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# Real-World Load and Wind Power Forecasting in Greek Island Energy Systems: A Deep Learning Perspective

*Classical statistical models vs. deep learning for minute-level load & wind forecasting on Samos and Ikaria*

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# Agenda


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Why island forecasting is hard — motivation & gap

2 **Related Work**
Statistical, ML and deep-learning forecasting

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What this paper adds

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5 **Evaluation Metrics**
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PART 01

# Introduction, Related Work & Contributions

*Why short-term island forecasting is hard — and what this paper adds*



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INTRODUCTION

# Forecasting Under Renewable-Rich, Island Conditions

## Forecasting underpins grid operation

Accurate short-term load & renewable forecasts are essential for stability, dispatch, and reserve management.

## Islands amplify the difficulty

Weakly interconnected grids have limited reserves and low inertia, so forecasting errors hit reliability harder.

## Statistical models assume stationarity

ARIMA-family methods are efficient and interpretable but their linearity/stationarity assumptions break in renewable-rich systems.

## Deep learning captures nonlinear dynamics

LSTM and DNN models model long-range dependencies and volatile behavior of demand and wind generation.



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# Problem Statement & Research Gap

## Problem

Provide accurate minute-level short-term forecasts of load and wind power on real island grids, where profiles are volatile, non-stationary, and strongly weather-driven — and where errors are costly.

## Research Gap

Most studies target large interconnected grids where aggregation smooths volatility; most evaluate only one-step-ahead prediction; and systematic comparisons on high-resolution real-world island data remain limited.



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RELATED WORK

# Where Existing Forecasting Approaches Stand

## Statistical / classical

ARIMA/SARIMAX variants are used operationally (e.g. Spanish island TSO). Efficient and interpretable, but lose accuracy on nonlinear, fast-changing signals.

## Machine learning

SVM, RF, KNN, XGBoost and LightGBM+NWP improve wind-ramp and speed forecasts (Kumar et al., Jeju island). More stable than pure statistics over longer horizons.

## Deep learning

LSTM/CNN reviews and data-transformation + DL pipelines (Andriopoulos et al.) show DL captures load/wind dynamics; VMD+LSTM further boosts wind accuracy.

**The gap:** prior work rarely benchmarks statistical vs. deep models on high-resolution real island data under realistic rolling and recursive multi-step deployment.



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# Contributions

## Statistical vs. deep comparison

1

A systematic comparison of ARIMA/SARIMAX/AutoReg against LSTM and DNN on high-resolution real-world island data from the grid operator.

## Realistic multi-step evaluation

2

Assessment under standard one-step-ahead plus rolling and recursive multi-step scenarios, probing long-horizon stability and error accumulation.

## Multi-dataset, multi-regime

3

Analysis across two islands, both load demand and wind generation, under grid and hybrid operational regimes.

## Deep learning wins, DNN is robust

4

Empirical evidence that deep models — a simple DNN in particular — consistently outperform statistical baselines and are more robust.



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PART 02

# Methodology & Models

*A sliding-window framework spanning statistical and deep models*



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METHODOLOGY

# Forecasting Framework

SUPERVISED SLIDING-WINDOW FORMULATION (LOOK-BACK = 60 MIN)

$$X_t = \{x_{(t-60)}, \ldots, x_{(t-1)}\} \qquad y_t = x_t$$

## Statistical baselines

ARIMA (AR + differencing + MA), SARIMAX (no exogenous regressors, for fair comparison), and AutoReg — a lightweight pure-AR model. A Moving Average serves as a sanity baseline.

## LSTM

Two stacked LSTM layers of 50 units with 0.2 dropout, followed by a Dense output. Recurrent gates maintain memory over the input sequence (3D tensor input).

## DNN

Fully-connected feed-forward net over the flattened window: two hidden layers (64, 32) with ReLU, sigmoid output. Adam + MSE, early stopping. Simple yet highly effective.



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EVALUATION METRICS

# How Forecasts Are Scored

## RMSE

Root Mean Squared Error — absolute error in normalized units, penalizing large deviations.

## MAE

Mean Absolute Error — average absolute error in normalized units.

## sMAPE

Symmetric MAPE — scale-independent percentage error, more robust than MAPE when true values are near zero.

**Consistency:** all models are evaluated on the same held-out test data, using chronological splits to prevent leakage.



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PART 03

# Evaluation & Results

*Samos & Ikaria · load & wind · standard, rolling and recursive*



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EXPERIMENT SETUP

# Datasets, Protocol & Environment

## Datasets — Samos & Ikaria

Load demand (MW) and non-curtailed wind production (MW) for 2023–2024, at hourly granularity, sourced from the Greek DSO.

## Preprocessing

Clip negative power to zero; MinMax-normalize targets to [0,1]; chronological 60/40 train/test split; 60-minute sliding windows (3D for LSTM, 2D for DNN).

## Training

Adam (lr 0.001), MSE loss, batch 64, up to 50 epochs, early stopping on a 10% validation split. statsmodels for statistical models, Keras for LSTM/DNN.

## Environment

Python (Pandas, statsmodels, Keras) on a MacBook Air M2 (8-core CPU, 8 GB unified memory) — no discrete GPU, yet sufficient for training and evaluation.



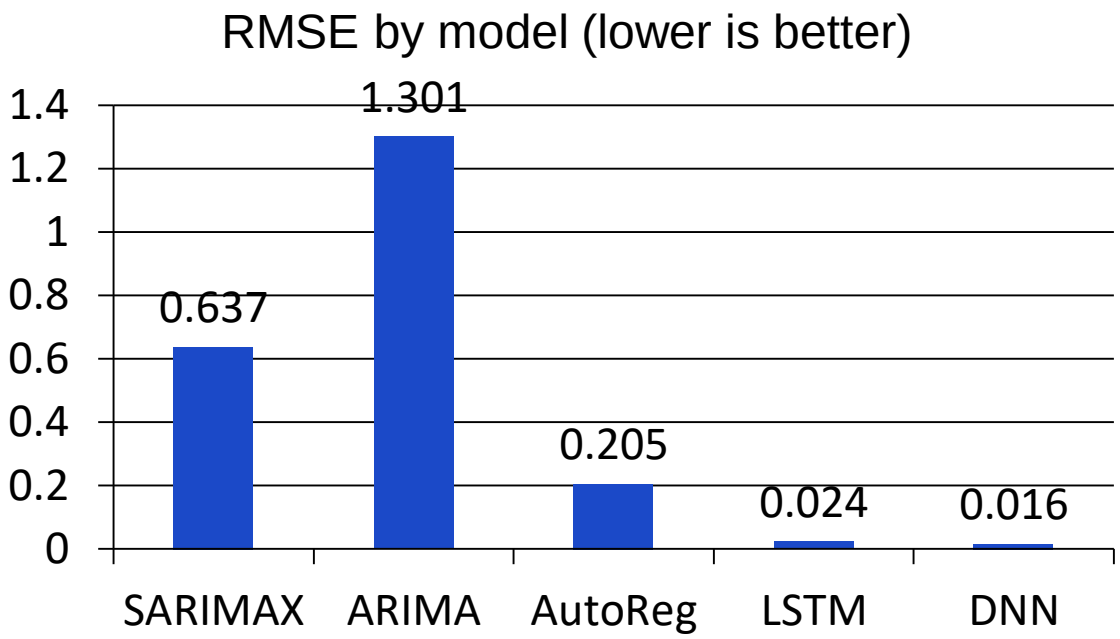
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RESULTS — SAMOS LOAD

# One-Step-Ahead Load Forecasting (Samos)

| Model | RMSE | MAE | sMAPE % |
|---|---|---|---|
| SARIMAX | 0.637 | 0.610 | 196.9 |
| ARIMA | 1.301 | 1.159 | 179.4 |
| AutoReg | 0.205 | 0.154 | 25.0 |
| LSTM | 0.024 | 0.019 | 2.84 |
| DNN | 0.016 | 0.011 | 1.72 |

*Table I — Samos load, full test set (normalized units)*




**Takeaway:** LSTM and DNN cut error by more than an order of magnitude vs. statistical models; the DNN is best on every metric (sMAPE 1.72%).



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RESULTS — STRESS TEST

# Rolling 7-Day Load Forecast on a Volatile Segment

**2.39%**

DNN sMAPE (7-day rolling)

**5.29%**

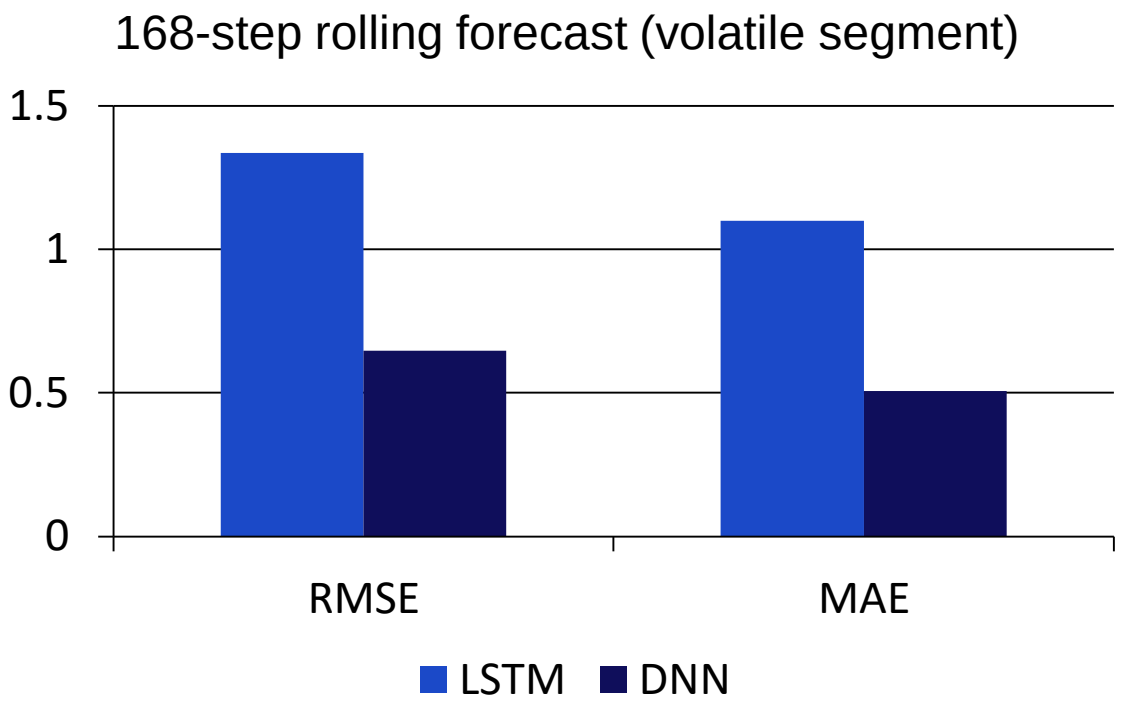
LSTM sMAPE (7-day rolling)

**0.647**

DNN RMSE

**1.335**

LSTM RMSE




**Robustness:** under multi-day rolling deployment the DNN tracks the true load far more closely; the LSTM accumulates noticeably more error.



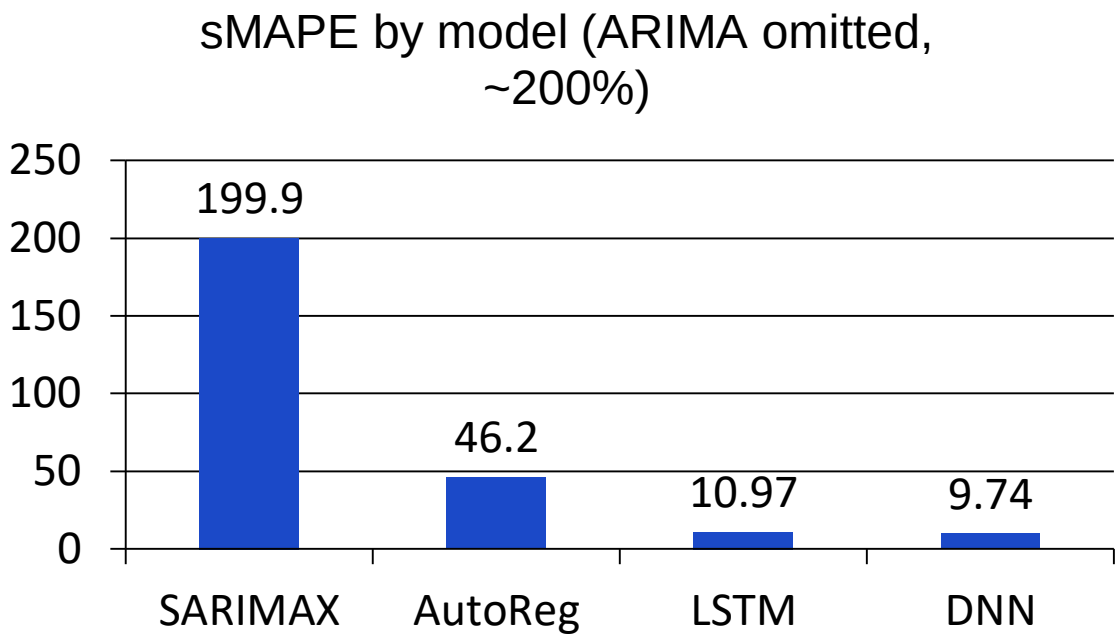
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RESULTS — SAMOS WIND

# Wind Power Forecasting (Samos)

| Model | RMSE | MAE | sMAPE % |
|---|---|---|---|
| SARIMAX | 0.553 | 0.497 | 199.9 |
| ARIMA | 2.624 | 2.377 | 199.9 |
| AutoReg | 0.254 | 0.206 | 46.2 |
| LSTM | 0.064 | 0.047 | 10.97 |
| DNN | 0.059 | 0.037 | 9.74 |

*Table II — Samos wind, test set (normalized units)*




**Harder than load:** statistical models sit near 200% sMAPE; both neural models drop error dramatically, with the DNN best (RMSE 0.059).



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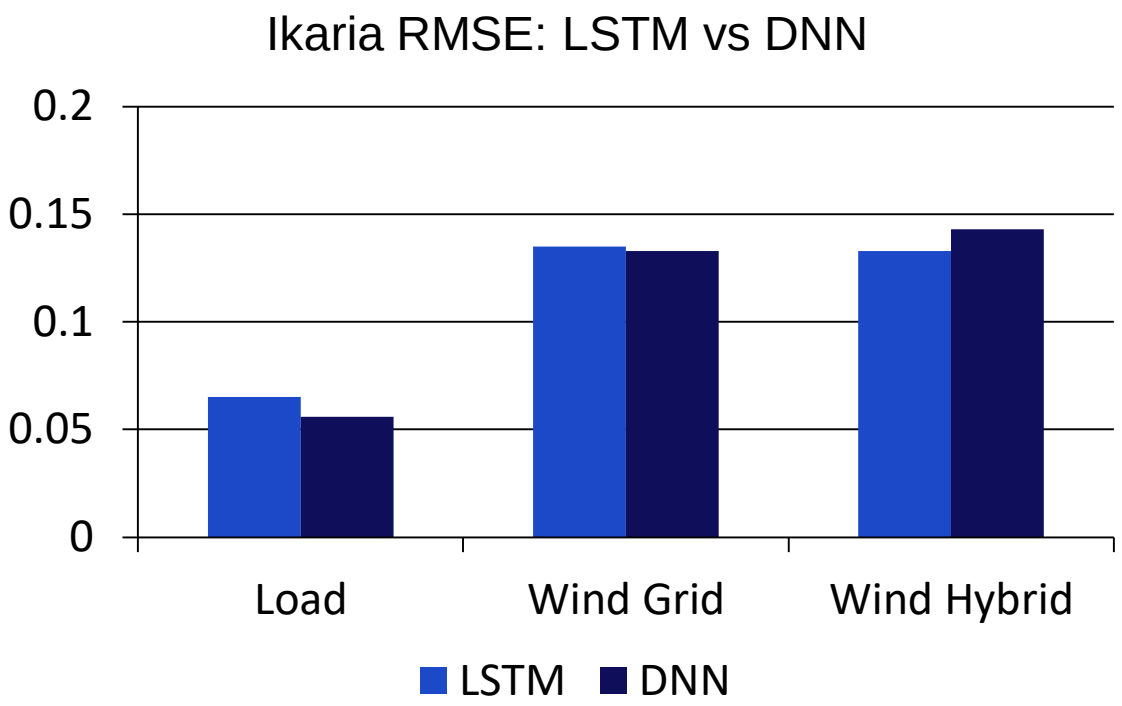
# Ikaria: Load and Wind (Grid & Hybrid)

| Model | Load | Wind Grid | Wind Hybrid |
|---|---|---|---|
| AutoReg | 0.244 | 0.333 | 0.333 |
| LSTM | 0.065 | 0.135 | 0.133 |
| DNN | 0.056 | 0.133 | 0.143 |

*RMSE — Ikaria (Tables III–V; statistical rows omitted for space)*

**Load is highly predictable** DNN best on Ikaria load (RMSE 0.056, sMAPE 7.82%); order-of-magnitude gain over statistical models.

**Wind stays challenging** Grid & hybrid wind regimes are close; LSTM slightly leads on grid, DNN on load — both dominate statistics.






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RESULTS — OVERALL

# RMSE Across All Datasets & Tasks

| Model | Samos Load | Samos Wind | Ikaria Load | Ikaria Wind (Grid) | Ikaria Wind (Hybrid) |
|---|---|---|---|---|---|
| SARIMAX | 0.637 | 0.553 | 0.476 | 0.510 | 0.510 |
| ARIMA | 1.301 | 2.624 | 0.257 | 1.015 | 1.014 |
| AutoReg | 0.205 | 0.254 | 0.244 | 0.333 | 0.333 |
| LSTM | 0.024 | 0.064 | 0.065 | 0.135 | 0.133 |
| **DNN** | **0.016** | **0.059** | **0.056** | **0.133** | **0.143** |

*Table VI — RMSE comparison across all forecasting tasks (normalized units)*

**Deep learning wins everywhere** Classical models are consistently one to two orders of magnitude worse than LSTM/DNN across every task.

**DNN is the most robust overall** The DNN achieves the best or near-best score in all scenarios and the best average normalized performance.



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PART 04

# Conclusions & Future Work

*What we showed — and where it goes next*



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CONCLUSIONS

# Key Findings, Limitations & Future Work

### Deep learning dominates
LSTM & DNN beat SARIMAX/ARIMA/AutoReg on both islands, both targets, all regimes.

### Add exogenous inputs
Meteorological forecasts and calendar features — especially to lift wind accuracy.

### DNN is most robust
Best stability under rolling and long-horizon recursive forecasting; LSTM strong one-step but accumulates error.

### Probabilistic forecasting
Move beyond point forecasts to uncertainty-aware, decision-support outputs.

### Wind harder than load
Load is highly predictable; wind stays hard due to intermittency and non-stationarity.

### Operational strategy
Prefer short-horizon rolling over recursive multi-step for highly stochastic wind.



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# Thank you for your attention!

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