Conference Summary

SAE Commercial Vehicle Engineering Congress (COMVEC) 2025

Sept 16 – 18, 2025, Schaumburg, Illinois, USA

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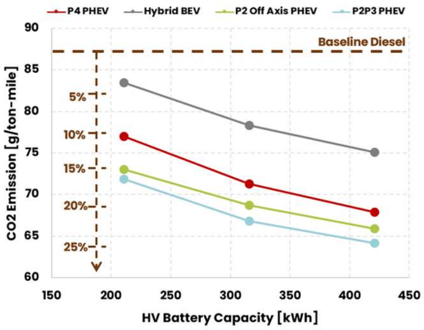
KEYNOTE TALK: "SHAPING THE FUTURE TOGETHER" – JOHN RICH, CTO PACCAR

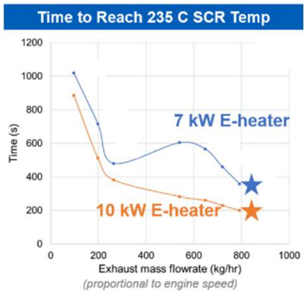
- These are unprecedented times - for the first time, the industry is seeing deregulations, leading to a relaxation of GHG standards. This has implications for powertrain strategies, these will be driven by consumer needs rather than policy push. Powertrain options include diesels, renewable fuels, electrics and plug-in hybrids.
- Hydrogen was missing from the chart, and is seen as a long shot given the current headwinds of fuel cost and lack of refueling infrastructure. Electricity is needed to make green H2, and it is increasingly being used to power data centers.
- Diesels are going strong. The EPA MY 2027 Low NOx standards might be re-evaluated and the industry believes they may be rescinded. But if they stay intact, then we could see a pre-buy in 2026 leading to a temporary boost to truck sales next year. Otherwise, the industry continues to be in a sales slump.
- Overall outlook for EVs is bleak. Europe is especially in a tough position with electric vehicles – it is the only place where per capita electricity has gone down.
- New technologies are being explored carefully. Software defined vehicles are "overhyped and underappreciated in terms of complexity" and can be a huge liability if not executed well. Self-driving technologies are getting real and entering validation phase. Connectivity is still in early stages and much more could be done with data. Predictive maintenance and diagnostics are getting better.
- OEMs are increasingly relying on unconventional partnerships (e.g. PACCAR working with Cummins and Daimler on batteries) – it is pragmatic to build the ecosystems required for new powertrains through partnerships as opposed to trying to do it all in-house.

PANEL: ADVANCES IN HYBRID POWERTRAIN TECHNOLOGY

1. Model-Based PHEV Optimization – Satyum Joshi, FEV North America: Hybrid and plug-in P2 – P4 architectures evaluated for Class 7 – 8 vehicle applications.
    - Battery pack sizing is a primary cost driver. Optimal battery size balances CO_2 reduction with cost, payload, and weight constraints.
    - Trade-offs for overall CO2 benefit were analyzed with respect to EV mode performance (time for 0 – 60 mph), cost and tractor weight.
    - Advanced model-based simulations allow trade-off evaluation across architectures, with optimization of controls (ECMS, machine learning) and thermal management strategies.

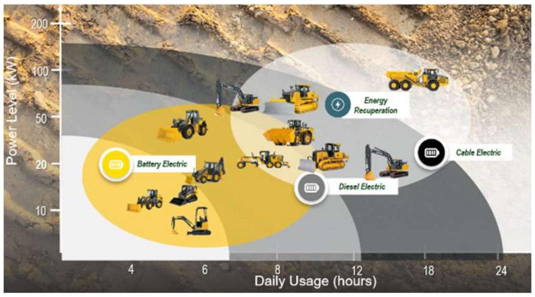


2. Eliminating Cold Start Emissions Using a Diesel Hybrid – James McCarthy Jr., Eaton: Hybridization with an electric drivetrain plus an auxiliary e-heater enables rapid heating of the SCR system (>235°C), significantly cutting cold-start NOx.
    - A 10 kW e-heater integrated with a diesel hybrid transmission reduced SCR warm-up from ~600 seconds (7 kW heater) to ~200 seconds.
    - Simulation and upcoming test data show potential to achieve near-natural gas levels of NOx while retaining diesel fuel infrastructure and performance.
    - Demonstrations are ongoing to validate benefits across city and CARB cycles.



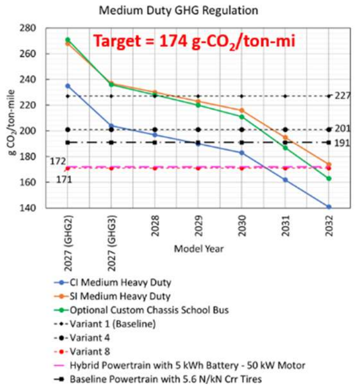
3. Hybrid Architecture Trade-offs – Chris Baillie, Allison Transmission: A market survey shows that Class 8 trucks need to achieve TCO parity with diesel within 2 years to secure market share.
    - This drives the need for component commonality between ICE, hybrids, and BEVs to reduce unit costs.
    - Modular design and reuse of components (e-motors, power electronics, batteries) across platforms can help achieve economies of scale and manage trade-offs between performance and cost.
    - Optimal hybrid architecture depends on duty cycle, weight, and annual mileage. Limited benefit for long-haul.
    - P2 hybrids benefit from leveraging conventional transmission volumes, offering wide applicability and lower cost, while power-split systems enable maximum fuel savings but at higher complexity and cost.

4. John Deere's Ongoing Electrification Journey: Delivering Customer Value – Kent Wanner, John Deere: For agriculture and construction, electrification must deliver customer value beyond CO_2 reduction: productivity, reliability, reduced maintenance, and noise reduction are key drivers.
    - Off-highway applications face harsher environments than on-road—extreme temperatures, dust, water, and vibration. Slow vehicle speeds result in very little cooling airflow. Energy storage systems must be rugged, reliable, and serviceable in remote conditions.
    - John Deere has deployed multiple hybrid and electric solutions. More than 3 million operating hours of diesel-electric wheel loaders (644 & 944 E-Drive) have been logged, demonstrating durability and field performance.
    - Electric Variable Transmissions (EVTs) with power off-boarding allow tractors to transfer power efficiently to implements, enabling features such as 8-wheel drive for greater traction and productivity.
    - Case studies include hybrid turf mowers (reducing noise and hydraulic leak risks), high-power agricultural tractors, and specialized applications like potato harvesting with electrified implements.
    - The company is pursuing a broad solution set: improving ICE efficiency, deploying hybrid and battery-electric vehicles, and integrating renewable fuels—reflecting the diversity of customer needs and operating contexts.



Cost Effective Pathways to Medium Duty Greenhouse Gas Phase 3 Compliance – Shubham Patil, SWRI*: The objective was development of Class 7 medium-duty vehicle meeting 2032 GHG target of 174 g-CO_2/ton-mi. Simulations were used to explore the reduction in CO_2 emissions with hybridization.

- The combination of a low carbon fuel such as propane, with low resistance tires, was shown to lower GHG emissions to meet the 2031 target.
- To further reduce CO_2 emissions, a P2 hybrid configuration was modeled, with a 5-kWh battery pack, and engine start stop functionality to eliminate idling emissions. This lowered the emissions to 172 g-CO_2/ton-mi.



This was a separate talk and* ***not* *part of the panel, but we include it here to show another study which discusses the use of hybridization along with a low carbon fuel – propane – and low resistance tires, to meet GHG Phase 3 standards.*

Conference summary continued below …

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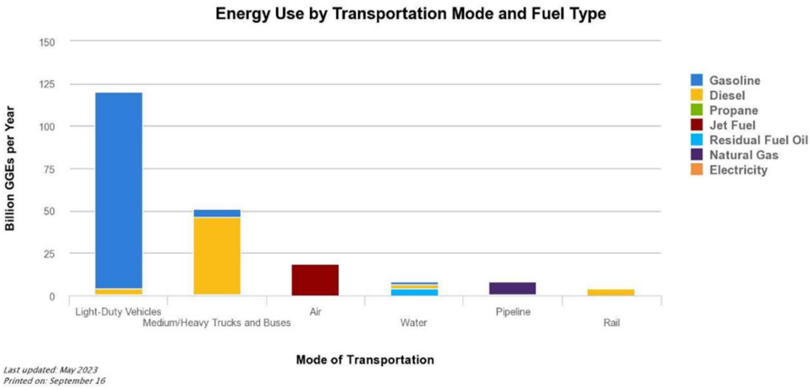
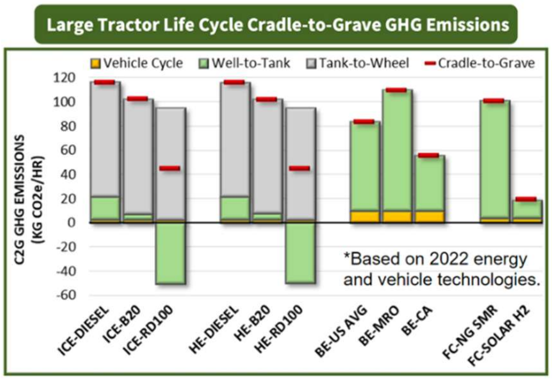
Panel: Alternate Power Solutions Evaluation for High-horsepower Off-Highway Applications

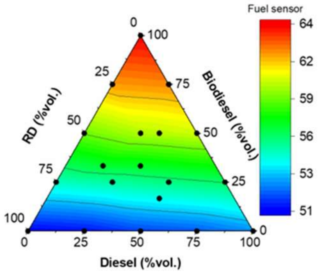
1. Transition Hurdles - Chris Atkinson, Ohio State University: Decarbonization of heavy-duty transport will proceed through several powertrain and fuel pathways.
    - High costs, mineral supply risks, charging infrastructure, and grid capacity will slow progress, making decarbonization a decades-long effort.
    - Heavy-duty, off-highway, rail, and marine face “fuel confusion” with no dominant pathway, while aviation is more decisive with SAF.
    - Biofuels are constrained by limited biomass; hydrogen and ammonia face “too many too many hurdles to adoption to succeed”
    - Innovation priorities: High-efficiency and flexible engines, Hybridization, Advanced aftertreatment & AI/ML-driven optimization



2. Lifecycle Analysis - Hao Cai, Argonne National Lab: Evaluation of new fuels & electrification will require considerations of lifecycle GHG assessment, vehicle range, infrastructure and grid carbon intensity. GREET model is ready for the task, covering well-to-wheels and infrastructure/material cycle assessments, propulsion systems across light-, heavy-duty, off-road, tractor, and rail applications with multiple fuels (diesel, biodiesel, RD, DME, FT-diesel, hydrogen, electricity, etc.).
    - For the example of a large tractor, it is seen that renewable diesel can reduce cradle-to-grave GHG emissions by ~ 60%, which is currently a greater reduction compared to battery electric operated on the California grid.
    - For biodiesels, it was shown that the reduction strongly depends on the feedstock and that indirect land-use change (ILUC) can significantly raise the carbon intensity. Waste-derived feedstocks (used cooking oil, tallow) achieve the lowest emissions.

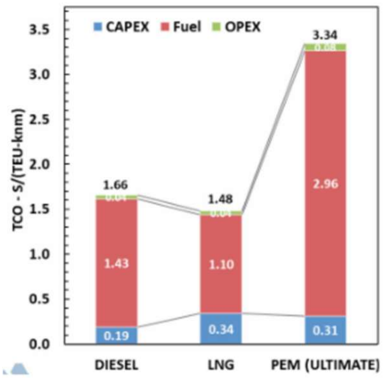


3. Fuel-Flexible Engines - Ryan Williams, Southwest Research Institute: True universality of “fuel-agnostic” engines is not practical: engines must be optimized for specific fuels despite some shared components.
    - This requires making critical choices in ignition source, compression ratio, and combustion method (swirl vs. tumble) depending on fuel type.
    - There are manufacturing constraints: Cylinder head design is central to performance but also expensive to retool. Developing a single casting adaptable to multiple fuel strategies could help manage production challenges
    - Novel port geometries and valve layouts could enable engines to handle both swirl and tumble on the same head, though combining direct injection with spark ignition remains a technical hurdle
    - Real-time fuel sensing of fuel properties could allow engines to adapt dynamically, ensuring better performance and emissions control across fuel types.



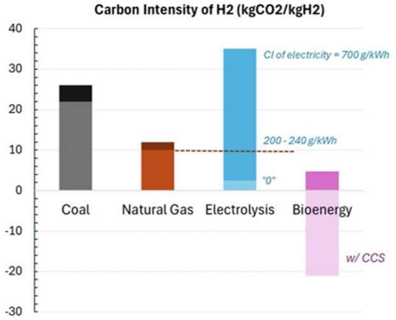
4. Considerations for moving to alternate fuels - Cathy Choi, Advanced Machine and Vehicle Innovation Center (AMVIC): Energy transition strategies have regional relevance, reflecting differences in availability and infrastructure.

- Incremental Changes: Dual-fuel powertrains (diesel-methanol, diesel-ammonia, ethanol blends) and hybrid/electric powertrains provide transitional solutions toward decarbonization.
- Big Shifts: H_2 powertrains for engines, ferries and locomotives represent a transformative step in reducing emissions from heavy transport sectors. Small modular reactors (SMRs) are a potential long-term energy source for fueling transport (being demonstrated for a ship in Korea).
- Cost is key: Total cost of ownership (TCO) analysis remains critical—covering CAPEX, OPEX, fuel costs, maintenance, training, and end-of-life. Example shown here for shipping, from Argonne.



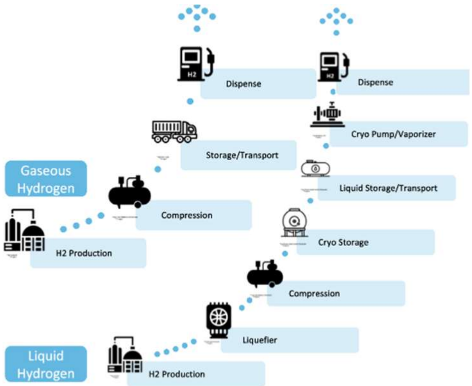
PANEL: HYDROGEN POWERTRAINS

1. Regulatory, technology, and market overview – Ameya Joshi, MobilityNotes: Various factors are driving (or deterring) the growth or hydrogen powered transport.
    - Green H2 availability could be a bottleneck, given the demand from other sectors which consume ~ 100 M tons annually
    - The GHG reduction potential is strongly tied to the feedstock: carbon intensity of electricity needs to reach < 200 – 240 g/kWh for electrolysis to be favored over current natural gas pathways. China and India dominate current investments in green H2, but both have high carbon intensity for their electricity generation
    - Cost of H2 production varies significantly across the world. TCO parity also depends heavily on the refueling and delivery costs.
    - H2-ICE may offer a pathway to utilize H2 at low investment, while fuel cell technology improves.



Source: IEA Global H2 Review (2024)

2. Scaling Hydrogen with Modular, Validated, and Compliant Systems - Paul Dawson, OneH2: The company is offering a one-stop shop for generating, distributing and refueling H2.
    - FCEV adoption will depend on the fuel (H2) being locally available, reliable and affordable. Modularity and scalability is key. Producing H2 near the point of refueling found to be effective to minimize transport-related costs.
    - Regulations and harmonization for fueling protocols, fuel quality, permitting, etc. are important
    - Compressed gaseous H2 is the preferred pathway (compared to liquid) due to simpler infrastructure and lower losses.



3. Cummins Hydrogen Internal Combustion Engine (H2-ICE) – Hui Xu, Cummins: H2-ICE offers a complementary solution to both diesels and natural gas/gasoline engines. It helps utilize existing installed capacity in engine and components manufacturing.

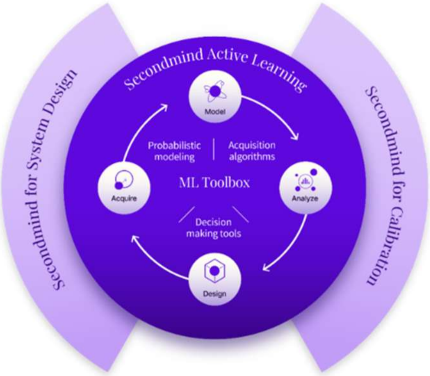
    - H2 has some unique properties leading to various development considerations, such as faster burn rate, high auto ignition temperature, low ignition energy, low gas density and high flammability range.
    - The H2-ICE architecture was discussed: need of turbocharger for high air flow, lean burn, DI fuel system, urea-SCR and positive crankcase ventilation, as examples.
    - Current commercialized Cummins engines include the 6.7L (max 290 hp) and 16L (max 530 hp) variants
    - Specs of an example Class 8 sleeper cab powered by H2-ICE were shown. The vehicle is expected to carry 80 kg H2 to meet 500 mile range, and weigh 2,500 lbs more than diesel.

4. <u>Fuel cell applications to support the growing H2 momentum in India - Mufaddel Dahodwala, KPIT</u>: India is increasing investments in hydrogen to support its net zero carbon and energy independence goals.
    - Fuel cell modules are being developed for automotive and marine applications
    - A H2 Fuel Cell-based hybrid power system has been designed for marine, defense, and industrial applications. The PEMFC stack is fueled by 350 bar H2, optimized for hybrid configurations, and provides 40 – 150 kW power, capable of operating 12 hrs continuously.
    - A H2 Fuel Cell-powered marine vessel has been launched, which has a 80 kW PEM stack

PANEL: AI & SIMULATION FOR POWERTRAIN DEVELOPMENT

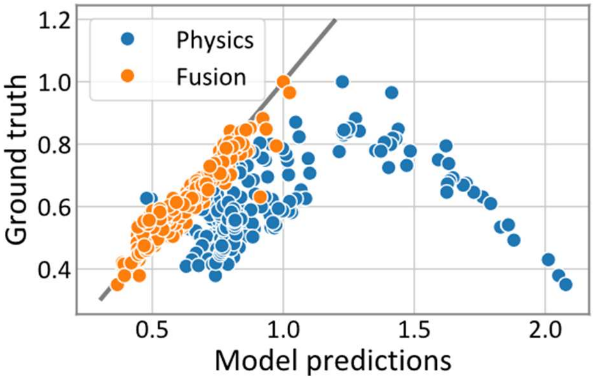
<u>AI for Model-Based Engineering – Morgan Jenkins, Secondmind</u>: Machine learning toolbox developed to select important data, and design and learn from data-efficient experiments, with specific applications for solving high-dimensional system design and calibration challenges.

- These tools capture complex relationships between automotive system data, guide data collection and generate actionable recommendations for complex engineering processes.
- Applications for system design include e-drive systems, hybrid powertrains, thermal management, brake systems, NVH, etc.
- For calibration, the technology reduces calibration time and data collection. Example shown for Mazda EV motor calibration shown to save 60% data.

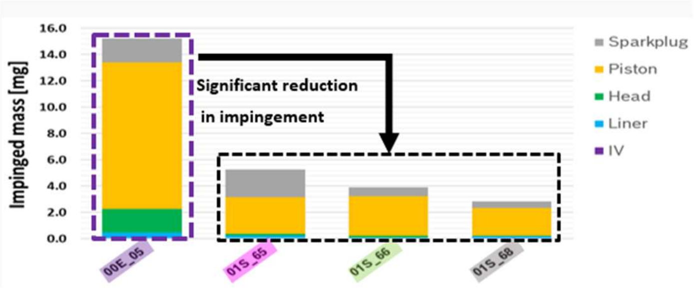


<u>Hybrid Analytics for Virtual Validation – L. Srinivasa Mohan, Ansys (Synopsys)</u>: Data-driven models or physics-based simulations have their strengths, but also present serious gaps in scalability and transferability.

- Hybrid models—fusing physics with data— reduce testing needs, improve predictions, and allow transfer learning between designs, lowering the recalibration burden for small hardware changes.
- Demonstrated examples included pollutant prediction in conceptual design and dynamic hybrid models for transient behavior such as gas temperature in a catalytic converter.



AI-Assisted Powertain Simulation – Fabian Koepple, Bosch: Bosch outlined its evolution from traditional simulation toward AI-driven methods.



- One example shown was AI-driven GDI spray layout optimization showed reduced wall impingement and improved mixture formation
- Another example discussed was an AI-based digital twin concept for acceleration of H2-ICE by enabling digital twins for predictive simulations without extensive measurement campaigns.
- Integration of Physics-in-AI (PI-AI) can potentially redefine simulations, unlock new capabilities and even lead to breakthrough designs

AI/ML for clean and efficient engines – Abdullah S. AlRamadan, Aramco: AI-based toolbox has advanced from supervised learning to generative, and is being used to optimize engine performance, fuel properties and emissions.

- Success stories include AI-guided optimization of engines with multiple design variables to lower fuel consumption (3 – 15% for cases shown) and particulate emissions (up to 78%)
- A specific case of active pre-chamber geometry optimization for heavy-duty engines was shown, with 300 geometries and 6 independent variables evaluated. A global optimum was found for reduced fuel consumption and emissions.
- AI-driven fuel property modeling (ChemSL “Chemical SuperLearner”) considers various properties such as octane numbers, vapor pressure, and distillation curves, enabling rapid evaluation of both fossil and renewable fuels.
- Looking ahead: physics-informed AI, generative AI for novel fuel design, and even quantum computing could transform combustion research and accelerate pathways to ultra-clean engines