Powertrain technologies – challenges and opportunities

Dr. Mihai Dorobantu
Eaton Corporation

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Eaton is a leader in power management...

We provide reliable, efficient and safe power management for...

Cities & Buildings  Industrial & Machinery  Information Technology  Transportation  Infrastructure  Energy & Utilities
Vehicle Group Product Portfolio
Focus on fuel efficiency

Valvetrain | Fuel Emissions & Powertrain Controls
Torque Control | Superchargers
Fluid Connectors & Plastics

Hybrid Power Systems

Roadranger Partner Offerings

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Crystall Ball

Drive the Technology Circle

Increase efficiency: Powertrain

Engine Downsizing

Engine Downsizing

Automation

Fuels

Electrification

Waste Energy

Reduce loads: Vehicle

Weight & Drag
Technology
No silver bullet… future is in smart systems and deep integration

- Engine Downsizing
- Engine Downspeeding
- Automation
- Electrification
- Fuels
- Waste Energy
- Advanced Combustion
- Systems Integration & Optimization
- Advanced Boosting
- Variable Valve Timing & Actuation
- Reduced loads
- Drag, Rolling resistance, Friction, Weight, Smart accessories
- Waste Heat Recovery
- Hybridization

- Smart and fast shifting
- Look-Ahead
- V2V and V2I
- Route planning
- Grade anticipation
- Road load management
- Natural Gas
- Micro-turbines
- EV: PHEV, Fuel Cells,
Electrification Challenge
Must improve payback: increase efficiency and reduce cost

Payback 5-15+ years based on saved fuel
EV buses and trucks
Enabling powertrain and HV component cost out

- 2-4 speed HD transmission:
  - 10-18% range improvement,
  - smaller motors
  - regular drivetrain
- Flexible HVDC power distribution
- HV Electronics
  - DC/DC converters
  - Inverters
- Fuel cell efficient air controls: 10% power rating improvement
Affordable MD Hybrids
Challenge: achieve 3 year payback, and then reduce to 2 years

1st Generation Architecture
• 25-30% efficiency
• $4000/year savings
• 5+ year payback

Next Gen architecture
• 30% - 50% efficiency
• $6000/year savings
• 3.5 year payback
Fuel Economy

Next Gen architecture is worth an additional 10-30% fuel economy over standard hybrid systems.
What else?

- Technology
  - More fuel savings
  - Lower cost components

- Market dynamics
  - $10,000 battery is the biggest barrier
  - Battery leasing business model
Engine Downs-speeding & Downsizing

**Boosting Challenges**

Downsized engines
  - Boost device efficiency decrease

Downsped engines
  - Lower exhaust energy

Deactivated cylinders at low speed
  - Induction system pressure fluctuations

**Solutions**

Mixed-Device Boosting
  - Positive displacement (response) plus turbo (peak full-load BSFC)
TVS® Supercharger for Diesel engines

Key enablers: Efficiency ~75% and Pressure Ration 2.5 – 3.1

- 80% Reduction in Transient Smoke
- 35 seconds faster DOC light-off
- 50% Reduction in Cycle NOx
- 14% Improvement in Fuel Economy
Compound Boosting for Fuel Economy
Instant boost → Engine downspeeding → Fuel economy

• Greatly reduced fuel consumption
  • Downspeed for maximum fuel economy = 14.3% reduction
  • Keep stock shift schedule for improved performance and fuel economy = 9.7% reduction

• Faster boost response allows higher average gear selection over driving cycles
E-superchargers

2011 Chevy Cruze ECO 1.4L T manual:
Initial eSC System Implementation

- **eMotor**
- **Boosting Device**
- **Internal Combustion Engine**
- **Clutch 1**
- **Clutch 2**
- **FEAD Belt**
- **Clutch/Brake**
- **Bypass**
- **Display**
- **Controller**
- **Battery**

- **2.8L V6**
  - 50% Down Sizing
  - 22 mpg
  - 170 n-m @ 1000 rpm

- **1.4L e-SC**
  - 34% FE Increase
  - 29.5 mpg
  - 195 n-m @ 1000 rpm

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Chassis Dynamometer Results:
Significant Down-sizing and Down-speeding enabled

Higher torque at all speeds maintains performance

Engine Speed (rpm)

Intake Pressure (kPa)

Torque Output

2.8L NA: 265Nm
1.4L eSC: 253Nm
1.4L TC: 200Nm

Very high low end torque enables downspeeding & fuel economy
Chassis Dynamometer Results: V6 Performance with Increased Fuel Economy

<table>
<thead>
<tr>
<th>Model</th>
<th>2.8lt NA</th>
<th>eAssist 2.4lt</th>
<th>eSC 1.4lt</th>
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<tr>
<td>Cruze</td>
<td>22 mpg</td>
<td>25.7 mpg</td>
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<td>LaCrosse</td>
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</tbody>
</table>

34.1% FE Improvement over 2.8 L baseline
14.8% FE Improvement over eAssist
Eaton e-SC Assist Benefits

Fuel Economy
- 30%+ fuel economy increase over naturally aspirated engine
- 10%+ fuel economy increase over compound turbo charged engines
- Uses regenerated energy to improve boosting system efficiency

Drivability / Performance
- Mitigate “turbo lag” – Engine independent variable speed boost
- 50% engine down-sized engine w/o performance loss
- Scalable system – 1 to 5 liter

Vehicle Integration
- Integrated start/stop function
- Low voltage (lower cost) electrical system
- Engine off accessory power
HD Engine Downspeeding
Transmission is the key enabler

- **Downsped Powertrains**
  - Optimized transmission and axle ratios
  - Optimized shift strategy and engine calibration
  - Reduction / elimination of torque interrupts

- **Advanced Powershift Technology**
  - Dual-clutch transmissions can enable downspeeding by powershifting with minimal losses
  - Under development by many CV powertrain manufacturers

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3-6% fuel economy
$80k year fuel bill
Waste Heat Recovery
It’s all about the expander: efficiency, speed, complexity, size

- Rankine system
- Turbo-compounders
- Thermo-electric
- Direct WHR

3-Stage Positive-Displacement Expander

Mechanical or Electrical?
HD Hybrid opportunity
WHR & Next Gen Hybrid & battery volume enable 2 year payback

Lower aero loads →
- lower cruise power
- more coasting
- more regen

WHR efficiency: engine at high load

Downsized engine: cruise power

WHR charges batteries, adds cruise power

Hybrid motor/batt: peak power

Electrification & WHR → more secondary power
Look-Ahead Powertrain Management

Make every driver a best driver

- Expected average >4% mpg improvement across the fleet

- 5.3%

- 2.5%

- Vehicle CAN bus

- GPS

- Wireless

- Engine ECU

- Trans ECU

- Forward Radar

- SBC w/3D maps LPM code

- Throttle Pedal

- CAN I/O

- V2V V2I DSRC* device
Predictive Battery Management for Commercial Hybrid Vehicles

Technology exploration: reduce 50% battery need
• Battery life prognostics
• Look-Ahead Powertrain Management
• Predictive Hybrid Powertrain Controls
Key takeaways

• Cost of fuel, regulations and societal forces drive electrification, but... payback based on saved fuel is the key

• Boosting, waste heat recovery and vehicle improvement help increase efficiency, but... need deep integration and smart controls

• Powertrain technology saves and help reduce cost, but... that may not be enough: need a step change in batteries (technology, controls and business model)