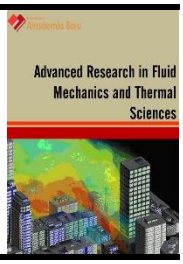
Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



A Model Identifying Factors Affecting the Sustainable Use of Solar Dryers: A Case Study

Open Access

Ali Mostafaeipour[1,*], Mojgan Zarezade[1], Joshuva Arockia Dhanraj[2]

[1] Industrial Engineering Department, Yazd University, Yazd, Iran
[2] Department of Mechanical Engineering, Hindustan Institute of Technology and Science, Chennai, India

ARTICLE INFO

Article history:
Received 29 January 2020
Received in revised form 5 May 2020
Accepted 8 May 2020
Available online 31 July 2020

ABSTRACT

Solar energy has been used to preserve agricultural products which require drying through a consistent application of relatively low heat. In the present study, the feasibility of implementation the solar dryer system in the city of Yazd in Iran is evaluated by examining the effective factors. By identifying factors which may somehow affect the design, construction and operation of solar drying systems, a questionnaire was prepared and distributed. Among the results of the analysis, six main factors were identified: "performance," "geographical location," "infrastructures," "interactions," "financial support" and "social, cultural and political issues." According to the results obtained from factor analysis and with Structural Equations Modelling (SEM) method, a model was introduced. Subsequently, the final model was developed with the use of path analysis method and with AMOS. Based on the final model, the three factors of infrastructures (with the coefficient of 0.44), interactions and cultural, social and political issues (both with the coefficient of 0.12) directly affect the possibility of implementing the solar dryer in Yazd. According to the proposed model, it was concluded that authorities should mainly focus their attentions on finance, science, economy and infrastructures to develop and promote use of solar drying systems.

Keywords:
Solar dryer; structural equations modelling (SEM); path analysis; sustainability; Yazd city

1. Introduction

With the growing expansion of the world, energy consumption has also increased. Fossil fuels currently supply most of the energy in the world. Fossil fuel consumption causes numerous environmental risks and repercussions. Thus recently, global attention has been focused on the development of the use of new and renewable energy resources, including nuclear energy, solar energy, hydroelectric energy, geothermal energy and wind energy [1]. Various studies have been conducted around the world regarding new energies and the development and promotion of related

* *Corresponding author:*
E-mail address: mostafaei@yazd.ac.ir

https://doi.org/10.37934/arfmts.73.2.1219

systems. Among the renewable energies, solar energy is a clean and completely free energy resource that may be a good alternative to fossil fuels. Factor analysis is an effective method explaining and quantifying the complex relationships in variety of fields [2] which could also be used in renewable energy areas. Many research works have been done about different kinds of renewable energies by author for the development and application of renewables [3-9].

In this study, factors which may in some way affect the progress of projects related to the construction and operation of solar drying systems of the city of Yazd in Iran have been identified and modeled using SEM method and AMOS software. Structural equation modeling is a multivariate statistical technique that examines the relationships among a number of variables at the same time; this method is actually a combination of factor analysis and path analysis methods [10]. In this study, factors are identified and then the relationships between the identified factors and the possibility of implementing solar dryers in the city of Yazd and also the internal relations among the factors have been provided in the format of a final version.

2. Geographic Characteristics

As can be seen from Figure 1, Yazd province is located in central Iran and is in a good location in terms of solar radiation, so that the solar radiation received on the horizontal surface of the city of Yazd, the capital of Yazd province, has been reported approximately 7787 MJ/m^2 per year [11].

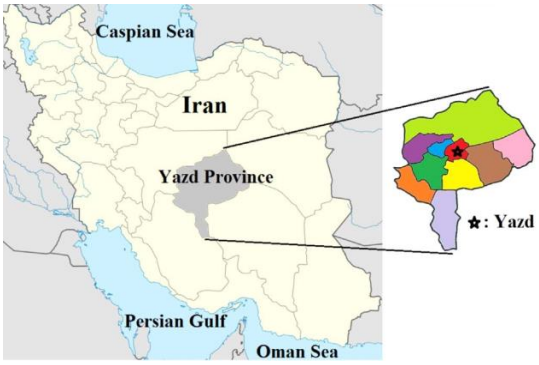


Fig. 1. Location of Yazd province

3. Solar Dryers

Drying foodstuffs in order to preserve them over long periods of time has long been customary among people. In agricultural countries, there are a lot of losses after harvesting, especially during peak harvest in which there are surplus products, this excess cannot be stored for a long time and is wasted as a result [12]. The loss of agricultural products in developing countries is estimated at approximately 30-40% [13]. Many of these products have high initial moisture and, consequently, if their moisture stays at the same level, they are subject to rapid decline in quality and even perishing [14]. For thousands of years, farmers spread their crops outdoors in the sun for drying them. Although this trend saves energy because of its use of the free and sustainable solar energy, yet it has shortcomings as well, including the fact that this method depends on weather conditions and that products might be destroyed by unexpected wind and rain or might fail due to decomposition or be attacked by pests, insects, birds or animals. In addition, this process is very arduous and costly and requires a large surface area to spread products, there is no control over the drying process and the time required for the products to dry is often long [14,15-17]. Implementing renewable energy is very important for many countries in the world, because of the global warming, environmental

hazards, and many other adverse effects of using fossil fuels. There have been numerous research works using different kinds of renewable energies [18-23].

4. Structural Equation Modelling (SEM)

This section discusses Structural equation modelling is a multivariate technique and a combination of factor analysis and path analysis; with this method, the correlational relationships between independent and dependent variables can simultaneously be evaluated [10]. With SEM method, the causal relationships between structures with multiple items and also the measured features of the structures can be examined. SEM often has application in the social sciences and is used extensively in literature. The reasons for the expansive use of SEM can be summarized as such: SEM clearly studies measurement error in the observed variables of a model, is successful in testing complex models, provides the possibility of doing several analyses simultaneously, presents the model layout again based on structural relationships of the model and the model output offered by it is highly accurate [24].

In SEM, the research focuses mainly on the structural model rather than the model measurement. In this method, each structure can be evaluated with conformity assessment of the model. Factor analysis and path analysis in SEM are actually conducted simultaneously. In this method, basically, the relationships between the two types of variables, the main variables (MV) and the latent variables (LV), are examined [25]. Jahangiri *et al.,* [26] investigated location optimization of using hybrid wind-solar systems in Qatar. Rezaei *et al.,* [27] analysed a hybrid wind-solar system for seven locations in Fars province of Iran. There have been numerous research works related to different kinds of renewable energy sources [28-34]. Kian and Che Sidik [35] did a research on designing a solar updraft tower power plant (SUTPP) which found that the system was suitable for remote regions. Hashim and Che Sidik [36] investigated heat transfer in an asphalt solar which their study concluded that high amount of heat would be collected.

The main variables can be directly observed due to their characteristics, while latent variables cannot be directly observed and explain the relationships between the main variables. The structural equation modelling involves all the LVs and the interrelations between them.

5. Analysis

5.1 Validity and Reliability

In this study, the reliability of the questionnaire was evaluated by calculating Cronbach's alpha coefficient with SPSS software. Cronbach's alpha coefficient was calculated 0.789 for the whole questionnaire indicating the reliability of the questionnaire. Required sample size according to Cochran's formula is estimated equal to 144.

Content validity of the questionnaire was confirmed by specialists and experts and validity of the questionnaire was also verified using confirmatory factor analysis method with SPSS software; among the 20 proposed indicators/items, 6 factors were identified as effective factors that explain 51.258% of the overall questionnaire and, among the 12 proposed indicators/items, 3 factors were identified for risks that explain 52.032% of the whole questionnaire. According to opinion of experts, many factors were introduced, but important factors were identified and were analysed for this study. Based on the results obtained from factor analysis, it can be concluded that in the classification of factors affecting the implementation of solar dryers in Yazd, six general factors can be identified, which consist of: “performance”, “geographical location”, “infrastructures”, “interactions”, “financial support”, and “social, cultural and political issues”.

Factors affecting the implementation of solar drying system in Yazd were identified using confirmatory factor analysis method. Thus, to ensure the suitability of conducting factor analysis method for each of the factors, the KMO criterion and Bartlett's test were used. After ensuring the appropriateness of using factor analysis method, factor loadings and coefficients of its constituent components were calculated and analysed for each component.

5.2 Structural Equation Modelling

This Based on the identified factors of the factor analysis, a few hypotheses are taken into account. The hypotheses intended to build an initial model in this research are

- Hypothesis 1: The performance of solar dryers directly affects the possibility of implementing solar dryers in Yazd. In this hypothesis, the solar dryer performance is meant the quality of the dried crops and the drying rate.
- Hypothesis 2: Geographical location and environmental issues directly affect the possibility of implementing solar dryers in Yazd. Solar radiation and climate change are among the effective factors constructing the components of geographic location and environmental issues.
- Hypothesis 3: Finance, economy, science, technology and infrastructures directly affect the advancement of projects related to the solar dryer.
- Hypothesis 4: Interactions and behaviour of authorities have a direct effect on the implementation of solar drying systems in the city of Yazd. In making this hypothesis, the presence of competition, manufacturing experience and executive management are among the effective factors constructing the component of interactions.
- Hypothesis 5: Financial support of solar drying projects directly affects the progress of the relevant project. The allocation of loans by banks and also the funds assigned by the government to investment in solar projects are among the factors constructing the component of financial support in this hypothesis.
- Hypothesis 6: Cultural, social and political issues directly affect the implementation of solar drying systems.

Next, in order to evaluate the intended hypotheses, a model is built. The proposed initial model is shown schematically in Figure 2. Coefficients shown in Figure 2 are calculated based on the obtained factor from factor analysis. As follows, the proposed model will be further discussed. For this purpose, AMOS software is used. In this evaluation, in each path, the regression coefficient of that path is examined, so that the null hypothesis of the regression coefficient is tested against the non-zero regression coefficient. In case of effectiveness of the path, the value of the standard estimates shows the effect of the related path. The review of the research model paths is presented in Table 1.

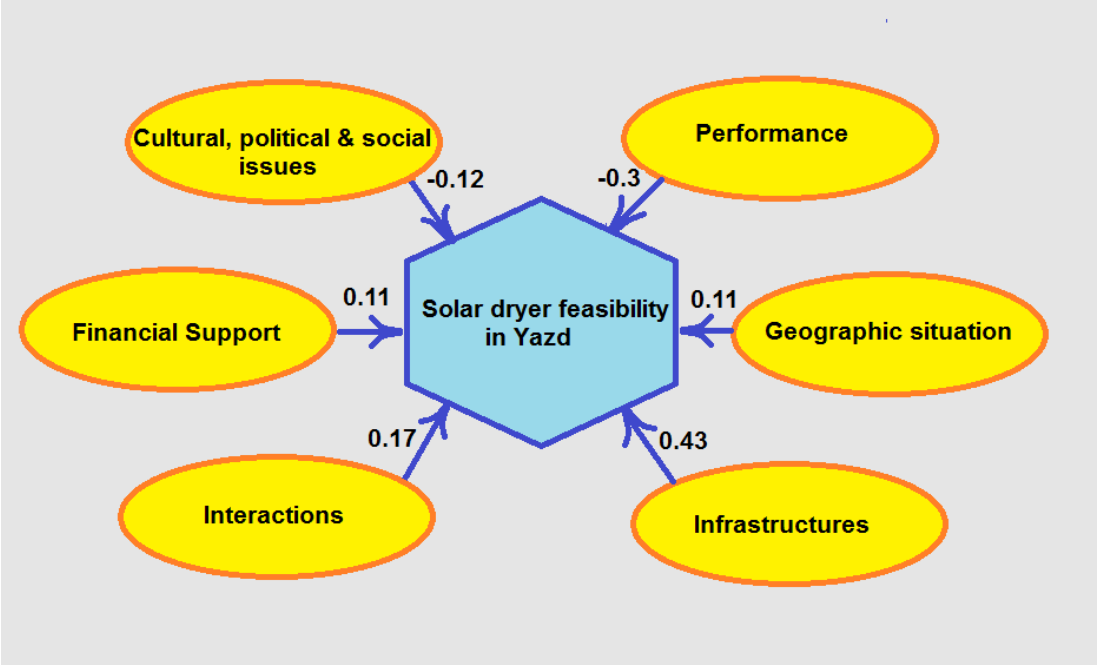


Fig. 2. Primary model

Table 1
The values of Reynolds number and velocity

Result	Significance Level	C.R.	Standard Error S.E.	Standard Estimation	Hypothesis
Rejection	0.503	-0.670	0.45	-0.34	performance ---> possibility of implementing solar dryers
	0.031	2.162	0.45	0.112	Geographical location and environmental issues ---> possibility of implementing solar dryers
	***	8.297	0.45	0.428	Finance, economy, science, technology, and infrastructures ---> possibility of implementing solar dryers
	0.001	3.189	0.45	0.165	Interactions ---> possibility of implementing solar dryers
	0.024	-2.257	0.45	-0.117	Financial support ---> possibility of implementing solar dryers
	0.036	2.098	0.45	0.110	Cultural, social and political issues ---> possibility of implementing solar dryers

After the elimination of the rejected paths from the initial model and doing several trial and errors in modelling and determining their fit, the final modified model is obtained. The final modified model is approved since all values of significance probability in the appraised paths are less than 0.05 and thus all the defined paths are accepted. From the final model (Figure 3), it can be inferred that among the factors affecting the possibility of implementing solar dryers in Yazd, the factor of finance, economy, science, technology and infrastructures with the coefficient of 0.44 has the highest effect on the possibility of implementing the solar dryer (dependent variable). Next to that, the factors of interactions and cultural, social and political issues (with the coefficient of 0.12) directly affect the possibility of implementing the solar dryer in Yazd. The rest of the factors do not directly affect the implementation of the solar dryer, yet have a role in this matter through affecting the other factors.

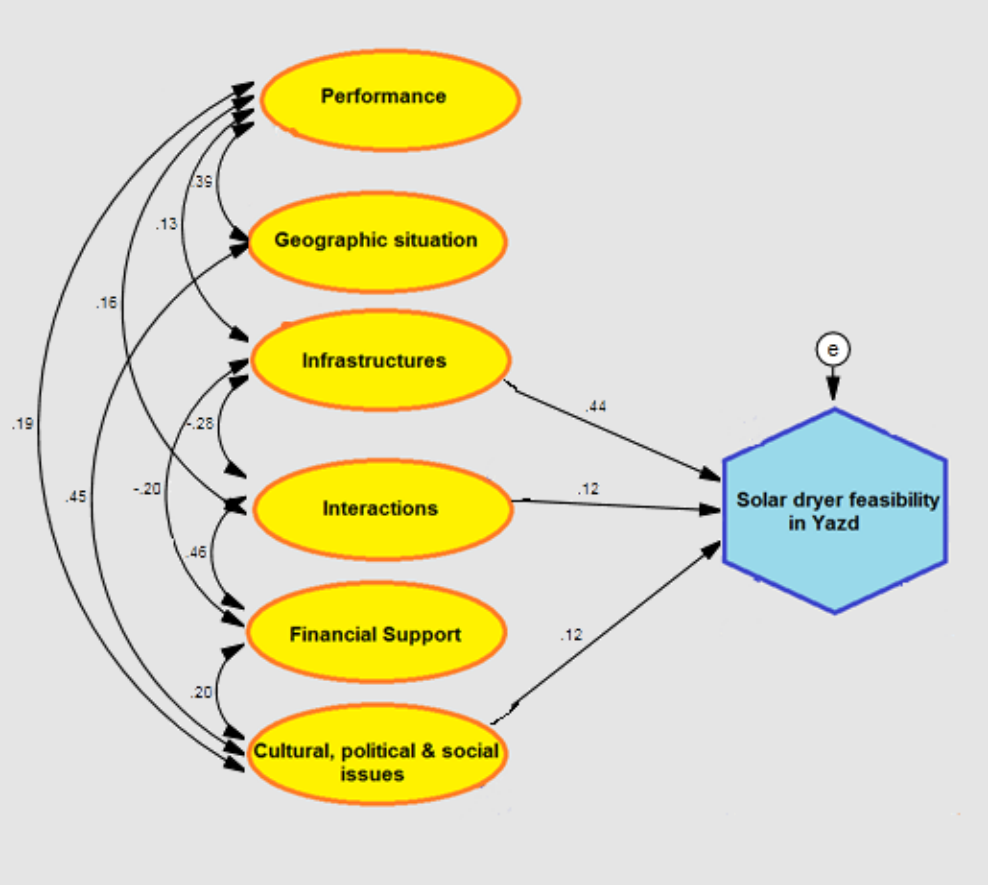


Fig. 3. Final model

6. Conclusion

Considering the numerous environmental consequences and hazards followed by the use of fossil fuels, global attention has been focused on developing and promoting the use of a variety of renewable energies. By identifying factors which may somehow affect the design, construction and operation of solar drying systems, a questionnaire was prepared and distributed among a small sample of the statistical population, involving the residents of the city of Yazd. According to the results obtained from factor analysis and with SEM method, a model was introduced to determine the relationships between the identified factors and the feasibility of implementing the solar dryer. The proposed model was appraised using the goodness of fit criteria. Subsequently, the final model was created with the use of path analysis method and with AMOS software by doing trial and errors. Based on the final model, the three factors of infrastructures (with the coefficient of 0.44), interactions and cultural, social and political issues (both with the coefficient of 0.12) directly affect the possibility of implementing the solar dryer in Yazd. The remaining factors do not directly affect the implementation of the solar dryer, but play a role in this respect by affecting the other factors. According to the proposed model, authorities should mainly focus their attention on finance, science, economy and infrastructures to develop and promote solar drying systems.

References

[1] Panwar, N. L., S. C. Kaushik, and Surendra Kothari. "Role of renewable energy sources in environmental protection: A review." *Renewable and sustainable energy reviews* 15, no. 3 (2011): 1513-1524. https://doi.org/10.1016/j.rser.2010.11.037

[2] Li, Guijun, Daohan Huang, Chengshuang Sun, and Yulong Li. "Developing interpretive structural modeling based on factor analysis for the water-energy-food nexus conundrum." *Science of The Total Environment* 651 (2019): 309-322.
https://doi.org/10.1016/j.scitotenv.2018.09.188
[3] Sedaghat, Ahmad, Arash Hassanzadeh, Jamaloddin Jamali, Ali Mostafaeipour, and Wei-Hsin Chen. "Determination of rated wind speed for maximum annual energy production of variable speed wind turbines." *Applied energy* 205 (2017): 781-789.
https://doi.org/10.1016/j.apenergy.2017.08.079
[4] Goudarzi, Hossein, and Ali Mostafaeipour. "Energy saving evaluation of passive systems for residential buildings in hot and dry regions." *Renewable and Sustainable Energy Reviews* 68 (2017): 432-446.
https://doi.org/10.1016/j.rser.2016.10.002
[5] Ramazankhani, Mohammad-Ebrahim, Ali Mostafaeipour, Hasan Hosseininasab, and Mohammad-Bagher Fakhrzad. "Feasibility of geothermal power assisted hydrogen production in Iran." *International Journal of Hydrogen Energy* 41, no. 41 (2016): 18351-18369.
https://doi.org/10.1016/j.ijhydene.2016.08.150
[6] Rezaei-Shouroki, Mostafa, Ali Mostafaeipour, and Mojtaba Qolipour. "Prioritizing of wind farm locations for hydrogen production: A case study." *International Journal of Hydrogen Energy* 42, no. 15 (2017): 9500-9510.
https://doi.org/10.1016/j.ijhydene.2017.02.072
[7] Mohammadi, Kasra, Ali Mostafaeipour, Yagob Dinpashoh, and Nima Pouya. "Electricity generation and energy cost estimation of large-scale wind turbines in Jarandagh, Iran." *Journal of Energy* 2014 (2014): 1-9.
https://doi.org/10.1155/2014/613681
[8] Zarezade, Mojgan, and Ali Mostafaeipour. "Identifying the effective factors on implementing the solar dryers for Yazd province, Iran." *Renewable and Sustainable Energy Reviews* 57 (2016): 765-775.
https://doi.org/10.1016/j.rser.2015.12.060
[9] Fereidooni, Mojtaba, Ali Mostafaeipour, Vali Kalantar, and Hossein Goudarzi. "A comprehensive evaluation of hydrogen production from photovoltaic power station." *Renewable and Sustainable Energy Reviews* 82 (2018): 415-423.
https://doi.org/10.1016/j.rser.2017.09.060
[10] Sadeghpour B, Moradi V. "Statistical analysis using SPSS and AMOS software." Mazandaran university publication. Mazandaran, Iran, 2011.
[11] Wilberforce, Tabbi, Ahmad Baroutaji, Zaki El Hassan, James Thompson, Bassel Soudan, and Abdul Ghani Olabi. "Prospects and challenges of concentrated solar photovoltaics and enhanced geothermal energy technologies." *Science of The Total Environment* 659 (2019): 851-861.
https://doi.org/10.1016/j.scitotenv.2018.12.257
[12] Stiling, James, Simon Li, Pieter Stroeve, Jim Thompson, Bertha Mjawa, Kurt Kornbluth, and Diane M. Barrett. "Performance evaluation of an enhanced fruit solar dryer using concentrating panels." *Energy for sustainable development* 16, no. 2 (2012): 224-230.
https://doi.org/10.1016/j.esd.2012.01.002
[13] El-Sebaii, A. A., and S. M. Shalaby. "Solar drying of agricultural products: A review." *Renewable and Sustainable Energy Reviews* 16, no. 1 (2012): 37-43.
https://doi.org/10.1016/j.rser.2011.07.134
[14] Sharma, Atul, C. R. Chen, and Nguyen Vu Lan. "Solar-energy drying systems: A review." *Renewable and sustainable energy reviews* 13, no. 6-7 (2009): 1185-1210.
https://doi.org/10.1016/j.rser.2008.08.015
[15] Ferreira, André G., Cristiana B. Maia, Márcio FB Cortez, and Ramón M. Valle. "Technical feasibility assessment of a solar chimney for food drying." *Solar Energy* 82, no. 3 (2008): 198-205.
https://doi.org/10.1016/j.solener.2007.08.002
[16] Saleh, A., and I. Badran. "Modeling and experimental studies on a domestic solar dryer." *Renewable Energy* 34, no. 10 (2009): 2239-2245.
https://doi.org/10.1016/j.renene.2009.03.001
[17] Forson, F. K., M. A. A. Nazha, F. O. Akuffo, and H. Rajakaruna. "Design of mixed-mode natural convection solar crop dryers: Application of principles and rules of thumb." *Renewable Energy* 32, no. 14 (2007): 2306-2319.
https://doi.org/10.1016/j.renene.2006.12.003
[18] Mostafaeipour, Ali, Mohammad Saidi-Mehrabad, Mostafa Rezaei, and Mojtaba Qolipour. "The ranking of southern ports and islands of Iran for seawater desalination plants using ELECTRE III method." *Journal of Renewable Energy and Environment* 4, no. 2&3 (2017): 10-22.

[19] Mostafaeipour, Ali, Mohammad Saidi Mehrabad, Mojtaba Qolipour, Mohadese Basirati, Mostafa Rezaei, and Amir Mohammad Golmohammadi. "Ranking locations based on hydrogen production from geothermal in Iran using the Fuzzy Moora hybrid approach and expanded entropy weighting method." *Journal of Renewable Energy and Environment* 4, no. 4 (2017): 9-21.
[20] Mostafaeipour, Ali, Mojtaba Qolipour, and Hossein Goudarzi. "Feasibility of using wind turbines for renewable hydrogen production in Firuzkuh, Iran." *Frontiers in Energy* 13, no. 3 (2019): 494-505. https://doi.org/10.1007/s11708-018-0534-6
[21] Jahangiri, Mehdi, Ahmad Haghani, Akbar Alidadi Shamsabadi, Ali Mostafaeipour, and Luis Martin Pomares. "Feasibility study on the provision of electricity and hydrogen for domestic purposes in the south of Iran using grid-connected renewable energy plants." *Energy Strategy Reviews* 23 (2019): 23-32. https://doi.org/10.1016/j.esr.2018.12.003
[22] Jahangiri, Mehdi, Ahmad Haghani, Ali Mostafaeipour, Adel Khosravi, and Heidar Ali Raeisi. "Assessment of solar-wind power plants in Afghanistan: A review." *Renewable and Sustainable Energy Reviews* 99 (2019): 169-190. https://doi.org/10.1016/j.rser.2018.10.003
[23] Mostafaeipour, Ali, Mojtaba Qolipour, Mostafa Rezaei, and Erfan Babaee-Tirkolaee. "Investigation of off-grid photovoltaic systems for a reverse osmosis desalination system: A case study." *Desalination* 454 (2019): 91-103. https://doi.org/10.1016/j.desal.2018.03.007
[24] Kaya, Funda, and Mehmet Marangoz. "Brand Attitudes of Entrepreneurs as a Stakeholder towards a City." *Procedia-Social and Behavioral Sciences* 150 (2014): 485-493. https://doi.org/10.1016/j.sbspro.2014.09.060
[25] Xiong, Bo, Martin Skitmore, and Bo Xia. "A critical review of structural equation modeling applications in construction research." *Automation in construction* 49 (2015): 59-70. https://doi.org/10.1016/j.autcon.2014.09.006
[26] Jahangiri, Mehdi, Akbar Alidadi Shamsabadi, Ali Mostafaeipour, Mostafa Rezaei, Yasaman Yousefi, and Luis Martin Pomares. "Using fuzzy MCDM technique to find the best location in Qatar for exploiting wind and solar energy to generate hydrogen and electricity." *International Journal of Hydrogen Energy* 45 (2020): 13862-13875. https://doi.org/10.1016/j.ijhydene.2020.03.101
[27] Rezaei, Mostafa, Ali Mostafaeipour, Mojtaba Qolipour, and Reza Tavakkoli-Moghaddam. "Investigation of the optimal location design of a hybrid wind-solar plant: A case study." *International journal of hydrogen energy* 43, no. 1 (2018): 100-114. https://doi.org/10.1016/j.ijhydene.2017.10.147
[28] Forootan, Marziyeh, Bahram Hosseinzadeh Samani, Amin Lotfalian, Sajad Rostami, Zahra Esmaeili, and Marziyeh Ansari Samani. "Assessment of Environmental Impacts and Energy of Biodiesel Production from Chicken Fat by Life Cycle Assessment Method." *Journal of Renewable Energy and Environment* 6, no. 3 (2019): 25-33.
[29] Gholami, Ashkan, Aryan Tajik, Shahab Eslami, and Majid Zandi. "Feasibility Study of Renewable Energy Generation Opportunities for a Dairy Farm." *Journal of Renewable Energy and Environment* 6, no. 2 (2019): 8-14.
[30] Barzanooni, Narges, and Hamid Reza Haghgou. "Designing and Application of Solar Active Systems for Hakim Sabzevari University: A Case Study of the Dining Hall." *Journal of Renewable Energy and Environment* 6, no. 1 (2019): 1-7.
[31] Rezagholizadeh, Mahdieh, Majid Aghaei, and Omid Dehghan. "Foreign direct investment, stock market development, and renewable energy consumption: Case study of Iran." *Journal of Renewable Energy and Environment* 7, no. 2 (2020): 8-18.
[32] Hosseinpour, Saeed, Seyed Alireza Haji Seyed Mirza Hosseini, Ramin Mehdipour, Amir Hooman Hemmasi, and Hassan Ali Ozgoli. "Energy Modeling and Techno-Economic Analysis of a Biomass Gasification-CHAT-ST Power Cycle for Sustainable Approaches in Modern Electricity Grids." *Journal of Renewable Energy and Environment* 7, no. 2 (2020): 43-51.
[33] Roohi, Reza, Alireza Bahramian, and Sepideh Samghani. "Numerical Simulation of the Freezing Process in Geothermal Boreholes Using Solar Heat Injection." *Journal of Renewable Energy and Environment* 5, no. 4 (2018): 40-45.
[34] Ameri, Mohammad, and Keivan Salimi. "Techno-Economic and Life-Cycle Cost Assessment of the CCHP/PV Hybrid System Application." *Journal of Renewable Energy and Environment* 4, no. 4 (2017): 1-8.
[35] Kinan, A., and NA Che Sidik. "Experimental studies on small scale of solar updraft power plant." *Journal of Advanced Research Design* 22, no. 1 (2016): 1-12.
[36] Hashim, Ghasaq Adheed, and NA Che Sidik. "Numerical study of harvesting solar energy from small-scale asphalt solar collector." *Journal of Advanced Research Design* 2, no. 1 (2014): 10-19.