Grid Benefits from Energy Storage

A Taxonomy for Smart Grid Benefits from Energy Storage

Vivian Sultan, Ph.D.
Professor of Information Systems and Business Management
California State University, Los Angeles
College of Business and Economics
5151 State University Dr., ST F603
Los Angeles, CA 90032-8126
Email: vsultan3@calstatela.edu

CAL STATE LA
CALIFORNIA STATE UNIVERSITY, LOS ANGELES

About Vivian Sultan, PhD

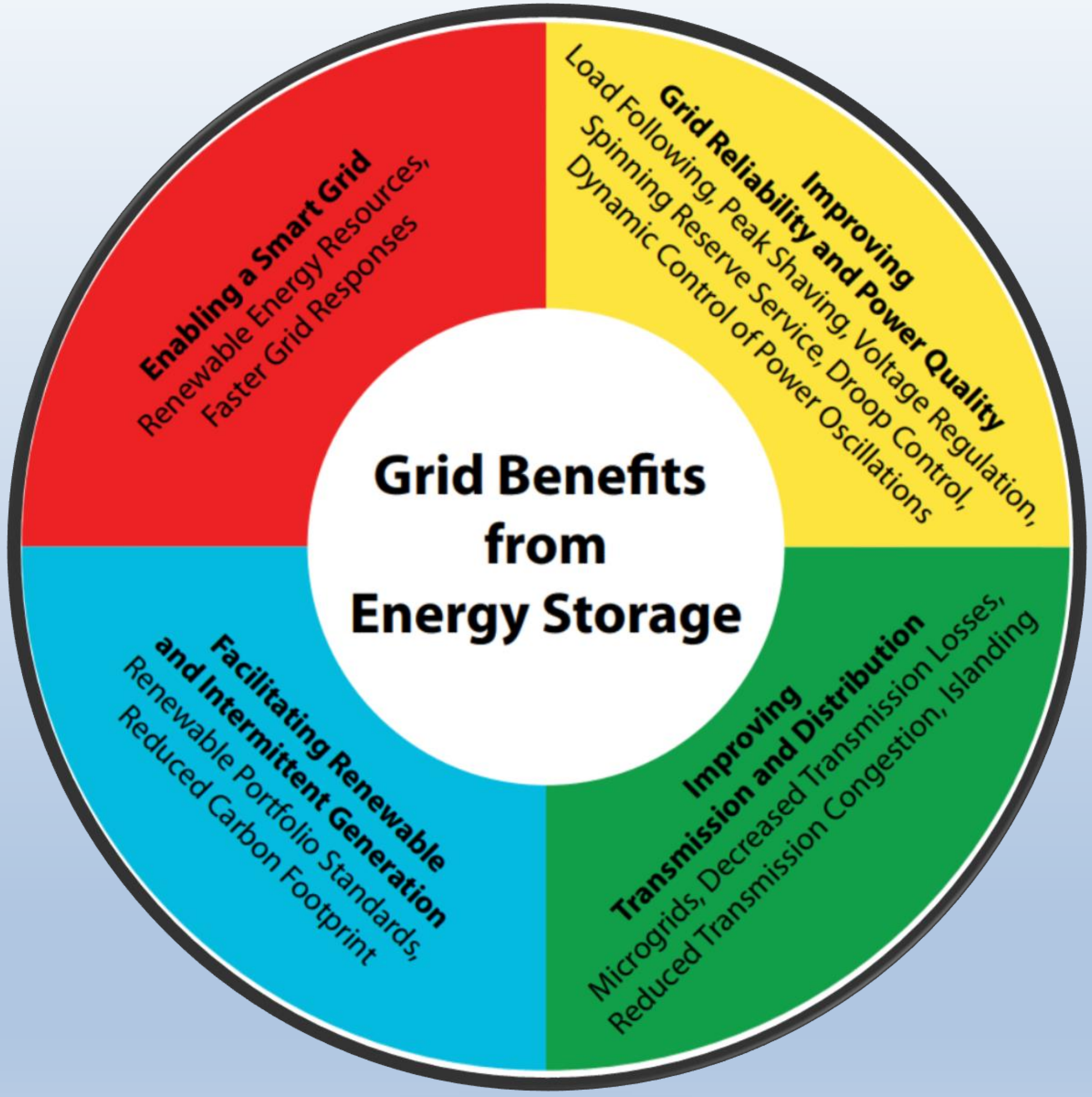
Professor of Information Systems and Business Management at California State University (CSULA). Dr. Sultan holds a PhD in Information Systems and Technology from Claremont Graduate University. She is a certified professional in supply management with experience in account product management, operations, and automated system projects development.

Prior to her current role at CSULA, Dr. Sultan served as a Senior Analyst at Southern California Edison, an Account Product Manager at the Walt Disney Studios. Her publications and research focus on energy informatics and the digital transformation within supply chains.

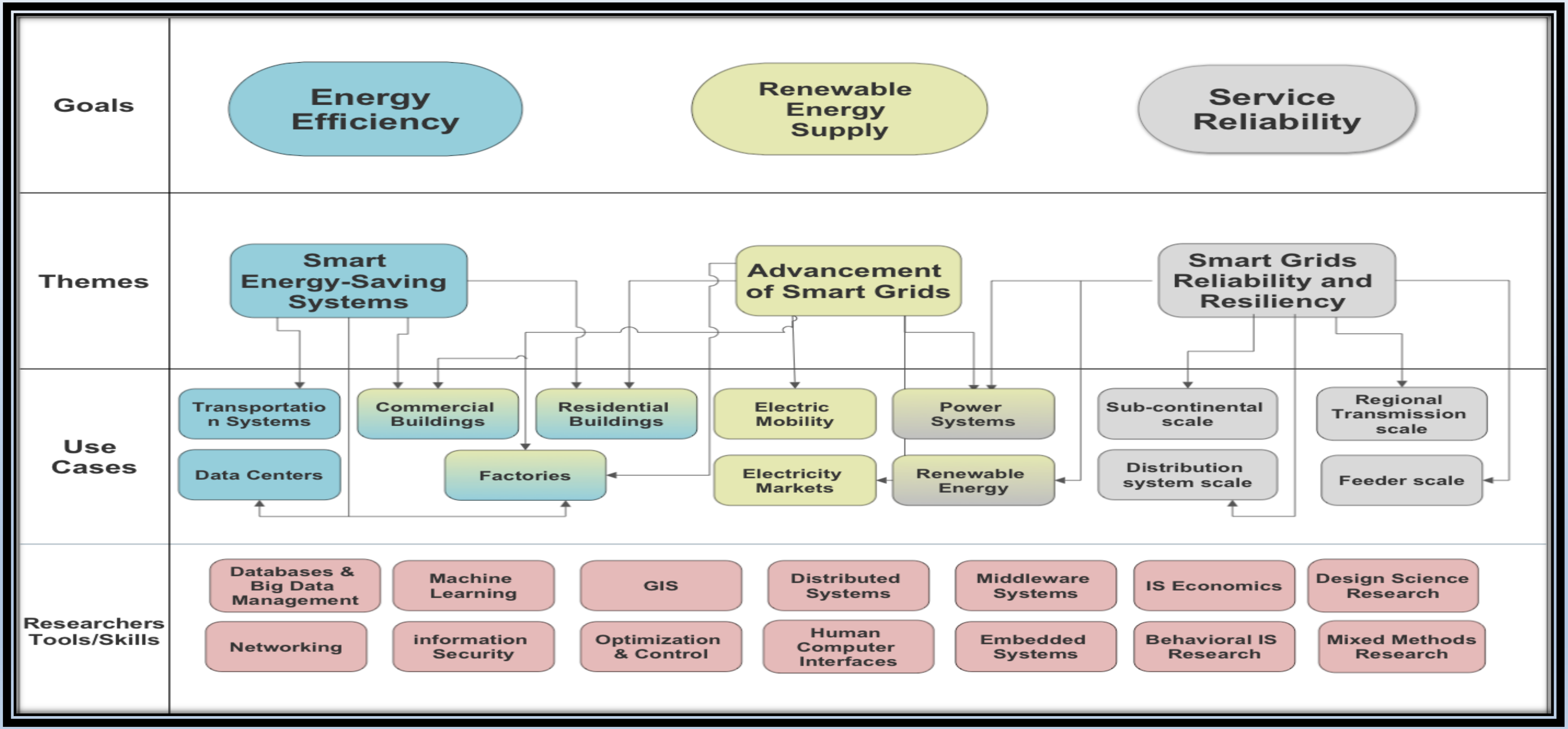
Currently, Sultan is working on renewable energy supply and smart grid development. She will be giving a presentation titled: A Taxonomy for Smart Grid Benefits from Energy Storage. The intent of this work is to aid in battery storage location choices and provide actionable information for utilities and other stakeholders who are concerned about the grid reliability.

Agenda

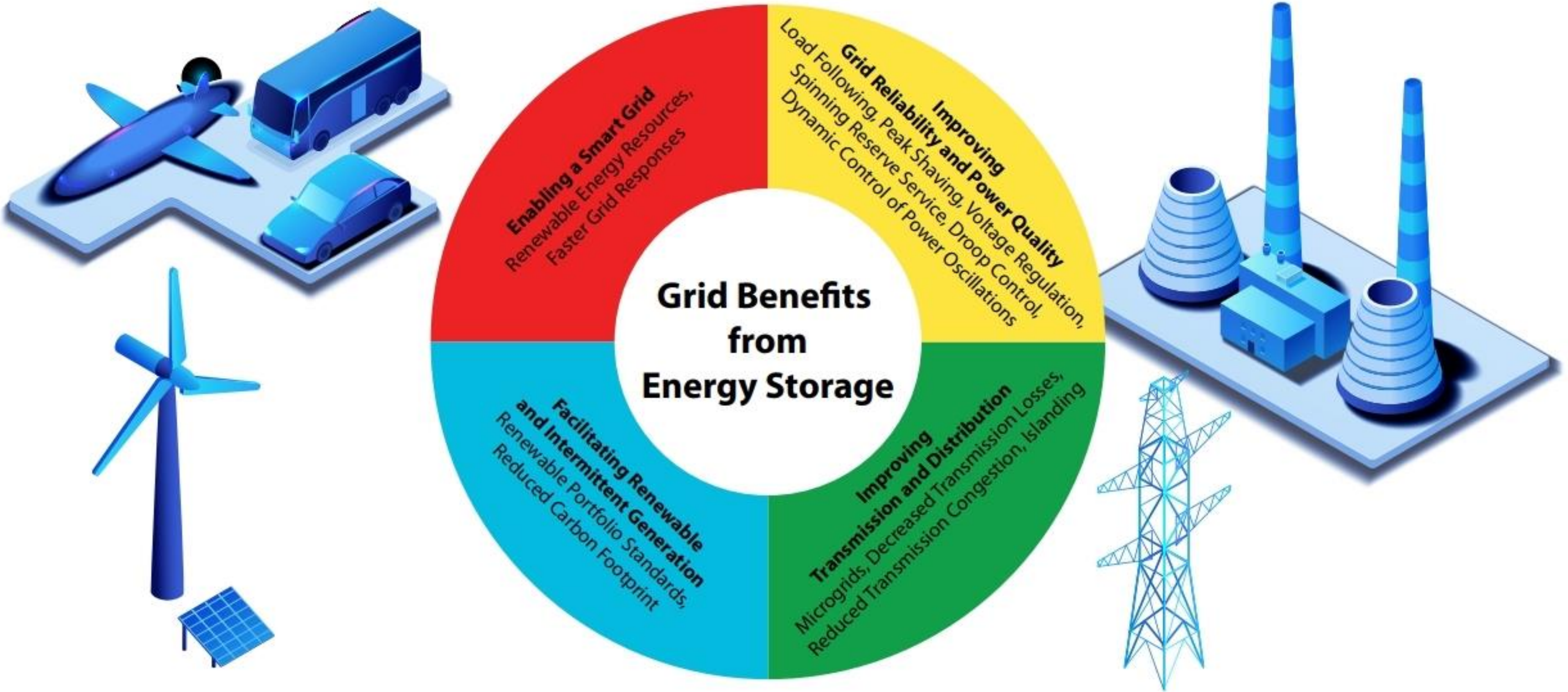
1. Energy Informatics introduction
2. Grid Reliability and Power Quality
   - Load Following
   - Peak Shaving
   - Voltage Regulation & Droop Control
   - Spinning Reserve
3. Improving Transmission and Distribution
   - Islanding
   - Reduction Of Transmission Losses
   - Soothing Transmission Congestion
4. Facilitating Renewable and Intermittent Generation
   - Meeting renewable portfolio standards
   - Lowering carbon footprint
5. Enabling the Smart Grid
   - Integration Of intermittent DERs
   - Technology for faster grid responses
6. Conclusion



Energy Informatics Research Framework (Sultan et al. 2018)



Four Classes Of Grid Benefits From Battery Storage (Sultan 2021)

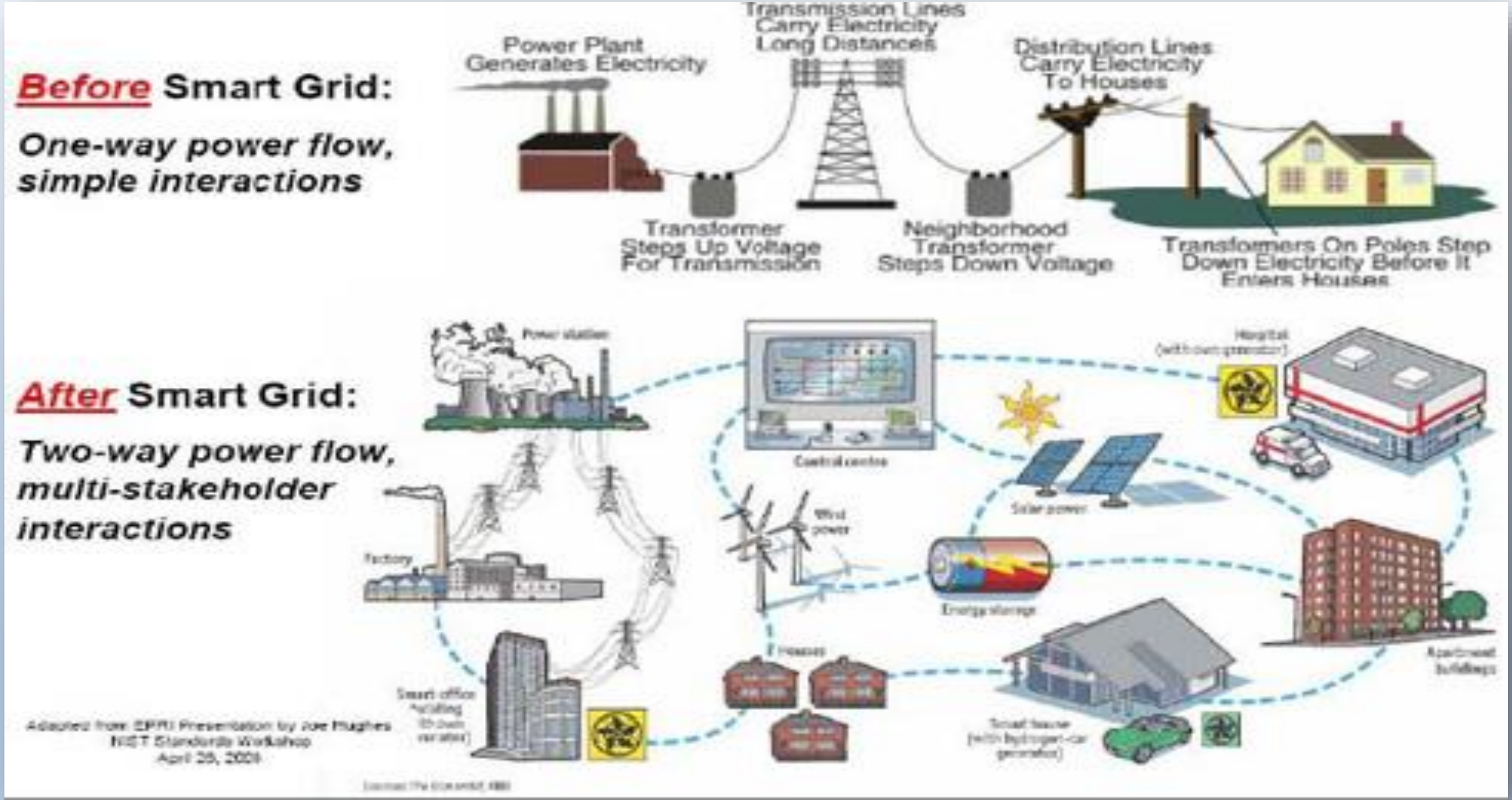


Smart Grid Reliability

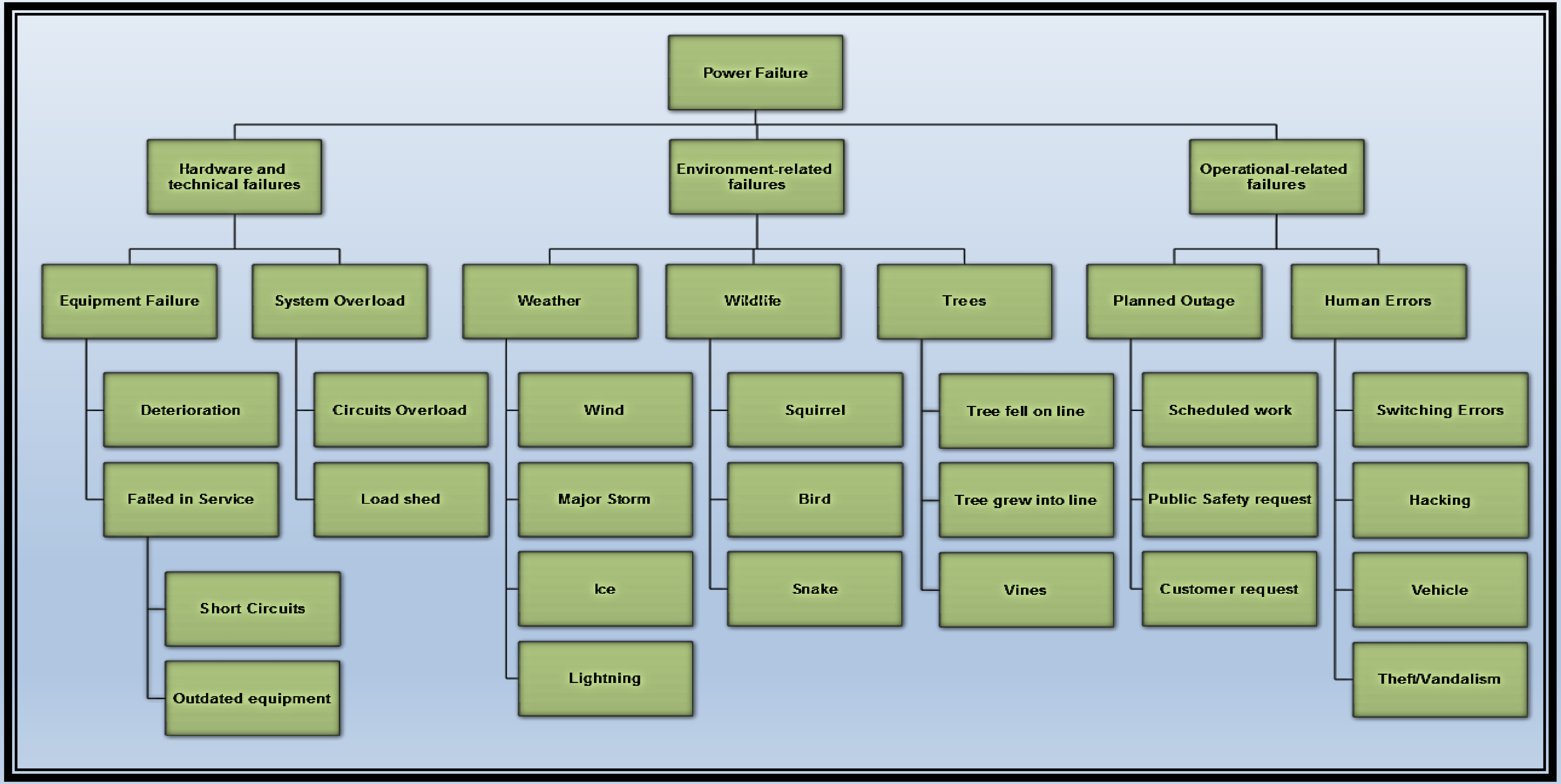
Smart Grid: a new class of technology to bring the electricity delivery system into the 21st century - Network technologies are the backbone of this system

- ✓ Must be adaptable, strong and responsive
- ✓ \$338–\$476 billion in the next twenty years to incorporate in DERs, intelligence technologies, advanced systems, and applications
- ✓ Tools for optimizing grid operations and to forecast future problems are crucial within the modern grid design

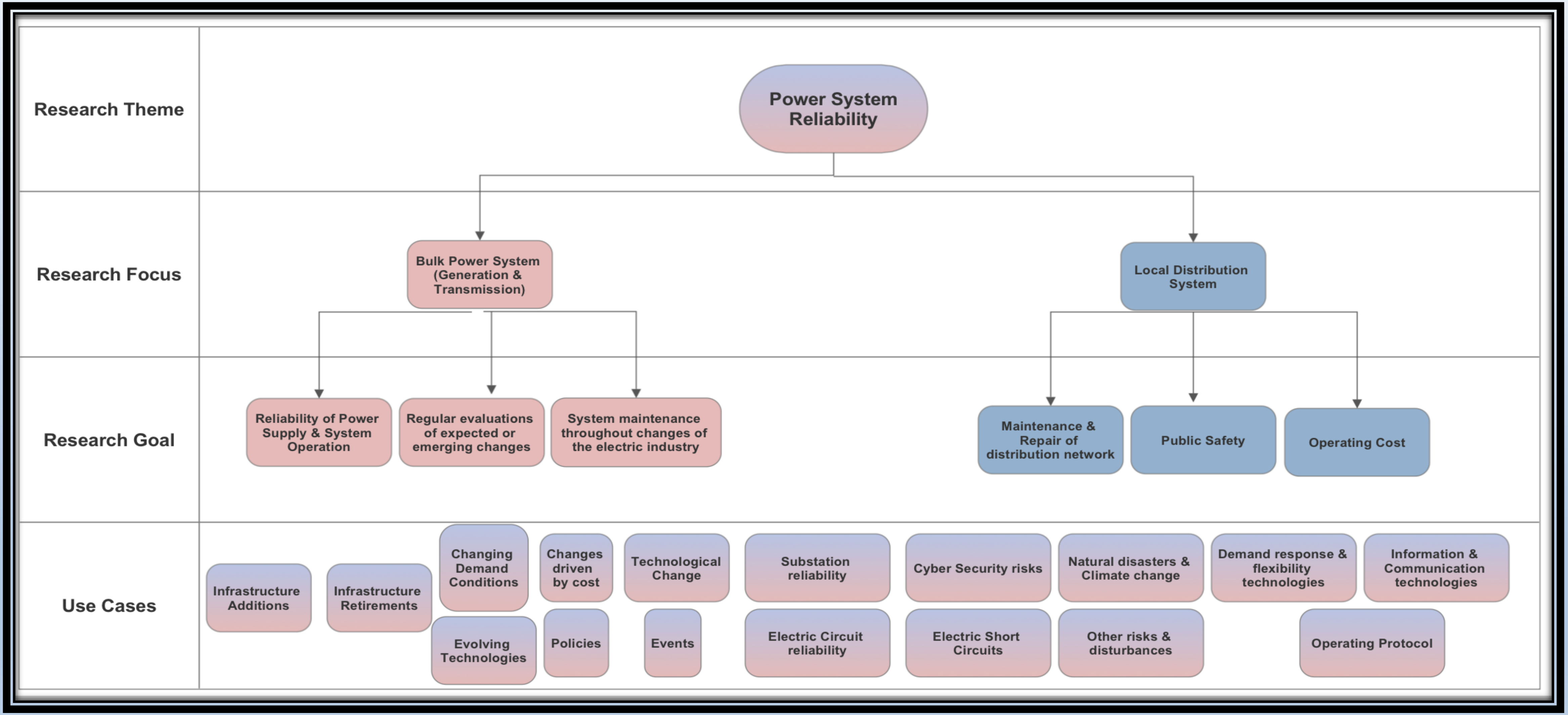
Reliability: the degree to which the performances of the elements of the electric system result in power being delivered to consumers within accepted standards and in the amount desired - Measured by outage indices


Before Smart Grid:
One-way power flow, simple interactions
Power Plant Generates Electricity
Transmission Lines Carry Electricity Long Distances
Distribution Lines Carry Electricity To Houses
Transformer Steps Up Voltage For Transmission
Neighborhood Transformer Steps Down Voltage
Transformers On Poles Step Down Electricity Before It Enters Houses
After Smart Grid:
Two-way power flow, multi-stakeholder interactions
Power station
Control centre
Factory
Wind power
Solar power
Energy storage
Houses
Apartment buildings

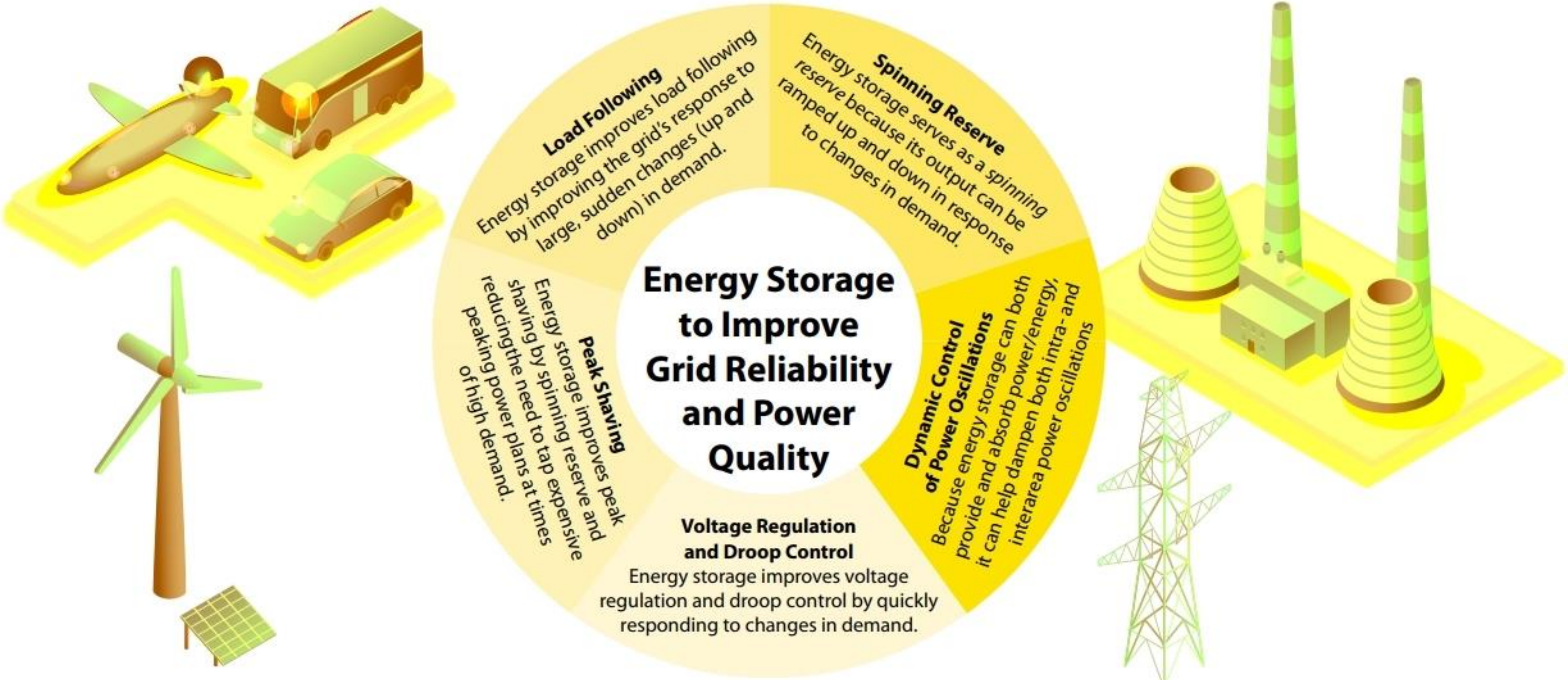
Smart Grid Reliability (Sultan et al. 2018)



Power System Reliability Research Framework (Sultan et al. 2019)



Energy Storage For Grid Reliability and Power Quality (Sultan 2021)

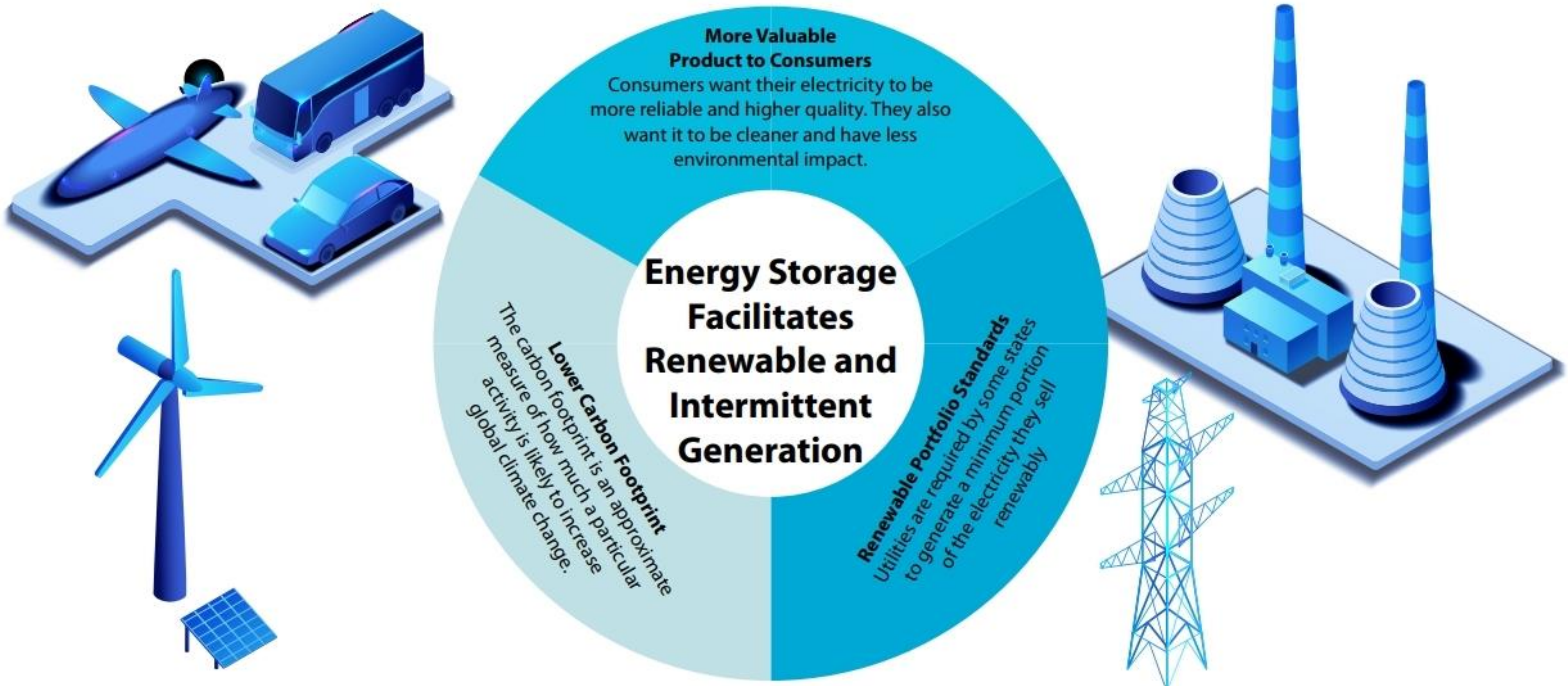


Battery Storage Integration Into The Electric Grid

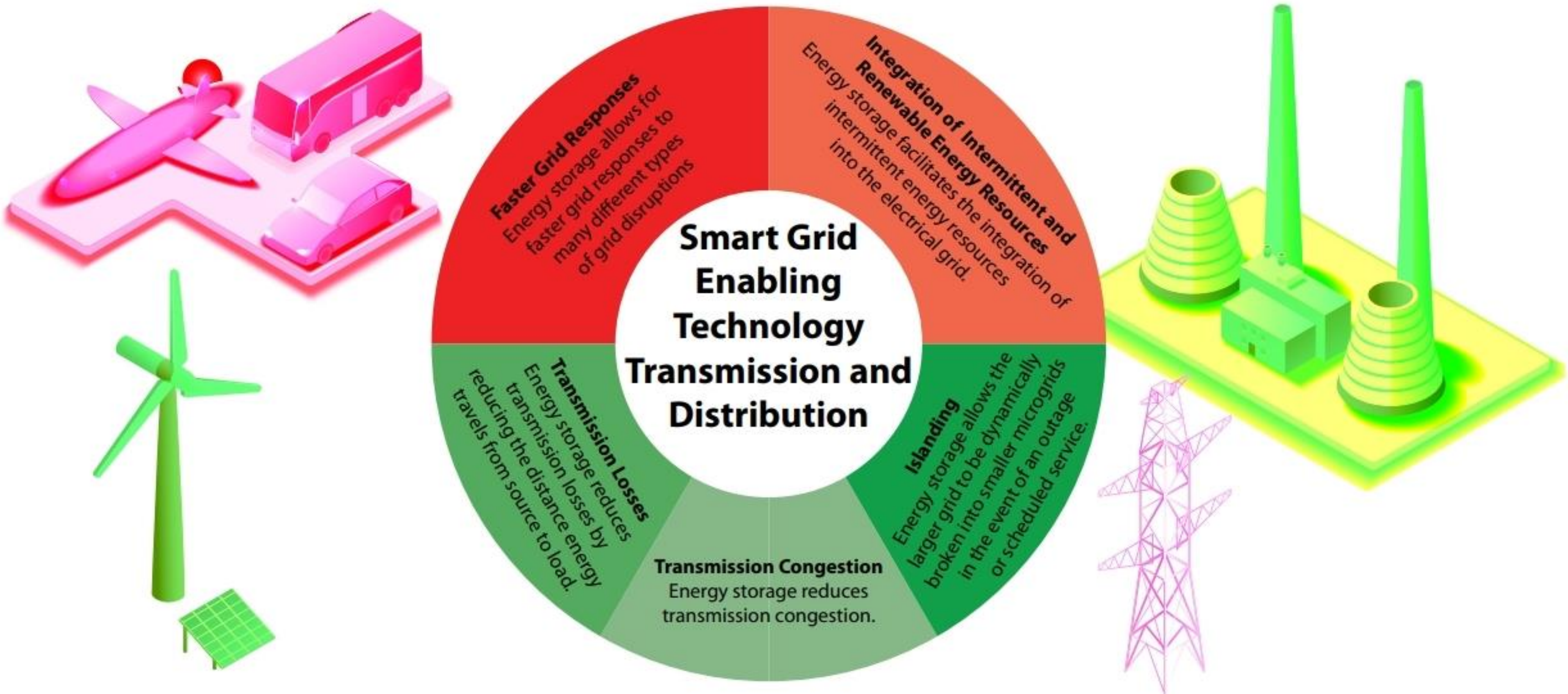
- Energy storage technology to contribute to the overall system reliability
  - Regulating generation fluctuation
  - Improving the grid's functionality
  - Providing redundancy options in areas with limited transmission capacity, transmission disruptions, or volatile demand and supply profiles
- Storage to promote energy independence and reduce carbon emissions
- Identifying optimal locations for energy storage is a challenge considering the electric grid constraints, the deployment requirements and the potential benefits to the grid

Energy Storage Resources	Use	Discharge Time	Energy-to-Power ratio (kWh/kW)	Examples
Short discharge time	Provide instantaneous frequency regulation services to the grid	Seconds or minutes	Less than 1	Double layer capacitors (DLCs), superconducting magnetic energy storage (SMES), and flywheels (FES).
Medium discharge time	Useful for power quality and reliability, power balancing and load following, reserves, consumer- side time-shifting, and generation-side output smoothing. May be designed so as to optimize for power density or energy density.	Minutes to hours	Between 1 and 10	Lead acid (LA), lithium ion (Li-ion), and sodium sulphur (NaS), flywheels may also be used.
Medium-to-long discharge time	Useful primarily for load-following and time-shifting, and can assist RE integration by hedging against weather uncertainties and solving daily mismatch of RE generation and peak loads.	Hours to days	Between 5 and 30	Pumped hydro storage (PHS), compressed air energy storage (CAES), and redox flow batteries (RFBs)which are particularly flexible in their design
Long discharge time	Useful for seasonal time shifting (storing excess generation in the summer and converting it back to electricity in the winter).	Days to months	Over 10	Hydrogen and synthetic natural gas (SNG)

Energy Storage For Efficient Adoption of Renewable and Intermittent Generation (Sultan 2021)



Energy Storage Enabling The Smart Grid Improving Transmission and Distribution (Sultan 2021)



Battery Storage Integration Into The Electric Grid

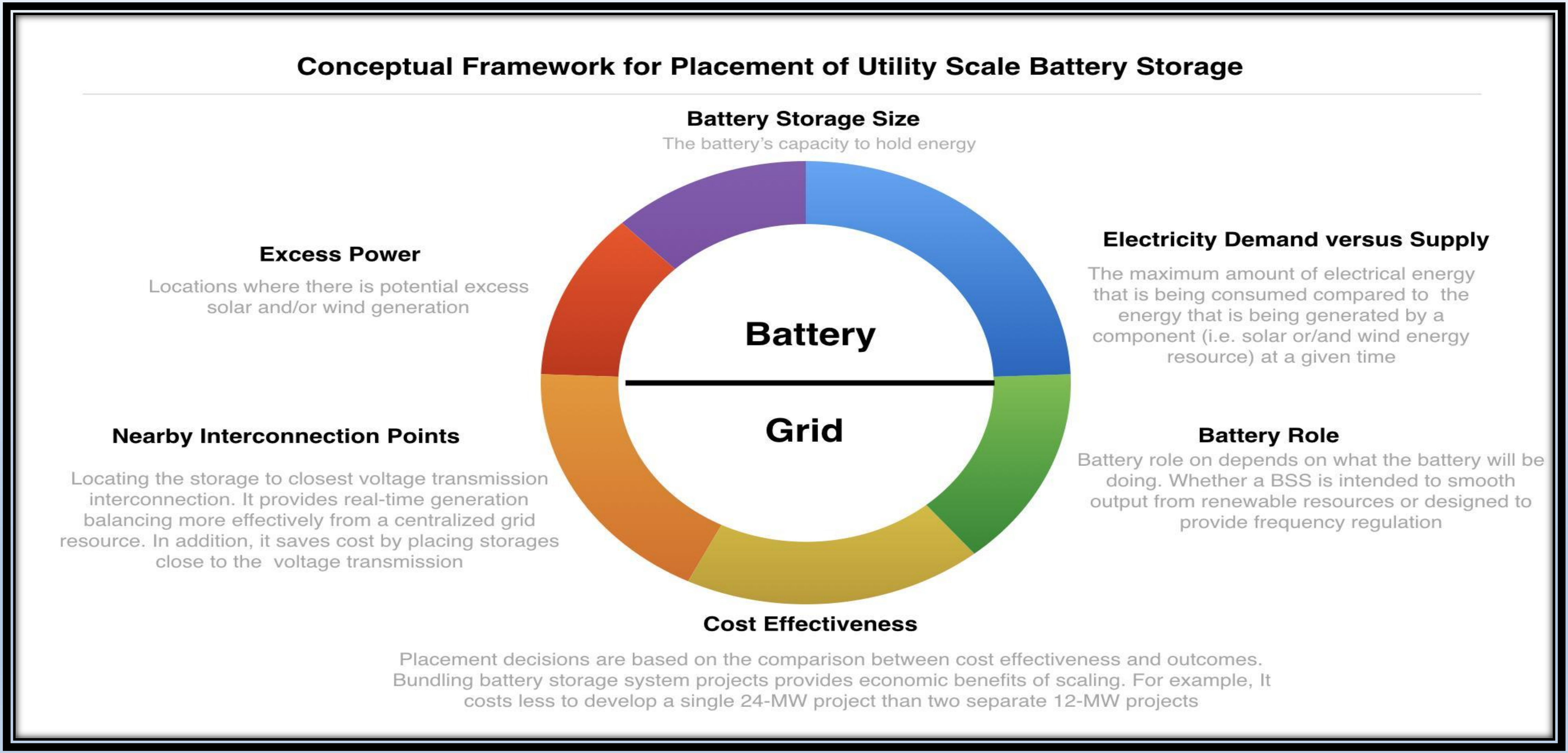
Factor	Definition	Tech. Specification	Resource
Battery Storage size	The battery's capacity to hold energy	Large centralized battery systems work better than smaller, distributed systems.	Chandy (2012) Overton (2016)
Excess Power	Locations where there is potential excess solar and/or wind generation	Statistically significant areas using kernel density estimation (KDE) where there is high potential solar and/or wind generation	Nelder et al. (2016)
Electricity demand versus supply	The maximum amount of electrical energy that is being consumed compared to the energy that is being generated by a component (i.e. solar or/and wind energy resource) at a given time	The situation when energy supply is exceeding the demand	Sultan (2016) Sjodin et al, 2012

Battery Storage Integration Into The Electric Grid

Factor	Definition	Tech. Specification	Resource
Nearby interconnection points	Locating the storage to closest voltage transmission interconnection. It provides real-time generation balancing more effectively from a centralized grid resource. In addition, it saves cost by placing storages close to the voltage transmission	Nearby 154-kV or 345-kV substations	Overton et al, 2016
Battery role	Battery role on depends on what the battery will be doing. Whether a BSS is intended to smooth output from renewable resources or designed to provide frequency regulation.	Based on Table 1 "Energy Storage Technologies"	Overton et al, 2016 IEC Market Strategy Board, 2012
Cost Effectiveness	Placement decisions are based on the comparison between cost effectiveness and outcomes. Bundling battery storage system projects provides economic benefits of scaling. For example, It costs less to develop a single 24-MW project than two separate 12-MW projects.	Single centralized battery storage systems is prefered	Overton et al, 2016

ID	Substation Name	Substation Type
1	WALNUT	S -- Sub-transmission
2	ROSEMEAD	D -- Distribution
3	GOULD	S -- Sub-transmission
4	MESA	S -- Sub-transmission
5	LAGUNA	S -- Sub-transmission
6	BULLIS	D -- Distribution
7	CENTER	S -- Sub-transmission
8	CORNUTA	D -- Distribution
9	LIGHTHIPE	S -- Sub-transmission
10	HASKELL	D -- Distribution
11	STADIUM	D -- Distribution

Battery Storage Integration Into The Electric Grid (Sultan et al. 2018)



System Model To Optimize DERs' Placement (Sultan et al. 2016)

Probability of event, P (event) =

$$\frac{1}{1+e^{(a+b1*x1+b2*x2+\cdots+b10*x10)}} =$$

$$\frac{1}{1+2.718^{(1.832+-2.516*x1+.193*x2+-.543*x3+0.543*x4+-1.592*x5+.297*x6+-1.039*x7+.261*x8+.006*x9+-0.579*x10)}}$$

$$E=A*r*H*PR$$

E = DER's total energy output

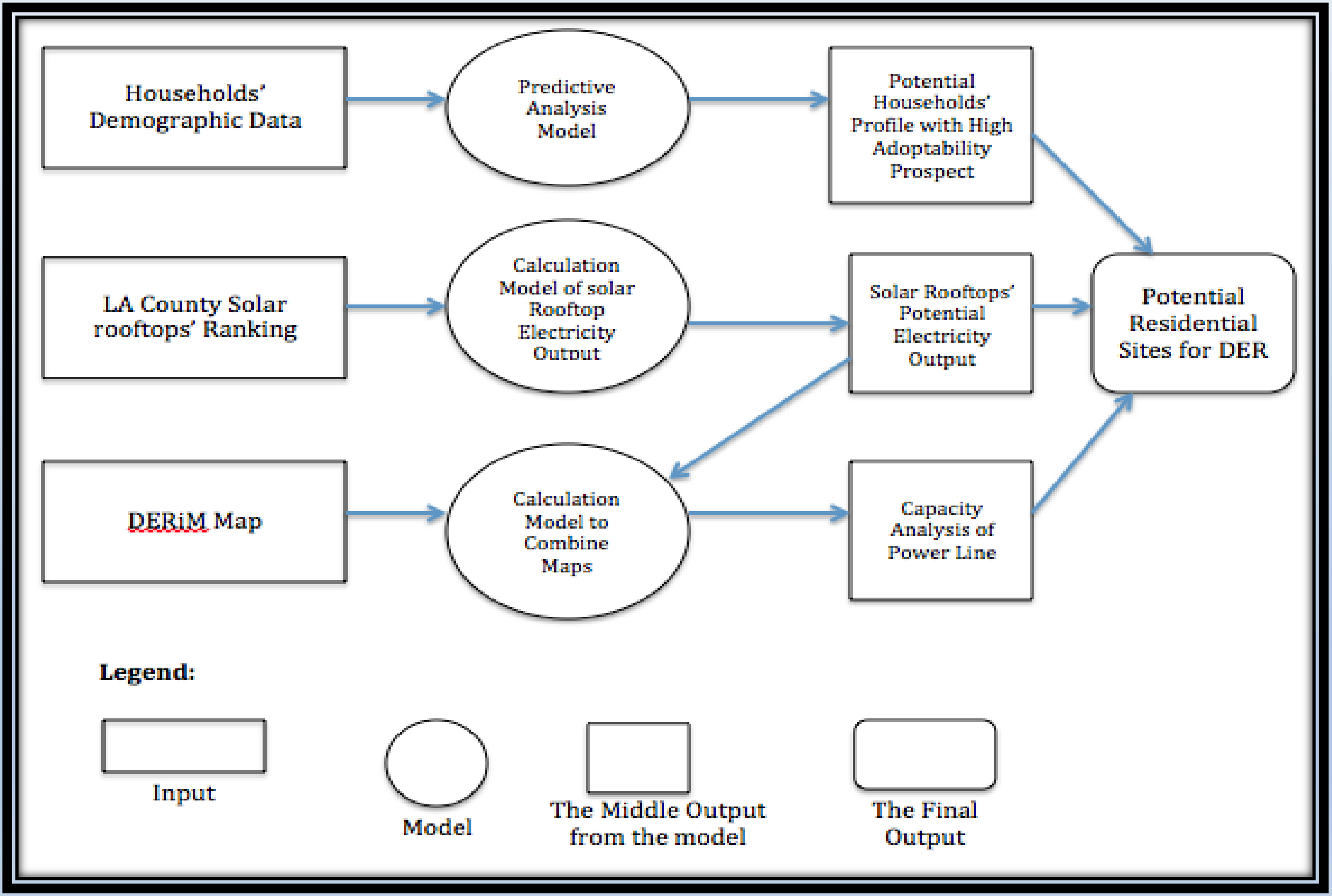
A = Total solar panel Area

r = solar panel yield

H = Annual average solar radiation on tilted panels

PR = Performance ratio

Maximum Remaining Generation Capacity = Current Capacity Load - (Solar Potential + Existing Generation)



Conclusion & Lessons Learned

Grid reliability is the greatest concern resulting from the current challenges facing electric utilities. The argument is that battery storage will play a significant role in meeting the challenges facing electric utilities by improving the operating capabilities of the grid, lowering cost and ensuring high reliability, as well as deferring and reducing infrastructure investments.

According to the United States Department of Energy, energy storage technology can help contribute to the overall system reliability as wind, solar, and other renewable energy sources continue to be added to the grid. Storage technology will be an effective tool in managing grid reliability and resiliency by regulating generation fluctuation and improving the grid’s functionality. It will provide redundancy options in areas with limited transmission capacity, transmission disruptions, or volatile demand and supply profiles. Utility-scale storage can be instrumental for emergency preparedness because of its ability to provide backup power, as well as grid stabilization services..

Together…. Shaping the Future of Electricity

Publications

- “A Predictive Model to Forecast Power Outages,” Proceedings of the 10th International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies.
- “An Inclusion of Electric Grid Reliability Research through the Enhanced Energy Informatics Research Framework,” Proceedings of the 8th International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies.
- “A Spatial Analytics Framework to Investigate Electric Power-Failure Events and Their Causes.” ISPRS International Journal of Geo-Information, 9(1), 54.
- “How May Location Analytics Be Used to Enhance the Reliability of the Smart Grid?” Inventions, 4(3), 39.
- “Electric Grid Reliability Research” Energy informatics Journal. Computer Science, 2(3).
- “Solving Electric Grid Network Congestion Problem with Batteries – An Exploratory Study using GIS Techniques,” International Journal of Smart Grid and Clean Energy, 7(2).
- “A Conceptual Framework To Integrate Electric Vehicles Charging Infrastructure Into The Electric Grid,” International Journal of Smart Grid and Clean Energy, 6(3).
- “Analysis Framework to Investigate Power-Failure Events and Their Causes?” Proceedings of the International Conference on Data Science, Las Vegas, USA.
- “Which Grid Infrastructure Needs Utilities’ Immediate Attention to Reduce the Risk of Power Outages?” Proceedings of the International Conference on Data Science, Las Vegas, USA.
- “How May Location Analytics Be Used to Enhance the Reliability of the Smart Grid?” Proceedings of the International Conference on Scientific Computing, Las Vegas, USA.
- “Where Should a Utility Improve Tree Cutting to Reduce the Risk of Vegetation Coming into Contact with Power Lines?” Proceedings of the 9th International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies.
- “Is Power Outage Associated With Population Density?” Proceedings of the 9th International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies, Athens.

Publications – Cont'd

- "Geographic decision support systems to optimize the placement of distributed energy resources," International Journal of Smart Grid and Clean Energy, 5(3).
- "Is California's aging infrastructure the principal contributor to the recent trend of power outage?" Journal of Communication and Computer, USA, 13 (5).
- "Exploring Geographic Information Systems To Mitigate America's Electric Grid Traffic Congestion Problem," Proceedings of the 4th International Symposium on Computational and Business Intelligence.
- "A Predictive Model to Forecast Customer Adoption of Rooftop Solar," Proceedings of the 4th International Symposium on Computational and Business Intelligence.
- "Geographic Decision Support Systems To Optimize The Placement Of Distributed Energy Resources," Proceedings of the 22nd Americas Conference on Information Systems.
- "Is California's aging infrastructure the principal contributor to the recent trend of power outage?" Proceedings of the 22nd Annual California GIS Conference.
- "A Conceptual Framework To Integrate Electric Vehicles Charging Infrastructure Into The Electric Grid," International Journal of Smart Grid and Clean Energy, 6(3).
- "Electric Vehicles charging infrastructure integration into the electric grid considering the net benefits to consumers," Proceedings of the 7th International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies.
- "Solving Electric Grid Network Congestion Problem with Batteries – An Exploratory Study using GIS Techniques," International Journal of Smart Grid and Clean Energy, 7(2).
- "Electric Substation Emergency Disaster Response Planning through the use of Geographic Information Systems," Proceedings of the 8th International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies.
- "Battery Storage Integration into the Electric Grid," Proceedings of the 8th International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies.