Fuel Saving Light Duty Vehicle Technology

March 22, 2016
The Pathways Initiative Workshop
Toronto, Ontario
All conventional technology forecasts are conservative

Donald Rumsfeld hit the nail on the head, although in a different context:

"there are known knowns; there are things that we know that we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns, the ones we don't know we don't know."
Any credible report assesses the “knowns”
  • 2011 NAS CAFE report was explicit that it only assessed current technology.

Agencies try to include the “known unknowns”
  • e. g. substantial effort to assess “Learning”

But the “unknown unknowns” – innovation – are rarely even acknowledged
  • Despite long history of constant technology innovation
### Accelerating Technology Introduction in the U.S. driven by Fuel Economy Regulation

<table>
<thead>
<tr>
<th>Year</th>
<th>GDI</th>
<th>Turbo</th>
<th>VVT</th>
<th>Stop/Start</th>
<th>Hybrid</th>
<th>6 speed</th>
<th>7+ speed</th>
<th>CVT non-hybrid</th>
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<tbody>
<tr>
<td>2004</td>
<td>-</td>
<td>4%</td>
<td>44%</td>
<td>-</td>
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<td>5%</td>
<td>0.4%</td>
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<td>49%</td>
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<td>0.4%</td>
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<td>2%</td>
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<td>-</td>
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<td>-</td>
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<td>79%</td>
<td>-</td>
<td>2.9%</td>
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<td>3%</td>
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<td>56%</td>
<td>14%</td>
<td>23%</td>
</tr>
</tbody>
</table>

Source: 2015 EPA Fuel Economy Trends Report – Cars only

GDI: Gasoline Direct Injection
CVT: Continuously Variable Transmission
VVT: Variable Valve Timing
Innovation not Anticipated in the 2017-2025 CAFE/CO₂ Rule

Technology assessments were conducted 4 to 5 years ago
The Real Technology Breakthrough

Computers

- Computer design, computer simulations, and on-vehicle computer controls are revolutionizing vehicles and powertrains.
- The high losses in the internal combustion engine are an opportunity for improvement.
- Transmissions are improving rapidly.
- Reducing size and cost of hybrid system.
- Especially important for lightweight materials:
  - Optimize hundreds of parts – size and material
  - Capture secondary weight – and cost – reductions
Innovation not anticipated in 2017-25 rule

- Manufacturers solving longstanding problems with **CVTs**
  - Non-hybrid car share jumped from 8% in 2010 to 23% in 2015

- **48-v hybrids**, with significant benefits at lower cost
  - Audi SQ7 TDI first production application

- Engine developments:
  - Mazda’s production **SkyActiv engine**, 13:1 compression ratio
  - Toyota **expanding Atkinson cycle engines** to non-hybrid vehicles
  - **Miller cycle** turbocharged engines
  - **E-boost**
  - 2-step connecting rod – **variable compression ratio** – FEV & AVL

- Many high-volume vehicles already achieve or exceed average projected weight reduction of **7% for 2025**
  - Ford F150 doubled the projected reduction – 10 years early
Turbo-Boosted EGR Engines

- Highly dilute combustion – considerable efficiency improvement
- Advanced ignition systems required
- 6% penetration for 2025 forecasted by EPA/NHTSA
Turbo Dedicated EGR Engines

- Highly dilute, low temperature combustion
- Advanced ignition systems required
- > 42% indicated efficiency (Alger)
- PSA 2018 introduction

Terry Alger and Barrett Mangold, SwRI, Dedicated EGR, SAE 2009-01-0694
E-Supercharger: 32% vs NA, 21% vs TC
50% engine downsizing, lower engine speed operations, mild hybrid at low power/voltage

Key features

- Allows fast boosting at low engine speed → downsizing and downspeeding engine
- Removes backpressure of turbo
- Start/Stop, electrical accessories, regenerative brake energy
- Low power (3-4 kW) and hence low voltage electrical system → low cost
- Results: 32% fuel economy compared to baseline 2.8L NA LaCrosse measured on chassis dyno, while maintaining performance (21% vs. dual turbo)

E-Helper
25.7 mpg

EAVS
32.3 mpg

Ability to boost at low engine speed vs TC

Better torque at 1.4L than 2.8L NA engine up to 3000 rpm

Eaton – Fuel savings technology for LD – April 17, 2015
Lightweighting Process Improvements

To reinforce the GM strategies, two statements from Peter Reyes, the chief engineer of the revamped F-150 pickup truck:

- 15 years ago, it took nine months for Ford Motor Co to make two possible designs for a vehicle frame. Now, he can create 100 different examples in that time.”

- “Ford used CAE tools to digitally experiment with more lightweight materials and test those components against "a blizzard of stiffness and strength requirements,”

These CAE tools are where the real competition is occurring, which means manufacturers will be able to optimize the material, shape, and thickness of every part on every vehicle before 2025. Average weight reductions of 20 to 25% should be easily obtained by 2030.

Other Consumer Benefits from Technology

- Turbocharging, GDI, FFV, hybrid – low rpm torque
  - F150 buyers aren't spending an extra $595 for the V6 turbo over the V8 in order to improve fuel economy - they want the low-rpm torque.
  - Hybrids provide instant torque response from the electric motor

- 7+ speed transmissions – better acceleration and less noise

- Lightweighting – better acceleration, braking, and handling
  - Ford isn't touting the improved efficiency from the aluminum body on the 2015 F150 as much as the improved acceleration, handling, and braking and the increased payload and towing capacity.

- High-strength steel and aluminum – better crash properties

- Aluminum – does not rust
Estimated Test Fuel Economy for Average New Vehicles

NAS Committee on Transitions to Alternative Vehicles and Fuels:

**Figure 2-1** Historical and Projected Light-duty Vehicle Fuel Economy

Note: All data is new fleet only using unadjusted test values, no in-use fuel consumption. FTP values, projections assume light duty fleet is 38% light duty trucks
Mid-Term Review Plans
ALPHA’s Role in the Overall Modeling of Potential Compliance Pathways

Data is obtained from multiple sources, including benchmarking lab data
- Data from 2013-2016 MY vehicles has been used to calibrate and validate ALPHA
- ALPHA can look at multiple packages and multiple case studies simultaneously
- Combinations of the best available technologies can be used to make efficiency projections for future vehicles
- Going forward, test data and modeling results will be used to update LPM
Role of Full Vehicle Simulation

- CAFE model inputs defining the analysis fleet are the foundation
  - Forward-looking representation of manufacturers’ products
  - Each vehicle has initial fuel economy level and preexisting technology content
  - DOT’s analysis will start with model year 2015 fleet
  - Volumes projected forward using information from EIA and Global Insight

- CAFE model inputs define available fuel-saving technologies
  - Cost to add technology
    - Impact on vehicle fuel consumption

- CAFE model estimates how manufacturers could (not “should”, “will”, or even “are likely to”) respond to existing or new CAFE standards
  - Inputs define fuel prices, buyers’ willingness to pay for fuel economy
  - Inputs define standards, credit provisions, etc.

- Using other inputs, CAFE model calculates impacts of this response
  - Travel demand
  - Fuel consumption, GHG and criteria emissions
  - Highway safety
  - Monetized social costs and benefits

Vehicle simulation results inform these inputs
ICCT Technology Briefs

- Each technology brief will evaluate progress since the 2017-25 rule (analyses were done 4-5 years ago):
  - How the current rate of progress (cost, benefits, market penetration) compares to projections in the rule
  - Recent technology developments that were not considered in the rule and how they impact cost and benefits
  - Customer acceptance issues, such as real-world fuel economy, performance, drivability, reliability, and safety.

- Improve credibility of reports by partnering with suppliers:
  - Provide data and analyses
  - Review drafts
Topics

- Hybrids
- Downsized, boosted gasoline engines
- Naturally aspirated gasoline engines,
- Diesel engines
- Lightweighting
- Transmissions
- Thermal Management (added by ITB)
Economic Opportunities
Consumers are, in general, LOSS AVERSE

2002 Nobel Prize for Economics
(Tversky & Kahnemann, J. Risk & Uncertainty 1992)

- **Uncertainty** about future fuel savings makes paying for more technology a risky bet
  - What MPG will I get (your mileage may vary)?
  - How long will my car last?
  - How much driving will I do?
  - What will gasoline cost?
  - What will I give up or pay to get better MPG?

“**A bird in the hand is worth two in the bush.**”

Causes the market to produce less fuel economy than is economically efficient
Technology is Paid by the Fuel Savings

- Decrease in amount paid for fuel is larger than the increase in monthly vehicle payments
- The average customer winds up with more money in their pocket

The fuel producers are the ones who pay for the benefits, not consumers
Barrier: Manufacturer Risk

- Manufacturers also risk averse
  - Mis-locating the accelerator pedal by < 1 inch cost Toyota billions of dollars

- What if consumers don’t accept technology?
  - Has been consumer dissatisfaction with some early idle stop systems and DCT and CVT transmissions (although some manufacturers did them well)

- What if my technology package to comply with standards costs $3,000 – and my competitor did it for $1,500?

- Manufacturers want to test all options before committing – more lead time
Summary

- Projections/studies based on “known” technology will always overstate costs
- Computers are transforming technology – and the pace is accelerating
- New technologies are better in other ways as well – only tradeoff is cost
- Improvements in conventional technology will make it more difficult for alternative technologies to compete and penetrate the market
- It’s going to be easier and cheaper to meet the standards than we think – but many paths to compliance create uncertainty and risk
- Paying more for technology and less for fuel will create jobs
Thank you!

John German, International Council on Clean Transportation