“Create a sustainable future in Greece by educating Greek Engineers in the design of bioclimatic buildings”

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Abstract: Given the magnitude of the energy consumption of buildings, the construction sector is certainly a very important energy study area. Today, the concept of bioclimatic architecture is fundamental and is now an obligation of all engineers and architects. Thus lay the foundations for improving the energy behavior of buildings, minimizing the consumption of conventional energy and greenhouse gas emissions, while also respecting and protecting the environment while ensuring comfortable living conditions, quality and health in people’s lives. The purpose of this study is to investigate the level of knowledge and views of construction professionals regarding the application of the principles of bioclimatic architecture in the design, construction and renovation of buildings in Greece and the reasons for the lack of environmental awareness of Greeks until in recent years, resulting in a limited number of bioclimatic buildings in the Greek building stock of the country. The role played by the state and Greek citizens in the construction of non-bioclimatic buildings until recently is also under consideration.Finally, the present study aims to propose measures that could be taken to improve the energy efficiency of buildings by educating citizens and especially Greek engineers.

Keywords: bioclimatic design, sustainability, educating engineers, environmental education.

Introduction

The concept of sustainable development was introduced by Brundtland (1987) in a report entitled 'Our Common Future' by the World Commission on Environment and Development. The goal of sustainable development is to meet the needs of today's generations in a way that does not jeopardize the ability of future generations to meet their own needs (Members of the Commission, Bruntland Report, 1987).

Buildings are a world leader in energy consumption, resource consumption and greenhouse gas emissions. They consume about 40% of total energy consumption in Europe, with increasing trends (European Parliament and Council of the European Union of 16 December 2002, 2003).

The bioclimatic design of buildings is not a modern affair, but a design technique with a history of several thousand years. However, in modern times, the application of excessive mechanical systems has downgraded the importance of climate and sustainability in architectural design, resulting in the over-consumption of conventional forms of energy that tend to disappear, the emission of harmful gases into the atmosphere and consequently climate change, environmental degradation and the threat to peoples and animals health. As a result, it is now imperative to design new and renovate existing buildings, based on the particular microclimate conditions of each place of the earth, with a view to harnessing the energy of the sun and air to provide internal thermal comfort to building users (Olgyay V. & Olgyay A., 1963).

The main objective is to achieve thermal comfort conditions in the building sector, while minimizing the conventional energy consumed for heating and cooling (Athienitis, A.K. et al., 2002; Manzano-Agugliaro, F. et al., 2015). Exploiting the particular climatic conditions prevailing at each site and adapting them to architectural design plays a key role in achieving the above objective (Nguyen, A.-T. et al., 2014).

Therefore, the education of engineers in the bioclimatic design plays a major role in sustainable living (Giannarou S. et al., 2019).

1. Background

For centuries man has been searching for smart solutions in the construction of his houses, with the aim of providing thermal comfort by taking advantage of the climatic conditions of the environment (Ionescu C. et al., 2015).

People in antiquity may not have understood the concept of "energy efficiency", but in building their houses they were looking for techniques to utilize wind and solar energy as well as various natural phenomena to improve their living conditions. These techniques have improved over time and new ones have been found. Each season brought something new or improved existing techniques. As a result, all construction techniques currently used have ancient relays (Ionescu C.et al., 2015). So, in order to understand what bioclimatic architecture means today, it is necessary to begin by looking at its origins.

Socrates, about 2400 years ago, proposed the idea of a "solar house". Specifically, Xenophon in his 'Memorabilia' refers to Socrates' instructions for building south-facing homes, where the sun shines in winter, while summer provides shade. The best solution is to build taller houses on the south side so that the winter sun can enter the house and lower north side to protect against cold winter winds (Bonnette AL. & Bruel C., 1994).

The Roman Empire, during its heyday, occupied territories with completely different climatic conditions, so the idea of a "solar house" came to perfection, the so-called "Roman villa". Vitruvius in the 1st century BC, reports that the houses were adapted to the climate of each particular place. Also, the orientations of the buildings were changed to form seasonal dwellings. Buildings such as the Roman baths were constructed in such a way as to take advantage of the "greenhouse effect" (Morgan M.H. & Warren H.L., 1914).

After the fall of the Roman Empire and until the industrial revolution, the idea of "solar architecture" was abandoned and the principles of traditional energy-saving architecture were then history.The 19th century in Europe, combined with the industrial revolution and the creation of factories, began a mass migration from the countryside to the city. The city was the "Eldorado" of the poor inhabitants of the village, so a new class, the working class, flourished. In the early 19th century, people in cities did not follow basic hygiene rules, resulting in diseases such as cholera. At that time, many European countries began to develop public health rules for active disease control. Governments have taken steps to improve the quality of life by installing water pipes, drains and more. The architects of the time may not have taken energy-saving measures yet, but have realized the importance of improving living conditions at home (Markov D., 2012).

In the 20th century, in order to accommodate Europe's great working class, architects were seeking solutions for mass production and standardization of housing, buildings were the same and repetitive, and the architecture was now massive. Le Corbusier, since 1914, has proposed a housing model called the Maison Dom-Ino, a repetitive mass-production building, with a focus on how construction should be practical and functional (Pangalos P., 2015). However, this widely mechanized concept based on repetition and mass production has begun to be questioned and criticized. Modern architecture now follows the principle of "planning for nature and not against it" (Markov D., 2012).

At the beginning of the century, the scientist of Russian-German origin Köppen W. and the German climatologist Geiger R. carried out the climate classification known as the Köppen-Geiger climate classification (Rubel F.& Kottec M., 2011). However, research into the bioclimatic design of buildings began after the end of World War II.

In 1933 Keck G.F. presented "The House of Tomorrow" at the Century of Progress World Exhibition in 1933 in Chicago. In 1940, the 'Sloan Solar House', designed by Keck G.F. in collaboration with Sloan H., it became the first modern building to use passive solar heating. It is a 12-corner construction, equipped with the latest technology for lighting, air conditioning and all modern appliances. Around them there were windows, from the floor to the roof, on the twelve sides of the second and third floors. However, with an exposed glass facade, the house was unbearably hot in the summer, so Keck explored methods of shading (Barber D.A., 2014).

In the 1960s, low fuel prices led to the abandonment of all environmental practices and the use of conventional forms of energy. By the mid-1970s, however, the energy crisis was over. Excessive dependence on fossil fuels has led architects to bioclimatic design paths.

In 1951, brothers Victor and Aladar Olgyay established bioclimatic architecture as a science. They relate the climatic conditions of each place, namely the sun, the air, the temperature, the humidity, etc. with the orientation, type, shape, environment, etc. of the building and determine the thermal comfort zone (Olgyay V. & Olgyay A., 1963).

Later in 1987, Brundtland G.H., for the World Commission on the Environment and Development, referred to the concept of sustainable or otherwise sustainable development, giving directions for the future of humanity (Members of the Commission, Bruntland Report, 1987).

Over the past four decades, Malaysian architect Ken Yeang has constructed more than 200 buildings. These are low energy green buildings in more than 20 countries worldwide. Among these buildings are several skyscrapers. He has developed an eco-design approach specifically designed for the design of high-rise buildings and demonstrated the positive impact of bioclimatic architecture on a person's physical and psychological state. His major work is to build an eco-friendly building in the heart of Singapore, the EDITT TOWER, a 26-story eco-friendly building (Anholts T., 2012).

These are some of the important architects who have given impetus to their theories and projects in the bioclimatic design of buildings.

Today, the concept of bioclimatic architecture is fundamental and is now an obligation of all engineers and architects. Thus, lay the foundations for ensuring quality and health in people's lives while ensuring comfortable living conditions.

2. Greece's Energy Policy

Since 1970, a large number of conventions have been introduced, dealing with specific arrangements, directly or indirectly, for the protection of the environment, around 300 international conventions. The content of these contracts is sometimes hard law and sometimes soft law. However, irrespective of the obligation to comply with the Conventions, Member States choose to apply a policy of obedience to them, always pursuing a common policy of all States to address environmental issues at global level (Samoti G.& Chaltas Gr., 1990).

As a member of the International Community, the European Union has adopted laws and rules for its Member States to pursue a common policy on environmental protection. The common objective of the Member States of the European Union is to build a common sustainable energy policy with a view to climate change (European Court of Auditors 12, 2017).

As a result, Greece, as a Member State of the European Union, is striving to harmonize its legislation by adopting laws, rules and directives, always in the context of a common European policy on the environment.

In Greece, the first measure taken to improve the energy efficiency of the Greek building was the Thermal Insulation Regulation in 1979. The Thermal Insulation Regulation began in theory in 1980 and was effective without change until 2010. Its purpose was to reduce consumption of the energy of buildings by insulating the elements of their outer shells (walls, floors, roofs) and thereby reducing the thermal requirements of buildings to a minimum level. Since then and for many years the Greek institutional framework for the energy performance of buildings has remained unchanged, until 2010 with KENAK 2010. Today KENAK 2010 has been replaced by KENAK 2017 which is still in force today.

The Greek authorities started to deal with energy policy issues very slowly and at the same time the Greek citizens didn't have energy conscience until recent years. As a result, most of the Greek buildings is far from the energy efficiency standards set by the European Union and bioclimatic architecture in Greece, until recently, confined to some public and private buildings at the will of their owners.

The Center for Renewable Energy Sources (CRES) conducted a survey on the energy category of buildings for the period 2011 - 2016, which showed that the largest percentage of existing Greek buildings, namely 65%, are buildings with high energy consumption, 32% are classified in one average energy category, while only 3% are energy efficient buildings (Center for Renewable Energy Sources (CRES), 2016).

The questions are: Why is this happening? Are Greek engineers educated enough to create a sustainable future in Greece by designing bioclimatic buildings? The above questions are the subject of this research.

3. Methodology

The survey was conducted from the end of 2018 until the beginning of 2019 in order to investigate the level of knowledge and views of civil engineers and architects, that is to say those who are specialists in the field of construction, in applying the principles of bioclimatic architecture. The reasons for the lack of environmental awareness of Greeks until recent years have also been investigated, resulting in the limited number of bioclimatic buildings in the Greek building stock of the country. The research questions identified the role played by the state and Greek citizens in the construction of non sustainable buildings to date and explored the measures that could be taken to improve the energy efficiency of buildings by educating citizens and especially its professionals of the construction sector.

The quantitative research has been carried out through 26 closed-ended questionnaires targeting all civil engineers and architects of Greece, derived from the data of the regular members of the Technical Chamber of Greece (in total 47,392 engineers), with a sample of 377 individuals.

The survey was conducted in the winter of 2018-2019 in Greece and included designers, manufacturers / contractors, university teachers / researchers, teachers and civil servants.

In order for the sample to be representative of the population of engineers as a whole and the conclusions can be extended to all engineers throughout Greece, the questionnaires are distributed to engineers in large urban centers (e.g. Athens, Thessaloniki), to medium-sized towns (e.g. Xanthi, Alexandroupolis, Serres, Drama) and small towns (e.g. Orestiada).

The characteristics of the population to be studied outline the knowledge, attitudes and views of civil engineers and architects on bioclimatic building design.

For this reason, more than 1000 questionnaires were distributed. As a result, the total number of questionnaires answered was 138.

The 26 questions in the questionnaire were all closed and great effort was made to validate and document the results.

The 138 fully completed questionnaires were collected and the statistical analysis was was performed with the help of the statistical software IBM SPSS (Statistical Package for Social Sciences).

A quantitative analysis of the questionnaires was performed. The results are presented in tables and graphs.

Finally, the correlations between the selected variables were investigated.

4. Results and Discussion

The analysis of the results of the survey showed that the majority of respondents stated that they know and apply the principles of bioclimatic construction, but most of them were not taught during their studies but attending seminars, internet and study of magazines / national laws. This result was to be expected, as bioclimatic architecture began to concern Greeks in the last decade, resulting in their systematic integration into university programs in recent years (Graph 1).

Greece, in its effort to comply with the strict energy efficiency guidelines in Europe, has enacted strict laws since 2010 (KENAK and the Technical Chamber of Greece) that engineers are required to follow, while at the same time being invited to take written exams in order to join the Building Inspectors Register. That is why engineers today know most of the bioclimatic design strategies such as the south orientation of the main facade of the building, the location of the most frequently used areas in the South, the insulation of the building's outer shell, the price control U, the exterior building windows which must be with double / triple glazed windows and good thermal behavior, the shading of the openings by planting evergreen trees in the surrounding area of the building.

In addition, 37.7% of engineers have participated in more than 6 energy efficiency projects in buildings, 28.3% in 1-5 projects and 34.1% in no projects (Graph 2).

The delayed harmonization of Greek legislation with European legislation makes it difficult to achieve the objective of reducing the energy consumption of buildings by 2020, as most of the building is classified as low energy consumption buildings.

Greek citizens have not adopted the bioclimatic principles in their lives and are not aware of energy saving issues. This is due to lack of customer awareness, high initial cost of construction, lack of skilled labor, uncertainty about future economic benefit, lack of national legislation, lack of low energy technologies, the inadequate market for low-energy materials.

Engineers also understand the need to implement educational actions to increase the environmental awareness of Greek citizens and to educate engineers on the bioclimatic design of buildings. The majority of respondents agree that the Ministry of Environment and Energy, the Technical Chamber of Greece, the Center for Renewable Energy, etc. should be active through the organization of seminars, workshops etc., the creation of new postgraduate programs related to the design of bioclimatic buildings, the development of technical knowledge in bioclimatic design, the promotion by the state of important bioclimatic projects and their benefits, the continuation and enhancement of research.

In addition, the majority of engineers agree that bioclimatic school buildings can function as "living laboratories" of environmental education for students and tomorrow's citizens.

Finally, the majority of respondents expressed a positive view of the need for engineers to inform clients about the long-term benefits of bioclimatic construction.

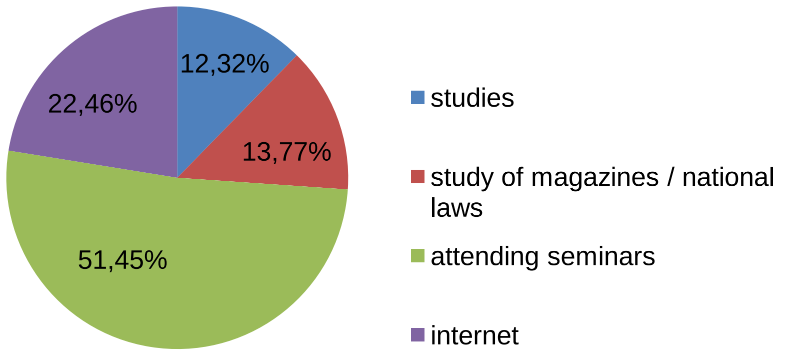
From the correlations between the qualitative (categorical) variables with the X^2 test, which were found to be of research interest, it appears that:

• Most engineers, regardless of occupation, have studied KENAK. Most of the designers and contractors, few researchers and no teachers and civil servants are registered in the Energy Inspector Register, this is justified by their employment and the number of energy efficiency projects they have participated in. Most designers and contractors have participated in projects (some 1-5 and others more than 6), few researchers have participated in 1-5 projects and all teachers and civil servants have not participated in building energy upgrades. The relationships between the variables appear to be statistically significant (Fig.1).

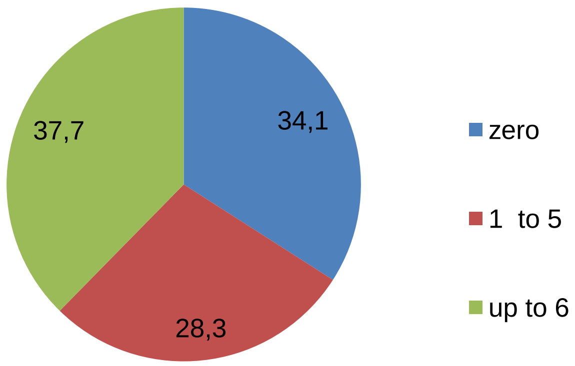
• Young engineers, with a little previous experience (0-5 and 6-9), responded that they acquired bioclimatic design knowledge during their studies while older ones (10-19 and 20 and above), mainly through seminar attendance and the internet. This is because Greece has adopted the bioclimatic design of buildings substantially since 2010 (Fig.2).

The correlation between the ordinal variables is tested with the correlation coefficients of Spearman and Kendall tau-b.

Following are suggestions and methods for educating Greeks on bioclimatic building design.



Graph 1. Quantitative analysis of the characteristic origin of bioclimatic design knowledge.



Graph2. Quantitative analysis of a characteristic number of energy performance studies of buildings.

Figure 1. Relevance of the working field of engineers and the study of the Energy Efficiency Regulation of Buildings (KENAK 2017), the registration in the Registry of Building Energy Inspectors and the number of energy efficiency studies that have taken place.

What is your main area of employment?			**Designers**	**Constructors**	**Researchers**	**Teachers**	**Civil Servants**
1. Did you study the Energy Efficiency Regulation (KENAK 2017) and the Technical Guidelines of TEE?	Yes	Count	**47**	**45**	**13**	**4**	**18**
		Expected Count	44,2	42,3	12,0	9,2	19,3
	No	Count	**1**	**1**	**0**	**6**	**3**

			Expected Count	3,8	3,7	1,0	,8	1,7
2.	**Are you registered in the Building Inspectors Register?**	Yes	Count	**44**	**45**	**3**	**0**	**0**
			Expected Count	32,0	30,7	8,7	6,7	14,0
		No	Count	**4**	**1**	**10**	**10**	**21**
			Expected Count	16,0	15,3	4,3	3,3	7,0
3.	**How many buildings energy efficiency studies have you participated in?**	0	Count	**4**	**2**	**10**	**10**	**21**
			Expected Count	16,3	15,7	4,4	3,4	7,2
		1-5	Count	**14**	**22**	**3**	**0**	**0**
			Expected Count	13,6	13,0	3,7	2,8	5,9
		>6	Count	**30**	**22**	**0**	**0**	**0**
			Expected Count	18,1	17,3	4,9	3,8	7,9

Chi-Square Tests

1.			**P-value**	Monte Carlo Sig. (2-sided)			Monte Carlo Sig. (1-sided)		
					99% Confidence Interval			99% Confidence Interval	
	Value	df	Asymp. Sig. (2-sided)	**P-value** Sig.	Lower Bound	Upper Bound	**P-value** Sig.	Lower Bound	Upper Bound
Pearson Chi-Square	43,545[a]	4	,000	,000[b]	,000	,000			
Fisher's Exact Test	24,511			,000[b]	,000	,000			

a. 5 cells (50,0%) have expected count less than 5. The minimum expected count is ,80.

2.	Value	df	**P-value** Asymp. Sig. (2-sided)
Pearson Chi-Square	106,713[a]	4	**,000**

a. 2 cells (20,0%) have expected count less than 5. The minimum expected count is 3,33.

3.				Monte Carlo Sig. (2-sided)			Monte Carlo Sig. (1-sided)		
					99% Confidence Interval			99% Confidence Interval	
	Value	df	**P-value** Asymp. Sig. (2-sided)	**P-value** Sig.	Lower Bound	Upper Bound	**P-value** Sig.	Lower Bound	Upper Bound
Pearson Chi-Square	108,653[a]	8	,000	,000[b]	,000	,000			
Fisher's Exact Test	111,054			,000[b]	,000	,000			

a. 6 cells (40,0%) have expected count less than 5. The minimum expected count is 2,83.

Figure2. Relationship between the number of years in the profession and the origin of bioclimatic design knowledge

	Number of years in the profession		**0-5**	**6-9**	**10-19**	**>20**
1. Your main knowledge of bioclimatic building design comes from:	Your studies	Count	**3**	**13**	**1**	**0**
		Expected Count	1,4	3,9	6,4	5,3
	The study of scientific journals / national. legislation	Count	**8**	**0**	**9**	**2**
		Expected Count	1,5	4,4	7,2	5,9
	Attending seminars	Count	**0**	**6**	**32**	**33**
		Expected Count	5,7	16,5	26,8	22,1
	The internet	Count	**0**	**13**	**10**	**8**

Expected Count	2,5	7,2	11,7	9,7

Chi-Square Tests

1.				Monte Carlo Sig. (2-sided)			Monte Carlo Sig. (1-sided)		
			P-value Asymp. Sig. (2-sided)	**P-value** Sig.	99% Confidence Interval		**P-value** Sig.	99% Confidence Interval	
	Value	df			Lower Bound	Upper Bound		Lower Bound	Upper Bound
Pearson Chi-Square	94,300[a]	9	,000	**,000**[b]	,000	,000			
Fisher's Exact Test	81,512			**,000**[b]	,000	,000			
a. 5 cells (31,3%) have expected count less than 5. The minimum expected count is 1,36.									

5. Educating Greek engineers

Schools of all levels of education can make a significant contribution to securing a sustainable future for Greek citizens by building bioclimatic structures. This document will outline some of the educating proposals.

A live environmental education lab, a "good example", may be the energy planning of classrooms and homes (Organization of School Buildings (OSC), 2010). In addition, Tombazis A. (2009), one of the most important Greek architects, rightly states that architecture can touch the heart, not only the mind (Tombazis A., 2009).

The education process is not limited to spatial (school) or temporal (youth) but extends throughout human life (Jessup F.W., 1969) (Self-education - Lifelong Learning - Distance education - New Technologies and Internet Use - New Graduate Programs and Research Bioclimatic Building Programs - Education Programs).

Architects and civil engineers shape the environment, so they are responsible for the sustainability of the environment through the designs they create. It is therefore important to instill the principles of sustainable development in engineering students so that they can secure a sustainable future for humanity (Smith P., 2001; Elnokaly A., et al., 2008). The educational community understands the need to introduce the principles of bioclimatic construction into the polytechnicuniversities of the country. However, consolidating sustainable design into engineer learning takes time because the issue of sustainability has not been fully adopted, but sporadically, by polytechnicuniversities as a continuation of the regular curriculum and, on the other hand, teaching sustainable construction requires a different approach than traditional (Stasinopoulos T.N., 2005).

Today, schools of bioclimatic architecture face insurmountable barriers to integrating sustainability into their curricula (Stasinopoulos T.N., 2005):

• The ambiguous identity of sustainable design, which is not just a new architectural style with an emphasis on neither the environment nor a new design culture,

• Few examples of bioclimatic buildings. But as architecture learns by example, many students are inspired by the shining examples of great architects, primarily seeking visual originality and style, and minor to the sustainability of the building,

• The high initial cost of building bioclimatic buildings,

• Lack of qualified teaching staff. As most teachers had limited or no training in the past and at the same time little experience in practice,

• Limited environmental technology,

• Lack of specialized technical staff etc.

But even if universities manage to overcome the above obstacles and introduce design programs for sustainable development into their studies, there will still be a vital point of social acceptance. "Green" architects need "green" clients, otherwise their bioclimatic knowledge will be of no value. Customers, however, who are accustomed to over-consumption, cannot appreciate an architecture that may have a high initial cost, but in the long run it costs less and offers more(Stasinopoulos T.N., 2005).

A sustainable future will be achieved by introducing sustainable design courses at universities to train and educate those involved in the construction sector, through public awareness on the benefits of sustainability, by promoting, encouraging and advertising bioclimatic buildings, bioclimatic demonstration applications, by organizing awareness campaigns and identifying the risks of conventional architecture.

In the building sector, the teaching of sustainable construction can be approached through experiential learning and practical training of students in the architectural and civil engineering departments, with experiments, simulations, external work. The concept of experiential learning is completely approached by John Dewey, who stated that only what you accepted with your soul, is what you learn and incorporate into your life and character(Dewey J. et al., 1897; Dewey J., 1938(1980)).

6. Conclusions

Over-consumption of conventional forms of energy has led to the destruction of the environment and the deterioration of the quality of life of animals and humans. The construction sector is at the forefront of conventional energy consumption, while at the same time having great potential for energy savings. Therefore, the bioclimatic design of buildings is an urgent need, as it is a socio-political issue and not a technical one, so what is needed is a change in people's attitudes and a redefinition of the priorities and goals of humanity.

This paper showed that although Greece, as a member of the European Union, had to harmonize its legislation with the EU guidelines on energy efficiency of buildings, it turned out that Greek engineers had not applied the principles of bioclimatic construction until recently. The state and all Greek citizens are also responsible for this situation. The result is the most of the Greek buildings are not sustainable and consume a large quantity of conventional forms of energy.

By analyzing and evaluating the results of research on the attitudes and knowledge of architects and civil engineers in bioclimatic architecture, conclusions were drawn on the need for effective educating methods for both engineers and all Greek citizens.

Finally, in this paper ways of educating students, engineers and building users in acquiring environmental conscience and understand the multiple benefits of bioclimatic design for the environment and the economy are proposed.

The results could also be used by academics to further research into new technologies and education methods in bioclimatic design.

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