Hybrid at Daimler Trucks – Technology for the world
Current status and working direction
Daimler consists of five divisions

- Mercedes-Benz Cars
- Daimler Trucks
- Mercedes-Benz Vans
- Daimler Buses
- Daimler Financial Services

2011

<table>
<thead>
<tr>
<th>Division</th>
<th>Revenues</th>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercedes-Benz Cars</td>
<td>€ 57.4 bn</td>
<td>99,091</td>
</tr>
<tr>
<td>Daimler Trucks</td>
<td>€ 28.8 bn</td>
<td>77,295</td>
</tr>
<tr>
<td>Mercedes-Benz Vans</td>
<td>€ 9.2 bn</td>
<td>14,889</td>
</tr>
<tr>
<td>Daimler Buses</td>
<td>€ 4.4 bn</td>
<td>17,495</td>
</tr>
<tr>
<td>Daimler Financial Services</td>
<td>€ 12.1 bn</td>
<td>7,065</td>
</tr>
</tbody>
</table>

Note: 2011: Revenue Group € 106.5 bn; Employees: 271,370; sales organization 49,699, Corporate/Others 5,836
Daimler Trucks worldwide vehicle portfolio
Trucks with high variety: Actros with more than 2,500 base variants

<table>
<thead>
<tr>
<th>Engine Performance</th>
<th>Cabs</th>
<th>Axles &amp; Wheel Bases</th>
<th>GVW**</th>
<th>Total Variants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9 (x)* 4 (x)* 28 (x)* 7 = 2,583*

Plus countless further combinations of fuel economy relevant options (e.g. aero devices, axle ratios, transmission options, ...)

In total more than 4,000 variants available for all MB Trucks products

* not all theoretically possible variants are actually offered  ** GVW = Gross vehicle weight
Trucks are international: China as the biggest market worldwide, every second truck is sold there

Sales Cars (in millions of Units)

Sales Trucks (> 6 t in thousands of Units)
Trucks are clean: In the past 20 years, emissions have been reduced by almost 100 % - what’s next?

From Euro 0 to Euro 6 (Emissions in g/kW)

(1) Average Truck before EURO1
S. Treusch - hybrid at Daimler - KIT Febr. 2013 - final
Contents

1 Daimler and Daimler Trucks
2 Hybrid at Trucks – System concept, Vehicles and Organization
3 Engineering working direction – Modularity, Components and Controls
4 Other Challenges – Customer and standardization
5 Summary
Fuel consumption is influenced by different things - truck technology is only one lever

Use profile / Infrastructure

- Significant influence

Vehicle technology

- Engineering competence of Daimler Trucks

Driver

- Up to 25% fuel consumption

Vehicle condition

- e.g. tire pressure and condition, correct position of aero devices
As conventional options are becoming scarce, we investigate alternative drivetrain options as well.

*) Synergies within Daimler
S. Treusch - hybrid at Daimler - KIT Febr. 2013 - final
Full electrical drive not an option for trucks in the near future due to low energy density of batteries

### Range

<table>
<thead>
<tr>
<th>Range</th>
<th>Diesel</th>
<th>100% electric with Li-ion battery</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vito</strong></td>
<td>75 Liter 64 kg</td>
<td>0.4 m³ electric with Li-ion</td>
</tr>
<tr>
<td>800 km range</td>
<td>80 km/h Vₚₘₙₓ</td>
<td>130 km range 80 km/h Vₚₘₙₓ</td>
</tr>
<tr>
<td>500 km 12 ton distribution</td>
<td>100 Liter 85 kg</td>
<td>2,6 m³ 5.2 t</td>
</tr>
<tr>
<td>3000 km 40 ton long-haul</td>
<td>990 Liter 837 kg</td>
<td>26 m³ 52 t</td>
</tr>
</tbody>
</table>

**Liquid fuels**

- Diesel
- Gasoline
- Biodiesel
- Ethanol

**Battery types**

- Li-Ion
- Nickel-metal-hydride

**Volume related energy density**

- 10 kWh = ~50l / ~100kg

**Weight related energy density**

- 10 kWh = ~1l / ~1kg

**Factor approx. 60 – 100**

1. (1)
Evaluation of hybrid architectures lead to P2 as most promising option for Trucks

<table>
<thead>
<tr>
<th>Concept</th>
<th>Starter Function</th>
<th>Electric Starting</th>
<th>Recuperation</th>
<th>Boosting</th>
<th>Assembly Complexity</th>
<th>Shunting w/o traction interruption</th>
<th>All wheel drive</th>
<th>ICE operating in the efficient area</th>
<th>E-Drive Clamping Performance</th>
<th>Overall Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>+</td>
<td>--</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3 -</td>
</tr>
<tr>
<td>P2</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>++</td>
<td>7 +</td>
</tr>
<tr>
<td>P1/2</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>++</td>
<td>--</td>
<td>-</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>3 +</td>
</tr>
<tr>
<td>P3</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>4 +</td>
</tr>
<tr>
<td>P4</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>4 +</td>
</tr>
<tr>
<td>P2/3</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>8 +</td>
</tr>
<tr>
<td>Dual-Hybrid</td>
<td>+</td>
<td>++</td>
<td>--</td>
<td>----</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>++</td>
<td>0</td>
<td>2 +</td>
</tr>
</tbody>
</table>

- The P2/3 design is less economical than the P2 design.
- The output of the P3 el. machine (after the transmission) is barely sufficient to exploit the advantages of serial driving and electrical starting. These advantages cannot compensate for the increased weight and costs.
Broad range of vehicles with hybrid technology

- S 400 HYBRID
- Vision S 500 Plug-in HYBRID
- E 300 BlueTEC HYBRID/E 400 HYBRID
- Fuso Canter Eco Hybrid
- Freightliner Business Class M2eHybrid
- Atego BlueTec Hybrid
- Citaro G BlueTec Hybrid
- Freightliner CC Walk-in Van Hybrid
Atego BlueTec Hybrid is the first hybrid series vehicle available in Europe

Till today, about 120 vehicles in the hands of customers

- P2 Hybrid
- 44 kW E-Motor, 420 Nm
- 1,9 kWh Li-Ion battery

- First European series hybrid truck
- Contribution to sustainable mobility
- Fuel Savings of 10-15%
- Significant CO₂-, NOx- und particle emission reduction
- Significant reduction of noise emissions
- Increases know-how in alternative and innovative powertrain applications in Mercedes-Benz Trucks
New Canter TF EcoHybrid represents the second generation of hybrid products at Daimler Trucks

From 2006:
- Canter TD EcoHybrid introduced into market
- More than 1,000 vehicles sold to customers
- First hybrid truck available with Li-Ion battery
- 15-30% improved fuel economy in Japanese applications

From 2008:
- 10 TD Canter EcoHybrid vehicle test fleet in London
- About 450,000 km total testing achieved
- Up to 15% better fuel economy

NEW Canter TF EcoHybrid
- All-new hybrid powertrain based on new Canter TF
- Significant progress
  - Improved performance (Power, Fuel economy)
  - Improved Comfort
  - Reduced weight
  - Reduced costs
Highlights – “DUONIC with Hybrid Motor” Wins 2013 RJC Car of the Year Special Award

- First in History for Commercial Vehicle Manufacturer to Win One of RJC Car of the Year Awards.
- LIFT HEV project will come to QG0 till at the end of this year.

RJC: Automotive Researchers’ & Journalists’ Conference of Japan
Broad HEV portfolio as technology base for future series vehicles – more than 5,500 sold as of today

<table>
<thead>
<tr>
<th>Japan</th>
<th>Europe</th>
<th>NAFTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDT</td>
<td>MB Econic HEV</td>
<td>FL Cascadia P4</td>
</tr>
<tr>
<td>Fuso Super Great HEV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MDT</td>
<td>MB Atego 12t HEV</td>
<td>FL MT45/55 HEV</td>
</tr>
<tr>
<td>Fuso Canter HEV</td>
<td></td>
<td>FL M2e</td>
</tr>
<tr>
<td>MDT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shaping Future Transportation. CleanDrive Technologies.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDT</td>
<td>Fuso Canter HEV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Technology vehicle**
- **Series vehicle**
To ensure the worldwide market success for Trucks, a global development organization is essential.

More than 5,000 engineers worldwide working together on future products and innovations.
Global Hybrid Center Trucks (GHC) delivers hybrid trucks to all Daimler Truck brands worldwide

- **GLOBAL**: All Daimler Truck brands worldwide
  - Mercedes-Benz  
  - Freightliner  
  - Fuso  
  - Western Star  
  - On-Highway Engines

- **HYBRID**: Target configuration is P2 Diesel-electric Hybrid System
  - Focus is main high volume models (and a possible use in bus coach)

- **CENTER** (Trucks)
  - From light duty truck (3.5 tons) to heavy duty truck (40 tons)
  - Standardized powertrain

- Provides **hybrid systems** with
  - standardized, modular components
  - common E/E interface for easy vehicle integration

- Provides **system functionality** for application & calibration in each regional project

- Leverages **global presence** of Daimler Trucks for new technology applications

- Realize synergies within Daimler
Daimler Trucks with integrated worldwide hybrid development to realize synergies

Only the integration of all worldwide hybrid activities in one organization leads to synergies in budget and cost. If this is done right, this allows at the same time vehicles with market and brand-specific benefits. Collaboration and alignment with key-partners leads to further improvements.
私たちは、三菱ふそうの国際的な経営陣として
三菱ふそうとダイムラークライスラーが持つ異なる文化・ビジネスモデル・伝統を互いに認め、尊重するが、新しい三菱ふそうを共に築くために、異なる文化的背景を持つ相手に対応する際は以下のことを考慮する。

日本人以外/ダイムラークライスラー側へのヒント:
1) ディスカッションでは、まず相手の言い分を聞く。
2) 注意: 沈黙は必ずしも合意ではない。
3) 注意: 自分ではアイデア・提案・意見のつもりの発言が、相手には命令と受け取られているかもしれない。
4) 相手の論旨の背景を考えてみること。
5) 結論を急がずに、オープンで同等な立場でのディスカッションを心がける

日本人/ふそう側へのヒント:
1) 言葉にしなければ伝えなかったことにはならない。
   (自分の気持ちや言いたいことを相手が察してくれると期待してはいけない。)
2) 自分の真意を伝えること。 (本音と建前) 
3) 報告をする際は、まず結論から始めること（そのあとに説明）。
4) よくわからない時は質問（確認）すること。
5) ふそうにいるDC派遣者もふそうの一員。
6) 親（株主）に対しても自分の意見は明確に説明すること。

＞英語はドイツ人にとっても日本人にとっても外国語
＞CVDのビジネスユニットは「兄弟」（同じレベルのパートナー）であり「親子」ではない。

＞私たちは同じ船に乗り、共通のゴールに向けて船を漕いでいる
Platform and module strategy to leverage scales in powertrain and vehicles of Daimler Trucks

**Common platforms for all brands**

- Engines
- Transmissions
- Exhaust after-treatment
- Axles
- Cabin
- Chassis
- Mechatronics

**Common powertrain components**

**Shared vehicle modules**
Three systems can cover all Daimler Trucks HEV – components partly scalable

- **High Power System (HPS)**
  - G211 AMT
  - e-motor

- **Mid Power System (MPS)**
  - G90 AMT
  - e-motor

- **Light Power System (LPS)**
  - DATAMT
  - e-motor
Due to yearly mileage, CO2 reduction effect of long-haul HEV is up to 5 times higher than in distribution

<table>
<thead>
<tr>
<th>Light Duty Truck HEV</th>
<th>Based on city delivery application for Fuso Canter (without ESS*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GVW: 5 t</td>
<td>Mileage: 30,000km p.a.</td>
</tr>
<tr>
<td></td>
<td>Quantity of annual CO2 reduction: 2 t</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heavy Duty Truck HEV</th>
<th>Based on long haul application (highway only) for HDT (25t) (without ESS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GVW: 25 t</td>
<td>Mileage: 150,000km p.a.</td>
</tr>
<tr>
<td></td>
<td>Quantity of annual CO2 reduction: 11 t</td>
</tr>
</tbody>
</table>

- Optimized system specification and hybrid control strategy bring high potential of recuperating energy even on highway.
- Actual measurement results on typical Japanese road and application show about 10% fuel consumption reduction compared to the conventional diesel truck.

* ESS = Engine Start-Stop
Hybrid systems consist of different elements

- A hybrid system consists mainly of HV components, cooling and control elements
- Some of these are already today available commodities (like cooling systems), others will be with the increased volumes in the automotive industry (e.g. HV cables, eMotors)
- Only a few are critical for best performance
Various and partly opposing requirements have to be considered for the specification of the HV-Battery

The HV-Battery is a complex component, combining electrical, chemical, mechanical and performance elements. With the boundary conditions in a truck, the right combination has to be defined.

Diagram showing various aspects such as safety, lifetime, cost, ambient conditions, cooling system, vehicle integration, power/energy control, E/E interface, cell type, cell chemistry, and E/E interface.
# Simulation process to evaluate feasible system configuration

- **Energy Analysis**: simulation tool for the basic dimensioning of hybrid systems (dimensioning of power and energy).
- **$I^2t$ limitation study**: process to consider battery limitations and lifetime restrictions
- Consideration of route specific driving/recuperation characteristic

## 1. Route definition

- **Route profile** has to be defined for relevant key-applications

## 2. Power profile by vehicle simulation

- **Power profile** is calculated by vehicle simulation

## 3. Lifetime study

- $I^2t$ is calculated by power profile
- $I^2t$ as limit for battery spec or usage
- If $I^2t$ exceeds the criteria, change to Battery hardware or hybrid control
Depending on circumstances, the fuel effect of a hybrid may even be negative

A hybrid for truck must be carefully selected depending on its usage!
The hybrid control strategy is a major lever for defining the success of a hybrid truck

<table>
<thead>
<tr>
<th>HEV feature</th>
<th>E-Drive</th>
<th>Hybrid drive</th>
<th>Conventional drive</th>
<th>Recuperation</th>
<th>Sailing</th>
<th>Engine start-stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topography</td>
<td><img src="topography" alt="Image" /></td>
<td><img src="topography" alt="Image" /></td>
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<td><img src="topography" alt="Image" /></td>
<td><img src="topography" alt="Image" /></td>
</tr>
<tr>
<td>Battery</td>
<td><img src="battery" alt="Image" /></td>
<td><img src="battery" alt="Image" /></td>
<td><img src="battery" alt="Image" /></td>
<td><img src="battery" alt="Image" /></td>
<td><img src="battery" alt="Image" /></td>
<td><img src="battery" alt="Image" /></td>
</tr>
<tr>
<td>FE* Long haul</td>
<td>![Image](fe* long haul)</td>
<td>![Image](fe* long haul)</td>
<td>![Image](fe* long haul)</td>
<td>![Image](fe* long haul)</td>
<td>![Image](fe* long haul)</td>
<td>![Image](fe* long haul)</td>
</tr>
<tr>
<td>FE* City delivery</td>
<td>![Image](fe* city delivery)</td>
<td>![Image](fe* city delivery)</td>
<td>![Image](fe* city delivery)</td>
<td>![Image](fe* city delivery)</td>
<td>![Image](fe* city delivery)</td>
<td>![Image](fe* city delivery)</td>
</tr>
</tbody>
</table>

- Most relevant features for HD hybrid differ significantly from other applications
Future hybrid functions have to consider engine-off and PHEV functionality

- The focus of hybrid development is today on classic hybrid functionality. Advanced hybrid functions will consider the shut-down of the Engine
- pZE and plug-in operations available in cars, and partly for LDT.
- Additional functionality might be required by the customer (ePTO, ZE), or by law (LEZ-ZEZ).
- In addition, synergies with existing components of other Daimler BU might be possible.
There are many topics than can be evaluated once the hybrid system is realized.
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1. Daimler and Daimler Trucks
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Besides technical challenges, different buying motivations exist - only one is stable for development

• Customers buy a HEV Truck for different reasons. They want to be eco-friendly (e.g. green image), they have to (out of legislation or access restrictions) or because of a monetary benefit (subsidies or by better TCO).

• Most trucks are bought to make money. The decision is simple:
  - how much does it cost?
  - How much do I get (in a reasonable time)?

• Besides legislation effects, a hybrid truck has to deliver real monetary benefit to get high volume.

• At the same time, the usage of the vehicle should not be restricted by the system (same durability, payload, functionality, performance, ...).

• As a result, a hybrid system has to be integrated in a way, that keeps the capability of the truck unchanged.
Das Grund-Dilema einer globalen Elektromobilität sind die unterschiedlichen, hundertjährigen Elektizitätssnetze

- Verschiedene Elektrizitätssnetze haben unterschiedliche Ladesysteme zur Folge

AC Laden Typ 1  AC Laden Typ 2  AC/DC Laden „Combo“ Typ 1/2  DC Laden „Chademo“ etc...

Die Fahrzeughersteller entwickeln die Fahrzeuge in unterschiedlichen Szenarien

Beispiel: Nissan Leaf  AC Laden Typ 1 oder 2  DC Laden „Chademo“  Induktives Laden*
Die Einigung auf wenige internationale Standards reduziert die Entwicklungs- und Produktions-Kosten

<table>
<thead>
<tr>
<th>Region</th>
<th>Aktuelle Situation AC/DC Fahrzeug Inlet</th>
<th>optimales Szenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IEC Combo 1 (AC + DC)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><em>passend für IEC Type 1 (AC) und Combo 1 (AC + DC) Connector</em></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>IEC Combo 2 (AC + DC)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td><em>passend für IEC Type 2 (AC + DC) und Combo 2 (AC + DC) Connector</em></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>IEC Type 1 (AC)</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>CHAdeMO (DC)</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>National Standard (AC)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td><em>GB Part 2, ähnlich IEC Type 2</em></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>National Standard (DC)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>GB Part 3</em></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>National Standard (AC)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td><em>Ähnlich IEC Type 1</em></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>National Standard (DC)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Ähnlich CHAdeMO</em></td>
<td></td>
</tr>
</tbody>
</table>

| Anzahl Varianten | 8 | 2 |

Source: Daimler Corporate Standardization
# Contents

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By continuously reducing cost and increasing the hybrid benefit, the magic moment is close

To reach the “magic” moment, two levers have to be used:

- The **monetary benefit** can be influenced mainly by vehicle development and improvements in operations strategy and vehicle integration. As shown with the different models of Canter EcoHybrid, the performance can be significantly improved by fine-tuning (with unchanged system hardware and cost).

- The system **costs** are directly linked to the volume of hybrid components that depend on the development of the automotive industry and the component specification. Governmental subsidies can help to bring volumes up.

- Today, the magic moment can only be reached with subsidies. This will drastically improve in the next few years.

---

* FE Potential*

| 5 % |  | >20 % |

- system costs

- TCO reduction by HEV

- Monetary Benefit

- Additional vehicle price for HEV

- with subsidies

*: depending on vehicle and application

S. Treusch - hybrid at Daimler - KIT Febr. 2013 - final
Summary

Trucks have specific boundary conditions
- Money driven business (TCO)
- Weight and packaging sensitive
- High variety in vehicles and usage - worldwide

Key success factors for hybrid systems in Trucks
- Optimized, modular system architecture and cost
- Individual operating strategy and seamless vehicle integration
- Strong network for synergies in functions, budget and time
- Target is the best performance/cost ratio!

Boundary conditions / challenges
- Most challenging component: HV battery
- Biggest uncertainty: governmental / City administrations priority
- Standardization as key driver for component cost and volume

Outlook
- HEV is the future for Trucks. But success and schedule are not in engineering responsibility
Thank you!!!