# AG2 PJM Load Forecast

## Next-Generation AI-Driven Load Forecasting Methodology and Performance Improvements

### White Paper

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# Executive Summary

Atmospheric G2 (AG2) has significantly enhanced its PJM Load Forecast product through a comprehensive upgrade of its weather ingestion, feature engineering, and machine learning forecasting framework. The updated system improves forecast accuracy across both short-range and extended-range horizons by leveraging multi-model numerical weather prediction (NWP) ensembles, ISO-specific weather processing, and advanced AI/ML demand translation techniques.

The new AG2 PJM Load Forecast methodology was designed to better capture the nonlinear relationship between weather and electricity demand while improving forecast consistency across changing weather regimes, seasonal transitions, and high-volatility load events.

Performance testing against the legacy AG2 PJM model demonstrates substantial Mean Absolute Percentage Error (MAPE) improvements across nearly all forecast horizons and forecast hours.

Key findings include:

- 18.7% improvement over the PJM Load Model
- 37.5% improvement over the previous AG2 Load Model
- Strongest gains observed in extended-range forecasts (Day 8–Day 13)
- Consistent short-range accuracy improvements in next-day through Day 5 forecasts
- Significant enhancement during evening peak load periods and overnight ramps
- Improved handling of weather-driven demand volatility and ensemble uncertainty

These upgrades position the AG2 PJM Load Forecast product as a more robust and reliable decision-support tool for energy traders, utilities, ISOs, asset operators, and risk management teams.

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# Introduction

Electricity demand forecasting within the PJM Interconnection footprint presents a uniquely complex challenge due to:

- Large geographic diversity
- Rapid weather variability
- Seasonal demand transitions
- Population density differences
- Increasing weather sensitivity of load behavior
- Growing renewable generation penetration
- Increasing demand from Data Centers

To address these challenges, AG2 developed a next-generation forecasting framework that integrates multiple weather models, ISO-specific weather processing, advanced feature engineering, and machine learning demand translation.

The upgraded AG2 PJM Load Forecast system improves both forecast precision and stability while maintaining responsiveness to evolving weather conditions.

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# Forecast Methodology

## 1. Multi-Model Weather Ingestion

At a broad level, the AG2 forecasting process converts numerical weather prediction (NWP) model output into power demand forecasts through several key stages.

The system ingests multiple weather model runs, including:

- ECMWF Op & Ensemble
- GFS Op & Ensemble
- GRAF (Proprietary Hi-Res Model)
- Additional deterministic and probabilistic guidance

Each model provides a unique representation of future atmospheric conditions. Ensemble systems further improve forecast reliability by capturing uncertainty and spread across multiple potential weather outcomes.

By integrating multiple weather sources, AG2 reduces dependence on any single model solution and improves robustness during:

- Extreme temperature events

- Frontal passages
- Tropical influences
- Seasonal transition periods
- High-volatility load environments

This multi-model architecture provides a more stable foundation for downstream demand forecasting.

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## 2. ISO-Specific Weather Processing

Because each ISO has distinct demand drivers, AG2 processes weather data using regionally optimized methodologies specific to PJM.

The system performs several critical transformations:

### Geographic Mapping

Raw weather model data is mapped to:

- PJM load zones
- Population-weighted demand centers
- High-impact metropolitan regions
- Historically weather-sensitive areas

This ensures that weather inputs reflect actual electricity consumption exposure rather than simple geographic averages.

### Weather Variable Derivation

The forecasting framework derives a comprehensive set of meteorological variables, including:

- Temperature
- Dew point
- Relative humidity
- Wind speed
- Cloud cover
- Solar radiation proxies
- Heating and cooling indices

### Composite Weather Metrics

AG2 additionally generates composite variables that historically correlate strongly with electricity demand, including:

- Heat index
- Apparent temperature
- Cooling degree relationships
- Heating degree relationships
- Persistence-adjusted temperature anomalies
- Multi-day weather stress indicators

These transformations improve the signal quality provided to downstream machine learning systems.

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## 3. Advanced Feature Engineering

Following weather processing, AG2 generates a large set of predictive features designed to capture the relationship between weather conditions and electricity demand.

The feature engineering framework includes:

### Weather-Driven Features

- Current and forecasted thermal stress
- Rate-of-change temperature signals
- Lagged weather variables
- Intraday temperature evolution
- Overnight cooling behavior
- Ensemble spread statistics

### Calendar Effects

The system incorporates:

- Hour-of-day effects
- Day-of-week behavior
- Weekend versus weekday demand patterns
- Holiday impacts
- Bridge-day demand adjustments
- Seasonal transition effects

### Historical Load Behavior

Historical load relationships are integrated through:

- Autoregressive demand behavior
- Trend normalization

- Seasonal baselines
- Weather analog relationships
- Residual correction methodologies

This multi-dimensional feature architecture enables the forecasting system to better capture nonlinear demand responses that traditional statistical approaches often miss.

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## 4. AI/ML Demand Translation

The engineered feature set is processed through machine learning models trained on historical weather and PJM load data.

These AI/ML systems learn the complex nonlinear relationship between:

- Weather conditions
- Demand sensitivity
- Seasonal behavior
- Human consumption patterns
- Regional demand response characteristics

When new weather model runs arrive, the forecasting system automatically applies the trained machine learning models to translate forecasted atmospheric conditions into expected PJM electricity demand in megawatts (MW).

The upgraded AG2 framework includes enhancements in:

- Ensemble blending
- Forecast calibration
- Regime classification
- Error correction
- Outlier handling
- Long-range stability

This results in improved forecast accuracy across both normal operating conditions and high-impact weather events.

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# Model Performance Evaluation

## Evaluation Methodology

The upgraded AG2 PJM Load Forecast model was evaluated against the prior AG2 forecasting system and the existing PJM model using Mean Absolute Percentage Error (MAPE) improvement metrics.

The evaluation compared forecast accuracy across:

- Forecast horizons from next-day through Day 15
- All 24 hourly forecast periods
- Multiple weather regimes and seasonal conditions

Positive values indicate improvement versus the legacy AG2 forecasting system and the existing PJM model.

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# Summary of Results

## Overall Improvement

Across the full evaluation dataset, the upgraded AG2 PJM Load Forecast model achieved:

- Approximately 38% average MAPE improvement overall from the previous AG2 model.
- Median improvement of approximately 38% from the previous AG2 model.
- Peak hourly improvements exceeding 43% during select long-range forecast periods from the previous AG2 model.
- 18.7% improvement over the PJM Load Model
- Median improvement of approximately 18% over the PJM model.

The results demonstrate that the upgraded forecasting framework delivers meaningful gains in both short-range and extended-range forecasting performance.

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## Short-Range Forecast Performance

Short-range forecasts showed strong and highly consistent improvement.

| | PJM | Prev. AG2 |
|---|---|---|
| Next day | 21.7% | 30.4% |
| Day 3 | 22.7% | 32.5% |
| Day 4 | 19.7% | 30.3% |
| Day 5 | 16.5% | 28.1% |

These gains are particularly important for:

- Day-ahead market operations
- Unit commitment planning
- Real-time balancing preparation
- Congestion risk management
- Utility operations

The next-day forecast improvements demonstrate enhanced responsiveness to rapidly evolving weather conditions and improved intraday load shape prediction.

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## Medium-Range Forecast Performance

The upgraded model maintained measurable forecast skill improvements through the medium-range period.

| | PJM | Prev. AG2 |
|---|---|---|
| Day 6 | 16.0% | 23.8% |
| Day 7 | 15.5% | 36.1% |

While medium-range forecasting naturally contains greater uncertainty, the upgraded system still outperformed the legacy AG2 model overall.

The improved ensemble integration and nonlinear feature extraction contributed to better forecast stability during these forecast periods.

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## Extended-Range Forecast Performance

The largest gains were observed in the extended-range forecast window.

| | Prev AG2 |
|---|---|
| Day 8 | 50.6% |
| Day 9 | 49.1% |
| Day 10 | 46.8% |
| Day 11 | 43.0% |
| Day 12 | 40.4% |
| Day 13 | 39.0% |
| Day 14 | 38.0% |
| Day 15 | 37.3% |

These results highlight the effectiveness of:

- Ensemble weather integration
- Regime-aware AI forecasting
- Improved long-range calibration
- Enhanced uncertainty handling

Long-range load forecasting has historically been one of the most difficult areas in power demand prediction. The upgraded AG2 framework demonstrates significant advancement in maintaining forecast skill deeper into the forecast horizon.

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# Hourly Forecast Improvements

The upgraded AG2 PJM Load Forecast model showed especially strong performance improvements during:

- Overnight ramp periods
- Morning load transitions
- Evening peak demand hours
- Weather-sensitive shoulder periods

The largest hourly gains over the previous AG2 model were generally concentrated in:

- Late evening hours (2000–2300)
- Overnight periods (0000–0400)
- Extended-range horizons

**AG2 PJM Load Forecast MAPE % Improvement Over Orig AG2 Model**

| | 0000 | 0100 | 0200 | 0300 | 0400 | 0500 | 0600 | 0700 | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | 2000 | 2100 | 2200 | 2300 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Next day | 24.3% | 30.3% | 32.9% | 30.1% | 19.1% | 24.0% | 30.8% | 30.7% | 30.5% | 30.8% | 33.1% | 34.8% | 34.2% | 34.5% | 34.5% | 36.2% | 35.5% | 31.3% | 26.4% | 26.0% | 31.0% | 30.4% | 29.6% | 28.2% |
| Day 3 | 30.6% | 37.8% | 40.1% | 39.2% | 33.7% | 33.2% | 36.9% | 37.1% | 32.6% | 32.6% | 32.1% | 30.7% | 30.6% | 28.7% | 32.6% | 32.7% | 33.2% | 29.5% | 26.8% | 27.5% | 33.9% | 32.7% | 28.3% | 26.2% |
| Day 4 | 24.6% | 31.5% | 35.3% | 35.5% | 29.9% | 27.8% | 34.2% | 36.3% | 30.2% | 32.7% | 33.7% | 31.2% | 28.9% | 28.8% | 27.6% | 28.5% | 29.5% | 27.3% | 24.5% | 25.7% | 32.2% | 33.1% | 29.8% | 29.2% |
| Day 5 | 28.5% | 30.5% | 31.5% | 31.1% | 22.8% | 22.5% | 24.1% | 28.9% | 27.6% | 30.5% | 30.9% | 29.4% | 28.0% | 27.7% | 27.6% | 27.4% | 29.9% | 28.9% | 24.9% | 26.7% | 31.5% | 30.8% | 26.8% | 26.1% |
| Day 6 | 25.0% | 28.6% | 27.6% | 26.7% | 18.1% | 15.7% | 19.3% | 23.1% | 24.2% | 22.5% | 21.5% | 24.1% | 23.7% | 22.6% | 24.8% | 23.6% | 25.8% | 23.7% | 22.9% | 24.6% | 26.3% | 26.9% | 25.3% | 24.4% |
| Day 7 | 21.5% | 24.7% | 22.3% | 16.7% | 15.9% | 36.0% | 45.8% | 45.9% | 32.2% | 22.3% | 21.6% | 24.4% | 28.2% | 31.0% | 34.1% | 37.3% | 40.1% | 39.1% | 40.9% | 46.5% | 54.8% | 61.7% | 63.7% | 60.5% |
| Day 8 | 48.7% | 56.2% | 39.7% | 36.8% | 57.5% | 67.3% | 65.6% | 46.3% | 29.2% | 36.6% | 42.2% | 40.2% | 39.7% | 38.5% | 38.4% | 38.8% | 42.4% | 45.6% | 51.2% | 59.4% | 68.4% | 74.5% | 76.5% | 74.8% |
| Day 9 | 68.1% | 55.2% | 37.9% | 33.6% | 51.6% | 62.6% | 61.2% | 43.1% | 28.4% | 34.5% | 40.1% | 39.2% | 37.3% | 35.9% | 35.3% | 38.2% | 41.5% | 43.8% | 49.0% | 57.3% | 65.8% | 72.2% | 74.8% | 72.5% |
| Day 10 | 65.2% | 52.4% | 35.4% | 33.2% | 49.1% | 59.2% | 57.0% | 39.9% | 25.4% | 30.1% | 36.5% | 36.7% | 35.8% | 35.1% | 35.3% | 35.7% | 38.5% | 42.1% | 48.4% | 56.5% | 64.3% | 69.5% | 71.9% | 70.0% |
| Day 11 | 61.8% | 47.1% | 30.5% | 25.6% | 42.6% | 53.8% | 51.8% | 34.5% | 22.3% | 27.3% | 33.0% | 32.5% | 32.0% | 31.6% | 31.8% | 33.0% | 35.0% | 39.7% | 45.8% | 53.6% | 61.7% | 67.5% | 69.9% | 67.6% |
| Day 12 | 59.3% | 44.8% | 28.9% | 22.7% | 38.4% | 50.4% | 49.1% | 32.9% | 22.4% | 26.5% | 30.5% | 31.7% | 30.5% | 28.2% | 27.8% | 28.8% | 31.1% | 35.6% | 42.6% | 50.9% | 59.0% | 65.5% | 67.9% | 65.4% |
| Day 13 | 56.9% | 42.5% | 26.1% | 22.1% | 36.2% | 48.2% | 46.4% | 29.8% | 18.4% | 23.2% | 28.4% | 30.6% | 30.0% | 28.7% | 28.8% | 29.6% | 32.0% | 35.4% | 41.6% | 48.8% | 57.1% | 63.9% | 66.4% | 63.9% |
| Day 14 | 55.9% | 43.3% | 27.2% | 20.9% | 34.7% | 45.7% | 43.5% | 24.0% | 13.7% | 20.5% | 27.2% | 30.3% | 30.6% | 29.8% | 29.8% | 31.0% | 32.7% | 35.5% | 41.6% | 48.7% | 56.6% | 62.6% | 65.0% | 62.2% |
| Day 15 | 54.4% | 41.8% | 25.4% | 18.2% | 31.8% | 43.6% | 41.1% | 21.9% | 12.9% | 19.8% | 27.6% | 29.7% | 29.1% | 29.2% | 30.5% | 32.0% | 34.6% | 37.3% | 42.0% | 47.9% | 55.6% | 62.3% | 64.5% | 61.4% |

The largest hourly gains over the PJM model were generally concentrated in:

- Late evening hours (0900-1700)

**AG2 PJM Load Forecast MAPE % Improvement over PJM**

| | 0000 | 0100 | 0200 | 0300 | 0400 | 0500 | 0600 | 0700 | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | 2000 | 2100 | 2200 | 2300 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Next day | 18.7% | 19.2% | 18.2% | 13.4% | 8.5% | 10.8% | 17.4% | 16.3% | 20.8% | 25.6% | 28.7% | 30.6% | 30.4% | 30.8% | 30.0% | 30.3% | 29.9% | 27.1% | 21.6% | 21.1% | 20.9% | 17.0% | 15.7% | 17.8% |
| Day 3 | 22.0% | 23.7% | 22.3% | 19.1% | 16.2% | 18.9% | 23.2% | 23.1% | 23.1% | 25.3% | 27.5% | 26.4% | 26.5% | 25.1% | 27.5% | 27.6% | 27.9% | 25.1% | 21.6% | 21.7% | 22.5% | 18.2% | 14.9% | 16.5% |
| Day 4 | 17.6% | 18.9% | 18.9% | 16.3% | 14.5% | 15.5% | 20.5% | 20.1% | 15.6% | 22.8% | 26.4% | 25.0% | 22.9% | 22.0% | 21.3% | 23.5% | 24.6% | 22.9% | 18.3% | 18.2% | 20.3% | 15.9% | 14.3% | 16.1% |
| Day 5 | 16.9% | 15.8% | 13.6% | 10.5% | 6.3% | 9.0% | 10.6% | 10.0% | 12.3% | 19.0% | 22.4% | 23.7% | 21.6% | 21.6% | 21.6% | 21.5% | 23.7% | 22.8% | 18.1% | 17.4% | 17.7% | 13.1% | 12.9% | 14.6% |
| Day 6 | 14.4% | 15.7% | 13.5% | 10.3% | 6.1% | 6.8% | 9.6% | 9.8% | 11.7% | 15.8% | 17.9% | 20.4% | 19.7% | 19.7% | 20.3% | 20.7% | 23.0% | 21.4% | 19.0% | 19.0% | 19.0% | 17.0% | 16.8% | 17.2% |
| Day 7 | 15.2% | 16.3% | 14.2% | 11.3% | 9.3% | 10.0% | 10.1% | 10.7% | 11.1% | 14.2% | 16.6% | 18.1% | 18.2% | 18.6% | 19.2% | 19.1% | 20.0% | 19.2% | 17.5% | 16.3% | 16.6% | 16.6% | 16.2% | 16.7% |

These improvements are particularly valuable for:

- Peak risk assessment
- Asset dispatch planning
- Ancillary services positioning
- Short-term trading strategies
- Reliability operations

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# Operational Benefits

The upgraded AG2 PJM Load Forecast product provides several operational advantages for market participants.

## Improved Decision Support

Higher forecast accuracy enables:

- Better market positioning
- Reduced operational uncertainty
- Improved generation scheduling
- More efficient risk management

## Enhanced Extreme Weather Performance

The multi-model ensemble framework improves handling of:

- Heat waves
- Cold outbreaks
- Rapid temperature swings
- Storm-driven volatility
- Seasonal transition events

### Greater Long-Range Stability

The upgraded system provides improved confidence in extended-range planning scenarios by maintaining stronger forecast skill through Day 15.

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## Conclusion

The upgraded AG2 PJM Load Forecast system represents a major advancement in AI-driven electricity demand forecasting.

By combining:

- Multi-model weather ingestion
- ISO-specific meteorological processing
- Advanced feature engineering
- Machine learning demand translation
- Enhanced ensemble calibration

AG2 has materially improved forecast accuracy across nearly all forecast horizons.

The results demonstrate:

- Strong next-day forecasting improvements
- Sustained medium-range gains
- Exceptional extended-range forecast enhancement
- Better handling of weather uncertainty and nonlinear demand behavior

These upgrades strengthen the AG2 PJM Load Forecast product as a high-value forecasting solution for energy market participants requiring accurate, weather-aware electricity demand guidance.

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## About Atmospheric G2

Atmospheric G2 (AG2) delivers advanced weather intelligence, energy forecasting, and AI-driven meteorological analytics for the global energy industry. AG2 combines atmospheric science expertise with machine learning technologies to provide actionable decision support tools for power markets, utilities, renewable operators, traders, and risk managers.