WHITEPAPER

AI and Energy - Partners for a Sustainable Future

The Power Couples of Innovation and Sustainability

Gleecus TECHLABS INC
Forward Thinking Digital Innovation

Table Of Contents

Executive Summary

As the energy sector becomes increasingly digital, AI is emerging as a powerful driver of innovation across the energy value chain. With 87% of CEOs vouching for AI as an important tool for climate change reversal, the role of AI in achieving more resilient, efficient, and sustainable energy operations is certainly widening. From renewable power generation to grid optimization, AI applications optimize energy production and supply. It is a powerful tool to tackle challenges like climate unpredictability and mechanical faults. Smart grid systems, supported by AI, offer two-way power and data flow to predict outages, manage demand, and automate grid responses, reducing waste by up to 20%.

AI also revolutionizes demand management, helping households and industries optimize energy usage with smart switching, adaptive heating, and virtual power plants. In materials discovery, AI accelerates the development of advanced, cost-effective materials for cleaner energy generation and storage, promoting a pathway toward decarbonization goals.

This white paper further outlines guiding principles for AI adoption, focusing on designing adaptable AI systems, enabling data standards, fostering education, and addressing ethical considerations. It is essential reading for energy leaders who aim to harness AI's potential to drive efficiency, sustainability, and long-term value in the transition to a net-zero energy landscape.

Role of AI Across the Energy Value Chain

AI-driven grid management can lead to a 20% increase in energy efficiency and a 15% reduction in energy waste. *- Nature*

In recent years, the energy sector has become increasingly digital. This digitalization with innovations such as artificial intelligence (AI), machine learning (ML) and advanced data analytics offers unprecedented insights and recommendations for every stage of the value chain.

Renewable Power Generation

87% of CEOs with decision-making power in AI and climate believe that the technology is an essential tool reversing climate change - Climate AI Survey 2022, BCG

The 2015 Paris Agreement sets a target for energy agencies to completely decarbonize by 2050 and become net zero emission company. To achieve deep decarbonization energy systems are embracing renewable power generation. Renewable power is largely dependent on solar and wind energy which is unpredictable and governed by climatic conditions. This is where the predictive analytics technology of AI kicks in. These are ML models trained with lots of historical climate data. They feed on real-time sensor data of wind speed, global irradiance, and satellite images of cloud cover, cyclonic build-up to predict wind speed and cloudy conditions in future that govern the availability of these energies. Energy companies also rely on AI to identify sites with the most favorable sun and wind resources for setting up their renewable energy plants.

Grid Operation and Optimization

The grid infrastructure is an integrated and decentralized energy system requiring optimization at both higher and lower voltage levels. AI can forecast power demand with predictive analytics to optimize grid operation and prevent blackouts or over production. Artificial Intelligence is the driving “intelligent agent” behind smart grids - a network that integrates energy distribution and digital communication technology in a two-way flow of electricity and data. Predictive analytics forecasts about high-demand strains that can be distributed over multiple plants and substations. The intermittent nature and volatility of electricity generation impacts grid stability. Long and short time memory (LSTM) network, a deep learning model can effectively predict wind power and photovoltaic power generation. As a result, power from such intermittent sources can be stored or distributed in steady and reliable streams.

The predictive capabilities of AI and the real-time data of smart meters can notify operators of outages right before they happen. Automated switching can be introduced to reroute energy or isolate affected areas based on the ability of AI tools to predict grid imbalances and to differentiate between a brief power interruption and a full-on outage. Feeding on sensors which monitor grid assets' health in real-time and video footage taken by helicopters or unmanned drones, AI can detect anomalies enabling operators to intervene for timely maintenance of costly grid equipment. Machine learning can also help operators understand the performance of transformers with the aid of "Digital Twin" technologies. In turn optimal operation ranges for transformers can be planned to avoid over-utilization and extend their lifetime.

AI-powered virtual architects utilize reinforcement learning (RL) to continually adapt through interaction with the energy grid, learning from observed outcomes. These RL agents leverage advanced deep learning models to make instantaneous decisions that stabilize the grid and optimize energy flow.

Energy Demand Management

AI tools can help households to automatically switch between battery power, rooftop solar PV system, or the grid. In factories and datacenters ML algorithms track equipment energy consumption and suggest improvements via prescriptive analytics. AI can spot machine inefficiency or processes that waste energy enabling action to optimize energy consumption. For households, AI can determine occupancy level and thermal behavior based on IoT and computer vision data and optimize electricity usage of heating and air conditioning units. Smart grids absorb solar and wind power that might otherwise be curtailed with the aid of data centers and cloud computing networks dedicated on "renewables matching." AI plays a crucial role in the operation of distributed energy resources and devices as "virtual power plants" (VPP). AI forecasts asset performance, energy demand and power prices that governs dispatching energy by small-scale assets like small-scale batteries, wind turbines, solar PV panels, EVs, biogas generators that are components of the VPP.

Predictive Maintenance

A network of IoT sensors with high-resolution imaging captures continuous infrared and thermal data to detect subtle temperature changes in power lines and substations. Advanced machine learning models process this data in real-time, supporting predictive maintenance by pinpointing areas at risk of overheating or potential faults.

Materials Discovery

Materials discovery is a part of CCUS (carbon capture, utilization and storage) technology where high-performance, low-cost materials are developed for clean energy storage and generation. The cost and energy requirements to convert CO2 into products are highly dependent on catalysts, often using expensive or scarce metals, which prohibit scaleup. Other potential innovation areas include energy efficient materials (e.g. phase-change materials that can store and release heat), thermoelectric materials that can convert heat into electricity, new solar panel materials capable of improved sunlight energy conversion and new battery materials and chemistries that improve performance and/or durability. AI could become a powerful tool to generate novel molecular structures which satisfy specific requirements for certain applications. In a process called autonomous materials discovery, AI combinedly with robotics can automatically synthesize and experiment on the properties of newly discovered molecules.

Decarbonization

Advanced optimization algorithms like Mixed-Integer Linear Programming (MILP) synchronize multiple energy sources by factoring in energy output rates, storage limits, weather forecasts, and carbon emissions data. The CCUS (Carbon, Capture, Utilization, and Storage) platform then orchestrates an ideal mix of energy sources, minimizing carbon output and ensuring a nearly carbon-neutral supply.

Guiding Principles for AI Adoption in Energy Sector Transition

As evident from the above sections AI has a potential to bring significant changes in the transition of energy sector into a net zero emission industry. The following principles play a key role in integrating AI for designing, enabling, and governing energy transition initiatives:

Designing

Automation

Design generation equipment and grid operations for automation and increased autonomy of AI.

The complexity in managing modern energy systems makes automation indispensable. As the energy sector gets more decentralized real-time decision making gets complicated and out of league for humans. This is where AI steps up automation in energy with simple augmented automation with AI solely assisting in human decision-making to full autonomy with AI making decisions autonomously without human supervision. Increased autonomy in grid operations should be aimed and new power system equipment must be designed and set up ready for automation.

Sustainability

AI may see 10x growth in power demand by 2026. Adopt the most energy efficient infrastructure as well as best practices around sustainable computing to limit the carbon footprint of AI.

Training and running some of the AI technologies like deep learning models are energy intensive as they use high-power GPUs and cooling systems. AI models should be designed in an energy-conservative fashion. The value of AI development, training, integration, and running must be able to far outweigh the cost of carbon emission resulting from it. Best practice approaches, tools, and methodologies should be adopted to build energy-efficient models and sustainable computing. This may involve running algorithms on hardware powered by green electricity, recycling waste heat, and recycling models across different applications or domains.

Design

Focus AI development on usability and interpretability.

AI should not be of limited access with specialists only. AI algorithms should be able to offer more transparency related to how they were trained and developed. It should be easy to be interpreted by everyone. Low-code AI tools, often powered by NLP (Natural Language Processing), that are easy to use by non-experts should be developed so that AI can become an integrated base layer for a variety of operational tasks.

Enabling

Data

Establish data standards, data sharing mechanisms, and platforms to increase the availability and quality of data.

Today SCADA (Supervisory Control and Data Acquisition) serves as the basis of monitoring data for most power systems. This is not very efficient in delivering real-time, granular operational data at the distribution level. To obtain large amounts of quality data in a consistent fashion for model training we need more sensors and better communications networks. A data governance protocol is essential to transform data into uniform format, label, and store it in suitable storage like a data lake or data warehouse to be shared across the organization preventing formation of data silos. Cloud-based platforms and services might be leveraged to maintain quality, consistency, and integrity of data supply. Energy companies need to agree to accept a common data standard across the sector for AI model interoperability.

Incentives

Create market designs and regulatory frameworks that allow AI use cases to capture the value that they create.

AI opens up scope of innovation in the energy sector and optimizes workflows beyond the human capacity. To encourage scaling of AI applications by energy business owners clear value propositions for customers and other market participants need to be established. Regulatory frameworks help to unlock the value proposition of automated demand-response bidding from behind-the-meter devices or AI-assisted microtransactions.

Education

Empower consumers and the energy workforce with a human-centered AI approach and invest in education to match technology and skill development.

To enable AI adoption and value creation in the power sector it is important to earn trust from the engineers, employees and managers who drive the operations. Teams need to be redesigned to bring forth and together employees with necessary knowledge and skillsets. This might involve putting together data scientists and energy engineers in a single team. Educating the consumers about the limits of AI functionalities or restrictions on personal data usage helps them better interact with AI.

Governing

Risk Management

Agree upon a common technological and educational approach for managing risks presented by AI.

Recent EU regulations portray AI as a high-risk application for the energy sector. For hassle-free scaling of AI applications and wide adoption within the energy sector, regulators and industry leaders need to understand and mitigate potential risks that AI might pose. Common regulatory and quality control procedures may involve decentralizing control structures to minimize damage, induction of certified AI systems and/or system operators, periodic auditing of algorithms. Technology can be your friend in mitigating risk via automated logging of AI systems' activities and decisions and monitoring for manipulative behavior within the market. Setting clear perimeters for operational scope of algorithms decreases risk. Education around AI risks and AI risk management helps regulators, policy-makers, energy sector employees and citizens gain a better understanding of AI and wider acceptance.

Standards

Implement compatible software standards and interoperable interfaces.

Interoperability among various IoT devices is crucial for maintaining data consistency and real-time implementation of AI solutions. Enterprises should look for standard protocols for software and machine communication like MQTT. Today, there are many different standards and protocols owing to different geographies and varying datatype used by devices like smart meters, EV chargers that form a part of the grid. All energy system stakeholders and market participants, including regulators, grid operators and equipment manufacturers, should adopt common standards and design and install interoperable "plug and play" devices.

Responsibility

Ensure that AI ethics and responsible use lies at the core of AI development and deployment.

With AI solutions penetrating into the energy sector and bringing about organizational changes while handling sensitive enterprise data, concerns about AI ethics are not invalid. To ensure beneficial outcomes and avoid societal harms, AI applications in the energy sector must adhere to the OECD's five core AI principles: inclusivity, fairness, transparency, robustness, and accountability. To implement this AI governance and risk-management practices should be placed following a risk-based approach and considering the use case. Thorough documentation and rigorous testing before implementation, ethical consideration at the core, and rapid identification and mitigation of emerging issues helps to minimize AI risks. As the industry expands its broader AI technology and management capabilities, it must proactively ensure that AI ethics and responsible use considerations are fully integrated into AI development and deployment processes.

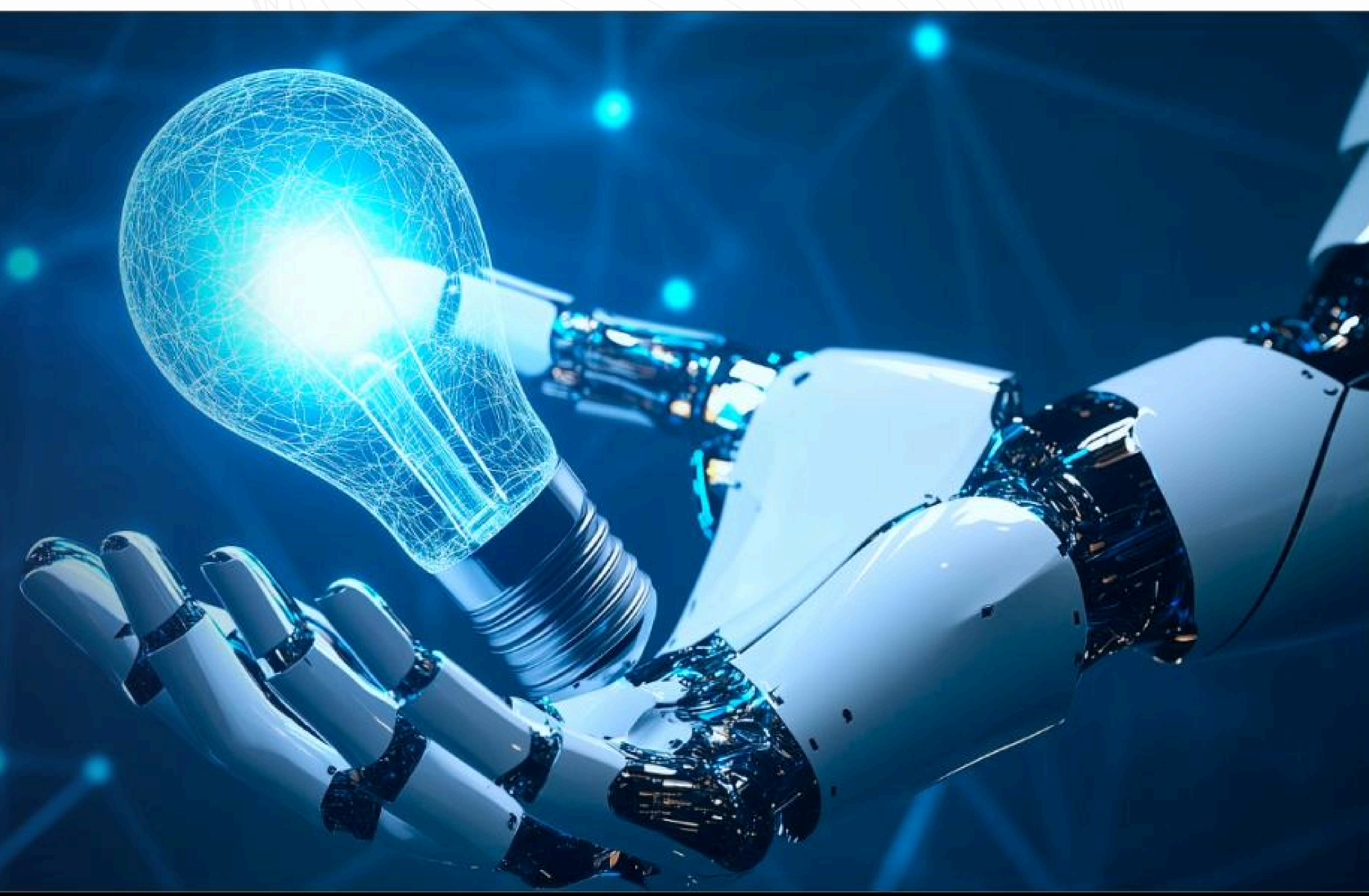
About Us

Gleecus TechLabs Inc. is one of the fastest growing IT innovation partners for startups, SMBs, and enterprises that help clients envision, build, and run more innovative and efficient businesses. We help energy enterprises solve their unique challenges with state-of-the-art digital transformation technologies like AI, ML, Data Engineering, and Cloud computing.

Our expertise in building AI and ML models covers every workflow of an energy business from energy demand forecasting to CRM management with predictive AI. Our services encompass data acquisition, preparation, and model upgradation of AI solutions for the energy sector liberating the internal team and stakeholders to engage in core business and engineering activities.

Build an AI solution for your energy & utility business today to ensure uninterrupted service and supply of power

Connect with Us



About Gleecus TechLabs Inc.

Gleecus TechLabs Inc. is an ISO 9001:2015 and ISO/IEC 20000-1:2018 certified Forward Thinking Digital Innovation partner creating impactful business outcomes with Engineering & Experience. With deep focus on Cloud, Data, Product Engineering, AI and Talent we help organizations become Digital Natives.

Gleecus TechLabs
Forward Thinking Digital Innovation

Email: hello@gleecus.com
Phone: +1 347 947 2022

www.gleecus.com