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Climate as an Input for Design: A Review Based on Norman Foster's Residential Buildings

Bir Tasarım Girdisi Olarak İklim: Norman Foster'ın Rezidans Yapıları Üzerinden Bir Okuma

Dilek Yasar[1]

Öz

İklim değişikliği ve beraberinde getirdiği küresel ısınma ve enerji krizi, mimarlık disiplininin önde gelen hususlarından biri olmuş ve iklimle uyumlu tasarım konusu mimarların öncelikli uğraşı hale gelmiştir. Özellikle yapı stoğu içerisinde en büyük paya sahip olan konut yapıları bu sebeple önem arz etmektedir. Bu noktadan hareketle çalışmada 21. yüzyıl konut yapılarının iklimsel veriler çerçevesinde nasıl biçim aldığı sorusuna yanıt aranmış ve sürdürülebilirlik bağlamında öncü mimarlardan biri olan Norman Foster'ın konut yapılarına odaklanılmıştır. Araştırma kapsamında Foster'ın farklı ülkelerde yer alan konut projeleri iklim ve tasarım ilişkisi bağlamında analiz edilmiştir. Çalışmanın sonuçları mimarın konut tasarımlarında genellikle kümelenmiş formlara yöneldiğini, güneşi ve rüzgârı kontrol altına alabilmek ve hatta onlardan yararlanabilmek için bu formları hem düşeyde farklı yükseklikler hem de yanal yüzeylerde bir dizi girintiler ve çıkıntılar yaratarak şekillendirdiğini göstermiştir. Foster, iç ve dış arasındaki sınırları bulanıklaştırmak ve aynı zamanda kullanıcılara doğal havayla temas edebilecekleri ortamlar yaratmak amacıyla balkonlara ayrı bir önem vermiş, çoğu tasarımında gölgeleme elemanlarını sanatsal bir tarzla kullanmıştır. Daha ziyade kahve, gri ve bej tonlarını tercih etmiş ve yine iklimsel faktörlere cevap verebilecek bir malzeme paleti kullanmıştır.

Anahtar Kelimeler: Sürdürülebilirlik, İklim, Konut Yapıları, Mimari Tasarım, Norman Foster

ABSTRACT

Climate change and associated global warming and energy crisis have become a prominent issue of architecture and considered one of the primary concerns of architects as regards climate-compatible design, especially in terms of residential buildings, the largest constituent of the building stock. Accordingly, the present study sought an answer to how the 21st century residential buildings took form vis-a-vis climatic data and focused on the residential buildings by Norman Foster, a leading architect in the context of sustainability. Therefore, Foster's projects in different countries were analyzed as regards the relationship between climate and design. The results of the study were indicative of the fact that Foster generally gravitated towards clustered forms in his residential designs, and shaped those forms by creating a series of indentations and protrusions on both vertical and lateral surfaces with an aim to control, and even benefit from, the sun and wind, to blur the boundaries between interior and exterior and at the same time attached special importance to balconies to create environments where users could come into contact with natural air, used shading elements in an artistic style in most of his designs, preferred brown, gray, and beige tones, and used a material palette, which could address climatic factors.

Keywords: Sustainability, Climate, Residence, Architectural Design, Norman Foster

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INTRODUCTION:

So far, fossil-based fuels have been used to meet the ever-increasing energy demands following the industrial revolution. Nevertheless, the use of the said relatively cheap and non-renewable energy as a straightforward way to improve the living standards of human society, has been associated with a high environmental cost (Olgyay, 2015): Global warming and energy crisis. These two topics have been subject to debate among scientists for many years now, and various sustainable strategies have been developed by different scientific disciplines with an aim to reduce energy consumption and address the factors that paved the way for global warming. For example, given that annually 30-40% of global energy supply was consumed by buildings (Sisson et al., 2009), it was necessary to introduce environmentally friendly and energy saving designs. The increased number of residential buildings as a direct reflection of the rapid increase in the world population has had an important place in the increase of the aforementioned cost. A review of the large share of the housing sector in total energy consumption and its mutual and determinant relationship with climate change may provide an insight towards a better understanding of the problem. There is an increased demand for energy in residences associated with climate change (Rosenthal, Gruenspecht & Moran, 1995; Radhi, 2009; Gong, Akash & Sumiyoshi, 2012) and one-third of the world's energy is consumed to meet the heating and cooling demands in residential buildings (Isaac & Van Vuuren, 2009). Residential buildings, as the most produced building type within the building stock, play a key role in climate change and are important as regards creating and ensuring quality of a healthy environment. For this reason, residential buildings production is one of the leading goals of the state in developed societies (Sayed Abdou Ahmed, 2021).

Today, one of the most important goals of architects is to reduce energy consumption of the construction industry without compromising human comfort and also through climate sensitive strategies (Nguyen et al., 2011). Accordingly, architects have developed various design strategies. One of these design strategies is the production of climate-sensitive forms. Indeed, form has a great impact on energy use in buildings (Steadman et al., 2014). The literature indicates that the relationship between building form and energy consumption is the subject of two types of research (Tian et al., 2015). One is to compare the effects of different building forms on energy use, and the other is to develop simple models to predict the energy use of various building forms (Wei et al., 2016). In the light of above, the present study sought an answer to the question of how residential buildings were shaped within the framework of climatic data. Therefore, the study focused on the residential buildings of Norman Foster, who, on the one hand, pioneered important concepts and ideas on sustainability, and on the other hand, developed his own architectural identity. In his environmentally oriented designs, Foster turns sustainability ideals into reality with the high technologies he uses and creates structures that reduce energy and encourage contact with the natural world with ecological-based designs. Foster suggested sustainable solutions for comprehensive issues, including climate change, energy, and resource use and the local and global impacts thereof (Pantoja et al., 2022; Ştefan, 2015). He introduced significant sustainable design strategies in his designs by conserving the environment, using local natural resources, respecting the historical context of the city, and adopting technologies compatible with the local climate character (Kang & Zhang, 2012). In that regard, a better understanding of Foster's approach towards sustainable design could be inspiring for architects in both theoretical and practical terms. The present study aimed to seek an answer to the question of how Foster, with a well-established sensitive approach towards environmental issues, made use of climatic data in his residential building designs and how the said data were reflected upon his designs. Accordingly, Foster's residential projects in different countries and different climatic zones were analyzed in the context of the relationship between climatic data and decisions associated with design.

1. Materials and Methods

Given that more importance was attached to climatic factors in the 21st century, the present study investigated how residential buildings were shaped vis-a-vis climatic data. Accordingly, the study focused on the residential buildings of Norman, a pioneer in sustainable solutions who took local climate criteria into consideration, which were designed after the year 2000. The residential buildings included in the research within the framework of the criteria described below were analyzed in the context of the relationship between climatic data and design decisions. Two data sources were used for the purposes of the analysis. The first data source was the Köppen-Geiger climate classification system, a widely used system across the world. Hence, data on climate were collected on this classification system. The second data source was a set of building characteristics associated with the design of the building: orientation, form, facade movements, roof formation, color, and materials used in the facade. The data from those two data sources, one based on climatic data and the other on design, were thereafter analyzed by placing them in matrix diagrams. Methodologically, matrix diagrams are used to analyze the relationship between variables. The residential buildings included in the study and the selection criteria are given below.

1.1. Residential Buildings in the Scope of the Study

Three criteria were determined in the selection of residential buildings to be included in the scope of the study. The first criterion is historical. Accordingly, the buildings built before the year 2000 were excluded from the scope of the study with an aim to focus on contemporaneous design concepts. The second criterion was climate-oriented. In this context, residential buildings were selected from different climatic zones by Köppen-Geiger climate classification. Therefore, it was possible to see what kind of climatic data was taken into consideration in a given climate zone and how those data were reflected on the form. The third criterion was the country in which the residential buildings were located. Residential buildings were selected from different countries. The aim was to be able to see whether the cultural values were also taken into consideration during the process of creating the form in accordance with the climatic factors, whether or not the designs benefited from certain variables, including local materials and technology specific to the place, and if so, how. Therefore, eight residential buildings were included in the scope of the research. The names, visuals, design dates, climatic zones, and countries of those buildings can be seen in the table below (Table 1). Information and images of buildings are taken from Foster's official website, excluding climate zones.

Table 1. Residential Buildings in the Scope of the Study

Building Name	Building Visual	Design History	Köppen-Geiger Climate Classification	Country/City
Principal Place		2013 - 2020	Humid temperature oceanic climate (Cfb)	UK / London
Residential Towers, Al Reem Island		2008 - 2020	Tropical and Subtropical Desert Climate (BWh)	UAE / Abu Dhabi

Arcoris Mont' Kiara		2009 - 2019	Tropical Rainforest Climate (Af)	MALAYSIA / Kuala Lumpur
3Beirut		2008 - 2018	Mediterranean Climate (Csa)	LEBANON / Beirut
Saqqara Residences		2011 - 2018	Mid-Latitude Steppe and Desert Climate (Bsh)	MEXICO / Nuevo Leon
Faena House		2011 - 2015	Tropical savanna climate (Aw)	USA / Miami
Providence Peak		2007 - 2012	Monsoon-influenced humid subtropical climate (Cwa)	CHINA / Hong Kong
DUO Central Park		2007 - 2018	Humid subtropical (Cfa)	AUSTRALIA / Sydney

1.2. Data Sources

The residential buildings selected based on the criteria above were analyzed within the framework of the relationship between climatic factors and design decisions. Those analyzes first reviewed the climatic characteristics of the region, where the relevant building was located, as the first data source. The widely used Köppen-Geiger climate classification system was accommodated to investigate the climatic features. The climate data is taken from the bibliography published by Kottek et al. (2006), which presents the current version of the Köppen-Geiger climate classification. The second data source consisted of a set of building characteristics associated with the design of the relevant building; orientation, form, façade movements, roof formation, color, and the material used in the façade. Then, matrix diagrams were used to analyze the data from the source. The plan, section, view and photographs of the related building were used as analytical tools for the second data source. Relevant

data are taken from Norman Foster's official website, as well as from two different architecture platforms, archdaily and dezeen. Descriptions of data sources are given in Table 2.

Table 2. Data Sources and Descriptions

KÖPPEN-GEIGER CLIMATE CLASSIFICATION	**DESCRIPTION**
Humid temperature oceanic climate (Cfb).	Winters are mild, summers are short and cool. All-season rainy climate. Maximum summer daytime temperatures above 17°C.
Tropical and Subtropical Desert Climate (BWh).	Hot, arid conditions with intense sunlight. Monthly averages in the range of 21–32°C. Rare cloud coverage.
Tropical Rainforest Climate (Af).	Climatic structure with high temperatures, humidity, and heavy rain. Average temperatures ranging between 20 and 29°C. The average temperature above 18°C.
Mediterranean Climate (Csa).	Hot and dry summers. Cool, rainy and mostly clear winters. Average temperature between 12.5°C and 30°C throughout the year.
Mid-Latitude Steppe and Desert Climate (Bsh).	Extremely variable temperature conditions with relatively little precipitation. An annual average temperature of 22.3°C. The coldest month is January with an average of 14.4°C. The hottest month is July with an average of 28.6°C.
Tropical savanna climate (Aw).	In winter, there is much less rainfall compared to summer. Average temperature is 24.6 °C. The hottest month is August with an average of 28.0°C and the lowest average temperature is in January with an average of 20.5°C.
Monsoon-influenced humid subtropical climate (Cwa).	Long summers and winters and relatively short springs and autumns. Temperatures ranging between 15°C and 20°C in winter. Humid and cloudy spring. In August, temperatures above 30°C.
Humid subtropical (Cfa).	No extreme seasonal variations. Precipitation is heavy in the first few months of the year; the rest is irregular. Average temperature in January, February and March varies between 22 and 23°C. It is around 14°C in June, July and August.
DESIGN BUILDING FEATURES	**DESCRIPTION**
Orientation.	The directional positioning of the form, such as east-west, north-south, in the face of natural environmental factors such as sun, wind, and rain.
Form.	The formal order/external mass of structure created by the combination of certain units in the external environment.
Facade Movements.	Compositions created on the facade-periphery surrounding the structure; solid facade, glazed facade, angled facade, sloping facade, recessed and/or protruding facade, etc.
Roof Formation.	Covers the building and protects it against weather conditions such as rain, snow, and hail.
Colour.	A phenomenon of light and visual perception.
Materials.	Layers that protect the facade from external factors and add characteristic features to it.

1.3. Analysis of Data Through Matrix Diagrams

As mentioned above, eight residential buildings were analyzed within the scope of the study upon collection of data, one based on building features for design and the other on climatic factors of the region, which were inserted in matrix diagrams. Diagrams can be seen in Table 3.

Table 3. Analysis Through Matrix Diagrams.

PRINCIPAL PLACE - UK / London		
Köppen-Geiger Climate Classification	Building Characteristics associated with Design	Description
Humid temperate oceanic climate (Cfb).	Orientation	The long axis of the building runs on an east-west axis.
	Form	The form of three slim and different-sized volumes arranged in a cruciform that measures less than 25 meters each side.
	Facade Movements	360-Degree active frontage. Floor-to-ceiling glazing and broad brass-coloured louvers and generous curved balconies that framed views out over the city.

	Roof Formation	Roof mounted photovoltaic panels and gray water harvesting.
	Colour	Partially beige along with mostly metal colors; including bronze and silver.
	Materials	Metal and glass.
RESIDENTIAL TOWERS, AL REEM ISLAND - UAE / Abu Dhabi		
Köppen-Geiger Climate Classification	Building Characteristics associated with Design	Description
Tropical and Subtropical Desert Climate (BWh).	Orientation	The long axis of the building runs along the northeast-southwest axis.
	Form	Forms of geometric rhombuses rise in clusters to break the scale.
	Facade Movements	The southern and northern façade are glazed and the eastern and western façade more solid. The southern façade has shaded internal balconies. The southern façade is punctuated by shaded internal balconies; along the solid western façade, inset horizontal light shafts.
	Roof Formation	Roof gardens extend over the lower tiers. There is a panoramic swimming pool and spa at the top of each tower.
	Colour	The color palette is a combination of browns, grays and whites respectively.
	Materials	Plaster, brick, glass.
ARCORIS MONT' KIARA - MALAYSIA / Kuala Lumpur		
Köppen-Geiger Climate Classification	Building Characteristics associated with Design	Description
Tropical Rainforest Climate (Af).	Orientation	The long axis of the building runs along the east-west axis.
	Form	A form with a series of protruding volumes on a rectangular prism.
	Facade Movements	A facade formed by recesses and protrusions. Horizontal brise-soleil providing shade, balconies and glazed openings attract attention.
	Roof Formation	Roof terraces and pools.
	Colour	Grey, brown and beige tones.
	Materials	Glass fiber reinforced cement (GFRC) unit system, unitized precast panel system glass and metal.
3BEIRUT - LEBANON / Beirut		
Köppen-Geiger Climate Classification	Building Characteristics associated with Design	Description
Mediterranean Climate (Csa).	Orientation	The three towers side by side stretch along the east-west axis. The northern facades of the three towers are glazed and to the south facing elevation steps down in height.
	Form	Three towers that move forward step by step, getting shorter and shorter with each overhang.

	Facade Movements	The northern facades of the three towers are glazed and the south facing elevation steps down in height. Also featuring balconies.
	Roof Formation	The towers are topped by green roofs.
	Colour	Gray and beige.
	Materials	Glass, cream coloured stone cladding and metal.
SAQQARA RESIDENCES - MEXICO / Nuevo León		
Köppen-Geiger Climate Classification	Building Characteristics associated with Design	Description
Mid-Latitude Steppe and Desert Climate (Bsh).	Orientation	The long axis of the building runs along the east-west axis and the towers are centered on the north-facing core.
	Form	Arranged vertically slender towers are interconnected and raised on stilts; each floor plate centered on a north-facing core is gently curved.
	Facade Movements	While the south is glazed and the east and west facades are solid; the building has generous balconies and terraces.
	Roof Formation	The towers are topped by green roofs.
	Colour	Beige and gray.
	Materials	High-tech natural stones, cladding, glass and metal.
FAENA HOUSE - USA / Miami		
Köppen-Geiger Climate Classification	Building Characteristics associated with Design	Description
Tropical savanna climate (Aw).	Orientation	The long axis of the building runs along the east-west axis.
	Form	The gently undulating form that includes the sculpted horizontal lines.
	Facade Movements	The curving sinuous balcony edges that wind around the building, which rise and fall at strategic points. Signature eaves and expansive glass walls that open to panoramic views. Gradual retreats visible in the upper floors.
	Roof Formation	The upper floors gradually recede so that the top floor is a dramatic 71 ft. A rooftop terrace with infinity edge pool, jacuzzi and outdoor kitchen is revealed.
	Colour	A palette of warm soft grays and whites with a lightly bronzed tint to the glazing.
	Materials	Glass reinforced concrete, glass, Corian exterior cladding and metal.
PROVIDENCE PEAK - CHINA / Hong Kong		
Köppen-Geiger Climate Classification	Building Characteristics associated with Design	Description
Monsoon-influenced humid	Orientation	Longest axis of the building runs along the northwest-southeast axis. The other relatively short axis runs along the east-west axis.

subtropical climate (Cwa).	Form	The vertically staggered to form is arranged in three clusters and they are a kind of a natural barrier between the busy road bounding the northern edge of the site and the waterfront.
	Facade Movements	North east facade is glazed with generous balconies and terraces; regular retreats and horizontal shading elements on the southwest façade.
	Roof Formation	The buildings are topped by gardens.
	Colour	A palette of warm soft grays; whites; a lightly gray tint on the glazing.
	Materials	Prefabricated glass reinforced concrete, glass and metal.
DUO CENTRAL PARK - AUSTRALIA / Sydney		
Köppen-Geiger Climate Classification	Building Characteristics associated with Design	Description
Humid subtropical (Cfa).	Orientation	The east-west axis of the building is almost equal to the north-south axis. However, the north-south axis is relatively longer compared to the other axis.
	Form	In the form of a rectangular prism. However, the middle axis of the long side is pulled in a little, creating a relatively active formal image.
	Facade Movements	The horizontal bands between the apartments which surround the façade, as well as the chamfered corners, are striking on the façades. A mirrored fin protrudes from its striking façade as well.
	Roof Formation	Green roof.
	Colour	Grey, beige, and black.
	Materials	Glass, metal, prefabricated glass reinforced concrete.

1.4. Results

Within the scope of the study, the data collected from two data sources, one based on climatic factors and the other on design, were analyzed by means of matrix diagrams as above.

The first of the important results was associated with the orientation. The buildings in the climate classes Cfb, Af, Csa, Bsh, and Aw were constructed with east-west orientation. Thus, wider façades faced north and south directions. Foster placed the long axis of the structures along the east and west directions, allowing the interiors to receive more natural light. On the other hand, he created movement on the facades or used shading elements to provide shade or direct the sunlight. The physical and natural environment of the building was another input in Foster's buildings along with climatic factors which determined the orientation. Related examples include design approaches such as opening to the street, giving a vista to the sea, opening to the river, and city views. The building from the BWh climate zone was placed along the northeast-southwest axis. To form a more solid eastern and western façade and to prevent solar gain the buildings were tilted on the site at a fifty-degree angle, with a glazed southern and northern façade. Located in the Cwa climate zone, the longer axis of the building extended towards the northwest-southeast direction, while the shorter axis extended in the east-west direction. Thus, while the long axis of the building casted a shadow on the short axis, both axes could benefit from the wind. Although the structure in the Cfa climate zone seemingly featured a square form, the north-south axis was actually designed longer. Therefore, natural light and ventilation were provided at the highest level besides improved view.

Another important result was associated with formal designs. The forms of the buildings in the Cfb, BWh, Csa, Bsh, and Cwa climatic zones were arranged so as to compose clusters. The clusters located in the Cfb, BWh, and Csa climatic zones, featured forms which differed in terms of height. The form of the building from the Af climate zone was striking with its different heights and a series of protruding movements on the lateral surfaces. However, the form rose again on a rectangular plan. The form of the building from the Aw climate zone, on the other hand, featured a different view compared to the others. The form narrowed by retraction in the upper floors. However, the footprint of the building again was suggestive of a rectangular plan.

As regards the facades, balconies were included as a structural element in all buildings. Therefore, the internal and external borders were blurred, and the users were provided with the opportunity to spend time in the open air as well. While the facades in all directions of the buildings in the Cfb and Aw climatic zones were covered with glass from floor to the ceiling, the east and west facades of the buildings in the BWh and Bsh climatic zones were left more solid. Shading elements used in facades had a special significance in Foster's designs. The horizontal shading elements used on the south and façades and the vertical shading elements on the east and west façades served as an aesthetic element incorporated by the architect onto the façade.

Foster not only considered roofs as important elements that addressed the climatic factors in his designs, but he also envisioned them as living spaces. For example, the roofs of residential buildings located in the BWh, Af, and Aw climatic zones featured habitable roofs. All the three buildings had swimming pools on the roofs. The buildings from the Cwa climate zone were covered with verdant gardens. The roof of the building located in the Cfb climate zone was designed with photovoltaic panels and gray water harvesting, unlike the others. Residential buildings located in Csa, Bsh, and Cfa climatic zones had green roofs. In this sense, it can be said that humidity and precipitation factors are effective in these design decisions, and the architect tries to establish a relationship between nature and the building by considering these climatic factors.

Foster did not prefer lively, dynamic, and enthusiastic colors in his residential building designs. Instead, he opted for gray, brown, and beige shades. Foster's choice of color in residential building designs can be associated with the climate as well as his attempt to emphasize and accentuate the characteristic features, form, and material of the building.

Finally, upon a review of the materials used on the facades of buildings located in different climatic zones and in different countries, the first striking result was that brick, a local material, was used in the building located in the BWh climate zone, taking into consideration the intense sunlight and dry conditions. In that sense, the architect emphasized the link between climate and culture through the local materials in use. Stone cladding was used as the facade material in the residential buildings located in the Csa and Bsh climatic zones. Thus, he aimed to prevent solar radiation exposure in the interiors by creating more solid surfaces in those hot climatic regions. Glass reinforced concrete was the material of choice for the facades in the buildings located in the Aw, Cwa, and Cfa climatic zones. Metal and glass were the two prominent materials on the facade of the residential building located in the Cfb climate zone. As regards the facades, glass parapets were mostly preferred instead of opaque materials especially on the balcony parapets. The results are summarized in Table 4.

Table 4. Summary of Results

SUMMARY OF RESULTS		
Building Characteristics associated with Design	Köppen-Geiger Climate Classification	Description
Orientation	Cfb, Af, Csa, Bsh, and Aw	East-west axis.
	Cwa	Northeast-southwest axis.
	BWh	Northeast-southwest axis.
	Cfa	North-south axis.
Form	Cfb, BWh, Csa, Bsh, and Cwa	Clustered volumes.
	Cfb, BWh, and Csa	Forms featuring different heights.
	Af	Both different heights and a series of recesses and protrusions on the lateral surfaces.
	Aw	Form narrows upon retracting at the upper floors.
Facade Movements	Cfb and Aw	Floor-to-ceiling glazed façades and generous curved balconies.
	BWh ve Bsh	More solid east and west facades, wide balconies and terraces.
	Af	A facade formed by recesses and protrusions. Horizontal brise-soleil, balconies and glazed openings providing shade.
	Csa	Glazed northern facades, the south-facing elevation descends with steps and features balconies.
	Cwa	The north east façade glazed with large balconies and terraces; regular retreats and horizontal shading elements on the southwest façade.
Roof Formation	BWh, Af, and Aw	Habitable roofs; swimming pools.
	Csa, Bsh, and Cfa	Green roof.
	Cfb	Roof mounted photovoltaic panels and gray water harvesting.
	Cwa	Covered with gardens.
Colour	Cfb, BWh, Af, Csa, Bsh, Aw, Cwa, and Cfa	Mostly gray tones and brown tones, partly beige.
Materials	BWh	Plaster, brick, glass.
	Csa and Bsh	Stone cladding.
	Aw, Cwa, and Cfa	Glass Reinforced Concrete.
	Cfb	Metal and glass.
	Colour	A palette of warm soft grays and whites with a lightly bronzed tint to the glazing.
	Af	Glass fiber reinforced cement (GFRC) unit system, Unitised precast panel system, glass and metal.

DISCUSSION AND CONCLUSION:

Global warming and the energy crisis have been one of the most debated issues across the world in the last few decades. The adverse effects of climate change on nature and people urged experts from various disciplines, especially architects, to produce new strategies. Architects like Norman Foster, who came to the fore with their sustainable design strategies in the field of architecture, aimed to mitigate those problems by designing buildings that are compatible with the climatic challenges. As a result, the reflections of the strong mutual relationship between climate and design decisions in the 21st century has become an important topic of research. Accordingly, Foster's residential buildings were analyzed within the framework of the relationship between climatic data and design decisions. In the context thereof, the results above provided an analysis of the design reflections of the climate, which Foster incorporated as an input into the design of residential buildings.

The results suggested that natural and physical environment data were as effective as climate in Foster's decision as regards building orientation in his residential designs. Foster, on the one hand, dealt with the effects of wind and sun on both the building and the user, and on the other hand, he wanted to offer beautiful views to the users, with due consideration of their physical and psychological needs. The forms often rose as clustered volumes. At the same time, gradual rises on the vertical axis or recesses and protrusions on the facades were included in the forms. The architect often designed the roofs as green roofs and/or habitable roofs with pools. Balconies went beyond a mere structural element for Foster. Depending on the climate, balconies were sometimes arranged as interior balconies and sometimes in the form of larger terraces. Similarly, the shading elements were an important element for Foster. He used the shading elements as an artistic work on the facades by placing them horizontally on the north and south facades, and vertically on the east and west facades. He preferred mostly brown and gray shades over dynamic and enthusiastic colors. Nevertheless, beige is also frequently seen in Foster's residential designs. While glass reinforced concrete and stone cladding were used in structures or facades intended to be more solid, metal and glass also saw frequent use.

As a result, although the relationship between climate and design could be traced back thousands of years, today the said relationship has a meaning beyond the protection of the user against the climate. The cutting-edge technology in both material and application, multidisciplinary approaches in design and most importantly the energy crisis have necessitated the residential designs to be visited from a different perspective. Reducing energy consumption, building sustainable houses, designing with nature, not against it have been the important objectives of certain architects, including Foster. The said approach can make an important contribution not only at the global scale, but also at the urban and individual scale. For example, Foster has made both socio-economic and socio-cultural contributions to the cities by means of his residential building designs compatible with climatic data (Ibrahim, 2016; Mezher, 2011). Reducing the economic costs incurred to the users for heating and/or cooling purposes in residential buildings by means of design strategies that would reduce energy consumption also contributes to both individual and environmental protection. Furthermore, he creates comfortable environments for the user by controlling the wind and the sun and directing it as necessary.

Compliance with Ethical Standard

Conflict of Interests: *There is no conflict of interest between the authors or any third party individuals or institutions.*

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EXTENDED SUMMARY:

Research Problem:

Climate change and associated global warming and energy crisis have become a prominent issue of architecture and considered one of the primary concerns of architects as regards climate-compatible design, especially in terms of residential buildings, the largest constituent of the building stock. Accordingly, the present study sought an answer to how the 21st. century residential buildings took form vis-a-vis climatic data and focused on the residential buildings by Norman Foster, a leading architect in the context of sustainability.

Research Questions:

How are climatic data reflected in Norman Foster's form designs? What kind of design strategies has Norman Foster used in the framework of sustainability?

Literature Review:

The literature review shows a large number of publications pointing to the large share of the residential sector in total energy consumption and its mutual and decisive relationship with climate change. Related to the subject, a group of studies focuses on the relationship between building form and energy consumption and discusses the effects of form on energy use in residential buildings.

Methodology:

The study focused on the residential buildings of Norman, a pioneer in sustainable solutions who took local climate criteria into consideration, which were designed after the year 2000. Selected residential buildings were analyzed in the context of the relationship between climatic data and design decisions. Two data sources were used for the purposes of the analysis. The first data source was the Köppen-Geiger climate classification system, a widely used system across the world. Hence, data on climate were collected on this classification system. The second data source was a set of building characteristics associated with the design of the building: orientation, form, facade movements, roof formation, color, and materials used in the facade. The data from those two data

sources, one based on climatic data and the other on design, were thereafter analyzed by placing them in matrix diagrams.

Results and Conclusions:

The results suggested that natural and physical environment data were as effective as climate in Foster's decision as regards building orientation in his residential designs. Foster, on the one hand, dealt with the effects of wind and sun on both the building and the user, and on the other hand, he wanted to offer beautiful views to the users, with due consideration of their physical and psychological needs. The forms often rose as clustered volumes. At the same time, gradual rises on the vertical axis or recesses and protrusions on the facades were included in the forms. The architect often designed the roofs as green roofs and/or habitable roofs with pools. Balconies went beyond a mere structural element for Foster. Depending on the climate, balconies were sometimes arranged as interior balconies and sometimes in the form of larger terraces. Similarly, the shading elements were an important element for Foster. He used the shading elements as an artistic work on the facades by placing them horizontally on the north and south facades, and vertically on the east and west facades. He preferred mostly brown and gray shades over dynamic and enthusiastic colors. Nevertheless, beige is also frequently seen in Foster's residential designs. While glass reinforced concrete and stone cladding were used in structures or facades intended to be more solid, metal and glass also saw frequent use.

As a result, although the relationship between climate and design could be traced back thousands of years, today the said relationship has a meaning beyond the protection of the user against the climate. The cutting-edge technology in both material and application, multidisciplinary approaches in design and most importantly the energy crisis have necessitated the residential designs to be visited from a different perspective. Reducing energy consumption, building sustainable houses, designing with nature, not against it have been the important objectives of certain architects, including Foster. The said approach can make an important contribution not only at the global scale, but also at the urban and individual scale. Reducing the economic costs incurred to the users for heating and/or cooling purposes in residential buildings by means of design strategies that would reduce energy consumption also contributes to both individual and environmental protection. Furthermore, he creates comfortable environments for the user by controlling the wind and the sun and directing it as necessary.