ECN

Energy research Centre of the Netherlands

Four years of electricity storage research at ECN: Why, what and how?

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Electricity storage at home

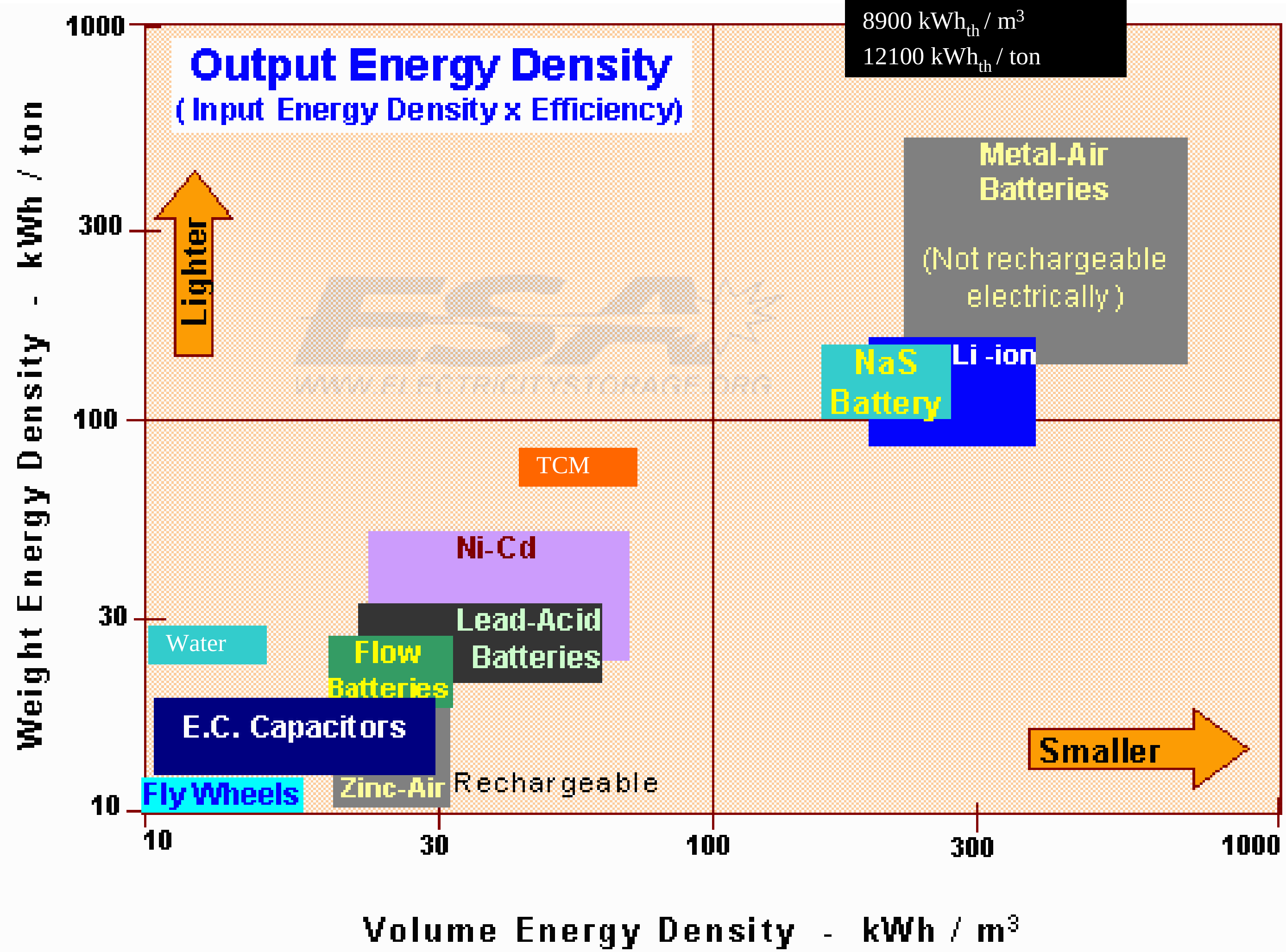
- About 350 million batteries (incl. 50 million rechargeable batteries) are bought every year by households in the Netherlands.
- In 2006 a Dutch household had on average 91 batteries. In 2003 this was 68 batteries.
- There are currently 100 million empty batteries in the Dutch households waiting to be handed in for recycling.
- 71% of all batteries used in Dutch households is recycled.

Source: StiBat

Hydrogen
3000 kWh_{th} / m^3
40000 kWh_{th} / ton

Electricity storage – many sizes and shapes

Petrol
8900 kWh_{th} / m^3
12100 kWh_{th} / ton



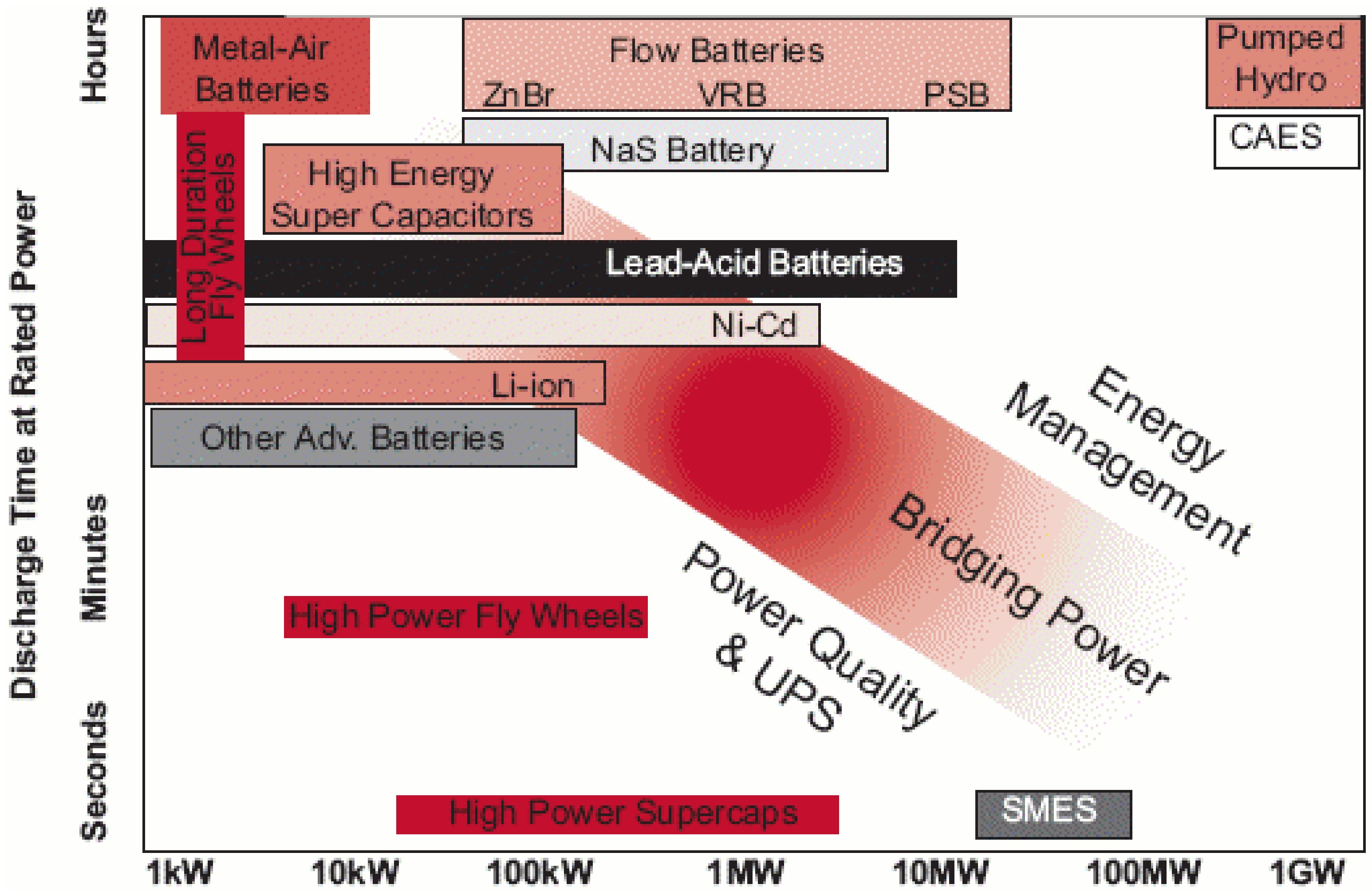
Grid connected electricity storage (GCES)

- Electricity storage systems that are connected to the main electricity grid for most of the time and have capacity available to support the stability and quality of the grid.

- Current world-wide GCES can provide about 4% of the total installed electricity production capacity.

- More than 90% of the current world-wide GCES is pumped-hydro.

Different storage types for different applications



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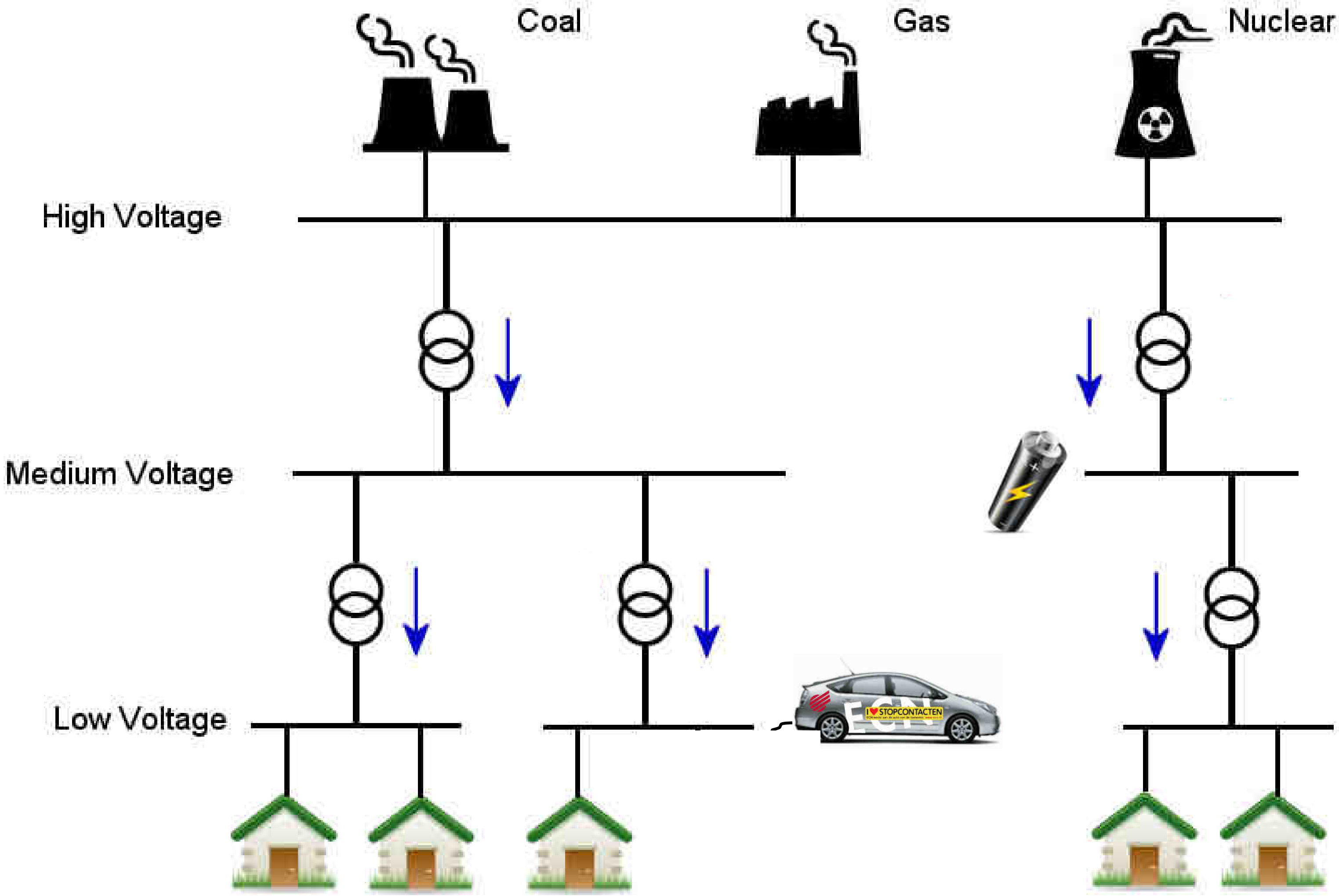
Purpose of GCES nowadays

- Peak shaving and Load levelling
  - Pumped hydro
  - Compressed air
  - Batteries

- Power quality improvement
  - Superconducting magnetic energy storage
  - Capacitors

GCES and the future electricity grid



The Challenge of the Changing System

Traditional situation:

- Demand
  - Behaves stochastically
  - Partially predictable
- Supply
  - Large scale production
  - Fully controllable
- Balancing
  - Centralised
  - Done by the supply-side

Future situation:

- Demand
  - Behaves stochastically
  - Partially predictable
- Supply
  - Behaves stochastically
  - Partially predictable
- Balancing
  - How to maintain the supply & demand balance?

The contribution of GCES to the future grid

- GCES provides the flexibility to balance supply and demand.
- GCES can solve power flow constraints by temporarily storing power produced by distributed generation (e.g. wind, PV)
- GCES can provide ancillary services (e.g. peak shaving)
- GCES can be a vital element in SmartGrids, where the storage systems are controlled intelligently

What type of GCES for future grids?

- Central GCES cannot solve congestion issues. It might even increase them.
- SmartGrids is all about decentralisation. Existing GCES systems are build with a centralised approach
- GCES should be decentralised: Pumped-hydro and compressed air are no option.

What type of GCES for future grids? (2)

- Battery technology most practical for decentralised application and fulfils balancing specifications.

- Lithium-ion batteries have the most promising performance.

- Plug-in (hybrid) electric cars are a serious candidate for future transportation
  - Decentralised
  - +/- 23 hours a day connected to the grid
  - Contain a significant amount of electricity storage
  - Are fitted with lithium-ion batteries

Lithium-ion batteries in ECN SmartGrids projects

- Universal Power Manager (UPM)
- Plug-in hybrid electric vehicles (Toyota Prius)
- Virtual Synchronous Generator (VSYNC)
- Electric vehicles & PowerMatcher (INTEGRAL)
- Intelligent Distribution Station (IntDS)

Why lithium-ion battery research at ECN?

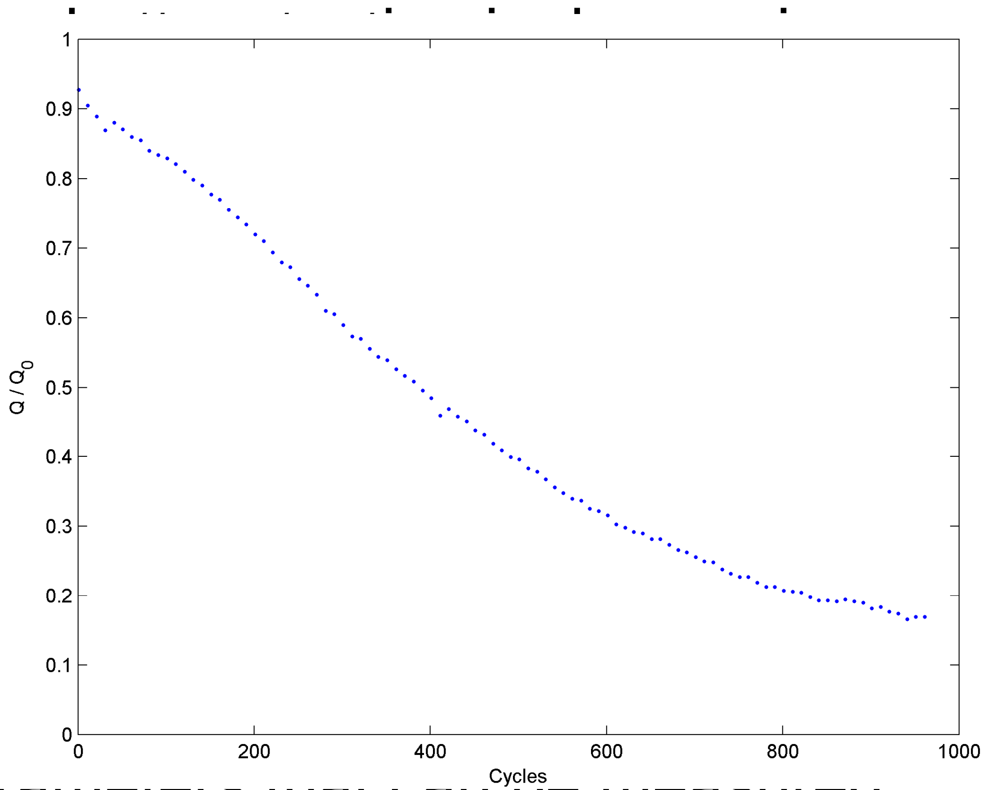
- Lithium-ion has the power and capacity to participate in SmartGrids.
- An important issue with lithium-ion batteries is ageing: Capacity and power reduces over time, while internal electric resistance is increasing.
- There is no public available information about lithium-ion battery ageing as function of time and depth of discharge.

Why lithium-ion battery research at ECN?

- Ageing characteristics is important for intelligent optimisation of GCES systems.
- Ageing characteristics are non-linear, hence over sizing storage systems might be profitable.
- There are no algorithms or models available to predict end of life.

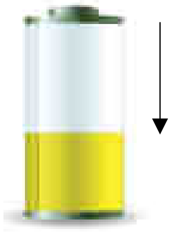
Why lithium-ion battery research at ECN?

- Com… “acce…
- Thes… repre… ge of batte…
- The a… e time… sing only parameters that can be measured



Characterising ageing behaviour is difficult!

- Dependency on many parameters
  - Current
  - Temperature
  - Depth of discharge
  - End of charge/discharge voltages

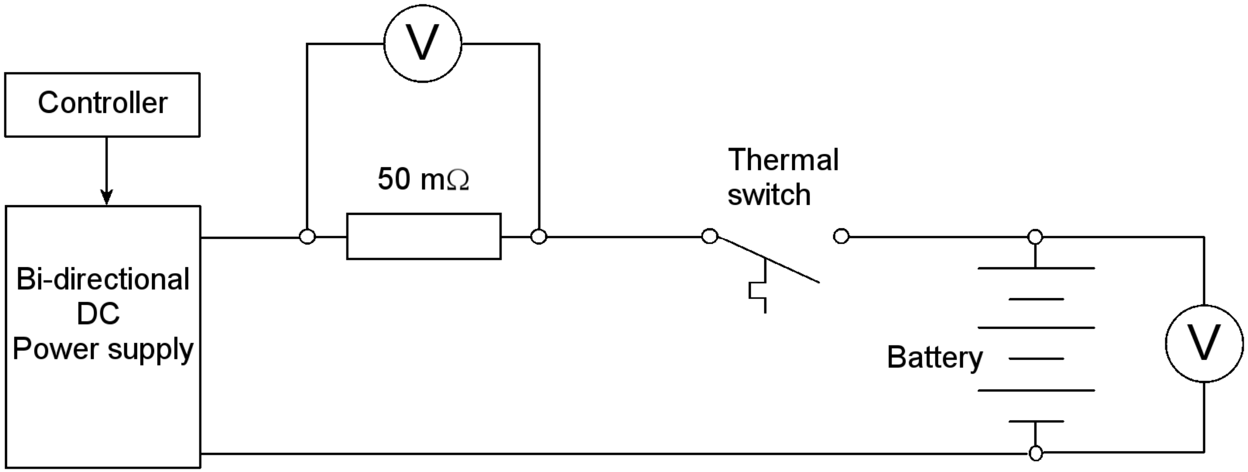


- Non-linear characteristics based on chemical reactions, ionic diffusion and mass transfer

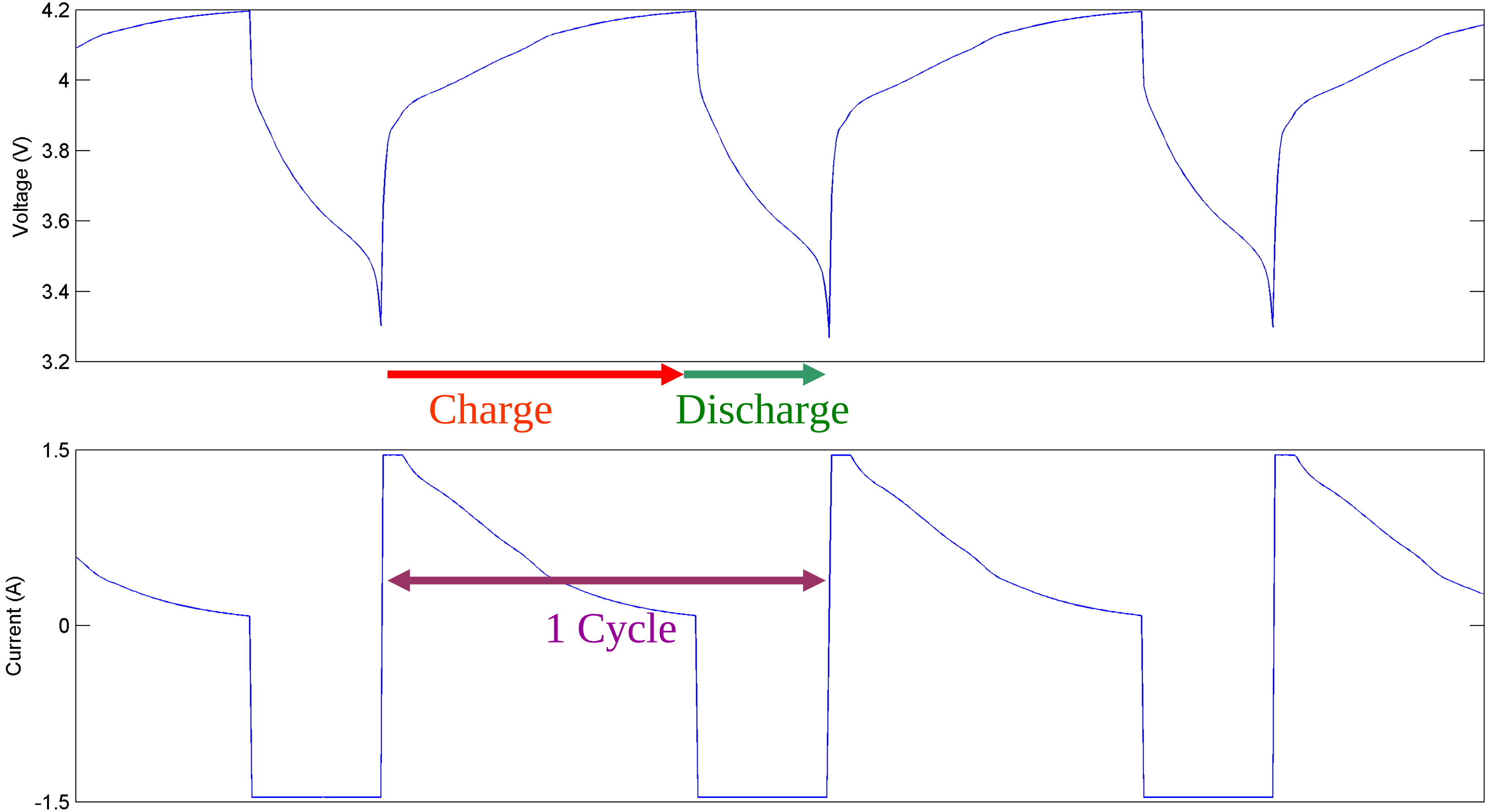
  → Black box approach

How to characterise battery ageing?

- A cyclic (charge/discharge) test pattern is applied on a battery in a conditioned environment.
- The test patterns have different depth of discharges.

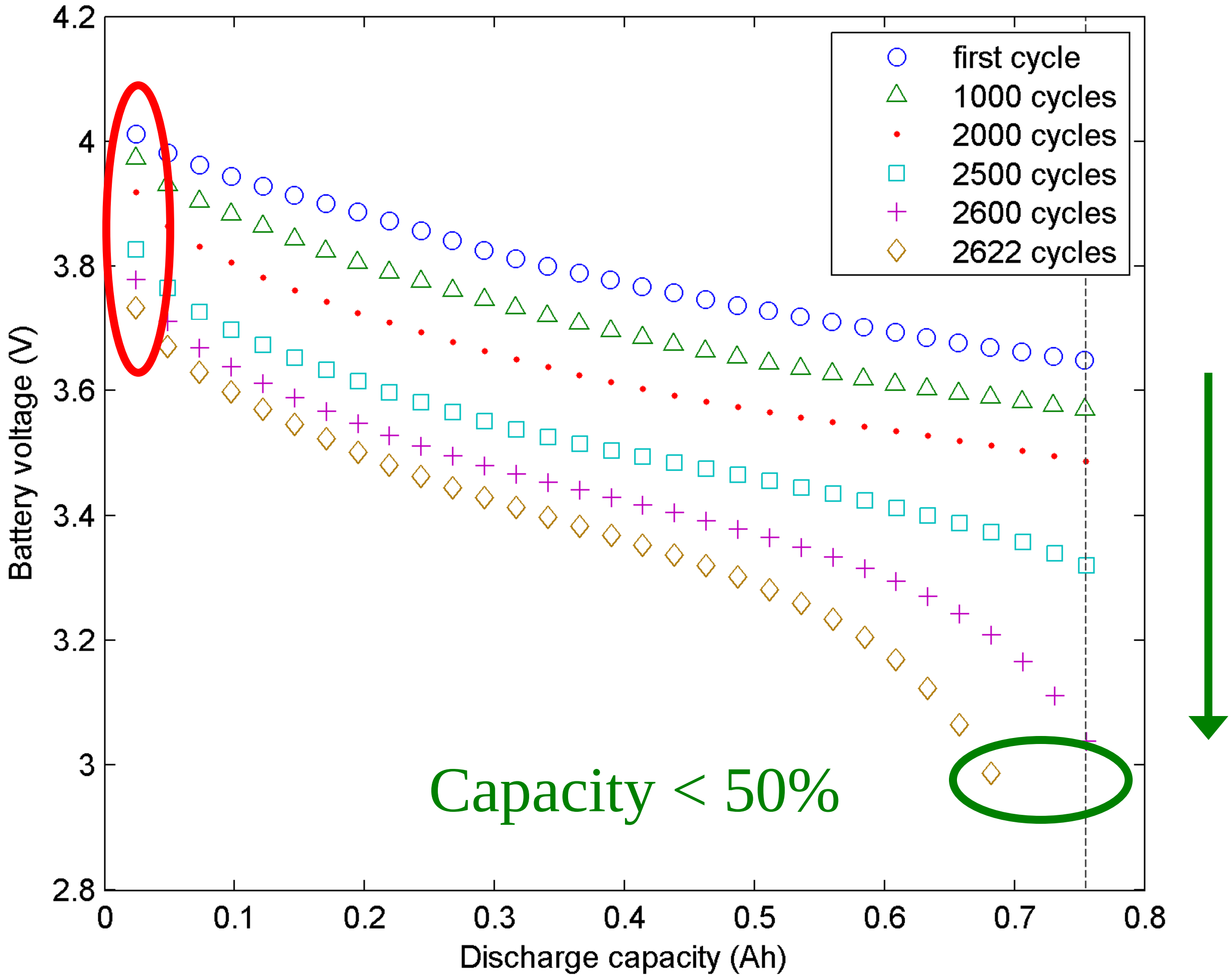


Cycle test pattern

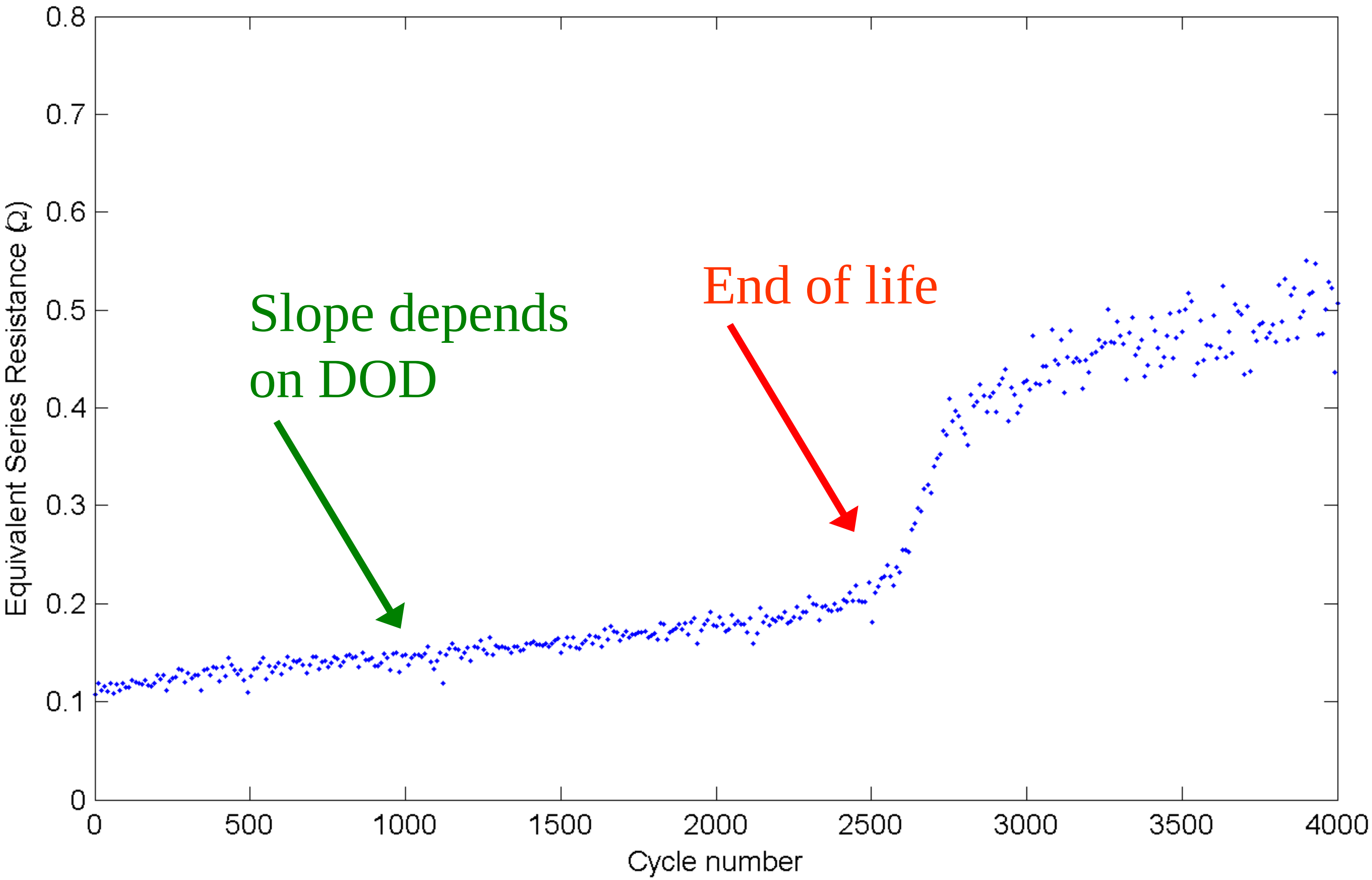


Discharge characteristics

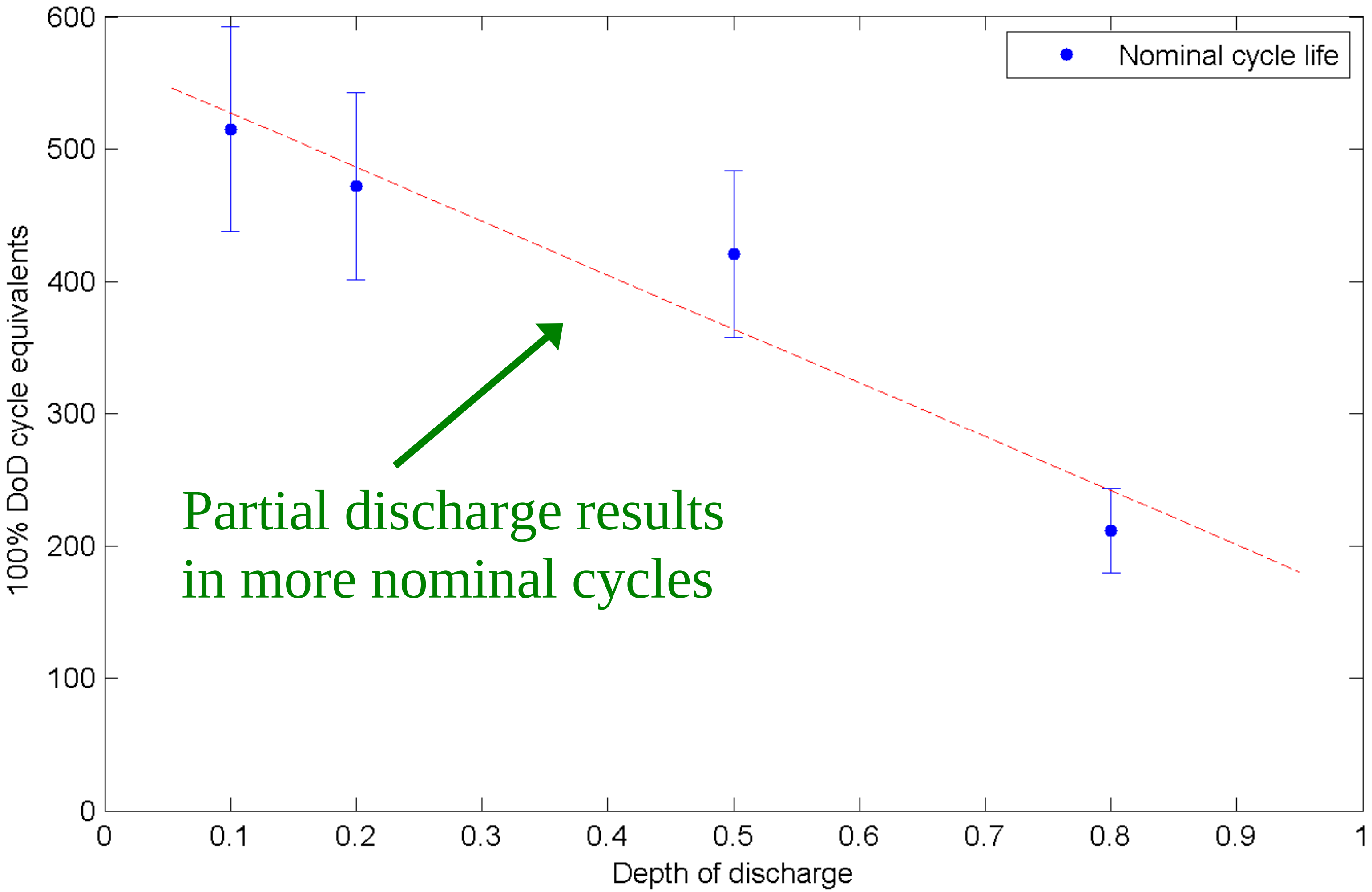
Increasing internal resistance



Equivalent series resistance (ESR)



Cycle life vs DOD (by 1.3Ri definition)



Conclusions

- Grid connected electricity storage will play a vital role in SmartGrids.
- Lithium-ion batteries are very suitable to take up this role, but their ageing behaviour needs to be characterised.
- First experimental results have laid the basis for a life-time expectancy model.

Future work

- Characterisation of PHET lithium-ion cells (Plug-in Toyota Prius)
- Improving experimental set-up with the lessons learned.
- Design of a non-electrochemical model to describe and predict lithium-ion battery ageing behaviour.
- Obtaining experimental data for design and validation of model.

Thank you for your attention