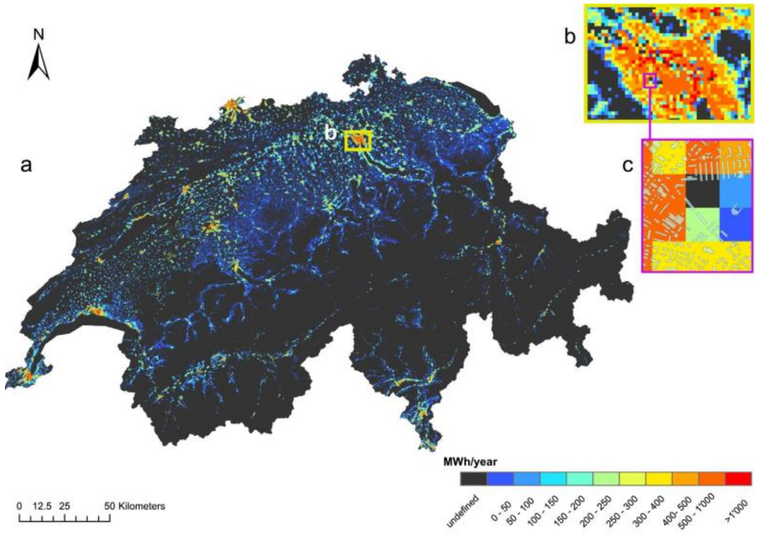
COMPLEX URBAN SYSTEMS

Project leader: Dr Nahid Mohajeri
PhD students: Dan Assouline, Alina Walch



Yearly technical potential for rooftop PV electricity production

In order to model the dynamics of the built areas and understand their sustainable development as well as their interactions with infrastructure networks and urban ecosystems we need a comprehensive theoretical understanding of cities as complex systems. The aim of this research is to use complex system theories and methods to reduce the negative environmental impact of cities through the following approaches: (1) developing energy-efficient urban forms, (2) modelling and identifying renewable energy resources from regional to city scale, (2) improving our understanding of urban metabolism, (3) improving the environmental impacts of urban infrastructure networks and mobility patterns through data-driven approaches and real-time data (4) assessing and minimising the ecological footprints of cities. The focus is hence on (1) Urban metabolism, (2) Energy-Efficient Urban Forms, (3) Size, Scaling Relations and Urban Metabolism, (4) Urban Data and Renewable Energy Potentials.

Published work relates to

- Statistical modelling of the built environment
- Physics of urban form
- GIS (Geographic Information Systems) and spatial data analysis
- Transportation networks
- Sustainable urban planning

2017 Activities

Research has advanced in the project "Energy performance at regional and national level", a collaboration between EPFL-LESO-PB, ETHZ, Empa, Geneva University and HSLU within the Swiss Competence Center for Energy Research "Future Energy Efficient Buildings and Districts". The LESO-PB focus in 2017 was on

- The complexity of roof-shape and solar energy potential. A multidisciplinary approach for classification of different roof shapes was further developed, analysing their solar potential and assessing them based on different characteristics to find out how well they receive solar energy. The method has been extended to provide the rooftop PV technical potential for each pixel of a grid covering the entire country.
- Street canyon and accessibility of solar energy potential. GIS tools and CitySim were used to investigate how street configuration controls solar potential, particularly with regard to street surface and facades.
- A web-service for large scale geo-building energy databases was further developed in collaboration with University of Geneva. This platform will help mapping the renewable energy potential of urban sites in the whole of Switzerland.
- Kick–off of the Hyenergy project (Hybrid Renewable Energy Potential for the Built Environment using Big Data: Forecasting and Uncertainty Estimation funded by Swiss National Science Foundation - NRP 75). Two PhD students were employed for this project in collaboration with UNIL.

Furthermore, several semester projects investigated the relation between Energy consumption and Urban Form and the Energy Hub concept for two villages in Switzerland.

Current Projects

SCCER FEEB&D Phase II, Task 3.2.1 Current potential of renewable energy sources
Funding: Commission for Technology and Innovation (CTI)
Duration: 2017-2020

We develop a novel methodology combining Geographic Information Systems (GIS) and a Machine Learning (ML) algorithm, Random Forests, to estimate the technical potential for rooftop PV solar energy at the scale of a country. The study focuses on Switzerland and provides the rooftop PV technical potential for each pixel of a grid covering the entire country. The methodology is generalizable to any region for which similar data is available and useful to assess the rooftop PV capacity of a region. Prediction Intervals are also provided for the different estimated variables to measure the uncertainty of estimations. The results show that Switzerland has a large potential for rooftop PV installations, i.e. for roofs orientated at $\pm 90°$ from due south, the total estimated potential PV electricity production is about 16.29 TWh/year, which corresponds to 25.3% of the total electricity demand in 2017.

HYENERGY - Hybrid renewable energy potential for the built environment using big data
Funding: Swiss National Science Foundation – National Research Program 75 "Big data"
Duration: 2017-2020

The objective of this project is to develop a method for forecasting the spatio-temporal potential of a combination of renewable energy resources for built areas. A data-driven approach and machine learning algorithms are used to (i) estimate the hybrid renewable energy potential in the built environment, in order to mitigate the effects of variability in individual energy resources and improve the reliability of power generation, (ii) develop machine learning algorithms for spatio-temporal environmental data processing and analysis as well as for LiDAR point cloud urban dataset classification, (iii) apply developed algorithms based on Extreme Learning Machine (ELM) to the built environment for predicting energy generation and potential energy savings of hybrid renewable resources, (iv) analyse the forecasting models according to the projected climate scenarios for 2035 and 2050, (v) estimate uncertainty and validate models using measurement data from weather stations and energy providers, (vi) propose Building Renewable Energy Database (BRED), geo-visualisation tools and renewable energy mapping to support evidence-based decision-making processes.

Integrating urban form and sociotechnical potentials of decentralised energy supply for sustainable urban development
Funding: SNSV – Advanced Postdoc Mobility fellowship Dr Nahid Mohajeri (host institute University of Oxford)
Duration: 2017-2019

Decentralising the urban energy supply, particularly through the use of PVs, requires a comprehensive assessment of their sociotechnical and techno-economic co-evolution. The project aims not only (a) to improve and refine our knowledge of the resource and technical PV potential for Switzerland with application to other areas (e.g., UK), but also (b) to analyse how solar energy technologies and associated social acceptance and affordability evolve together, and (c) how their co-evolution may affect sustainable urban development and energy policies. More specifically, the project aims at exploring (i) the effects of physical urban forms, particularly urban density and the shapes of rooftops, at national scale on the efficiency of energy production through PVs, and to connect urban forms to (ii) different sociotechnical aspects of decentralised electricity production and (iii) to the associated socio-economic parameters (costs, acceptance, affordability, etc.), as well as (iv) to the saving CO2 emissions and energy policies of the local energy production.

Selected 2017 publications

- Assouline D., Mohajeri N., Scartezzini J.-L., Quantifying rooftop photovoltaic solar energy potential: A machine learning approach, in Solar Energy, vol. 141, p. 278-296, 2017
- Mohajeri N., Assouline D., Gudmundsson A., Scartezzini J.-L., Effects of city size on the large-scale decentralised solar energy potential, Energy Procedia. CISBAT 2017, p. 697-702, 2017
- Assouline, D., Mohajeri, N., Scartezzini, J.L., 2017, Rooftop geometric features classification using random forests for large scale PV deployment. Remote Sensing conference, Warsaw, Poland, 2017
- Le Guen, M., Mosca, L., Perera, A.T.D., Coccolo, S., Mohajeri, N., Scartezzini, J.L. 2017. Achieving energy sustainability in future neighbourhoods through building refurbishment and energy hub concept: a case study in Hemberg-Switzerland, Energy Procedia, CISBAT 2017, Lausanne, Switzerland, 2017
- Kuehner, A., Mdeihli, N., Coccola, S., Perera, A.T.D., Mohajeri, N., Scartezzini, J.L., Extending building integrated photovoltaics (BiPV) using distributed energy hubs. A case study in Cartigny, Switzerland. Energy Procedia, CISBAT 2017, Lausanne, Switzerland, 2017