Lasso Regression Modeling for Multi-Source Renewable Energy Forecasting using Climate and Atmospheric Data

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The lasso regression model is selected for its capability to perform variable selection and model regularization , improving the interpretability of results while minimizing overfitting high dimensional meteorological datasets. By integrating multi-source renewable datasets and optimizing predictive performance, the research aims to develop a data-driven forecasting model that contributes to efficient smart energy management systems

Introduction

- Renewable energy outputs fluctuate due to variable weather conditions

- Accurate forecasting is critical for grid stability

- Multi-source datasets improve prediction accuracy

Key Objectives

- Integrate multi-source renewable generation data (solar, wind, distributed PV, etc.) with atmospheric and climatic predictors.
- Design LASSO regression to select variables, avoid overfitting, and improve interpretability.
- Tune regularization (λ) using cross-validation and assess stability of selected variables.
- Compare Lasso against baseline models (OLS, Ridge, Elastic Net, and a simple tree/ensemble).
- Deliver interpretable predictor sets and decision rules for smart energy management.

Data Sources & Preprocessing

- Renewable Data: Solar PV, wind turbines
- Atmospheric Data: Irradiance, wind speed/direction, temperature, pressure, humidity
- Preprocessing: Cleaning, Standardization, feature engineering
- Multi-source integration for richer inputs

LASSO Regression Overview

- Linear regression with L1 penalty
- Benefits: Selects relevant features, reduces complexity, minimizes overfitting

Data Normalization

LASSO requires standardized predictors:

- Z-score normalization applied:

$$X_{std} = \frac{X - \mu}{\sigma}$$

Model Specification

The LASSO optimization objective is:

$$\hat{\beta} = \arg\min_{\beta} \left(\frac{1}{2n} \|y - X\beta\|_2^2 + \lambda \|\beta\|_1 \right)$$

Hyperparameter Tuning

Use **k-fold cross-validation** (k = 5 or time-series CV) to determine the optimal value of λ.

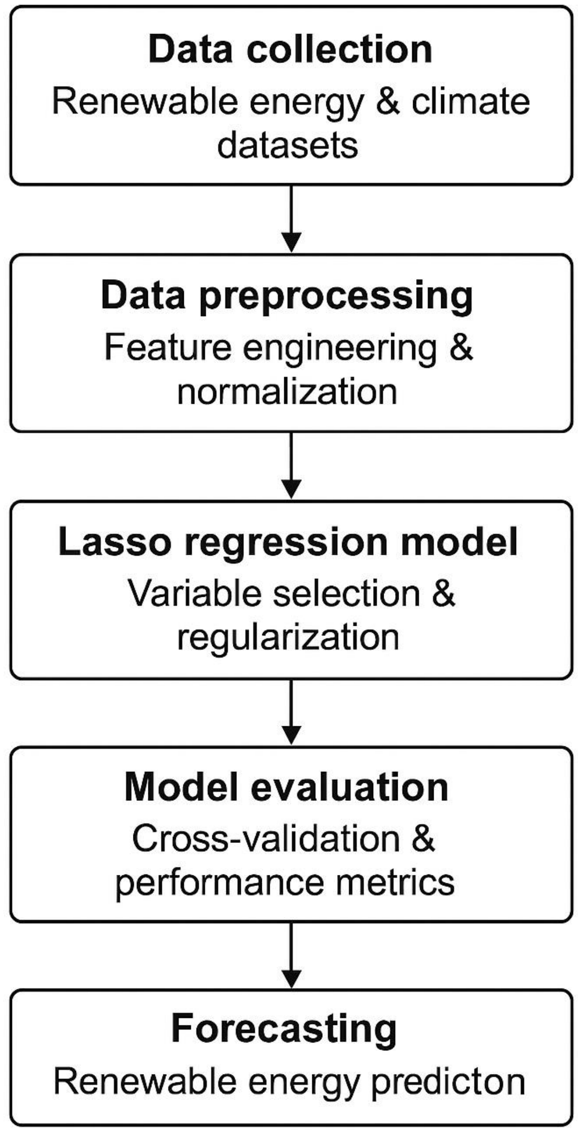
Two forms will be evaluated:

- **λ_min:** Value giving lowest CV error
- **λ_1SE:** Simpler model within one standard deviation of minimum error

Model Development

- 1. Merge and clean multi-source data
- 2. Feature engineering
- 3. Train/test split
- 4. Hyperparameter tuning
- 5. Model fitting
- 6. Validation

Project plan



Multi-Source Data Integration

- Incorporate heterogeneous inputs: meteorological forecasts, historical generation
- LASSO selects most informative predictors

Forecasting Performance

- Improves accuracy and robustness
- Sparse models focus on meaningful variables
- RMSE reduction, fewer samples, robust to anomalies

Expected Outcomes

- Identification of the most influential meteorological variables affecting renewable energy output.
- A robust and interpretable LASSO regression model capable of forecasting multi-source renewable energy with high accuracy.
- A unified data-driven framework suitable for integration into smart energy management systems.
- Enhanced decision-making for grid operators, energy storage planning, and load balancing.

Conclusion

- LASSO handles high-dimensional multi-source data
- Provides interpretable and robust forecasts
- Enables smart energy management
- Future work: ensemble models, real-time data

Ethical Considerations

- All datasets are open-source and publicly accessible.
- No personal or sensitive human data involved.
- Environmental research ethics maintained.

Thank You