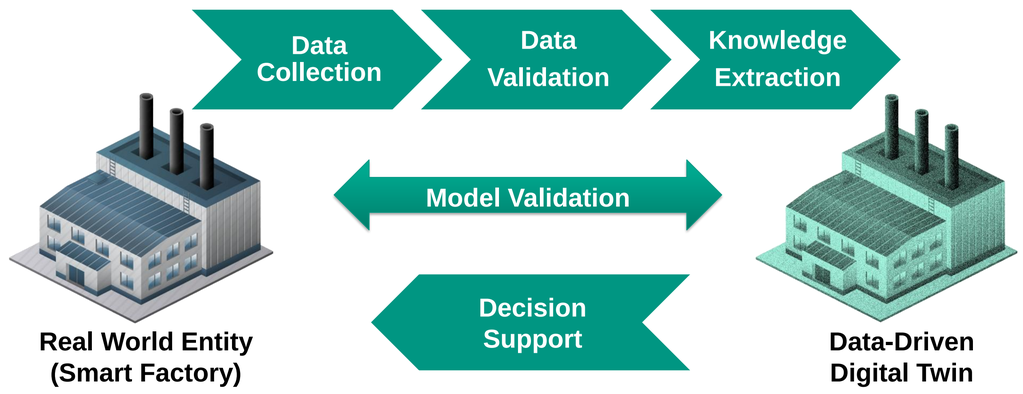
Towards Sustainable Manufacturing: Digital Twins for Enhanced Energy Efficiency

Author: Atieh Khodadadi
Supervisor: Prof. Dr. Sanja Lazarova-Molnar

Introduction

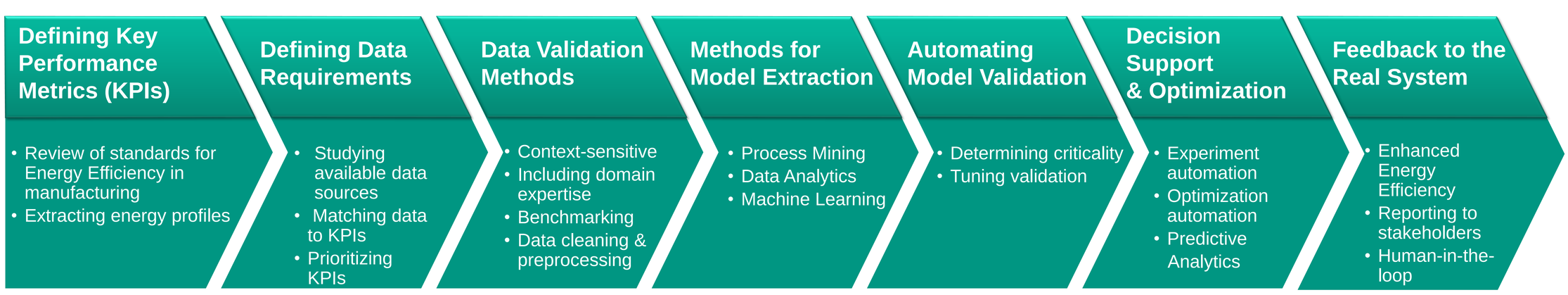
The manufacturing industry is responsible for more than 30% of total primary energy consumption and 36% of total greenhouse gas emissions [1]. Rapid industrialization and increasing energy demand necessitate **energy efficiency (EE)** in various industries. Intelligent manufacturing techniques, including **digital twins (DTs)**, offer solutions to **optimize energy consumption**, **minimize waste**, and **transition to renewable energy sources**, ensuring comprehensive EE in industrial settings [2].



Overview of a Digital Twin in a manufacturing system.

Goal and Methodology

Goal: Digital Twins for Enhanced Energy Efficiency in Manufacturing Systems.



Challenges

- **Limited data availability:** Obtaining real-time energy consumption data and pertinent parameters from manufacturing systems.
- **Complex system dynamics:** Intricate energy usage patterns and interdependencies within the systems.
- **Integration of hybrid models:** Careful design, validation, calibration, and optimization strategies to ensure the accuracy, reliability, and effectiveness of the hybrid models, typical for this use case.
- **Integration with legacy systems:** Diverse technologies and protocols involved.
- **Integration of renewable energy sources:** Technical incompatibilities, infrastructure limitations, grid stability concerns, retrofitting complexities, and optimizing intermittent renewable sources.
- **Selecting appropriate KPIs and standards:** Identifying necessary standards, KPIs, and data sources to align with the DT goals.
- **High computational requirements:** Requirement of substantial computational resources.
- **Privacy and Security:** Need for strong measures to protect against cyber threats and ensure data integrity and confidentiality.
- **Uncertain energy models:** Complexities stemming from energy consumption patterns, production conditions, and equipment performance uncertainties.
- **Cost considerations:** Need substantial technology, resources, and training investments.
- **Organizational readiness:** Requires the organization to obtain the necessary resources, infrastructure, corporate culture, workforce skills, and process optimization.

References

[1]. J. Zou, Q. Chang, J. Arinez, and G. Xiao, "Data-driven modeling and real-time distributed control for energy efficient manufacturing systems," *Energy*, vol. 127, pp. 247–257, 2017.[2] Kritzinger, W., Karner, M., Traar, G., Henjes, J. and Sihn, W., 2018. Digital Twin in manufacturing: A categorical literature review and classification. *Ifac-PapersOnline*, *51*(11), pp.1016-1022.
[2]. Yu, W., Patros, P., Young, B., Klinac, E. and Walmsley, T.G., 2022. Energy digital twin technology for industrial energy management: Classification, challenges and future. Renewable and Sustainable Energy Reviews, 161, p.112407.

Acknowledgment
The authors extend their thanks to the funding received from the ONE4ALL project funded by the European Commission, Horizon Europe Programme under the Grant Agreement No 101091877.

Funded by the European Union

atieh.khodadadi@kit.edu
atieh-khodadadi
Atieh-Khodadadi