Unidade de Economia de Recursos

COMO O CONSUMO DE ELETRICIDADE NA INDÚSTRIA ESTÁ DISTRIBUÍDO NO TERRITÓRIO EM PORTUGAL CONTINENTAL

Webinar / Palestra LNEG ONLINE
8 fevereiro 2023

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LNEG
Laboratório Nacional de Energia e Geologia, I. P.

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Os slides estão em inglês mas a apresentação é feita em Português

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LNEG Laboratório Nacional de Energia e Geologia, I. P.

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LNEG's RESOURCE ECONOMICS UNITS (UER)

The unit is **crosscutting the Energy and Geology areas** of LNEG.

Develops I&D&D activities and decision-support for both public policy-makers and the private sector on **energy and geology resource economics, towards carbon neutrality and sustainable resource exploitation and use**

UER applies techno-economic & social analytical approaches in the following I&D domains:

1

Sustainable energy systems (decarbonization, systems modelling, climate change impacts)

2

Resource use for energy production and consumption

3

Classification of geological deposits in a global economy

4

Economic and social impact of the energy transition

5

Circular economy, including design of products, services, systems and business models

6

Circular and sustainable public procurement

https://www.lneg.pt/unit/unidade-de-economia-de-recursos/

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Como parte do desafio comunitário de acelerar a transição energética do RepowerEU surgiu a necessidade de reflexão acerca das áreas propícias ao desenvolvimento de centros eletroprodutores de fonte renovável. Um dos fatores a ser levado em consideração é uma projeção da procura de eletricidade como um todo e nas diferentes regiões de cada Estado-Membro.

Neste webinar apresentamos os resultados de um estudo do LNEG para Portugal continental que combina informações públicas sobre a ocupação do território produzida pela Direção Geral do Território com informações do consumo setorial de eletricidade nos municípios produzida pela Direção Geral de Energia e Geologia.

Onde estão os maiores consumidores industriais de eletricidade atualmente? Quais poderiam ser as prováveis evoluções futuras destes consumos industriais espacializados de acordo com os cenários do Roteiro de Neutralidade Carbónica? Qual o papel que tecnologias como o solar e a eólica poderão ter na satisfação desta procura futura?

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Outline

I. Map of electricity consumption in industry in Portugal

II. Assessing how much industry power consumption could be supplied with “own” rooftop solar PV

III. Possibilities for deploying solar PV power plants (utility-scale) nearby current industrial areas

I. Map of electricity consumption in industry in Portugal

Methods | map current industry power consumption

Allocate each COS2018 "industry" polygon to corresponding municipality in mainland Portugal*

← DGT COS2018 (land occupation)
← DGT CAOPS (municipalities borders)

Calculate industry annual average power consumption per area (kWh/m^2) per municipality

← DGEG | kWh 2016 to 2021 (except 2020)
← DGT COS2018 | m^2 of municipal industry areas (excluded extractive industry)

×

Area in m^2 of each industry polygon (area) in COS2018

← DGT COS2018 | m^2 area for each industry polygon

Map of current annual average power consumption in each industry area in Portugal (GWh)

d·gTerritório

https://geo2.dgterritorio.gov.pt/cos/COS2018/COS2018v2-shp.zip

Direção-Geral de Energia e Geologia

https://www.dgeg.gov.pt/pt/estatistica/energia/eletricidade/consumo-por-municipio-e-setor-de-atividade/

* There are 6885 industry areas classified as such in COPS2018. When allocating them to municipalities using DGT CAOPS a total of 7178 areas are obtained. Of these, 13 industry areas (or polygons) are very small (totaling 0.04km^2) and located on the border of the municipalities as in CAOPS. For these 13 it was not possible to allocate a municipality and they were left out of this analysis.

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Where are current industry areas in Portugal?

According to COS2018 there are 7 165 industry areas in mainland Portugal located across 275 municipalities

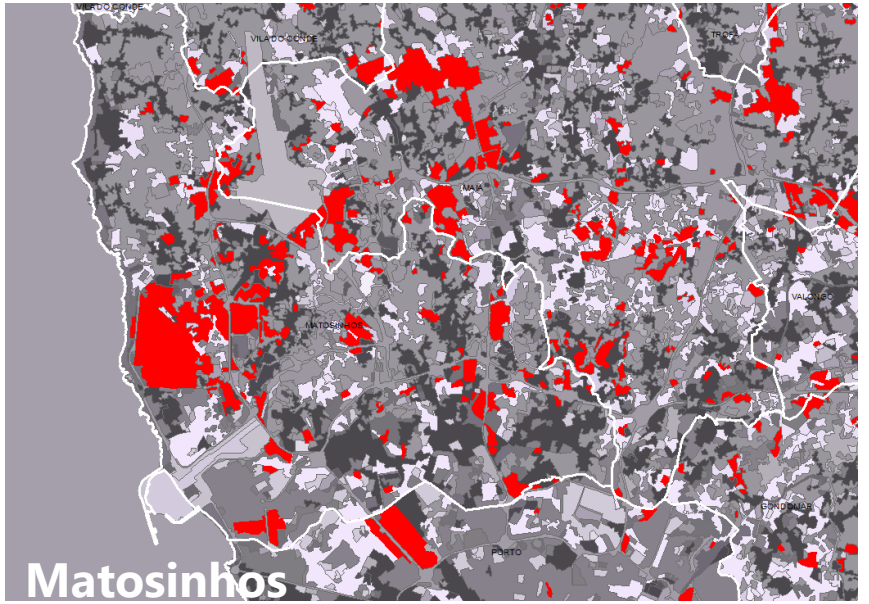
No industry areas only in 3 municipalities Castelo de Vide, Crato and Mesão Frio

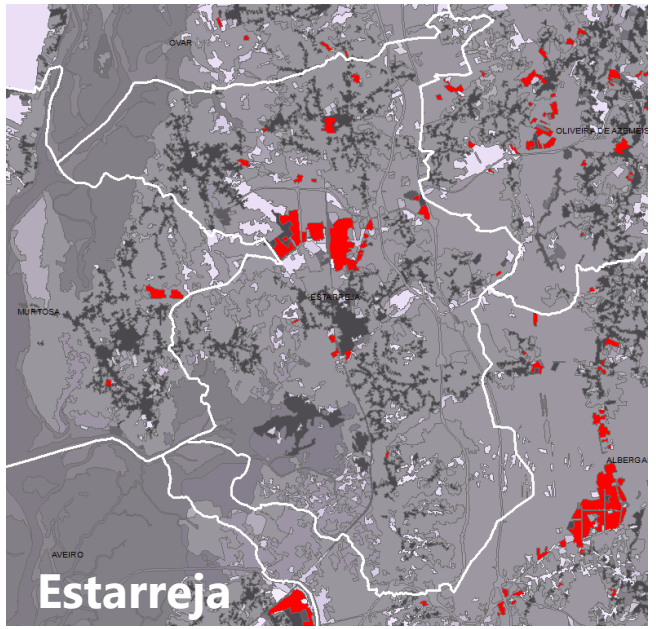
1 single industry area may have many industries there located

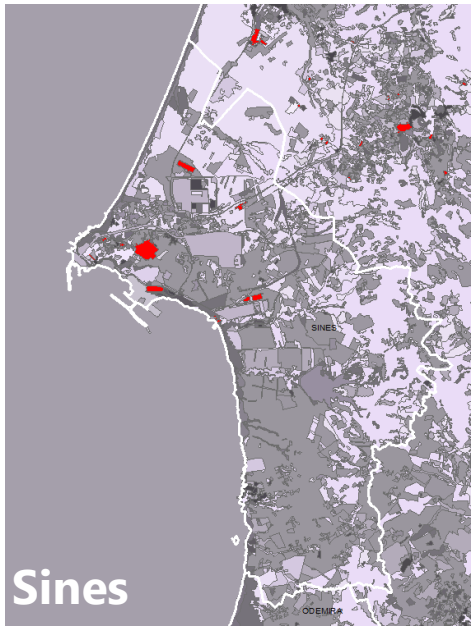
Carta de Uso e Ocupação do Solo (COS) para 2018 da Direção-Geral do Território (DGT)

d·gTerritório

https://www.dgterritorio.gov.pt/Carta-de-Uso-e-Ocupacao-do-Solo-para-2018?language=en







Industry areas

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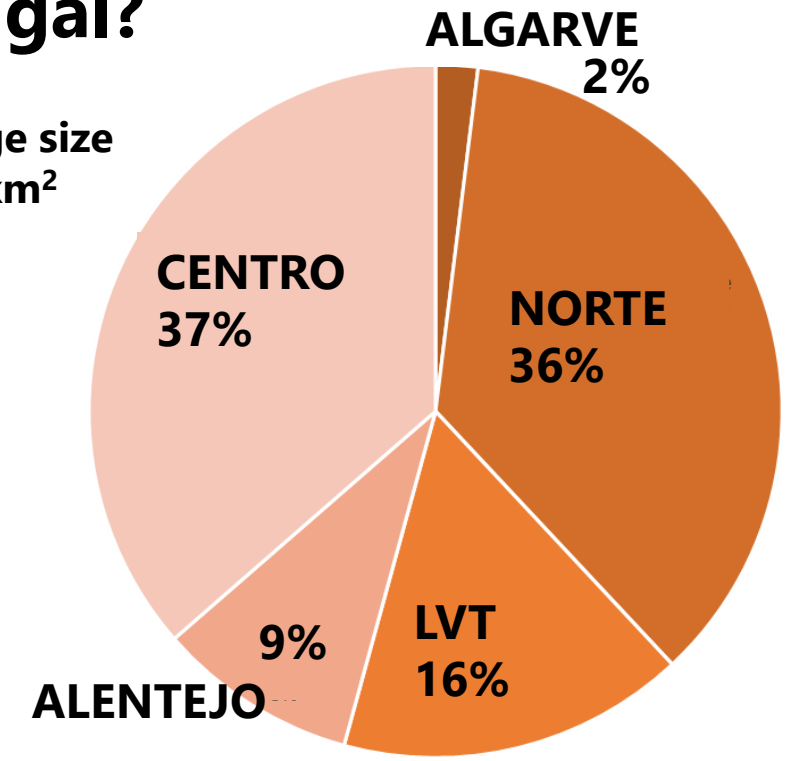
Example of satellite image of industry area in Seixal municipality

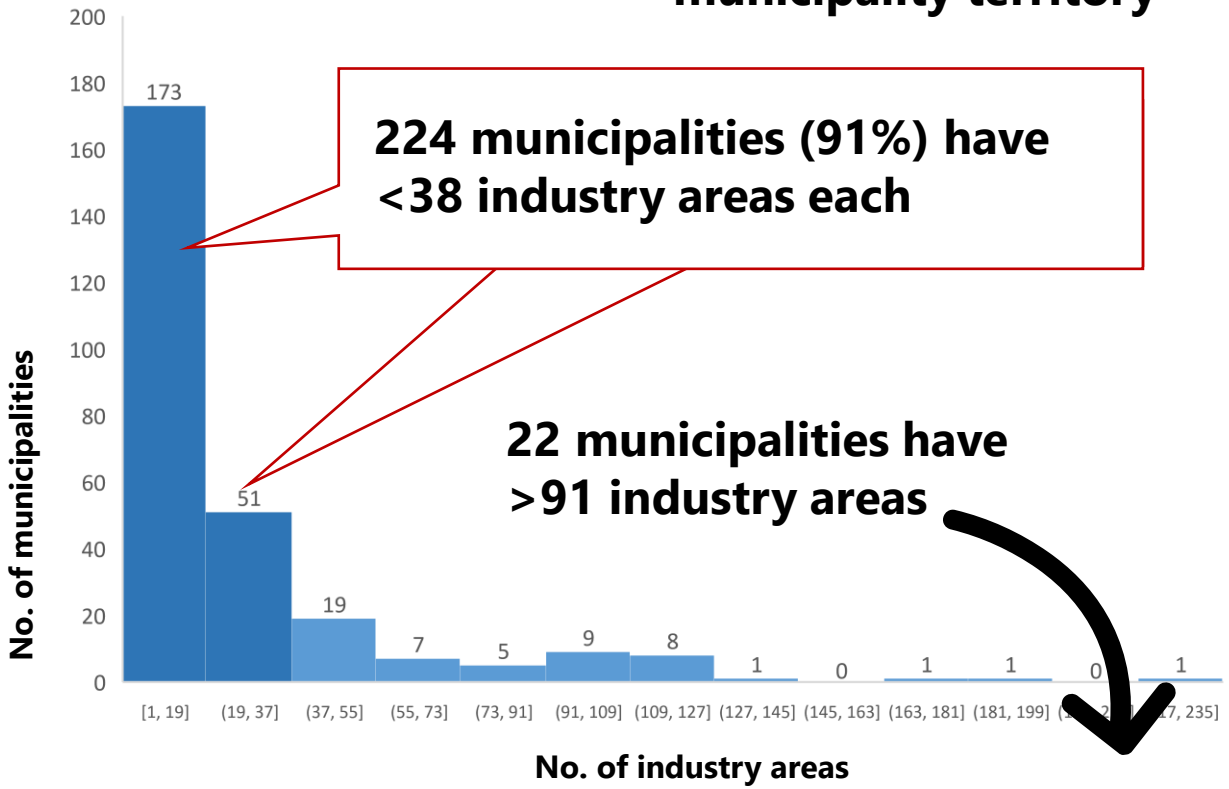
Where are current industry areas in Portugal?

Average size ~0.05km²



Region	Areas			% of municipality area		
	Max (km²)	Min (m²)	Average (km²)	Max	Min	Median
Centro	1.61	1.27	0.05	3%	0.02%	0.44%
LVT	1.77	1.11	0.06	6%	0.20%	2.5%
Norte	2.72	0.18	0.05	13%	0.004%	0.23%
Alentejo	2.08	6.48	0.06	2%	0.005%	0.09%
Algarve	0.47	371.12	0.04	1%	0.004%	0.17%
Total	2.72	0.18	0.05	13%	0.004%	

Occupation of ~0.02% to 13% of municipality territory



22 municipalities with more than 91 industry areas (highest to lower no.)

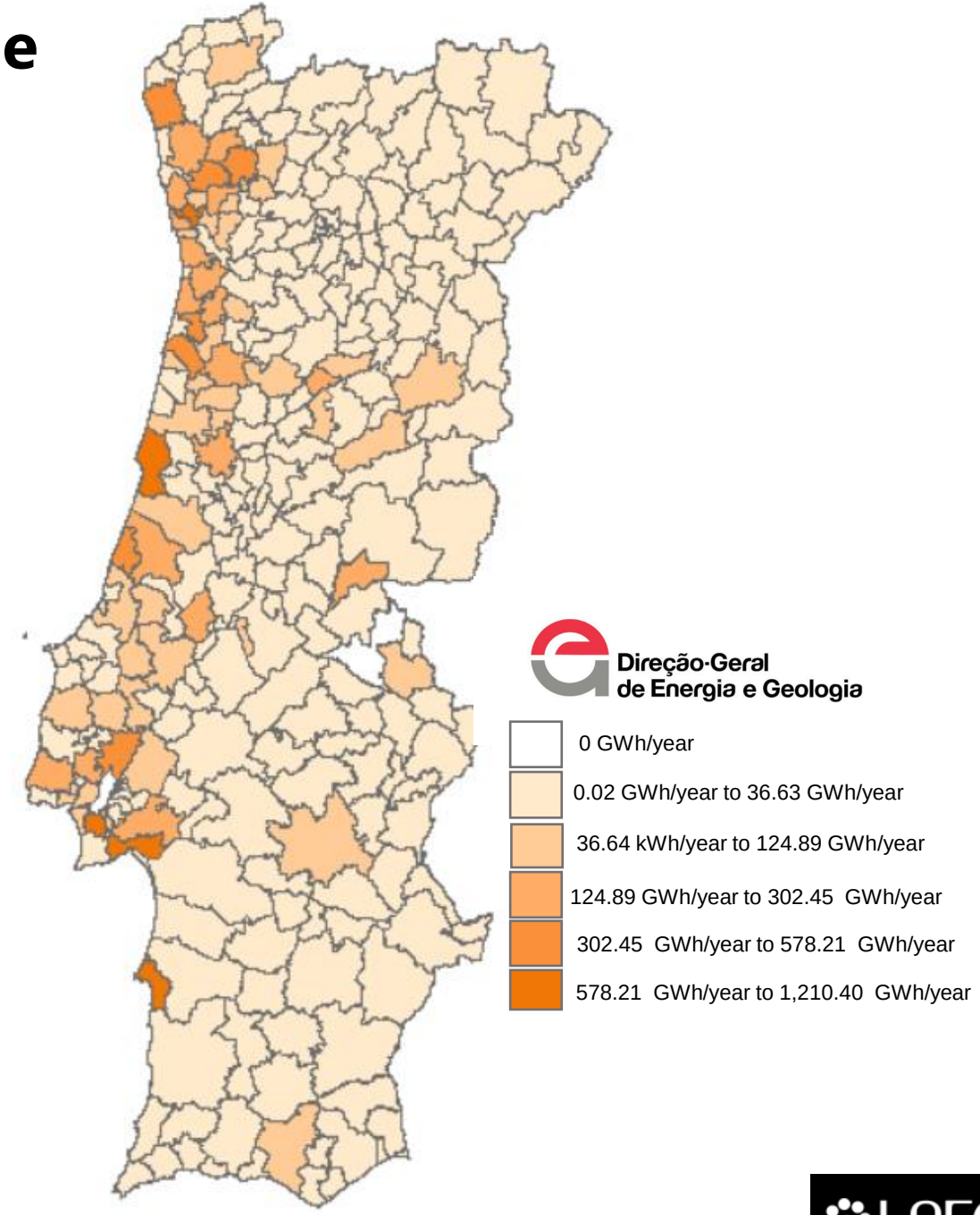
1. Leiria
2. Sintra
3. Loures
4. Guimarães
5. Alcobaça
6. Vila Nova de Famalicão
7. Mafra
8. Palmela
9. Vila Nova de Gaia
10. Maia
11. Barcelos
12. Santa Maria da Feira
13. Ourém
14. Santo Tirso
15. Vila do Conde
16. Paredes
17. Oliveira de Azeméis
18. Braga
19. Torres Vedras
20. Santarém
21. Montijo
22. Coimbra

What is current industry annual average power consumption per municipality?

0.02 GWh to 1 210.40 GWh
median 7.70 GWh
Municipal industry power consumption
(annual average 2016, 2017, 2018, 2019, 2021)

Municipal power consumption hotspots in Portugal

Municipality	Annual average consumption (GWh)
Figueira da Foz	1,210.40
Sines	1,020.26
Setúbal	964.56
Maia	827.22
Seixal	747.05
Estarreja	578.22
Vila Nova de Famalicão	519.18
Aveiro	468.66
MARINHA GRANDE	418.80
VILA FRANCA DE XIRA	416.91
GUIMARÃES	349.87
VIANA DO CASTELO	349.59
SANTA MARIA DA FEIRA	302.46
MATOSINHOS	300.75
VILA NOVA DE GAIA	286.59
LEIRIA	271.94
SANTO TIRSO	258.28
PALMELA	252.52
VILA VELHA DE RÓDÃO	234.93
OLIVEIRA DE AZEMÉIS	214.69



Results: Municipal territorial power intensity index of industry (kWh/m²)

industry annual average power consumption per municipal industry area

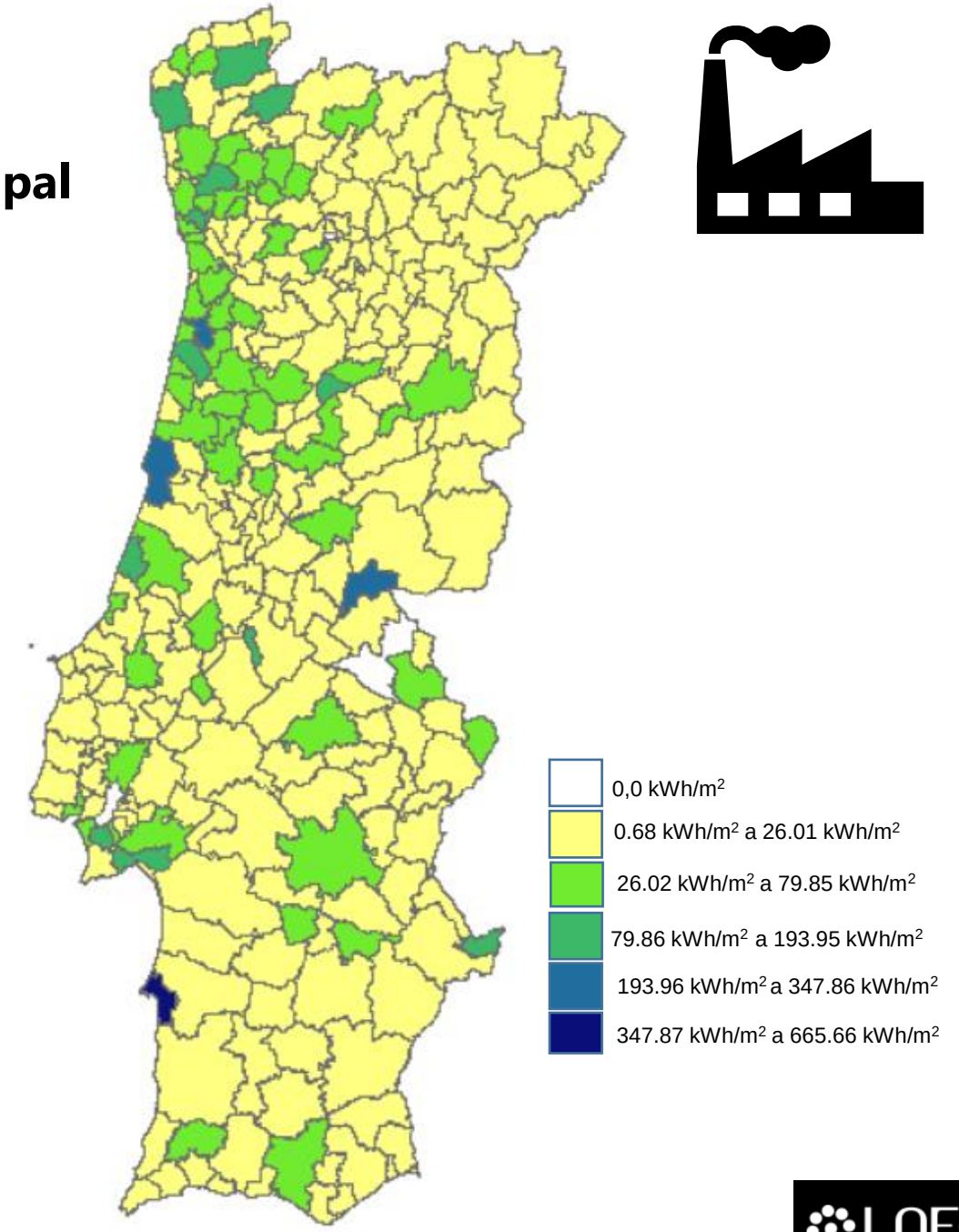
Municipal territorial power intensity of industry varies between

0.68 kWh/m² in Pampilhosa da Serra

665.66 kWh/m² in Sines

median is 13.66 kWh/m²

197 municipalities (72% of mainland Portugal municipalities) estimated to have a municipal territorial power intensity of industry between 0.68 to 26 kWh/m² (the yellow municipalities in the map)



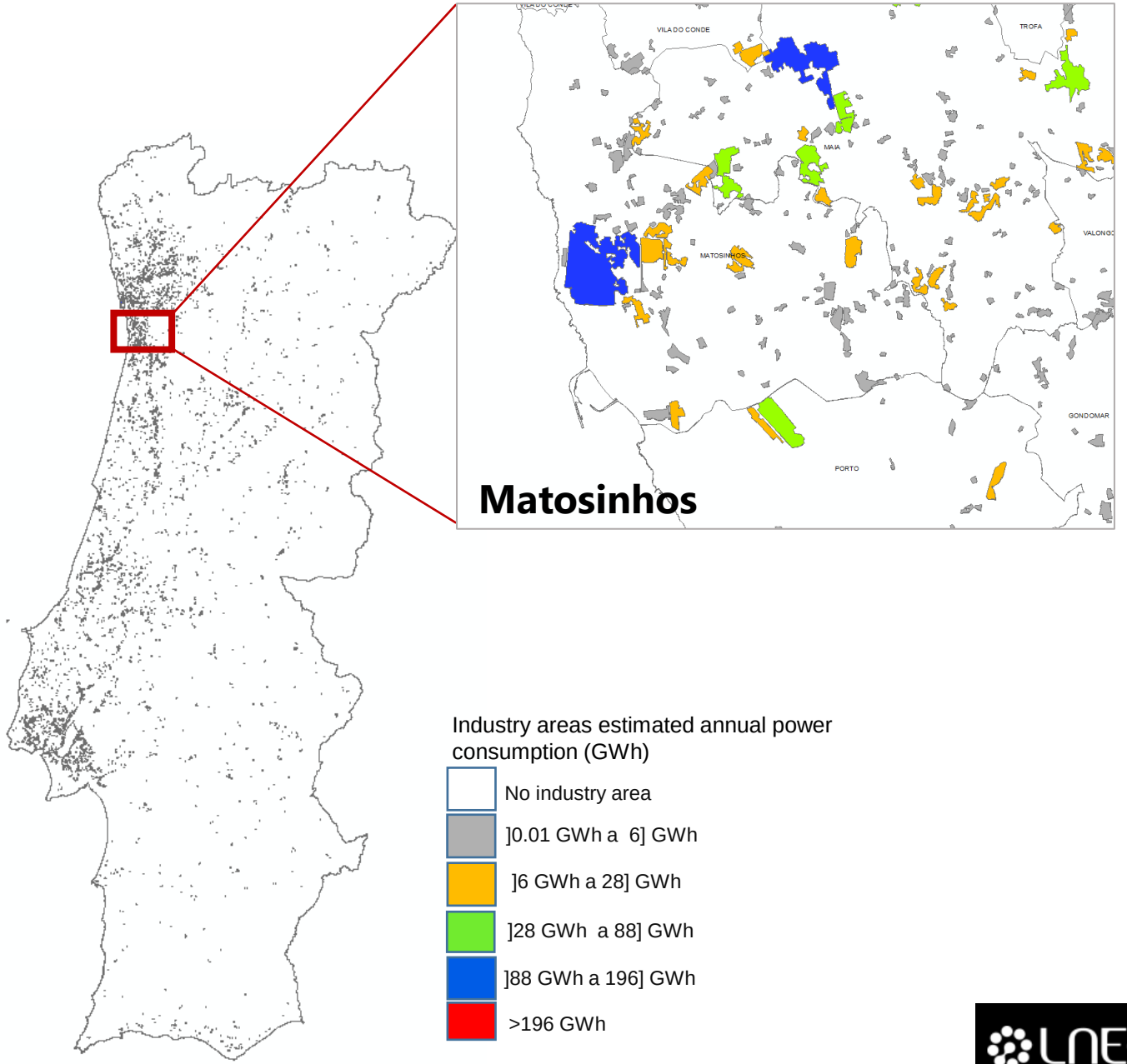
Results: Map of current industry areas power consumption (annual average)

Annual estimated industry areas power consumption median is 0.5 GWh
maximum is 458.42 GWh in Sines

Most industry areas are <0.75 km² and are estimated to consume <= 6 GWh/year
These occupy most of total estimated industry area (240.38 km² of 373.10 km² or 64%)

Annual power consumption (GWh)	No. industry areas	Area (km²)			
		Min*	Max	Average	Total
<=6	6 707	0.00001*	0.75	0.03	240.38
6 to 28	387	0.02	2.08	0.24	90.75
28 to 88	54	0.04	1.61	0.46	26.01
88 to 196	12	0.20	2.72	0.87	13.01
> 196	5	0.69	1.47	0.99	2.96
Total	7 165				373.10

*Note that 124 resulting industry areas are probably unrealistically small (below 1000m²) – these will be removed at a later stage.

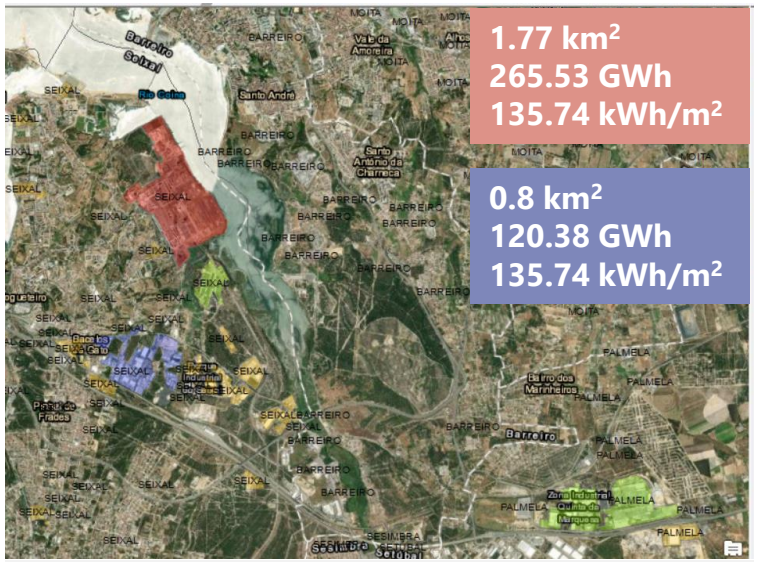


Results: Hotspots of current annual average industry power consumption

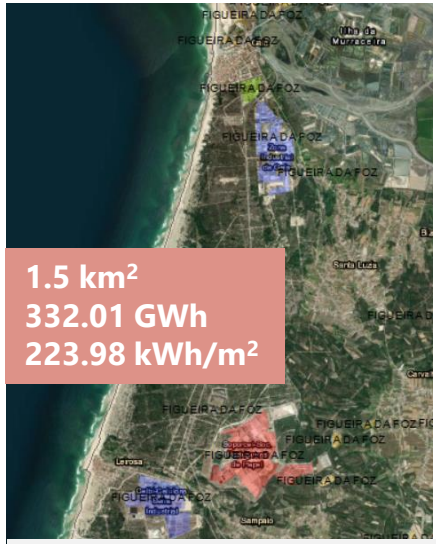
16 industry areas with highest estimated anual power consumption in mainland Portugal

Municipality	Area (km^2)	Annual power consumption (GWh)	Territorial power consumption index (kWh/m^2)	Name of industry area obtained via satellite image (and example of industry plant)
Seixal	0.80	120.38	135.74	Zona Industrial Casal do Marco (S. N. L. II)
	1.77	265.53		(Megasa)
Setúbal	1.38	219.16	166.64	(The Navigator Company)
	0.57	90.93		BlueBiz Global Parques (Lauak)
Sines	0.20	132.58	665.66	ZILS (REN Atlântico, Terminal de GNL)
	0.69	458.42		Zona de Indústria Ligeira 2 (Fripex)
	0.22	148.38		ZILS (Enerfuel)
Estarreja	0.80	212.42	282.33	Parque Empresarial da Quimiparque (Bondalti)
Figueira da Foz	0.87	192.82	223.98	(Celbi)
	1.50	332.01		(The Navigator Company)
	0.84	185.15		Zona Industrial da Gala (United Resins)
Maia	1.35	159.13	109.51	Zona Industrial I (WEGeuro)
Matosinhos	2.72	99.27	40.08	(Refinaria Petrogal)
Viana do Castelo	1.22	141.75	111.79	Zona Industrial do Neiva (Suavecel)
Nelas	1.00	91.06	87.69	Zona Industrial 1 (Luso Finsa)
Marinha Grande	0.72	96.52	142.61	Zona Industrial do Casal da Lebre (Crisal)

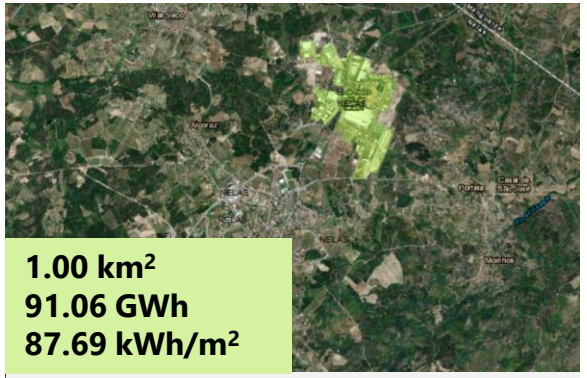
Results: Hotspots of current annual average industry power consumption



ZI Seixal: Megasa & SN Longos

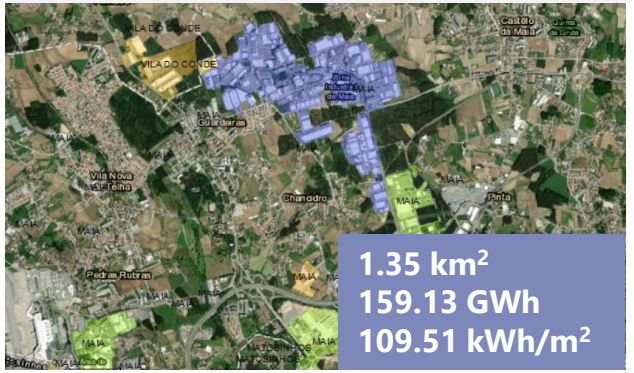


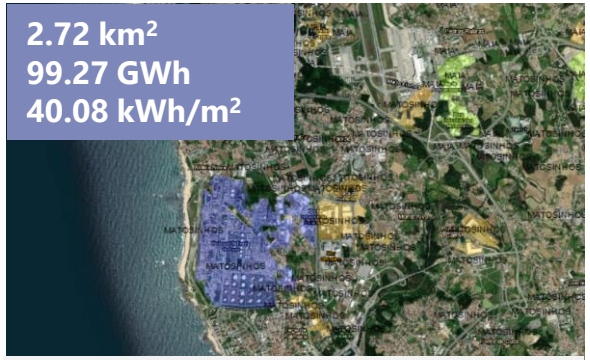
ZI: Figueira da Foz (Navigator)



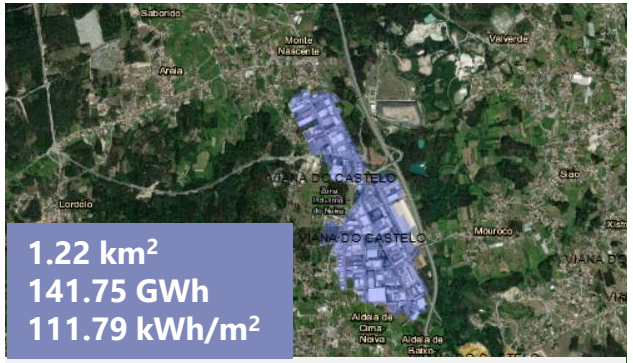
ZI 1: Nelas

ZI I: Maia





ZI: Matosinhos



ZI Neiva: Viana do Castelo

Industry areas estimated annual power consumption (GWh)

- No industry area
-]0.01 GWh a 6] GWh
-]6 GWh a 28] GWh
-]28 GWh a 88] GWh
-]88 GWh a 196] GWh
- >196 GWh

ZI: Setúbal

ZI = Industry area

Areas obtained by merging COS2018 with CAOPS and thus are rough estimate and slightly different from "official" industry areas

II. Assessing how much industry power consumption could be supplied with “own” rooftop solar PV

Methods: Could “own” rooftop PV supply part of industry electricity consumption?

In each industry area

Area available for rooftop PV

PV panel area corresponds to 1% of the industrial area

Assumed % of total industry area that could be used

Panel efficiency

Assumed 0.2 kWp/m² of PV panel

PV Power output (kWh/kWp)
[for optimal inclination and south orientation]

Annual average from Global Solar Atlas
(“Long term average of PVout, 1994-2018”)

Rooftop PV Electricity generated in the industry area in one average year (GWh)

Annual average power consumption (GWh)

Share of power consumption satisfied with “own” rooftop PV (%)

Results: Could “own” rooftop PV supply part of industry power consumption?

Total across all industry areas

746 MW of rooftop PV deployed
1 177 GWh power generated in average year

Direção-Geral de Energia e Geologia

Statistics for Portugal in 2022: Solar PV

3.14 TWh
(28.9 TWh from RES)

2.59 GW
1.57 GW “conventional” + 0.79 GW UPAC + 0.17 GW mini/micro

Dimension Rooftop PV systems

0.0045* to 5.44 MW
(median size of 42.5 kW)

*Note that some of the estimated solar PV plants are probably unrealistically small and will be removed at a second stage

228 industry areas can generate more than enough power with rooftop PV

These the areas with lowest consumption (not necessarily the ones with largest area or located where solar resources are higher)

Where? Next slide

The 7 165 industry areas are translated to 7 301 areas considering the different PV output (some areas are located in different solar PV resource)

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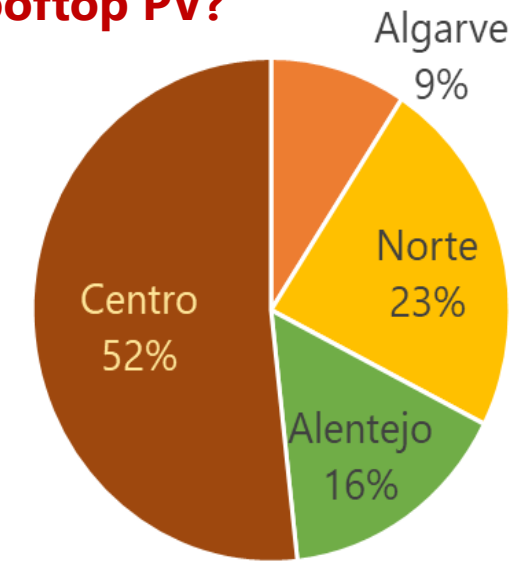
RESULTS: How the % of annual consumption satisfied with rooftop PV varies across mainland Portugal

Rooftop PV panel area equal to 1% of each industry area

% of annual consumption the can supplied with own rooftop PV	No. industry areas	Regional distribution (NUTs II)				
		Algarve	Norte	Lisboa e Vale do Tejo	Alentejo	Centro
<=25%	5 414	29	2 195	865	345	1 980
26% to 50%	1 195	23	310	227	149	486
51% to 75%	309	30	40	88	122	29
75% to 100%	155	45	20	0	39	51
>100%	228	21	53	0	36	118
Number of industry areas						
Total	7 301	148	2 618	1 180	691	2 664

Where are the 228 "more than self-sufficient" industry areas with rooftop PV?



RESULTS: What if rooftop PV panel area >1% of industry area?

Rooftop PV panel area equal to 1% of each industry area

% of annual consumption the can supplied with own rooftop PV	No. industry areas	Regional distribution (NUTs II)				
		Algarve	Norte	Lisboa e Vale do Tejo	Alentejo	Centro
<=25%	5 414	29	2 195	865	345	1 980
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75% to 100%	155	45	20	0	39	51
>100%	228	21	53	0	36	118
Number of industry areas						
Total	7 301	148	2 618	1 180	691	2 664

2% of each industry

% of annual consumption the can supplied with own rooftop PV	No. industry areas	Regional distribution (NUTs II)				
		Algarve	Norte	Lisboa e Vale do Tejo	Alentejo	Centro
<=25%	3 440	22	1 641	432	198	1 147
26% to 50%	1 974	7	554	433	147	833
51% to 75%	645	0	196	59	138	252
75% to 100%	550	23	114	168	11	234
>100%	692	96	113	88	197	198
Number of industry areas						
Total	7 301	148	2 618	1 180	691	2 664

5% of each industry area

% of annual consuption the can supplied with own rooftop PV	No. industry areas	Regional distribution (NUTs II)				
		Algarve	Norte	Lisboa e Vale do Tejo	Alentejo	Centro
<=25%	814	0	422	137	17	238
26% to 50%	1 932	22	1 156	240	57	457
51% to 75%	1 157	0	137	123	130	767
75% to 100%	832	0	362	170	35	265
>100%	2 566	126	541	510	452	937
Number of industry areas						
Total	7 301	148	2 618	1 180	691	2 664

- In a scenario of 5% of occupation, those more than auto-sufficient areas are greater than a third of the total areas
- In the Norte region, even in 2% or 5% alternatives, most areas have a share of supplied consumption lower than 50%

III. Possibilities for deploying solar PV power plants (utility-scale) nearby current industrial areas

What if we think about ground mounted PV instead of rooftop?

If we do not install PV panels **within** the industrial areas, but **nearby**

Less Sensitive areas for deployment of Renewable solar and wind (here)

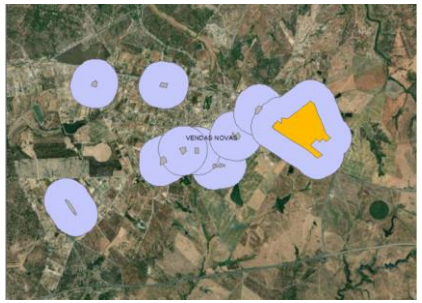
Methods

For each industry area

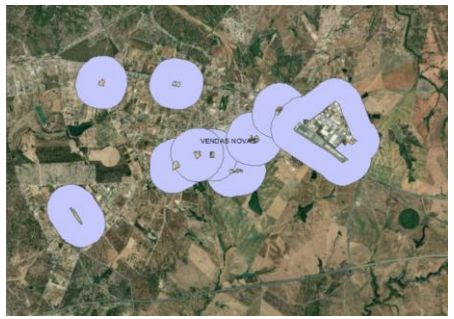
Industry Area

7301 industry areas

Draw a linear buffer of 500m



Exclude the industrial area



Combine the surrounding area with less sensitive areas

Find the surrounding area with less sensitive areas

27014 areas of 3337 industrial areas

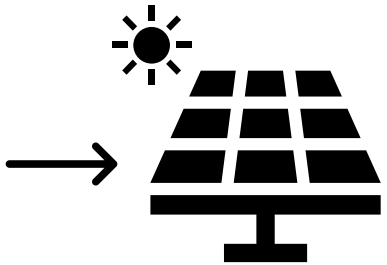
What if we think about ground mounted PV instead of rooftop?

If we do not install PV panels **within** the industrial areas but **nearby**

Methods
For each industry area

Find the surrounding area with less sensitive areas

Land use per MW



Assumed 0.05 kWp/m² or 2 ha/MW
[considers PV panel area plus additional land needed for panel distancing and equipment]

PV Power output (kWh/kWp)
[for optimal inclination and south orientation]

Annual average from Global Solar Atlas
("Long term average of PVout, 1994-2018")

Ground-mounted PV Electricity generated around the industry area in one average year (GWh)

÷

Annual average power consumption (GWh)

=

Share of power consumption satisfied with nearby PV (%)

Results: What if we think about ground mounted PV instead rooftop?

1 795.75 km² of potentially available area

i.e. located within 500m distance of current industry areas and have lower environmental & heritage sensitivity

corresponds roughly to ~86.92 GW of solar PV ground-mounted that potentially could be deployed

and 135.5 TWh that can be generated

Region	Area (km²)	Capacity (GW)	Generation (GWh)
Algarve	9.00	0.45	766.57
Norte	677.06	33.85	51,454.54
Alentejo	129.28	6.46	10,653.28
LVT	178.02	8.90	14,508.97
Centro	744.99	37.25	58,092.71
Total	**1,738.35**	**86.92**	**135,476.07**

Direção-Geral de Energia e Geologia

Statistics for Portugal in 2022: Solar PV

3.14 TWh
(28.9 TWh from RES)

2.59 GW
1.57 GW "conventional" + 0.79 GW UPAC + 0.17 GW mini/micro

RNC2050 Carbon Neutrality Roadmap

14.4 GW 2050 solar PV

PNEC 2030 PLANO NACIONAL ENERGIA E CLIMA

2 GW rooftop PV
7 GW ground PV

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LIMITATIONS – this is a preliminary study

- Very large **uncertainty on estimated annual power** consumption
- Some resulting industry areas are **unreasonable small** and should be removed from calculations
- In some industry areas even a PV panel area of 1**% of the industrial area may be unfeasible**
- Power generation estimates consider **optimal inclination and south facing panels** – shading effects not considered
- Not possible to **discount all existing rooftop and ground mounted PV** within industry areas
- Industry areas can also have **ground mounted PV within its "borders"** and not necessarily in nearby areas
- Assumes that **all generated solar power can be stored and used locally** - did not consider seasonal nor intraday variation of solar PV outputs nor of power demand
- Did not consider **hybrid solutions** combining rooftop and ground mounted solar PV (nor hybridization with wind power, for example)
- (…)

Next steps

- Evolution scenarios for future map including planned industry areas
- Removal of too small industry areas and too small solar PV plants
- Correction with already existing solar PV plants within / nearby industry areas
- …

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