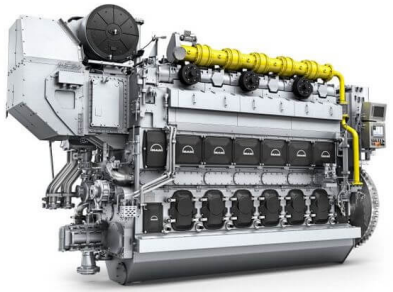
# Agenda

| | | |
|---|---|---|
| **10.00-11.30 Digital meeting** | **10.00 Opening words by Svend Søyland, Nordic Energy Research**<br>**10.05 Introduction to CAHEMA by Xue-Song Bai, Lund University, CAHEMA coordinator** | |
| | 10.10 Introduction of project partners | |
| | Presentations of project partners | 10.10 Lund University, Xue-Song Bai<br>10.20 Norwegian University of Science and Technology (NTNU), Terese Løvås<br>10.30 Aalto University, Ossi Kaario<br>10.40 FORSEA, Jens Ole Hansen<br>10.45 Wärtsilä, Jari Hyvönen<br>11.50 MAN Energy Solutions, Stefan Mayer<br>10.55 Stolt Tankers, Jose Gonzalez<br>11.00 World Maritime University, Aykut Ölcer<br>11.10 Discussion |
| | 11.30 Closing remarks | |

# Concepts of Ammonia/Hydrogen Engines for Marine Application - CAHEMA

## Kickoff Meeting, April 9, 2021



Xue-Song Bai, Dept of Energy Sciences, Lund University

**www.fm.energy.lth.se**

# Concepts of Ammonia/Hydrogen Engines for Marine Application

Marine transport contributes to

- 90% of goods traded around the world
- 940 million tons CO2 emission each year

IMO mandatory measures aim at

- 70% CO2 reduction by 2050 from marine transport

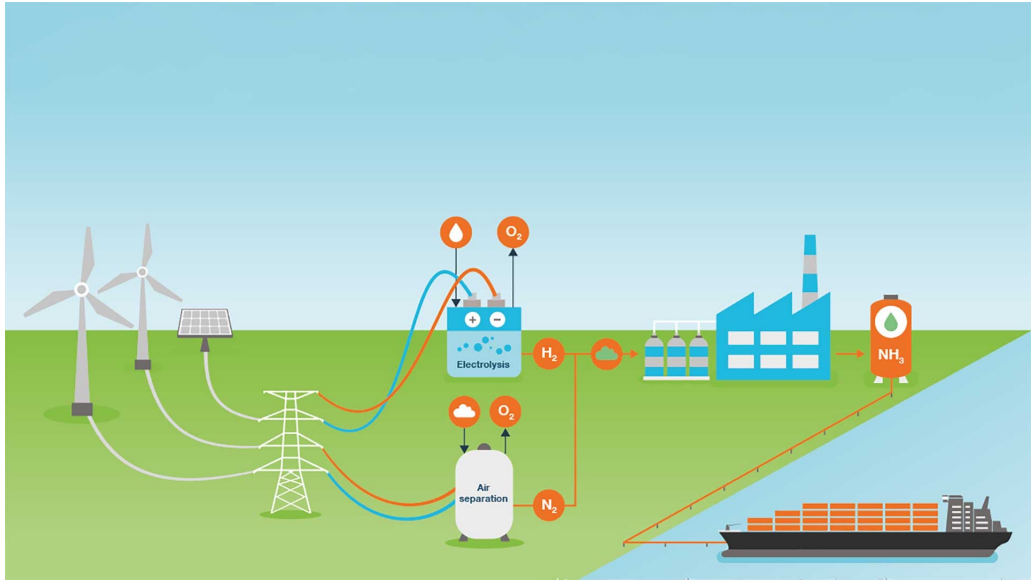
Ammonia attracts the attention as marine fuel

- Zero emission ammonia production from green electricity
- Easier to store & transport (than hydrogen)
- Ammonia combustion does not emit CO2

Ammonia engine faces certain challenges

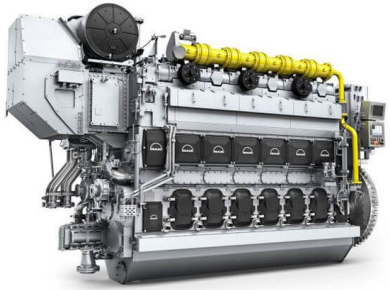
- Low energy density, difficult to burn
- Ammonia/hydrogen/diesel dual fuel concept

**MAN Energy Solutions aims to have a commercially available two-stroke ammonia engine by as early as 2024**



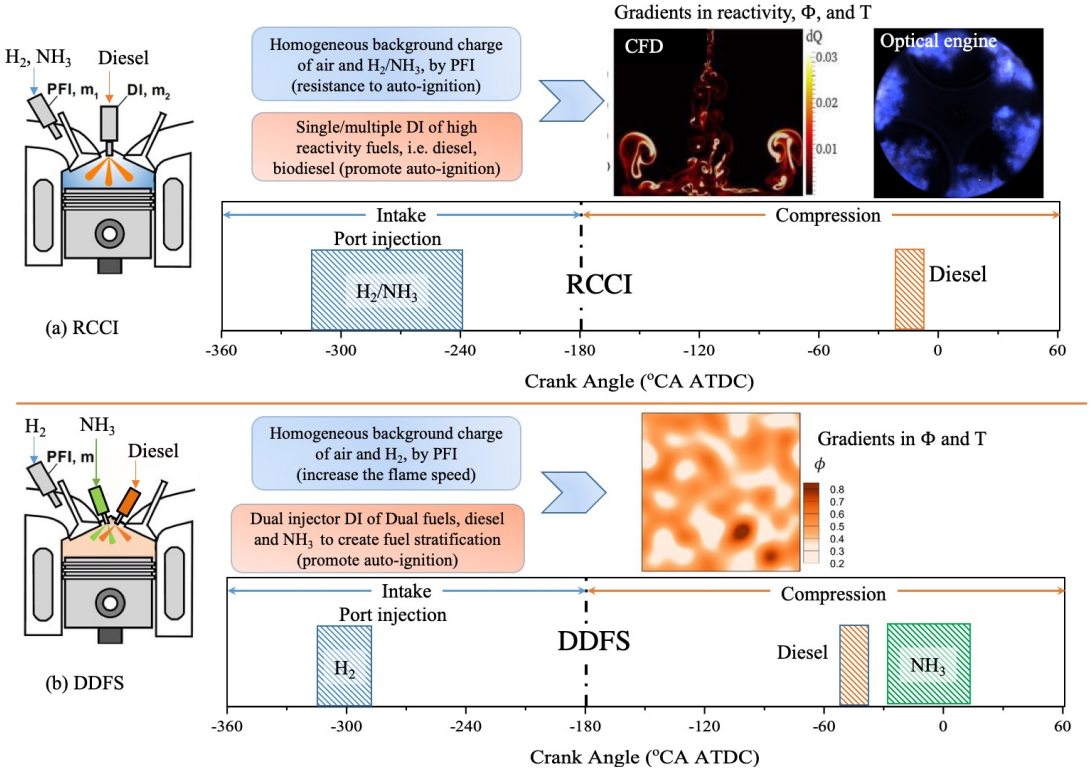

https://www.man-es.com/discover/two-stroke-ammonia-engine

# Concepts of Ammonia/Hydrogen Engines for Marine Application



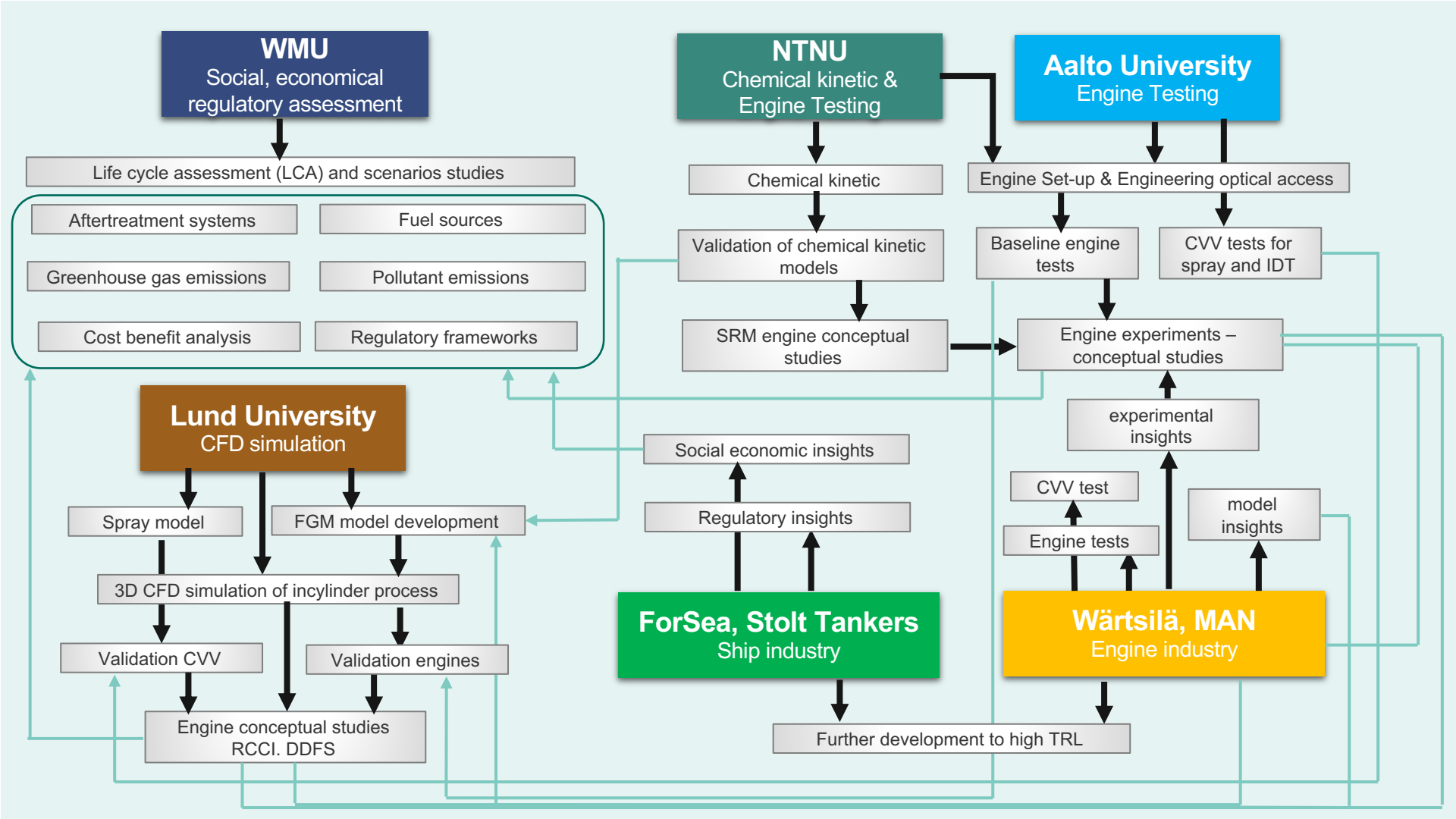
**MAN ES** AMMONIA ENGINE PROJECT - AENGINE

**WÄRTSILÄ** AMMONIA AND HYDROGEN RESEARCH



# Goals

- To develop a chemical kinetic mechanism of ammonia co-firing with high reactivity fuels such as hydrogen and diesel surrogate (e.g. n-heptane)
- To develop and validate CFD modelling tools for analysis of ammonia/hydrogen combustion with diesel/surrogate ignition in marine engines
- To verify two different engine concepts firing with ammonia/hydrogen fuels with a n-heptane/diesel as ignition improver for marine application
- To assess environmental (climate change) and socio-economic (public health) impact of ammonia/hydrogen marine engines, using life-cycle assessment of ammonia and hydrogen as a marine fuel
- To give suitable recommendations for emissions regulations on the basis of a cost-benefit analysis comparing the economic cost of engine and emissions abatement technologies


WMU
Social, economical regulatory assessment
Life cycle assessment (LCA) and scenarios studies
Aftertreatment systems
Fuel sources
Greenhouse gas emissions
Pollutant emissions
Cost benefit analysis
Regulatory frameworks
NTNU
Chemical kinetic & Engine Testing
Aalto University
Engine Testing
Chemical kinetic
Engine Set-up & Engineering optical access
Validation of chemical kinetic models
Baseline engine tests
CVV tests for spray and IDT
SRM engine conceptual studies
Engine experiments – conceptual studies
experimental insights
Lund University
CFD simulation
Social economic insights
CVV test
model insights
Spray model
FGM model development
Regulatory insights
Engine tests
3D CFD simulation of incylinder process
ForSea, Stolt Tankers
Ship industry
Wärtsilä, MAN
Engine industry
Validation CVV
Validation engines
Engine conceptual studies RCCI. DDFS
Further development to high TRL

# Work packages and time plan

WP1: Chemical kinetic modeling (PI: NTNU; co-PI: LU, AU)
WP2: Numerical investigation of different engine concepts (PI: LU, co-PI: AU, NTNU)
WP3: Engine experiments on different engine concepts (PI: AU, co-PI: NTNU, LU)
WP4: Regulatory, economic, and environmental analysis (PI: WMU, co-PI: LU, NTNU, AU)

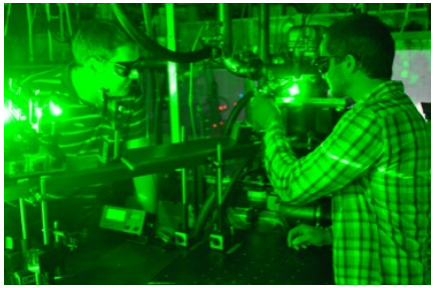
| WPs | Month 3 | Month 6 | Month 9 | Month 12 | Month 15 | Month 18 | Month 21 | Month 24 | Partners |
|---|---|---|---|---|---|---|---|---|---|
| WP1.1 | | | | | | | | | NTNU |
| WP1.2 | | | | | | | | | NTNU, AU, Wärtsilä, DTU |
| WP2.1 | | | | | | | | | LU, NTNU, MAN, Wärtsilä |
| WP2.2 | | | | | | | | | LU, NTNU, AU, Wärtsilä |
| WP3.1 | | | | | | | | | AU, Wärtsilä |
| WP3.2 | | | | | | | | | AU, NTNU, LU, AIP |
| WP4 | | | | | | | | | WMU, NTNU, AU, LU, AIP |

# Competence and activities at Lund University

- Six divisions at LU are involved in combustion research

- Combustion Physics
- Combustion Engines
- Fluid Mechanics
- Thermal Power Engineering
- Heat Transfer
- Fire Safety Engineering

Engine lab with 15 test engines



Laser based optical engine exp

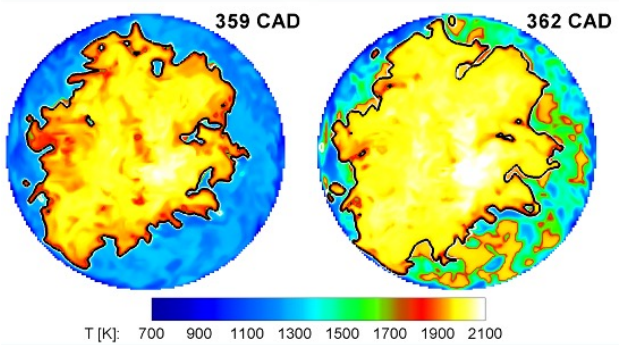
- KCFP: LU competence center for combustion process for ICE
- CeCOST: national center for combustion science and technology
- Large scale facility

- 10 professors
- 80 researcher


Combustion CFD modeling. We are one of the larger users of Swedish HPC computers

# Competence and activities at Lund University

- Personnel (combustion modeling group)
  - Xue-Song Bai, professor
  - R. Yu, associate professor
  - H. Fatehi, assistant professor
  - 9 PhD students/postdoc
- CFD modeling of ICE combustion process
  - New ICE engine concepts (HCCI, SACI, PPC, RCCI, DDFS)
  - Diesel engine (liftoff, jet-jet interaction, jet/wall interaction, jet/swirl interaction
  - Gas engine with pre-chamber ignition
  - DISI methanol/ethanol engine
- Model development for ICE combustion simulations
  - FGM
  - Transported PDF modeling
  - Chemistry coordinate mapping
  - Flamelet modeling of ignition/SI flame interaction
  - Multiple objective optimization algorithm based on machine learning




LES of SI flame and onset of ignition in ethanol engine

LES of methanol spray flame in Scania D13 PPC engine

# WP2: Numerical investigation of different engine concepts (PI: LU, co-PI: AU, NTNU)

*WP 2.1: Development of FGM-ESF model*

- Methodology for FGM tabulation based on the chemical kinetic mechanism from WP1.
- Modeling of turbulence/chemistry interaction (TCI). FGM is to be coupled to flow simulations using a more accurate method, transported PDF method within the framework of Eulerian Stochastic Field (ESF).
- Modeling of ammonia/n-heptane spray dynamics including atomization, breakup, and evaporation.
- Validation of spray and combustion models using the CVV data from WP1.2 and engine experiments planned in WP3.1.
- The work will be completed in Month 9.

# WP2: Numerical investigation of different engine concepts (PI: LU, co-PI: AU, NTNU)

*WP 2.2: CFD study of engine concepts for ammonia/hydrogen combustion in marine engines*

- The CFD tools will be used to investigate two different engine concepts: RCCI and DDFS
- The engine geometry to be considered are those at the NTNU and AU labs
- The numerical results will be used for the design of experiments in lab scale engine test in WP3.2.
- The work will continue along with engine experiments for close interaction and validation.
- The work is to be carried out in close collaboration with all partners, in particular MAN and Wärtsilä.

# Thank you for your support

Nordic Energy Research

BUSINESS FINLAND

The Research Council of Norway

TRAFIKVERKET
SWEDISH TRANSPORT ADMINISTRATION


PhD student
Mark Treacy (50%)

Postdoc
Leilei Xu (50%)

# Steering committee and reference group

*Steering committee*

- One person from each partner group
- Stefan Mayor (MAN), Jari Hyvönen (Wärtsilä), Jose Gonzalez (Stolt Tankers), Jens Ole Hansen (ForSea)
- Bai, Terese, Aykut, Ossi

*Reference group (industrial partners)*

- Eric Baudoin, Kar Mun Pang, Stefan Mayor
- Wärtsilä: Jeudi (PM), Heikki (WP1.1, WP2), Antonino (WP1.1, WP1.2), Juho (WP2, WP3), Sebastiaan (WP4), Jari (all WPs)
- Stolt Tankers: Jose Gonzalez (WP4)
- ForSea: Jens Ole Hansen (WP4)
- Reference group meeting on demand, at least two times per year
- Annual report, annual meeting
- Final seminar at WMU

# Consortium agreement, home pages …

*Consortium agreement*

- Signed partners: WMU, Stolt Tankers, ForSea
- Agreed: Aalto, LU, NTNU
- Evaluating: MAN, Wärtsilä

*Home pages*

- Alessandro designed a CAHEMA logo
- CAHEMA home page in progress

*Project start/end time*

- March 1, 2021 (start)
- March 1, 2023 (end)
- Possible change of ending time?