School of Science and Technology
Computer Science (Class LM-18)

Efficient energy prediction through the use of machine learning techniques

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Group:
Energy 2

a.y. 2023/2024

Research Methodology

1 Introduction

- Number of electrical devices in homes

→ **Strain** in grid[1]
(reliability issues, failures)

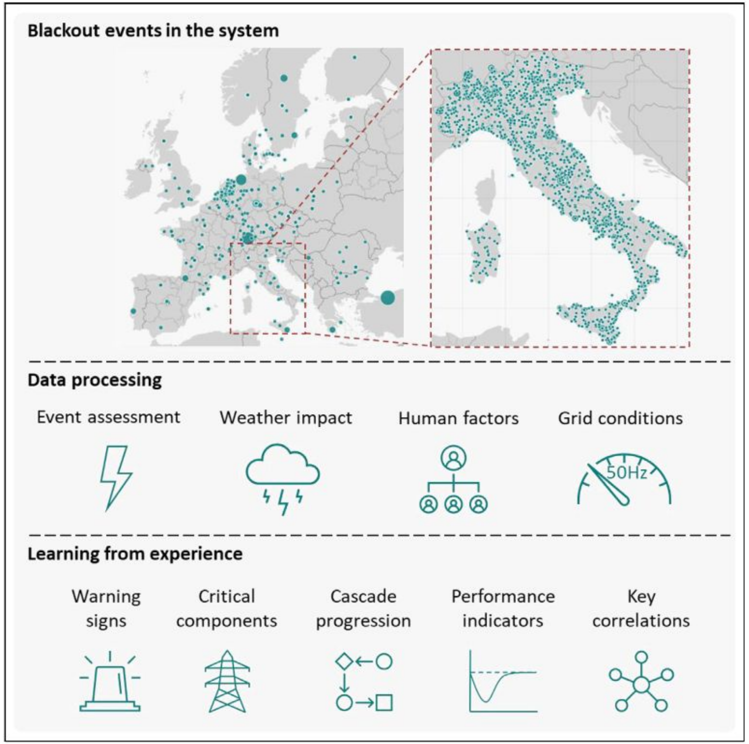
[1] K. Brigham, "Why the electric vehicle boom could put a major strain on the U.S. power grid," Jul. 2023. https://www.cnbc.com/2023/07/01/why-the-ev-boom-could-put-a-major-strain-on-our-power-grid.html



1 Introduction

High demand is a major contributor to **cascading failures** in the electrical grid structure, accounting for[2]:

- ➔ 91% of the total Demand Not Served (DNS)
- ➔ 89% of the recovery time in severe events



[2] Andrej Stankovski, et al. "Power blackouts in Europe: Analyses, key insights, and recommendations from empirical evidence" Nov. 2023. https://doi.org/10.1016/j.joule.2023.09.005

1 Introduction

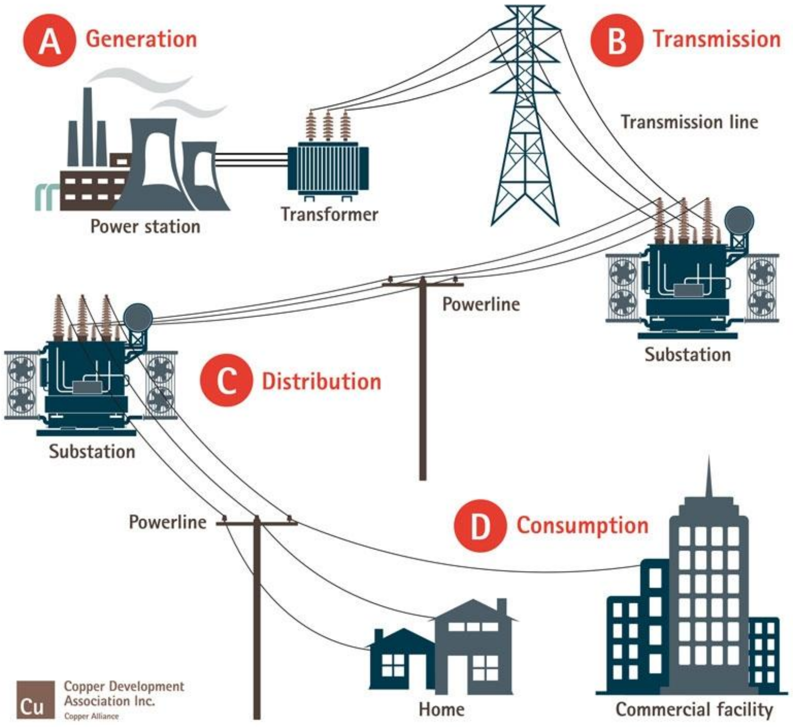
Environmental issues, sustainability[3,4]

Accurate **prediction** of energy consumption is **key**

[3] International Energy Agency, "Emissions savings – Multiple Benefits of Energy Efficiency – Analysis," Tech. Rep., Mar. 2019. https://www.iea.org/reports/multiple-benefits-of-energy-efficiency/emissions-savings
[4] Sense Team, "Why Energy Efficiency is a Win-Win for Consumers and Utilities," Jun. 2023. https://blog.sense.com/why-energy-efficiency-is-a-win-win-for-consumers-and-utilities/

2 Background and Theory

Component	Reliability	Repair Costs
Power Stations	90%	$1 to $5 million
Transformers	99%	$2 to $7.5 million
Substations	98%	$2 to $5 million
Distribution Lines	97%	$2 to $50 thousand



Sourcres: https://link.springer.com/ https://www.eia.gov/ https://www.energy.gov/sites/default/files/2023-11/FINAL_CESER%20Electricity%20Grid%20Backgrounder_508.pdf https://electrical-engineering-portal.com/ https://www.nae.edu/

2 Background and Theory

Our research question aims at understanding how integrating forecasting technologies affect the efficiency and reliability of the electrical structures.

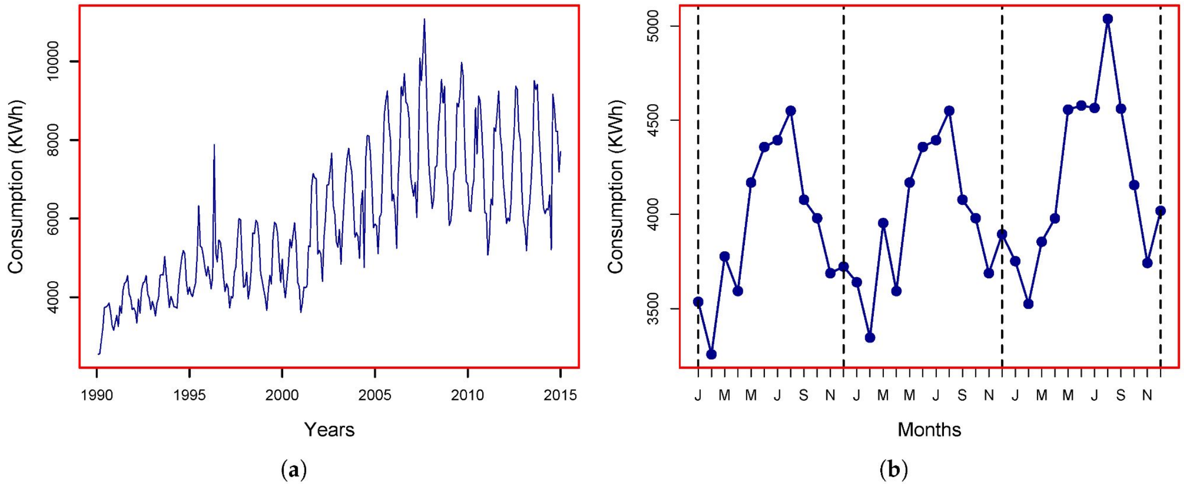


Image source: https://www.mdpi.com/2571-9394/2/2/9

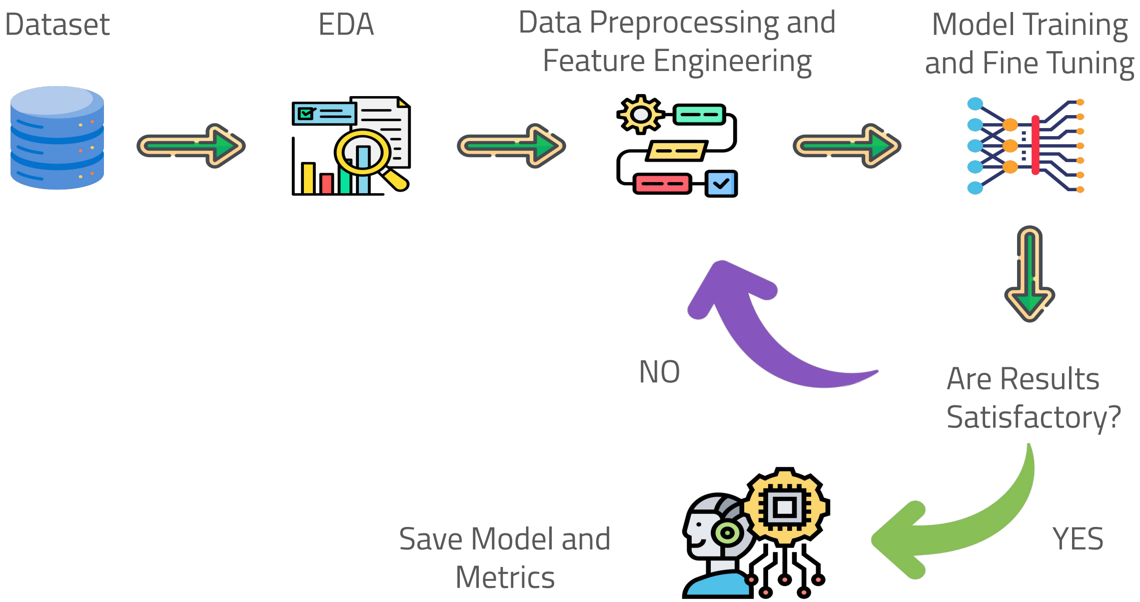
2 Background and Theory

The state of the art approaches for forecasting energy consumption currently include:

- Time Series Models
  - ARIMA
  - SARIMA
  - LSTM
  - ETS
- Linear Regression Models
  - Random Forest
  - Extra Trees
  - XGBoost
  - LightGBM

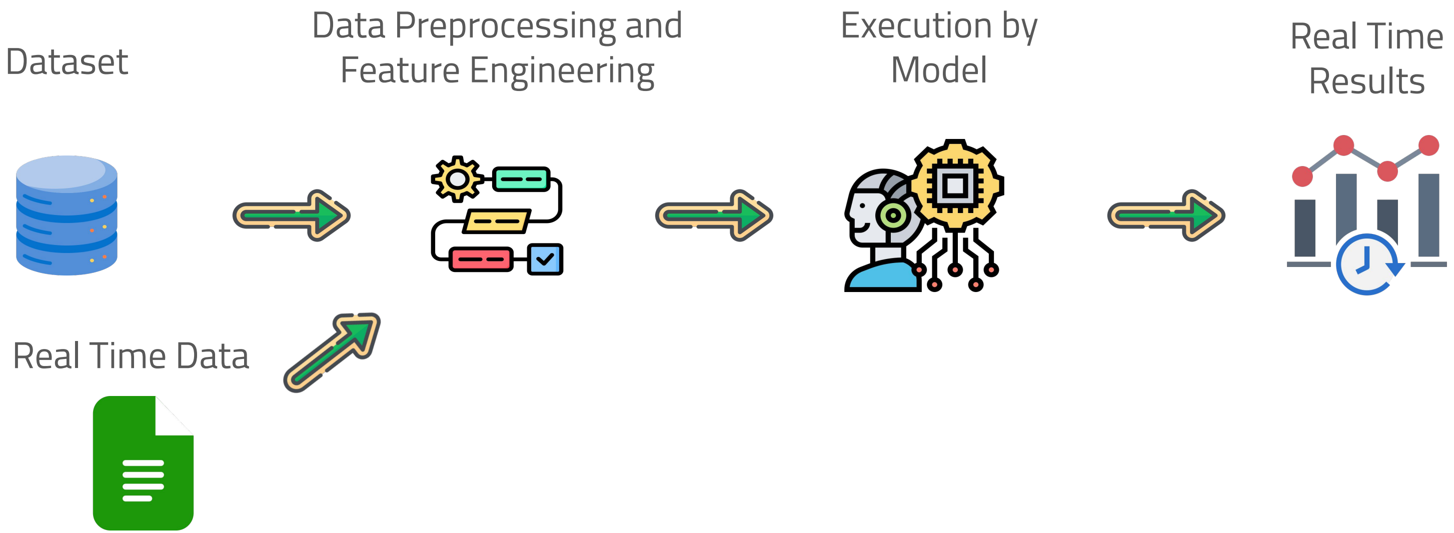
3 Methodology

The following is the pipeline used for training all the models:



3 Methodology

The following is an architecture proposal for the final product:



4 Results

High demand is a major contributor to **cascading failures** in the electrical grid structure, accounting for[4]:

- ➔ 91% of the total Demand Not Served (DNS)
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The economic loss prevented by avoiding power outages can be of several hundred million euros[5].

Table 3-2. Economic assessment of a one-hour outage in Austria by means of APOSTEL

Sector as per NACE 2008	Name	No. of severely/very severely affected units*	No. of persons in severely/very severely affected units**	Electricity not supplied (in MWh)	Total losses (in 1,000 €)
A	Agriculture	179,552	474,145	569	3,218
B	Mining	335	6,063	328	902
C	Manufacturing	25,038	605,668	11,456	69,891
D	Electricity and gas supply	1,452	27,006	4,643	8,866
E	Water supply, waste management	1,903	16,830	1,115	1,523
F	Construction	28,476	263,269	246	18,141
G	Wholesale and retail trade	69,331	576,027	1,186	73,321
H	Transport	13,005	200,417	1,567	16,928
I	Accommodation and food services	41,333	237,837	300	6,874
J	Information and communication	14,300	84,119	264	7,899
K	Finance and insurance	6,339	117,366	699	14,516
L	Real estate	14,407	38,528	279	5,772
M	Professional, scientific and technical services	50,709	182,833	466	11,293
N	Administrative and support services	10,955	178,985	356	8,469
OPQRSTU	Public sector	N/A*****	996,469	2,821	28,743
	Households***	1,043,495	2,396,009**	8,478	10,617
TOTAL		1,500,630	N/A****	34,774	286,972

[4] Andrej Stankovski, et al. "Power blackouts in Europe: Analyses, key insights, and recommendations from empirical evidence" Nov. 2023. https://doi.org/10.1016/j.joule.2023.09.005
[5] Reichl, et al. "Power outage cost evaluation: reasoning, methods and an application" April 2013 Link

4 Results

+9 M$/h of avoided damages when power outages are avoided[5]

-4M$/h extra maintenance costs for inaccurate prediction[6,7]

Preventative maintenance before a potential power outage can reduce greatly the economic losses.

The extra costs can be very high, but are outweighed by the prevented loss.

[5] Reichl, et al. "Power outage cost evaluation: reasoning, methods and an application" April 2013
[6] The University of Texas "Executive Summary: The Full Cost of Electricity" April 2018 Link
[7] statista.com "Electricity end use in the United States from 1975 to 2023" March 2024 Link

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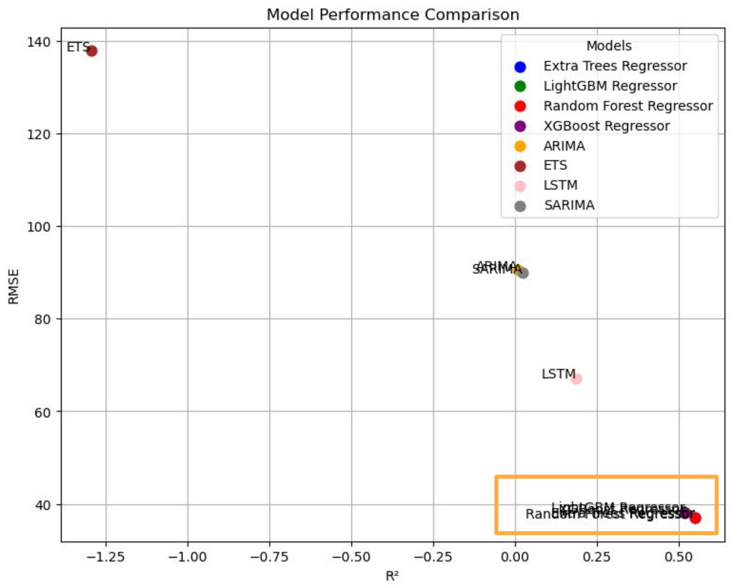
4 Results

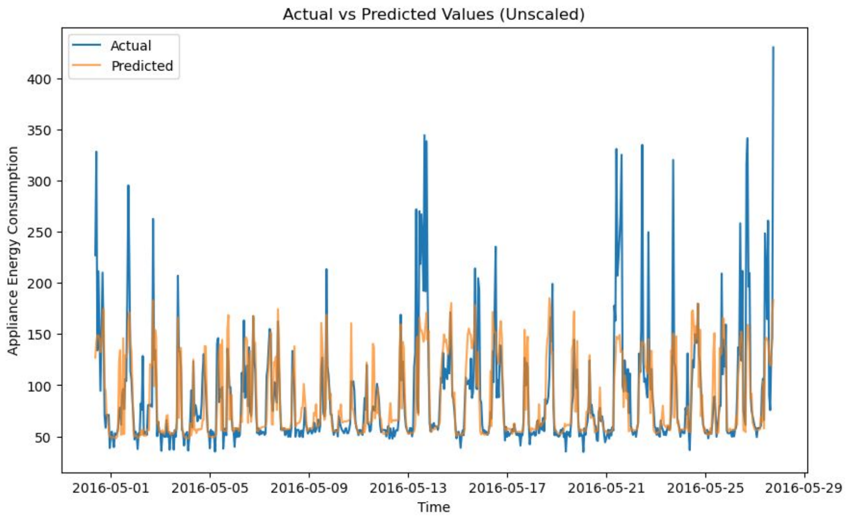
	MAE	MSE	R^2	RMSE
ETS	70.21	19015.31	-1.29	137.89
ARIMA	52.02	8200.08	0.01	90.55
SARIMA	51.24	8077.14	0.02	89.87
LSTM	42.299	4509.528	0.188	67.153
RFR	20.552	1367.768	0.55	36.983
ETR	20.295	1374.939	0.55	37.080
XGBoost	20.861	1448.366	0.52	38.057
LightGBM	20.445	1468.749	0.52	38.324

4 Results

5 6 7



Performance scatter plot



Random Forest Regressor

5 Results: Discussion

	Predictions	Feature importance
Regression models	↑	↑
Time Series models	↓	↓

5 Results: Discussion

However… don't be *biased*.

No temporal pattern in 4.5 months worth of data

Features important to determine the consumption

6 Future Directions

Improve dataset

- Use a larger dataset to take advantage of time-series models
- Include additional data such as details on house construction

Update models

- Explore more advanced machine learning techniques
- Keep up to date with new models

7 Concluding remarks

✅ **Key findings**

- Accurate predictions with regression models
- Effective for reducing grid instability and unwanted repair costs

⚠️ **Limitations**

- Data from a single house
- Dataset was already extensively studied

7 Concluding remarks

Key findings

✅ *Effective energy consumption prediction*

⚠️ *Limited dataset*

Future work

1. *Use dataset with a longer timespan*
2. *Include additional relevant data (e.g. house construction details)*
3. *Keep up-to-date with future ML models*

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Thanks for the attention!

github.com/Staffilon/
EnergyConsumptionForecast