Smart Grid Investment Readiness Scorecard for Ontario Zones

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# Abstract

In the context of Ontario’s evolving energy landscape, identifying priority zones for Smart Grid investment is essential for efficient, equitable, and future-proof infrastructure develop ment. This project presents a data-driven scorecard that evaluates the readiness of various Ontario electricity zones for Smart Grid investment, using a weighted scoring methodol ogy grounded in multi-criteria analytics. Drawing on publicly available datasets from the Independent Electricity System Operator (IESO), the scorecard synthesizes indicators in cluding hourly demand variability, pricing volatility, grid stress deviations, and transmission outage frequency. By delivering a composite index for each zone, this research enables evidence-based prioritization to inform policymakers, utilities, and private investors. The project emphasizes accessibility and replicability by utilizing Python, Jupyter Notebooks, and transparent computation frameworks suitable for analysts without machine learning expertise.

# Introduction

Ontario’s grid modernization journey is increasingly driven by the dual imperatives of re silient infrastructure and sustainable investment. With Smart Grids being foundational to energy transitions globally, region-specific assessments of grid readiness become essential. This project addresses this gap by introducing a Smart Grid Investment Readiness Score card (SGIRS) for Ontario electricity zones, integrating data from demand patterns, grid events, and outage reports. The aim is to deliver actionable insights.

# Problem Statement and Context

The growing complexity of Ontario’s energy grid—driven by climate mandates, electrifica tion, and increased reliance on renewables—demands strategic and data-informed invest ments. The challenge lies in identifying which zones are most in need and most ready for Smart Grid technologies. This project develops a readiness scorecard to assess and rank Ontario zones based on volatility, operational resilience, and outage history. The broader objective is to support equitable, cost-effective modernization strategies.

# Research Questions and Justification

1. Which Ontario electricity zones exhibit the highest volatility and infrastructure stress based on empirical indicators?

2. How do transmission outages and dispatch deviations correlate with peak demand and zonal price behavior?

3. Can a composite readiness index support evidence-based Smart Grid investment strate gies across zones?

These research questions are closely aligned with the central goal of identifying priority in vestment zones. They reflect an integrated systems-level approach, using operational data to assess both reliability risks and readiness potential. The questions are intentionally designed to be data-driven, regionally scalable, and supportive of ongoing energy transition policy efforts.

# Dataset Selection and Rationale

This project uses publicly available datasets from the Independent Electricity System Operator (IESO) of Ontario. These include:

* Hourly Zonal Demand Report (DemandZonal/)
* Real-Time Zonal Demand Report (RealtimeDemandZonal/)
* Dispatch Deviation Report (DispDeviation/)
* Transmission Outages Report (TxOutages\*/)

These datasets are selected for their time granularity (hourly), zone-specific detail, and direct linkage to operational resilience metrics. They allow for comparative and trend-based analysis and are suitable for time-series and scoring model applications.

# Proposed Methodology and Tools

A Weighted Scoring Model (WSM) is used to compute a Smart Grid Readiness Index (SGRI) per zone. Four indicators are used: • Demand Volatility Index (DVI): Coefficient of variation in hourly demand • Price Volatility Index (PVI): Normalized standard deviation in zonal energy prices • DispatchDeviation Score (DDS): Frequency of deviations between scheduled and actual dispatch • Outage Frequency Index (OFI): Outage frequency and duration from transmission outage logs Each index is normalized and combined with weighted coefficients, optionally derived via expert consultation or Analytic Hierarchy Process (AHP). The methodology includes scoring logic development, visualization of metric distributions, and sensitivity testing on weight assignments.

# Tools and Techniques for Data Analysis

This project will employ a range of data wrangling, exploratory analysis, and scoring tech niques using Python. The following tools and methods will be utilized to analyze the IESO datasets:

* **Data Wrangling & Preprocessing:–** pandas for reading CSV files, filtering rows by zone/date, handling missing values, and performing aggregations (mean, std, counts)– numpy for statistical operations and array manipulation– Normalization using min-max scaling and z-score transformation
* **Data Visualization:–** matplotlib and seaborn for line plots, boxplots, and heatmaps– plotly for interactive dashboards and choropleth maps
* **Scoring and Index Development:–** Weighted Scoring Model (WSM) to derive final readiness scores– Optional AHP method to determine weights
* **Correlation & Sensitivity Analysis**:– scipy.stats for testing statistical relationships– Manual perturbation of weights to test robustness
* **Documentation & Reproducibility:–** Jupyter Notebooks for step-by-step workflow– GitHub for version control and submission Tech Stack
* **Python (Pandas, NumPy, Plotly, Seaborn)**
* **Jupyter Notebooks**
* **Power BI / Tableau (optional)**
* **GitHub**

# Benefits of Research

This project enables data-informed decisions in Smart Grid infrastructure planning, pro vides transparent and adaptable analysis methods, and supports regulatory and investment decision-making. The methodology supports automation, scaling to other regions, and im proved transparency for public and private stakeholders.

# Intended Audience

* Energy policymakers and regulators
* Utility companies and system operators
* Infrastructure investors Academic researchers and students

# Justification of References and Related Work

Key references from peer-reviewed literature were selected to support the methodology and context:

* H. Asadi Aghajari et al., Applied Energy, 2025– RES & cybersecurity
* N. Xu et al., Energies, 2025– Smart grid RL frameworks
* V. Ethirajan et al., J. of Elec. Sys. & Info Tech, 2025– Reliability metrics
* G.B. Gaggero et al., IEEE Access, 2025– Anomaly detection
* H. Dincer et al., Renewable & Sust. Energy Reviews, 2025– MCDM investment
* M.G.M. Almihat et al., Energies, 2025– Microgrid policy & urban integration Expected Outcomes
* Smart Grid Readiness Index for all Ontario zones
* Zonal dashboards for volatility, pricing, and outages
* Policy insights for targeted Smart Grid investments

# Limitations and Future Work

Limitations include lack of DER penetration data and customer-level insights. Future work may integrate GIS, machine learning models, or real-time IoT analytics to enhance zone-level forecasting and automation.