sccer mobility

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

In Zusammenarbeit mit der KTI

Energie
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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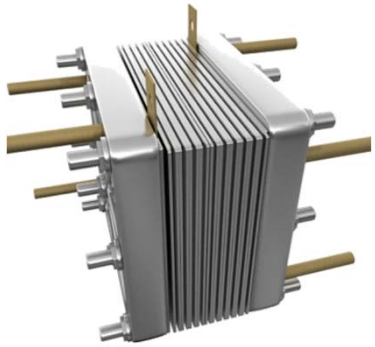
Kommission für Technologie und Innovation KTI

Chemical Energy Converter (CA A2)

Christian Bach, Felix Büchi

1st Annual SCCER Mobility Conference
11th of September 2014

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

Combustion Research Laboratory
Ionnis Mantzaras

zhaw

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

Core industrial partner

BUCHER schörling — Hybrid and fuel cell operated road sweeper

CNG combustion concepts

FPT POWERTRAIN TECHNOLOGIES — Diesel and CNG operated heavy duty truck engines

LIEBHERR — Construction machines and stationary engines

Weber Motor — Range extender, CNG operation

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

Fuel Cell Systems (A2.1)

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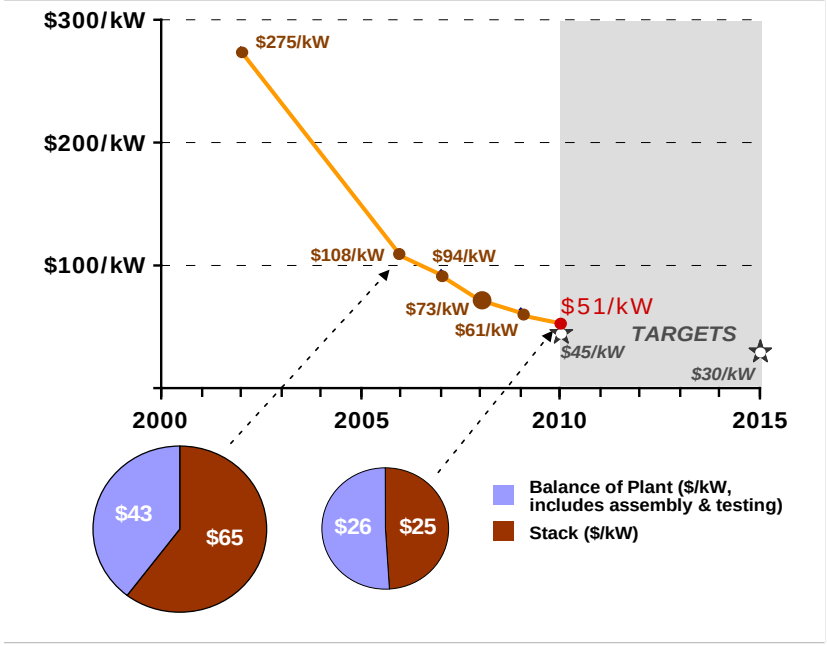
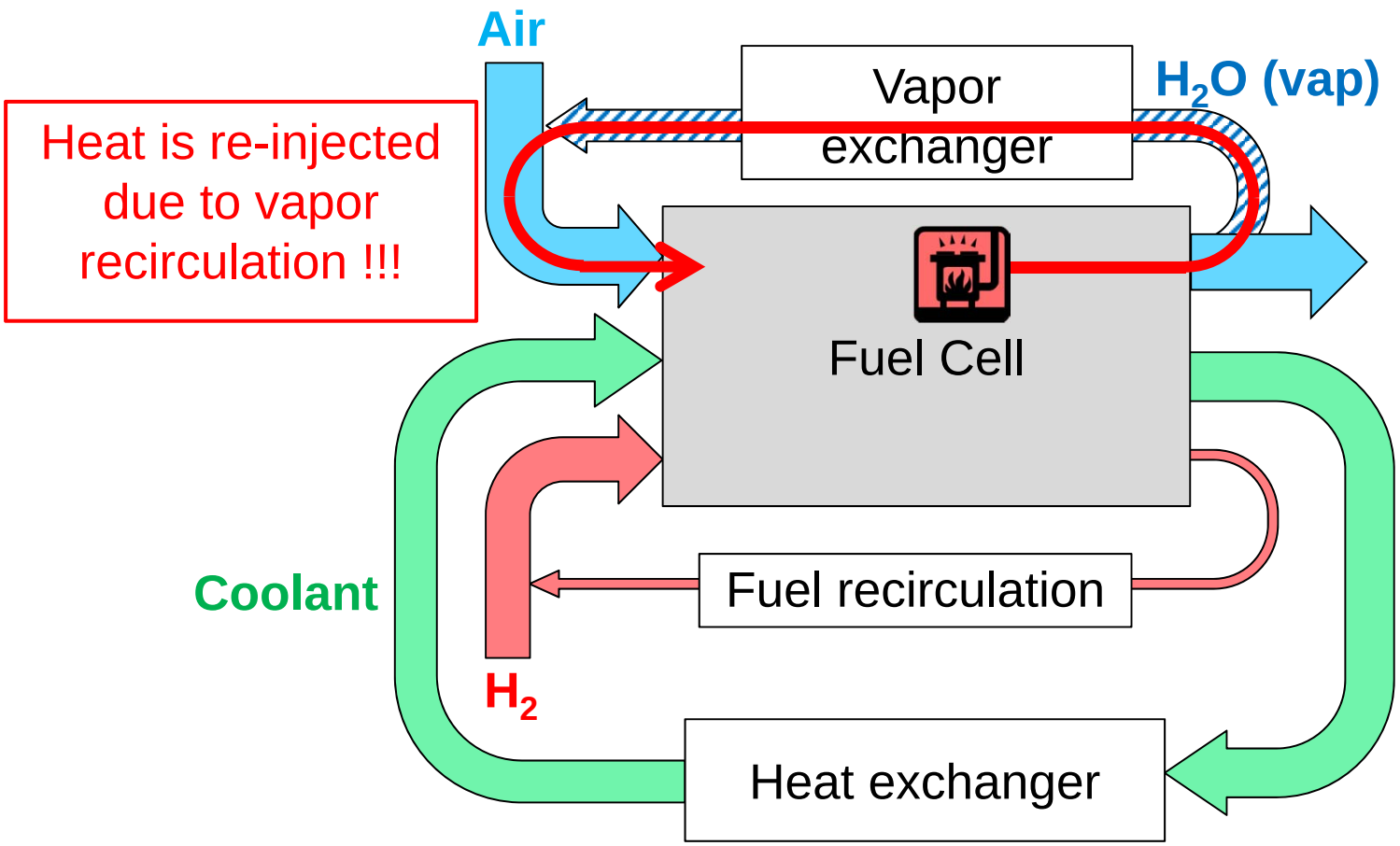
Fuel Cell Systems in Mobility



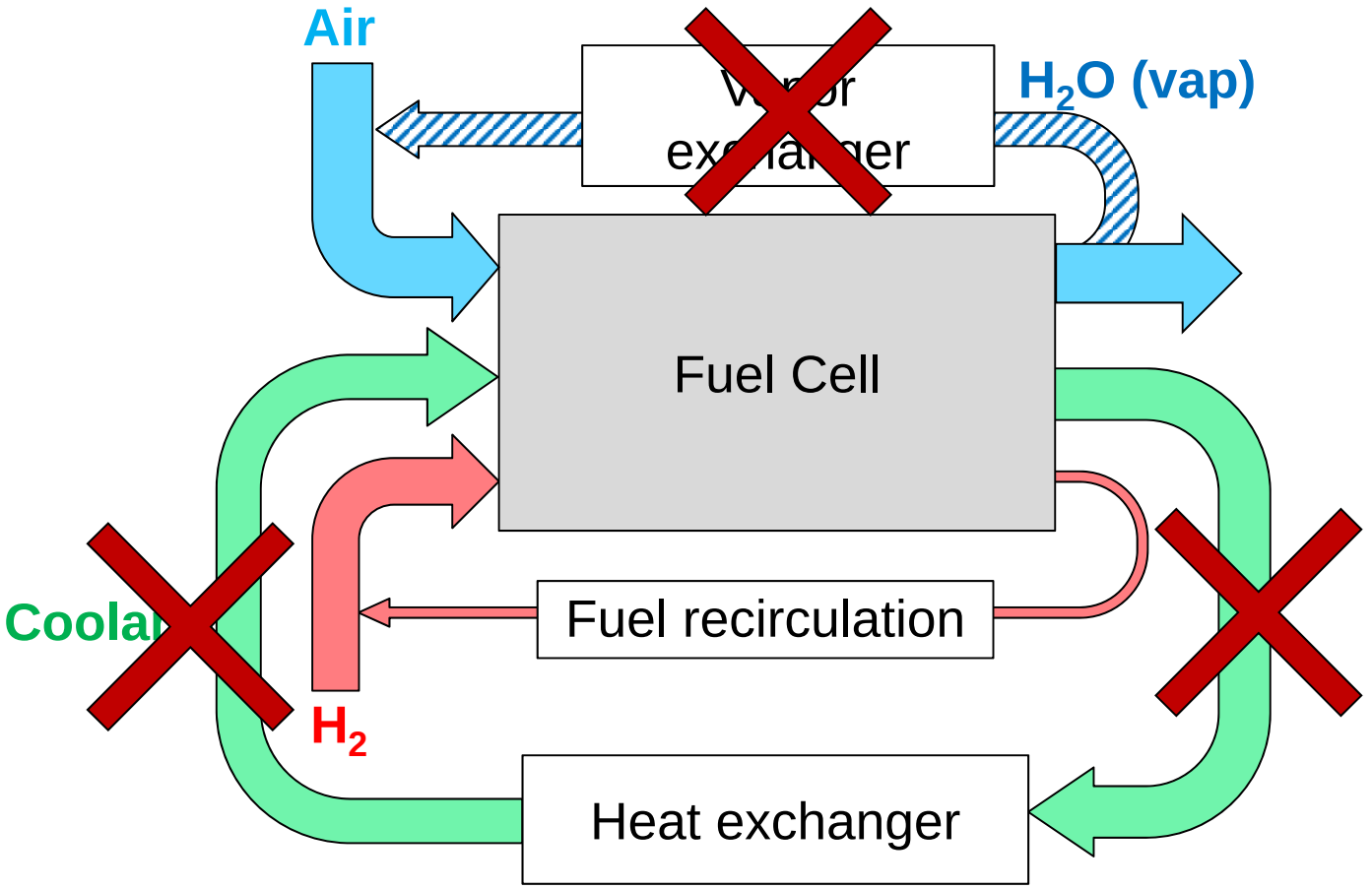
need to fill a cost gap !

from: DoE Hydrogen program:
http://www.hydrogen.energy.gov/pdfs/10004_fuel_cell_cost.pdf

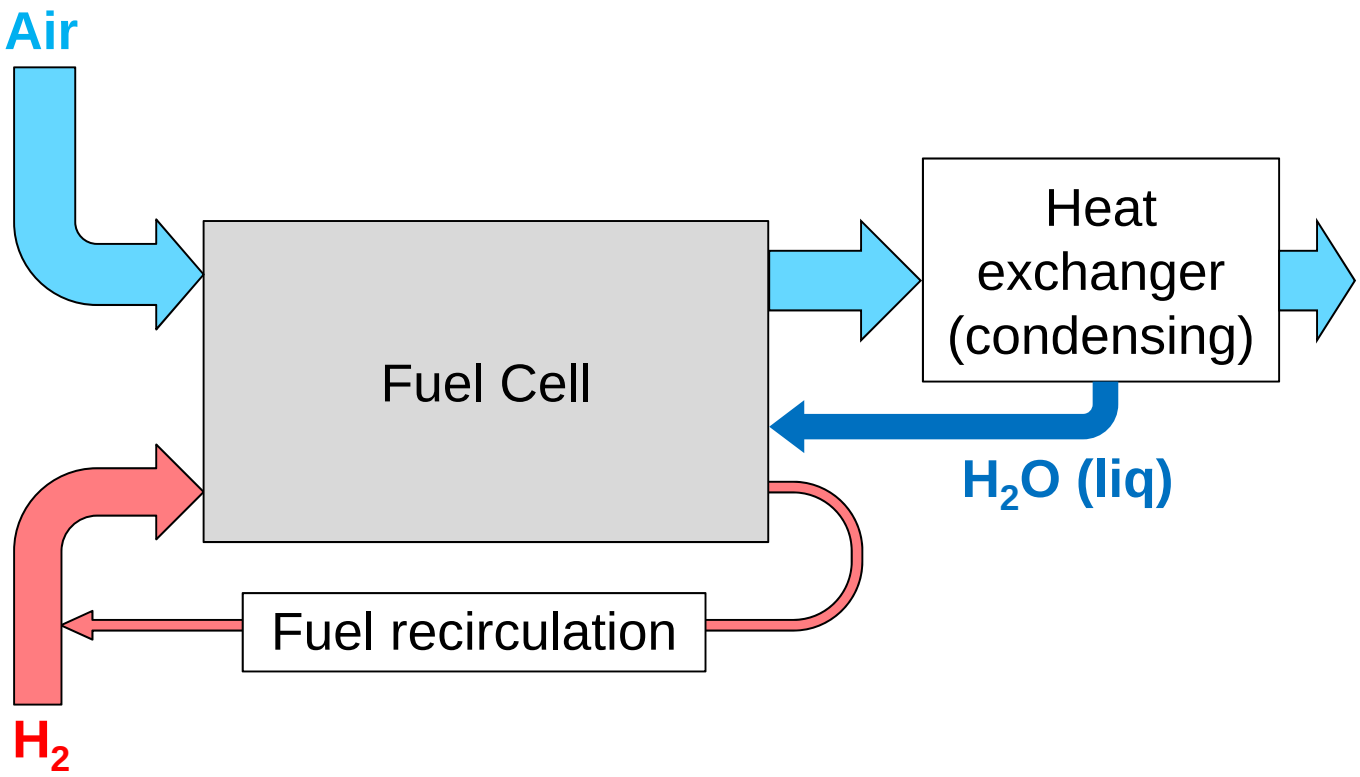
Classical fuel cell system



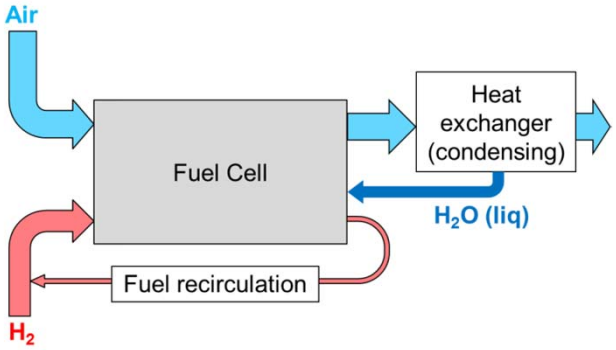
Simplify classic fuel cell system



Fuel cell system with evaporation cooling



Fuel cell system with evaporation cooling



- The concept of fuel cell evaporation cooling is already known from scientific literature / patents
- PSI is developing a new strategy of water injection / management which is
  1) More compact and
  2) More economical

  than existing solutions
- Details of the method are coming soon … (patents being filed)

Work on fuel cells in the SCCER Mobility (CA A2)

- developed new porous materials at **PSI-LEC** for water evaporation in stack

- improve the understanding of water and heat management on the microstructure level and on the cell level

Collaboration
PSI-LEC (X-ray imaging) and
PSI-CRL (LBM simulation)

Collaboration
PSI-LEC (Neutron imaging) and
ZHAW-ICP (Cell level simulation)

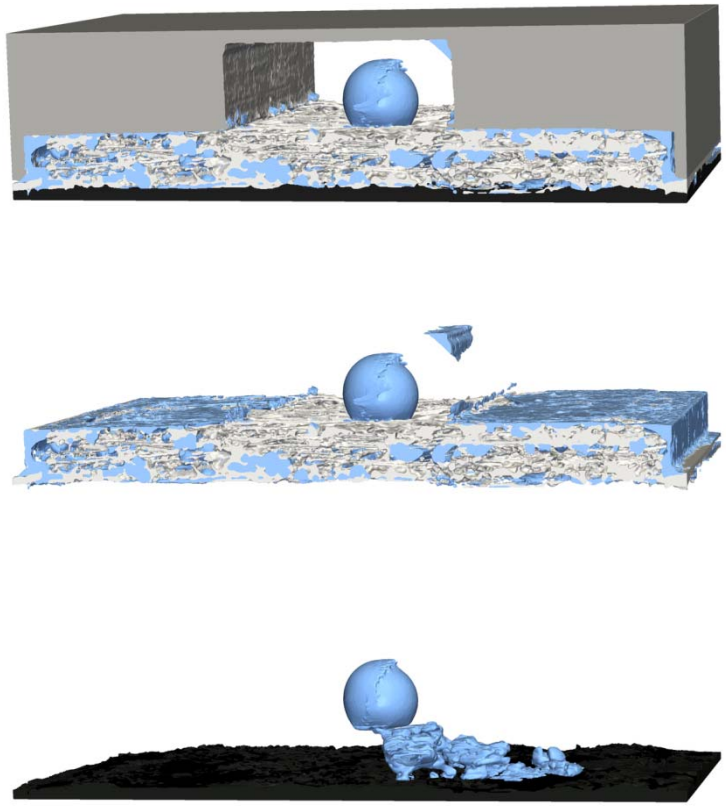
PSI Electrochemistry Laboratory: Fuel Cell Systems and Diagnostics group

Targets

- Determine liquid water phase in porous fuel cell structures under evaporating conditions.
- Develop concepts for controlling the saturation levels in the GDLs

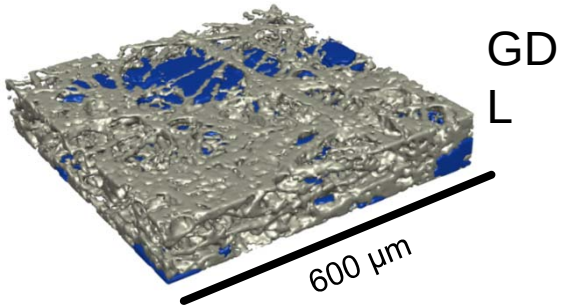
Approach

- Develop X-ray tomographic imaging methodology to measure *in-operando* and with defined boundary conditions.



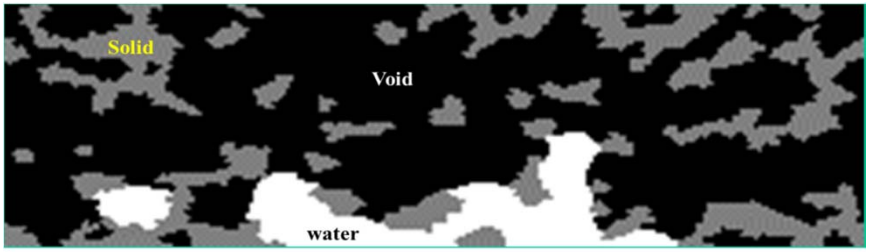
Example: XTM image of water saturation under normal FC conditions.

PSI Combustion Research Laboratory: Combustion Fundamentals Group



Targets

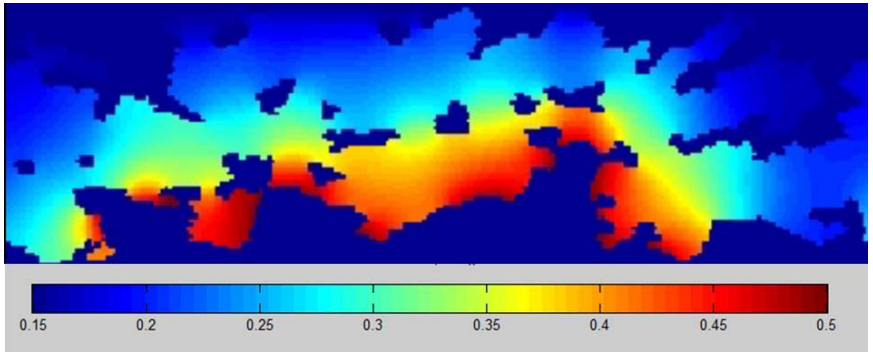
- Assess the evaporation cooling power.
- Develop concepts for controlling the saturation levels in the GDLs



Simulation domain – evaporation- heat transfer

Approach

- The Lattice Boltzmann simulation framework is used for the microscopic modeling of all underlying processes.

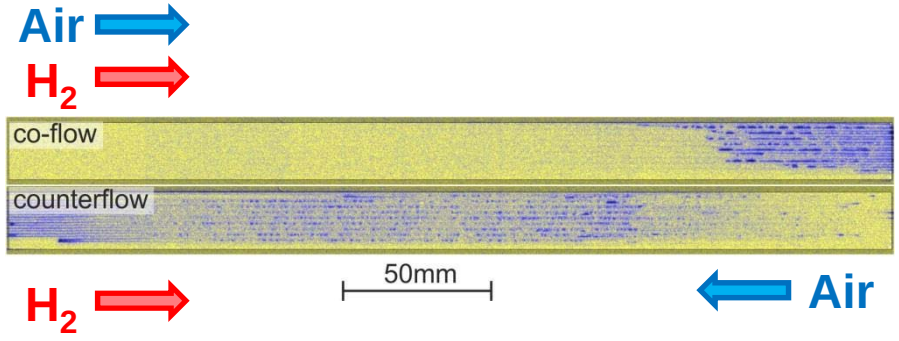


Example: Water Vapor mass fraction.

PSI Electrochemistry Laboratory: Neutron Radiography Project

Targets

- Determine *in operando* liquid water distribution on the cell level.
- Demonstrate experimentally the new evaporation cooling approach.



Example: Measurement of water distribution in different gas flow configurations

Approach

- Synthesize new materials for advanced water management.
- Design new thermal management test rigs.
- Compare imaging and modeling to understand water/heat management

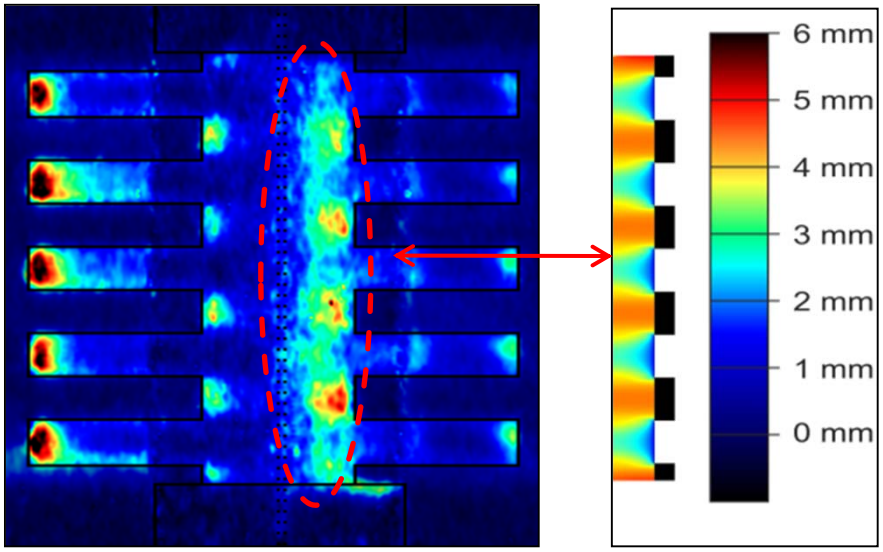
ZHAW Institute of Computational Physics:

Targets

- Refine the modeling of water / heat management on the cell level
- Use modeling to support the new design

Approach

- A macro-homogeneous approach is used to model water, heat and gas species transport on the cell level.



Neutron imaging (PSI)

Macro-homogeneous simulation (ZHAW)

Example: Comparison of experimental (left) and simulated (right) water distribution in a gas diffusion layer (collaboration with PSI electrochemistry lab).

Posters Topic A2.1 Fuel Cell Systems

- ”Microscopic modeling of evaporative heat and mass transfer in the diffusion layer of PEFCs”
  N. I. Prasianakis*, R. Sui*, I. Mantzaras*, F. N. Büchi#.
  * - Combustion Research Laboratory – CRL, Paul Scherrer Institut – PSI
  # - Electrochemistry Laboratory – LEC, Paul Scherrer Institut – PSI

- “XTM Imaging of GDLs During Pressure Driven Water Imbibition and Drainage”
  A. Lamibrac*, J. Roth*, M. Toulec*, F. Marone#, F.N. Büchi*
  * - Electrochemistry Laboratory – LEC, Paul Scherrer Institut – PSI
  # - Swiss Light Source – SLS, Paul Scherrer Institut – PSI

- "Computer simulation of liquid water saturation in porous media of fuel cells".
  J. Dujc*, L. Capone*, J.O. Schumacher*, J. Biesdorf#, P. Boillat#
  * - Institute of Computational Physics – ICP, Zurich University of Applied Sciences – ZHAW, 8401 Winterthur, Switzerland
  # - Electrochemistry Laboratory – LEC, Paul Scherrer Institut – PSI

- “Towards gas diffusion layers with patterned wettability”
  A. Forner Cuenca*, L. Gubler*, T.J. Schmidt*, P. Boillat*
  * - Electrochemistry Laboratory – LEC, Paul Scherrer Institut – PSI

Internal Combustion Engines (A2.2)

1st Annual SCCER Mobility Conference
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Internal Combustion Engines

Several new IC powertrain concepts

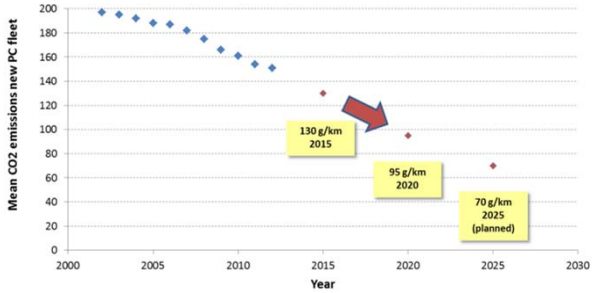
Conventional powertrains (e.g. HD)

Gaseous fuels

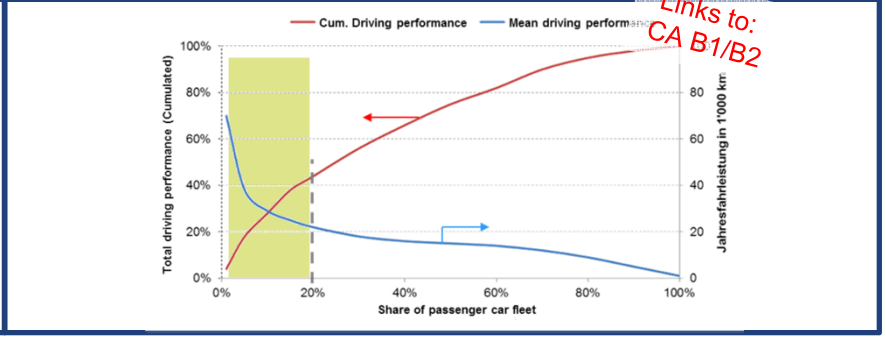
(Plug in) Hybrid electric powertrains

Range Extender in Electric Vehicle

Main driver



CO_2 regulations for new fleets



Long distance driver / utility vehicles

In cooperation with the CTI
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Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Commission for Technology and Innovation CTI

Chemical Energy Carriers for Combustion in Transportation

Experimental Methods

New Synthetic Fuels

- Fuel auto-ignition characterization
- Analysis of oxygenated fuels' combustion phasing

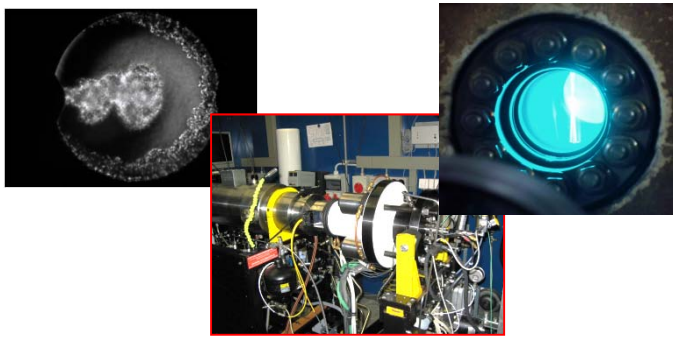
New Combustion Modes

- Homogeneous charge compression ignition (HCCI)
- Dual-fuel or Reactivity controlled compression ignition (RCCI)
- Advanced multi-injection strategies

Highly-Efficient and Zero-Emission Combustion in Transportation

Advanced Experimental Methods

Optical diagnostics at real engine conditions



Highly instrumented test engines

In cooperation with the CTI
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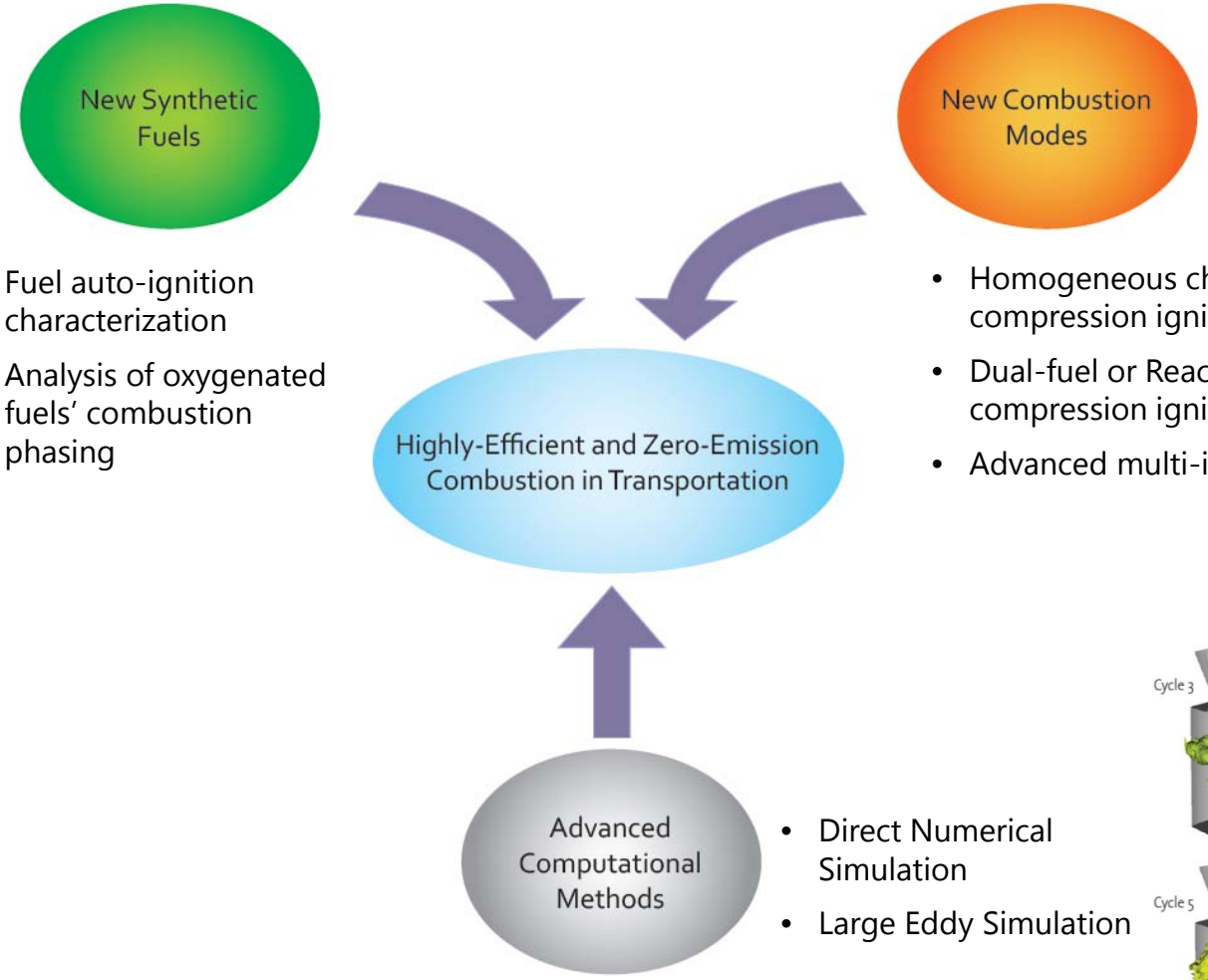
Chemical Energy Carriers for Combustion in Transportation

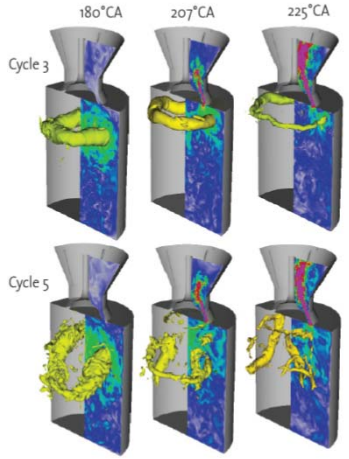
Computational Methods



- Fuel auto-ignition characterization
- Analysis of oxygenated fuels' combustion phasing

- Homogeneous charge compression ignition (HCCI)
- Dual-fuel or Reactivity controlled compression ignition (RCCI)
- Advanced multi-injection strategies

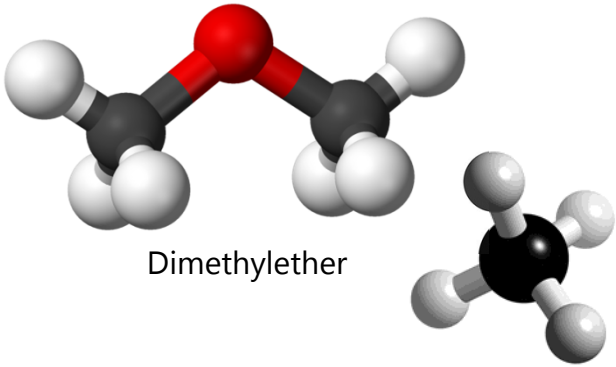
- Direct Numerical Simulation
- Large Eddy Simulation



Project "next**ICE**"

Background

- Actual engines don't use the full potential of gas/DME fuels

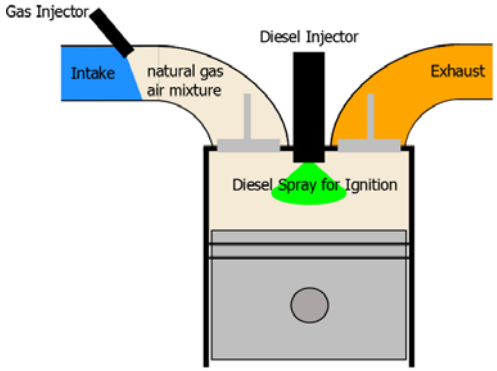


Dimethylether

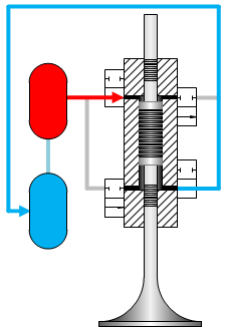
Methane

Targets

- Realization of an efficient DME combustion process (ETH-LAV)
- Thermal Management & unburned HC avoidance for PI-CNG engine (ETH-IDSC)
- Efficient, fully variable gas-exchange valve actuation (Empa-ICEL)



Combustion control for lean PI-CNG operation



Fully variable gas exchange valve with recuperation

Project "Spark-induced breakdown spectroscopy"

Targets

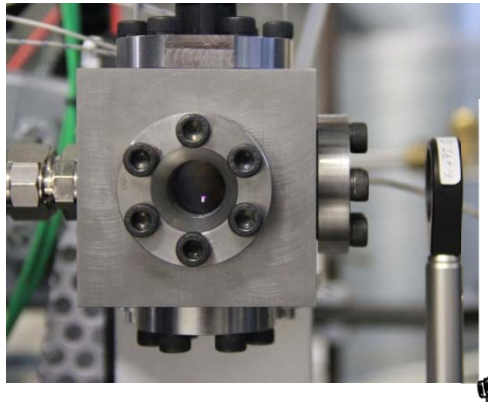
- Understanding the process from ignition to flame kernel formation in compressed natural gas engines

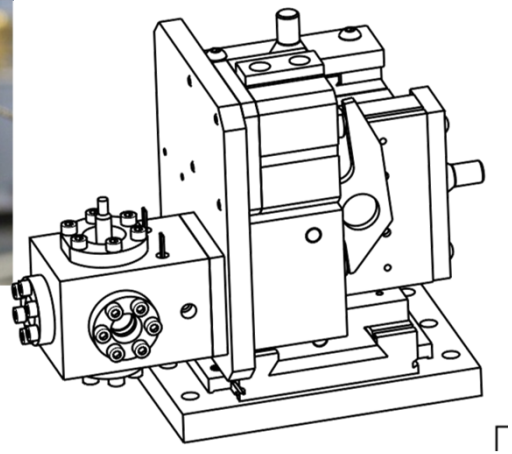
Experimental Investigations

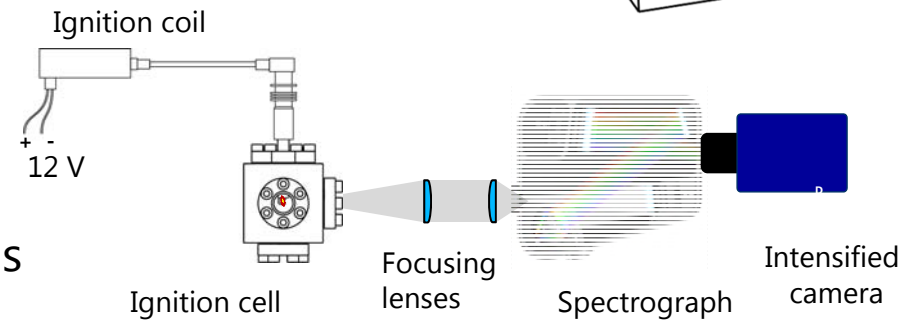
- Constant volume combustion chamber at Empa
- Rapid compression expansion machine at ETH

Transfer to real engines

- Minimal invasive in-cylinder diagnostics on a real IC engine with a fiber spark plug as an optical access







Project "Future Mobility Demonstrator"

Targets

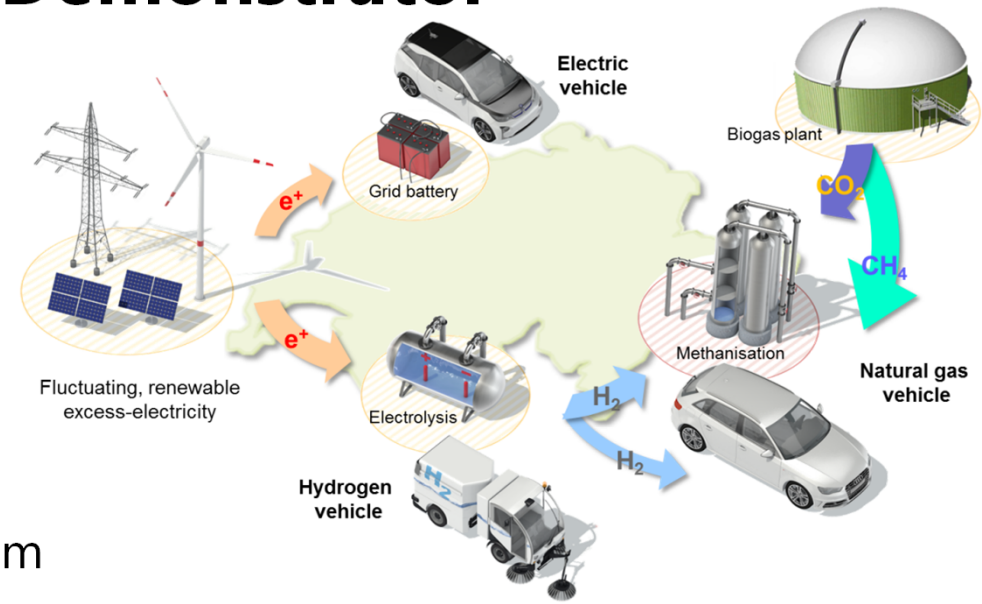
- Utilization of fluctuating renewable excess electricity for Mobility

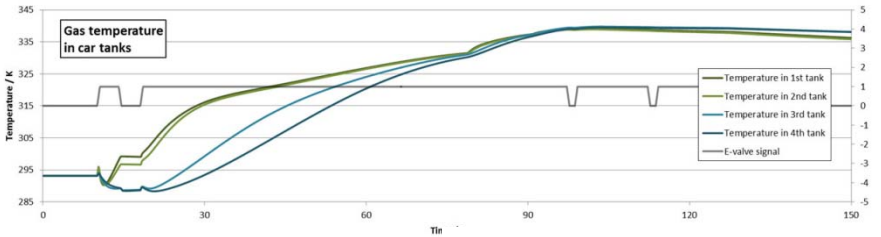
Hydrogen enriched Natural Gas

- Realization of a H_2- CNG blending station at Empa
- Field testing with delivery-vehicles from Mobility Solutions AG

Simulation of fueling process

- Minimal invasive in-cylinder diagnostics on a real IC engine with a fiber spark plug as an optical access





Posters Topic A2.2 Internal Combustion Engines

- ”New fuels and new combustion modes: A path to zero emissions/high efficiency mobility systems”
  D. Mitakos*, S. Schlatter*, B. Schneider*, Y. M. Wright*, C. Brückner*, P. Kyrtatos*, K. Boulouchos*.
  * - Laboratory for Aerothermochemistry and Combustions Systems, ETH

- ”Natural Gas-Diesel Engine with diesel pilot injection; high efficient without lean NOx” aftertreatment
  R. Hutter*, T. Ott*, F. Zurbriggen*, C. Onder*, L. Guzzella*.
  * - Institute for Dynamic Systems and Control

- ”Spark-Induced Emission Spectroscopy”
  T. Kammermann*, W. Kreutner*, P. Soltic*, C. Bach*.
  * - Internal Combustion Engines Laboratory, Empa

- ”Future Mobility Demonstrator”
  U. Cabalzar*, B. Buchmann#, M. Brügger*, C. Bach*.
  * - Internal Combustion Engines Laboratory, Empa
  # - Department for Mobility, Energy and Environment, Empa