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LNG
Liquefied
natural gas

Go strong.

| THIS IS DNV |

DNV is a global provider of services for managing risk. Established in 1864, DNV is an independent foundation with the purpose of safeguarding life, property and the environment. DNV comprises 300 offices in 100 countries, with 8,000 employees. DNV has four business areas, DNV Energy, DNV Maritime, DNV Industry and DNV IT Global Services. Our vision is global impact for a safe and sustainable future.

DNV provides world-class expertise in technology, operations, management and risk. We combine our know-how into a professional service concept designed to safely improve the performance of your business. So you can go strong on all dimensions.

DNV serving the energy industry

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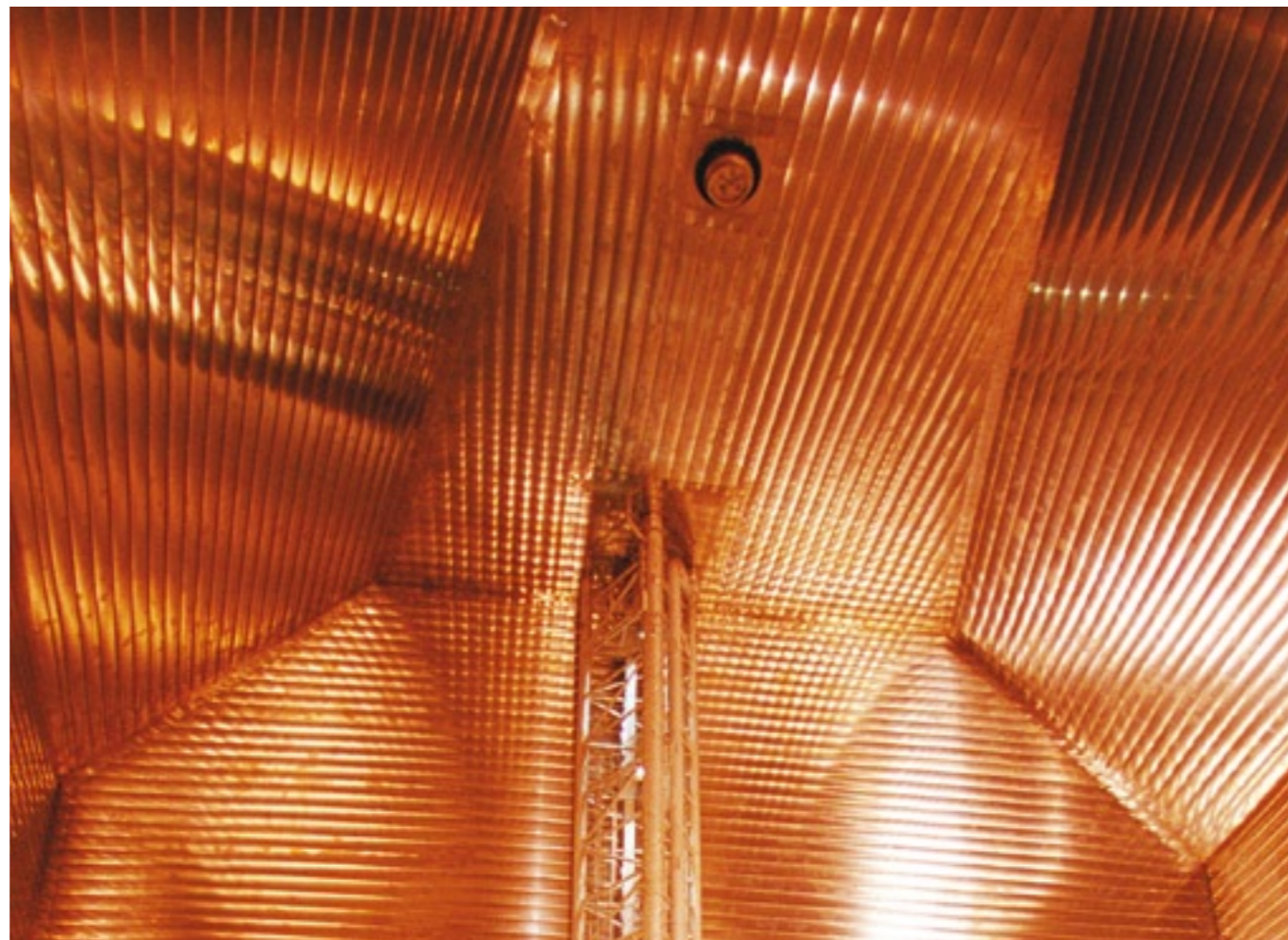
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MANAGING RISK



DNV SERVICES TO THE ENERGY INDUSTRY

- ▶ Enterprise Risk Management
- ▶ SHE Risk Management
- ▶ Technology Qualification
- ▶ Verification
- ▶ Offshore Classification
- ▶ Asset Risk Management
- ▶ Training
- ▶ IT Risk Management
- ▶ Certification



Natural gas has become an attractive source of energy, drawing **new entrants** into an increasingly fluid, global LNG market. This has stimulated record levels of **growth** in LNG infrastructure, technological innovation and employee recruitment. On the other hand, public **concern** regarding LNG's potential and security risks has risen dramatically. These developments have significantly increased the visibility, scale and **risk profile** of the LNG sector.

Go clean and cool

TARGET SEGMENTS

Through these services, our teams of highly qualified professionals deliver cutting-edge solutions to customers across the industry:

- ▶ Deep and ultra-deepwater field development
- ▶ Floating offshore installations
- ▶ Fixed offshore installations
- ▶ Offshore and onshore pipelines
- ▶ Natural Gas/LNG
- ▶ Refining and petrochemicals
- ▶ Power generation and transmission
- ▶ Wind, wave and tidal energy
- ▶ Arctic operations and technology
- ▶ Operations excellence
- ▶ Carbon capture and storage



DNV has played a leading role in the LNG industry's technological evolution due to its in-depth expertise in all aspects of the LNG value chain. A **global** team of engineers, scientists and business analysts provides a full range of services to help you **manage** and **mitigate risks** related to your LNG operations.

THE BUSINESS LIFE CYCLE

DNV – assisting companies in the energy industry along the entire life cycle to safeguard and improve business performance

PROJECT PHASES:



DNV DELIVERIES:



SERVICES OVERVIEW

A comprehensive approach to LNG risk management

The LNG industry is growing rapidly to meet the surging energy demand. To succeed in this complex industry, DNV helps operators manage the individual risks through a holistic approach.



DNV provides risk management services across the LNG value chain.

Global economic development has stirred worldwide demand for energy. LNG is therefore evolving into a high-growth, fast-paced global market. At the same time, public awareness of climate change has boosted LNG's image as one of the cleanest sources of carbon-based energy. Political and security considerations have also placed more importance on diversifying energy sources. This development has increased the demand for natural gas, which is now set to exceed that of petroleum by 2030.

However, the industry remains capital intensive and politically unpredictable, making risk management more critical than ever.

COMPLEX RISK FACTORS

The LNG sector is experiencing record levels of activity, investment and technological change. Stakeholders are making huge investments in gas exploration, production, liquefaction, shipping, regasification and technology development. For example, there

are approximately 40 liquefaction trains under construction or in planning, and the LNG fleet has doubled in size over the past 10 years.

Although this growth is undoubtedly positive for the LNG industry, it increases the need for risk management in order to protect the industry's outstanding safety record. The industry is complex and is dependent on a vast range of regulatory regimes, public policies and market conditions. These factors create financial co-dependency across the LNG value chain, from the wellhead, across oceans, to receiving terminals and gas markets.

HOLISTIC RISK MANAGEMENT

DNV's global team of engineers, scientists and business analysts provides a full range of engineering, technical and business services. Our approach emphasises that each transaction in the LNG value chain has its own inherent risks, and these have both upstream and downstream impacts. First, the individual risks are identified, followed by the assessment,

quantification and mitigation of the potential exposure. Next, DNV puts its expertise in enterprise risk management into a comprehensive risk management framework.

The result of this process is insight into the various factors and interdependencies that both affect and determine the success of LNG projects. The comprehensive risk management framework is also more robust and able to reduce the likelihood of unexpected surprises.

GLOBAL CAPABILITY

From the early beginnings of the LNG industry, DNV has played a leading role in its development. Our expertise spans the entire LNG value chain, from exploration through to end-of-life decommissioning. DNV has a presence on all continents, with a network of 300 offices in 100 countries.

We are currently involved in more than one third of the ongoing LNG projects worldwide,

in addition to classifying one fifth of the LNG carrier fleet on order. The following services are provided to the LNG industry worldwide:

- ▶ **Ship Classification** services to ensure vessel reliability and safety under all possible conditions
- ▶ **Offshore Classification** services to assure all stakeholders that LNG facilities comply with applicable requirements
- ▶ **Risk-based Verification**, creating a customised and streamlined system to ensure that project targets are met
- ▶ **Technology Qualification**, safely unlocking the potential of new and existing technologies by identifying and mitigating the risks inherent in them
- ▶ **Enterprise Risk Management**, creating value for stakeholders by using a cross-disciplinary approach to identify and manage opportunities and threats
- ▶ **Asset Risk Management** to help clients obtain maximum value from facilities,

equipment and people, without compromising safety or the environment

- ▶ **Public Safety**, helping clients meet public scrutiny by developing, implementing, maintaining and continually improving best practices in safety, health and environmental risk management
- ▶ **Environmental Risk Management**, assisting clients and their stakeholders in improving public reputation by proactively managing environmental risks
- ▶ **Technical Analysis**, using our industry-leading analysis and investigation capabilities to develop new technical solutions or resolving issues involving failures in existing ones

DNV'S DIARY OF INNOVATION NATURAL GAS CARRIERS

1959 LNG research team established.

1962 Membrane cargo containment system (predecessor to GT Mk III) developed and successfully tested by DNV's research engineers.

1962 First classification society to publish rules for gas carriers.

1969–72 Development of Moss spherical cargo tank (type B) system extensively supported by a number of DNV engineers covering a wide range of specialities.

1972 Basic design criteria for type B tanks were formulated in Rules.

1970–76 Model testing of sloshing, crack propagation, fatigue and buckling to confirm compliance with the design for LNG tank type B.

1970–76 DNV was prime contributor to the development of the IMO gas carrier code.

1977 Established rules and design criteria for floating LNG FPSOs.

1988 Conceptual design of floating LNG production facility.

1989 Structural analysis and strength assessment of IHI SPB LNG carrier.

2001 First classification society to publish rules for Gas Fuelled Engine installations.

2003 First classification society to publish rules for Compressed Natural Gas (CNG) carriers.

2004 Technical guidance for offshore LNG terminals.

2006 Publication of Classification Note: Sloshing Analysis of LNG Membrane Tanks.

2007 Lead role in JIP to assess consequences from LNG releases.



SHIP CLASSIFICATION

Ensuring vessel safety and reliability

In parallel with the LNG boom, the complexity of the vessel operations is increasing. DNV offers world-class ship classification services to help you meet this challenge safely.



Ship classification has long been crucial for mitigating risks in the maritime LNG sector. However, the scale of the challenge is growing. Vessel sizes have risen steeply to the current level of 260,000 m³, and the worldwide LNG fleet size will double over the next few years.

With these challenges looming, DNV possesses the classification resources the industry needs. We provide extensive experience, highly qualified experts in a wide range of relevant disciplines and state-of-the-art software for performing structural and hydrodynamic analysis.

CLASSIFICATION PIONEER

DNV is widely acknowledged as a pioneer in all aspects of ship classification. In the LNG segment, DNV helped pioneer the development of both the Moss and membrane carrier designs. In fact, all currently-used cargo containment systems have been approved by DNV, including both the original SPB (IHI) cargo containment system and its recent

revisions. DNV continues to invest extensively in R&D to extend its leadership in LNG technical development. Recent examples include the industry-leading Rules for Gas Fuelled Engine Installations issued in 2001 and our Classification Note for Sloshing Analysis of LNG Membrane Tanks issued in 2006.

LIQUID MOTION AND SLOSHING

The challenges of liquid motion and sloshing inside LNG membrane tanks are becoming increasingly important to the industry. Voyages with partially filled cargo tanks are increasing as vessel sizes rise and new trades are established across rougher seas. Spot trading, offshore discharge and ship-to-ship transfers are also increasing.

DNV has widely respected in-house resources which focus on extending the theoretical understanding of liquid motion and sloshing and utilising that insight in practical applications.

HARSH WEATHER CLASSIFICATION

LNG has developed an additional classification notation, Comfort, to address the potential risks caused by crew stress during extended operations in harsh climatic conditions.

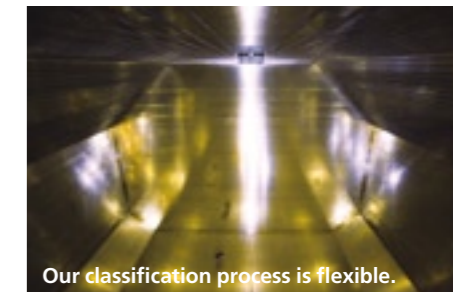
The first vessels to be awarded this classification are four LNG carriers built to carry cargo from the Snøhvit field off the coast of Northern Norway. These LNG carriers, the first to be built for Arctic trade, are winterised. They have been built to very strict specifications, including a design fatigue life of 25 years in North Atlantic trade.

Through advances such as these, DNV is helping the industry develop cold-climate LNG operations.

OFFSHORE CLASSIFICATION

Demonstrating safety and compliance with regulations

Our offshore classification services assure owners, authorities and other stakeholders that facilities meet an acceptable level of safety and comply with rules and requirements.



Offshore classification provides verification to all stakeholders that offshore LNG facilities meet agreed project technical safety requirements. It is also used to document that offshore installations are compliant with relevant regulatory requirements.

DNV offers classification services for the design, construction and operation of floating LNG units, FSRUs (Floating Storage and Regasification Units), LNG FPSOs (Floating Production, Storage and Offloading Units) and other LNG facilities. We have updated and developed a set of offshore standards to address LNG applications. Our approach combines a prescriptive and risk-based approach, resulting in both predictability and flexibility when addressing novel solutions. The classification process is adaptable to the shelf-state verification regime the client is required to operate under and is typically used as a means of documenting compliance with relevant shelf-state regulations. DNV has experience of working with regulations

specified by shelf-states in all the world's major offshore locations. Also DNV is a recognised verification agency in areas where such agencies are employed as part of the offshore regulatory regime, such as the US, UK, Australia, Canada and China.

Currently, DNV is involved in classifying the first LNG FPSO units to be built. In this process, we have been engaged in studies to identify key safety challenges associated with carrying out LNG liquefaction offshore and with assessing the application of novel solutions and technology. Stakeholders have through close cooperation been ensured that designs are sufficiently safe without being prohibitively conservative.

The first FSRU to be deployed has been classed by DNV in close cooperation with the industry to ensure safe design and compliance with regulatory requirements. We have assessed and adapted requirements from land-based industry, the maritime LNG industry and the

offshore oil industry to ensure that relevant best practices and experience are captured.

DNV is also engaged in a number of projects to assess both large-scale and smaller-scale offshore LNG liquefaction projects with a view to issuing Approvals in Principle. This is an assessment of whether or not there are technological or regulatory obstacles to employing a specific concept. Risk techniques are used to determine novel areas to be specifically addressed by engineering studies and can be combined with DNV's Technology Qualification service.

CASE: KNUTSEN OAS SHIP CLASSIFICATION

Up to 30% of LNG reserves are 'stranded' in locations that are too distant from sources of demand. Knutsen OAS of Norway aimed to make such reserves viable, using a Pressurised Natural Gas (PNG) transportation system at ambient temperatures. This would require only standard carbon steel and thus, minimise vessel costs.

Methods for shipping non-liquefied gas on-keel had previously been unsuccessful. Even so, Knutsen planned to extend known design principles as far as possible, drawing on best practices from the pipeline and shipping industries, and minimising system complexity. However, International Gas Code (IGC) was not intended

to cover compressed natural gas cargo (CNG) containment systems, and no existing rules were available for (CNG) carriers.

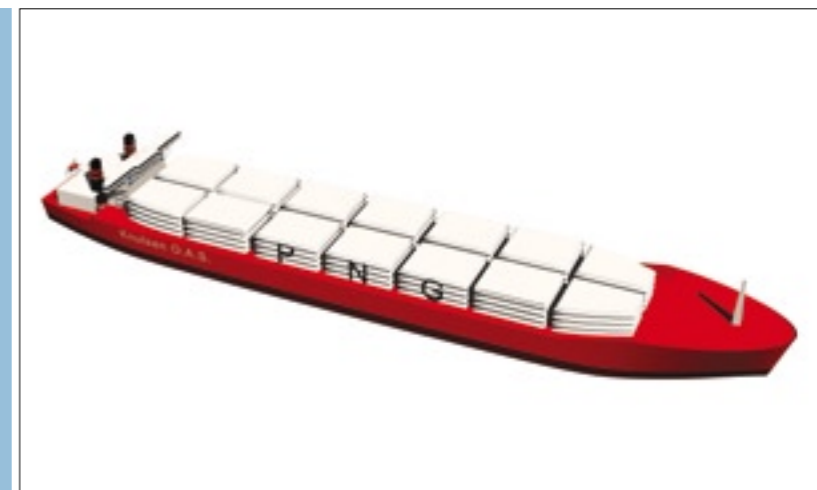
Knutsen engaged DNV and pipeline fabricator Europipe GmbH, to create a solution. We developed Rules, using the IMO (2002) FSA procedure for assessing new solutions not covered by current practice. These Rules set a standard in the market, as they were the first to be developed for CNG carriers. Knutsen was successful in developing its CNG system for Offshore Loading and Discharging, and Terminal-to-Terminal PNG vessels. It was one of only two designers able to offer these CNG designs.

CRITICAL ISSUE: No existing rules for CNG carriers.

SOLUTION: Developed classification rules for CNG (PNG) carriers.

KEY DELIVERABLES: Supported Knutsen OAS in development efforts. Carried out initial load, load response, and strength analyses.

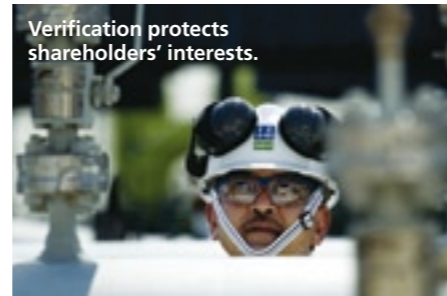
VALUE TO CLIENT: Developed two types of PNG vessel and gained market-leading position.



RISK-BASED VERIFICATION

Keeping projects on track

To ensure that project targets are met, DNV provides a customised and streamlined risk management system.



Given the large scale and complex inter-dependencies involved in LNG projects, a risk-based project management process is crucial for protecting the interests of all stakeholders.

To deal with this, DNV provides a risk-based verification scheme that can be tailored and adapted to suit the particular needs of individual projects. This methodology for verification activities is both cost-effective and transparent. It has successfully been implemented in a variety of facilities and operations, such as pipelines, subsea installations, platforms and hook-up and installation operations.

The DNV Offshore Service Specification OSS-309 addresses the verification, certification and classification of gas export and receiving terminals. The verification work on LNG projects is typically also carried out using DNV's 'Rules for Planning and Execution of Marine Operations' and 'DNV

OS-F101 Rules for Submarine Pipeline Systems' as standard references.

Risk-based Verification is currently utilised during construction of both import and export facilities for LNG. Currently DNV is engaged at South Hook to create the written scheme of examination for pressure systems (WSE) through the use of Risk-based Inspection planning for LNG and utility systems, safety valves and jetty and flare structures. Further DNV carried out detailed inspection planning and loaded this into the DNV-supplied inspection management software ORBIT IDS. DNV also assisted with loading the plan into SAP and developing inspection management and execution procedures. In addition, an NDT contractor was hired to carry out periodic NDTs over the next few years. A DNV Inspection Engineer and team provided support to SHLNG operations personnel during the commissioning and hand-over process, with continuing

inspection management and execution over a three-year period.

DNV was chosen as the contractor for the Risk-based Inspection (RBI) due to its technical solutions and experience in how to apply these practically in real situations, and because DNV was able to demonstrate commitment and added value.

Now, DNV is also expanding its Risk-based Verification standards to include shore-based regasification terminals to prove a visible and simple legislative framework for development of such terminals. The objective is not to invent new standards, but to align existing ones such that they cover the full facility and are consistent.

TECHNOLOGY QUALIFICATION

A systematic approach to ensuring the reliability of new technologies

We assure that developers and investors safely unlock the potential of new technologies and find new ways of applying existing ones.



The LNG industry is seeking to enhance its competitiveness. Technologies that can improve the cost, reliability and speed of the LNG chain are valuable. However, the LNG industry has a hard-earned reputation for reliability and safety that must be protected. Moreover, the business risk involved in the failure of one element in the LNG chain is potentially catastrophic, with a far-reaching impact. The industry is therefore conservative and reluctant to employ novel technology.

Technology qualification helps solve the challenge of bringing new technology to the market. It builds confidence by documenting that a concept will function reliably within specific conditions. Technology qualification follows a rational, systematic and well-documented approach to creating confidence in novel solutions. This focuses on high-risk issues and on reducing the risk of unforeseen events.

Qualification can be conducted in parallel with the technology development project. Through cooperation between the technology stakeholders, the qualification work process ensures that all aspects of the novel technology are adequately addressed. It also proves that the technology is proved to comply with stated functional requirements and reliability targets. In this respect, known technology in a new application is also included. An additional benefit of this systematic approach is cost savings during the development phase – testing accounts for as much as 90% of the cost of technology development projects.

DNV has in-depth expertise in technology qualification in a wide variety of industries. We have tried-and-tested processes that are designed to mitigate the risk involved in the process. Within the LNG industry, we also have an extensive background in helping the industry to move forward by qualifying novel technologies for use in LNG-related applications.

DNV has been an active driver in the qualification of novel LNG technologies in areas such as:

- ▶ Development of spherical containment systems
- ▶ Sloshing resistance in membrane tanks
- ▶ Cargo transfer systems for offshore offloading
- ▶ Pipe-in-pipe systems for LNG transfer
- ▶ Liquefaction processes

Our practice has been refined over many years and has now been distilled into a Recommended Practice for Technology Qualification. This approach is systematic and comprehensive and ensures transparent and verifiable documentation.

CASE:

GOLAR TECHNOLOGY QUALIFICATION

The shortage of LNG import capacity and suitable port locations has driven interest in converting existing LNG carriers into Floating Storage and Regasification (FSRU) receiving terminals. This approach is also attractive due to its short construction time and flexibility of site selection.

A critical aspect of this approach was the transfer of cargo from shuttle carriers, using an enhanced version of the traditional marine loading arm system, with extended motion and a semi-automatic connection device. It was unclear if this design would be viable for transfers between floating vessels, with significant wave motion. GOLAR, the

LNG transportation operator, engaged DNV to qualify the novel aspects of the design and verify that the traditional elements complied with applicable codes and standards.

DNV applied the approach outlined in our RP A203 Qualification of New Technology, to identify novel elements and applications of the existing technology. We identified potential failure mechanisms, which shaped the verification programme by focusing analyses and inspection on the critical issues. We also developed routine controls required for the certification process. Based on this comprehensive review, DNV issued a certificate of fitness for service.

CRITICAL ISSUE:

Safety of loading arm design.

SOLUTION:

Assessment of novel design, combined with traditional verification.

KEY DELIVERABLES:

Statement of Fitness for Service.

VALUE TO CLIENT:

Stakeholder confidence in proposed solution.



ENTERPRISE RISK MANAGEMENT

Visualising the cost of risk

Value can be created for stakeholders by using a cross-disciplinary approach to identifying and managing both opportunities and threats.



DNV's Enterprise Risk Management service increases the project's value throughout the LNG value chain. With this, you experience fewer surprises and are provided with decision-making support and assistance to meet project objectives.

INTEGRATED RISK MANAGEMENT

LNG investments typically involve large uncertainties. These stem from a wide range of sources, occur at different points and can be of various types, for example technical, financial, market, credit and performance.

DNV assesses the investment's total risk. Relevant uncertainties are included in the cash flow elements, for example costs, availability and schedule. This contrasts with the traditional discounted cash flow (DCF) approach, which instead integrates these risks into the discount rate.

Our approach to risk management improves the understanding of the drivers' impact and

the starting point for the risk management of the investment project that typically follows the investment.

This service helps clients rank the most important risks in a project, identify relevant mitigating actions and then estimate the likelihood of achieving specific financial and scheduling outcomes.

DUE DILIGENCE

Due diligence investigations are carried out before investment transactions, such as bank funding or equity investment decision. These improve decision making by providing insight into risks and risk mitigation options.

DNV often acts as an independent adviser, conducting due diligences in projects throughout the entire LNG value chain and across the energy industry. Due diligences are provided for the following aspects of projects:

- ▶ Technical
- ▶ Commercial

- ▶ Contractual
- ▶ Safety, health, and environment

MULTI-SHIPPER ASSESSMENTS

There is a growing need for multi-shipper assessments. Relatively small offshore regasification-terminal projects are becoming increasingly common. Meanwhile, carrier vessels are growing in size and many import terminals are being opened up to multiple shippers as a result of third-party access regulations. These changes mean that complex scheduling is increasingly required in order to optimise the use of import terminal capacities.

DNV has broad experience in assessing such complex operational environments and advises on the best methods of optimising and protecting their rights.

ASSET RISK MANAGEMENT

Maximise asset returns through a proactive approach

DNV helps clients obtain maximum value from facilities, equipment and people – without compromising safety or the environment.



In all industries, minimising asset costs and uncertainties is a key driver of operational efficiency. We work closely with operators to understand the risks posed to their assets and develop an optimal solution for managing them.

OPERATIONAL EXCELLENCE

In a difficult business climate, the focus must be on improving the return on capital employed (ROCE). In the LNG sector, the capital is heavily invested in assets and operations and DNV applies a risk-based approach to focusing resources where they are most effective.

The systematic DNV approach to operations excellence starts with appraisal. Businesses must identify the strengths and weaknesses of their assets. Following the initial phase, we work to develop and implement optimal inspection and maintenance programmes for assets.

Through this systematic approach, we are able to help operators consistently reduce operational expenses, increase regularity and prolong asset lifetimes.

PERFORMANCE FORECASTING AND LIFECYCLE ECONOMICS

All existing and future asset developments are typically under pressure to increase performance and reduce costs. DNV can assess the viability and lifecycle profitability of systems and projects in the concept stage or at any other decision point through the project's lifetime.

For this type of work, a risk-based approach is utilised. We systematically identify the key technology risks for specific concepts. Following this, priorities are set for further technology development, qualification and testing, in order to reduce and manage the key identified risks.

DNV offers the following risk management services:

- ▶ Assessment/benchmarking of asset operations
- ▶ Asset operations management
- ▶ Production optimisation
- ▶ Maintenance and inspection
- ▶ Development of solutions to failures

CASE:
GRAN CANARIA AND TENERIFE ENTERPRISE RISK MANAGEMENT

In many locations around the world, offshore-based terminals are a preferred solution for LNG projects. This is due to the fact that they produce a reduced environmental impact compared to onshore terminals. In addition, offshore terminals can be moved faster through regulatory approval processes.

DNV Energy has performed an independent assessment of two proposed land-based LNG receiving, storage and re-gasification terminals on Gran Canaria and Tenerife. The terminals will supply natural gas for electricity generation in the existing power plants on the islands. From a safety perspective, the proposed terminals

were assessed to determine the potential consequences of leaks and exposure to nearby villages and surroundings. In addition, DNV reviewed environmental concerns, such as the terminals' impact on marine life, birds and plants in the area.

DNV also assessed several offshore concepts for Gran Canaria and Tenerife. However, given the prevailing weather conditions and currently available technology, these concepts would not have been able to meet safety and reliability requirements.

CRITICAL ISSUE:
Quality of the concept study.

SOLUTION:
Comparative study.

KEY DELIVERABLES:
Confidence in project development process.

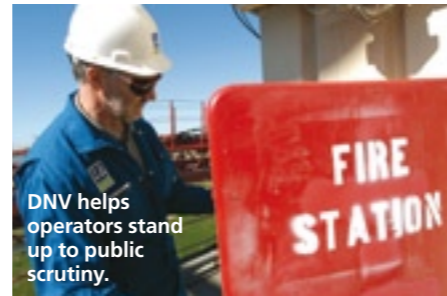
VALUE TO CLIENT:
Third-party view on choices made to date.



PUBLIC SAFETY

Managing public perception by going beyond compliance

The increasing public scrutiny poses a challenge to LNG stakeholders. DNV helps meet the public's safety expectations.



The LNG industry – justifiably – prides itself on having completed more than 40,000 vessel voyages without a single significant incident. The effectiveness of cryogenic technology in liquefaction, vessel transport and receiving terminals, is well established. However, the industry cannot rest on its laurels. The visibility of the energy industry is so high that just one serious LNG incident could severely undermine the industry's near-perfect record – and probably redefine the risk perception of most stakeholders.

To help mitigate this risk, DNV's public safety service applies risk-based methods and advanced software tools. This ensures that hazards are identified and understood, consequences are assessed and risks are managed in a cost-effective manner.

MANAGEMENT SYSTEMS

Every company has a management system. The challenge is to develop, implement, review and improve systems in order to

enhance business performance. DNV has over 25 years of experience in helping organisations realise the benefits of effective management systems. The root causes of most major accidents lie in organisational failings. Effective safety and environmental management programmes must therefore be implemented throughout all project stages; from concept studies, through design and operation, to abandonment and recycling.

RISK ASSESSMENTS

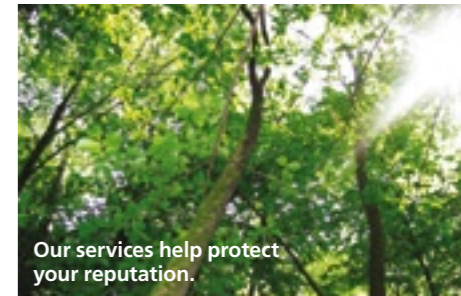
LNG operators are facing a fundamentally new – and more challenging – operating environment. In this new context, there is zero tolerance for consequential damage. Practically speaking, this means that stakeholders now demand that LNG operators demonstrate, first and foremost, that they have a full understanding of the likelihood and impact of accidents. Secondly, they also require evidence that operators are actively working to reduce those risks and their associated costs.

DNV has a strong ability to model such situations. Operators are supported in understanding the technical risks and potential consequences of operations and thereby make better decisions.

ENVIRONMENTAL RISK MANAGEMENT

Assuring stakeholders by proactively managing risks

An environmentally responsible public image is essential for both business and public organisations. DNV provides integrated risk management services to help operators achieve this.



There is increasing pressure on all organisations to effectively manage the environmental and social impacts of their operations. DNV helps environmental stakeholders, such as businesses and governmental bodies, to develop effective and appropriate environmental risk management solutions.

Drawing on our considerable industry experience, we take a holistic approach to environmental risk management, which creates insights into the issues from all perspectives. DNV's position as an independent third party also helps assure all stakeholders that the guidance and recommendations provided accurately reflect the true status of an activity or operation.

SAFEGUARDING THE ENVIRONMENT

DNV helps operators improve the environmental sustainability of new projects and existing assets worldwide. We provide comprehensive assessments of environmental impact and risk.

DNV provides management and decision support at all organisational levels, throughout the oil and gas value chain. We offer:

- ▶ Environmental impact assessments based on international standards
- ▶ Environmental risk management, including:
 - Pollution dispersion and fate modelling
 - Spill preparedness and response
 - State-of-the-art GIS-based oil spill management tools
- ▶ Assessments relating to discharges to sea

Biodiversity management including:

- ▶ Baseline survey and impact monitoring
- ▶ Environmental sensitivity mapping
- ▶ Environmental information systems and databases
- ▶ Environmental footprint reduction
- ▶ Remediation of polluted soils and sediments
- ▶ Discharge/emission control and reduction, including carbon capture and storage

- ▶ Invasive species risk management (e.g. ballast water management)
- ▶ Life Cycle Assessment (LCA)

CORPORATE SOLUTIONS

DNV provides management and decision support at all organisational levels throughout the LNG value chain. We offer:

- ▶ Development and implementation of environmental management systems
- ▶ Establishment of corporate reporting routines
- ▶ Public consultation and communication of risk
- ▶ Environmental Due Diligence Audit (EDDA) for asset acquisition
- ▶ Verification and reporting of greenhouse gas emissions

CASE:

RABASKA, QUEBEC PUBLIC SAFETY

Rabaska is a US \$840 million natural gas project in Québec, Canada. The project includes a deepwater jetty in the St. Lawrence River for tankers carrying liquefied natural gas (LNG), underground cryogenic pipes connecting the jetty to two reservoirs, re-gasification equipment, and a 40-kilometre pipeline.

The project required authorisation from various Canadian federal and provincial departments and agencies. However, there was a history of public opposition to LNG projects in North America, due to safety and security concerns. In particular, Rabaska would be the first LNG terminal in the world with domestic homes connecting the terminal and the jetty. As a result,

the project developers (Gaz Métro, Enbridge Inc., and Gaz de France) engaged DNV to provide proof that the project met safety requirements, and to assist in the approval process.

DNV provided third-party risk assessments of the import terminal and the passage in the St. Lawrence waterway, including berthing and departing the terminal. We represented the Rabaska project in the public hearing process and assisted with ad-hoc aspects of gaining regulatory approval. This included interfacing with the local population on behalf of the project. The work to date has been successful and the terminal has received regulatory authorisation.

CRITICAL ISSUE:

Novel project required regulatory approval.

SOLUTION:

Conduct safety assessment and assist in approval process.

KEY DELIVERABLES:

Third-party risk assessment.

VALUE TO CLIENT:

Project received regulatory authorisation.



TECHNICAL ANALYSIS

Industry-leading analysis and investigation capabilities

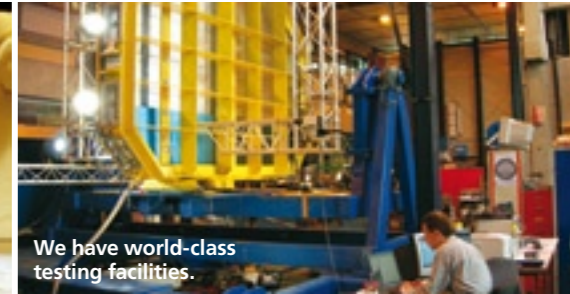
Technical analysis is crucial for developing new solutions and resolving issues involving failures in existing ones. DNV conducts theoretical and experimental analyses to provide such insights.



DNV has expertise in carrying out failure investigations.



Our teams collaborate to solve clients challenges.



We have world-class testing facilities.

With our extensive expert staff resources and access to a wide collection of analytical tools, DNV is able to provide high quality and complex technical services to all disciplines in the LNG chain. These services typically involve:

- ▶ Fluid and flow analysis
- ▶ Structural response and strength
- ▶ Inspection and maintenance
- ▶ Risk and reliability, environment
- ▶ Fitness for service assessments
- ▶ Sloshing
- ▶ Laboratory assessments

DNV has fully equipped laboratories that have underpinned our long track record of qualifying new technical solutions and developments for the LNG industry. Here we can perform full-scale component and functionality testing as well as static and dynamic material testing at cryogenic temperatures. These services apply to metallic materials, thermoplastic materials, elastomers and fibre-reinforced plastics.

FAILURE INVESTIGATIONS

DNV is also widely recognised for its expertise in conducting failure investigations. These cover a number of topics, ranging from major breakdowns to the failure or cracking of small individual components. The main goal of failure investigations is to prevent new failures and increase safety and/or optimise operations. Establishing the root cause of failures also enables:

- ▶ Appropriate modifications of design and operation procedures
- ▶ Inspection parameters or intervals
- ▶ Development/improvement of procedures, rules and routines
- ▶ Determination of responsibility

TECHNICAL ANALYSIS

We have a long history of conducting technical analyses to help the LNG industry overcome its key challenges safely. Recently, these challenges have included rapid increases in the size of LNG carriers, the expansion of offshore loading and unloading activities, and an increase in the number of voyages with cargoes of partially filled LNG tanks.

In response to this, DNV has completed a comprehensive study of sloshing effects in LNG tanks. The results have been presented in the DNV Classification Note called 'Sloshing Analysis of LNG Membrane Tanks'. This note focuses on sloshing loads and tank system strengths for normal tank fillings, as well as the reduced tank filling operations of membrane-type LNG carriers. It is intended to help ensure safe transportation by providing guidelines for assessing sloshing in the new generation of large-size LNG carriers.

For some Floating Liquefaction projects, DNV has also calculated relative movements between the producing and off taking units, including forces effecting mooring hawsers. DNV also participates in the Safe Offload Project, where the availability of side-by-side operation was estimated based on long-term weather data for Australia and West Africa.

Further, our accumulated knowledge base and highly skilled workforce enable us to address a wide range of technical challenges related to LNG developments, both on the terminal side as well as in the maritime environment. Some examples of these issues are; jetty constructability, heating effects of high voltage lines following accidental fires, suitability of flares, strength evaluation of LNG tanks and LNG jetties, heat balance in ballast tanks used for heating in LNG vaporisers, and flow assurance in deep sea suction risers for cooling liquefaction processes.

A COMMERCIAL VIEW

Our technical services are commonly combined with Enterprise Risk Management to address the project development's commercial issues. Some of our recent examples here are our multi-user assessments of import terminals, in which operators are helped to secure the planned throughput in contractual negotiations, based on a combination of a RAM analysis, a technical availability evaluation of the site and legal expertise.

CASE:

EPC CONTRACTOR TECHNICAL DUE DILIGENCE

An international EPC contractor was planning to enter the LNG liquefaction market and one of its options was to acquire a proprietary technology still at the demonstration stage. Since the contractor was also considering other technologies, the technology developer would not give the EPC contractor access to details of the technology.

DNV was engaged to conduct a third party evaluation of the technology, with a focus on process layout, efficiency and robustness of the process, as well as novel equipment in the process. We benchmarked the new liquefaction technology against existing technologies.

We conducted process simulation to assess the efficiency of the process, as well as interviews and workshops with the technology provider. For the novel technology elements, we performed a technology assessment according to DNV RPA203.

Finally, we conducted a market assessment, with a focus on the suitability of technology in several market segments: floating production, BOG re-liquefaction and small/medium scale plants. As a result, the EPC contractor was able to make a decision on the acquisition of the technology.

CRITICAL ISSUE:

Assess quality and competitiveness of a novel LNG technology.

SOLUTION:

Analysis and benchmarking.

KEY DELIVERABLES:

Recommendation and market analysis.

VALUE TO CLIENT:

Decision support.



DNV locations

DNV serves the energy industry from more than 40 primary locations worldwide. In addition, we draw on DNV's entire worldwide network of 300 offices in 100 countries.

