

# Prophet Model Improvements:

## ① Professional Error Handling:

- ↳ Comprehensive try-catch blocks for file loading, data-validation, model training.
- ↳ Proper exception propagation with descriptive error message
- ↳ Graceful degradation instead of crashing

## 2) Data type standardization

- ↳ Automatic conversion of all columns to numeric types with error coercion
- ↳ Handling of Null and infinite values before training
- ↳ Proper datetime conversion with validation

## 3) Realistic Growth Constraints

- Renewable energy share capped at maximum level
- Non-negative enforcement for electricity generation forecasts
- Bounded growth assumptions for population, GDP, ...

## 1) Model Configuration Optimization

- Appropriate seasonality settings for annual data
- Proper interval width configuration
- Regressor standardization for better convergence

## Random Forest :

### ① Feature Engineering Enhancements

- multiple lag feature (lag1, lag2, ... ) instead of just one
- Rolling statistics with multiple window sizes
- Interaction feature (GDP per Capita \* energy intensity)
- time polynomial features

### 2) Historical Growth Rate Utilization

- Using average historical growth rates instead of last period's growth
- Avoiding the last value problem where future features become constant

### 3) Cross-validation Implementation:

- ↳ Time-series cross validation for realistic performance evaluation.
- ↳ multiple fold evaluation to prevent overfitting
- ↳ MAE (mean Absolute Error) metrics for each validation fold

### XGBoost Model Improvements:

#### 1) Growth Rate Problem Solution:

- Fixed the issue where growth rates were always zero for the last period
- Using historical average growth rates as learning

#### 2) Monte Carlo Uncertainty Framework

- 100 iteration simulation for robust uncertainty estimation
- Random variation in growth assumptions ± 5%
- Statistical aggregation across multiple simulation runs.

### 3) Comprehensive Feature Sets

- multiple lag feature (1, 2, 3, periods)
- Rolling mean and Standard deviation statistic
- Economic interaction terms (GDP per Capita, ...)
- time-based Features (index, squared)