Data-Driven LDT Models for Accelerating the Green Transition

Henrik Madsen, Razgar Ebrahimy, Peder Bacher
DTU Compute

(IFD projects: FED + IoT Annex + Cool Data)
(EU projects: ELEXIA + ARV + ebalance-plus + CitCom.ai)

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ebalanceplus
www.h2020-bridge.eu

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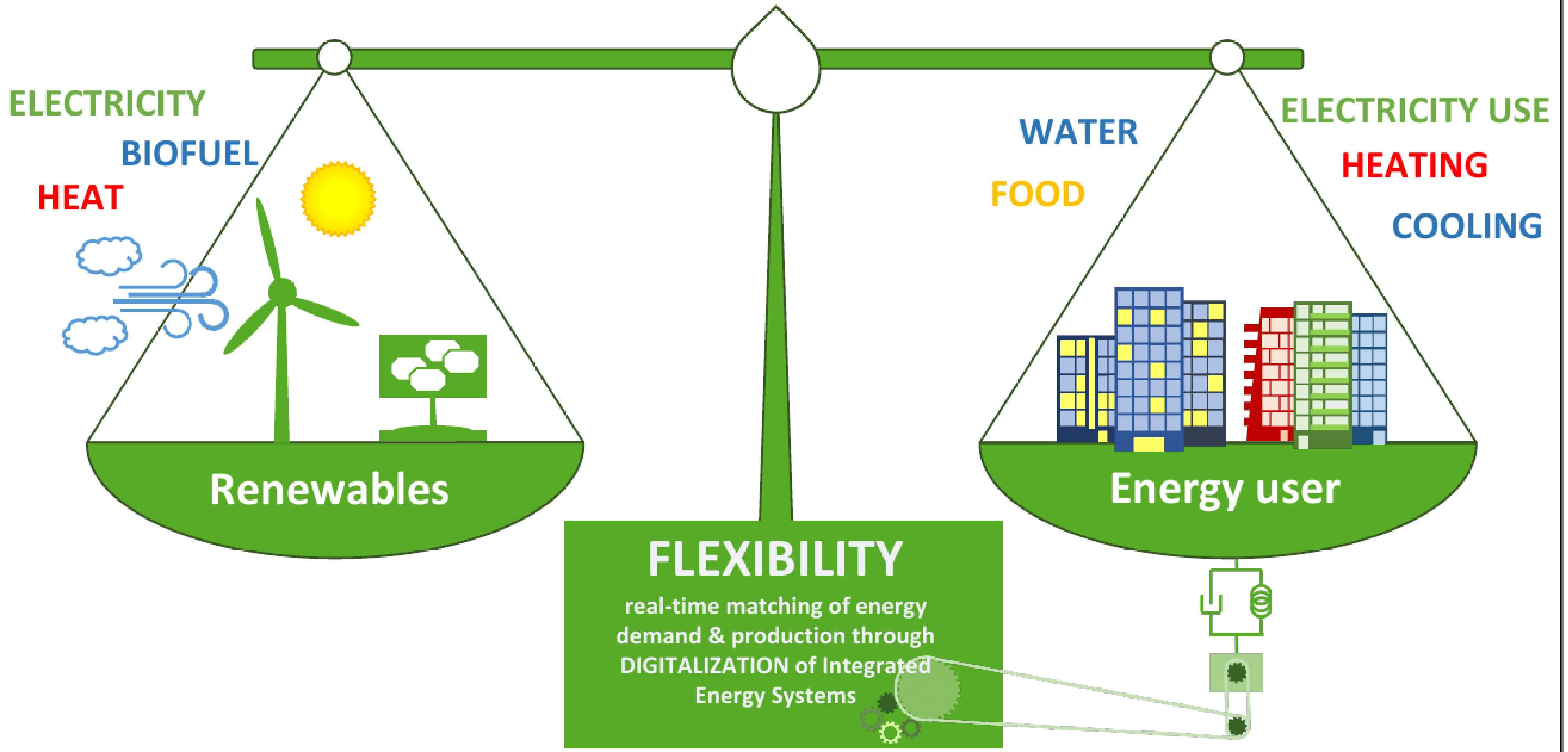
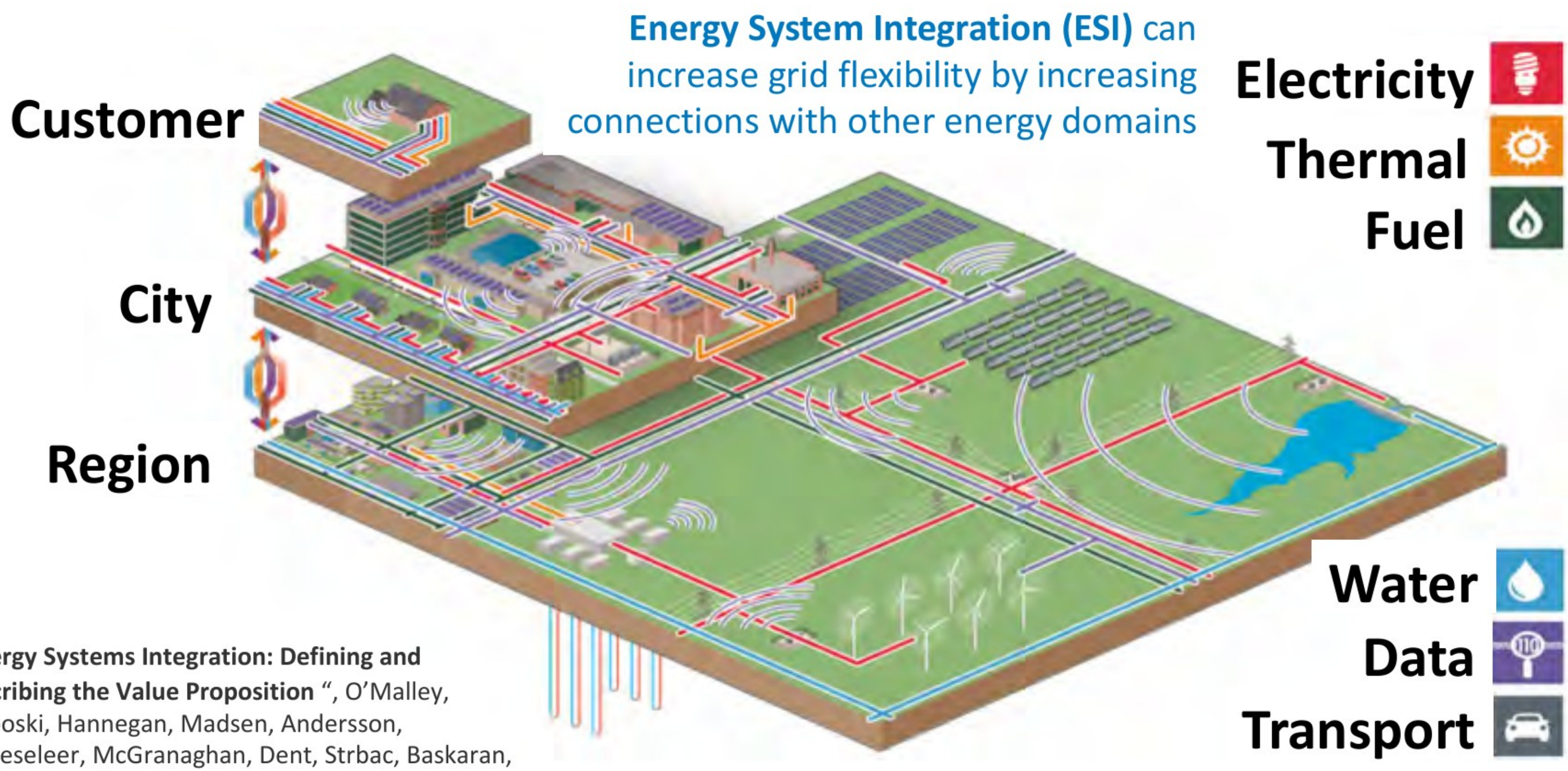
The Challenge: Denmark Fossil Free 2050



Energy Systems Integration

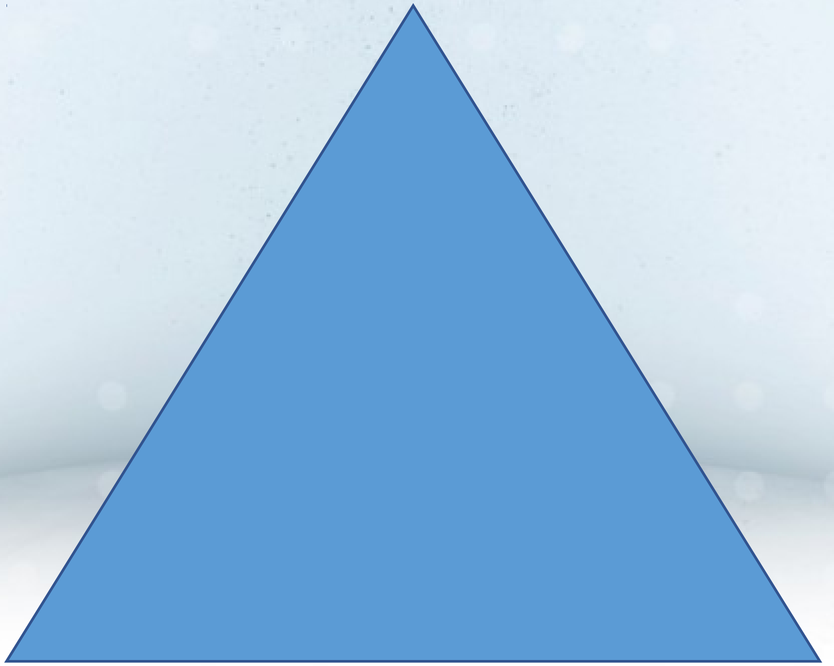


"**Energy Systems Integration: Defining and Describing the Value Proposition** ", O'Malley, Kroposki, Hannegan, Madsen, Andersson, D'haeseleer, McGranaghan, Dent, Strbac, Baskaran, Rinker., NREL/TP-5D00-66616. June 2016

Space of Solutions

Flexibility

(enabled by **AI, Local Digital Twin, Communication, IoT**)



Grids **Batteries**

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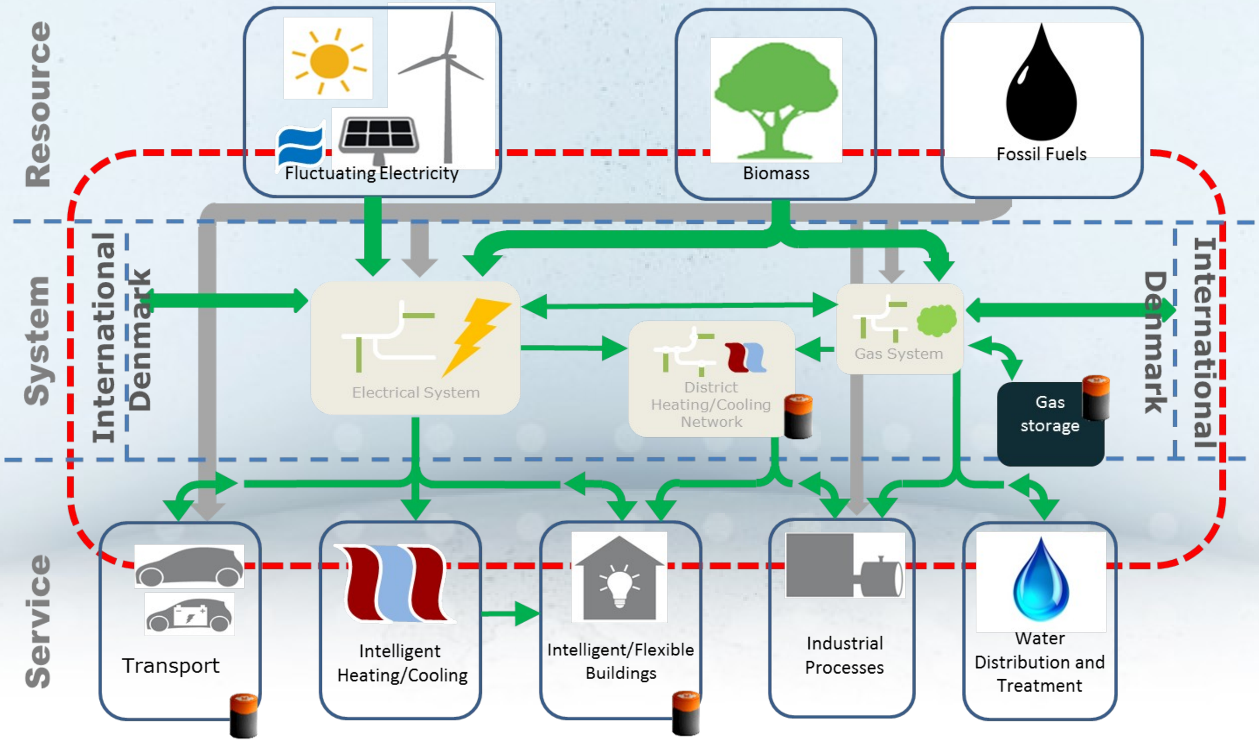
Data-driven Local Digital Twins for Real Time Applications

Data-driven LDT models are simplified models facilitating system integration and use of sensor data in real-time



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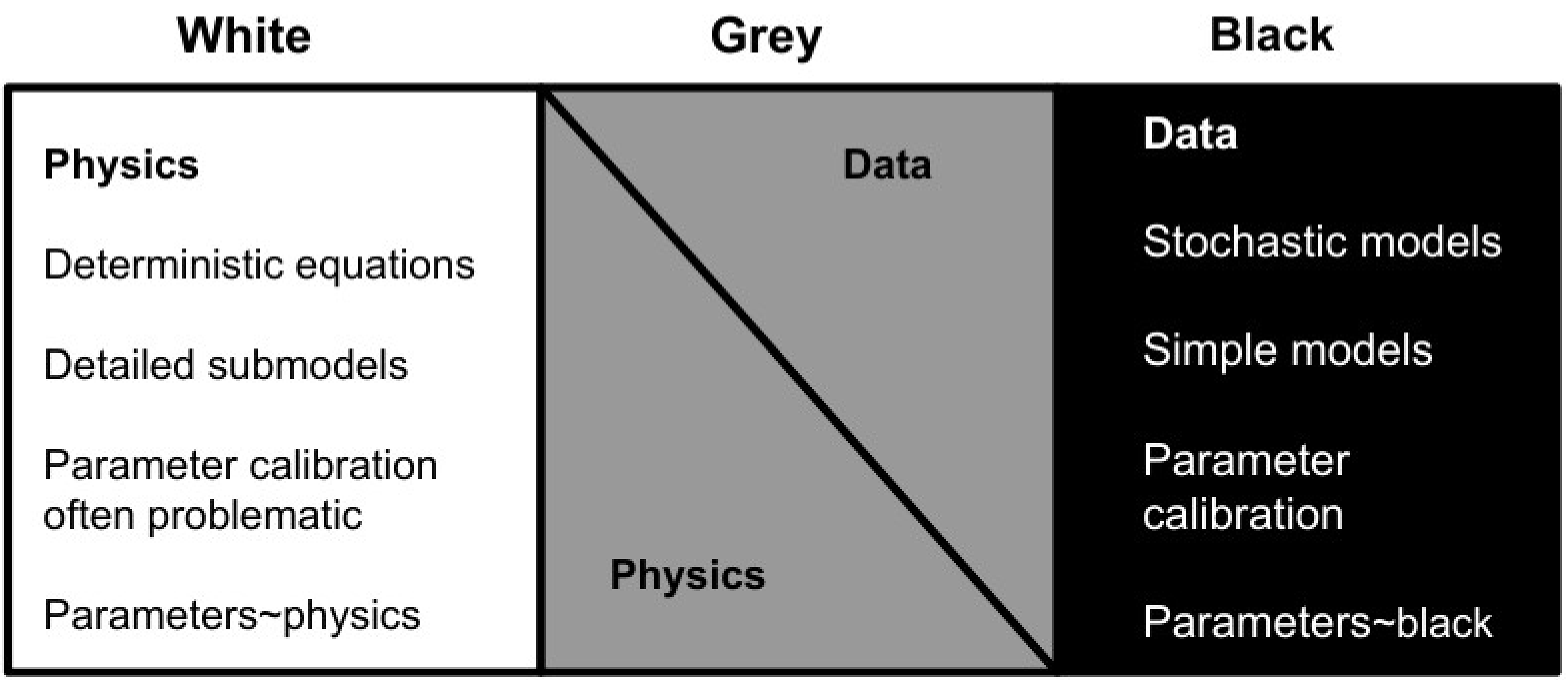
LDT / Grey-box Models

Often a set of partially observed stochastic differential equations



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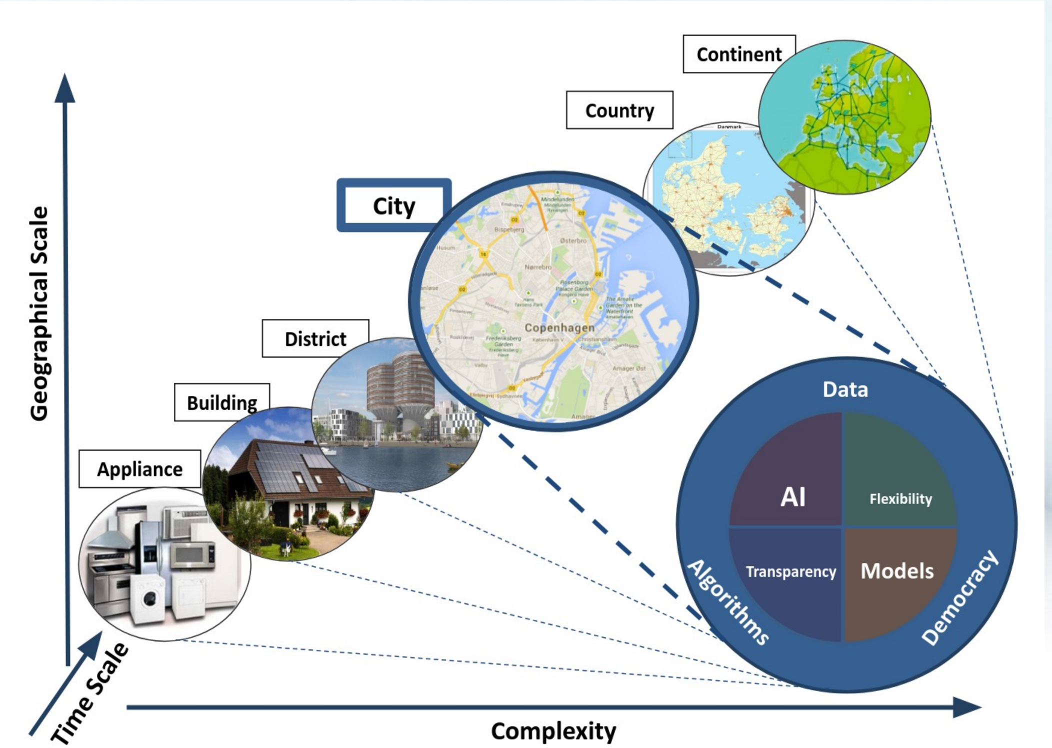
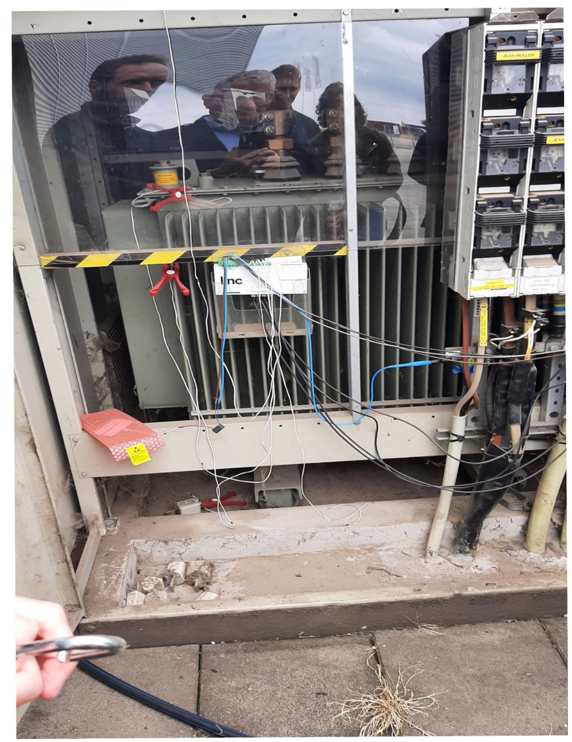
Temporal and Spatial Coherency

A so-called ***Smart-Energy Operating-System (SE-OS)*** based on a ***Hierarchy of Data-Driven LDT*** models is developed for forecasting, optimization, control, communication) of ***operating flexible electrical energy systems*** at **all scales**.



Case Study:

DSO - Smart Grid Intelligence
Models for Dynamic Transformer Rating



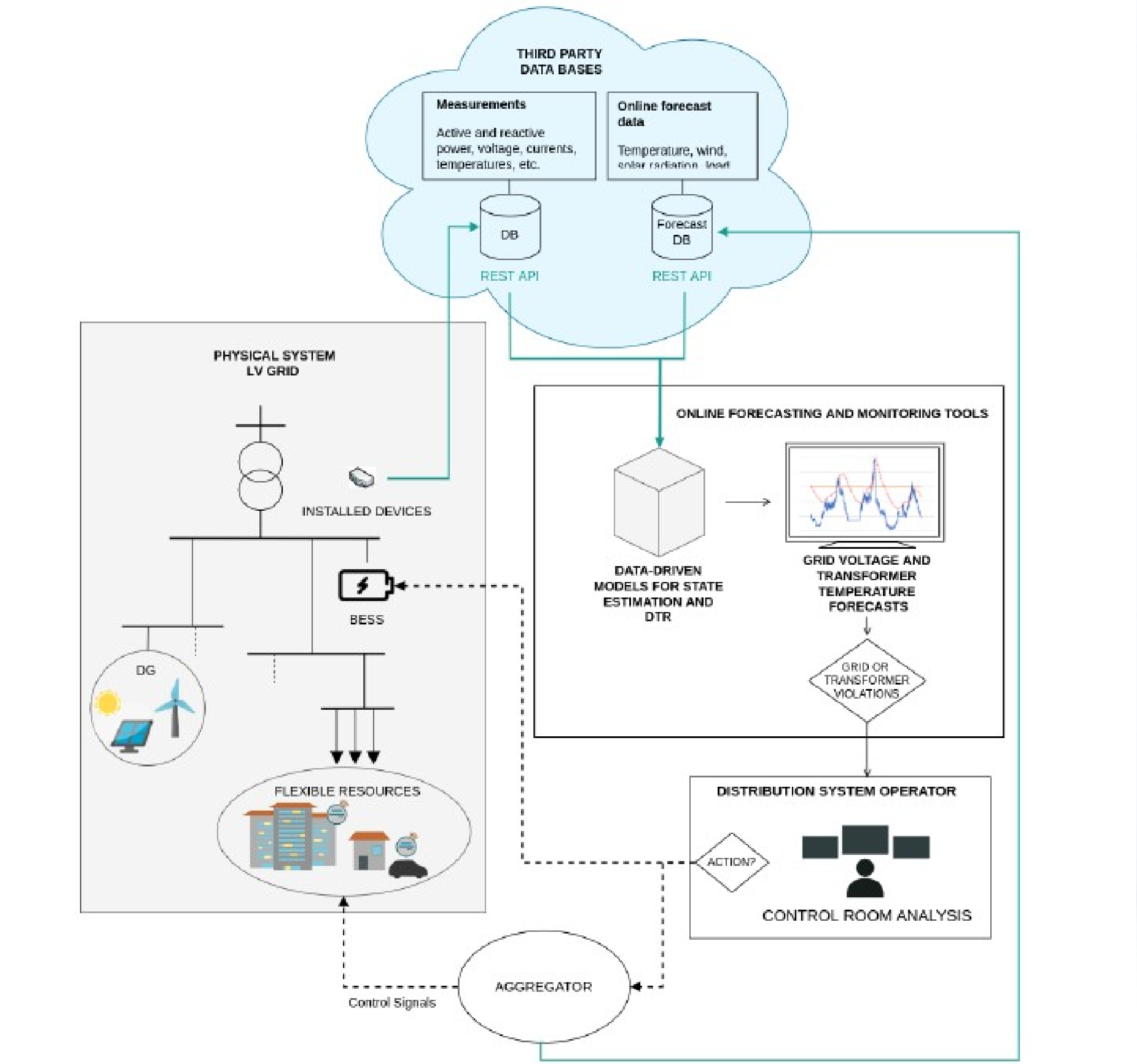


Figure 5.1: Operational framework for adaptive DSO smart grid operation. Turquoise lines indicate data flows and dotted lines indicate communication signals.

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Sensor setup for transformators

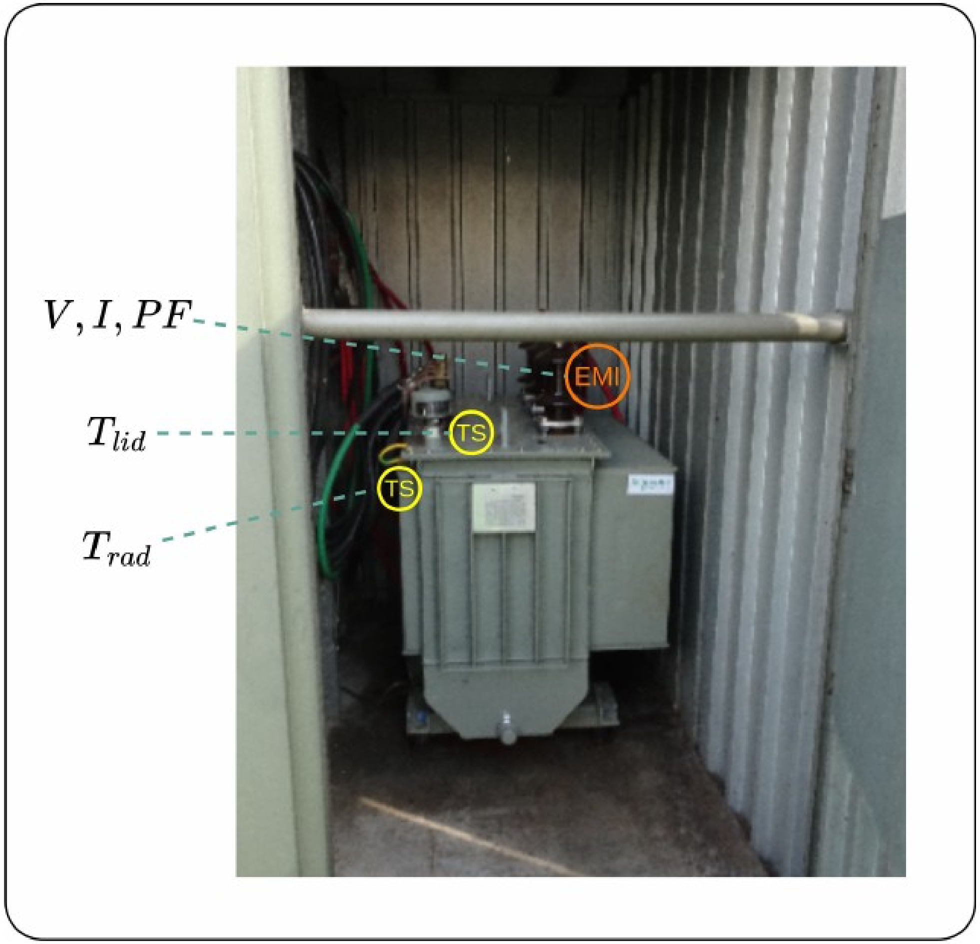


Figure 5.2: Suggested final setup for the transformers, with temperature sensor (TS) and electronic measurement instruments (EMI).

Data-driven LDT model for transformator stations

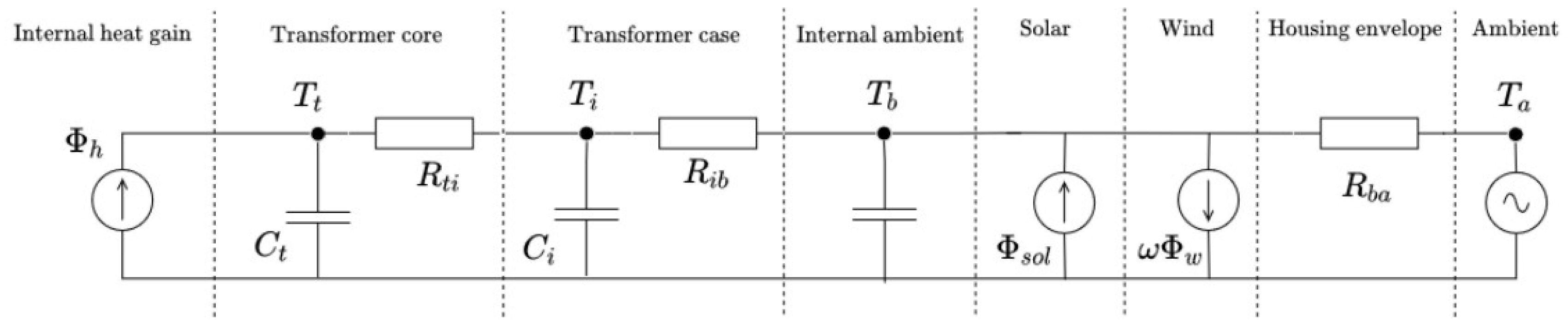


Figure 7: RC circuit of the three state model $TiTtTb$.

Model performance; 6-hour predictions

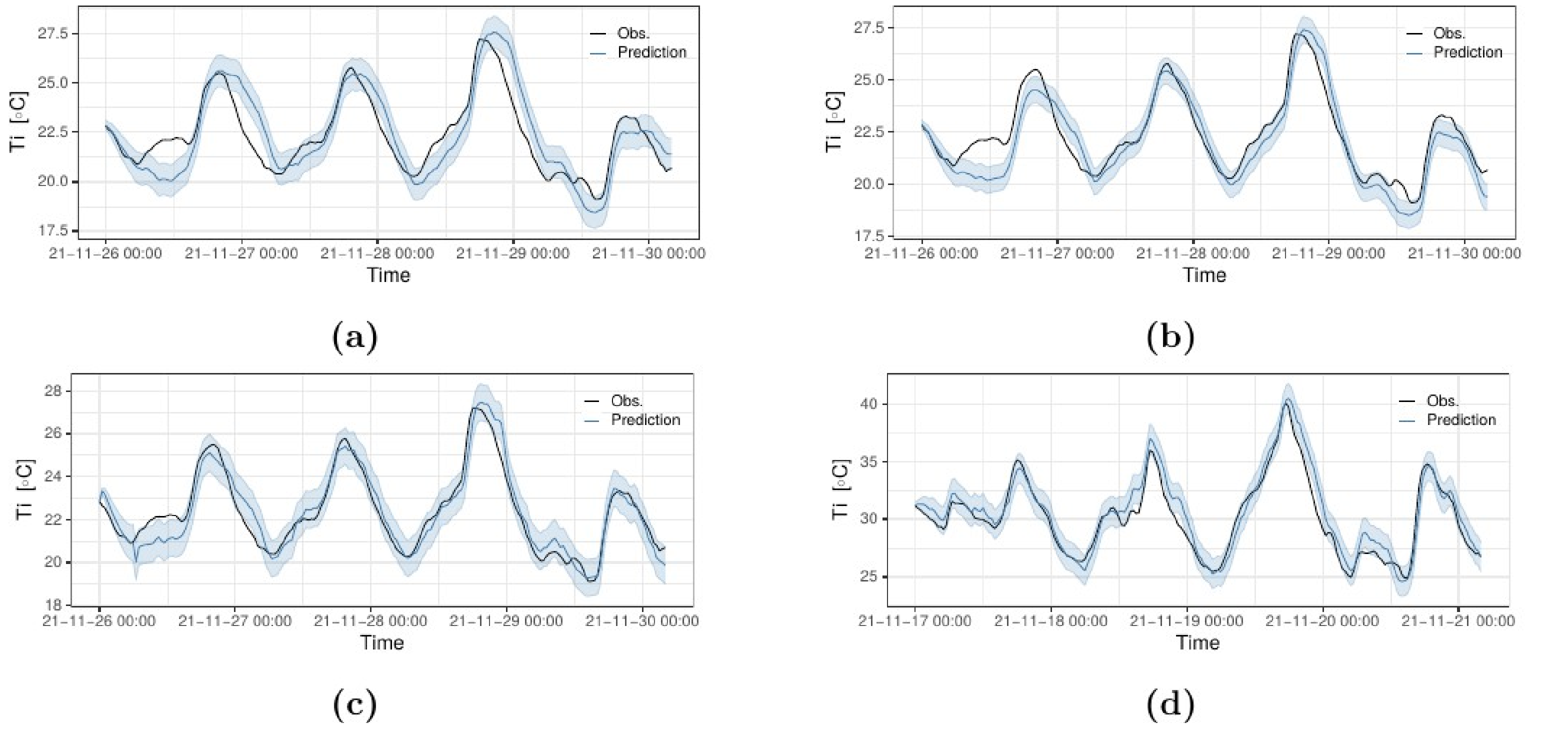
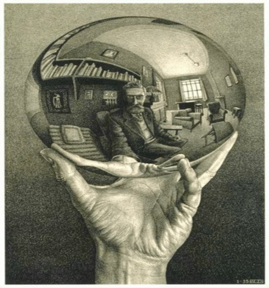


Figure 11: Prediction analysis for 12 step ahead (6 hours) predictions. Subfigures (a)-(c) show predictions for TRF 1 using the one state model (a), extended two state model (b) and the final three state model (c). Subfigure (d) shows predictions for TRF 2 using the final three state model. Black line – observations, Blue line – predictions, Light blue area – 95% PI.

Dynamic Transformer Rating

- Relies on data-driven Local Digital Twins of the Transformer stations
- Gives good predictions of the hidden states (e.g., oil temperatures) more than 6h ahead
- DTR can reduce the risk of overloading
- The models can be used to predict failures of transformators
- Experiences show that transformers often can be overloaded (up to 120 pct) without any problem
- **Wind farms can be expanded up to 60 pct** without problems (since wind speed and wind power generation are highly correlated)



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Wind Power Forecasting for DSOs and TSO using Spatial Hierarchies of LDT Models

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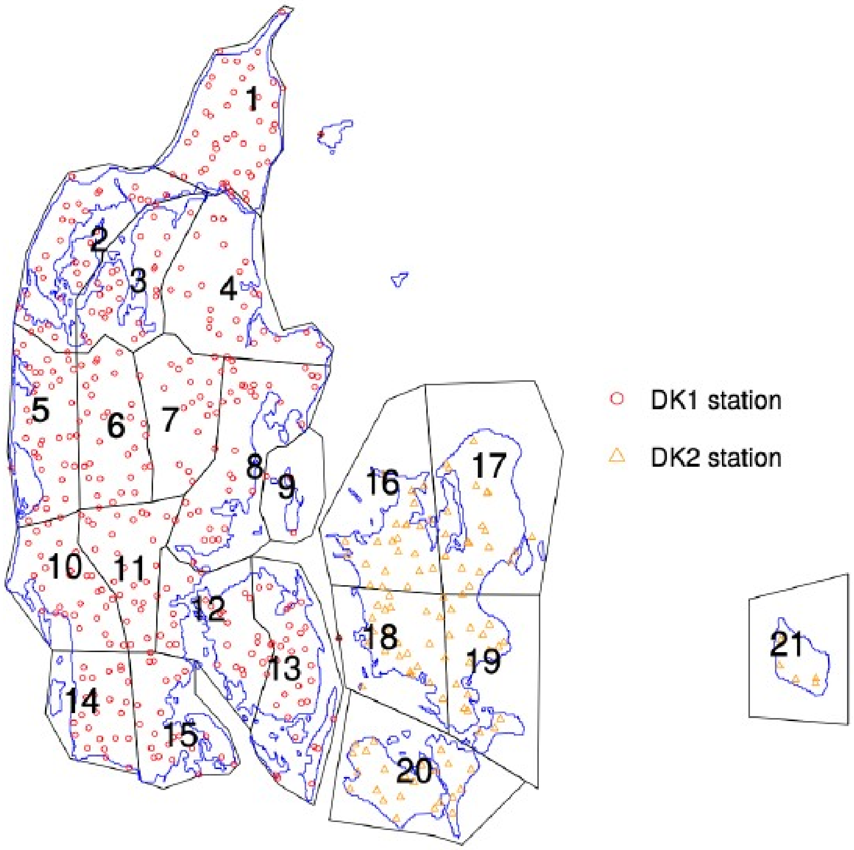
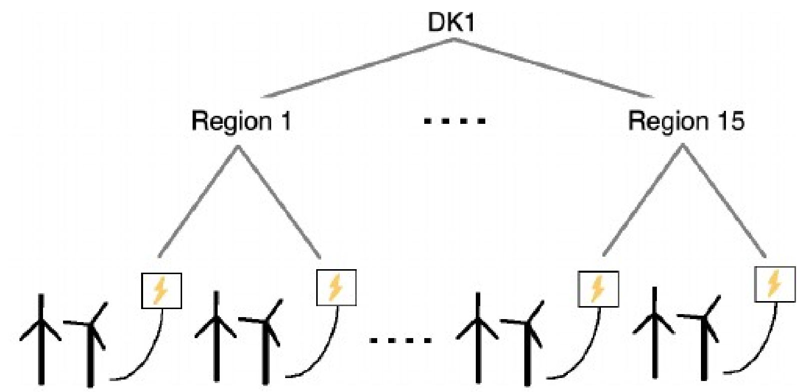
3rd meeting of SF-SSCC/TG Local Digital Twin, January 2023

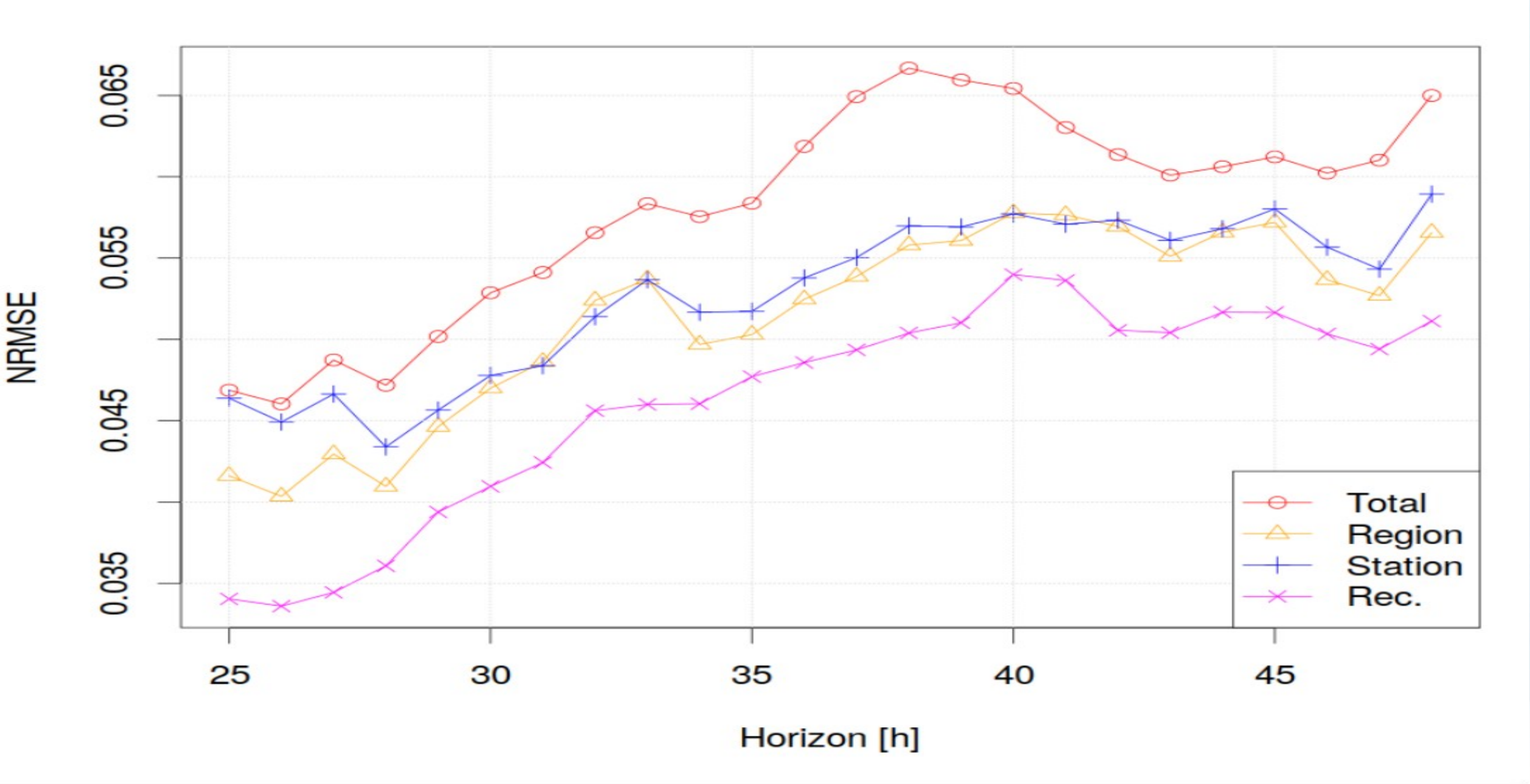
Wind Power Forecasting Using a Hierarchy of LDT Models



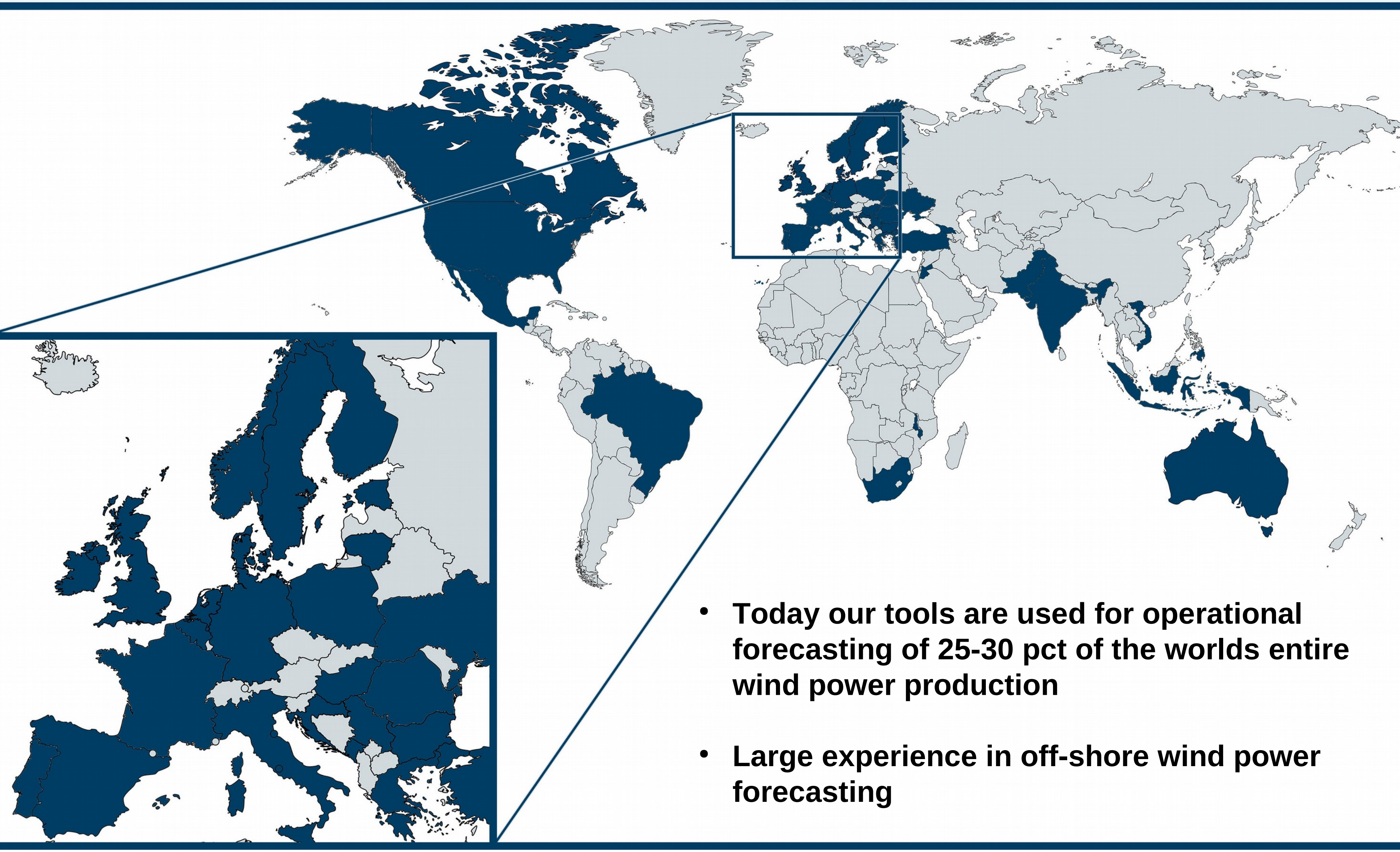


(b) Illustration of the spatial hierarchy for DK1 with 407 individual conversion stations at the bottom level, 15 regions at the middle level, and the total of Western Denmark at the top.

Wind Power Forecasting in DK1 (improvements 20 pct)



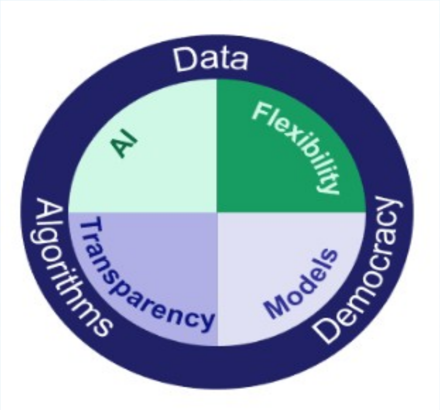
Wind Power Forecasting Using API's developed at DTU



- **Today our tools are used for operational forecasting of 25-30 pct of the worlds entire wind power production**
- **Large experience in off-shore wind power forecasting**

Summary

- An efficient implementation of the **future weather-driven** energy system calls for **data-driven LDTs for implementing digitalized Smart Energy Systems**
- The is a need for **disruptions** and we need a **Mission-driven approach**
- We need **Data-driven LDTs for assimilating information from sensors** in (almost) real-time
- We need a **hierarchy of LDTs** which are **coherent across all spatial-temporal domains**
- We need **LDT to bridge the gap between different domains (electricity, heat, water, etc)**
- **Minimum Interoperability Mechanisms (MIMs) are building blocks** for sector coupling and for implementing IoT solutions
- We need **transparent**, **safe, fair** and **democratic** solutions
- We need **LDTs for Human-in-the-Loop control** of energy systems (e.g. the FeedMe APP)



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