General

Over a century ago in the U.K., omnibus was already purpose-built double-deck. Since then double-deck buses have become an indispensable part of public transport in the country until this very day. With British influence, in 1949 Kowloon Motor Bus (KMB) of Hong Kong introduced the first double-deck bus into the territory, unveiling the chapter of double-decker bus being the backbone of road public transport. The unique conditions for operation of public buses in Hong Kong, such as the combinations of hilly terrain, frequent start-stop, over-loading, high ambient temperature and relative humidity and the demand for air-conditioning, are onerous and these have made the task of developing reliable and durable double-deck buses particularly challenging for the bus suppliers at all times.
Alexander Dennis (ADL) is one of the very few companies successful in supplying double-deck buses to Hong Kong consistently. Its Loline double-decker model delivered to China Motor Bus in 1962 was the first double-deck bus on the roads of Hong Kong Island. 13 years later, from 1975 onward it supplied hundreds of units of Jubilant, the bespoke front-engine model tailored proprietarily for the Hong Kong market, and became a principle double-deck bus supplier for the territory. The subsequent breakthroughs of three axle, air-conditioning, low-floor, step-free and others ADL has never been absent from. With the success of and reputation in Hong Kong, ADL has expanded its business beyond the U.K. and Hong Kong, to North America, Oceania and Middle East.

In the past, ADL fabricated both complete chassis and body components in the U.K. and shipped them abroad. Nowadays it shifts the production to location close to the market in order to reduce cost in labour and transport, while the engineering and product development remain in the U.K. For instance, the current Enviro 500 Next Generation chassis supplied to Hong Kong are fabricated in Malaysia using locally sourced steelwork, and the assembly of bus body is done in Zhuhai of Guangdong Province in the mainland China, where is 200 kilometres from Hong Kong.

With the generous support of ADL, for the first time ever for the learned societies in Hong Kong, a 23 member delegation of ASME Hong Kong Section and Institution of
Mechanical Engineers Hong Kong Branch visited the bus body assembly workshop in Zhuhai on 23 December 2014 (Saturday) and appreciated first-hand the process of double-deck bus body assembling from start to finish.

The Company

Formed in 2004, ADL is a U.K.-based supplier of completed buses and coaches comprising three (3) brands, namely Dennis, Alexander and Plaxton. Established by the Dennis Brothers, Dennis first built pedal-bicycles in Guildford, Surry, in 1895 and then motor-cycles and, moved into the bus market and built its first bus in 1903. In Falkirk, Scotland, Walter Alexander was a bus operator and, in 1924 it started to build bus bodies for its own fleet and became a major bus body supplier in the country. Plaxton in Scarborough, commenced coach building in 1924 and continues constructing coaches in the North Yorkshire city. Today ADL headquarters in Falkirk with body and chassis assembly as well as body engineering at the same site, while Guildford associates with chassis assembly and engineering.

ADL engages local contractors to fabricate chassis and assembly bodies abroad. In the fulfilment of orders from Hong Kong and Singapore, ADL contracts Zhuhai Granton Bus Limited (Granton) to assemble bodies with structural components procured and packed from Falkirk. ADL has worked with Granton since 2012. Started with one (1) production line, now it has four (4) production lines outputting 14 completed vehicles per week. In 2014, ADL delivered over 600 double-deck buses to Hong Kong alone, in addition to 101 units for fulfilling the order of 199 buses from SMRT Corporations in Singapore. To meet the demand, 95 staff members (excluding the spray shop workers) from various provinces of China work 48 hours per week.

Engineering and Bus Technologies

Sheer size of Granton’s workshop for assembling ADL Enviro500 buses (Jimmy Lee)
Source of Materials

Though assembled in China, ADL emphasises its bus bodies are designed and manufactured in the U.K. Currently all aluminium alloy-made structural members are machined, by either extrusion or CNC, in the U.K. and packed in Falkirk, as well as the jigs on which the components are assembled to become sub-sections. Nevertheless, non-structural components such as glasses and glass reinforced plastic-made (GRP) interior kits, have been sourced locally. Localisation of supply of structural members and other materials currently from the U.K. are actively explored.

Model Evolution

The ADL buses assembled by Granton are the three (3) axle Envior500 Next Generation (NG) model, which evolution is abstracted as below:-

<table>
<thead>
<tr>
<th>Model</th>
<th>Trident</th>
<th>Enviro500 (first generation)</th>
<th>Enviro500 NG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>1997</td>
<td>2002</td>
<td>2012</td>
</tr>
<tr>
<td>Emission</td>
<td>Euro II</td>
<td>Euro III</td>
<td>Euro V</td>
</tr>
<tr>
<td>Features</td>
<td>First generation super-low floor entry</td>
<td>Disc-braked front axle • Wider body</td>
<td>Lower weight • Higher seating capacity • All round disc-braked ZF-made axles • ZF Ecolife transmission</td>
</tr>
</tbody>
</table>
In the development of NG, ADL communicated with customers and referenced their experiences of operating the preceding model in the past ten (10) years. 50 reliability issues were identified and numerous improvements are as a result found on NG, for instance:-

- the cooling system was reconfigured with remote mounted thermostat and aluminium radiator to facilitate better cooling effect;
- the originally Dyner-supplied axles were bespoke design and difficult in parts sourcing and replaced by ZF-made standard products;
- all axles were fitted with disc brakes;
- the engine compartment was designed to accommodate Euro VI engine in future, and integrated with chassis for better performance in heat insulation and noise abatement;
- electronic brake and “bus-stop” brake were adopted for saving of compressed air and hence minimising the loading of compressor and extending compressor life;
- the compressor inlet was deployed with cooling coil in reducing air inlet temperature for the protection of water ingress into the air system.

**Engine and Emissions**

The current NG is good to Euro V emission standard in reducing nitrogen oxide (NO\textsubscript{x}) emission, which is attained by Selective Catalytic Reduction (SCR). Aqueous urea is heated to become ammonia which reacts with NO\textsubscript{x} in the exhaust gas formed during combustion to become nitrogen gas and water vapour discharged at the tail-pipe.

An alternative is Exhaust Gas Recirculation (EGR). Since the generation of NO\textsubscript{x} is proportional to the combustion temperature, in EGR, part of the exhaust gas is recirculated into the combustion chamber to reduce the oxygen level in combustion;
thus suppressing the combustion temperature and NO\textsubscript{x} formation. Soot, or carbon particles causing “black smoke” for diesel engines, is processed by Diesel Particular Filter, in which Continuously Regenerating Trap is fitted to decompose soot with nitrogen dioxide catalysed by platinum, at temperature lower than the engine combustion temperature to become carbon dioxide (CO\textsubscript{2}) gas and water vapour.

Euro VI demands more stringent tightening on NO\textsubscript{x} emission and is complied with only by the adoption of both SCR and EGR in conjunction with variable turbo-charger geometry in provision of higher back pressure for the turbo-charger at low speed. Slip Catalyst is also deployed to recover the unreacted ammonia, or ammonia slip, in SCR before reaching the tail-pipe. The new Euro VI-compliance system weights 86 kilograms will be packed in the space reserved for which in the engine compartment.

**Pursuit of Low-Carbon Emission**

Every litre of diesel emits 2.65 grams of CO\textsubscript{2} and ADL tenders a number of means in fuel saving and hence further reduction of CO\textsubscript{2} emission:-

<table>
<thead>
<tr>
<th>Means</th>
<th>Feature(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration Rate Management</td>
<td>Limit acceleration rate to 1.2 m/s\textsuperscript{2} (in the case of operations in London, the U.K.)</td>
</tr>
<tr>
<td>Idle shut-down</td>
<td>Shut-down engine when the vehicle idles in depot for longer than certain time</td>
</tr>
<tr>
<td>Telemetry</td>
<td>Real-time display of driving parameters in facilitation of fleet management</td>
</tr>
<tr>
<td>Driver reward scheme</td>
<td>Material award in promotion of fuel-saving-conscious driving behaviour, translating into maximum 50% fuel save</td>
</tr>
<tr>
<td>Weight saving</td>
<td>Lightweight of vehicle</td>
</tr>
<tr>
<td>Driveline specification</td>
<td>Optimised selection of gear ratio in suiting operating conditions</td>
</tr>
<tr>
<td>Transmission features</td>
<td>Topographical software on gearbox to optimise gear selection</td>
</tr>
<tr>
<td>Tyres</td>
<td>Suitable tyre profile and pressure in minimising undesired road frictions</td>
</tr>
<tr>
<td>Hybridisation</td>
<td>Switch of electric drive-line of vehicle</td>
</tr>
</tbody>
</table>

Amongst the above, ADL subscribes and has invested heavily in hybridisation for achieving lower carbon emission. From the first delivery to the U.K. and Australia in 2008 and 2010 respectively, to June 2014 ADL delivered 686 hybrid buses operating on three (3) continents, and 162 vehicles were on its order book in mid-2014.

**Hybrid Power-Train**

Out of the two (2) hybrid power-train modes, parallel and series which features are compared below, the model supplied to Hong Kong, Enviro500H, adopts the latter mode:-

<table>
<thead>
<tr>
<th>Feature</th>
<th>Parallel Hybrid</th>
<th>Series Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical link between</td>
<td>Retained</td>
<td>No link</td>
</tr>
</tbody>
</table>

ASME-HKS cum IMechE-HKB Technical Visit to ADL Zhuhai on 13/12/2014  Page 6 of 13
Hybridisation of buses, according to ADL, achieves better fuel economy by enabling engine to down-size [from about ten (10) litre to 6.7 litre] and recovery of braking power (as much as 200 kilo-Watts), which is transformed into heat and dissipated during deceleration, in electrical form stored into batteries. In a case of U.K. operation, while the hybrid bus was principally stopped by regenerative braking, the base brake was rarely used that the original brake pads broke because they were not maintained by sufficient braking heat.

Notwithstanding the advantages of lower emissions, smoother acceleration and deceleration and quieter operation, hybrid buses are concerned by the additional cost and weight (about 300 kilograms heavier than conventional power-train model), on-board high voltage, battery life and others.

ADL adopts BAE System-developed electric-drive package in hybridising buses. The package comprises generator coupled with the engine, 600-volt motor, battery and control system. Being a dictating factor of the performance of hybrid bus, the high-power density-domain energy storage system is with technical features tabled as below:-

<table>
<thead>
<tr>
<th>Particular</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>11.6 kWh</td>
</tr>
<tr>
<td>Power</td>
<td>200 kW peak</td>
</tr>
<tr>
<td>Voltage</td>
<td>635 volt nominal</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>From -10 ºC to 52 ºC</td>
</tr>
<tr>
<td>Length</td>
<td>2,170 mm</td>
</tr>
<tr>
<td>Width</td>
<td>1,026 mm</td>
</tr>
<tr>
<td>Height</td>
<td>304 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>365 kg</td>
</tr>
<tr>
<td>Coolant</td>
<td>Forced ambient air</td>
</tr>
<tr>
<td>Construction</td>
<td>16 replaceable lithium-ion modules in single air-cooled enclosure</td>
</tr>
<tr>
<td>Design life</td>
<td>Six (6) years above</td>
</tr>
</tbody>
</table>

In light of the fact that some depots may not have charging infrastructure, the ADL hybrid is charge neutral (no provision of external charging of on-board battery). The system, which is turn-key supplied by BAE System, functions fully automatically, offering indistinguishable driving experience in comparison with conventional vehicles, as well as over 30 % fuel consumption saving (on non-air-conditioned model only).
Translating into operation terms, the system has achieved over 98% of vehicle availability, and per annum, powered 690 million journeys, saved over 35 million litres of diesel fuel and 100,000 tonnes of CO₂ emission.

The Enviro500H prototypes supplied to Hong Kong were built and tested in the U.K. and delivered in complete vehicles, featuring start-stop device, motor-powered air-conditioning and hand-brake interlocked electric power steering.

“Virtual Electric”

Beyond current constant hybrid drive-line, ADL is advancing into dual electric-hybrid referred as “Virtual Electric”. In addition to diesel engine and on-board battery, “Virtual Electric” equips with two (2) 50 kilo-Watt (30 kilo-Watt for prototype) coils under floor to recharge the battery by induction. Each time the bus recharges at stops fitted with ground-mounted inductor, enabling the bus to carry sufficient power to travel 30 to 40 minutes inside pollution sensitive area at zero emission independently. Once entering non-sensitive area, the bus runs on hybrid; thus overall the carbon emission of the bus is further reduced without compromise on range and operation flexibility.

“Virtual Electric” is being trailed on route 69 of London Buses and also in Scotland in the U.K.

Assembly Workshop

ADL bus body workshop attached to Granton comprises three (3) halls of 200 metre by 60 metres each. Two body assembly lines are housed in two (2) halls one (1) hall is assigned for storage.
ADL assembles bus bodies for orders from Citybus, New World First Bus and Mass Transit Railways Corporation in Hong Kong and SMRT of Singapore and delivers to these customers in the form of complete build-up (CBU; i.e. the vehicle is completely built upon delivery). Orders from Kowloon Motor Bus (KMB) in Hong Kong are under different arrangement. ADL delivers chassis and complete sets of bus body components only, or complete knock-down (CKD), and KMB appoints contractor(s) to execute the assembly works. Granton is contracted to assemble KMB buses, currently at the rate of six (6) buses per week, and the assembly line is adjacent to that of ADL.

The CBU buses are quality-controlled by ADL personnel though the physical assembly works is conducted by Granton. Quality check is performed at the end of each work stage. From a fully built-up chassis with body components in CKD form to delivery of the completely built-up bus, the process typically takes 4.5 weeks.

Production

The chassis arrived at the start of the production line is first water-levelled (levelling is attained by the use of laser in the U.K.). In parallel, the aluminium alloy-made and CNC-profiled body kits from the U.K. such as pillars and beams are put together against jigs to become sub-assembled sections such as side frames, intermediate roofs and top roofs.
The bus formed its shape with body components integrated together and attached on the chassis (Benny Sit)

The side frames are attached to the chassis by mono-bolts. Once the intermediate roof, front and rear panels and the top roof are attached, the bus takes its shape. The connection of all components and integration of the body with chassis is attained by mechanical fastening and no welding is involved. The sections are well-engineered so that the components fit with each other with minimal requirement on workmanship.

Close-up of aluminium-made nearside body frame (Edmund Leung)
The chassis integrated with body skeleton is pushed manually to the next bay for the fittings. Glasses, GRP kits, aluminium sheets for interior surfaces and accessories are local-sourced. The skin panel adopts etalbond of Elval Colour in Greece, a sandwich-type composite panel consisting of a non-toxic polyethylene core firmly bonded between fine aluminium facing and backside sheet. It enjoys high strength-to-weight ratio, light weight and importantly low thermal expansion coefficient, meaning that pre-tensioning of panels to avoid corrugation in high temperature and maintain flatness is unnecessary; thus simplifies the body assembly process. Attachments and fixtures are met by mechanical fastening or adhesion.

The next stage is painting. The prepared and masked grey bodies are first prime-coated and then sanded-down for refining the surfaces. First and second coating with PPG-made non-water borne automotive paints from the U.S. and baking is performed in a temperature- and humidity-controlled spray booth.
After the under-body is coated with under-body wax one (1) week prior to delivery to protect from corrosion, the bus undergoes pre-delivery inspection including tyre alignment examination. Finally, where the road test is satisfactory, the bus is ready for hand-over to customer.

Remarks
Though monstrous in size on roads, buses were assembled not complexly. The process of body assembly does not require heavy equipment other than overhead cranes for easy lifting of sub-sections, whereas hand-held tools to put components together orderly by means of bolting or adhesion. Being well-engineered, ADL buses need not be completely built in its country of origin and there is obvious cost saving by assembling bus bodies in Zhuhai where the labour cost is relatively low and the location is close to the customer in Hong Kong. This explains why ADL buses have been so receptive in Hong Kong and increasing number of new buses of this brand have been put on the Hong Kong roads in the recent years.

The ADL buses in Hong Kong have been designed for future. While Hong Kong may impose more stringent emission control regime for the improvement of air quality, the ADL models are ready to comply with it by advancing into Euro VI. In addition, ADL is well-positioned in developing hybrid so that vehicular emission is further lowered, while development of new technologies may enable it to leap into zero emission.

ASME-HKS and IMechE-HKB thank Mr. Andrew Boulton and Mr. Steve Campbell for their generous support to and hospitality in the visit.

- END -

Encl.
AW/WHT

Photographs were taken by Mr. Jimmy F.K. Lee, Mr. Edmund K.H. Leung and Mr. Benny C.Y. Sit with permission to use. Copyright reserved.
Alexander Dennis (ADL) has supplied passenger transport vehicles, principally double-decker buses, to Hong Kong for over three decades. Since 2011, ADL assembles buses in Zhuhai, Guangdong Province of China and ships the completed vehicles to Hong Kong for delivery.

For the first time ever, together with IMechE Hong Kong Branch, ASME Hong Kong Section is privileged to arrange a technical visit to witness first-hand the complete process of bus assembly and testing, as well as appreciate the basics of bus engineering. Members interested in automotive, transport, manufacturing or buses should not miss this rare opportunity.

IMechE member: HK$310 (Round trip tickets and lunch are included)

Date: 13 Dec 2014 (Sat)
Time: 0700 hrs – 1630 hrs
Gathering time and venue:
0700 hrs. Gather at in Hong Kong China Ferry Terminal, 33 Canton Road, Kowloon
0730 hrs. Ferry departure from Hong Kong China Ferry Terminal

Places are limited to 25 with priority given to IMechE and ASME members. Event details and enrolment please visit http://www.asmehk.org/events.html/ or contact industrial@asmehk.org

By courtesy of Alexander Dennis with compliment
Alexander Dennis Welcomes HKIMechE to Zhuhai

13th December 2014
Welcome to GT in Zhuhai

Andy Boulton
13th December 2014
• Background
• Innovation
• Double deck Evolution
• Euro VI
• Fuel Consumption
• Hybrid developments
• ADL hybrid experience
• What’s next?
1895  Dennis Brothers started in Guildford, England
1903  Bus manufacture started in purpose built factory
1924  Walter Alexander started in Scotland
1962  First Dennis Loline delivered to Hong Kong
1975  Became major suppliers to Hong Kong market
1988  Launch of Dennis Dart midibus
1997  Launch of low floor accessible d/d buses in Hong Kong
2004  Formation of Alexander Dennis
2009  Launch of 2-axle double deck in Hong Kong
2010  JV with Kiwi Bus
2012  JV with New Flyer in North America
       Market leader in UK, Hong Kong, USA, Canada, New Zealand
2013  Launch of NEW Enviro500 in Hong Kong
2014  Launch of first hybrid 3 axle double deck to Hong Kong
Falkirk, Scotland
• 900 employees (Factory + Central HQ)
• ADL HQs
• Body and chassis assembly plant
• Body engineering

Scarborough, England
• 560 employees
• Coach, body and chassis assembly

Skelmersdale, England
• 250 employees
• Aftermarket HQs.
• Product Engineering support

Guildford, England
• 310 employees
• Chassis assembly plant.
• Chassis engineering
ADL INTERNATIONAL PRESENCE

Alexander Dennis Inc (California, US)

JV with New Flyer

Alexander Dennis Ltd (UK, Headquarters)

ADL in South East Asia

Alliance with Kiwi Bus (New Zealand)

Alliance with Zhuhai Granton Bus & Coach (China)

New channel partners in M East

Alexander Dennis Asia Pacific (Hong Kong)

Alexander Dennis Inc (California, US)
Innovation

• Innovation is not about producing a ‘flashy’ concept vehicle, it is using technology to develop and deliver a product to customer’s specification which delivers flexibility, reliability and economy in the demanding bus depot environment.

• We do not want to experiment with customer’s livelihoods
• No compromise on component selection
• Process of evolutionary design, learning from experience
ADL 3 axle Low Floor Double Deck Development

**Trident launched**
Super Low Floor entry
Euroll emissions engine

**Enviro500 launched**
Wider body, straight staircase
Disc braked front axle
Euroll emissions engine

**Timeline**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>Trident launched</td>
</tr>
<tr>
<td>2003</td>
<td>Enviro500 launched</td>
</tr>
<tr>
<td>2012</td>
<td>Enviro500 Next Generation</td>
</tr>
</tbody>
</table>

- Lighter weight
- Increased seating capacity
- ZF axles – disc brakes all round
- Major focus on all-round improvements
- Euro5 emissions engine
- ZF Ecolife transmission
Reviewed last 36 months of warranty and campaign data
Rated by frequency and customer impact
Identified 50 key reliability issues
Analysis by
- Engineering
- Customer Feedback
- Local Engineers
IMPROVED RELIABILITY

- ZF axles with disc brakes
- Reduce air consumption to reduce compressor loads
- Improved braking system with change of tag axle spring actuator
- New cooling system with remote mounted thermostat and aluminium radiator
- Full test and sign off program including durability. Service access and maintainability review - Design Protect for Euro VI
- Urea system installation to focus on system temperatures and locations
- Bus stop brake
- Cooling coil in front of radiator to reduce air temperatures
1,436 - E500 diesel Hong Kong
6 - E500 hybrid Hong Kong
40 - E500 diesel Malaysia (RapidKL)
201 - E500 diesel Singapore (SMRT)
HD On-Highway Emission Regulations EU Standards & Effect Dates

<table>
<thead>
<tr>
<th>Year</th>
<th>NOx Total</th>
<th>PM Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euro II</td>
<td></td>
<td></td>
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<tr>
<td>Euro III</td>
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<tr>
<td>Euro IV</td>
<td>55%</td>
<td>94%</td>
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<tr>
<td>Euro V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euro VI</td>
<td>Further 88%</td>
<td>Further 50%</td>
</tr>
</tbody>
</table>

Oxides of Nitrogen (g/kWh)

Particulate Matter (g/kWh)
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<td>1</td>
<td>Equivalent Nox Emissions</td>
<td>Euro VI = x20</td>
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<td>14</td>
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<td><strong>Euro VI = x36</strong></td>
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<td>12</td>
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</table>
NOx - PM trade off

- Euro 5
- Euro 6
- Euro 3
- Euro 4
- Euro 2
- DPF
- EGR
- SCR
- PM-optimised combustion

Graph showing the trade-off between NOx and PM emissions for different Euro standards, with arrows indicating improvements in emissions reduction through EGR and SCR technologies.
Euro VI System Architecture

CCV → VGT Turbo

Charge Air Cooler → EGR-Cooler

Diesel Oxidation Catalyst → DEF Doser

Diesel Particulate Filter

SCR / AMOX Catalyst

DEF Tank

To be incorporated at 2015 only
Petrol
Diesel
Hybrids
Ethanol + Bio fuels
LPG /CNG
Gaseous Fuels
Fuel Cells
H₂
Breakthrough Technology

Emission – g CO₂ / km

Current
Carbon
Low
Carbon
Zero
Carbon

Evolution

Time

Time Now
10/15-years

Liquid Fuels

Breakthrough Technology
Lowering Carbon Emissions

- Acceleration Rate Management
- Idle shut down
- Telemetry
- Driver reward scheme
- Weight
- Driveline Specification
- Transmission Features
- Tyres
- Hybridisation
What is a Hybrid?

- Electric driveline + energy store
- Downsize engine
- Reduced fuel consumption
- Reduced emissions
- Recover free braking energy

££££££
Hybrid Benefits

- Low emissions
  - Global warming – CO$_2$
  - Local air quality – NOx, PM
- Better fuel economy
- Smooth acceleration and performance
- Quieter operation
- More reliable than alternative fuels

Customer Concerns

- Added cost and weight
- Relatively immature technology
- Training & maintenance requirements
- High voltage concerns
- Battery life
Parallel Hybrid
Retains mechanical drive between engine and axle
Electrical motor / generator blended in to assist acceleration and retardation
As used in Enviro500 with the Allison hybrid drive and Volvo B5

Series Hybrid
No mechanical link between engine and axle
Engine drives a generator, electric motor connected to axle
As used in Enviro200 & Enviro400 with the BAE Systems Hybridrive
A family of products

- **HDS100**
  - 11-18 Ton
  - 120/195 kW motor
  - 140 kW generator

- **HDS200**
  - 16-22 Ton
  - 160/200 kW motor
  - 200 kW generator

- **HDS300**
  - 22-26 Ton
  - 190/245 kW motor
  - 230 kW generator
Lithium-ion energy storage system

• Best power and energy density of any commercially available solution
• Nano-phosphate technology
• Design life 6+ years
• Ambient air-cooled
• Superior energy storage supports full ZEV operation

RATINGS
• Power: 200 kW peak
• Voltage: 635 Vdc Nominal
• Operating Temperature: -10C to 52C (-40C to 52C w/cold weather package)

SIZE
• Length: 85.4 in. (2170 mm)
• Width: 40.4 in. (1026 mm)
• Height: 12 in. (304 mm)
WEIGHT: 800 lbs. (365 kg)
COOLANT – Forced Ambient Air
• Maximise brake energy recovery

• Load following - not charge following – not exercising the battery

• Emulate conventional driving characteristics

• Charge neutral

• Onboard equalisation

• Turn-key systems with supplier support
• 686 hybrid buses in service
• 162 hybrid buses on order
• Operating on 3 continents
• Hybrid product range are LCEB compliant
• >30% fuel consumption improvement met
• Better than 98% vehicle availability achieved
• Very positive customer feedback for hybrid drive system
• Popular with drivers and operators alike
• More than 4,200 systems in service
• The most successful series hybrid system in the world
• Powering 690 million passenger journeys every year
• More than 35 million litres of fuel saved every year
• 100,000 tons of CO$_2$ emissions prevented every year
2008
1st Generation HybriDrive® - Propulsion Only
First vehicles enter TfL trial: 12 E400H & 5 E200H
25% fuel savings

1st Generation HybriDrive® - incremental improvements
E400H sees sales outside the TfL trial with GBF1
30% fuel savings

2010
2nd Generation HybriDrive® - Propulsion Only
Continued UK sales with GBF2
35% fuel savings

2011
2nd Generation HybriDrive® Stop Start
Continued UK sales with GBF3
40% fuel savings

2012

2013

2014

2014

Virtual Electric bus trial running in Scotland,
with Enviro350H with On Route Recharging
Next Technology Step – “Virtual Electric” Bus

Today’s Hybrid Electric

ADL “Virtual Electric” concept: A Range Extender EV with Opportunity Recharge

Today’s Hybrid Electric

ADL “Virtual Electric” concept: A Range Extender EV with Opportunity Recharge

Operates as Zero Emission EV in City Centre zone or other AQ hazard zones on route

Elsewhere it operates as low emission hybrid vehicle

ZE range typical 30 - 40 min between charge phases

Contactless Inductive Recharge capability out on route means bus can make use of “fuel” from the grid without lengthy recharge layovers or return to depot.

Flexibility of operation is at the heart of this concept. That means near-zero compromise vs standard diesel bus operations:
- charge time aligned to service timetables
- capable of diesel-equivalent shift length
- compact package size means OK for Double Deck
- no reduction in passenger capacity

“Conventional EV”

Conventional concept battery-only bus is:
- Range limited
- Heavy

“Conventional EV”

Conventional concept battery-only bus is:
- Range limited
- Heavy
Operational Concept:
EV with all day Operation Capability

Depot
Enter City Centre ZE Zone

Recharge Station

Leave City Centre ZE Zone

AQ Hotspot or Noise Hotspot

Route Start

Hybrid Mode in Suburb & Enroute from Depot

EV Mode

Vehicle in Hybrid Mode

Hybrid Mode in Non Sensitive Area (Dual Carriageway)

Route End

Hybrid Mode in Suburb

Remote Charging Station

Vehicle in ZE Mode

Virtual Electric Vehicle
Thank You, Any Questions?