



AI for Sustainable Energy

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VP – AI & Digital Transformation, GE Digital

Agenda

- GE History
- Industrial AI Introduction & Motivation
- Energy Transition Drivers
- GE Industrial AI examples for Energy Transition
 - Wind Turbine- Early warning Prediction (physics + ML) and Industrial Inspections
 - Humble AI and Wind Turbine Performance Optimization
 - AI for Power grid with inertia prediction and management
 - Power Grid AI-Based Vegetation Management
- Q&A



GE History... Tackling the World's Challenges for 130 Years



Enabling a better quality of life



1879
First Incandescent Lamp



1896
X-Ray Machine



1910
First Electric Range



1927
First Home TV Reception



1942
First US Jet Engine

Innovating technologies and redefining what's possible



1957
First US Licensed Nuclear Reactor



1962
World's First LED



1969
Technologies for First Moon Landing



1983
MRI



1992
MARS Observer



1995
GE90 Aircraft Engine

Building a sustainable tomorrow



2002
Wind Power Business



2009
VSCAN- Handheld Ultrasound



2014
Digital Grid Industrial Internet



2015
HA Turbine



2016
Clinical Command Center



2016
CFM Leap Engine



2018
Leading Nuclear Design-SMR



2019
Haliade™-X OffShore Wind Turbine



2020
GE9X Engine



2021
Healthcare Edison AI Platform



GE Aerospace



~3B

Passengers flew with GE technology^(a) under wing in 2022



Every **2** seconds

A GE or JV^(a) powered aircraft takes off



3 out of **4**

Commercial flights powered by GE or JV^(a) engines



1st

High-voltage, MW class, high-altitude Hybrid Electric test^(b)



GE VERNOVA



~30%

World's electricity generated with the help of our technology



54K

Wind turbines installed > 50 countries ... #1 ONW in U.S.^(a)



2,200 GW Global installed base

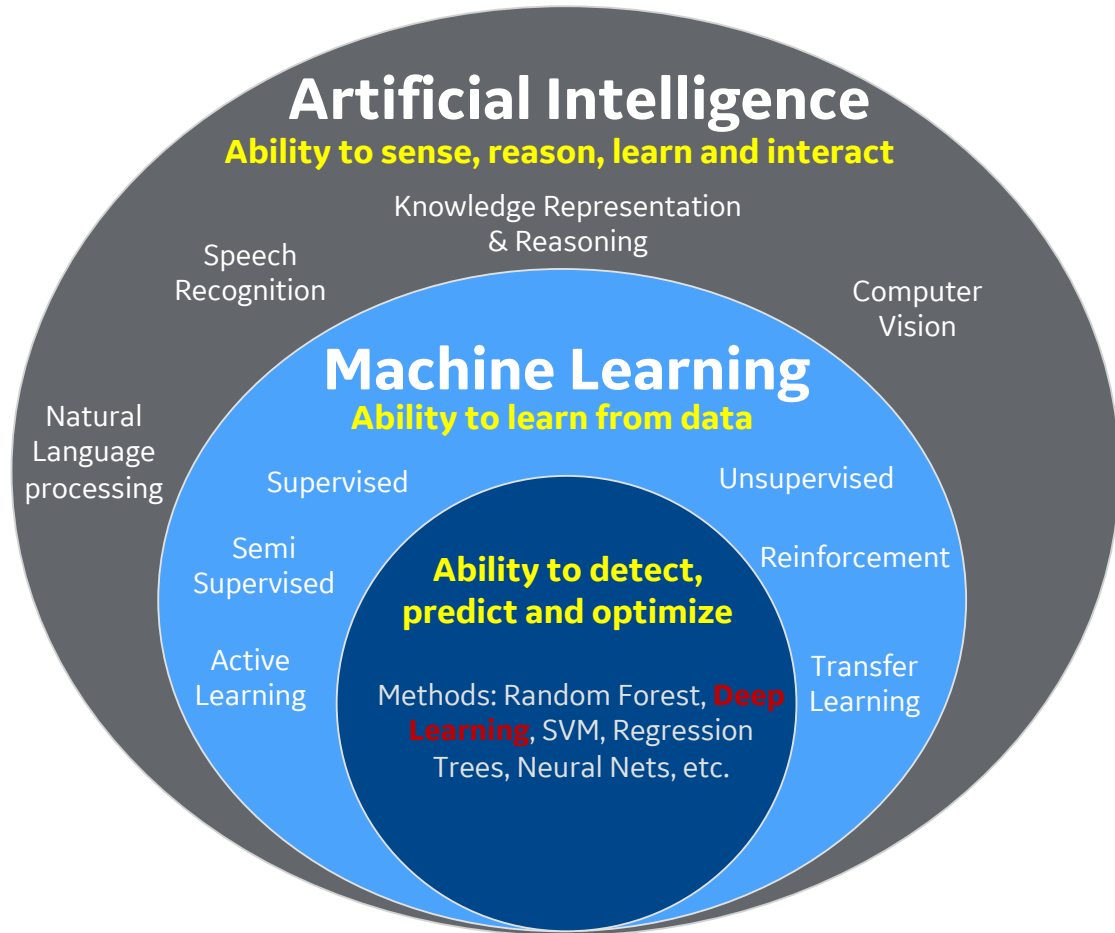


30%

Global utilities served by our software

(a) - Includes equipment made by CFM & Engine Alliance joint ventures

(a) - Source: American Clean Power Association

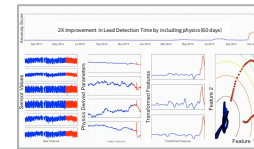


Industrial AI: Application of AI to Industrial challenges for productivity improvement, cost reduction, asset optimization, safety, and risk management.

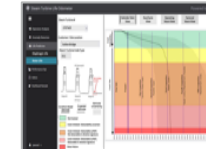
Industrial AI Application Examples

Predictive Maintenance

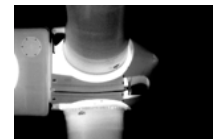
Early Warning Prediction



Damage Prognostics



Inspection Services

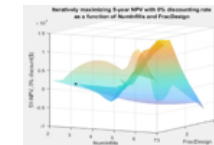


Business and Operations Optimization

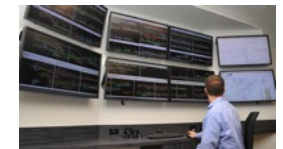
Forecasting



Operations Optimization



Network Optimization

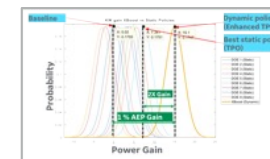


Automation & Controls

Digital Ghost
(Cyber Protection)



Controls & Optimization



Process Insights & Automation

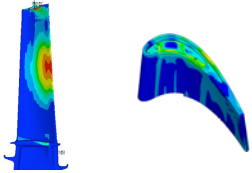


Industrial AI Applications & Challenges



Industrial Applications

Design



Design Optimization & Materials Discovery

Manufacturing



Throughput, Quality & Cost

Asset O&M



Safety, Asset Mgmt., Operations Opt. & Control

Customer Service



Customer Experience & Services Productivity

Industrial AI Challenges

Low No. of Events



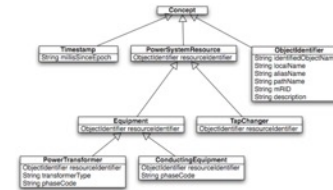
High Cost /Transaction



Interpretability



Domain Ontologies



Expensive Labeled Data



Robustness



Industrial AI Key Elements

- ✓ Rare event ready
- ✓ Explainable

- ✓ Safe & robust
- ✓ Physics-informed

- ✓ Continual learning

Advancing the Future of Energy



Energy Transition Drivers and Dynamics

MARKET

DECARBONIZATION



↑ **Renewables Growth** –
30% in 2020->70% by 2050
Carbon neutrality by 2050

DIGITIZATION



↑ **Exponential Growth**
of connected devices & smart sensors
Energy Internet, Digital utility

DE-CENTRALIZATION



↑ **Growing Penetration**
of Prosumers, Microgrids,
Distributed Energy Resources

ELECTRIFICATION



↑ **Electrification Growth**
of Energy Intensive Uses (e.g.,
electrified homes, transportation)

GE

1/3 OF THE WORLD'S ELECTRICITY



12K
TURBINES

7K+ gas turbines, representing
800+ GW of power generation



54K
WIND TURBINES

GE's Haliade™-X turbine, the
world's most powerful offshore
wind turbine



30% World Power
ELECTRIC GRID SOFTWARE

90% of power transmission utilities
worldwide have been equipped with GE
technology

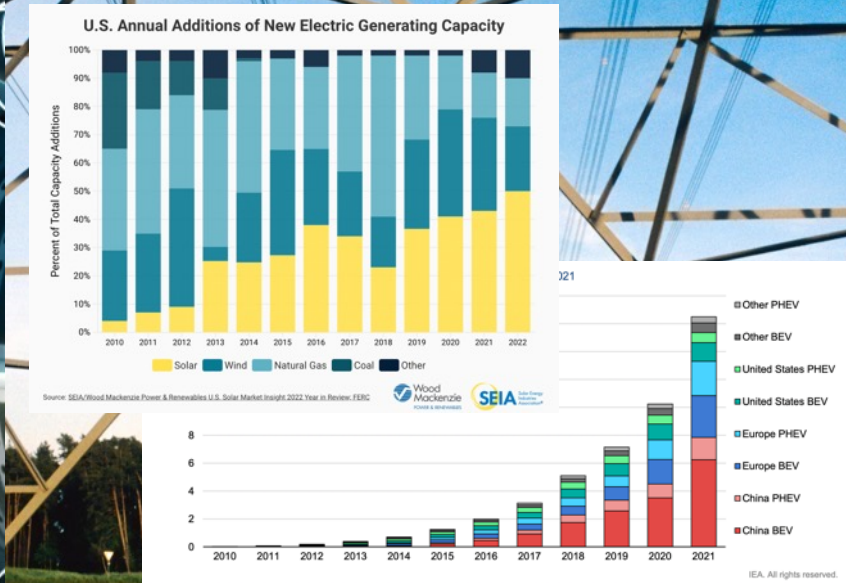
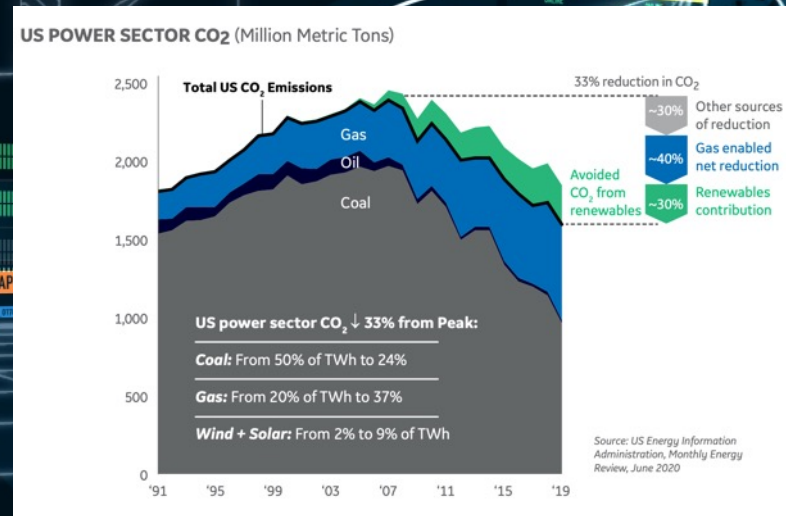


AI Technology is Vital for the Energy Transition

ENABLING **MORE RENEWABLES**

DECARBONIZING THE PLANET

TRANSFORMING **THE GRID**



AI technologies for sustainability and generating more business value

Early Warning Prediction



Outcome Variation

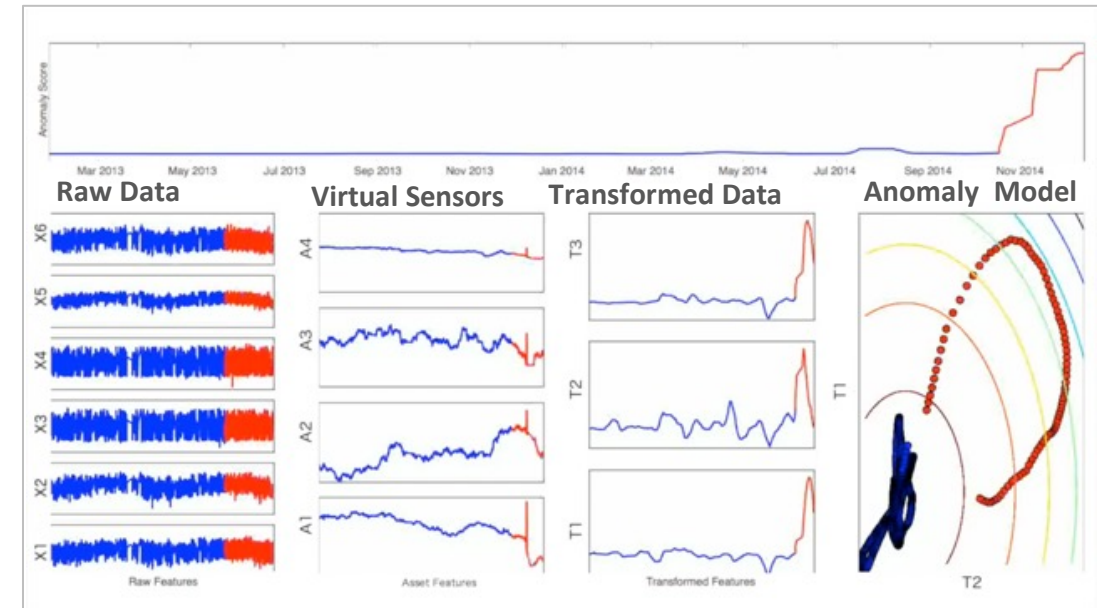
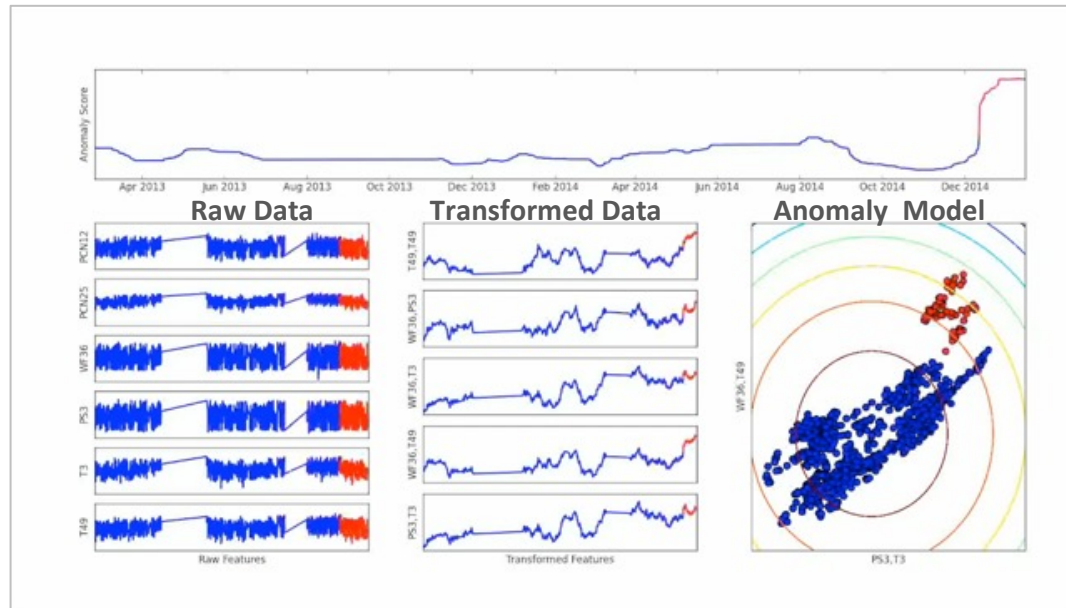
- Complex interactions
- Limited sensing

Machine Learning on Raw Data

Machine Learning + Physics Model

ML+Physics Impact

- Early detection
- Fault isolation



Early warning for failure prediction and diagnostics to reduce unplanned downtime

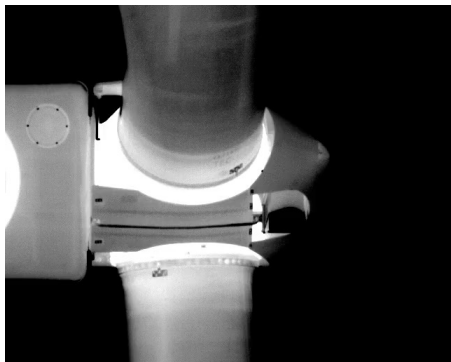


Wind Turbine Blade Inspection Example

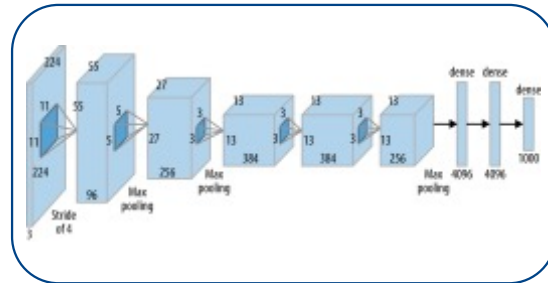


Inspection campaigns turning **reactive** blade *exchanges* to **proactive** blade *repairs*

Image/Video Summarization



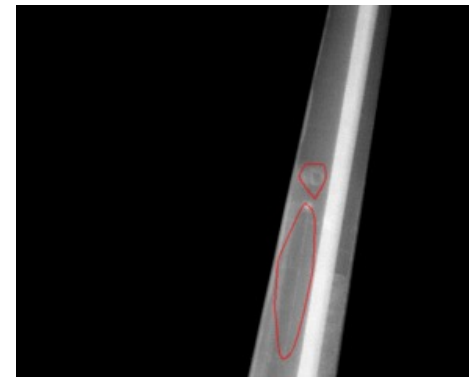
9000 frames per turbine



AI model processes to 150 frames per turbine

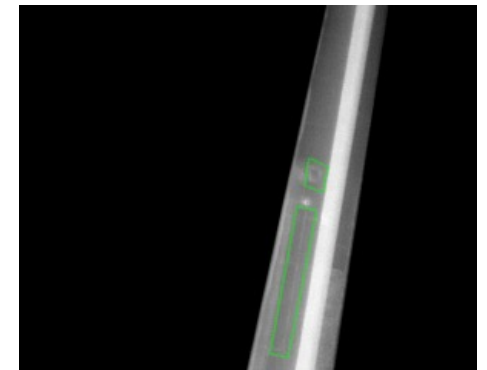
Defect Detection, Classification & Measurement

Defect **Identified**



AI defect models highlight areas of concern

Expert Validated



Experts validate & refine model

Inspection data enabling digital twin development and continuous learning and improvement

Accelerating Business Value | Increasing adoption with Humble AI

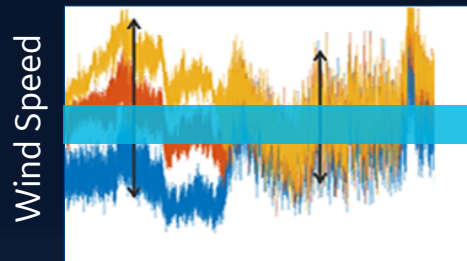
An AI that is aware of its own competence and improves its competence via learning

Adoption



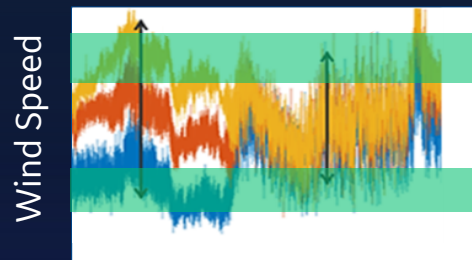
Use **Humble AI** to determine when to trust DTs and relinquish control to a safe default ensuring safe and reliable operation (ML + Active Learning)

Tested on 69 Wind Turbines; Potential to improve 0.5-1% AEP



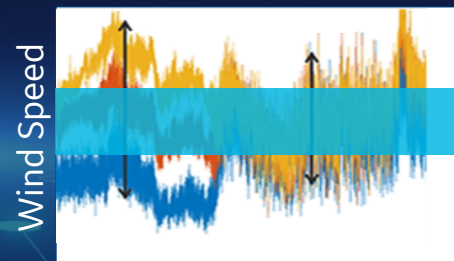
In Region of Competency - use ML model

24-hour cycle



Outside Region - Use known deterministic algorithm

24-hour cycle



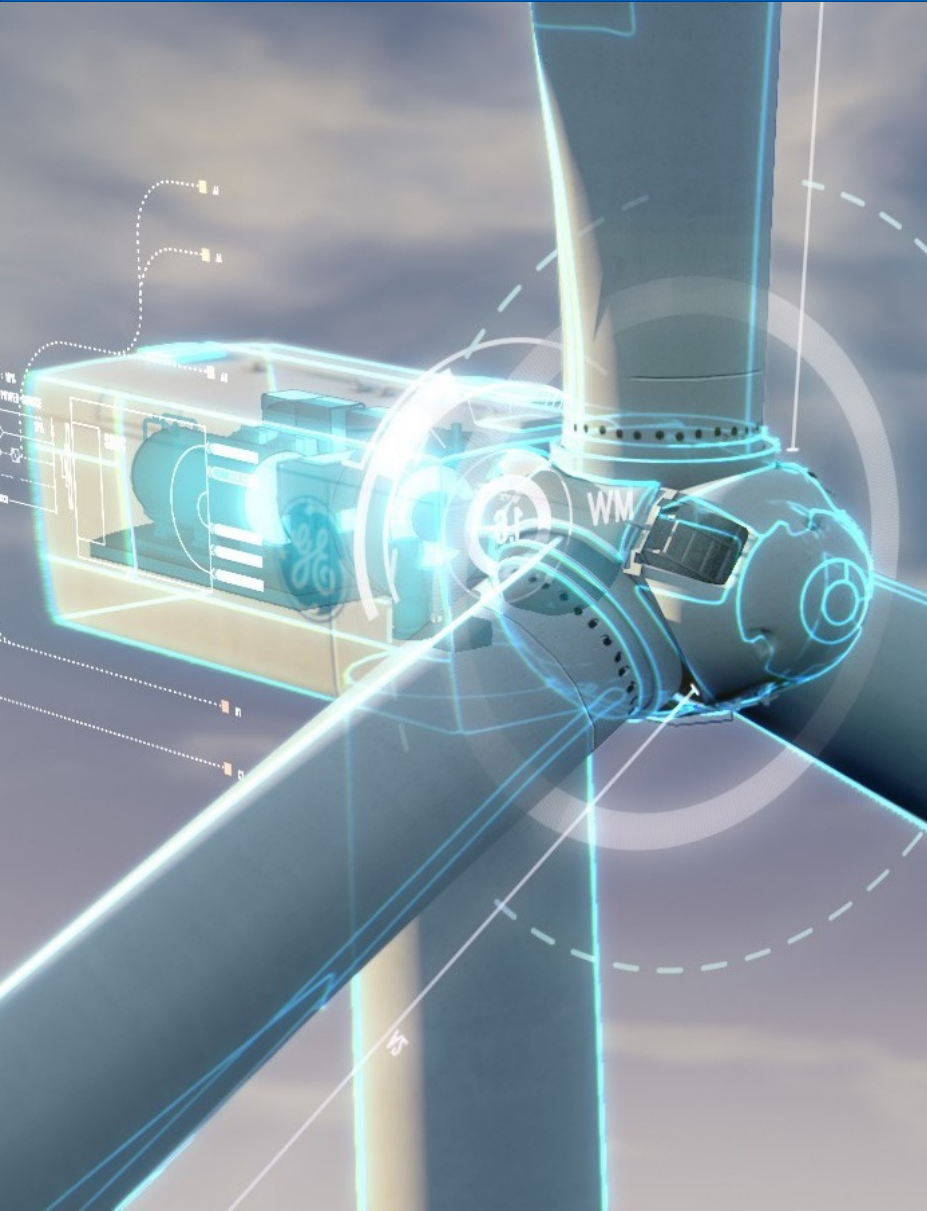
Perform safe exploration & Learn from new data - Expand region of competency for twin

24-hour cycle

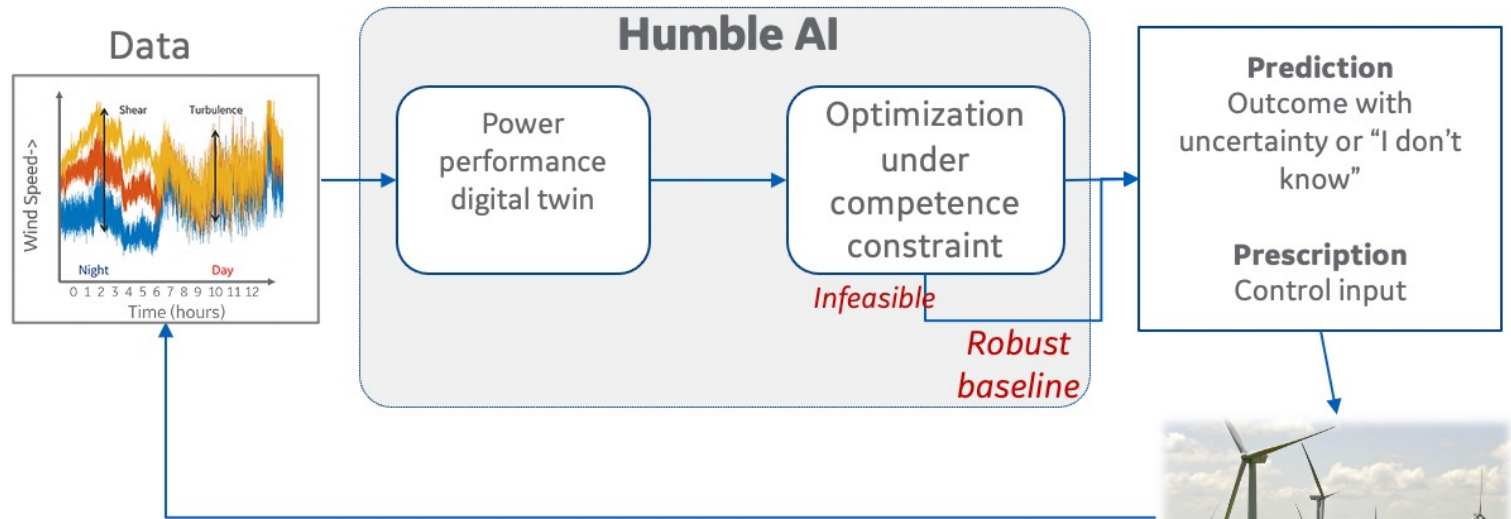
Industrial AI for Wind Turbine Performance



Producing More Renewable Energy



Goal: Dynamically optimize individual turbine settings to unique wind and site conditions.



Use Humble AI to determine when to trust DTs and relinquish control to a safe default to ensure safe and reliable operation

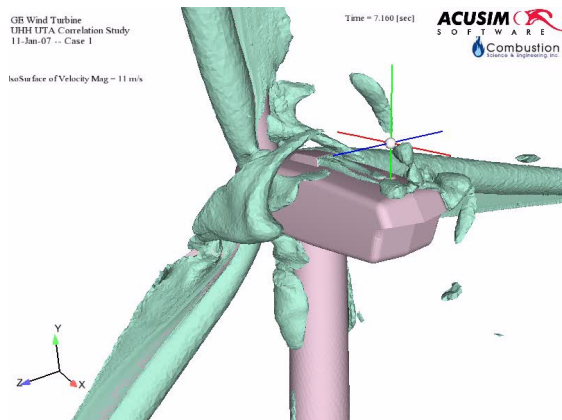
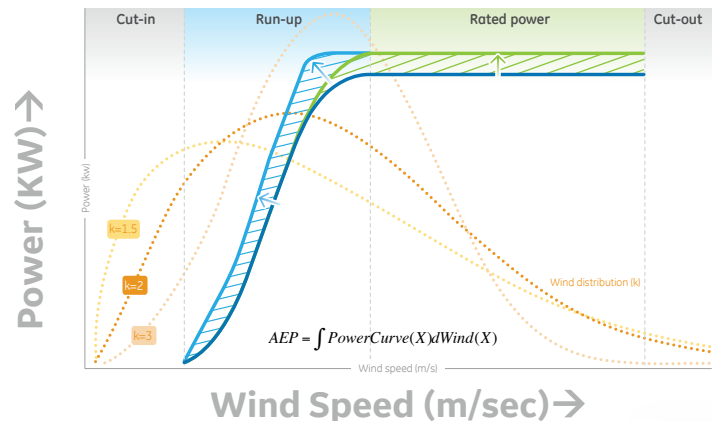
Potential to Improve **0.5-1%** AEP improvement

How to Validate Benefits of Upgrade



Improved Power Output

Goal: Make Better Uses of Wind Resource Through Upgrades



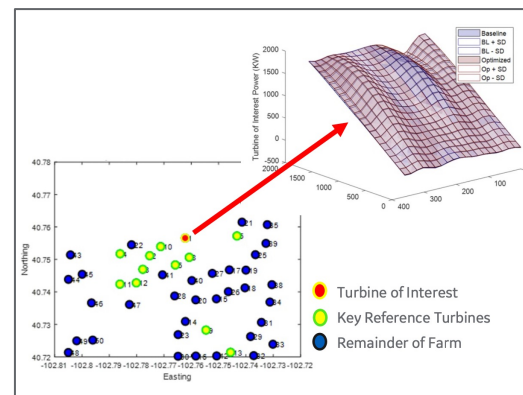
Wind turbine blades stall at low wind velocities



Vortex generators concentrate flow (1-2% AEP Improvement)

Wind - Upgrade Improvement Quantification

Uses neighboring turbines as "Virtual" Metmasts to build Machine Learning model



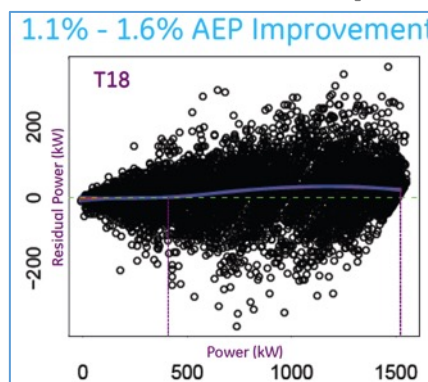
Simplified example of statistical solution:

$$WTG1 \text{ kW} = a + b * WTG2 \text{ kW} + c * WTG3 \text{ kW} + d * WTG4 \text{ kW} + e * WTG5 \text{ kW}, \dots$$

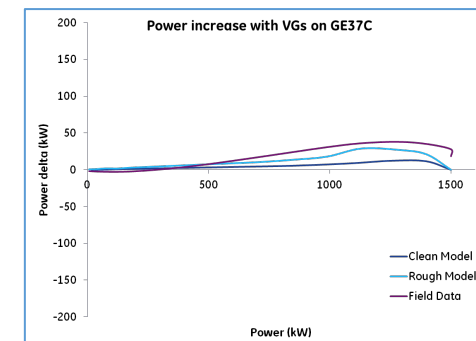
Machine Learning determines coefficients a, b, c, d, e,

Stepwise Linear Regression, M5', Random Forest, SVM, Neural Networks

Data Driven Output



Physics Simulation

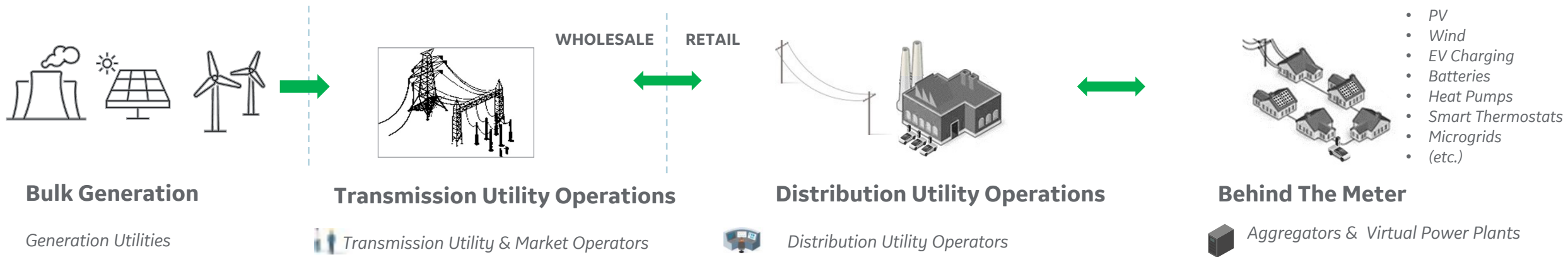


Analytics Tool Output Matches Physics Model Simulation

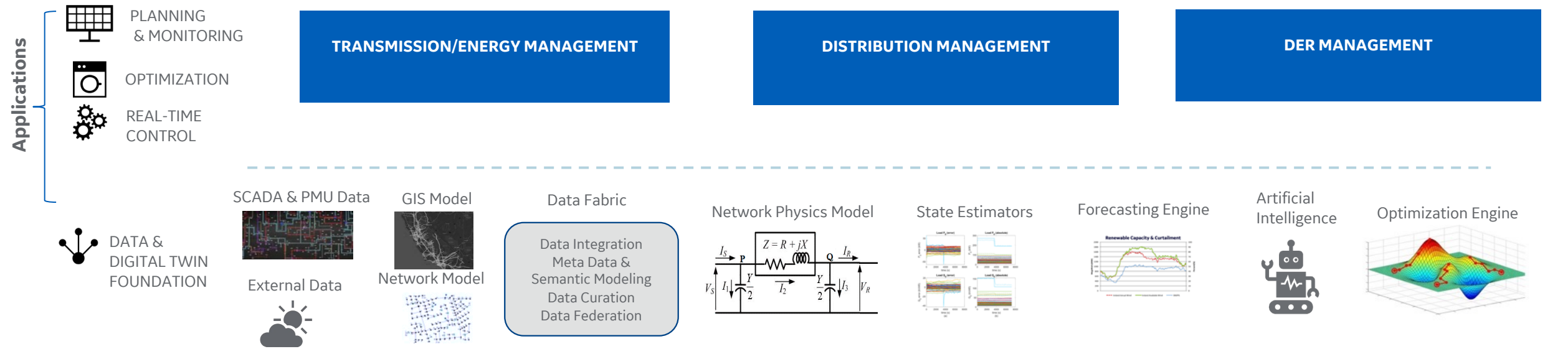


Renewables/Distributed Energy Resource Growth

Connecting More Renewable Generation and DERs to Power Grid



- PV
- Wind
- EV Charging
- Batteries
- Heat Pumps
- Smart Thermostats
- Microgrids
- (etc.)



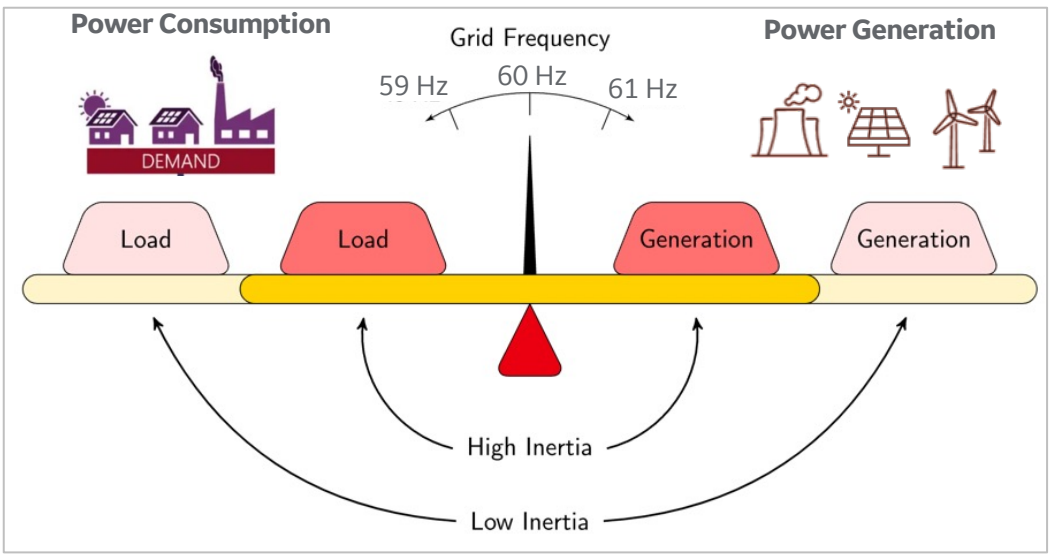
AI Will Play Vital Role in Enabling Electric Grid Reliability, Resilience, and Affordability

AI Example for Inertia Monitoring and Prediction

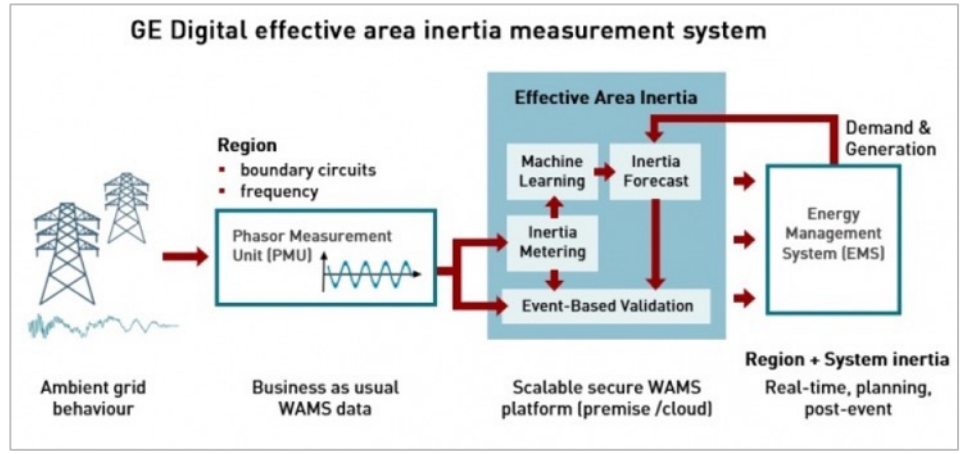


Prepare the Grid for High Renewable Penetration

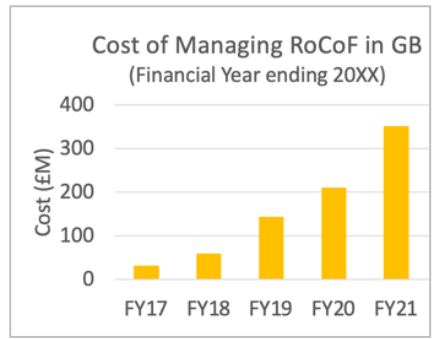
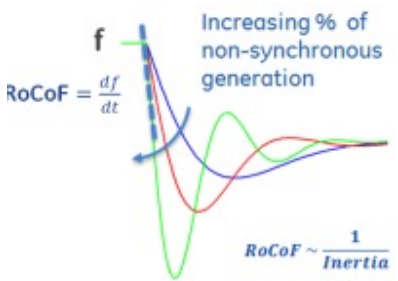
Balancing The Grid



Machine Learning for Inertia Monitoring, Prediction and Management



High Renewable Penetration Driving Stability Issues



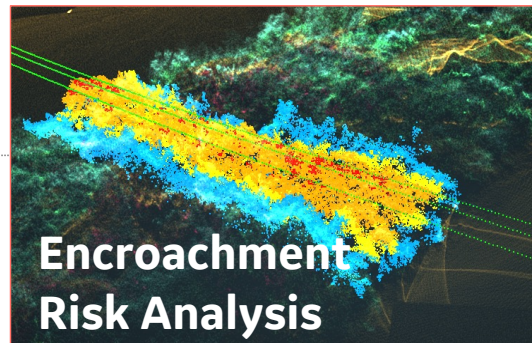
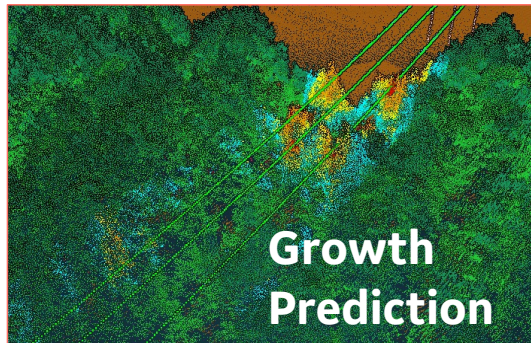
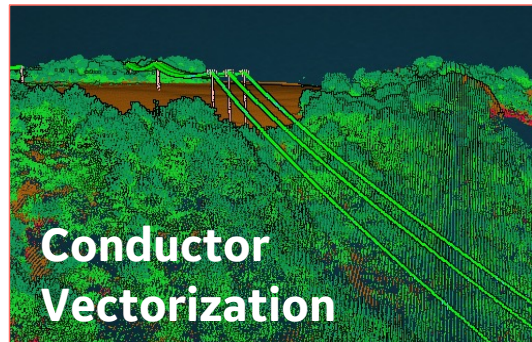
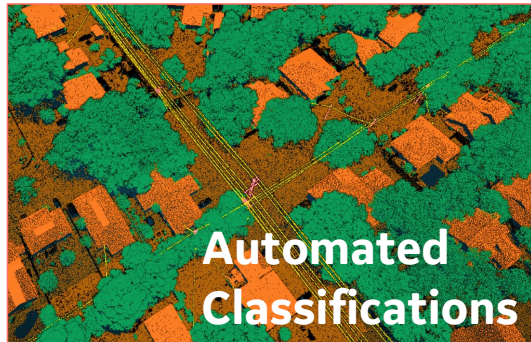
Source: https://www.naspi.org/sites/default/files/2021-06/20210630_naspi_webinar_system_inertia.pdf



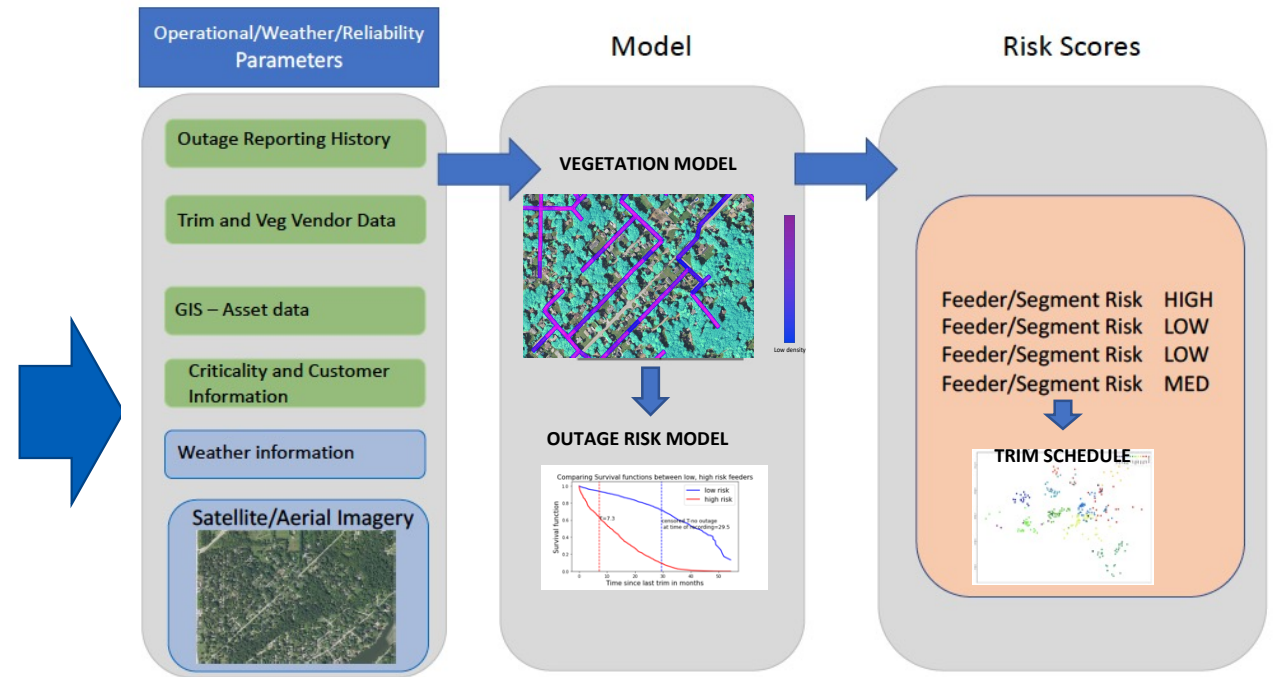
Industrial AI Example: Power Grid Visual Intelligence

Bringing diverse data sources to generate deeper insights and outcomes through AI and digital twins

AI-Based Vegetation Management



Risk Management & Cost Reduction

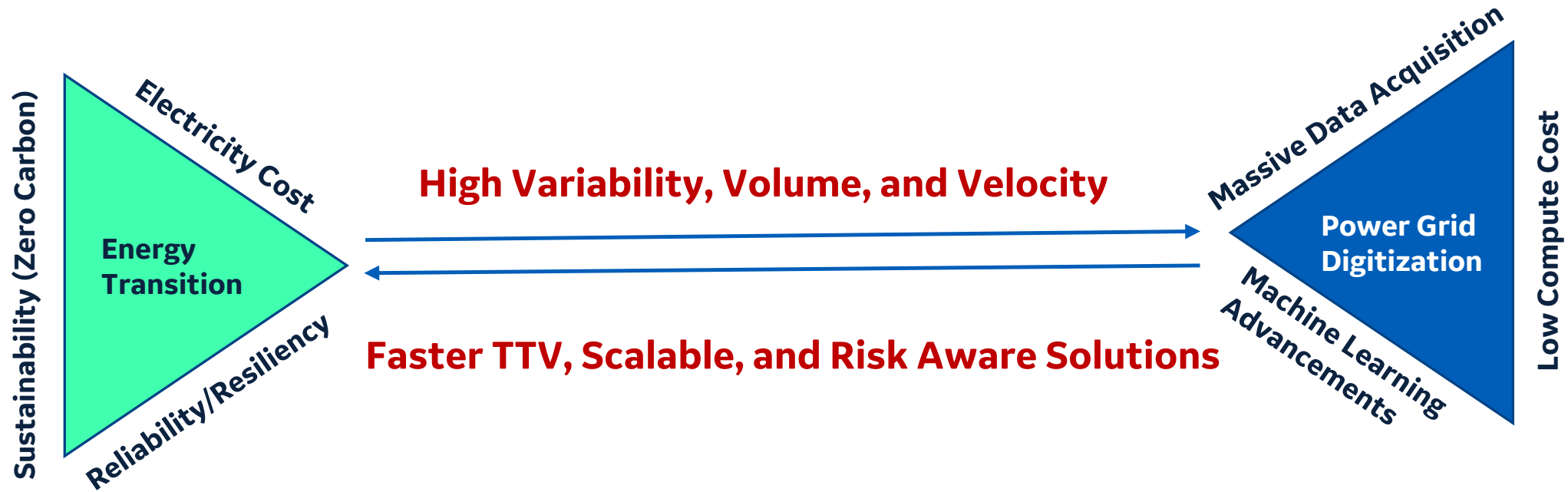


http://www.classic.grss-ieee.org/earthvision2021/papers/Jain_Combining_Remotely_Sensed_Imagery_With_Survival_Models_for_Outage_Risk_CVPRW_2021_paper.pdf

- Expected 30% Reduction in Tree-Caused Outages
- Expected 27% Cost Savings in Veg. Mgmt. O&M
- Improved Major Risk Mgmt. Wildfire, Safety Risk, etc.

Summary

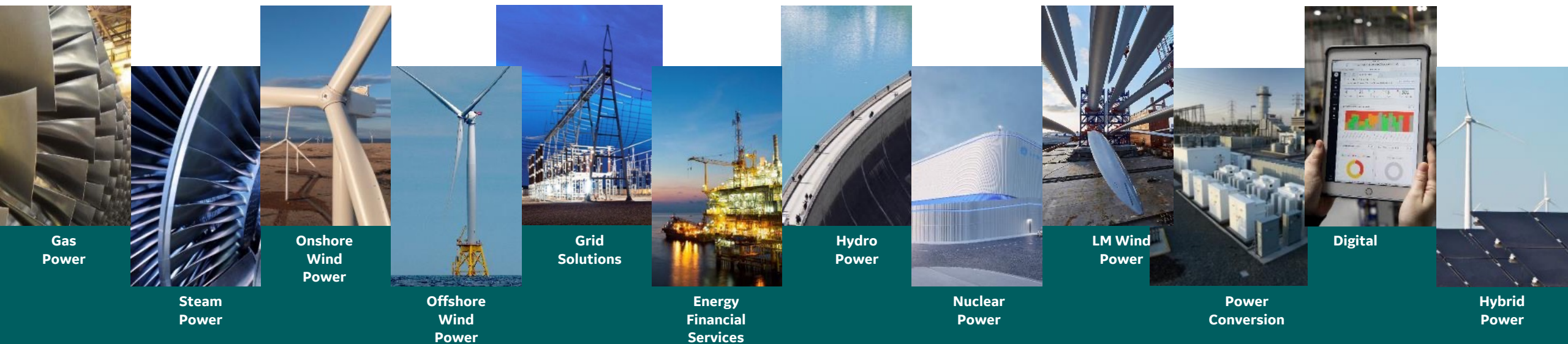
AI has several energy use cases today and a promising path forward



AI will shape the future of energy... government, academia and industry partnership needed



Thank You!



The Energy to Change the World