Eidgenössische Technische Hochschule Zürich
Ecole polytechnique fédérale de Zurich
Politecnico federale di Zurigo

IEA Networking event 25th Sept. 2015, Forum Fribourg

IA combustion – Gas engine collaborative task

Yuri M. Wright and Konstantinos Boulouchos

mailto:wright@lav.mavt.ethz.ch

ETH Zürich, Aerothermochemistry and Combustion Systems Laboratory, Switzerland

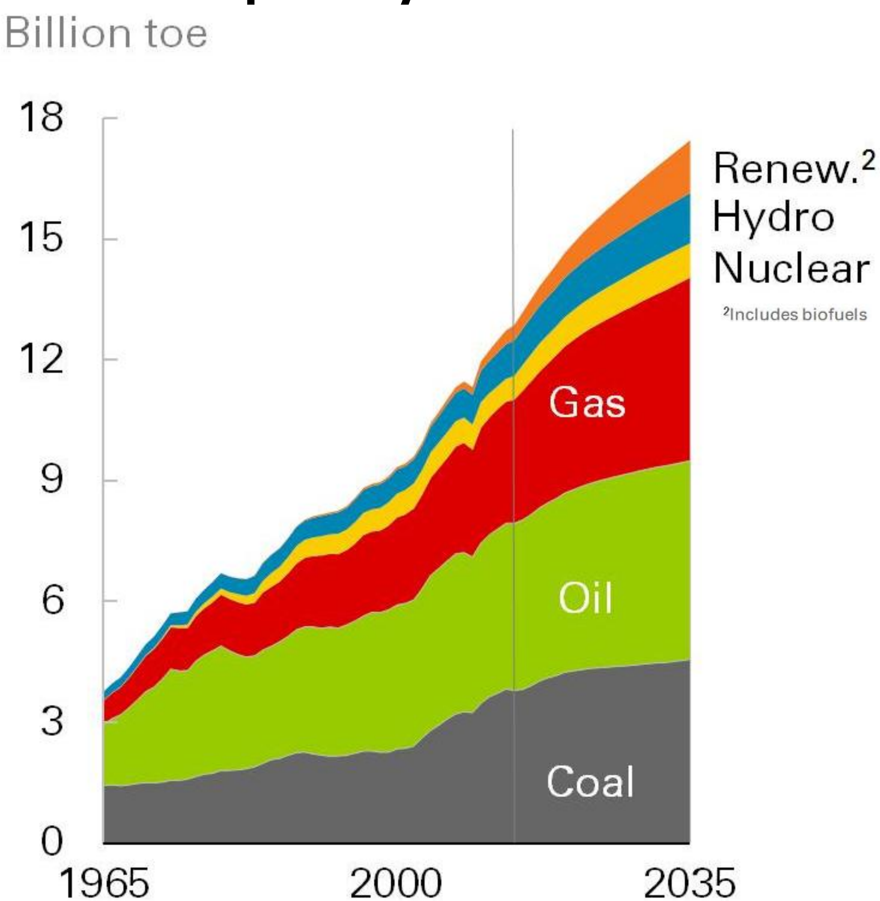
Outline

- **Natural gas**
- **Gas Engines (Internal Combustion Engines - ICE)**
  - Motivation
- **Specific challenges and research areas**
- **Collaborations within task and interfaces to other IAs**
- **Outlook**

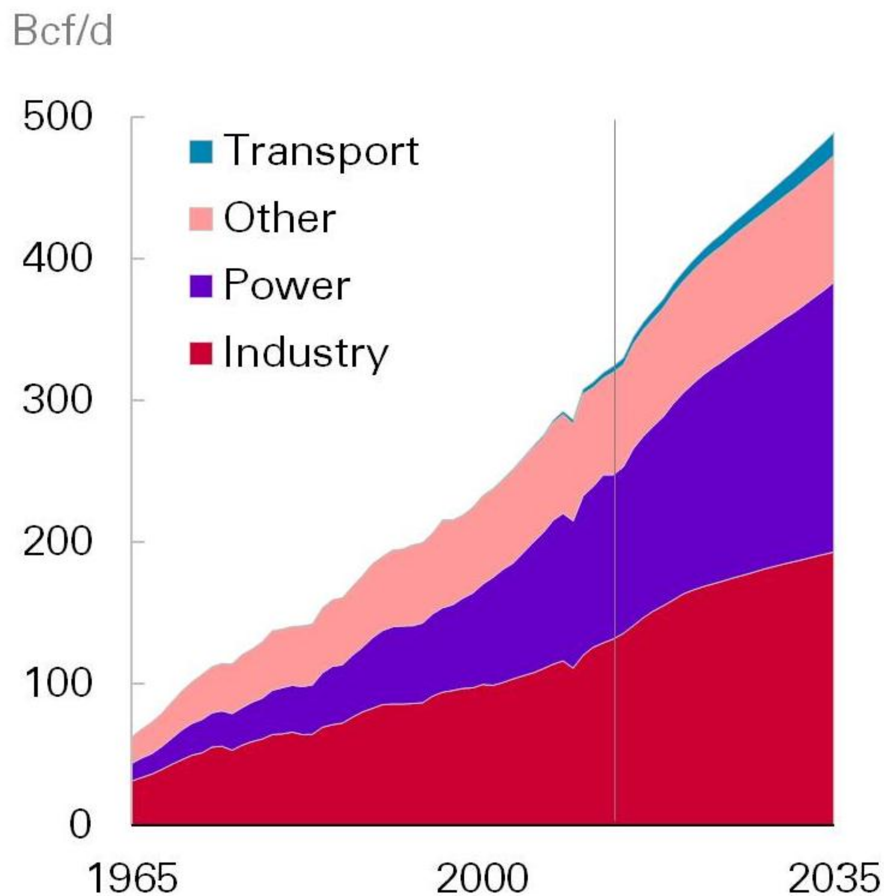
Natural gas – it's projected role in the future energy mix

© BP energy outlook 2035

Consumption by final sector



Natural gas: demand by sector



Switzerland – CHP potential with GAS

- **END user energy:**
  - Total 245 TWh, of which 30 TWh GAS (~12.5%)
  - Almost exclusively used for *heating*
- **Use same GAS amount for CHP instead?**
  - Assume η_{el} > 40% and η_{th} > 50 % (and a COP 4)
  - 12 TWh electricity and 15 TWh of heat (high temperature)
  - For remaining required 15 TWh heat, 3.75 TWh needed for heat pumps

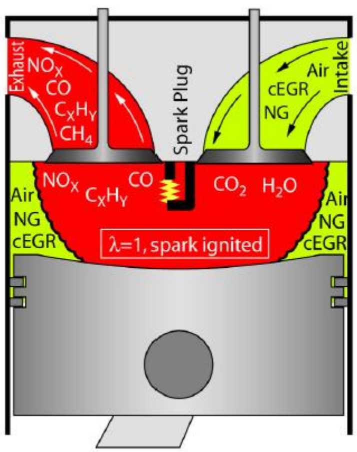
'left over' 8.25 TWh corresponds to 1/3rd Swiss nuklear power

- **Biomass for GAS**
  - Estimated resources are 23 TWh (R. Zah, EMPA)
  - Assume η_{CH4} > 65% -> 15 TWh of thermal input for biogas CHP plants
  - Potential for 6 TWh of CO_2 free electricity *on demand,* 9 TWh thermal

Types of gas engines

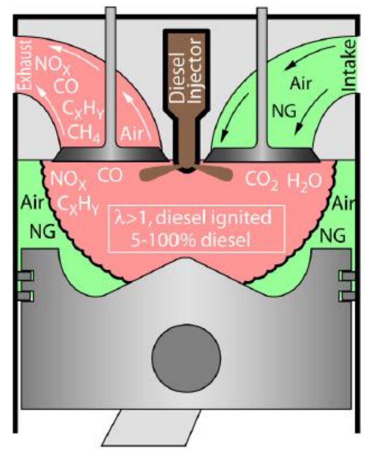
Single fuel (natural gas) | Dual fuel (natural gas + Diesel)

Spark/Prechamber Ignition



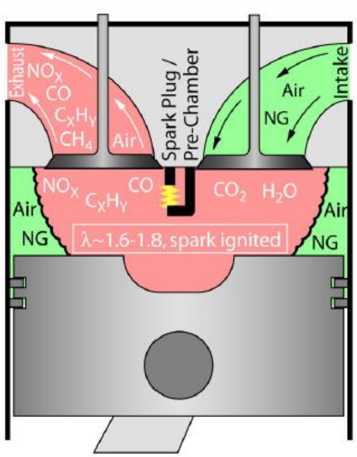
Stoichiometric Spark Ignition

- Premixed intake, NG+air+cEGR
- 3-way catalyst
- ~36% efficiency
- 100% NG
- Cummins, Scania, Waukesha, IVECO



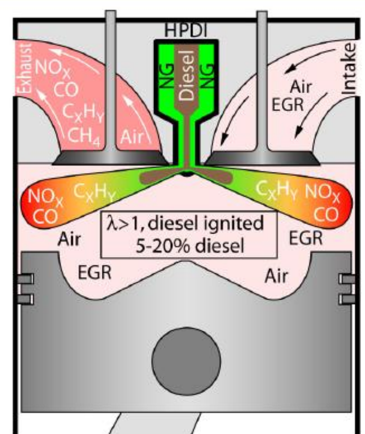
Lean Premixed Diesel Pilot

- Premixed intake, NG+air+cEGR
- Oxy-catalyst
- ~45% efficiency
- 0-95% NG
- Volvo (Hardstaff, G-Volution retro.)



Lean Premixed Spark Ignition

- Premixed intake, NG+air+EGR
- Oxy-catalyst
- ~44% efficiency
- 100% NG
- Cummins, MAN, Doosan, GE



Direct Injection Diesel Pilot

- intake: air + EGR
- Catalyzed DPF, Urea SCR
- ~46% efficiency
- ~90% NG
- Westport, Volvo

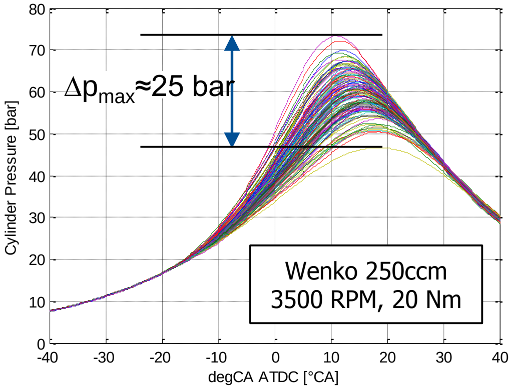
Diesel-Pilot Ignition

Source: Musculus et al., Sandia National Labs., IEA 37th Task Leader Meeting, St.Andrews, UK.

Challenges and research areas

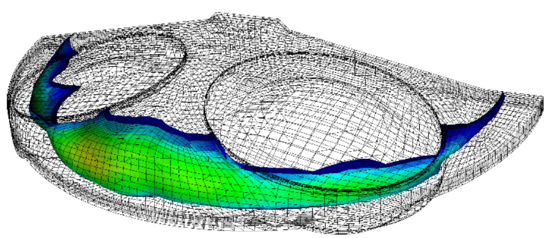
- **High cycle-to-cycle variability**
  - Misfire -> UHC emissions
  - Limit engine efficiency

Combustion 'initiation'

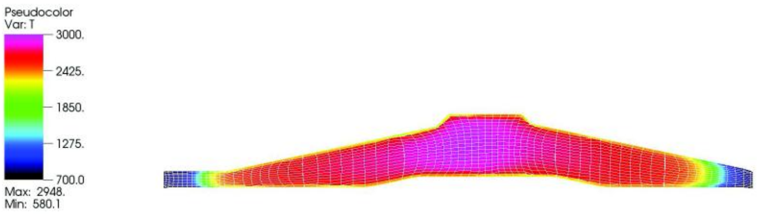


Measurement K. Steurs et al.

- **Engine knock**
  - Auto-ignition in the end gas ahead of flame

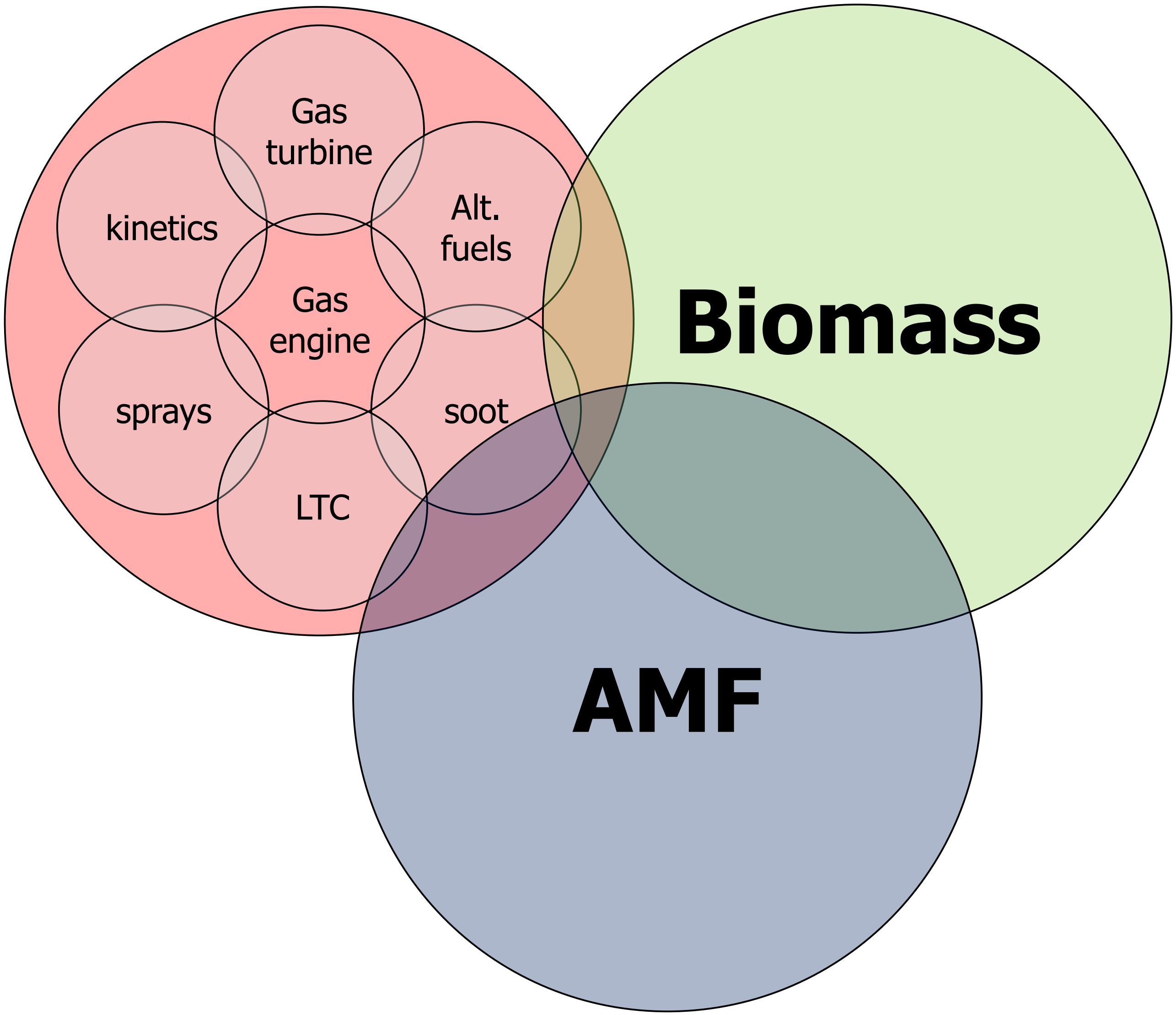


- **Flame-wall interactions**
  - Heat transfer
  - Flame quenching



Combustion 'termination'

Interfaces to other tasks and IAs



Collaborators within Gas Engine Task

- **Aalto University, Finland:**
  - Experimental diagnostics of hollow-cone gas jets
  - Wall heat transfer modelling: PhD exchange
- **Birmingham University, UK**
- **Chiba University, Japan**
- **KAIST, Korea**
- **Glasgow Caledonian University**
- **Instituto Motori, Italy**
- **Orléans, France**
- **Lund University, Sweden**
- **Sandia National Laboratories, USA**
- **University of British Columbia, Canada**

Outlook

- **Ongoing Gas Engine Collaborative Task seminar series**
  - Established in 2014
  - talks so far from Aalto, Lund, Hannover and Kyushu Universities
  - welcome presentations from IEA member countries world-wide
- **Deepen existing collaborations and foster new establishment**
- **Workshop on Gas engines 2016**

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

LAV

2016 workshop on "Gas engine combustion fundamentals"

- **Focus on «combustion fundamentals»**
  - Dual fuel combustion
    - Pilot ignition in premixed base charges
    - Under-expanded jets/real gas effects for HPDI setups
  - Early flame kernel growth
  - Flame-wall interactions
  - Wall heat losses
  - Straining of flame torches (pre-chambers)
  - Fuel effects: kinetics, flame speeds
  - …
- **Venue: ETH Zurich**
  - June 13, 2016 (after CIMAC congress in Helsinki June 6-10)
- **in collaboration with ERCOFTAC SIG 28 (combustion)**

Acknowledgements

- **Swiss Federal Office of Energy**
  - Gas engine related projects
  - Dual fuel combustion research
  - Operating Agent support
- **CCEM**
  - «RENERG2»
  - «ScheDual»
- **FOGA**
- **KTI**
- **Liebherr Machines Bulle**
- **EU H2020 «GasON»**

Eidgenössische Technische Hochschule Zürich
Ecole polytechnique fédérale de Zurich
Politecnico federale di Zurigo

Funding from Swiss Federal Office of Energy is gratefully acknowledged

Thank you.

Yuri M. Wright and Konstantinos Boulouchos

mailto:wright@lav.mavt.ethz.ch

ETH Zürich, Aerothermochemistry and Combustion Systems Laboratory, Switzerland