



NOVEL AND SYSTEMATIC VALIDITY ASSESSMENT OF LI-ION BATTERY LIFETIME PREDICTIONS

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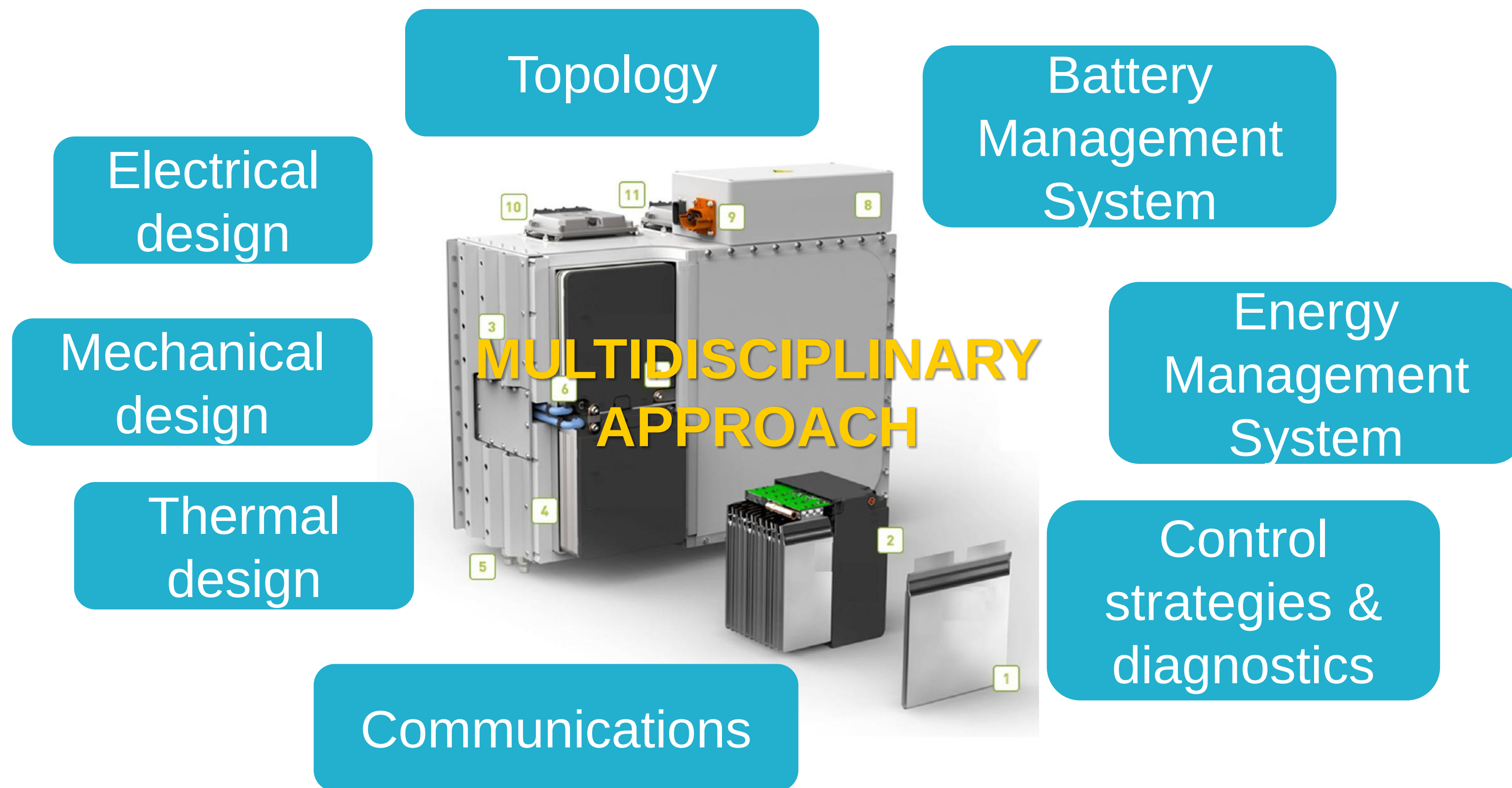


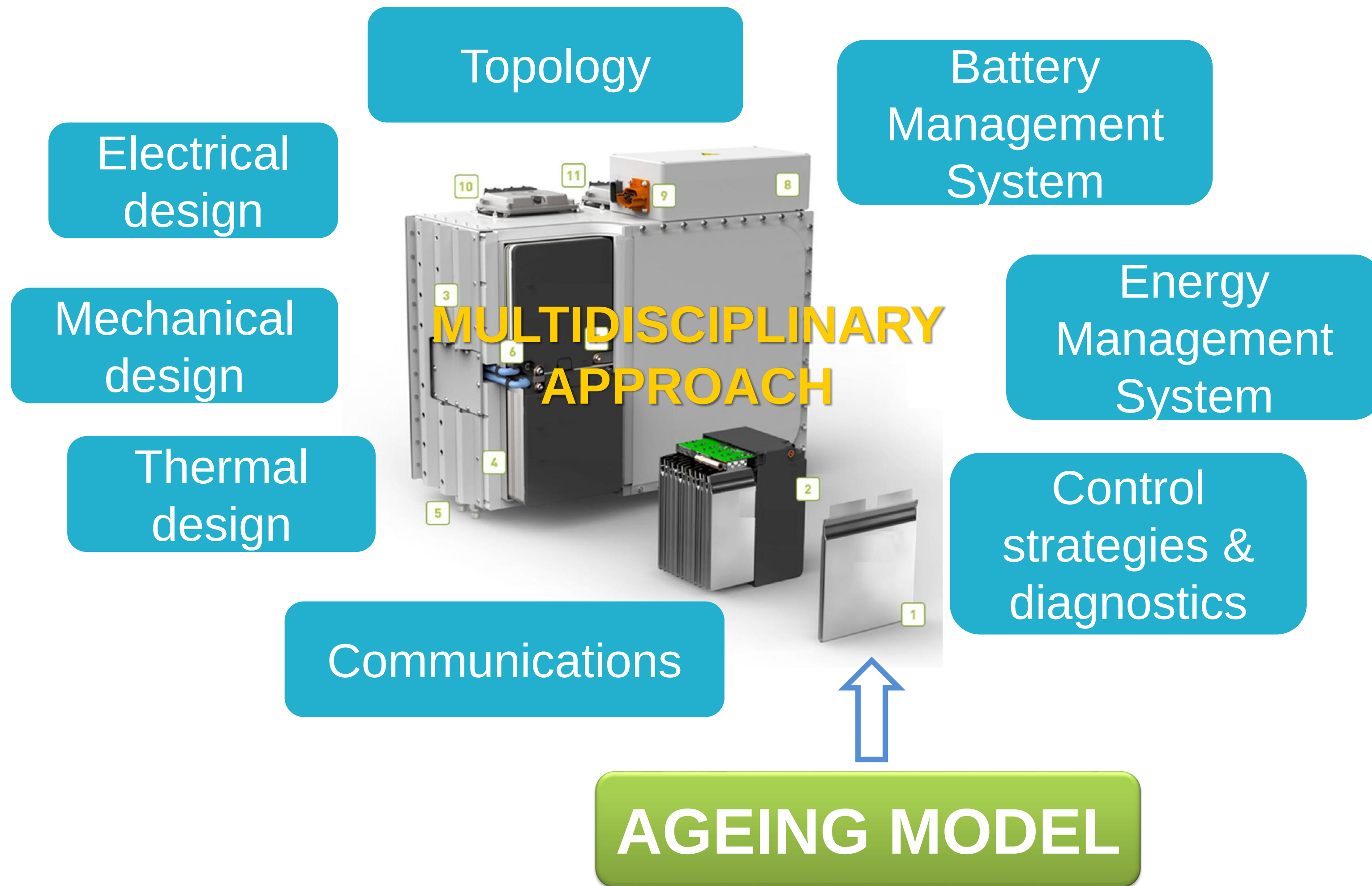
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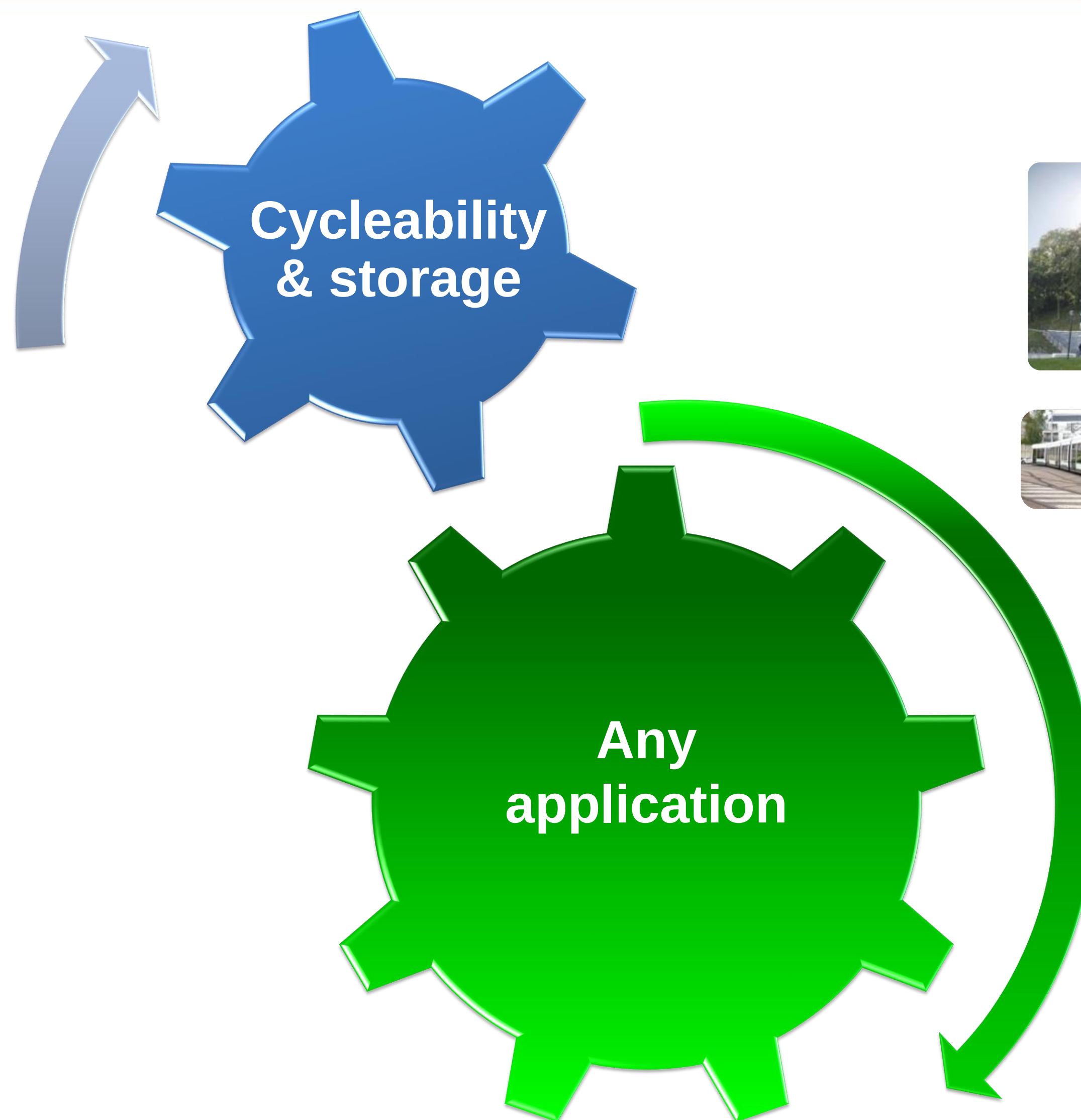
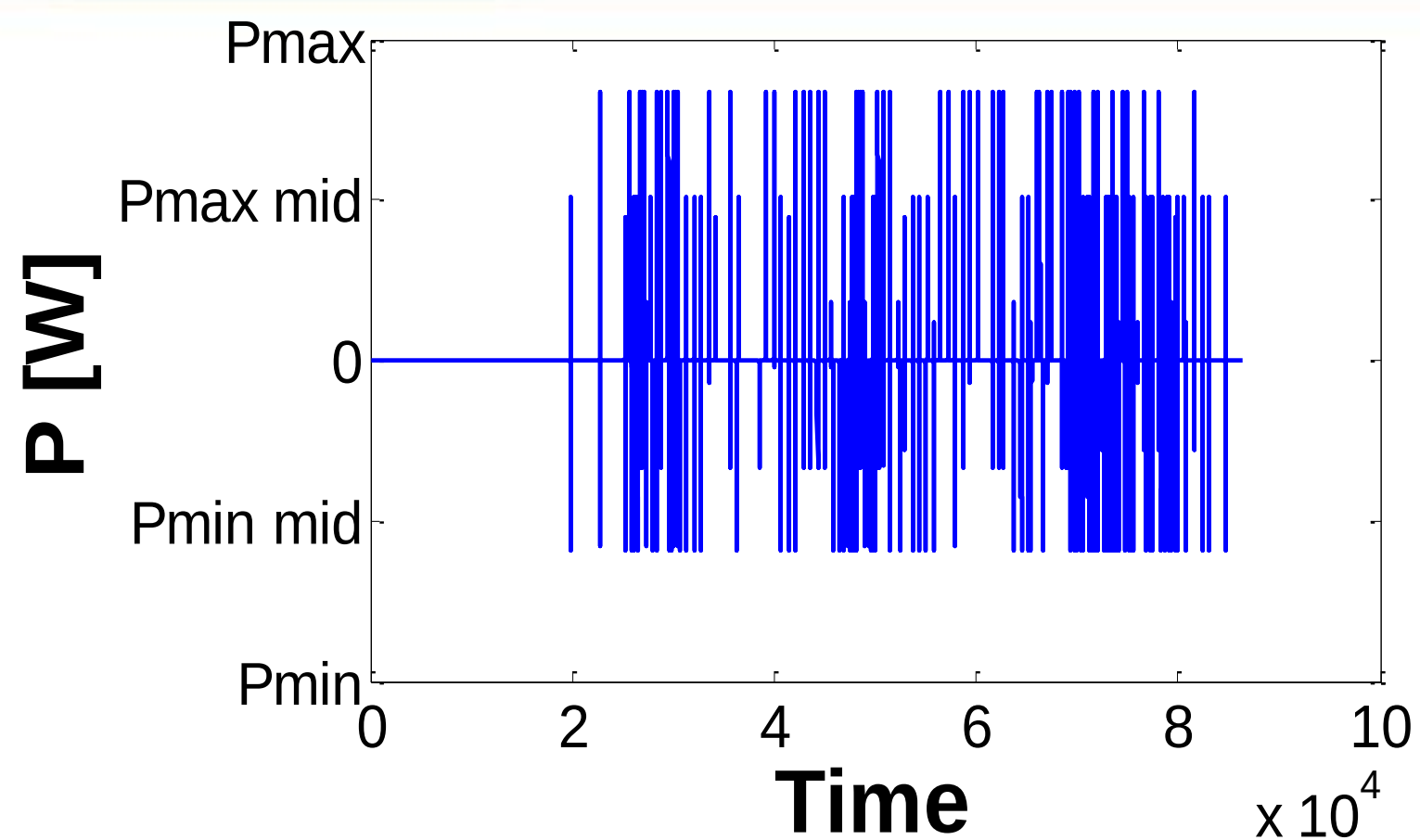




MOTIVATION

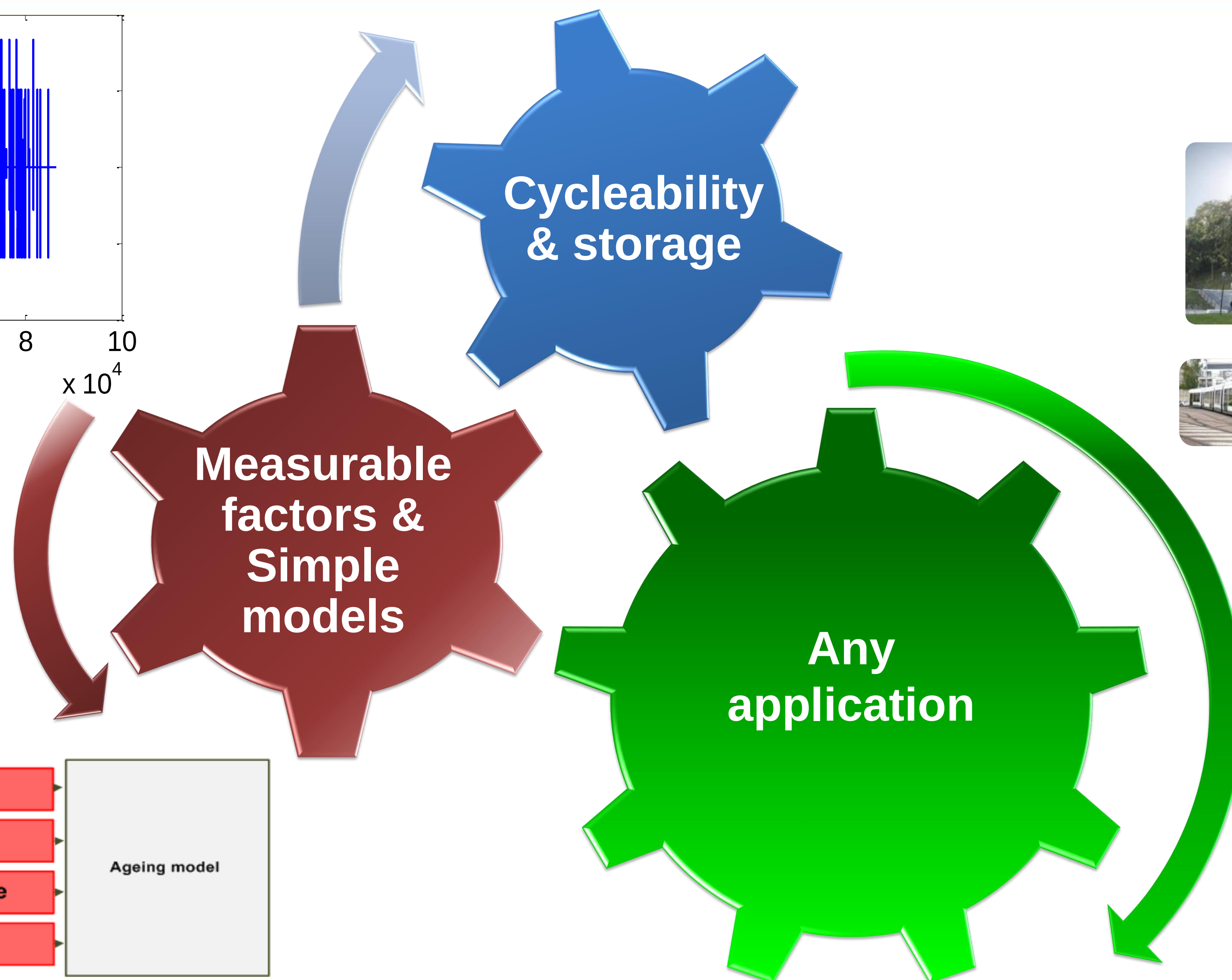
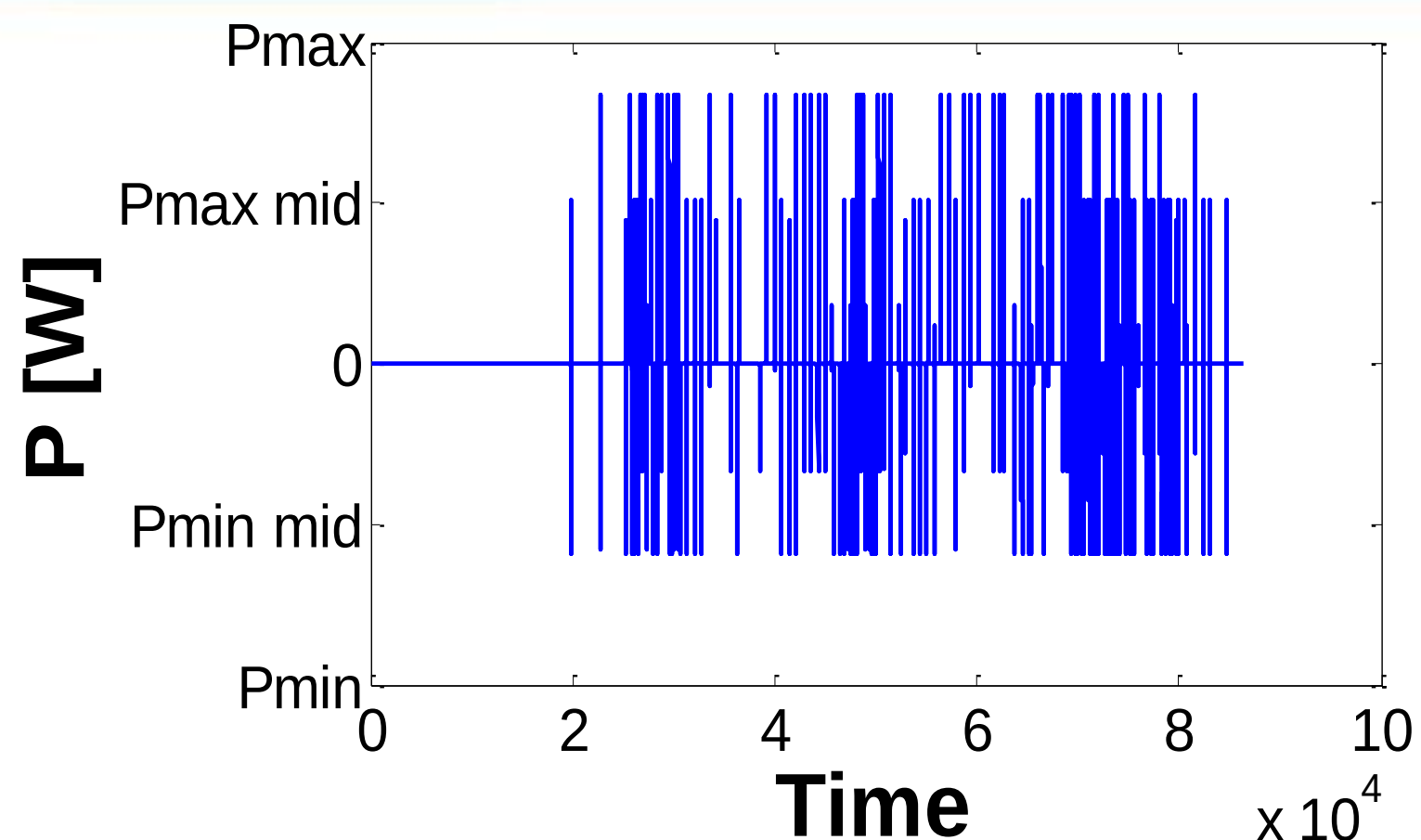
AGEING MODEL



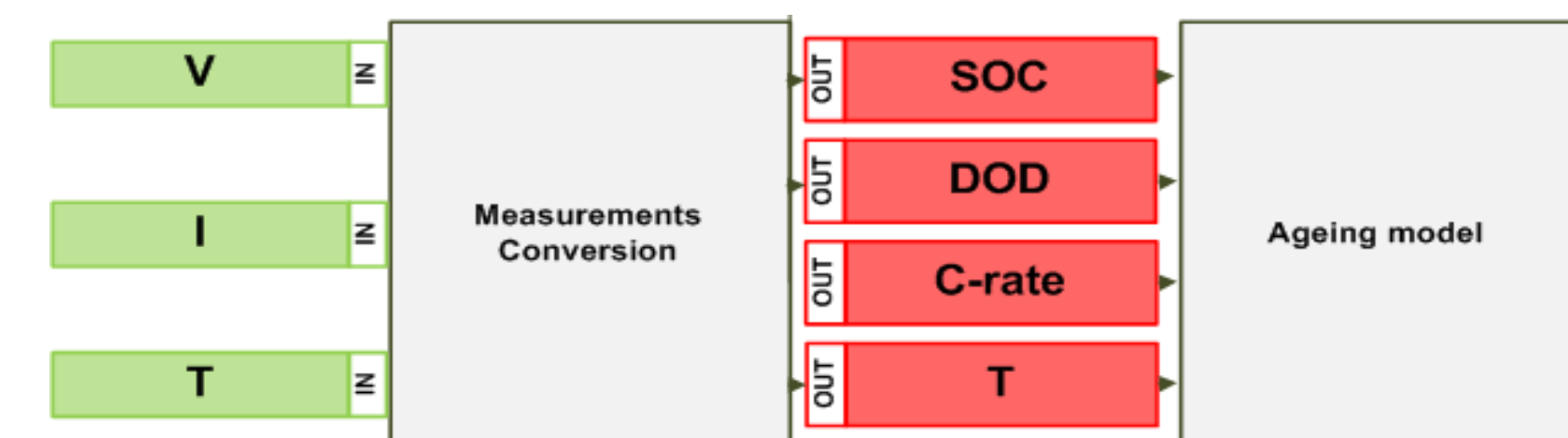


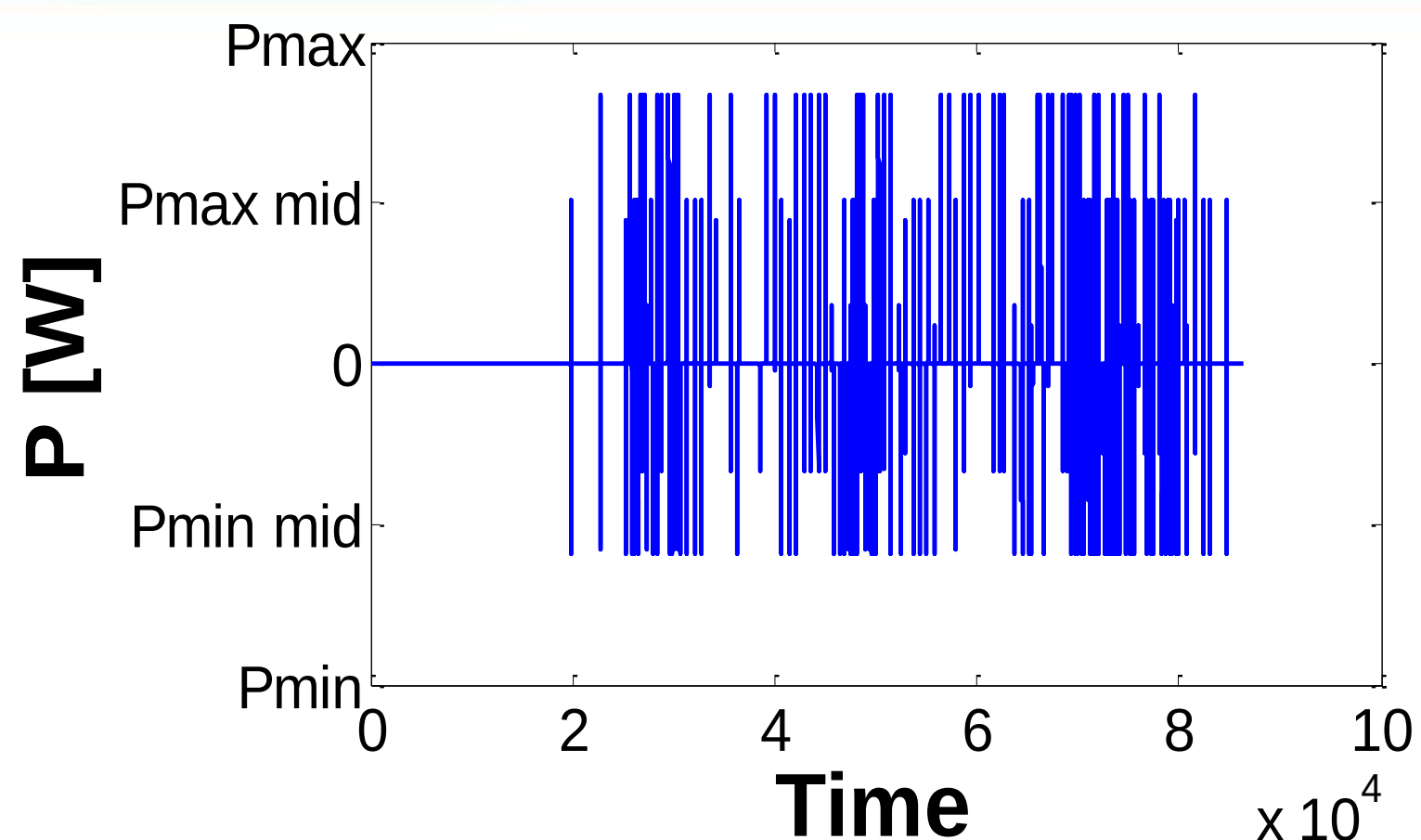
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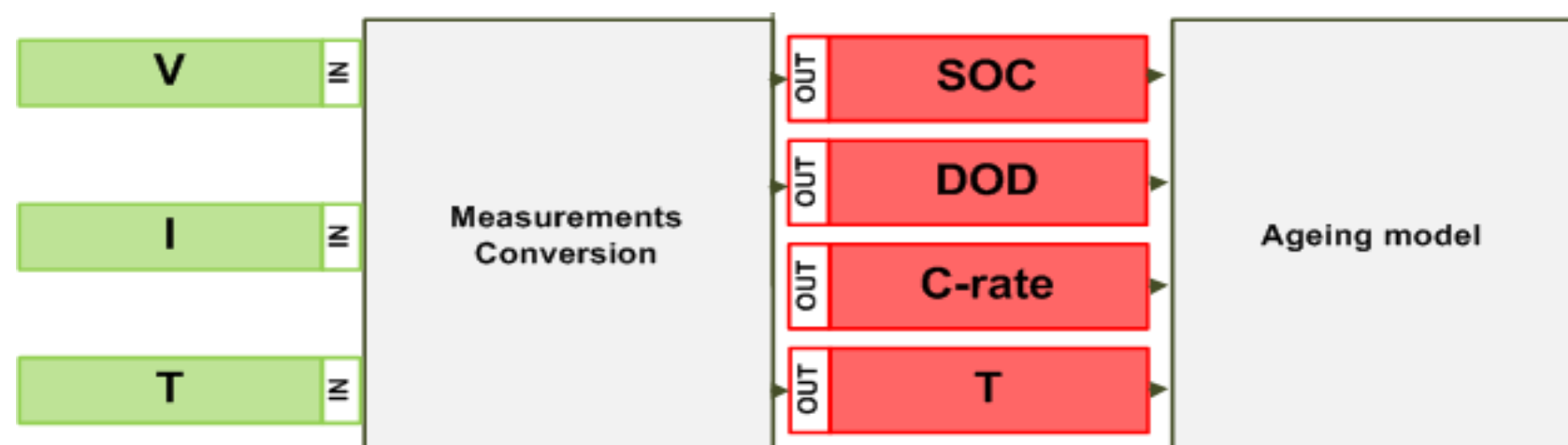
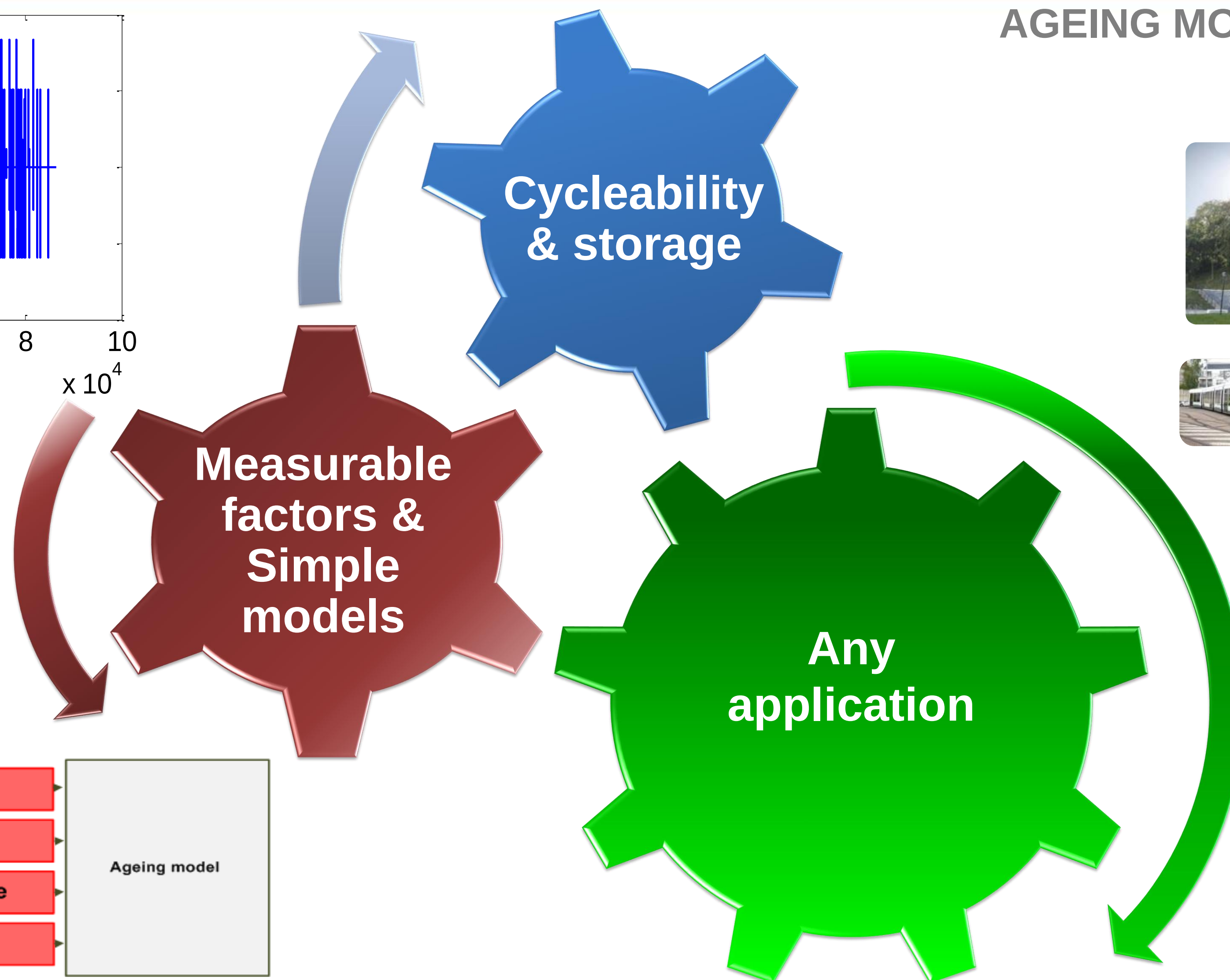


AGEING MODEL





AGEING MODEL VALIDATION



01

INTRODUCTION

Lifetime prediction methodology

02

OBJECTIVES

03

AGEING MODEL VALIDATION

04

CONCLUSION AND FUTURE WORK



01

INTRODUCTION

Lifetime prediction methodology

02

OBJECTIVES

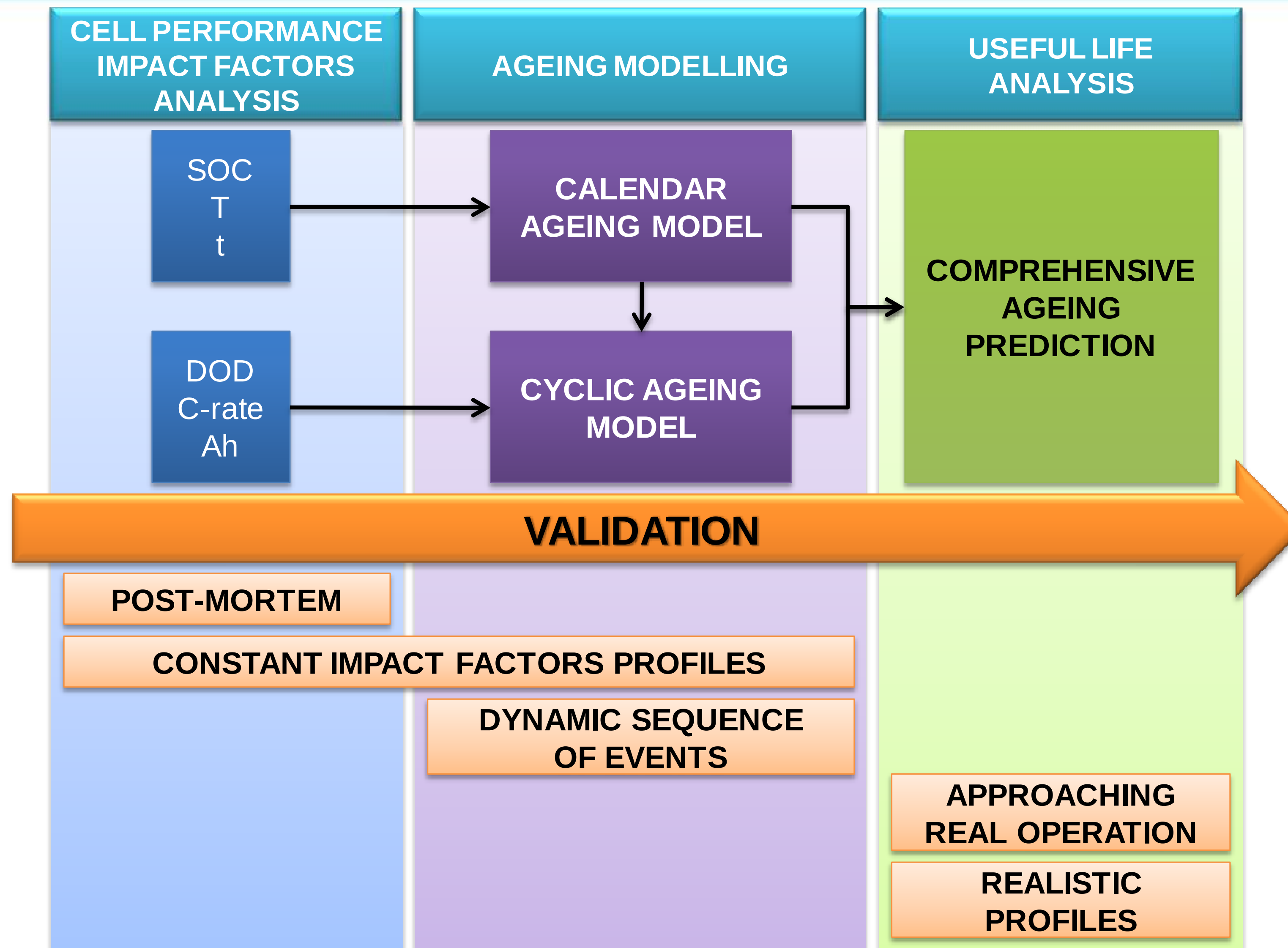
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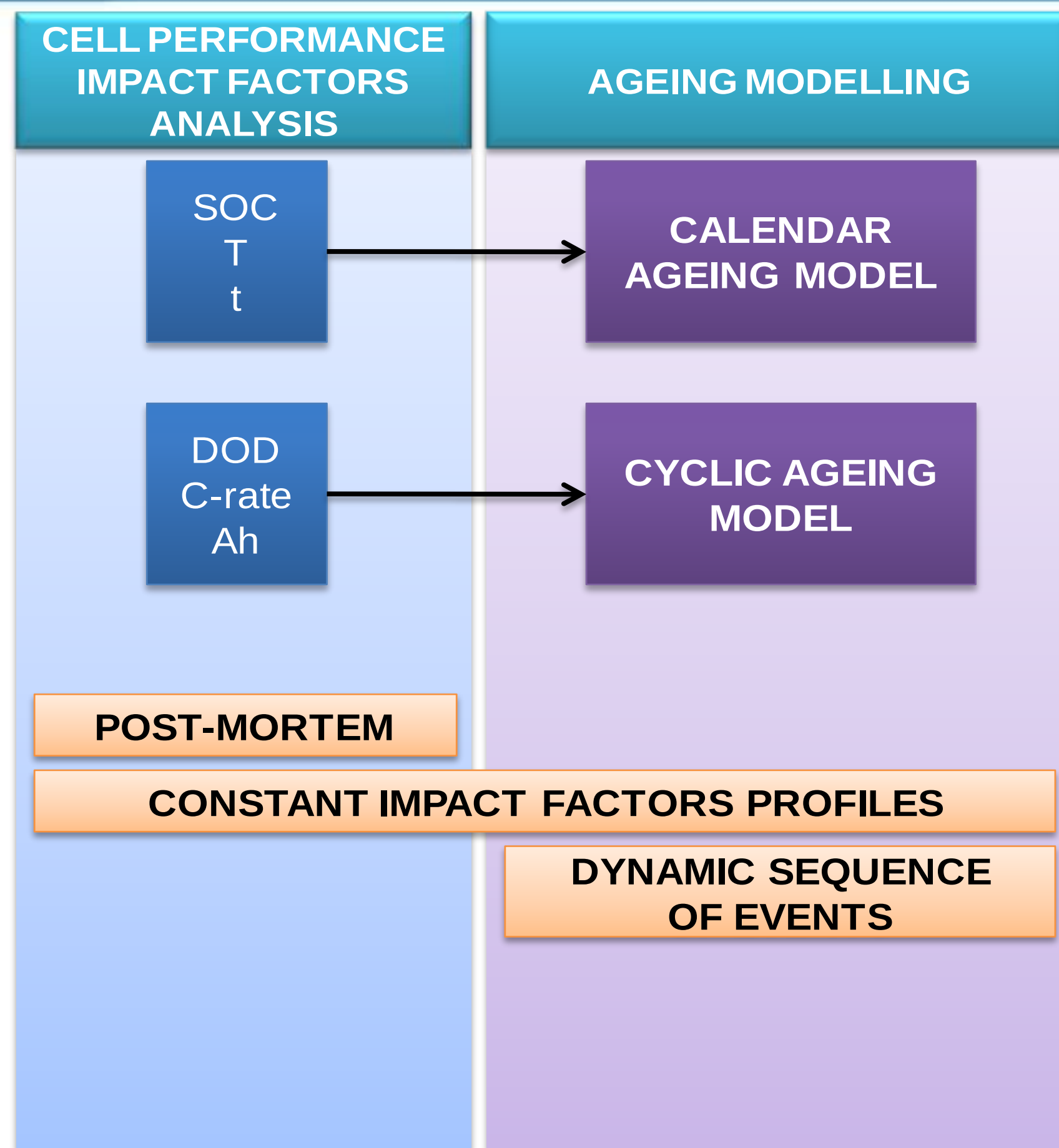
AGEING MODEL VALIDATION

04

CONCLUSION AND FUTURE WORK







$$Q_{\text{loss_cal}} [\%] = \alpha_1 \cdot \exp (\beta_1 \cdot T^{-1}) \cdot \alpha_2 \cdot \exp (\beta_2 \cdot \text{SOC}) \cdot t^{0.5} \quad (1)$$

$$Q_{\text{loss, cyc}} [\%] \quad (10\% \leq \text{DOD} \leq 50\%) = \quad (2)$$

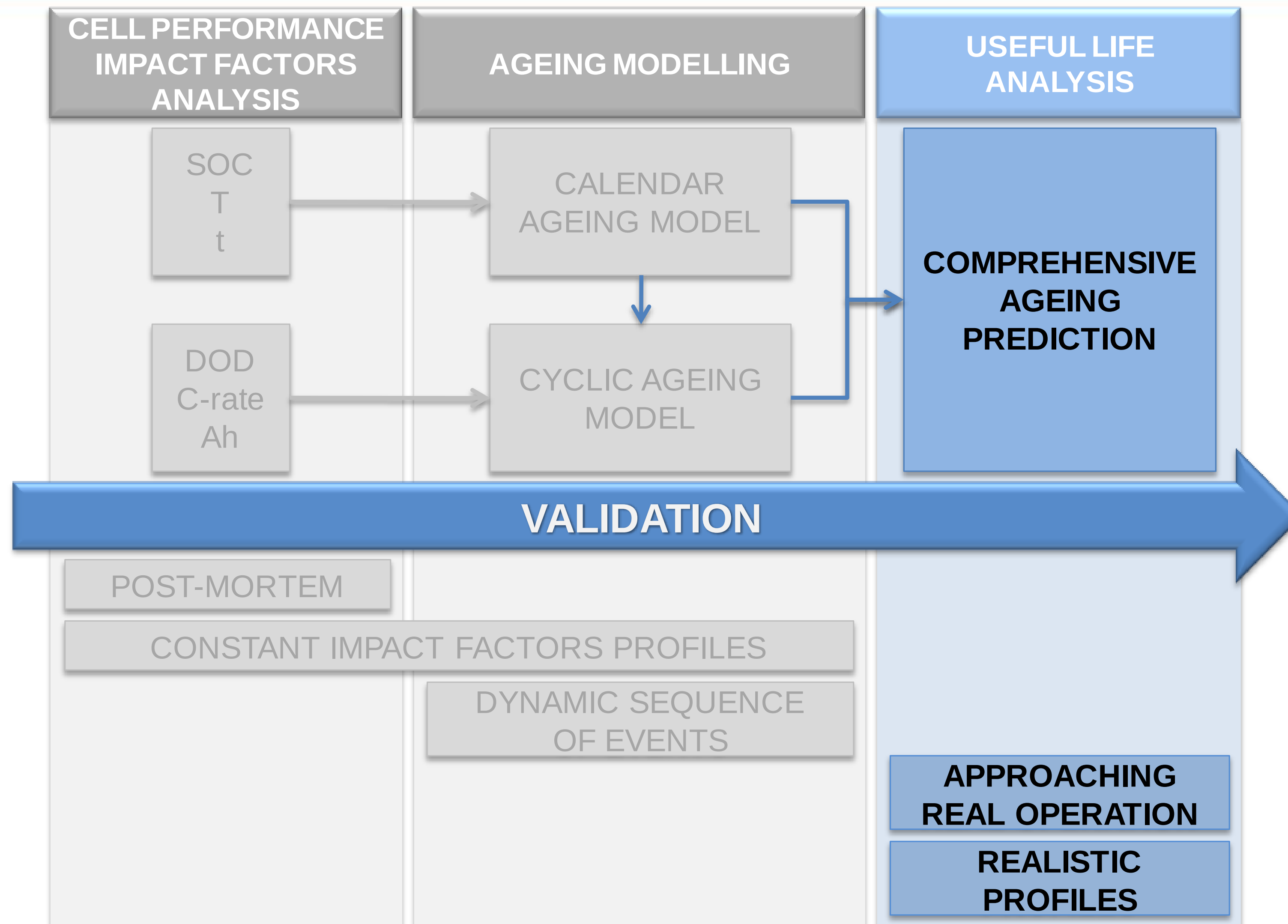
$$= (\gamma_1 \cdot \text{DOD}^2 + \gamma_2 \cdot \text{DOD} + \gamma_3) \cdot k \cdot \text{Ah}^{0.87}$$

$$Q_{\text{loss, cyc}} [\%] \quad (\text{DOD} < 10\% \ \& \ \text{DOD} > 50\%) = \quad (3)$$

$$= (\alpha_3 \cdot \exp (\beta_3 \cdot \text{DOD}) + \alpha_4 \cdot \exp (\beta_4 \cdot \text{DOD})) \cdot k \cdot \text{Ah}^{0.65}$$

$$Q_{\text{loss}} = Q_{\text{loss_cal}} + Q_{\text{loss, cyc}}$$

- E. Sarasketa-Zabala, I. Gandiaga, L.M. Rodriguez-Martinez, I. Villarreal, **J. Power Sources** 272 (2014) 45-57
- E. Sarasketa-Zabala, F. Aguesse, I. Villarreal, L.M. Rodriguez-Martinez, C.M. López, P. Kubiak, **J. Phys. Chem. C** 119 (2015) 896-906
- E. Sarasketa-Zabala, I. Gandiaga, E. Martinez-Laserna, L. M. Rodriguez-Martinez, I. Villarreal, **J. Power Sources** 275 (2015) 573-587



01

INTRODUCTION

Lifetime prediction methodology



02

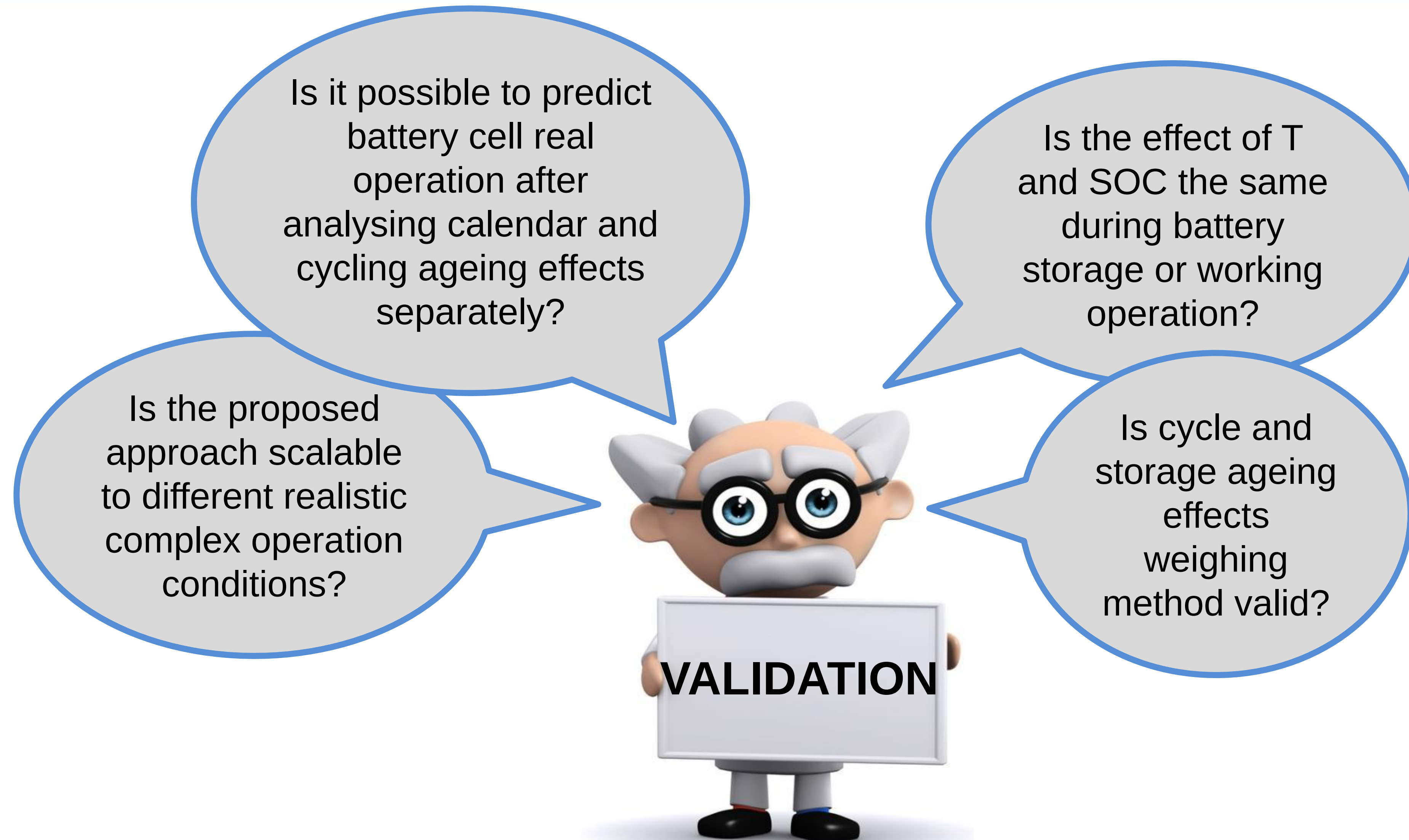
OBJECTIVES

03

AGEING MODEL VALIDATION

04

CONCLUSION AND FUTURE WORK



01

INTRODUCTION

Lifetime prediction methodology

02

OBJECTIVES

03

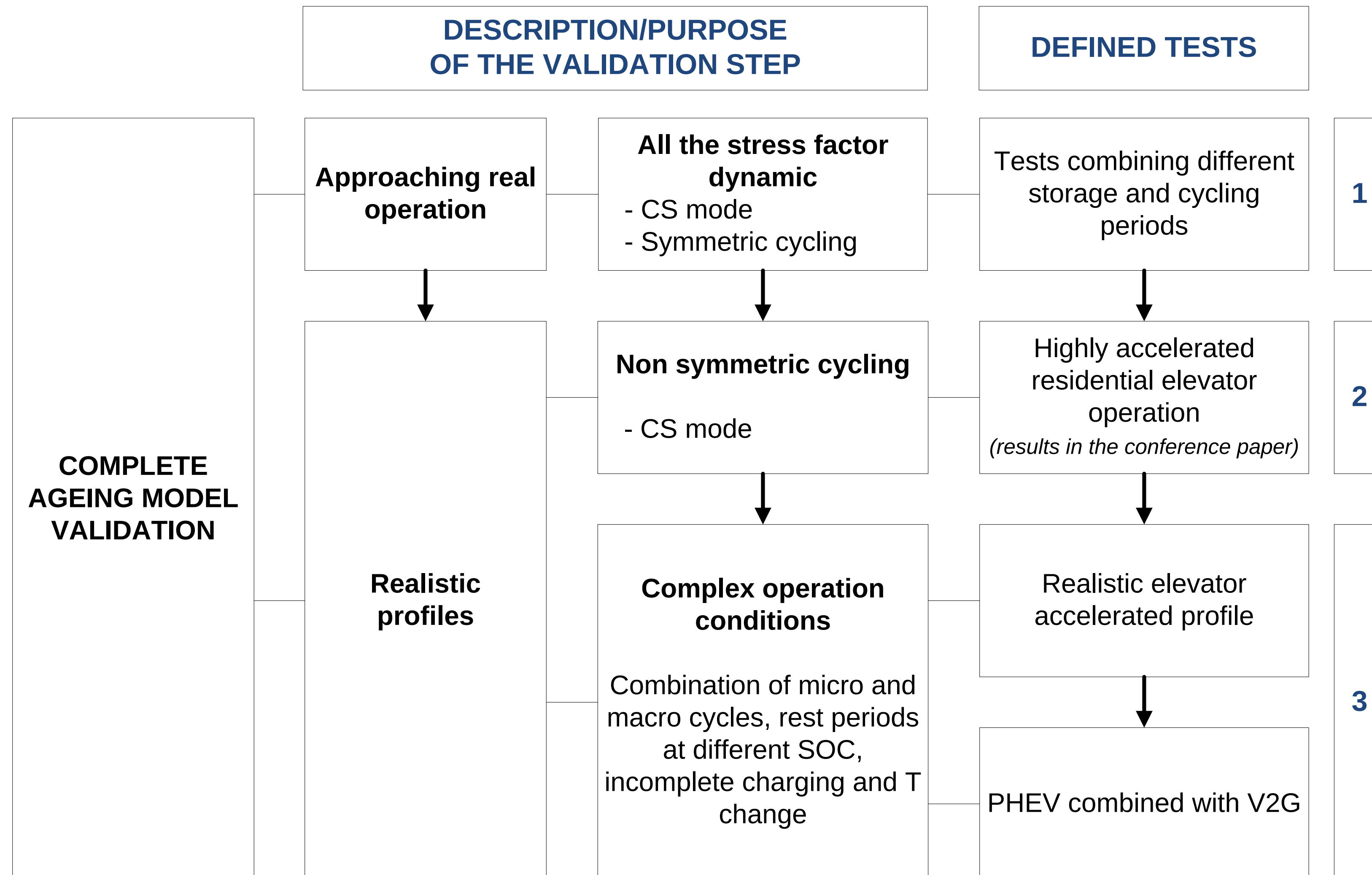
AGEING MODEL VALIDATION

04

CONCLUSION AND FUTURE WORK

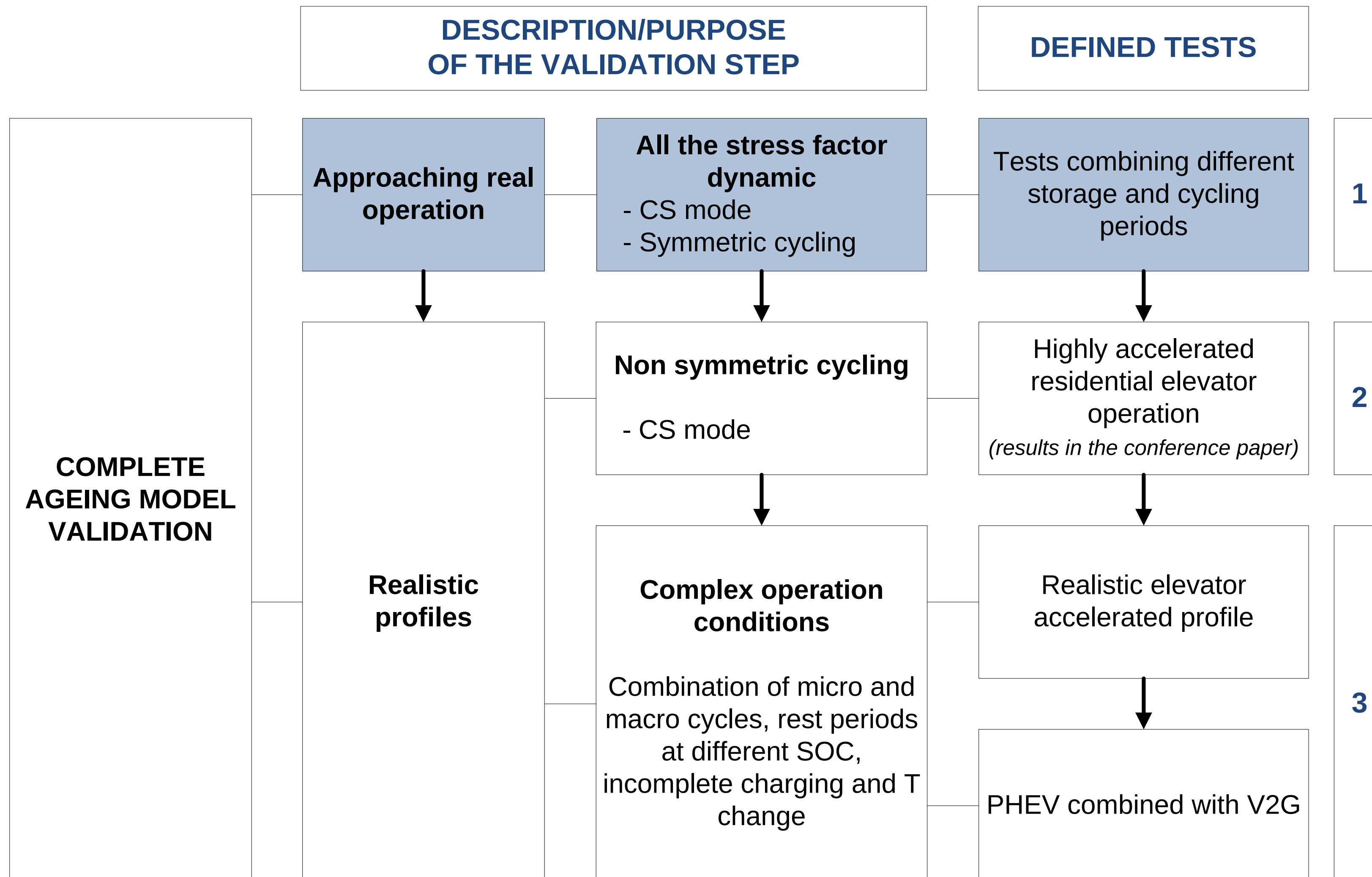
AGEING MODEL VALIDATION

APPROACH



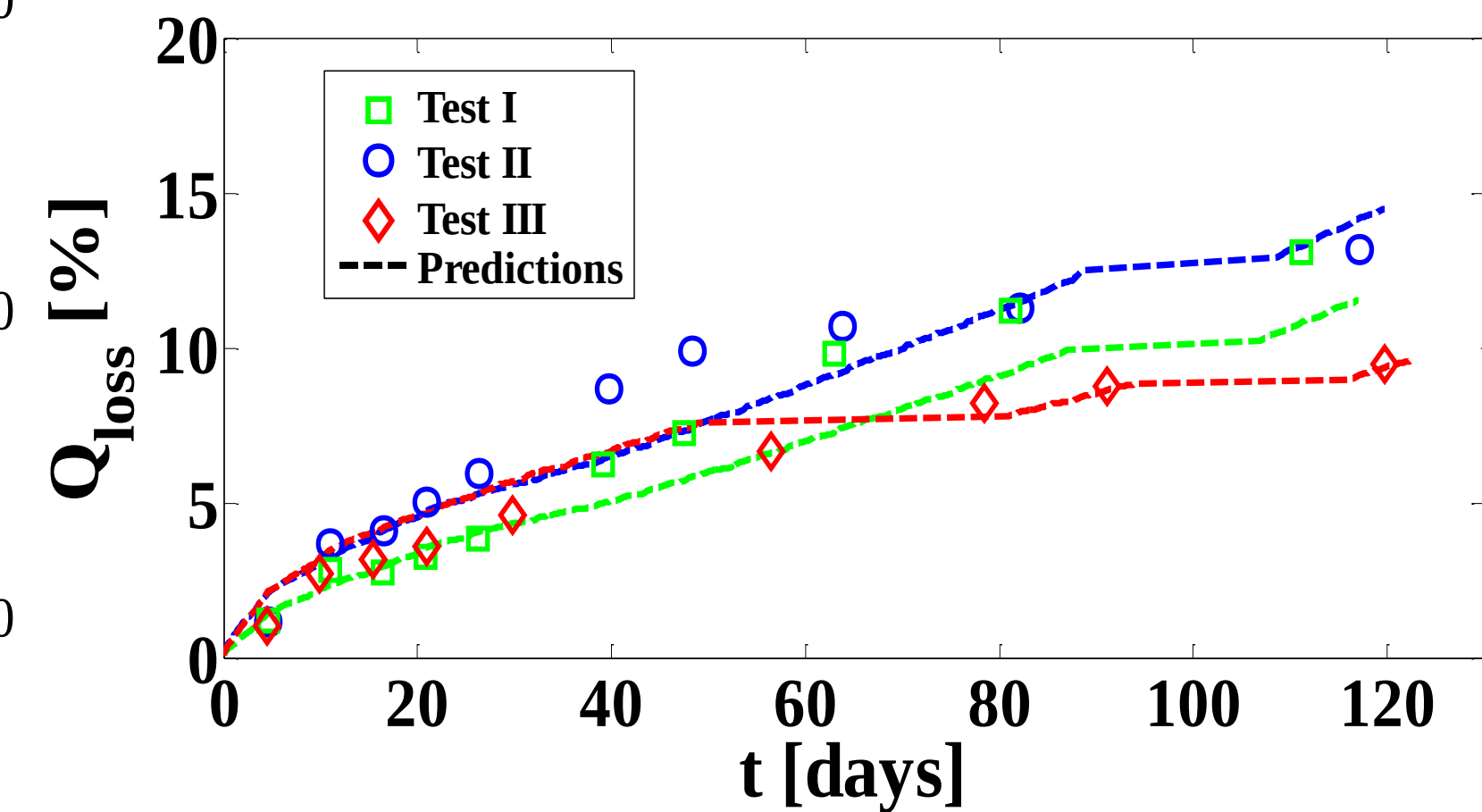
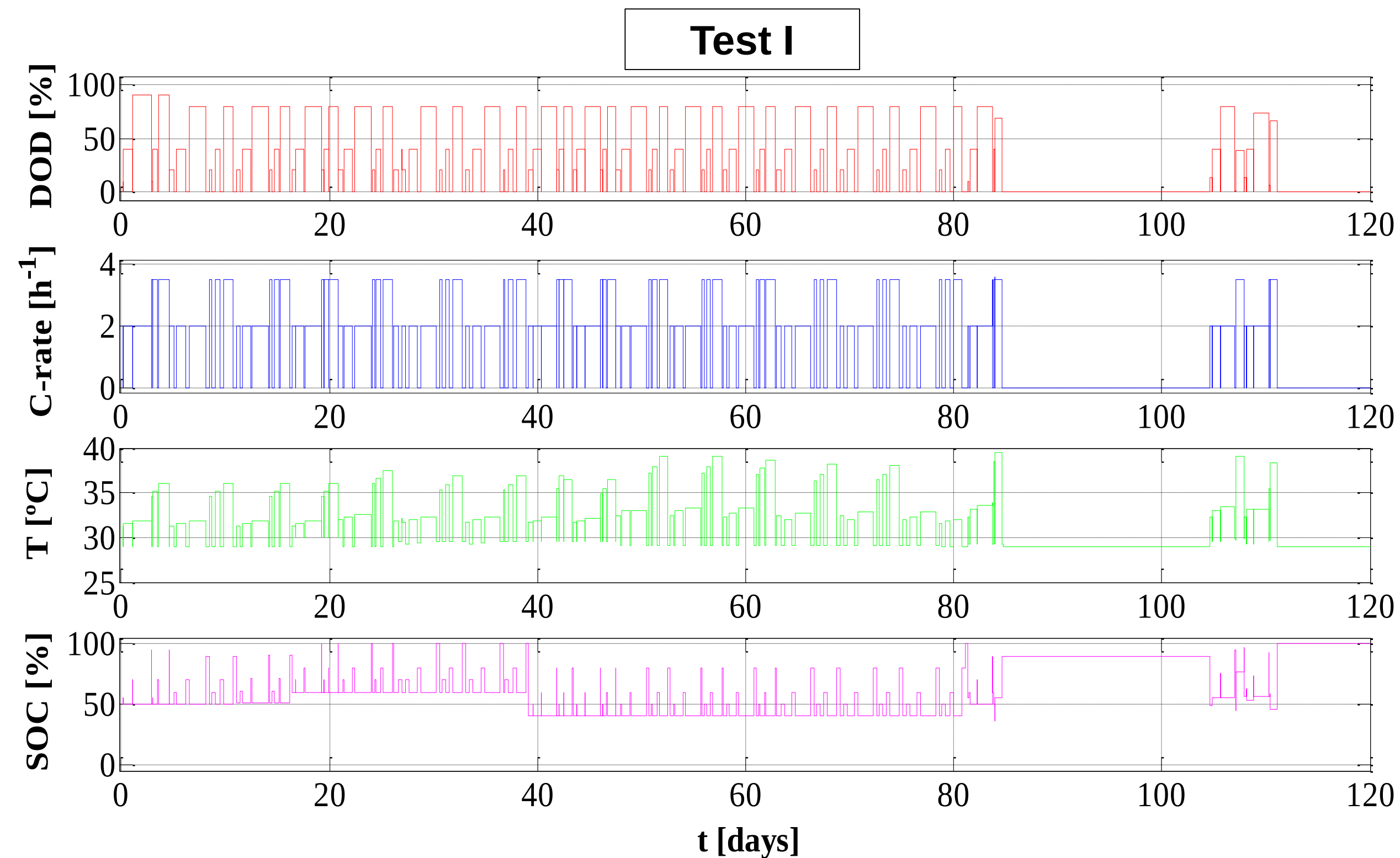
AGEING MODEL VALIDATION

APPROACH



AGEING MODEL VALIDATION

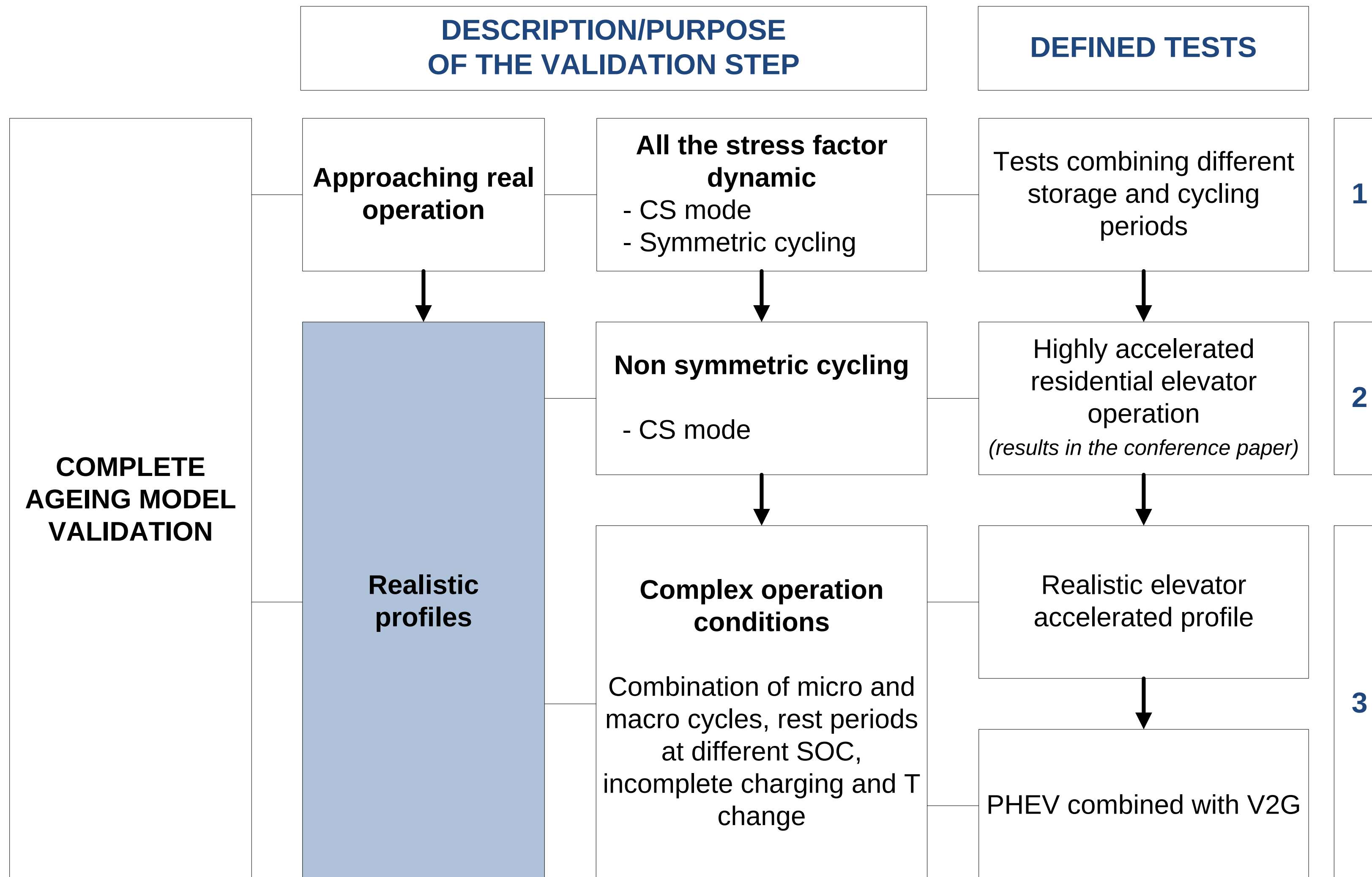
RESULTS 1: COMBINATION OF STORAGE AND CYCLING



- 1.23% RMSE
- Normal distribution of residuals
- **The ageing model follows battery cell capacity loss under operation conditions that combine different storage and cycling events**

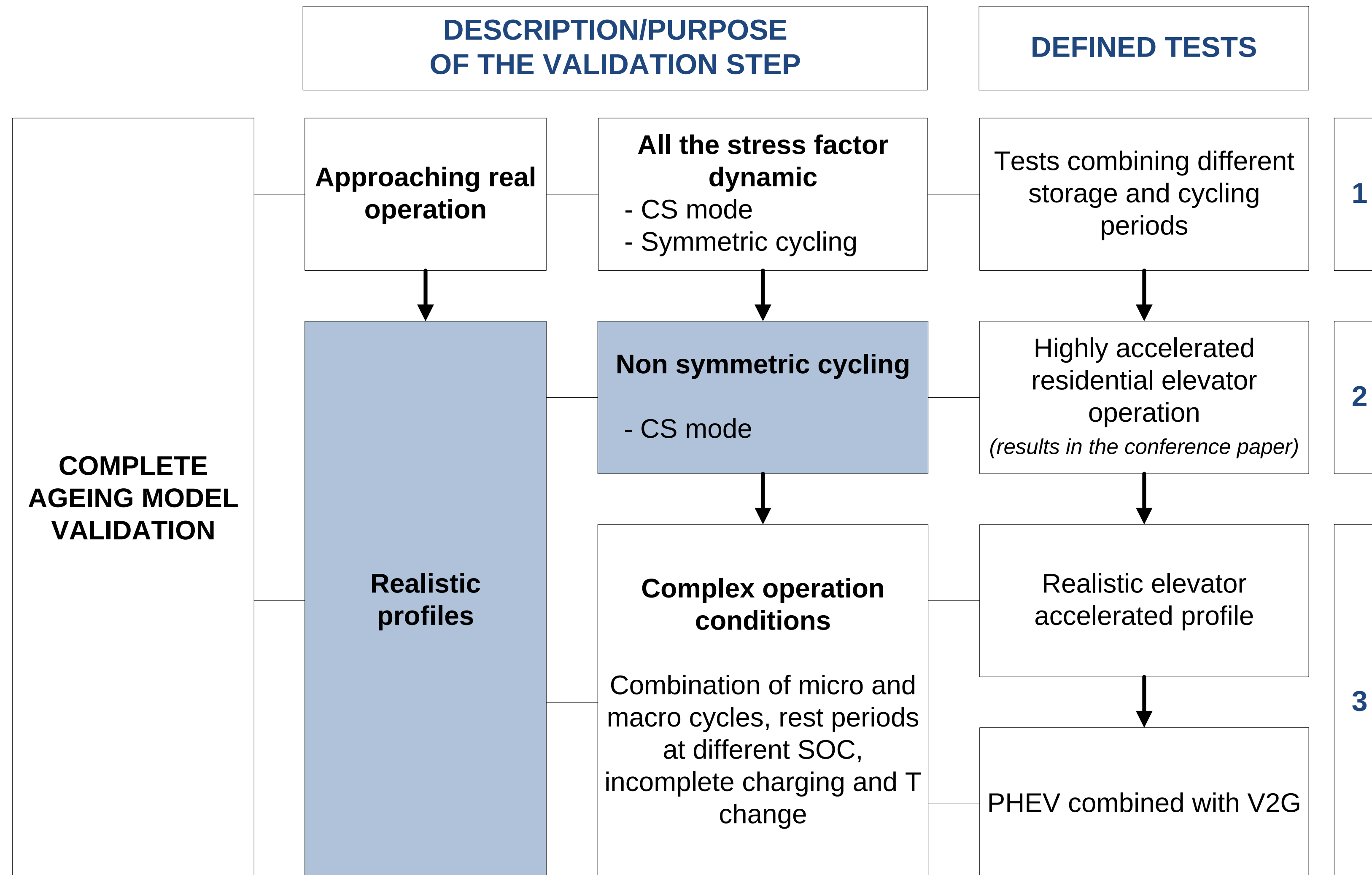
AGEING MODEL VALIDATION

APPROACH



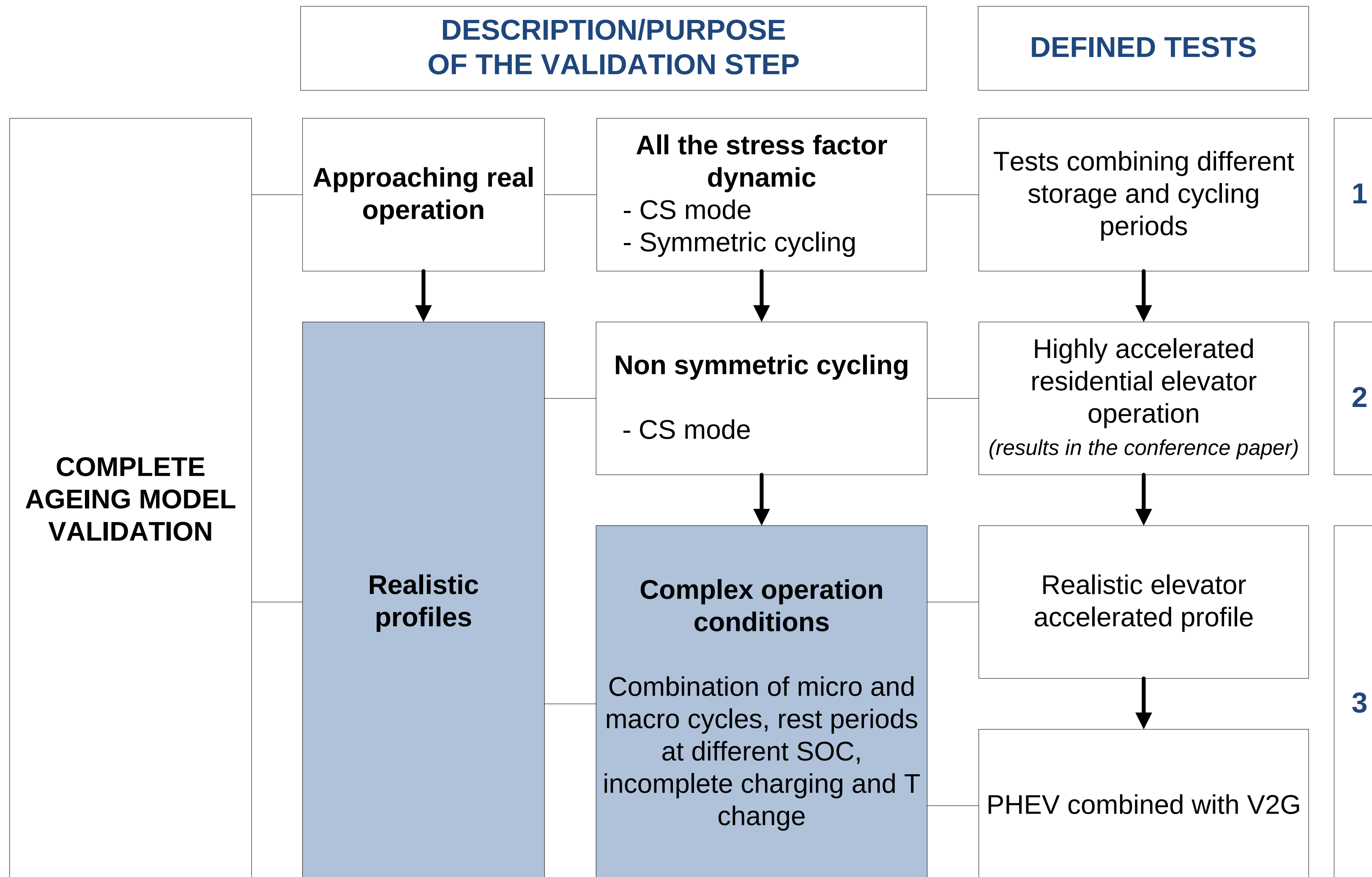
AGEING MODEL VALIDATION

APPROACH



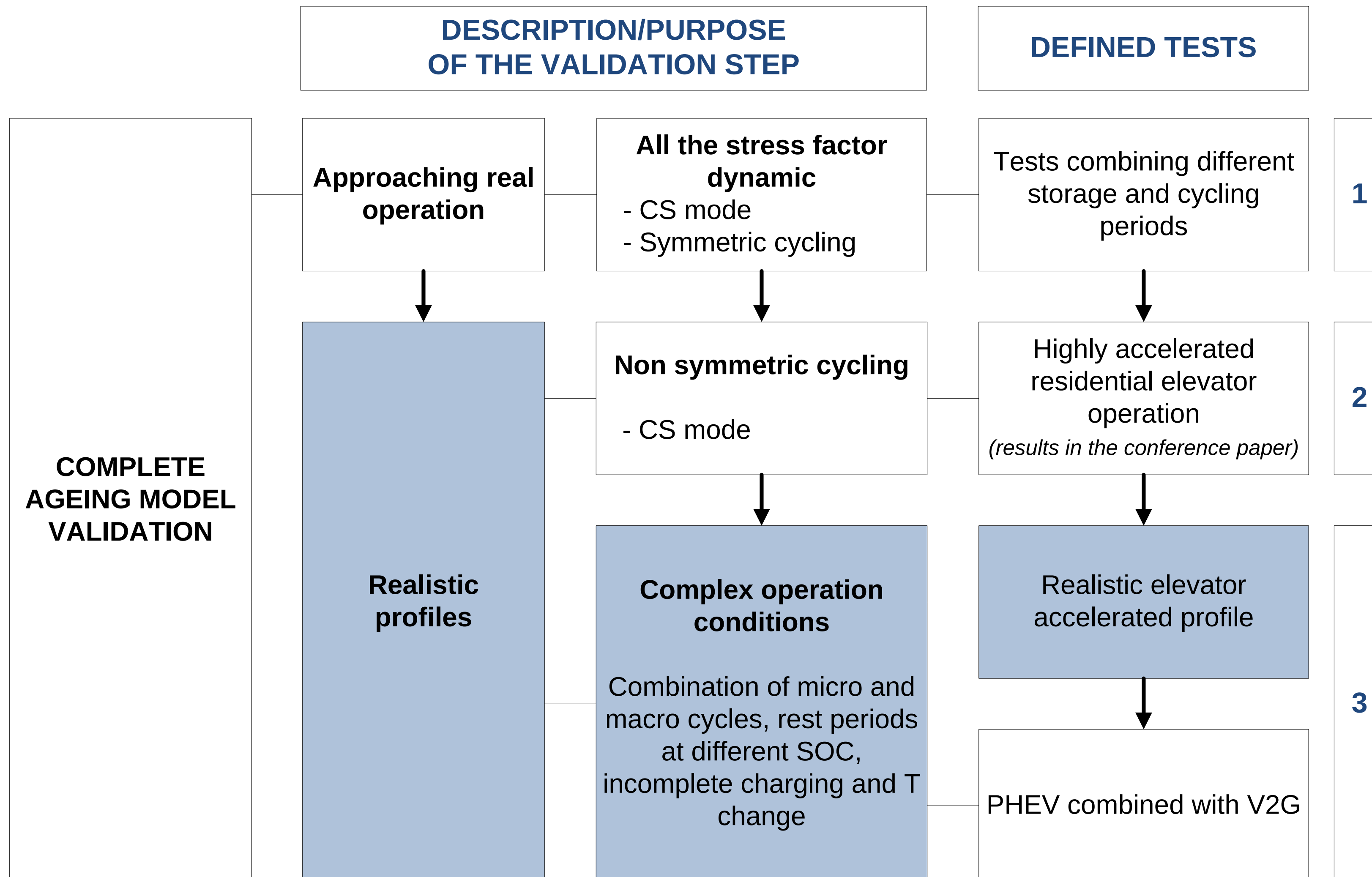
AGEING MODEL VALIDATION

APPROACH



AGEING MODEL VALIDATION

APPROACH

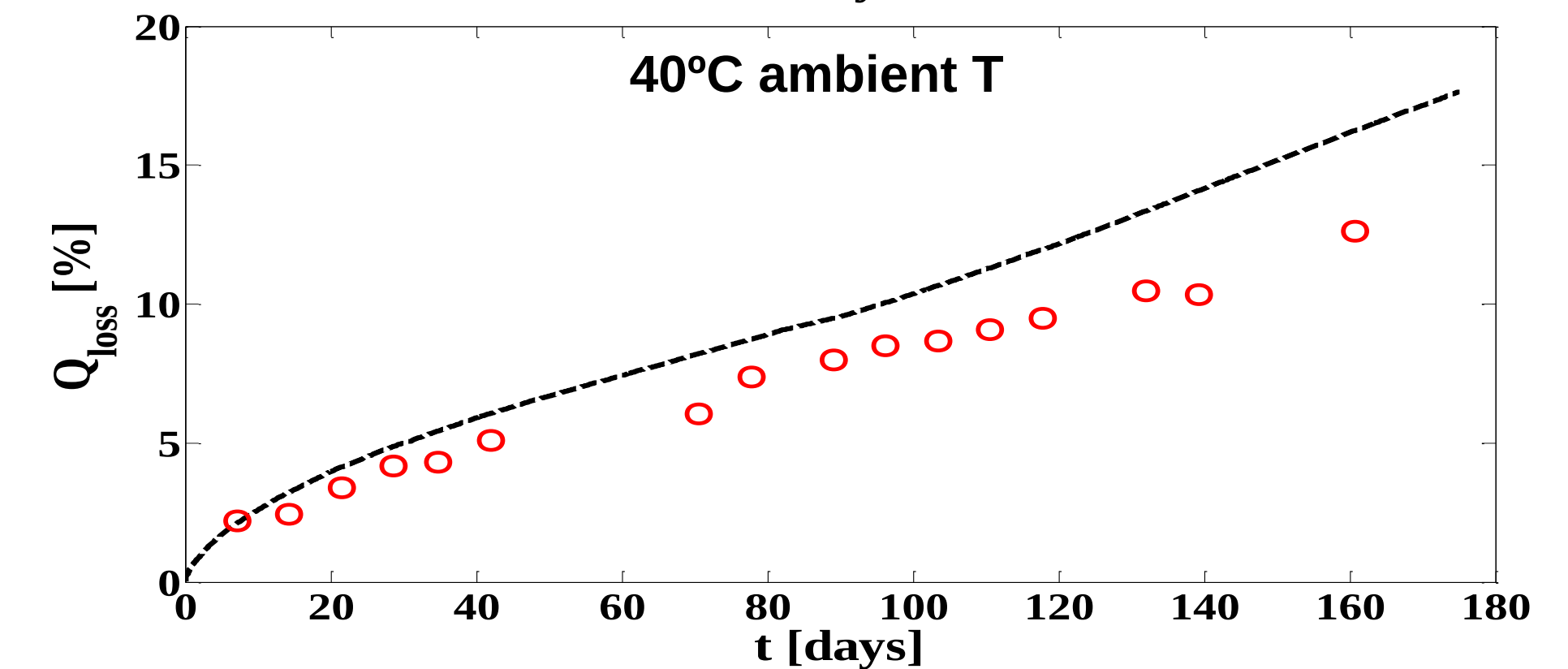
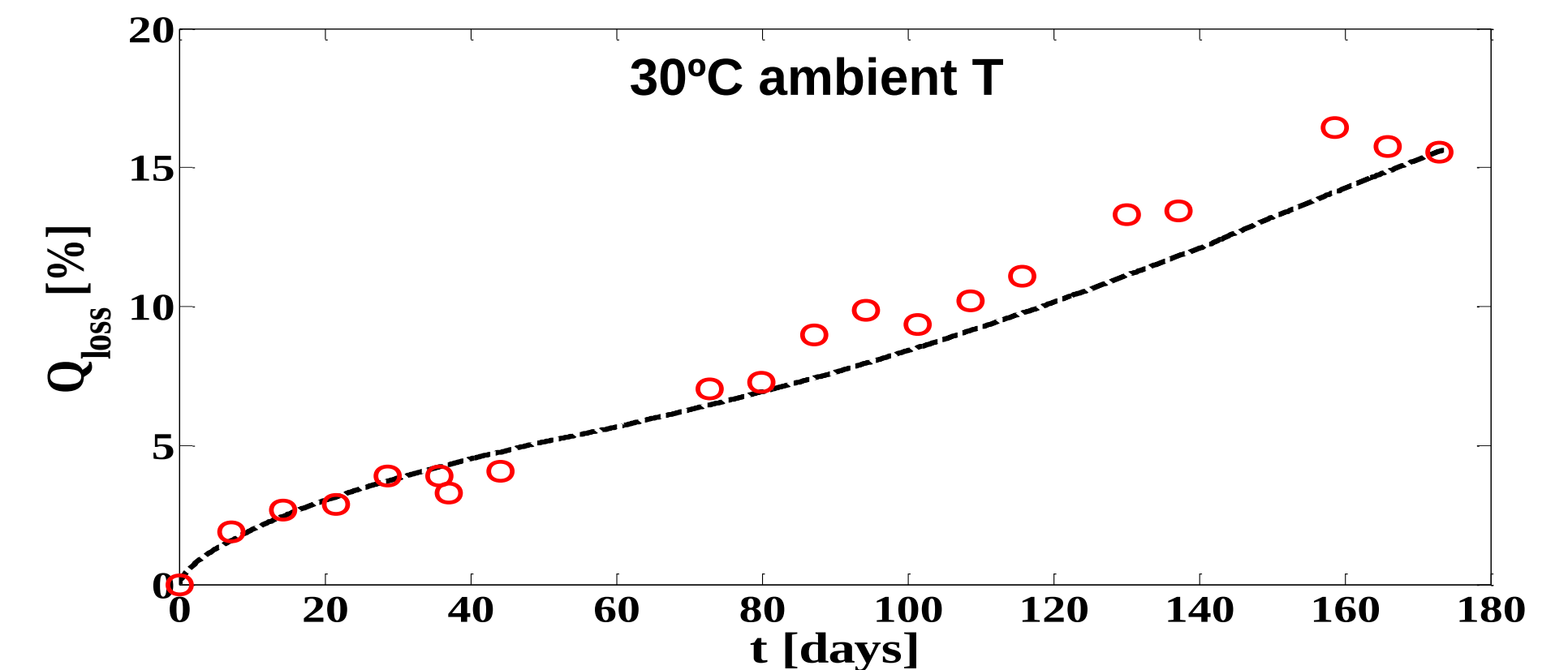
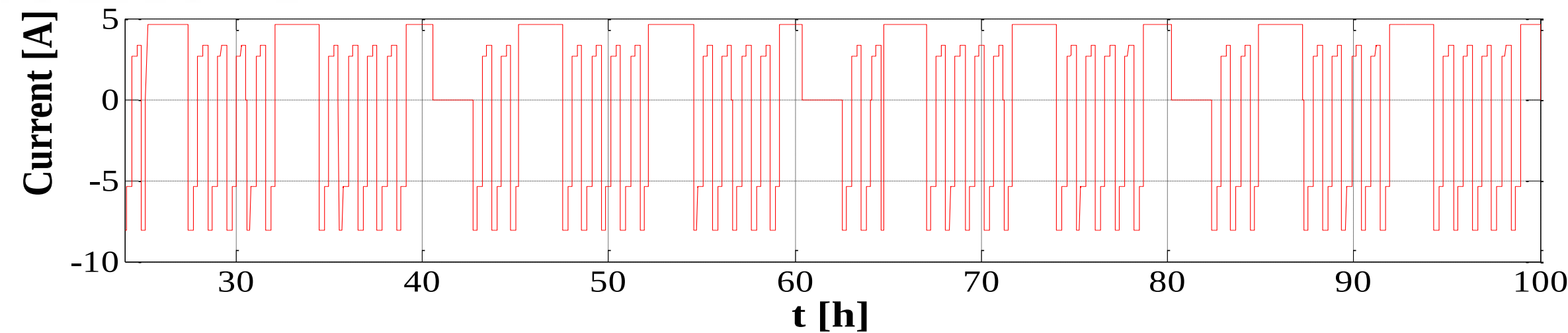
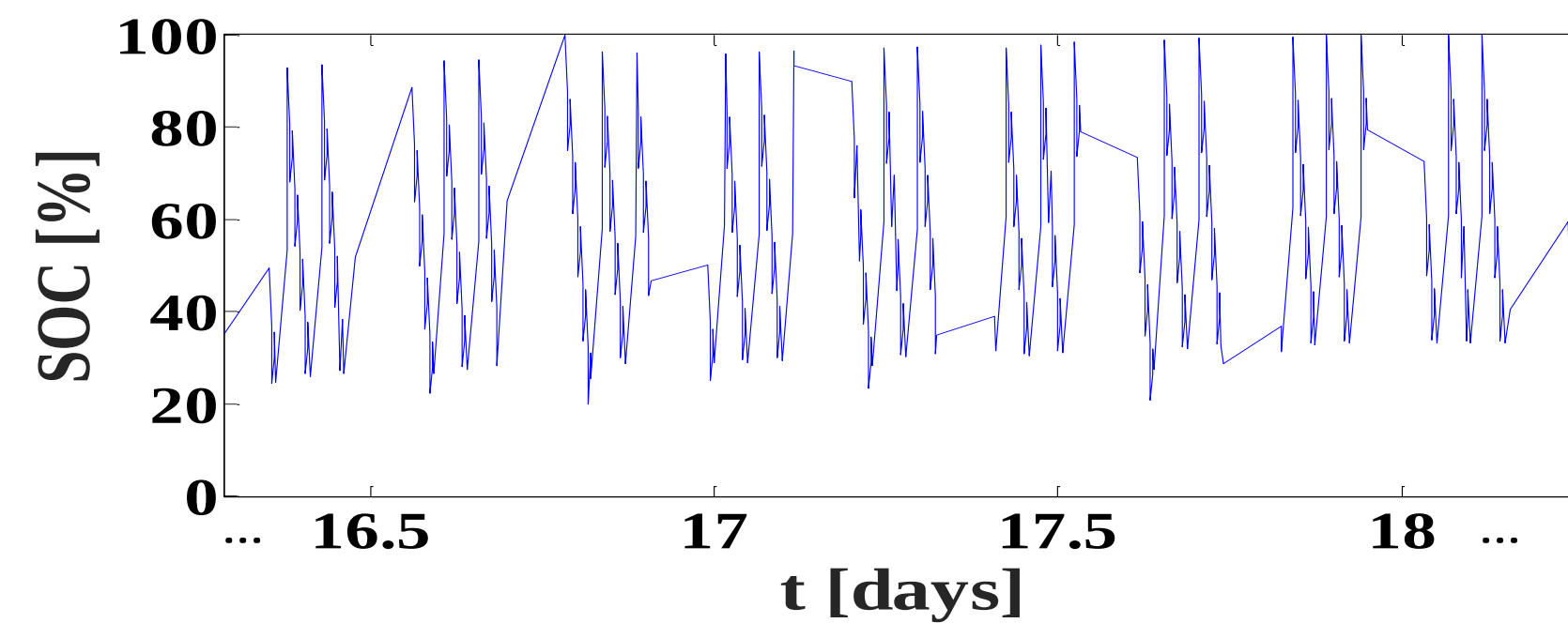


AGEING MODEL VALIDATION

RESULTS 3: COMPLEX OPERATION CONDITIONS I



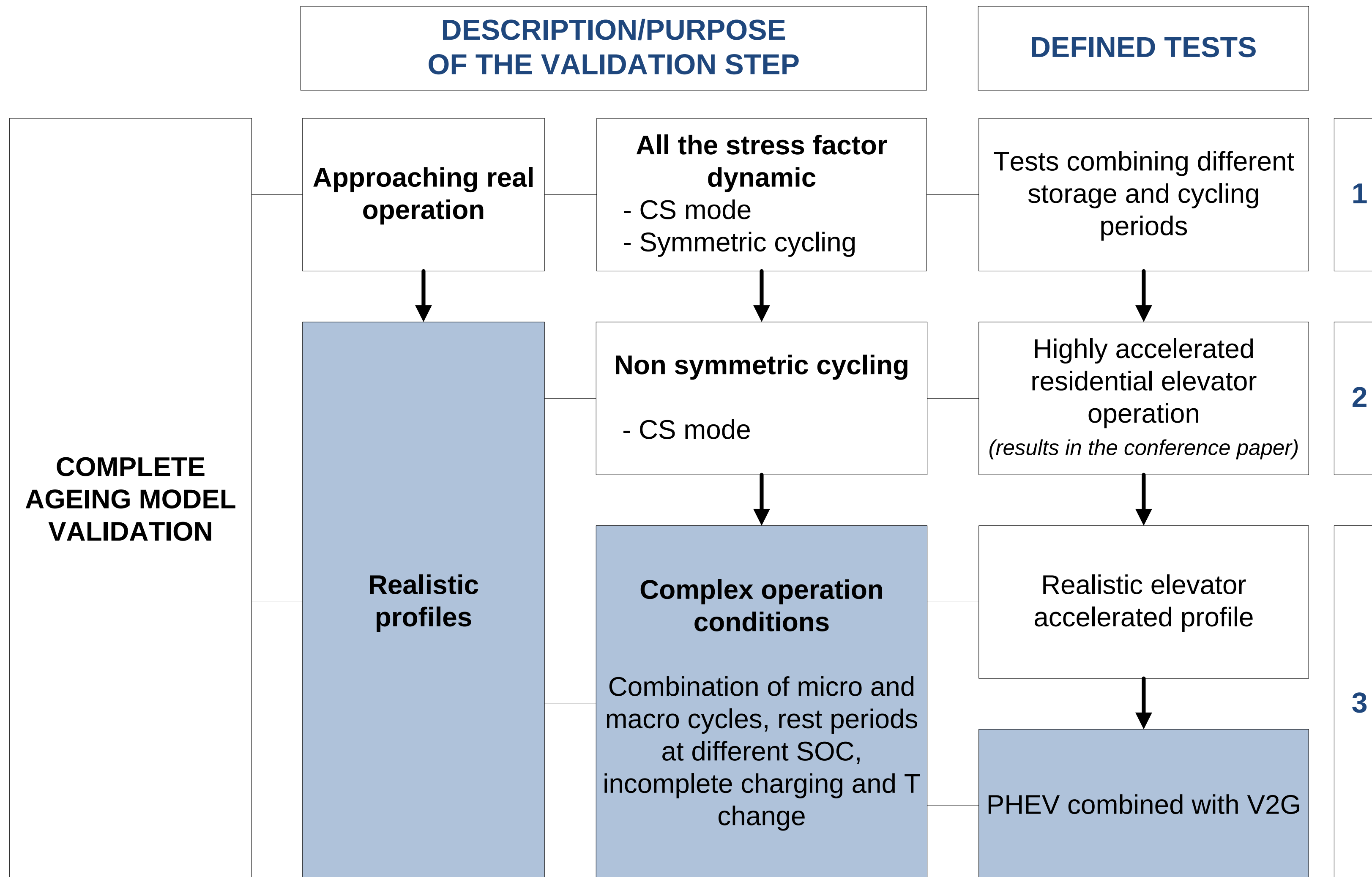
ACCELERATED ELEVATOR PROFILE



- 1.35% RMSE
- Different bias distribution depending on T. Larger residuals at higher temperature
- **The ageing model follows the complex ageing evolution with high accuracy**

AGEING MODEL VALIDATION

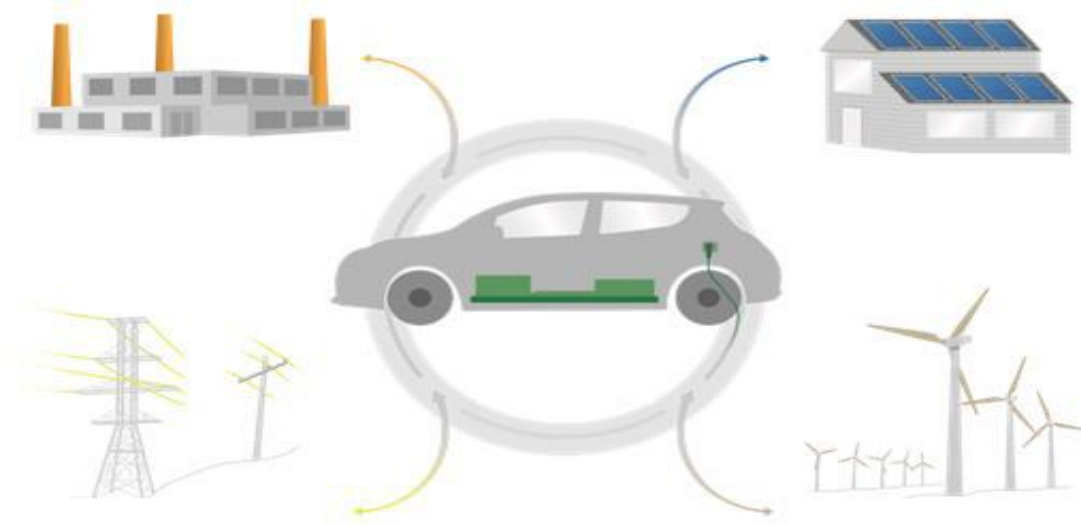
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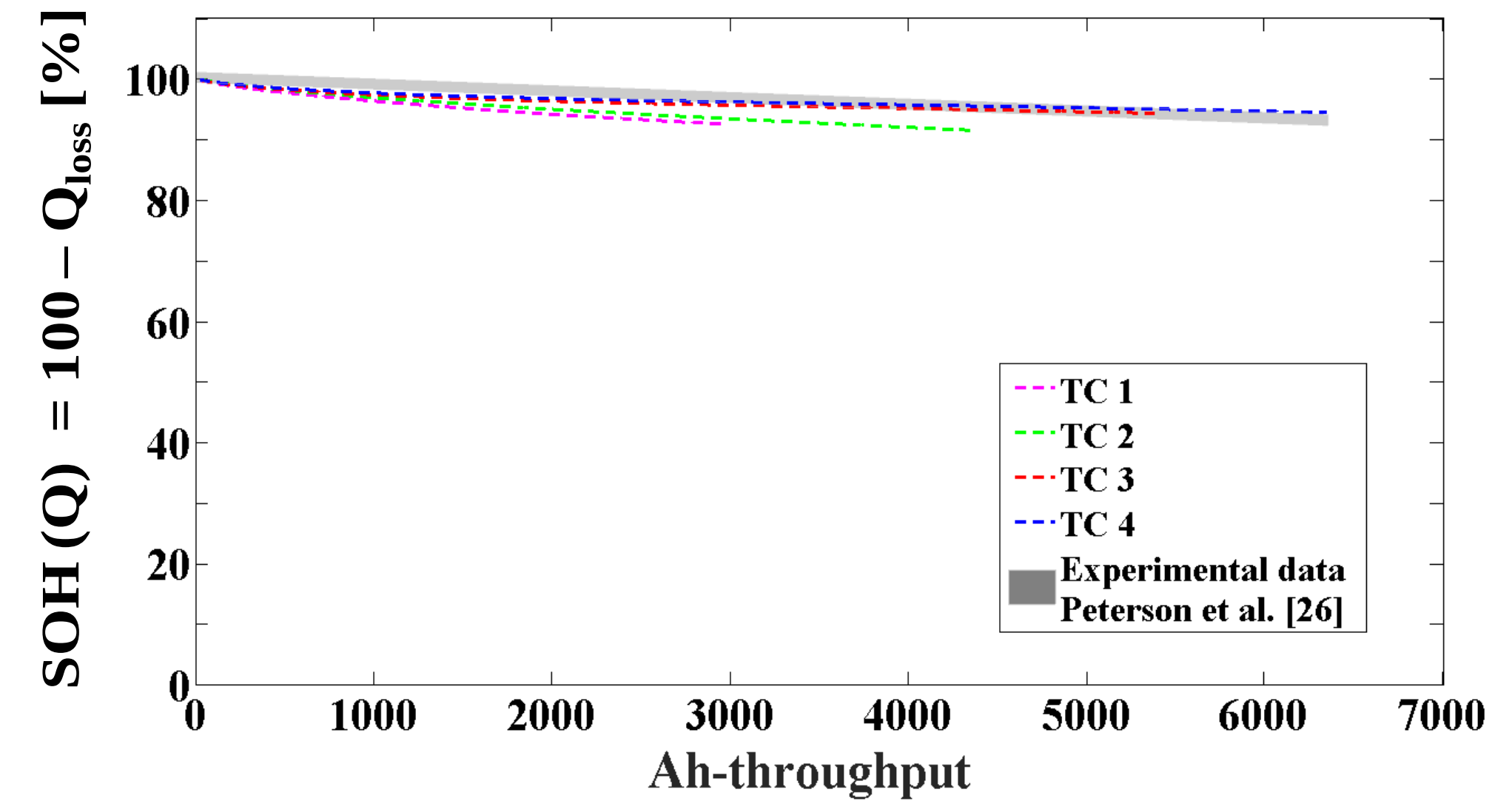
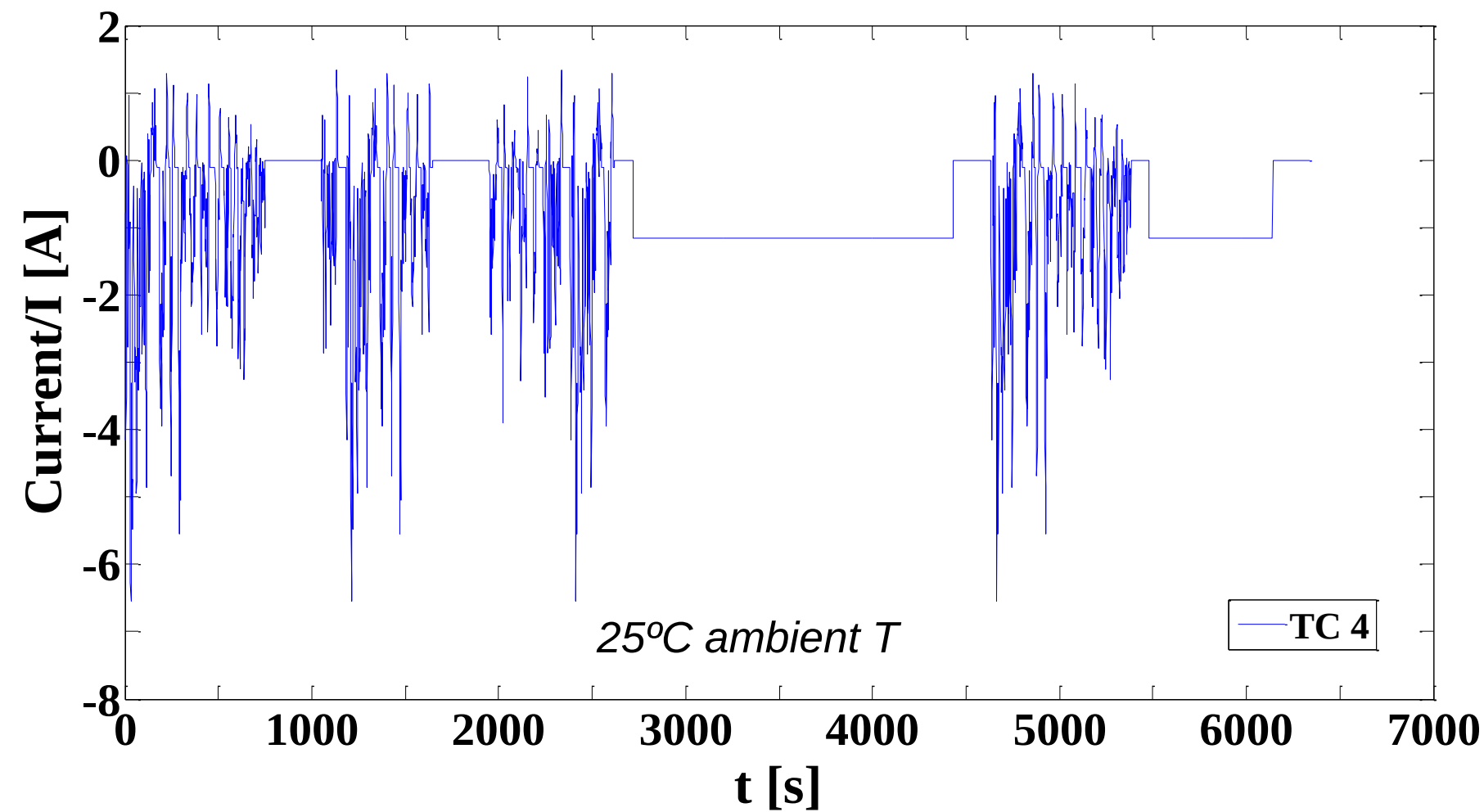
AGEING MODEL VALIDATION

RESULTS 3: COMPLEX OPERATION CONDITIONS II

PHEV + V2G



Four different Test Cycles (TC) from Peterson et al.*



The developed ageing model is valid to estimate the capacity degradation under different applications operation profiles

* S.B. Peterson et al., J. Power Sources 195(8) (2010) 2385-2392.

01

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02

OBJECTIVES

03

AGEING MODEL VALIDATION

04

CONCLUSION AND FUTURE WORK



- ✓ Combination of single calendar and cycle ageing impact factors effects for ageing prediction under complex operation conditions
- ✓ SOC and T effects equal during battery storage or cycling
- ✓ Validation methodology essential for the model improvement process
- ✓ The developed model can predict accurately (1.35% RMSE) the lifetime under different realistic complex operation conditions
 - Simplification of several specific models into a single one
 - Single calendar and cycling ageing as well

- ✓ Applying the lifetime prognosis methodology to other battery technologies
 - Additional improvements
 - Further analysis of the scope and advantages of the presented approach

- ✓ Ageing model integration into BMS



ACKNOWLEDGEMENT

Thanks for your kind attention!



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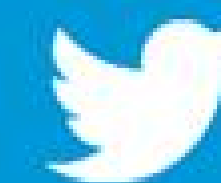
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