



*Greening Energy  
Market and Finance*

Project website: <http://grenfin.eu>

# Case Study on Renewable Energy Communities

Gonalo de Moura Elias (Ing.)

June 7<sup>th</sup>, 2021



With the support of the  
Erasmus+ Programme  
of the European Union



# Renewable Energy Communities



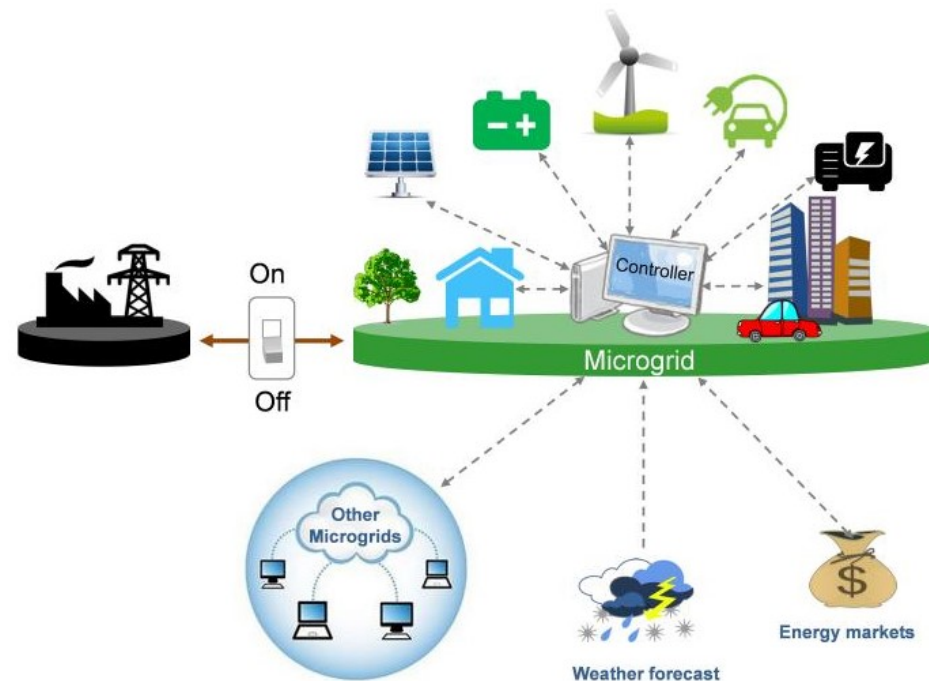
Local Energy Communities have been fostered for some decades now (District Heating, etc.).



Enterprises typically managed by a local Public authority, a citizens-group or NGO, often in partnership with small and medium enterprises and energy utilities.



RECs add the benefit of Green Energy sourcing.



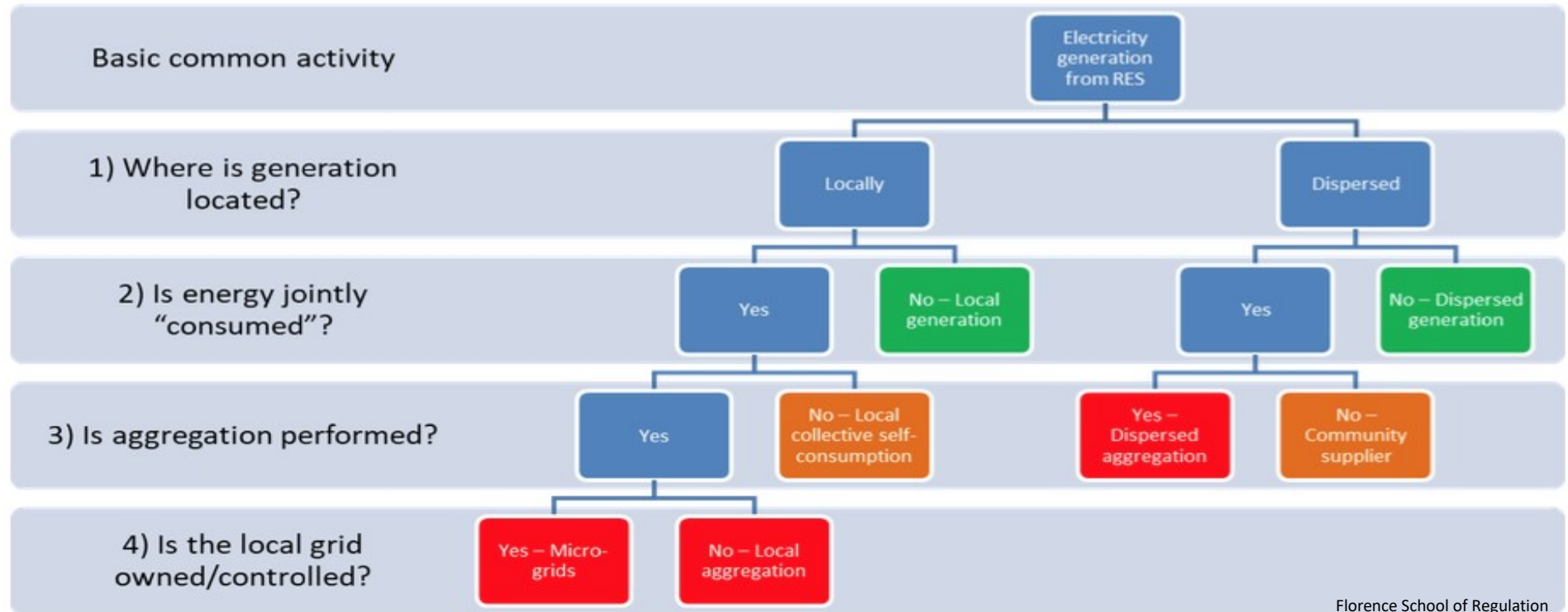
Copyright Berkeley Lab



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Possibilities



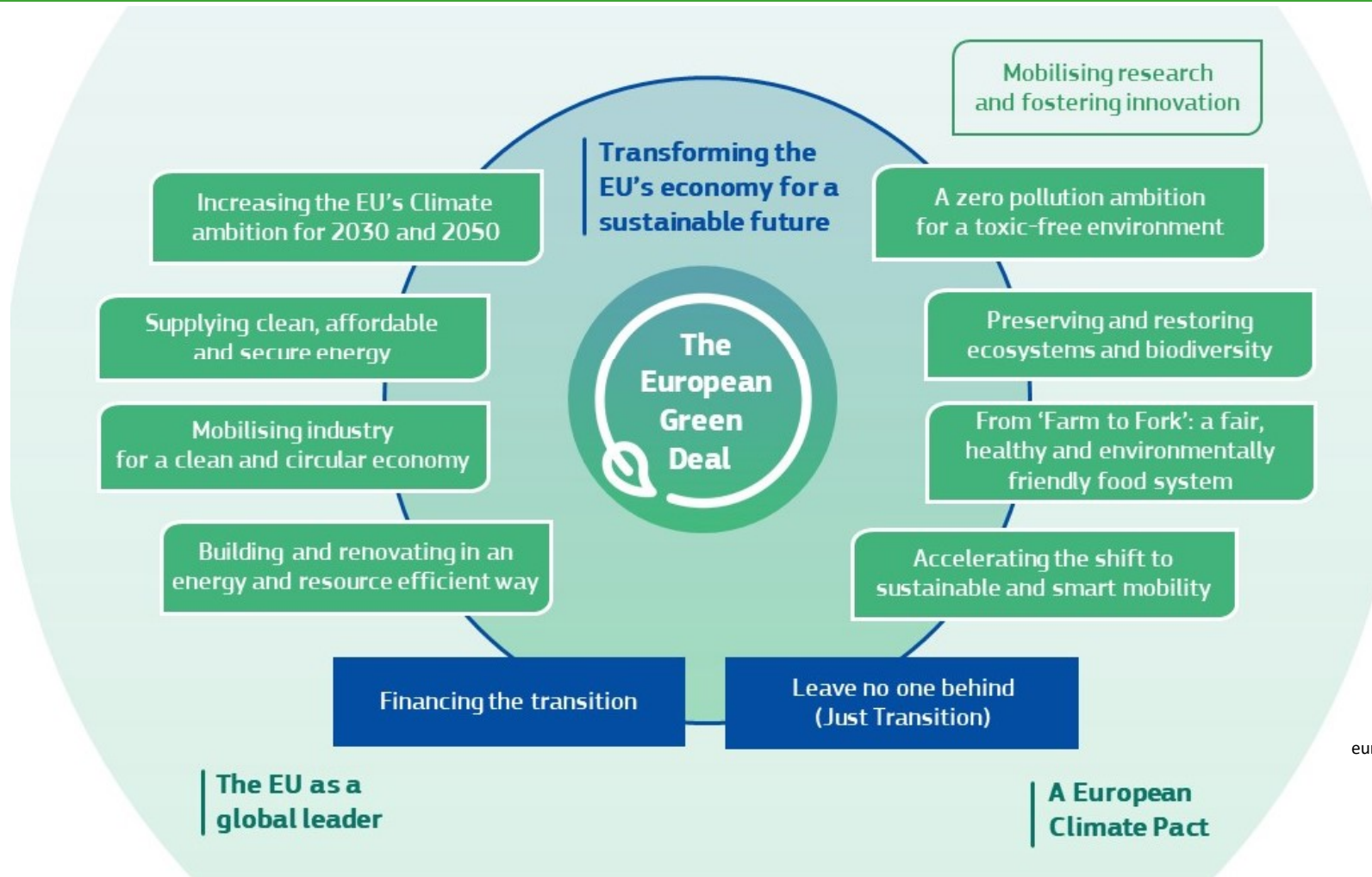
Clean Energy Package (2019, still being adopted and translated at national level) aims to stimulate Microgrids, where the produced energy is locally consumed



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Context



[eur-lex.europa.eu](http://eur-lex.europa.eu)



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Advantages



Energy system's improved efficiency, with fewer overall losses and waste



Empowerment and accountability, greater transparency and flow control



Green Energy sourcing and fewer GHG emissions from fewer transformation steps



Local employment and circular economy



With the support of the  
Erasmus+ Programme  
of the European Union

## Slajd 5

---

**GE1**

Gonalo Elias; 2021-05-28



# REC Opportunities



REC's are a growing phenomenon which involves a range of possible activities around renewable energy:

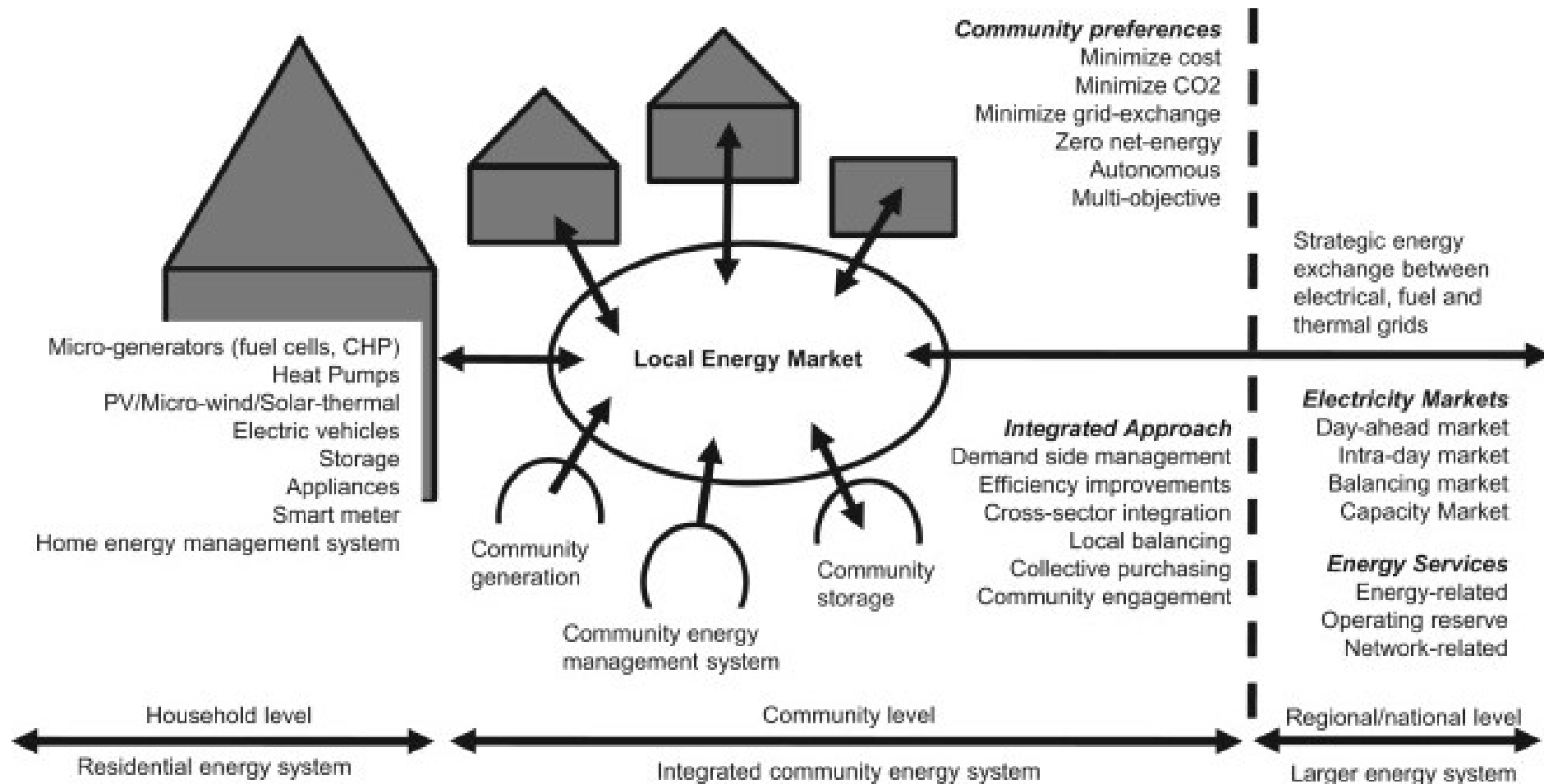
- Production;
- Supply;
- Storage;
- Distribution;
- Sharing;
- Aggregating;
- Consumption.



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Structure: Context



Koirala et al., 2016

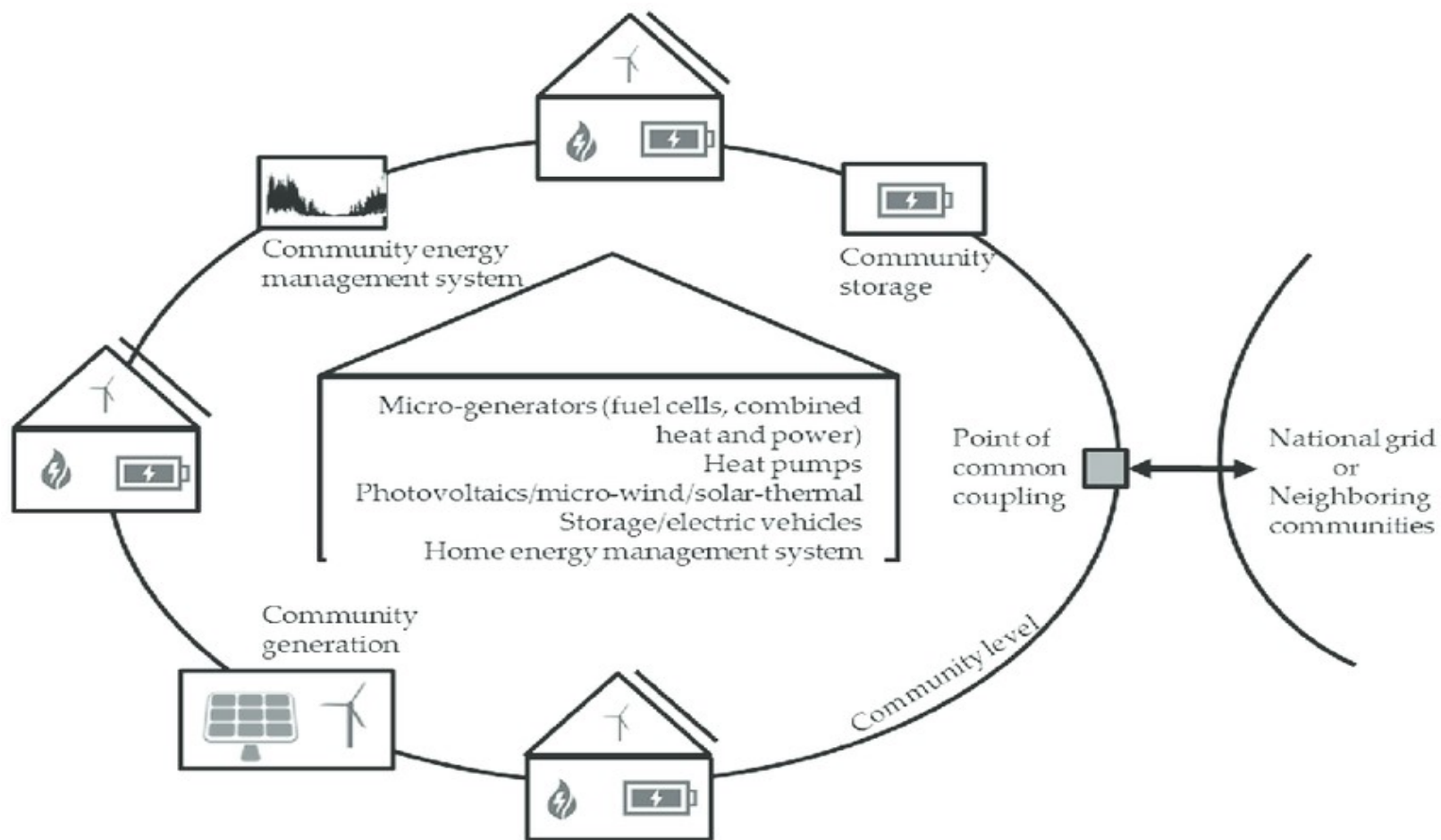


With the support of the  
Erasmus+ Programme  
of the European Union





# REC Structure: Functions



Koirala et al., 2016



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Structure: Agents



Consumers: typically, many low-level units with little or no production capacity



Prosumers: Existing middle-scale units with a history of consumption and with existing or eventual production capacity based on existing infrastructure



Public Authorities: Existing consumption and eventual production capacity based on existing infrastructure



Private Equity investors, Utilities, Consultants

**Question: Who is the most important Agent?**



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Structure: Drives



Consumers: Cheaper energy, lower carbon footprint



Prosumers: Cheaper energy, lower carbon footprint, sale of the energy surplus



Public Authorities: Cheaper energy, lower carbon footprint, reputation



Private Equity investors, Utilities, Consultants: ROI, reputation



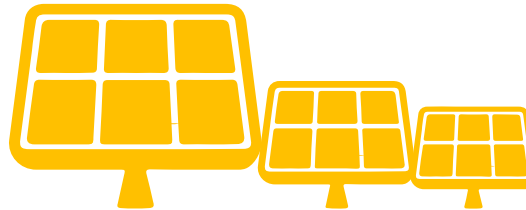
With the support of the  
Erasmus+ Programme  
of the European Union



# Prosumer

Person or group directly involved with the production of a good  
(Toffler, 1980 - *The Third Wave*)

Adapted to



Substantial gap between:

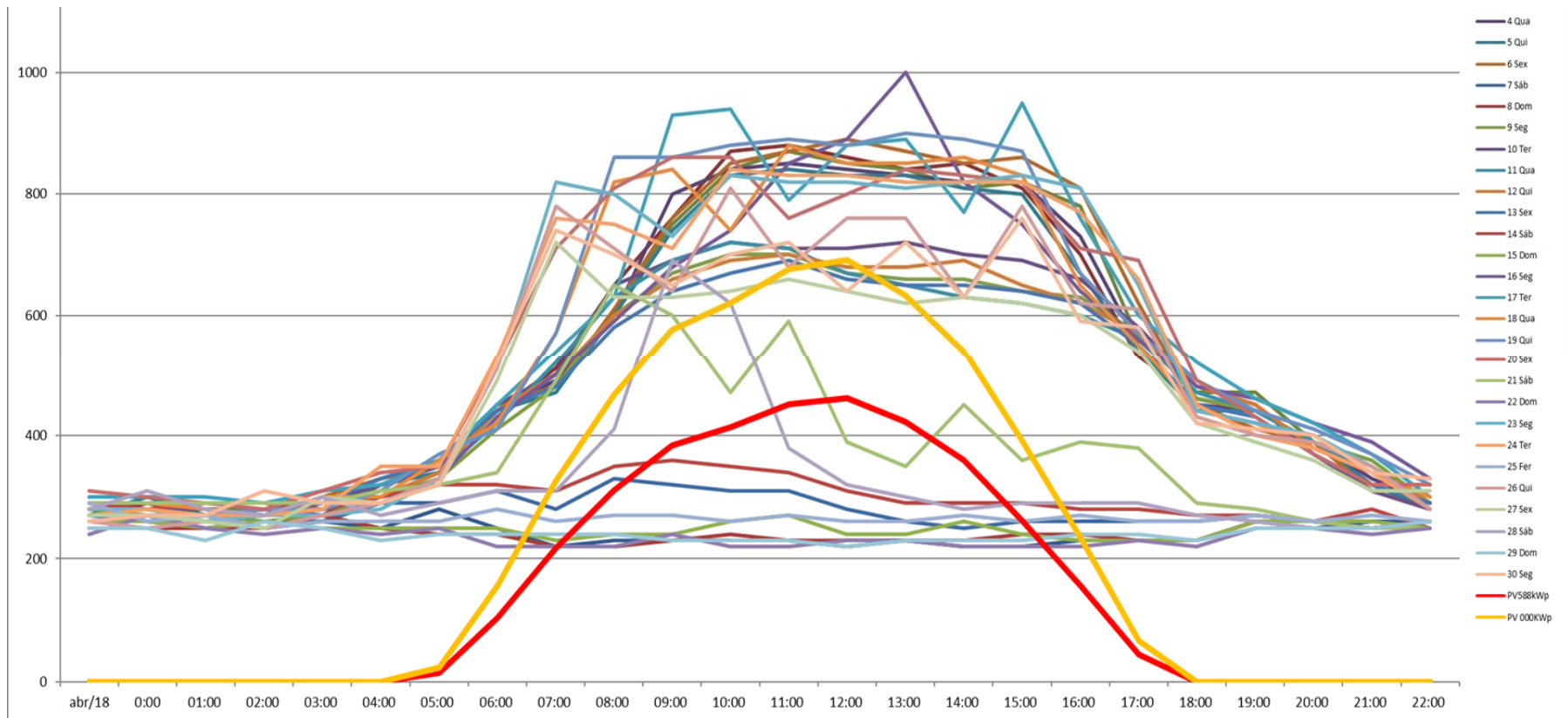
- the high energy price the prosumer pays
- the low price of the energy surplus the prosumer sells (the energy the plant is generating in excess to the unit's consumption)



With the support of the  
Erasmus+ Programme  
of the European Union



# Prosumer



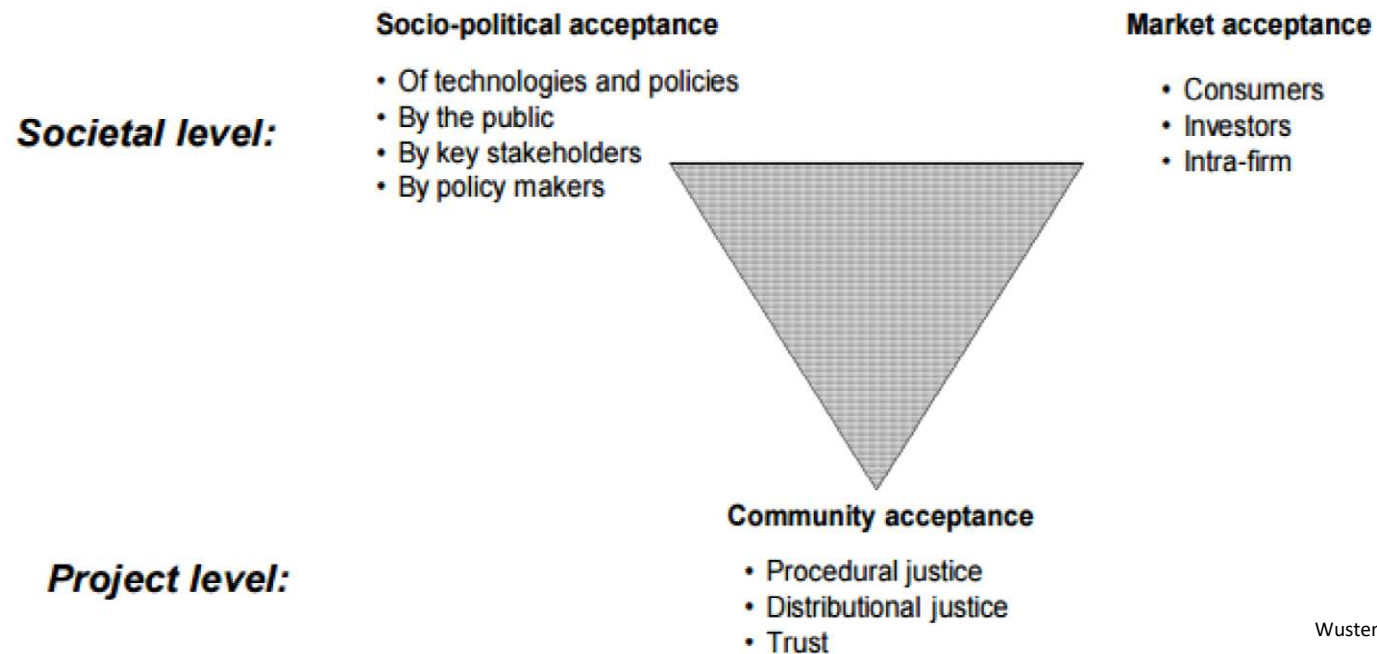
Prosumer's baseload diagram and two different sizes of PV Plants



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Design



Input and acceptance must come from all agents at all levels

In Portugal, 1 MW limit for each (geographically continuous) REC



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Design



New production must be (geographically) near consumption sites



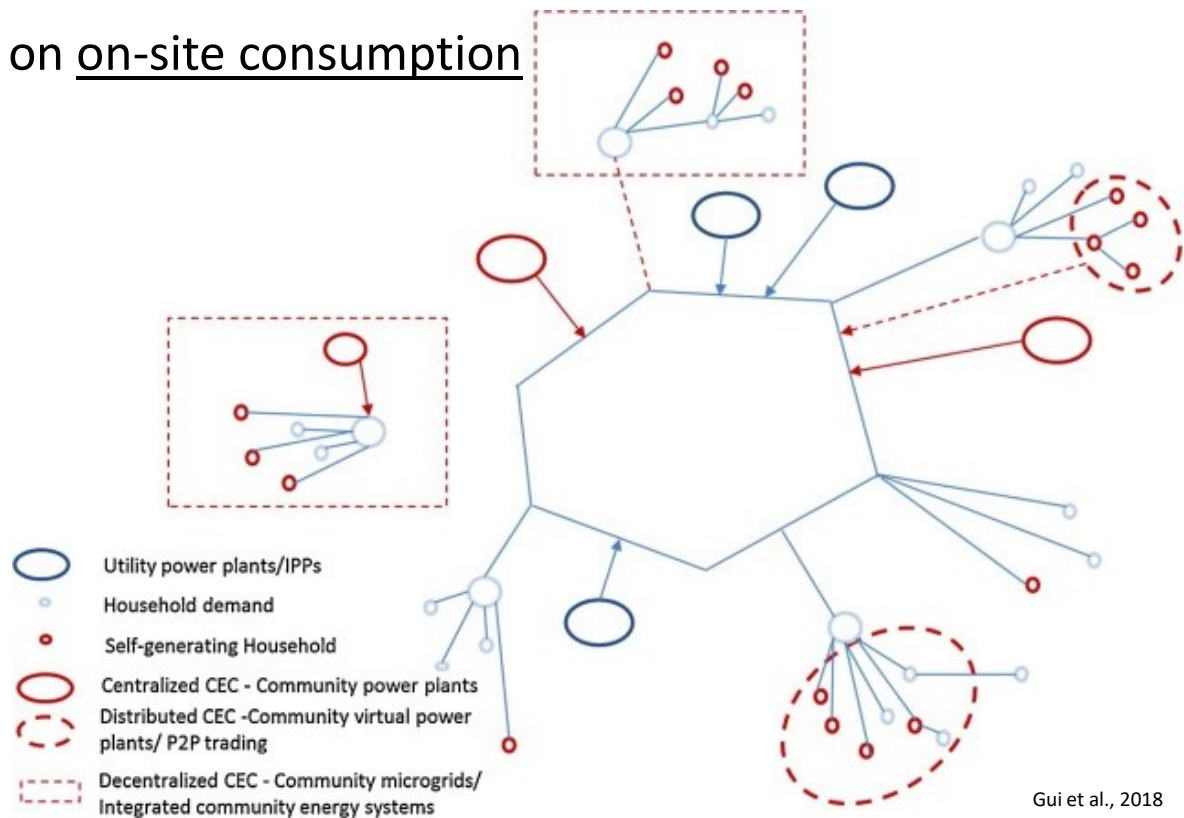
Prosumers' sizing: focus on on-site consumption



Public Authorities' infrastructures can be highly valued



Several techs can be used but solar PV is currently the most viable



Gui et al., 2018



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Design – Case Study in Portugal



Municipality wishes to take advantage of several infrastructures and propose a REC to the community



Municipality manages six buildings with considerable consumptions and available rooftops for PV plants



Some buildings located in densely populated areas and near private and public large consumers



Municipality also manages seventeen schools with smaller consumptions with available rooftops for PV plants scattered throughout the territory



With the support of the  
Erasmus+ Programme  
of the European Union





# REC Implementation Design – Case Study in Portugal



With the support of the  
Erasmus+ Programme  
of the European Union





# REC Implementation Design – Case Study in Portugal



Schools' size, and often considerable distance to other consumption possibilities, limit REC implementation on rural areas with smaller urban aggregates



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Design



New production must be (geographically) near consumption sites



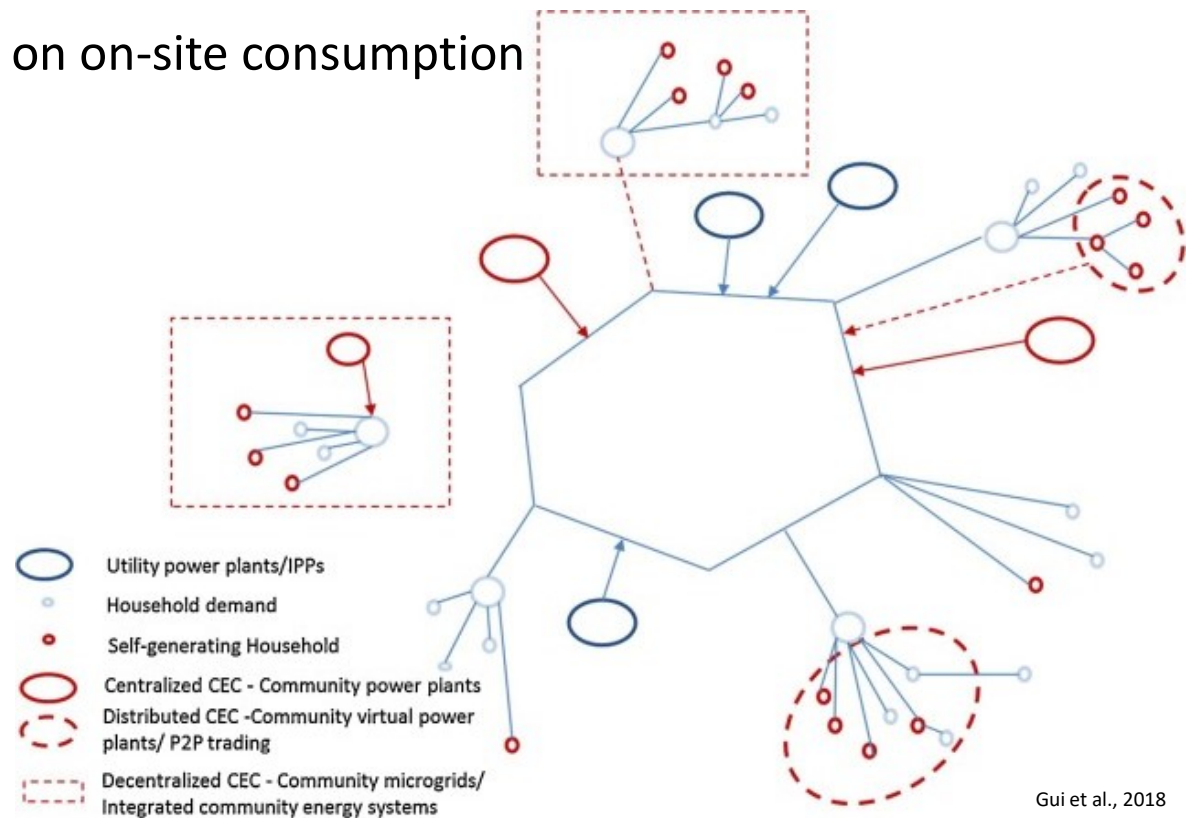
Prosumers' sizing: focus on on-site consumption



Public Authorities' infrastructures can be highly valued



Several techs can be used but solar PV is currently the most viable



Gui et al., 2018



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Design – Suggested Task I



Design of a simplified REC based on Solar Photovoltaic project(s)



Prosumers' sizing: focus on on-site consumption.



Selected the site, follow this methodology:

- Calculate the site's available area – Google Earth
- Consider modules' azimuth and slope (20° for flat surfaces)
- Estimate plant's power: around 1,5 kW per 10 m<sup>2</sup>
- Estimate plant's Annual Energy Supply: PVGIS



With the support of the  
Erasmus+ Programme  
of the European Union





# REC Implementation Design – Suggested Task I



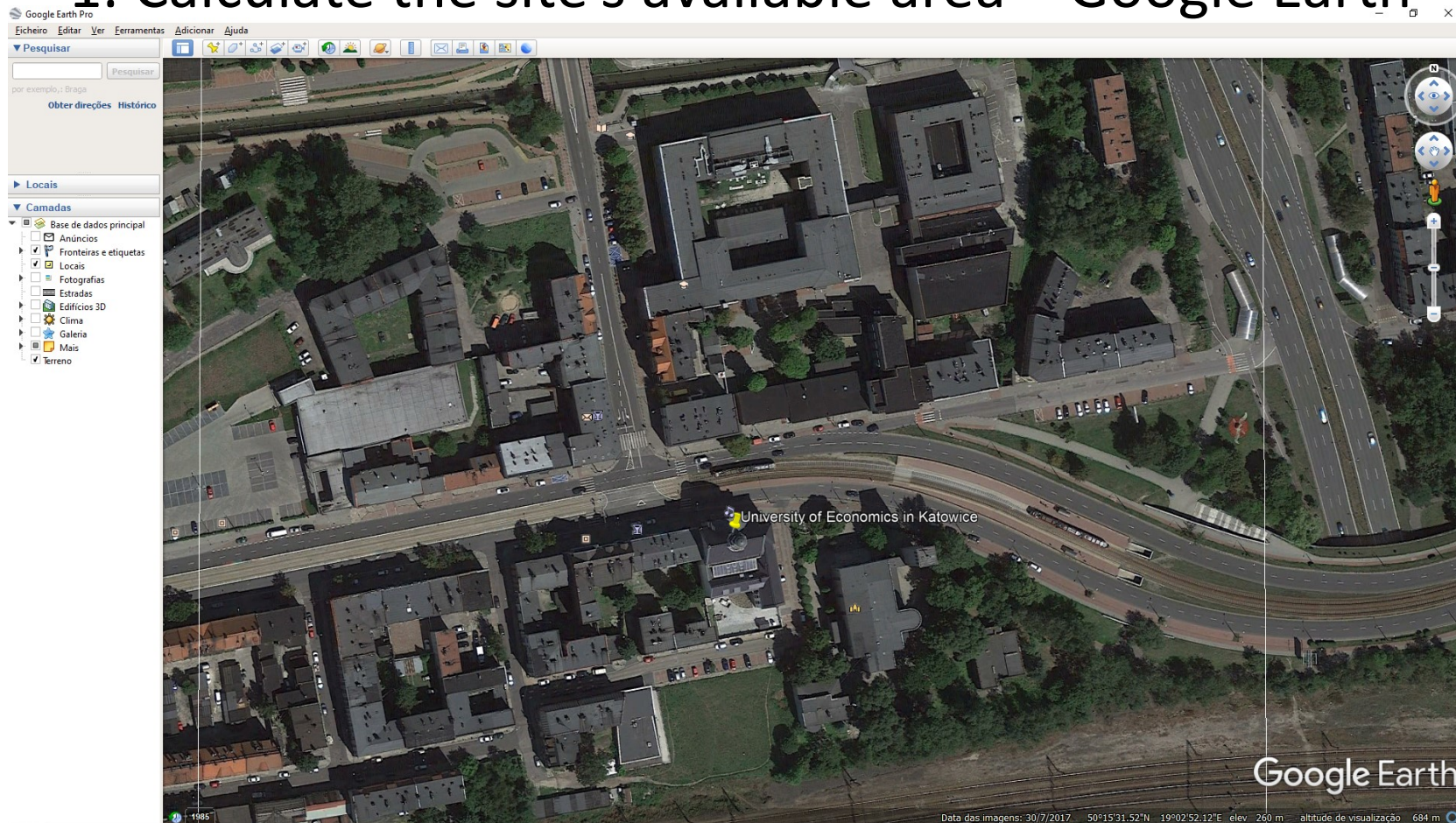
With the support of the  
Erasmus+ Programme  
of the European Union





# REC Implementation Design – Suggested Task I

## 1. Calculate the site's available area – Google Earth



With the support of the  
Erasmus+ Programme  
of the European Union





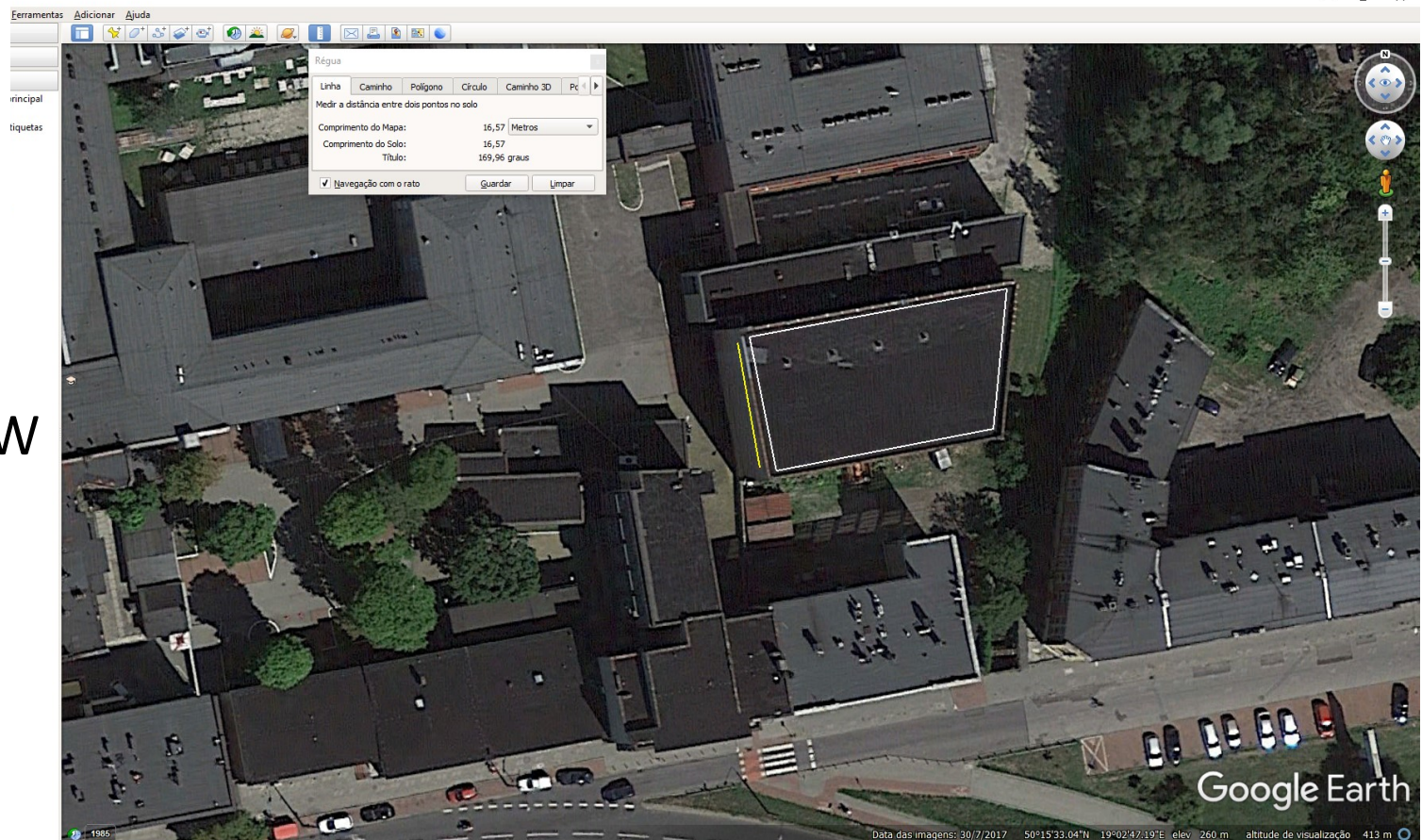
# REC Implementation Design – Suggested Task I

1: Calculate the site's available area – Google Earth

2: Google  
Earth  
calculates  
Azimuth

3:

- $550\text{m}^2 \approx 82\text{kW}$
- Slope  $20^\circ$
- Azimuth:  
 $170^\circ$  North is  
 $-10^\circ$  South



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Design – Suggested Task I

## 4: Estimate plant's Annual Energy Supply: PVGIS <https://ec.europa.eu/jrc/en/pvgis>

PV  
Performance  
Tool

Photovoltaic Geographical Information System (PVGIS)

Try the PVGIS tools:

- PV Performance**  
Grid connected, Tracking PV, Off grid
- Solar radiation**  
Monthly, Daily, Hourly
- TMY**  
Typical Meteorological Year  
Temperature, wind, humidity, air pressure, ...

PVGIS is available in English, French, Italian and Spanish for any location in Europe and Africa, as well as large part of Asia and America.

PVGIS provides free and open access to:

- PV potential for different technologies and configurations of grid connected and stand alone systems.
- Solar radiation and temperature, as monthly averages or daily profiles.
- Full time series of hourly values of both solar radiation and PV performance.
- Typical Meteorological Year data for nine climatic variables.
- Maps, by country or region, of solar resource and PV potential ready to print.
- PVMAPS software includes all the estimation models used in PVGIS.

**Map disclaimer**

*The designations employed and the presentation of material on the maps do not imply the expression of any opinion whatsoever on the part of the European Union concerning the legal status of any country, territory, city or*



With the support of the  
Erasmus+ Programme  
of the European Union





# REC Implementation Design – Suggested Task I

## 4: Estimate plant's Annual Energy Supply: PVGIS

- Address.  
I just wrote  
Katowice and  
identified the  
buildings

The screenshot shows the PVGIS web interface. The top navigation bar includes the European Commission logo and the title 'PHOTOVOLTAIC GEOGRAPHICAL INFORMATION SYSTEM'. Below the navigation bar, there is a map of Europe and Africa. A cursor is positioned over Poland, and the 'Selected' location is displayed as 'Poland'. The right panel contains configuration options for the PV system, including 'Solar radiation database', 'PV technology', 'Installed peak PV power [kWp]', 'System loss [%]', 'Fixed mounting options', and 'PV electricity price'. The bottom of the interface shows the address field with 'Eg Ispra, Italy' and the coordinates field with 'Eg 45.815, Eg 8.611'.



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Design – Suggested Task I

## 4: Estimate plant's Annual Energy Supply: PVGIS

- Select area
- Grid connected
- Crystalline
- Adjust slope and azimuth

JRC Photovoltaic Geographical Information System

re.jrc.ec.europa.eu/pvg\_tools/en/#PVP

Montepio Energia Eficiente Pessoal Para organizar Tiago Teresa Bookmarks Google SAPO - Portugal On... Facebook Portal SIG E: A... Biblioteca Nacional... FCG - Biblioteca de... Repositório Aberto... Outros marcadores Lista de leitura

**Cookies**  
This site uses cookies to offer you a better browsing experience. Find out more on [how we use cookies](#) and [how you can change your settings](#).  
[I accept cookies](#) [I refuse cookies](#)

Legal notice | Cookies | Contact | English (en)

PHOTOVOLTAIC GEOGRAPHICAL INFORMATION SYSTEM

European Commission > EU Science Hub > PVGIS > Interactive tools

Home Tools Downloads Documentation Contact us

Address:  Eg. Ispra, Italy  Lat/Lon:  Eg. 45.815  Eg. 8.611

Cursor: Selected: 50.259, 19.046  
Elevation (m): 263

Use terrain shadows:  
☒ Calculated horizon  
☐ Upload horizon file

[CSV](#) [JSON](#)  
[Escolher ficheiro](#) Nenhum ficheiro selecionado

GRID CONNECTED

TRACKING PV OFF-GRID MONTHLY DATA DAILY DATA HOURLY DATA TMY

**PERFORMANCE OF GRID-CONNECTED PV**

Solar radiation database\* PVGIS-SARAH  
PV technology\* Crystalline silicon  
Installed peak PV power [kWp]\* 82  
System loss [%]\* 14

Fixed mounting options  
Mounting position\* Free-standing  
Slope [°]\* 20  
Azimuth [°]\* -10  
☐ Optimize slope  
☐ Optimize slope and azimuth

☐ PV electricity price  
PV system cost (your currency)  
Interest [%/year]  
Lifetime [years]

[Visualize results](#) [CSV](#) [JSON](#)

Last update: 15/10/2019 Top



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Design – Suggested Task I

## 4: Estimate plant's Annual Energy Supply: PVGIS

Comma separated values file:

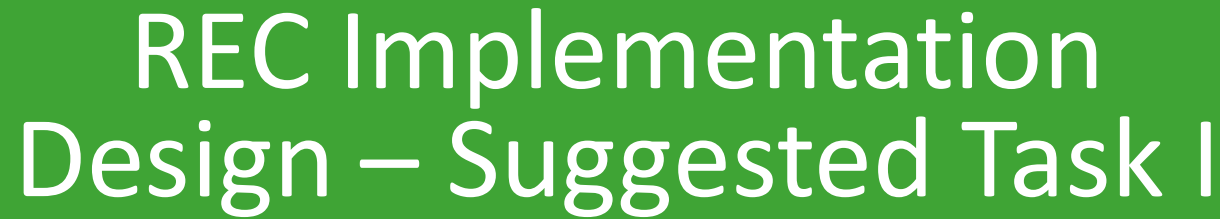
PVdata\_50.259\_19.046\_SA\_crystS  
i\_82kWp\_14\_20deg\_-10deg

- Select entire first column
- Data/Text to Columns
- Select Delimited > Next
- Tabs > Finish

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Latitude (decimal degrees):	50.259											
2	Longitude (decimal degrees):	19.046											
3	Radiation database:	PVGIS-SARAH											
4	Nominal power of the PV system (c-Si) (kWp):	82.0											
5	System losses(%):	14.0											
6	Fixed slope of modules (deg.):	20											
7	Orientation (azimuth) of modules (deg.):	-10											
8													
9	Fixed angle												
10	MonthE_dE_mH(i)_dH(i)_mSD_m												
11	176.212362.61.134.02548.43												
12	2127.193561.351.8250.84853.02												
13	3209.46491.513.0694.961284.51												
14	4304.099122.844.6138.061289.33												
15	5322.149986.394.97154.21779.72												
16	6340.010200.05.33159.941147.88												
17	7348.8410813.935.56172.481390.13												
18	8315.149769.364.98154.271096.3												
19	9259.697790.833.99119.741235.67												
20	10175.215431.522.6281.31289.8												
21	1197.472924.091.4543.4715.24												
22	1273.92290.811.0933.77480.47												
23	Year221.226728.773.39103.08341.86												
24	AOI loss (%)Spectral effects (%)Temperature and low irradiance loss (%)Combined loss (%)												
25	Fixed angle:-3.351.63-5.76-20.39												
26													
27	E_d: Average daily energy production from the given system (kWh/d)												
28	E_m: Average monthly energy production from the given system (kWh/mo)												
29	H(i)_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2/d)												
30	H(i)_m: Average monthly sum of global irradiation per square meter received by the modules of the given system (kWh/m2/mo)												
31	SD_m: Standard deviation of the monthly energy production due to year-to-year variation (kWh)												
32													
33													
34	PVGIS (c) European Union, 2001-2021												



With the support of the  
Erasmus+ Programme  
of the European Union



- “E\_m” column shows monthly production!
- We have a design of an affordable, clean power source
- We can assume this production will decrease around 0,7% per year





# REC Implementation Financial Model – Task II

## Suggested Task II: Model a Potential REC community

- 1) A Prosumer wants project leadership, has PV potential but no willingness to invest;
- 2) Many consumers have no PV potential and no willingness to invest;
- 3) Rooftops and landowners have PV potential but no willingness to invest;
- 4) Industrial consumers may have PV potential and may have some willingness to invest;
- 5) Private Equity has willingness to invest, but demand control.





# REC Implementation Financial Model – Task II

- Design a project for your REC (Task I)
- Agents: Define possibilities and respective Drives/Motivations
- Impacts: Define possible social (jobs, typically 1-2 per PV plant) and environmental (GHG emission factors vary widely per country) outcomes
- Financial Models for attracting Investors

## Business Plan



With the support of the  
Erasmus+ Programme  
of the European Union

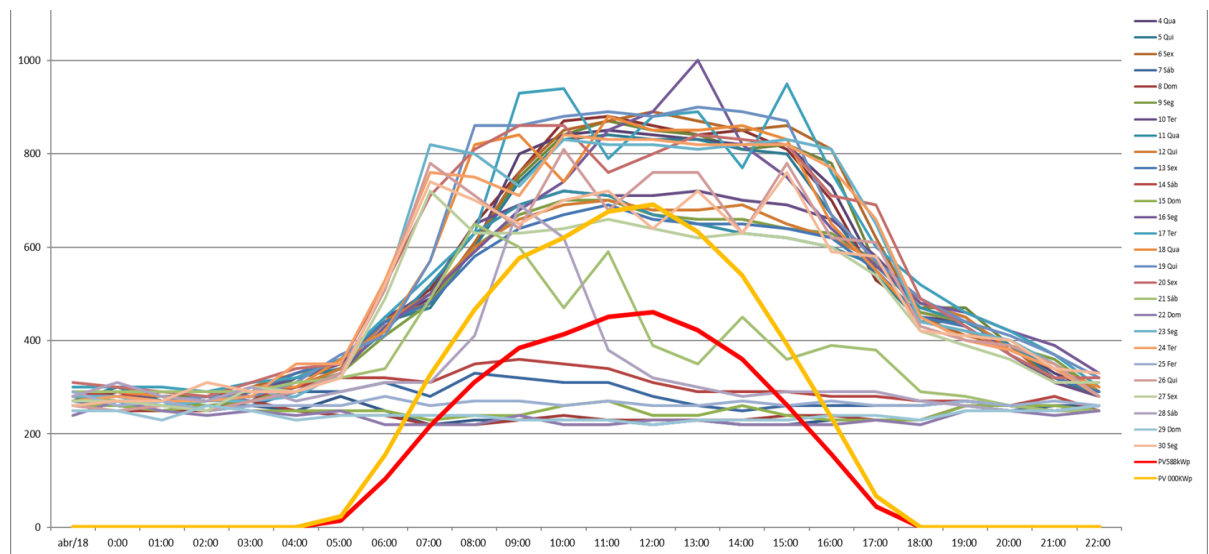




# REC Implementation Financial Model – Task II

Agent #1: Prosumer's baseload diagram needed to assess how much energy will be consumed on-site and how much will be sold

For this exercise and on the lack of timely models, we will assume 80% of the electrical energy is to be consumed by the prosumer and 20% will be available for sale



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Financial Model – Task II

## Agent #2: Small consumer

Is the chain's weakest link – each one has little influence

Pays the most expensive energy price

Not only one but many

Can be an influencer, an investor and a voter

EU policies are built towards his concerns

## **The most important Agent**

Ideally, scenarios must be built considering the adoption of the REC by large numbers of small consumers, which consume between 3 and 15 MWh per year.



With the support of the  
Erasmus+ Programme  
of the European Union





# REC Implementation Financial Model – Task II

Agent #3: Medium-level producer

Necessary when no large production facility can be found

Prosumer model

Agent #4: Medium-level consumer

Can be of great relevance using energy surpluses

Prosumer model

In the lack of appropriate and timely data, we can assume these consumptions between 100 and 1500 MWh per year.



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Financial Model – Task II

Agent #5: Private Equity Investor

Necessary since most important agents are not willing to invest  
ROI, IRR, NPV

Agent #6: Consultant / Manager

Operational expenditures



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Financial Model – Task II

## **Tariffs on the lack of substantiated data**

Main Prosumer: 150€/MWh

Small Consumer: 200€/MWh

Medium or Industrial Consumer: 130€/MWh

## **Costs to be supported by Private Equity Investor**

PV Plant: 650€/kW installed

Fee to pay to Grid Manager (usually a public entity): 40€/MWh

Fee to pay to System Manager: 24.000€/year

Fee to pay to System O&M&I: 24.000€/year



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Financial Model – GOALS



Project must be interesting to Private Equity Investor:

- Receives profits from sales to all agents
- NPV (4% rate) positive after 10 years
- IRR-20 years over 10%



Project must be interesting to Prosumers and consumers:

- At least a 10€/MWh decrease in the tariff of the Prosumer and for the medium-level consumer and 100€ for the small consumer
- At least one medium-level consumer and 20 small consumers adhere to the REC



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Financial Model – EXTRAS



Project may simulate several scenarios, depending on its adoption by the community in the long-term



Solar Plant may use PV modules with special Characteristics (monocrystalline technology); Investment rises to 750€/kW installed but losses on the PVGIS simulation reduce to 10% (instead of 14%)



With the support of the  
Erasmus+ Programme  
of the European Union



# REC Implementation Design and Financial Model

Any questions?

[goncalo.elias@delab.pt](mailto:goncalo.elias@delab.pt)



With the support of the  
Erasmus+ Programme  
of the European Union



## Greening Energy Market and Finance

Project website: <http://grenfin.eu>



The information and views set out in this publication are those of the authors and do not necessarily reflect the official opinion of the European Union. Neither the European Union institutions and bodies nor any person acting on their behalf may be held responsible for the use which may be made of the information contained therein.



With the support of the  
Erasmus+ Programme  
of the European Union