Renewable energy on rural landscapes. An overview in south germany.[1]

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Abstract

The aim of the research is to analyse the complexity that rural territories should achieve in order to provide food, energy, entertainment and quality of life. The concentration of population in cities, the almost exhaustion of natural resources and the imminent change in climatic conditions make it necessary to redefine the way of life on a territorial scale. In the European context, where communities strengthen competitive models to maintain and improve the quality of life of their citizens, southern Germany reinforce the enhacement of its most valuable assets: the diversity of landscapes, the wealth of resources and the goodness os weather conditions, taking into account the perservation of natural and productive areas and the structure of settlements originated in traditional rural economies.
The research focuses on the production of renewable energy from wind, sun, water and biomass, mainly in the Bavarian region.

Word-keys: Climate change, renewable energy, rural-land development.

Introduction

During the last decades, the capacity of the countryside to supply air, water, nutrients and ecological diversity has been managed to be compatible with the avalability of open spaces for the spare time (Forman, 1995). It has been also introduce the necessity of the implementation of renewable energies in landscape, being aware of the challenge of defining a kind of social contract that balances the impacts of such infrastructures, the values of cultural landscapes and the welfare of their communities (Schöbel, 2018).
Besides, the urgency of diminishig global warming caused by the greenhouse effec leads to changing the model of energy production from the use of fossil fuels to the production of renewable energy from wind, sun and biomass.
The combination of all this requirements affects in different ways the supporting territory, in attendance of local specificities such as low densities areas or places in between (Der Zwischenstadt) sized by parameters as urbanity, social density, centrality or identity (Sieverts, 1997). Focusing on the rural and in-between territory as energy producers, the question arised is to design infrastructures of generation and distribution of renewable energy that allow a sustainable development and the enhacement of the identity characteristic of their landscapes.
Nowadays, the inhabitants of rural and in-between areas have to deal with pressures on the territory that can reduce their quality life conditions, therefore the interest in deep on the discussion about the strategical location of renewable energies infrastructures and the maintenance of good quality of life in the area.



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Img.1. Renewable energy infrastructures in southern Germany. 1.1 Wind park with leisure sport facility and forestry exploitation, near Bachern, Friedberg, Bayern. 1.2. Photovoltaic power plant and biomass plant in Sinsheim, Baden-Württemberg. 1.3. Wieblingen Hydroelectric power plant. Heidelberg, Baden-Württemberg. Source: M. Somoza, Augus 2023.

Method, Case Studies

The investigation follows an inductive methodology by the analysis of certain real practises, the specfic observations extracted from them, the recognition of patterns and the general conclusions formulated at the end.

Img.2. Windpark in Schwegenheim. Rheinland-Pfalz. Photography and sketch plan. Source: M. Somoza, Augus 2023.

To get a glimpse of the complexity of rural territories in South Germany, there were visited different areas, taking into account a large diversity of tipologies of renewable energy infrastructures. The analyses has been focused in sectors of territory that include one or more of those producers (water, wind, solar, biomass), using the idea of “transect” as a method of analyse (Bosselman, 2011). It has also been included some cases of good practices in Bayern (Fuchstal, Wildpoldsried).

Img.4. Sketch plan of areas1 and 2. Source: M. Somoza, Augus 2023.

The Area 1 is situated in the Pfaffenhofen district, in the urban region of München. The transect covers a surface of 24 Km^2 of a open valley with a broad horizontal component. There are smoth hilly elevations to the west and isolated hills to the east, varying the topographic altitudes between 523 m. and 470 m. above see level. The A-9 highway crosses it from south to north-west connecting Munich to Nuremberg. The small and medium size settlements are emplaced on altitudes around 500 m.a.s.l. and distributed on land surrounded by crops and connected by a network of roads. In the transect are 18 villages and hamlets (municipalities of Schweitenkirchen and Paffenhofen) with a population of 1.084 inhabitants (46 Inh./Km^2). The average incomm per inhabitant in those municipalities is 37.355 € each year (https://www.deutschland123.de/).
In the area has been established between 2002 and 2022 a group of wind, solar and biogas power stations that generates a total of 20.330.063 kWh (2021), enougth to supplied 4.066 homes per year. The first wind park of one tower was built in Neuenberg (523 m. alt.) in 2002, just 560 m far

form Frickendorf, with a total height of 133 m (98+70/2). The second wind park was built in Burgstall “wald of the burg” in 2016, with a tower emplaced at 504 m.a.s.l., 760 m. far from Riedhof and of a total height of 206,5 m (149+115/2). In this case part of the inversion and benefits belong to the municipalitiy of Pfaffenhofen and some citizens-inversors (website Pfaffenhofen), and nowadays they are planning to build another one, oppening a system of selling shares to the interested citizens.

Img. 3. Renewable energy infrastructures in Area 1. 3.1, 3.2, 3.3. Wind turbine near Riedhof. 3.4 Wind turbine near Frickendorf. 3.5 Wind turbine near Frickendorf and photovoltaic power plant near Preinerszell. 3.6. Wind turbine near Frickendorf,wind turbine near Sünzhausen, Biogas plant in Thalhof seen from Riedhof. Source: M. Somoza, Augus 2023

The isolated wind towers generate a system of milestones in the landscape, considering other two towers emplaced in the surroundings. The monolits guideline the progression through the roads and create elements that help to interpretate and orientate oneself in the territory. In the proximity the perception of the higher interacts with the chapel nearby, although when approaching it, its figure is disolved in the forest. The older, in the border between fieldcrops and woodland, is accesible following a path that end in the sumit, generating a viewpoint facing north and west.

The five photovoltaic power plants were built during the last decade (2012-2022), filling voids of disactivated gravel and sand pits, dumps and strips of land along the roads. The surface extensions vary between 1 Ha to 3 Ha., with unevens of up to 25 m in the old deponie of Eberstetten (10%, 6º). The photovoltaic panels are disposed in geometrically ordered packages that follow the undulations of the topography.

Finally, the biomass installations show hemispheric volumes (20 and 27 m diameter) surrounded by other farm constructions. Whereas the fields attached to this energy producers expand out of the area, considering that part of the raw material comes from maize crops, the size of the infrastructure accommodates well in the scale of the hamlet.

Area 1 represents a territory characterized by settlements traditionally sparsed on an agriculture land, nowadays influenced by the urban activities of Munich urban region. The different initiatives of renewable energies carried out over the last years in the area interweave a complex set of diversified sources producers of renewable energy (wind 40%, solar 23%, biomass 37%).

Area 1. Schweitenkirchen and Paffenhofen

	Code (Bayern energy atlas) Distribution Network operator Dimensions	Performance energy		Distance to houses Area/Height
1. Wind turbine	E218750110000000000000299365400000 Distribution network operator: Bayernwerk Netz GmbH.	1.800 Kw 1.913.742 Kw (2021) 1.063 Hours	2002	Neuenberg 523 m.a.s.l. 560 m to Frickendorf 98+70/2= 133 m height
2. Wind turbine	E2104101EA010000000000079780200001 Distribution network operator. Stromversorgung Pfaffenhofen a. d. Ilm GmbH & Co. KG	3.000 Kw 6.204.010 Kw (2021) 2.068 Hours	2016	Burgstall: 504 m.a.s.l. 760 m. to Riedhof Height: 149+115/2= 206,5 m
3. Photovoltaic power plant	E2104101SZP0000000000035485100001 Distribution network operator: Stromversorgung Pfaffenhofen a. d. Ilm GmbH & Co. KG	999 kWp 1.058.791 kWh (2021) 1.060 Hours	2012	Eberstetten Dump 325 m to Siebenecken 185m x 198m, 32.790 m^2; 474-499 m.a.s.l., 25 m. uneven
4. Photovoltaic power plant	E2104101S000000000000094991200001 Distribution network operator: Bayernwerk Netz GmbH	750 kWp 797.646 kWh (2021) 1.064 Hours	2018	A9; 682 m to Preinerszell 122m x 92m, 10.303 m^2, 472-486 m.a.s.l.,14 m. uneven
	E2104101S000000000000094991200002 Distribution network operator: Bayernwerk Netz GmbH	256 kWp 272.238 kWh (2021) 1.064 Hours	2020	
5. Photovoltaic power plant	E2104101S000000000000103801900001 Distribution system operator: Bayernwerk Netz GmbH	749 kWp 855.843 kWh (2021) 1.143 Hours	2018	A9;260 m to Frickendorf North part: 176m x67m, 11.527 m^2 498-506 m.a.s.l., 6 m uneven
	E2104101S000000000000104146000001 Distribution network operator: Bayernwerk Netz GmbH	749 kWp 837.310 kWh (2021) 1.118 Hours	2018	A9; 270 m to Frickendorf South part: 202m x 66m, 12.164 m^2 ; 494-504 m.a.s.l., 10 m uneven
6. Photovoltaic power plant	E2999901So000000000000000139600001 Distribution network operator: Stromversorgung Pfaffenhofen a. d. Ilm GmbH & Co. KG	750 kWp 834.721 kWh (2021) 1.113 Hours	2019	590 m to Siebenecken 103m x 162m, 16.389 m^2; 499-506 m.a.s.l., 7 m uneven
7. Photovoltaic power plant	SEE921008334266 Without information	750 kWp	2022	567 m to Seugen
8. Biomass powered power plant: Biogas Electricity+Heat	06-09-186-9000-0001 bzw. E218750110000000000000354154800000 Fuel type:gaseous. Fuel: Biogas Distribution network operator: Stromversorgung Pfaffenhofen a. d. Ilm GmbH & Co. KG	Electrical output: 999 Kw Electricity production: 5.675.377 kWh (2021) 5.681 Hours Combustion heat output: 1,5 MW	2005	In Thalhof Diameter: 20 m
9. Biomass powered power plant: Biogas Electricity+Heat	E2104101100000000000003966070000000 bzw. A8777690182744 Fuel type:gaseous. Fuel: Biogas (electricity on site) Distribution network operator: Bayernwerk Netz GmbH	Electrical output:390 Kw Electricity production:1.880.385 kWh (2021) 4.822 Hours	2011	In Stelzenberg Diameter: 27 m, 25 m
	847.086 kWh/Km^2 each year	20.330.063 kWh (2021)	4.066 houses/year	

Table 1. Quantitative descriptions of the infrastructures of renewable energy in Area 1. Source: Own elaboration based on data by Energie Atlas Bayern and Bayern Atlas. It is considered that one house of three members consums 5.000 kWh per year.

The Area 2, another transect of 24 Km^2, is emplaced east from the previous one, comprehending part of the municipalities of Au in der Hallertau, Nandlstadt and Attenkirchen (Freising District), with a total population of 1.088 (2011) inhabitants distributed in 23 settlements (45,3 inh./km^2). The topography presents steadily undulating surfaces with continuous changes of slope and orientation, with a total uneven of 80 m (460 to 520 m.a.s.l.).
The villages and hamlets are positioned on relatively elevated locations in relation to the nearby water courses and are surrounded by fertile cultivated land.

Img. 5. Area 2. Au in der Hallertau and Attenkirchen. Photovoltaic power plants (P.P.P.) in the area. 5.1. P.P.P. Near Sindorf, in an old gravel pit. 5.2. Two P.P.P around Pfettrach. 5.3. P.P.P near Staudhausen. Source: M. Somoza, Augus 2023.

Along the last years there have been established four photovoltaic power plants, one in an old pit (Au in der Hallertau Municipality), and other three fragmented as land occupations between cultivated plots (Attenkirchen Municipality). The one built on the hill generated due the excavation activity near Sindorf, introduced variations on the geometry pattern because of tha adaptation to the wavy surface profil and also due the rotation of one of the row of panels with respect from the main orientation of the rest. The wildy growth of herbaceous and shrubby vegetation on the plot, the high of the panels (1,2 to 2,5 m. approximately) and the presence of water at the border, favor the presence of fauna on the site (a deer was seen during the visit). The other power plants in the area follow a ordered geometric pattern and produce a more shaped presence in their surroundings. Nevertheless, the vegetation on the fences dissolves in some sections the foreground vision of the panels and the fragmentation in plots of the infrastructure allows the maintenance of the preexisting paths.

Area 2. Au in der Hallertau and Attenkirche

	Code Distribution Network operator	Performance energy		Distance to houses Area/Height
1. Photovoltaic power plant	E2104101S0000000000000118274400001 Distribution network operator: Bayernwerk Netz GmbH	750 kWp 842.599 kWh (2021) 1.124 Hours	2020	100 m. to Sindorf, 475 m to Mailendorf 60 m x 133 m, 8.680 m^2 472-487 m.a.s.l., 15 m uneven
2. Photovoltaic power plant	210410110000000000000384425900000, E2104101100000000000000387953200000 Distribution network operator: Bayernwerk Netz GmbH	1.276 kWp 1.460.239 kWh (2021) 1.145 Hours	.2009	90 m to Pfettrach 155 m x 170 m, 23.092 m^2 496-508 m.a.s.l., 12 m uneven
3. Photovoltaic power plant	E2104101100000000000000386388700000, E2104101100000000000000390021900000 Distribution network operator: Bayernwerk Netz GmbH	2.745 kWp 3.056.092 kWh (2021) 1.113 Hours	2010	230 m to Pfettrach 280 m x 198 m, 45.200 m^2 482-501 m.a.s.l., 19 m uneven
4. Photovoltaic power plant	E2104101100000000000000392733000000 Distribution network operator: Bayernwerk Netz GmbH	1.956 kWp 2.243.820 kWh (2021) 1.147 Hours	2010	280 m to Staudhauen 120 m x 326 m, 39.866 m^2 496-511 m.a.s.l., 15 m uneven
316.781 kWh/Km^2 each year		7.602.750 kWh (2021)	1.520 houses/ year	

Table 2. Quantitative descriptions of the infrastructures of renewable energy in Area 2. Source: Own elaboration based on data by Energie Atlas Bayern and Bayern Atlas. It is considered that one house of three members consums 5.000 kWh per year.

Best practice. Fuchstal.

In South-west Bayern there are two municipalities that since more than a decade have implement infrastructures to produce renewable energy, managing it as an integrated system. The planning and administration of it have given besides benefits to the residents.

Fuchstal, in Landsberg am Lech district, covers 39,75 km^2 with part of the alluvial plain of the river Lech, the valley of the Wiesbach river, the Ascher valley and the mountainous foothills between the two streams reaching the highest elevation to the soutwest at the King-holz (King´s wood), with altitudes that rise 788 m.a.s.l. The population of 4.129 (2022) inhabitants (3502 in 2011; 32.682 Einkommen pro Jahr) dwells in three villages (Asch, Leeder, and Seestall) and 16 hamlets and farm houses.

In 2021 the German Society for Quality awarded the muncipality of Fuchstal with the"German Sustainability Prize", recognizing the work done since 2006 to implement sustainable development in the area[2]. The project integrate different strategies related to mobility, participation, local economy and energy. The municipality deals with concepts of mobility such as car sharing, the development of a mobility app, the increase of e-charging stations, disposal of benches for the passengers and footpath concepts. The local government is also concerned with the democratic participation that is going to be improved through a digital networking and the creation of better opportunities for it.

On the other hand, the municipality produces renewable energy using community wind turbines, photovoltaic power plants, a hydroelectric power station and a biogas plant. The electricity is used by the inhabitants, sold, storaged or used to produce heat for the community heat infrastructure. The renewable energy infrastructures in open air areas produce 31.625.102 kWh per year, that represent the consum of 6.325 houses.....The distribution of the resources is :Wind (69,5%), Solar (10,2%), Biomass (20,2%), and Water (without data). The solar panels installed on the roofs generate also about 4 millions kWh (545 emplacements till 30 kWp) and it is expected to be increased in the future.

Some of the infrastructures have been financed to some extent by the municipality, and the sales profits of the energy produced is invested each year in projets and services for the benefit of the community. It is the case of a municipal open air photovoltaic power plant (Fuchstal Solar) that generates circa 2 million kWh and the Fuchstal biogas plant, that produces more than 6 million

[2] DGQ Deutsche Gesellschaft für Qualität. Regionalkreis München (2022). "Besuch der Smart-City Fuchstal – Nachhaltigkeitssieger 2021" https://www.dgq.de/event/besuch-der-smart-city-fuchstal-nachhaltigkeitssieger-2021/. Consulted on line 08.09.2023.

kWh. The Fuchstal wind park, that produces more than 21 million kWh that is fed into the network every year, includes among the shareholders the muncipality and about one hundred mainly local people.
Recently the municipality is undertaken new projects to become an energy self supplier in both electricity and heat for the community[3]. The forthcoming construction of another wind park in Sachsenrieder Forst, near the existing one, will be partially financed by the municipality, deriving that part of the income generated there will be reinvested in the community. Besides the wind park is linked to a research project on camera-based monitoring, which is carried with the Weihenstephan-Triesdor fUniversity of Applied Sciences[4].

Area Fuchstal (39,75 Km^2)

	Code (Bayern energy atlas) Distribution network operator	Performance energy		Distance to houses Area/Height
1. Wind energy park	E311770100000000005007845010-00001 Distribution network operator: LEW Verteilnetz GmbH.	4x 3.000 Kw 21.937.752 kWh (2021) 1.828 Hours	2016	Kingholz 755 m.a.s.l. 2000 m to Frankenhofen 149+115/2= 206,5 m height
2. Photovoltaic power plant	E311770100000000005007800568-00000 Distribution network operator: LEW Verteilnetz GmbH.	957 kWp 1.107.269 kWh (2021) 1.157 Hours	2011	Energie-Speicher-Fuchstal GmbH In Vorderer Huttenbügel, 450 m to Wildbad 270m x 375m 107.630 m^2; 678-710 m.a.s.l., 32 m. uneven
3. Photovoltaic power plant	E311770100000000005007876041-00000 Distribution network operator: LEW Verteilnetz GmbH.	749 kWp 822.068 kWh (2021) 1.097 Hours	2019	Commercial area at the train station 543 m to Asch 262m x 74m 17.114 m^2; 654-656 m.a.s.l., 2 m. uneven
	E311770100000000005007876041-00002 Distribution network operator: LEW Verteilnetz GmbH.	750 kWp 799.498 kWh (2021) 1.066 Hours	2021	
4. Photovoltaic power plant	E311770100000000005007796501-00000 Distribution network operator: LEW Verteilnetz GmbH.	455 kWp 505.891 kWh (2021) 1.157 Hours	2011	Commercial area at the train station 512 m to Asch 184 m x 50 m 9.282 m^2; 653-670 m.a.s.l., 7 m. uneven
5. Biomass powered power plant: Biogas Electricity+Heat	06-09-181-9001-0001 Fuel type:gaseous. Fuel: Biogas	Combustion heat output: 9,4 MW	2016	Commercial area at the train station.864 m to Asch
6. Biomass powered power plant: Biogas Electricity+Heat	06-09-181-8077-0001 bzw. E311770100000000005007514829-00000 Fuel type:gaseous. Fuel: Biogas Distribution network operator: LEW Verteilnetz GmbH.	Electrical output: 1.000 Kw 6.410.180 kWh (2021) 6.410 Hours Combustion heat output: 3,3 MW	2005	Commercial area at the train station.864 m to Asch
8. Hydroelectric power plant	Water Management Authority: WWA Weilheim	Performance class: 2 x 5000 kw or bigger		2 centrals in Lech river: Zankerwiesen, near Lechmühle
9. Hydroelectric power plant	Water Management Authority: WWA Weilheim	Performance class: till x 499 kw (x6)		5 in Lech chanel in Lechmülen and Grasmühle; 3 in Wiesbach stream; 1 in Schmiedbächl -Aschtal-
795.600 kWh/Km^2 each year		31.582.658 kWh	6.325 houses/ year	

Table 3. Quantitative descriptions of the infrastructures of renewable energy in Fuchstal municipality. Source: Own elaboration based on data by Energie Atlas Bayern and Bayern Atlas. It is considered that one house of three members consums 5.000 kWh per year.

[3] Agentur für Erneuerbare Energien (2022). “Energie-Kommune des Monats: Fuchstal”. https://www.unendlich-viel-energie.de/fuchstal/. Consulted on line 08.09.2023.
[4] Umwelt Bank. “Bürgerwind Fuchstal Gemeindewald. https://www.umweltbank.de/firmen/projekte-finanzieren/windkraft/buergerwind-fuchstal-gemeindewald. https://www.unendlich-viel-energie.de/fuchstal/. Consulted on line 09.09.2023.

Moreover the “Energy future Fuchstal” project proposes a storage system of unused electricity and heat. The heat produced in the biogas plant that won´t be used in warm days can be stored and fed to the municipal heating network. Otherwise, the electricity from wind turbines, which is not sold in times of low demand, will be used to produce thermal energy using a power to heat system or stored in a battery storage system and fed back nto the network if necessary. This will contribute to stabilize the municipal network during times of low production and will allow to extend from 130 up to 400 properties connected to the heating network.

Some kilometers west to Fuchstal is the municipality of Wildpoldsried (Oberallgäu District), that since 2000 has also developed a sustainable model of production of renewable energy. With an area of 21,35 km^2 and 2.519 inhabitants (2011) distributed in the village, two hamlets about 15 small places. The income per year is 34.590 €. The wind park was build gradually on the ridge that forms the border between the Upper and Ostallgäu over the las two decades till reach the eleven community wind turbines it currently has. The inhabitants could invest in equity capital in the companies founded specifically for the projects. On the other hand, there is also solar energy produced with photovoltaic systems installed on roofs of private and public buildings and in the open air site. Finally, the biogas plants produce electricity to be consumed or fed into the electricity network and also to generate heat to feed into the local heating network of the vllage heating system, covering also a hamlet and a commercial area (Allgäu Innovation Park). Besides the CO²-neutral generation of electricity and heat, other positive effects for our environment are the fermentation processing plant with nitrogen, the no deed of purchasing mineral fertilizer, and the use of manure input from ten surrounding dairy farms[5].
The distribution of the energy production is rural land is :Wind 71,6%, Solar 0,6% and Biomass (27,8%). The solar panels installed on the roofs (311 emplacements till 30 kWp) generate also about 3.113.603 kWh each year.

Area Wildpoldsried (21,35 Km^2)

	Code (Bayern energy atlas) Distribution network operator	Performance energy		Distance to houses Area/Height
1. Wind energy park	E31177010000000005007680871-00001 Distribution network operator: LEW Verteilnetz GmbH. AllgäuNetz GmbH & Co. KG AllgäuNetz GmbH & Co. KG (two of them)	10x 2.000 Kw=19.100 kWh 33.398.070 kWh (2021) 1.749 Hours	2000, 2001, 2002, 2007, 2012, 2015	Hochbachtel, Fuchsbau 875 m.a.s.l In the limit with the municipality of Kraftisried. 1270 m to Eufnach 90+77/2= 129 m height 108+82/2= 149 m height 138+82/2= 179 m height
2. Photovoltaic power plant	E318060187499002000000000020019732 Distribution network operator: AllgäuNetz GmbH & Co. KG	305 kWp 297.259 kWh (2021) 976 Hours	2012	Am Riedbach 512 m to Frohnschwenden 95 m x 56 m 4.864 m^2; 747-753 m.a.s.l., 6 m. uneven
3. Biomass powered power plant: Biogas Electricity+Heat	E318060187634S00000000000000001448 bzw. A7612757073744 Fuel type:gaseous. Fuel: Biogas (electricity on site). Distribution network operator: AllgäuNetz GmbH & Co. KG	Electrical output: 250 Kw 841.789 kWh (2021) 3.367 Hours	2001	Eufnach Diameter: 20 m
4. Biomass powered power plant: Biogas Electricity+Heat	E318060187499S00000000000000001695 bzw. A7169670226202 Fuel type:gaseous. Fuel: Biogas (electricity on site). Distribution network operator: AllgäuNetz GmbH & Co. KG	Electrical output: 1.335 Kw 4.040.701 kWh (2021) 3.027 Hours	2004	Eufnach Diameter: 30 m +25 m
5. Biomass powered power plant: Biogas Electricity+He	E318060187499002000000000020004427 Fuel type:gaseous. Fuel: Biogas (electricity on site). Distribution network operator: AllgäuNetz GmbH & Co. KG	Electrical output: 386 Kw 1.629.126 kWh (2021) 4.221 Hours	2007	Eufnach

[5] Website of the municipality of Wildpoldsried. https://www.wildpoldsried.de/erneuerbare-energien.html

at				
6. Biomass powered power plant: Biogas Electricity+Heat	E318060187499002000000000020008001 bzw. A9547474035196 Fuel type:gaseous. Fuel: Biogas (electricity on site). Distribution network operator: AllgäuNetz GmbH & Co. KG	Electrical output: 460 Kw 2.440.030 (2021) 5.304 Hours	2008	Am Riedbach
7. Biomass powered power plant: Biogas Electricity+Heat	E318060187499002000000000020013552 bzw. A2735771035170 Fuel type:gaseous. Fuel: Biogas (electricity on site). Distribution network operator: AllgäuNetz GmbH & Co. KG	Electrical output: 460 Kw 1.874.759 (2021) 4.076 Hours	2010	Wildpoldsried, Im Osch.
8. Biomass powered power plant: Biogas Electricity+Heat	E318060187499002000000000020008183 Fuel type:gaseous. Fuel: Biogas (electricity on site). Distribution network operator: AllgäuNetz GmbH & Co. KG	Electrical output: 250 Kw 1.560.213 (2021) 6.241 Hours	2008	Wildpoldsried, Am Hungersberg.
9. Biomass powered power plant: Biogas Electricity+Heat	E318060100000000051126110223000001 Fuel type:gaseous. Fuel: Biogas (electricity on site). Distribution network operator: AllgäuNetz GmbH & Co. KG	Electrical output: 100 Kw 590.760 (2021) 5.908 Hours	2020	Wildpoldsried, Kemptener Str.
10. Biomass powered power plant: Biogas Heat	E318060100000000051126110223000001 Fuel type:gaseous. Fuel: Woodpellets	Combustion heat output: 0,44 MW	2006	Wildpoldsried, Kemptener Str.
11. Hydroelectric power plant	Water Management Authority: WWA Kempten	Performance class: till x 499 kw		2 in Wildpoldsrieder stream, Dörfmühlstrasse and Wolkenberger Mühle
2.186.075 kWh/Km^2 each year		46.672.707 kWh	9.334 houses/ year	

Table 4. Quantitative descriptions of the infrastructures of renewable energy in Wildpoldsried municipality. Source: Own elaboration based on data by Energie Atlas Bayern and Bayern Atlas. It is considered that one house of three members consums 5.000 kWh per year.

Conclusions

Rural land presents rich diversity of situations where is intertwined residence, mobility, agriculture, recreative areas, biodiversity and open spaces for the production of renewable energy. The manner these layers overlap determines the way in which interactions are established between them varying degrees of compatibility and resulting synergies.

In order to mitigate the climate change, the necessary infrastructures that generate energy from wind, sun and biomass, have created during the last two decades a system that, together with the previously built hydroelectric power stations,feed into the electricity network part of the needed power to sustain the current way of life. To analyse the settled built complexes we can focus its interpretation applying four concepts: position, diversity, multifunctionality and management.

The position refers to the desirable location of the set of energy-producer elements. It introduces the aspect of efficiency, since each type of infrastructure meets certain requirements to optimise its productivity, as well as suitability, taking into account the proximity to the existing network through which the high voltage is transported. Therefore wind turbines are more profitable where the wind blows steadily and with enough force, photovoltaic panels are more advantageous in positions and orientations of greater daily sunshine and biogas power plants should be located where greater local biomass supply is guaranteed so as to reduce the need for crop supplemetes from maize fields. In the case of wind turbines, a certain distance to existing dwellings should also be considered in order to avoid possible disturbances due to wind noise in propellers and the effec of shadow flicker at certain times of the day.Their position has to be also compatibilized studying their perception, considering the characteristic features of each landscape and the vision of certain

elements of cultural heritage. With regard to photovoltaic panels, the first suitable location is on existing roofs as well as on disused gravel pits and dumps, avoiding as first option the consumption of fertile soils.
In relation with the idea of diversity it is contemplated the variability of the climate conditions that does not allow the permanet production of energy. Therefore it is advisable to implement varios types of infrastructures to ensure the generation of a certain amount of energy in atmospheric conditions of low wind or cloudy skies, as well as the availability of batteries to store energy that cannot be fed into the collapsed electricity network on sunny days.
With regard to multi-functionality, the layout of built elements in rural land should allow the exploitation of the productive soil on which the installation takes place. In this way, the presence of wind parks can be combined with the forest exploitation of the mass of trees below, cultivated fields at lower altitudes or meadows with livestock grazing nearby. It is also commendable to integrate recreational areas and trails for walking or cycling when it is possible. In the case of solar energy the tendence is to implement agrophotovoltaic facilities, with structures that release the soil to be cultivated and make possible the sharing of sunlight for crops and panels (panels over fruits to give shadows, vertical panels like walls, high panels in strips following the grooves of plantations, ...). The species to be grown must be compatible with the reduction of sun exposure, beeing rewarded with a mitigation of the stress caused by high temperatures and the attenuation of UV damage.
Finally, it is also worth to consider the management of those infrastructures sited on rural land. There is a certain right of the inhabitants of a region to share part of the benefit of an energy production facility that is located on the territory of their hamlet, village or municipality, even if the ownership of the plot does not belong to the community. In those localities where the management of such infrastructures is cooperated by the local government, the acceptance by the population of the introduction of that kind of infrastructures in the landscape, particularly as regards wind turbines, is greater, and these are generally energy installations that are improved and increased over the years. The result is that the produced energy is fed into the electricity network of the muncipality to be consumed by them, or that part of the sales profits is invested in projects that pass directly on the wellbeing of the inhabitans.
Summarizing all this, the production of renewable energy from wind, sun and biomass is necessary to mitigate climate change. However, the fragility of rural territories makes that the emplacement of these infrastructures on rural land must take into account the suitability of the location, the configuration of complex systems with diversity of typlogies and the overlapping of different funcions simultaneously on the plot. In addition, the local management of these facilities ensures their cohabitation with the community and the improvement of the daily living conditions.

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