TECHNOLOGY COLLABORATION PROGRAMMES (TCPs)

EUWP ANNUAL BRIEFING TEMPLATE

TCP NAME	Report Date
Clean and Efficient Combustion (Combustion TCP)	2/19/2018

Main Technology Policy Messages/Recommendations

extracted from the Combustion TCP's recent research findings

Worldwide, more than 80% of the energy used is converted by combustion to usable forms in the areas of transportation, power generation, and industrial, commercial, and residential heat.

- Vehicles powered by internal combustion engines will be the dominant part of the light-duty vehicle fleet for many decades.
  - Low temperature combustion processes can improve light-duty vehicle fuel economy by 20-25% while maintaining ultra-low emissions.
  - Adapting combustion technologies to make optimal use of alternative, renewable fuels will be an important factor in the transition to a low-carbon future.
  - Dual fuel engine technologies can provide diesel-like efficiencies while reducing particulate emissions and enabling efficient use of renewable oxygenated fuels.
- Despite increased renewable sources, gas turbine engines will remain a critical component of the electric grid infrastructure through the latter half of the century.
  - Current gas turbines can tolerate up to 20% hydrogen without compromising performance, thus providing a path for early adoption of hydrogen and reduced greenhouse gas emissions in the power sector.
- Natural gas engines will play an increasing role in both stationary power applications as well as transportation.
  - Fuels with a low fuel carbon to hydrogen ratio promise up to 25% CO_2 reduction.
  - The use of bio-methane from sustainable sources provides additional greenhouse gas savings.
  - Improved ignition systems enable both efficiency increases and reduction of pollutant emissions.
- Solid fuel combustion technologies allow local use of biomass, reducing waste and providing access to low CO_2 energy to specialized industries as well as isolated communities.
  - Selection of optimal pathways for biomass conversion requires knowledge of the combustion kinetics as well as the gasification or liquefaction characteristics of various feedstocks, coupled with feedstock specific combustor design.
- Fundamental chemistry, fuel spray, and particulate formation investigations provide the basis to incorporate realistic chemical and physical processes into computer-optimized design of multiple combustion technologies. Progress in all of these areas is critical to achievement of the lowest possible CO and pollutant emissions.

Achievements

Outward facing

- A panel session on low-temperature combustion was organized and held at the Society of Automotive Engineers World Congress and Exposition meeting (WCX17) in April 2017.
- The Spray Task organized a workshop in conjunction with (WCX17).
- A policy analysis session was integrated into the 2017 Task Leaders Meeting (TLM) with presentations by IEA Desk Officer P. Cazzola, U.S. Department of Energy Analyst J. Ward, and industry guests.
- Numerous technical, task-level achievements are detailed in the table «Ongoing Annexes».

Internal

- A TCP strategy meeting was held April 2017 in Greifswald/Berlin to review RfE feedback in depth, and provide background to the ExCo.
- The TLM was redesigned to enable TCP wide discussions on enhanced collaborations and a stronger focus of technical task efforts on IEA relevant objectives.
- The TCP leadership was restructured to provide greater continuity and efficacy.

Outlook to the Future

- A 2nd workshop on Gas Engines is being planned to be held in Zurich in June 2018.
- A workshop is being planned to examine unique requirements imposed on vehicle combustion systems by hybridization (date and location TBD).
- We plan to participate in the September 2018 electro-fuels workshop to represent end-use issues.
- We will seek to increase industry participation in upcoming TLMs to broaden our impact.

Dissemination and publications

- Extensive publications in peer reviewed scientific journals and presentations at technical conferences
- The 39th TLM was held in Spain with 42 technical presentations and discussion among tasks leaders, scientists and industry representatives.
- The TCP webpage redesign and renewal has commenced and will be completed by mid-2018.

Collaboration and Co-operation

- The TCP participated in the March 2017 "Gaps and Barriers for Energy Technology Development and Deployment" Workshop organized by the EUWP, the September 2017 meeting of the IEA Transport Coordination Group, and the October 2017 IEA TCP Universal Meeting.
- The document "The Future of Trucks-Implications for energy and the environment" published by IEA in 2017 incorporates the input of companies that, with our mediation, attended the workshop organized by IEA for this purpose.
- We are reaching out to the IEA TCPs on Hydrogen, Bioenergy and Advanced Motor Fuels to investigate potential for collaboration, with the possibility of joint ExCo events and coordinated activities at task/annex level.

Membership

- Belgium and Italy withdrew in 2017.
- Efforts underway to broaden participation of current member countries
- Initiatives to include new members on hold, pending the outcome of the upcoming request for extension

Management

- Significant efforts in TCP renewal, addressing:
  - strategic focus,
  - organization and governance,
  - outreach and communication;

  to be presented in the next Request for Extension, September 2018

MEETINGS OR WORKSHOPS

2017 ExCo meetings			**2018 ExCo meetings**	
Place	*Date*		*Place*	*Date*
Greifswald, Germany (Strategy Meeting)	4/23/17		Orléans, France (Strategy Workshop, with task leaders)	2/12-14/18
Berlin, Germany	4/25/17		Paris, France	4/23-24/18
Baiona, Spain	6/22/17		Fréjus, France	6/14-15/18
virtual meeting	11/8/17			

Future annex or task meetings

Annex/Task	**Place**	**Date**
Annual Combustion TCP Task Leaders Meeting TLM	Fréjus France	6/11-14/18
Gas Engine Task Workshop	Zurich, Switzerland	6/18/18
Combustion & Hybridization Workshop	TBD	TBD

CLOSED ANNEXES

Name	Objectives / key deliverables	Launch/end dates	Participants	Key learnings
Alternative fuels		The official termination of this Annex needs to be approved at the ExCo meeting		This Annex has been dormant during the last 2 years. Though the activity on Alternative Fuels continues, the TCP leadership has decided that this cross-cutting topic is better covered in a transverse way by integrating it into the work of the other active Annexes.

ONGOING ANNEXES (“TASKS“)

Our “Tasks” consist of applied, technology development efforts as well as supporting fundamental research. In both cases, the Tasks provide a stable framework of broader research areas, which serves to organize more specific sub-tasks with a shorter life-cycle (3–5 years).

Name	Objectives / key deliverables	Launch /end dates	Participants	Key learnings/achievements so far
Sprays in combustion	Objective: A capability for computational design of the fuel and air mixture by developing a foundational scientific understanding of spray formation and mixing Key deliverables: • High precision measurements of injector nozzle geometry to be distributed worldwide • High quality Measurements of Tip Wetting • Understanding of the influence of Sprays on Diesel Dual-Fuel Combustion • Improved modeling approaches for RANS simulations of heat transfer and wall impingement	2012-2019	Germany Spain US Japan France Switzerland Finland	• Completed a Study Assessing the Influence of Spray Phenomena on Soot Formation • Achieved Experimentally-Validated Simulations of Ignition in Diesel Engines • Completed a Study of the Influence of Spray Evolution on Combustion in Large-Bore Marine Engines • Completed Flow Measurements in a Transparent Gasoline Injector • Developed the capability for micron-scale measurements of internal nozzle geometry

Name	Objectives / key deliverables	Launch /end dates	Participants	Key learnings/achievements so far
Low Temperature Combustion (LTC)	Objective: Understanding of the in-cylinder processes governing efficiency and emissions formation; assessment of the potential of LTC concepts for reducing fuel consumption in vehicle applications Key deliverables: • Assessment of the drive-cycle fuel consumption of LTC and advanced SI combustion systems • Evaluation of fuel effects on LTC operation and appraisal of the effectiveness of std. fuel quality metrics (RON, MON) • Evaluation and further development of LTC combustion phasing control methodologies • Further development of LTC by examining different exhaust gas recirculation (EGR) concepts and multiple injection strategies • Clarification of the connection between local fuel-to-air ratio and ignition	2015-2019	France Sweden USA Japan Korea	• Demonstration of LTC concepts with novel EGR modes for superior engine efficiency • Demonstration of an LTC operable load range exceeding current commercial technology with best in class efficiency • Confirmation that for conventional spark ignition combustion, standard fuel quality metrics are able to predict fuel performance over wide ranges of alternative fuel composition

Combustion in Gas Turbines	Objective:
	Develop combustion technologies for high efficiency, ultra-low emission gas turbine engines.
	Key deliverables:
	• Data supporting the adoption of low carbon fuels, including operational limits (flashback, blow-out, max. load gradients) and remedial measures/design modifications
	  o CH4/H2 (Methane/Hydrogen) fuel mixtures
	  o Various NH3 (Ammonia) fuel mixtures
	• Predictive models for thermos-acoustic phenomena
	• Quantitative species, flow, and temperature measurements supporting design evaluation and model development
		2012-2019	France
			Switzerland
			Japan
			UK
			Sweden
			France
			Norway
				• Performance and emissions evaluation of a range of H_2/CH_4 mixtures; H_2 found to have a limited impact on efficiency/operation for mixtures of up to 20% vol. H2
				• H2 addition is found to allow NOx (nitrous oxides)reduction by extending lean limits of operation or reduce CO (carbon monoxide) emissions at constant stoichiometry

Name	Objectives / key deliverables	Launch /end dates	Participants	Key learnings/achievements so far
Gas Engines	Objective: Deepened fundamental understanding of ignition and combustion in gaseous fuel engines to enable next-generation high-efficiency, lowest-emission concepts for transportation and power (co-)generation. Key deliverables: • Data-base of LPG (liquefied petroleum gas)/Diesel operation at standardized conditions • Identification of ignition regimes and development computational models for these regimes • Assessment of the potential of various fuels to optimize gas engine efficiency and emissions • Assessment and improvement of chemical kinetic, flame–wall interaction, heat transfer and CH_4/NH_3 slip models • Identification of factors leading to autoignition	2013-2019	Finland France Japan Korea Switzerland USA	• Advanced wall heat transfer model developed; collaborative effort with ETH to assess predictive capabilities in progress • Dual-fuel database data acquired; advanced laser-based optical diagnostics specific for dual-fuel micro pilots developed • New optical pre-chamber test rig developed; characterization of production grade pre-chamber spark plug in optically accessible rapid compression expansion machine • Single-cylinder pre-chamber gas engine commissioned • Numerical simulation approach developed for combustion in IC gas engines with unscavenged pre-chambers

Combustion Chemistry	Objective:
	Predictive chemical kinetic models for renewable fuels and their blends with petroleum fuels to support computational optimization of combustion devices
	
	Key deliverables:
	• Quantitative data on species concentrations, flame speeds, and ignition delay to support the development of chemical kinetic mechanisms
	• Identification of important oxidation pathways needed for model development
	• Validated kinetic models
		2012-2019	France
			Sweden
			Switzerland
			USA
				• Chemical kinetic model for diisobutylene, a high-octane component, developed and validated based on
				  o Species concentrations measured in a jet-stirred reactor
				  o Flame speeds measured over a range of equiv. ratio
				• Developed techniques to measure rate constants of single isomer reactions selectively
				• Identified previously unknown decomposition pathways for biofuels
				• Kinetic mechanism for anisole, a high-octane fuel component that represents fuels from pyrolysis products of biomass

Name	Objectives / key deliverables	Launch /end dates	Participants	Key learnings/achievements so far
Soot	Objective: • Foundational scientific understanding and experimental data characterizing soot formation and oxidation processes to enable prediction of soot mass, particle number, and particle structure for a variety of fuels • Understanding of how soot toxicity and environmental impact changes with fuel and combustion concepts Key deliverables: • Detailed predictive models describing formation of gas-phase species leading to soot formation, the soot nucleation process, and soot particle oxidation • Reduced complexity engineering models with sufficient accuracy for design optimization • Characterization and understanding of the effects of engine operating parameters on formation, oxidation, and emissions	2016-2019	US Sweden France	• Developed means to image 3D structures with atomic resolution (relevant to soot inception) • Identified pressure-invariant soot onset temperature at engine relevant pressures • Developed high-speed optical diagnostic for quantifying soot formation and oxidation in transient combusting sprays • Established effects of internal nozzle geometry on soot formation characteristics in diesel injectors • Summarized soot morphological characteristics of soot under conventional diesel and RCCI conditions
Solid Fuel Combustion	Objective: To gain a better understanding on thermochemical conversion of solid fuels to contribute to the development of more flexible, cleaner and efficient CHP (Combined Heat and Power) systems. Key deliverables: • Improved designs of solid-fuel combustors • Advanced models for solid fuel gasifier or combustor pyrolysis and char oxidation that: o Incorporate improved kinetic mechanisms accounting for secondary reactions o Include agricultural residues with high inorganic content • Development of advanced sensors for process monitoring	2016-2019	Germany Spain Japan	• Advanced bed-furnace integration (bed embedded into the CFD as a reacting porous media) • Advanced model for particle dynamics in the combustor bed • Assessment of feeding strategies on combustion performance • Development of particle reactor coupled with spectroscopy based diagnosis technologies to investigate the pyrolysis and char oxidation processes in thermally thick particles

PLANNED ANNEXES

Being defined in the ongoing strategic renewal process