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Chair of Structural
Mechanics & Monitoring

Wind Energy: Opportunities and Grand Challenges

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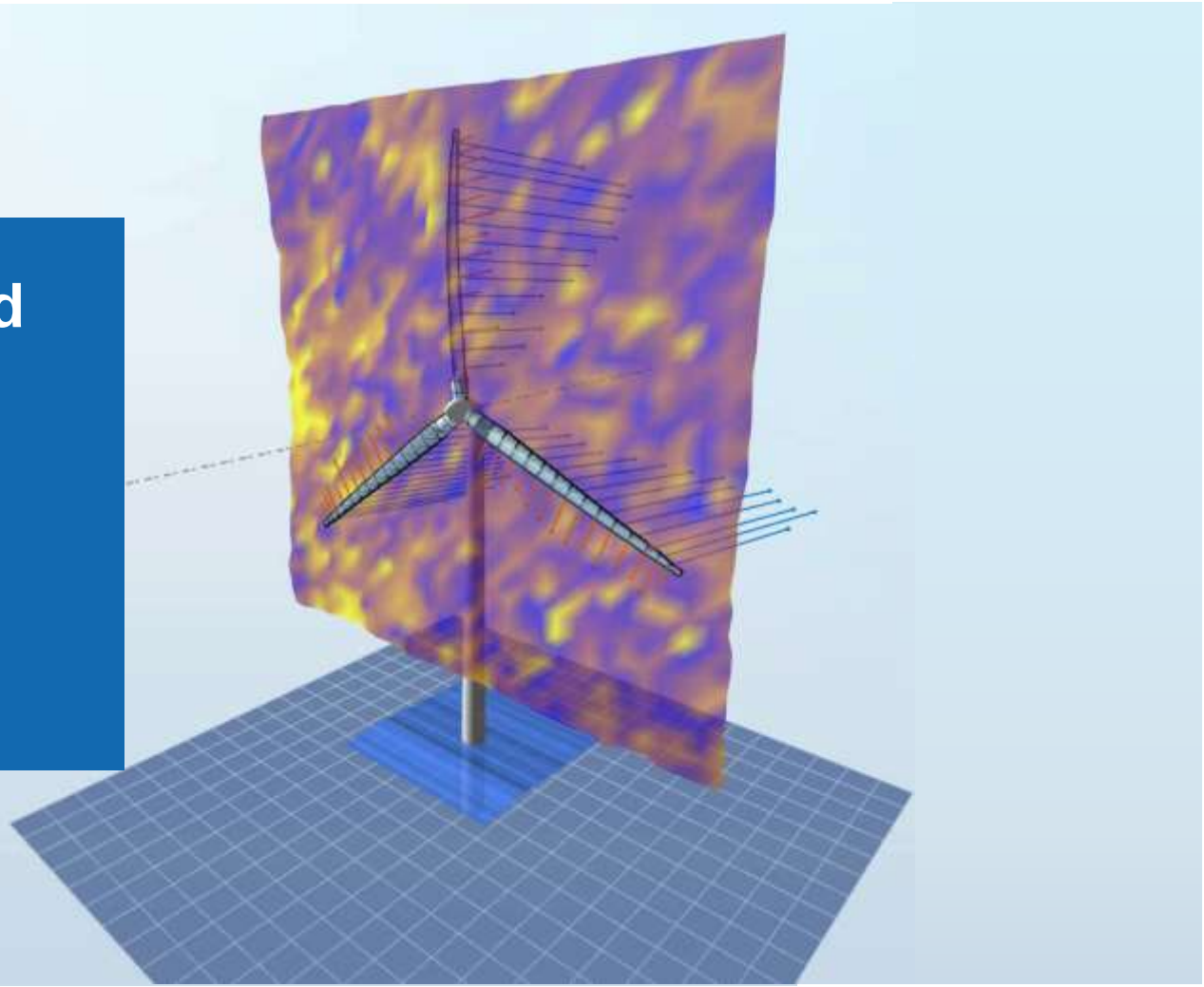
ETH Zürich |
European Academy of Wind Energy



eawe european academy of wind energy

D BAUG

The Rise of Wind Energy

Sustainable Energy Goals

Wind energy is crucial for reducing greenhouse gas emissions and achieving global climate targets through its clean, renewable nature.

Global Importance

Wind power is a leading renewable energy source worldwide, contributing significantly to the global energy mix and providing a reliable, environmentally-friendly alternative to fossil fuels.

Global Installed Capacity

The global installed wind energy capacity has grown exponentially in the past decades, reaching almost 900 GW by end of 2022

Wind energy has become a global powerhouse in the clean energy transition, playing a crucial role in achieving sustainable energy goals through its widespread adoption and continued growth worldwide.

The Rise of Wind Energy

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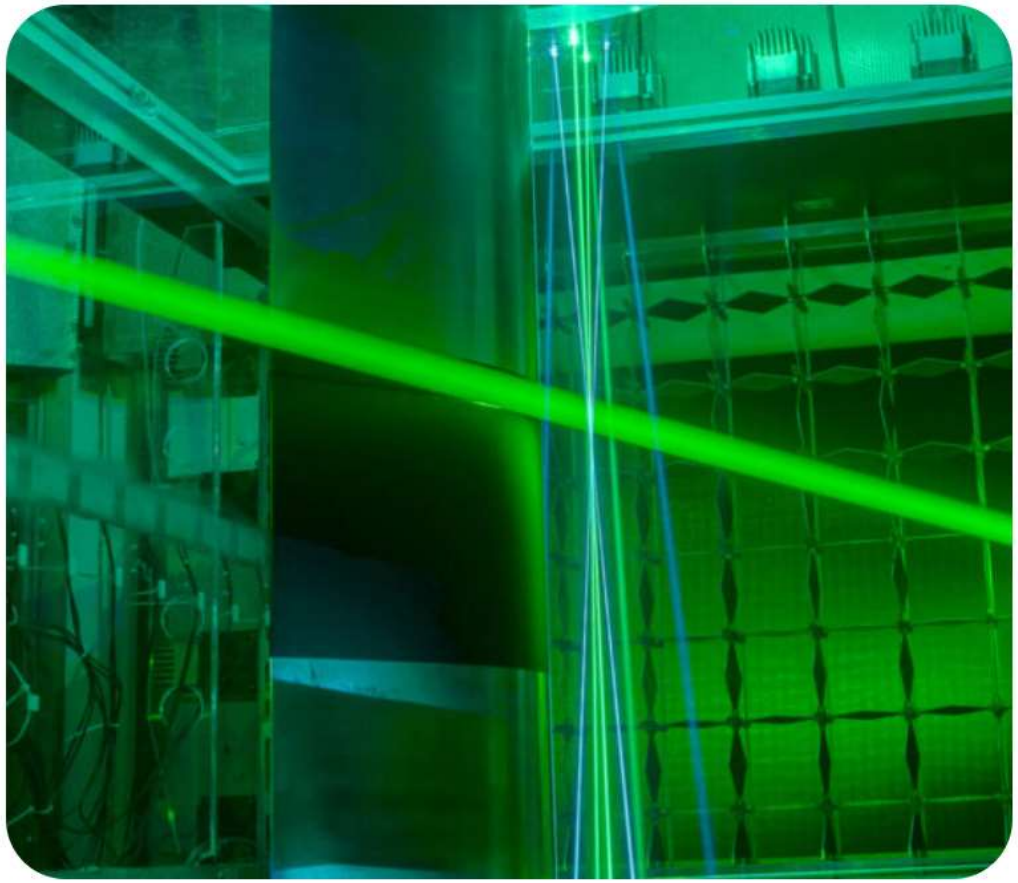
The European Academy of Wind Energy | EAWE

THE ORGANISATION

Pioneering the Future of Wind Energy

EAWE is an international non-profit organization that promotes and supports the development of wind energy science. Our goal is to exploit wind energy to its full potential for the benefit of the world.

As an international alliance of more than 60 universities in Europe and the US, EAWE is a community of worldwide experts in wind energy that provides a credible voice of tomorrow's wind energy research.

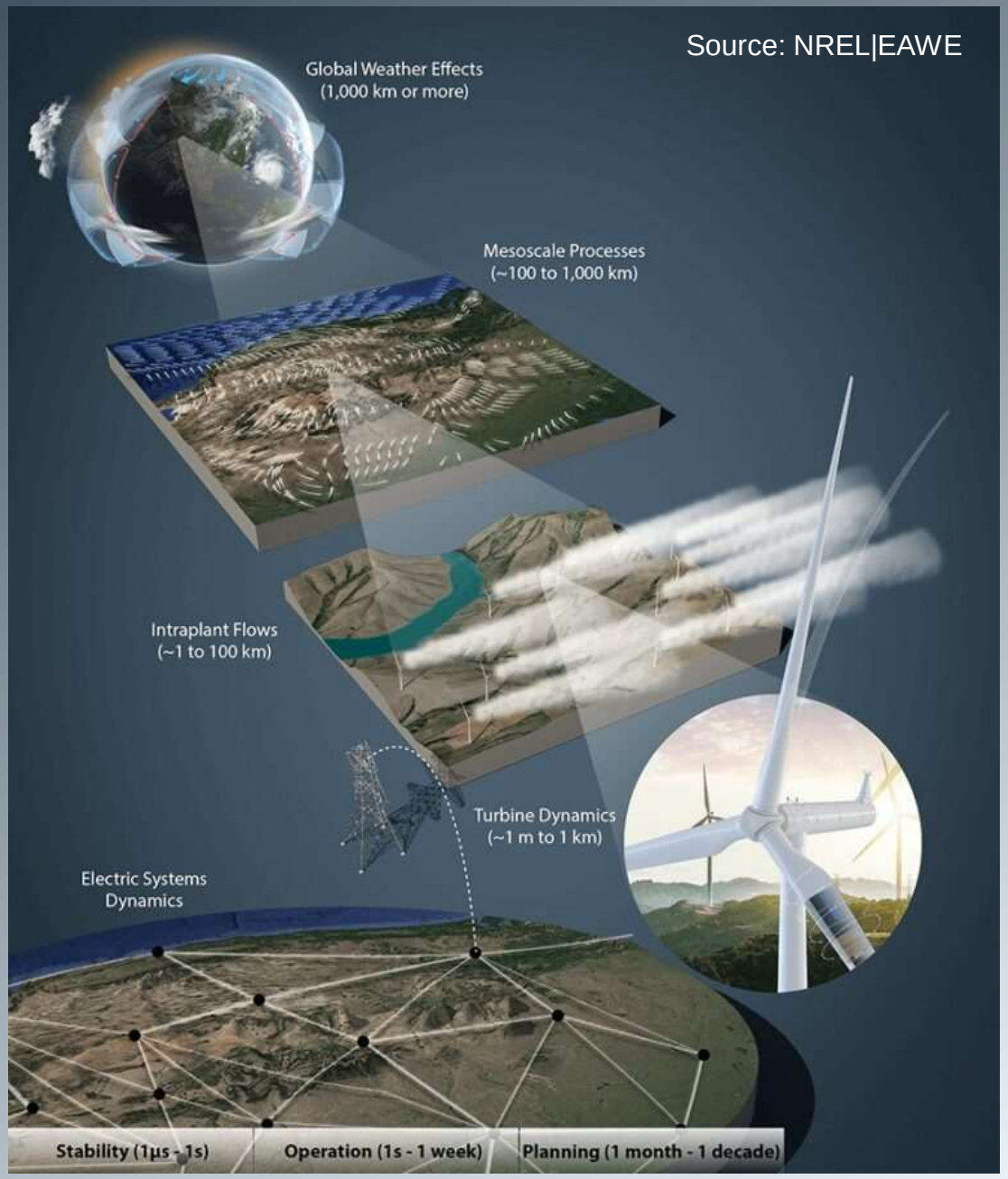


EAWE Website

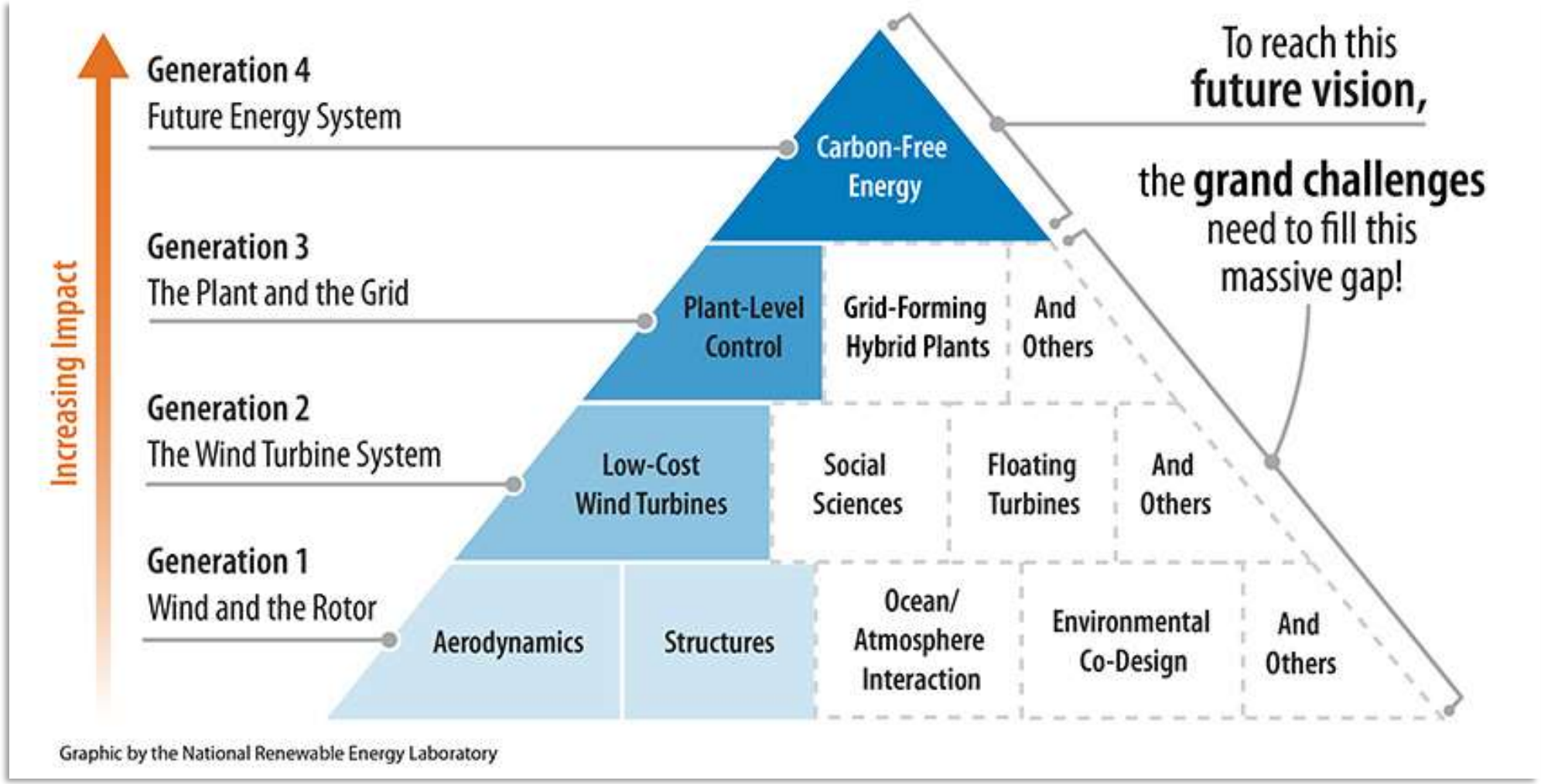
Wind Energy across Scales

Grand Challenges (WES Journal)

- Wind resources, atmospheric science, and the physics of air flow at wind farms
- System dynamics and materials involved in wind turbines and wind farm technology
- Optimization and control of wind farm operation and maintenance for reliability and resiliency
- Environmental co-design to situate wind farms to local constraints and opportunities
- Social science to identify how wind plants can add value to host communities
- Crosscutting and emerging initiatives, such as digitalization and education.

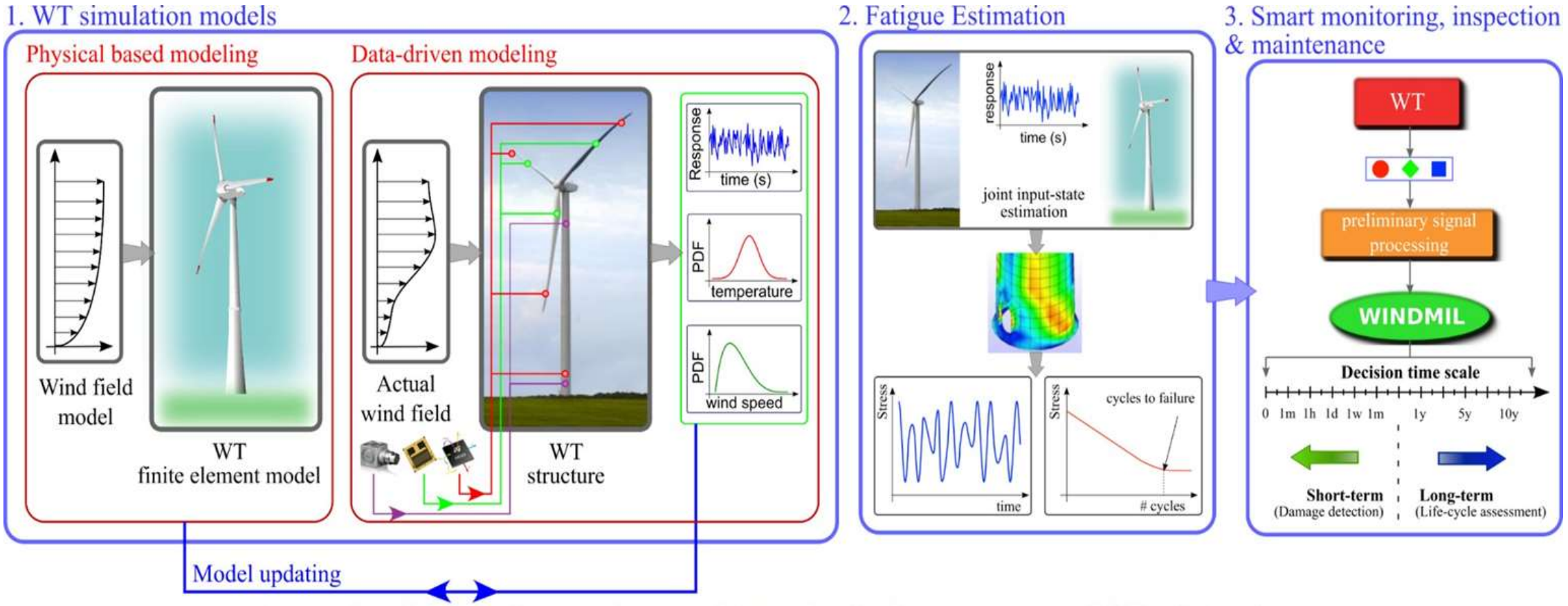


Next Generation of Wind Energy



Wind Energy at the Chair of SMM

Smart Monitoring, Inspection and Life-Cycle Assessment of Wind Turbines

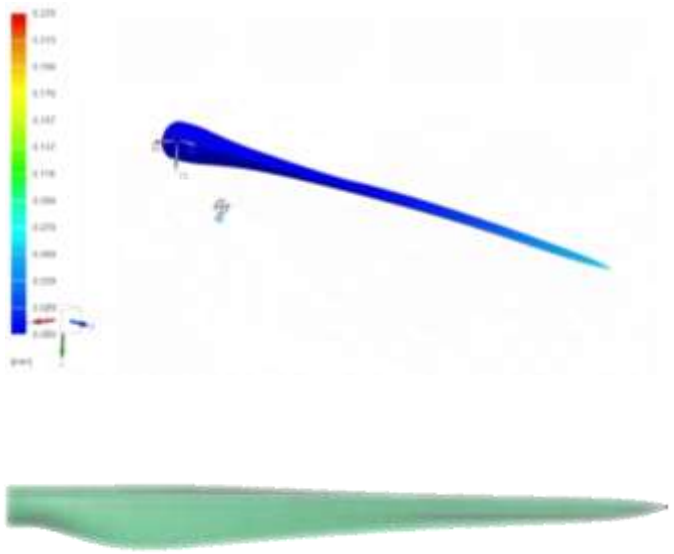


Research at the Chair of Structural Mechanics & Monitoring

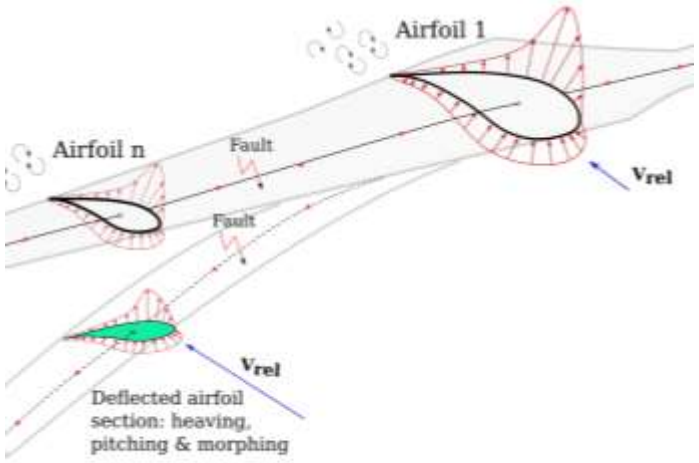
Academic Partnerships

UNIVERSITY OF OXFORD · CentraleSupélec · cnrs · University of Sheffield · DTU · OST

Virtual Sensing & Digital Twinning



Diagnostics & Prognostics



Farm Level Assessment

Smyth and Elliott, 2014

Industry Partnerships

SIEMENS · SIEMENS Gamesa RENEWABLE ENERGY · VATTENFALL · osmos · HBK HOTTINGER BRÜEL & KJÆR · RWE

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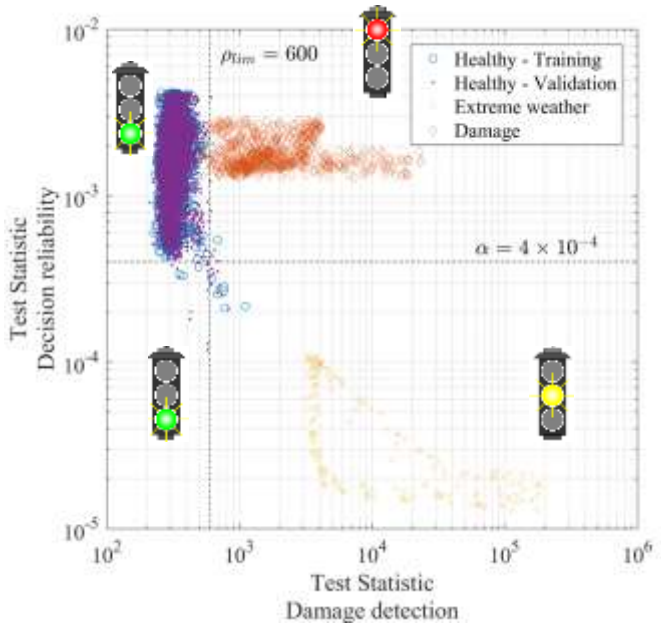
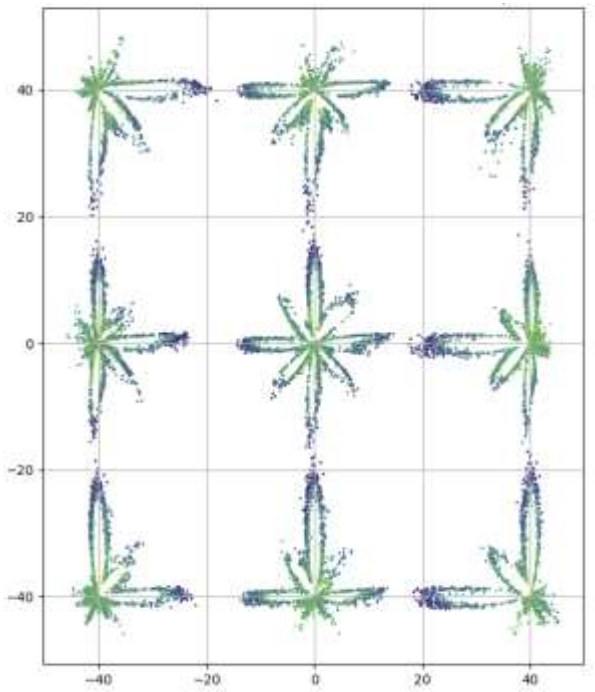


Farm Level Assessment



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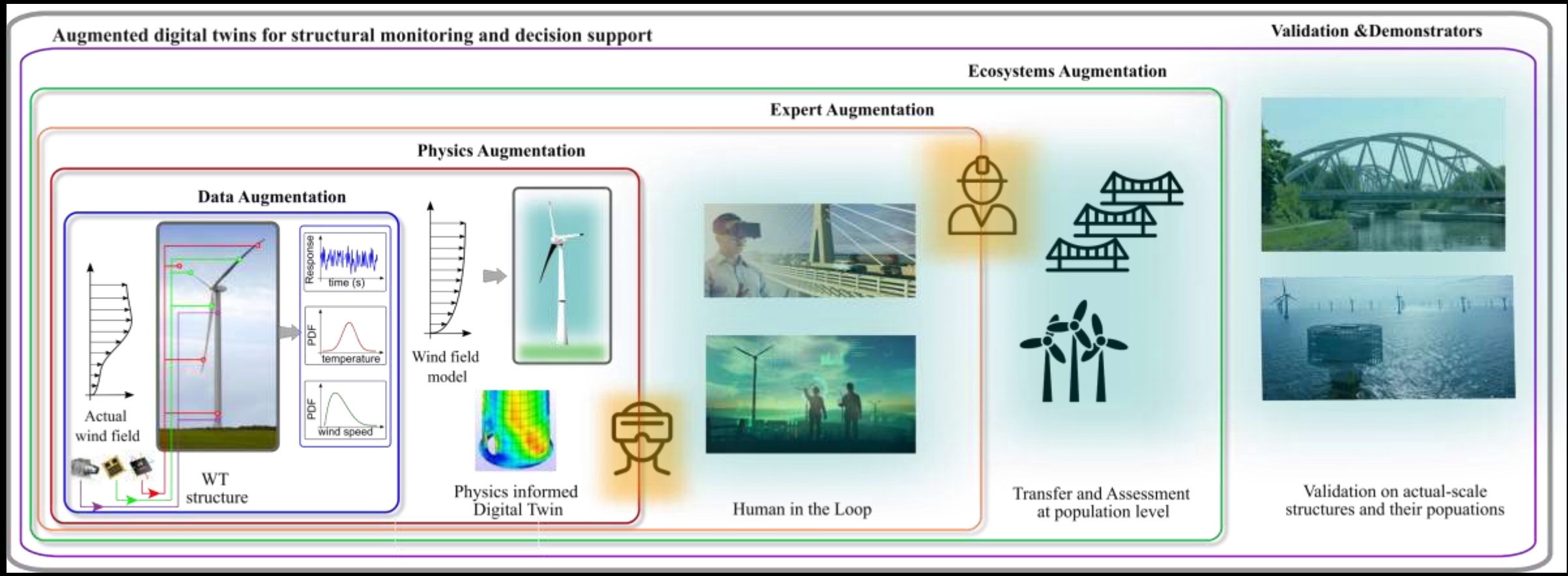
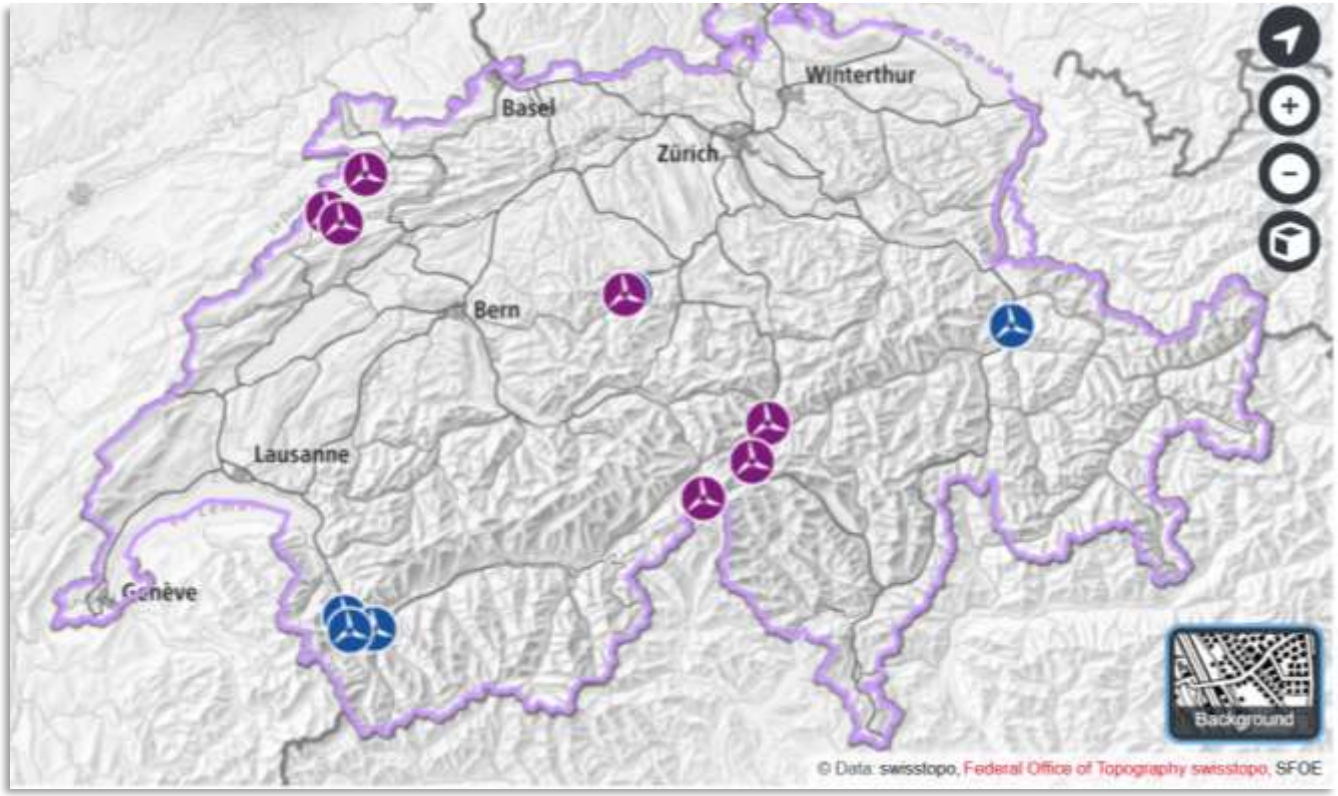
A Long-term Vision for Resilient & Performant Wind Energy Structures



Wind Energy in Switzerland

- The first wind energy facility in Switzerland was put into operation in 1986 near Soolhof and had an output of 28 kW.
- Currently, almost 40 large wind energy facilities in operation in Switzerland (combined total of around 140 GW·h of electricity)
- Largest wind park: Mont Crosin in the Bernese Jura | 16 wind turbines with a total output of 37.2 MW.
- Other large facilities are in operation in the Rhône Valley (canton of Valais), Entlebuch (canton of Lucerne) and on the Gütsch (above Andermatt, canton of Uri).



Source: bfe.admin.ch

Wind Energy in Switzerland | Challenges

Research challenges and needs for the deployment of wind energy in hilly and mountainous regions, in terms of:

- *Site prospecting*
- *Wind resource assessment*
- *Project planning*

Challenge	R&D need
Increased uncertainty of wind turbine performance models (Sect. 4.1)	Data sets for verification of multi-variate power performance models
	Acceptance of black-box approaches
Additional information required for wind farm design (Sect. 4.2)	Data needed for multi-variate power performance models
	Wake models for complex terrain
Increased financial uncertainties (Sect. 4.3)	Guidelines for dealing with additional risk at complex sites
Increased conflict potential between stakeholders (Sect. 4.4)	Better understanding of the sources of stakeholder conflict
	Better understanding of the physics of sound in complex terrain

Source: Clifton, A., Barber, et al. (2022), Wind Energ. Sci.

Wind Energy in Switzerland | Challenges

Research challenges and needs for the deployment of wind energy in hilly and mountainous regions, in terms of:

- *Site prospecting*
- *Wind resource assessment*
- *Project planning*
- *Wind turbine design*
- *Operation of wind plants*

Challenge	R&D need
Lack of standards for performance verification tests at complex sites (Sect. 6.1)	Standards for using nacelle-mounted lidar in complex terrain
Accurate site-specific power prediction (Sect. 6.2)	Multi-parameter power prediction tools
	Use and acceptance of machine learning
Forecasting weather and power at operational plants (Sect. 6.3)	Simplified or standardised model evaluation processes
Downscaling forecasts to individual turbines (Sect. 6.4)	Collaborative exercise on downscaling wind forecasts
Predicting the likelihood and impact of icing conditions (Sect. 6.5)	Improved weather models
	Improved ice accretion models
	Improved turbine performance models
	Climate-controlled test facilities
	Test facilities in icing locations

Source: Clifton, A., Barber, et al. (2022), Wind Energ. Sci.

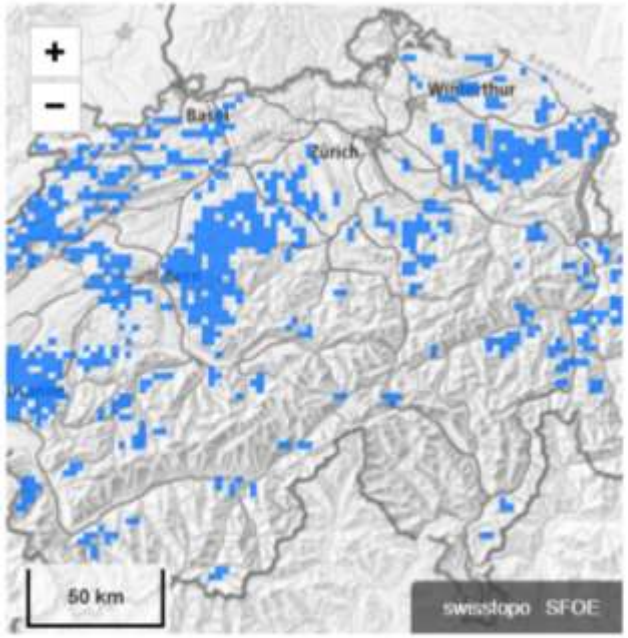
Wind Energy in Switzerland | Challenges

Federal government interests are based on a synthesis of the restrictions that apply with regard to

- noise abatement,
- the federal government's sectoral plans,
- measures to conserve the landscape, nature and cultural heritage and protect endangered species,
- as well as technical facilities which fall within the federal government's authority.

Source: www.uvek-gis.admin.ch/BFE

areas with wind-power potential



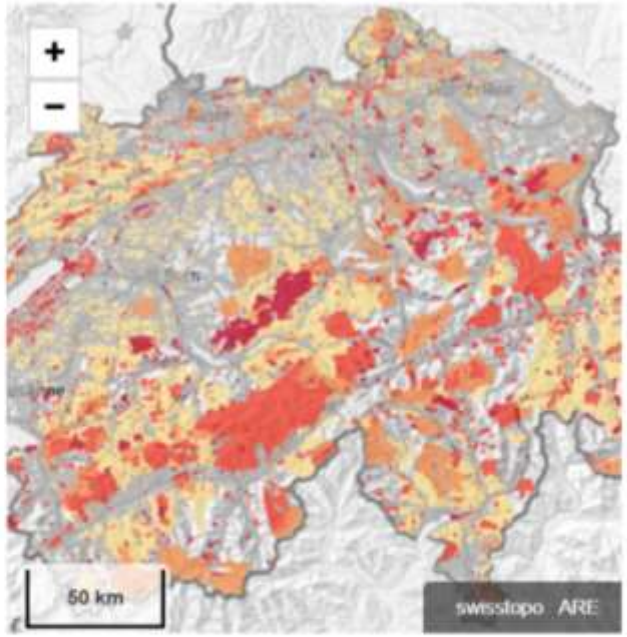
Full screen

Im Rahmen der Richtplanung abzuklärende Gebiete

Gebiete mit hohem Windpotenzial

Die Analyse macht unterhalb von 1:50'000 keine Aussage

federal government interests



Full screen

Building zones with buffer (noise abatement)

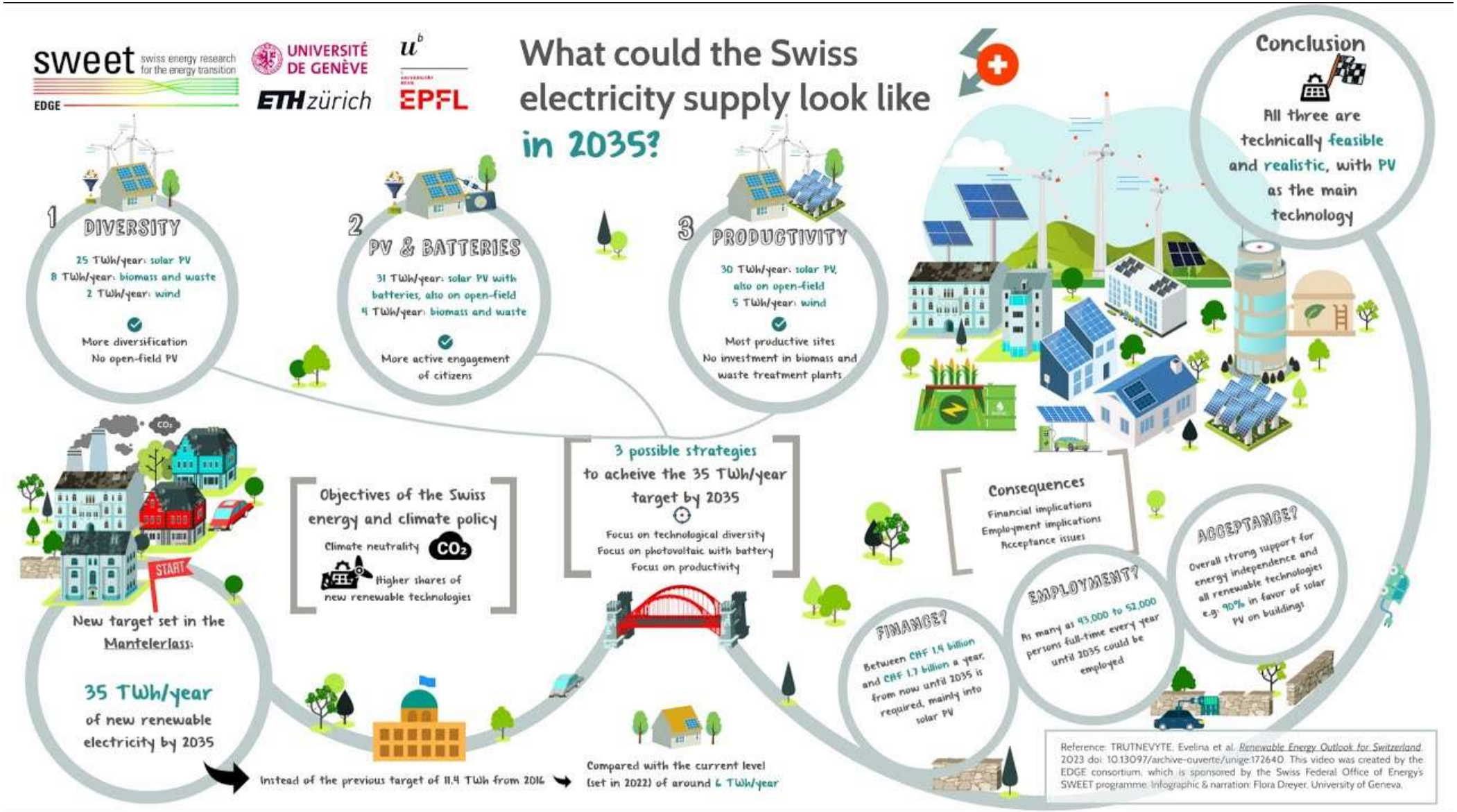
Protected areas without a balancing of interests

Areas to be excluded in principle

Areas subject to inter-authority coordination (not exhaustive)

Other restrictions

Green Energy in Switzerland | Diversity is Key



Green Energy in Switzerland | Diversity is Key

Hydropower

Switzerland's primary renewable energy source, accounting for over 55% of total electricity generation. Hydropower can be integrated with wind energy to provide a stable and reliable electricity supply.

Geothermal Energy

Emerging as a small but promising renewable energy source in Switzerland. Wind energy can be used to power the infrastructure and operations of geothermal plants.

Solar Energy

Rapidly growing in Switzerland, with photovoltaic installations on residential and commercial buildings. Seasonal and Landscape complementarity

Bioenergy

Excess wind power can be used to produce synthetic biogas through a process known as Power-to-Gas. This technology converts surplus wind electricity into hydrogen or methane that can be stored and later used in bioenergy plants to produce electricity or heat.

Summary

Challenges

Limited land availability.

Public Concerns.

Grid integration and transmission infrastructure challenges to connect wind farms to the national electricity grid.

Opportunities

Abundant wind resources in mountainous regions, particularly in the Jura and Alpine regions.

Technological advancements in wind turbine design and improved grid integration and storage solutions can enhance viability.

Requirements

Careful site selection and mitigation measures to minimize impact on wildlife/ landscape.

Addressing public concerns.

Adopting economies of scale & policy support.

Diversifying the energy mix.

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We welcome questions/comments/collaboration:
chatzi@ibk.baug.ethz.ch