Evaluation, control and Mitigation of the EnviRonmental impacts of shippinG Emissions - EMERGE

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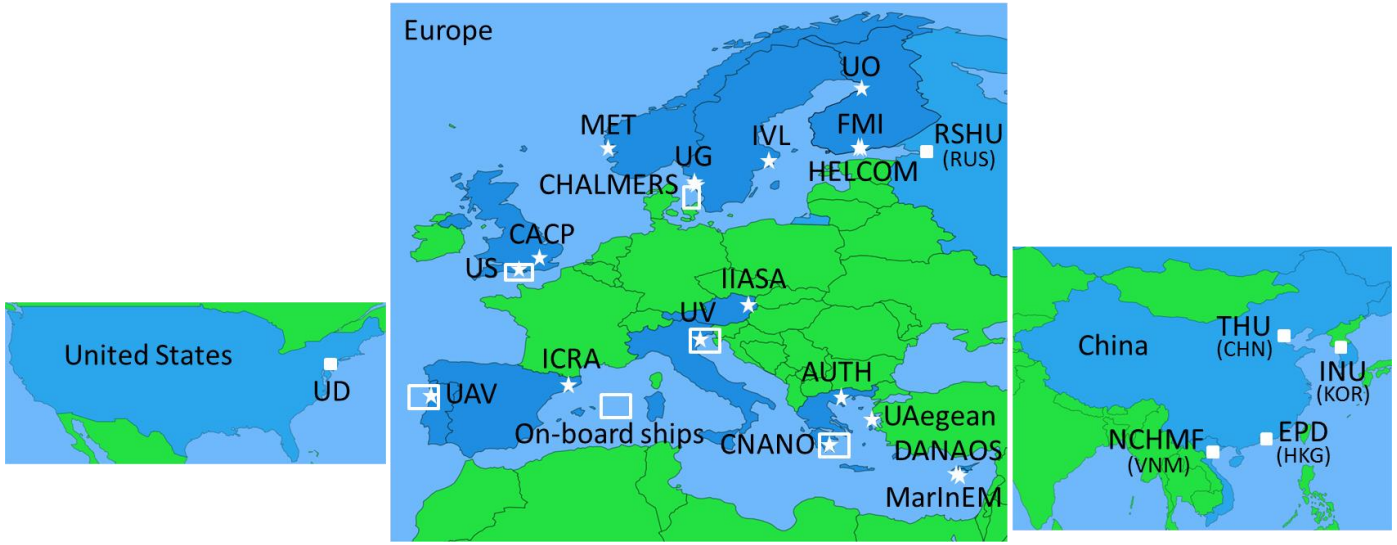
Evaluation, control and Mitigation of the EnviRonmental impacts of shippinG Emissions – EMERGE

- Feb 2020 to Jan 2024, duration 4 years
- EC contribution 7.5 Million €



In total, 18 partners, 10 countries

- Nine universities (UO, US, UV, UAV, UAegean, AUTH, UG, CHALMERS, CACP)
- Six research institutes (FMI, MET, IVL, IIASA, MarinEM, ICRA)
- One intergovernmental organization (HELCOM)
- Two companies (DANAOS, CNANO)
- Six international partners

Six case studies

- Mediterranean: Aveiro (PT), Venice (IT), Athens (GR), onboard ships in Mediterranean
- Northern and North-western: Solent Strait (UK), Öresund Strait (SE)

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Environmental impacts of shipping - why ?

- **New global standards** since 2020 for shipping emissions. The new limit for fuel sulphur content will be 0.5 %. In so-called **Sulphur Emission Control Areas (SECA's)**, a stricter regulation of 0.1 % fuel sulphur content has been in place since 2015.
- In complying with the limit values within SECAs, ships are currently mandated to use **fuel oil with fuel sulphur content within the limits**. Alternatively, vessels may be equipped with **abatement systems** - SO_x scrubbers.
- The exhaust gas cleaning systems, i.e., scrubbing, use large volumes of seawater. There is limited data on the **toxicity of scrubber washwater** released back to the sea.
- Combustion in ship engines produces a range of primary and secondary pollutants that have important **environmental, health, economic and climatic impacts**.

Need to

- **Evaluate the environmental impacts of emission reduction technologies**
- **Comprehensive evaluations, cost-efficient solutions and policy support**

The overarching aims of EMERGE

1. **Comprehensively quantify and evaluate the effects of a range of potential emission reduction solutions for shipping in Europe, and**
2. **Develop more effective strategies and measures to reduce the environmental impacts of shipping.**

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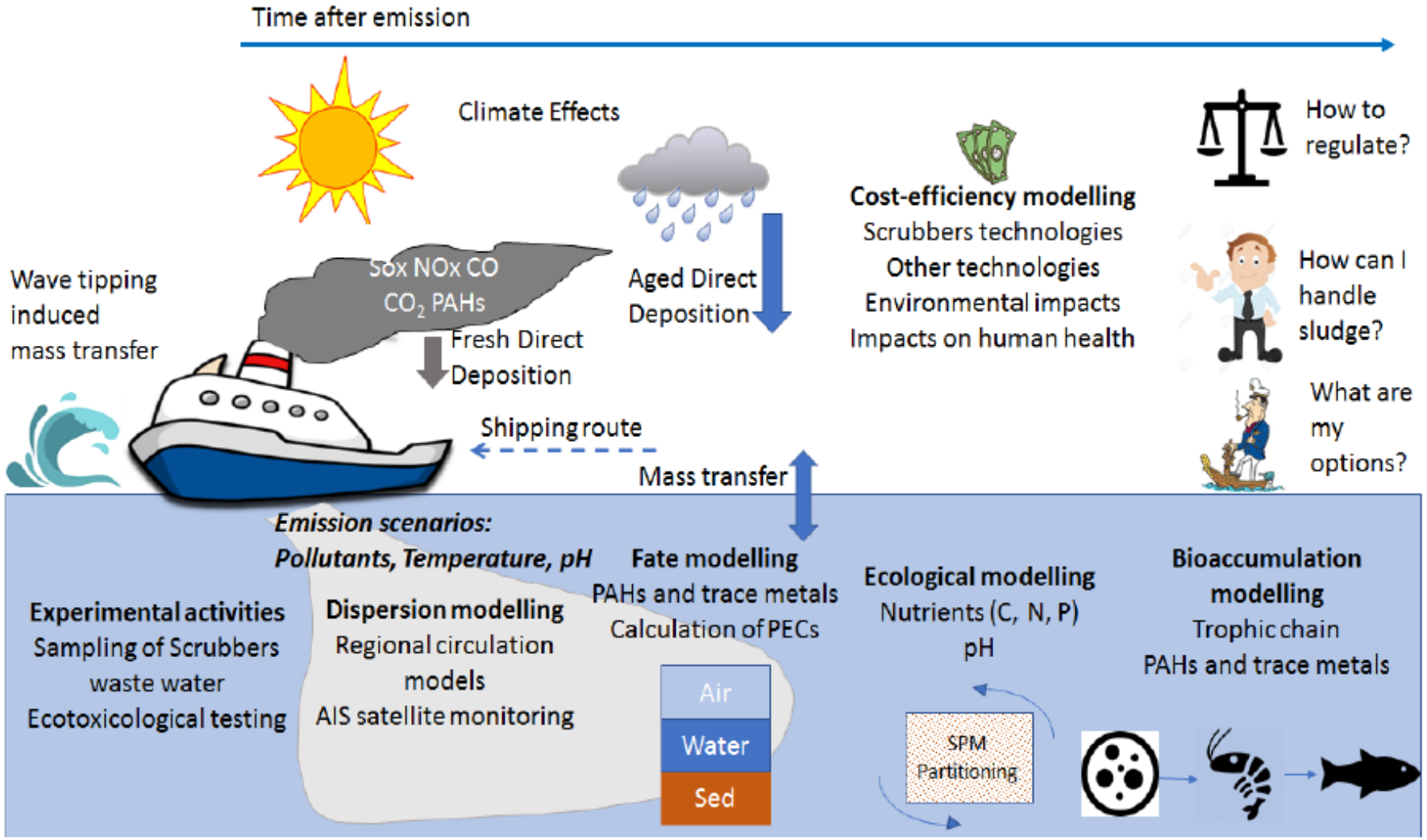
Specific objectives

1. Collect and synthesize experimental evidence on air emissions and waste streams of ships with potential emission control technologies
2. Develop an integrated modelling framework to assess the combined impacts of shipping emission control options on the aquatic and atmospheric environments
3. Deploy the modelling framework to assess the suitability, cost-effectiveness and impacts of a variety of shipping emission control scenarios to the marine environment
4. Provide recommendations and guidance for the stakeholders and decision-makers on the most suitable, effective and cost-beneficial options to significantly reduce marine pollution

The scope and approach



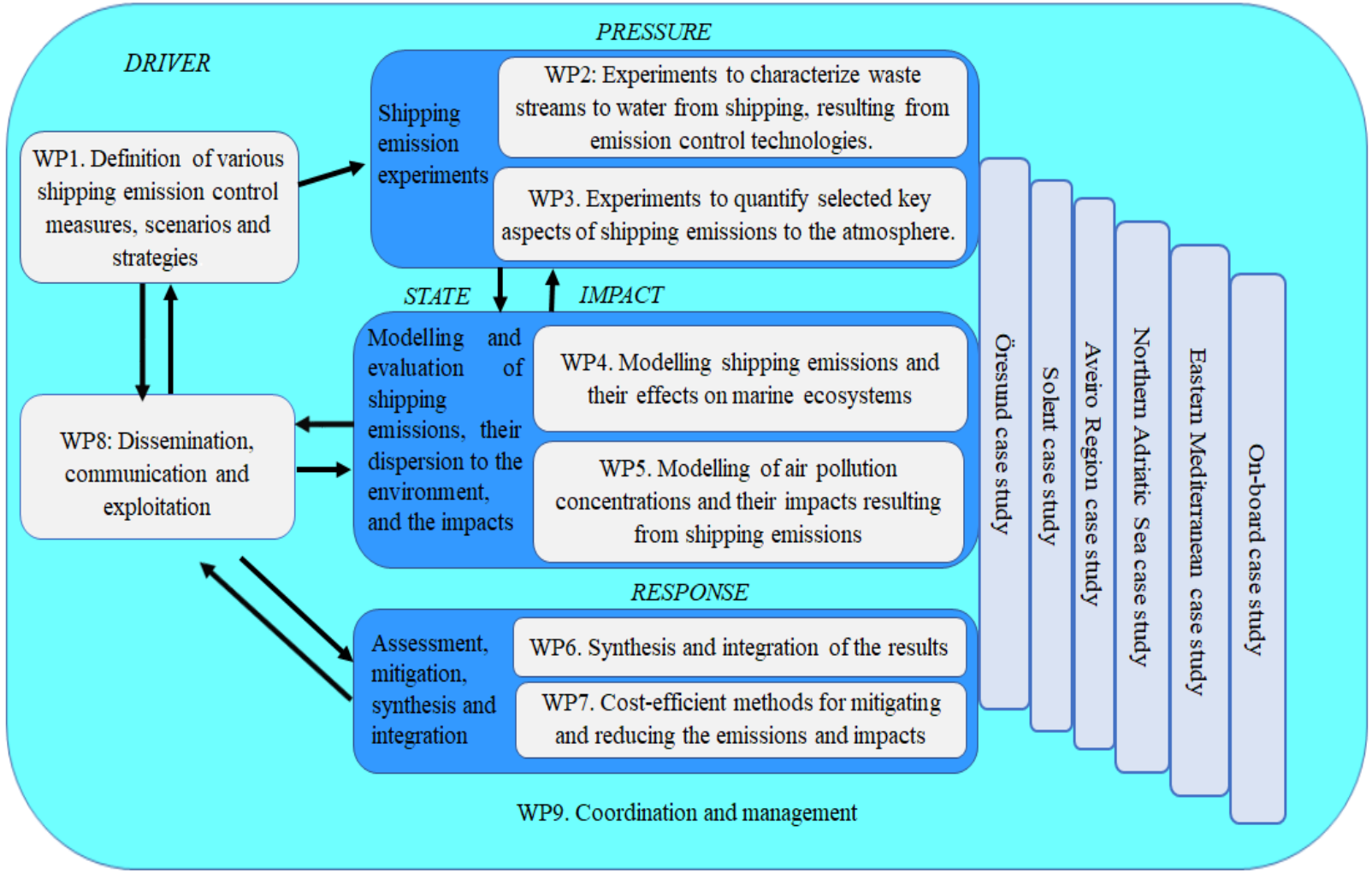
Wide scope, includes impacts on

- marine environments, ecology, plants, animals, bioaccumulation, etc.
- Atmosphere and health
- Climate
- Cost-benefit analyses

Notation: PEC = predicted environmental concentration, SPM = suspended particulate matter, PAH = polycyclic aromatic hydrocarbon.

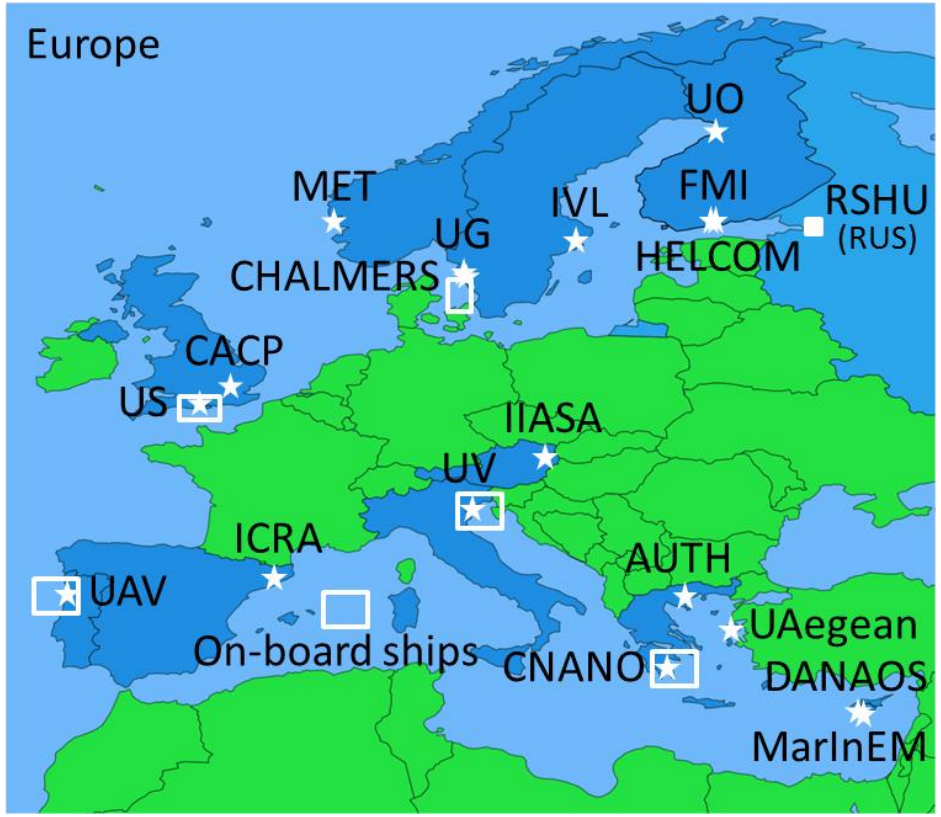
The overall structure of the project

- Basic structure:
  - ✓ Scenarios
  - ✓ Experiments (water and air)
  - ✓ Modelling (water and air)
  - ✓ Cost efficiency
  - ✓ Synthesis
- The project follows the DPSIR (drivers, pressures, state, impact and response) approach
- Six selected case studies as cross-cutting components



Case studies

- Ecologically vulnerable regions, with dense shipping traffic, including estuaries, enclosed waters and straits
- Five selected geographic case studies and one mobile onboard case study:
  - ✓ Öresund case study (Sweden)
  - ✓ Solent case study (U.K.)
  - ✓ Aveiro Region case study (Portugal)
  - ✓ Northern Adriatic Sea case study (Italy, includes Venice)
  - ✓ Eastern Mediterranean case study (including Piraeus, Greece)
  - ✓ On-board case study (mainly in Mediterranean)
- The approach: study both the European-scale water and air pollution, and the case study regions in more detail, in an integrated manner. The results obtained in the case studies will be set to a wider context, by using the European-scale modelling of both water and air pollutants.
- The case studies include measurements regarding the bioaccumulation of pollutants, and the ecological and biological state of these environments.



Methods

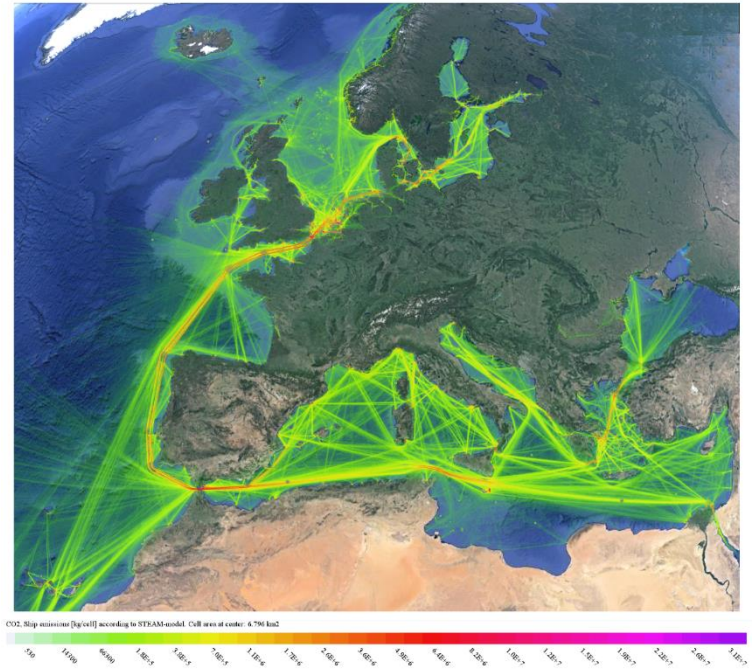
Experimental

- Characterisation of pollutants in discharges and air emissions
- Field measurements of distribution, dispersion and fate of pollutants in the case study areas
- Ecotoxicological studies of the effect of discharged scrubber water on marine organisms in water and sediments

Modelling

- Modelling the release of pollutants from ships to water and air
- Modelling of the transport and dilution of pollutants in water, and their effects on ecological processes
- Hydrodynamic and biogeochemical models
- Atmospheric dispersion modelling
- Health impacts of shipping emissions

Image from Sabater et al, Contrib. Sci., 10 (2014) 207.



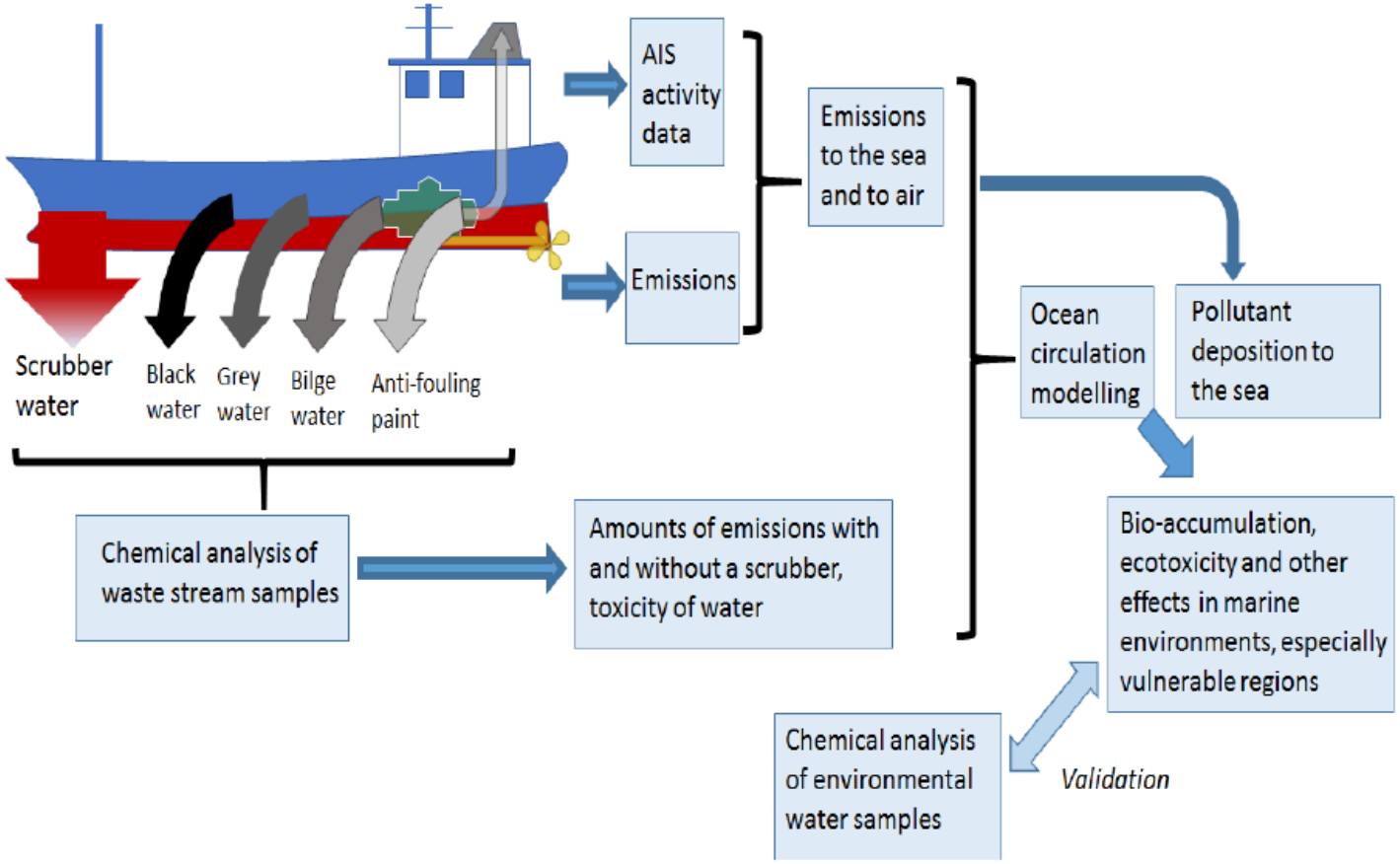
Novel aspect: EMERGE addresses both water and air pollution

Emphasis on new waste streams, e.g., sea water spraying of exhaust, SOx scrubbing

- Antifouling paint residues
- Waste water, wash water releases
- Food waste nutrients
- Oil leaks

Experiments

- Ecotoxicology
- Onboard sampling



Evaluation of various emissions of ships to water and air, together with their measurement and modelling. EMERGE will focus especially on the various emissions related to the use of scrubbers.

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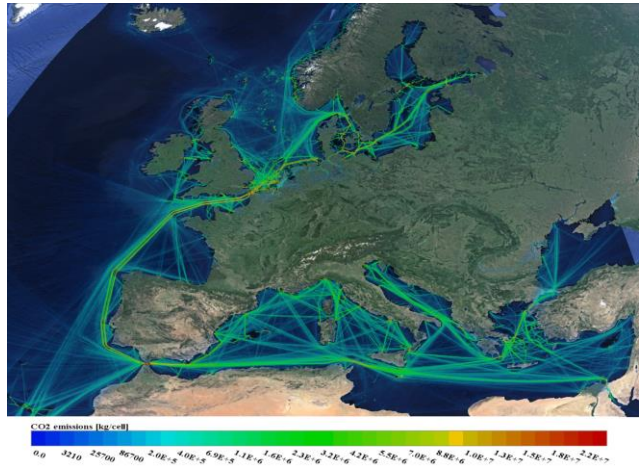
Integrated modelling of water and air

- Ship emission model STEAM: both discharges to water and emissions to air
- Dispersion of pollutants in air and water
  - Human health, climate effects, ecotoxicology
- Atmospheric models:
- Water pollution models:
  - ✓ Currently partly separate models for dispersion and bio/geochemistry; EMERGE aims to integrate these
- Cost and benefit analysis model: GAINS model by IIASA



The predictions of the STEAM model.

Above: The predicted washwater releases to sea, from open-loop SO_x scrubbing in ships in 2016.

Below: Emissions of CO_2 from ships in 2011.

The colour codes indicate emissions in mass units (per annum) per computational grid area.

Some innovations, beyond the state-of-the art

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- Comprehensive evaluation of all the environmental impacts of shipping, including marine environments, ecology, atmosphere, health impacts, climatic impacts and cost-benefit analyses
- The approach: study water and air pollution both on a European scale, and within the case study regions, in a harmonious manner. Investigation of six vulnerable case study regions using unified methods, including novel, unique experimental techniques
- Integrated modelling
  - ✓ of the dispersion and impacts both in the seas and in the atmosphere (including the STEAM model)
  - ✓ of transport and chemistry in the seas, and ecological modelling
- Modelling of the cost-effectiveness of abatement methods for shipping on a European scale
  - ✓ Extending the capabilities of the IIASA GAINS model for discharges to water

The EMERGE information network, including the stakeholder group and advisory board.

Tailored messages for:

- **Industry**
- **Policy**
- **Science**
- **General public**

EMERGE INFORMATION NETWORK

EMERGE STAKEHOLDER GROUP

Industry

1. Wärtsilä Corporation, advisor role (Jan Gunnar Gannefors, Patent Inventor; Tho Quang Che, Senior Development Engineer)
2. Alfa-Laval, advisor role (Ilkka Herrala, Sales Manager and Business Management)
3. Port of Aveiro, Portugal, case study representative (Maria Manuel Cruz, Environmental Manager)
4. Port of Piraeus, case study representative (Dimitris Spyrou, Consultant)
5. European Sea Ports Organisation, organisation coordinating port reception facilities (Kirsti Tarnanen-Sariola, Deputy Director)
6. Finnish Port Association, organisation coordinating port reception facilities (Kirsti Tarnanen-Sariola, Deputy Director)
7. Finnish Shipowners' Association, represents ship companies and owners (Sinikka Hartonen, Senior Adviser)

Policy Makers

1. Finnish Transport and Communications Agency, national IMO delegate and environmental authority (Anita Mäkinen, Chief Adviser)
2. Finnish Transport Infrastructure Agency, responsible for communications, including e.g. AIS signals (Kaisu Heikonen, Senior Technical Adviser)
3. Euroshore International VZW represents the European reference for maritime waste management (Guido Van Meel, Honorary Secretary General; Sophie Delair, Secretary General)
4. The Convention for the Protection of the Marine Environment of the North-East Atlantic (the 'OSPAR Convention'), Communication of information in the North Sea region (Philip Stamp, Deputy Secretary)
5. European Sea Ports Organisation (ESPO) (Sotiris Raptis, Senior Policy Advisor for Environment and Safety, EcoPorts Coordinator)

EMERGE ADVISORY BOARD

Industry

1. Finnish Shipowners' Association (Sinikka Hartonen, Senior Adviser)
2. Wärtsilä Corporation, advisor role (Jan Gunnar Gannefors, Patent Inventor; Tho Quang Che, Senior Development Engineer)
3. Alfa-Laval, advisor role (Ilkka Herrala, Sales Manager and Business Management)

Policy Makers

1. Swedish Agency for Marine and Water Management-SwAM (Tobias Porsbring, Senior analyst)
2. "United Nations Conference on Trade And Development (UNCTAD) (Regina Asariotis, Chief Policy and Legislation Section) "
3. Air Policy Division of the Environmental Protection Department of the Hong Kong Special Administrative Region in China (Dr. Peter Louie, Senior Environmental Protection Officer)
4. Marine Hydro-meteorological forecasting division of the National Centre for Hydrometeorological Forecasting in Vietnam (Dr. Nguyen Ba Thuy, Chief of the division)

Scientific & Academic Community

1. Tsinghua Univ. in China (Prof. Huan Liu)
2. School of Marine Science and Policy of the Univ. Delaware in USA (Prof. James J. Corbett)
3. Satellite Oceanography Laboratory (SOLab) of the Russian State Hydrometeorological Univ. in St. Petersburg, Russia (Dr. Vladimir Kudryavtsev)
4. Department of Environmental Engineering of the Incheon National Univ. in South Korea (Prof. Heekwan Lee)

Selected links to other initiatives

EMERGE as a user	EMERGE as a provider

- Copernicus Marine, until 2021
  - ✓ Weather-influenced emissions: **Wind, waves, currents, ice cover**
  - ✓ **Oceanographic data for drift and bio-geochemical modeling**
- Copernicus Atmosphere, until 2021
  - ✓ CAMS-81, 2017 - 2020: **Ship emissions, next generation of emission inventories**, **large scale validation of emissions**
  - ✓ **Weather data**
  - ✓ **Scenarios ? Discharges ?** → New potential contributions to Copernicus
- Remote sensing, TropOMI
  - ✓ **NOx, SOx (sister project H2020/SCIPPER, compliance monitoring)**
  - ✓ **CH4, formaldehyde, others (EMERGE)**
- Monitoring, Reporting, Verification (directive EU/2015/757)

Final results

1. Cost-effectiveness of available technology options, measures and strategies
2. Identification of the most affected locations, and evaluation of impacts for these regions
3. Current and potential future impacts of shipping to marine environments
4. Recommendations for policy actions in EU and globally
   - Timing of outputs will be a challenge
     - GESAMP, EEA, Danish EPA, ARPA-FVG

Conclusions

- EMERGE will be a major effort to combine both marine and atmospheric expertise
- Evalution of the effects of potential emission reduction solutions for shipping
- Wide scope:
  - discharges,
  - atmospheric contributions,
  - dispersion of pollutants in water and air,
  - effects on the state of the seas, flora and fauna, human health and climate
- Extension of integrated assessment modeling of IIASA to water issues
- The policy guidance and recommendations will be of a wide interest and of a major economic value

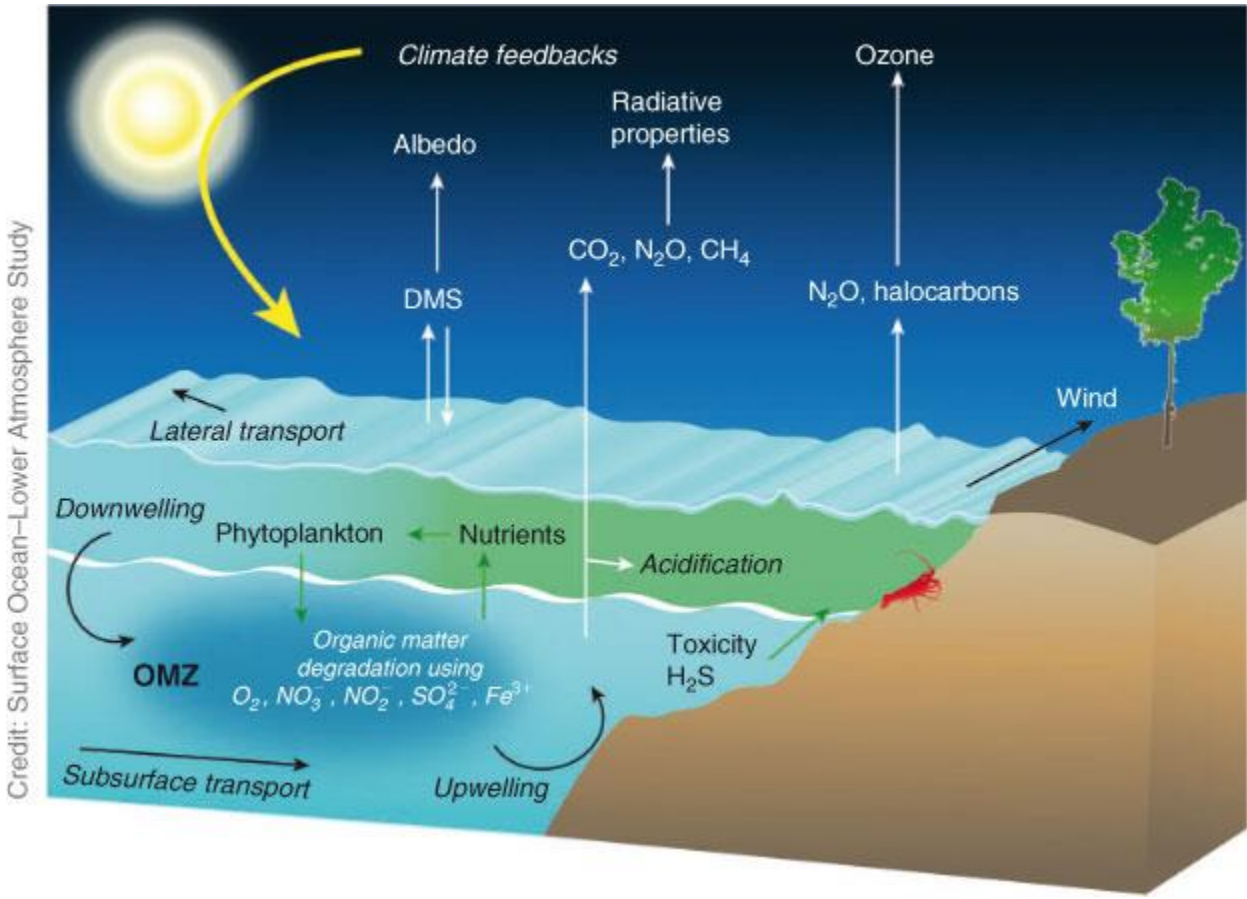
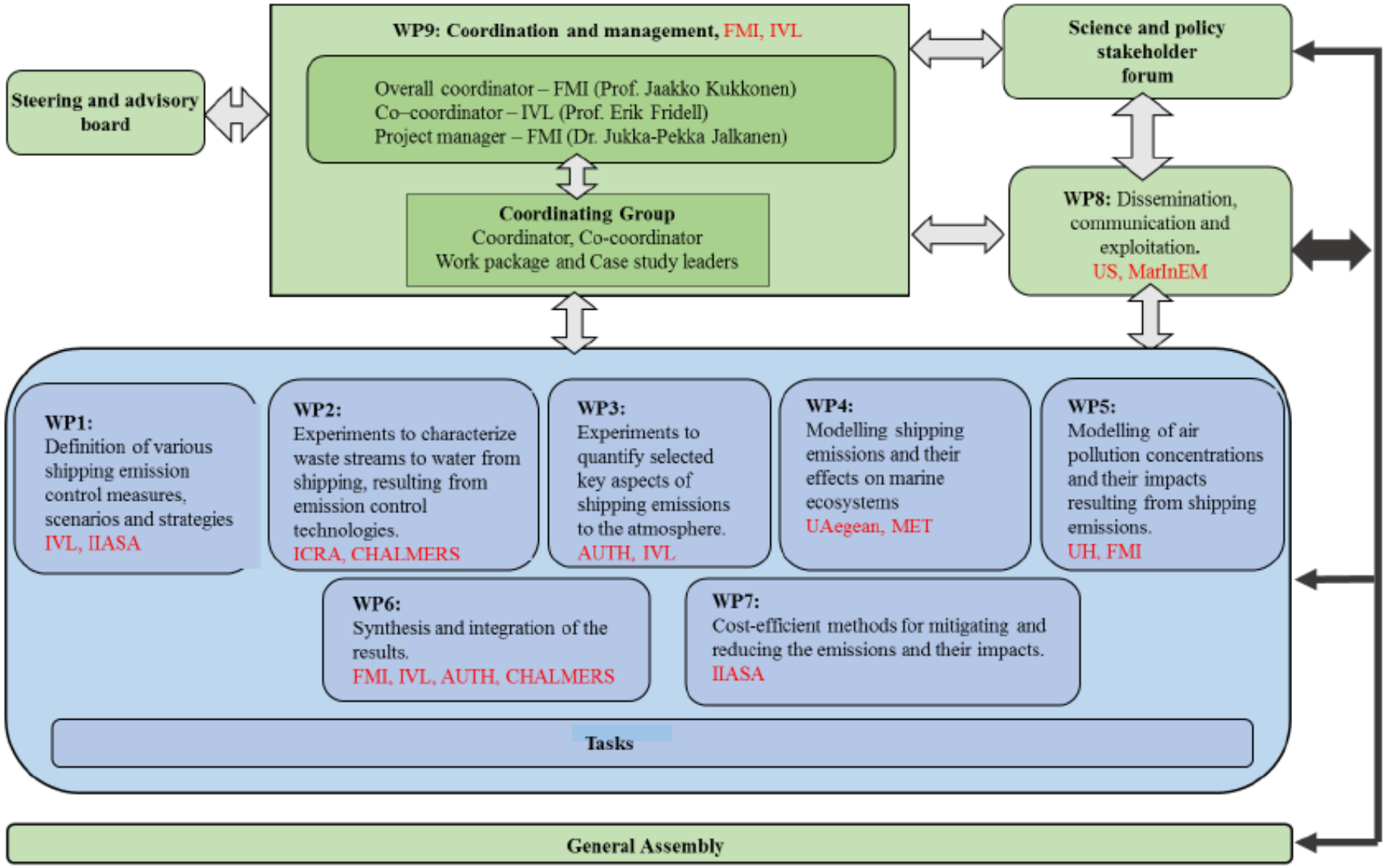


Image from Law et al, Env. Chem., 10 (2012) 1-16

Additional slides

Organisational structure of EMERGE



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Alternative abatement and control technologies

- Exhaust gas treating system, i.e., scrubber
- Low-sulphur fuel oil
- Alternative fuels, such as Liquefied Natural Gas (LNG), methanol, H_2, biofuels
- Electricity and wind power

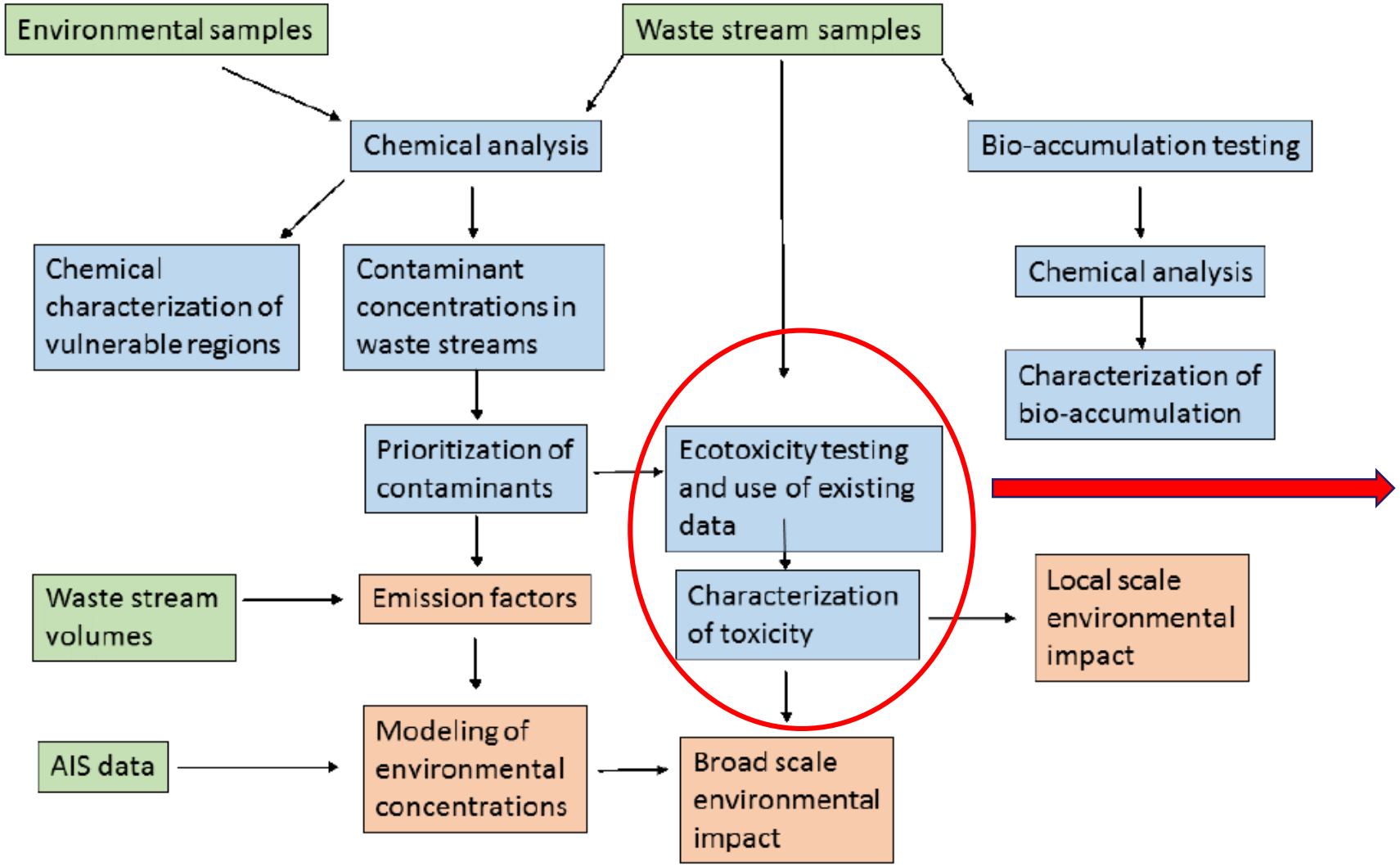
For abatement of NO_x EMERGE will analyse the available options such as Selective Catalytic Reduction (SCR), Exhaust Gas Recirculation (EGR) and fuel change (LNG and others). The secondary emissions from SCR, like ammonia slip, will be included. For EGR, small scrubbers are normally used to clean the recirculated air and these scrubbers have similar risks as the scrubbers for SO_2 abatement.

For abatement of PM, we will investigate the effect of scrubbers, SCR and EGR and compare with other options such as Diesel Particulate Filters and Electrostatic Precipitation.

Work package coordinators

- WP1: Adj. Prof. Erik Fridell, IVL and Dr. Jens Borken-Kleefeld, IIASA.
- WP2: Prof. Mira Petrovic, ICRA and Dr. Erik Ytreberg, CHALMERS.
- WP3: Assoc. Prof. Leon Ntziachristos, AUTH and Dr. Jana Moldanova, IVL
- WP4: Prof. Lars R. Hole, MET and Prof. Vassilis Zervakis, Univ. Aegean.
- WP5: Prof. Ranjeet Sokhi, UH and Prof. Mikhail Sofiev, FMI.
- WP6: Dr. Jukka-Pekka Jalkanen, FMI, Dr. Jana Moldanova, IVL, Assoc. Prof. Leon Ntziachristos, AUTH and Assoc. Prof. Ida-Maja Hassellöv, CHALMERS.
- WP7: Dr. Jens Borken-Kleefeld, IIASA, Dr. Jukka-Pekka Jalkanen, FMI.
- WP8: MA. Sofia Maragkidou and MSc. Angelos Ktoris, MarInEM, and Prof. Ian Williams, US.
- WP9. Prof. Jaakko Kukkonen, FMI and Adj. Prof. Erik Fridell, IVL

Pathway for water analysis



Species	Species
calanus	*allivibrio fischeri*
Larvae of *ostrea edulis*	*paracentrotus lividus*
crassostrea gigas	Larvae of *mytilus galloprovincialis*
mytilus edulis	*acartia tonsa*
ceramium tenuicorne	*Phytoplankton*

List of partners

- Northern Europe: Finland (3 partners), Sweden (3), Norway
- North-western Europe: U.K. (2)
- Central Europe: Austria
- Mediterranean: Portugal, Spain, Italy, Greece (3), Cyprus (2)

In total: 18 partners, 10 countries

Participant No.	Participant organization name	Short name	Country
1 (Coord.)	Finnish Meteorological Institute	FMI	Finland
2	IVL Swedish Environmental Research Institute	IVL	Sweden
3	Chalmers University of Technology	CHALMERS	Sweden
4	Aristotle University of Thessaloniki-The Laboratory of Heat Transfer and Environmental Engineering	AUTH	Greece
5	International Institute for Applied Systems Analysis	IIASA	Austria
6	University of Hertfordshire, Centre for Atmospheric and Climate Physics	CACP	UK
7	University of the Aegean	UAegean	Greece
8	University of Aveiro	UAV	Portugal
9	University of Southampton	US	UK
10	University of Venice	UV	Italy
11	Norwegian Meteorological Institute	MET	Norway
12	University of Gothenburg	UG	Sweden
13	University of Oulu	UO	Finland
14	Catalan Institute for Water Research	ICRA	Spain
15	DANAOS	DANAOS	Cyprus
16	Maritime Institute of Eastern Mediterranean	MarInEM	Cyprus
17	HELCOM (Baltic Marine Environment Protection Commission - Helsinki Commission)	HELCOM	Finland
18	Creative Nano	CNANO	Greece

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