Gery Ordan
ETV Motors Chief Engineer

ETV Motors Ltd

Microturbine Technology for Series Hybrid Cars

19.11.09
EP3 Series hybrid Technology

EP3 – Electric Power Propulsion Platform

- Global Warming
- Hybrid Concepts
- e-Teg 2060 MicroTurbine
- Toyota Prius conversion
- Microturbines for HEV Road Map
Turbine Technology for Series Hybrid

Global Warming
An inconvenient truth...
A historical turning point: G8 countries have committed to take the lead in greenhouse gas reduction

CO₂ fleet emission targets of key automotive markets

1. No cycle conversion considered; gasoline assumed for non-EU countries
2. For 65% of the fleet from 2012 on, gradually increased of up to 100% of the fleet until 2015
3. New national fuel economy program proposed by Barack Obama
4. New passenger car sales; km/l based on J09 cycle; China: new fuel economy standards to improve fuel economy by an additional 18% by 2025
5. Target based on that of total automotive fuel efficiency

Sources: EPA, DOT, NHTSA; EU Commision; JAMA; ICCT; Roland Berger; ETVM

Additional information: www.etvmotors.com
ICE powertrain optimization is not enough to meet EU CO₂ emissions limits of 95 g/km in 2020.

European CO₂ fleet emissions 2008 – 2020E

- Large SUV: 155 g/km CO₂ fleet emissions 2008, 1% market size
- Compact SUV: 15% market size
- Luxury car: 4% market size
- Large car: 15% market size
- Mid-size car: 33% market size
- Compact car: 41% market size

Source: JD Power; Roland Berger; RBSC; ETV Motors
ICE powertrain optimization is not enough to meet EU CO₂ emissions limits of 95 g/km in 2020

European CO₂ fleet emissions 2008 – 2020E

- **Large SUV**
  - CO₂ fleet emissions 2008: 155 g/km

- **Compact SUV**

- **Luxury car**

- **Large car**

- **Mid-size car**

- **Compact car**

**Notes:**
1. Without considering EV/PHEVs
2. For 55% of the fleet from 2012, gradually increased up to 100% until 2015

Source: JD Power, Roland Berger; RBSC, ETV Motors
ICE powertrain optimization is not enough to meet EU CO₂ emissions limits of 95 g/km in 2020

European CO₂ fleet emissions 2008 – 2020E

- ICE powertrain optimization is not enough to meet EU CO₂ emissions limits of 95 g/km in 2020.
- CO₂ fleet emissions 2020 (estimated) for different vehicle segments:
  - Large SUV: 110 g/km
  - Compact SUV: 110 g/km
  - Luxury car: 110 g/km
  - Large car: 110 g/km
  - Mid-size car: 110 g/km
  - Compact car: 110 g/km

- Market size of vehicle segment:
  - Large SUV: 20%
  - Compact SUV: 25%
  - Luxury car: 15%
  - Large car: 10%
  - Mid-size car: 20%
  - Compact car: 20%

- Emissions gap of >10 g/km for all segments in 2020.

Note: 1. Without considering EV/PHEVs
2. For 65% of the fleet from 2012, gradually increased up to 100% until 2015
3. Source: JD Power, Roland Berger; RBSC; ETV Motors

Copyright © 2009 ETV Motors Ltd. All rights reserved
Company internal – confidential and proprietary
Additional information: www.etvmotors.com
Turbine Technology for Series Hybrid

We need:

- High efficiency
- Low emissions
- High Power density

Vehicle Propulsion platform
Energy Density of Power Sources

Practical Energy Content of Batteries, Fuel Cells and Hydrocarbon fuels

Effective fuel-to-electricity Converter

- Battery
- FC - H2
- FC - CH3OH
- Gasoline, CNG, etc

H2 Storage

FC – Fuel Cell

Engine efficiency

50%

25%

10%

3%
Turbine Technology for Series Hybrid

Hybrid Electric Propulsion Concepts
Hybrid Electric Concepts

Parallel Hybrid Electric

- GASOLINE
- ENGINE
- GENERATOR
- MOTOR
- BATTERY
- ELECTRICAL OUTLET

Series Hybrid Electric

- GASOLINE
- ENGINE
- GENERATOR
- MOTOR
- BATTERY
- ELECTRICAL OUTLET

Copyright © 2009 ETV Motors Ltd. All rights reserved
Company internal – confidential and proprietary
Additional information: www.etvmotors.com
Serial Hybrid – Power Train System
Series Hybrid operational modes

1. Engine start
2. Engine drive
3. Regenerative Braking
4. Night charge

Table:

<table>
<thead>
<tr>
<th>Mode</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-drive</td>
<td></td>
<td></td>
<td></td>
<td>Regenerative Braking</td>
<td>Night charge</td>
</tr>
<tr>
<td>Engine start</td>
<td></td>
<td></td>
<td></td>
<td>Engine drive</td>
<td>Night charge</td>
</tr>
<tr>
<td>Engine drive</td>
<td></td>
<td></td>
<td></td>
<td>Night charge</td>
<td></td>
</tr>
<tr>
<td>Regenerative Braking</td>
<td></td>
<td></td>
<td></td>
<td>Night charge</td>
<td></td>
</tr>
<tr>
<td>Night charge</td>
<td></td>
<td></td>
<td></td>
<td>Night charge</td>
<td></td>
</tr>
</tbody>
</table>
Turbine Technology for Series Hybrid

E-Teg 2060 MicroTurbine
eTeg 2060 – Dual Mode – Base Model

9-40 KW Electrical Output
80 K RPM, 400 VAC 3 Ø 1300 Hz
P.R : 3
Thermal Efficiency 36 %
Weight: 120kg
eTeg 2060 - Dual Mode Performance

Part load Efficiency - Model G1-DFR

Part load Efficiency - Model G1-SFR
Compressor - P.R = 3

Why so low?

Optimum compressor pressure ratio falls with increase of regenerator effectiveness.
**Diesel engine**

Power output and Efficiency as function of rpm

*Yanmar TNV 70*
- Power: 10Kw
- Weight: 84 Kg
- Engine: Diesel
- Speed: 3600 RPM

Max. power @ 3,600rpm
Max. efficiency @ 2,000rpm

Power output and Efficiency as function of rpm.
Combustion Chamber

RQL Concept
Combustion Chamber – RQL Technology

Nitric Oxide Formation

RQL Strategy

Difference between ideal and achieved is dependent on mixing rate

Copyright © 2009 ETV Motors Ltd. All rights reserved
Company internal – confidential and proprietary
Additional information: www.etvmotors.com
Turbine Technology for Series Hybrid

System Simulation
Driving Tests

US06 Drive Cycle

Time [s] Velocity [km/hr]
ETVM's "Moving Average" mode of operation

- The TEG system will have a very wide range of power at high efficiency (>35%)

This unique performance allows for a patented power utilization strategy.
ETVM's "Moving Average" mode of operation

The TEG delivers the local average power demand of the electric motor while the battery takes care of the power peaks.
Toyota Prius Conversion

Toyota Prius Conversion
Toyota – Battery integration

Microturbine and power electronics

Copyright © 2009 ETV Motors Ltd. All rights reserved
Company internal – confidential and proprietary
Additional information: www.etvmotors.com
eJet 21 Charging System

**LMT 3080**
AC Alternator
11 Kw, 110 v AC
Max RPM : 50000 RPM
Weight : 1.6 Kg
Diameter : 60 mm
L = 120 mm

**6 Kw free turbine Turboshaft**
Max RPM : 170000 RPM
Weight : 5 Kg
eJet 21 Charging System
eJet 21 Charging System - Packaging
eJet 21 Charging System - prius Integration
eJet 21 Charging System – Drive Test

Driving distance: 50 Km
On board Charging system
eTeg 2060

Microturbine Development
Rod Map
Ceramic Regenerator

Recuperator

Ceramic Regenerator
ETV Motors Ltd

Microturbine Technology for Series Hybrid Cars

Thank you

Gery Ordan
ETV Motors
Chief Engineer

19.11.09