

Sustainable Power Electronics in Industrial Applications

Prof. Dr. Rolf Hellinger

ECCE 2024

Darmstadt | September 5, 2024



Agenda

**Sustainable
Power Electronics**
in Industrial Applications

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Why?
Importance of sustainable
Power Electronics



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What?
R&D plays the decisive role



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How?
4S approach
Selected Sustainability
Use Cases



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Why?

Importance of sustainable
Power Electronics

Our vision is to **hand-over a world** to our children,
worth living in for them and future generations.

25 %

of CO₂ emitted by industry¹

➤ CO₂-neutrality

70 %

of electrical power
in industry for drives

➤ High energy efficiency

13 %

only, of global waste is
recycled

➤ Resource efficiency
& Circular economy

¹ Source: International Energy Agency 2022

Power Electronics is everywhere

Power Electronics is the key enabler for the transition to a **sustainable energy system**

Fossil era



All-electric society

Power Electronics

Renewable energy,
Power grid,
Large-scale Storage



Industrial drive,
e-Mobility



Battery storage,
Health care,
Data center



Industrial
inverter market



€54bn
in 2018¹



€91bn
in 2023¹



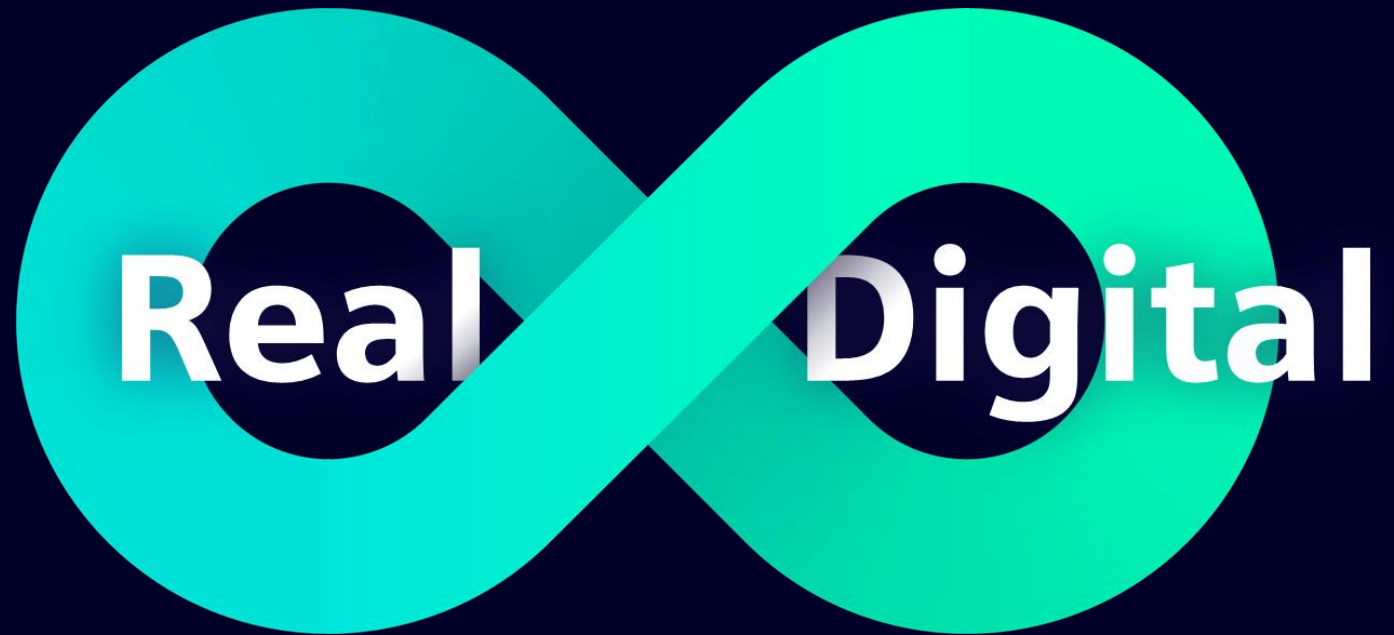
€134bn
in 2028¹

¹ Source: Status of the Power Electronics Industry 2023 Market and Technology Report, YOLE Intelligence, July 2023

Digitalization in Power Electronics **drives sustainability**

We provide accurate models for design & manufacturing, collect process data, monitor & plan tasks for operation, and service, and **influence the system.**

By combining the real and the digital world, we make our customers **more competitive, resilient and sustainable.**



What?

R&D plays the decisive role



With our **Siemens DEGREE** sustainability framework, we balance social, ecologic and economic sustainability and support the **Sustainable Development Agenda 2030** of UNEP¹



Decarbonization

support the 1.5°C target to fight global warming

Ethics



Governance

Resource efficiency

achieve circularity and dematerialization

Equity



Employability

¹ UNEP United Nations Environment Programme

Sustainable Power Electronics from Cradle-to-Cradle in three steps – Evaluation of product environmental impact, optimization and realization

Product Environmental Impact

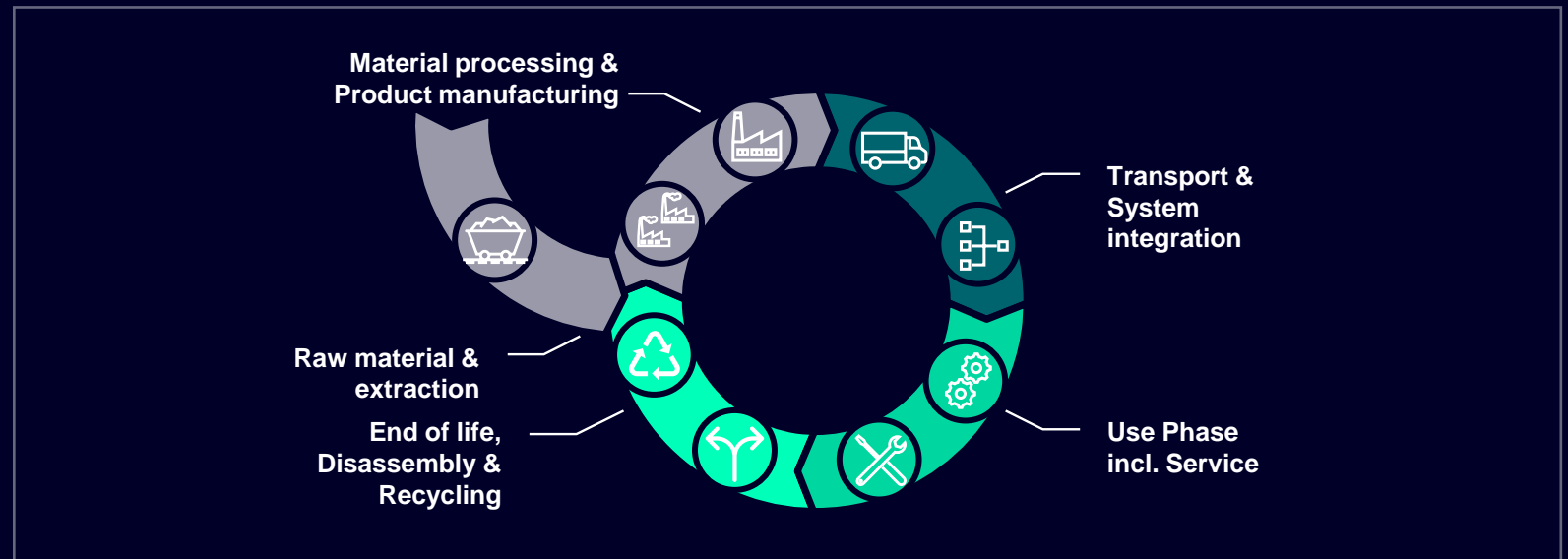
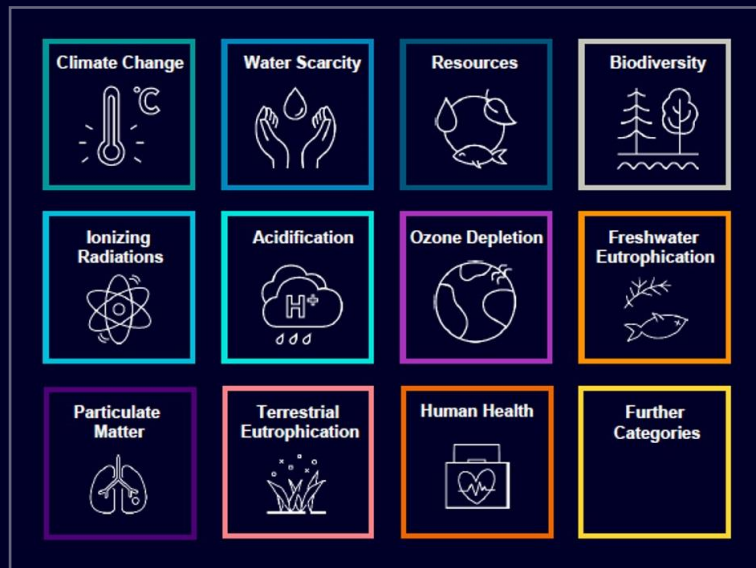
- Understand, calculate, report and verify data based on Impact categories
- Conduct a Life Cycle Assessment (LCA)

Optimize

- Simulate and optimize dynamically the Product Environmental footprint in terms of impact and costs
- Siemens GreenDigitalTwin

Realize

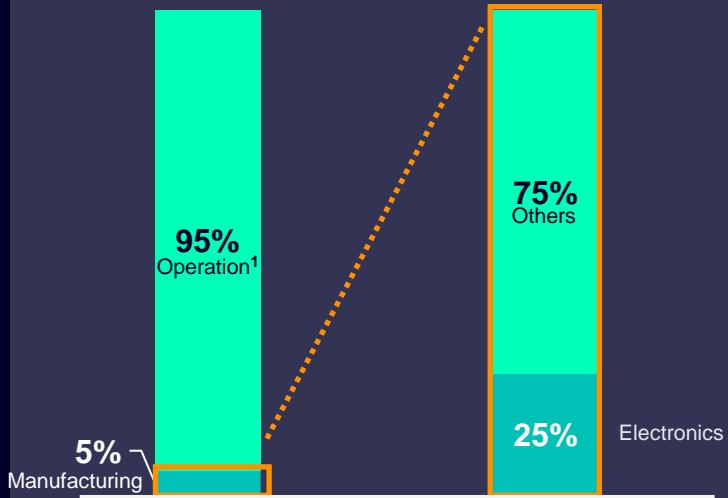
- Realize, track, validate, certificate and publicate
- Environmental Product Declaration (EPD) & Digital Product Passport (DPP)



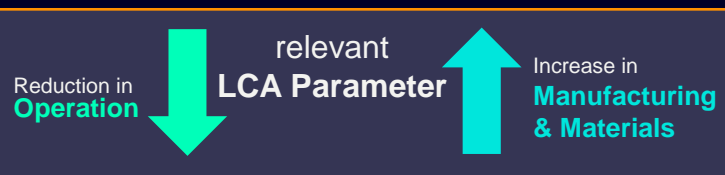
Create environmental impact transparency by Lifecycle Assessment (LCA) – Example: **CO2 footprint of inverter and power module**

1 LCA for Industrial Inverter

G220 - CO₂-Emission Split over Lifetime



Transition to Clean Energy shifts the Equation



2 Identified Challenges

Actual situation today

- Incomplete material data along the supply chain
- Different material databases lead to different results
- Low data transparency especially for electronic components

3 Definition of Action Fields

Reduction of CO₂-emissions by LCA

Design & Manufacturing

- Dematerialization
- Increase of secondary materials
- Avoiding interfering materials for disassembly & recycling process

Operations

- Energy efficiency optimized product and system
- Long lifetime and easy to repair
- New business models, e.g. performance contracting

¹ Energy mix Germany 2023

Strong **Research and Innovation Ecosystem** to realize the design targets for sustainable Power Electronics



- 1** Dematerialization
- 2** Eco-material selection
- 3** Green supply chain
- 4** Longevity & effective use
- 5** Energy efficiency
- 6** Circularity efficiency

➤ R&D plays the fundamental role for sustainable products and services. Digitalization & AI are the main levers.

How?

4S approach

Selected Sustainability

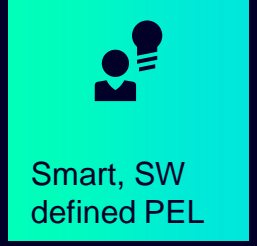
Use Cases



Sustainability, Smartness, and Scalability through comprehensive functional integration across the entire technology stack

4 Sustainable and Smart, SW-defined Functionality, Siemens Xcelerator-ready

- Sensing, condition monitoring, data analytics
- Prediction and prescription based on Gen AI
- SW-defined adaptation to address adjacent markets



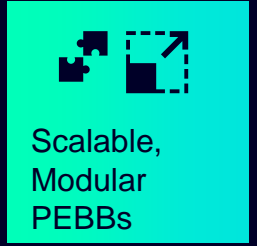
3 Applications and Application Control

- Application related topology
- Functional integration
- Ease of use



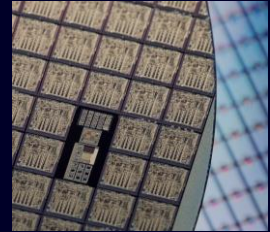
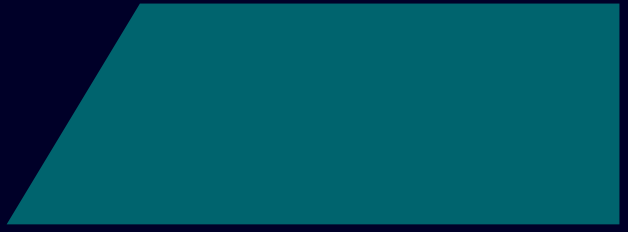
2 Scalable, Modular, Power Electronic Building Blocks (PEBBs)

- Easy to adapt and scale by Standard HW PEBBs
- High power density and robustness by seamless design
- Dematerialization and Robust Ecodesign



1 Power Semiconductor

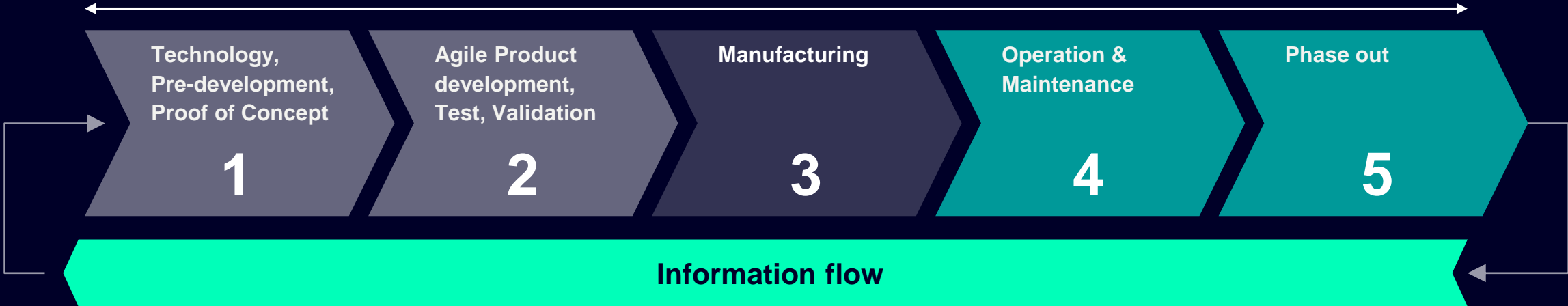
- Depending on application
- Si or
 - Low loss, fast switching Wide Band Gap SiC or GaN



Vertical Integration

Seamless horizontal integration for **Sustainability and Speed** through a connected data value chain, enabling agile workflows throughout the entire life cycle

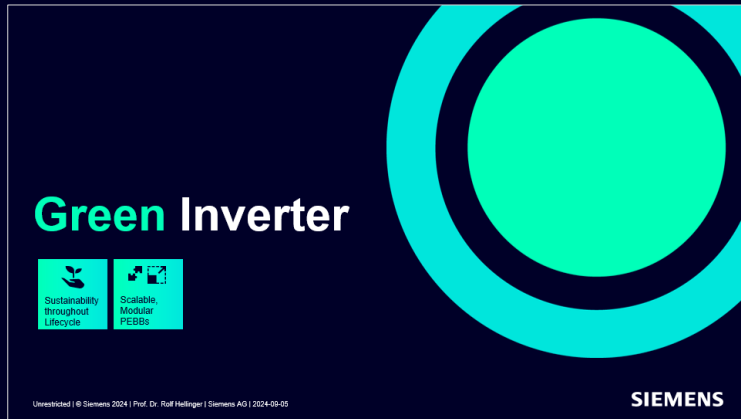
Horizontal Integration



Speed & Productivity along PLM

Sustainability throughout Lifecycle

4S approach – Selected examples



Green Inverter

Sustainability throughout Lifecycle | Scalable, Modular PEBBs

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The slide features a large green circular graphic on the right side. The text 'Green Inverter' is in white. Below it are two small icons: a leaf for 'Sustainability throughout Lifecycle' and a circuit board for 'Scalable, Modular PEBBs'. The Siemens logo is at the bottom right.

Sustainability



Scalable Inverter

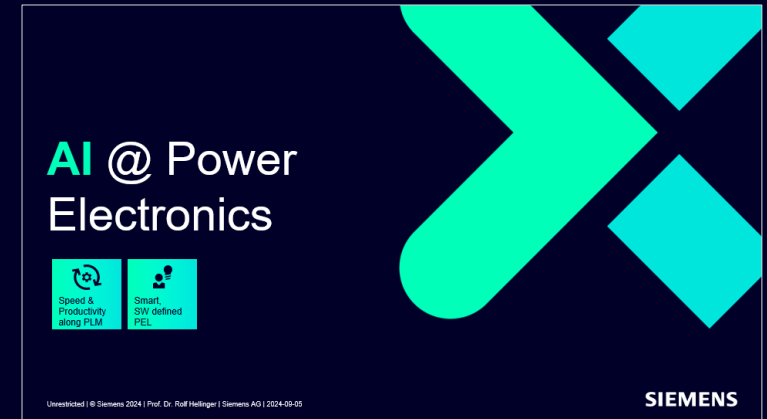
Sustainability throughout Lifecycle | Scalable, Modular PEBBs | Smart, SW defined PEL

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The slide features a large green infinity symbol on the right side. The text 'Scalable Inverter' is in white. Below it are three small icons: a leaf for 'Sustainability throughout Lifecycle', a circuit board for 'Scalable, Modular PEBBs', and a person with a gear for 'Smart, SW defined PEL'. The Siemens logo is at the bottom right.

Scalability



AI @ Power Electronics

Speed & Productivity along PLM | Smart, SW defined PEL

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The slide features a large green 'X' graphic on the right side. The text 'AI @ Power Electronics' is in white. Below it are two small icons: a gear for 'Speed & Productivity along PLM' and a person with a gear for 'Smart, SW defined PEL'. The Siemens logo is at the bottom right.

Smartness & Speed

Scalable Inverter



Sustainability
throughout
Lifecycle



Scalable,
Modular
PEBBs



Smart, SW
defined PEL



Sustainable, Scalable and Smart Industrial Inverter Design based on Technology Building Block System (TBBS)

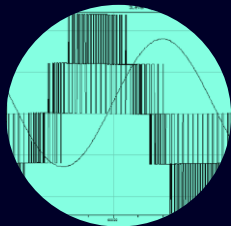
Smart, SW-defined Power Electronics

- Scalable, Modular sensors & gate drivers
- Health monitoring
- Predictive protection
- AI based online parameter estimation & optimization
- Prescriptive operation and service



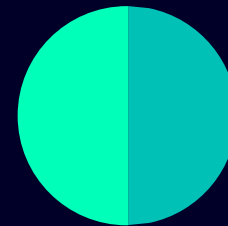
Optimized Scalable, Modular Inverter and Filter Design

- Model-based system design optimization
- SW-based filter damping



Advanced Power Unit Technology & Design

- Fast switching
- Wide Band Gap SC
- Planar Assembly & Joining Technology
- Advanced cooling
- Functional integration



Optimized System Topology

- Higher efficiency @ higher switching frequencies
- Reduced size of passives
- Improved EMC behavior

Functional integration and Technology Building Blocks are applied in our newest products – SINAMICS G220 for Grid friendliness ...

- Grid friendly
- Efficient
- Sustainable
- Reliable
- Seamless

Clean Power



- Sustainability throughout Lifecycle
- Scalable, Modular PEBBs
- Smart, SW defined PEL

Comply with IEC61000-3-12/-2, IEEE 519

G220 CP
Best-in-class Low Harmonics Drive
Game changer in regards **Integrated Functionality, Compactness** and future **Grid Compliance**

Vertical Integration enables the new SINAMICS G220 Clean Power

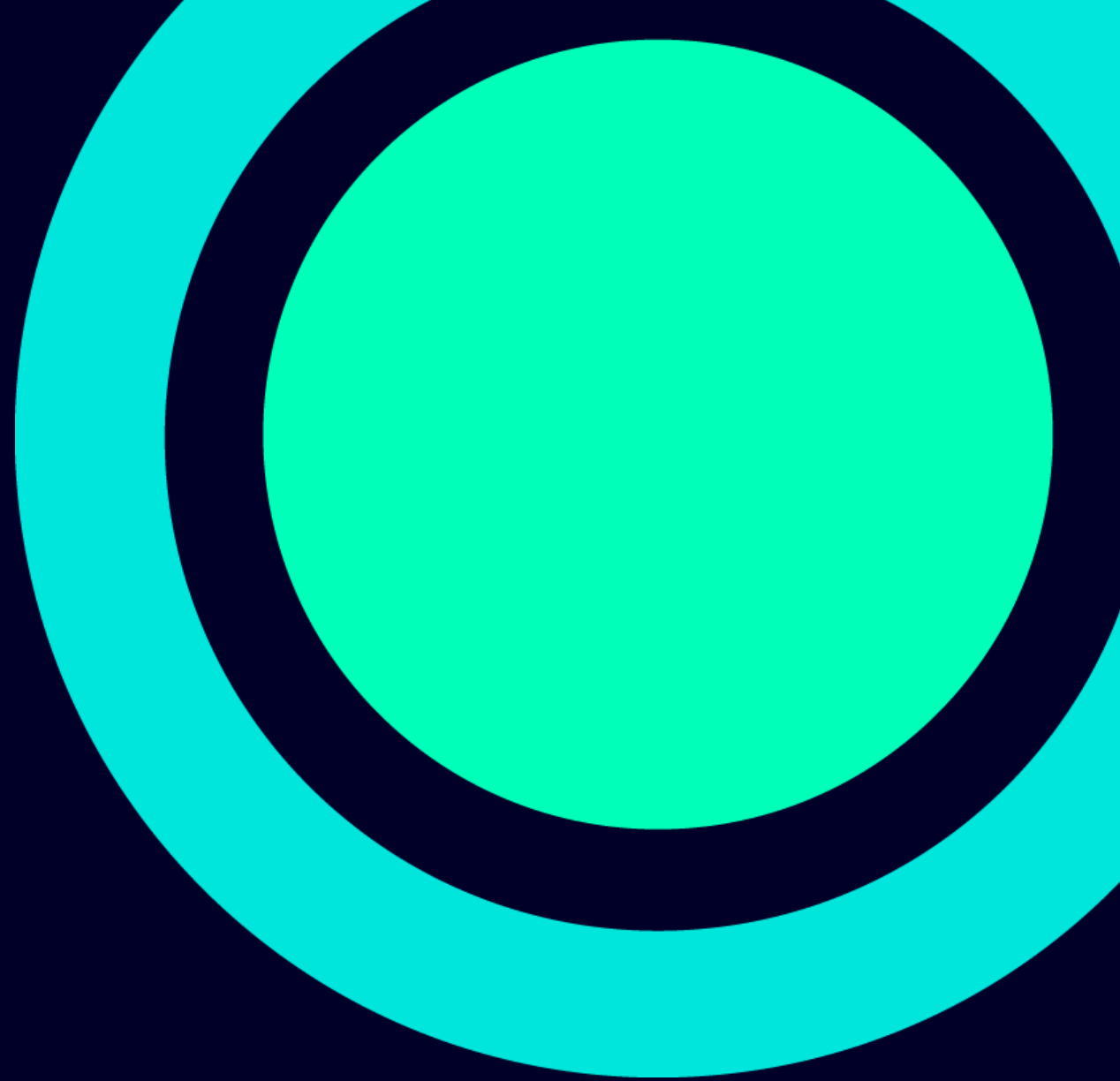
Green Inverter



Sustainability
throughout
Lifecycle



Scalable,
Modular
PEBBs



Collaborate to Innovate for Sustainability – The Green Inverter Consortium

New dimensions in Lifetime, Repairability, Upgradability and Recyclability



RIE Co-creation



Lifetime increase

by homogenous temperature distribution



Resource savings

by less raw material usage and circularity

Goals

- ✓ Lifetime increase > 30 %
- ✓ Resource savings by 30 %
- ✓ Power loss reduction by 70 %
- ✓ Recyclability > 90 %

Recyclability

by system development focused on material selection and disassembly for circularity



Power loss reduction

by use of fast switching SiC and GaN semiconductors and advanced cooling

Supported by the



AI @ Power Electronics



Speed &
Productivity
along PLM

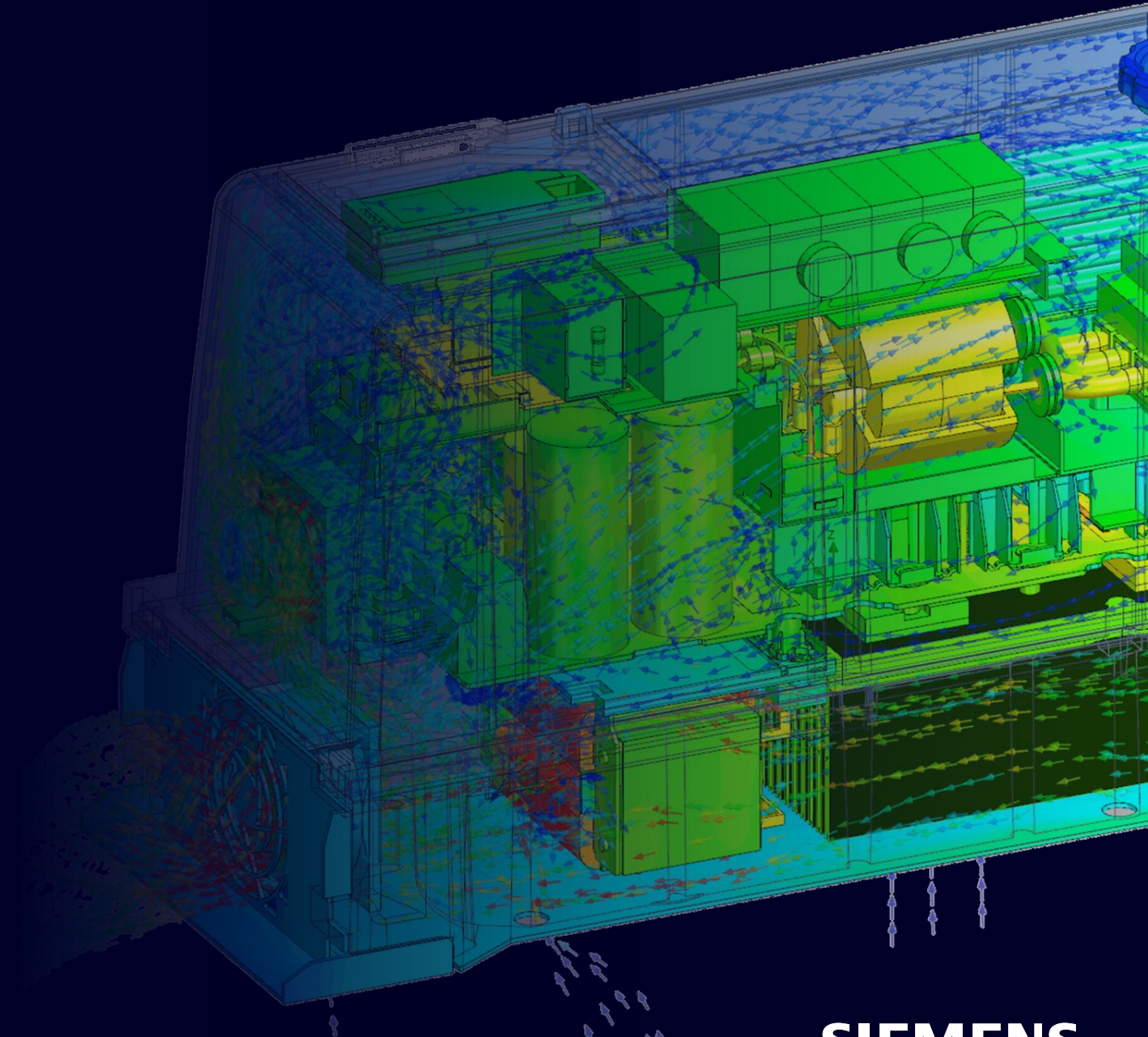


Smart,
SW defined
PEL

Ai

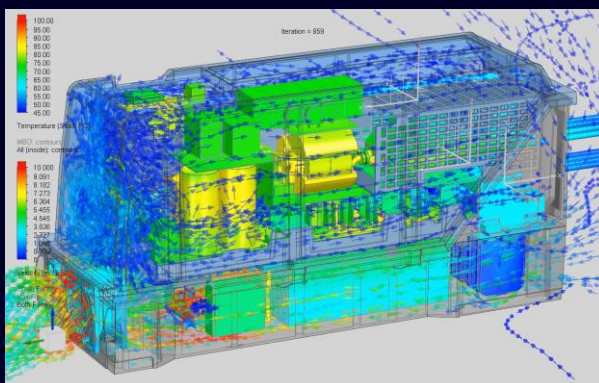
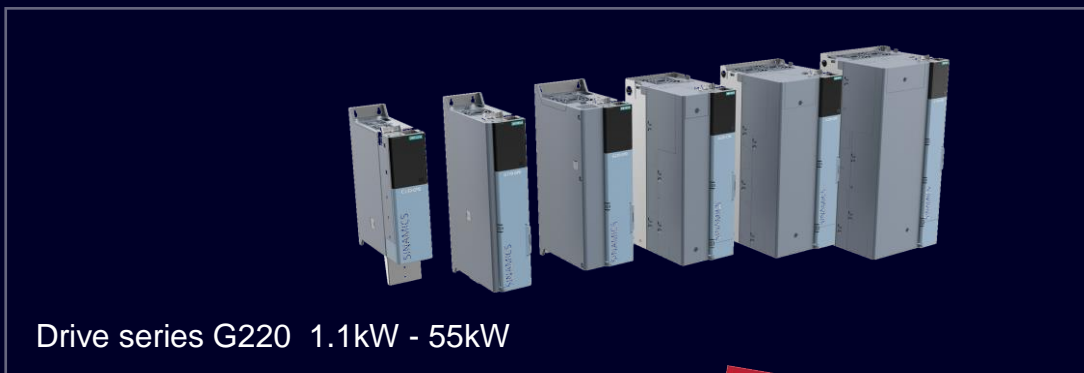
Inverter Certification

Siemens and UL catapult digital twins into valid quality for product certification



Model-based Inverter Certification

Siemens and UL Solutions demonstrate paradigm shift



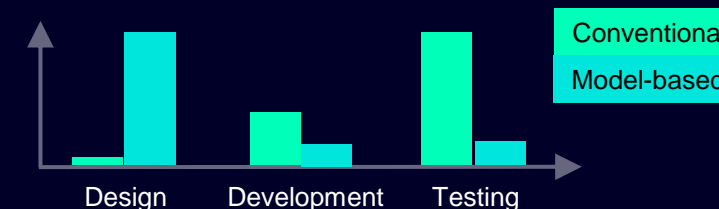
IMV&V reports are the door opener for the acceptance of simulation results in product certification as UL, CE.

Why – Customer Challenge

- Certification requires exhaustive physical tests
-> high costs, efforts & long time-to-market

How – Technical Approach

- Perform tests on digital simulations



What - Benefits

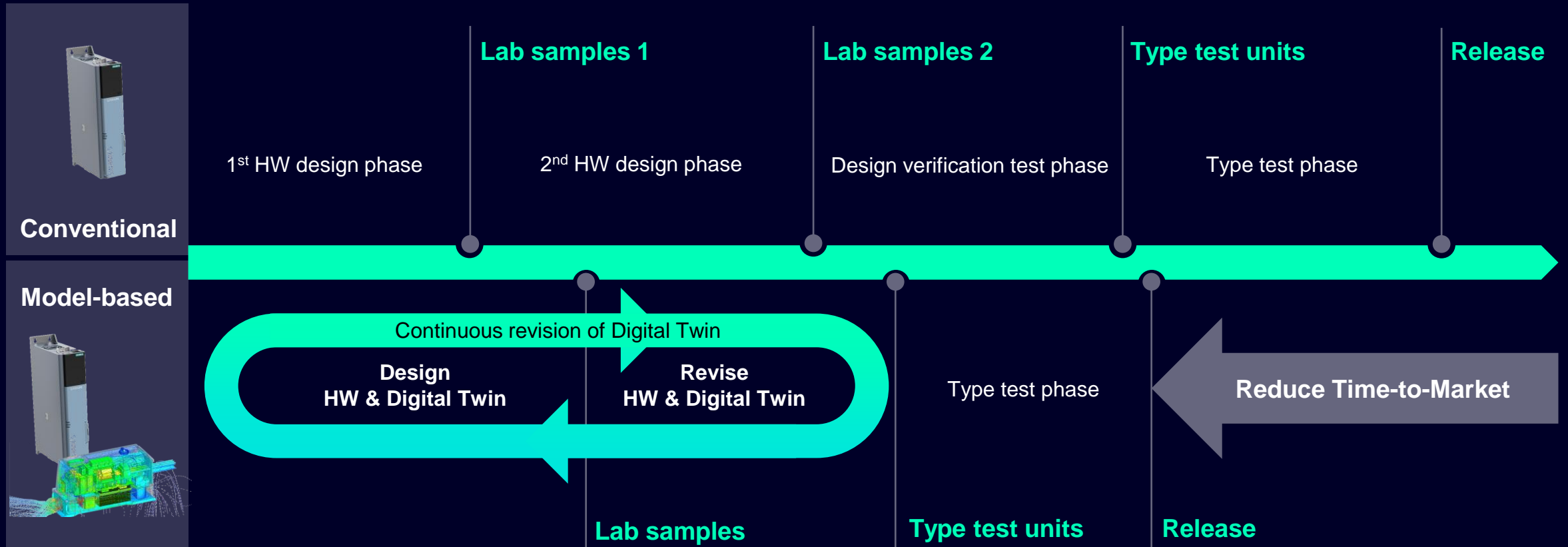
- Reduced Costs and Efforts for Tests
- Accelerated Time-to-Market
- Reduced development risk by continuous tests during development (agile)
- Better design space exploration
- Scalability by parallelization

Model-based Design Process

Reduces time-to-market & improves design space exploration



Inverter Certification





Ai

Inverter Production

Siemens Electronics Factory Erlangen (GWE)

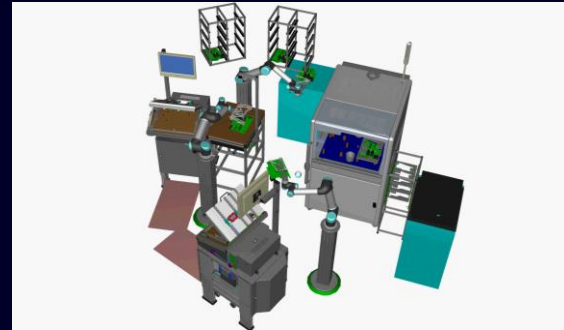
Foundation of the Industrial Metaverse

Siemens Electronics Factory Erlangen

Customer Zero for production innovations in the brown field

Production Digital Twin

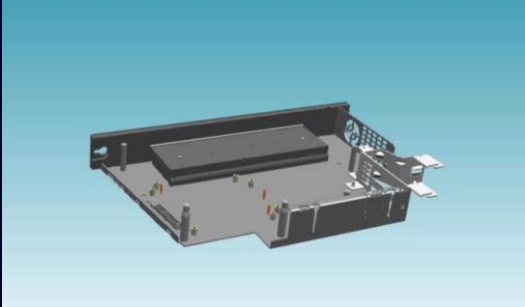
25 % investment cost reduction
6 months less commissioning time
by fully digital planned production



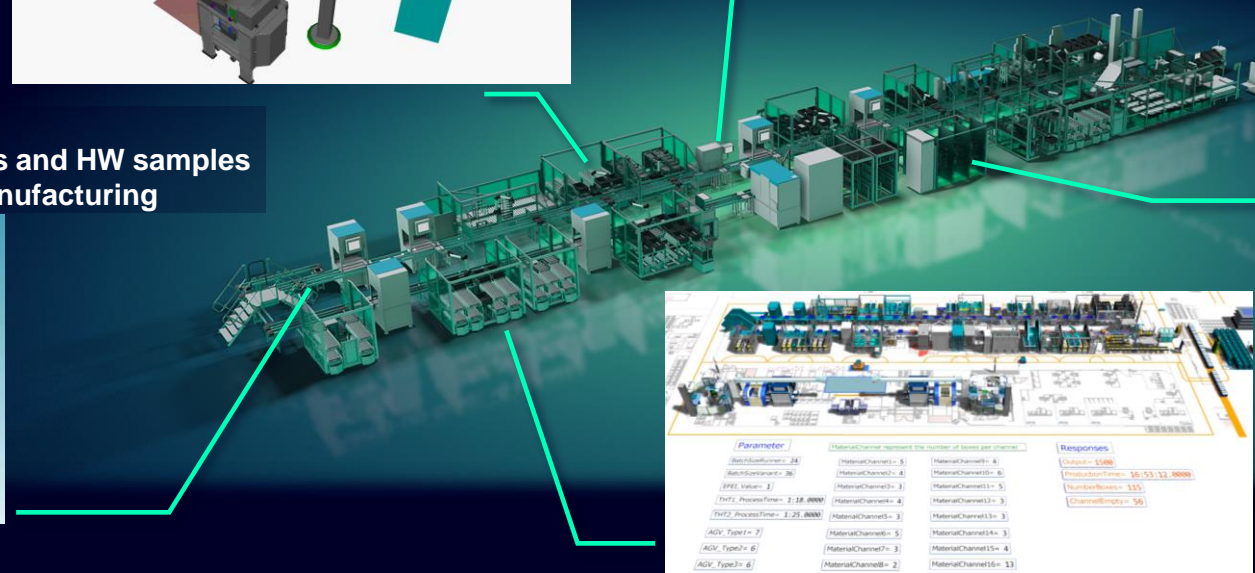
AI Training on Synthetic Image Data
50 % logistic cost reduction and less packaging material by bin-picking system

Product Digital Twin

80 % reduction of manual efforts and HW samples
by first-time-right design for manufacturing



AI-based Parameter Optimization
60 % pseudo faults reduction and lower reject rate



Parameter	MaterialChannel represents the number of items per channel			Responses
MaterialChannel= 24	MaterialChannel= 4	MaterialChannel= 4	MaterialChannel= 4	Value= 1500
MaterialChannel= 36	MaterialChannel= 4	MaterialChannel= 4	MaterialChannel= 4	ProductionTime= 10:53:12.0000
EPK_Value= 3	MaterialChannel= 3	MaterialChannel= 3	MaterialChannel= 3	NumberBoxes= 135
Takt1_ProcessTime= 2:18.0000	MaterialChannel= 4	MaterialChannel= 3	MaterialChannel= 3	ChannelLength= 56
Takt2_ProcessTime= 1:25.0000	MaterialChannel= 3	MaterialChannel= 3	MaterialChannel= 3	
ADV_Type1= 7	MaterialChannel= 5	MaterialChannel= 4	MaterialChannel= 4	
ADV_Type2= 6	MaterialChannel= 3	MaterialChannel= 4	MaterialChannel= 4	
ADV_Type3= 6	MaterialChannel= 2	MaterialChannel= 3	MaterialChannel= 3	

Multivariate Simulation

> 40 % material box reduction by fully digital planned logistics

Closing Thoughts & Outlook



Take aways

1

Power Electronics is the key enabler for the transition to sustainable energy systems. Digitalization & AI in Power Electronics are driving sustainability.

2

Sustainability is assuming a full life cycle approach – Cradle-to-Cradle

3

R&D plays the fundamental role – from dematerialization to sustainable business models. Digitalization & AI are the main levers.

4

For these reasons, we focus on the **4S-approach** – **Sustainability, Scalability, Smartness and Speed**

System complexity is increasing.

➤ Together with our strong Research & Innovation Ecosystem we are excellently positioned to reach our Sustainable Development Goals!



RIE Co-creation

Contact

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