ADVANCED POWERTRAIN FORUM
AN ELECTRIFICATION TIPPING POINT?

Ben Schlimme
EVALUATION OF ELECTRIFICATION TIPPING POINT?

Factors for Identifying & Predicting “Tipping Point”

- Environment
- Regulations
- Fuel Price
- Customer

Electrification Tipping point evaluation through the lens of: Environment, Regulations, Fuel Price, and Consumer
ENVIROMENTAL TIPPING POINT?

Growth of global industry and technology since the 20th century

Surge in fossil fuel consumption

Growth of motorization around the world

Energy security (crude oil)

Climate Change (increasing GHGs)

Air pollution (ozone, SPM, etc.)

Catalysts towards electrification.
REGULATORY TIPPING POINT?

Light Duty Fuel Economy Regulation 1978-2025

Catalysts towards electrification.

ZEV Mandate

Figure 1. On Road Light-Duty Vehicle Scenario to Reach 2050 Goal
FUEL PRICE TIPPING POINT?

Fuel Price & Hybrid Sales

Source: EIA, RL Polk

Catalyst towards electrification?
CONSUMER TIPPING POINT?

Hybrid Evolution

**10-Million Hybrid Sales**

- **Japan**
- **North America**
- **Europe**
- **Other**
- **Cumulative**

**3.2 Million**

**1997**

**2017**

*Toyota - 13 Hybrid Models*

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**Success is born out of delivering a compelling value proposition in an ever evolving market!**

Join us in the future!!!

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**R&D**

Unit Function

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8/1/2017
Electrification is the future and pairs well with the internal combustion engine.

**Addressing Potential Tipping Points**

- **Conventional gasoline and diesel**
- **HV**
- **PHV**

**Corolla Segment**

**Challenge:**
Zero Emission

**Zero CO₂**

**Zero Emission**

**HC, CO, NOₓ, PM**
TOYOTA’S VISION

NEW GLOBAL ARCHITECTURE (TNGA)
POWERTRAIN DEVELOPMENT THEMES

Outstanding driving Performance

High Environmental Performance

Direct & Smooth

⇒ Further Toyota’s driving performance
TOYOTA NEW GLOBAL ARCHITECTURE

TNGA marks significant advancements in platform, engine, transmission and hybrid systems.

New Platform

New Powertrain

Engine

Hybrid System

Dynamic Force Engine

Transmission

Direct Shift-8AT (FF)

Direct Shift-10AT (FR)
Dynamic Force Engine (2.5-liter)

2018 CAMRY
Give in to your desires.

206hp  41 MPG Highway
Dynamic Force Engine Development Concept

**Environmental performance**
- Improved thermal efficiency

**Direct & Smooth**

**A) Loss reduction**
1. Exhaust
2. Cooling
3. Friction
4. Pumping

**B) Combustion quality**

**C) Improved intake efficiency**

**Evolution of fundamental technologies**

**Creation of common architecture through TNGA**
### Technologies Incorporated in Dynamic Force Engines

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VVT-i (Exhaust)</td>
<td>Laser-cladded valve seat</td>
</tr>
<tr>
<td>VVT-iE (Intake)</td>
<td>Widened angle between intake and exhaust valves</td>
</tr>
<tr>
<td>IN-VVT delayed-closing control</td>
<td>Multi-hole direct injector (new D-4S)</td>
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<tr>
<td>Atkinson cycle</td>
<td>High compression ratio</td>
</tr>
<tr>
<td>Compact hydraulic lash adjuster</td>
<td>High-volume cooled EGR</td>
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<tr>
<td>Small-concave-profile camshaft</td>
<td>High-response EGR valve</td>
</tr>
<tr>
<td>Tumble-maintaining shape, lightweight pistons</td>
<td>Cylinder heads with built-in EGR cooler function</td>
</tr>
<tr>
<td>High-strength connecting rod</td>
<td>New-structure water jacket spacer</td>
</tr>
<tr>
<td>Low-friction chain</td>
<td>Motor-driven water pump</td>
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<tr>
<td>Improvement of piston skirt surface</td>
<td>Electrical control thermostat</td>
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<tr>
<td>Resin-coated bearings</td>
<td>Continuous variable-capacity oil pump</td>
</tr>
<tr>
<td>Optimization of bore/stroke ratio</td>
<td>Flow shutoff valve</td>
</tr>
<tr>
<td>Balancer</td>
<td></td>
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</tbody>
</table>

**Dynamic Force Engines adopt a wide range of technologies.**

- **Response**
- **Quietness**
- **Stability**
- **Fuel economy**
- **Output**
- **Clean**
TOYOTA NEW GLOBAL ARCHITECTURE
TOYOTA NEW GLOBAL ARCHITECTURE

Performance of New Dynamic Force Engines

Power & Torque

<table>
<thead>
<tr>
<th>Engine rpm (rpm)</th>
<th>Torque (Nm)</th>
<th>Output (kW)</th>
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<tbody>
<tr>
<td>800</td>
<td>140</td>
<td>70</td>
</tr>
<tr>
<td>1000</td>
<td>160</td>
<td>80</td>
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<tr>
<td>1200</td>
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<td>1600</td>
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<td>380</td>
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<tr>
<td>7200</td>
<td>780</td>
<td>390</td>
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</table>

Exhaust Performance

PM particle count

-60%

Improved output and torque through optimal combustion and achieved cleaner exhaust
Performance of New Dynamic Force Engines

**Conventional engine-powered vehicle**
- New Engine (2.5-liter) & New 8AT Transmission
- 20% improvement
- 12% shorter Acceleration time (contribution by powertrain)
- Previous powertrain (2AR-FE + 6AT)

**HV**
- New Engine (2.5-liter) & New THS II
- 20% improvement
- 10% shorter Acceleration time (contribution by powertrain)
- Previous system (2AR-FXE + THS II)

2.5L TNGA improves acceleration & fuel economy
ICE engine improvement benefits customers while supporting regulatory requirements.
LEXUS LC 500h

Great driving performance + great environmental performance
New hybrid system development concept

1. Improved hybrid effect
   - Engine-off in low-efficiency range
   - Use of engine’s high efficiency area
   - Energy regeneration

2. Improved transmission efficiency

3. More compact dimensions and lighter weight

4. Evolution of control technology

5. THS additional value

New THS II enhancements began with new Prius.
ELECTRIFICATION STRATEGIES

New THS II system for 2.5-liter engines

**TRANSAXLE**

**POWER CONTROL UNIT**

**BATTERY**

- Lithium-ion
- Nickle-metal hydride

- Packaging
- Efficiency
- Mass
- Control Strategies

- Size
- Charge Performance

Improved THS II paired with Dynamic Force 2.5L L4
Multi-stage THS II combines outstanding fuel economy and road performance for rear-wheel-drive passenger vehicles.
Use of Dual Motor Drive system makes powerful EV driving possible
ELECTRIFICATION STRATEGIES

Future EV development set to support global electrification towards ZERO CO2.
Fuel Cell Vehicle

Powering the future
Hydrogen fuel cell vehicles could change mobility forever

Fuel Cell technology commitment continues with Project Portal!

Image: Dittmar Muller
ELECTRIFICATION PHILOSOPHY

Toyota’s Vision of Mobility Zones

Just like ICE, electrified powertrains are not a “1 size fits all”.

Energy Sources
- Electricity
- Hydrocarbon
- Hydrogen

Vehicle Size
- Home Delivery Vehicle
- Short-distance
- Personal Mobility
- EV

Travel distance
- HV/PHV Zone
- HEV
- PHV
- EV Zone
- Shuttle bus
- FCV Zone
- FCV
- Class 8 Truck
- Home delivery truck
- FCV (BUS)
- Passenger Car

8/1/2017
ELECTRIFICATION FUTURE

Contribution of Growth in Advanced Technologies

Sales Volume

Vehicles with conventional engines

2010 2020 2050 Year

HV

PHV

FCV

EV

TOYOTA MOTOR NORTH AMERICA
R&D Unit Function

CAR Management Briefing Seminars
8/1/2017
Thank you for your kind attention