Extended Range Electric Vehicles components preliminary sizing based on real mission profiles

Filippo Colzi
The context: EVs hurdles

COSTS AND RANGE

<table>
<thead>
<tr>
<th>Car Model</th>
<th>Cost</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>RENAULT</td>
<td>21.850* €</td>
<td>210 km</td>
</tr>
<tr>
<td>LEAF</td>
<td>24.790* €</td>
<td>199 km</td>
</tr>
<tr>
<td></td>
<td>31.950 €</td>
<td>150 km</td>
</tr>
<tr>
<td></td>
<td>36.499 €</td>
<td>190 km</td>
</tr>
<tr>
<td></td>
<td>79.440 €</td>
<td>502 km</td>
</tr>
</tbody>
</table>

* Not including the battery pack

MID-LEVEL FUEL CAR

- Cost: 20.000 €
- Range: 800 km
Mid-term solutions

PLUG-IN HYBRIDS

Extended Range Electric Vehicles - EREVs
### EREVs powertrain: actual situation

#### MANUFACTURERS DIFFERENT CHOICES

<table>
<thead>
<tr>
<th>Car Model</th>
<th>BP capacity [kWh]</th>
<th>RE Power [kW]</th>
<th>RE type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chevrolet Volt / Opel Ampera</td>
<td>16</td>
<td>63</td>
<td>1.400 cc – 4 cylinders</td>
</tr>
<tr>
<td>Fisker Karma</td>
<td>20.1</td>
<td>175</td>
<td>2.000 cc – 4 cylinders</td>
</tr>
<tr>
<td>Suzuki Swift Erev</td>
<td>2.66</td>
<td>-</td>
<td>660 cc – 3 cylinders</td>
</tr>
<tr>
<td>Audi A1 e-tron</td>
<td>12</td>
<td>15</td>
<td>254 cc - Wankel</td>
</tr>
<tr>
<td>Volvo C30</td>
<td>24</td>
<td>45</td>
<td>nd – 3 cylinders</td>
</tr>
<tr>
<td>Hyundai i-oniq</td>
<td>-</td>
<td>45</td>
<td>1.000 cc – 3 cylinders</td>
</tr>
<tr>
<td>BMW i3 Rex*</td>
<td>18.8</td>
<td>25</td>
<td>647 cc – 2 cylinders</td>
</tr>
<tr>
<td>Lotus/Proton Emas</td>
<td>11.5</td>
<td>35</td>
<td>1.200 cc – 3 cylinders</td>
</tr>
<tr>
<td>Tata Megapixel</td>
<td>13</td>
<td>22</td>
<td>325 cc – 1 cylinder</td>
</tr>
</tbody>
</table>
OBJECTIVE
Preliminary define a rational sizing for Battery Pack capacity and Range Extender power.

MEANS
• Real Mission profiles data
• Vehicle dynamic model
• EREV behaviour simulation model
EREV requirements

- Pure electric everyday-life usage
- Coherence between battery life-span and vehicle life-span
- No forced changes in driving habits

Minima requirements

Worst-case Analysis
Every-day usage

Real missions data

- **4 cars**
- **5 months** of data acquisition

![Bar chart showing mean daily driven distance](chart.png)

- **63 km/day**
Battery/car life-span

- Common car life: 150,000 km
- Declared Battery Life: 2,000 cycles.
- Objective: 2,000 cycles have to cover minimum 150,000 km

1 cycle = 150,000 / 2,000 = 75 km

Minima requirements choice

- Everyday-life range: minimum 63 km/day
- Battery life-span required: minimum 75 km/day

--> 75 km/day
Minimum Battery capacity

Mean specific wheel energy required

75 km/day --> 15,47 kWh
January, 10th 2012

- Distance covered: **601 km**
- Mean speed: appr. 100 km/h
- Maximum speed: >150 km/h
- Energy consumption: **178 kWh**
How much hybrid? - Power

![Graph showing energy in the battery pack and energy produced by the RE over time.](image)

**Energy in the Battery Pack [kWh]**
- 0 kW
- 8 kW
- 20 kW
- 32 kW

**Energy produced by the RE [kWh]**
- 150 kWh
- 95 kWh
- 40 kWh

**Time [hh.mm]**

- 0.00
- 3.00
- 6.00
- 9.00
- 12.00
- 15.00
- 18.00
- 21.00
- 24.00
How much hybrid? - Costs

Hp:
- Electric energy: 0.15 €/kWh
- Fuel: 1.80 €/l
- B.P.: 600 €/kWh
- R.E.: 1.500 to 2.500 €
How much hybrid? – Choice

Battery Pack capacity: **15.47 kWh**
R.E. nominal power: **38.95 kW**
How much hybrid? – Choice

- Energy in the Battery Pack [kWh]
- Energy produced by the RE [kWh]

Graphs showing energy consumption and production over time.
**Additional analyses**

1. **Natural gas** instead of gasoline
   - Lower fuel cost
   - Same sizing

2. Economic comparison with traditional vehicle for the 5 months-use
   - **No significant differences:** + 2.1%

3. **Speed limitations**
   - **120 km/h**
   - **90 km/h**

<table>
<thead>
<tr>
<th></th>
<th>RE Power [kW]</th>
<th>B.P. capacity [kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>No limits</td>
<td>38.95</td>
<td>15.4</td>
</tr>
<tr>
<td>Limit 120km/h</td>
<td>31.65</td>
<td>15.4</td>
</tr>
<tr>
<td>Limit 90km/h</td>
<td>17.92</td>
<td>15.4</td>
</tr>
</tbody>
</table>
Conclusions

• Simple process but identification of a preliminary sizing
  o Rational requirements
  o Close to final users (real missions data)

• Battery pack sizing → everyday-life usage
• Thermal engine sizing → performances and exceptional routes

• Work composed by many parts, each one wants to be discussed and improved
Filippo Colzi
Filippo.Colzi@rse-web.it