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Grid Modernization and Renewable Energy Transition

Towards a Smart, Sustainable and Resilient Power System

Date: 23rd July 2026

Watch Webinar Recording Here

Presenter: Dr. Munira Batool

EIT Lecturer and Research Supervisor

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- Master of Science (Power System Analysis and Renewable Integration)
- Master of Science (Industrial Automation and Instrumentation Control)

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ECST delivers a **South African accredited qualification** on-campus. ECST is committed to providing students with a world-class education, where they acquire the knowledge and skills that are applicable and valued in industry.

- Bachelor of Engineering Technology in Electrical Engineering (SAQA 123645)

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The Engineering College of Science and Technology (Pty) Ltd is provisionally registered with the Department of Higher Education and Training until 31/12/2028 as a private higher education institution under the Higher Education Act, 1997. Registration certificate no. 2025/HE07/007.

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- Electrical Engineering
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Prospective students should refer to the relevant institution's official website for accurate, up-to-date information specific to their location, including course availability, fees, regulatory status, and enrolment conditions.

- For the Engineering Institute of Technology (EIT) visit: https://www.eit.edu.au/
- For the Engineering College of Technology (ECT) visit: https://www.ect.ac.uk/
- For the Engineering College of Science and Technology (ECST) visit: https://www.ecst.ac.za/

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Breaches may lead to removal.

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Introduction – Presenter

Dr. Munira Batool

MUNIRA BATOOL (Senior Member, IEEE) received the bachelor's degree in electrical engineering from Bahauddin Zakariya University, Multan, Pakistan, in 2007, the master's degree in electrical engineering from the University of Engineering and Technology, Taxila, Pakistan, in 2012, and the Ph.D. degree from Curtin University, Australia, in May 2019. She has over 17 years of extensive experience of teaching and research in the university sector. She is currently an Assistant Professor with the University of Engineering and Technology. She is also a Postgraduate Research Supervisor with the Electrical Engineering Department, EIT, Australia. She has commendable teaching experiences in power system generation, power system transmission, power system distribution and utilization, power system protection, and power system analysis. Her research interests include distributed energy generation-based power systems, renewable energy sources integration and microgrids, and smart grids. Initially, this was applied to improve the performance of distributed energy generation systems using Meta- heuristic optimization techniques. More recently, her research efforts have involved the optimal sizing and siting of renewable energy sources (such as PV and wind) in distribution networks using novel power electronic converters and controllers. She is a subject matter expertise on modeling and simulating renewable energy-based power system networks using software commonly used in the industry. The results of her research have been published in high ranked journals and conference papers.

Agenda

1	Introduction
2	Grid Modernization
3	Renewable Integration
4	Smart Grids
5	AI
6	Storage
7	EVs
8	Cybersecurity
9	Case Studies
10	Q&A

Global Energy Transition

Why Are We Transitioning?

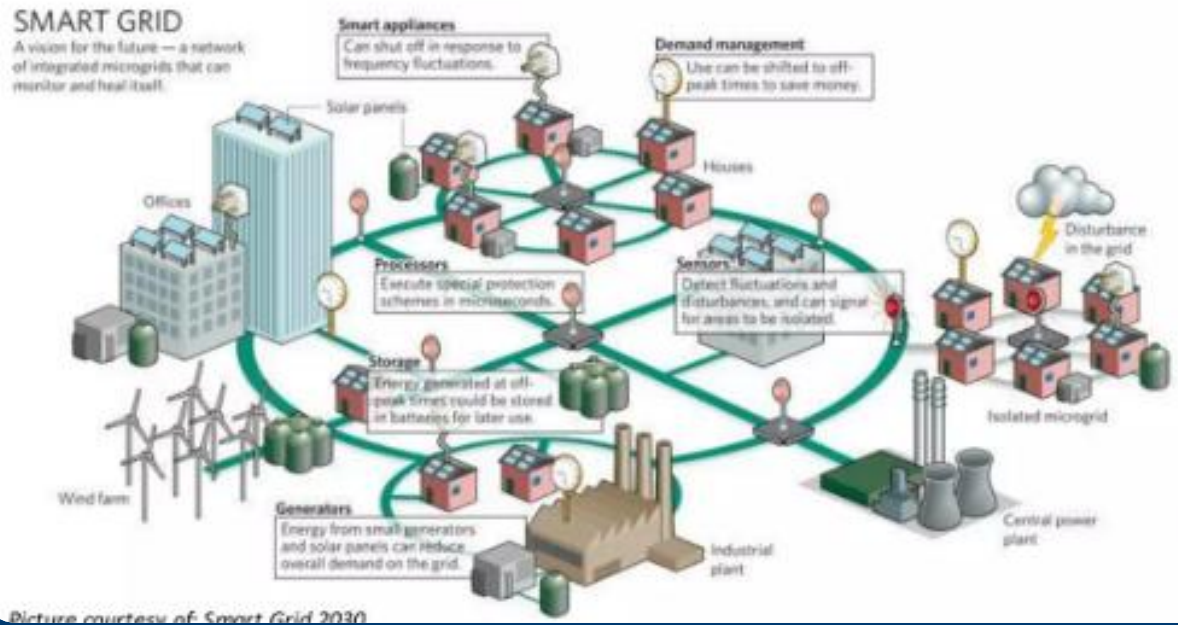
Key Drivers

- Climate change mitigation
- Net-zero carbon emissions
- Increasing electricity demand
- Declining renewable energy costs
- Government policies
- Energy security

Global Renewable Growth

- Solar PV
- Wind Energy
- Hydropower
- Battery Storage

A world of interdependent and variable distributed systems that are optimized at multiple scales – including transmission – to maximize local resources in providing secure, resilient, and clean energy to all users at all times.



Picture courtesy of: Smart Grid 2030

Our capabilities support this vision:

- DER and renewable energy integration
- Power electronics and controls
- Secure and scalable microgrids
- Advanced grid analytics/complex systems
- Infrastructure interdependencies
- Cyber and physical security
- Embedded sensors, information processing, and secure manufacturing
- Energy storage systems

Traditional Grid vs Smart Grid

Traditional Grid	Modern Smart Grid
Centralized generation	Distributed generation
One-way power flow	Two-way power flow
Manual monitoring	Real-time monitoring
Limited automation	Intelligent automation
Slow fault detection	Self-healing capability

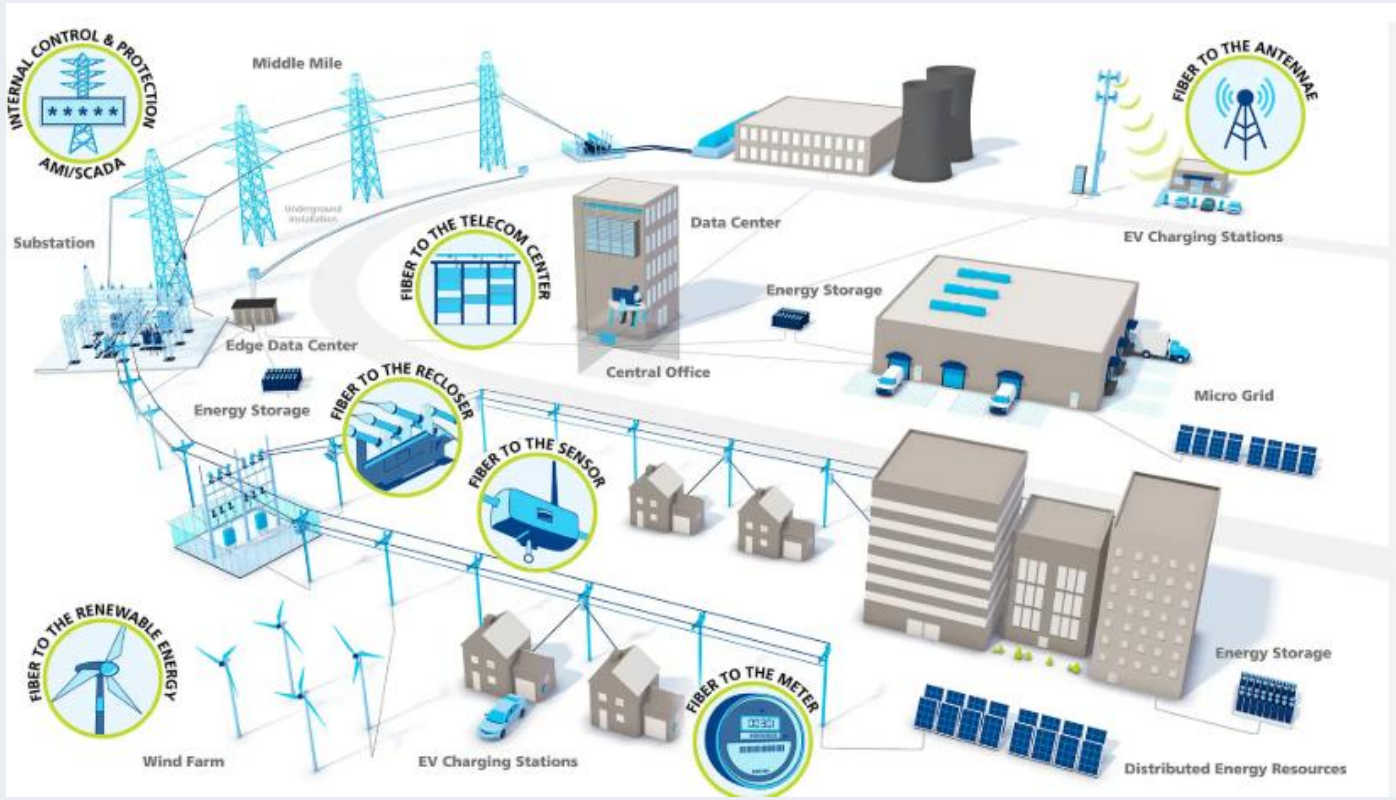
What is Grid Modernization?

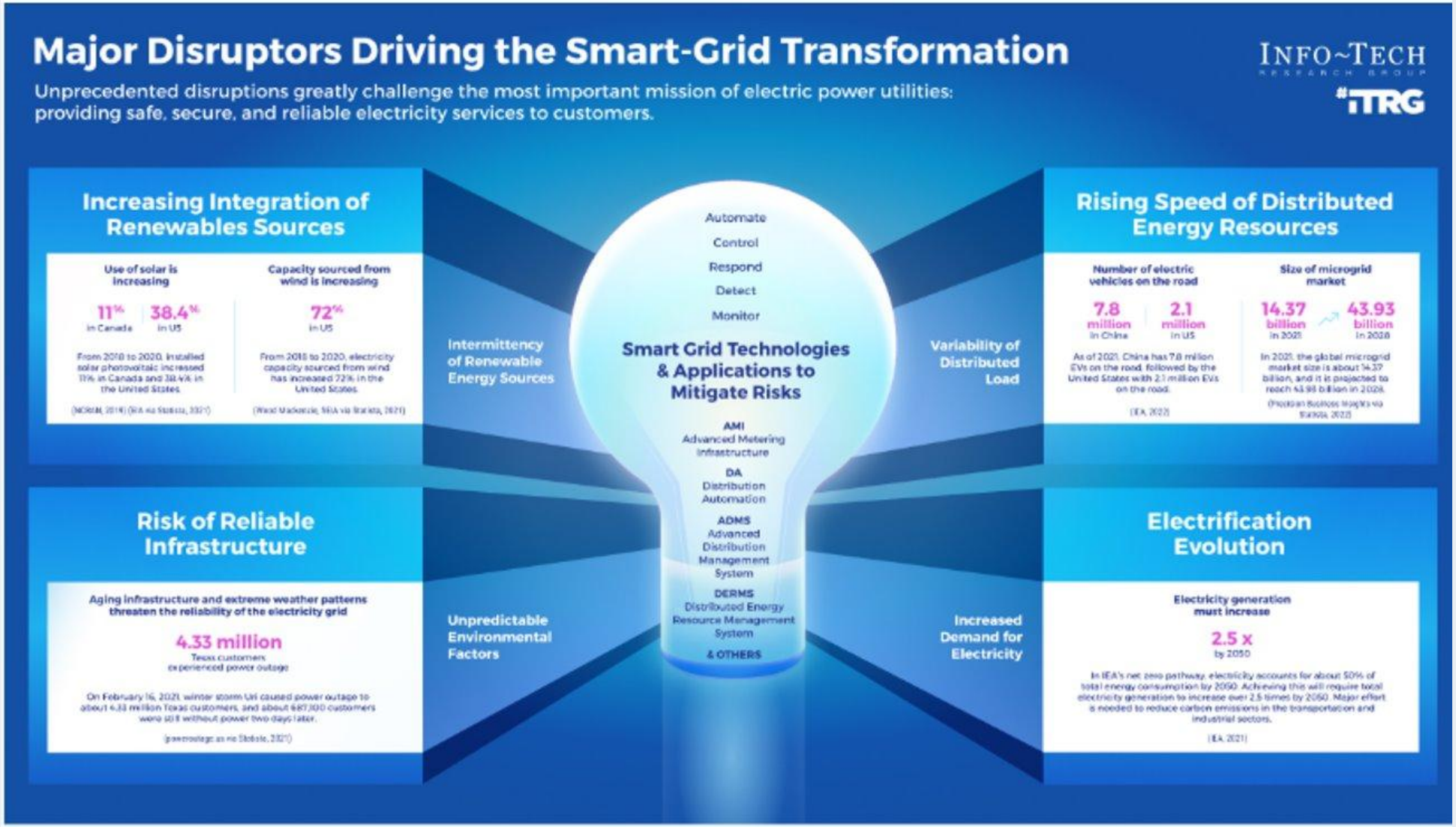
Grid modernization refers to upgrading existing electrical infrastructure using digital technologies to improve:

- Reliability
- Flexibility
- Efficiency
- Security
- Sustainability

Main Components

- Smart meters
- Advanced sensors
- PMUs
- SCADA
- Communication networks
- Advanced protection systems

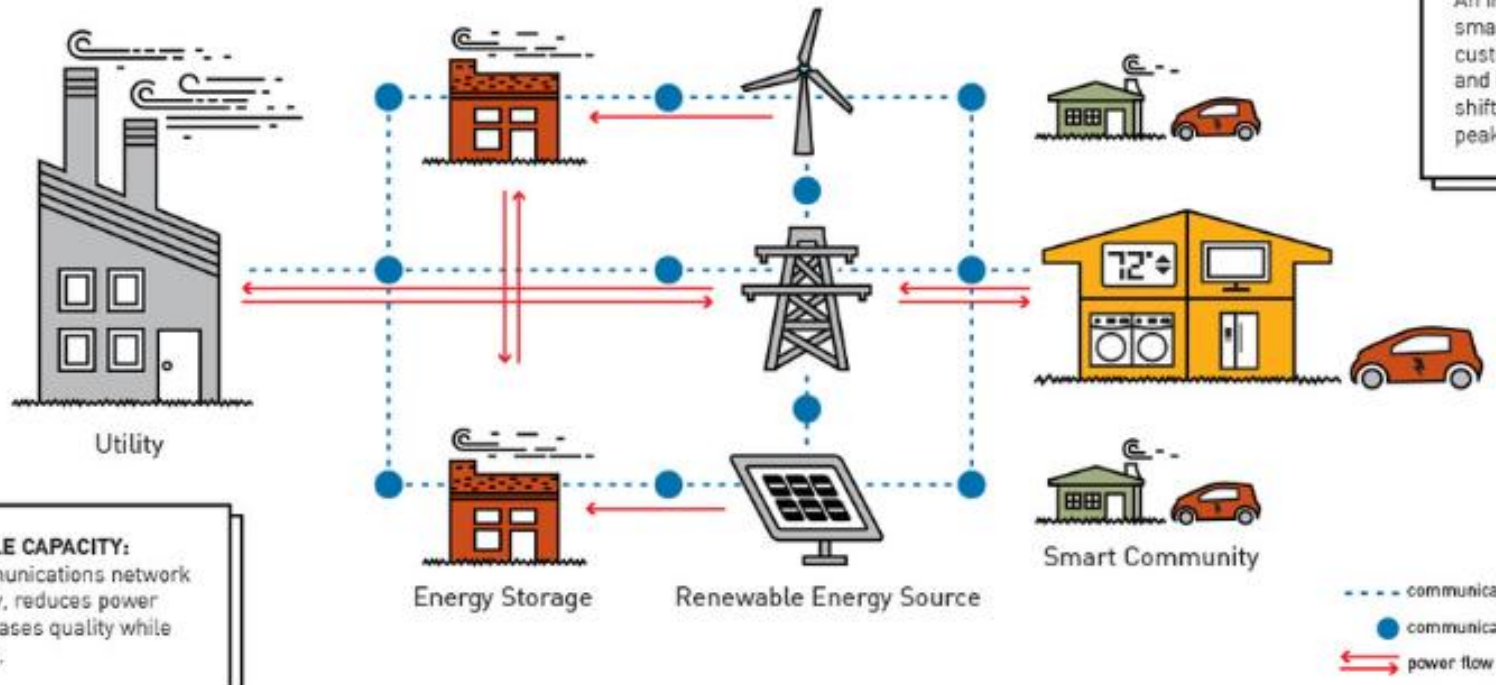



Major Disruptors Driving the Smart-Grid Transformation
Unprecedented disruptions greatly challenge the most important mission of electric power utilities: providing safe, secure, and reliable electricity services to customers.
INFO-TECH RESEARCH GROUP
#ITRG
Increasing Integration of Renewables Sources
Use of solar is increasing
11% in Canada
38.4% in US
From 2010 to 2020, installed solar photovoltaic increased 11% in Canada and 38.4% in the United States.
Capacity sourced from wind is increasing
72% in US
From 2015 to 2020, electricity capacity sourced from wind has increased 72% in the United States.
Intermittency of Renewable Energy Sources
Automate
Control
Respond
Detect
Monitor
Smart Grid Technologies & Applications to Mitigate Risks
AMI Advanced Metering Infrastructure
DA Distribution Automation
ADMS Advanced Distribution Management System
DERMS Distributed Energy Resource Management System
& OTHERS
Variability of Distributed Load
Rising Speed of Distributed Energy Resources
Number of electric vehicles on the road
7.8 million in China
2.1 million in US
As of 2021, China has 7.8 million EVs on the road, followed by the United States with 2.1 million EVs on the road.
Size of microgrid market
14.37 billion in 2021
43.93 billion in 2028
In 2021, the global microgrid market size is about 14.37 billion, and it is projected to reach 43.93 billion in 2028.
Risk of Reliable Infrastructure
Aging infrastructure and extreme weather patterns threaten the reliability of the electricity grid
4.33 million
Texas customers experienced power outage
On February 16, 2021, winter storm Uri caused power outage to about 4.33 million Texas customers, and about 687,300 customers were still without power two days later.
Unpredictable Environmental Factors
Increased Demand for Electricity
Electrification Evolution
Electricity generation must increase
2.5 x
by 2050
In IEA's net zero pathway, electricity accounts for about 50% of total energy consumption by 2050. Achieving this will require total electricity generation to increase over 2.5 times by 2050. Major effort is needed to reduce carbon emissions in the transportation and industrial sectors.
(IEA, 2021)

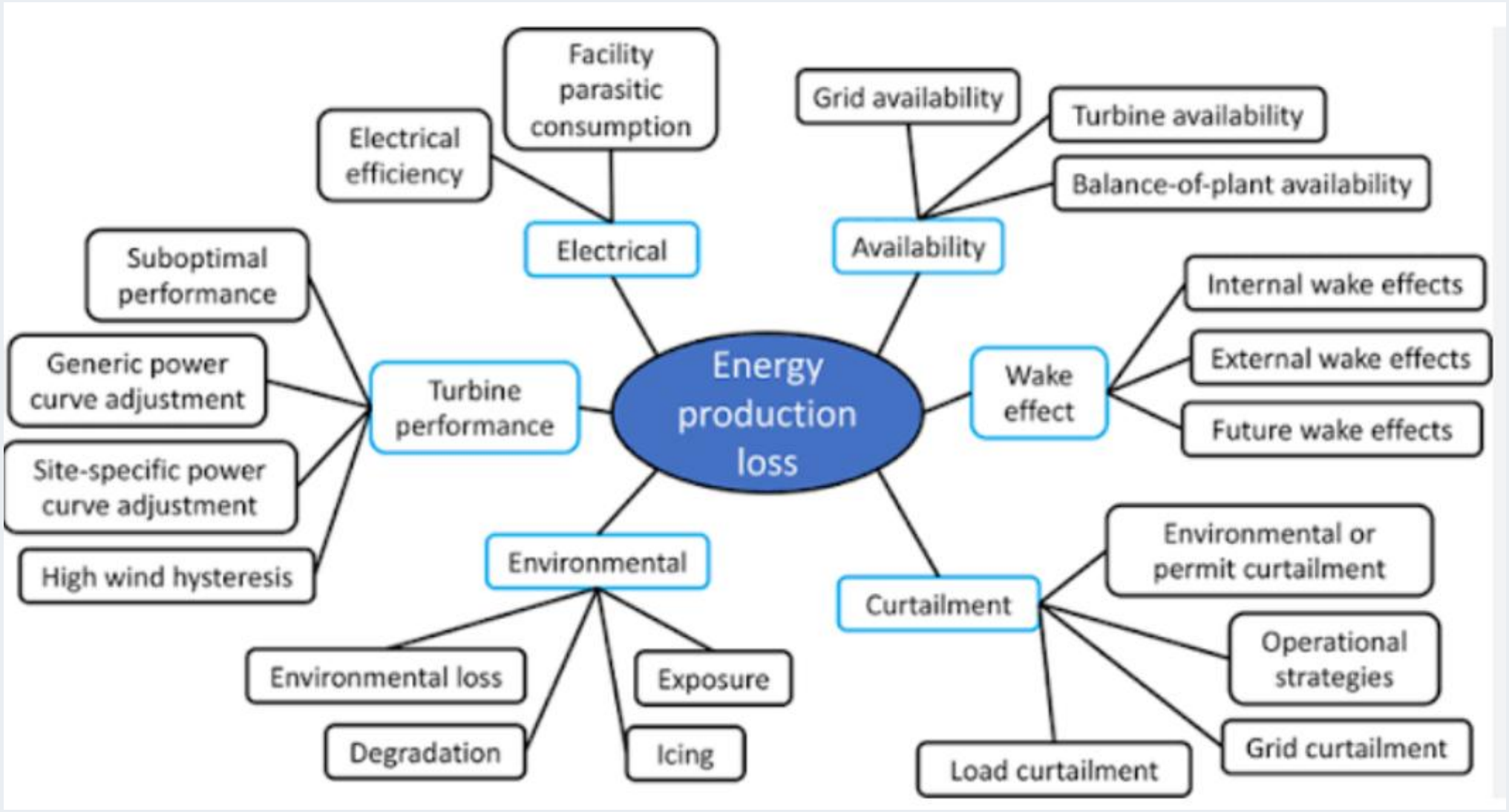
GRID MODERNIZATION

INSTANTANEOUS RESPONSE AND INTEGRATION: The electricity grid joins the digital age with fast, reliable and secure communications that enable automated, optimized grid management. Efficiency and speed will drive down rates.

CUSTOMER ENGAGEMENT: An integrated grid with smart meters gives customers the information and incentives they need to shift their energy use from peak to non-peak times.



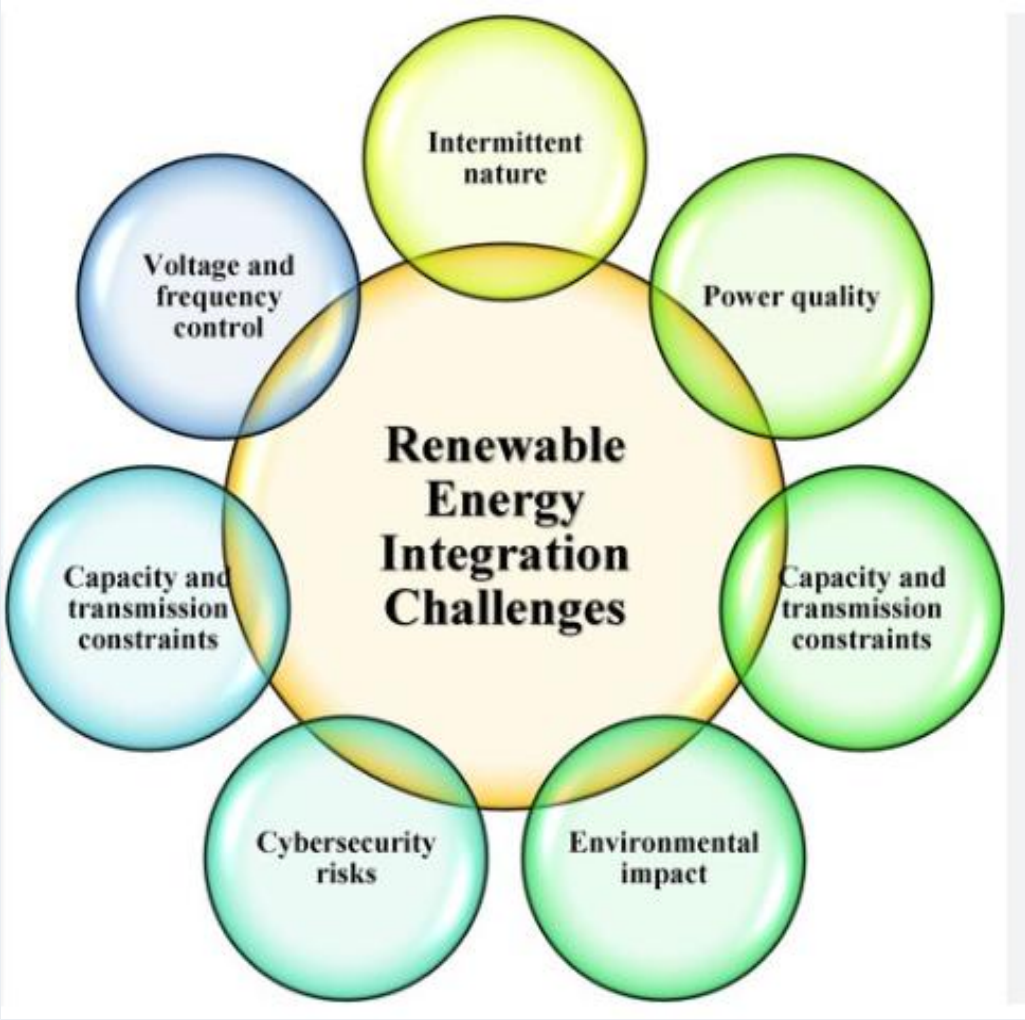
MORE RENEWABLE CAPACITY: A converged communications network improves reliability, reduces power outages, and increases quality while balancing demand.

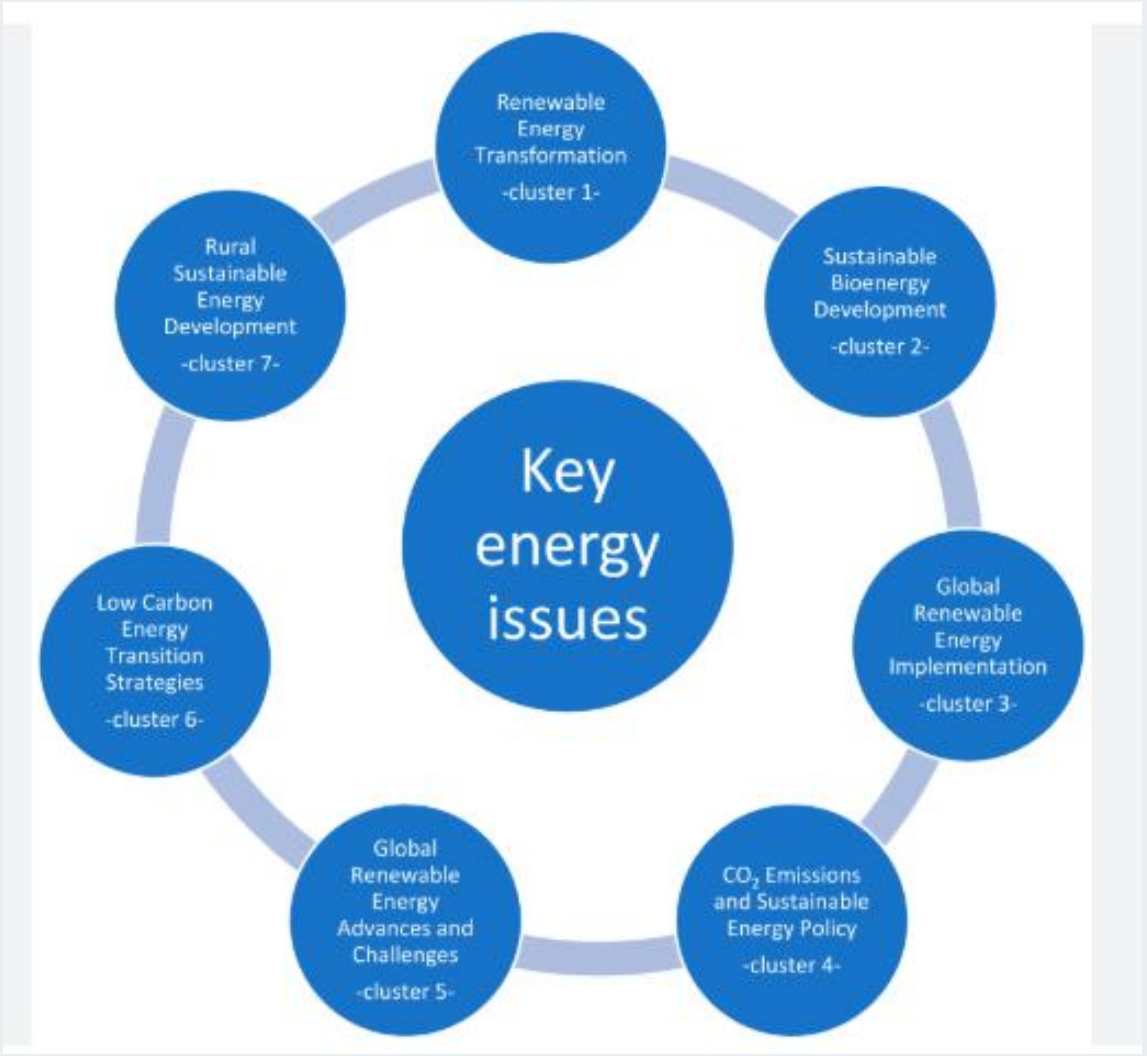

Energy production loss
Electrical
Facility parasitic consumption
Electrical efficiency
Availability
Grid availability
Turbine availability
Balance-of-plant availability
Turbine performance
Suboptimal performance
Generic power curve adjustment
Site-specific power curve adjustment
High wind hysteresis
Wake effect
Internal wake effects
External wake effects
Future wake effects
Environmental
Environmental loss
Degradation
Exposure
Icing
Curtailment
Environmental or permit curtailment
Operational strategies
Grid curtailment
Load curtailment

Renewable Energy Integration Challenges

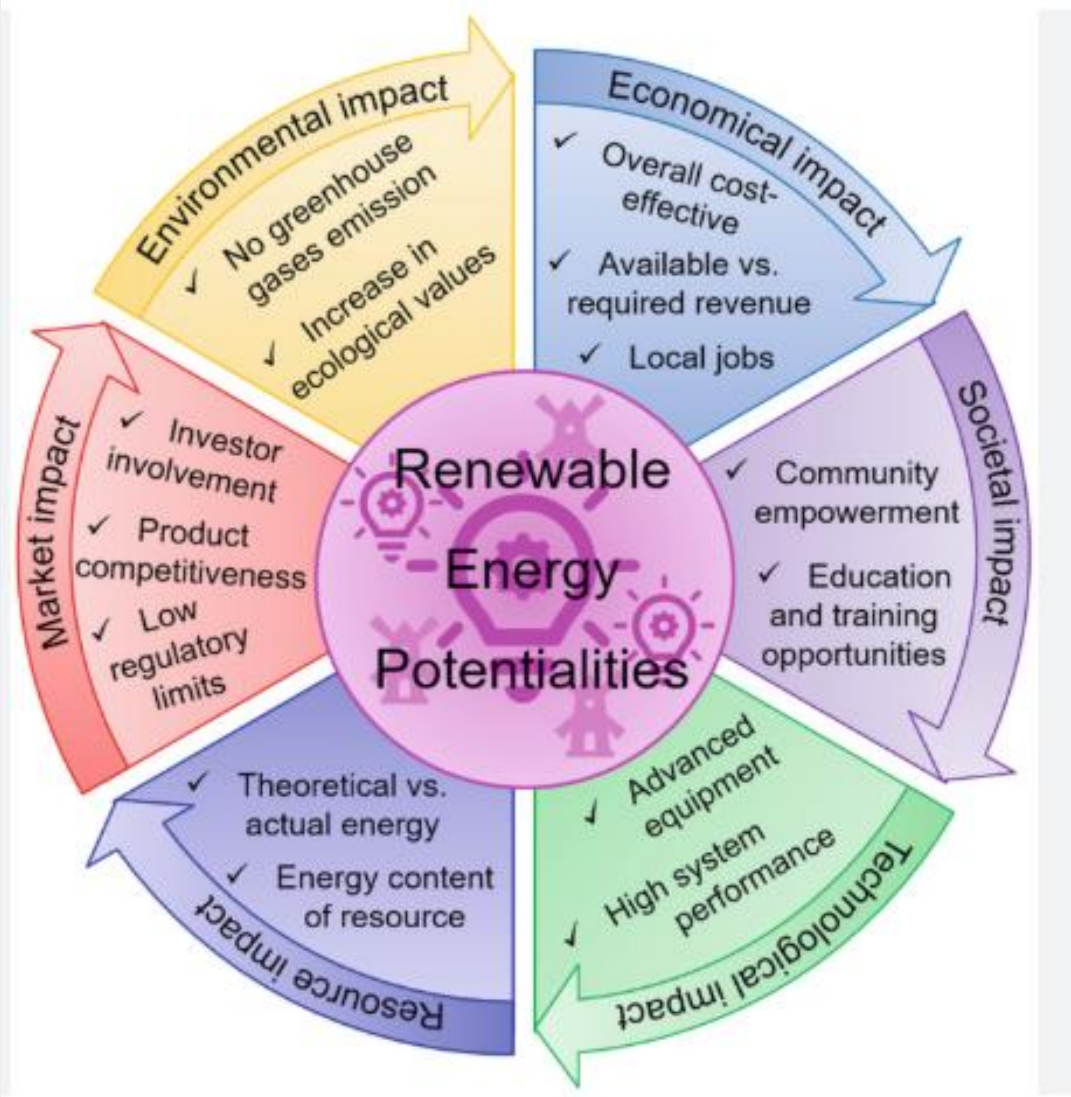
Technical Challenges

- Intermittent solar generation
- Variable wind power
- Voltage instability
- Frequency deviations
- Reduced system inertia
- Reverse power flow
- Grid congestion




Key energy issues
Renewable Energy Transformation -cluster 1-
Sustainable Bioenergy Development -cluster 2-
Global Renewable Energy Implementation -cluster 3-
CO_2 Emissions and Sustainable Energy Policy -cluster 4-
Global Renewable Energy Advances and Challenges -cluster 5-
Low Carbon Energy Transition Strategies -cluster 6-
Rural Sustainable Energy Development -cluster 7-

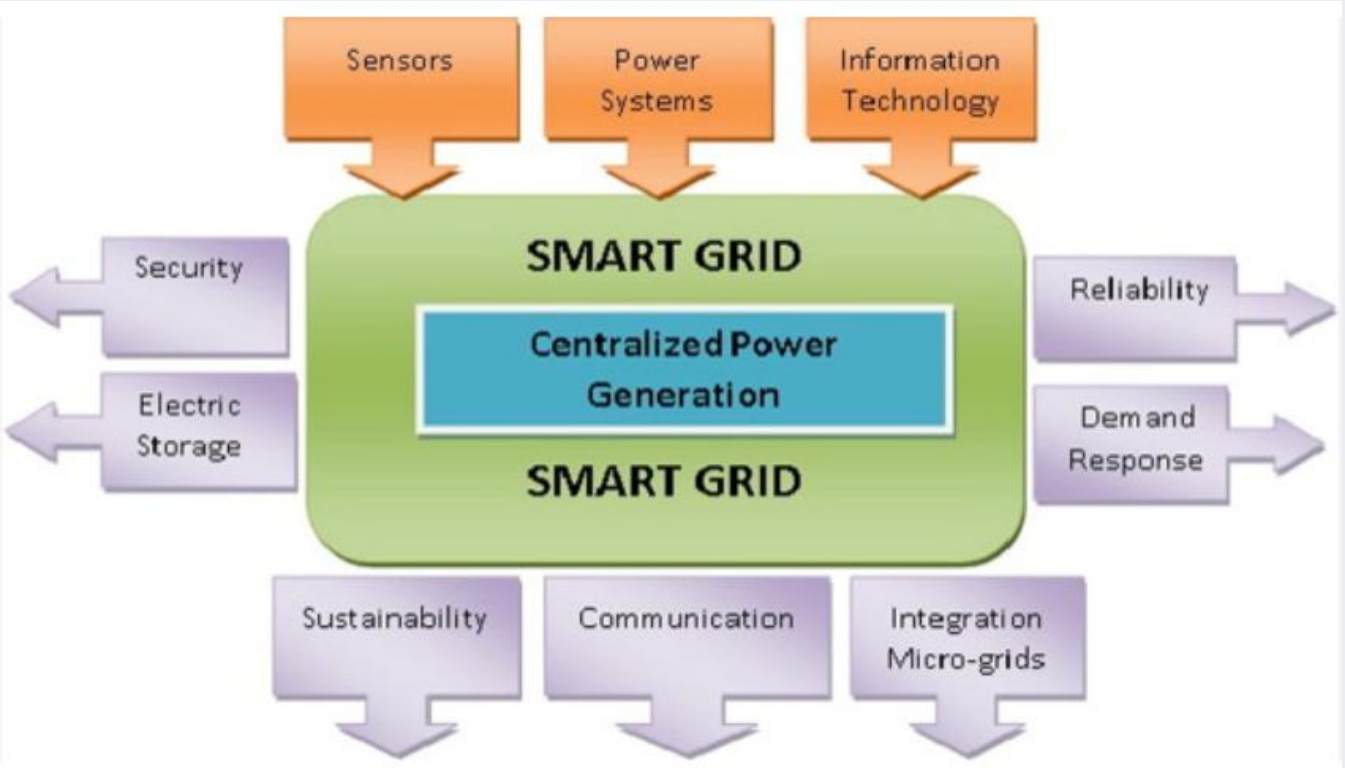

Causes of energy crisis
Over population
Poor infrastructure
Energy waste
Power plant commisioning delays
Unused renewable options
Poor distrib-ution
Major Accidents Natural calamities
Wars and attacks
Politics Border obstruction
Lack of storage
Over consumption

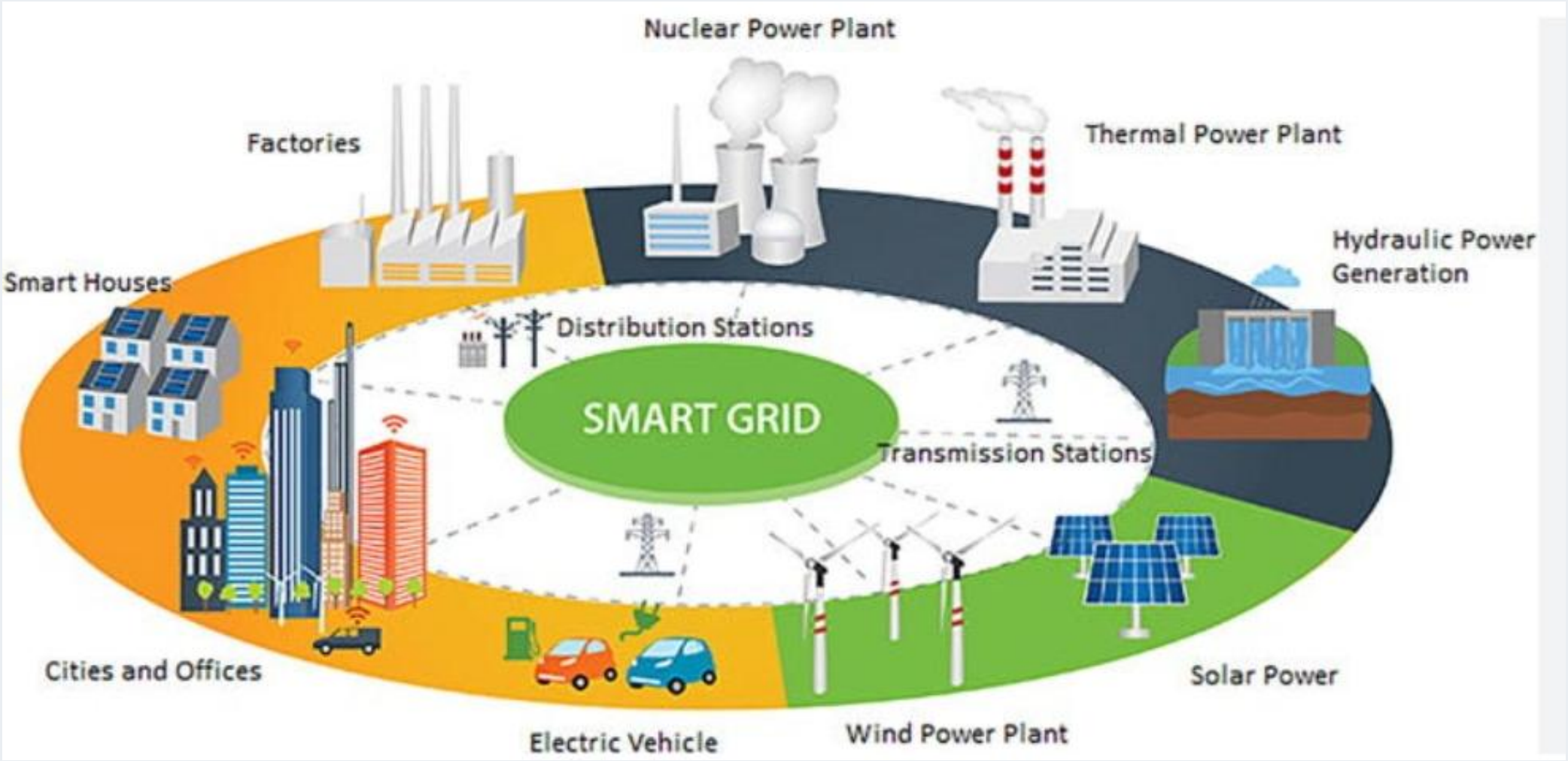

Renewable Energy Potentialities
Environmental impact
No greenhouse gases emission
Increase in ecological values
Economical impact
Overall cost-effective
Available vs. required revenue
Local jobs
Societal impact
Community empowerment
Education and training opportunities
Technological impact
Advanced equipment
High system performance
Resource impact
Theoretical vs. actual energy
Energy content of resource
Market impact
Investor involvement
Product competitiveness
Low regulatory limits

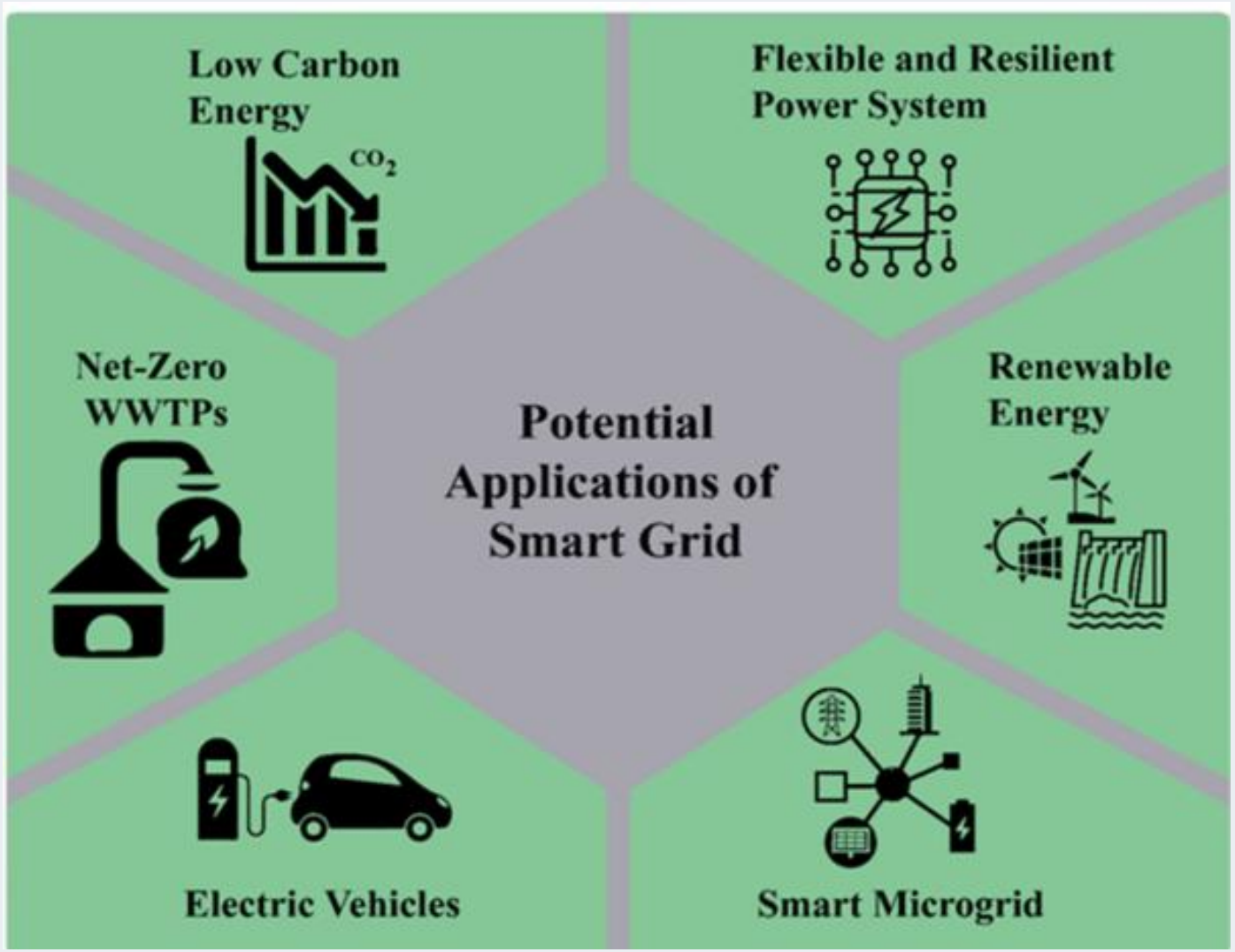
Smart Grid Technologies

Key Technologies

- Internet of Things (IoT)
- Advanced Metering Infrastructure (AMI)
- SCADA
- Phasor Measurement Units (PMUs)
- Wide Area Monitoring Systems
- Digital substations
- Distribution Management Systems




Nuclear Power Plant
Factories
Thermal Power Plant
Hydraulic Power Generation
Smart Houses
Distribution Stations
SMART GRID
Transmission Stations
Cities and Offices
Solar Power
Electric Vehicle
Wind Power Plant


Low Carbon Energy
CO_2
Flexible and Resilient Power System
Net-Zero WWTPs
Potential Applications of Smart Grid
Renewable Energy
Electric Vehicles
Smart Microgrid

Energy Storage Systems

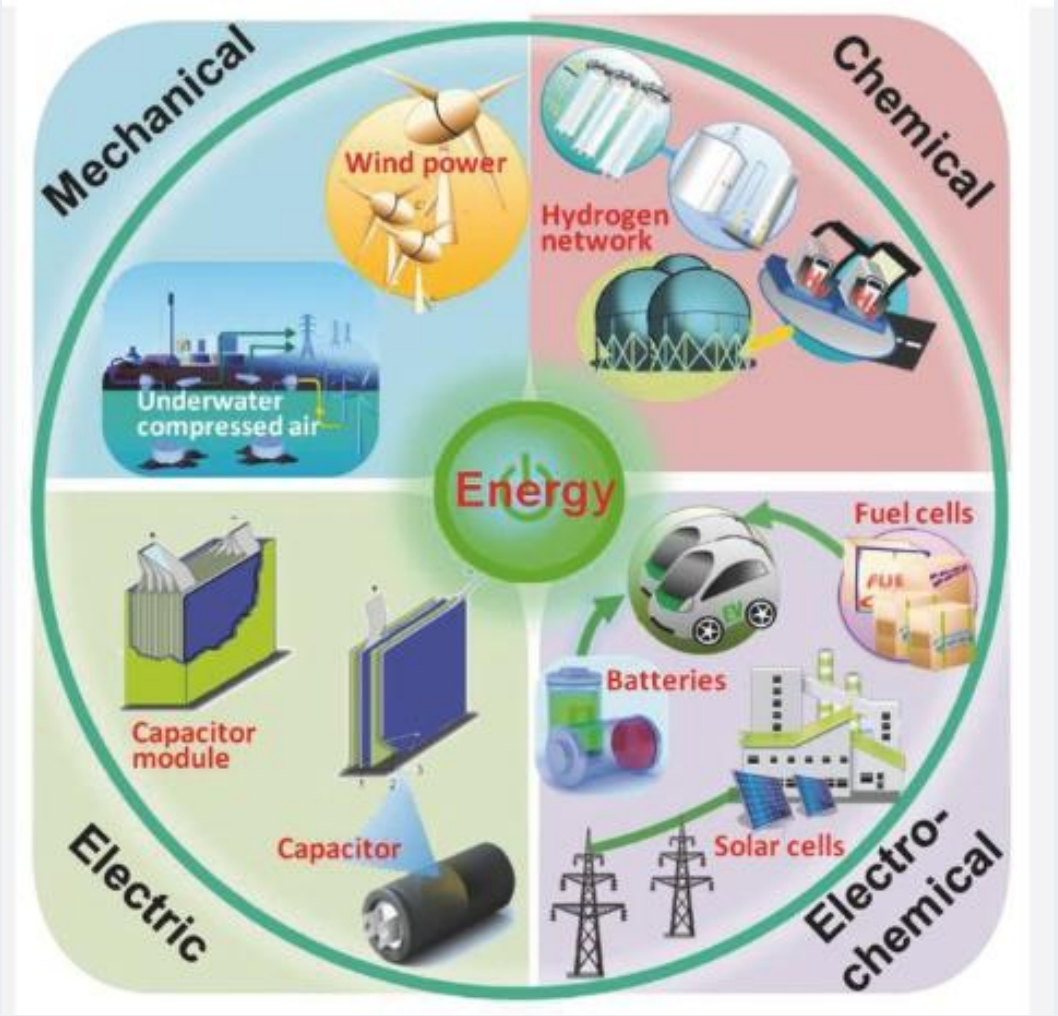
Energy storage solves renewable intermittency.

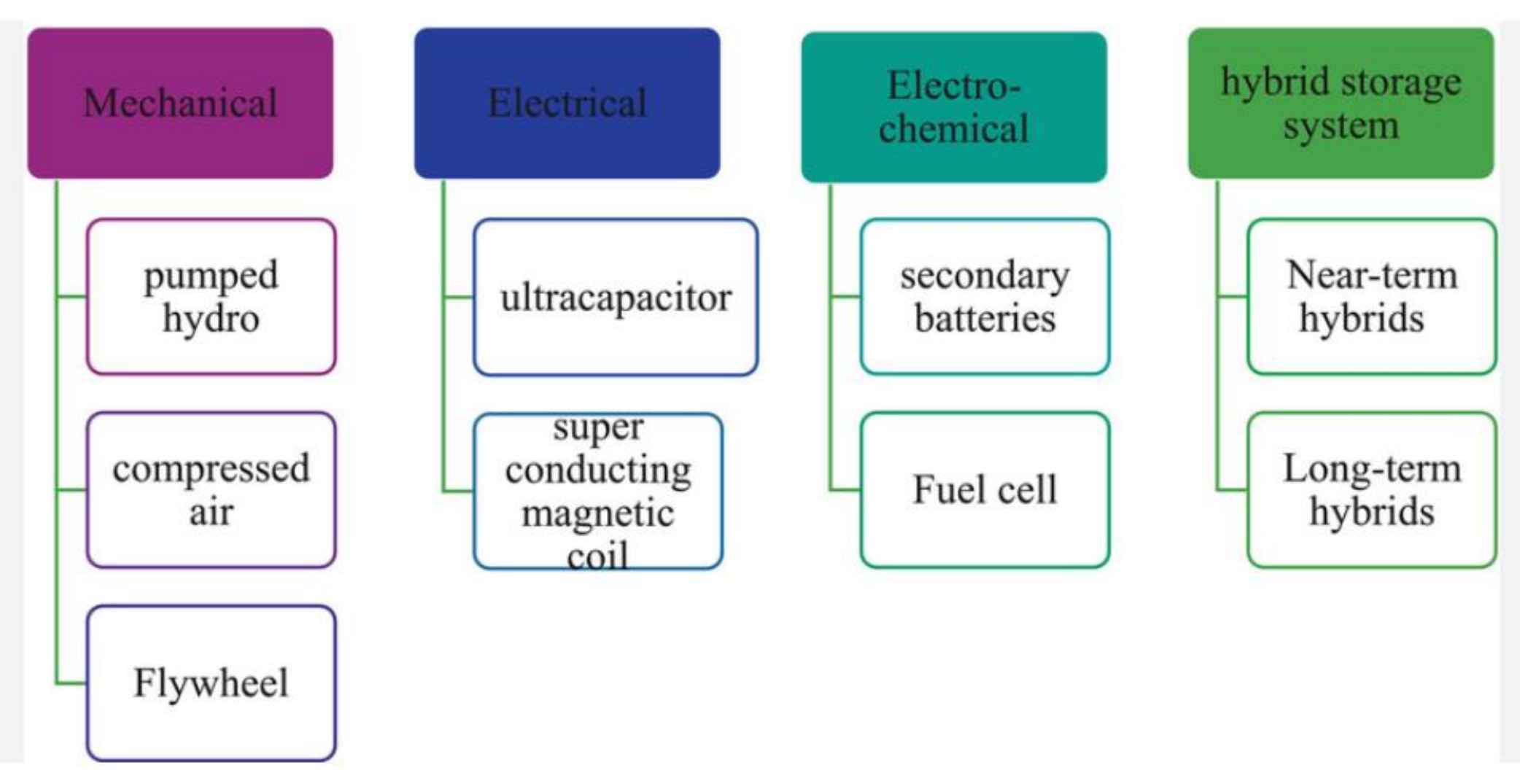
Technologies

- Lithium-ion Batteries
- Flow Batteries
- Pumped Hydro
- Flywheels
- Hydrogen Storage

Benefits

- Peak shaving
- Frequency regulation
- Backup power
- Renewable smoothing




Mechanical
pumped hydro
compressed air
Flywheel
Electrical
ultracapacitor
super conducting magnetic coil
Electro-chemical
secondary batteries
Fuel cell
hybrid storage system
Near-term hybrids
Long-term hybrids

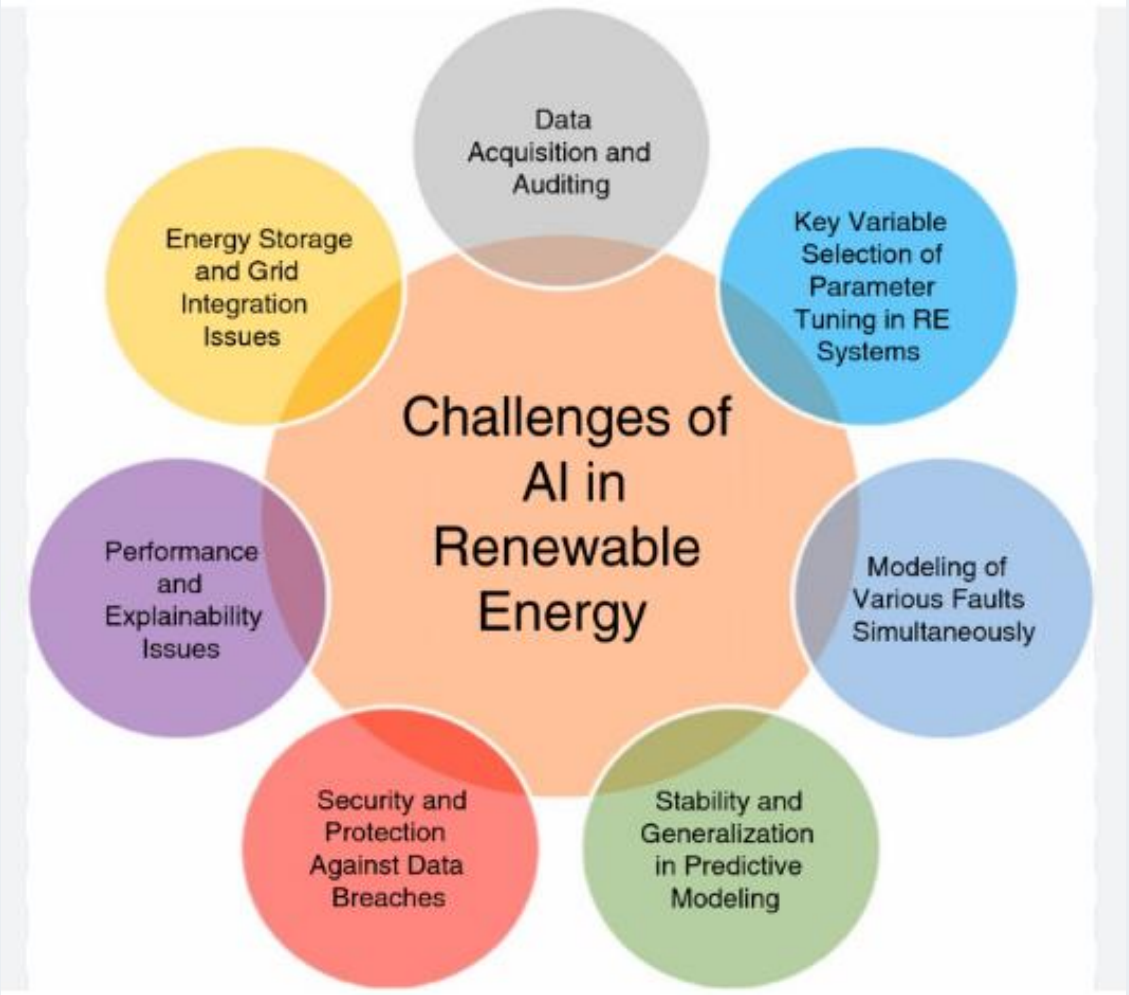
Artificial Intelligence in Grid Modernization

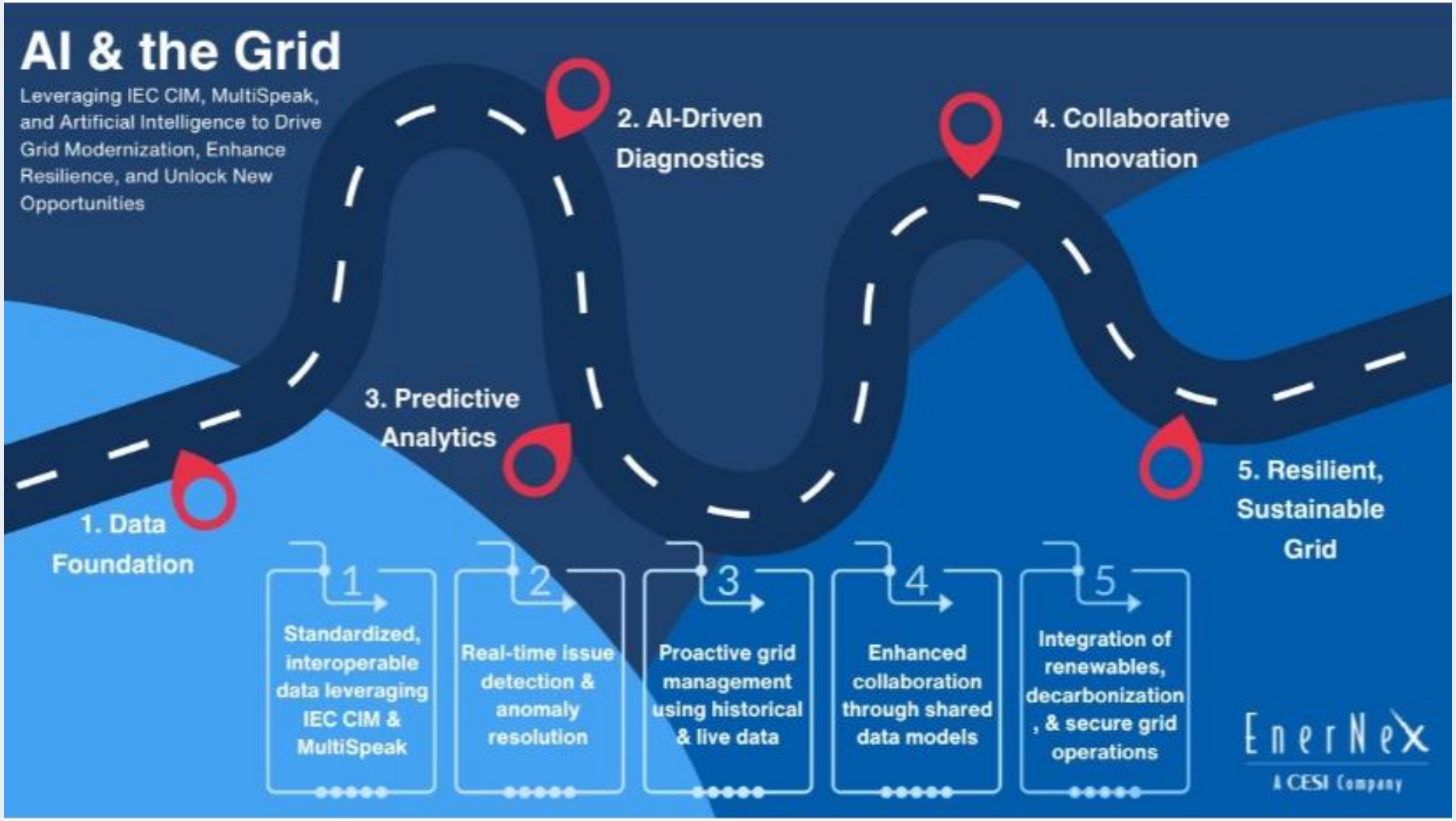
AI Applications

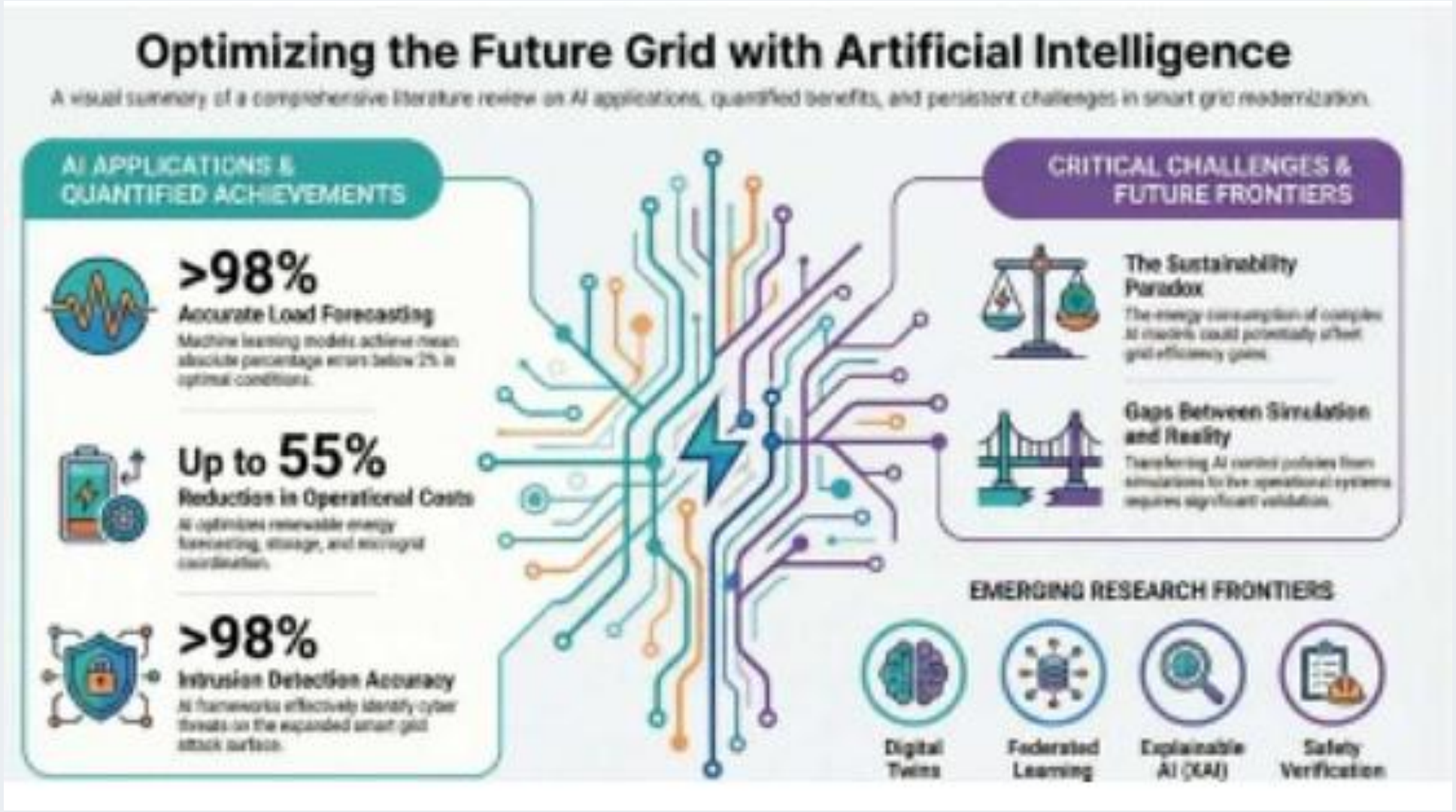
- Load forecasting
- Renewable generation prediction
- Fault diagnosis
- Predictive maintenance
- Voltage optimization
- Demand response
- Energy management

Machine Learning Algorithms

- ANN
- Random Forest
- XGBoost
- LSTM
- Deep Learning




AI & the Grid
Leveraging IEC CIM, MultiSpeak, and Artificial Intelligence to Drive Grid Modernization, Enhance Resilience, and Unlock New Opportunities
1. Data Foundation
2. AI-Driven Diagnostics
3. Predictive Analytics
4. Collaborative Innovation
5. Resilient, Sustainable Grid
1
Standardized, interoperable data leveraging IEC CIM & MultiSpeak
2
Real-time issue detection & anomaly resolution
3
Proactive grid management using historical & live data
4
Enhanced collaboration through shared data models
5
Integration of renewables, decarbonization, & secure grid operations
EnerNex
A CESI Company


Optimizing the Future Grid with Artificial Intelligence
A visual summary of a comprehensive literature review on AI applications, quantified benefits, and persistent challenges in smart grid modernization.
AI APPLICATIONS & QUANTIFIED ACHIEVEMENTS
>98%
Accurate Load Forecasting
Machine learning models achieve mean absolute percentage errors below 2% in optimal conditions.
Up to 55%
Reduction in Operational Costs
AI optimizes renewable energy forecasting, storage, and microgrid coordination.
>98%
Intrusion Detection Accuracy
AI frameworks effectively identify cyber threats in the expanded smart grid attack surface.
CRITICAL CHALLENGES & FUTURE FRONTIERS
The Sustainability Paradox
The energy consumption of complex AI models could potentially offset grid efficiency gains.
Gaps Between Simulation and Reality
Transferring AI control policies from simulations to live operational systems requires significant validation.
EMERGING RESEARCH FRONTIERS
Digital Twins
Federated Learning
Explainable AI (XAI)
Safety Verification

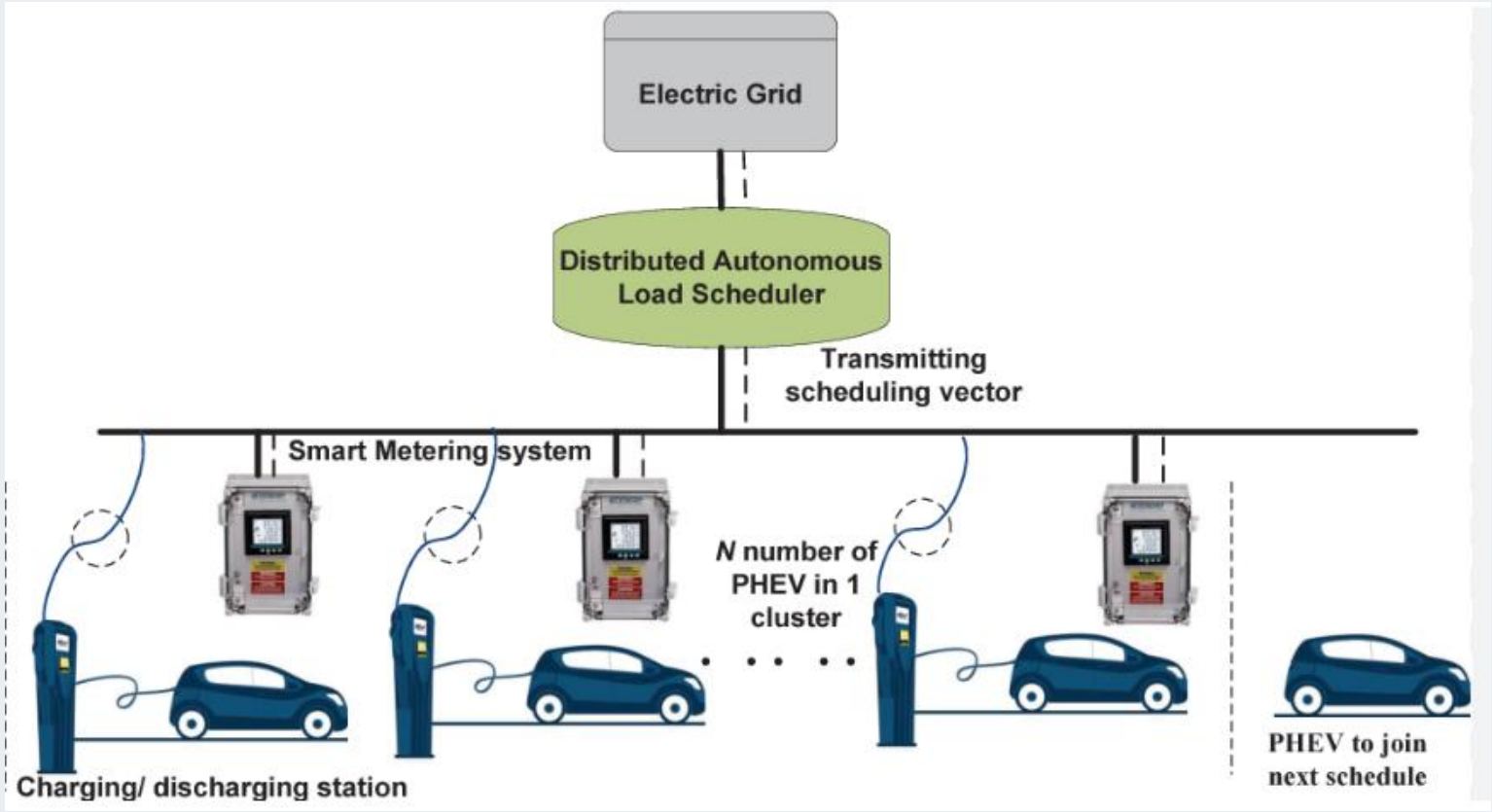
Electric Vehicles and Smart Grids

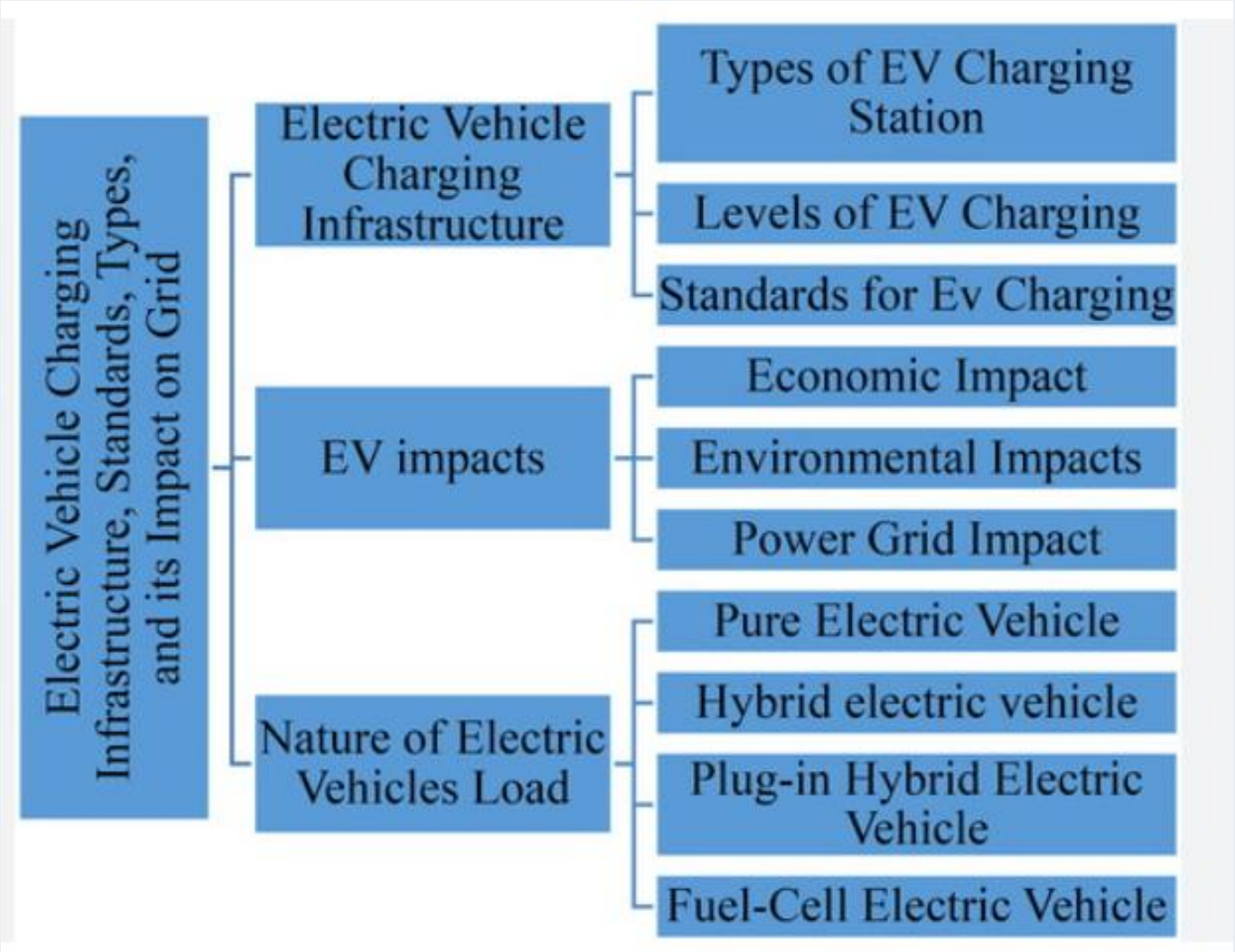
EV Challenges

- Increased electricity demand
- Peak loading

Smart Solutions

- Smart charging
- Vehicle-to-Grid (V2G)
- Demand response
- Dynamic pricing




Electric Vehicle Charging Infrastructure, Standards, Types, and its Impact on Grid
Electric Vehicle Charging Infrastructure
Types of EV Charging Station
Levels of EV Charging
Standards for Ev Charging
EV impacts
Economic Impact
Environmental Impacts
Power Grid Impact
Nature of Electric Vehicles Load
Pure Electric Vehicle
Hybrid electric vehicle
Plug-in Hybrid Electric Vehicle
Fuel-Cell Electric Vehicle

Cybersecurity in Smart Grids

Threats

- Malware
- Ransomware
- Data theft
- SCADA attacks
- False data injection

Protection

- Encryption
- Authentication
- Intrusion Detection Systems
- Blockchain
- AI-based monitoring

Real World Case Studies

Germany

- High renewable penetration
- Smart grid investments

Denmark

- Wind energy leadership

China

- Ultra High Voltage transmission
- Large-scale renewable integration

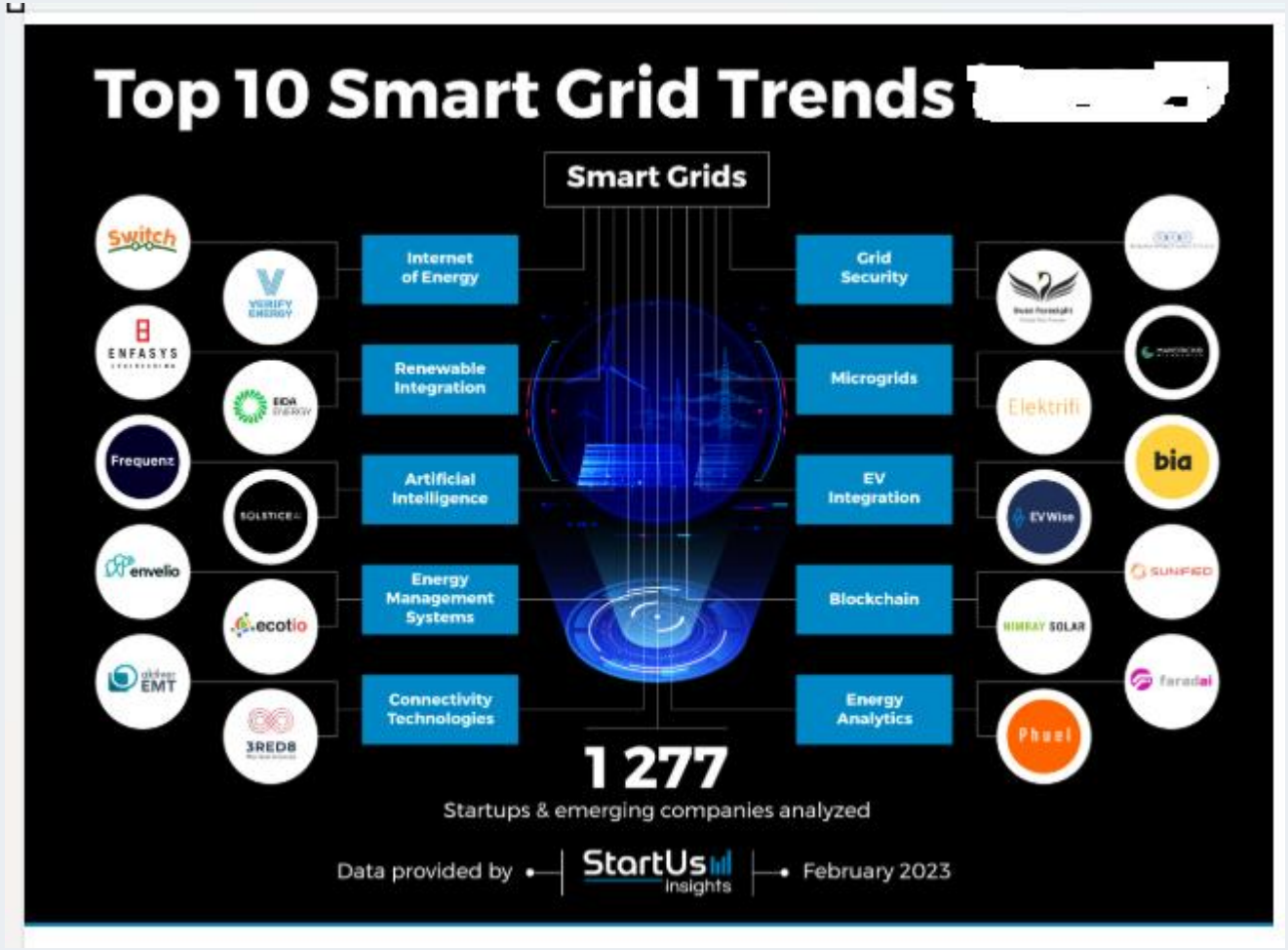
Australia

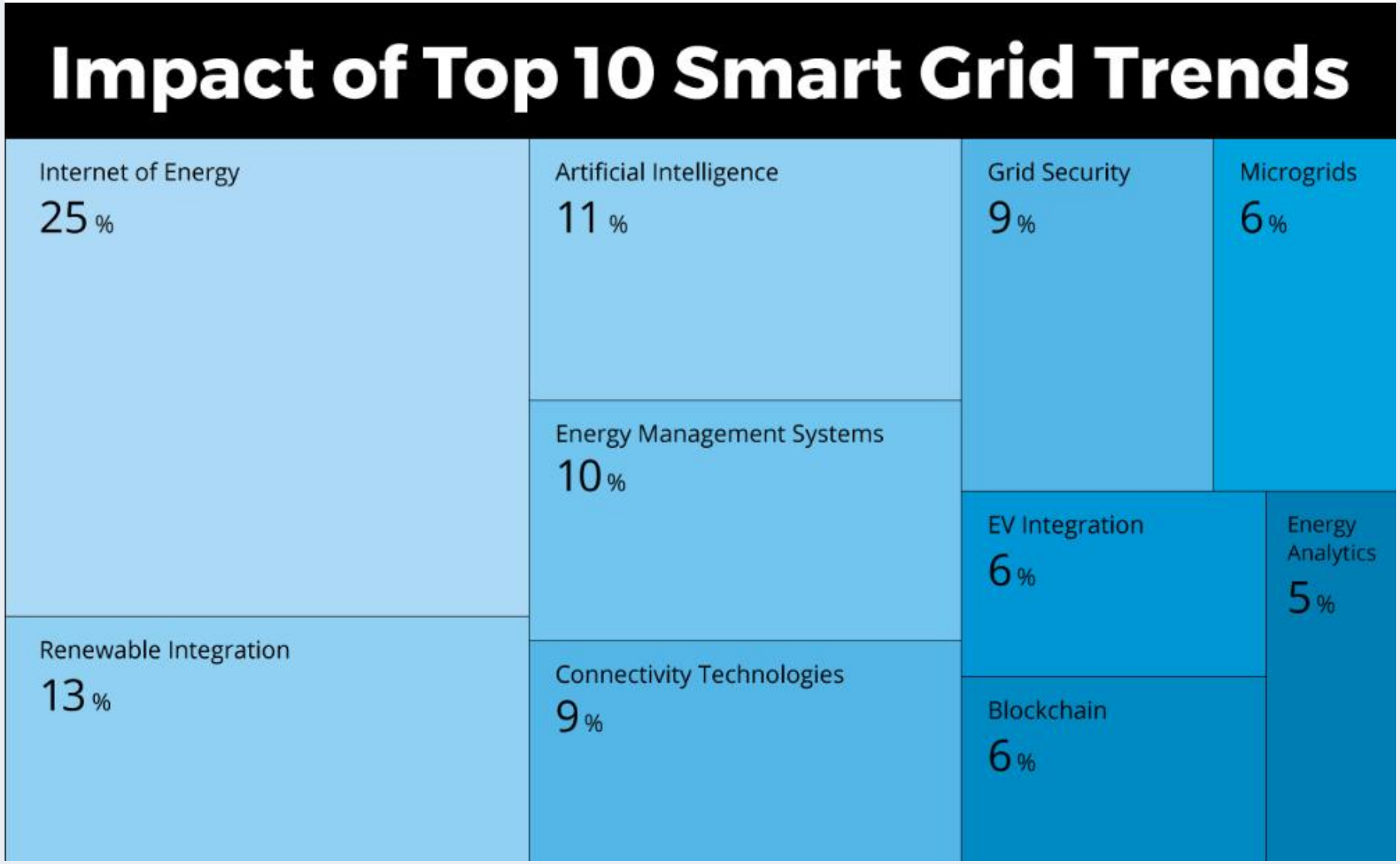
- Virtual Power Plants
- Rooftop solar adoption

Future Trends

Emerging Technologies

- AI-driven autonomous grids
- Digital Twins
- Blockchain
- Peer-to-peer energy trading
- Green hydrogen
- Microgrids
- Virtual Power Plants (VPPs)
- Grid-forming inverters




Impact of Top 10 Smart Grid Trends
Internet of Energy
25 %
Artificial Intelligence
11 %
Grid Security
9 %
Microgrids
6 %
Energy Management Systems
10 %
EV Integration
6 %
Energy Analytics
5 %
Renewable Integration
13 %
Connectivity Technologies
9 %
Blockchain
6 %

Key Takeaways

✓ Renewable energy requires grid modernization

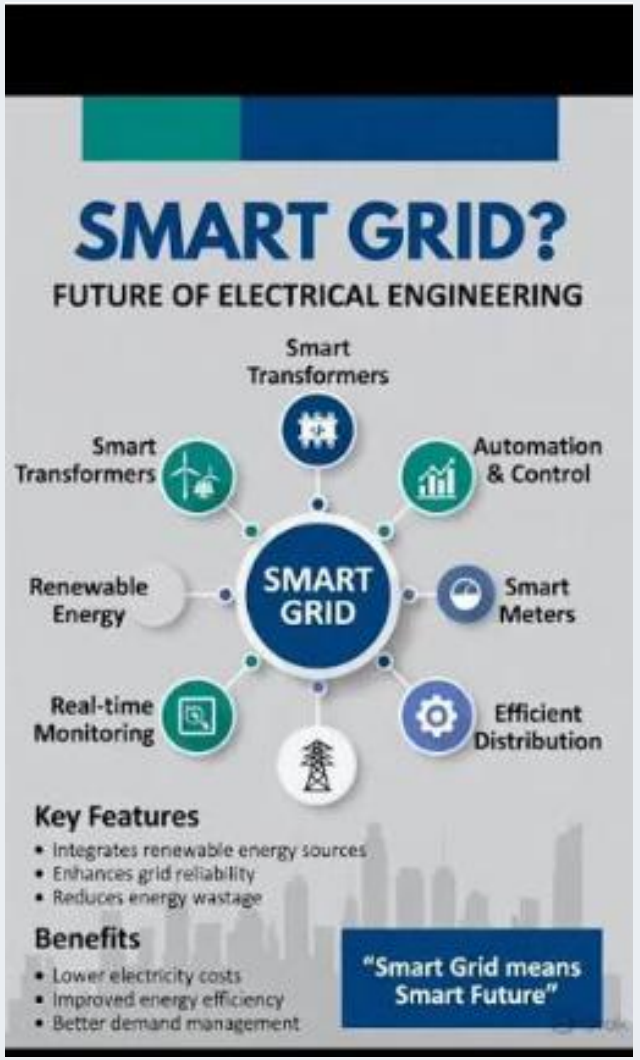
✓ Smart grids improve efficiency and reliability

✓ AI and digitalization are transforming power systems

✓ Energy storage enhances grid flexibility

✓ Cybersecurity is becoming increasingly important

✓ Future grids will be intelligent, decentralized and sustainable



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Thank You!

Upcoming Courses

Please note: courses listed below are subject to their own regulatory requirements—refer to the relevant website for further information.

Engineering Institute of Technology (EIT) *Australian Accredited Qualifications & Short Courses*	Start Date
52888WA Advanced Diploma of Applied Electrical Engineering (Power Industry)	1 September 2026
52892WA Advanced Diploma of Electrical and Instrumentation (E&I) Engineering in Mining	1 September 2026
52910WA Graduate Certificate in Hydrogen Engineering and Management	6 October 2026
Professional Certificate of Competency in Power Distribution	3 November 2026
Graduate Certificate in Power System Analysis and Design	4 January 2027
Master of Engineering (Electrical Systems)	4 January 2027
Master of Engineering – Applied Research (Electrical Systems)	4 January 2027
Associate Degree in Electrical Engineering	8 February 2027
Bachelor of Science (Electrical Engineering)	17 July 2027

Upcoming Courses

Please note: courses listed below are offered by separate institutions in the UK and South Africa, each subject to their own regulatory requirements - refer to the relevant website for location-specific details.

Engineering College of Technology (ECT) *UK qualifications*	Start Date
Bachelor of Engineering (Honours) in Industrial Automation	21 September 2026
Bachelor of Engineering (Honours) in Electrical Engineering	21 September 2026
Master of Science (Power System Analysis and Renewable Integration)	5 October 2026
Master of Science (Industrial Automation and Instrumentation Control)	5 October 2026

Engineering College of Science and Technology (ECST) *South African accredited qualification & ECSA-endorsed*	Start Date
Bachelor of Engineering Technology in Electrical Engineering	3 August 2026

Q&A

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Programmes
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Website
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Outside South Africa: +27 11 823 4497

Programmes
www.ecst.ac.za/course-types/bachelor-of-engineering/