Potential Energy savings in compressed air systems in industrialized cities. A case study in Barranquilla and Cartagena

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Potential Energy savings in compressed air systems in industrialized cities. A case study in Barranquilla and Cartagena

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Abstract. The increase of energy consumption, global warming, resource depletion and the rise of policies focused on climate change and greenhouse gas emissions reductions, have promoted to countries and industries the implementation of strategies focused on increase energy efficiency and reduce GHG emissions. Compressed Air Systems (CASs) are one of the most widespread systems used in industry. In countries such as China, USA, Australia, France and Italy, CASs accounts around 10% of the overall electricity costs. In Colombia the energy used in the industrial sector, rise the 33 % of the total energy consumption, equal to 481.429 TJ/year; the electricity consumption is a 13 % of this value, equivalent to 13,3 TWh/year. This paper determine the potentials energy saving of CASs for two industrial cities of the Colombian Caribbean Coast region, showing that there is a high energy saving potential, around 50 GWh/year and a reduction of CO_2 emissions of 10,702 tons of CO_2/year, which can be taken in consideration by the government and organizations to develop projects focused on reduce energy consumption and mitigate CO_2 emissions.

1. Introduction

Worldwide energy consumption will increase 1.2% per year to 2040, being the industrial sector the biggest consumer, with about 54% of the total energy consumption [1, 2]. This growth is led by gas consumption and electricity uses as it is shown in Figure 1.

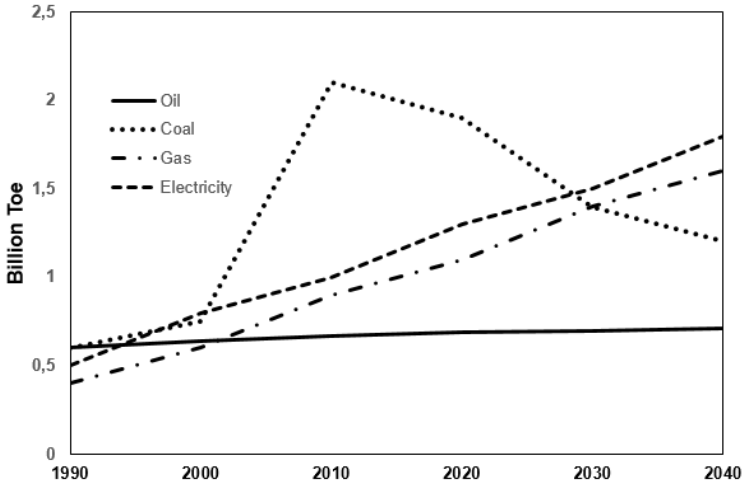

Figure 1. Worldwide energy consumption in industry by fuel

In Colombia the energy used in the industrial sector, rise the 33 % of the total energy consumption, equal to 481.429 TJ/year; the electricity consumption is a 13 % of this value, equivalent to 13,3 TWh/year [3]. In Colombia is estimated that the electricity uses will have a growth rate of 52% between 2016 and 2030 [4] highlighting the Cost-Caribbean region as the fastest growing. Figure 2 shows this trend by region.

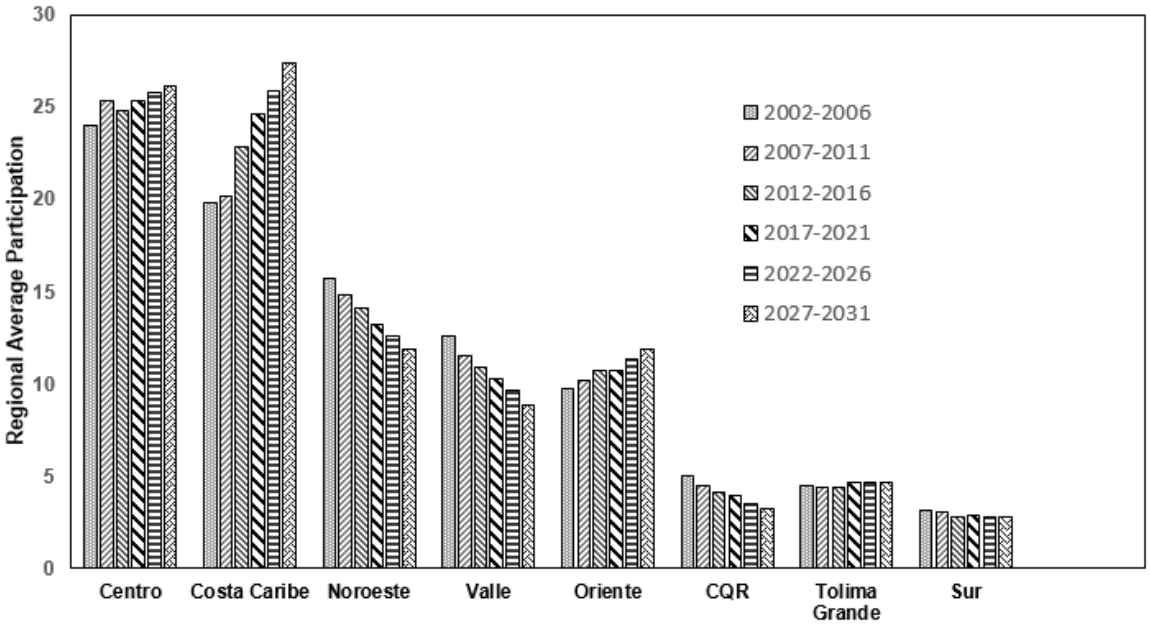

Figure 2. Electricity consumption in Colombia by region from 2002 to 2031.

This increase in energy consumption, the global warming, the resource depletion and the rise of policies focused on climate change and greenhouse gas emissions reductions, have promoted to countries and industries the implementation of strategies focused on increase energy efficiency and reduce GHG emissions [5-7]. Colombia is committed to this, and the government has proposed a group of policies which includes: The Indicative Action Plan (PROURE), Law 1715, National Development Plan (PND) and the Colombian Low Carbon Development Strategy (ECDBC) [8]. These policies focus on reducing 20% of GHG by 2030 considering an inertial scenario, a commitment

proposed by Colombia at COP 21 [9]. The implementations of good practices in compressed air systems are outstanding strategies to develop the indicative action plan for energy efficiency 2017-2022 [4].

Compressed Air (CA) is one of the most widespread systems used in pneumatic systems to operate valves and cylinders, transporting products, cleaning, among others uses, due to factors such as good transportability, speed, cleanness, and riskless [10-16]. In many countries as China, USA, Australia, France and Italy Compressed Air Systems (CASs) accounts around the 10% in the overall electricity costs for industries [17, 18]. In Colombia this value reaches the 8 %, equivalent to 1.39 TWh/year [19-21]. However, CASs has been recognized as one of the most expensive forms of energy, only about the 19 % of the consumed energy reaches the end use point [22, 23]. Energy losses can be caused by heat, inefficient uses, pressure drops, inadequate storage, leaks, among others [24, 25]. According with [26] the energy cost required to operate a CASs can be up 75 % of total life cycle cost, higher than investment and maintenance which represents the 13 % and 12 % respectively [27, 28].

The energy efficiency measures applied in CASs such as: reducing the compressors pressure, matching the supply and demand, adequate storage capacity, reducing the air intake temperature, optimizing the air compressor location and to reduce leaks, may give energy savings between 20-60 % with a usual payback lower than two years [29-31]. Furthermore, energy savings, increase energy efficiency in CASs, may ensure other Non-Energy Benefits (NEBs) such as: maintenance cost reduction, capital avoidance, productivity improvement [32, 33]. These are reasons why CASs can be considered as one of the main targets in the implementation of energy efficiency actions at country, region and industry level [11].

In some industries, staff are quick to identify energy losses from pump systems, hot surfaces, but do not pay same attention to the losses involved in the generation of compressed air, because they do not produce dirt, residues or accidents; also, the wrong approach considering compressed air as cheap, or even it is considered a free source of energy [34-36]. Another aspect is that CASs is often considered as a common utility and in most cases, they are not assigned to a specific area and therefore they become difficult to manage [37]. However, the only moment where CASs gets all the attention is when the air losses and pressure drops interfere with the normal operation of the plant [26]. This paper analyzes the potential savings in CASs for two important cities in the Caribbean Coast Region of Colombia if the different energy efficiency measures are taken there is a potential energy savings around 50GWh/year and reduction the CO2 emission in 10 702 tonnes of CO2/year.

2. Potential energy savings in Compressed Air Systems.

CASs are composed by two fundamental areas: Supply and Demand. In the Supply side the inlet air is converted in compressed air, this side include compressors, controls, air dryers, air receivers, filters and drains; in the demand side the air is carry out to the end use equipment and it is comprises of distribution lines, filters, pressure and flow controls and end-use consumers as is shown in Figure 3.

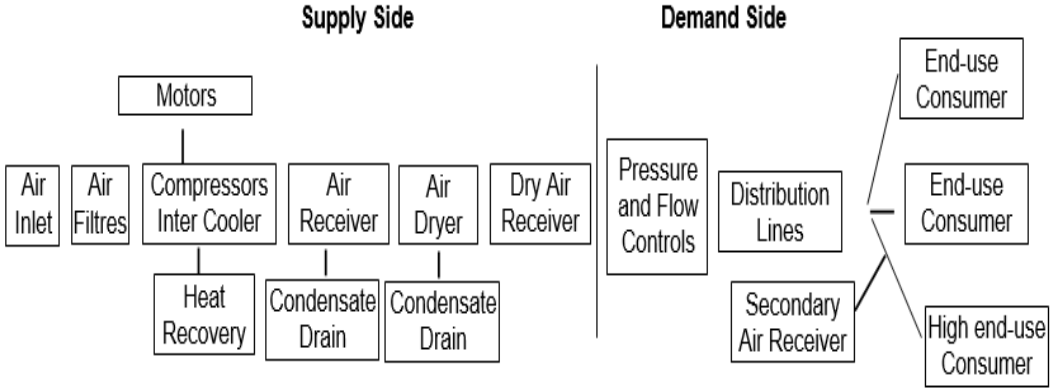

Figure 3. CASs structure and elements divided according to supply and demand sides. Source of data: Prepared by the authors based on data from: [16, 32].

In [6, 26, 37] have found that the 50-70% of the overall energy efficiency measures are related to demand side, the main measures are: air leaks reduction, inappropriate uses, reduction artificial demand, recover waste heat, inefficiencies in air system distribution and an inadequate maintenance. On the supply side the main measures are: to improve compressor operation and control, to reduce intake air temperature and to install new technologies based in efficiency concept. Table 1 shows these strategies, energy savings, applicability, payback period and costs.

Table 1. Strategies for saving Electricity in CASs. Source of data: Prepared by the authors based on [6, 26, 37].

Energy savings strategy	Annual Energy savings %	Applicability %	Potential Contribution %	Payback Period (Months)	Annual Cost ($$)
Using cooler intake air	10	40	4	5	1400
Compressors Controls	10	30	3	8	7900
Compressors pressure reduction	15	50	7,5	4	2800
Reducing air leaks	30	53	15,9	3	3900
Eliminating or reducing compressors air used	25	10	2,5	6	7300
Air compressor Waste Heat Recovery	20	20	4	10	2700
Improving filter maintenance	2	40	0,8	-	-
Use variable speed drives	15	25	3,8	-	-
Total			41,5		

3. Energy savings in Barranquilla and Cartagena Cities.

3.1 Structure of manufacturing sector.

In Colombia, the manufacturing sector is formed by 23 divisions, as product of the revision 3.1 A.C updated by the Statistics Administrative Department (DANE), adopting the revision 4 A.C which corresponds with the fourth revision of the International Standard Classification of All Economic Activities [38, 39]. This sector is made up by more than 8000 companies. Tables 2 shows a detailed

structure of the manufacturing sector, the number of companies by division and the electricity consumption in Barranquilla and Cartagena cities respectively.

3.2 Energy savings by divisions.

A study developed by [19, 20, 21] in more than five hundred manufacturing companies in the country established the percent of electricity consumption in CASs by divisions of total electricity consumption. The CASs electricity share costs in all divisions are around 8%, highlighting divisions such as textile manufacturers, where it was reached a 24%. Table 3 shows these values.

Figure 4 shows the energy savings potential in the CASs in Barranquilla and Cartagena for all divisions. In most of the divisions the saving potentials in the city of Barranquilla are greater than Cartagena, only in the sectors of Manufacture of chemicals and chemical products, Manufacture of rubber and plastics products, Manufacture of other non-metallic mineral products and Manufacture of coke and refined petroleum products, the saving potential is greater in Cartagena.

Table 2. A Detailed structure of manufacturing section in Barranquilla and Cartagena: Data source: Prepared by the authors based on [38, 39].

Section	Division	Description	Number of companies in Barranquilla	Electricity consumption (Kwh/year)	Number of companies in Cartagena	Electricity consumption (Kwh/year)
C. Manufacturing	10	Manufacture of food products	70	164.761.051	16	34.030.948
	11	Manufacture of beverages.	9	90.604.089	4	33.773.345
	12	Manufacture of tobacco products	-	-	-	-
	13	Manufacture of textiles	10	37.070.428	-	-
	14	Manufacture of wearing apparel	22	2.505.818	-	-
	15	Manufacture of leather and related products	6	9.760.246	-	-
	16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	3	154.376	4	189.657
	17	Manufacture of paper and paper products	5	48.111.729	-	-
	18	Printing and reproduction of recorded media	21	6.167.848	-	-
	19	Manufacture of coke and refined petroleum products	7	886.154	9	124.953.234
	20	Manufacture of chemicals and chemical products	27	85.756.298	21	606.271.720
	21	Manufacture of pharmaceuticals, medicinal chemical and botanical products	7	30.993.542	-	-
	22	Manufacture of rubber and plastics products	22	47.623.089	13	161.469.858
	23	Manufacture of other non-metallic mineral products	23	98.529.920	8	162.296.034
	24	Manufacture of basic metals	10	75.179.118	4	1.158.365
	25	Manufacture of fabricated metal products, except machinery and equipment	23	10.631.964	10	2.191.413
	26	Manufacture of computer,	-	-	-	-

Section	Division	Description	Number of companies in Barranquilla	Electricity consumption (Kwh/year)	Number of companies in Cartagena	Electricity consumption (Kwh/year)
		electronic and optical products				
	27	Manufacture of electrical equipment	-	-	-	-
	28	Manufacture of machinery and equipment N.E.C.	14	4.861.090	3	1.490.521
	29	Manufacture of motor vehicles, trailers and semi-trailers	3	138.526	-	-
	30	Manufacture of other transport equipment	-	-	-	-
	31	Manufacture of furniture	14	8.318.401	-	-
		Total	296	722.053.687	92	1.127.825.095

Table 3. CASs electricity share costs of total electricity consumption in all divisions.

Divisions	% of electricity Consumption	**Divisions**	% of electricity Consumption
Manufacture of food products	10	Manufacture of pharmaceuticals, medicinal chemical and botanical products	3.2
Manufacture of beverages.	11	Manufacture of rubber and plastics products	12.8
Manufacture of tobacco products	2	Manufacture of other non-metallic mineral products	4.2
Manufacture of textiles	24	Manufacture of basic metals	2
Manufacture of wearing apparel	12	Manufacture of fabricated metal products, except machinery and equipment	4.3
Manufacture of leather and related products	15	Manufacture of computer, electronic and optical products	6.8
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	17	Manufacture of electrical equipment	2.7
Manufacture of paper and paper products	3	Manufacture of machinery and equipment.	2.8
Printing and reproduction of recorded media	9	Manufacture of motor vehicles, trailers and semi-trailers	4.1
Manufacture of coke and refined petroleum products	5.1	Manufacture of other transport equipment	7.7
Manufacture of chemicals and chemical products	4.1	Manufacture of furniture	6.8

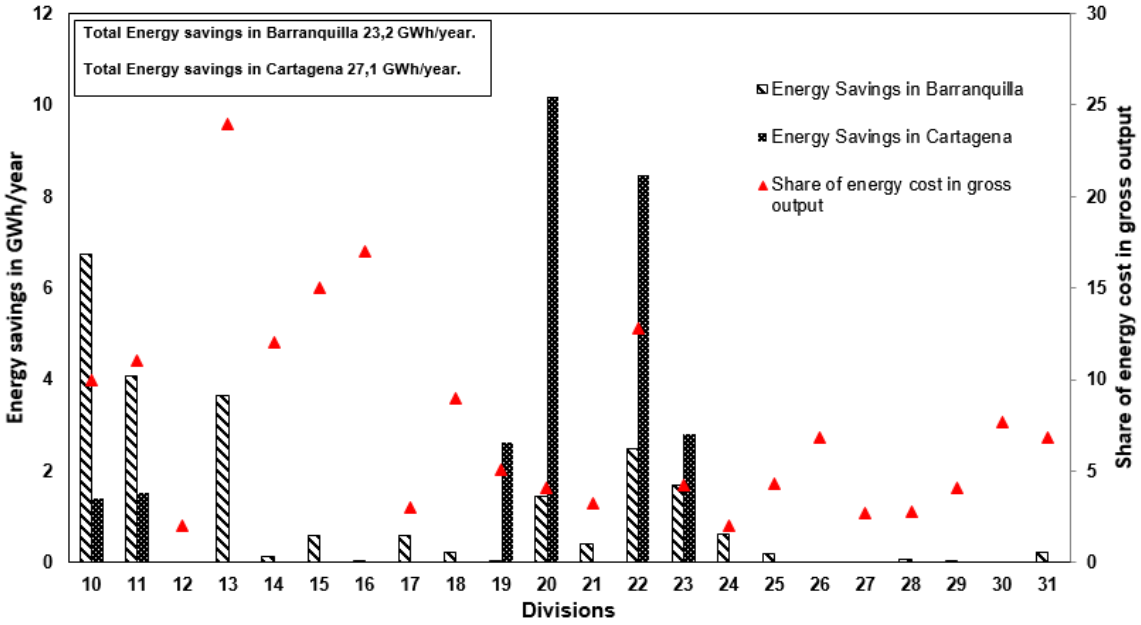

Figure 4. Savings potential in the compressed air system in the city of Barranquilla and Cartagena for different divisions.

Although in Cartagena there are three times fewer industries than in Barranquilla, the energy savings potential are greater due to the fact that the existing industries are large consumers of electricity.

3.3 Potential of CO_2 reduction.

Figure 5 shows the impact in the reduction of CO_2 emissions, considering the specific emission factor for power generation in Colombia of 0.2129 $kgC0_2/kWh$ (Roa and Castellanos, 2018). The total reduction is equivalent to 10.702 tonnes of CO_2/year, 4.939.169 in Barranquilla and 5.763.157 in Cartagena.

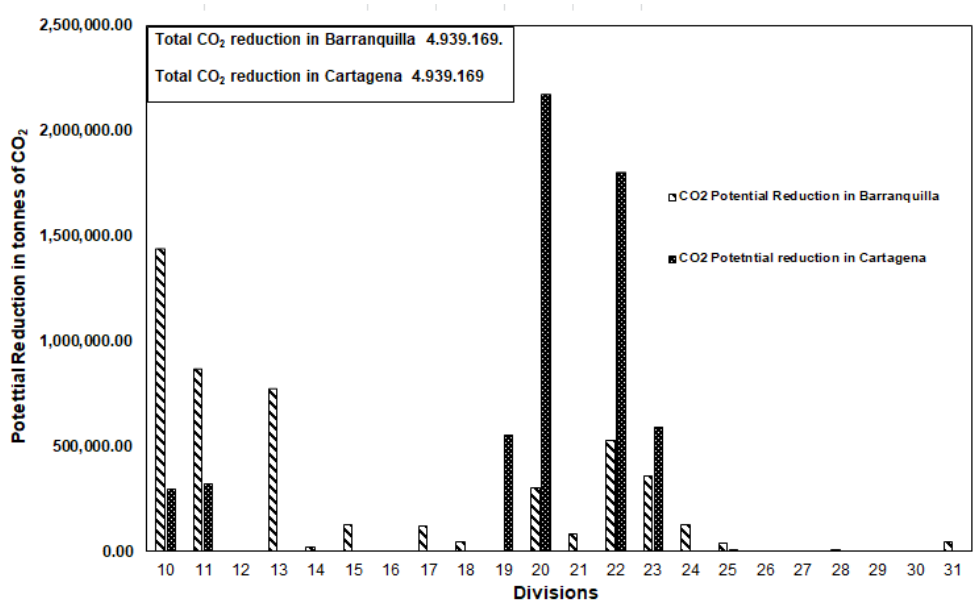

Figure 5. Potential of CO_2 reduction in energy efficiency measures are applied.

4. Conclusions.

Compressed Air Systems (CASs) are one of the most widespread systems used in industry. In countries such as China, USA, Australia, France and Italy CASs accounts around 10% of the overall electricity costs. However, CASs has been recognized as one of the most expensive form of energy, applied energy efficiency measures may give between 20-60 % of energy savings with a usual payback lower than two years. These are reasons why CASs can be considered as one of the main targets systems for the implementation of energy efficiency actions in many country, regions and industry levels.

The implementation of good practices in CASs is one of the strategies to be developed by governments focused on reduce energy consumption. This paper shows the potential energy savings and CO_2 reduction in CASs for two cities of the Colombian Caribbean Coast region, which are around 50GWh/year and 10 702 tonnes of CO_2/year, these results can be used by the government and organizations to implement energy efficiency projects in the identified energy savings potentials, which is related with the Colombia commitment focused on reduce a 20% of GHG by 2030, considering an inertial scenario, as it was proposed during COP 21.

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