Connected & Demountable Fuel Cell Range Extender for Electric Vehicles

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(EP Tender, 2012)
1. Project Background
2. Problem Locating
3. Feature & Superiority of FC Range Extender
4. Typical Current Solutions
5. Ideal System Model Demonstration
6. Challenges
**Project Background**

### PRODUCT ROADMAP 2017: PASSENGER CAR

<table>
<thead>
<tr>
<th>DRIVERS</th>
<th>Low emissions zones</th>
<th>Ultra-low emission zones in cities</th>
<th>Regionally regulated zero emission zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission zones</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU tailpipe emissions</td>
<td>Euro 6b</td>
<td>Euro 6d Temp</td>
<td>Beyond Euro 6</td>
</tr>
<tr>
<td>EU tailpipe CO₂</td>
<td>130g/km</td>
<td>95g/km</td>
<td>Further regulation</td>
</tr>
<tr>
<td>Environmental</td>
<td>Tailpipe emissions CO₂ -&gt; NOx -&gt; PM</td>
<td>Well to wheel</td>
<td>Total life cycle impact</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ZERO TAILPIPE EMISSION</th>
<th>Infrastructure required for mass market acceptance</th>
<th>Range extended fuel cell and fuel cell prime mover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery electric vehicle (BEV)</td>
<td>BEV – tailored for application</td>
<td></td>
</tr>
<tr>
<td>Plug-in hybrid (PHEV) – modest range</td>
<td>PHEV – full utility</td>
<td></td>
</tr>
</tbody>
</table>

| LOW TAILPIPE EMISSION             | Mild hybrid / full hybrid                           |                                                   |
| Downsized current gen. TPS       | Next gen. high efficiency TPS                       | Hybrid focussed thermal propulsion systems (TPS)  |
| TECHNOLOGY ENABLERS              | Connected and autonomous – level 1/2/3             | Connected and autonomous – level 4/5              |
|                                   | Reduced vehicle energy demand and smart energy management |                                                   |

![Roadmap](https://example.com/roadmap.png)

Figure: UK Passenger Vehicle Roadmap 2017 (UK Automotive Council, 2017)
Problem Locating

1. “Range Anxiety” – BEV’s Limited Range

2. “Convenience” – Charging Infrastructure, Charging Speed

3. “Cost” – Manufacture Investment, Purchase Price & Running Cost
“Range Anxiety”

- More than 70% BEV owners worried about Limited Range. (Krupa et al., 2014)

Range /km of 5 Best-Selling EV vs ICE Vehicles
“Convenience” – Infrastructure Dependency

- Customer concern most on infrastructure before purchase

- Amount of charging position vs petrol station (EU)
  - Electric charging position: 131,675 – 13.4% fast chargers (>7kW), end of 2017
  - Fuel pump: 1,157,290, end of 2016

- Charging speed vs ICEV & FCV
  - Slow charging (up to 3kW): 6–8 hours
  - Fast charging (7kW – 22kW): 3–4 hours
  - Rapid charging (43, 50, or 120kW): 30 minutes for 80% charge
  - ICE & FC vehicle: Less than 10 minutes

“Cost” – Manufacture, Purchase & Running

- Longer Range Needed for BEVs ("Range Anxiety")
  - Larger & Heavier Battery Pack ($0.25 \, \text{kW} \cdot \text{h/kg}$ & $0.21 \, \text{kW} \cdot \text{h/L}$)
  - Higher Manufacture Cost ($£225/\text{kW} \cdot \text{h}$)
  - Expensive Purchase Price & Running Cost

Customers Concern Most on Cost

High Energy Density of Hydrogen →

\[ 1kg \ H_2 + \text{Air} \xrightarrow{\text{PEMFC}} \approx 20kW \cdot h\ \text{Electricity} + \ H_2O \]

Extending Range /km for EVs

- **Range% Extending** (2kg \( H_2 \)) > 30% for large EVs
- > 50% for small EVs

- Range After Extending > 500km – Not Far Away to the ICEVs
Feature – Reduce Infrastructure Dependency

- Demountable Design → Reduce dependency of charging positions

   Save time for drivers → Avoid queueing or looking for charging positions in peak travel periods, reduce charging time

   Flexible refuelling method

     Stage 1 → Rent & Replace + Centralized Refueling & Distribution

     Stage 2 → Fast Self-Refuelling

- Reduce pressure on the National Grid System → High power and electricity consumption charging facilities

- Increase utilisation of hydrogen fuelling station before FCV commercialised & broaden application for FC technology
High Energy Density of Hydrogen → Reduce Weight & Size of Power Unit

Toyota's 70 MPa Hydrogen: 33.3 kW·h/kg & 1.4 kW·h/L

Tesla's Panasonic Lithium battery: 0.25 kW·h/kg & 0.21 kW·h/L

- For manufacturer → Reduce battery investment
- For customer → Lower purchase and running cost

Fulfil occasional long distance trip demand

Flexible & economical choice – rent & replace FC range extender instead of buying or renting expensive large BEVs

% of cars making long distance trips
(per tranche of number of trips >130 km per annum)

<table>
<thead>
<tr>
<th>% of cars</th>
<th>0</th>
<th>1 to 6</th>
<th>7 to 15</th>
<th>15 to 30</th>
<th>over 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main car</td>
<td>1%</td>
<td>9%</td>
<td>10%</td>
<td>8%</td>
<td>4%</td>
</tr>
<tr>
<td>Second car</td>
<td>15%</td>
<td>12%</td>
<td>4%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>Single car</td>
<td>3%</td>
<td>14%</td>
<td>12%</td>
<td>4%</td>
<td>3%</td>
</tr>
</tbody>
</table>

19% Never >130km
62% Occasionally >130 km
19% Frequently >130 km

(TNS SOFRES, 2014)
EP Tender – BEV + Gasoline Engine

1. Range → 500km extra range
2. Convenience → Fast & convenient fueling facilities
3. Green → Fossil fuel, emission & time domain
4. Efficiency → ICE around 30%

Typical Solutions

http://www.eptender.com/
Avoid over-discharge & extend lifespan for battery pack
Reduce temperature impact on battery performance
Connect vehicle with live traffic information
- Smooth and prioritise traffic flow → reduce traffic congestion
- Driver assist → route optimization, charging & rental point reminder
- Choose the best drive mode → Vehicle could response appropriately according to duty cycle and traffic condition
Ideal System Demonstration

Physical Connection

Charging Interface

Communication Path

External Live Traffic Information
Challenge & Future Focus

- Durability of Fuel Cell Stack
- Hydrogen Production, Storage and Transportation
- Cost of Core Component (e.g. Pt catalyst, PEM Material and Hydrogen Tank)
- Connection & Interface Adaption with Different EV

Connected & Demountable Fuel Cell Range Extender
Thank you for Listening
Reference


Appendix

Power Comparison: EV Charger vs Total Household Appliances /kW

- Household Appliances Total Power (average): 10
- Slow Family Charger: 3
- Normal Fast Charger: 22
- Tesla SC: 135

Electricity Consumption: EV vs Household /kWh

- Household Daily Electricity Consumption: 13
- BMW i3: 22
- Nissan Leaf: 24
- VW e-Golf: 24
- Tesla Model S: 70
- BYD E6: 82