

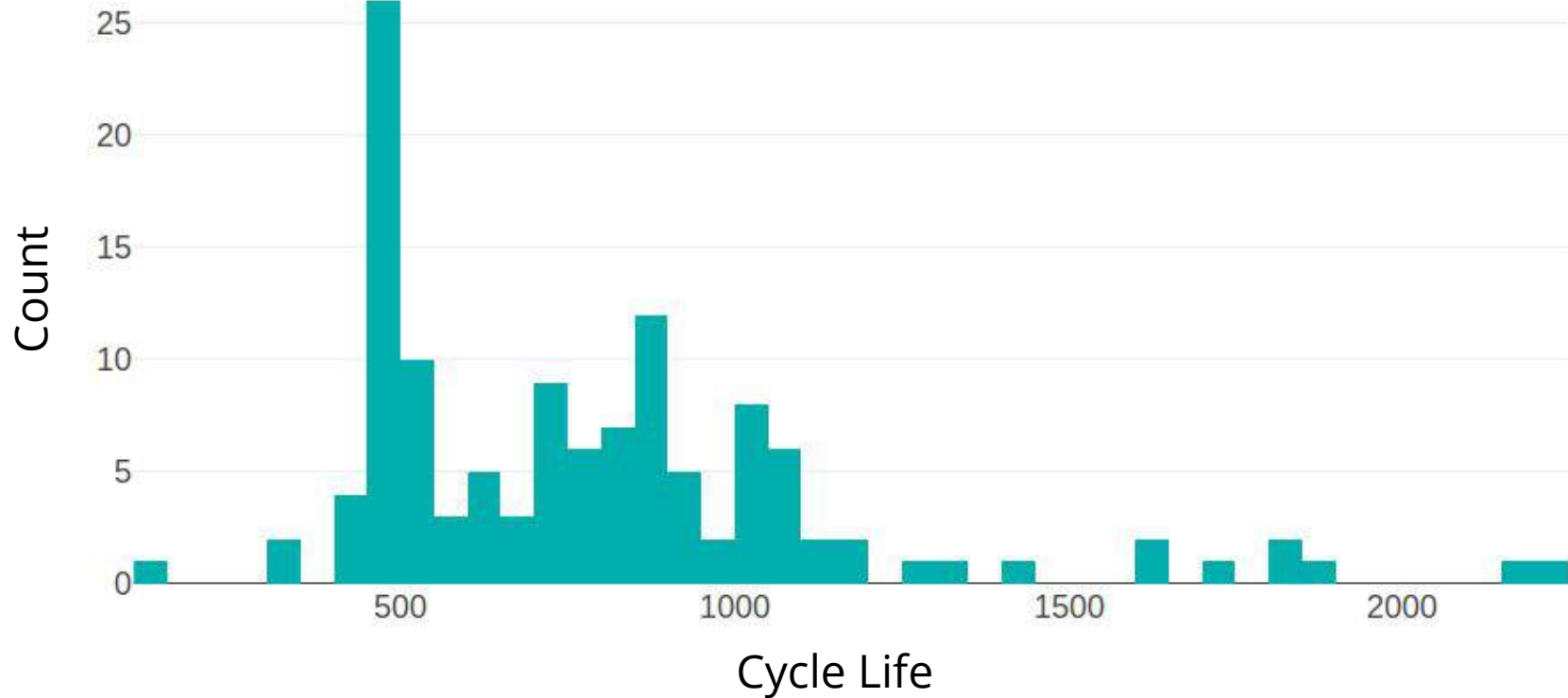


ION AGE

Forecasting battery lifetime



Lithium-ion batteries



Lithium-ion batteries

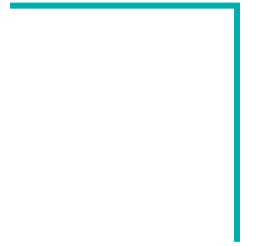
Quality assessment

How good is my battery
right now?

Long-term planning

When do I have to react
to a failing battery?

DEMO



A perspective view of a server room with rows of server racks on both sides. The racks are filled with server units, many of which have glowing lights. The floor is highly reflective, mirroring the lights from the racks and the ceiling. The overall atmosphere is dark and technical. The word "DATA" is overlaid in the center in a large, white, sans-serif font.

DATA

Dataset

'Data driven prediction of battery cycle life before capacity degradation' by K.A. Severson, P.M. Attia, et al.

Nature Energy vol. 4, 383–391 (2019)

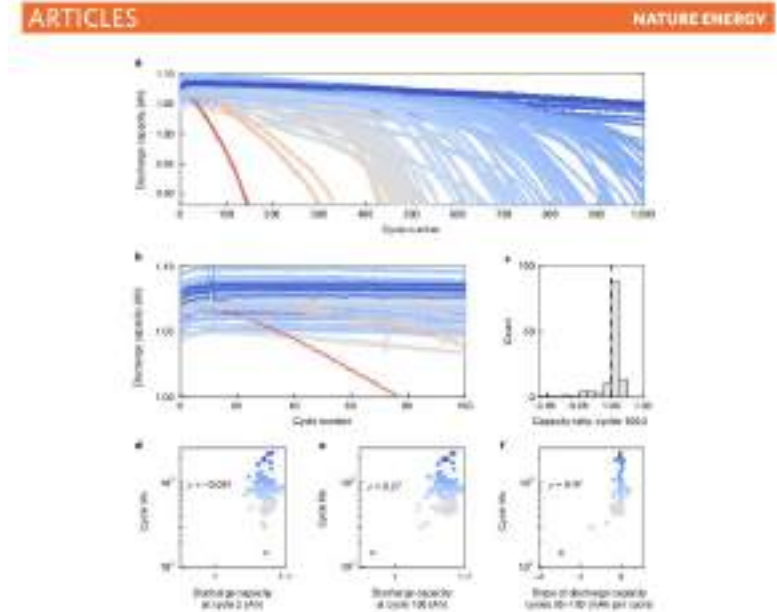
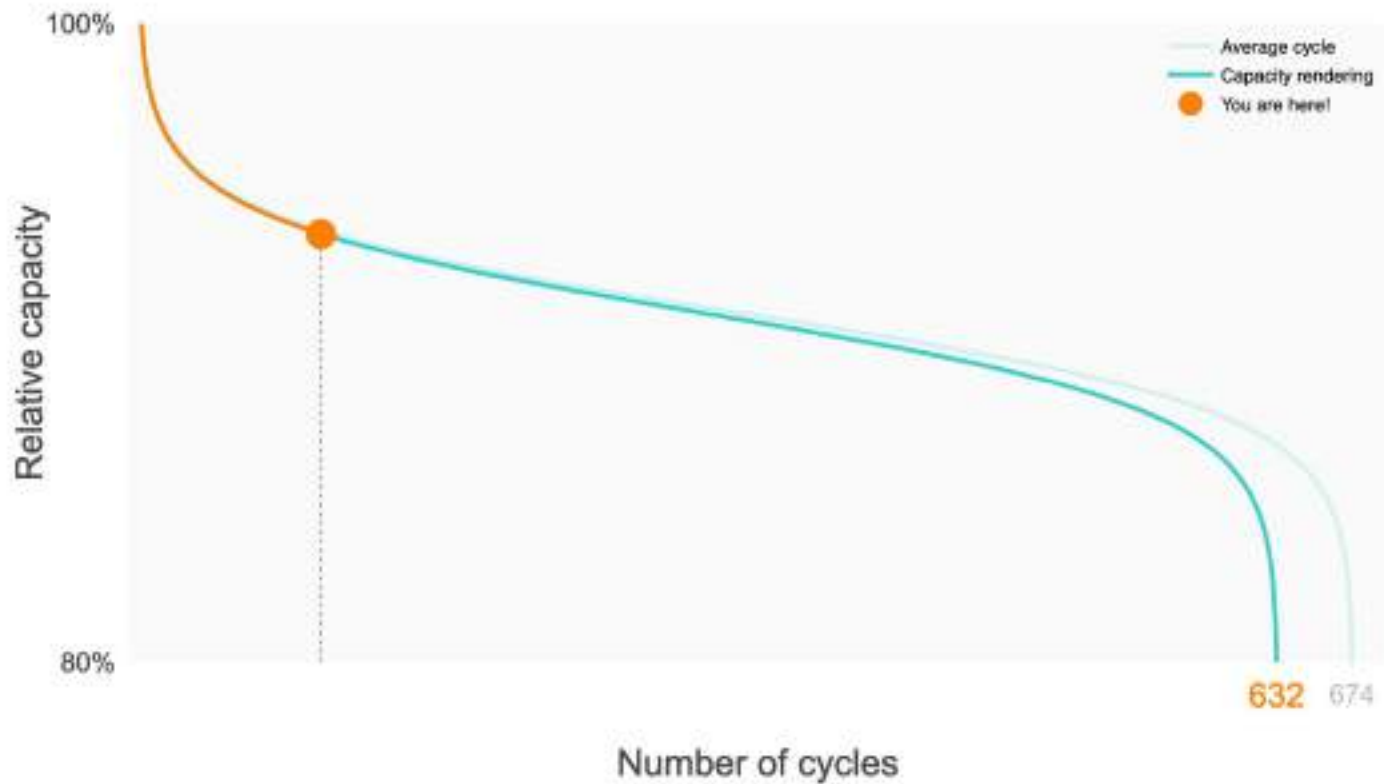


Fig. 1 | Data-driven performance characteristics based on discharge capacity in the first 100 cycles. **a**, Discharge capacity for the first 1000 cycles of 1000 cycles (left). The color of each curve is coded by that battery's cycle life, as it does throughout the manuscript. **b**, Detailed view of **a**, showing only the first 100 cycles. A clear ranking of cycle life by initial capacity (cycle 100) is observed throughout the rest of the data set. **c**, Histogram of the ratio between the discharge capacity of cycle 100 and that of cycle 2. The cell with the highest degradation (90%) is highlighted to show the detail of the rest of the data set. The distribution indicates a ratio of 1.00. Most cells have a slightly higher capacity at cycle 100 relative to cycle 2. **d**, Cycle life as a function of discharge capacity at cycle 2. The correlation coefficient of capacity at cycle 2 and log cycle life is -0.081 . Parameters arranged as indicated on the axes. **e**, Cycle life as a function of the slope (coefficient of variation) of capacity at cycle 100 and the capacity at cycle 100. The correlation coefficient is 0.27 . **f**, Cycle life as a function of the slope (coefficient of variation) of capacity at cycle 100 and the capacity at cycle 100. The correlation coefficient is 0.16 .

Dataset



Dataset

Original Paper

feature engineering

linear regression

first 100 cycles

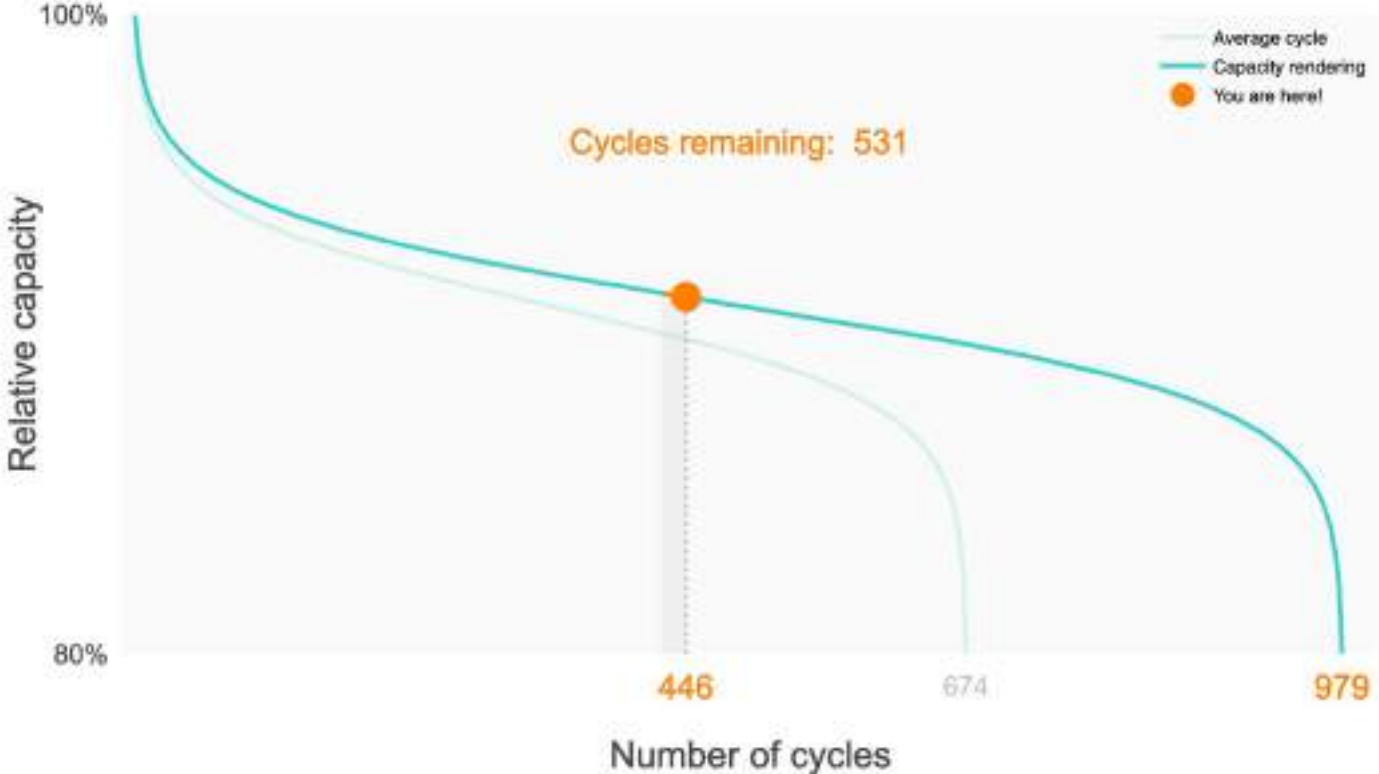
Ion Age

raw data

deep learning

any 20 cycles

Dataset



Dataset

124 cells



630



560



1105

Dataset

124 cells



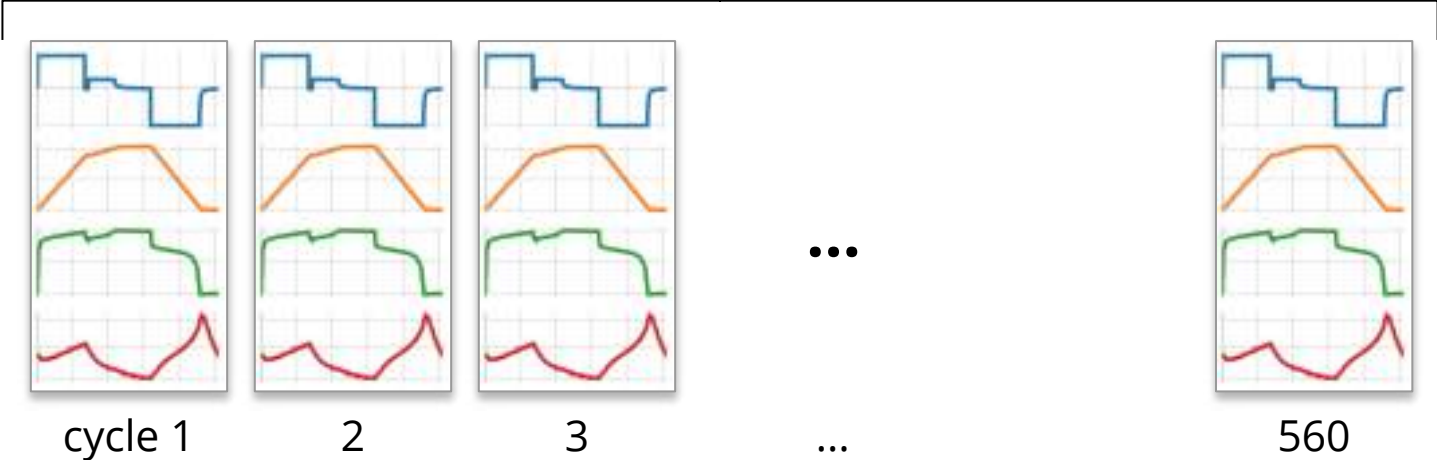
630



560

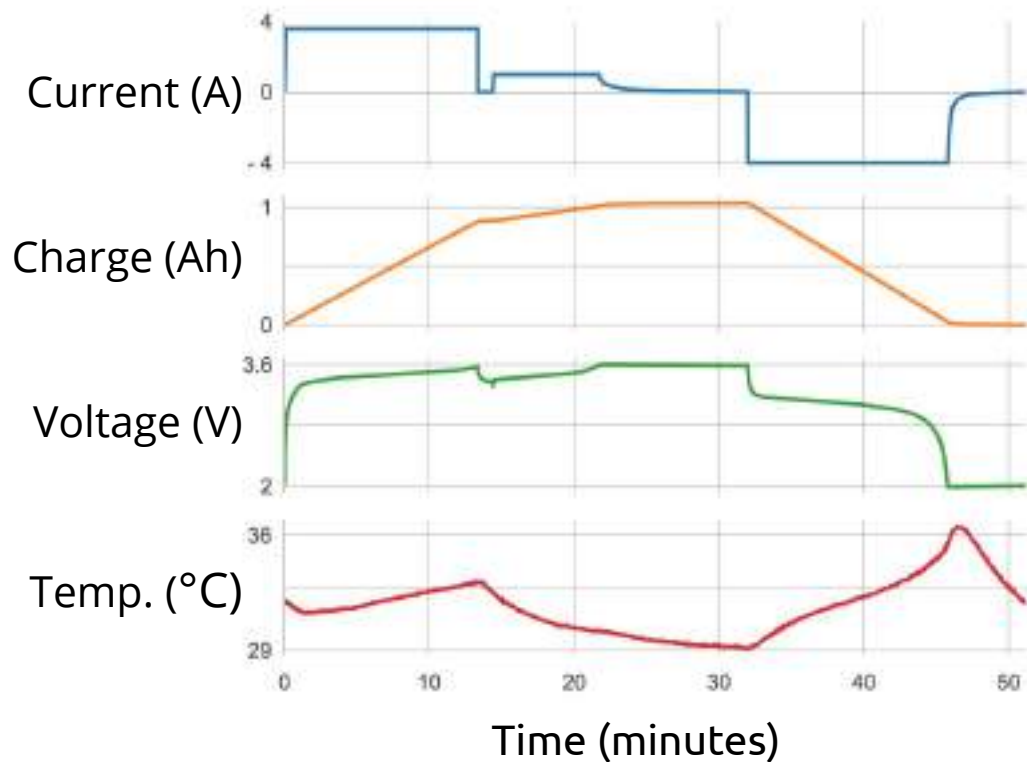


1105



Inside One Cycle

Time-Scale Features



Scalar Features

Internal Resistance (Ω)

Total Charge (Ah)

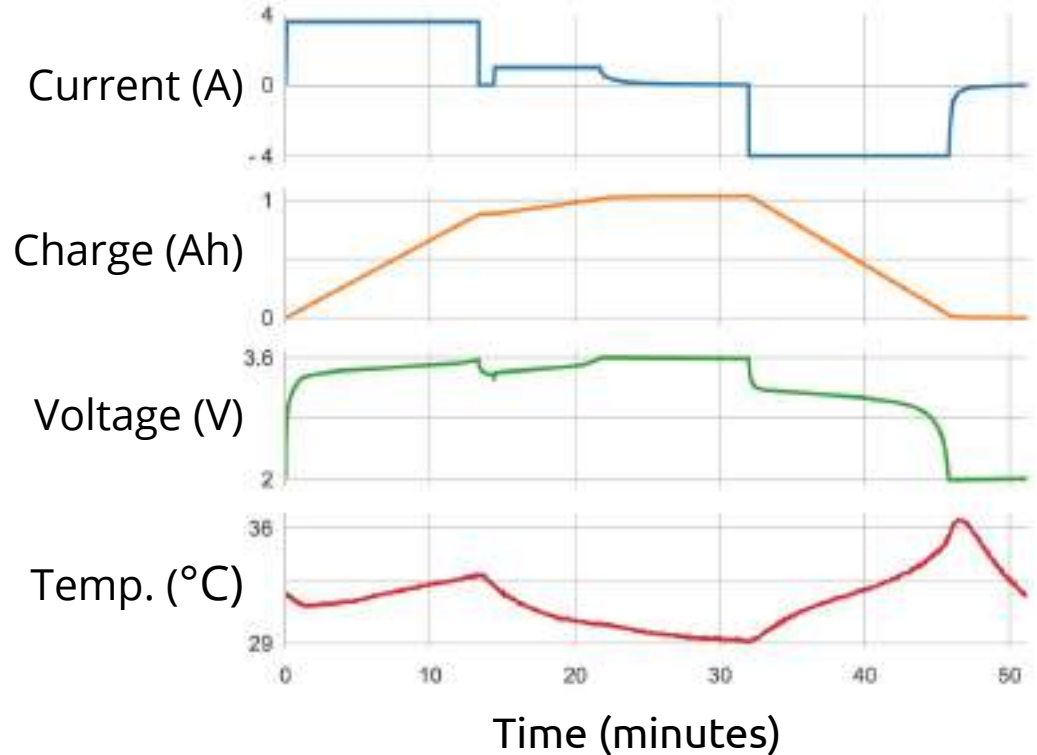
Total Time (minutes)

Temperature Stats ($^{\circ}\text{C}$)

Data Processing

Challenges

- Charging conditions not uniform
- Time measurements not uniform



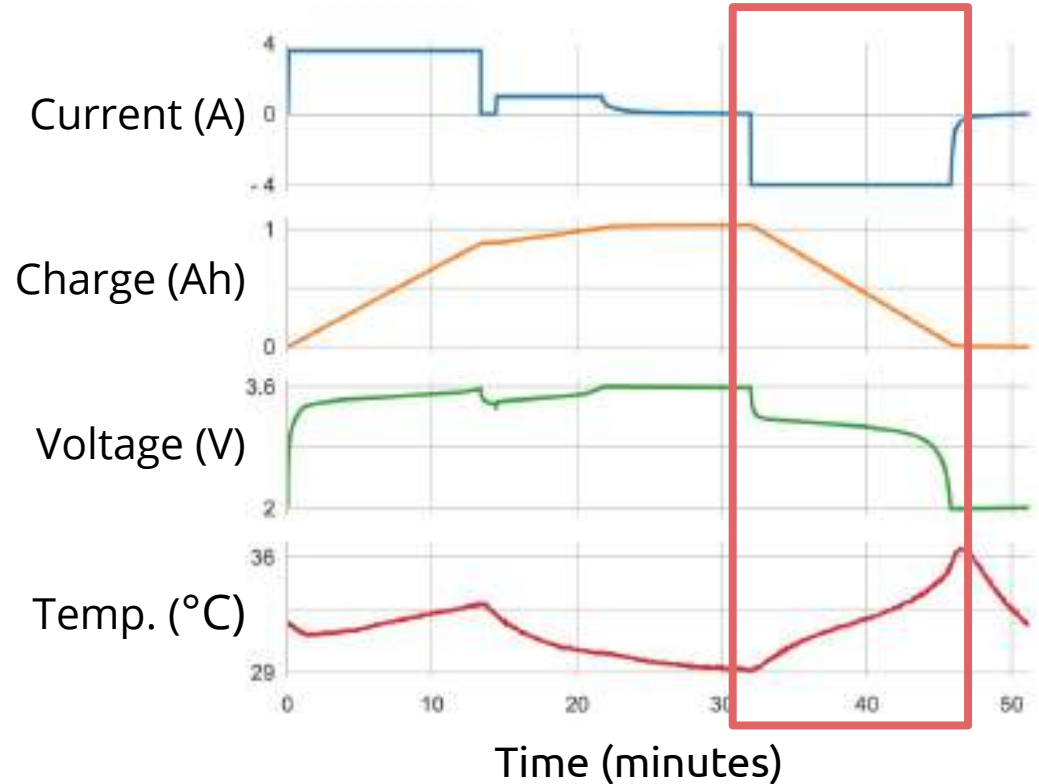
Data Processing

Challenges

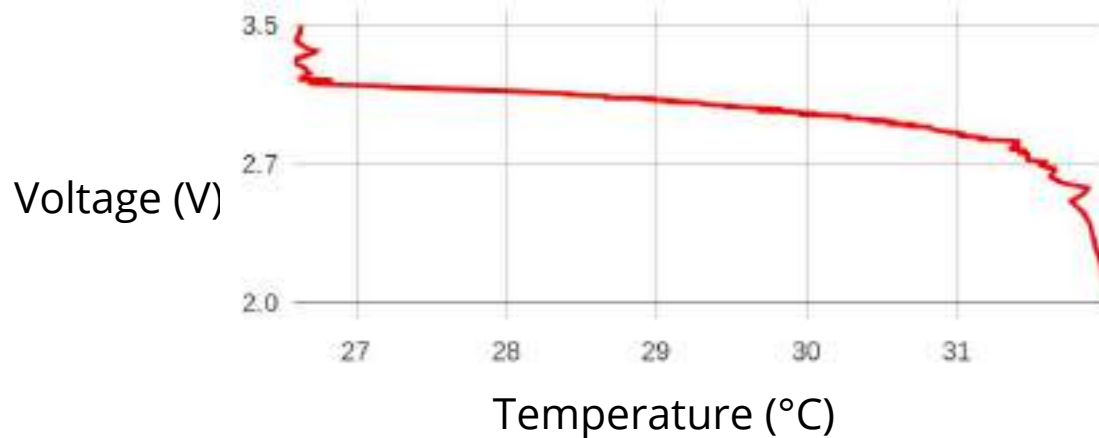
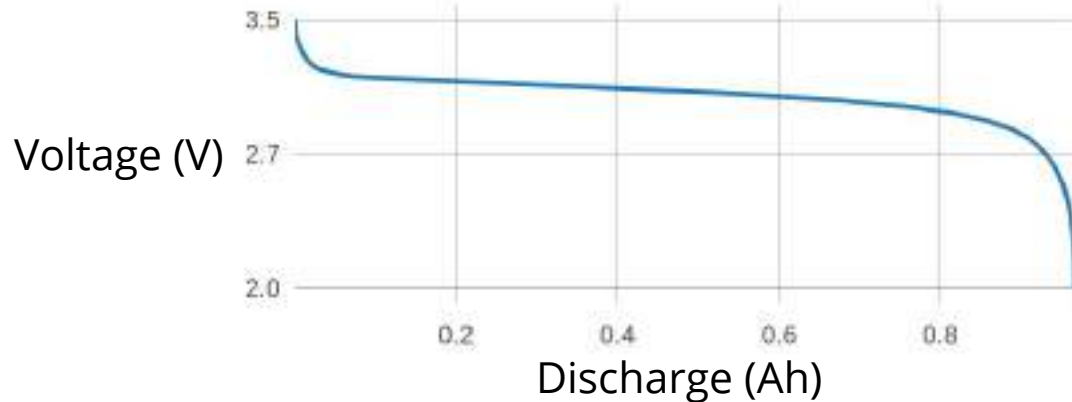
- Charging conditions not uniform
- Time measurements not uniform

Solutions

- Focus on discharge curve
- Resample uniformly across voltage range



Data Processing



Scalar Features

Internal Resistance (Ω)

Total Charge (Ah)

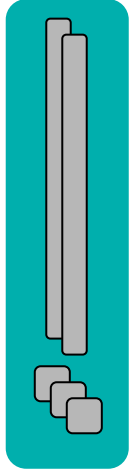
Discharge Time (minutes)

The image features a dark background with a complex network of light blue lines and nodes. The nodes are small circles, some of which are highlighted in a slightly darker shade. The lines connect these nodes, creating a web-like structure that fills the frame. The word "MODEL" is centered in the middle of the image in a bold, white, sans-serif font.

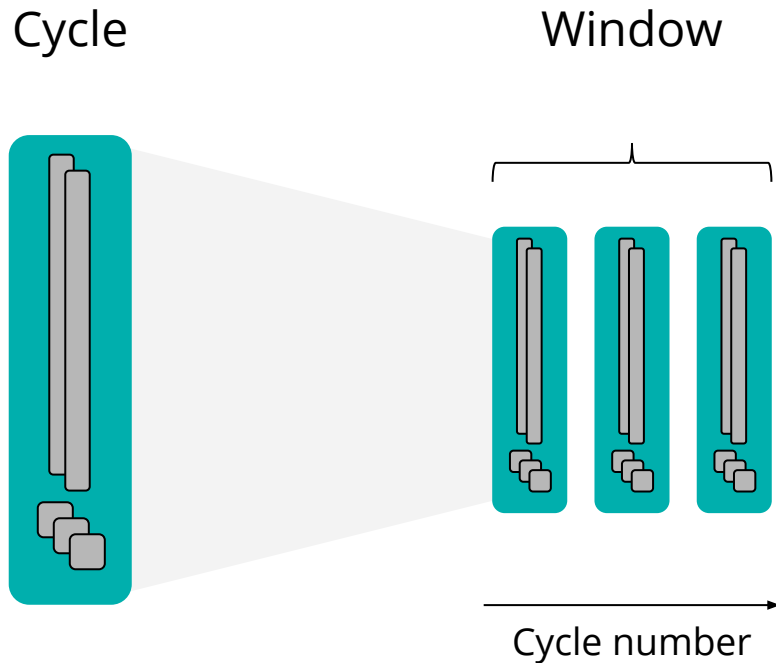
MODEL

Model input and output

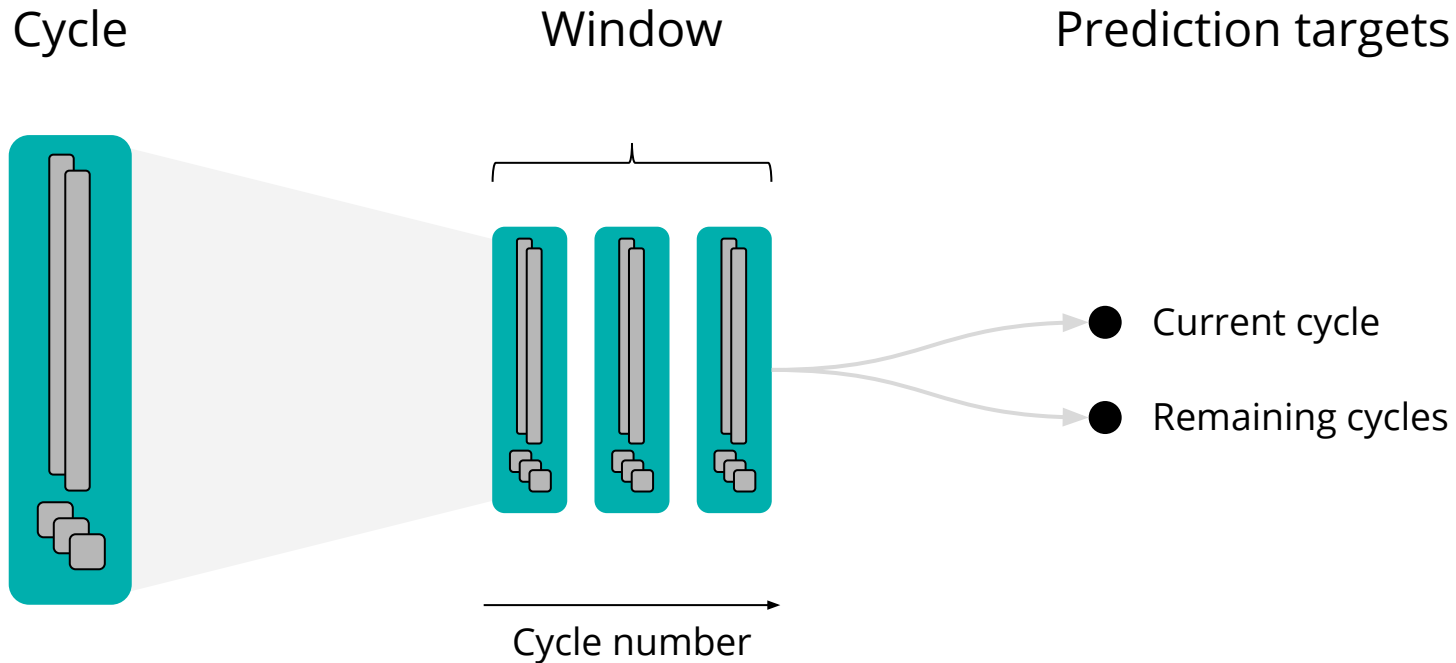
Cycle



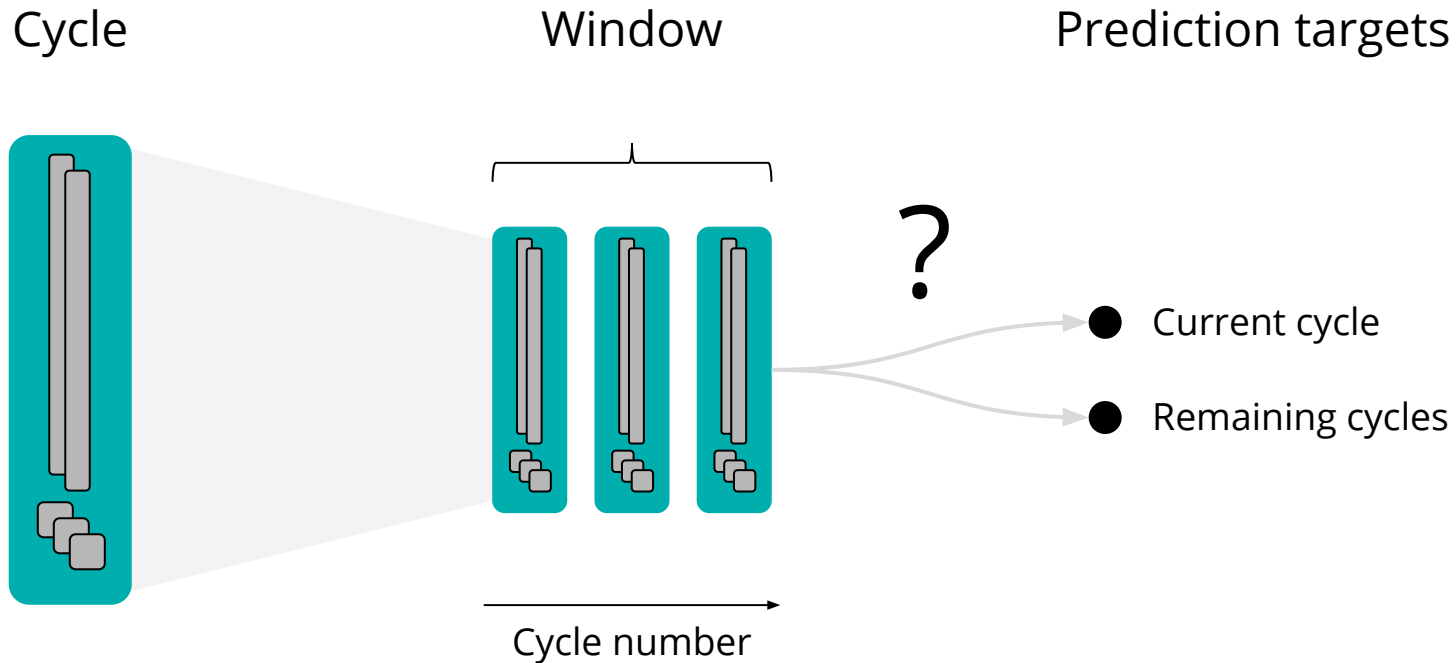
Model input and output



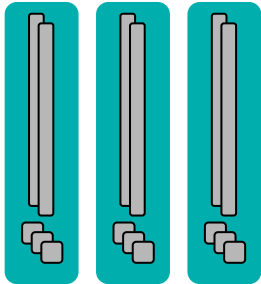
Model input and output



Model input and output

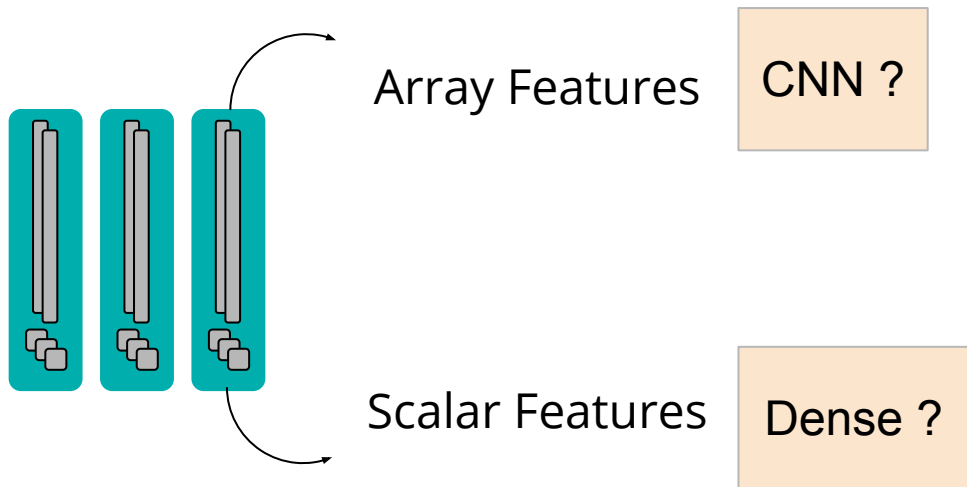


Model ideas



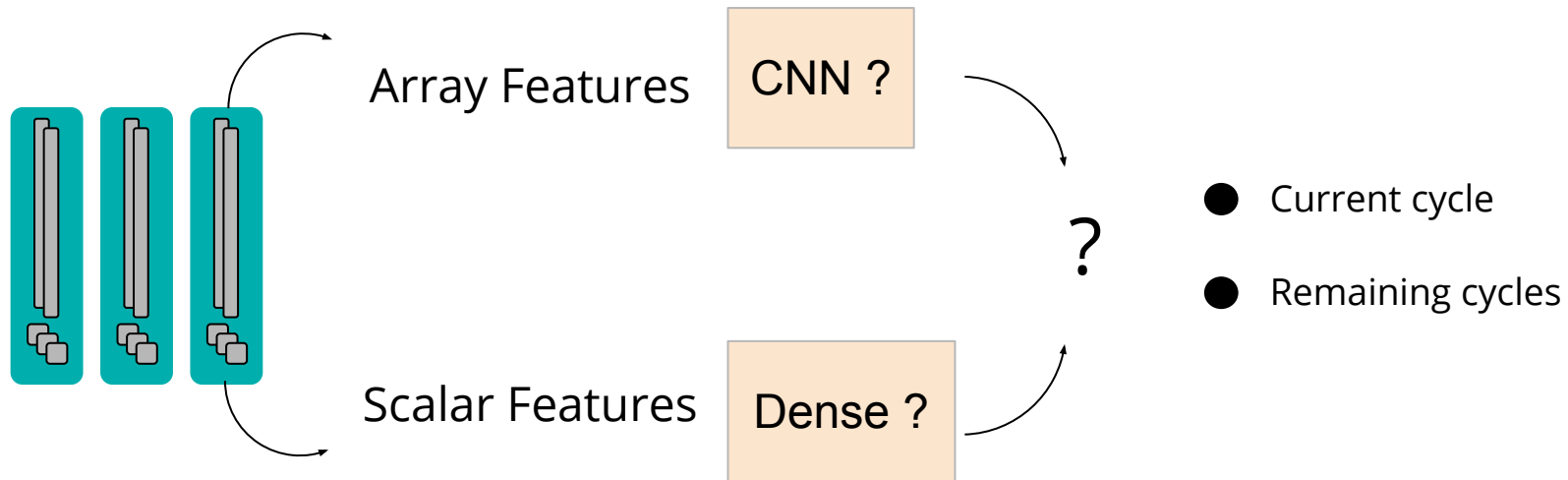
- Current cycle
- Remaining cycles

Model ideas

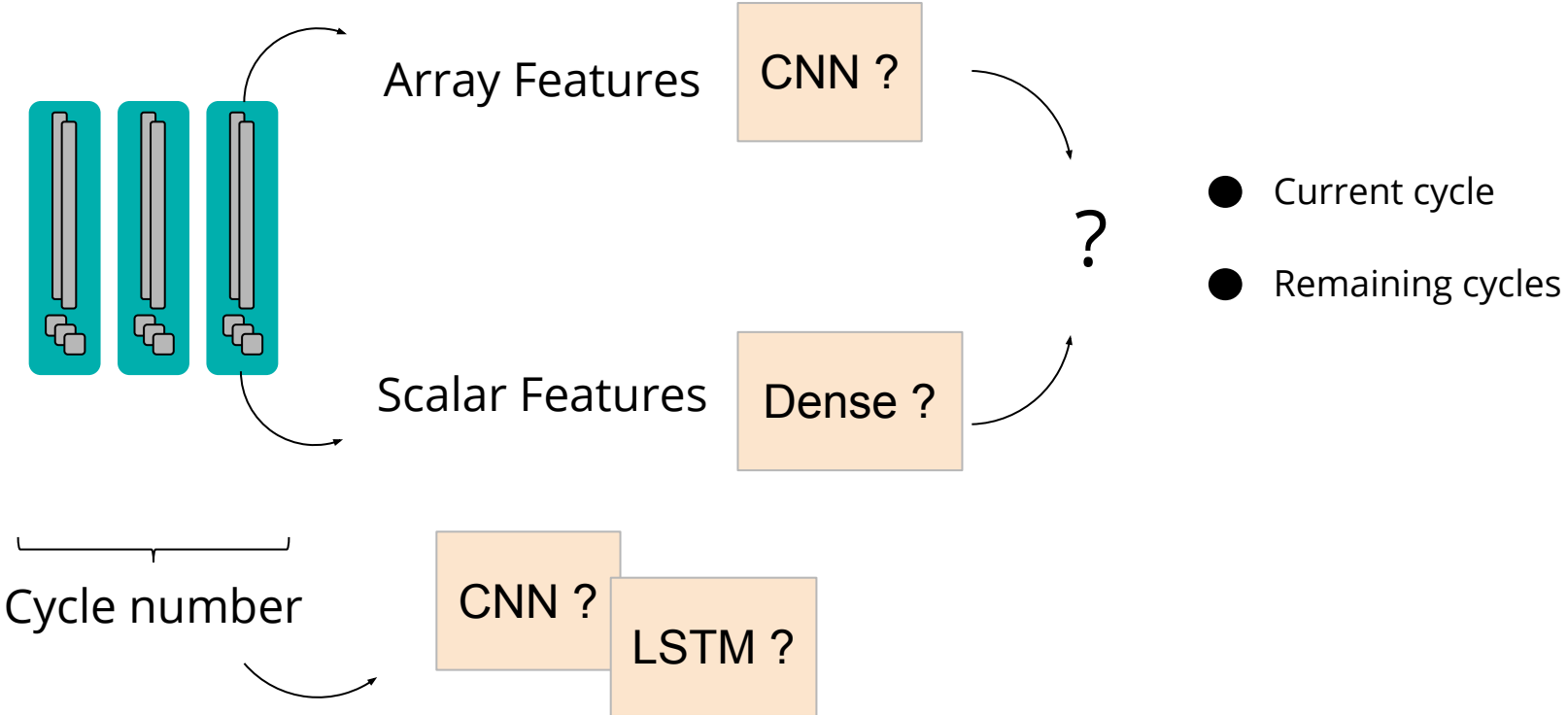


- Current cycle
- Remaining cycles

Model ideas



Model ideas



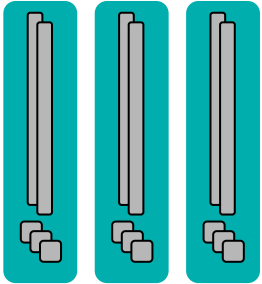
Engineering

- Parallel job runs
- Keep track of test setups and results
- Free hardware access
- Easy to work in a team

A screenshot of the Google Cloud Platform 'Jobs' page. The page title is 'Google Cloud Platform' and the user is logged in as 'Ice Age'. The page shows a list of training jobs with columns for Job ID, Type, HyperTune, Create time, and Age. The jobs are listed in descending order of create time.

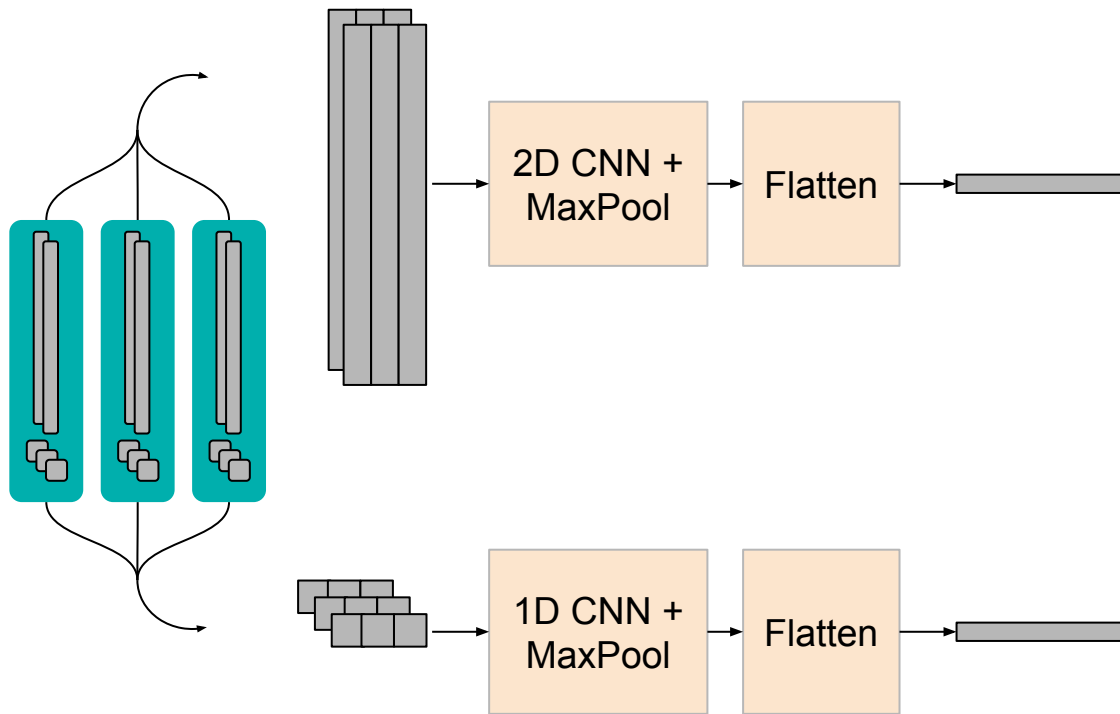
Job ID	Type	HyperTune	Create time	Age
ice_age_20190701_142228	Custom code training	No	Jul 1, 2019, 2:22:03 PM	1:9
ice_age_20190701_142244	Custom code training	No	Jul 1, 2019, 2:22:40 PM	1:9
ice_age_20190701_142260	Custom code training	No	Jul 1, 2019, 2:22:06 PM	1:9
ice_age_20190701_141458	Custom code training	No	Jul 1, 2019, 2:15:02 PM	1:9
ice_age_20190629_185434	Custom code training	No	Jun 29, 2019, 1:54:36 PM	2:0
ice_age_20190629_185364	Custom code training	No	Jun 29, 2019, 1:53:08 PM	1:4
ice_age_00000000_000000	Custom code training	No	Jun 29, 2019, 1:53:08 PM	1:4

Model architecture



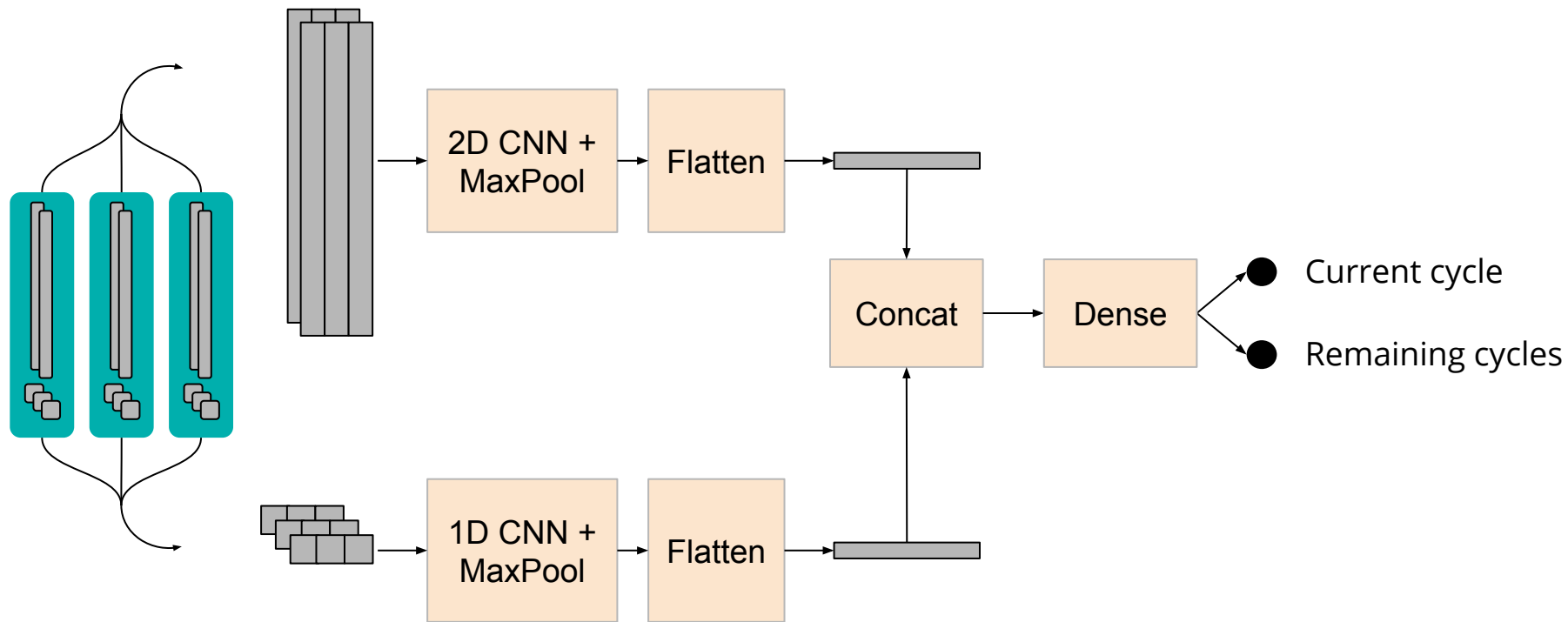
- Current cycle
- Remaining cycles

Model architecture

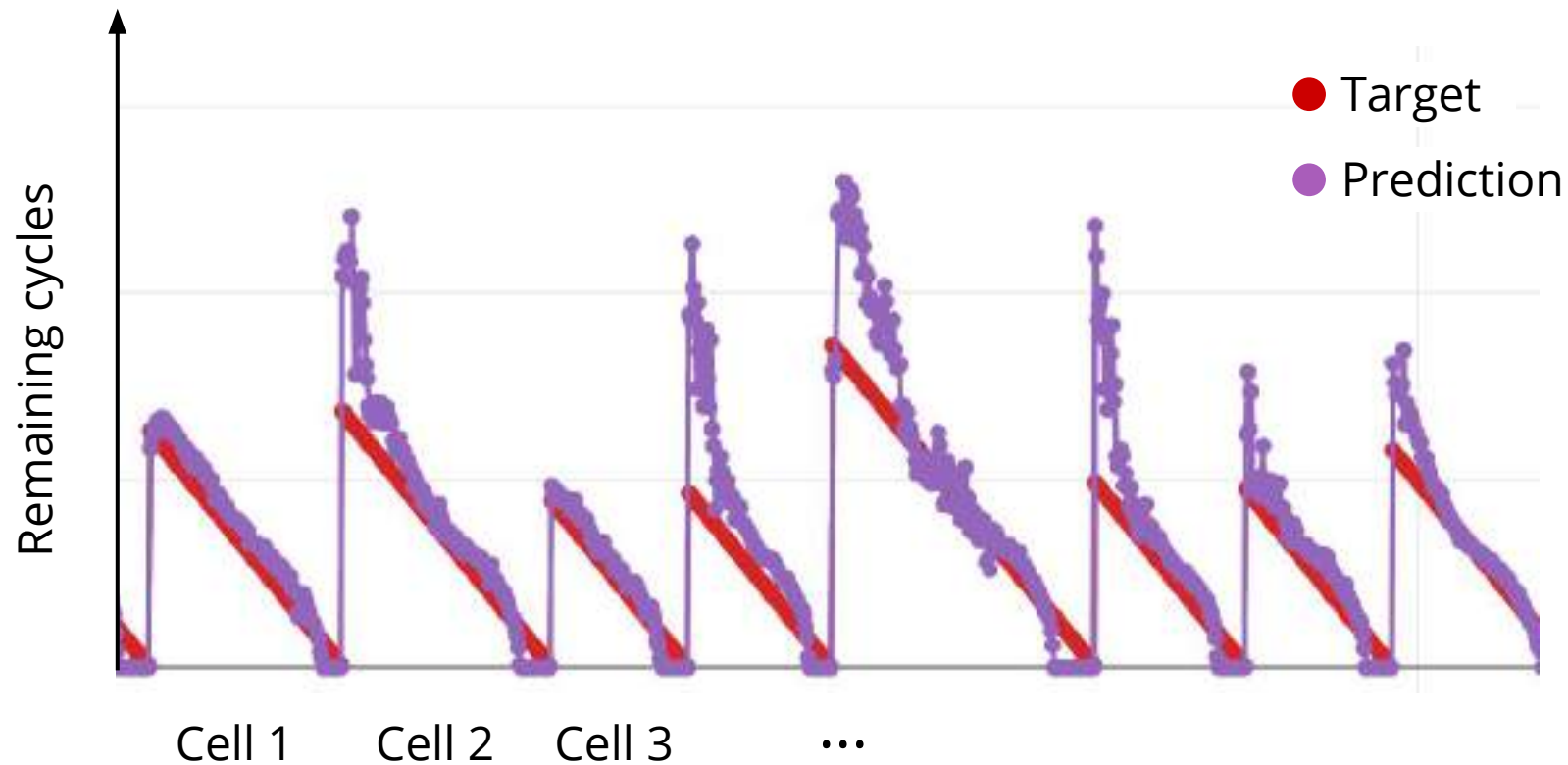


- Current cycle
- Remaining cycles

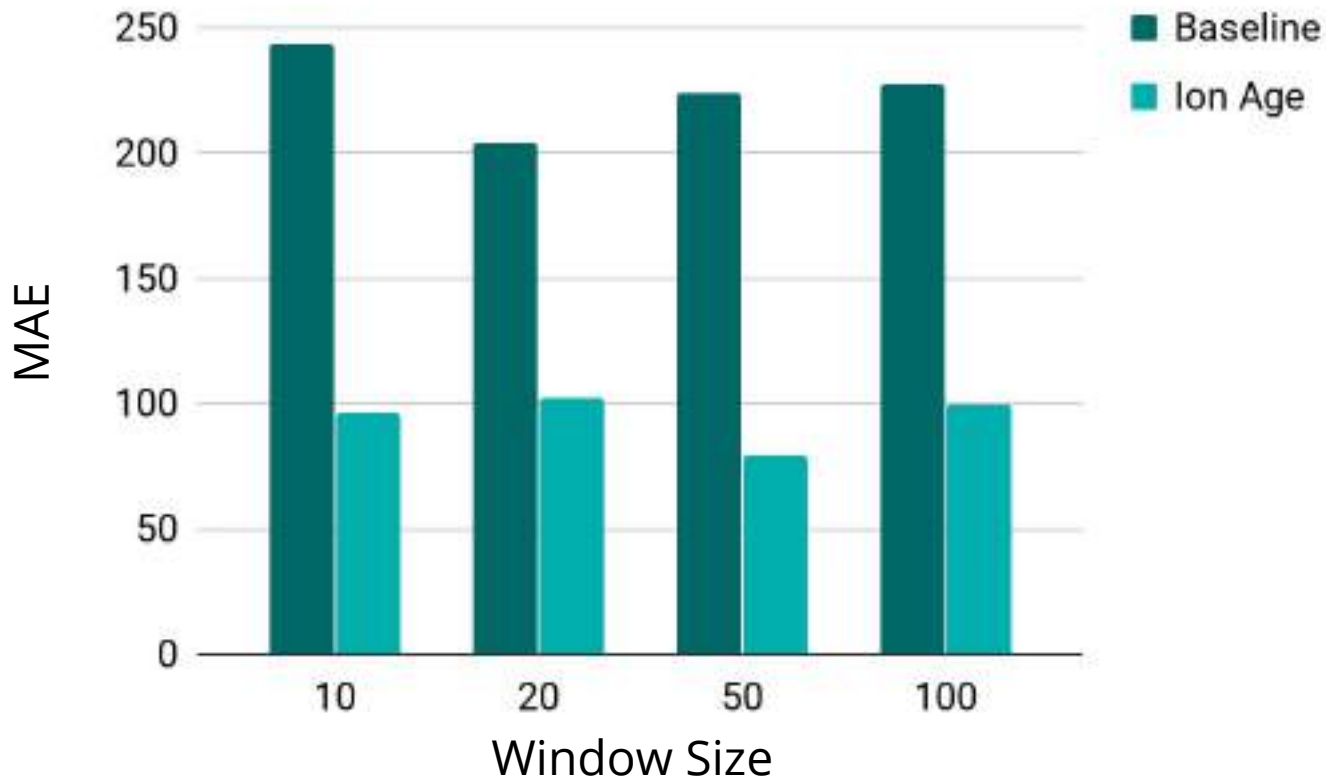
Model architecture



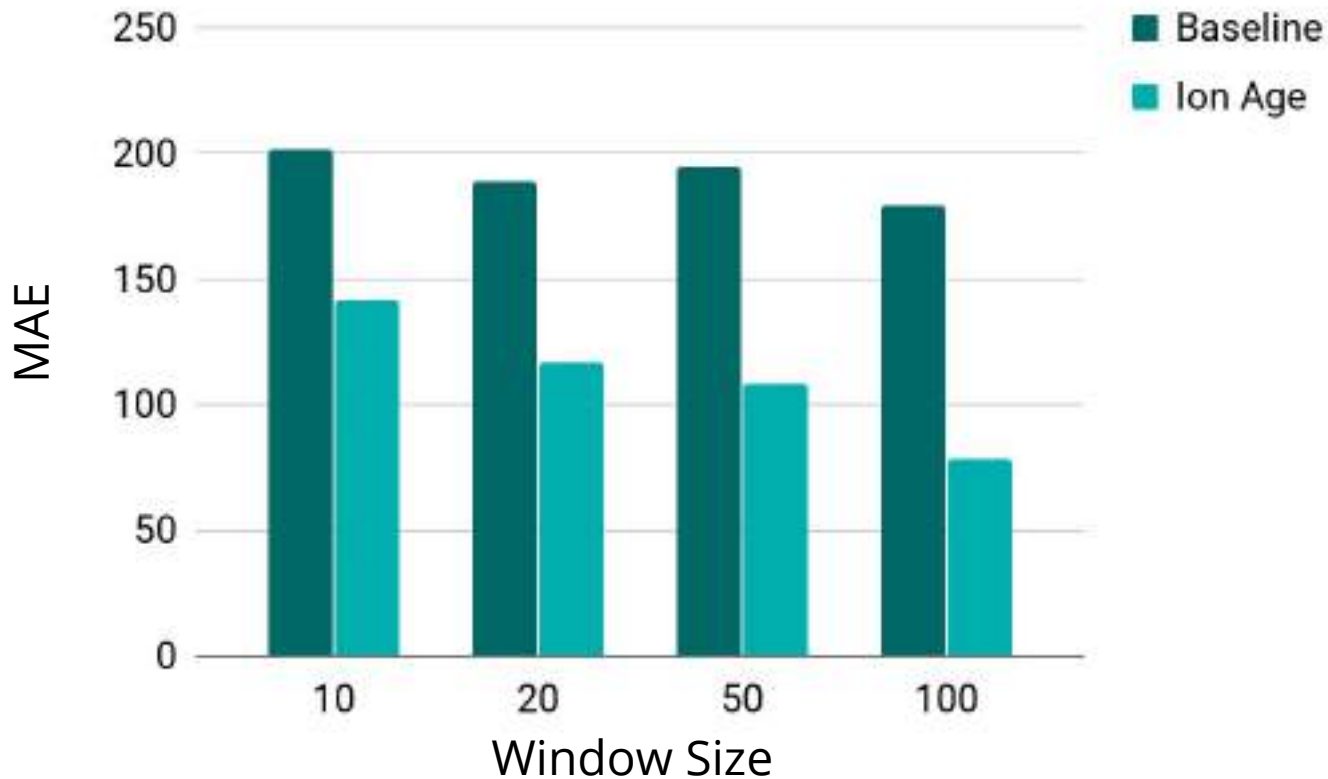
Predictions – Remaining cycles



Mean Absolute Error – Current cycles



Mean Absolute Error – Remaining cycles



Who we are




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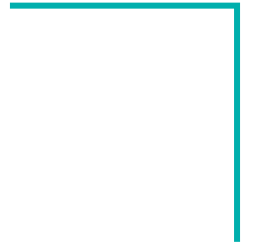


<https://github.com/dsr-18/long-live-the-battery>

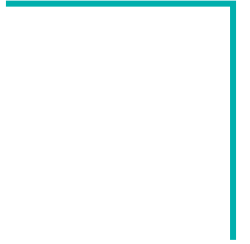
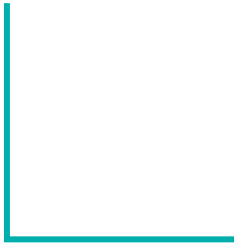


<https://bit.ly/2Lx0ywE>

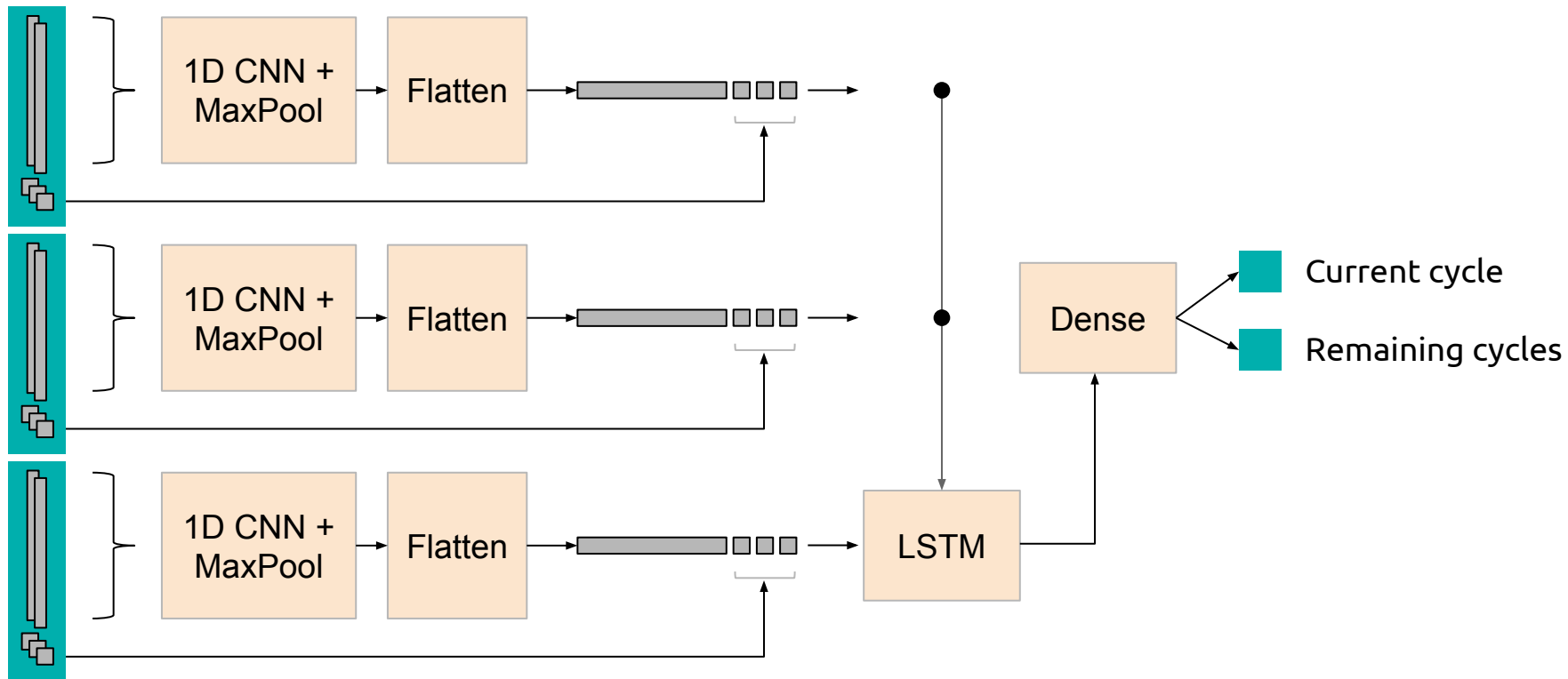
Q & A



Backup



Model architecture



Recap

- Predicting battery cycle life is a relevant but tough problem
- Measurement data requires a lot of preprocessing for deep learning
- It's hard to have an intuition what makes a complex model perform well
- Having a solid infrastructure pays off
- CNNs work well for time series data



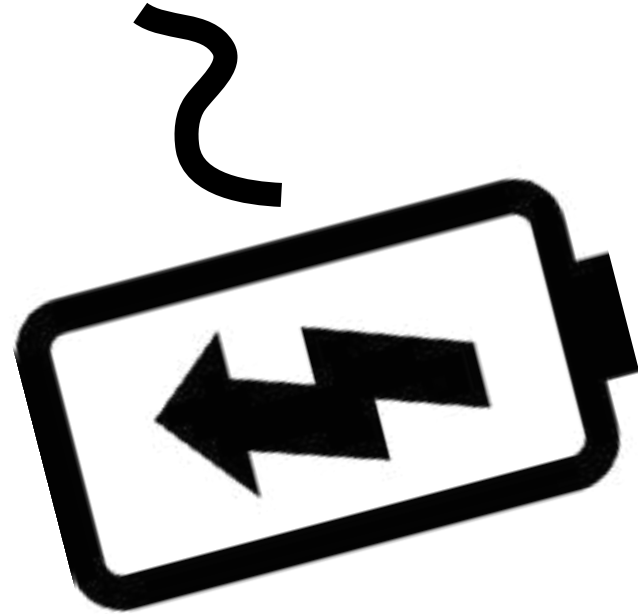
ION AGE

Forecasting battery life
time



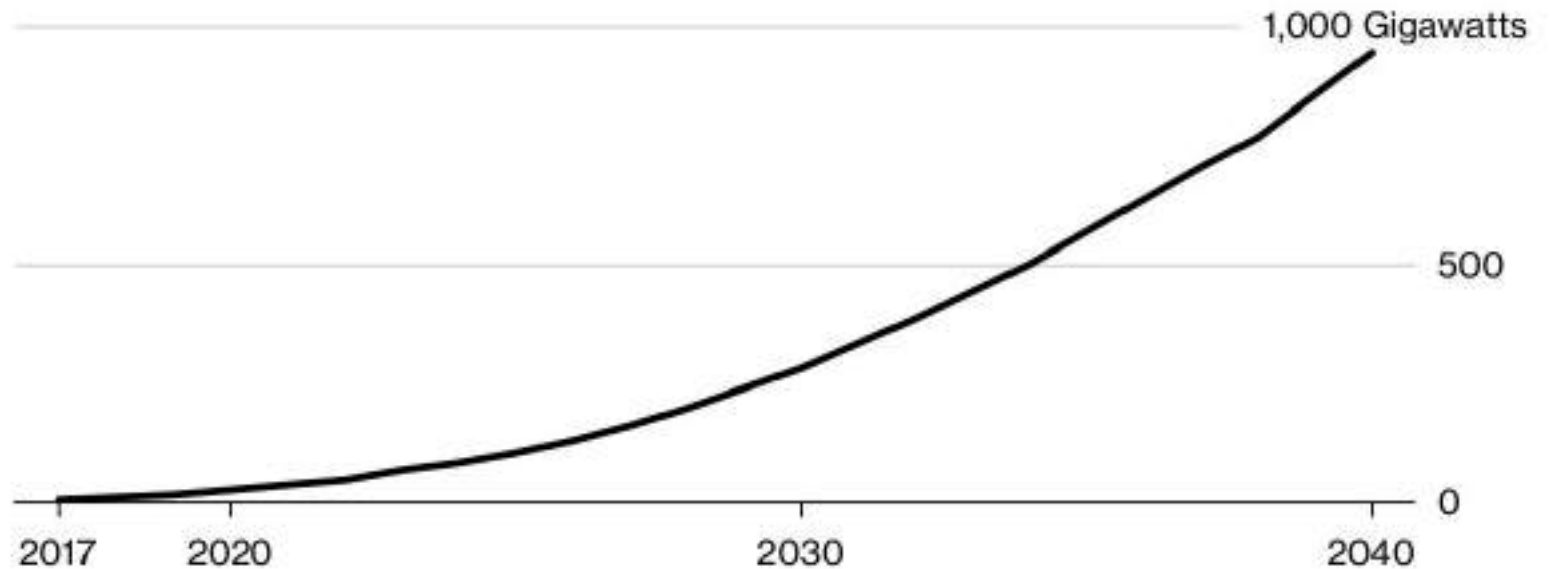
What did we do?

Predict the total lifetime of batteries, measured in remaining charging cycles



Lithium-ion batteries

Global energy storage

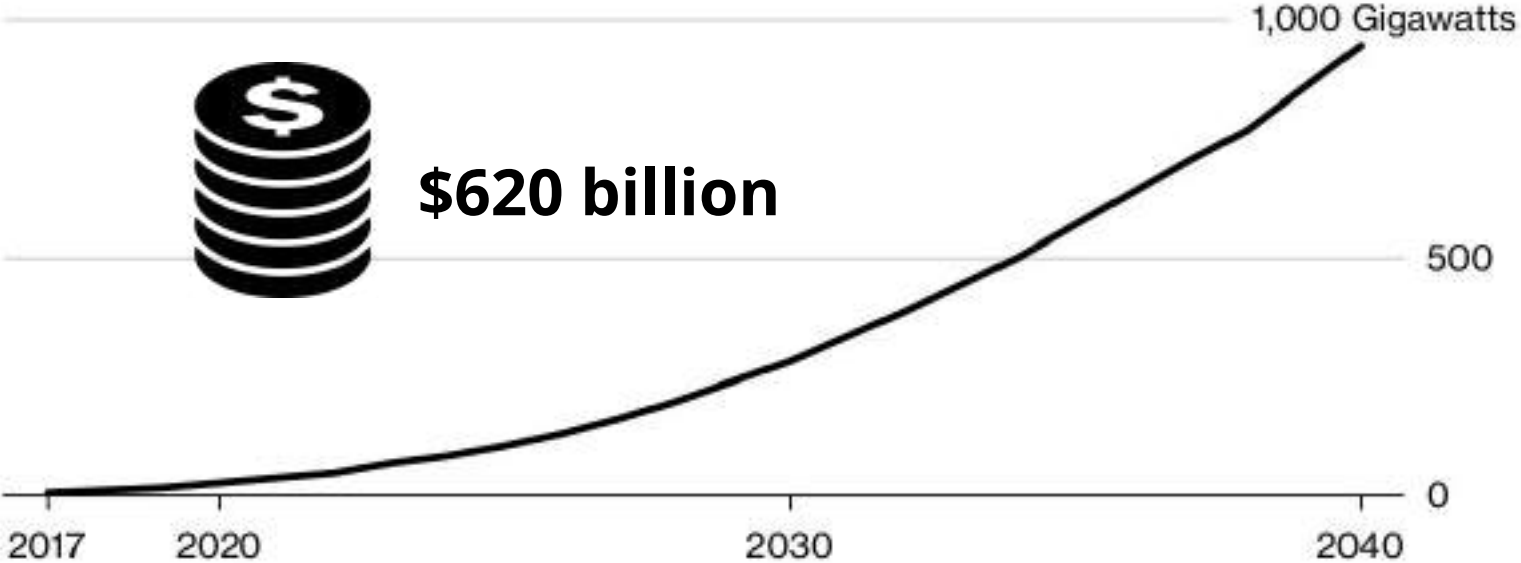


Bloomberg NEF

Bloomberg

Lithium-ion batteries

Global energy storage



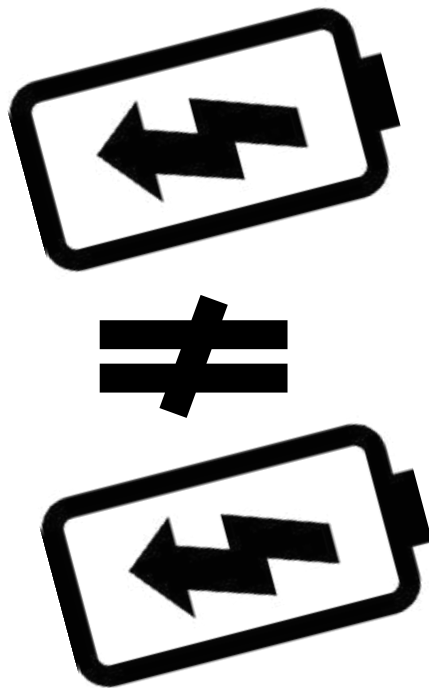
Bloomberg NEF

Bloomberg

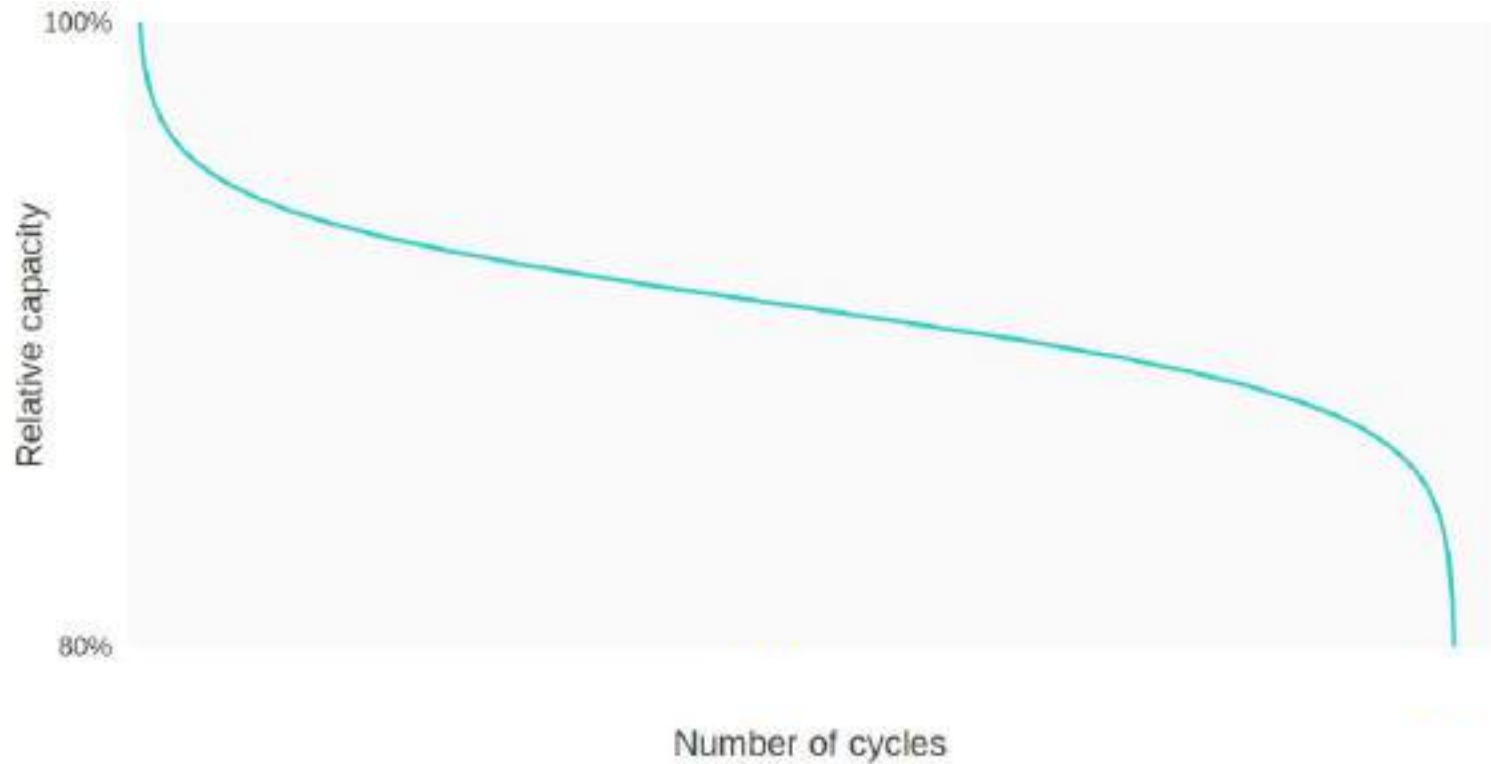
Lithium-ion batteries

vastly different lifetime expectations

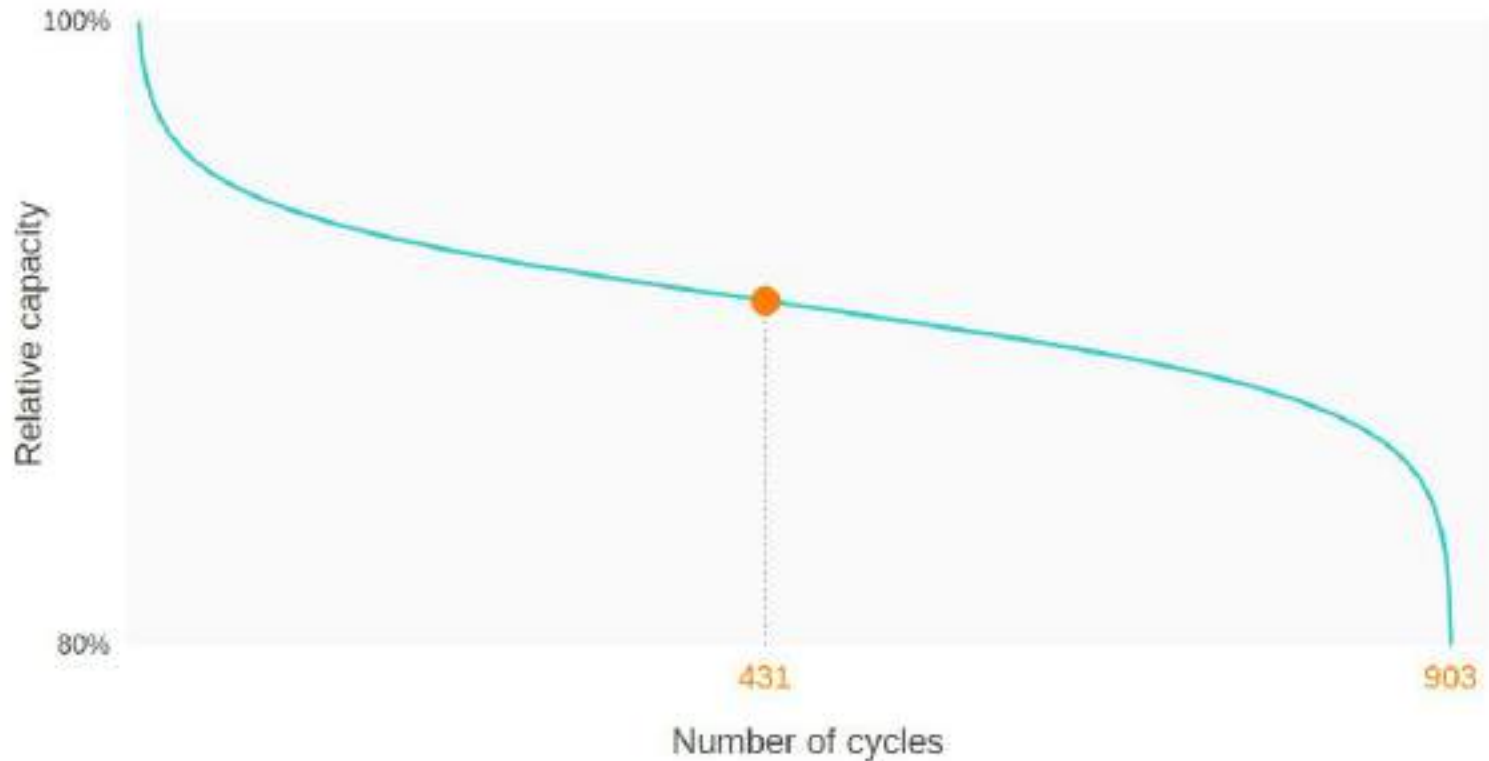
forecasts were expensive and time-consuming



Cell degradation



Cell degradation



ION AGE

The image shows a city at night with a blue monochromatic color scheme. Overlaid on the city's buildings and streets are a network of glowing blue lines and nodes, suggesting a data network or energy grid. The lines connect various points across the city, with some nodes appearing brighter than others. The background shows the city's lights and a river in the foreground.

Forecasting
battery lifetime

Lithium-ion batteries



