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Comparative Experimental FWA & FOWA Aggregated VLCSPPs' LUR Estimation for GIS Based VEED

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Abstract- Solar power conversion technologies are photovoltaics (PV), concentrated solar power (CSP), and concentrated photovoltaics (CPV). These technologies need sufficient amount of appropriate land. In super grids and Global Grid, large sized power plants play the key role, so that this study only focuses on very large solar power plants (VLSPP). VLSPPs are defined as the power plants that have the installed power of 1.000 MW (peak in PV) or more in this study. Solar land use requirements (LUR) should be studied, analyzed and estimated for each solar power technology. This study investigates only the LUR of very large concentrated solar power plants (VLCSPPs). Under unsharp conditions, a fuzzy weighted average/weight averaging (fuzzy WA: FWA) aggregated and an ordered fuzzy weighted average/weight averaging (fuzzy OWA: FOWA) aggregated solar LUR models on a worldwide basis are built for LUR prediction on the geospatial information systems (GIS) at the very early engineering design (VEED) phase. These two models are presented in a comparative way. Five experimental criteria (direct normal irradiance: DNI, engineering design year, net installed power, cooling method, storage capacity) are only included in these models. The mean absolute percentage error (MAPE) of land area (hectares) and solar field aperture area (m^2) are respectively %331,35 (FWA), %505,14 (FOWA) and %914,86 (FWA), % 1374,45 (FOWA).

Keywords Concentrated solar power, FuzzME, Fuzzy Ordered Weighted Average, Fuzzy Weighted Average, land use requirement.

1. Introduction

Solar power can supply the largest electricity amount to humans by 89.000 TW_p theoretical, 58.000 TW_c extractable, and 7.500 TW_c technical world potential estimations (TW_p: terawatt equivalent photonic fuel power, TW_c: terawatt equivalent chemical fuel power) [1]. It is presented that only 0,00015 TW_c was supplied in 2001 [1].

The research, development, demonstration, and deployment (RD^3) engineers try to increase the usage of this resource. In today's capabilities, there are three solar power technologies: photovoltaics (PV) [2], concentrated solar power (concentrating solar power, concentrated solar thermal) (CSP) [3], concentrated photovoltaics (CPV) [4].

Today, the CSP technology is usually classified under parabolic trough, linear Fresnel, power tower, and parabolic dish technologies [5,6] as shown in Fig.1. This study investigates all of these CSP technologies at once.

Line Focus Systems		Point Focus Systems	
Parabolic Trough	Linear Fresnel	Power Tower	Parabolic Dish

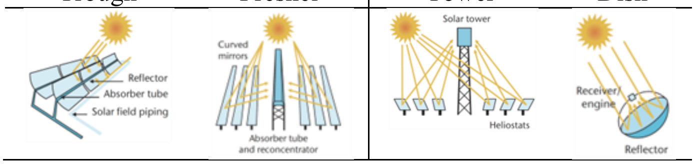


Fig. 1. CSP technology families (Source: [5,6]).

The most efficient investment approach in solar power plants is by economies of scale approach (see [7] for economies of scale). As a result, large size solar power plants shall first be investigated in detail.

Very large concentrated solar power plant (VLCSPP) concept is researched in this manner. The definition isn't clear yet, but it is discriminated as the CSP plants that have the installed power of 1.000 MW or more [8].

The most effective way of generating and consuming of electricity is also by considering economies of scale. Therefore, super grids and Global Grid are researched and tried to be modelled and designed (e.g. European Supergrid [9], Supergrid for America [10], DESERTEC [11], Gobitec [12,13], Asian Super Grid [12,13], Global Grid [14]).

A detailed literature review on Google Scholar [15] and Directory of Open Access Journals [16] was performed by some key terms in this study. It had been observed in previous studies that Google Scholar had been the most dominant academic publication online database (highest number of documents for each search term: author's experience). Moreover, both of these online websites had "open access" publications, so that all RD^3 engineers would be able to find these publications.

The search term of this study was "land use" and "concentrated solar". Only English documents were searched on Google Scholar (1930 results) and Directory of Open Access Journals (0 results) until 21/12/2015. The titles and abstracts were first reviewed and the related documents (papers, reports, presentations, etc.) with this study were saved in their specific folder (only 19 studies). After this observation, previously known documents on some websites (e.g. [17-21]) were also once more checked. Only a few documents could be added, but one of them was the most important one (Ong et.al.'s study at the National Renewable Energy Laboratory (NREL): author's point of view).

Ong et.al. studied the direct land use ("disturbed land due to physical infrastructure development") and the total land use ("all land enclosed by the site boundary") requirements of the utility scale ground mounted small and large photovoltaic (PV) and concentrating solar power (CSP) plants in the United States [22]. There were 25 projects with a capacity (MW_{AC}) of 3747 in the total land use requirements for CSP plants (parabolic trough, tower, dish Stirling, linear Fresnel) analysis. The capacity weighted average land use (acres/MW_{AC}) was presented as 10 and the generation weighted average land use (acres/GWh/yr) was given as 3,5. There were 18 projects with a capacity of 2218 in the direct land use requirements analysis. The capacity weighted average land use was presented as 7,7 and the generation weighted average land use was presented as 2,7. In their dataset, the least installed power (MW_{AC}) was 1,5 (Maricopa Solar Project with Stirling Engine) followed by 5 (Sierra SunTower with tower). The most installed power was 370 (Ivanpah all with tower) followed by 354 (SEGS all with parabolic trough) and 280 (Solana all with parabolic trough) [22]. Purohit et.al. investigated the possibility of generating electricity from CSP technologies (parabolic trough collector, linear Fresnel reflector, central receiver system: tower with heliostats, parabolic dish) in the Northwestern India [23]. They presented that the area (collector/heliostat) (m^2) was 34–550 (parabolic trough), 40–120 (central receiver), 92 (dish). They also added that the land requirement (m^2/MW) was 40000 (parabolic trough), 83600 (central receiver), 18000 for linear Fresnel and 16000 for dish [23]. Other studies also gave some similar information (see [24-29]).

It was understood that fuzzy WA and OWA aggregated based models hadn't been applied in any CSP LUR analysis study until 21/12/2015. Hence, this study is also one of the first studies that step up VLCSPP designs on the World, however, it had to be underlined that there were already some announced intentions (Morocco's Noor-Ouarzazate Solar Complex aimed 2000 MW, designed as only for 510 MW by I, II, III at a cost of US$ 2677 million [30,31,32], Oman's Miraah aimed 1021 MW thermal only for steam at a cost of US$ 600 million [33,34], China's Ordos aimed 2000 MW at a cost of US$ 5 billion [35,36], Tunisia's TuNur CSP farm aimed 2250 MW at a cost of US$ 13.8 billion, with a note of the DESERTEC's cancellation/withdrawal at a cost of US$ 530 billion [37,38,39,40]). Thus, VLCSPP designs are only remained as intentions today.

Shortly; it is deducted that by looking at figures E-1 to E-4 on [22], LUR and capacity of CSP plants in the U.S.A. don't show any linear characteristics. It is stated that this study is most probably a unique (the only one and first) in this field in this respect. There are five aims of this study as to start helping to model Global Grid, to start helping design process of VLCSPPs in Global Grid and other grids, to start helping to find possible alternative VLCSPPs locations in Global Grid by geographic information system (GIS) tools (e.g. ArcGIS, Google Earth, Netcad) in very early engineering design (VEED) stages, to start studying LUR estimations of VLCSPPs and CSPPs, to start modelling LUR estimations by fuzzy weighted average/weight averaging (fuzzy WA) aggregated models and ordered fuzzy weighted average/weight averaging (fuzzy OWA) aggregated models, to start a GIS tool RD^3 for VLCSPP design process.

2. Preliminaries & Experimental Fuzzy WA & OWA Models for VLCSPP Design GIS Tool

These experimental proposed fuzzy WA and OWA aggregated models have 5 factors/inputs and 2 outputs/findings (Factor 1: F_1: Direct Normal Irradiance, F_2: engineering design year, F_3: net installed power, F_4: cooling method, F_5: storage capacity factors, Finding 1: O_1: solar field aperture area, O_2: land area). The author believes that simple models obeying strictly main principles and approaches will show the RD^3 progress direction (factor reduction or increment, defining membership functions). One of the important modelling principles in this subject is the magical number 7 (George Armitage Miller (1920–2012) (magical number 7) [41], Richard M. Shiffrin (1968–alive) and Robert M. Nosofsky (alive) (magical number 7, 7±2 rule) [42]). Accordingly, only 5 factors are used in this study as:

- F_1: Direct Normal Irradiance (DNI) (kWh/m^2/year):

"direct irradiance received on a plane normal to the sun over the total solar spectrum" [43]. DNI is used for CSP and concentrating photovoltaic (CPV) systems [8,43,44]. Solar spectrum discrimination isn't taken into account in this study.

CSP minimum DNI rule of thumb or application ($kWh/m^2/year$): 2000 [6], 1800 (technical), 2000 (economical), 1600 (future technical) [23], 902 (demonstration solar tower), 2012 (commercial example) [26], 2000 (commercial) [28], 1800 (5 $kWh/(m^2$ day) [29], 800–900 W/m^2 (normal incident radiation), 1600–2800 kWh/m^2 (annual normal incident radiation) [45], 2,2 $MWh/m^2/year$ or 6,0 $kWh/m^2/day$ (annual average) [46], limited suitability below 1800, suitable 1800–2000, highly suitable 2000–2500, excellent 2500–3000 [47], 800 W/m^2 (normal incident radiation) and range 1600–2800 [48].

Location & design constraint: DNI ≥ 1600 $kWh/m^2/year$ (decision in this study).

It can be seen on Fig.2, that the possible VLCSPPs' regions are dispersed on the World very smoothly just like created for only super grids and Global Grid. The Creator wants us to think on a worldwide basis (only one piece, spacious enough). Hence, super grids and Global Grid is seemed very possible.

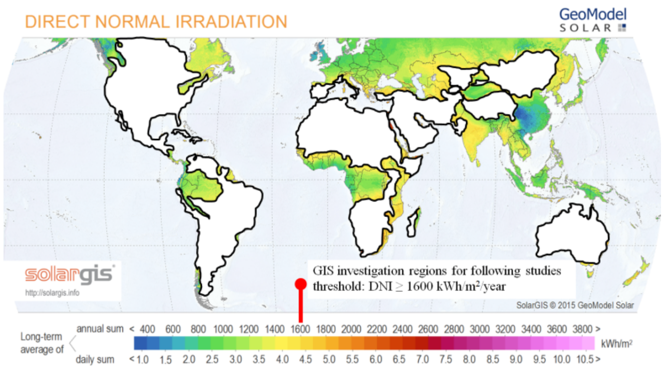


Fig. 2. Rule of thumb representation on DNI World Map for following GIS investigation studies (white regions) (Basemap: GeoModel Solar [49]) (generated by Microsoft Office Excel 2007 https://products.office.com/en-us/home or Apache OpenOffice 4.1.5 http://www.openoffice.org/ & Paint.NET http://www.getpaint.net/index.html).

➢ F_2: Engineering Design Year:

The RD[3] engineer (author) thinks that technical and technological breakthroughs are important in CSP technology, so that it should be taken into account during modelling.

The author (also by his own conceptual design studies) very well knows and experiences that design date and grid connection date has more than some decades duration gap. Technical and technological capabilities are related to design. Hence, engineering design years are tried to be estimated in this study (10 years earlier than generation start date).

➢ F_3: Net Installed Power (Net Turbine Capacity in MW):

This factor is the most important factor in this study. When the installed power of a CSP plant increases the LUR increases. The net installed power and the net turbine capacity are used in the same manner in this study. The unit is taken as megawatt (MW). The current model covers up to 5.000 MW according to design of 1.000 MW at first.

➢ F_4: Cooling Method:

There are three systems (wet: once-through or recirculating, dry: direct or indirect, hybrid: water conservation or plume abatement) [50,51]. The design preferences are made according to water availability. The current model has two distinguishable systems as wet and dry cooling methods.

➢ F_5: Storage Capacity (hours):

There are three main thermal energy storage concepts as active (two-tank systems, thermocline, steam accumulators), passive (enhanced heat structures, packed bed systems) and combined according to Kuravi et.al.'s approach [52]. The Energy Initiative Massachusetts Institute of Technology has two groups (short term and long term thermal energy storage) [53]. The author thinks that this factor is important in this study, because the LUR varies with these criteria.

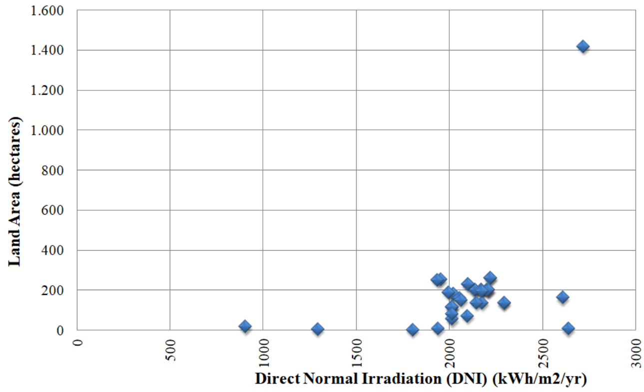
➢ O_1: Solar Field Aperture Area (m^2):

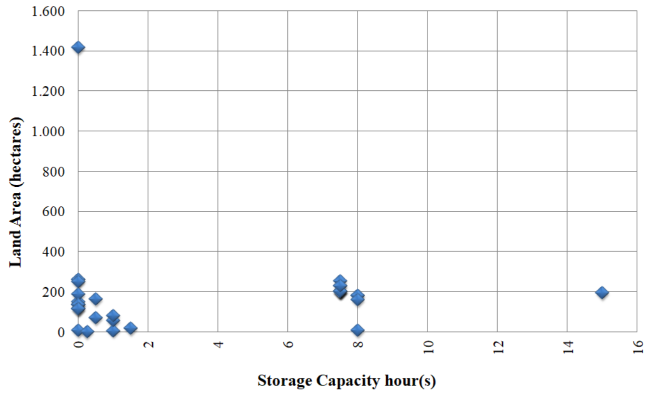
It is defined as "the area in which the solar radiation enters the collector" [54].

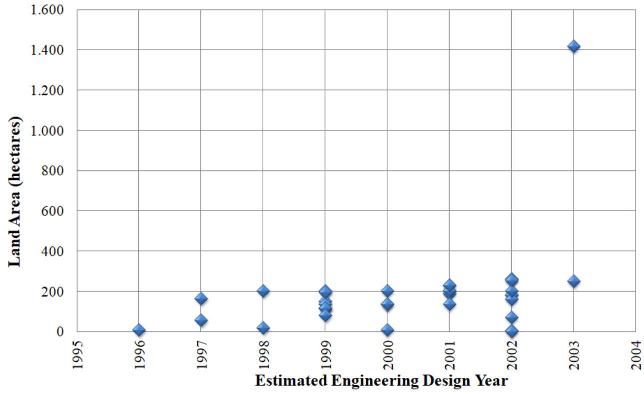
➢ O_2: Land Area (hectares):

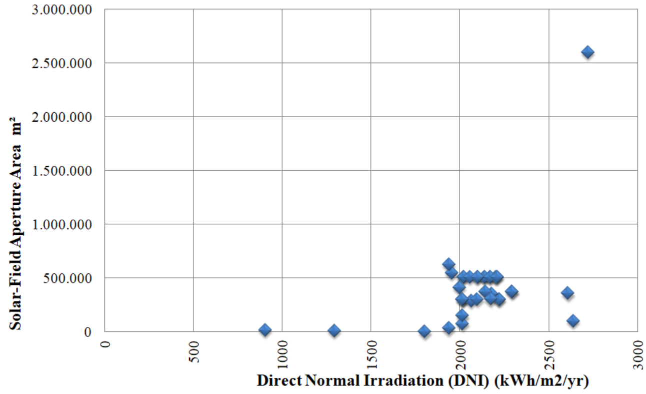
It is defined as "land area required for the entire system including the solar field land area" [55].

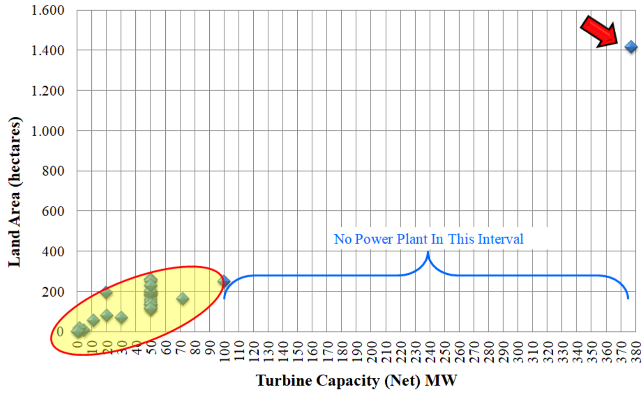
There are only 36 previous projects' data (from the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, NREL official webpage [56]) in the current dataset (electronic supplementary material files: ESM, please visit author's researcher's profiles such as ResearchGate). All data and information are used directly without any verification and validation. There are 28 parabolic trough, 6 power tower and 2 linear Fresnel reflector applications in this dataset. The inputs and output in this dataset are presented in Fig.3. The minimum values are 902 (F_1), 1996 (F_2), 0,3 (F_3), 400 (O_1), 1 (O_2). The maximum values are 2717 (F_1), 2003 (F_2), 377 (F_3), 2600000 (O_1), 1417 (O_2).

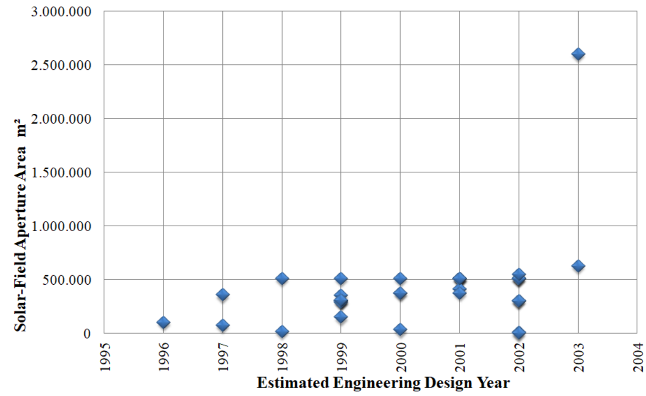

Land Area (hectares)
Direct Normal Irradiation (DNI) (kWh/m2/yr)

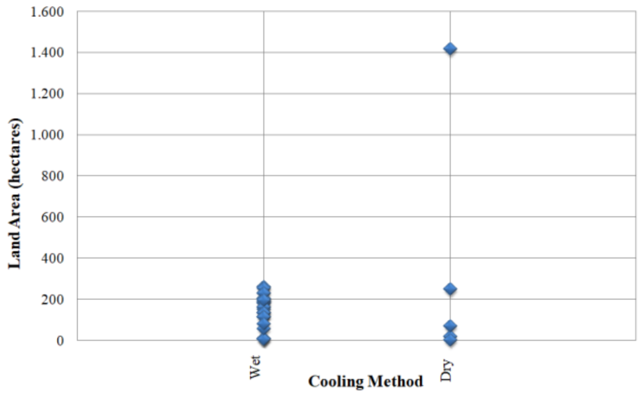

Land Area (hectares)
Storage Capacity hour(s)

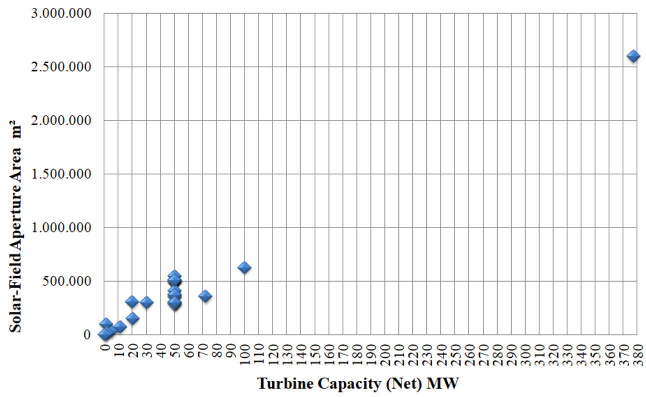

Land Area (hectares)
Estimated Engineering Design Year


Solar-Field Aperture Area m²
Direct Normal Irradiation (DNI) (kWh/m2/yr)


Land Area (hectares)
No Power Plant In This Interval
Turbine Capacity (Net) MW


Solar-Field Aperture Area m²
Estimated Engineering Design Year


Land Area (hectares)
Wet
Dry
Cooling Method


Solar-Field Aperture Area m²
Turbine Capacity (Net) MW

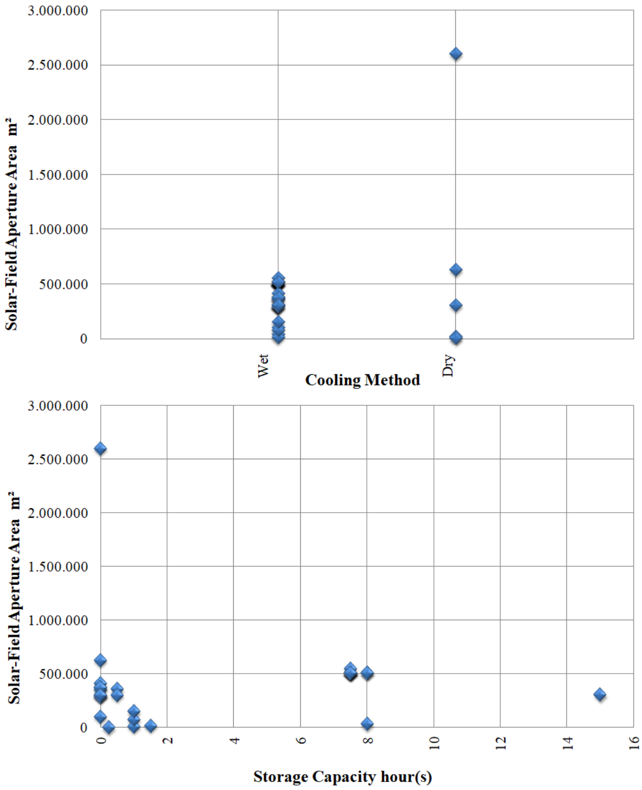


Fig. 3. Inputs and outputs (top to bottom): DNI, engineering design year, net installed power, cooling method, storage capacity versus land area and then solar field aperture area (see ESM) (generated by Microsoft Office Excel 2007 or Apache OpenOffice 4.1.5 & Paint.NET), Data: [56].

Before current modelling, two important rules of thumb are also investigated as:

- CSP rule of thumb for slope:

terrain slope angle (%) < 4, 1, 7, 1, 1 (in that study and others) [6], solar field slope (%) < 1−2 (parabolic trough), 2−4 (central receiver), 4 (linear Fresnel), 10 or more (dish) [26], slope (%) < 3 (1 most economical) [29], slope < 2,1 [47].

- CSP rule of thumb for cost:

capital (Dollars/kW) 3972 (parabolic trough), 4000+ (solar tower), 12578 (dish) [28], cost installed ($/W) 3,49–2,34 (parabolic trough), 3,83–2,16 (central receiver), 11,00–1,14 (dish) [48], capital cost ($/kW) 2900 (parabolic trough), 2400–2900 (power tower), 2900 (dish) [29]. Accordingly, the cost of a VLCSPP will be in almost five to ten of billions dollars.

In this study, the models are directly built on the FuzzME Software (developed by Holecek, Talasova, Pavlacka and Bebcakova [57,58]). There are many modelling options on it (fuzzy weighted average, OWA, WOWA, Choquet integral, expert system). Fuzzy WA & OWA are only applied in this experimental study due to the inspiration of some studies by fuzzy WA and OWA in other fields (e.g. [59,60]).

A few preliminaries of fuzzy WA and OWA:

Fuzzy weighted average (see original [61] to avoid any misinterpretation or shift):

normalized fuzzy weights ∀ fuzzy numbers

$V_i \in [0,1], i = 1,2, \ldots\ldots, m$ if

$\forall \alpha \in (0,1] \wedge \forall\, i \in \{1,2,\ldots,m\}$ following holds

$\forall\, v_i \in V_{i\alpha}$ there exists

$v_j \in V_{j\alpha}, j = 1,2,\ldots,m, j \neq i$ s.t. $v_i + \sum_{j=1, j\neq i}^{m} v_i = 1$

fuzzy weighted average ∀ fuzzy numbers

$U_i \in [0,1], i = 1,2, \ldots\ldots, m \ \wedge\ W_j \in [0,1], j = 1,2, \ldots\ldots, m$

membership function

$U(u)\ \forall\, u \in \mathfrak{R}$ is

$$U(u) = \max\{\min\{U_1(u_1), U_2(u_2), \ldots\ldots, U_m(u_m), W_1(w_1), W_2(w_2), \ldots\ldots, W_m(w_m)$$

$$u = \frac{w_1 u_1 + w_2 u_2 + \cdots \ldots\ldots + w_m u_m}{w_1 + w_2 + \cdots \ldots\ldots + w_m}, \sum_{i=1}^{m} w_i \neq 0\}$$

For the computing algorithm of its calculation see [61,62].

Fuzzy ordered weighted average (see original [62,63]):

$$u = \frac{w_1 u_{\emptyset(1)} + w_2 u_{\emptyset(2)} + \cdots \ldots\ldots + w_m u_{\emptyset(m)}}{w_1 + w_2 + \cdots \ldots\ldots + w_m}, \sum_{i=1}^{m} w_i \neq 0$$

where $\emptyset$ a permutation of the set of indices

$u_{\emptyset(1)} \geq u_{\emptyset(2)} \geq \cdots \ldots\ldots \geq u_{\emptyset(m)}$

For the computing algorithm of its calculation see [62,63].

These preliminaries are all founded on the ordered weight averaging (OWA) operator by Ronald Robert Yager (alive) [64] and the fuzzy set and logic by Lotfali Askar Zadeh (1921–alive) [65]. The fuzzy logic operators are clearly presented by Henrik Legind Larsen [66] (Fig.4).

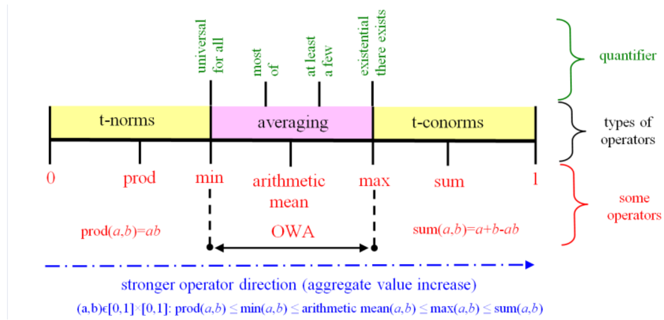


Fig. 4. Representation of fuzzy logic operators (drawn, redrawn and generated based on [66]).

The membership functions of these experimental models are modelled directly on FuzzME (Fig.5) (in ESM). In these experimental models, the uniform weights are assigned first, and then the fuzzy weights are defined by the guidance of FuzzME (Fig.6) (in ESM).

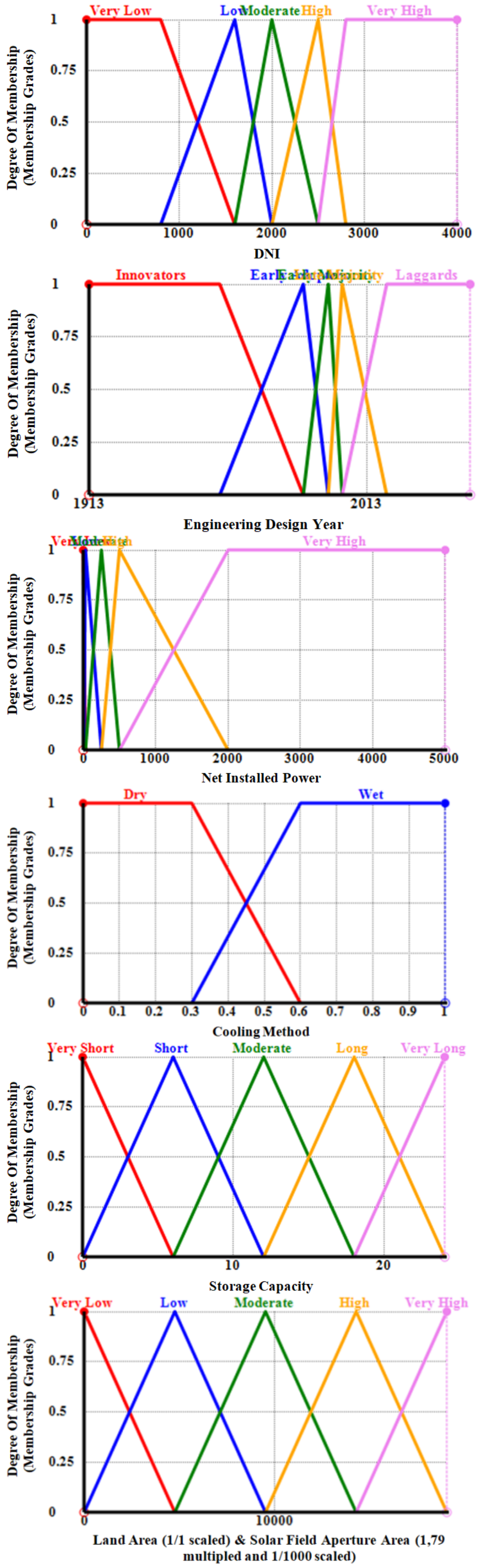


Fig. 5. Membership functions on FuzzME (open FuzzME models) * Note: from top to bottom: DNI (Increasing Scale: higher values are better), engineering design year (Increasing), net installed power (Increasing), cooling method, storage capacity (Increasing), Land Area (1/1 scaled) & Solar Field Aperture Area (1,79 multiplied and 1/1000 scaled) on the FuzzME.

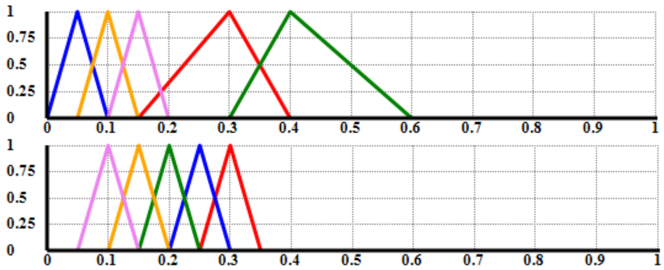
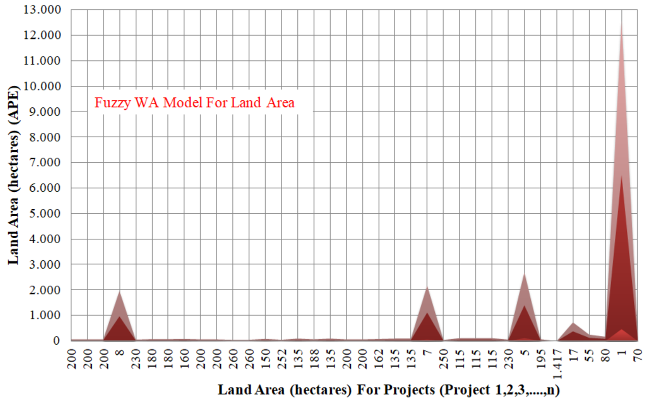
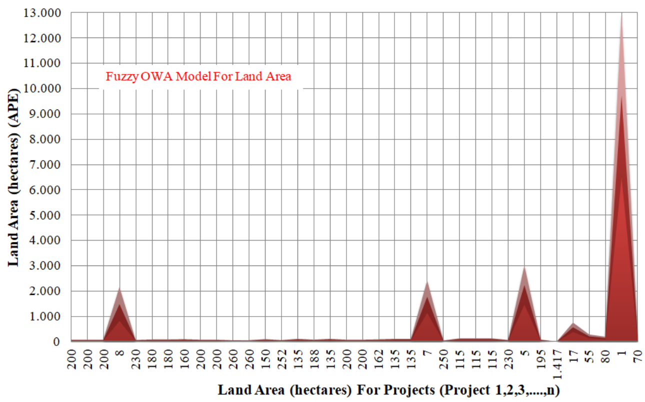
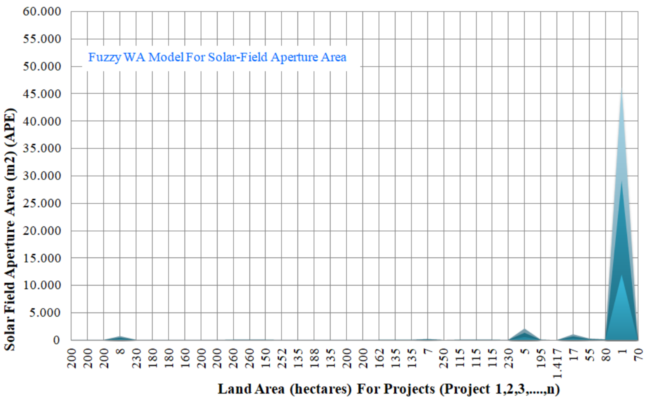


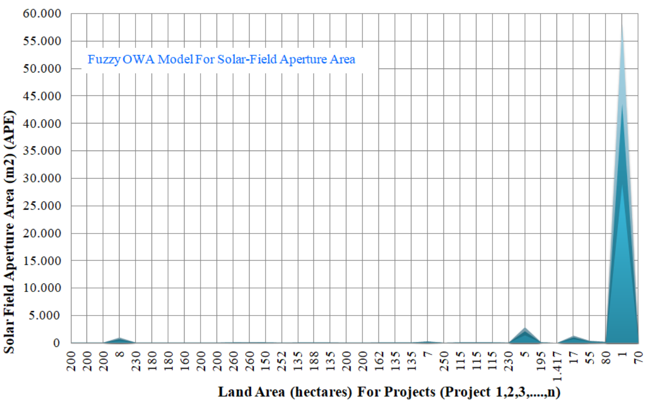
Fig. 6. Weights of fuzzy WA & OWA on FuzzME (open FuzzME models) * Note: Fuzzy WA weights (top), Fuzzy OWA weights (bottom)

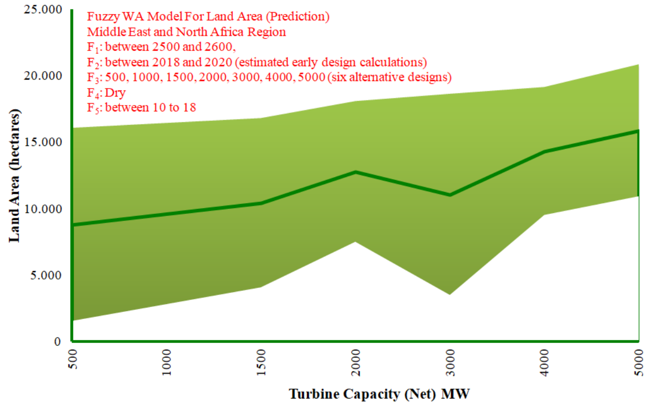
These experimental models are tested on the historical projects data and information (see ESM) by using FuzzME and Microsoft Office Excel or Apache OpenOffice 4.1.5 (Fig.7). The errors are calculated according to the absolute percentage errors (APE), the maximum absolute percentage error (MAP), and the mean absolute percentage error (MAPE) like demand forecasting studies (see [67-72]). The MAPE of land area (hectares) (O_2) is %331,35 (FWA) and %505,14 (FOWA). The main errors occur for very small land area projects or small installed power projects (land area: 8; 6,5; 5,3; 1). When these projects are removed from the data set the model performance for MAPE increases approximately 6 times better. When the installed capacities increase in this model, the performance increases very well (For 377 MW error rate is %4). As a result, this model works well in bigger CSP plants rather than in small CSP plants in its current form (Fig.7). The MAPE of solar field aperture area (m^2) (O_1) is %914,86 (FWA) and % 1374,45 (FOWA). The same problem is observed in these models too. The main errors occur for very solar field aperture area projects or small installed power projects (solar field aperture area: 31860; 100000; 10000; 17650; 75000; 150000; 400). When these projects are removed from the data set the model performance for MAPE increases approximately 18 times better. When the installed capacities increase in this model, the performance increases very well (For 377 MW error rate is %4). As a result, this model works well in bigger CSP plants rather than in smaller CSP plants in its current form (Fig.5). When these fuzzy WA and fuzzy OWA models are compared, it is observed that the current fuzzy WA model is performed better. However, it is very clear, that these models need very serious improvement efforts, but it is also thought that this study is a good start for this research aim. Finally, some very large concentrated solar power plants (VLCSPPs) designs' land use requirement predictions are also made by the experimental FWA model (better performed model) on the Middle East and North Africa Region (F_1: between 2500 and 2600, F_2: between 2018 and 2020 (estimated early design calculations), F_3: 500, 1000, 1500, 2000, 3000, 4000, 5000 (six alternative designs), F_4: Dry, F_5: between 10 to 18) (Fig.7).











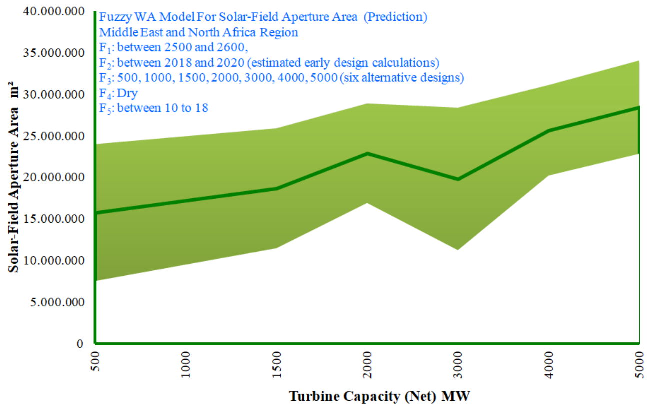


Fig. 7. FWA land area APE per project, FOWA land area APE per project, FWA solar field aperture area APE per project, FOWA solar field aperture area APE per project, FWA land area predictions, FWA solar field aperture area predictions (open ESM and FuzzME model files) *Note: from top to bottom.

One of the main outputs of these R&D efforts shall be some GIS applications (online and offline) for personal, laptop and tablet computers and also mobile phones. The design studies will be performed according to GIS software, coding and cognitive ergonomics principles and constraints in some specially organized R&D studies in near to medium term (Fig.8).

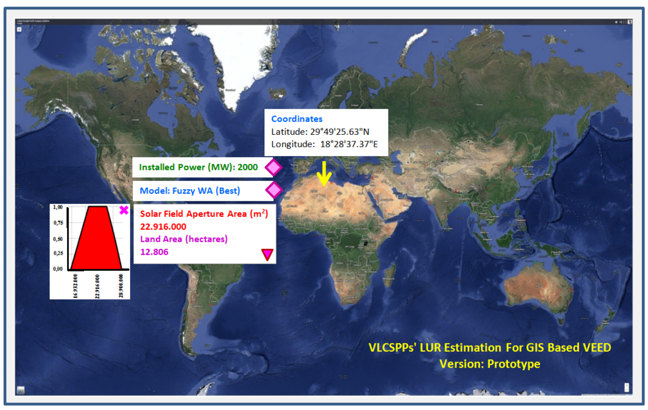


Fig. 8. GIS application interface screen view 1st prototype draft idea (see for base [73,74]) (e.g. Google Earth, ESRI, Autodesk Applications) (only current graphical interface study).

3. Conclusions and future work

This study presents a new idea of developing some plugins and applications on the geographic information systems software for the concentrated solar power plants land use requirements and estimations.

A comparative experimental fuzzy weighted average (fuzzy WA) and ordered fuzzy weighted average (fuzzy OWA) aggregated VLCSPPs land-use requirement estimation model is presented for very early engineering design studies (only on FuzzME, no integration of any GIS yet).

It is believed that these kinds of plugins, applications, and tools will increase the efficiency and effectiveness in the early engineering stages.

The models should be studied in detail with different approaches and views. Afterwards, GIS plugins and tools can be developed and presented for real world applications of international organizations, multinational foundations, governments, and investors.

These tools will hopefully very helpful for developing Supergrids and Global Grid, that will urgently be a must in mid to long term, when some critical issues are taken into account (see critical issues [75,76]).

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References

[1] J. Tsao, N. Lewis, and G. Crabtree, Solar FAQs Working Draft Version 2006 Apr 20, www.sandia.gov/~jytsao/Solar%20FAQs.pdf accessed on 14/10/2015.

[2] Wikipedia, Wikimedia Foundation Inc., Photovoltaics, http://en.wikipedia.org/wiki/Photovoltaics accessed on 14/10/2015.

[3] Wikipedia, Wikimedia Foundation Inc., Concentrated solar power, http://en.wikipedia.org/wiki/Concentrated_solar_power accessed on 14/10/2015.

[4] Wikipedia, Wikimedia Foundation Inc., Concentrated photovoltaics, http://en.wikipedia.org/wiki/Concentrated_photovoltaics accessed on 14/10/2015.

[5] The International Energy Agency (IEA), Technology Roadmap Solar Thermal Electricity, 2014.

[6] J. Clifton, B.J. Boruff, "Assessing the potential for concentrated solar power development in rural Australia", Energy Policy, Vol. 38, pp. 5272–5280, 2010.

[7] Investopedia: Economies of scale, http://www.investopedia.com/terms/e/economiesofscale.p accessed on 17/10/2015.

[8] B.O. Saracoglu, "An Experimental Fuzzy Expert System Based Application For The Go/No-Go Decisions To The Geospatial Investigation Studies Of The Regions Of The Very Large Concentrated Solar Power Plants In The European Supergrid Concept", In Advances In Intelligent and Soft Computing, The 18th Online World Conference on Soft-Computing in Industrial Applications (WSC18), 6 December 2014.

[9] Friends of the Supergrid: Roadmap to the Supergrid Technologies Final Report. http://www.cesi.it/news_ideas/ideas/Documents/FOSG%20%20WG2%20Final-report.pdf accessed on 14/10/2015.

[10] T.J. Overbye, C. Starr, P.M. Grant, and T.R. Schneider, National Energy Supergrid Workshop Report. Crowne Plaza Cabana Palo Alto Hotel, Palo Alto, California, www.supergrid.illinois.edu/sg1/SuperGridReportFinal.pdf accessed on 14/10/2015.

[11] DESERTEC Foundation: http://www.desertec.org/ accessed on 11/06/2015.

[12] S. Mano, B. Ovgor, Z. Samadov, M. Pudlik, V. Julch, D. Sokolov, and J.Y. Yoon, Gobitec and Asian Super Grid for renewable energies in Northeast Asia. Spotinov print Ltd., 2014.

[13] B. Seliger, G.E. Kim, Tackling climate change, increasing energy security, engaging North Korea and moving forward Northeast Asian integration – "Green Growth" in Korea and the Gobitec project. Gobitec Outline Paper 1-03 10112009, 2009.

[14] S. Chatzivasileiadis, D. Ernst, G. Andersson, "The Global Grid", Renewable Energy, Vol. 57, pp. 372–383. doi:10.1016/j.renene.2013.01.032, 2013.

[15] Directory of Open Access Journals, http://doaj.org accessed until 21/12/2015.

[16] Google Scholar, http://scholar.google.com.tr/ accessed until 21/12/2015.

[17] Global Energy Network Institute (GENI), http://www.geni.org/ accessed until 21/12/2015.

[18] Defense Technical Information Center, http://www.dtic.mil/dtic/ accessed until 21/12/2015.

[19] California Energy Commission, http://www.energy.ca.gov/ accessed until 21/12/2015.

[20] International Finance Corporation (IFC), http://www.ifc.org/ accessed until 21/12/2015.

[21] National Renewable Energy Laboratory (NREL), www.nrel.gov accessed until 21/12/2015.

[22] S. Ong, C. Campbell, P. Denholm, R. Margolis, and G. Heath, Land-use requirements for solar power plants in the United States. Technical Report NREL/TP-6A20-56290 June 2013, Contract No. DE-AC36-08GO28308, Golden, CO: National Renewable Energy Laboratory, 2013, http://www.nrel.gov/docs/fy13osti/56290.pdf accessed on 14/10/2015.

[23] I. Purohit, P. Purohit, S. Shekhar, "Evaluating the potential of concentrating solar power generation in Northwestern India", Energy Policy, Vol. 62, pp. 157-175, 2013.

[24] R.R. Hernandez, S.B. Easter, M.L. Murphy-Mariscal, F.T. Maestre, M. Tavassoli, E.B. Allen, C.W. Barrows, J. Belnap, R. Ochoa-Hueso, S. Ravi, and M.F. Allen, "Environmental impacts of utility-scale solar energy". Renewable and Sustainable Energy Reviews, Vol. 29, pp. 766-779, 2014.

[25] T. Wanderer, S. Herle, "Using a web-based SDSS for siting solar power plants", Environmental Informatics and Renewable Energies. pp. 100-108, 2013 http://enviroinfo.eu/sites/default/files/pdfs/vol7995/0100.pdf accessed on 14/10/2015.

[26] O. Behar, A. Khellaf, K. Mohammedi, "A review of studies on central receiver solar thermal power plants", Renewable and Sustainable Energy Reviews, Vol. 23, pp. 12-39, 2013.

[27] R.M. Horner, C.E. Clark, "Characterizing variability and reducing uncertainty in estimates of solar land use energy intensity", Renewable and Sustainable Energy Reviews, Vol. 23, pp. 129-137, 2013.

[28] A. Ummadisingu, M.S. Soni, "Concentrating solar power–technology, potential and policy in India", Renewable and Sustainable Energy Reviews, Vol. 15, No: 9, pp. 5169-5175, 2011.

[29] K. Kaygusuz, "Prospect of concentrating solar power in Turkey: the sustainable future", Renewable and Sustainable Energy Reviews, Vol. 15, No: 1, pp. 808-814, 2011.

[30] The World Bank Group, Morocco's Noor-Ouarzazate Solar Complex: A Global Public Good (video file), http://www.worldbank.org/en/news/video/2014/10/01/morocco-noor-ouarzazate-solar-complex, https://youtu.be/pitmsgaAlJM accessed on 14/10/2015.

[31] Sameh I. Mobarek (The World Bank Group Noor Ouarzazate Concentrated Solar Power Project Team Leader) e-mail correspondence on 21/12/2015.

[32] The World Bank Group, MA- Noor Ouarzazate Concentrated Solar Power Project, http://www.worldbank.org/projects/P131256?lang=en accessed on 14/10/2015.

[33] GlassPoint Solar, Petroleum Development Oman Miraah http://www.glasspoint.com/miraah/ accessed on 14/10/2015.

[34] C. Helman, "Ironic Or Economic? Oil Giant To Build World's Largest Solar Project", Forbes/Energy, 2015. http://www.forbes.com/sites/christopherhelman/2015/07/08/oil-giant-to-build-worlds-largest-solar-project/ accessed on 14/10/2015.

[35] Wikipedia®, List of solar thermal power stations https://en.wikipedia.org/wiki/List_of_solar_thermal_power_stations accessed on 22/12/2015.

[36] T. Woody, "Solar and Biomass Plants to Work in Tandem in China", The New York Times Company, 2010, http://green.blogs.nytimes.com//2010/01/11/solar-and-biomass-plants-to-work-in-tandem-in-china/ accessed on 14/10/2015.

[37] Nur Energie: Tunisia, TuNur, http://www.nurenergie.com/index.php/english/projects/tunisia accessed on 22/12/2015.

[38] A. Ebbage, "Low carbon brings Nur Energie closer to CSP export". CSP Today, http://social.csptoday.com/markets/low-carbon-brings-nur-energie-closer-csp-export on 22/12/2015.

[39] E. Stenger, "Desertec abandons Sahara solar energy export dream", http://www.edouardstenger.com/2013/07/24/desertec-abandons-sahara-solar-energy-export-dream/ on 22/12/2015.

[40] J. Deign, "Desertec and Dii: the end of the affair", CSP Today, http://social.csptoday.com/markets/desertec-and-dii-end-affair on 22/12/2015.

[41] G.A. Miller, "The magical number seven, plus or minus two: some limits on our capacity for processing information", The Psychological Review, Vol. 63, pp. 81–97, 1956.

[42] R.M. Shiffrin, R.M. Nosofsky, "Seven plus or minus two: a commentary on capacity limitations", Psychological Review, Vol. 101, Issue. 2, pp. 357–361, 1994.

[43] P. Blanc, B. Espinar, N. Geuder, C. Gueymard, R. Meyer, R. Pitz-Paal, B. Reinhardt, D. Renne, M. Sengupta, L. Wald, and S. Wilbert, "Direct normal irradiance related definitions and applications, the circumsolar issue", Solar Energy, Vol. 110, pp. 561-577, 2014.

[44] B.O. Saracoglu, "An Experimental FOWA Aggregated Location Selection Model For The VLCPVPPs In The MENA Region In The Very Early Engineering Design", In Advances In Intelligent and Soft Computing, The 18th Online World Conference on Soft-Computing in Industrial Applications (WSC18), 6 December 2014.

[45] M. Romero-Alvarez, E. Zarza, Concentrating Solar Thermal Power. D.Y. Goswami, F. Kreith, (Eds.). Handbook Of Energy Efficiency And Renewable Energy, CRC Press, 2007.

[46] A. Miller, B. Lumby, Utility Scale Solar Power Plants, A Guide For Developers and Investors. The International Finance Corporation (IFC), 2012.

[47] S. Hermann, A. Miketa, N. Fichaux, Estimating the Renewable Energy Potential in Africa A GIS-based approach. The International Finance Corporation (IFC), 2014.

[48] M. Romero, A. Steinfeld, "Concentrating solar thermal power and thermochemical fuels", Energy & Environmental Science, Vol: 5, Issue: 11, pp. 9234-9245, 2012.

[49] GeoModel Solar, http://solargis.info/doc/free-solar-radiation-maps-DNI on 22/12/2015.

[50] U.S. Department of Energy (DOE U.S.): Concentrating solar power commercial application study: reducing water consumption of concentrating solar power electricity generation. In Report to Congress. Washington, DC, 2009.

[51] Electric Power Research Institute (EPRI), Comparison of Alternate Cooling Technologies for U.S. Power Plants: Economic, Environmental, and Other Tradeoffs, Palo Alto, CA, 2004.

[52] S. Kuravi, J. Trahan, D.Y. Goswami, M.M. Rahman, and E.K. Stefanakos, "Thermal energy storage technologies and systems for concentrating solar power plants", Progress in Energy and Combustion Science, Vol. 39, Issue. 4, pp. 285-319, 2013.

[53] Energy Initiative Massachusetts Institute of Technology, The Future of Solar Energy An Interdisciplinary MIT Study https://mitei.mit.edu/futureofsolar, 2015.

[54] European Solar Thermal Industry Federation (ESTIF), Recommendation: Converting solar thermal collector area into installed capacity (m^2 to kW_{th}), http://www.estif.org/fileadmin/estif/content/press/downloads/Technical_note_solar_thermal_capacity-4.doc accessed on 14/10/2015.

[55] F. Kreith, S. Krumdieck, Principles of sustainable energy systems, CRC Press, 2013.

[56] The National Renewable Energy Laboratory (NREL), Office of Energy Efficiency and Renewable Energy, the U.S. Department of Energy, http://www.nrel.gov/csp/solarpaces/by_project.cfm accessed latest accessed on 14/10/2015.

[57] J. Talasova, P. Holecek, Multiple-Criteria Fuzzy Evaluation: The FuzzME Software Package, IFSA/EUSFLAT Conference 2009, pp. 681–686, 2009.

[58] The website of FuzzME, http://www.fuzzme.net, http://fuzzme.wz.cz/ accessed until 14/10/2015.

[59] S. Linares-Mustaros, J.M. Merigo, J.C. Ferrer-Comalat, "Processing Extreme Values in Sales Forecasting", Cybernetics and Systems, Vol. 46, Issue: 3-4, pp. 207-229, 2015.

[60] H. Song, R. Zhang, Y. Zhang, F. Xia, and Q. Miao, "Energy consumption combination forecast of Hebei province based on the IOWA operator", Energy Procedia, Vol. 5, pp. 2224-2229, 2011.

[61] O. Pavlacka, J. Talasova, The fuzzy weighted average operation in decision making models, The 24th International Conference Mathematical Methods in Economics, 13th-15th September 2006, Plzen (Ed. L. Lukas), pp. 419–426, 2006.

[62] J. Talasova, O. Pavlacka, I. Bebcakova, and P. Holecek, A framework for fuzzy models of multiple-criteria evaluation, International Conference On Fuzzy Set Theory And Applications Conference (FSTA), 2012.

[63] P. Holecek, J. Talasova, T. Talasek, "Fuzzified weighted OWA (FWOWA) operator", International Journal Of Mathematics And Computers In Simulation, Vol. 9, pp. 213–221, 2015.

[64] R.R. Yager, "On Ordered Weighted Averaging Aggregation Operators in Multicriteria Decision Making", IEEE Trans. On Systems, Man and Cyberneics Vol: 3, No: 1, pp. 183–190, 1988.

[65] L.A. Zadeh, "A Fuzzy-Set-Theoretic Interpretation of Linguistic Hedges", Journal of Cybernetics, Vol: 2, Issue: 3, pp. 4–34, 1972.

[66] H.L. Larsen, FL-04 Fuzzy knowledge operators aggregation operators (AAUE Course in Fuzzy Logic lecture note). received via e-mail on 01/01/2016.

[67] B.O. Saracoglu, "SEGS VI & Topaz Solar Farm SAM Empirical Trough & PVWatts Models Case Studies & Validation", International Journal of Research in Advanced Engineering Technologies, Vol: 1, Issue: 1, pp. 28-41, 2017.

[68] B.O. Saracoglu, "An Experimental Fuzzy Inference System for the Third Core Module of the First Console on the Global Grid Peak Power Prediction System & Its Forecasting Accuracy Measures' Comparisons with the First and the Second Core Modules", Journal Of Energy Systems, Vol: 1, Issue: 2, pp. 75-101, 2017.

[69] B.O. Saracoglu, "Comparative Study On Experimental Type 1 & Interval & General Type 2 Mamdani FIS for G^2P^3S", Global Journal of Researches in Engineering: J General Engineering, Vol: 17, Issue: 2, pp. 27-42, 2017.

[70] B.O. Saracoglu, "Comparative Study On Experimental 2 to 9 Triangular Fuzzy Membership Function Partitioned Type 1 Mamdani's FIS For G^2EDPS", Global Journal of Researches in Engineering: J General Engineering, Vol: 17, Issue: 2, pp. 1-18, 2017.

[71] B.O. Saracoglu, "G^2EDPS's First Module & Its First Extension Modules", American Journal of Applied Scientific Research, Vol: 3, Issue: 4, pp. 33-48, 2017.

[72] B.O. Saracoglu, "Solar star projects SAM version 2017.9.5 PVwatts version 5 model case study & validation", International Journal of Energy Applications and Technologies, Vol: 5, Issue: 1, pp. 13-28, 2018.

[73] Google Earth Blog, http://www.gearthblog.com/wp-content/uploads/2015/06/Imagery-Updates-Large-May-27th-2015.jpg

[74] Google Earth, https://www.google.com/earth/ accessed until 14/10/2015.

[75] G. Hansen, D. Stone, Assessing the observed impact of anthropogenic climate change, Nature Climate Change, 2015.

[76] M.T. van Vliet, D. Wiberg, S. Leduc, and K. Riahi, Power generation system vulnerability and adaptation to changes in climate and water resources, Nature Climate Change, 2016.