# DIGITAL BUILDING TWINS

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Industry 4.0

Digital Commissioning

Co-Simu-lation

Digital Twin

Software in the Loop

Internet of Things (IoT)

Hard-ware in the Loop
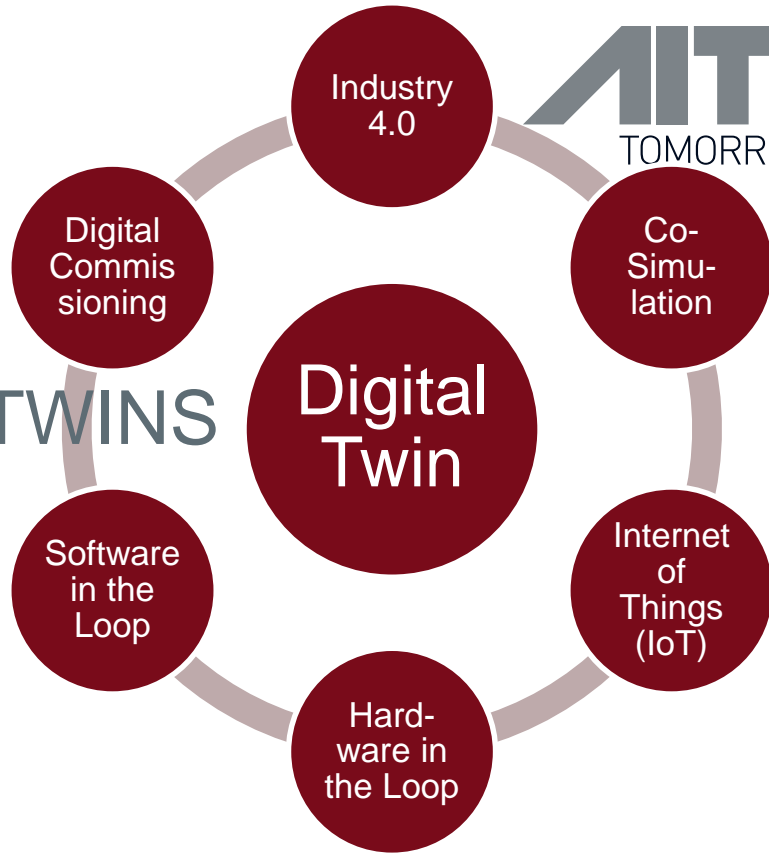
# DIGITAL TWIN

- Digital Twins originate from industrial production
- Virtual counterpart of a physical system
  - Kopplung Modellsimulation mit realen Betriebsdaten
  - Often runs in cloud
- Ingredients
  - Models
  - Simulations
  - Algorithms
  - Knowledge
  - Operation Data
- Lifespan: design – construction – operation
- Typical applications:
  - Optimize robot design
  - Determine optimal path
  - Diagnostics in operation (ageing)

# DIGITAL BUILDING TWINS IN INDUSTRY

Project DigiBatch

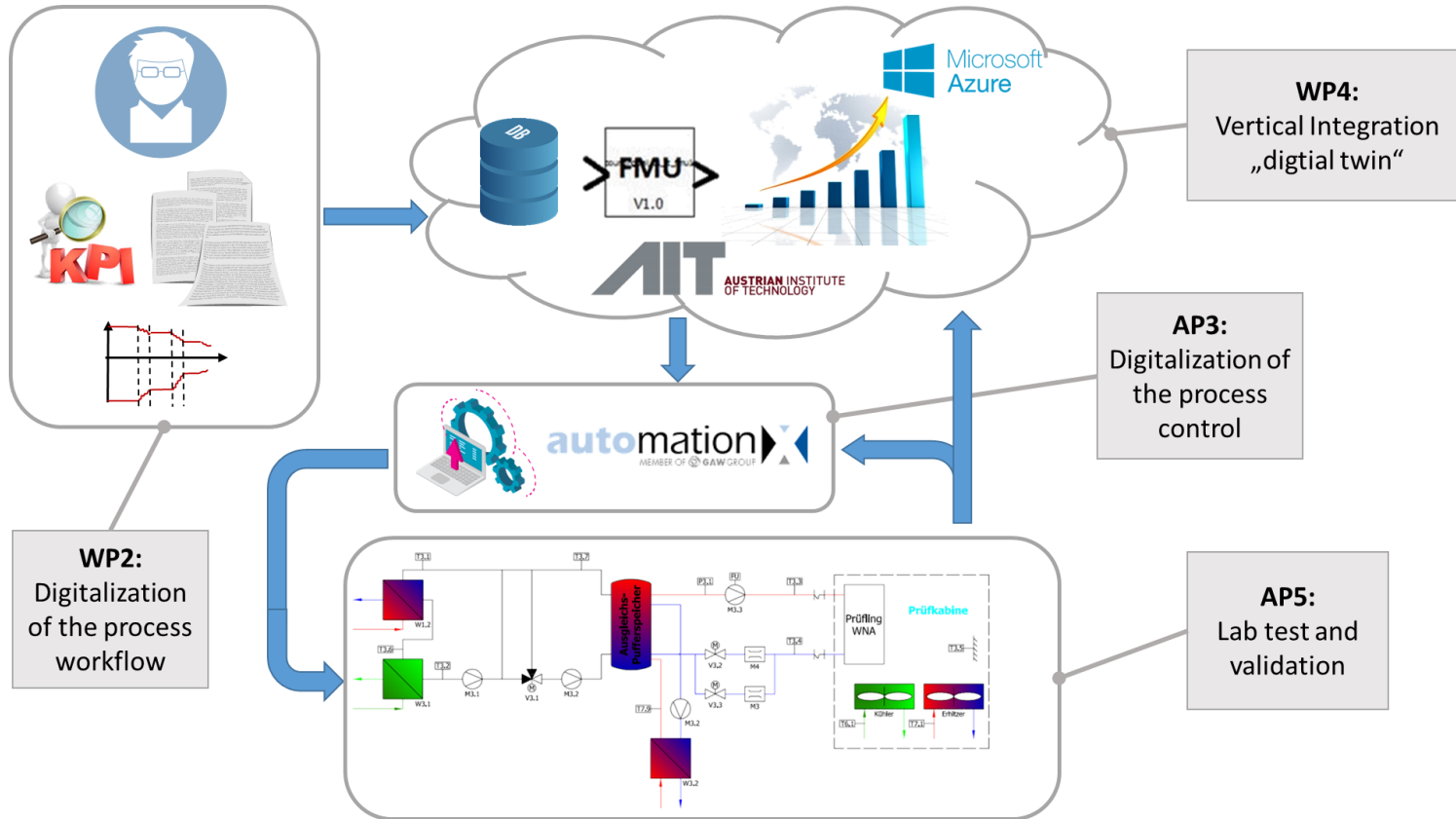Digitalization of Existing Recipe-oriented Production Systems in Process Industries

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TOMORROW TODAY

# PROJECT CONTEXT

- Digitalization of process industries
  - Flexibilization vs. continuous processes ("lot size of 1")
  - Optimized over a long period


- many (sub-)processes as batch
  - E.g. drying, sterilization, cooking, baking, casting…
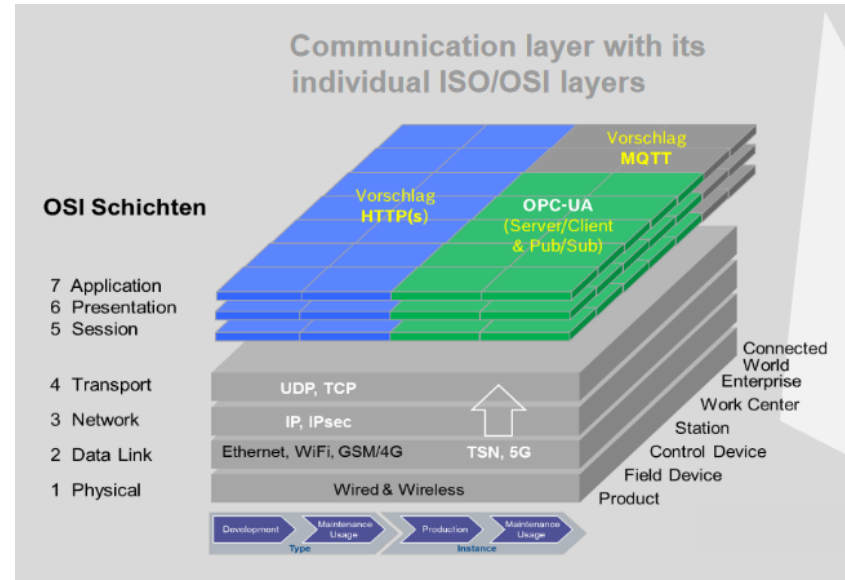  - Advantage through easy customization

# GOALS

- A showcase for further experimental development
  - Process optimization
  - Process recalibration

- Demonstrate Digital Twin consisting of
  - Knowledge base
  - Co-simulation
  - Cloud platform
  - Operation data

- Achieve quantifiable
  - Utilization
  - Availability
  - Energy efficiency
  - User intervention

WP4:
Vertical Integration „digtial twin"

AP3:
Digitalization of the process control

WP2:
Digitalization of the process workflow

AP5:
Lab test and validation

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# OPC UNIFIED ARCHITECTURE (OPC UA)

- OPC UA
    - is a data exchange standard
    - is a service oriented architecture (SOA)
    - has a security model, which is audited by the German BSI (Bundesamt für Sicherheit in der Informationstechnik)
    - is vendor neutral
- OPC UA can
    - Transport semantics with data
    - Publisher/Subscriber communication
    - Client/Server communication
    - Historical data access
    - Use Information Models (e.g. ISA-95)
    - Companion Models (e.g. BACnet)



https://www.plattform-i40.de/PI40/Redaktion/EN/Downloads/Publikation/rami40-an-introduction.pdf

# DIGITAL TWIN AND CLOUD INTEGRATION I

- The core process is modeled in Modelica/Dymola (FMU)
- Two time intensive iterative processes are identified
  - Hydraulic problem
  - Thermal problem

- A recommender system is setup
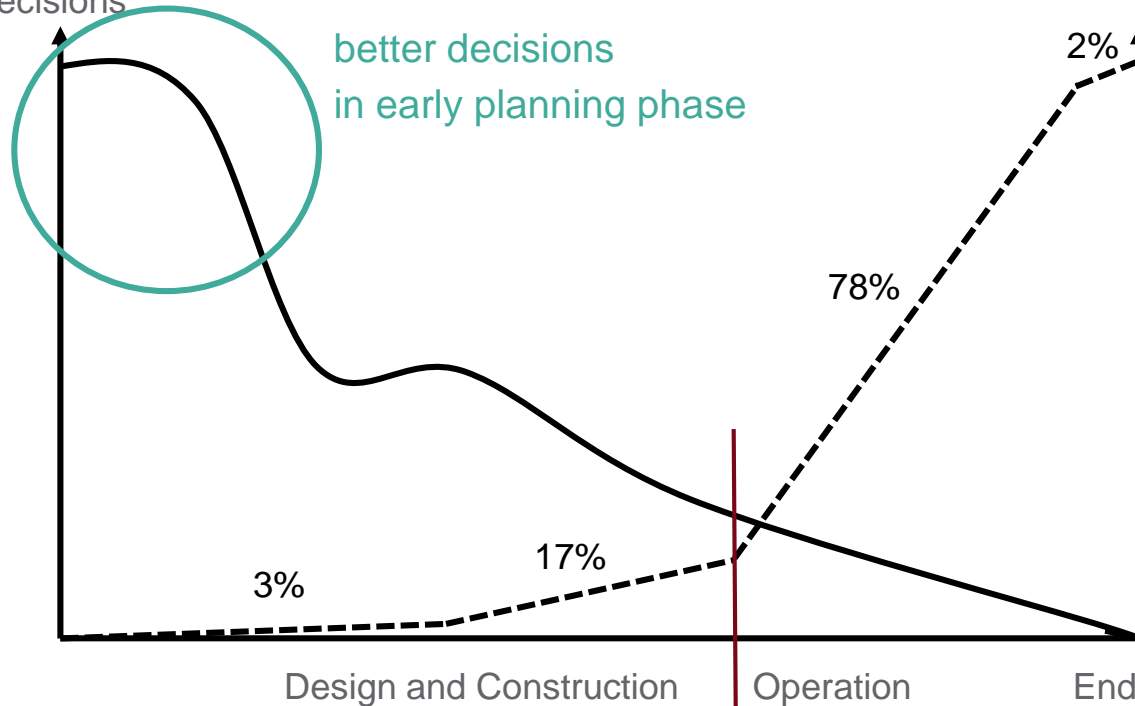  - Define target → simulate FMU → optimization → returns desired setpoint to the operator
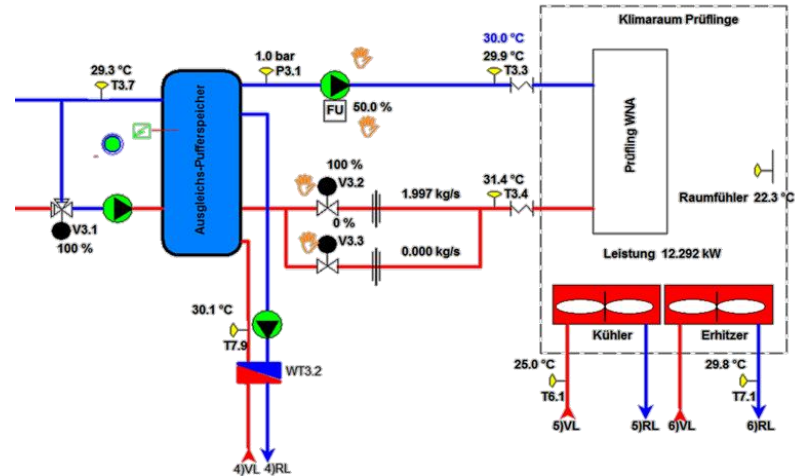
# DIGITAL BUILDING TWIN

# 80% OF COSTS IN BUILDINGS DURING OPERATION PHASE



Impact on Decisions

better decisions
in early planning phase

Costs in the Life Cycle

2%

78%

3%

17%

Design and Construction | Operation | End of Life

# BIM

## "**BIM as single source of truth in planning, construction and operation**"

- Tendering Evaluation (Digitale Baueinreichung)

- Model-based controller validation

- Semantic data analysis

- Procedural Design in HVAC

- Combination of
  - AI methods for clustering and identification
  - Open semantic interoperability standards
  - Heuristics
- Model transformations for domains
  - HVAC systems
  - Building Controls
  - Facility Management
- Machine learning framework
  - Model checking
  - Semi-automated model fixing
  - Extracting relevant substructures from the model (e.g. HVAC)

Tendering & Competition → Planning → Construction → Commissioning → Monitoring & Optimization

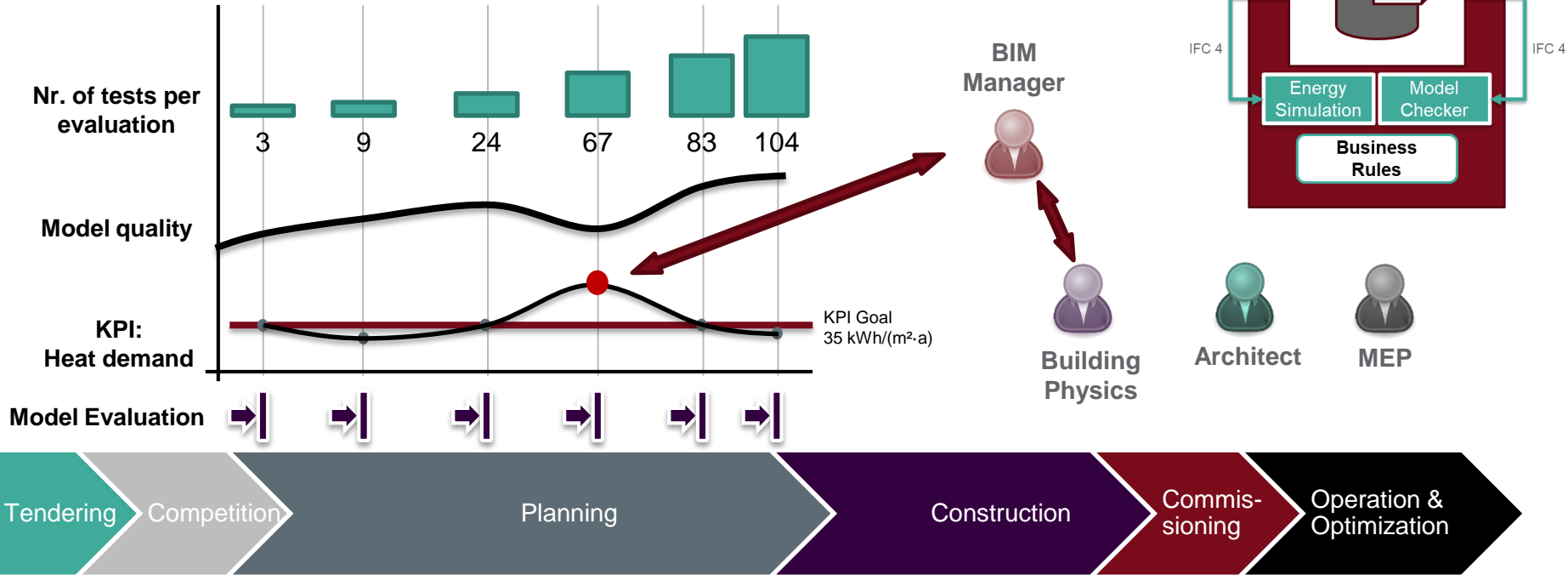# RESEARCH PROGRAM ON EUROPEAN LEVEL: „DIGITAL BUILDING TWINS"

**Scope: Develop a digital building twin – a real-time digital representation of a building or infrastructure**

- Go beyond the data provided through BIM

- Answer to the lack of open semantic interoperability standards between actual BIM and future BIM

- Automated progress monitoring allowing to verify that the completed work is consistent with plans and specifications

- Tracking of daily changes in an as-build model, allowing early detection of discrepancies

- Quality assessment by image processing technologies should allow verification of structure conditions and detection of cracks or material displacement

- Optimisation of equipment usage by advanced imaging and automatic tracking
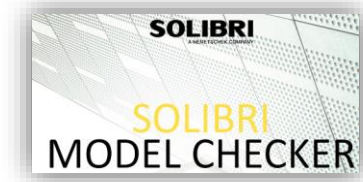
Budget: 5-6M€    TRL: 4-6    Research and Innovation Action (RIA)

# MODEL CHECKING IN BIM



Nr. of tests per evaluation

3    9    24    67    83    104

Model quality

KPI: Heat demand

KPI Goal
35 kWh/(m²·a)

Model Evaluation

Tendering | Competition | Planning | Construction | Commissioning | Operation & Optimization

BIM Manager

Building Physics

Architect

MEP

Business Logic Platform

BIM

IFC 4    IFC 4

Energy Simulation | Model Checker

Business Rules

# METHODS FOR BIM MODEL CHECKING

- IFC-based rule definitions
  - Solibri model checker
  - E. g. „is the building envelope complete?"

- Thermal simulation
  - EnergyPlus
  - CYPE
  - IDA ICE
  - AIT Building Model Generator
  - E.g. „What is the thermal load of the current design?"

# CONTROLLER-IN-THE-LOOP (CIL)
# DIGITAL TEST-RIG FOR BUILDING CONTROLS



**Thermische Simulation**

**Gebäudeleittechnik**

source: www.sauter.com
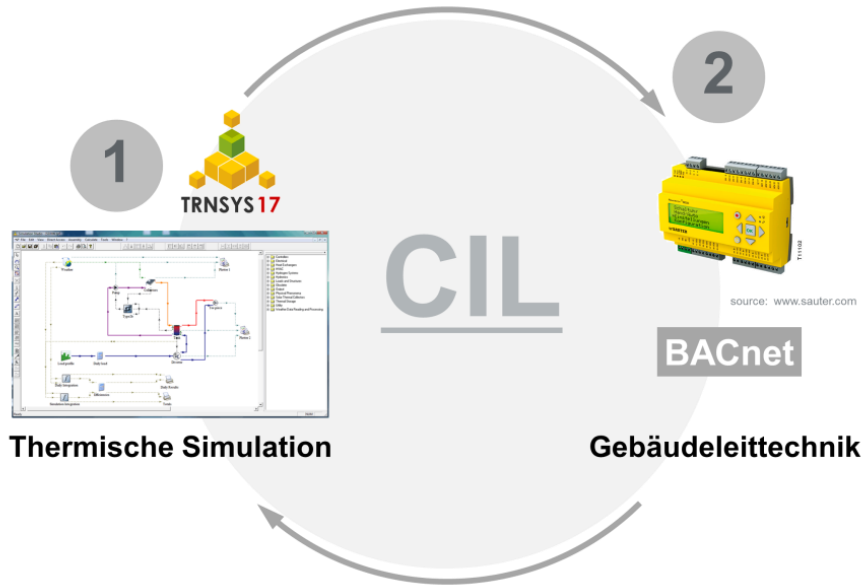
BACnet

Methods

- Co-simulation (Ptolemy II)
- TRNSYS system simulation
- Building automation protocols
  - BACnet, Modbus, …
- Real-time coupling of simulation and hardware

# CONTROLLER-IN-THE-LOOP (CIL) DIGITAL TEST-RIG FOR BUILDING CONTROLS



**Headquarter Post, Vienna:**

- Check and optimize control strategies

- Reduced commissioning time for building controllers

- Early identification of bugs before real-world operation (e.g. during part load operation)
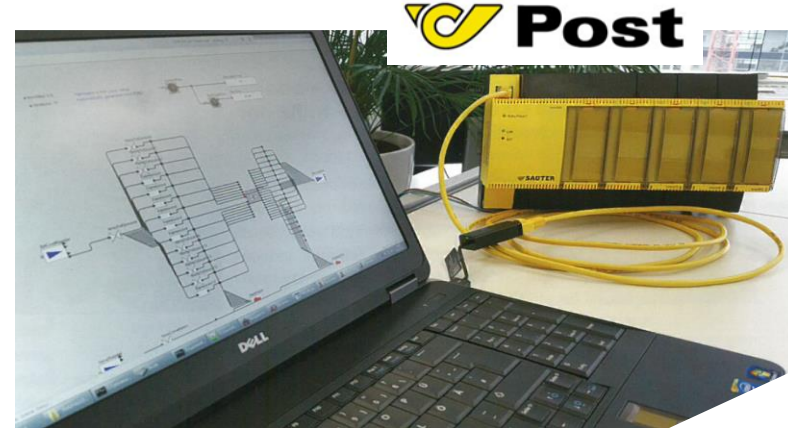
# SUMMARY

Digital Twin in Buildings

- Enables coupling of domain specific tools
  - Thermal simulation
- Enables linking of design and operation data
  - Living energy certificate
- Is a source of data for city and infrastructure

- Requires:
- Avoiding re-design of models in the workflow
- Thorough quality checking:
  - Validity
  - Consistency
- Improved standardization of parameters

# THANK YOU

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