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Fraunhofer Twin Transition Series

Green beginnings 2.0: Digitalized circularity for batteries

May 24, 2023

Green beginnings 2.0: Digitalized circularity for batteries

Fraunhofer Twin Transition Series

12:30	**Moderation by Katrin Mögele** Fraunhofer EU Office
	Welcome and introduction by Chris Eberl Fraunhofer Institute for Mechanics of Materials IWM
12:40	**Setting the scene by Anna Cavazzini** Patron of the webinar, Member of the European Parliament
12:50	**Expert presentation I "Interaction of Digital Twins in a Sustainable Battery Cell Production" by Alexander Kies** Fraunhofer Institute for Production Technology IPT
	Expert presentation II "Towards a Comprehensive Semantic Information Structure in the Battery Value Chain" by Guinevere Giffin Fraunhofer Institute for Silicate Research ISC
13:15	**Discussion**
13:30	**End of the event**

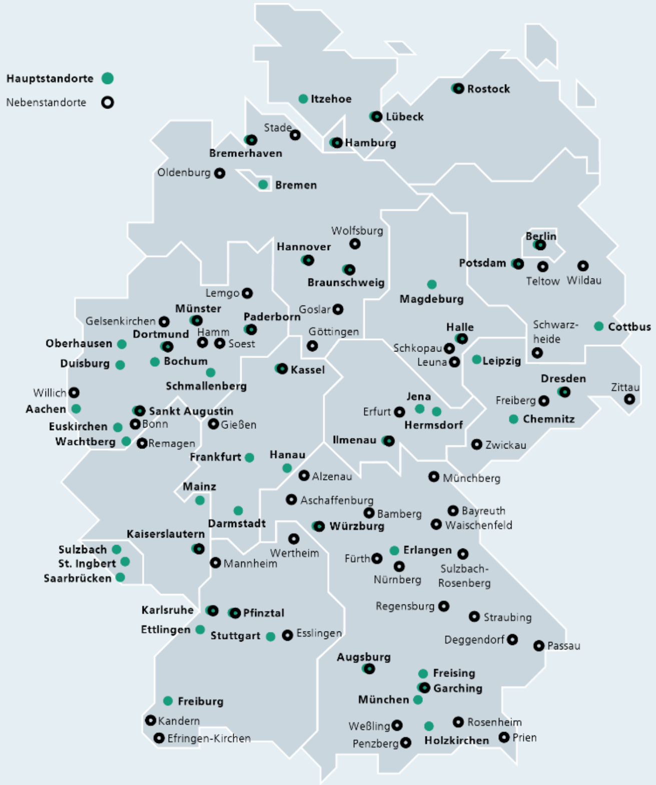
The Fraunhofer-Gesellschaft

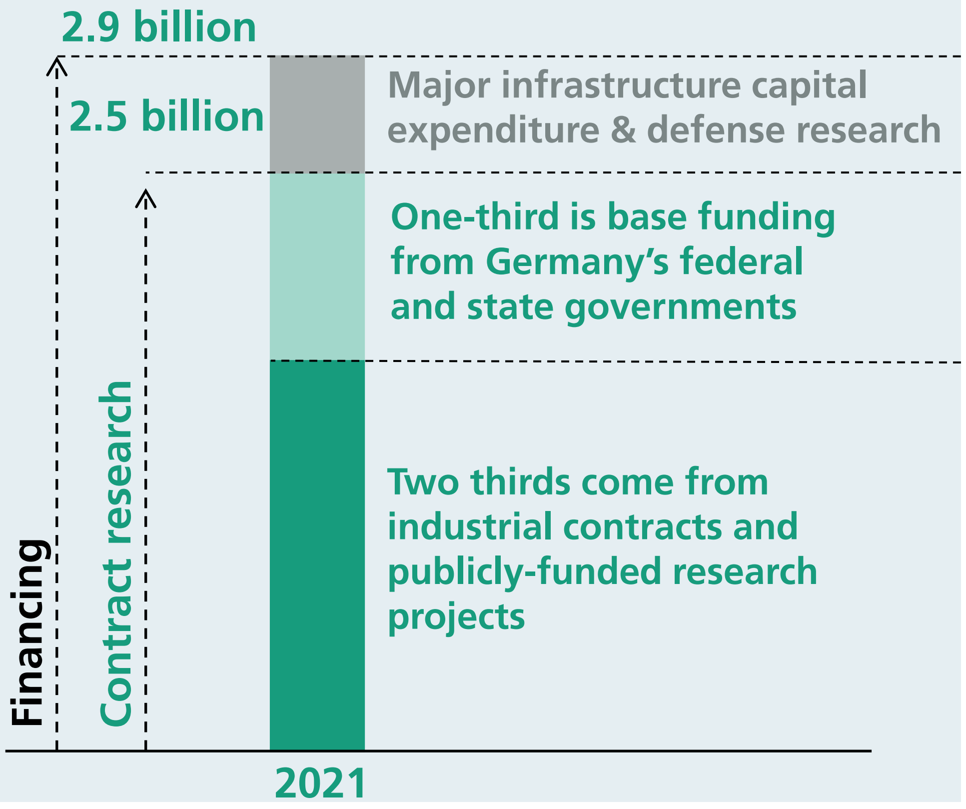
At a glance

Applied research with a focus on key future-relevant technologies and the commercialization of findings in business and industry. A trailblazer and trendsetter in innovative developments.

> 30,000 employees

76 institutes and research units





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Welcome and Introduction

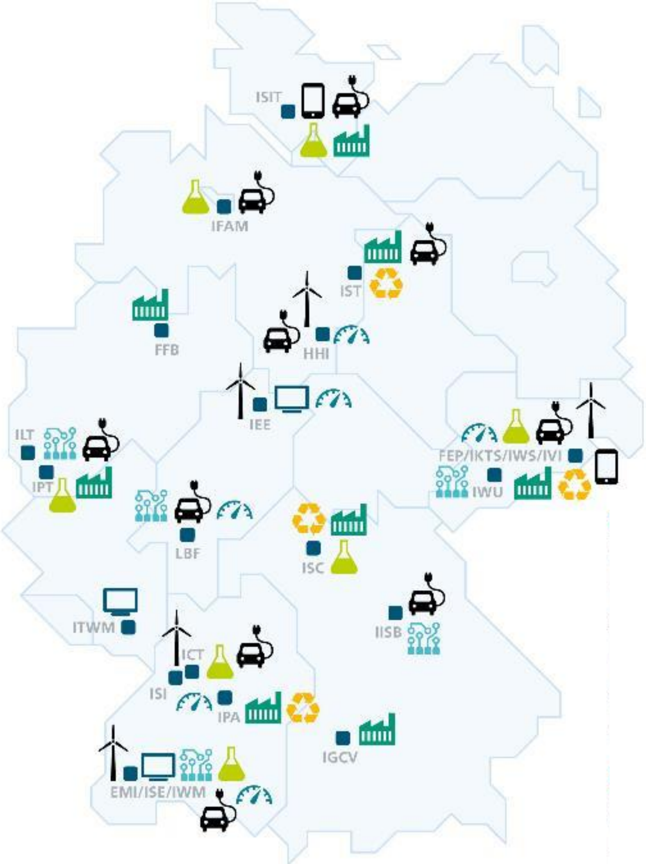
Chris Eberl

Fraunhofer IWM

The Fraunhofer Battery Alliance

The Fraunhofer Battery Alliance at a Glance

630 staff



24 institutes and research units

- Competences along the battery value chain
- Broad research and development skills in various battery technologies
- Your development and cooperation partner with extensive experience and technical equipment

Core competences

- Material and Cells
- Cell production
- System and Integration
- Recycling
- Simulation
- Testung and Evaluation

Markets and applications

- **Energy Storage Devices** (**Electromobility**, Heavy Duty, Rail, Aviation)
- **Stationary Energy Storage**
- **Powertools/ Consumer**

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Lessons learned from
BatterieDigital: a 7 month, 87 experts project

Why do we need a FAIR Research Data Infrastructure and what has to be done?

Digital Transformation in applied research and ToDos for all stakeholders

Why do we need to go through a Digital Transformation

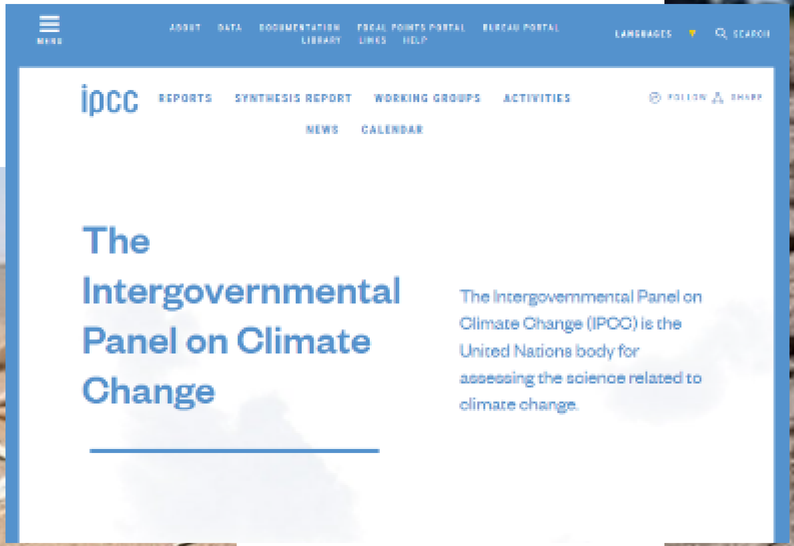
Societal needs and long-term goals

- Climate change
- Energy transition
- Circular economy
- Poverty
- Hunger
- Education
- …

Why do we need to go through a Digital Transformation

Societal needs and long-term goals

- Climate change



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Why do we need to go through a Digital Transformation

Societal needs and long-term goals

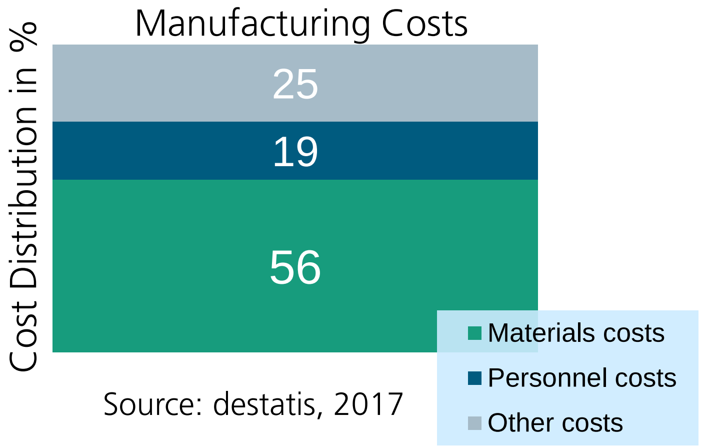
- Energy transition

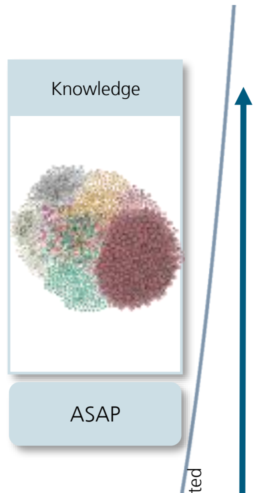
Energiewende – BMBF: Effizientere Energieversorgung: Bis 2020 soll 20 Prozent weniger Energie verbraucht werden als noch im Jahr 2008.© thinkstock

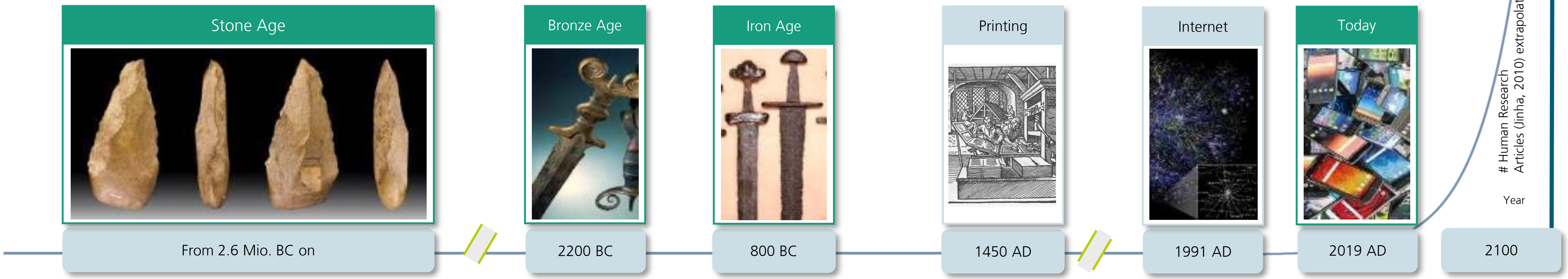
Why do we need to go through a Digital Transformation

Societal needs and long-term goals

- Circular economy







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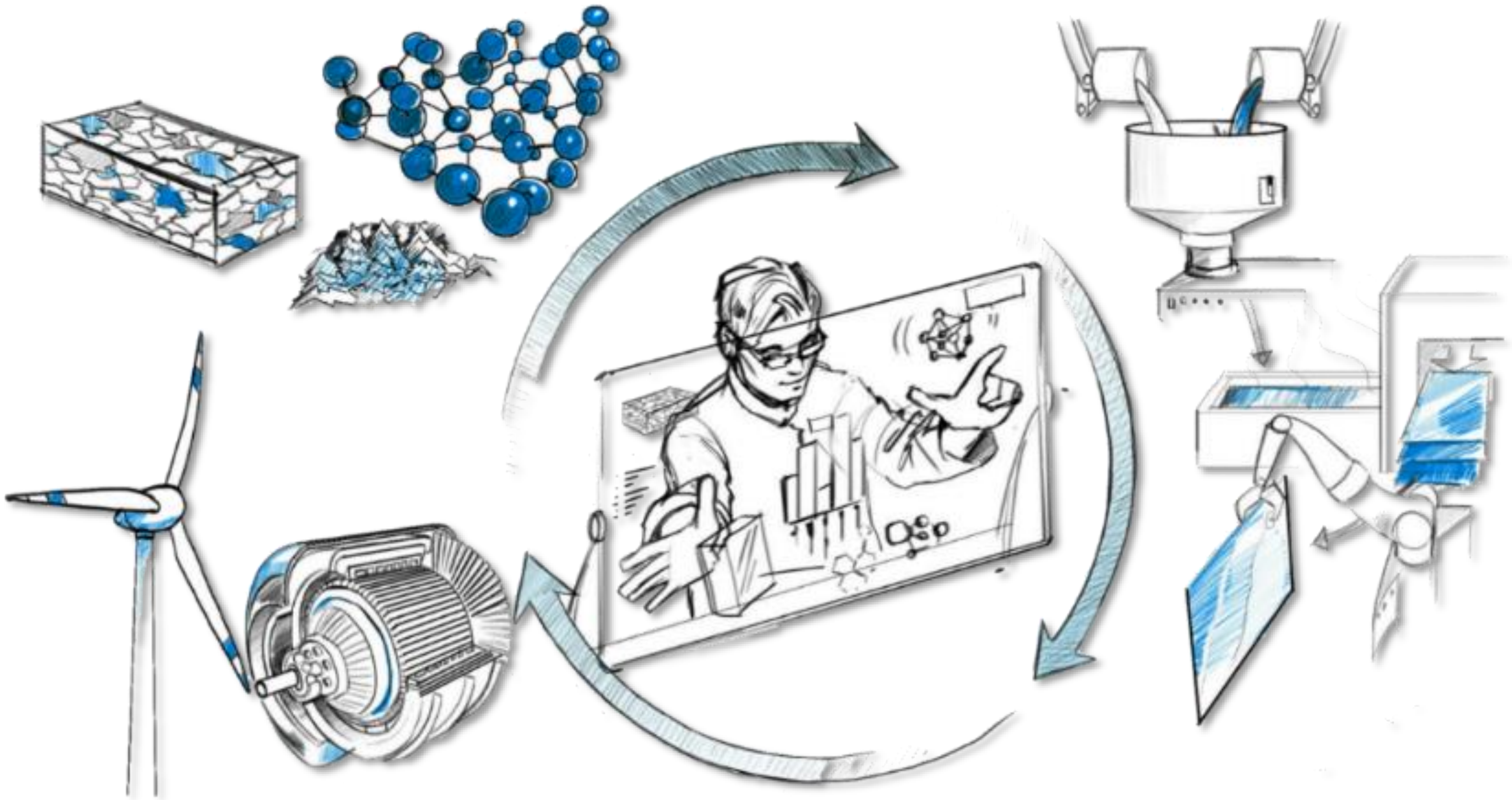
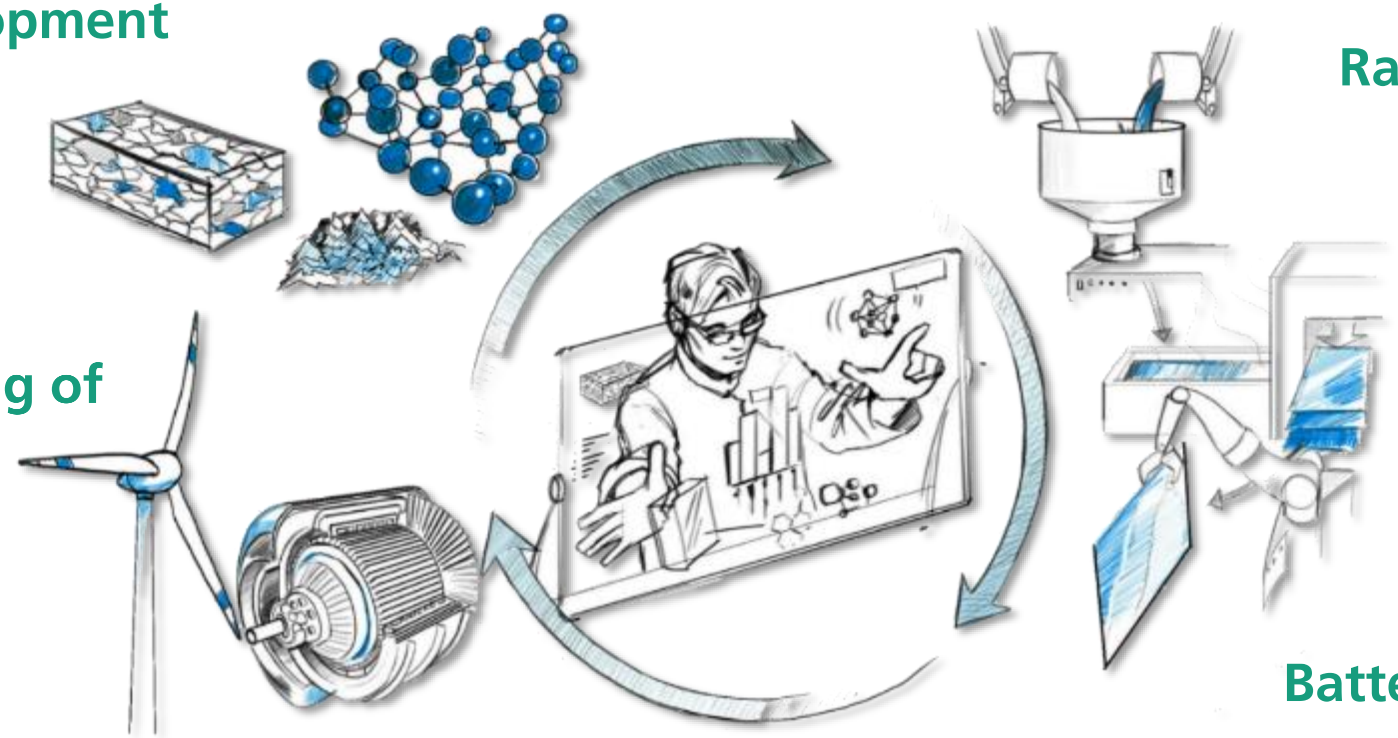
Why do we need to go through a Digital Transformation

Societal needs and long-term goals



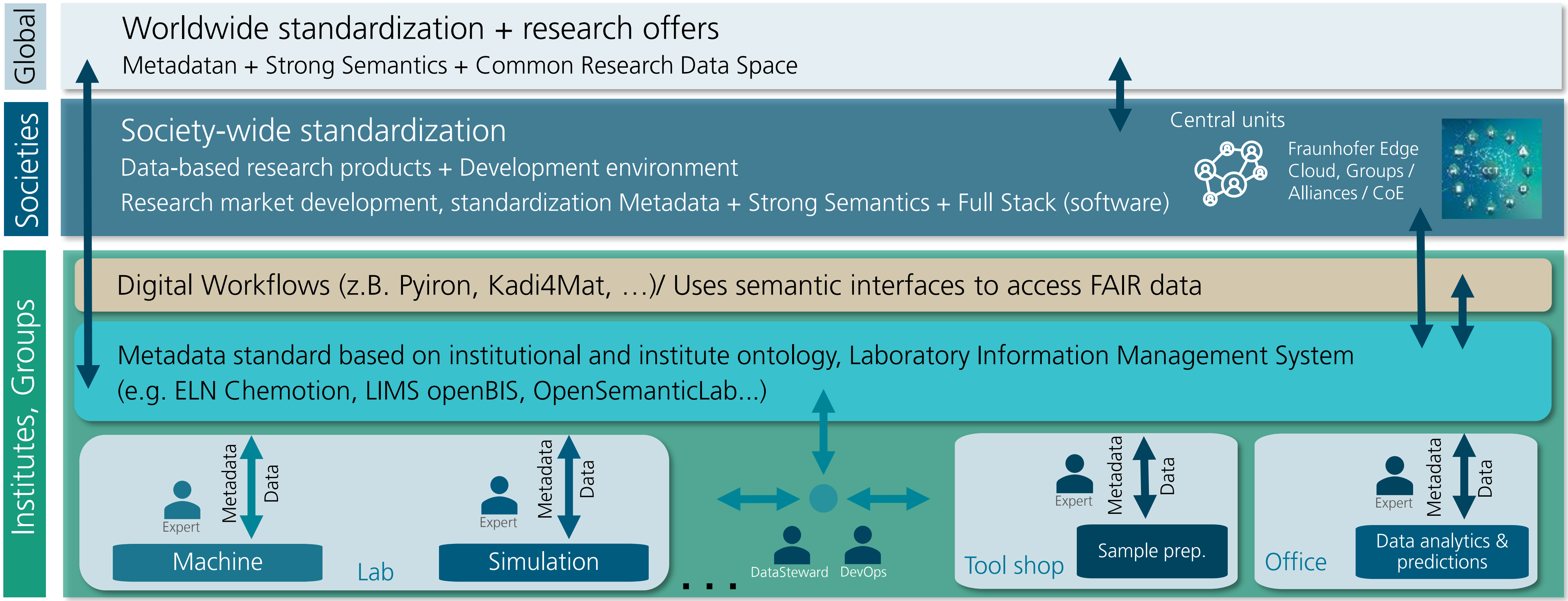
Why do we need to go through a Digital Transformation

Societal needs and long-term goals



Why do we need to go through a Digital Transformation

Tasks in science and economy



Tasks and Opportunities

Stakeholder in the Digital Transformation

Science community:

- Prototype implementation of semantic data standards across value chain and stakeholders
- Envision dimensions and linkages of data spaces
- Create and populate FAIR data spaces
- Explore and integrate knowledge representation (AI, simulation, knowledge graphs)

Economics:

- Implement usable data spaces
- Identify and implement business models

Policy Makers:

- Encourage and require development – scaling of funding needs
- Rework boundary conditions early and quickly (exploration)

It can only be done together in new forms of collaboration

How can we implement the digital transformation and infrastructure?

How can common goals be quickly translated into functioning shared infrastructure? How can legal framework conditions for data room use be created?

Science

Possibilities are enormous, these must be explored and rolled out, needs close cooperation.

Industry

Competition and innovation rate worldwide is very high, great willingness to collaborate and use data spaces as early adopters.

Society

Contribution with data and cooperation.

Politics

Demand and promote with higher tact or more freedom.

Setting the Scene

Anna Cavazzini

Member of the European Parliament

Interaction of Digital Twins in a Sustainable Battery Cell Production

Expert Presentation I

Alexander Kies

Fraunhofer IPT

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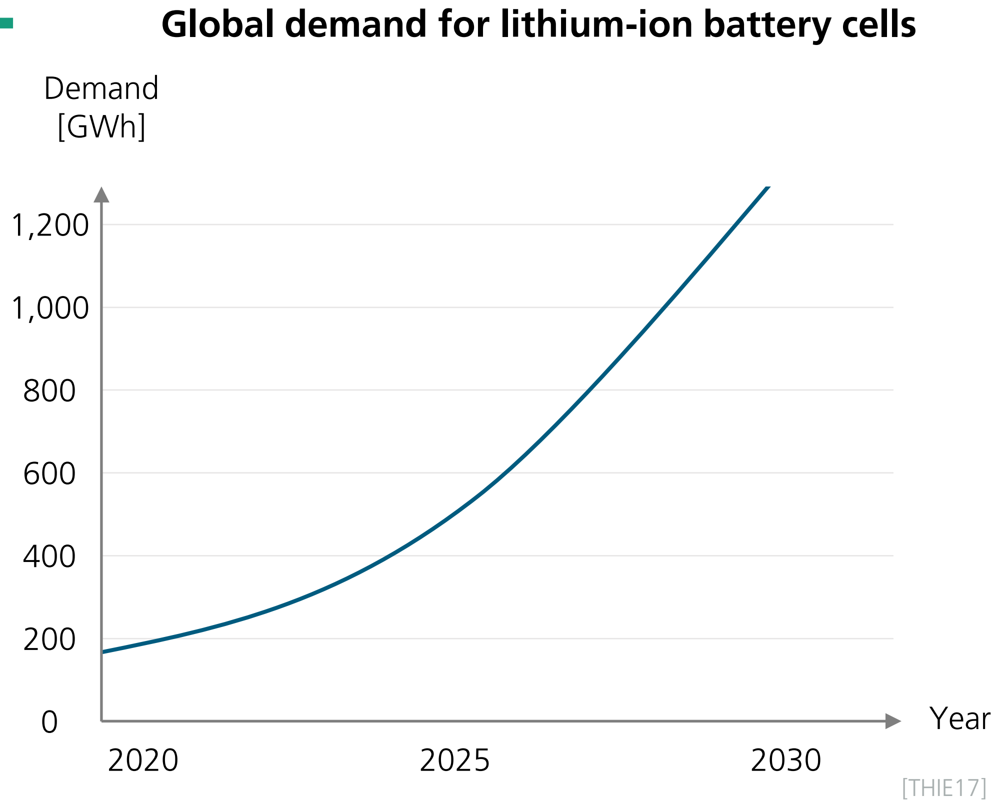
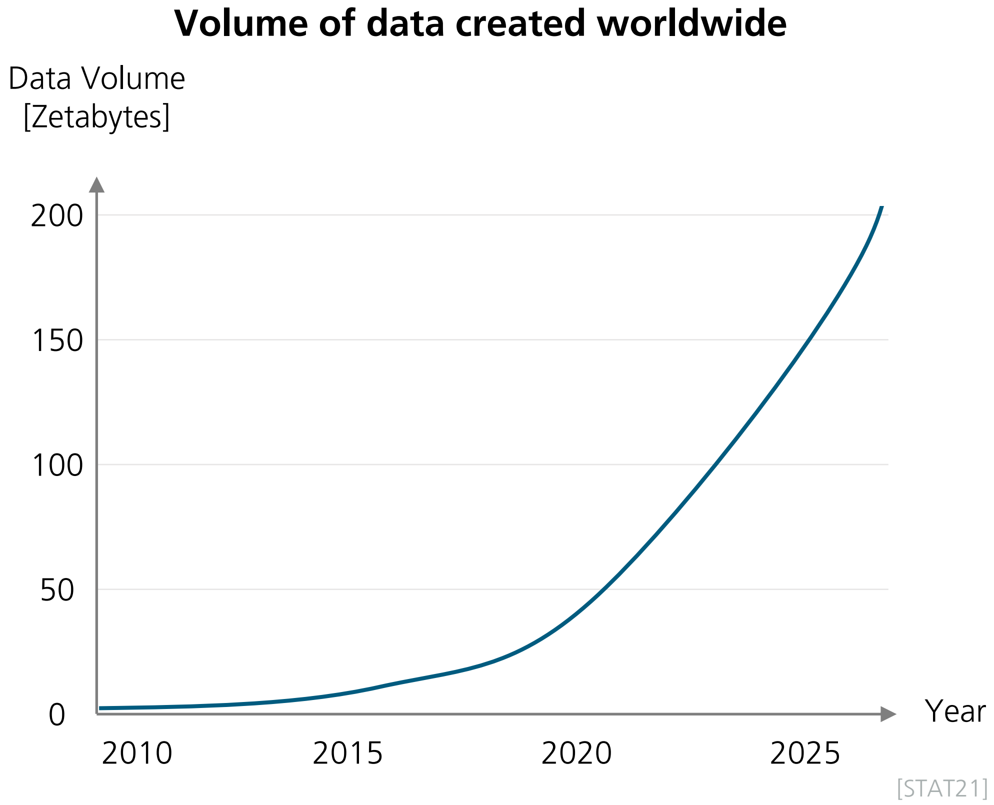
Interaction of Digital Twins in a Sustainable Battery Cell Production





How can the data collected be made available to increase sustainability in growing battery cell production?

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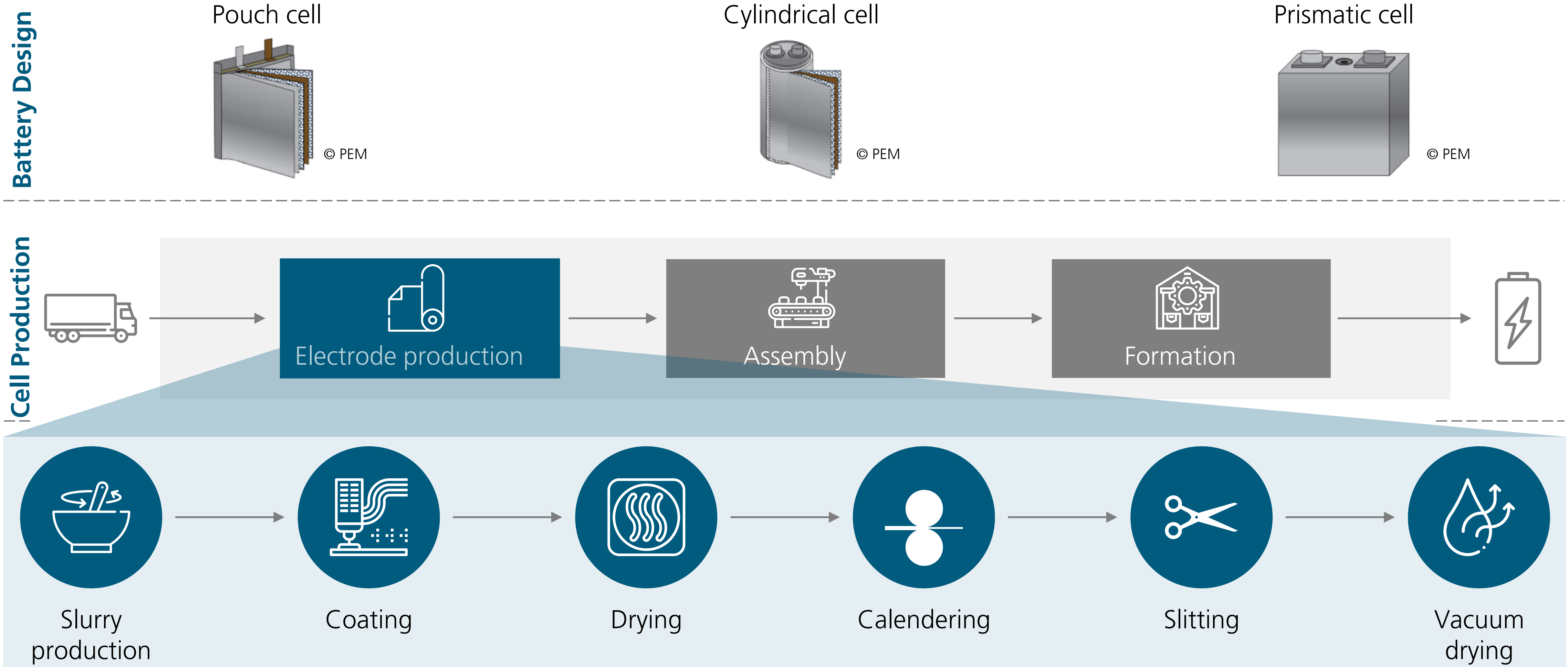
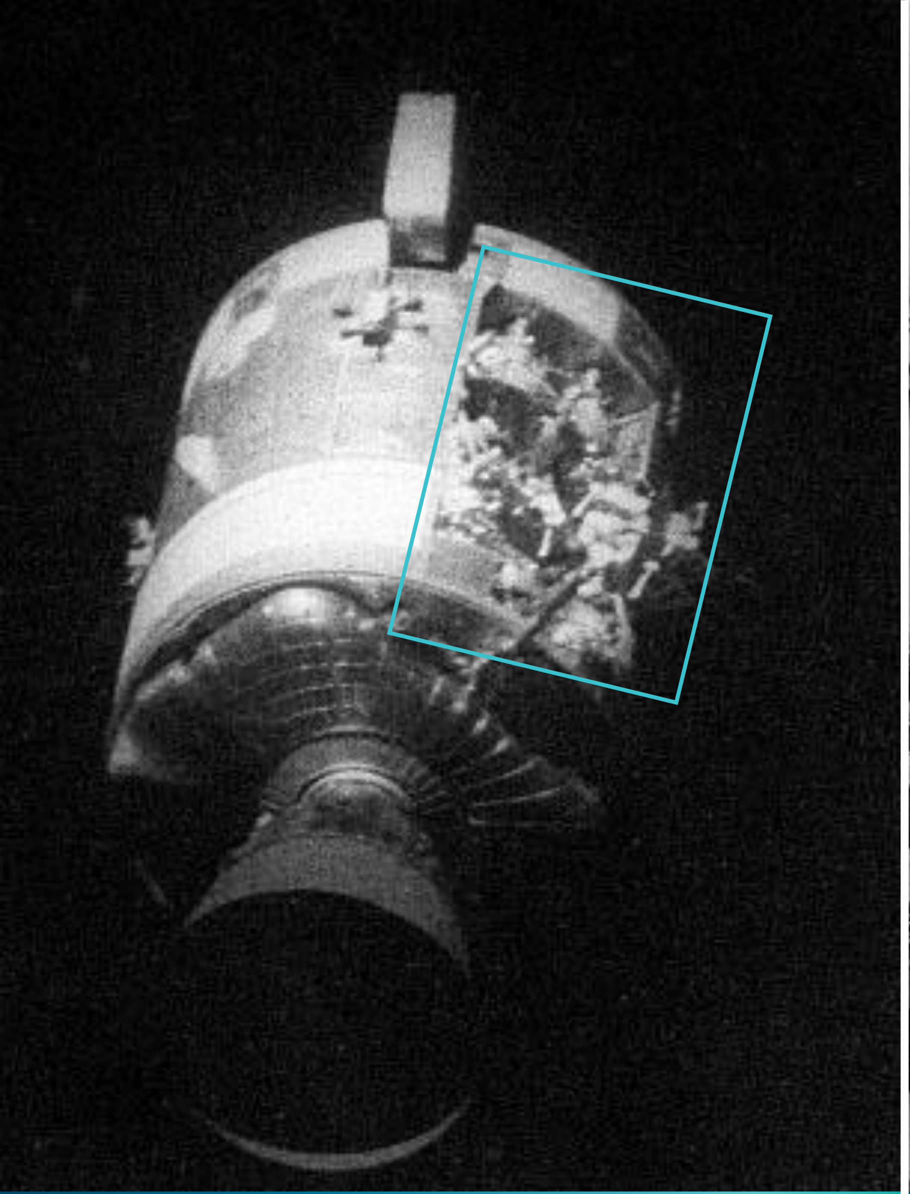
Interaction of Digital Twins in a Sustainable Battery Cell Production



  [KAMP14, HEIM18, PEM15] **Public information** Fraunhofer



»Houston, we've had a problem.«

Jack Swigert, Apollo 13, 1970

[NASA20]

Johnson Space Center

Houston, Texas

Interaction of Digital Twins in a Sustainable Battery Cell Production

Digital Twin as an Enabler for a Sustainable Battery Cell Production

Physical twin:
Already used for a long time (NASA)

Digital twin in production:
Implementation is made possible

Industry 4.0:
Transformation of the production landscape

Battery cell production

Digital twin

The purpose of this presentation is to answer the questions:

1. What is a digital twin for the battery cell production?
2. How can it be linked to sustainability activities?
3. How is realization possible?

[SCHL17, DURA18]

How can the digital twin be defined and brought into battery cell production?

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:
"[…] 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:
"[…] 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 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.

Interaction of Digital Twins in a Sustainable Battery Cell Production

Physical Objects Represented by a Digital Twin

The digital twin: a digital representation of a specific object	It comprises the properties, states and the behavior of the object	… via data, models and information. [STAR17]	Incl. all data, models, and simulations from the entire life cycle that can be useful in each of the life cycle phases

How can digital twins interlink with sustainability activities in battery cell production?

Interaction of Digital Twins in a Sustainable Battery Cell Production

Life Cycle Assessment (LCA) and Battery Passport

- ISO normed method to quantify environmental impacts over the entire life cycle of a product, service, process, company, etc. – by looking at energy and material flows
- Goal: Identification of hotspots in the value chain or compare and quantify environmental impacts
- Collection of data time-consuming

- Based on EU Guideline and mandatory for >2kWh batteries beginning of 2026
- Goal: Reporting tool for improve transparency, benchmarking capabilities, and 2nd life possibilities
- Technical realizations still in development

Battery Passport and LCA are two examples, where a technical solution for the availability of product-related data is of high benefit.

  [EU21, GEO22, BIO20] **Public information**

Interaction of Digital Twins in a Sustainable Battery Cell Production

Three Strategies to Directly Increase Sustainability

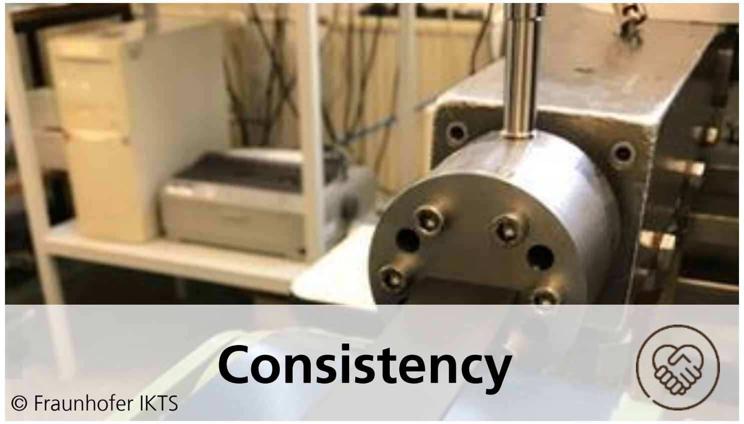
© Bühler

Efficiency

»better«
How can we optimize the Input-Output ratio?

Maximizing output or minimizing input.

Example: Continuous Extrusion



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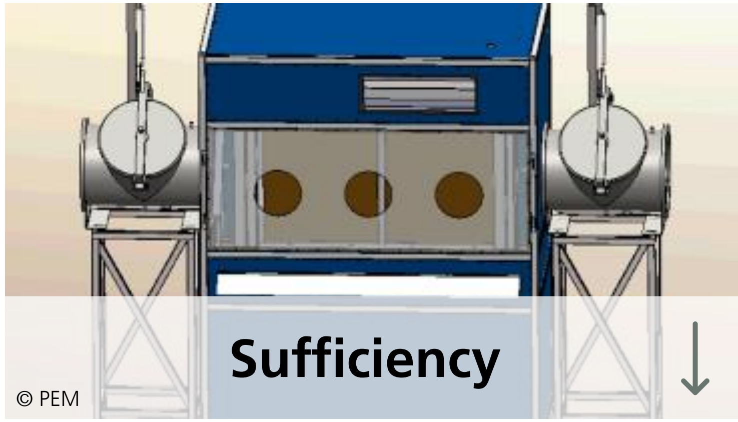
Consistency

»different«
How can a circular economy and cradle to cradle business models be realized?

Unite technology and nature to enhance circularity.

Example: Dry Coating



© PEM

Sufficiency

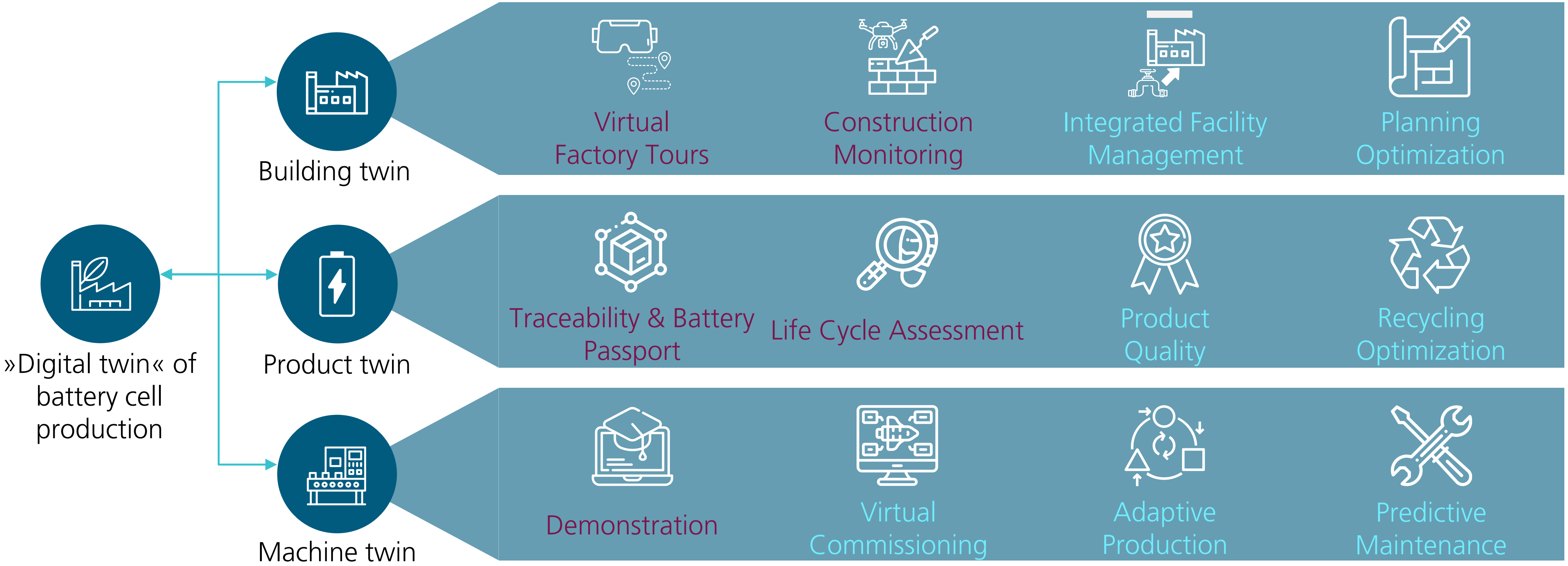
»less«
Which needs have to be met – and what is superfluous?

Focus on what really is needed.

Example: Mini-Environments

Interaction of Digital Twins in a Sustainable Battery Cell Production

Potentials of the Digital Twin in Battery Cell Production

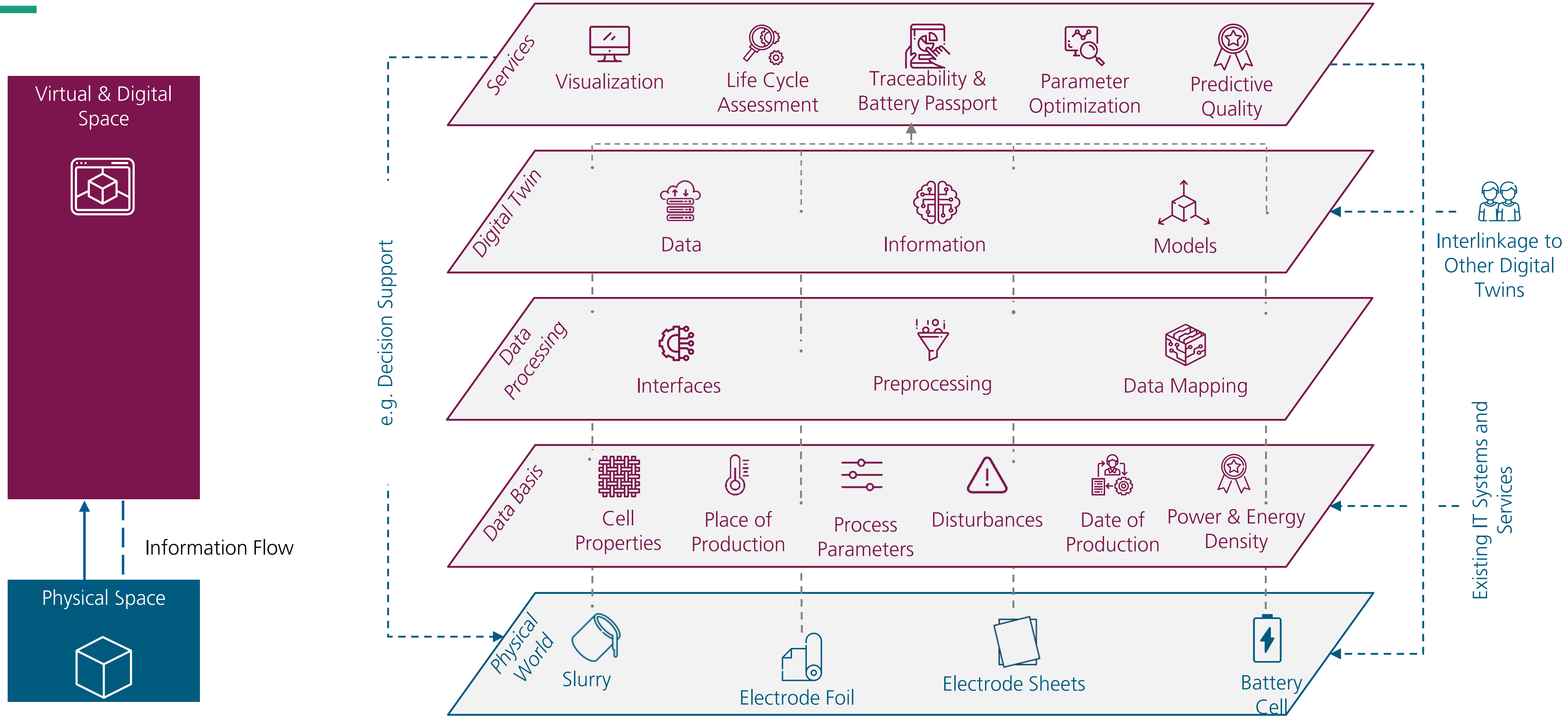


By providing data, digital twins can function as enablers for more transparency in sustainability.
Services such as simulation can help in increasing sustainability directly.

How can the digital twin be realized?

Interaction of Digital Twins in a Sustainable Battery Cell Production

Digital Product Twin



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Conclusion

Interaction of Digital Twins in a Sustainable Battery Cell Production

Lessons Learned – Main Takeaways

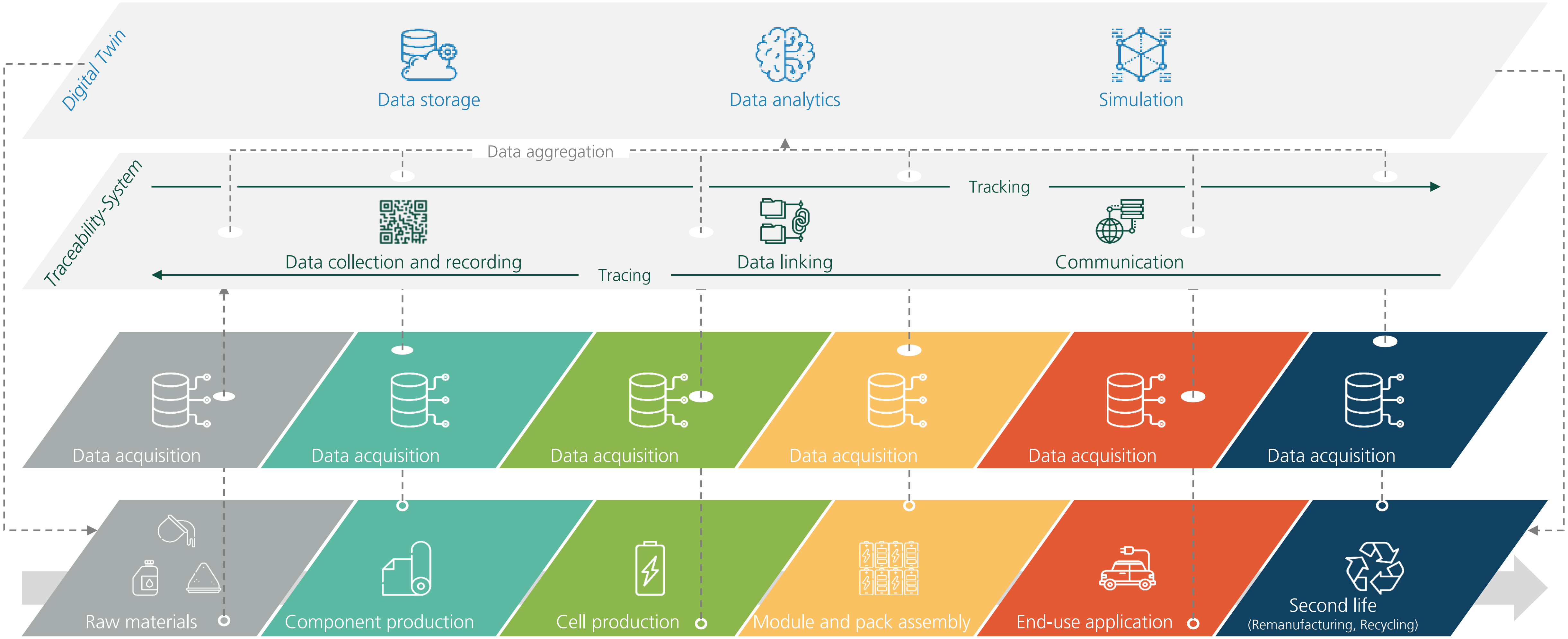
No standardized definition
In the research field of the digital twin, a multitude of definitions exists - and new views are continuously emerging. The goals and components of a Digital Twin are therefore highly dependent on the respective use case.

Two ways to interlink digital twins with sustainability
By providing data, digital twins can function as enablers for more transparency in sustainability (LCA, battery passport). Services such as simulation can help in increasing sustainability directly.

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.

Interaction of Digital Twins in a Sustainable Battery Cell Production

Outlook – How Can the Entire Value Chain Be Influenced by the Digital Twin?



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B-K

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Funding Reference

The project »Forschungsfertigungsförderung Batteriezelle FFB« is being funded by the Federal Ministry of Education and Research Germany.
(Funding Reference: 03XP0256)

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Towards a Comprehensive Semantic Information Structure in the Battery Value Chain

Expert Presentation II

Guinevere Giffin

Fraunhofer ISC

Battery Value *Chain* is Actually a *Network*

Complex, and continuously quickly evolving

A battery is extremely complex! The complexity of the value chain mirrors the battery itself.

Various raw materials, suppliers, battery chemistries, processing routes, cell/product types, applications, recycling routes

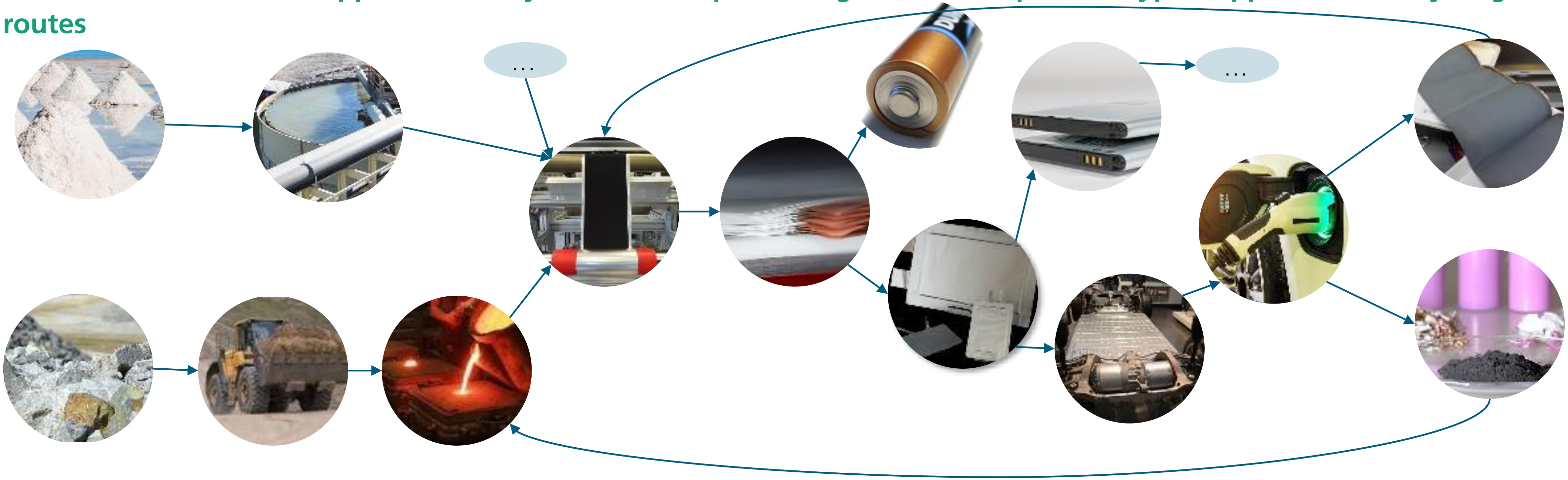
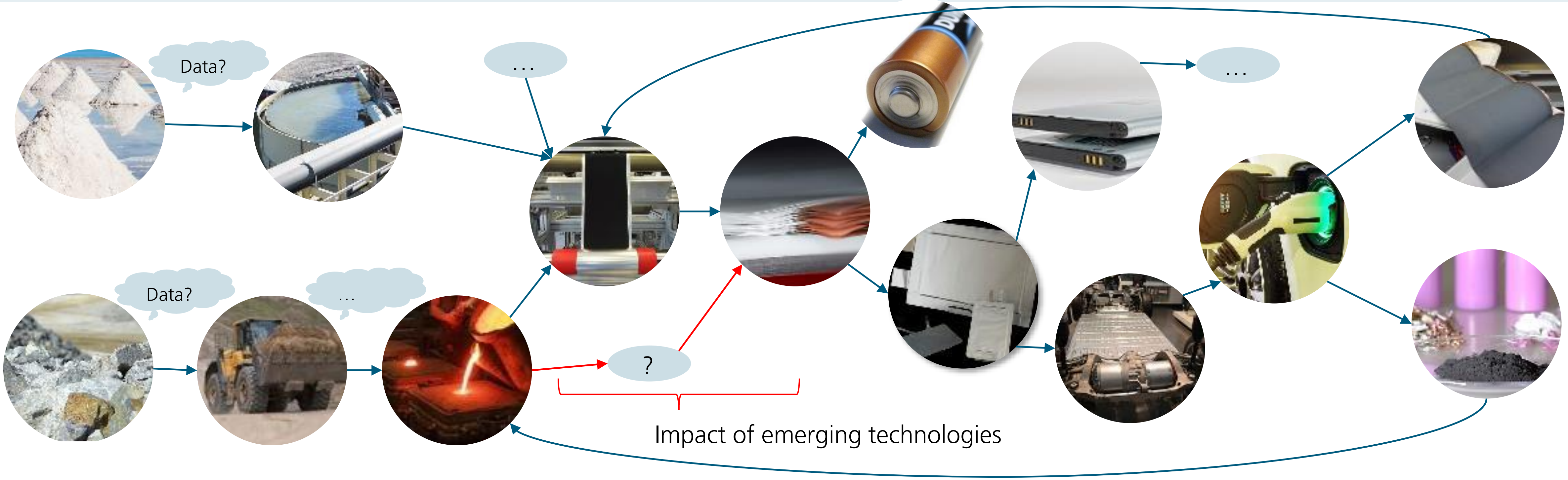


Image Sources: Wikimedia Commons, https://lithium-institute.eu/, Fraunhofer ISC

Battery Value *Chain* is Actually a *Network*

Challenges to comply with changing regulatory requirements

Regulatory shift from "What is inside a product" to "What are the processes behind how a product is made?" – Raw materials, CO_2 footprint and overall sustainability



Challenges in terms of applying conventional LCAs

Challenges to react dynamically to emerging technologies, regulations and changing market scenarios

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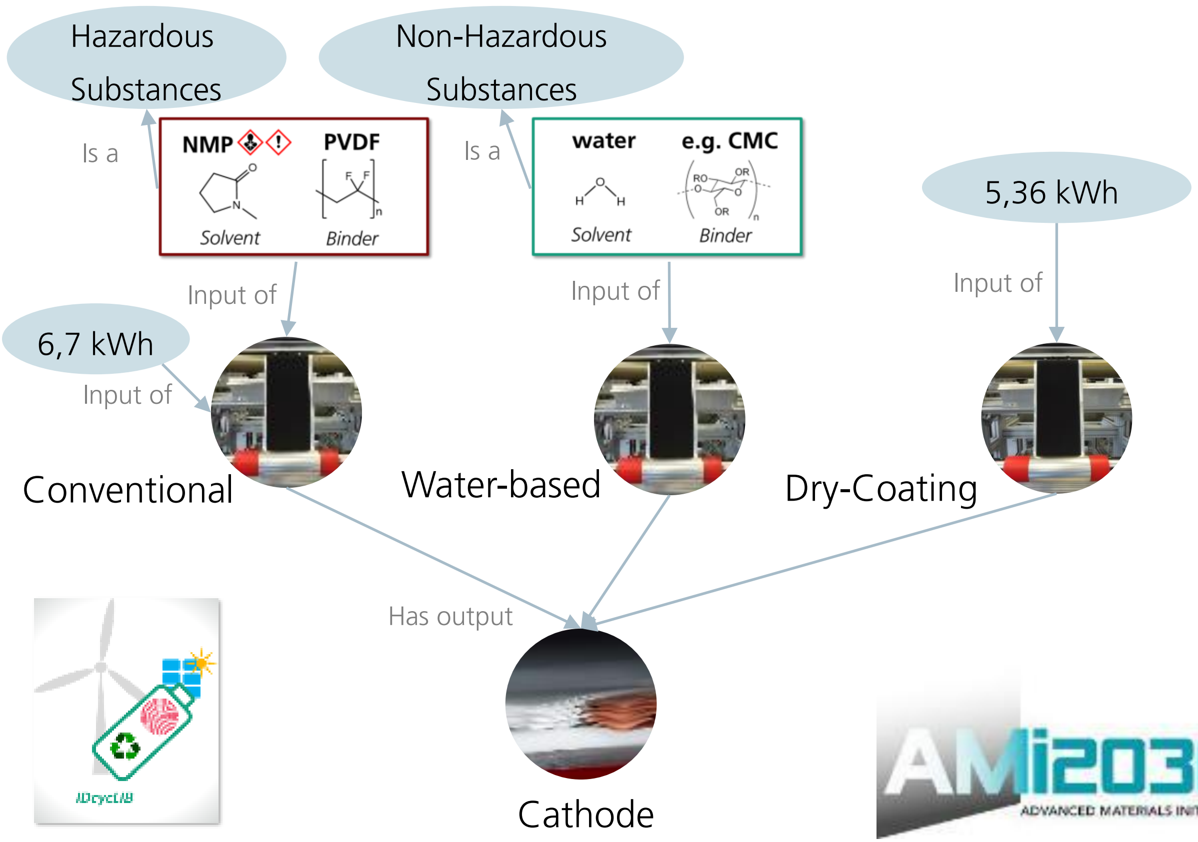
Solution: Consistent Semantic Information Structure along the Value Chain

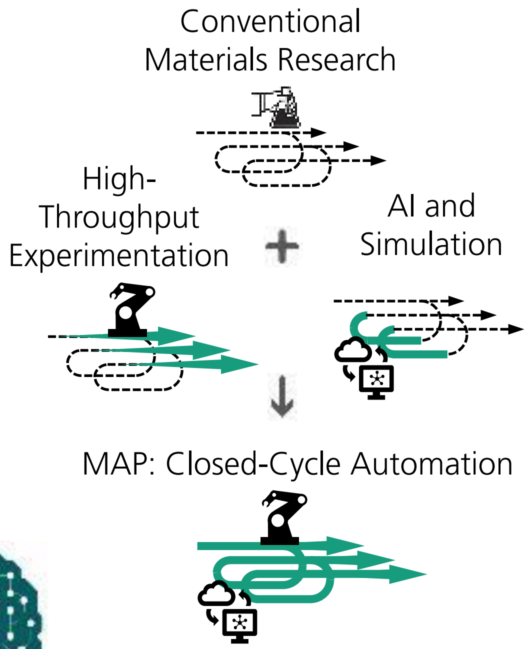
Empowering Emerging Technologies



AMI2030 ADVANCED MATERIALS INITIATIVE

BIG-MAP

supported by Material Acceleration Platforms (MAPs)



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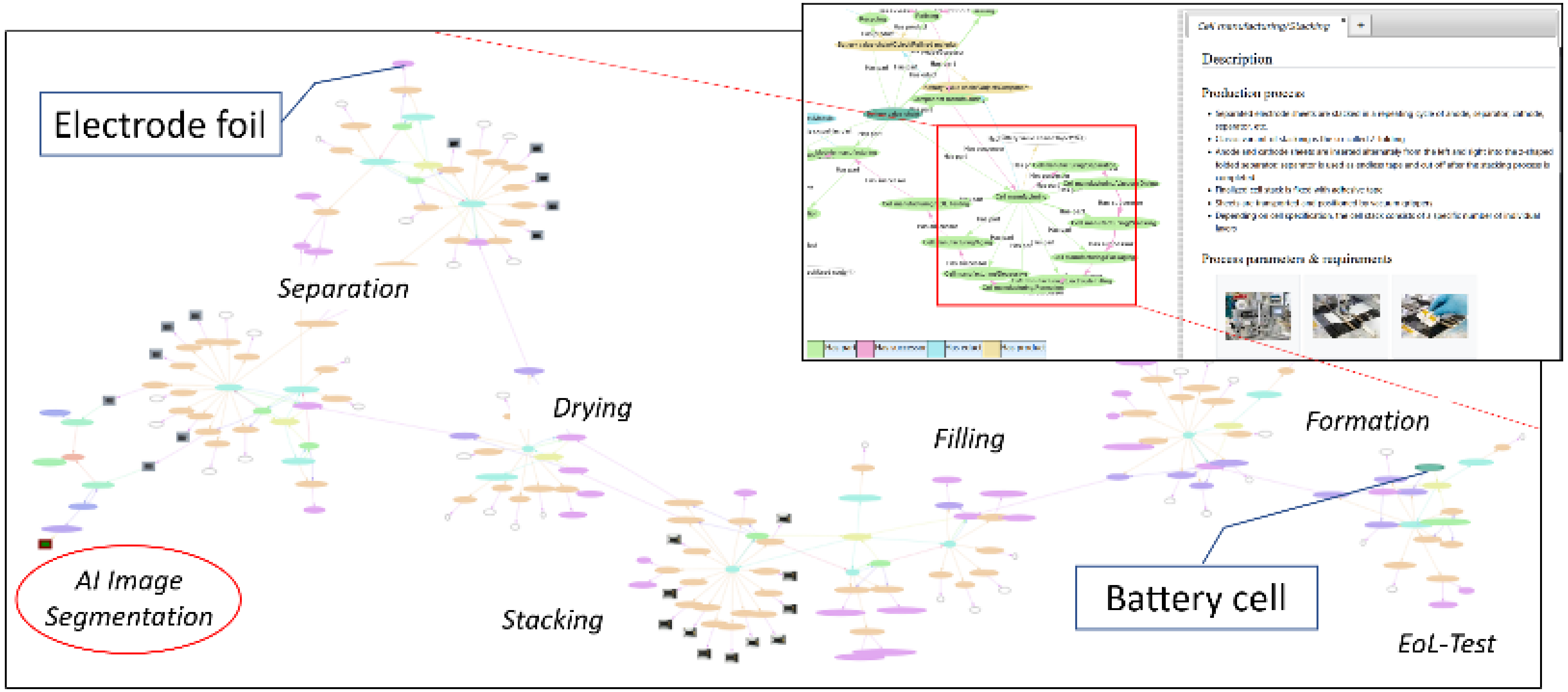
Solution: Consistent Semantic Information Structure along the Value Chain

Result: Technology and Value Chain Knowledge Graphs, combining Expert Knowledge and Interoperable Data



KIpro Batt

Batterie Digital

EMMC

Projects: BIG-MAP, BatterieDigital, KIproBatt, AMI2030, …

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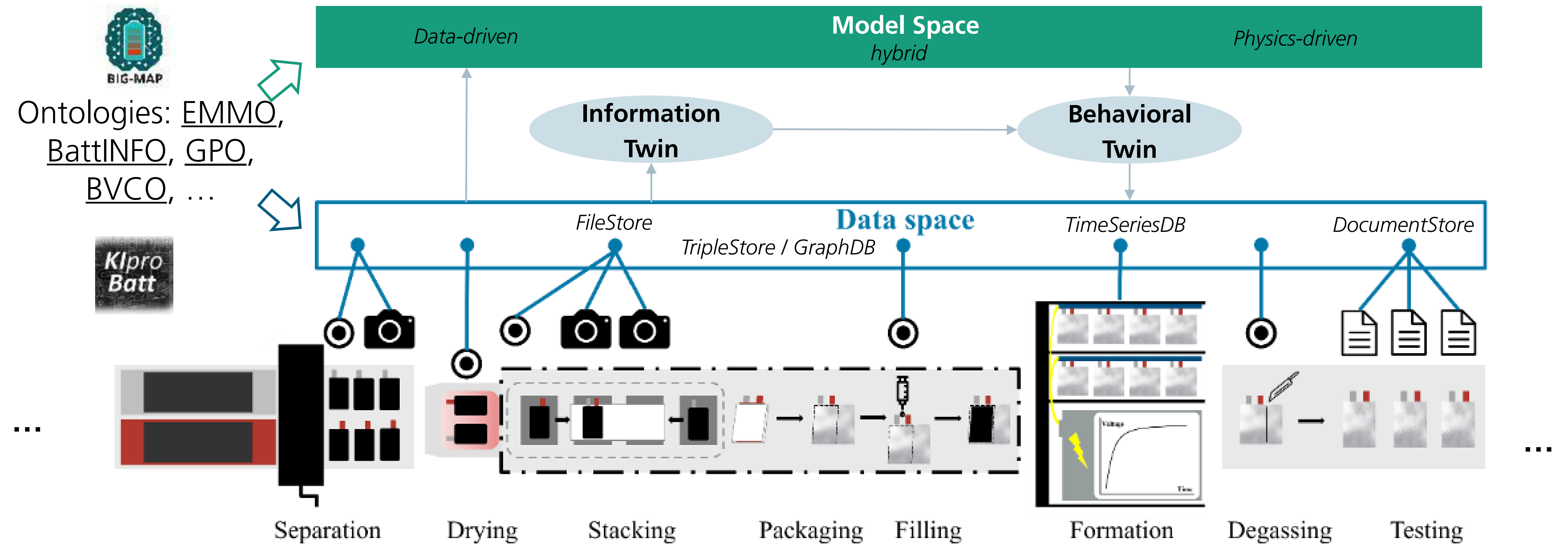
Comprehensive Semantic Information Structure in the Battery Value Chain

Enables efficient creation and validation of Digital Twins

Provides the foundation for a seamless coupling of *informational* and *behavioral* digital twin

Ontologies: EMMO, BattINFO, GPO, BVCO, …



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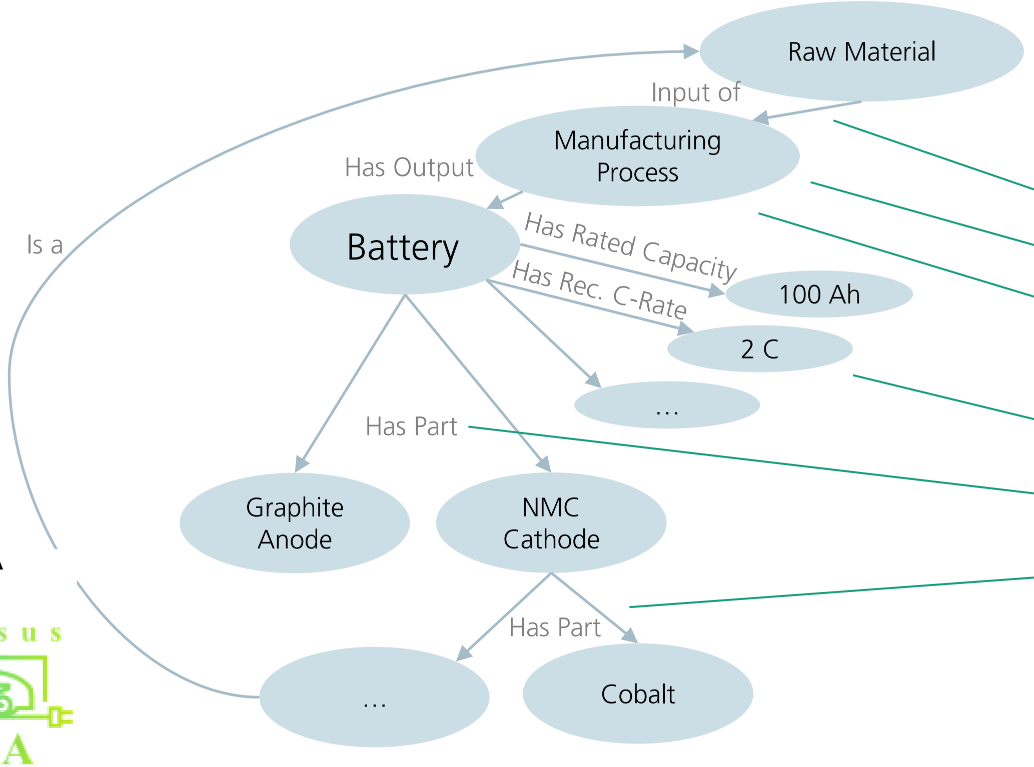
Solution: Consistent Semantic Information Structure along the Value Chain

Enables efficient **implementation** of regulatory requirements

Enables **automatic creation** and **validation** of digital product passports



- Critical raw materials
- Carbon footprint
- Supply chain due diligence report
- Performance
- Chemistry
- Location & concentration of hazardous substances
- …

HiQ-LCA

TranSensus LCA

Battery Pass

https://thebatterypass.eu/

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Digital Twins and Comprehensive Semantic Information Structures

Where are we now and where are we going?

To enable the **Green Deal**, we need Green Technologies – this implies a shift from looking at the product itself (What is inside?) to how did we get here (What is it and How was it made?)

→ **Expertise along the full value chain is needed to facilitate this transition – this implies not only e.g., the battery scientists**

We are laying the foundation for the **Twin Transition** through the development of advanced and standardized digital twins themselves and through the semantic layer (i.e., the information structure) that connects them to the physical world.

→ **Substantial efforts are still needed to connect all the process steps in the value chain (a battery is complex), but at the same time we need input from our industrial partners to develop suitable and target-oriented solutions**

Discussion

Katrin Mögele

Fraunhofer EU Office

Pose your questions either directly to the speakers or write them in the chat – we will then ask the question for you!

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