PENERAPAN SISTEM PENDUKUNG KEPUTUSAN MULTI KRITERIA BERBASIS GIS UNTUK PENENTUAN LOKASI *HYBRID RENEWABLE ENERGY SYSTEM*: STUDI KASUS PROVINSI LAMPUNG

SKRIPSI

Diajukan untuk memenuhi sebagian syarat memperoleh gelar Sarjana
Pendidikan Teknik Elektro Konsentrasi Teknik Tenaga Listrik

Oleh:

Agil Chairulloh

E.0451.2003622

PROGRAM STUDI PENDIDIKAN TEKNIK ELEKTRO

FAKULTAS PENDIDIKAN TEKNOLOGI DAN KEJURUAN

UNIVERSITAS PENDIDIKAN INDONESIA

BANDUNG

2024

Lembar Hak Cipta

PENERAPAN SISTEM PENDUKUNG KEPUTUSAN MULTI KRITERIA BERBASIS GIS UNTUK PENENTUAN LOKASI *HYBRID RENEWABLE ENERGY SYSTEM*: STUDI KASUS PROVINSI LAMPUNG

Oleh
Agil Chairulloh

Sebuah skripsi yang diajukan untuk memenuhi salah satu syarat memperoleh gelar Sarjana Pendidikan pada Program Studi Pendidikan Teknik Elektro

LEMBAR PENGESAHAN

AGIL CHAIRULLOH

PENERAPAN SISTEM PENDUKUNG KEPUTUSAN MULTI KRITERIA BERBASIS GIS UNTUK PENENTUAN LOKASI *HYBRID RENEWABLE ENERGY SYSTEM*: STUDI KASUS PROVINSI LAMPUNG

Disetujui dan disahkan oleh:

Dosen Pembimbing

06 May 2024

Prof. Dr. Ade Gafar Abdullah, S.Pd., M.Si.

NIP. 19721113 199903 1 001

Mengetahui,

Ketua Program Studi Pendidikan Teknik Elektro

13/5 2024

Dr. Ir. Maman Somantri, S.Pd., M.T., IPM

NIP. 19720119 200112 1 001

LEMBAR PERNYATAAN

Dengan ini saya menyatakan bahwa skripsi dengan judul "**PENERAPAN SISTEM PENDUKUNG KEPUTUSAN MULTI KRITERIA BERBASIS GIS UNTUK PENENTUAN LOKASI *HYBRID RENEWABLE ENERGY SYSTEM*: STUDI KASUS PROVINSI LAMPUNG"** ini beserta seluruh isinya adalah benar-benar karya saya sendiri. Saya tidak melakukan penjiplakan atau pengutipan dengan cara-cara yang tidak sesuai dengan etika ilmu yang berlaku dalam masyarakat keilmuan. Atas pernyataan ini, saya siap menanggung risiko/sanksi apabila di kemudian hari ditemukan adanya pelanggaran etika keilmuan atau ada klaim dari pihak lain terhadap keaslian karya saya ini.

Bandung, 17 April 2024

Pembuat pernyataan,

Agil Chairulloh

NIM 2003622

UCAPAN TERIMA KASIH

Segala puja, puji, dan syukur penulis panjatkan kepada Allah SWT Tuhan yang Maha Esa, atas berkat seluruh limpahan rahmat dan karunia-Nya sehingga penulis mampu menyelesaikan skripsi yang berjudul "Penerapan Sistem Pendukung Keputusan Multi Kriteria Berbasis GIS untuk Penentuan Lokasi *Hybrid Renewable Energy System*: Studi Kasus Provinsi Lampung" dengan tepat waktu. Tidak lupa *sholawat* serta salam semoga tercurah dan terlimpahkan kepada Nabi Muhammad SAW. Kepada keluarganya, sahabatnya, dan para pengikutnya semoga kita termasuk di dalamnya. Selama menjalani penelitian dan penulisan skripsi ini, penulis menerima banyak bantuan dari beberapa pihak, baik secara langsung maupun tidak langsung. dalam bentuk bimbingan dan arahan. Untuk itu penulis ingin menyampaikan terima kasih sebanyak-banyaknya kepada:

1. Kedua orang tua penulis, Bapak Warijo dan Ibu Lestari yang telah memberikan dukungan penuh, baik moril maupun materil. Terima kasih telah berjuang untuk membesarkan dan membimbing penulis dengan penuh kasih sayang hingga sejauh ini.
2. Kedua saudara penulis, Ahmad Kurniawan dan Artanti Khairunisa. Kalian merupakan motivasi terbesar penulis agar bisa menyelesaikan skripsi ini dengan tepat waktu.
3. Bapak Prof. Dr. Ade Gafar Abdullah, S.Pd., M.Si., selaku Dosen Pembimbing Skripsi.
4. Bapak Dr. Ir. Maman Somantri, S.Pd., M.T., IPM, selaku Ketua Program Studi Pendidikan Teknik Elektro FPTK UPI.
5. Bapak Dr. Tasma Sucita, M.T., selaku Ketua Kelompok Bidang Keahlian pada Program Studi Pendidikan Teknik Elektro FPTK UPI.
6. Ibu Ir. Hj. Arjuni Pantjawati, M.T. dan Bapak Dr. I Wayan Ratnata, S.T., M.Pd., selaku Dosen Pembimbing Akademik.
7. Seluruh dosen dan staf FPTE FPTK UPI yang tidak bisa penulis tuliskan satu persatu.
8. Rekan-rekan kelas PTE-B 2020 dan LT 2020 yang membersamai proses belajar penulis semasa perkuliahan.

9. Teman-teman Gaffar Cluster 11, Gustanov, Reza, Purnomo, Renaldiansyah, Putri, Krisna, dan Faridz yang selalu memberikan energi positif kepada penulis dalam penyusunan skripsi ini.
10. Teman-teman dekat penulis semasa perkuliahan, Irgi, Diki, Fikri, Arza, Fajar, Fayyadh, dan Rheina yang telah memberikan motivasi, dukungan, maupun bantuan kepada penulis selama masa perkuliahan.
11. Semua pihak yang terlibat dalam penyusunan skripsi ini namun tidak dapat disebutkan satu persatu.

Penulis menyadari bahwa terdapat kesalahan maupun kekurangan dalam skripsi ini. Oleh karenanya, penulis memohon maaf bila terjadi kesalahan juga kekurangan yang terletak pada skripsi ini. Penulis juga bersedia untuk menerima kritik dan saran yang konstruktif untuk meningkatkan kualitas penulisan skripsi. Terakhir, penulis berharap agar skripsi ini dapat bermanfaat bagi siapapun yang membacanya.

Bandung, 17 April 2024

Penulis

Agil Chairulloh

NIM. 2003622

ABSTRAK

Penggunaan bahan bakar fosil untuk pembangkit listrik mengakibatkan dampak buruk bagi lingkungan dan menjadikan ketersediaannya semakin menipis. Hal ini yang mendorong beberapa negara beralih ke energi terbarukan sebagai sumber pembangkit listrik. Dalam beberapa tahun ke belakang, *Hybrid Renewable Energy System* (HRES) khususnya tenaga surya dan angin banyak dipertimbangkan karena memiliki potensi besar dalam transisi energi menuju energi ramah lingkungan. Langkah pertama dan paling vital untuk perluasan penggunaan listrik dari HRES adalah penentuan lokasi. Perbandingan dari dua metode *Multi-Criteria Decision Making* (MCDM) yaitu *Technique for Order of Preference by Similarity to Ideal Solution* (TOPSIS) dan *Simple Additive Weighting* (SAW) yang keduanya terintegrasi dengan *Geographic Information System* (GIS) digunakan untuk pengambilan keputusan lokasi HRES. Terseleksi sembilan kriteria yang digunakan dan aspek iklim serta lokasi merupakan aspek yang paling banyak diperhitungkan oleh peneliti melalui jurnal-jurnal internasional. Metode TOPSIS-GIS memperoleh hasil bahwa Desa Tamansari, Kecamatan Pugung, Kabupaten Tanggamus (A3) terpilih sebagai alternatif paling optimal untuk lokasi HRES di Provinsi Lampung dengan nilai kedekatan terhadap solusi ideal sebesar 0,62775. Begitu juga dengan metode SAW-GIS, alternatif A3 terpilih sebagai alternatif paling optimal untuk lokasi HRES di Provinsi Lampung dengan nilai sebesar 0,73369. Dengan pendekatan MCDM ini, lokasi terbaik untuk HRES telah ditentukan, dan Desa Tamansari, Kecamatan Pugung, Kabupaten Tanggamus, diusulkan menjadi prioritas dalam pembangunan HRES di Provinsi Lampung.

Kata Kunci : HRES, Pemilihan Lokasi, GIS, MCDM, TOPSIS, SAW

ABSTRACT

The use of fossil fuels for electricity generation has a negative impact on the environment and causes its availability to become increasingly scarce. This has encouraged several countries to switch to renewable energy as a source of electricity generation. In recent years, Hybrid Renewable Energy Systems (HRES), especially solar and wind power, have been widely considered because they have great potential in the energy transition towards environmentally friendly energy. The first and most important step to expand the use of electricity from HRES is location determination. Comparison of two Multi-Criteria Decision Making (MCDM) methods, namely Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Simple Additive Weighting (SAW), both of which are integrated with the Geographic Information System (GIS) used for making HRES location decisions. Nine criteria were selected and the climate and location aspects were the aspects most taken into account by researchers through international journals. The TOPSIS-GIS method obtained results that Tamansari Village, Pugung District, Tanggamus Regency (A3) was selected as the most optimal alternative for the HRES location in Lampung Province with a closeness value to the ideal solution of 0.62775. Likewise, with the SAW-GIS method, alternative A3 was selected as the most optimal alternative for the HRES location in Lampung Province with a value of 0.73369. With this MCDM approach, the best location for HRES has been determined, and Tamansari Village, Pugung District, Tanggamus Regency, is proposed to be a priority in developing HRES in Lampung Province.

Keywords **:** *HRES, Site Selection, GIS, TOPSIS, SAW*

DAFTAR ISI

DAFTAR TABEL

DAFTAR GAMBAR

DAFTAR LAMPIRAN

DAFTAR PUSTAKA

Abdi, A., Astaraei, F. R., & Rajabi, N. (2024). GIS-AHP-GAMS based analysis of wind and solar energy integration for addressing energy shortage in industries: A case study. *Renewable Energy*, *225*(November 2023), 120295. https://doi.org/10.1016/j.renene.2024.120295

Achbab, E., Rhinane, H., Maanan, M., & Saifaoui, D. (2020). Developing and applying a GIS-Fuzzy AHP assisted approach to locating a hybrid renewable energy system with high potential: Case of Dakhla region-Morocco-. *Proceedings - 2020 IEEE International Conference of Moroccan Geomatics, MORGEO 2020*. https://doi.org/10.1109/Morgeo49228.2020.9121891

Asadi, M., & Pourhossein, K. (2019). Wind and Solar Farms Site Selection Using Geographical Information System (GIS), Based on Multi Criteria Decision Making (MCDM) Methods: A Case-Study for East-Azerbaijan. *2019 Iranian Conference on Renewable Energy and Distributed Generation, ICREDG 2019*, *Mcdm*, 11–12. https://doi.org/10.1109/ICREDG47187.2019.190216

Asadi, M., Pourhossein, K., & Mohammadi-Ivatloo, B. (2023). GIS-assisted modeling of wind farm site selection based on support vector regression. *Journal of Cleaner Production*, *390*(December 2022), 135993. https://doi.org/10.1016/j.jclepro.2023.135993

Asadi, M., Pourhossein, K., Noorollahi, Y., Marzband, M., & Iglesias, G. (2023). Uma nova estrutura de decisão para seleção de locais de usinas híbridas solares e eólicas usando modelagem de regressão linear baseada em GIS-AHP. *Sustainability*, *15*(10), 8359.

Aydin, N. Y., Kentel, E., & Sebnem Duzgun, H. (2013). GIS-based site selection methodology for hybrid renewable energy systems: A case study from western Turkey. *Energy Conversion and Management*, *70*, 90–106. https://doi.org/10.1016/j.enconman.2013.02.004

Barzehkar, M., Parnell, K. E., Mobarghaee Dinan, N., & Brodie, G. (2021). Decision support tools for wind and solar farm site selection in Isfahan Province, Iran. *Clean Technologies and Environmental Policy*, *23*(4), 1179–1195. https://doi.org/10.1007/s10098-020-01978-w

Chen, H. H., Kang, H. Y., & Lee, A. H. I. (2010). Strategic selection of suitable projects for hybrid solar-wind power generation systems. *Renewable and Sustainable Energy Reviews*, *14*(1), 413–421. https://doi.org/10.1016/j.rser.2009.08.004

Cunden, T. S. M., Doorga, J., Lollchund, M. R., & Rughooputh, S. D. D. V. (2020). Multi-level constraints wind farms siting for a complex terrain in a tropical region using MCDM approach coupled with GIS. *Energy*, *211*, 118533. https://doi.org/10.1016/j.energy.2020.118533

Demir, A., Dinçer, A. E., & Yılmaz, K. (2023). A novel method for the site selection of large-scale PV farms by using AHP and GIS: A case study in İzmir, Türkiye. *Solar Energy*, *259*(May), 235–245. https://doi.org/10.1016/j.solener.2023.05.031

Effat, H. A., & El-Zeiny, A. M. (2022). Geospatial modeling for selection of optimum sites for hybrid solar-wind energy in Assiut Governorate, Egypt. *Egyptian Journal of Remote Sensing and Space Science*, *25*(2), 627–637. https://doi.org/10.1016/j.ejrs.2022.03.005

Elkadeem, M. R., Younes, A., Sharshir, S. W., Campana, P. E., & Wang, S. (2021a). Sustainable siting and design optimization of hybrid renewable energy system: A geospatial multi-criteria analysis. *Applied Energy*. https://doi.org/10.1016/j.apenergy.2021.117071

Elkadeem, M. R., Younes, A., Sharshir, S. W., Campana, P. E., & Wang, S. (2021b). Sustainable siting and design optimization of hybrid renewable energy system: A geospatial multi-criteria analysis. *Applied Energy*, *295*(May), 117071. https://doi.org/10.1016/j.apenergy.2021.117071

Fardi Asrami, R., Sohani, A., Zamani Pedram, M., & Sayyaadi, H. (2023). An eco-friendly remote sensing assisted development procedure to install renewable energy infrastructure for highest techno-economic gain. *Energy Conversion and Management: X*, *20*(November), 100490. https://doi.org/10.1016/j.ecmx.2023.100490

Genger, T. K., Luo, Y., & Hammad, A. (2021). Multi-criteria spatial analysis for location selection of multi-purpose utility tunnels. *Tunnelling and Underground Space Technology*, *115*(June), 104073. https://doi.org/10.1016/j.tust.2021.104073

Gil-García, I. C., Ramos-Escudero, A., García-Cascales, M. S., Dagher, H., & Molina-García, A. (2022). Fuzzy GIS-based MCDM solution for the optimal offshore wind site selection: The Gulf of Maine case. *Renewable Energy*, *183*, 130–147. https://doi.org/10.1016/j.renene.2021.10.058

González, A., Riba, J. R., & Rius, A. (2015). Optimal sizing of a hybrid grid-connected photovoltaic-wind-biomass power system. *Sustainability (Switzerland)*, *7*(9), 12787–12806. https://doi.org/10.3390/su70912787

Hidayatno, A., Setiawan, A. D., Wikananda Supartha, I. M., Moeis, A. O., Rahman, I., & Widiono, E. (2020). Investigating policies on improving household rooftop photovoltaics adoption in Indonesia. *Renewable Energy*, *156*(2020), 731–742. https://doi.org/10.1016/j.renene.2020.04.106

Holloway, R., Ho, D., Delotavo, C., Xie, W. Y., Rahimi, I., Nikoo, M. R., & Gandomi, A. H. (2023). Optimal location selection for a distributed hybrid renewable energy system in rural Western Australia: A data mining approach. *Energy Strategy Reviews*, *50*(June), 101205. https://doi.org/10.1016/j.esr.2023.101205

Hooshangi, N., Mahdizadeh Gharakhanlou, N., & Ghaffari Razin, S. R. (2023). Evaluation of potential sites in Iran to localize solar farms using a GIS-based Fermatean Fuzzy TOPSIS. *Journal of Cleaner Production*, *384*(October 2022), 135481. https://doi.org/10.1016/j.jclepro.2022.135481

Imam, A. A., Abusorrah, A., & Marzband, M. (2024). Results in Engineering

Potentials and opportunities of solar PV and wind energy sources in Saudi Arabia : Land suitability , techno-socio-economic feasibility , and future variability Internal Rate of Return. *Results in Engineering*, *21*(January), 101785. https://doi.org/10.1016/j.rineng.2024.101785

Jahangiri, M., Rezaei, M., Mostafaeipour, A., Goojani, A. R., Saghaei, H., Hosseini Dehshiri, S. J., & Hosseini Dehshiri, S. S. (2022). Prioritization of solar electricity and hydrogen co-production stations considering PV losses and different types of solar trackers: A TOPSIS approach. *Renewable Energy*, *186*, 889–903. https://doi.org/10.1016/j.renene.2022.01.045

Jain, A., Das, P., Yamujala, S., Bhakar, R., & Mathur, J. (2020). Resource potential and variability assessment of solar and wind energy in India. *Energy*, *211*, 118993. https://doi.org/10.1016/j.energy.2020.118993

Jong, F. C., & Ahmed, M. M. (2024). Novel GIS-based fuzzy TOPSIS and filtration algorithms for extra-large scale optimal solar energy sites identification. *Solar Energy*, *268*(October 2023), 112274. https://doi.org/10.1016/j.solener.2023.112274

Karipoğlu, F., Ozturk, S., & Efe, B. (2023). A GIS-based FAHP and FEDAS analysis framework for suitable site selection of a hybrid offshore wind and solar power plant. *Energy for Sustainable Development*, *77*(June). https://doi.org/10.1016/j.esd.2023.101349

Kartite, J., & Cherkaoui, M. (2019). Study of the different structures of hybrid systems in renewable energies: A review. *Energy Procedia*, *157*(2018), 323–330. https://doi.org/10.1016/j.egypro.2018.11.197

Khan, A. A., Minai, A. F., Pachauri, R. K., & Malik, H. (2022). Optimal Sizing, Control, and Management Strategies for Hybrid Renewable Energy Systems: A Comprehensive Review. *Energies*, *15*(17). https://doi.org/10.3390/en15176249

Lumbantoruan, G., Purba, M. J., Harianja, E. J. G., Nainggolan, R., Perangin-Angin, R., & Manalu, D. (2019). Determines the Weight Criteria of Simple Additive Weighting Method Using Certainty Factor. *2019 International Conference of Computer Science and Information Technology, ICoSNIKOM 2019*. https://doi.org/10.1109/ICoSNIKOM48755.2019.9111539

Martínez-Martínez, Y., Dewulf, J., & Casas-Ledón, Y. (2022). GIS-based site suitability analysis and ecosystem services approach for supporting renewable energy development in south-central Chile. *Renewable Energy*, *182*, 363–376. https://doi.org/10.1016/j.renene.2021.10.008

Moghaddam, H. A., & Shorabeh, S. N. (2022). Designing and implementing a location-based model to identify areas suitable for multi-renewable energy development for supplying electricity to agricultural wells. *Renewable Energy*, *200*(October), 1251–1264. https://doi.org/10.1016/j.renene.2022.10.023

Oksuztepe, E., & Yildirim, M. (2024). PEM fuel cell and supercapacitor hybrid

power system for four in-wheel switched reluctance motors drive EV using geographic information system. *International Journal of Hydrogen Energy*, *xxxx*. https://doi.org/10.1016/j.ijhydene.2023.12.207

Raillani, B., Mezrhab, A., Amraqui, S., Moussaoui, M. A., & Mezrhab, A. (2022). Regression-based spatial GIS analysis for an accurate assessment of renewable energy potential. *Energy for Sustainable Development*, *69*, 118–133. https://doi.org/10.1016/j.esd.2022.06.003

Raza, M. A., Yousif, M., Hassan, M., Numan, M., & Abbas Kazmi, S. A. (2023). Site suitability for solar and wind energy in developing countries using combination of GIS- AHP; a case study of Pakistan. *Renewable Energy*, *206*(May 2022), 180–191. https://doi.org/10.1016/j.renene.2023.02.010

Redaputri, A. P., & Yusuf S Barusman, M. (2021). The analysis of renewable energy management to generate electricity in lampung province Indonesia. *International Journal of Energy Economics and Policy*, *11*(6), 347–352. https://doi.org/10.32479/ijeep.11549

Rehman, A., & Ahmad, W. (2023). Site Selection for Sustainable Wind-Solar Hybrid Energy Harvesting Plant. *International Journal of Academe and Industry Research*, *4*(3), 105–131. https://doi.org/10.53378/353014

Rekik, S., & El Alimi, S. (2023a). Optimal wind-solar site selection using a GIS-AHP based approach: A case of Tunisia. *Energy Conversion and Management: X*, *18*(November 2022), 100355. https://doi.org/10.1016/j.ecmx.2023.100355

Rekik, S., & El Alimi, S. (2023b). Unlocking renewable energy potential: A case study of solar and wind site selection in the Kasserine region, central-western Tunisia. *Energy Science & Engineering*, *November*. https://doi.org/10.1002/ese3.1650

Rezaei, M., Khalilpour, K. R., & Jahangiri, M. (2020). Multi-criteria location identification for wind/solar based hydrogen generation: The case of capital cities of a developing country. *International Journal of Hydrogen Energy*, *45*(58), 33151–33168. https://doi.org/10.1016/j.ijhydene.2020.09.138

Rizka, A., Efendi, S., & Sirait, P. (2018). Gain ratio in weighting attributes on simple additive weighting. *IOP Conference Series: Materials Science and Engineering*, *420*(1). https://doi.org/10.1088/1757-899X/420/1/012099

Rohman, M. Z., Irwansyah, & Sari, W. E. (2020). The Medical Facilities Selection Based on Location-Based Services Application Using SAW and TOPSIS Algorithm. *Journal of Physics: Conference Series*, *1577*(1). https://doi.org/10.1088/1742-6596/1577/1/012012

Rojas-Flores, S., Nazario-Naveda, R., Benites, S. M., Gallozzo-Cardenas, M., Delfín-Narciso, D., & Díaz, F. (2022). Use of Pineapple Waste as Fuel in Microbial Fuel Cell for the Generation of Bioelectricity. *Molecules*, *27*(21). https://doi.org/10.3390/molecules27217389

Roth, A., Boix, M., Gerbaud, V., Montastruc, L., & Etur, P. (2019). A flexible

metamodel architecture for optimal design of Hybrid Renewable Energy Systems (HRES) – Case study of a stand-alone HRES for a factory in tropical island. *Journal of Cleaner Production*, *223*, 214–225. https://doi.org/10.1016/j.jclepro.2019.03.095

Şahin, G., Koç, A., & van Sark, W. (2024). Multi-criteria decision making for solar power - Wind power plant site selection using a GIS-intuitionistic fuzzy-based approach with an application in the Netherlands. *Energy Strategy Reviews*, *51*(November 2023). https://doi.org/10.1016/j.esr.2024.101307

Santana-Sarmiento, F., & Velázquez-Medina, S. (2021). Development of a Territorial Planning Model of Wind and Photovoltaic Energy Plants for Self-Consumption as a Low Carbon Strategy. *Complexity*, *2021*(1). https://doi.org/10.1155/2021/6617745

Sekeroglu, A., & Erol, D. (2023). Site selection modeling of hybrid renewable energy facilities using suitability index in spatial planning. *Renewable Energy*, *219*(P1), 119458. https://doi.org/10.1016/j.renene.2023.119458

Setyani, R. E., & Saputra, R. (2016). Flood-prone Areas Mapping at Semarang City by Using Simple Additive Weighting Method. *Procedia - Social and Behavioral Sciences*, *227*(November 2015), 378–386. https://doi.org/10.1016/j.sbspro.2016.06.089

Shao, M., Han, Z., Sun, J., Xiao, C., Zhang, S., & Zhao, Y. (2020). A review of multi-criteria decision making applications for renewable energy site selection. *Renewable Energy*, *157*, 377–403. https://doi.org/10.1016/j.renene.2020.04.137

Shorabeh, S. N., Firozjaei, H. K., Firozjaei, M. K., Jelokhani-Niaraki, M., Homaee, M., & Nematollahi, O. (2022). The site selection of wind energy power plant using GIS-multi-criteria evaluation from economic perspectives. *Renewable and Sustainable Energy Reviews*, *168*(July), 112778. https://doi.org/10.1016/j.rser.2022.112778

Silalahi, D. F., Blakers, A., Stocks, M., Lu, B., Cheng, C., & Hayes, L. (2021). Indonesia's vast solar energy potential. *Energies*, *14*(17). https://doi.org/10.3390/en14175424

Soares, J., Oliveira, A. C., Dieckmann, S., Krüger, D., & Orioli, F. (2018). Evaluation of the performance of hybrid CSP/ biomass power plants. *International Journal of Low-Carbon Technologies*, *13*(4), 380–387. https://doi.org/10.1093/ijlct/cty046

Syahputra, R., Purwanto, K., & Soesanti, I. (2022). Performance investigation of standalone wind power system equipped with sinusoidal PWM power inverter for household consumer in rural areas of Indonesia. *Energy Reports*, *8*(2022), 4553–4569. https://doi.org/10.1016/j.egyr.2022.03.145

Tarife, R., Nakanishi, Y., Zhou, Y., Estoperez, N., & Tahud, A. (2023). Integrated GIS and Fuzzy-AHP Framework for Suitability Analysis of Hybrid

Renewable Energy Systems: A Case in Southern Philippines. *Sustainability (Switzerland)*, *15*(3). https://doi.org/10.3390/su15032372

Ur Rehman, O., & Ali, Y. (2021). Optimality study of China's crude oil imports through China Pakistan economic corridor using fuzzy TOPSIS and Cost-Benefit analysis. *Transportation Research Part E: Logistics and Transportation Review*, *148*(February), 102246. https://doi.org/10.1016/j.tre.2021.102246

Virgianti, L., Setiawan, A., Tugiyono, & Bakri, S. (2021). Priority Analysis of Regional Rehabilitation Activities Irrigation Way Apu System by using Simple Additive Weighting (SAW) Method. *IOP Conference Series: Earth and Environmental Science*, *1012*(1). https://doi.org/10.1088/1755-1315/1012/1/012008

Waewsak, J., Ali, S., Natee, W., Kongruang, C., Chancham, C., & Gagnon, Y. (2020). Assessment of hybrid, firm renewable energy-based power plants: Application in the southernmost region of Thailand. *Renewable and Sustainable Energy Reviews*, *130*(June), 109953. https://doi.org/10.1016/j.rser.2020.109953

Watson, J. J. W., & Hudson, M. D. (2015). Regional Scale wind farm and solar farm suitability assessment using GIS-assisted multi-criteria evaluation. *Landscape and Urban Planning*, *138*, 20–31. https://doi.org/10.1016/j.landurbplan.2015.02.001

Weschenfelder, F., de Novaes Pires Leite, G., Araújo da Costa, A. C., de Castro Vilela, O., Ribeiro, C. M., Villa Ochoa, A. A., & Araújo, A. M. (2020). A review on the complementarity between grid-connected solar and wind power systems. *Journal of Cleaner Production*, *257*, 120617. https://doi.org/10.1016/j.jclepro.2020.120617