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# Team Zero

**iCEM**

integrated Climate Energy Module



120 houses located in Zoetermeer



# Research Question

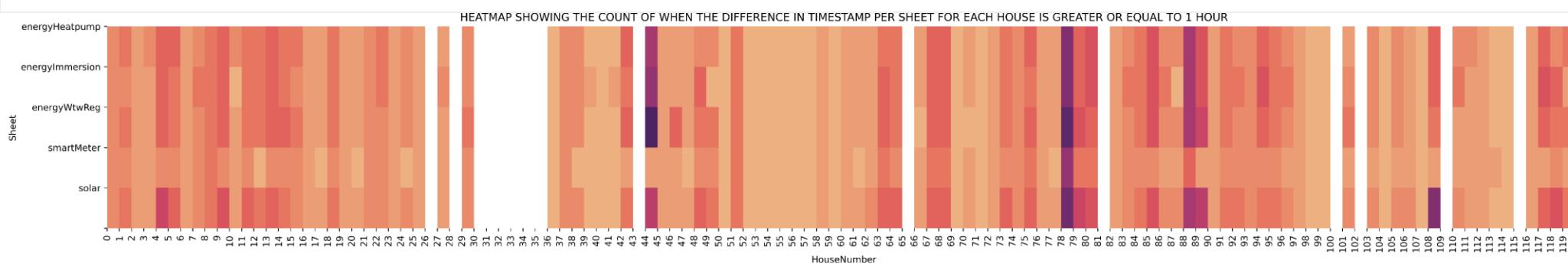
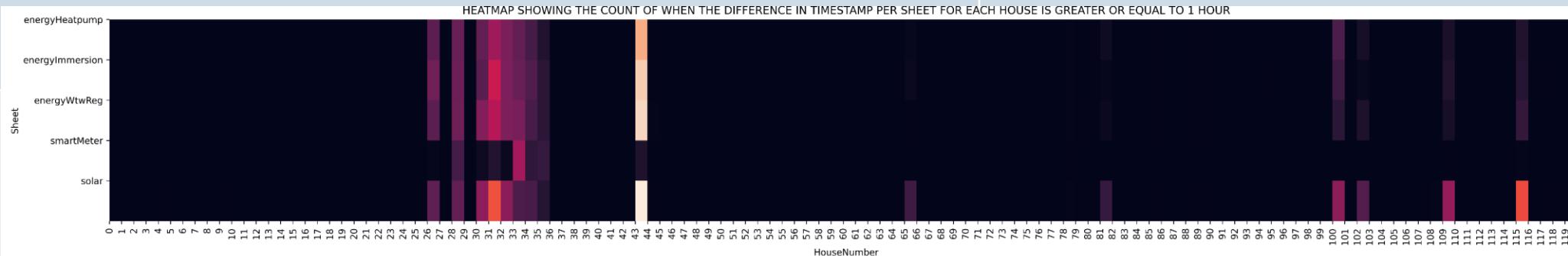
What is a suitable machine learning model to predict energy use & production of a “zero at the meter” residential house, one day in advance with (if possible) an hourly resolution?

# Consumption

- Energy Consumption =  $\text{Smart}_{\text{in}} + \text{Solar}_{\text{out}} - \text{Smart}_{\text{out}}$
- Week mean, day mean
- Hour of measurement one hot encoded (0 or 1)
- 15 weeks training
- 16<sup>th</sup> week validation
- 17<sup>th</sup> week test

# Production

- Energy Production =  $\text{Solar}_{\text{out}}$
- Hourly resolution
- 10 months training, 10 days validating, 10 days test
- Weather data from Voorschoten (within 15km radius from Zoetermeer)
  - Global irradiance (24,48,72 hours ago)
  - Outside temperature (24,48,72 hours ago)
  - Temperature (24,48,72 hours ago)



# Literature

## Short-term energy use prediction of solar-assisted water heating system: Application case of combined attention-based LSTM and time-series decomposition

Deep learning for estimating building energy consumption\*

Amirreza Heidari\*, Dolaana Khovalyg

Elena Mocanu\*, Phuong H. Nguyen, Madeleine Gibescu, Wil L. Kling<sup>1</sup>

Department of Electrical Engineering, Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands

Thermal Engineering for the Built Environment Laboratory (TEBEL), École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

## Forecasting residential gas consumption with machine learning algorithms on weather data

Brian de Keijzer<sup>1</sup>, Pol de Visser<sup>1</sup>, Victor García Romillo<sup>2</sup>, Victor Gómez Muñoz<sup>2</sup>, Daan Boosten<sup>1</sup>, Megan Meezen<sup>1</sup> and  
Tadeo Baldiri Salcedo Rahola<sup>1\*</sup>

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The Netherlands

<sup>2</sup>Faculty of Engineering, University of the Basque Country, Paseo Rafael Moreno 3 48013 Bilbao, Vizcaya, Spain

<sup>1</sup>Escuela Politécnica Superior, University Francisco de Vitoria, Carretera Pozuelo a Majadahonda, Pozuelo de Alarcón, Madrid,  
Spain

## Development of prediction models for next-day building energy consumption and peak power demand using data mining techniques

Cheng Fan, Fu Xiao \*, Shengwei Wang

Department of Building Services Engineering, The Hong Kong Polytechnic University, Kowloon, Hong Kong

Building electrical energy consumption forecasting analysis using  
conventional and artificial intelligence methods: A review

## Accuracy analyses and model comparison of machine learning adopted in building energy consumption prediction

Mohammad Azhar Mat Daut<sup>a,b</sup>, Mohammad Yusri Hassan<sup>a,b,\*</sup>, Hayati Abdullah<sup>a,c</sup>,  
Hasimah Abdul Rahman<sup>a,b</sup>, Md Pauzi Abdullah<sup>a,b</sup>, Faridah Hussin<sup>a,b</sup>

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Zhijian Liu<sup>1</sup> , Di Wu<sup>1</sup>, Yuanwei Liu<sup>1</sup>,  
Zhonghe Han<sup>1</sup>, Liyong Lun<sup>2</sup>, Jun Gao<sup>3</sup>,  
Guangya Jin<sup>1</sup> and Guoqing Cao<sup>4</sup>

# Models

- ✓ SVR
- ✓ MVLR
- ✓ MLP
- ✓ LSTM

## R<sup>2</sup>: R-squared error

The value of this error represents the linearity between the predicted value (typically called  $\hat{y}$ ) and the actual value ( $y$ ).  
[0-1]

## RMSE: Root Mean Squared Error

Is more sensitive to peaks or outliers in the data.  
[0-∞]

## MAPE: Mean Absolute Percentage Error

Represents the percentage error between  $\hat{y}$  and  $y$ .  
[0%-100%]

## MAE: Mean Absolute Error

Represents the absolute error between  $\hat{y}$  and the average value of  $y$ .  
[0-∞]

$$R^2(y, \hat{y}) = 1 - \frac{\sum_{i=0}^{n_{\text{samples}}-1} (y_i - \hat{y}_i)^2}{\sum_{i=0}^{n_{\text{samples}}-1} (y_i - \bar{y})^2}$$

$$\text{RMSE} = \sqrt{\sum \frac{(y_{\text{pred}} - y_{\text{ref}})^2}{N}}$$

$$\text{MAPE} = \frac{1}{n} \sum_{t=1}^n \frac{|Y_t - \hat{Y}_t|}{Y_t}$$

$$\text{MAE} = \frac{1}{n} \sum_{j=1}^n |y_j - \hat{y}_j|$$

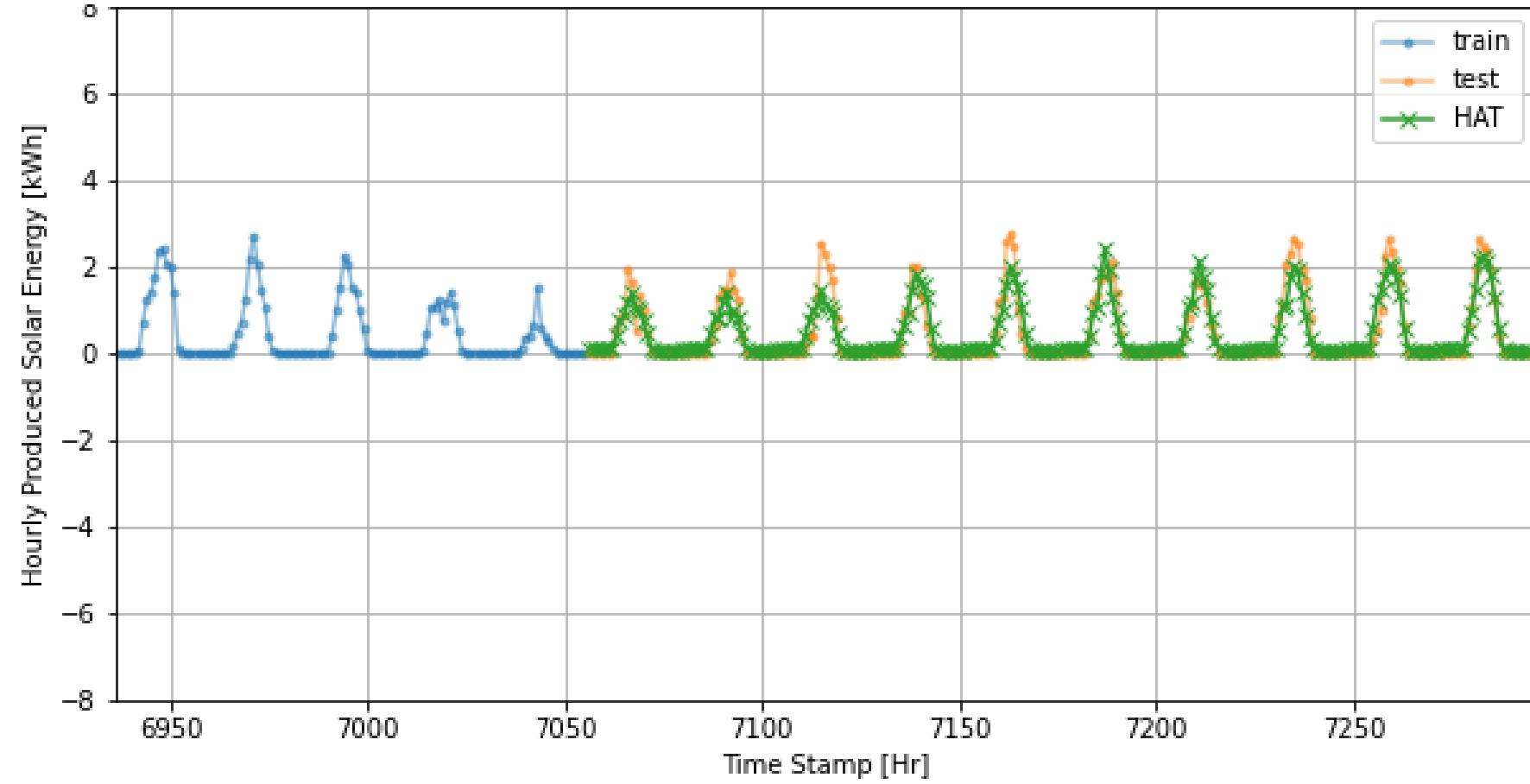
# Evaluation Metrics

Problems:

- MAPE error has trouble with really small values
- RMSE has difficulty with energy consumption data

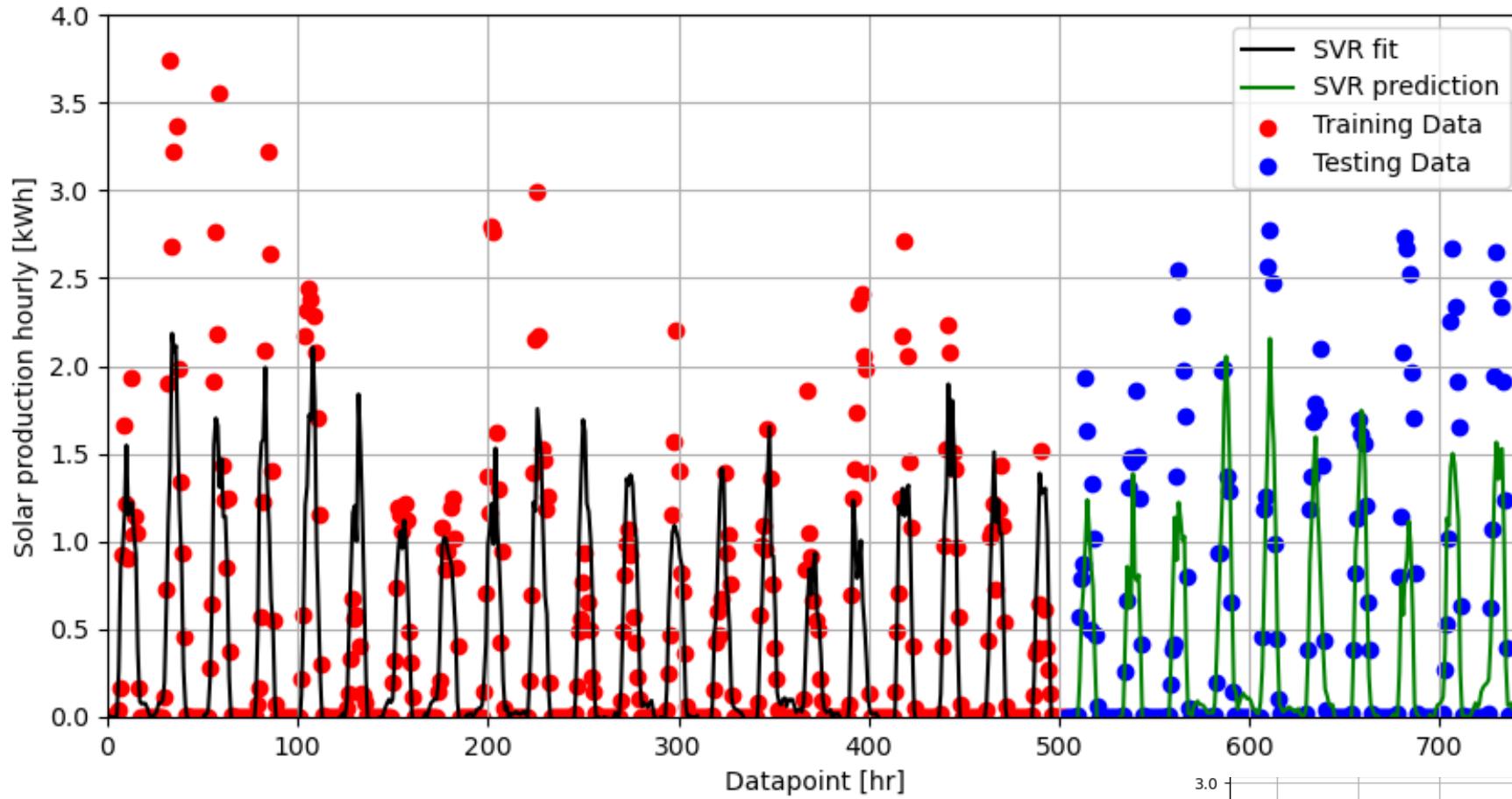
# Production

Regular patterns



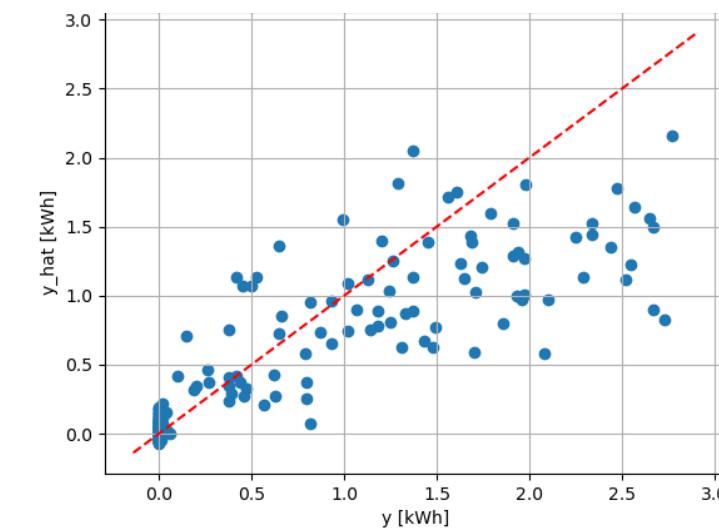
# MVLR

Multi Variate Linear Regression – Machine Learning



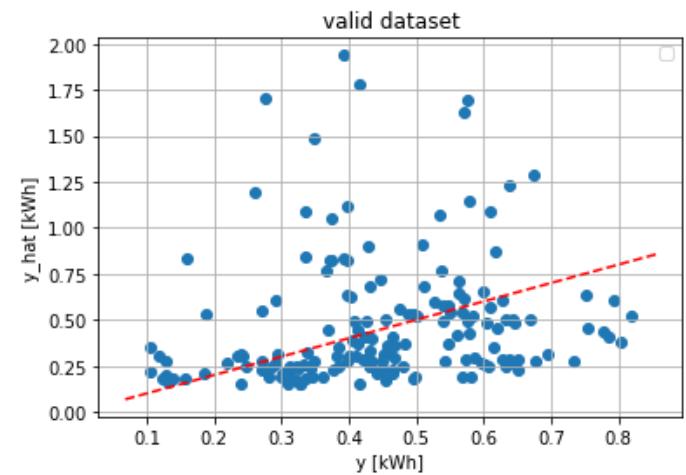
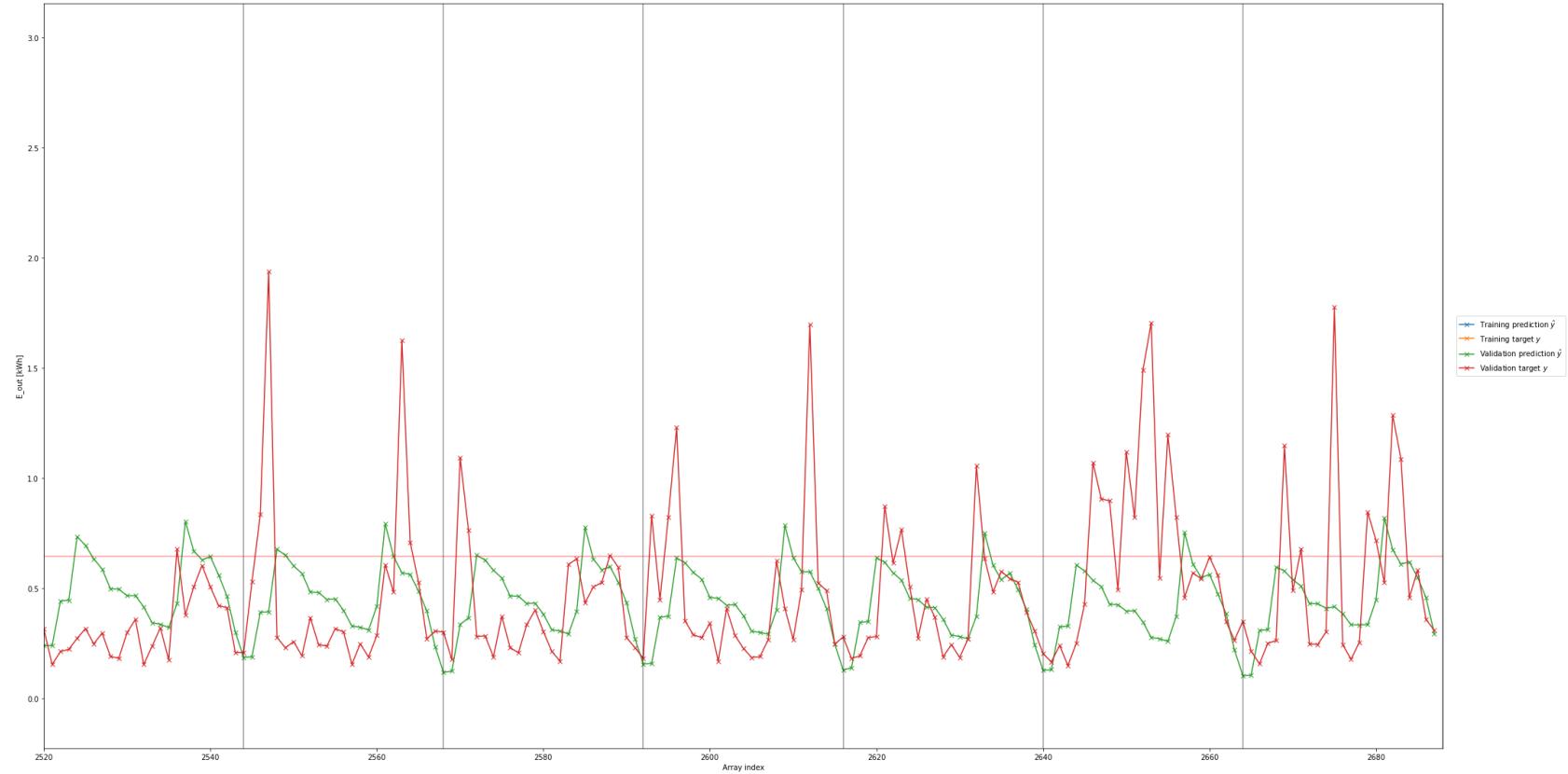
**SVR**  
(Support Vector Regression)

C-parameter: 1.0



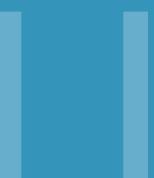
# Consumption

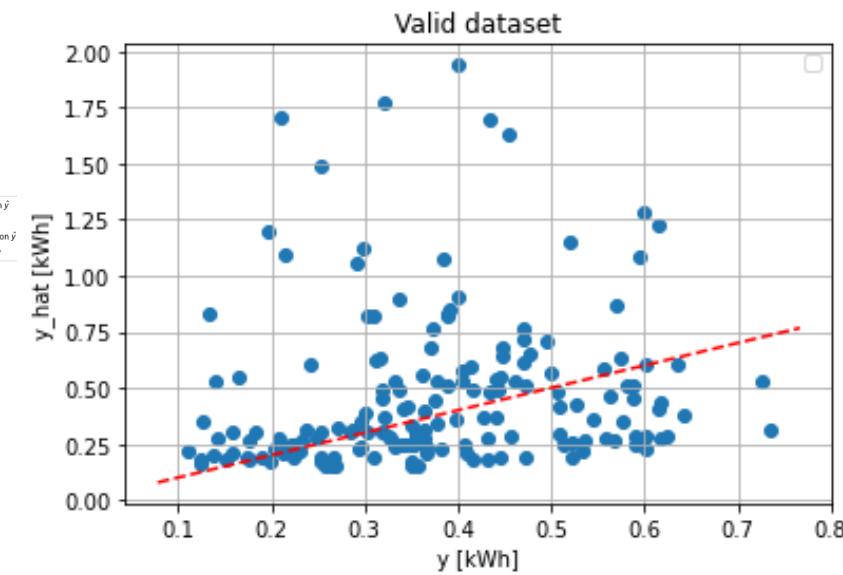
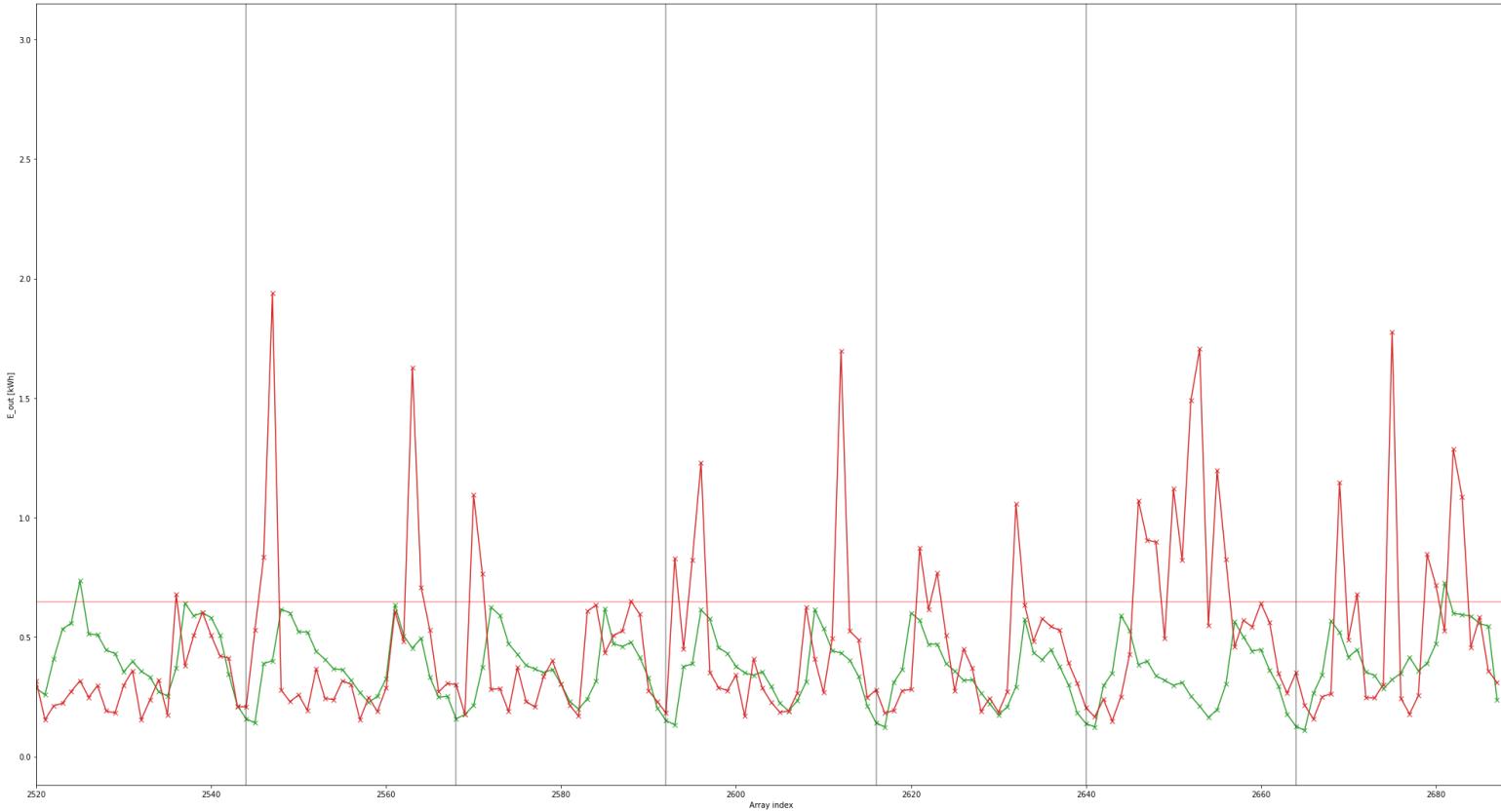
Very irregular patterns



# MVLR

(Multi Variate Linear Regression – Machine Learning)

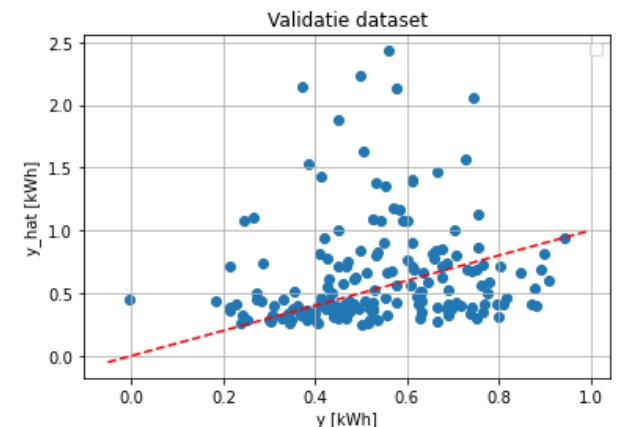
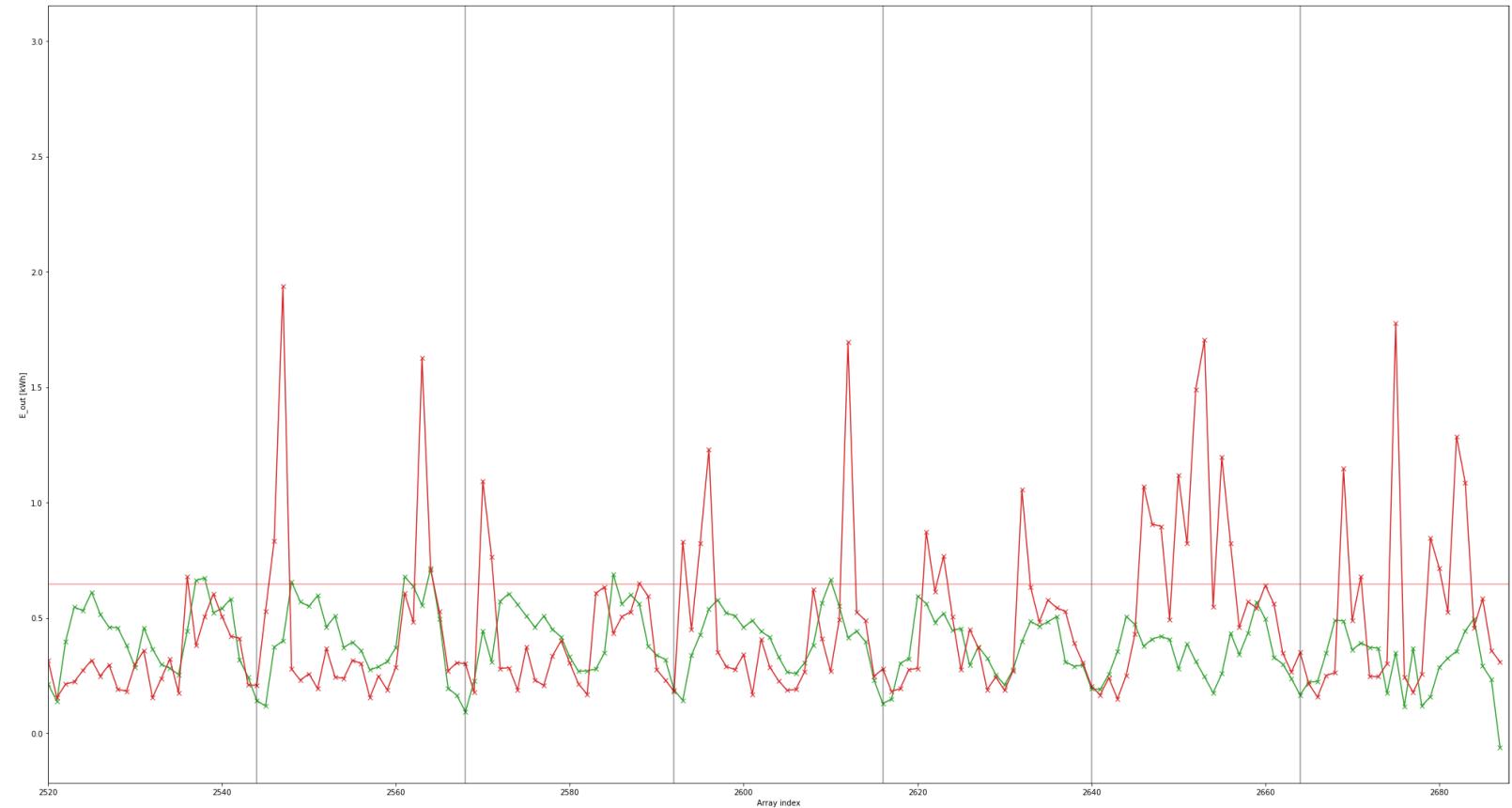




# SVR

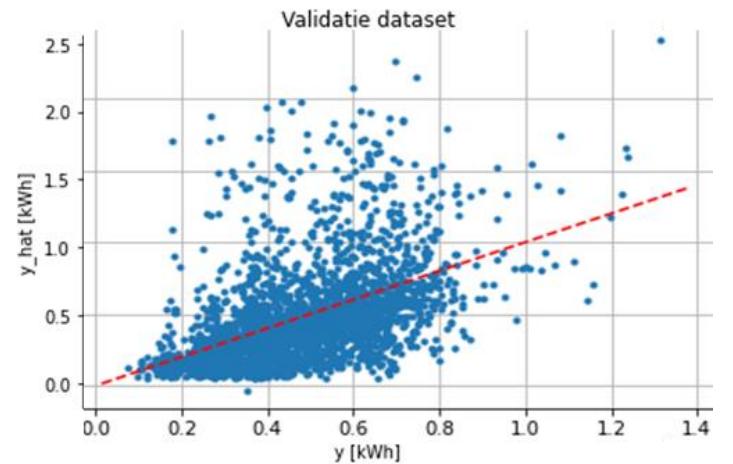
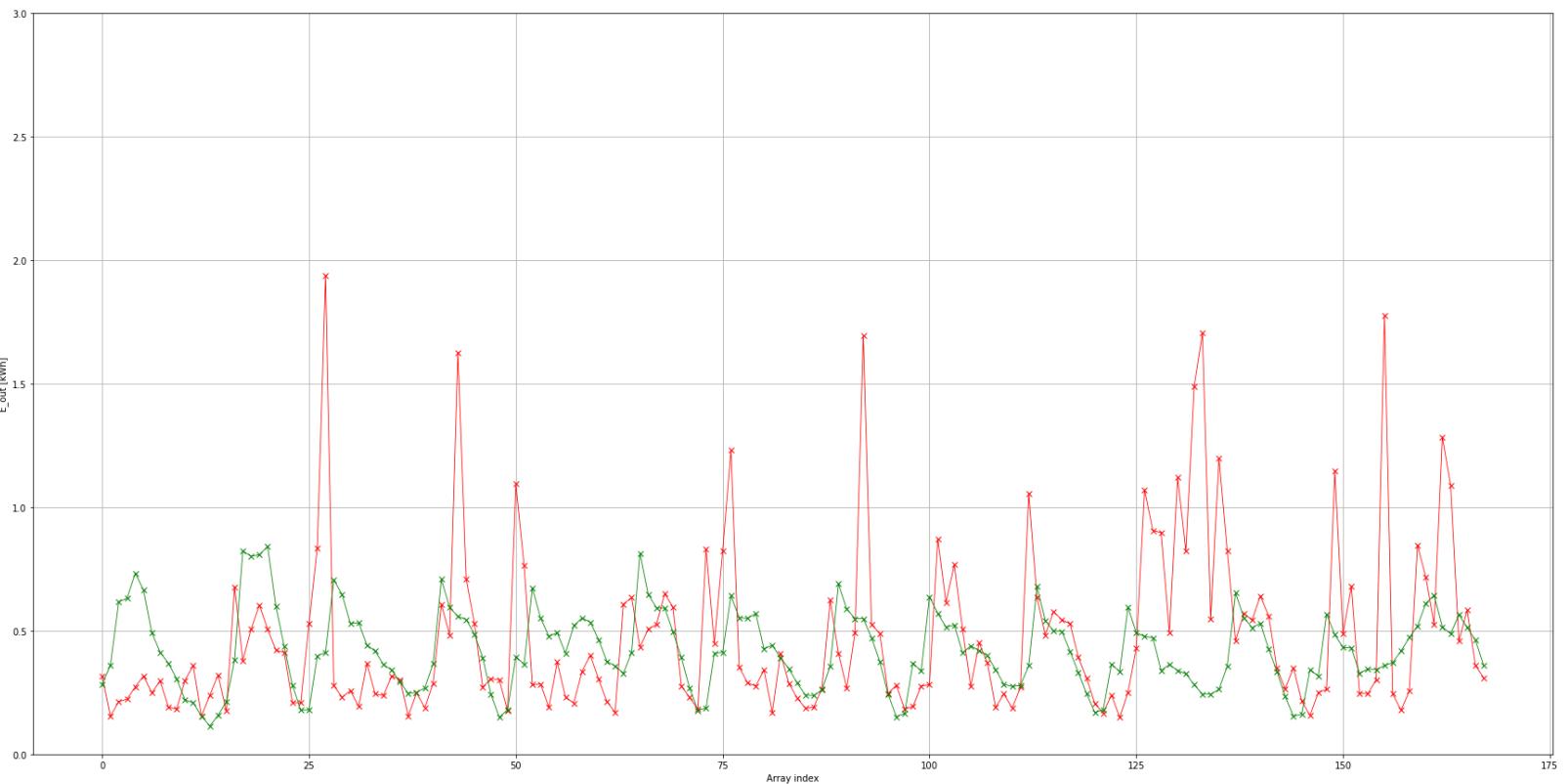
(Support Vector Regression - SVM)

C-parameter: 1.0



**MLP**  
(Multilayer Perceptron - ANN)

2 Linear layers  
loss function: MSE - loss



# LSTM

(Long Short Term Memory - RNN)

2 LSTM cells that feeds  
in 1 linear layer  
loss function: MSE - loss

# Summary

LSTM is the best method

Energy Production (over validation)

	MVLR	SVR	MLP	LSTM
R <sup>2</sup>	0.77	0.42	NTB	NTB
MAE	0.20	0.23	NTB	NTB
RSME	0.30	0.41	NTB	NTB
MAPE	Inf	inf	NTB	NTB

Energy Consumption (over validation)

	MVLR	SVR	MLP	LSTM
R <sup>2</sup>	-4.09	-5.87	-5.50	-1.77
MAE	0.24	0.23	0.29	0.20
RSME	0.36	0.37	0.45	0.30
MAPE	55.69	59.69	42.75	65.13

Green: The best score per score

# Future

- Create 2 LSTM's for peak data and non-peak data for energy consumption
- Create a similar LSTM for production
- Continue to write our paper

Remarks,  
Suggestions,  
Questions



# Open Questions:

- How much energy does a real zero at the meter house consume?
- Which appliance uses the most energy in the house?
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