

## Documents

Fayaz, H.<sup>a</sup>, Khan, S.A.<sup>b</sup>, Saleel, C.A.<sup>c</sup>, Shaik, S.<sup>d</sup>, Yusuf, A.A.<sup>e</sup>, Veza, I.<sup>f</sup>, Fattah, I.M.R.<sup>g</sup>, Rawi, N.F.M.<sup>h</sup>, Asyraf, M.R.M.<sup>i</sup>, Alarifi, I.M.<sup>j</sup>

**Developments in Nanoparticles Enhanced Biofuels and Solar Energy in Malaysian Perspective: A Review of State of the Art**

(2022) *Journal of Nanomaterials*, 2022, art. no. 8091576, .

**DOI:** 10.1155/2022/8091576

<sup>a</sup> Modeling Evolutionary Algorithms Simulation and Artificial Intelligence, Faculty of Electrical & Electronics Engineering, Ton Duc Thang University, Ho Chi Minh City, Viet Nam

<sup>b</sup> Department of Mechanical Engineering, Faculty of Engineering, International Islamic University, Kuala Lumpur, Malaysia

<sup>c</sup> Department of Mechanical Engineering, College of Engineering, Khalid University, PO Box 394, Abha, 61421, Saudi Arabia

<sup>d</sup> School of Mechanical Engineering, Vellore Institute of Technology, Tamilnadu, Vellore, 632014, India

<sup>e</sup> Department of Mechanical and Automobile Engineering, Sharda University, Knowledge Park III, UP, Greater Noida, 201310, India

<sup>f</sup> Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal, Melaka, 76100, Malaysia

<sup>g</sup> Centre for Green Technology, Faculty of Engineering and IT, University of Technology Sydney, Ultimo, NSW 2007, Australia

<sup>h</sup> Bioresource Technology Division, School of Industrial Technology, Universiti Sains Malaysia, Penang, 11800, Malaysia

<sup>i</sup> Institute of Energy Infrastructure, Universiti Tenaga Nasional, Jalan IKRAM-UNITEN, Kajang, Selangor, 43000, Malaysia

<sup>j</sup> Department of Mechanical and Industrial Engineering, College of Engineering, Majmaah University, Al-Majmaah, Riyadh, 11952, Saudi Arabia

**Abstract**

The rapid rise in global oil prices, the scarcity of petroleum sources, and environmental concerns have all created severe issues. As a result of the country's rapid expansion and financial affluence, Malaysia's energy consumption has skyrocketed. Biodiesel and solar power are currently two of the most popular alternatives to fossil fuels in Malaysia. These two types of renewable energy sources appear to be viable options because of their abundant availability together with environmental and performance competence to highly polluting and fast depleting fossil fuels. The purpose of adopting renewable technology is to expand the nation's accessibility to a reliable and secure power supply. The current review article investigates nonconventional energy sources added with nanosized metal particles called as nanomaterials including biodiesel and solar, as well as readily available renewable energy options. Concerning the nation's energy policy agenda, the sources of energy demand are also investigated. The article evaluates Malaysia's existing position in renewable energy industries, such as biodiesel and solar, as well as the impact of nanomaterials. This review article discusses biodiesel production, applications, and government policies in Malaysia, as well as biodiesel consumption and recent developments in the bioenergy sector, such as biodiesel property modifications utilizing nanoparticle additions. In addition, the current review study examines the scope of solar energy, different photovoltaic concentrators, types of solar energy harvesting systems, photovoltaic electricity potential in Malaysia, and the experimental setup of solar flat plate collectors (FPC) with nanotechnology. © 2022 H. Fayaz et al.

**Index Keywords**

Biodiesel, Electric power systems, Energy harvesting, Energy policy, Energy utilization, Fossil fuels, Nanoparticles, Nanostructured materials, Solar power generation; 'current, Alternative to fossil fuels, Energy-consumption, Environmental concerns, Malaysia, Malaysians, Oil Prices, Rapid expansion, Renewable energy source, State of the art; Solar energy

**References**

- Energy, G. (2019) *CO2 Status Report*, Paris, France IEA

- Dudley, B.  
*BP Energy Outlook: Report Bp's Energy Outlook*,  
April 2022 <https://www.vcmstudy.ir/wp-content/uploads/2017/04/bp-energy-outlook-2017-presentation-slides.pdf>
- Susskind, L., Chun, J., Goldberg, S., Gordon, J.A., Smith, G., Zaerpoor, Y.  
**Breaking out of carbon lock-in: Malaysia's path to decarbonization**  
(2020) *Frontiers in Built Environment*, 6, p. 21.
- Marikatti, M., Banapurmath, N.R., Yaliwal, V.S., Basavarajappa, Y.H., Soudagar, M.E.M., Márquez, F.P.G., Mujtaba, M.A., El-Seesy, A.I.  
**Hydrogen injection in a dual fuel engine fueled with low-pressure injection of methyl ester of thevetia peruviana (METP) for diesel engine maintenance application**  
(2020) *Energies*, 13 (21), p. 5663.
- Mujtaba, M., Masjuki, H.H., Kalam, M.A., Noor, F., Farooq, M., Ong, H.C., Gul, M., Razzaq, L.  
**Effect of additivized biodiesel blends on diesel engine performance, emission, tribological characteristics, and lubricant tribology**  
(2020) *Energies*, 13 (13), p. 3375.
- Eia  
**Short-term energy outlook**  
(2022) *Energy Information Administration*,
- Outlook, B.P.E.  
**BP statistical review of world energy 2017.2017-18**  
(2017) *British Petroleum.*,
- Administration Us, Ei  
*Annual energy outlook 2018*,  
April 2022 [https://d1wqtxts1xzle7.cloudfront.net/43247432/EIA\\_AEO\\_2010-with-cover-page-v2.pdf](https://d1wqtxts1xzle7.cloudfront.net/43247432/EIA_AEO_2010-with-cover-page-v2.pdf)
- Agency, IEWorld  
(2017) *CO<sub>2</sub> Emissions from Fuel Combustion*,  
OCEDiLibrary
- Agency, I.E.  
(2017) *CO<sub>2</sub> emissions from fuel combustion: Overview (2017 Edition)*,  
Elsevier
- Hockstad, L., Hanel, L.  
(2018) *Inventory of U.S. Greenhouse Gas Emissions and Sinks*,  
United States: N
- Iea  
(2021) *Global energy-related CO<sub>2</sub> emissions by sector, IEA, Paris*,  
<http://www.iea.org/data-and-statistics/charts/global-energy-related-co2-emissions-by-sector>
- Hussain, F., Alshahrani, S., Abbas, M.M., Khan, H.M., Jamil, A., Yaqoob, H., Soudagar, M.E.M., Munir, M.  
**Waste animal bones as catalysts for biodiesel production; a mini review**  
(2021) *Catalysts*, 11 (5), p. 630.

- El-Seesy, A.I., Hassan, H., Ibraheem, L., He, Z., Soudagar, M.E.M.  
**Combustion, emission, and phase stability features of a diesel engine fueled by Jatropha/ethanol blends and n-butanol as co-solvent**  
(2020) *International Journal of Green Energy*, 17 (12), pp. 793-804.
- Khan, T., Soudagar, M.E.M., Khandal, S.V., Javed, S., Mokashi, I., Baig, M.A.A., Ismail, K.A., Elfasakhany, A.  
**Performance of common rail direct injection (CRDi) engine using Ceiba Pentandra biodiesel and hydrogen fuel combination**  
(2021) *Energies*, 14 (21), p. 7142.
- Tahir, M.F., Haoyong, C., Guangze, H.  
**A comprehensive review of 4E analysis of thermal power plants, intermittent renewable energy and integrated energy systems**  
(2021) *Energy Reports*, 7, pp. 3517-3534.
- Teja, K.M.V., Prasad, P., Reddy, K., Banapurmath, N.R., Soudagar, M.E.M., Khan, T.M., Badruddin, I.A.  
**Influence of combustion chamber shapes and nozzle geometry on performance, emission, and combustion characteristics of CRDI engine powered with biodiesel blends**  
(2021) *Sustainability*, 13 (17, ARTICLE 9613).
- Basha, J.S., Jafary, T., Vasudevan, R., Bahadur, J.K., Ajmi, M.A., Neyadi, A.A., Soudagar, M.E.M., Fattah, I.M.R.  
**Potential of utilization of renewable energy technologies in gulf countries**  
(2021) *Sustainability*, 13 (18), p. 10261.
- Tahir, M.F., Chen, H., Khan, A., Javed, M.S., Cheema, K.M., Laraik, N.A.  
**Significance of demand response in light of current pilot projects in China and devising a problem solution for future advancements**  
(2020) *Technology in Society*,
- Lu, X., Chen, S., Nielsen, C.P., Zhang, C., Li, J., Xu, H., Wu, Y., He, K.  
**Combined solar power and storage as cost-competitive and grid-compatible supply for China's future carbon-neutral electricity system**  
(2021) *Proceedings of the National Academy of Sciences of the United States of America*, 118 (42).
- Afgan, N.H., Al Gobaisi, D., Carvalho, M.G., Cumo, M.  
**Sustainable energy development authority**  
(1998) *Renewable and Sustainable Energy Reviews*, 2 (3), pp. 235-286.
- Fayaz, H., Rahim, N.A., Saidur, R., Solangi, K.H., Niaz, H., Hossain, M.S.  
*Solar energy policy: Malaysia vs developed countries*,  
2011 IEEE Conference on Clean Energy and Technology (CET) June 2011 Kuala Lumpur, Malaysia
- Qazi, A., Bhowmik, C., Hussain, F., Yang, S., Naseem, U., Adebayo, A.A., Gumaei, A., Al-Rakhami, M.  
**Analyzing the public opinion as a guide for renewable-Energy status in Malaysia: a case study**  
(2021) *IEEE Transactions on Engineering Management*, pp. 1-15.

- Rakyat, N.  
(2019) *Sustainable Energy, Malaysia, SEDA, Editor*, Malaysia SEDA
- Ölz, S., Beerepoot, M.  
**Deploying renewables in Southeast Asia**  
(2010) *Trends and potentials*,
- Qazi, A., Fayaz, H., Raj, R.G.  
(2014) *Discourse on data mining applications to design renewable energy systems*, Proceedings of International Conference on Advances in Engineering and Technology March 2014 Singapore
- Kumar, S.  
**Assessment of renewables for energy security and carbon mitigation in Southeast Asia: the case of Indonesia and Thailand**  
(2016) *Applied Energy*, 163, pp. 63-70.  
2-s2.0-84947080897
- Razzaq, L., Mujtaba, M.A., Soudagar, M.E.M., Ahmed, W., Fayaz, H., Bashir, S., Fattah, I.M.R., El-Seesy, A.I.  
**Engine performance and emission characteristics of palm biodiesel blends with graphene oxide nanoplatelets and dimethyl carbonate additives**  
(2021) *Journal of Environmental Management*, 33453625
- Akram, N., Sadri, R., Kazi, S.N., Ahmed, S.M., Zubir, M.N.M., Ridha, M., Soudagar, M., Tong, G.B.  
**An experimental investigation on the performance of a flat-plate solar collector using eco-friendly treated graphene nanoplatelets-water nanofluids**  
(2019) *Journal of Thermal Analysis and Calorimetry*, 138 (1), pp. 609-621.
- Akram, N., Sadri, R., Kazi, S.N., Zubir, M.N.M., Ridha, M., Ahmed, W., Soudagar, M.E.M., Arzpeyma, M.  
**A comprehensive review on nanofluid operated solar flat plate collectors**  
(2020) *Journal of Thermal Analysis and Calorimetry*, 139 (2), pp. 1309-1343.
- Khan, H., Soudagar, M.E.M., Kumar, R.H., Safaei, M.R., Farooq, M., Khidmatgar, A., Banapurmath, N.R., Taqui, S.N.  
**Effect of nano-graphene oxide and n-butanol fuel additives blended with diesel - Nigella sativa biodiesel fuel emulsion on diesel engine characteristics**  
(2020) *Symmetry*, 12 (6), p. 961.
- Akram, N., Montazer, E., Kazi, S.N., Soudagar, M.E.M., Ahmed, W., Zubir, M.N.M., Afzal, A., Sarsam, W.S.  
**Experimental investigations of the performance of a flat-plate solar collector using carbon and metal oxides based nanofluids**  
(2021) *Energy*,
- Soudagar, M.E.M., Khan, H.M., Khan, T.M.Y., Razzaq, L., Asif, T., Mujtaba, M.A., Hussain, A., Safaei, M.R.  
**Experimental analysis of engine performance and exhaust pollutant on a single-cylinder diesel engine operated using Moringa Oleifera biodiesel**  
(2021) *Applied Sciences*, 11 (15), p. 7071.

- Hussain, F., Soudagar, M.E.M., Afzal, A., Mujtaba, M.A., Fattah, I.M.R., Naik, B., Mulla, M.H., Rahman, S.M.A.  
**Enhancement in combustion, performance, and emission characteristics of a diesel engine fueled with Ce-ZnO nanoparticle additive added to soybean biodiesel blends** (2020) *Energies*, 13 (17), p. 4578.
- Sateesh, K.A., Yaliwal, V.S., Soudagar, M.E.M., Banapurmath, N.R., Fayaz, H., Safaei, M.R., Elfakhany, A., El-Seesy, A.I.  
**Utilization of biodiesel/Al<sub>2</sub>O<sub>3</sub> nanoparticles for combustion behavior enhancement of a diesel engine operated on dual fuel mode** (2021) *Journal of Thermal Analysis and Calorimetry*,
- Soudagar, M.E.M., Nik-Ghazali, N.N., Kalam, M.A., Badruddin, I.A., Banapurmath, N.R., Bin Ali, M.A., Kamangar, S., Akram, N.  
**An investigation on the influence of aluminium oxide nano-additive and honge oil methyl ester on engine performance, combustion and emission characteristics** (2020) *Renewable Energy*, 146, pp. 2291-2307.
- Afzal, A., Soudagar, M.E.M., Belhocine, A., Kareemullah, M., Hossain, N., Alshahrani, S., Saleel, C., Mujtaba, M.A.  
**Thermal performance of compression ignition engine using high content biodiesels: a comparative study with diesel fuel** (2021) *Sustainability*, 13 (14), p. 7688.
- Gavhane, S., Kate, M.A., Pawar, A., Safaei, M.R., Soudagar, M., Mujtaba, M.E., Abbas, M., Ahmed, W.  
**Effect of zinc oxide nano-additives and soybean biodiesel at varying loads and compression ratios on VCR diesel engine characteristics** (2020) *Symmetry*, 12 (6, ARTICLE 1042).
- Sathish, T., Mohanavel, V., Arunkumar, M., Rajan, K., Soudagar, M.E.M., Mujtaba, M.A., Salmen, S.H., Sivakumar, S.  
**Utilization of Azadirachta indica biodiesel, ethanol and diesel blends for diesel engine applications with engine emission profile** (2022) *Fuel*,
- Halewadimath, S., Banapurmath, N.R., Yaliwal, V.S., Prasad, M.G., Jalihal, S.S., Soudagar, M.E.M., Yaqoob, H., Safaei, M.R.  
**Effect of manifold injection of hydrogen gas in producer gas and neem biodiesel fueled CRDI dual fuel engine** (2022) *International Journal of Hydrogen Energy*,
- Yaliwal, V., Banapurmath, N.R., Soudagar, M.E.M., Afzal, A., Ahmadi, P.  
**Effect of manifold and port injection of hydrogen and exhaust gas recirculation (EGR) in dairy scum biodiesel - low energy content gas-fueled CI engine operated on dual fuel mode** (2022) *International Journal of Hydrogen Energy*, 47 (10), pp. 6873-6897.
- Catarino, M., Ferreira, E., Soares Dias, A.P., Gomes, J.  
**Dry washing biodiesel purification using fumed silica sorbent** (2020) *Chemical Engineering Journal*,

- Soudagar, M.E.M., Nik-Ghazali, N.N., Badruddin, I.A., Kalam, M.A., Kittur, M.I., Akram, N., Ullah, M.A., Mokashi, I.  
**Production of honge oil methyl ester (HOME) and its performance test on four stroke single cylinder VCR engine**  
(2019) *AIP Conference Proceedings*,
- Harari, P., Banapurmath, N.R., Yaliwal, V.S., Soudagar, M.E.M., Khan, T.M.Y., Mujtaba, M.A., Safaei, M.R., El-Seesy, A.I.  
**Experimental investigation on compression ignition engine powered with pentanol and thevetia peruviana methyl ester under reactivity controlled compression ignition mode of operation**  
(2021) *Case Studies in Thermal Engineering*,
- Sanjeevannavar, M.B., Banapurmath, N.R., Soudagar, M.E.M., Atgur, V., Hossain, N., Mujtaba, M.A., Khan, T.Y., Elfasakhany, A.  
**Performance indicators for the optimal BTE of biodiesels with additives through engine testing by the Taguchi approach**  
(2021) *Chemosphere*,
- Soudagar, M.E.M., Mujtaba, M.A., Safaei, M.R., Afzal, A., Ahmed, W., Banapurmath, N.R., Hossain, N., Shahapurkar, K.  
**Effect of Sr@ ZnO nanoparticles and Ricinus communis biodiesel-diesel fuel blends on modified CRDI diesel engine characteristics**  
(2021) *Energy*,
- Ramos, M., Dias, Puna, Gomes, Bordado  
**Biodiesel production processes and sustainable raw materials**  
(2019) *Energies*, 12 (23), p. 4408.
- Chu, M.M.  
(2020) *Malaysia palm oil June end-stocks fall as exports surge 25%*, in *Reuters*,
- Akkoli, K.M., Banapurmath, N.R., Shivashimpi, M.M., Soudagar, M.E.M., Badruddin, I.A., Alazwari, M.A., Yaliwal, V.S., Safaei, M.R.  
**Effect of injection parameters and producer gas derived from redgram stalk on the performance and emission characteristics of a diesel engine**  
(2021) *Alexandria Engineering Journal*, 60 (3), pp. 3133-3142.
- Sawin, J.L., Sverrisson, F., Seyboth, K., Adib, R., Murdock, H.E., Lins, C., Edwards, I., Satzinger, K.  
(2016) *Renewables 2017 global status report*,
- Bala Prasad, K., Meduri, O., Dhana Raju, V., Azmeera, A.K., Venu, H., Subramani, L., Soudagar, M.E.M.  
**Effect of split fuel injection strategies on the diverse characteristics of CRDI diesel engine operated with tamarind biodiesel**  
(2020) *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, pp. 1-19.
- Kareemullah, M., Afzal, A., Rehman, K.F., Kc, V., Khan, H., Soudagar, M.E.M., Kaladgi, A.R.  
**Preparation and physicochemical properties evaluation of epoxidized neem oil-based bio-lubricant**  
(2021) *Australian Journal of Mechanical Engineering*, pp. 1-10.

- Wategave, S., Banapurmath, N.R., Sawant, M.S., Soudagar, M.E.M., Mujtaba, M.A., Afzal, A., Basha, J.S., Sajjan, A.M.  
**Clean combustion and emissions strategy using reactivity controlled compression ignition (RCCI) mode engine powered with CNG-Karanja biodiesel**  
(2021) *Journal of the Taiwan Institute of Chemical Engineers*, 124, pp. 116-131.
- Mujtaba, M.A., Kalam, M.A., Masjuki, H.H., Soudagar, M.E.M., Khan, H.M., Fayaz, H., Farooq, M., Munir, M.  
**Effect of palm-sesame biodiesel fuels with alcoholic and nanoparticle additives on tribological characteristics of lubricating oil by four ball tribo-tester**  
(2021) *Alexandria Engineering Journal*, 60 (5), pp. 4537-4546.
- Razzaq, L., Imran, S., Anwar, Z., Farooq, M., Abbas, M.M., Mehmood Khan, H., Asif, T., Rahman, S.M.A.  
**Maximising yield and engine efficiency using optimised waste cooking oil biodiesel**  
(2020) *Energies*, 13 (22), p. 5941.
- Mujtaba, M.A., Kalam, M.A., Masjuki, H.H., Razzaq, L., Khan, H.M., Soudagar, M.E.M., Gul, M., Ong, H.C.  
**Development of empirical correlations for density and viscosity estimation of ternary biodiesel blends**  
(2021) *Renewable Energy*, 179, pp. 1447-1457.
- Bala Prasad, K., Dhana Raju, V., Ahamad Shaik, A., Gopidesi, R.K., Sreekara Reddy, M.B.S., Soudagar, M.E.M., Mujtaba, M.A.  
**Impact of injection timings and exhaust gas recirculation rates on the characteristics of diesel engine operated with neat tamarind biodiesel**  
(2021) *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, pp. 1-19.
- Atabani, A.E., Silitonga, A.S., Badruddin, I.A., Mahlia, T.M.I., Masjuki, H., Mekhilef, S.  
**A comprehensive review on biodiesel as an alternative energy resource and its characteristics**  
(2012) *Renewable and Sustainable Energy Reviews*, 16 (4), pp. 2070-2093.
- Sharma, Y., Singh, B., Upadhyay, S.  
**Advancements in development and characterization of biodiesel: a review**  
(2008) *Fuel*, 87 (12), pp. 2355-2373.  
2-s2.0-43849102383
- Anuar, M.R., Abdullah, A.Z.  
**Challenges in biodiesel industry with regards to feedstock, environmental, social and sustainability issues: a critical review**  
(2016) *Renewable and Sustainable Energy Reviews*, 58, pp. 208-223.
- Janaun, J., Ellis, N.  
**Perspectives on biodiesel as a sustainable fuel**  
(2010) *Renewable and Sustainable Energy Reviews*, 14 (4), pp. 1312-1320.
- Hirkude, J., Padalkar, A.S.  
**Experimental investigation of the effect of compression ratio on performance and emissions of CI engine operated with waste fried oil methyl ester blend**  
(2014) *Fuel Processing Technology*, 128, pp. 367-375.

2-s2.0-84907357908

- Pugazhvadivu, M., Jeyachandran, K.  
**Investigations on the performance and exhaust emissions of a diesel engine using preheated waste frying oil as fuel**  
(2005) *Renewable Energy*, 30 (14), pp. 2189-2202.
- Hossain, A.K., Davies, P.A.  
**Plant oils as fuels for compression ignition engines: a technical review and life-cycle analysis**  
(2010) *Renewable Energy*, 35 (1), pp. 1-13.
- Varatharajan, K., Cheralathan, M.  
**Influence of fuel properties and composition on NO <sub>x</sub> emissions from biodiesel powered diesel engines: a review**  
(2012) *Renewable and Sustainable Energy Reviews*, 16 (6), pp. 3702-3710.  
2-s2.0-84860263319
- Wu, F., Wang, J., Chen, W., Shuai, S.  
**A study on emission performance of a diesel engine fueled with five typical methyl ester biodiesels**  
(2009) *Atmospheric Environment*, 43 (7), pp. 1481-1485.  
2-s2.0-59349093197
- Hoekman, S.K., Broch, A., Robbins, C., Cenicerros, E., Natarajan, M.  
**Review of biodiesel composition, properties, and specifications**  
(2012) *Renewable and Sustainable Energy Reviews*, 16 (1), pp. 143-169.  
2-s2.0-82355190242
- Lin, B.-F., Huang, J.-H., Huang, D.-Y.  
**Experimental study of the effects of vegetable oil methyl ester on DI diesel engine performance characteristics and pollutant emissions**  
(2009) *Fuel*, 88 (9), pp. 1779-1785.  
2-s2.0-66849115591
- Babu, A.K., Devaradjane, G.  
(2003) *Vegetable oils and their derivatives as fuels for CI engines: an overview*, SAE Technical Paper
- Varatharajan, K., Cheralathan, M.  
**Effect of aromatic amine antioxidants on NO <sub>x</sub> emissions from a soybean biodiesel powered DI diesel engine**  
(2013) *Fuel Processing Technology*, 106, pp. 526-532.  
2-s2.0-84870498591
- Srivastava, A., Prasad, R.  
**Triglycerides-based diesel fuels**  
(2000) *Renewable and Sustainable Energy Reviews*, 4 (2), pp. 111-133.  
2-s2.0-0034209860
- Rao, P.  
**Effect of properties of Karanja methyl ester on combustion and NO<sub>x</sub> emissions of a diesel engine**  
(2011) *Journal of Petroleum Technology and Alternative Fuels*, 2 (5), pp. 63-75.



- Ramadhas, A.S., Jayaraj, S., Muraleedharan, C.  
**Biodiesel production from high FFA rubber seed oil**  
(2005) *Fuel*, 84 (4), pp. 335-340.  
2-s2.0-10844266088
- Mofijur, M., Atabani, A.E., Masjuki, H.H., Kalam, M.A., Masum, B.M.  
**A study on the effects of promising edible and non-edible biodiesel feedstocks on engine performance and emissions production: a comparative evaluation**  
(2013) *Renewable and Sustainable Energy Reviews*, 23, pp. 391-404.  
2-s2.0-84875832002
- Lin, L., Cunshan, Z., Vittayapadung, S., Xiangqian, S., Mingdong, D.  
**Opportunities and challenges for biodiesel fuel**  
(2011) *Applied Energy*, 88 (4), pp. 1020-1031.  
2-s2.0-78650535333
- Knothe, G.  
**Dependence of biodiesel fuel properties on the structure of fatty acid alkyl esters**  
(2005) *Fuel Processing Technology*, 86 (10), pp. 1059-1070.  
2-s2.0-18144385855
- Yoshimoto, Y.  
**Performance and emissions of a diesel engine fueled by biodiesel derived from different vegetable oils and the characteristics of combustion of single droplets**  
(2009) *SAE International Journal of Fuels and Lubricants*, 2 (1), pp. 827-838.  
2-s2.0-77953144990
- Sharma, Y., Singh, B.  
**A hybrid feedstock for a very efficient preparation of biodiesel**  
(2010) *Fuel Processing Technology*, 91 (10), pp. 1267-1273.
- Atabani, A.E., Badruddin, I.A., Badarudin, A., Khayoon, M.S., Triwahyono, S.  
**Recent scenario and technologies to utilize non-edible oils for biodiesel production**  
(2014) *Renewable and Sustainable Energy Reviews*, 37, pp. 840-851.
- Thet, M.Y.O., Kinoshita, E., Tsuru, H., Hamasaki, K.  
(2007) *Combustion characteristics of a DI diesel engine with palm kernel oil biodiesel and its blend (B20)*,  
SAE Technical Paper
- Demirbaş, A.  
**Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: a survey**  
(2003) *Energy Conversion and Management*, 44 (13), pp. 2093-2109.  
2-s2.0-0037411635
- Sanford, S.D., White, J.M., Shah, P.S., Wee, C., Valverde, M.A., Meier, G.R.  
**Feedstock and biodiesel characteristics report**  
(2009) *Renewable Energy Group*, 416, pp. 1-136.
- Allen, C.A., Watts, K.C., Ackman, R.G., Pegg, M.J.  
**Predicting the viscosity of biodiesel fuels from their fatty acid ester composition**  
(1999) *Fuel*, 78 (11), pp. 1319-1326.

- Zullaikah, S., Lai, C.C., Vali, S.R., Ju, Y.H.  
**A two-step acid-catalyzed process for the production of biodiesel from rice bran oil**  
(2005) *Bioresource Technology*, 96 (17), pp. 1889-1896.
- Vijayan, S.K., Naveena Victor, M., Sudharsanam, A., Chinnaraj, V.K., Nagarajan, V.  
**Winterization studies of different vegetable oil biodiesel**  
(2018) *Bioresource Technology Reports*, 1, pp. 50-55.
- Nautiyal, P., Subramanian, K., Dastidar, M.  
**Experimental investigation on performance and emission characteristics of a compression ignition engine fueled with biodiesel from waste tallow**  
(2017) *Clean Technologies and Environmental Policy*, 19 (6), pp. 1667-1677.  
2-s2.0-85017412121
- Sander, A., Koščak, M.A., Kosir, D., Milosavljević, N., Vuković, J.P., Magić, L.  
**The influence of animal fat type and purification conditions on biodiesel quality**  
(2018) *Renewable Energy*, 118, pp. 752-760.
- Suryawanshi, J., Deshpande, N.  
**The effects of combination of EGR, injection retard and injection pressure on emissions and performance of diesel engine fuelled with jatropha oil methyl ester**  
(2006) *ASME 2006 International Mechanical Engineering Congress and Exposition*, 47837, pp. 3-14.
- Sarin, A., Arora, R., Singh, N.P., Sharma, M., Malhotra, R.K.  
**Influence of metal contaminants on oxidation stability of Jatropha biodiesel**  
(2009) *Energy*, 34 (9), pp. 1271-1275.  
2-s2.0-68349146521
- Kandpal, J., Madan, M.  
**Jatropha curcus: a renewable source of energy for meeting future energy needs**  
(1995) *Renewable Energy*, 6 (2), pp. 159-160.  
2-s2.0-0029271878
- Jayed, M., Masjuki, H.H., Kalam, M.A., Mahlia, T.M.I., Husnawan, M., Liaquat, A.M.  
**Prospects of dedicated biodiesel engine vehicles in Malaysia and Indonesia**  
(2011) *Renewable and Sustainable Energy Reviews*, 15 (1), pp. 220-235.  
2-s2.0-78149411936
- Banapurmath, N., Tewari, P., Hosmath, R.  
**Performance and emission characteristics of a DI compression ignition engine operated on Honge, Jatropha and sesame oil methyl esters**  
(2008) *Renewable Energy*, 33 (9), pp. 1982-1988.
- Akbar, E., Yaakob, Z., Kamarudin, S.K., Ismail, M., Salimon, J.  
**Characteristic and composition of Jatropha curcas oil seed from Malaysia and its potential as biodiesel feedstock**  
(2009) *European Journal of Scientific Research*, 29 (3), pp. 396-403.
- Atadashi, I., Aroua, M.K., Abdul Aziz, A.R., Sulaiman, N.M.N.  
**Production of biodiesel using high free fatty acid feedstocks**  
(2012) *Renewable and Sustainable Energy Reviews*, 16 (5), pp. 3275-3285.  
2-s2.0-84858732365

- Nabi, M.N., Rahman, M.M., Akhter, M.S.  
**Biodiesel from cotton seed oil and its effect on engine performance and exhaust emissions**  
(2009) *Applied Thermal Engineering*, 29 (11-12), pp. 2265-2270.
- Özbay, N., Oktar, N., Tapan, N.A.  
**Esterification of free fatty acids in waste cooking oils (WCO): role of ion-exchange resins**  
(2008) *Fuel*, 87 (10-11), pp. 1789-1798.
- Canakci, M., Van Gerpen, J.  
**Biodiesel production from oils and fats with high free fatty acids**  
(2001) *Transactions of the ASAE*, 44 (6), p. 1429.
- Lam, M.K., Lee, K.T., Mohamed, A.R.  
**Homogeneous, heterogeneous and enzymatic catalysis for transesterification of high free fatty acid oil (waste cooking oil) to biodiesel: a review**  
(2010) *Biotechnology Advances*, 28 (4), pp. 500-518.  
2-s2.0-77955684995 20362044
- Ong, H.C., Masjuki, H.H., Mahlia, T.M.I., Silitonga, A.S., Chong, W.T., Leong, K.Y.  
**Optimization of biodiesel production and engine performance from high free fatty acid Calophyllum inophyllum oil in CI diesel engine**  
(2014) *Energy Conversion and Management*, 81, pp. 30-40.
- Martín, C., Moure, A., Martín, G., Carrillo, E., Domínguez, H., Parajó, J.C.  
**Fractional characterisation of jatropha, neem, moringa, trisperma, castor and candlenut seeds as potential feedstocks for biodiesel production in Cuba**  
(2010) *Biomass And Bioenergy*, 34 (4), pp. 533-538.
- Gouveia, L., Oliveira, A.C.  
**Microalgae as a raw material for biofuels production**  
(2009) *Journal of Industrial Microbiology & Biotechnology*, 36 (2), pp. 269-274.  
2-s2.0-59449094424
- Chisti, Y.  
**Biodiesel from microalgae**  
(2007) *Biotechnology Advances*, 25 (3), pp. 294-306.
- Kirubakaran, M., Selvan, V.A.M.  
**A comprehensive review of low cost biodiesel production from waste chicken fat**  
(2018) *Renewable and Sustainable Energy Reviews*, 82, pp. 390-401.  
2-s2.0-85029808145
- Adewale, P., Dumont, M.-J., Ngadi, M.  
**Recent trends of biodiesel production from animal fat wastes and associated production techniques**  
(2015) *Renewable and Sustainable Energy Reviews*, 45, pp. 574-588.  
2-s2.0-84923553902
- Lim, S., Teong, L.K.  
**Recent trends, opportunities and challenges of biodiesel in Malaysia: an overview**  
(2010) *Renewable and Sustainable Energy Reviews*, 14 (3), pp. 938-954.

- Yusoff, M.H.M., Ayoub, M., Jusoh, N., Abdullah, A.Z.  
**The challenges of a biodiesel implementation program in Malaysia**  
(2020) *Processes*, 8 (10, ARTICLE 1244).
- Shankar, A.  
(2021) *Implementation of B20 biodiesel mandate in Sabah, Peninsular Malaysia delayed again*,  
<http://theedgemarkets.com/>
- Wahab, N.A.A.  
(2021) *B20 biodiesel rollout delayed further, now end of 2022*,  
<http://paultan.org/>
- Ahmed, W., Kazi, S.N., Chowdhury, Z.Z., Johan, M.R.B., Mehmood, S., Soudagar, M.E.M., Mujtaba, M.A., Ahmad, M.S.  
**Heat transfer growth of sonochemically synthesized novel mixed metal oxide ZnO+ Al<sub>2</sub>O<sub>3</sub>+ TiO<sub>2</sub>/DW based ternary hybrid nanofluids in a square flow conduit**  
(2021) *Renewable and Sustainable Energy Reviews*,
- Ahmed, W., Kazi, S.N., Chowdhury, Z.Z., Johan, M.R.B., Soudagar, M.E.M., Mujtaba, M.A., Gul, M., Kamangar, S.  
**Ultrasonic assisted new Al<sub>2</sub>O<sub>3</sub>@ TiO<sub>2</sub>- ZnO/DW ternary composites nanofluids for enhanced energy transportation in a closed horizontal circular flow passage**  
(2021) *International Communications in Heat and Mass Transfer*,
- Soudagar, M.E.M., Banapurmath, N.R., Afzal, A., Hossain, N., Abbas, M.M., Haniffa, M.A.C.M., Naik, B., Mubarak, N.M.  
**Study of diesel engine characteristics by adding nanosized zinc oxide and diethyl ether additives in Mahua biodiesel-diesel fuel blend**  
(2020) *Scientific Reports*, 10 (1, ARTICLE 15326).
- Mujtaba, M.A., Cho, H.M., Masjuki, H.H., Kalam, M.A., Farooq, M., Soudagar, M.E.M., Gul, M., Raju, V.D.  
**Effect of alcoholic and nano-particles additives on tribological properties of diesel-palm-sesame-biodiesel blends**  
(2021) *Energy Reports*, 7, pp. 1162-1171.
- Mujtaba, M.A., Kalam, M.A., Masjuki, H.H., Gul, M., Soudagar, M.E.M., Ong, H.C., Ahmed, W., Yusoff, M.  
**Comparative study of nanoparticles and alcoholic fuel additives-biodiesel-diesel blend for performance and emission improvements**  
(2020) *Fuel*,
- Abdelhamid, H.N., Badr, G.  
**Nanobiotechnology as a platform for the diagnosis of COVID-19: a review**  
(2021) *Nanotechnology for Environmental Engineering*, 6 (1), pp. 1-26.
- Soudagar, M.E.M., Nik-Ghazali, N.N., Kalam, M.A., Badruddin, I.A., Banapurmath, N.R., Yunus Khan, T.M., Bashir, M.N., Afzal, A.  
**The effects of graphene oxide nanoparticle additive stably dispersed in dairy scum oil biodiesel-diesel fuel blend on CI engine: performance, emission and combustion characteristics**

(2019) *Fuel*,  
2-s2.0-85071489854

- Jathar, L.D., Ganesan, S., Shahapurkar, K., Soudagar, M.E.M., Mujtaba, M.A., Anqi, A.E., Farooq, M., Safaei, M.R.  
**Effect of various factors and diverse approaches to enhance the performance of solar stills: a comprehensive review**  
(2021) *Journal of Thermal Analysis and Calorimetry*, pp. 1-32.
- Khan, Y., Soudagar, M.E., Kanchan, M., Afzal, A., Banapurmath, N., Akram, N., Mane, S.D., Shahapurkar, K.  
**Optimum location and influence of tilt angle on performance of solar PV panels**  
(2020) *Journal of Thermal Analysis and Calorimetry*, 141 (1), pp. 511-532.
- Fayaz, H., Rahim, N.A., Saidur, R., Hasanuzzaman, M.  
**Techno-economic analysis of evacuated tube solar water heater using F-chart method**  
(2018) *IOP Conference Series: Materials Science and Engineering*,
- Tahir, M.F., Haoyong, C., Guangze, H.  
**Exergy hub based modelling and performance evaluation of integrated energy system**  
(2021) *Journal of Energy Storage*,
- Vaka, M., Walvekar, R., Rasheed, A.K., Khalid, M.  
**A review on Malaysia's solar energy pathway towards carbon-neutral Malaysia beyond Covid'19 pandemic**  
(2020) *Journal of Cleaner Production*,  
32834565
- Abdullah, K.  
**National renewable energy policy and action plan: highlights and updates**  
(2014) *Applied Mechanics and Materials*, 465, pp. 275-279.
- Jpppet  
(2008) *National Renewable Energy Policy and Action Plan*,
- Tahir, M.F., Haoyong, C.  
**Socioeconomic analysis of integrated energy system of China for 2020**  
(2020) *IEEE Systems Journal*, 15 (2), pp. 1979-1988.
- Fayaz, H., Rasachak, S., Shakeel Ahmad, M., Kumar, L., Zhang, B., JeyrajSelvaraj, Mujtaba, M.A., Rasoul Omidvar, M.  
**Improved surface temperature of absorber plate using metallic titanium particles for solar still application**  
(2022) *Sustainable Energy Technologies and Assessments*,
- Sattar, A., Farooq, M., Amjad, M., Saeed, M.A., Nawaz, S., Mujtaba, M.A., Anwar, S., Ali, Q.  
**Performance evaluation of a direct absorption collector for solar thermal energy conversion**  
(2020) *Energies*, 13 (18, ARTICLE 4956).

- Arshad, Z., Khoja, A.H., Shakir, S., Afzal, A., Mujtaba, M.A., Soudagar, M.E.M., Fayaz, H., Saeed, M.  
**Magnesium doped TiO<sub>2</sub> as an efficient electron transport layer in perovskite solar cells**  
(2021) *Case Studies Thermal Engineering*,
- Tahir, M.F., Haoyong, C., Mehmood, K., Ali, N., Bhutto, J.A.  
**Integrated energy system modeling of China for 2020 by incorporating demand response, heat pump and thermal storage**  
(2019) *Ieee Access*, 7, pp. 40095-40108.  
2-s2.0-85065221857
- Taylor, R.A., Phelan, P.E., Otanicar, T.P., Adrian, R., Prasher, R.  
**Nanofluid optical property characterization: towards efficient direct absorption solar collectors**  
(2011) *Nanoscale Research Letters*, 6 (1), pp. 1-11.  
2-s2.0-82655187063
- Hussain, F., Rahman, M.Z., Sivasengaran, A.N., Hasanuzzaman, M.  
**Energy storage technologies**  
*Energy for Sustainable Development*, pp. 125-165.  
Cambridge Academic Press
- Ahmad, S., Ab Kadir, M.Z.A., Shafie, S.  
**Current perspective of the renewable energy development in Malaysia**  
(2011) *Renewable and sustainable energy reviews*, 15 (2), pp. 897-904.
- Sorensen, B.  
(2004) *The origin of renewable energy flows*,  
Cambridge,USA Elsevier Academic Press
- Dawn, S., Tiwari, P.K., Goswami, A.K., Mishra, M.K.  
**Recent developments of solar energy in India: perspectives, strategies and future goals**  
(2016) *Renewable and Sustainable Energy Reviews*, 62, pp. 215-235.
- Belkhode, P.N., Shelare, S.D., Sakhale, C.N., Kumar, R., Shanmugan, S., Soudagar, M.E.M., Mujtaba, M.A.  
**Performance analysis of roof collector used in the solar updraft tower**  
(2021) *Sustainable Energy Technologies and Assessments*,
- Irena, Irea  
(2019) *Renewable Energy and Jobs: Annual Review 2019*,  
United Arab Emirates International Renewable Energy Agency (IRENA)
- Gomesh, N., Daut, I., Irwanto, M., Irwan, Y.M., Fitra, M.  
**Study on Malaysian's perspective towards renewable energy mainly on solar energy**  
(2013) *Energy Procedia*, 36, pp. 303-312.  
2-s2.0-84897520450
- Petinrin, J., Shaaban, M.  
**Renewable energy for continuous energy sustainability in Malaysia**  
(2015) *Renewable and Sustainable Energy Reviews*, 50, pp. 967-981.

- (2020) *Driving national renewable energy agenda with solar roadshow*, Malaysia Sustainable Energy Development Authority
- *The Renewable Energy Roadmap, National Energy Security*, 2012 Conference Closing the Energy Supply-Demand Gap 2012 Malaysia
- (2020) *The World Bank, Source: Global Solar Atlas 2.0, Solar Resource Data: Solargis*,
- Kamath, H.G., Ekins-Daukes, N.J., Araki, K., Ramasesha, S.K.  
**The potential for concentrator photovoltaics: a feasibility study in India**  
(2019) *Progress in Photovoltaics: Research and Applications*, 27 (4), pp. 316-327.  
2-s2.0-85059066885
- Ahmadi, M., Mohammadi, O., Sadeghzadeh, M., Pourfayaz, F., Kumar, R., Lorenzini, G.  
**Exergy and economic analysis of solar chimney in Iran climate: Tehran, Semnan, and Bandar Abbas**  
(2020) *Mathematical Modelling of Engineering Problems*, 7 (1), pp. 55-67.
- Venkatachalam, T., Cheralathan, M.  
**Effect of aspect ratio on thermal performance of cavity receiver for solar parabolic dish concentrator: an experimental study**  
(2019) *Renewable Energy*, 139, pp. 573-581.  
2-s2.0-85062106462
- Ejaz, A., Babar, H., Ali, H.M., Jamil, F., Janjua, M.M., Fattah, I.R., Said, Z., Li, C.  
**Concentrated photovoltaics as light harvesters: outlook, recent progress, and challenges**  
(2021) *Sustainable Energy Technologies and Assessments*,
- Kodama, T.  
**High-temperature solar chemistry for converting solar heat to chemical fuels**  
(2003) *Progress in Energy and Combustion Science*, 29 (6), pp. 567-597.  
2-s2.0-0242364108
- Sierra, C., Vazquez, A.J.  
**High solar energy concentration with a Fresnel lens**  
(2005) *Journal of Materials Science*, 40 (6), pp. 1339-1343.  
2-s2.0-27544483225
- Gallagher, S., Norton, B., Eames, P.  
**Quantum dot solar concentrators: electrical conversion efficiencies and comparative concentrating factors of fabricated devices**  
(2007) *Solar Energy*, 81 (6), pp. 813-821.
- Lovegrove, K., Pye, J.  
**Fundamental principles of concentrating solar power systems**  
(2022) *Concentrating Solar Power Technology*, pp. 4491-4522.  
Elsevier
- Riffat, S., Mayere, A.  
**Performance evaluation of v-trough solar concentrator for water desalination applications**  
(2013) *Applied Thermal Engineering*, 50 (1), pp. 234-244.  
2-s2.0-84866485964

- O'Neill, M.J.  
(1978) *Solar concentrator and energy collection system*,
- Kussul, E.R.N.S.T., Baidyk, T.A.T.I.A.N.A., Makeyev, O.L.E.K.S.A.N.D.R., Lara-Rosano, F.E.L.I.P.E., Saniger, J.M., Bruce, N.E.I.L.  
**Flat facet parabolic solar concentrator with support cell for one and more mirrors**  
(2008) *WSEAS Transactions on Power Systems*, 3 (8), pp. 577-586.
- Bagnall, D.M., Boreland, M.  
**Photovoltaic technologies**  
(2008) *Energy Policy*, 36 (12), pp. 4390-4396.  
2-s2.0-55249123553
- Sharafeldin, M.A., Gróf, G., Mahian, O.  
**Experimental study on the performance of a flat-plate collector using WO<sub>3</sub>/water nanofluids**  
(2017) *Energy*, 141, pp. 2436-2444.
- Sundar, L.S., Singh, M.K., Punnaiah, V., Sousa, A.C.  
**Experimental investigation of Al<sub>2</sub>O<sub>3</sub>/water nanofluids on the effectiveness of solar flat-plate collectors with and without twisted tape inserts**  
(2018) *Renewable Energy*, 119, pp. 820-833.
- Fayaz, H., Ahmad, M.S., Pandey, A.K., Abd Rahim, N., Tyagi, V.V.  
**A novel nanodiamond/zinc nanocomposite as potential counter electrode for flexible dye sensitized solar cell**  
(2020) *Solar Energy*, 197, pp. 1-5.
- Rehman, Q., Khan, A.D., Khan, A.D., Noman, M., Ali, H., Rauf, A., Ahmad, M.S.  
**Super absorption of solar energy using a plasmonic nanoparticle based CdTe solar cell**  
(2019) *RSC Advances*, 9 (59), pp. 34207-34213.
- Labeckas, G., Slavinskas, S., Mažeika, M.  
**The effect of ethanol-diesel-biodiesel blends on combustion, performance and emissions of a direct injection diesel engine**  
(2014) *Energy Conversion and Management*, 79, pp. 698-720.
- Afzal, A., Ansari, Z., Alshahrani, S., Raj, A.K., Saheer Kuruniyan, M., Ahamed Saleel, C., Nisar, K.S.  
**Clustering of COVID-19 data for knowledge discovery using c-means and fuzzy c-means**  
(2021) *Results in Physics*,  
34513577
- Sharath, B.N., Venkatesh, C.V., Afzal, A., Aslfattahi, N., Aabid, A., Baig, M., Saleh, B.  
**Multi ceramic particles inclusion in the aluminium matrix and wear characterization through experimental and response surface-artificial neural networks**  
(2021) *Materials (Basel)*, 14 (11), p. 2895.  
34071305
- Jilte, R., Afzal, A., Islam, M.T., Manokar, A.M.  
**Hybrid cooling of cylindrical battery with liquid channels in phase change material**  
(2021) *International Journal of Energy Research*, 45 (7), pp. 11065-11083.



- Afzal, A., Saleel, C.A., Suvanjan, K.P., Mohammed, B.  
**Parallel finite volume method - based fluid flow computations using OpenMP and CUDA applying different schemes**  
(2021) *Journal of Thermal Analysis and Calorimetry*, 145 (4), pp. 1891-1909.
- Meignanamoorthy, M., Ravichandran, M., Mohanavel, V., Afzal, A., Sathish, T., Alamri, S., Khan, S.A., Saleel, C.A.  
**Microstructure, mechanical properties, and corrosion behavior of boron carbide reinforced aluminum alloy (Al-Fe-Si-Zn-Cu) matrix composites produced via powder metallurgy route**  
(2021) *Materials*, 14 (15), p. 4315.  
34361508
- Samyilingam, L., Aslfattahi, N., Saidur, R., Mohd, S., Afzal, A.  
**Solar Energy materials and solar cells thermal and energy performance improvement of hybrid PV/T system by using olein palm oil with MXene as a new class of heat transfer fluid**  
(2020) *Solar Energy Materials & Solar Cells*,
- Benoudina, B., Attia, M.E.H., Driss, Z., Afzal, A., Manokar, A.M., Sathyamurthy, R.  
**Enhancing the solar still output using micro/nano-particles of aluminum oxide at different concentrations: an experimental study, energy, exergy and economic analysis**  
(2021) *Sustainable Materials and Technologies*,
- Prasad, A.R., El, M., Attia, H., Al-Kouz, W., Afzal, A., Athikesavan, M.M.  
**Energy and exergy efficiency analysis of solar still incorporated with copper plate and phosphate pellets as energy storage material**  
(2021) *Environmental Science and Pollution Research*, 28 (35), pp. 48628-48636.  
33913110
- Attia, M.E.H., Driss, Z., Kabeel, A.E., Afzal, A., Manokar, A.M.  
**Phosphate bed as energy storage materials for augmentation of conventional solar still productivity**  
(2021) *Environmental Progress & Sustainable Energy*, pp. 1-9.
- Jilte, R., Afzal, A., Panchal, S.  
**A novel battery thermal management system using nano-enhanced phase change materials**  
(2021) *Energy*,
- Murugan, M., Saravanan, A., Elumalai, P.V., Kumar, P., Ahamed Saleel, C., Samuel, O.D., Setiyo, M., Afzal, A.  
**An overview on energy and exergy analysis of solar thermal collectors with passive performance enhancers**  
(2022) *Alexandria Engineering Journal*, 61 (10), pp. 8123-8147.

**Correspondence Address**

Alarifi I.M.; Department of Mechanical and Industrial Engineering, Al-Majmaah, Saudi Arabia; email: i.alarifi@mu.edu.sa

**Publisher:** Hindawi Limited

**ISSN:** 16874110

**Language of Original Document:** English

**Abbreviated Source Title:** J. Nanomater.

2-s2.0-85131373220

**Document Type:** Review

**Publication Stage:** Final  
**Source:** Scopus

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