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The role of bioclimatic architecture in the reduction of the emission of co_2 in arid environments

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ABSTRACT

The energy consumption for energy conditioning using natural/liquefied gas and electric power of the San Juan's Metropolitan Area housing is studied. The study quantifies the savings that could be obtained if dwellings had been designed bearing in mind concepts of bioclimatic architecture. Estimatesthe CO_2 emissions in both cases: a conventional house and another designed using natural energies. It is concluded that, in the second case, there would be a decrease of 74% of CO_2 emissions. If this reduction is for electric power saving, the decrease would be 84% and if by natural/ liquefied gas savings: 56%. Quantifying the complete housing of the city, the decrease in the total carbon footprint using bioclimatic design strategies would be 72%.

KEYWORDS

Carbon footprint;
Bioclimatic architecture;
Arid environments.

INTRODUCTION

Although the climate is the result of several factors, among which the most important is the solar energy, others as the concentration of GHG and aerosol in the atmosphere or the properties of the Earth's surface, are also involved. All these factors determine the proportion of solar energy that is absorbed or reflected to space.

The United Nations Convention on climate change (UNFCCC), in its article 1, defines climate change as "change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is added to natural climate variability observed over comparable time periods". The UNFCCC separates, then, between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes[1].

These human activities have produced an increase of gases that occur naturally in the atmosphere but whose increase has generated a greenhouse effect with planetary consequences.

Within the greenhouse effect gases, dioxide of carbon (CO_2), methane (CH_4) and nitrous oxide (N_2O), have increased markedly since the beginning of the industrial revolution, particularly due to human activities, such as the change in the uses of the land, burning fossil fuels and agriculture.

The level of emissions of carbon dioxide (CO_2) has increased by 31%; methane (CH_4) has increased by 145% and nitrous oxide (N_2O) by 15%.[2].

Particularly with respect to the increase of CO_2 emissions, it consequences are: increase of the average temperature of the Earth's surface; increase in the sea level; increase in erosion and salinization in coastal areas; increase and spread of infectious diseases; displacement of species to colder latitudes or altitudes; increase in frequency and intensity of extreme weather events.

In urban environments, the greenhouse effect due to the increase of CO_2 levels greatly contributes to the generation of the urban heat island, main aspect of the urban climatology.

Some authors define the heat island as: "Global warming of the city compared to the pre-urban conditions"; "differences between urban and non-urban area temperature" and "... an `inverse oasis' where air and surface temperatures are warmer than those in rural environments".

For Oke, T.R. (2006), this phenomenon of urban heat island has a direct impact on the quality life of the inhabitants, mainly in those urbanizations located in arid zones, by the hygrothermal discomfort that it causes in warm environments and by the air pollution associated with the gas dome that is generated over the cities.

In arid environments such pollution increases due to its ecosystemicfragility, and its inhabitants are subject to prolonged droughts accompanied by severe temperature variations during the day and throughout the year; and violent winds that cause displacement of sand and strong wind erosion. These are regions suffering from an intense evapotranspiration, strong salinization of soils and aquifers, and a lack of organic matter and nitrates in the soil.

At the same time, the developments impinge strong pressure on the climatic load and the hygrothermal comfort of its population, by the different morphological and typological characteristics of the spatial distribution of the city.

The use of environmental conditioning equipmentfor cooling and heating, using fossil fuels, is one of the negative effects of urbanization on human health, since the CO_2 emitted due to it greenhouse effect, contributes to the air pollution.

Therefore, such pollution is human responsibility, as it's mitigation strategy. One of them is precisely the reduction of the emissions generated by the thermal conditioning equipment, which use fossil fuels.

Although fossil fuels have been the main drivers of the economy in the last 150 years, letting that the population multiplied six times, this growth produced an increase in the complexity of urban systems over time and generated an indiscriminate exploitation of natural resources with the consequent increase of the pressure on the environment.

Therefore, the virtual exhaustion of those reserves caused by the indiscriminate use of them as generators of energy resources, is one of the biggest problems facing the world civilization.

The situation is exacerbated in emerging countries such as Argentina with 75% of its territory falling in the arid Diagonal of South America, where there are large tracts of infertile land, where the scarcity of natural resources, greatly limits the possibilities of development.

The sustainable use of energy resources in building, along with the use of flow resources to satisfy their energy requirements, would be associated with energy savings. It is also considered that the efficient use of energy is a source of energy and therefore savings in a sector will mean greater possibilities for use particularly in the productive sector, which cannot be replaced by other alternative flow resources.

global estimationaccording to the IEA[12], indicates that optimizing buildings in relation to their requirements of refrigeration, heating, ventilation, lighting and water heating, the annual energy saving would represent 500 MTOE by the year 2030.

During the 1997 - 2007 decade[5], the CO_2 emissions in Argentina's increased by 57%. Energy consumption in our country produces 3.89Gg/$10CO_2$ emissions per capita, higher than the 3.01Latin American averages. The residential sector accounts 23% of this contamination[13].

All these practices create high unsustainable conditions that compromise the necessary ecosystemic balance on the planet, affecting first of all in the cities by their continuing energy demand to satisfy their growing needs.

ARID ENVIRONMENTS - METROPOLITAN AREA OF SAN JUAN

Arid ecosystems represent approximately 47% of the emerged lands of our planet and 14% of the world's population lives in them.

In South America the Cordillera de los Andes is a climatic barrier very effectively in the presence of atmospheric circulation. This circulation has two aspects[4]:

One strictly atmospheric with an investment from the general airflow at 30 ° South latitude: towards South flows with West sense and towards North circulates withEast sense; this generates the known South American arid fringe which covers 60% of Argentina. This fringe is an extended strip of several hundreds of kilometers wide; the northbound begins at the Peruvian Pacific coast and ends to the South on the Atlantic coast of Patagonia.

The other aspect produces reverse oceanic circulations: the cold Humboldt Current to the West and the warmfrom Brazil to the East, affecting significantly the adjacent coasts.

In our country, arid areas have only 12% of surface water resources and its population is approximately 30% of the national total.

As the Atlas of arid zones of Latin America and the Caribbean (2010), the province of San Juan has five areas in which this agency classifies the aridity. These are: xerica, hiperarid; arid, semi-arid and subhumid. It is located in the mountainous Andean sub-region, with a disposition of his reliefs that determine the lack of rain and a high solar radiation.

The most important conurbation of the province of San Juan, the San Juan Metropolitan Area, is located in such arid fringe at latitude - 31° 32'24"and longitude - 68° 31'48". The city has a very high percentage of urban population: 88.35% and a rate of urban concentration of 69.9%.

The urban climate of the San Juan Metropolitan Area, located to the southeast of the province, is arid (Thornthwaiteindex = 0.0794) and Continental (Gorczynsky index [K] = 34.12). Thethermal amplitudes are high daily, seasonal and annual (17.3 °C). Low amount of humidity (annual average = 40.92%). Very low summer rainfall regimen (annual = 77.72mm). The solar radiation is high year-round (490W/m^2), as a result of a decreasing low cloud cover. The water deficit is about 979.28 mm. Throughout the year the most frequent wind is from the South sector (average 7 km/h), with intense gusts associated with dust storms in times of change of time. Prior to the changes of time usually appears a local wind known as "Zonda", which is an effect föhen, characterized by very dehydrated and torrid air that can last from hours to several days[11].

The temperature, relative humidity and solar radiation trend in the last 19 years, period 1995-2013 results[6]:

Temperature: increase of the maximum temperature; on average in 2013it was 0.95°C higher than in 1995. The increase in the average temperature is 3.48°C and 4.66°Cin the minimum temperature.

Relative humidity: decrease of the maximum relative humidity; on average, in 2013 it was 2.66% less than in 1995. The reduction in the average relative humidity is 2.05% and 2.00% in the minimum relative humidity.

Solar radiation: increase of the solar radiation; on average in 2013, there were 91.2W/m^2 more than in 1995, indicating a clear tendency to the decrease of cloudiness from the beginning until the end of the study period.

ENERGY CONSUMPTION IN THE AMSJ FOR THERMAL CONDITIONING

The structure of energy consumption for thermal conditioning in the San Juan Metropolitan area, was obtained from a survey of consumption, associated with actual data billed during 2013.

The universe studied consisted of a sampling of homes inhabited by families constituted from 1 to 6 people and located in areas of the city with different characteristics of space occupation, i.e. different percentages of soil occupation; building heights; and building volumes. These features correspond to the so-called Urban CharacteristicBands[3].

Due to the particularities of the use of appliances to provide cooling and heating to homes, the consumption was calculated from 2 types of data: type and power of the appliance, and consumption checked for July, September and December.

The calculation of the consumption in July and December to get typical months of winter and summer consumption, showed:

- July: Gas = 48%; EE = 42%; December: EE = 59%

Of all the Gas consumed in the coldest month (July), 48% was destined to heating. In the same month, of the total electric power (EE) invoiced, 42% had the same destiny. In addition, the difference between the consumption of electrical energy between December andSeptember was indicative of consumption for cooling in the first month, resulting in the remaining consumption for lighting, pumps, etc. Therefore, the total of consumed electricity in the warmest month, 59 % went to cooling and ventilation.

PASSIVE AND ACTIVE STRATEGIES OF BIOCLIMATIC ARCHITECTURE

The building bioclimatic chart obtained by Watson (1983), adapted by Cúnsulo[10], which subdivides the chart into 17 areas (or strategies), ranging from active or conventional heating to the mechanical cooling, including the comfort zonewas used for the calculation of the amount of monthly, seasonal and annual hours of implementation of each bioclimatic strategy. That calculationis showed in TABLE 1 with the month-to-month values of passive, active and comfortstrategies.

ENERGY CONSUMPTION FOR THERMAL CONDITIONING WITHOUT APPLICATION OF BIOCLIMATIC ARCHITECTURE STRATEGIES

The procedure followed for the calculation of the energy consumption of homes designed without taking into account bioclimatic strategies adapted to the local climate, was as follows:

A) Gas and EE consumption in July and December, for a home in the AMSJ:
   - July: GAS: 383m^3 and EE: 343KWh
   - December: GAS: 77m^3 and EE: 522KWh

B) The previous consumption was applied to the values of the structure of energy consumption for thermal conditioning.

TABLE 1 : Hours and percentages of each monthly and annual strategy of bioclimatic architecture (BioArch)

	ESTRATEGIES OF BIOCLIMATIC DESIGN													
	PASSIVE STRATEGIES				ACTIVE STRATEGIES						COMFORT		ANNUAL	
MONTH	Hours of Passive Heating	Hours of Passive Cooling	% Passive Heating	% Passive Cooling	Hours of Active Heating	Hours of Active Cooling	Active Heating	Active Cooling	Hours of Mechanical Humidification	% Mechanical Humidification	Comfort Hours	% Comfort Hours	Hours	% Hours
January	11	272	0.01	0.37	0	180	0.00	0.24	1	0.00	280	0.38	744	100
February	29	255	0.04	0.38	0	170	0.00	0.25	16	0.02	206	0.30	676	100
March	154	212	0.21	0.29	0	32	0.00	0.04	4	0.01	341	0.46	743	100
April	258	131	0.35	0.18	0	8	0.00	0.01	2	0.00	344	0.46	743	100
May	509	11	0.68	0.01	2	0	0.00	0.00	41	0.06	181	0.24	744	100
June	587	2	0.82	0.00	15	0	0.02	0.00	94	0.13	37	0.05	720	100
July	584	1	0.78	0.00	115	0	0.15	0.00	30	0.04	14	0.02	744	100
August	513	31	0.69	0.04	68	0	0.09	0.00	129	0.17	3	0.00	744	100
September	454	20	0.63	0.03	65	23	0.09	0.03	82	0.11	76	0.11	720	100
October	173	182	0.23	0.24	0	43	0.00	0.06	127	0.17	219	0.29	744	100
November	143	201	0.20	0.28	0	103	0.00	0.14	68	0.09	205	0.28	720	100
December	3	311	0.00	0.42	0	289	0.00	0.39	31	0.04	110	0.15	744	100

TABLE 2 : Energy consumption calculation per house in the AMSJ without usingBioclimatic Architecturalstrategies

MONTH	ENERGY CONSUMPTION PER HOUSE IN THE AMSJ A: Checked and Modeled				CONSUMPTION STRUCTURE(Incidence % on the total consumption) B: Statistic of cases.				CONSUMPTION FOR CONDITIONING PER HOUSE C = A x B			WEIGHTING OF YEARLY HOURS OF HEATING AND COOLING(PASSIVE AND ACTIVE) D		MONTHLY CONSUMPTION PER HOUSE FOR THERMAL CONDITIONING WITHOUT USE OF BioArch E = 100 x E/% Cal o Ref		
	HEATING		COOLING		HEATING		COOLING		HEATING		COOL			HEATING		COOL./HUMID.
	GAS (m^3)	EE (KWh)	GAS (m^3)	EE (KWh)	GAS (m^3)	EE (KWh)	GAS (m^3)	EE (KWh)	GAS (m^3)	EE (KWh)	EE (KWh)	HEATING	COOL./HUMID.	GAS (m^3)	EE (KWh)	EE (KWh)
JAN												1.6%	74.5%	3	2	230
FEB												4.6%	78.2%	9	7	241
MAR												22.8%	40.7%	42	33	125
APR												38.4%	23.2%	71	55	71
MAY												72.1%	8.5%	133	104	26
JUN												79.9%	16.3%	147	115	50
JUL	383	343			48%	42%			184	144		100.0%	5.1%	184	144	16
AUG												73.7%	25.6%	135	106	79
SEP												71.7%	20.5%	132	103	63
OCT												22.0%	52.6%	40	32	162
NOV												20.1%	58.9%	37	29	181
DEC			77	522				59%			308	0.4%	100.0%	1	1	308

TABLE 3 : Monthly and annual EE and gas energy consumption for housingthermal conditioning

MONTH	MONTHLY CONSUMPTION PER DWELLING FOR THERMAL CONDITIONING WITHOUT USE OF BioArch			MONTHLY CONSUMPTION PER DWELLING FOR THERMAL CONDITIONING WITH USE OF BioArch		
	HEATING		COOLING	HEATING		COOLING
	GAS (m^3)	EE (KWh)	EE (KWh)	GAS (m^3)	EE (KWh)	EE (KWh)
JAN	3	2	230	0	0	117
FEB	9	7	241	1	1	127
MAR	42	33	125	4	3	38
APR	71	55	71	7	5	17
MAY	133	104	26	13	10	22
JUN	147	115	50	18	14	49
JUL	184	144	16	45	35	15
AUG	135	106	79	27	22	68
SEP	132	103	63	28	22	56
OCT	40	32	162	4	3	98
NOV	37	29	181	4	3	103
DEC	1	1	308	0	0	184
ANNUAL	933	731	1553	151	118	894

C) Percentage of consumption for thermal conditioning based on previous values of A and B.

D) The percentage of hours per month of passive and active bioclimatic design strategies was incorporated.

E) The previous percentages were applied to the energy for thermal conditioning.

MONTHLY, SEASONAL AND ANNUAL ENERGY CONSUMPTION PER HOUSE IN THE AMSJ USING BIOCLIMATIC ARCHITECTURE TOOLS

The monthly and annual values of EE and Gas energy consumption per dwelling for thermal conditioning are obtained using the previous tables.

The seasonal consumption per dwelling without using BioArch and using BioArchis shown in the following table:

ENERGY SAVING BY APPLYING STRATEGIES OF BIOCLIMATIC ARCHITECTURE

Starting from the percentage of annual hours of passive strategies, the savings in energy consumption that would be generated in a house designed with passive heating and cooling guidelines was calculated, using the same procedure used in the calculation of the energy consumption for thermal conditioning regardless of BioArch strategies.

QUANTIFYING CO_2 TOTAL EMISSIONS PER YEAR FOR THE AMSJ USING BIOCLIMATIC DESIGN TOOLS

Taking into account the emission values calculated in the previous Item and according to the statistics of Energía San Juan and ECOGAS (2014) andthe quantity of residential users of electricity and gas, the annual emissions of the total housing would be:

➔ Without use of BioArch strategies:

- Residential users of electricity: 169,346.00homes.

Annual emissions from a house: 0.96936 TCO_2

Total emissions due EE: 164,157.00 TCO_2 per year

- Residential users of Natural/Liquefied Gas: 94,025.00homes.

Annual emissions from a house:1.81935TCO_2

Total emissions due Gas: 171,064.00 TCO_2per year

➔ UsingBioArch strategies::

- Residential users of electricity: 169,346.00 homes.

Annual emissions from a house:0.43012TCO_2

Total emissions due EE: 164,157.00 TCO_2per year

- Residential users of Natural/Liquefied Gas: 94,025.00 homes.

Annual emissions from a house:0.29445TCO_2

Total emissions due Gas: 171,064.00 TCO_2per year

- ➔ Total CO_2 emissions to the atmosphere by thermal conditioning in homes in the metropolitan area of San Juan: 335,222.00 TCO_2 per year.
- ➔ Total CO_2 emissions to the atmosphere by thermal conditioning in homes in the metropolitan area of San Juan if they are designed with bioclimatic architecture tools: 100,525.00 TCO_2 per year.
- ➔ Reduction of CO_2 emissions to the atmosphere by thermal conditioning in homes in the metropolitan area of San Juan, if they are designed with bioclimatic architecture tools: 70%.
- ➔ Emissions of$CO_2$to the atmosphere
- ➔ The sum of average emissions of CO_2 from a home in the AMSJ caused by energy consumption for thermal conditioning without using principles of bioclimatic architecture is: 2.79 TCO_2 and using them, 0.72 TCO_2 per year.
- ➔ Annual reduction of CO_2 emissions to the atmosphere using BioArch
- ➔ The reduction of air emissions generated by the use of conventional energy in housing results about 74%, using bioclimatic architecturetools.

The reduction percentage per house, by type of energy used results:

GAS: 84%

EE : 56%

Seasonal emissions per housein the AMSJ using BioArch:

WINTER

- Natural/liquefied gas: decrease percentage: 81%.

- Electric power: decrease percentage: 60%.

SUMMER

- Natural/liquefied gas: decrease percentage: 83%.

- Electric power: decrease percentage: 46%.

AUTUMN (FALL)

- Natural/liquefied gas: decrease percentage: 90%.

TABLE 4 : Seasonal and annual energy consumption by dwelling without use of BioArch and with use of BioArch

MONTH	SEASONAL CONSUMPTION PER DWELLING FOR THERMAL CONDITIONING WITHOUT USE OFBioArch			SEASONAL CONSUMPTION PER DWELLING FOR THERMAL CONDITIONING WITH USE OF BioArch		
	HEATING		COOLING	HEATING		COOLING
	GAS (m^3)	EE (KWh)	EE (KWh)	GAS (m^3)	EE (KWh)	EE (KWh)
SUMMER	12	10	778	1	1	429
AUTUMN	245	192	223	24	19	77
WINTER	466	365	145	90	71	133
SPRING	209	164	406	35	28	256
ANNUAL	933	731	1553	151	118	894

TABLE 5: Energy consumption per dwelling in the AMSJ, using BioArch strategies.

MONTH	ENERGY CONSUMPTION PERHOUSING INTHE AMSJ – A: Relieved andModelled – July – GAS (m^3)	July – EE (KWh)	December – GAS (m^3)	December – EE (KWh)	Consumption Structure (incidence % on the total consumption) – B: Statistic of cases – HEATING – GAS (m^3)	HEATING – EE (KWh)	COOL./HUMID – GAS (m^3)	COOL./HUMID – EE (KWh)	ConsumptionforConditioning – C = A x B – HEATING – GAS (m^3)	HEATING – EE (KWh)	COOL. HUMID – HUMI.D. – EE (KWh)	PASSIVE STRATEGIES (%)hours/month as AMSJ climate – D – Heating	D – Cool./Humid	ConsumptionsavingswithBioArch – E= C x D – Heating – Gas (m^3)	Heating – EE (KWh)	Cool./Humid. – EE (KWh)
Jan												1.48	36.51	3	2	112
Feb												4.19	36.85	8	6	113
Mar												20.62	28.38	38	30	87
Apr												34.63	17.58	64	50	54
May												64.84	1.40	119	93	4
Jun												70.27	0.25	129	101	1
Jul	383	343			48%	42%			184	144		75.45	0.13	139	109	0
Aug												58.76	3.55	108	85	11
Sep												56.61	2.49	104	82	8
Oct												19.86	20.90	37	29	64
Nov												18.15	25.51	33	26	79
Dic			77	522				59%			308	0.39	40.13	1	1	124

- Electric power: decrease percentage: 77%.

SPRING

- Natural/liquefied gas: decrease percentage: 83%.

- Electric power: decrease percentage: 50%.

Total emissions of CO_2 to the atmosphere by thermal conditioning in homes in the AMSJ: 335,222.00 TCO_2 per year.

Total emissions of $CO_2$to the atmosphere by thermal conditioning in homes in the AMSJ if designedwith bioclimatic architecture tools: 100.525,00 TCO_2 per year.

CONCLUSIONS

Among the greenhouse effect gases, the carbon dioxide (CO_2), represents one of which has increased steadily since the end of the 18th century.

In human settlements, the consequences of the increase in their emissions have influenced on the air pollution, contributing to the spread of infectious diseases, as well as, on the urban heat islandeffect, which has a direct impact on the quality of life of the inhabitants, mainly in those houses located in arid areas, characterized by its ecosystemic fragility.

The CO_2 emission in cities are derived mainly from the use of cooling and heating devices for thermal conditioning that use energy coming from fossil fuels.

If houses,which constitute the greater number of buildings in cities, decrease their consumption of conventional energy for thermal conditioning during the year, there would be in turn a reduction of the carbon dioxide emissions.

If houses located in a city of arid zone of medium density as the Metropolitan Area of San Juan are designed using bioclimatic architecture tools, the CO_2 emissions to the atmosphere coming fromthermal conditioning, would decrease by 74%.

Considering the type of energy used, this reduction is composed by an 84% of savings in the electricity use and a 56% of savings in the natural/liquefied gas use.

Taking into account the housing in the Metropolitan Area of San Juan supplied with electricity(169,346.00 houses) and those supplied with Natural/liquefied Gas (94,025.00 houses), the savings on CO_2 emissions to the atmosphere would be 72%.

The reductions of the carbon footprint obtained, would contribute largely with the reduction of the greenhouse effect gases, collaborating significantly with the reductionof the global climatic change effects.

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