Battery Health Estimation in a Vehicle-to-Grid Scenario

Maitane Berecibar[1,2*], C. de Cauwer[1,2], T. Coosemans[1,2], J. Van Mierlo[1,2], M. Messagie[1,2]

[1]*Vrije Universiteit Brussel, MOBI Research Group, Pleinlaan 2, 1050 Brussels*

[2]*Flanders Make, 3001 Heverlee, Belgium*

(maitane.berecibar@vub.be)

VUB - MOBI


1979 - Vrije Universiteit Brussel


2014 - Vrije Universiteit Brussel

http://mobi.vub.ac.be/home/

Key Assets

Electric and hybrid vehicles

Battery Innovation Centre

Sustainable logistics

Urban mobility

http://mobi.vub.ac.be/home/

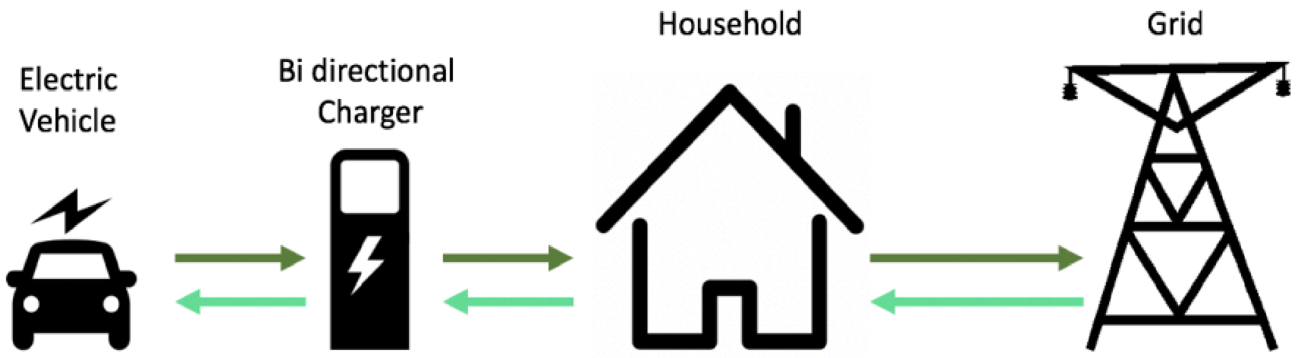
Key Data

40 years of expertise	**150** projects over last 5 years	**16** current EU Projects
5 M€ turnover 2016	**100** team members	**20** nationalities

http://mobi.vub.ac.be/home/

Agenda

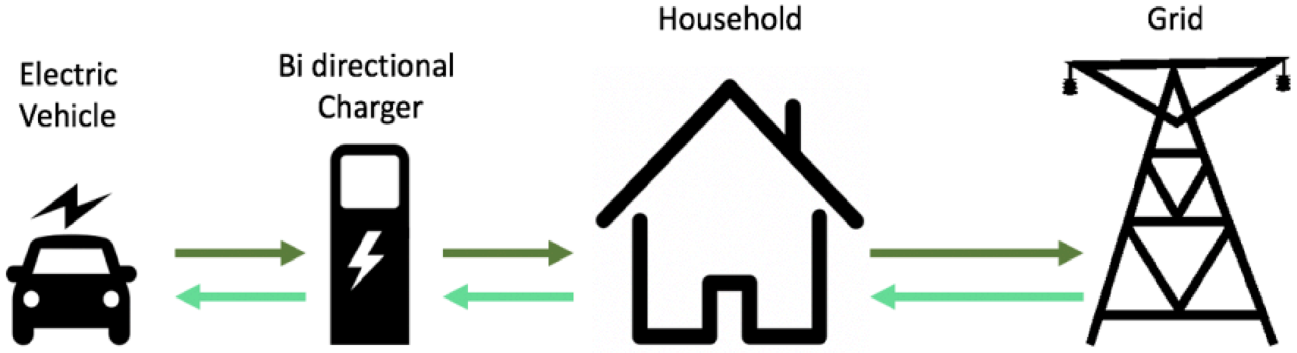
1. Motivation
2. Objective
3. Battery Health Algorithm
   1. Methodology
   2. Machine Learning
   3. Characteristics
4. Results
5. Conclusions



maitane.berecibar@vub.be

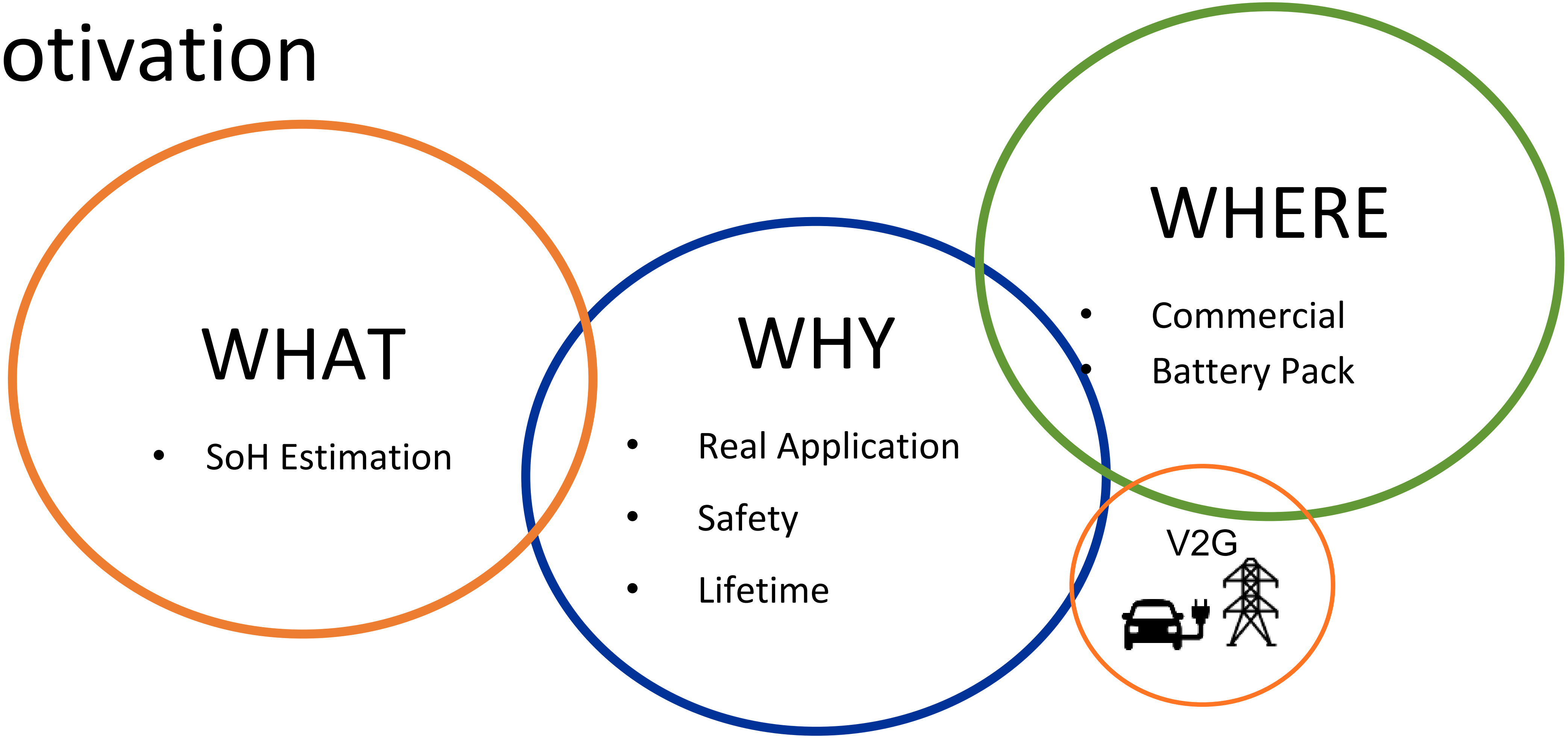
Agenda

1. Motivation
2. Objective
3. Battery Health Algorithm
    1. Methodology
    2. Machine Learning
    3. Characteristics
4. Results
5. Conclusions



maitane.berecibar@vub.be

Motivation



M. Berecibar et al., *"Critical Review of State of Health estimation methods of LiIon batteries for real applications"*, Renewable & Sustainable Energy Reviews

maitane.berecibar@vub.be

Motivation

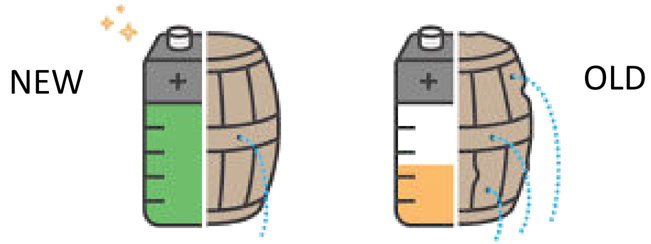
State of Health is the ability of a battery to store energy relative to its initial or ideal conditions

- 100% means the battery is fresh.
- 80% the battery is considered not usable for an Electric Vehicle and should be removed.

Why estimate the SoH?

- Recognize battery degradation.
- Prevent a possible failure.

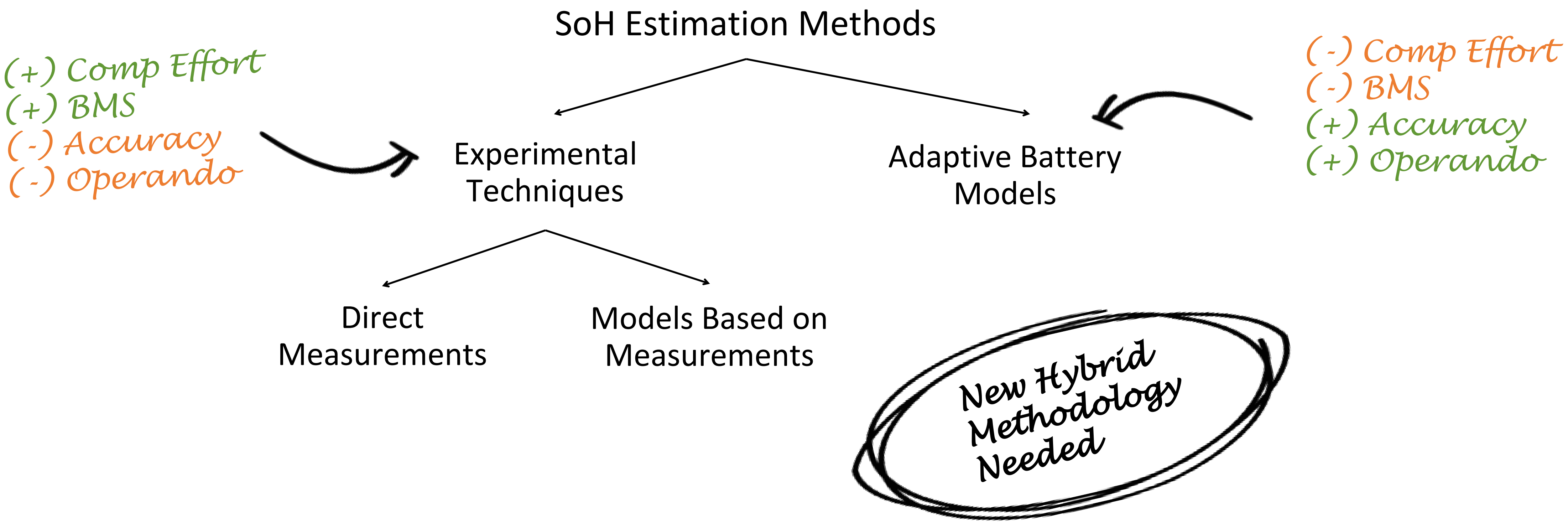
OLDER BATTERIES LOSE POWER FASTER



M. Berecibar et al., *“Critical Review of State of Health estimation methods of LiIon batteries for real applications",* Renewable & Sustainable Energy Reviews

maitane.berecibar@vub.be

Motivation

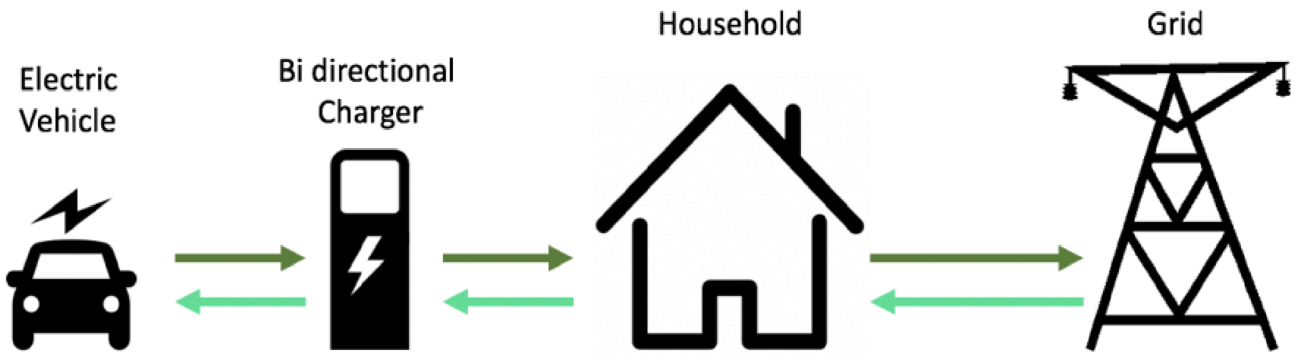


M. Berecibar et al., *"Critical Review of State of Health estimation methods of LiIon batteries for real applications"*, Renewable & Sustainable Energy Reviews

maitane.berecibar@vub.be

Agenda

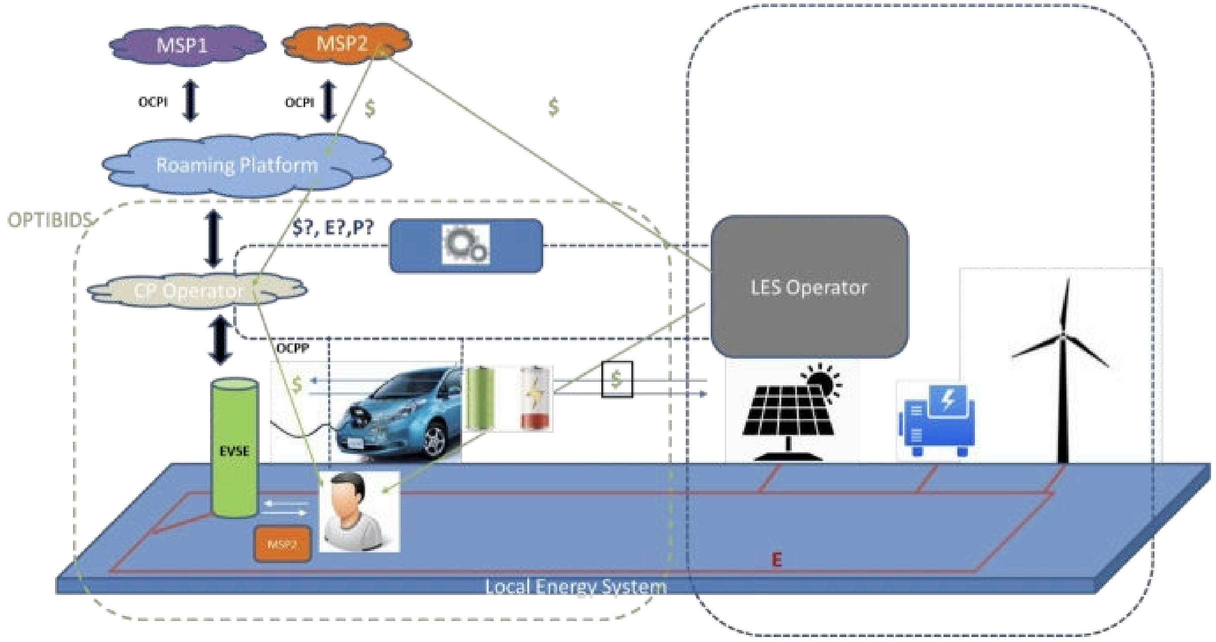
1. Motivation
2. Objective
3. Battery Health Algorithm
   1. Methodology
   2. Machine Learning
   3. Characteristics
4. Results
5. Conclusions



maitane.berecibar@vub.be

Context; OPTIBIDS

1. **Optimization of energy assets** in LES based on mobility needs.
2. **Develop intelligent smart and bi-directional charging strategies** for integration in LEC.
3. **Development** of off-board and on-board smart and **bi-directional DC chargers** with integrated local storage.
4. **Integration** of smart -and bidirectional chargers in the LES as sustainable ecosystems.



OPTIBIDS, Project grant agreement no: HBC.2018.0519, VLAIO, FLUX50
maitane.berecibar@vub.be

Objective

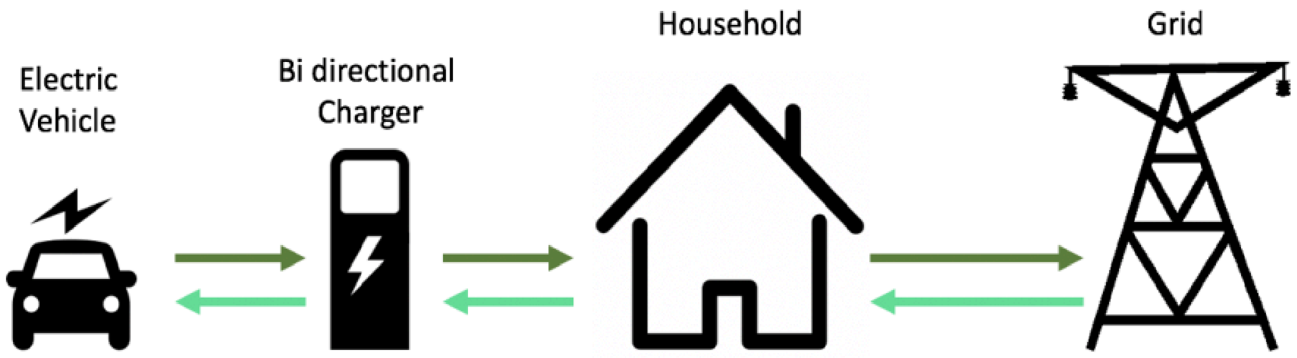
BMS Implementation	**EoL Detection**	**Error <1%**	**Application always available**
• Low computational effort • Real application	• Alarm • User Awareness	• Accurate • Reliable • Precise	• Costumer Needs • Energy Efficiency

M. Berecibar et al., *"Critical Review of State of Health estimation methods of LiIon batteries for real applications",* Renewable & Sustainable Energy Reviews

maitane.berecibar@vub.be

Agenda

1. Motivation
2. Objective
3. Battery Health Algorithm
    1. Methodology
    2. Machine Learning
    3. Characteristics
4. Results
5. Conclusions



maitane.berecibar@vub.be

Battery Health Algorithm: Methodology

- SoH estimation based on the capacity fade:

$$SoH_E = \frac{Q_{current}\,(Ah)}{Q_{fresh}\,(Ah)}\ x\ 100\%$$

- SoH estimation based on the internal resistance increase:

$$SoH_P = \frac{R_{current}\,(\Omega)}{R_{fresh}\,(\Omega)}\ x\ 100\%$$

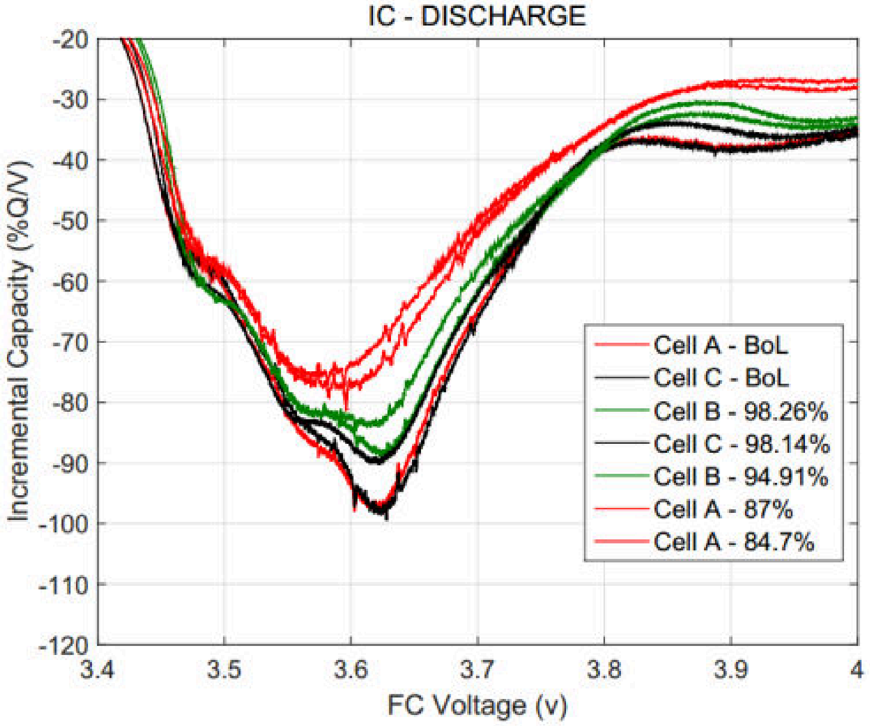
- Degradation mechanisms detection

M. Berecibar et al., *"Battery Health Estimation in a Vehicle-to-Grid Scenario"*, EVS32
maitane.berecibar@vub.be

Battery Health Algorithm: Methodology

Incremental Capacity Curves

- Quantify the Degree of Degradation of a cell
- Reveal Battery Degradation Mechanisms
    - Loss of Lithium Inventory
    - Loss of Active Material
    - Internal Resistance Increment Detection

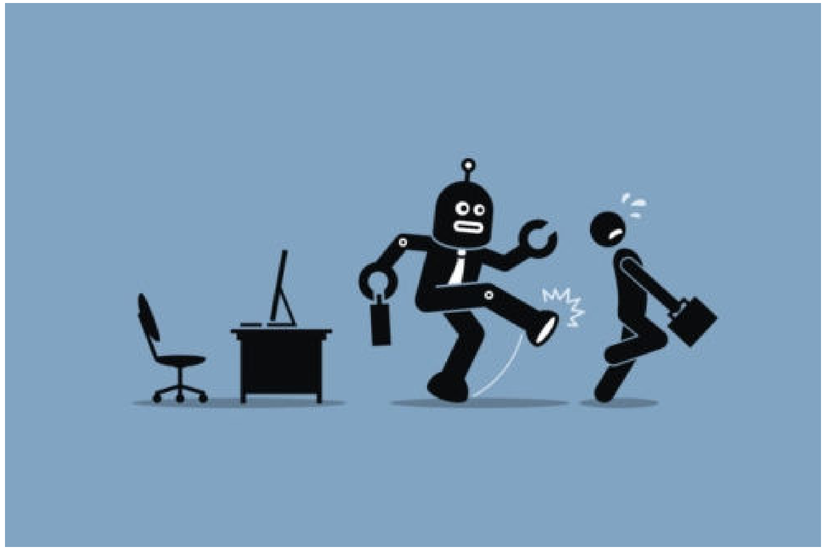


M. Berecibar et al., *"Online State of Health estimation on NMC cells based on Predictive Analytics"*, Journal of Power Sources

maitane.berecibar@vub.be

Battery Health Algorithm: Machine Learning

- Learning methods for V2G algorithms
  - Extended Kalman Filter
  - Unscented Kalman Filter
  - Genetic Algorithm
  - Particle Swarm Optimization
  - Gaussian Process Regression



M. Berecibar et al., *"Battery Health Estimation in a Vehicle-to-Grid Scenario"*, EVS32

maitane.berecibar@vub.be

Battery Health Algorithm: Characteristics

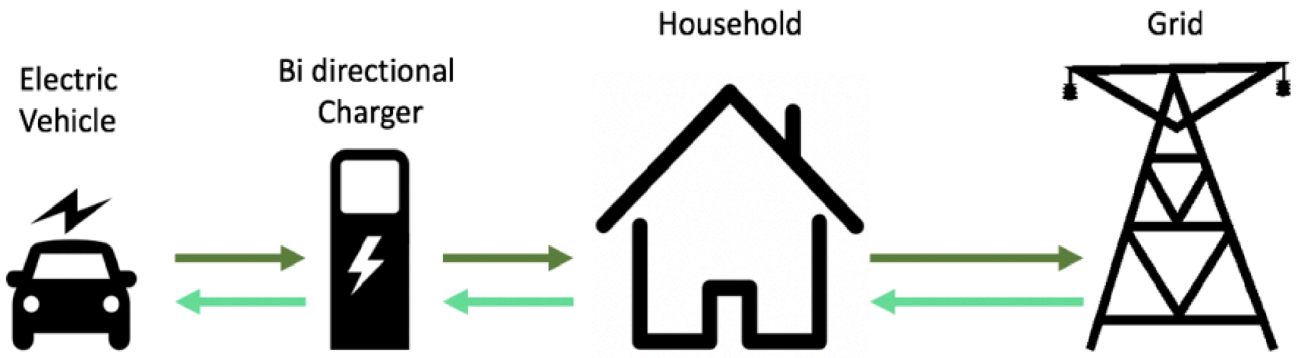
- Accuracy
- Training time
- Response time
- Linearity
- Self-learning

- Speed
- Predicting numeric
- Dimension reduction
- Simplicity
- Large data set performance

M. Berecibar et al., *"Battery Health Estimation in a Vehicle-to-Grid Scenario"*, EVS32
maitane.berecibar@vub.be

Agenda

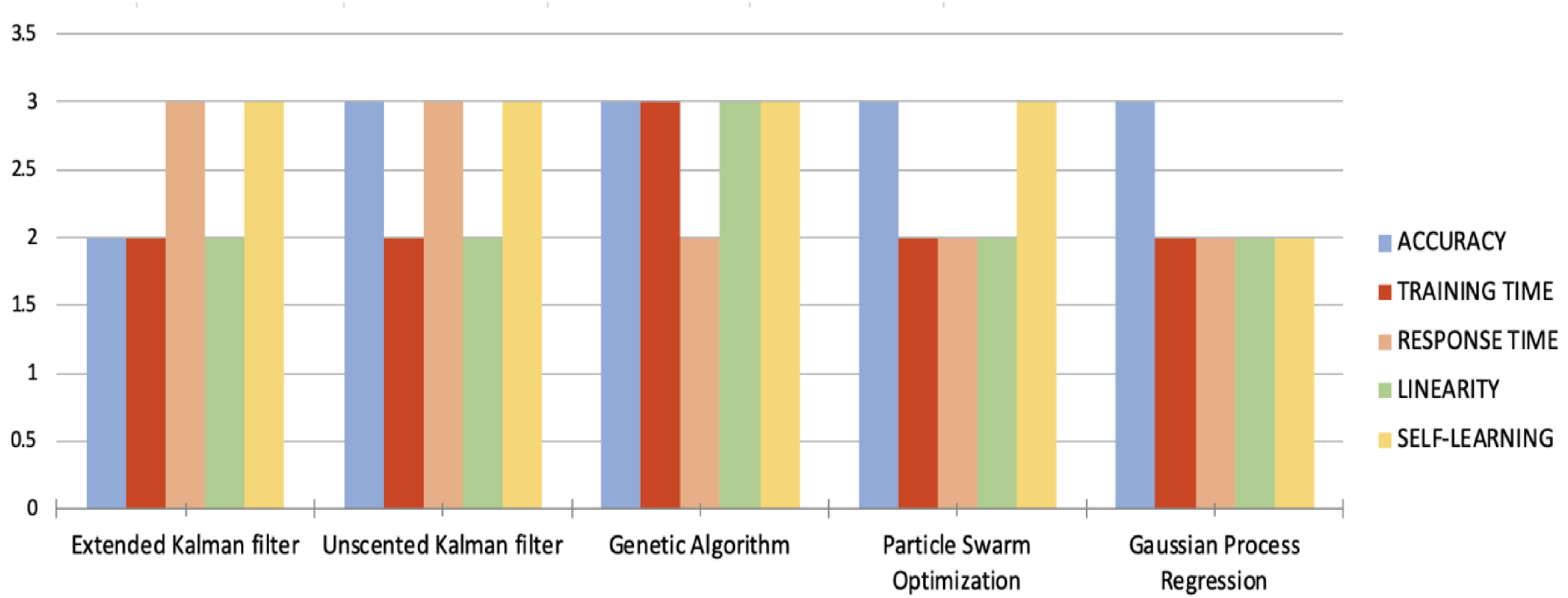
1. Motivation
2. Objective
3. Battery Health Algorithm
    1. Methodology
    2. Machine Learning
    3. Characteristics
4. Results
5. Conclusions



maitane.berecibar@vub.be

Results

- Accuracy, training time, response time, linearity and self-learning characteristics

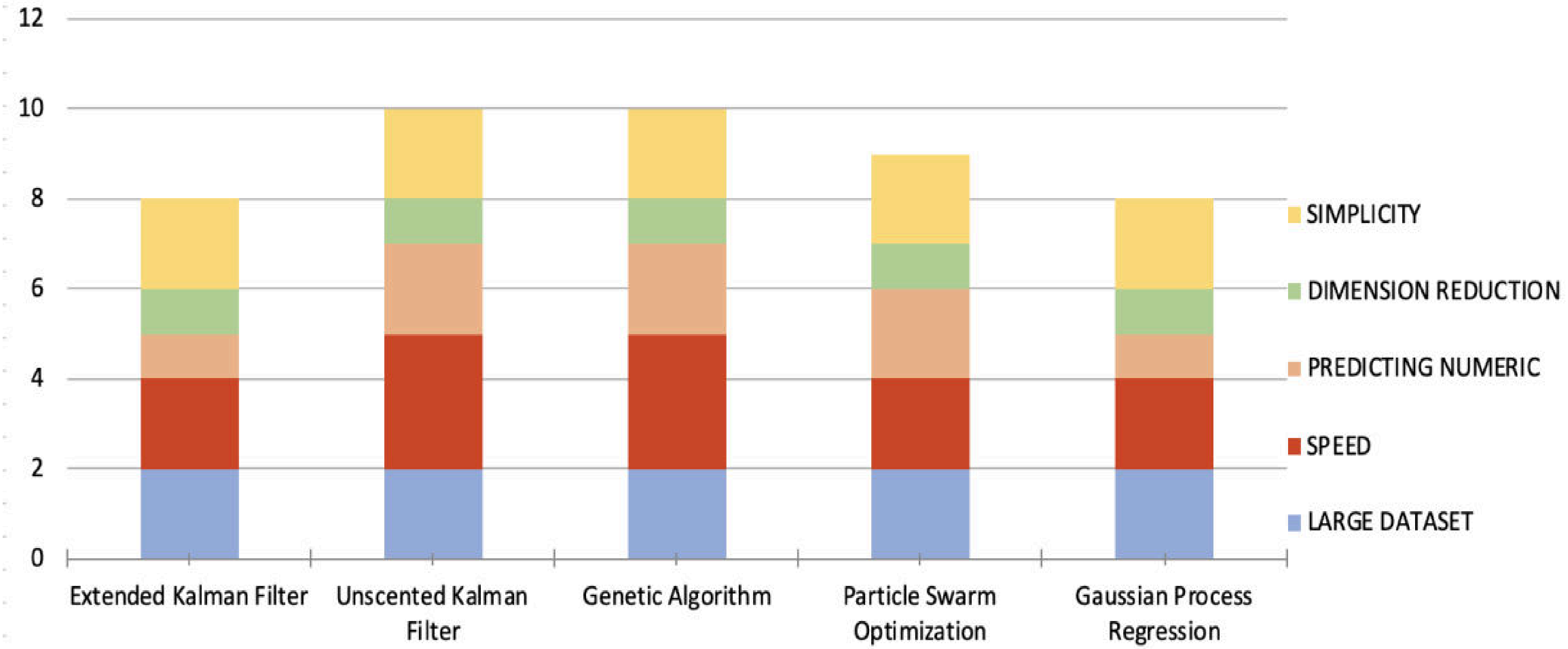


M. Berecibar et al., "Battery Health Estimation in a Vehicle-to-Grid Scenario", EVS32

maitane.berecibar@vub.be

Results

- Speed, predicting numeric, dimension reduction, simple and large data set performance characteristics



M. Berecibar et al., "Battery Health Estimation in a Vehicle-to-Grid Scenario", EVS32
maitane.berecibar@vub.be

Ranking

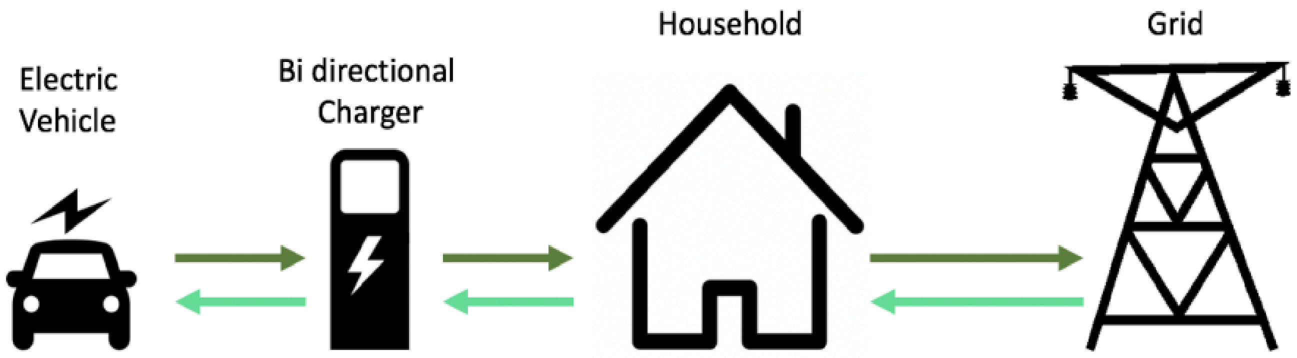
1. Genetic Algorithm:
   Very good in accuracy, training time, linearity and speed
2. Unscented Kalman Filter:
   Very good in accuracy, response time, self-learning and speed.
3. Particle Swam Optimization:
   Very good in accuracy and self-learning.
4. Extended Kalman Filter:
   Very good in response time and self-learning.
   Poor in predicting numeric.
5. Gaussian Process Regression:
   Very good in accuracy.
   Poor in predicting numeric.

M. Berecibar et al., "Battery Health Estimation in a Vehicle-to-Grid Scenario", EVS32

maitane.berecibar@vub.be

Agenda

1. Motivation
2. Objective
3. Battery Health Algorithm
    1. Methodology
    2. Machine Learning
    3. Characteristics
4. Results
5. Conclusions



maitane.berecibar@vub.be

Conclusions

BMS Implementation	EoL Detection	Accuracy	Application always Available	V2G

- Incremental Capacity Curves + Genetic Algorithm
- Implemented in OPTBIDS project
- Validation in 3 different demo sites

M. Berecibar et al., "Battery Health Estimation in a Vehicle-to-Grid Scenario", EVS32

maitane.berecibar@vub.be

Thank you!

- **M. Berecibar**, I. Gandiaga, I. Villarreal, N. Omar, J. Van Mierlo, P. Van den Bossche, *"Critical Review of State of Health estimation methods of LiIon batteries for real applications",* Renewable & Sustainable Energy Reviews.

- **M. Berecibar**, M. Gamendia, I. Gandiaga, J. Crego, I. Villarreal, *"State of Health estimation algorithm of LiFePO4 battery pack based on differential voltage curves for BMS application",* Energy.

- **M. Berecibar**, F. Devriendt, M. Dubarry, I. Villarreal, N. Omar, W. Verbeke, J. Van Mierlo, *"Online State of Health estimation on NMC cells based on Predictive Analytics",* Journal of Power Sources.

- M. Dubarry, **M. Berecibar**, A. Devie, D. Ansean, N. Omar, I.Villarreal, *"State of Health Battery Estimator Enabling Degradation Diagnosis: Model and Algorithm Description",* Journal of Power Sources.

Dr. Eng. Maitane Berecibar

Senior Researcher at MOBI

maitane.berecibar@vub.be