SMART GRIDS

Fault detection? Restoration?
Data processing?
Privacy, security?
Pricing schemes?

Distributed generation (large scale)
Green energy sources (fluctuating)

ICT infrastructure

Distributed generation (small scale)

Local energy storage

Demand side management

New services & business models

PHEV charging (car parks)

PHEV charging (residential)

MODELING EV CHARGING

Literature:

- Model EV usage from regular vehicle usage
- Aggregated EV load estimation
- Pre-defined EV user types (e.g., residents, taxis, commuters...)
- Flexibility as fraction of time spent charging
- ...

Gap: data-driven EV modeling & real-world flexibility assessment

1. Typical behaviors in terms of time of arrival and departure?
2. Statistical models of sojourn vs time spent charging?
3. What amount of power can we shift over how much time?

## CONTENTS

1. Intro & motivation
2. Datasets
3. EV session analysis
4. Flexibility characterization

DATASETS: **iMove (BE)** AND **ELaadNL**

<table>
<thead>
<tr>
<th></th>
<th>iMove</th>
<th>ELaadNL</th>
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<tbody>
<tr>
<td>PERIOD</td>
<td>03/2012 – 03/2013</td>
<td>01/2012 – 03/2013</td>
</tr>
<tr>
<td># SESSIONS</td>
<td>8 520</td>
<td>1 141 849*</td>
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<tr>
<td># USERS</td>
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<td>CAR TYPE</td>
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<td>CHARGE POINT</td>
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<td>Public</td>
</tr>
<tr>
<td>TRIP DETAILS</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

**iMove**: Flemish EV field trial; data from 50 EVs shared 3 x 2 months

**ELaadNL**: EV innovation in NL; data from ~3000 public stations

* : Analysis on data from 1 Jan.–31 Mar. 2015 (N = 90 562)

### TYPICAL ARRIVAL AND DEPARTURE TIMES (1/2)

- **Elaad**
  - Daytime charging (9.4%)
  - Anytime charging, short sojourn (61.5%)
  - Nighttime charging (29.1%)

- **iMove**

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Typical Arrival and Departure Times (2/2)

- **Anytime charging, short sojourn (61.5%)**
  - Park to charge
  - AM/Noon/PM peaks on weekdays

- **Nighttime charging (29.1%)**
  - Charge near home

- **Daytime charging (9.4%)**
  - Charge near work
  - Shift to later times on weekends

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Average charging time ≈ 3h 42min

Average idle time ≈ 23min

SOJOURN AND IDLE TIMES (2/2)

Anytime charging, short sojourn (61.5%)

Nighttime charging (29.1%)

Daytime charging (9.4%)

Week ≈ Weekend

Longer in weekend

Shorter in weekend
Lower var. in week

QUANTIFICATION OF FLEXIBILITY: CALCULATION

\[ P_{\text{FLEX}}(t, \Delta) = \text{Maximal power that DR could either consume constantly, or not at all, in interval } [t, t+\Delta] \]

- Charging session has to include \([t, t+\Delta]\)
- Charging duration \(\geq \Delta\) [else we could not consume in full interval]
- Flexibility = session duration − \(\Delta\) ≥ charging duration [we can move it away]

Upper bound: we disregard impact of using/suppressing power in \([t, t+\Delta]\) on flexibility at other times \(t’\)

QUANTIFICATION OF FLEXIBILITY: RESULT

- Park to charge:
  - Daytime flexibility
  - Weekend: ≈ volume, but ≠ timing

- Near home:
  - Nighttime flex
  - Weekend: lower & more spread

- Near work:
  - Daytime flex
  - Low in weekend

CONCLUSION

- Real world data set
- Three major types of charging sessions
- Statistical models of user behavior
- Methodology to quantify flexibility

Application?
E.g., extrapolation of iMove data to 3% of Flemish fleet by 2020:
  - ~100k cars out of ~3.2M
  - E.g., noon in weekend ⇒ can have ~7MW extra for 2h
THANK YOU ... ANY QUESTIONS?

... It is not easy being green...
THANK YOU ... ANY QUESTIONS?

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