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Facilitating a smoother transition to Renewable Energy with AI (AI4Renewables)

Two-days of learning, fun and networking - with AI and sustainability enthusiasts from across the world

Day 1- Social @ICLR 2022

25th and 27th April 2022 (11 am – 1 pm GMT)

Event Webpage:
https://www.ai4renewables.org

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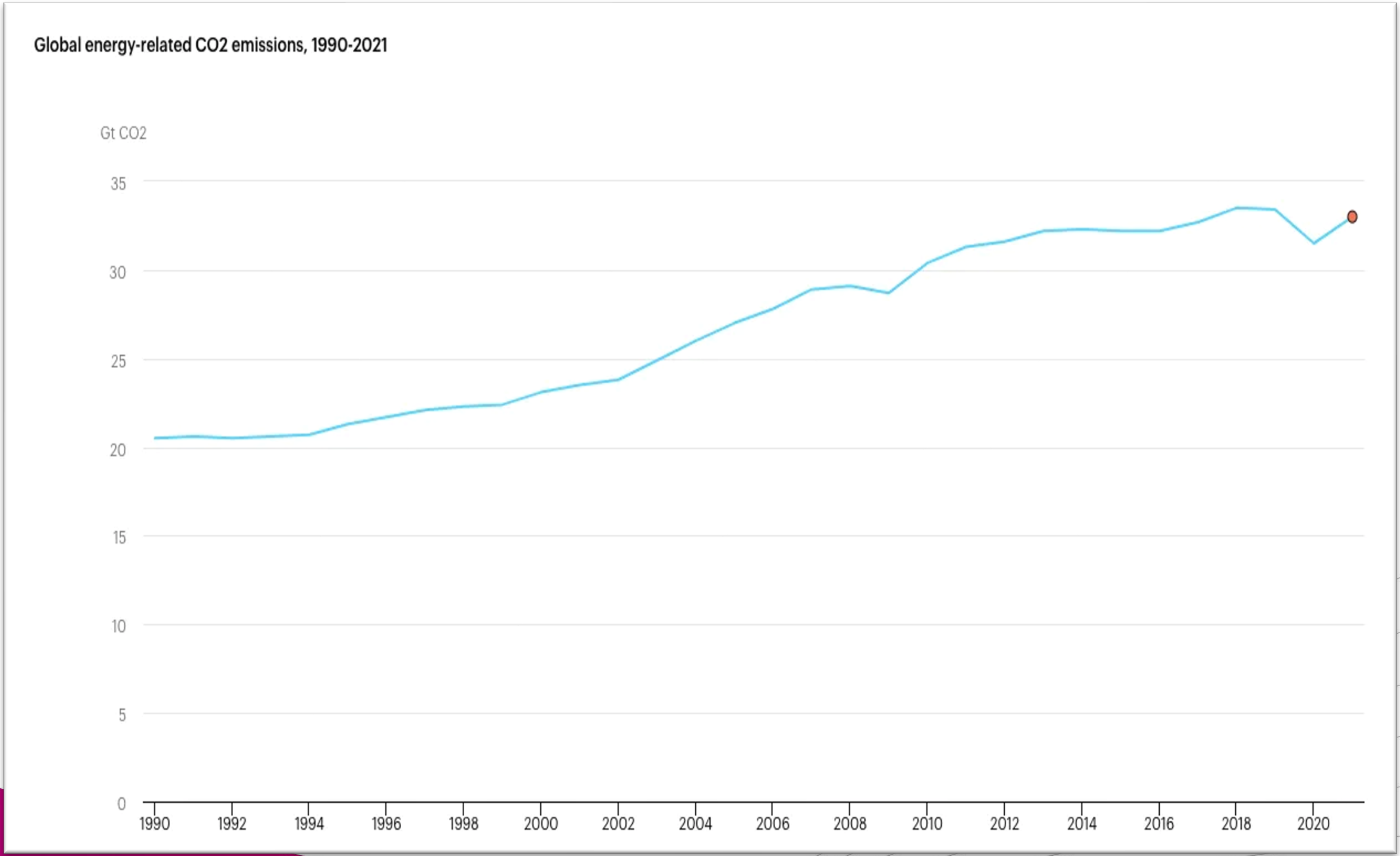
BIG DATA ANALYTICS

Introduction

In 2021, **the global energy-related CO2 emissions** rebounded to record numbers - **second-highest in history**!



Reference: International Energy Agency (IEA), March 2022

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Introduction

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- To prevent a recurrence of this **dire phenomenon**, **electricity from renewables** must underpin our future energy system.
- According to the International Renewable Energy Agency (IRENA), **renewable energy can immediately, and significantly facilitate reduction in global CO2 emissions**.
- Interestingly, the **share of electricity in final energy consumption is only set to grow**, scaling exponentially from around current 20% to a **whooping 50% in 2050.**

Reference: International Renewable Energy Agency (IRENA), 2019

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The promise of renewable energy sources

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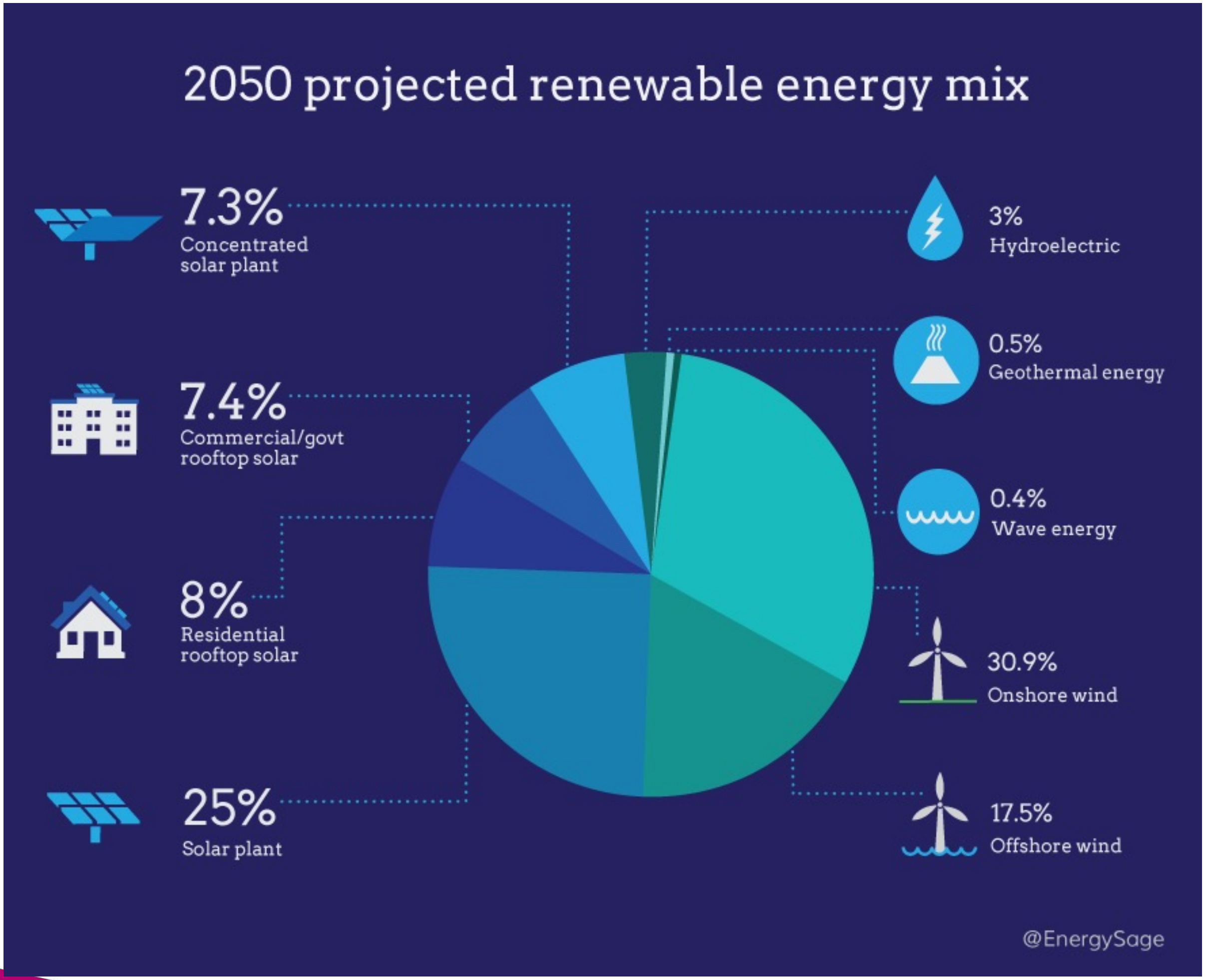

Reference: EnergySage, 2021

- **Wind energy** would potentially account for around 48.4% of renewables in the US by 2050!
- **Solar energy** is also promising, with around 47.7% of contribution to renewable energy mix in the US by 2050.
- **Majority of the energy demands can be met by wind and solar**, and remaining with geothermal heat and water.
- **Global installed wind capacity is predicted to grow** from **709GW in 2020** to **5.9TW in 2050.**

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Challenges in transitioning to renewables

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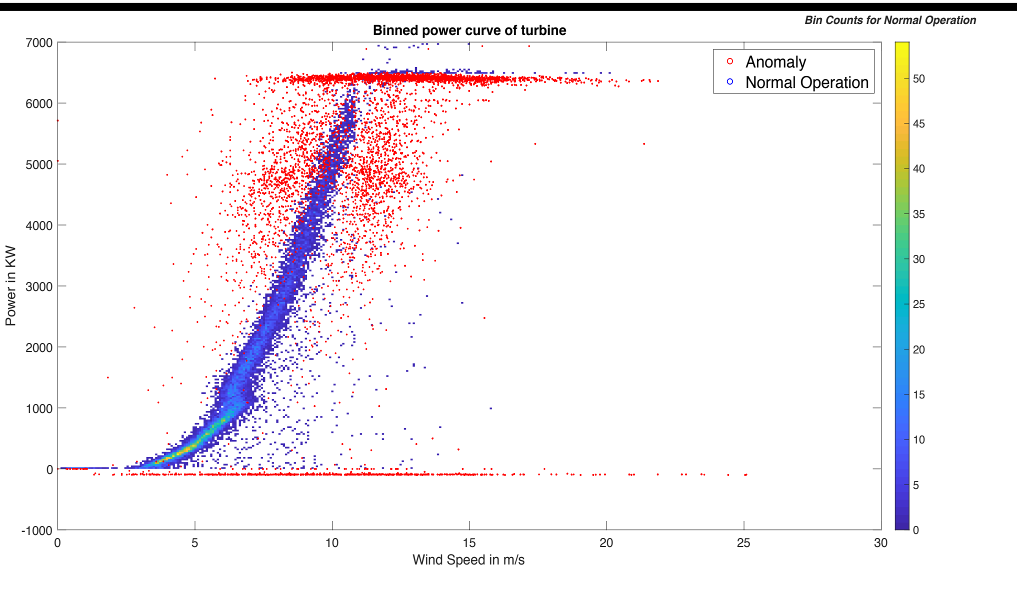
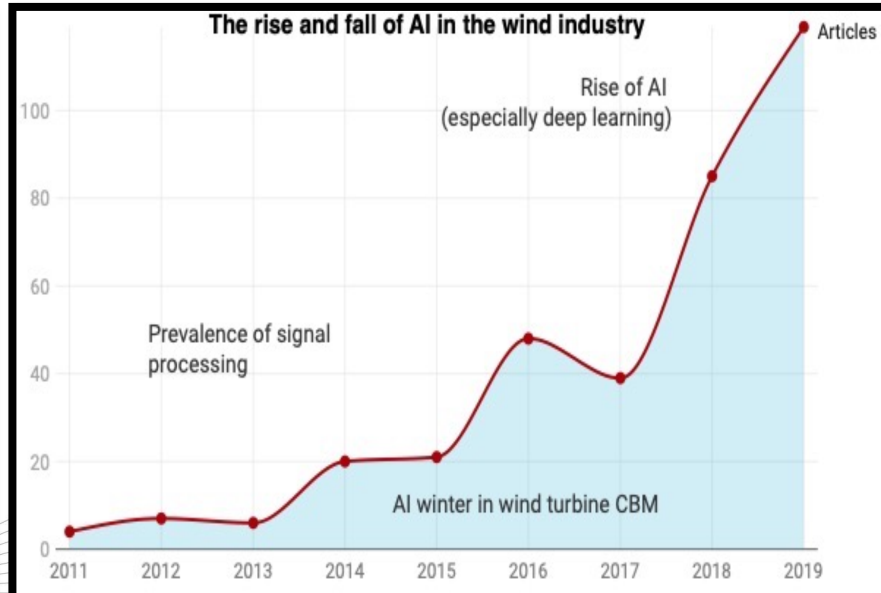
- However,….. the **transition to renewable energy sources like wind energy doesn't come without hurdles** - being complex engineering systems, **wind turbines regularly suffer from operational inconsistencies and failures.**
- This leads to **high operations & maintenance (O&M) costs**, unexpected **downtimes**, energy **production short of full potential** etc.
- **Modern wind turbines presently have multiple SCADA sensors** which record information on parameters right from external environmental conditions (e.g. wind speed and direction) to more low-level details like rotor speed, gearbox oil temperature etc.
- **AI can help reduce O&M costs**, bring down downtimes and **increase availability** of energy systems **by learning from such data during Condition-based monitoring (CBM).**
- But sadly, the **focus on leveraging AI in the renewables domain is very limited** at present.





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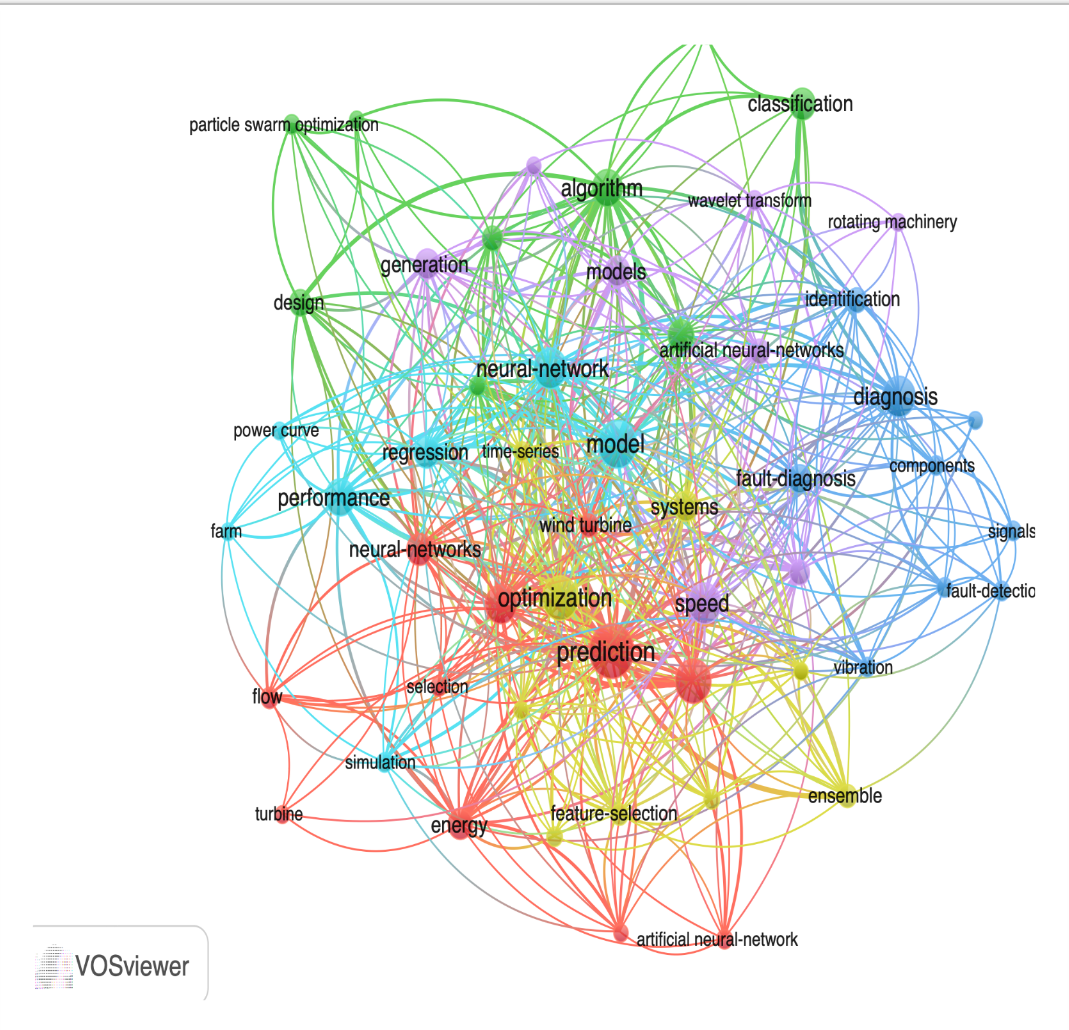
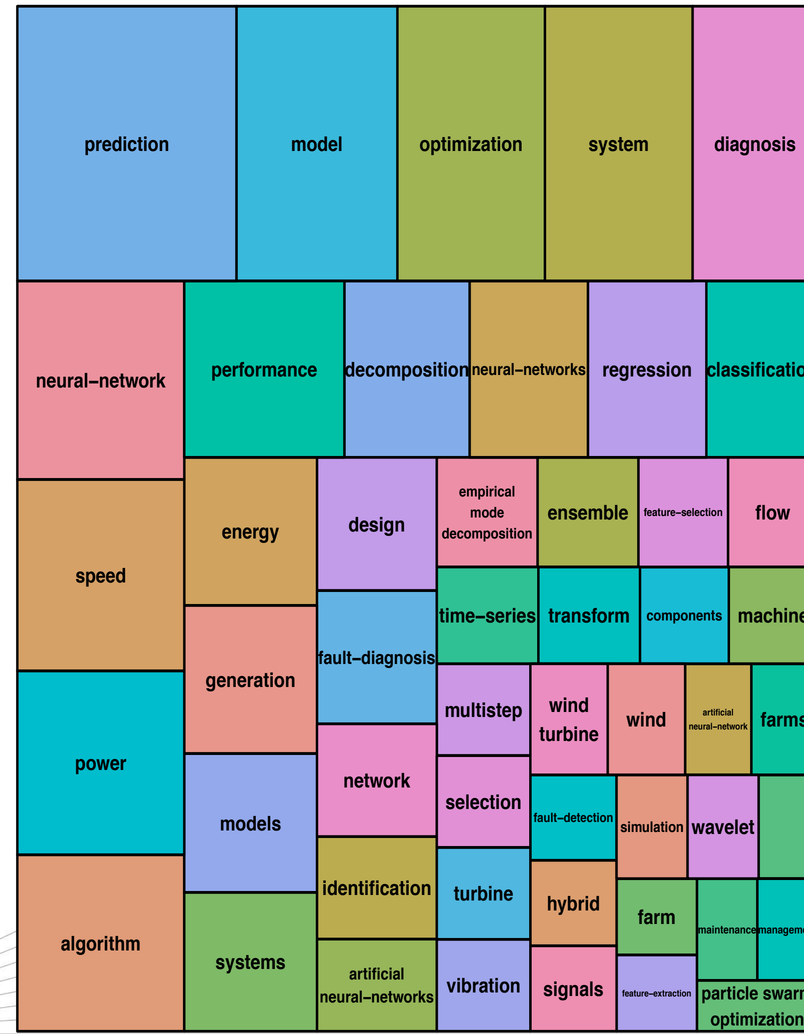
The multifaceted nature of AI in the wind energy domain

Reference: Chatterjee, J. and Dethlefs, N., “Scientometric review of artificial intelligence for operations and maintenance of wind turbines”, Renewable and Sustainable Energy Reviews, 2021.



TreeMap for application of AI techniques in CBM
Frequency



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The goal behind the AI4Renewables social

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- Now that we know **that AI can, and is already being used with multiple perspectives in the renewables domain, we want to spread the word through this social!** Bring more AI and sustainability researchers in to join the promising efforts in facilitating a smoother transition to renewable energy with AI!
- The social will focus on **building a stronger community that is passionate about applying AI for improved availability and reliability of renewable energy sources.**

Day 1

A glance into the schedule – all times in GMT

25 APRIL 2022

11 a.m.-11.15 a.m. — Welcome and introduction to the event

Dr. Joyjit Chatterjee and Dr. Nina Dethlefs

11.15 a.m.-12.40 p.m. — Panel discussion on AI4Renewables with the invited panellists

All invited panellists - see here.

12.40 p.m.-1 p.m. — Open Q&A from audience to the invited panellists

All audience

Organisers

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@bda_hull

Dr. Joyjit Chatterjee
Data Scientist (KTP Associate) at Reckitt and University of Hull, UK

Dr. Nina Dethlefs
Senior Lecturer and Director of Research in Computer Science at University of Hull, UK

Please visit https://bda-hull.github.io for more insights on AI4Renewables and other sustainability-related projects being pursued by the organisers. We are always open to ideas and collaborations!

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We are excited to be joined by wonderful experts today

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Eminent Panellists

Dr. Natalia Efremova
Lecturer in digital economy, Queen Mary University of London and CTO at Deep Planet, UK

Clym Stock-Williams
Manager of Performance Analysis and Improvements at Vattenfall, Netherlands

Dr. Shruti Kulkarni
Senior Data Scientist at Deloitte, Belgium

Alexandra Klang
Chairperson of the board, United Nations Association Malmö and Sustainability Consultant at Exceed, Sweden

Dr. Ravi Pandit
Lecturer in Instrumentation and AI at Cranfield University, UK

- The panel discussion would initially focus on **5 questions centered around the theme of this social.**
- We would request the panelists to share their views in around **3.5 minutes for each individual question.**
- The panelists would share their views based on their **significant personal experience and expertise in sustainability and/or AI.**
- After the panel discussion concludes, we will **have time for the audience to ask questions to the panellists.**

For detailed information about the panellists, please visit: https://www.ai4renewables.org

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Let’s start with the panel discussion now!

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Facilitating a smoother transition to Renewable Energy with AI (AI4Renewables)

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Day 2 - Social @ICLR 2022

25th and 27th April 2022 (11 am – 1 pm GMT)

Event Webpage:
https://www.ai4renewables.org

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Agenda for the day

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- Welcome to Day 2 of the AI4Renewables social!
- Today, **our focus would be on knowledge sharing in the AI4Renewables domain** – providing a brief overview of open-source datasets, insightful papers, future roadmap etc. for a smoother transition to renewable energy with AI.
- Later today, **we would also be joined by an invited speaker to get some fascinating insights on applying AI for climate change mitigation** through smoother energy transition.
- We would also have **2 socialising sessions with breakout rooms during today's event**– (i) For the audience to share their sustainability vision and past/present research with other attendees. (ii) All audience to discuss and explore collaboration opportunities, knowledge exchange etc. at the intersection of industry and academia.

Time (in GMT)	Agenda
11 a.m.-11.05 a.m.	Welcome and detailing of agenda for the day – **Dr. Joyjit Chatterjee**
11.05 a.m. -11.20 a.m.	Knowledge sharing in the AI4Renewables domain - open-source datasets, insightful papers etc. – **Dr. Joyjit Chatterjee and Dr. Nina Dethlefs**
11.20 a.m.-12 p.m	Virtual Breakout Rooms (1)
12 p.m.-12.20 p.m.	Invited talk on the role of AI in Energy Transition for Climate Change Mitigation + Brief Q&A - **Marcus Voß**
12.20 p.m. -12.45 p.m.	Virtual Breakout Rooms (2)
12.45 p.m.-12.55 p.m.	Final Q&A session
12.55 p.m. – 1 p.m.	Vote of thanks from the organisers

Organisers

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@bda_hull

Dr. Joyjit Chatterjee
Data Scientist (KTP Associate) at Reckitt and University of Hull, UK

Dr. Nina Dethlefs
Senior Lecturer and Director of Research in Computer Science at University of Hull, UK

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A glance into the schedule – all times in GMT

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Learning resources in the wind energy domain

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A fantastic **portal for open-source datasets** which can be used to train AI models **for wind turbine power forecasting, fault prediction, operations and maintenance planning, optimization and turbine placement planning** etc. - **Maintained by the International Energy Agency (IEA)'s Wind Task 43 on Wind Energy Digitalization.**

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IEA Wind Task 43

- Home
- About the task
- Proceedings & Work Products
  - Meeting 3-Virtual
  - Open Data Resources
- Work Package 1: Roadmap
- Technical Area 2: Data Standards
- Technical Area 3: Data Science
- Work Package 4: Digital WRA
- Work Package 5: Operations and Maintenance
- Team

The following table is a collection of open data sources, found or contributed by the members of IEA Wind Task 43. We hope it provides a one-stop place for facilitating researchers, educators, practitioners, and policy makers to find the existing open data sources.

It is still a work in progress. We welcome anyone to add new open data sources or help improve the presentation of the table. You can do so by emailing us at yuding@tamu.edu or using the email address at the bottom of the page.

Portal	Contents (values, duration)	Data's public availability	Has it been used in a published study?	Stakeholder (government, industry, or academia)	Additional information
A2e	The Data Access Portal for the U.S. Department of Energy, Wind Energy Technologies Office's *Atmosphere to Electrons* (A2e) initiative contains datasets supporting its projects.	Most project data are publicly available. Registration is required for data download. Some datasets have restricted access to project members only.	A2e maintains a publications list and guidelines for citing the data are on the website.	Government	Data types include: archive data; source code; images; raw data; structured data; other data types; meteorological data; power generation data
Copernicus Open Data	Copernicus houses the remote sensing data from several satellites and a global network of thousands of land, air, and marine-based sensors that create the most detailed pictures of Earth. Copernicus is the largest space data	The vast majority of data on Copernicus is free and open. A self registration is needed but the self-registration		Government	A maximum of 2 concurrent downloads per user is allowed in order to ensure a download capacity for all users

https://www.ieawindtask43.org/

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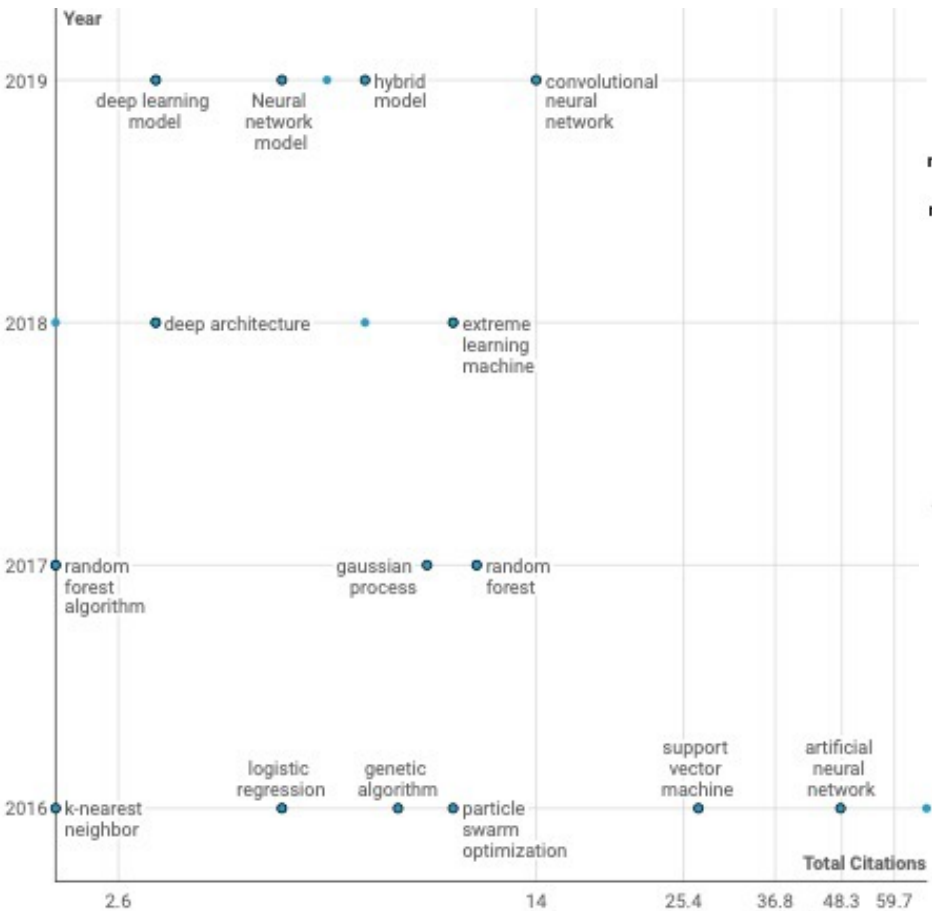
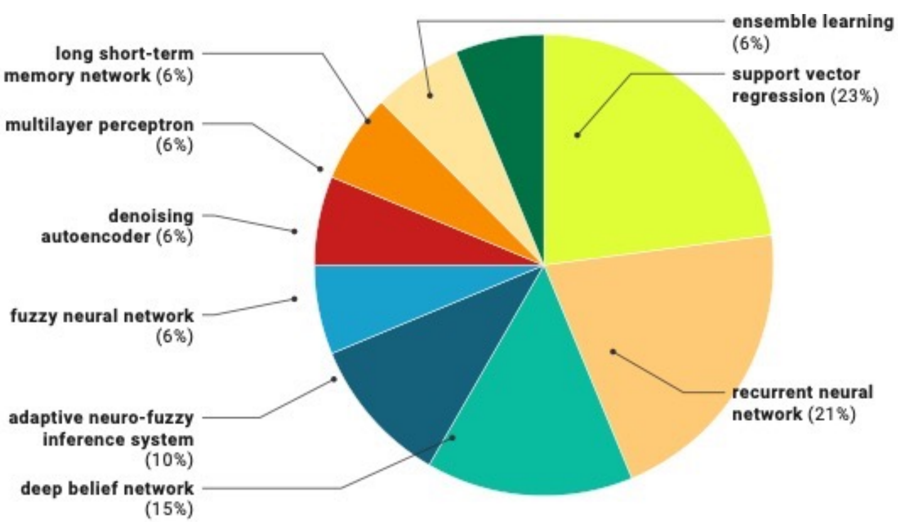
Most popular AI models in the wind energy domain?

You would notice that there has been a **highly varying trend** – with **simpler AI models (like SVMs) being heavily cited early on in 2016**, while **deep learners are recently starting to see increasing number of citations** since 2019.



Reference: Chatterjee, J. and Dethlefs, N., “Scientometric review of artificial intelligence for operations and maintenance of wind turbines”, Renewable and Sustainable Energy Reviews, 2021.



This pie chart shows the break-down of deep learners in publications till 2021. SVR and vanilla RNNs are most popular. Very **minimal usage of LSTMs and other suitable models**, despite the **time-series nature of data** in the wind energy sector

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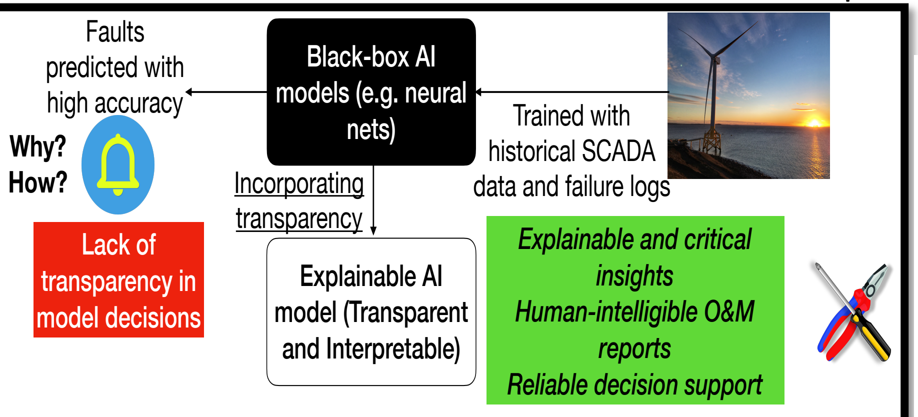
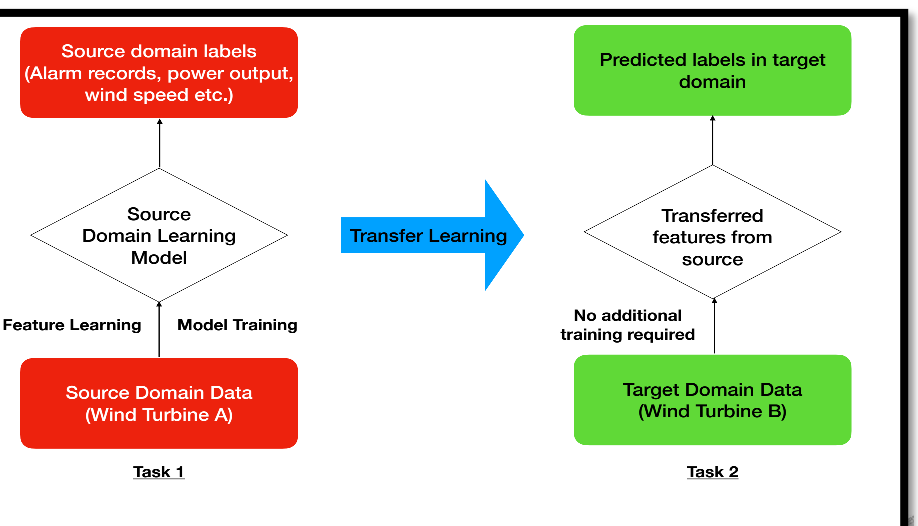
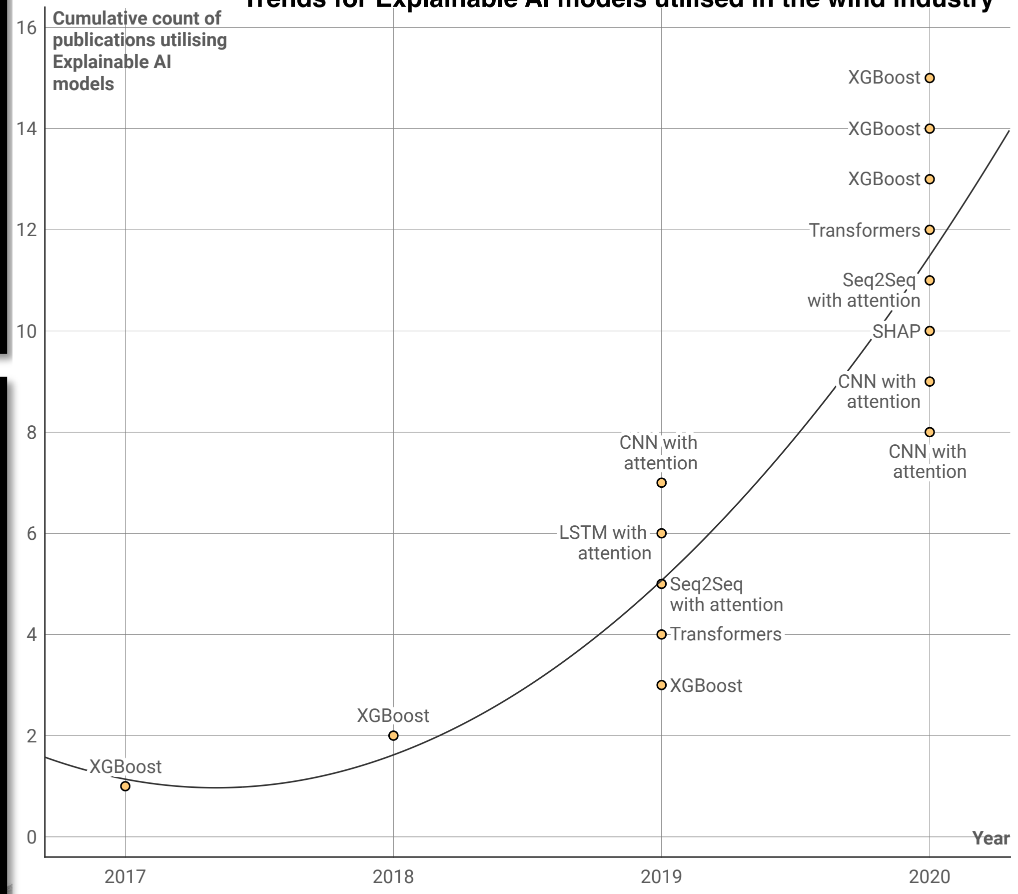
Hurdles in applying AI in the wind industry

Biggest hurdle is the reluctance of wind farm operators **to develop confidence and trust in the decisions** made by AI models. **Explainable AI could be a game-changer** to help tackle this challenge**. Another challenge is scalability** – **lack of data in newer wind turbines** that haven't been operational for long **– transfer learning** could be useful here!





Trends for Explainable AI models utilised in the wind industry



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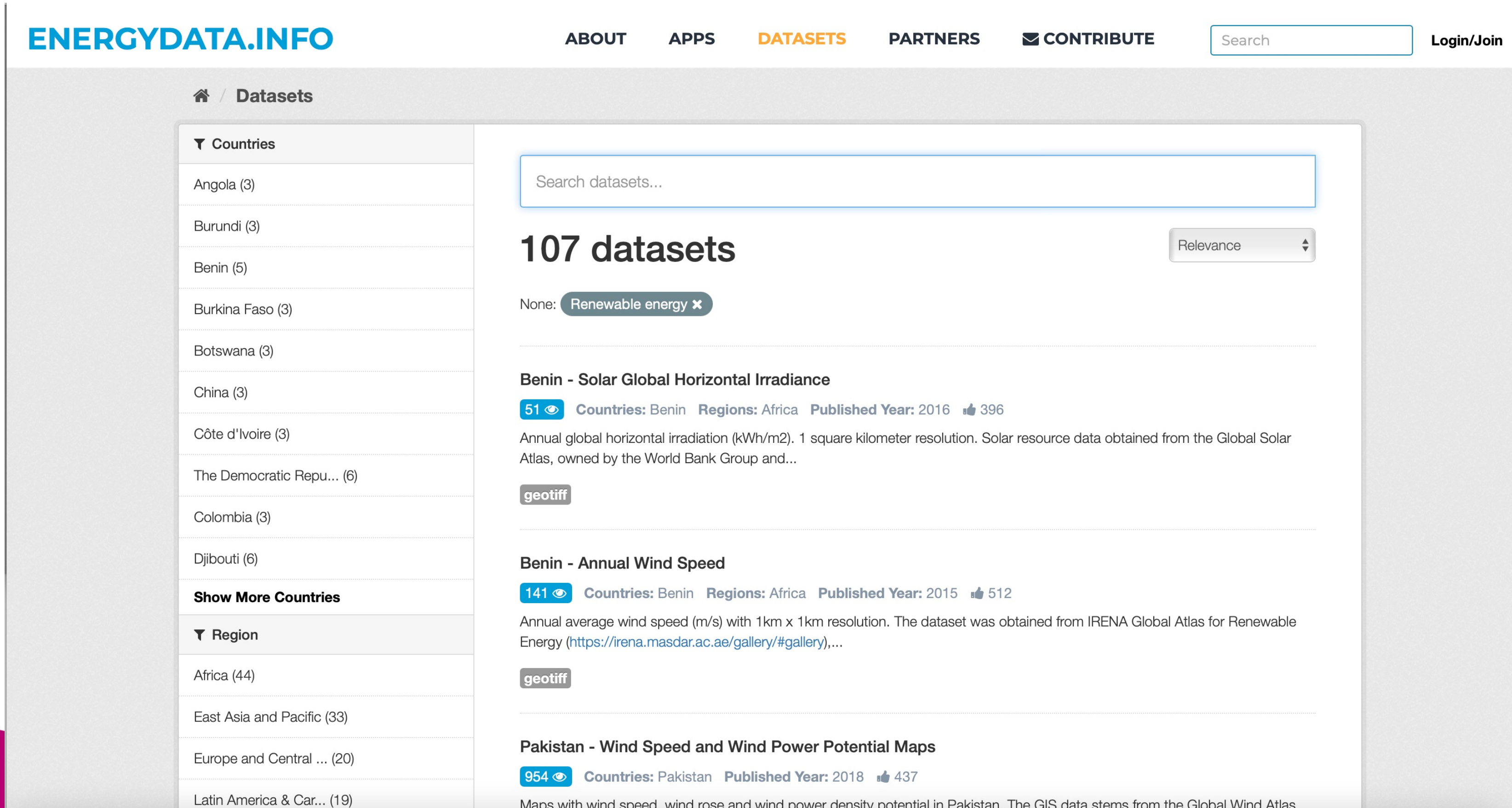
Beyond wind energy – datasets for other renewables sources

EnergyData platform provides an easy-to-utilise interface wherein, we can search **for hundreds of datasets in the renewables domain**. Not all datasets here are useful to train AI models, but **some can potentially be used to generate simulated data** which can later be used for model development in useful applications!



http://energydata.info

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Climate Change AI Wiki – A wonderful resource on readings and open-source data

We would be joined by Marcus later today, for the invited talk, who is a core team member at Climate Change AI.

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Climate Change AI

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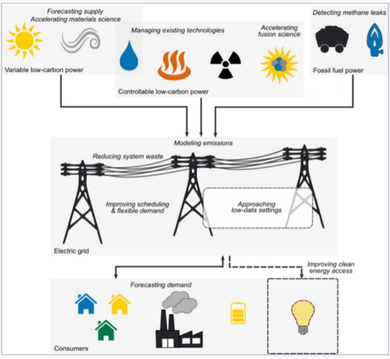
Electricity Systems

This is the approved revision of this page, as well as being the most recent.

This page is about the intersection of electricity systems and machine learning (ML) in the context of climate change mitigation. For an overview of electricity systems as a whole, please see the Wikipedia page on this topic. The energy supply sector contributes about 35% of human-caused greenhouse gas emissions,[2] within which decarbonizing electricity supply plays an important role. In addition, many climate change strategies in sectors such as buildings, transportation, and industry rely on low-carbon electricity. To reduce greenhouse gas emissions from electricity systems, it will be necessary to both transition quickly to low-carbon electricity sources (e.g., solar, wind, and nuclear) and to reduce emissions from existing electricity system operations in the meantime.

AI and machine learning are often discussed in the electricity sector in the context of smart grids,[3][4][5] which broadly refer to the concept of "intelligent" electric grids managed automatically in a data-driven manner. In particular, ML has been used to forecast electricity supply and demand, to improve power system optimization, and to improve system efficiency through applications such as predictive maintenance. In addition, ML has also been used to accelerate scientific discovery of clean energy technologies, and to gather electricity infrastructure data that may be useful for system planners and policymakers.[1]



A schematic of selected opportunities to reduce greenhouse emissions from electricity systems using machine learning. From "Tackling Climate Change with Machine Learning."[1]

Contents [hide]

https://wiki.climatechange.ai/

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Useful resources for a head start in applying AI for O&M of wind turbines

XAI4Wind: A Multimodal Knowledge Graph Database for Explainable Decision Support in Operations & Maintenance of Wind Turbines

Joyjit Chatterjee*[1], Nina Dethlefs[1]

Department of Computer Science & Technology, Dependable Intelligent Systems Research Group, University of Hull, Cottingham Road, Hull, HU6 7RX, United Kingdom

Abstract

Condition-based monitoring (CBM) has been widely utilised in the wind industry for monitoring operational inconsistencies and failures in turbines, with techniques ranging from signal processing and vibration analysis to artificial intelligence (AI) models using Supervisory Control & Acquisition (SCADA) data. However, existing studies do not present a concrete basis to facilitate explainable decision support in operations and maintenance (O&M), particularly for automated decision support through recommendation of appropriate maintenance action reports corresponding to failures predicted by CBM techniques. Knowledge graph databases (KGs) model a collection of domain-specific information and have played an intrinsic role for real-world decision support in domains such as healthcare and finance, but have seen very limited attention in the wind industry. We propose XAI4Wind, a multimodal knowledge graph for explainable decision support in real-world operational turbines and demonstrate through experiments several use-cases of the proposed KG towards O&M planning through interactive query and reasoning and providing novel insights using graph data science algorithms. The proposed KG combines multimodal knowledge like SCADA parameters and alarms with natural language maintenance actions, images etc. By integrating our KG with an Explainable AI model for anomaly prediction, we show that it can provide effective human-intelligible O&M strategies for predicted operational inconsistencies in various turbine sub-components.

Email addresses: j.chatterjee-2018@hull.ac.uk (Joyjit Chatterjee*), n.dethlefs@hull.ac.uk (Nina Dethlefs)

Renewable Energy 133 (2019) 620–635

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/renene

ELSEVIER

Review

Machine learning methods for wind turbine condition monitoring: A review

Check for updates

Adrian Stetco [a, *], Fateme Dinmohammadi [b], Xingyu Zhao [b], Valentin Robu [b], David Flynn [b], Mike Barnes [c], John Keane [a], Goran Nenadic [a]

[a] School of Computer Science, University of Manchester, UK
[b] School of Engineering and Physical Sciences, Heriot-Watt University, UK
[c] School of Electrical and Electronic Engineering, University of Manchester, UK

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ABSTRACT

This paper reviews the recent literature on machine learning (ML) models that have been used for condition monitoring in wind turbines (e.g. blade fault detection or generator temperature monitoring). We classify these models by typical ML steps, including data sources, feature selection and extraction, model selection (classification, regression), validation and decision-making. Our findings show that most models use SCADA or simulated data, with almost two-thirds of methods using classification and the rest relying on regression. Neural networks, support vector machines and decision trees are most commonly used. We conclude with a discussion of the main areas for future work in this domain.

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Knowledge Graphs for Explainable Decision Support

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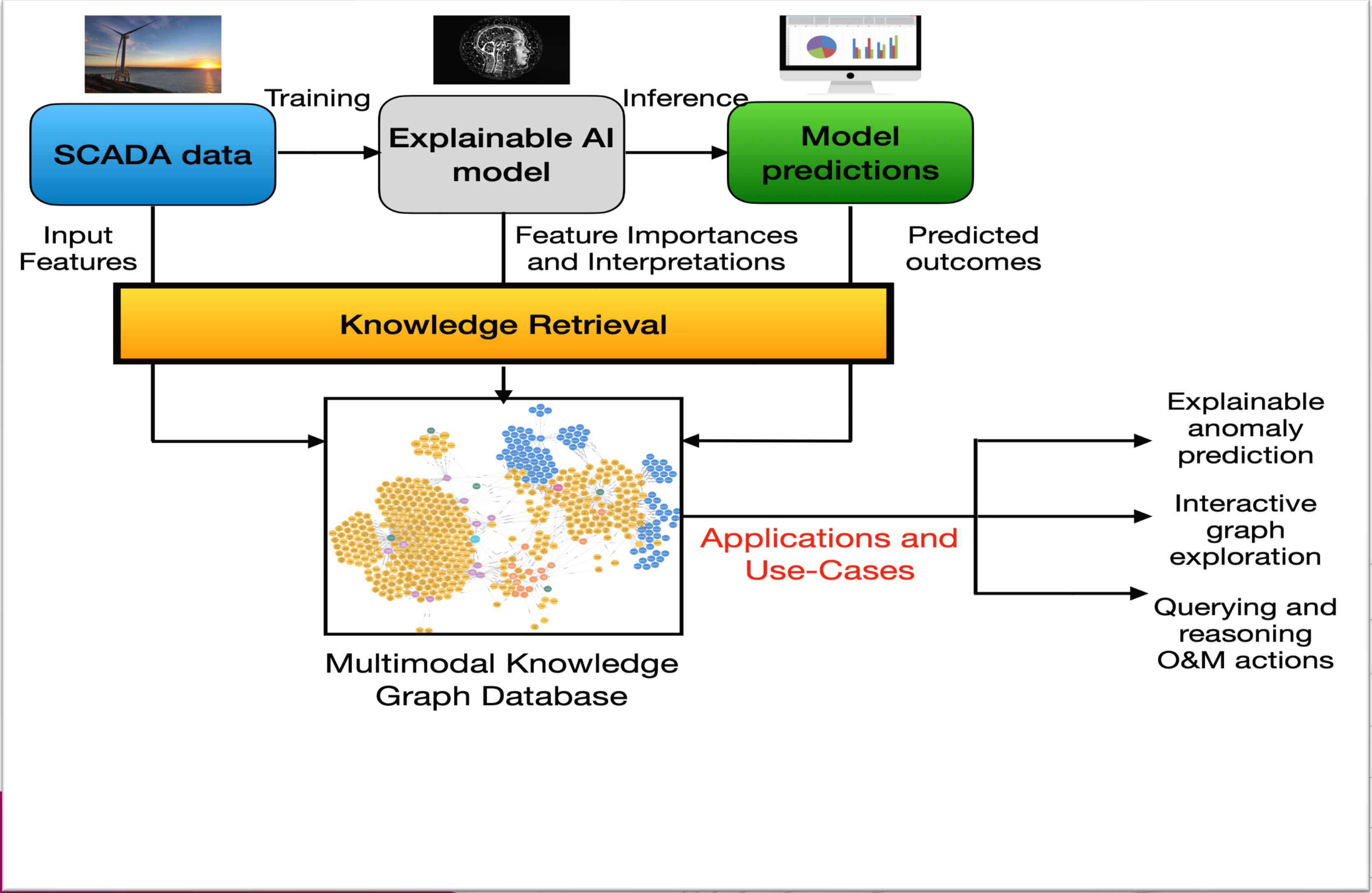

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Knowledge Graphs for Explainable Decision Support

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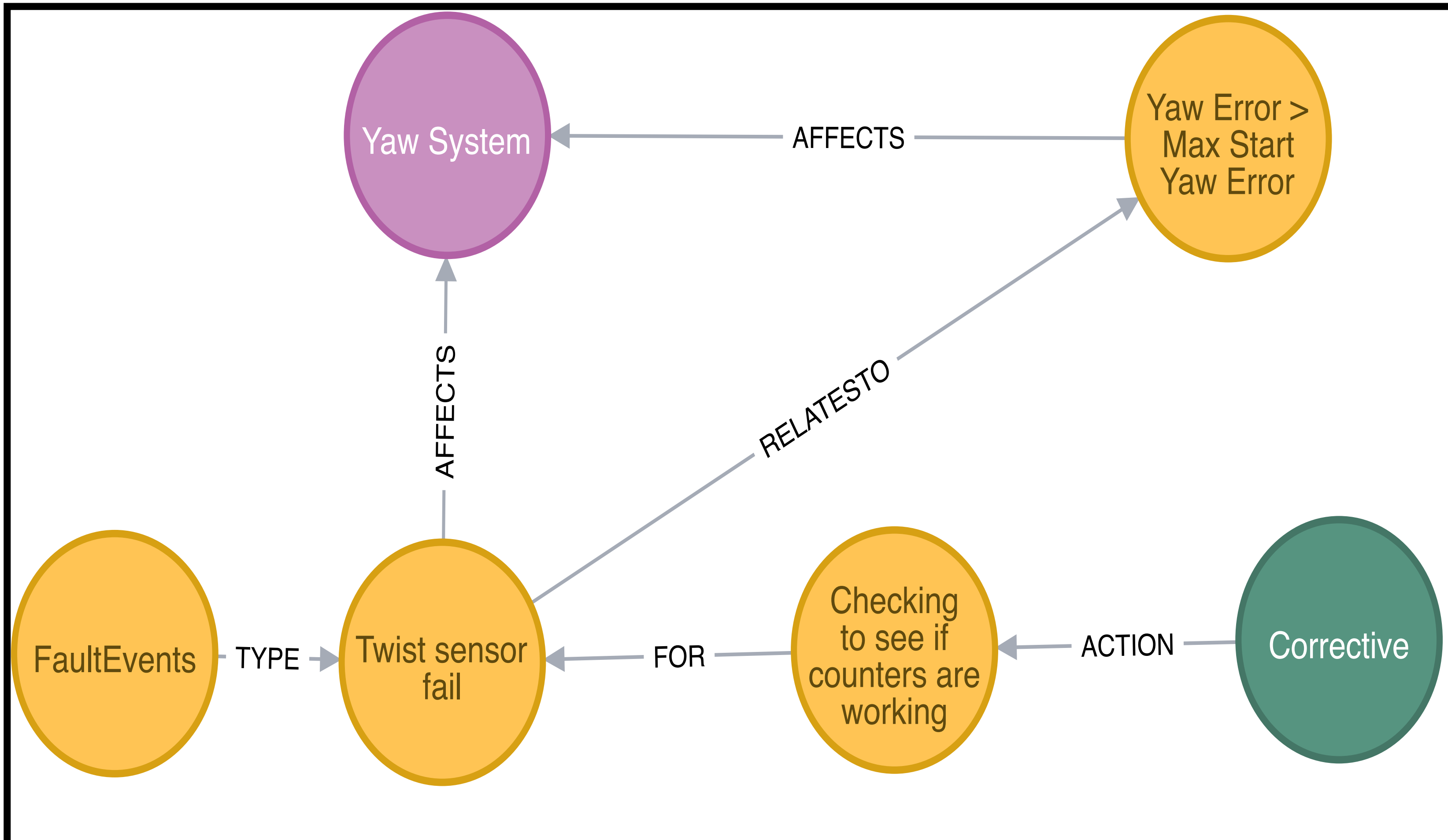

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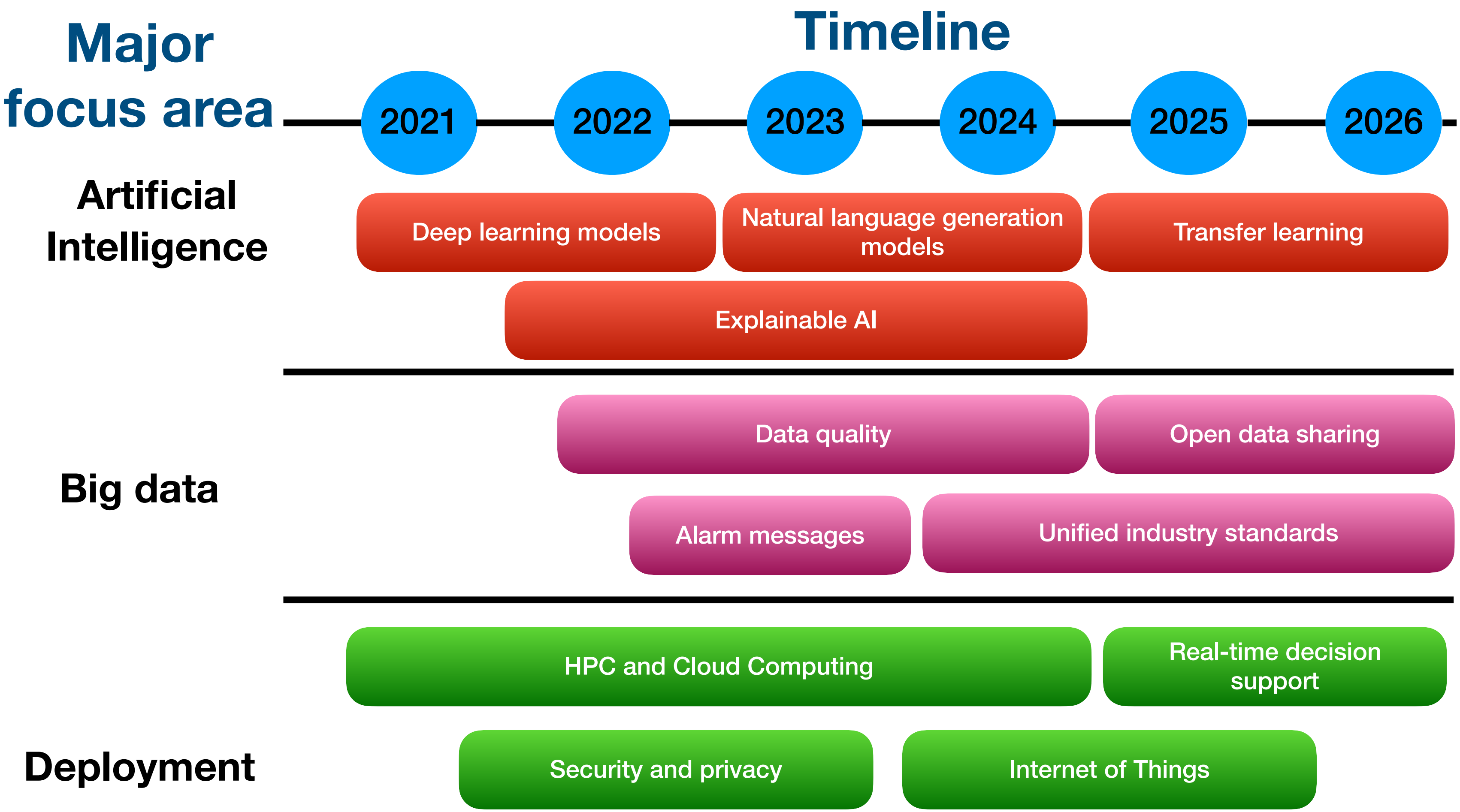
Potential future roadmap for the AI4Renewables community

As a community, it may help to focus on a systematic roadmap in the next five years – so that hopefully, we would see more research in this very promising area in the near future**!**



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Thank you for your attention.

Any questions, comments, feedback?

We will put up information on learning resources and continue to update them in the near future on the AI4Renewables dedicated webpage: https://www.ai4renewables.org

We invite you to follow us on Twitter (@bda_hull) to stay updated!

Next, we are going to jump straightaway into virtual breakout rooms for the socialising session (i).