



# hybridisation & electrification of cargo, delivery and utility vehicles

*the quickest and most cost-effective way to lower emissions*

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Connecting Clean Mobility

## SP Innovation: Advanced batteries & (H)EV market

- **High-power / high-energy automotive Lithium batteries**
- **Plug-in Prius demo vehicle**
- **Worldwide 'alternatively propelled vehicle' database**
- **Consultancy/policy-making advice on low-emission transport & battery technology**
  - utilities
  - (local) governments

## Agenda

- 1. Hybridisation of passenger cars and ultra heavy-duty vehicles; a prelude?**
2. Drivers for hybridisation & electrification
3. Advantages and potential of hybrid-electric cargo, delivery and utility vehicles
4. A selection of (to be) available products
5. Summary and conclusions

# Market- and technology developments come both from 'ultra heavy-duty' as well as from light-duty HEVs



## Light-duty hybrid-electric drive trains

- 40-50% growth in 2007
- road experience from 1997
- growth will accelerate
- 1% of light vehicle market

## Medium & heavy duty hybrid drive trains

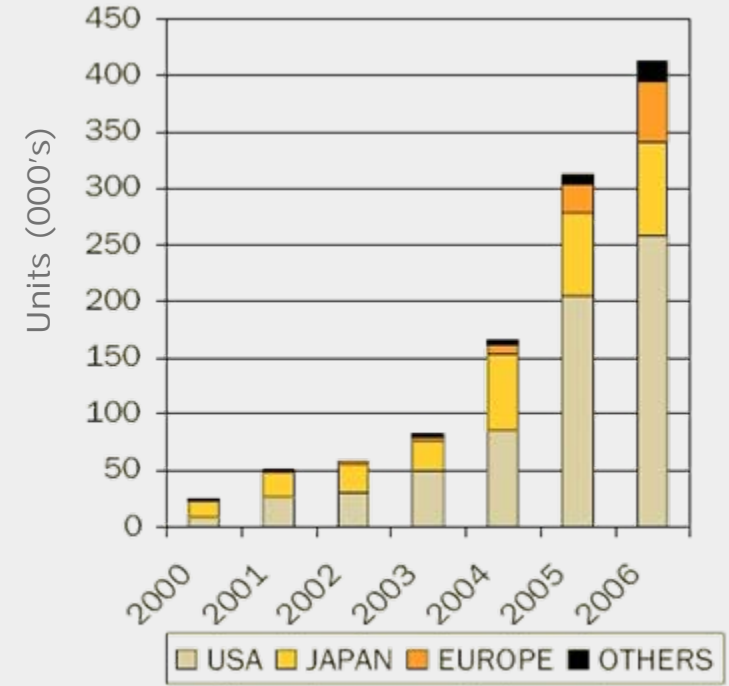
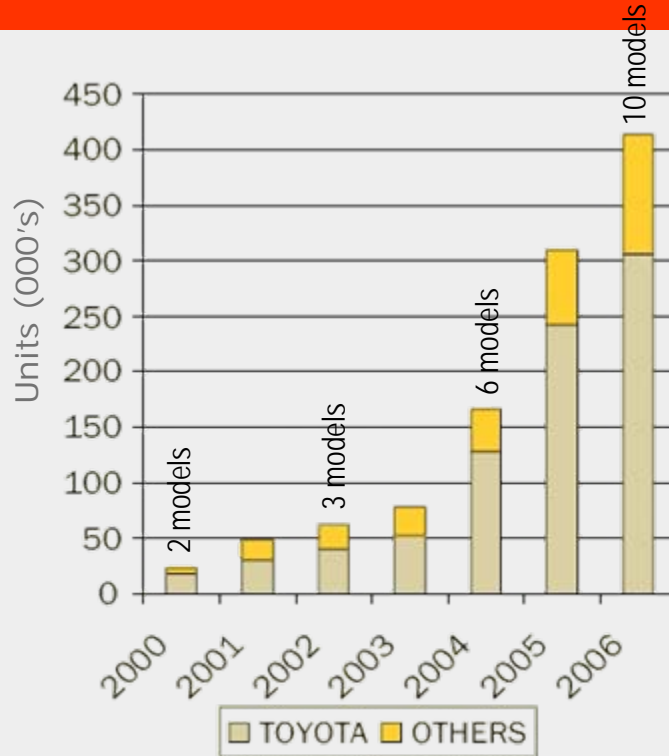


The next high-growth area

## Very heavy duty diesel-electric drive trains

*mature market, proven technology*

## Hybrid-electric passenger vehicles are on the rise: Toyota set the trend, other OEMs are now following



Source : The HEV market 2005-2015, Impact on the battery business , AVICENNE, Dec 2006

- 2007: 13 models, ±600k HEV sedans and light trucks (1% of global market)
- Up to now, only 3 main manufacturers: Toyota, Honda, Ford
- But many OEMs have announced HEV models at Frankfurt autoshow, available from 2010

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## Technology, (geo-)politics, economics, air quality and public awareness are driving vehicle electrification

### 1. **Technology: substantial progress in the last 10 years**

- battery technology
- electric motors and power electronics

### 2. **Geopolitics: Developed World is too dependent on M.E. oil**

US: reduction of oil consumption is a strategic goal.

### 3. **Economics**

Hybrid and pure electric drive train technologies reduce primary fuel consumption between 20% and 60%.

### 4. **Air quality**

Increasingly, air quality is a concern in urban areas.

### 5. **Consumer awareness**

Having 'smelled' alternatives, the general public will demand (hybrid-) electric vehicles.

## Technology has made substantial progress in the last 10 years, which facilitates hybridisation/electrification

*"Electrification will reduce the complexity of drive trains significantly"*

### 1. The latest generation of electric motors are small, light, efficient and powerful



UQM electric motor for (H)EV

- 75kW (100hp) peak power
- brushless, permanent magnet
- 40kg
- 28cm diameter

### 2. Latest generation of batteries: safe, light, fast- (and often) chargeable and environmentally friendly



Latest generation of Lithium batteries is very robust

- some types allow full charging in under 10 minutes\*
- some types have a cycle life of >15,000 full cycles\*

\* at the expense of energy density

## (Geo-)politics

- **All Western countries –especially the US- are looking for ways to reduce oil dependence**

Bush in 2006 state of the Union: *"By applying the talent and technology of America, this country can dramatically improve our environment, move beyond a petroleum-based economy, and make our dependence on Middle Eastern oil a thing of the past."*

- **(Local) governments set targets for the reduction of CO2**

"In a modern world city, people should have the opportunity to live and work without fear of being poisoned by the air they breathe. Thousands of Londoners suffer ill-health from pollution released by traffic fumes.

This is why we are launching the London-wide Low Emission Zone."

*Ken Livingstone, Mayor of London*

- **Politicians gain votes by 'cleaning up' road transport**
  - London: congestion tax
  - New York: Hybrid taxis and buses
  - Amsterdam: CityCargo

## Public awareness

"The hybrid bus is quieter, and rides and accelerates smoother than a standard diesel bus."

*Passenger survey of  
Baltimore Region (US)  
Hybrid Bus Test*

- **Hybrid vehicles feel more advanced, modern, convenient**

- passenger
- operator
- passer-by

"Once you have paid attention to a hybrid or electric vehicle drive off from a traffic light, you start to realise how pre-WWII the old situation was."

*Inhabitant of London's Low  
Emission zone*

- **Inner-city exhaust fumes will be out of fashion**

Inner-city exhaust fumes will increasingly be experienced as 'old-fashioned' and 'not done', and will be banned from city centres (in analogy to smoking).


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## Hybridisation / electrification has the potential to substantially reduce (inner-city) emissions

- **Hybridisation is especially beneficial for vehicles with a highly varying load on the drive train (many start-stops)**

increasing benefit of hybridisation

- 
- Long-haul cargo
  - Public transport
  - Delivery
  - Utility (e.g. cleaning, garbage collection)
  - Construction

hybrid bus: 25-35%

hybrid utility/construction equipment: 50-60%

- **Lower fuel consumption; typical 25-35% (up to 60%)**

PM: -90%

NOx: -40%

CO: -50%

- **Reduction of up to 90% in PM emissions is possible**

- **Reduction of noise as an added benefit**

- **Next evolution in hybridisation will enable reductions of local emissions up to 100%**

- 'green zone' hybrids
- plug-in hybrids

## HEVs with larger batteries that can be charged from the grid are a logical evolution: 'Plug-in Hybrids'

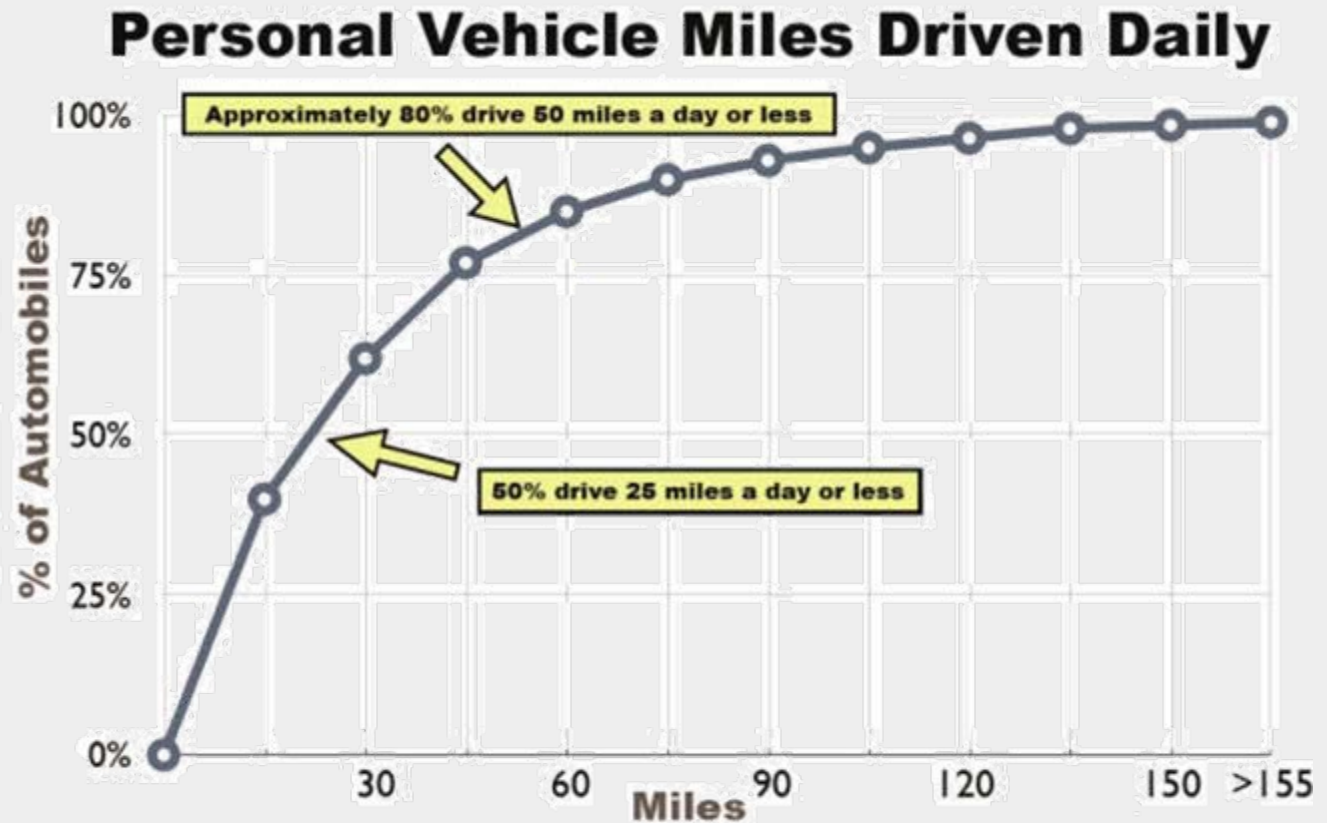


*Plug-in Prius (SP Innovation company car)*



*GM Volt: Plug-in hybrid for 2010?*

HEVs with larger batteries that can be charged from the grid are a logical evolution: 'Plug-in Hybrids'



Source: U.S. Department of Transportation, Federal Highway Administration, 1990 Nationwide Personal Transportation Survey (NPTS), Volpe National Transportation Systems Center, Cambridge, MA, 1999. Nationwide Personal Transportation Survey 1990

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## Hybrid drive trains in public transport



Phileas (NL)



Eletra Hybrid (Brasil)



Nabi 60-BRT Hybrid (US)



FAW Hybrid (China)

- $\pm 20$  hybrid bus manufacturers Worldwide, fewer proprietary drive trains
- Daimler is leader in hybrid bus sales (1,500 Orion buses on the US roads)
- Most hybrid buses in US, both deployment and manufacturing  
*US drive trains come from BAE systems (series) or GM Allison (parallel)*
- EU lagging behind in hybrid bus adoption (but many CNG buses)
- Also hybrid bus manufacturers in developing countries (China:3, Brasil:1)

## Hybrid drive trains in utility & construction vehicles



**Eaton Hybrid Aerial Lift truck (US)**



**Renault concept hybrid garbage truck**



**Kobelco (Jp) hybrid excavator (prototype)**



**A Mack Granite® diesel-electric hybrid truck**

## Hybrid drive trains for cargo vehicles



**Autocar (US) E3 RunWise  
Hydraulic Start-stop Hybrid**



**Kenworth / DAF (PACCAR)  
Hybrids**



**Peterbilt (PACCAR)  
Start-stop Hybrid**

- **Long-haul cargo: Mostly start-stop (mild) hybrids**
- **PACCAR seems to be the furthest ahead**
- **Daimler announced the production of 1,500 hybrid M2 Freightliner trucks in three years**

## Hybrid drive trains for delivery vehicles



**UPS hydraulic hybrid**



**Eletra (Brasil) diesel-electric hybrid**



**Nissan / Isuzu H43 Diesel-electric Hybrid**



**VehiZero hybrid-electric van (Mexico)**

## Full-electric delivery vehicles; specifications suffice for inner-city delivery purposes



*Smith Electric: 3.5t payload, >200km range*



*MODEC: 2t payload, 170km range*

- Inner-city distribution increasingly electric
- UK –especially London- is leading
- Batteries 50-100kWh

## Larger plug-in hybrid drive trains emerging



**Dodge Plug-in Hybrid  
Electric Sprinter  
(electric range: 30km)**



**Odyne Plug-In Hybrid Aerial  
Lift Truck  
(8-hour zero-emission  
operation)**



**Plug-In Hybrid Electric  
School Bus**

## Technology choices observed

- Most manufacturers of 'larger' hybrid-electric vehicles choose *parallel diesel*-electric configurations.
- However (I), the largest fleet of diesel-electric hybrid vehicles is based on the *series* Hybridrive system by BAE.
- However (II), the higher torque of hybrid systems makes the fuel choice more ambivalent, which is why we see *gasoline-powered* 'large' hybrids emerge.
- Some companies are experimenting with hydraulic hybrids.
- A wide range of batteries is still in use, but a gradual shift towards Lithium-based batteries is expected and observed.

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## **Hybridisation of medium- and heavy duty drive trains is technically feasible, very effective and economic**

- **There is enough 'proven' technology to show that 'larger' hybrid vehicles are possible and lead to good results**
- **Preliminary data on large-scale production costs shows that fuel savings would justify the higher costs of these larger hybrids**
- **The US is leading the way, both in the number of vehicles in operation, as well as in the number of manufacturers that are developing hybrid vehicles**
- **The technology is ready for scale-up, although there is relatively little experience (<2 years) with the latest generation of Lithium batteries**

## Conclusions/recommendations

- **Hybridisation is by far the most (cost-) effective and certain way of reducing emissions;**
  - *hybrid-electric is the most economic lower-emission drive train*
  - *technology is proven and closest to market*
  - *no infrastructure issues (such as with CNG or H2)*
  - *best cost/CO2-reduction ratio (most efficient use of taxpayer's money)*
- **EU governments should absorb the –temporarily- higher costs associated with hybrid-electric drive trains**

### On Compressed Natural Gas (CNG)

A study by NREL for the City of New York has resulted in a clear choice for hybrid buses over CNG: The hybrid buses were more fuel-efficient (by 100%) and had lower maintenance costs.

*Source: "New York City Transit (NYCT) Hybrid (125 Order) and CNG Transit Buses Final Evaluation Results". R. Barnitt National Renewable Energy Laboratory K. Chandler (November 2006), p39*

### On Hydrogen

"For the foreseeable future, hybrids are the best available solution for maximizing fuel economy and reducing emissions at an affordable price."

The well-to-wheel efficiency of fuel cell vehicles is 30% lower than that of hybrid-electric vehicles.

*Source: "hybrids or hydrogen?" (Toyota Hybrid Synergy View Newsletter)*

# QUESTIONS / COMMENTS

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