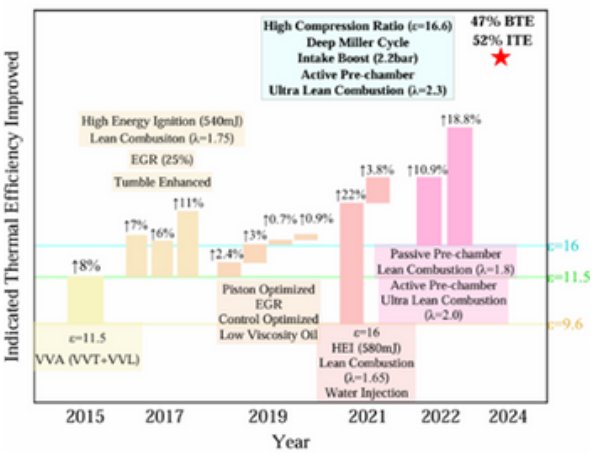
Conference Summary
SAE WCX 2025

Detroit, USA, April 8 - 10, 2025

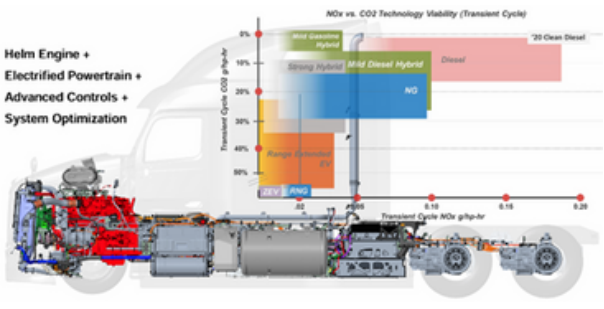
The Future of Internal Combustion Engines

Improving thermal efficiency in ICEs is approaching its physical limits (BTE of diesels > 53% and gasoline à 44%). Prof. Li from **Tongji University** presented a technology pathway for gasoline engines to exceed 50% BTE (see figure) utilizing increased compression ratio, improved air handling, deep Miller Cycle, pre-chamber ignition, ultra-lean combustion (λ > 2) and water injection.

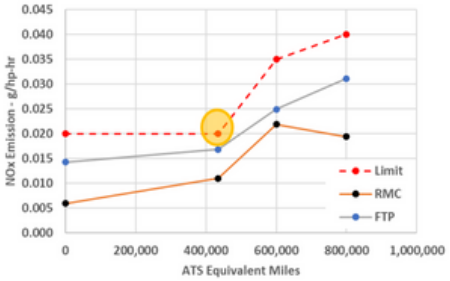


Hybrids are expected to retain a significant market share for the foreseeable future. In China in 2024, NEVs accounted for 40.9% of total sales, but plug-in hybrids (PHEVs) and Range Extender EVs (REEVs) represented 40% of NEV sales, indicating a strong adoption of hybridized powertrains. In their NEV roadmap, China expects hybrids to account for 75% of conventional passenger cars by 2030 and 100% by 2035.

Hybridization can lead to substantial CO_2 emission reductions. Ameya Joshi from **MobilityNotes** highlighted a recent study by **ICCT** showing hybrids delivering on average ~ 43% reduced CO_2 for cars and 29 - 41% for light-duty trucks. Future improvements in hybrid CO_2 emissions will come from dedicated hybrid engines with BTE > 45%, along with other technologies such as advanced lubricants, higher injection pressures, electric boosting, improved air handling, in-cylinder fuel reforming, and waste heat recovery.



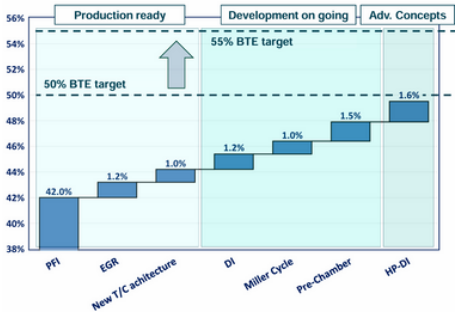
Hybridization is also being applied to heavy-duty trucks and off-road machines. **Cummins** showed the use of mild, strong hybrids and range-extended EVs as options for reducing both CO_2 and NOx.
Efficiency of heavy-duty engines are already exceeding 53% in production and reaching over 55% in advanced concepts. Waste heat recovery promises to contribute to significant efficiency gains, in addition to improved combustion, friction & parasitic losses, air handling, and heat retention.



Vaibhav Kale from **AchatesPower** showed impressive test results for their 10.6L 3-cylinger HD diesel opposed piston two-stroke engine, paired with a conventional after-treatment of DOC, DPF and dual SCR. The system was aged to 800K miles according to the accelerated aging procedure. Tailpipe emissions were found to be lower than the California NOx and CO2 limits for all cycles (FTP, RMC and LLC).

Alternative and Low-Carbon Fuels

Hydrogen and ammonia are promising fuels for achieving zero-carbon emissions in ICEs. China has issued new funds for projects on “ammonia-hydrogen fusion” powertrains for heavy-duty, and there are industry alliances formed on these two fuels. Research is also being done at **Tongji University** on an "Argon Power Cycle H_2-fueled engine", which replaces N_2 with Ar to provide an additional ~ 15% increase in efficiency, resulting in net indicated thermal efficiency of 70%.



Gianmarco Boretto from **Dumarey** presented a technology walk for improving efficiency of heavy-duty (13L) H_2 engines (see figure). These will rely on improvements made in diesels to extend their efficiency to 50% BTE. Diesels have further shown BTE 55% using waste heat recovery.

Pairing advanced powertrains with renewable fuels is a pragmatic pathway for rapid GHG reductions. The key considerations for alternative fuels are infrastructure and TCO. **Cummins** highlighted their readiness to meet diverse customer needs while reducing GHG emissions through their offering of fuel agnostic engine platforms. Renewable natural gas is seen as a mature option for decarbonization, with the potential for available RNG to displace nearly 70% of US on-road diesel fuel. Prof. Dr.-Ing. André Casal Kulzer, **Univ. Stuttgart/FKFS Stuttgart** discussed the role of eFuels as an important technological complement to electrification.

Renewable gasoline presents a powerful pathway for decarbonizing light-duty vehicles. David Vuilleumier described work being done at **Chevron** to advance renewable fuels. Existing refineries can be adapted to make renewable fuels, but there are challenges in terms of optimizing the processing and tracking the fuels for credits. The figure here shows that moving to a combination of hybrid powertrain and low carbon intensity fuel can lower carbon emissions by 74% on a well-to-wheel basis.

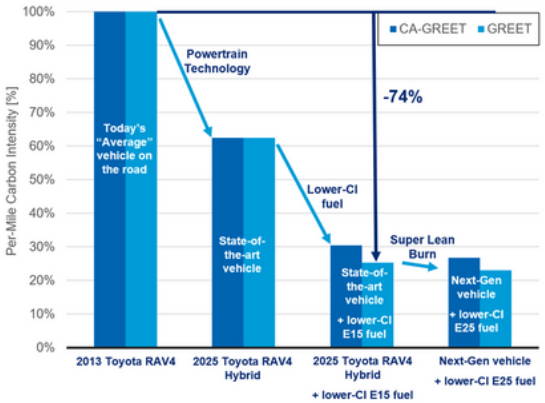


Figure adapted from the ANL study

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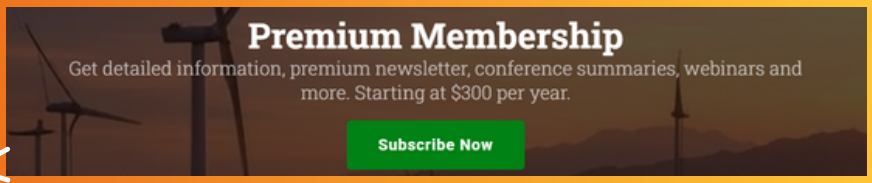

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