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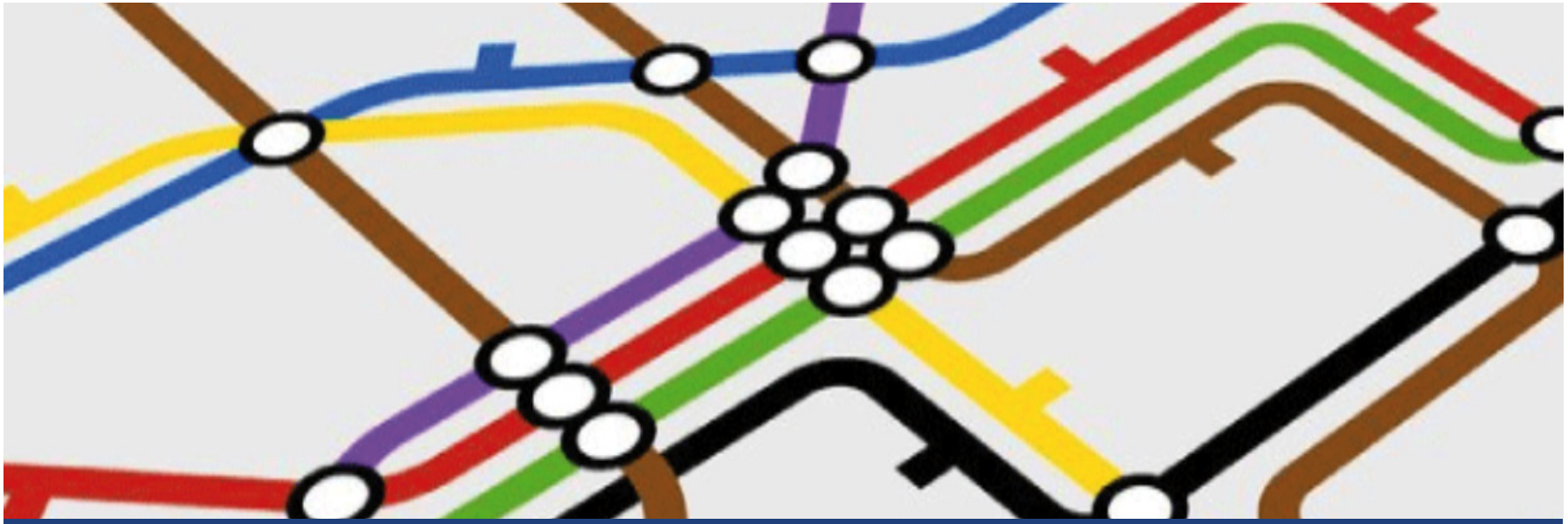
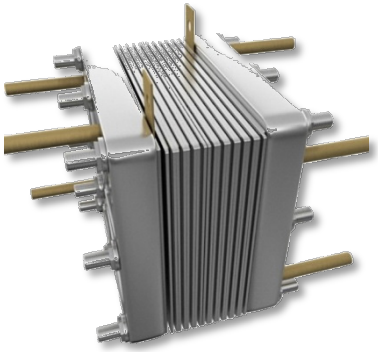


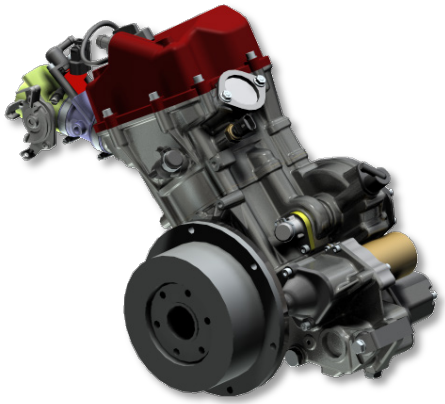
Chemical Energy Converter (CA A2)

Coordination: Christian Bach, Felix Büchi

2nd Annual SCCER Mobility Conference
26th of August 2015

Chemical Energy Converter (CA A2)





Topic A2.1
Fuel Cell Systems
Cost reduction (thermo-neutral system)

Topic A2.2
Internal Combustion Engines
Renewable fuels (Methane, H_2-blending, DME)
Efficiency increase (combustion, gas exchange)
Zero pollutants (thermal management)

PAUL SCHERRER INSTITUT PSI

Fuel Cell Systems and Diagnostics
Felix Büchi

zhaw

Combustion Research Laboratory
Ionnis Mantzaras

Institute of Computational Physics
Jürgen Schumacher

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Lab for Aerothermochemistry and Combustion Systems
Konstantinos Boulouchos

Institute for Dynamic Systems and Control
Chris Onder

EMPA
Materials Science & Technology

Internal Combustion Engines Lab
Christian Bach

Roadmap

Topic A2.1: Fuel Cell Systems

- *Short term:* Understanding 2-phase flow and phase change processes for evaporative fuel cell cooling (thermo-neutral operation)
- *Medium term:* Demonstration of the potential of thermo-neutral operation concepts
- *Long term:* Proof of concept, demonstration of high power density, low complexity thermo-neutral fuel cell system in a vehicle of an industrial partner

Topic A2.2: Internal Combustion Engines

- *Short term:* Ignition/flame kernel formation and combustion studies on gas and DME operated engines on state-of-the-art combustion processes
- *Medium term:* Demonstration of key-technologies for new, efficient and renewable energy based combustion process
- *Long term:* Proof of concept of new, renewable operated, 25% more efficient internal combustion engine in a typical load profile

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Topic A2.1: Fuel Cell Systems in Mobility

…separate presentation from Felix Büchi

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Topic A2.2: Internal Combustion Engines

Investigation of gas-engine **ignition phase** (ETH-LAV, Empa-APTL)

Understanding **combustion process** by detailed simulation (ETHZ-LAV)

Combustion control of gas-engines (ETHZ-IDSC)

Synthetic fuel/gas engine combustion process (ETHZ-LAV, ETHZ-IDSC, Empa-APTL)

Hybridization (ETHZ-IDSC, Empa-APTL)

Synthetic gaseous fuel production (Empa-APTL)

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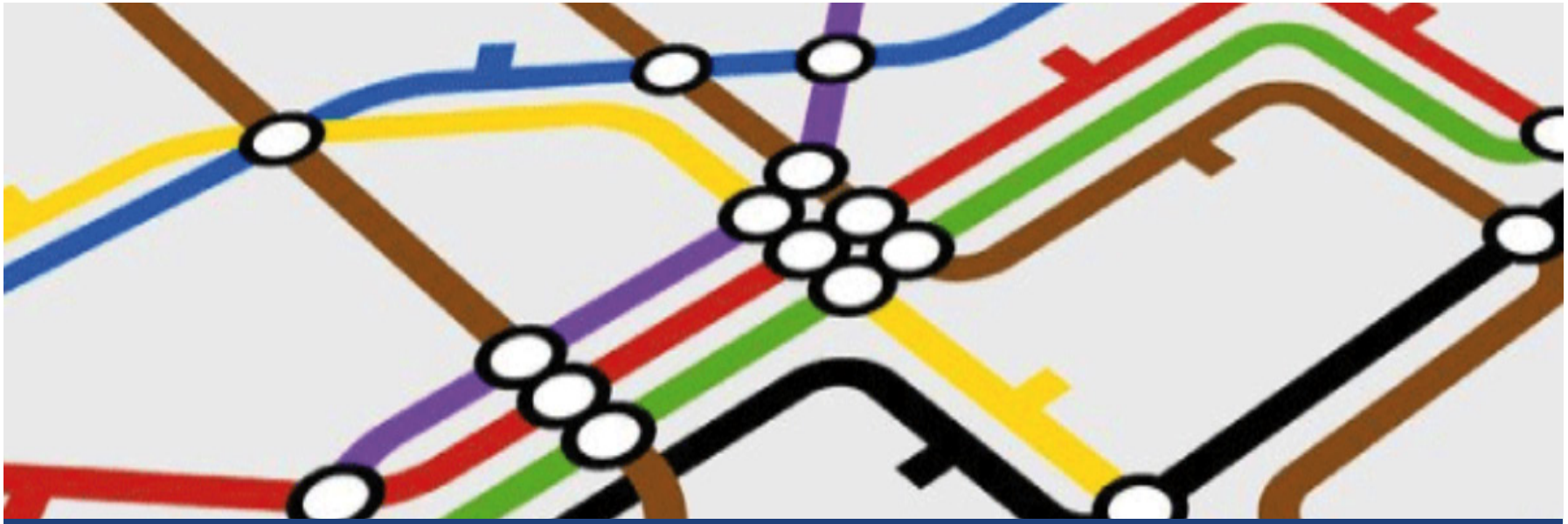

SwissTrolley+, CNG engines

Institute for Dynamic Systems and Control (IDSC)
Prof. Dr. Christopher Onder
ETH Zürich

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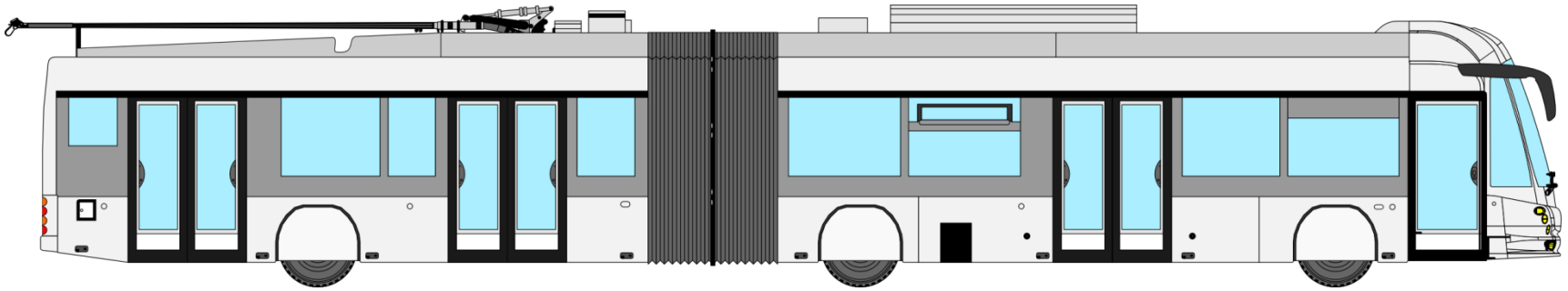
SwissTrolley+

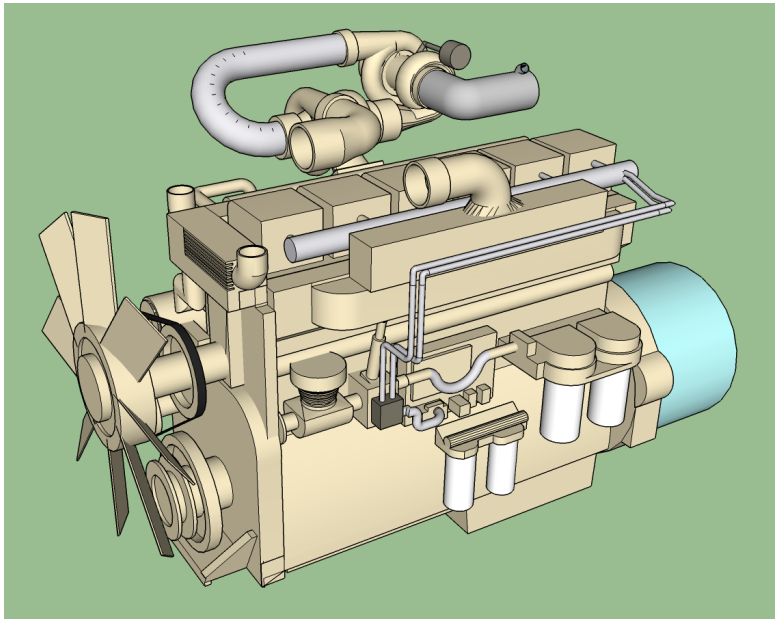
A battery-assisted trolley bus



HESS VBZ Zürich Linie ETH Zürich IDSC Berner Fachhochschule

SwissTrolley+

- State-of-the-art: 50kW Diesel-generator
  - Depot maneuvering
  - Outage of electricity
  - «Dead Weight» ~0.5t
  - Local emissions
  - Noise
  - …



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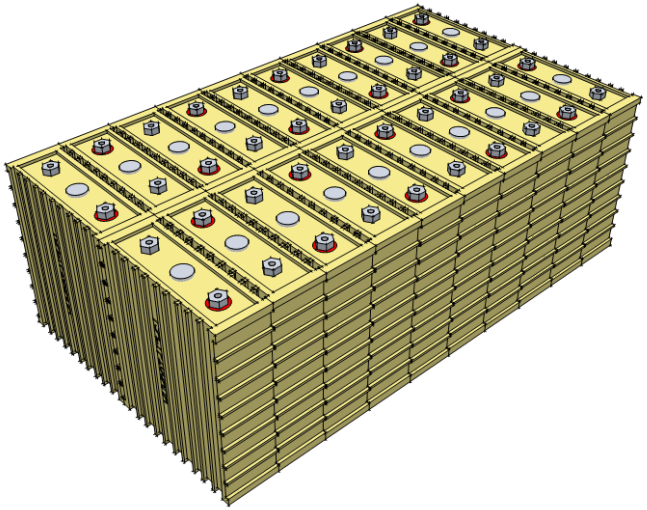
SwissTrolley+

- New: traction battery
  - 30 kWh
  - ~0.6 t

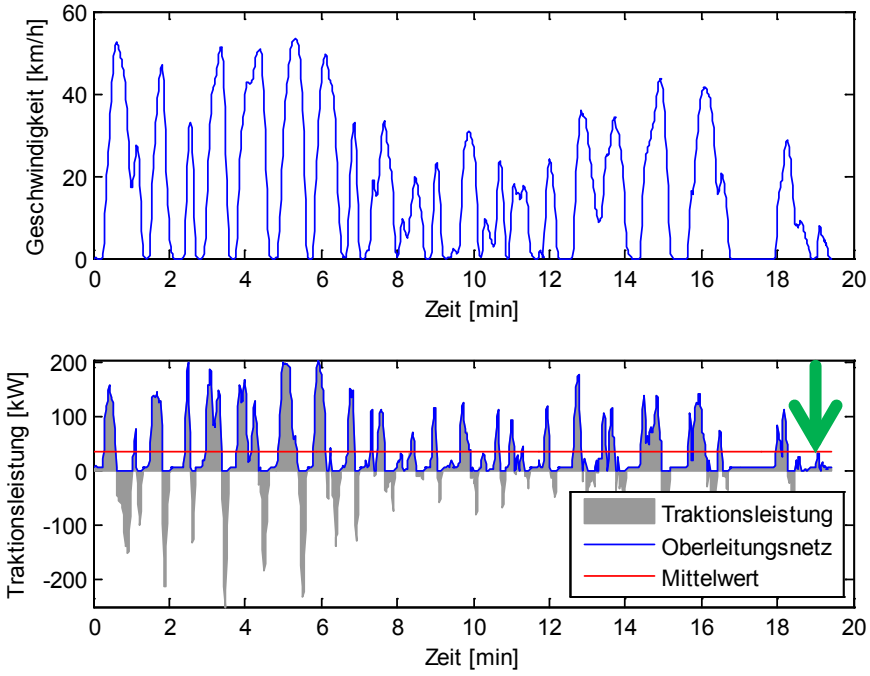


- Benefits
  - Recuperation: ~-15% energy savings
  - Pure battery-electric range >10 km
    - Extension of existing trolley-lines
    - Removal of overhead wires in city centers
    - Zero local emissions and noise
  - Peak-load reduction in electricity grid


Source: HESS AG

SwissTrolley+

Grid load of a standard trolley bus without traction battery

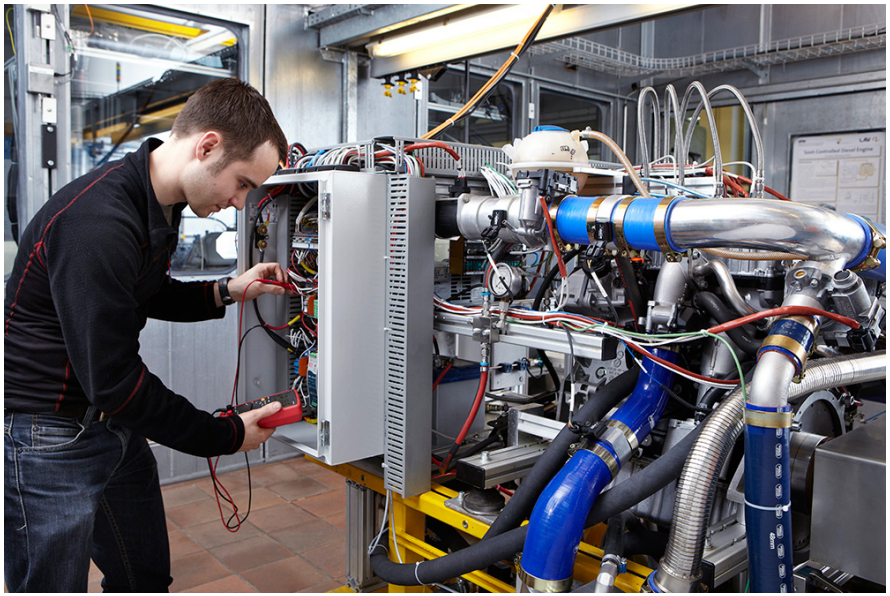


Reserved power plant capacity ≈ 200 kW

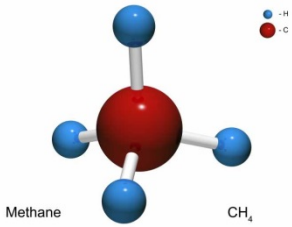
Average load ≈ 35 kW

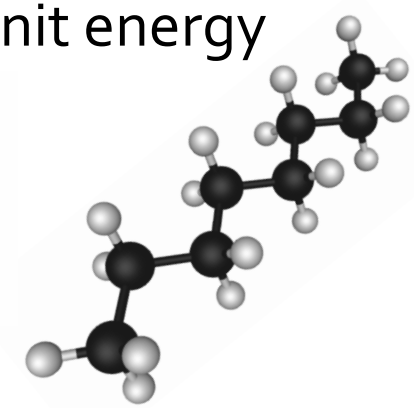
Idea: use battery to reduce peak load

Natural Gas Engines



CNG contains less carbon atoms per unit energy

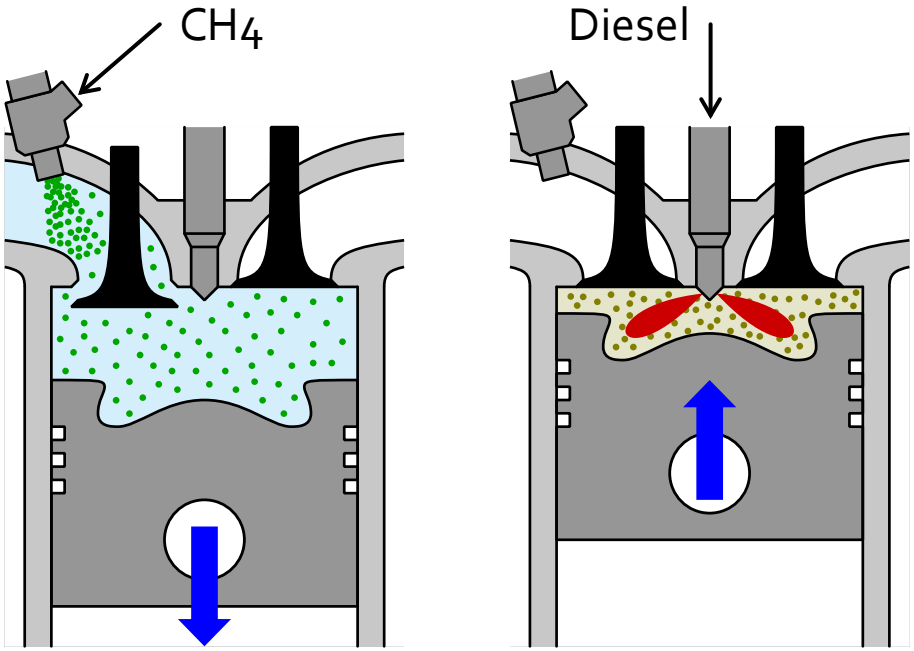




-> less CO_2 emissions

NextICE

A *Diesel-ignited* high-efficiency natural gas engine



ETH Zürich

IDSC

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NextICE

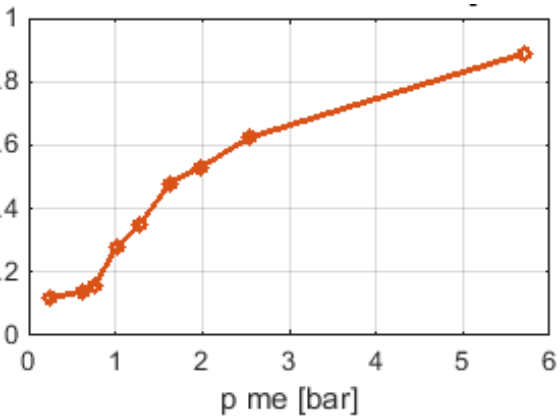
Challenge:

- CH_4 very stable
- Lean conditions

→ incomplete combustion

→ CH_4 engine-out emissions

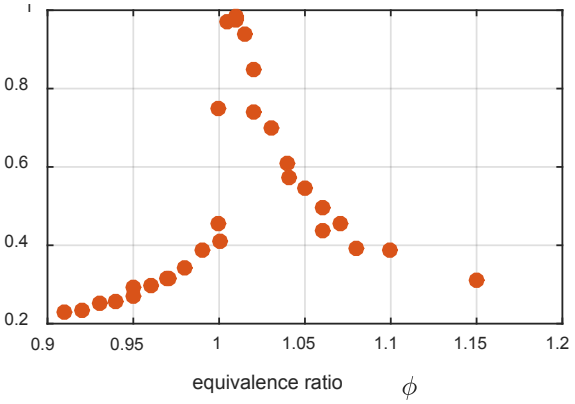
$\frac{\dot{m}_{CH_4,\text{burned}}}{\dot{m}_{CH_4,\text{eng.-in}}}$



- State-of-the-art three-way catalysts have poor CH_4 conversion efficiency

→ motivation for development of CH_4-catalysts

$\frac{\dot{m}_{CH_4,\text{converted}}}{\dot{m}_{CH_4,\text{eng.-out}}}$

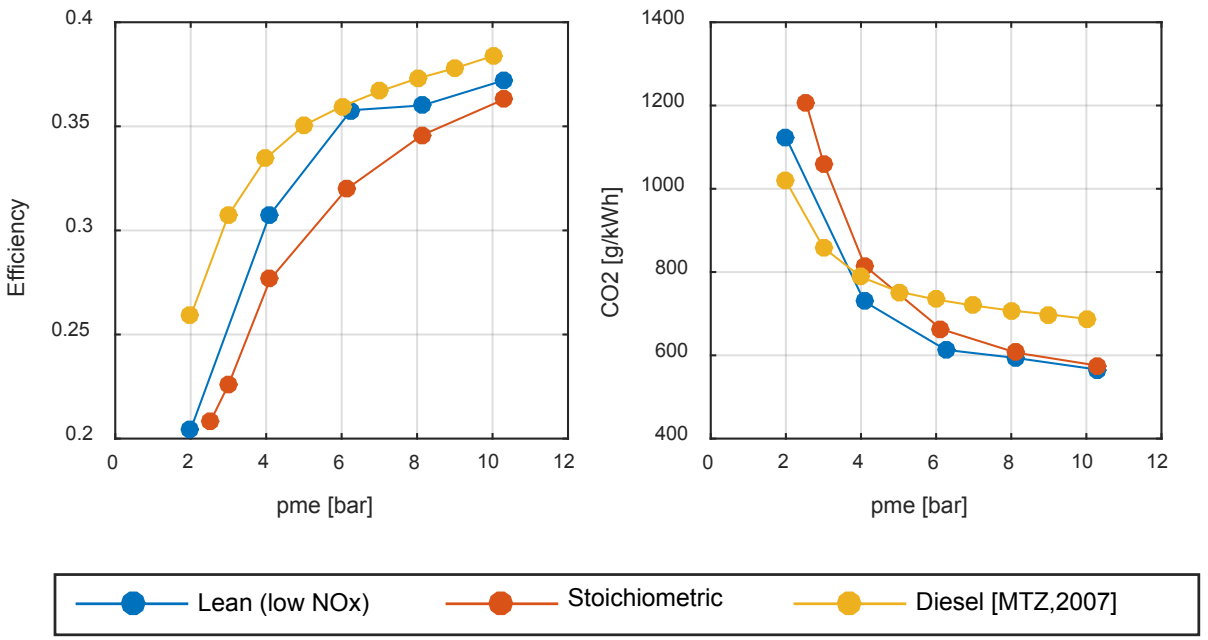


NextICE

Motivation to investigate operating modes:

CO2-optimal:

- "Diesel only" for low load
- "Lean" or "stoichiometric" for high load



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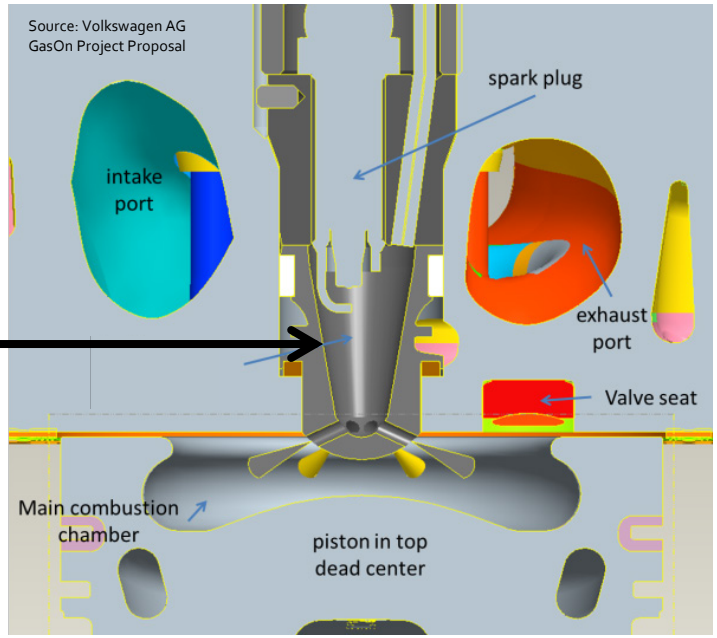
GasOn

Development of a *pre ignition chamber*

for a lean-burning high-efficiency natural gas engine

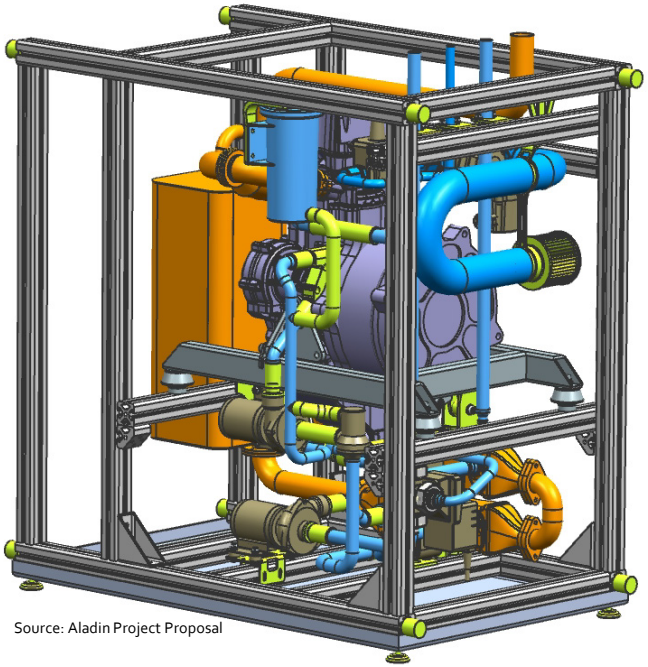
Pre-ignition chamber



Materials Science & Technology

Aladin

A very small CNG "combined heat and power" unit



Source: Aladin Project Proposal

MOTOREX
swissauto WENKO AG
Hoval
ETH Zürich
LAV
IDSC

sccer mobility

Swiss Competence Center for Energy Research
Efficient Technologies and Systems for Mobility

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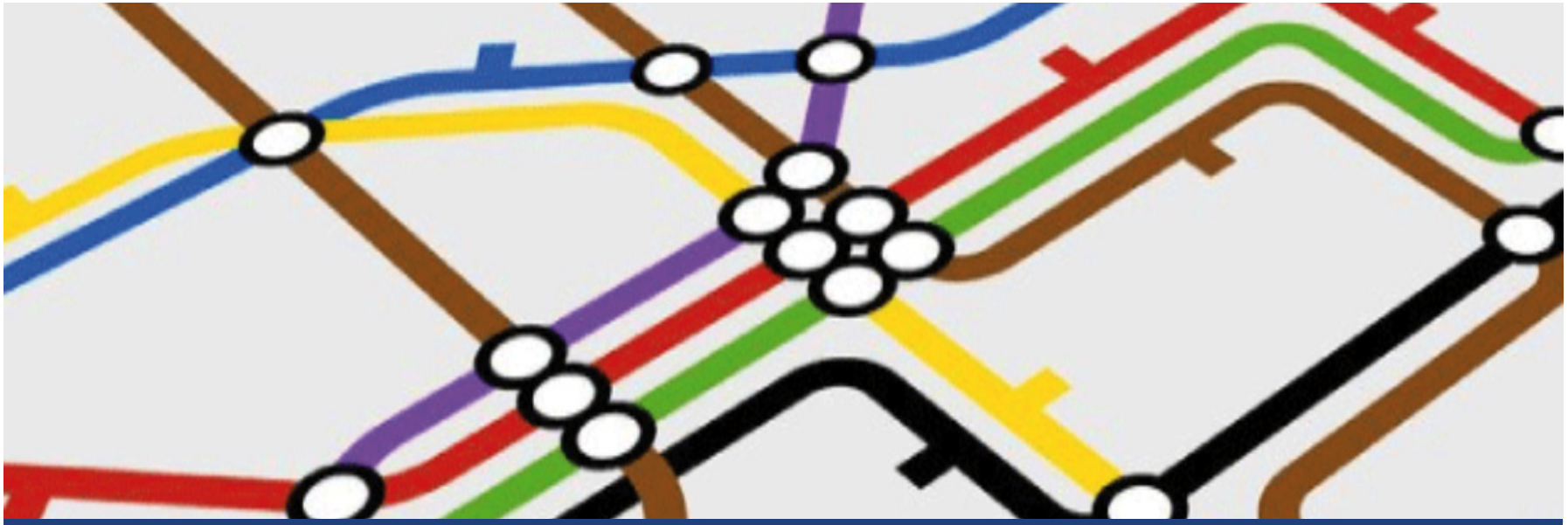


CNG engines, engine process, renewable fuels

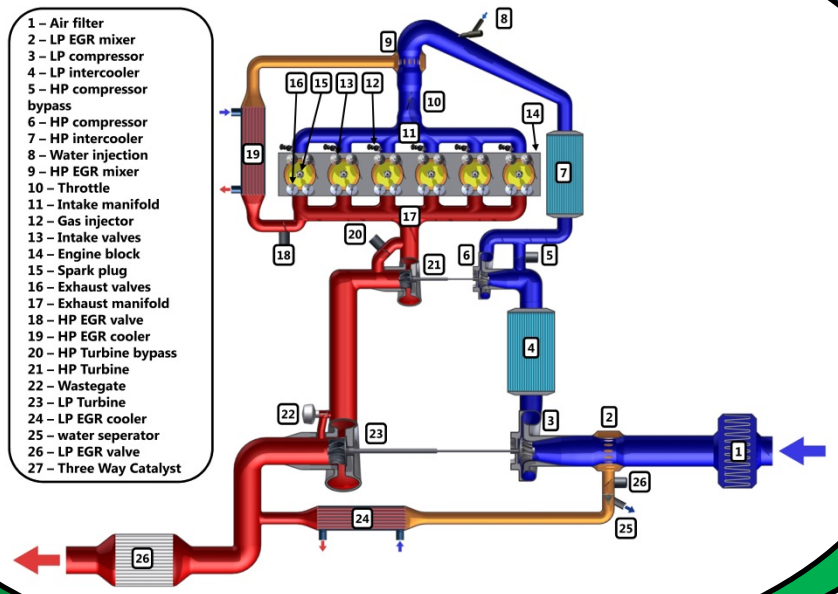
Automotive Powertrain Technologies Laboratory (APTL)

Christian Bach, Dr. Patrik Soltic, Dr. Jakub Rojewski

Empa Duebendorf

HD CNG engine simulation

Now: simulation of different approaches

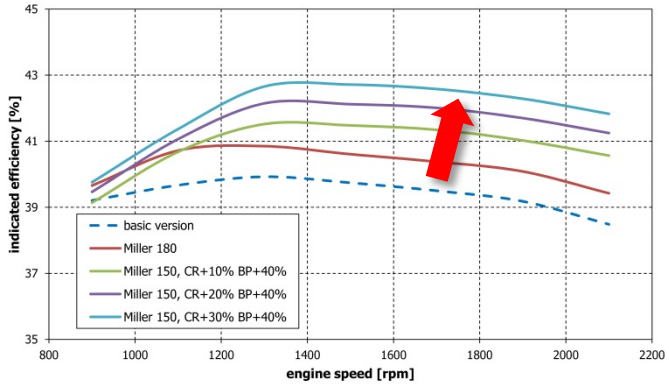


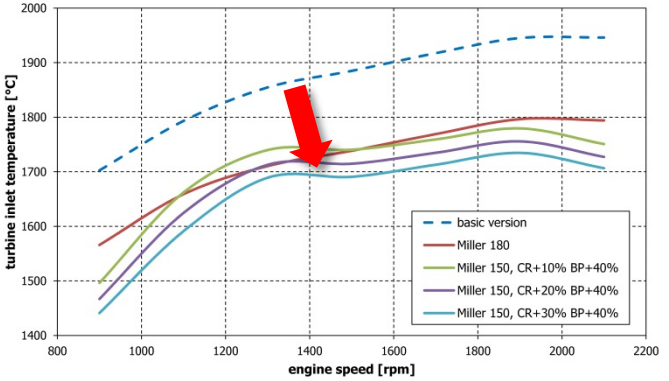
Future: tests on test bench in cooperation with FTP

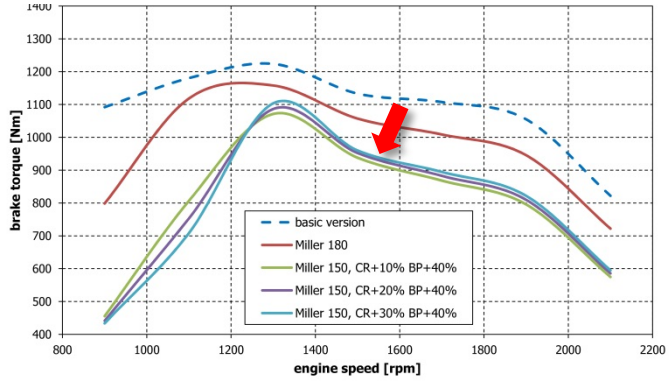
On-going simulations (2015):

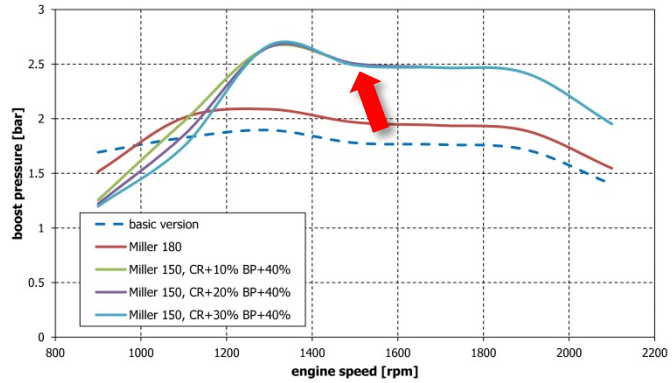
- Otto and Miller valve timing
- single and double stage turbocharging
- high and low pressure EGR loops

HD CNG simulation: first results (1D simulation)









Utilization of a 10% energetic potential is possible by adapting the turbocharging system

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HD CNG engine testing

cycle
- Miller
- Otto

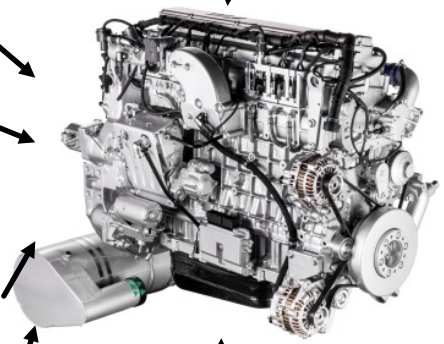
EGR
- high pressure
- low pressure

Turbocharging
- 1 stage
- 2 stage
- series
- sequential

Others
- water injection
- …

?

Gas supply (open issue)



Control strategy

modernized test bench (2015)

Move: Future Mobility Demonstrator

Construction of a **Power-to-Stored Electricity/Gas** plant to demonstrate different pathways of utilizing renewable excess electricity in the mobility sector.

Funding partner:

ccem.ch Competence Center Energy and Mobility

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Bundesamt für Energie BFE

FOGA
Forschungs-, Entwicklungs- und Förderungsfonds der schweizerischen Gasindustrie
Fonds de recherche, de développement et de soutien de l'industrie gazière suisse

Industrial partner:

Atlas Copco

Glattwerk

FPT POWERTRAIN TECHNOLOGIES
Mobility Solutions

Stadt Dübendorf

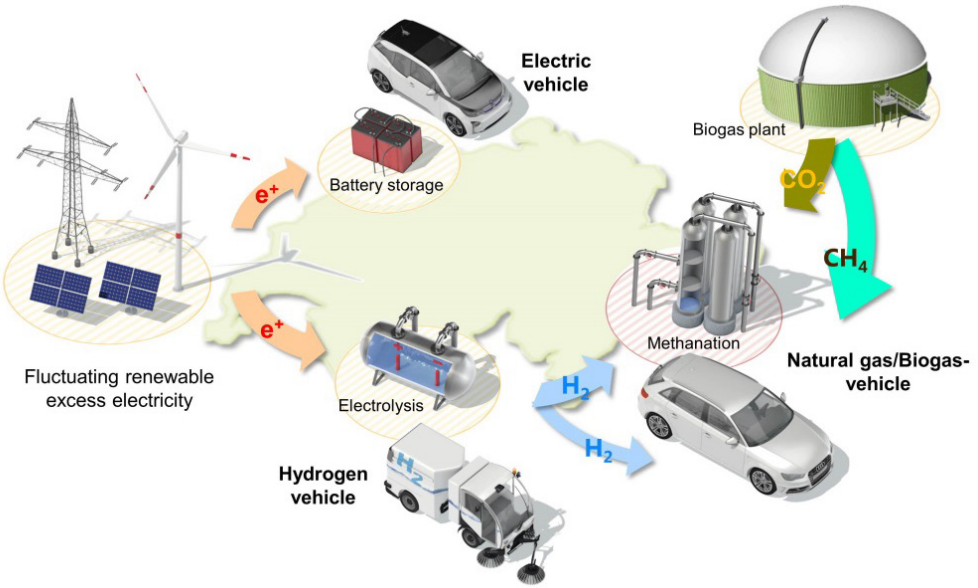
Endress+Hauser
People for Process Automation

DIE POST

Scientific partner:

PAUL SCHERRER INSTITUT PSI

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



3 possible pathways for future mobility

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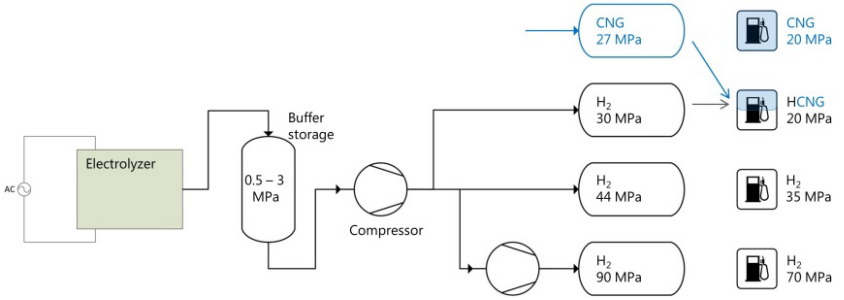
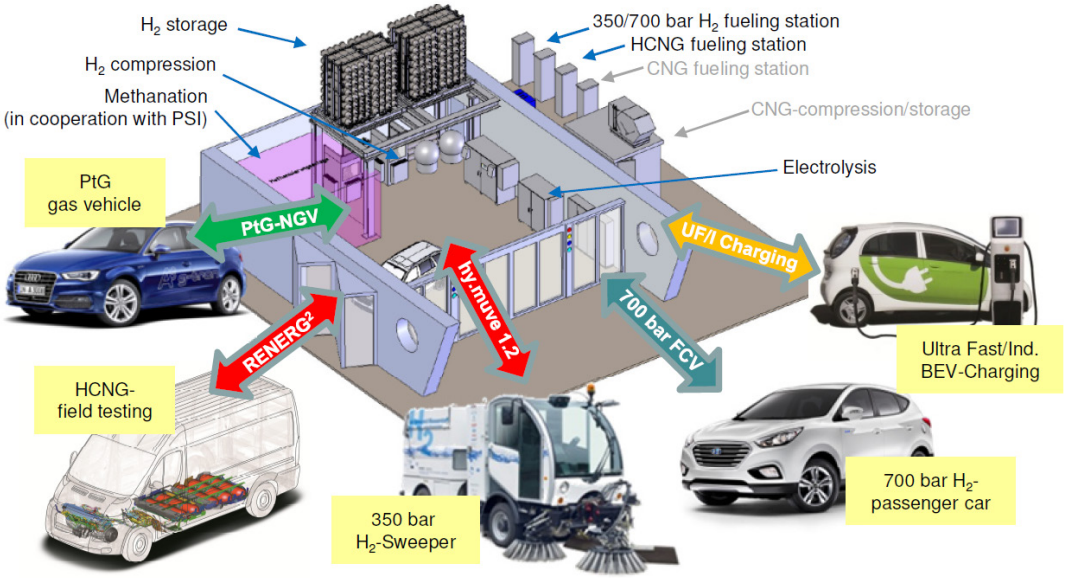
Move: Future Mobility Demonstrator (1st phase)

- Realization of a Power-to-Gas plant including refueling station for vehicles running on alternative fuels (CNG, HCNG, H_2)
- Monitoring and evaluation of the plant's operation as well as its components
- Development of strategies to optimize operation of the plant regarding energetic as well as economic aspects (using models)
- Build a platform for various research endeavors pursued by Empa but also by industrial partners
- Provide an informative demonstration site to introduce the Power-to-Gas technology to relevant stakeholders, politicians as well as the public



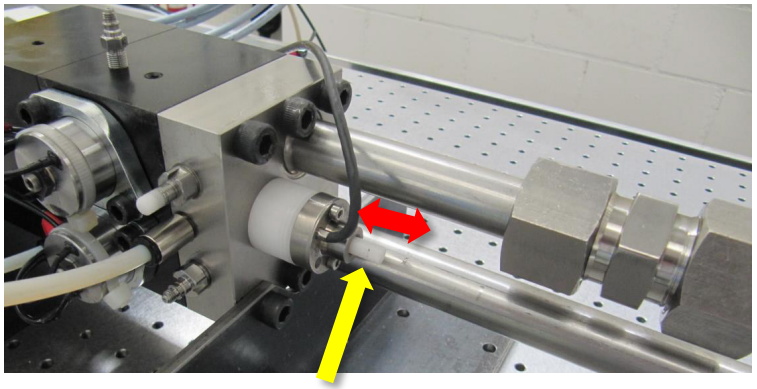


nextICE: variable valve actuation (idea)

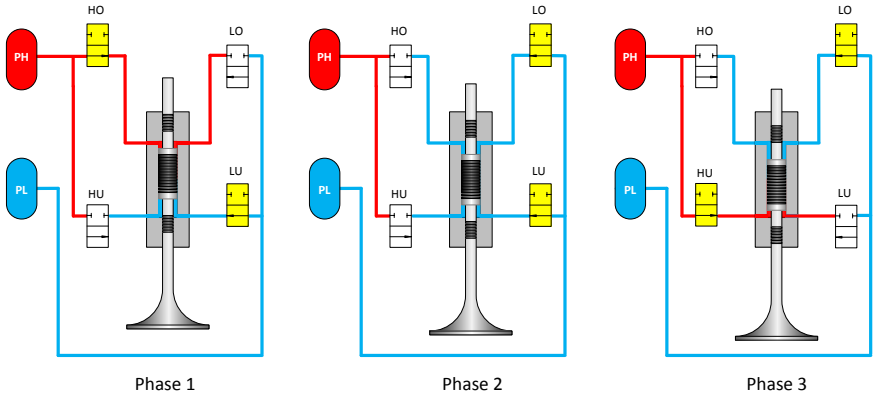
Invent, simulate and realize a variable valve actuation system for a spark ignition engine with the main specifications

- Dissipation not larger than for mechanical valve actuation
- Cost efficient layout
- Flexible (from cycle to cycle)
- Easy to control

} problems of known systems (>500 patents on this topic)



Demonstrator with moving mass



Patented recuperating valve actuation

nextICE: variable valve actuation (next step)

- Functional model has been built
- Technical goal: realize a 9mm lift of the intake valves (open and close) within 5 ms with minimal dissipation (-> efficient hydraulic recuperation)