What the Future Holds for Automotive Powertrains

Bob Wimmer
Director, Energy & Environmental Research

Center for Energy Economics

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Outline

• How did we get here .......... or where did all these regulations come from?

• Future powertrains already among us
  – Hybrids
  – Plug-in Vehicles
  – Fuel Cell Vehicles

• Alt fuel infrastructure

• The future
For Decades it was About Air Pollution
Then Energy Security
Now Green House Gases

Global Temp (meteorological)

Temperature Anomaly (°C)

SHRINKING ICE CAPS

The Arctic sea ice cover reaches its minimum in September. The remaining ice is called the perennial ice cover. CryoSat determines variations in its thickness so total ice volume can be worked out.

Product Regulatory Affairs

TOYOTA

12/08/2016
### Resulting in a Plethora of Automotive Regulations

<table>
<thead>
<tr>
<th>Type of Regulation</th>
<th>Federal</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOT/NHTSA</td>
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</tr>
<tr>
<td>Fuel Economy</td>
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<tr>
<td>GHG</td>
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</tr>
<tr>
<td>Well to Tank</td>
<td>RFS (Biofuel)</td>
<td>RPS (Renewable Electricity)</td>
</tr>
<tr>
<td>Tech Mandate</td>
<td></td>
<td>Zero Emission Vehicle</td>
</tr>
</tbody>
</table>

Upon request of industry, DOT, EPA & CA combined their separate requirements into a single One National Program (ONP) targeting a fleet average CO₂ of 163 g/mi by 2025.
What Does Compliance Look Like

CAFE Standards vs. Fleet Fuel Economy

One National Requirement

CA Air Resources Board CO₂ Compliance Scenario

Compliance requires a portfolio of technologies

Product Regulatory Affairs

12/08/2016
Toyota’s Corporate Challenge

Reduce Tank-to-wheel CO₂ Emissions

* Compared to Toyota’s 2010 global average

Powertrain Diversity will Expand

Product Regulatory Affairs
Hybrid is Step One and Toyota’s Core Strategy

- **Toyota Camry Hybrid**
  - 41 MPG

- **Toyota Prius**
  - Up to 56 MPG

- **Toyota Prius V**
  - 42 MPG

- **Toyota Prius Plug-In**
  - ~120 MPGe/~55 MPG

- **Toyota Prius c**
  - 50 MPG

- **Toyota RAV4 Hybrid**
  - 33 MPG

- **Toyota TS-050 Hybrid**
  - Li-Ion Battery

- **Lexus GS 450h**
  - 31 MPG

- **Lexus CT 200h**
  - 42 MPG

- **Lexus ES 300h**
  - 39 MPG

- **Lexus CT 200h**
  - 42 MPG

- **Lexus ES 300h**
  - 39 MPG

- **Lexus NX 300h**
  - 33 MPG

- **Lexus LS600hL**
  - 20 MPG

- **Lexus LS600hL**
  - 20 MPG

- **Lexus RX 450h**
  - 30 MPG

- **Lexus RX 450h**
  - 30 MPG

Fuel Economy – EPA MPG (Combined); Actual mileage will vary.
A Portfolio of Technologies is Needed

Hydrogen Fuel Cell EV (Step three)

Plug-in Hybrid EV (Step two)

Hybrid is Toyota’s Core Technology

Product Regulatory Affairs

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Technology Kinship

**Fuel**

**Hybrid**
- Gasoline
- Battery
- Fuel tank

**CO₂ Emissions**
- Low (up to 58 mpg city)

**Plug-in Hybrid**
- Gasoline
- Electricity
- Larger Battery
- Fuel tank

**CO₂ Emissions**
- Lower (up to 25 mi all electric range & 55 mpg city)

**Hydrogen Fuel Cell**
- Hydrogen
- Battery
- H₂ tank

**CO₂ Emissions**
- Zero Tailpipe (Only water vapor)

**Product Regulatory Affairs**

12/08/2016
One Size / Technology Does Not Fit All
2017 Mirai Fuel Cell Electric Vehicle Benefits

**Energy Diversity**
Hydrogen generated from variety of sources

**Zero Emissions**
Zero tailpipe emissions

**Sustainable**
When hydrogen is produced from low/no carbon sources

**Fun to Drive**
- High torque electric drive
- Low CG for nimble handling

**Attributes**
- + 300 mile range
- 3-5 minute refueling
How a PEM Fuel Cell Works
Fuel Tank Safety
# Zero Emission Vehicle Attributes Vary by Technology

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Battery EV</th>
<th>Fuel Cell EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Availability</td>
<td>Many nationwide</td>
<td>CA &amp; NE (in 2017)</td>
</tr>
<tr>
<td>Fuel Price</td>
<td>Varies – free to ???</td>
<td>Free for 3 yrs ($10-$12/kg)</td>
</tr>
<tr>
<td>Vehicle Price</td>
<td>$30K - +$135K</td>
<td>$57,500 (Mirai)</td>
</tr>
<tr>
<td>Incentives</td>
<td>Up to $7500</td>
<td>Up to $8000 (Expires 12/31/16)</td>
</tr>
<tr>
<td>Range</td>
<td>100 – 315 miles</td>
<td>265 – 366 miles</td>
</tr>
<tr>
<td>Refueling Speed</td>
<td>~3 mi/min (fastcharger)</td>
<td>~ 100 mi/min refueling</td>
</tr>
<tr>
<td>Infrastructure Availability</td>
<td>Inconsistent</td>
<td>Limited in CA &amp; NE in 2017</td>
</tr>
<tr>
<td>Renewable Fuel Potential</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Cold Weather Performance</td>
<td>Degraded</td>
<td>Little impact</td>
</tr>
</tbody>
</table>
H₂ Station Status

- 23 public H₂ stations open in CA. Expecting ~25 by years end.
- 12 stations in the Northeast (NJ, NY, CT, RI & MA)

Plug-in Infrastructure

- ~15,000 Public charging stations
- ~38,500 Chargers
ZEV Infrastructure Cost per Vehicle

**Hydrogen Infrastructure**

- **Today**
  - $7000 (CEC)
- **2025**
  - $3000 (CEC)
- **2030**
  - $1750 (NAS)

**Battery Infrastructure**

(Home Level 2 + share of public)

- **Today**
  - $3700 (INL, DOE & Toyota)
- **2030**
  - $2900 (NAS)

**Assumes**

- Capital & Install cost
- Cost burden/EV = 10-40% of single public charger

**CEC Est. Assumes**

- 75% utilization
- 67 mpge today, 85 mpge in 2025

CEC = CA Energy Commission,
NAS = National Academies of Science

INL = Idaho National Lab
Mirai Status

- Over 880 Mirai delivered in CA since introduction (Oct 2015)
  - Retail, fleet & employee purchase/lease
  - 2016 models sold out

- Enhanced pricing on 2017 models
  - Lease - $349/mo for 36 months, $2499 due at signing (12,000 mi/yr)
  - Purchase - $57,500, 0% for 60 months & $7500 purchase support
  - Continues to include three years’ worth of complimentary fuel

- Sales begin in NE states late next year

- Targeting 3000 deliveries by end of 2017
Future

➢ A transition to electric drive & renewable fuels will be required to meet long-term climate goals

➢ A portfolio of technologies is needed to meet:
  ➢ Customer needs & wants
  ➢ Achieve compliance volumes

➢ Consumers, not technology, are the greatest challenge

➢ Autonomous and shared use vehicles will impact this transition. In what way is TBD.
Thank You For Your Attention