DIGITAL BUILDING TWINS

What we can learn from Industry

Gerhard ZUCKER

AIT Austrian Institute of Technology

Industry 4.0

Co-Simu-lation

Digital Commis sioning

Digital Twin

Internet of Things (IoT)

Software in the Loop

Hard-ware in the Loop
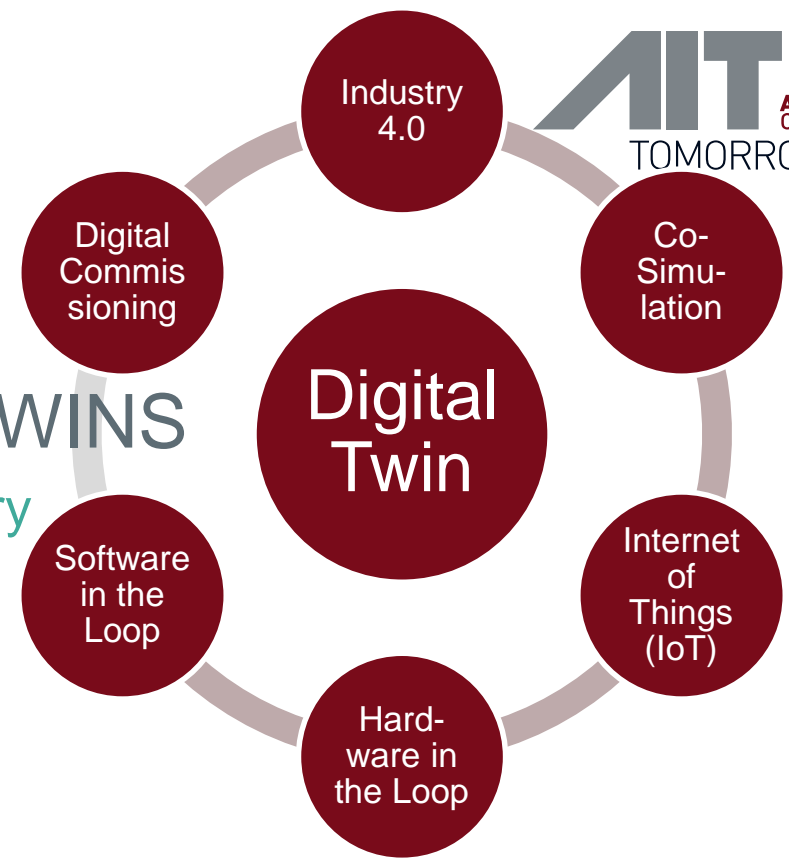
AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

AIT Austrian Institute of Technology

Seibersdorf Labor GmbH

Nuclear Engineering Seibersdorf GmbH

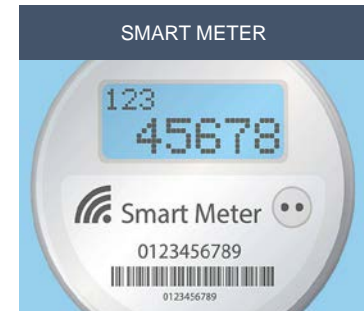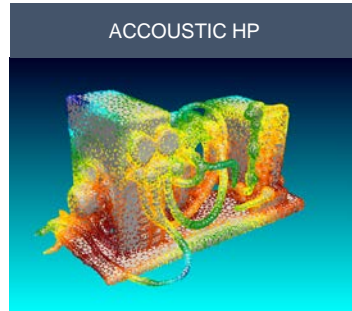|			
Energy	Health & Bioresources	Digital Safety & Security	Vision, Automation & Control
Mobility Systems	Low-Emission Transport	Technology Experience	Innovation Systems & Policy

RESEARCH IN BUILDING TECHNOLOGIES

AIT offers profound knowledge and infrastructure for research, development and testing of energy technologies for buildings. Amongst others these are:

HEAT PUMPS / AIR CONDITIONING UNITS

ACCOUSTIC HP

THERMAL STORAGES

PHOTOVOLTAICS

SMART GRID

BATTERY STORAGE

CHARGING INFRASTRUCTURE

SMART METER

DIGITAL TWIN

- Digital Twins originate from industrial production
- Virtual counterpart of a physical system
  - Coupling simulation with real world operation data
  - 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
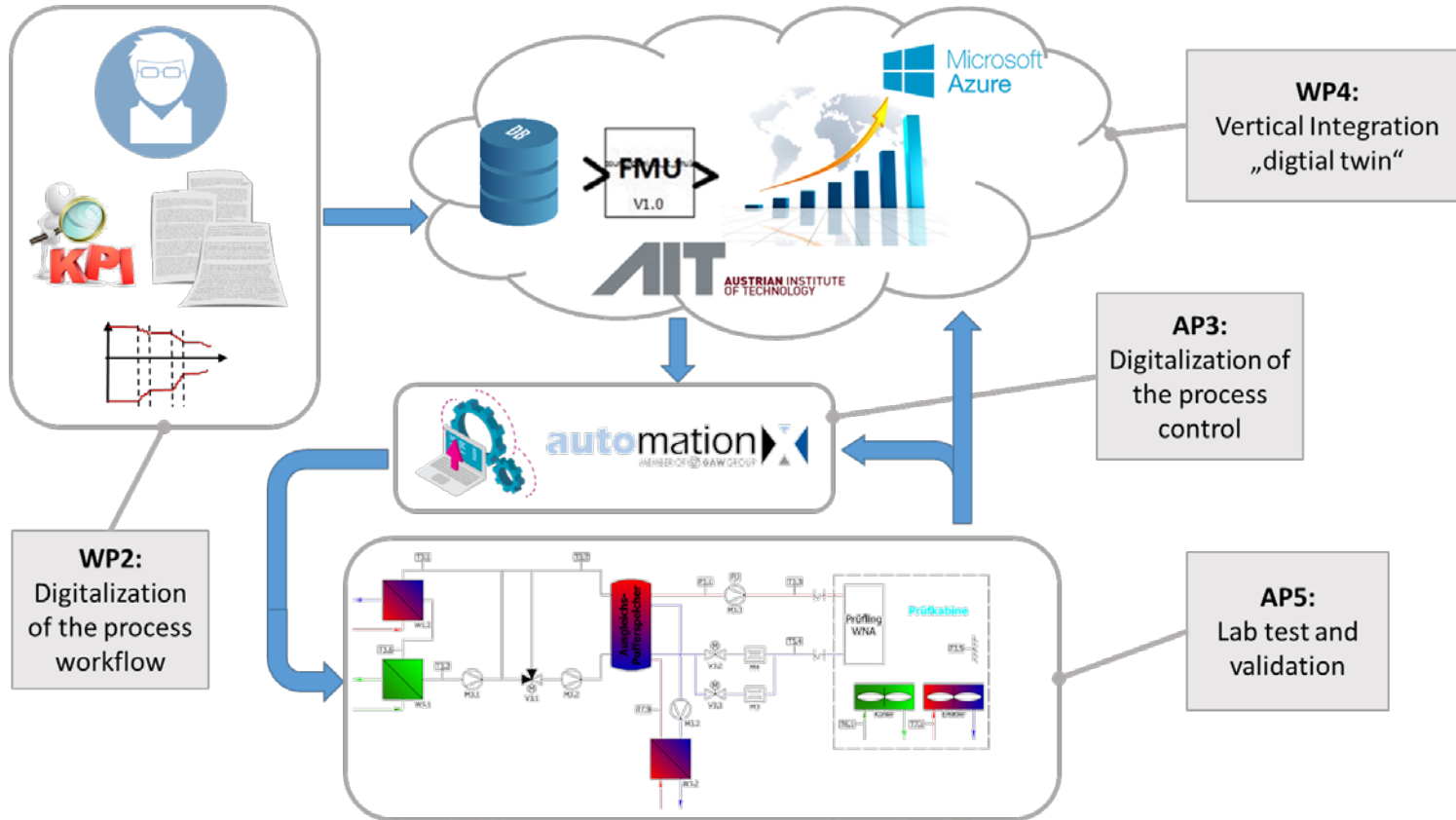
PROJECT CONTEXT

- 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…
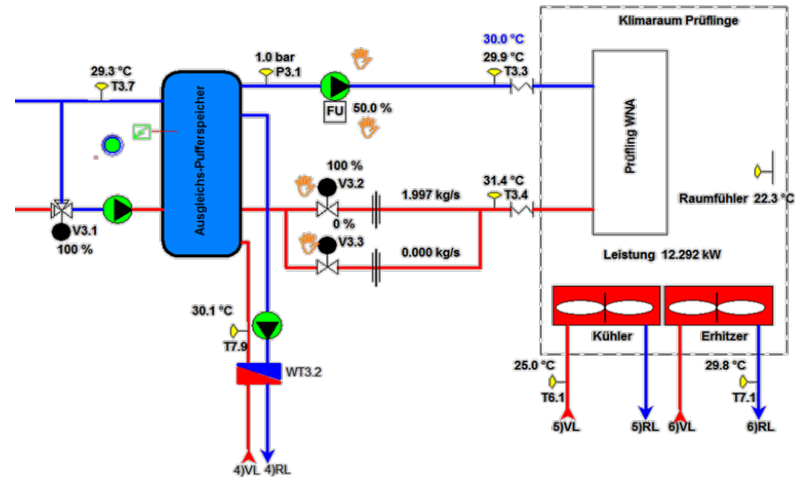 - Advantage through easy customization

GOALS OF THE DIGITAL TWIN

- 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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DIGITAL TWIN AND CLOUD INTEGRATION

- 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
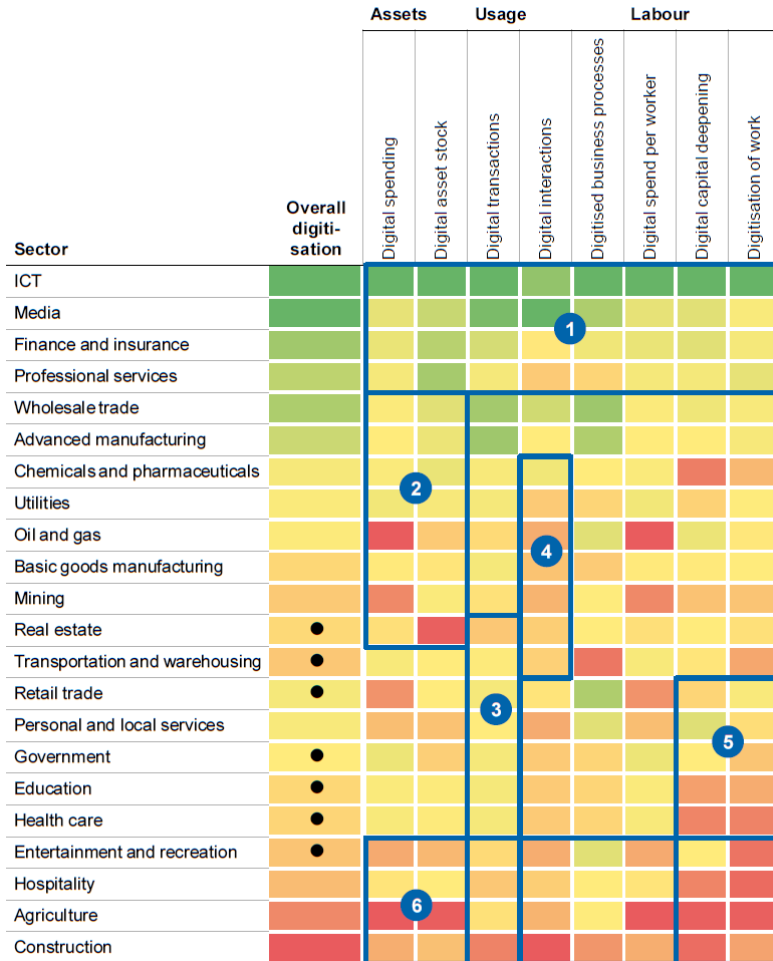 - Define target → simulate FMU → optimization → returns desired setpoint to the operator

DIGITAL BUILDING TWIN

Âre we there yet?

McKinsey: The MGI Industry Digitisation Index for Europe

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Sector	Overall digiti-sation	Assets — Digital spending	Assets — Digital asset stock	Usage — Digital transactions	Usage — Digital interactions	Usage — Digitised business processes	Labour — Digital spend per worker	Labour — Digital capital deepening	Labour — Digitisation of work
ICT									
Media					①				
Finance and insurance									
Professional services									
Wholesale trade									
Advanced manufacturing									
Chemicals and pharmaceuticals		②							
Utilities									
Oil and gas					④				
Basic goods manufacturing									
Mining									
Real estate	●								
Transportation and warehousing	●								
Retail trade	●			③					⑤
Personal and local services									
Government	●								
Education	●								
Health care	●								
Entertainment and recreation	●								
Hospitality									
Agriculture		⑥							
Construction									

Legend

Relatively low digitisation ———— Relatively high digitisation

● Digital disruptors within relatively less-digitized sectors

Cluster descriptions

① Knowledge-intensive sectors that are highly digitised across most dimensions

② Capital-intensive sectors with the potential to further digitise their physical assets

③ Service sectors with long tail of small firms having room to digitise customer transactions

④ B2B sectors with the potential to digitise their customer interactions

⑤ Labour-intensive sectors with the potential to provide digital tools to their workforce

⑥ Highly localised and fragmented sectors that lag across most dimensions

1 Value added as proxy for GDP; 15 countries used as proxy by EU-28.
2 EU-28.
NOTE: The level of sector digitisation measures digital assets, usage, and labour by sector. It does not refer to the intensity of digital competitive threat in a sector.

SOURCE: EU Klems; Eurostat; OECD; McKinsey Global Institute analysis

WHY THE LAG? AND WHAT TO DO ABOUT IT?

- Traditionally no IT affinity
- Multi-Stakeholder Processes: information boundaries
- Complexity

Solutions:
- „Good Practise" examples
- Standardization
- Education
- Testing and evaluation of digital models

BIM – BUILDING INFORMATION MODELING
"**BIM as single source of truth in planning, construction and operation**"

Applications

- Tendering Evaluation (Digitale Baueinreichung)

- Planning Support

- Procedural Design in HVAC

- Model-based controller validation

- BIM as a source for City Modeling (Urban Information Model UIM)

Methods

- 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

BIM IN THE CITY CONTEXT

Urban Information Model (UIM)

DIGITAL ECOSYSTEM: EXISTING COMPONENTS

Buildings and Housing Register Austria (Gebäude und Wohnungsregister – GWR)

Central register for statistics, research and planning; local register for administration and local research

existing

Under development

New paths / research

Grids

Neigborhood

Building register (GWR)

Building / Building parts

Position / Address

Geometry / Topology

Attributes (static)

Function (dynamic)

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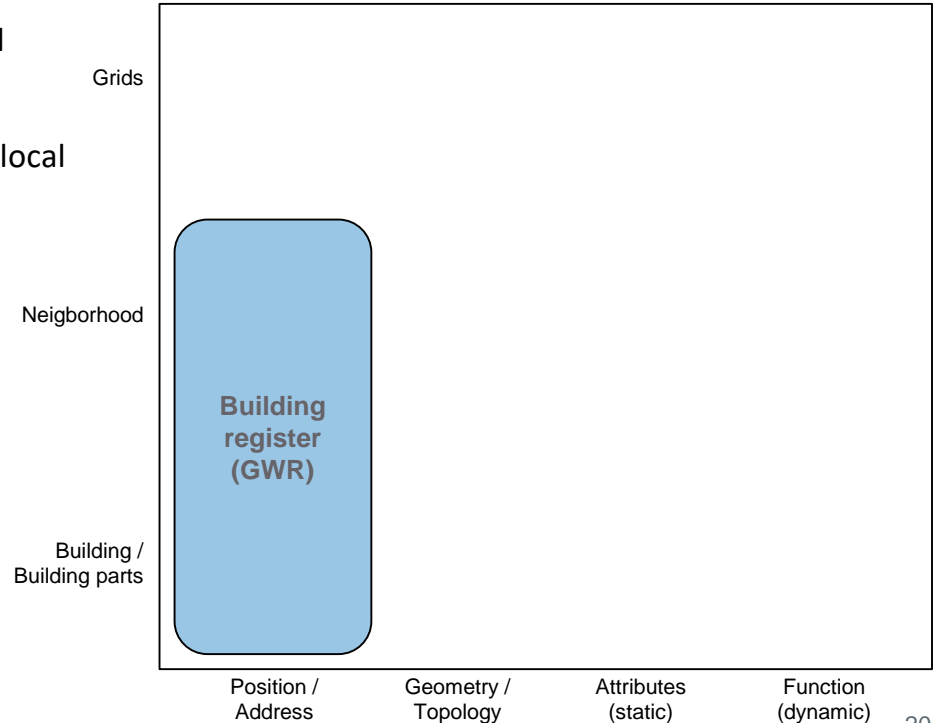
DIGITAL ECOSYSTEM: COMPONENTS UNDER DEVELOPMENT

Building Information Modeling (BIM)

Central virtual building model for all data throughout the life cycle, including additional metadata

technical documentation, equipment, architecture, structural engineering data; operation data, maintenance scheduling information

https://www.solar-computer.de/index.php?seite=BIM&sub=SOLAR-COMPUTER-BIM-plattform
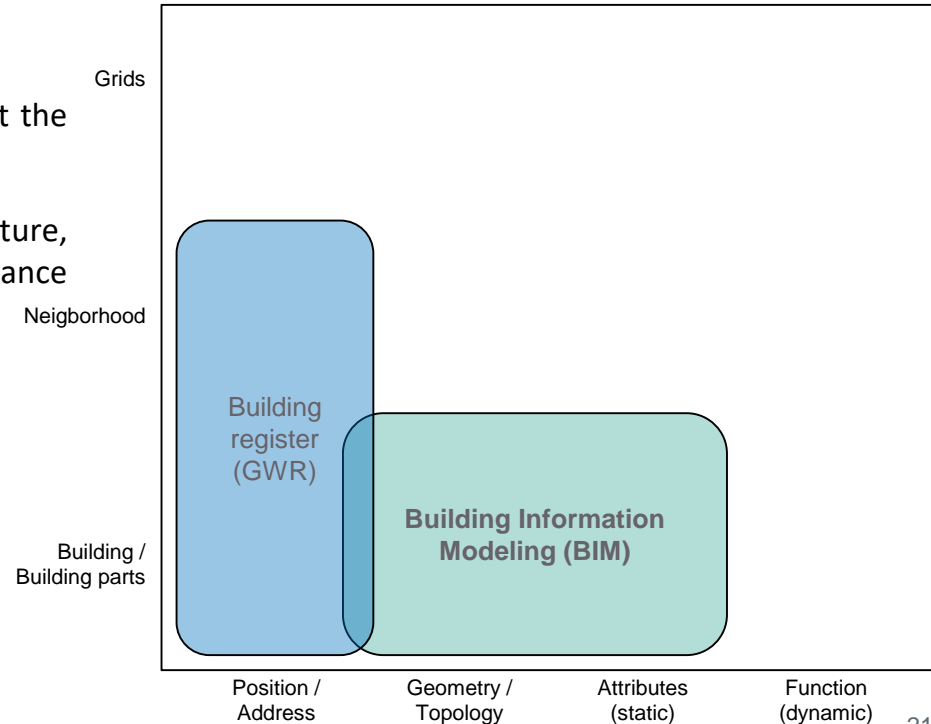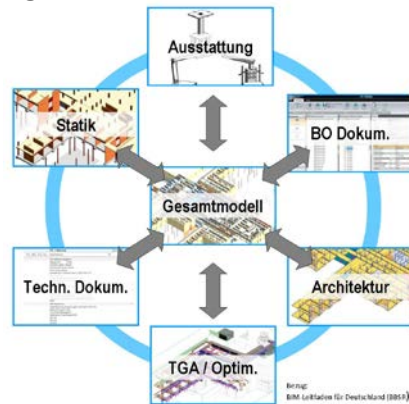
DIGITAL ECOSYSTEM: COMPONENTS UNDER DEVELOPMENT

Urban Information Model (UIM)

Central virtual city model throughout the life cycle. Acts as an interface and database for the different areas

Heat emissions, solar irradiation, utility networks, thermal remote sensing, solar potential, heating energy requirements

https://www.gis.bgu.tum.de/projekte/3dcitydb/
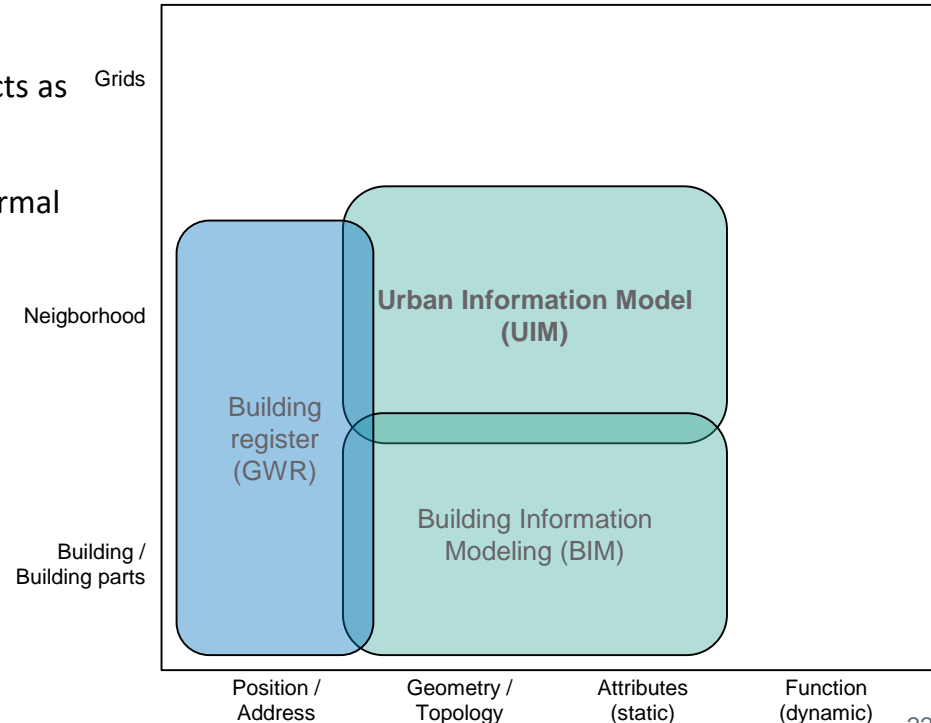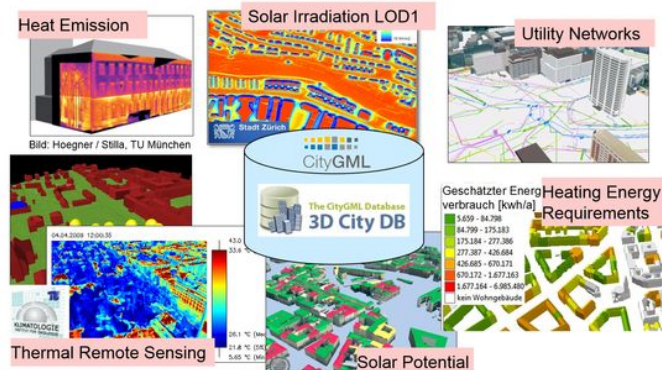
DIGITAL ECOSYSTEM: COMPONENTS UNDER DEVELOPMENT

GIS-based Grid Models

Models of suppy grids (eletric, district heating, gas, water, waste water), including analysis of local heat demand density and heat sources

https://heatroadmap.eu/peta4/

https://www.4dh.eu/images/Joseph_Maria_Jebamalai_2018.pdf
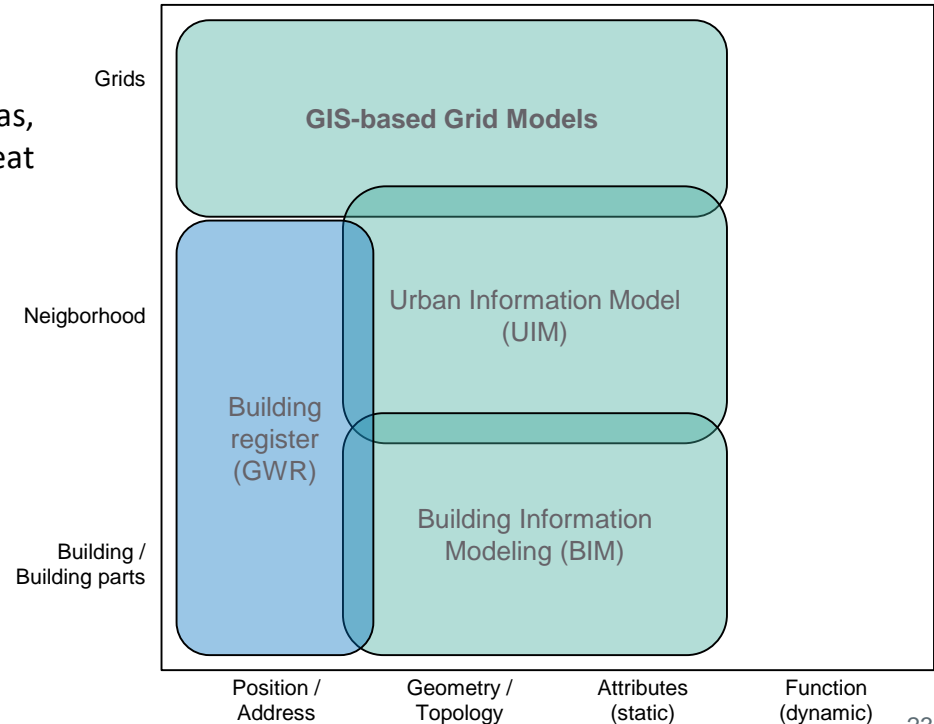
DIGITAL ECOSYSTEM: NEW PATHS AND RESEARCH

Dynamic Grid Simulation

Dynamic grid simulation: development of control strategies and validation of real-world load flows, simulation models for predictive controls

Operation management system: online or real-time mode, integration into SCADA systems, operation data monitoring, component controllers


http://7t.dk/products/termis/Product-Information/termis-simulation-modes.aspx
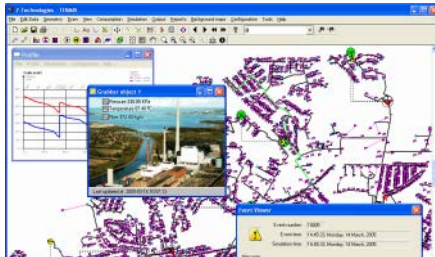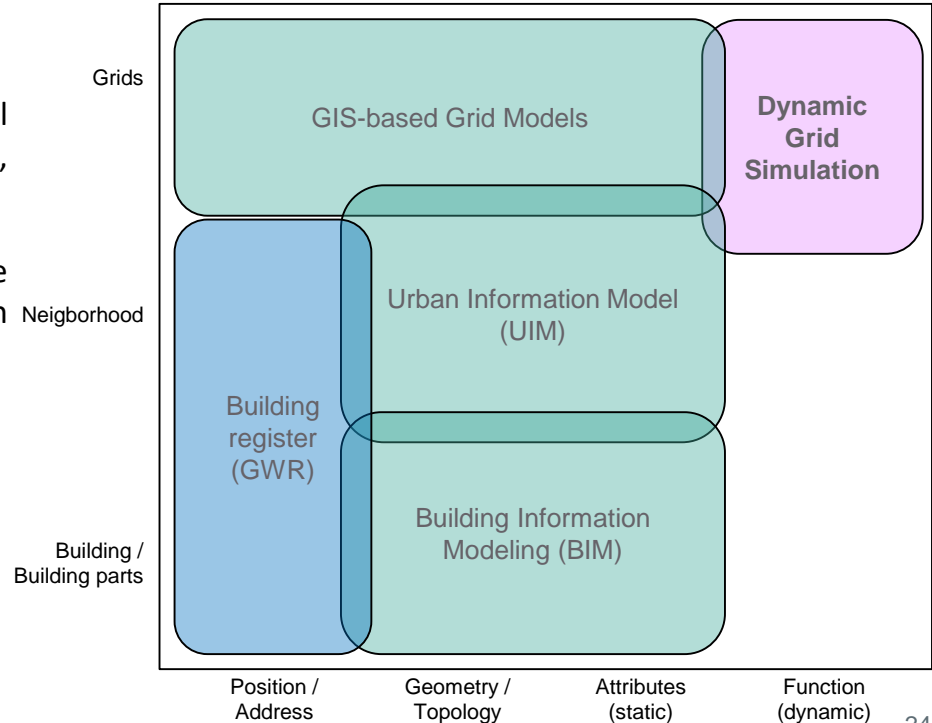
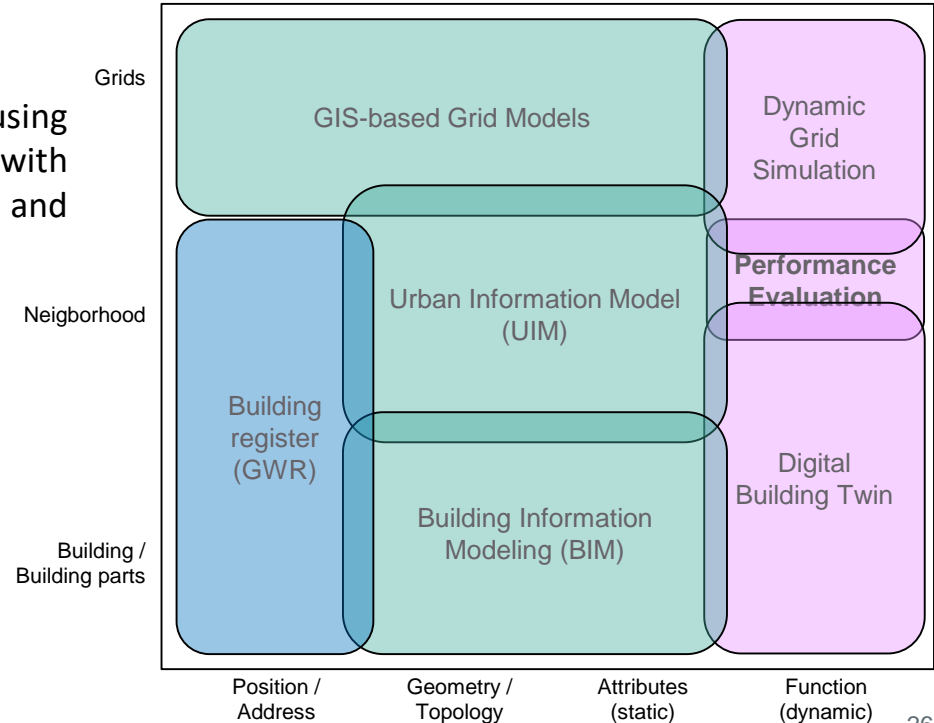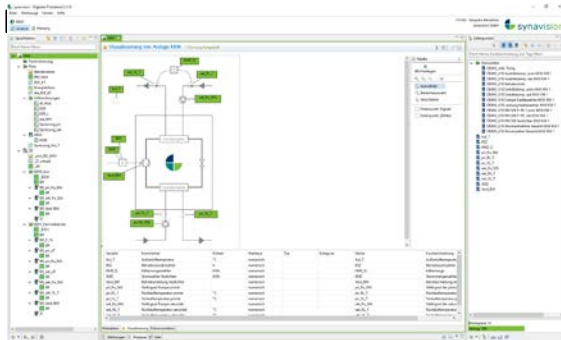# DIGITAL ECOSYSTEM: NEW PATHS AND RESEARCH

Digital Building Twin

BIM-based as-built model reflecting the current state of the building (not the planning state). Contains static data (architecture, components, …), thermal models for simulation as well as historic and current energy consumption data,

https://www.autodeskresearch.com/projects/dasher
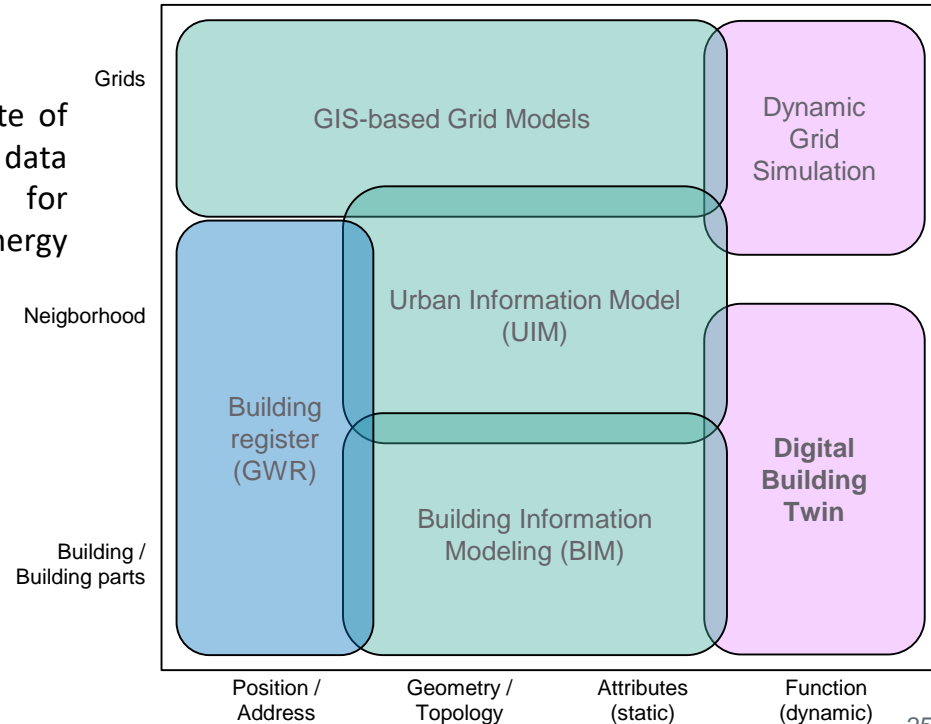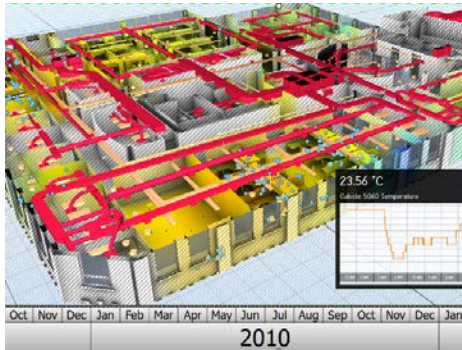
DIGITAL ECOSYSTEM: NEW PATHS AND RESEARCH

Performance Evaluation

Performance Evaluation and Benchmarking using baseline data from planning and compare them with actual performance data of buildings and neighborhoods

Grids

GIS-based Grid Models

Dynamic Grid Simulation

Neigborhood

Urban Information Model (UIM)

Performance Evaluation

Building register (GWR)

Building / Building parts

Building Information Modeling (BIM)

Digital Building Twin

Position / Address | Geometry / Topology | Attributes (static) | Function (dynamic)

APPLICATION USE CASES

Dynamic Energy Certificate

- On building level
- On city level

Planning and optimization of district heating grid

Local energy planning of photovoltaics production focusing on on-site energy usage
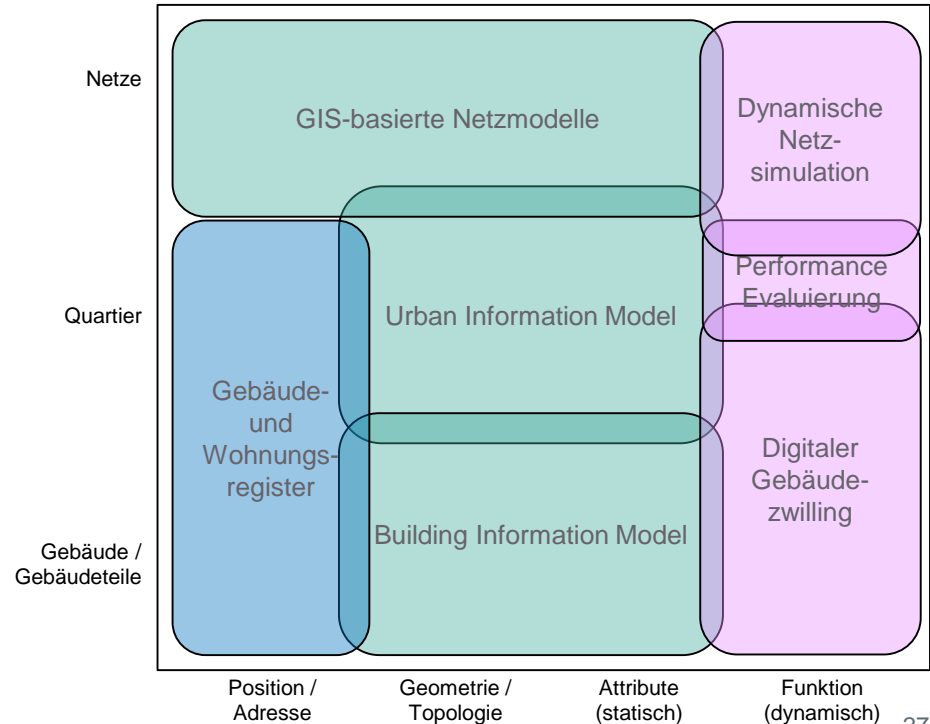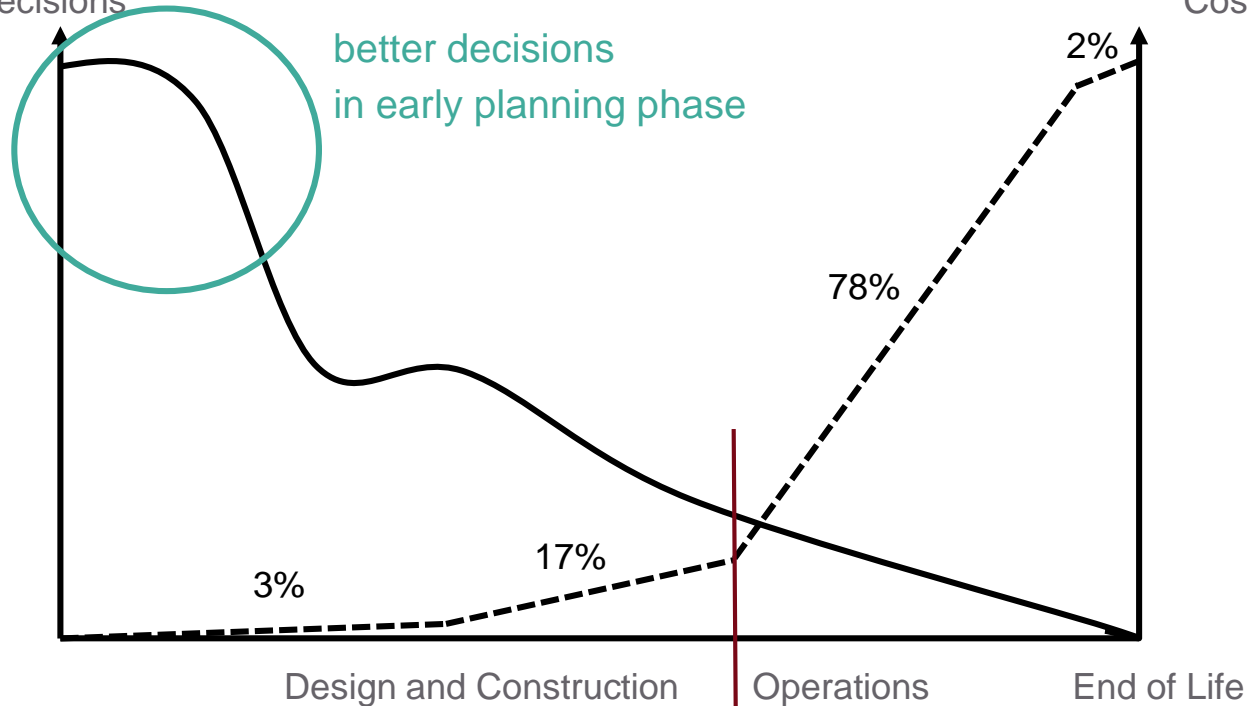
DIGITAL BUILDING TWIN

Ongoing Research

80% OF COSTS IN BUILDINGS DURING OPERATION PHASE

Impact on Decisions

Costs in the Life Cycle

better decisions
in early planning phase

2%

78%

17%

3%

Design and Construction | Operations | End of Life
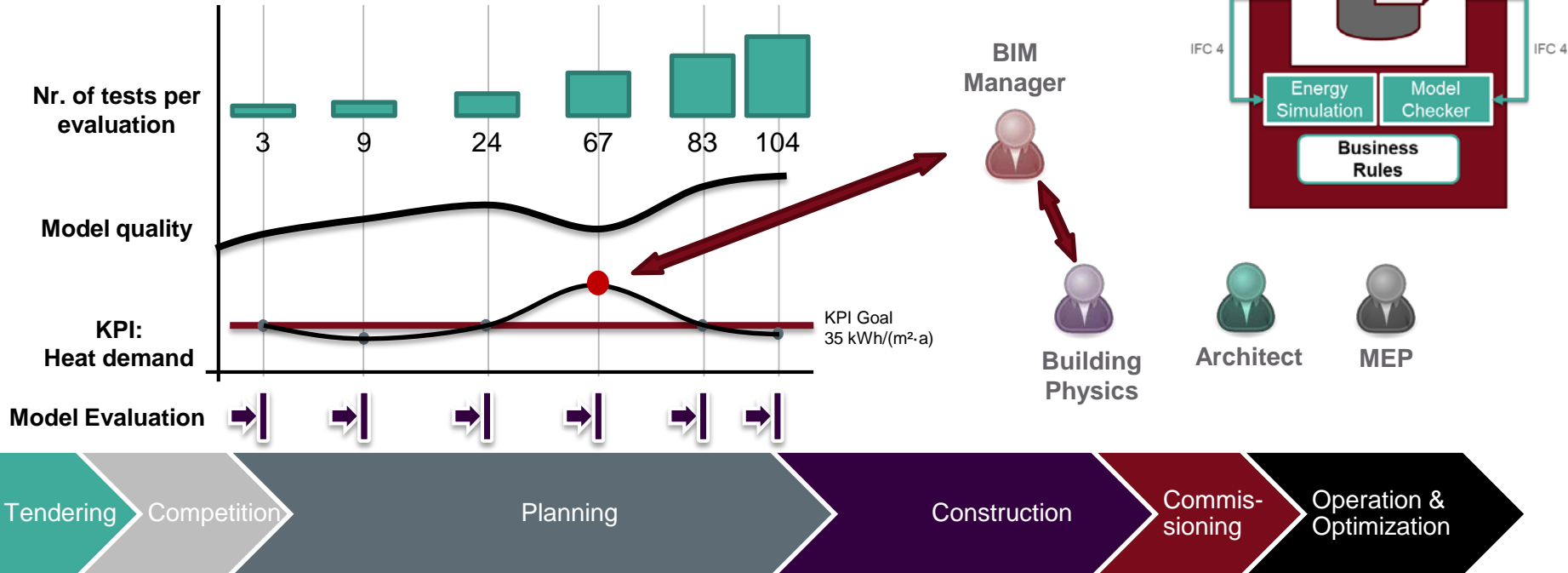
BUILDING MODEL CHECKING

Project BIMSaves Energy

MODEL CHECKING IN BIM

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
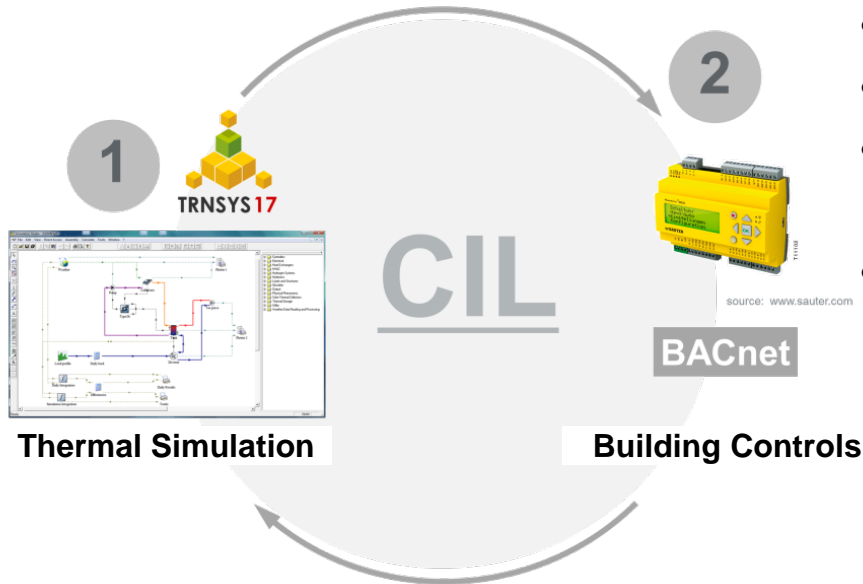 - E.g. „What is the thermal load of the current design?"

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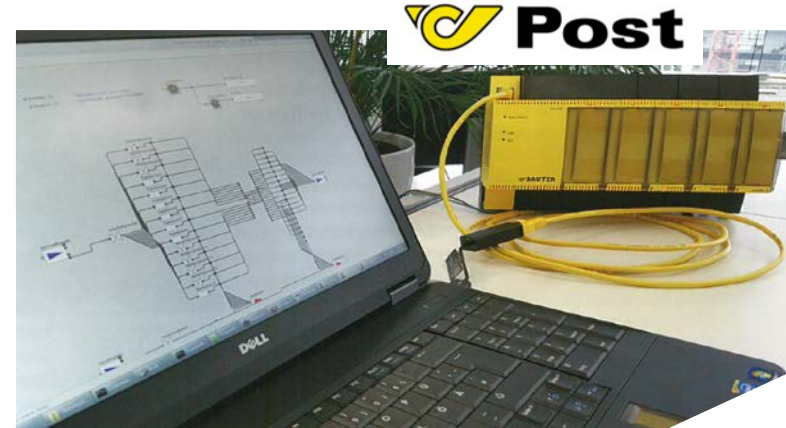

Thermal Simulation   **Building Controls**

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
  - Urban Information Model (UIM)

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

THANK YOU

Gerhard ZUCKER

gerhard.zucker@ait.ac.at