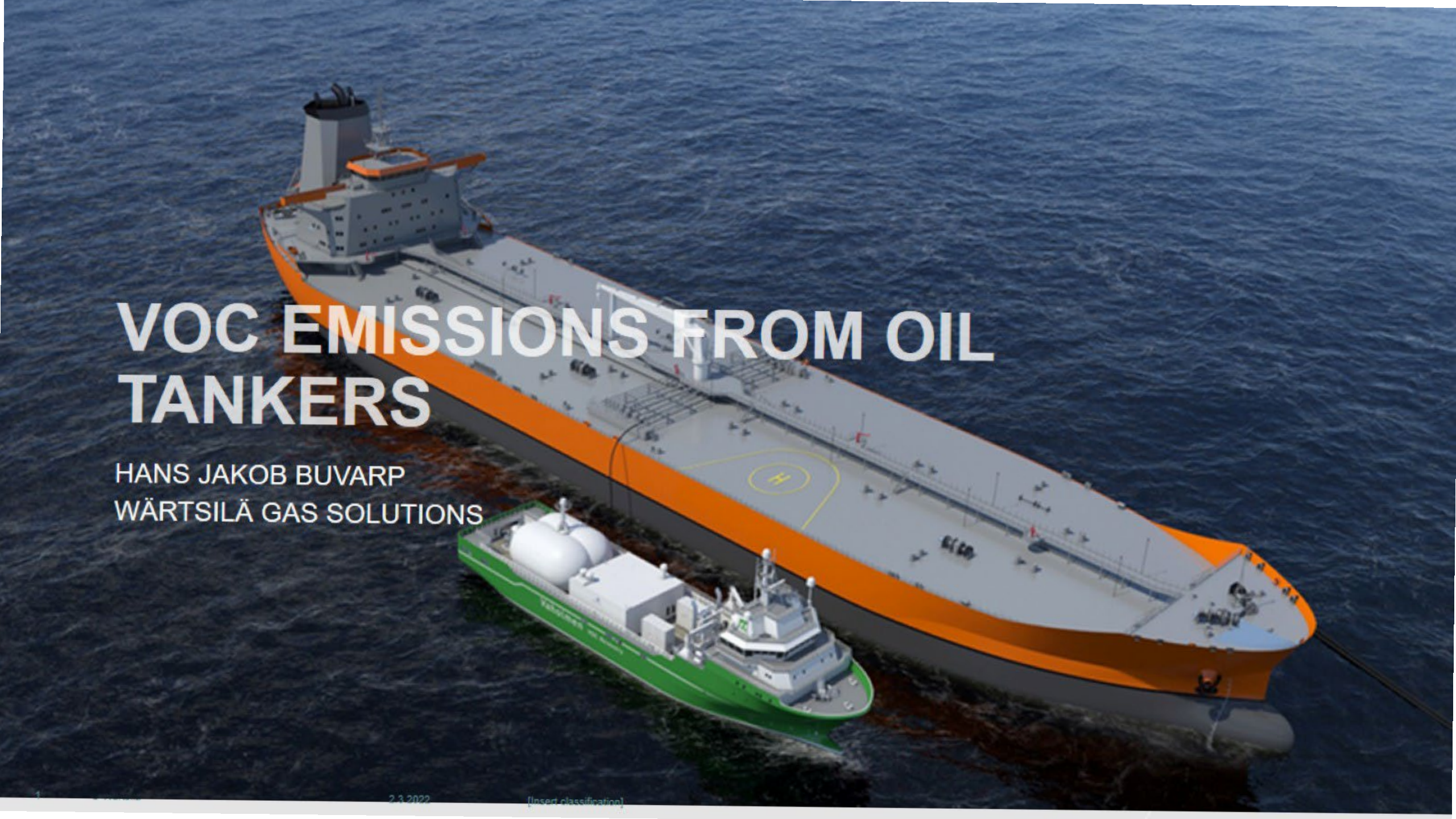
Crude oil cargo emissions and Volatile Organic Compounds

Panellist documents

Page 2: Hans Jakob Buvarp, Wärtsilä Oil and Gas Systems
Page 16: Ole Oldervik, SINTEF Ocean
Page 20: Captain Rohit Bhatia, Wade Maritime Group

Part of
Tanker Shipping & Trade
Webinar Week

TANKER
SHIPPING & TRADE



VOC EMISSIONS FROM OIL TANKERS

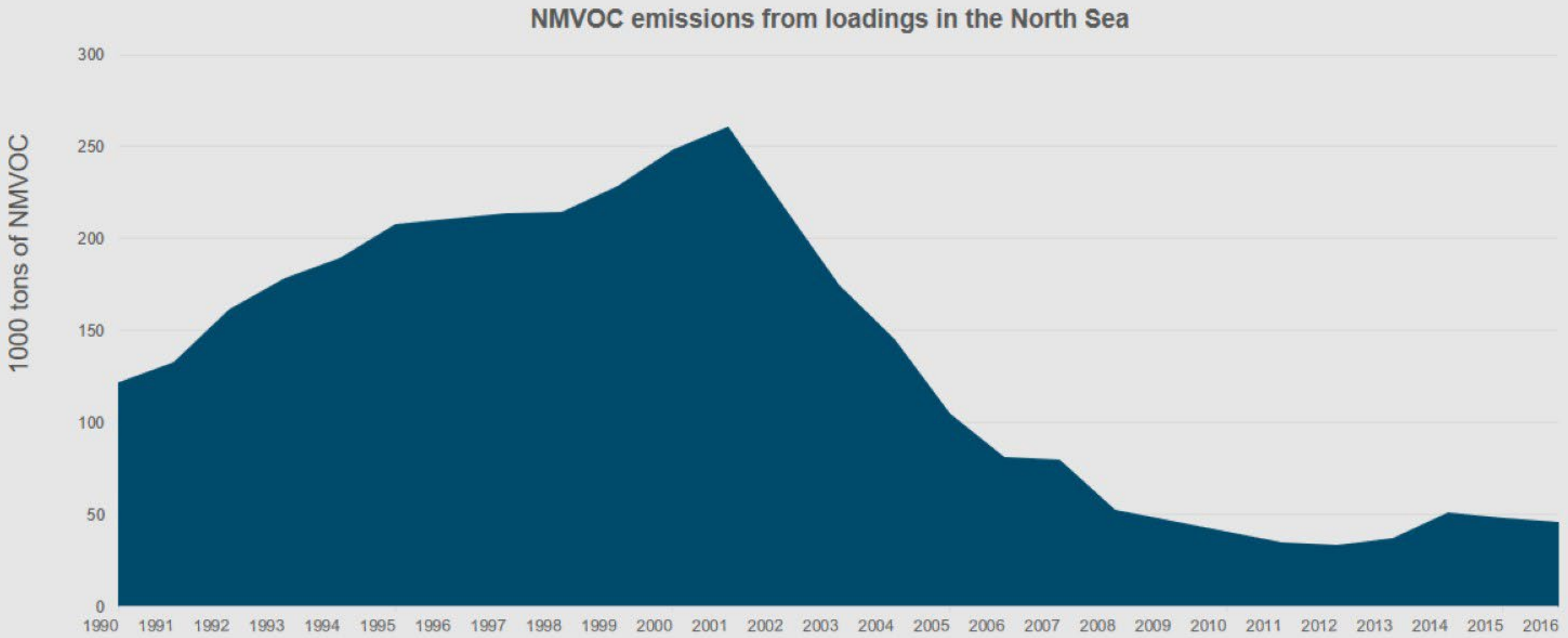
HANS JAKOB BUVARP
WÄRTSILÄ GAS SOLUTIONS

What is VOC?

- Known as “Crude Oil Vapour”, and stands for “volatile Organic Compound
- A more precise description is: A mix of light and heavy hydrocarbons
- Big emissions of VOC during loading of Crude oil Carriers
- Emissons are generated by:
  - Displaced volume in cargo tanks: Up to 350 000 m3
  - Emission ratio from crude oil: Up to 50% of cargo tank volume
- From year 2000 Wärtilä have delivered 15 VOC recovery systems to North Sea shuttle tankers

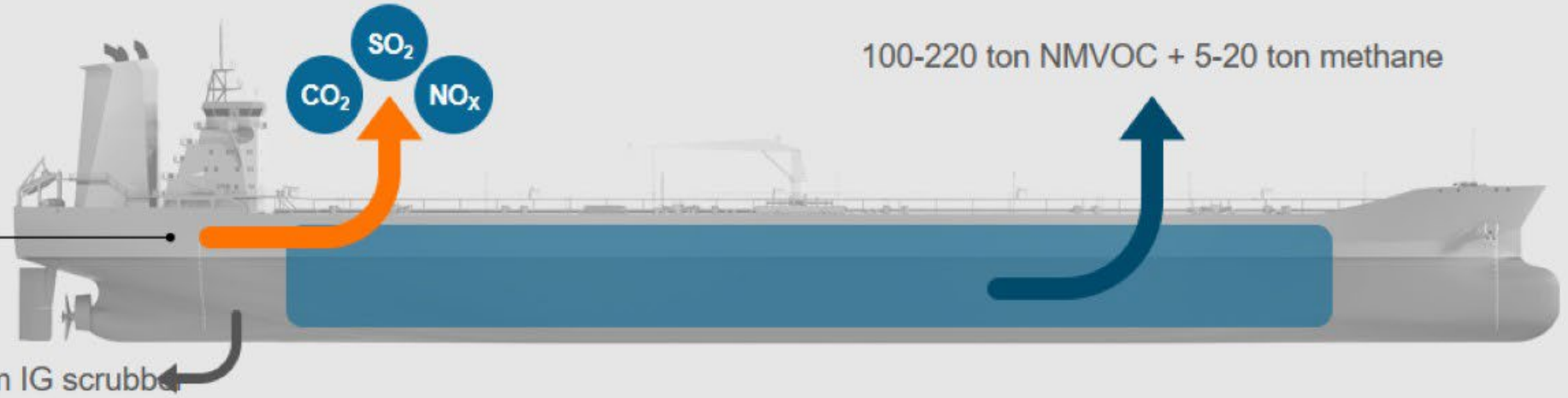


VOC - from problem to resource

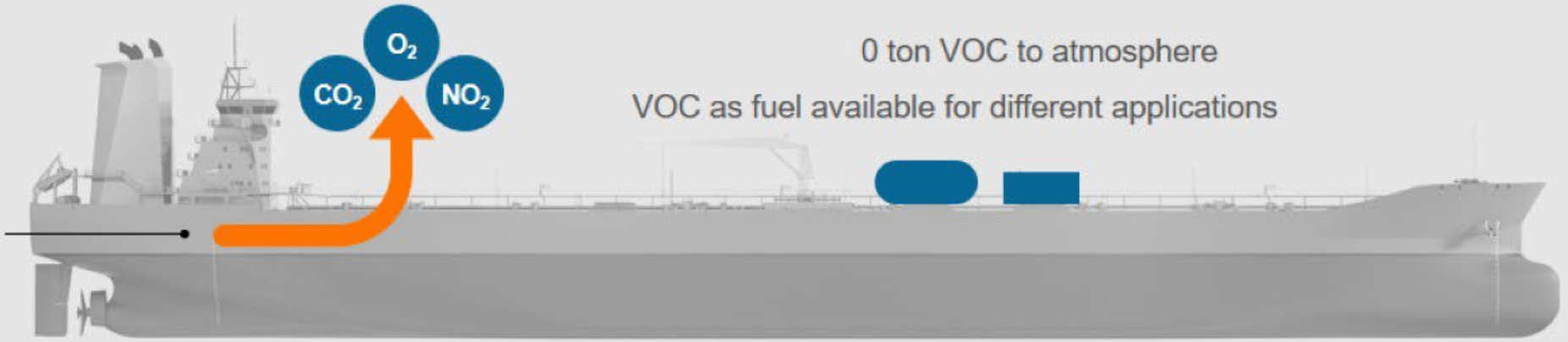


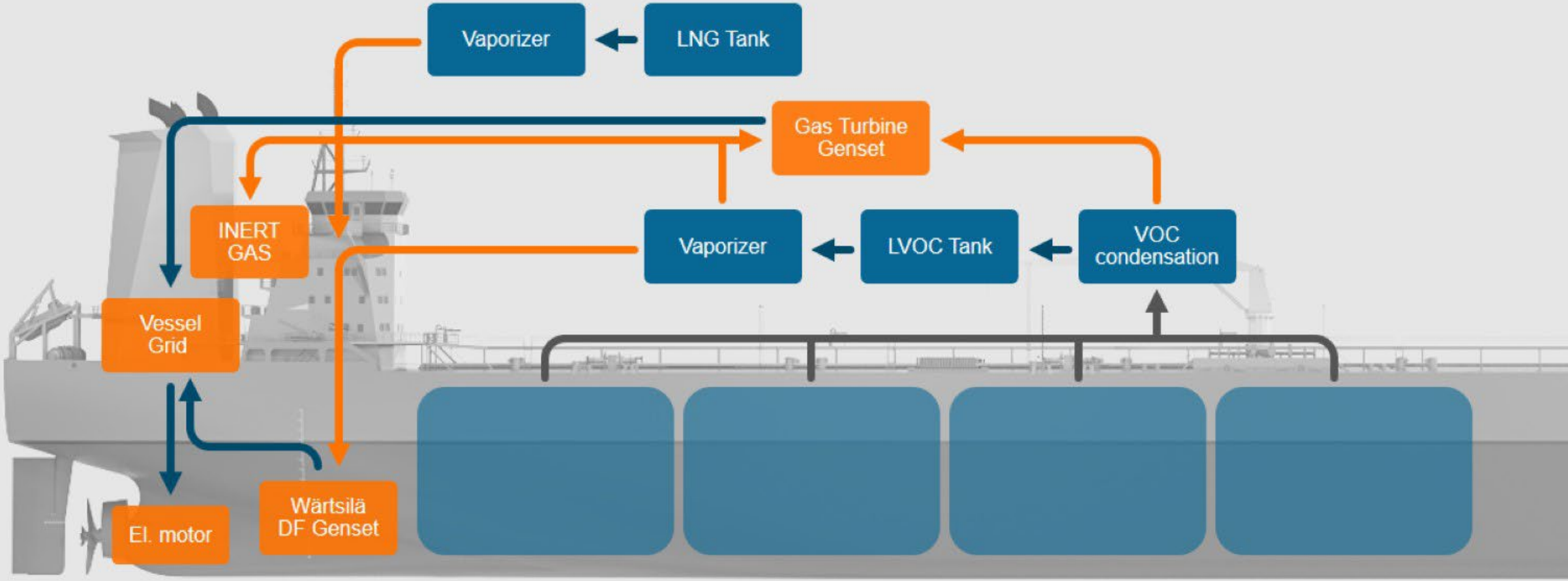
VOC emissions per loading

Without VOC recovery



With VOC recovery




Vaporizer
LNG Tank
Gas Turbine Genset
INERT GAS
Vaporizer
LVOC Tank
VOC condensation
Vessel Grid
El. motor
Wärtsilä DF Genset

MAKING A DIFFERENCE GLOBALLY



IN CLOSE COOPERATION WITH VAHOLMEN VOC REVOVERY

WÄRTSILÄ

THE CHALLENGE – VALUES ARE GOING ASTRAY WHEN LOADING CRUDE OIL CARRIERS

- During Loading of Crude Oil Tankers huge Volumes of valuable Volatile Organic Compounds ("VOC") are emitted to the Atmosphere – 150-450 tons per VLCC[1)] per Loading. **This should be avoided for several reasons**

- Limited Space on **Sea Island** for Compressors etc. and costly subsea Pipes to Shore

- No space for VOC handling Equipment when loading from **Buoys**

- Logistical Issues when loading from **Remote Quays**

- Extensive and expensive Shore based, and Sea Island Facilities required for VOC handling and Disposal





1) VLCC: Very Large Crude Oil Carrier

© Wärtsilä

GLOBAL SUSTAINABILITY ISSUE: PRESERVING THE RESOURCES GONE ASTRAY AND ELIMINATES THE ENVIRONMENTAL ISSUES

WÄRTSILÄ

1 Valuable Hydrocarbons Lost



- During loading of Crude Oil Tankers huge Volumes of valuable Petroleum Gases ("VOC") are emitted directly to Air – 150-450 ton per VLCC Loading
- Around 0.1% of exported Crude Oil is released to the Atmosphere as VOC
- **A fleet of 50 Vaholmen Units may contribute to up to USD ~2.6 bn worth of Petroleum Gases per year being gathered and sent back into the Loop ensuring a sustainable circular Economy**

2 Global Warming (CO_2 Emissions)



- Avoiding Emission of VOC to the Atmosphere during Loading is important
- **A fleet of 50 Vaholmen Units would contribute to up to ~16 million tons Reduction in Emission of CO2 Equivalents per year (corresponds to approx. half of CO2 emissions for mainland Norway)1)**

3 Health Problems (O_3 Emissions)[2)]



- VOC exposed to Sunshine creates ground level Ozone, harmful to Humans
- Concentration of VOC/hydrocarbons around the VLCC is a hazard to crews' Health
- And may also cause Damages to Population in general (more difficult to breathe deeply and vigorously, etc.)
- **We contribute to avoidance of ground level Ozone (O3) – a major local health Problem**

4 Safety Issue – Risk of Explosions



- Safe and uninterrupted Loading of Crude Oil Tankers is imperative
- High Concentration of VOC/Hydrocarbons around the VLCC causes risk for Explosions and Disruption of Operations
- If high Densities of Hydrocarbons at the Crude Oil Tanker, the Vessel must be evacuated
- **We contribute to safe and uninterrupted Loading Operations**

3) ~50 million CO_2 equivalents released from Norwegian territory in 2019, of which ca. 36 million excluding oil and gas extraction
Source: Wärtsilä, Vaholmen analysis, Statistics Norway (https://www.ssb.no/en/klimagassn), Refinitiv

© Wärtsilä

Vaholmen VOC Recovery

ABS

ISO 9001:2015 CERTIFIED

VAHOLMEN UNIT

patent trademark design Norwegian Industrial Property Office GCC/PCT

PATENT PROTECTED

Sjøfartsdirektoratet Norwegian Maritime Authority

APPROVAL IN PRINCIPLE

ABS

APPROVAL IN PRINCIPLE

Hose/hook-up

VOC Recovery Plant delivered by Wärtsilä (20 yrs track Record)

DP2 PSV (or purpose built Vessel)



WÄRTSILÄ

2) Petroleum gases also referred to as Volatile Organic Compounds («VOC»)

© Wärtsilä

HOOK UP DETAIL AND STATION KEEPING BY DYNAMIC POSITIONING (DP2)

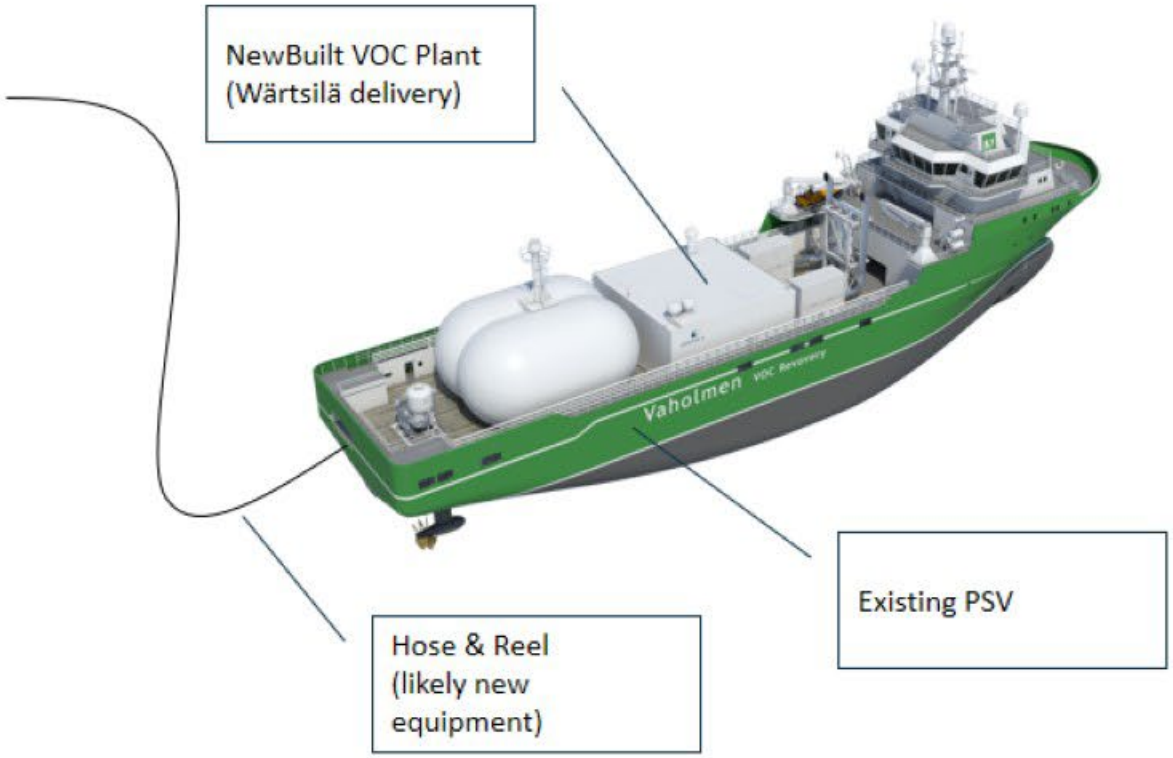


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SECONDHAND VESSEL ALTERNATIVE

VESSEL SET-UP



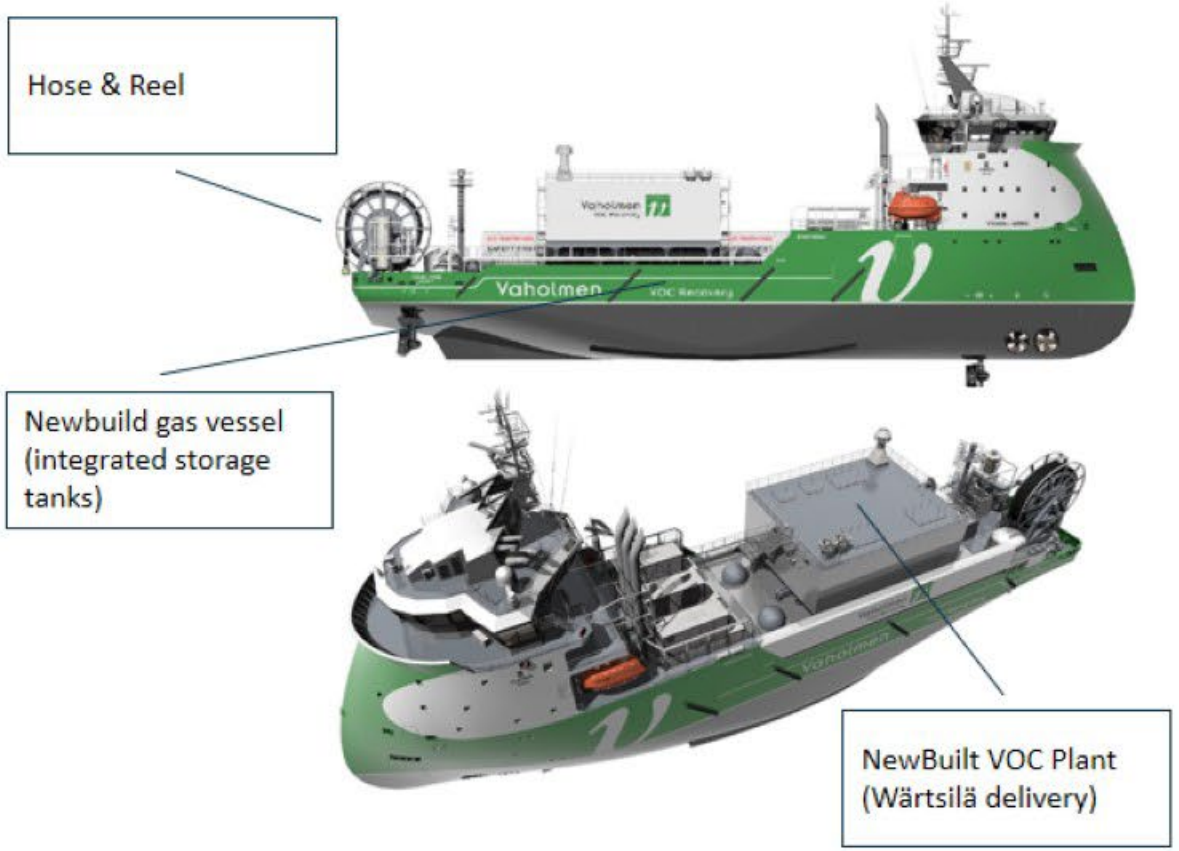
- Second Hand OSV
- DP2 and preferably Diesel Electric Propulsion
- 700 – 1 000 m^2 Deck Area
- LVOC tank capacity 800 – 1 200 m^3
- New Built VOC Plant

© Wärtsilä

WÄRTSILÄ

ULSTEIN/VAHOLMEN DP2 GAS CLASS VRV

VESSEL SET-UP



VESSEL HIGHLIGHTS

- Based on well known Ulstein OSV design
- DP2 capabilities
- 2 500 – 3 000 m^3 LVOC tank capacity
- 3rd Gas Turbine to power Vessel
- High Degree of integration Vessel/VOC plant

© Wärtsilä

THE SOLUTION OFFERS AN ATTRACTIVE PROPOSITION TO THE CUSTOMERS

	250T per loading	350T per loading	450T per loading
Liquefied VOC	250	350	450
Loadings per week	3	3	3
Bbls/ton	10.55	10.55	10.55
Liquefied VOC per year	0.41	0.58	0.74
USD / Bbl	110	110	110
Value Liquefied VOC per Year (mUSD)	**45.3**	**63.4**	**81.5**
USD per day	*123 999*	*173 598*	*223 198*
Tons liquefied VOC / year	39 107	54 750	70 393
Tons CO_2 equivalents / year	178 005	249 207	320 408
$C0_2$ price (USD/ton)	73	73	73
Value CO_2 savings (mUSD)	**13.0**	**18.2**	**23.4**
USD per Day	*35 601*	*49 841*	*64 082*
Total Value (mUSD)	**58.3**	**81.6**	**104.9**
Revenue per VRV (USD/day)	*159 600*	*223 439*	*287 279*

DISTRIBUTION AND TRADING OF HYDROCARBONS

- Reinjection into onshore crude oil storage
- Resell as condensate as a commercial grade of liquid hydrocarbons
- Use as fuel for power production

COMMENTS

- VOC emissions emitted directly to air today represent valuable hydrocarbon resources
- By leasing or buying a VOC Recovery Vessel, crude oil exporters can capture the VOC resources and generate substantial revenue for themselves
- Collected VOC emissions are processed into LVOC (liquid VOC) and re-injected into export oil stream and therethrough implicitly sold at the export crude oil price
- The illustration of value creation per Vaholmen Unit for oil exporters to the left indicates gross revenue of:
  - Middle East case: Up to USD 159k – 287k per day[1)] (continuous operations with 3 loadings per week)

1) Assumes oil price of USD 73.3/bbl and CO_2 price of USD 73.0/tons (EU carbon price is 61.6 EUR/ton as of Sept. 2021 (Source: Refinitiv)



THANK YOU!

Mechanisms to reduce the release of carbon from tankers

- Reduce the content of light ends in loaded cargo
- Lower cargo temperature
- Reduce time needed to fill a cargo tank

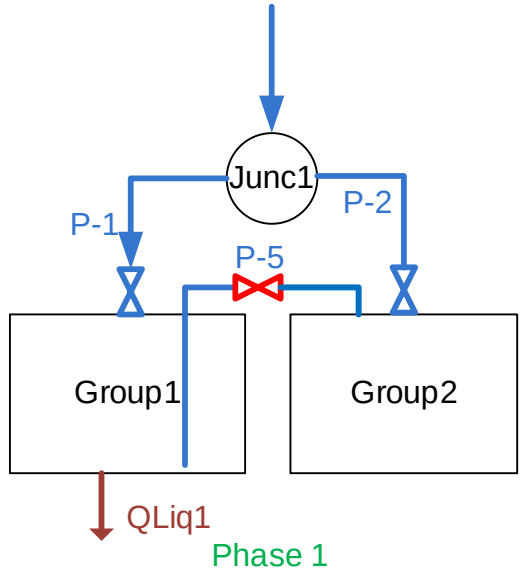


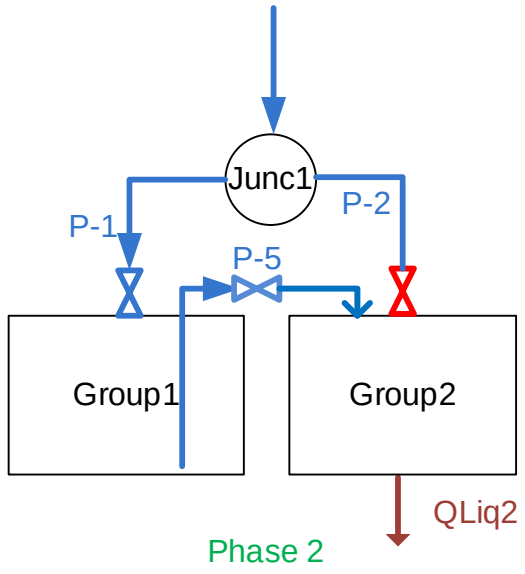
Increase partial pressure of VOC, 1

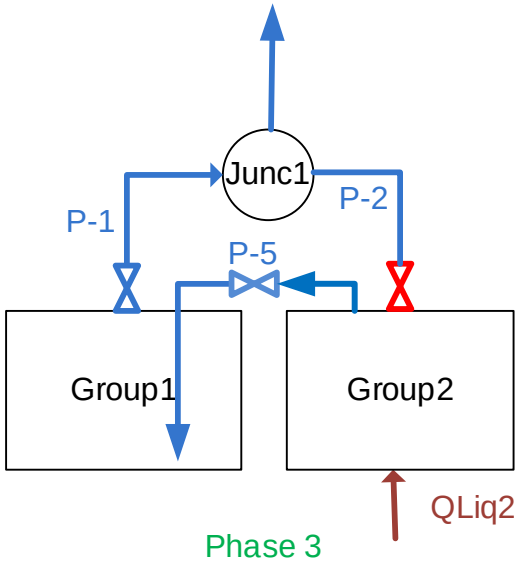
- Increased cargo tank pressure (0.5) barg
  - <19, 31> % reduced VOC release
  - Larger % reduction for volatile crude
  - Laden voyage (almost) without emission
  - Closed cargo surveying → less IG needed

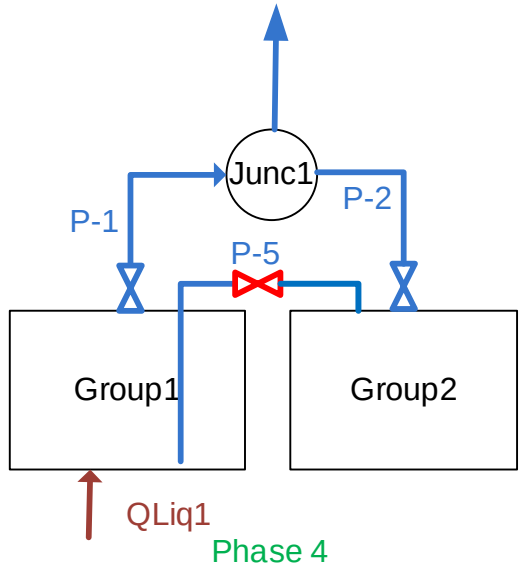
Increase partial pressure of VOC, 2

- STTA:
  - 1.50 bara → 26 % VOC reduction
  - 1.10 bara → 12 % VOC reduction



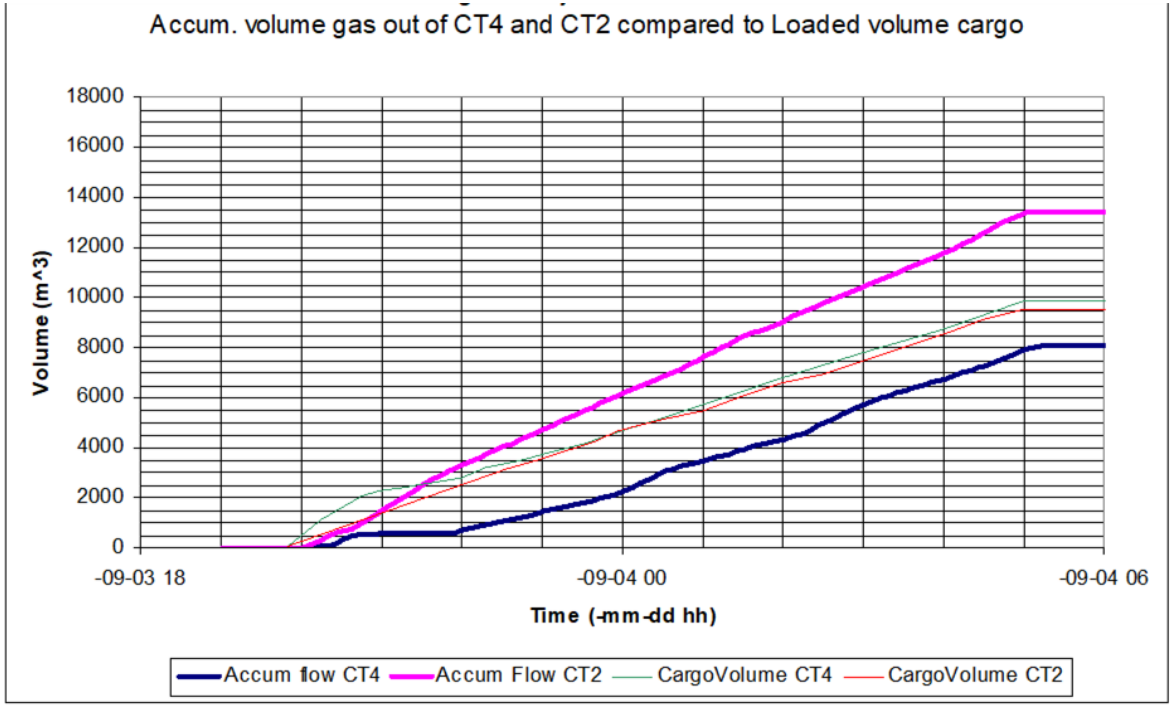






Increase partial pressure of VOC, 3

- VOC blanket gas:
  - Where to get the VOC blanket gas?
  - How to recover and store the VOC displaced during loading for use during discharge?
  - FPSOs



WADE MARITIME GROUP

Crude oil cargo emissions and Volatile Organic Compounds webinar

Part of
Tanker Shipping & Trade
Webinar Week

7-11 March 2022

11 March 2022 • 09:00-09:45 GMT

IMO GHG Reduction Strategy

Decarbonisation Strategy

Mainly focussed on



What about VOCs?



Initiate consideration of mid-term measures under Phase I of the Workplan (October-November 2021)

Further consideration of assessment of impacts on States of candidate GHG measures (October-November 2021)

EEDI phase 3 in effect for certain ship types with up to 50% carbon intensity reduction for new build large containerships

EEXI survey requirements take effect (November 2022)

Carbon intensity measures enter into effect

Revision of the IMO Initial GHG Strategy

Start of carbon intensity data (CII) collection under the short-term measure

EEDI phase 3 in effect - up to 30% reduction in carbon intensity for newbuild ship

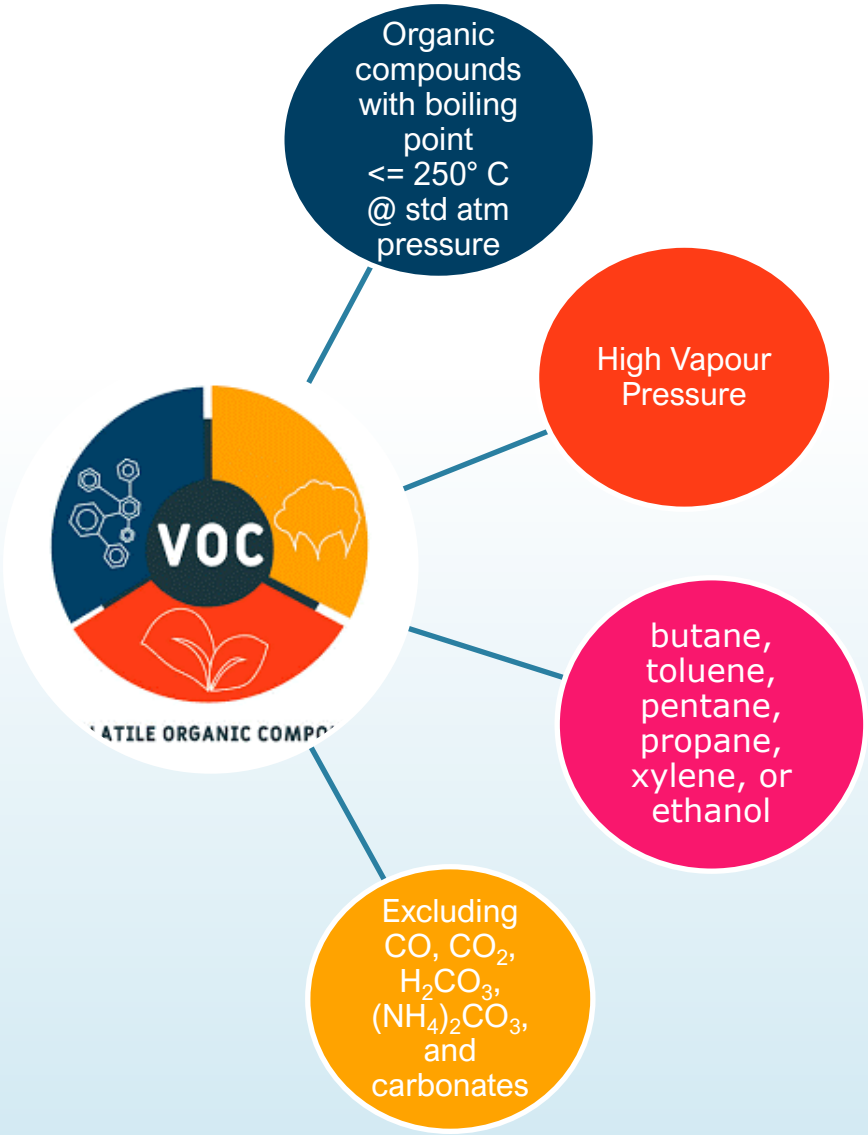
IMO Initial GHG Strategy objective of 40% reduction of CO_2 emissions per transport work compared to 2008, as an average across international shipping

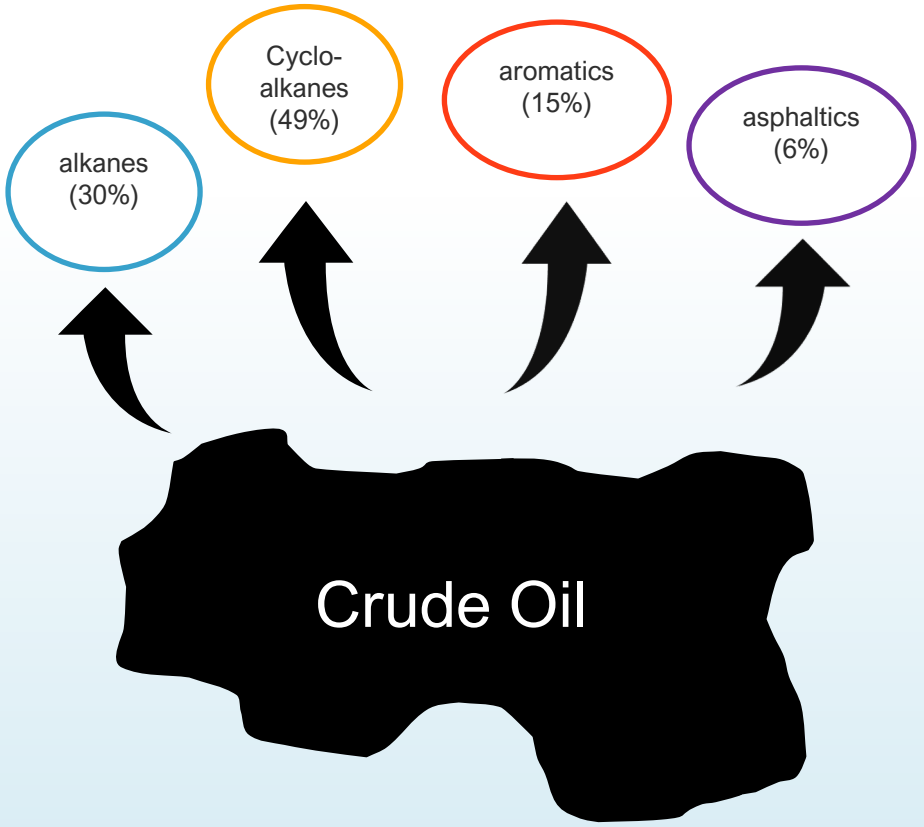
IMO Initial GHG Strategy objectives of 50% reduction of the total annual GHG emissions and 70% reduction of CO_2 emissions per transport work compared to 2008 whilst pursuing efforts towards phasing them out - as a point on a pathway of CO_2 emissions reduction consistent with the Paris Agreement temperature goals

2022 2023 2024 2025 2030 2050

Source: IMO

What are VOC's ?

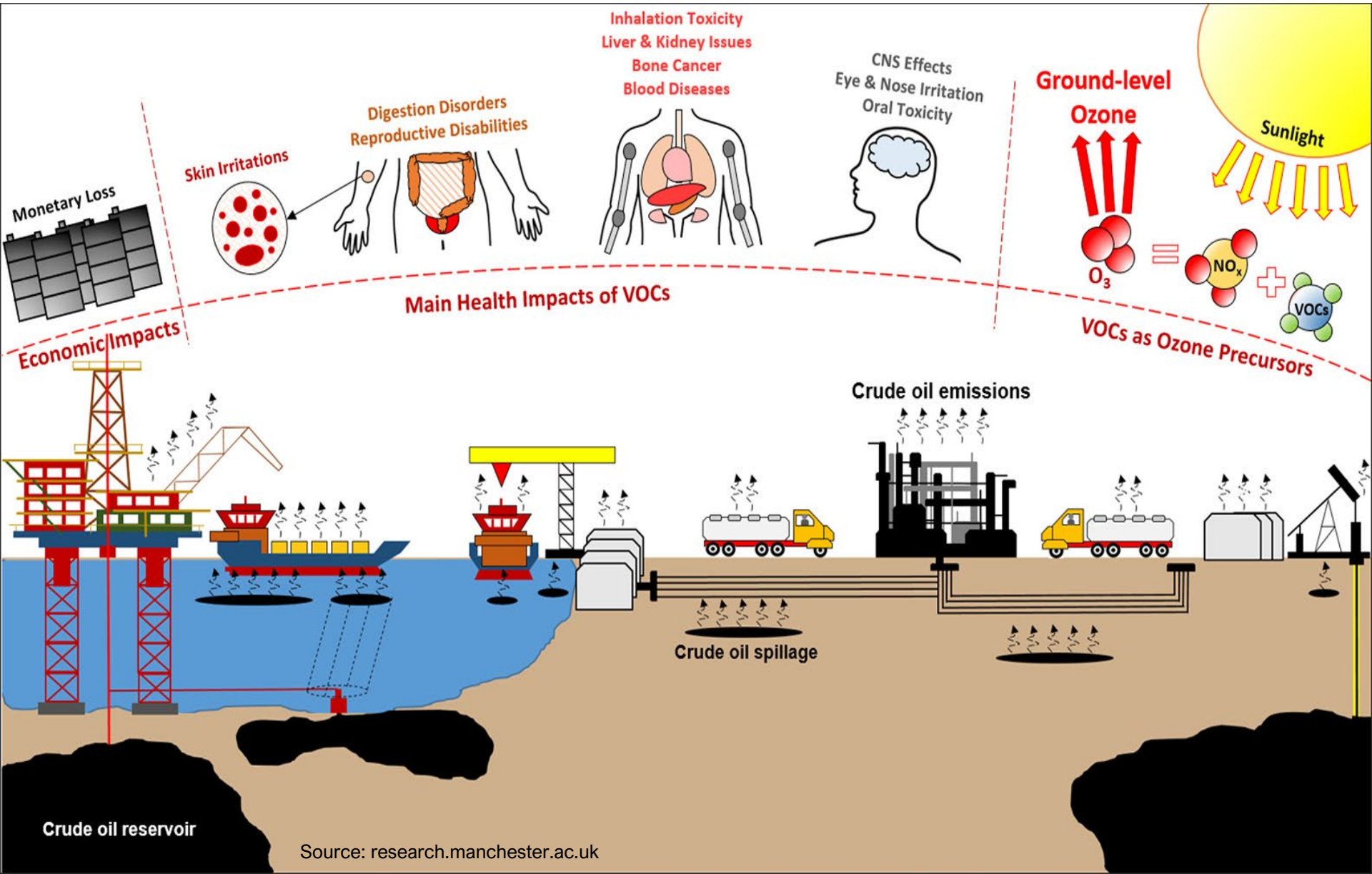




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Main Impacts of VOCs



Source: research.manchester.ac.uk

VOC - REGULATIONS

VECS MSC/Circ 585 April 1992

Vapour Emission Control System

- MARPOL Annex VI/15 – Standards developed for the design, construction and operation of VECS on tankers.
- No mandatory requirement for VECS as opposed to one for VOC Management Plan

Circular MEPC.1/Circ680 Jul 2009

VOC Management Plans

- Technical information on system and operational guidelines for development of VOC management plans.

Resolution MEPC 185(59) Jul 2010

VOC Management Plans

- Required all member states to develop to develop a VOC management plan that follows MEPC guidelines.

NCPD Reg Jan 2012

NMVOC Emissions Regulation

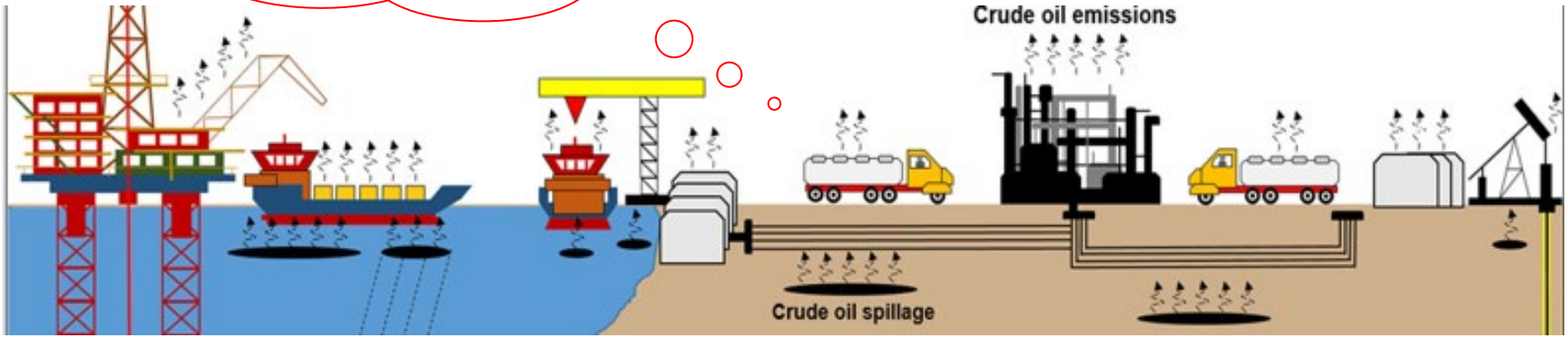
- The Norwegian Climate and Pollution Directorate (NCPD) imposed an upper limit of 0.45 kg of NMVOC/Sm3 of crude oil per loading point as a mean value per calendar year with a maximum of 135,000 tonnes of emissions per year.
- Between 2015 & 2019, this limit was raised to 0.68 kg/Sm3

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Evaporative Loss: Quantum

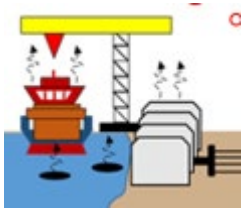
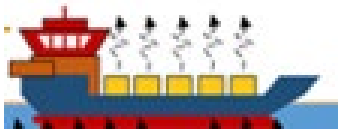
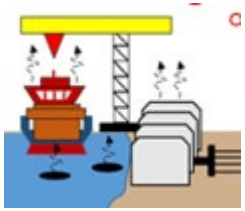
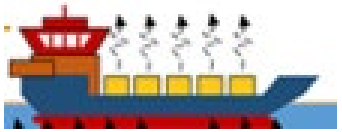
2002: Global Oil Cargo Vapour Losses equalled about 1 mil tonnes

$ >850 million
Basis current prices



Source: Rohit Bhatia et al, Lloyds List, Manchester University

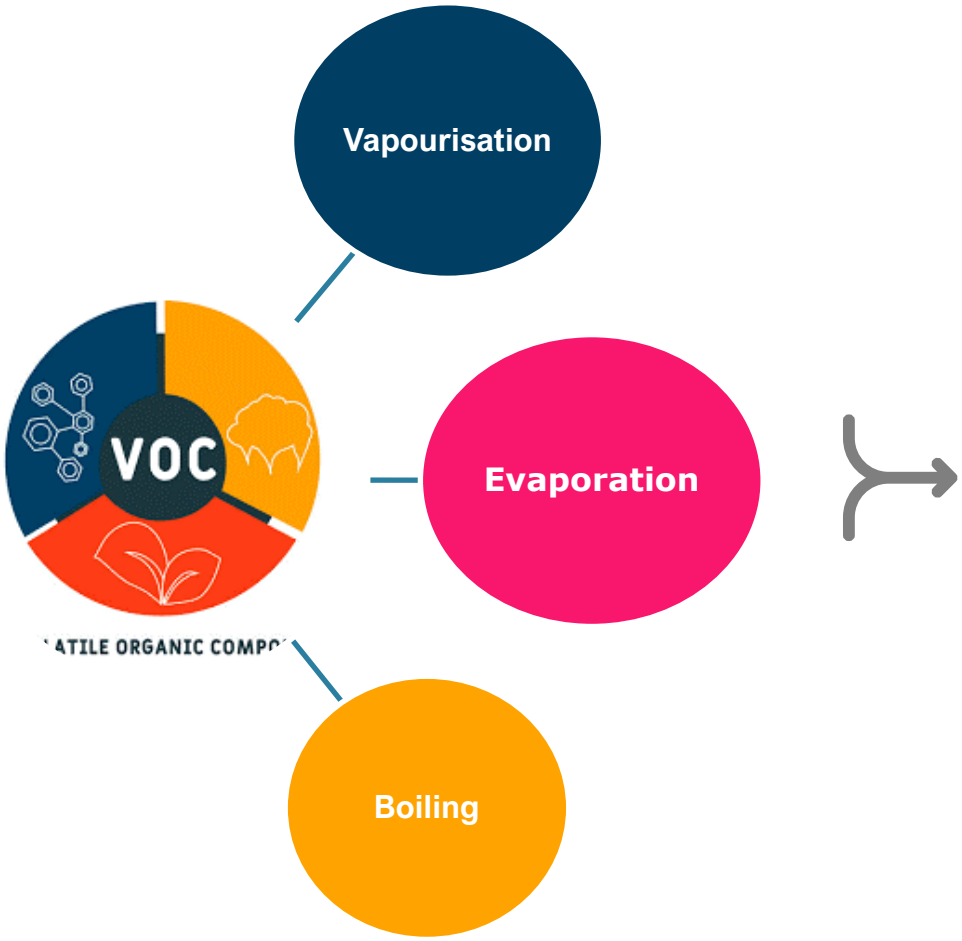
Evaporative Loss: Typical VLCC AG to Europe voyage = 0.15% or about 450 mt

0.079 %	0.015 %	0.033 %	0.027 %
			
Loading	**Loaded Voyage**	**Discharging**	**Ballast Voyage**

Source: Uhlin 1985, Rohit Bhatia et al 2004

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VOCs Generation and Control Mechanisms



Active Recovery

- Compression
- Condensation
- Absorption
- Adsorption

Passive Recovery

- Vapour Emissions Control System (VECS)
- Cargo Pipeline Partial Pressure Control

Other Controls

- Sequential Transfer of Tank Atmosphere
- Vapour Pressure Release Control System (VOCON procedure)

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VOC Control: Concerns

- **Use of Low Sulphur Fuels – Impact on emissions of VOCs**
  - Recent study in 2018 indicates that emissions factors for VOCs increased 14 fold after implementation of low sulphur fuels in the Pearl River Delta region ECA (China).
- **VOC emissions are less controlled during crude oil extraction stage (well-to-tank)**
- **Necessity to implement control measures to regulate emissions in primary steps of extraction-to-refinery pathways.**
- **Access to cost-effective real-time monitoring devices for VOCs detection is urgent.**
- **Extensive knowledge gaps in occupational exposure limits and control measures exist.**



Source: Rajabi, Mosleh et al, 2020, Zengfeng Wu, Yanli Zang et al, 2018, Rohit Bhatia & John Dinwoodie, 2004

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