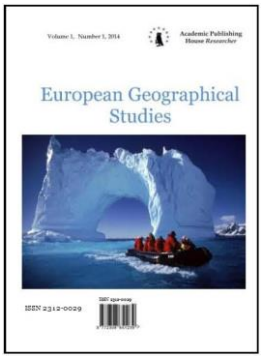
Published in the Slovak Republic
European Geographical Studies
Has been issued since 2014.
ISSN: 2312-0029
E-ISSN: 2413-7197
2017, 4(2): 61-69

DOI: 10.13187/egs.2017.2.61
www.ejournal9.com



Articles and Statements

Exploring the Relationship between Energy Consumption and Socio-Economic Criteria based on Sensitivity Analysis

Soufiane Boukarta [a, b, *]

[a] Institut d'architecture et d'urbanisme, université de Blida 1, Algeria
[b] Laboratoire Ville, Urbanisme et Développement Durable (VUDD), Ecole Polytechnique d'Architecture et d'Urbanisme (EPAU), Algeria

Abstract

This paper aims to give more understanding reasons of the energy implication of the socio-economic criteria in an arid and semi-arid climate zone based on a statistical approach. The paper considers the yearly Gas and electricity energy consumption (2013) of the municipalities of the department of Djelfa. The method is organised in three steps; (a) A multiple linear regression is used to perform two estimative models of Gas and Electricity. The models performed have more than 99 % of accuracy for both models. (b) Estimating Gas and energy consumption for 2008 according to the developed models. (c) Organisation of the census Data of 2008 in six dimensions: The structural dimension of the municipal territory, population characteristics and activities, dwelling typology and occupancy and finally the households' appliance possession. (d) A set of sensitivity analysis is performed based on Principal Component Analysis (PCAs) and Pearson's bi-variate correlation. The results show globally that the socio-economic criteria are reducing the energy consumption by – 11.3 % the Gas consumption while it increases the Electricity consumption by 2.7 %. The most important factors reducing Electricity consumption are population activities and dwelling occupancy while all the six socio-economic dimensions are reducing gas consumption.

Keywords: energy consumption, Statistical approach, sensitivity analysis, socio-economic criteria, energy potential saving.

1. Introduction

The energy consumption in the world has, as never, been a crucial problematic. The population around the world is increasing and the energy demand and consumption are increasing as well. The priority of the entire world summits is given to the energy saving by implementing a several policies to reduce the energy consumption and carbon footprint emissions.

Algeria since 1985 has founded the APRUE to elaborate methods and tools to rationalise the energy demand and consumption in all the sectors. APRUE (Aprue, 2012) shows that the residential

* Corresponding author
E-mail addresses: sofiansasse@gmail.com (S. Boukarta)

building is the most consumer sector in Algeria with a consumption of 41 %. The Algerian energy policy (Bouamama, 2013) is made within several strategies. We can enumerate 4:

The first strategy aims to prepare architects and engineers to be able to assess the energy demand by introducing a set of formation in universities, schools and institutes as well. Also, APRUE and GIZ have developed a project interpreted in two ways; (a) a guide-book (GIZ, 2015) containing the different strategies aiming to reduce the energy consumption in building according to their climate zone. The guide is distributed for free by APRUE. The guide book is how ever very ambitious because it proposes for example a U value of 0.25 to 0.5 w/m².k for walls. These values are considered in the industrial countries. The guide book has no power to constrain architects or engineer to respect its orientations. (b) The second way is to make online the actual thermal regulation of Algeria. The web-site is reta.cder.de (Reta, 2015) and it contains an easy method to assess the building energy efficiency based on the quality of the envelope within a static method.

The second strategy is interpreted by pilot project in different climate zone. The main orientation is to improve insulation level of the considered buildings. Some conclusions show a gap between the studied project and the realisation. This conclusion highlights the crucial role of monitoring in this kind of project.

The third strategy aims to communicate the rationalisation of the energy consumption beside consumers. A several media spots are broadcasted on Radio and television. This spots aims to give some orientation on how to use rationally the heater or the air conditioner.

The fourth strategy is based on supporting the use of renewable energy by the consumers. The government supports 50 % of the use of the natural Gas in cars, and 45 % is also supported by the government to acquire solar water heater. From 2016, the government helps also households to improve the insulation of their housing. An ambition of 100 000 housing per year to insulate is fixed by the government. Which is noticeable here is the weak spreading of this program and it is due to the weak supporting media.

The strategies supported by the government don't take into account the importance of the urban realm implication in the energy demand and consumption. We (Boukarta, 2016, Boukarta et Berezowska, 2017, Boukarta et Berezoska-Azzag, 2017) have shown within the case of Algiers the implication of the density in both electricity and gas consumption. The density explains – 56 and – 65 % respectively the gas and electricity consumption.

In this paper, we aim to highlight within a holistic approach the socio-economic criteria implication in the Gas and electricity consumption in the residential buildings.

2. Materials and methods

To be able to assess the socio-criteria implication in the energy demand in arid and semi-arid climate zone, we have adopted a statistical-based approach. The energy consumption has been acquired from Sonelgaz (ONS, 2013), the firm in charge to invoice the energy consumption in Algeria. We have got the energy consumption of all the municipalities of Djelfa, for Gas and Electricity for the year of 2013. Based on this data of 2013, we can't use the census Data of 2008 (ONS, 2008). To overpass this gap we have performed two estimative models to be able to estimate the energy consumption of both electricity and Gas for the year of 2008. The models are performed based on a multivariate linear regression. For the Gas consumption, the model considers the number of subscribers linked to the gas and electricity network, the number of the population living in secondary agglomeration and the density. The model is performed with an R^2 of 99.7 %.

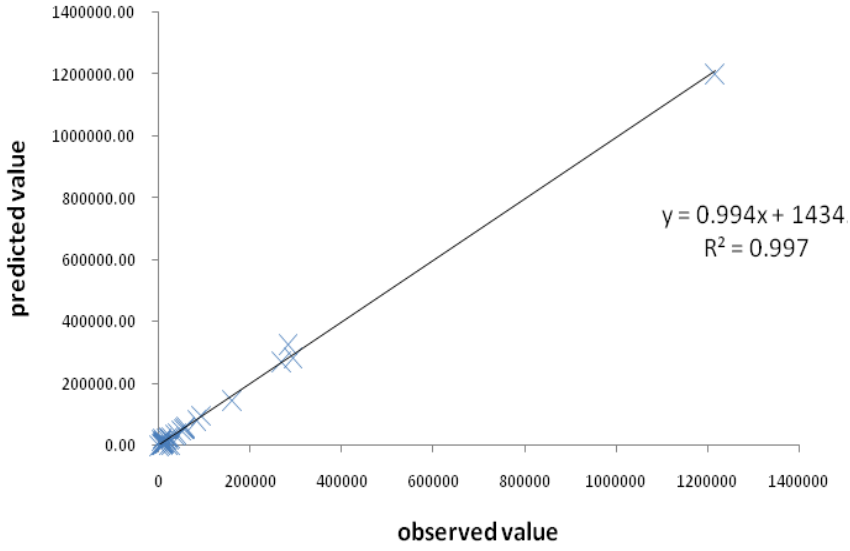


Fig. 1. Accuracy of the gas model

Table 1. Gas model summary

Model	Unstandardized Coefficients		Standardized Coefficients	Sig.
	B	Std. Error	Beta	
(Constant)	10968,596	4465,951		,020
subs_gas_13	63,596	5,803	2,276	,000
subs_ele_13	-31,895	5,136	-1,246	,000
density_2013	-106,610	27,930	-,076	,001
Sec_agglo_2013	3,315	1,379	,037	,022

The electricity model is also performed with an accuracy of 99.2 %. The model considers only the number of subscribers of both, Gas and Electricity (see the figure and table below).

Based on these two models, we have estimated the energy consumption for the year of 2008 by introducing in the models the number of subscribers of Gas, Electricity of 2008, the density and the number of the population living in secondary agglomeration of 2008.

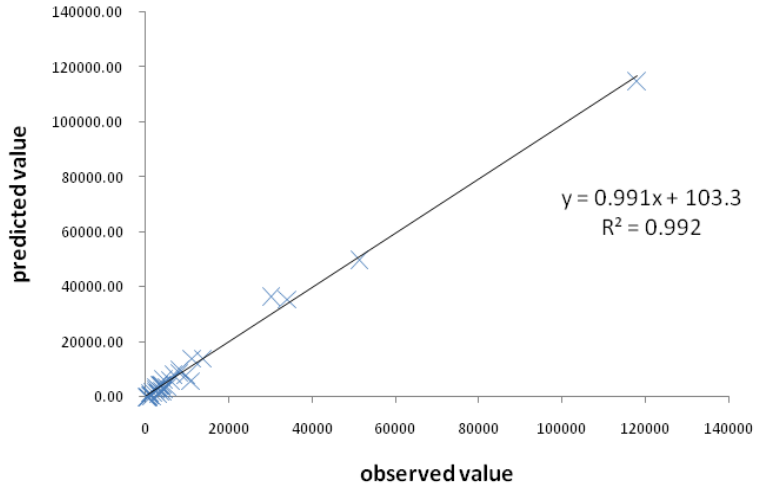


Fig. 2. Accuracy of the Electricity model

Table 2. Gas model summary

Model	Unstandardized Coefficients		Standardized Coefficients	Sig.
	B	Std. Error	Beta	
(Constant)	-1086,976	494,001		,035
subs_ele_13	4,395	,627	1,697	,000
subs_gas_13	-1,988	,684	-,704	,007

2.1 Managing census Data:

In Algeria, "The General Census of Population and Housing" is carried out by the government every ten years to collect information about population and their housing. Getting the energy consumption for the Gas and Electricity allows us to get more understanding reasons from the socio-economic parameters obtained from the 2008 census Data, which presents a large panel of potential determinants able to decrease or increase the energy demand.

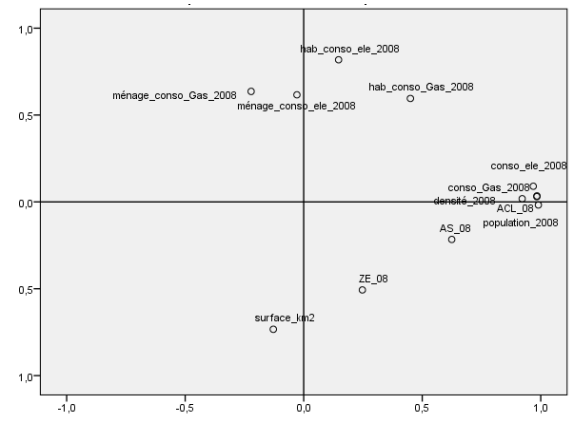
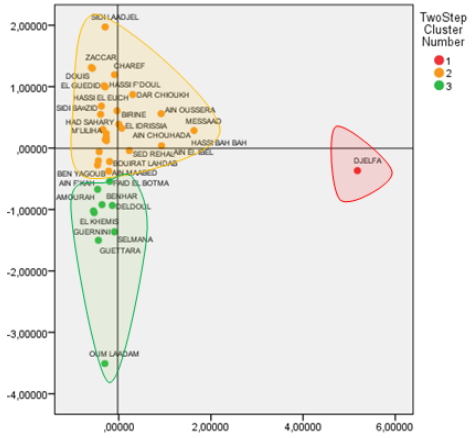
We have organized the data in six dimensions. (i) structural dimension of the municipal territory which contains the municipalities' area, the density of population, the number of population, the number of population in the chief-department, the number of population living in secondary agglomeration and scattered zone. (ii) Population characteristics, with Civil status (single rate, married rate, divorced rate and widowed rate), Gender (feminine and masculine rate), mean age per municipality and Instruction level. (iii) Population activity: with Active population, Housewives rate, Children going to school rate and Retired person's rate. (iv) Dwelling occupancy with Household size and Room occupancy rate.(v) Dwelling typology, with typology of housing rate per city (number of Dwelling, secondary residence, collective housing, individual and traditional housing), the average value of rooms per housing per municipality and the average area of housings. (vi) Household appliance, which contains the appliance rate TV, cooker, refrigerator, washing machine, air conditioner, computer and internet access rate per municipality.

3. Results

3.1. Sensitivity Analysis of the census data with energy consumption Based on PCAs:

The sensitivity analysis is based on a panel of six PCAs for each dimension to identify the criteria reducing the energy consumption and to cluster municipalities according to the dimension studied.

Table 3. PCAs maps combining energy consumption and the census data of 2008

D	Factorial analysis with each dimension considered as discriminant	Clustering municipalities according to each dimension.
1		
	Factorial analysis with territory structuring as discriminant. Quality of representation : 67.5%	

2

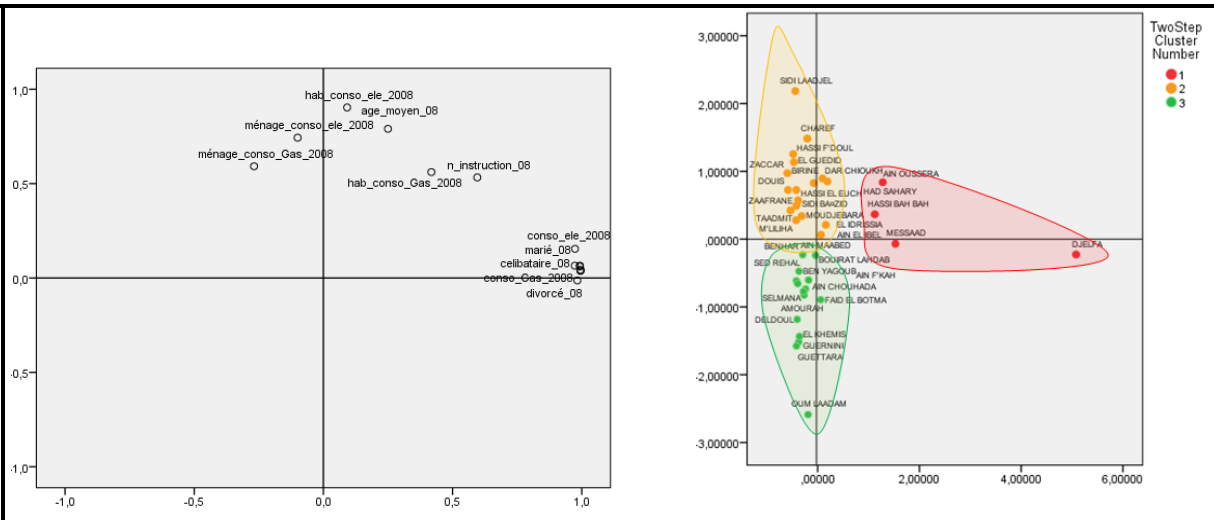
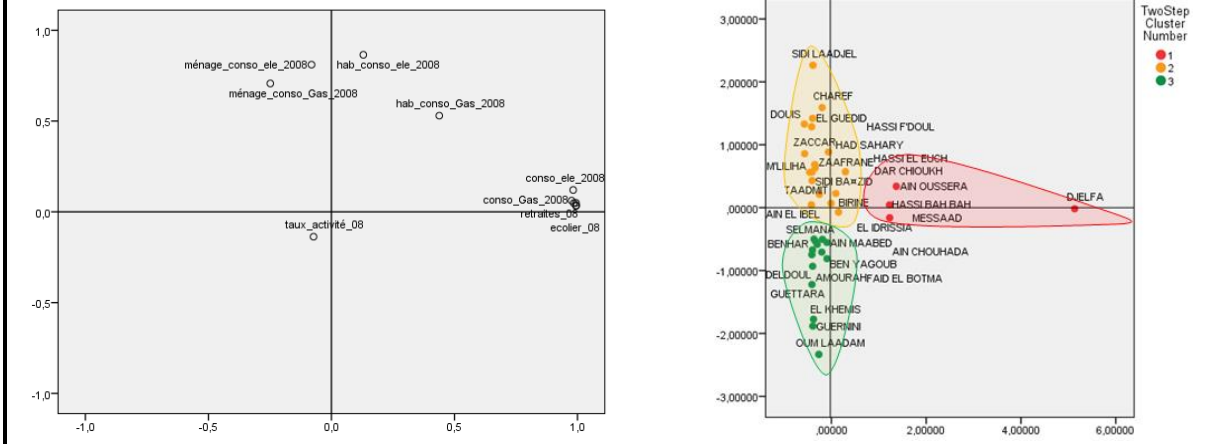


Fig. 1 :

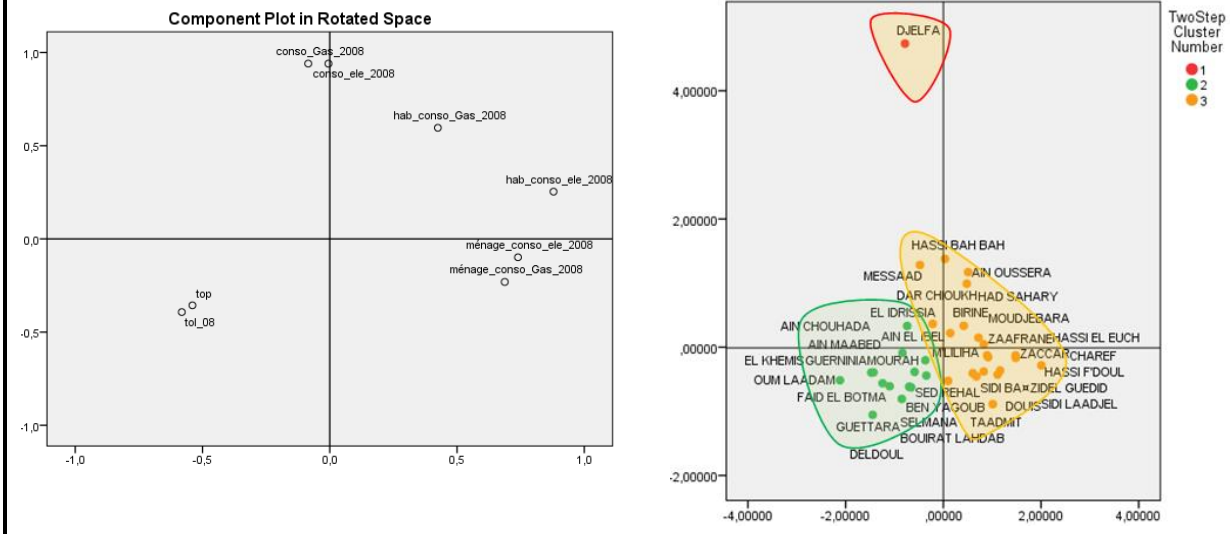
Factorial analysis with Population characteristics as discriminant. Quality of representation : 81.9%

3

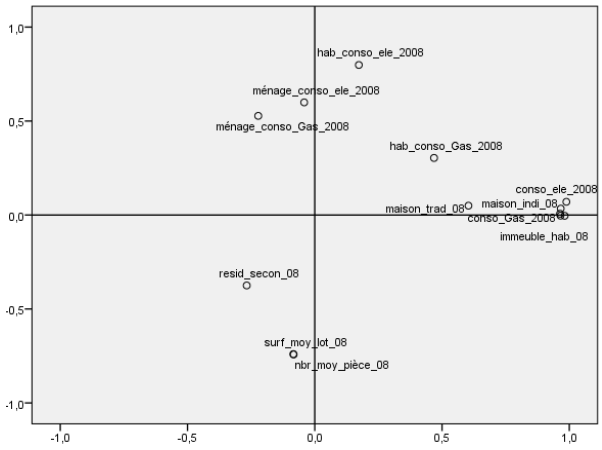
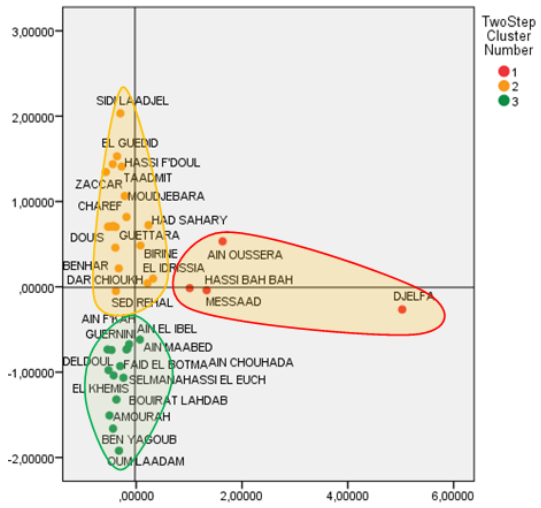
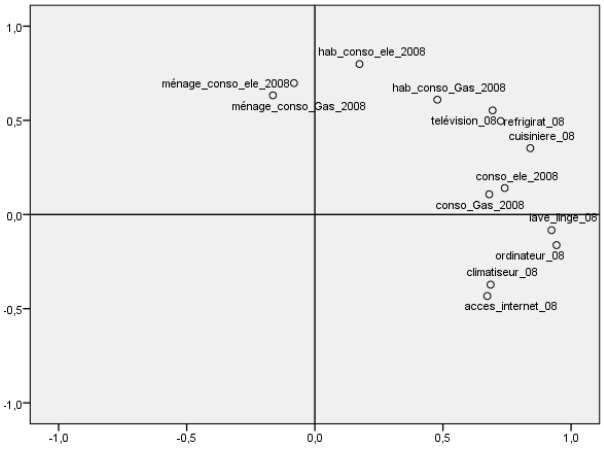
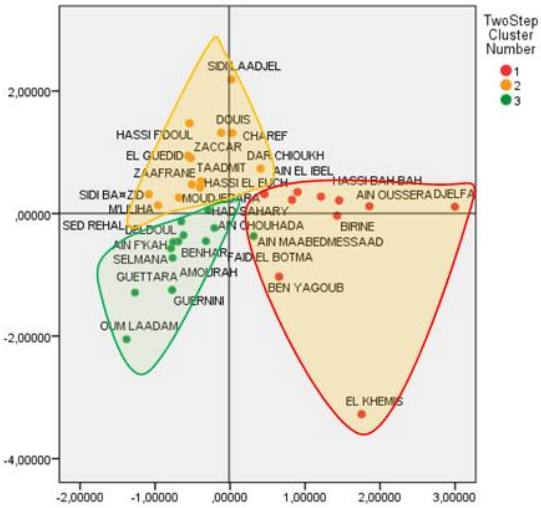


Factorial analysis with Population activities as discriminant: Quality of representation 76.03%

4



Factorial analysis with Dwelling occupancy as discriminant. Quality of representation 64.26%

5		
	Factorial analysis with dwelling typology as discriminant. Quality of representation : 62.30 %	
6		
	Factorial analysis with household appliance as discriminant. Quality of representation : 66.17%	

Based on the organization of the census data as shown above, we clustered the municipalities in three profiles according to their six dimensions of the socio-economic criteria, their energy consumption per municipality, per households and per inhabitant. (a) The wasteful municipalities (red colour) which consumes more energy per municipality and an average consumption by household. (b) The standard or intermediate profile, represented by the orange colour. This class consumes more energy per households and average consumption per municipality. (c) And the thrifty profile which consumes less energy per household and per municipality.

The structural dimension of the municipal territory shows that the energy consumption has two behaviours based on the observation's level, household, inhabitant or municipality level. The energy consumption by municipality is projected at the right of the map with the density, the population number, the Chief-place agglomeration, the Secondary agglomeration and the scattered one. The correlation is positive, the energy consumption increases with the population number. But, the energy consumption per household and inhabitant is projected in the opposite way than the municipalities' area, scattered zone, and the secondary agglomeration. This means that households consume less energy in bigger municipalities than in smaller and most populated ones. The biggest and less populated municipalities are not as rich as the smallest ones. This is why we think that the consumption is here constrained by the income. Our assumption is confirmed by the sixth PCA presenting the appliance possession rate per municipality where smaller and most

populated municipalities have higher appliance possession rate. It is logically recognized that households with higher income have higher appliance possession rate as well.

The characteristics of population have also an impact on the energy consumption. The average age and the instruction level are positively correlated to energy consumption which means that older and more instructed municipalities consume more energy. Oum Laadam has the less level of instruction and the higher average age, and remains the less energy consumer per municipality and household

Within population activities, the map above shows that the most active households consume less energy. Also, having more retired and children going to school rate par municipality indicate less energy consumption.

Within Housing occupancy as discriminant, the rate of occupancy per room and housing is projected oppositely with energy consumption for both households and municipalities which interprets a negative correlation. The more important is the rate of dwelling and room's occupancy, the less important is the energy consumption considered at the municipality and dwelling scale.

Within dwelling typology, the energy consumption is negatively correlated to the rate of secondary residence, average area and number of rooms per housing.

The household's PCA above shows that the rate of computers, air conditioner, internet access and washing machine reduces the households' energy consumption while the rate of cookers and refrigerator increase for housings.

3.2. Pearson's Bi-variate correlation:

To complete the overview of the most important socio-economic parameters, we have performed a bivariate correlation between the energy consumption of Gas and Electricity household level. The correlation analysis evaluates the degree of standardized covariance between the variables. The results are shown in figure below. The Pearson's correlation coefficient (r) is a measure of the strength of linear dependence between two variables with a value between −1 and +1. The proportion of shared variance (R2) can be calculated by squaring the Pearson's r. In other words, R2 represents the proportion of variability in one variable that is accounted for by another variable. The values range from 0 to 1, where 1 indicates a perfect fit (Field, 2010).

The figure below is a synthetic view of the Pearson's bivariate correlation at the housing level.

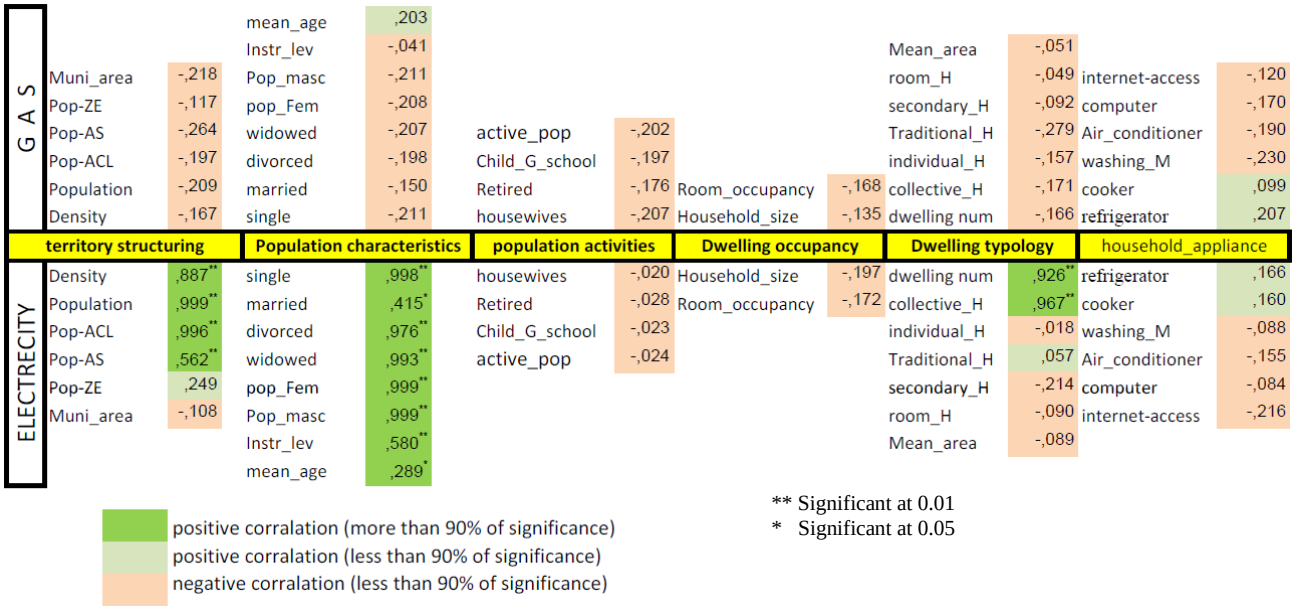


Fig. 3. Pearson's bivariate correlation

The most important factors increasing the electricity consumption are observed with population characteristics where the significance of the entire parameters is above 90 %. While the

most important factors reducing the electricity consumption are population activity and dwelling occupancy where all the parameters are negatively correlated to the electricity consumption. In the other hand, the most important factors reducing Gas consumption are observed with all the dimensions. The most important value is observed with retired person's rate per municipality (-28 %). Followed by traditional housings (-27.9 %) and this could be interpreted by the materials used in the traditional housing, where the stone and adobe walls are frequently used in the traditional housing. These materials have a weak U values comparing with hollow bricks.

Also the average age per housing and per municipality is posotovely correlated to the energy consumption for both Gas and Electricity. One way to explain this relationship between age and energy is to look at the thermal comfort perception. older people have a lower thermal comfort perception (Chen et al., 2013).

To get more understanding reasons, we have aggregated, as shown in the figure below the negative and positive correlations per dimension to be able to assess the impact of each dimension on the energy consumption. A total impact of the socio-economic criteria of the department of Djelfa is presented also as an aggregated value (see the figure below).

GAS	housi	positive	,000	positive	,203	positive	,000	positive	,000	positive	,000	positive	,153	,059
		négative	-,195	négative	-,175	négative	-,195	négative	-,151	négative	-,138	négative	-,177	-,172
		territory structuring		Population characteristics		population activities		Dwelling occupancy		Dwelling typology		household_applianc		total	
ELECTRECI	housi	négative	-,108	négative	,000	négative	-,024	négative	-,185	négative	-,103	négative	-,123	-,136
		positive	,739	positive	,781	positive	,000	positive	,000	positive	,650	positive	,180	,163

Fig. 4. Impact of the socio-economic criteria based on pearson's correlation

The figure above considering the Gas and Electricity consumption and the socio-economic criteria at the housing scale shows globally that the socio-economic criteria are reducing the Gas energy consumption by up to – 11.3 % and increasing the electricity consumption by up to 2.7 %. the most important dimension reducing the Gas consumption are, the structuring territory, population activities, Dwelling occupancy and typology. The most important dimension increasing the electricity consumption are the territory structuring with an average value of 73.9 %, population characteristics (78.1 %) and dwelling typology with 65 %.

4. Conclusion

In this paper we have performed a set of sensitivity analysis to assess the energy impact of socio-economic criteria based on PCAs and a bi-variate Pearson correlations. The results show a clear correlation between socio-economic criteria and the energy consumption. The structuring territory, population activities, Dwelling typology and occupancy are the most important criteria reducing the energy consumption. This paper highlights the importance and potential energy saving of the socio-economic criteria which could help politics to focus on the structuring territory, population characteristics and dwelling typology to understand how these parameters could reduce the energy consumption in particular the electricity consumption instead of increasing it.

References

Aprue, 2012 – Aprue (2012). Site web of national agency for the promotion and energy use rationalization. [Electronic resource]. URL: http://www.Aprue.org.dz/

Bouamama, 2013 – *Bouamama Wahiba* (2013). "Au Sujet De La Politique D'efficacité Energétique En Algérie: Approche Systémique Pour Un Développement Durable.Cas De: Programme Eco-Bat Cnerib", magister thesis, university of tlemcen, Algeria.

Boukarta, 2016 – *Boukarta S.* (2016). Densité, énergie et changements climatiques, quelle résilience? In le climat dans tous ses états, newsletter, n°02.

GIZ, 2015 – Giz (2015). Guide Pour Une Construction Eco-Energétique En Algérie.

ONS, 2008 – ONS (2008). Office national de statistiques, Census data.

ONS, 2013 – ONS (2013). Office national de statistiques, population Data.

Reta, 2015 – RETA (2015). Website of the thermal regulation in Algeria. [Electronic resource]. URL: www.reta.cder.de

Field, 2010 – *Field A*. (2010). Discovering Statistics using SPSS, third ed., Sage Publications, London.

Chen et al., 2013 – *Jun Chen, Xiaohong Wang, Koen Steemers* (2013). A statistical analysis of a residential energy consumption survey study in Hangzhou, China, *Energy and Buildings,* 66, pp. 193–202.

Boukarta et Berezowska, 2017 – *Boukarta, S., Berezowska, E.* (2017). Exploring the Energy Implication of Urban Density in Residential Buildings. *Journal of Applied Engineering Sciences*, 7(1), pp. 7-14. Retrieved 28 Aug. 2017, doi: 10.1515/jaes-2017-0001

Boukarta, Berezoska-Azzag, 2017 – *Boukarta, Soufiane, Berezowska-Azzag, Ewa*. "Urban island" as an energy assessment tool. The case of Mouzaia, Algeria, *Journal of applied engineering science,* 15 (2017) 2, 128-139. doi: 10.5937/jaes15-12951.