Africa-Europe Bioclimatic Collaboration 21

Africa-Europe BioClimatic buildings for XXI century

ANALYSIS OF POLICIES FOR THE EXPLOITATION OF RESULTS

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ABC 21 project

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Executive summary

This report represents a synthesis of work done on regulations of energy efficiency in buildings, bioclimatic materials and design, and standards related to bioclimatic materials and constructions in ABC 21 project. This synthesis includes but is not limited to the work of the different project partners. ABC 21 covered the efforts of Europe and N-W Africa in terms of promoting and implementing bioclimatic materials and design. The analysis of the work in ABC 21 on policies related to energy efficiency in Europe and N-W Africa is presented and discussed here. The identification of strengths and weaknesses of these policies in terms of the implementation of bioclimatic materials and design is conducted, additional information from several other sources is also presented and discussed.

The energy efficiency in buildings in Europe is governed by the Energy Performance of Buildings Directive (EPBD) regulation. The latter serves as a guideline for the approval of energy efficiency policies in European countries, aiming for a decrease in energy consumption of 27% by 2030 in buildings. To reduce the use of fossil fuel primary energy, the EPBD regulations are based on the concept of nearly or zero energy buildings. The European countries allow for the self-consumption of renewable energy to reduce the use of primary energy. The EPBD regulation is interesting in terms of minimizing the primary fossil fuels dependency and the Greenhouse gas (GHG) emissions, however this approach does not decrease the energy need for heating and cooling regardless of its source. Renewable energies are considered as zero CO_2 emitters by many regulations, neglecting their embedded energy during the process of fabrication, transport, maintenance, and disposal.

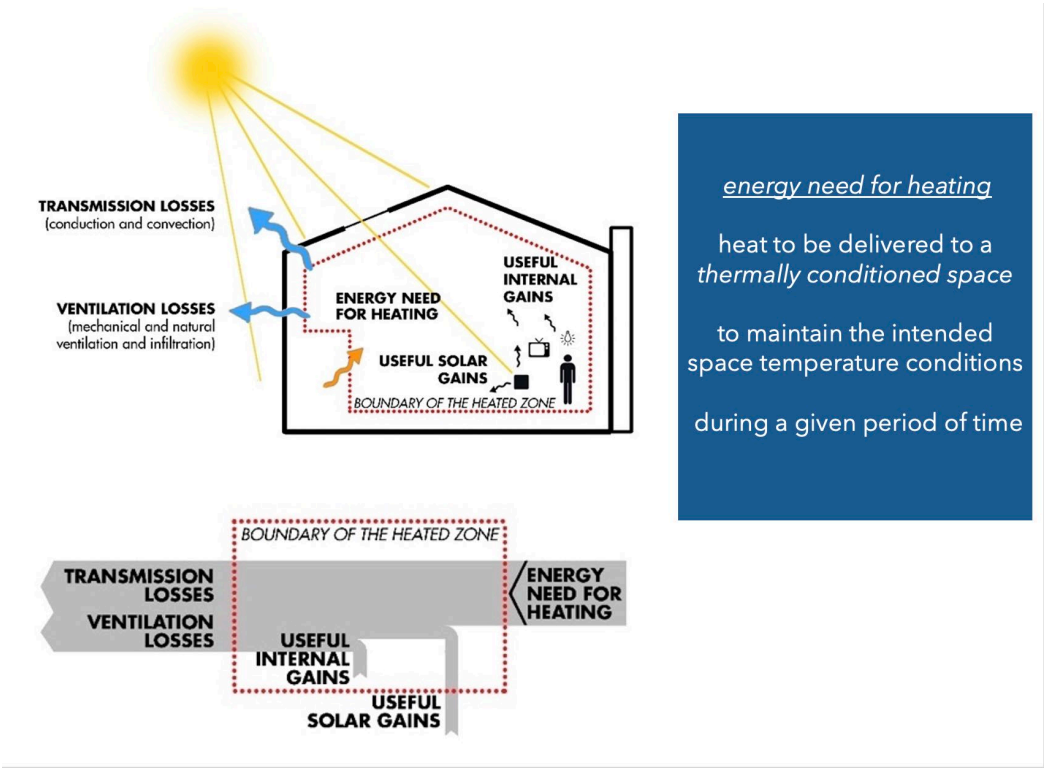
On the other hand, the African Regional Organization for Standardization (ARSO/ORAN) created the ARSO/TC 71 on energy management and energy efficiency to set the standards in the field of energy management and energy savings, energy management, data for energy management systems, methodological framework of calculation and reporting on energy savings, energy savings in regions, economics and financial evaluation, energy savings evaluators, and evaluation of energy savings of thermal power plant. ARSO/TC 71 is equivalent to ISO/TC 163, ISO/TC 301, and CEN/TC 371. Even though both continents have regulations governing energy efficiency in buildings, the European regulations are well detailed depending on the country context and their applicability is very high compared to the African countries. The African countries are urged to develop and improve their regulatory infrastructure to meet the national and international expectations. It should be kept in mind that some N-W African countries already have advanced EE-regulations that can be considered as an example for other countries. However, the enforcement of these regulations is very weak due to lack of incentives, awareness, and juridical follow up.

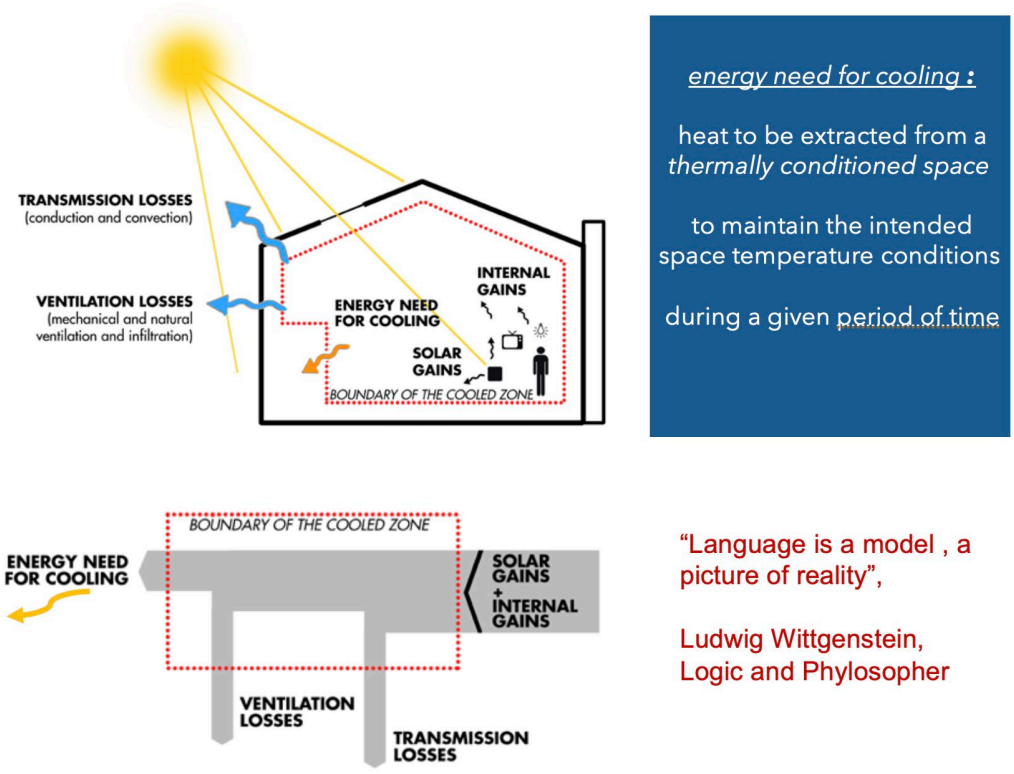
The second part of this synthesis defines the bioclimatic materials and design indicators in order to assess the current policies in Africa and Europe in terms of integration of bioclimatic materials and design.

Bioclimatic buildings consider both climate conditions and local natural resources to create a sustainable, energy efficient, and comfortable indoor environment. Bioclimatic buildings are mainly based on local bioclimatic construction materials with low embedded energy and carbon

footprint. In recent years, bioclimatic architecture was subjected to a severe neglection after the transition to concrete, steel, and glass-based constructions. Consequently, modern cities all over the world tend to look similar, whereas historical buildings reflect the history, culture, and the creativity of the local societies.

In the passive design approach, the four physical heat transfer components (transmission, ventilation, radiation, and internal heat gain) controlling the energy gain/loss in buildings are effectively used with the aim to minimise ***energy needs for heating and cooling***. Furthermore, the use of water harvesting, and renewable energy technologies is an important aspect of bioclimatic design. It is worth mentioning that a bioclimatic building is different than a Net Zero Energy building and a Nearly Zero Energy building because the focus of bioclimatic design is to reduce the total energy need regardless of the primary source of energy used in the building.





Graphical representation of the energy need for heating and for cooling (S. Erba, L. Pagliano)

The bioclimatic design is assessed through a set of indicators that quantify the building energy performance according to the terminology and guidelines provided by EN -ISO standards. The choice of suitable indicators enriches conventional assessment tools such as bioclimatic charts and may vary depending on the context and goals of the project. Following the previous recommendations, the bioclimatic design cannot be limited to a building as an independent entity from its surroundings. Therefore, the bioclimatic approach should be extended to the level of cities and districts since these will affect thermal, acoustic, visual, and indoor air quality of buildings.

Bioclimatic materials can be divided in three main classes depending on their origin: earth-based, plant-based, or animal-based. Earth-based bioclimatic materials include among others adobe, rammed earth, stone, and clay bricks with additives. Plant based materials are mainly used as insulation materials. Thanks to their very low thermal conductivity they can also be used as additives in construction materials. Examples of plant-based materials are wood, bamboo, straw, typha, reed, and sugar cane. Animal based materials include sheep wool, animal skin, and fur.

To ensure a smooth transition from the conventional construction materials to bioclimatic ones, the regulatory infrastructure must protect constructors when using bioclimatic materials and provide them with technical guidelines to follow. Research on the existing regulations for bioclimatic constructions revealed that there are outdated regulations in Europe that are no longer available or used, except for Germany, which presents a leading code model (DIN 18942-1, DIN 18945, DIN 18946, DIN 18947, DIN 18948, DIN 18942-100, DIN 18945, and DIN 18946) that can

be followed. As for N-W Africa, there is also a lack of regulations except for Morocco ("RPCTerre 2011" and "RPACTerre 2011") and Tunisia (NT 21.33; NT 21.35), who set the example of a detailed regulation. As for central Africa, there is an old norm that dates to 1995 (ORAN/CT3) that needs to be reviewed and updated to answer to the actual needs of constructions. However, this sets an important reference for building regulations and standards related to bioclimatic constructions.

Based on all information gathered in the ABC 21 project, a guideline for developing and updating actual EE-policies in Europe and N-W Africa is presented. The Bioclimatic Energy Efficiency Policy (BEEP) certification consists of a series of questions that will enable the assessment and creation of new policies that enforce the use of bioclimatic designs and local bioclimatic materials. Morocco is used as a case study for the assessment of its current EE-policy. The results show that Moroccan regulations are consistent with most key indicators, mainly the focus on the envelope to reduce *energy needs for heating and cooling*. Morocco also sets the example for other countries when it comes to the norms of earth-based construction materials. However, there is lack of promotion of bioclimatic materials, the effects of thermal mass are not sufficienctly considered, e.g. via dynamic simulation or simplified indicators, the process is not adaptive, and the air velocity is not considered in the estimation of the summer comfort conditions. Using the BEEP tool, a list of recommendations is proposed and will help in the reviewing of the current policy.

Finally, other means for exploitation of the ABC 21 project results are represented in the preparation of educational and training programs related to bioclimatic materials and design using the tools developed by ABC 21 like the MOOC, the BestEnergy Simulation Tool, and the technical guidelines.

CONTENTS

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ABREVIATIONS:

EE	Energy Efficiency
GHG	Greenhouse Gases
EPBD	Energy Performance of Buildings Directive
ARSO	African Regional Organization for Standardization
BEEP	Bioclimatic Energy Efficiency Policy

1. Introduction

According to the International Energy Agency (IEA), in 2021, the building sector was responsible for approximately 34% of all energy demand, or 135 EJ, with 10 Gt CO_2-emissions making up the largest portion of all sectors at 37%, as shown in figure 1.

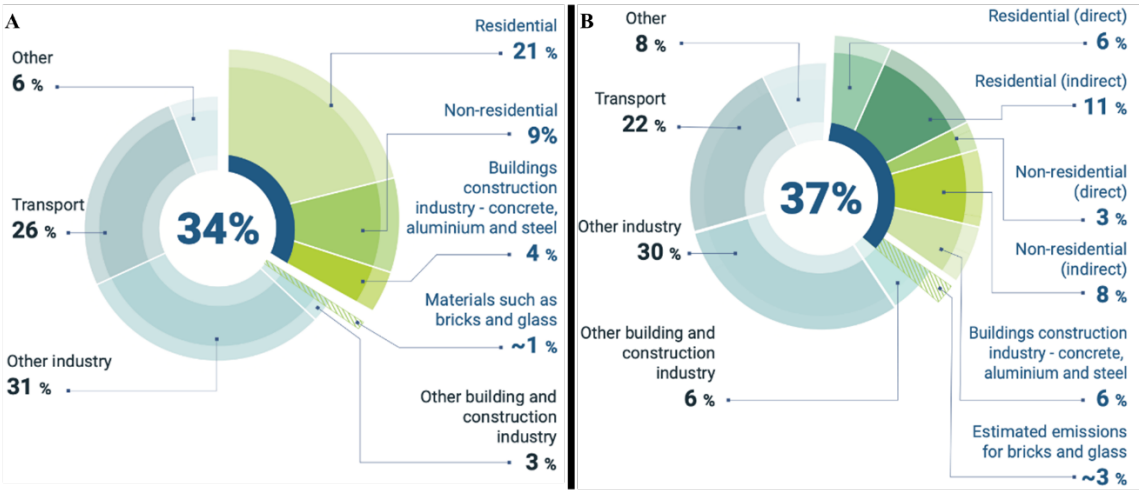


Figure 1: Global share of buildings and construction (A) final energy demand; (B) operational and process CO_2 emissions, 2021[1].

According to Global Alliance for Buildings and Construction (GlobalABC), building energy regulations must be adopted globally and current building energy standards must be enhanced to attain zero emissions. The ambitious goal for building emissions is impacted by weak regulations and policies related to bioclimatic constructions and designs. Governments have increased efforts in energy efficiency, notably in the building industry, to reduce GHG emissions to the levels necessary to comply with the Paris Agreement. For this, 40% of the alliance countries had established building energy laws, and 26% of them had demanded codes for both residential and tertiary buildings [1].

Despite the efforts and investments in renewable energy infrastructure made to lower the primary energy consumption in buildings in terms of fossil fuels, in 2022, the Buildings Global Status Report (GRS) [7] reported that the building sector is still a high emitter of CO_2 with an increase of 4% between 2020 and 2021, the largest increase in the last 10 years. The building and construction sector is not on track to achieve the goals of decarbonization by 2050 as required by the Paris Agreement. Therefore, serious measures should be taken to deviate from this trend and the Buildings GSR is urging the international community to look for innovative solutions and presents the switch to bioclimatic design and bio- and geo-sourced materials as a very promising answer to this problem.

The main aim of ABC 21 project is to study all aspects related to a switch to bioclimatic design and bio- and geo-sourced materials in N-W Africa and Europe. ABC 21 has produced several reports on the following subjects:

- Review of housing needs, construction practices and urbanisation trends in North-West Africa
- Review of training and regulatory infrastructure in N-W Africa and EU (existing and planned) and EU
- Review of infrastructure for production of construction materials in N-W Africa and EU
- Review of policies supporting passive and bioclimatic approach, and development of local materials and production chains in N-W Africa and EU
- Review and choice of performance indicators for energy, demand flexibility and comfort
- Indicators and weather files for Future climate as input for design of building and districts
- Review and analysis of materials and construction practices (local and/or adapted to local conditions)
- Case studies of European and African Bioclimatic buildings
- Technical guidelines and tools for future-proof passive design in warm climates
- Update and specialization of training tools

This report represents an exploitation and synthesis of the project results. It presents also some suggestions of options for policies and actions to leverage on project's results. Based on the analysis made in WP2 and WP3, a procedure to evaluate and review policies for the promotion of the bioclimatic approach and the increased utilization of local materials. The proposed procedure considers the issues of affordability and connection with an urban development favorable to bioclimatic architecture and sustainability.

This report first covers the definition of bioclimatic design and its indicators, followed by a summary of the EE regulatory infrastructure in Europe and Africa. The third part of this report covers the screening of the existing norms and standards on bioclimatic construction materials.

Based on the results, the fourth part of the report is the development of a procedure (BEEP Certification) to evaluate to which extent current EE policies are conform to the bioclimatic approach.

The Moroccan policy was used as a case study where the BEEP was applied to review and propose recommendations towards a regulation that takes the passive and bioclimatic approach into consideration. Finally, other means for exploitation of the results of the ABC 21 project are presented mainly in the preparation of educational and training programs related to bioclimatic materials and designs using the tools developed by the ABC 21 project like the MOOC, BestEnergy Simulation Tool, and handbook.

2. Bioclimatic Design and Its indicators

"Bioclimatic architecture", according to Baruch Givoni, a master of this type of architecture, involves architectural design and choice of materials aiming at providing comfort while minimizing

energy use (since it deals with the building fabric and not with active systems, this is equivalent to minimizing the *energy needs for heating and cooling, in the language of EN-ISO 52000)*. To achieve these aims, different architectural features need to be properly designed:

- the layout of the building and its orientation,
- the number, size, location, and details of its windows,
- the shading devices,
- the thermal resistance and heat capacity of its envelope.

The proper use of the above means results in a **minimization of the diurnal indoor average temperature, which remains anyway higher than the diurnal outdoor average temperature**.

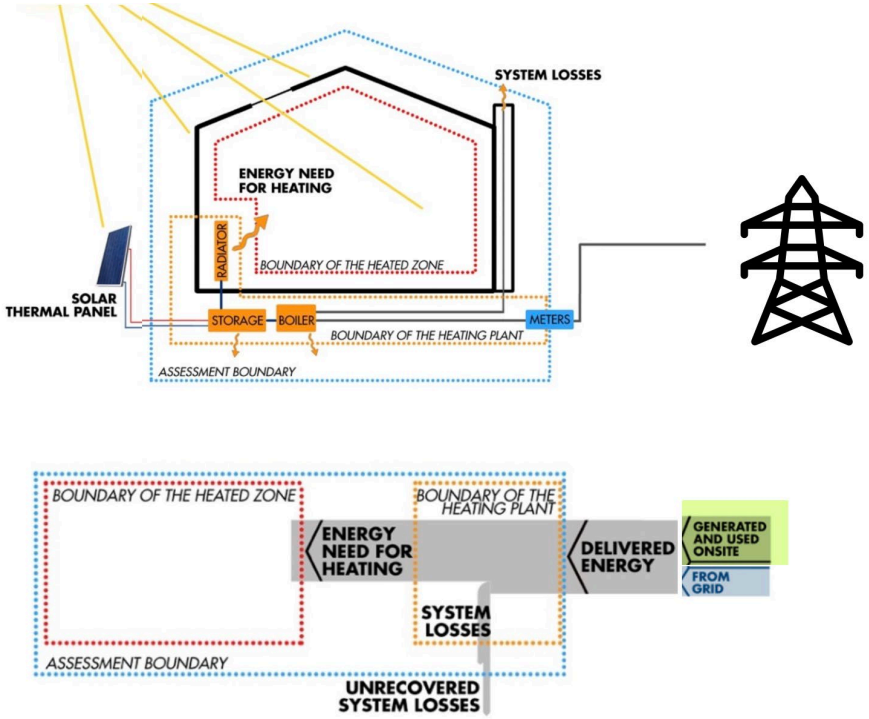
B. Givoni also provides a definition for ***passive cooling systems***, which can transfer heat from the building and occupants to the available environment heat sinks, thus **lowering the indoor average temperature below the outdoor average**.

Proper architectural *bioclimatic design* in a region with hot climate can be thus considered as a precondition for the application of *passive cooling systems*, such as:

- comfort ventilation,
- nocturnal ventilative cooling,
- radiant cooling to the sky,
- direct evaporative cooling,
- indirect evaporative cooling,
- soil cooling,
- cooling of outdoor spaces.

In addition, bioclimatic design offers a high degree of creativity in construction practices that are inspired from nature, and the long experience accumulated in vernacular architecture. In recent years, this type of architecture was subjected to a severe neglection after the transition to concrete and glass-based constructions. Consequently, modern cities all over the world tend to look similar, whereas historical buildings reflect the history, culture, and the creativity of the local societies. In this passive design approach, the four physical heat transfer components (transmission, ventilation, radiation, and internal heat gain) controlling the energy gain/loss in buildings are appropriately used depending on the location, orientation, thermal mass of the envelope, air tightness, and wind velocity. Furthermore, the use of water harvesting, and renewable energy technologies is an important aspect of bioclimatic design. It is worth mentioning that Bioclimatic building is different from a Net Zero Energy Building and near Zero Energy Building (which often are defined based on *non-renewable primary energy with compensation* for export to the grid – see ABC21 report on energy performance indicators) because the focus of bioclimatic design is

to first minimise the *energy needs for heating and cooling* regardless of the primary source of energy used in the building.



The choice of geo and bio-based local materials is a key in the bioclimatic design, these materials have advanced thermal properties. Their mechanical properties vary with their process of fabrication and formulation which opens a broad level of applications. There is a large spectrum of types of geo and bio-based materials depending on their origin and composition, this enables a high level of creativity and research development possibility. In general, those materials can be divided in three main classes depending on their origin: earth-based, plant-based, or animal-based. Earth-based materials include adobe, rammed earth, stone, clay bricks with additives… Plant based materials are mainly used as insulation materials thanks to their very low thermal conductivity, they can be also used as additives in construction materials; for example, wood, bamboo, straw, typha, reed, sugar cane… Animal based materials like sheep wool are less diffuse, also because of more limited supply. More details are available in ABC 21 report D3.7 Review and Analysis of Materials of Construction and Practices.

The bioclimatic design is assessed through a set of indicators that quantify the building energy performance according to the terminology and guidelines provided by EN -ISO standards. The choice of suitable indicators promotes further detail compared to other assessment tools such as psychrometric charts. According to the ABC 21 project's Report on Comfort Indicators and Scenarios (Report D3.2), a tentative list of additional indicators is presented as follow:

Thermal comfort indicators

1. Percentage of time outside an operative temperature range (Adaptive)
2. Percentage of time outside an operative temperature range (Fanger)
3. Degree-hours (Adaptive)
4. Degree-hours (Fanger)
5. Percentage of time inside the Givoni comfort zone (with air velocity of 1 m/s)
6. Percentage of time inside the Givoni comfort zone (with air velocity of 0 m/s)
7. Number of hours within a certain temperature range

- Acoustic comfort indicators

1. Airborne sound insulation
2. Equivalent continuous sound Level
3. HVAC noise level
4. Reverberation time
5. Masking/barriers

- Visual comfort indicator

1. Light level (illuminance)
2. Useful Daylight Illuminance (UDI)
3. Glare control
4. Quality view
5. Zoning control

- Indoor Air Quality indicators

1. Organic compound
2. VOCs
3. Inorganic gases
4. Particulates (filtration)
5. Minimum outdoor air provision
6. Moisture (humidity, leaks)
7. Hazard material

Following the previous recommendations, the bioclimatic design cannot be limited to the building as an independent entity from its surroundings, therefore, the bioclimatic approach should be extended to the level of cities and districts since it will be affecting thermal, acoustic, visual, and indoor air quality. For example, to enable the correct functioning of natural ventilation, increase of

air velocity inside the building during the summer, that proved its efficiency in terms of lowering the energy need for cooling, the building should be in a calm location with good air quality. Additional strategies for bioclimatic cities and districts include incorporating green spaces, promoting active transportation such as walking and cycling, implementing strategies for water management (rainwater harvesting, wastewater treatment, water conservation…), and adopting waste reduction strategies (recycling programs, composting facilities…)

3. Policies in Europe and Africa

In this chapter, a summary of the report on the regulatory infrastructure of Europe and Africa developed in the framework of ABC 21 project is covered to shed light on the current Energy Efficiency policies of both continents.

According to the European Construction Sector Observatory, buildings and building construction sector accounts for 40% of EU's energy and 55% of EU's electricity consumption, with a CO_2 emission exceeding 36% [2].

To solve this issue, the EU has developed tools such as "Energy Performance Certificates" [3] that is based on three pillars:

- Public acceptance and use of energy certificates
- Awareness and compliance enforcement
- Quality control

The Energy Efficiency in buildings in Europe is governed by the Energy Performance of Buildings Directive (EPBD) regulation. The latter serves as a guideline for the approval of energy efficiency policies in the European countries and aiming for a decrease in energy consumption of 27% by 2030 in buildings.

To reduce the use of fossil fuel primary energy, the EPBD regulations are based on the concept of nearly or zero energy buildings. The European countries allow for the self-consumption of renewable energy produced on-site to reduce the use of non-renewable primary energy. The renewable energy produced on site and exported to the grid may or may not be accounted for.

The EN-ISO 52000 defines a k_{exp} factor varying between 0 and 1. k_{exp}= 0 that the EE policy of the EU country does not allow for compensation for exported energy to the grid, while a k_{exp}= 1 means that the energy exported offsets to the imported one from the grid in the evaluation of net-zero energy over a year. The second case implies an energy balance on paper which is very far from physical reality (the grid is considered as a virtual inter-seasonal storage with zero energy losses). Some Member States don't allow for this type of compensation or only for a limited version. E,g in Italy the energy nbalance is performd on a monthly basis and energy exported to the grid e.g. in July is not accounted in compensation of fossil import from the grid in e.g. December.

The EPBD regulation is interesting in terms of minimizing the primary fossil fuels dependency, however this approach does not explicitly promote the reduction of the *energy need for heating and cooling* regardless of the source of supply. Renewable energies are considered as zero CO_2

emitters by many regulations, neglecting their embedded energy during the process of fabrication, transport, maintenance, and disposal. Consequently, a possible review of the EPBD regulations might improve it by including the bio- and geo-sourced materials and bioclimatic design, to better align to the United Nations Sustainable Development Goal. Furthermore, the SDG indicator 11.3.1: "Ratio of land consumption rate to population growth rate" postulates that when this ratio is high, such a "growth turns out to violate every premise of sustainability that an urban area could be judged by". The limitation of land use might be a very important aspect in the creation of bioclimatic cities and districts. The last version of the EPBD has moved towards this direction by including recommendations for "holistic urban planning" and mandating the creation of parking spaces for bikes in buildings. This is an interesting step towards sustainable mobility and is coherent with the bioclimatic approach.

3.1 Examples of energy efficiency efforts in Europe

Germany as a leading European country in EE in buildings, has set an ambitious target of reducing its primary energy use by 80% by 2050. Germany has created several regulations to comply with the European Directive on Energy Performance of Buildings, the Energy Saving Act was modified. In 2009, Germany implemented the "German Integrated Energy and Climate Program, IEKP 2007". In 2013, the "Fourth Law Amending the Energy Saving Act" was amended, and a Nearly Zero Energy Buildings was adopted by the German government. The strategy of Germany is based on a continuous development and update of its regulations following global guidelines and technological advancements in this field. The most interesting aspect of the German regulations is its focus on the passive part of the building; however, the future climate forecasts are not considered.

When it comes to Spain, the country has National Energy Efficiency Action Plan, NEEAP that is updated following the Directive 2010/31/EU. Furthermore, Spain also focuses on the renovation of public administration buildings to be set as an example for improving EE in buildings for the private sector [4].

In the case of Portugal, the residential sector accounted for 17% of the total energy consumption in 2018. The main important result of the application of the EE regulations, National Energy Efficiency Action Plan (NEEAP), is the reduction of the heating need by 36% in comparison with 2003 [5]. Unlike Germany, Portugal is preparing future weather files to be considered in the development of future regulations. Other very interesting aspects of the Portugal case is the permission of the use of bioclimatic designs, the effect of the latter is very noticeable in the reduction of energy need in heating.

3.2 Energy Efficiency Efforts in Africa:

The African continent contribution to CO_2 emissions is relatively low, around 3% of the global CO_2 emissions according to IEA, and has an extremely low level of cumulated emissions compared to e.g. the EU and the USA. However the energy use and CO_2 emissions are expected to know a drastic increase in the future because of the rapid demographic growths and economic activity

increase. In the case of North African countries, the building sector accounts for more than 20% of total energy consumption, with an expected increase of new buildings of around 50 million by 2040. The new EE strategies in the region have set an aim to save 40% of energy from new buildings, and between 10% to 15% of energy savings from existing buildings. This project is also focusing on the Western part of the African continent, where the first center of Renewable Energy and Energy Efficiency "ECREEE" was founded in 2010, whose main goal is to improve energy access, energy security, climate change mitigation, and emissions reduction.

In Africa, the African Regional Organization for Standardization (ARSO/ORAN) is an intergovernmental body that sets the basis and conformity of regulations, norms, and standards among the 40 member states to reduce the technical barriers and promote inter-African and international trade. To promote energy efficiency in Africa, the ARSO/TC 71 (Energy management and energy efficiency) sets the standards in the field of energy management and energy savings, standardization in the field of energy management and energy savings, energy management, data for energy management systems, methodological framework of calculation and reporting on energy savings, energy savings in regions, economics and financial evaluation, energy savings evaluators, and evaluation of energy savings of thermal power plant. ARSO/TC 71 is equivalent to ISO/TC 163, ISO/TC 301, and CEN/TC 371.

In its effort towards EE in buildings, Morocco adopted a National Energy Strategy in 2009, to improve energy supply security and availability, as well as to increase general access to energy at reasonable prices. The goals of this EE policy are to establish an institutionalized public management system for EE issues, as well as a suitable legislative and regulatory framework, and to promote norms and standards. In 2014, Morocco has developed the RTCM (Règlementation Thermique dans la Construction au Maroc) under the law 47-09 that targets an improvement in EE by 20% by 2030.

Unlike Morocco, Egypt has high cooling needs due to its arid hot climate and large population. Therefore, the Egyptian government has set several building and appliances codes and standards under the Energy Efficiency Code for Buildings (EPC 306-2005).

From West Africa, Senegal has put in a real effort to control the energy sector because it is considered as a critical political issue, therefore the Senegalese government developed new energy sector development policy (LPDSE, 2012) that aims at increasing the integration of renewable energies to at least 15% by 2025.

Ghana is cited in this report because of its interesting energy efficiency strategy, as an example, the Building Code GS1207: 2018 that aims to increase energy efficiency while focusing on the envelope requirements and on the use of new materials, efficient lighting, and HVAC systems. It also sets requirements for water efficiency for green buildings approach.

All the previous examples show the effort deployed by the African nations in terms of EE regulations. However, an effort towards an effective implementation and development of regulations should be taken very seriously, learning from successes and mistakes in the European continent.

4. Regulations and Norms on Bioclimatic Construction Materials

Europe and Africa have an accumulated experience of thousands of years in Earth construction. However, a noticeable switch to concrete-steel structures with large unshaded glazing surfaces can be observed globally. This is leading to a loss of expertise in the field, loss of local jobs, increase of greenhouse gases and CO_2 emission in the construction phase and a growth of *energy needs for heating and cooling* at least in the overly-glazed buildings. The solution to the rise of energy consumption and CO_2 emissions resides in an effective re-alignment to and update of bioclimatic principles and passive systems.

To make this transition, the development of regulations for bioclimatic architecture, passive systems and bio- and geo-based materials in Africa and Europe should be part of the efforts of EE regulations. Intensive research on regulations was conducted and a real lack of the above types of regulations or updated ones was noticed in Europe and Africa.

At the opposite, “currently conventional” materials like concrete-based materials, are well covered by regulations that specify exactly the applicability and process of each product. Therefore, constructors, who chose to use bio- and geo-based materials, need e.g. to make their own judgement on the mechanical properties of latter compared to the conventional ones to be able to implement them as bearing or non-bearing structures. Similarly there is a need for regulation and certification about hygro-thermal properties.

A literature review showed that African countries are covered by the technical committee on buildings and civil engineering, ORAN/CT3 of the Regional African Organization of Normalization, ORAN.

4.1 Policies supporting bioclimatic design in Africa:

Morocco is setting an example to both African and European countries when it comes to regulations governing Earth-based constructions. In 2013, the Moroccan government has approved the seismic regulation of earthen constructions by the decree n° 2-12-666. This regulation is divided into two sections, the first one “RPACTerre 2011” covers the best practices for earthen auto-construction when no architectural study is conducted, while the second one “RPCTerre 2011” covers the standards that should be respected when building with earth-based materials for safety, these standards are used by civil engineers, architects, and technicians. The regulation divides Morocco into zones based on their seismic properties; the regulation limits the number of floors to two and bearing walls height depending on the zone and the intended use of the building. The earth-based materials that are targeted in this regulation are namely, adobe, stabilized adobe, compressed earth block, rammed earth, cob, and earth mortar. Although this regulation represents an interesting document that can revive the earth-based construction and bioclimatic designs, it under-estimates the possibilities offered by the earth-based constructions, as seen in the figure 2, skyscrapers from the 16th century reaching up to 30 m in Yemen are still standing to this day showing that there is a potential for building several floors using unfired clay bricks.

Figure 2: Earth-Based Skyscrapers in Yemen [6]

Just like most African countries, Senegal has many traditional bioclimatic buildings, which are estimated to represent around 23% of total constructions. The main bio- or geo-sourced materials used in Senegal are earth-based materials, typha, bamboo, and straw. Currently, the country is facing a major barrier in the integration of these materials in construction, and this is mainly due to the lack of regulatory infrastructure. At the present time, Senegal does not have any official standards or regulations for earth-based materials, which makes their usage difficult. However, the “Code des Marchés 28” allows the development of pilot projects with earthen materials, and the Nubian Vault Association has developed guidelines for the fabrication process of earth bricks and the process of construction using earth-based materials. Finally, the development of the Senegalese thermal regulation is identified as an opportunity to promote the standardization of bio- and geo-sourced materials in the country.

4.2 Policies supporting bioclimatic design in Europe

France is an example of a European country that had developed in the past several regulations concerning the use of earthen materials in constructions namely, “Réef DTC 2001 Béton de terre et béton de terre stabilisée, 1945”, “Reef DTC 2101 construire en béton de Terre, 1945”, and “Reef DTC 2102 béton de terre stabilisée aux liants hydrauliques, 1945”, however, these regulations date from 1945 are not updated, and probably no longer applied in constructions.

Currently, Germany has the best set of regulations that most constructors and researchers are using as reference when it comes to earth-based materials: DIN 18942-1, DIN 18945, DIN 18946, DIN 18947, DIN 18948, DIN 18942-100, DIN 18945, and DIN 18946 specifies the terms for applying clay materials in buildings. Some regulations on straw bale constructions were set such as the International Code Council, 2018 International Residential Code, and Specification for Compressed Straw Building Slabs.

These regulations should be taken as a seed for new regulations governing the bioclimatic switch. Currently, Africa is a leading continent in the use of bio- and geo-sourced materials and processes since the switch to concrete-based constructions is slow due to poverty, lack of technology and industrialization. Many of the bioclimatic processes are still in use in Africa, however they must be improved and adapted to the twenty-first century lifestyle. Because of Global warming, the average temperature in Europe is knowing a noticeable increase leading to an increase in cooling

need, therefore, adapting the know-how gathered in Africa on how to build in hot and arid region represents a very good learning opportunity to Europe.

5. Bioclimatic Energy Efficiency Policy (BEEP) Certification

The aim of this part of the report is to present a methodology of assessment of EE policies to check their compliance with the bioclimatic requirements as set by BEEP Certification. This methodology is based on the development of a set of questions related to bioclimatic materials and key indicators of bioclimatic design as described by the ABC 21 recommendations and reports. Therefore, the study of the EE policy of a country is based on the answers to the questions. Finally, recommendations on the improvement of the policy are suggested. A country's policy that conforms to all requirements and the key indicators of bioclimatic design and enabling an effective use of bio- and geo-sourced materials, is granted the BEEP Certification.

Methodology of Assessment for BEEP Certification

The ABC 21 project made an intensive study on all aspects related to bioclimatic architecture, passive systems and bio- and geo-sourced materials. The results of these efforts can be exploited and valorised through the development of a list of questions that summarizes the essence of bioclimatic and passive design able to decrease the energy need and carbon footprint of the construction sector. The questions are as follow:

- Do policies explicitly mandate reductions of "*energy needs for heating and cooling*"? (Propose sanctions, incentives for application)
- Do policies promote reduction of *total primary energy use* and not only of *non-renewable primary energy use*? E.g., do they promote low and zero energy balance with a physical rather than fictional accounting approach?
- Do policies explicitly refer to the *Adaptive comfort* model?
- Do policies allow and promote the use of air velocity as a key factor for summer comfort?
- Do policies correctly consider both stationary parameters (e.g., stationary thermal transmittance) and dynamic parameters (e.g., periodic thermal transmittance, phase shift and attenuation of heat wave through walls and roofs)?
- Do policies promote physical and regulatory frameworks that enable low-energy lifestyles (i.e., sufficiency, as defined in IPCC Sixth Assessment Report Chapter 5 on energy demand?
- Do policies promote clean, silent, low temperature districts where to build?
- Do policies support a "societal point of view" in investment analysis? e.g., using "cost of conserved energy" or Internal rate of return rather than (short time oriented) payback time as indicator? Societal discount rates (e.g., 1-2%) rather than private discount rates (e.g., 5-10%)?

- Do policies include external costs (pollution, health damage) in calculating the optimal level of energy needs or energy performance of buildings to be enforced?
- Do policies support the conscious and skilled use of local materials and their integration in the design and construction workflow?
- Do policies support the adoption of bio-climatic approach and passive techniques in general terms or via precise, verifiable approaches and parameters as e.g., the above-mentioned ones?
- Do policies promote the testing of air quality in buildings, natural ventilation, in other words, setting a minimum and maximum Air Change per Hour ACH?
- Do policies promote the use of floors as heat sinks?
- Do policies consider the effect of solar gain during the summer and shading techniques?

6. Case Study Morocco

6.1 Moroccan Legislation Procedure

After submitting the Moroccan EE regulations to the process proposed by this study BEEP, a list of recommendations will be produced. All these recommendations might be used as a reference in the review of the current Moroccan policy.

The process for the update of a piece of legislation / regulation starts with the approva by the ministry of Ministry of “l'Aménagement du territoire national, de l'Urbanisme, de l'Habitat et de la Politique de la ville, MANTHUP” then by the Moroccan parliament and later promulgated by the King as described below.

A decree in the Moroccan legal system is an executive act adopted by the government or one of its ministers to implement the adopted laws. Decrees in Morocco are adopted by the executive branch to provide more detailed regulations with a more specific scope. Decrees must be promulgated by the king and then published in the Official Gazette to become enforceable. It should be kept in mind that if a law, a decree, a regulation, or a guide is missing an aspect that affects that specific sector, a revision could be done based on the different propositions submitted.

6.2 BEEP-Application to the Moroccan EE Policies

Do policies EXPLICITLY mandate reductions of “*energy needs for heating and cooling*”? (Propose sanctions, incentives for application)

According to the Law 47-09 and RTCM, the EE regulations in buildings are mandatory however, there are no sanctions nor incentives and no follow ups to enforce their application. So, the answer to this question is NO.

Recommendation 1: Create a follow up planning that includes the following:

the legal document proving that the building is conform to RTCM requirements should be filled by official consulting office before the start of construction process and be added to the official documents for the acquisition of the construction permission. Currently, the document is available however, it is not mandatory in the application for construction permission.

Do policies promote reduction of *total primary energy use* and not only of *nonrenewable primary energy use*, do they promote low and zero energy balance with a physical rather than fictional accounting approach?

Yes, For the application of this general building regulation RTCM, the national territory is divided into well-defined six climatic zoning. The RTCM focuses on controlling the transmission of heat through the envelope, defines thresholds for the *energy need for heating and cooling* for residential and tertiary buildings in the different zones.

Do policies explicitly refer to the Adaptive comfort model?

No, the comfort temperature is fixed to 20°C in winter and to 26°C in summer

Do policies allow and promote use of air velocity as key factor for summer comfort?

No, the comfort temperature is fixed to 20°C in winter and to 26°C in summer.

Recommendation 2: air velocity should be considered as an element of thermal comfort in summer, as e.g. in ASHRAE 55: 2020. The calculation of the comfortable combination of air, surface mean radiant temperature and air velocity can be easily calculated via the online tool https://comfort.cbe.berkeley.edu/

Do policies correctly consider both stationary parameters (e.g. stationary thermal transmittance) and dynamic parameters (e.g. periodic thermal transmittance, phase shift and attenuation of heat wave through walls and roofs)?

No, only steady state parameters are considered. The thermal mass of the envelope is not considered.

Recommendation 3: transitory measurements considering the thermal mass of the building can be very beneficial for more accurate simulations and for taking into account the effect of attenuation and delay of the heat flow from outdoor to indoor actuated by the thermal capacity of massive elements.

Do policies promote physical and regulatory frameworks that enable low-energy lifestyles (i.e., sufficiency, as defined in IPCC Sixth Assessment Report Chapter 5 on energy demand?

Morocco has implemented policies aimed at reducing the overall demand for energy, such as the promotion of energy-efficient appliances (Moroccan Standard NM 14.2.300), the use of

public transportation, and the development of compact, walkable communities. These policies can help to create physical and regulatory frameworks that enable low-energy lifestyles, as defined in the IPCC Sixth Assessment Report Chapter 5 on energy demand. Overall, Morocco has made significant efforts to promote low-energy lifestyles and reduce energy consumption, and these efforts are reflected in the creation of several green cities in Morocco such as Bouskoura, Benguerir, Zenata, and Cherafat.

Recommendations 4: inclusion of law relative to the creation of bicycle paths and bike-parking in buildings and at connections with public transport.

Do policies promote clean, silent, low temperature districts where to build?

There is no regulation except of the creation of new green cities

Recommendation 5: introduce explicit thresholds for the degree of noise and air quality for residential districts.

Do policies support a "societal point of view" in investment analysis? e.g., using "*cost of conserved energy*" or "*Internal rate of return*" rather than (short time oriented) *payback time* as indicator? Societal discount rates (e.g., 1-2%) rather than private discount rates (e.g., 5-10%)?

The RTCM only uses the payback period to give an estimation on the profitability of investing in the EE in buildings.

Recommendation 6: use the "*cost of conserved energy*" or "*Internal rate of return*"for a more accurate estimation of the profitability of the investments in buildings, which have generally life times of various decades. Enable the use of Bio-based local materials that have a lower cost than the conventional insulation materials, to reduce the capital cost.

Do policies include external costs (pollution, health damage) in calculating the optimal level of energy needs or energy performance of buildings to be enforced?

Not explicitly nor with explicit procedures.

Recommendations 7: the RTCM must include external costs such as pollution and health damage in the calculation of optimal levels of *energy needs* to be mandated in legislation

Do policies support the conscious and skilled use of local materials and their integration in the design and construction workflow?

Yes, Morocco has very detailed regulations and norms when it comes to the use of earth-based materials.

Do policies support the adoption of bio-climatic approach and passive techniques in general terms or via precise, verifiable approaches and parameters as e.g., the above-mentioned ones?

Yes, the RTCM sets a Maximum value for the coefficient heat transmission U value for the walls, ceilings and roofs depending on the percentage of openings and the climatic zone location.

The orientation of the building and the solar heat gain is controlled through the proportion of openings and threshold for the solar factor depending on the orientation of the wall and the climatic zone of the building. However, the heat loss or gain through ventilation and infiltration is not mentioned, and the later can represent a heavy load in term of heat loss in cold regions and a large driver in cooling need during daytime in the hot climate, while nocturnal ventilative cooling offers high potential in the areas close to the sea and wherever night air temperature drops at or below comfort level.
The RPCTerre 2011is the Moroccan norm for earth-based construction that considers the seismic characteristics of each zone to specify the requirements and the minimum mechanical properties.

Do policies promote the testing of air quality in buildings, natural ventilation, in other words, setting a minimum and maximum Air Change per Hour ACH?

No, the RTCM does not cover these aspects.

Recommendation 8: the ACH in buildings in the cold season should have a threshold that depends on the region.

Do policies promote the use of floors as heat sinks?

No, it is not mentioned in the regulation

Recommendation 9: To regulate the temperature, floors should be used as heat sinks in hot regions in low rise buildings

Do policies consider the effect of solar gain during the summer and shading techniques?

The policy only considers the transmission factor of glass; however, it does not consider the different types of shading techniques and vegetation shading.

Recommendation 10: the regulation should introduce a list of different types of shading techniques with their assigned shading factor and mandate a minimum lecvel of solar protection of all glazed surfaces, as e.g. in Switzerland, (SIA regulation)

7. Education and Training Programs Related to Bioclimatic Approach:

According to the report on the regulatory and training infrastructure in North-West Africa and Europe (T 2.2) EU public and private actors in education and training succeeded to offer a wide range of programs in EE in buildings and urban planning, including modules covering bioclimatic architecture. However, despite the existence of such programs in Europe and North-West Africa, there is still a lack in terms of awareness of the importance of bioclimatic architecture, therefore its presence in training programs is almost absent. When it comes to the outcomes of ABC 21 and ICBMB conference, several interesting exploitations of the results of the project were manifested in the following future activities related to trainings, education programs and future conferences:

- The consortium of the ABC 21 in collaboration with several keynote speakers is working in a preparation of a master's program merging both Engineering, Architecture, and passive designs that will be submitted to the Masters Conjoins Erasmus Mundus. More details on the Masters Conjoins Erasmus Mundus are covered in the following link: https://www.eacea.ec.europa.eu/scholarships/erasmus-mundus-catalogue_fr
- The exploitation of the educational tools prepared under the ABC 21 project, namely MOOC, BestEnergy Simulation Tool, and handbook are represented in the preparation of other educational and training programs related to bioclimatic designs and local geo- and bio-based materials.

Exchange of the know-how between the participating institutions present at the conference and planning of training and workshops. The first training will be offered by the Senegalese partner in the ABC 21 project Ernest Dione who will organize a training in favour of local artisans in the region of Ifrane, Al Akhawayn University about thatched roofs.

The conference shed light on the importance of bioclimatic designs and local geo- and bio-based materials in achieving energy efficiency and sustainable architecture. Various innovative ideas and best practices related to bioclimatic design strategies, materials, and construction techniques were presented and thoroughly discussed. The conference served as a platform for promoting and exploring the potential of bioclimatic solutions.

The success of the current conference led to discussions about organizing a second version of the event, in 2024. The ABC 21 partners and key participants of the International Conference on Bioclimatic Materials and Designs (ICBMB) are actively engaged in planning the subsequent conference. This future event aims to further advance the knowledge exchange, collaboration, and exploration of innovative ideas in the field of bioclimatic materials and designs.

8. Conclusion

The bioclimatic design is assessed through a set of indicators that quantify the building energy performance according to the terminology and guidelines provided by EN -ISO standards. The

choice of suitable indicators enriches conventional assessment tools such as bioclimatic charts and may vary depending on the context and goals of the project.

The EPBD regulation is interesting in terms of minimizing the primary fossil fuels dependency and the GHG emissions, however this approach does not decrease the energy need regardless of its source. Renewable energies are considered as zero CO_2 emitters by many regulations, neglecting their embedded energy during the process of fabrication, transport, maintenance, and disposal. Consequently, a review including the bio- and geo-sourced materials in the EPBD regulations might be needed to align with the United Nations Sustainable Development Goals.

This study shows the efforts deployed by the African nations in terms of EE regulations. However, an effort towards an effective implementation and development of regulations should be taken very seriously considering the successes and failures on the European continent.

To make this transition, the development of regulations enabling bioclimatic architecture and the use of bio- and geo-sourced materials in Africa and Europe should be part of the efforts of EE regulations.

Germany and Morocco have a promising set of regulations in the above direction. These regulations might be taken as a seed for new regulations governing a switch in other countries

Based on all information gathered in the ABC 21 project, a guideline for developing and updating actual EE policies in Europe and N-W Africa is presented. The Bioclimatic Energy Efficiency Policy (BEEP) certification consists of a series of questions that will enable the assessment and creation of new policies that enable/promote/enforce the use of bioclimatic designs and local bio- and geo-sourced materials. Morocco is used as a case study for the assessment of its current EE policy and results shows that, the Moroccan regulation is conform with most key indicators mainly, the focus on the envelope in decreasing the energy need, Morocco also sets the example for other countries when it comes to the norms of earth-based construction materials. However, there is lack in the promotion phase of bio- and geo-sourced materials, neglection of the effects of thermal mass and in general odf dynamic effects, the process is not adaptive, and the air velocity is not considered in the estimation of the summer comfort temperature. Using the BEEP, a list of recommendations is proposed and might be an input for reviewing of the current policy.

Finally, other means for exploitation of the results of the ABC 21 project are represented mainly in the preparation of educational and training programs related to bioclimatic materials and designs using the tools developed by the ABC 21 project like the MOOC, BestEnergy Simulation Tool, and handbook.

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