Towards next-generation sustainable marine propulsion system with fuel-flexible reactivity-controlled compression ignition (RCCI) combustion for green shipping

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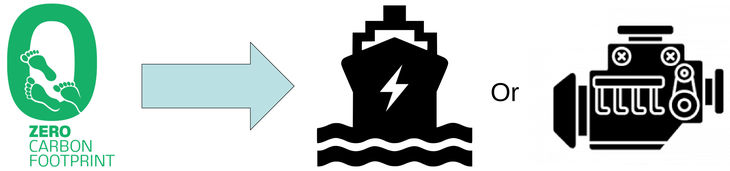
Background & Motivation

Rapid energy transition in maritime sectors towards **decarbonization**

Conventional marine fuels (HFO, MDO, MGO) → **low or zero carbon fuels (Natural Gas, Methanol, Ammonia, H2) & fuel-flexible combustion**



Full electrification : not feasible in large bore marine engines

ICE will remain as a prime power source in shipping industry (in the short to medium term) → **Novel RCCI combustion is a promising solution – superior thermal efficiency (> 50%), ultra low emissions (NOx, PM)**

Introduction

- **What?** Demonstration of the feasibility and excellence of RCCI combustion concept in a large bore engine platform
- **Why?** Several challenges to hinder practical implementation:

limited load range (25-75% load), high HC and CO emissions, increasing engine noise, cycle-to-cycle variation, poor exhaust thermal management

- **How?** Advanced variable valve actuation (VVA) + Hydrogen blend
- **Goals**

G1) **55% thermal efficiency** and **emissions below EU Stage V or IMO Tier III**

G2) Development of an **integrated VVA solution for load range extension (±10%), better thermal management (+50K) simultaneously**

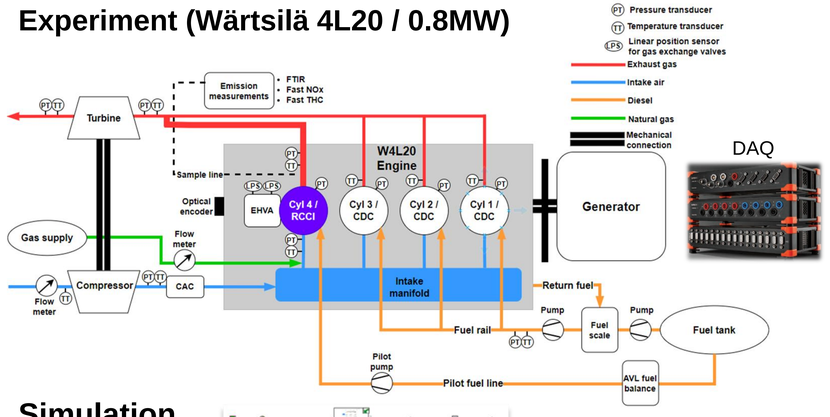
G3) **Noise mitigation < 110dB** without penalizing BTE and emissions with H2 blend

Research plan

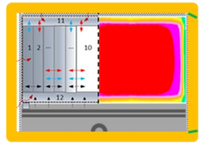
- **Stage1: Demonstration of ultra-efficient and low emission RCCI combustion (2023-2024)**
- Stage2: Integrated VVA solution (2024-2025)
- Stage3: Fuel-flexible RCCI operation with H2 blend (2025-2026)

Methodology

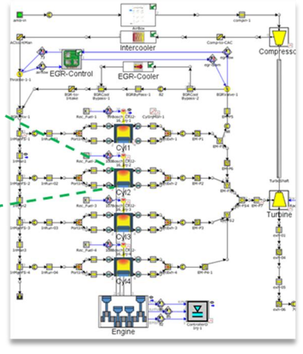
- **Experiment (Wärtsilä 4L20 / 0.8MW)**

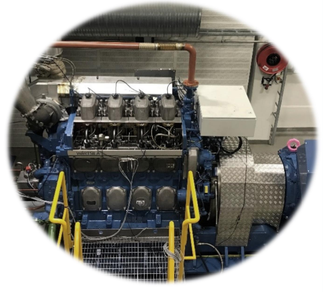


- **Simulation**



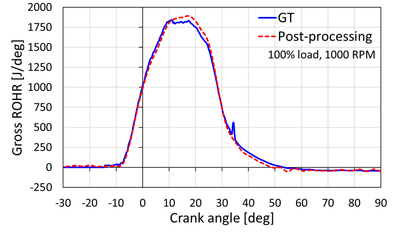
Fully predictive modelling toolchain

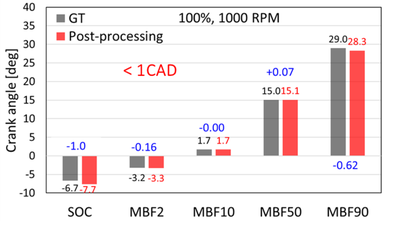




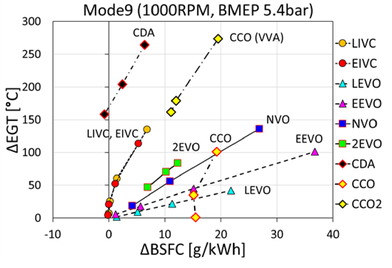
Current work progress and Results

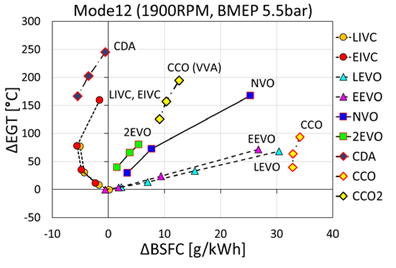
- **Development of real time post processing routine**





- **Efficient exhaust thermal management with VVA**





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