Electric Vehicle Battery Re-use in Stationary Applications

Fintan McLoughlin

Dublin Energy Lab
Overview

Electric Vehicles
Vehicle types

Battery Technologies
Chemistry type

Stationary Applications
Building Integrated Photovoltaics (BIPV)
Vehicle Types

**Conventional (ICE)**
No electrification

**Start-stop**
ICE shuts down under braking and rest

**Class I**

**Class II**

**Micro/mild hybrid**
Start-stop combined with regenerative braking used to boost vehicles acceleration
Vehicle Types

**Class II**  
**Full-hybrid (HEV)**  
Start-stop combined with regenerative braking  
used for electric driving

**Class III**  
**Plug-in hybrid (PHEV)**  
Charged off the grid and used for Electric  
driving (20-50km)

**Battery Electric Vehicles (BEV)**  
Battery is the vehicles only energy source
Electric Vehicles (Batteries)

Class I
Traditional and advanced lead based batteries

Class II
Nickel-Metal Hydride (NiMH) and Lithium Ion (Li-Ion)

Class III
Li-Ion or Sodium Nickel Chloride (NaNiCl2) for heavy duty vehicles
Electric Vehicles (Batteries)

<table>
<thead>
<tr>
<th>EV Type</th>
<th>Battery Capacities</th>
<th>Battery Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEV</td>
<td>1 – 5 kWh</td>
<td>NiMH</td>
</tr>
<tr>
<td>PHEV</td>
<td>5 – 15 kWh</td>
<td>NiMH/Li-Ion</td>
</tr>
<tr>
<td>BEV (EREV)</td>
<td>greater 15kWh</td>
<td>Li-Ion</td>
</tr>
</tbody>
</table>
Projected worldwide market penetration for battery technology by vehicle type

EV Type

* 405,000 BEV and PHEV on the road globally in early 2014

Source: IEA
Battery (characteristics)

Energy Density
Specific energy (Wh/kg) and Specific power (W/kg)

Cost
€/kWh and €/kW

Lifetime
Chemistry type
Battery specific energy & power

Battery (characteristics)

**Energy Density**
Specific energy (Wh/kg) and Specific power (W/kg)

**Cost**
€/kWh and €/kW

**Lifetime**
Chemistry type
## Battery cost

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>€/kWh</td>
</tr>
<tr>
<td>Lead based</td>
<td>100 - 250</td>
</tr>
<tr>
<td>NiMH</td>
<td>400 - 500</td>
</tr>
<tr>
<td>Li-Ion</td>
<td>300 - 450</td>
</tr>
</tbody>
</table>

Battery (characteristics)

**Energy Density**
Specific energy (Wh/kg) and Specific power (W/kg)

**Cost**
€/kWh and €/kW

**Lifetime**
Chemistry type
Battery lifetime

<table>
<thead>
<tr>
<th>Type</th>
<th>Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead based</td>
<td>3 – 8 years</td>
</tr>
<tr>
<td>NiMH</td>
<td>8 – 10 years</td>
</tr>
<tr>
<td>Li-Ion</td>
<td>10 years*</td>
</tr>
</tbody>
</table>

* Can be significantly less if operated under high DoD > 80%

Other important battery characteristics

Self-discharge
Dependent on temperature and SOC

Temperature range
During charging & discharging

Recharge power (C-rate)
Vehicle types
Self discharge

<table>
<thead>
<tr>
<th></th>
<th>Discharge rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead based</td>
<td>~ 3%</td>
</tr>
<tr>
<td>NiMH</td>
<td>~ 15% - 20%</td>
</tr>
<tr>
<td>Li-Ion</td>
<td>~ 5%</td>
</tr>
</tbody>
</table>

Other important battery characteristics

Self-discharge
Dependent on temperature and SOC

Temperature range
Affects charging & discharging

Recharge power (C-rate)
Vehicle types
Temperature range

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead based</td>
<td>-30 to +75°C</td>
</tr>
<tr>
<td>NiMH</td>
<td>-10 to +45°C</td>
</tr>
<tr>
<td>Li-Ion</td>
<td>-25 to +55°C</td>
</tr>
</tbody>
</table>

Other important battery characteristics

**Self-discharge**
Dependent on temperature and SOC

**Temperature range**
Affects charging & discharging

**Recharge power (C-rate)**
Vehicle types
Re-charge power (C-Rate)

<table>
<thead>
<tr>
<th></th>
<th>kW/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead based</td>
<td>0.35</td>
</tr>
<tr>
<td>NiMH</td>
<td>$1^{ab}$</td>
</tr>
<tr>
<td>Li-Ion</td>
<td>$0.5 - 2C^a$</td>
</tr>
</tbody>
</table>

$^a$ Charge must be managed by an active cooling system

$^b$ Charge must be managed by an adequate electronic and electric control system

So why recycle batteries from electric vehicles??

**Specific Energy**
EV can no longer sustain minimum travel distance

**Specific Power**
A minimum acceleration velocity is no longer attainable

These points are generally accepted to occur when storage capacity has reduced by 20% or when available peak power has decreased by 25% of its maximum

However between 70 – 80% of original battery capacity still remains and can be considered for re-use in other applications
Stationary application

Building integrated Photovoltaic's (BIPV)
Growing market of BIPV installations

Operational control strategies
High penetrations of PV & excess capacity is causing network stability problems on grid such as voltage and frequency disturbances

Battery storage
A need to balance supply and demand at a local level
Global grid connected PV installed capacity projections

Global grid connected PV by sector

BIPV operation

General configuration of a grid connected PV system with battery storage

BIPV operation

Legend
- Battery Charge
- Self Consumption
- Battery Discharge
- Import Grid

Electricity Power (kW)

Time of Day

00:30 06:00 12:00 18:00 00:00
EV charging profile

Source: Electric Vehicle Behaviors: Adoption and Charge Times
http://wiki-energy.org/
EV discharging profile (speed proxy)

how will battery perform subjected to building load profiles???

**Building profiles**

Building load profiles are very different to EV profiles

**BIPV control strategies**

Control strategies may be necessary to limit battery cycle use
Conclusions

**EV and battery availability**
Currently it is estimated that there are 405,000 PHEV & BEV’s on the road and projected 20 million by 2020.

**PV penetration**
BIPV market penetration is growing worldwide and a means of storing excess electricity capacity will be required to avoid overloading network grid infrastructure.

**EV battery re-use**
Reusing EV batteries for BIPV can provide a “cheap” method of providing storage as between 70-80% of capacity still remains after being retired from the automotive industry.
Questions?

Email:

fintan.mcloughlin@dit.ie