ARRIVING AT CHARGING SCHEMES AND SUPPORT INFRASTRUCTURE

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Agenda

1. ZERO EMISSION BUS DEPLOYMENT
2. APPROACH TO CHARGING NEEDS
3. SUMMARY OF KEY FINDINGS
4. TAKEAWAYS & INSIGHTS

Offer a birds-eye view and to highlight points of interest in the planning process

How CFF is considering the charging system for the ZEB deployment with TransJakarta
In Context

ZERO EMISSION BUS DEPLOYMENT PLANNING

- Survey current bus tech
- Understand bus route network
- Analyse specifics & benefits
- Business & financial modelling
- Design bus schedules & pick depots
- Discuss w/ operators and OEMs
- Charging and power supply
- Procure electric buses

Feasibility

Business Case

$ Tender

12 Nov Webinar

19 Nov Webinar

we’re here

26 Nov Webinar
Our Approach

**Transjakarta e-bus trials**
- Simulated passenger load
- Air conditioning usage
- Route elevation
- Weather and temperature

**Battery Performance (measured)**

**Route Analysis**
- Route and service profile
- Passenger ridership
- Number of buses
- Replacement Ratio
- Total Cost of Ownership

**Ideal E-Bus Specifications**
- e.g. battery size, passenger capacity, etc.

**Charging needs and Infrastructure**
- e.g. depot + opportunity or depot-only scheme, etc.
- Energy demand
Summary of Key Findings

A **324 kWh** battery pack has a theoretical maximum range of **382 km**

**Factors** that affect the effective range:
- Depth of discharge x **0.80** 305 km
- Air conditioning use x **0.92** 281 km
- Passenger loading x **0.85** 238 km

- **324 kWh battery** vs. TJ e-bus trials
  - ~ **1.36 kWh/km**
  - ~ **0.8 - 1.46 kWh/km**

**Route Analysis**

<table>
<thead>
<tr>
<th>Selected Routes</th>
<th>Daily Bus Utilisation</th>
<th>Route Length</th>
<th>Trip Duration</th>
<th>Passenger Ridership</th>
<th>TCO vs Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRT (“A”)</td>
<td>&gt; <strong>240 km/bus/day</strong></td>
<td>~28 km</td>
<td>1.5 hr</td>
<td>~35k/day</td>
<td>+ 6-11%</td>
</tr>
<tr>
<td>Non-BRT (“B”)</td>
<td>&lt; <strong>180 km/bus/day</strong></td>
<td>~10 km</td>
<td>0.7 hr</td>
<td>~05k/day</td>
<td>+ 24-36%</td>
</tr>
<tr>
<td>Non-BRT (“C”)</td>
<td></td>
<td>~32 km</td>
<td>1.0 hr</td>
<td>~04k/day</td>
<td></td>
</tr>
</tbody>
</table>
Battery pack selection and Initial Charging Scheme

Battery pack sizes in general are consistent across manufacturers. In our case, ‘medium’ stores 180 kWh and ‘large’ stores 324 kWh.

<table>
<thead>
<tr>
<th>Selected Routes</th>
<th>Daily Bus Utilisation</th>
<th>Battery Pack</th>
<th>Charging Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRT (&quot;A&quot;)</td>
<td>&gt; 240 km/bus/day</td>
<td>180 kWh</td>
<td>Depot w/ Opportunity</td>
</tr>
<tr>
<td>Non-BRT (&quot;B&quot;)</td>
<td>&lt; 180 km/bus/day</td>
<td>324 kWh</td>
<td>Depot-only (overnight)</td>
</tr>
<tr>
<td>Non-BRT (&quot;C&quot;)</td>
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Since a large battery pack cannot cover the entire range of BRT Route “A”, in-route charging will remain necessary. Thus, a medium battery pack was chosen to save on cost.

Charging Power Rate:
- Depot (slow): 50 kW, 1 unit : 2 e-buses
- Opportunity (fast): 150+ kW, 1 unit : 5 e-buses
Energy Demand and Peak Load

Using the calculated energy consumption of \(1.3 - 1.5 \text{ kWh/km}\), the number of e-buses, and utilisation, a rough daily energy demand can be estimated.

<table>
<thead>
<tr>
<th>Selected Routes</th>
<th>Daily Bus Utilisation</th>
<th>E-bus Deployed</th>
<th>Energy Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRT (&quot;A&quot;)</td>
<td>&gt; 240 km/bus/day</td>
<td>70</td>
<td>21.8–25.2 MWh</td>
</tr>
<tr>
<td>Non-BRT (&quot;B&quot;)</td>
<td>&lt; 180 km/bus/day</td>
<td>30</td>
<td>7.0–8.1 MWh</td>
</tr>
<tr>
<td>Non-BRT (&quot;C&quot;)</td>
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We estimate that around \(15\) e-buses (BRT) will be using the opportunity charging at a given time. By using the selected charging rate of \(150 \text{ kW}\), we get a rough estimate of \(2.25 \text{ MW peak load}\).
Initial look: Electricity Grid (Jawa-Bali System)

- Average daily load curve from PLN
- Information period: July 2018 – July 2019
- Relatively ‘flat’ demand profile
- Peak to off-peak ratio around 1:1.3
- Peak day can be 35% higher than an average day
- Note: uniform pricing during peak and off-peak
Initial look: Great Jakarta Power Grid

- Information period: July 2019
- Jakarta highest peak load of 5,573 MW
- Supplied by 7 subsystems
- Total Capacity of 12,090 MW
- Total Load of 9,140 MW
- +32% margin

Source: M. Ikhsan Asaad, PLN, July 2019
Ongoing next steps

- An analysis of the local power grids where the pertinent bus depots are located; consider smart charging systems

- An analysis of distributed renewable energy generation e.g. Rooftop Solar PV, to manage peak load, improve operations, and increase environmental and public health benefits

- Fine-tuning individualized charging strategy to actual bus timetables
1. Bus technologies and their requisite charging strategies need to be analysed as a system. It is not necessarily true that shorter routes require smaller batteries and longer routes require larger batteries.

2. A deployment strategy that replaces all of the buses on a designated route with zero-emission vehicles is highly advantageous. From infrastructure, data gathering, analysis, and decision making...
3. It is necessary to understand the relationship between operational requirements and measured battery performance to develop an optimal charging strategy.

4. The preferred charging schemes and infrastructure must be considered within the context of local grid capacity and the potential to upgrade capacity in the future.
5. Bus depots are often ideal locations for installing distributed renewable energy generation, such as rooftop solar photovoltaic (PV) systems, which can reduce operational costs, improve air quality and deliver significant climate benefits.