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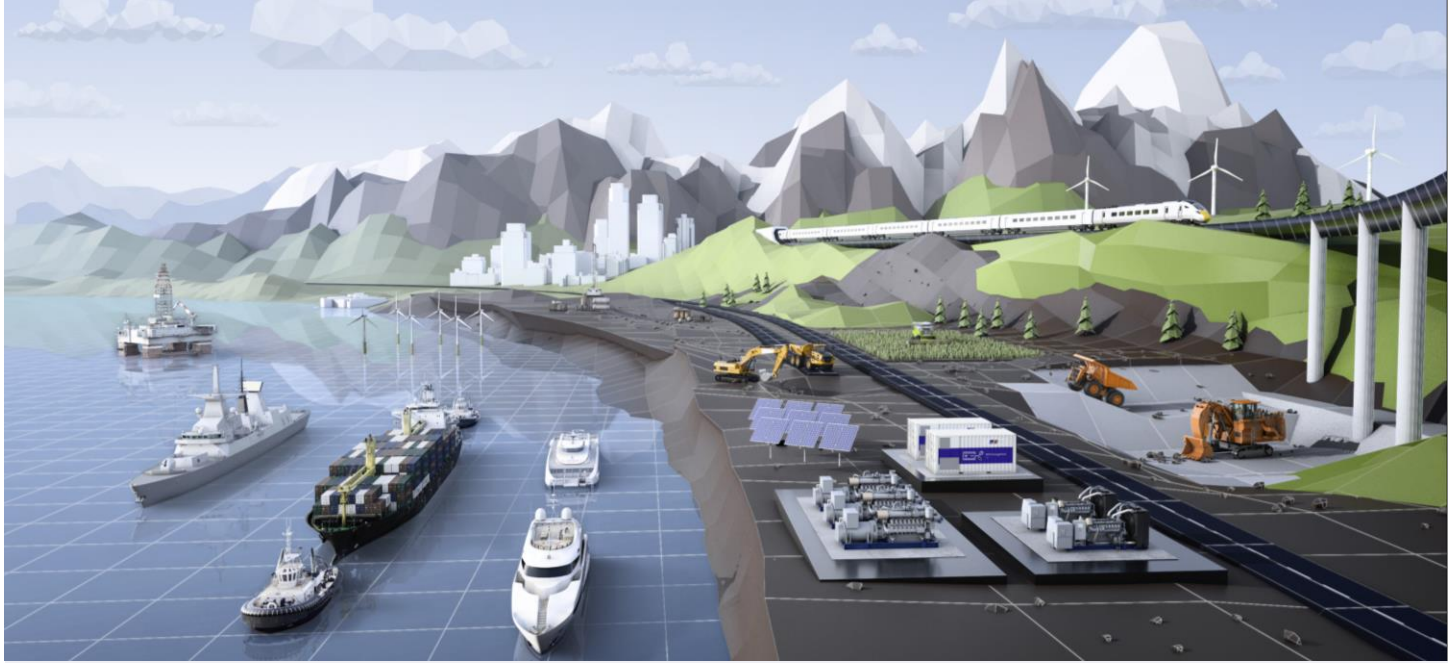


Simulation Based Techno-Economic Evaluation of Self-Sufficient Microgrid Systems with Renewable Energy and Power-to-X

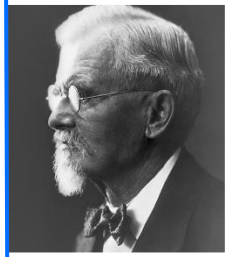
Rolls-Royce Solutions GmbH

Dr. Zhenan Zhang, Dr. Alexander Buttler, Pawel Wienclaw, Dr. Claus-Oliver Schmalzing, Jona Siebert, Dr. Andreas Flohr

September 21th, 2022

A Rolls-Royce solution

Building on a successful 110-year history



1909

Wilhelm & Karl Maybach found "Luftfahrzeug-Motorenbau" GmbH

1969

The company changes its name to "Motoren- und Turbinen Union" (MTU)

2006

MTU becomes part of Tognum AG

2011

Rolls-Royce & Daimler jointly acquire Tognum which is renamed to Rolls-Royce Power Systems

2019

Power Systems starts rebranding; ***mtu*** brand as "a Rolls-Royce solution"

110-years of positive earnings

1910

Maybach AZ engine is used for the first time in Zeppelin LZ6

1996

The Series 4000 line is introduced – the first engine with common-rail direct fuel injection

2011

Power Systems enters the continuous gas market under its MTU Onsite Energy brand

2014

Rolls-Royce buys shares of Daimler and takes full ownership of Rolls-Royce Power Systems

2020

Power Systems acquires KINOLT

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Rolls-Royce group

A world-class technology company, built on three strong and complimentary business units.

Power Systems is the group's 2nd largest business and frontrunner in electrification.

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Civil Aerospace

35
types of commercial aircraft powered by us

13,000
engines in service around the world

19,000
total employees

5.089bn
underlying revenue

Defence

150
customers in over 100 countries

16,000
engines in service around the world

9,000
total employees

3.366bn
underlying revenue

Power Systems

>40,000
customers in 13 different industries

20,000
reciprocating engines sold per year

≈ 9,000
total employees

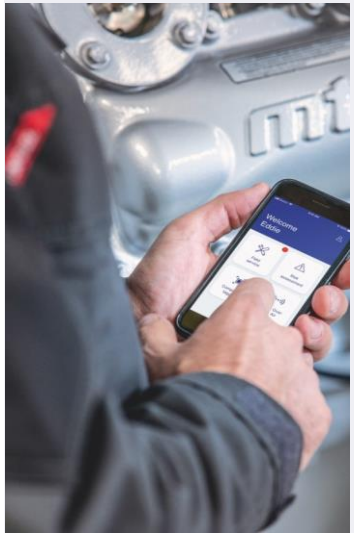
2.745bn
underlying revenue

mmm

Our mission

We anticipate the vital power needs of Marine and Infrastructure customers globally by creating interconnected solutions valued for their lifecycle performance, energy optionality and coordinated interaction.

A Rolls-Royce solution



A comprehensive product and solution portfolio

Original Equipment

- Diesel engines
- Power modules diesel & gas
- Gas engines
- Open power units diesel & gas
- PowerPacks
- Emission reduction technologies
- Gensets
- Energy storage

Systems

- Automation systems
- Microgrids
- Diesel systems
- Gas systems
- Rail drive systems
- Propulsion systems
- Rail hybrid
- Marine hybrid

Lifecycle Solutions

- Connectivity
- ValueCare agreements
- Advanced trouble shooting
- Predictive maintenance
- Fleet management
- Digital solutions
- Operations analytics
- Reman

Instructions

01 **Goals and Backgrounds**
MethPower, MethGrid

02 **Created Microgrid concepts**
EE(Renewable Energy)-PtG(Power-to-Gas)-CHP

03 **Selected results**
Method, selected industrial site, Karlsruhe harbor

04 **Summary**

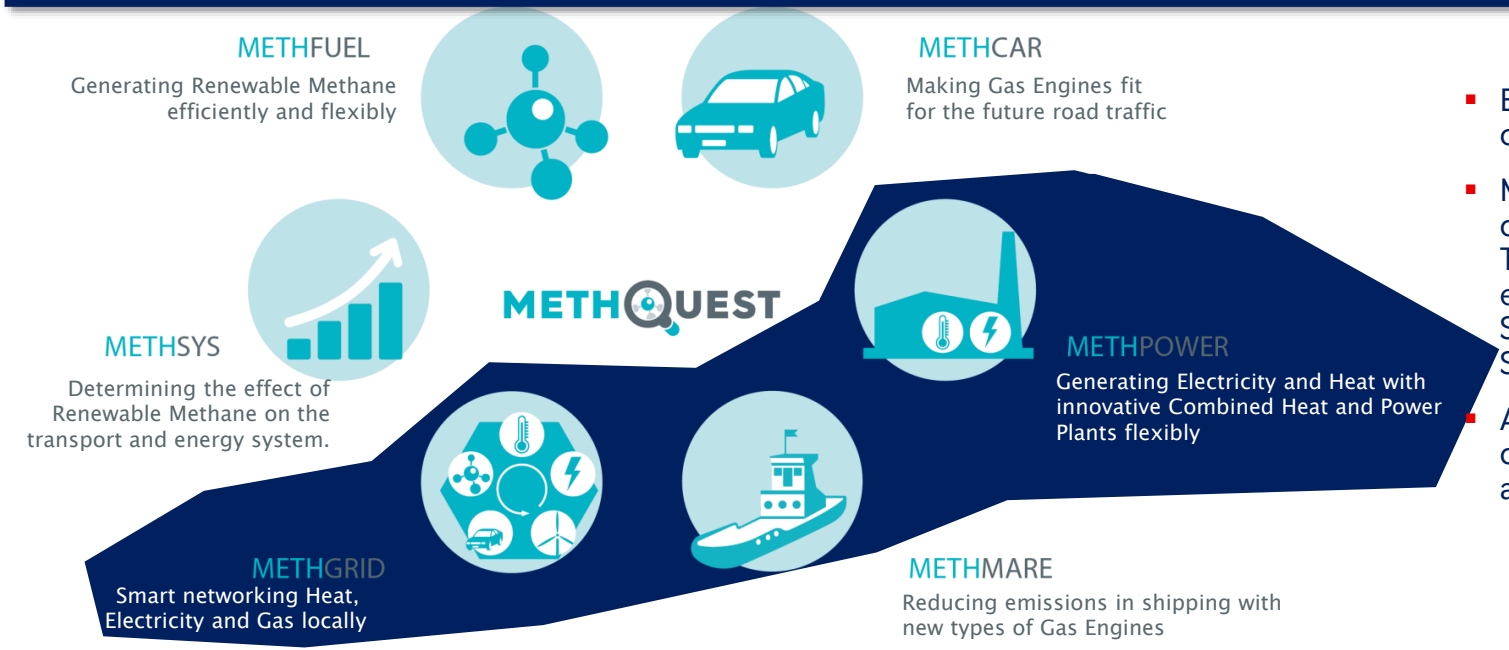
01

Goals and Backgrounds

MethPower, MethGrid

Goals and Backgrounds - MethGrid MethPower

The leading project MethQuest is a strong alliance of 6 joint projects with 27 partners from industry and science



- EE-PtG-CHP Microgrid concepts
- Method and Toolchain for creation, sizing and Techno-Economic evaluation of PtG-CHP Self-Sufficient Microgrid Systems
- Application using example of selected industrial site and Karlsruhe harbor

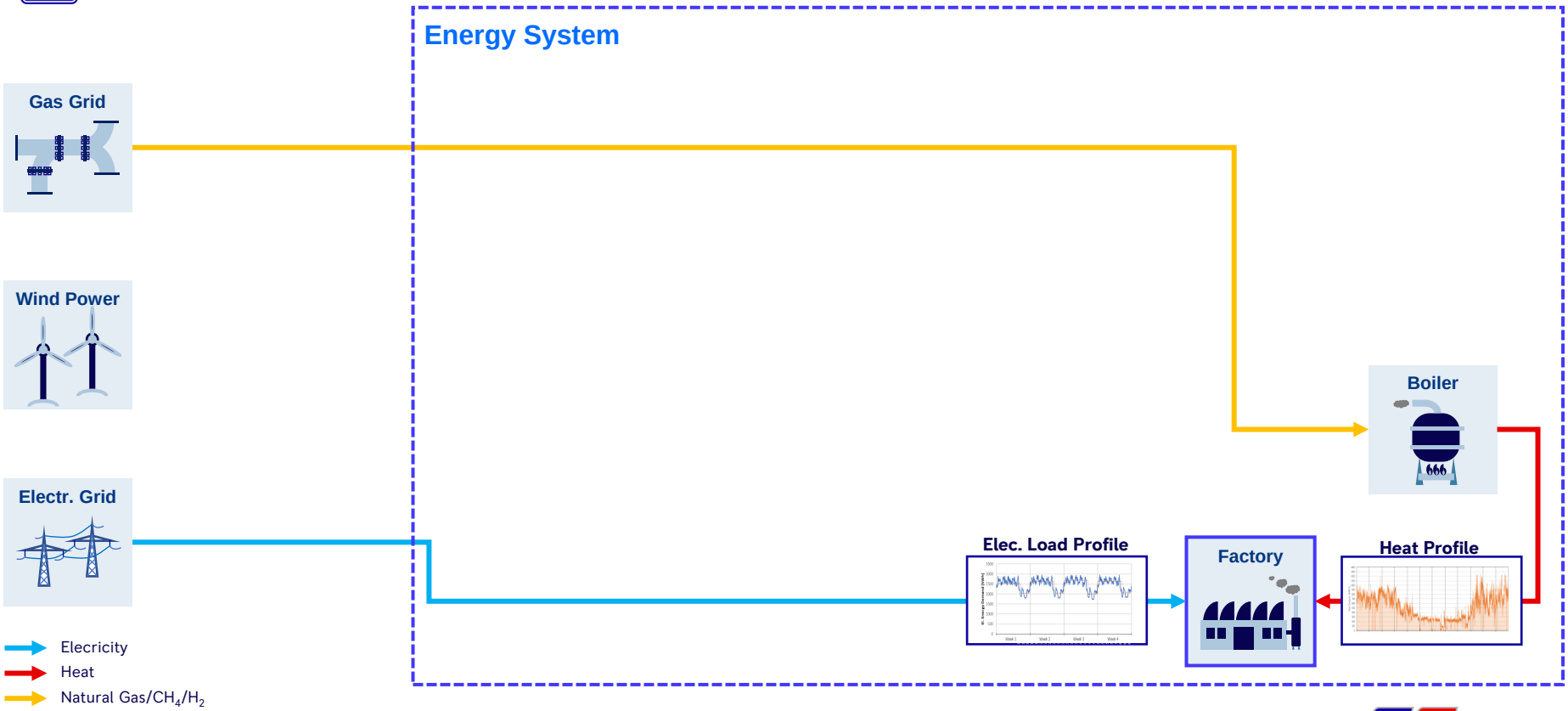
A Rolls-Royce solution

02

Created Microgrid concepts

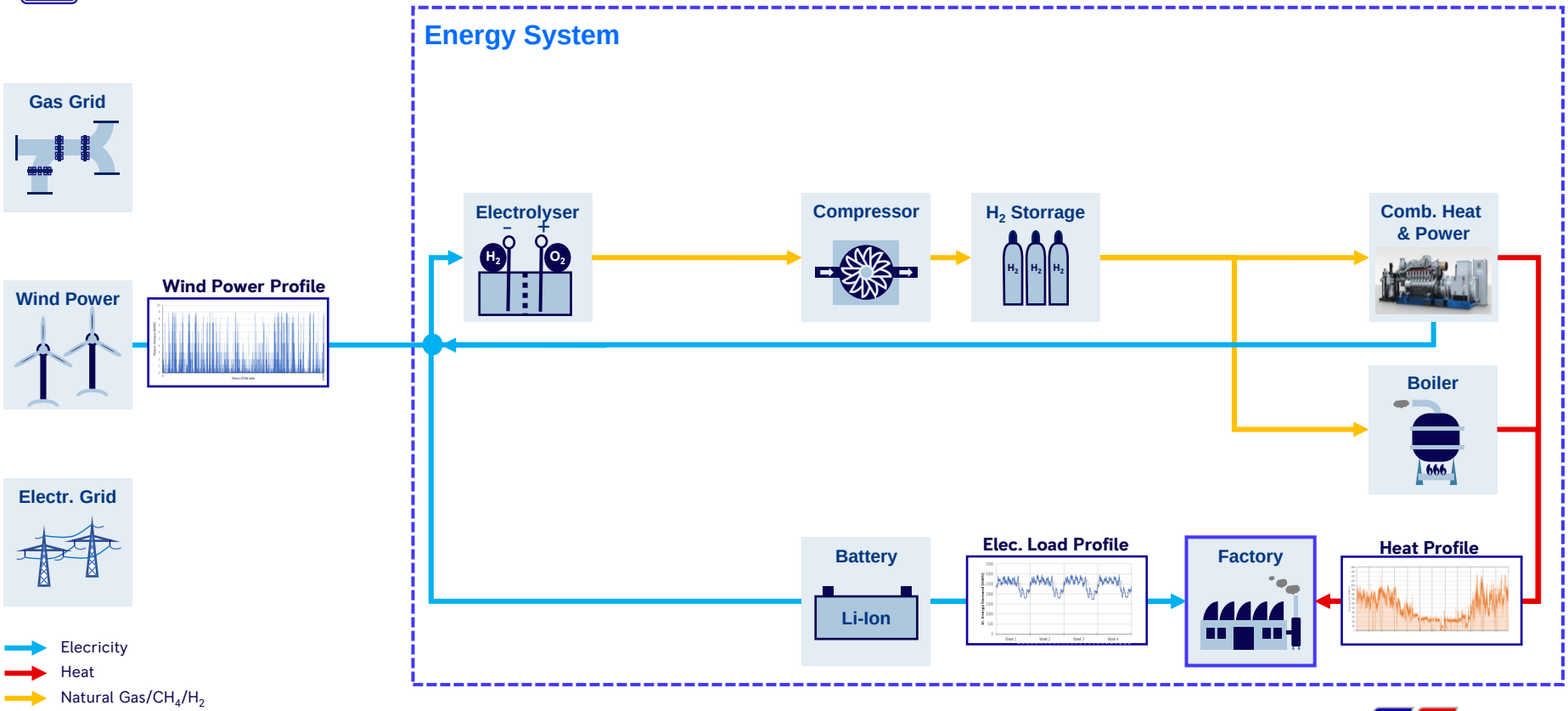
EE(Renewable Energy)-PtG(Power-to-Gas)-CHP

Grid Connection only (Reference)



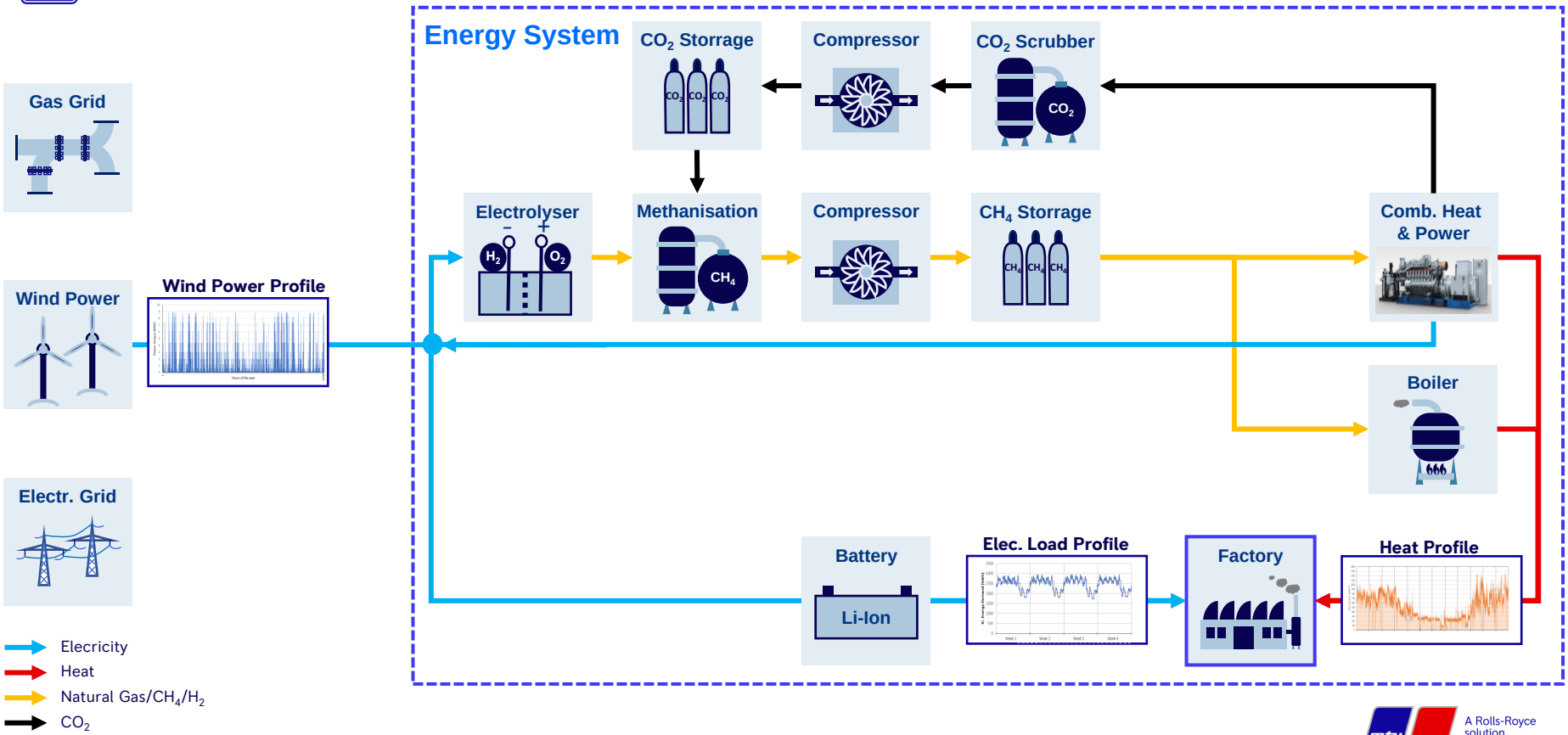
A Rolls-Royce solution

Power-to-H_2 & CHP with H_2 Engine (Off-Grid) – PtH2-CHP



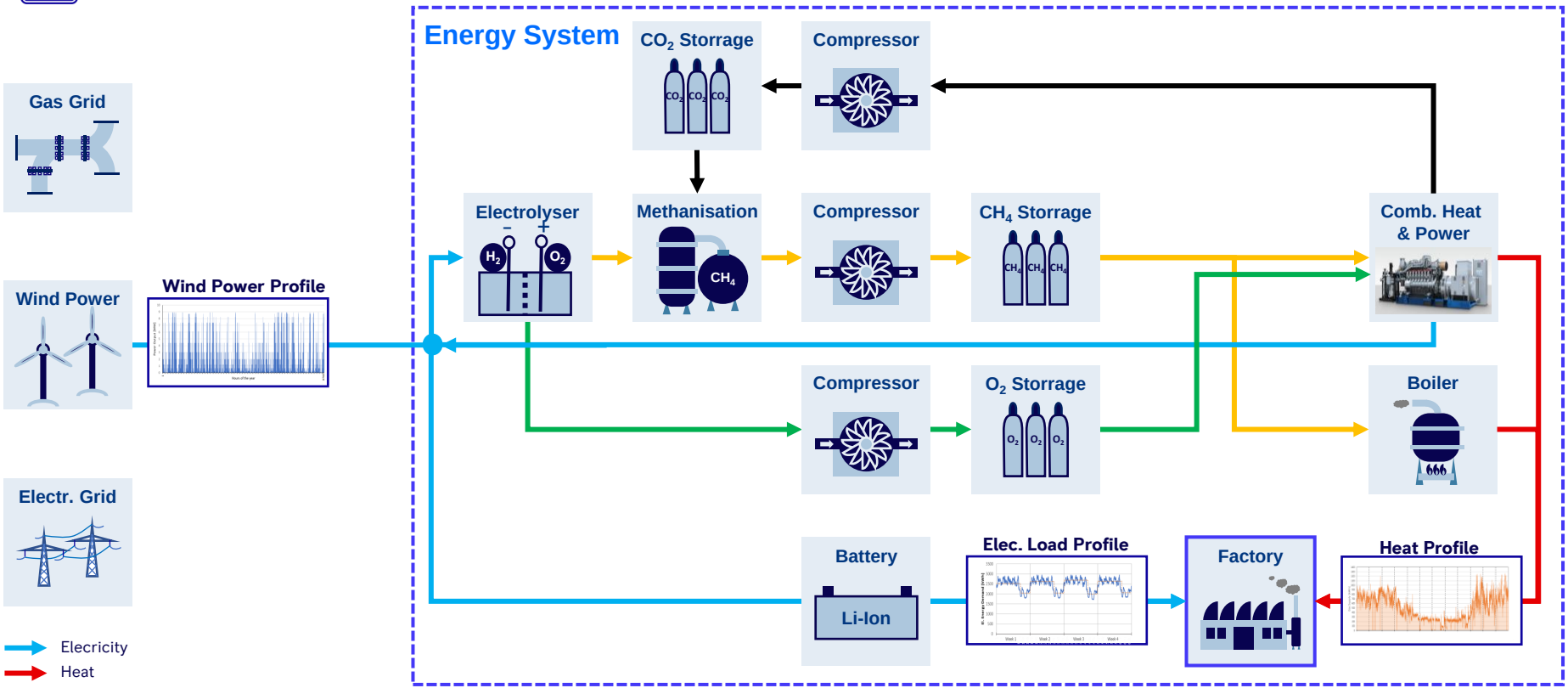
A Rolls-Royce solution

Power-to-CH_4 & CHP with Syntetic CH_4 (Off-Grid) – PtCH4-CHP

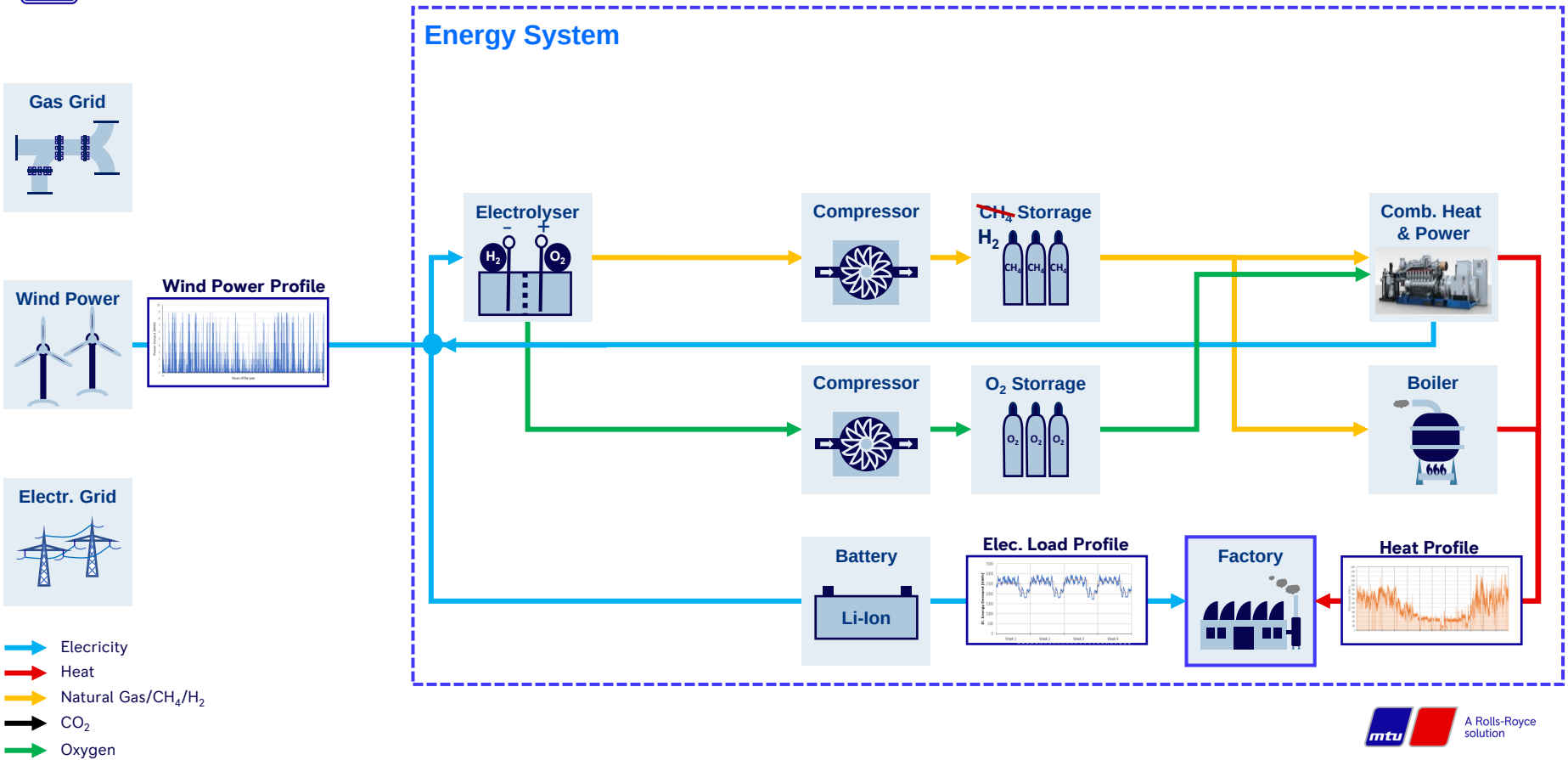


A Rolls-Royce solution

Power-to-CH_4 & CHP with Oxyfuel (Nitrogen Free) Engine (Off-Grid) - PtCH4-Oxy-CHP



Power-to-H_2 & CHP with Oxyfuel (Nitrogen Free) Engine (Off-Grid) - PtH2-Oxy-CHP



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Rolls-Royce Solutions GmbH, Dr. Zhenan Zhang

03

Selected results

- Method
- Selected industrial site
- Karlsruhe harbor
- Optimal Sizing

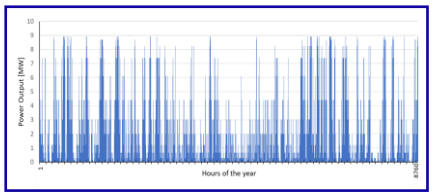
Method applied for Techno-Economic Evaluation

Use case as example:
- The selected industrial site with specific electrical and thermal load profile
- On-Shore wind park with up to 32 ENERCON Wind Turbines and typical wind profile

Technical Assessment | Economic Assessment | Post Processing and Analysis

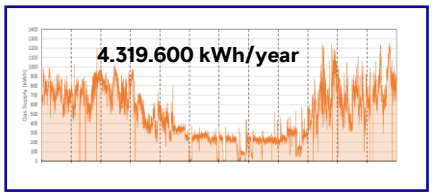
Input

Wind Power Profile

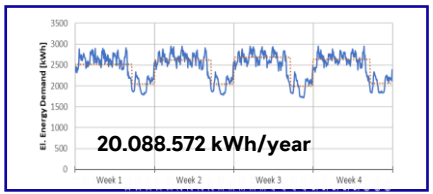


Demand

Heat Profile



Elec. Load Profile



Technology scenarios with size

- Grid connection (Reference)
- PtH_2 & CHP with Hydrogen Engine
- $PtCH_4$ & CHP with Gas Engine
- ...

Simulation Investigation

Results:
- Net Present Cost (NPC)
- Levelized Cost of Electricity (LCOE)
- Fuel balance sheet cost
- Power performance
- Annualized cost
- Self-Sufficiency rate

Autom. creation of variants in search space → **Technical evaluation** → **Economic evaluation of valid variants** → **Identification of the optimal variant**

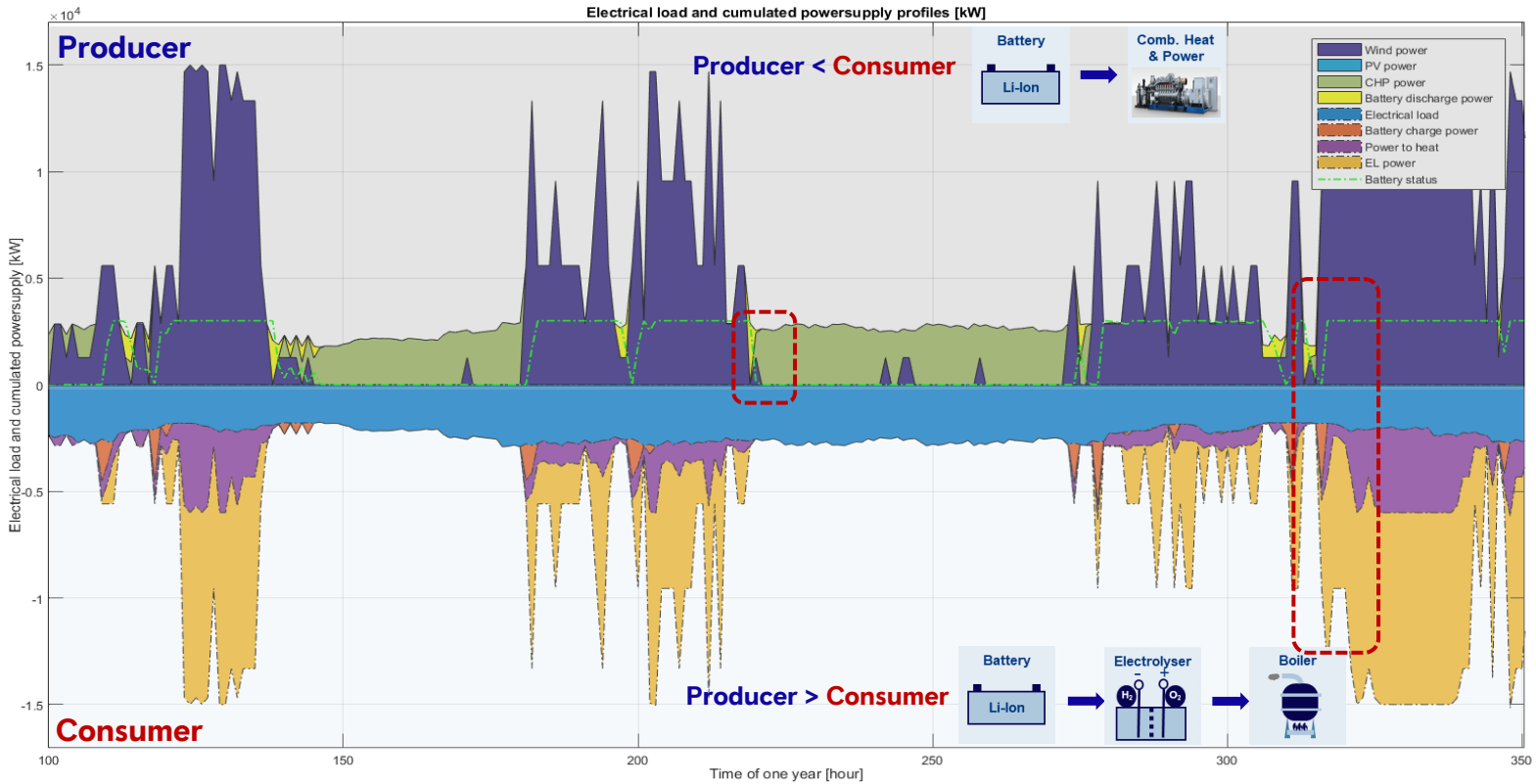
A Rolls-Royce solution

03

Selected results

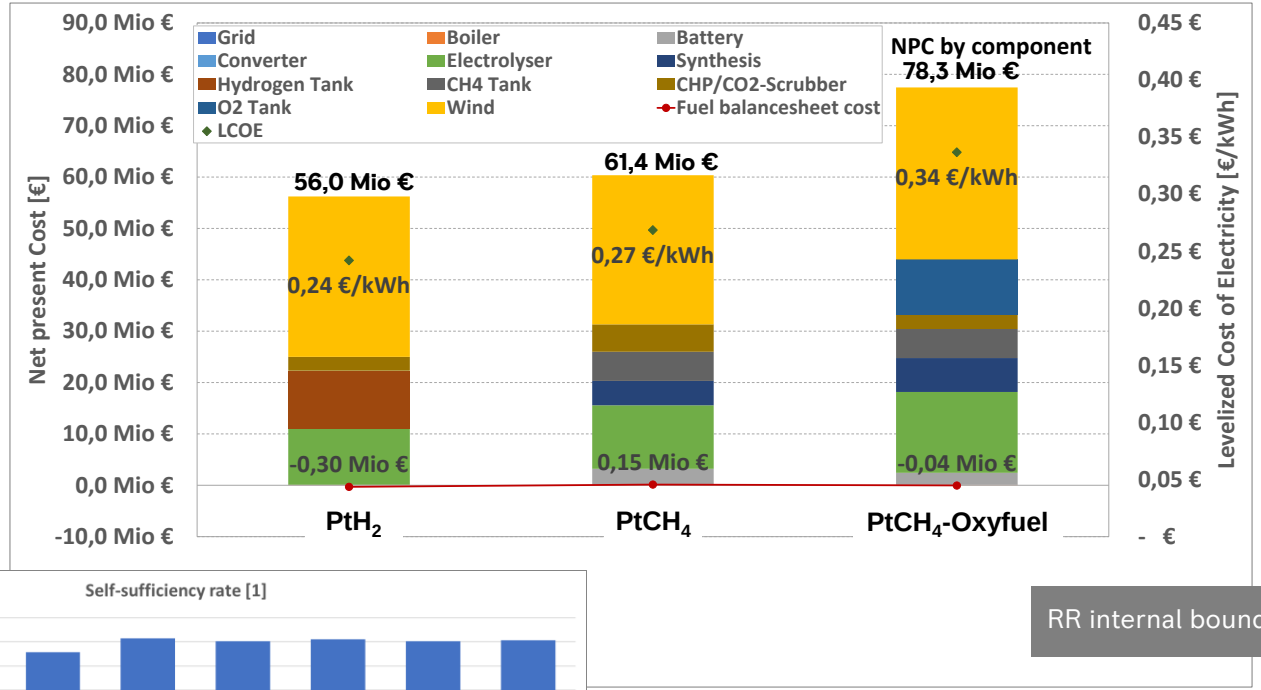
- Method
- Selected industrial site
- Karlsruhe harbor
- Optimal Sizing

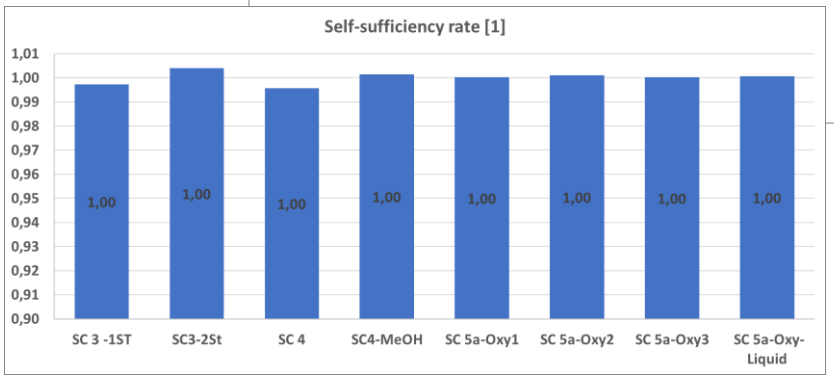
Sample of Power Supply and Energy Storages performance



A Rolls-Royce solution

Techno-Economic Evaluation results for the selected industrial site





RR internal boundary conditions

- Off-Grid costs are higher than On-Grid reference case but competitive with household prices before 2022
- PtH2 is the most competitive concept followed by PtCH4

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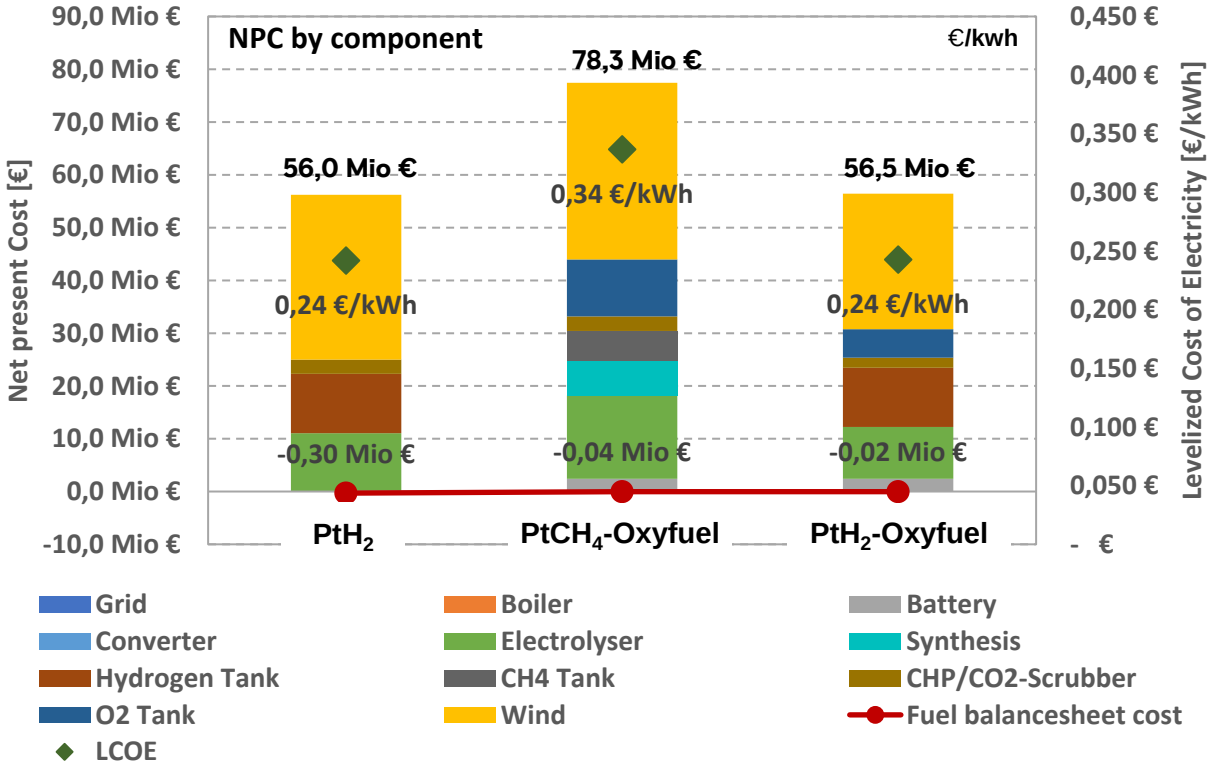
Techno-Economic Evaluation results with PtH2-Oxyfuel for the selected industrial site



- PtH_2-Oxyfuel can be competitive to PtH_2
- Higher Efficiency of H_2-CHP balances the increased cost of O_2-Storage
- Complete new development of CHP would be necessary for PtH_2-Oxy variant

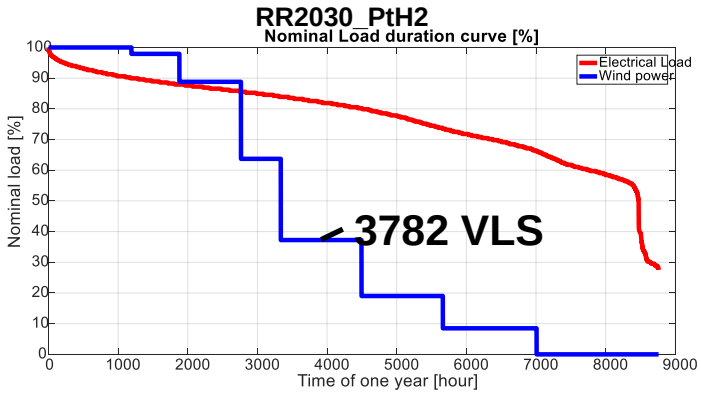
**Results based on the selected industrial site with high Wind potential*

03

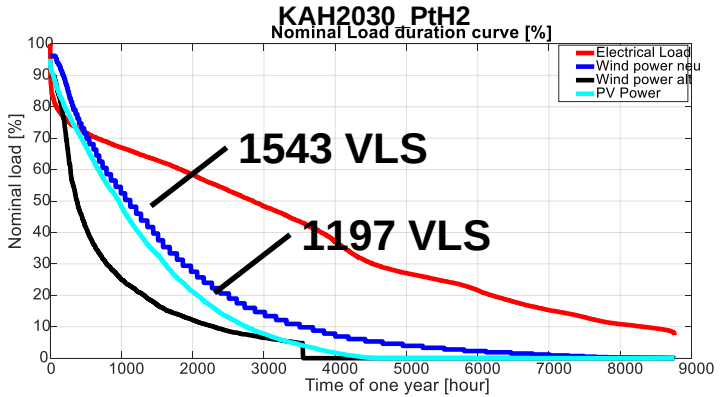
Selected results

- Method
- Selected industrial site
- Karlsruhe harbor
- Optimal Sizing

Application of the Knowledge-Based in-house tool for sizing, optimization and analysis of PtG-CHP-Microgrids based on Karlsruhe harbor (KAH) and selected industrial site (RR)



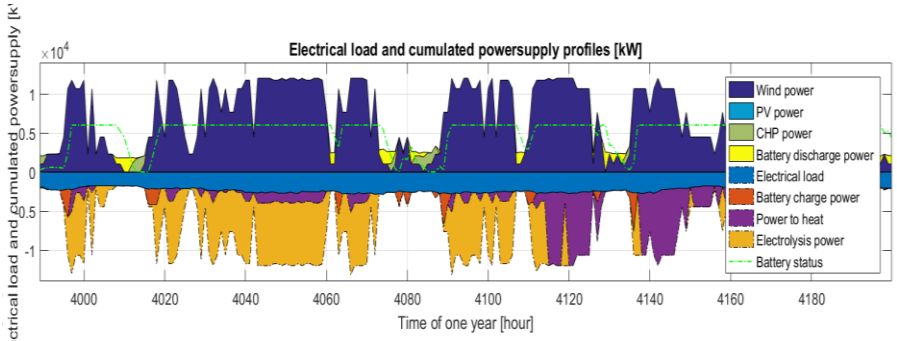
Industrial site (RR) with base load power demand and good wind location, no PV

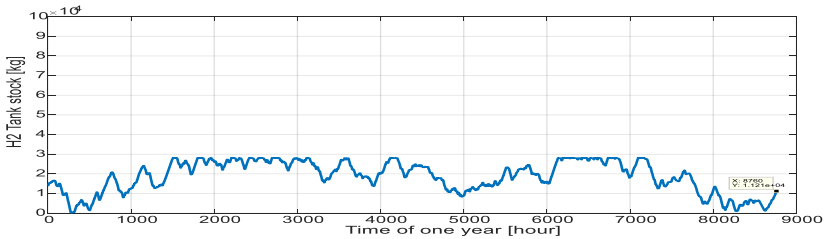


Karlsruhe harbor with medium load power demand and medium wind location, PV has good correlation to power demand

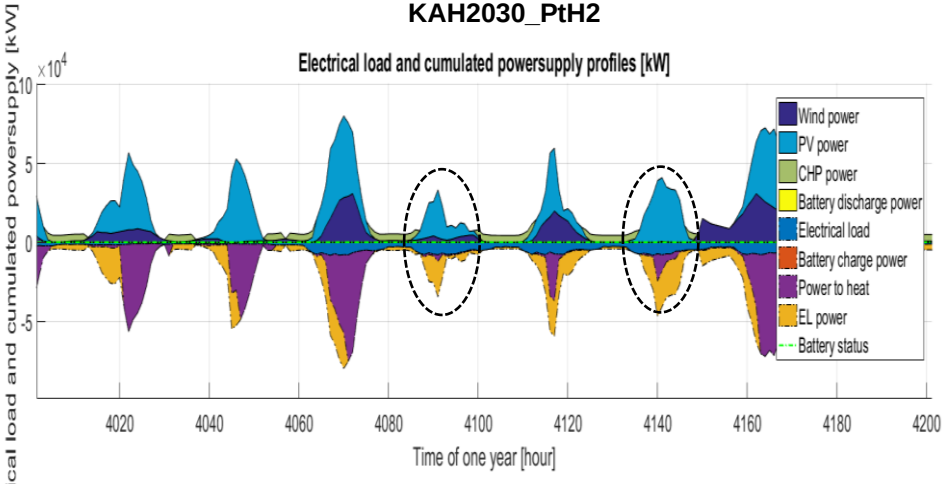
Application of the Knowledge-Based in-house tool for optimization and analysis of PtG-CHP-Microgrids based on Karlsruhe harbor (KAH) and selected industrial site (RR)

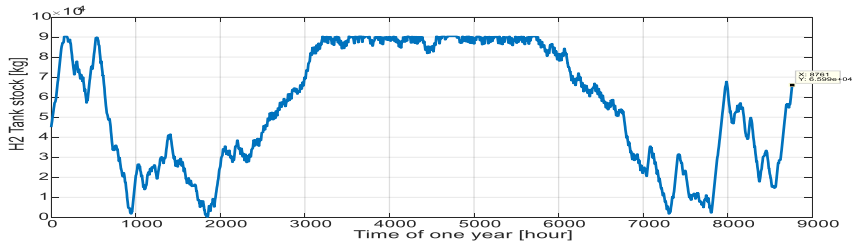
RR2030_PtH2





KAH2030_PtH2





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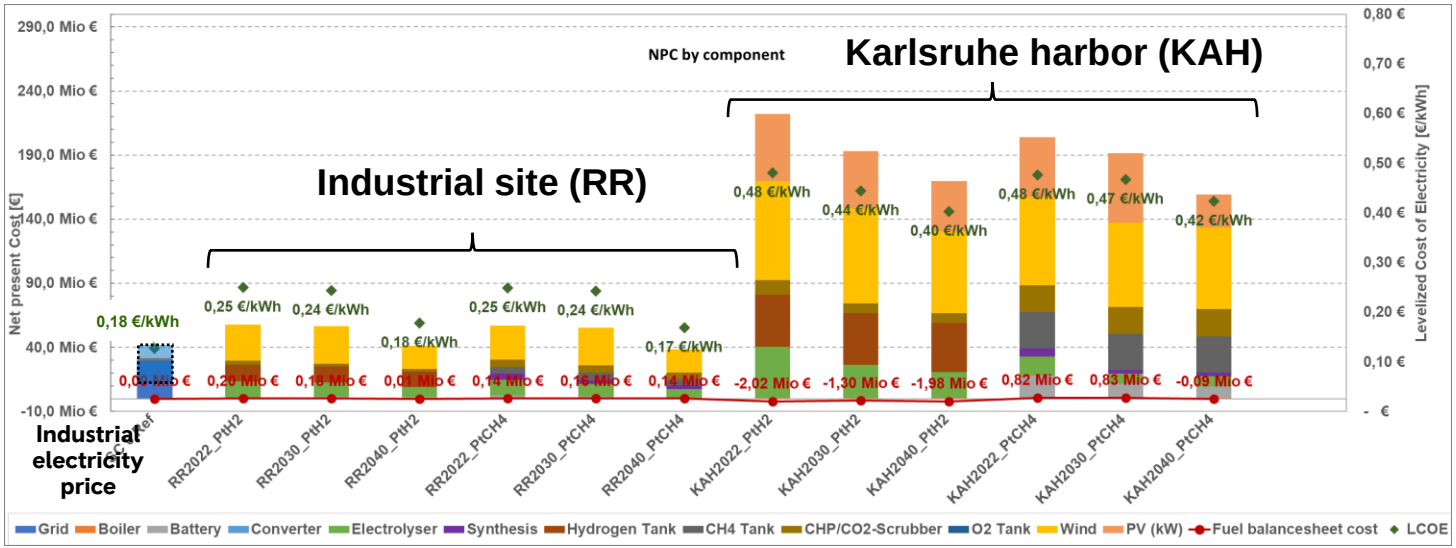
Techno-Economic Evaluation results of Self-Sufficient PtG-CHP-Microgrids and Comparison



SC 0 Ref: Reference case RR with Electricity and Gas supply from Grid

PtH2: Power-to-H2 case with H2-CHP

PtCH4: Power-to-CH4 case with CH4-CHP

LCOE: Levelized Costs of Energy

NPC: Net Present Costs)

- H_2-CHP and CH_4-CHP achieve almost similar LCOE
- Decreasing LCOE in the medium term due to leaning effects (especially PtG)
- Industrial site (RR) can reach competitive LCOE due to good wind location
- LCOE of Karlsruhe harbor has potential for reduction due to its medium EE-potential

MethGrid boundary conditions (aligned with DVGW)

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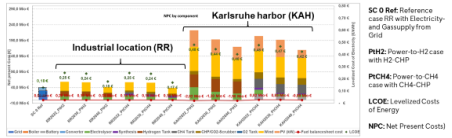
04

Summary

Summary

- Power-to-H_2 & CHP with Oxyfuel (Nitrogen Free) Engine (Off-Grid)
- Method applied for Technical-Economic Evaluation
- Sample of Power Supply and Energy Storages performance
- Technical-Economic Evaluation results for Rolls-Royce plant
- Application of the Knowledge-based in-house tool for sizing, optimization and analysis of PtG-CHP-Microgrids based on Karlsruhe harbor (KAH) and Rolls-Royce-plant (RR)
- Technical-Economic Evaluation results with PtH2-Oxyfuel for Rolls-Royce-plant
- Technical-Economic Evaluation results of Self-Sufficient PtG-CHP-Microgrids and Comparison



- H_2-CHP and CH_4-CHP achieve almost similar LCOE
- Decreasing LCOE in the medium term due to leaning effects (especially PtG)
- Industrial location (RR) can reach competitive LCOE compared with householder electricity price due to good wind location
- LCOE of Karlsruhe harbor has potential for reduction due to its medium EE-potential

Deliverable:

- ✓ EE-PtG-CHP Microgrid concepts have been created and investigated
- ✓ Method, Toolchain (inhouse developed tool) for creating concepts, sizing, Techno-Economic evaluation as well as optimization have been established and successfully applied
- ✓ Application for investigating EE-PtG-CHP Microgrid concepts for selected industrial site and Karlsruhe harbor have been achieved

Conclusion:

- Rolls-Royce Solutions GmbH is able to create, evaluate and optimize system solutions according to customer requirements and conditions
- Renewable Energy potential of a location has big impact on competitiveness of a EE-PtG-CHP Microgrid
- EE-PtH_2-CHP and EE-PtH_2-Oxyfuel-CHP Self-Sufficient microgrid concepts at the selected industrial site can achieve competitive LCOE
- The ideal solution for a given site depends strongly on the concrete boundary conditions, thus emphasizing the need for a customer specific system optimization.

Thank you for your attention!

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