9. From Local Measures to Regional Sustainability – An Attempt of Upscaling

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The prototypes demonstrate a range of local measures for a more sustainable development of villages, suburbs and small towns. However, to develop holistic regional sustainability strategies, it is necessary to assess the impact of local measures at a regional scale and beyond. In this chapter, we endeavor to extrapolate the effects of the scenarios to the scale of the study regions we focused on in Lower Saxony.
This is based on the hypothesis that the TOPOI types introduced in Chapter 2 describe settlement units sharing the same characteristics of form, function, and linkages, and that our scenarios for prototypical TOPOI types could thus be theoretically transferred to units of the same class. Consequently, the impacts of local measures could be evaluated for entire regions. From the thirteen TOPOI identified and described, we have in this book focused on scenarios for the following TOPOI classes: Disseminated Hamlet (prototype Eydelstedt, Chapter 4), Exo Satellite Town (prototype Detmerode, Chapter 5), and Periurban Village (prototype Schöppenstedt, Chapter 6). To evaluate the impact those local measures had after having been implemented in all settlement units of the respective type, we apply a two-step analysis. First, we calculate the changes for each prototype. Table 9.2 shows the quantified changes in relation to the status quo of specified attributes such as population or number of bus stops for each prototype. In a second step this percentage change for each attribute is calculated individually for each of the total 1,122 settlement units respective TOPOI. Put more concretely: if for scenario A we develop a measure which increases bus stops by 50% and if in the status quo the total number of bus stops in one of the Disseminated Hamlets is 6, the new value would be 9. We include a total of

1,071 Disseminated Hamlets, 9 Exo Satellite Towns, and 42 Periurban Villages in our study out of the existing 6,301 settlement units across all TOPOI classes. These selected TOPOI cover nearly a fifth of the area of all settlement units with a total of 274,000 inhabitants, which is 17% of the overall population in the study regions (Carlow et al. 2022; Table 9.1).

The scenarios have different outcomes with regard to topics such as building density, population development, land consumption, open space development, or public transport provision. To establish comparability, we define specific attributes from the scenarios and determine the corresponding values for the status quo and each of the scenarios. We collect basic data such as the total area of the settlement unit, number and footprint of all buildings, number of inhabitants, and number of public transport stops. For the population development, we approximate the change based on the new residential gross floor area, which is 46 m^2 per resident (UBA 2021). Based on this, we calculate the population density (inhabitants per hectare), the building density (buildings per hectare), the ratio of built-up to unbuilt area, and the public transport coverage for the area and the inhabitants (Table 9.2). For an additional evaluation of the public transport, we apply the Public Transport Access Score (PTAS), which we developed in collaboration with transport scientists. It is based on parameters such as available public transport modalities, their catchment areas, operating frequencies, and connectivity (Carlow et al. 2021). The PTAS rates accessibility at the levels of High (≤ 36 – ≥ 25 points), Medium (≤ 24 – ≥ 13 points), Low (≤ 12 – ≥ 1 point), and No Access (0 points) based on the recommendations for the quality of service in public transport by the Association of German Transport Companies (VDV 2019) and the Road and Transportation Research Association (FGSV 2010). Especially in TOPOI types such as Disseminated Hamlets, bus services are often limited to school transport. The PTAS is not applicable in Scenarios C and D because they are based on the assumption that new technologies such as autonomous driving will replace current public transport systems, so that, among other changes, static stops are becoming superfluous.

The analysis enables the assessment of the land take, the change in built-up areas and subsequently available open space, the number of inhabitants, and accessibility by public transport due to local measures at the regional scale as well as for each of the 1,122 individual settlement units that were not investigated in detail. In the following, we will explore this for each prototype (Tables 9.3 – 9.5) and extrapolate the findings to the TOPOI class (Table 9.6). We use total values and, if not applicable, the mean value known as the median. Since the median divides the individual values into two equal halves, it is more robust to outliers.[1]

The first prototype Eydelstedt belongs to the TOPOI class of Disseminated Hamlets. Disseminated Hamlets are the second most common TOPOI type in our study regions in terms of numbers, having 1,071 units, covering a total area of about 77 km^2 with a population of 22,800 inhabitants. This is about

1 For legibility, the derived values, which we subsequently used for our calculations, have been rounded. This may lead to minor deviations in totals and percentages.

	TOTAL				SHARE (of all TOPOI, n=6,301)			
	Count	Area [ha]	Population [inh]	Built-up Area [ha]	Count	Area	Population	Built-up Area
Node City	1	3,660	159,297	729	0.0%	3.7%	10.1%	5.2%
Node Town	7	8,290	200,324	1,465	0.1%	8.3%	12.7%	10.4%
Periurban Town	24	12,774	316,307	2,191	0.4%	12.8%	20.0%	15.5%
Exo Satellite Town	9	846	42,222	140	0.1%	0.8%	2.7%	1.0%
Periurban Village	42	10,277	208,995	1,595	0.7%	10.3%	13.2%	11.3%
Small Periurban Village	37	2,271	40,661	308	0.6%	2.3%	2.6%	2.2%
Exo Village	524	28,539	465,593	3,915	8.3%	28.5%	29.4%	27.8%
Small Exo Village	73	1,121	12,254	131	1.2%	1.1%	0.8%	0.9%
Disseminated Village	160	6,808	61,721	782	2.5%	6.8%	3.9%	5.5%
Agri Village	35	1,007	6,809	113	0.6%	1.0%	0.4%	0.8%
Disseminated Hamlet	1,071	7,729	22,769	842	17.0%	7.7%	1.4%	6.0%
Disseminated Living Agri Hamlet	4,283	15,244	44,243	1,296	68.0%	15.2%	2.8%	9.2%
Exo Industrial Zone	35	1,605	391	599	0.6%	1.6%	0.0%	4.2%
TOTAL	6,301	100,172	1,581,586	14,105	100%	100%	100%	100%
TOPOI types selected (3)	1,122	18,852	273,986	2,577	17.8%	18.8%	17.3%	18.3%

Table 9.1
13 TOPOI types describing a total of 6,301 settlement units have been identified in the two study regions in Lower Saxony. The TOPOI types of the selected prototypes cover roughly 17–18% in terms of population, area, and count of all settlement units. Data: Carlow et al. 2020.

	VALUES					CHANGE FROM SQ [%]			
	Status quo (SQ)	Scenario				Scenario			
		A	B	C	D	A	B	C	D
Eydelstedt (Disseminated Hamlet)									
Total Area of Settlement Unit [ha]	11.7	11.7	11.7	14.6	11.7	0.0	0.0	24.8	0.0
Population [inh.]	53	179	240	176	126	237.7	352.8	232.1	137.7
Population Density [inh./ha]	4.6	15.3	20.5	12.1	10.7	232.6	345.7	163.0	132.6
Built-up Area [ha]	0.80	1.09	0.82	1.22	1.28	36.3	2.5	52.5	60.0
Building Density [building/ha]	6.66	8.41	6.92	9.67	6.02	26.3	3.9	45.2	-9.6
Open Space Ratio	0.93	0.91	0.93	0.92	0.89	-2.2	0.0	-1.1	-4.3
Public Transport Density [inh./stop]	53	179	120	-	-	237.7	126.4	-	-
Public Transport Access Score (PTAS)	14.7	19.0	19.0	-	-	29.3	29.3	-	-
Detmerode (Exo Satellite Town)									
Total Area of Settlement Unit [ha]	145.8	145.8	145.8	154.0	145.8	0.0	0.0	5.6	0.0
Population [inh.]	7,241	8,655	8,977	8,189	8,721	19.5	24.0	13.1	20.4
Population Density [inh./ha]	49.7	59.4	61.6	53.2	59.8	19.5	24.0	7.0	20.3
Built-up Area [ha]	26.71	28.52	27.13	28.28	26.42	6.8	1.6	5.9	-1.1
Building Density [building/ha]	5.67	5.95	5.72	5.53	5.47	4.9	0.9	-2.5	-3.5
Open Space Ratio	0.82	0.80	0.81	0.82	0.82	-2.4	-1.2	0.0	0.0
Public Transport Density [inh./stop]	905	1,082	1,122	-	-	19.6	24.0	-	-
Public Transport Access Score (PTAS)	22.0	26.0	26.0	-	-	18.2	18.2	-	-
Schöppenstedt (Periurban Village)									
Total Area of Settlement Unit [ha]	211.2	211.2	211.2	222.5	211.2	0.0	0.0	5.4	0.0
Population [inh.]	4,198	4,616	5,191	5,108	5,196	10.0	23.7	21.7	23.8
Population Density [inh./ha]	19.9	21.9	24.6	23.0	24.6	10.1	23.6	15.6	23.6
Built-up Area [ha]	18.15	18.65	18.18	19.22	18.81	2.8	0.2	5.9	3.6
Building Density [building/ha]	15.25	15.64	15.27	15.29	15.31	2.6	0.1	0.3	0.4
Open Space Ratio	0.91	0.91	0.91	0.91	0.91	0.0	0.0	0.0	0.0
Public Transport Density [inh./stop]	467	513	399	-	-	9.9	-14.6	-	-
Public Transport Access Score (PTAS)	28.0	31.0	31.0	-	-	10.7	10.7	-	-

Table 9.2
Quantifying the qualitative scenarios: computed changes of defined attributes for the scenarios of the prototypes Eydelstedt, Detmerode, and Schöppenstedt

	VALUES					CHANGE FROM SQ [%]			
	Status quo (SQ)	Scenario				Scenario			
		A	B	C	D	A	B	C	D
Disseminated Hamlets									
Total Area [ha]	7,729.3	7,729.3	7,729.3	9,644.5	7,729.3	0	0	24.8	0
Population – new [inh.]	-	53,613	79,750	52,383	30,826	-	-	-	-
Population – total [inh.]	22,769	76,382	102,519	75,152	53,595	235.5	350.3	230.1	135.4
Land Take [ha]	-	-	-	1,915.2	-	-	-	-	-
Built-up Area – new [ha]	-	306.1	21.4	442.6	505.8	-	-	-	-
Built-up Area – total [ha]	842.1	1,148.2	863.5	1,284.7	1,347.9	36.3	2.5	52.6	60.1
MEDIAN VALUES									
Public Transport Access Score	12.7	16.7	16.7	-	-	31.5	31.5	-	-
Open Space Density [m²/inh.]	3,224	920	715	1,186	1,284	-71.5	-77.8	-63.2	-60.2
Population – new [inh.]	-	33	49	32	18	-	-	-	-

Table 9.3
Summarized values of the computed impact of local measures extrapolated to all 1,071 Disseminated Hamlets in the study regions

7.7 % of the overall area of all settlement units and 1.4% of the population in both study regions (Carlow et al. 2020). The Disseminated Hamlets have the second lowest building density – 4.5 buildings per ha (median) – while having a compactness of 81% (median) and second highest open space ratio at 91.4% (median) (see Chapter 2). About 70% of the population living here has no or only low access to public transport (Carlow et al. 2021).

The low building density allows for a high degree of densification within the boundaries of the settlement unit. An increase of the built-up area by up to 60.0% in scenario D, *Communities Repurposed!*, is possible without reducing the available share of open spaces or without designating new building land for a population that has grown by 137.7% (Table 9.2). The maximum growth of 352.8% is possible with scenario B, *Planned Happy Futures?*, also by converting and expanding existing building stock in response to changing use requirements, for example a change from agricultural purposes to housing. The increase of the building density in scenario A, *Green Communities*, by 26.3% comes along with the reduction of the Open Space Ratio by 2.2% and an increase in population by 237.7%. Scenario C results in similar values but increases the area of the settlement unit by about 25%. The population growth potentially allows the improvement of public transport in terms of frequency and connectivity since the number of inhabitants served per bus stop is increasing by nearly 238% in scenario A – assuming a subsequent increase of the operating frequency and the ensuing public transport connectivity, i.e. to how many other settlement units it is connected to by public transport (Carlow et al. 2022). The accessibility by public transport is improved by almost 30% both for scenarios A and B. However, due to new technologies such as autonomous driving, scenarios C and D also consider eliminating static stops altogether. The evaluation of accessibility to transportation options then depends on the availability of these options, which we assume to be given in these scenarios.

Extrapolating the relational change of the prototype Eydelstedt to each Disseminated Hamlet shows that the creation of housing for a total of up to 79,750 new inhabitants across all 1,071 settlement units within their existing boundaries would be possible in scenario B (Table 9.3). The change per settlement unit is relatively minor with a median growth of 49 inhabitants. This however reduces the amount of open space available per person from an average of 3,224 m² per capita today to 715 m². The built-up area only increases by a total of 21 ha. In comparison, in scenario A the median population increase per settlement unit amounts to 500 inhabitants (total growth potential of approximately 53,600 inhabitants), while reducing the available open space per person to a third (see Table 9.3) but leading to an overall increase of built-up area by over 36%. Both scenarios A and B provide public transport to all Disseminated Hamlets and significantly increase accessibility. Currently, 44% of the settlement units of this type (i.e. 476 settlement units) are not accessible by public transport (see Figure 9.1). Disseminated Hamlets have one of the highest potentials for large-scale change due to their low population numbers and low building density coupled with a high TOPOI count.

Our second prototype Detmerode belongs to the TOPOI class of Exo Satellite Towns. Exo Satellite Towns have the highest population density with 48.2 inhabitants/ha (median) at an average size of 81 ha with very low residential land take across the study regions. About 42,500 people live in a total of only nine units covering an area of 8.5 km² (Carlow et al. 2020). This is about 0.8% of the overall area of all settlement units and 2.7% of the population in both study regions. A comparable population density of 43.5 inhabitants per ha is found only in the Node City with about 160,000 inhabitants on an area of 37 km². About two-thirds of the Exo Satellite Towns have only mediocre public transport connections (Carlow et al. 2021).

The urban structure of the settlements from the 1960s–1970s allows a densification of up to 4.9% in scenario A, *Green Communities*, which leads to a reduction of the open space ratio by 2.4% for a population that has grown by 19.5% (Table 9.2). The maximum growth of nearly 24% is made possible by scenario B, *Planned Happy Future?*, with only a small reduction in available open space. This is achieved not least by converting and adding storeys to the existing building stock. In Scenario C, *New Settlers*, building density is reduced despite an increase in population by 13.1%. This is partly due to the fact that the settlement unit expands by 5.6% in terms of area. Scenario D, *Communities Repurposed!*, allows for a 20.4% population growth while reducing the built-up area by 1.1%.

The improvement in public transport in scenarios A and B results in an improvement in public transport accessibility from medium to high (Carlow et al. 2021),

	VALUES					CHANGE FROM SQ [%]			
	Status quo (SQ)	Scenario				Scenario			
		A	B	C	D	A	B	C	D
Exo Satellite Towns									
Total Area [ha]	845.5	845.5	845.5	893.3	845.5	0	0	5.7	0
Population – new [inh.]	-	8,233	10,133	5,531	8,613	-	-	-	-
Population – total [inh.]	42,222	50,455	52,355	47,753	50,835	19.5	24.0	13.1	20.4
Land Take [ha]	-	-	-	47.8	-	-	-	-	-
Built-up Area – new [ha]	-	9.5	2.3	8.3	-1.5	-	-	-	-
Built-up Area – total [ha]	139.9	149.4	142.2	148.2	138.4	6.8	1.6	5.9	-1.1
MEDIAN VALUES									
Public Transport Access Score	22.0	25.0	25.0	-	-	13.6	13.6	-	-
Open Space Density [m²/inh.]	187	155	151	175	156	-17.1	-19.3	-6.4	-16.6
Population – new [inh.]	-	686	844	461	720	-	-	-	-

Table 9.4
Summarized values of the computed impact of local measures extrapolated to all 9 Exo Satellite Towns in the study regions

primarily due to an increase in frequency. This becomes feasible also due to the population growth, which results in an increase in inhabitants per stop to up to over 1,100 persons (from today's 900). Due to the specifics of scenarios C and D, the public transport stops are removed and replaced by means of new transport systems such as options of autonomous vehicles. The evaluation of accessibility to transport options then depends on the availability of these options, which we assume to be given in these scenarios.

Extrapolating the relational change of the prototype Detmerode to each Exo Satellite Town, the creation of housing for a total of roughly 8,000 new inhabitants in scenarios A and D is possible (Table 9.4). For scenario B, more than 10,000 new inhabitants across all nine existing Exo Satellite Towns (median growth per settlement unit 844 inhabitants) would be possible within their respective boundaries. With the proposed measures, such as the addition of new floors to buildings, the available open space per inhabitant would be reduced from nearly 190 m^2 today to about 150 m^2 in these scenarios. In scenario C, the open space per capita decreases to 175 m^2, but this would allow only for an overall population growth of just over 5,500 and, furthermore, 47.8 ha of land are newly sealed across all Exo Satellite Towns (see Table 9.4). Both scenarios A and B result in an improvement of the share of people having access to public transport: a total of 50,500 (A) or 52,500 (B) residents

	VALUES					CHANGE FROM SQ [%]			
	Status quo (SQ)	Scenario				Scenario			
		A	B	C	D	A	B	C	D
Periurban Villages									
Total Area [ha]	10,276.6	10,276.6	10,276.6	10,837.9	10,276.6	0	0	5.5	0
Population – new [inh.]	-	20,900	49,532	45,352	49,741	-	-	-	-
Population – total [inh.]	208,995	229,895	258,527	254,347	258,736	10.0	23.7	21.7	23.8
Land Take [ha]	-	-	-	561.3	-	-	-	-	-
Built-up Area – new [ha]	-	44.6	3.2	94.1	57.4	-	-	-	-
Built-up Area – total [ha]	1,594.9	1,639.5	1,598.1	1,689.0	1,652.3	2.8	0.2	5.9	3.6
MEDIAN VALUES									
Public Transport Access Score	28.0	30.0	30.0	-	-	7.1	7.1	-	-
Open Space Density [m²/inh.]	432	371	349	374	347	-14.1	-19.2	-13.4	-19.7
Population – new [inh.]	-	432	1,025	938	1,019	-	-	-	-

Table 9.5
Summarized values of the computed impact of local measures extrapolated to all 42 Periurban Villages in the study regions

enjoys now high accessibility, which is three times to today's 17,500 (see Figure 9.1).

The third prototype Schöppenstedt belongs to the TOPOI class of Periurban Villages. Periurban Villages show the third strongest increase in housing-related land take since the 1970s, after Exo Villages and Periurban Towns (Mühlbach et al. 2021). Close to 209,000 people live in a total of 42 settlement units with an area of 103 km². This is about 10.3% of the overall area of all settlement units and 13.2% of the population in both study regions (Carlow et al. 2020). Periurban Villages have a rather low compactness at 38% (median), while having the second highest building density of 15.2 buildings per ha (median). In comparison, the seven Node Towns covering 83 km² (8.3%) and recording a population of roughly 200,000 (12.7%) have a compactness of 22% (median) with the overall highest building density of 15.5 buildings per ha (median). More than half of the inhabitants of the Periurban Villages have only mediocre public transport connections.

The high building density and low compactness indicate that a substantial part of the building stock consists of single-family houses. The scattered development in parts of the settlement units and larger fallow areas, e.g., formerly used for agriculture, offer the potential for punctual building densification. Furthermore, larger transformation areas, e.g., former industrial and commercial facilities, are located on the edges, allowing substantial additions. Scenarios B, *Planned Happy Future?*, C, *New Settlers*, and D, *Communities Repurposed!*, have similar population growth of between 21.7 and 23.8% (i.e. around 1,000 persons). This is accomplished in scenario B without increasing the built-up area. In contrast, scenario D shows an increase of 3.6% of the built-up area and scenario C of 5.9% (Table 9.2). The latter takes up 5.4% additional land area, which results in a slightly lower population density. Scenario A, *Green Communities*, has the lowest population growth of 10%, but the highest increase in building density of 2.6%, with the built-up area also increasing by nearly 3%. All four scenarios show no negative change of the open space ratio. Given the increase in population, this leads to a reduction in the amount of open space available per capita.

Scenarios A and B focus on the promotion of public transport. The negative trend in the number of residents per stop in scenario B is the result of additional new stops, but all the stops still serve about 400 people each (the status quo is 466). The already very good accessibility (PTAS: High) is further improved by about 10% through an increase of the service frequency. Due to the specifics of scenarios C and D, the public transport stops are removed and replaced by options provided by the introduction of autonomous vehicles. The evaluation of accessibility to transport options then depends on the availability of these options, which we assume to be given in these scenarios. Extrapolating the relational change of the Schöppenstedt prototype to all of the Periurban Villages, in summary, housing for approximately 21,000 new residents could be realized in scenario A and up to 45–50,000 new residents in scenarios B, C, and D (median growth per settlement unit: approx. 1,000 inhabitants) for all 42 Periurban Villages (Table 9.5). The open space will be reduced by a maximum of 85 m^2 and range between 349 and 374 m^2 per person, while it is 432 m^2 per person at present. Scenario B stands out because it allows for a very high population growth while only slightly increasing the built-up area (see Table 9.5). Both scenarios A and B see an increase of the accessibility to public transport by 7.1%. All 42 Periurban Villages will have a PTAS of High (currently 24 are rated Medium and 18 High). This could mean an improvement in the situation for more than 100,000 people (see Figure 9.1) without changing the public transport network as such.

By quantifying the changes in the prototypes and extrapolating these to all settlement units of the respective TOPOI types, we can deduce the impacts at the regional level. In this context, the method demonstrates in particular the possibilities that arise from the developed scenarios. We can show, e.g., that the development of residential space on a relevant scale is possible by means of balanced inner densification without taking up new land for construction beyond the current perimeter of the settlement units (Scenarios A, B, and D). This amounts to a possible population increase of between 82,000 and 140,000 inhabitants in the scenarios we have developed. Rather than concentrating on large cities, our scenarios are addressing villages, suburbs, and small towns that are subject to transformations as a result of structural changes. Focusing on areas outside large cities, approaches for the sustainable development of the urban-rural gradient could be shown. Against the backdrop of the urgent need to develop (affordable)

SUM of all TOPOI, i.e. 6,301 settlement units

	Status quo	Scenario A	Scenario B	Scenario C	Scenario D
Total Area [ha]	100,172.4	100,172.4	100,172.4	102,696.7	100,172.4
Population – new [inh.]	-	82,746	139,415	103,266	89,180
Population [inh.]	1,581,586	1,664,332	1,721,001	1,684,852	1,670,766
Land Take [ha]	-	-	-	2,524.3	-
Built-up Area – new [ha]	-	360.3	26.9	545.0	561.7
Built-up Area – total [ha]	14,104.6	14,464.9	14,131.5	14,649.6	14,666.3

SUM of Disseminated Hamlets, Exo Satellite Towns, and Periurban Villages, i.e. 1,122 settlement units and share of SUM in all TOPOI

	Status quo		Scenario A		Scenario B		Scenario C		Scenario D	
Total Area [ha]	18,851.4	19%	18,851.4	19%	18,851.4	19%	21,375.7	21%	18,851.4	19%
Population – new [inh.]	-		82,555	-	140,110	-	103,186	-	89,117	-
Population [inh.]	273,986	17%	356,732	21%	413,401	24%	377,252	22%	363,166	22%
Land Take [ha]	-		-		-		2,524.3	-	-	
Built-up Area – new [ha]	-		360.3	-	26.9	-	545.0	-	561.7	-
Built-up Area – total [ha]	2,577	18%	2,937	20%	2,604	18%	3,122	21%	3,139	21%

Table 9.6
Comparative presentation of the changes at the level of the entire two study regions

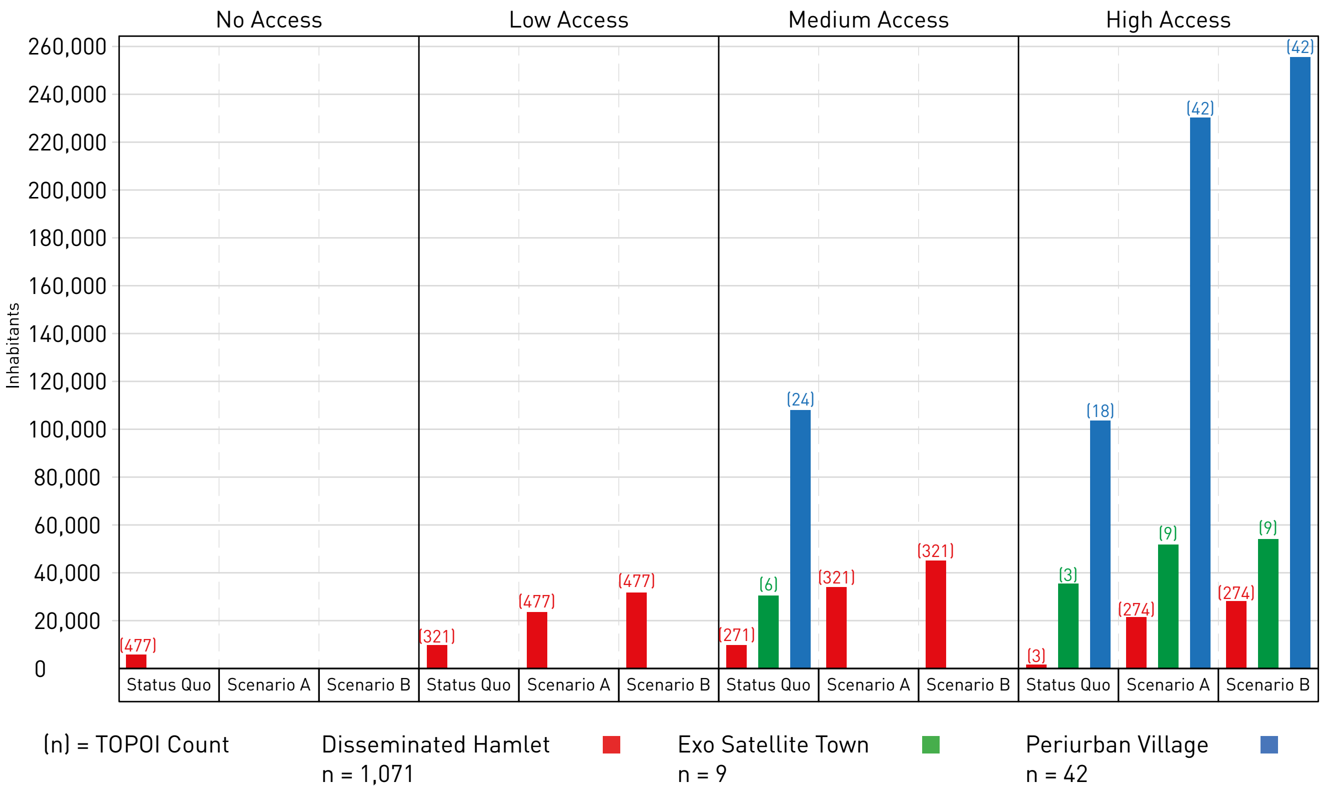
housing (BMWSB 2022) and the associated required space (Blum et al. 2022), while at the same time making efficient use of land, this shows new perspectives for new forms of living outside metropolitan centers. In that sense, in particular the Exo Satellite Town is an interesting settlement type, which stands out positively in terms of, e.g., land consumption in relation to population density.

All scenarios have in common that they allow for population growth in the respective settlement units. To facilitate this growth, different measures are underlying, especially with regard to new construction of housing or the conversion of existing buildings. The data that we can derive from the developed scenarios allow us, on the one hand, to quantify the growth and, on the other hand, to calculate the change in the ratio of built-up area to open space or also the density of buildings. A generalized conclusion with regard to other sustainability dimensions, however, would require the intersection with further data, e.g., of the embedded and operational energy usage of existing or planned buildings. This is especially important as some scenarios call for a renovation-focused development, while others aim for new development with higher standards.

Scenario C is the only one that involves the development of land beyond the current settlement area. Although an expansion of three hectares is not particularly large in itself, the extrapolated analysis reveals that applied to all 1,071 settlement units of the TOPOI type Disseminated Hamlet, this would mean a total land take of about 1,900 hectares. The same applies to Periurban Villages, where the land consumption totals slightly more than 560 hectares across the 42 settlement units. Given Lower Saxony's declared target of limiting new land take to a maximum of four hectares per day (MU 2020), this means the equivalent land budget of 1.6 years, not even taking into account associated requirements, e.g. for transport infrastructure. This would be largely at the expense of agricultural land, which is continuing to decline (Basedow et al. 2021).

Next to densification and growth opportunities, the focus of our analysis was on public transport provision. The improvement of public transport can be measured by the number of people in the catchment areas of public transport stops and the frequency with which they are served. With the assumptions we have made and changes we proposed, such as increasing the frequency and adding new stops on already existing lines, as implemented in scenarios A and B, we show the great potential for strengthening public transport even in the countryside to improve the service for the existing and potentially new population. In Figure 9.1, we show for how many settlement units and people accessibility is improved. By increasing the availability and accessibility of public transport by at least one PTAS level (e.g., from PTAS Low to Medium), we are able to improve the public transport accessibility in these study areas compared to the status quo. For about 130,000 people, given the status quo population in the 1,122 analyzed settlement units, access to public transport could improve from PTAS Medium to PTAS High.

The production of regenerative energies inevitably requires new space to install the necessary infrastructures. In order to reduce the amount of land required, the generation of solar energy, for example, can be combined with buildings to enable the hybrid use of sealed surfaces. This is intensively promoted in Germany for private building owners as well (eg. Mussack and Rudloff 2022) in order to achieve the climate targets (BMU 2021). Assuming an average energy production of 90 kWh per square meter of photovoltaics per year (Sanalmis 2019), this means that Periurban Villages with a total built-up area of 1,594 ha could mathematically generate about 1.4 terawatts. That is five times the total energy demand of all private households in these Periurban Villages, assuming an energy demand per person of 1,500 kWh. Even Exo Satellite Towns with a built-up area of 139 ha and a population of 42,222 would mathematically produce double the amount of energy needed for residential purposes. The 1,071 Disseminated Hamlets could produce approximately 760 megawatts, of which 95% is surplus due to the small population. Even though these numbers were derived arithmetically, it still shows the inherent potential. Disseminated Hamlets, in particular, could thus become energy villages that export energy or facilitate new forms of local value creation and production. This energy could also be used for charging fleets of autonomous electric vehicles for public transport, which could potentially overcome the contradiction between living in rural



9.1 Public Transport Access Score (PTAS)
Scenarios A and B include measures for improving the access to public transport. Applying the Public Transport Access Score (PTAS), we can rate the quality (No, Low, Medium, High Access) of each of the 1,122 settlement units (totals in parentheses) and thus also the number of respective inhabitants living in the area of the determined PTAS (bars on the x-axis).

communities, high transport needs, and limited access. About a quarter of the population in Germany lives in municipalities with less than 10,000 inhabitants. Another third live in small towns with 10,000–50,000 inhabitants (Destatis 2021). The endeavor that we have undertaken with our work presented here was to identify and prototype the great potentials that exist in settlement types outside the large metropolitan areas. We were able to reveal some of the challenges connected to that. On the other hand, potentials that emerge not least from the viewpoint of creating equal living conditions could be identified, too: how "little" is necessary to provide for much needed housing solutions, for improving access to public transport in semi-urban and rural areas, and to equalize the livability of urban and rural communities. We therefore conclude that extrapolating the presented, context-specific approaches to a regional scale allows us to envision a more sustainable future with livable spaces for all.