Calculation of current land use for renewable energy in Germany

Nils Koldrack[1]

Abstract

The energy revolution in Germany is a nationally and internationally highly acclaimed and debated topic. The phase-out of nuclear energy by the end of 2022 opens the door to enter the age of renewable energy. Energy system of the future should be eco-friendly and secure. Currently, Germany is a pioneer of this global development. The implementation of the energy revolution implicates increased space requirements for renewable energy. Thus, particular areas for wind turbine, biogas plants, open space photovoltaic units, hydroelectric power stations and the technical infrastructure are used. The dynamic expansion of renewable energies in all sectors and the rapid expansion and modernization of power grids will change the characteristic landscape of Germany conspicuously. For this reason in this paper the current land use of renewable energy is analysed. The observation of further development asks for appropriate indications and the necessary data bases. One more focus of this paper is to examine the effects of land use for renewable energy to protected resources and landscape features.

As a result the current land use of renewable energy systems is being visualized and analyzed. In concrete terms, a current land use of 180 km² was observed (up to 2012). Thereof open space photovoltaic units take up 60.2 % and thus the most of the area. If required cultivable acreage for renewable resources for biogas plants are included, the current total land requirement is about 28,000 km². This represents about 7.8 % of the area of the Federal Republic of Germany. During investigation it became clear, that there are still significant gaps in the data. Therefore the results may underestimate the real situation.

1. Introduction

As part of a Master Thesis [5] which was developed on the Leibniz Institut für ökologische Raumentwicklung (IÖR) in Dresden, the occupied area by the renewable energies in Germany was analyzed. In particular, wind turbines, open space photovoltaic units, biomass plants and pumped storage power plants were investigated.

Installations of geothermal and hydroelectric power plants were also considered, but is not signify because of the small number of plants and land use overall. Solar panels on house roofs were not included, because they are already installed on a sealed surface. Objectives were:

- to ascertain and evaluate the current land use,
- to examine what data bases are available for a current survey,
- to find and close data gaps,
- identify ways of the repetition (monitoring).

2. Geospatial localization of land use

For regular monitoring of land use by plants which produce renewable energy a data base is necessary, which is collected as regularly as possible and with a great attention to detail. For this Germany's available spatial data source of the Basis-DLM (ATKIS) of the national survey

[1] University of Rostock, 18059 Rostock, Germany, Nils.Koldrack@uni-rostock.de, Professorship of Geodesy and Geoinformatics

administrations may be one of the best sources. Therefore, the main focus of the investigation lies on ATKIS data. In addition, there are a variety of other data sources that provide such information. It should be emphasized to use only those that are spatially located, or have reference surface and are regularly updated.

It quickly became apparent that from the Erneuerbare-Energien-Gesetz (EEG)-data a good overview of the distribution of the individual plants can be obtained. However, these data are georeferenced by the postal code and some sections (e.g. biogas plants) are also incomplete.

The other data bases are mostly for singular studies or they are only sectorally created or not available for the entire country. In addition the underlying spatial data are often inaccessible.

So far only ATKIS has a good data base for **wind turbines** on mainland. 21,137 plants were performed as point-like objects under the property "AX_BauwerkeOderAnlageFuerIndustrieUndGewerbe" with the value "1220" in the data from the year 2012. With the rapid establishment of turbines throughout Germany, it is almost impossible to achieve an exact number of wind turbines. The Fraunhofer Institute for Wind Energy & Energy System Technology (IWES) stated on 12/1/2012 that in the Federal Republic 23,043 systems have been installed [4]. The Deutsche WindGuard estimated the number at 22,664 on the 7/15/2012 [3]. In the AAA-Model of ATKIS for 40 % of wind turbines under the identification "HHO" (average height of 103.4 meters) the height is given. The federal state of Saxony is the only state that has assigned a height for each facility. Thuringia in turn is the only state, which indicates an area to wind turbines. Approximately for 87 % of the facilities in Thuringia a "primary energy surface" are assigned. The average size amounts to 1,044 m². The Bundesamt für Bauwesen und Raumordnung estimates the land use for each plant similar. It indicates that for a wind power plant an area of 0.1 ha is required. Based on this information an area-based extrapolation could be done.

The Bundesamt für Seeschifffahrt und Hydrographie collects and provides data for offshore wind turbines in the North- and Baltic Sea. In contrast to the data of the onshore data the offshore installations are digitalized as surface geometry. In the German Baltic Sea 7 km² are currently used through offshore wind turbines and only 3.9 km² in the North Sea [1].

The **open space photovoltaic units** are recorded in the ATKIS feature class catalogue in the property "AX_IndustrieUndGewerbefläche" under the identification "PEG 3000" but they have been documented only partially by the federal states so far. 713 open space photovoltaic units are collected in the ATKIS-data in 2012. The data of the EEG of 6/4/2013 implies that 3,288 open space photovoltaic units are distributed in Germany. Since the operators are required to report data like location, capacity and date of commissioning according to §§ 45 and 46 EEG, it can be considered a very good actuality of the EEG-data. Because the information of the EEG-data are not geo-referenced, but include the specific postal code, location and sometimes roads, other data sources (e.g. Geoportal Baden-Württemberg and Brandenburg, Raumplanungsinformationssystem Sachsen) was needed. Furthermore a large part of plants were captured manually with digital orthophotos (DOP) of the Bundesamt für Kartographie und Geodäsie (BKG). Due to the lack of timeliness of aerial images newer photovoltaic units could not be documented. The internet portal "Energy Atlas Bayern 2.0" by the Bavarian State Ministry of Environment and Consumer Protection includes geo-referenced open space photovoltaic units for Bavaria and makes the data available for download. A total of 1,984 plants are maintained [6]. Because the constructions were geo-referenced only as points and not as surface data, the plants were just captured manually as in the EEG-data. Overall 1,470 open space photovoltaic units were collected on this way.

The **hydropower, geothermal and biomass plants** are indeed just as clearly defined in the ATKIS feature catalogue in the property "AX_IndustrieUndGewerbefläche", but also out patchy, as the

open space photovoltaic units. The ATKIS-data of 2012 recorded 1,319 hydropower plants with an average area of 3,452.2 m²/plant. However the EEG-data shows that there are 7,449 plants for electricity generation from hydropower in Germany. Seven geothermal plants for electricity production are documented in the EEG-data, while on the other hand ATKIS collects 15 plants which are used for electricity and heat production (Ø 8,286.1 m²). According to the EEG-data in July 2013 14,348 biomass plants are distributed on the area of the Federal Republic of Germany. On the other hand ATKIS lists only 1,397 plants (Ø 1,325.6 m² land use). As in the EEG-data for all plants, the rated power is specified, a method for the approximate calculation of the land use of the required biomass surface was developed as part of the investigation. To answer the question how much land is required to produce 1 MWh/a, the substrate consumption of biomass plants had to be determined. For this purpose, information was used of the operator surveys of the DBFZ from 2012 [2]. On the basis of the average parameters (example: to generate 1 MWh/a with energy crops, an area of 125 m² is required) the land use was calculated. Summarized for all substrates an average of 726.7 m² are required to produce 1 MWh/a. With a current power production of biomass from 36,427,461 MWh/a, area of about 2.6 million ha is needed. This approximate estimate has to take into account, that substrates are also imported from neighbouring states of the Federal Republic of Germany.

3. Evaluations for selected types of renewable energy

In the following sections, selected results from Koldrack [5] are presented.

3.1. Wind turbines

Nearly a quarter of 21,137 wind turbines have been installed in Lower Saxony (including Bremen 5,129), followed by North Rhine Westphalia (2,809). In the period from 2006 to 2012 Lower Saxony had an increment of 38.8 %, which is immense in view of the already high number of wind turbines in 2006 (3,695). The state of Brandenburg (including Berlin) owns with 79.6 % the second highest rate of growth. Only Saarland has a higher rate (188.5 %). The distribution of the wind turbines per km² (Fig. 1) shows, that North Germany over a wide range has significantly higher values than southern Germany. Along the North Sea and Baltic Sea, there are many counties with a value exceeding 0.11 plant/km². The two counties Emden and Dithmarschen on the North Sea coast of Lower Saxony have the highest values (0.68 and 0.51 plant/km²). In contrast most counties of Baden-Württemberg and Bavaria have mostly a value below 0.025 plant/km².

Extrapolating the average land use of wind turbines of 1,044 m² on the number which depends on the data source (Fraunhofer Institute for Wind Energy & Energy System Technology or ATKIS) a land use between 22.1 km² to 24.1 km² results.

Another method was used to assess the claim of space from a planning point of view. Around each wind turbine, a buffer of 155 m (average height of wind turbines in 2012) was created. The claimed area arises from the common distance space of wind turbines. Because these covered areas deprives other structural measures. With this method, wind turbines cover an area of 794.9 km² in Germany. An analysis of local conditions of all wind turbines in Saxony showed, that 94 % of all plants are installed on vegetation areas (81 % farmland, 16 % grassland, 4 % forest and wooded area, 1 % heaths and 1 % woodland). 4 % are installed on formerly urbanized surface and 2 % on recreational areas.

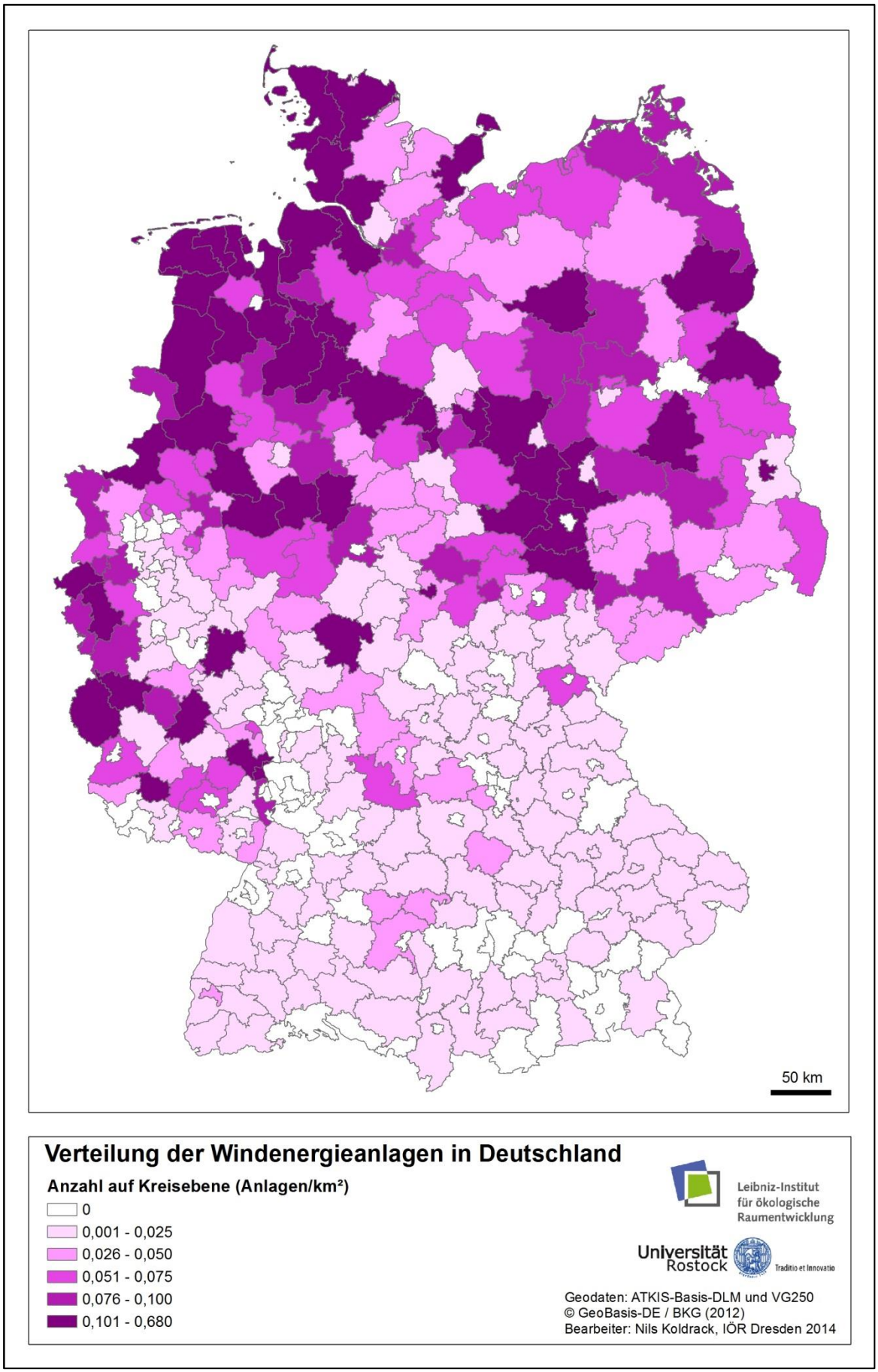

Figure 1: Distribution of wind turbines in Germany on administrative districts

3.2. Open space photovoltaic units

In distribution of photovoltaic open space units on administrative districts it is conspicuous that most of the 1,470 systems were mainly installed in south and east of Germany. Bavaria protruded with 873 systems, well ahead of Saxony with 145 plants. In the district of Passau on the border to Austria the most systems are installed (59), followed by the district Straubing-Bogen with 33 (Fig 2).

A reason for many abutting districts in Lower Saxony, North Rhine-Westphalia and Schleswig-Holstein, where no open space photovoltaic units were installed, may be the low solar potential in the regions, but also the patchy data base can be a reason for that.

Nationwide, 1,470 plants were recorded, which occupy a total area of 112.8 km². In correlation to the large number of plants in Bavaria the largest surface of photovoltaic units was built (45.9 km²), followed by Brandenburg (18.2 km²). This is remarkable, because in Brandenburg in comparison to other provinces, relatively few systems have been installed (30). In the district of Potsdam-Mittelmark open space systems were installed on an area of 5.5 km². It is the district with largest land use of open space systems, followed by Elbe-Elster district around 4.4 km².

A local analysis at the example of Saxony showed that 26.8 % of newly installed ground-mounted systems were installed on forest and wooded area, followed by grassland (25.2 %) and farmland (18.5 %). Random samples showed that forest and wooded areas are mostly former landfills and mining areas, former barracks or military training areas.

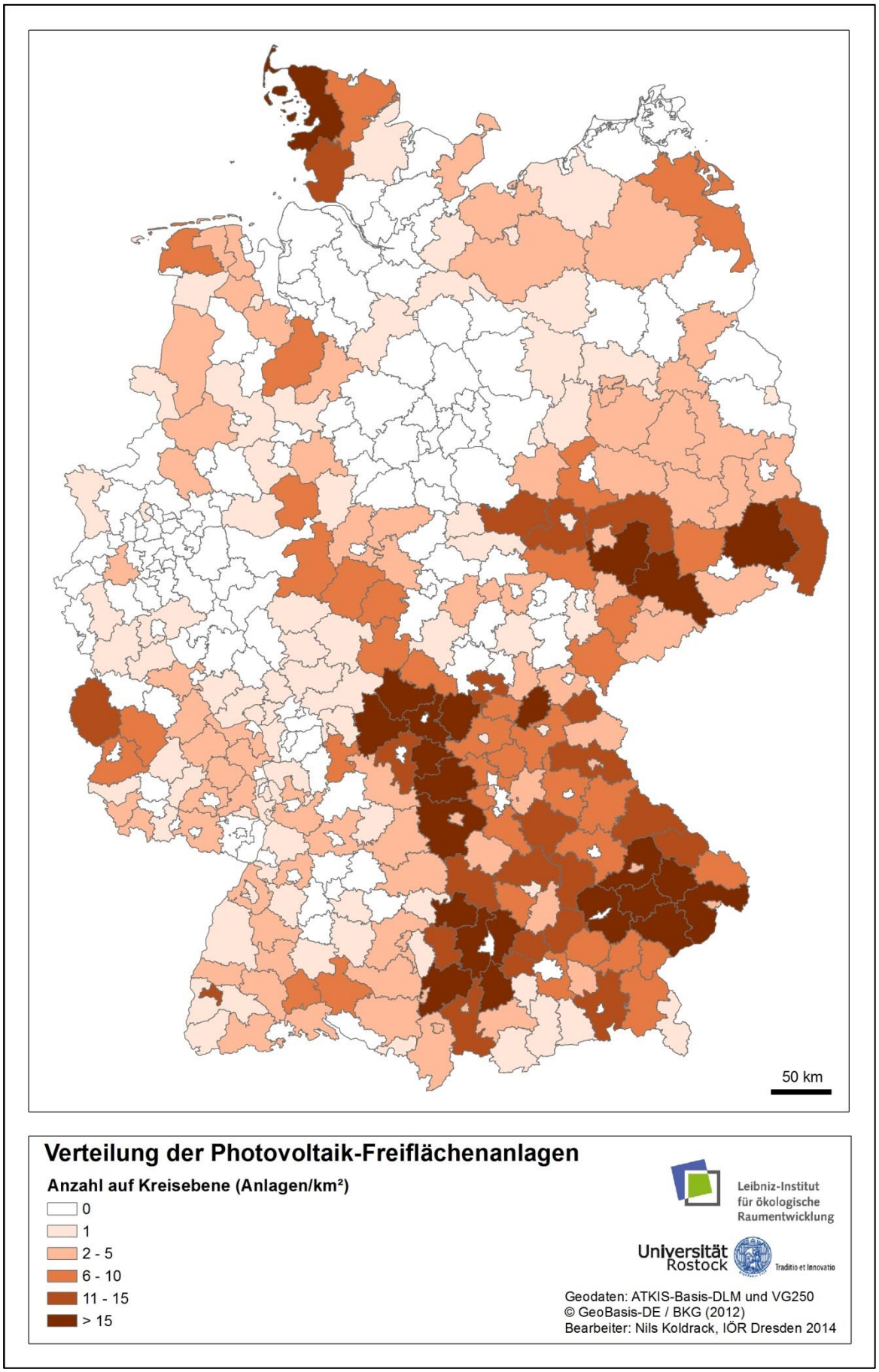

Figure 2: Distribution of the open space photovoltaic units on administrative districts

4. Results and conclusions

Overall, information for almost 43,000 plants was collected [5]. In the analysis of direct land use through renewable energy installations a total area of 179.2 km² was determined. In the used spatial data, the surface data were mostly documented inadequate or incomplete. Therefore average values for area calculation for wind energy, biomass, hydropower and geothermal plants were used. Therefore a certain span of land use must be considered. By using a confidence interval of 95 % a span of direct land use of 175.8 km² to 188.1 km² results.

In the distribution of direct land use of the facilities for the renewable energy, open space photovoltaic units make up the largest part, followed by the hydropower plants (Fig. 3). If the acreage of biomass is included, this would take 99.3 % of the land to generate renewable energy.

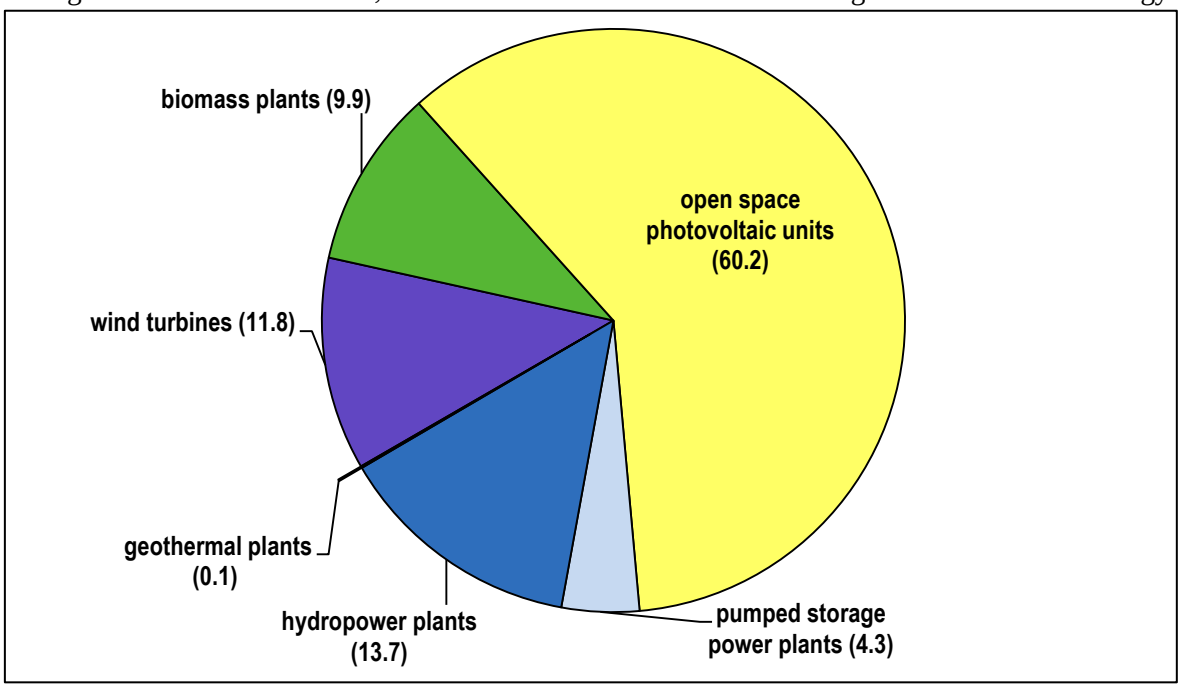

Figure 3: Percentage distribution of the areas of renewable energy plants in the respective divisions, own evaluation based on data bases: ATKIS basic DLM © Geobasis-DE / BKG (2012), DGS (2013), RAPIS (2013) AROK (2013), GDI-BE/BB (2013)

For the topicality it can be stated that the renewable energy installations are recognized only incomplete in the current ATKIS data. Wind turbines constitute an exception. The essentials for acquiring the turbines are given in the ATKIS object catalogue of the basic DLM, but they are not sufficiently used by the federal states yet. The cadastre of the regional planning of the individual federal states have not fully adapted to the digital capture of the buildings for renewable energy sources. It would be desirable that countries provide geospatial information for current use or planned construction of such facilities at all levels, as for example in the Raumplanungsinformationssystem Sachsen (RAPIS). An opportunity to ensure a nationwide basic timeliness of plants in the institutions can be, that the offices include the EEG-data. Through the compulsory registration of operators for renewable electricity generation, a nationwide basic timeliness of plants could be depicted. An area calculation with average values could be avoided and an accurate calculation of land use of renewable energy systems will be performed. In view of the importance of the energy transition a current official data source should contain the systems and their area consumption. In this regard, ATKIS is to be well on the way and a continuous monitoring would be possible.

The evaluations demonstrate the significant area requirements for the generation of renewable energy. In particular, biomass cultivation is by far the largest area. Wind turbines and solar fields have only fraction of the land use, but they mark the landscape through their technical character. Information about sites and use of land can be used for further studies, for example, for analysis on the effects on environment and nature. In view of the climate change, a better management for the conversion of energy sources on renewable, sustainable energy, with a suitable data base should be used to minimize the impact on nature and environment.

References

[1] BSH, Bundesamt für Seeschifffahrt und Hydrographie, http://www.bsh.de/de/Meeresnutzung/Wirtschaft/CONTIS-Informationssystem, Hamburg, 2013.

[2] DBFZ, Deutsches Biomasseforschungszentrum, http://www.dbfz.de/web/fileadmin/user_upload/Berichte_Projektdatenbank/3330002_Stromerzeugung_aus_Biomasse_Endbericht_Ver%C3%B6ffentlichung_FINAL_FASSUNG.pdf, Leipzig, 2012.

[3] DWG, Deutsche WindGuard, Bundesverband Wind Energie, http://www.wind-energie.de/sites/default/files/attachments/page/statistiken/fact-sheet-statistik-we-2012-12-31.pdf, Varel, 2013.

[4] IWES, Fraunhofer Institut für Windenergie und Energiesystemtechnik, http://www.fraunhofer.de/content/dam/zv/de/forschungsthemen/energie/Windreport-2011-de.pdf, Kassel, 2012.

[5] Koldrack, N., “Flächeninanspruchnahme für Energieinfrastruktur,“ Master’s thesis, Rostock, 2013.

[6] StMUG, Bayerisches Staatsministerium für Umwelt und Verbraucherschutz, http://geoportal.bayern.de/energieatlas-karten/?0, München, 2013.