Development of a Structural Equation Model for Studying the Renewable Energy Acceptance in Universitary Students

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***Abstract*—** The development of energy generation projects from renewable sources (wind, geothermal, hydro, tidal, solar, biomass and biofuels) in Europe and North America, allow you to see the potential and large environmental, socio-cultural and economic benefits that are derived from its implementation. The paper presents a structural equation modeling (SEM) to evaluate the variables that most influenced the acceptance of renewable energy sources. Was used a representative sample of 243 university students of the Politécnico Jaime Isaza Cadavid in Medellin, Colombia. The sample was selected considering a margin of error of 5 % and a confidence level of 90 %, the size of the population was 2464 students. The results Sphericity Kaiser-Meyer-Olkin (KMO) test and Bartlett's test, indicated that the factorial analysis is adequate, all the constructs are statistically significant. The goodness-of-fit test indicated that the model fits well with the data. This paper concludes that, of all the constructs considered: use, utility, government support and training, the construct that most influences the latent variable adaptability is the use. The construct that most influences the latent variable perception is the government support. An improvement in the results of both constructs contributes to an improvement in the acceptance of renewable energy sources.

***Keywords*—**economic, renewable energy, structural equation modeling, students, statistics.

I. Introduction

RENEWABLE energy sources have the potential to play an important role in providing energy with sustainability to the vast populations in developing countries who as yet have no access to clean energy [1]. Although economically viable for several applications, renewable energy has not been able to realize its potential due to several barriers to its penetration. A framework has been developed in this paper to identify the barriers to renewable energy penetration and to suggest measures to overcome them [1]. The application of renewable energy sources might modify not only the background system, but also further downstream aspects, such as consumer behavior. This effect is, however, strongly context and technology dependent [2].

This paper presents the development of a structural equation model (SEM), which seeks to examine the variables and factors that influence the acceptance, implementation and use of renewable energy sources in university students belonging to the Politécnico Jaime Isaza Cadavid in Medellin, Colombia. Five constructs were considered: use, utility, government support, training and two latent variables were used: adaptability and perception. It is important to know people's perception on the use of renewable energy sources, since the development and financial support by the government and non-governmental entities is going to rely directly on the good perception and acceptance that have the same. In the rest of the paper presents a general contextualization on renewable energy sources (wind, geothermal, hydraulic, tidal, solar, biomass and biofuel), the methodology used and the analysis of the results. Finally, the study concludes.

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II. Renewable Energy

Over the past few decades, renewable energy has gained momentum at the global level with a significant impact on sustainable development [3]. The renewable energies investment and climate change mitigation varies a considerably according to political ideologies or priorities and thus varies both in time and by country [4]. The growing demand for energy increases fossil fuels imports from countries rich in natural gas and oil, which involve economic costs [5]. Political and economic problems and challenges of supplier countries are a source of uncertainty and risk in energy supply and the increasing dependence on foreign energy sources could lead to rivalry by deciding who gets control over global energy resources that could escalate to a military confrontation [6]. The main renewable power sources are:

-*Wind*: in the last decade this renewable power source has been increasing rapidly worldwide due to fossil energy depletion and environmental pollution. According to the Global Wind Energy Association, the global wind power installed capacity is 486.66 GW by the end of 2016 [7].

-*Geothermal*: this energy for electricity generation has been produced commercially since 1913, and for four decades on the scale of hundreds of MW both for electricity generation and direct use [8]. The utilization has increased rapidly during the last three decades. In 2000, geothermal resources have been identified in over 80 countries and there are quantified

records of geothermal utilization in 58 countries in the world. The worldwide use of geothermal energy amounts to 49 TWh/a of electricity and 53 TWh/a for direct use. Electricity is produced with geothermal steam in 21 countries spread over all continents. Five countries obtain 10–22% of their electricity from geothermal energy [8].

-*Hydraulic*: this resources are fully optimized to match their full generation hours with high demand hours [9]. This is produced by the water which is stored in reservoirs and lakes at a high altitude. If at a given moment it falls to a lower level, this energy is transformed into kinetic energy and afterwards into electrical energy in the hydroelectric plant [9].

-*Tidal*: this renewable power source has a greatest advantage over other alternative energy sources is that it is almost entirely independent of the weather and hence, although it is variable, it is also predictable [10]. Tidal movements can be used in the same way as flowing water to generate power using barrages and turbines. This is achieved by building a barrage across a tidal estuary so that water can be trapped behind as the tide flows out. This creates a head of water that can be used to drive turbines [10].

-*Solar*: this is one of the best sources of renewable energy because of its inexhaustible nature and easy implementation [11]. Solar energy is a clean, abundant and easily accessible renewable energies [12]. This received at the earth's surface has been calculated as equivalent to 178 000 TW-year. In 1990, it was estimated that this amount was 15 000 times greater than the overall consumption. However, about 30% of this energy is reflected in the space, 50% is absorbed, converted into heat and forwarded to the earth's surface; from this 50 %, 49 000 TW-year are forwarded as heat energy in the form of electromagnetic radiation and 40 000 TW-year as caloric energy.

-*Biomass*: the development and utilization of biomass energy can help to change the ways of energy production and consumption and establish a sustainable energy system that can effectively promote the development of the national economy and strengthen the protection of the environment [13].

-*Biofuel*: is a clean renewable fuel due to its properties, which is similar to diesel but generated from renewable resources such as vegetable oils, animal fats and energy crops [14]. Table 1 and Table 2, presents a general comparison of the main renewable power sources where: High (3), Medium (2) and Low (1).

Table 1. Renewable power sources - Part I

Cost and application criteria	Solar		Wind	Tidal
	Collector	PV		
Initial investment cost	1	3	3	3
Use cost	1	1	1	1
Maintenance cost	1	2	2	3
Waste cost	2	3	1	3
Ease of application	2	2	3	1
Ease of use	1	1	1	1
Ease of Maintenance	2	2	2	3

Source: adapted from [15]

Table 2. Renewable power sources - Part II

Geothermal	Hydroelectric	Biomass	Biofuel
High	2	3	3
Low	1	2	3
Low	3	3	2
Medium	3	3	3
Medium	1	3	2
Medium	1	2	3
High	2	3	3

Source: adapted from [15]

III. METHODOLOGY

SEMs are often formulated using a pre-specified parametric structural equation and uses latent and estimated variables to determine the relationship of entire networks between variables [17]. We used multivariate statistical techniques; regression and factor analysis in the statistical software STATA 15. The analysis SEM is composed of two models; a measurement model and a structural model in which specifies the relationship between the latent and observable variables [17]. Through a set of statistical tests of goodness of fit (adjustment index index of comparative CIF, Tucker Lewis, RMSEA and coefficient of determination - CD), discusses how well it adapts the model to the data later to assess the direct and indirect effects between the latent variables and independent [17].

In this paper, we analyzed the relationships between four constructs (use, utility, government support and training) and two latent variables (adaptability and perception), which enable you to analyze students' attitudes about the use and deployment of renewable energy sources in the development of day-to-day activities.

Was used a database that met the responses from a survey on the use and deployment of renewable energy sources. The survey was applied to a representative sample of 243 active students (72% men and 28% women) of engineering programs of the Politécnico Jaime Isaza Cadavid, Medellin, Colombia. The sample was selected considering a margin of error of 5 % and a confidence level of 90 %, the size of the population was 2464 students.

$$n = \frac{Z^2(p*q)}{e^2 + \frac{(Z^2(p*q))}{N}}$$

Where:

n: sample size, Z: confidence level, p: proportion of the population with the desired characteristic, q: proportion of the population without the desired characteristic, e: error level willing to commit, N: population size.

Figure 1 and Figure 2, presents the description of each variable used in the development of the model (SEM). These were measured in a Likert scale where 5: strongly agree, 4: something in accordance, 3: neither agree nor disagree, 2: something in disagreement, 1: and 0: strongly disagree [18].

Question	Variable	Construct
Do you think that it is easy and viable implement renewable energies in your home	AA1	Use (AA)
Do you think that would have drawbacks when deploying renewable energies in your home	AA2	
Do you think that the implementation of renewable energies will allow you to perform their jobs and daily activities of an easier and more efficient manner	AB1	Utility (AB)
Believes that renewable energy sources are useful in your working life	AB2	
Believes that the implementation of renewable energies will allow you to improve your quality of life	AB3	
Believes that the Government encourages the use and deployment of renewable energy, such as alternative energy sources, endeavor to prevent the development and care of the planet	AC1	Government Support (AC)
Do you think that the national government should promote the implementation and use of renewable energy sources in the processes carried out in all sectors of the economy (commercial, financial, educational, cultural, industrial, construction, manufacturing, agricultural, livestock, mining, fishing, etc.)	AC2	
Perceived that people would be in favor of granting a greater use to renewable energy sources in their daily activities if they receive support from the government	AC3	
Perceived that people value renewable energy sources as a useful tool in your daily life	AD1	Training (AD)
Do you think that people should receive further training to use renewable energy sources as practical tools in the development of day-to-day activities	AD2	

Figure 1. Observed variables

Question	Variable	Construct
Believes that you would enjoy more work and the development of day-to-day activities if you could perform them with renewable energy sources	AE1	Adaptability (AE)
Believes that incorporate work experiences by means of renewable energy sources in the day-to-day activities would be a pleasant experience	AE2	
Believes that those closest to me would be willing to use renewable energy sources for development of their activities	AF1	Perception (AF)
You would use renewable energy sources such as alternative tools for the development of activities if my colleagues do the same	AF2	
It considers that the mass media influence the use of renewable energy sources in the development of daily activities	AF3	

Figure 2. Latent variables

IV. RESULTS

Table 3 and Table 4, presents the results of the Kaiser Meyer Olkin (KMO) test, any KMO is below 0.5, which is why it can be said that factor analysis is valid. The evidence of sphericity rejected at any level of significance considering the results of the Bartlett's sphericity test, the matrix of correlations is not an identity matrix [17].

Table 3. Results of KMO and Bartlett's sphericity test - Part I

		AA	AB	AC
Measurement of sample adequacy of Kaiser - Meyer - Olkin (KMO)		,689	,500	,500
Approximate Chi square		269,125	29,832	123,521
Bartlett's sphericity test	gl	3	1	1
	sig	,000	,000	,000

Source: author elaboration

Table 4. Results of KMO and Bartlett's sphericity test - Part II

		AD	AE	AF
Measurement of sample adequacy of Kaiser - Meyer - Olkin (KMO)		,642	,500	,500
Approximate Chi square		108,526	27,452	39,541
Bartlett's sphericity test	3	1	1	1
	,000	,000	,000	,000

Source: author elaboration

In the construction of the SEM model was used the builder tool of the statistical software STATA 15. Was developed an analysis of main components of four constructs (use, utility, government support and training), which helped reduce its dimensions to only one variable (Figure 3):

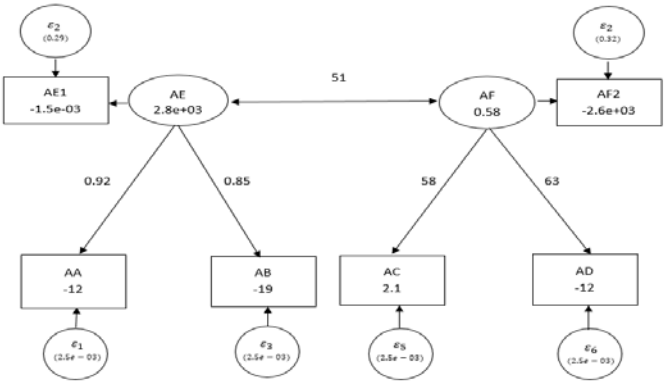

Figure 3: SEMs– Renewable energy acceptation

Table 5, presents the results of the goodness of fit test: Comparative Fit Index (CFI) and Tucker Lewis Index (TLI), which take values of 0.958 and 0,918 respectively, results that indicate a good fit. Finally, the Coefficient of determination was 0.957, is approaching 1 that indicates a good fit. The lower and upper limits of the statistic RMSEA are 0,048 and 0.15 respectively, which indicates that the setting is good. These results allow us to conclude that, the SEMs model developed is properly adjusted to data and explains the phenomenon.

Table 5. Goodness-of-fit statistics of the estimated model

Fit statistic	Value	Description
Population error		
RMSEA	0.079	Root mean squared
90 % CI, lower bound	0.048	error of approximation
Upper bound	0.15	
p close	0.041	
		Probability RMSEA <= 0,05
Information criteria		
AIC	16725.525	Akaike's information criterion
BIC	16795.241	Bayesian information criterion
Baseline comparison		
CFI	0.958	Comparative fit index
TLI	0.918	Tucker-Levis index
Size of residuals		
SRMR	0.038	Standardized root mean squared residual
CD	0.957	Coefficient of determination

Source: author elaboration

All the signs of the coefficients of the slopes are positive, indicating a strong and direct correlation between the latent variables and constructs [17]. Improvements in the qualifications of the constructs will improve the adaptability and perception in the implementation of renewable energy sources, which are the two latent variables of the model. On the latent variable adaptability, the construct that has greater influence is the use, whose coefficient is 0.92. For its part, the construct that affects most on the latent variable perception is the training with a coefficient of 63. There is a direct relationship between the two latent variables (adaptability and perception), which was estimated with a covariance of 51, indicating that both variables are strongly correlated.

V. Conclusion

The structural equation model (SEM) developed allows identifies the influence of the constructs; use, utility, government support, training, adaptability and perception on the acceptance of renewable energy sources. The model identified a positive relationship and direct link between the four constructs and the two latent variables considered (adaptability and perception), which allows affirm that an increase in the indicators that compose the constructs will improve the acceptance of renewable energy sources in the students of the Politécnico Jaime Isaza Cadavid. It has also identified a strong correlation and direct link between the two latent variables (adaptability and perception), for which an increase or decrease in any of them, will generate the same effect in the other.

References

[1] M. Pehnt, "Dynamic life cycle assessment (LCA) of renewable energy technologies," Renew. Energy, vol. 31, no. 1, pp. 55–71, 2006.

[2] M. Y. Recalde, D. H. Bouille, and L. O. Girardin, "Limitaciones para el desarrollo de energías renovables en argentina," Probl. Desarro., vol. 46, no. 183, pp. 89–115, 2015.

[3] T. N. Sequeira and M. S. Santos, "Renewable energy and politics: A systematic review and new evidence," J. Clean. Prod., vol. 192, pp. 553–568, 2018.

[4] M. Pacesila, S. G. Burcea, and S. E. Colesca, "Analysis of renewable energies in European Union," Renew. Sustain. Energy Rev., vol. 56, pp. 156–170, 2016.

[5] S. Karaganov, "A New Epoch of Confrontation," Russ. Glob. Aff., vol. 5, no. 4, pp. 23–36, 2007.

[6] G. Ren, J. Wan, J. Liu, D. Yu, and L. Söder, "Analysis of wind power intermittency based on historical wind power data," Energy, vol. 150, pp. 482–492, 2018.

[7] I. B. Fridleifsson, "Geothermal energy for the benefit of the people," Renew. Sustain. Energy Rev., vol. 5, no. 3, pp. 299–312, 2001.

[8] D. Azofra, E. Martínez, E. Jiménez, J. Blanco, and J. C. Saenz-Díez, "Comparison of the influence of biomass, solar-thermal and small hydraulic power on the Spanish electricity prices by means of artificial intelligence techniques," Appl. Energy, vol. 121, pp. 28–37, 2014.

[9] G. Rajgor, "Tidal developments power forward," Renew. Energy Focus, vol. 17, no. 4, pp. 147–149, 2016.

[10] L. Photovoltaic, S. Energy, and S. America, "Development of Large Photovoltaic Solar Energy Projects in South America," J. Eng. Technol., vol. 2, no. 2, pp. 34–48, 2013.

[11] P. K. Chawdhry, "Potential Applications of Renewable Energy Sources Exergetic Analysis of Solar Thermal Energy as a Primary Source of India," vol. 10, no. 1, pp. 34–40, 2015.

[12] G. Mao, N. Huang, L. Chen, and H. Wang, "Research on biomass energy and environment from the past to the future: A bibliometric analysis," Sci. Total Environ., vol. 635, pp. 1081–1090, 2018.

[13] M. Acaroğlu and H. Aydoğan, "Biofuels energy sources and future of biofuels energy in Turkey," Biomass and Bioenergy, vol. 36, pp. 69–76, 2012.

[14] EnergyFive, "What are Renewable Energy Sources?" Clean Energy, 2017. [Online]. Available: https://energyfive.net/2017/10/06/what-are-renewable-energy-sources/. [Accessed: 25-Aug-2018].

[15] Y. Q. Zhang, G. L. Tian, and N. S. Tang, "Latent variable selection in structural equation models," J. Multivar. Anal., vol. 152, pp. 190–205, 2016.

[16] A. Valencia Arias, G. Gonzalez Uribe, and M. Castaneda Riascos, "Structural equation model for studying the mobile-learning acceptance," IEEE Lat. Am. Trans., vol. 14, no. 4, pp. 1988–1992, 2016.

[17] [O. D. Duncan and M. Stenbeck, "Are Likert scales unidimensional?" Soc. Sci. Res., vol. 16, no. 3, pp. 245–259, 1987.

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