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Leveraging the energy data space for deploying Digital Twins and big data AI services to speed up energy transition

The emerging physics-enhanced closed loop Digital Twin for Smart Energy Grids

Charukeshi Joglekar, Fraunhofer Center Digital Energy, Fraunhofer FIT

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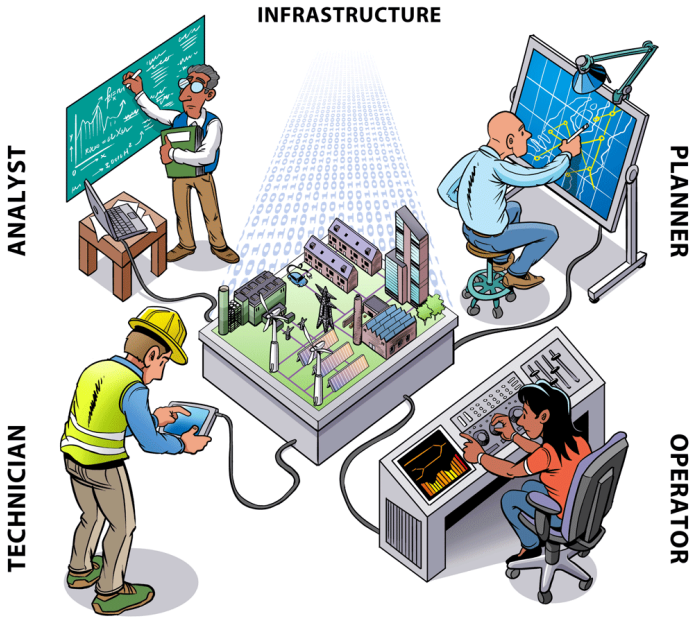
- Research Associate at **Fraunhofer Center for Digital Energy, Fraunhofer FIT**
- Energy System Digitalization
- Smart Grid Resilience
- Energy Data Spaces

Digital Twins(DTs) for Smart Energy Grids

CHALLENGES

- Lack of **consensus on the definition** of digital twin and its functionalities
- **Insufficient synchronization** of digital models/replicas **with real assets**
- **Lack of concrete reusable DTs implementations** at pan-European level

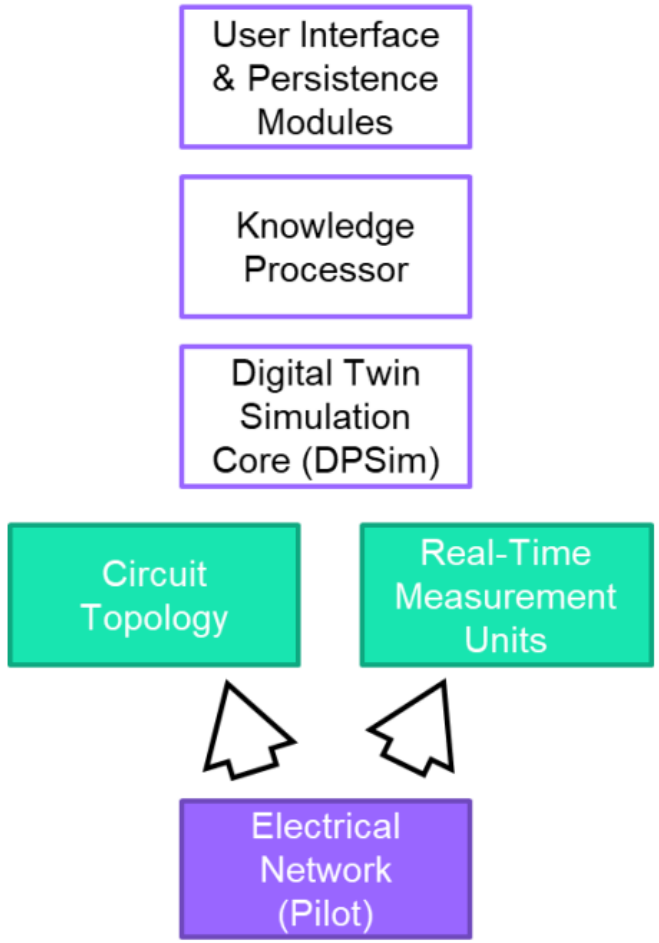
DIGITAL TWINS: APPLICATIONS FOR THE ENERGY SYSTEM



Source: Palensky P, Cvetkovic M, Gusain D and Joseph A. Digital twins and their use in future power systems [version 2; peer review: 2 approved]. Digital Twin 2022, 1:4 (https://doi.org/10.12688/digitaltwin.17435.2)

Use cases for DTs

- Operation and Maintenance
- Flexibility and capacity planning
- Cyber-physical resilience assesment and enhancement
- And more….

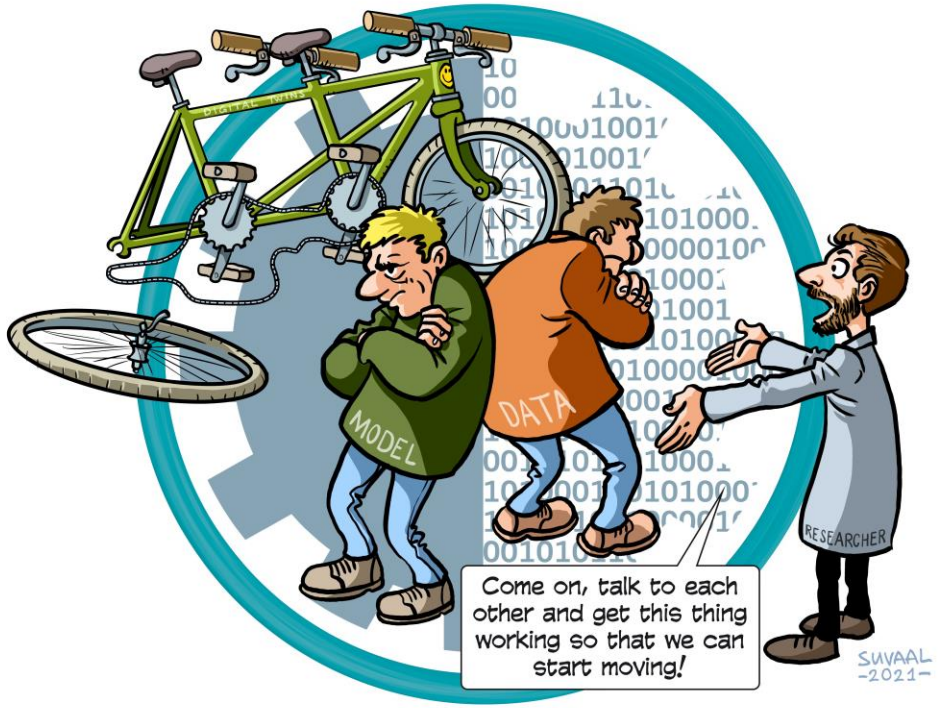


High-level architecture of the DT for flexibility in electrical networks
Source: Enershare Project

Challenges for DTs for Smart Energy Grids

FURTHER CHALLENGES

- Lack of an agreed standardizable approach to grid modelling which fits to everybody
- Insufficient understanding of Interoperable Digital Twins as an effective way to support cross-stakeholder cooperation and respective data sharing and exchange
- A DT needs also interfaces outside the energy sector to cover challenges such as resilience assessment and planning and then a link between a European DT and a European Energy Data Space is critical
- DT cannot be simply developed but needs to be tested at an unprecedented scale



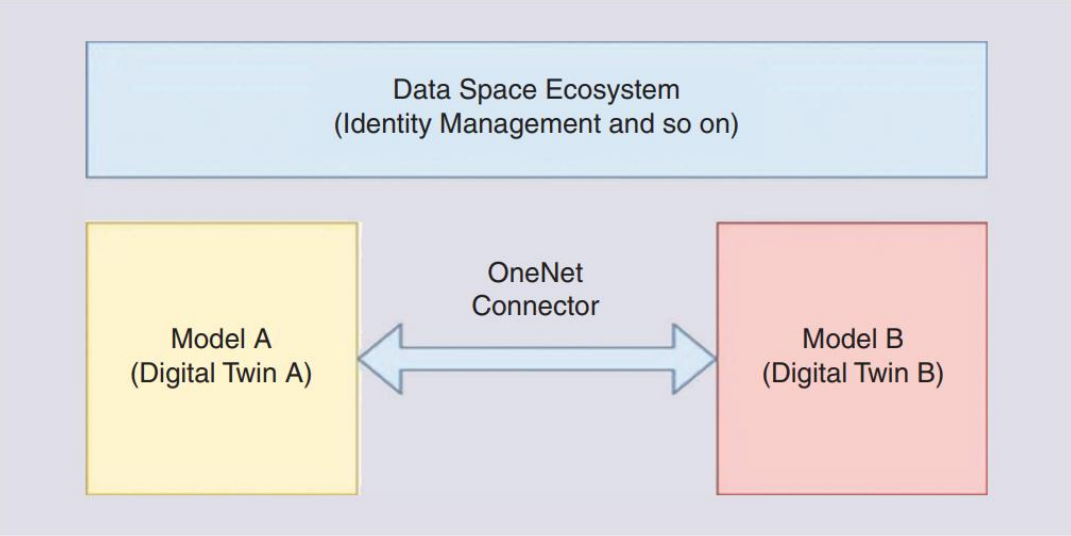
Source: TU Delft

TwinEU approach

DEFINITION

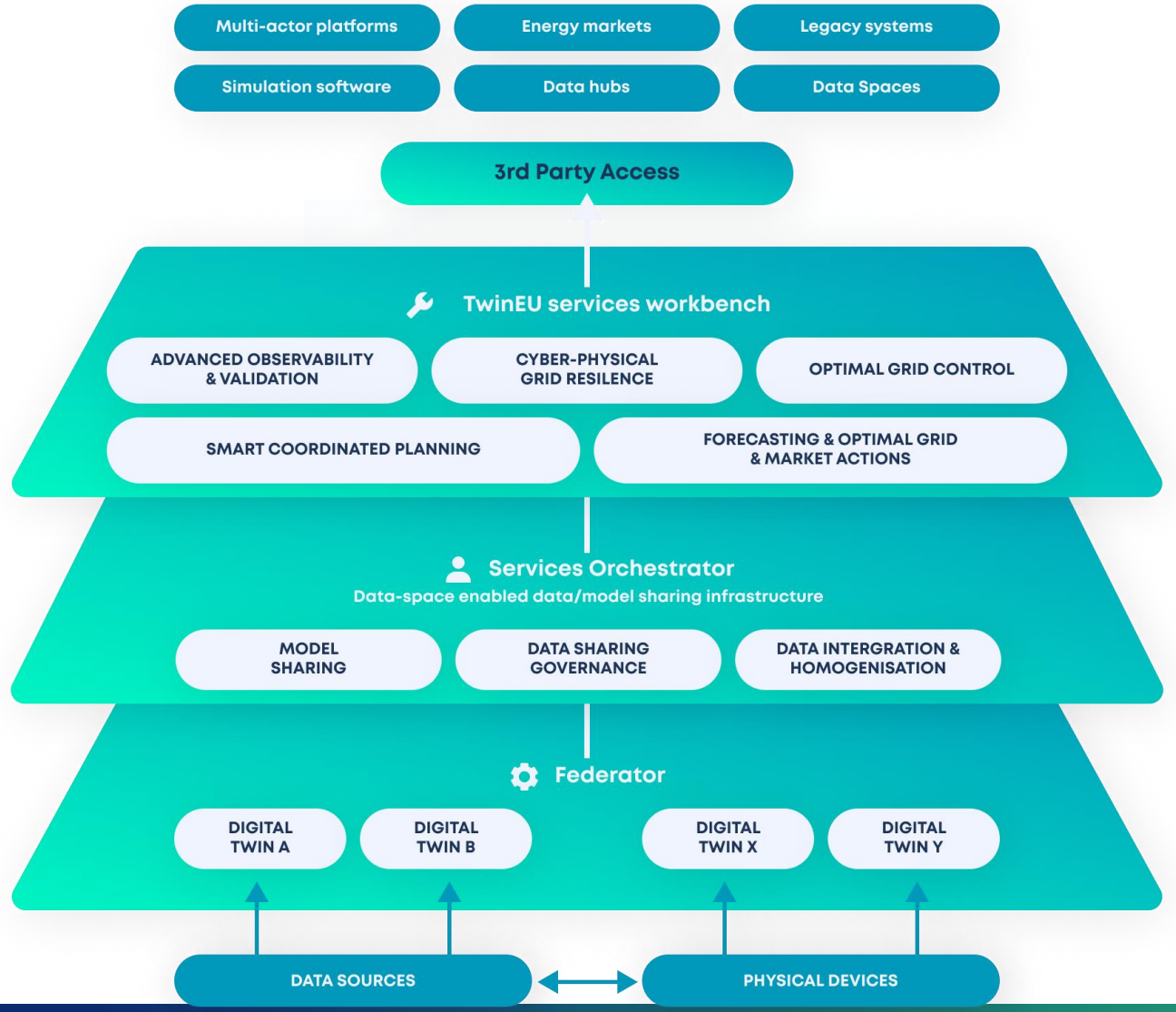
- Model of an electrical system of components
  - Supported by appropriate data exchange
  - Capable of evolving over time
  - Reliable representation of the system

THE DATA SPACE FEDERATION



Source: A. Monti, B. Dolley, P. Palensky and A. Parisot, "Building a Digital Twin for European Energy Infrastructure: The role of open source," in IEEE Electrification Magazine, vol. 12, no. 3, pp. 78-84, Sept. 2024, doi: 10.1109/MELE.2024.3423168.
keywords: {Europe;Standardization;Electrification;Digital twins;Power grids;Smart grids;Electricity supply industry},

TwinEU Approach



Path ahead

- **Define a set of scenarios** for the use of digital twin that will benefit from **data sharing and exchange among operators (intra and cross-country**) and the corresponding requirements for implementation.
- Define and implement a **Reference Architecture for the creation of a European-scale Digital Twin**
- Define and implement a **federated digital twin**, consisting of a variety of **closed loop adaptive DT instances**, to support European-level wider replication
- Enhance **data models and semantic interoperability** to better support the digital twin use cases
- Leverage on and adapt the emerging concept of **energy data space** to **break data silos**
- Leverage advanced technologies such as **physics-informed AI** and **High-Performance Computing** to go beyond classical modelling approaches for digital twin
- Develop and deploy a variety of **DTs services** which will create the conditions for a more resilient and reliable European power network
- **Demonstrate** the TwinEU approach in **real scenarios validating the complete energy and data value chains**
- **Large adoption of the TwinEU approach** creating the condition for a real implementation at European scale.
- Creating the conditions for **the long-term sustainability development of the TwinEU vision** and open new business opportunities based on DT.

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Track ENERGY

Leveraging the energy data space for deploying Digital Twins and big data AI services to speed up energy transition

Marilena, Lazzaro

October 4, 2024, 9:00 – 10:00

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Technical Manager Iot Solutions and Digital Twin Research Area

Smart Buildings/DT applied to Buildings

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ENERGY

Integrating BIMs with Digital Twins for optimizing energy management in smart buildings

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Outline

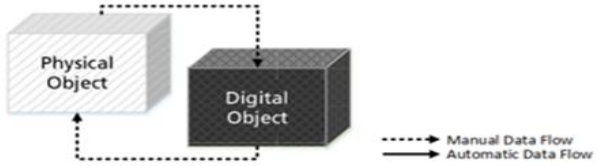
- Digital Twin concept
- DigiBUILD Digital Twin definition
- Overview of the DigiBUILD Digital Twin services
- Digital Twins key features and benefits

Digital Twin concept

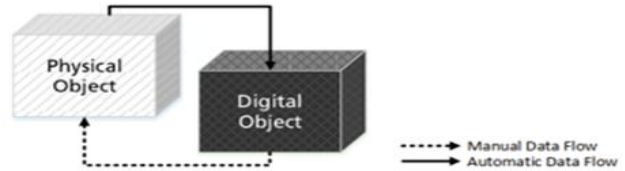
Krtizinger distinguishes between:

- Digital Model (DM) as a copy of a real or potential physical entity, without automated data exchange between the two.
- Digital Shadow (DS) if there's a one-way interaction where the physical system updates the digital model (monitoring system).
- Digital Twin (DT) involves a two-way automated interaction between the physical and digital entities.

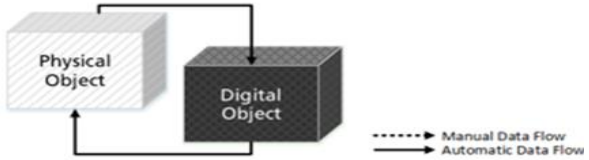
Digital Twin Consortium defines DT as a "virtualized representation of real-world entities and processes that is synchronized with a specified frequency and fidelity"



Digital Model



Digital Shadow



Digital Twin

Maturity element (logarithmic scale of complexity and connectedness)	Defining principle	Outline usage
0	– Reality capture *(e.g. point cloud, drones, photogrammetry, or drawings/sketches)*	– Brownfield (existing) as-built survey
1	– 2D map/system or 3D model *(e.g. object-based, with no metadata or BIM)*	– Design/asset optimisation and coordination
2	– Connect model to persistent (static) data, metadata and BIM Stage 2 *(e.g. documents, drawings, asset management systems)*	– 4D/5D simulation – Design/asset management – BIM Stage 2
3	– Enrich with real-time data *(e.g. from IoT, sensors)*	– Operational efficiency
4	– Two-way data integration and interaction	– Remote and immersive operations – Control the physical from the digital
5	– Autonomous operations and maintenance	– Complete self-governance with total oversight and transparency

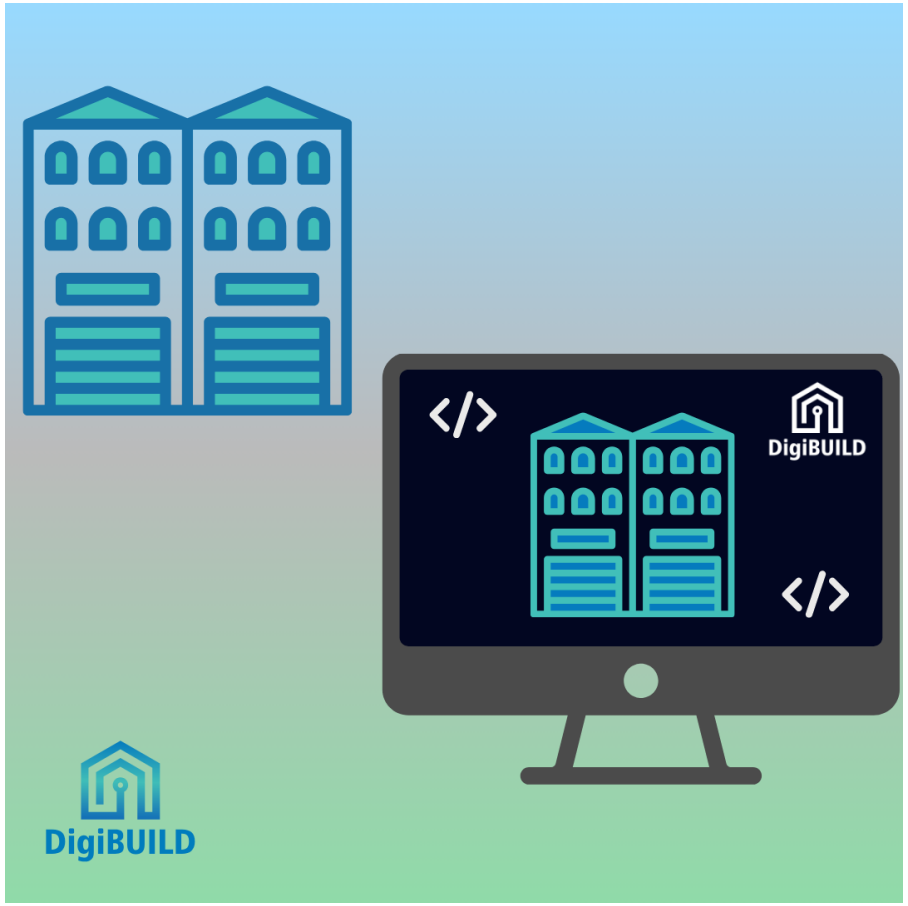
DigiBUILD

DigiBUILD Digital Twin

The DT in this project is conceived as **the virtual counterpart of a physical system.**

DigiBUILD DT **uses real-time and historical data** to represent the present and the past, **works as simulation environment for machine learning and optimisation techniques** to support the decision-making process and might also act as **controlling instance of the physical object**.

The possibility to implement the control of the physical object is strictly related to **the level of integration between the physical system and its virtual representation that is addressed by defining different level of maturity.**



Overview of the DigiBUILD Digital Twin services

DigiBUILD Digital Twins are based on high-quality data and data-driven services for:

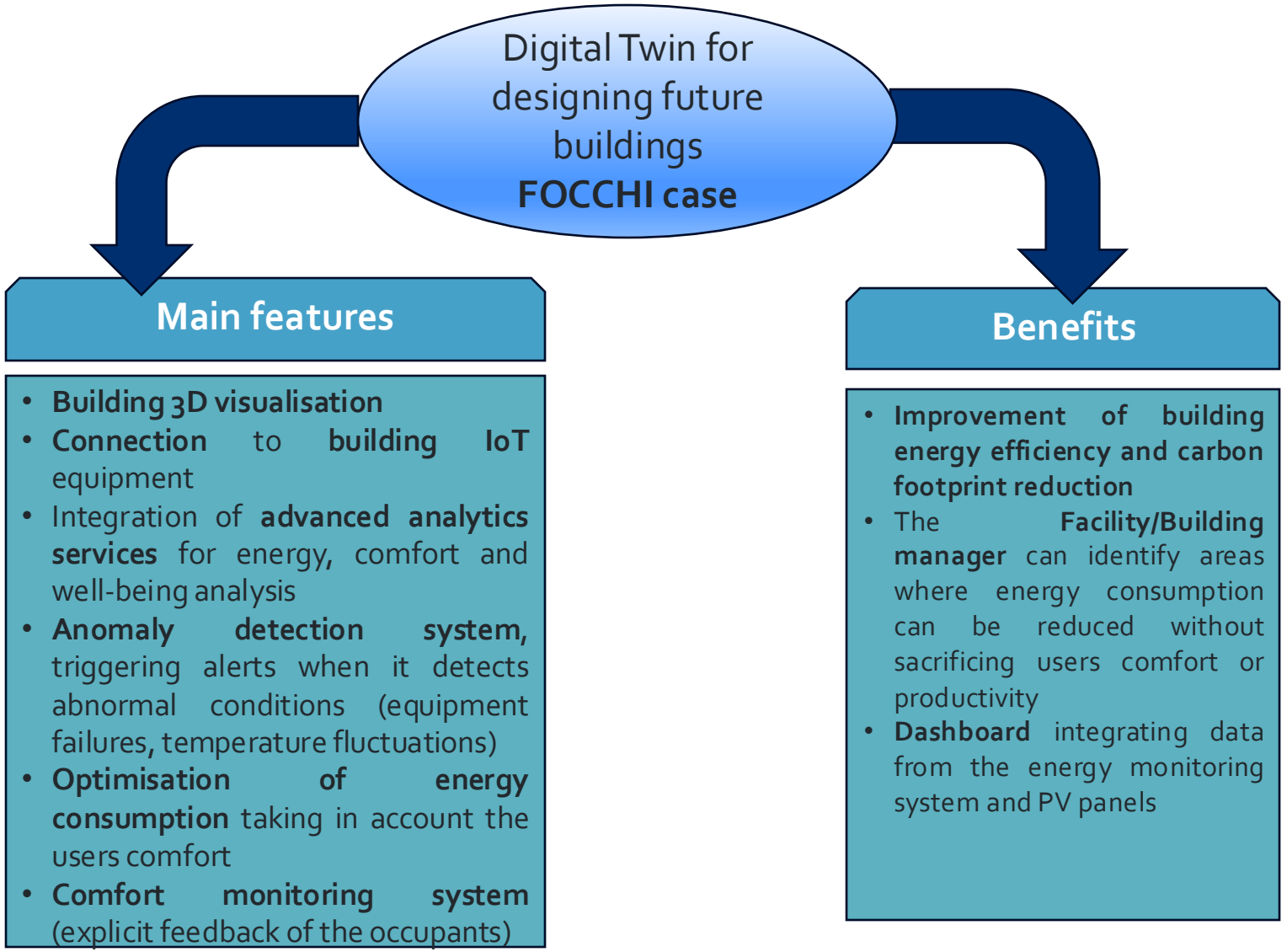
- designing future **buildings** and for managing their efficiency through **optimal energy management** (energy efficient building)
- optimizing building **renovation** strategies
- **district heating** management and operation

and….**Digital Building logbook**

DigiBUILD DT services per pilot and related maturity level

Digital Twin service	Pilot	Maturity Level
Digital Twin for designing future buildings (ENG)	Pilot 5b: Designing Future Buildings and Building Processes in Industrial Areas (**Focchi**)	Level 3 -> Level 4
Digital Twin for optimal energy management (ENG)	Pilot 5a: EV fleet smart charging management to increase office building efficiency (**EMOT**)	Level 3
	Pilot 6: Positive Energy Buildings with Flexible Assets (**HERON**)	Level 3
Digital Twin for planning of building Infrastructure (EDF)	Pilot 2: Retrofitting Old Building with Smart HVAC System (**EDF**)	Level 2 -> Level 3
District Digital Twin (ENG, UCL)	Pilot 1: Big Data Analytics for Proactive Facility Management (**UCL**)	Level 3
District Network Digital Twin - **Rio Vena (ENG)** - **CP Fasa (CARTIF)**	Pilot 4: Improving Data Quality and Analytics in Thermal Networks (**VEOLIA**)	Level 4

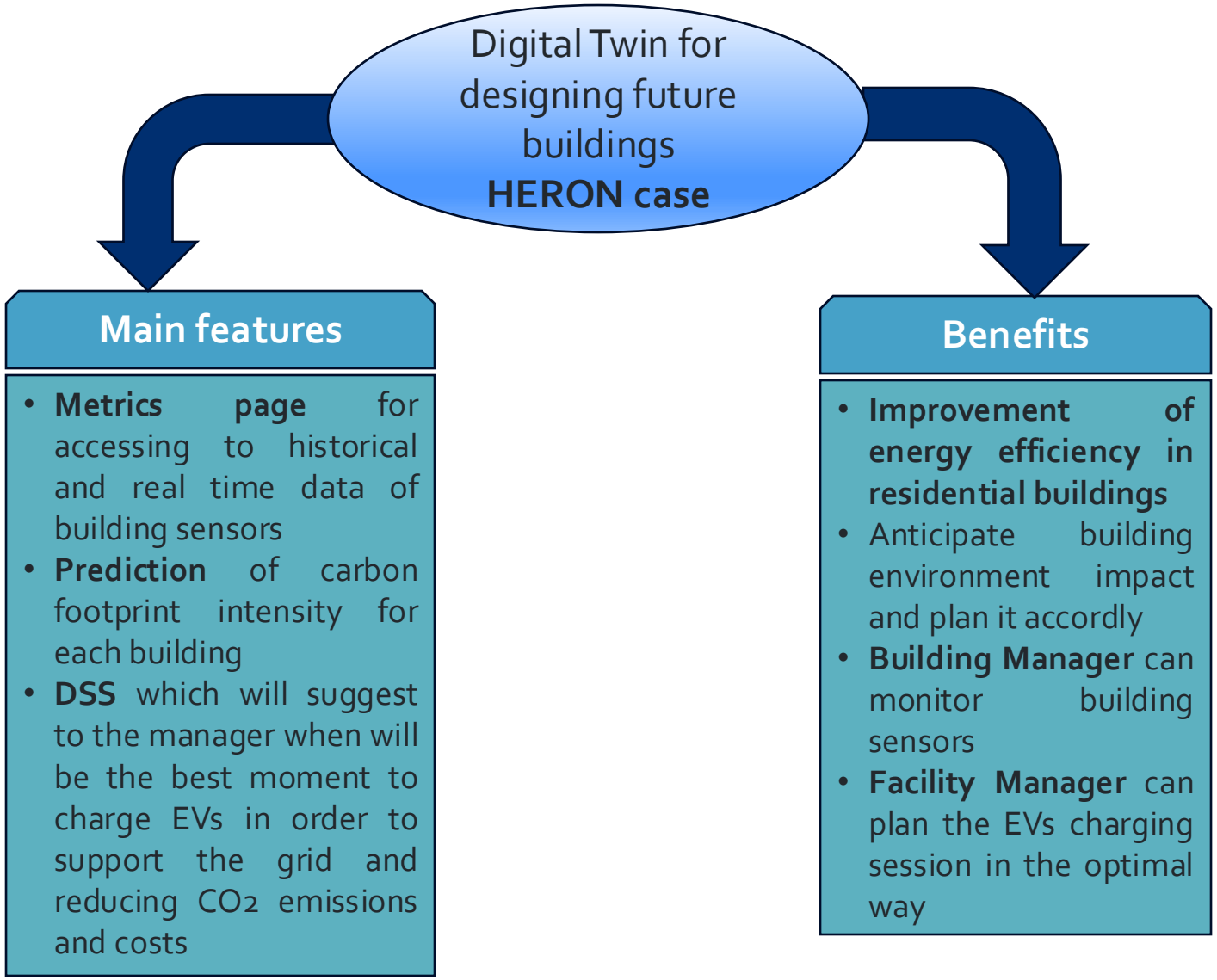
DigiBUILD Digital Twins for designing future buildings and building processes



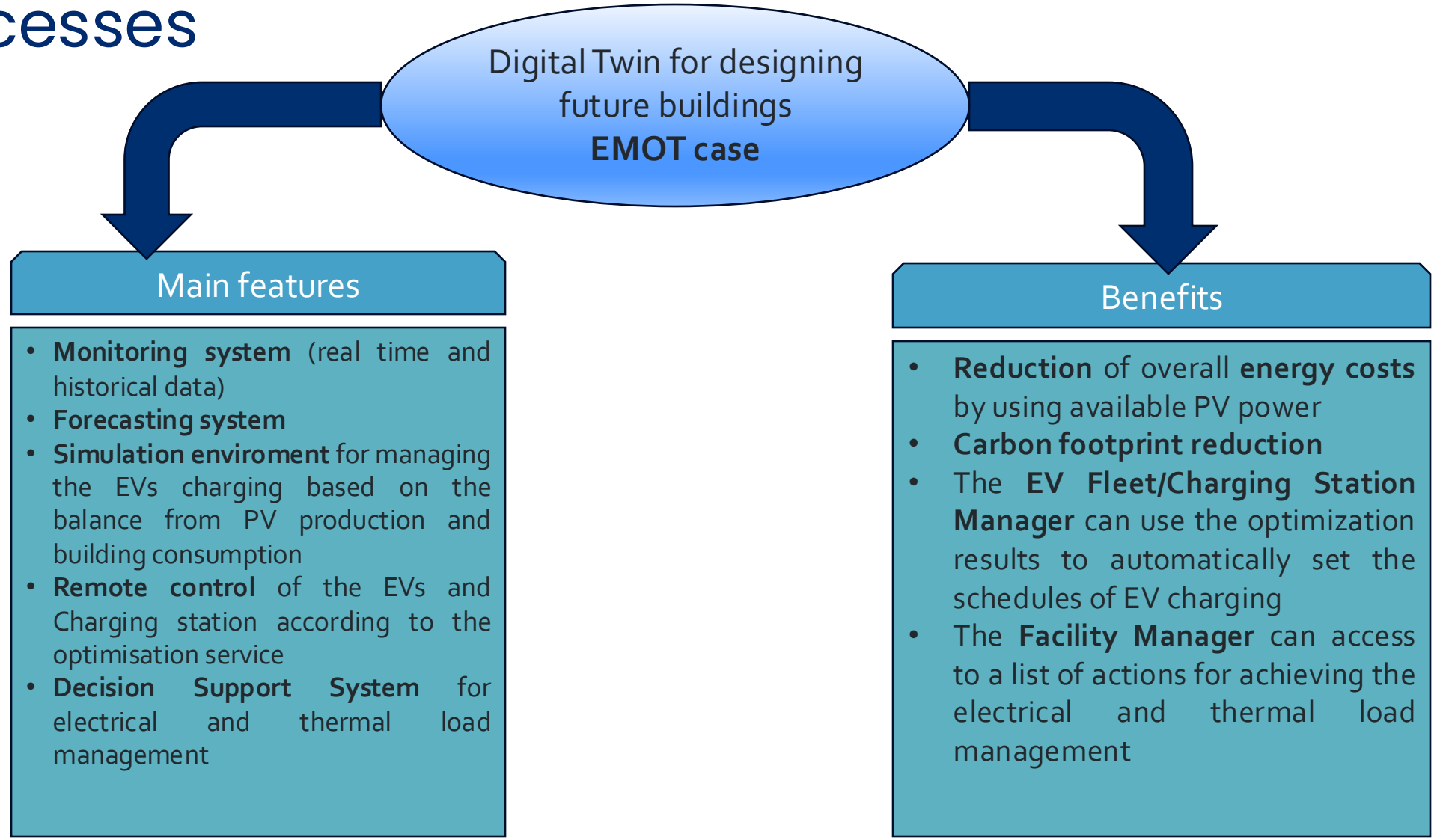
- **Building 3D visualisation**
- **Connection** to **building IoT** equipment
- Integration of **advanced analytics services** for energy, comfort and well-being analysis
- **Anomaly detection system,** triggering alerts when it detects abnormal conditions (equipment failures, temperature fluctuations)
- **Optimisation of energy consumption** taking in account the users comfort
- **Comfort monitoring system** (explicit feedback of the occupants)

- **Improvement of building energy efficiency and carbon footprint reduction**
- The **Facility/Building manager** can identify areas where energy consumption can be reduced without sacrificing users comfort or productivity
- **Dashboard** integrating data from the energy monitoring system and PV panels

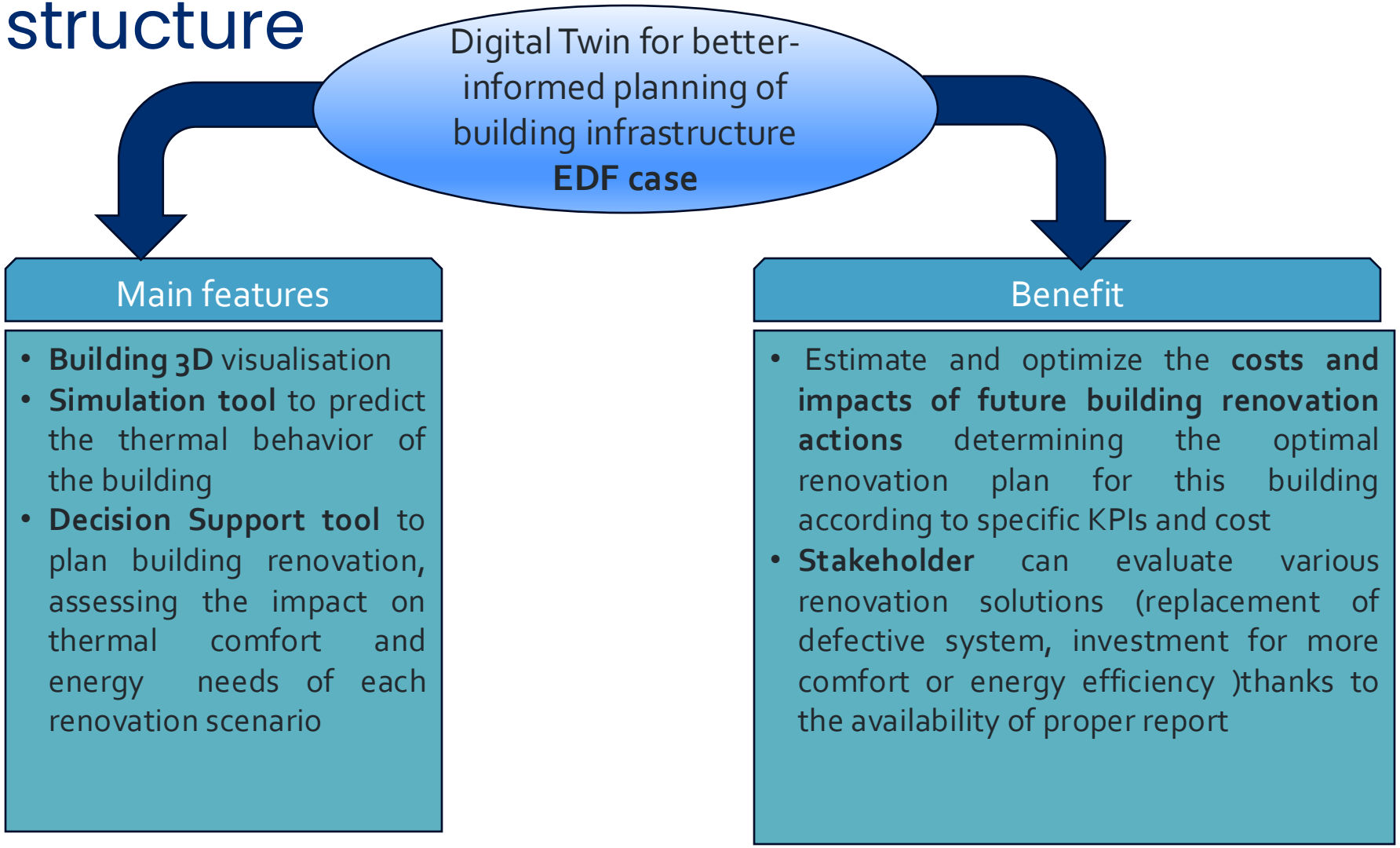
DigiBUILD Digital Twins for designing future buildings and building processes



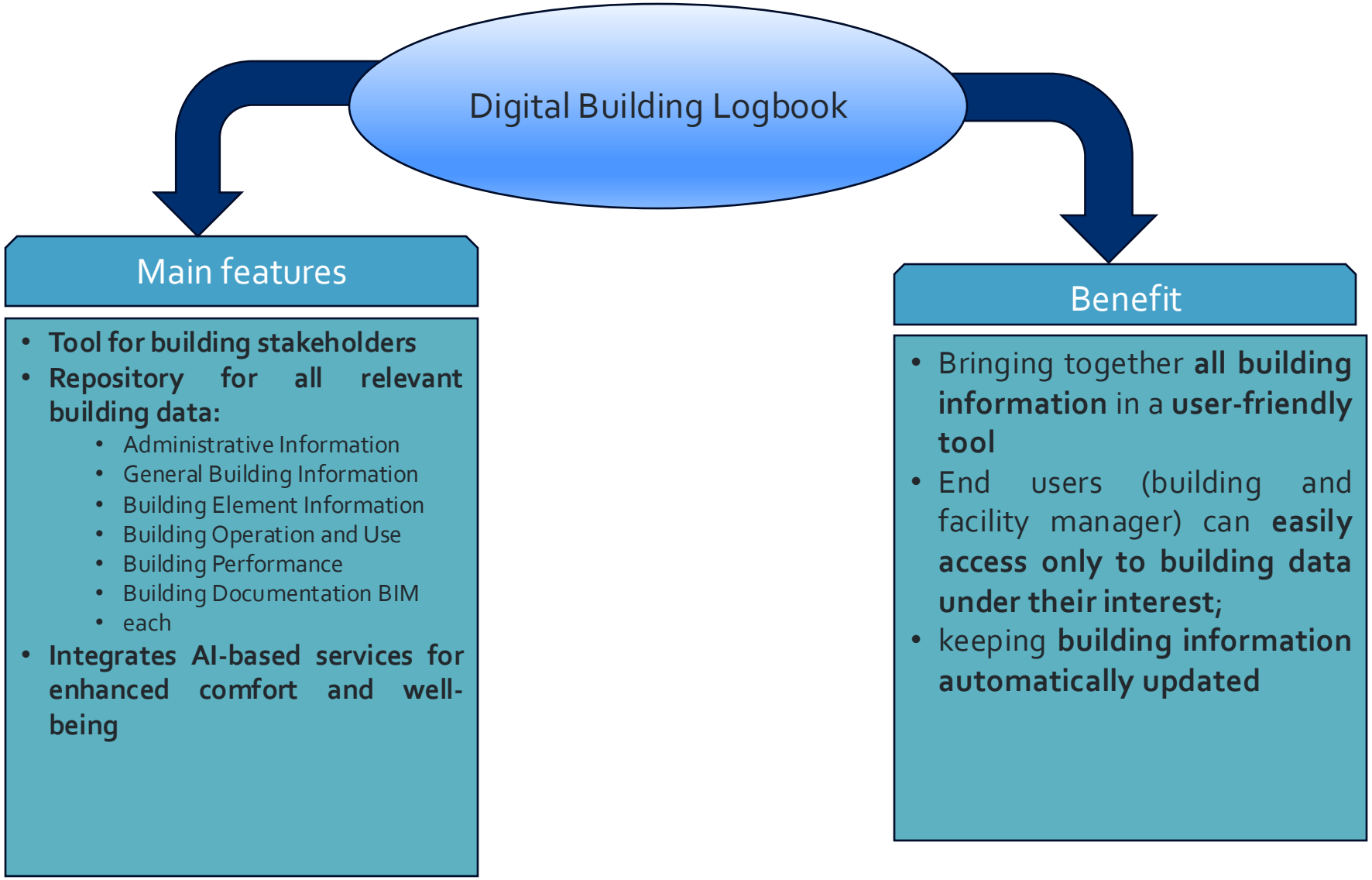
DigiBUILD Digital Twins for designing future buildings and building processes



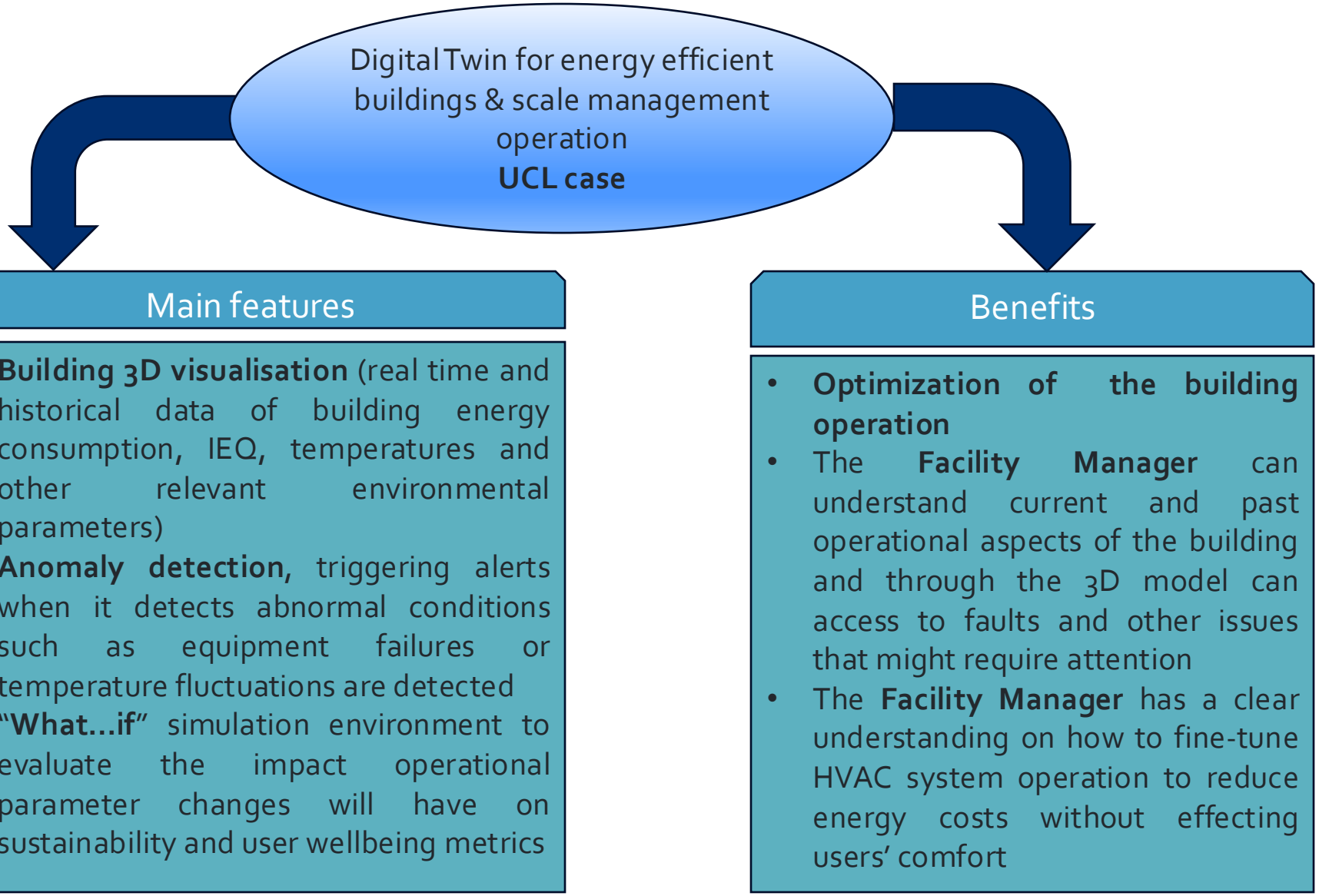
DigiBUILD Digital Twin for better-informed planning of building infrastructure



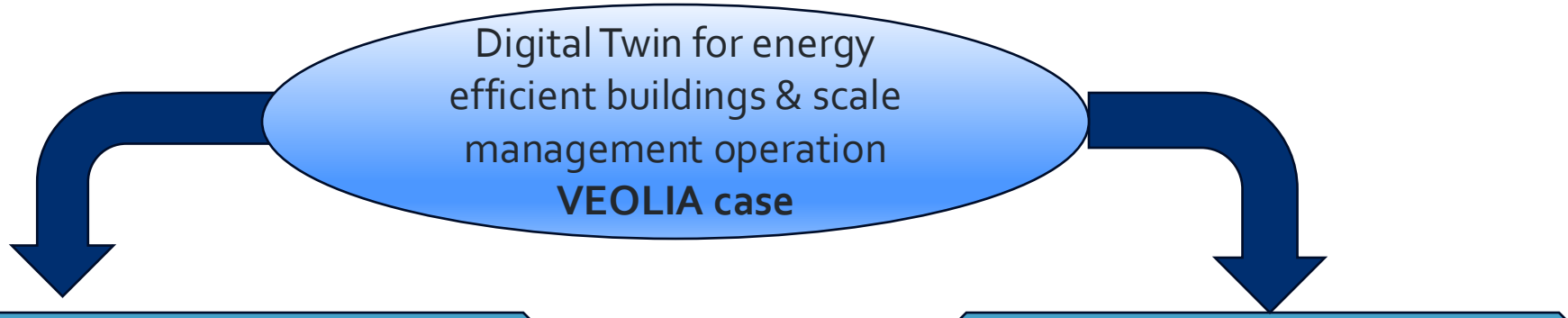
DigiBUILD Digital Twin for better-informed planning of building infrastructure



DigiBUILD Digital Twin for energy efficient buildings & scale management operation



DigiBUILD Digital Twin for energy efficient buildings & scale management operation



Main features

- **Simulation environments** for DHN optimisation strategies
- **Dashboard** for a facility manager/DHN Manager to show real time and historical information about the heating system network (es. PV energy production and boilers production)

Benefits

- **Increase the energy efficiency** and reduce the energy costs for suppling the heat in the district
- **Facility managers** can smartly access to historical and real time data and effectively control the network for optimal performance

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