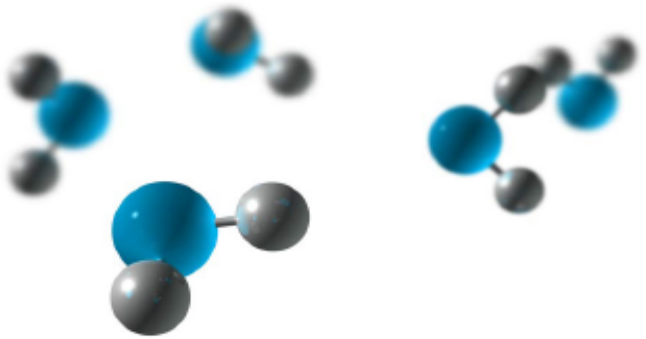
DNV GL Perspective- Regulations, Codes and Standards

H2@Ports Workshop

Anthony Teo

11 September 2019



ABOUT DNV GL -
Leading the surge towards the future

MARITIME

- **Maritime** is our core industry
- **11,678 ships & mobile offshore units** in DNV GL class, 280.6 mGT
- **Strong presence** in all ship segments
- **Dedicated ship type expert teams** support our clients worldwide
- **Among top performing class societies** in Port State Control statistics
- **200 Maritime offices** across the world

24%
Market share (measured in GT)

3,600
Maritime staff worldwide

OIL & GAS

ENERGY

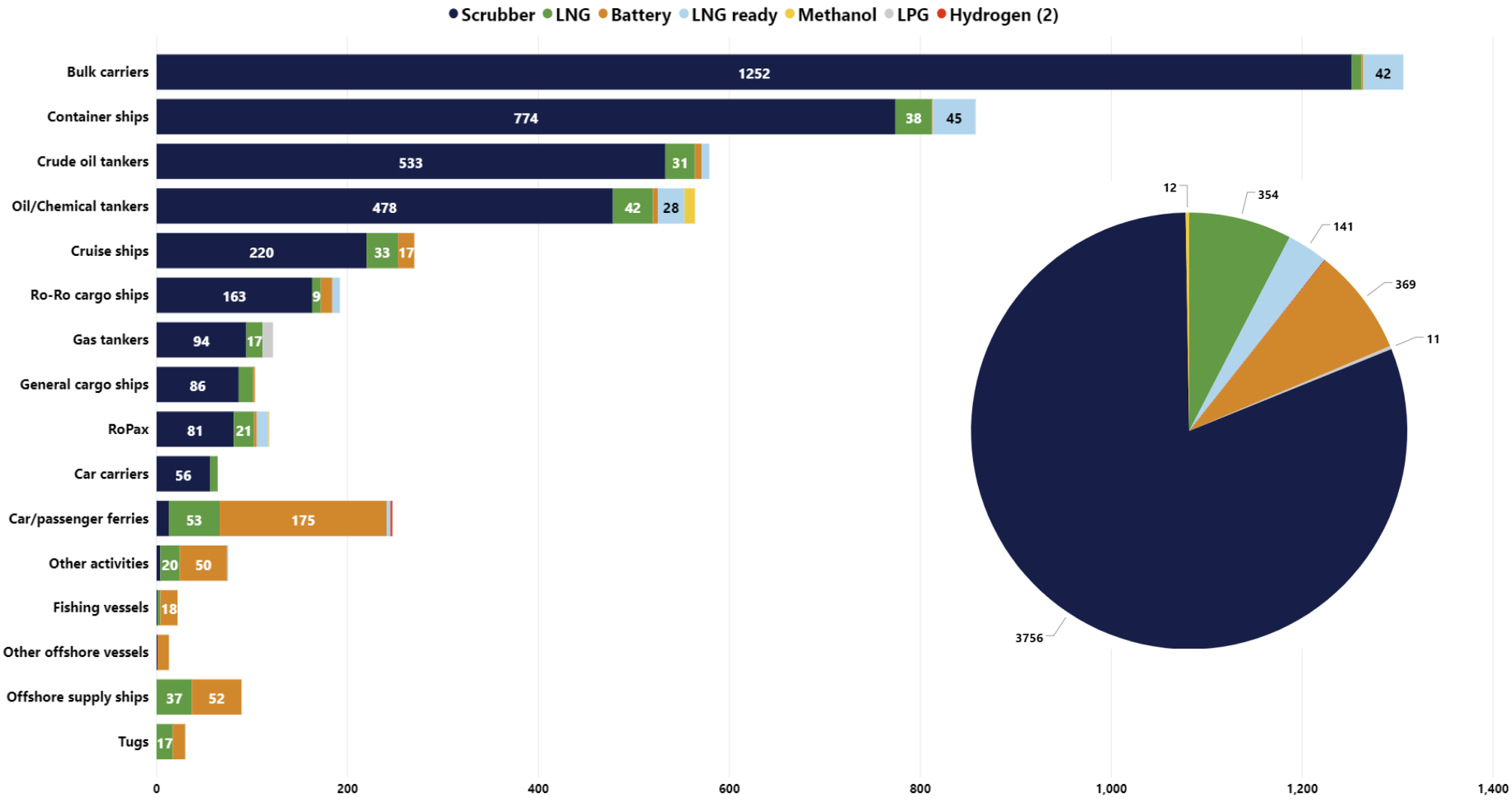
BUSINESS ASSURANCE

DIGITAL SOLUTIONS

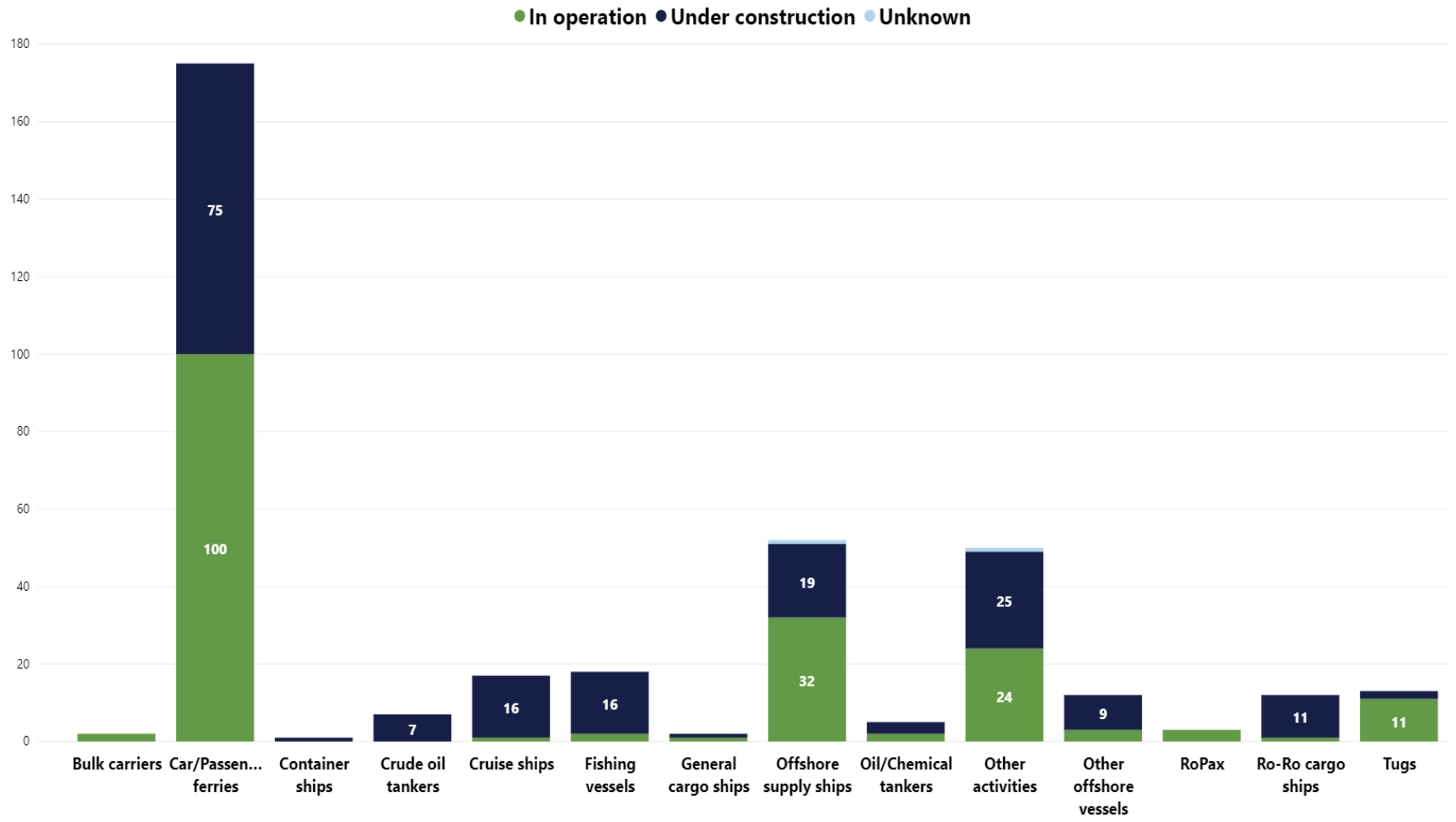
12,500
employees groupwide

5%
revenue invested in R&D activities

Total number of ships (in operation and on order)



Number of ships with batteries by ship type



Towards zero emissions in shipping

- **HYDROGEN – FUEL CELLS**
  - Next generation
  - Increased range
  - Reduced weight possible
  - More flexible charging/bunkeri

Maritime FC- Noteable Projects






FellowSHIP	320 kW MCFC system for auxiliary power of Offshore Supply Vessel	Eidesvik Offshore, Wärtsilä, DNV	2003-2011	MCFC	320 kW	LNG
ZemShip - Alsterwasser	100 kW PEMFC system developed and tested onboard of a small passenger ship in the area of Alster in Hamburg, Germany	Proton Motors, GL, Alster Touristik GmbH, Linde Group etc.	2006-2013	PEM	96 kW	Hydrogen
E4Ships - SchIBZ MS Forester	100 kW containerized SOFC system developed and tested for the auxiliary power supply of comercial ships. Scalable up to 500 kW units.	Thyssen Krupp Marine Systems, DNVGL, Leibniz University Hannover, OWI, Reederei Rörd Braren, Sunfire	Phase 1: 2009-2017 Phase 2: 2017-2022	SOFC	100 kW	Diesel
E4Ships – Pa-X-ell MS MARIELLA	60 kW modularized HT-PEM fuel cell system developed and tested for the decentralized auxiliary power supply onboard passenger vessel MS MARIELLA.	Meyer Werft, DNVGL, Lürssen Werft, etc	Phase 1: 2009-2017 Phase 2: 2017-2022	HTPEM	60 kW (each stack is 30 kW)	Methanol
Nemo H2	Small passenger ship in the canals of Amsterdam	Rederij Lovers etc	2012-present	PEM	60 kW	Hydrogen
RiverCell	250 kW modularized HT-PEM fuel cell system developed and to be tested as a part of a hybrid power supply for river cruice vessles	Meyer Werft, DNVGL, Neptun Werft, Viking Cruises	Phase 1: 2015-2017 Phase 2: 2017-2022	HTPEM	250 kW	Methanol
SF-BREEZE	Feasibility study of a high-speed hydrogen fuel cell passenger ferry and hydrogen refueling station in San Francisco bay area	Sandia National Lab., Red and White Fleet	2015 - present	PEM	120 kW per module. Total power 2.5MW	Hydrogen

Zero/V - Hydrogen Fuel-Cell Coastal Research Vessel

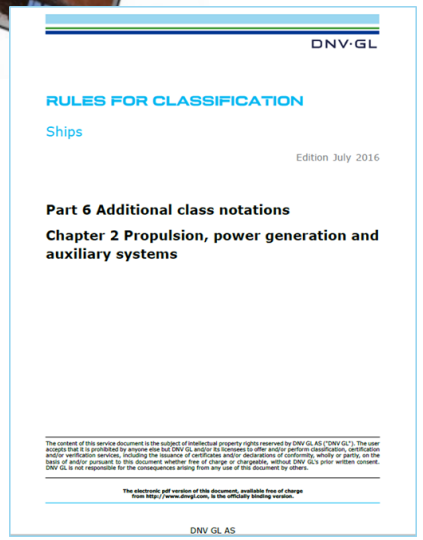
Sandia partnered with the Scripps Institution of Oceanography, the naval architect firm Glosten and the class society DNV GL to assess the technical, regulatory and economic feasibility of a hydrogen fuel-cell coastal research vessel.

Report published on 7th May- http://energy.sandia.gov/transportation-energy/hydrogen/market-transformation/maritime-fuel-cells/

Regulatory situation – a main barrier

- The IGF Code entered into force Jan 1st 2017
- Governs the use of low flashpoint liquids and gaseous fuels

- DNV GL Class Rules for fuel cells and the class notations FC(Safety) and FC(Power)
  - Section 3 – Fuel cell installations – FC
    - Sets requirements FC power systems, design principles for FC spaces, fire safety, control and monitoring systems



- **No fuel specific requirements (hydrogen)**
- **No prescriptive hydrogen requirements available**
- **The applicable part of the IGF Code (Part A) requires that an "Alternative design" approach is followed**

Regulation overview - status

Requirements for on board energy generation systems

Fuel specific requirements

Maritime Fuel Cell Systems

INTERNATIONAL MARITIME ORGANIZATION

IGF code entered into force Jan. 1st 2017

Contains detail requirements for natural gas as fuel only, and internal combustion engines, boilers and gas turbines

Work started on technical provisions for methyl /ethyl alcohols as fuel and fuel cells

Alternative Design Approach

Most classification societies have established Rules covering fuel cells and to some extent low flashpoint liquids

Regulation overview - Alternative Design

Currently, for Fuel Cells and Hydrogen

- IGF codes provides the possibility for alternative design process
- The *equivalence* of the alternative design shall be demonstrated by a ***risk-based approach*** as specified in SOLAS regulation II-1/55 and approved by the Administration
- The "Guidelines on Alternative Design and Arrangements for SOLAS Chapters II-1 and III (MSC.1 / Circ. 1212)" providing guidance to perform the ***Alternative Design Process***

Preliminary Analysis

- Identification of rule deviations
- Hazard Identification
- Scenarios, methods and assumptions for quantification

Quantitative Analysis

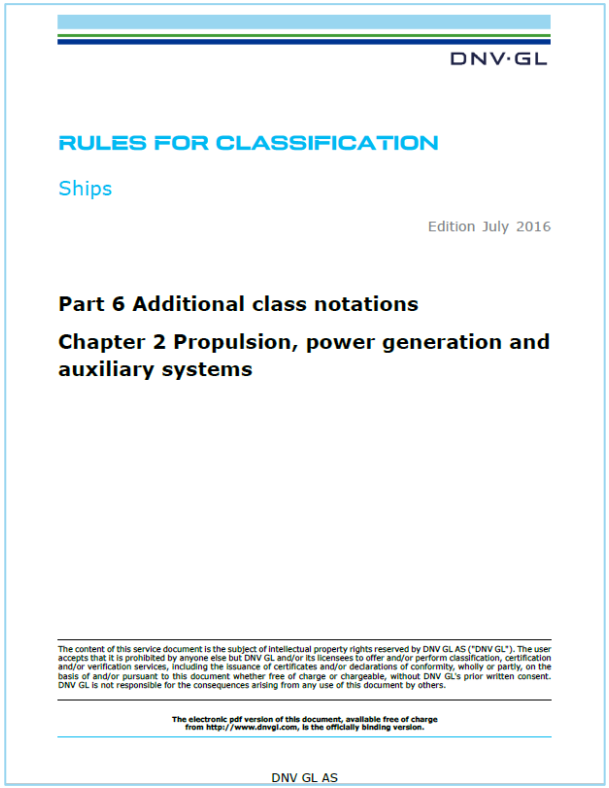
- Quantification of selected scenarios
- Comparison to conventional design

Report of Assessment

- Documentation
- Presentation to flag

Regulation overview -DNVGL Fuel Cell Rules

- DNVGL Rules for Classification – Ships
  - Part 6 Chapter 2 Section 3 – **Fuel Cell Installations – FC**
    - The Rules offer two class notations:
    - **FC(Power)**
      - Given to ships that fulfils design requirements in the Rules, where the FCs are used for essential-, important- or emergency services.
    - **FC(Safety)**
      - Given to ships that fulfils the environmental- and safety requirements in the Rules, where the FCs are not used for essential-, important- or emergency services.



DNV·GL

RULES FOR CLASSIFICATION

Ships

Edition July 2016

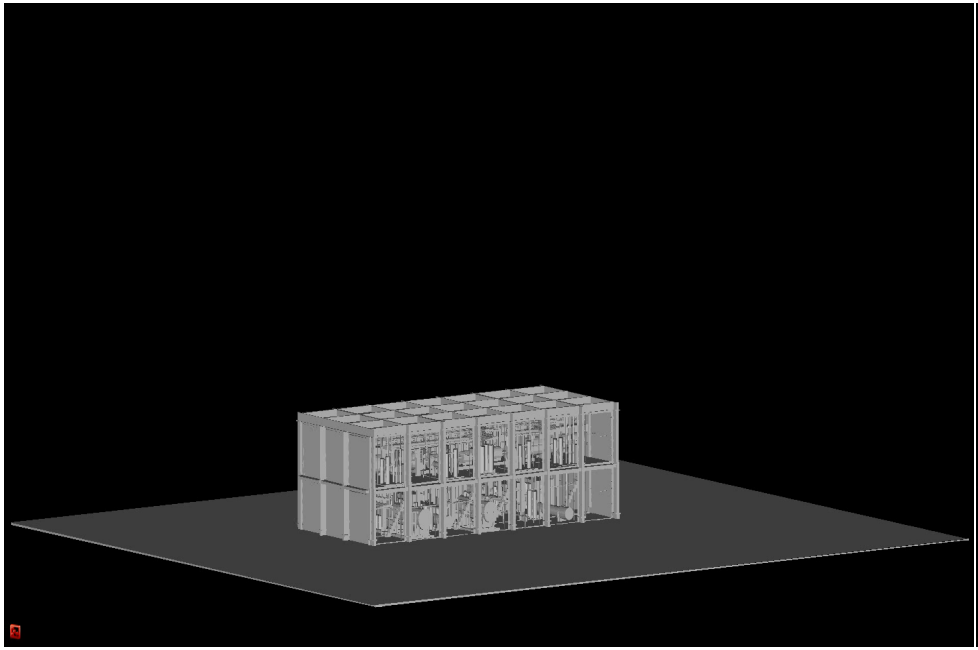
Part 6 Additional class notations

Chapter 2 Propulsion, power generation and auxiliary systems

DNV GL AS

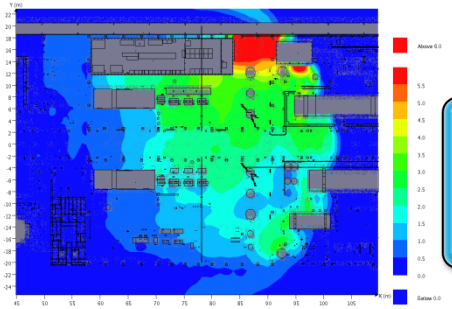
Hydrogen Safety- Experiments and simulations

- Major Hazards Research and Testing Facility (Spadeadam)
- Enables us to understand hazards and to develop and validate models



Explosion Risk Analysis (ERA) approach

CONCEQUENCE ANALYSIS WITH FLACS



CFD Converting geometry

CFD Ventilation

CFD Dispersion

CFD Explosion

Response surfaces

FREQUENCY AND SYSTEM ANALYSIS

Leak frequency

Flow conditions and ESD segments

Ventilation

Gas detection

Ignition sources

Risk analysis:

- DNV program EXPRESS
- Response surfaces
- JIP Ignition model
- Monte Carlo simulations

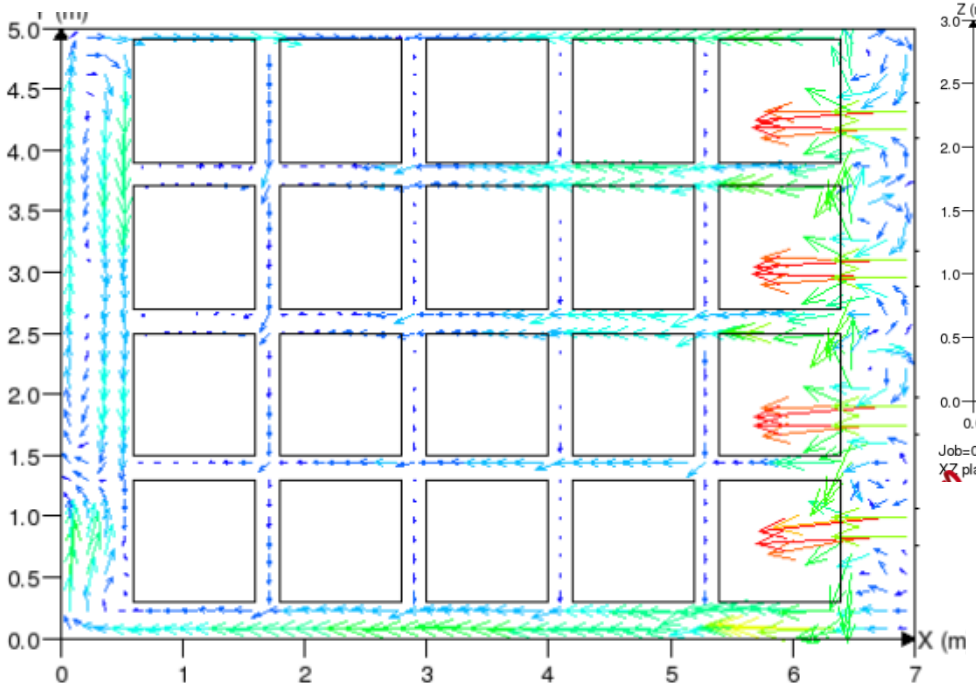
Improve design

Design effects and recommendations

Explosion DAL

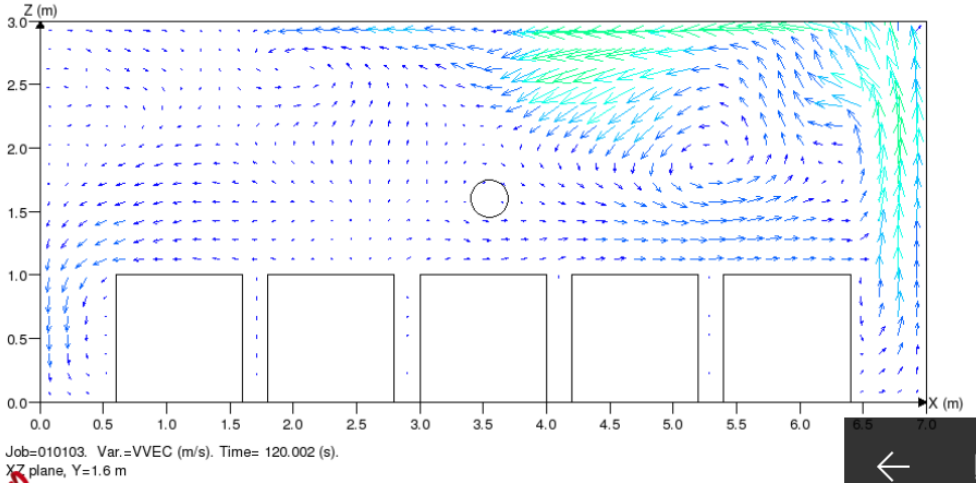
Ventilation example

- Horizontal cut



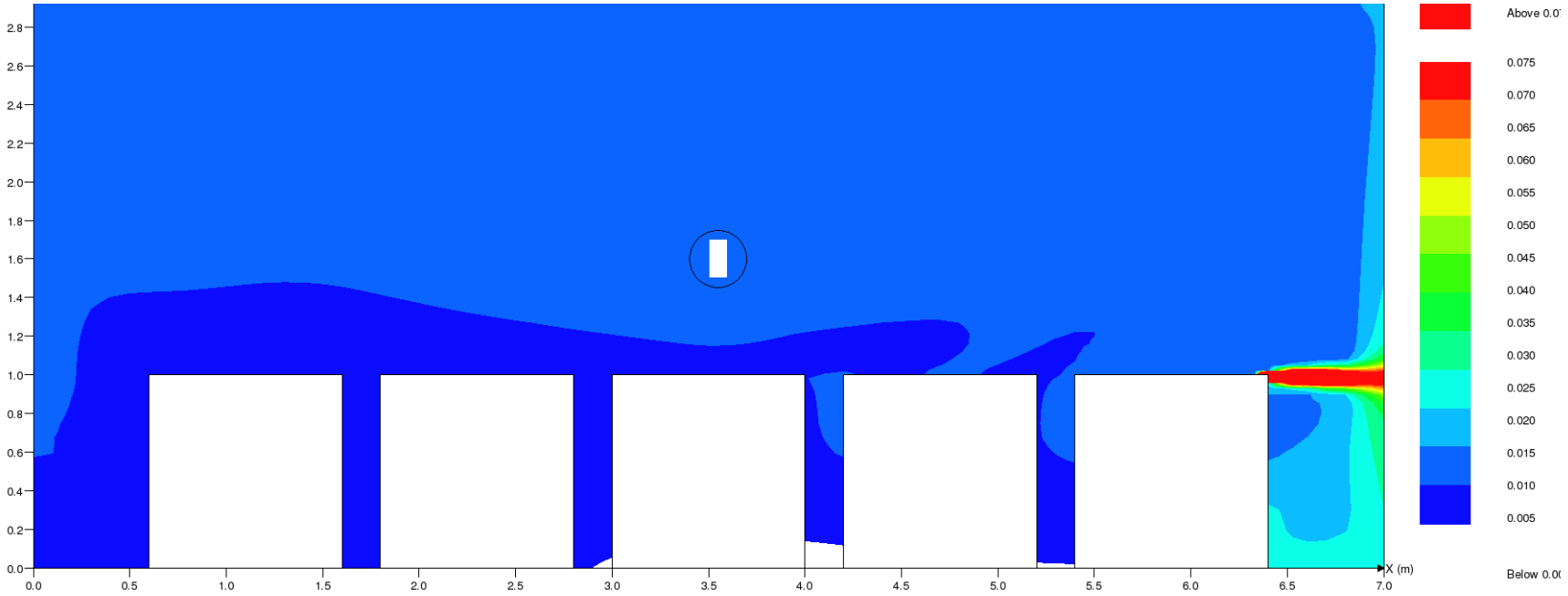
Job=010101. Var.=VVEC (m/s). Time= 120.000 (s).
XY plane, Z=0.5 m

- Vertical cut



Job=010103. Var.=VVEC (m/s). Time= 120.002 (s).
XZ plane, Y=1.6 m

Gas leak dispersion example hydrogen



Technology overview- Fuel Cells types

Electro-galvanic fuel cell (EgFC)
Enzymatic Biofuel Cells (EnzFC)
Magnesium-Air Fuel Cell (Mg-AFC)
Metal hydride fuel cell (MHFC)
Protonic ceramic fuel cell (PCFC)
Microbial fuel cell (MFC)

Alkaline fuel cell (AFC)
Direct borohydride fuel cell (DBFC)
Direct carbon fuel cell (DCFC)
Direct formic acid fuel cell (DFAFC)
Direct methanol fuel cell (DMFC)
Direct-ethanol fuel cell

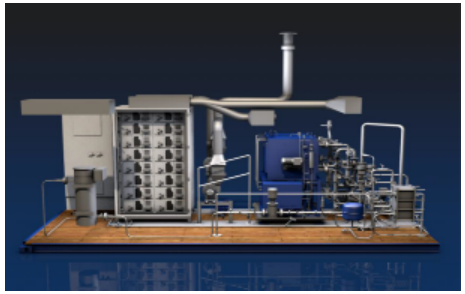
Molten carbonate fuel cell (MCFC)
Phosphoric acid fuel cell (PAFC)
Solid oxide fuel cell (SOFC)
PEMFC
High Temperature PEM
Reformed methanol FC (R-MFC)

Regenerative fuel cell (RegFC)
RFC – Redox
Solid acid fuel cell (SAFC)
Upflow microbial fuel cell (UMFC)
Zinc-air battery

Maturity and Relevance

Solid Oxide Fuel Cell | Molten Carbonate FC | Phosphoric Acid FC | **HT PEM fuel cell** | Alkaline fuel cell | **PEM fuel cell** | Direct Methanol FC

Tolerance for cycling
Lifetime
Efficiency
Emissions
Relative cost
Modular power levels (kW)



Safety aspects
Physical size
Flexibility towards type of fuel
Sensitivity for fuel impurities
Technological maturity

Maritime Fuel Cell Product Certification/Type Approval – under development

- DNVGL has initiated the development of a class program **CP** for Fuel Cell Power Installations, describing the procedures and technical requirements for the approval and certification of such systems (similar to the **DNV GL CP-0418** for Lithium Batteries https://rules.dnvgl.com/docs/pdf/DNVGL/CP/2015-12/DNVGL-CP-0418.pdf).

- Technical basis will be e.g. the draft of the IGF-Code for fuel cells, the **DNVGL CG-0339** 'Environmental test specification for electrical, electronic and programmable equipment and systems' https://rules.dnvgl.com/docs/pdf/DNVGL/CG/2015-11/DNVGL-CG-0339.pdf and the IEC 62282 'Fuel Cell Technologies'.

- Since the technical requirements for fuel cell power installations are equivalent for case-by-case or type approval (only the procedure is different) and due to the very different kinds of fuel cells (PEM, HTPEM, HTFC etc.) the procedures and the technical requirements for approval and certification of such systems will be developed together with manufacturer and class until the above mentioned Class Program is available.

DNV GL initiative – MARHYSAFE: Maritime Hydrogen Safety Joint Development Project

Goal:

- Remove regulatory and approval barriers
- Develop the knowledge required for safe and reliable onboard hydrogen storage, bunkering and use of hydrogen in shipping

Indication of partners:

- Public: Norwegian Maritime Authority, Norwegian Public Roads Administration, Norwegian Defence Material Agency (Navy, NDMA)
- Private: Equinor, Scandlines, RCCL, Air Liquide, HySeas Energy, Redrock (Canada), UMOE, Hexagon, Standards Council of Canada

R&D partners:

- University of South-Eastern Norway (USN)

Status:

- Currently discussing with potential partners
- Open for more partners
- Planning to start the project soon (2019)

MARHYSAFE

DNV GL's services on Fuel Cell / Hydrogen

R&D	•Applied research and development including *experimental* setups •Explosion and fire experiments and research
Innovation & demonstration	•Realization of *demonstration* projects •Techno-economic *road mapping* for technology or solutions •System integration with renewables/electricity/..
Implementation support	•Technology qualification •Explosion and fire save design analysis •*Recommended practice* and standards development •Guideline for HRS user interface improvement process
Realisation support	•Consortium initiation/execution •*Safety assessments* (HAZOP, HAZID, QRA, RRR, CFD modeling)
Operational excellence	•Custody transfer •Performance validation •Process optimization •H2 Incident and accident database (HIAD)

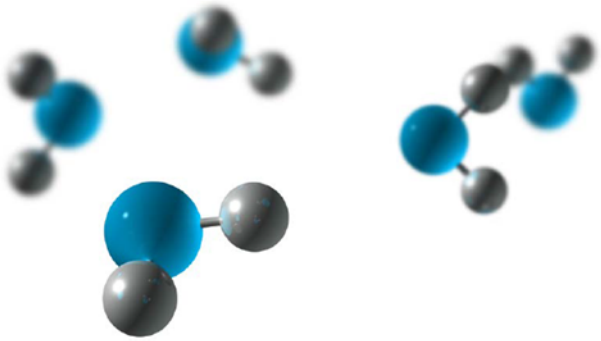
Safer, Smarter, Greener...

EMSA Report available at http://www.emsa.europa.eu or search www: EMSA + DNVGL + fuel cell

Anthony Teo
Tse.yen.teo@dnvgl.com
+1-281-396-1507

www.dnvgl.com

SAFER, SMARTER, GREENER



Alternative Fuels Insight

afi.dnvgl.com