Powertrain Electrification for the 21st Century

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PTS Engineering R&D Director
Agenda

- Brief Overview of Valeo Organization
- Global Drivers for Powertrain Electrification
- Predicting 2020/25 Technologies
- Vehicle Segments & Impact on Powertrain Electrification
- Examples of Valeo’s Electrified Powertrain Technologies
- Summary
Valeo Presence

2013 Global Sales

$16.1 Bn

10% of 2013 sales reinvested in R&D

- 29 Countries
- 77,000 Team Members
- 124 Production Sites
- 51 R&D Centers
Valeo in North America

- 19 Production Sites
- 8 R&D Centers
- 11,500 Team Members

2013 Regional Sales

$2.6 Bn

United States of America

Top Employer 2014

Certified Excellence in Employee Conditions
Valeo Group is comprised of 4 balanced, coherent Business Groups with strong market positions

- **Powertrain Systems**: 28% of Valeo Group, 31 Plants
- **Thermal Systems**: 28% of Valeo Group, 43 Plants
- **Comfort & Driving Assistance**: 21% of Valeo Group, 30 Plants
- **Visibility Systems**: 23% of Valeo Group, 32 Plants
Powertrain Systems Business Group

4 Product Groups

Electrical Systems Product Group “PES”
- Alternators
- Starters
- Reinforced & Change-of-mind Starters
- Belt Starter Generator
- Electric Motors

Transmission Systems Product Group “PTR”
- Manual Transmissions
- Hydraulic Clutch Actuation
- Friction Materials
- Automatic Transmissions
- Powershift Transmissions

Combustion Engine Product Group “PCE”
- Mechanical Actuators
- Powertrain Sensors
- Air Charging Systems
- EMS ECUs
- Ignition & Injection

Electronics Product Group “PEL”
- Electronics for e-Machines
- High Power Electronics for HEVs & EVs
- Control & Electric Network

System Engineering & Innovation
- CO₂ Emission Reduction
- Pollutants Emission Reduction
- Hybrid and Electric

Powertrain electrification technologies
Global Drivers for Powertrain Electrification
All countries now regulate CO2 emissions, triggering similar evolution in powertrain systems development at a similar pace.
CO₂ Generation – Fundamental Physics

A balanced approach is needed to achieve higher “operational” powertrain efficiency.

To reach 75 g/km with 30% of energy recuperated, engine efficiency required: 38%

To reach 95 g/km with 30% of energy recuperated, engine efficiency required: 32%

2025 EU threshold

(Reference: Continental, Paper - Aachen 2012)

To reach the 2025 targets, increasing engine operational efficiency is paramount. Reducing vehicle losses & stop-start help but vehicle powertrain electrification is necessary.
Predicting 2020/25 Technologies
Regulations (Push) vs Consumer (Pull)

**Voice of the consumer**

Historically slow adoption & growth in consumer purchases of HEV/PHEV/REEV/EVs

**Regulations**

CO$_2$ targets necessitate powertrain electrification technologies which increase cost of vehicles

**Sales/Profit**

High cost for electrified powertrain technologies can impact sales and profit

OEM’s need low cost high benefit technologies ($/gram CO$_2$/mile) and blend these across the ‘right’ vehicle platforms
Challenges in developing CO$_2$ Technologies for 2020/25

- **Tier 1 Suppliers need to provide a broad portfolio**
  - Need to provide a range of products for both combustion engine and electrified powertrains
  - The technology solution will vary as function of vehicle segment and image/branding
  - No silver bullet exists – multiple solutions required for multiple platforms & market segments
  - The technology may be short lived as the legislated regulatory target varies over time

- **Monitor, analyze and understand the market**
  - Steps: Search & explore → assess, measure & analyze → deep dive & understand → repeat/update
    - Market research (auto market, macro trends, domestic car usage, …)
    - Voice of the OEM customer (meetings, platform image/branding, RFI/RFQ, …)
    - Voice of the consumer (market trends, sales, focus groups, …)
    - Voice of the regulators (regulations, meetings, interim review, …)

- **Monitor & analyze different technologies**
  - Analyze & assess alternative technologies for cost benefit ratio ($/gram CO$_2$/mile)
  - Optimize systems and right-size technologies to minimize the cost benefit ratio

- **Plan ahead - develop internal roadmaps**
  - React to market needs → build the right mix of cost competitive products
  - Continually revisit and update technology roadmaps
Electrification: NAFTA Trend (a prior 10yr forecast from 2012)

Vehicles <6T, Oil barrel $120 2020, Li-Ion Battery 300 €/kWh 2020

Initially high future growth anticipated for hybrids in 2012 for 10 year roadmap, but then significantly reduced in 2014

Source: Valeo Powertrain 2012 Forecast
Electrification – NAFTA Trend

Vehicles <6T, Oil barrel $120 2020, Li-Ion Battery 300 €/kWh 2020

Source: Valeo Powertrain 2014 Forecast

Stop-Start is finally being adopted in the US (mainly pushed by German OEMs & applied by USA OEMs)
There will be significant increases in powertrain electrification before 2025
Electric & fuel cell vehicle remain a niche market limited to ZEV mandate states
Expect a highly segmented market: mild (C segment), Full (pick-up truck) to Plug-in (D segments)

Future growth projections for hybrids is dependent upon cost effective battery technologies and ability to compete against other technologies ($/g CO₂/mi)
Downsizing and boosting create new challenges and opportunities for electrified powertrain solutions using electric supercharger.
Recent Powertrain Focus Groups in the USA

To help better understand 2025 powertrain trade-offs

**3 different target groups from 6 to 8 persons**

- **Mainstream D Segment 2,5 liters max**
  - Screening Vehicles
  - Camry, Accord, Altima, Fusion, Sonata, Malibu, Optima, Sebring, Passat, Avenger, Legacy

- **Big Size Engine Big SUVs & Pickups > 4liters engines**
  - PICKUPS: F Series LDuty, Silverado, F-Series Super Duty, Ram Pickup, Tacoma, Sierra, Tundra, Silverado, Frontier
  - SUVs: Traverse, Pathfinder, Tahoe, Durango, Suburban, Yukon XL, Expedition, Armada, Sequoia, Navigator, Endeavor

- **C&D HEV PHEV owners**
  - Prius, C-Max, Volt, Jetta, Fusion, Optima, Sonata, Subaru Crosstrek

**2 different regions**

- **June 20th-21st**
  - Sherman Oaks
  - California

- **June 18th-19th**
  - Montvale
  - New Jersey

**Discussion Structure**

- Car usages & Purchase (~30 min)
- Powertrain questions (~1h00)
- 2025 trade-off (~1h00)
Big Size Engines // Large SUVs and Pickups
Quotes during focus group discussion

New Jersey

“What’s an engine? It’s part of what’s makes a truck a truck. The engine and the look are for me the two things that makes a truck”

“Was the engine important in my purchase? Of course! You’re driving a truck for a reason, otherwise, just buy a car!”

California

“I don’t want to sacrifice power. I don’t want to sacrifice sound. I don’t want to sacrifice how it feels when you’re driving, when you’re in it.”

Are you worried about your CO2 emissions? “No it sounds ridiculous. If you really care about the environment, then take the bus”

Strong identification & affinity to trucks. More reluctant to change or compromise.
HEV & PHEV owners // C&D segments
Quotes during focus group discussion

**New Jersey**

"Owners of hybrids tend to feel socially responsible, and it represents my viewpoint of the world”

"My car is not fun, but it fits a lifestyle that I have chosen now. I loved my previous Jeep, that Jeep was fun”

**California**

"I like having the up to date technology. It keeps me entertained. I like the fact that it has this little thing where you can see the energy go up when you brake. It’s like a little game”

Strong affinity to high-tech green technology.
Appear willing to jump onto the next high-tech generation green technology.
Vehicle Segments and Impact on Powertrain Electrification
By areas, Powertrain needs seem different…

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- **North America**
  - Buick Lacrosse
  - Dodge Durango

- **Europe**
  - VW Golf 7
  - Peugeot 208

- **Asia**
  - Great Wall C50
  - Bajaj RE60

- **South America**
  - Fiat Uno
  - VW Gol

- **Russia**
  - Lada Priora

**Powertrain Specifications**:

- **D & SUV**
  - Gasoline – 6 cyl
  - 180 kW – 3.5l
  - AT

- **B-C**
  - Gasoline & Diesel
  - 4 cyl - 90 kW – 1.6l
  - MT

- **C**
  - Gasoline - 4 cyl
  - 80 kW – 1.8l
  - MT

- **B**
  - Ethanol – 4 cyl
  - 63kW – 1.3l
  - MT

- **A**
  - Gasoline (Diesel)
  - 2-3 cyl - <50 kW – <1l
  - MT (AT)
In reality there are large similarities in each segment.
<table>
<thead>
<tr>
<th>Category</th>
<th>2013</th>
<th>2030</th>
<th>and beyond</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>City</strong></td>
<td>Zoe</td>
<td>Gasoline, MT</td>
<td>Semi-Autonomous Electric City Car</td>
</tr>
<tr>
<td></td>
<td>Pivo</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Premium</strong></td>
<td>Durango</td>
<td>V6 Hybrid AT for SUV Diesel A/T for Long Range Car</td>
<td>Plug-In Hybrid BioGas / BioDiesel Long Range Car AT/MT/DCT</td>
</tr>
<tr>
<td></td>
<td>3-5 series</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>B-C</strong></td>
<td>Golf</td>
<td>Gasoline A/T (US) Diesel MT (Europe)</td>
<td>Mild Hybrid BioGas /BioDiesel AT/MT/DCT</td>
</tr>
<tr>
<td></td>
<td>208</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Entry</strong></td>
<td>Logan</td>
<td>Gasoline, MT</td>
<td>Downsized BioGas or CNG, MT/AMT/DCT</td>
</tr>
<tr>
<td><strong>ULC</strong></td>
<td>Bajaj RE60</td>
<td>Gasoline, MT</td>
<td>BioGas or CNG, MT</td>
</tr>
</tbody>
</table>
Examples of Valeo’s Electrified Powertrain Technologies
Primary Electrification Classification Groups

- **CMG**
  - e-Motor between ICE and gearbox, eventually separated by a clutch

- **GMG**
  - e-Motor on the gearbox or beyond (rear axle, wheels)

**Front end**
- i-StARS / i-BSG
  - e-Motor directly on the Internal Combustion Engine (ICE)
  - Mild hybrids

**Integrated**
- CMG
  - Energy recovery efficiency

**Rear**
- GMG
  - Energy recovery efficiency

3 types of E-motor integration in the driveline
- Valeo product roadmaps include all three types of location for e-motors
# System Comparison

**Hybrid systems vs main functions**

<table>
<thead>
<tr>
<th>Function</th>
<th>i-StARS 14V (2 to 4 kW)</th>
<th>i-BSG 48V (8 to 12 kW)</th>
<th>GMG 48V (8-15kW)</th>
<th>CMG &gt; 48V (15 to 90 kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold start</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Change of Mind</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Stop &amp; Start</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>HE generator</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Durability (1mcy)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td>Comfort Start</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td>Stalling help</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Sailing / coasting</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Boost (GSI*)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Regenerative</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Torque Monitoring</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Electrical Take off</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td>Electrical drive /ZEV</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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</table>
FE Benefits from Stop-Start to 12v-48v Hybrids

- **Stop-Start 12V**
  - Stop-Start at 0 mph speed
- **Stop-Start 12V**
  - Stop-Start until 12 mph speed
  - Change of Mind
- **Stop-Start Coasting 12V**
  - Stop-Start until 60 mph speed
  - Change of Mind
  - & coasting
  - Regen 5kW
- **Mild HEV Coasting 48V**
  - Stop-Start
  - Change of Mind & coasting
  - Regen & Boost 12kW

<table>
<thead>
<tr>
<th>Test Cycle</th>
<th>NEDC</th>
<th>WLTC</th>
<th>FTP</th>
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</thead>
<tbody>
<tr>
<td>Fuel economy gain</td>
<td>3% - 4%</td>
<td>2% - 3%</td>
<td>3% - 4%</td>
</tr>
<tr>
<td>CO₂ reduction</td>
<td>4% - 6%</td>
<td>3% - 4%</td>
<td>4% - 5%</td>
</tr>
<tr>
<td>Estimate fuel economy benefits</td>
<td>6% - 8%</td>
<td>12% - 15%</td>
<td>10% - 13%</td>
</tr>
<tr>
<td></td>
<td>10% - 15%</td>
<td>15% - 20%</td>
<td>15% - 20%</td>
</tr>
</tbody>
</table>
Micro Hybrid 12V Belt Starter Generator Solution

- BSG « StARS » in production since 2004 (integrated electronics since 2010)
  - 1,5 Mu @ PSA, BMW, Daimler, Nissan, Subaru + 3 new customers
- Allows 1 M cycle recrank and Change of Mind
- Allows coasting, with up to 7,5% fuel economy on WLTC
- Allows Mechanical or Electrical Boost and Regenerative braking (5kW)
- Best NVH @ recrank + controlled engine stalling
- Allows « Hybrid » tag in Japan and possibly in Europe if combined with dual battery
  - Demonstrated on Nissan Serena
Valeo Electric Supercharger
A smart way to use ‘free’ regen energy

Centrifugal compressor
max. 70,000 rpm

Integrated power electronics 12V to 48V

- Robust design without magnet & rare earth
- Low inertia → faster transient response
- Electric efficiency >82% achievable
- All electronics are housed in the rear of the machine
- Significantly reduced electrical losses and improved EMC
- Easily packaged under-hood

Typical VES Applications
- Fast response to 70k rpm (0.25s-0.35s)
- Flexible control
- Excellent use of ‘free’ regenerative energy
- High efficiency and FUN to DRIVE

1. Boosted Engines
   - fast time to torque (incl. at altitude)
   - increased torque reserve
   - improves downsizing performance
   - improves downspeeding performance

2. Miller Cycle
   - higher engine efficiency
   - increased torque

3. Cylinder Deactivation
   - torque reserve in cyl. deact mode
   - extends time in cyl. deact mode
   - higher operating efficiency

4. Transient EGR
   - rapid EGR increase during tip-in
   - reduced NOx and knock

VES improves Engine Operating Efficiency while also enhancing ‘FUN-TO-DRIVE’
Range Extender Generator

- High voltage generator
  30kW, 300V

PM synchronous 30kW generator coupled with 2 cyl engine in the vehicle trunk

First range extender generator on the market. SOP Q4 2013 on BMW i3 EV
Summary
Summary

- Recent predictions indicate lower growth in hybrid powertrains than previously anticipated with alternative lower cost technologies being adopted.
- Success of implementing any electrification technology is directly related to its cost benefit ratio ($/gram CO₂/mile) as there are many other competing technologies.
- Highest anticipated growth will initially be in stop-start/micro hybrids and mild hybrids.
- Systems approach is needed to extract the maximum benefit for the hybrid architectures, generating an increased demand for 12v/48v electric superchargers on downsized engines.
- Growth of hybrid systems will be very dependent upon the cost competitiveness of these technologies ($/gram CO₂/mile), necessitating both advances & cost reduction in batteries.
- Lower cost hybrid architectures will initially be adopted in larger higher cost segments and platforms, eventually being replaced by higher cost architectures as regulatory targets become more challenging: micro → mild → full → PHEV.
- Hybrid architectures will progressively move to lower cost segments and platforms as regulatory targets become more challenging.
- The pending 2017 interim review has the potential to change projections – similar to the one year delay for the 95g EU CO₂ target.
- Valeo has developed a wide range of powertrain electrification products covering all the electrification components except for the energy storage system, with various solutions from 12v to 800v to meet customers needs for the differing market segments.