UK National Clean Maritime Research Hub

Clean Maritime Assembly 2026

Collaboration | Innovation | Transformation

Engineering and Physical Sciences Research Council

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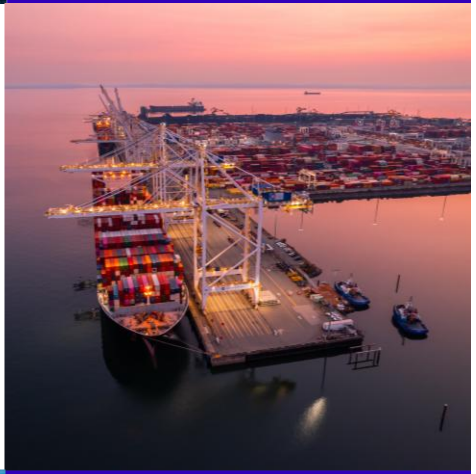
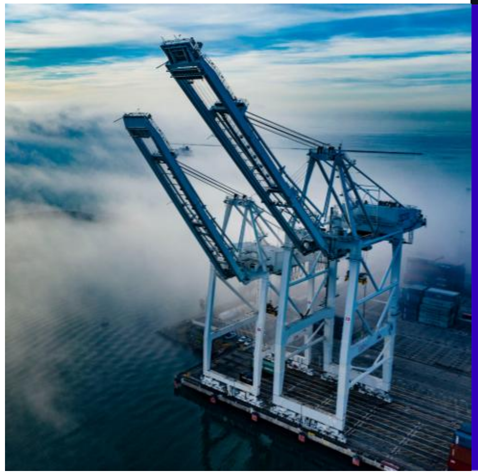
Beyond the Horizon

Session 1

DNV Spadeadam: Advancing the Maritime Energy Transition Through Large-Scale Testing

- Hosted by Mike Johnson, DNV





WHEN TRUST MATTERS

Advancing the Maritime Energy Transition Through Large-Scale Testing

Mike Johnson, Dan Allason

24 June 2026

Overview

- Introduction to DNV Spadeadam
- Hazardous events and process safety
- Case study – LNG as a maritime fuel
- Energy transition
  - Implications of introducing new fuels
  - Gaps in understanding
- Summary
- Q&A

A global assurance and risk management company

15,000+
employees

100,000+
customers

100+
countries

5%+
of revenue to R&D

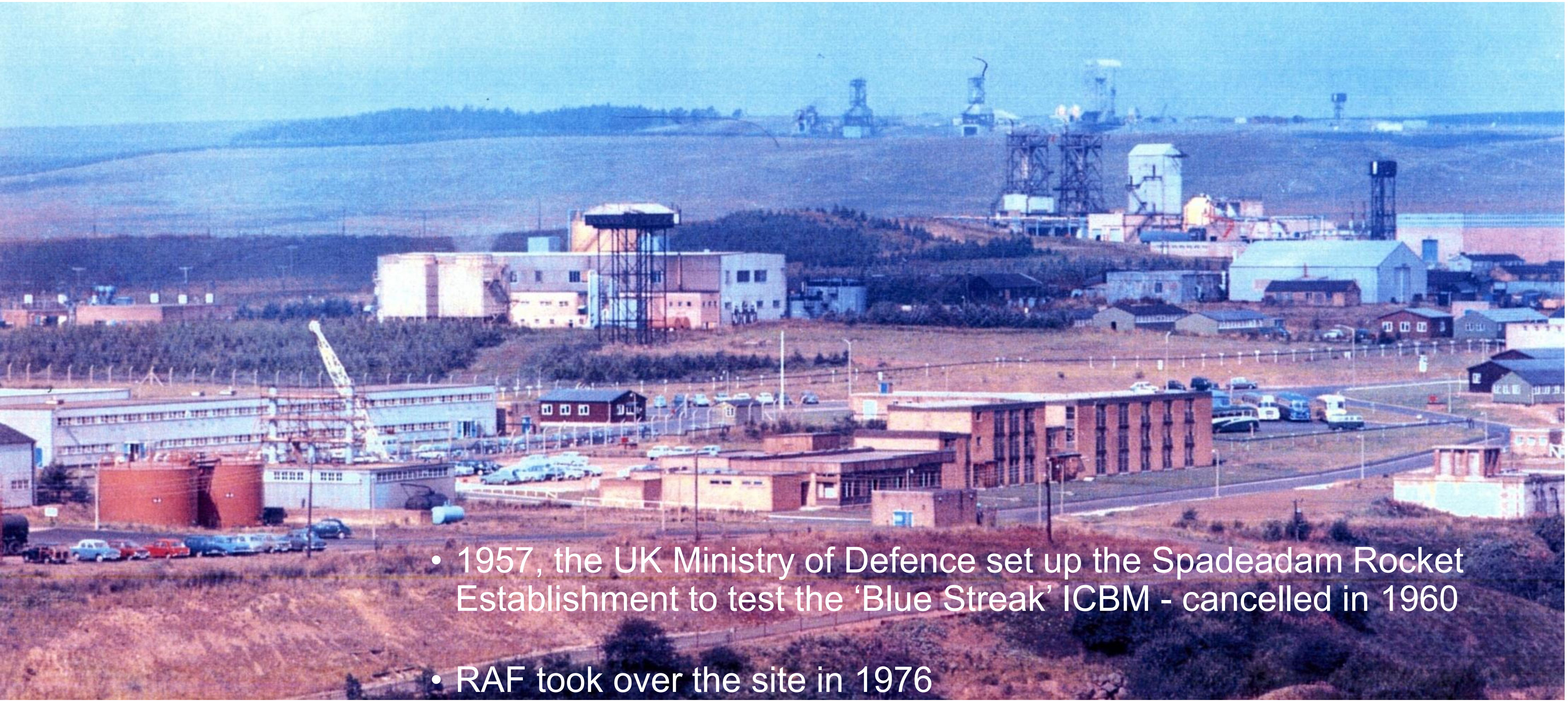
Ship and offshore classification and advisory

Energy advisory, certification, verification, inspection and monitoring

Software, cyber security, platforms and digital solutions

Management system certification, supply chain and product assurance

Spadeadam Site Heritage and History



- 1957, the UK Ministry of Defence set up the Spadeadam Rocket Establishment to test the 'Blue Streak' ICBM - cancelled in 1960
- RAF took over the site in 1976

DNV Spadeadam

- Leased from UK Ministry of Defence in 1977
  - Study of pipeline rupture
  - Continuously manned since then
- Remote & secure site covering an area of 60 hectares
- Safe conduct of potentially hazardous research and testing

DNV

BLEVE of LPG Vessel

Process Safety:

Management of Major Accident Hazards

Case Study – Onshore Gas Terminal

- What hazards can you see in this picture?
- What are the potential consequences?

Work Area

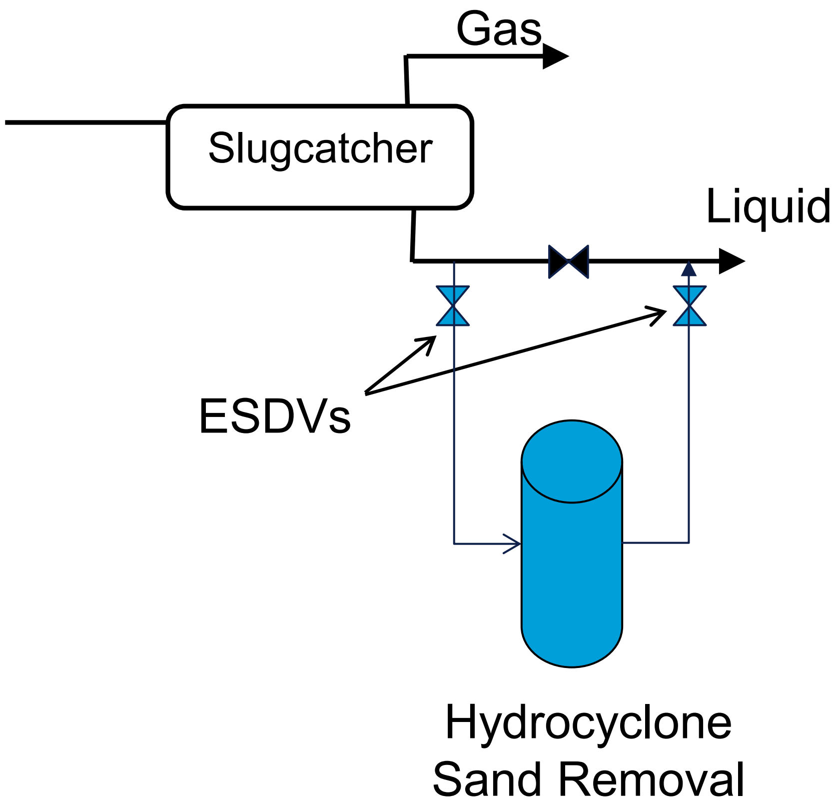

Finger type slugcatcher,
Inventory >20 Tonnes of high pressure gas
Work area by ‘Boot’ for collecting liquids
MERPRO

Hazard Management

- Operator experienced sand production into the slugcatcher
  - Filling Boot forcing shutdown

- Temporary solution: installed a hydrocyclone to separate sand from condensate

- Remotely operated Emergency Shutdown Valves (ESDVs) to be fitted to isolate from the slugcatcher if a leak occurred on the temporary pipework



The Problem

- So, what type of valve is installed on the temporary pipework?

Why was a Manual Valve Fitted?

- ESDV failed, spare not available
- Manual valve fitted as replacement
- Valve would be inaccessible if a leak occurred
- Contents of the slugcatcher would be released (more than 20 tonnes)
- But the most likely outcome – an easier life!!
- The risk is hidden (literally in this case)

Case Study – LNG

Some History for the UK

- The British Gas Corporation was formed from the nationalisation of more than 1,000 independent gas companies
  - Producing Towns Gas from coal

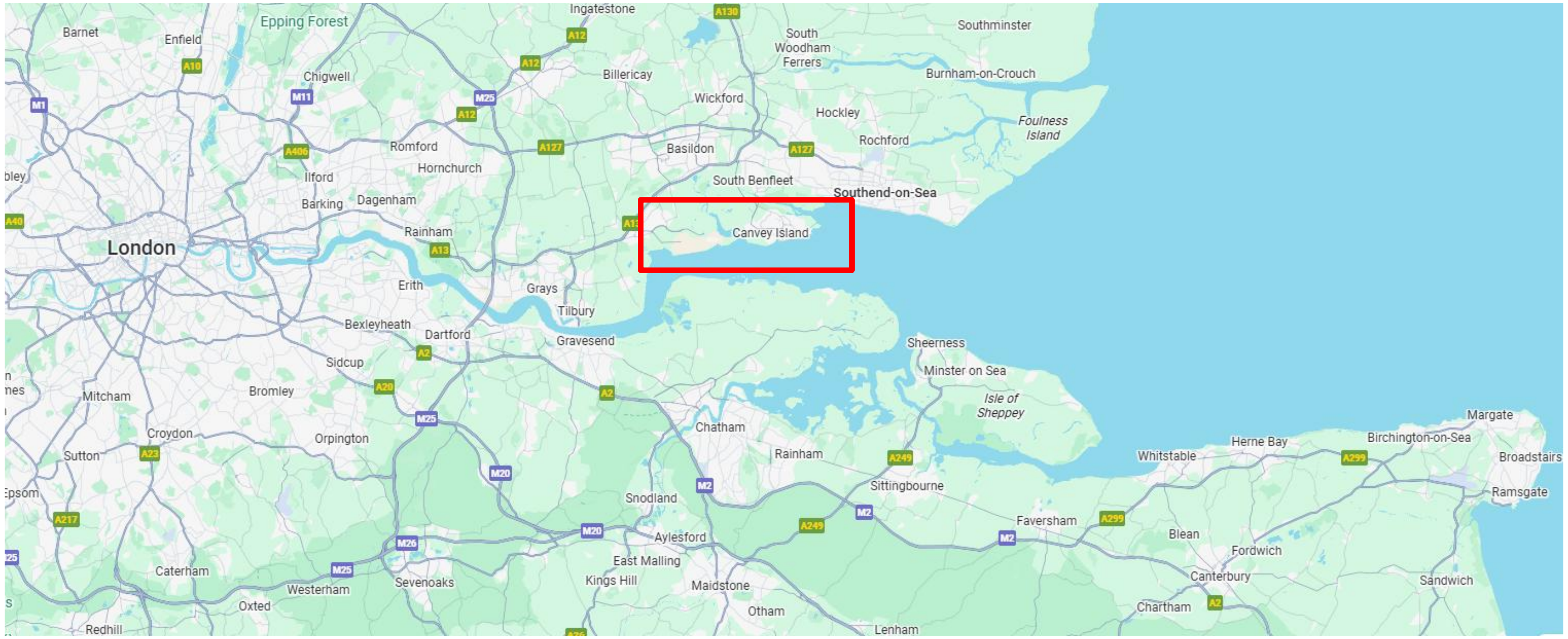
- There was a pressing need to modernise the industry

The Transition to Natural Gas

- The world's first ocean cargo of LNG was delivered from Louisiana to Canvey Island, Thames Estuary, UK in 1959
- This was followed by the first commercial LNG operations from Algeria in 1964
- The development of LNG transportation and onshore storage resulted in concerns about the hazards

North Thames Estuary

- In the 1970s the Thurrock and Canvey Island area on the North Thames estuary hosted a considerable number of petrochemical facilities as well as the LNG terminal
- Additionally, there were proposals for further expansion



Public Concern and Response

- The residents expressed their views
- In response, the government commissioned a public inquiry into the major hazards
- The UK HSE published two reports*
- The LNG terminal was allowed to continue in operation if improvements were made

* *Canvey : An investigation of potential hazards from operations in the Canvey Island/Thurrock area. Publ. HMSO 1978.*
Canvey : A second report. A review of potential hazards from operations in the Canvey Island/Thurrock area three years after the publication of the Canvey Report. Publ. HMSO 1981.

Major Hazards Research

- A significant amount of experimental research was carried out during the 1980’s to understand LNG hazards
  - Dispersion
  - Pool fires
  - Explosions (vapour cloud and rapid phase transition)

Influencing Design and Operations

Experiments
- Provide data
- Understand physical processes

→

Models
- Phenomenological behaviour
- Validated using data

→

Design/Operations
- Severity of the hazard
- Extent of the hazard

- This was all in the context of large quantities of LNG in tanks onshore or vessels
- LNG as a fuel changes the context of the hazard

LNG as a Maritime Fuel

- Primarily for reduction in SOx, particulate matter and NOx.

- Potential for reducing GHG emissions by ~20%
  - Requires management of methane slippage

- Same fluid, different context

- Introduces hazards that are not present for traditional fuels

Edwin - stock.adobe.com

DNV

Experimental Research

- Not just dispersion across open ground

- Potential for impacting structures (most likely the receiving vessel)

Application

- Experimentally validated models support development of guidance for LNG bunkering
- The Society of Gas as a Marine Fuel have developed guidance for bunkering operations
- Based on an understanding of the hazards and the distance the hazard can affect

DNV

Application

- Safety distance based on representative leak sizes (not worst case)
- DNV carried out >4 million pool and dispersion simulations with results placed into a database
- Implemented by SGMF in its BASiL application
  - Used globally by ports and operators


SGMF

BASIL TOOL

SGMF: BUNKERING AREA SAFETY INFORMATION LNG

BASiL (Bunkering Area Safety information LNG) is SGMF's automated LNG gas dispersion tool. It can be used to manage bunkering risks on a consistent basis through the definition of a safety zone that depends on the type of bunkering operation being undertaken.

FEATURES:

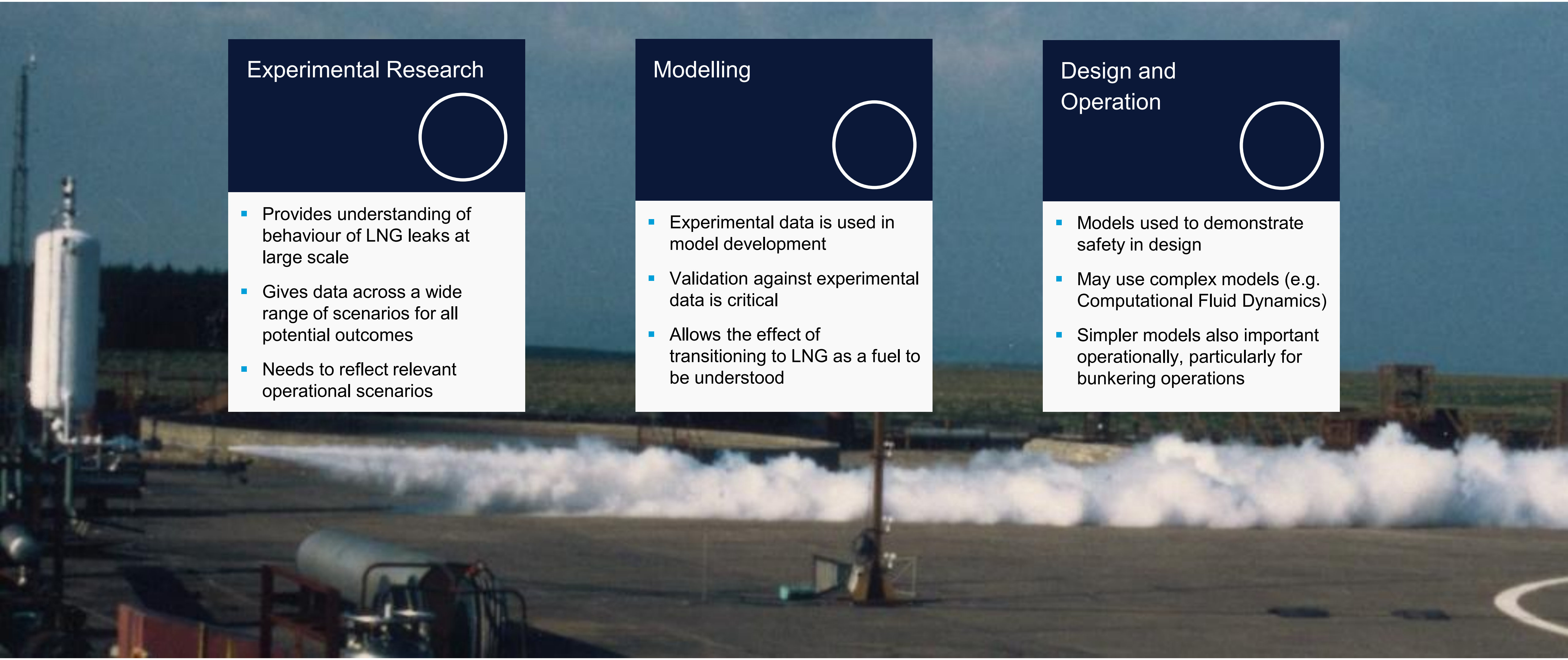
- Intuitive
- Fast turnaround
- Graphical output
- Unique reference number for audit purposes
- Recognised by leading port authorities

ADVANTAGES OF BASIL FOR YOUR PROJECT:

- Cost effective
- Fast turnaround
- Covers all bunkering scenarios, including road tankers
- Simulates all

BASIL IS AVAILABLE FOR MEMBERS AND NON-MEMBERS ON A SUBSCRIPTION BASE AND AS PER ONE-OFF REPORTS.
THESE CAN BE PURCHASED IN THE SGMF SHOP

Summary – LNG Case Study



Experimental Research

- Provides understanding of behaviour of LNG leaks at large scale
- Gives data across a wide range of scenarios for all potential outcomes
- Needs to reflect relevant operational scenarios

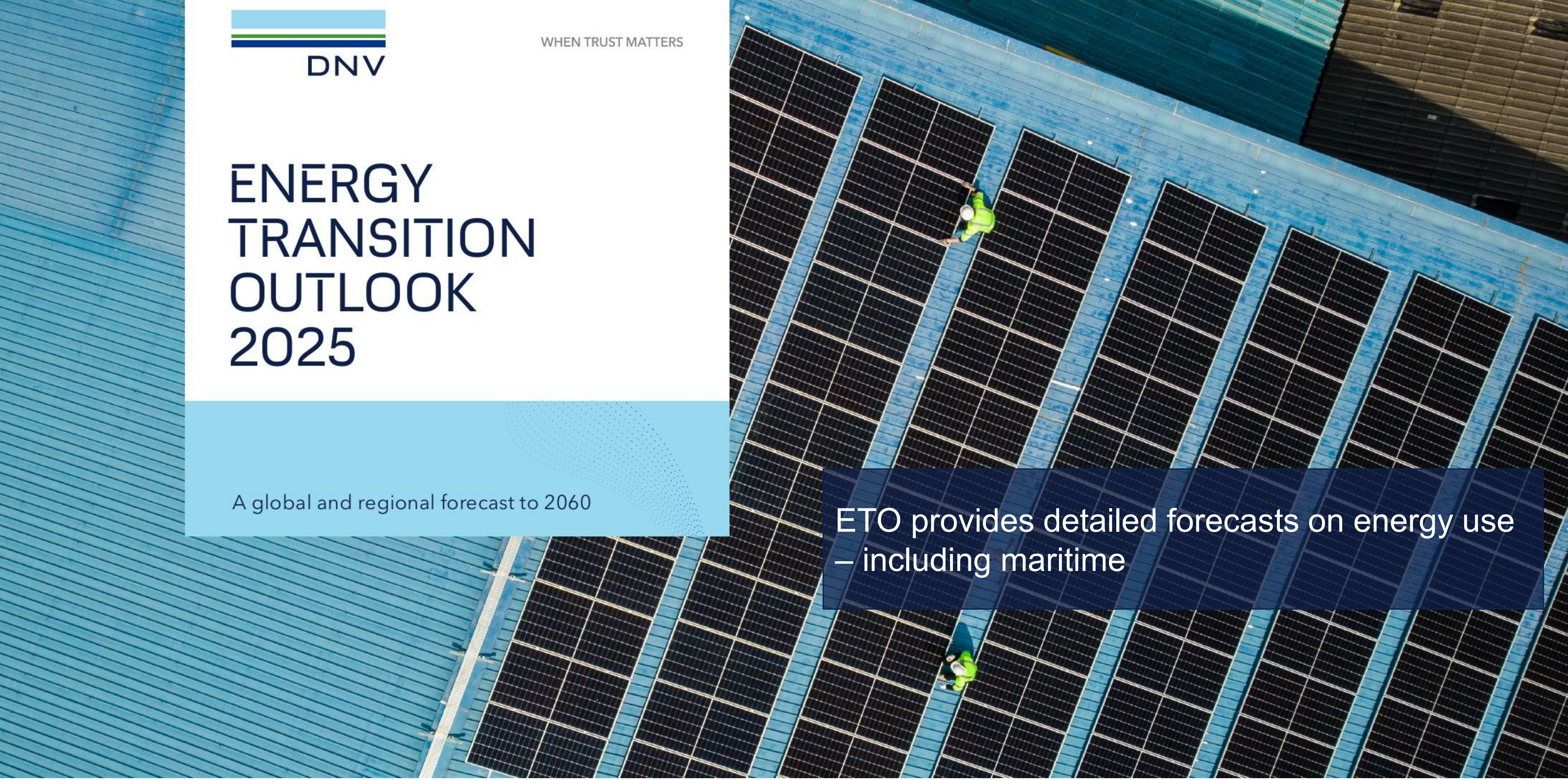
Modelling

- Experimental data is used in model development
- Validation against experimental data is critical
- Allows the effect of transitioning to LNG as a fuel to be understood

Design and Operation

- Models used to demonstrate safety in design
- May use complex models (e.g. Computational Fluid Dynamics)
- Simpler models also important operationally, particularly for bunkering operations

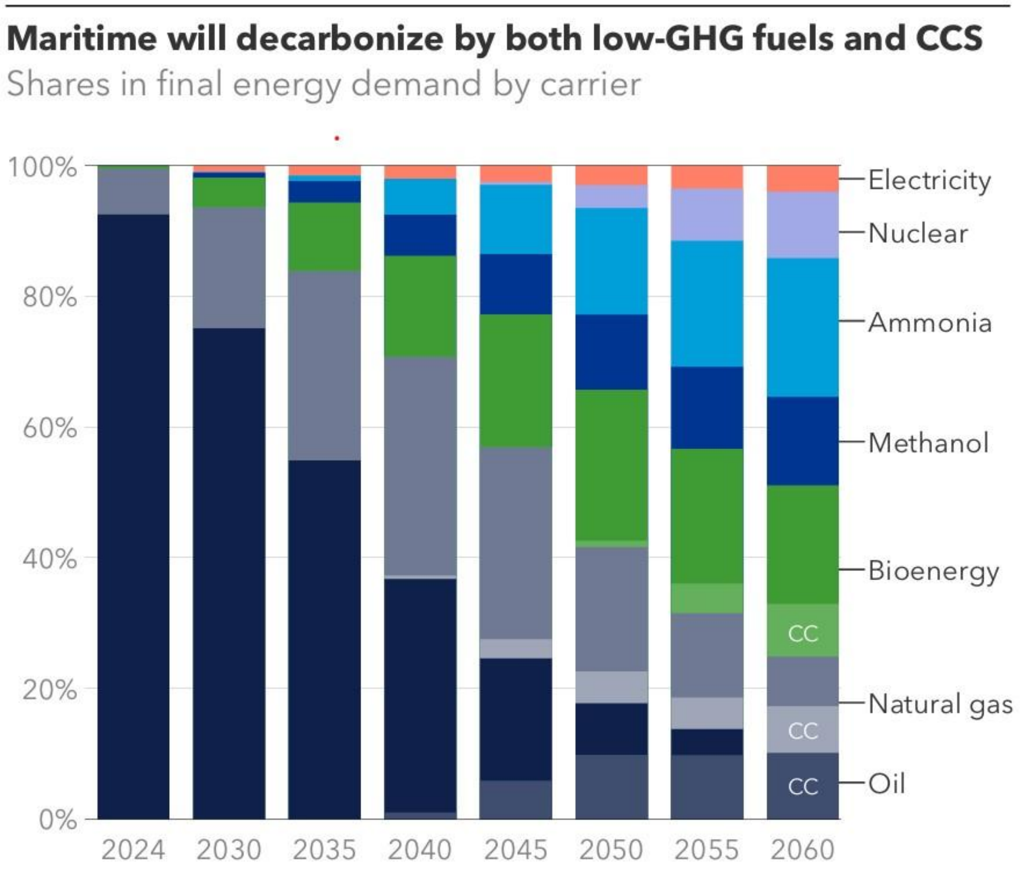
Energy Transition



ETO provides detailed forecasts on energy use – including maritime

Maritime Energy Transition

- Current forecast shows transition primarily achieved with low-GHG fuels and onboard CCS
- Currently forecasts little direct use of hydrogen as a fuel
  - Hydrogen derivatives – particularly ammonia
  - Possibility of cracking ammonia onboard but direct burning of ammonia is more energy efficient



CC - onboard carbon capture

Energy Transportation

- LH_2 is a potential means of energy transportation

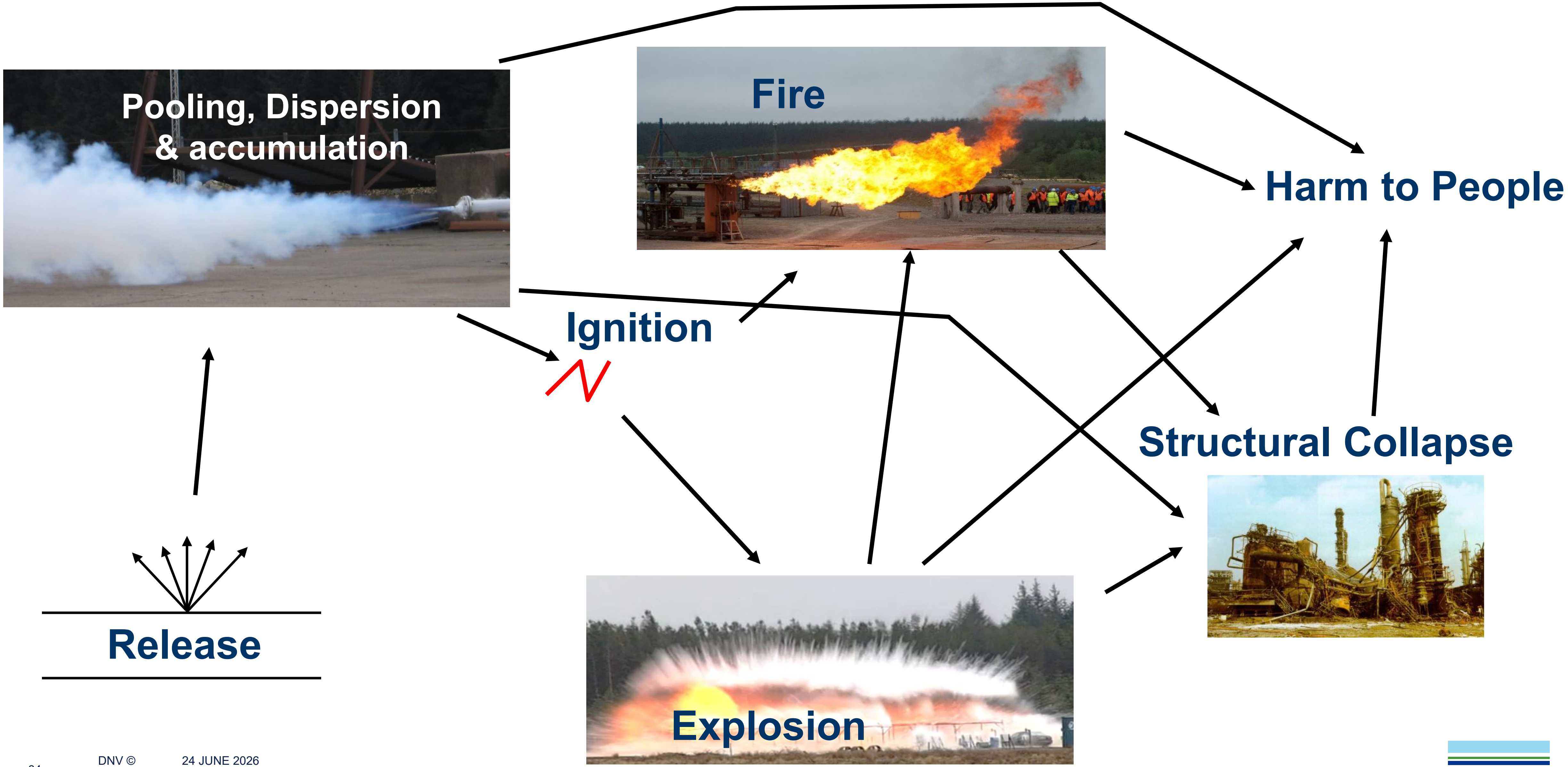
- January 2026 – KHI signed a contract to build a 40,000m^3 LH_2 carrier

Energy Transition Hazards

- Other Major Hazards phenomena have a similar research story spanning the hydrocarbon era.
- Energy Transition involves the same phenomena but the severity and likelihood need to be understood
  - Likelihood needs statistics and some engineering judgement
  - Severity needs research
- It is interesting and important to consider:
  - the currently accepted hazards today
  - societal perception of those and new hazards

What is a currently accepted hazard?

Hazards From Incidents



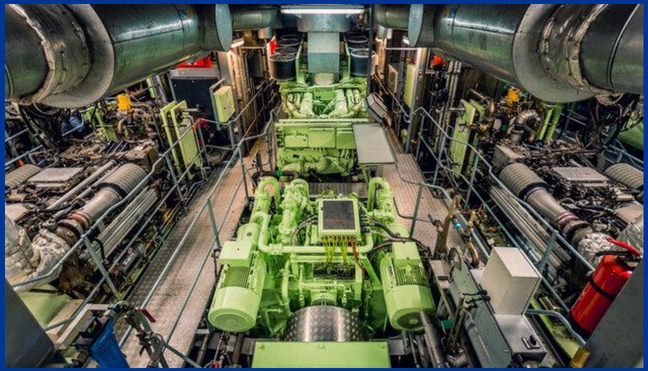
How will these change?

Modern ship engine room layout

Layout and structure

A modern ship's engine room is the main machinery space where all propulsion, power generation, and essential support systems are installed.

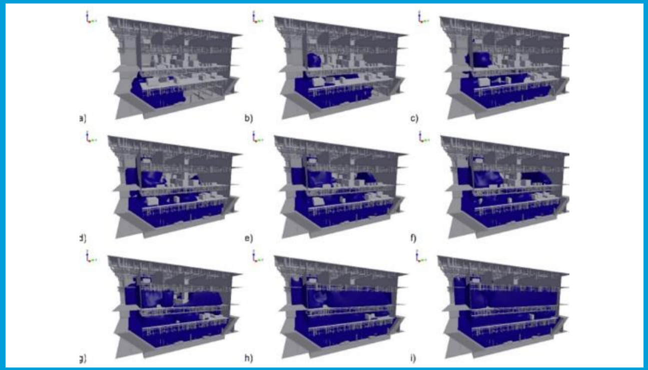
Even without referring to a specific vessel type, most engine rooms share the same core layout, functions, and atmosphere.



Gas accumulation hazard

LNG, methanol, batteries, ammonia, and hydrogen are all emerging as cleaner fuel options.

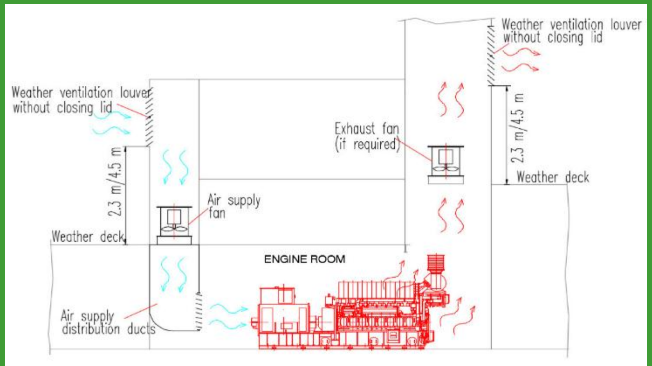
Each brings with it new hazard and design considerations, such as how gases associated with the fuel propagate and accumulate with a ship environment.



Ventilation and gas flow

Airflow through a ship's engine room follows a deliberate, engineered path designed to supply oxygen for combustion, cool the machinery, remove heat, and maintain safe working conditions.

If not fully considered, the ventilation and air flow through the ship could unintentionally transport toxic or flammable gases to more hazardous areas.



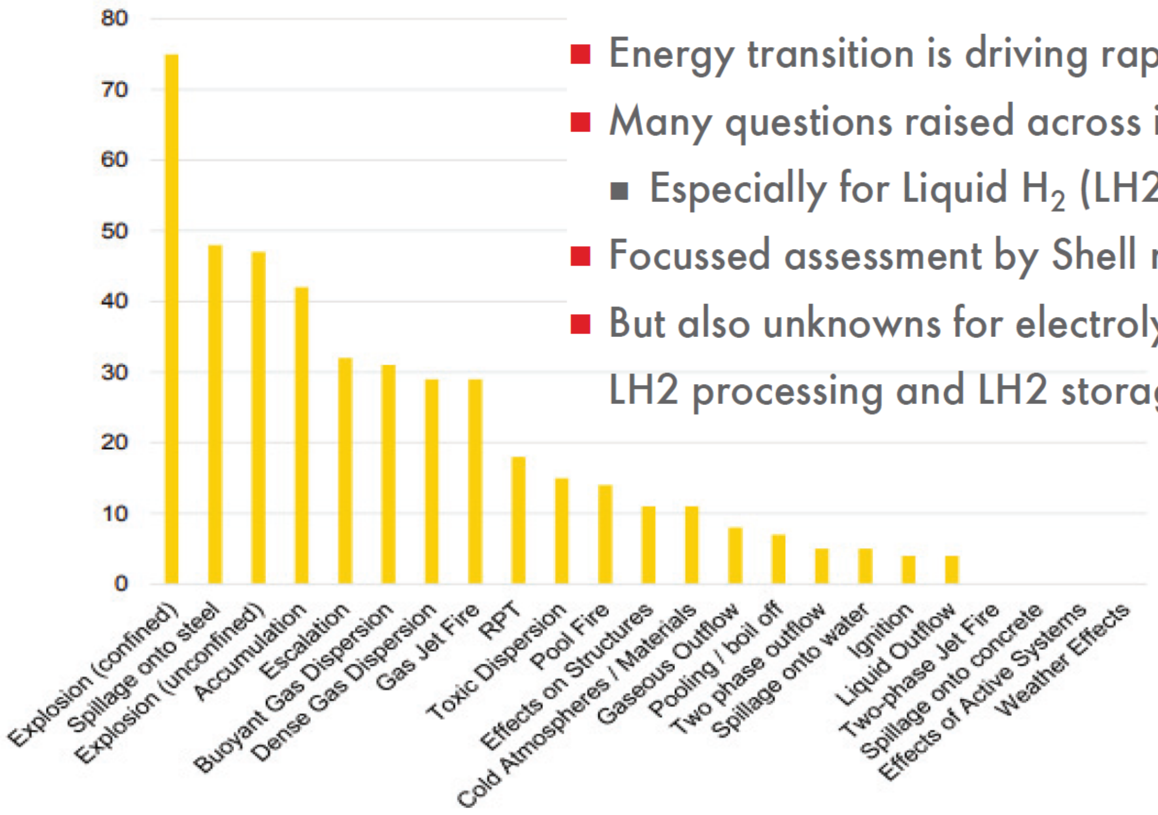
Knowledge Gaps

- Energy Transition involves the same phenomena but the severity and likelihood need to be understood
  - Likelihood needs statistics and some engineering judgement
  - *Severity needs research*
- Today I will focus on the obvious knowledge gaps that I perceive to remain as an issue from my position at DNV Spadeadam:
  - Focus mainly on the Hazards
  - Frequency and probability are also areas of active research at present:
    - Failure frequencies (integrity)
    - Ignition Probability
  - If you are interested in any of the info – please get in contact!

Maritime Perspective

- DNV study for STASCO
- STASCO, DNV expert forum
  - Major Hazards
  - Maritime
- Quantified different aspects
- Graph shows a prioritisation score based on ‘Knowledge Position’, Consequence and Relevance to Marine

Further quantification of major hazards required

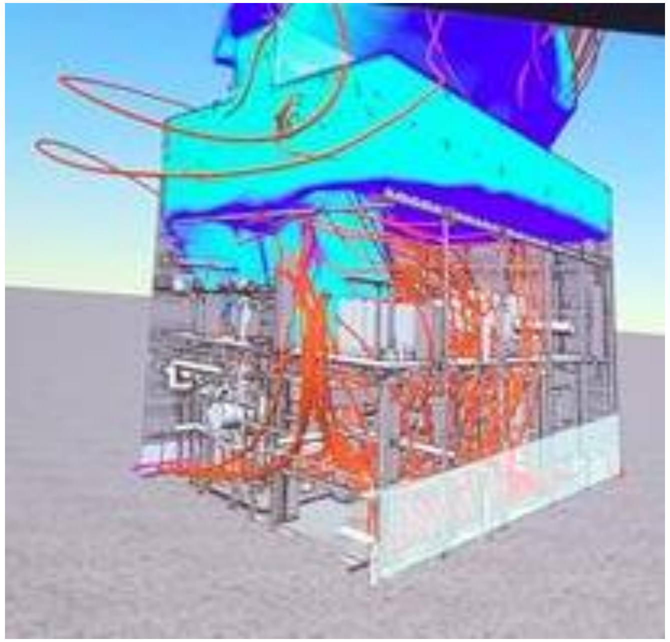


- Energy transition is driving rapid change
- Many questions raised across industry
  - Especially for Liquid H_2 (LH2)
- Focussed assessment by Shell marine business
- But also unknowns for electrolyser plants, LH2 processing and LH2 storage

18 April 2023 7

Hydrogen Accumulation

- Facilities are now being designed with significant active ventilation systems
  - CFD predictions used to design to deal with majority of leaks.
  - Large leaks can still produce stratified, reactive H_2 clouds.
- Need some verification of the CFD at representative scales?



Credit: Equinor @ HySchool 2025

H2 Explosions Versus Structures

- Structural response and explosion are coupled
- Example shows H2 ***can*** be significantly worse than hydrocarbon

- Hydrogen undergoes DDT more easily than most fuels
- Recent experiments investigated the potential for DDT in various geometries and mostly with high pressure hydrogen releases

Liquid Hydrogen

- Lack of v.large release data
- Lack of large scale explosion data
- Problem with generation of solid products of air
  - Conditions for generation
  - Explosion

LH_2: Confined Vented Explosion

- Compared to gaseous release:
  - Greater expansion ratio
  - Embrittlement issues for steelwork
  - Presence of liquid / solid products of air

Ammonia

Ammonia – Potential for Harm

- For LNG, the hazard boundary well defined as the extent of the flammable cloud
  - Harm occurs for personnel inside the cloud, no harm if outside the cloud

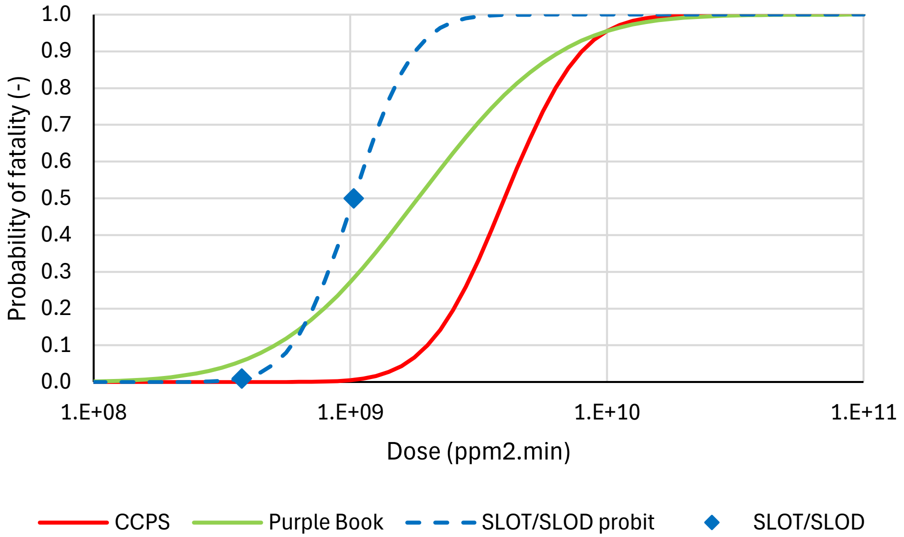
- Ammonia is significantly more complex
  - The potential for harm depends on the concentration of ammonia and the duration of exposure

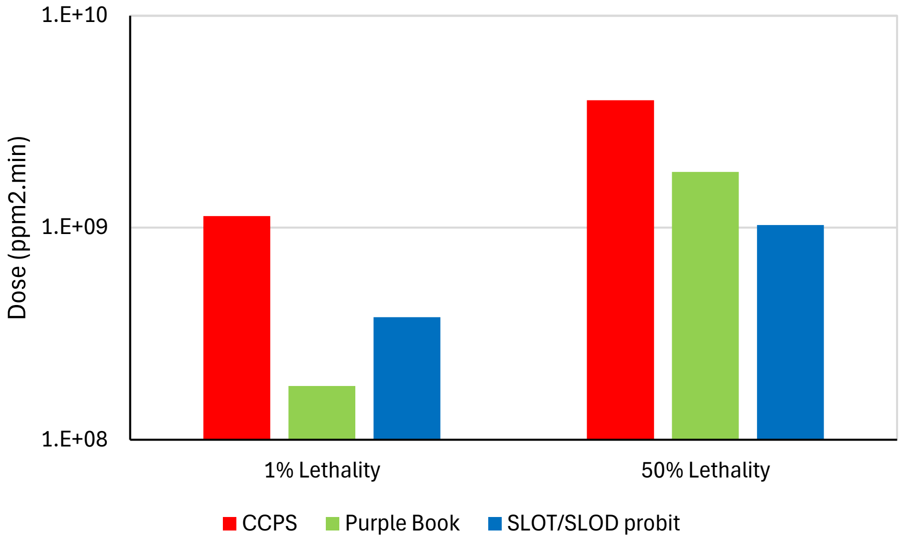
- In addition, harm comes in many forms, ranging from discomfort to irreversible/serious health effects to immediate danger to life

- Hazard extent for ammonia bunkering releases can be significantly greater than for LNG
  - We need to understand the benefit provided by mitigation measures

Ammonia – Potential for Harm

- Combined with this, there is no consensus for the ‘dose’ that causes serious harm or fatality
- Graphs show three examples of dose criteria:
  - Center for Chemical Process Safety (CCPS)
  - Purple book – UN Globally Harmonised System
  - UK HSE
    - SLOT (Specified Level Of Toxicity) 1-5% chance of lethality
    - SLOD (Significant Likelihood Of Death) 50% chance of lethality





NH_3 Challenge: change in use

Hazards of ammonia *fairly* well understood

Energy transition will see increase in NH3 as a bulk energy carrier – already carried in bulk today

Changes in its use will now include bunkering and use as a marine fuel.

There are no large scale experimental datasets for releases of ammonia in / onto water

Needed for model validation

The JIP ARISE looks to perform ~100kg/s releases, 60km off the south coast of France

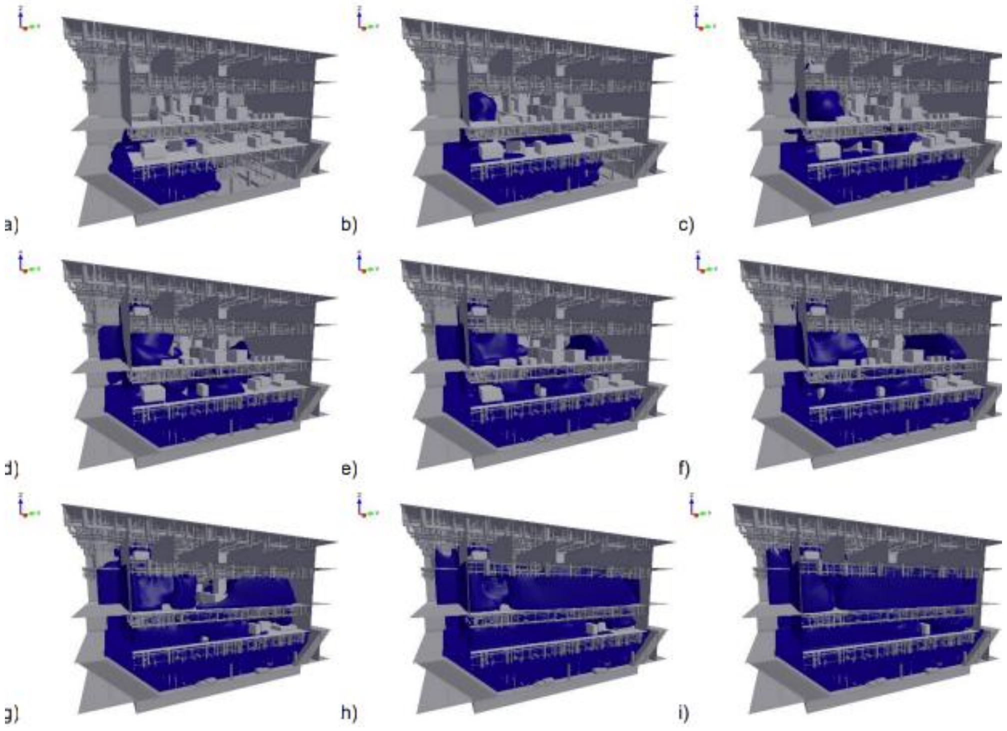
Dealing with smaller, bunkering and fueling system leaks – mitigation and hazard reduction

Ammonia Experiments

- Toxic dispersion hazard
  - Can be significantly larger than LNG LFL distance
- Significant interaction with water

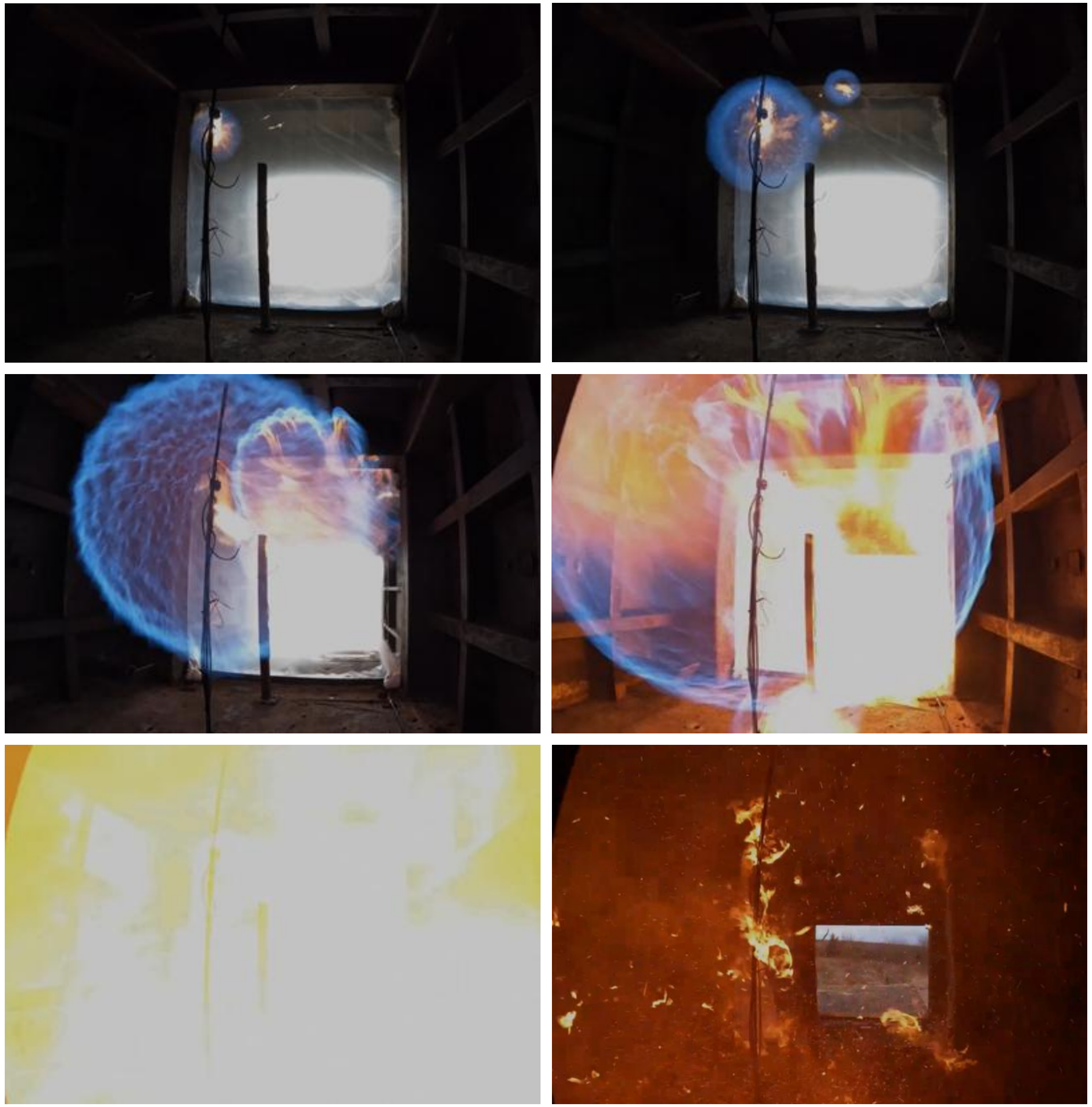
Accumulation in Confined Spaces

- Validation of CFD work needed
- Maritime use involves NH_3 inside ships – very different to existing NH_3 applications
- Toxicity, exposure times, mitigation all need developing



Batteries

- Li-Ion Batteries are not without hazards
- Cells can fail in variety of ways:
  - Mechanical damage
  - Overcharging
  - Overheating
- Fires and Explosions are possible consequences
- Need to understand



Critical lithium–ion battery hazards

Thermal runaway fires – Failing batteries can trigger a self-accelerating chain reaction that releases heat, flammable gases, and rapid fire growth. Testing is required on a variety of battery systems to understand heat loads, flame propagation, and to qualify mitigations such as fire protective materials.

Thermal runaway off-gases – When batteries fail and enter thermal runaway, a variety of highly flammable and toxic gases are released dependent on the battery chemistry. Studies into the composition and dispersion of these vapours are critical to ensure safety during and following failure events.

Vapour cloud explosions – Flammable gases released during thermal runaway can accumulate and ignite, rapidly accelerating into an explosion causing severe overpressure. Dedicated explosion chambers at DNV Spadeadam investigate the nature and consequences of this hazard in a controlled environment.

Marine Battery System Hazards

Lead – acid batteries

- Energy density: 30-50 Wh/kg
- Lifespan: 3-5 years (300-800 cycles in marine conditions)
- Usable capacity: 30-50%
- Charging rate: slow

Safety profile

- Risk of hydrogen gas release
- Risk of acid spills

Hazards well understood and mitigated

Lithium – ion batteries

- Energy density: 150-200 Wh/kg
- Lifespan: 8-15 years (3000-5000 cycles in marine conditions)
- Usable capacity: 80-90%
- Charging rate: fast

Safety profile

- Risk of self-sustaining thermal runaway fire
- Risk of flammable and toxic vapour release and subsequent gas explosion

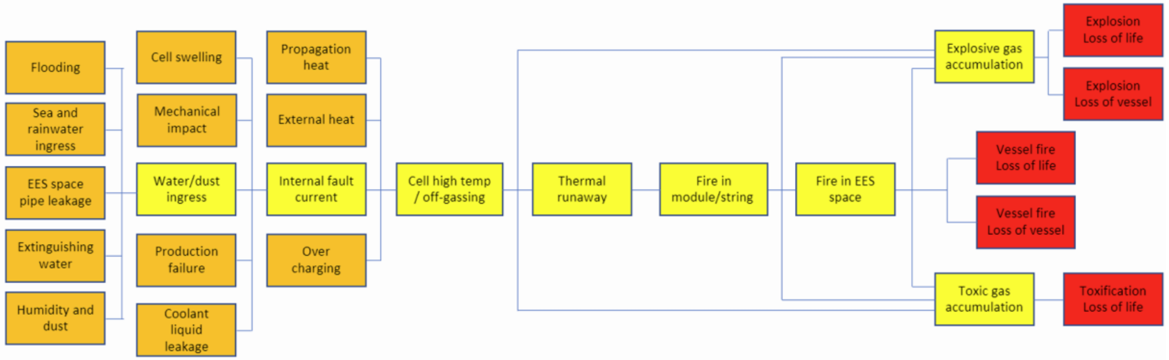
Hazards and mitigations not sufficiently understood

Also as a cargo:

Felicity Ace – 656 ft Ro-Ro car carrier capsized following fire with EVs (2022)

Fremantle Highway – 653 ft Ro-Ro car carrier salvaged due to EV fire (2023)

Morning Midas – 600 ft cargo ship carrying 3,000 new vehicles sank due to EV fire (2025)



DNV-CG-0660, pg.8, Figure 2 Illustration of chain of events for fires in electrical energy storage systems: *"The major hazards related to the design concepts are in general known, however, effective technical solutions to prevent or mitigate the incidents may still be under development."*

Battery & energy storage system research

DNV Spadeadam Research & Development

Explosion relief testing for RHINO

- Testing in accordance with:
  ISO 23693 - Determination of the resistance to gas explosions of passive fire protection materials

- Deflagration panels tested against various rates of pressure rise and peak overpressure

Carbon Dioxide

Large CO_2 Releases

- CO_2 behaves as a dense gas
- Initial plume at release point and vapour slumps to the ground
- Spreads into two shallow valleys either side of the site
- Wind blowing from bottom to top of view
  - Some vapour spreads upwind

CO_2 Running Ductile Fracture

Summary – ET Changes in Hazards

Energy Transition

- Will see incumbent fuels replaced with some mix of Ammonia, battery, biofuel
- CCS and Hydrogen may play a role on ships

Hazards

- Mostly understood for LNG, HFO, biofuels
- Changes in risks posed needs to be understood
- Ammonia, Hydrogen, CO_2, batteries pose different hazards with knowledge gaps

Safety and Risk

- Managing toxic hazard different to managing flammable hazard
- Flammable hazards might be different
- Mitigations need to be proven
- Implementation and verification

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Thank You

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