5th International Conference on Smart Energy Systems
Copenhagen, 10-11 September 2019
#SESAAU2019

# Machine learning algorithms for modelling consumption in district heating systems

Danica Maljković
Energy Institute Hrvoje Požar
Zagreb, Croatia

Powered by

# Motivation & Background

- DH systems introduced mandatory individual metering in accordance with EU EED Art 14 resulting in significant dissatisfaction with a large share of final consumers
- Stipulations of the Law on Heat Market were halted from 2016 (!?) – still 30% of final consumers have not introduced individual metering (!?!?)
- Doubt that individual metering results in savings (apartment, building, network, national) – let's evaluate with AI
- Twofold application – prediction and evaluation of energy efficiency measures

# Heat Consumption (in DH)

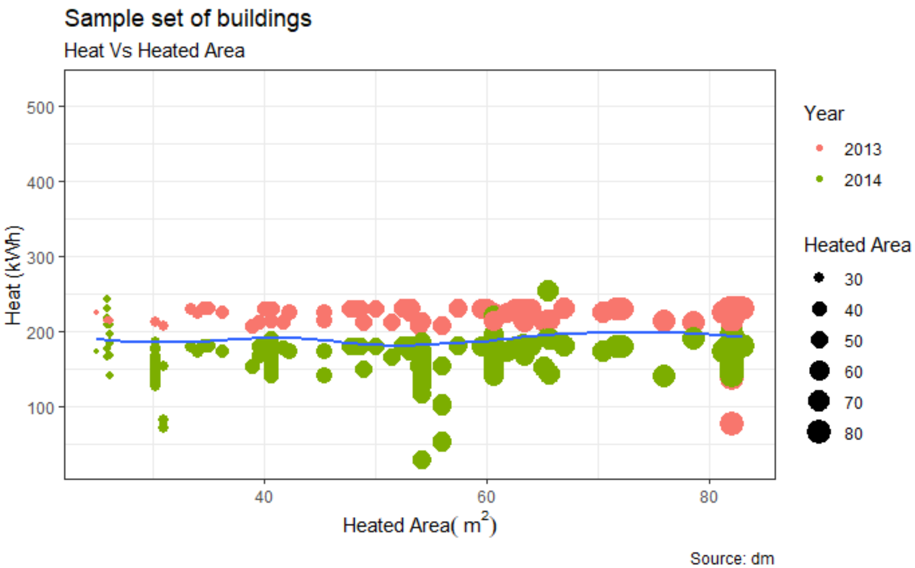
- Depends on a number of parameters of which some measurable and predictable, while other are hard to predict
- Measurable/predictable:
  - building envelope characteristics
  - heating degree days (climatology)
  - number of occupants
  - schedule of space usage
  - energy source
  - building heat installation losses (including heating substation)
  - position of the apartment in the building
  - formula for calculating consumption in case of HCA
  - existence of individual metering
- Hard to predict:
  - heat gains/losses form adjacent apartments
  - heat comfort level in the apartment
  - mode od space usage (opening windows)
  - income level of the owner, readiness to pay

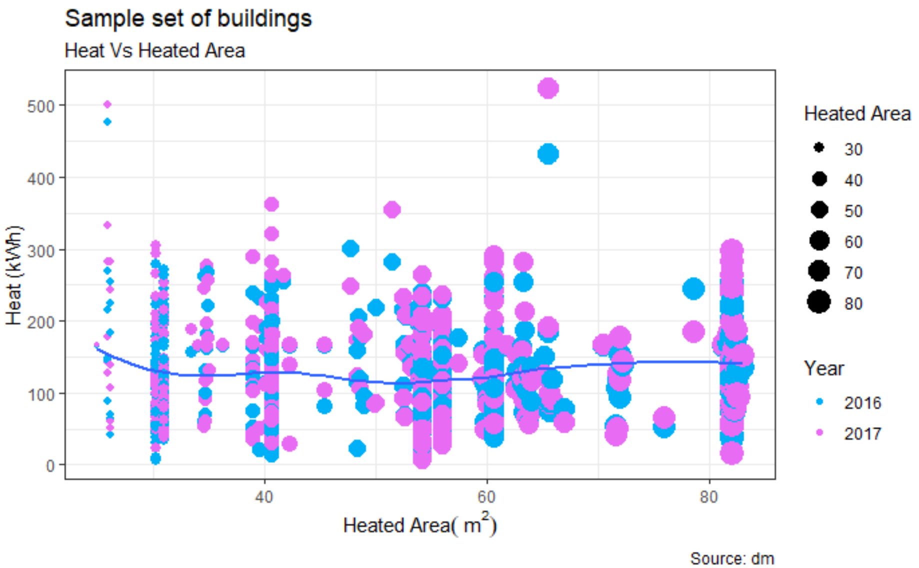
# Data ?

- Most accessible and reliable = billing data
- Time series: from 2010 to Dec 2018 (individual metering introduced in 70% of buildings in 2015)
- Additionally – questionnaire with behavioral data
- Data frame matrix of ~5,000,000 observations in 50 predictors
- Statistical learning with machine learning algorithms:

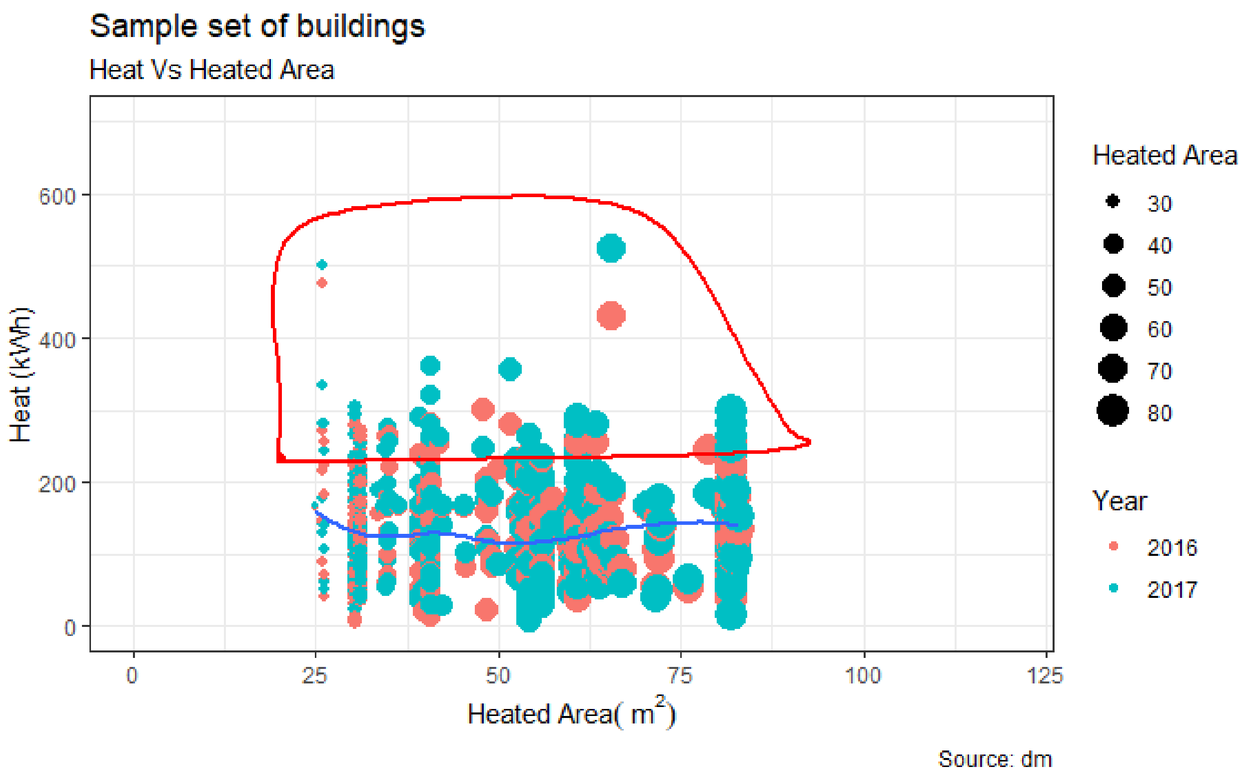
  Linear Regression, Logistic Regression, Decision Trees, Random Forest, Support Vector Machines (for now)

# Did we save? Yes…

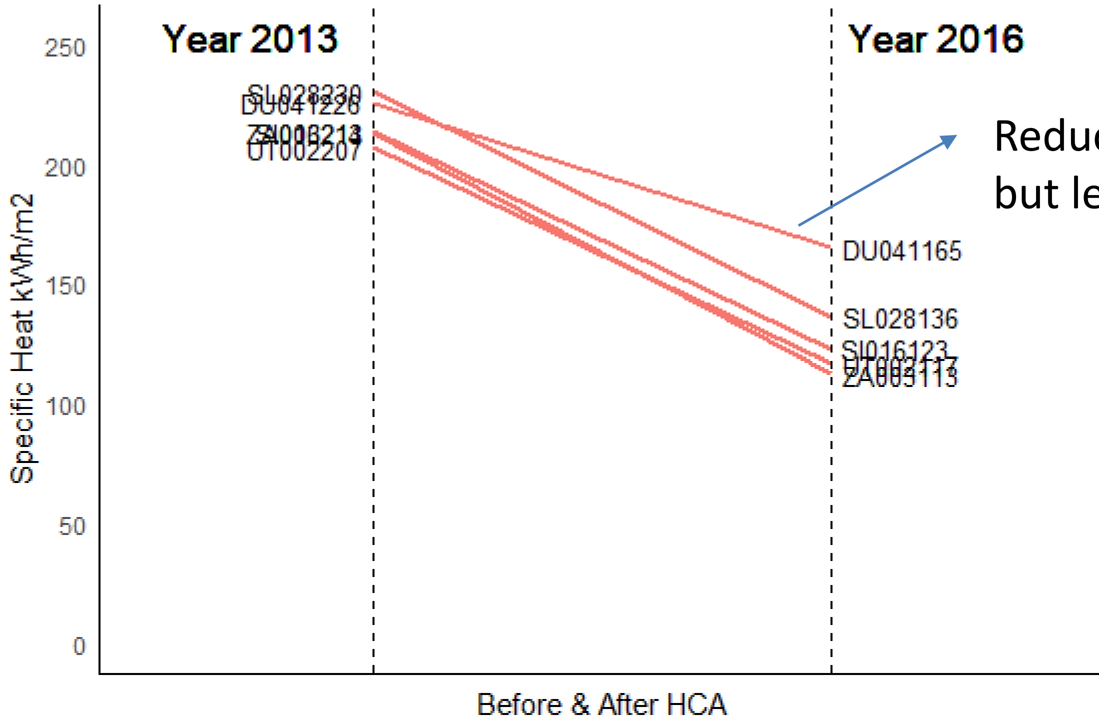


# ...but... (on the apartment level):

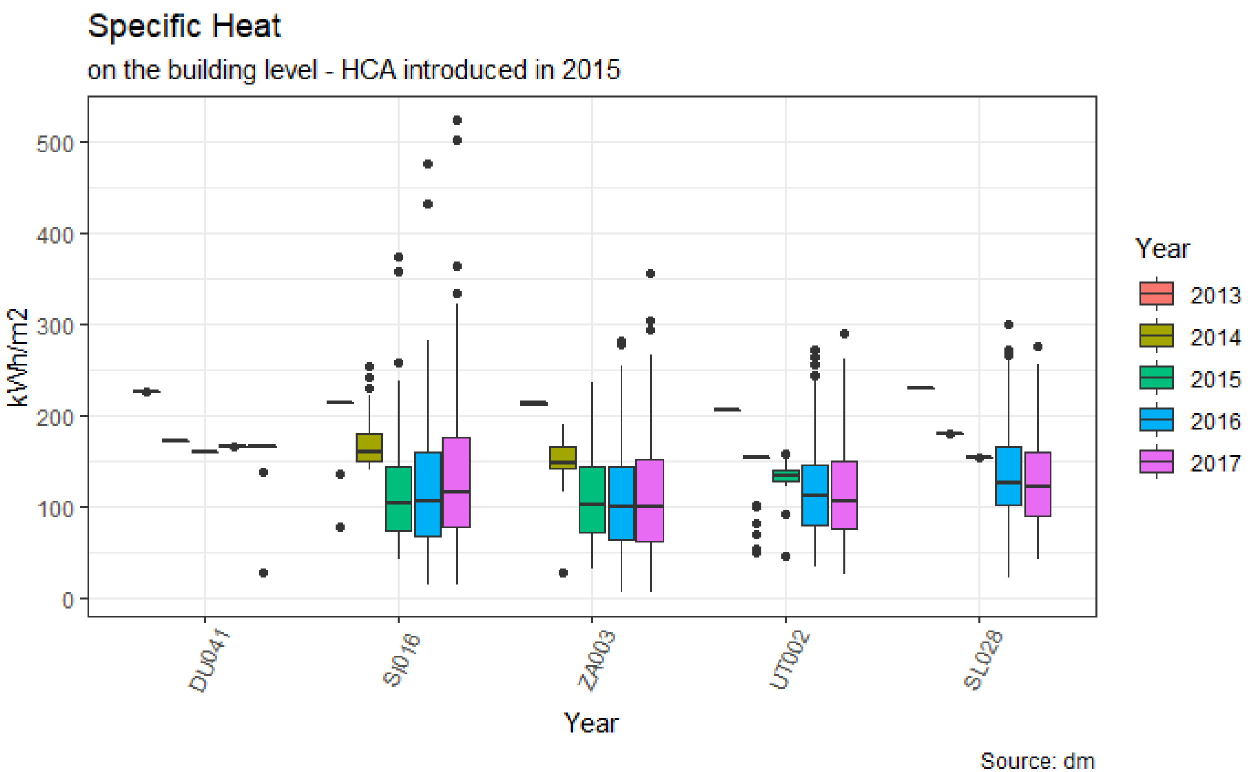


# Building level?

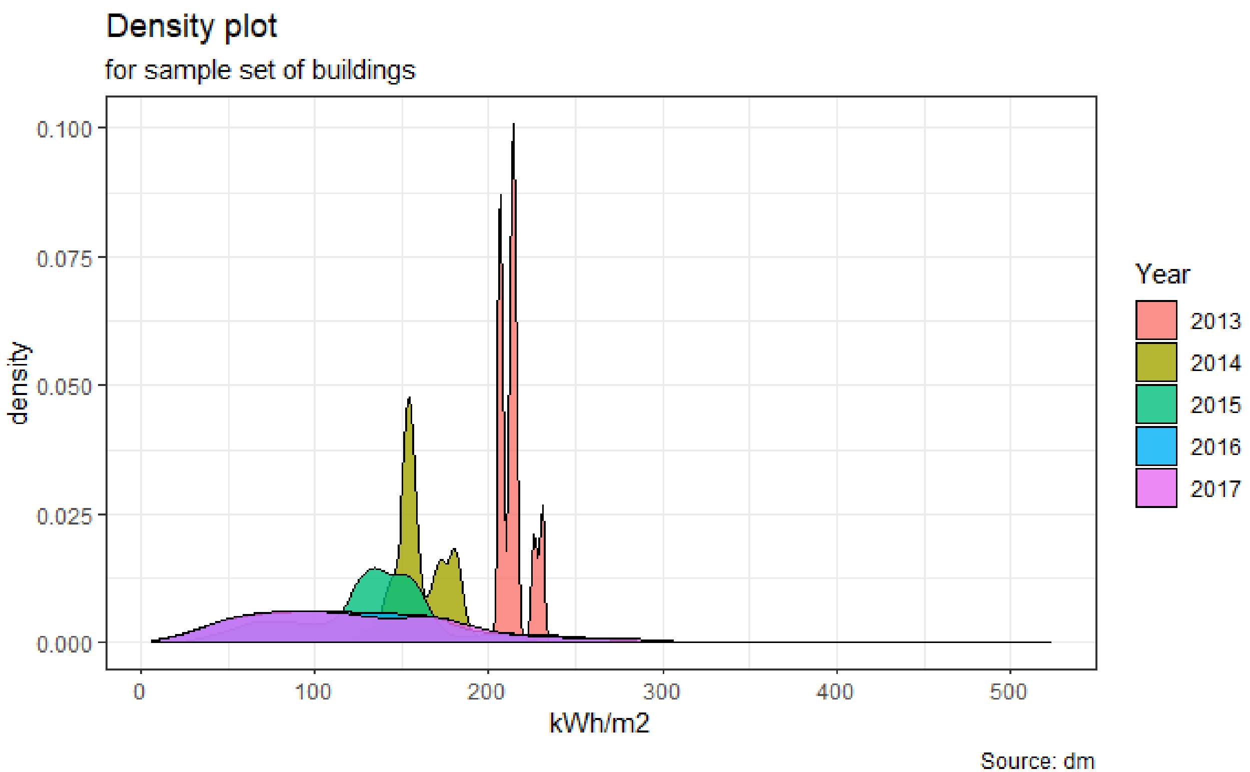



Reduced, as well, but less steep…

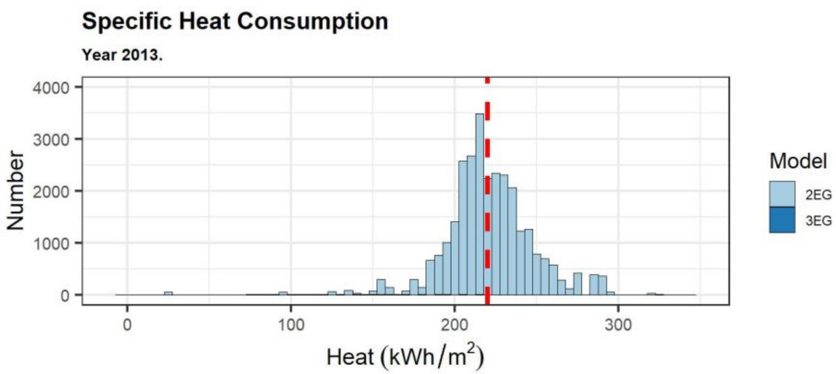
# Here come the outliers

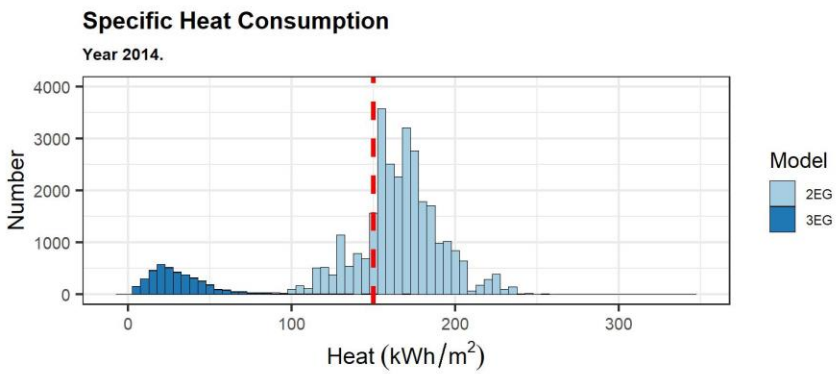


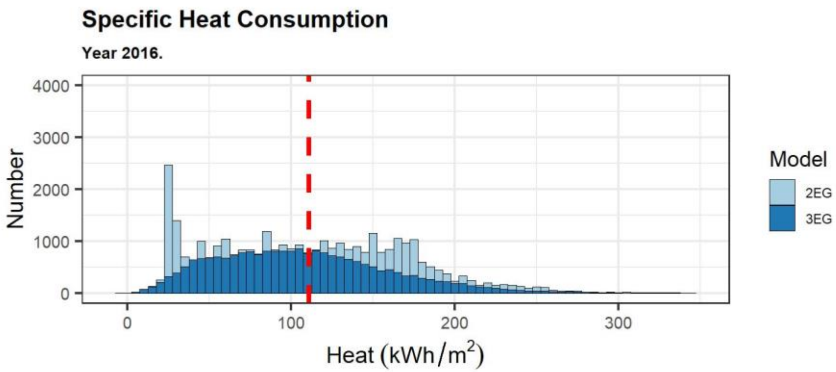
# Data distribution seems more “normal”

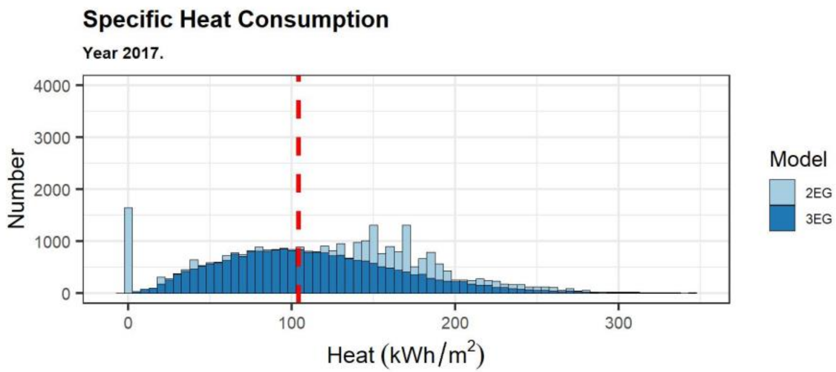


# Network / Town Level



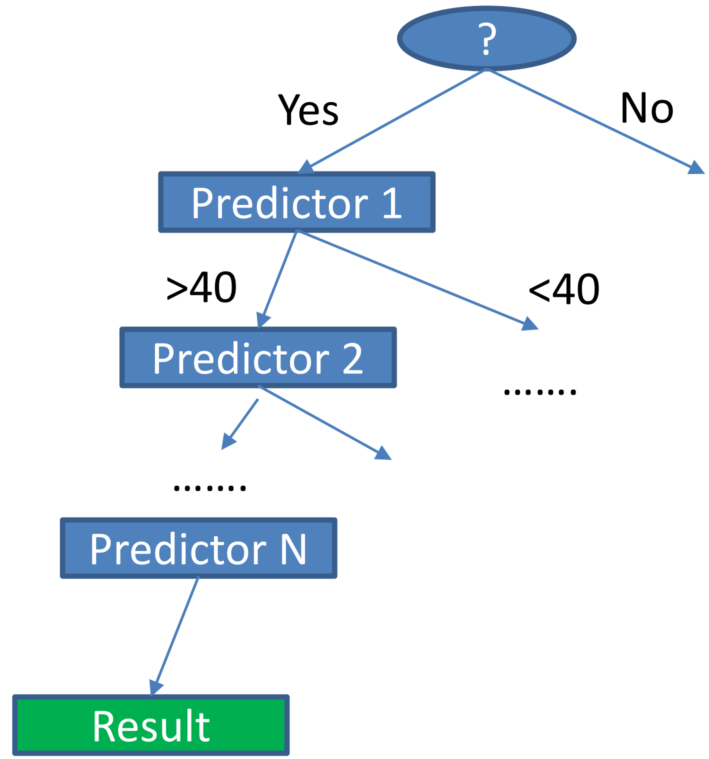



# Learning and predicting

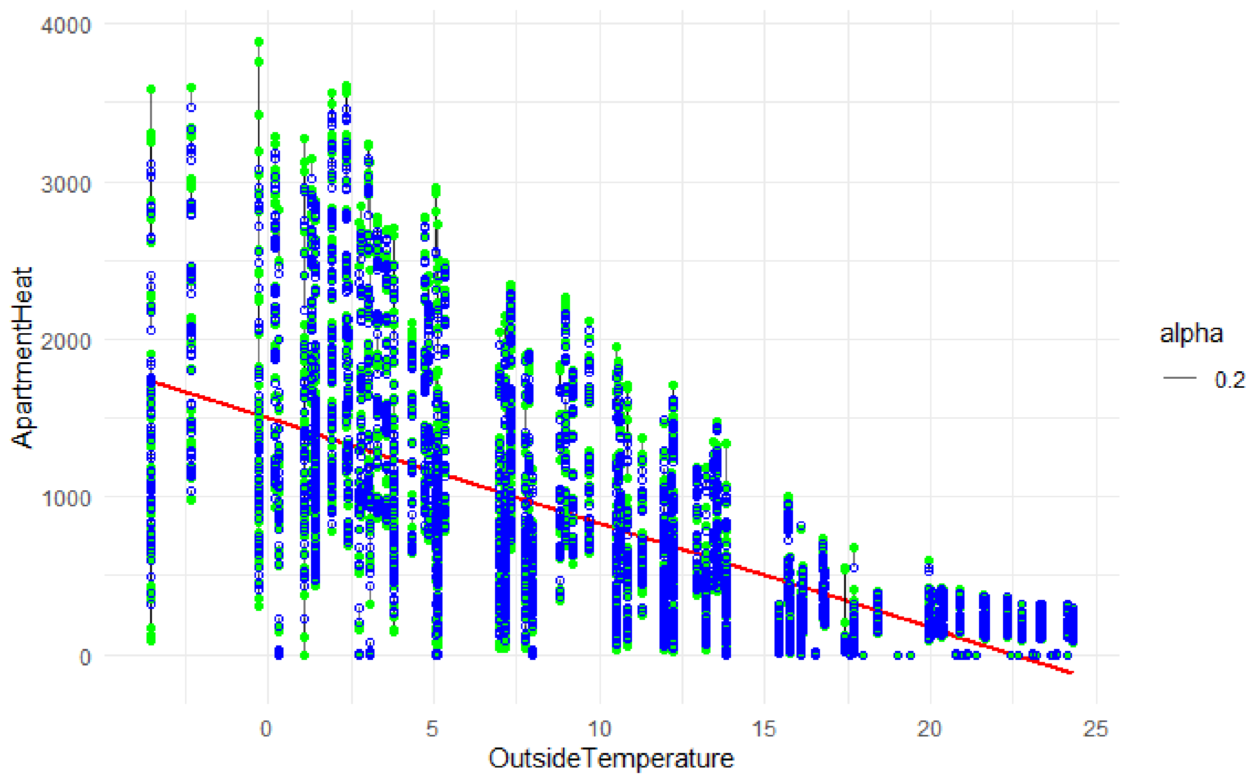
1. Take a portion of the data set (60-80%) and learn on it.
2. Test what you have learned on the remaining portion (20-40%). If accuracy level is satisfactory:
3. Predict on the “new” data and use the model.

# Foresting the District Heating

- Random Forest – best fit for (green) DH
- Pros:
  - great prediction performance, robust, good variable importance estimate
- Cons:
  - less interpretable, computationaly intensive



# Fitting of new data - prediction



# Fitting accuracy is quite high

Type of random forest: regression

Number of trees: 500

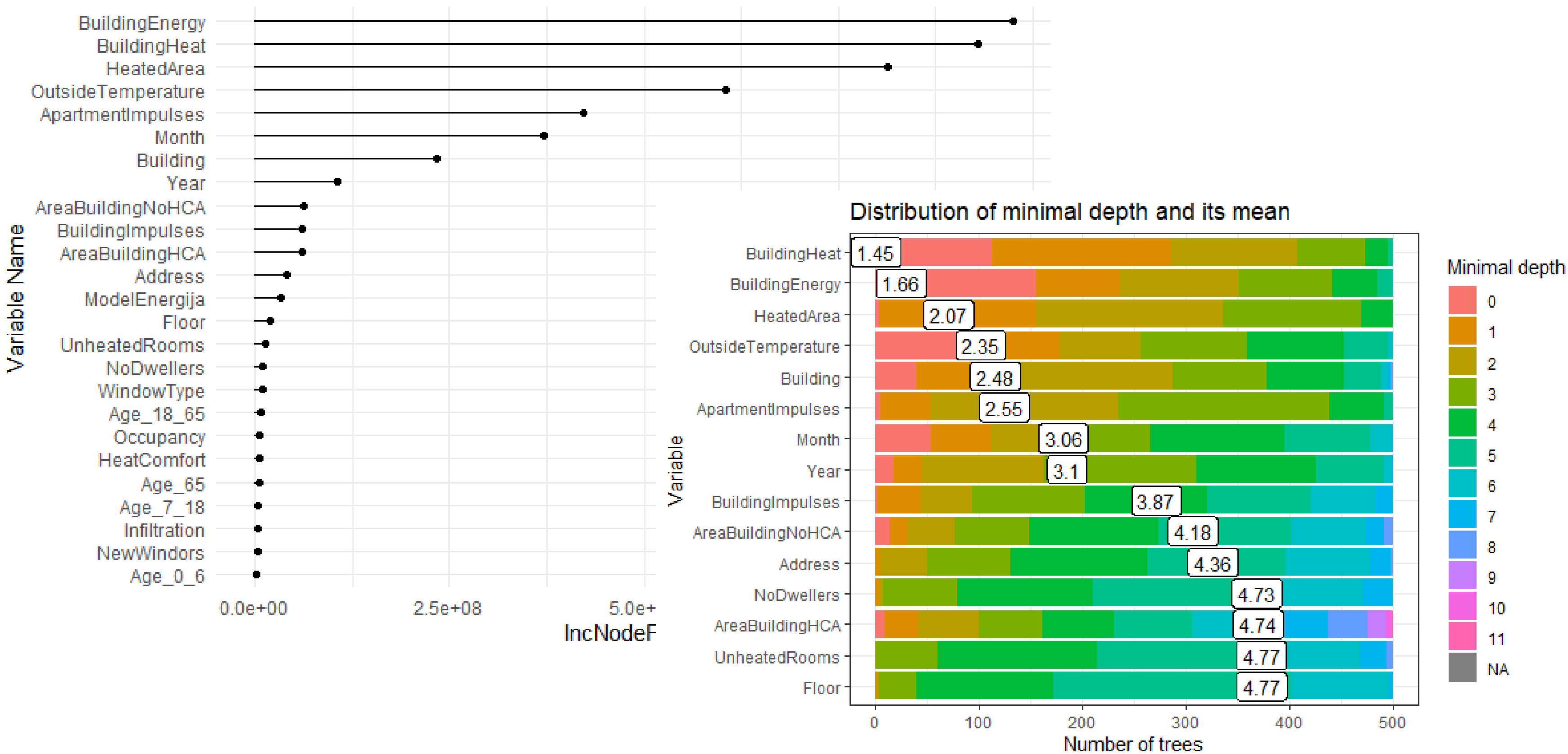
No. of variables tried at each split: 8

Mean of squared residuals: 3075.775

(~55 kWh error)

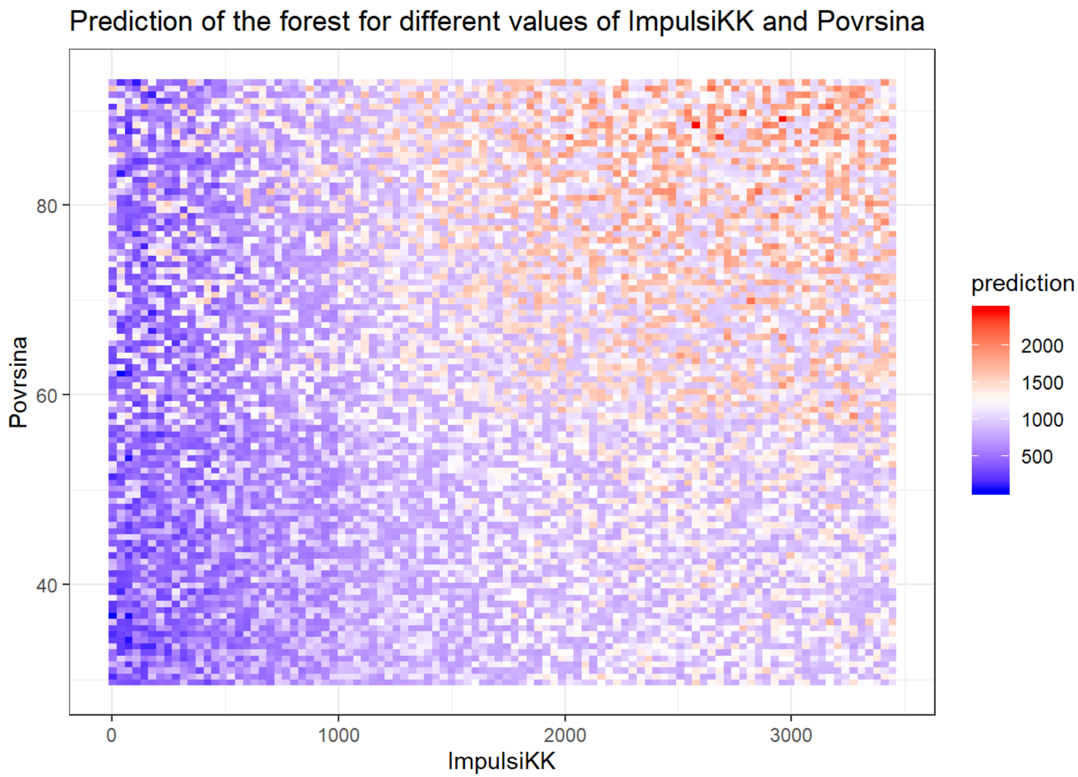
% Var explained: 99.44

# Importance plot




Powered by

# Predicting


Prediction of the forest for different values of ImpulsiKK and Povrsina
Povrsina
80
60
40
0
1000
2000
3000
ImpulsiKK
prediction
2000
1500
1000
500

# Conclusions & Further Steps

- Building energy consumption modelling and the usual methods used are traditional multiple regression models, simulation methods and methods of artificial neural networks
- In the last years machine learning has gain larger application in various fields – „chewing of data"
- Gives good results in cases where large amounts of data are to be processed with an aim to recognize a pattern and correlation of each of the relevant parameter as well as in the cases where the problem is too complex for a human intelligence to solve
- Testing the results on other data sets, networks, cities, climates
- Important variables crucial for determing policy in energy efficiency
- Deep learning

Danica Maljković
Energy Institute Hrvoje Pozar
Zagreb, Croatia
dmaljkovic@eihp.hr

# QUESTIONS & THOUGHTS?