American International Journal of Business Management (AIJBM)
ISSN- 2379-106X, www.aijbm.com Volume 2, Issue 4 (April - 2019), PP 133-141

From Policy to Implementation: Evaluating Alternative Allocation Systems for Electricity Subsidies in Colombia.

Enrique B. Cedeno
School of Management, New York Institute of Technology, Nanjing, China
**Corresponding Author: Enrique B. Cedeno*

ABSTRACT:- In Colombia electricity is provided at subsidized prices to 90% of residential customers during the study period. The system is financed by contributions from higher income consumers and commercial and industrial sectors. This cross-subsidy system was implemented after restructuring the sector in 1994 following a severe energy crisis in 1992. The system under-collects requiring budget subsidies from the government of around 15%.

In addition, there are near one million homes in the first income decile for which monthly electricity bill represents approximately 90% of the household income. This research presents a macro-level study that proposes several alternatives to improve the performance of the current system. These alternatives are based on the current allocation system and on an income-based allocation system. They give full subsidy to low income consumers and do not require budget subsidies. However, these alternatives before implementation required changes in policies and regulations to allow increasing the contribution factors and redefining the size of the subsidized and contributing groups. It is shown in this research that the current allocation system cannot collect enough money by contributions from residential customers alone since it would require excessive increases in the residential tariffs. It is also shown that by increasing the size of the contributors with more reasonable tariff increases the system could give full subsidies to low income consumers. The analysis presented here requires further detailed studies involving all the stakeholders in setting, defining and implementing energy policies in Colombia to reach feasible agreements that can improve the performance of the subsidy system while respecting the social goals established in the restructuring of the sector.

KEYWORDS: electricity tariffs, cross-subsidy, Colombia, income-based allocation, deregulated electricity sector.

I. INTRODUCTION

Deregulation, re-regulation or liberalization (Heald, 1996; Voll, Pabon-Agudelo, & Rosenzweig, 2003) are the most common forms of restructuring of public industries. In public network industries, this restructuring generally seeks to provide lower prices, promote competition, increase efficiency and attract new investments (Baumol, 2001; Palmer, 1992). These are some of the reasons for the restructuring of the electric sector in Colombia in 1994 (Larsen, Dyner, Bedoya V, & Franco, 2004) following the energy crisis of 1992.During year 1992 hydrological generation capacity was reduced due to an extremely dry season, requiring a long period of load rationing to avoid rolling blackouts. The political consequences of the energy crisis, transformed politicians and energy planners into risk avoiders favoring an electric system with excess capacity (Barrera Rey & García Morales, 2010; Larsen et al., 2004). In Latin American countries deregulation has been considered a means to generate the financial resources to add capacity to guarantee the provision of public services. Restructuring of the electricity sector in Colombia in 1994 included provisions to allocate subsidies based on equity and social responsibility principles. In Colombia the electricity services are provided at a subsidized price to approximately 90% of all the residential consumers during the period analyzed in this research (Departamento Administrativo Nacional de Estadisticas, 2006). The electricity system is financed by contributions from higher income residential customers, as well as by contributions from industrial and commercial customers. However, there is near one million homes in Colombia for which monthly electricity bill could represent approximately 90% of the household income (Cedeno, 2016). In addition, the cross-subsidy system under-collects requiring budget subsidies from the government. Therefore, the objective of this research is to present a macro-level study that identifies several alternatives for allocation of electricity subsidies based on the current allocation method and on an income-based allocation method (Cedeno, 2019a). These alternatives provide full subsidies to customers in the first income decile and required no budget subsidies. However, they required changes in policies and regulations to be successfully implemented. Results from this research show that using the current allocation method for electricity subsidies it is not feasible to propose reasonable changes to modify the system to be financed by contributions from residential customers only. In India, using an increase in electricity prices for industrial customers to provide for residential and agricultural sectors as a financial mechanism was determined to be unsustainable because price increases caused reductions in industrial demand; subsequently the system failed to collect sufficient money to pay for subsidies (Chattopadhyay, 2007). Then in the analysis presented here, it is considered that the system is financed by contributions from residential customers only. It is assumed electricity demand for high income customers is almost price insensitive. Reductions in electricity demand from high income consumers in Colombia is not very likely to decrease because for them it may not be attractive or convenient to install their own electricity generators in contrast with industrial and commercial customers. This holds some similarity to the strategy implemented in the tariff redesign for the electric sector in China in which higher income consumers with low price elasticity of demand pay a higher price (Sun & Lin, 2013).

Subsidies occur when products or services are priced below their marginal costs. Subsidies also occur when the government provides a payment to either producers or consumers directly or indirectly to lower the price of the product or to lower production costs (Lin and Jiang, 2011). Subsidies can be used by the government to promote equity, universal access and national development (Chattopadhyay, 2007; Faulhaber, 1975).Tariffs to promote universal access often price basic services low relative to costs, whereas other services are priced high relative to costs to compensate (Palmer, 1992). This pricing creates cross-subsidies. Subsidized customers are encouraged to consume more, whereas subsidizing customers reduce their consumption (Chattopadhyay, 2007; Lin and Jiang, 2011; Liu and Li, 2011; Voll et al., 2003). Then, some limitations of subsidies are that they are considered to promote over consumption and have the risk of missing the target population providing benefits to customers that do not need them (Lin & Jiang, 2011; Pineau, 2008; Sun & Lin, 2013). Electricity subsidies in China (Sun & Lin, 2013) and in British Columbia, Canada (Pineau, 2008) have been reported missing the target population providing benefits to higher income consumers. Hence, the importance of a study like the one presenting here seeking to identify strategies to create allocation systems for subsidies that do not require budget subsidies from the government, increasing the number of contributors while providing full subsidies to low income customers.

Cross-subsidies may be needed because of political and equity considerations, as in the electricity sector in Colombia described in this research. In China, to provide a competitive edge, electricity tariffs are lower than the cost of supply (Lin & Jiang, 2011) and cheaper than in developed countries (Liu & Li, 2011). In Brazil large industrial customers also benefit from lower tariffs to increase their competitiveness (Voll et al., 2003). A combination of cross-subsidies and budget subsidies could be implemented in electricity markets in which the government owns and regulates the public network (Heald, 1997; Pineau, 2008). However, when operation and ownership are separated from regulation, as for instance in the MISO (Midwest Independent System Operator) and PJM (Pennsylvania, New Jersey and Maryland interconnection) markets in the US, with no political power to access budget subsidies, regulators only have access to cross-subsidies to achieve their social or political goals (Heald, 1997).

Budget subsidies provide a less expensive way to finance social goals than cross-subsidies (Heald, 1997). Budget subsidies do not impose penalties on customers who are charged higher prices causing equity issues (Faulhaber, 1975; Voll et al., 2003). Social welfare losses are also likely to be less than in the case of using cross-subsidies (Chattopadhyay, 2004). Budget subsidies and direct subsidies preserve economic signals and are more efficient than cross-subsidies (Voll et al., 2003). Taxes to higher income classes consuming price inelastic goods or services that can be priced using average cost pricing (Chattopadhyay, 2004) can provide the funds to finance budget subsidies and direct subsidies. However, Colombia has to its advantage the tradition of having been using a system of cross-subsidies well known by its citizens since 1994. Then, changing to a regimen of budget subsidies after reforming the tax system may require perhaps more political and social support.

Subsidies are characteristics of network monopolies developed under public ownership (Heald, 1997). Subsidies can be used to promote network development; however, once the network is mature, they can be discontinued (Heald, 1997; Sawkins and Reid, 2007). Then, in countries with mature network industries research on energy subsidies provides more importance to determining the size of the subsidy and the impact of removing subsidies (Lin & Jiang, 2011; Sawkins & Reid, 2007). This research differs from previous studies by presenting an analysis for an emerging country with an electricity sector which is not mature and that is seeking opportunities to improve the performance of its electricity sector. This research extends the work presented in (Cedeno, 2016; Cedeno, 2018; Cedeno, 2019a) proposing alternative allocations for cross-subsidies in Colombia based on the current allocation system and on an income-based system (Cedeno, 2019a). Proposed alternatives improve the current allocation system by giving full subsidy to low income customers avoiding the need for budget subsidies. The identification of these alternatives allows recognizing any policy and regulatory changes required to implement them. It also allows identifying the key factors required for the success of the proposed alternatives.

Subsidies have been used in the telecommunications industry in France and Canada (Heald, 1997; Palmer, 1992); postal services in the US (Heald, 1997); the water industry in Scotland (Sawkins and Reid, 2007); fossil fuels in China, India, Indonesia, Egypt, Thailand, Venezuela, Saudi Arabia, Iran, Iraq and Mexico (Lin and Jiang, 2011; Liu and Li, 2011; Plante, 2014); natural gas in Ukraine (Plante, 2014) and China (Wang and Lin, 2014); and in the electricity sector in China, Colombia, Brazil, Bolivia, Honduras, Panama, Nicaragua, El Salvador, Mauritania, Jordan, Senegal, Lebanon and Canada (Lin and Jiang, 2011; Pineau, 2008; Plante, 2014; Sun and Lin, 2013).

II. RESIDENTIAL ELECTRICITY PRICES IN COLOMBIA.

Laws 142 and 143 of 1994 (Congreso República de Colombia, 1994a, 1994b; Larsen et al., 2004) provide the legal framework for the deregulation of the electric sector in Colombia. Law 143 (Congreso República de Colombia, 1994b)regulates all the activities of generation, transmission, distribution and commercialization. This law authorizes the Gas and Energy Regulatory Commission (CREG) to define the methodology to determine electricity prices (or tariffs)and transmission charges(Comisión de Regulación de Energía y Gas (CREG), 1994a, 1994b, 1995, 1996, 1997a, 1997b, 2000). Resolution 012-93(Comisión de Regulación de Energía y Gas (CREG), 1993)mandates that electricity distribution companies in Colombia should apply residential tariffs according to the same residential classification employed in the provision of residential public water service. Based on the residential classification of homes, there are six residential groups from 1 to 6 in increasing order of financial wealth. Groups 1 to 3 are considered low income groups and are the beneficiaries of the subsidies. Group 4 is considered neither a contributor nor a subsidized sector; it only covers the cost of supply. Groups 5 and 6 are considered contributors since they have more financial resources. They contribute to the subsidies in addition to the contributions made by industrial and commercial customers.Residentialelectricity tariffs are defined in resolutions CREG 80-95 (Comisión de Regulación de Energía y Gas (CREG), 1995), CREG 09-96 (Comisión de Regulación de Energía y Gas (CREG), 1996) and CREG 78-97(Comisión de Regulación de Energía y Gas (CREG), 1997a), whereas non-residential electricity tariffs are defined in CREG 79-97(Comisión de Regulación de Energía y Gas (CREG), 1997b).

Based on the rules for the sector asimplified general expression to compute electricity tariffs(prices) is provided below (Cedeno, 2016; Cedeno, 2018):

$$T(t)_{ijk} = (1+\rho_{ik}(t))\ C_{jk}(t) \tag{1}$$

Where:

$T(t)_{ijk}$: tariff for customer from group*i* at voltage level *j* provided by company *k* at time *t*.

$\rho_{ik}(t)$: subsidy or contribution factor for customer from group*i* at time *t*provided by company *k*.

$C_{jk}(t)$: cost of supply at voltage level *j* provided by company *k* at time *t*.

Cost of supply $C_{jk}(t)$ are defined in (Comisión de Regulación de Energía y Gas (CREG), 1997a) for each one of the thirty companies serving the sector during the first two years of the restructuring process. Contribution factors during these years for customers in groups 5 and 6 were, on average, 60 and 68%, respectively (Comisión de Regulación de Energía y Gas (GREG), 1996).Subsequent residential contribution factors per company defined in CREG 80-95(Comisión de Regulación de Energía y Gas (CREG), 1995)range from 20 to 35% for customers from group 5 and from 20 to 48% for group 6. All contribution factors were established to be lower or equal to the limiting factor of 20% after 2000(Comisión de Regulación de Energía y Gas (CREG), 1997b). Initial maximum subsidy factors (Comisión de Regulación de Energía y Gas (CREG), 1997a) are negative 50, 40 and 15% for groups 1, 2 and 3 respectively. Residential customers from group 4 are only required to cover their cost of supply. Then $\rho_{4k}(t) = 0 \ \ \forall k$. Subsidized prices are provided to a maximum of the subsistence level of consumption which is set at 200 Kwh per month (Comisión de Regulación de Energía y Gas (CREG), 1995, 1997a). Additional consumption is priced higher at the cost of supply(Comisión de Regulación de Energía y Gas (CREG), 1995).

III. ELECTRICITYDEMAND AND PRICES IN COLOMBIA (CEDENO, 2016; CEDENO,2018; CEDENO, 2019a).

The research presented here reports on all the available aggregate data per company serving the electricity sector in Colombia for all residential consumers during years 2005, 2006 and 2007 (Sistema Unico de Información (SUI), 2014). These data are used to compute the averages reported in this section. Limiting the study period at the moment of conducting this research to these three years is due to access to census data for year 2005 with forecast for years 2006 and 2007 (Departamento Administrativo Nacional de Estadisticas, 2006).

Values in table 1 indicate that the majority of residential customers belong to the subsidized groups. Group 1 represents 24% of residential customers; whereas groups 2 and 3 represent 40% and 25% respectively. Then, approximately 90% of residential customers received subsidies from the system during the three-year study period.

Year	2005	2006	2007
G1	1.688.190	2.036.695	2.319.139
G2	3.158.880	3.269.392	3.543.892
G3	1.978.779	1.953.378	2.144.513
Total Subsidized Subscribers	6.825.849	7.259.465	8.007.544
G4	497.920	500.839	593.237
G5	235.417	244.844	273.781
G6	135.190	142.652	175.451
Total Residential	7.694.376	8.147.800	9.050.013

Table 1. Subscribers per group per year.

Average electricity prices presented in table 2 for subsidized groups increased moving from group1 up to group 4. This corresponds with the design of the system. Electricity prices for contributing residential sectorsduring two yearsare greater for group 5 than for group 6. The opposite behavior is expected since group 6 is the most affluent group. A similar behavior is observed in electricity prices for the capital city of Bogota in 2006 (Secretaría Distrital de Planeación, 2007; Codensa, 2013). This may be due to the way additional consumption is priced for these consumers.

Year	G1	G2	G3	G4	G5	G6
2005	0.12	0.14	0.18	0.19	0.22	0.21
2006	0.11	0.13	0.16	0.17	0.20	0.19
2007	0.10	0.12	0.14	0.16	0.17	0.17
Average	0.11	0.13	0.16	0.17	0.20	0.19

Table 2 Average electricity price $/Kwh (Constant US$ for 2007)

Year	G1	G2	G3	G4	G5	G6
2005	168.11	141.92	174.16	219.74	286.48	437.24
2006	148.11	138.34	171.81	217.15	273.56	417.93
2007	124.83	134.58	167.36	206.48	255.91	360.79
Average	147.02	138.28	171.11	214.45	271.98	405.32

Table 3. Average electricity consumption per subscriber (Kwh per month)

Average electricity consumption (table 3) for all subsidized sectors is below the subsistence level of 200 Kwh per month (Comisión de Regulación de Energía y Gas (CREG), 1995, 1997a). However, during two years average consumption for group 1 is higher than that of group 2. This may indicate overconsumption due to low electricity prices (Cedeno, 2018). Average electricity consumption in residential sectorsincreases as one moves up in the social groups.Average consumption for residential customers in group 6 is more than twice the consumption for group 1. In India, another emerging country, cross-subsidies to domestic sector and rural areas have been increasing as demand keeps increasing (Chattopadhyay, 2004). Regulators and policy makers need to pay attention to this situation since there is a risk of the system becoming unsustainable.

Year	G1	G2	G3	G4	G5	G6
2005	22.42	19.35	23.09	28.50	35.57	53.57
2006	19.54	18.27	21.86	26.99	32.48	49.12
2007	15.67	16.54	19.75	23.91	28.16	39.48
Average	19.21	18.05	21.57	26.47	32.07	47.39

Table 4. Average electricity bill per subscriber per monthin USD.

Table 4 presents average electricity bill per subscriber per month in constant USD for 2007. There is no much difference in the average bill between groups 1 and 2 despite the subsidy level each group receive is different (Cedeno, 2018). This is because of the high consumption of group 1 as compared to that of group 2 (Table 3). Average percentage subsidy for group 1 is almost 42%, whereas for group 2 is only 30% (Cedeno, 2018).Subsidy for group 3 is less than 9%. Average electricity bill per subscriber in group 5 is less than that for subscribers in group 6. Electricity consumption in group 6 is approximately 50% higher than the consumption in group 5 (Table 3).Average contributions from groups 5 and 6 during the study period are almost 18% (Cedeno, 2016; Cedeno, 2019a).The system under-collects requiring on average 15% of budget subsidy from the government (Cedeno, 2019) in addition to the contributions from industrial and commercial customers.

IV. ALTERNATIVE ALLOCATIONS BASED ON CURRENT SYSTEM.

The decision making problem of determining the size of the subsidized and contributing sectors, as well as subsidy and contribution factors, involves the cross-product of these decision variables (Cedeno, 2019b). This is characterized as a self-referential non-linear programming problemsince it involves determining also the electricity demand and the price, where electricity demand depends on the price which is a function of the subsidy or contribution factor (Cedeno, 2019b; Cedeno, 2016). Solution of this problem in real-life systems is simplified by input from various stakeholders in the problem. This problem, can also be defined as a bilinear problem (Cedeno, 2019b; Cedeno and Arora, 2013). In a bilinear problem, once one variable is specified the problem becomes a linear programming problem in the other variable (Cedeno and Arora, 2013). Proposed alternatives presented in tables 5 to 8 are obtained using the algorithm presented in (Cedeno, 2019b).

Table 5 presents the current allocation system considering average bill values presented in table 4. Payments are obtained by multiplying columns 2 and 3. Cost for each group is determined using the average bill for group 4 times the corresponding number of users in that group. In this case, total cost exceeds total payments then budget subsidy is necessary to cover the deficit. This correctly reflects the situation of the system during the study period.

Year	2007	Average Bill	Payments	Cost
G1	2319139	$19.21	$44,550,660.19	$61,387,609.33
G2	3543892	$18.05	$63,967,250.60	$93,806,821.24
G3	2144513	$21.57	$46,257,145.41	$56,765,259.11
G4	593237	$26.47	$15,702,983.39	$15,702,983.39
G5	273781	$32.07	$8,780,156.67	$7,246,983.07
G6	175451	$47.39	$8,314,622.89	$4,644,187.97
Total	9.050.013		$187,572,819.15	$239,553,844.11

Table 5. Performance of the current system.

Table 6 presents an alternative that requires increasing average bill for groups 3 to 6 in 76%, 62%, 51% and 34% respectively. This alternative is self-financed and does not require budget subsidies from the government. However, it requires changes in the policies to open the possibility of making groups 3 and 4 contributors to the system. It may also require adjustments in the percentage average bill increase for all groups to make it more equitable. An easy suggestion is to increase all factors to 76%. Then allocate any surplus in contributions to a reserve fund.

Year	2007	Proposed Avg. Bill	Payments	Cost
G1	2319139	$19.21	$44,550,660.19	$61,387,609.33
G2	3543892	$18.05	$63,967,250.60	$93,806,821.24
G3	2144513	$37.88	$81,235,059.87	$56,765,259.11
G4	593237	$42.78	$25,378,929.88	$15,702,983.39
G5	273781	$48.38	$13,245,640.63	$7,246,983.07
G6	175451	$63.70	$11,176,302.94	$4,644,187.97
Total	9.050.013		$239,553,844.11	$239,553,844.11

Table 6. Alternative allocation Increasing Avg. Bill for groups 3 to 6.

Table 7 presents another alternative that provides full subsidy to group 1 financed completely by contributions from groups 5 and 6. The idea to provide full-subsidy to customers in group 1 is because for customers in the first income decile average electricity bill represents almost 90% of the household income (Cedeno, 2016; Cedeno, 2019b). This alternative does not require any changes in the definition of the subsidized groups. However, it requires regulatory approval to increase the average bill for groups 5 and 6 almost 7 times. This may not be a realistic feasible option.

Year	2007	Proposed Avg. Bill	Payments	Cost
G1	2319139	$0.00	$0.00	$61,387,609.33
G2	3543892	$18.05	$63,967,250.60	$93,806,821.24
G3	2144513	$21.57	$46,257,145.41	$56,765,259.11
G4	593237	$26.47	$15,702,983.39	$15,702,983.39
G5	273781	$205.64	$56,299,312.68	$7,246,983.07
G6	175451	$336.67	$59,068,591.94	$4,644,187.97
Total	9.050.013		$241,295,284.02	$239,553,844.11

Table 7. Alternative allocation Increasing Avg. Bill for groups 5 and 6 providing full subsidy to group 1.

Year	2007	Proposed Avg. Bill	Payments	Cost
G1	2319139	$0.00	$0.00	$61,387,609.33
G2	3543892	$18.05	$63,967,250.60	$93,806,821.24
G3	2144513	$44.87	$96,224,079.25	$56,765,259.11
G4	593237	$66.54	$39,476,740.91	$15,702,983.39
G5	273781	$79.13	$21,665,416.28	$7,246,983.07
G6	175451	$105.64	$18,534,164.91	$4,644,187.97
Total	9.050.013		$239,867,651.95	$239,553,844.11

Table 8. Alternative allocation Increasing Avg. Bill for groups 3 to 6 providing full subsidy to group 1.

Table 8 presents another alternative that gives full subsidy to customers in the first income decile financed by increases in the average bill of groups 3 to 6 in the range of 2 to 2.5 times. This alternative requires policy and regulatory changes to make groups 3 and 4 part of the contributors and to allow increases in the contribution factors to double the average bill for groups 3 to 6.

V. ALTERNATIVE INCOME-BASED ALLOCATION METHOD FOR CROSS-SUBSIDIES (CEDENO, 2016; CEDENO, 2019b).

This section presents an income-based allocation method for cross-subsidies since the current allocation method used in Colombia does not correlate with the household income (Rosero, 2004; Uribe-Mallarino, 2008; Cedeno, 2019a). Then, the current system does not allow identifying customers that need additional financial support. It may also be providing benefits to customers that do not need them.Similarly, with the last alternatives presented in the previous section, here the cross-subsidy system is considered to be financed only by contributions from higher incomeresidential customers. These alternatives are detailed in (Cedeno, 2019a).

Table 9 presents an alternative allocation method considering distribution of homes per household income in deciles(Departamento Administrativo Nacional de Estadisticas, 2006).The difference in the total number of subscribers and the total number of households is perhaps due to the characteristics of the country where under one electricity subscription there could be more than one household.Column 4 presents the proposed average bill for each group (Cedeno, 2019 a). Decile 1 corresponds to group 1. Deciles 2, 3 and 4 corresponds to group 2. Deciles 5 and 6 corresponds to group 3. Decile 7 corresponds to group 4. Decile 8 corresponds to group 5. Deciles 9 and 10 corresponds to group 6. Then, each decile is assigned the corresponding average bill for each group presented in table 4. Column 6 presents the effective subsidy (S) or Contribution (C). Subsidy factors are given in brackets to represent negative values. For customers in the first income decile, electricity bill represents almost 90% of their average income (Cedeno, 2016). Column 7 gives the payments received from each group; whereas, column 8 gives the total electricity cost for each group computed as the product of the number of users in each decile times the cost of supply given by the average price for group 4 or decile 7. Comparison of total payments and total costs, indicates that this alternative would generate a surplus that could be assigned to a reserve fund (Cedeno, 2019b).

Decile	Total Homes	Max. Income (USD)	Average Income (USD)	Proposed Avg. Bill	Effective S or C	Payments	Cost
Decile 1	1114223	64.15	21.59	19.21	(0.27)	$21,404,223.83	$29,493,482.81
Decile 2	1114352	124.1	95.24	18.05	(0.32)	$20,114,053.60	$29,496,897.44
Decile 3	1114815	182.84	154.75	18.05	(0.32)	$20,122,410.75	$29,509,153.05
Decile 4	1114365	231.42	206.69	18.05	(0.32)	$20,114,288.25	$29,497,241.55
Decile 5	1113203	291.82	261.52	21.57	(0.19)	$24,011,788.71	$29,466,483.41
Decile 6	1114972	384.92	337.96	21.57	(0.19)	$24,049,946.04	$29,513,308.84
Decile 7	1115437	509.15	442.93	26.47	0.00	$29,525,617.39	$29,525,617.39
Decile 8	1114106	697.67	595.6	32.07	0.21	$35,729,379.42	$29,490,385.82
Decile 9	1114820	1076.45	856.27	47.39	0.79	$52,831,319.80	$29,509,285.40
Decile 10	1114555	22428.45	1982.39	47.39	0.79	$52,818,761.45	$29,502,270.85
Total	11144850					$300,721,789.24	$295,004,126.56

Table 9. Alternative subsidy allocation based on household income.

Decile	Total Homes	Max. Income (USD)	Average Income (USD)	Proposed Avg. Bill	Effective S or C	Payments	Cost
Decile 1	1114223	64.15	21.59	0	(1.00)	$0.00	$29,493,482.81
Decile 2	1114352	124.1	95.24	18.05	(0.32)	$20,114,053.60	$29,496,897.44
Decile 3	1114815	182.84	154.75	18.05	(0.32)	$20,122,410.75	$29,509,153.05
Decile 4	1114365	231.42	206.69	18.05	(0.32)	$20,114,288.25	$29,497,241.55
Decile 5	1113203	291.82	261.52	21.57	(0.19)	$24,011,788.71	$29,466,483.41
Decile 6	1114972	384.92	337.96	21.57	(0.19)	$24,049,946.04	$29,513,308.84
Decile 7	1115437	509.15	442.93	26.47	0.00	$29,525,617.39	$29,525,617.39
Decile 8	1114106	697.67	595.6	32.07	0.21	$35,729,379.42	$29,490,385.82
Decile 9	1114820	1076.45	856.27	51.66	0.95	$57,591,601.20	$29,509,285.40
Decile 10	1114555	22428.45	1982.39	57.34	1.17	$63,908,583.70	$29,502,270.85
Total	11144850					$295,167,669.06	$295,004,126.56

Table 10. Alternative subsidy allocation based on household income providing full subsidy to customers in the first income decile.

Table10presents an alternative that provides full subsidy to customers in the first decile (Cedeno, 2019a).The balance between payments and costs presented in this alternative is obtained by following the algorithm presented in (Cedeno, 2019b). In this alternative the effective increase considering average bill for decile 9 is only 9% and for decile 10 is 21%. These increases in the average bill seem more reasonable that the ones needed in the alternatives presented in the previous section, however they require policy changes and regulatory approval to perform a complete restructuring of the cross-subsidy system.

VI. CONCLUSIONS

This paper presents several alternatives based on two different allocation systems for the electricity sector in Colombia. According to the available data at the moment of this research average electricity bill for customers in the first income decile represents almost 90% of the household income (Departamento Administrativo Nacional de Estadisticas, 2006; Cedeno, 2016; Cedeno, 2019a). Then, proposed alternatives considered improving the current allocation system by giving full electricity subsidies to low income customers. This follows principlesof equity and social responsibility formulated in the restructuring of the electricity sector in Colombia in 1994. In order for any of the proposed alternatives to be implemented successfully some policy and regulatory changes are needed to increase subsidy and contribution factors and to redefined contributing groups. Alternatives that are based on the current allocation system considering six residential groups are easier to implement since they required less changes in policies. However, alternatives based on the household income required not only policy and regulatory changes before a possible implementation but the design of a system that registers and classifies customers according to household income and then assigns corresponding electricity tariffs. In general terms, the success of the proposed alternatives presented in this research is based on increasing the number of contributors as well as the contribution factors. The analysis conducted here is a macro-level study considering average aggregate data. Then although, this research shows that it is possible to propose alternatives that could improve the performance of the allocation systems more detailed studies are needed involving all the relevant stakeholders in setting and implementing energy policies in Colombiato reach feasible agreements that can improve the performance of the subsidy system while respecting the social goals established in the restructuring of the sector in 1994.

REFERENCES

[1]. Barrera Rey, F., & García Morales, A. (2010). Desempeño del mercado eléctrico colombiano en épocas de niño: lecciones del 2009-10. Alcogen.

[2]. Baumol, W. J. (2001). Economically defensible access pricing, competition and preservation of socially desirable cross subsidy. Utilities Policy, 10, 151.

[3]. Cedeno, E. B. & Arora, S. (2013) Convexification method for bilinear transmission expansion problem. International Transactions on Electrical Energy Systems, 24(5). https://doi.org/10.1002/etep.1721.

[4]. Cedeno, E. B. (2016) Cross-subsidies for the Electric Sector in Colombia: are they enough to help poor families? Poverty and Social Protection Conference, Bangkok, Thailand, pp. 38–51.

[5]. Cedeno, E. B. (2018) ANOVA Study of Efficient Management and Allocation of Residential Electricity Subsidies in Colombia. The International Journal of Management. 7(4), 1-10.

[6]. Cedeno, E. B. (2019a) Self-financed income-based cross-subsidy allocation for the Electricity sector in Colombia. Global Journal of Engineering Science and Researches. 6 (3), 273-283.http://www.gjesr.com/Issues%20PDF/Archive-2019/March-2019/32.pdf.

[7]. Cedeno, E.B. (2019b)Algorithm for cross-subsidy allocation: application to the Electricity sector in Colombia. Submitted for publication.

[8]. Chattopadhyay, P. (2004). Cross-subsidy in electricity tariffs: Evidence from India. Energy Policy, 32(5), 673–684. http://doi.org/10.1016/S0301-4215(02)00332-4

[9]. Chattopadhyay, P. (2007). Testing viability of cross subsidy using time-variant price elasticities of industrial demand for electricity: Indian experience. Energy Policy, 35(1), 487–496.

[10]. Codensa. (2013). Tarifas de energía eléctrica, 1(Febrero).

[11]. Comisión de Regulación de Energía y Gas (CREG). CREG 012-93 (1993).

[12]. Comisión de Regulación de Energía y Gas (CREG). CREG 02-94 (1994).

[13]. Comisión de Regulación de Energía y Gas (CREG). CREG 17-94 (1994).

[14]. Comisión de Regulación de Energía y Gas (CREG). CREG 80-95 (1995).

[15]. Comisión de Regulación de Energía y Gas (CREG). CREG 09-96 (1996).

[16]. Comisión de Regulación de Energía y Gas (CREG). CREG 78-97 (1997).

[17]. Comisión de Regulación de Energía y Gas (CREG). CREG 79-97 (1997).

[18]. Comisión de Regulación de Energía y Gas (CREG). CREG 103-2000 (2000).

[19]. Comisión de Regulación de Energía y Gas (GREG). CREG 124-96 (1996).

[20]. Congreso República de Colombia. Ley 142 (1994).
[21]. Congreso República de Colombia. Ley 143 (1994).
[22]. Departamento Administrativo Nacional de Estadisticas. (2006). Reporte Pobreza y Condiciones de Vida. Retrieved July 1, 2015, from http://www.dane.gov.co/index.php/estadisticas-por-tema/pobreza-y-condiciones
[23]. Faulhaber, G. R. (1975). Cross-Subsidization: Pricing in Public Enterprises. The American Economic Review, 65(5), 966–977.
[24]. Faulhaber, G. R., & Levinson, S. B. (1981). Subsidy-Free Prices and Anonymous Equity. American Economic Review, 71(5), 1083–1091.
[25]. Heald, D. (1996). Contrasting approaches to the “problem” of cross subsidy. Management Accounting Research, 7(1), 53–72. http://doi.org/10.1006/mare.1996.0003
[26]. Heald, D. (1997). Public policy towards cross subsidy. Annals of Public and Cooperative Economics, 68, 591–623.
[27]. Larsen, E. R., Dyner, I., Bedoya V, L., & Franco, C. J. (2004). Lessons from deregulation in Colombia: successes, failures and the way ahead. Energy Policy, 32(15), 1767.
[28]. Lin, B., & Jiang, Z. (2011). Estimates of energy subsidies in China and impact of energy subsidy reform. Energy Economics, 33(2), 273–283.
[29]. Liu, W., & Li, H. (2011). Improving energy consumption structure: A comprehensive assessment of fossil energy subsidies reform in China. Energy Policy, 39(7), 4134–4143. http://doi.org/10.1016/j.enpol.2011.04.013
[30]. Ministerio de Minas y Energía, U. D. P. M. E. (Upme). (2013). Boletín Estadístico de Minas y Energía 2000-2013, 263. Retrieved from http://www.upme.gov.co/Boletines/Boletin Estadistico 2000-2013.pdf
[31]. Ministerio de Minas y Energía, & Unidad de Planeación Minero Energética (UPME). (2011). Boletín Estadistico de Minas y Energia 1990-2010.
[32]. Palmer, K. (1992). A test for cross subsidies in local telephone rates: do business customers subsidize residential customers? RAND Journal of Economics, 23(3), 415–431. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=5173395&site=ehost-live&scope=site
[33]. Pineau, P.-O. (2008). Electricity Subsidies in Low-Cost Jurisdictions: The Case of British Columbia. Canadian Public Policy / Analyse de Politiques, 34(3), 379.
[34]. Plante, M. (2014). The long-run macroeconomic impacts of fuel subsidies. Journal of Development Economics, 107, 129–143. http://doi.org/10.1016/j.jdeveco.2013.11.008
[35]. Rosero, L. M. (2004). Estratificación socioeconómica como instrumento de focalización. Economía Y Desarrollo, 3(1), 53.
[36]. Sawkins, J. W., & Reid, S. (2007). The measurement and regulation of cross subsidy. The case of the Scottish water industry. Utilities Policy, 15(1), 36–48. http://doi.org/10.1016/j.jup.2006.07.001
[37]. Secretaría Distrital de Planeación. (2007). Las tarifas de los servicios públicos frente a la capacidad de pago de los hogares Bogotanos. Sintésis de Coyuntura Dirección de Políticas Sectoriales.
[38]. Sistema Unico de Información (SUI). (2014). No Title. Retrieved February 1, 2015, from http://reportes.sui.gov.co/
[39]. Sun, C., & Lin, B. (2013). Reforming residential electricity tariff in China: Block tariffs pricing approach. Energy Policy, 60, 741–752. http://doi.org/10.1016/j.enpol.2013.05.023
[40]. Uribe-Mallarino, C. (2008). Estratificación social en Bogotá : de la política pública a la dinámica de la segregación social. Universitas Humanística, no.65(enero-junio), 139–171.
[41]. Voll, S. P., Pabon-Agudelo, C., & Rosenzweig, M. B. (2003). Alternatives for the Elimination of Cross-Subsidies: The Case of Brazil. The Electricity Journal, 16(4), 66–71.
[42]. Wang, T., & Lin, B. (2014). China’s natural gas consumption and subsidies-From a sector perspective. Energy Policy, 65, 541–551. http://doi.org/10.1016/j.enpol.2013.10.065

Corresponding Author: Enrique B. Cedeno
School of Management, New York Institute of Technology, Nanjing, China