Phd day

Meteorology forecasts, machine learning and technical losses forecasts

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Personal research interest

- Enabling high penetration of renewables into power systems

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- Enabling high penetration of renewables into power systems
  - Energy storage
    - How to get around high cost?
    - Using existing (or soon to be existing) infrastructure
    - Electric vehicles + V2G (vehicle to grid)
  - Renewables forecasting
    - Very low cost (once developed)
    - A few supercomputers for the whole world
    - A lot of sensors (input data)

Research goals (or hopes)

- Apply forecasting to Croatia:
  - Wind (in progress)
  - Solar (hopefully from satellite images)
  - Loss (this presentation)
  - Load (maybe)
- Determine necessary dynamic reserves
  - Present scenario
  - High penetration of renewables scenario
  - Calculate cost from traditional reserve sources
- Include electric vehicles
  - Calculate the cost of supplying reserve from electric vehicles

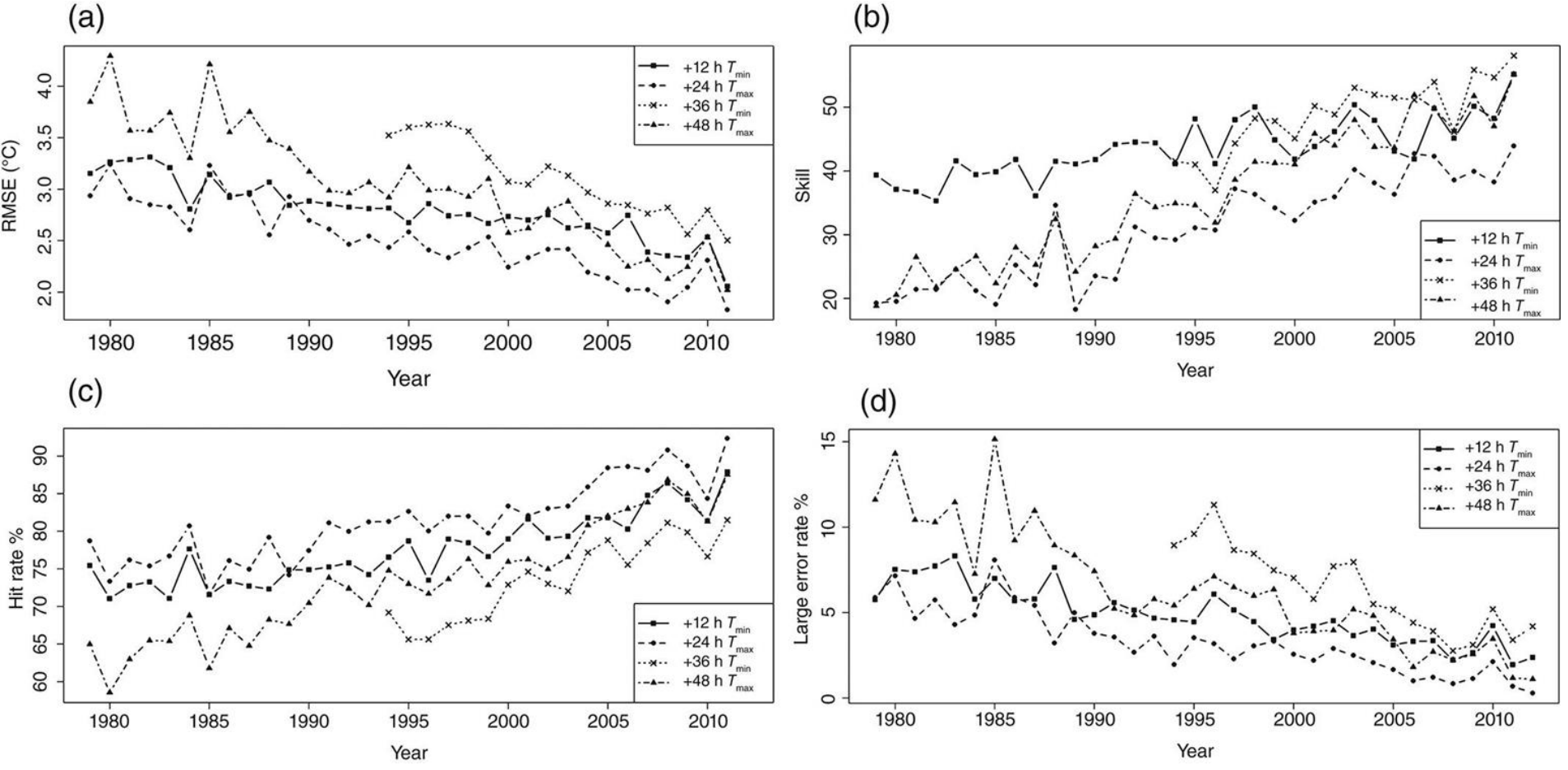
Research tools

- Weather forecasts
  - Always increasing in accuracy and precision (slow, but steady progress)

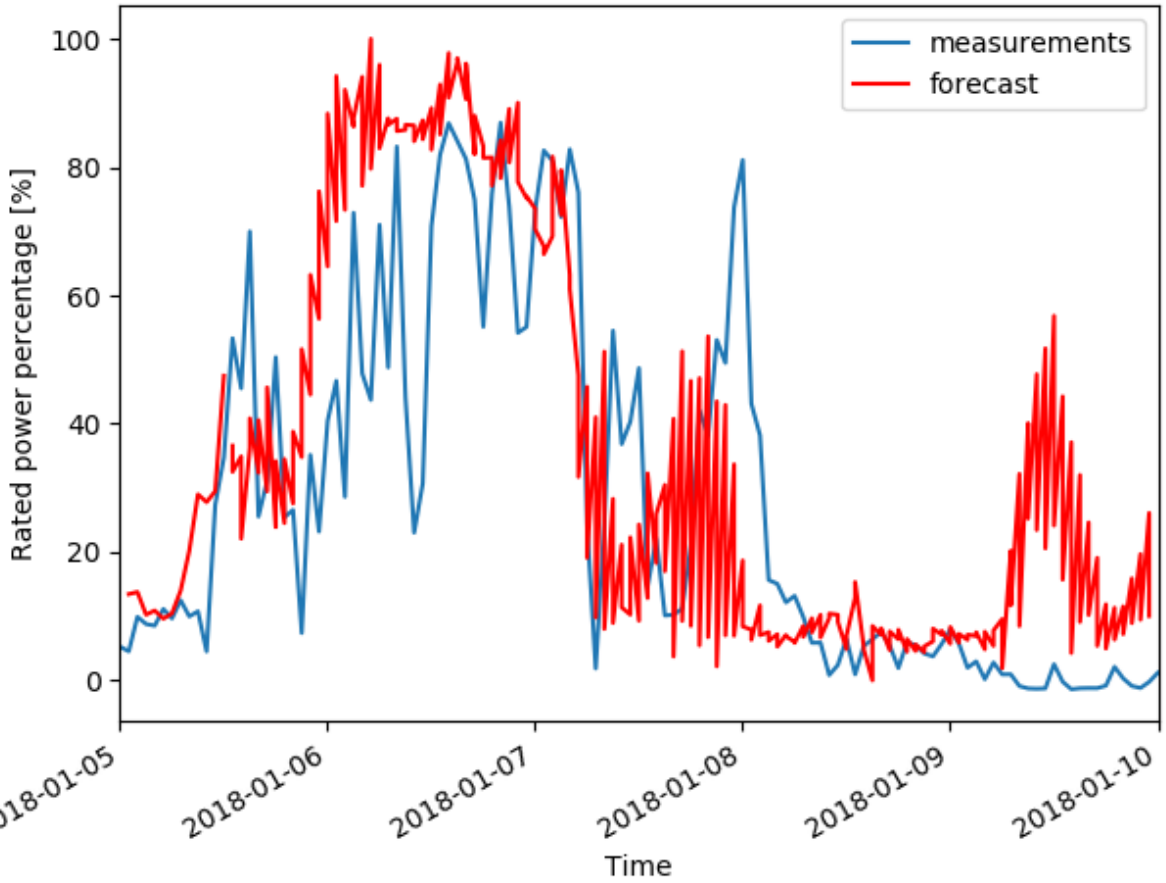
- Machine learning
  - Recent explosion of algorithms
  - Increasing size of data
  - Increasing hardware capabilities
  - Decreasing hardware cost (cloud GPU rental)
  - Extremely fast improvement

Meteorological forecasts

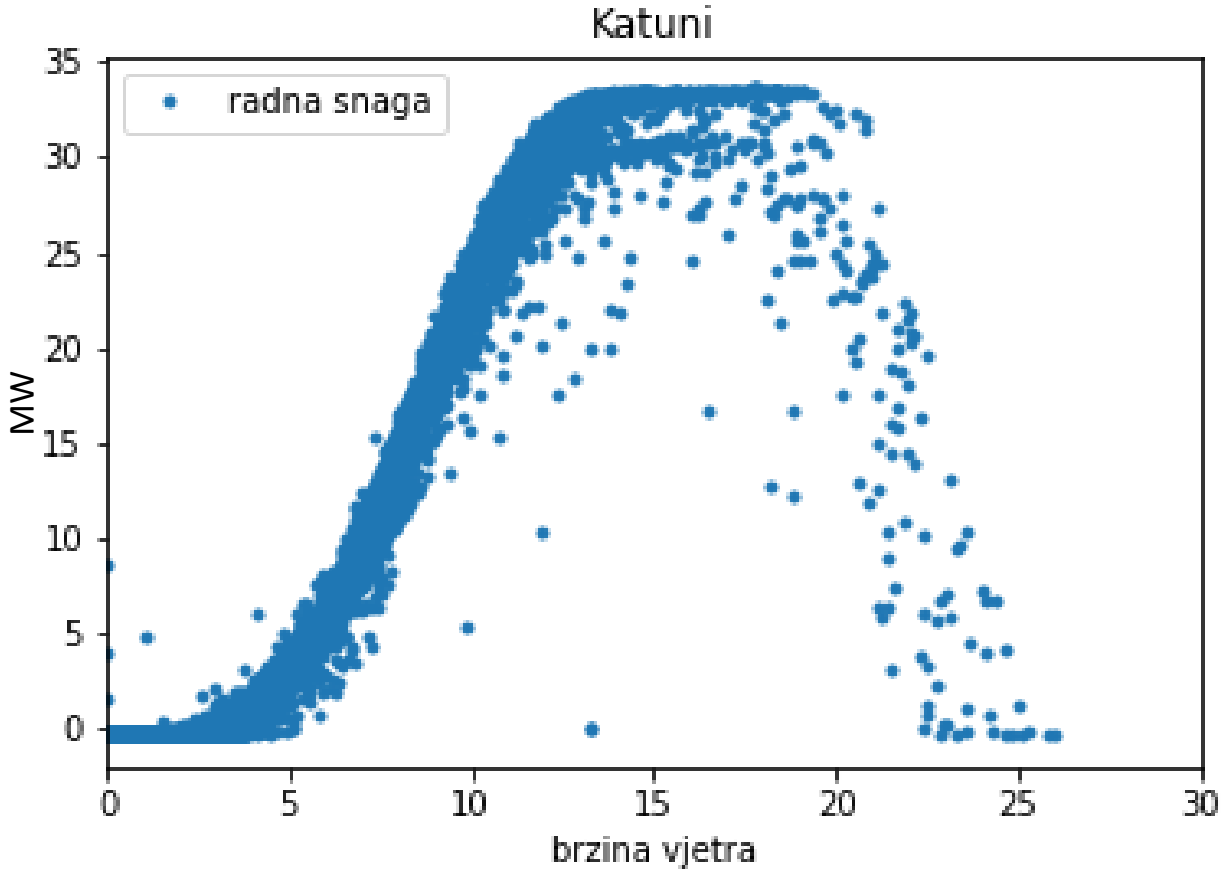
Meteorological error rate reduction



Wind forecasts

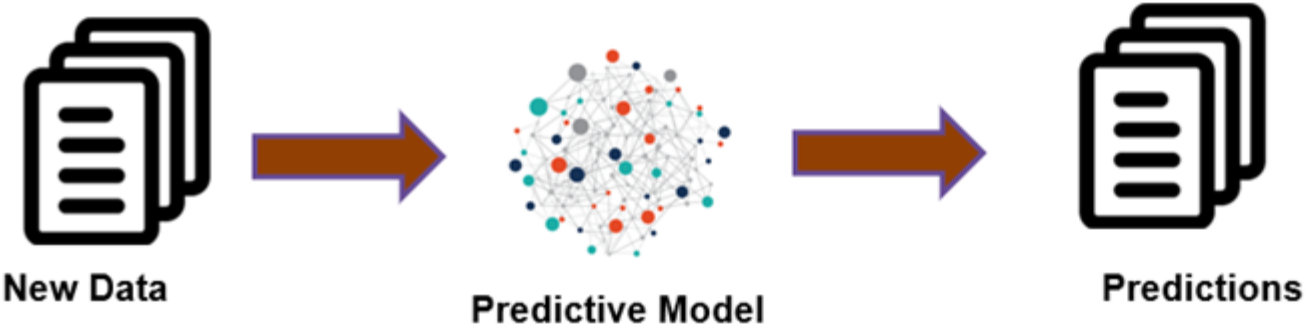


Weather forecast

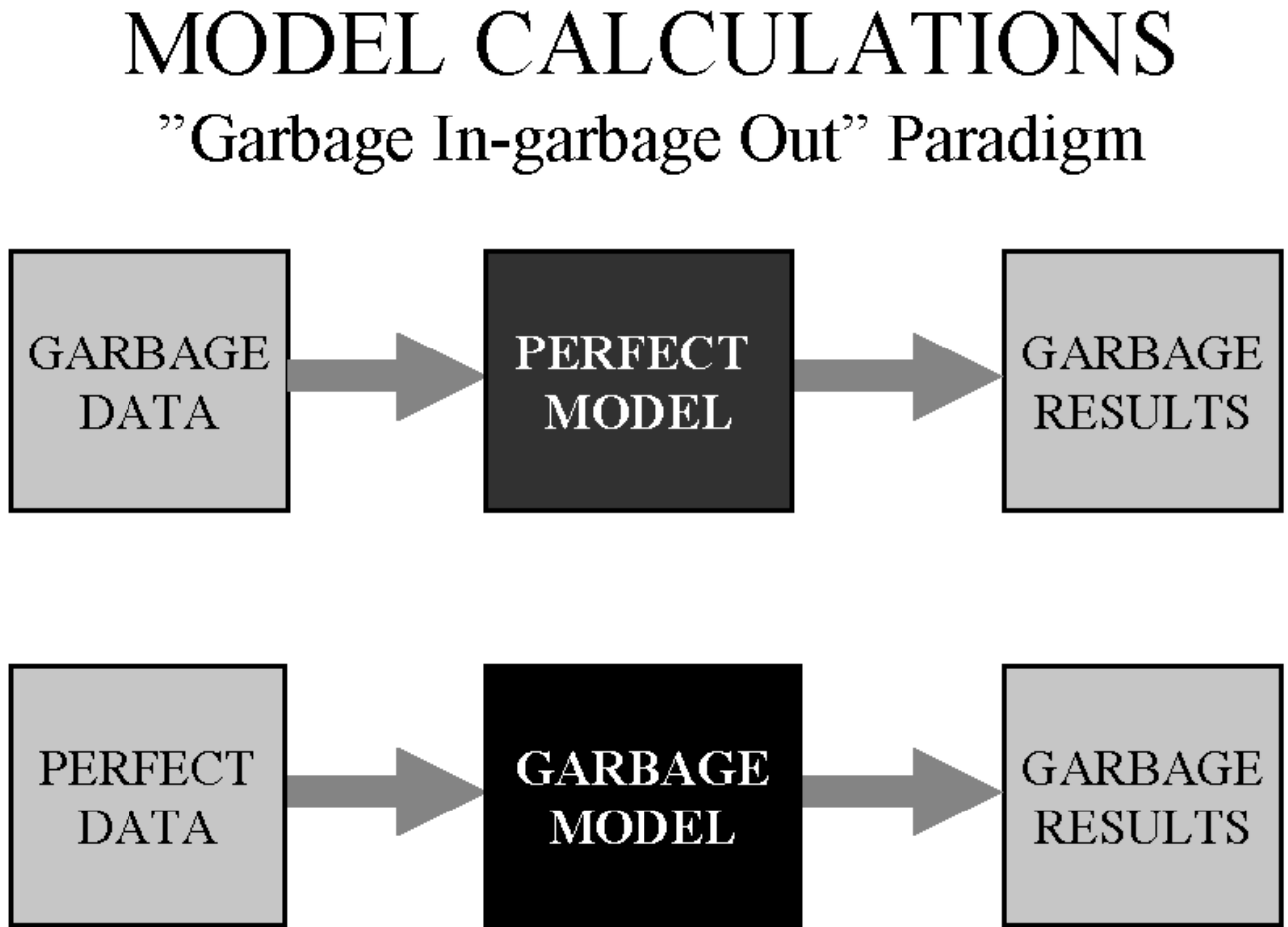


Machine learning tools

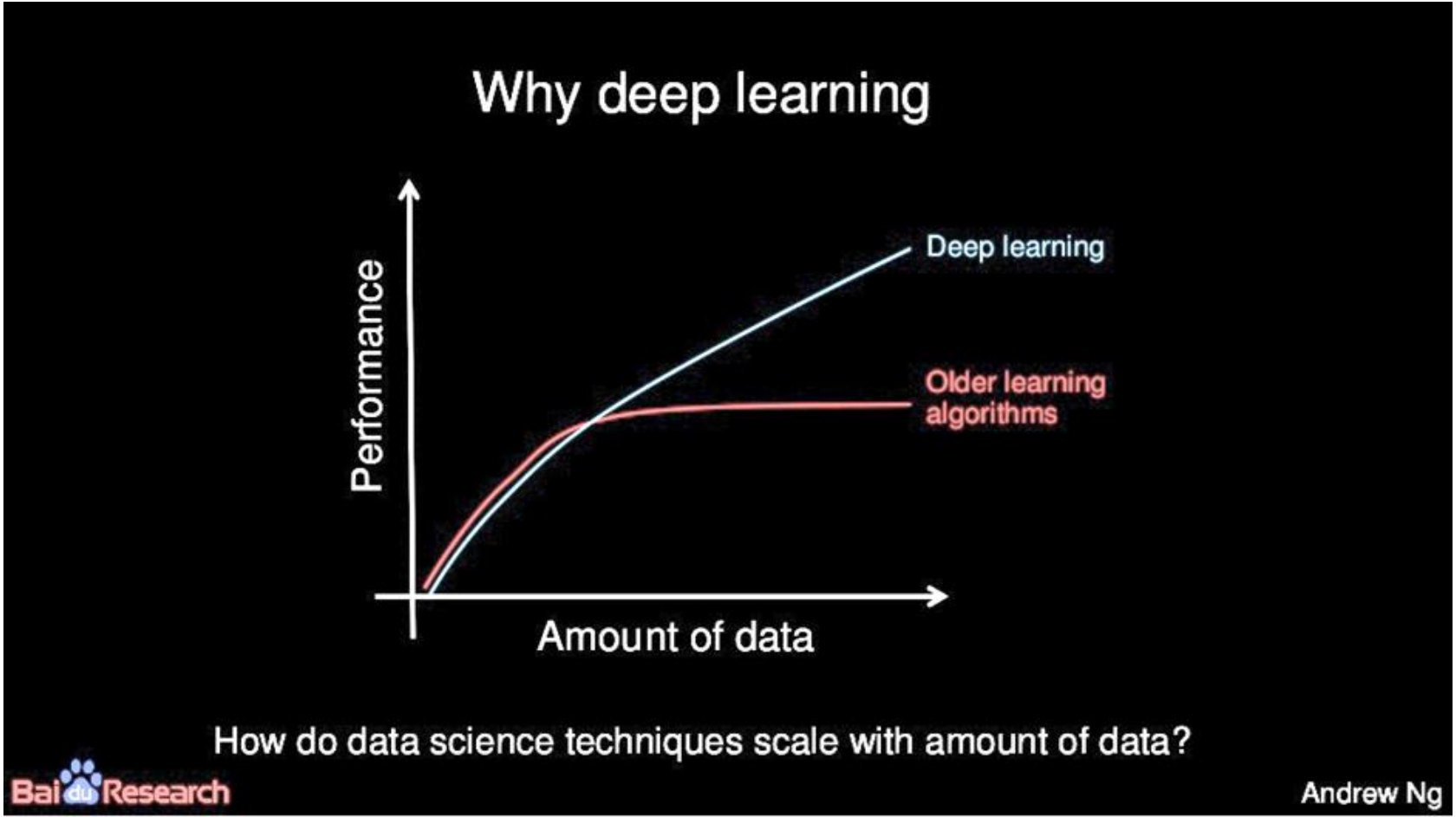
Machine learning - different type of programing



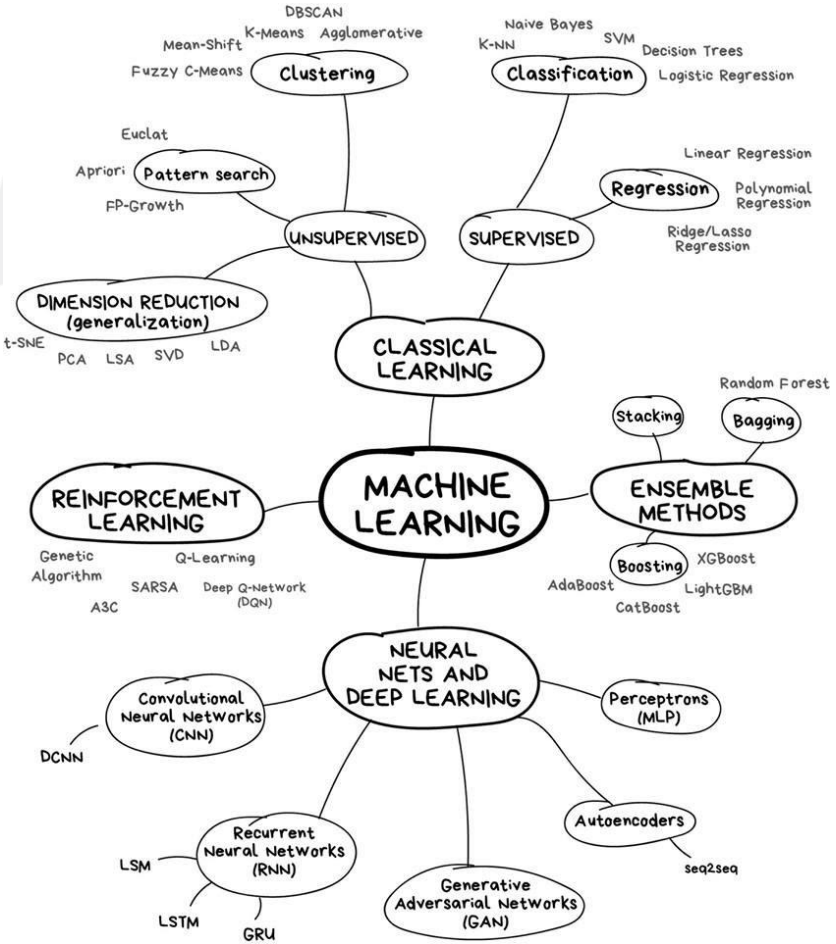
Importance of data in machine learning



Deep learning vs. classical machine learning



Machine learning algorithms



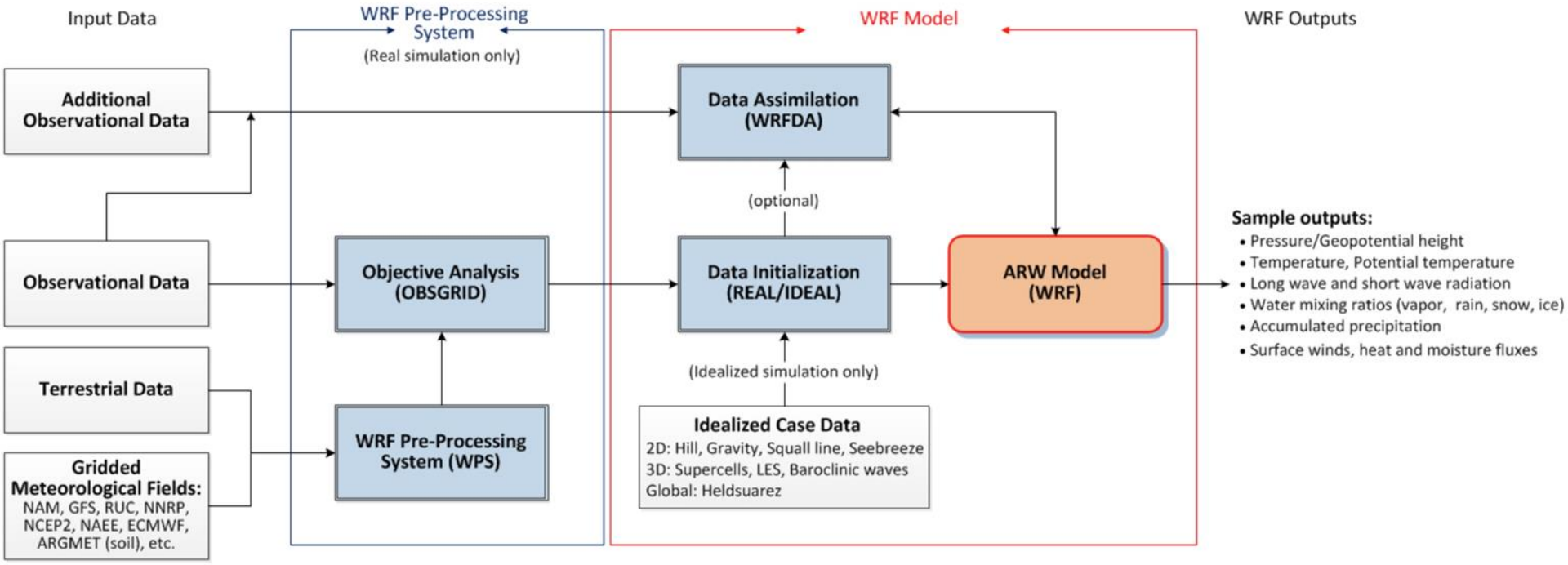
Loss forecast for Croatian TS (HOPS) as a whole

Loss forecast approaches

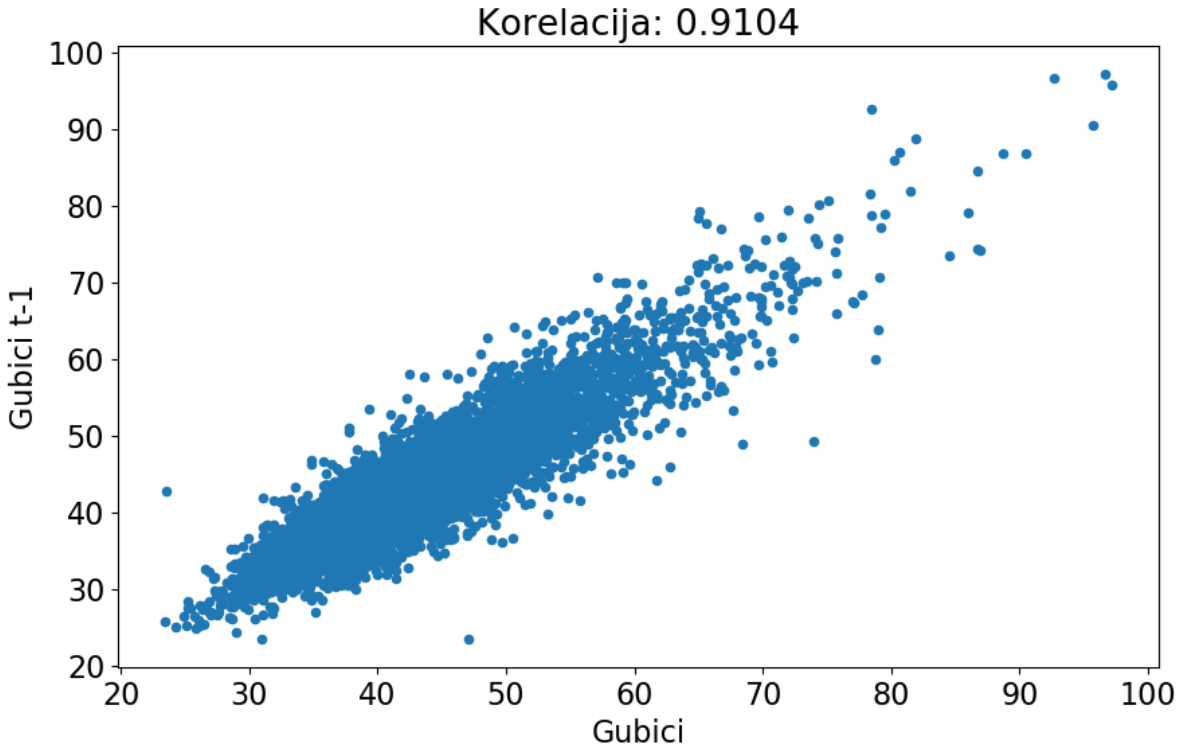
- Forecasting approaches:
  - Expert approach
  - Data driven - machine learning
- Expert approach to loss forecast:
  - Power flow forecasting (for each line)
  - Load forecast
  - Loss forecast
    - Joule loss model
    - Corona loss model
    - Leakage loss model
- Machine learning
  - Based on a very large input datasets
  - Possible without (a lot of) expert understanding

Input data for the machine learning model

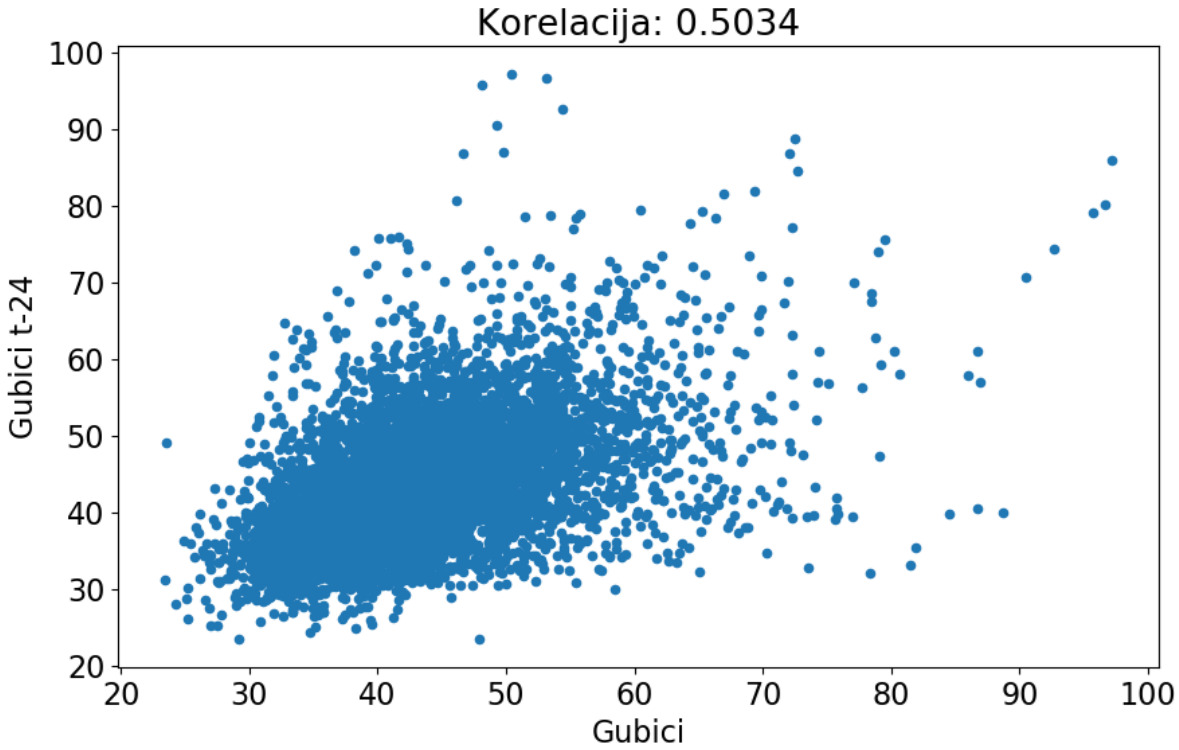
Weather Research and Forecasting (WRF) Model



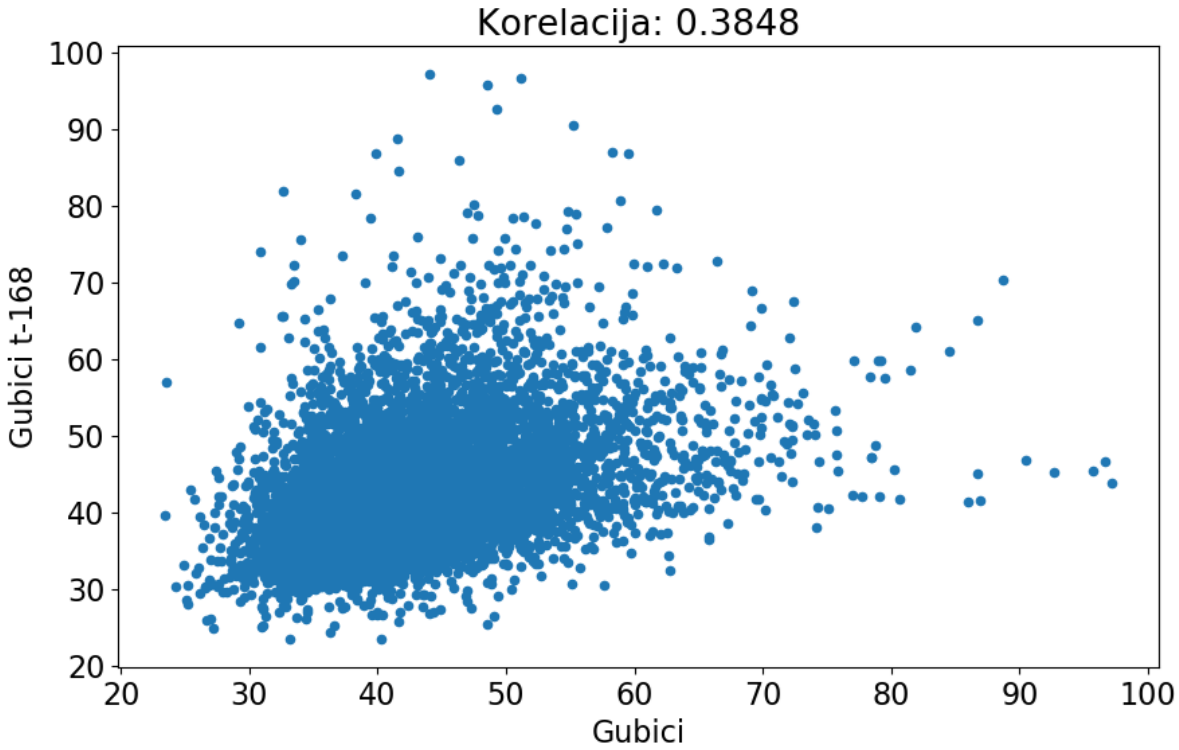
Time correlation of line losses - hour before



Time correlation of line losses - day before



Time correlation of line losses - week before

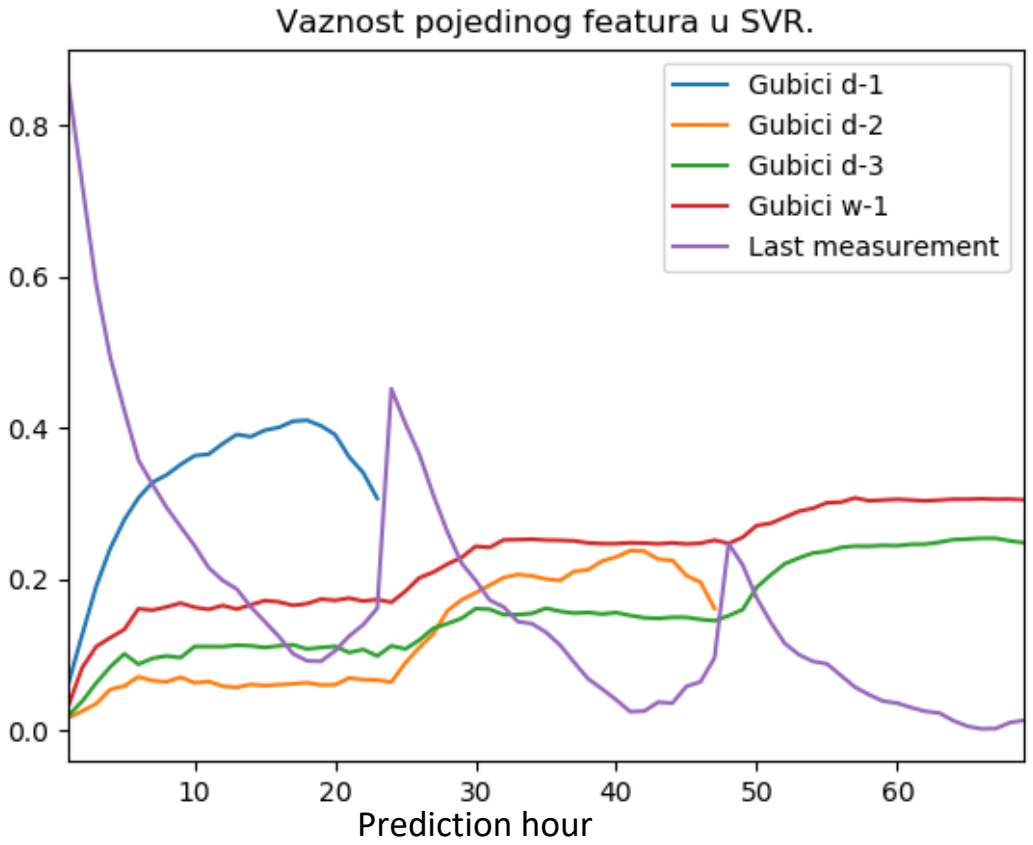


SVR model (Machine learning) results

Predictor analysis - without meteo

Predictor weight:

Loss w-1	1
Last measurement	11.675584
Loss d-3	1
Loss d-1	7
Loss d-2	5

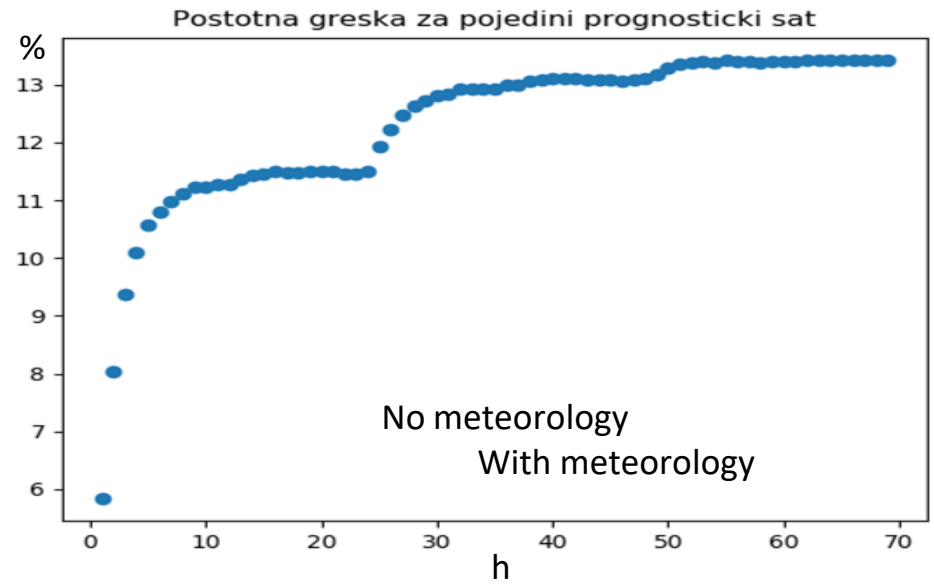


Predictor analysis - with meteo

Predictor weight:

SnowAMP TS Osijek1	194.869347
SnowAMP TS Pehlin	83.703287
Wind speed (80m)AMP TS Vrboran	73.991987
Wind speed (80m)AMP TS Pehlin	64.360965
SnowVE Benkovac	60.940352
Wind speed (50m)AMP TS Pehlin	31.591584
Wind speed (10m)AMP TS Vrboran	29.622861
Wind speed (30m)AMP TS Pehlin	26.213715
Tlak zraka n. m. razini VE Benkovac	25.883561
Wind speed (50m)VE Benkovac	19.217919
loss w-1	16.225416
Temp. zraka (2m)AMP TS Vrboran	14.291587

SVR model results - percentage error for each hour



HOPS baseline forecast vs. FER-SVR forecast

Improvement over baseline:

March - October 2019.

FER realistic data: 31%

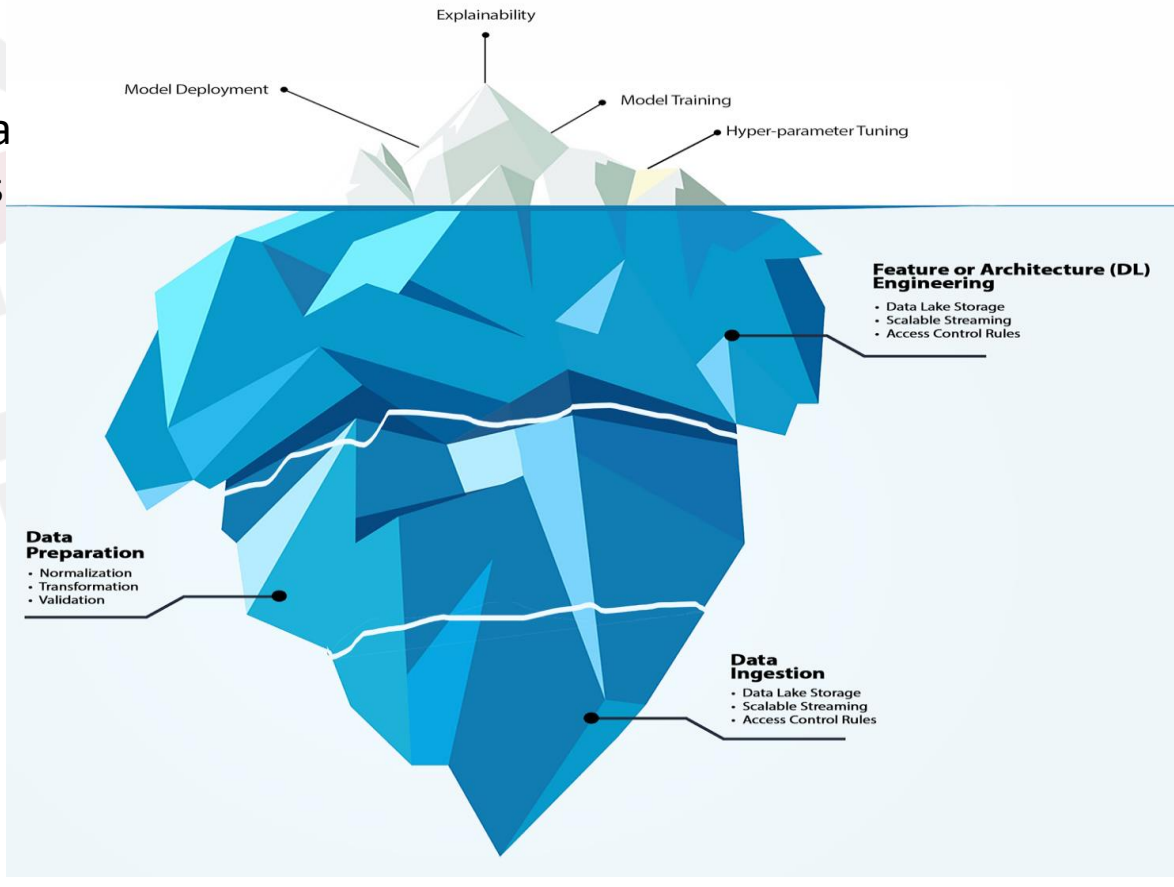
FER all data: 48%

Future work and conclusions

Conclusion

- Created loss forecasting tool
- Learned to use
  - meteorological forecast data
  - basic machine learning tools

- Future work
- Forecasting:
  - Finish wind forecast
  - Solar forecast
- Dynamic reserves cost analysis
- Dynamic reserves cost reduction (by including electric vehicles)



Thank you for you attention!

Acknowledgments

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