20th International Conference on Renewable Energies and Power Quality (ICREPQ'22)
Vigo (Spain), 27th to 29th July 2022
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, Volume No.20, September 2022

Solar energy potential calculation methods

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Abstract. Several European municipalities developed an information map called solar cadaster that provide qualitative information for the citizens about the possible locations and amount of the small scale household solar PV system installations. The objective of these cadasters is the promotion and fostering of the distribution of the PV systems.
Most of the cadasters are based on remote sensing roof measurements and irradiation information but provide only indicative data. Our solution is based on ten implementation type categories such as individual small houses, housing estates, solar carports, public institutions, etc.
We looked for which segment of the solutions can raise the penetration with greater efficiency. We found that in Budapest there are eight large 10 storeys block-type housing estates with 100 thousand flats. Here 20-40 kWp can be installed for each staircase that is about 300-600 MWp for 1500 staircase. The total additive PV potential in Budapest is 1500 MW.

Keywords. PV cadaster, PV potential, dissemination for citizens' personal use

I. Introduction

Nowadays the local municipalities are committed to foster the spread over of PV applications. The Budapest local government runs a project to promote small scale (household) PV systems. To set a target a technical potential estimation is forthcoming. It helps for the decision makers and means support for citizens. The project also provides information about installation of existing technologies.
Recently, in order to promote and disseminate renewable energy sources, several local governments have solar cadasters are made. The possible locations of the solar system installation and the size of the systems are displayed on the map of the settlement. These solar cadasters look good but differ significantly in usability and technical content.
Nowadays dozens of different methods and tools are available for solar power and solar potential calculation [1][2][3][4][5].

A. The meaning of cadaster

There are a lot of different definitions of notion "cadaster":

- Register book, which shows the economic data of the land belonging to a settlement and the data on the owners of the land. [1]
- A record kept of items belonging to the same group or persons belonging to an occupation. [1]
- land register, registration
- 'register': wooden cadaster, church cadaster, educational cadaster, cultural cadaster, chimney cadaster, monument cadaster, etc. Based on the data, it seems that these are new developments, and are probably chosen by the speakers instead of the word simple register, to indicate that it is not a simple census, a register, but one that is compiled and organized according to certain principles. [9]

We define "solar cadaster":

> *A visual map based data base that refers the amount of PV Systems that can be installed/is installed already at an investigated rea – in MW unit.*

B. The energy potential

In the case of fossil energy sources, one may talk about explored or exploited reserves. Meanwhile, in the case of renewable energy sources, we cannot talk about this, but give the energy potential that can be extracted annually (Solar Energy, Hydropower, Wind Energy, Geothermal Energy, Biomass). Its unit is J, MJ, PJ, kWh, TWh / year.

Energy potential can mean (see Tab. I.)

- Principally maximum - the entire surface of Hungary
- Physically possible - no road, no train track, no forest
- Technically possible (E.g. top of a tower exposed to high winds is appropriate?)
- Legally possible - protected area (Natura 2000), owner allows

- Economically viable - profitable according to existing rules
- Controlled by Life Cycle Assessment – is it really worth? Are we really doing good for the Earth?

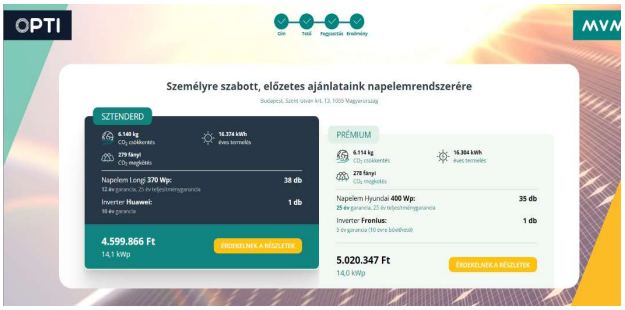
1. Table: Different solar potential calculations

	km^2	kwh/m^2	TWh	How much times covers the annual consumption
Theoretical solar energy arriving to Hungary	93000	1300	120900	3022,5
Theoretical solar energy arriving to Budapest	525,2	1300	682,76	45,5
	km^2	kwh/m^2	cell efficiency %	GWp
The amount of solar panels that can be installed in Budapest in principle	525,2	1300	0,15	81,9
	km^2	MWp/ha	MWp	
If we were to cover the city with the current fixed installation system	525,2	0,5	26260	

II. Solar potential estimating Systems

A. *MVM OPTI*

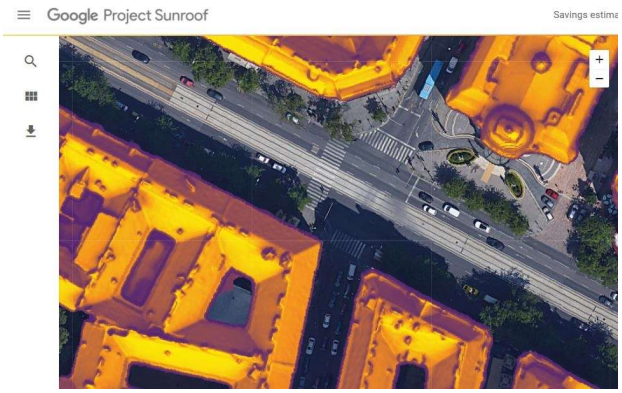
The MVM Opti [10] is a PV system size calculator for nonprofessional users (see Fig. 1.). After put in data of roof size, orientation, yearly energy consumption it calculates the recommended maximum power. It also offers a certain product too. The program checks the amount of irradiation. The power is calculated from the zero net electrical energy balance.



***1**. Figure: Screenshot of solar potential estimator application [10]*

B. *Google Project Sunroof*

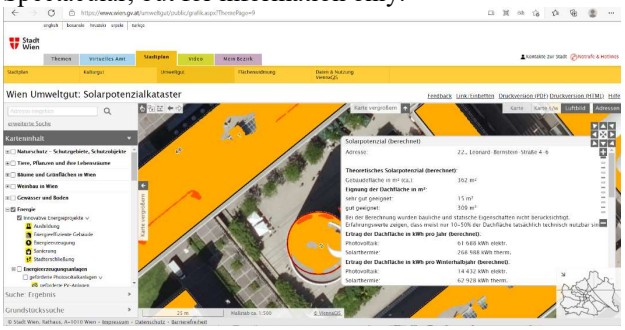
The Google Project Sunroof [11] is a satellite remote sensing based PV potential estimator program (see Fig. 2.). The remote sensing scans the shape and orientation of the roof. The irradiation is allocated to the roof from a database. From the yearly irradiation and from the consumer's yearly energy bill recommends a system size. Also provides some financial help to estimate the cost in case of leasing, buy or loan). In the building shape cadaster one can find the USA cities and some European parts, also Budapest, Hungary too.



***2**. Figure: Google Project Sunroof [11]*

C. *Wien Umweltgut*

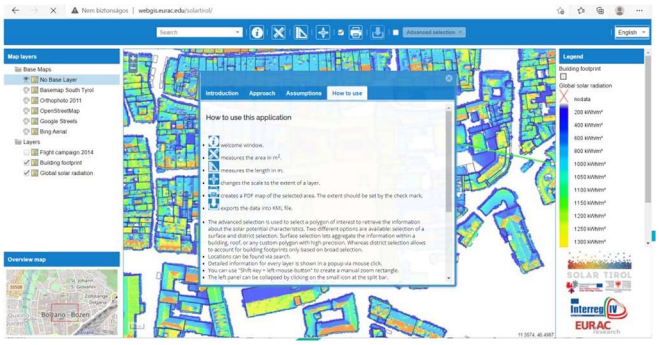
The Wien Umweltgut [12] gives an informative recommendation on what is a good installation location, how much energy can be obtained, but does not say system performance (see Fig. 3.). It places the result of the radiation measurement based on satellite remote sensing on the base map. It takes into account the total coverage of the roof, it does not take into account how much energy consumption. Protected (downtown) areas are indicated. Spectacular, but for information only.



***3**. Figure: Wien Umweltgut [12]*

D. *Solar Tirol*

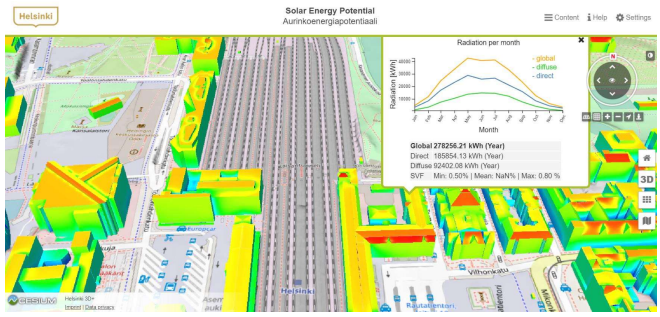
The Solar Tirol [13] is a cadaster dealing with Land Tyrol (also in Austria and Italy) , with center the Autonomous Province of Bolzano (see Fig. 4.). The information are based Lidar measurements, satellite irradiation measurements, and that all are visualized in the Google-Earth application. It calculates the irradiation for the whole surface of the roofs – but there is no any details about the kWp, about the structure and size of the roof. At the end a final document can be printed from the system.



4. *Figure: Solar Tirol [13]*

E. *Helsinki*

The Helsinki system [14] based on a 3D vector model extended with astronomical irradiation calculation corrected by meteorological data (see Fig. 5.). The radiation is presented by yearly radiation curve. No kWp is calculated – but all the vertical surfaces (e.g. walls to North) has irradiation data. Some well situated sites (hot spots) are pointed but architectural heritages are not marked.



5. *Figure: The Helsinki application [13]*

F. *Other tools*

There are many other local municipalities that has solar cadaster, as Solarkataster.ch, Switzerland; Solar Cadastre, Basel Stadt, Switzerland; Mapdwell Solar System, Cambridge, etc. Also dozens of irradiation simulators and calculators are available for architects and PV system designers (Shadow analyzer[15], PV-F Chart [16], Ecotect [17], eQuest [18], PVSYS [19], PVSim [20], Sandia IVT racer [21], Sun Path [22], Solar Sizer [23], RETScreen [24])

III. Recommendations for Budapest Municipality

There is a running project at Budapest Municipality (Hungary) in the frame of the European Climate Initiative (EUKI) project No. 81263388 funded by German Federal Ministry for Environment, Nature Conservation and Nuclear Safety. The objective of the project is to break barriers to low carbon investment in Budapest. In partnership with Budapest Municipality and Association for Solar Energy the Óbuda University worked on „How to install more PV on the roof of Budapest buildings?”. Based on the above mentioned solutions we recommended a new solar cadaster technique:

Constraints:

- in Budapest there are more than 345 000 pcs buildings with potential roof for PV installation
- the floor plan doesn’t inform us about the slope of the roof
- the enclosing size of the roof tells nothing about
    - is it allowed?
    - is it worth to set up?
    - is it fit from edge-to-edge?
    - can we connect it to the utility network?
    - is there any special shadow situation?

Budapest is composed from smaller homogenous districts. In these districts the size, age, shape of the buildings are similar (e.g. residential area von the beginning of the XX. century, housing estate from the fifties or eighties, downtown, cottage area, etc.). Instead of the individual answer regarding the 345 000 buildings we defined special area types, where typical solutions can be realized/can be recommended (see Fig. 6. and 7.). These typified designs are the followings:

- Panel house, 5 and 10 storeys
- Detached houses, ground floor
- Condominium - sloping roof, downtown
- Condominium - flat roof, mountains
- Business Center
- Malls
- Open air parking lots (solar carports) [6][7]
- Newly built, multi-storeys 2-4 apartment condominium with flat roof
- Office building, public institution
- 4-5 storeys panel / brick housing estate with flat roof
- Cottage
- Restricted area (Parks, industrial area (not the subject of the work), highlighted architectural heritage)

6. Figure: Colored PV application type blocks in Budapest

7. Figure: Colored PV application type blocks in Budapest

Main features of the existing systems

- Provides information on yearly irradiation
- My property (user's house) is visible - it's very friendly
- Some systems provide information on the kWp that can be installed – but only for information
- Significant inaccuracy
- These systems do not give an aggregation for the whole
- No application types / no area filtering
- doesn't really takes into the physical network connection possibilities
- Each realized system requires an unique system design
- A number of professional design software is available

The recommended cadaster should

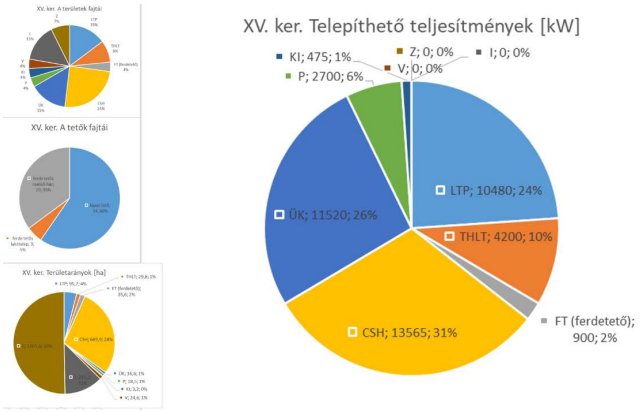
- Inform the user about a possible solution
- Provides information on a map basis
- Proposes a certain solution for a micro-region / building
- Does not give a detailed and specific plan
- A concrete solution comes from hundreds of contractors
- A summary and screening for the whole of Budapest is necessary
- the results can be visualized by Google Earth display (see Fig. 8. and. 9.)
- local/regional statistics are provided
- a possible solution type is shown/recommended to the user

8. Figure: Housing estate quarter with 5 storeys block houses

9. Figure: Typified solution for housing estates

The key of the cadaster making is the expert estimation of the blocks, to assess the solution type, the possible power, etc. Finally reports can be printed out easily about the

- area size
- solar potential of the area
- no. of possible installation
- block types and sizes
- different ratios, etc. (see Fig. 10.)



10. Figure: Statistics

IV. Conclusion

Our aim is to raise the PV penetration in Budapest. We were looking the PV installation type that raises the penetration with greater efficiency (more MW with less investment). We found that in Budapest there are eight large 10 storeys block-type housing estates with 100 thousand flats. Here 20-40 kWp can be installed for each staircase that is about 300-600 MWp total for 1500

staircase. The advantage of this solution is the possible standardization (all the block houses has similar shape) meanwhile the individual small houses aren't similar. The total additive PV potential in Budapest is 1500 MW apart from the "brown" industrial areas.

V. Acknowledgement

The research was done in frame of the European Climate Initiative (EUKI) project No. 81263388 funded by German Federal Ministry for Environment, Nature Conservation and Nuclear Safety.

References

[1] Solar cadastre (cythelia.fr) https://www.cythelia.fr/en/renewable-energies/expertise/solar-cadastre/
[2] Solar panel and battery calculation: the complete guide – Sunslice (sunslice-solar.com) https://sunslice-solar.com/blogs/sunslice-blog-english/solar-panel-and-battery-calculation
[3] Ewelina WERNER: A Solar Cadastre; Journal of Young Scientist, Volume IV, 2016 ISSN 2344 - 1283; ISSN CD-ROM 2344 - 1291; ISSN Online 2344 - 1305; ISSN-L 2344 – 1283 207
[4] Agugiaro, G., Remondino, F., Stevanato, G., De Filippi, R., Furlanello, C., 2011: Estimation of solar radiation on building roofs in mountainous areas. IAPRS&SIS, Vol. 38(3/W22), pp. 155-160
[5] G. Agugiaro, F. Nex, F. Remondino, R. De Filippi, S. Droghetti, C. Furlanello: Solar radiation estimation on building roofs and web-based solar cadastre;ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume I-2, 2012 XXII ISPRS Congress, 25 August – 01 September 2012, Melbourne, Australia
[6] Istók R: Solar panel Carport with second life electric vehicle batterises, In: The 16th International Conference of Constructive Design and Technological Optimization in Machine Building Field; (2021) p. 134
[7] P., Kádár ; R., Istók ; L., Reizer: Solar Carport with Energy Storage Capabilities; In: Nádai, László 2021 IEEE 4rd International Conference and Workshop in Óbuda on Electrical and Power Engineering (CANDO-EPE); Piscataway (NJ), USA IEEE (2021) 197 p. pp. 89-94. , 6 p
[8] wikiszotar.hu
[9] https://ujszo.com/kultura
[10] OPTI - by MVM Optimum (ezzing.com) https://mvm-opti.ezzing.com/simulator-map
[11] https://www.google.com/get/sunroof
[12] Wien Umweltgut https://www.wien.gv.at /umweltgut/public/grafik.aspx?ThemePage=9
[13] Solar Tirol (eurac.edu) http://webgis.eurac.edu/solartirol/
[14] Solar Energy Potential (hel.fi) https://kartta.hel.fi/3d/solar/
[15] http://www.drbaumresearch.com/
[16] www.fchart.com/pvfchart/
[17] http://usa.autodesk.com/ecotect-analysis/
[18] www.doe2.com/eQUEST/
[19] www.pvsyst.com
[20] http://photovoltaics.sandia.gov/docs/
[21] www.mauisolarsoftware.com/MSESC/IVTracer.htm
[22] www.sunpathonline.com/
[23] www.solarray.com
[24] www.retscreen.net