DNV·GL

GROUP TECHNOLOGY AND RESEARCH

RESEARCH REVIEW 2017

Solutions for a Sustainable, Digitized Future

SAFER, SMARTER, GREENER

Cover image is inspired by the art installation
Crystal Universe / Future world: where art meets science
http://exhibition.team-lab.net/singapore/art/art01.html

SOLUTIONS FOR A SUSTAINABLE, DIGITIZED FUTURE

At DNV GL, we invest in total 5% of our revenues into research and innovation. 1% of this goes into long-term strategic research and technology development which primarily delivers prototypes for future services to meet our customers' needs in an ever changing and challenging world.

An example of that changing environment is the increasing number of extreme weather events with severe consequences around the world for our customers' assets. Further indications of regional temperature anomalies, causing flooding in some locations or drought in others, are also playing havoc with some customers' businesses and their supply chains, while associated effects like record low arctic summer ice cover are opening previously unpassable transportation routes.

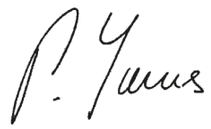
Driven by sensors, connectivity, data storage and analytics, industries are undergoing a transformation, while many established businesses are disrupted. Massive global investments in artificial intelligence bring on the next wave of analytics and autonomous decision making. Blockchain is now widely regarded as key infrastructure for future automated transactions and DNV GL has started to utilize it as the backbone of our electronic certificates. However, we have also witnessed how the vulnerabilities of the digital world to cyber attacks can severely affect our customers' businesses and infrastructure as well as wider society.

Mostly driven by advances in digitalization, new business models have emerged, such as the selling of performance instead of products, as well as the platform model. For DNV GL, this means understanding how our customers' business relationships change, as well as how we ourselves need to change and to experiment with such new business models. Most recently, we launched Veracity, our multi-sided open industry data management platform which will facilitate future digital delivery of our core services but also enables entirely new platform business.

With these examples of change in mind, DNV GL is constantly evaluating its impact on our customers and their markets, tailoring our research programmes to respond to developing trends.

Examples of our work in 2017 are presented in this research review. One deliverable, however, stands out: Energy Transition Outlook 2050. This outlook reflects the accelerating installation of renewable energy generation capacity at record low prices, leading to increased electrification, such that we are forecasting that close to 50% of all energy supply in 2050 is expected to be delivered by renewables. However, even at this pace, we will likely miss the climate targets set out in the Paris Agreement. I would urge you to download our main report and its supplements which address the maritime, energy and oil & gas sectors specifically.

In the meantime, I hope you enjoy reading this research review and take this opportunity to thank you, our research partners, for engaging with us to deliver better solutions, so addressing our vision to achieve a global impact for a safe and sustainable future.



Dr.-Ing. Pierre C. Sames
Group Technology and Research Director

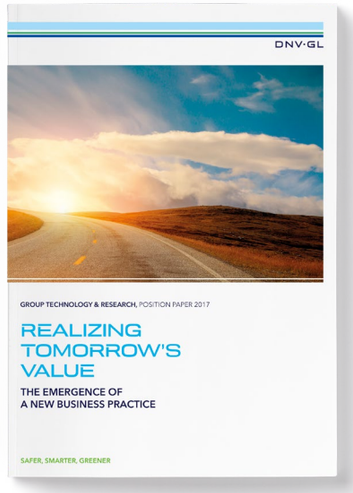
POSITION PAPERS PUBLISHED IN 2017

A Position Paper from DNV GL Group Technology and Research is intended to highlight findings and viewpoints from our research programmes. These papers can be downloaded for free at Technology and innovation publications: dnvgl.com/technology-innovation/latest-publications.html

Climate disruption and sustainable solutions

Changing cities in a changing climate

In this paper, we examine urban areas from the perspective of their ecological system, structural system, socioeconomic system and governance system. Using this framework, we combine systems thinking, simulation and data to devise tools that help communities adapt and build resilience to climate change.

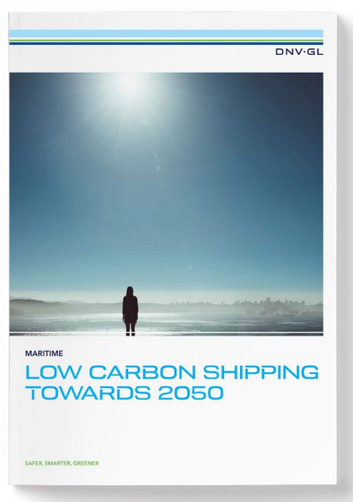


Realizing tomorrows value

How do companies know that their strategy is sustainable? How do you best convince stakeholder – customers and investors – that your company and its products and services offer a truly sustainable source of value? These questions are central to this position paper from DNV GL, which addresses how businesses measure, manage and strategize value creation in the broadest sense.

LPG as marine fuel

In recent years, regulators have put increasing emphasis on reducing sulfur emissions from fuel consumption by ships. This calls for alternative fuels as a means of compliance. In this study, DNV GL considered the possibility of using LPG as a fuel, based on financial viability, safety considerations, fuel availability, technology maturity and environmental impact.



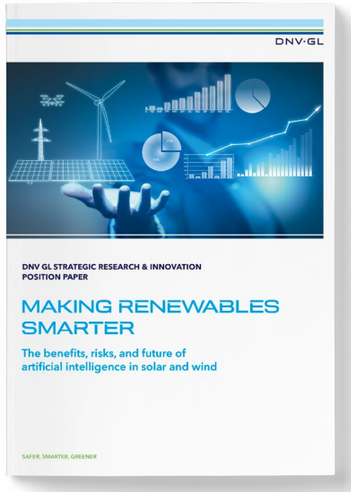
DNV GL Low Carbon Shipping Towards 2050

Reducing GHG emissions from shipping is a chall-enging task. Current solutions include the use of energy efficiency measures and alternative fuels. Shipping will be expected to reduce GHG emissions and DNV GL is ready to assist the industry to negotiate the transition into a low carbon future.

Digital technologies and cyber-physical systems

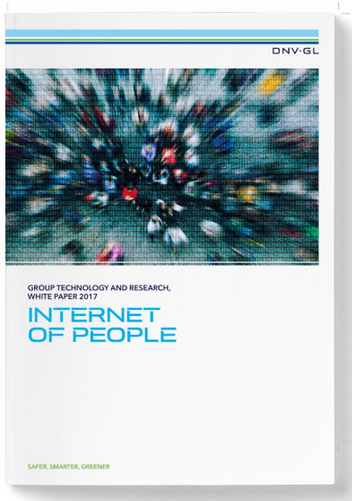
Flexibility in the power system

In the electric power system, electricity supply needs to be balanced with electricity demand and network losses at all times to maintain safe, dependable and stable system operation. This paper explores the need, opportunity and value of flexibility.



Making renewables smarter

The use of artificial intelligence in industries continues at an impressive rate – in manufacturing, engineering, healthcare, transportation, finance, telecommunications, services, and energy. This paper explores The benefits, risks, and future of artificial intelligence in solar and wind energy.



Internet of People 2017 (whitepaper)

The Internet of People (IoP) has the potential to transform how patients engage with care services, improve the efficiency and coordination of care, and support people to manage their own health and well-being. Our whitepaper explores these new opportunities.

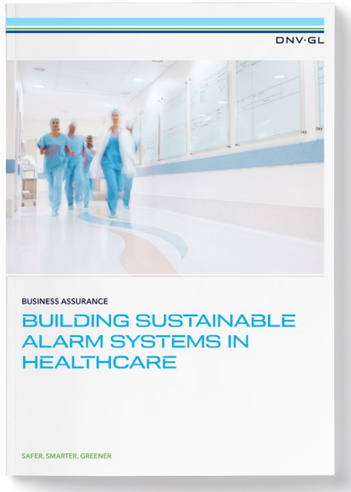
Standardisation as an enabler of digitalization – in the maritime industry

The paper addresses how standards could be used to improve data flow and thereby enable new digital services based on sensor data from ships.

Future profitable business and delivery models

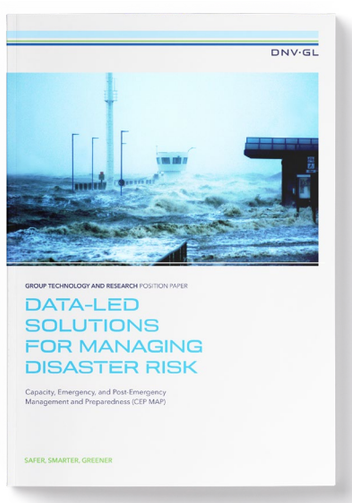
Maintaining confidence. Dynamic risk management for enhanced safety

This position paper presents recent work by researchers at DNV GL Group Technology and Research to develop more dynamic risk assessment methods and tools for the future.



Building sustainable alarm systems in healthcare

Incidents caused by poorly managed alarm systems negatively impact patients and those working in healthcare institutions. Alarms designed to protect patients can all too often lead to direct patient harm and even death as well as contributing to clinical staff burn out.



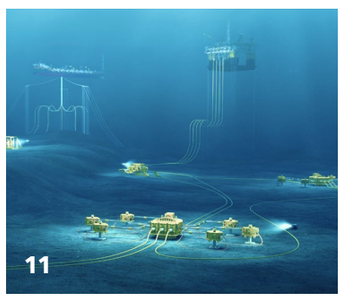
Data-led solutions for managing disaster risk

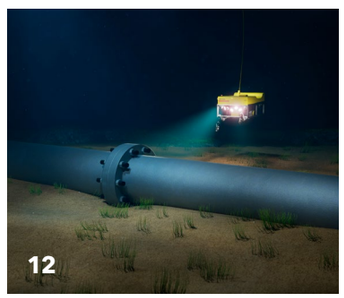
Every year, millions of people are affected by disasters – resulting in serious disruptions of the functioning of a community or a society. DNV GL has developed an integrated, data-led risk management and preparedness system with the purpose of improving resilience to the impacts of extreme weather events and other types of hazards.

Aquaculture going offshore

The aquaculture industry pursues new territories for sustainable food production to a growing world population. Opportunities and challenges in the rougher environments are identified and assessed from a DNVGL perspective.

FEATURE PROJECTS





Climate disruption and sustainable solutions

Digital technologies and cyber-physical systems

Future profitable business and delivery models

EXWAMAR PROJECT

The ExWaMar project aims to develop improved warning criteria indicating increased risk of extreme or rogue waves for the shipping and offshore industries. The criteria will be included in current operational procedures for marine structures in DNV GL, as well as implemented in the forecasting system of the Norwegian Meteorological Institute.

Waves represent the dominating environmental load for most marine structure and a good understanding of the wave environment is therefore crucial for design and operation of ships and marine installations. In ExWaMar we work, together with our project partners – the Norwegian Meteorological Institute and the University of Oslo – to improve our understanding of extreme and rogue waves. Enhancing the forecast of extreme and rogue waves is especially important for operability assessment in marine operations, and for the wave forecasting services provided by MET Norway to shipping and oil companies today.

The project comprises wave data from field measurements, advanced numerical models for wave forecasting and simulation of nonlinear waves, as well as theoretical models. As a part of the project we develop and improve the nonlinear wave code based on the Higher

«As any seaman could tell you, the heights of waves are not as important to him as is their steepness»

Blair Kinsman Professor, Johns Hopkins University, USA Kinsman, B., 1965. "Wind Waves" by Prentice-Hall, Inc. Englewood Cliffs, N.J.

Order Spectral Method (HOSM), previously developed in GTR. This tool allows for numerical simulations of nonlinear ocean waves on deep, intermediate and shallow water, and enhances the description of general wave statistical properties. In many applications, the nonlinear effects of waves should be considered, and numerical models that can describe nonlinear waves are of importance, too, for design work and advisory services.

The main output of this project will be warning criteria for rogue waves, which will be suggested for implementation in DNV GL Rules and Standards as well as in MET Norway wave forecasting services, ultimately improving safety at sea. The proposed revision of rules and standards will also include the developed nonlinear wave statistics as well as information about identified changes in wave description due to climate change. Further, the output of the project includes:

- The nonlinear wave code HOSM (Higher Order Spectral Method) able to receive wave input from MET Norway's spectral wave model and field data.
- Effects such as finite water depth and wave breaking in the HOSM code as well as combining HOSM with Computational Fluid Dynamic (CFD) codes.
- Analysis of wave hindcast spectra in the past and future wave climate in North Atlantic and Norwegian waters, based on data generated in the previous RCN project ExWaCli.
- Surface wave analysis of field measurements and numerical data, and enhanced description of wave statistics.
- Investigations of modulational instability and occurrence of rogue waves in JONSWAP sea states and crossing seas.
- Validation of warning criteria.

The project started in 2016 and will be completed in 2019.

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CLIMATE SERVICES
for the renewable energy sector

Climate change may cause regional changes in the availability of renewable resources for energy production. In addition, it may influence energy demand due to changing weather and temperature patterns. Plausible changes due to different emission pathways and different model projections will provide us with a range of probable futures for different renewable energy resources.

The energy sector is responsible for nearly two-thirds of global greenhouse gas emissions, and efforts are being made to decarbonize the industry via green technology and renewable energy investments. Renewables also provide diversification of the country's energy mix, enabling a more resilient system.

The DNV GL Energy Transition Outlook highlights an upcoming era of abundant, clean energy. It is important to recognise, however, that global warming might alter the intensity and pattern of winds, changes in cloud fraction and available water resources. In addition, indirect effects through changes in extreme events may hamper the industry. These changes may require corresponding updates to codes and standards for the design, verification and assessment of renewable energy infrastructure.

«Renewable energy is energy obtained from naturally repetitive and persistent flows of energy occurring in the local environment»

John Twidell and Tony Weir

The DNV GL Climate Action Programme works to better understand the impact that climate change may have on both the design and operation of renewable energy production. The project evaluates the high-resolution climate models (RCMs) wind and solar performance over United States and United Kingdom, both near and long-term periods for different emission scenarios. The Weather Research and Forecast (WRF) model results from DNV GL and NCAR collaboration are used, also including publicly available Co-Ordinated Regional Climate Downscaling Experiment (CORDEX) models for the study areas.

Preliminary results indicate that the employed model runs reproduce historical wind climatology (as derived from reanalysis and observational datasets) with acceptable accuracy over United States and United Kingdom. Model uncertainties, however, are a major concern in both the scientific and industrial community and the results must be further validated and used with caution.

The project is considering future climate scenarios (medium and high emission) and many ensembles from each modelling centre (with varying physics and dynamics combinations) to overcome the issues of single model/physics uncertainty and provide a range of outputs. The percentage changes in accumulated power output at hub height of 100m are calculated using generic power curve for different time-periods. Future changes in wind power potential are estimated in comparison with baseline time-period over United States, and United Kingdom in both on-shore and offshore locations. These probable changes are related to large-scale interannual variability changes likely due to Arctic Amplification, influencing the Rossby waves in mid-latitude and polar circulation features.

In summary, results indicate that climate change may influence wind production in certain regions. However, expected technological advancements and consequent cost reductions in LCOE calculations will likely outpace the projected changes in wind power potential. The project has been carried out in close collaboration with DNV-GL Energy.

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ENGINEERING MODELS AND WIND FARM CONTROL

Using a range of advanced flow models, DNV GL is pushing the boundaries of wind farm design, control, and analysis. A modern wind farm is more than a collection of autonomous wind turbines – it is a wind power station, feeding significant amounts of power into the electricity grid.

It is also a highly complex physical system, as the individual turbines interact with one another through wake effects. It is important, therefore,to consider how the plant behaves as a whole, and how it should be controlled.

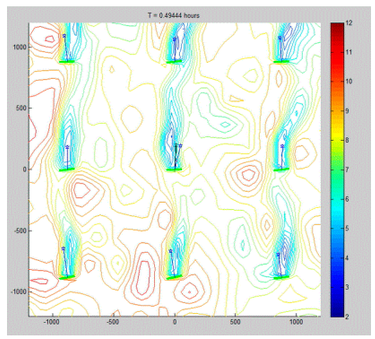
Optimal performance cannot be obtained without first considering the effect of each turbine on the rest of the plant. This project has two main strands: development of improved modelling capabilities, and that of the wind farm controller itself.

The required modelling improvements include the development and validation of models with greater accuracy and fidelity. However, this requires greater computational resources, and an advanced Computational Fluid Dynamics (CFD) model capable of resolving the wake flows in a large wind farm in sufficient detail is bound to run very slowly. In parallel therefore, we are also developing simple engineering models which can run quickly while still capturing the most important effects sufficiently and accurately.

«Optimal performance cannot be obtained without first considering the effect of each turbine on the rest of the plant.»

Ervin Bossanyi - Senior Principal Researcher, Renewables

Optimised wind farm control aims to reduce the cost of energy by mitigating wake interaction effects, thereby increasing energy production and reducing turbine fatigue loads. Although several commercial owners have expressed an interest in this field, it is still at the research stage. DNV GL is therefore collaborating with researchers across Europe, including Horizon 20-20 projects CL-Windcon and TotalControl, slated to start in 2018, as well as German project, OWP-Control.



High-fidelity flow modelling and wind farm blockage

As a primary contributor to the Simulated Wake Effects Platform for Turbines (SWEPT2) project – part-funded by the UK government – we have developed a CFD-based wind farm flow model capable of directly simulating the two-way coupling that occurs between wind farm and atmosphere – something the wind industry has traditionally ignored.

This new model has already uncovered evidence that may overturn a key assumption applied across the industry. When estimating energy production for a proposed wind farm, the industry assumes that the fluid dynamic interaction between turbines is limited to wakes and their impact on turbines downstream. Our own comprehensive analysis of measurements and CFD simulations, however, suggests that turbines can also substantially influence conditions upstream and laterally. Most notably, turbine interaction appears to cause a wind-farm-scale blockage large enough to represent a material bias in current energy prediction procedures. Our results – from a novel approach to analysing field observations – are consistent with this theory.

As the first to embark on this research, DNV GL is in a position to change how the industry assesses and even designs prospective wind farms, giving us a significant competitive advantage as a thought leader in this area, as well as a head start in developing profitable new services.

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ENERGY TRANSITION OUTLOOK

What will our energy future look like? The answer to this question is of major importance to DNV GL and our stakeholders. In its Energy Transition Outlook, DNV GL is answering this question, with a forecast that has garnered record attention.

Over the next three decades the global energy transition will unfold, with decarbonization, electrification, uptake of new technologies, and various other changes. The Energy Transition Outlook (ETO) is based on our independent, in-house developed model of the world's energy systems through to 2050. Designed by Group Technology and Research modelers, it has benefitted from technology and sector expertise from over one hundred colleagues from our business areas, as well as additional external experts.

In the outlook, we provide one central case for the energy future, rather than a set of scenarios. Acknowledging uncertainties in the forecast, we also discuss the sensitivities of our assumptions. Based on our equal footing in the fossil and renewable energy industries, we present an unbiased view of what we in DNV GL regard as a "most likely" future. The model therefore presents the energy future as we expect it to unfold, not as we would prefer it to appear.

The core of the model is a system dynamics feedback model, implemented in Stella software. The model incorporates the entire

«Despite this rapid energy transition, our outlook forecasts that the Paris ambitions will not be met, as continued fossil fuel use will ensure that the 2°C carbon budget is exceeded well before 2050.»

Sverre Alvik project manager for Energy Transition Outlook

energy system from source to end-use, and includes the consumers of energy (buildings, industry and transportation) as well as all the sources supplying that energy. The model divides the world into 10 regions and present the energy future as regional outlooks, in addition to one global outlook. The learning curve effects with cost learning rates and reduced cost of technology is a major driver for what the future will look like, but also energy policies, future economic and population growth and improvements in energy efficiencies are major contributor to the results.

We find that the world's total final energy demand will level off after 2030, and that the share of this energy provided by electricity will double to 40% by 2050. The electricity mix is changing rapidly, and by 2050, one third of electricity will be produced by solar PV, and another third by wind. The world's aggressive uptake of renewables will cause fossil fuels' share of the energy mix to decline, from 81% today to 52% in 2050,The biggest reductions will be seen in coal, while oil demand will peak in the 2020s, followed by gas taking over as the largest energy source in 2034. The decline in the world's energy intensity will be an average of 2.5% annually, and is a major factor in the levelling-off in energy demand.

Despite this rapid energy transition, our outlook forecasts that the Paris ambitions will not be met, as continued fossil fuel use will ensure that the 2°C carbon budget is exceeded well before 2050.

In addition to the main report, DNV GL is also producing three companion reports on the transition implications for the oil and gas industry, for the power and renewables industry, and for the maritime industry.

The full report can be downloaded on https://eto.dnvgl.com/2017/

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The project aims at exploring how to use Blockchain as a key technology to implement trust in the new distributed and open digital world

DNV GL's core business areas -Maritime, O&G, Energy and Business Assurance - provide services related to trust, specifically quality assurance and risk management. However, considering the rapid development of digital technologies, and the disintermediation of business models and relationships, it is necessary to find new technologies that can be used to implement trust in an open digital world.

Blockchain has been identified as a technology which can form the basis of trust services for businesses and individuals in distributed open environments. It has the potential to dismantle and disrupt established business relationships, shifting influence from organizations to individuals, building trusted decentralized decision processes, and empowering consumers. Blockchain is the main technology behind cryptocurrencies, Bitcoin and Ethereum, and its main promises are to solve threats to privacy, security, and inclusion with help of cryptography. Blockchain provides a data structure that is used to create an immutable digital transaction ledger that, instead of resting with a single provider, is shared among a distributed network of computers.

«Blockchain has been identified as a technology which can form the basis of trust services for businesses and individuals in distributed open environments»

In this project, after interviewing several key players in the Maritime BA, it was concluded that blockchain could potentially change the way we provide services. A case study was carried out to explore, and to demonstrate through prototyping, how Blockchain could be used to transform the current "Approval letter" process.

- **Current process:** The selected process is sequential and is centred around evaluation of documentation, such as drawings and designs, of ships at build time. This process is quite communication intensive and each actor, the shipyard and DNV GL, is independently storing documents and comments. The main problem of this process is the weak synchronisation and lock mechanisms of documentation and comments. Sharing information with third parties involved in construction of the ship, such as subcontractors of ship owners, depends either on the versioning procedures of the shipyard or those of DNV GL, which requires an unsupervised delegation of trust. This makes any audit process complicated and costly for DNV GL, since during audits DNV GL needs to grant access to all necessary resources, personnel and infrastructure.

- **A Blockchain based process:** The process can be made transparent and traceable by recording essential information in a Blockchain at each step of the interactions. The basic process does not have to change, since it is still necessary for the customer to submit designs for review, and DNV GL will assess these and respond with comments about issues which need to be fixed. However, adding at each step a recording in a blockchain, shared between the DNV GL and customers, will address the weaknesses in the current process. Since there is no sensitive intellectual property information stored in the blockchain recordings, there is no concern in sharing between class societies and actors in the industries.

As mentioned, Blockchain can provide traceability and transparency to any process, two important prerequisites for trust in an open and distributed digital world.

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CONTROL HARDWARE IN THE LOOP

Test bench for wind farm controllers

DNV GL has opened the first commercial control-hardware-in-loop (CHIL) test bench for renewable energy generation plants. This Power Cybernetics initiative combines the rigour of lab-based testing with the flexibility and speed of computer simulation.

Validation of a wind farm controller has traditionally been costly and effort- intensive, requiring connection to the wind farm and the grid. Carrying the test meant multi-party coordination, lengthy downtime and high risks in case of failure.

This project has developed a control- hardware- in- the- loop test bench for the validation of a wind farm controller, with the purpose of offering an alternative approach to the development and validation of controllers. Using CHIL testing takes advantage of a completely flexible testing platform addressing the certification requirements by the German technical guideline (FGW TG3) and removing the high-risk component from the testing phase.

The test bench uses a controller hardware in the loop test setup, this means that the wind farm and grid are represented in an electrical model running in a real-time simulator. Moreover, the communication layer for the master SCADA acting as a grid operator is emulated by

«The test bench uses a controller hardware in the loop test setup, this means that the wind farm and grid are represented in an electrical model running in a real-time simulator.»

Alejandra Fabian - Project Manager for the Control Hardware in the Loop Project

our in-house software UniGrid Telecontrol Simulator. The controller under test is integrated into this cyber-physical setup, providing all the flexibility to emulate different grid conditions in a laboratory.

CHIL validation offers testing and development before deployment on- site, minimizing project risks. It aids controller development, reduces downtime caused by on-site testing and potential incorrect operation and/or grid code compliance, and validates the controller ready to go into the market.

This project undertakes the strategic vision for the digitalization of the services offered by the company and the identified needs to support the market's energy transition. This initiative opens a pathway for potential business models for Power Cybernetics in model validation for:

- Smart power devices, and
- Controllers, hardware and software.

Which will be a large percentage of the components that will be found in the grid as the penetration of DER (Dsitributed energy resources) and electrical energy storage systems increases. The project has been carried out in close cooperation between the DNV GL units Global Technology and Research and the business providers at the Renewable Measurements Department in Germany.

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CYBERSEA IN THE CLOUD

Online simulation model library and co-simulation cloud service for digital advisory and classification services.

As cyber-physical systems become increasingly advanced, we see software replacing human decision-making. The safety aspects of such systems must be addressed, and the CyberSea in the Cloud project has developed new simulation-based verification tools to be applied in future advisory and classification services.

To meet the challenges of assuring safe operation of complex integrated systems, the CyberSea in the cloud project aimed to develop a cloud-enabled co-simulation infrastructure, to enable

- Co-simulation as a service
- Standardization of simulation model interface
- Secure sharing and storage of simulation models

Building on CyberSea, the simulation technology from legacy Marine Cybernetics, and findings of DNV GL's Nauticus Twinity project, the project has further developed the technology to run in the cloud, delivering a first version of the ecosystem consisting of the modules Twinity Workbench, Twinity Storage and Twinity Simulator.

In addition, two pilots are set up for testing the concept. One simulates the DNV GL ReVolt autonomous container vessel concept in closed loop with its dynamic positioning (DP) system; another simulates a digital twin of a real offshore supply vessel, incorporating the same Rolls-Royce DP system software used on-board the real vessel.

Twinity Simulator
The maritime industry requires a standardized interface for easier exchange of simulation models and reduced effort to set up simulations. Pioneered by automotive industry OEMs, the functional mock-up interface (FMI) is now starting to become just such an established technology in that domain (fmi-standard.org). By adding support for the Functional Mockup Interface in CyberSea, the resulting Twinity Simulator can co-simulate Functional Mockup Units (FMUs), allowing multiple users to integrate simulation models, originating from various simulation tools, into larger co-simulations.

Twinity Storage
An online repository for secure storage and sharing of simulation models, Twinity Storage consists of

- A web user interface for model management
- Storage for the models and a database for meta data
- An API providing the model management service for other tools

Facilitating model governance and collaboration, this central model repository is a valuable service in its own.

Twinity Workbench
Workbench leverages both simulators and storage to provide co-simulation as a service. Users can set up simulation projects by selecting models from Twinity Storage; use visual tools for model configuration and signal connections; and start new Twinity Simulators which run on virtual computer nodes in the cloud, giving the user execution control and features like signal trending, signal manipulation, and parameter configuration.

As well as giving insight into overall system behaviour by simulating the integration of cyber physical systems, component models and environment models, it enables:

- Early prototyping, system integration and testing
- Virtual commissioning
- Optimization against feature, interface and safety flaws
- Design optimization
- Reliable change management
- Secure exchange of simulation models

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BIGMED

Enabling precision medicine in Norway

‘Precision medicine’ is a medical model that proposes the customization of healthcare, with medical decisions, practices, or products tailored to the individual patient. BigMed aims to lay the foundation for an ICT platform that addresses the bottlenecks for implementation of precision medicine in Norway.

Despite the fact that a single disease can manifest itself differently in different individuals due to the characteristics of the illness itself or a patient’s unique biology, traditional healthcare systems treat diseases with one-size-fits-all remedies. With technological advances and increased molecular knowledge, new opportunities are developing for individualized and personalized care. Clinical use of next-generation genomic sequencing (NGS) is set to change the way healthcare is delivered in the following areas:

- Improved diagnostics for cancer, rare diseases, and infectious diseases;
- Precision treatments through improved drug selection and dosing;
- Development of novel drugs through stratified trials.

«We have large amounts of good data that we do not use well enough. That is why we have the BigMed project.»

Bent Høie, Minister og Health, Norway.

To date however, clinical use of NGS has been slow to realize its potential. The implementation of precision medicine challenges existing healthcare models, technologies, and legal and regulatory frameworks. BigMed is currently the largest precision medicine initiative in Norway, and is funded by the Norwegian Research Council (NRC). The three-year project is hosted by Oslo University Hospital (OUS) and is a joint initiative with 15 partners from both academia and industry. As an important industry partner, DNV GL manages many of the work packages and shares management of the project with OUS.

Through BigMed, we aim to lay the foundation for an ICT platform that addresses the bottlenecks for implementation of precision medicine in Norway. The project makes use of three clinical cases to develop and test technological solutions. These clinical cases are Sudden Cardiac Death (SCD), Colorectal cancer with liver metastasis (CRC) and rare diseases. The challenges addressed through these examples encompass various aspects of precision medicine for individualized decision making, from big data and data analytics to genomics. As an example, the CRC case will draft a clinical decision dashboard designed to gather relevant patient information for clinicians in Multidisciplinary Team (MDT) meetings. The dashboard will enable the team to efficiently create more precise treatment plans for CRC patients.

Genomic information is an integral part of this picture. BigMed will also develop tools to make clinical genomics data available and actionable. These include genomic databases and decision support tools that enable controlled use of structured data across different patient samples, institutions and borders. These facilitate the identification of similar patient cases, thereby increasing the diagnostic sensitivity for rare diseases. There is also a focus on the development of quality assurance frameworks for processes throughout the analytical pipeline. The combination of these two aspects has the effect of and potential to drive quality improvement in the field, where equity in healthcare is a recognized goal.

Precision medicine means tailoring diagnostics and treatment for individual patients for which capturing the full breadth of human variation is a prerequisite, As a result, there is a need for trusted, large-scale datasets as a basis for knowledge building and consequent clinical decision making.

CONTACT PERSONS

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REASON-MD

The digital future of medical device assurance

REASON-MD is a digital inference tool for smart conformity assessment of medical device.

The medical device industry, alongside pharmaceuticals, are some of the most tightly regulated industries. An extensive compliance assessment is generally required prior to market authorization, a process that takes an average of 210 man-days shared between manufacturers and Notified Bodies. In the interests of improving patient safety, medical device regulations are becoming more stringent in response to rapid technology innovation and the globalization of medical device manufacturing processes. The European Parliament recently published new Medical Device Regulations (MDR) in May 2017, with more stringent requirements governing manufacturers and Notified Bodies. Changing rules and regulations is a major concern for this industry, especially for the small and medium enterprises (SMEs) who may not be equipped to comply with the changing requirements. Knowing that most medical device manufacturers are SMEs, business-as–usual for conformity assessment is not an option.

In response to the challenges described above, together with Business Assurance, the Life Sciences program has developed a new digital solution, REASON-MD, for medical device conformance management for manufacturers, their suppliers, and Notified Bodies.

«Reason MD is a unique tool, which increases the efficiency of conformity assessment, both for the manufacturer of devices and the certification body evaluating them.»

Otto Hughes Global Product Assurance Manager Business Assurance, DNV GL

REASON-MD is based on existing DNV GL tool which demonstrated a 30% efficiency gain for technology qualification in DNV GL Oil and Gas. Specifically, REASON-MD contains an IT inference tool which arranges and links supporting documents in a logical way to support a specific claim, such as claim of conformity or a sub-clause requirements of a standard. Moreover, REASON-MD utilizes an in-house template that echoes medical device rules and regulations (the current version of the template is based on European Commission Medical Device Directive - MDD). With REASON-MD, manufacturers can prepare their conformity application using the template and perform detailed self-assessment before submission to a Notified Body. Assessment results of all specific requirements and their impact on the overall product conformity are registered and visualized through color-coding, providing a comprehensive overview to manufacturers and Notified Body assessors at all time. Notified Body assessors can remotely access the conformity application of the device and address areas of non-conformity.

In summary, REASON-MD provides:

- Prepopulated conformance templates based on rules and regulations
- A logical and flexible way to link all compliance requirements to supporting documents
- Automatic reporting functionalities
- Real-time conformity monitoring and change management reporting
- Suppliers' conformity management

The functionality of REASON-MD has been validated by medical device assessors, and a trial is currently ongoing to evaluate the usability of the tool by a medical device manufacturer, and provide input for further development.

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SAFE AND SUSTAINABLE AQUACULTURE

The aquaculture industry pursues new territories for sustainable food production to the growing world population. One approach is expanding from near-shore to installations further away from the coastline. The rougher conditions require knowledge-building in several areas, such as site structures, fish welfare and working conditions for employees.

GTR in DNV GL has identified drivers, opportunities and challenges as aquaculture farming expands into more exposed areas. The development is, among other, a consequence of environmental challenges in the fjords, the challenge of mitigating lice, and spatial conflicts. This is especially prevalent in salmon farming but also other species run into similar challenges.

The new locations, the new installations and the support systems gives a more complex aquaculture industry. This requires more advanced integrated technologies and digitalization tools, creating an opportunity for DNV GL to build on existing aquaculture services:

- **Structural strength calculations:** new standards and rules will enable bigger, better structures.
- **Certification** in the food supply chain: standards will develop, especially regarding sustainability and transparency requirements.

«The development is, among other, a consequence of environmental challenges in the fjords, the challenge of mitigating lice, and spatial conflicts.»

Ole Andreas Flagstad - Project Manager for the Safe and Sustainable Aquaculture Project

- In addition, **technological development** will require facilitation throughout the value chain, providing opportunities for a variety of existing and new professionals.
- **Logistics.** Current food supply chains are often long and simplifications are to be expected. Push from market and existing bottlenecks are driving this. It will also include specialisations of vessels used in the operations.
- **Genetics.** Advancements in genetics allow for breeding based on individual fish genetics rather than the generic print of a broodstock family. Knowledge at individual level is also key to develop vaccines targeted for the individual fish.
- **Disease mitigation.** Sea lice are the main challenge for this industry, and considerable resources are being invested in finding a solution. Relocation, gene-editing and cage developments are some of the approaches currently being employed.
- **Improved recirculation** technologies allow longer growing period in tanks, which will facilitate offshore aquaculture by providing bigger post-smolt fish for harsher water conditions. At the same time, the ongoing development provides an opportunity to keep the full production cycle onshore.
- **Digitalization** will affect operations by providing new tools and systems for automation, safety and other uses.

DNV GL will work with aquaculture actors to build knowledge and implement new technologies to achieve sustainable growth and enable safe solutions in the industry.development.

CONTACT PERSONS

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TQ 4.0
Technology Qualification supporting the «fourth industrial revolution»

The coming years will see increasing automation, autonomy, use of complex software-dependent systems, and data volumes. The implementation of such systems in subsea installations requires that operators have sufficient confidence in these technologies and are able to qualify them within time and budget constraints.

As systems become more automated and autonomous, being capable of handling software-intensive and increasingly complex systems will become more important. DNV-RP-A203 and related service documents must therefore be updated with regards to enhanced focus on qualification of software and software-intensive systems. Current qualification methods largely rely on those developed for hardware systems. However, hardware- and software-dependent systems are typically failing for different reasons.

Based on work performed by Group Technology & Research (GTR) and feedback from two round-table workshops with upstream oil & gas industry operators in 2016, GTR developed TQ 4.0 in collaboration with DNV GL Oil & Gas. The project was initiated to improve existing methods for technology qualification with regards to the systems- and software perspective including development of a digitalized TQ service. Our main customer for the outcome of this work are oil and gas operators, but system integrators and suppliers will also benefit from

«The TQ 4.0 project will position DNV GL as an independent party, helping the industry cut costs and increase innovation»

a digitalized- system qualification approach to technology qualification. For operators, the main value lies in allowing faster and easier development and implementation of new technology. For suppliers, the value lies in faster market access for new products.

Operators need DNV GL assurance to build trust when employing a new technology to ensure its safety and reliability. The TQ 4.0 project will position DNV GL as an independent party, helping the industry cut costs and increase innovation, through:

- **A digital platform** for TQ services based on the REASON tool, which enables a more efficient co-operation with the customer and keeps track of qualification documentation and progress, allowing us to meet increasing cost pressure without compromising quality. This platform provides a framework and a basis for industry harmonization of TQ and information sharing.

- **Updated guidelines** for managing the full system perspective in TQ with focus on systems, software and subsea technology. These guidelines focus on a systems' approach to qualification, i.e. from today's hardware focus to system focus, such as assurance based methods, function- based failure mode analysis and system hazard analysis.

- **Establishing a TQ industry forum** for knowledge sharing, compromising operators and vendors in the upstream oil & gas industry. The forum has provided input to the work in the TQ 4.0 project and will continue in 2018 as part of updating the DNVGL TQ service documents. The forum has also acted as an informal meeting place to discuss experience from the application of DNV-RP-A203 in the upstream oil & gas sector.

Our customer workshops revealed that our approach would cut costs and enable faster qualification through reuse and sharing of qualification efforts. Increased harmonization of TQ procedures, standardized documentation of TQ efforts, and closer integration of the TQ process with the project development process (Capital Value Process) are important aspects that facilitate this. The work carried in TQ 4.0 will be used to update DNV-RP-A203 and DNVGL-SE-0160 in 2018.development.

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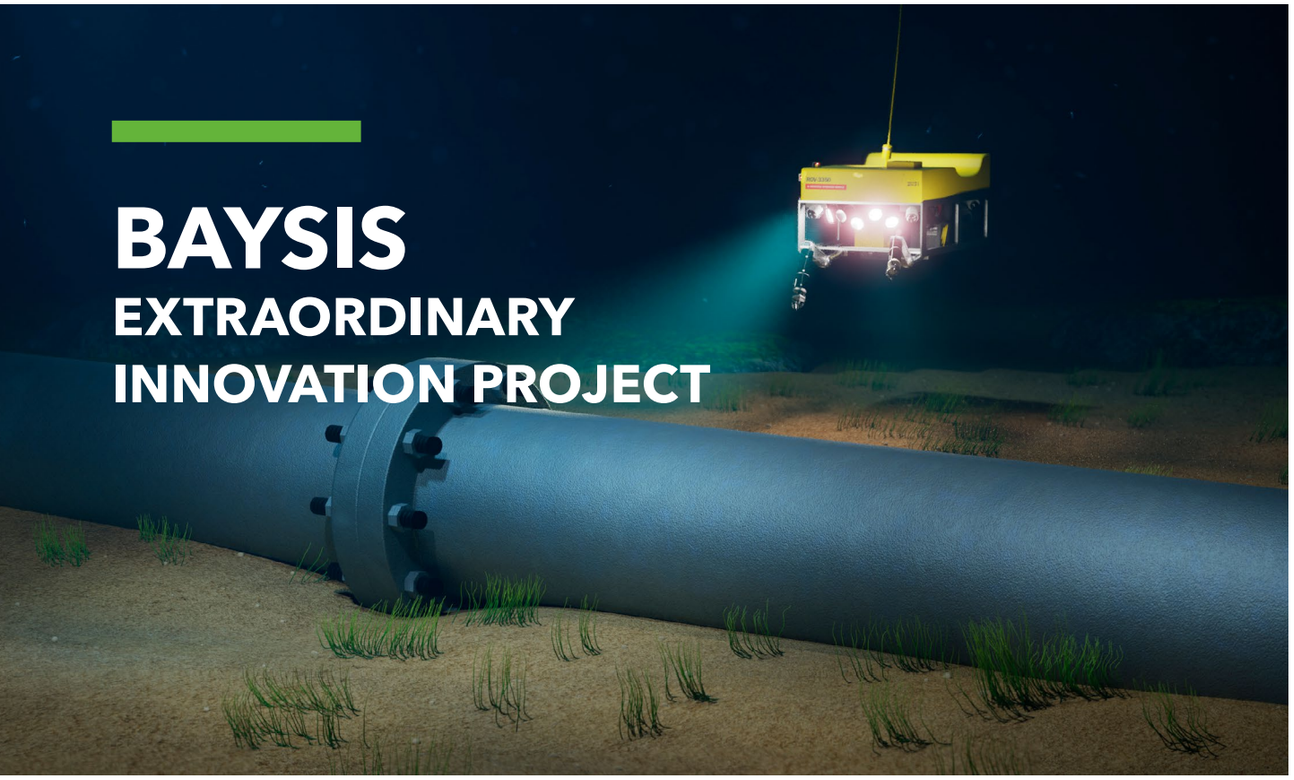


BAYSIS
EXTRAORDINARY INNOVATION PROJECT

Once a year, DNV GL invites its employees to propose extraordinary innovation projects that explore new ideas or concepts. The final project selection is made by the Group President and CEO.

The selected projects work intensively for 3–5 months before presenting their results to all DNV GL employees. This year, two projects ran during the spring with delivery in June. A third project was carried out during the autumn and was presented in November. The projects are:

- «Baysis»
- «Big data custodian-Aquaculture»
- «Nerves of Steel»

Below, the main ideas and innovation in the «Baysis» project is outlined.

At the very core of advisory services performed by DNV GL lies development, and maintaining various models that encapsulates the technical issues our experts are looking at. The models are aligned with our standards and recommended practices and therefore acts as knowledge banks for the industry. In the digital change, it is nothing but a natural step to let our industry partners interact with DNV GL hosted models and extract results themselves.

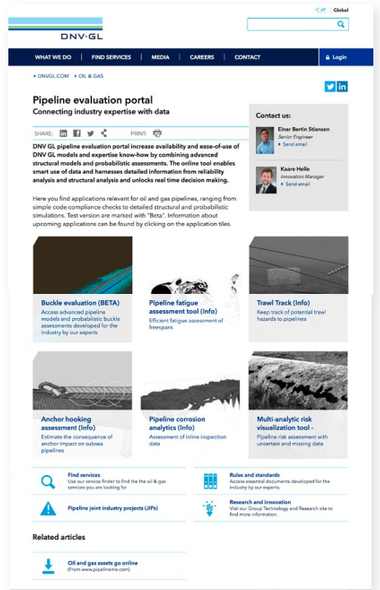
«A user will now be able to ask questions such as «how safe is my pipeline?» and «Will altering the operational parameters jeopardize the code compliance?»

The “Baysis” project demonstrated how a model quantifying the probability of failure for lateral buckling of subsea pipelines may be implemented and delivered as an online service. The project established a fully operational web page where a user can change parameters relevant for pipeline operation and receive instant feedback from the model on how the probability of failure is influenced. The interactive service makes use of Bayesian networks to model the interdependencies of uncertain parameters, and applies machine learning on a pre-populated database of finite element analyses results. A combination which creates a workflow similar to that of high-level screening tools, but with the accuracy of finite element analyses.

A user will now be able to ask questions such as “how safe is my pipeline?”, and “Will altering the operational parameters jeopardize the code compliance?”, and receive responses in real-time with limited DNV GL involvement. This has the potential to bring DNV GL and our industry partners closer together, and at the same time increase the efficiency of our services.

The innovation project targeted a specific type of problem: Physical response of structures paired with probability analysis. This class of problems requires models combining physics with statistics and probability theory. These are the key components of Structural Reliability Analysis (SRA), which constitutes the basis for our offshore standard and recommended practices. Such models have been established through years of research and industry experience, and are continuously being improved and developed further to serve as state-of-the-art resources.

Our vision is to provide access to results from our quality assured models, through the digital interface, “Pipeline Evaluation Portal”, where our customers can interact with the results they need – whenever they need it.



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TECHNOLOGY EXCELLENCE NETWORKS

DNV GL puts considerable effort into developing new competencies, methods and tools, and Technology Excellence Networks (TENs) stimulate and support this through cross Business Area collaboration. As well as leading to new commercial assignments and Joint Industry Projects for DNV GL, TENs contribute to making DNV GL an attractive employer for top technical talents and experts.

GROUP TECHNOLOGY AND RESEARCH

Group Technology and Research enables long-term business growth through strategic research and technology development and innovation activities. We are organized in seven programmes, of which four are aligned with the main industries we serve and three are cross-industry. Our deliverables are principally: i) position papers describing emerging technologies and their impacts, and ii) pilot technology concepts as milestones towards novel products for DNV GL's business areas.

TECHNOLOGY EXCELLENCE NETWORKS

In 2017 we introduced the new TENs, an evolution of the Technology Leadership Programs we had in the past, to increase impact through focus. We deliver one large Demo Case Project per TEN, introducing new topical areas addressing the priorities in the current strategy, and accelerating technology uptake through joint development of technologies. Each is run by a TEN Manager leading an Expert Panel nominated from the Business Areas/ wider DNV GL.

These panels are responsible for selecting their TEN Demo Case project, which must:

- Facilitate technology collaboration across the Business Areas
- Accelerate uptake through transfer of existing solutions to another Business Area
- Focus on joint solutions through cross BA technology development
- Support knowledge exchange and increase competence in the selected technology areas.

SUSTAINABLE AND INTEGRATED ENERGY SOLUTIONS

Objective

Bootstrap a pathway towards sustainable energy.

Demo case project:

The Energy Transition Game

- Combine upstream variable renewables power generation with power-to-gas and storage on a fictitious 'island'.
- Investigate integrated energy solutions in different rounds in a transition path
- using real power and gas load models, demand profiles, economics, software and hardware.
- Gain insight into the drivers, behaviour of actors and markets, integration possibilities, complexity and consequences of the energy transition phases
- Test the assumptions in DNV GL's Energy Transition Outlook, providing an illustrative demonstration for customers.

EMERGING DIGITAL SOLUTIONS

Objective

Explore new digital technologies for use across all business areas.

Demo case project:

Hyperspectral Imaging

- Evaluate feasibility and business potential for detection of corrosion, coating breakdown or other structural findings with hyperspectral imaging technology.
- Automated detection and assessment of structural degradation.
- Enhance remote sensing capabilities
- Reduce scope of manual close-up inspections

CYBER PHYSICAL SYSTEMS

Objective

Strengthen DNV GL's position as a technology leader, aligning and developing our competencies in cyber-physical and integrated machinery systems.

Demo case project:

Improving cyber security verification competence in DNV GL

- Develop cyber security test and training labs in Trondheim and Madrid
- Extend BA cyber security understanding into automative, and use of the ProtoCrawler fuzz test tool into maritime
- Develop global cyber security training program
- Establish practical guide on how to choose assets to test based on cyber security RP-G108, including checklist

FUTURE PROFITABLE BUSINESS AND DELIVERY MODELS

Objective

Select, run and share results from the selected cross- BA Demonstrator Project to increase awareness and generate insights, contributing to a successful transformation of DNV GL's business model for the digital age.

Demo case project:

Develop, test and refine business model for assurance services with significant automation and customer self-service element

- Assess and identify similarities in the design verification process for four identified BA applications; Offshore Containers, CMC self-service for simple components, Turbine Certification and Certification of Medical Equipment
- Develop a cross BA prototype business and delivery model for assurance services, exploring value proposition, pricing and cost models, changes in delivery, sales, customer services and interaction, maintenance of services, tasks, competence and skillsets and impact on HR strategies
- Test out the business model on the four selected BA cases, updating the model if needed

RISK MANAGEMENT

Objective

Develop and maintain DNV GL's technology leadership position within services based on risk-management principles and the technology behind risk, reliability and human factors.

Demo case project:

Develop the concept of a Human Digital Twin (HDT)

- The current version of the HDT visualizes how humans interact with a physical asset using sensor data to improve performance.
- In the future, the HDT could be used to simulate training for real-time risk management and risk prediction on individual, group or asset level, with augmented reality procedures and human behaviour tracking capabilities presented in 4d (adding time) and used as a basis for human behaviour modelling and machine learnin.

FLUID DYNAMICS

Objective

Strengthen DNV GL's position in fluid dynamics through high-performance technical projects.

Demo case project:

'The Next Wave'

- Apply Higher Order Spectral Method (HOSM) wave model to ocean engineering problems relevant for Oil & Gas, Maritime, Energy and Software business areas.
- Deliver implementation of HOSM in existing tools, framework development and a software library with a well-documented Application Program Interface (API).

MATERIALS AND STRUCTURES

Objective

Develop innovative, cost effective and safe structures using advanced numerical modelling and simulation.

Demo case project:

Connecting materials models and simulations across length and time scales

- Conceptualize a framework of models for the next generation of material selection from codes to e.g. machine learning. Delineate a strategy for selecting of constitutive material models for use in design pipelines, mooring lines and hull structures, Addressing steel, composites and polymers.

Demo case 2:

Structural health/integrity status in operation based on smart use of numerical models in combination with monitoring.

- Utilize and complement the sensor scope by making use of our physical models and knowledge. Calculate load effects relevant for evaluating the structural integrity.

INDUSTRY-ALIGNED PROGRAMMES

New knowledge in key areas with long term impact

MARITIME

Objective

Develop knowledge and prototype services for accelerating the safe and sustainable uptake of digital and automated solutions in shipping.

Themes:

- Digital Class
- Remote Controlled and Autonomous Ships
- Safe and Sustainable Shipping

POWER & RENEWABLES

Objective

Build competence, methods and tools to achieve competitive advantage and prepare DNV GL for the future of the rapid changing power industry.

Themes:

- Super Grid
- Smart Grid
- Energy Storage
- Renewables

OIL & GAS

Objective

Develop the foundations and prototypes for risk-based and model-centric services on system level, enabling BA Oil & Gas to provide new disruptive services in their market.

Themes:

- Subsea System Qualification
- Virtual System Testing
- Real-time Risk Management

LIFE SCIENCES

Objective

Support the development of DNV GL in the life sciences sector focusing on Preserving Health and Providing Food by building knowledge, developing consepts and service prototypes

Themes:

- Future healthcare systems
- Precision Medicine
- Interconnected Food Safety

OCEAN SPACE

Objective

Contribute to building knowledge and develop the foundations and prototypes enabling DNV GL to provide services to new ocean industries.

Themes:

- Offshore Food Production
- Ocean Stewardship
- Ocean subsurface resources

DIGITAL ASSURANCE

Objective

Develop methods and systems enabling real-time TIC services and mastering the complexity and integration of cyber-physical systems

Themes:

- Emerging digital technologies
- Digital Class
- Cyber-physical Systems' verification

CLIMATE ACTION

Objective

Develop knowledge and associated products that address the low-carbon energy transition and risk-based decision making for climate resilience, adaptation and disaster management

Themes:

- Resilience, adaptation & disaster management
- Climate Change governance
- Energy Transition

MORE INFORMATION

For more information of the different programs and related projects – please visit our Technology and Innovation pages at:

https://www.dnvgl.com/technology-innovation/index.html

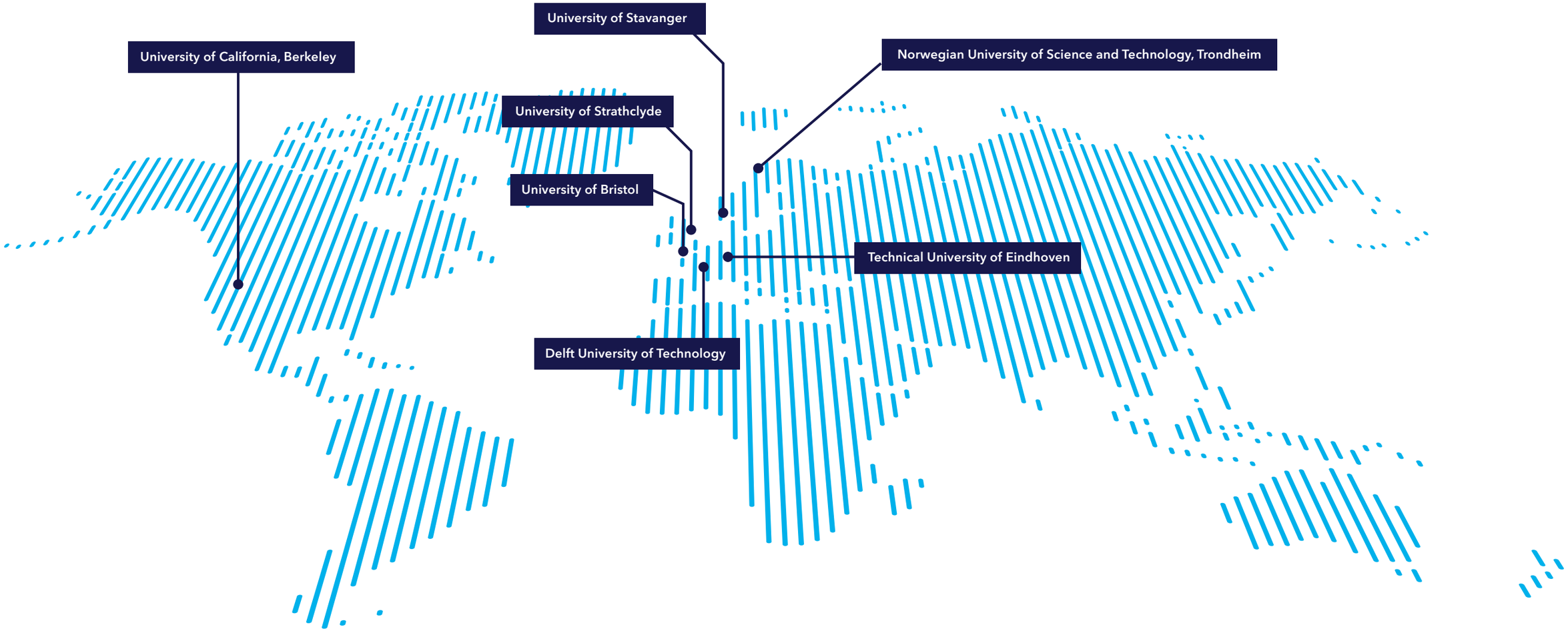
UNIVERSITY RELATIONS

DNV GL is a knowledge-based company, constantly developing our services based on new industry experience and scientific progress. Important knowledge is created and applied at the interface between academia, industry and DNV GL.

DNV GL's interactions with universities include the sponsoring of professorships, lectures by our employees, common research projects, and the supervision of students. DNV GL also collaborates closely with top international universities through programmes for leadership development and sustaining cutting-edge technical expertise.

DNV GL's relationships with universities provide many benefits to both organizations:

- Universities provide the knowledge base underpinning most of the services offered by DNV GL, acting as incubators for new ideas
- DNV GL has been able to recruit accomplished graduates from the universities it supports
- Universities provide places for DNV GL staff to conduct innovative research that complements their activities in DNV GL
- The relationships provide important branding benefits to both organizations



PERSONAL HIGHLIGHTS

Christian Agrell, senior researcher, Oil & Gas

As a mathematician 2017 has been a very exciting year with our ambitious strategy on digitalization and machine learning technologies. Coming from the Oil & Gas business area I have, through various digital innovation projects, explored how our core services, based upon probabilistic modelling of physical systems, can evolve with these new technologies. I believe that for safety critical models relying on machine learning, understanding the flow of uncertainty and associated risks will be important for DNV GL in the years to come. I'm excited to continue this work through a PhD project in the GTR Oil & Gas program.

Guro Meldre, principal researcher, Life Sciences

2017 is the year we made great advances to position DNV GL as a third-party enabler of precision medicine. Through the BigMed project we are exploring and testing the legal and technical possibilities for sharing of quality assured data on genetic variants. Taking the lead with the BigMed white paper on precision medicine in Norway, we are harvesting knowledge from a wide range of stakeholders. The crescendo of the year will be hosting the first ever symposium of the Nordic Alliance for Sequencing and Personalized Medicine at Høvik in November, organized in collaboration with leading clinical genomics laboratories.

Onur Özgün, senior researcher, Climate Action

2017 has been a very rewarding year for me. We published DNV GL's first Energy Transition Outlook after a busy and challenging development period, and I had the opportunity to work closely with many colleagues from BA Energy, Oil & Gas, and Maritime, and from research, to understand and model the energy supply chain. It is very exciting to be part of this project not only because of the personal development and networking opportunities it brings, but also for the chance to have a direct contribution to DNV GL's vision of global impact for a safe and sustainable future.

Alejandra Fabian, researcher, Power & Renewables

This year I have started my journey at the GTR Power and Renewables team as a researcher for Power Cybernetics. From the very beginning, I had the opportunity to be fully in charge for my first project, the development of a control hardware in the loop test bench for the validation of a wind farm controller (see related article). This challenging and exciting project has helped me to dive into the modeling and grid codes, and get my hands on the laboratory equipment. Following the successful conclusion of the project, I am motivated to keep on working on research that allows us to build trust and support the renewable energy integration.

Øystein Engelhardtsen, senior researcher, Maritime

2017 has been an exciting year for me and my colleagues focusing our research on remote- and autonomous operation of ship functions. Over the last few years, we have witnessed a near exponential increase of attention from the maritime industry in this field. This has culminated in the announcement of the building of Yara Birkeland this year, a vessel nearly identical to the ReVolt concept we released in 2014. It is inspiring to be a part of this pioneering development, challenging so many of the established standards for safety and therefore raising so many more interesting questions for us to tackle.

Odd Ivar Haugen, principal researcher, Digital Assurance

Coming from Marine Cybernetics, which was acquired by DNVGL three years ago, 2017 was my first year in GTR - Digital Assurance. In addition to an interesting research project, this year has been about adapting to the new working environment and colleagues. I am particularly happy how we, the newcomers from Trondheim, have been received in GTR. Our new colleagues in GTR have been genuinely interested, and curious about the knowledge and capabilities of GTR-DA. Personally, I've been working closely with "Oil&Gas and Energy Systems" regarding new approaches to Technology Qualification of complex software intensive systems.

DNV GL GROUP TECHNOLOGY & RESEARCH PUBLICATIONS 2017

This list contains publications authored by DNV GL employees in scientific journals, conference proceedings or other papers made available for public access in 2017. External, non DNV GL employees may have contributed as authors to some of these publications, but only DNVGL authors are listed in this publications list

The following publications are available digitally.
Links where last accessed 1st of December 2017.

Climate Action

A sea level rise simulator for coastal communities
Author: Bradd Libby, Alexander Christiansen Flesjø Paper presented at 35th International Conference of the System Dynamics Society, 16.–20. July, 2017, Cambridge, Massachusetts, US Proceedings

Changing cities in a changing climate: systems thinking: a foundation for resilience
Author: Alexander F. Christiansen, Bradd Libby, Mark Irvine; Onur Özgün; Vidyunmala Veldore

Component importance in infrastructure networks subject to spatially distributed hazards
Author: Luca Garrè, Yongtao Yang Paper presented at 26th European Safety and Reliability Conference, ESREL 2016, 25. – 29. September 2016, Glasgow, UK. Published in Risk, Reliability and Safety: Innovating Theory and Practice, Edited by Lesley Walls, Matthew Revie and Tim Bedford, CRS Press 2017, pages 362-371

Energy transition outlook 2017: a global and regional forecast of the energy transition to 2050
Author: Sverre Alvik, Bent Erik Bakken, Caroline Brun Ellefsen, Özgün, Onur, Erik Dugstad, Anne Louise Koefoed, Mark Irvine(Editor) The report has been prepared by DNV GL as a cross-disciplinary excercise between the DNV GL Group and our business areas of Oil & Gas, Energy, and Maritime.

One world or two? Science–policy interactions in the climate field
Author: St. Clair, Asuncion Lera et al Notes: Critical Policy Studies, 10. September 2017, pages 1-21

On the relationship between climate sensitivity and modelling uncertainty
Author: Tatjana Zivkovic, Vidyunmala Veldore Notes: published in Tellus A: Dynamic Meteorology and Oceanography, 2017, Volume 69, Issue 1, pages 1327765.

Realizing tomorrows value: The emergence of a new business practice
Author: Anne Louise Koefoed, Caroline Brun Ellefsen, Erik Andreas Hektor, Cecilie Hultmann

Realizing tomorrow's value – Understanding the principles underpinning a green & inclusive economy and their consequences for disclosure
Author: Anne Louise Koefoed Notes: Presentation held at 4th International Conference of the Reporting 3.0 platform 2017. Disclosure for the Green, Inclusive & Open Economy - Blueprinting the Future, 30.-31. May 2017, Amsterdam, Netherlands

Reliability and Component Importance in Networks Subject to Spatially Distributed Hazards Followed by Cascading Failures
Author: Luca Garrè Notes: Published in ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part B: Mechanical Engineering, Volume 3, Issue 2, 2017

Stepping up to drive change in Climate Policy Outlook 2017
Author: Sverre Alvik, Bent Erik Bakken, Anne Louise Koefoed

The tail equivalent linearization method for nonlinear stochastic processes, genesis and developments
Author: Luca Garrè Published in Risk and Reliability Analysis: Theory and Applications, Springer Series in Reliability Engineering, Springer International Publishing, 2017. - 34 p

Transforming communication and knowledge production processes to address high-end climate change
Author: Asun Lera St. Clair Published in Environmental Science & Policy, Volume 70, April 2017, Pages 31-37

Life Sciences

A safety culture assessment by mixed methods at a public maternity and infant hospital in China
Author: Tita Alissa Listyowardojo; Stephen Leyshon; Bobbie Ray-Sannerud Published in: Journal of Multidisciplinary Healthcare, 3 July 2017, Volume 2017:10, Pages 253–262 Available through:

Building sustainable alarm systems in healthcare
Author: Tita Listyowardojo, Eva Turk, Lars-Martin Berglund
Available through:

How regulators assess and accredit safety and quality in surgical services
Author: Stephen Leyshon, Tita Listyowardojo Bach, Eva Turk, Aileen Orr, Bobbie N. Ray-Sannerud Published in: Surgical Patient Care: Improving Safety, Quality and Value, Springer International Publisher 2017, Pages 755-783

Internet of people: White Paper 2017
Author: Turk, Eva, Listyowardojo, Tita Alissa, Berglund, Lars-Martin, Thrane, Jon Eivind, Courivaud, Frédéric, Alagaratnam, Sharmini, Ghaem Maralani, Shahram, Kadal, Jørgen Chistian, Binz, Vibeke, Løvaas, Jahn Henry, Pedersen, Guro Meldre and Ray-Sannerud, Bobbie Nicole.

Maritime

A comparison study on the estimation of extreme structural response from different environmental contour methods
Author: Erik Vanem Published in: Marine Structures, Volume 56, November 2017, pp 137-162

Anomaly detection using dynamical linear models and sequential testing on a marine engine system
Author: Erik Vanem Published in: Proceedings of the Annual Conference of the Prognostics and Health Management Society 2017 (PHM 2017), St. Petersburg, Florida, USA, October 2-5 2017, pp. 185-200

A novel measure to reduce ship resistance in waves
Author: Bingjie Guo, Bjørn-Johan Vartdal, Sverre Steen Paper presented at: ASME 36th International Conference on Ocean, Offshore and Arctic Engineering, OMAE2017, June 25-30, 2017, Trondheim, Norway OMAE2017-61949

A regional extreme value analysis of ocean waves in a changing climate
Author: Erik Vanem Published in: Ocean Engineering, Volume 144, 1 November 2017, pp 277-295

Battery-powered ships: A class society perspective
Author: Øystein Åsheim Alnes, Bjørn-Johan Vartdal Notes: Published in Institute of Electrical and Electronics Engineers, IEEE Electrification Magazine, 2017, volume 5, issue 3, pp 10-21

Climate change and safe design of ship structures
Author: Elzbieta M. Bitner-Gregersen, Erik Vanem, Gramstad, O. Available through: Ocean Engineering, OE-D-17-01105, 2017.

Climatic forecasting of wind and waves using fuzzy interference systems
Author: Erik Vanem Paper presented at: ASME 36th International Conference on Ocean, Offshore and Arctic Engineering, OMAE2017, June 25-30, 2017, Trondheim, Norway.

Cluster based anomaly detection with applications in the maritime industry.
Author: Andreas Brandsæter, Erik Vanem Paper presented at: 2017 International Conference on Sensing, Diagnostics, Prognostics, and Control (SDPC), IEEE Reliability Society, Shanghai Aircraft Customer Service Corporation, China, 16. - 18. August 2017

Comparison of wind and wave climate in open sea and coastal waters
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