Smartness of hybrid storage technologies Operating Multi-Carrier Energy Systems?

FLEXINet Workshop – Realizing Hybrid Storage
3/10/2023

TU Delft

Content

01

Motivation

What are we doing and why?

TU Delft

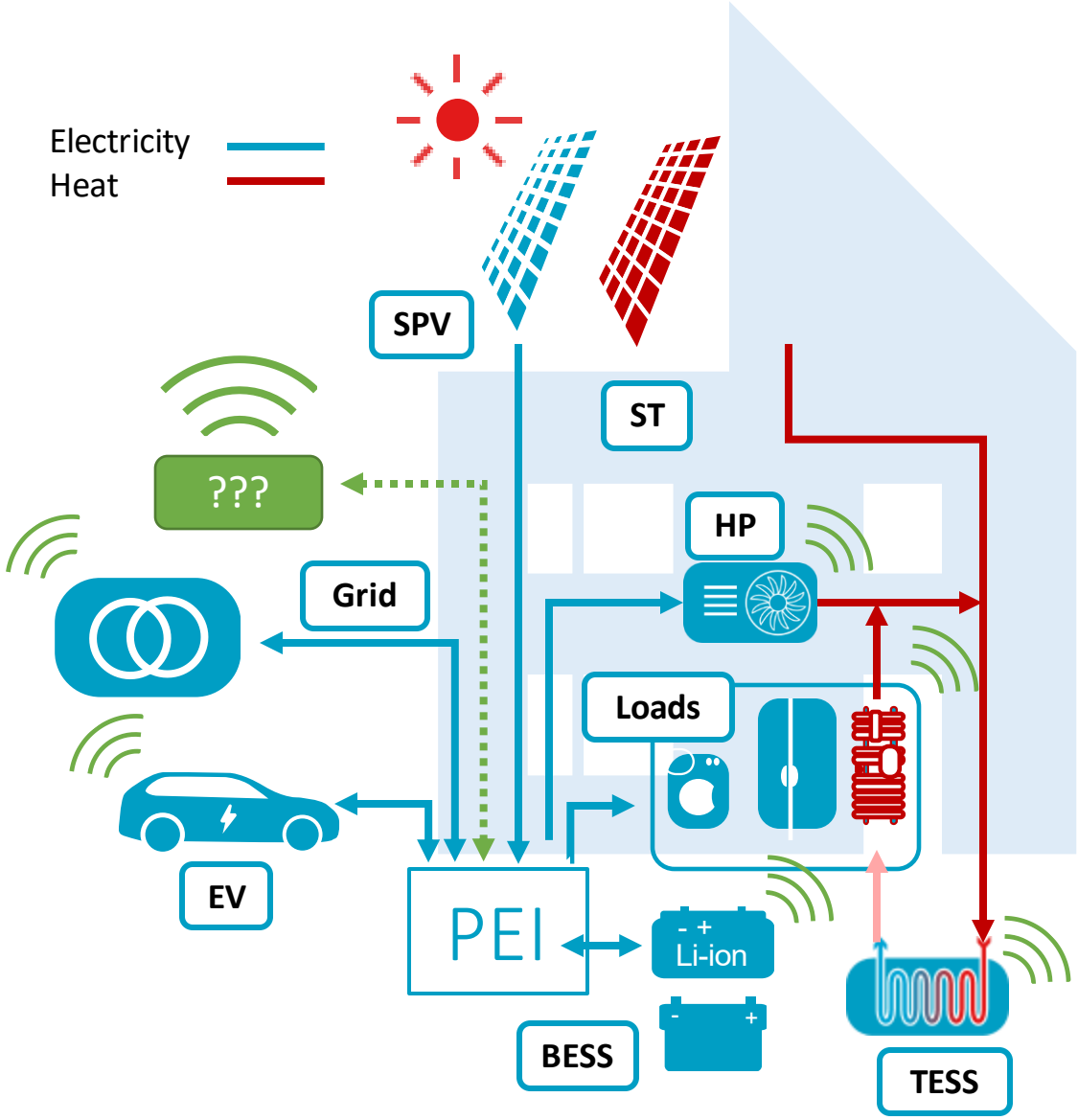
DCE&S
DC systems, Energy conversion & Storage

Motivation

Electrified building

- A lot of devices → complexity
  - Thermal
  - Electrical
- Diverse uncertainty → robustness
- Dynamic environment → speed

We need an automatic system that solves all three at the same time



TU Delft

DCE&S
DC systems, Energy conversion & Storage

Energy Management Systems (EMS) decide the **best way to operate** the Multi-Carrier Energy System (MCES)

02

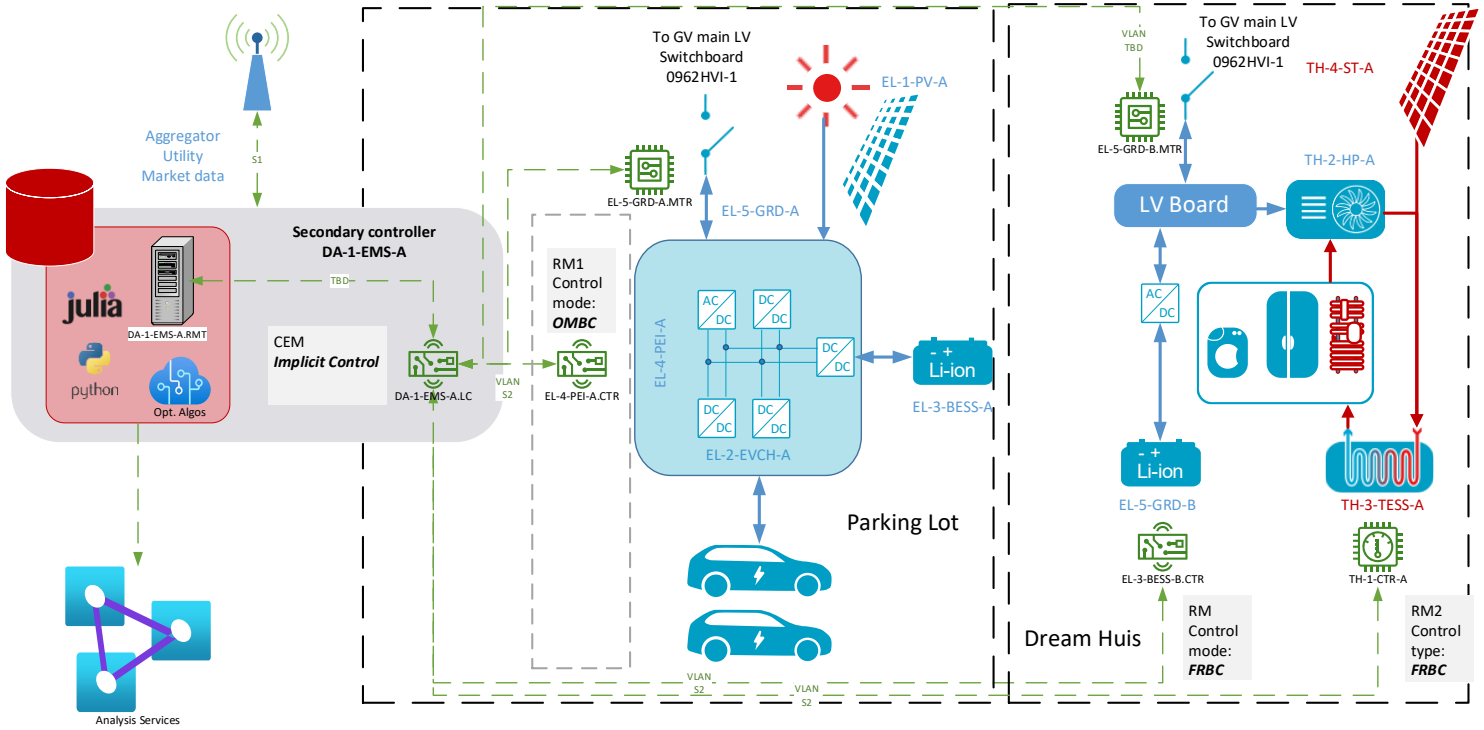
Building our first EMS

How do we start?

2.1 Infrastructure

Let's get real

- Standardized connection to improve products (plug & play).
- Use flexibility focused comm. protocols (S1 and S2) to enable flexible services!
- Working closely with TNO and Flexible Power Alliance



FLEXIBLEPOWER ALLIANCE NETWORK

TNO

TU Delft

DCE&S
DC systems, Energy conversion & Storage

How do we start?

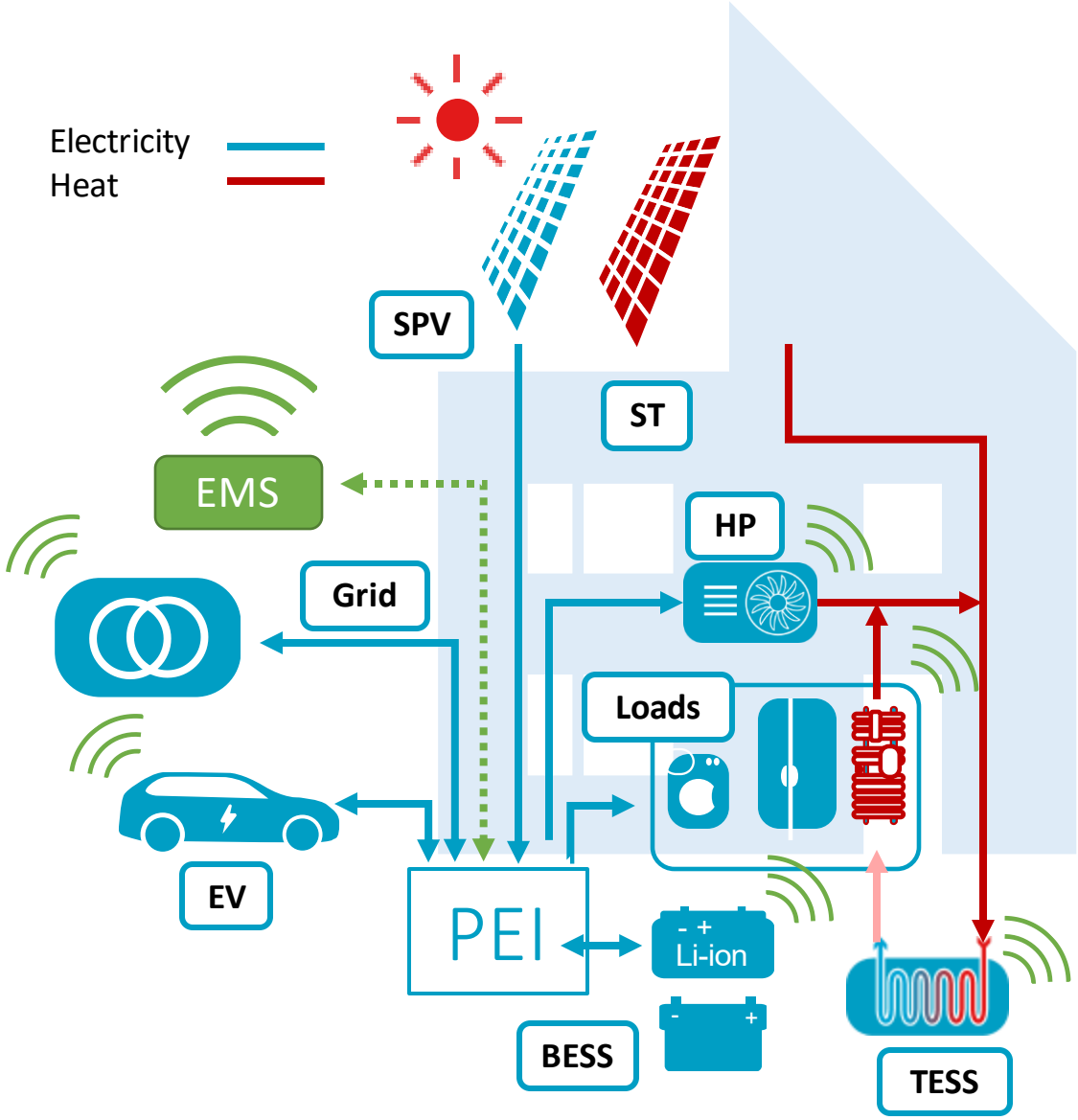
Electrified building

$$\min_{P^*} C_{grid} + W_{SoC} ||\varepsilon_{SoC}||_2^2$$

$$C_{grid} = \int_0^T \lambda_{buy} . P_{grid}^- - \lambda_{sell} . P_{grid}^+ . dt$$

$$\varepsilon_{SoC} = SoC_{n_{EV}}(t_{dep}) - SoC_{n_{EV},dep}$$

$$\forall\ n_{EV} = 1, \dots, N_{EV}$$



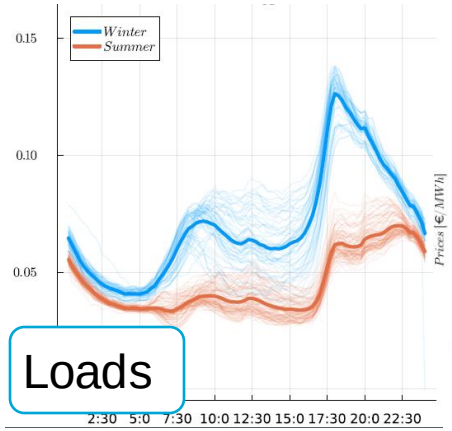
DCE&S
DC systems, Energy conversion & Storage

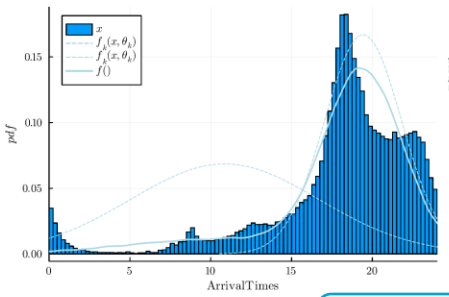
2.2 EMS algos

Settings

Tamb

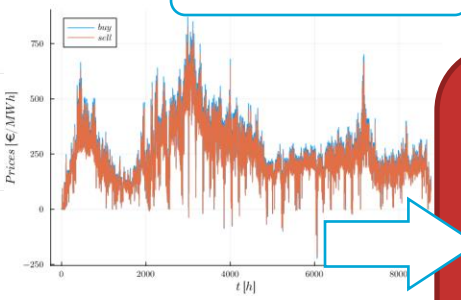
Loads

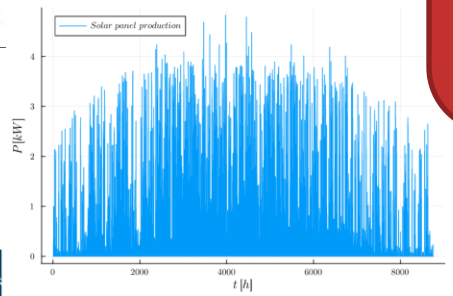




EV av

Market Data





PV prod

Approximation

$$\min_{P^*} C_{grid} + W_{SoC}||\varepsilon_{SoC}||_2^2$$

Sequential Decision Making

$$\min_{\pi} \quad \mathbb{E}\left[\sum_{t=0}^{T} C(S_{a,t}, P^*_{a,t})\right]$$

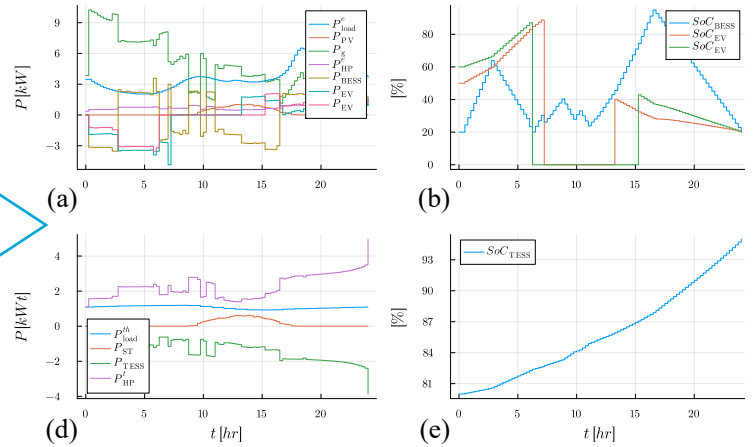
$$s.t. \quad S_{a,t+1} = S^M_{a,t}(S_{a,t}, P^*_{a,t}, W_{t+1}|\theta_{a,t})$$

$$P^*_{a,t} = X^\pi_t(S_{a,t}) \in \mathcal{P} \qquad \forall a \in \mathbb{A}$$

$$S_{a,t} \in \mathcal{S} \qquad \forall a \in \mathbb{A}$$

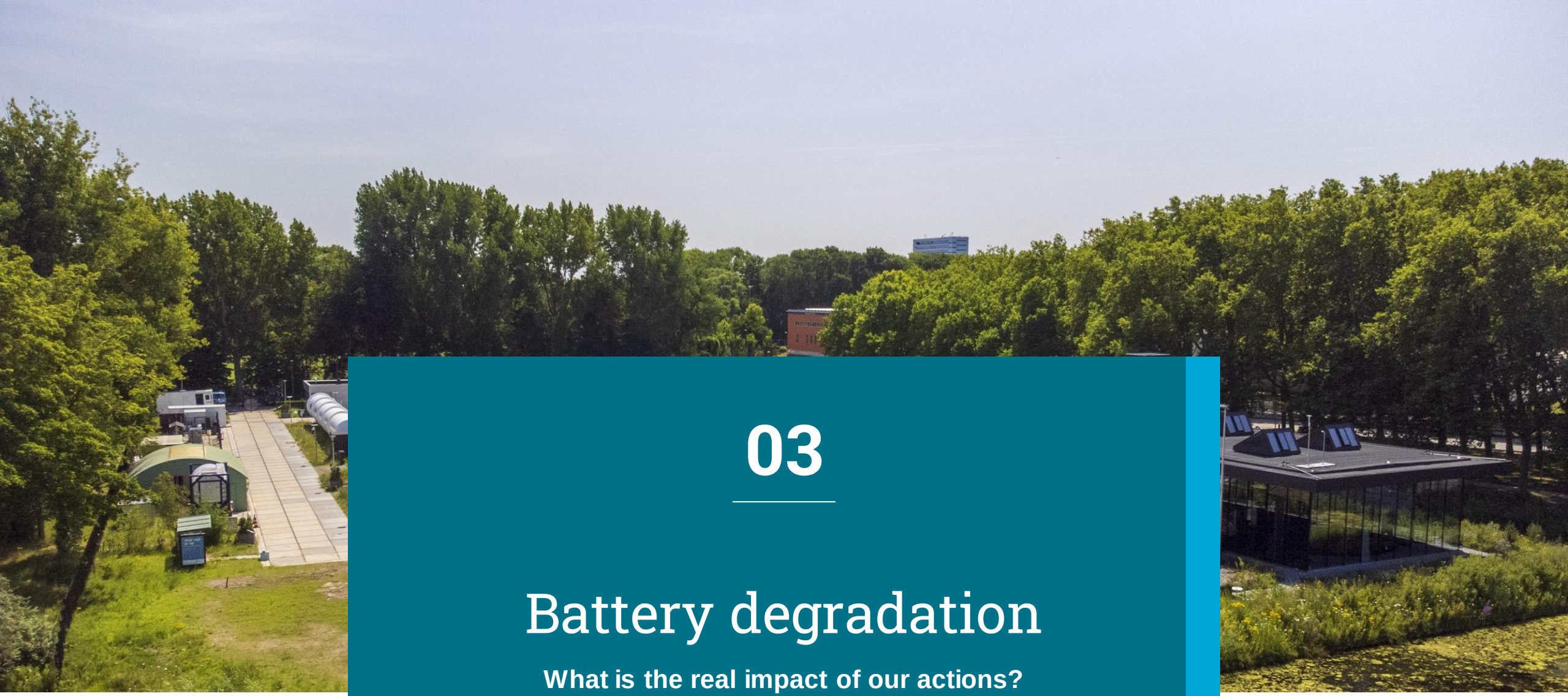
Linear Constraints

EMS Dashboard



TU Delft

DCE&S
DC systems, Energy conversion & Storage



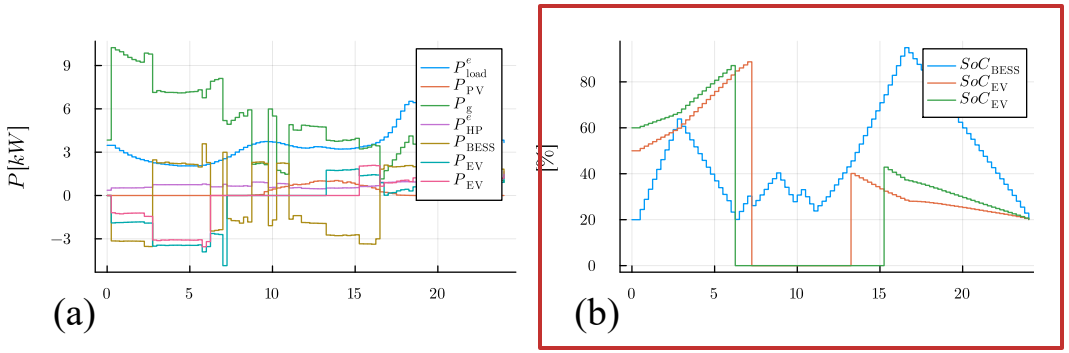
03

Battery degradation

What is the real impact of our actions?

3 Battery degradation

- What happens to the batteries when we use them?
- Complex systems with multiple mechanisms at the same time.
- But how do we model this?



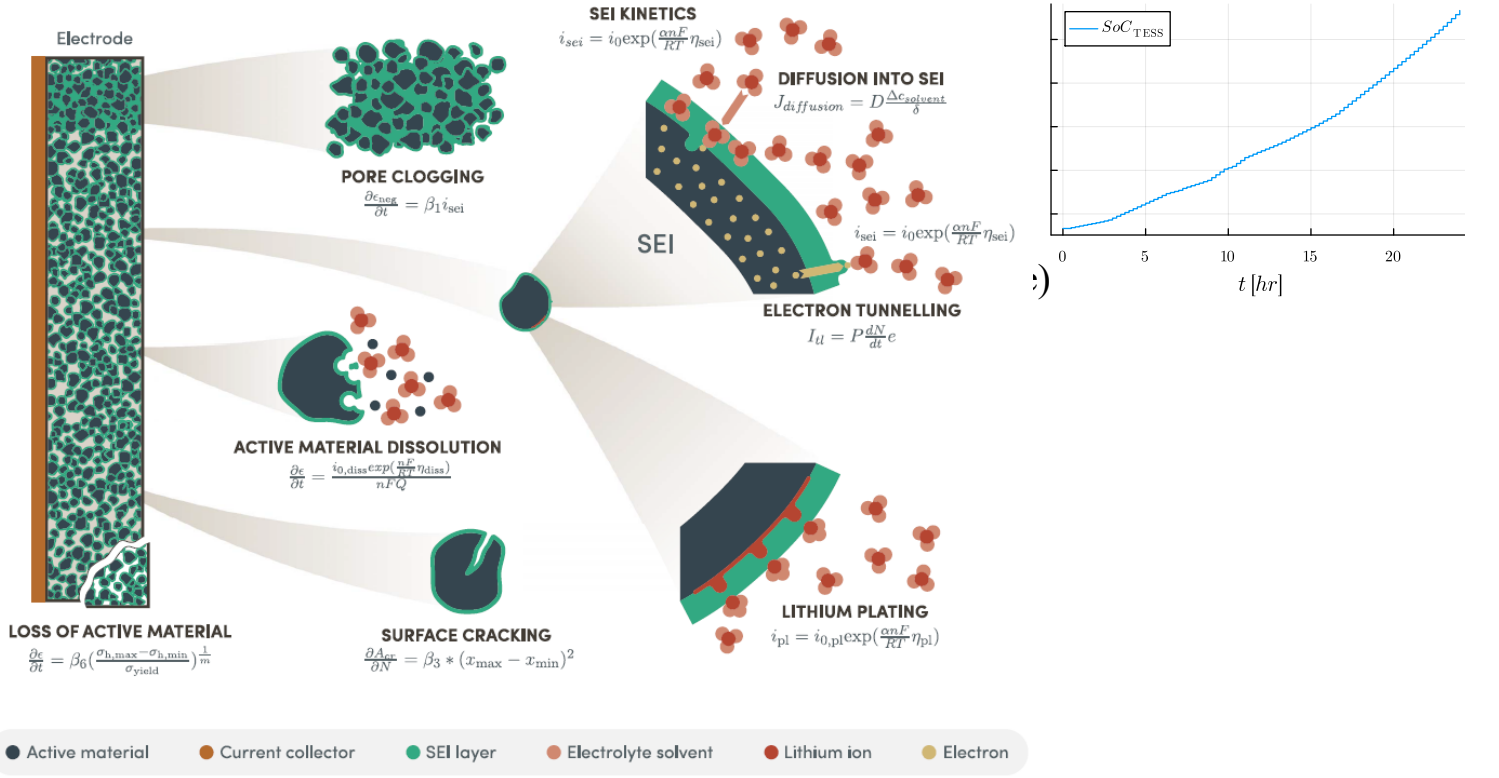
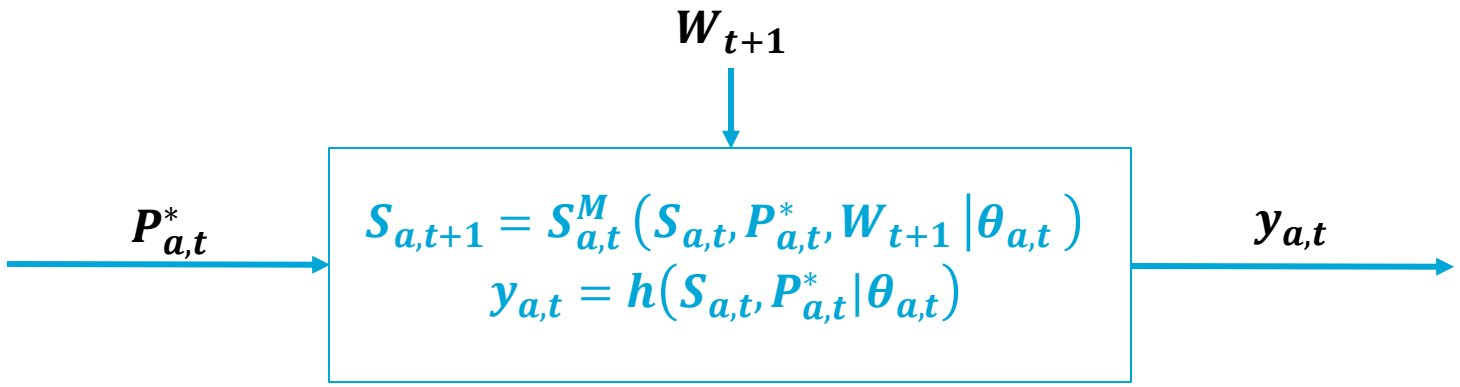


Figure 1. Graphical illustration of the various degradation mechanisms with typical equations modelling each mechanism.

TU Delft

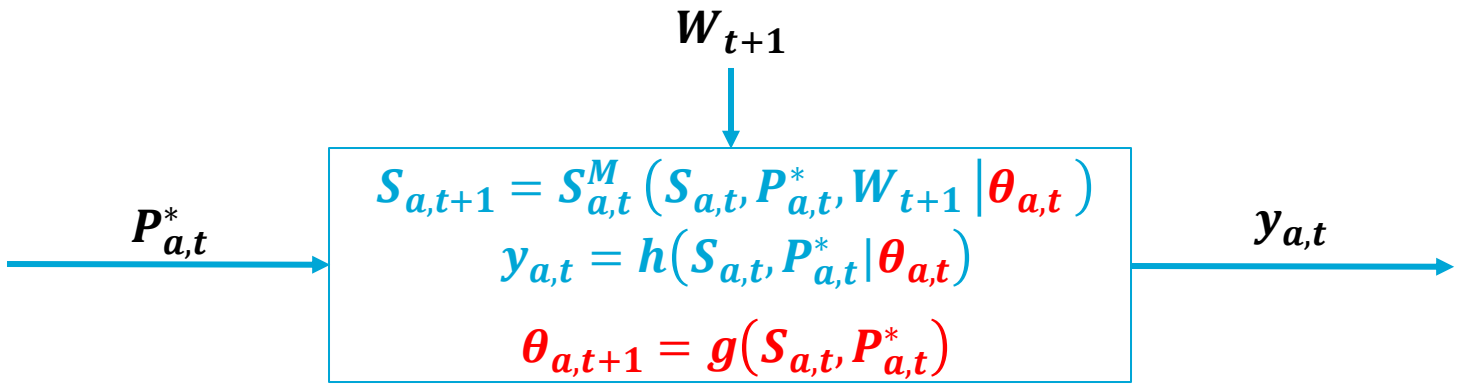
DCE&S
DC systems, Energy conversion & Storage

3.1 Battery degradation



- Every device a has a model like this.
- Best case scenario $S^M_{a,t}(.)$ and $y_{a,t}(.)$ are linear. → but reality is non-linear!

3.1 Battery degradation

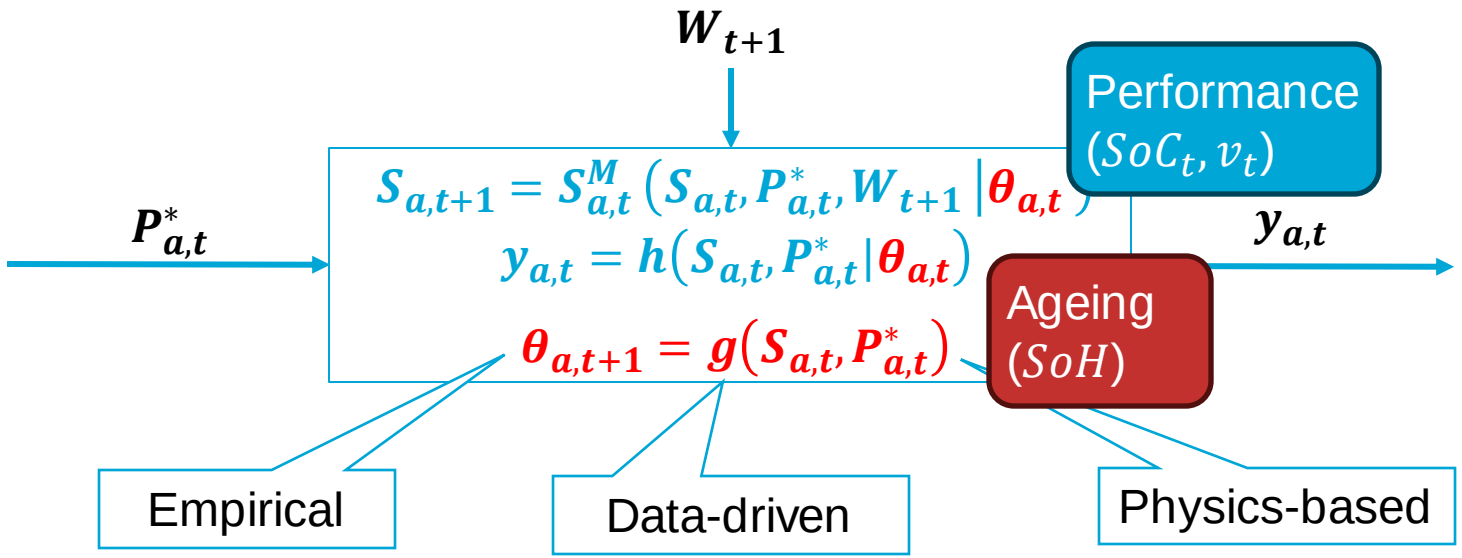


- Every device a has a model like this.
- Best case scenario $S^M_{a,t}(.)$ and $y_{a,t}(.)$ are linear. → but reality is non-linear!
- **Add a ageing sub-model.**

TU Delft

DCE&S
DC systems, Energy conversion & Storage

3.1 Battery degradation

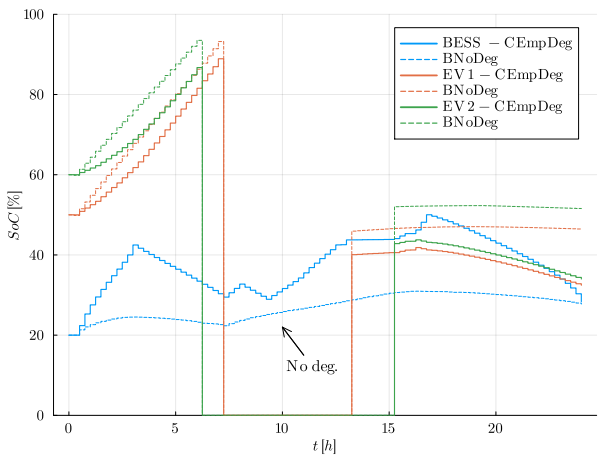


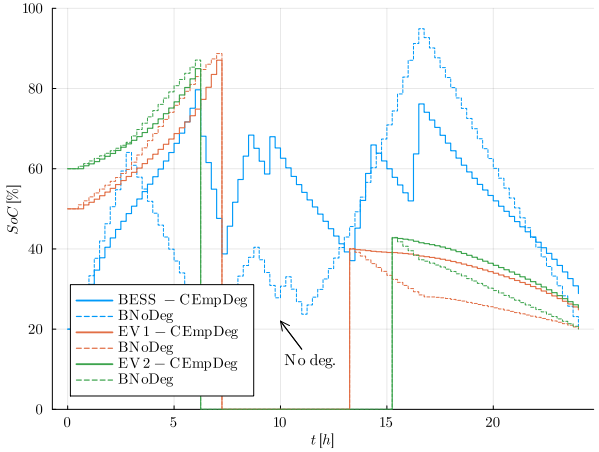
- Every device a has a model like this.
- Best case scenario $S^M_{a,t}(.)$ and $y_{a,t}(.)$ are linear. → but reality is non-linear!
- **Add a ageing sub-model.**

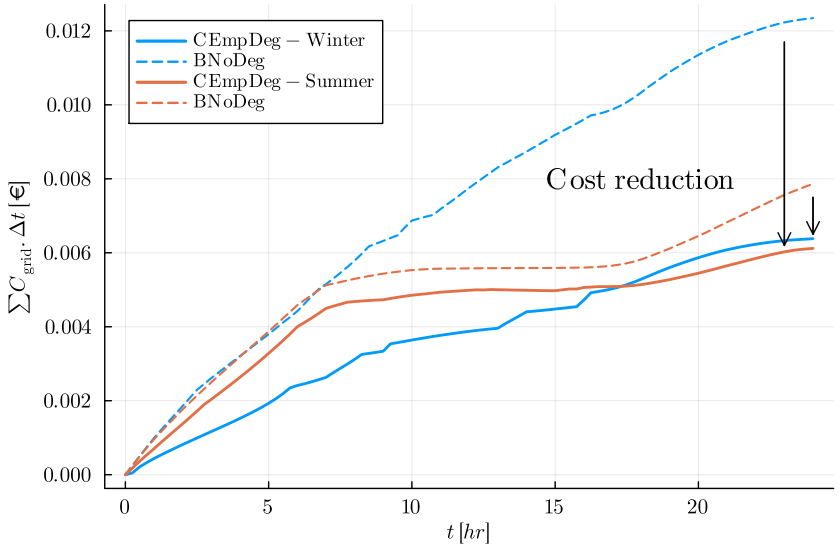
TU Delft

DCE&S
DC systems, Energy conversion & Storage

3.1 Battery degradation







Approximation

$$\min_{P^*} C_{grid} + W_{SoC}||\varepsilon_{SoC}||_2^2 + C_{loss}$$

Sequential Decision Making

$$\min_{\pi} \quad \mathbb{E}\left[\sum_{t=0}^{T} C(S_{a,t}, P^*_{a,t})\right]$$

$$s.t. \quad S_{a,t+1} = S^M_{a,t}(S_{a,t}, P^*_{a,t}, W_{t+1}|\theta_{a,t})$$

$$P^*_{a,t} = X^\pi_t(S_{a,t}) \in \mathcal{P} \qquad \forall a \in \mathbb{A}$$

$$S_{a,t} \in \mathcal{S} \qquad \forall a \in \mathbb{A}$$

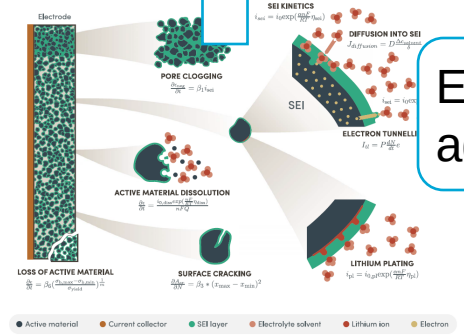


Figure 1. Graphical illustration of the various degradation mechanisms with typical equations modelling each mechanism.

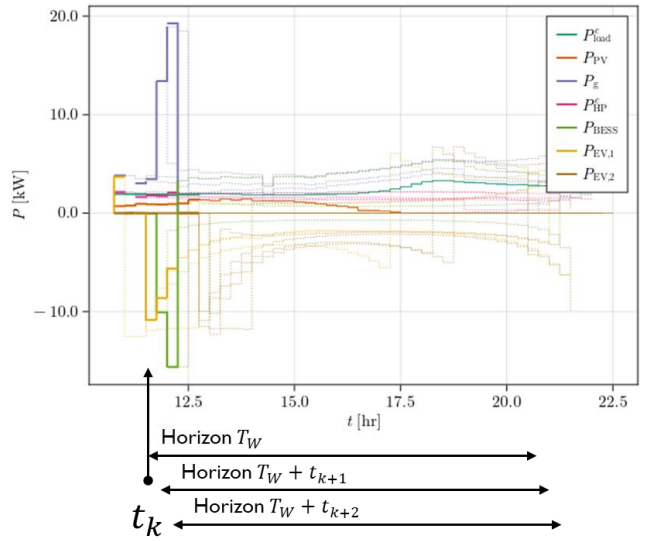
Empirical ageing

TU Delft

DCE&S
DC systems, Energy conversion & Storage

Ongoing research

- Implementing Rolling Horizon Optimal Controllers with PBROM models (perf.& ageing)
- Identifying models online!
- Developing physics-informed machine learning methods to gain speed and include uncertainty (dynamic adaptive policies).
- Improving the other devices and stacking services (FCR, mFFR, aFFR)



TU Delft

DCE&S
DC systems, Energy conversion & Storage

@DarioSlaifsteinSk

DCE&S
DC systems, Energy conversion & Storage

TU Delft

Thank you!

Dario Slaifstein