Research trends in green networking

Marco Ajmone Marsan, **Michela Meo**,
Daniela Renga, Greta Vallero

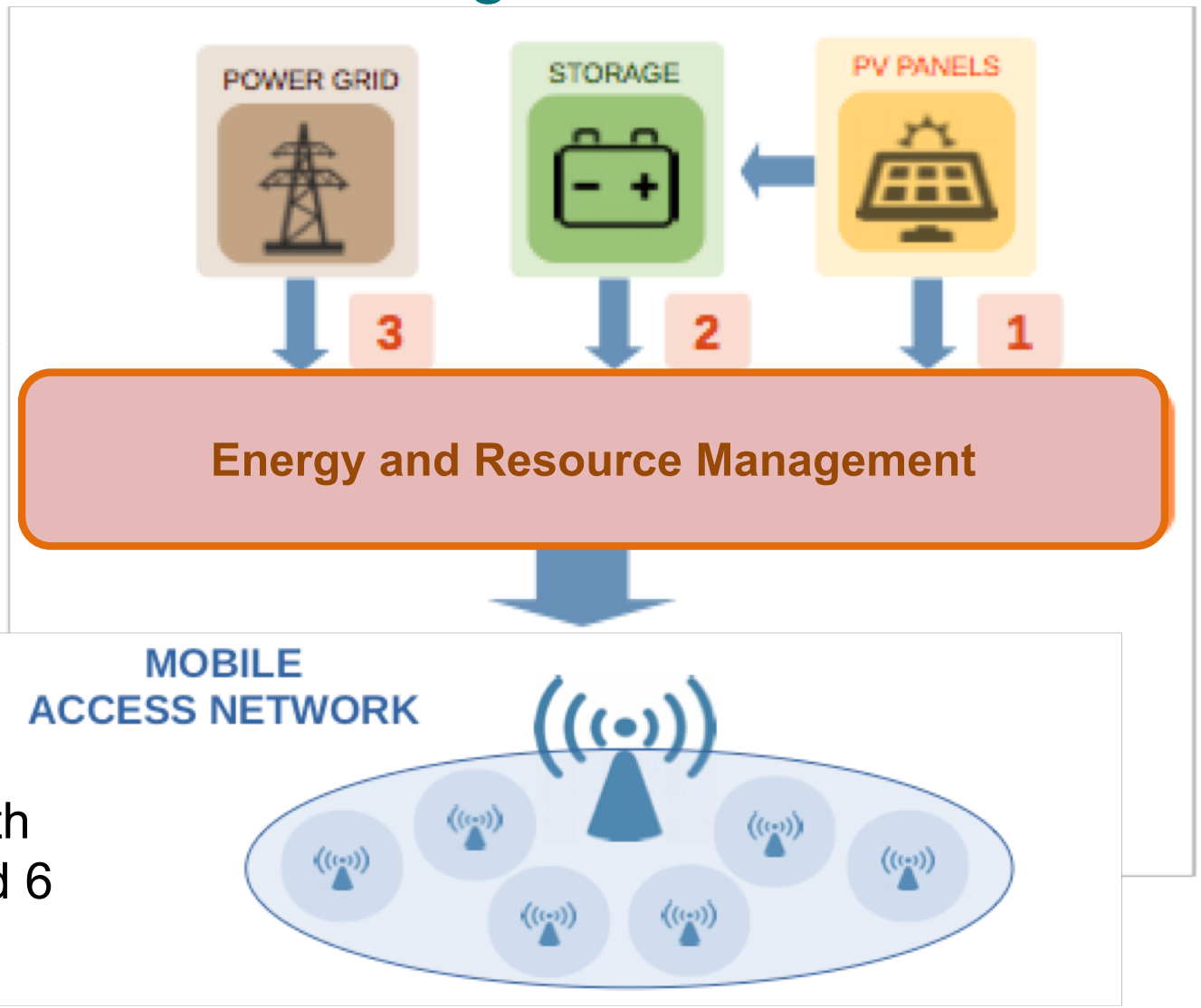
Politecnico di Torino

Green networking

- Much has been done for energy efficiency of the networks (ICT in general) but for sustainability it is not enough
- Sustainability calls for new energy generation principles: need to use renewable energy sources but they are
  - Intermittent and highly variable
  - Difficult to predict
- ICT services
  - Require reliability and continuity of power supply
- Power supply and service provisioning must be considered **jointly**
  - Power supply → tailored for service
  - Service provisioning → aware of power supply

Energy and resource management

choose where to get energy from: priority to renewable energy



clusters of cells with one macro-cell and 6 micro-cells

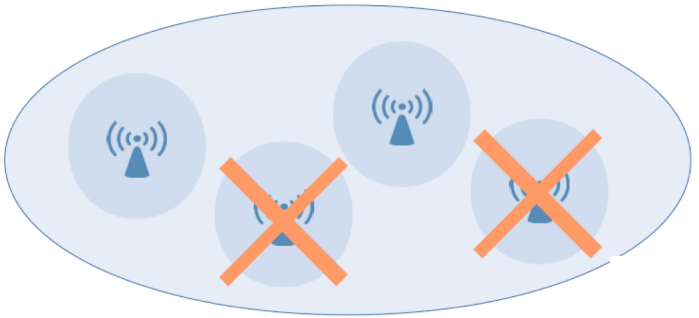
Energy and resource management

Need to take decisions on
- energy to use
- resource to allocate

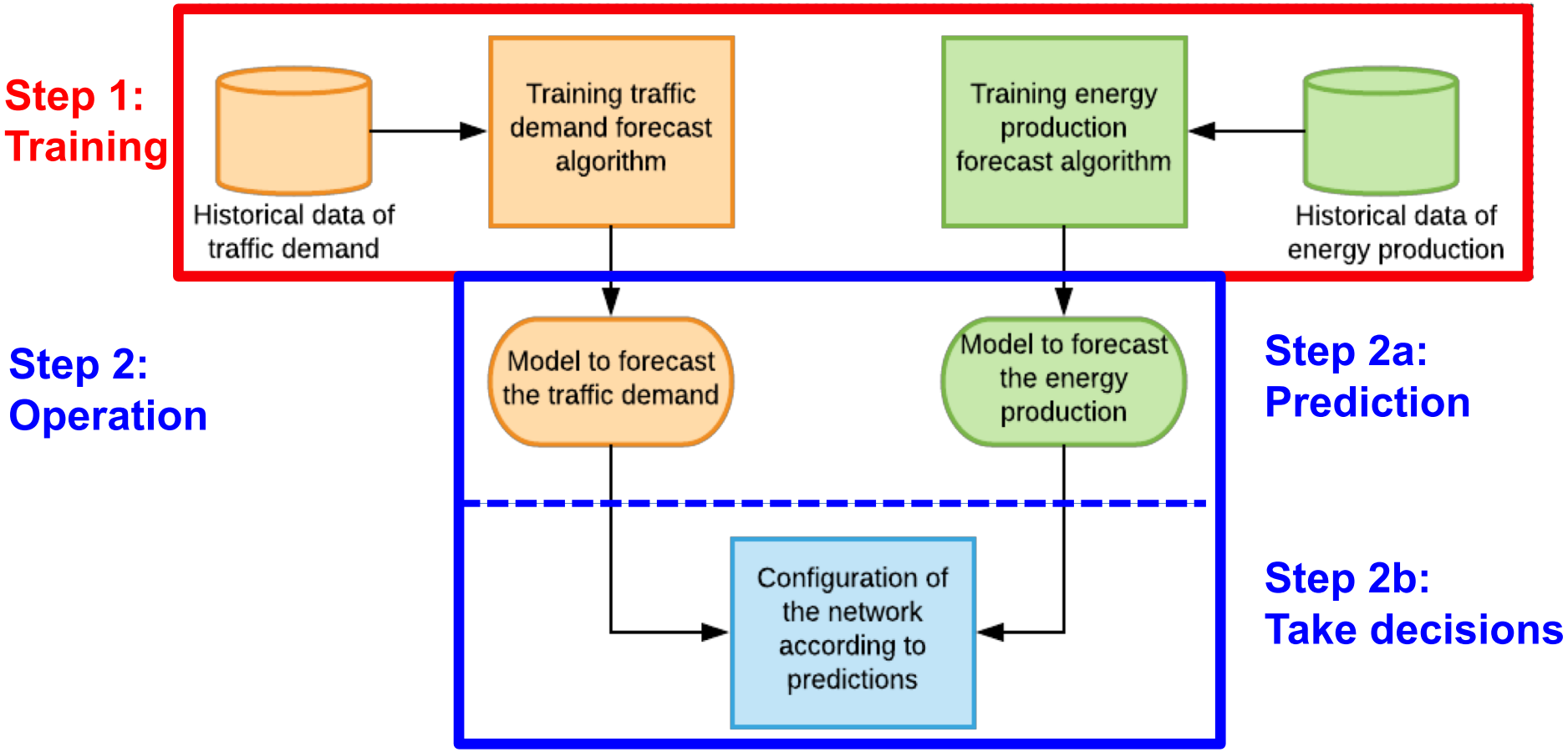
Need to know (predict)
- generated energy
- traffic demand

Switch some BSs off

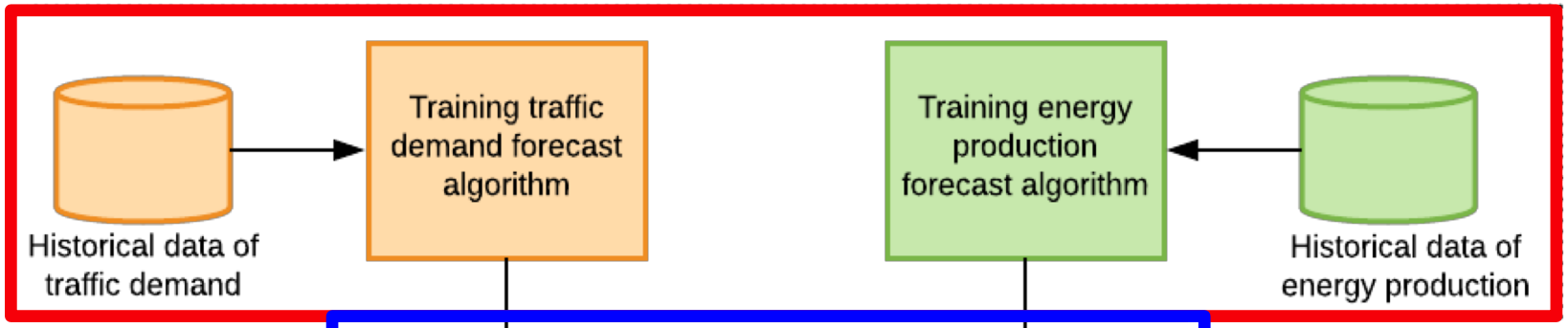
put micro-cells in sleep mode if the macro can carry the traffic



Methodology: ML for traffic & energy prediction



Methodology: ML for traffic & energy prediction



- Block Linear Regression
- Artificial Neural Networks (1, 2, 24, 48)
- Long Short Term Memory Cell
- Baseline (based on mean and variance)
- Baseline with ANN to estimate difference from the mean

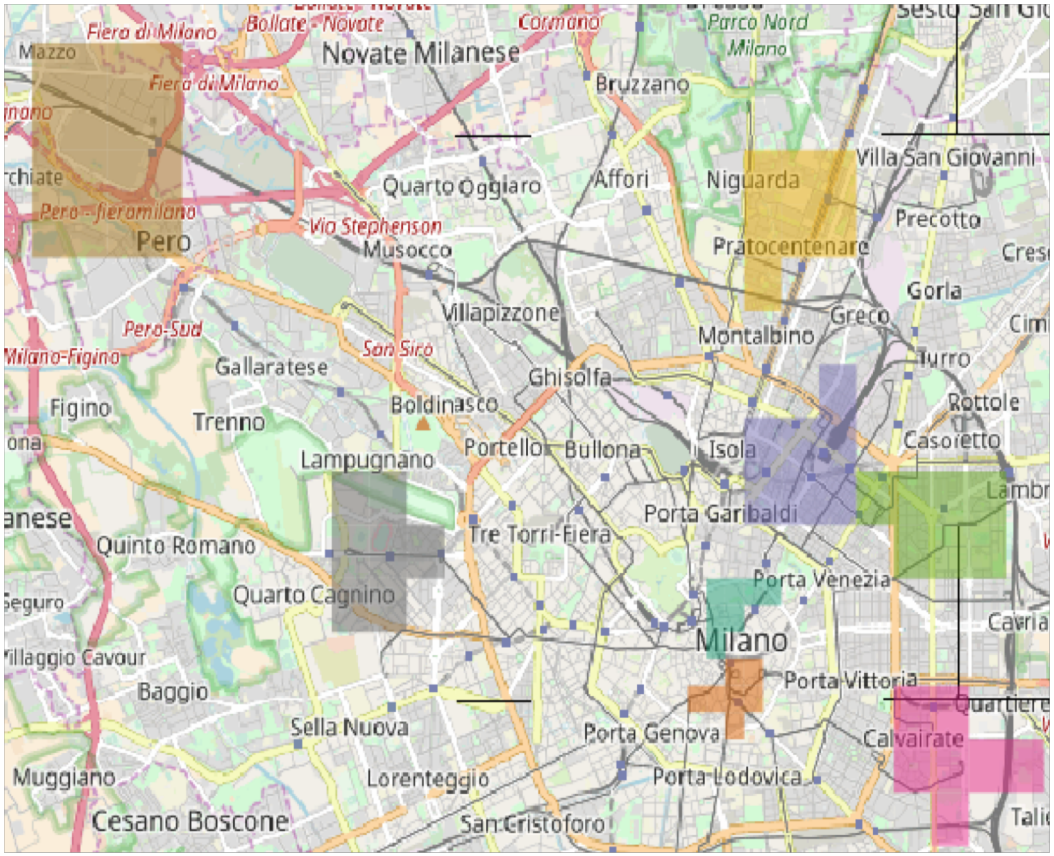
- Linear Regression

- Energy source
- BS sleep mode

Scenario

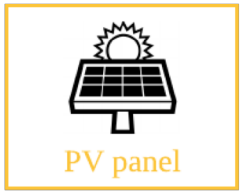
From the real data of an Italian operator, consider the following areas of Milan:

1. Residential
2. Business
3. Politecnico di Milano (campus)
4. Duomo (turistic)
5. Industrial
6. FS (Train station)
7. San Siro (stadium)
8. Rho Fiere (exhibitions)



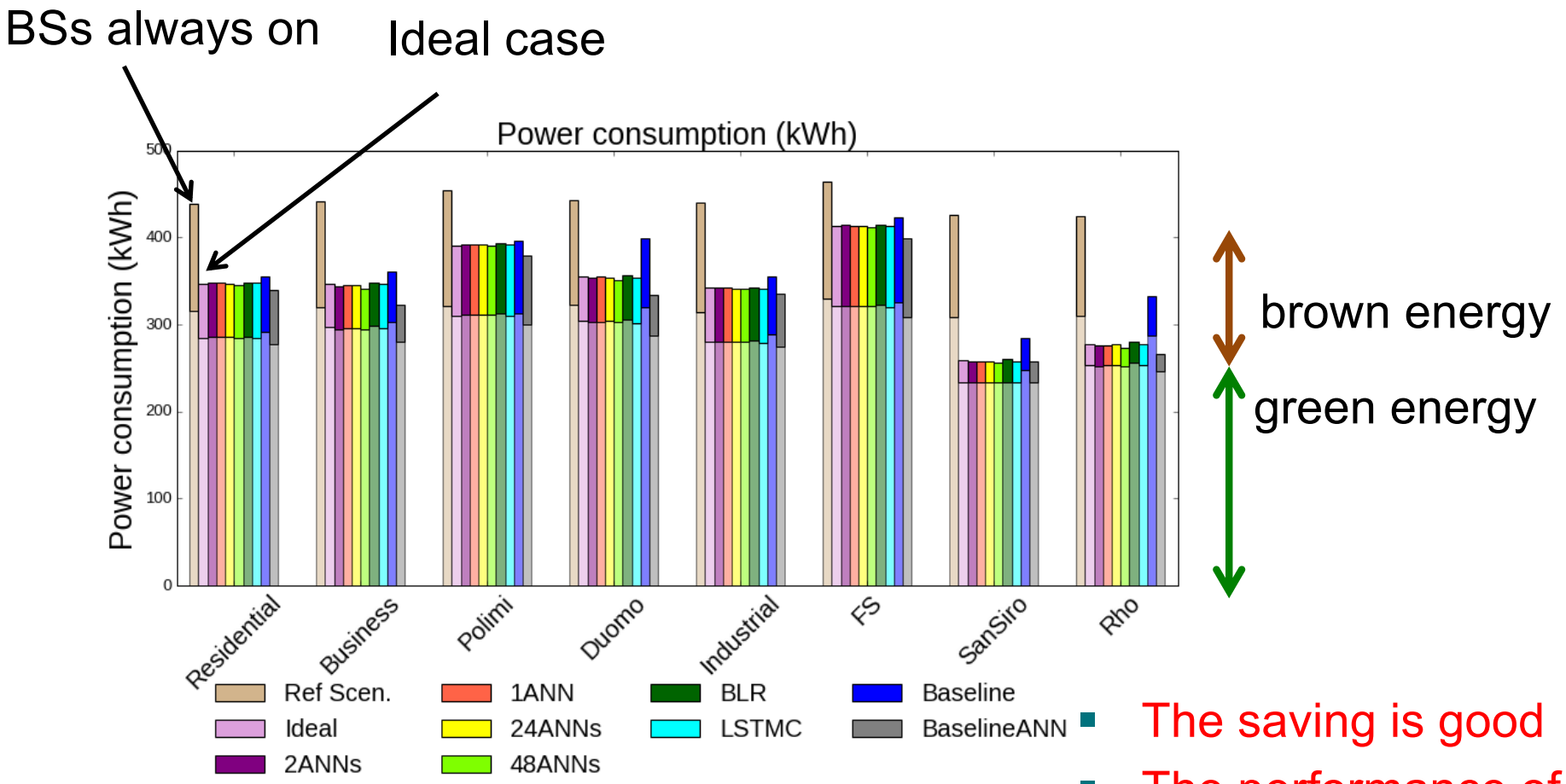
2 months of data

- 1.5 month of training
- 14 days of operation



- 10 kWp of capacity per cluster
- Data from PVWatt (by NREL)

Comparison among ML algorithms

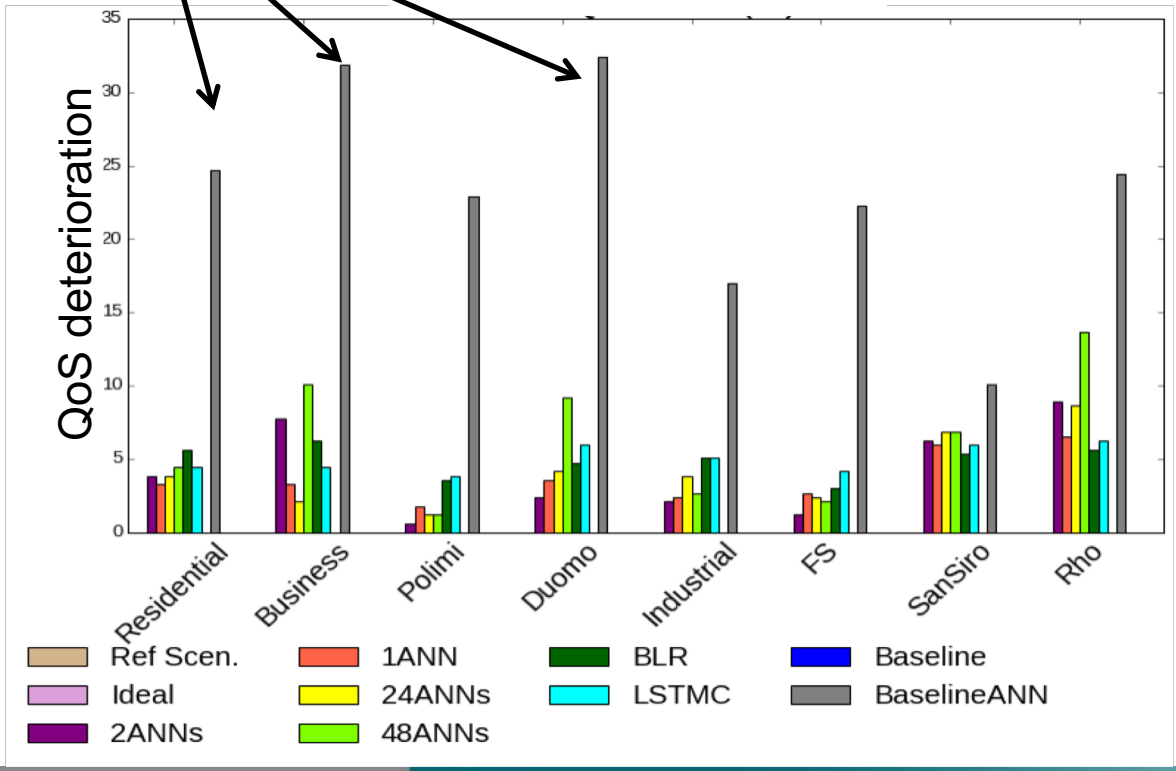


- The saving is good
- The performance of the ML algorithms is similar

Comparison among ML algorithms

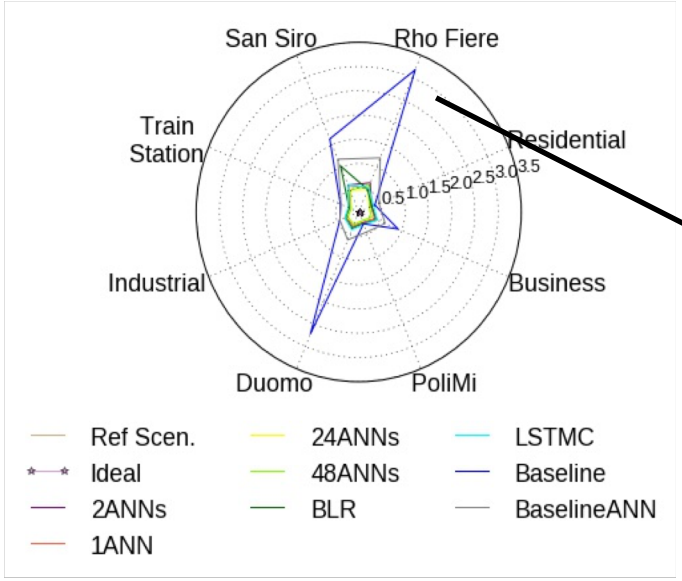
Baseline with ANN: While with similar power saving, QoS deterioration is significantly worse

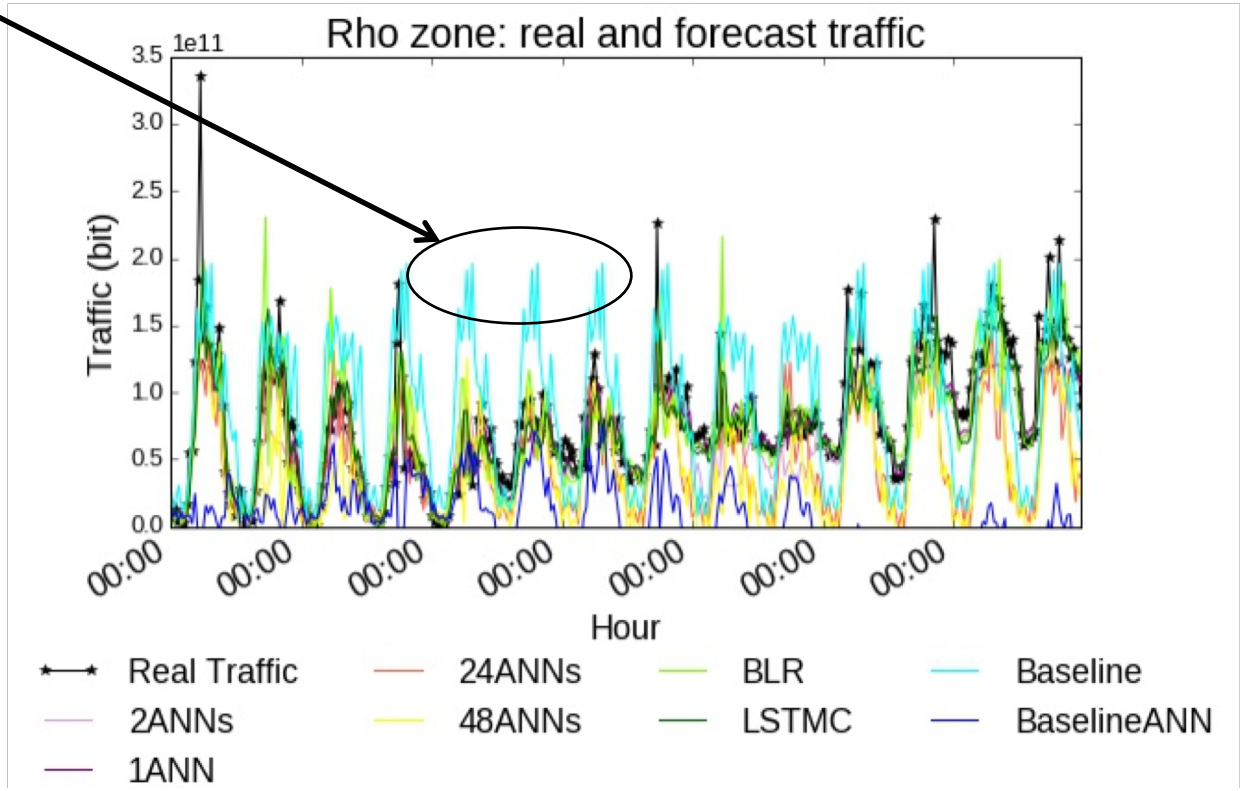
Performance vs QoS is a complex trade-off and predictions are critical for the trade-off



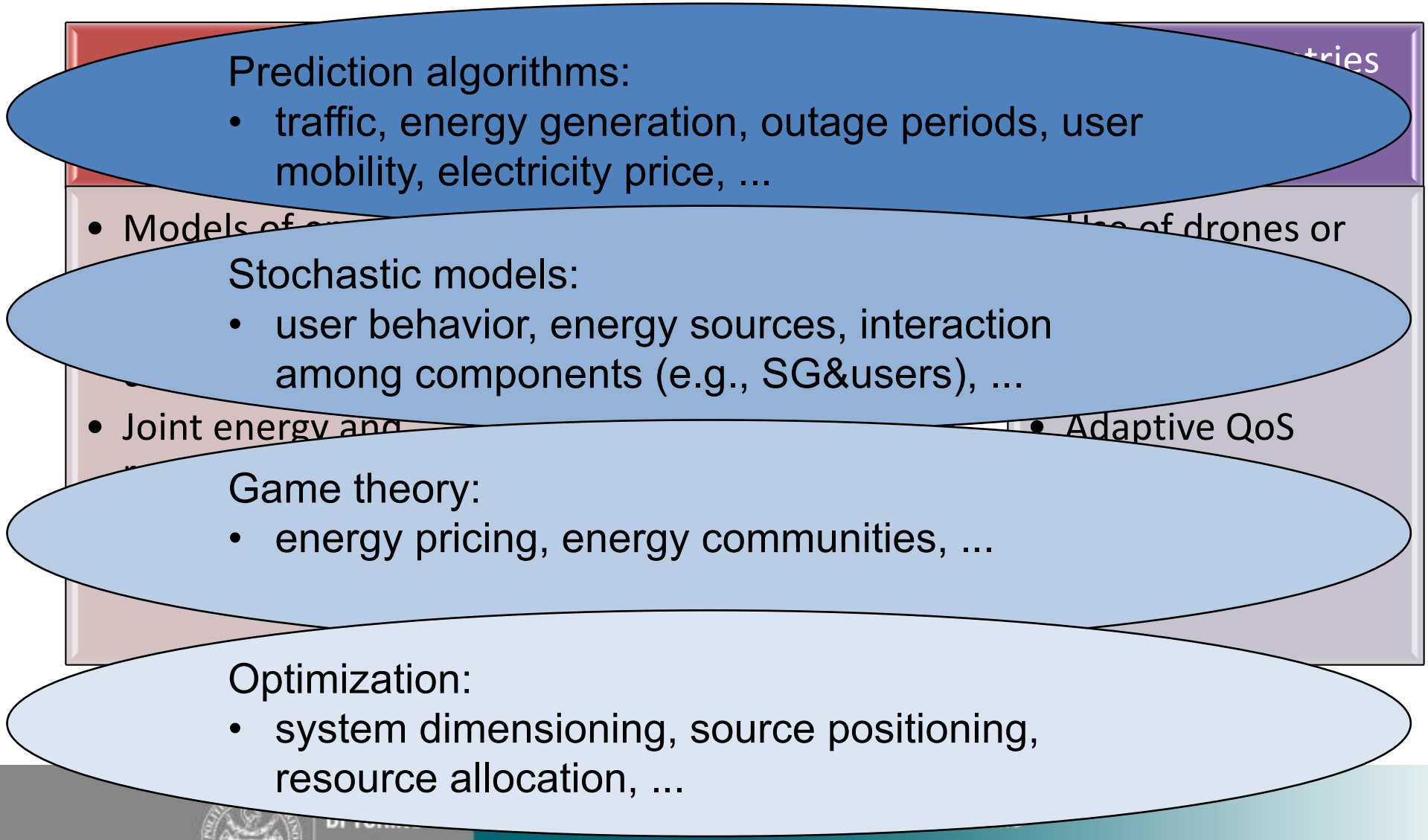
Traffic prediction

Error in periods that do not impact on BS operations and related decisions
→ predictions must be evaluated based on their impact on decisions



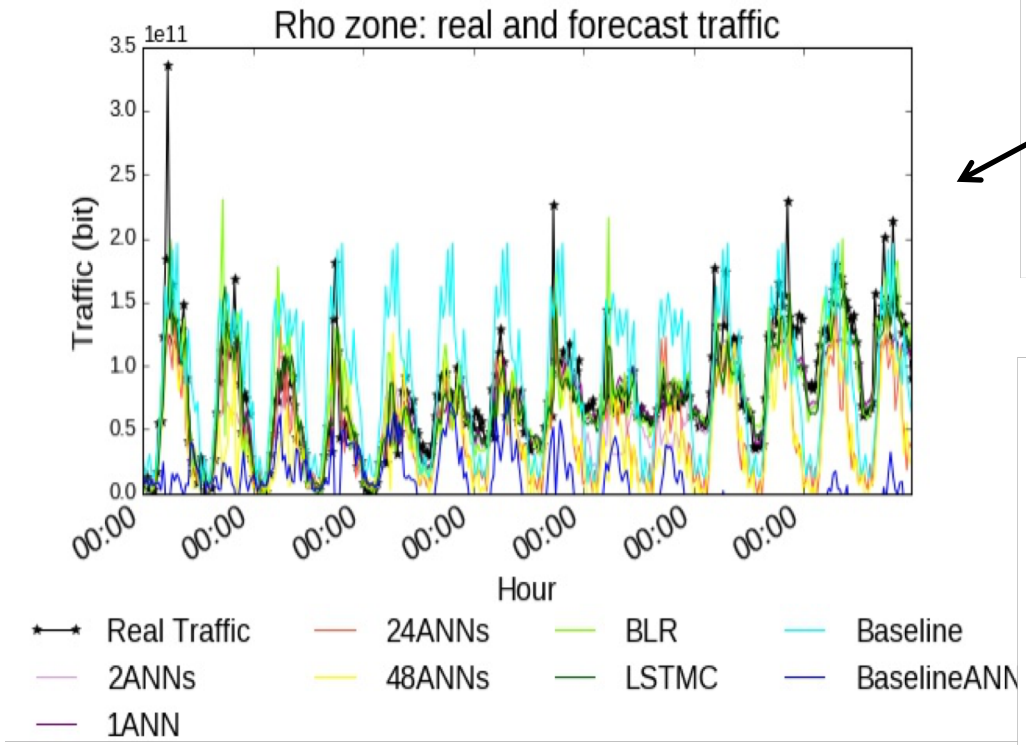


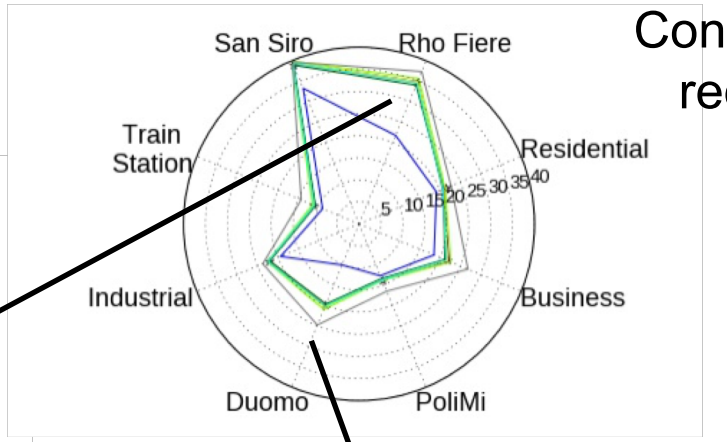
Research trends and topics



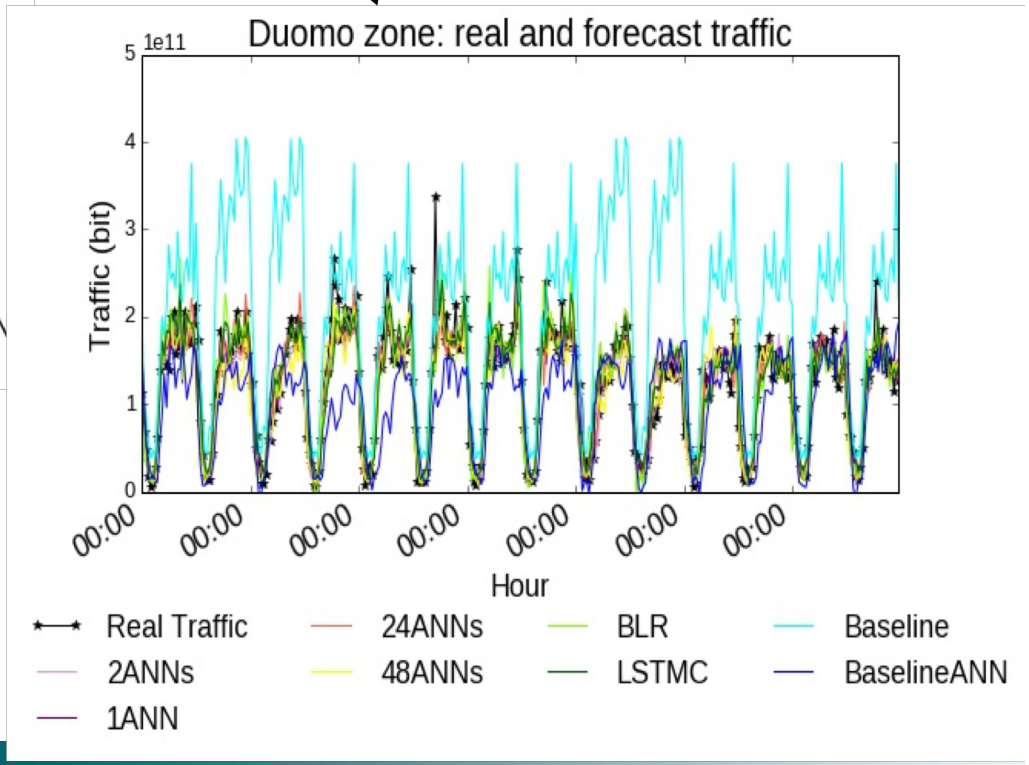
GRAZIE!

Impact of traffic pattern





Consumption reduction

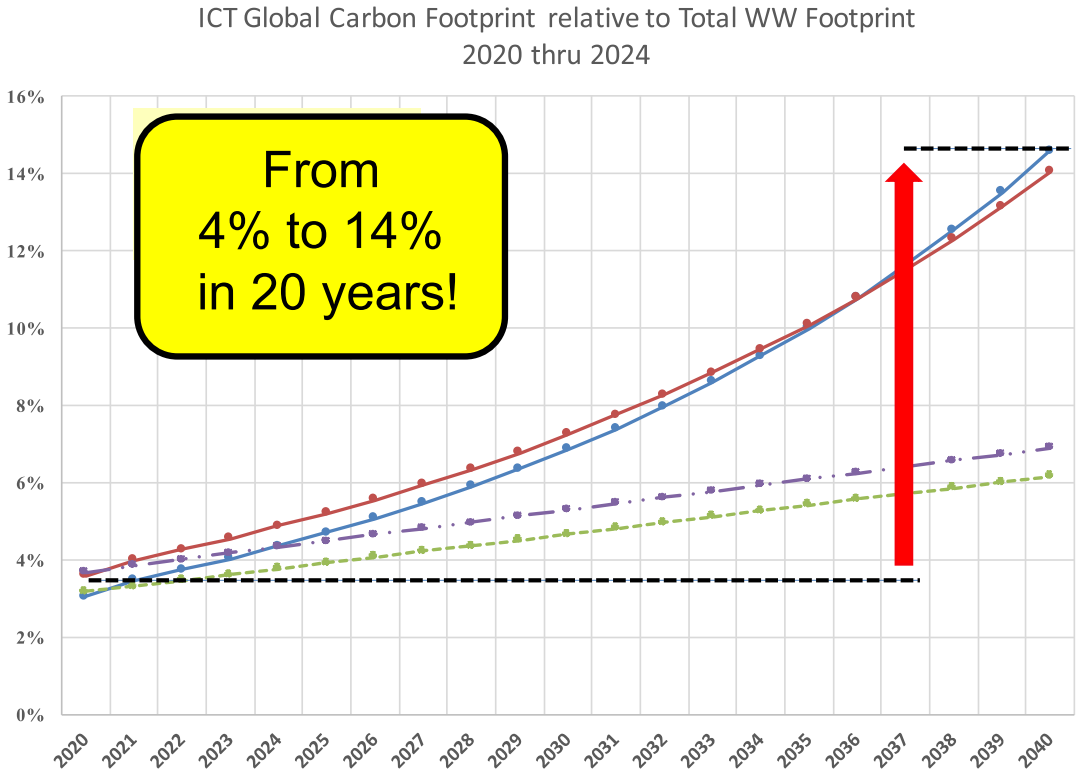


Different areas have quite different performance → ML predictions are needed to automatically adapt to the area characteristics

Is ICT sustainability an issue?

- According to recent estimates, ICT industry
  - generates about 3% of emissions today
  - might generate up to 14% emissions by 2040

- Much has been done for energy efficiency but it is not enough



Source: Lotfi Belkhir, Ahmed Elmeligi, ''Assessing ICT global emissions footprint: Trends to 2040 & recommendations", Elsevier Journal of Cleaner Production 177 (2018) 448-463

Research trends and topics

Renewables & power supply	Smart grids	Emerging countries and emergency situations
• Models of energy production • Models of battery charge/discharge • Joint energy and resource management	• Pricing & business models • Behavioral models of users and systems • Multi-service provisioning of: communication, energy, mobility	• Use of drones or moving BSs • Reconfigurable networks • Adaptive QoS • System dimensioning

Research trends and topics

Prediction algorithms:
- traffic, energy generation, outage periods, user mobility, electricity price, ...

Stochastic models:
- user behavior, energy sources, interaction among components (e.g., SG&users), ...

Game theory:
- energy pricing, energy communities, ...

Optimization:
- system dimensioning, source positioning, resource allocation, ...