### Technology Indicators for Light Duty and Heavy Duty Applications

Technology indicators that industry is likely to achieve in a mass-market competitive environment. All the cost and performance metrics are ambitious, but relate to the same technology.

#### Light Duty Vehicles

<table>
<thead>
<tr>
<th>Year</th>
<th>2020</th>
<th>2025</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/kW (System)</td>
<td>112</td>
<td>68</td>
<td>40</td>
</tr>
<tr>
<td>$/kW (Stack)</td>
<td>70</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>System Efficiency (%)</td>
<td>60</td>
<td>65</td>
<td>70</td>
</tr>
<tr>
<td>Stack Durability (Hrs)</td>
<td>5,000</td>
<td>6,000</td>
<td>8,000</td>
</tr>
</tbody>
</table>

#### Heavy Duty Vehicles

<table>
<thead>
<tr>
<th>Year</th>
<th>2020</th>
<th>2025</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/kW (System)</td>
<td>455</td>
<td>195</td>
<td>80</td>
</tr>
<tr>
<td>$/kW (Stack)</td>
<td>285</td>
<td>115</td>
<td>40</td>
</tr>
<tr>
<td>System Efficiency (%)</td>
<td>60</td>
<td>65</td>
<td>70</td>
</tr>
<tr>
<td>Stack Durability (Hrs)</td>
<td>15,000</td>
<td>22,000</td>
<td>30,000</td>
</tr>
</tbody>
</table>

#### Hydrogen Storage Tank

<table>
<thead>
<tr>
<th>Year</th>
<th>2020</th>
<th>2025</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/kW (System)</td>
<td>470</td>
<td>365</td>
<td>200</td>
</tr>
</tbody>
</table>

**Notes:**

- All indicators are based on averaged data and volume-corrected figures derived from the following published data - US Department of Energy (DoE), the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), Strategy Council roadmaps from China and Japan.
- System Efficiency values are based on specific rated load values for PEM and SOFC. These do not represent a fuel efficiency target and cannot be compared as such.
- Although single point efficiency values are shown, these are not accurate indicators of real world vehicle efficiency which will vary across propulsion technologies and product applications.

Indicators are based on the following global FCEV production volumes:

<table>
<thead>
<tr>
<th>Year</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>15,000</td>
<td>50,000</td>
<td>750,000</td>
<td>&gt; 3,000,000</td>
<td></td>
</tr>
</tbody>
</table>

1. PEM @25% rated load; SOFC @80% rated load  
2. PEM specific technology
This roadmap represents a snapshot-in-time view of the global automotive industry propulsion technology forecast for mass market adoption. Specific application-tailored technologies will vary from region to region.

### Fuel Cell Stack
- **Low PGM catalysts**, low-cost durable membranes
- **Bi-polar plates and coatings optimised for durability**
- **Electrode and GDL for higher conductivity and lower cost**
- **Materials tolerant to a range of commercial fuels**

### Thermal Systems
- **Compact and efficient heat exchangers**
- **Cold-start support i.e. battery, thermal energy storage, improved thermal inertia**

### Balance of System
- **Degradation mgm’t for cell durability**
- **Reduced parasitic losses and local energy demand mgm’t**
- **High efficiency DC boost**
- **Improved durability and cost blowers, compressors and turbo-expanders**
- **Fluid handling, water management for performance and cost**

### Fuel Storage and Management
- **Light weight, low cost CFRP H2 tanks**
- **Multi-fuel tolerant SOFC**
- **Improving H2 fuel quality, pump, connectors, regulators, valves, nozzles**
- **Reduced size and more efficient fuel reformer systems**

### Control Systems
- **On-board diagnostics and model predictive controls for increased efficiency, durability and life**
- **Internal sensors and software enhancing performance and durability**
- **Efficient recovery of high-value materials e.g. Pt, CFRP**

### Life Cycle
- **Environmentally focussed processes e.g. for MEA and catalyst mfg**
- **Design for net zero and disassembly**

### Report Indicators
- **Light bar**: SOFC Specific technologies for mass market application
- **Dark bar**: Common or PEM – technology is in a mass market application. Significant innovation is expected in this time frame
- **Transition**: Transitions do not mean a phase out from market but a change of R&D emphasis
- **Dotted line bar**: Market Mature – technology has reached maturity. Likely to remain in mass market until it fades out where it’s superseded

This roadmap can be seen on page 1.