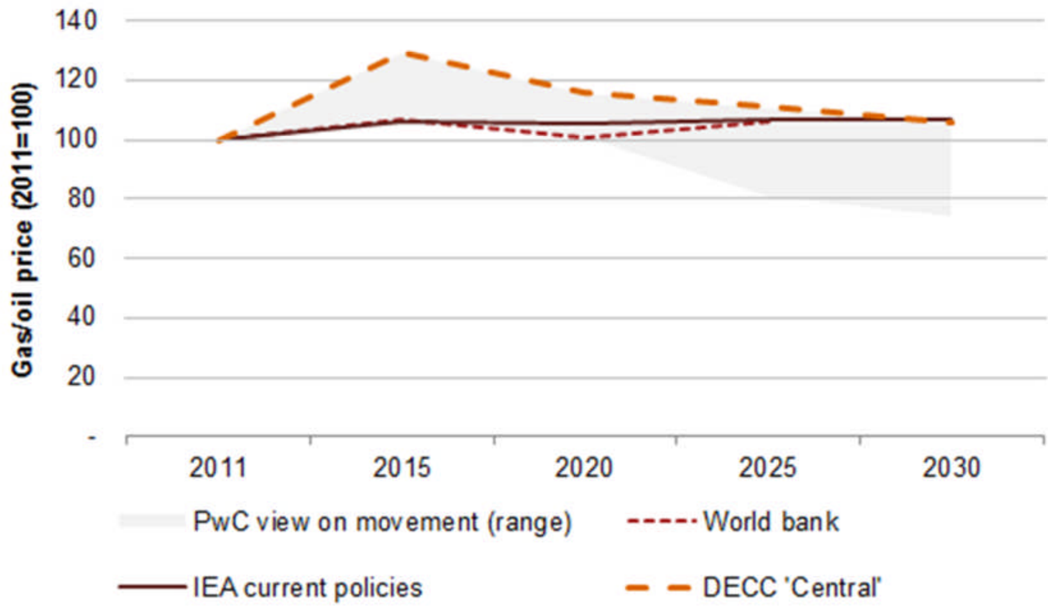
In Figure 4.5, we also included a proxy for the price development of contracts that are oil-indexed and for gas prices on TTF. These gas prices were, in 2011 and 2012, lower than the price of diesel products (expressed in energetic value). As discussed in 4.2.3, the spread between gas and diesel prices is one of the reasons why LNG can be an attractive transportation fuel.

## 4.3. Projections of future oil and gas prices

In Figure 4.6, we have included the projections of the IEA, the World Bank and DECC; these are not forecasts but more used for long-term planning. It includes the ratio of gas to oil prices; an increase in the index means that the gas price increases relative to the price of oil. As the figure shows, there is no consensus over price developments. In the projections of the IEA and the World Bank, oil and gas prices follow a broadly similar trend, whereas in the projections of DECC, the relative price of gas decreases after a peak in 2015. Especially in the longer time horizon (after 2020), many uncertainties should be considered when thinking about long-term trends. Our qualitative view, based on our latest analyses of global oil and gas markets and the "*Energie Wende*", is projecting first a tightening in LNG markets followed by a more loose market at the end of this decade if and when all proclaimed LNG projects are coming on stream, and then the potential that oil will become relatively more expensive than gas in the next decade.

[13] MGO; Marine gas oil, HFO; heavy fuel oil, BAFA; Gas import price of the Federal Office of Economics and Export Control TTF; Title Transfer Facility (virtual trading point for natural gas in the Netherlands).

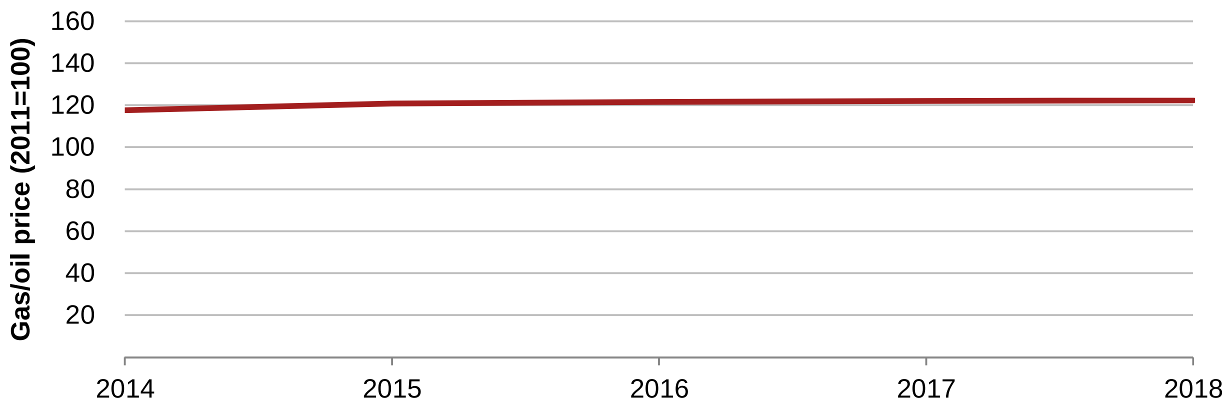
### Figure 4.6: Gas price relative to price of oil (projections)[14]




*Source: IEA, World Bank, DECC, PwC analysis*

Figure 4.7 shows the natural gas to oil price spread based on prices of futures. These prices incorporate the expectations of price developments of all the market participants. Between 2014 and 2018, the natural gas to oil price spread remains more or less at the same level but markets are not very liquid especially towards the end of the period.

### Figure 4.7: Gas price relative to price of oil (futures)




*Source: Endex, ICE, PwC analysis*

Although there are considerable uncertainties, a number of conclusions can be drawn from Figures 4.6 and 4.7 and the discussion of trends in oil and gas markets in this chapter. In conclusion, it is not unlikely that in the first coming years, natural gas and LNG prices could rise a bit, both in absolute and relative (to diesel) terms.

[14] *DECC projections refer to UK (NBP) prices. PwC view is based on a variety of studies and market feedback.*

But when more LNG supplies come online, price pressure is expected to drop, allowing LNG prices to go down, at least relative to diesel prices. Although there are significant uncertainties in this area, there are convincing arguments that oil price risks are skewed to the upside, while gas price risks are skewed to the downside. This makes LNG increasingly attractive as a transportation fuel compared to diesel.

## *4.4. LNG price for small scale LNG*

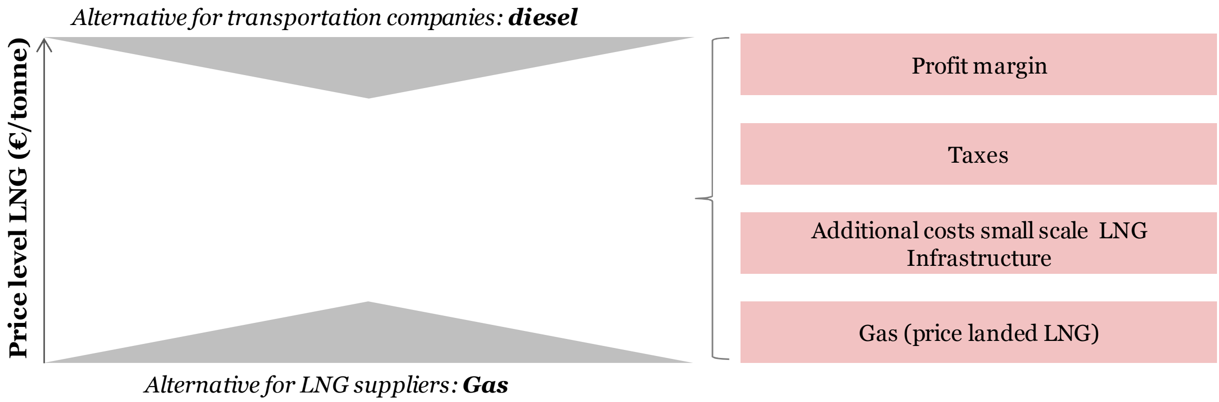
The retail price of LNG for end users is not equal to the price at which suppliers import LNG. This price is mainly related to the costs of winning, liquefaction and large scale transportation. The specific cost of small scale distribution should be added to that price (i.e. cost of transport to stations, bunker solutions, refuelling stations). Second, the government taxes LNG and the supplier will demand a profit margin.

We think the development of the LNG prices at the fuel station will depend on the competitive position of LNG suppliers and end users. This means the price will be somewhere between the price of diesel and that of natural gas *(please refer to Figure 4.8)*. If retail LNG at the pump is priced higher than diesel, there will be limited demand as there is no incentive to switch to LNG. Prices have to be higher than that of natural gas to enable suppliers recover their investments in the LNG infrastructure and make a profit margin. This said, end users looking for a "guaranteed" price advantage over diesel, i.e. looking for a comparative price advantage rather than a less certain absolute price level, should strive for a stronger link of LNG retail prices at the pump to diesel prices. Others, willing to accept volatile price differentials (between LNG retail prices and diesel), should opt for prices linked to world LNG prices.

We understand that certain suppliers offer LNG contracts to fleet and shipowners with contracts with a price linked to the price of diesel guaranteeing a fixed price advantage. These contracts can have a maturity of up to five years. These contracts hedge the price risk for the end users, which is a major advantage as it reduces the risk of an investment in LNG.

LNG and diesel used for road transport are taxed differently, with LNG taxes currently being lower than those for diesel. This means that taxes are an important part of the retail price; so the level of fuel taxes is one of the drivers of the uptake of small scale LNG.

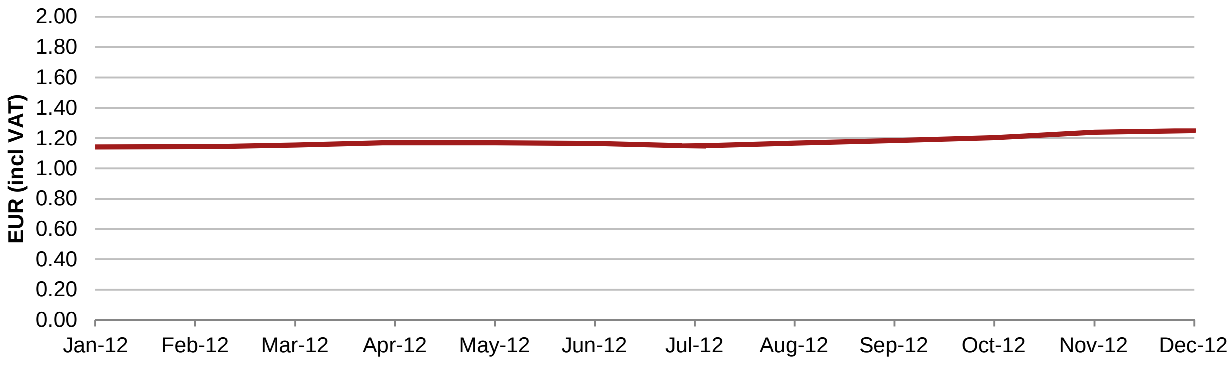
**Figure 4.8: Price dynamics in the small scale LNG market**




*Source: PwC analysis*

As the current number of open access LNG fuel stations is still small, the availability of market prices is limited. Figure 4.9 shows the prices of LNG 24 in 2012. GDF Suez quotes a price of €0.75 per diesel litre equivalent or €1.09 per kg. (Source: GDFSUEZ.nl, February 2012). We understand from interviews that suppliers currently offer contracts with LNG retail prices fixed at 60-75% of the diesel price.

**Figure 4.9: LNG prices LNG 24 (€/kg)**




*Source: LNG 24*

For the shipping industry, the prices of different fuels also show a wide range. For instance, the prices for different products (Rotterdam quotations[15]) on 1 March 2013 were as follows: MDO (middle distillate) at USD 894/MT, LSFO (low sulphur fuel oil) at USD 632/MT, HSFO (high sulphur fuel oil) at USD 602/MT and LNG at USD 467/MT[16].

But the oil product prices are delivered at FOB prices, while the LNG price is a hub-based price. Once we add the additional costs for logistics to derive a comparable retail price, the TTF price would be about €50/MWh, which translates into a price of USD 602/MT, or very similar to HFO prices. Moreover, prices have moved in opposite directions lately, where LNG prices increased over the last six months, while HFO prices dropped given the oversupplied markets and less demand (due to less freight in depressed European markets). LNG is still attractive compared with Middle Distillates (Diesel and Gasoil) and with expected higher demand for these products post 2015 after the new legislation comes into force, the price differential could stay or even improve, again this also depends on the development of global LNG markets in the second half of this decade.

[15] Bloomberg, Platts bunkerwire & Spliethoff.
[16] Corrected for higher energy content (+14%).

# 5. The business case for end users

*Emission reduction and cost savings are the main drivers for fleet owners to switch to LNG. Since the small scale LNG market is in the development phase, pioneers currently face an uncertain financial business case. In addition, they need to handle some operational hurdles such as limited availability of LNG infrastructure and time-consuming permitting processes. Yet, we believe LNG offers a viable business case with attractive repayment periods in the future. This is mainly driven by our expectations of declining LNG vehicle prices and of a positively developing LNG price gap. The government can play an important role in the roll-out phase by helping pioneers via subsidies and a stable tax regime.*

## 5.1. Introduction

Our society is increasingly focusing on a cleaner environment, which results in stricter emission restrictions for the transport sector. One option to reduce emissions is by using LNG as fuel. Secondly, LNG offers an attractive price setting compared to oil, which can lead to significant fuel cost savings. Especially, with declining oil reserves, which could drive oil prices to even higher levels, LNG can be an attractive alternative.

Yet, as the small scale LNG market is still in the development phase, end users currently face high investment costs and uncertainty around the future LNG price gap. Although emission reduction is an important driver, the business case must be viable for end users to switch; especially because end users can choose between alternative solutions to meet (regulatory) emission requirements. Viability of the business case is important as the small scale LNG market can only be rolled out if end users start adopting LNG on a larger scale. In this chapter, we further elaborate on the (expected) dynamics around the end-user business case.

## 5.2. End-user considerations for switching to LNG

Potential end users of LNG are mainly transport companies in the shipping and truck sector. They currently operate on oil-based fuels mainly. When companies start to consider using LNG, they will need to evaluate the various factors that involve switching. The main reasons to use LNG (i.e. emission reduction, fuel cost savings) must outweigh the hurdles (i.e. uncertainty around the financial business case, lack of infrastructure and time-consuming permitting). We will now discuss the key factors that end users currently face in relation to the LNG business case and how we expect these factors to develop.

### 5.2.1. Key drivers

***Increased focus on emission reduction***

Transport companies are becoming increasingly focused on emission reduction. For the shipping sector, this is mainly driven by strict (international) emission standards. For the trucking sector, this is also driven by the increased focus of end customers on sustainability. Using LNG is a way to reduce emissions and to meet regulatory standards. Appendix C1 provides an overview of possible emission reductions by LNG by different type of vehicles.

*International Maritime Organisation (IMO) sets stricter $SO_x$ regulation for shipping in SECA area*

On 1 January 2015, the IMO will bring into force a stricter sulphur emission regulation[17] for shipping in the Baltic Sea, the North Sea and the English Channel (sulphur emission control (SECA) area). This means most

[17] The regulation prescribes that fuel sulphur content has to be decreased from 1.0 % (set in July 2010) to 0.1.

(short sea) ships currently sailing in the SECA area *(Figure 5.4)* must lower sulphur emission. In 2020 (probably delayed till 2025), emission restrictions will become stricter worldwide[18].

**Figure 5.1: Overview of SECA (in light blue)**

*Source: DMA 2012*

*Dutch government increasingly sets environmental zones for trucks*

There are certain "environmental zones" in the Netherlands such as city centres where there are emission restrictions, meaning Euro II and III trucks[19] are not allowed to enter. We expect the number of environmental zones to increase further. For example, as of 2014, Euro VI trucks are only allowed to enter the "Maasvlakte" area.

*(International) standards require increasingly "clean" ship and truck engines*

The IMO will set stricter $NO_x$ standards for new short sea ship engines built in 2016. Newly built engines of inland ships need to comply with CCNR emission standards[20]. CCNR standards are expected to be strengthened in 2016 by introducing CCR4.

The European Union has set emission standards (including limits for various pollutant emissions) for trucks. To limit the negative impact of road vehicles on environment and health as much as possible since the 1990s. Currently, the Euro V standard is in place for heavy trucks.[21] Euro VI with stricter emission norms will replace Euro V as of January 2014.

[18] A sulphur limit of 0.5% is planned to be set globally, meaning emission restrictions will become stricter worldwide.
[19] Currently, almost 40% of the Dutch truck fleet consists of trucks manufactured before 2005, which means Euro III or lower (RAI 2012). Please note that these trucks can reduce emission via a soot filter. The government provides subsidies to encourage installing these.
[20] Set by Central Commission for the Navigation of the Rhine (CCNR)
[21] All new trucks currently produced must cover the Euro V standard. As Euro standards only apply to new vehicles, not all trucks in the Dutch fleet are based on the current Euro V norms.

*Increased focus on sustainability of truck end customers*

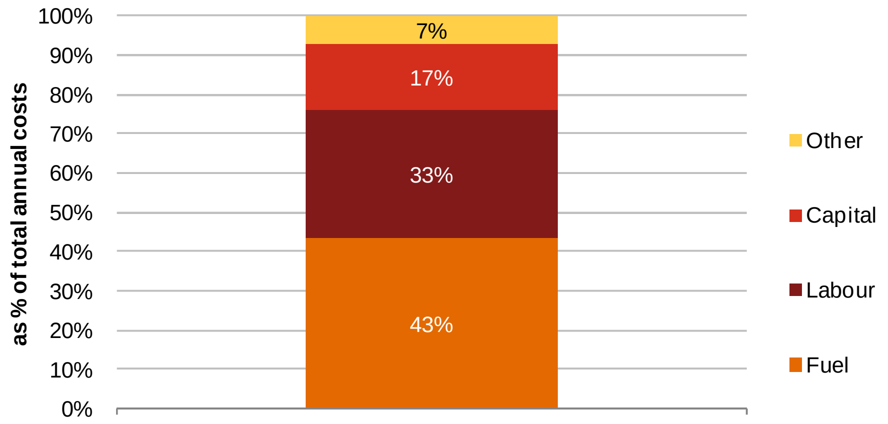
Sustainability is increasingly becoming a key pillar of company strategies, driven by the aspiration to have a "green" company image and the willingness to contribute to a cleaner environment[22].

The aspiration for having a "green" image is also driven by end-user customers, who prefer, or are even required, to work with "green" distributors as part of their own company policies. So emission levels begin to play a more important role in transport tender processes.

***Fuel cost savings***

For transport companies, fuel costs represent a significant part of annual transportation costs. For example, fuel represents c.50% of the annual costs for a truck driving 100,000km a year[23]. As shown in Figure 5.6, fuel costs for an inland ship easily represent more than 40% of total annual costs. This percentage is even larger for short sea ships.

**Figure 5.6: Annual costs for an inland ship (110x10.5m, 2,500ton load) sailing from Utrecht to Breisach**




*Source: Source: NEA / CBRB 2009*

As we discussed in Chapter 4, the LNG price gap is expected to develop positively, which means transport companies can save significantly on fuel costs when switching to LNG. *Please refer to Chapter 4 for an extensive discussion of the LNG prices compared to diesel.*

***Other***

An additional driver for truck companies to switch to LNG can be noise reduction. The Dutch government has set standards for noise emission during loading and unloading in retail trade and craft businesses. This means trucks are only allowed to distribute stores within restricted hours in inner cities (7:00-19:00hrs). LNG trucks can produce up to 8dB(A) less noise[24] than diesel trucks and some (mono-LNG engines only) have been assigned a QuietTruck "PIEK-keur"[25].With the "PIEK" mark, trucks have the option to supply outside restricted hours. This offers truck companies the possibility to avoid traffic jams and deliver more efficiently. This can lead to significant cost savings. It is also safer to deliver outside restricted hours as fewer people are around.

[22] E.g. companies are increasingly, in their annual reports, starting to include metrics on their footprint, including emission targets.
[23] Fuelswitch 2012
[24] Provincie Zuid Holland 2011
[25] This mark indicates that the truck produces less than 72dB. To receive a PIEK-keur, the truck must also meet noise levels for (un)loading.

## 5.2.2. Key hurdles

***LNG vehicles not a suitable option for all fleet owners***

*Only part of existing ship fleet is suitable for an LNG retrofit*

Ships have an average lifetime of 20-30 years. This means that the largest part of the current ship fleet will not be replaced by a new ship in the coming years. Yet, to switch to LNG an existing ship can be retrofitted. This means that the diesel engine is adjusted or replaced and that an LNG tank must be installed on the ship. Though for part of the ship fleet it is not possible to install an LNG tank due to space restrictions.

*LNG trucks mostly suitable for national distribution*

On average, LNG trucks have 200 to 300 horsepower (hp)[26] and are most suitable for national distribution. Currently, LNG trucks are less suitable for long-haul, heavy-freight distribution, limiting the size of the possible adoption target segment *(please refer to Chapter 6)*. Dual-fuel trucks have more power on average though. Volvo, for instance, chose to market a dual-fuel truck to target the long-haul segment instead of the city distribution segment. We think technological development may lead to a larger applicability for LNG trucks.

***Current lack of LNG infrastructure***

Transport companies can be reluctant to switch to LNG as the available infrastructure has been scarce *(please refer to Chapter 3for details)*. The limited number of LNG stations forces LNG trucks and ships to adjust their routes, which can lead to extra kilometres. As the LNG infrastructure is now being rolled out in the Netherlands, we expect that at the national level this hurdle will be removed. Yet, for international transport, the lack of infrastructure might remain a key barrier for a longer time.

***Uncertainty around repayment periods***

*Initial investment required is currently relatively high*

LNG vehicles are more expensive than oil-based vehicles *(please refer to Appendix C2 for an overview of investment costs)*. This is partly driven by higher material costs (the LNG tank is expensive), higher safety restrictions that must be taken into account, and by the low number of vehicles currently produced.

Driven by the current economic situation, companies are reluctant to make those large investments, especially as positive returns of the LNG business case have not yet been proved in practice. Particularly the shipping sector faces financial difficulties due to declining demand, overcapacity and increasing competition. For those reasons, banks are reluctant to provide financial support. Also, the shipping fleet is relatively young, which currently discourages buying new ships.

Please note that we expect prices of LNG vehicles to decline in the future as the market will become more commoditised (i.e. economies of scale and increased competition)[27].

*Transport companies are reluctant to make the high investment as future price developments are uncertain*

As the price for LNG relative to oil is a key driver for the financial business case, future price developments are the key. A change in the LNG price gap can significantly impact the repayment period and thus the viability of the business case.

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[26] A diesel truck has more than 400hp

[27] For example, medium-duty CNG trucks were priced at €50,000 more than the diesel variant in 2008 (US). The technology has become more commonplace now and the price difference has decreased to only around €20,000 (IHS, 2012).

Although we expect the LNG price gap to develop positively *(please refer to Chapter 4),* a lot of uncertainty is involved around future developments. Some transport companies perceive that the gap will become smaller and so the LNG price advantage will not make up for the large initial investment made.

In case of truck owners, the uncertain future excise tax regime of the Dutch government plays a role as well. Recently, the Dutch government announced increasing the excise tax on LNG as of 1 January 2014, with an increase similar to the increase in the tax on LPG (i.e. €0.07 per litre). This means the tax on LNG will almost double (resulting in €0.325 per kg according to TNO 2013). It is uncertain whether the government will continue to increase excise taxes[28].

Please note that the shipping sector is not subject to any tax on LNG. This is based on the so-called Mannheim pact which prescribes no tax for all European waterways connected to the Rijn. As this is a European agreement, no changes are expected in the short to medium term.

***Other***

Another barrier for transport companies to switch to LNG is the current regulatory framework. There are no regulations yet for LNG vehicles, which means that their use is not allowed by law. Fleet owners need to demand exemption if they want to switch to LNG. This involves a lot of time and paperwork. Please note that regulation related to LNG vehicles (including safety norms and procedures) is expected to come into force in the coming years. This will make the switch easier for fleet owners.

## 5.3. Repayment periods

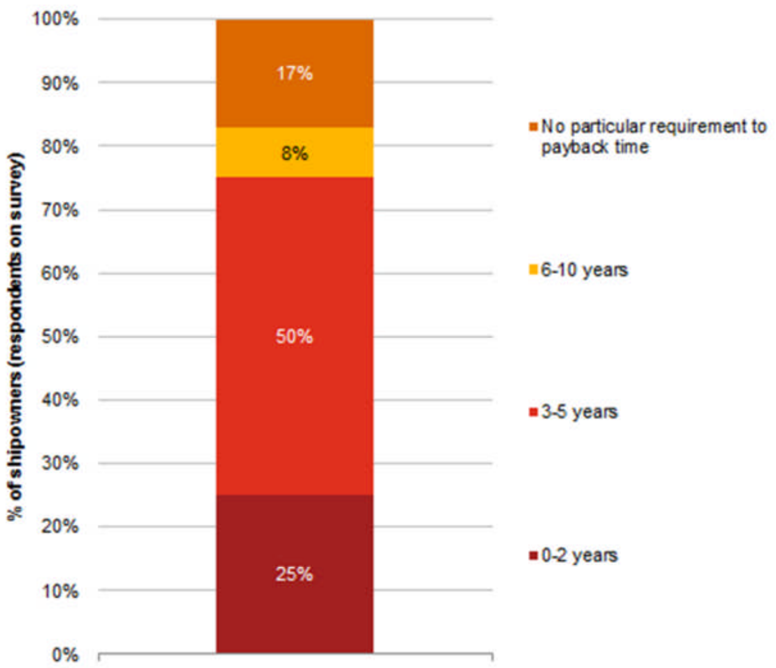
Transport companies will estimate the repayment period of the additional investment they need to make, to decide whether a switch to LNG is economically viable for them.

*The required repayment period differs per end user*

Please note that the required repayment period differs per end user. Truck owners in general demand a shorter repayment period than shipowners as a truck has a shorter lifetime (5-8 years for trucks compared to 20-30 years for ships). Figure 5.9 shows that for example the investment horizon differs by shipowners.

[28] Please note that an increase in the small scale LNG market does not necessarily mean lower incomes for the government. Lower excise tax incomes will (partly) be compensated by increased corporate taxes

## Figure 5.9 Shipowners' expected payback time (investment horizon) – Based on 24 interviews

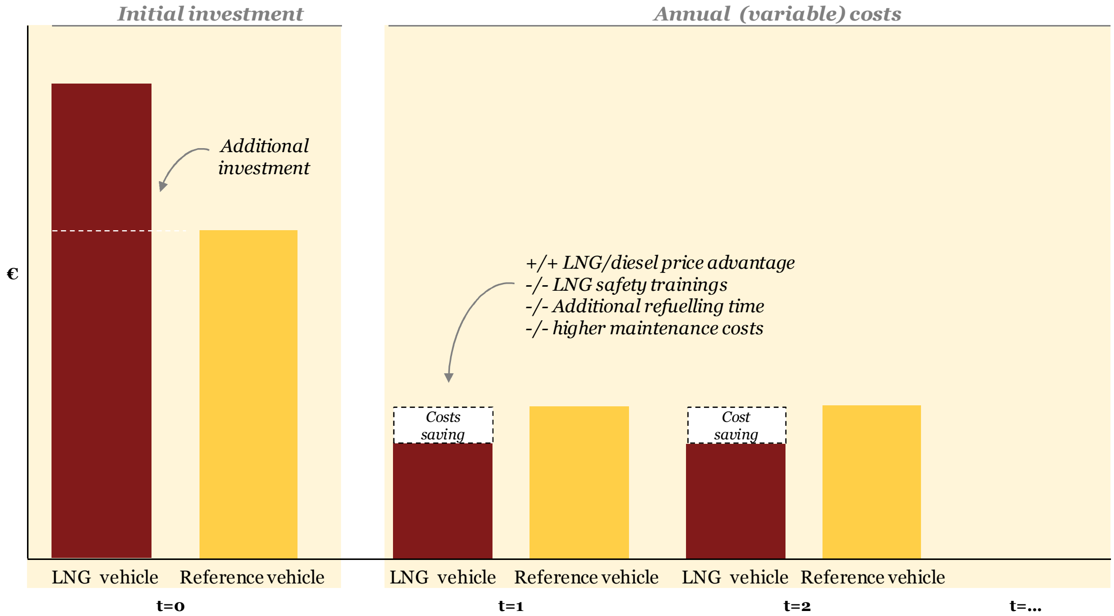



*Source: DNV 2012*

*The estimated repayment period depends on a range of factors*

The repayment period for an investment in an LNG vehicle consists of the number of years that are needed to financially compensate for the additional initial investment via annual cost reductions *(please refer to Figure 5.10 for an illustrative overview).*

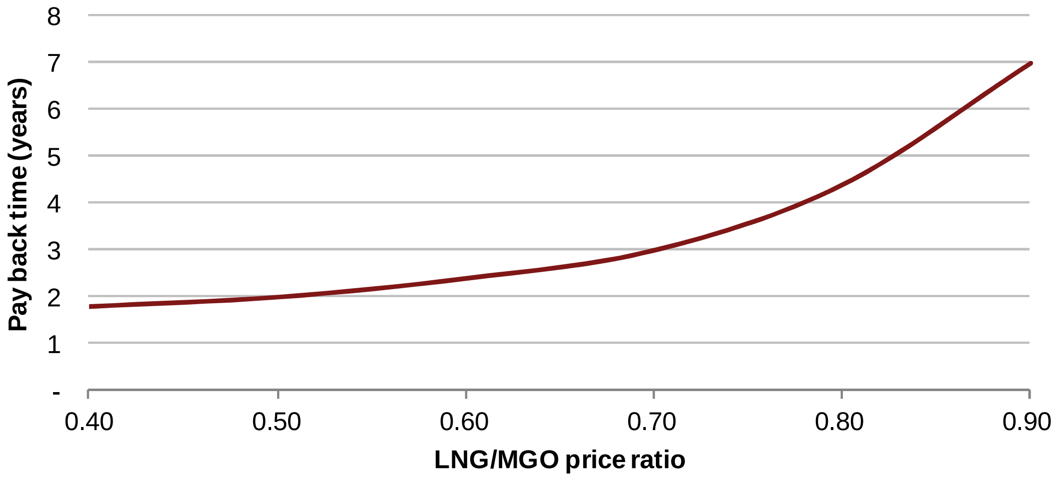
## Figure 5.10: Overview of financial business case for LNG vehicles (simplified)




*Source: PwC analysis*

The length of the repayment period depends on many factors, yet the main variable is the LNG price gap. The example in Figure 5.11 shows how the two are related in case of a short sea ship.

**Figure 5.11: Payback time for a big roll-on/roll-off (RoRo) shipowner as function of LNG/MGO price ratio**




*Source: DMA 2012*

Other factors that must be taken into account when analysing the repayment period include the difference in maintenance costs, extra refuelling costs and additional training materials that need to be followed by personnel (e.g. safety and tank instructions).

Market feedback suggests that maintenance costs for LNG vehicles are somewhat higher than for oil-based vehicles (e.g. driven by more frequent valve adjustments and oil replacements, and also because of a current lack of experienced mechanics). We expect that LNG maintenance cost relative to oil-based vehicles will decline in the future.

Also, refuelling costs are higher as LNG vehicles must be refuelled more often and refuelling takes more time. Market feedback states, for example, that an LNG truck must be refuelled 1.5 times more often than a diesel truck and that a refuelling stop takes more time. Due to the current limited availability of LNG infrastructure, additional kilometres might also be needed for refuelling. As infrastructure is expected to be rolled out further, we expect that additional refuelling cost will decline.

Also, the repayment period is influenced by the numbers of hours and the operating mode of a vehicle as these relate to fuel use. The more kilometres a vehicle covers per annum and the higher the operating mode, the shorter the repayment period will be (keeping all other factors constant).

Finally, the type of LNG engine that is chosen will influence the repayment period. There are LNG vehicles which operate fully on LNG and there are vehicles which operate on a mix of LNG and an oil-based fuel. Fuel cost savings for vehicles operating fully on LNG are higher than for vehicles which only partly operate on LNG. *Please refer to Appendix C3 for an explanation of the different type of LNG engines.*

*The government can influence the repayment period via various instruments*

The government can make use of instruments, such as tax and subsidies, to influence the repayment period for end users. Positive use of these tools can shorten repayment periods and thus stimulate the adoption of LNG vehicles.

The Dutch government currently provides subsidies related to LNG. For example, companies wanting to invest in LNG trucks can be considered for the "Proeftuinen duurzame mobiliteit: Truck van de Toekomst" subsidy programme. In addition, the Dutch government provides incentives to companies to invest in energy-efficient and environmental-friendly company assets via fiscal tools such as the EIA, MIA and VAMIL[29].

The government can influence the gap between LNG and diesel prices for trucks via its fiscal regime. The announced excise tax increase negatively affects the repayment period.

### *5.3.1. Repayment period for ships*

Short sea shipowners compare the investment in an LNG ship with one of the two compliance strategies which they need to follow to meet IMO sulphur regulations. A large part of the short sea ships currently sails on heavy fuel oil (HFO). To reduce sulphur emission, they must either install a scrubber, or switch to a cleaner fuel (i.e. MGO or LNG).

Switching to MGO is attractive because the shipowner only needs to make a small investment. Yet, sailing on MGO is relatively expensive compared to HFO and does not offer any cost advantage in the long run. The other option, installing a scrubber[30], requires a large investment and the scrubber produces waste which needs to be handled. In case of an open scrubber, the waste is dumped in the water, which raises questions whether a ship with such a scrubber reduces environmental impact. Scrubber technologies are still being developed. Also, there is a compliance risk for this abatement technology, which raises the question that who will be held responsible if a scrubber does not work when inspected by the competent supervisory authorities. The advantage of a scrubber for the shipowner is that he can continue to use HFO.

The third solution, a switch to LNG,[31] is the only option offering the opportunity to financially benefit from the initial investment depending on developments in fuel prices. Although the investment that needs to be made is high, it also offers the potential advantage to reduce fuel costs which could be a significant upside.

DMA 2012 compares the repayment period for the different compliance strategies (*please refer to Figure 5.12*). Payback times for a newly built (short) sea vessel vary from one to four years, depending on the type of ship and the expected LNG price spread development.[32]

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[29] Via the EIA, companies can deduct 41.5% of their energy-efficient investment costs from fiscal profits. MIA provides the possibility to deduct an extra percentage of the investment costs from fiscal profits, depending on the used techniques. Via VAMIL, it is possible to depreciate a company asset randomly.

[30] Please note that installing a scrubber is not possible for every ship due to space requirements.

[31] Not all existing ships can be retrofitted to LNG because of space requirement *(please refer to Chapter 5.3.2.2)*.

32 Please note that if LNG prices increase significantly, comparing the "as is" situation (HFO without scrubber) will lead to significantly longer payback times.

**Figure 5.12: Payback times in years relative to MGO compliance strategy[33]**

| | Retrofit | | | New builds | | |
|---|---|---|---|---|---|---|
| | RoRo | Costal tanker | Container ship | RoRo | Costal tanker | Container ship |
| **Low LNG prices** | | | | | | |
| HFO (incl. scrubber) | 2-3 | 2-3 | 1-2 | 1-2 | 2-3 | 1-2 |
| LNG | 1-2 | 2-3 | 1-2 | 1-2 | 2-3 | 1-2 |
| **Central LNG prices** | | | | | | |
| HFO (incl. scrubber) | 2-3 | 2-3 | 1-2 | 1-2 | 2-3 | 1-2 |
| LNG | 2-3 | 2-3 | 1-2 | 2-3 | 2-3 | 1-2 |
| **High LNG prices** | | | | | | |
| HFO (incl. scrubber) | 2-3 | 2-3 | 1-2 | 1-2 | 2-3 | 1-2 |
| LNG | 2-3 | 3-4 | 2-3 | 2-3 | 3-4 | 1-2 |

*Source: DMA 2012*

The shipping industry has only limited experience with sailing on LNG and so the exact payment times are yet to be seen in practice.

In our interviews with market parties, the payback time is noted to be longer for a short sea ship than DMA 2012 results and ranges from 4 to 10 or even 12 years (assuming a constant 20% price spread).

While short sea LNG shipping is already further developed in Scandinavia, meaning there is already some experience, inland shipping is a relatively new area. Market feedback estimates the repayment period for an inland ship to be shorter than for a short sea ship (also assuming a 20% price spread), between four and nine years.

Please note that we expect payback times to develop positively. The small scale LNG market is currently in the development phase, meaning relatively high cost for pioneers. When the market starts to commoditise, LNG vehicle purchase prices are likely to decrease and LNG prices are likely to become more stable. The government can play an important role in the roll-out phase by creating a favourable environment for investments in small scale LNG (including a stable tax regime).

### *5.3.2. Repayment period for trucks*

Based on earlier studies, we estimate the repayment period for the investment in an LNG distribution truck between 2.5 and 10 years. This is relative to a diesel truck.

To illustrate, IHS CERA (2012) estimates the payback period for European LNG trucks driving 150,000km a year and using 80% diesel and 20% LNG at 3.1 years. A report written for the Department of Transport in the UK (2012) estimates the payback time for a long-haul dual-fuel truck to be between two and four years, and for a mono-LNG truck to be between one and three years. For regional delivery, it estimates longer payback times; five to ten years for a dual-fuel engine and three to six for a mono-LNG engine.

Dutch truck producers and fleet owners which already have experience with LNG trucks say that the business case is still very thin. This is mainly driven by start-up obstacles, high current LNG truck prices and a relatively low LNG price cost advantage compared to some other countries such as the UK.

Like ships, we expect payback times for trucks to become shorter (i.e. commoditisation of the market). The government can play a key role in the roll-out phase by creating a favourable environment for investments in small scale LNG (including a stable tax regime).

[33] *Price scenario's based on constant MGO price of €875/ton and LNG price of €315/ton (low) €440/ton (central) and €570/ton (high)*

# 6. Small scale LNG demand in 2030

*We estimate that the uptake of small scale LNG will result in a demand between 0.5m ton and 2.5m ton LNG in 2030 (scenario-based approach). This reflects 3-15% replacement of current diesel used in the transport sector. Key drivers underlying this range are governmental policies, availability of "clean" alternatives, the LNG price gap and the growth of the transport sector. Although we expect the trucking segment to adopt LNG most quickly, the shipping sector will make the largest impact.*

## 6.1. Introduction

The key is to understand how large the demand for small scale LNG can be in 2030 to make an estimate of the possible economic impact. The uptake of LNG to 2030 depends on the development of various factors, such as government policies and the LNG/oil price spread. As the development of these factors is largely uncertain, it is difficult to predict how the demand for small scale LNG will develop further. So we use a scenario-based approach. Based on underlying drivers, we set up three scenarios which reflect what the uptake of LNG could look like. In this Chapter, we will further elaborate on those scenarios and in the next Chapter we will discuss how these outcomes can impact the Dutch economy.

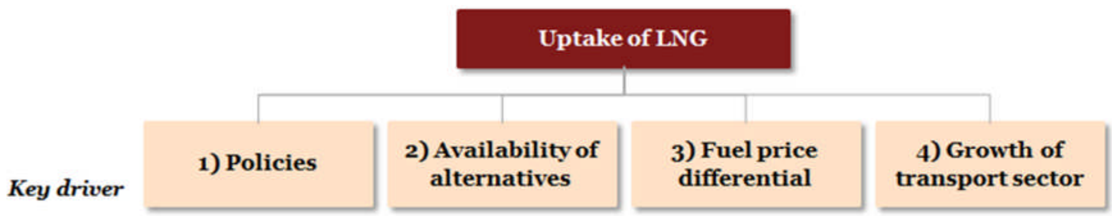
## 6.2. Key drivers of LNG uptake

*Boundary conditions for LNG roll-out on a large scale include a positive price spread development, emission regulations, standardisation of engines, lack of attractive alternatives and a stable investment climate*

In addition to key drivers, certain (boundary) conditions are needed to facilitate the roll-out of small scale LNG. First of all, regulations around emissions will be required to stimulate (clean) alternatives for oil-based fuels. And of course, LNG needs to be one of the attractive alternatives to oil-based fuels. If a dominant alternative arises, LNG roll-out might be difficult. Also, a positive oil/gas spread is needed to make a switch to LNG economically attractive for end users and infrastructure providers. At the same time, LNG ships and trucks will need to be developed on large scale to reach standardisation and, thus, a reduction of investment costs. In addition, a stable investment climate is required to facilitate a switch to LNG-based ships or trucks, and also for building up infrastructure.

*The further uptake of LNG is driven by four key factors in which the government can play a key role* (please refer to Figure 6.1 for an overview).

**Figure 6.1: Key drivers of small scale LNG uptake**



### 1) *Policies*

The government can use policy instruments to stimulate (or discourage) the use of small scale LNG in the long run. As discussed earlier, emission regulations for vehicles can stimulate the use of LNG. Both implementing and monitoring such regulations play a key role in the further roll-out of small scale LNG. The tighter the regulations set, the higher is the penetration of LNG vehicles.

### 2) *Availability and attractiveness of "clean" alternatives*

Even if strict government policies push end users towards "clean" vehicles, they might not choose LNG if (technically and economically) more attractive alternatives are available. Firstly, diesel vehicles have become increasingly more efficient and cleaner *(please refer to Appendix D1)*, and this trend is likely to continue (e.g. Euro VI truck engine). In addition, alternative fuels such as ethanol and hydrogen might develop as attractive alternatives as well. The government can also play a role in the preference of one or more solutions, by setting up stimulating/discouraging policies such as explained above.

### 3) *Fuel price differential*

As switching to LNG is not the only option to meet emission requirements, the choice for LNG must be attractive from a financial point of view. Whether switching to LNG is attractive largely depends on the LNG price compared to the diesel/MGO/HFO price. If the price spread is smaller, LNG might be a relatively expensive and, thus, a less attractive solution.

### 4) *Growth of the transport sector*

The size of the transport fleet is correlated to the size of the transport market. If the transport market experiences positive growth (driven by positive economic developments), the fleet will need to grow as well. So the positive development of the underlying transport market can positively impact the uptake of LNG, as growth will lead to additional truck investments (next to replacement investments). In addition, there is more room for relatively expensive "green" solutions in a growing market.

## *6.3. Limitations to the uptake*

The maximum demand for small scale LNG is expected to lie between 22m and 44m ton in 2030. This reflects the situation where the total Dutch fleet of transport vehicles would switch to LNG *(please refer to Appendix D2)*. Yet, not all vehicles in the Dutch fleet are suitable to switch to LNG (at least on the short to medium run). This limits roll-out potential on the large scale. Please note that we take these limitations into account in our scenario analyses.

*Short sea ships are likely to adopt LNG in the short to medium run to meet sulphur emission requirements*

Short sea ships have a relatively long lifetime of 20-25 years, so not all ships will be replaced by new ones before 2030. For these ships, a retrofit will be applicable (suitable for most types). Currently, the short sea shipping sector is using LNG only on a very limited scale. Yet, we expect that with the increasingly strict emission policies (sulphur reduction 2015) and by stimulating infrastructure policies at EC level, short sea ships might start adopting LNG relatively quickly.

*LNG retrofit is only suitable for part of the existing inland shipping fleet. This might be a barrier in the short to medium term*

The Dutch inland shipping fleet largely consists of general cargo vessels, push freight barges and tank vessels (55%).[34] The lifetime of an inland ship ranges between 20 and 30 years. As the Dutch shipping fleet is relatively

[34] IVR

young (10-12 years on average), a large part of the fleet will not be replaced by new ships before 2030; more so as the inland shipping industry currently faces financial difficulties and large overcapacity. Existing ships can switch to LNG via a retrofit, yet not all ships are suitable for this, for example, as the LNG tank cannot be placed on top of the ship. New designs are better able to integrate the tank in the ship. Passenger ships are also looking at LNG but adoption might take more time due to safety restrictions. Market feedback suggests that between 40% and 60% of the current fleet is suitable for an LNG retrofit.

With the first inland ship currently sailing on LNG and three permits granted, the inland shipping sector is gradually starting to adopt LNG. Yet, restrictions for retrofitting and large overcapacity in the market will limit potential roll-out in the short to medium run.

*National distribution trucks are most likely to adopt LNG in the short to medium run, yet international distribution trucks might follow on larger scale in the medium to long run*

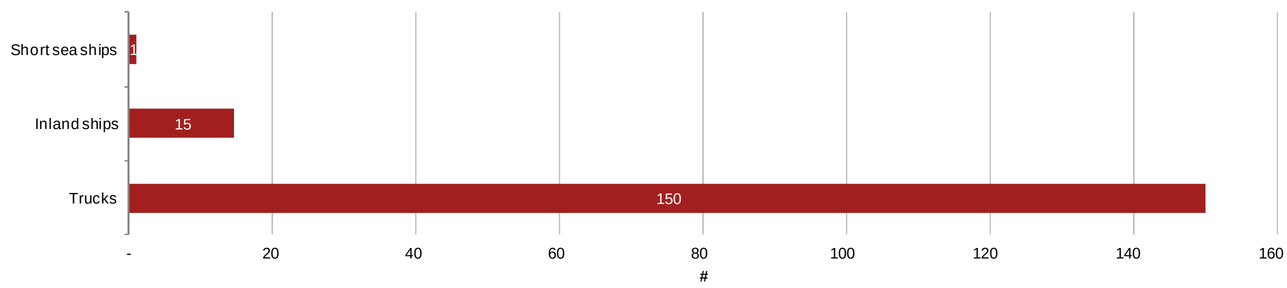
The Dutch truck fleet mainly consists of trucks >16 ton (75%) and tractor trucks (41%).[35] Currently, LNG appears most viable for distribution trucks and for trucks driving in city areas (e.g. cleaning trucks). Already 70-100 trucks (mainly national distribution) have started using LNG. We expect LNG to become more viable for long-haul trucks as well, with engines being further developed in the future. We expect that in 2030, the largest part of the fleet could be suitable to drive on LNG. As trucks have an average lifetime of 5-8 years, each truck owner can consider switching to LNG from now to 2030.

*The truck sector is adapting LNG most quickly, yet LNG demand of the shipping sector will quickly pass LNG truck demand*

The LNG truck industry is already further developed than the LNG shipping industry. Currently, around 70-100 LNG trucks are operating in the Netherlands and the first refuelling stations have been set up. If circumstances develop positively, the road segment is ready to accelerate further. The shipping segment lags behind, with only a few ships sailing on LNG and very limited infrastructure available at present.

Yet, please note that the impact on total LNG demand of ships switching to LNG is significantly larger than the impact of trucks. Ships are much more fuel-intensive than trucks.

**Figure 6.2: No. of inland ships and trucks needed to meet similar LNG demand of one short sea ship (illustrative)[36]**




*Source: TNO 2013, PwC analysis*

[35] RAI

[36] Based on TNO 2013, which assumes an annual usage of 25,000kg LNG (truck), 110,000 to 400,000kg LNG (inland vessel) and 3,750,000 kg LNG (short sea ship).

## 6.4. Our scenarios

*Our scenarios for the uptake of LNG are based on how underlying drivers could possibly develop*

We prepared three scenarios which we call "Clean growth", "Current policies" and "Frozen" *(please refer to Figure 6.3 for a brief overview)*. We assume that the small scale LNG market will pick up; which means that even the lower scenario will include positive growth of small scale LNG, but to a more moderate extent.

### Figure 6.3: Overview of key scenario assumptions

| Key driver | | 'Frozen' | 'Current policies' | 'Clean growth' |
|---|---|---|---|---|
| 1) | Policies | • Limited enforcement of proposed policies to curb $CO_2$, NOx, SOx, PM<br>• No change in $CO_2$-policies | • Current policies enforced to curb $CO_2$, NOx, SOx, PM | • Policies enforced to curb $CO_2$, NOx, SOx, PM<br>• Carbon tax for trucks and shipping |
| 2) | Availability and attractiveness of 'clean' alternatives | • High | • Moderate | • Low |
| 3a) | Prices maritime fuels (energetic value) | • LNG: 0.9-1.0* HFO<br>• LNG: 1.3-1.5* MGO | • LNG: 0.7-0.9* HFO<br>• LNG: 1.0-1.3* MGO | • LNG: <0.7* HFO<br>• LNG: <1.0* MGO |
| 3b) | Prices fuel road transport (energetic value) | • LNG: 0.8-1.0* Diesel | • LNG: 0.6-0.8* Diesel | • LNG: <0.6* Diesel |
| 4) | Growth of the transport sector* | • <2% | • 2-4% | • >4% |

*Source: PwC analysis*

In the "Clean growth" scenario, we assume that a variety of policies are enforced to curb emissions, which become stricter over the years. The transport market experiences positive growth and the LNG price spread is very attractive. Limited LNG alternatives are available.

In the "Current policies" scenario, we assume that current (planned) policies are enforced to curb emissions. We assume moderate growth for the transport market and a stable LNG price spread. The availability of non-LNG alternatives is moderate.

In the "Frozen" scenario, we assume limited enforcement of the proposed policies to reduce emissions, limited growth of the transport market, a relatively small LNG price spread and relatively large availability of attractive non-LNG alternatives.

The price assumptions in the "Current policies" scenario are based on current market conditions for LNG in the Netherlands. As discussed in Chapter 4, LNG prices are c.60-75% of diesel prices (expressed in energetic value and including taxes). If the LNG price spread is significantly higher than the range of 0.6-0.8 times the diesel price, LNG is much less attractive from a financial perspective. If we apply the same LNG price for water transport as for road transport (excluding taxes), this corresponds to an LNG/MGO ratio of c.0.7-0.9.[37]

We assume a growth rate of 2-4% for transport sector for the base case scenario ("Current policies"). This is in line with the growth rate forecast of the EU road transport sector (based on the number of kilometres) of c.3% per annum up to 2030 (World Energy Outlook 2012). Please note that we assume an average growth of 2-4 % for all transport segments. Growth might differ through each segment.

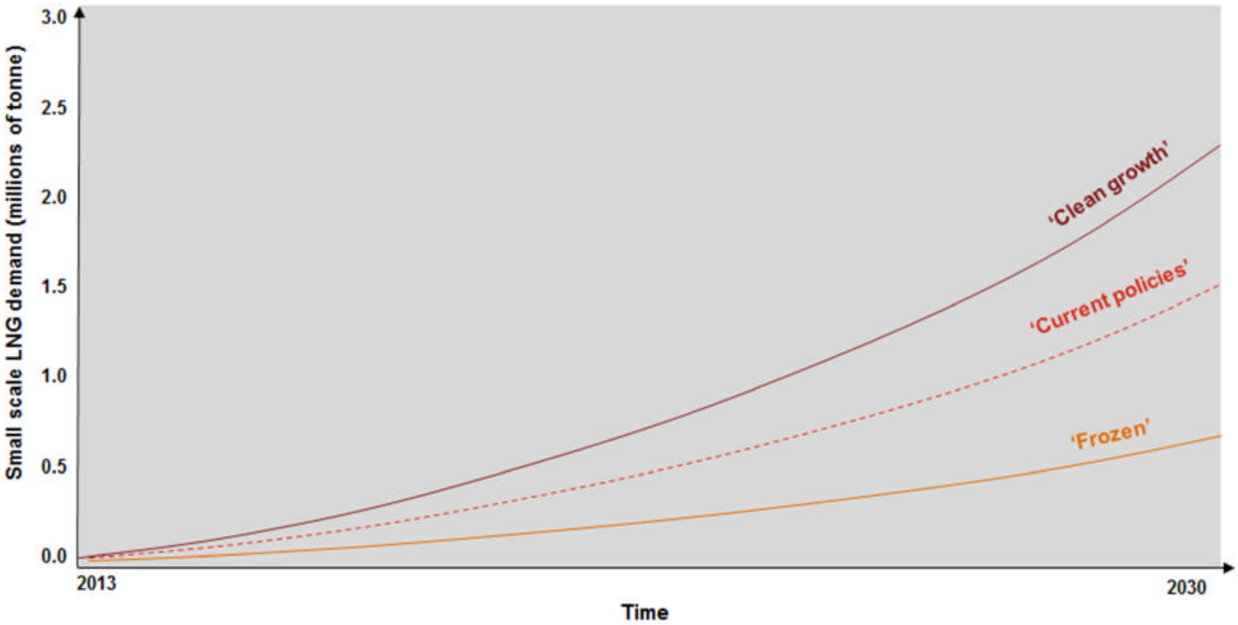
Please note that the limitations such as discussed in Chapter 6.3 are equal for all three scenarios.

[37] Assuming an MGO price of c.€ 1,000 per ton (Source: www.bunkerworld.com, February 2013)

## 6.5. Possible demand in 2030

Based on the discussed assumptions and limitations, we estimate that small scale LNG demand could lie between 0.5m and 2.5m ton in 2030 *(please refer to figure 6.4).*

**Figure 6.4: Overview scenario – demand 2030 (illustrative)**




*Source: PwC analysis*

*The "Clean growth" scenario refers to the Green Deal target and assumes 2.5m ton LNG in 2030*

As a starting point, we have used the 2-3m ton of LNG in 2030 set by the Green Deal. Based on our analyses and market feedback, we have concluded that the Green Deal target is ambitious, but can be met if underlying factors develop positively.

To meet the target of 2.5m ton small scale LNG, 15% of the diesel currently consumed in the Netherlands needs to be replaced by LNG.[38] Based on our assumed transport market growth of 2-4%, this would mean 6% of total fuel used in 2030 *(please refer to Figure 6.5)*. This relates to either 100,000 trucks (60% of current fleet, 25% of estimated 2030 fleet), or 9,804 inland ships (96% vs 40%) or 667 short sea ships (22% vs 9%), which should switch to LNG.

Of course, a combination of the various vehicles is more likely. For example, if c.45,000 trucks, 1,000 inland ships and 300 short sea ships switch to LNG, they will use c.2.5m ton LNG in the Netherlands *(please refer to Figure 6.5)*. In our view, this is a realistic example of how LNG could develop per segment.

We believe the above penetration rates and the related number of vehicles that need to switch to LNG are relatively high, given the current situation and the limitations for part of the fleet to easily switch to LNG. Also in a broader, global context, a projection of 15% LNG in the fuel mix is high when compared to the projections of leading market analysts, who forecast c.2-5% *(please refer to Appendix D3)*.

[38] Based on CBS figures relating to the current amount of diesel that is being sold for transport purposes in the Netherlands (i.e. consumption in the Netherlands). Please note that the diesel is bought in the Netherlands but is used for both national and international transport.

*"Current policies" assumes 1.5m ton LNG demand in 2030*

We believe that the "Current policies" scenario, which reflects an LNG demand of 1.5m ton, could be more likely. In this scenario, underlying factors develop in a stable manner, but positively.

We assume that an LNG output of 1.5m ton could be reasonable; also, considering the projections of other market analysts, 1.5m ton LNG relates to 9% replacement of current diesel or 5% of expected 2030 diesel by LNG. This means either 60,000 trucks (36% of current fleet vs 21% of 2030 estimated fleet), or 5,882 inland ships (58% vs 34%) or 400 short sea ships (13% vs 8%) must switch to LNG.

An example of a combination includes c.30,000 trucks, 600 inland ships and 160 short sea ships.

*"Frozen" assumes 0.5m ton LNG demand in 2030*

The "Frozen" scenario assumes only limited enforcement of the proposed policies; this means that LNG use is stimulated only to a limited extent. In addition, price spread becomes less attractive and there is limited growth in the transport market. We assume an output of only 0.5m ton LNG in this scenario (3% of current diesel or 2% of expected 2030 diesel should be replaced by LNG). This related to 20,000 trucks (12% of current fleet vs 10% of estimated 2030 fleet), or 1,961 inland ships (19% vs 16%) or 133 short sea ships (4% vs 4%).

An example includes c.7,000 trucks, 150 inland ships and 75 short sea ships.

**Figure 6.5a: Possible LNG demand in 2030 per segment per scenario**

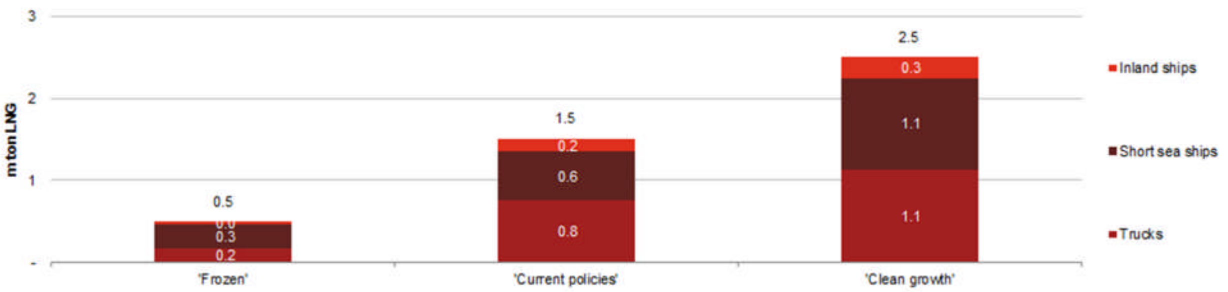



**Figure 6.5b: Penetration of estimated fleet in 2030 per segment per scenario**

| | 'Frozen' | 'Current policies' | 'Clean growth' |
|---|---|---|---|
| **Inland ships** | 1% | 3% | 4% |
| **Short sea ships** | 2% | 3% | 4% |
| **Trucks** | 4% | 11% | 11% |

# 7. Economic impact of small scale LNG

*The roll-out of small scale LNG benefits our economy in various ways. We estimate that in the "Current policies" scenario, a total of around 8000 job years will be added due to investments in infrastructure, and trucks and vessels. Production of bio-LNG also contributes to GDP and employment. By diversifying the fuel mix, there is the potential to benefit from a higher gas to oil spread. In the short term, this can form a competitive advantage. If the Netherlands becomes a frontrunner in the field of small scale LNG, there is the potential to benefit from the export of expertise and know-how. A reduction of emissions could have an estimated economic value between €100m and €400m per annum in 2030.*

## 7.1. Background

In previous Chapters, we have investigated the current situation of small scale LNG in the Netherlands and presented scenarios for future uptake. This Chapter describes the economic impact small scale LNG can have in the Netherlands, based on the "*Current policies*" scenario as described in Chapter 6. We do not report the economic impact in the scenarios "*Clean growth*" and "*Frozen*" in detail, as the economic impact in those scenarios is more or less in line with the uptake of LNG.

We have identified five ways in which small scale LNG can have an economic impact, demonstrated in Figure 7.1:

❶ *Investments in LNG vessels and trucks:* In the Current policies scenario, truck owners will invest in new LNG trucks and shipowners will build new ships or retrofit their existing fleet. The investment in LNG technology creates an impulse for the economy.

❷ *Investments in small scale infrastructure:* Chapter 3 describes the required infrastructure for the roll-out of small scale LNG. As the LNG infrastructure does not replace existing infrastructure in the short term, we have assumed that all investments in the LNG infrastructure are investments that would not have been made without the roll-out of LNG. The investments in infrastructure create an impulse in economic activity, just as the investments in LNG vessels and trucks do.

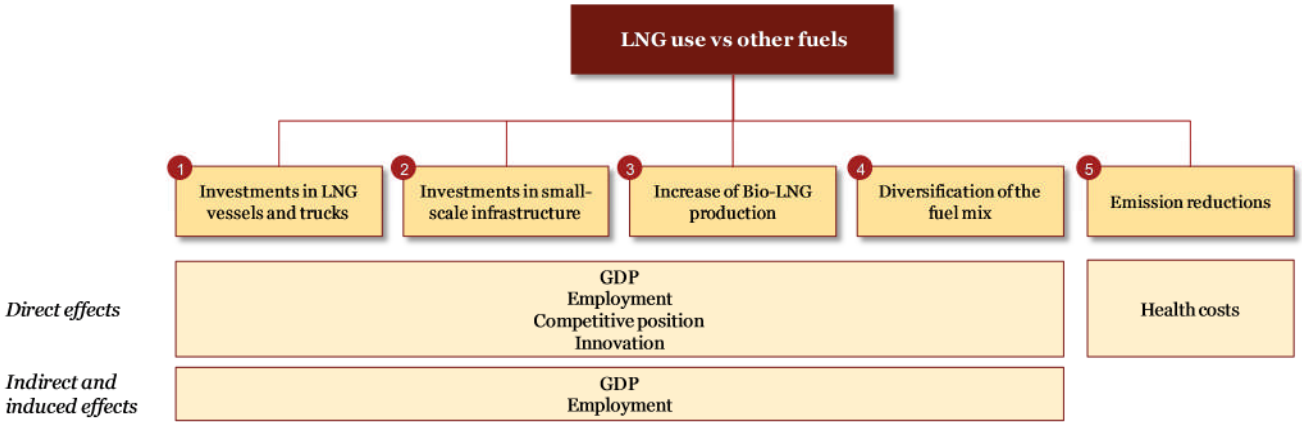
❸ *Increase of bio-LNG production:* An increase in LNG use will increase the demand for LNG imports, as fossil LNG is not produced in the Netherlands. In contrast, bio-LNG (or LBG) can be produced nationally. An increased demand for LNG and the availability of small scale LNG infrastructure provide incentives for the production of LBG. If these LBG projects are new, and would not have been there without the roll-out of LNG, they will increase economic activity in the Netherlands.

❹ *Diversification of the fuel mix:* Currently, the transport sector largely depends on the oil market; LNG is an alternative type of fuel, which makes it possible to diversify fuel supply sources. Fuel mix diversification provides portfolio advantages and reduces the energy import bill. In Chapter 4, we discussed that it is possible that the oil-gas spread will increase. In that case, LNG can provide competitive advantages to the Dutch economy.

❺ *Emission reductions:* LNG can reduce emissions of pollutants.[39] This reduction in pollutants can have positive health effects and contributes to the reduction of greenhouse gasses.

[39] TNO (2013)

## Figure 7.1: Economic impact of LNG use vs the use of other fuels




In our analysis, we distinguish the following economic effects through which LNG use impacts economic welfare:

*Gross domestic product (GDP) and employment:* Additional investments in LNG infrastructure affect the economy directly and indirectly through its demand for materials, (construction) services, machinery, energy consumption, etc. Investment in an industry will lead to increased demand for employees to deliver the required goods or services.

*Competitive position and innovation:* Small scale LNG can potentially offer competitive advantages for the Dutch transportation sector and, as a result, also for companies in other industries. It can also reduce the exposure to the oil market. If the Netherlands becomes one of the frontrunners in the roll-out of LNG, there may be opportunities to export expertise and know-how to other countries.

*Health costs:* LNG has the potential to reduce emissions of sulphur, nitrogen, greenhouse gases and particulate matter. So health costs related to these emissions decline. We will not put a precise number on the economic contribution of lower emissions but will discuss why there can be positive economic effects of such a reduction.

*Economic impact in the Netherlands and abroad*

In the analysis, we assumed that all economic effects besides the production of trucks and vessels in other countries will be attributed to the Netherlands. In practice, this might not be the case as a significant share of the total kilometres travelled by trucks and vessels are not within Dutch borders, thereby also affecting other countries (for example, through emissions). In Chapter 7.8, we discuss the regional distribution of the economic effects in the Netherlands.

To broaden the perspective on the economic impact of LNG use for transport, Chapter 7.9 will discuss the implications of LNG use for the German economy.

In the following Chapters, we discuss the results of the input-output model per impact after a short explanation of the method used for economic impact analysis.

## *7.2. Method*

The effects on GDP and employment are measured by the use of an "input-output model". This model is based on an input-output table, which uses so-called multipliers to estimate the direct, indirect and induced production effects in the economy of direct investments.[40] These three levels of economic effects are explained in Figure 7.2.

### Figure 7.2: Three levels of economic effects

| Effect | Description | Example |
|---|---|---|
| **Direct** | Total value of spending in the economy directly related to LNG infrastructure construction | €2.0m spent on machinery and equipment requiring 5 more FTEs |
| **Indirect** | Impact on industries which provide goods and services to the industry in which direct investment took place (inter-industry purchases) | The €2.0m spent on machinery and equipment results in €0.5m of purchases in metal products and €0.3m in energy consumption (€0.8m impact on GDP), requiring 12 FTEs (employment impact) |
| **Induced** | Impact on the Dutch economy resulting from changes in household spending related to a shock in wages due to the indirect and induced effects | The €2.0m direct spending, the €0.8m indirect inter-industry purchases, and the 17 additional FTEs generate additional household income. €1.2m of this income is spent in the economy (e.g. on food, transportation), creating 20 additional FTEs (the induced effect on GDP and employment) |

*Source: the Brattle Group 2012, PwC analysis*

An input-output table lists a large number of different industries in the Dutch economy and their interrelationships with respect to input and output. For our analysis, we have used an input-output table of the Centraal Planbureau (CPB), created in 2008, which is the most extensive and relatively recent table, including the shipbuilding and car industry. Appendix E.1 provides more detail on the model, its underlying assumptions and how results of the model should be interpreted.

*Gross effects and net effects*

Investments in an industry will lead to increased demand for employees to deliver the required goods or services. However, the increased demand does not automatically lead to new jobs. This depends to a large extent on the unemployment level as "new" jobs can only be created as long as there are people to fulfil them. An increase in demand for labour will put upward pressure on wages. The higher wages can be considered a positive economic effect but might crowd out economic activity in other sectors of the economy. Especially in the long term, this crowding-out effect will be quite large, as it is projected that the Dutch economy will face a shortage of technically skilled labour.[41] In the short term, unemployment is expected to be at such a level that additional demand for labour will result in an increase in employment.[42] The results we report should be considered as the *gross* effects as we have not quantified the crowding-out effect. This means that the net effects on GDP and employment could potentially be smaller.

Further, as we have used an input-output table with 2008 prices, investments and their respective effects are potentially lower than projected in our outcomes. However, we expect that this leads to minor differences.

[40] Appendix V of the Brattle Group 2012, has a good introduction on input-output analysis.
[41] According to Scheepsbouw Nederland, the association of the shipbuilding industry and the pool of technical students is too low compared to (future) demand (Source: Scheepsbouw Nederland 2012)
[42] In January 2013, the employment rate in the Netherlands was 7.2% (Source: Statistics Netherlands)

# 7.3. Investments in LNG vessels, and trucks and small scale infrastructure

In the *Current policies* scenario, we have taken a moderate perspective on the LNG potential and assume an output of 1.5m ton LNG can be reached in 2030. Based on this scenario, and the required infrastructure for the roll-out of small scale LNG as described in Chapter 3 we have estimated total direct investments of €824m in LNG infrastructure.[43] These investments are capital expenditures only, as we assume LNG use generally replaces current fuel use and so will not generate major additional operational expenditures. The details behind our estimations are provided in Appendix E.1.

***Effect on GDP***

In total, the impact on GDP of investments in LNG vessels, and trucks and small scale infrastructure is estimated at €1.4bn until 2030. The results are summarised in Figure 7.3.

**Figure 7.3: Impact on GDP by investment and level of effect**

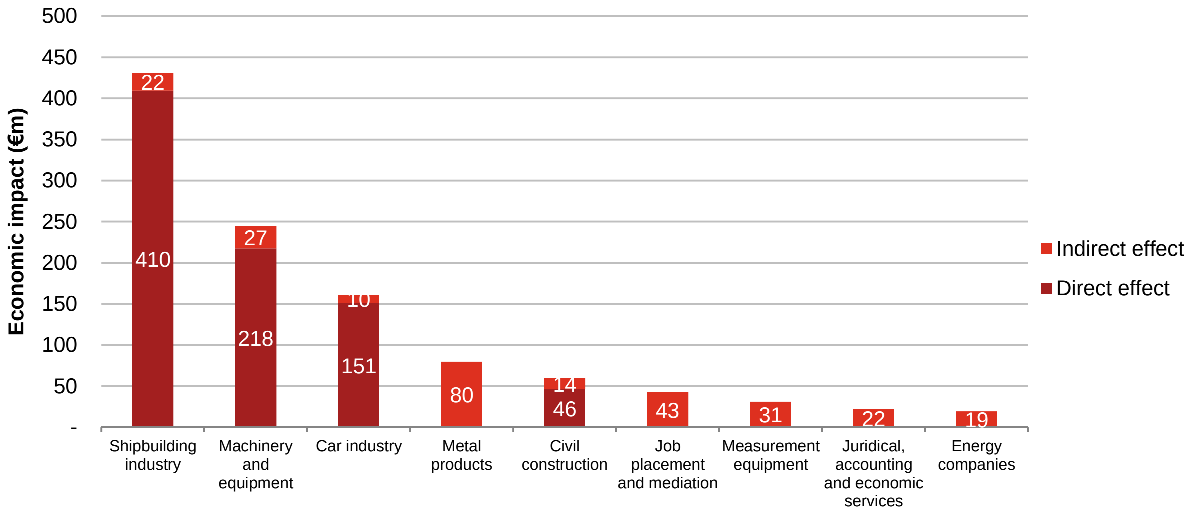
| | Direct effect (€m) | Indirect effect (€m) | Induced effect (€m) | Total effect (€m) |
|---|---|---|---|---|
| **Investments in LNG vessels and trucks** | 634 | 356 | 77 | 1,067 |
| **Investments in small scale infrastructure** | 190 | 126 | 25 | 341 |
| **Total** | 824 | 482 | 102 | **1,408** |

*Source: PwC analysis*

The indirect effect of €482m is spread over several industries, of which 9 out of 104 industries account for more than 55%. Figure 7.4 shows the industries that experience the largest economic effects of the investments in LNG infrastructure. The induced effect of €102m is the effect of €67m extra household spending as a result of a shock in wages due to the direct and indirect effects. The induced effect is mainly visible in services such as energy, financial services, real estate and airlines.

[43] In our analysis, we assumed that 70% of direct investments, apart from the production of trucks (10%), are attributed to the Netherlands. The other share of investments is assumed to be made abroad.

## Figure 7.4: Direct and indirect effect on GDP, by industry




*Source: PwC analysis*

### *Employment effects*

The employment effect of investments in LNG infrastructure totals around 6,200 job years until 2030 *(please refer to Figure 7.5)*. Most direct employment is created in the shipbuilding industry, where the investment boost is highest. Most indirect employment is created in the industries job placement and mediation services, metal products, and machinery and equipment. The induced effect on employment is especially evident in the areas where induced output was created (i.e. retail, secondary school, and public transport).

## Figure 7.5: Impact on employment by investment and level of effect

| | Direct effect (FTE) | Indirect effect (FTE) | Induced effect (FTE) | Total effect (FTE) |
|---|---|---|---|---|
| **Investments in LNG vessels and trucks** | 2,144 | 2,061 | 464 | 4,669 |
| **Investments in small scale infrastructure** | 705 | 690 | 152 | 1,547 |
| **Total** | 2,849 | 2,751 | 616 | **6,217** |

*Source: PwC analysis*

In 2010, the Dutch shipbuilding sector accounted for around 9,700 employees and the Dutch harbours for around 30,410 employees (in office work as well as in on-the-ground services). A large share of employees in these sectors is older than 45 years and, in comparison with the Dutch average and the average in other maritime sectors, the educational level is low. The level of education is increasing but a demand for higher and technically educated employees persists in the Dutch shipbuilding sector, requesting engineers, project managers, metal workers, etc. However, the labour market is tight with respect to technically educated people, especially regarding higher educated ones.[44]

[44] Stichting Nederland Maritiem Land (2011)

Because most trucks are constructed abroad, there are not many employment opportunities related to the construction of LNG trucks in the Netherlands, except for truck finalisations (e.g. installing an LNG engine in a CNG truck). Higher and technically educated people are required for this.

## *7.4. Investments in bio-LNG production*

Bio-LNG (LBG) is produced through liquefaction of biogas. So far, LBG is in the test phase of production, and as discussed in Chapter 2, LBG is currently imported from the UK. There are a number of conversion options for biogas. Biogas is currently mainly used as “green gas” by upgrading the gas and injecting it in the gas network.

In 2010, biogas production was 8.3 PJ (equivalent to c.7-8 PJ green gas). In “Energierapport 2011”, the Dutch government estimated that the potential for green gas will be 56 PJ in 2020. An Agentschap NL commissioned PwC study confirms that 56 PJ is theoretically feasible (PwC 2012). The report argues that a feed-in level of 56 PJ of green gas into the national gas network is a high estimate, but expects that part of this potential can be realised in the coming years.

Rabobank (2013) argues that an increase in the production of biogas depends on the availability of sufficient biogas against favourable prices, and the availability of investment subsidies. A stable revenue stream is necessary to provide enough security for bio-LNG investments. But even if these conditions apply, the capacity of regional distribution networks could pose a problem if all produced green gas has to be fed into the gas network, especially during warm periods when demand is low (i.e. summer season) (PwC 2012).

The production of LBG forms an alternative to feeding green gas into the gas network. The use of LBG as a transportation fuel would lift the problem of supply and demand in the regional and national gas distribution network. This will provide opportunities for biogas projects that are struggling to be rolled out. In our analysis, we assume that 10% of the total biogas potential (5.6 PJ) will be used for LBG in 2030.[45] We consider this potential to be part of the economic impact of LNG as we think it is reasonable to assume that some biogas projects would not be economically feasible without LNG as a distribution option.

***Effect on GDP***

We assume that investments in biogas installations are required to reach 5.6 PJ or c.100.000 tons LBG production. Based on a price assumption of €0.75/kg (excluding taxes and infrastructure costs) for LNG and linear production growth, we have estimated the total production costs of LBG to reach €637m[46] in 2030. Detailed calculations and underlying assumptions are provided in Appendix E.1.

In the analysis, we have considered total (capital and operational) production expenditures of LBG, as we believe that biogas projections will result in additional demand for biomass, which is also an impulse for the economy.

In total, the GDP effect of capital investments in LBG production is estimated at €1,262m until 2030, demonstrated in Figure 7.6.

[45] 5.6 PJ equals c.100,000 tons of LBG. In the Current policies scenario, which is 7% of total LNG consumption in 2030.
[46] In our analysis, we assumed 100% of production investments can be attributed to the Netherlands. In practice, this percentage can be somewhat lower due to investment leakages abroad.

**Figure 7.6: Impact on GDP by level of effect**

| | Direct effect (€m) | Indirect effect (€m) | Induced effect (€m) | Total effect (€m) |
|---|---|---|---|---|
| **Investments in bio-LNG production** | 637 | 592 | 33 | **1,262** |

*Source: PwC analysis*

***Employment effects***

Employment directly related to LBG production is minimal, as the production of biogas and the process of liquefaction is not labour-intensive and can often be performed by a single person, for example a farmer. However, indirect employment effects are larger, as the energy sector requires inputs from several other industries.

**Figure 7.7: Impact on employment by level of effect**

| | Direct effect (FTE) | Indirect effect (FTE) | Induced effect (FTE) | Total effect (FTE) |
|---|---|---|---|---|
| **Investments in bio-LNG production** | 345 | 1,173 | 207 | **1,725** |

*Source: PwC analysis*

## 7.5. Total estimated economic impact

In the previous Chapters, we have demonstrated the effects on GDP and employment per investment impact. A summary of the results is provided in Tables 7.8 and 7.9.

***Effect on GDP***

Based on the input-output analysis, we have estimated a potential economic impact of c.€2.7bn on GDP related to direct investments of c.€1.5bn. Over 17 years, this would amount to yearly boosts of c.€100m to the economy. However, we assume that this effect is not spread evenly in the years until 2030. In the years until 2020, we expect that especially investments in LNG small scale infrastructure will take place. The subsequent uptake of LNG by vessels and trucks will most probably take off at a slower pace, and a larger share of investments is expected after 2020.

**Table 7.8: Impact on GDP by investment and level of effect**

| | Direct effect (€m) | Indirect effect (€m) | Induced effect (€m) | Total effect (€m) |
|---|---|---|---|---|
| **Investments in LNG vessels and trucks** | 634 | 356 | 77 | 1,067 |
| **Investments in small scale infrastructure** | 190 | 126 | 25 | 341 |
| **Investments in bio-LNG production** | 637 | 592 | 33 | 1,262 |
| **Total** | 1,461 | 1,074 | 135 | **2,670** |

*Source: PwC analysis*

## *Effect on employment*

The employment effect is estimated to reach around 8,000 job years in 2030. Over 17 years, this comes down to around 500 annual job years. Based on the assumption that most investments will take place after 2020, the impact on FTEs will probably also be greater from 2020 to 2030 than until 2020.

### Figure 7.9: Impact on employment by investment and level of effect

| | Direct effect (FTE) | Indirect effect (FTE) | Induced effect (FTE) | Total effect (FTE) |
|---|---|---|---|---|
| **Investments in LNG vessels and trucks** | 2,144 | 2,061 | 464 | 4,669 |
| **Investments in small-scale infrastructure** | 705 | 690 | 152 | 1,547 |
| **Investments in bio-LNG production** | 345 | 1,173 | 207 | 1,725 |
| **Total** | 3,194 | 3,924 | 823 | **7,941** |

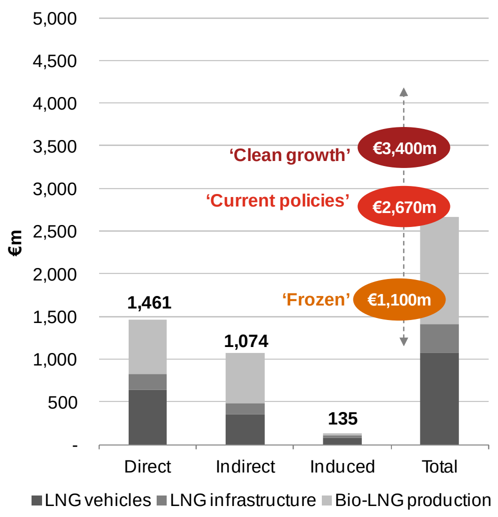
*Source: PwC analysis*

Our economic impact analysis has been based on the *"Current policies"* scenario. To estimate the impact for the other two scenarios, we have taken a similar ratio to the linear uptake of LNG (e.g. 0.5m ton LNG, 1.5m ton LNG and 2.5m ton LNG respectively).

In the estimation of all scenarios, we have assumed constant infrastructure investments (as based on *"Current policies"* scenario) and a maximum production of 100,000 tons kg bio-LNG (i.e. the scenario "*Clean growth"* is unchanged with respect to bio-LNG investments). Figures 7.10 and 7.11 demonstrate the potential impact on GDP and employment according to each scenario.

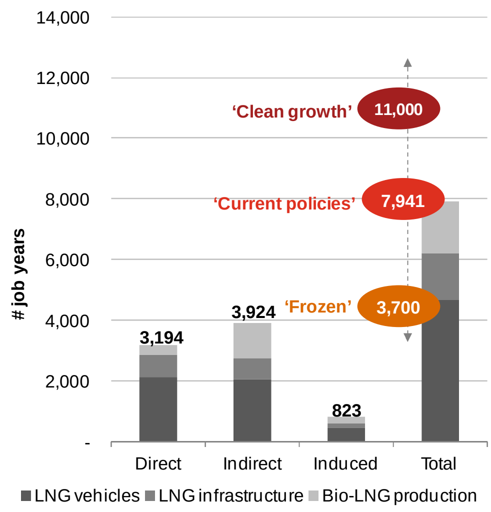
We estimate the potential economic impact on GDP at €1,100-3,400m and on employment at 3,700-11,000 job years.

### Figure 7.10 GDP effect 2030




*Source: PwC analysis*

### Figure 7.11 Employment effect 2030




*Source: PwC analysis*

## *7.6. Diversification of the fuel mix*

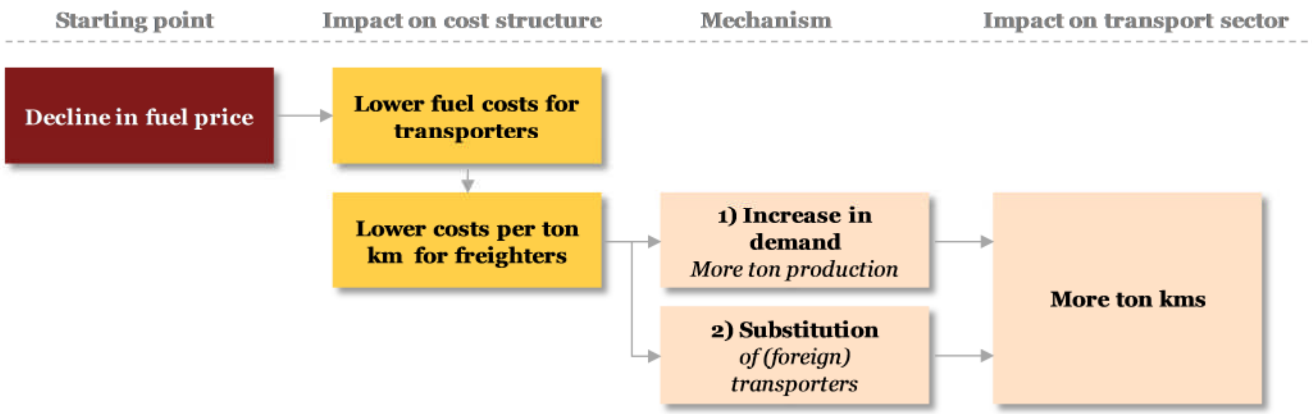
An increased use of LNG will lead to higher diversification of our fuel mix. At present, the fuel mix for transport largely consists of oil-based fuels (i.e. diesel). If diesel is increasingly replaced by LNG (gas-based fuel), it means that we become less dependent on oil. If the LNG price spread develops positively, this could result in competitive advantages for a variety of sectors, which we describe below. Please note that the described impact is less relevant if the LNG price gap develops negatively *(please refer to Chapter 4)*.

The discussion of benefits of fuel mix diversification below is limited to benefits for the Dutch economy. On a European and global scale, there are additional arguments to nurture/enable/foster alternative fuels to blossom. By 2025, by far, the most incremental oil demand comes from the heavy trucking and shipping industry (and less from cars). Alternative fuels such as LNG can lift price pressure from the oil market. Lower oil prices are positive for the growth of the world economy. As a recent PwC study shows, the benefits of lower oil price for the world economy are considerable. [47]

### *7.6.1. Impact on the Dutch transport sector*

Fuel is a key operating cost for transport companies. As LNG is priced lower than diesel, transport companies should be able to offer transport services to freighters at lower costs (assuming declining initial investment costs and, thus, lower price per km) boosting the transport sector. The effects of this are twofold: (1) lower transport costs will lead to increased transport demand per freighter and (2) lower transport costs will increase the competitive position of Dutch transport companies.

**Figure 7.12: Effects of lower fuel prices on the transport sector**




*Source: PwC analysis (based on CE Delft 2001 and 2010)*

*(1) Increased demand for transport services (LT)*

Assuming that transport companies will pass on at least part of their fuel cost advantage to their customers, transport costs for freighters will become lower. This will enable them to offer their products at lower prices to customers, which will drive increasing consumption/demand. This will lead to an increased demand for transportation services, although we expect this effect to be relatively modest. As an illustration, CE Delft 2010[48] estimates the fuel price elasticity with regard to changes in road freight transport demand to be -0.1. This means that a 1% decrease in fuel price will result in 0.1% more demand for transport services.

*(2) Increased competitive position for Dutch transport companies (MT)*

[47] PwC (2013), "Shale oil: the next energy revolution". In this study, an econometric model is used to estimate the effects of a lower oil price on GDP.
[48] Based on extended literature research including Beuthe et al., De Jong and Windisch.

Dutch transporters have to increasingly compete with foreign transport companies. These companies are able to offer low-priced services, primarily as a result of low personnel costs (e.g. transport companies located in Eastern Europe). In the present situation, foreign transport companies are putting greater pressure on prices and are taking away market share from Dutch transporters. Switching to LNG will enable transporters to improve their competitive position by lowering their costs and prices. So, freighters will be able to substitute foreign transporters by local transport companies.

We assume that this effect will be only in the medium term. This is mainly because it is likely that other European countries will also adopt LNG as a transport fuel in the future (e.g. driven by measures recently announced by the European Commission).

Please note that research (EC 2010) shows that an *increase* in fuel price will result in increased fuel efficiency (more km/l) and higher transport efficiency (more tons per km). These are driven by the need to compensate for the higher fuel costs (e.g. development of lighter products, more efficient engines and shorter transport routes). As the Dutch transport sector is highly competitive, we do not expect that declining fuel costs will lead to higher inefficiencies. This would mean that the cost advantage that is reached will be (partly) eroded.

*Increased competitive position of the Dutch harbours (MT)*

LNG is becoming increasingly important in the international fuel mix. This means that the availability of small-scale LNG in key transport routes will contribute to the competitive position of a harbour. At present, the Netherlands does not have its own small scale LNG supply. LNG must be imported from abroad (e.g. LNG from Belgium, Spain and bio-LNG from the UK). When the plans to further roll out small scale LNG infrastructure are realised, the competitive position of the Dutch harbours will increase.

As we expect that in the medium or even short term, most harbours in other countries will start offering small-scale LNG facilities as well, the effect will also last for the short to medium term.

*Increased revenues for the Dutch gas industry (LT)*

In addition, local small scale LNG supply will lead to increased investments and employment. At present, small scale LNG must be imported, meaning that there is a financial outflow. If the Netherlands can supply its own small scale LNG, the Dutch economy will benefit from LNG scale and distribution (also to other countries).

### 7.6.2. Impact on the Netherlands as a whole

*Reduced exposure to high oil prices/lower import bills*

When looking at a broader perspective, becoming less dependent on oil will positively impact the Netherlands. Increasing energy prices have driven growing import bills of oil over recent times, and this can be a significant burden, especially during an economic downturn. When part of the oil is being replaced by (lower-priced) natural gas, the Netherlands will become less dependent on increasing oil prices. As a result, import bills will be lower, which can increase the competitive position of the country.

For example, since the US discovered large amounts of shale gas, the country has become less dependent on oil and can benefit from low national gas prices. The US oil import bill is even expected to fall from USD 364bn in 2011 to USD 135bn in 2035 (EIA 2012). In the US, the price of gas is now three to five times lower than in the EU and Asia. The country at present has not issued full authorisation to export gas. There is discussion that this may hurt the competitive position of the US. The final decision around gas export still needs to be taken. The gap between the US and international gas prices provides US industries with a competitive advantage estimated to be worth USD 1bn a day (Wall Street Journal 2012). IHS (2011) estimates that shale gas will contribute USD 231bn to the US economy by 2035 and will support over 1.6 million jobs in 2035. CitiGPS (2012) estimates real GDP gains of 2-3% by 2020.

## 7.7. Emission reduction

By adopting LNG in the transport sector, emissions of PM, $SO_x$, $NO_x$, $CO_2$ and also noise can be reduced. This can positively impact our economy in various ways *(please refer to Appendix D.1)*.

Firstly, all emission reduction can positively affect businesses. Some Dutch companies face expansion limitations because they have reached regulatory boundaries[49] in relation to emissions (e.g. $CO_2$, $NO_x$) they produce. Via a switch to LNG, companies are able to lower emissions, which offers opportunities to further expand their business.

Emission (and noise) reduction can also positively affect the environment and people's health. As a result, costs related to environmental damage and people's health can be reduced (we estimate a reduction of €214m based on "Current policies"). In this chapter, we further elaborate specifically on emission-related effects.

*Decrease in particulate matter (PM)*

Exposure to particulate matter (PM) affects people's health negatively. It can lead to a reduction of lung capacity, can cause or worsen lung diseases and can negatively affect blood vessel function, and particularly, the heart. In 2009, around 1% of emergency hospital admissions for lung, heart or vascular diseases were due to the effect of short-term exposure to PM.[50]

High concentrations of PM are generally found close to industrial areas, harbours and highways. The Environmental And Nature Planning Agency (MNP), in cooperation with the National Institute for Public Health and The Environment (RIVM), estimated that 30-45% of PM is produced a result of human behaviour (such as road traffic). Around 15% of that has its origin in the Netherlands.[51]

*Decrease in sulphur dioxide ($SO_x$) and nitrogen ($NO_x$)*

Liquid and solid fuels naturally contain sulphur. During fuel combustion, sulphur dioxide ($SO_x$) and nitrogen ($NO_x$) are formed. People exposed to high concentrations of $SO_x$ may suffer from coughing and painful eyes. Long-term exposure to c.1ppm can reduce lung function, cause bronchitis and emphysema. $SO_x$ also adds to acidification of ecosystems and changes water quality, causing a loss of biodiversity. High concentrations of $NO_x$ affect human airways and lungs. It decreases the functioning of lungs and reduces resistance to lung infections, which can lead to hospital admission.

$SO_x$ is especially produced in the shipping sector, resulting in relatively high concentration in harbour areas.

*Noise reduction*

Traffic noise can negatively affect people's health and can lead to diseases such as (severe) sleep disturbance and acute myocardial infarction. The RIVM estimated that long-term exposure to road traffic causes around 20-150 acute myocardial infarctions per year, equal to 0.3% of the total number of myocardial infarctions in the Netherlands per year (based on noise higher than 60db).[52]

As (mono) LNG trucks produce less noise than diesel trucks (c.8dB(A)), LNG will reduce traffic noise. This is likely to help improve people's health.

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[49] In the Netherlands, emission rights are registered and controlled by the "Nederlande Emissieautoriteit" (NEa). These emission rights are derived from the Kyoto Protocol, in which the Netherlands committed to lower emissions at a country level.
[50] CBS, PBL, Wageningen UR (2011)
[51] MNP and RIVM (2005)
[52] RIVM (2008)

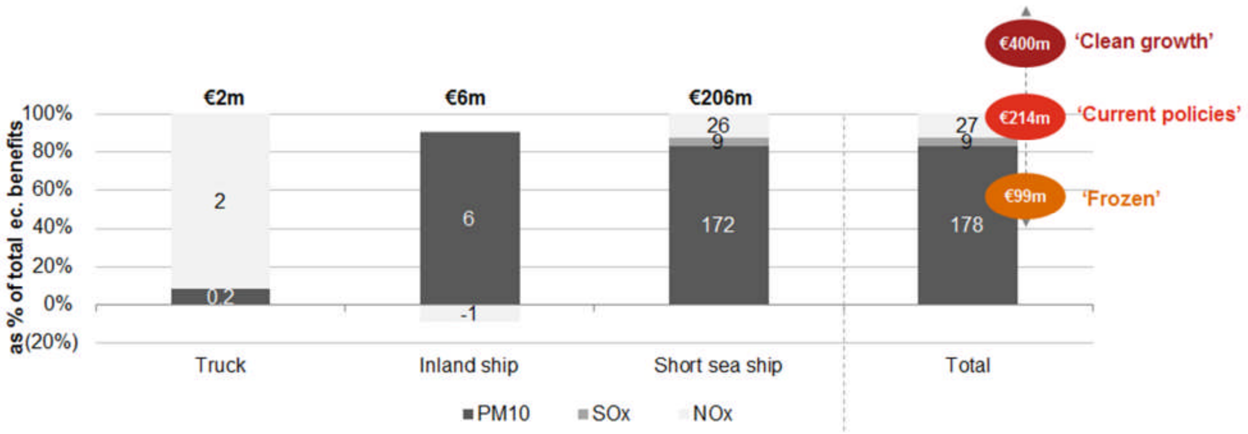
*Public health improvement*

We estimate that public health benefits of LNG emission reduction could be between €100m and €400m per annum in 2030. This is based on emission reduction that could be realised by the number of LNG ships and trucks in 2030 and the price assigned to emission reduction[53]. *Please refer to Appendix E.2 for the basis of our analysis.*

The size of the benefits is mainly driven by the short sea sector, which is responsible for the largest part of possible emission reduction (mainly PM10 and $NO_x$).

Please note that short sea ships largely produce emissions at areas other than along the Dutch coast or harbours. This would mean the estimated range is likely to be smaller. On the other hand, we based our analysis on a conservative assumption around price reduction.

**Figure 7.13: Economic benefits of emission reduction on health by type of vehicle "Current policies" (based on TTW emissions TNO 2013)**




*Source: TNO 2013, PwC analysis*

Noise reduction can lead to additional cost reductions of c.€30, per dB per person.

*Decrease in carbon dioxide (CO2) and greenhouse gas effect mitigation*

$CO_2$ is often identified as one of the key causes of global heating[54] and, therefore, emission reduction could improve the environment.

The effect of $CO_2$ emission on people's health is difficult to measure. Noticeable effects such as sleeplessness are often linked to $CO_2$ emissions, but are only experienced during exposure to very high $CO_2$ concentrations (much above normal air quality levels).

As there is a lot of discussion around the effects of $CO_2$ emissions and impact must be considered at a global level instead of at a national level, we have not estimated the associated cost reductions that could be involved.

[53] Based on KBA-kengetallen (used by the Dutch government to analyse infrastructural planning) which estimates public health welfare effects at €87.95-376.91 (per kg PM10), €5.03- 12.56 (per kg $SO_x$) and €8.79 -15.08 (per kg $NO_x$) per kg emission (based on 2010 price level, including tax). The cost ranges are based on inside and outside built-up areas. We used the lower outside built-up-related costs to show a conservative view. NOx effects for short sea shipping are based on calculations of PBL Netherlands Environmental Assessment Agency (on average €1.9 per kg NOx in 2020)
[54] Chen, 2007

## 7.8. Regional distribution of the economic impact

Most of the potential economic benefits of LNG are distributed evenly across the country. The benefits of the diversification of fuel supply, for example, are not limited to companies in a certain geographical area. As short sea ships offer the most potential for emission reductions, especially coastal regions and cities with a harbour will benefit from a reduction in emissions.

The employment effects of LNG infrastructure are likely to be centred in Rotterdam because the GATE terminal is located there and bunker ships will supply fuel. Our analysis shows that the shipbuilding industry will benefit because ships need to be retrofitted, or new LNG-fuelled ships must be built. The shipbuilding industry in the Netherlands is located in various regions of the country, with a high share in the province of Zuid-Holland.[55]

## 7.9. Impact on the German economy

In this report, we analysed the economic impact that small scale LNG can have in the Netherlands, but the potential benefits of small scale LNG are not limited to the Netherlands alone. In this Chapter, we describe what our results would mean for the German economy.

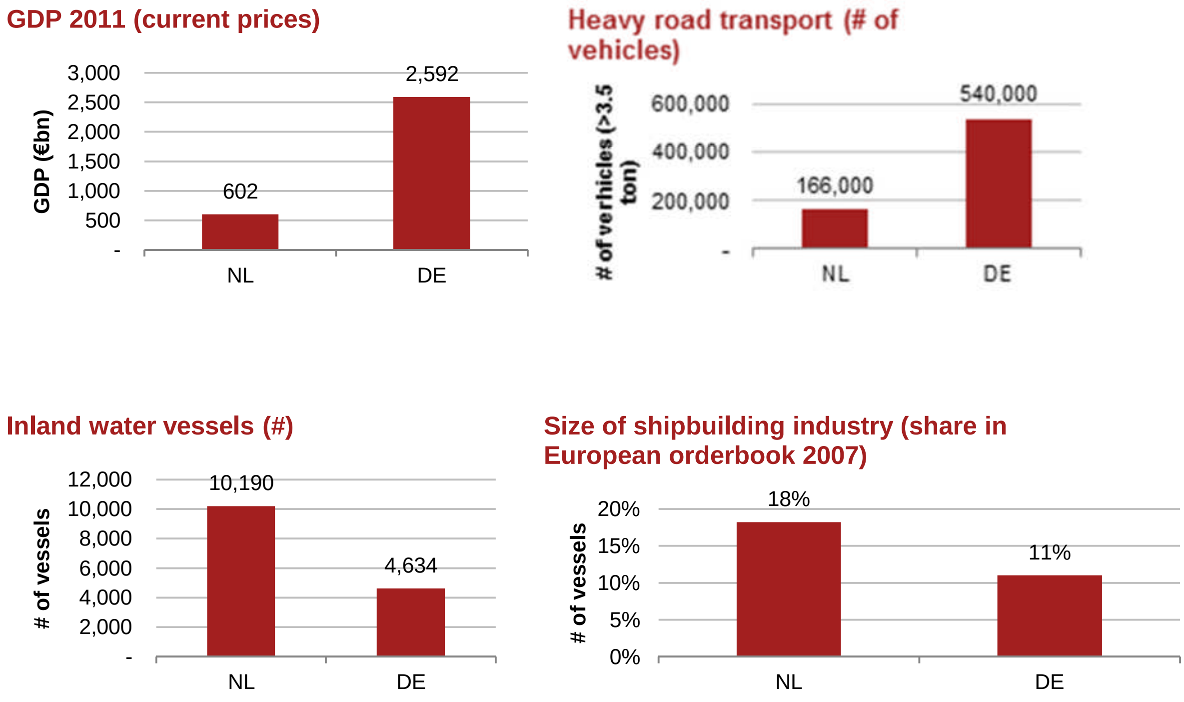
Contrary to the Netherlands, there is no emerging LNG infrastructure in Germany. The main reason for this is probably because there is no LNG regasification terminal in Germany.

There is considerable experience with natural gas as a fuel as many buses and other vehicles use CNG. But there is no major reason why the potential for LNG would differ in Germany from the Netherlands. Sourcing of LNG should not be a problem when infrastructure develops in other countries, such as the Netherlands and Belgium. An LNG import terminal is not a necessary condition for rolling out small scale LNG in Germany. But fuel stations will need to be built to cater to road transport. Initially, it should be possible to bunker ships and inland vessels with facilities in the Netherlands and Belgium, but in the long run, bunker stations and distribution stations will be necessary.

The size and the composition of the transport sector in Germany are a bit different from the Netherlands. The size of the road transport fleet is bigger, taking into account the size of the German economy. Germany has a considerable inland vessel fleet but it is smaller in comparison to the Dutch fleet. The same is true for the number of short sea ships.

[55] 45% of total employment in the shipbuilding industry is located in this province (Source: De Nederlandse Maritieme Cluster (2010)).

**Figure 14: Statistics – Germany**




*Sources: Eurostat, Statistics Netherlands, Kraftfahrtbundesamt, DIW, DESTATIS, Ecorys, 2009 (study on competiveness of the European shipbuilding industry)*

We believe that the economic impact of small scale LNG in Germany is more or less comparable to the impact on the Dutch economy. GDP and employment will be affected in a similar way. But the German trucking industry, the fleet of inland vessels and the shipbuilding industry are comparatively smaller which means that the expected economic benefits will also be somewhat smaller. As there is no infrastructure at present, it is likely that the roll-out of LNG will lag behind the growth of small scale LNG in the Netherlands, which means that there will also be a lag in realising the economic benefits. With regard to emission reductions, the impact might be more limited as the density of population is lower in Germany.

One of the challenges for the small scale LNG market is that as yet, there is no network of fuel stations that covers a sufficiently large region. For transport companies, there are great benefits if LNG is a success in entire Europe. The European Commission has acknowledged this is its initiative to stimulate the roll-out of LNG infrastructure. In our view, it is unlikely that the potential economic benefits of small scale LNG described in the report will be reaped completely if the roll-out of small scale LNG in neighbouring countries is unsuccessful.

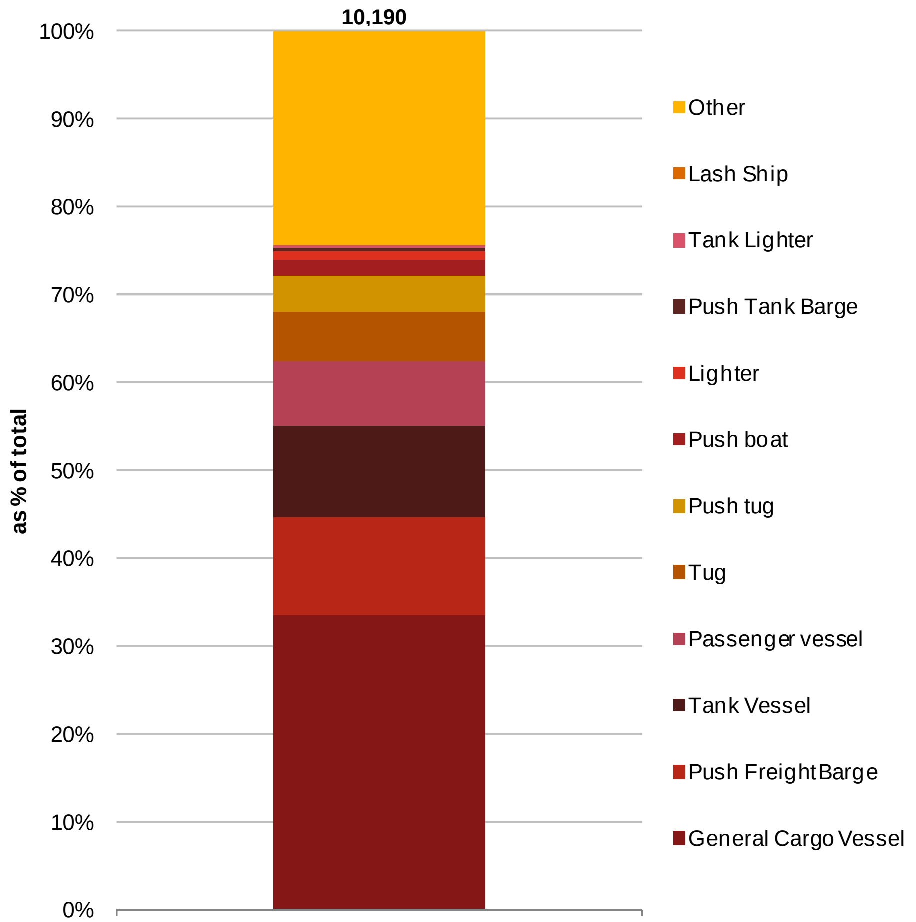
# *Appendix A. - Value chain*

### *Short sea ships*

We estimate the short sea ship fleet to be 3,000 ships. This number is based on 276m ton of cargo transported to and from the Netherlands (Eurostat 2010), 6.0 tons carried per DWT and around 15,000 DWT per ship (based on world fleet calculation of Bloem Doze Nienhuis 2012).

### *Inland ships*

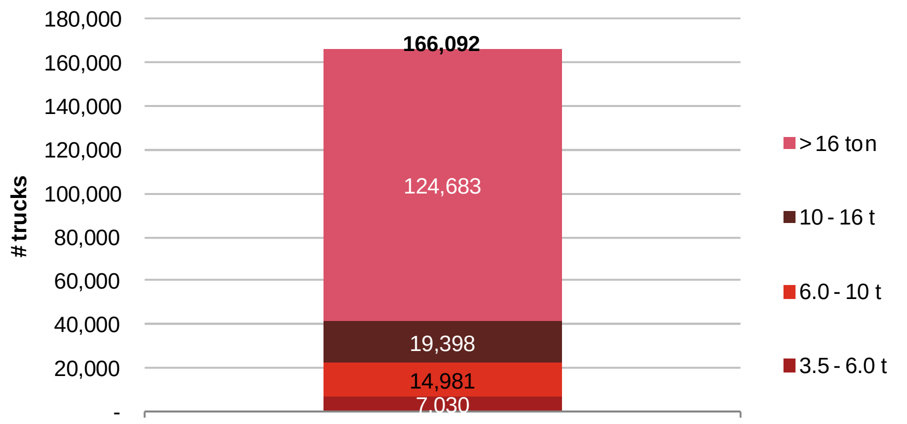
**Figure A1: Dutch inland ship fleet by type of ship 2012**




*Source: IVR 2012*

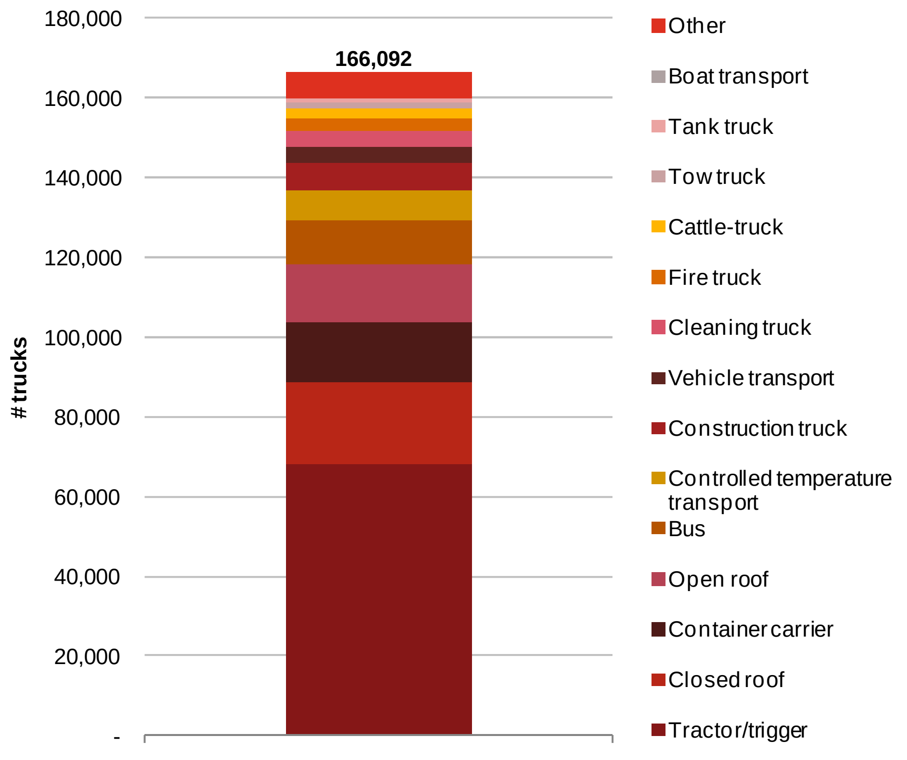
### *Trucks*

## Figure A2: Dutch truck fleet by weight 2012




*Source: RAI 2012*

## Figure A3: Dutch truck fleet by type of truck 2012

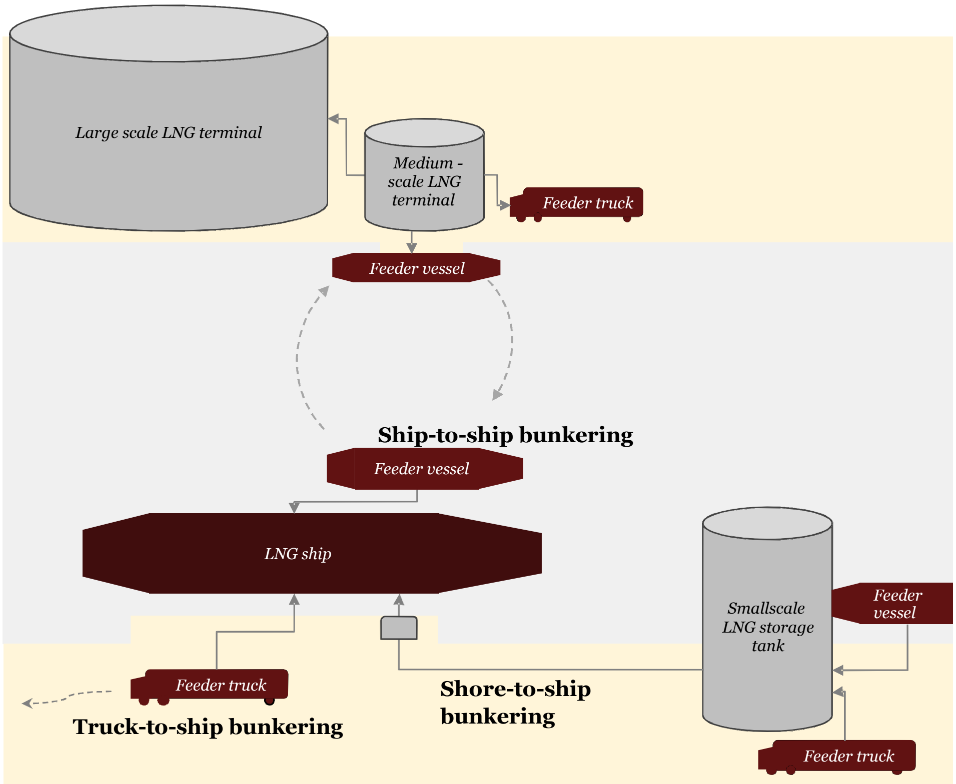



*Source: RAI 2012*

# Appendix B. - Infrastructure

## B.1. Bunkering solutions for ships

### Figure B1: Bunker solutions for ships (illustrative)



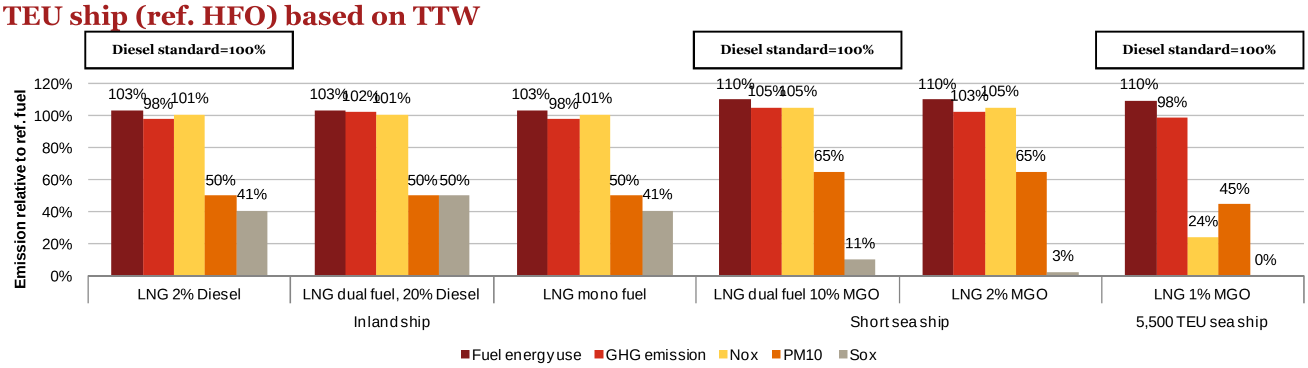

*Source: DMA 2012, PwC analysis, PwC interviews*

# Appendix C. - usiness case

## C.1. Emission reductions

Figure C1. shows the result of an analysis by TNO, ENC and CE (TNO, 2013). According to their research, a switch to an LNG ship reduces PM10 and $SO_x$ emission substantially (please note that results are based on 2025). The reduction of greenhouse gas (GHG) emissions (expressed as $CO_2$ (eq)/km) and $NO_x$ are less convincing and appears to be driven by the so-called methane slip. A methane slip is referred to as an incomplete combustion of methane in the cylinders, releasing methane on the exhaust side. Please note that the methane slip is expected to be further reduced due to technical developments and, therefore, emissions can be reduced further.

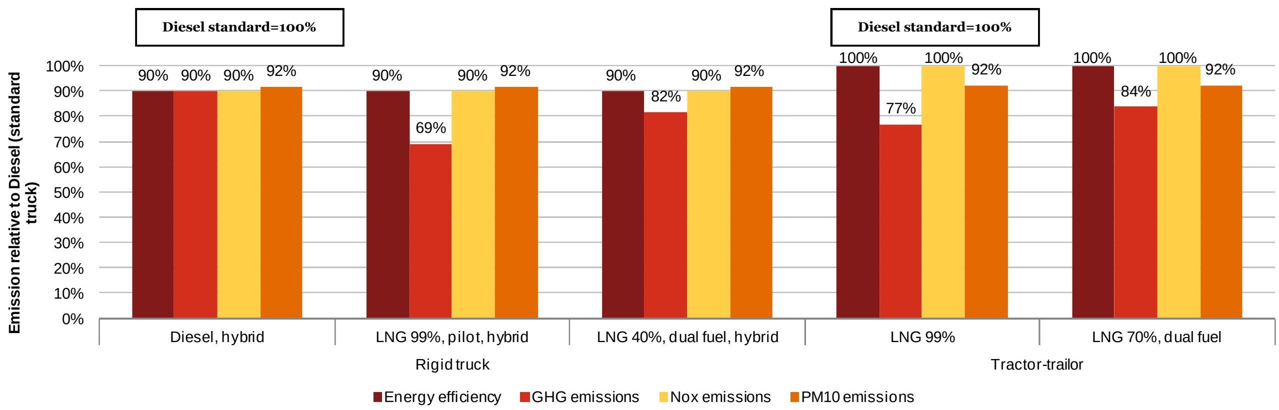
**Figure C1: Emission factors for an inland ship (ref. MGO), short sea ship (ref. MGO) and 5,500 TEU ship (ref. HFO) based on TTW**




*Source: TNO 2013*

Figure C.2. shows that an LNG truck engine is cleaner than a standard diesel Euro VI truck. Greenhouse gas (GHG) emissions (expressed as $CO_2$ (eq)/km) have shown greatest development.

**Figure C2: Emission factors for a rigid distribution truck and a tractor-trailer (long-haul) truck based on TTW**




*Source: TNO 2013*

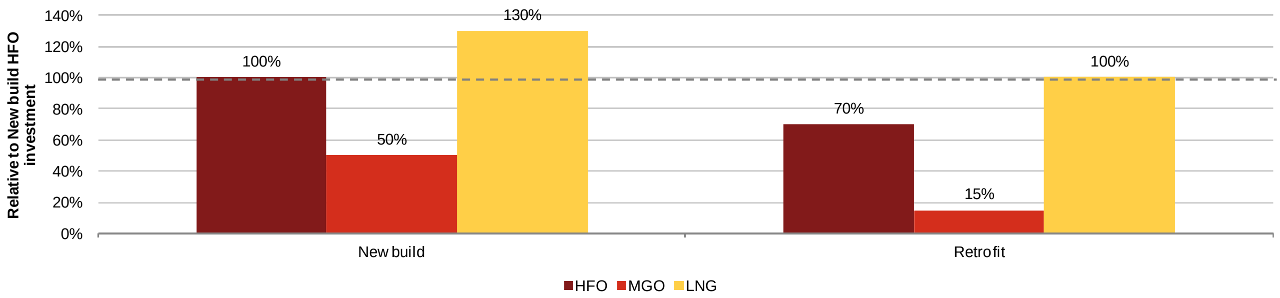
Please note that the above emissions concern tank-to-wheel emissions (TTW) only. For an overview of well-to-wheel emissions (WTW), we refer to section 7 of the TNO 2013 study. We base our analysis on TTW only as this is most relevant for the effects on the Dutch society. For an international perspective, we would recommend analysing the WTW emissions.

# C.2. Investment costs of LNG vehicles

### *Short sea ships*

On average, machinery-related costs for a new build LNG (short sea) ships are around 30% larger than for new build HFO ship (including scrubber). Compared to an MGO ship, machinery-related costs are almost two to three times more[56]. *Please refer to Figures C3 and C4.*

**Figure C3: Comparison of estimated machinery-related investment costs for a short sea ship (base = new build HFO ship)**




*Source: DMA 2012, PwC analysis*

**Figure C4: Overview of machinery-related investment costs for different types of ships (thousand EUR)**

| Type of ship | Fuel | Retrofit | New build |
|---|---|---|---|
| Container ship | HFO | 3,400 | 4,800 |
| | MGO | 600 | 2,400 |
| | LNG | 4,800 | 6,400 |
| RoRo | HFO | 2,300 | 3,300 |
| | MGO | 500 | 1,600 |
| | LNG | 3,200 | 4,300 |
| Coastal tanker | HFO | 3,700 | 5,100 |
| | MGO | 700 | 2,500 |
| | LNG | 5,100 | 6,800 |

*Source: DMA 2012*

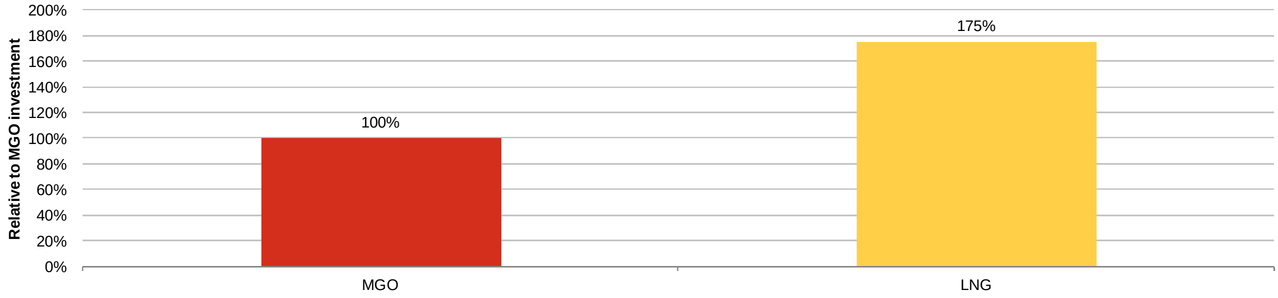
Based on DMA 2012 and market feedback, we estimate that a short sea ship costs between €25m and €150m. Machinery-related costs account for c.10-15% of total ship costs. The exact percentage depends on various factors such as the type of ship (e.g. dry versus liquid bulk) and the required action radius.

### *Inland ships*

According to market feedback, machinery-related investment costs for an inland LNG ship (i.e. between €0.5-3m) are around 1.5-2 times more than the machinery-related investment costs for an inland MGO ship (Figure C5).

[56] MGO ship does not need an HFO scrubber

## Figure C5: Overview of machinery-related investment costs for inland ships



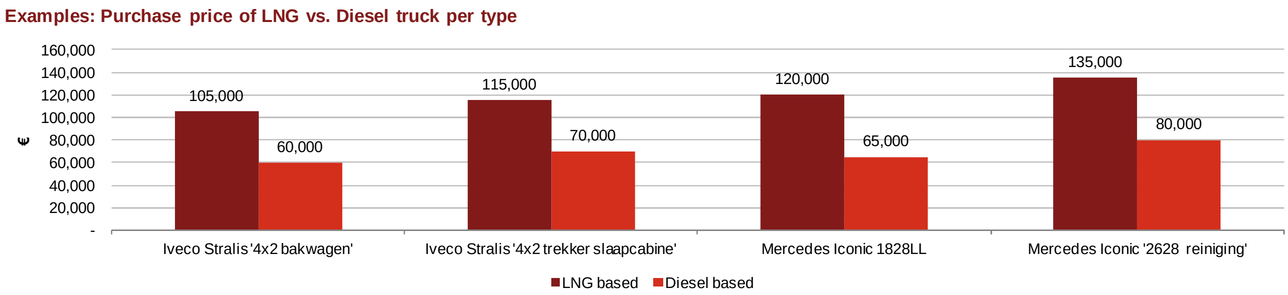

*Source: Market feedback, PwC analysis*

Since a new build inland ship costs c.€4-20m (depending on size and complexity), the machinery-related costs account for c.10-15% of the total ship investment. For example, a 100m45 inland MGO ship costs c.€4m, the LNG variant costs €4.5.

### *Trucks*

A new LNG truck is now around 1.5-2 times as expensive as a diesel truck, depending on brand and type of truck (i.e. costing €45,000-55,000 more). A common diesel distribution truck costs c.€60,000-75,000, while a comparable LNG truck costs €105,000-140,0000. The retrofit of a diesel truck costs at least €15,000-20,000, mainly driven by the expensive LNG tank that must be fitted. These amounts are based on Fuelswitch.nl and market feedback. *Please refer to Figure C6 for some examples.*

## Figure C6: Examples of LNG truck investment costs compared to diesel trucks




*Source: Fuelswitch.nl*

# C.3. Different type of LNG engines

Different types of LNG engine options are available. They are described below.

***Mono LNG***

A mono-LNG[57] engine runs on LNG only and is based on the Otto principle. Key difference with a diesel ship or truck is in the cryogen tank that must be installed to store LNG[58]. This counts for all trucks and ships that (partly) operate on LNG. A mono-LNG engine produces less noise than a diesel engine.

***Pilot LNG***

A pilot LNG engine is able to run on both diesel and LNG, stored in separate tanks. The engine always needs diesel for ignition, but can fully run on LNG (or diesel) from there. In operation, the engine uses only a low percentage of diesel on average and can run almost fully on LNG.

***Dual fuel***

A dual-fuel engine is based on a diesel engine and simultaneously burns diesel and LNG. We understand that a dual-fuel engine uses on average 60-80% LNG and 20-40% diesel. It can fully run on diesel as well.

One of the main reasons for transport companies to prefer pilot LNG or dual-fuel above the (cleaner) mono-LNG engine is the ability of the vehicle to fully run on diesel. This offers the advantage of switching to diesel if there is no LNG infrastructure and/or uncertain development of LNG prices.

In addition, a dual-fuel truck has higher engine efficiency than a mono-LNG engine. It is able to generate more power and is better suited for long-haul and heavy-duty transportation. Dual fuel/pilot LNG ships have the technical ability to manoeuvre more easily into harbours as the engine is directly linked to the screw. This is largely related to the fact that mono fuel engines had not yet been developed for ships.

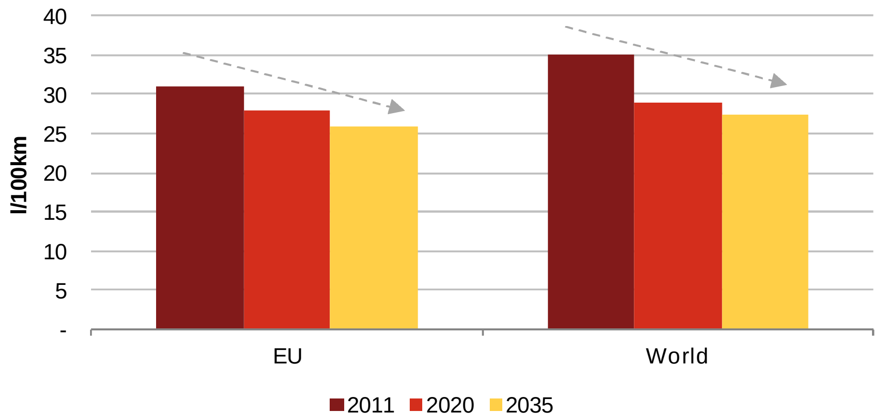
Via retrofitting, an existing oil-based vehicle is turned into an LNG vehicle. The engine can either be adjusted or be replaced. Also, an LNG tank must be installed at the vehicle to store the LNG. For trucks, retrofitting appears to be a less attractive solution. According to market feedback, retrofitted trucks are less efficient than new-built trucks, and factory guarantees are lost. Retrofitting is more suitable for ships. While truck engines are never replaced, ship engines need to be replaced anyhow after 10-20 years (relates to inland ship). Yet, retrofitting is only possible for part of the present ship fleet. Liquid bulk vessels are most suitable for an LNG retrofit as the tank can be placed on top of the ship. Yet, for dry bulk ships (open at top), placing an LNG tank is more difficult.

[57] Current LNG trucks are mostly based on the already developed CNG truck models which have a similar engine. The main difference is the LNG tank which must be installed.
[58] LNG is a very cold product and must be stored in a cylinder-shaped, RVS based, high-quality tank.

# Appendix D. - Uptake of LNG

## D.1. Truck engine efficiency

**Figure D.1: Average on-road fuel consumption of heavy-freight trucks**



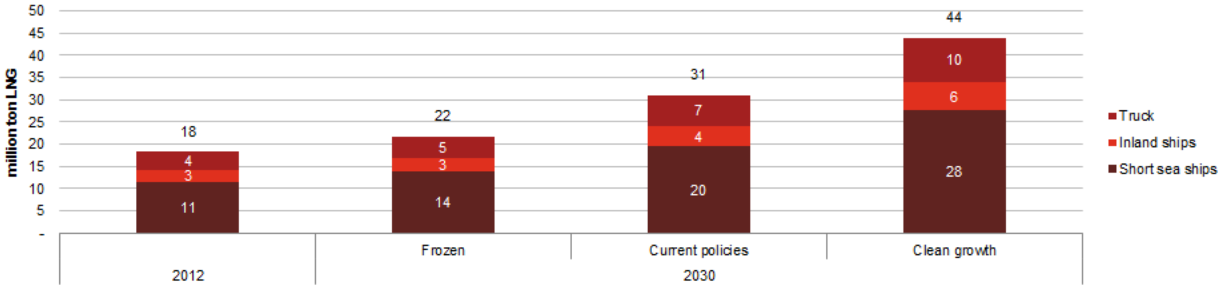

*Source: World Energy Outlook 2012*

# D.2. Maximum LNG output

Based on the present fleet of transport vehicles, we calculated the maximum LNG output that can be reached based on the size of the fleet in 2012 and the projected size in 2030 in the three scenarios. Maximum means all vehicles in the fleet will use LNG instead of any other fuel. Please note that this is a non-realistic scenario, as, for example, not all ships in the present fleet are suitable for an LNG adjustment (retrofit), and all vehicles are not likely to switch to LNG.

Based on the present fleet of transport vehicles (ships/trucks), this would mean 18m ton of LNG in 2030. In the future, we assume that the fleet will grow in line with the transport market. For the three scenarios, this would mean a maximum of 22-44m ton of LNG in 2030 *(Figure D2)*.

**Figure D2: Maximum LNG output per scenario – 2012 versus 2030[59]**




| | | | | |
|---|---|---|---|---|
| **Truck #** | 166,092 | 198,761 | 282,761 | 399,720 |
| **Inland shipping #** | 10,190 | 12,189 | 17,348 | 24,523 |
| **Short sea #[60]** | 3,066 | 3,667 | 5,219 | 7,378 |

*Source: CBS, IVR, TNO 2013, PwC analyses*

[59] Based on TNO 2013 which assumes annual usage of 25,000kg LNG (truck), 110,000kg to 400,000kg LNG (inland vessel) and 3,750,000kg LNG (short sea ship).
[60] Based on 276m ton of cargo transported to and from the Netherlands (Eurostat 2010), 6.0 tons carried per DWT and c.15,000 DWT per ship (based on world fleet calculation of Bloem Doze Nienhuis 2012).

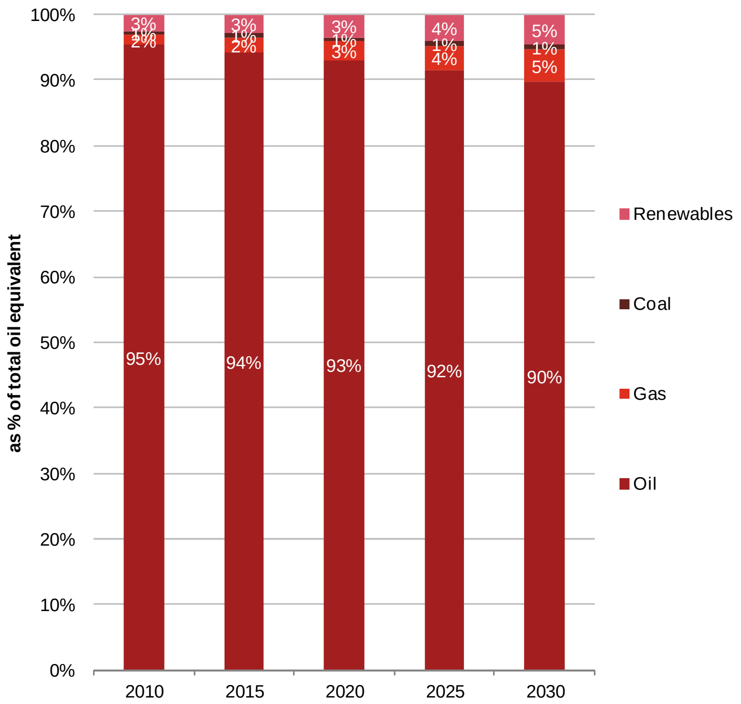
# D.3. A global perspective on small scale LNG uptake

In the industry, several studies have been undertaken to analyse the uptake of small scale LNG at a global level. Some have a more optimistic view (i.e. gas will replace 5% of diesel in 2030), while others are more conservative (i.e. LNG/CNG will replace only 1% of diesel in 2030). But all are convinced that diesel will remain the dominant transport fuel in the coming years. Below, we present an overview of the different outcomes, also to put the output of our own scenarios in a broader perspective later on.

### *Global transport in 2030 – BP Energy Outlook 2012*

BP estimates that the amount of gas used in the transport sector (worldwide) will increase from c.2% in 2010 to c.5% in 2030 (Figure D3).

**Figure D3: Global fuel consumption in the transport sector – 2010-2030**

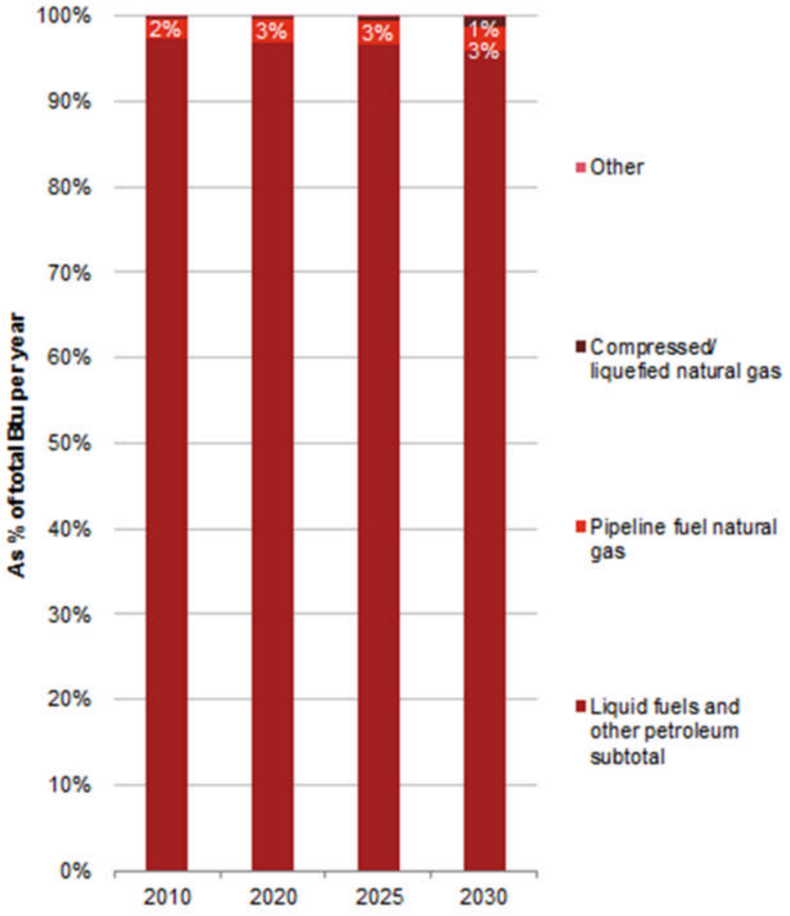



*Source: BP Energy Outlook 20112*

### *Global transport in 2030 – EIA Annual Energy Outlook 2013*

The Energy Information Administration (EIA), a US government agency, is more cautious and estimates LNG and CNG to represent only c.1% of total fuel consumption in 2030 (Figure D4). According to EIA's projections, gas is the fastest-growing transportation fuel, though with an annual growth rate of c.7% in 2011-2030.

**Figure D4: Global fuel consumption in the transport sector – 2010-2030**

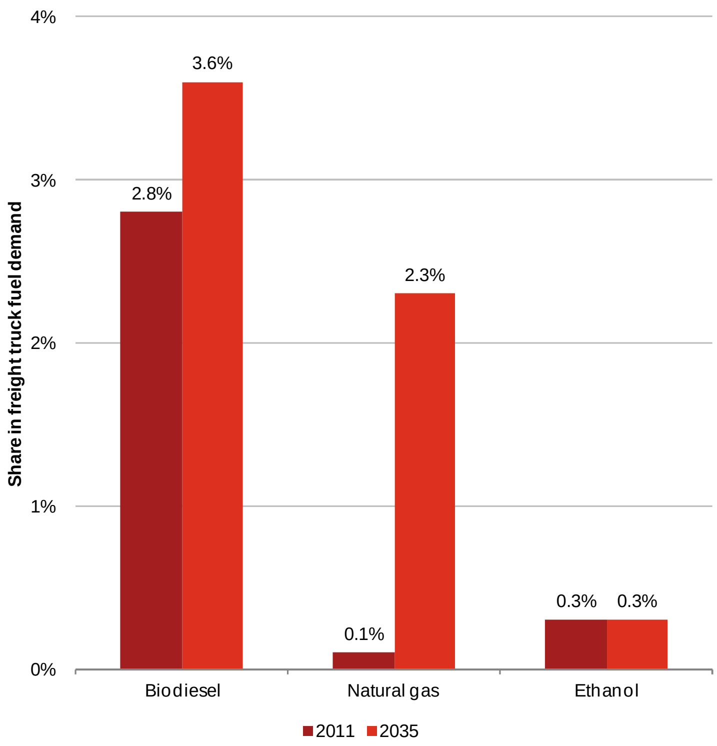



*Source: EIA 2012*

### *Global trucking in 2035 – World Energy Outlook 2012*

In its World Energy Outlook, the IEA projects that diesel will remain the dominant transport fuel on the road (Figure D5). They expect that alternative fuels will be responsible for c.5% of total freight truck fuel usage. Natural gas (among which is LNG) will represent around half of that (growth from 0.1% in 2012 to 2.3% in 2035).

### Figure D5: Alternative fuel use by freight trucks (new policies)




*Source: World Energy Outlook 2012*

***Global shipping in 2020 – DNV'12***

DNV has analysed how the global shipping sector could develop up to 2020 based on four scenarios (Figure D6). Based on the assumptions below, it expects that the maritime sector will consume c.8-33m ton LNG globally in 2020. This relates to c.2-9% of LNG for maritime fuel consumption (Figure D7).

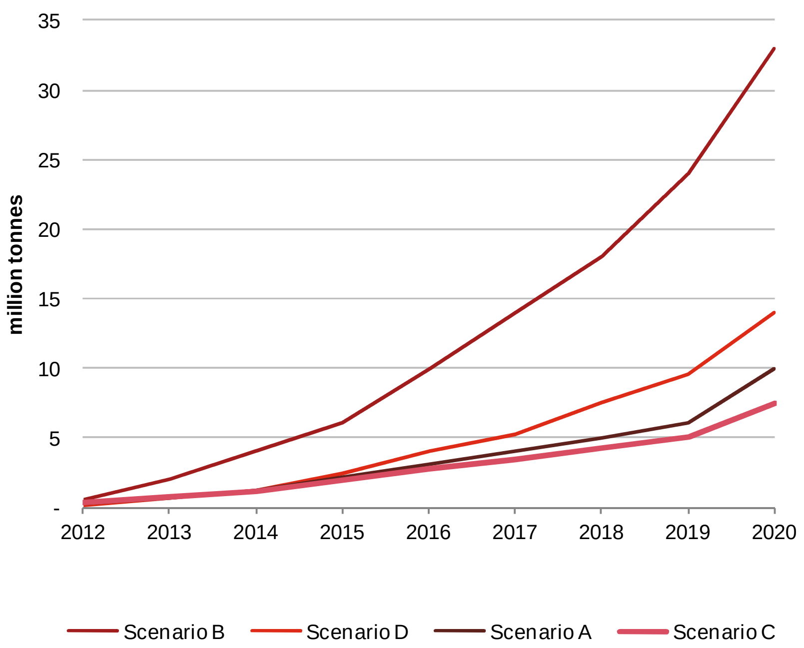
Scenario A: high economic growth; high fuel prices; little regulatory or stakeholder pressure on the environment.

Scenario B: high economic growth; low LNG prices, decoupled from oil prices; high regulatory and stakeholder pressure on the environment.

Scenario C: low economic growth; low fuel prices in general but high demand keeps the marine gas oil (MGO) prices up; high regulatory and stakeholder pressure on the environment.

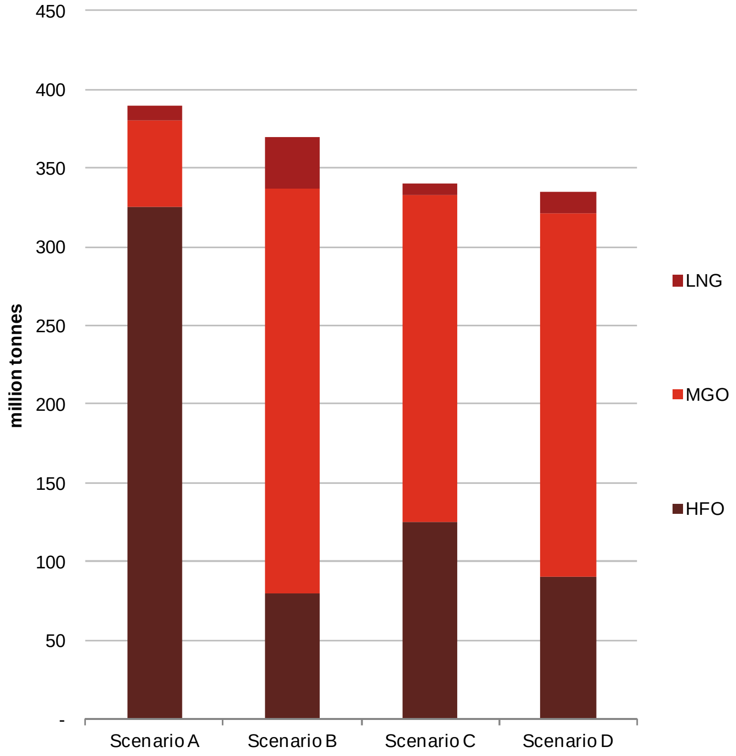
Scenario D: low economic growth; LNG prices decoupled from oil prices; low regulatory or stakeholder pressure on the environment.

**Figure D6: LNG global maritime fuel consumption scenarios – 2012-2020**




*Source: DNV 2012*

**Figure D7: Fuel demand and mix per scenario 2020**

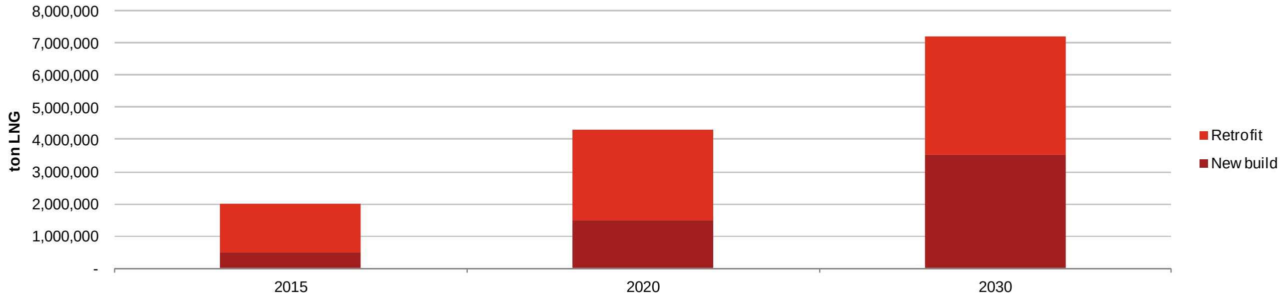



*Source: DNV 2012*

***North European LNG Infrastructure Project – DMA 2012***

DMA 2012 estimates that LNG demand for shipping in the SECA area will be around 7m ton per year in 2030 (Figure D8).

**Figure D8: LNG demand from retrofits and new builds (assuming a moderate price scenario)**




*Source: DMA 2012*

# Appendix E. - Economic impact

## E.1. Input-output model

An input-output model lends itself for rapid computation of changes in demand due to investment injections. The calculated economic effects for the commercial phase must be interpreted with care. The assumption is made that the structure of the economy remains unchanged until 2030. Obviously, projecting the structure or competitive state of the economy so many years ahead is fraught with difficulties. The input-output model does not consider dynamic effects such as increase in prices due to demand increase.

Otherwise, people will just switch jobs, and the investment will lead to the so-called "crowding-out effect". In this study, the crowding-out effect is not quantified, and so has not been taken into account. This means that the GDP and employment effect could potentially be smaller.

*Productivity increases*

The analysis is based on the level of investments in 2013 price levels and did not take into account that investment levels may be lower due to increases in productivity. Some of the investments considered in the analysis will take place in the next decade; it is likely that labour productivity will increase in this period. As a result, less labour may be needed to produce and retrofit trucks and vessels than what is assumed in the analysis.

### E.1.1. Model analysis

The effects of direct investments in LNG infrastructure are measured in the input-output model by defining the impulses per industry. The multiplier effect relates to the type of industry in which the impulse is given and subsequently calculates the indirect economic effects on output and employment. In Figure E1, we have identified the industries relevant to our analysis of economic impact of small scale LNG.

**Figure E1: Industries receiving direct spending**

| Industry \ Impact | Investments in LNG vessels and trucks | Investments in small scale infrastructure | Bio-LNG production |
|---|---|---|---|
| **Machinery and equipment** | X | X | |
| **Car industry** | X | X | |
| **Shipbuilding industry** | X | X | |
| **Civil construction** | | X | |
| **Energy companies** | | | X |

*Source: CPB, PwC analysis*

Investments for the roll-out of small scale LNG are placed under four different categories. Investments in vessels and trucks mainly concern the car industry and shipbuilding industry. Other investments, such as special LNG storage tanks are under the industry machinery and equipment, and investments that relate to the construction of tank stations and the break-bulk terminal have been put under the industry civil construction. Investments for Bio-LNG (LBG) production have been placed under the industry energy companies.

For estimating induced economic effects on output and employment, we use household spending statistics. Household spending largely goes to a small number of industries, such as retail, transportation, energy companies (e.g. for food, energy consumption). In Figure E2, we have identified these industries and the percentage distribution per industry according to the distribution of spending in an average household.[61] For the estimation of the induced effect, we have assumed that 30% of the additional household spending is re-spent in the economy. The other 70% is savings, tax payments and spending outside the country.

### Figure E2: Industries receiving extra household spending

| Industry | % |
|---|---|
| Confection | 4.4 |
| Leather products and footwear | 1.6 |
| Household equipment | 2 |
| Furniture and mattresses | 3.5 |
| Energy companies | 5.5 |
| Retail | 18.1 |
| Public transport | 16.8 |
| Travel agencies | 7.6 |
| Insurance companies | 1.2 |
| Housing operations | 23.9 |
| Secondary school | 4.1 |
| Medical services | 2.4 |
| Culture, sports, recreation, radio and television | 4.2 |
| Other services | 1.6 |
| Household services | 3 |
| | **100** |

*Source: CBS*

## *E.1.2. Direct investment estimations*

### Figure E3: Direct investments in LNG vessels and trucks

| | Number | Price (€m) [62] | Impulse (€m) | Production in the Netherlands (%) | Investments (€m) |
|---|---|---|---|---|---|
| **Short sea vessel construction** | 160 | 2.0 | 320 | 70% | 224.0 |
| **Inland vessel construction** | 600 | 0.5 | 300 | 70% | 210.0 |
| **Truck construction**[63] | 50,000 | 0.04 | 2,000 | 10% | 200.0 |
| **Total investments** | | | 2,620 | | **634** |

*Please note that the additional investment costs of LNG vessels and trucks might be further reduced than the numbers as stated above. Yet, we based our analyses on a price estimate which presently appears reasonable based on market feedback*

*Source: Fuelswitch 2012; DMA 2012; market feedback; PwC analysis*

[61] The distribution is based on CBS 2007 data on household spending.
[62] To estimate the actual effect of LNG investments, we deducted the average costs of reference technologies. For example, an LNG truck costs €40,000 more than a diesel truck based on present pricing. The same differences apply for retrofit trucks.
[63] According to market feedback, the life of trucks is between 5 and 8 years and for vessels between 25 and 30 years. Taking into account a life of 6.5 years for trucks and 27.5 years for vessels, we increased the number of trucks to a total production of 50,000 until 2030.

## Figure E4: Direct investments in small scale infrastructure

| | Number | Price (€m) [64] | Impulse (€m) | Production in the Netherlands (%) | Investments (€m) |
|---|---|---|---|---|---|
| **Fuel stations** [65] | 36 | 0.6 | 22 | 70% | 15.2 |
| **Feeder trucks (to vessels and trucks)** | 60 | 0.2 | 12 | 10% | 1.2 |
| **Break-bulk terminal** | 1 | 60 | 60 | 70% | 42.0 |
| **Feeder vessels** | 5 | 32 | 160 | 70% | 112.0 |
| **Storage tanks (shore to ship)** | 4 | 7 | 28 | 70% | 19.6 |
| **Total investments** | | | 282 | | **190** |

*Source: DMA 2012; EC 2013; CBS; market feedback; PwC analysis*

## Figure E5: Direct investments in bio-LNG

| | Total production until 2030 (tons kg) | Price per kg LNG (€)[66] | Production per year (€m) | Impulse until 2030 (€m) | Impulse assuming linear production growth (€m) | Production in the Netherlands (%) | Investments (€m) |
|---|---|---|---|---|---|---|---|
| **Bio-LNG investments** | 100.000 | 0.75 | 75 | 1,275 | 637 | 100% | **637** |

*Source: PwC 2012; PwC analysis*

[64] The assumptions behind these investment numbers and related costs are based on market feedback and a report of the Danish Maritime Authority (2012). As LNG small scale infrastructure will be built from scratch, the full costs of investments are taken into account.
[65] The European Commission has proposed, in its clean fuel strategy of 2013, the installation of LNG refuelling stations 1 every 400km along the roads of the Trans European Core Network by 2020. Based on the total amount of Dutch national and provincial kilometres in 2012 (CBS), we have estimated that Around 36 refuelling LNG stations will be required.
[66] We have estimated the price of LNG at c.€ 0.75 per kg, excluding taxes and infrastructure costs. Also see Chapter 4.

# E.2. Emission reduction

**Figure E6: Emission reduction (in millions of kg) by type of vehicle based on "Current policies"**

| Type of emission | Truck | Inland ship | Short sea ship | Total |
|---|---|---|---|---|
| PM10 | 108 | 8,640 | 552,961 | **561,709** |
| Sox | - | 1,123 | 488,663 | **489,786** |
| Nox | 11,880 | (8,640) | 3,870,728 | **3,873,968** |

*Source: TNO 2013, PwC analysis*

# Appendix F. - List of interviewees

| Name of company/institution: |
|---|
| AF Consult |
| Anthony Veder |
| Centraal Bureau voor de Rijn en Binnenvaart (CBRB) |
| DAF |
| Damen |
| Eneco |
| Energy Valley |
| G.C.M. Deen Shipping |
| Gasunie |
| GDF Suez |
| Koninklijke Vereniging van Nederlandse Reders (KVNR) |
| Mercedes-Benz |
| Mitsubishi |
| Pon Holdings |
| Rederij Doeksen |
| Schipco |
| Shell |
| Simon Loos |
| Scania |
| Volvo |
| Vopak |
| VOS logistics |
| Wärtsilä |
| World Port Center |

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