Abstract
Ausschreibung Phil.Alp und Pro Monte Preis
Neuner Sophia

Master thesis "*Geospatial illustration of technical solar, wind and biomass potential in the Alpine Space area on a municipality level*"

The goal of the European Union is until the year 2030 a reduction of 40 % of the green-house gases; a share of 30 % renewable energies and an increase of the energy efficiency by 40 %, until the year 2030 in comparison with the year 1990. At the Alpine Convention energy protocol from 2005, it was agreed to make a long-term contribution of the Alpine Space Area to meet Europe´s energy needs, including the Swiss Federation. The basic commitments were, harmonise energy-saving plans, optimize overall use of the infrastructure in the Alpine region to limit the impact of energy use to the environment. In the Article 2.1 (c) a focus on the use of renewable energy sources, to reach remaining demands of energy is explicitly mentioned. The goals have not been achieved and the harmonizing of the energy-saving plans and the infrastructure has only made progress in some parts of the Alpine Space area. The research area of this thesis is the Alpine Space Area, which covers all parts of the Alps and their enclosing lowlands. The main types of renewable energy sources are: solar, wind, water, geothermal and biomass, which are all used in the Alpine Space area. Despite everything, renewable energies have only in the last few years seen more and more controversy, regarding social acceptance, land use conflicts, impacts on ecosystem services and biodiversity protection. Not every potential of renewable energy should be used, in every circumstance, because conflicting interests appear frequently, e.g. in the Alps where there are land use conflicts. Like mentioned in Hastik et al. (2015) *"currently, only limited and highly fragmented data regarding the actual exploitation of renewable energy sources in the Alpine area are available*."

This demand of Alpine Space wide maps and data information leaded to this Master thesis. Through the application of parameters on several existing datasets new valuable information are generated. The main research objectives are, which technical potential of solar, wind and biomass energy is available in which municipalities? Where can spatial disparities in the Alpine Space area be found?

The technical energy potential is after Kaltschmitt et al. (2014) defined as the theoretical potential minus technical and non-technical restrictions. Non-technical restrictions were focused on land use conflicts.

For solar energy the Europe wide dataset of the Joint Research Center from the European Commission was used (Šúri et al. (2007)) and an average roof surface area after Bergamasco and Asinari (2011) calculated. This implies the method of Izquierdo et al. (2008) which was developed for large scale photovoltaic evaluations. A state of the art are mono-crytalline photovoltaic cell with an efficiency factor of η = 18% was used for the calculations. The results are the available roof surface area, the sum of solar energy in MWh and the solar energy per unit area and municipality.

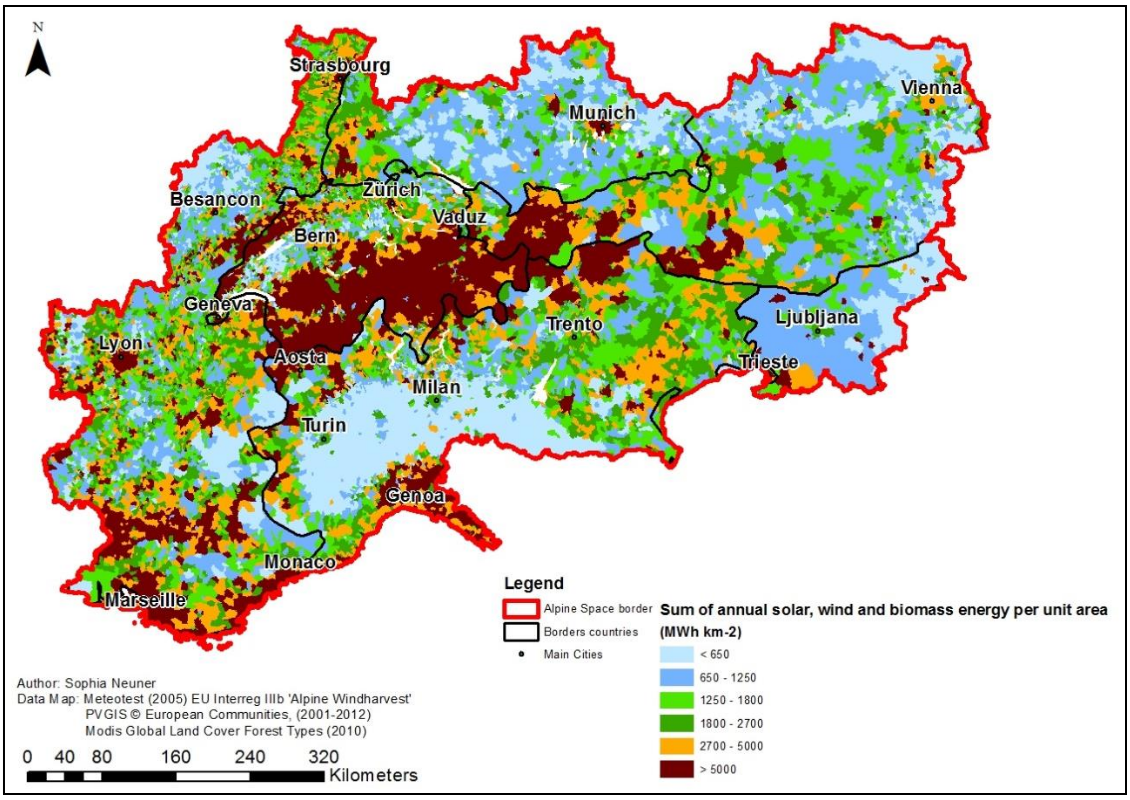
The database for the calculation of the technical wind potential was the dataset from Meteotest (2005) in the framework of the EU Interreg III b project "Alpine Windharvest" (Schaffner and Remund 2005). After Dixon and Hall (2014) the minimum annual wind speed for a wind speed for a profitable wind usage should be 5 m s^{-1} or higher. So all regions in the Alpine Space area with less than 5 m s^{-1} were excluded from the calculations, as well as all protected areas and a minimum distance of 1.5 km to settlement areas. This setback of 1.5 km was selected out of different rules from all over Europe, they vary from 100m up to 2 km. A state of the art onshore wind turbine with 2.3 MW and a diameter of 82 meters of the rotor was used for calculations. After Özdirk et al. (2014) and Samaroni (2013) results this an area of 0.285 km^2 per wind turbine. For the calculations an annual average of 2500 full load hours was used after Özdirik and Kaltschmitt (2014). The results are the potentially installable number of wind turbines, the sum of annual wind energy in MWh and the MWh per unit area and municipality.

The annual solid biomass potential was calculated based on the MODIS land cover forest data, after that eight different forest types are defined (Broxton et al. 2014). The annual C-NPP (carbon net primary productivity in C m^{-2} $year^{-1}$) values for eight different forest types were used after Chirici et al. (2007). The results are the sum of annual biomass energy in MWh and the MWh per area and municipality.

The overall result is, that in the Alpine Space area a high potential of solar, wind and biomass energy, is available. These sums are listed in the following table:

Type of energy	Sum (TWh)	Average energy per unit area (MWh km^{-2})
Solar	325	1,176
Wind	520	828
Biomass	189	409
Sum of all energy types	1,034	804

It is visible that the amount of potential energy is over 1,000 TWh. The sum of net electricity generation from the year 2013 from all Alpine Space member countries is 1,565 TWh. The geospatial disparity within the Alpine Space area is illustrated in the following figure. Here the sums per unit area of all three energy types are calculated. It is visible that on the main Alpine area the high Alpine mountain chain and in the south west area of the Alpine Space area the highest potentials of renewable energy sources exist.



These results are important to reach the goal of the European Union and the Alpine Convention for further use of renewable energy and to point out that even with high restrictions there is still a major potential in the Alps. The developed methodology, has the aim to include socio-economic factors into large scale energy potential evaluations.

Bibliography

Bergamasco, L., & Asinari, P. (2011, February). Scalable methodology for the photovoltaic solar energy potential assessment based on available roof surface area: Application to Piedmont Region (Italy). Solar Energy, pp. 1041 - 1055.

Chirici, G., Barbati, A., & Maselli, F. (2007, April). Modelling of Italian forest net primary productivity by the integration of remotely sensed and GIS data. Forest Ecology and Management, pp. 285 - 295.

Dixon, S., & Hall, C. (2014). Chapter 10 – Wind Turbines. In Fluid Mechanics and Thermodynamics of Turbomachinery (Seventh Edition) (S. 419-485). Oxford: Butterworth-Heinemann.

Hastik, R., Geitner, C., Haida, C., Höferl, K.-M., & Berchthold, M. (2013). Erneuerbare Energien im Alpenraum - Ein aktuelles Thema und eine inter- und transdisziplinäre Herausforderung. Innsbrucker Jahresberichte 2011-2013. Geographische Gesellschaft - Institut für Geographie Universität Innsbruck., p. 46.

Izquierdo, S., Rodrigues, M., & Fueyo, N. (March 2008). A method for estimationg the geographical distribution of the available roof surface area for large-scale photovoltaic energy potential evaluations. Solar Energy, S. 929 - 939.

Kaltschmitt, M., Streicher , W., & Wiese, A. (2014). Erneuerbare Energien - Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Berlin: Springer Verlag.

Özdirk, B., Kaltschmitt, M., Skiba, M., & Schulz, D. (2014). 7.2 Systemtechnische Beschreibung. In M. Kaltschmitt, W. Streicher, & A. Wiese, Erneuerbare Energien - Systemtechnik, Wirtschaftlichkeit, Umweltaspekte (pp. 471 - 523). Berlin Heidelberg: Springer Vieweg.

Samorani, M. (2013). The wind farm layout optimization problem. In P. M. Pardalos, S. Rebennack, M. V. Pereira, & N. A. Iliadis, Handbook of Wind Power Systems (pp. 21 - 38). Berlin Heidelberg: Springer Vieweg.

Schaffner, B., & Remund, J. (2005). Alpine Windharvest - Development of information base regarding potentials an the necessary technical, legal and socio-economic conditions for expanding wind energy in the Alpine Space. Alpine Windharvest Report No. 7-2 by the Alpine Winharvest Partnership Networks.

Šúri, M., Huld, T. A., Dunlop, E. D., & Ossenbrink, H. A. (2007, October). Potential of solar electricity generation in the European Union member states and candidate countries. Solar Energy, pp. 1295–1305.