



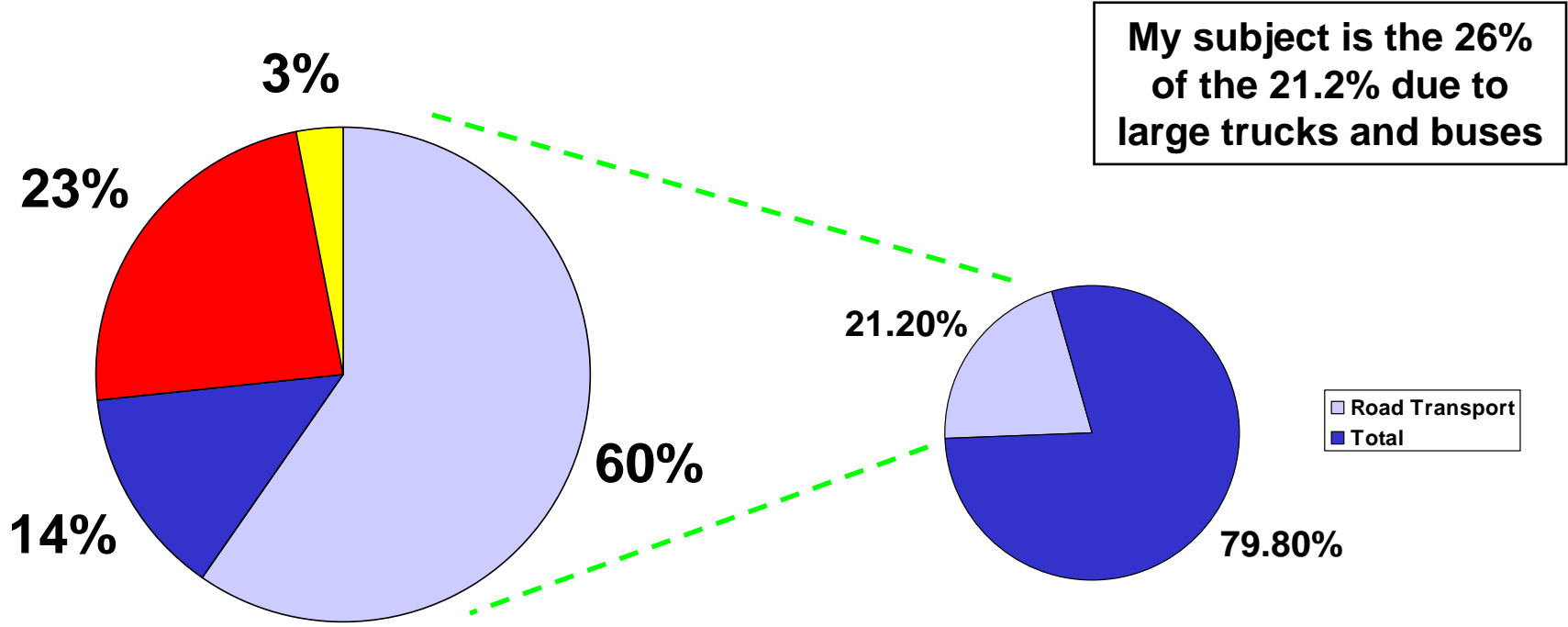
Hybrid Technology in Trucks and Buses

Adrian Wickens

Product Planning, Volvo Bus Ltd



UK Carbon Emissions from Road Transport



152.5 M tonnes Carbon UK Total
32.4 M tonnes from Road Transport
8.6 M tonnes from HGV and Bus&Coach
Information from House of Commons
Environmental Audit Committee

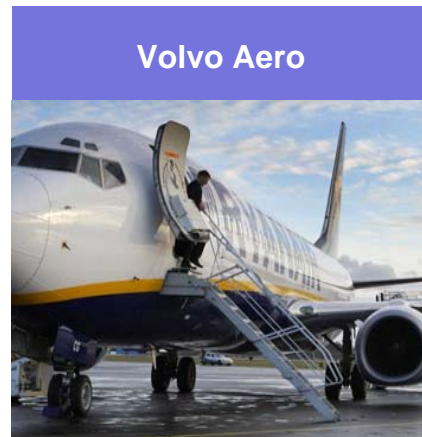
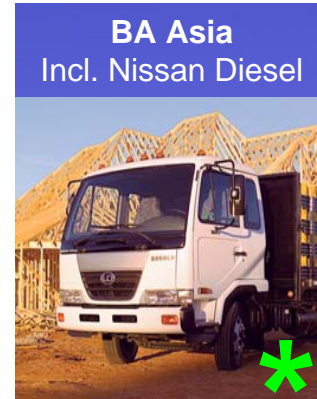


Preview

- Trucks and Buses are Capital Equipment
- For the Manufacturer....
 - Economies of Scale
 - Return on Investment
 - Amenable to the Aftermarket Network (“One Stop Shop”)
- For the Operator
 - Return on Investment
 - Reliability and Confidence
 - No Cost Surprises
- Investment Horizon
 - Payback within 2-5 years



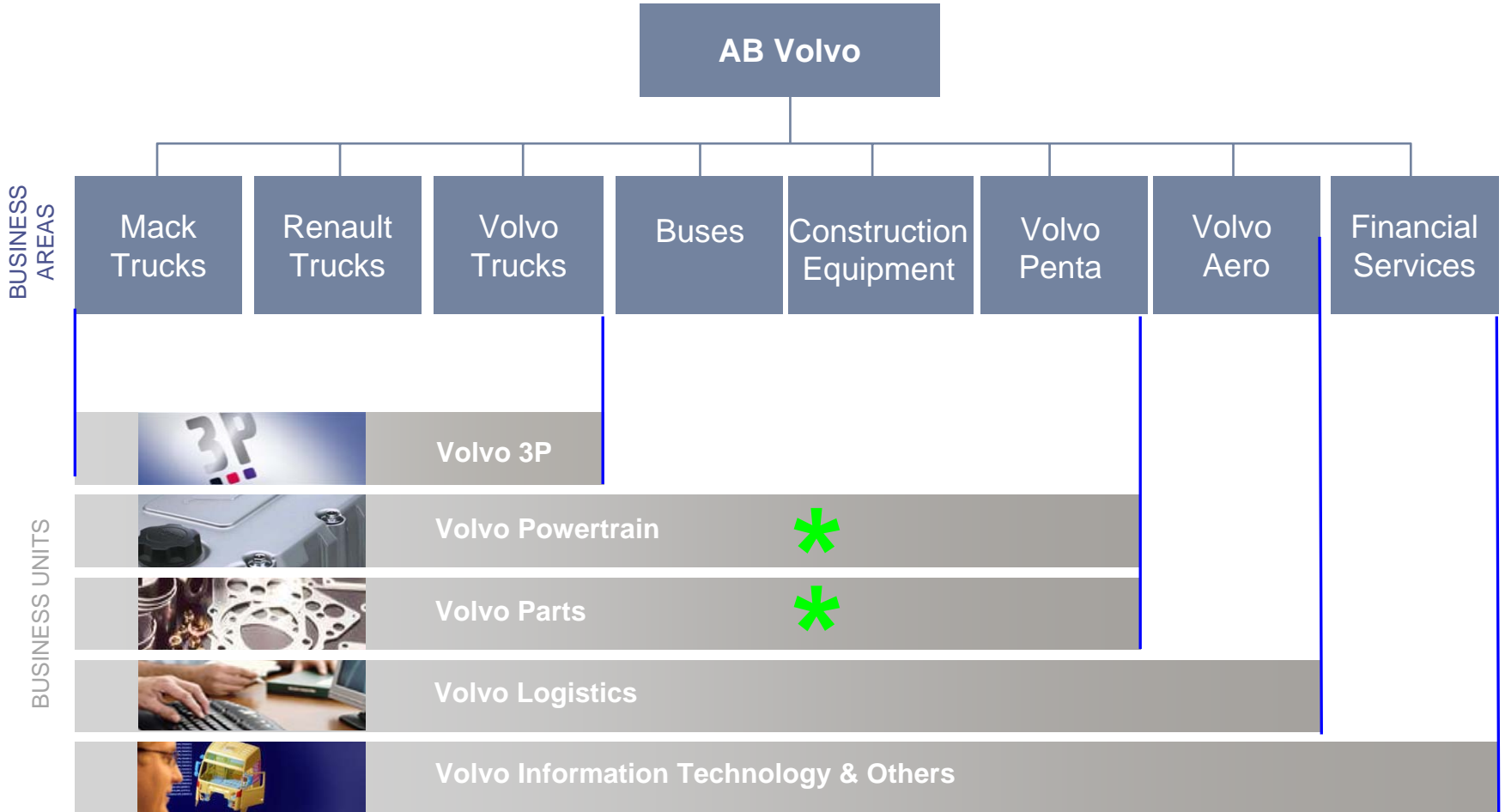
Volvo Group: Business Areas



* Hybrid Potential as we see it today



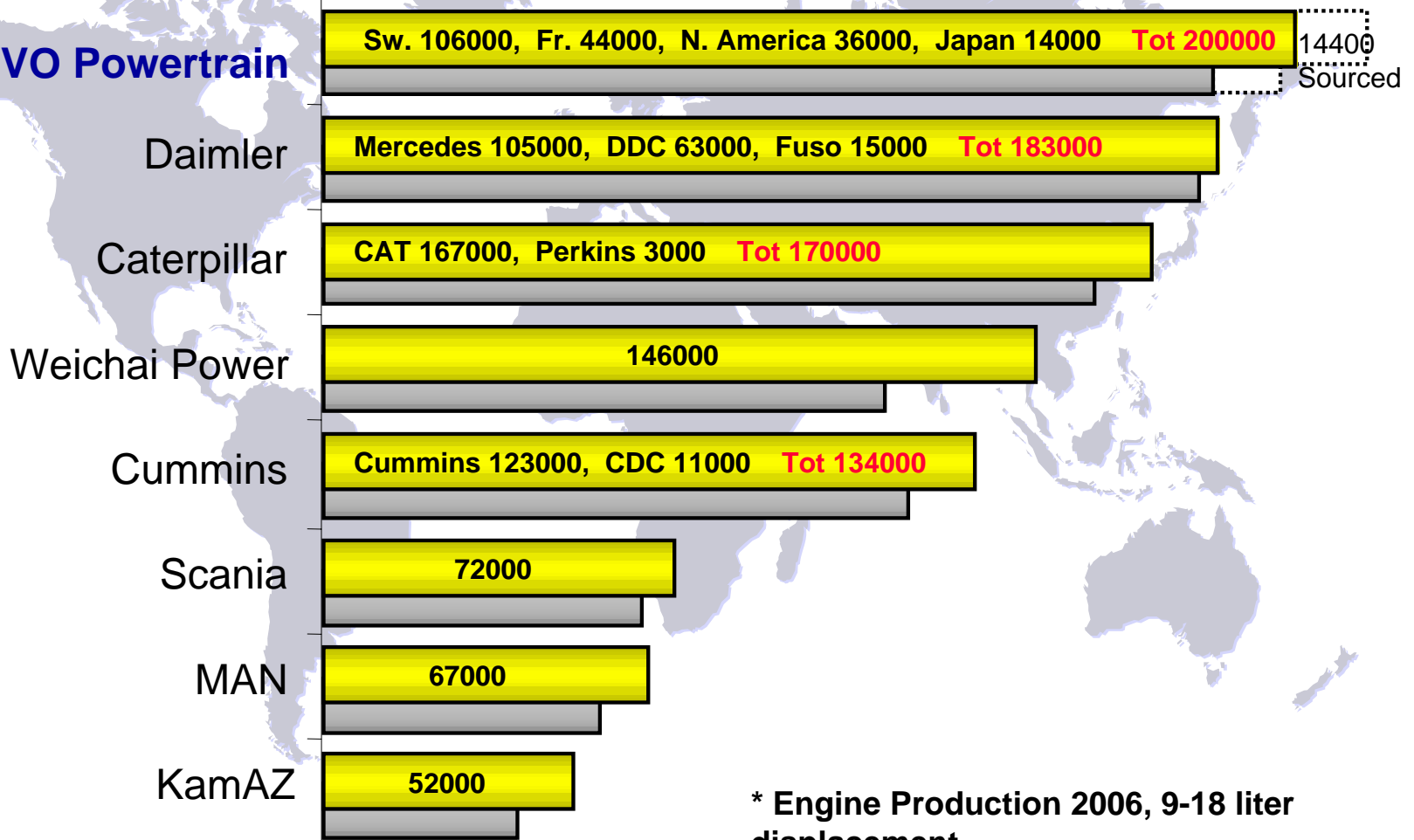
Volvo Group organisation





Heavy Duty Diesel Engines Production*

VOLVO Powertrain



**Grey bars = Year 2005
Production Volume**

*** Engine Production 2006, 9-18 liter displacement**

(excluding licensees / minority JV's) Source: Power Systems Research



Driveline Thinking: Europe vs. North America

Europe

- 6 Main Truck/Bus Producers
- Vertical Integration
- In-house Engines
- In-house gearboxes (some)
- Parts and Service through dealer network
- In-house Hybrids and systems from Suppliers

North America

- Proprietary Components
 - Engine
 - Gearbox
 - Axles
- Unique Components
 - Cabs
 - Chassis
- Parts and Service mixed
- Hybrid Packages from “Suppliers”



Gearbox Thinking

Urban

- Automatic gearboxes for reduced wear (torque converter)
- No clutch to damage
- Lower efficiency
- Special demand for comfort on urban buses

Long Haul

- Manual gearbox for fuel economy
- Move to automated “manual” gearboxes, the AMT
 - Coach
 - Truck
 - Volvo Urban Hybrid



Volvo Hybrids from the past: 1986

- Diesel-Hydraulic Drive
- Hydraulic Accumulators for Energy Recovery
- 30% fuel consumption reduction on trial in London
- Dismantled and converted to regular driveline



Photo Ian Smith, Ian's Bus Stop



Volvo Hybrids from the Past 1996



- Gas Turbine/Electric
- Methanol Fuelled
- Hydraulic Active Suspension
- 4 Wheel Steering
- Central Driver Position
- Now in the Volvo Museum





Hybrid Buses in North America

- Diesel is 38 p/litre on the forecourt
- Standard Urban Buses achieve around 2.8-3.0 mpg (UK > 5 mpg)
- Fuel Savings of 25-30% are being seen
- >1000 Hybrid Buses in Operation
- Air Quality Improvement is a key driver
- US Federal Funding is another encouragement





Commercial Vehicle Auxiliary Systems

- Compressed Air: Brakes, Suspension, Doors (Bus)
- Hydraulics: Power Steering, Cooling Fan Drive (Bus)
- Electrics: Lighting, Control Systems; Bus use includes Saloon Lighting, Destination Indicators, Comms., CCTV, In Coach Entertainment, Air Conditioning
- Mechanical: Air Conditioning Compressor
- Engine driven systems mean low performance at idle or low engine speed
- Saloon heating From engine cooling water (when the engine is running!)



Two Fuel Saving Opportunities

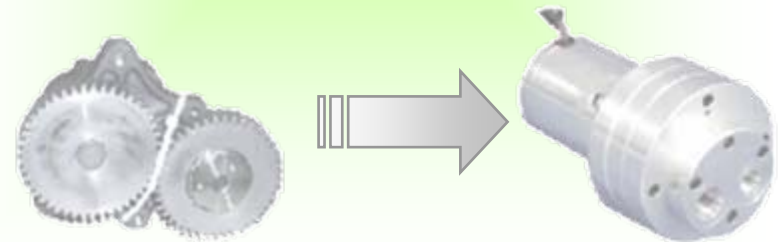
Hybrid propulsion

- **Electric hybrids**
 - provides power & torque assist
 - recover brake energy
 - zero emission / silent mode
 - non idling functionality (at bus stops for example)
 - engine downsizing



Alternative drive of engine and vehicle auxiliaries

- **Electric auxiliaries**
 - are easier to control
 - are only driven when needed
 - are driven at optimal working points independent of engine speed
 - have minimum idling losses





The Volvo Group Hybrid – Layout

Vehicle Control

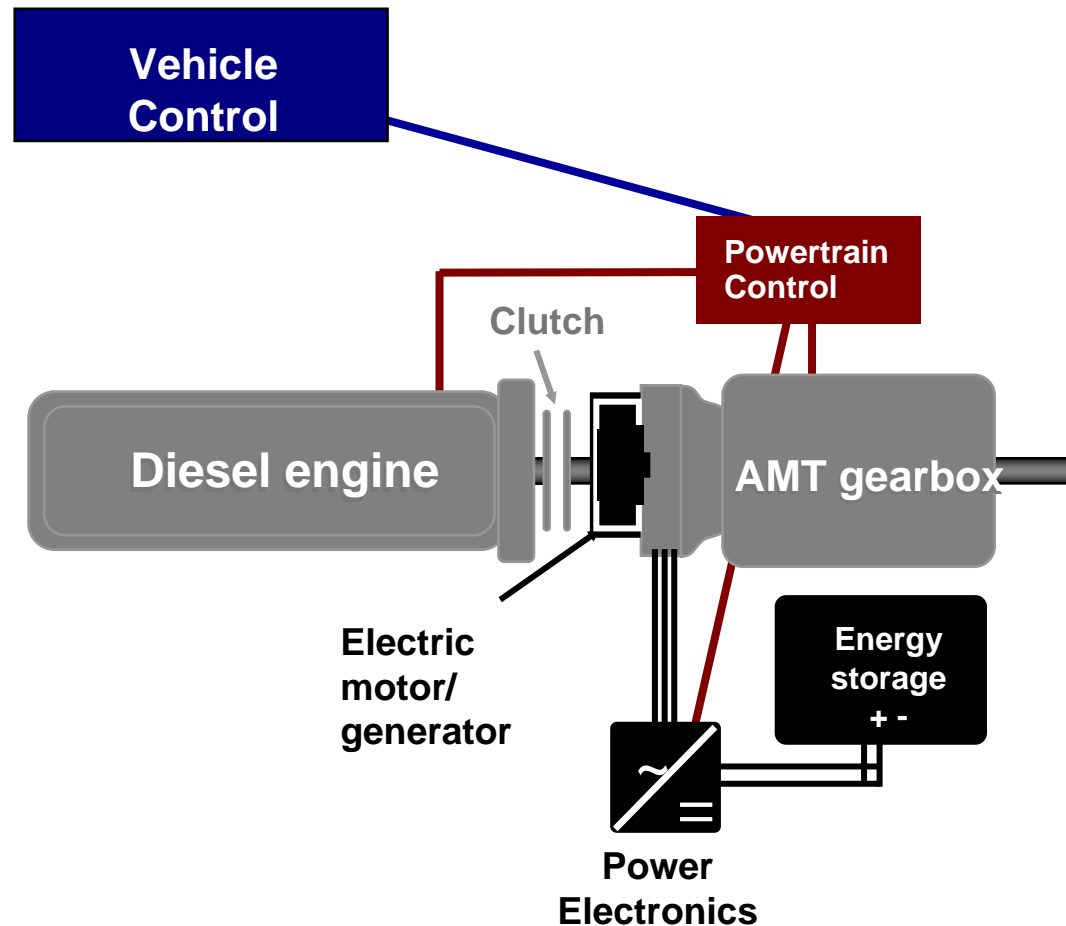
Powertrain Control

Conventional driveline

- Diesel engine for fossil fuel/bio-fuel
- Auto Manual Transmission
- Clutch

Electric driveline

- Electric motor/generator
- Power electronics
- Energy storage





Hybrid Prototype at NEC Show 2006



- Exhibition Debut
- Announcement of UK Hybrid Project





Potential fuel saving



25 - 35 %

Refuse truck

5 - 8 %



Long haul truck



20 - 35 %

City bus

20 - 50 %



Wheel loader

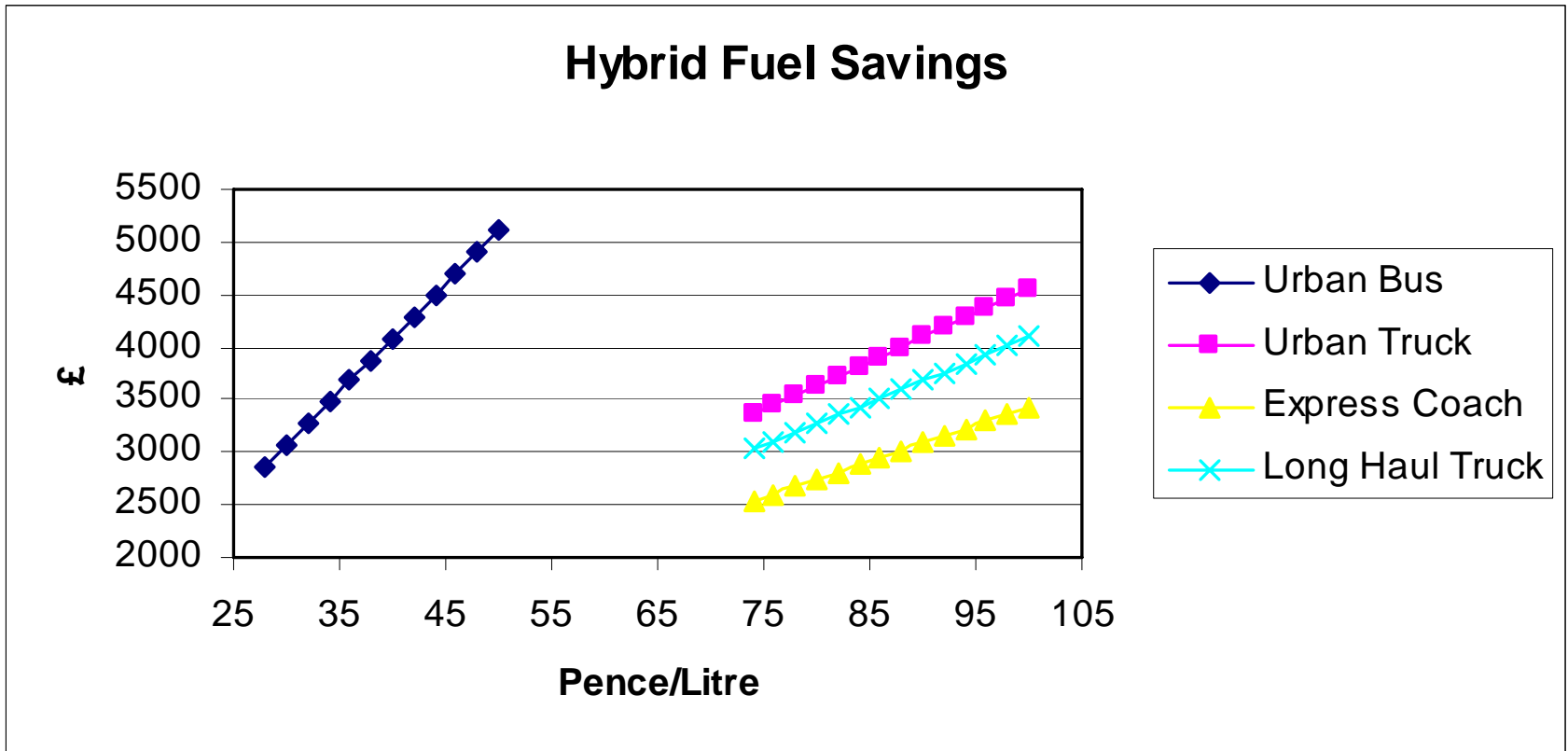


Worked Hybrid Examples from the UK

Application	Long Haul Truck	Suburban Truck	Long Haul Coach	Urban Bus
Annual Mileage	120000	50000	132000	38200
Fuel Consumption (mpg)	8	12.5	10.5	5.1
Litres Per Annum	68190	18184	57150	34045
% Hybrid Fuel Saving	6%	25%	6%	30%
Litres Saved	4091	4546	3429	10213
Saving at 80 p per litre (36 p per litre for urban bus)	£3270	£3637	£2743	£3677
VED Saving (RPC Euro 5 only)	£500	£370	£165	£335
Carbon Dioxide Reduction (Tonnes)	11	12.3	9.3	27.6
Social Benefit (@ \$85/tonne)	£469	£521	£393	£1172



Return on Investment?





Bus Funding in England

- “The Two Billion Pound Subsidy”
 - BSOG £350 M (“Fuel Duty Rebate”)
 - Concessionary Fares £500 M
 - Bus Support £950 M (for non-commercial routes)
 - Total £1.8 Bn

- Of which London £660 M approx.

- Outside London, Bus operation is deregulated
- Approx. 85% of the network is commercially operated



What Next in the UK?

- Get Hybrid Experience
 - Determine impact on maintenance costs
 - Battery Life/Replacement/Recycling
- Establish the Business Case for the Operator
- Transport for London
 - 800 Hybrid Buses on the road by 2012
 - Hybrids only from 2012 on new tenders
- But outside London...
- Do not push up the price of fuel to make the economic case!
- Be careful with changing BSOG
- Make the Hybrid a sensible investment, not a subsidy drain
 - Some Start-up Support may be necessary



What Next for Volvo?

- 8 Hybrid Test Buses
 - 2 Single Deckers in Sweden
 - 6 Double Deckers in London (2008)
 - Test and Proving
 - Programming and adapting to the Route
- Hybrid Truck Programme in development
- Construction Equipment applications
- Series Production Target is end 2009

- Confirm the Business Case for our Shareholders



Hybrid Buses Cannot Save The World

- 20,000 Double Deckers on the road
- 27 tonnes of Carbon Dioxide per bus per annum saving
- 147,000 Tonnes of Carbon per annum saved
- This is worth £6.2 M to society
- < 0.1% of UK total
- If each bus could carry the users of just 6 more cars*.....
 - > 200,000 tonnes of carbon could be saved.....
- How?
 - Congestion charging
 - Road Use Charging

* cars with an average of 168 g/km of carbon dioxide
Average rush hour car occupancy is 1.39 in London
Current average bus load in London is 15 passengers