

A large cargo ship is shown from an aerial perspective, sailing on the water. The ship is filled with numerous stacked shipping containers. The image is semi-transparent and serves as a background for the right side of the slide. A bright green vertical bar is located in the top right corner of the slide.

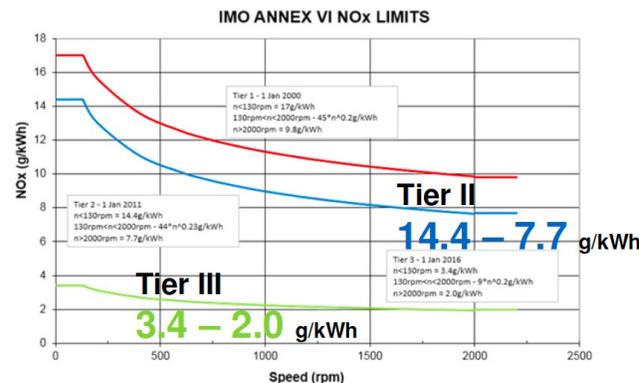
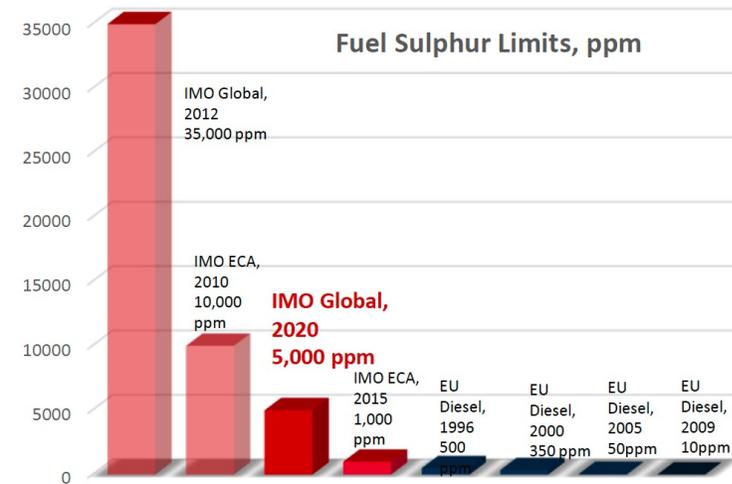
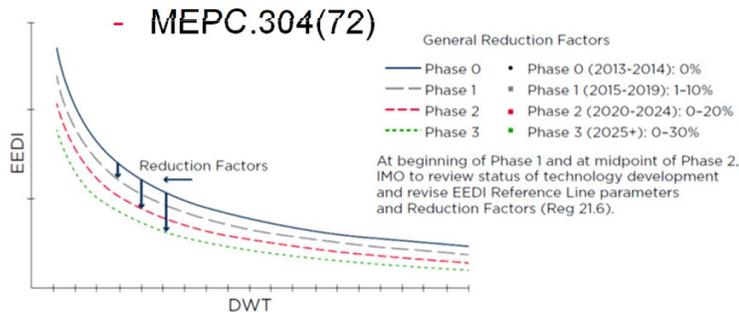
# Collaboration

Prof. Toms Torims

Riga Technical University

# Environmental rules are tightening IMO MARPOL Annex VI

- MARPOL Annex VI – Regulations for the prevention of air pollution from ships
- Regulation 13 - Nitrogen Oxide Emissions (NOx)
- Regulation 14 – Sulphur Oxides (SOx)
- Chapter 4 - Energy Efficiency Design Index (EEDI)
- IMO GHG Reduction Strategy



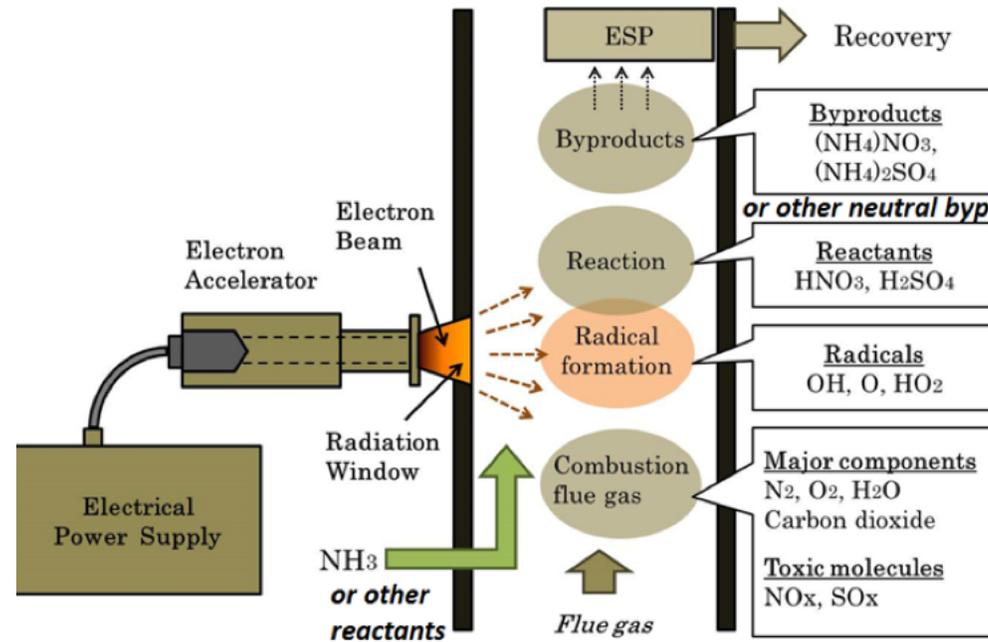
- EU Sulphur Directive 1999/32/EC, codified as 2016/802



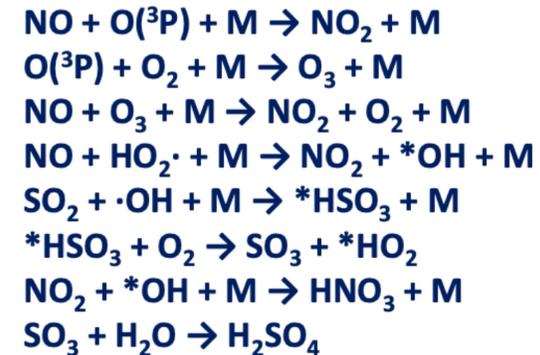
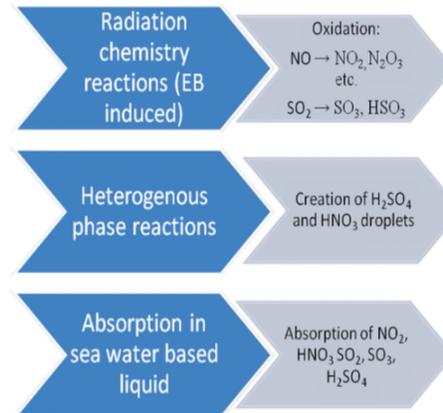
# ARIES Project

Accelerator  
Research and  
Innovation for  
European  
Science and  
Society

Proof-of-  
Concept



NO<sub>x</sub>  
SO<sub>x</sub>  
PM  
VOC



Courtesy of INCT, Warsaw



**HERTIS**

### Inlet of the installation

Exhaust gases with high concentration of NO<sub>x</sub>, SO<sub>x</sub> and VOC (PAH).

### Electron Beam

Oxidation of the NO to NO<sub>2</sub>, NO<sub>2</sub> to higher oxides and HNO<sub>3</sub> and SO<sub>2</sub> to higher oxides and H<sub>2</sub>SO<sub>4</sub>

### Wet scrubbing

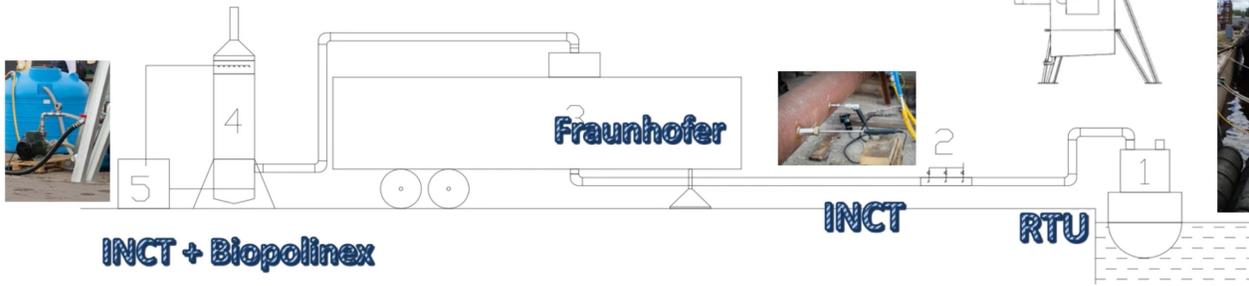
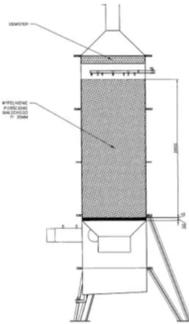
Absorption of NO<sub>2</sub> and higher nitrogen oxides, SO<sub>3</sub> and higher sulphur oxides, HNO<sub>3</sub> and H<sub>2</sub>SO<sub>4</sub>

### Outlet of the installation

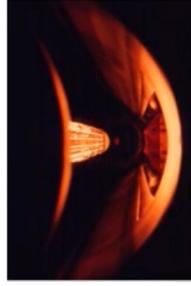
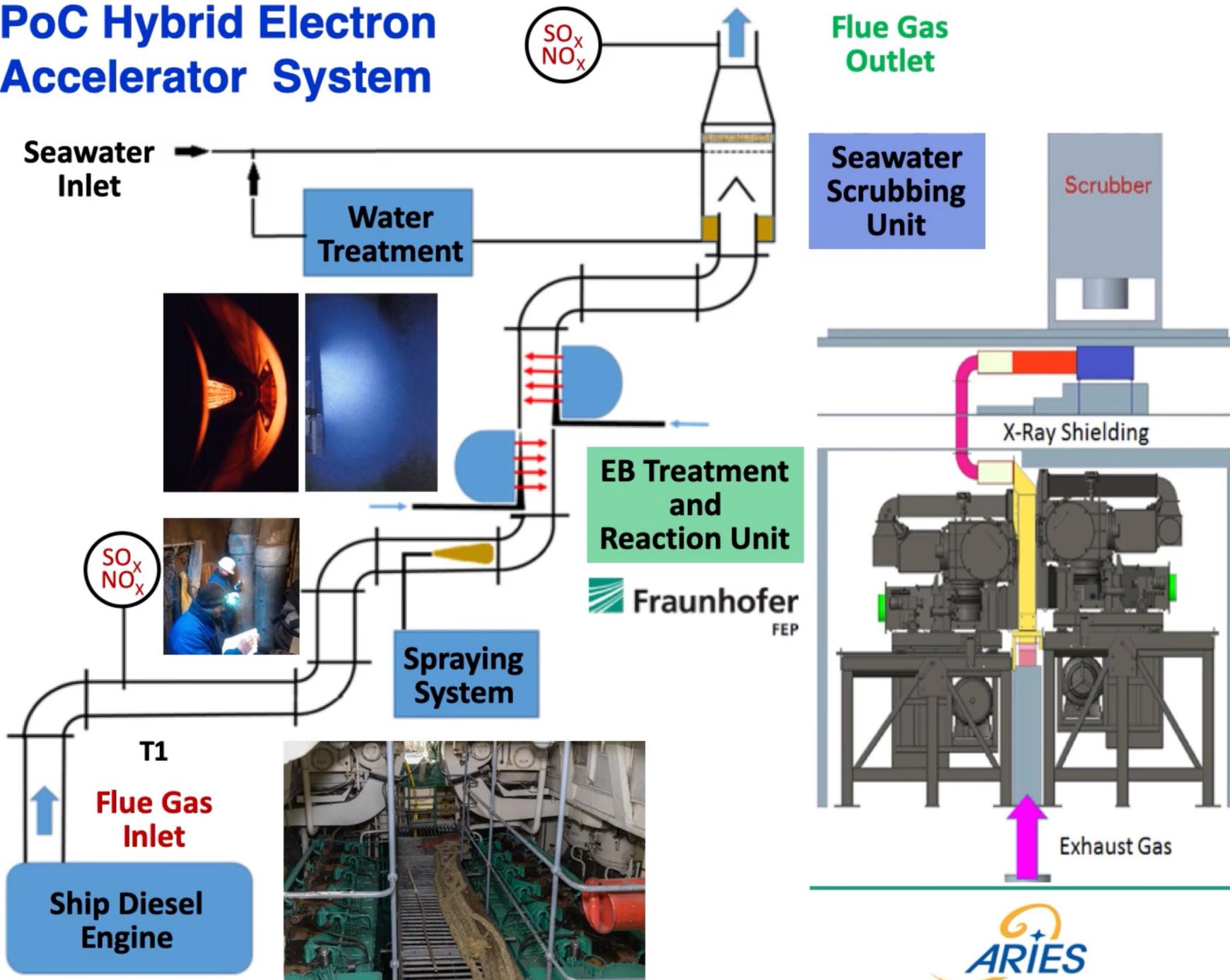
Clean exhaust gases matching the imposed regulations

## Hybrid system

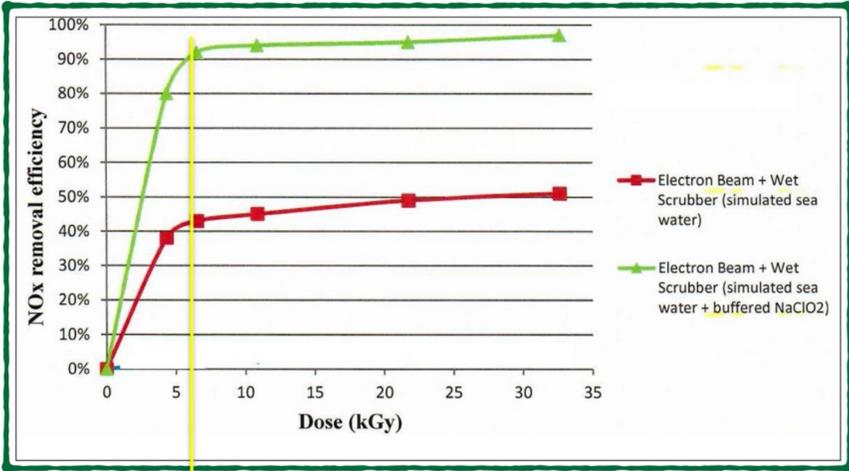
e-beam  
interaction with  
the exhaust  
gases + wet  
scrubbing



# PoC Hybrid Electron Accelerator System



- good agreement was obtained with laboratory tests in the maximum available at field test dose range.

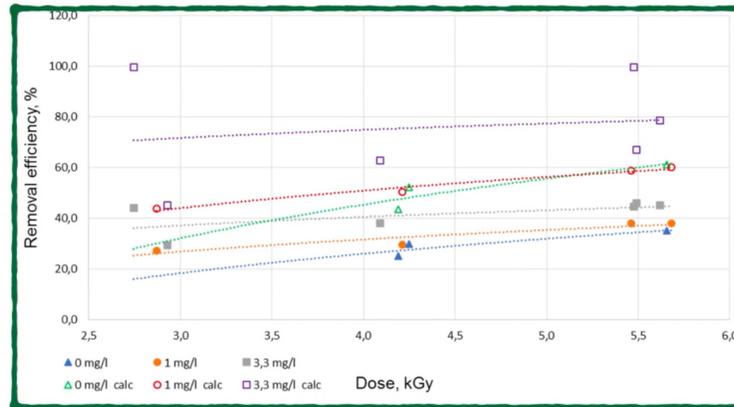
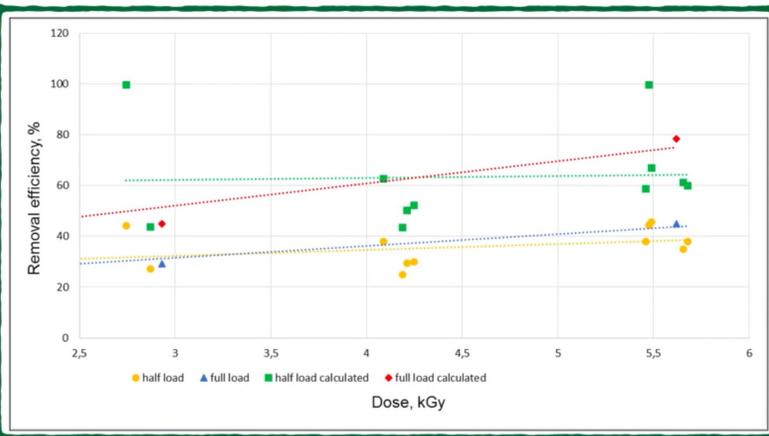


Max dose applied in Riga experiment



# ARIES PoC results

# NO<sub>x</sub> removal efficiency



Engine load	%	0	50												100		
Gas flow rate	Nm <sup>3</sup> /h	3316,1	4763,9	4831,2	4771,8	4703,0	4807,1	4942,7	4751,7	4915,2	4950,0	4917,8	4927,6	4605,5	4494,6	4804,1	
Removal rate	NO	%	81,8	48,2	39,1	58,2	39,2	46,3	55,3	57,4	65,2	60,4	100,0	100,0	43,2	26,5	77,6
	NO <sub>x</sub>	%	38,8	30,0	25,0	35,1	27,3	29,6	38,1	38,0	45,8	38,1	44,2	44,4	29,2	18,7	45,0

# ARIES PoC results Economic Analysis

Cost calculations were based on discounted cash flow method:

-  Net Present Value ( **NPV** ),
-  Internal Rate of Return ( **IRR** ),
-  Modified Internal Rate of Return ( **MIRR** ),
-  Profitability index ( **PI** ),
-  Discounted Payback Period ( **DPP** ).

Based on a comparison of the marine diesel (low SOx) price v/s HFO together with the purification cost.

Three scenarios:

-  OPTIMAL,
-  OPTIMISTIC
-  PESSIMISTIC

*[sic] ... definitely show profitability of both optimistic and optimal scenario... The results of the analysis indicate the high market potential of the technology being developed*

 **ARIES**



► Economic analysis confirmed profitability of the hybrid technology vis-à-vis Heavy Fuel Oil (HFO) option with the conventional scrubber off-gases abatement costs.

► This is true for both optimistic and optimal financial risk associated scenarios, indicating the **high market potential** of the maritime application of the hybrid technology.



**HERTIS**

# ARIES PoC is success story

- ▶ [ARIES PoC video](#)
- ▶ [PoC Final Report](#)
- ▶ T. Torims et al., "Development of a Hybrid Electron Accelerator System for the Treatment of Marine Diesel Exhaust Gases", presented at the 11th Int. Particle Accelerator Conf. (IPAC'20), Caen, France, May 2020, paper THVIR14.
- ▶ Y. Sun et al., "Organic pollutant removal from marine diesel engine off-gases under electron beam and hybrid electron beam and wet scrubbing process" in Proceedings NUTECH 2020, Warsaw, Poland, October 2020.
- ▶ Pawelec et al., "Plasma technology to remove NOx from off-gases" in Proceedings NUTECH 2020, Warsaw, Poland, October 2020.
- ▶ Master Thesis: "Impact on the Maritime Industry from an Introduction of a Hybrid Exhaust Gas Cleaning Technology" Master th. by Mr. A. Ābele @ Western Norway University of Applied Sciences
- ▶ "Qualitative and Quantitative Analysis of The Hybrid Electron Accelerator Exhaust Gas Abatement Technology Impact to the Selected Maritime Logistics Aspects" Master th. by Ms. E. Tskhay @ RTU



So what?  
What's next?

## HERTIS Collaboration

Hybrid Exhaust-Gas-  
Cleaning and Accelerator  
Technology for International  
Shipping

- ▶ HERTIS **Collaboration shall build upon** highly successful ARIES Proof of the Concept project “*Development of a hybrid electron accelerator system for the treatment of marine diesel exhaust gases*”
- ▶ Some 20 + meetings since 2017

<https://indico.cern.ch/category/9244/>



# Stakeholders interest Emissions – GHG Reduction Strategy

- By 2030, reduce CO<sub>2</sub> emissions per cargo transport work by 40%, aiming at 70% in 2050, compared to 2008
- By 2050, reduce total GHG emissions by at least 50% compared to 2008



## Key activities prior to 2023 adoption of revised IMO strategy

- Data collection from ships (January 2019)
- Fourth IMO GHG study using data from 2012-2018
- Review energy efficiency requirements (EEDI) for new ships

- ▶ Maritime industry and major Stakeholders are experiencing a **strong interest in the field for the exhaust gas abatement technologies**
- ▶ Including prospective particle accelerator applications to address, *inter alia*, the exhaust emission equipment trends and **opportunities for control of new emissions associated with emerging fuels**

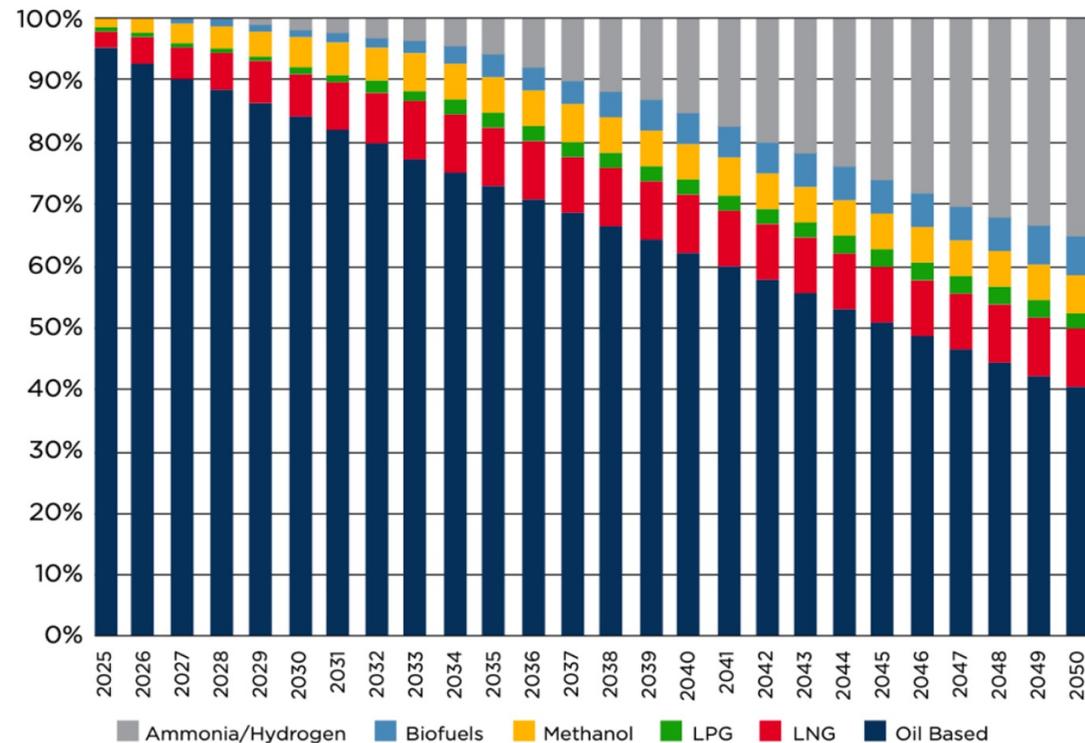
Courtesy of American Bureau of Shipping



**HERTIS**

# Marine Fuel Demand

- Significant change in demand profile overnight from 1 January 2020
- Approximately 3million barrel/day (155million tonnes/year) switch
- Predominantly met with MGO and 0.1/0.5% S fuels - VLSFO
- LNG and other alternative fuels currently play a small part
- Strong interest in ammonia moving forward



Courtesy of American Bureau of Shipping

# Future Emission Control and Reduction

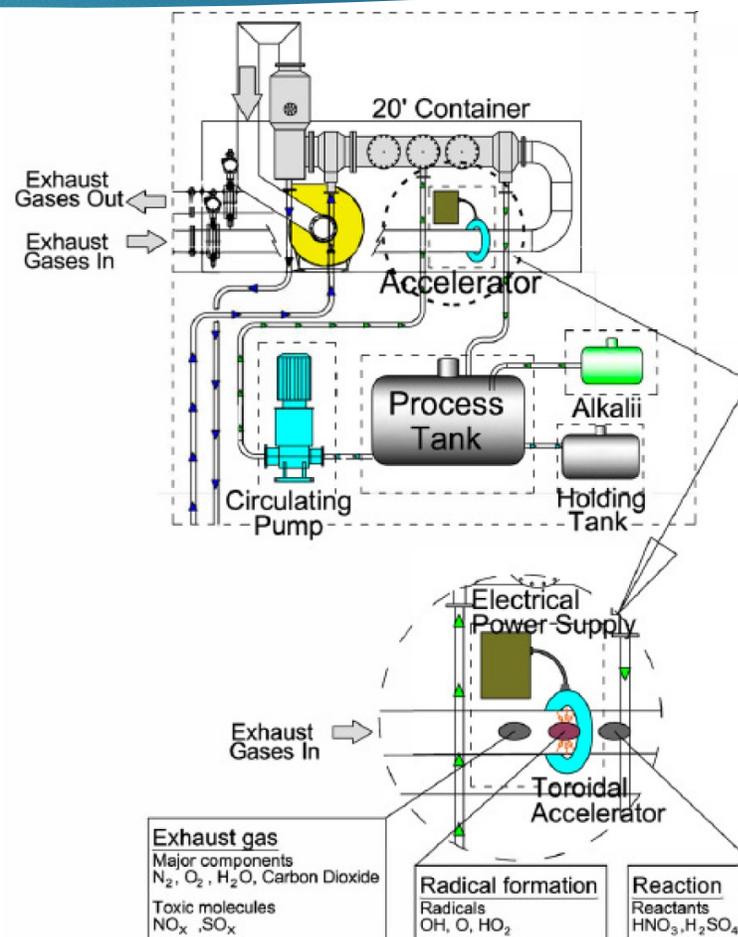
- In the absence of impending further marine fuel reductions, SOx control by scrubbers only needed for high sulphur fuel applications – reducing fuel price differential? Reducing applications?
- All alternative fuels being applied and considered – biofuels, LNG, methanol, ethane, LPG, eDiesel, ammonia, hydrogen – inherently negligible sulphur content - **SOx control not required**
- **NOx control remains main marine requirement**
- Awareness of CH<sub>4</sub> and N<sub>2</sub>O impacts
- Ammonia introduces NH<sub>3</sub> control



# Application of Accelerators

- EB irradiation - Application to exhaust gas systems of engines operating on alternative fuels?
- Explore potential reduction of pollutants: CH<sub>4</sub> (methane slip), CO<sub>2</sub>, NH<sub>3</sub> (ammonia slip), N<sub>2</sub>O
- Without alkali reactant?
- Potential for further reductions of NO<sub>x</sub> (may lead to improved SFOC)
- Explore compatibility of use with existing water scrubbing systems in LPEGR or HPEGR systems

Courtesy of American Bureau of Shipping





# HERTIS Collaboration

Collaborative approach and joint strategy to define the most efficient ways of synergy between industry, academia and research labs

To overcome technological and administrative barriers in order to create and support innovative and sustainable Pan-European Partnership in Maritime Hybrid Exhaust-Gas-Cleaning Technology

# HERTIS Mission

- ▶ To pool resources and knowledge to work together
- ▶ Coordinated Strategy, Activities and Projects
- ▶ To develop and implement the Maritime Hybrid Exhaust-Gas-Cleaning and Accelerator Technologies



# HERTIS

## Founding Partners

1. European Organization for Nuclear Research (CERN) 🇨🇭
2. Fraunhofer-Gesellschaft zur Förderung der angewandten (Fraunhofer FEP) 🇩🇪
3. Institute of Nuclear Chemistry and Technology (INCT) 🇵🇱
4. Riga Technical University (RTU) 🇱🇻
5. Grimaldi Euromed S.p.A. (Grimaldi) 🇮🇹
6. American Bureau of Shipping (ABS) 🇺🇸 🇬🇷
7. KPMG Baltics AS (KPMG) 🇱🇻
8. University of Tartu (UT) 🇪🇪
9. Stiftinga Vestlandsforsking (WNRI) 🇳🇴
10. Ecospray Technologies S.R.L. (Ecospray) 🇮🇹
11. Biopolinex Sp. z o. o. (Biopolinex) 🇵🇱





# HERTIS Strategic Goal

Contribute in meaningful and timely manner to:

- ▶ High-priority initiatives of the **European Strategy for Particle Physics**
- ▶ Goals of the **Strategy on Reduction of GHG Emissions from Ships** of IMO
- ▶ **EU Green Deal** Policy and related initiatives

# HERTIS contribution to European Strategy for Particle Physics

---

Innovation in accelerator technology is the **High-priority** initiative

---

Synergies between **scientific fields and industry** should be exploited to increase technology transfer **benefiting society at large**

---

**Collaborative platforms and consortia** must be adequately **supported**

---

To **intensify accelerator R&D** and ramp up effort of **advanced accelerator technologies**

---

**HEP community** and the **EC link** to be strengthened, exploring **funding opportunities** for the realisation of ... **R&D programmes** in cooperation **with other fields of science and industry**

---

Knowledge and technology transfer and the associated **societal impact** is important

---

Particle physics research centres should promote **knowledge and technology transfer**

---

HEP community should **engage with industry** to facilitate **knowledge transfer** and **technological development**

# HERTIS Contribution to the IMO

## Strategy on Reduction of GHG Emissions from Ships

---

To provide mechanisms for:

- information sharing
- technology transfer
- capacity-building
- technical cooperation

to improve the energy efficiency of ships

---

To consider and analyse:

- emissions of methane
- Volatile Organic Compounds



The Marine Environment Protection Committee (MEPC)

# HERTIS Contribution to the EU Green Deal

## Policy and legislative initiatives

---

Fuel EU Maritime - **Green European Maritime Space** and European Parliament Resolution on the **European Green Deal**

---

Called for measures to move away from the use of heavy fuel oil and for **urgent investments in research into new technologies to decarbonise** the shipping sector, and in the development of **zero-emission and green ships**

---

<https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-fuel-eu-maritime>

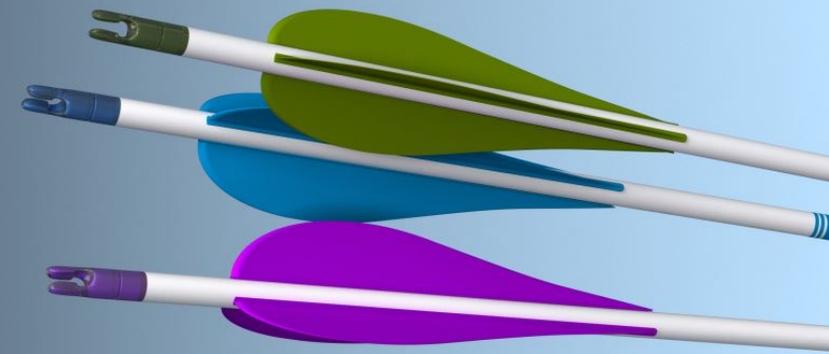
---

[https://www.europarl.europa.eu/doceo/document/TA-9-2020-0005\\_EN.pdf](https://www.europarl.europa.eu/doceo/document/TA-9-2020-0005_EN.pdf)



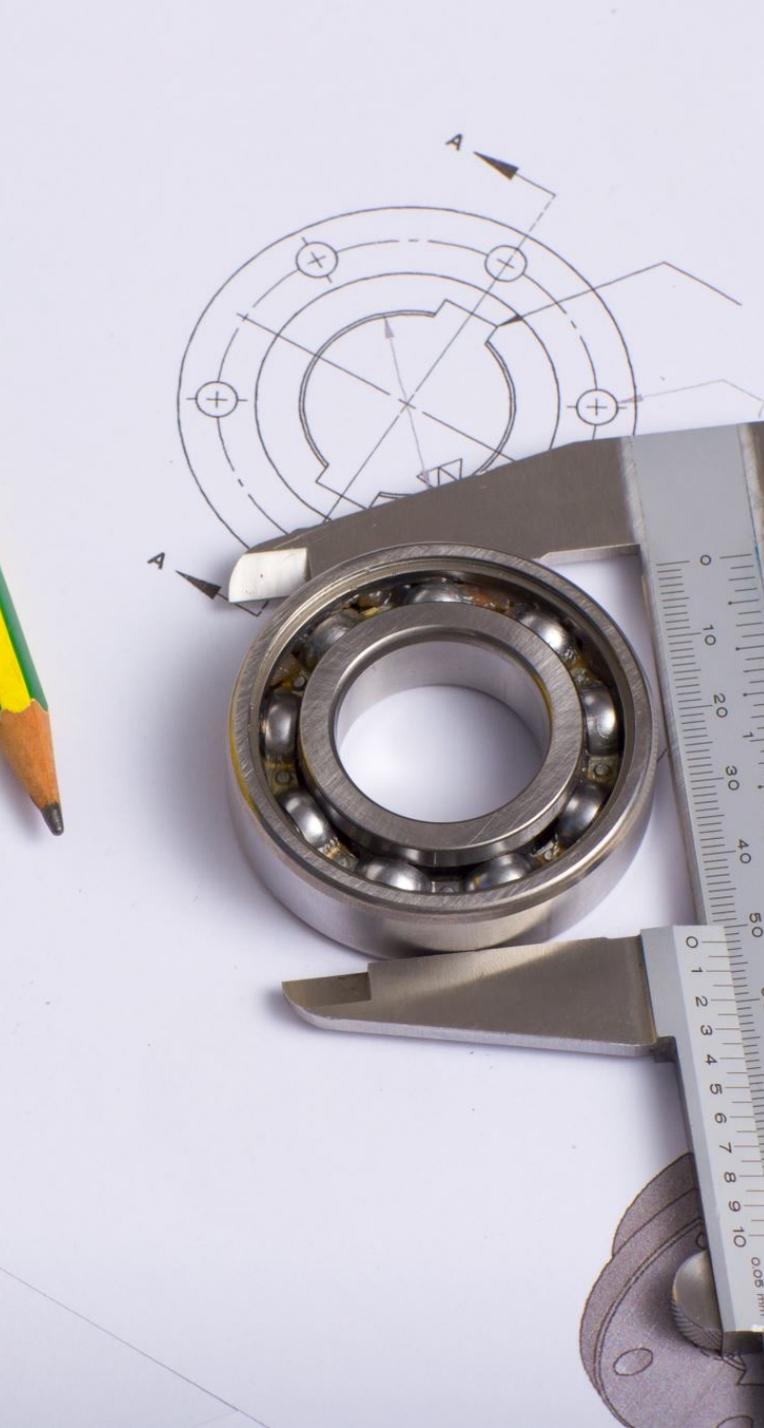
# HERTIS Objectives

- ▶ To develop and maintain joint **Strategy** and to undertake **Activities** in the common interest of Partners
- ▶ To prepare and submit the **Projects** on behalf of the Collaboration
- ▶ To create a strong and efficient **exchange mechanism** allowing creation of a common view and a joint platform
- ▶ To exchange of up-to-date information among the partners and in **one-voice** vis-a-vis Stakeholders, Policy makers as well as Maritime and Accelerator Communities
- ▶ To coordinate relevant research and **technology development** Activities
- ▶ To foster multidisciplinary **cooperation between Accelerator and Maritime Communities** and generate new opportunities via joint Projects, contacts and events



# HERTIS Projects

- ▶ **Joint Activities with industry**, academic and research partners on common concerns, through European, regional or national funding programmes
- ▶ **Providing** the European maritime and accelerator community with a much-needed innovative, cost-effective **technological solutions**
- ▶ To help improve substantially performance of fleets, by **significantly reducing maritime environmental footprint**



# HERTIS Projects

- ▶ Several HERTIS Collaboration Partners are taking part in the I.FAST project WP12: **Societal applications** and benefiting from opportunities which are arising from such EU co-funded funded Project <https://ifast-project.eu/home>
  - access to the pan-European accelerator community and advanced technological expertise of the Project partners
  - excellent platform for dissemination of the HERTIS Collaborations projects, challenges and achievements
- ▶ An **extensive collaborative effort** was made by HERTIS Partners to prepare Proposal for EU Framework Programme Call: H2020-MG-2019
- ▶ Although it has in principle received a favourable evaluation, Proposal was ranked just below the available budget threshold for funding. Subsequently said proposal has been put on the EC reserve list and finally was formally rejected, since no additional funding became available.

[https://indico.cern.ch/event/811370/contributions/3380993/attachments/1922740/3181531/HERTIS\\_flyer\\_A4.pdf](https://indico.cern.ch/event/811370/contributions/3380993/attachments/1922740/3181531/HERTIS_flyer_A4.pdf)

# HERTIS Projects Group

- ▶ Funding selection and project preparation Working Group
- ▶ In charge of funding opportunities and Calls (e.g. EU, Regional or National) evaluation
- ▶ When the appropriate Calls are selected, Projects Group in liaison with the Sci-Tech Group is responsible for the Project Proposal preparation and submission
- ▶ Currently working on **HORIZON-CL5-2022-DEST5CCT-02-04: Transformation of the existing fleet towards greener operations through retrofitting**

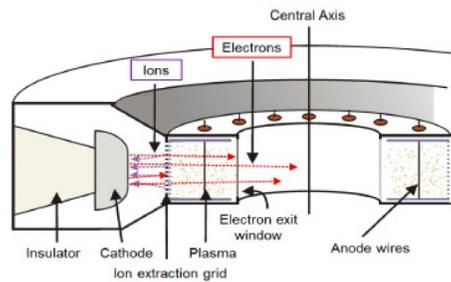
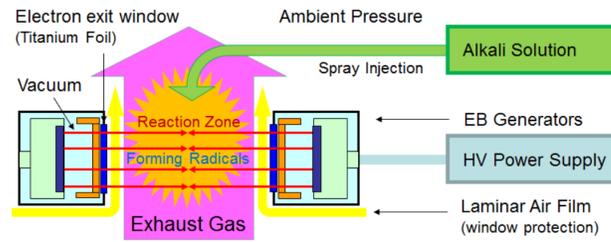
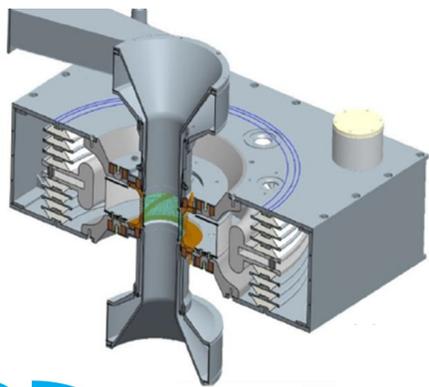
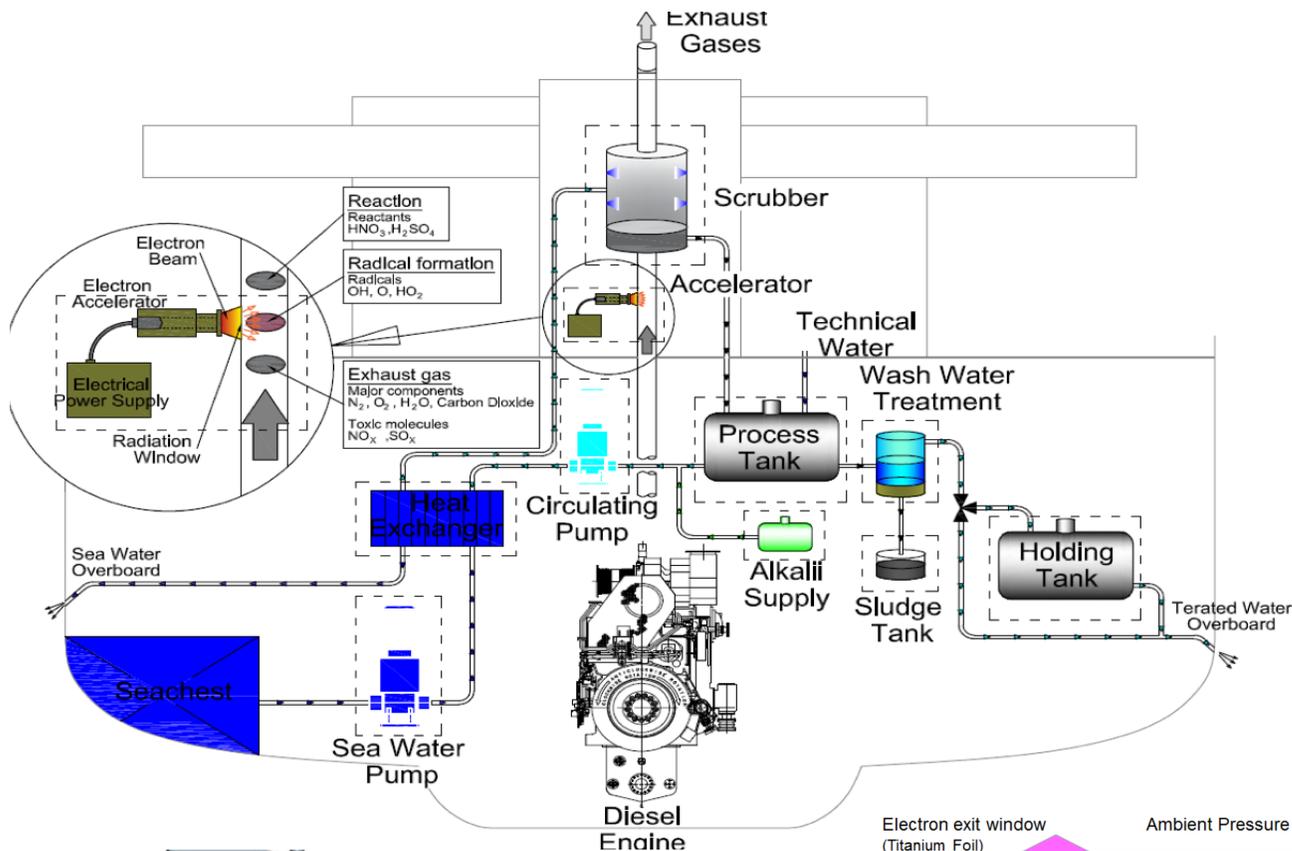


# HERTIS Sci-Tech Group

- ▶ Technology and Scientific strategy Working Group
- ▶ Responsible for the Technology development strategy
- ▶ Setting of priorities in relation to the scientific developments and their direction for the benefit of the Collaboration

# HERTIS

# Sci-Tech Group



# HERTIS Outreach Group

- ▶ Liaison with Stakeholders and Outreach Working Group
- ▶ Responsible for the regular dissemination of the HERTIS Collaboration ideas and achievements
- ▶ Work with major stakeholders, accelerator community and maritime industry

# HERTIS Outreach Group

---

Close link with DG MOVE, Research and Innovation Unit and DG RTD

---

Advise of the Italian Coast Guard

---

Lunch-time conference in Brussels – DG MOVE to address policy makers – in person Sep/Oct 2021

---

TIARA Council

---

CERN Baltic Group

---

Accelerator Community at large; e.g. engagement in ARIES and I.FAST



# HERTIS Collaboration

Wishes you

Fair Winds and Following Seas