32nd Electric Vehicle Symposium (EVS32)

Electric vehicle range and battery lifetime: a trade-off

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Outline

1. Introduction
2. Battery ageing
3. Electric vehicle use case
4. Results
5. Conclusion

Introduction

- Electric vehicle's market is growing very fast
  - Global electric car stock (IEA*): 0.5 million in 2014, 2 million in 2017

* International Energy Agency

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- ...what is the impact of increasing the battery size on its longevity?
- ...how much can we extend the battery lifetime by charge optimisation?

Battery ageing

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- Main characteristics
  - Capacity (Ah) ⇔ Energy (Wh) ⇔ Vehicle range (km)
  - Impedance (Ω) ⇔ Maximum power (W) ⇔ Vehicle maximum acceleration ($m \cdot s^{-2}$)

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- Battery performances degrade over time
  - Cycling ageing: degradation due to charges/discharges
  - Calendar ageing: degradation during rest time
  - Parasitic reactions $\Rightarrow \begin{cases} \text{Capacity} \searrow & \Rightarrow \text{Energy} \searrow \\ \text{Impedance} \nearrow & \Rightarrow \text{Power} \searrow \end{cases}$
  - End of Life: Capacity $= 0.8 \cdot$ Initial Capacity

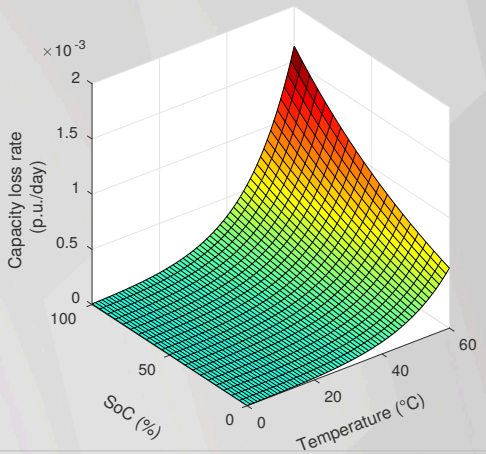
Battery ageing

Calendar ageing model

- Chemical reactions ⇒ Lithium consumption ⇒ Capacity fade

- Electric Vehicle
  - Battery is most of time at rest
  - Current rates are relatively low

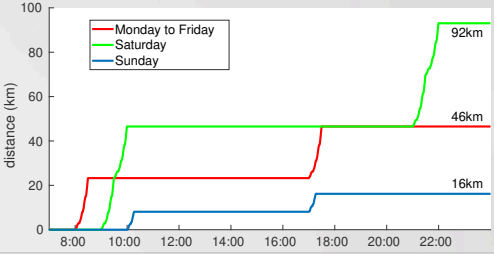
  ⇒ Calendar ageing
- Eyring's law for capacity fade
  - $\frac{dQ_F}{dt} = A \cdot \exp\left(\frac{-E_a}{k \cdot T} + B \cdot SoC\right)$

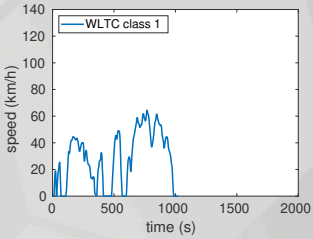


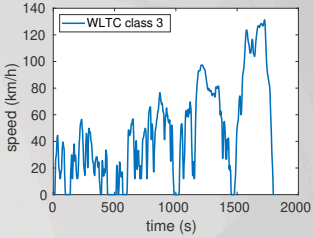
Electric vehicle use case

- Monday to Friday: home to work
  - WLTC class 3 (23 km)
- Saturday: leasures trip
  - 2x WLTC class 3 (46 km)
- Sunday: short trip
  - WLTC class 1 (8 km)

* WLTC = Worldwide harmonized Light vehicles Test procedure Cycle







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Charging strategies

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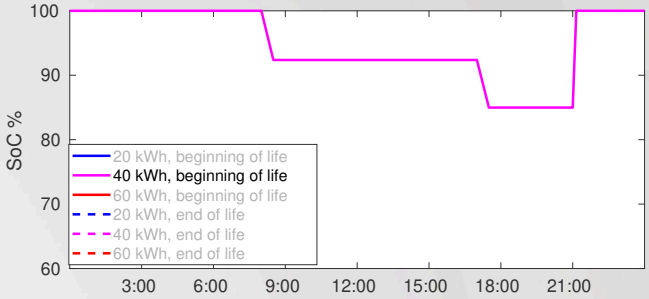

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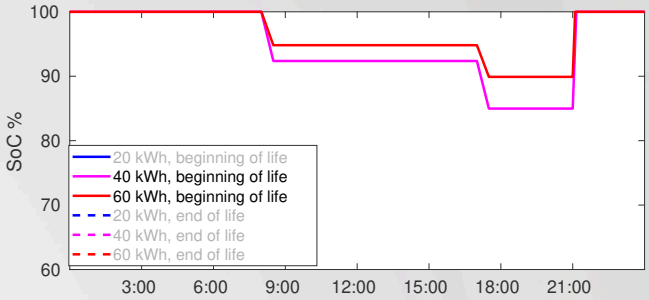

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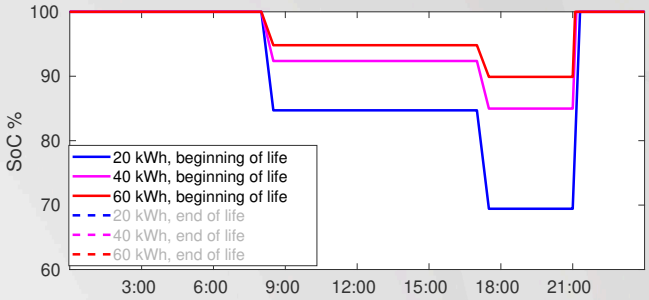

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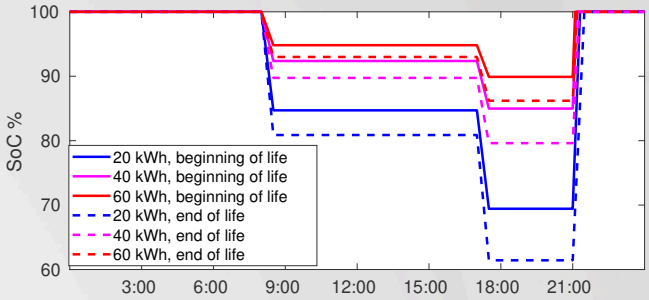

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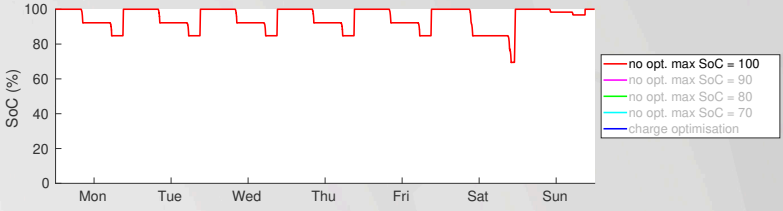

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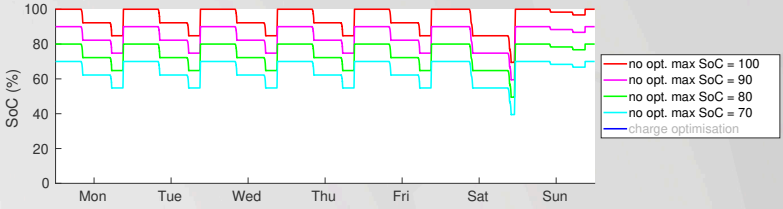

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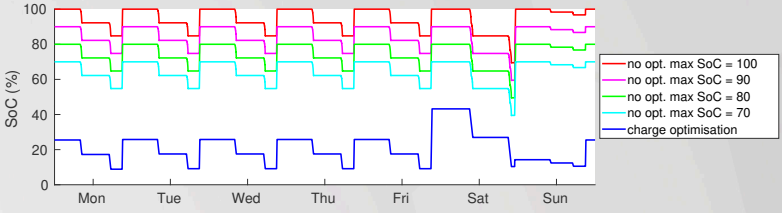

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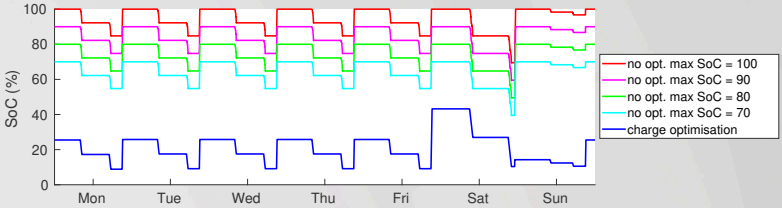
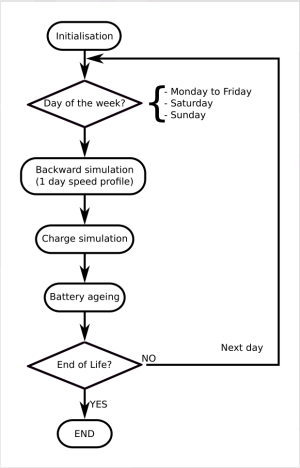


SoC profile depends on:

travelled distance, battery size, charging strategy and state of health

Electric vehicle use case

Simulation process



Initialisation

- Vehicle characteristics (mass, chassis, . . .)
- Battery characteristics (technology, size in kWh)
- Climate (constant temperature: 25 ℃)
- Trip conditions (speed profile)

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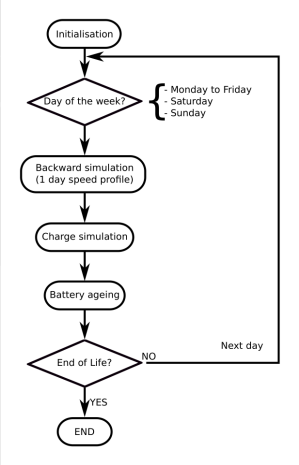
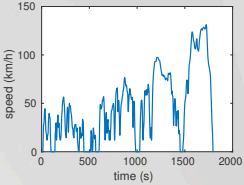


Backward simulation:



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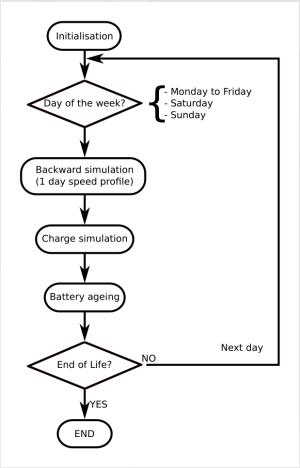

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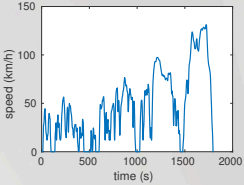

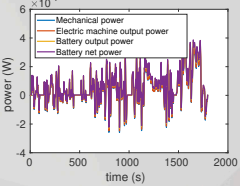

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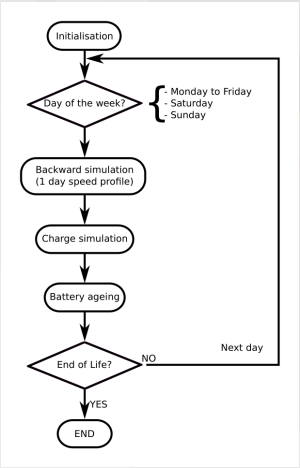

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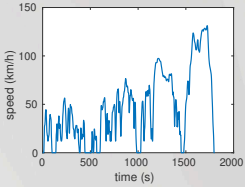

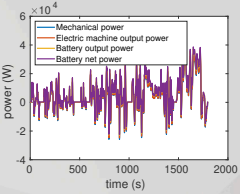

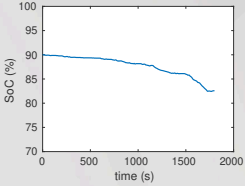

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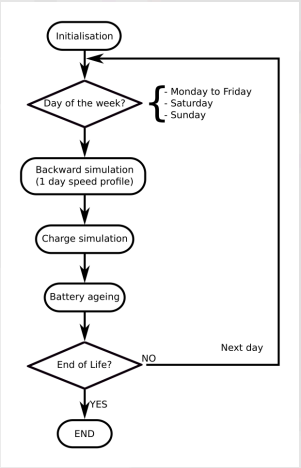
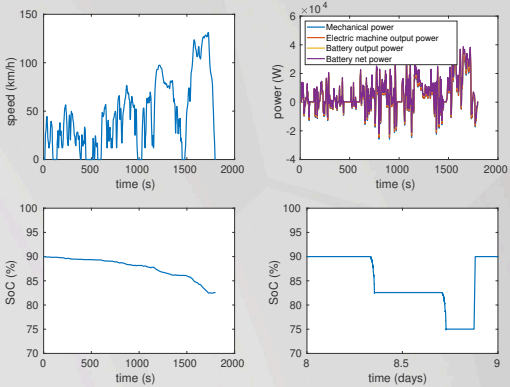


Charge strategy simulation:



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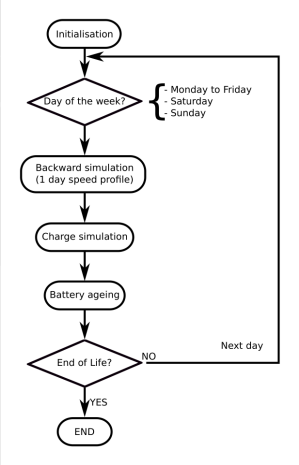
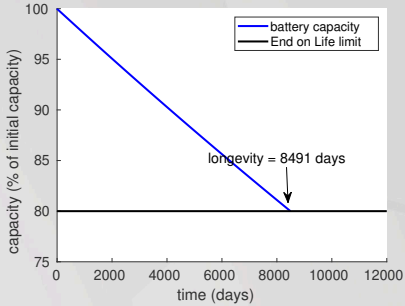


Battery ageing:



Results

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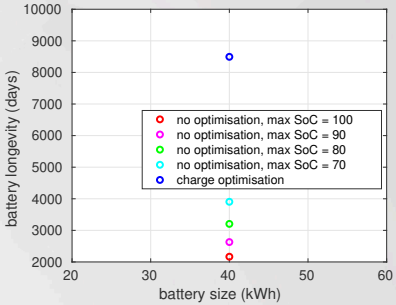
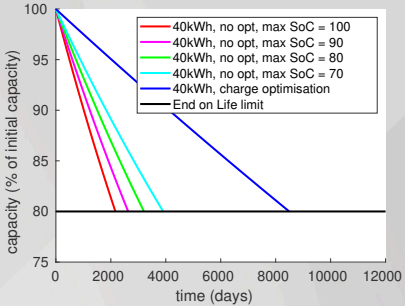


Capacity versus time (40kWh):



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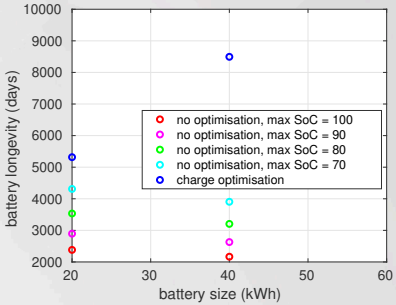
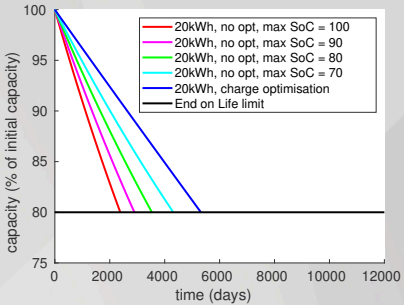


Capacity versus time (20kWh):



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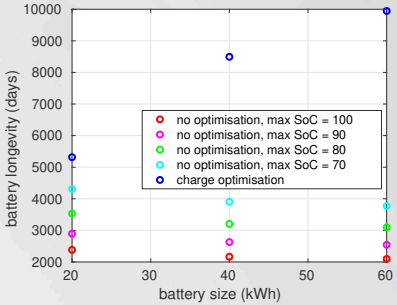
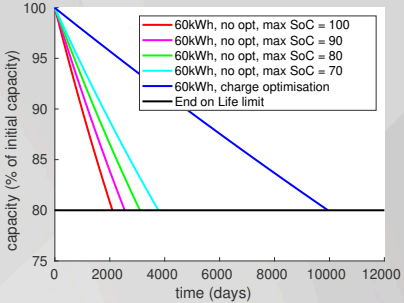


Capacity versus time (60kWh):



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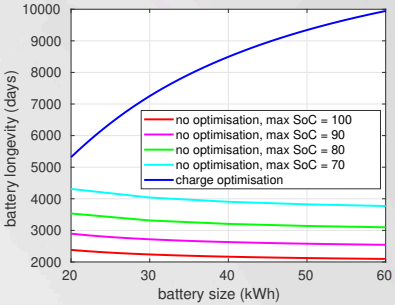

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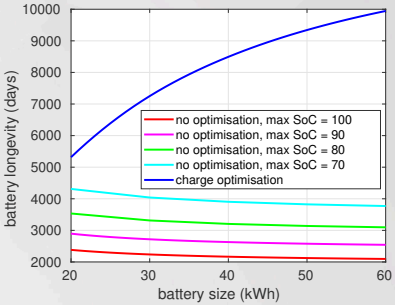

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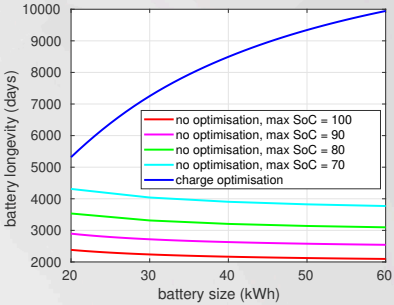

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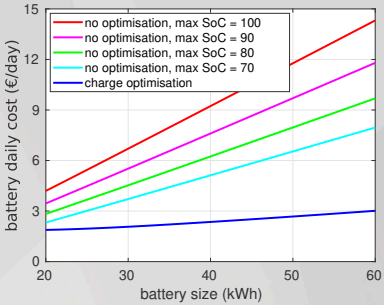

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* Battery cost = 500 €/kWh

Conclusions

- Battery size (and thus electric range) is increasing as manufacturing costs are becoming lower
- In bigger batteries, if charge is not optimised, mean state of charge is higher, impacting their longevity
- Charge optimisation can lead to a significant lifespan improvement
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Further work

- Battery ageing sensitivity
  - variable climatic conditions
  - trip conditions
  - user choices
- Combined ageing model: cycling + calendar
- Global environmental assessment

Thank you for your attention

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Ampère

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SoC profiles for a 40kWh battery