Forecast Model for Electromobile Loads at Stuttgart Airport and Fair

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Mobility Concepts and Infrastructure
1. Motivation I
Airports and Fairs as electromobile hotspots

- world’s largest parking facilities
- particularly affected by EV-mass-deployment

A) International Airports

B) International Fairgrounds
1. Motivation II
Scientific questions for Stuttgart Airport and Fair

(1) Which \textbf{maximum loads in kW} arise from passengers, employees, exhibitors and visitors from 2017-2027?

(2) Which daily \textbf{energy turnovers in kWh/d} can be expected within this time period?

(3) Are there any essential \textbf{peak-times} over the day?

(4) How does land-sided electromobility influence the site’s \textbf{overall energy consumption}?
2. Scientific Approach I
Within the MATLAB environment in two steps:

I. The **mobility behaviour** of each user group is reconstructed for half an year by means of site-specific data.

   a) Airport user groups: passengers & employees
   b) Fair user groups: employees, visitors & exhibitors

II. By means of probability factors, all *trips are omitted* which statistically do not result in a charging event.

   What are those probability factors?
2. Scientific Approach II
How many charging events result from an arriving plane?

<table>
<thead>
<tr>
<th>reduction of the overall probability:</th>
<th>probability factor</th>
<th>data source:</th>
</tr>
</thead>
<tbody>
<tr>
<td>arriving aircraft with a maximum of xx seats</td>
<td>= 100%</td>
<td>flight schedule and airport homepage</td>
</tr>
<tr>
<td>average aircraft load factors</td>
<td>x 75%</td>
<td>balance sheet airline company</td>
</tr>
<tr>
<td>amount of passengers travelling by car</td>
<td>picked up x 35%</td>
<td>passenger survey 2015</td>
</tr>
<tr>
<td>average load factor ca (1 person = 100%)</td>
<td>x 50%</td>
<td>own assumption</td>
</tr>
<tr>
<td>EV market share (here for 2027)</td>
<td>contra x 3.8%, moderate x 10.5%, pro x 19.6%</td>
<td>see assumption slide no. 6</td>
</tr>
<tr>
<td>chosen parking area (TA=terminal access, 10% outside)</td>
<td>parks x 30%, TA x 60%, (…) (…)</td>
<td>passenger survey 2015</td>
</tr>
<tr>
<td>AC and DC share</td>
<td>AC 70%, DC 30%, AC/DC 100%</td>
<td>derived from parking data</td>
</tr>
<tr>
<td>Plug-in probability (here for 2027)</td>
<td>x 25%, x 25% x 0%*</td>
<td>see assumption slide no. 6</td>
</tr>
</tbody>
</table>

probability factor @2027 & contra EV

~1 out of 10,000 arriving passengers
~3 out of 10,000 arriving passengers
3. General Assumptions

Which parameters change with time?

1. Market share of electric vehicles
2. Battery capacity
3. Plug-in probability of electric vehicles (EV)
4. Proportion of PHEV and full EV

Other assumptions:
- Consideration of 36 full EV and 33 PHEV according to ¹)
- EV consumption 20kWh/100km
- Constant mobility behaviour
- Static charging performances of 22kW\text{AC} and 50kW\text{DC}

¹) https://www.greengear.de, last accessed 26.08.2017
4. Simulation Results I

Maximum loads and daily energy turnover

Stuttgart Airport
“much energy at moderate power rates”

- 0.5 MW
- Pro Scenario
- Moderate Scenario
- Contra Scenario

Stuttgart Fair
“little energy at high power rates”

- 2 MW
- Pro Scenario
- Moderate Scenario
- Contra Scenario

Power in kW

Energy in kWh/d

- 50 x car per day
- 35 x car per day

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4. Simulation Results II

Essential peak times and load shift potentials

A) Stuttgart Airport
~0,5MW @2027, pro EV
- continuous operation
- good load shift potentials:
  passenger : employee 1 : 1

B) Stuttgart Fair
~2MW @2027, pro EV
- harsh peak time
- event-driven occupation
- limited load shift potentials:
  visitor : employee/exhibitor 6 : 1
Even in long-term, electromobile loads from passengers and employees will have no significant influence on the Airport’s overall energy consumption and generation.
Building load **correlates strongly** with the electromobile power peaks.

Existing power network is already **considerably stressed** by major events; EV-deployment further aggravates this situation.
5. Conclusion

Summary and field of application

- **Proof of Concept:**
  - For an optimistic EV market penetration of 20% by 2027, *uncontrolled EV loads* up to **0.5MW for Stuttgart Airport** respectively **2MW for Stuttgart Fair** can be expected.
  - BUT: model did not account for (a) air-sided EV-deployment or (b) e-mobile taxis, buses, business fleets and delivery vehicles.
  - Necessity of public transport expansion.

- **Wide range of applications:**
  - infrastructure dimensioning & evaluation of grid-strengthening.
  - development of load management strategies.
  - economic and ecological assessments.
  - need for additional power generation capacities.
  - development of new billing systems.
Thank you for your attention!

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### Back-up I:
General assumptions Airport loads

#### TABLE I
**Assumptions Arrival and Resting Time**

<table>
<thead>
<tr>
<th>EV arrival time</th>
<th>arriving aircraft $t_a$ + 10min</th>
<th>$t_a$ + 10min</th>
<th>departing aircraft $t_d$</th>
<th>$t_d$ - 120min</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>⓫</td>
<td>⓫</td>
<td>DC</td>
<td>⓫</td>
</tr>
<tr>
<td>AC</td>
<td>⓫</td>
<td>⓫</td>
<td>AC</td>
<td>⓫</td>
</tr>
<tr>
<td>±</td>
<td>30 min normally distr.</td>
<td>45 min normally distr.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### TABLE II
**Assumptions Catchment Area Passengers**

<table>
<thead>
<tr>
<th>arrival share</th>
<th>departure share</th>
<th>passenger provenence</th>
<th>distance in km</th>
<th>variance in km</th>
</tr>
</thead>
<tbody>
<tr>
<td>11%</td>
<td>11%</td>
<td>Boeblingen</td>
<td>19</td>
<td>±5</td>
</tr>
<tr>
<td>11%</td>
<td>14%</td>
<td>Esslingen</td>
<td>16</td>
<td>±5</td>
</tr>
<tr>
<td>2%</td>
<td>3%</td>
<td>Göppingen</td>
<td>38</td>
<td>±10</td>
</tr>
<tr>
<td>3%</td>
<td>8%</td>
<td>Heilbronn</td>
<td>74</td>
<td>±15</td>
</tr>
<tr>
<td>4%</td>
<td>9%</td>
<td>Ludwigsburg</td>
<td>30</td>
<td>±10</td>
</tr>
<tr>
<td>4%</td>
<td>25%</td>
<td>Ostalbkreis</td>
<td>94</td>
<td>±20</td>
</tr>
<tr>
<td>5%</td>
<td>-</td>
<td>Stuttgart</td>
<td>13</td>
<td>±7</td>
</tr>
<tr>
<td>37%</td>
<td>14%</td>
<td>Tuebingen</td>
<td>33</td>
<td>±5</td>
</tr>
<tr>
<td>4%</td>
<td>6%</td>
<td>Rems-Murr-Kreis</td>
<td>52</td>
<td>±10</td>
</tr>
<tr>
<td>4%</td>
<td>9%</td>
<td>Reutlingen</td>
<td>30</td>
<td>±5</td>
</tr>
<tr>
<td>22%</td>
<td>25%</td>
<td>Other</td>
<td>50</td>
<td>±45</td>
</tr>
</tbody>
</table>

#### TABLE III
**Employment Groups and their Assumptions**

<table>
<thead>
<tr>
<th>share</th>
<th>employment group</th>
<th>working model in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>27%</td>
<td>airline staff, flight crew</td>
<td>C: 50</td>
</tr>
<tr>
<td>20%</td>
<td>domiciled companies airport</td>
<td>O: 10</td>
</tr>
<tr>
<td>13%</td>
<td>runway monitoring, passenger handling, ground handling services and flight operations</td>
<td>O: 85</td>
</tr>
<tr>
<td>10%</td>
<td>customs, (federal) police, security service and flight safety</td>
<td>O: 95</td>
</tr>
<tr>
<td>7%</td>
<td>haulage and cargo handling</td>
<td>O: 60</td>
</tr>
<tr>
<td>6%</td>
<td>retailers and restaurant business</td>
<td>O: 25</td>
</tr>
<tr>
<td>5%</td>
<td>energy and water supply, cleansing and waste disposal</td>
<td>O: 65</td>
</tr>
<tr>
<td>3%</td>
<td>commercial department, internal services, public relation</td>
<td>O: 30</td>
</tr>
<tr>
<td>3%</td>
<td>facility and IT management</td>
<td>O: 10</td>
</tr>
<tr>
<td>6%</td>
<td>other (accumulated)</td>
<td>O: 20</td>
</tr>
</tbody>
</table>

#### TABLE IV
**Assumptions Work Models & Shifts**

<table>
<thead>
<tr>
<th>name of the working model</th>
<th>from - to</th>
<th>no. of shifts</th>
<th>shift begin hh:mm/hh:mm/hh:mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>C core hour</td>
<td>8:00 - 17:00</td>
<td>8</td>
<td>4/10/16</td>
</tr>
<tr>
<td>F flight operation</td>
<td>6:00 - 23:30</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>P flight crew</td>
<td>4:00 - 20:00</td>
<td>3</td>
<td>equally distributed</td>
</tr>
<tr>
<td>24 24h operation</td>
<td>0:00 - 0:00</td>
<td>3</td>
<td>5/13/21</td>
</tr>
<tr>
<td>O opening hours</td>
<td>variable</td>
<td>1-2</td>
<td>airport booklet</td>
</tr>
</tbody>
</table>