Wind Energy Systems Engineering Workshop

Vestas Plant Design System Engineering

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The undisputed global leader in wind energy

+30,000
employees

Every day, our employees help create a better world by designing, manufacturing, installing, developing, and servicing wind energy and hybrid projects all over the world

+55,000
turbines under service

Our service technicians keep the world spinning by servicing a global portfolio of more than 153 GW - the largest fleet in the world

+185 GW
installed wind turbine capacity

We have installed more wind turbine capacity than any other company in the world, with installations in 88 countries

243m
tonnes CO_2e avoided annually

Our total aggregated installed fleet annually help the World avoid emissions of 231 million tonnes CO_2e

Vestas' core businesses

Onshore

Undisputed market leader within the onshore wind market

Offshore

New technology platform in place to become a market leader

Service

Undisputed market leader with expanding scale and capabilities servicing onshore and offshore

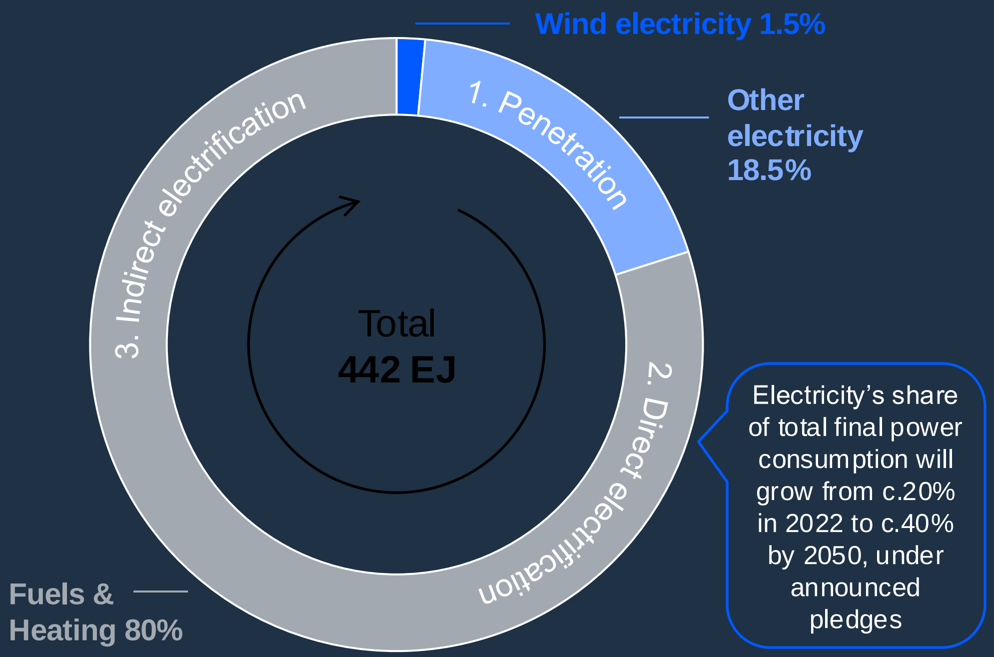
Development

Unique presence and knowledge drives growing pipeline of attractive, undiscovered wind projects

The green transition continues to hold tremendous growth potential for wind

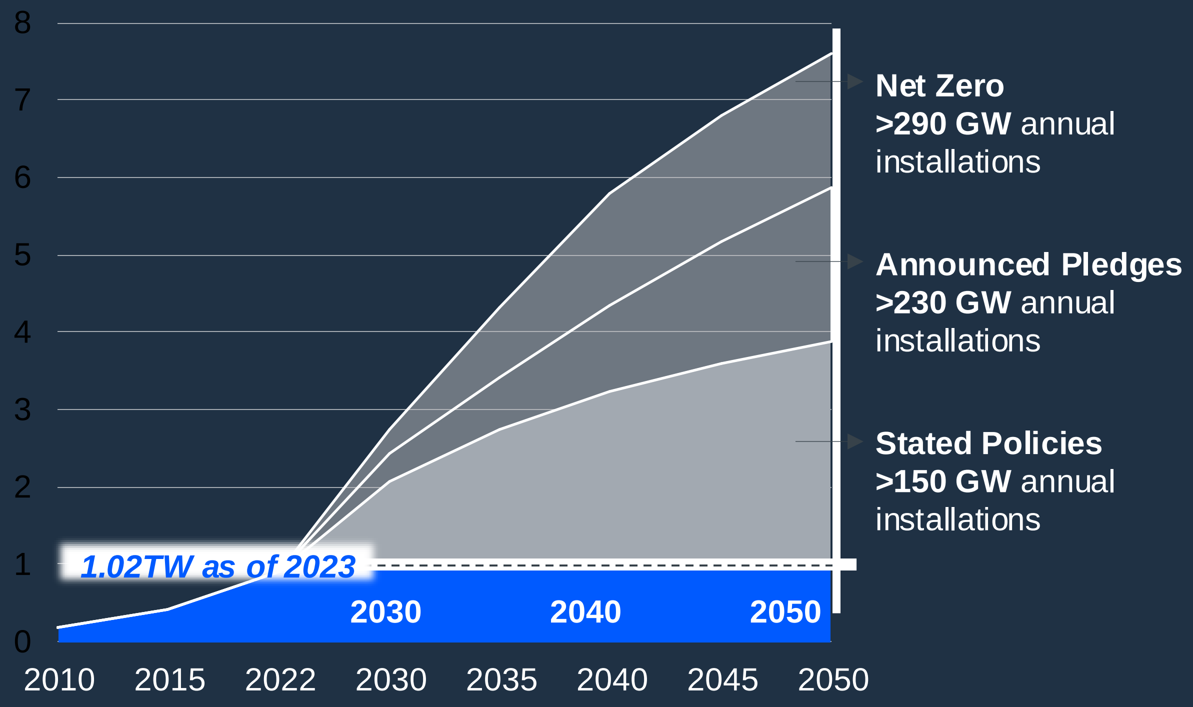
Global energy consumption by source

In exajoule (EJ) and percent (%), 2022



Global wind generation capacity scenarios

In TW



Sources: IEA World Energy Outlook (2023); Global Wind Energy Council, Global Wind Report (2023)

Vestas

Plant Design

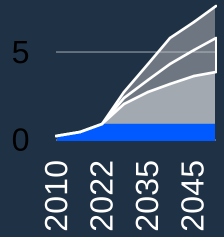
System Engineering

illustration by Mikkel Noe-Nygaard

Industry context

Designing a plant is a complex task involving a **large amount of technical - social - commercial design objectives and constraints**

Modular wind turbine products offers a much larger set of hardware and software configurations to explore



The overall global demand for design is growing year on year and according to energy transition projections **will double within the next decade.**

Suboptimal plant designs can result in **substantial value loss for Wind Farm owners and manufacturers.**

Outline

Plant Design context

Industry context and challenges

System design and objectives

Functions in scope

Addressing design challenges

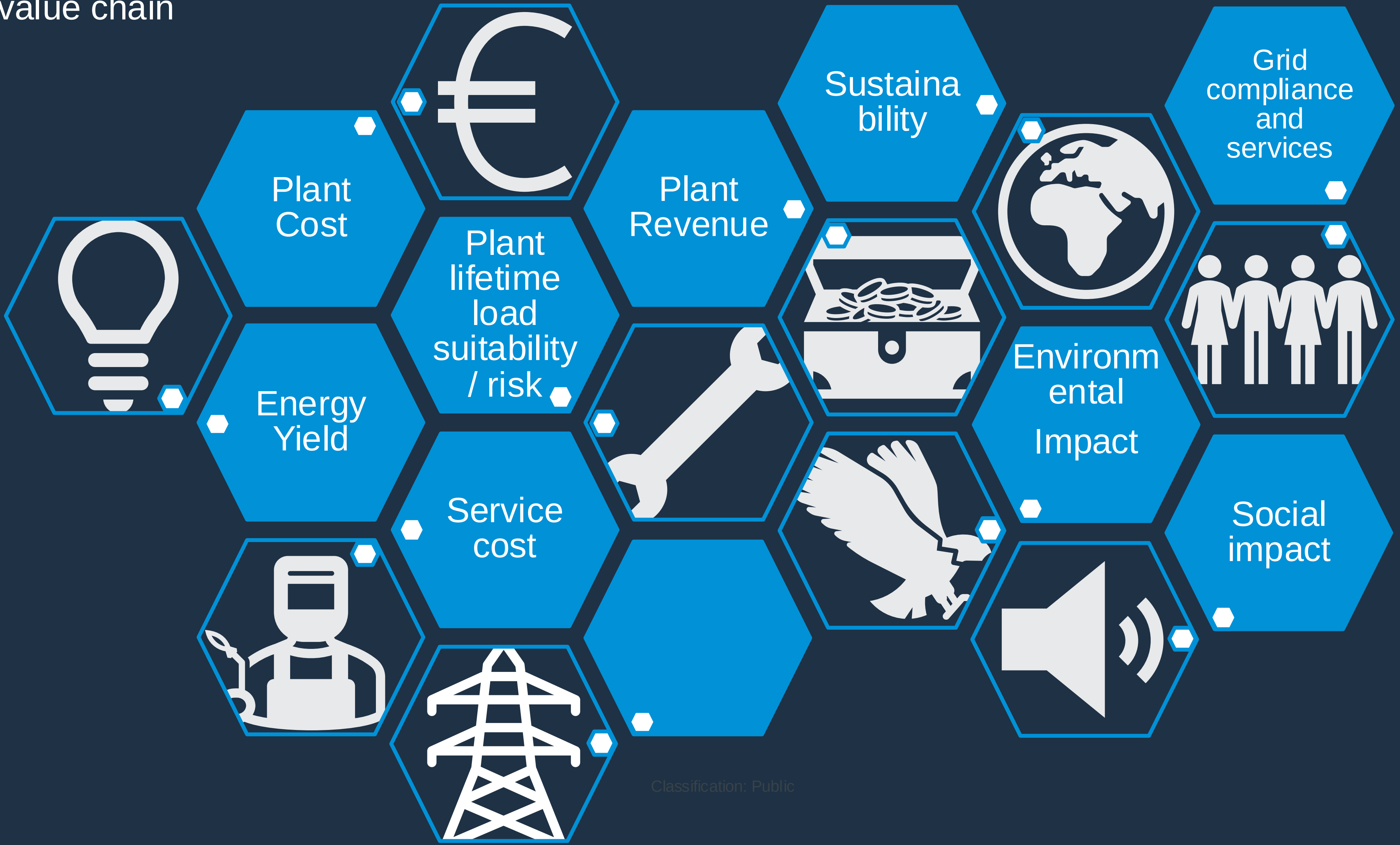
Surrogate modeling in the industry

Opportunities

Increasing the deployment of surrogates in the industry

System design objectives / constraints

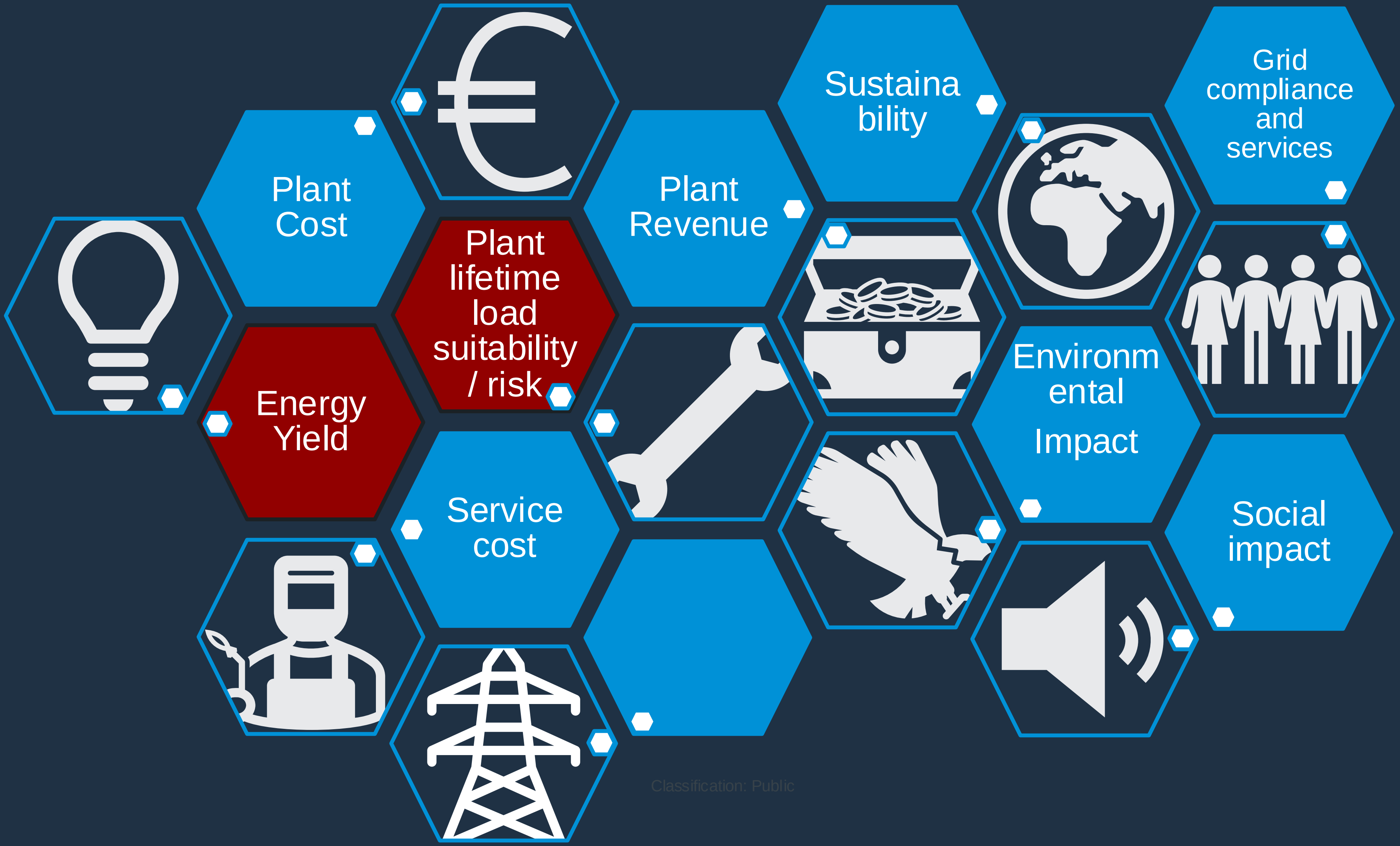
Complex value chain



Classification: Public

System design objectives / constraints

Dive

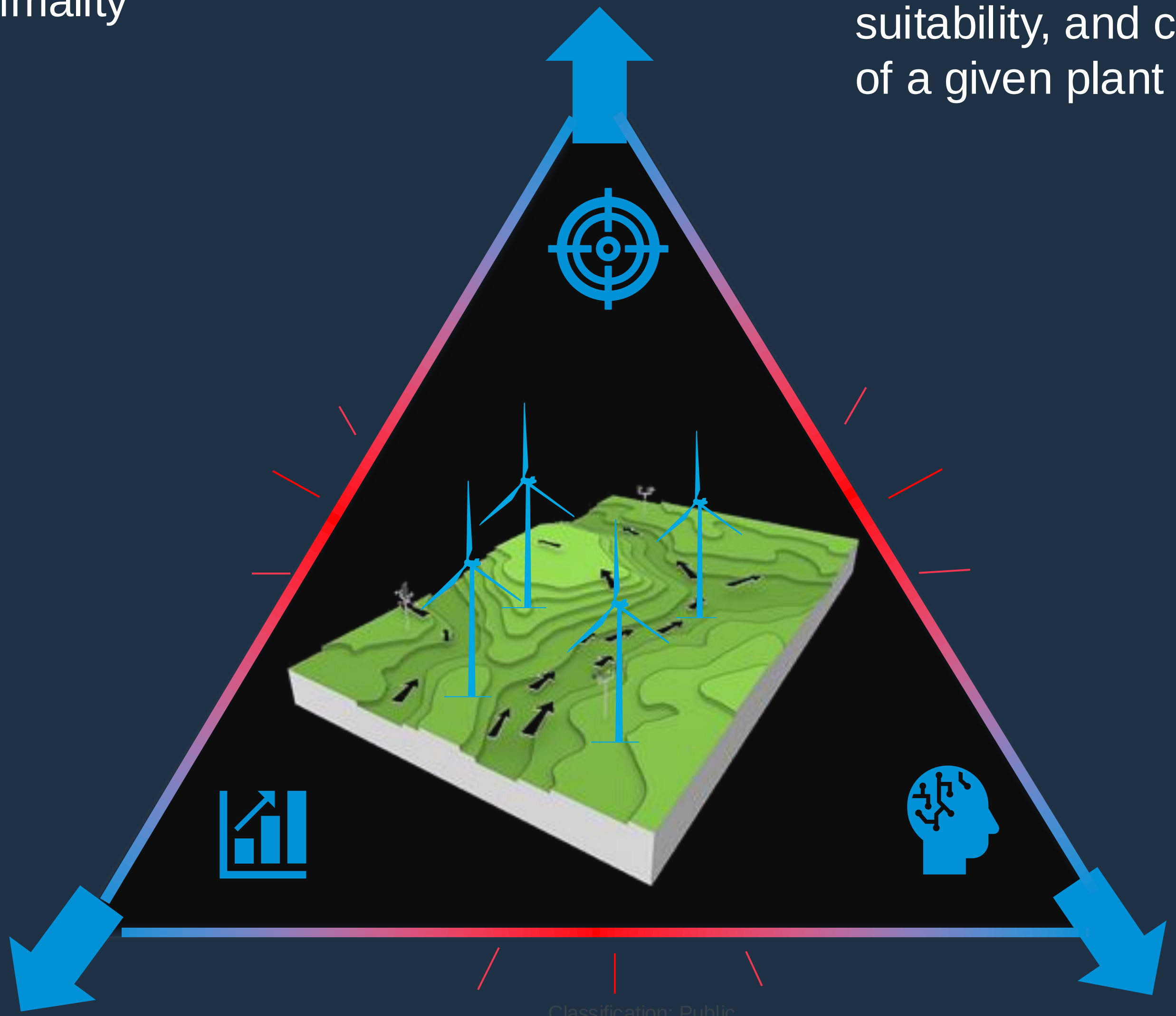


Plant Design paradigms

Scalability, accuracy, optimality

Accuracy

Ability to perform accurate prediction of yield, site suitability, and cost/revenue of a given plant configuration



Ability to perform evaluation on a growing scale without increase resources and time

Ability to reach a (technical, social, financial) optimal solution from a large design space (globally) in short timelines

Scalability

Optimality

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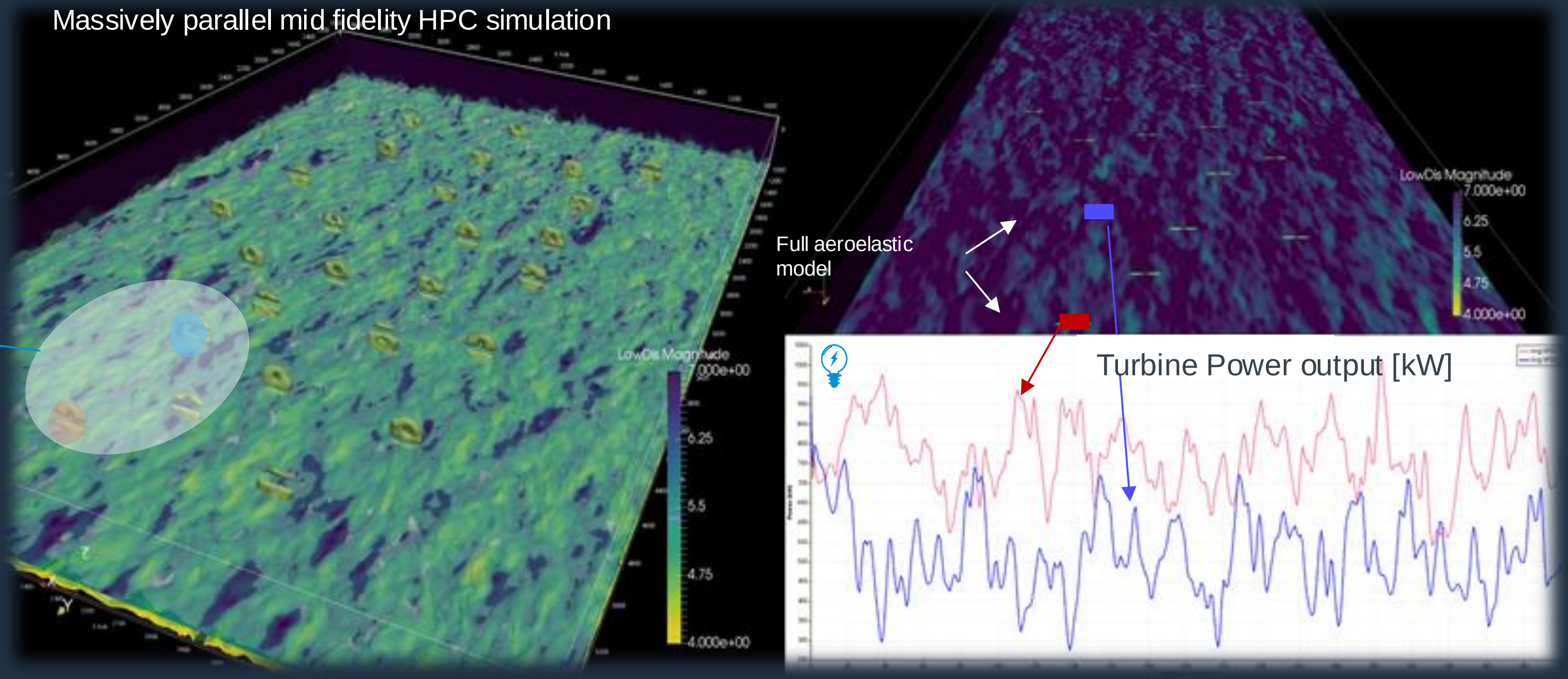
Accuracy, speed and scale?

INDUSTRY STANDARD. Low fidelity, scalable but questionable accuracy

Added turbulence intensity. S. Frandsen
Source DTU pywake

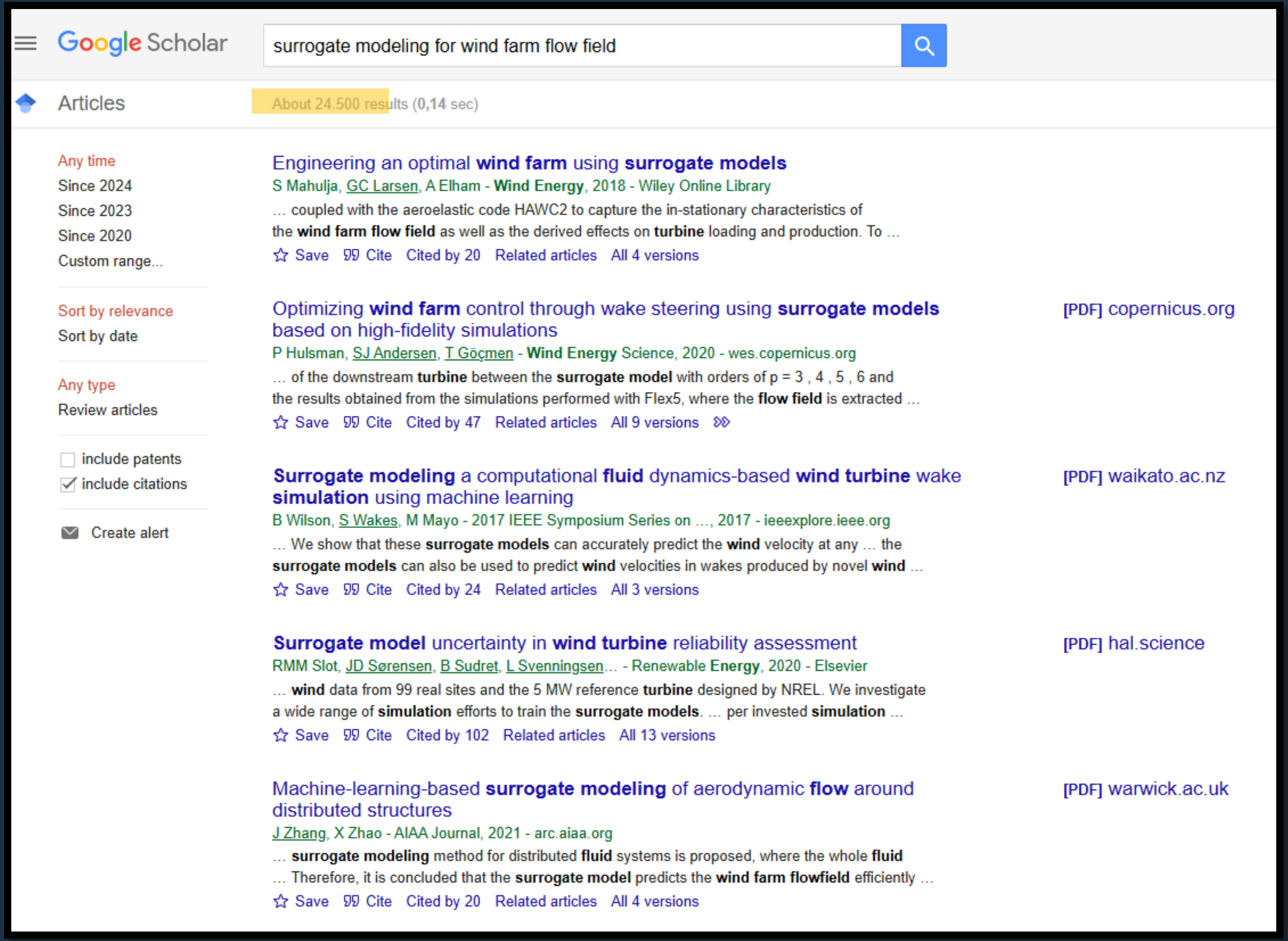
Research: High / mid fidelity, not scalable but (supposedly) accurate



30min of simulated operation

Addressing design challenges

High research focus on surrogate models.



WINDFARMER

CFD.ML wake & blockage model

- High research activities
- A few commercial offerings (DNV)

- **Vast majority internal development, proof-of-concepts.**

What are the barriers towards broader utilization and standardization in the industry? Sunsetting standard engineering models

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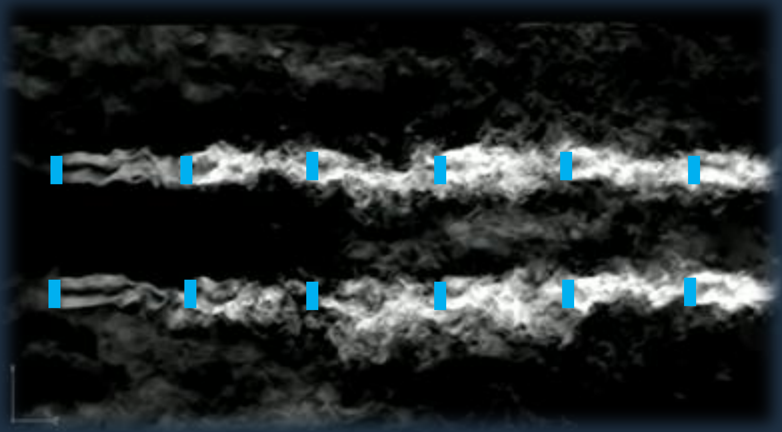
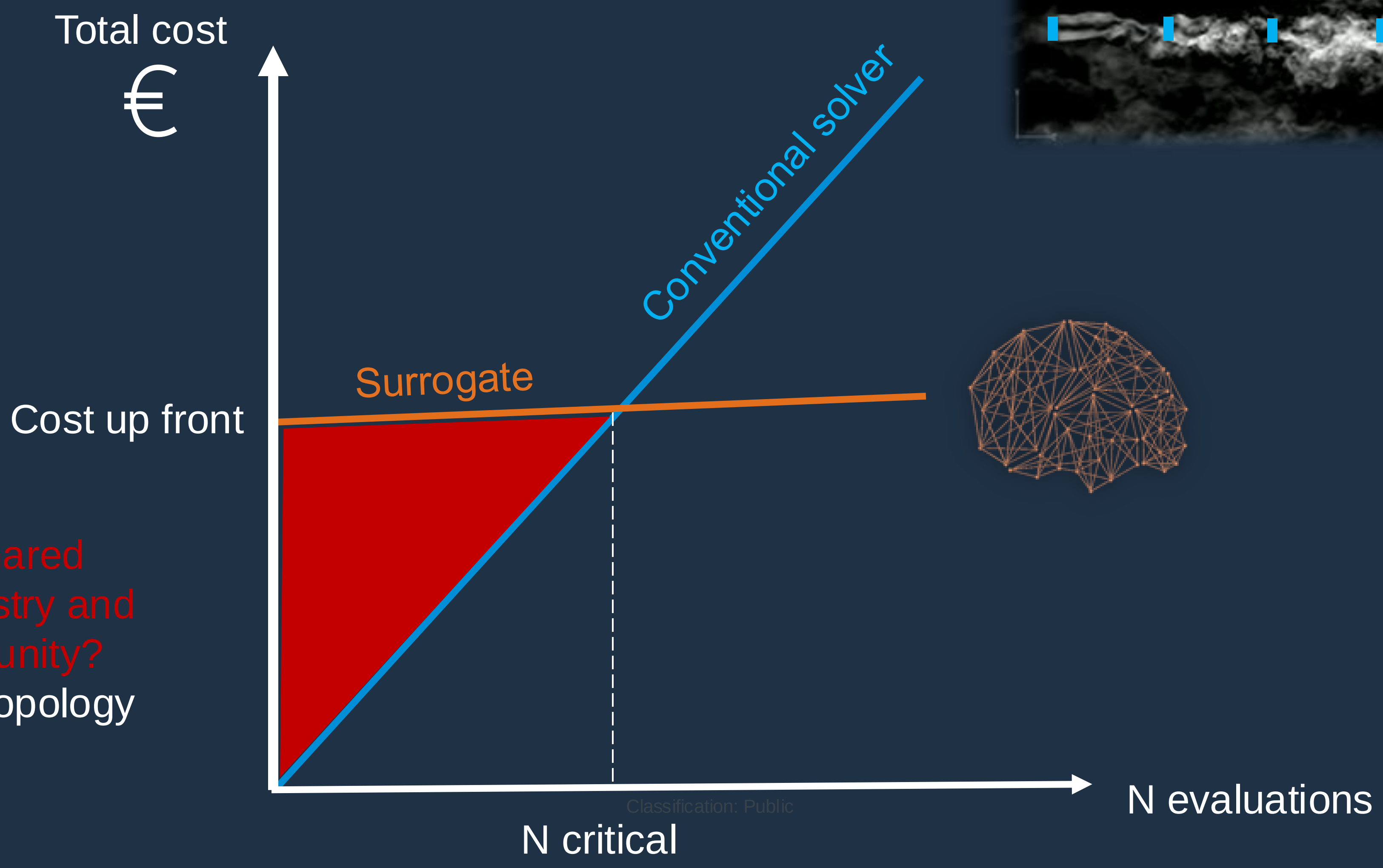
Addressing design challenges

Evaluations and costs considerations





Can effort be shared across the industry and research community?

Generalize for topology

Climates

Terrains

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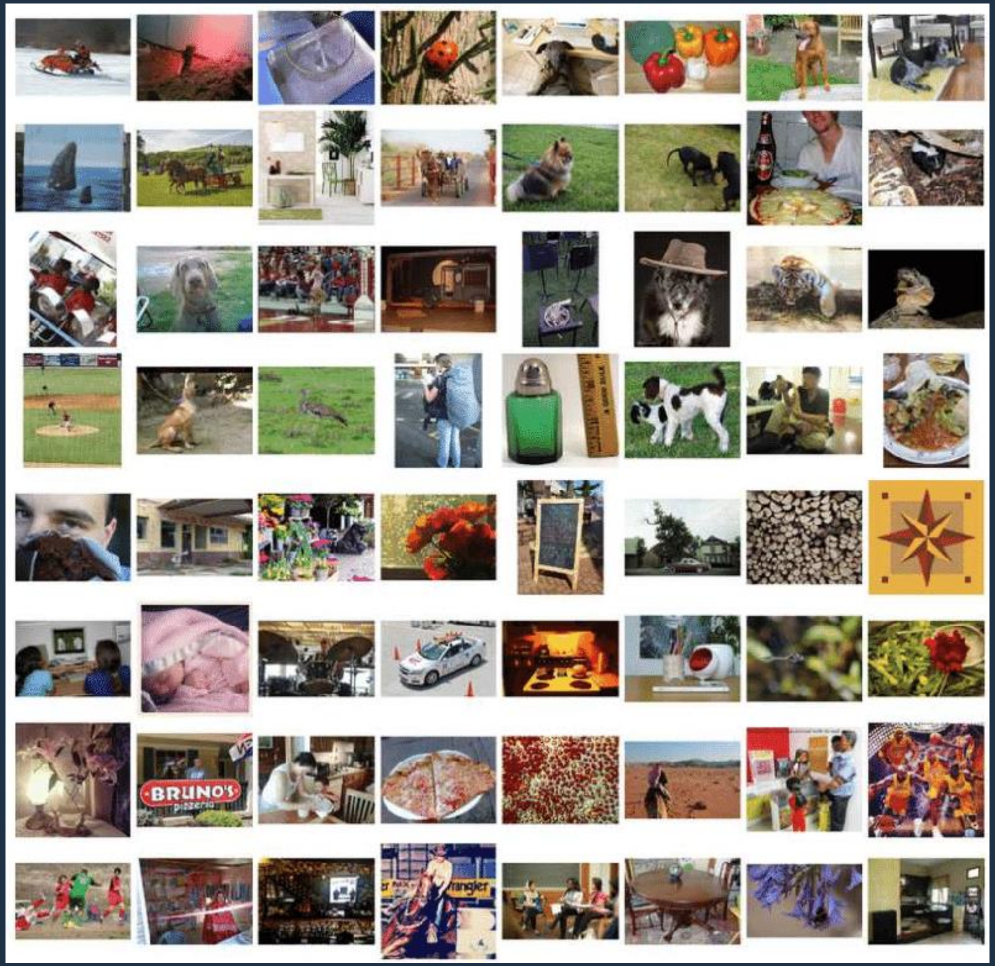
Open Training Datasets?

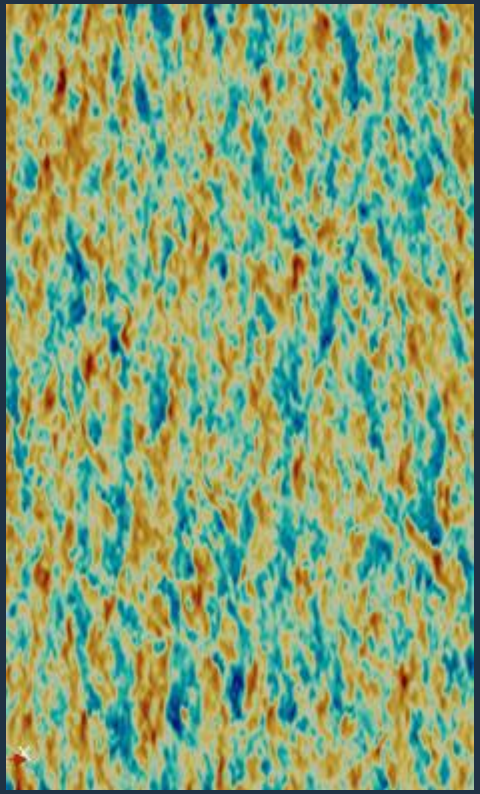
Inspired by the ML/AI age



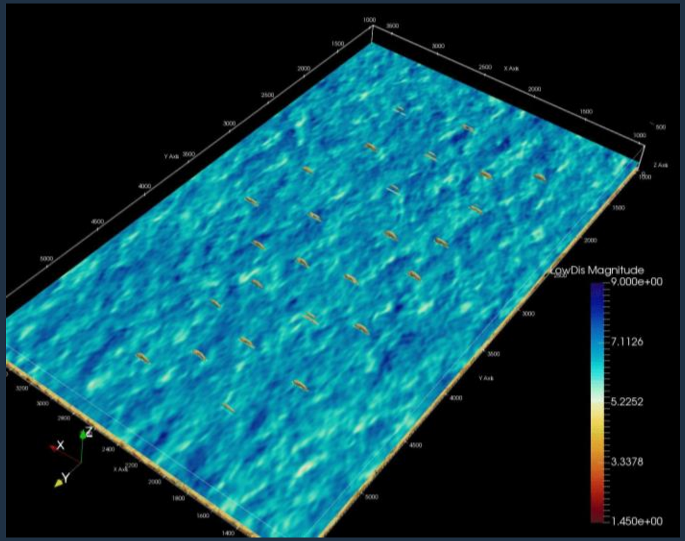
Example **ImageNet dataset**, instrumental in advancing computer vision and deep learning research.

?

An open microscale wind covering a wide range of atmospheric conditions – improved wind assumptions for model base design



NREL SOWFA LES ABLsolver - 2019
Neutral ABL flat terrain ambient climate



Addition of WTG aerodynamics
DWM type wake modeling

Standardization of methods to generalize to any terrains (nontrivial)

Final remarks

- AI/ML will without doubts power the growth needed for the energy transition (large research focus witnessed)

- The industry sits with a large wealth of data, from multi-scale multi fidelity models to real world measurements (Vestas - 185GW).

- Data ownership and OEMs secrecy to be considered.

- Can the industry (manufacturer, academia) further collaborate on generalization and standardization of surrogate models?

    - Sunsetting legacy engineering models and drive IEC standard further to embrace applied ML.
    - Open microscale wind dataset?

End

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Appendix

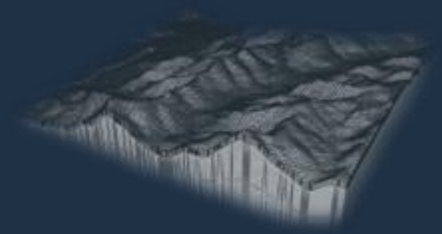
Plant Design System Engineering

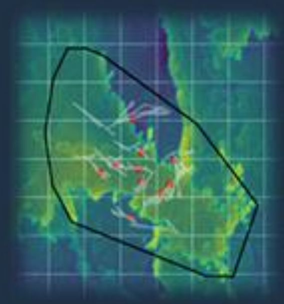
High level “functional” decomposition

Highly iterative
~ million, billion

Measurement → **Mesoscale Climate** → **Ambient flow** → **Plant flow** → **Plant configurations**

Vestas Climate Library





Energy yield

Lifetime load
Site suitability

x, y, z

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Surrogate scope consideration

High level

Source traceability

- Model origin
  - Surrogate version
  - computational set up
  - access code repository

Training data

Training dataset
- Source (model, SCADA,…)
- Size, dimensions
- coverage

Model accuracy

- Predictive power, approximation capability: training dataset fits
- Generalization capabilities (unseen data)

Compute

- Simulation architecture (GPU/CPU)

Vestas

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