# Contents

1. EXECUTIVE SUMMARY AND CONCLUSIONS .............................. 1
   1.1. Definitions ............................................................................. 1
   1.2. Manufacturing buses and taxis ............................................. 2
   1.3. Hybrids are key for now ....................................................... 2
   1.4. Advantages of electric buses ............................................... 9
   1.5. Basis for forecasting global bus sales by region ................... 15
   1.6. Demand and production in China ........................................ 17
   1.7. Adoption of electric buses vs electric cars ......................... 18
   1.8. Taxis ................................................................................... 25
   1.9. Electric bus design is ahead of cars ................................. 36
   1.10. Radically different bus powertrains .............................. 39

2. INTRODUCTION ..................................................................... 41
   2.1. Electric vehicles in general ............................................... 41
   2.2. Advantages of electric buses ............................................. 42
   2.3. Highlights 2011-2021 ...................................................... 45
   2.4. Definitions and trends ....................................................... 45
   2.5. Modest success of electric microbuses ......................... 47
   2.6. Convergence of hybrid and pure electric buses. ............... 55
   2.7. Convergence of trolley buses and free running electric buses 56
   2.8. CNG Preferred for Los Angeles Buses .......................... 64

3. ELECTRIC BUS MANUFACTURERS AND TECHNOLOGIES .... 65
   3.1. History of electric buses .................................................... 65
   3.2. Main components of hybrid bus power trains ................... 85
   3.3. Superbus ............................................................................. 96
   3.4. Fuel cells rescued by batteries ....................................... 97

4. PROFILES OF SOME INTERESTING SUPPLIERS .................. 101
   4.1. Alexander Dennis UK ..................................................... 101
   4.2. Anhui Ankai Automobile Company China ....................... 102
   4.3. BYD China ........................................................................ 104
   4.4. Daimler Germany ............................................................... 104
   4.5. Hino Motors and parent company, Toyota Japan ............... 107
   4.6. IVECO Italy ....................................................................... 108
   4.7. ISE Corp, USA .................................................................. 109
   4.8. MAN hybrid bus Germany: supercapacitor not battery .... 110
   4.9. Navistar USA .................................................................... 111
4.10. New Flyer Industries Canada 112
4.11. Nova Bus Canada 112
4.12. Optare UK 113
4.13. Proterra 114
4.14. Ryobi Bus Japan 114
4.15. TATA India 115
4.16. Volvo Sweden 117
4.17. Wrightbus UK 119
4.18. Zhongtong Bus Holding Co., Ltd, China 119

5. BUS DRIVE TRAINS 121
5.1. Adura Systems USA 121
5.2. Allison Transmission USA 122
5.3. Azure Dynamics USA 125
5.4. BAE Systems UK, USA 125
5.5. BLK China 127
5.6. Eaton USA 128
5.7. ISE Corporation 128
5.8. SIM Drive Corporation Japan 129
5.9. SR Drives UK, Green Propulsion Belgium 130
5.10. ThunderVolt USA 132

6. ELECTRIC TAXI MANUFACTURERS AND TECHNOLOGIES 133
6.1. Electric taxi projects in US, UK, Europe, China, Japan and Mexico 134
6.1.1. China 134
6.1.2. Mexico 137
6.2. Mitsubishi taxi rollout in Japan 141
6.2.1. Mitsubishi MiEV taxi 142
6.3. Dalian China 142
6.4. Huge order in the Philippines in 2013 142

7. TRACTION BATTERIES, FUEL CELLS, RANGE EXTENDERS 145
7.1. Traction batteries 145
7.2. Who is winning in traction batteries and why 147
7.2.1. The needs have radically changed 147
7.2.2. It started with cobalt 152
7.2.3. Great variety of recipes 152
7.2.4. Other factors 153
7.2.5. Check with reality 153
7.2.6. Lithium winners today and soon 153
7.2.7. Reasons for winning 154
7.2.8. Lithium polymer electrolyte now important 154
### 7.2.9. Winning chemistry

### 7.2.10. Titanate establishes a place

### 7.2.11. Laminar structure

### 7.2.12. Niche winners

### 7.2.13. Fluid situation

### 8. FUEL CELLS

#### 8.1. Trials of fuel cell powered vehicles

#### 8.2. Fuel cell 2000 summary of fuel cell bus trials to 2010

#### 8.3. Range extenders

### 9. MARKET STATISTICS AND FORECASTS

#### 9.1. Past trends

##### 9.1.1. Commercial vehicles

#### 9.2. Buses – historical trends

#### 9.3. School buses – North America

#### 9.4. Past trend in bus production by country

#### 9.5. US population of buses by type

#### 9.6. Transport modes in India

#### 9.7. Motor vehicle production by leading producers

#### 9.8. Global electric bus deliveries to start of 2011

#### 9.9. Forecasts to 2023

##### 9.9.1. Global demand for electric buses and taxis

##### 9.9.2. Manufacturing buses and taxis

#### 9.10. Technology future

##### 9.10.1. Hybrids are key for now

#### 9.11. Future leading manufacturers

##### 9.11.1. Today’s leading electric bus manufacturer

##### 9.11.2. Future leading user nation

##### 9.11.3. Buses and taxis a good launch pad for new technologies

##### 9.11.4. Global conventional and electric bus demand 2010-2021

##### 9.11.5. Advantages of electric buses

#### 9.12. Decade of the hybrid

#### 9.13. Liberty Electric Cars

#### 9.14. Basis for forecasting global bus sales by region

#### 9.15. Conventional and electric bus demand and production in China

#### 9.16. Adoption of electric buses vs electric cars

#### 9.17. Global electric vehicle manufacturers by application

#### 9.18. Chinese manufacturers of electric vehicles by application

##### 9.18.1. Taxis

#### 9.19. Adoption of green taxis

#### 9.20. Electric vehicles in East Asia

#### 9.21. Total change
# Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1.1</td>
<td>Global demand for electric buses and taxis $ billion 2012-2023</td>
<td>1</td>
</tr>
<tr>
<td>Table 1.2</td>
<td>Global electric bus demand market forecast for 2012-2023, in numbers hybrid and numbers pure electric in thousands with total</td>
<td>5</td>
</tr>
<tr>
<td>Table 1.3</td>
<td>Electric vs all buses purchased globally and % penetration of electric 2012-2023 in thousands rounded</td>
<td>7</td>
</tr>
<tr>
<td>Table 1.4</td>
<td>Market drivers of global growth of bus and electric bus sales 2011-2021 and impediments</td>
<td>8</td>
</tr>
<tr>
<td>Table 1.5</td>
<td>Approximate annual purchase of hybrid electric replacement buses by major cities in the period 2015-2021</td>
<td>9</td>
</tr>
<tr>
<td>Table 1.6</td>
<td>Advantages of pure electric buses, enjoyed to some extent by hybrid electric buses</td>
<td>9</td>
</tr>
<tr>
<td>Table 1.7</td>
<td>Number, unit price and market value of hybrid electric buses 2012-2023, rounded</td>
<td>10</td>
</tr>
<tr>
<td>Table 1.8</td>
<td>Pricing of hybrid buses in 2010 and premium over conventional equivalent</td>
<td>12</td>
</tr>
<tr>
<td>Table 1.9</td>
<td>Number, unit price and market value of pure electric buses 2012-2023, rounded</td>
<td>12</td>
</tr>
<tr>
<td>Table 1.10</td>
<td>Pricing of pure electric buses in 2010 and premium over conventional equivalent</td>
<td>14</td>
</tr>
<tr>
<td>Table 1.11</td>
<td>The total global market $ billion for electric buses 2012-2023</td>
<td>15</td>
</tr>
<tr>
<td>Table 1.12</td>
<td>Market drivers of future purchasing of buses by region and % growth</td>
<td>16</td>
</tr>
<tr>
<td>Table 1.13</td>
<td>In China, demand for electric vs all buses in thousands of units and % share 2012-2023</td>
<td>17</td>
</tr>
<tr>
<td>Table 1.14</td>
<td>Estimates of hybrid bus transmission sales by manufacturer in 2009</td>
<td>24</td>
</tr>
<tr>
<td>Table 1.15</td>
<td>Hybrid bus sales 2008-2013 – forecasted numbers globally for some leading suppliers</td>
<td>24</td>
</tr>
<tr>
<td>Table 1.16</td>
<td>Growth rate of market by numbers for buses and electric buses, hybrid and pure electric, 2011-2021</td>
<td>25</td>
</tr>
<tr>
<td>Table 1.17</td>
<td>Total number of taxis sold 2012-2023 and number of electric taxis 2012-2023 in thousands and % market share</td>
<td>26</td>
</tr>
<tr>
<td>Table 1.18</td>
<td>Global demand for electric taxis 2012-2023 by number, unit value and market value</td>
<td>28</td>
</tr>
<tr>
<td>Table 1.19</td>
<td>Demand in China for taxis and electric taxis, thousands and % penetration of taxis in China and of global electric taxis for 2012-2023</td>
<td>30</td>
</tr>
<tr>
<td>Table 1.20</td>
<td>Number, unit value and market value of electric taxis in China 2012-2023</td>
<td>31</td>
</tr>
<tr>
<td>Table 1.21</td>
<td>Registered motorised taxis, with driver provided, by region in the world in 2010</td>
<td>32</td>
</tr>
<tr>
<td>Table 1.22</td>
<td>Examples of taxi population in leading cities</td>
<td>32</td>
</tr>
<tr>
<td>Table 1.23</td>
<td>2009 production statistics</td>
<td>36</td>
</tr>
<tr>
<td>Table 2.1</td>
<td>Advantages of pure electric buses, enjoyed to some extent by hybrid electric buses</td>
<td>42</td>
</tr>
<tr>
<td>Table 2.2</td>
<td>Challenges of electric buses and taxis</td>
<td>42</td>
</tr>
<tr>
<td>Table 2.3</td>
<td>Main market drivers 2011-2021</td>
<td>44</td>
</tr>
<tr>
<td>Table 2.4</td>
<td>Electric vehicle highlights 2011-2021</td>
<td>45</td>
</tr>
<tr>
<td>Table 2.5</td>
<td>Limitations of trolleybuses and trams</td>
<td>45</td>
</tr>
<tr>
<td>Table 3.1</td>
<td>78 examples of manufacturers of hybrid electric buses, with country of headquarters and image</td>
<td>68</td>
</tr>
<tr>
<td>Table 3.2</td>
<td>53 Manufacturers of pure electric buses, country of headquarters and image</td>
<td>86</td>
</tr>
<tr>
<td>Table 6.1</td>
<td>Eight projects testing pure electric taxis</td>
<td>138</td>
</tr>
<tr>
<td>Table 7.1</td>
<td>What is on the way in or out with traction batteries</td>
<td>151</td>
</tr>
</tbody>
</table>
Table 7.2  71 vertically integrated lithium traction battery cell manufacturers, their chemistry, cell geometry and customer relationships (not necessarily orders)

Table 9.1  2009 production statistics

Table 9.2  Bus production by country in 2002

Table 9.3  Global sales of buses by region 2002

Table 9.4  Country percentage share of heavy bus and school bus production in 2009

Table 9.5  US aircraft, vehicles and other conveyances 1995-2006

Table 9.6  US transportation capital stock by mode 1995-2007 current $ billion

Table 9.7  Indian Cities Mode Split, 2007 (Wilbur Smith 2008)

Table 9.8  The UK top five bus suppliers in 2006 and 2007

Table 9.9  Global demand for electric buses and taxis $ billion 2012-2023

Table 9.10  Global electric bus demand market forecast for 2012-2023, in numbers hybrid and numbers pure electric in thousands with total

Table 9.11  Electric vs all buses purchased globally and % penetration of electric 2012-2023 in thousands rounded

Table 9.12  Market drivers of global growth of bus and electric bus sales 2011-2022 and impediments

Table 9.13  Approximate annual purchase of hybrid electric replacement buses by major cities in the period 2015-2021

Table 9.14  Advantages of pure electric buses, enjoyed to some extent by hybrid electric buses

Table 9.15  Number, unit price and market value of hybrid electric buses 2012-2023, rounded

Table 9.16  Pricing of hybrid buses in 2010 and premium over conventional equivalent

Table 9.17  Number, unit price and market value of pure electric buses 2012-2023, rounded

Table 9.18  Pricing of pure electric buses in 2010 and premium over conventional equivalent

Table 9.19  The total global market $ billion for electric buses 2012-2023

Table 9.20  Market drivers of future purchasing of buses by region and % growth

Table 9.21  In China, demand for electric vs all buses in thousands of units and % share 2012-2023

Table 9.22  Estimates of hybrid bus transmission sales by manufacturer in 2009

Table 9.23  Hybrid bus sales 2008-2013 - forecasted numbers globally for some leading suppliers

Table 9.24  Growth rate of market by numbers for buses and electric buses, hybrid and pure electric, 2011-2021

Table 9.25  Total number of taxis sold 2012-2023 and number of electric taxis 2012-2023 in thousands and % market share

Table 9.26  Global demand for electric taxis 2012-2023 by number, unit value and market value

Table 9.27  Demand in China for taxis and electric taxis, thousands and % penetration of taxis in China and of global electric taxis for 2012-2023

Table 9.28  Number, unit value and market value of electric taxis in China 2012-2023

Table 9.29  Registered motorised taxis, with driver provided, by region in the world in 2010

Table 9.30  Examples of taxi population in leading cities

Table 9.31  The percentage value share by country of the East Asian electric vehicle market 2011-2021
Figures

Fig. 1.1  Global market for electric taxis based on regular cars as a percentage of the total electric car market in 2021 at ex-factory prices  
2

Fig. 1.2  Global electric bus demand market forecast 2012-2023, in numbers hybrid and pure electric in thousands  
6

Fig. 1.3  Electric vs all buses purchased globally of units 2012-2023 rounded  
8

Fig. 1.4  Bus size vs fuel consumption  
10

Fig. 1.5  Number, unit price and market value of hybrid electric buses 2012-2023, rounded  
11

Fig. 1.6  Number, unit price and market value of pure electric buses 2012-2023, rounded  
13

Fig. 1.7  The total global market $ billion for electric buses 2012-2023  
15

Fig. 1.8  Number of buses purchased in 2011 by region  
16

Fig. 1.9  In China, demand for electric vs all buses in thousands of units and % share 2012-2023  
17

Fig. 1.10  Kent electric city bus from China  
18

Fig. 1.11  Hino Blue Ribbon hybrid diesel electric bus in China  
18

Fig. 1.12  Electric bus in China  
18

Fig. 1.13  Bus by Tongkun New Energy Technologies Co. and FAW Bus and Coach Co  
19

Fig. 1.14  Electric pick-up truck from China Vehicles Company  
19

Fig. 1.15  Garbage collecting electric car by Shandong Shunxing Machinery  
20

Fig. 1.16  Approximate number of manufacturers of electric vehicles worldwide by applicational category in 2011  
20

Fig. 1.17  The approximate number of Chinese manufacturers of electric vehicles by applicational category in 2011  
21

Fig. 1.18  Total number of taxis sold 2012-2023 and number of electric taxis 2012-2023 in thousands  
27

Fig. 1.19  Cumulative number of hybrid car models and projected number of hybrid sales to 2020  
28

Fig. 1.20  Global demand for electric taxis 2012-2023  
29

Fig. 1.21  Number of taxis sold 2012-2023 and number of electric taxis in China 2012-2023 in thousands  
30

Fig. 1.22  Number, unit value and market value of electric taxis in China 2012-2023  
31

Fig. 1.23  Registered motorised taxis, with driver provided, by region in the world in 2010  
32

Fig. 1.24  Examples of taxi population in leading cities  
33

Fig. 1.25  MAN Lion urban bus with supercapacitors and no traction battery  
38

Fig. 2.1  Isuzu sales of buses 2005-2009  
47

Fig. 2.2  Electric bus in Nepal  
48

Fig. 2.3  PhUV pure electric bus  
48

Fig. 2.4  Tara pure electric Shuttle  
49

Fig. 2.5  A Volvo hybrid powertrain for buses is shown below  
52

Fig. 2.6  Orion VII NG hybrid bus  
55

Fig. 2.7  Possible evolution of affordable, mainstream electric buses showing the convergence of hybrid and pure electric technologies as the conventional internal combustion engine ICE is abandoned  
56
Fig. 2.8  Rome trolleybus raising its trolley arms to switch from battery to overhead-wire power. In the view on the right the pick-up has yet to properly locate itself around the overhead wires

Fig. 2.9  Opbrid pantograph for fast recharging

Fig. 2.10  Hydrogen fuel cell for buses etc from UTC Power

Fig. 2.11  Ultracapacitor layout in a MAN hybrid bus

Fig. 2.12  In-road charging of small buses in Turin, Italy

Fig. 2.13  Straddling bus concept

Fig. 3.1  Pure electric bus in 1907

Fig. 3.2  Proposal for new London double decker hybrid electric bus

Fig. 3.3  Capco driverless electric bus concept

Fig. 3.4  Insectbus concept

Fig. 3.5  78 examples of hybrid electric bus producers by country of headquarters

Fig. 3.6  78 examples of hybrid electric bus producers by continent of headquarters

Fig. 3.7  Sample of 53 pure electric bus manufacturers by continent

Fig. 3.8  Sample of 53 pure electric bus manufacturers by country

Fig. 3.9  Superbus

Fig. 3.10  Trend of size of the largest (in red) and smallest (in green) fuel cell sets used in 98 bus trials worldwide over the last twenty years.

Fig. 3.11  Evolution of traction batteries and range extenders for large hybrid electric vehicles as they achieve longer all-electric range over the next decade.

Fig. 3.12  Three generations of lithium-ion battery with technical features that are sometimes problematical

Fig. 4.1  Alexander Dennis Enviro400 hybrid bus configuration

Fig. 4.2  Hefei pure electric bus demonstration operation start ceremony

Fig. 4.3  Daimler bus production locations

Fig. 4.4  Unit sales of the Daimler bus division 2008-9

Fig. 4.5  Daimler bus sales by global region H1 2009

Fig. 4.6  Daimler bus market share and market share of leading competitors in 2007

Fig. 4.7  Daimler’s technology roadmap for launching new bus technologies to 2015

Fig. 4.8  HyFLEET:CUTE fuel cell bus project in Europe and the US

Fig. 4.9  Hino hybrid bus

Fig. 4.10  Hino “no plug in” bus.

Fig. 4.11  The positioning of the planned Toyota fuel cell hybrid bus FCHV-BUS

Fig. 4.12  Iveco pure electric bus elements

Fig. 4.13  Iveco configurations

Fig. 4.14  ISE lean burn hybrid bus

Fig. 4.15  ISE initial hybrid configuration

Fig. 4.16  MAN Lion urban hybrid bus

Fig. 4.17  MAN Lion urban hybrid bus in section showing supercapacitors (ultracapacitors) in place of traction battery

Fig. 4.18  Ryobi solar assisted electric bus

Fig. 4.19  The Bladon Jets microturbine range extender is the size of two large cans of beans

Fig. 4.20  Jaguar concept car demonstrated late 2010
Fig. 4.21 Tata electric roadmap of launches

Fig. 4.22 Volvo presentation at eCarTec Munich where it advocated hybrid urban buses after claiming to have delivered more pure electric buses than anyone else [500 of them]

Fig. 4.23 A Zhongtong pure electric bus

Fig. 5.1 Adura’s MESA Powertrain

Fig. 5.2 Azure Dynamics powertrain

Fig. 5.3 BAE Systems Hybridrive series hybrid bus powertrain

Fig. 5.4 Eaton hybrid powertrain

Fig. 5.5 ISE Corp hybrid powertrain

Fig. 5.6 SIM Drive in wheel traction

Fig. 5.7 SR drives series parallel power unit

Fig. 5.8 ThunderVolt hybrid drive train for ISE buses

Fig. 6.1 Taxi fire caused by a bad lithium-ion battery in a Chinese electric taxi

Fig. 6.2 Mitsubishi Minicab i-MiEV

Fig. 6.3 Mitsubishi MiEV Minicab

Fig. 6.4 The Terra Motors e-trike

Fig. 6.5 Chinese electric car

Fig. 6.6 Japanese ten meter long deep sea cruising AUV, the URASHIMA

Fig. 6.7 Bionic dolphin

Fig. 6.8 Deepflight Merlin

Fig. 6.9 The Terra Motors e-trike

Fig. 6.10 Oshkosh truck

Fig. 6.11 Approximate percentage of manufacturers offering traction batteries with less cobalt vs those offering ones with no cobalt vs those offering both. We also show the number of suppliers that offer lithium iron phosphate versions.

Fig. 7.1 Traction battery experience curve for pure electric battery electric vehicles

Fig. 7.2 Volkswagen forecasts the following cost trend for the favoured types of traction battery

Fig. 7.3 Progress in improving energy density vs power density of traction batteries

Fig. 7.4 Comparison of benefits and challenges for various types of traction battery

Fig. 7.5 Geely IG solar car

Fig. 7.6 Japanese ten meter long deep sea cruising AUV, the URASHIMA

Fig. 7.7 Bionic dolphin

Fig. 7.8 Deepflight Merlin

Fig. 7.9 Cri-Cri pure electric stunt plane new in 2010

Fig. 7.10 Oshkosh truck

Fig. 7.11 Approximate percentage of manufacturers offering traction batteries with less cobalt vs those offering ones with no cobalt vs those offering both. We also show the number of suppliers that offer lithium iron phosphate versions.

Fig. 8.1 Series hybrid bus being developed by Mobile Energy Solutions

Fig. 8.2 MAN hybrid fuel cell bus

Fig. 8.3 Van Hool fuel cell buses on trial

Fig. 8.4 Fuel cell powered Hyundai bus on trial in Australia

Fig. 8.5 Mercedes Benz fuel cell bus trial

Fig. 8.6 World heavy bus production by country and type for 2008-9

Fig. 8.7 North American sales of school buses 2000-2009

Fig. 8.8 Daimler Group vehicle production by type in 2009

Fig. 8.9 Fiat Group vehicle production by type in 2009

Fig. 8.10 GAZ Group vehicle production by type in 2009

Fig. 8.11 General Motors vehicle production by type in 2009

Fig. 8.12 Hyundai Group vehicle production by type in 2009

Fig. 8.13 Mahindra Group vehicle production by type in 2009

Fig. 8.14 Navistar Group vehicle production by type in 2009

Fig. 8.15 General Motors vehicle production by type in 2009
Fig. 9.10  Tata Group vehicle production in 2009  
Fig. 9.11  Volvo group production in 2009  
Fig. 9.12  Global market for electric taxis based on regular cars as a percentage of the total electric car market in 2021  
Fig. 9.13  Global electric bus demand market forecast 2012-2023, in numbers hybrid and pure electric in thousands  
Fig. 9.14  Electric vs all buses purchased globally of units 2012-2023 rounded  
Fig. 9.15  Bus size vs fuel consumption  
Fig. 9.16  Number, unit price and market value of hybrid electric buses 2012-2023, rounded  
Fig. 9.17  Number, unit price and market value of pure electric buses 2012-2023, rounded  
Fig. 9.18  The total global market $ billion for electric buses 2012-2023  
Fig. 9.19  Number of buses purchased in 2011 by region  
Fig. 9.20  In China, demand for electric vs all buses in thousands of units and % share 2012-2023  
Fig. 9.21  Approximate number of manufacturers of electric vehicles worldwide by applicational category in 2011  
Fig. 9.22  The approximate number of Chinese manufacturers of electric vehicles by applicational category in 2011  
Fig. 9.23  Total number of taxis sold 2012-2023 and number of electric taxis 2012-2023 in thousands  
Fig. 9.24  Cumulative number of hybrid car models and projected number of hybrid sales to 2020  
Fig. 9.25  Global pure electric car sales 2009-2020 excluding golf cars and cumulative number of new models since 2000  
Fig. 9.26  Global demand for electric taxis 2012-2023  
Fig. 9.27  Number of taxis sold 2012-2023 and number of electric taxis in China 2012-2023 in thousands  
Fig. 9.28  Number, unit value and market value of electric taxis in China 2012-2023  
Fig. 9.29  Registered motorised taxis, with driver provided, by region in the world in 2010  
Fig. 9.30  Examples of taxi population in leading cities  
Fig. 9.31  The percentage value share by country of the East Asian electric vehicle market 2011  
Fig. 9.32  The percentage value share by country of the East Asian electric vehicle market 2021