Title:

Modelling flows of recreational ecosystem services in Germany

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Abstract

While policy interest and research on recreational ecosystem services (RES) has increased substantially, insights into the actual flows of benefits to people have remained scarce, especially at levels beyond local communities. The aim of this paper is to model RES flows and benefits for Germany. We use Germany as a case study due its diversity of landscapes and availability of relevant spatial and empirical data. We develop and apply an assessment approach that considers RES demand and supply based on user preferences. Our results show distinct demand-supply matches and mismatches, for example in south-west Germany, and highest flows near population centres. Monetary benefits are highest in counties with high RES Supply that are close to densely populated areas. Our results can usefully inform planning and decision making, for example to improve and further justify destination management, landscape development and investments in RES at local, regional and national levels.

Keywords:

cultural ecosystem services; mapping and assessment; quantification; national level; demand; supply; flow; benefits; valuation

Introduction

Recreational ecosystem services (RES), understood as the contributions of nature and landscape to the recreation of people, receive significant attention in science and policy (Kadykalo et al. 2019). RES provide substantial benefits for individuals and society, in particular through improving physical and mental health (Twohig-Bennett and Jones 2018; Lackey et al. 2021), and restoration (Hartig 2021). While high-level policies like the EU biodiversity strategies 2020 and 2030 (European Commission 2013, 2020) or the UN's System of Environmental Accounting (UN SEEA-EA 2021) are leaning towards an economic assessment (cf. Hein et al. 2020), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) advocates for diverse values of (Díaz et al. 2018; IPBES 2022). Still, their common goal is to better inform decisions and work towards a sustainable future for humanity. Environmental planning and regional governance need comprehensive information about RES qualities, quantities, and flows to tackle the grand challenges of transforming landscapes in response to climate change, the energy and mobility transition, or demographic changes without compromising too much on the supply of RES.

Haines-Young and Potschin (2018) provide a classification of ecosystem services that could become standard. According to the cascade model first introduced by Haines-Young and Potschin (2010) and subsequently adapted to landscape planning by Haaren et al. (2014) and Albert et al. (2016a), ecosystem services are a function of the ecosystems' capacity to provide services, the human inputs necessary to use them, and society's demand for such services. The flow of ecosystem services connects the ecosystem with the socioeconomic system and leads to benefits. A key difference with almost all other ES is that RES are "user movement related" (Costanza 2008), meaning that there must be a flow of people from service-benefitting areas (SBAs, Syrbe and Walz 2012) to service-providing areas (SPAs, Syrbe and Walz 2012) for RES Flow to occur. At the same time, they are also what Costanza (2008) calls "local proximal (depends on proximity)", especially regarding nearby recreation. We suggest a set of terms and definitions to better differentiate the RES cascade (Table 1) that account for these differences.

Table 1: Terms and definitions for the RES cascade

Term	Definition
Recreational Ecosystem Services (RES)	RES are the biotic and abiotic characteristics of nature that enable activities promoting health, recuperation or enjoyment through active or immersive and/or passive or observational interactions (Haines-Young and Potschin 2018). These are direct, in-situ and outdoor interactions that depend on the presence in the environmental setting. RES and additional ecosystem services form the broader category of Cultural Ecosystem Services (CES, Haines-Young and Potschin 2018).
Nature-Based Recreation (NBR)	NBR is the term for all recreational activities that involve some elements of nature, for example, terrain, plant or animal species, or water features.
RES Capacity	RES Capacity is the natural contribution to the generation of → RES that may provide benefits to humans today or in the future. They are usually valued by humans but not necessarily used today (Haaren et al. 2014).
Human inputs	Human inputs are the anthropogenic contributions to the generation of → RES, thereby converting → RES Capacity into → RES Supply), including, the development of recreational infrastructure.
RES Supply	RES Supply is the actual provision of → RES in a particular place, i.e. opportunities for → NBR. RES Supply relies on contributions from ecosystems (→ RES Capacity) and people (→ human inputs such as recreational infrastructure).
Service-providing areas (SPAs)	Service-providing areas (SPAs, Syrbe and Walz 2012) are places with → RES Supply. They are potential destinations for → NBR trips.
Service-benefitting areas (SBAs)	Service-benefitting areas (SBAs, Syrbe and Walz 2012) are the areas (settlements) where RES beneficiaries are located. They are the sources for → NBR trips.
RES Demand at SBAs	RES Demand at → SBAs refers to the need for → NBR by the population (Albert et al. 2016b). It depends on the size of the population of SBAs and their willingness to interact with the ecosystem, i.e., to take NBR trips. This demand resides at SBAs but is directed towards the landscape because it cannot be fulfilled at the SBAs.
Potential RES Demand at SPAs	Potential RES Demand at SPAs is the → RES Demand at SBAs assigned to → SPAs. Because → RES are 'user movement related' and 'local proximal' (Costanza 2008), spatial relationships between SPAs and → SBAs are crucial. The proximity and the transport network determine the permeability of the space between them (Syrbe and Grunewald 2017). As poor permeability creates socioeconomic trade-offs, the number of → SPAs relevant for an SBA is limited, and vice versa. This allows for identifying relevant SPAs and distributing the RES Demand at SBAs among them. Potential RES Demand at SPAs depends on the RES Demand at relevant SBAs, the travel time their population would tolerate to reach respective NBR opportunities, and the availability of alternative destinations.
RES Flow	RES Flow refers to the → RES that are generated (→ RES Supply) and actually used in a specific area and time (Albert et al. 2016b). RES Flow depends on → RES Supply at SPAs, the respective user preferences, and the → Potential RES Demand at SPAs (converting → RES Supply into → RES Flow). In other words, in-situ RES Flow is the modelled or measured extent of → NBR visits per temporal and spatial unit. Other commonly used terms are RES use or utilisation (Haaren et al. 2014).
RES Benefits	RES Benefits are created among people in response to → RES Flow. RES Benefits occur at different locations and levels. At an individual level, people improve their (mental) health and well-being through → NBR. At the → SBAs level, communities benefit when their citizens enjoy → NBR, become healthier, work more productively, and relieve the healthcare system. At the → SPAs level, destinations providing → RES can benefit from on-site expenses on → NBR trips leading to income for local businesses. RES Benefits thus flow (are exchanged) between SPAs and SBAs.

A comprehensive and spatially explicit qualitative evaluation and quantification of the whole (R)ES cascade is indispensable for supporting planning, policy development and decision-making (Peña et al. 2015). It could motivate and provide recommendations for landscape protection and development to increase supply or flow (Ekinci et al. 2022) or to prevent overuse (Salvatori et al. 2023). It could help improve the consideration of RES in the multifunctional management of landscapes (cf. Neyret et al. 2023) and inform potential cooperation between regions or regulations on higher decision levels, e.g. through payments for ecosystem services (Schirpke et al. 2016).

Addressing the increasing interest in nature's capacities to deliver RES, various approaches have been published on how to map and assess RES (Hermes et al. 2018b; Cheng et al. 2019). All provide valuable input on which to draw, but an assessment that comprehensively supports planning decisions is still lacking. The decision relevance of ES research is still limited because the connection between the supply of ES and its beneficiaries is rarely included in ES assessments (Longato et al. 2021; Mandle et al. 2021). Earlier studies focused on assessing ES capacities and later turned to quantifying the supply and demand (Hernández-Morcillo et al. 2013; Milcu et al. 2013; Yahdjian et al. 2015). Most previous studies on RES quantification incorporating demand and supply focus on their monetary value or the number of visits (Boerema et al. 2017; Hermes et al. 2018b). They are usually conducted on local to regional scales or cover only a part of the territory. They focus on urban green space accessibility (e.g. Wüstemann et al. 2017; Weber et al. 2022), specific ecosystems or 'touristic' landscapes (Elsasser et al. 2016; Ghermandi 2018; Kulczyk et al. 2018; Inácio et al. 2022), or National Parks (e.g. Heagney et al. 2018; Mayer and Woltering 2018; Sinclair et al. 2020).

Most approaches consider RES Demand at SPAs through visitor surveys or social media data but fail to meaningfully connect it to the sources of recreational trips (SBAs). Other approaches generate spatially aggregated results (e.g. Ezebilo 2016) and can give only general recommendations for planning and management. There are very few comprehensive large-scale studies. Paracchini et al. (2014) and Vallecillo et al. (2019) include only areas with high RES Supply and use linear distance buffers of up to 4 km around them to consider the RES Flow. Using buffers around potential destinations or sources to count potential visitors is problematic. Only the nearest sources or destinations are considered when buffers do not overlap or potential visitors are counted for multiple destinations due to overlapping buffers. Sen et al. (2014) present an approach that solves this issue but falls short in adequately incorporating the RES Supply. They include RES Capacities of the whole territory but ignore human inputs like recreational infrastructure or points of interest that enable or support their utilisation (Sen et al. 2011). To the best of our knowledge, there are no large-scale studies analysing RES Benefit Flows. Existing regional or local scale assessments (e.g. Burkhard et al. 2012; Peng et al. 2020) usually calculate them within administrative units, which is important information but does not facilitate planning responses for balancing services or for developing offsetting mechanisms between deficient and oversupplied units.

The territory of Germany provides a valuable case study given its diversity of landscape characteristics, harmonious spatial data, and existing results from prior national-level assessments. Walz and Stein (2017), Hermes et al. (2018a), and Roth et al. (2018) find comparable levels of RES Capacity across Germany. Hermes et al. (2021) present a national-level empirical study on the RES Demand of the German population. Schwarz-von Raumer et al. (2019) incorporate supply and modelled demand to map the importance of landscapes for recreation. Their demand model considers accessibility of potential destinations but is not yet empirically grounded.

A remaining challenge is to develop comprehensive spatially-explicit indicators that adequately incorporate RES supply, demand and flow at national levels (Kulczyk et al. 2018). A particular difficulty is their dependence on user movement. Accounting for proximity or accessibility is indispensable as the RES Supply can only be enjoyed when people have access to it (Costanza 2008; Yahdjian et al. 2015). Hence, convincing models must incorporate spatial connections between SPAs and SBAs.

An improved assessment of RES needs to fulfil three key requirements: (1) It must combine a profound mapping of the RES Supply of the ecosystem with a convincing model of the RES Demand in the socio-economic system to achieve reliable modelling of the RES Flow. (2) It should replicate the trade-off between the effort (time, nerves, money) required to reach a potential destination and the expected health and well-being benefits tied to its RES Supply, incorporating user preferences. (3) It needs to disentangle the complex co-dependencies between supply and demand, and fashion RES Flow indicators that can help answer different management questions to usefully inform planning, policy and decision-making.

This paper aims to spatially model the flow of recreational ecosystem services in Germany, applying a novel method that fulfils the requirements outlined above. Our research objectives are

(i) to spatially model the Potential RES Demand at SPAs to spatially connect them to SBAs,
(ii) to map spatial matches and mismatches between Potential RES Demand at SPAs and their RES Supply,
(iii) to estimate the spatial distribution of RES Flow across Germany,
(iv) to quantify the flow of RES Benefits between German counties.

Such knowledge about demand, supply, flow and their interrelation can support landscape planning by identifying areas where supply should be improved to meet the demand, and by motivating respective measures. Furthermore, areas of high supply and flow can be targeted for considering measures for avoiding overuse or to protect them from potentially harmful developments (e.g. renewable energy transition (Wiehe et al. 2021) or traffic infrastructure). A monitoring would allow exploring temporal dynamics of RES (cf. Rau et al. 2020).

We focus on NBR-related day trips by car, which is the most relevant NBR trip type in Germany in terms of absolute time and cost allocation (Hermes et al. 2021). Day trips are understood as journeys of at least four hours but without overnight stay.

Materials and Methods

Research design

We use a raster-based iterative spatial modelling approach consisting of four steps with each addressing one objective.

To model *Potential RES Demand at SPAs*, we first determine the RES Demand at SBAs using data from a previous empirical study on NBR in Germany (Hermes et al. 2021) and census data. Demand for RES can be measured in terms of preferences and values, or as the direct use of ecosystems for recreational purposes, irrespective of where RES were provided (Burkhard et al. 2012). The latter means equating demand and flow, which refers to the equilibrium between demand and supply often assumed in economics (Wolff et al. 2015). We follow this approach using empirical data on people's behaviour and preferences regarding actual NBR trips (Hermes et al. 2021). This includes the participation rate and willingness to travel to SPAs (travel time tolerance). Census data provides the locations and population of SBAs across Germany. Incorporating the road network and assumptions on travel speeds our iterative model calculates the Potential RES Demand at SPAs, expressed as the potential number of visits to an SPA, depending on its travel time from accessible SBAs and their demand.

Next, we map <u>*spatial matches and mismatches*</u> between Potential RES Demand at SPAs and their RES Supply. They ultimately determine the RES Flow (Vallecillo et al. 2019) that may be realized. We spatially overlay them employing a classification matrix to map and classify demand-supply matches and mismatches at SPAs. The result is a spatially explicit qualitative indicator describing the nature of the relationship between SBAs and SPAs.

For quantifying the RES Flow, we need to know where people might want to go in addition to where they could go. Hence, we modified the model from step one to include spatial data on the RES Supply levels at SPAs and corresponding user preferences. Our resulting <u>*RES Flow indicator*</u> is the number of visitor days to a place, depending on its RES Supply (incl. user preferences), its proximity to accessible SBAs (incl. travel time tolerance), the population per SBA, and the quality and proximity of all other SPAs for a given SBA (alternative destinations).

We then explore the flow of <u>*monetary RES Benefits*</u> between counties. The in-situ RES Flow is associated with expenses for recreationists, which in turn is income for local businesses. We use a lump sum for on-site expenses per trip (Hermes et al. 2021). We aggregated the expenses linked to SBAs per county and compare it to the income through modelled RES Flow at SPAs per county. The resulting balance reflects the exchange of benefits across county borders. We can assume that the emerging patterns also reflect the benefits that individuals derive from NBR, but with reversed polarity.

Preparing input data

Hermes et al. (2018a) mapped the aesthetic quality of landscapes in Germany (RES Capacity). They disregard human inputs such as recreational infrastructure that turn the capacity into RES Supply (Albert et al. 2016b; Kulczyk et al. 2018) or support recreational use (Kulczyk et al. 2018). We modified their approach to include human inputs, namely the road and trail network suitable for recreational activities and points of interest that add value to potential destinations (Haaren et al. 2014). For a description of the modifications see Appendix S1. We use the resulting RES Supply map as input data (Figure 3 top left).

Census points at the settlements across Germany are the sources of NBR trips in our model. We consider one point to represent one SBA. Hence, settlements consist of multiple SBAs. Therefore, we can account for travel time through cities, which is particularly relevant in larger agglomerations. We aggregated the original dataset with 1 km point spacing (inhabited 1 km^2-cells; Federal Statistical Office (2015)) to 3 km point spacing. Only SBAs with at least 300 inhabitants (0.3 inhabitants/km^2) were considered further. This reduces the number of points from 214 633 to 26 115 while still representing nearly 98 % of the population. It is a compromise between representativeness and required processing power. Points outside of settlements were moved to the nearest boundary of one to avoid distortions in travel time modelling.

Hermes et al. (2021) analysed the NBR preferences of 2455 respondents in their nationwide representative survey. Their respondents reported their general behaviour regarding NBR (e.g. participation in different trip types, characteristics of trips) and their last respective trip. Hermes et al. (2021) found that 56% of respondents participated in no less than four-hour NBR day trips at least once in the year prior to the survey. The average frequency was 29 trips per person per year. We use these values to calculate the RES Demand at SBAs. The annual number of trips emanating from each SBA is its population multiplied by the NBR day trip participation rate and trip frequency per person. Note that we use data on actual NBR trips to extrapolate demand. Therefore, demand corresponds to actual use or flow. However, demand could be higher than use if people cannot meet their need for NBR day trips due to limited availability of RES supply. They might choose overnight trips or other activities instead.

Data on respondents' last trip surveyed by Hermes et al. (2021) include starting points and destinations of the trips. They calculated travel time and distance for each surveyed trip based on a cost-distance approach. Based on their data, we assessed the share of surveyed day trips by car in 10-minute increments (travel time zones, Figure 1), which represents the travel time tolerance in our model.

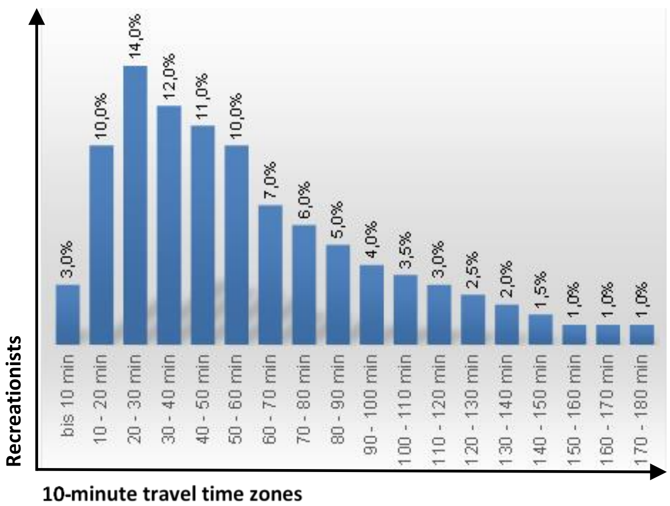

Figure 1: Share of surveyed day trips by car in 10-minute travel time zones (one way; data: Hermes et al. (2021))

Hermes et al. (2021) transformed a dataset of the German road network into a cost surface for their cost-distance model. The cost surface is a 1 km raster with the time needed to cross a grid cell as values. It is based on average road speed estimates of different road types (Table 2) and walking speed for cells that do not intersect roads. We use the same cost surface to incorporate travel time in our models.

Table 2: Average road speed estimates based on Schnabel and Lohse (2011) and Gerlach (2009)

Road type	Out of town	In town
Motorway (Autobahn)	110 km/h	80 km/h
Federal road (directions separated)	110 km/h	45 km/h
Federal road	72 km/h	40 km/h
State road (directions separated)	80 km/h	40 km/h
State road	51 km/h	29 km/h
District road (directions separated)	58 km/h	29 km/h
District road	39 km/h	19 km/h
Municipal road (excluding pedestrian zone)	22 km/h	18 km/h

By analysing the RES Supply levels at the destinations of the trips surveyed by Hermes et al. (2021), we derive the corresponding user preferences. More precisely, we use the density of trips per RES Supply level. First, we calculated the share of surveyed destinations per level. We extrapolated to the parent population (both from Hermes et al. 2021) to project the number of trips per level. Finally, we estimated the expected density (Table 3). We use the density because areas with very high RES Supply are rarer and often less accessible (Bredemeier and Hermes 2019). However, accessible areas are visited significantly more often, which the trip density indicates better. Finally, we assume that the ratios between the densities reflect the preferences and calculate respective factors accordingly. We assigned them to the RES Supply map to create the additional input for our RES Flow model.

Table 3: Estimated trip densities and preference factors for RES Supply levels

RES supply level	Relative landscape quality	Area [km²]	Surveyed destinations	Projected trips [Mio.]	Trip density [Trips/km²]	Preference factor
Very low	0 – 27	28 148	4 %	44.07	1566	0.08
Low	27 – 39	73 611	19 %	212.08	2881	0.15
Average	39 – 50	120 544	36 %	413.15	3427	0.18
High	50 – 62	86 741	28 %	322.26	3715	0.19
Very high	62 – 100	19 219	13 %	151.49	7882	0.40
All levels		328 262		1143.05	3482	

Spatially modelling Potential RES Demand at SPAs

We project the RES Demand at SBAs onto the landscape accessible from each SBA to establish a spatial connection with the SPAs. The Potential RES Demand at SPAs is the potential number of visits per year. Every place (1x1 km grid cell) outside built-up areas is a potential destination (or SPA) for NBR trips. Accessibility refers to the travel time needed to get to SPAs from a given SBA and the travel time tolerance of the population. Our model considers the following factors:

- locations of SBAs in Germany,

- RES Demand at SBAs (population X average annual number of NBR day trips per person),
- travel time to relevant SPAs,
- travel time tolerance, and
- availability (amount and accessibility) of alternative destinations.

The model combines the demand indicators 'population density' and 'proximity to settlement centres' proposed by Albert et al. (2016b). In addition, it considers almost all settlements, differentiates between the locations of SBAs within settlements, and incorporates the availability of alternative destinations.

Every SBA has limited accessible destinations, and SPAs can be visited from multiple SBAs. We use an iterative model to account for that. It distributes the RES Demand at SBAs for each SBA separately among the relevant SPAs. The accumulated number of potential visits per SPA from all iterations then indicates the Potential RES Demand at SPAs. The model (Figure 2) first selects an SBA. It then calculates the accessibility of relevant SPAs. Starting from the SBA, the model assigns the travel time accumulated over the cost surface with increasing distance to every cell up to 70 minutes. Like that, the accessible area extends further (in distance) from the SBA if, for example, there is a motorway nearby. This approach is more precise than Euclidean distances, even if they are adjusted for travel speeds. While it is less accurate than a network analysis approach, it requires less computational power.

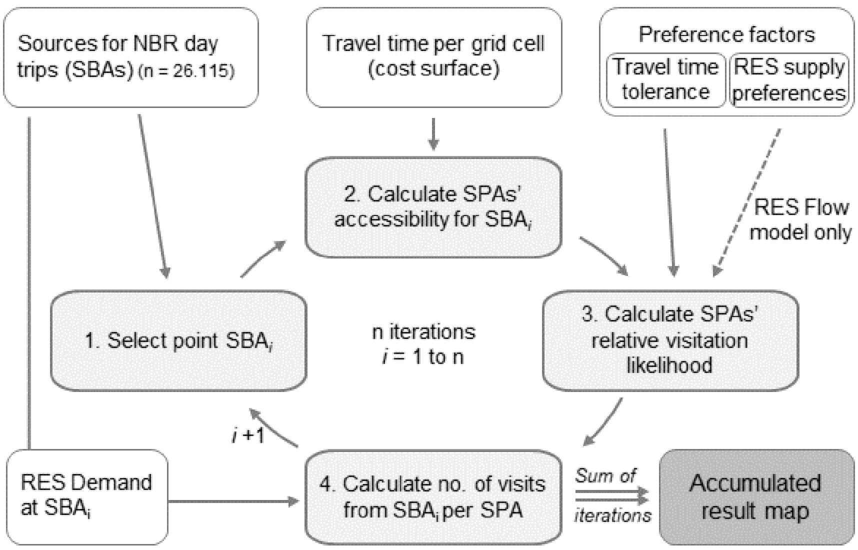

Figure 2: Flowchart of the model for mapping Potential RES Demand at SPAs and RES Flow

The model calculates a relative visitation likelihood per SPA, depending on the travel time distance between an SPA and the SBA and the travel time tolerance. We assign the respective share of trips to each cell in a travel time zone. The values of the individual cells divided by the sum of all cell values in the accessible area produce the relative visitation likelihood of each cell. An individual SPA is less likely to be visited with more cells in equal proximity to the SBA and the bigger the accessible area is. This reflects that the population may distribute thinner with more available alternatives.

The relative visitation likelihood per SPA (share of the demand) multiplied by the RES Demand at the SBA equals its potential number of visits from that SBA. The model adds this to the results from previous iterations and continues with the next source. The accumulated number of potential visits from all iterations is the Potential RES Demand at SPAs.

Mapping spatial relationships between Potential RES Demand and RES Supply at SPAs

Potential RES Demand at SPAs is ignorant of RES Supply. Therefore, some places cannot realise their potential because of low supply and high supply areas have to compensate for that. A spatial overlay of the RES Supply map and the Potential RES Demand at SPAs map identifies the nature of their spatial relationship. The matrix we suggest (Figure 3 bottom left) displays all possible combinations of levels in the resulting map. This allows for identifying the exact nature of the relationship. We classified the Potential RES Demand at SPAs into quintiles, meaning that all five levels cover roughly the same area. We combined this with the RES Supply levels map, giving a unique value to every possible combination. The resulting map displays the relationship between the RES Supply of a place and the RES Demand directed at it.

Spatially modelling RES Flow

We quantify RES Flow to complement the descriptive information given through the overlay matrix. The annual number of visits to a place indicates the RES Flow. It depends on its RES Supply level and respective user preferences, its accessibility from relevant SBAs, their RES Demand, and the supply level and accessibility of alternative destinations for the relevant SBAs. Low RES Demand, sparse transport infrastructure (impaired accessibility) and/or low RES Supply of an SPA can hamper the RES Flow. We use the same modelling approach as for the Potential RES Demand at SPAs but additionally incorporate the RES Supply levels of SPAs, to which we assigned the respective preference factors (Table 3). Changes to the model described above (Figure 2) only occur in step three, the calculation of relative visitation likelihood of SPAs. We multiply the travel time tolerance factors in the accessible area with the RES Supply preference factors per SPA before calculating the relative visitation likelihood just like before. The RES Demand at SBAs is again distributed accordingly among all SPAs in the accessible area.

Visitation likelihoods per SPA per iteration are unique to the spatial relation between one SBA and its surrounding landscape. The resulting map, however, is a spatially explicit quantification of RES Flow that shows accumulated visits to an SPA from all relevant SBAs. The fact that longer travel times may be accepted when supply is low or to reach areas with higher supply is disregarded.

Quantifying the Flow of RES Benefits between German counties

Quantitative information on RES Benefit flows between SBAs and SPAs can justify investments in better RES Supply and inform regional marketing. We distinguish individual health and well-being benefits through NBR assigned to SBAs, from economic benefits through income for local businesses from on-site expenses of recreationists. This income would not have occurred if the trips had not been taken. Since NBR was the main reason for the trips, this income can be attributed to RES at SPAs. We analyse these monetary benefits on a broader spatial scale. By balancing expenses of residents per county based on the RES Demand at SBAs and the income through RES Flow per county, we get an indication of the RES Benefit flows between counties. If residents realise their RES Demand inside their home county, the RES Benefits remain in the county. If they realise their demand in a neighbouring county, the benefits flow (are exchanged) between them.

At the SPA level, destinations providing RES can benefit from on-site expenses on NBR trips leading to income for local businesses. This income flows from the sources to the destinations, enabling or improving the livelihood of other individuals, also leading to welfare gains at societal level. Expenses for travel also occur but the resulting income is difficult to locate. On-site expenses represent only a fraction of the overall welfare gain, but are still relevant and relatively easy to measure and allocate.

We first multiplied the RES Demand at SBAs and the RES Flow at SPAs with the average expenses per person per trip (EUR 15.44 (Hermes et al. 2021)) to calculate expected expenses from SBAs and income for local businesses at SPAs. We applied a zonal statistic on the SBAs and SPAs datasets to sum up the expenses and income per county. The income-expense-balance indicates the Flow of RES Benefits between counties

Results

Distribution of Potential RES Demand at SPAs

The map of Potential RES Demand at SPAs accessible within a maximum 70-minute drive (Figure 3 top right) shows the highest values naturally in and around densely populated areas. By far the largest is the Rhine-Ruhr agglomeration, where ten to twelve million people live. The greater Berlin area, the Rhine-Main area, or Munich and Stuttgart metropolitan areas have only between five and six million inhabitants. The map reflects these differences. Highest demand exists in the Rhine-Ruhr area, followed by the area around and between Frankfurt and Stuttgart. Nationwide, the motorways make some areas accessible to people from the more densely populated areas. Berlin is a good illustration of how the Potential RES Demand at SPAs decreases with increasing distance from the conurbation and of the strong influence of the road network. The example of Hamburg shows how the Elbe represents a dividing line that leads to significantly lower values on its western side. Areas at the lower end of the scale are either sparsely populated or far away from population centres. This applies to parts of eastern Germany, the Alps, the Bavarian Forest and the German coasts.

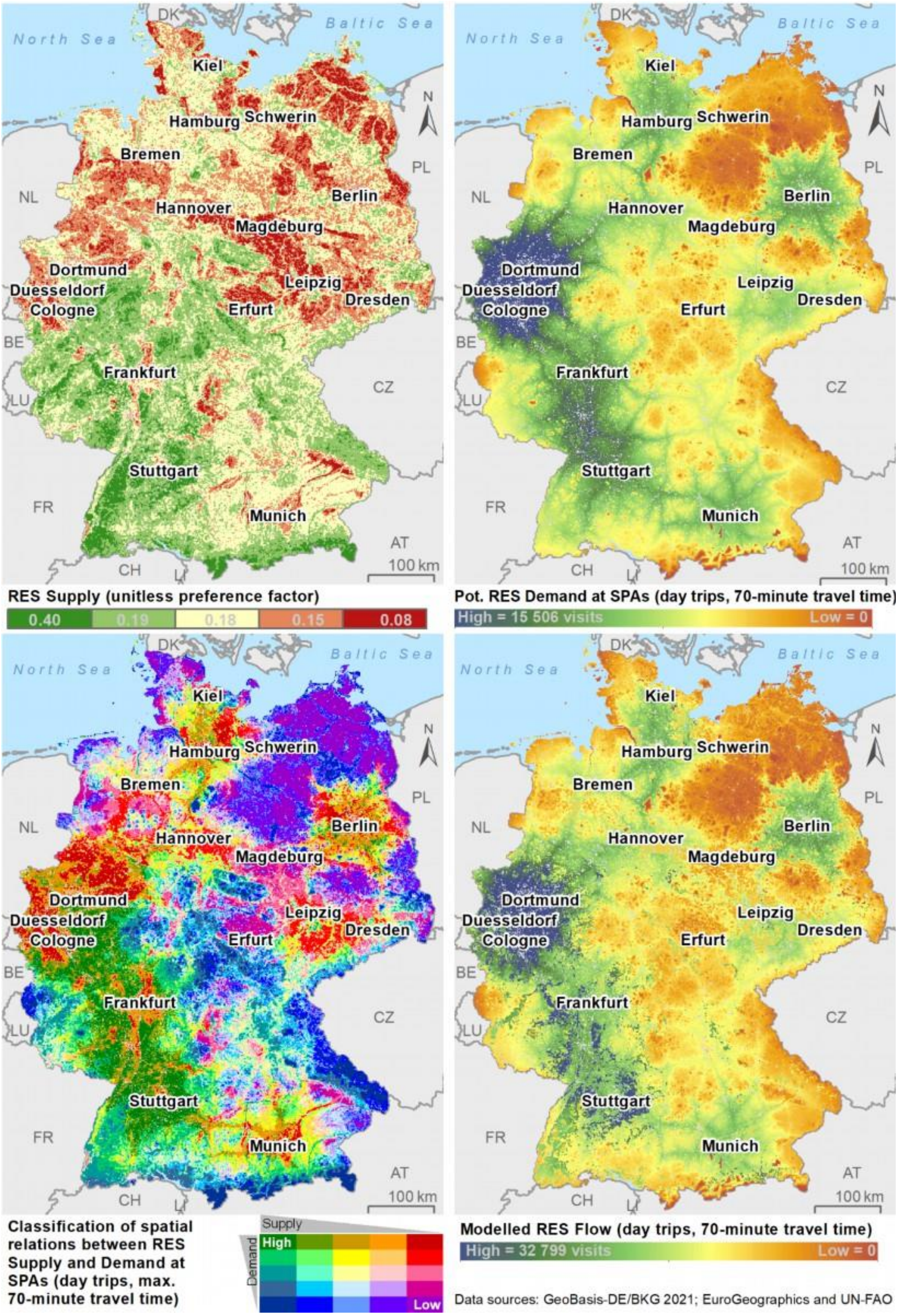

Figure 3: Maps of RES Supply (top left; further developed from Hermes et al. 2018a, see Appendix S1), Potential RES Demand at SPAs (top right), classified spatial RES demand-supply-relationships (bottom left), and modelled in-situ RES Flow (bottom left) for Germany. Demand model specific for NBR day trips with maximum 70-minute drive by car.

Spatial relationships between Potential RES Demand and RES Supply at SPAs

The spatial classification of relationships between RES Supply and Potential RES Demand at SPAs (Figure 3 bottom left) reveals that landscapes between the Rhine-Ruhr Area in the north and the Swabian Alb south of Stuttgart in the south are most important for NBR day trips with a maximum 70-minute drive by car. In these areas, the high demand in large parts meets a high supply level. Elsewhere, this combination only occurs on a much smaller scale south of Kiel, south of Berlin, between Hannover and Dortmund and north and south of Munich. The identified areas are widely known in Germany as attractive destinations for NBR.

High RES Demand but low RES Supply is found mainly in and around large conurbations such as Hamburg, Berlin, and Munich. The low RES Supply there results either from the expansive urban and sub-urban areas or from intensive agricultural use around them.

Areas with high supply but low demand are found on the German coast and islands, the Mecklenburg lake district, the southern heath between Hamburg and Hannover, the Alps, and various lower mountain ranges and river valleys. Those are often well-known touristic destinations. However, since our demand model only considers day trips with maximum 70 minutes travel time by car, they are not accessible for most people.

Areas with low supply and demand are found primarily in northern and eastern Germany and, to a smaller degree, in central and southeast Germany. Those areas are sparsely populated and under intensive agricultural use.

Distribution of RES Flow

The distribution of modelled in-situ RES Flow (bottom right) resembles the Potential RES Demand at SPAs (i.e. the link to population density and the road network). However, a differentiation caused by the RES Supply levels is also clearly visible. For example, the RES Flow in areas with high demand but low supply is visibly lower than in neighbouring areas with similar demand but higher supply. This can be seen in areas around the Rhine-Ruhr agglomeration, where the RES Flow in some low to medium supply areas is indeed high in a nationwide comparison due to the higher demand. Still, neighbouring areas with higher supply generate even more flow.

Further south, on the other hand, the reverse is visible. Landscapes such as the Moselle Valley or the Upper Middle Rhine Valley have a high attraction due to their very high supply and are therefore visited more on NBR trips than the supply-ignorant Potential RES Demand at SPAs suggested. The difference between the highest numbers of NBR visits per year between the two maps (RES Flow and RES Demand) results from this differentiation and concentration of RES Flow in the high-supply areas.

Flow of RES Benefits between German counties

The map of RES Benefits per county (Figure 4 top right) shows the balance between income through realised RES Flow at indigenous SPAs (Figure 4 bottom left) and NBR expenses from indigenous SBAs (Figure 4 top right). The balance indicates the flow or RES Benefits between counties in monetary terms. Positive values show where the RES Flow realised inside a county is higher than the RES Demand at its SBAs, meaning that they benefit from cash inflow. Conversely, negative values indicate that the demand per county is higher than the flow realised in it, which leads to cash outflow. Counties with cash outflow benefit from the RES Supply in surrounding counties in terms of positive effects on their residents' health and well-being. The amount shows the size of the difference.

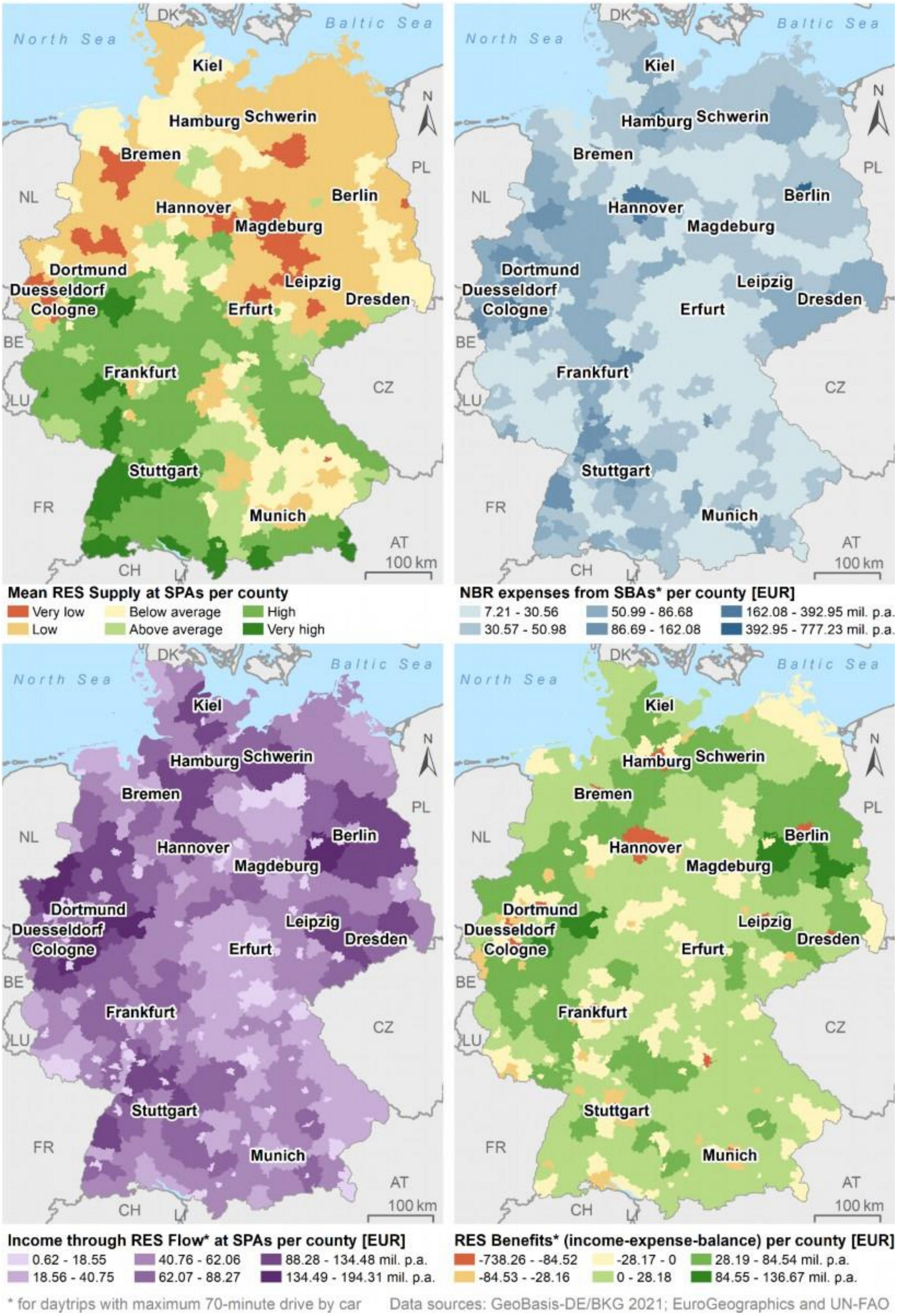

Figure 4: Mean RES Supply per county (top left), expected onsite expenses on NBR trips from SBAs (based on Demand at SBAs) inside counties (top left), income from onsite expenses generated through RES Flow at SPAs inside counties (bottom left), and

monetary RES Benefits (income-expense-balance) per county (bottom right). Results only refer to NBR day trips with maximum 70-minute drive by car.

The spatial patterns of the previous maps are also present here, but distorted due to the aggregation per county. Most counties in Germany benefit from RES-related cash inflow. However, the average is a 3.7 million EUR cash outflow. Although this is relatively close to equilibrium, it shows that the bigger part of the population cannot meet their RES Demand in their home county. At the same time, most (predominantly rural) counties have a moderately positive (0-28 million EUR) balance, meaning that they meet the demands of their population and have some visitors. This dichotomy results from the uneven distribution of population and SPAs among the counties.

The RES Benefit flow between counties depends on their RES Demand at SBAs and average RES Supply (Figure 4 top left), and those of their neighbours. But their size and share of urban areas are also decisive. Berlin, Hamburg, Munich and Cologne are urbanised to a large degree, expressed in a high population density and a big difference between RES Supply of the landscape and of the whole territory (Table 4). They are the counties with the highest cash outflow. Hannover has a much lower population density due to its large size, and has the sixth-highest cash outflow. However, while more than 90% of the expenses from Berlin, Hamburg and Munich flow to neighbouring counties, it is only 55% in Hannover. Freiburg has the ninth highest RES Supply at SPAs but still has cash outflow. This is due to Freiburg's high population density, small size, and uncertainties in the model specifications described in the discussion. Most counties in the Rhine-Ruhr area have high to moderate cash outflow, although combined they host a large part of the population. This is because their individual population densities are lower, and they provide some degree of RES Supply in close proximity. The highest cash inflows are modelled for Oberbergischer Kreis and Hochsauerlandkreis due to high RES Supply and accessibility from the Rhine-Ruhr area, and for Potsdam-Mittelmark and Dahme-Spreewald, which have below national average RES Supply but benefit from the high demand in Berlin. Dahme-Spreewald has the highest RES Supply in that region (apart from Potsdam county) whereas Potsdam-Mittelmark has lower supply but benefits from additional demand in Potsdam county.

Table 4: RES Flow modelling results for selected counties in Germany (complete list in table S2)

County name	Population [tsd. inh.]	Area [km²]	Population density [inh. /km²]	Mean RES supply (at SPAs)	Mean RES supply (SBAs = 0)	Income at SPAs [mil. EUR p.a.]	Expenses from SBAs [mil. EUR p.a.]	RES-related Benefit flow [mil. EUR p.a.]	Income-expense-ratio
Berlin	3 664	891	4112	37.78	18.30	38.97	777.23	- 738.42	- 95%
Hamburg	1 852	755	2453	39.29	21.74	36.94	392.95	- 356.10	- 91%
Munich	1 488	311	4790	34.67	14.78	11.18	315.68	- 304.57	- 96%
Cologne	1 083	405	2675	37.41	22.19	48.20	229.83	- 181.68	- 79%
Hannover	1 155	2 297	503	35.74	30.75	110.54	245.07	- 134.58	- 55%
Freiburg	231	153	1509	64.05	49.55	7.73	48.99	- 41.26	- 84%
Hochsauerlandkreis	259	1 960	132	58.34	55.07	151.5	54.95	96.54	176%
Dahme-Spreewald	173	2 275	76	43.25	41.00	134.48	36.76	97.71	266%
Potsdam-Mittelmark	218	2 592	84	42.08	39.98	175.11	46.23	128.87	279%
Oberbergischer Kreis	272	919	296	61.44	54.93	194.3	57.63	136.66	237%
Germany	**83 155**	**357 580**	**233**	**45.87**	**42.29**	**~17 640**	**~17 640**	**0.00**	**0.00**

Discussion

We present three indicators of RES Flow, each for answering different planning questions. They consider the spatial relationships between RES Supply of the landscape and the demand directed at it, including the population density and travel time tolerance for day trips. One is a spatially explicit qualitative indicator classifying the nature of this relationship. The second is a spatially explicit quantitative indicator of in-situ RES Flow. The third is a spatially aggregated quantitative indicator of RES Benefit Flows between German counties. The three indicators, along with a map of RES Supply, have different implications for planning, destination management, and the development of respective policies.

We model Potential RES Demand at SPAs using the starting points of NBR day trips, the road network, average road speed estimates, and travel time tolerance to predict the demand at potential destinations. While this approach is not new (e.g. Sen et al. 2014), it is still common practice, especially in larger-scale travel cost approaches, to use Euclidean distance buffers representing average travel time or cost per kilometre (Mayer and Woltering 2018; Vallecillo et al. 2019). Our results showcase the significant influence the road network has on accessibility. Furthermore, it solves the issue of multiple counts of potential visitors or limits to nearest sources or destinations when assessing multiple sites. Hence, we advocate using this modelling approach more frequently in travel-cost approaches[1]. However, network analyses are even more precise and can incorporate public transport. This is already more common on a local scale (e.g. Weber et al. 2022) and might be possible on a national scale in the future.

Our approach to mapping demand-supply relationships identifies areas of particular deficiency and high need for investments in natural capital, areas with potential for development, highly important areas that might need management to avoid overuse, and areas that are less relevant for providing

[1] Data will be available at https://doi.org/10.25835/0006102 upon publication of this manuscript.

RES (Table 5). This is essential information for local planning authorities to develop adequate measures. Our results are more informative than the demand-supply-mismatch matrix proposed by Albert et al. (2016b) or the importance matrix from Schwarz-von Raumer et al. (2019). Analysing the difference between Potential RES Demand at SPAs and the RES Flow can also indicate potential welfare gains by investing in natural capital to increase RES Supply in high-demand areas (Albert et al. 2016b), which is crucial for informing planning and destination management. We can only provide this information by modelling potential demand in addition to RES Flow.

Table 5: Examples of how our results can inform and support planning and decision making

Result	Information for planning and decision-making	Examples for recommendations
Potential RES Demand at SPAs	Accessibility of SPAs Quantity of unrealised potentials (through comparison with RES Flow)	Develop areas with high potential demand Enhance access to selected areas with unrealised potentials
Spatial matches and mismatches between RES Supply and Demand	Classification of the current situation supports choice of suitable measures and prioritisation.	Prioritise preservation and/or management in areas with high supply and demand to prevent overuse; consider developing alternative destinations Prioritise developing RES Supply in areas with high demand but medium to low supply Prioritise preservation in areas with low demand but high supply; assess importance for tourism; consider improving daytrip accessibility Prioritize other ES and land uses in areas with low demand and supply
RES Flow	Additional quantitative arguments for measures, investments and prioritisation Option for monitoring Possibility for nationwide and regional comparisons	Avoid RES impacting projects in areas with high flow (indicates high sensitivity / potential for conflict) Prioritize other ES and RES-impacting projects in areas with low flow (consider possible touristic importance)
Flow of monetary RES Benefits	Additional monetary arguments for measures, investments and prioritisation Option for monitoring Possibility for nationwide and regional comparisons	Invest in RES supply in counties with negative balance (this may yield welfare gains) Strengthen leisure and tourism sector, target marketing to neighbouring counties and further develop RES Supply in counties with positive balance Explore opportunities for mutually beneficial cooperation between neighbours with contrasting balance Use comparison results for marketing

We consider the whole territory outside built-up areas to be able to supply a certain degree of RES. How much RES Flow is generated depends on the RES Supply, people’s preferences and travel time tolerance. Our model reflects that even low-supply areas are used for NBR by some, if no better alternatives are available. Therefore, it is a more comprehensive evaluation of the RES Flow than previous studies have presented (e.g. Vallecillo et al. 2019; Mayer and Woltering 2018; Ezebilo 2016; Sen et al. 2011; Sen et al. 2014). A novelty we present is the consideration of trip densities rather than visits per supply level when analysing revealed preferences. This better reflects the rarity and uneven distribution of areas of very high supply across the country in the modelling (cf. Bredemeier and Hermes 2019).

Our results for the flow of RES Benefits between counties quantify a part of the return of investments in RES. They visualise the exchange of well-being and income through the provision and use of RES and show counties with deficit or oversupply. They also identify which counties provide a supply for neighbouring counties and quantify it. This information could motivate and supply arguments for local planning authorities (who are responsible for the provision of nearby NBR opportunities) to invest in RES supply and its accessibility. Measures to positively affect the RES Flow balance mean that more NBR-related expenses are transferred from one county inhabitant (recreationist) to another (local business owner), instead of leaving the county. They can also mean that more income is generated through visitors. Furthermore, such investments would reduce travel times, related costs and CO_2 emissions, and might increase the participation in NBR among the population if better NBR opportunities were available. Lastly, the information our model provides could also help initiate cooperation between counties, e.g. through payments for ecosystem services (Schirpke et al. 2016).

When applied in monitoring schemes, our indicators could help revealing changes in RES Flow over time. However, analysing the reasons for changing RES Flow in a particular area is difficult. It may decrease or increase for various reasons:

- changes in RES supply of that location,
- changes in its accessibility (road network),
- growing or decreasing population at relevant sources, and/or
- changes in RES Supply and/or accessibility of alternative destinations.

In some cases, the flow could still increase while the RES Supply decreases, and vice versa. Therefore, analyses of temporal dynamics should look at all three of our indicators comparatively and relate them to changes in input data (supply, population, road network). In addition, preferences and travel time tolerance may also change over time, requiring adjustments.

RES Demand and Flow are typically measured or indicated by counting or modelling visits (demand-supply-equilibrium, Wolff et al. 2015). The more visits, the higher the RES Flow. Schägner et al. (2018) conclude that accurate estimates of visitor numbers are of greater relevance than accurate estimates of the value per visit. However, this approach is unable to account for demands which are not met. They refer to individual needs for recreation opportunities to reach a level of personal well-being and quality of life (Costanza et al. 2007). It also disregards that areas with high RES Supply may provide bigger individual benefits than a medium RES Supply area with the same number of visits (i.e. equal flow). Future research should focus more on this aspect.

A certain degree of uncertainty in the results due to the model specifications was inevitable. The fixed 70-minute accessible area means that every raster cell in that area will receive a small share of visitor days even if the supply is deficient and there are many high-supply alternatives closer to the respective source. This represents that all landscapes are used for NBR in some capacity, but may also include overestimations. This effect could be mitigated by making the travel time tolerance depend on the availability of RES supply. People living in high-supply regions may be much less tolerant of travel time or have different RES preferences than those in low-supply regions. Our model could be adapted accordingly, but the empirical data did not support such differentiation. The same goes for including differences between socio-economic groups.

A test modelling of RES Flow with a maximum travel time of 180 minutes generated a noticeably different result (Figure S3). The overall patterns are similar, but some areas that were now accessible to more people gained in RES Flow, while some medium and low-supply areas lost. Overall, the RES Flow is distributed wider over German landscapes, as indicated by the highest value now being only 15 000 annual visitor days. It shows the high influence of assumptions on modelling results. It also stresses that our results are only applicable for daytrips.

Further developing the flow model to incorporate accumulated travel costs from various sources to a RES supplying cell to express appreciation in monetary terms would be possible. This would follow the latest recommendations for economic valuation and environmental accounting by the UN SEEA-EA (2021).

Lastly, a larger sample would allow for a more advanced statistical analysis of the correlations between RES Supply and travel time tolerance. It would also enable incorporating socio-demographic and regional differences and modelling RES Flow on shorter leisure activities and multi-day trips. The modelling approach we present is suitable for integrating such results.

Conclusions

This study contributes to the state of knowledge in mapping and assessing recreational ecosystem services by evaluating the whole RES cascade from supply to benefits with a consistent approach. Especially the nationwide modelling of RES Flow from all (semi-)natural areas based on spatial relationships between SPAs and SBAs and their respective attributes is an important step towards better considering RES in planning, destination management, and policy making. Our results can inform local planners and decision makers about where measures are necessary or desirable and what kind of measures (development, protection, management) would be adequate. This aids the efficient use of funds to improve RES. Furthermore, quantifying the flow of RES benefits between counties can motivate action and steer investments in natural capital by making the potential benefits and their flow more tangible. This could facilitate cooperation between RES-supplying regions and those demanding this supply. Our results also support a better consideration of the spatial relationships between RES Demand and Supply in general spatial planning and impact assessments, especially on the national level, e.g. to allocate impacting development projects (e.g. renewable energy transition (Wiehe et al. 2021) or traffic infrastructure) to less important regions.

Monitoring RES Supply, Demand, and Flow using our approach can provide valuable insights into their spatio-temporal dynamics. For this purpose, we recommend applying our models at regular intervals with updated spatial data. Since preferences change much slower than land use, a survey could be repeated at longer intervals.

Taken together, we showed that modelling RES Flow from landscapes to people can help answer diverse questions around the safeguarding and enhancing of RES at local to national scales. Further research should focus on integrating modelling results for shorter leisure activities and multi-day trips, on empirical validation studies in selected case study areas, and on investigating the transferability of our approach to other countries in Europe and beyond.

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Appendix S1: Adjustment and further development of the assessment of the aesthetic quality of landscapes in Germany by Hermes et al. (2018).

Hermes et al. (2018)[2] mapped the aesthetic quality of landscapes in Germany using landscape diversity, naturalness and uniqueness as established indicators for landscape attractiveness. They apply several landscape metrics as proxies to spatially evaluate and map each of them in a multi-criteria GIS analysis. The resulting values are indicative, showing where quality is higher or lower compared to other places on a scale between 0 and 100, where 100 is the highest value found in Germany.

We modified their approach to account for peer feedback and our own reflections on the original model and results, and to better represent RES Supply. Hermes et al. (2018) mapped the ecosystems' capacity to supply RES. They disregard human inputs that turn the capacity into RES Supply (Albert et al. 2016), or complement the supply. Human inputs are the network of roads and trails suitable for recreational activities to make landscapes accessible, and points of interest that add value to potential destinations (Haaren et al. 2014).

Modifications to Hermes et al. (2018)

First, we reduced the study area compared to Hermes et al. (2018). According to our definition of RES, the open landscape, as well as urban green spaces, were to be assessed. Therefore, larger continuous urban areas were excluded from the assessment. Our study area includes the area of Germany without urban areas (incl. industry and commerce) and road, rail and air traffic areas (except for disused areas), based on the DLM250 (BKG 2020) (minimum size for the areal representation usually ≥ 40 ha). However, the urban green spaces depicted in the LBM-DE (BKG 2011) according to CORINE land use classification remained part of the study area. The assessment excludes the marine area itself but considers its aesthetic influence on the land area. The resulting mask defines the area relevant to RES Supply in the assessment.

The calculated values of individual grid cells represent the value of the respective landscape metric in a circular neighbourhood with a 1 km radius around that cell. For landscape metrics that measure the density of landscape elements, we now use the distance-weighted density (kernel density) instead of the density (elements per area). Landscape elements in the neighbourhood of a cell thus lose significance as the distance to the cell increases. Furthermore, the model now normalizes the natural logarithm of the results of individual metrics. This ensures that the effect of a few areas with extremely

[2] Preprint at https://doi.org/10.25835/0006102

high density is put into perspective. Previously, areas with low or medium density in relation to areas with extremely high density were no longer valued with sufficient differentiation after normalisation.

For the sub-indicator 'relief diversity', the relief energy ('elevation difference between highest and lowest point') in a 10 km radius around each grid cell is incorporated in addition to the density of contour lines in the 1 km neighbourhood. This highlights landscapes with particular long-distance views or spectacular horizons.

We changed the metric for the sub-indicator 'absence of noise' from a lump sum per road type on the basis of a linearly modelled sound propagation to one based on modelled noise bands (Esswein and Schwarz-v. Raumer 2004, data provided by Schwarz-v. Raumer). Their model uses sound propagation curves depending on traffic volume data and landscape structure.

We also improved the assessment of landscape uniqueness. In addition to the rarity of the landscape types, we now also consider whether a landscape is a riverine or hedgerow landscape according to Gharadjedaghi et al. (2004, updated in BfN (2014)) and whether it is part of a set of nationally significant landscapes in Germany according to Schwarzer et al. (2018a, 2018b). They include landscapes with special significance as natural landscapes, historically grown cultural landscapes, near-natural cultural landscapes with little technological influence, or other special individual landscapes, e.g. landscapes dominated by mining or military activities. Both factors indicate a higher uniqueness. For areas to which they apply, the revised model increases the initial rating based on rareness alone. The updated sub-indicator value is the normalized mean level in the 1 km neighbourhood.

Additions to better represent RES Supply

Two new metrics indicate the human inputs that turn the RES Capacity into RES Supply. The density of points of interest, and the density of the road and trail network relevant for nature-based recreation.

We consider points of interest as a form of human input. They comprise a subset of the landscape elements included in the assessment of uniqueness by Hermes et al. (2018), but go beyond that. Next to its effect on the aesthetic quality, a point of interest is highlighted by more intense maintenance, provision of information on site or online and in brochures, as well as additional recreational infrastructure (e.g. a kiosk, restrooms, events, guided tours). Some may also enable specific recreational activities, like climbing rocks, bathing waters or protected areas (for wildlife watching). Additional data sets are: UNESCO natural heritage sites, Ramsar sites, Natura 2000 sites, biosphere reserves, national parks, nature parks, EU bathing waters, and a map of climbing rocks from the German Alpine Association.

For landscape accessibility we distinguish (minor) roads from trails (based on BKG (2013)). Roads are approved for general traffic and are therefore not free of traffic and noise, as preferred by many recreationists. Trails include all farm roads, paths, tracks and the like that are only approved for agricultural and forestry traffic, or are exclusively for bikers and hikers. Due to their higher suitability for recreation, trails are weighted double in the calculation of density.

All metrics where calculated for a 100 m grid, as suggested by Hermes et al. (2018). The updated results are available online (Hermes 2023). We aggregated them to a 1 km grid. This was necessary because the lower resolution is less resource intensive and therefore takes less time in the more advanced iterative modelling of RES Flow. Lastly, we classified the indicative landscape quality values into five RES Supply levels, according to the national average and standard deviation (Tab. 2 in the manuscript).

Result: Supply of recreational ecosystem services in Germany

The area of Germany – excluding built-up areas – is roughly 339.000 km². The majority of that (36 %) has a medium supply level (Fig. 3 top left in the manuscript). High supply (27 %) is more common than low supply (22 %). Very high (6 %) or very low (8 %) supply levels are naturally rare, due to the classification method. Very high and high supply is closely linked to high landscape diversity, especially relief diversity, and naturalness. Examples are the Alps, lower mountain ranges like the Black Forest, and some river valleys such as the Moselle. The opposite is true of vast, open agricultural landscapes in the northern half of Germany, especially between Hanover, Magdeburg, Leipzig and Erfurt, and in north-east Germany. Big cities like Berlin, Hamburg or Munich also have few high supply areas in the immediate vicinity, unlike e.g. the Rhine-Ruhr agglomeration (Cologne, Duesseldorf, Dortmund), Frankfurt, and Stuttgart. The cities named on the map are either state capitals or have more than 500,000 inhabitants.

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Table S2: RES Flow modelling results for German counties

County name	Population [tsd.]	Area [km²]	Population Density [inh. / km²]	RES supply [0-100] at SPAs (excl. SBAs)		RES supply [0-100] incl. SBAs (= 0)		RES use at indigenous SPAs [mil visits p.a.]	Income at indigenous SPAs [mil. EUR p.a.]	Demand at indigenous SBAs [mil. visits p.a.]	Expenses from indigenous SPAs [mil. EUR p.a.]	RES use balance [mil. visits p.a.]	RES-related benefit flow	
				MEAN	StD	MEAN	StD						[mil. EUR p.a.]	ratio
Ahrweiler	130	787	166	59,19	6,81	55,78	15,28	6,18	95,42	1,79	27,68	4,39	67,73	245%
Aichach-Friedberg	135	780	173	44,35	7,02	41,44	12,91	2,92	45,03	1,86	28,65	1,06	16,39	57%
Alb-Donau-Kreis	198	1 359	146	53,08	9,43	49,99	15,44	5,38	83,08	2,72	42,05	2,66	41,03	98%
Altenburger Land	88	569	155	31,29	8,60	29,64	10,90	1,75	27,06	1,21	18,75	0,54	8,32	44%
Altenkirchen (Westerwald)	129	642	201	59,07	5,09	53,68	17,70	4,04	62,43	1,77	27,39	2,27	35,04	128%
Altmarkkreis Salzwedel	83	2 294	36	40,49	5,49	39,52	8,23	2,11	32,54	1,14	17,54	0,97	14,99	85%
Altötting	112	569	196	45,05	8,46	41,90	14,09	1,06	16,44	1,53	23,69	- 0,47	- 7,25	-31%
Alzey-Worms	131	588	222	55,04	11,28	51,39	17,51	4,22	65,08	1,80	27,73	2,42	37,35	135%
Amberg	42	50	839	52,72	4,30	39,56	23,12	0,11	1,68	0,58	8,92	- 0,47	- 7,24	-81%
Amberg-Sulzbach	103	1 256	82	52,87	4,85	50,95	10,98	2,85	43,96	1,42	21,85	1,43	22,11	101%
Ammerland	126	731	172	45,66	4,40	41,67	13,57	2,49	38,45	1,73	26,66	0,76	11,79	44%
Anhalt-Bitterfeld	157	1 454	108	33,11	11,55	30,93	13,86	2,82	43,57	2,16	33,36	0,66	10,22	31%
Ansbach	185	1 971	94	47,16	6,48	45,42	10,92	4,79	73,94	2,55	39,32	2,24	34,62	88%
Ansbach	42	100	417	48,91	4,70	42,38	17,19	0,26	3,95	0,57	8,84	- 0,32	- 4,89	-55%
Aschaffenburg	71	62	1135	48,46	6,85	35,00	22,47	0,25	3,87	0,97	15,03	- 0,72	- 11,16	-74%
Aschaffenburg	175	699	250	52,69	6,56	47,85	16,44	2,73	42,15	2,40	37,06	0,33	5,09	14%
Augsburg	296	147	2015	40,67	11,72	27,33	21,38	0,41	6,28	4,07	62,77	- 3,66	- 56,49	-90%
Augsburg	256	1 071	239	47,05	8,10	42,51	15,88	3,74	57,78	3,52	54,29	0,23	3,49	6%

County name	Population [tsd.]	Area [km²]	Population Density [inh. / km²]	RES supply [0-100] at SPAs (excl. SBAs)		RES supply [0-100] incl. SBAs (= 0)		RES use at indigenous SPAs [mil visits p.a.]	Income at indigenous SPAs [mil. EUR p.a.]	Demand at indigenous SBAs [mil. visits p.a.]	Expenses from indigenous SPAs [mil. EUR p.a.]	RES use balance [mil. visits p.a.]	RES-related benefit flow	
				MEAN	StD	MEAN	StD						[mil. EUR p.a.]	ratio
Aurich	190	1 287	148	44,81	6,03	40,84	13,96	2,29	35,31	2,61	40,35	- 0,33	- 5,04	-12%
Bad Dürkheim	133	595	224	60,68	9,14	56,11	18,26	4,41	68,06	1,83	28,22	2,58	39,84	141%
Bad Kissingen	103	1 137	91	52,44	8,97	49,81	14,41	2,23	34,38	1,42	21,89	0,81	12,49	57%
Bad Kreuznach	159	864	184	60,30	7,78	56,58	16,34	5,07	78,25	2,18	33,68	2,89	44,57	132%
Bad Tölz-Wolfratshausen	128	1 111	115	58,22	6,31	56,22	12,28	3,44	53,15	1,76	27,20	1,68	25,95	95%
Baden-Baden	55	140	396	67,79	7,48	59,77	23,00	0,90	13,91	0,76	11,76	0,14	2,15	18%
Bamberg	77	55	1404	41,78	7,00	26,06	20,98	0,11	1,65	1,05	16,27	- 0,95	- 14,61	-90%
Bamberg	147	1 168	126	49,89	7,12	47,65	12,45	3,13	48,33	2,03	31,29	1,10	17,04	54%
Barnim	187	1 480	127	44,10	8,19	40,75	14,09	6,55	101,06	2,57	39,75	3,97	61,32	154%
Bautzen	298	2 396	124	46,34	10,01	42,95	15,45	6,35	98,11	4,10	63,23	2,26	34,88	55%
Bayreuth	104	1 274	81	53,66	5,56	51,73	11,39	3,16	48,77	1,42	22,00	1,73	26,77	122%
Bayreuth	74	67	1107	54,48	4,70	37,39	25,58	0,14	2,17	1,02	15,71	- 0,88	- 13,54	-86%
Berchtesgadener Land	106	840	127	63,56	7,75	60,93	14,74	1,14	17,53	1,46	22,56	- 0,33	- 5,03	-22%
Bergstraße	271	719	377	56,19	11,90	49,80	21,06	4,93	76,06	3,72	57,50	1,20	18,56	32%
Berlin	3 664	891	4112	37,78	8,16	18,30	19,71	2,52	38,97	50,35	777,39	- 47,83	- 738,42	-95%
Bernkastel-Wittlich	113	1 168	96	59,18	9,45	56,82	14,83	3,87	59,82	1,55	23,91	2,33	35,91	150%
Biberach	202	1 409	143	51,93	6,42	48,92	13,64	4,07	62,86	2,78	42,91	1,29	19,95	46%

County name	Population [tsd.]	Area [km²]	Population Density [inh. / km²]	RES supply [0-100] at SPAs (excl. SBAs)		RES supply [0-100] incl. SBAs (= 0)		RES use at indigenous SPAs [mil visits p.a.]	Income at indigenous SPAs [mil. EUR p.a.]	Demand at indigenous SBAs [mil. visits p.a.]	Expenses from indigenous SPAs [mil. EUR p.a.]	RES use balance [mil. visits p.a.]	RES-related benefit flow	
				MEAN	StD	MEAN	StD						[mil. EUR p.a.]	ratio
Bielefeld	334	259	1289	45,11	9,55	30,37	22,56	1,16	17,91	4,58	70,76	- 3,42	- 52,85	-75%
Birkenfeld	81	777	104	58,36	6,48	55,17	14,68	2,51	38,69	1,11	17,15	1,40	21,54	126%
Böblingen	393	618	636	58,19	6,03	49,79	21,20	3,58	55,29	5,40	83,36	- 1,82	- 28,07	-34%
Bochum	364	146	2502	39,90	8,29	18,18	20,64	1,06	16,36	5,01	77,32	- 3,95	- 60,97	-79%
Bodenseekreis	218	665	328	60,27	5,37	55,59	16,93	1,85	28,51	2,99	46,23	- 1,15	- 17,73	-38%
Bonn	331	141	2344	46,22	9,00	26,07	23,90	0,90	13,94	4,54	70,14	- 3,64	- 56,20	-80%
Börde	171	2 367	72	32,20	12,18	30,61	13,77	3,90	60,17	2,34	36,19	1,55	23,98	66%
Borken	372	1 421	262	36,59	7,87	33,45	12,71	8,93	137,94	5,11	78,90	3,82	59,03	75%
Bottrop	117	101	1167	40,72	6,01	29,47	18,91	0,99	15,22	1,61	24,91	- 0,63	- 9,69	-39%
Brandenburg an der Havel	72	230	314	49,36	6,80	42,58	18,13	0,95	14,67	0,99	15,28	- 0,04	- 0,61	-4%
Braunschweig	249	193	1290	34,01	8,48	22,94	17,39	0,50	7,66	3,42	52,74	- 2,92	- 45,08	-85%
Breisgau-Hochschwarzwald	265	1 378	192	59,57	12,26	56,43	17,88	4,66	71,93	3,64	56,20	1,02	15,73	28%
Bremen	567	318	1781	36,65	8,25	20,41	19,22	0,74	11,36	7,79	120,21	- 7,05	- 108,85	-91%
Bremerhaven	114	101	1120	42,73	6,54	27,76	21,06	0,14	2,17	1,56	24,09	- 1,42	- 21,93	-91%
Burgenlandkreis	178	1 414	126	34,27	10,52	32,07	13,20	3,93	60,69	2,44	37,68	1,49	23,01	61%
Calw	160	797	201	64,76	6,50	59,94	18,12	5,66	87,41	2,20	33,98	3,46	53,43	157%
Celle	179	1 551	116	44,09	7,63	41,30	13,03	3,65	56,38	2,46	38,06	1,19	18,32	48%
Cham	128	1 527	84	56,52	5,89	54,62	11,73	1,94	29,92	1,76	27,18	0,18	2,75	10%
Chemnitz	244	221	1106	39,01	8,43	25,58	19,75	0,75	11,61	3,36	51,85	- 2,61	- 40,24	-78%

County name	Population [tsd.]	Area [km²]	Population Density [inh. / km²]	RES supply [0-100] at SPAs (excl. SBAs)		RES supply [0-100] incl. SBAs (= 0)		RES use at indigenous SPAs [mil visits p.a.]	Income at indigenous SPAs [mil. EUR p.a.]	Demand at indigenous SBAs [mil. visits p.a.]	Expenses from indigenous SPAs [mil. EUR p.a.]	RES use balance [mil. visits p.a.]	RES-related benefit flow	
				MEAN	StD	MEAN	StD						[mil. EUR p.a.]	ratio
Cloppenburg	173	1 420	122	31,31	8,08	28,89	11,41	3,15	48,61	2,37	36,63	0,78	11,98	33%
Coburg	87	590	147	46,16	7,00	43,05	13,40	1,10	16,94	1,19	18,37	- 0,09	- 1,43	-8%
Coburg	41	48	846	49,49	7,53	33,89	23,83	0,09	1,44	0,56	8,67	- 0,47	- 7,23	-83%
Cochem-Zell	62	692	89	58,37	9,34	56,51	13,76	2,42	37,35	0,85	13,06	1,57	24,29	186%
Coesfeld	221	1 112	198	33,09	8,02	31,12	11,04	8,14	125,73	3,03	46,83	5,11	78,90	168%
Cottbus	99	166	596	42,73	7,93	31,99	19,77	0,19	2,87	1,36	20,94	- 1,17	- 18,07	-86%
Cuxhaven	199	2 059	97	44,97	5,88	42,32	12,03	4,12	63,55	2,73	42,18	1,38	21,37	51%
Dachau	155	579	268	43,92	4,75	41,23	11,50	2,56	39,58	2,13	32,91	0,43	6,67	20%
Dahme-Spreewald	173	2 275	76	43,25	7,72	41,00	12,19	8,71	134,48	2,38	36,77	6,33	97,71	266%
Darmstadt	159	122	1304	46,18	7,59	35,08	20,82	0,56	8,63	2,19	33,77	- 1,63	- 25,14	-74%
Darmstadt-Dieburg	298	659	452	48,10	12,17	42,34	19,35	3,87	59,75	4,09	63,16	- 0,22	- 3,42	-5%
Deggendorf	119	861	139	45,07	14,62	42,33	17,80	1,56	24,09	1,64	25,35	- 0,08	- 1,26	-5%
Delmenhorst	78	62	1241	42,01	3,76	24,11	20,97	0,17	2,62	1,06	16,44	- 0,90	- 13,82	-84%
Dessau-Roßlau	79	245	324	39,43	8,13	34,52	15,07	0,64	9,94	1,09	16,84	- 0,45	- 6,90	-41%
Diepholz	218	1 991	110	38,13	9,35	35,97	12,67	5,39	83,20	3,00	46,27	2,39	36,93	80%
Dillingen a.d. Donau	97	792	123	40,65	8,50	37,97	13,01	1,73	26,78	1,34	20,62	0,40	6,17	30%
Dingolfing-Landau	97	878	111	42,22	9,79	40,23	13,10	1,94	29,95	1,34	20,63	0,60	9,32	45%
Dithmarschen	133	1 428	93	37,33	11,64	35,14	14,30	2,80	43,28	1,83	28,27	0,97	15,01	53%
Donau-Ries	134	1 275	105	42,56	8,94	40,10	13,18	2,85	44,03	1,85	28,50	1,01	15,53	54%

Supplementary Information

Preprint: Modelling flows of RES from landscapes to people: Insights from Germany

County name	Population [tsd.]	Area [km^2]	Population Density [inh. / km^2]	RES supply [0-100] at SPAs (excl. SBAs) MEAN	StD	RES supply [0-100] incl. SBAs (= 0) MEAN	StD	RES use at indigenous SPAs [mil visits p.a.]	Income at indigenous SPAs [mil. EUR p.a.]	Demand at indigenous SBAs [mil. visits p.a.]	Expenses from indigenous SPAs [mil. EUR p.a.]	RES use balance [mil. visits p.a.]	RES-related benefit flow [mil. EUR p.a.]	ratio
Donnersbergkreis	76	645	117	51,73	9,54	49,49	14,07	3,28	50,57	1,04	16,03	2,24	34,55	216%
Dortmund	588	281	2094	38,23	8,05	21,28	19,92	2,17	33,52	8,08	124,69	- 5,90	- 91,17	-73%
Dresden	556	328	1693	41,95	8,68	27,93	21,02	0,93	14,34	7,64	118,01	- 6,71	- 103,68	-88%
Duisburg	496	233	2130	41,17	7,79	23,09	21,25	1,78	27,44	6,81	105,21	- 5,04	- 77,77	-74%
Düren	265	941	282	39,76	14,65	34,39	19,24	6,59	101,72	3,64	56,25	2,94	45,46	81%
Düsseldorf	621	217	2854	40,23	10,33	23,22	21,37	1,73	26,75	8,53	131,65	- 6,79	- 104,91	-80%
Ebersberg	144	549	262	42,42	8,66	39,75	13,28	2,09	32,20	1,98	30,57	0,11	1,63	5%
Eichsfeld	99	943	105	46,25	10,76	44,63	13,56	1,88	29,07	1,37	21,10	0,52	7,97	38%
Eichstätt	133	1 214	110	42,74	7,09	40,77	11,33	3,35	51,71	1,83	28,25	1,52	23,46	83%
Eifelkreis Bitburg-Prüm	100	1 627	61	55,20	5,89	53,50	11,16	2,23	34,37	1,37	21,23	0,85	13,14	62%
Eisenach	42	104	403	48,91	15,48	42,75	21,74	0,25	3,93	0,58	8,90	- 0,32	- 4,98	-56%
Elbe-Elster	101	1 899	53	36,35	6,79	34,41	10,51	2,70	41,76	1,39	21,45	1,32	20,32	95%
Emden	50	112	444	43,11	5,60	33,73	18,47	0,19	2,92	0,69	10,58	- 0,50	- 7,66	-72%
Emmendingen	167	680	245	61,89	8,55	58,05	17,08	2,39	36,89	2,29	35,40	0,10	1,49	4%
Emsland	329	2 884	114	37,63	8,99	34,91	13,05	5,72	88,27	4,52	69,79	1,20	18,48	26%
Ennepe-Ruhr-Kreis	323	410	789	55,34	7,60	43,10	23,93	5,15	79,48	4,44	68,56	0,71	10,92	16%
Enzkreis	200	574	348	59,19	7,01	52,46	19,92	4,04	62,36	2,74	42,38	1,29	19,98	47%
Erding	139	871	160	40,10	8,25	38,34	11,51	3,28	50,71	1,91	29,47	1,38	21,24	72%
Erfurt	214	270	792	33,50	10,12	27,10	16,01	0,45	6,95	2,94	45,34	- 2,49	- 38,39	-85%
Erlangen	112	77	1460	40,07	8,74	27,73	19,88	0,14	2,23	1,54	23,84	- 1,40	- 21,61	-91%
Erlangen-Höchstadt	138	565	245	48,73	7,18	44,99	14,68	1,53	23,66	1,90	29,30	- 0,37	- 5,64	-19%

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Erzgebirgskreis	332	1 828	182	52,56	6,79	46,77	17,65	5,15	79,53	4,56	70,42	0,59	9,11	13%
Essen	582	210	2769	49,48	12,40	24,39	26,22	2,06	31,73	8,00	123,57	- 5,95	- 91,84	-74%
Esslingen	534	641	832	61,74	10,00	50,51	25,47	4,28	66,08	7,33	113,22	- 3,05	- 47,14	-42%
Euskirchen	194	1 249	156	49,82	12,11	46,59	16,95	7,49	115,71	2,67	41,24	4,82	74,47	181%
Flensburg	90	57	1585	34,98	4,56	19,54	17,70	0,04	0,63	1,24	19,08	- 1,20	- 18,45	-97%
Forchheim	117	643	181	58,75	7,24	54,96	16,03	2,17	33,48	1,60	24,74	0,57	8,74	35%
Frankenthal (Pfalz)	49	44	1111	44,61	5,48	34,34	19,38	0,21	3,22	0,67	10,34	- 0,46	- 7,12	-69%
Frankfurt (Oder)	57	148	386	32,74	6,68	27,87	13,18	0,40	6,14	0,78	12,10	- 0,39	- 5,96	-49%
Frankfurt am Main	764	248	3077	35,03	9,02	22,58	18,26	0,86	13,28	10,50	162,12	- 9,64	- 148,84	-92%
Freiburg im Breisgau	231	153	1509	64,05	9,10	49,55	27,97	0,50	7,73	3,17	49,00	- 2,67	- 41,26	-84%
Freising	180	800	225	44,43	7,61	41,67	13,02	3,35	51,78	2,48	38,26	0,88	13,52	35%
Freudenstadt	118	870	136	61,76	7,40	58,48	15,61	4,11	63,48	1,63	25,11	2,48	38,36	153%
Freyung-Grafenau	78	984	80	59,26	4,89	57,33	11,57	1,29	19,84	1,08	16,62	0,21	3,22	19%
Friesland	99	610	162	44,14	5,97	40,32	13,66	1,55	23,97	1,36	21,00	0,19	2,97	14%
Fulda	223	1 380	162	57,79	7,17	54,22	15,55	3,70	57,15	3,06	47,32	0,64	9,83	21%
Fürstenfeldbruck	219	435	503	37,65	8,99	33,23	14,77	1,65	25,46	3,01	46,41	- 1,36	- 20,95	-45%
Fürth	128	63	2024	39,14	7,45	24,85	19,76	0,11	1,67	1,76	27,20	- 1,65	- 25,53	-94%
Fürth	119	307	386	46,32	4,89	41,31	15,12	0,74	11,40	1,63	25,18	- 0,89	- 13,78	-55%
Garmisch-Partenkirchen	88	1 012	87	61,23	6,20	59,34	12,24	2,06	31,79	1,21	18,73	0,85	13,06	70%
Gelsenkirchen	259	105	2469	39,15	5,09	19,05	19,89	0,77	11,86	3,56	54,97	- 2,79	- 43,11	-78%
Gera	92	152	605	34,63	8,18	29,10	14,74	0,49	7,54	1,27	19,55	- 0,78	- 12,01	-61%
Germersheim	129	463	278	52,76	7,14	47,47	17,24	2,30	35,49	1,77	27,37	0,53	8,12	30%

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County name	[tsd.]	[km²]	[inh. / km²]	MEAN	StD	MEAN	StD	[mil visits p.a.]	[mil. EUR p.a.]	[mil. visits p.a.]	[mil. EUR p.a.]	[mil. visits p.a.]	[mil. EUR p.a.]	ratio
Gießen	272	855	318	52,19	9,31	47,13	17,80	3,53	54,51	3,73	57,64	- 0,20	- 3,13	-5%
Gifhorn	177	1 568	113	42,07	5,96	39,75	11,22	3,50	53,96	2,44	37,60	1,06	16,36	44%
Göppingen	259	642	403	61,19	8,70	54,35	20,95	4,02	62,06	3,56	54,90	0,46	7,16	13%
Görlitz	251	2 111	119	44,91	11,33	40,28	17,36	3,28	50,70	3,44	53,16	- 0,16	- 2,46	-5%
Goslar	135	967	139	51,40	9,79	48,28	15,52	3,49	53,96	1,85	28,58	1,64	25,38	89%
Gotha	135	936	144	40,71	15,62	37,83	18,32	1,59	24,54	1,85	28,55	- 0,26	- 4,01	-14%
Göttingen	324	1 755	185	48,86	10,92	45,26	16,53	4,43	68,41	4,45	68,72	- 0,02	- 0,31	0%
Grafschaft Bentheim	138	982	140	42,97	5,67	39,97	12,24	2,21	34,16	1,89	29,26	0,32	4,91	17%
Greiz	97	846	114	42,39	9,54	39,95	13,55	2,81	43,45	1,33	20,51	1,49	22,94	112%
Groß-Gerau	276	453	609	42,42	10,86	36,48	17,84	2,20	33,89	3,79	58,52	- 1,59	- 24,63	-42%
Günzburg	127	762	167	47,40	5,61	43,60	13,96	2,53	39,12	1,75	27,02	0,78	12,10	45%
Gütersloh	365	969	376	42,17	9,15	36,96	16,32	5,02	77,43	5,01	77,40	0,00	0,03	0%
Hagen	189	160	1176	53,05	7,52	38,37	24,58	1,70	26,28	2,59	40,03	- 0,89	- 13,75	-34%
Halle (Saale)	238	135	1762	37,98	9,93	24,94	19,75	0,36	5,52	3,27	50,47	- 2,91	- 44,95	-89%
Hamburg	1 852	755	2453	39,29	9,88	21,74	20,87	2,39	36,94	25,46	393,03	- 23,06	- 356,10	-91%
Hameln-Pyrmont	149	798	186	44,20	7,70	41,08	13,55	3,04	46,88	2,04	31,52	0,99	15,35	49%
Hamm	179	226	790	34,98	9,07	26,91	16,74	1,71	26,34	2,46	37,97	- 0,75	- 11,63	-31%
Harburg	256	1 248	205	45,71	6,70	41,60	14,56	6,00	92,65	3,52	54,32	2,48	38,33	71%
Harz	211	2 105	100	41,74	15,76	39,31	18,14	4,43	68,37	2,90	44,76	1,53	23,61	53%
Haßberge	84	956	88	46,62	6,94	44,83	11,25	2,00	30,88	1,16	17,88	0,84	13,00	73%

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	[tsd.]	[km²]	[inh. / km²]	MEAN	StD	MEAN	StD	[mil visits p.a.]	[mil. EUR p.a.]	[mil. visits p.a.]	[mil. EUR p.a.]	[mil. visits p.a.]	[mil. EUR p.a.]	ratio
Havelland	165	1 727	95	37,55	9,89	35,46	12,91	5,07	78,31	2,26	34,94	2,81	43,37	124%
Heidekreis	141	1 881	75	48,30	7,36	46,24	12,12	7,30	112,78	1,94	29,89	5,37	82,89	277%
Heidelberg	159	109	1459	49,36	14,09	38,04	24,16	0,64	9,92	2,18	33,68	- 1,54	- 23,75	-71%
Heidenheim	133	627	212	50,15	6,88	46,16	15,10	1,84	28,37	1,83	28,18	0,01	0,19	1%
Heilbronn	346	1 100	315	53,86	8,47	48,89	17,56	6,16	95,05	4,76	73,49	1,40	21,56	29%
Heilbronn	126	100	1266	54,08	8,54	40,36	24,66	0,57	8,81	1,74	26,83	- 1,17	- 18,02	-67%
Heinsberg	256	628	408	34,07	9,12	28,27	15,26	4,12	63,60	3,52	54,41	0,60	9,19	17%
Helmstedt	92	676	135	36,88	9,67	34,34	13,20	1,86	28,71	1,26	19,42	0,60	9,30	48%
Herford	251	450	556	38,42	7,57	29,38	17,59	1,89	29,23	3,44	53,16	- 1,55	- 23,92	-45%
Herne	157	51	3052	39,56	6,66	15,31	19,71	0,31	4,82	2,16	33,30	- 1,84	- 28,48	-86%
Hersfeld-Rotenburg	120	1 098	110	54,54	5,37	51,56	13,44	2,46	38,04	1,65	25,52	0,81	12,52	49%
Herzogtum Lauenburg	199	1 263	158	39,67	11,97	37,10	15,15	4,92	75,97	2,74	42,25	2,18	33,72	80%
Hildburghausen	63	938	67	51,92	8,26	50,26	12,22	1,70	26,30	0,86	13,29	0,84	13,01	98%
Hildesheim	275	1 208	228	40,02	11,96	36,89	15,73	3,87	59,68	3,79	58,44	0,08	1,24	2%
Hochsauerlandkreis	259	1 960	132	58,34	8,27	55,07	15,64	9,81	151,50	3,56	54,96	6,25	96,54	176%
Hochtaunuskreis	237	482	492	57,56	8,19	50,57	20,31	2,68	41,32	3,26	50,34	- 0,58	- 9,02	-18%
Hof	45	58	779	46,60	4,98	34,13	21,07	0,14	2,12	0,62	9,58	- 0,48	- 7,46	-78%
Hof	95	893	106	49,04	5,09	46,58	11,80	2,22	34,31	1,30	20,05	0,92	14,25	71%
Hohenlohekreis	113	777	145	55,87	10,66	53,48	15,37	3,48	53,78	1,55	23,92	1,93	29,86	125%

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	[tsd.]	[km²]	[inh. / km²]	MEAN	StD	MEAN	StD	[mil visits p.a.]	[mil. EUR p.a.]	[mil. visits p.a.]	[mil. EUR p.a.]	[mil. visits p.a.]	[mil. EUR p.a.]	ratio
Holzminden	70	694	101	52,11	7,01	49,46	13,34	2,08	32,04	0,96	14,90	1,11	17,15	115%
Höxter	140	1 201	116	45,65	10,51	43,28	14,40	3,28	50,65	1,92	29,65	1,36	21,00	71%
Ilm-Kreis	106	805	131	50,73	10,70	48,06	15,39	1,71	26,44	1,45	22,41	0,26	4,03	18%
Ingolstadt	137	133	1027	44,12	9,59	32,12	21,27	0,40	6,23	1,88	29,06	- 1,48	- 22,83	-79%
Jena	111	115	965	54,02	7,30	44,47	21,64	0,42	6,42	1,52	23,49	- 1,11	- 17,08	-73%
Jerichower Land	89	1 577	57	37,72	10,54	36,22	12,70	2,68	41,33	1,23	18,97	1,45	22,36	118%
Kaiserslautern	106	640	166	53,53	7,28	49,44	15,85	2,95	45,50	1,46	22,56	1,49	22,94	102%
Kaiserslautern	100	140	713	57,12	8,08	45,13	24,34	0,78	11,97	1,37	21,14	- 0,59	- 9,18	-43%
Karlsruhe	308	173	1779	51,16	8,69	34,30	25,08	0,79	12,25	4,24	65,44	- 3,44	- 53,19	-81%
Karlsruhe	447	1 085	412	57,06	7,22	49,67	20,31	6,62	102,28	6,14	94,81	0,48	7,47	8%
Kassel	201	107	1882	46,30	9,13	26,15	23,96	0,19	2,87	2,76	42,66	- 2,58	- 39,79	-93%
Kassel	237	1 293	183	46,99	8,89	43,25	15,32	2,71	41,87	3,26	50,28	- 0,55	- 8,42	-17%
Kaufbeuren	45	40	1116	49,05	3,99	34,86	22,49	0,12	1,89	0,61	9,48	- 0,49	- 7,59	-80%
Kelheim	123	1 065	116	46,96	7,08	44,63	12,32	3,25	50,18	1,70	26,18	1,55	24,00	92%
Kempten (Allgäu)	69	63	1089	49,94	6,20	37,32	22,36	0,11	1,67	0,95	14,63	- 0,84	- 12,95	-89%
Kiel	247	119	2078	39,96	5,94	24,77	19,95	0,33	5,17	3,39	52,32	- 3,05	- 47,15	-90%
Kitzingen	92	684	134	40,58	12,01	38,17	15,09	1,59	24,54	1,26	19,45	0,33	5,08	26%
Kleve	314	1 233	254	38,24	8,83	34,31	14,31	8,43	130,22	4,31	66,53	4,12	63,69	96%
Koblenz	113	105	1077	53,91	11,56	39,68	25,75	0,52	8,09	1,56	24,06	- 1,03	- 15,97	-66%
Köln	1 083	405	2675	37,41	9,78	22,19	19,86	3,12	48,20	14,89	229,88	- 11,77	- 181,68	-79%

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Konstanz	287	818	351	58,48	6,21	53,25	17,71	2,09	32,31	3,94	60,87	- 1,85	- 28,55	-47%
Krefeld	227	138	1646	34,87	6,81	20,59	17,93	1,04	16,01	3,12	48,13	- 2,08	- 32,12	-67%
Kronach	66	652	102	53,20	4,99	49,89	13,72	1,12	17,24	0,91	14,08	0,21	3,17	22%
Kulmbach	71	658	109	53,04	4,84	50,10	13,02	1,55	23,97	0,98	15,15	0,57	8,81	58%
Kusel	70	574	122	56,32	5,67	53,25	13,91	2,17	33,56	0,96	14,87	1,21	18,69	126%
Kyffhäuserkreis	74	1 038	71	39,87	11,09	38,25	13,41	1,83	28,20	1,01	15,60	0,82	12,60	81%
Lahn-Dill-Kreis	253	1 066	238	57,72	6,99	52,26	18,15	4,98	76,89	3,48	53,76	1,50	23,13	43%
Landau in der Pfalz	47	83	563	65,72	7,95	55,72	24,71	0,66	10,16	0,64	9,90	0,02	0,25	3%
Landsberg am Lech	121	804	150	45,12	9,68	42,28	14,42	2,90	44,75	1,66	25,68	1,24	19,07	74%
Landshut	73	66	1110	42,47	10,24	31,14	20,73	0,19	3,01	1,00	15,50	- 0,81	- 12,49	-81%
Landshut	161	1 348	120	44,34	5,96	42,42	10,74	4,25	65,64	2,21	34,20	2,04	31,44	92%
Leer	171	1 086	158	44,70	7,38	40,07	15,30	2,73	42,13	2,36	36,38	0,37	5,75	16%
Leipzig	597	298	2006	36,49	11,64	23,03	19,89	0,81	12,51	8,21	126,77	- 7,40	- 114,25	-90%
Leipzig	258	1 651	156	40,20	11,05	36,22	15,95	6,01	92,72	3,55	54,82	2,45	37,90	69%
Leverkusen	164	79	2078	45,53	9,05	25,73	23,57	0,73	11,34	2,25	34,78	- 1,52	- 23,44	-67%
Lichtenfels	67	520	128	54,63	6,76	51,81	13,76	1,32	20,45	0,92	14,16	0,41	6,29	44%
Limburg-Weilburg	172	738	233	52,14	9,44	47,47	17,41	3,59	55,39	2,37	36,55	1,22	18,84	52%
Lindau (Bodensee)	82	323	254	54,56	4,53	51,13	13,94	0,63	9,77	1,13	17,42	- 0,50	- 7,64	-44%
Lippe	347	1 246	278	49,91	8,13	44,39	17,43	5,27	81,34	4,77	73,62	0,50	7,72	10%
Lörrach	229	807	284	66,62	6,04	61,98	17,94	2,72	42,07	3,14	48,55	- 0,42	- 6,49	-13%

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				MEAN	StD	MEAN	StD						[mil. EUR p.a.]	ratio
Lübeck	216	214	1008	37,58	8,37	28,29	17,76	0,68	10,44	2,97	45,80	- 2,29	- 35,36	-77%
Lüchow-Dannenberg	49	1 227	40	45,27	5,10	44,39	8,03	0,96	14,75	0,67	10,29	0,29	4,46	43%
Ludwigsburg	545	687	794	50,90	11,50	42,60	21,54	3,63	56,11	7,49	115,62	- 3,85	- 59,51	-51%
Ludwigshafen am Rhein	173	77	2229	41,26	8,02	22,48	21,39	0,29	4,55	2,37	36,61	- 2,08	- 32,07	-88%
Ludwigslust-Parchim	212	4 767	44	41,24	8,89	39,98	11,28	6,89	106,34	2,91	44,95	3,98	61,40	137%
Lüneburg	184	1 328	139	46,53	5,26	43,78	12,10	3,90	60,20	2,53	39,09	1,37	21,11	54%
Magdeburg	236	201	1173	31,66	9,47	22,45	16,44	0,35	5,44	3,24	50,02	- 2,89	- 44,58	-89%
Main-Kinzig-Kreis	422	1 397	302	55,39	8,71	50,33	17,98	5,29	81,69	5,79	89,47	- 0,50	- 7,78	-9%
Main-Spessart	126	1 321	95	52,92	6,16	50,64	12,33	3,31	51,06	1,73	26,73	1,58	24,33	91%
Main-Tauber-Kreis	133	1 304	102	54,48	9,08	52,44	13,64	3,74	57,69	1,82	28,15	1,91	29,54	105%
Main-Taunus-Kreis	239	223	1075	48,00	11,35	37,26	22,36	1,14	17,58	3,29	50,76	- 2,15	- 33,19	-65%
Mainz	217	98	2222	50,92	8,75	32,49	25,45	0,45	6,97	2,98	46,07	- 2,53	- 39,09	-85%
Mainz-Bingen	212	605	349	63,10	8,56	57,09	20,24	5,09	78,59	2,91	44,88	2,18	33,71	75%
Mannheim	310	145	2136	39,59	8,94	24,35	20,50	0,55	8,51	4,26	65,71	- 3,70	- 57,20	-87%
Mansfeld-Südharz	134	1 449	92	38,98	13,52	36,83	15,86	3,35	51,73	1,84	28,36	1,51	23,36	82%
Marburg-Biedenkopf	246	1 262	195	52,64	8,94	48,79	16,17	3,41	52,62	3,38	52,17	0,03	0,44	1%
Märkischer Kreis	409	1 061	385	55,49	6,88	48,48	19,53	10,84	167,31	5,62	86,70	5,22	80,60	93%

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Märkisch-Oderland	197	2 159	91	34,28	9,17	32,10	12,19	6,52	100,63	2,71	41,84	3,81	58,79	141%
Mayen-Koblenz	215	818	263	49,65	12,80	44,79	19,12	3,86	59,57	2,95	45,57	0,91	14,00	31%
Mecklenburgische Seenplatte	258	5 496	47	38,80	11,92	37,94	13,10	3,84	59,25	3,55	54,75	0,29	4,50	8%
Meißen	240	1 455	165	34,10	9,60	31,48	12,95	4,18	64,51	3,30	51,00	0,88	13,51	26%
Memmingen	44	70	633	48,81	5,53	38,98	20,19	0,23	3,57	0,61	9,41	- 0,38	- 5,84	-62%
Merzig-Wadern	103	557	186	52,60	6,34	47,48	16,70	1,28	19,78	1,42	21,95	- 0,14	- 2,17	-10%
Mettmann	484	407	1189	47,95	8,00	34,09	22,76	4,47	69,03	6,66	102,76	- 2,18	- 33,73	-33%
Miesbach	100	866	116	57,07	7,63	54,84	13,35	3,05	47,08	1,38	21,26	1,67	25,83	122%
Miltenberg	129	716	180	53,15	6,36	49,40	14,93	2,57	39,60	1,77	27,31	0,80	12,29	45%
Minden-Lübbecke	310	1 152	269	37,75	7,78	32,78	14,68	3,99	61,67	4,26	65,83	- 0,27	- 4,16	-6%
Mittelsachsen	301	2 117	142	34,60	8,21	31,27	12,85	7,11	109,77	4,14	63,96	2,97	45,80	72%
Mönchengladbach	260	170	1523	34,21	5,46	21,79	17,02	1,28	19,77	3,57	55,09	- 2,29	- 35,32	-64%
Mühldorf a. Inn	116	805	145	44,83	7,09	42,93	11,39	2,39	36,93	1,60	24,71	0,79	12,22	49%
Mülheim an der Ruhr	171	91	1872	49,05	8,92	27,69	25,22	0,78	12,06	2,35	36,26	- 1,57	- 24,20	-67%
München	1 488	311	4790	34,67	7,40	14,78	17,81	0,72	11,18	20,45	315,75	- 19,73	- 304,57	-96%
München	350	664	526	37,37	7,77	32,42	14,58	2,43	37,59	4,81	74,19	- 2,37	- 36,61	-49%
Münster	316	303	1043	39,08	7,08	30,88	17,11	2,06	31,88	4,35	67,13	- 2,28	- 35,25	-53%
Neckar-Odenwald-Kreis	144	1 126	128	53,70	6,49	50,63	13,96	4,40	67,88	1,98	30,51	2,42	37,37	122%
Neuburg-Schrobenhausen	98	740	132	45,95	5,70	42,67	13,04	2,05	31,68	1,34	20,73	0,71	10,95	53%

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				MEAN	StD	MEAN	StD						[mil. EUR p.a.]	ratio
Neumarkt i.d. OPf.	135	1 344	101	51,36	7,17	49,68	11,53	3,47	53,60	1,86	28,69	1,61	24,91	87%
Neumünster	80	72	1115	48,23	5,32	29,63	23,84	0,30	4,61	1,10	16,95	- 0,80	- 12,35	-73%
Neunkirchen	131	250	525	48,79	6,83	37,76	21,27	0,58	9,02	1,80	27,83	- 1,22	- 18,81	-68%
Neustadt a.d. Aisch-Bad Windsheim	101	1 267	80	43,11	9,21	41,73	11,82	2,64	40,76	1,39	21,49	1,25	19,27	90%
Neustadt a.d. Waldnaab	95	1 428	66	52,66	4,82	50,81	10,79	2,25	34,72	1,30	20,08	0,95	14,64	73%
Neustadt an der Weinstraße	53	117	455	64,06	7,43	54,80	23,55	0,91	14,01	0,73	11,31	0,17	2,70	24%
Neu-Ulm	176	516	341	46,96	6,08	41,54	16,06	1,82	28,05	2,42	37,30	- 0,60	- 9,25	-25%
Neuwied	183	627	292	57,91	6,03	52,02	18,41	4,82	74,49	2,52	38,85	2,31	35,63	92%
Nienburg (Weser)	122	1 401	87	37,58	8,81	35,02	12,73	3,96	61,20	1,67	25,81	2,29	35,39	137%
Nordfriesland	167	2 084	80	40,37	9,33	38,56	12,36	2,55	39,33	2,30	35,46	0,25	3,86	11%
Nordhausen	82	714	115	42,11	14,68	39,75	17,24	1,43	22,15	1,13	17,49	0,30	4,65	27%
Nordsachsen	197	2 029	97	34,28	9,54	32,40	12,13	4,46	68,83	2,71	41,89	1,74	26,94	64%
Nordwestmecklenburg	158	2 127	74	37,09	11,16	35,88	12,80	4,25	65,62	2,17	33,52	2,08	32,11	96%
Northeim	132	1 269	104	49,46	10,80	47,34	14,56	3,56	54,93	1,81	27,96	1,75	26,97	96%
Nürnberg	516	186	2765	36,22	6,54	19,79	18,67	0,35	5,35	7,08	109,38	- 6,74	- 104,03	-95%
Nürnberger Land	171	800	214	53,87	9,86	50,26	16,49	2,53	39,04	2,35	36,31	0,18	2,73	8%
Oberallgäu	156	1 528	102	60,40	9,15	58,88	13,08	2,70	41,76	2,15	33,16	0,56	8,59	26%

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Oberbergischer Kreis	272	919	296	61,44	5,75	54,93	19,67	12,58	194,30	3,73	57,65	8,85	136,66	237%
Oberhausen	210	77	2718	39,04	5,81	16,80	19,70	0,52	7,95	2,88	44,46	- 2,36	- 36,51	-82%
Oberhavel	214	1 808	118	42,58	7,25	39,72	12,75	6,84	105,69	2,94	45,45	3,90	60,23	133%
Oberspreewald-Lausitz	108	1 223	89	43,71	7,89	40,89	13,16	3,43	52,97	1,49	23,00	1,94	29,97	130%
Odenwaldkreis	97	624	155	54,95	5,88	51,53	14,45	2,94	45,43	1,33	20,53	1,61	24,90	121%
Oder-Spree	179	2 257	79	40,46	8,66	38,16	12,59	6,96	107,41	2,46	38,04	4,49	69,38	182%
Offenbach	357	356	1001	42,67	6,36	33,21	18,59	1,50	23,09	4,90	75,65	- 3,40	- 52,56	-69%
Offenbach am Main	131	45	2916	40,55	5,21	26,67	19,70	0,17	2,57	1,80	27,77	- 1,63	- 25,20	-91%
Oldenburg	131	1 065	123	33,11	6,52	31,19	10,00	3,22	49,72	1,81	27,89	1,41	21,83	78%
Oldenburg (Oldb)	170	103	1645	39,28	8,05	19,55	20,45	0,22	3,37	2,33	35,98	- 2,11	- 32,61	-91%
Olpe	133	712	187	61,26	5,82	56,80	16,87	6,28	96,98	1,83	28,29	4,45	68,68	243%
Ortenaukreis	433	1 860	233	63,86	11,90	58,38	21,20	7,10	109,59	5,94	91,78	1,15	17,81	19%
Osnabrück	359	2 122	169	35,35	7,18	33,12	11,05	7,60	117,27	4,94	76,27	2,66	41,00	54%
Osnabrück	164	120	1371	36,27	4,70	22,47	17,99	0,45	6,95	2,26	34,84	- 1,81	- 27,89	-80%
Ostalbkreis	314	1 511	208	55,57	7,43	51,73	15,80	5,22	80,62	4,32	66,68	0,90	13,94	21%
Ostallgäu	142	1 394	102	50,54	7,52	48,51	12,36	3,29	50,77	1,95	30,11	1,34	20,66	69%
Osterholz	115	653	176	46,08	5,10	41,14	15,04	1,78	27,44	1,58	24,32	0,20	3,12	13%

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Ostholstein	201	1 393	145	37,78	12,43	35,74	14,80	3,03	46,79	2,77	42,75	0,26	4,05	9%
Ostprignitz-Ruppin	99	2 526	39	38,64	11,16	37,50	12,80	4,95	76,37	1,36	20,96	3,59	55,40	264%
Paderborn	308	1 247	247	44,58	9,54	40,76	15,45	5,25	81,03	4,24	65,42	1,01	15,61	24%
Passau	193	1 530	126	49,15	8,13	46,63	13,43	2,08	32,17	2,66	41,04	- 0,57	- 8,87	-22%
Passau	52	70	754	51,88	6,55	39,28	22,96	0,10	1,57	0,72	11,12	- 0,62	- 9,55	-86%
Peine	136	537	253	28,11	6,12	25,30	10,24	1,44	22,24	1,87	28,82	- 0,43	- 6,58	-23%
Pfaffenhofen a.d. Ilm	129	761	170	48,94	5,72	45,78	13,23	3,33	51,49	1,77	27,40	1,56	24,09	88%
Pforzheim	126	98	1286	61,66	7,75	46,09	27,61	0,71	10,96	1,73	26,74	- 1,02	- 15,77	-59%
Pinneberg	317	664	477	43,71	8,92	36,57	18,11	2,66	41,07	4,36	67,27	- 1,70	- 26,20	-39%
Pirmasens	40	61	655	59,11	5,65	45,07	25,64	0,22	3,46	0,55	8,52	- 0,33	- 5,07	-59%
Plön	129	1 084	119	46,46	9,95	44,44	13,57	3,37	52,02	1,78	27,44	1,59	24,58	90%
Potsdam	182	188	967	49,87	6,69	40,37	20,48	0,95	14,70	2,50	38,64	- 1,55	- 23,93	-62%
Potsdam-Mittelmark	218	2 592	84	42,08	7,49	39,98	11,72	11,34	175,11	2,99	46,24	8,35	128,87	279%
Prignitz	76	2 139	36	32,28	8,13	31,53	9,39	1,06	16,34	1,05	16,14	0,01	0,19	1%
Rastatt	232	738	314	64,40	9,43	57,44	21,88	4,10	63,34	3,19	49,24	0,91	14,10	29%
Ravensburg	286	1 632	175	54,68	5,72	52,36	12,36	3,95	61,00	3,93	60,66	0,02	0,34	1%
Recklinghausen	614	761	806	40,49	7,08	31,45	17,97	6,93	107,06	8,43	130,18	- 1,50	- 23,12	-18%
Regen	77	975	79	59,00	4,45	57,29	10,82	1,38	21,37	1,06	16,40	0,32	4,97	30%

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Regensburg	152	81	1883	39,83	7,69	22,01	20,61	0,16	2,53	2,09	32,31	- 1,93	- 29,77	-92%
Regensburg	194	1 392	140	45,01	10,81	42,93	14,17	3,13	48,37	2,67	41,22	0,46	7,15	17%
Region Hannover	1 155	2 297	503	35,74	8,86	30,75	14,87	7,16	110,54	15,88	245,12	- 8,72	- 134,58	-55%
Regionalverband Saarbrücken	328	411	797	48,39	6,82	36,07	21,88	0,81	12,45	4,50	69,48	- 3,69	- 57,04	-82%
Remscheid	112	75	1496	52,80	9,67	33,41	26,59	0,82	12,65	1,53	23,66	- 0,71	- 11,01	-47%
Rems-Murr-Kreis	427	858	498	64,11	7,21	57,12	21,11	5,89	91,00	5,87	90,66	0,02	0,34	0%
Rendsburg-Eckernförde	275	2 190	125	43,62	9,27	41,33	13,27	7,62	117,73	3,78	58,30	3,85	59,43	102%
Reutlingen	287	1 092	263	59,98	7,88	55,20	17,92	5,35	82,54	3,95	61,00	1,40	21,55	35%
Rhein-Erft-Kreis	470	705	666	33,82	9,80	25,63	16,81	5,33	82,24	6,45	99,64	- 1,13	- 17,39	-17%
Rheingau-Taunus-Kreis	187	811	231	59,27	8,66	55,95	16,01	5,25	81,07	2,58	39,77	2,67	41,30	104%
Rhein-Hunsrück-Kreis	103	991	104	54,98	7,58	53,35	11,94	4,22	65,09	1,42	21,94	2,79	43,15	197%
Rheinisch-Bergischer Kreis	283	437	648	60,05	6,70	49,91	23,31	6,42	99,08	3,89	60,10	2,52	38,98	65%
Rhein-Kreis Neuss	452	576	784	31,88	8,88	23,79	15,85	4,66	71,88	6,21	95,90	- 1,56	- 24,02	-25%
Rhein-Lahn-Kreis	123	782	157	56,28	8,33	53,82	14,09	4,23	65,35	1,68	26,01	2,55	39,34	151%
Rhein-Neckar-Kreis	548	1 062	516	55,02	10,41	47,88	20,88	6,56	101,23	7,53	116,32	- 0,98	- 15,09	-13%
Rhein-Pfalz-Kreis	155	305	507	53,31	7,40	45,43	20,11	1,69	26,12	2,13	32,83	- 0,44	- 6,72	-20%
Rhein-Sieg-Kreis	600	1 153	521	52,35	11,29	44,80	21,16	11,04	170,42	8,25	127,38	2,79	43,04	34%
Rhön-Grabfeld	80	1 022	78	48,36	11,20	46,46	14,45	1,70	26,30	1,09	16,87	0,61	9,43	56%

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				MEAN	StD	MEAN	StD						[mil. EUR p.a.]	ratio
Rosenheim	64	37	1709	55,04	6,34	35,22	26,90	0,12	1,89	0,87	13,49	- 0,75	- 11,60	-86%
Rosenheim	262	1 439	182	55,75	7,34	52,54	14,81	5,36	82,77	3,60	55,53	1,76	27,24	49%
Rostock	217	3 431	63	35,00	10,25	34,04	11,61	3,72	57,43	2,98	46,06	0,74	11,37	25%
Rostock	209	181	1153	39,01	6,59	29,31	17,81	0,18	2,82	2,87	44,36	- 2,69	- 41,53	-94%
Rotenburg (Wümme)	164	2 075	79	45,50	4,81	42,71	11,86	7,41	114,38	2,26	34,90	5,15	79,48	228%
Roth	127	895	142	46,92	6,53	44,49	12,20	2,37	36,61	1,75	26,98	0,62	9,63	36%
Rottal-Inn	122	1 281	95	45,50	4,99	43,97	9,56	2,07	31,91	1,67	25,84	0,39	6,07	23%
Rottweil	140	769	182	57,98	6,05	52,93	17,34	3,23	49,86	1,93	29,74	1,30	20,12	68%
Saale-Holzland-Kreis	83	815	102	45,50	8,47	43,85	11,88	2,99	46,23	1,14	17,57	1,86	28,66	163%
Saalekreis	183	1 434	128	29,71	11,78	27,42	13,81	3,31	51,09	2,52	38,92	0,79	12,17	31%
Saale-Orla-Kreis	80	1 151	69	49,43	7,93	48,02	11,35	3,25	50,12	1,09	16,90	2,15	33,22	197%
Saalfeld-Rudolstadt	102	1 009	101	52,95	6,88	50,76	12,52	2,02	31,21	1,40	21,67	0,62	9,54	44%
Saarlouis	194	459	422	49,25	6,79	40,01	20,18	0,94	14,48	2,66	41,10	- 1,72	- 26,62	-65%
Saarpfalz-Kreis	142	418	339	50,65	7,34	42,85	19,49	1,05	16,17	1,95	30,05	- 0,90	- 13,88	-46%
Sächsische Schweiz-Osterzgebirge	245	1 654	148	47,25	9,66	43,17	16,17	4,45	68,66	3,36	51,92	1,08	16,74	32%
Salzgitter	104	224	463	31,80	10,76	25,90	15,72	0,58	8,96	1,43	22,04	- 0,85	- 13,08	-59%
Salzlandkreis	187	1 428	131	25,50	9,00	23,49	11,03	2,54	39,18	2,58	39,77	- 0,04	- 0,59	-1%

County name	Population [tsd.]	Area [km²]	Population Density [inh. / km²]	RES supply [0-100] at SPAs (excl. SBAs) MEAN	StD	RES supply [0-100] incl. SBAs (= 0) MEAN	StD	RES use at indigenous SPAs [mil visits p.a.]	Income at indigenous SPAs [mil. EUR p.a.]	Demand at indigenous SBAs [mil. visits p.a.]	Expenses from indigenous SPAs [mil. EUR p.a.]	RES use balance [mil. visits p.a.]	RES-related benefit flow [mil. EUR p.a.]	ratio
Schaumburg	158	676	234	39,10	8,88	35,18	14,46	2,75	42,46	2,18	33,61	0,57	8,86	26%
Schleswig-Flensburg	203	2 071	98	38,41	8,96	36,90	11,52	3,47	53,61	2,78	42,99	0,69	10,62	25%
Schmalkalden-Meiningen	124	1 251	99	57,04	6,63	53,83	14,64	2,38	36,82	1,71	26,36	0,68	10,46	40%
Schwabach	41	41	1006	49,97	4,28	35,25	23,06	0,11	1,63	0,56	8,71	- 0,46	- 7,08	-81%
Schwäbisch Hall	198	1 484	133	51,19	10,56	48,86	14,85	4,73	73,02	2,72	41,98	2,01	31,04	74%
Schwalm-Eder-Kreis	180	1 539	117	47,11	10,28	44,56	14,61	3,25	50,19	2,47	38,16	0,78	12,03	32%
Schwandorf	148	1 458	102	51,50	4,87	49,06	11,93	2,63	40,60	2,04	31,50	0,59	9,10	29%
Schwarzwald-Baar-Kreis	213	1 025	208	53,85	6,42	50,15	14,98	2,95	45,56	2,93	45,16	0,03	0,40	1%
Schweinfurt	53	36	1494	41,60	10,41	24,85	21,93	0,06	0,88	0,73	11,31	- 0,68	- 10,44	-92%
Schweinfurt	116	841	137	41,68	10,10	39,58	13,42	1,57	24,20	1,59	24,54	- 0,02	- 0,34	-1%
Schwerin	96	131	733	44,89	5,85	36,62	18,18	0,23	3,56	1,31	20,28	- 1,08	- 16,72	-82%
Segeberg	278	1 344	207	41,85	9,50	37,95	15,16	6,17	95,20	3,82	58,98	2,35	36,21	61%
Siegen-Wittgenstein	275	1 133	243	61,50	6,05	55,00	19,76	5,69	87,79	3,79	58,45	1,90	29,34	50%
Sigmaringen	131	1 204	109	53,10	5,61	50,30	13,06	3,04	46,89	1,80	27,78	1,24	19,11	69%
Soest	301	1 329	227	35,26	10,52	32,10	14,22	7,36	113,61	4,14	63,87	3,22	49,74	78%
Solingen	159	90	1778	55,37	12,75	31,25	29,08	1,20	18,55	2,19	33,78	- 0,99	- 15,22	-45%

County name	Population	Area	Population Density	RES supply [0-100] at SPAs (excl. SBAs)		RES supply [0-100] incl. SBAs (= 0)		RES use at indigenous SPAs	Income at indigenous SPAs	Demand at indigenous SBAs	Expenses from indigenous SPAs	RES use balance	RES-related benefit flow	
	[tsd.]	[km²]	[inh. / km²]	MEAN	StD	MEAN	StD	[mil visits p.a.]	[mil. EUR p.a.]	[mil. visits p.a.]	[mil. EUR p.a.]	[mil. visits p.a.]	[mil. EUR p.a.]	ratio
Sömmerda	69	807	86	27,86	10,92	26,66	12,09	1,12	17,29	0,95	14,66	0,17	2,63	18%
Sonneberg	57	461	124	53,73	4,84	50,17	14,17	0,76	11,79	0,78	12,10	- 0,02	- 0,31	-3%
Speyer	51	43	1188	58,40	5,06	38,65	27,93	0,25	3,91	0,70	10,77	- 0,44	- 6,86	-64%
Spree-Neiße	113	1 657	68	41,78	7,63	38,33	13,61	1,96	30,33	1,55	23,98	0,41	6,35	27%
St. Wendel	86	476	182	51,86	5,34	46,97	15,99	1,36	20,92	1,19	18,34	0,17	2,58	14%
Stade	205	1 267	162	44,83	5,40	41,08	13,46	3,68	56,89	2,82	43,57	0,86	13,32	31%
Städteregion Aachen	557	707	787	48,24	11,07	38,32	21,85	3,94	60,79	7,65	118,10	- 3,71	- 57,30	-49%
Starnberg	137	488	280	49,01	8,56	44,37	16,49	1,98	30,52	1,88	28,98	0,10	1,54	5%
Steinburg	131	1 056	124	43,03	8,70	40,03	13,81	3,96	61,10	1,80	27,73	2,16	33,37	120%
Steinfurt	448	1 796	250	34,51	6,47	31,45	11,59	7,99	123,31	6,16	95,09	1,83	28,21	30%
Stendal	110	2 424	46	34,82	10,26	33,74	11,77	1,41	21,74	1,52	23,44	- 0,11	- 1,71	-7%
Stormarn	245	766	320	36,56	10,46	32,61	15,05	3,28	50,67	3,37	51,98	- 0,08	- 1,30	-3%
Straubing	48	68	704	30,30	9,54	24,09	14,90	0,08	1,30	0,65	10,10	- 0,57	- 8,80	-87%
Straubing-Bogen	102	1 202	85	45,71	14,75	44,17	16,67	2,25	34,78	1,40	21,59	0,85	13,19	61%
Stuttgart	630	207	3040	50,95	9,81	30,43	26,11	0,84	12,90	8,66	133,73	- 7,83	- 120,83	-90%
Südliche Weinstraße	111	640	173	64,26	7,89	60,76	16,48	4,64	71,69	1,52	23,50	3,12	48,18	205%
Südwestpfalz	95	954	100	58,45	6,46	55,63	14,01	3,62	55,82	1,30	20,14	2,31	35,68	177%
Suhl	36	142	257	58,28	6,66	51,48	19,72	0,35	5,45	0,50	7,72	- 0,15	- 2,27	-29%
Teltow-Fläming	172	2 104	82	39,12	9,85	37,12	12,89	7,63	117,75	2,36	36,40	5,27	81,35	224%

County name	Population [tsd.]	Area [km²]	Population Density [inh. / km²]	RES supply [0-100] at SPAs (excl. SBAs) MEAN	RES supply [0-100] at SPAs (excl. SBAs) StD	RES supply [0-100] incl. SBAs (= 0) MEAN	RES supply [0-100] incl. SBAs (= 0) StD	RES use at indigenous SPAs [mil visits p.a.]	Income at indigenous SPAs [mil. EUR p.a.]	Demand at indigenous SBAs [mil. visits p.a.]	Expenses from indigenous SPAs [mil. EUR p.a.]	RES use balance [mil. visits p.a.]	RES-related benefit flow [mil. EUR p.a.]	RES-related benefit flow ratio
Tirschenreuth	72	1 084	66	50,79	5,47	49,02	10,77	1,31	20,22	0,99	15,21	0,32	5,01	33%
Traunstein	177	1 534	116	54,41	9,30	52,30	13,90	3,50	54,07	2,44	37,66	1,06	16,41	44%
Trier	111	117	945	62,78	7,59	48,81	26,95	0,35	5,46	1,52	23,48	- 1,17	- 18,03	-77%
Trier-Saarburg	151	1 102	137	59,36	9,22	56,62	15,37	3,48	53,78	2,07	31,94	1,41	21,84	68%
Tübingen	228	519	440	61,64	6,28	54,61	20,47	3,08	47,55	3,14	48,47	- 0,06	- 0,93	-2%
Tuttlingen	142	734	193	54,27	5,32	50,10	15,32	1,85	28,53	1,95	30,06	- 0,10	- 1,53	-5%
Uckermark	118	3 077	38	36,68	12,84	35,46	14,24	3,85	59,48	1,62	25,09	2,23	34,39	137%
Uelzen	93	1 463	63	36,96	8,26	35,87	10,26	2,06	31,86	1,27	19,64	0,79	12,23	62%
Ulm	126	119	1065	50,28	9,81	38,27	23,08	0,45	6,91	1,74	26,82	- 1,29	- 19,91	-74%
Unna	394	543	725	35,96	8,63	28,35	16,57	4,82	74,37	5,41	83,51	- 0,59	- 9,15	-11%
Unstrut-Hainich-Kreis	102	980	104	37,20	13,10	35,44	15,03	1,34	20,70	1,40	21,58	- 0,06	- 0,88	-4%
Unterallgäu	146	1 230	119	48,55	5,30	45,85	12,26	4,16	64,25	2,01	31,01	2,15	33,24	107%
Vechta	144	814	176	32,45	8,33	29,58	12,17	2,33	35,95	1,97	30,49	0,35	5,46	18%
Verden	138	789	174	40,43	7,23	36,96	13,26	2,87	44,34	1,89	29,19	0,98	15,15	52%
Viersen	299	563	530	33,22	6,87	27,17	14,25	4,46	68,80	4,10	63,34	0,35	5,46	9%
Vogelsbergkreis	106	1 459	72	58,07	8,45	56,21	13,18	4,92	75,96	1,45	22,38	3,47	53,57	239%
Vogtlandkreis	224	1 412	159	49,18	6,63	44,53	15,71	3,45	53,31	3,08	47,50	0,38	5,80	12%

County name	Population [tsd.]	Area [km²]	Population Density [inh. / km²]	RES supply [0-100] at SPAs (excl. SBAs) MEAN	StD	RES supply [0-100] incl. SBAs (= 0) MEAN	StD	RES use at indigenous SPAs [mil visits p.a.]	Income at indigenous SPAs [mil. EUR p.a.]	Demand at indigenous SBAs [mil. visits p.a.]	Expenses from indigenous SPAs [mil. EUR p.a.]	RES use balance [mil. visits p.a.]	RES-related benefit flow [mil. EUR p.a.]	ratio
Vorpommern-Greifswald	236	3 946	60	35,05	11,21	33,86	12,72	2,61	40,37	3,24	50,02	- 0,63	- 9,66	-19%
Vorpommern-Rügen	225	3 216	70	36,74	12,88	35,57	14,22	2,83	43,75	3,10	47,82	- 0,26	- 4,06	-9%
Vulkaneifel	60	912	66	58,30	6,46	56,33	12,30	2,96	45,73	0,83	12,83	2,13	32,90	256%
Waldeck-Frankenberg	157	1 849	85	50,57	8,56	48,52	13,02	3,85	59,45	2,15	33,21	1,70	26,24	79%
Waldshut	171	1 131	151	60,92	6,28	57,57	15,17	2,98	45,99	2,35	36,33	0,63	9,66	27%
Warendorf	277	1 319	210	30,19	5,37	28,07	9,29	6,82	105,30	3,81	58,86	3,01	46,44	79%
Wartburgkreis	118	1 267	93	53,55	10,45	50,90	15,45	2,54	39,27	1,62	25,03	0,92	14,24	57%
Weiden i.d. OPf.	43	71	603	52,34	3,75	41,14	21,72	0,11	1,65	0,58	9,02	- 0,48	- 7,37	-82%
Weilheim-Schongau	136	966	141	53,19	5,12	50,42	12,84	3,00	46,36	1,87	28,88	1,13	17,48	61%
Weimar	65	84	771	48,74	10,15	40,16	20,72	0,20	3,08	0,89	13,81	- 0,70	- 10,73	-78%
Weimarer Land	82	804	102	39,72	11,65	38,26	13,65	1,88	29,03	1,13	17,46	0,75	11,57	66%
Weißenburg-Gunzenhausen	95	971	98	47,44	6,19	45,15	11,83	2,05	31,61	1,31	20,18	0,74	11,43	57%
Werra-Meißner-Kreis	100	1 025	98	55,88	6,54	53,23	13,48	2,41	37,17	1,37	21,23	1,03	15,94	75%
Wesel	460	1 043	441	43,49	7,47	37,46	16,55	9,99	154,28	6,32	97,62	3,67	56,66	58%
Wesermarsch	89	825	107	42,25	5,71	39,86	11,24	2,33	35,97	1,22	18,78	1,11	17,19	92%
Westerwaldkreis	203	989	205	56,96	5,43	52,33	16,42	5,23	80,76	2,79	43,03	2,44	37,73	88%
Wetteraukreis	310	1 101	282	49,83	14,08	45,75	19,19	4,84	74,66	4,26	65,85	0,57	8,81	13%

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				MEAN	StD	MEAN	StD						[mil. EUR p.a.]	ratio
Wiesbaden	279	204	1367	48,87	12,86	36,39	24,03	0,98	15,13	3,83	59,11	- 2,85	- 43,98	-74%
Wilhelmshaven	75	107	702	44,20	5,22	29,48	21,26	0,20	3,10	1,03	15,95	- 0,83	- 12,85	-81%
Wittenberg	124	1 932	64	38,23	8,24	36,56	11,22	3,82	58,93	1,71	26,35	2,11	32,59	124%
Wittmund	57	657	87	42,95	5,82	41,17	10,28	1,28	19,70	0,79	12,17	0,49	7,53	62%
Wolfenbüttel	119	724	165	31,72	10,11	29,93	12,25	1,89	29,20	1,64	25,32	0,25	3,88	15%
Wolfsburg	124	205	605	44,88	5,98	35,29	19,15	0,55	8,56	1,70	26,27	- 1,15	- 17,72	-67%
Worms	83	109	768	57,25	8,61	45,32	24,49	0,74	11,50	1,15	17,71	- 0,40	- 6,21	-35%
Wunsiedel i. Fichtelgebirge	72	606	119	51,67	4,32	48,77	12,63	0,96	14,75	0,99	15,27	- 0,03	- 0,52	-3%
Wuppertal	355	168	2108	51,65	10,44	31,61	26,46	1,91	29,43	4,88	75,32	- 2,97	- 45,89	-61%
Würzburg	163	968	168	39,62	13,42	37,17	16,12	2,17	33,56	2,24	34,52	- 0,06	- 0,96	-3%
Würzburg	127	88	1449	42,62	8,19	27,55	21,41	0,23	3,52	1,74	26,94	- 1,52	- 23,42	-87%
Zollernalbkreis	190	918	207	58,65	6,19	53,05	18,21	3,57	55,05	2,61	40,28	0,96	14,77	37%
Zweibrücken	34	71	481	51,11	4,79	39,75	21,67	0,17	2,58	0,47	7,21	- 0,30	- 4,63	-64%
Zwickau	312	950	329	36,88	8,08	30,09	16,05	3,08	47,62	4,29	66,20	- 1,20	- 18,58	-28%
Germany	83 155	357 580	233	45,87	12,44	42,29	17,15	1 142,66	17 642,66	1 142,66	17 642,66	0,00	0,01	0%

Figure S3: Modelled RES Flow in Germany considering maximum 180-minute travel time