International Battery Production Conference 2021

Braunschweig, 1st November 2021

»Digital Twin in Battery Production 4.0 – From Data Management and Traceability System to Target-Oriented Application«

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[PIXA21]

AGENDA

Motivation, Challenge & Problem Statement

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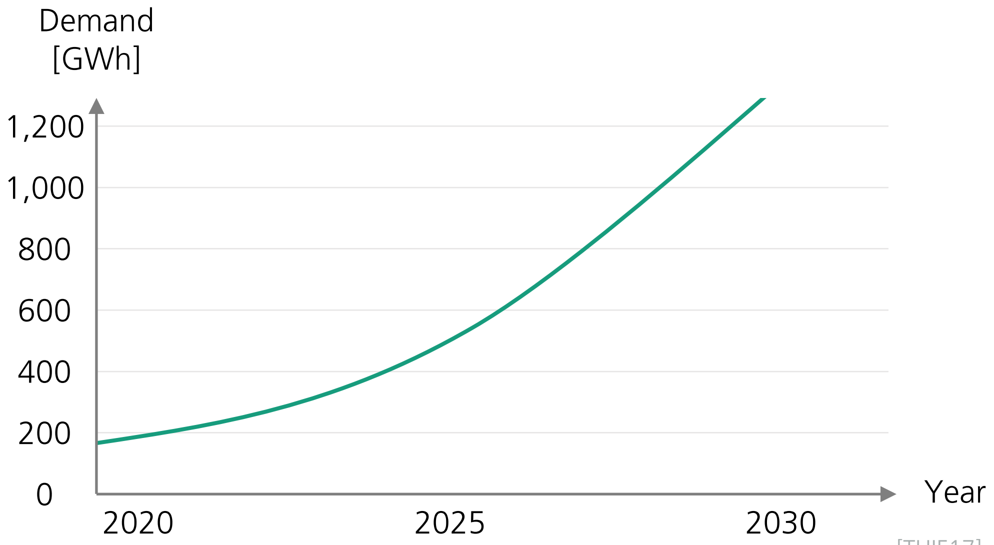
Battery Cell Market Development & Increase of Data Creation

Global demand for lithium-ion battery cells



[THIE17]

Challenges

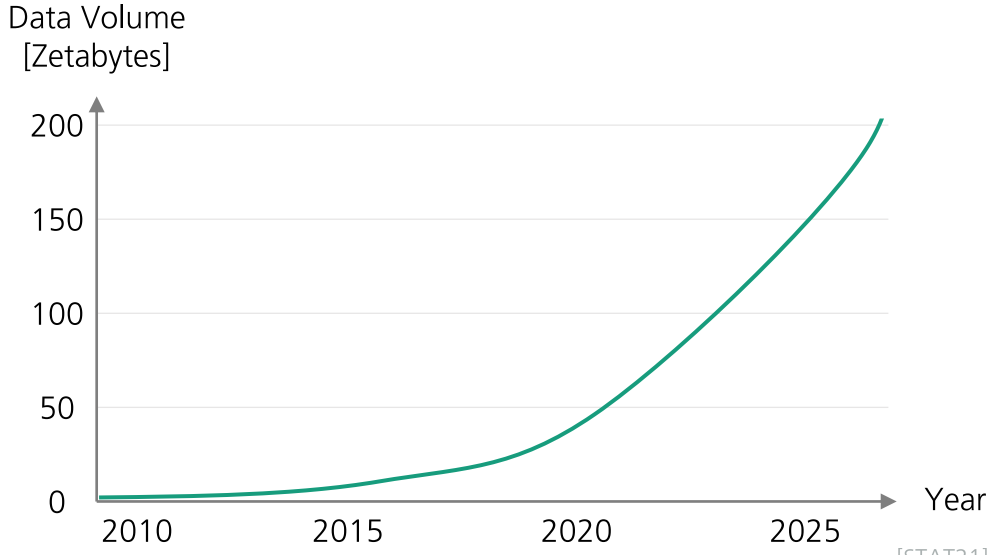
- Optimizing quality of battery cells
- Reducing scrap rate in production
- Ensuring sustainability of battery cell production

Potential of Data

»Information is the oil of the 21st century,
and analytics is the combustion engine.«
Peter Sondergaard, 2011

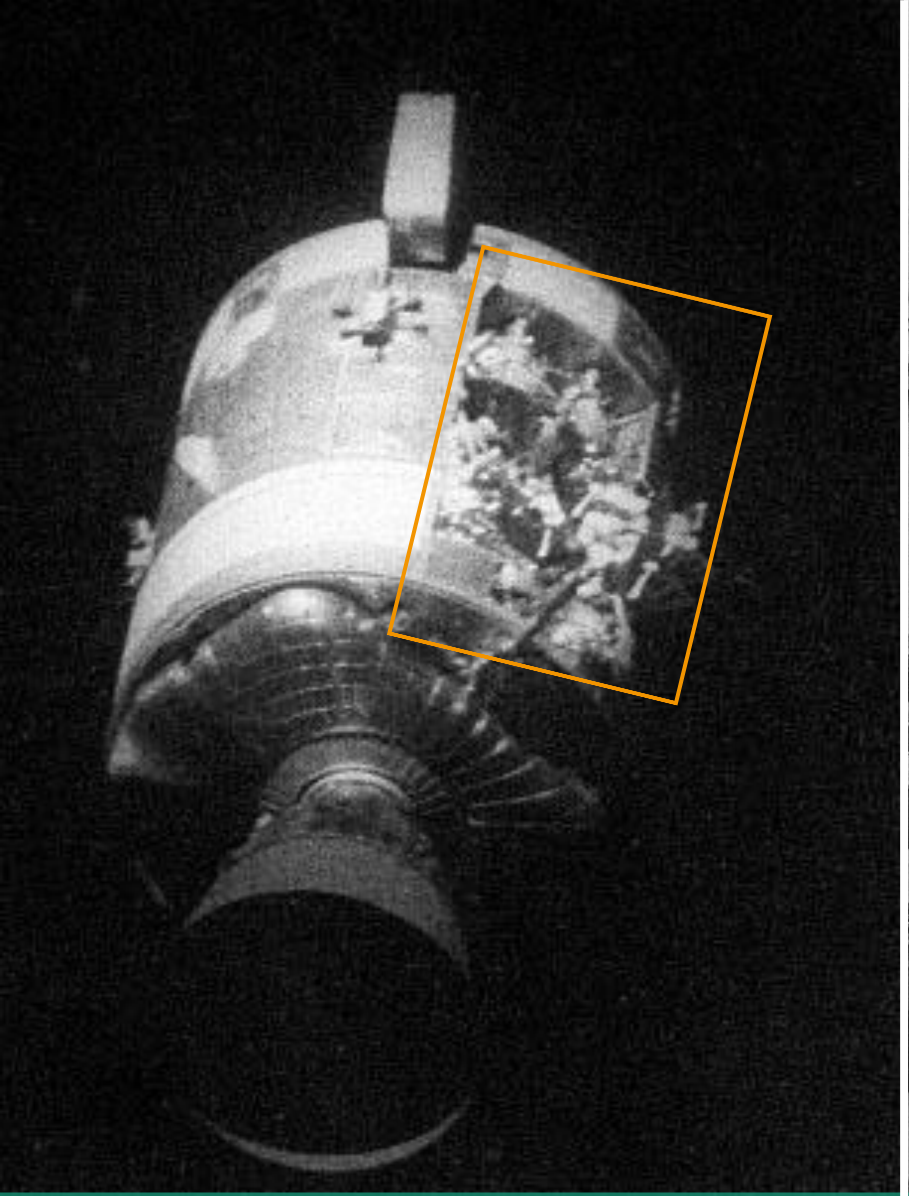
[SOND11]

Volume of data created worldwide



[STAT21]

How can the data collected be made available to address existing challenges and exploit the potential of data in production?



»Houston, we’ve had a problem.«

Jack Swigert, Apollo 13, 1970

[NASA20]

Johnson Space Center

Houston, Texas

Motivation, Challenge & Problem Statement
Digital Twin in Battery Production 4.0

Physical twin:

Already used for a long time (NASA)

Idea of the Digital Twin:

Implementation is made possible

Industry 4.0:

Transformation of the production landscape

Lack of a standardized definition:

Dependence on specific use case

Battery cell in production

Concept of Digital Twin

The purpose of this presentation is to demonstrate the application-oriented conceptualization of the digital twin of the battery cell during its production.

[SCHL17, DURA18]

Digital Twin in Battery Production 4.0

A Digital Twin is …

Shafto et al., 2010 (NASA):

"[...] an **integrated multiphysics, multiscale, probabilistic simulation** of an as-built vehicle or system that uses the best available physical **models, sensor updates, fleet history**, etc., to **mirror the life of its corresponding flying twin** [...]."

[SHAF10]

Stark et al., 2017:

"A Digital Twin is the digital representation of a unique asset (product, machine, service, product service system or other intangible asset), that compromises its **properties, condition and behavior** by means of models, information and data."

[STAR17]

Boschert and Rosen, 2016:

"[...] a **comprehensive physical and functional description of a component, product or system**, which includes more or less all **information** which could be useful in all – the current and subsequent – life cycle phases."

[BOSC16]

Klostermeier et al., 2018:

"[...] comprises at least the individual, **virtual image of a physical object or process**, intelligently providing the data of the physical object for different use-cases."

[KLOS18]

Grieves and Vickers, 2017:

"The Digital Twin is a **set of virtual information constructs that fully describes a potential or actual physical manufactured product from the micro atomic level to the macro geometrical** level. At its optimum, any information that could be obtained from inspecting a physical manufactured product can be obtained from its Digital Twin."

[GRIE17]

Madni et al., 2019:

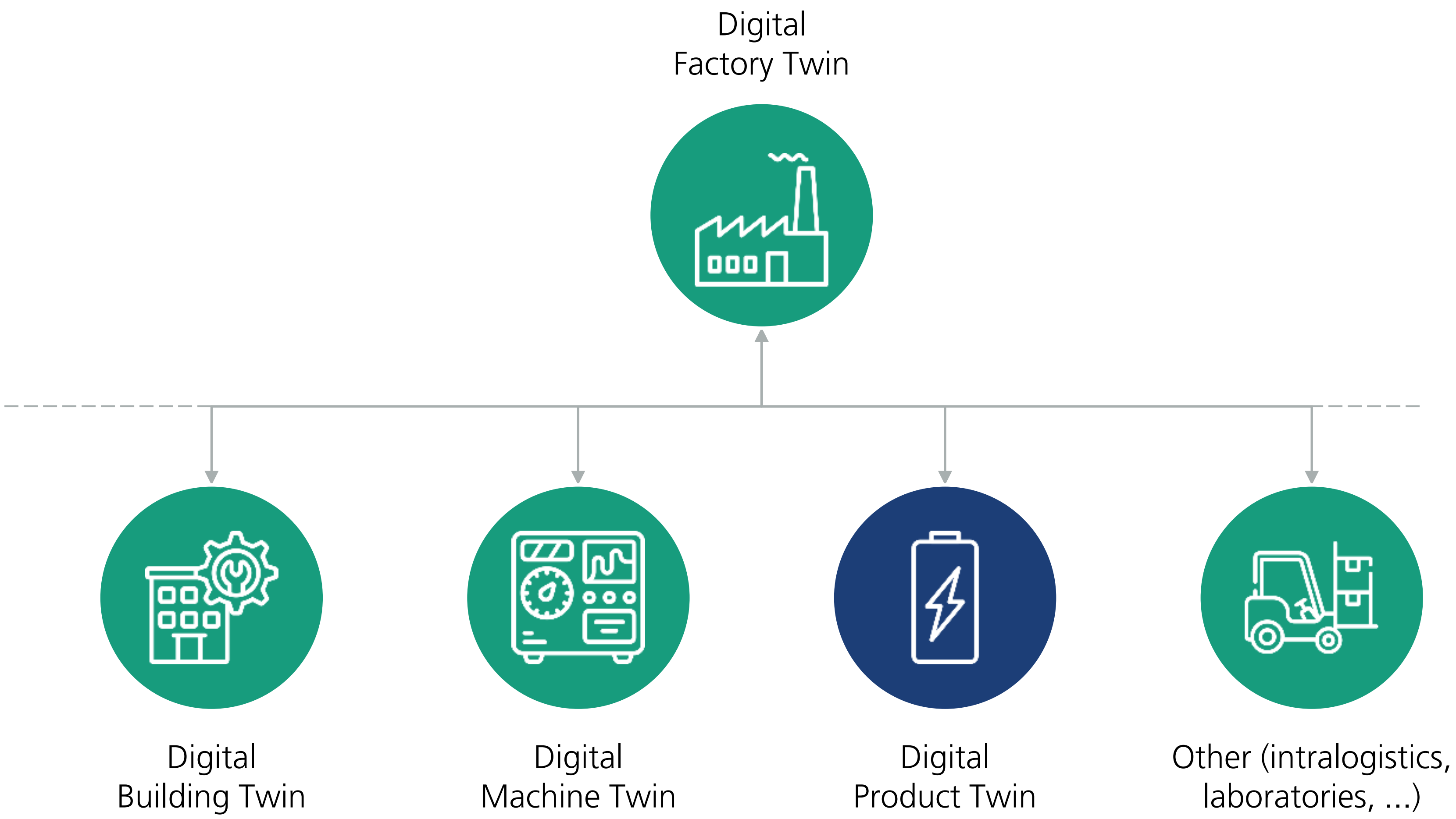
"A digital twin is a virtual instance of a physical system (twin) that **is continually updated** with the latter's performance, maintenance, and health status data throughout the physical system's life cycle."

[MADN19]

How the digital twin is understood, which components it consists of, and which goals are pursued with it, **depends strongly on the respective use case.**

Digital Twin in Battery Production 4.0

Physical Objects Represented By a Digital Twin



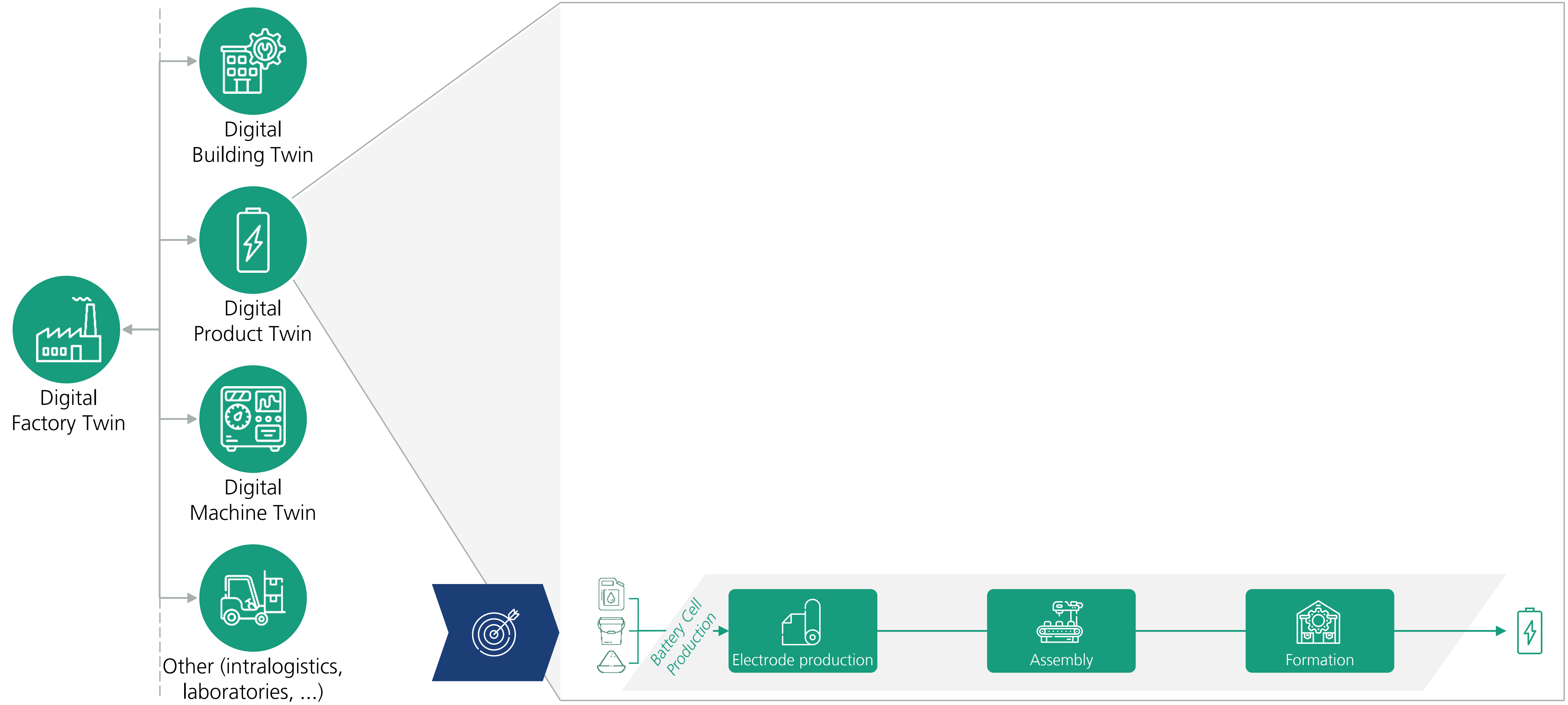
Overview: Phases of the Conceptualization of the Digital Product Twin

The conceptualization of the digital twin follows a modular structure that provides various steps to achieve the goal:

Goal definition → Data management → Traceability system → Application

Expert knowledge is to be used for the development of the individual modules.

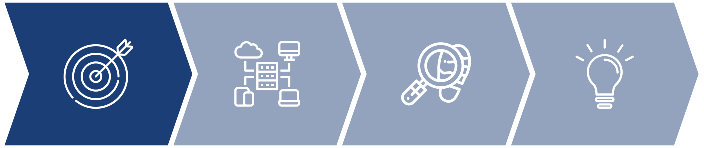
Digital Twin in Battery Production 4.0
Phase 1 – Definition of Goals



[KAMP18]

Digital Twin in Battery Production 4.0

Phase 1 – Definition of Goals



Description

- Goal classification
- Goal specification
- Delimitation of the involved life cycles
- Delimitation of the involved participants

Practical realization

Goal: Conceptualization of a Digital Twin for the battery cell along the entire process chain of cell production.

Ensuring highest quality of the battery cell, reduction of scrap rate, sustainability of production

- Parameters
- IT and metrology
- Granularity of the data acquisition
- Data aggregation across processes

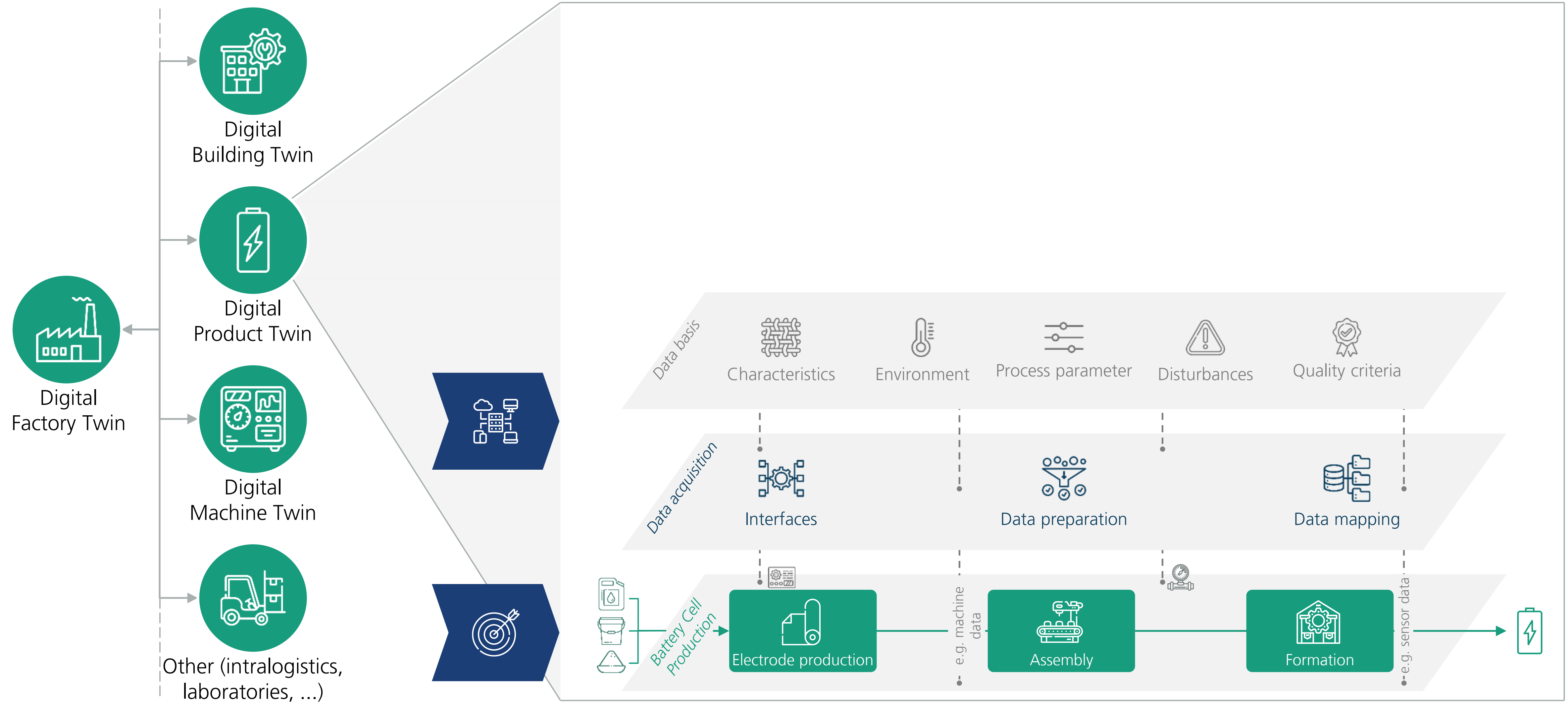
Involved life cycles: Production of battery cells

Involved participants: Institutes involved in project »FoFeBat«

The goal definition is the basis for the further steps of the conceptualization, which are oriented on it.

[MASS20, FOFE21]

Digital Twin in Battery Production 4.0
Phase 2 – Data Management



[KAMP18]

Digital Twin in Battery Production 4.0
Phase 2 – Data Management

Description

- Identification of the quality-relevant parameters and their target values
- Determination of the necessary measurement technology
- Data acquisition in appropriate granularity
- Ensuring data transfer, pre-processing and storage

Practical realization

Example of parameter identification

Characteristics input
Porosity before calendering

Process parameters
Calender gap

Quality characteristics
Porosity after calendering

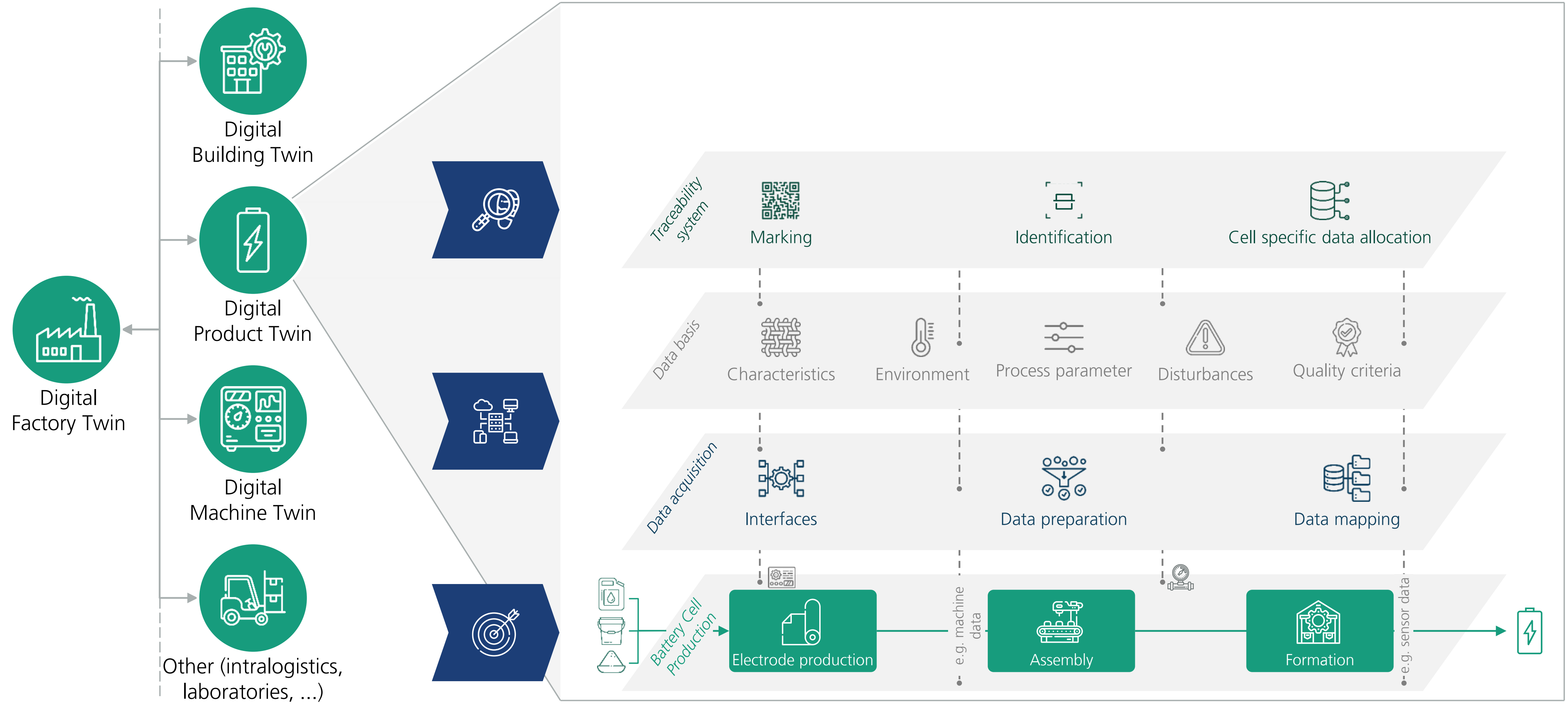
Influencing parameters

Environmental parameters
Temperature

Disturbances
Damage on cylinder

Type	Parameter	Parameter-ID	Target value	Tolerance	Relevance
Characteristics input	Porosity before calendering	10d.E.1	as consistent as possible	40-70 %	High
Quality characteristics	Porosity after calendering	10d.Q.2	20-40 %	+/- 2 %	High

Digital Twin in Battery Production 4.0
Phase 3 – Traceability System



[KAMP18]

Digital Twin in Battery Production 4.0
Phase 3 – Traceability System

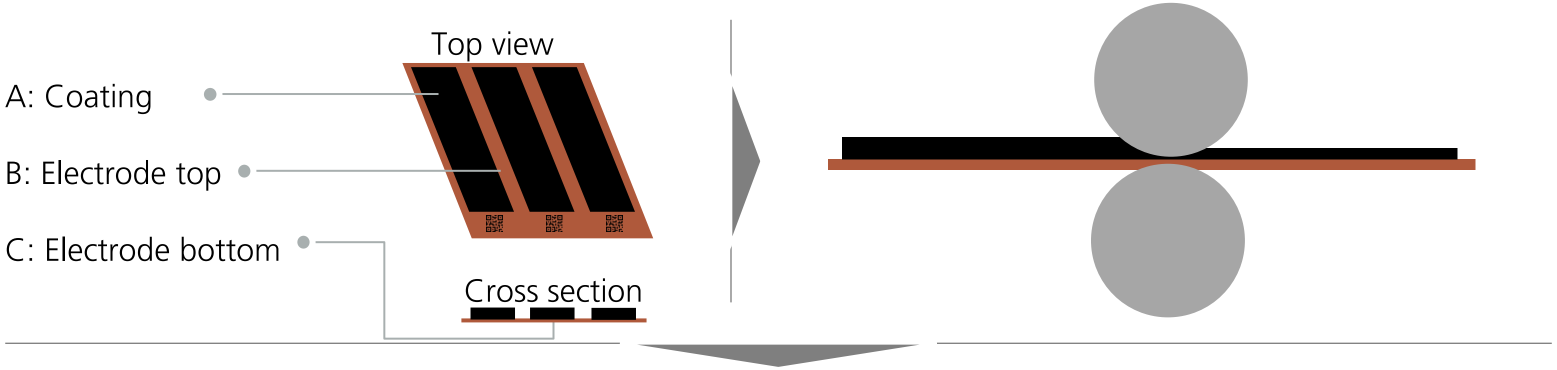
Description

- Development of a system to ensure traceability based on automatic identification.
- Ensuring the core elements:
    - Identification
    - Data acquisition and recording
    - Data linkage
    - Communication

Practical realization

Example of data acquisition and recording

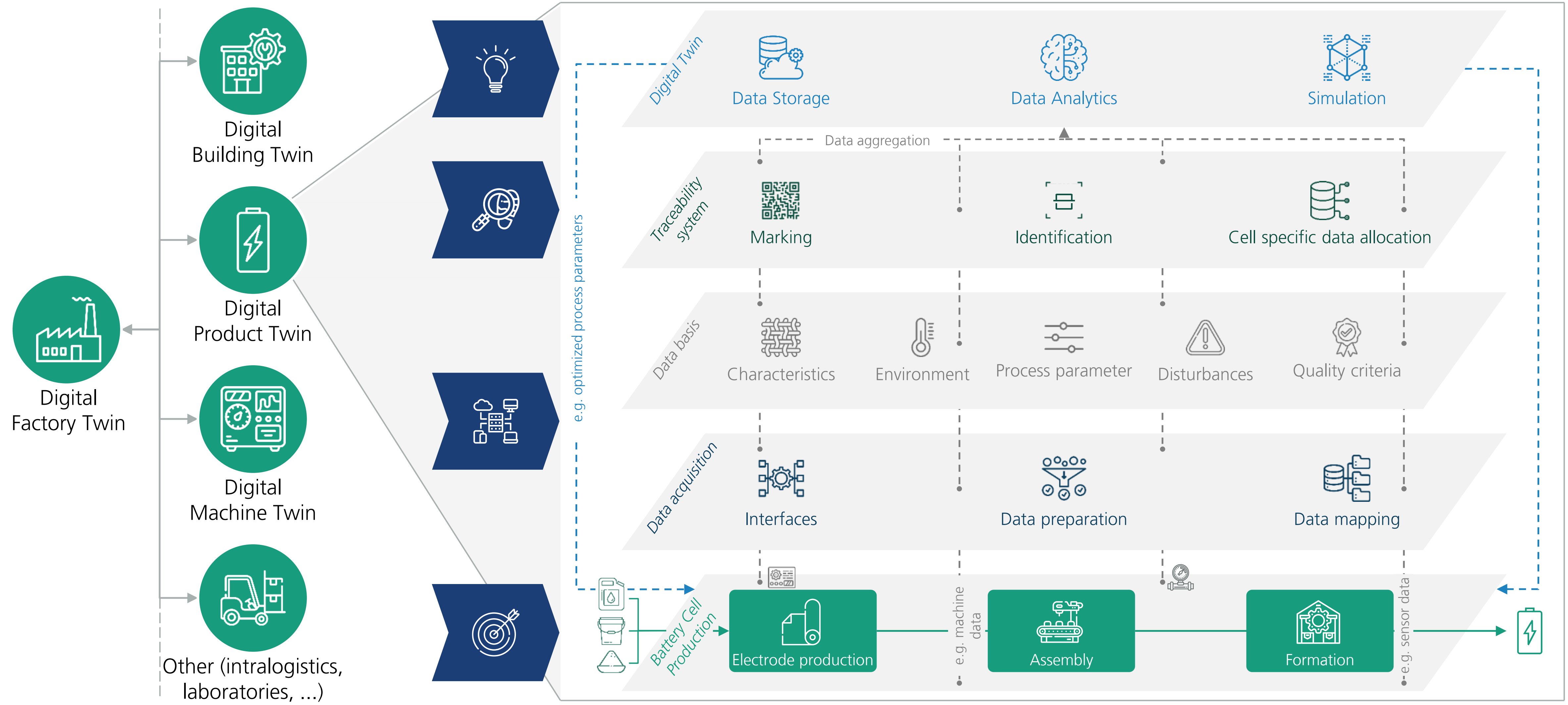
How can automatic identification be ensured?



All surfaces are machined during calendaring.
This must be considered for finding a solution!

- Excluded:
    - RFID (due to calendering pressure)
- Identified possible solutions:
    - Engraving of coding on electrode by means of laser
    - Coding by means of inkjet

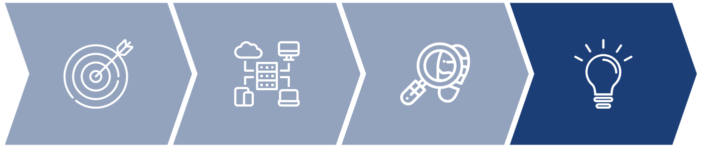
Digital Twin in Battery Production 4.0
Phase 4 – Target-Oriented Application



[KAMP18]

Digital Twin in Battery Production 4.0

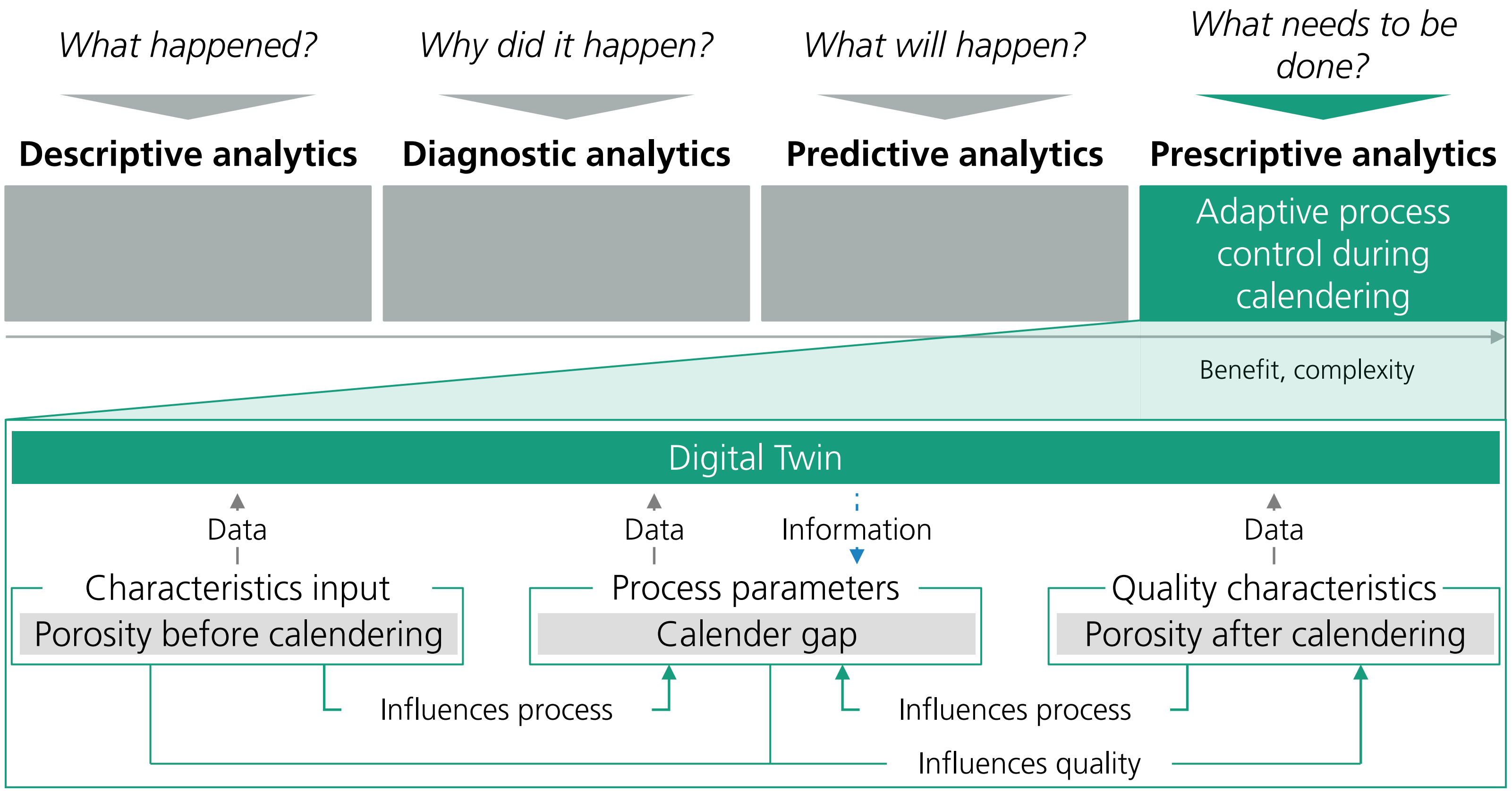
Phase 4 – Target-Oriented Application



Description

- Derivation of use cases on previously generated information
- Categorization of use cases based on the levels of data analysis

Practical realization



[SALL14]

Conclusion

Conclusion

Lessons Learned – Main Takeaways

No standardized definition

In the research field of the Digital Twin, a multitude of definitions exists - and new views are continuously emerging. The goals and components of a digital twin are therefore highly dependent on the respective use case.

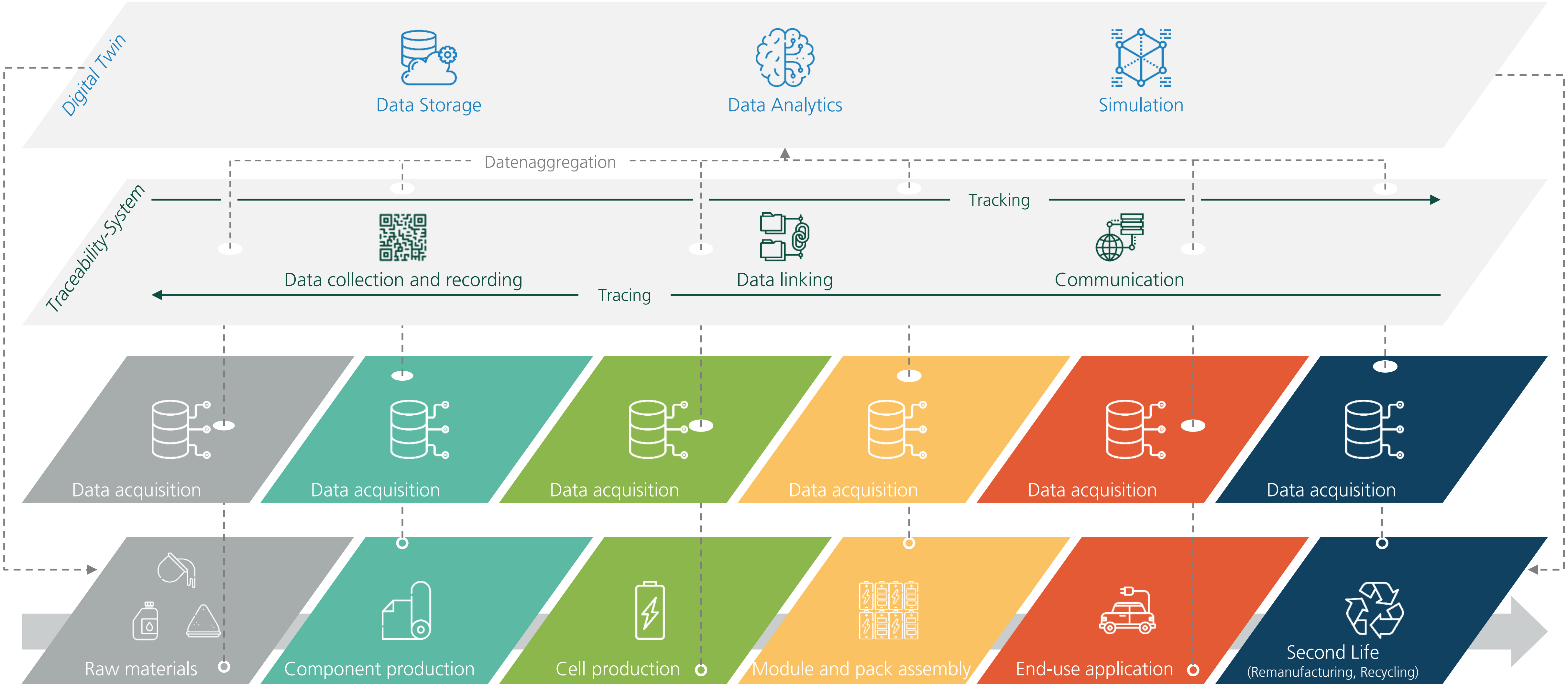
Traceability enabling the Digital Product Twin

A traceability system serves as an enabler for generating a Digital Product Twin. Through a customized solution, data can be clearly assigned to an individual product throughout the entire production process and thus be used even in later value-added steps - for example, to optimize the remanufacturing or recycling of battery cells.

Target-oriented use of Digital Twins

The application examples of Digital Twins are manifold. Target-oriented use should always be at the center of the development of a digital twin, as this is the only way to generate real added value through it.

Conclusion
Outlook



Thank You!

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References
B-P

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PIXA21	URL: https://pixabay.com/images/id-3382507/ [accessed: 28.10.2021]

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S-T

Abbreviation	Source
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