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Africa-Europe Bioclimatic Collaboration 21

Africa-Europe BioClimatic buildings for XXI century

FINAL REPORT ON UPDATED TECHNICAL GUIDELINES AND TOOLS

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ABC 21 project

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Executive summary

During the last century, the erroneous perception of availability of an infinite and cheap source of energy thanks to the improvements of technologies for the use of fossil fuels has separated the design of buildings from their surrounding environment. Since the realization of the first building using the new technology of mechanical production of chilled water (in 1906 was completed the Larking office building in Buffalo, designed by Franck Lloyd Wright), in the previous decades invented and used for industrial applications, and other technological developments in lighting and glazing, construction practice has gradually and steadily moved away for a careful consideration of local climate and resources, culminating in buildings whose conception is essentially disconnected from local climate and context, extremely tall, overly glazed, unshaded, based on materials with high embedded energy and often imported from very distant places

This has created a scenario where buildings are only able to deliver comfortable conditions by using large amounts of energy. Whenever mechanical conditioning systems fail or are turned off due to poor maintenance or high energy costs, buildings perform very badly. This poor performance can be lethal during extreme events.

Meanwhile, Europe and Africa are facing challenges in the building construction and housing sector. Europe is struggling with an ageing building stock, whose rapid and radical transformation is needed to meet the goals of reducing energy use and protecting the climate. Various forms of climate disruption and prolonged heat waves are affecting the planet. These effects are significant in the South of Europe and severe in Africa. Retrofits and improved designs of both buildings and cities across the European and African continents are needed to ensure the comfort and health of citizens. New buildings should be designed following concepts that will make them robust against expected climatic changes during their lifetime, the next 50 to 100 years. African countries are facing an acute housing shortage, with the continent's population projected to double by 2050, and the fastest urbanization rate in the world.

In such a condition there is a growing need for comfortable and affordable building space with high environmental performance. There is renewed interest in bioclimatic principles and use of bio- or geo-sourced local building materials in both continents.

Ongoing and further development of simple, effective, well documented, open access software focused on passive design can bring new support to pre-design and design-phase predictions of bioclimatic building performance.

Bioclimatic architecture in hot regions, according to B. Givoni, a master of this type of architecture, involves architectural design and choice of materials aiming at providing comfort while minimizing the demand for energy used. To achieve these aims, different architectural features need to be properly designed: the layout of the building, 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 average diurnal outdoor temperature.

Givoni provides also a definition for ***passive cooling systems***, which are capable of transferring heat from the building to the available natural heat sinks thus **lowering the indoor average temperature below the outdoor level**.

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.

Several guidelines and studies have been developed to support bioclimatic design over the last decades. And the physical principles regarding heat transfer, interaction of radiation with materials, daylighting, energy involved in phase changes... and their application to the design of effective building envelopes remain all valid (though underutilized).

There are, however, important changes that ask for an update of that knowledge and application.

Namely the development **and refinement of our knowledge about thermal comfort**, which has been translated in the last few years into updated comfort model and incorporated in International Standards, thus providing both renewed dignity to elements of bioclimatic approach (such as **the role of air velocity** in the provision of summer thermal comfort, which had been mostly excluded from practice in the recent decades) and better analytical basis for their incorporation into design.

At the same time new modelling tools have become available for incorporating the new findings into the design workflow. Several simple tools allow now to rapidly evaluate comfort conditions resulting from early design choices, e.g., according to the new “adaptive comfort model” or “elevated air speed model”, to graphical describe the climate of the place, to optimize the shape of shading elements, etc. Dynamic simulation tools now also incorporate the new comfort models and allow for better energy and comfort conscious detailed design, when needed.

Simple technologies with a long history such as ceiling fans have evolved with airfoil blades developed via a sophisticated aerodynamic approach rather than flat ones and efficient motors whose velocity can be remotely adjusted in close steps or continuously, attaining the noise of a whisper, high stability against oscillations and extremely low energy use (besides nice esthetics).

Some traditional construction materials manufactured using local resources, such as raw earth, benefit now of better compression methods which ensure the resulting bricks have high resistance to compression even without the addition of cement, which makes them more reliably usable even as structural elements for low rise buildings and fully recyclable at end of life.

New materials have emerged able to radiate energy mainly in the transparency window of the atmosphere, hence able at daytime to transfer more energy to the sky than they receive by the sun. Radiative cooling, traditionally used at nighttime, is now possible under the sun, with surfaces which can remain cooler than ambient air, while fully exposed to the energy flow from the sun. As it is possible for the Sahara ant, able with its thin and particularly shaped air to radiate to the sky and keep cool under the sun. We elected this astounding animal as our symbol in the ABC 21 project since it sheds light to an important avenue for passively cooling our buildings and cities.

We need now to acknowledge that even succeeding to mitigate climate change, the gases we disposed of in the atmosphere will continue to produce an increase in average temperature and frequency of extreme weather conditions. The design of the envelopes (both new and retrofitted) needs now more than ever to fully incorporate bioclimatic strategies and passive cooling systems, to be able to both protect occupants from harsher conditions and use as little energy as possible. In doing so designers need to have available a description of the local weather for the period of life of the building, which might (and should) extend for a century or more. Hence, we need reliable, publicly certified, weather file coherent to the future climate. On the contrary we are generally designing now (especially during the decisive early design phase) on the base of weather files or indicators produced as a statistical summary of past decades, greatly inadequate to represent the future.

Urban density will likely increase, to a certain extent motivated by the objective of providing housing and services to a growing population and its concentration in urban areas, without requiring too much land, infrastructures and energy for mobility. Even though what is the preferable density and corresponding height of the buildings is still a matter of research, and it will probably be a medium density, with buildings not extremely tall, also to avoid the high embedded energy required by the highly increased structural requirements of tall buildings compared to lower buildings, it is likely we will still see for some time the construction of some "tall" buildings. They were generally not a specific subject of previous guidelines, and they present specific challenges for the application of bioclimatic and passive principles, to which we dedicate a chapter.

The present guidelines represent an effort to respond to the changes described above and offer an updated view of the future of bioclimatic architecture (which might be *the* architecture in a climate-compatible future of humanity) under the new boundary conditions of XXI century, while taking advantage of accumulated wisdom and the work of the pioneers of previous century. More work is needed, but we hope this collaboration between Africa and Europe offers suggestions for taking steps in the right direction.

The guideline was developed as output of the EU funded project ABC 21 - ***Africa-Europe bioclimatic buildings for XXI century***.

Abbreviations

Term	Name
ABC 21	Africa-Europe bioclimatic buildings for XXI century
IEQ	Indoor Environmental Quality
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfied
EN	European Norm
ISO	International Organization for Standardization
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
SET	Standard Effective Temperature
NaOR	Nicol et al.'s Overheating risk indicator
KPI	Key Performance Indicator
ALD	ASHRAE Likelihood of Dissatisfaction
CO_2	Carbon dioxide
HVAC	Heating, Ventilation and Air Conditioning
NV	Natural Ventilation
NNV	Night-time natural ventilation
nZEB	nearly Zero Energy Building
VC	Ventilative Cooling
NCV	Natural Cross Ventilation
SSV	Single-Sided Ventilation
NVTB	Natural Ventilation in Tall Buildings
MM	Mixed Mode
CIBSE	Chartered Institution of Building Services Engineers
EAHE	Earth-Air Heat Exchangers
PCM	Phase Change Materials
CTBUH	Council on Tall Buildings and Urban Habitat
BIV	Building Integrated Vegetation
HTD	Heat Transfer Devices
CBE	Center for the Built Environment
LCA	Life Cycle Assessment
CFD	Computational Fluid Dynamics
BES	Building Energy Simulation
TOD	Transit Oriented Development

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1. Introduction

Climate change and resource depletion are the main challenges that global society must face in the 21st century. Climate change is expected to result in an increased frequency and intensity of hot extreme weather events, affecting agriculture [1], water resources [2] and energy systems [3,4]. In the long term, the entire humanity is exposed to risks, but the most immediate threats affect the world's poorest and most vulnerable populations.

The buildings and buildings construction sectors combined are responsible for 30% of total global final energy consumption and 27% of total energy sector emissions [5]. Energy demand from buildings and buildings construction continues to rise, driven by improved access to energy in developing countries and overall, growing demand for air conditioning in tropical countries, greater ownership and use of energy-consuming appliances, and rapid growth in global buildings floor area.

If buildings are not prepared for the changing climate, in addition to extra costs for trying to maintain comfortable indoor conditions, there can be significant health risks for the occupants, with exposure to high indoor temperatures potentially leading to heat strokes and even mortality [6]. The design of urban settlements and buildings is a key issue in addressing global warming and the quality of life for people. Due to the significant differences between design principles related to tropical or arid climates and those that apply to cities in temperate climates, tailored strategies need be taken into account to exploit the natural resources of the location.

The EU funded ***ABC 21 project – Africa-Europe bioclimatic buildings for XXI century*** has been developed with the aim to increase the energy performance, quality of life and sustainability of African and European buildings through the identification, strengthening and effective deployment of affordable bioclimatic designs and local materials under the XXI century conditions of warm climate, accelerated urbanisation in Africa and ageing building stock in Europe. The cooperation and the exchanges between African and European partners and Allies aimed to provide a larger view on **bioclimatic buildings** with examples and experiences from different contexts to identify practical **technical guidelines and tools** for **future-proof passive designs**.

Bioclimatic building design is an architectural and engineering practice most commonly defined as using climatic resources of a particular location with the help of building envelope elements to ensure living comfort, while energy sources are efficiently utilized [7]. In literature, various qualitative definitions of bioclimatic architecture can be found.

A rather detailed one, for hot regions, is proposed by B. Givoni [8], according to whom ***bioclimatic architecture*** in hot regions involves architectural design and choice of materials aiming at providing comfort while minimizing the demand for energy used. It involves minimizing and delaying heat transfer through the opaque elements of the envelope, minimizing solar heating of the envelope surfaces and solar penetration through windows, attenuating indoor temperature fluctuations by use of exposed thermal mass, and so on. To achieve these aims, different architectural means need to be properly designed: the layout of the building, 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 average diurnal outdoor temperature***.

Givoni provides also a definition for ***passive cooling systems*****,** which are capable of transferring heat from the building to the available natural heat sinks thus ***lowering the indoor average temperature below the outdoor level***.

Proper architectural *bioclimatic* design in a region with hot climate can be thus considered as a precondition for the application of *passive cooling systems*, and the two approaches supplement and reinforce one another.

Givoni classifies *passive cooling systems* as:

comfort ventilation,

nocturnal ventilative cooling,

radiant cooling to the sky,

direct evaporative cooling,

indirect evaporative cooling,

soil cooling,

cooling of outdoor spaces.

1.1 Scope and objectives

This report has the objective to provide guidance on the design of bioclimatic buildings in warm climates considering 21st century boundary conditions. This report includes some of the key outputs of the ABC 21 project, which can be further explored in the dedicated deliverables available on the project website (abc21.eu).

Starting from the bioclimatic guidelines available in the literature, these guidelines focus on the aspects expected to be most relevant for future-proof passive design in warm climates that have been analysed during the project. The guidelines focus on the architectural design elements and the passive strategies for buildings. Solutions for energy efficiency of active systems and integration of renewables are out of the scope of the present report.

1.2 Guidelines structure

The guidelines include:

- a review of existing documentation for the design of bioclimatic buildings;
- the state of advancement in indoor thermal comfort models in warm climates and recommendations for carrying out measurement campaigns and post occupancy evaluations;
- the role of natural and hybrid ventilation under future weather conditions;
- daylighting and the control of solar heat gain;
- the progress in construction materials for daytime radiative cooling;
- a review of tools for the assessment of thermal comfort and the design of bioclimatic building;
- a review of existing energy simulation tools for modelling bioclimatic buildings;

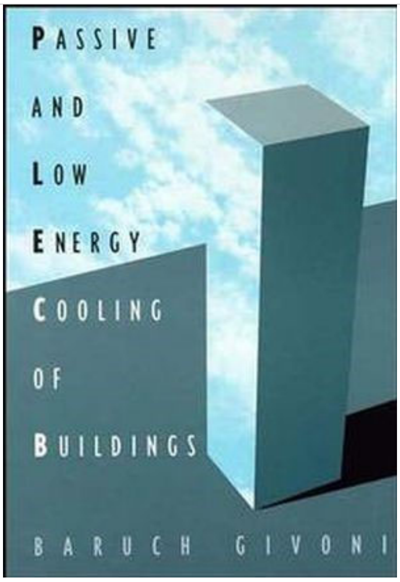
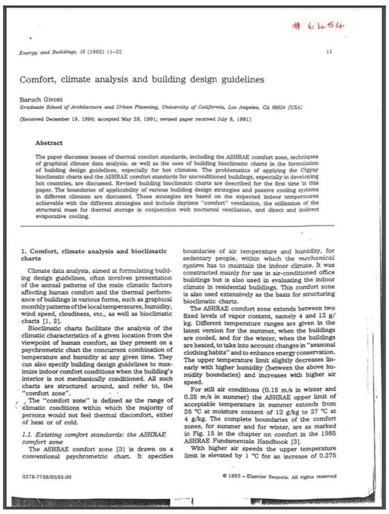
- an analysis of bioclimatic strategies with examples of application in real case studies;
- guidelines on urban/district/village design.

NOTE: all the terms defined in ISO or EN Standards or the EU Directives will be written in *underlined italics* in this text.

2. Literature review about existing guidelines for bioclimatic buildings

Architectural design based on bioclimatic features has long been of interest to many designers. The literature review has highlighted that several guidelines and studies have been developed in the last decades [9] targeting different areas and strategies. However, few existing sources are specifically focused on African countries, while none of them takes into consideration the whole Africa, considering the different climates within the continent as well as local sources and constrains. Table 1 lists the main sources currently available, while in Annex A we present an in-depth analysis of the main references. For the freely available sources, we provide the link to download the document.

Table 1 Overview about existing guidelines for bioclimatic buildings' design

	Title	Author/s or Publisher	Year of publication
	Passive and low energy cooling of buildings. A fundamental book for the systematization and nomenclature about *bioclimatic architecture* and *passive cooling systems*. Offers a wealth of data on design and performance.	Baruch Givoni	1994
	Comfort, climate analysis and building design guidelines. A fundamental paper by one of the pioneers of bioclimatic design and passive cooling Download	Baruch Givoni	1992

#6454

Energy and Buildings, 18 (1992) 11-23 11

Comfort, climate analysis and building design guidelines

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Abstract

The paper discusses issues of thermal comfort standards, including the ASHRAE comfort zone, techniques of graphical climate data analysis, as well as the uses of building bioclimatic charts in the formulation of building design guidelines, especially for hot climates. The problematics of applying the Olgyay bioclimatic charts and the ASHRAE comfort standards for unconditioned buildings, especially in developing hot countries, are discussed. Revised building bioclimatic charts are described for the first time in this paper. The boundaries of applicability of various building design strategies and passive cooling systems in different climates are discussed. These strategies are based on the expected indoor temperatures achievable with the different strategies and include daytime "comfort" ventilation, the utilization of the structural mass for thermal storage in conjunction with nocturnal ventilation, and direct and indirect evaporative cooling.

1. Comfort, climate analysis and bioclimatic charts

Climate data analysis, aimed at formulating building design guidelines, often involves presentation of the annual patterns of the main climatic factors affecting human comfort and the thermal performance of buildings in various forms, such as graphical monthly patterns of the local temperatures, humidity, wind speed, cloudiness, etc., as well as bioclimatic charts [1, 2].

Bioclimatic charts facilitate the analysis of the climatic characteristics of a given location from the viewpoint of human comfort, as they present on a psychrometric chart the concurrent combination of temperature and humidity at any given time. They can also specify building design guidelines to maximize indoor comfort conditions when the building's interior is not mechanically conditioned. All such charts are structured around, and refer to, the "comfort zone".

The "comfort zone" is defined as the range of climatic conditions within which the majority of persons would not feel thermal discomfort, either of heat or of cold.

1.1. Existing comfort standards: the ASHRAE comfort zone

The ASHRAE comfort zone [3] is drawn on a conventional psychrometric chart. It specifies boundaries of air temperature and humidity, for sedentary people, within which the *mechanical system* has to maintain the indoor climate. It was constructed mainly for use in air-conditioned office buildings but is also used in evaluating the indoor climate in residential buildings. This comfort zone is also used extensively as the basis for structuring bioclimatic charts.

The ASHRAE comfort zone extends between two fixed levels of vapor content, namely 4 and 12 g/kg. Different temperature ranges are given in the latest version for the summer, when the buildings are cooled, and for the winter, when the buildings are heated, to take into account changes in "seasonal clothing habits" and to enhance energy conservation. The upper temperature limit slightly decreases linearly with higher humidity (between the above humidity boundaries) and increases with higher air speed.

For still air conditions (0.15 m/s in winter and 0.25 m/s in summer) the ASHRAE upper limit of acceptable temperature in summer extends from 26 °C at moisture content of 12 g/kg to 27 °C at 4 g/kg. The complete boundaries of the comfort zones, for summer and for winter, are as marked in Fig. 15 in the chapter on comfort in the 1985 ASHRAE Fundamentals Handbook [3].

With higher air speeds the upper temperature limit is elevated by 1 °C for an increase of 0.275

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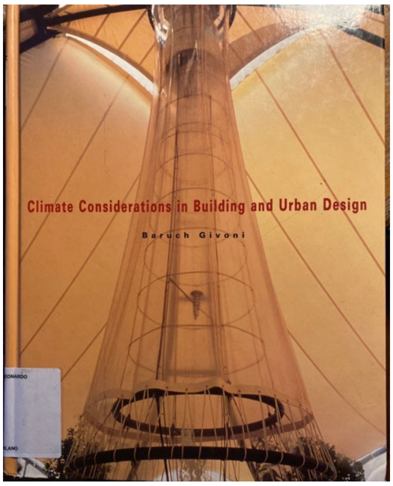
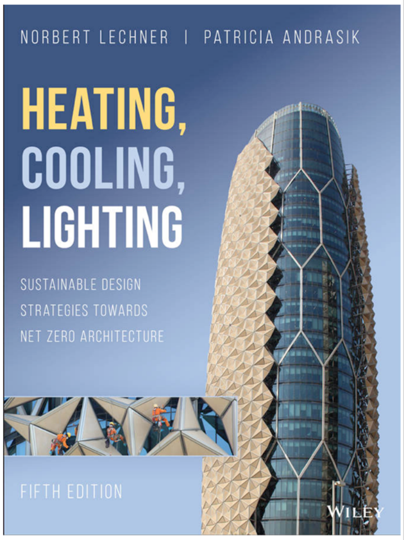
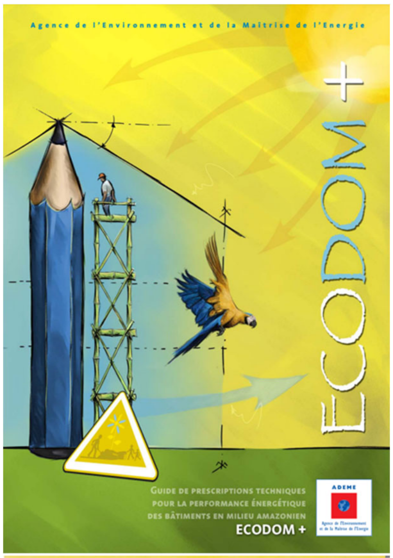
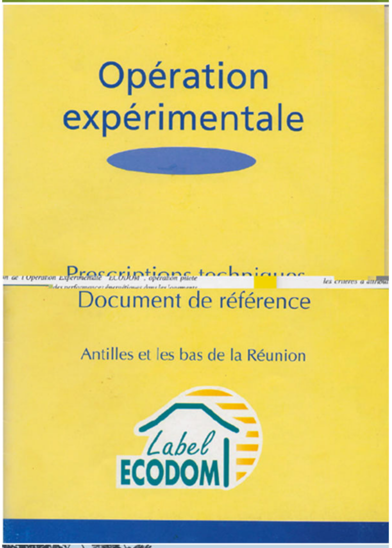
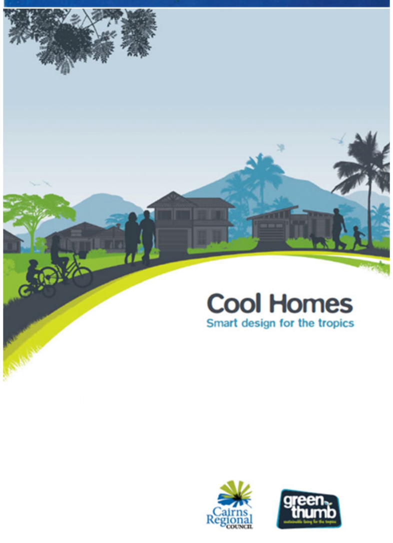
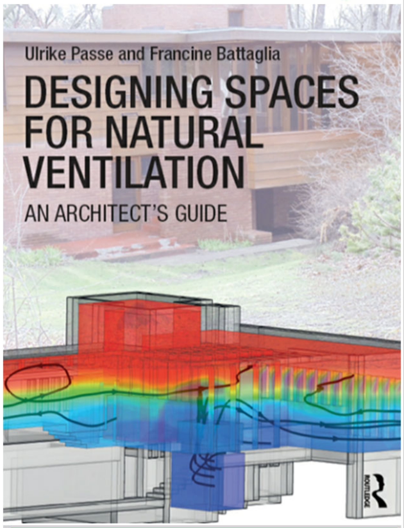
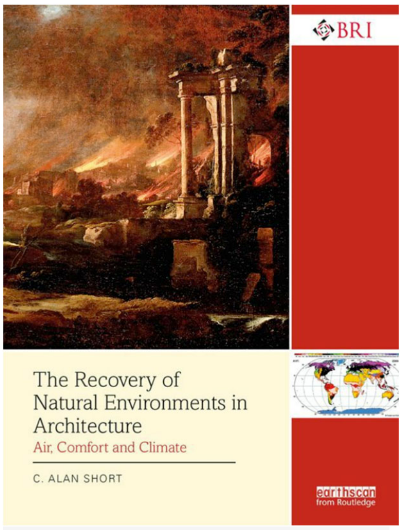
 	Climate Considerations in Building and Urban Design. Offers a wealth of data from monitored case studies, and a generalisation from them into a set of orders of magnitude and design principles. Mathematics kept as little as possible, while providing deep physical insight	Baruch Givoni	1998
 	Heating, cooling, lighting. Sustainable design strategies towards net zero architecture. Provides physical insight and calculation aid at a level which is operational and not intimidating	Norbert Lechner, Patricia Andrasik	2021
 	Ceiling Fan Design Guide Download	Paul Raftery, David Douglass-Jaimes	2020

	Guide de prescriptions pour la performance énergétique des bâtiments en milieu amazonien. ECODOM + Download	ADEME	2010
	Label ECODOM. Opération expérimentale. Prescriptions techniques. Document de reference. Antilles et les bas de La Réunion	EDF La Réunion	1998
	Cool Homes. Smart design for the tropics	Cairns Regional council	2014

	Ventilation naturelle en pratique. Méthodologie pratique du développement de la ventilation naturelle an la construction appliquée à l'Ile de La Réunion	ADEME, Jacques Gandemerr	2018
	Designing Spaces for Natural Ventilation An Architect's Guide. An Architect and a fluid dynamic Engineer offer an integrated vision to the design of natural ventilation	Ulrike Passe, Francine Battaglia	2015
	Ventilation naturelle. Respirer sans machines… » Case studies at exhibition at École Nationale Supérieure d'Architecture de Paris-la Villette, April 2023 Download	Exposition + Conférences 27 mars—22 avril 2023	2023

	The Recovery of Natural Environments in Architecture. Air, Comfort and Climate	C. Alan Short. (BRI Research Series). New York : Routledge	2017
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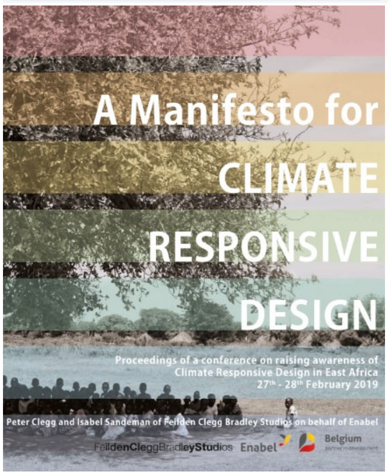
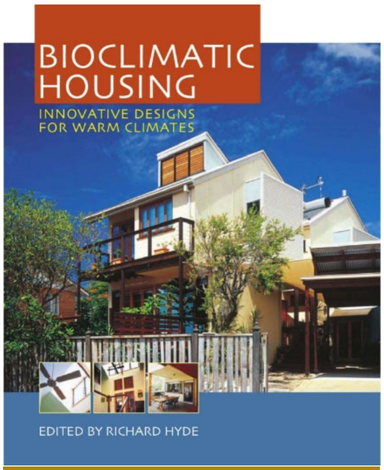
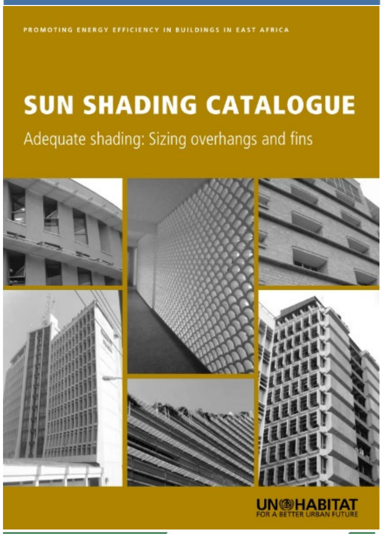
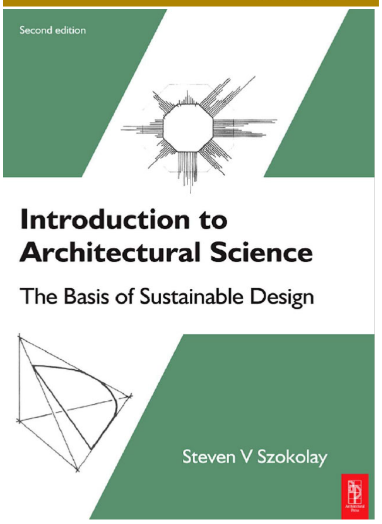
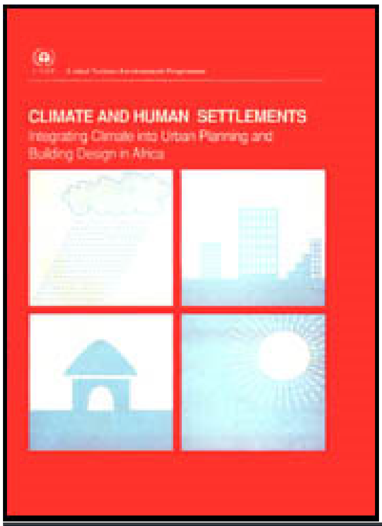
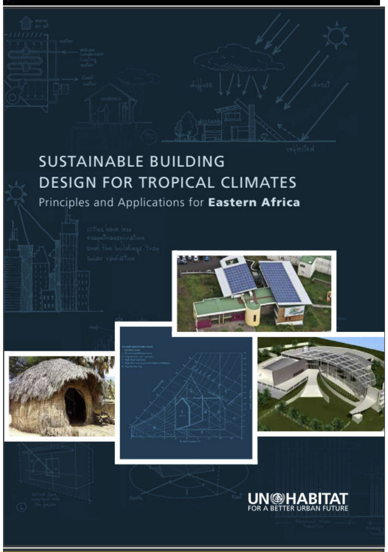
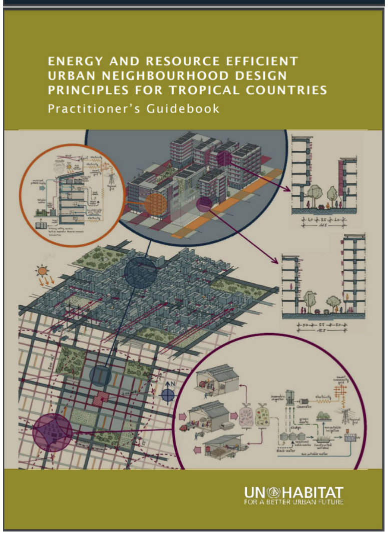
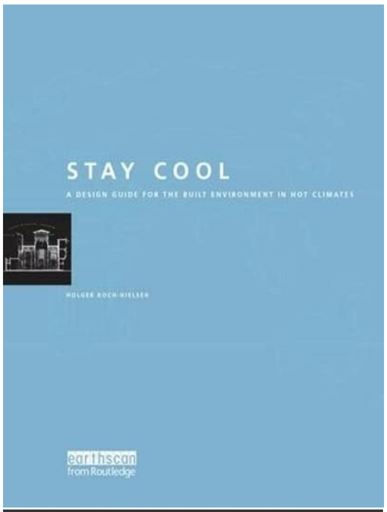
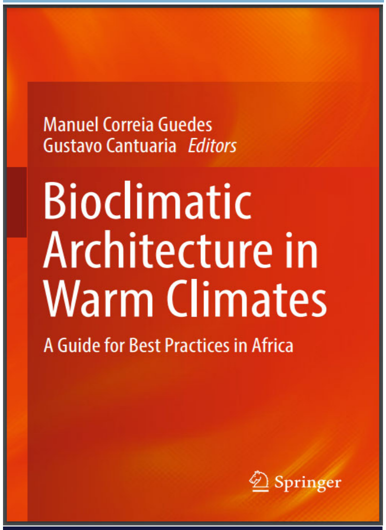
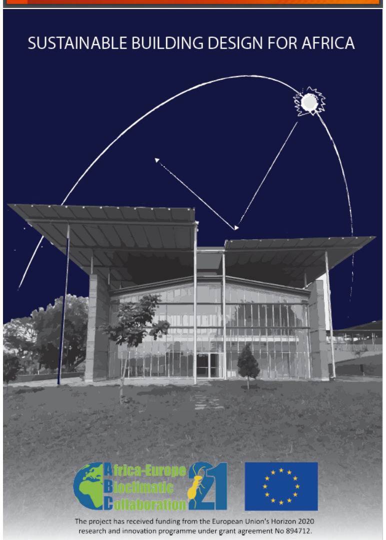
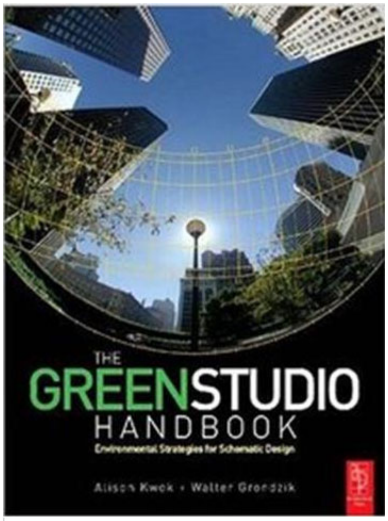
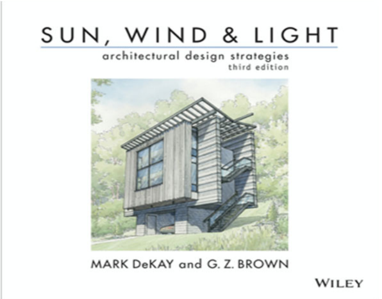
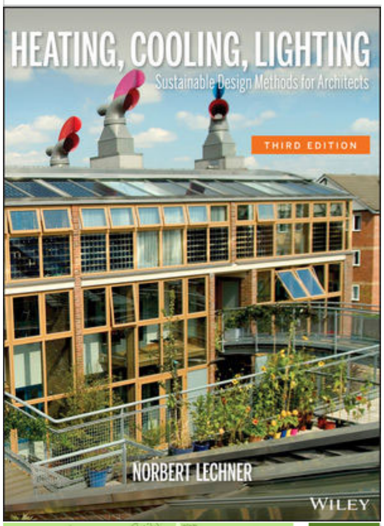
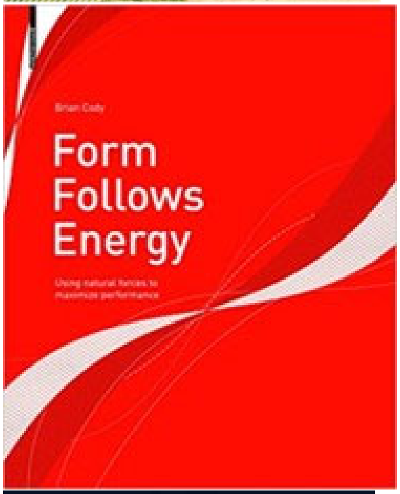
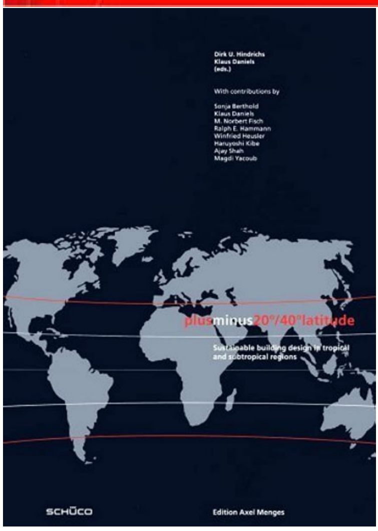
	A Manifesto for CLIMATE RESPONSIVE DESIGN Download	Peter Clegg and Isabel Sandeman	2019

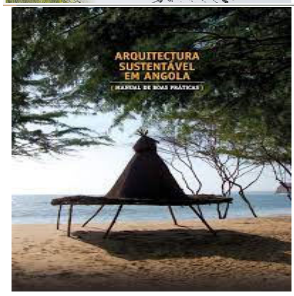
	BIOCLIMATIC HOUSING. Innovative designs for warm climates	Richard Hyde	2008
	Sun shading catalogue. Adequate shading: sizing overhangs and fins Download	Publisher: UN-Habitat	2018
	Introduction to Architectural Science. The Basis of Sustainable Design. Introduction to the physical principles for energy and comfort conscious design	Steven V. Szokolay	2008

	Climate and human settlements. Integrating Climate into Urban Planning and Building Design in Africa Download	Adebayo, Yinka R. UNEP	1991
	Sustainable building design for tropical climates. Principles and Applications to Eastern Africa. Download	Publisher : UN-Habitat	2015
	Energy and resource efficient urban neighbourhood design principles for tropical countries. Practitioner's Guidebook Download	Publisher: UN-Habitat	2018

	Stay cool. A design guide for the built environment in hot climates. Basic principles and applications with visuals	Holger Koch-Nielsen	2002
	Bioclimatic Architecture in Warm Climates. A Guide for Best Practices in Africa	Manuel Correia Guedes, Gustavo Cantuaria	2019
	Sustainable Building Design for Africa. Examples for various African climates and updates in some chapters with respect to the 2015 book. Download	M. Butera, Rajendra Adhikari, Niccolò Aste.	2022 (updated version)

	The GreenStudio Handbook	Alison Kwok, Walter Grondzik	2006 (1st edition)
	Sun, wind & light. Architectural design strategies	G. Z. Brown Mark DeKay	2014
	Heating, Cooling, Lighting. Sustainable Design Methods for Architects.	Norbert Lechner	2015
	East Africa Climatic Data and Guidelines for Bioclimatic Architectural Design Download	Publisher: UN-Habitat	2016

	Architecture Bioclimatique et efficacité énergétique des bâtiments au Senegal Download	R. Célaire et L. Rakotomalala Ministère De L'environnement Et Du Développement Durable CRAterre	2017
	Form Follows Energy	Brian Cody	2017
	Plusminus 20/40 Latitude: Sustainable Building Design in Tropical and Subtropical Regions	Edition Axel Menges	2007

	La ventilation naturelle à La Réunion: 12 enseignements à connaitre Very detailed guide for design options for noise protection, solar protection, positioning of ceiling fans Download	Agence qualité construction	2019
	Arquitectura Sustentàvel em Angola: Manual de Boas Pràticas	Manuel Correia Guedes	2011

The present guidelines represent an effort to respond to the changes described above and offer an updated view of the future of bioclimatic architecture (which might be *the* architecture in a climate-compatible future of humanity) under the new boundary conditions of XXI century, while taking advantage of accumulated wisdom and the work of the pioneers of previous century.

The list of books above offers a non-exhaustive but rather complete view over the type of guidance available, particularly for the pre-design stage, where the most important and impactful decisions need to be taken, many details are still missing, and hence it is more important to apply well proven and understood physical knowledge, rather than performing complex numerical simulations.

The guidance that can be found in the above books is hence of the type offered in the examples below:

- SITE: consider and privilege, when possible, a choice of site that allows orientation of the building along the east-west axis, with the main openings facing north or south depending on the hemisphere.
- FORM: Prioritize elongated east-west layouts, compact designs. Employ atriums to centralize lighting and views, utilize covered atriums for greater compactness. adapt building projections and facade designs according to solar orientation for enhanced energy efficiency and sustainability.
- PLAN: In hot and humid climates and large lake climates, open building designs are advisable to facilitate ample ventilation, while in hot and arid as well as semi-arid/savannah regions, compact building layouts are favored for mutual shading, the generation of cool spaces through plant and water feature integration, and protection against scorching, dry winds. This approach includes the use of buffer spaces on the east and west sides, promoting physical activity by discouraging short elevator trips,

and implementing open floor plans to maximize both natural daylight and ventilation, contributing to a sustainable and comfortable indoor environment.

- WINDOWS: Strategically design openings for natural ventilation and daylighting, tailoring their size to climate conditions – favor larger openings for hot and humid climates, and opt for smaller openings in hot arid and hot semi-arid/savannah regions. On the east and west facades, limit the number of windows, while emphasizing north or south orientations for more openings. Position windows at a height that maximizes daylight penetration and consider operable windows with a linked system for cooling shut-off when open. For climates where heating is needed in part of the year install low-transmittance windows or provide indoor night insulation to ensure energy efficiency and indoor comfort.
- DAYLIGHTING: Utilize light shelves on south and necessary east and west windows, opt for high ceilings, and consider clerestories facing the sky rather than the sun path for top lighting. Avoid skylights due to their seasonal sun collection. Employ atriums with north- or south-facing clerestories depending on hemisphere. Explore light tubes, high R-value light-transmitting panels for roofs, and indoor blinds for glare control. Consider prismatic daylighting glass, limit translucent walls, and maximize borrowed light with glass partitions and doors. Enhance daylight penetration by using light-colored paving outside first-floor windows, always remembering the importance of daylighting quality.
- SHADING: Implement effective solar radiation protection for all openings by employing suitable shading devices. Consider outdoor venetian blinds or roller shades to block low east and west sun. Avoid vertical fins on east and west windows, opting for horizontal louvers, and use trees and plants for natural shading. Thoroughly test shading designs to prevent solar outflanking and extend shading strategies to include roofs, walls, and the surrounding landscape. In taller buildings, give priority to vegetated walls, especially on the east and west sides. Acknowledge the superior efficiency of outdoor shading solutions over indoor methods, and choose appropriate glazing to suit heating requirements while ensuring windows remain shaded during the overheated periods of the year.
- COLOR: Optimize building performance through light-colored or reflective external surfaces to minimize their collection of sun energy and their re-irradiation towards the building. Emphasize greenery while reducing paved areas around the building. Enhance lighting efficiency with high-reflectance white ceilings, light-colored walls, furniture, and floor finishes, ensuring well-lit spaces with minimal lighting demands.
- THERMAL MASS: In hot and humid climates, favor light-weight building envelopes as the limited night discharge potential hinders energy accumulation in thermal capacity. Conversely, in hot semi-arid/savannah regions, opt for medium-weight building structures. For ***Nocturnal ventilative cooling***, ensure mass is exposed to airflow, and avoid covering with insulating materials; employ sound absorption acoustic panels and partitions for sound control.
- GLAZING: Use different types on each facade and even within windows. For daylighting without excessive heat. Explore insulated translucent panels instead of glazing for clerestories and small skylights, but avoid using them on lower walls due to potential glare. Reflective glazing should be avoided in situations causing glare or overheating issues. Single glazing is unsuitable for heated or cooled buildings. Outdoor shading devices are best for blocking direct solar radiation, while glazing with low solar heat-gain is more suitable for blocking diffuse and reflected radiation.
- AIR BARRIER: in climates where heating is required, enhance building performance by implementing an effective air barrier to reduce infiltration. Employ windows and doors with high-quality weatherstripping, consider the use of a vestibule or revolving

door at the entrance, and opt for a heat exchanger ventilation system to maintain indoor air quality, minimizing the reliance on infiltration.

- NATURAL VENTILATION: Increase natural ventilation with solar and stack-effect chimneys, cowl-type roof ventilators, and exterior wing walls to divert wind and maximize airflow for improved environmental performance.

The above list (neither complete, nor to be taken as such, but rather an invitation to get to the details and rationale that the books offer, see e.g. [10,11]), is given here to highlight the type of high-level decision, to be taken in the early phase of the design, relying on physical principles and accumulated experience rather than on detailed calculations. Calculations (from a spreadsheet to dynamic simulation), in later stages might confirm the choices and allow their fine-tuning.

Most of the above guidelines, also due to their date of publication, do not present in detail an up to date description of the comfort models and the comfort objectives to be used as a target for the design and for the assessment of the results achieved. We hence include in the next chapters a review of the recent updates and changes in the international standards, which summarises for practical application the knowledge gathered in the last decade. Those have relevant implications for the design and assessment of bioclimatic and passive strategies.

In some of the above publications, case studies provide tangible examples of how sustainable design principles have been applied and can inspire innovative solutions tailored to the specific conditions. When using case study applications, it is important to consider the unique characteristics of each project and adapt the lessons learned to the specific context of the target city or district.

3. Thermal comfort in hot climates

Thermal comfort is defined as: ‘that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation’ [12]. It is the parameter of indoor environmental quality (IEQ) which has been more widely investigated and extensive documentation is available in literature [13–15]. To evaluate the indoor thermal comfort conditions, a large number of surveys about thermal sensations have been the base for the development of various comfort models aiming at predicting the average comfort perception of groups of people exposed to a certain environment.

The assessment of thermal comfort presented in the Standards EN 16798-1:2019 [16] and ASHRAE 55:2020 [12] indicates two main typologies of comfort model:

- the “Fanger (PMV/PPD) model” (EN ISO 7730 [17]), proposed for actively conditioned buildings,
- while the “Adaptive Model” is proposed for naturally conditioned spaces and when active systems, even if installed, are not in use (ASHRAE 55:2020)

In tropical climates and naturally conditioned spaces, field studies have found that the International standard for indoor climate, ISO 7730 [17] based on Fanger’s predicted mean vote equations, does not adequately describe comfortable conditions [18–20]. In warm climate conditions, PMV predicts that people will feel hotter than they actually do and therefore tends to encourage the use of more air conditioning than necessary. Fanger himself did recognise that “in non-air-conditioned buildings in warm climates, occupants may sense the warmth as being less severe than the PMV predicts“ [21].

In the last decades, a number of design activities and successful construction activities have taken place based on the Givoni’s comfort zone [22,23] or the Standard Effective Temperature (SET*) model developed by Gagge [24–26] and growing evidence of comfort acceptance by occupants of those buildings has been found [27,28].

Studies and tools are available in literature to compare different thermal comfort models (e.g. Attia et al. [29] developed an analysis application for bioclimatic design strategies in hot humid climates and showed the comfort models comparison for the two major cities of Madagascar, situated off the southeast coast of Africa).

3.1 The Adaptive Comfort Model

The adaptive comfort theory has been developed from field studies and considers the building occupants as active agents interacting with their built environment [15]. This model relates indoor design temperatures or acceptable temperature ranges to outdoor meteorological or climatological parameters.
There are currently two main standards related to indoor thermal comfort assessment which propose the adaptive model in buildings without mechanical cooling or heating systems in operation: the European EN 16798-1 [16] and the American ASHRAE 55 [12].

The European adaptive comfort model

According to the European model [16] the acceptable indoor *operative temperature*[1] is evaluated through the running mean external temperature that is "the exponentially weighted running mean of the daily mean outdoor air temperature" and is calculated by means of formula (1):

$$T_{rm} = (1-\alpha)\cdot\{T_{ed-1} + \alpha T_{ed-2} + \alpha^2 T_{ed-3} + \cdots\} \qquad (1)$$

Where:

- T_{rm} = Outdoor Running mean temperature for the considered day (°C).
- T_{ed-1} = daily mean outdoor air temperature for previous day
- α= constant between 0 and 1 (recommended value is 0,8)
- T_{ed-i}= daily mean outdoor air temperature for the *i-th* previous day

The following approximate formula (2) shall be used where records of daily running mean outdoor temperature are not available:

$$T_m = (T_{ed-1} + 0.8T_{ed-2} + 0.6T_{ed-3} + 0.5T_{ed-4} + 0.4T_{ed-5} + 0.3T_{ed-6} + 0.2T_{ed-7})/3.8 \qquad (2)$$

Once the running mean temperature is calculated, it is possible to estimate the indoor comfort range as shown in Figure 1. The comfort boundaries are related to the running mean through a linear equation and are differentiated between the following categories:

Category I	upper limit:	T_o = 0.33 T_{rm}+ 18,8 + 2	(3)
	lower limit:	T_o = 0.33 T_{rm}+ 18.8 - 3	(4)
Category II	upper limit:	T_o = 0.33 T_{rm}+ 18,8 + 3	(5)
	lower limit:	T_o = 0.33 T_{rm}+ 18,8 - 4	(6)
Category III	upper limit:	T_o = 0.33 T_{rm}+ 18,8 + 4	(7)
	lower limit:	T_o = 0.33 T_{rm}+ 18,8 – 5	(8)

The limits only apply when 10 < T_{rm} < 30 °C.

[1] The uniform temperature of an imaginary black enclosure, and the air within it, in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual nonuniform environment [12]. In most practical cases where the relative velocity is small (< 0,2 m/s) or where the difference between mean radiant and air temperature is small (< 4 °C), the operative temperature can be calculated with sufficient approximation as the mean value of air and mean radiant temperature [30].

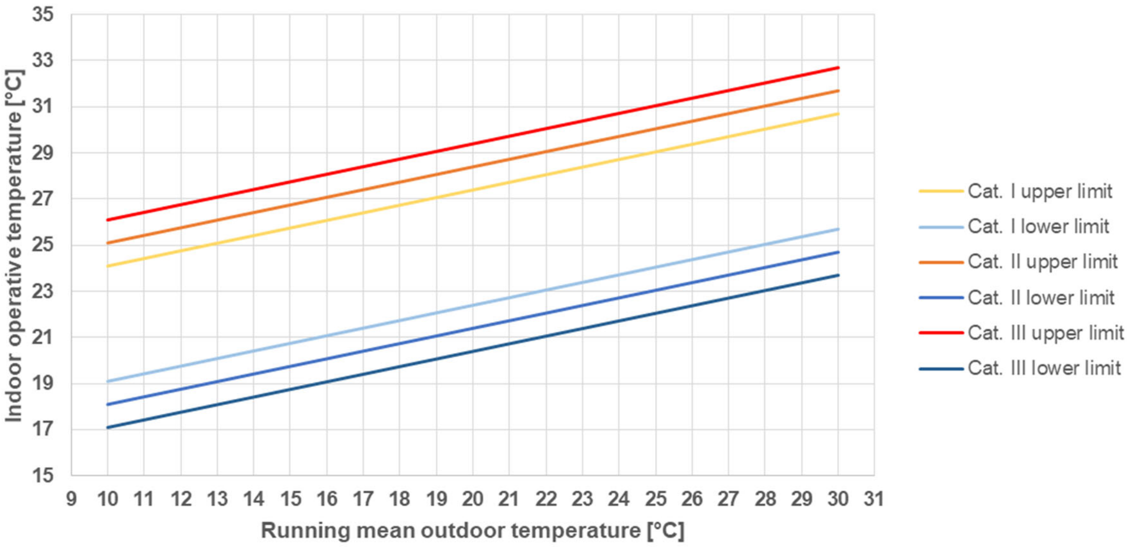


Figure 1: Comfort temperature ranges according to the three categories defined in [16].

Based on the EN adaptive thermal comfort model [6] it has been developed the Nicol et al.'s Overheating risk (NaOR) indicator [31]. It proposes that thermal dissatisfaction is not anchored to a fixed indoor temperature value, but rather to the difference, ΔT, between the actual operative temperature in a space at a given time and the EN 15251 (revised by EN 16798) adaptive optimal operative temperature T_c, the latter being a function of outdoor running mean temperature T_{rm}. The NaOR index is asymmetric and predicts the percentage of individuals, P(ΔT), voting +2 (warm) or +3 (hot) on the ASHRAE thermal sensation scale, as described in equation (9):

$$P(\Delta T) \equiv \frac{\exp(0.4734 \cdot \Delta T - 2.607)}{1 + \exp(0.4734 \cdot \Delta T - 2.607)} \in [0.069; 1] \quad (9)$$

Where the optimal operative temperature $T_{c,EN}$ [°C] is calculated using the formula (10):

$$T_{c,EN} = 0.33 \cdot T_{rm} + 18.8 \quad (10)$$

The ASHRAE adaptive comfort model

The ASHRAE adaptive thermal comfort model instead, provides 80% and 90% acceptability threshold temperatures on either side of the adaptive comfort temperature optimum, which is calculated as a function of the prevailing mean outdoor air temperature $t_{pma(out)}$ as eq. (11):

$$T_{c,ASHRAE} = 0.31 \cdot t_{pma(out)} + 17.8 \quad (11)$$

The limits are calculated according to the following equations (12)(13)(14)(15) and are reported in Figure 2:

Upper 90% acceptability limit (°C) = 0.31 $t_{pma(out)}$ + 20.3 (12)

Lower 90% acceptability limit (°C) = 0.31 $t_{pma(out)}$ + 15.3 (13)

Upper 80% acceptability limit (°C) = 0.31 $t_{pma(out)}$ + 21.3 (14)

Lower 80% acceptability limit (°C) = 0.31 $t_{pma(out)}$ + 14.3 (15)

According to the ANSI/ASHRAE Standard 55:2020 [12], this method defines acceptable thermal environments only for occupant controlled naturally conditioned spaces that meet all of the following criteria:

a. There is no mechanical cooling system or heating system **in operation**.
b. Representative occupants have metabolic rates ranging from 1.0 to 1.5 met.
c. Representative occupants are free to adapt their clothing to the indoor and/or outdoor thermal conditions within a range at least as wide as 0.5 to 1.0 clo.
d. The prevailing mean outdoor temperature is greater than 10°C and less than 33.5°C.

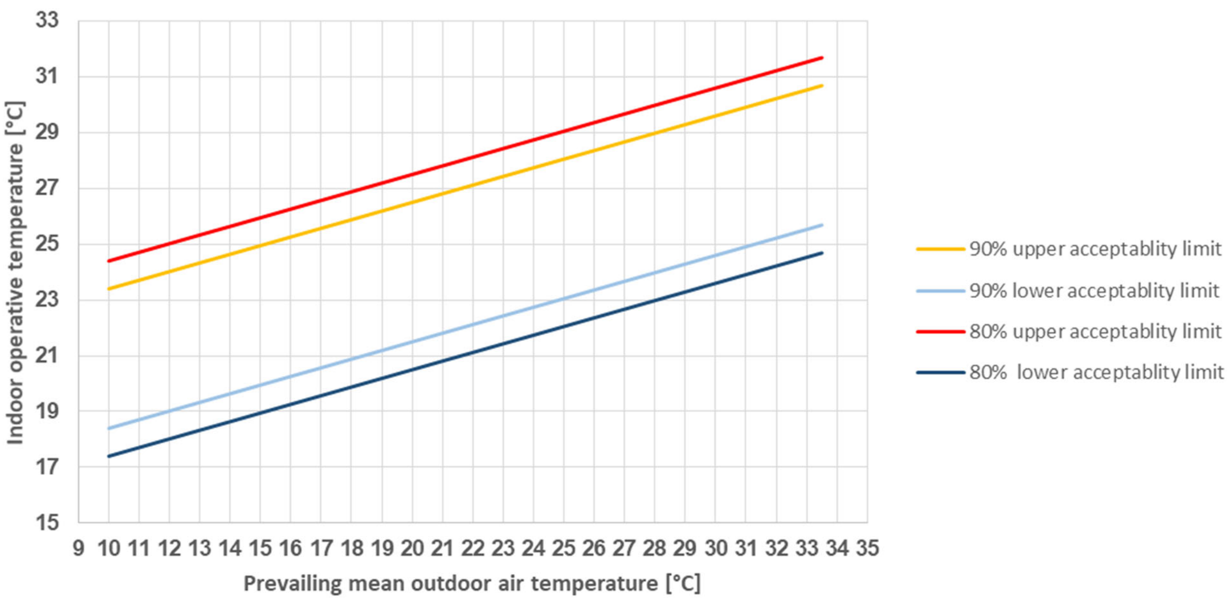


Figure 2: Acceptable operative temperature ranges for naturally conditioned spaces according to [12]

The adaptive model is based on statistical analyses of the two official ASHRAE databases; the second one [32] has recently been published and contains a large set of worldwide data from comfort surveys in real buildings.

Both the European and the American Standard indicates that under summer comfort conditions with indoor operative temperatures > 25 °C, increased air velocity can be used to reduce the adverse effects of increased air temperatures.

Where there are fans (that can be controlled directly by occupants) or other means for personal air speed adjustment (e.g. personal ventilation systems, or personally operable windows) it is permitted to consider an increase of the upper acceptability temperature limits by the corresponding Δt_0 reported in Table 2:

Table 2 Increases in acceptable operative temperature limits (Δt_0) in occupant-controlled naturally conditioned spaces according to [12]

Average Air Speed V_a [m/s]	Δt_0 [°C]
0.6	1.2
0.9	1.8
1.2	2.2

Updates about adaptive thermal comfort models

In the standard ASHRAE 55:2020 [10], compared to previous versions: "applicability was expanded of the Adaptive Model used for naturally conditioned spaces. ***The model is now applicable to buildings that have a mechanical cooling system installed, as long as the system is not running****".*

3.2 The Elevated Air Speed Comfort Zone Method

According to the standard ASHRAE 55:2020, the Elevated Air Speed Comfort Zone method uses the Analytical Comfort Zone Method combined with the Standard Effective Temperature (SET).

It is permissible to apply the method to all spaces within the scope of the ASHRAE 55:2020 standard where the occupants have activity levels that result in average metabolic rates between 1.0 and 2.0 met, clothing insulation I_{cl} between 0.0 and 1.5 clo, and average air speeds V_a greater than 0.20 m/s.

Figure 3 represents two particular cases (0.5 and 1.0 clo) of the Elevated Air Speed Comfort Zone Method and it is applicable as a method of compliance for the conditions specified in the figure. The figure also defines comfort zones for air movement with occupant control (darkly shaded) versus without occupant control (lightly shaded).

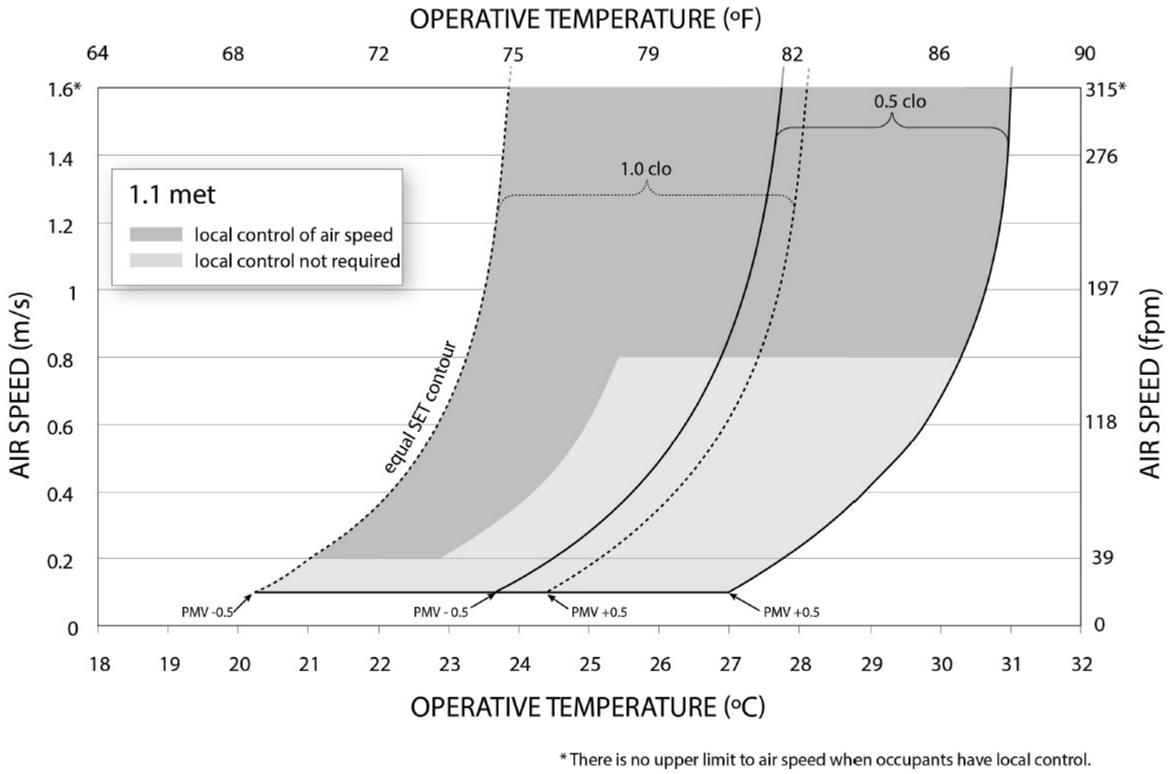


Figure 3: Acceptable ranges of operative temperature t_o and average air speed V_a for 1.0 and 0.5 clo comfort zones at humidity ratio 0.010, according to the ASHRAE Elevated Air Speed Comfort Zone Method [12]

Figure 4 provides a graphical example of a comfort zone using the Elevated Air Speed Comfort Zone Method (lighter shade zone) compared to one using the Analytical Comfort Zone Method (darker shade zone). Direct use of this chart to comply with the Elevated Air Speed Comfort Zone Method using the lighter shade zone is allowable for the specific input conditions described on the chart. It should be noted that the influence of relative humidity on the comfort range is relatively small, as already stated by Fanger.

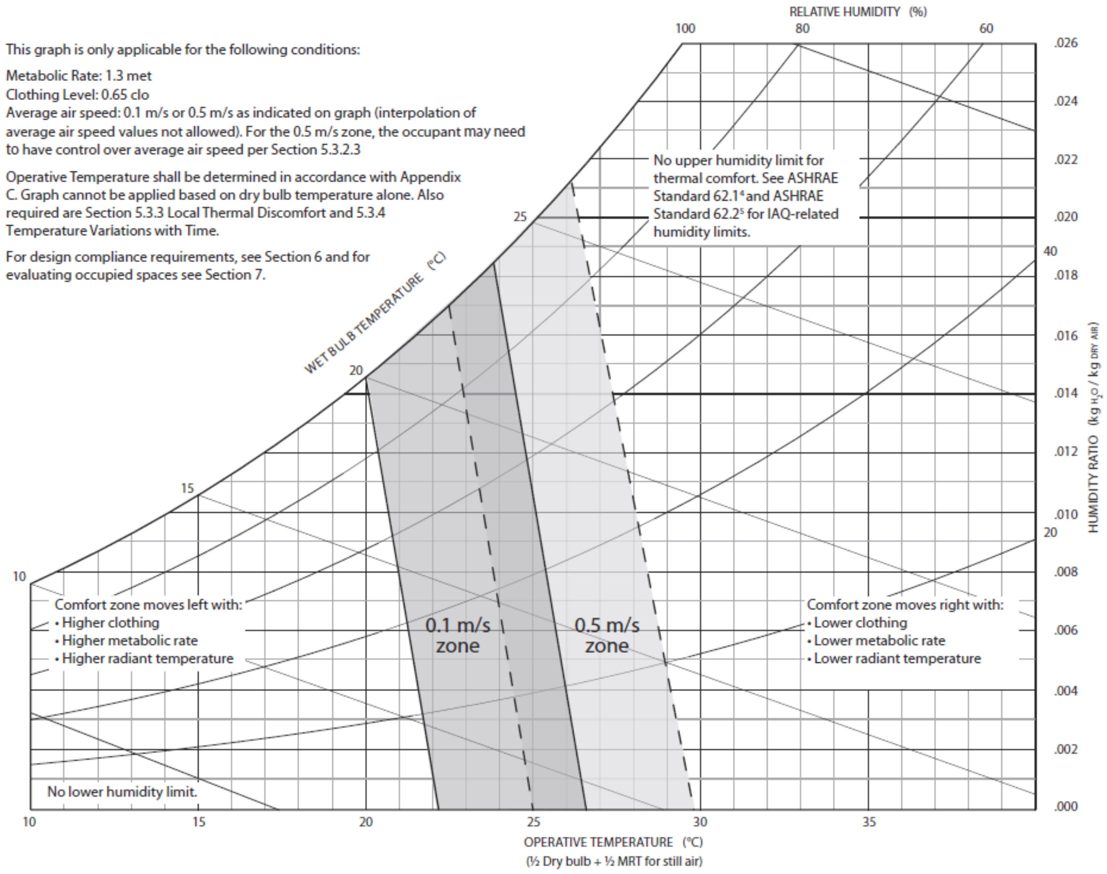


Figure 4: Comfort zones in terms of operative temperature and relative humidity. Elevated Air Speed Comfort Zone Method example (lightly shaded zone) compared to the Analytical Comfort Zone Method example (darkly shaded zone) [10]

3.3 Bio-climatic charts

When designing bioclimatic buildings, it is common to use bioclimatic charts, which are simple tools that take into account climate conditions to recommend appropriate design for different climates.

Various types of bioclimatic charts have been developed such as the Olgyay Bioclimatic chart, the Givoni–Milne Bioclimatic chart, the Szokolay Bioclimatic chart and the Mahoney Table [33].

For hot climates, it is recommended to use the Givoni bioclimatic chart. The originality of the work proposed by Givoni is to use the psychrometric chart as the base layer to characterise comfort zones [11,34].

Givoni has developed several comfort zones depending on:

- the level of air velocities on the users (0 to 2 m/s);
- the level of development of countries (developed countries and developing countries).

For developing countries, the upper limits of accepted temperature and humidity are higher than in developed countries, assuming that people are acclimatised to hot and humid conditions .

Comfort zone for still air conditions (v = 0 m/s)

In the conditions defined for this zone, it is assumed that a person wearing light clothes – i.e. 0,5 clo is in thermal comfort conditions in the indoor space. According to Givoni, it can be noted that people can be in thermal comfort conditions in different boundaries of relative humidity (between 20% and 80%) and air temperature (between 20°C and 26°C), with still air.

Comfort zone for air velocity around 1-2 m/s

If the temperature in the indoor space exceeds 26°C or relative humidity is quite high, natural cross ventilation can improve the thermal comfort. In hot and humid climates, natural cross ventilation (or the use of ceiling fans) is the simplest strategy to adopt if the indoor temperature is almost the same as the outdoor temperature. Givoni assumes that the maximum allowed indoor air speed is about 1-2 m/s (which is a range considered now in ASHRAE 55:2020), thus ventilation on the users maintains comfort up to an outdoor temperature limit of 30°C (for developed countries) and of 32°C (for hot-developing countries), as shown in Figure 5.

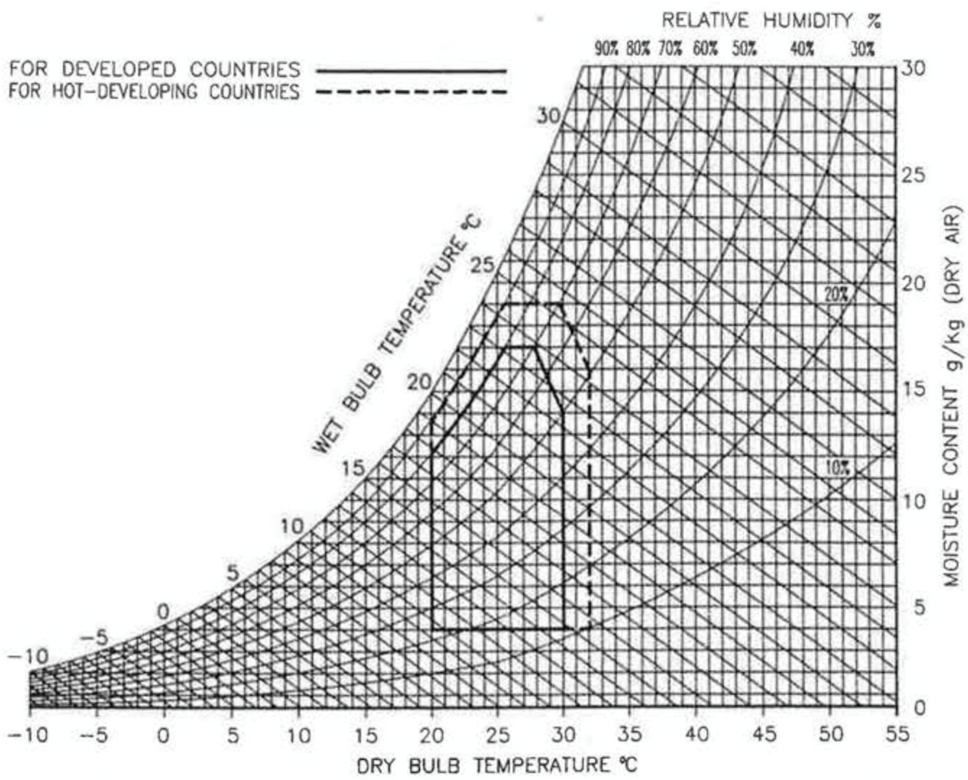


Figure 5: Comfort zones defined by Givoni [22,34] for an air speed of 2 m/s

The Givoni bioclimatic chart is a useful tool to assess thermal comfort at the design stage or during the post occupancy evaluation process. Figure 6 shows the results of measured data in an office space during the hot and humid season in La Reunion. One can notice that the comfort conditions are reached 96% of time in the comfort zone of 1m/s. The percentage of time inside one specific zone can be set as a clear performance indicator of thermal comfort.

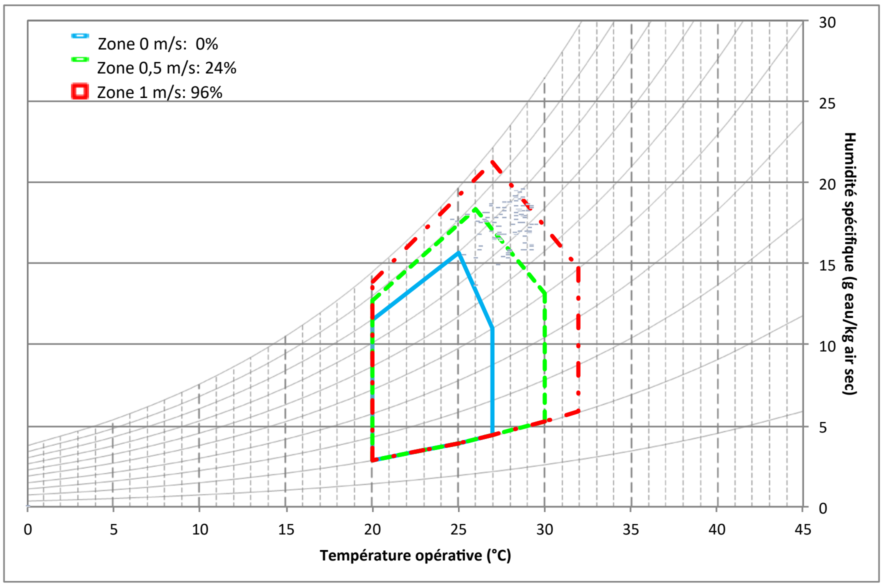


Figure 6: Assessment of thermal comfort in an office building in La Reunion

3.4 The KPIs to support bioclimatic design

Key Performance Indicators (KPIs) are essential to quantify the building performance, detect malfunctioning or misuse of the building by the occupant or users, synthetise complex information. Several KPIs for thermal comfort assessment are available in literature and standards. Two main categories can be identified:

- indices that focus on comfort conditions at a certain time and position in space (e.g., the ASHRAE Likelihood of Dissatisfaction ALD [35], the overheating risk index NaOR [31])
- long-term comfort indices that aim at assessing thermal comfort quality of a building over a span of time and considering all the building zones [36].

Table 3 reports a selection of the reviewed indicators for assessing thermal comfort in bioclimatic buildings. They can be used to monitor and verify the conditions of the indoor thermal comfort in buildings, offer a comparison between the case studies and provide guidelines for bioclimatic design in warm climates.

Table 3 Long-term thermal comfort indicators

n	Thermal comfort index	UoM	Definition
1	Percentage of time outside an operative temperature range (Adaptive)	%	Calculate the number or percentage of hours, during the hours the building is occupied, the operative temperature is outside a specified range calculated according to the adaptive thermal comfort model.
2	Percentage of time outside an operative temperature range (Fanger)	%	Calculate the number or percentage of hours, during the hours the building is occupied, the operative temperature is outside a specified range defined according to the Fanger comfort model.
3	Degree-hours (Adaptive)	h	The time during which the actual operative temperature exceeds the specified range (calculated according to the adaptive thermal comfort model) during the occupied hours is multiplied with a weighting factor which is a function of how many degrees the range has been exceeded. The product of

			each hour for the corresponding weighting factor is then summed up over the period of interest, (e.g. summer)
4	Degree-hours (Fanger)	h	The time during which the actual operative temperature exceeds the specified range (defined according to the Fanger comfort model) during the occupied hours is multiplied with a weighting factor which is a function of how many degrees the range has been exceeded. The product of each hour for the corresponding weighting factor is then summed up over the period of interest, (e.g. summer)
5	Percentage of time inside the Givoni comfort zone for air velocity at 1 m/s	%	Calculate the number or percentage of hours during the hours the building is occupied, when the pair "operative temperature/relative humidity" is inside the specified comfort zone
6	Percentage of time inside the Givoni comfort zone for still air conditions, i.e. v = 0 m/s	%	Calculate the number or percentage of hours during the hours the building is occupied, when the pair "operative temperature/relative humidity" is inside the specified comfort zone
7	Number of hours during which the operative temperature is within a certain range	-	Calculate the number of hours during which the operative temperature is within a certain temperature range

1-2: The Percentage of time outside an operative temperature range or a PMV range is calculated as the number or percentage of hours during the hours the building is occupied, the PMV or the operative temperature is outside a specified range (definition from EN ISO 7730:2005 – method A [37]). When considering the operative temperature ranges, it is possible to apply the adaptive method or the Fanger one.

3-4:*Degree-hours* is calculated as the time during which actual operative temperature exceeds the specified comfort range during occupied hours is weighted by a factor, wf, which is a function of how many degrees the range has been exceeded (definition from EN ISO 7730:2005 – method B [37]).

The weighting factor, wf_i, has two different formulations according to the two above-mentioned standards:

$$wf_i|_{ISO7730} = 1 + \frac{|T_{op,i} - T_{op,limit}|}{|T_{op,comfort} - T_{op,limit}|}$$

$$wf_i|_{EN16798} = T_{op,i} - T_{op,limit}$$

For a characteristic period during a year (warm period/cold period), the product of the weighting factor and time is summed. The summation of the product has the unit of *hours* according to the ISO 7730 and of *degree · hours* following the EN16798-2, in spite of an error in the technical report. The degree-hour criterion can be evaluated applying the Adaptive comfort method or the Fanger one.

5-6: The percentage of time inside the Givoni comfort zone is calculated as the number or percentage of hours during the hours the building is occupied, when the pair "operative temperature/relative humidity" is inside the specified comfort zone.

7: The last KPIs calculates the number of hours during which the operative temperature is within a certain range.

3.5 Guidelines for assessing indoor thermal comfort

The literature analysis has highlighted a gap in measured data and occupant's feedback in buildings in Africa. In particular, this has been underlined in the ASHRAE Global Thermal comfort Database II [32] which offers a total of 2163 data collected in African buildings, compared e.g. to the 31392 data from European one. The African field studies available in the dataset are from Nigeria and Tunisia (Figure 7).

Figure 7 The ASHRAE Global Thermal Comfort Database II [32]

As a consequence, the ABC 21 project has put efforts in collecting existing data and new ones realising measurement campaigns and post occupancy evaluations in a set of buildings. The results of the monitoring activities are reported in the deliverable D3.9 – Case studies of European and African Bioclimatic buildings.

In the following we report the main recommendations to carry out thermal comfort assessments in bioclimatic buildings.

The procedure should include:

1. objective methods based on **physical measurements**;
2. subjective methods based on **occupants' surveys** to investigate their satisfaction with the indoor environment.

Measurements campaign of physical parameters

Three different levels of monitoring strategies are suggested, in relation to the availability of resources:

- the first level is a basic monitoring level with sensors capable of measuring the indoor air temperature and relative humidity (RH) in selected spaces inside the building. Outdoor conditions are limited to air temperature and RH measured with the same kind of sensors that are protected from solar radiation with a naturally ventilated shield;
- the second level is the same as level one with an additional weather station on site. The weather station has to measure at least global horizontal solar radiation, wind speed/wind direction, temperature and relative humidity;

- the third one is a more detailed monitoring with, in addition of level 2, the measurement of all indoor thermal environment parameters (i.e. the air temperature, the relative humidity, the black globe temperature and the air velocity). The measurements should last at least 2 or 3 months during the hottest period.

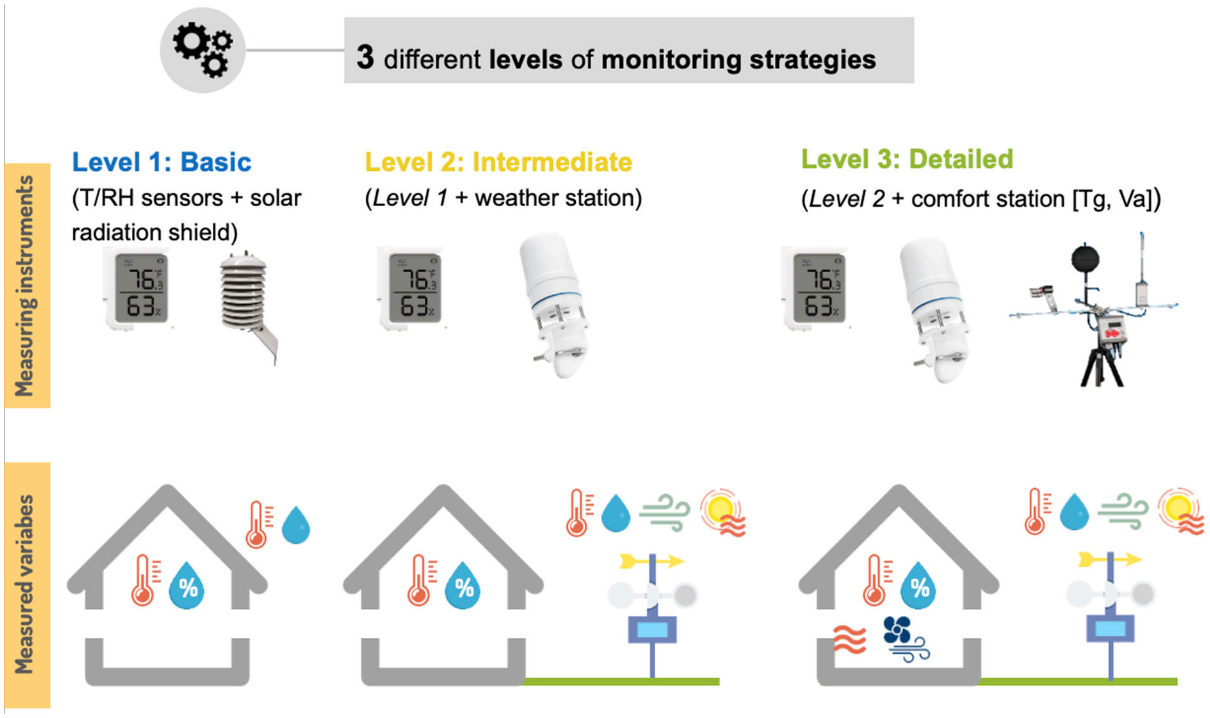


Figure 8 Different levels of indoor thermal comfort monitoring campaigns in bioclimatic buildings

Following the standard EN ISO 7726 [30], specific recommendations regarding the most appropriate position of the sensors, the time span and installation tips were drawn up and are reported in deliverable D3.9B.

The measurement instrumentation used for the evaluation of the thermal environment shall meet the requirements given in the standard EN ISO 7726: Ergonomics of the thermal environment - Instruments for measuring physical quantities

Occupants' surveys

To collect a comprehensive set of information from the occupants of the buildings it is recommended to use spot surveys and general satisfaction surveys.

Spot surveys are short questionnaires with the objective to receive feedback from the occupant **right at the moment** when the survey is answered. These types of questionnaires are generally **correlated with simultaneous measurements of the indoor environmental variables**, i.e., air temperature, relative humidity, air velocity and mean radiant temperature (black globe temperature).

Physical and subjective measures should be done “at times of the day when conditions are representative of the environments to which people are exposed. Conditions to which people are exposed can be influenced by outside weather and it could be necessary to measure throughout the day or to carry out a long-term survey across the year.” (EN ISO 28802:2012).

The standard ISO 10551 [38] describes the various judgements which are recommended for an assessment of comfort or stress based on subjective data, as reported in Table 4.

The standard EN ISO 10551:2019 provides guidance of the development of the questions according to the subjective judgement scales

Table 4 Stress assessment according to EN ISO 10551:2019 [38]

	1	2	3	4	5
TYPE OF JUDGEMENT	**Perception**	**Evaluation**	**Preference**	**Personal acceptability**	**Personal tolerance**
Subject under judgement	**Personal state**			**Physical ambience**	
Wording	"How do you feel (at this precise moment)?"	"Do you find it…..?"	"Please state how you would prefer to be now"	"How do you judge this environment (local climate) on a personal level?"	"Is it…..?"
	7 or 9 degrees	4 or 5 degrees	7 (or 3) degrees	2 category statement form or 4 degrees	5 degrees
e.g., for assessing thermal environments	from COLD (or extremely cold) to HOT (or extremely hot)	from COMFORTABLE to very (or extremely) UN-COMFORTABLE	from (much) COLDER to (much) WARMER	“On a personal level, this environment is for me: Acceptable rather than unacceptable; Unacceptable rather than acceptable” From clearly acceptable to clearly unacceptable	from TOLERABLE to INTOLERABLE

It's important also to include questions to collect information about the activities performed and the garments worn in order to understand the corresponding metabolic rate and the insulation values respectively. Finally, it's recommended to collect information about the status of the controls (e.g. if the door is open or closed, if the windows are open or close, the fans..).

The questionnaires should be distributed **at least twice a day** on the days the measurements are conducted, namely, in the morning and in the afternoon.

The general **satisfaction surveys** have the objective of tracking the general evaluation of the indoor environment by the occupant. Simultaneous measurements of physical parameters are not required.

They should be conducted in the same year as measurement, and done by a significant number of occupants. The survey must be conducted **at least one year after the building is fully occupied** and if possible to conduct it **two times a year in different seasons** (summer/winter).

3.6 Highlights

The possibility to apply (as a user of a building as much as a designer or manager of a building) measures such as ***nocturnal ventilative cooling*** during summer nights and use **ceiling fans** during the day instead of (or to reduce use of) air-conditioning depends on explicit recognition at the regulation level of the following issues:

1. **the same level of thermal comfort** can be achieved via various combinations of the physical parameters (operative temperature, relative humidity and air velocity), each with different values of *energy need for cooling* and *energy need for dehumidification*.
2. **The choice of the comfort category** (I, II or III according to EN 16798-1, or A, B, C according to ASHRAE 55) which is aimed at by the building design and/or controls, **strongly affects energy use**.
3. A number of research works show that Comfort category I (A), which is the more energy demanding, cannot be perceived subjectively and it is below the accuracy of measurements. In the EU standard (EN 16798) category I (A) is reserved to buildings occupied by fragile people (children, elderly, persons with disabilities, etc.), but it may nevertheless be perceived by designers and presented to clients/operators as the "best" condition.
4. An important parameter affecting comfort in the warm season is the **insulation level of clothing and of furniture**.

4. Natural and hybrid ventilation

4.1 Introduction

The EU's buildings remain generally inefficient [39], accounting for 40% of final energy consumption and 36% of the EU's total CO_2 emissions [40]. This energy consumption has been increasing significantly in the buildings sector, and together with the transport sector are the fastest growing areas of energy consumption [41], estimated to represent a 26% increase in 2030 compared to 2005 [42]. The temperature rise due to climate change and the increased expectations of thermal comfort by users has led to an increase in cooling use. Thus, the HVAC systems are one of the main contributors for this increase in energy consumption, being expected that in non-residential buildings, the energy use due to cooling will increase by 275% by 2050 [43].

In order to counteract this trend, building designers should be encouraged to use *bioclimatic* principles (geometry, orientation, shading…) and *passive cooling systems*. As for the use of *Natural Ventilation* to this purpose, using the nomenclature of Givoni [8] we can distinguish (among the passive cooling systems):

Comfort ventilation

When the indoor temperature, under still air conditions, seems to be too warm to occupants, it is possible to provide comfort through higher indoor air velocity (as seen in the previous chapter). This can be achieved via natural ventilation through the windows and/or other openings. This enhanced velocity, improving heat exchange by convection and evaporation form the skin, can provide a direct physiological cooling effect even if outdoor air is rather warm, up to about 30 °C. Hence the name of "*comfort ventilation*". It is useful to adopt this strategy only when indoor comfort can be experienced at outdoor air temperature (with acceptable indoor air speed). Alternatively, if conditions are not favourable for opening windows, increased air velocity can be provided by well-designed and positioned ceiling fans, standing fans, desk fans.

Nocturnal ventilative cooling

When a building is ventilated at night its masses are subject to convective exchange with the (generally cooler) outdoor air, bypassing the thermal resistance of the envelope and exportin energy from the building to outdoors. During the daytime the cooled masses, if they are adequately thermally insulated from the outdoors, can serve as a heat sink, absorbing in their thermal capacity the solar and internal heat gains. To achieve this effect the building should be ventilated during daytime only to the low level needed for Indoor Air Quality in order to avoid the interior being heated by the warmer outdoor air. Hence daytime comfort ventilation and nocturnal ventilative cooling are in many cases mutually exclusive. Figure 9, taken from [10] gives a qualitative idea of the type of climates where the two systems may be usefully adopted. Note that Lechner uses the term "night flush cooling" for the passive system which Givoni calls "*Nocturnal ventilative cooling"*

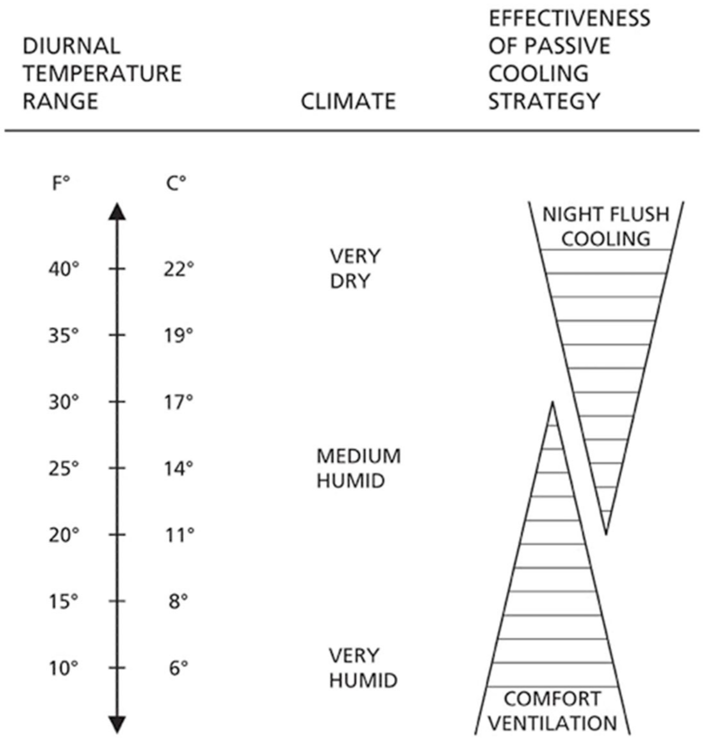


Figure 9 The performance of night-flush cooling and comfort ventilation is a function of diurnal temperature range (max – min outdoor temperature). Note that Lechner uses the term "night flush cooling" for the passive system which Givoni calls "Nocturnal ventilative cooling" [10]

Natural ventilation

In this report we call *Natural Ventilation* (NV), ventilation achieved in the building by use of natural forces alone, with the purpose to achieve *comfort ventilation*, or *nocturnal ventilative cooling.*

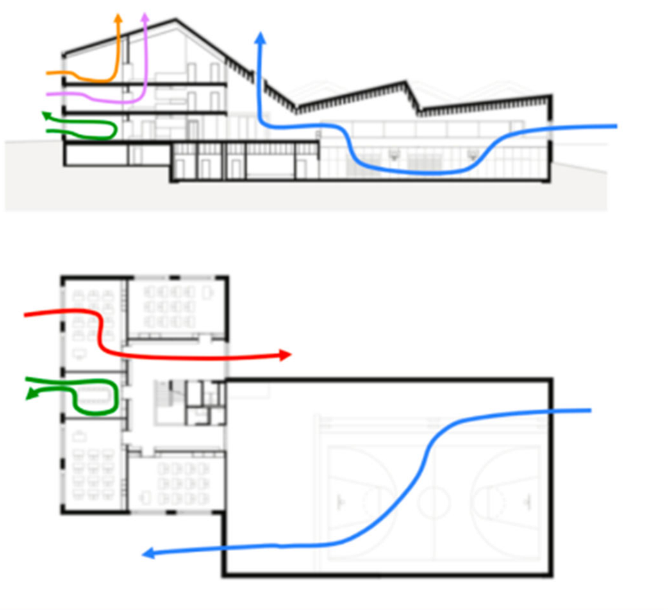


Figure 10 Possible airflow paths in *Natural Ventilation*. Source: IEA EBC Annex 62 [44]

Figure 11: example of louvre opening for *Natural Ventilation*. Source: IEA EBC Annex 62 [44]

Hybrid ventilation

Hybrid ventilation systems can be described as systems providing a comfortable internal environment using both natural ventilation and mechanical systems but using different features of the systems at different times of the day or season of the year. It is a ventilation system where mechanical and natural forces are combined in a two-mode system [45].

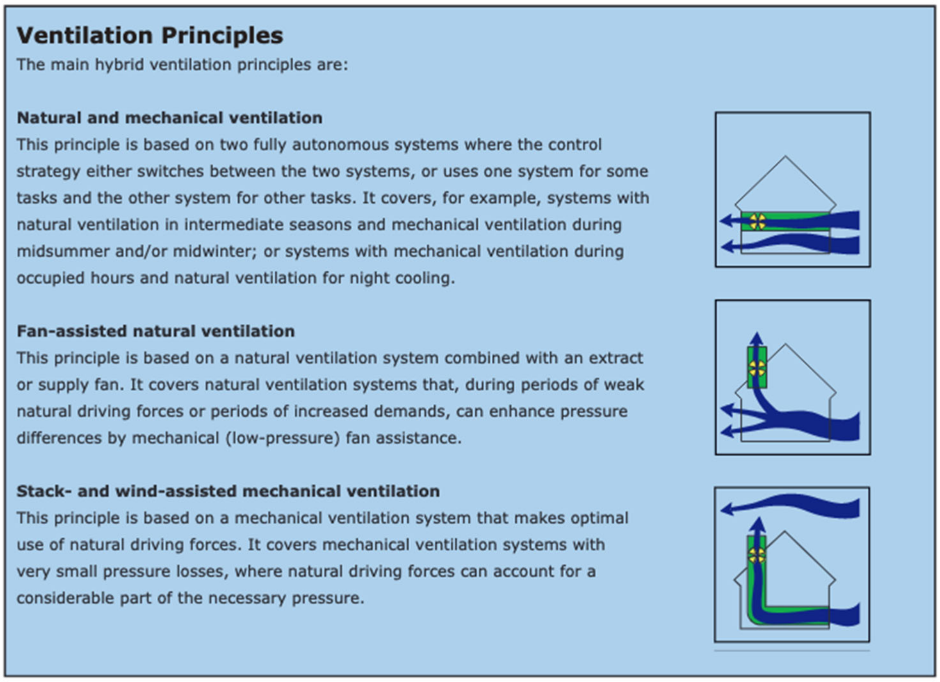


Figure 12 Classification of hybrid ventilation systems. Source: IEA annex 35 [46]

Comfort ventilation and *Nocturnal Ventilative Cooling* use the outdoor climate as an energy source [47]. Thus, their performance is highly dependent on the weather conditions, in particular, outdoor air temperature, wind speed, wind direction and relative humidity [48]. Natural ventilation is seen as a fundamental passive system in order to achieve Nearly Zero Energy Buildings (nZEBs) [49].

Research about *Advanced Natural Ventilation* schemes which take advantage of the stable driver delivered by stack effect, finds a relevant energy saving potential (up to 50%) in various European-mediterranean climates (Figure 13) by applying what they call night-time natural ventilation (NNV) (which in the adopted nomenclature of Givoni would be called _Nocturnal Ventilative Cooling_) [50]. It should be noted that the cited study sets the cooling setpoint at 24 °C and assumes zero air velocity indoors. By setting a more relaxed set point at 26 °C, well within the comfort range even when adopting the Fanger model with zero or moderate air velocity, provided e.g by ceiling fans (see Figure 4), the saving potential would be further significantly increased.

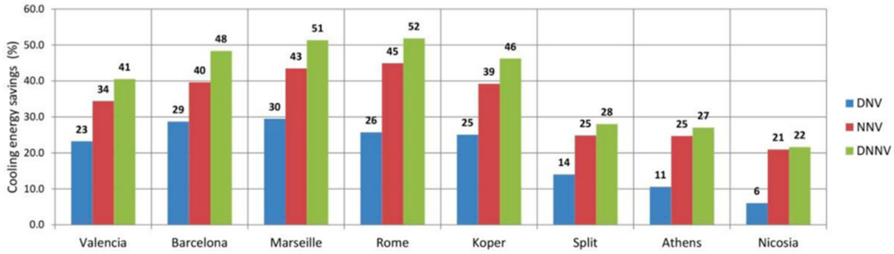


Figure 13 Comparison of total cooling energy savings (ES) (%) by each city and by each Advanced Natural Ventilation mode: cooling period April-October

We should note that the increase of air temperatures due to climate change would reduce the effect of _Nocturnal Ventilative Cooling_ in the warmest months, but it will increase its necessity and effect in the “shoulder months” as recalled e.g., by [51].

NV in a building occurs when fresh air intentionally enters through existing openings in the building (doors, windows, or openings specifically dedicated to natural ventilation as e.g. louvres, grilles,..). This airflow entering in a building results from the pressure differences between the outdoor and the indoor caused by the action of the wind, the indoor-outdoor temperature, or a combination of these two driving forces.

The buoyancy consists of the difference in hydrostatic pressure caused by the weight of the air columns that exist indoors or outdoors. The hydrostatic pressure in air depends on air density and the relative height above the reference point, considering the effect of air stratification by the existence of a temperature gradient along the interior or exterior air column. On the other hand, when the wind faces the building, it creates a static pressure distribution along the building surfaces. Static pressure takes positive values for windward surfaces and negative values for the remaining surfaces and the upper part of pitched roofs [quote Lechner book]. The static pressure depends not only on the air volume mass and wind speed but also on the pressure coefficient that evaluates how it behaves given the wind direction, the orientation of the surfaces, the shape of the building, its elements that impose a separation of the flow, and the presence of obstacles/elements of roughness in the surroundings. The action of the wind is determinant in the design of a natural ventilation system since the stack effect is weaker than the wind effect [52]. Thus wind-driven cooling systems tend to be more effective [53]. However, all geographical areas have periods where the pressure derived from the wind effect is zero, so natural ventilation systems should be designed based on the worst case scenario and hence take profit of stack ventilation, which is not driven by the wind [52].

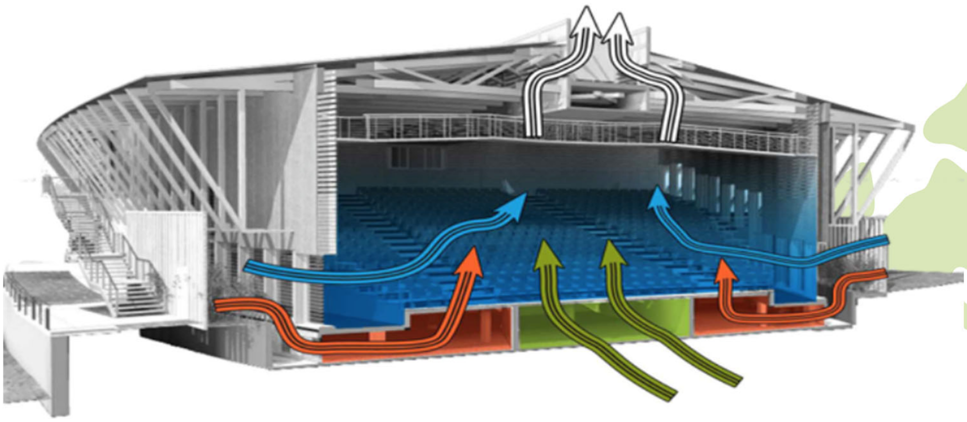


Figure 14 Visualization of the airflows through the low-pressure shaft on top of the roof and the different air inlets located underneath the seats and at the side louvers of the Moufia bioclimatic theater, in La Reunion.

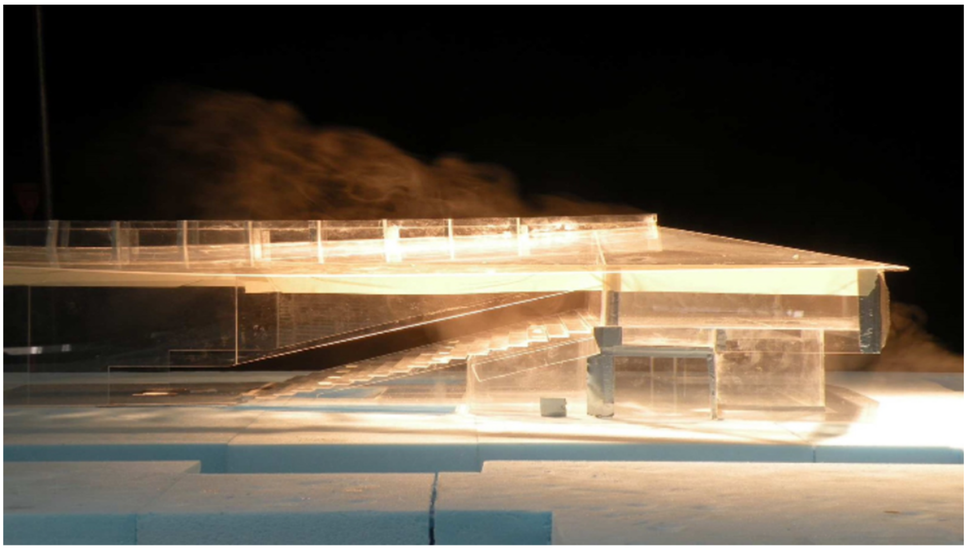


Figure 15 Wind tunnel tests carried out to validate the natural ventilation strategy set up for the Moufia bioclimatic theatre, in La Reunion.

In cold climates, the challenge is introducing the required airflow of fresh air to remove excess heat (which may build up in certain hours due to internal and solar gains) without compromising the comfort of the occupants. If the airflow is greater than necessary, this will result in increased *energy needs for heating*. In temperate climates, an optimized NV system can meet fresh air requirements and cooling needs [52]. However, in such climates, the challenge is to implement technical solutions to overcome periods when the outdoor-indoor temperature difference is very small, thereby the driving forces are limited. In windy climates, solutions that boost the action of the wind should be implemented, such as wind catchers. On the other hand, in sunny climates, technical solutions that increase the buoyancy forces, such as solar chimneys, should be used. In hot and dry climates, the airflow should be controlled, depending on outdoor temperature, so that the air introduced into the area is not an additional heat source. Thus, *Night Ventilative Cooling* is of particular interest in such climates for removing the heat accumulated during the day and consequently cooling the thermal mass of the building. *Night Ventilative Cooling* is shown to perform better in these climates compared to daytime and full day ventilation (*comfort ventilation*) [50,54,55]. In the future, the potential effective cooling by for night ventilation will be lower in the warmer months and higher in the colder months. In most cases, therefore, the importance of *Nocturnal ventilative cooling* will shift rather than diminish. Suppose the Nocturnal Ventilative Cooling potential is high and the other building configurations are well designed (thermal mass, shading, window-to-wall ratio, etc.). In that case, during the day the indoor temperature will be lower than the outdoor one. Otherwise, additional natural or mechanical cooling solutions will be required.

4.2 Guidelines for Ventilative Cooling Design

The design process must be carried out logically and sequentially since passive design requires to consider the features of the entire building, not just elements or machines in isolation. This is intended to minimize solar and heat gains and maximize the ability of a natural ventilation system to remove the cooling load. A Natural Ventilation design procedure consists of different phases, namely: conceptual design phase, basic design phase, detailed design phase and design evaluation. The Figure 16 illustrates the design procedure of a ventilation cooling system.

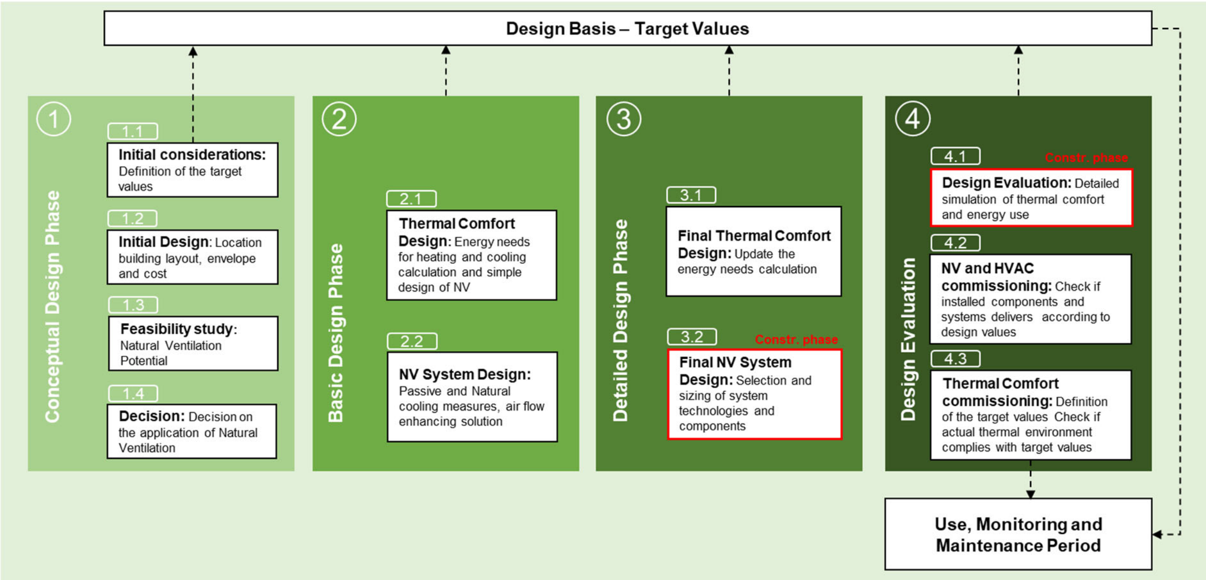


Figure 16 Design procedure for Ventilative Cooling

4.2.1 Conceptual Design Phase

The first step in this phase should be the definition of the desired level of thermal comfort, energy performance objectives and other requirements. A set of target values should be defined regarding the metrics that allow to assess thermal comfort and energy performance to verify that the design is going in the right direction. The target values may need to be specified at different levels of detail to be used at different design stages. Energy use targets and initial and operating costs (preferred life cycle cost) should also be defined.

Since the NV potential varies due to factors of different scales of detail, from the weather to the type of opening used, in this first step, the potential for Ventilative Cooling (VC) of the local climate should be analysed. According to Annex 62 Ventilative Cooling can be defined “as the application of the cooling capacity of the outdoor air flow by ventilation to reduce or even eliminate the cooling loads and/or the energy use by mechanical cooling in buildings, while guaranteeing a comfortable thermal environment.”. However, this climate analysis cannot replace a more detailed analysis since buildings with different use patterns, levels of internal gains, and envelope characteristics react differently to the external climate.

The environmental conditions greatly influence the performance of the NV system, given its interference with the forces involved in a NV system. Disturbances in the wind caused by other buildings reduce its speed, which results in lower pressure coefficients on the building facades. Thus, the airflow of a natural ventilation system in an urban environment differs greatly compared to the same system in an undisturbed environment, as is more common in a rural areas [56]. Also, the air temperature in urban areas is usually higher than in rural areas, decreasing the stack effect [56]. On the other hand, the environment in large cities is also not conducive to natural ventilation due to air pollution and noise [52]. It should also be noted that " The outdoor and indoor pollution have different sources and usually refer to different types of pollutants. After a threshold in wealth is attained, when the financial and technological means become available, the outdoor pollution diminishes with the economic development. " [56]

Some of the case studies analysed within ABC 21 are effectively designed to reduce both noise, pollution and temperature around the buildings by the use of trees and reduction of the presence of cars, at least at surface level in the surroundings of the buildings.

Other approaches, like the design method described by certain authors as Advanced Natural Ventilation aim at creating zones protected from noise and pollution from where to draw the intake air [57]. One of the geometrical arrangements of the spaces relies on a one or more central lightwells or courtyards and stack chimneys at the outer border of the building to create a center-in edge-out air flow. Intake air is drawn from these central protected spaces. The resulting air flow is "essentially wind neutral, that is, wind pressures will not hinder, or assist, the airflow; this gives added reliability to predictions of their likely, as-built, performance." [57]

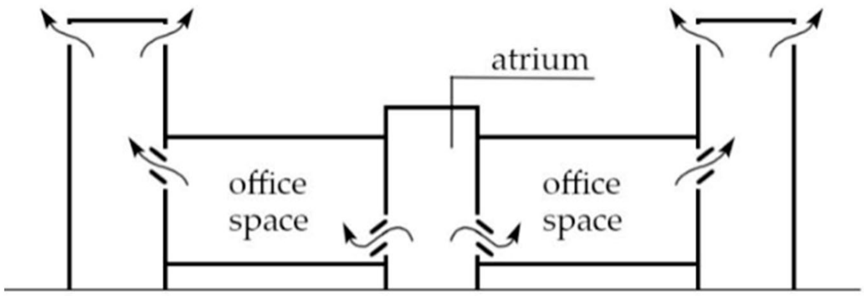


Figure 17 Schematic diagram of stack ventilation form "center-in, edge-out", in order to draw air from a space relatively protected from noise and pollution. Source: [50]

For certain nonresidential buildings, unoccupied at night, the night (only) ventilation strategy might allow to flush out energy at night when the absence of occupants removes the problem of disturbance by external noise. In some European cities the extension of pedestrian areas and the reduction of speed to 30 or 20 km/h as e.g. in Paris, might offer new spaces where the problems associated with noise and pollution are removed or significantly reduced. For new areas to be developed for the growing African population, a clear view of the need to co-design building and districts might help to create positive conditions for natural ventilation. Finally, new, quieter, mobility solutions for cities such as e-bikes, electric public transport, shared mobility,.. are expected to significantly improve the urban environment. A discussion about the interrelation of building and urban level is presented in this report in a subsequent chapter and a matrix of interactions can be found in [58].

This first analysis should be performed using simplified models that assess the Ventilative Cooling potential based on the expected internal loads, the characteristics of the building and its surrounding environment and the local climate. This analysis is fundamental in the decision process because it allows the identification of the most efficient cooling strategies. It may be necessary to introduce a supplementary natural or mechanical cooling system to ensure that the thermal comfort requirements are met during the hottest months. During the conceptual design phase, a wide range of solutions should be considered to avoid the risk of overlooking some solutions that may be advantageous. Assuming that everything has been done to minimize solar and internal gains (limited ratio window to walls, shading, thermal insulation of opaque surfaces, low solar absorptance of external surfaces,…, possibly amelioration of the microclimate in the vicinity of the building) and the decision of implementing Natural Ventilation is taken, the next step would be to analyse whether there are reasons which suggest that the natural flow might benefit of the assistance of fans, in a hybrid ventilation configuration.

Given the choice to adopt a Natural Ventilation strategy, we present in table Table 5 and Table 6 an example of a procedure for assessing if a hybrid strategy (Natural ventilation assisted in certain moments by fans) would be helpful/needed and if additional (passive or active) cooling systems are needed.. These tables are intended not only to describe design concepts but also to establish boundary conditions for the use of NV.

This initial analysis has been divided into different categories (F1-F5 and C1-C4) where for each category, the user must choose only those options that apply to the case study. Whenever a subcategory is divided into several options (for example, F1.1.1. to F1.1.4.), the designer must choose only one option. **In both tables, only the blanks are available choices**. The designer should choose only among the options which are blank spaces. The other spaces are not available.

First, in this procedure, users should identify the distribution of answers to the question: is additional mechanical/fan assistance needed? Is an additional cooling (passive or active) system needed? Answer may be No's, M(aybe) and Yes's based on the building program data and thus evaluate the available options. Secondly, define one or two VC concepts for further analysis or consider changes to the building that reduce the need for mechanical assistance and/or reduce the need for supplemental natural or mechanical cooling solutions. The procedure presented in Table 5 and Table 6 is an iterative procedure. In addition, design concepts involving "Yes" should be avoided to ensure that certain ventilative cooling concepts are possible without additional costs and delays. A survey of the additional costs, delays, and problems to be expected for designs involving a "Yes" should be conducted. It should be noted that increased "Yes's" will involve a marked increase in risks, which should be evaluated when discussing building construction contracts. It is advisable to study and consult expert guides and consultants, and when available, use references such as well-documented case studies on buildings with similar exterior conditions.

Table 5 Evaluation of the need for mechanical assistance ((by fans or additional passive means) in driving the air flow .

Ventilative cooling: Is there need for mechanical assistance (by fans or additional passive means)?						
F1. Outdoor environment		N		M		Y
F1.1.1. Cold	Winter (heat recovery needed)					
	Summer					
F1.1.2. Moderate	Winter					
	Summer					
F1.1.3. Hot and dry	Winter					
	Summer (low temp. difference)					
F1.1.4. Hot and humid	Winter					
	Summer (mechanical cooling needed for part of the time)					
F1.2. Dense urban area with low wind speeds (low natural driving force)						
F1.3. Dense urban area with high night temperatures (heat island)						
F1.4. High pollution level in the area (air filtration needed)						
F1.5. Noisy surroundings (high noise insulation needed)						
F2. Building heat load level		N		M		Y
F2.1.1. Low heat loads < 20 W/m² during occupation	Cold (> 10ºC from comfort zone) (heat recovery needed)					
	Temperate (2-10ºC from comfort zone)					
	Hot and dry (-2ºC …. +2ºC from comfort zone)					
	Hot and humid					
F2.1.2. Medium heat loads 20-30 W/m² during occupation	Cold (> 10ºC from comfort zone) (heat recovery needed)					
	Temperate (2-10ºC from comfort zone)					
	Hot and dry (-2ºC …. +2ºC from comfort zone)					
	Hot and humid					
F2.1.3. High heat loads > 30 W/m² during occupation	Cold (> 10ºC from comfort zone) (heat recovery needed)					
	Temperate (2-10ºC from comfort zone)					
	Hot and dry (-2ºC …. +2ºC from comfort zone)					
	Hot and humid					
F3. Thermal comfort		N		M		Y
F3.1.1. High requirements for 95% of occupancy hours						
F3.1.2. Normal requirements for 90% of occupancy hours						
F3.1.3. Normal requirements for 80% of occupancy hours						
F3.1.4. Requirements adaptive to outdoor conditions						
F4. Integration with other natural cooling solutions		N		M		Y
F4.1. Chilled slab by ground water exchange						
F4.2. Earth to air heat exchanger						
F4.3. Evaporative cooling						
F5. Building and system		N		M		Y
F5.1.1. Low level of exposed building thermal mass						
F5.1.2. Moderate level of exposed building thermal mass						
F5.1.3. High level of exposed building thermal mass						
F5.2. High space- and use-flexibility						

Table 6 Evaluation of the need of supplementary natural or mechanical cooling solutions.

Ventilative cooling system: is there a need for supplementary cooling?						
C1. Outdoor environment		**N**		**M**		**Y**
C1.1.1. Cold (> 10ºC from comfort zone)			■	■	■	■
C1.1.2. Temperate (2-10ºC from comfort zone)		■				■
C1.1.3. Hot and dry (-2ºC …. +2ºC from comfort zone)		■	■			
C1.1.4. Hot and humid		■	■	■	■	
C1.2. Dense urban area with low wind speeds (low natural driving force)		■				■
C1.3. Dense urban area with high night temperatures (heat island)		■				■
C1.4. High pollution level in the area		■	■			
C1.5. Noisy surroundings		■	■			
C2. Building heat load level		**N**		**M**		**Y**
C2.1.1. Low heat loads < 20 W/m² during occupation	Cold (> 10ºC from comfort zone) (heat recovery needed)		■	■	■	■
	Temperate (2-10ºC from comfort zone)				■	■
	Hot and dry (-2ºC …. +2ºC from comfort zone)	■	■			
	Hot and humid	■	■	■	■	
C2.1.2. Medium heat loads 20-30 W/m² during occupation	Cold (> 10ºC from comfort zone) (heat recovery needed)			■	■	■
	Temperate (2-10ºC from comfort zone)	■				■
	Hot and dry (-2ºC …. +2ºC from comfort zone)	■	■	■		
	Hot and humid	■	■	■	■	
C2.1.3. High heat loads > 30 W/m² during occupation	Cold (> 10ºC from comfort zone) (heat recovery needed)	■				■
	Temperate (2-10ºC from comfort zone)	■	■			
	Hot and dry (-2ºC …. +2ºC from comfort zone)	■	■	■	■	
	Hot and humid	■	■	■	■	
C3. Thermal comfort		**N**		**M**		**Y**
C3.1.1. High requirements for 95% of occupancy hours		■	■			
C3.1.2. Normal requirements for 90% of occupancy hours		■				■
C3.1.3. Normal requirements for 80% of occupancy hours					■	■
C3.1.4. Requirements adaptive to outdoor conditions				■	■	■
C4. Building and system		**N**		**M**		**Y**
C4.1.1. Low level of exposed building thermal mass		■				■
C4.1.2. Moderate level of exposed building thermal mass					■	■
C4.1.3. High level of exposed building thermal mass			■	■	■	■
C4.2. High space- and use-flexibility		■				■

4.2.1.1 Application example CML Kindergarten

This chapter exemplifies the application of the principles mentioned in the case study of the CML kindergarten in Portugal. A survey for climate, site and design characterization is presented, derived from Table 5 and Table 6. The information gathered provides useful insight to guide designers and highlight potential design challenges.

The detail presented in Table 5 and Table 6 may not apply to all projects. Thus in Table 7 and Table 8, only the categories that fit the case study of the CML kindergarten Portugal are presented. The answer to each category is marked by the letter "O", and a number was added to each answer to clarify/justify the selected choices.

Table 7: Survey of the need for mechanical assistance (by fans or additional passive means) for CML kindergarten, Portugal.

Ventilative cooling: Is there a need for mechanical assistance (by fans or additional passive means)?						
F1. Outdoor environment		**N**		**M**		**Y**
F1.1.3. Hot and dry	Winter	O				
	Summer (low temp. difference)			O[1]		
F1.2. Dense urban area with low wind speeds (low natural driving force)					O	
F1.5. Noisy surroundings (high noise insulation needed)				O[2]		
F2. Building heat load level		**N**		**M**		**Y**
F2.1.3. High heat loads > 30 W/m^2 during occupation	Cold (> 10ºC from comfort zone) (heat recovery needed)	O[3]				
	Temperate (2-10ºC from comfort zone)	O[3]				
	Hot and dry (-2ºC …. +2ºC from comfort zone)				O[1]	
F3. Thermal comfort		**N**		**M**		**Y**
F3.1.4. Normal requirements for 90% of occupancy hours					O[3]	
F5. Building and system		**N**		**M**		**Y**
F5.1.3. High level of exposed building thermal mass		O[4]				

Notes for the table " is there need for mechanical assistance (by fans or additional passive means) ":

1. Although Lisbon's weather is hot in summer, the option "Maybe" was chosen due to the closing of kindergartens in August.

2. The project of which the CML kindergarten was part comprised eleven kindergartens spread throughout the urban area of Lisbon. Some were located in noisy urban areas. However, the project's cost constraints prevented using advanced acoustic attenuation solutions.

3. According to EN15251 or its update in 2017, it is a requirement that temperatures outside the comfort range can only occur in less than 5% of the time (number of hours) of occupancy.

4. The project's building design included exposed concrete interior and exterior walls (exterior insulation was applied) and exposed concrete floors.

By assigning each row in the "need for mechanical assistance" table a value according to the answer given (No=1, Maybe=3 and Yes=5) and averaging the result of each row, you get an indication of whether or not the project may need mechanical (active or additional passive) assistance. In the example shown above, the average is 2.4, which indicates that the project may need fan or other assistance. In this specific project, it was chosen to use chimneys that would provide the level of assistance needed.

Table 8 Survey of the need for supplementary natural or mechanical cooling solutions for CML kindergarten, Portugal.

Ventilative cooling system: is there a need for supplementary cooling?						
C1. Outdoor environment		**N**		**M**		**Y**
C1.1.2. Temperature (2-10°C from comfort zone)				O		
C1.2. Dense urban area with low wind speeds (low natural driving force)				O		
C1.3. Dense urban area with high night temperatures (heat island)			O			
C1.5. Noisy surroundings				O		
C2. Building heat load level		**N**		**M**		**Y**
C2.1.3. High internal loads > 30 W/m2 during occupation	Temperate (2-10ºC from comfort zone)			O		
C3. Thermal comfort		**N**		**M**		**Y**
C3.1.4. Normal requirements for 90% of occupancy hours				O		
C4. Building and system		**N**		**M**		**Y**
C4.1.3. High level of exposed building thermal mass		O				
C4.2. High space- and use-flexibility			O			

As with the "need for mechanical assistance" table, its interpretation can be simplified by assigning a value to each row based on responses and averaging each result, indicating whether or not supplemental cooling is needed. For this project, a mean value of 2.1 was obtained, which suggests a low need for supplemental cooling. In 2016 (spring and early summer), a monitoring campaign corroborated the quantitative interpretation of this table. The project adopts a *Nocturnal Ventilative Cooling* strategy combined with a daytime *Comfort Ventilation* aided by the chimneys.

4.2.2 Basic Design Phase

In the conceptual design phase, an analysis of availability for VC is performed, and a wide range of solutions are defined that aim to achieve the objectives defined in this first design phase. The basic design phase should be carried out in three distinct steps.

This step starts with the design of the building to minimize internal loads, so this phase should result in the orientation of the building and the layout of the building in order to create airflow paths and effectively remove the excess of heat loads. The bad decisions adopted in this phase will drastically influence the performance of passive cooling systems and the overall performance of the building. The components that characterize the building envelope, such as the window-to-wall ratio, shading devices, and thermal mass, are crucial parameters in the design phase for naturally ventilated buildings [59]. The orientation of the building is also one of the parameters that most influence the performance of a NV system [60]. In Climates and season with considerable swing in temperature between day and night, designing buildings with high thermal mass allows, via *Nocturnal Ventilative Cooling* to reduce the operating temperature of the building by 2 to 4 degrees [52]. According to the experimental results obtained, in a nZEB school that had been designed for the inclusion of passive cooling systems, it was concluded that without *Nocturnal Ventilative Cooling*, it would not be possible to use only daily *Comfort Ventilation* alone to provide the necessary cooling to not compromise the comfort of the occupants. It was also concluded that solar gains are the main factor that should be controlled in summer to optimize the occupants' comfort and the building's energy consumption. Thus, it is important to consider the window-to-wall ratio when designing the building [61].

The second phase of this design phase should consist of developing the Natural Ventilation system with supplementary strategies to increase the Ventilative Cooling capacity if necessary. Appropriate decisions in this step will greatly impact the performance of the passive cooling system and, consequently, the energy performance of the building.

Several natural ventilation strategies have been applied in buildings, with Natural Cross Ventilation (NCV) and Single-Sided Ventilation (SSV) being the most common approaches in naturally ventilated buildings. In non-residential buildings, the most common strategy is SSV systems [52]. SSV strategy can occur when there are openings on a single façade of the room, through which airflow is introduced. NCV is considered one of the most effective ways to naturally ventilate a building. The effectiveness of this strategy depends directly on wind speed and direction. In some cases, it can become uncomfortable for the building's occupants due to the intense air drafts created. The stack effect and wind effect increase the NV potential in SSV configurations. The same is not true for NCV configurations since the configuration of the openings can oppose the natural driving forces [52]. Thus, in NV systems with NCV configurations, the zones should have a geometry that allows an optimized exhaustion. The inlet airflow is made by a lower zone in the facade and extracted at the top of the opposite facade [52], and therefore avoiding the opposing forces. Still, the airflow in SSV is usually smaller than in NCV systems, so they have less cooling potential [62]. On the other hand, according to experimental results obtained, in Japan, in 30 naturally ventilated buildings using the NCV strategy, it was found that this type of strategy presents high variations in airflow compared to SSV configurations [63].

Buildings with narrow footprint or large spaces with high ceilings are design techniques that favour the performance of a NV system [52]. According to experimental data in areas with high-ceiling buildings, the stack effect is quite efficient [61]. In SSV configurations the penetration depth of NV is usually equal to twice the zone's height; therefore, these configurations perform best in areas with low depth and high ceiling heights [52]. CIBSE recommends that the maximum zone depth for single-sided systems should be 2.5x the zone height [64]. However, experimental studies have shown that these limits are very restrictive, and depths of 3H can be achieved [65,66]. On the other hand, for NCV, the depth of the space should not exceed five times the height of the space [67]. In buildings where there are areas with constant occupation and low height, it is necessary to implement chimneys or N systems in order to promote a fresh air intake that is significant for the occupants [52].

High-rise buildings are less influenced by their surroundings than low buildings, which makes the wind an additional driving force to achieve the desired airflow rates [68]. Due to the decreasing of temperature with height, the upper half of these buildings can take advantage of the lower temperatures to exploit NV systems [52]. Tall buildings are subject to large pressure differences [69] since wind speed and pressure also increase with height [70]. Increasing wind speed results in increasing airflow, and a linear relationship has been found between wind speed and airflow for all wind directions independent of the number of openings [71]. Thus, in tall buildings, the NV system must operate differently in the first 4-6 floors due to the lack of wind-driven NV arising from the barrier effect caused by the surrounding buildings [52]. In high-rise buildings, this increase in pressure with height leads to some problems in the design of the opening area and type. In wind-driven ventilation, the airflow follows the pressure gradient and can be realized by other systems, such as wind catchers [67]. Wind catchers have demonstrated high performance in hot and dry climates [72,73].

The use of a single ventilation strategy may be insufficient. The combination of different passive systems may be the solution since they can offer advantages that are impossible to achieve with a single system. In this sense, it has already been shown that combining earth-air heat exchangers (EAHE) with solar chimneys is a very effective strategy for maintaining thermal comfort in severe weather conditions [74]. According to [75], these systems achieve a temperature reduction of 10º to 13º with respect to the outdoor temperature. In the EAHE technique, the underground is used as a heat sink to supply air to the building at a constant temperature [74]. The temperature and relative humidity of the surrounding air, the type of soil and the groundwater level are the main factors affecting the performance of this system. Pre-cooling the air using an EAHE is one type of application of these systems to improve the thermal and ventilation performance of a passive system [76]. There are many successful implementations in non-residential buildings while they are not very frequent in residential buildings due to space requirements and costs. Another widely used strategy to improve the performance of natural ventilation systems is coupling passive storage systems such as Phase-Change Materials (PCMs). According to the literature, coupling these passive storage systems with solar chimneys can increase the number of ventilation hours [77]. The coupling of these storage systems with wind towers has also been shown to be quite effective, reducing the air temperature between 9ºC and 12ºC [78]. In areas where the wind is not predominant and, therefore, wind-driven ventilation is not efficient, the combination of solar chimneys with wind catchers can be a solution that increases the efficiency of the natural ventilation system.

In the last step of the basic design phase, mechanical cooling systems are designed to supplement passive cooling systems in periods when they do not have the necessary capacity.

4.2.3 Detailed Design Phase

The last phase of the design should consist of optimizing the developed solution. In this step, the specific components of the natural ventilation system are determined, such as the openings' type, size and location.

It is critical to develop a credible model to optimize the design. A simulation model is always a simplification of reality, and thus the simulation model results will never fully replicate reality. In order to use the models correctly and obtain reliable results, several issues have to be considered, such as the correct specification of the relevant boundary conditions, evaluation and justification of the model simplifications, decision on the necessary time discretization, and evaluation of the risk associated with using detailed performance simulation model. The quality of the results obtained from simulation models is directly related to the quality of the input data. On the other hand, the modeller's technical capability is also highly important for the results' reliability. The modeller is responsible for making appropriate decisions during the various design phases, such as simplifying the geometry, specifying boundary conditions, taking into consideration a typical occupancy profile, size and location of openings, etc.

For the design of a passive cooling system, it is essential to know the parameters that impact the performance of this type of system from the early design stages. The parameters that affect solar and internal gains have a dominant influence on reducing the cooling demand. In contrast, the discharge coefficient and the opening factor notably impact the number of hours of comfort.

When developing a VC system, determining the required air flow rate is critical in determining the strategy used. The required opening sizes depend on the required airflow and the available driving forces. Therefore, the size and location of the opening have to be determined for different scenarios to achieve the optimal configuration.

When applying a strategy of *Comfort Ventilation*, since in some hours the driving force of wind or stack might be insufficient to achieve the desired air velocity in (part of) the areas where there are people, the design should generally include ceiling, standing or desk fans, to be activated as needed.

Simple technologies with a long history, ceiling fans have evolved from having flat blades to airfoil blades (similar to airplane wings in section) with sophisticated aerodynamic design and efficient motors whose velocity can be remotely adjusted in close steps or continuously. Those improved models are attaining the noise of a whisper, high stability against oscillations and extremely low energy use (besides nice esthetics).

The curvature of airfoil blades helps increase the air flow and minimize the turbulence at the exit edge. The airfoils are designed with steeper angles toward the centre of the fan to maximize air flow for the low blade speed in this region, and reducing to shallower angles toward the tips where the blade speed is high in order to limit drag and maximize energy efficiency.

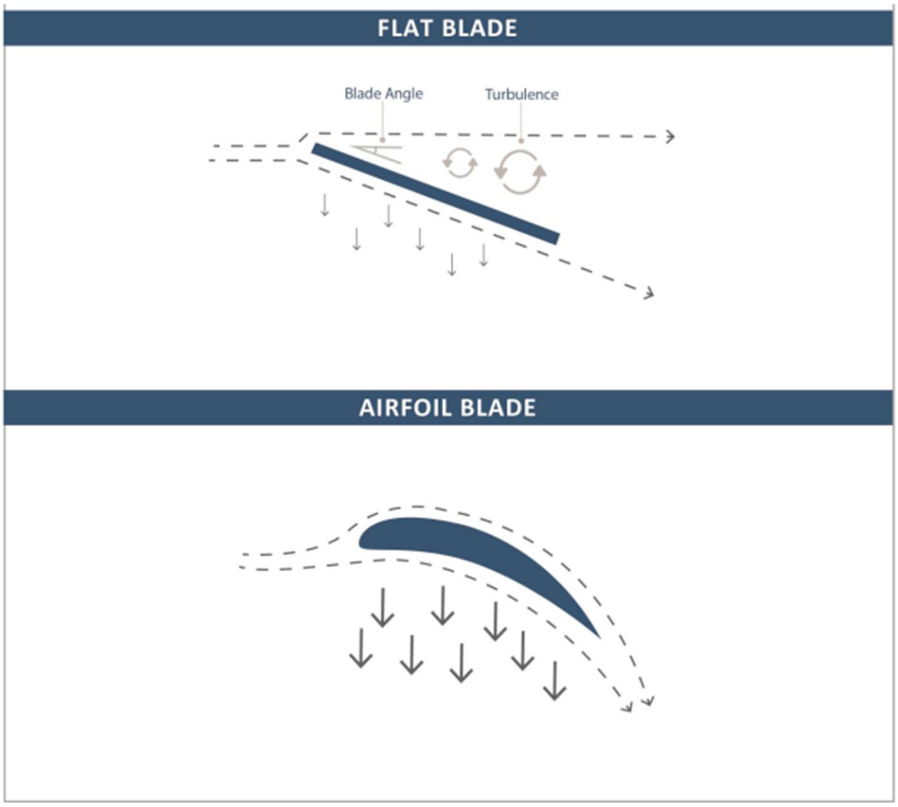


Figure 18 Blade types and schematics of their interaction with air. Source: [79]

The number of blades can vary from as many as 6-8 to as low as 2.

Generally, the ability of a fan to operate efficiently at lower speed improves as the diameter increases. Very large diameters for large spaces are now currently available, or multiple fans of smaller diameter can be efficiently installed to deliver well distributed air velocity across the entire space where needed. CFD analysis is now routinely available, even by manufacturers, to support the choice of sizes and distribution of the fans. Or simplified tools can be used to provide reliable design assistance too.

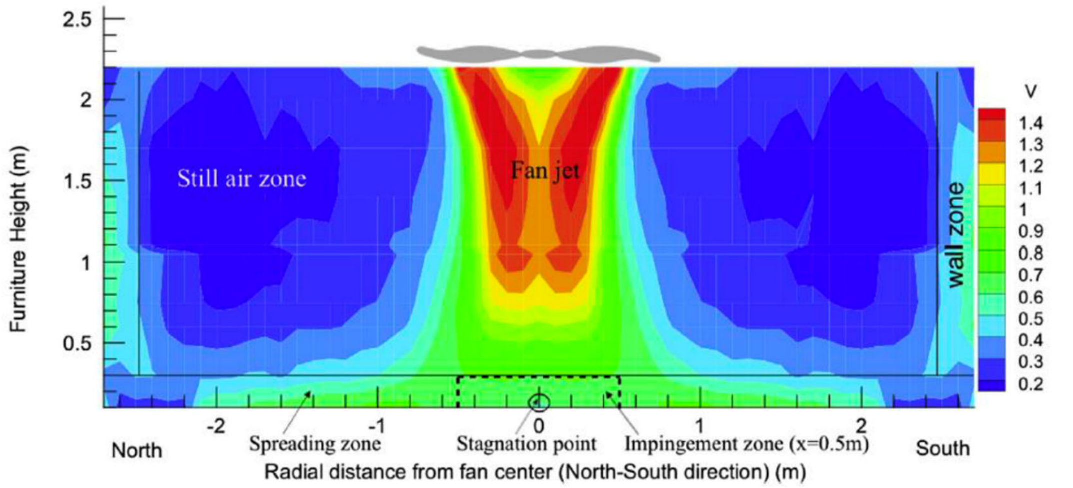
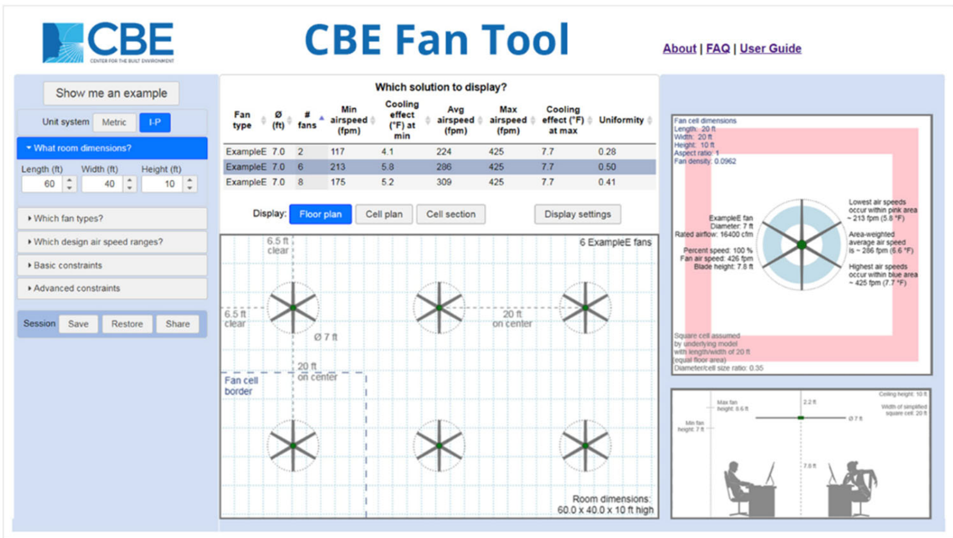


Figure 23: Example air speed distribution from a ceiling fan (Source: Gao, Y. et al., 2017)



Advanced Ceiling Fan Design Tool

Facilitating appropriate specification and layout of fans based on key design parameters.

4.2.4 Design Evaluation

Finally, detailed simulations of thermal comfort and energy use are made in the design evaluation phase to control whether the design meets the project objectives. The design tools and methods' wealth of detail and complexity increase as the design develops. The level of detail of the information and expectations about the accuracy of the predictions' results also increase.

4.3 Natural ventilation in tall buildings (NVTB) in warm climatic regions of Africa & Europe

This chapter explores the case for applying Natural Ventilation in Tall Buildings (NVTB) in warm climates and to shed light on its associated challenges and advantages.

4.3.1 Design Criteria

4.3.1.1 Climate

Africa and Europe have a diverse spectrum of weather conditions. Africa's climate zones include Tropical, Subtropical, Arid/Desert, Mediterranean, and Temperate [80,81]. Europe's climates are Oceanic, Mediterranean, and Humid Continental [81]. It is critical to identify the climatic conditions and base on them the design and management of NV[82,83].

4.3.1.2 Building Typology

Building typology can be defined by its usage, which might be a single function or mixed-use.[89] the type of occupation (only at daytime, as in many commercial and educational buildings, or 24/24, etc. Influences the time when ventilation is desirable or unwanted.

4.3.1.3 Building Height

The criteria of the height that determine a building to be tall depends on the local region's architectural codes or ordinances. Under local codes, tall structures are measured with respect to the number of floors or numeric height in meters [90]. According to the U.S. National Fire Protection Association 101®, Life Safety Code 2012 edition [91], any building equal to or taller than 23 m (75.5 ft) is considered a high-rise. The ASHRAE Technical Committee for Tall Buildings defines a building more than 91 m (300 ft) as tall [92]. The following analysis uses the Council on Tall Buildings and Urban Habitat (CTBUH)'s (2019) definition of a tall building . A tall building meets one or more of the following CTBUH criteria [88,93,94].

- The building has evidentially more height as compared to other buildings surrounding it i.e., urban context.
- The building is slender enough to have the appearance of a tall building then it may also be referred to as tall i.e., proportion of the overall building form.

The technologies used in buildings are the same as the ones being used in tall buildings i.e., the use of curtain walls.

4.3.2 Mechanism of NV

NVTB is governed by the same two factors or their combination that affect low-rise buildings. These two factors are:

- wind from the outdoors,
- buoyant forces that occur owing to temperature variations within the building

Similarly, energy savings and other advantages/challenges associated with indoor air quality under NV are relevant for both high and low-rise buildings [95,96]. The airflow patterns and airflow rates of ventilation are two crucial elements of strategy. There are several design characteristics and architectural components that, when combined, can improve airflow patterns and rates. [97].

4.3.2.1 Geometrical Parameters

Taller structures encounter a greater number of challenges concerning the design of the envelope and its openings. The observed phenomenon can be attributed, in part, to the amplification of the potential magnitudes of the two driving forces, namely wind pressure, and buoyancy. Additionally, the relative magnitudes of these forces exhibit a wider range of variation. The significance of aerodynamics escalates commensurate with the altitude of the edifice due to its augmented susceptibility to the effects of wind. Furthermore, the abundance of available openings plays a significant role in augmenting the quantity of potential envelope configuration variations [95]. Important geometrical parameters guaranteeing NV's efficacy in warm climates for tall buildings are:

The geometry of the building is crucial in this respect since it determines how air moves around the structure and can either drag air along or cause a vortex to form. It has been determined that filleted corners are superior for improving aerodynamics [88,98,99]. In addition, the drag coefficient is lowest and the shape is aerodynamically most effective when there are fewer edges [99,100]. Furthermore, Rotation, stepping, and scaling can be used to create effective pressure variations along the overall building form for efficient natural airflow and to reduce wind loads on the structure[101].

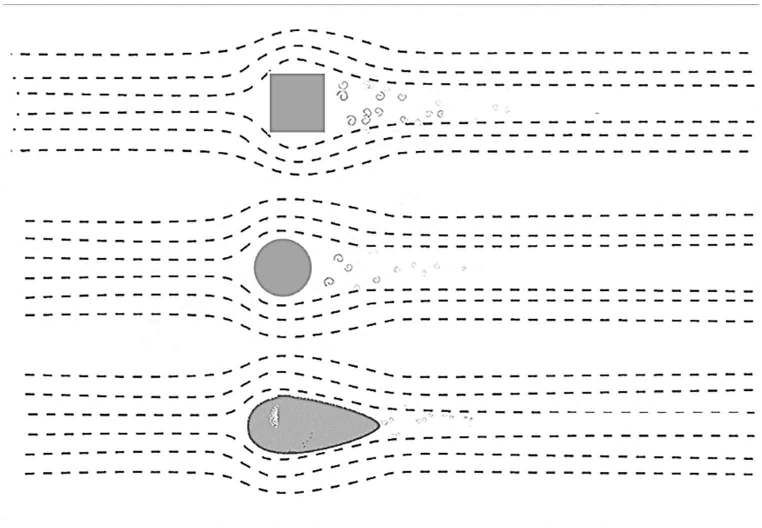


Figure 19 Floor plan shape effect on drag (Source: Adapted from [99,102])

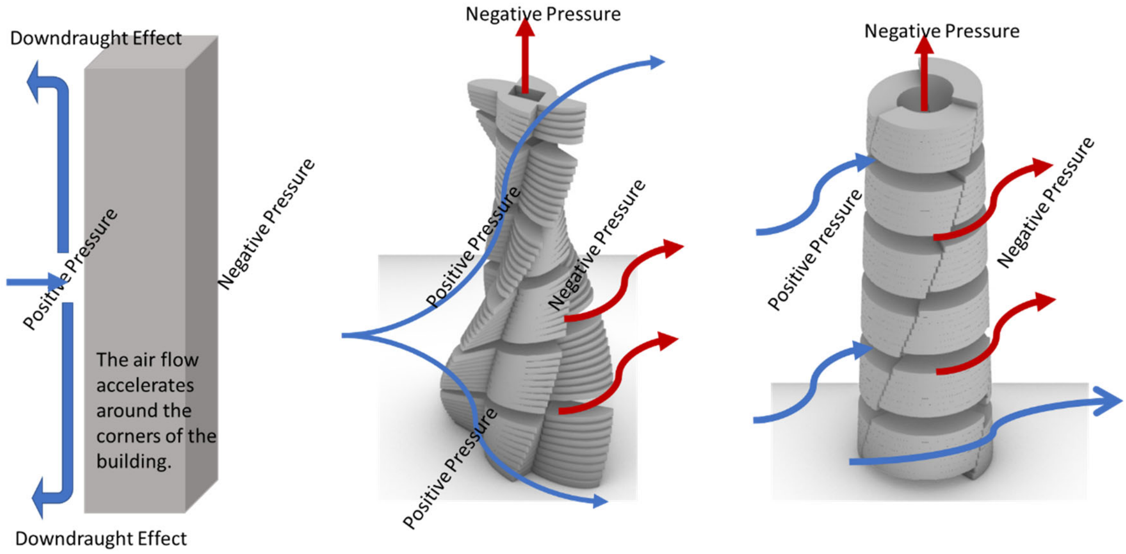


Figure 20 Wind Flow Pattern around tall buildings with different geometrical features(Source: Adapted from [100,101])

Furthermore, the depth of the room must not exceed five times its height for effective cross-ventilation, the minimum and maximum floor width/plan depth that can be ventilated by natural wind flow mechanisms are 10 m and 21 m, respectively [103,104], hence is a good idea to incorporate a central atrium or courtyard in case of a large building footprint [105].

Ventilation shaft: Figure 21 which may be used as a solar chimney or wind catcher in hot climates. The key is to decide the orientation and location of the atrium together with the levels of leeward and windward openings [106].

The overall shape of the building: develops effective pressure differences for efficient natural airflow and may be chosen to lessen the wind loads on the structure [101].

Windows size: these are the openings, with various sizes and shapes on the building façade. The air is exchanged in a space inside the building through these openings. They work usually on wind-driven ventilation principle, however sometimes NV through windows occurs due to the buoyancy effect depending on the location of the window on the façade. both driving forces i.e. wind and buoyancy are effective for this element and the wind is channelized through cross, single-sided, or stack ventilation depending on the location of the exhaust window [107].

Segmentation: Figure 21 is also another important concept for channelizing wind flows across tall buildings. It refers to dividing the building into several parts along its vertical development separating parts by open spaces and each part, while interacting with the wind acts as a low-rise building, so the wind pressure reduces along the building facade [95,108].

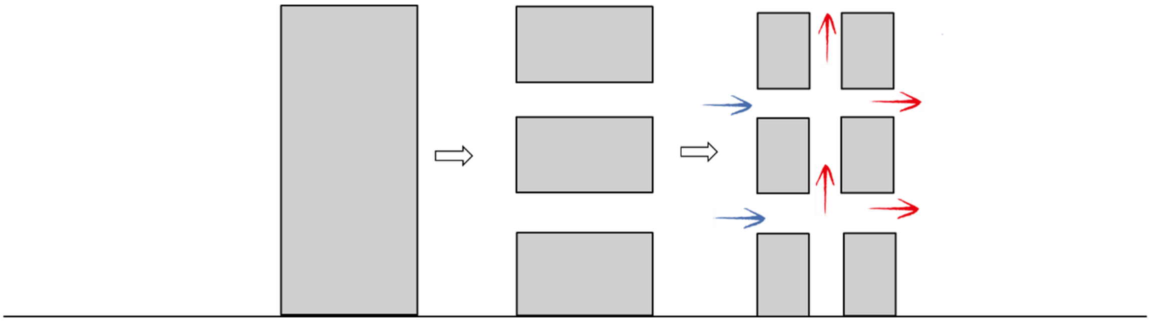


Figure 21 Incorporation of the concept of NV through segmentation (Source: Adapted from [100,109–111])

4.3.2.2 Architectural Elements

The solar chimney is an excellent passive ventilation system that relies on a natural driving force, that is, the energy from the sun [112].

Wind catchers: The windcatcher is one of the first forms of passive cooling technique and itis still in use today. It is a NV system located on top on buildings, uses wind energy, and has no moving parts; thus, they are quiet and low maintenance. It can provide sufficient ventilation for buildings by making use of pressure differentials and the buoyancy effect [113,114]. A square windcatcher with a curving roof is proven to be the most effective at distributing air throughout space. Research has shown that ventilation effectiveness is much improved when the windcatcher is combined with other NV devices like a solar chimney or a wing wall [115]. Middle Easterners have used windcatchers for thousands of years. Modern windcatchers are commonly used in schools and business buildings. Recent installations of over 7000 windcatchers have benefited the UK [114].

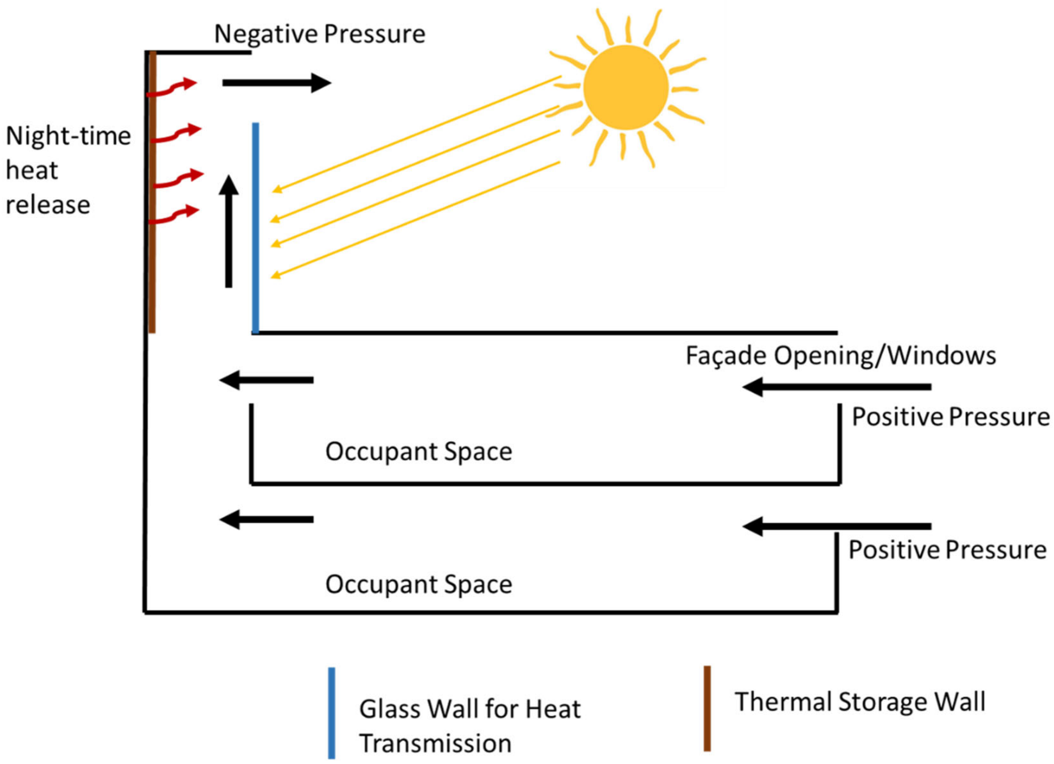


Figure 22 Airflow pattern in the building through the solar chimney (Source: Adapted from

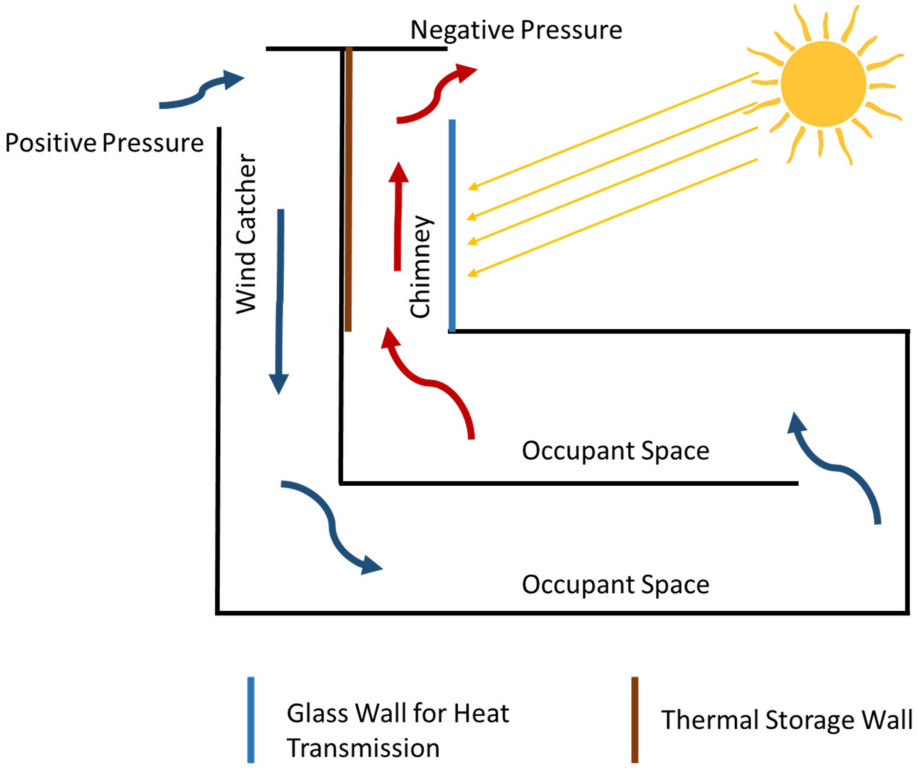


Figure 23 Airflow pattern in the building by coupling solar chimney and wind catcher

Atrium: For tall buildings located in hot and humid climates, the central atrium is found a good element for achieving thermal comfort. The main mechanism of ventilation in the case of the central atrium is the pressure difference between the indoor and outdoor environments due to wind [97,116]. Wind-driven ventilation is at its most efficient in locations that have a reasonably high average wind speed. Nevertheless, the role of wind is restricted by a wide variety of circumstances, such as the building's exposure to the wind. For instance, the influence of wind force is not what one would expect in crowded metropolitan regions that are surrounded by other tall structures. Moreover, due to seasonal variations, the wind direction might also change causing a change in the airfield surrounding the building and the atrium may start to act like a wind catcher, and the inlet windows may become the vents [97].

4.3.2.3 Coupling with Bioclimatic Strategies

Several bioclimatic techniques when coupled with the wind flow through the building, help improve the thermal comfort for the occupants. Some of these techniques are as follows:

Evaporative Cooling: NV is made more efficient in hot climates by some of the defining features and methods. . While reducing air temperature through the evaporation process can serve to cool a dry, hot climate, this method is less effective in a hot, humid one. [117–119]. A building that combines NV and evaporative cooling has the potential to withstand heat waves [120].

Building Integrated Vegetation (BIV): Studies have demonstrated that the utilization of NV and BIV systems can yield significant ecological advantages. The practice of incorporating green terraces within the partitioned areas of tall buildings is commonly known as sky gardens. This technique not only improves NV but also offers superior thermal conditions in comparison to green balconies. The local temperature can be reduced up to 3ºC through this method. In addition, they can alleviate congestion and yield positive psychological effects in high-rise structures. Niu (2004) posited in his research that the integration of sky gardens in high-rise buildings located in warm climates can effectively enhance the thermal comfort of inhabitants during the summer season. [122]. Alnusairat (2017) proposed the implementation of a hybrid approach that integrates Sky Courts or sky gardens with NV systems in tall buildings as a means of mitigating cooling energy consumption. [123].

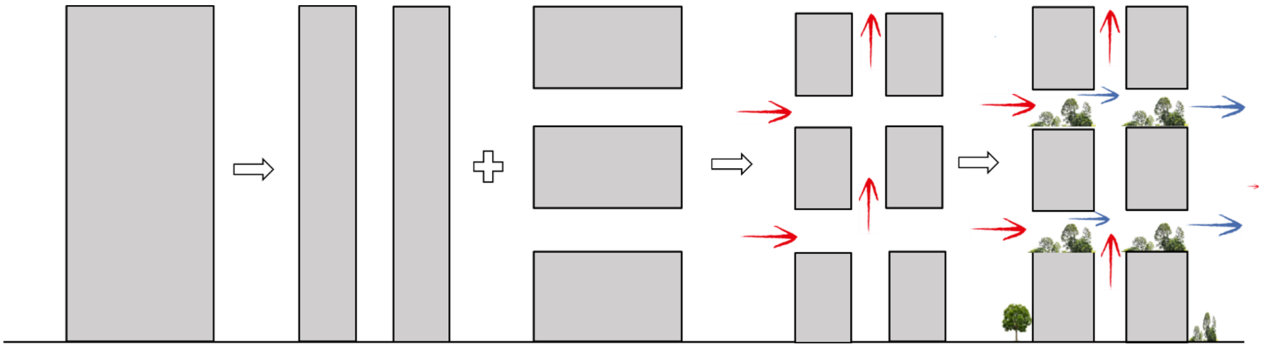


Figure 24 Incorporation of the concept of NV through atrium, segmentation, and Sky-gardens (Source: Adapted from [109,110])

4.3.3 Global challenges

Many works in literature attempt to improve NV by increasing the airflow rate and thermal comfort it provides by increasing the wind utilization buoyant impact. Yet, it has been found that globally in heat-intensive circumstances, NV alone cannot provide the need for thermal comfort, hence mixed-mode or hybrid systems are increasingly being used.[124]. Bamdad et al. (2022) tested the energy-saving potential of Mixed-Mode (MM) ventilation to find out that it can substantially reduce energy consumption in office buildings in Australia during the hot summer months [125]. Mixed-mode ventilation and ceiling fans have the potential to reduce energy consumption, although this may (or may not) alter in the future [125]. For instance, the use of ceiling fans can reduce cooling energy use by as much as 23% [125].

Studies on the thermal comfort of windcatchers have been carried out mostly in regions with hot climates, such as the Middle East. In addition to night ventilation, the review investigated various sorts of cooling technologies that can be incorporated with windcatchers. These include evaporative cooling, earth-to-air heat exchangers (EAHE), and heat transfer devices (HTD). In temperate and cold settings, night ventilation was found to be effective, however, in hot temperatures, additional cooling via evaporative cooling, EAHE, and HTD was found to be necessary [113]. Although wind catchers and solar chimneys offer hope for improving the quality of indoor air in regions with warm climates, more research is necessary on NV systems that can withstand heat waves in regions with warm climates. [120].

According to Liu et al., 2022 global warming may alter building ventilation by altering window opening behavior, which may pose a threat to public health given that the average occupant spends more than 80% of their time indoors. They discovered that the variation in window opening duration by season indicates a distinct spatial distribution, which is anticipated to decrease for nearly all populations during the summer. According to the findings of this study, approximately forty percent of the population is anticipated to reside in environments with reduced ventilation. [126,127].

Aside from climate change, several airborne infections have resulted in unfavorable living conditions, resulting in health outbreaks[128]. The present time necessitates a more comprehensive response that goes beyond simple measures like seclusion and physical distancing. To protect occupants from the spread of airborne illnesses, adequate ventilation is essential. Numerous research has been conducted to study the significance of proper ventilation in lowering viral concentrations and lowering the level of inhaled doses by humans existing in the environment[129]. Ventilation issues can emerge in public buildings, businesses, offices, schools, and restaurants, among other places[130]. When using windows for ventilation, the velocity of outer airflow is affected by unique local characteristics such as opening sizes, relative placements, and climatic and weather conditions; thus, it is critical to design the space in such a way that required positive and negative pressures develop naturally, avoiding the spread of contaminations, microbes, and viruses in indoors, that is a major challenge for the designers[131].

4.3.4 Conclusion

Architects in Europe and Africa are using NV to regulate air quality and chill commercial buildings to save energy, as opposed to mechanical cooling and fan operation [132]. However, the implementation of NV in tall buildings is still a challenging process [133]. There may need to be more than single-sided or cross-ventilation alone for thermal comfort in tall buildings in a future hotter environment [120], since the feasibility of implementing NV techniques is very context-dependent, as climate conditions vary drastically around the globe. [82,83]. Hence the potential realization of incorporating NV systems in tall buildings is contingent upon developing robust NV systems that can withstand diverse scenarios, including but not limited to future pandemics and climate change. Developing and incorporating advanced natural and hybrid ventilation systems might be the future evolution also in tall buildings to cope with climate change.

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5. Solar shading, daylighting and solar gain control

In the following section the main content related to guidelines and tools described in the handbook Sustainable Building Design for Africa, developed within the project are provided.

5.1 Principles of daylighting and visual comfort

First of all, the parameters able to determine the quality of lighting are introduced. Such factors such as luminance distribution, the level of illumination, the daylighting factor, the dependence on artificial light, the glare, the colour of the light, are illustrated through simplified drawing easy to read also from non-specialized users (Figure 25).

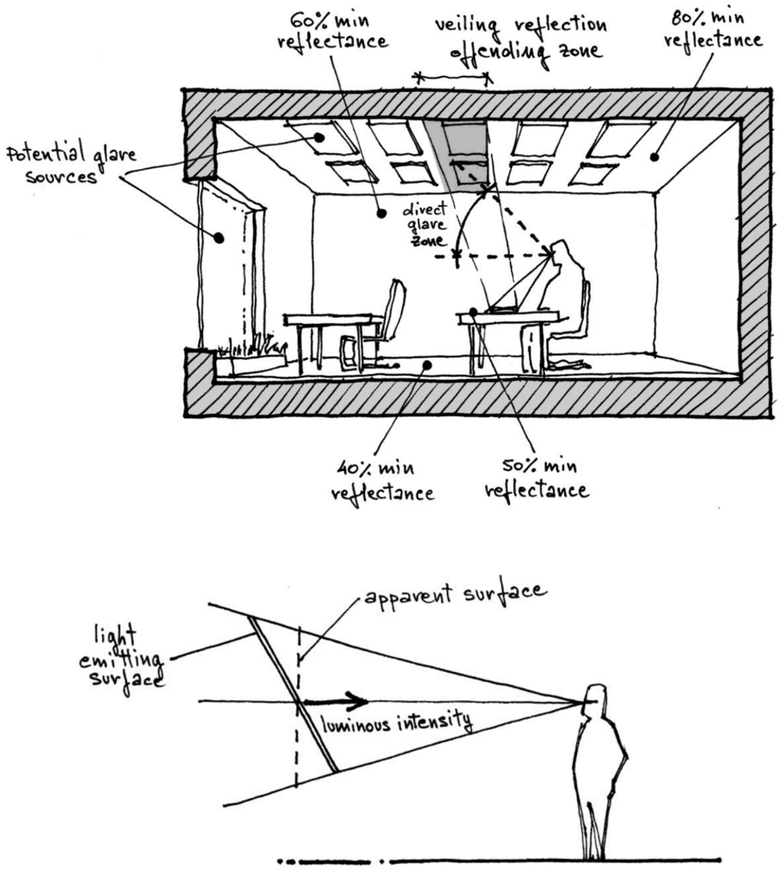


Figure 25 Samples of pictures drawn specifically for the Handbook (Up - Potential sources of glare and recommended reflectance; Down - luminance calculation scheme)

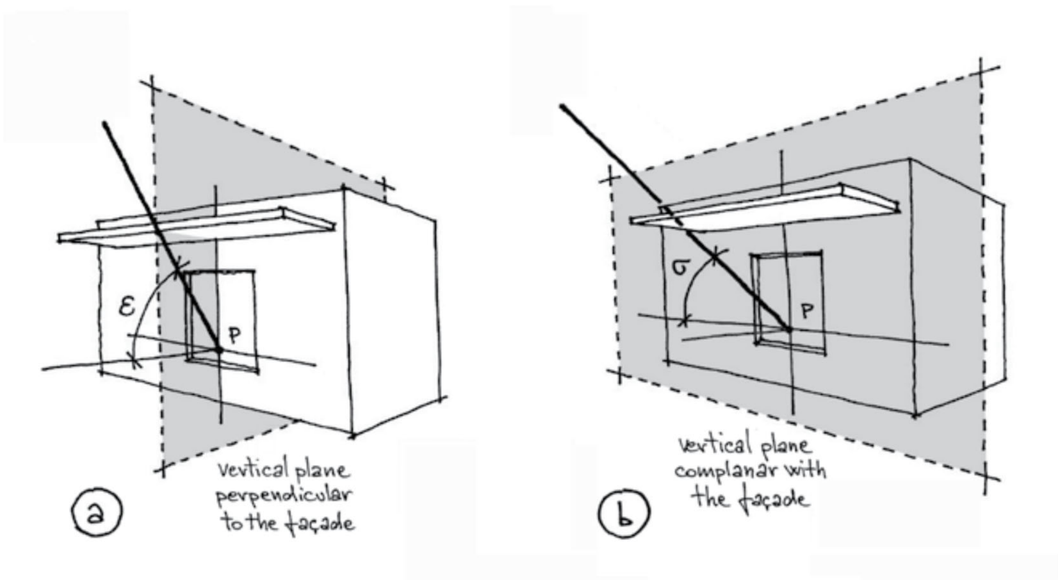
After that, in order to overcome the oversizing deriving from the sole use of abovementioned parameters in windows design for optimum daylighting, also other index, such the Daylight Autonomy and Useful Daylight Illuminance, were introduced.

5.2 Methods and tools to evaluate natural lighting due to obstruction

There are many methods for evaluating the shadows cast on a surface by projecting elements or by surrounding obstructions, based on the use of diagrams or on analytical tools.
In the handbook the following are described in detail:

- Sundial;
- Shading masks.

The first one is a chart showing the paths of the shadow of a peg (also called a gnomon) at different times of selected days of the year, while the second can be used for studying the shading related to a particular site during the year, and for drawing the profile of the sun obstructions due to the surroundings (mountains, houses, trees), using the same angular coordinates that are used to describe the position of the sun. Some pictures that show the step-by-step guidelines to apply the tool are applied hereafter (Figure 26).



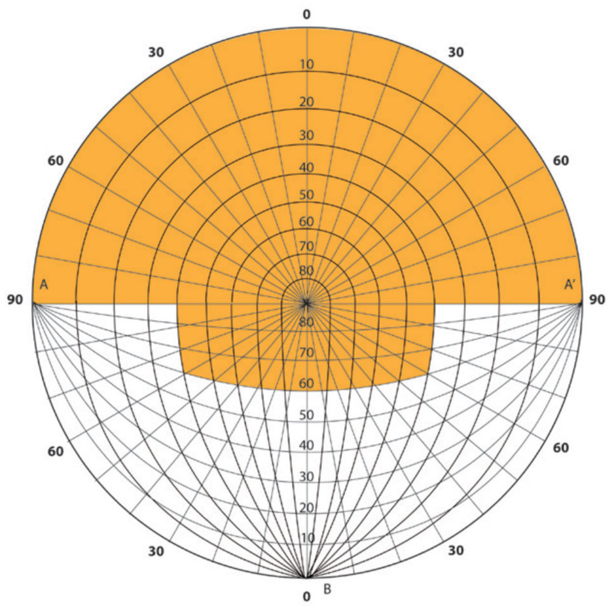


Figure 26 Shading mask construction steps (up) and shading mask protractor (down)

Finally, in order to provide to the user a simplified tool to apply immediately the acquired knowledge learned from the chapter, a set of shading masks of the main devices are outlined (Figure 27).

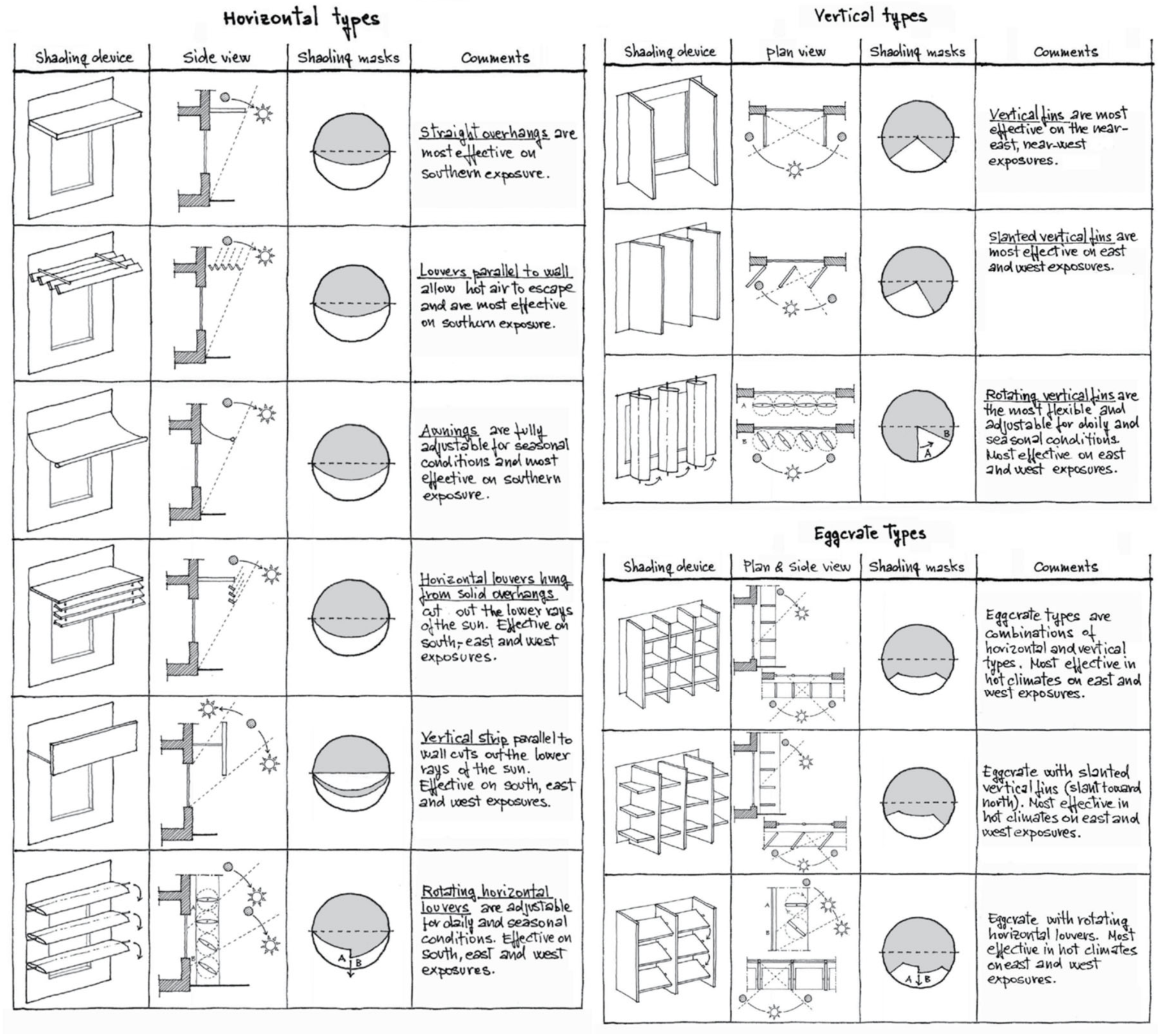


Figure 27 Characteristics of different types of shading devices

5.3 Systems to enhance natural lighting

Even if windows are sized to make the most of natural light, it may be insufficient or poorly distributed. When it is not possible to obtain the desired natural lighting or light penetration due to obstructions or to glare caused by the excessive size of the glass surface or due to a conflict with solar gains, solutions can be adopted that allow better control of natural lighting.
In such respect, the handbook provides in-depth description of the following system, providing also sizing rules (as show in Figure 28):

- Light shelf;

- Venetian blinds with reflective slats;
- Anidolic system .

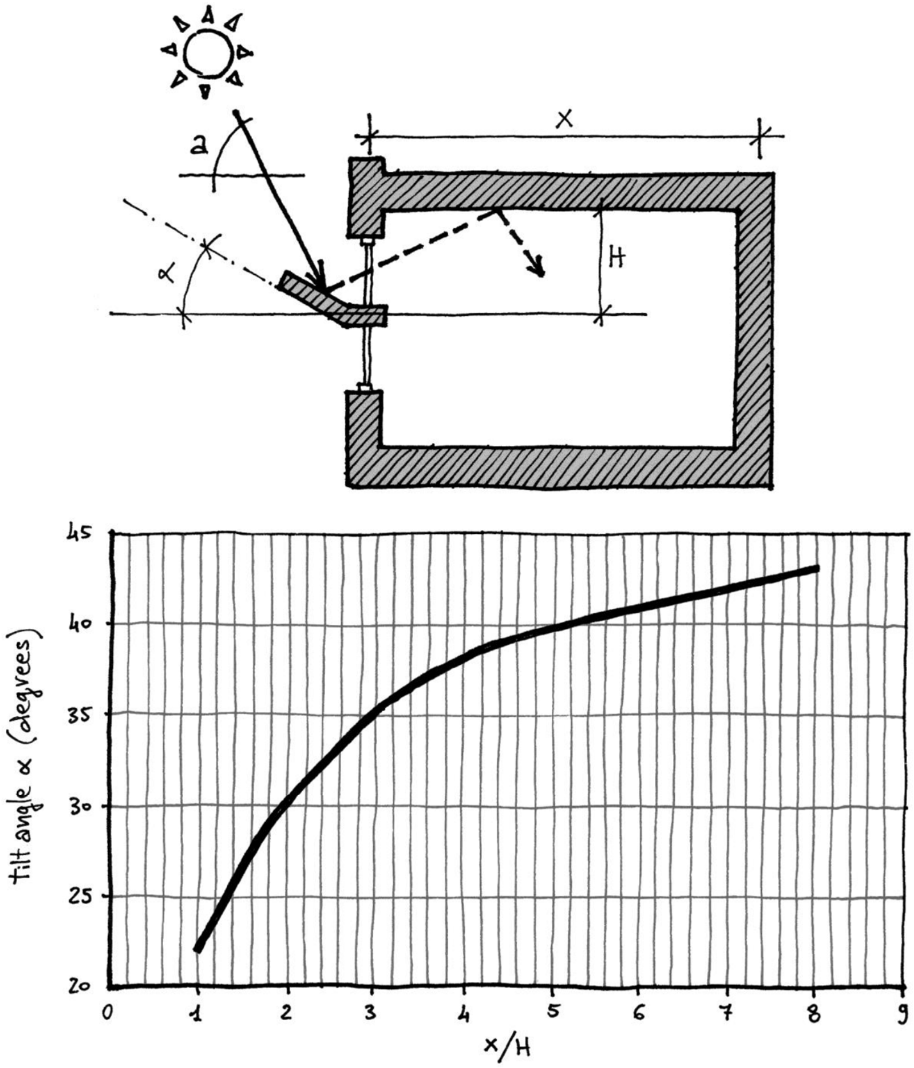


Figure 28 Light shelf sizing

5.4 Tips to size openings and enhance natural lighting

Finally, a specific chapter of the handbook, dealing with the proper sizing and design of openings, provide to designers all the practical information to enhance the natural lighting.

Some of them are briefly reported hereafter:

- The best orientations for daylight sources are north and south: the high angle of the sun is easy to control with a horizontal overhang.
- Avoid east and west-facing windows for daylighting. The low angle of the sun makes it difficult to control direct sunlight penetration via overhangs or other fixed shading devices.

- Any window orientation more than 15 degrees off of true north or south requires careful assessment to avoid unwanted sun penetration.
- The ideal orientation may not be possible in urban situations where plot sizes may be constrained. In such cases increase the surface area of exposure toward the south and north. This may be done by using light shafts, light wells or light courts such that the west-and east-facing walls are shaded and receive diffused light.
- Windows should provide three basic services: protect from rain and wind (when required); provide lighting; provide exterior view. Fulfilling these requirements is not free: a large window, that should provide the maximum light and the widest view lets also enter a large amount of solar radiation, with its consequent solar gain, and – if it is not properly designed – causes the very unpleasant phenomenon of glare.
- Consider that large windows require more control. The larger the window, the more critical the selection of the type of glass and the effectiveness of shading in order to control glare and solar gains. Designing a window, it is not only matter of size and shape, it is also matter of glazing: the choice of the type of glass is of paramount importance for the energy and comfort performances of a window.

Some pictures that illustrate the main recommendations are reported in Figure 29.

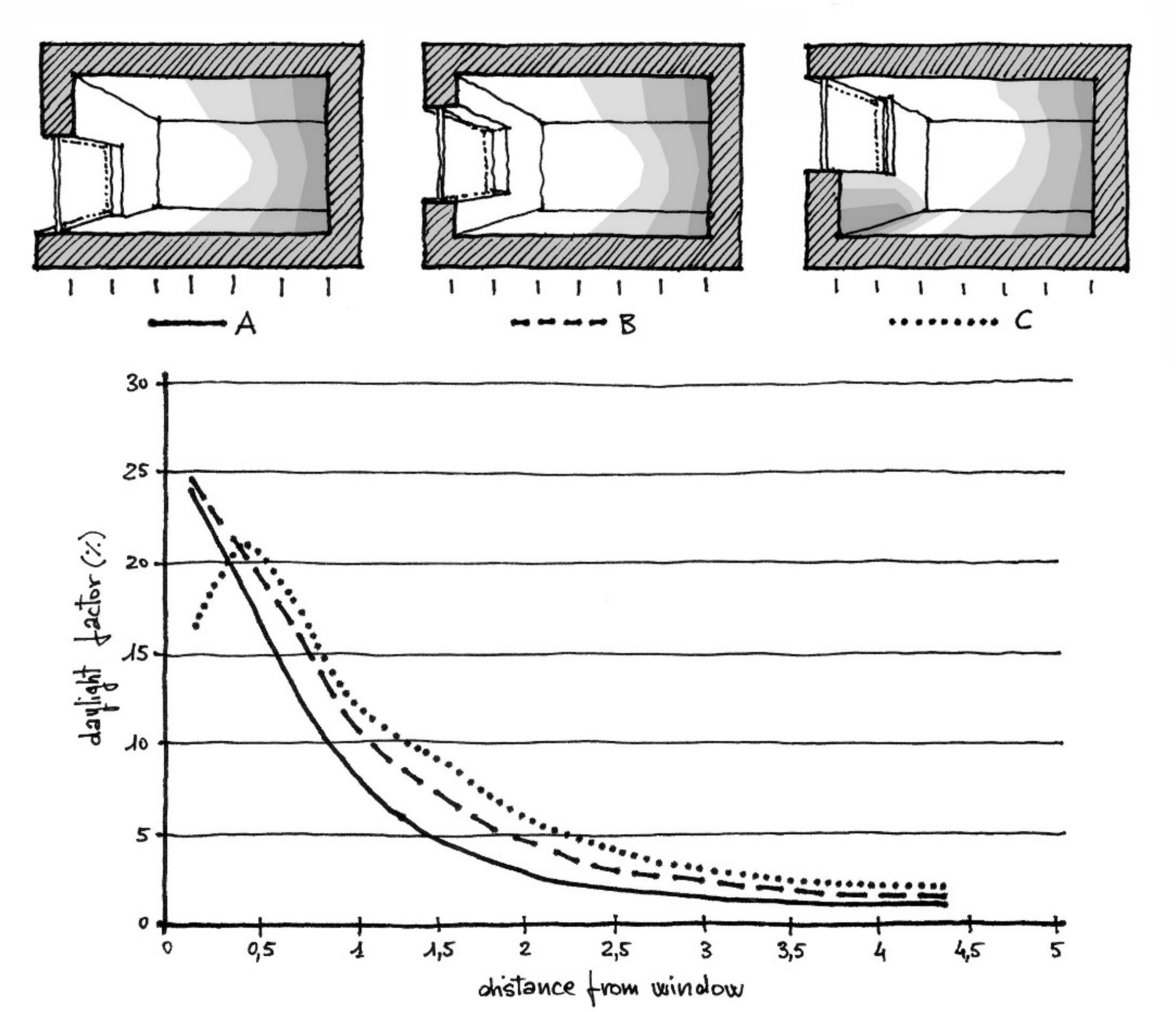


Figure 29 Samples of recommendation to enhance the visual comfort

6. Cooling by exchange with the ground

Direct geothermal usage for heating and cooling integration with high performance building design techniques such as high insulation and solar shading can help achieving buildings with low *energy needs for heating and cooling*. One important feature of geothermal systems is due to the fact that they will maintain more easily than night air their feature of heat sink under the scenario of climate change due to the large thermal capacity of the soil.

Furthermore, the application of the ground as a thermal mass offers an opportunity to enhance building energy flexibility. Despite observing temperature fluctuation in the ambient air throughout the year, the ground (subsoil) temperature remains relatively constant [134]. Ground surface temperature is affected by solar heat transfer through radiation, convection, and conduction to a certain depth as shown in Figure 30. The intensity of solar heat gain to the ground depends on geolocation, vegetation, soil property, and morphology. Undisturbed ground temperature occurs where the effect of solar radiation and heat gain from the earth's crust remains little on temperature distribution. The undisturbed ground temperature is characterized by yearly temperature fluctuation of less than 0.1 ℃. Studies also show that for summer comfort applications additional techniques such as shading and evaporative cooling of the ground can reduce the intake of energy from sun and air by the soil, reduce hence the disturbance to underground temperature profile and increase cooling performance [135].

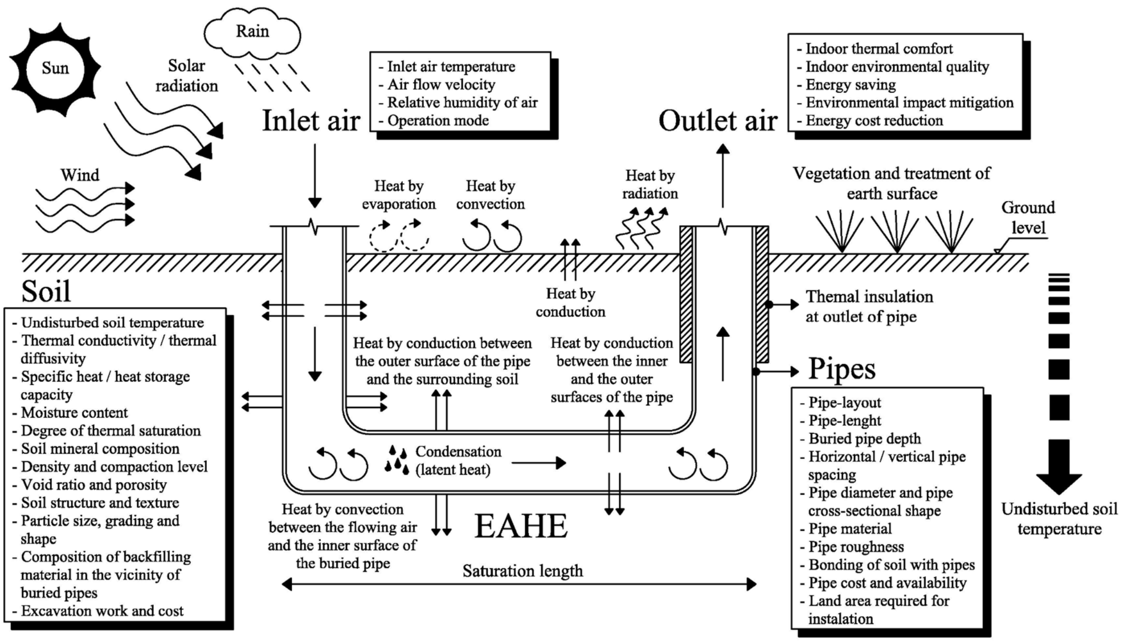


Figure 30 Schematic of a standalone EAHE system in the cooling mode [136]

Earth-Air Heat Exchanger (EAHE) is one of the practical techniques that can help heat or preheat air in winter and cool it in summer by taking advantage of the thermal capacity of the ground. The EAHE systems have a long history in arid parts of the world to achieve thermal comfort in an indoor environment [137]. In general, the construction of the EAHE system consists mainly of pipes buried underground in a desirable depth where undisturbed ground temperature occurs. Air is used as a working fluid to carry the heat and the ground serves as a heat source or sink thanks to its thermal capacity. The system has a simple working principle where active or passive systems are employed to drive air into the system. In active systems, mechanical fans are employed to blow air and in passive systems wind catchers are used to drive air into the system. As air passes through the piping system a heat transfer occurs between the air and the ground through convection and conduction, with direction depending on the season and is channelled to desired space. The systems are reported cutting on energy needs with minimal or no negative environmental impact to cool or heat space [138].

In general, the system has a significant advantage over similar passive systems that utilize the ground inert nature such as air source heat pumps, integral-type solar assisted heat pumps, and ground-source heat pumps. Some of these advantages are the system requires less operational energy, air pollution is lower, it doesn't require extra heat amid extremely cold outside temperatures in Mediterranean and tropical areas, no need for a compressor, CFC, or any refrigerants, uses air as working fluid, less construction and maintenance cost, and no exposure for weathering condition of the system [139]. Considering that, the system also shows some disadvantages such as transfer of fan noise in active systems, and vapor condensation which can be alleviated by integrating drainage systems at the lowest points of the piping layout. In such cases the performance of the system may decline due to the additional energy needed. Finally, an air filtration system can be integrated as in other ventilation systems, to improve air quality. To overcome some of the shortcomings related to energy needs, the system can be integrated with onsite renewable energy generation.

6.1 Types of EAHE systems

Based on air circulation, the system can be classified as an open loop where air does not recirculate in the system or a closed loop where air can be recirculated in the system as shown in Figure 31. The open loop configuration has a minimalist design and can be easily constructed. Since air is not recirculated in the system and is directly exhausted to outdoor environmental concerns for airborne particles are less. Studies also highlight a disadvantage in the open loop system that the system requires higher maintenance, less accuracy, and less reliability. On the other hand, the closed loop system has the advantage of accuracy and reliability, less maintenance, and less noise over the open loop system. But the system is complex in design and construction since it introduces a filtration system which leads to higher cost and increase in pressure drop requiring larger air blowers.

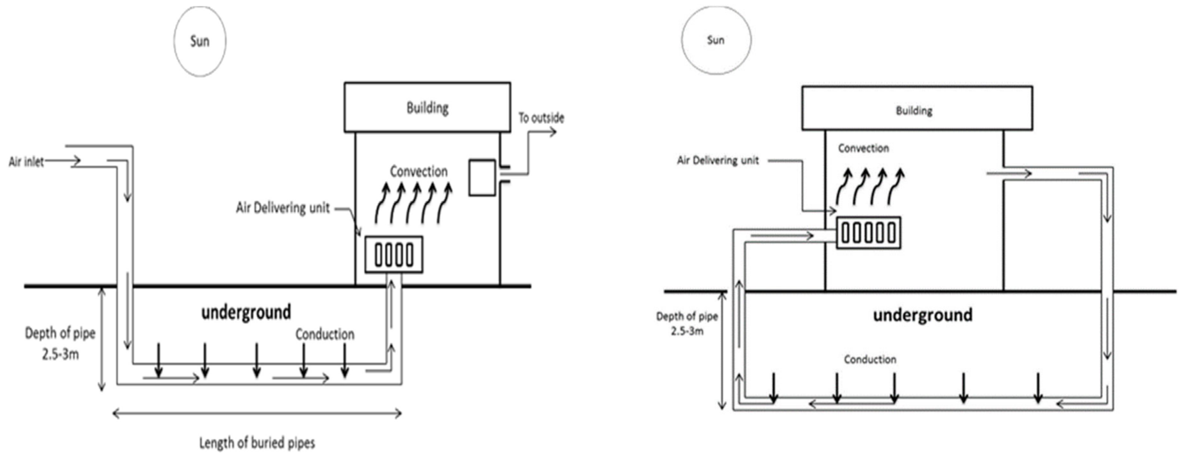


Figure 31 Schematics of open and closed loop earth to air heat exchanger [140]

Based on the geometrical construction of the buried pipes the system also can be classified as a horizontal and vertical system. Both these systems can offer their own unique characteristics and application potential. Land occupation is one of the major parameters that come into play in design decisions to select between the two piping structural characteristics where the vertical system is more appropriate to be used where land availability is limited such as in urban environments. By far the literature suggests that horizontal system design is widely employed, and it can be single or multiple pipe configuration. In most cases the depth at which the pipes are buried averages 5 meters. In recent years the vertical system attracted increasing interest for higher thermal performance. The system also allows the integration of the system in highly densified metropolitan areas where land is expensive. The vertical system is mainly designed with U shape configuration in small deep holes that can reach over 10 m.

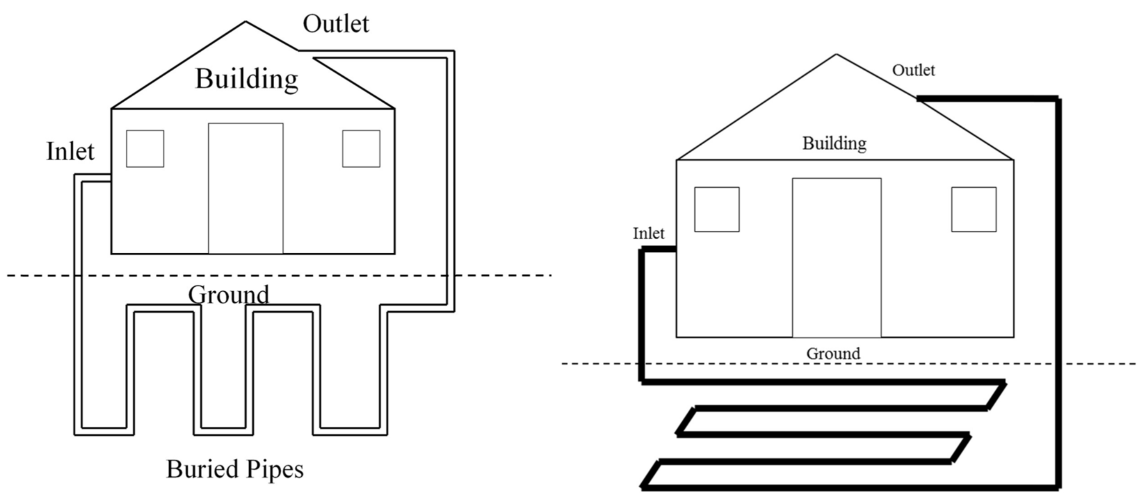


Figure 32 Schematics of horizontal loop and vertical loop system [140]

The integration of EAHE systems with other passive and active systems is also common practice and it's called a hybrid EAHE system. The system can be coupled with conventional air conditioning systems, air source heat pumps, heat recovery units, evaporative cooling systems, building integrated photovoltaic systems, solar air heaters, solar chimneys, wind towers, and thermal mass or phase-changing materials [136].

6.2 EAHE system design in Mediterranean region

The overall thermal performance of the EAHE system depends on three major parameters: the EAHE piping system, the employed blower, and the soil characteristics and moisture content. Each parameter also has a sub factor that can influence its performance. To get optimal performance for the system it's clear that the design and development of the system require optimization of the parameters that are unique for specific locations. That's where studies such as [9] aim to find the best combination of EAHE parameters based on location and building.

In the Mediterranean region, a study conducted by Mahach and Benhamou [141] aims to design the EAHE system for thermal comfort in school buildings in Morocco. The main two parameters that drive the design decision are to achieve desired temperature output of 20-26 ℃ with air change per hour of 2000 m^3/h. The authors performed a parametric study with the help of numerical simulation. Based on their assessment the author concluded that the best HAHE system design that can deliver the needed qualities consists of 4 pipes with 100 m length and 0.195 m internal diameter and buried at 5.7 m depth with air operation velocity of 4.6 m/s.

In the same region, a similar study [142] was conducted in France to cool a nursing home dining area with a floor space of 380 m^2, the system design has 11 pipes with a diameter of 0.2 m and the system has a 2 m depth. The design system has provided air at 2 m^3/s and has a cooling capacity of 14 kW in the months of July and August. Another study conducted in three different regions of Algeria [143] using both experimental and numerical approaches recommend the burial of the pipe at a depth of 3 m, an optimal pipe length of 25 m, and a pipe diameter of 0.18 m for humid and hot climate conditions. The same study also highlighted in the dryer part of the region a system design configuration of a pipe burial depth of 2 m, a pipe length of 30 m, with a pipe diameter of 0.24 m recommended for best thermal performance. For both cases, the air velocity of 0.45 m/s is recommended. As it can be understood from the review, that the EAHE system should be designed to meet specific design criteria. Therefore, it is essential to derive a relation between inlet and outlet pipe temperature using analytical, experimental, and numerical analysis methods.

6.3 Design Parameters

The geometrical parameters that characterize the EAHE are the diameter of the tube (D), the length of the tube (L), and the number of tubes in the heat exchanger (N). As already has been discussed, the design requirement of the built environment determines the design of the EAHE system. The relation between geometrical parameters and design constraint parameters is shown in Equation 1. Using the known data, the value for geometrical parameters can be obtained.

$$\underline{m} \equiv \frac{\frac{\pi}{4} D^2 \rho v_a}{N} \qquad (1)$$

Where m is flow rate, D is pipe diameter, p is working fluid density (air in our case), v is flow velocity, and N is the number of pipes.

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The first parameter that comes to influence the design is the rate of air flow through the tube. This value can be obtained from the required air change rate of the room to be ventilated. Air change rate or Air Change per Hour (ACH) is a calculation of how many times per hour the entire volume of air in each space is replaced with supply and/or recirculated air to ensure acceptable indoor air quality and described mathematically in Equation 2. The ACH value is dependent on the application of the room and can be obtained from international standards. The ASHRAE Ventilation for Acceptable Indoor Air Quality, Standard 62-200, provides detailed recommended air changes per hour for typical building types. These air changes per hour are calculated using common occupancy rates and room sizes, which include those for houses, hotels, businesses, schools, and retail spaces. The room volume can be obtained from design decisions, measurements and building layout. By substituting these values, the flow rate of the system can be obtained.

$$ACH = \frac{flow\,rate}{Room\,volume} \tag{2}$$

The flow rate value then can be used to initiate the selection of size and the number of the pipes using Equation 1 which can meet the EAHE performance. The equation shows that the size and number of pipes have an inverse relation. The diameter of the pipe can be selected from the manufacturer catalogue and our selection can directly determine the number of pipes that will be used in the system. The working velocity of air in the system is determined considering issues such as noise, pressure drop, and heat transfer rate. Also, acceptable air velocity in the built environment is influenced by the occupant’s satisfaction.

These parameters must be chosen by the designer to satisfy boundary conditions and maintain heat exchanger performance. This means that the choice of tube length and tube count is constrained by the building's location, available space, design type, and costs. It's critical to be able to assess how different parameters configuration affect performance and the system needs to be optimized as required. And maintaining a satisfactory thermal performance for the occupant needs to be prioritized. Once the system design is completed, it follows selecting and sizing air driving mechanisms that will be employed in the system. To select and size the air driving mechanism, the pressure drop in the entire system needs to be analysed.

6.3.1 Pressure drop

Because of the movement of the working fluid inside the tubes, it is expected to observe a pressure drop in the EAHE system. In general, the term pressure drop is defined as a total pressure difference between two points in a fluid carrying system, at the inlet and outlet. Pressure difference occurs due to a frictional force applied on the moving fluid as it passes through the system. In an ideal smooth tube, the pressure drop is given as Equation 3. From the mathematical expression in Equation 3, it can be understood that the length of the tube has a linear influence over the pressure drop of the system whereas the diameter of the pipe and air flow rate have a combined influence over the pressure drop.

$$\Delta P = \xi \frac{L}{D} \rho \frac{V_{air}^2}{2} \tag{3}$$

The least pressure loss is produced by tubes with a large diameter and a low flow rate per tube. This would necessitate increasing the number of pipes in the system as in Equation 1. Using small diameter pipes could increase the pressure drop of the system. On the other hand, increasing the number of tubes is advantageous in both situations. Thus, it is necessary to optimize the tube length-diameter combination. A specific pressure drops value of a given system can be calculated using more advanced numerical tools such as computational fluid dynamics. Both the flow rate and pressure drop of the system then can be used to select a fitting air driving mechanism whether it is passive or active.

6.3.2 Heat transfer effectiveness

The main parameters that come into play to describe the heat transfer phenomena in the EAHE system are air flow rate, inlet air temperature, the desired outlet air temperature and ground temperature. The flow rate and outlet air temperatures are set by the design requirement as discussed earlier. The air inlet temperature and the ground temperature are determined by the local climate condition.

$$\varepsilon = 1 - e^{-NTU} \qquad (4)$$

where: $NTU = \frac{hA}{m_{air}c_{p,air}}$

The main heat transfer occurs inside the pipes where heat transfer from the moving air to the pipe through convection. There is also heat transfer from the pipe surface to the ground through the condition, however, the logarithmic average temperature between the two mediums is taken to be constant. Thus, in most literature, the contact between the tube and the earth is taken as perfect. The thermal capacity of the earth is very high when compared to the contact surface resistance, hence, wall temperature inside the tube is assumed to be constant through the system. With this consideration simplifying the problem, we can conclude that if the tube has an infinite length, the air will be heated or cooled to the wall temperature. Following this assumption, the effectiveness of the designed heat exchanger (NTU) can be derived from the total heat transferred and heat transferred through convection between the wall and expressed as Equation 4. Where m_{air} is air the air mass flow rate, $C_{P,\,air}$ is the specific heat capacity of air, and h is the convection coefficient of the air inside the tube.

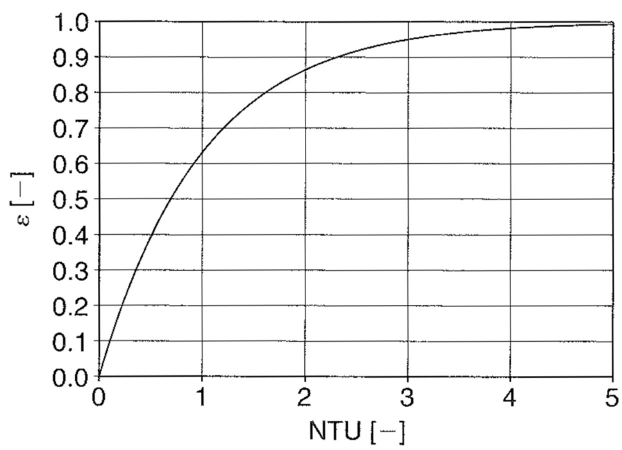


Figure 33 Effectiveness as function of NTU [144]

The NTU is a dimensionless group that determines the effectiveness of the heat exchanger. As the NTU value increases, the effectiveness of the heat exchanger increases as shown in Figure 4. However, the relative gain after NTU>3 is very small. Thus, it is recommended to construct an earth air heat exchanger to obtain a given NTU. The effectiveness parameter is influenced by different parameters as expressed in the mathematical equation. To help make the design section's main parameters, discussed in the early section, effect on the effectiveness of the system summarized below.

6.4 Summary

The design of earth to air heat exchanger follows a separate procedure from the building design and it comes after it. Once the required ventilation is known from the building design and purpose, the design of EAHE only depends on thermo-hydraulic parameters with construction and economic constraints. While designing EAHE systems, the main two parameters that the designer needs to pay attention to are thermal performance and pressure drop. Thermal performance refers to the heat transfer rate that has a direct relation with our design outlet temperature. Whereas the pressure drop determines the selection of the air driving unit that directly affects the energy performance of the system. And as has been discussed in the early section these performance parameters can be positively or negatively influenced by different design decisions. The effect of the primary design parameters over the design parameters has been summarized in this section to help design decisions.

Thermal performance: Pipe material is one of the parameters often discussed in the literature for its effect on the heat transfer performance of the system. Initially, steel pipes were used in the system design for their higher thermal conductivity. However, recent studies show that plastic materials can deliver similar thermal performance and offer a cheaper and long-life cycle alternative. Polypropylene does not emit dangerous vapours and is recyclable. In General, the analysis shows that the convective heat transfer phenomena play a more significant role than conduction. An increment in the length of the pipe shows a positive influence on the thermal performance of the system, yet the parameter is required to meet constraints such as land coverage. Pipe diameter also has a similar effect as length where larger diameter tubes have better thermal performance. More number of pipes in parallel enhance the thermal performance of the system. Air velocity inside the tube, on the other hand, has a reverse relation with the thermal performance of the system. Even If the convection heat transfer coefficient of air increases with the velocity, the duration to which the system encounters the pipe surface reduces. Therefore, smaller temperature changes may be obtained in higher velocity.

Pressure drop: Pressure drop recorded in the system can directly determine system energy demand. Determining the system pressure drop in a system can be a challenging task as it accounts for every part of the system such as valves, fittings, air inlet and outlet louver, pipe surface roughness, diameter and radius of curvatures, moisture content etc in the system. The pressure drop of an EAHE system increases with length of the pipe whereas a larger pipe diameter can help decrease the pressure drop. Using smaller diameter pipes means the air velocity needs to be increased to meet the air flow rate demand. This results in a changing Reynolds number, introducing turbulence in the system that can result in unneeded noise and vibration in the system.

From the performance parameters, it can be understood that none of the design parameters have an independent influence over the performance of the earth-to-air heat exchanger. This introduces a performance trade-off between the design parameters. Hence, the designer's responsibility is to find the best combination of these parameters that can deliver the expected performance. To assist the design decision, it is suggested to employ thermo-hydraulic coupled numerical simulation. Modules for ground exchange are included in EnergyPlus and TRNSYS. For small systems case studies and reported performance in literature may provide information on suitable configurations.

7. Materials for daytime radiative cooling

7.1 Executive summary

Radiative cooling techniques are well known and employed since the ancient times. The principle is simple and is based on the ability of terrestrial surfaces to dissipate heat in the form of infrared radiation to the low temperature extra-terrestrial space through the atmospheric window, the interval of wavelengths (8-13 μm) at which the atmosphere is highly transparent to thermal radiation emitted by all earth surfaces, including those of man-made bodies. Historically the technique has been used at night, in accordance with available materials, when surfaces are not subject to the high radiation input from the sun.

Daytime radiative cooling is a very efficient new technology able, taking full profit of the atmospheric window, to achieve sub ambient surface temperature under the summer sun, contribute to decrease up to 4-5 °C the peak temperature of cities and decrease considerably the cooling demand of buildings.

Several types of daytime radiative coolers have been recently developed and commercialised. Four main technological clusters of products are available presenting different optical, thermal and performance characteristics.

Despite the very high cooling potential of daytime radiative coolers, several limitations and constraints are associated with their use. Problems like supercooling of surfaces during the winter period, optical annoyance caused by the very high reflectance and limited cooling potential when humidity is high, seems to be the most important of them.

Recent research has proposed and provided technological solutions that help to overcome the limitations and enhance the performance of the daytime radiative coolers.

This chapter provides information on the principles of the technology, the existing types of products, their cooling performance while it describes the main limitations and the developed technologies to overcome potential problems.

Finally, it provides practical information on commercially available radiative cooling products, their characteristics, and their expected performance.

7.2 Introduction

1. Global and regional climate change increases the temperature of cities and skyrockets the cooling energy use of buildings. Higher ambient temperatures have a very serious impact on the energy consumption of buildings, heat related mortality and morbidity, environmental quality, human productivity and quality of life of vulnerable and low income population [43].

2. The use of conventional compression cycle air conditioning causes important and serious problems. E.g. it increases the peak electricity demand and obliges utilities to build additional power plants that operate for a limited number of hours per year increasing the cost of the electricity supply [145].

3. Furthermore, air conditioning can be an important source of environmental and indoor air quality problems, like the ozone depletion and the potential warming of the ambient environment [146]. The considerable operational cost of air conditioning is a serious burden for low-income population that is living in non-thermally protected buildings, with the associated high *energy needs for cooling* [147].

4. Because of the lack of financial resources, low-income population is exposed to extreme indoor temperatures highly exceeding the health and comfort thresholds [148].

5. Climate change in combination with several technological, economic and social drivers determine the future energy consumption of the buildings sector, which is expected to grow significantly in absence of strong and effective policies [149].

6. During the recent years, several passive and active alternative cooling technologies for buildings and open spaces have been developed and successfully tested [150]. Several of the proposed cooling technologies are based on the development of advanced materials presenting exceptional thermal and optical characteristics and properties. Among the most successful developments are the infrared reflecting materials, fluorescent surfaces, thermochromic surfaces, caloric materials and photonic and plasmonic and photonic radiative coolers [151].

Day time radiative coolers, seem to be the most advanced materials offering a very high potential for urban heat mitigation and space cooling. Recent data have shown that photonic daytime radiative coolers exhibit sub-ambient surface temperatures under the sun, a tremendous scientific achievement.

The present document aims to present the main principles of day time radiative cooling, then to identify and discuss the main types of materials, to discuss their cooling potential, to analyse their advantages and limitations, and finally to present some of the most common commercially available radiative cooling materials.

7.3 Materials for daytime radiative cooling

Radiative cooling techniques are well known and employed since the ancient times. The principle is quite simple and is based on the ability of terrestrial surfaces to dissipate heat in the form of infrared radiation to the low temperature extra-terrestrial space through the atmospheric window, the interval of wavelenghts (8-13 μm) at which the atmosphere is highly transparent to radiation (transparency approaching the value 1, and correspondingly absorptance approaching the value zero, see Figure 34). All bodies on the earth surface emit infrared electromagnetic radiation at wavelengths that correspond to the atmospheric window, while they absorb solar and infrared radiation out of the specific atmospheric window.

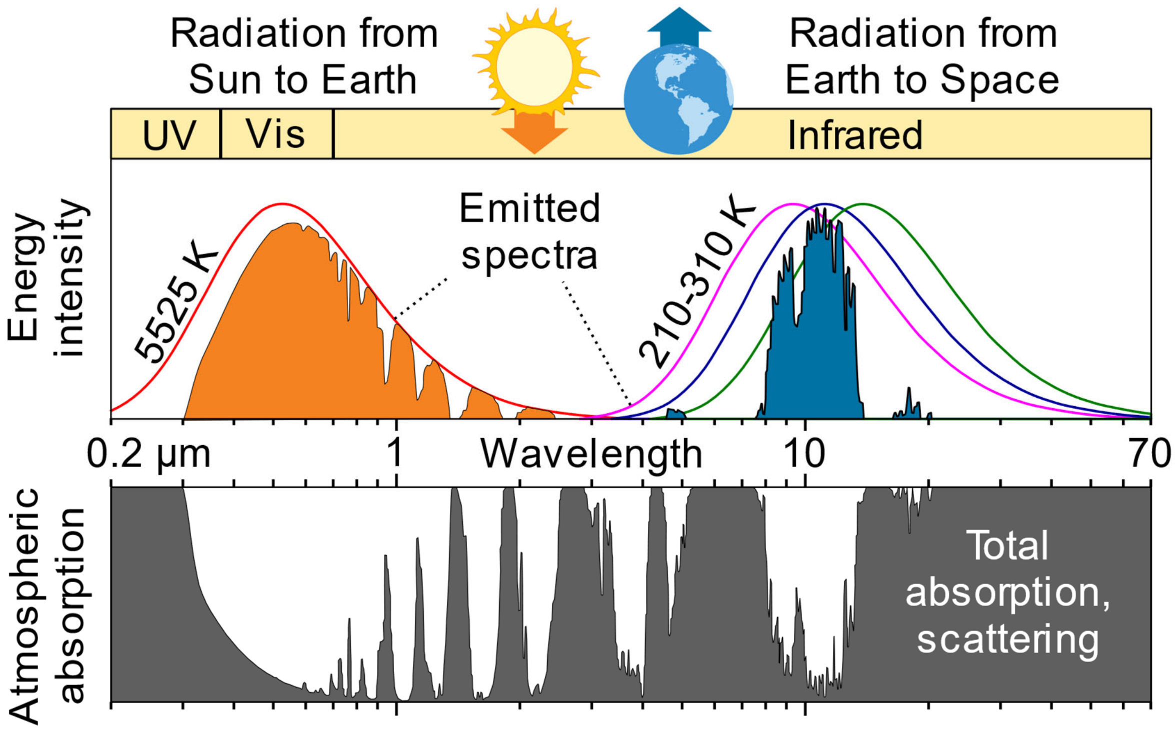


Figure 34 Atmospheric absorption as a function of wavelength, showing the atmospheric window (8 to 13 micro meters) where absorption of infrared radiation by gases in the atmosphere is very low. Hence providing a "transparence window" through which object on earth surface can send infrared radiation directly to the deep sky. ***Source: Robert A. Rohde for the Global Warming Art project, via Wikipedia. (https://en.wikipedia.org/wiki/Atmospheric_window)***

When the atmosphere is clear, thanks to a low presence of water vapour[2], the radiation emitted by bodies on the earth surface is not absorbed and re-emitted (partly back to the earth surface) by the atmospheric gases, but on the contrary it can escape to the space. When the heat losses by a body are higher than the heat gains, the body undergoes a net loss of energy, and its surface temperature may be considerably lower than the temperature of ambient air. In this case, the cool surfaces may be used as heat exchangers to decrease the ambient temperature or to provide cooling to buildings (a passive system named "radiant cooling" by Givoni).

The net density of heat flow of a radiative cooler, Q_{rc} (W/m^2), is equal to:

$$Q_{rc}(T_c, T_a) = E_{asw} + E_{alw}(T_a) + E_{rlw}(T_c) + Q_{cl}$$

Where E_{asw} (W/m^2) is the absorbed shortwave radiation, E_{rlw} (W/m^2), is the emitted infrared radiation, E_{alw} (W/m^2), is the absorbed longwave radiation, and Q_{cl} (W/m^2), is the heat exchanged by convection. All flows are considered positive if entering the surface and negative if leaving the surface. T_a is the ambient temperature and T_c the surface temperature of the emitter.

[2] As measured e.g. by the parameter "Precipitable Water Vapour"

The cooling potential of a radiative cooler is a direct function of its surface temperature, T_c (K). The higher the depression of the surface below the ambient air temperature, T_a (K), the higher the cooling potential of the cooler.

In the past, several radiative cooling technologies like selective surfaces, thin films, reflective covers etc have been developed and tested. While during the night period such surfaces presented a substantial temperature drop below the ambient air temperature, they failed to achieve sub- ambient temperatures during the daytime when solar radiation is quite high, and hence during daytime their cooling potential was negligible [43].

Given that buildings present the maximum of the *energy needs for cooling* during the daytime period, the need to develop daytime radiative coolers was obvious.

Recent research carried out to develop advanced photonic and plasmonic materials has resulted in the development of surfaces able to present a net heat loss (a negative value of Q_{rc}) during the day time and exhibit sub ambient surface temperatures, when positioned horizontally directly exposed to sun radiation, and with view of the sky [151].

Day time radiative components are classified in four main technological clusters of materials [152]:

(a) Multilayer Planar Photonic Structures;

(b) Metamaterials and 2D-3D photonic structures;

(c) Polymers for Radiative Cooling and

(d) Paints for Radiative Cooling.

The main optical characteristics of the most commercial structures are reported below in Table 10.

7.4 Main Typologies of the Daytime Radiative Cooling Materials

7.4.1 Multilayer Planar Photonic Structures

Multilayer planar photonic radiative structures are composed by two main parts, one aiming to increase the reflectivity of the components in the short wavelength range (0.3–2.5 μm, which is the range of the radiation form the sun), and the other to enhance the monochromatic emissivity (or equivalently the monochromatic absorptivity, according to Kirchoff theorem) of the structure in the atmospheric transparence window (8–13 μm). To increase the reflectance either silver (Ag) or aluminum (Al) mirrors are used or structures of alternative layers of low and high refraction index materials. The average reflectance is varying between 0,9 to 0,98, (10-11) [153,154].

The structure of a Multilayer Planar Photonic Structure is given in Figure 35.

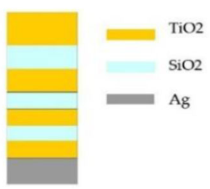


Figure 35 Structure of a Multilayer Planar Photonic Structure [153]

To increase the absorptivity (or equivalently the emissivity) of the structure in the atmospheric window, films composed by one up to four different materials are used. Materials used include SiO_2, PDMS, HfO_2, PPMA, VO_2, MgF_2 , Si_3N_4 and Al_2O_3. The achieved absorptivity = emissivity value in the atmospheric window in most of the cases exceeds 0,9, which is close to the maximum (= 1 by definition) possible value [155,156].

The thermal performance of the multilayer Planar Photonic structures has been evaluated both theoretically and experimentally. The achieved daytime and nighttime surface temperature depression below the ambient (air) temperature depends on the characteristics of the structure and the testing conditions and in general varies between 4 and 10 C °C. Much higher temperature drops are reported under vacuum conditions where the convective gains and losses are minimised. Given the high diversity between the testing conditions and the simulation assumptions, it is impossible to compare the performance reported for the different radiative coolers [157].

7.4.2 Metamaterials and 2D-3D photonic structures

To boost the emission of radiation in the infrared spectrum the use of two- or three-dimensions photonic crystals and metamaterials have been proposed. Such structures present a very high reflectance in short wave radiation combined with very high emissivity values in the atmospheric window [158–160].

The major limitation of metamaterials and 2D-3D photonic structures is the low scalability since the manufacturing process requires a quite complex and expensive microfabrication.

The structure of a metamaterial designed for daytime radiative cooling is given in

Figure 36 [161].

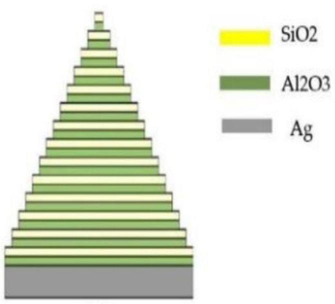


Figure 36 Structure of a metamaterial developed for daytime radiative cooling [161]

The shown micro-pyramids are composed by 19 alternate Al_2O_3/SiO_2 pairs of variable length thin film with a silver layer at the bottom. Calculations of the emissivity in the far infrared range have shown that it is very close to one, while the absorptivity of the structure in the solar spectrum range is found very close to zero. Fabrication of such a structure is quite complex as it requires either a layer-by-layer fabrication or a nano imprint physical vapor deposition. The structure is found to provide a cooling power close to 122 W/m^2.

Figure 37 presents another 2D metal dielectric photonic structure designed to provide daytime radiative cooling [162]. The system consists of a thermally selective emitter on top of a broadband mirror. The reflector is composed of three sets of 5 bilayers of MgF_2 and TiO_2 over a silver substrate. The emitter is composed of two 2D layers of SiC and Quartz. The structure presents a daytime temperature drop of 8,25 °C below the ambient temperature under 800 W/m^2 solar radiation and 35 °C air temperature.

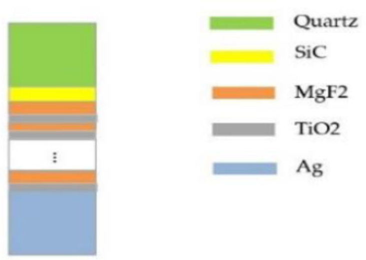


Figure 37 Structure of a 2D metal dielectric photonic structure designed to provide daytime radiative cooling [162].

7.4.3 Polymers for Radiative Cooling

The use of polymers doped with nanomaterials may result in materials with very high emissivity in the atmospheric window [163–165].

Figure 38 presents a daytime radiative cooler composed by commercially available spectrally selective polymers fabricated by coextruded combinations of many bilayers [166].

Figure 38 A daytime radiative cooler composed by spectrally selected polymers [166]

The polymer used, presents a high reflectivity in short wave radiation, and an average emissivity in the atmospheric window range close to 0,96. When the material is combined with a metal reflector like Ag its combined reflectance in short wave radiation is close to 0,97. Experimental testing of the composite material have shown that its surface temperature was almost 2 °C below the air temperature, while under the sun [166].

7.4.4 Paints for Radiative Cooling

Passive radiative cooling materials under the form of paints are available and easy to use [154,167].

A passive radiative material under the form of a paint is proposed in [168]. The material can be applied in building structures and it is based on an hierarchically porous poly(vinylidene fluoride-cohexafluoropropene) (P(VdF-HFP)HP) coating that exhibits superior optical properties. It has a reflectance in the solar spectrum close to 0,96 and an emissivity in the atmospheric window close to 0,97 while it is substrate independent.

The above properties are due to the micro- and nano-pores in the coating that are able to backscatter sunlight and enhance thermal emittance. The coating was tested outdoors under the sun, without a convective protection, and has achieved a daytime temperature depression up to 6 °C below the ambient temperature and a net cooling power close to 96 W/m^2.

7.5 Limitations and Constraints Associated to the Use of Day Time Radiative Coolers

Although radiative cooling components present an extraordinary cooling potential, there are several limitations associated with their use. Radiative coolers show a maximum cooling capacity when the water vapour content of the atmosphere is low, since water vapour has large monochromatic absorptance values in the far infrared range and hence it blocks the atmospheric window. Their potential for application is hence high in arid and semi-arid regions and limited to some months for regions that present a humid/rainy season.

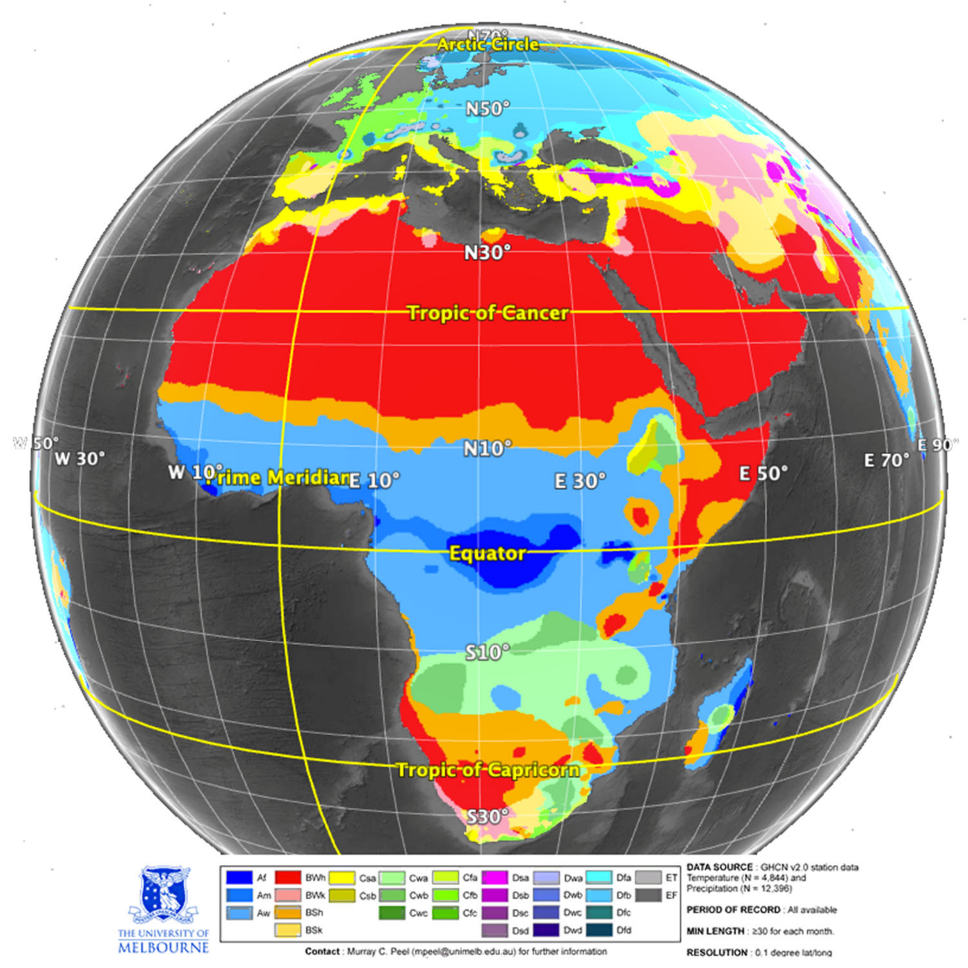


Figure 39 Africa and Europe view of Köppen climate classification

Table 9 Köppen climate classification

Group A: Tropical/megathermal climates	
	Af: Tropical rainforest climate
	Am: Tropical monsoon climate
	Aw: Tropical savanna climate
Group B: Dry (desert and semi-arid) climates	
	BWh: Arid desert hot climate

	BWk: Arid desert cold climate
	BSh: Semi-arid (steppe) hot climate
	BSk: Semi-arid (steppe) cold climate
Group C: Temperate/mesothermal climates	
	Csa: Mediterranean hot summer climates
	Csb: Mediterranean warm/cool summer climates
	Csc: Mediterranean cold summer climates
	Cfa: Humid subtropical climates
	Cfb: Oceanic climate
	Cfc: Subpolar oceanic climate
	Cwa: Dry-winter humid subtropical climate
	Cwb: Dry-winter subtropical highland climate
	Cwc: Dry-winter subpolar oceanic climate
Group D: Continental/microthermal climates	
	Dfa/Dwa/Dsa: Hot summer continental climates
	Dfb/Dwb/Dsb: Warm summer continental or hemiboreal climates
	Dfc/Dwc/Dsc: Subarctic or boreal climates
	Dfd/Dwd/Dsd: Subarctic or boreal climates with severe winters

The potential of radiative cooling components is seriously reduced under conditions of high humidity. When the concentration of water vapor in the atmosphere is high the transparency of the atmospheric window is decreasing considerably as the infrared radiation absorbed by the atmosphere at those wavelengths is increasing [169].

It is characteristic, that when the concentration of the atmospheric water vapor is increasing by 4 fold, the transmissivity of the atmospheric window is decreasing by 50 %. Several experiments and simulations carried out in humid weather conditions aiming to determine the cooling potential of daytime radiative coolers, have shown that it is almost impossible to achieve sub ambient surface temperatures [159,170]. To overcome the problem and improve the cooling potential of the daytime radiative coolers in humid climates/periods, the use of an asymmetric electromagnetic window on the structure of the radiator is proposed by several researchers [171]. Asymmetric electromagnetic windows seem to permit the transmission of the outgoing radiation by the material, while reflecting most of the incoming atmospheric radiation at the same wavelengths. In spite of the intensive research carried out on this subject, no practical improvements have been achieved yet.

A second important problem associated with the use of daytime radiative coolers is related to the risk of supercooling that may be caused during the heating period. Given the very high solar reflectance and far infrared emissivity of the materials, their surface temperature during the cold period can be quite low causing an important increase of the energy needs for heating of buildings whose surfaces with those materials, unless they are strongly insulated at the external faces. To face the problem, additional components able to modulate the reflectance and the emissivity of the materials are proposed. Several techniques are proposed, based mainly on the use of thermochromic and phase change materials like VO_2 on the top of the radiative materials. The combination of thermochromic and phase change materials can achieve surfaces that are absorbing and of low emissivity during the heating period and reflecting with high emissivity during the warm period. Such a combination can provide cooling during the summer and heating during the winter period [172]. Simulations for the city of Calcutta in India have shown that such a system may decrease the peak summer temperature in the city up to 4,5 °C and increase the average daytime ambient temperature during the winter up to 2 °C [172].

A third limitation associated with the use of the daytime radiative coolers is related to the potential optical problems like glare and contrast that can be annoying to people, because of the extremely high reflectance of the materials. To avoid optical annoyance, daytime radiative coolers are usually implemented only on the roof of high-rise buildings. To overcome the problem, new design of radiative cooling materials is based on the use of coloured reflecting materials that present a substantially lower reflectance than the white ones. To counterbalance the loss caused by the reduction of the reflectance, fluorescent materials are combined with the coloured reflector. Fluorescent materials emit most of the absorbed solar radiation and thus present an important cooling potential, but the emission is diffuse on all angles hence avoiding optical annoyance [173].

Composite photonic – fluorescent materials are already developed and tested. It is found that such materials present a very significant cooling potential, without showing any optical annoyance problems. Preliminary experimental results show that red and orange combinations of photonic and fluorescent materials present a surface temperature 3-4° C lower than a conventional white material. It is reasonably expected that this new technology of super cool coloured materials will be commercially available in the very near future.

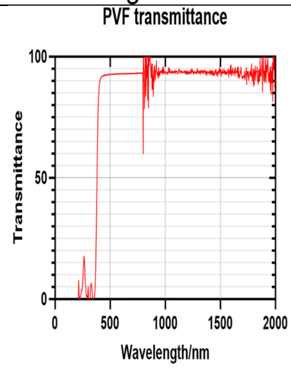
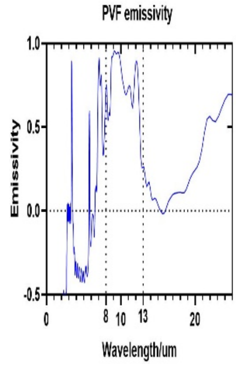
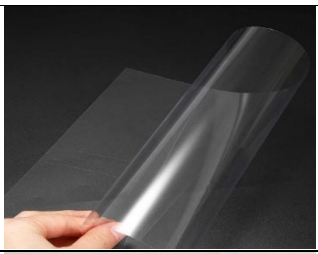
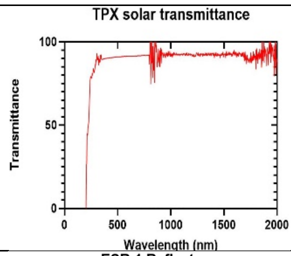
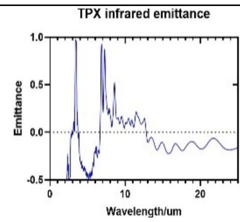
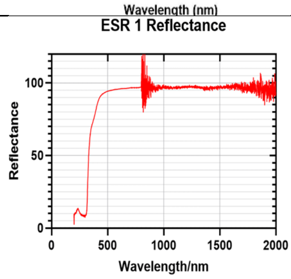
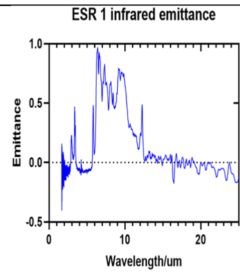
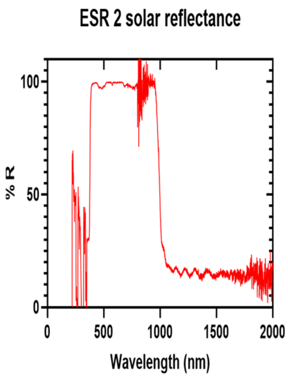
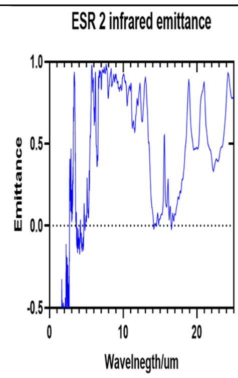
The last important problem of daytime radiative cooling systems when used as an active cooling technology, radiative collectors, it is related to space limitations. As estimated in [174] an active air conditioning system based on radiative collectors may need a total area of 13,5 square meters to provide a cooling power of 607 W during a sunny summer day. Considering that the cooling load of buildings is in the order of several kW, it is evident that the availability of space may be a serious constraint for the active systems of radiative cooling. The use of the active radiative system as a support to the condenser of a conventional air condition system could decrease substantially the required area of collectors and provide energy savings up to 40 % [174].

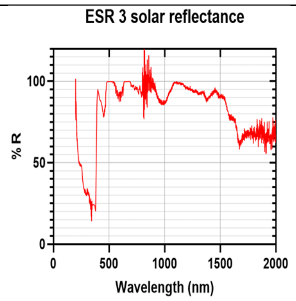
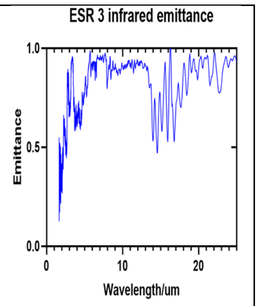
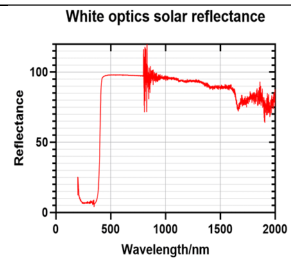
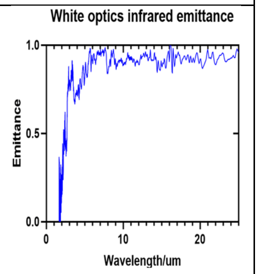
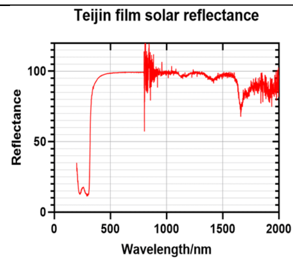
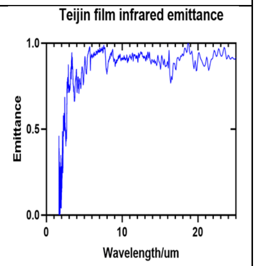
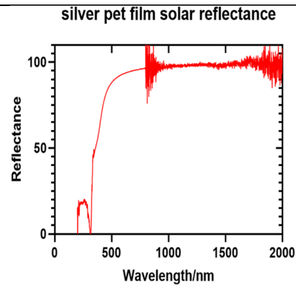
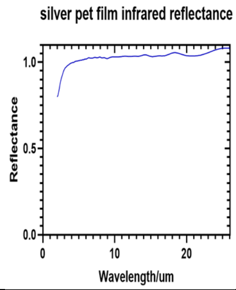
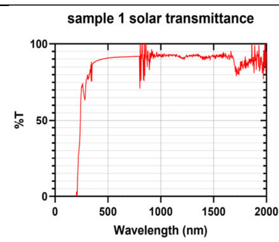
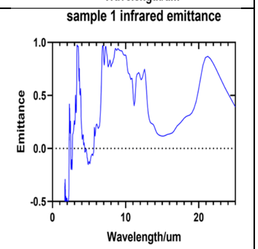
7.6 Commercially Available Radiative Cooling Products

Several day time radiative materials are available on the market. Most of the materials are films, hence they than can be applied easily on any building surface or any active heat exchanger. Although several paints have been theoretically proposed, most of the products of this type are in the testing phase and are not commercially available. According to the manufacturers, paints are expected to be on the market at latest by the end of 2023.

Table 10 presents the characteristics of the existing and commercially available daytime radiative coolers. The monochromatic optical characteristics of the materials and their monochromatic emissivity and reflectance are given. The specific optical characteristics are measured in the laboratory of the High Performance Architecture of the School of Architecture of UNSW. Pictures as well as information on the supplier is also given.

Table 10 Examples of some of the most diffused commercially available day time radiative coolers

Name	Description	Appearance	Optical Properties in Solar Range	Optical Properties in Infrared Range
PVF	PVF film contains C-H and C-F bonds and it is manufactured by Dupont, America. (https://www.dupont.com/solar-photovoltaic-materials/photovoltaic-backsheet-films.html)			
TPX	TPX film is manufactured by Mitsui, Japan.			
ESR-1	ESR 1 is a highly reflective film manufactured by 3M. It has two sides: one silver reflective side and one black side.			
ESR-2	ESR 2 is a highly reflective film manufactured by 3M. It has two silver reflective sides			

ESR-3	ESR 3 is a highly reflective film manufactured by 3M. It has two sides: one silver reflective side and one black side.			
White Optics	White optics is a white diffuse reflecting film. (https://www.whiteoptics.com/reflectance-film/)			
Teijin film	is a white diffuse reflecting film manufactured by Teijin, Japan.			
Silver-PET film	A Chinese manufacturer coated silver on the transparent PET film			
TPX+silica sphere	100um thick - 4% volume fraction - sphere radius 4um			

7.7 Thermal Performance of the Radiative Cooling Materials

Although the cooling potential of the daytime radiative cooling components and materials varies substantially as a function of the local climatic conditions, it would be important to report the cooling potential of the materials as measured under commonly specified conditions. Unfortunately, such nominal conditions are not yet agreed.

ABC21 is funded by the
EU's H2020 programme

Figure 40 provides information on the inhibited drop of the material's surface temperature below the ambient one, as measured by the developers. For example, if the ambient air temperature is T_a and the surface temperature is T_c, the inhibited drop is T_a-T_c. It has to be clear that the monitoring and the conditions are not the same for all the materials. However, the supplied information provides a clear and indicative evidence about the cooling potential of the various materials. The figure is adapted from [152].

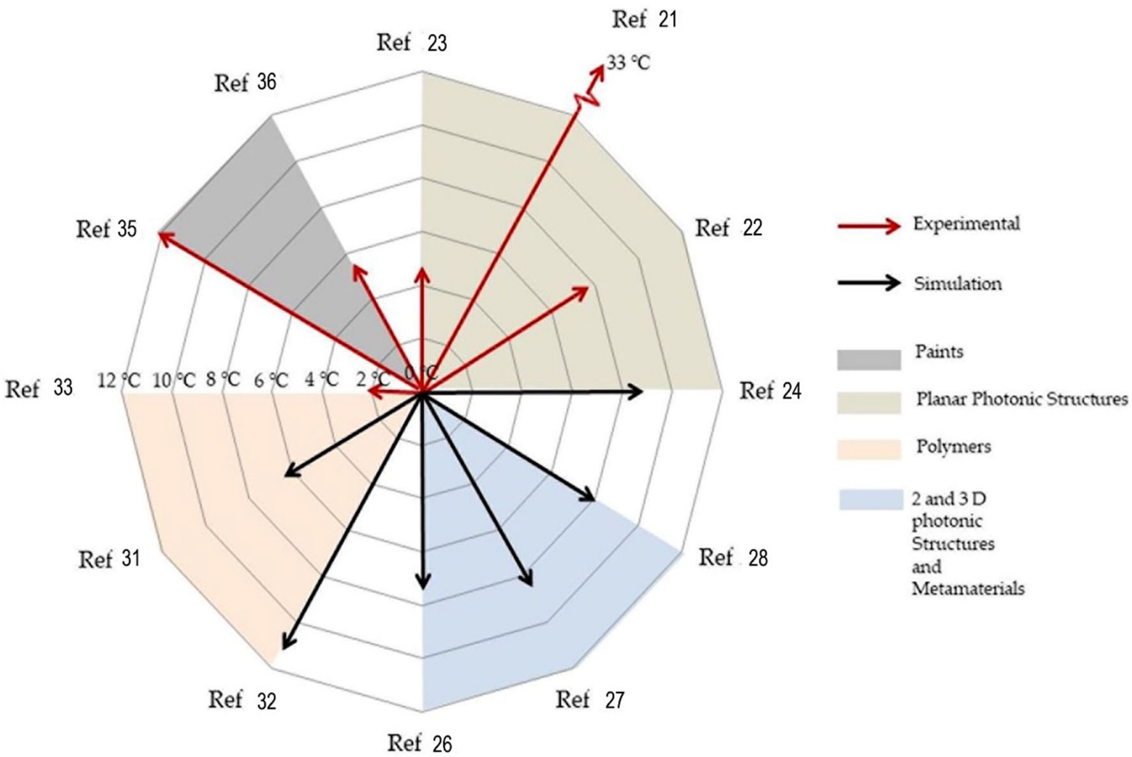


Figure 40 Temperature drop of selected daytime radiative coolers below the ambient temperature, (Adapted from [152]), during daytime.

7.8 Conclusions

Daytime radiative coolers can provide sub ambient cooling and contribute highly to decrease the temperature of overheated cities and reduce the cooling demand of buildings. Several technologies based on metamaterials, planar, 2D or 3D photonic structures, polymeric photonics and paints have been developed and tested with impressive results. Several products are commercially available and testing has shown that it is possible to achieve a surface temperature drop of up to 15 °C below the air temperature, even when the surface is exposed to the sun. Use of the materials to mitigate urban heat in cities may decrease the peak ambient temperature up to 4-5 °C, while when used in buildings may cover a very substantial part of their *energy needs for cooling*.

Still, there are several constraints and limitations related to the use of the daytime radiative coolers, and research is ongoing to overcome those limitations. Intensive recent and ongoing research has designed and brought to high Technology Readiness Levels advanced solutions that improve considerably the applicability of this new cooling technology.

8. Tools for bioclimatic buildings design

This section provides an overview of some freely available tools useful for the early design phase of bioclimatic buildings. The chapter describes tools to:

- assess indoor thermal comfort: CBE Thermal Comfort Tool and the Psychrometric Chart by A. Marsh;
- select and layout ceiling fans: CBE Fan Tool;
- show sun movement and sunlight phases during the given day at the given location: SunCalc;
- calculate U-values, perform LCA assessments and moisture transfer analysis of building components: ubakus.

8.1 The CBE Thermal Comfort Tool

The CBE Thermal Comfort Tool is a free and open-source web based tool to calculate and visualize thermal comfort indices [175]. It complies with the ASHRAE 55–2017, ISO 7730:2005 and EN 16798–1:2019 Standards. It incorporates the major thermal comfort models and provides dynamic and interactive visualizations of thermal comfort zones. The CBE Thermal Comfort Tool has several practical applications and is used by users with different backgrounds including engineers, architects, researchers, educators, students, facility managers and policymakers.

Figure 41 shows as an example a screenshot of the home page for the CBE Thermal Comfort Tool, selecting the standard EN-16798 and the adaptive method. The left side contains the input values that users can modify and adjust. The right side displays the results and an interactive chart. The chart and the results update in real-time as users change the input values.

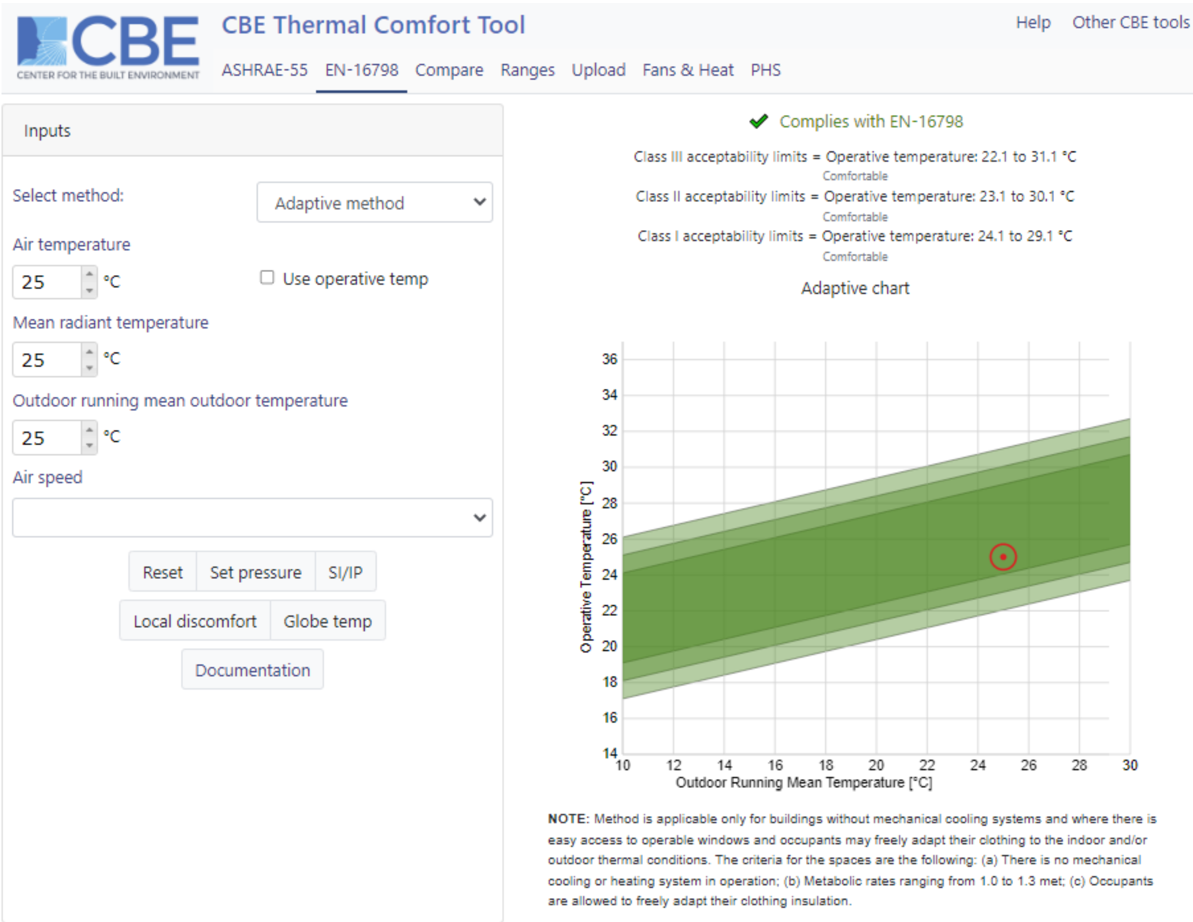


Figure 41 A screenshot of the CBE Thermal Comfort Tool

8.2 The Psychrometric Chart by A. Marsh

The Psychrometric Chart by Andrew Marsh [176] is a web app which displays a psychrometric chart on which you can overlay a range of comfort metrics and psychrometric process lines, as well as loading and viewing EnergyPlus/OpenStudio weather data (.EPW) and output files (.CSV). This tool offer the possibility to evaluate appropriate strategies according to the analysed weather file.

Figure 42 reports an example obtained from the online application, considering the weather of Dakar, Senegal. Once uploading the weather data file in .epw format into the browser window containing the psychrometric chart, you can display the data using a grid, as individual hourly data points, as monthly min/max lines or as a daily outline. In this case individual hourly data points are shown.

When you have data displayed, you can overlay a range of comfort information on top of it which help to identify the most appropriate design responses for that climate. One of the best tools for this is the Givoni-Milne Bioclimatic Chart (as reported in Figure 42) which shows potential extensions of the comfort zone resulting from building design characteristics such as cooling and ventilation strategies, solar gains or the use of internal thermal mass.

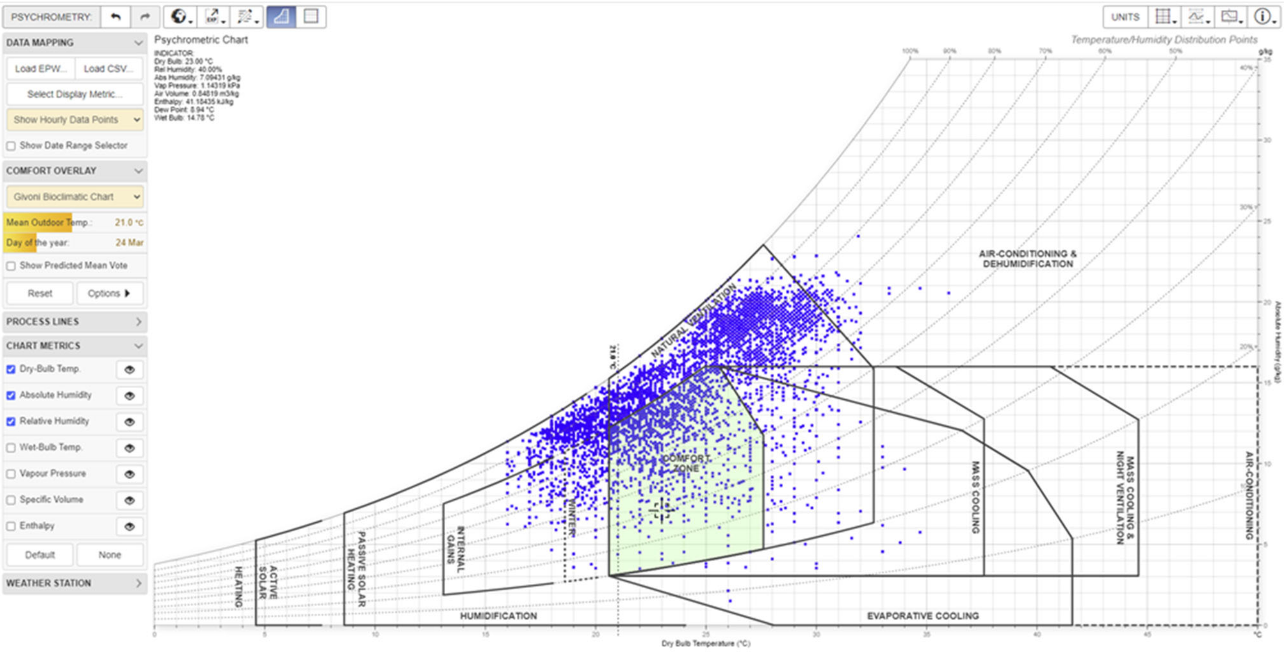


Figure 42 A screenshot of the Psychrometric Chart app by A. Marsh: bioclimatic strategies according to the Givoni bioclimatic chart

8.3 The CBE Ceiling Fan Design Tool

The CBE Fan Tool [177] allows designers to quickly select and layout ceiling fans in a room to meet their desired airspeed requirements, and to facilitate incorporation of fans into designs.

As discussed in chapter 3, having the ability to increase the air speed with fans provides benefits in terms of occupant comfort besides energy efficiency and perceived air quality. Ceiling fans increase air speed, and increased air speed accelerates convection and evaporation. Thus, ceiling fans accelerate heat loss from the body, providing a cooling sensation. The cooling sensation from increased air speed allows the body to maintain thermal comfort at higher air temperatures than what would be comfortable in still air.

The tool allows users to input room dimensions, design air speed ranges, and other parameters to determine optimal ceiling fan placement. The tool includes characteristics for a range of default ceiling fan options, or users can input specific details of other ceiling fan models to determine appropriate layouts. In addition to providing recommended fan layouts, the tool provides estimate for airspeeds (minimum, average, and maximum), cooling effect (minimum and maximum), and airspeed uniformity for each proposed layout, as shown in Figure 43. The tool also provides visualizations for the overall ceiling fan plan for the space, as well as ceiling fan "cell" plan and section showing details on airspeeds within each fan cell, and ideal mounting heights [79]. Additionally, it is available on online User Guide.

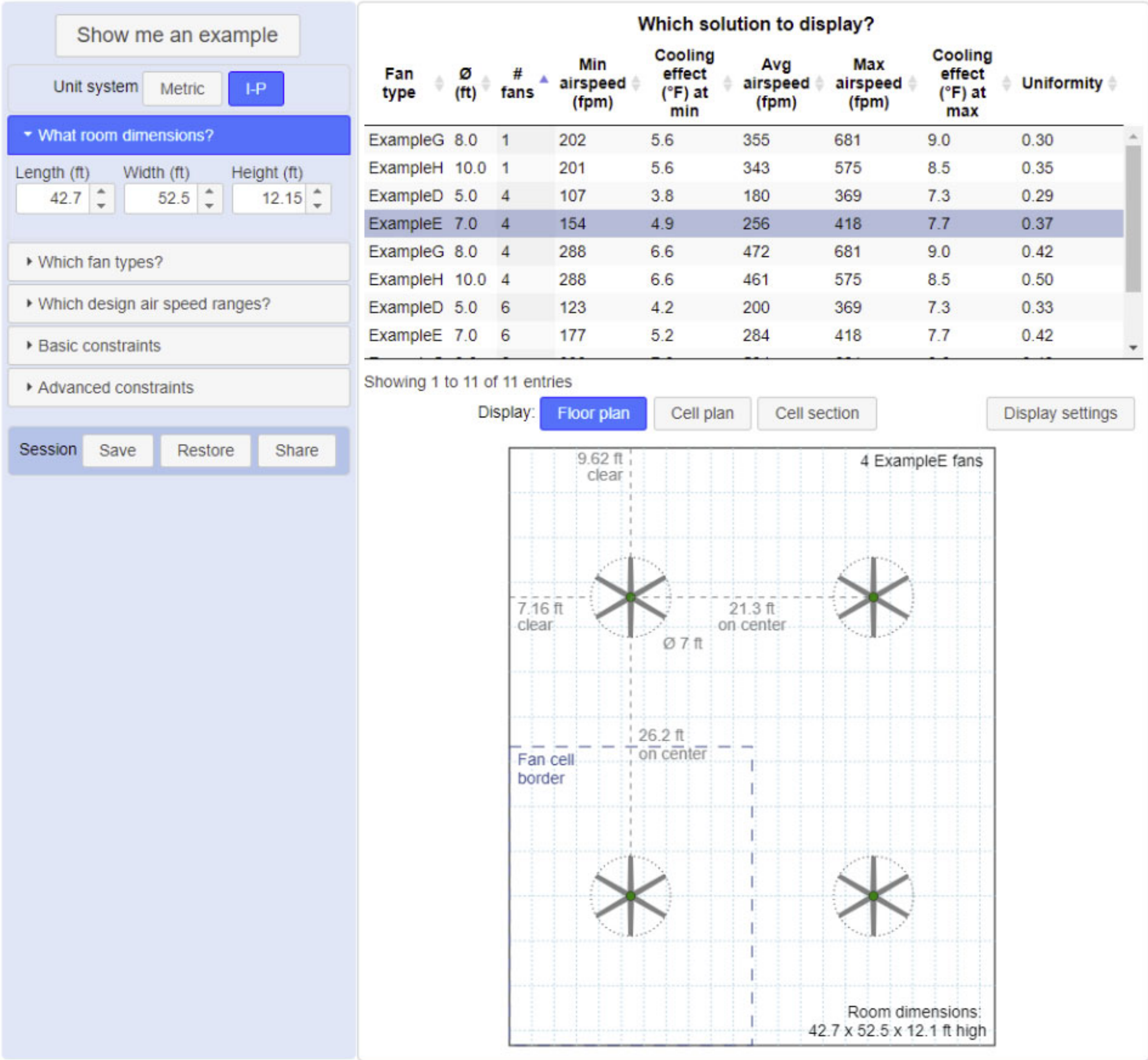


Figure 43 A screenshot of the CBE Fan Tool

8.4 SunCalc

SunCalc is an online application that shows sun movement and sunlight phases during the given day at the given location. You can see sun positions at sunrise, specified time and sunset. The thin orange curve is the current sun trajectory, and the yellow area around is the variation of sun trajectories during the year. The closer a point is to the center, the higher is the sun above the horizon. The colors on the time slider above show sunlight coverage during the day (Figure 44).

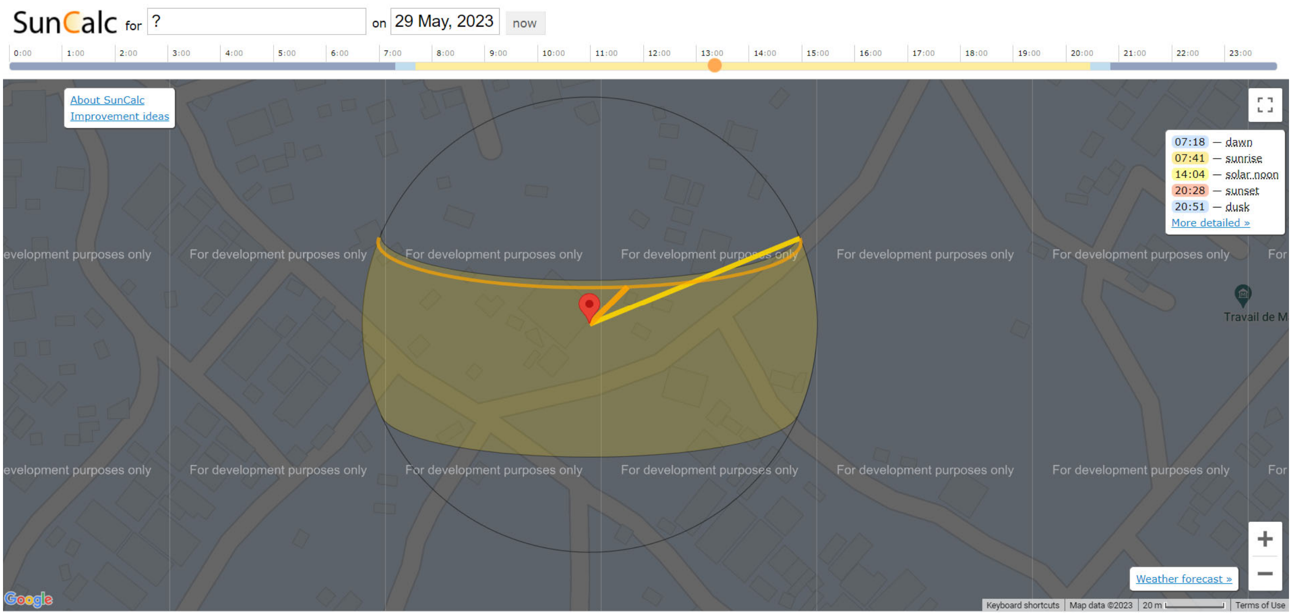


Figure 44 A screenshot of the SunCalc tool

8.5 Ubakus

Ubakus is an online tool which allows to calculate the stationary thermal transmittance (between two zone with air at constant temperature, eg outdoor an indoor) of building elements composed of several layers starting from a large library of materials (Figure 45).

It also provides:

- the attenuation and phase shift of the heat wave going from the outside surface to the inside one under the action of periodic input,
- the risk of surface and interstitial condensation,
- and the environmental impact of the selected materials

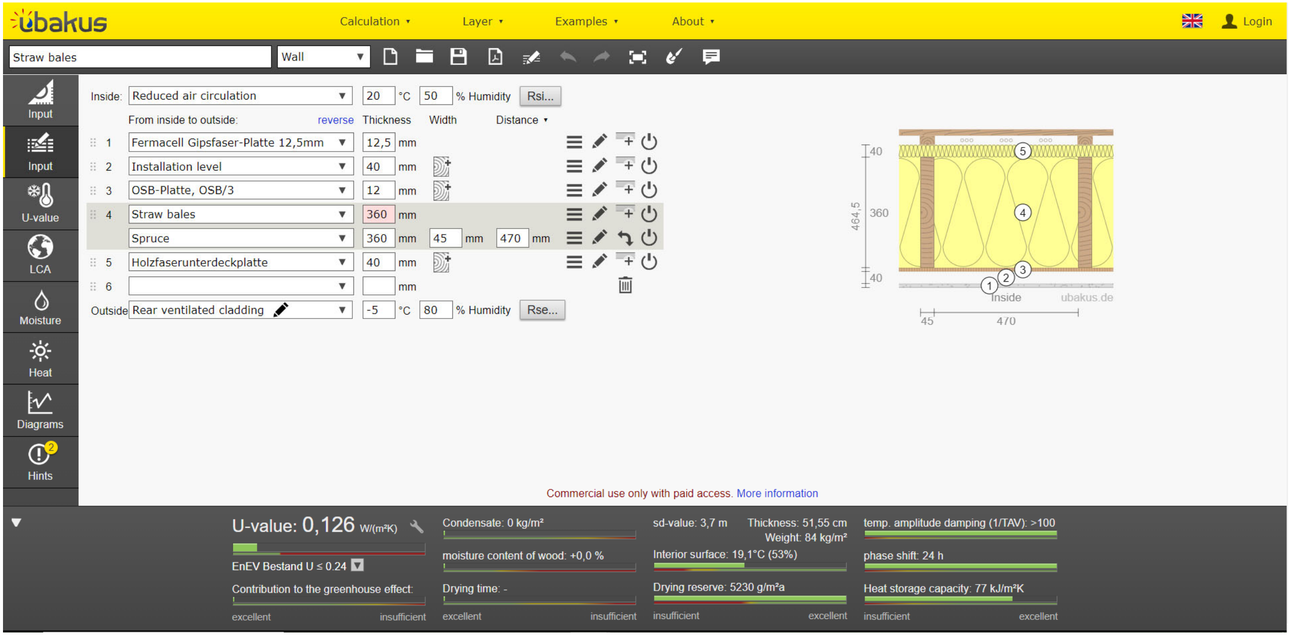


Figure 45 A screenshot of the ubakus tool

9. Review of available simulation tools in N-W Africa with suggestions for their development

Since different levels of detail characterize the building design, models with different levels of detail will also be needed. Natural ventilation performance is highly related to building design. Finally, in the detailed design phase and the design evaluation phase, detailed computational models should be used.

9.1 Early stage modelling tools

Simplified models are key in the early design phases. Specifically, the conceptual and basic design phases, to calculate the existing thermal requirements and explore different design solutions. These models enable key decision-making in these early design phases.

9.1.1 Monozone Models

These simulation tools use only one zone with internal temperature and pressure to represent the whole or part of the building. These simplified models allow an understanding of the thermal behaviour of the zone under study and the airflows that result from the interaction of this zone with the exterior. **NatVent** [178] is an example of a simplified design tool developed for office buildings. This tool is only compatible with the Windows operating system. It is a software that calculates the airflow rates and the temperature of the area under study. However, it is not possible to implement any control strategy for the NV system. In order to optimize the design of the interior spaces of a building, the Laboratory of Urban Architecture and Energy Reflection (LAURE/EPFL) developed the software **DIAL+suite** [179] that evaluates the impact of daylighting and natural ventilation on the thermal behaviour of the area under study. This tool uses the outdoor-indoor temperature difference, the area and the location of the opening to calculate the airflow rates resulting from a natural ventilation system. Unlike NatVent, this tool allows the introduction of some control strategies. It also allows to calculate the cooling needs and the airflow rates required to achieve the defined user comfort levels.

9.1.2 Multizone Models

These simulation models allow the building to be represented in more than one zone, enabling the first analysis of airflows, infiltration and natural ventilation resulting from the type of openings chosen. Developing a user-friendly tool for simulating the building thermal behaviour is vital in the early design stages. In this regard, the Massachusetts Institute of Technology (MIT) has developed a NV system design tool called **CoolVent** [180], which allows the comparison of different NV system configurations. **SUNREL** [181] and **CONTAM** [182] are other tools that allow a simplified simulation of the building's energy consumption. The National Renewable Energy Laboratory (NREL) developed the first one to enable a simplified calculation of the HVAC needs. The second tool mentioned was developed by the National Institute of Standards and Technology (NIST) and allows the calculation of the airflow required to achieve the set targets, the variation of airflow during building operation, infiltration rates and indoor air quality.

9.2 Detailed Modelling Tools

Several models have been developed to determine airflows in buildings. Most of these models allow the coupling to building thermal simulation models, thus allowing the modelling of the interactions of airflow with the thermal behaviour of the building.

9.2.1 Computational Fluid Dynamics

CFD has been widely used for airflow analysis in naturally ventilated buildings [183]. CFD uses the Navier-Stokes equations to calculate the dynamic properties and motion of the airflow. The building or area under study is divided into control volumes, and the equations are solved for each control volume on the mesh created. This tool can calculate the distribution of air velocity, temperature and pressure in the area under study, so it is of particular interest to study the effectiveness of various parameters such as the type and area of the opening, its configuration, the type of ventilation and the orientation of the building [69]. These computer simulations require a high computational capacity, and the accuracy of the results is highly dependent on high technical knowledge through the quality of the grid used and the definition of the correct boundary conditions. Several studies [184] demonstrate the reliability of this tool in the simulation of airflows in natural ventilated buildings with different natural ventilation strategies. Still, CFD has some problems reproducing complex turbulent flows [69]. The ability of CFD to simulate with high accuracy several parameters during the design phase makes this software a fundamental tool in designing a VC system. Thus, the main applications of this simulation tool in the design of a NV system are the calculation of the indoor air temperature and air velocity on the mesh created for the space under study, the calculation of the wind-induced pressure distribution and the discharge coefficients for the type of openings used. CFD simulations are usually used only during the detailed design phase and in the design evaluation phase, given the time-consuming calculation and the high dependence on the correct boundary conditions. Using this software in an earlier design phase will be counterproductive. Most CFD simulation tools are commercial, and ANSYS Fluent is the most widely used.

9.2.2 Building Energy Simulation Tools

Assessing the building's ***energy needs for heating and cooling*** requires estimating all relevant energy flows that describe its thermal behaviour and operation. This involves defining the geometry, orientation, shading types, openings and their operation control strategy, physical elements that delimit the indoor air volume of each room/thermal zone, the occupancy and equipment usage profile, the required air flow rates for IAQ, the airtightness of the envelope, the presence and performance of heat recovery on ventilation. Reducing energy needs is the first and more effective step and it is mostly influenced by choices at the pre-design stage, pior to detailed calculations might be performed. Simulations might allow to confiim and optimize the choices made at pre-design stage.

As second step delivered energy an primary nergy may be calculated, by additionally describing the technical systems responsible for air conditioning, ventilation and lighting. Creating a model that describes the operation of a building is of some complexity, especially because the heat transfer phenomena are transient. These are described by differential equations and are associated with the thermal inertia effect of the materials that make up the room's envelope.

There are different tools for developing a Building Energy Simulation model. According to a survey made to engineers and architects [185], the most used software for building geometrical modelling are Sketch up [186], Autodesk Revit [187] and Rhino [188]. According to this survey, EnergyPlus [189] and eQUEST [190] are the most used tools for BES, followed by DesignBuilder [191].

EnergyPlus® is a software that allows the dynamic simulation of a building, applying the basic principles of heat transfer, to obtain the *energy needs for heating and cooling* [192]. Care should be taken to the fact that energyplus does not comply with the nomenclature of International Standards (e.g EN-ISO 52000). *Energy needs for heating and cooling* are labelled as "ideal loads" in the IDF file and as "District heating and cooling" in the output Html file.

In Africa, where energy demand is increasing and access to energy is limited in some regions, these tools can play a critical role in promoting energy efficiency and reducing energy costs. In this review, we will explore some examples of building energy simulation tools that have been used in Africa. The first subsection focuses on the Batipei 3.4 software, the second subsection examines the RETSEN tool, and finally the third subsection looks at the CLIP tool. Each of these subsections provides an overview of the features and applications of these tools in different contexts in Africa.

9.2.2.1 Batipei 3.4

Batipei 3.4 is a dynamic thermal simulation software developed by Solener. It is aimed at individuals, architects, building engineers and, in general, all construction professionals. The purpose of this software is divided into five parts:

1. Information: Provide useful information for designing with the environment (e.g., direction of prevailing winds, annual local climate).
2. Comfort: Evaluate the thermal comfort in the simulated space, through:
    1. Average overheating (static or dynamic)
    2. The number of hours above a threshold temperature (example: 30 ° C)
    3. The diagram of the humid air of Givoni (taking into account the hygrothermal aspect)
3. Natural air conditioning: Simulate the natural ventilation of a space to deduce the air renewal (hourly, daily, annual)
4. Artificial air conditioning: Simulate the action of an air conditioner / heating on comfort or size an air conditioner for the area to be treated (and deduce the operating cost and its impact on CO_2 emissions)
5. Efficiency requirements: Publish a summary report of the project's compliance with parameterized requirements (solar factor, façade porosity,...).

There is an abundance of dynamic thermal simulation software on the market. Batipei stands out for being more accessible (free and supported by widely used software), easier to use (modelling of a surface and reduced amount of information to enter) and specialised in the problems of countries with hot and humid climates.

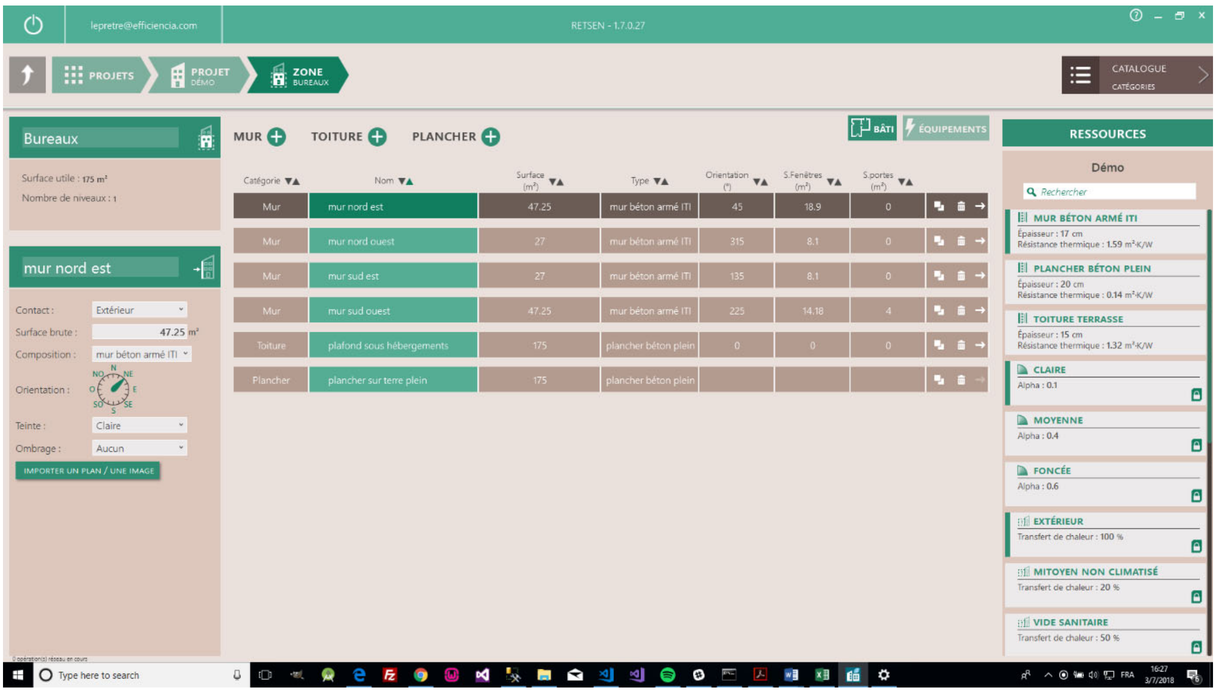
Before using the Batipei application, it is important to carry out a description of the building to be simulated:

1. Dimensions: Measure all the dimensions of the building (living area, facades, roofs, windows, doors – including the proportion of glazed part)
2. Composition of the envelope: know all the components (and thicknesses) of the opaque walls (vertical and horizontal) as well as the materials of the joinery and the types of glazing.
3. Orientation: Locate the building in space by assessing the orientation of each façade and constructing a relief diagram of the building's surroundings (using a camera or specialized instrument)
4. Internal inputs: Make a list of all sources of internal input and their radiative/convective energy emission as well as their wet inputs (humans, plants, machines, ...)
5. Schedules: Establish daily and weekly schedules of occupation, operation of internal inputs and use of sun protection.
6. Designation: If the building to be modeled is complex, it may be preferable to give a clear designation to each element (bays, walls, roofs, internal inputs etc ...) in order to recognize them more easily (example: "South wall to garden", "Kitchen swing window".

9.2.2.2 RETSEN

RETSEN is a tool for calculating and simulating the energy performance of buildings (Figure 46). Its users are architects and engineers in the design of buildings and the administrations responsible for issuing building permits in Senegal. This tool is the basis for the development and implementation of thermal regulations in Senegal.

It was developed as part of the PNEEB/TYPHA project and is used by architects and engineers during the design of buildings to select, from a predefined and modifiable list, the elements to which they can have access in order to comply with the regulations in force. Similarly, during the study and validation of building permits, it allows government officials to verify the compliance of projects with existing regulations.



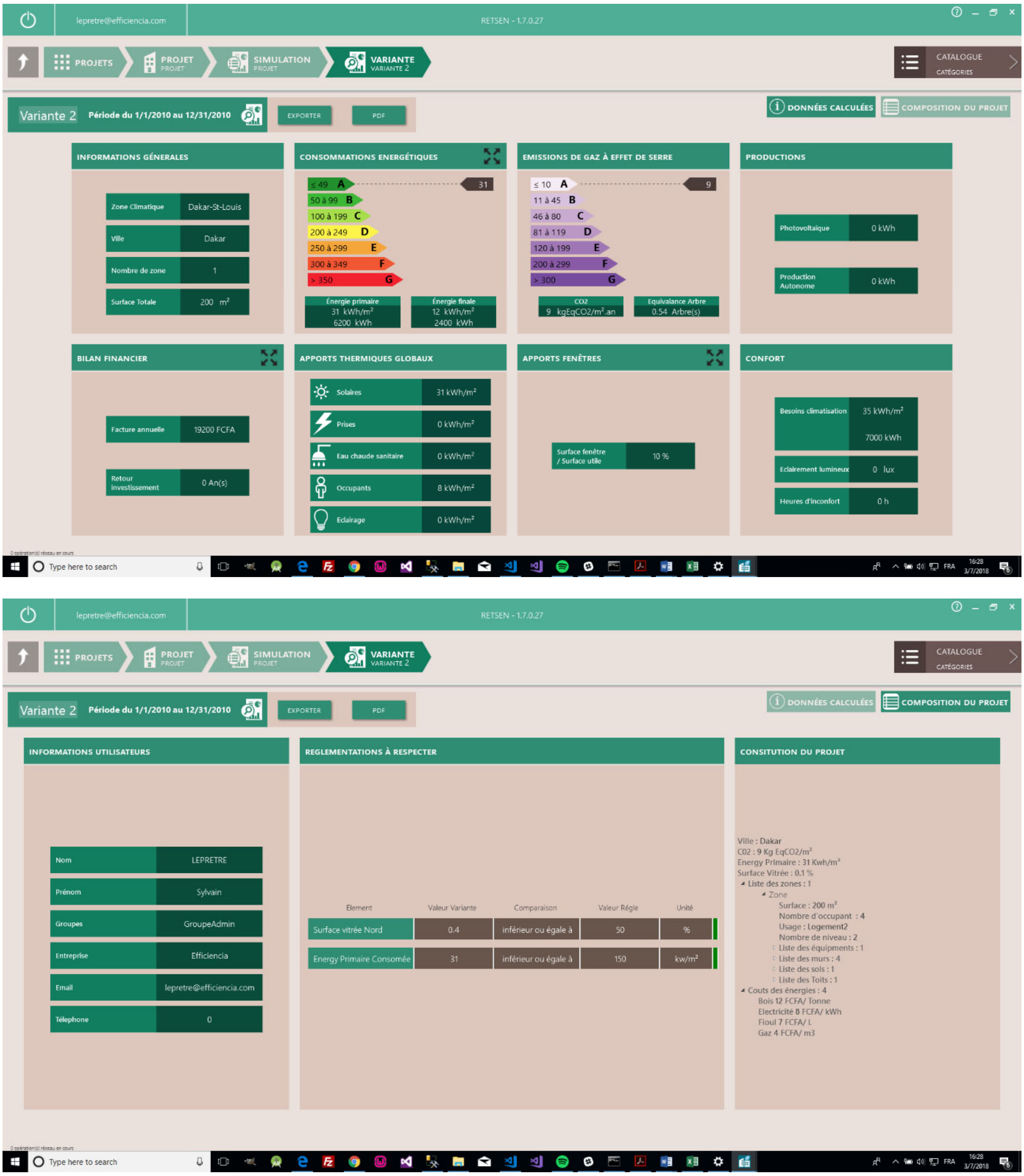


Figure 46 Screenshots of the RETSEN tool

9.2.2.3 CLIP

CLIP is a simplified software developed in Tunisia. It is useful for the design of offices and individual houses. The options are limited and give little design freedom. Their calculation methods are generally based on so-called "static" modelling (heating and cooling degree-hours).

The results have limited reliability. Related to the simplicity of the software Clip has evolved a lot at the moment.

9.2.3 Coupled CFD-BES models

A common approach is to couple CFD with BES models to increase the accuracy of natural ventilation impacts on the building's thermal behaviour [69]. This combination of tools is critical for thermal comfort assessments and determining the thermal energy consumption required to maintain desired comfort conditions. Several studies have already demonstrated that coupling CFD with a BES model allows for achieving predictions closer to reality [193,194]. According to [195,196], this coupling of tools allows a better definition of the boundary conditions in CFD and a prediction with greater accuracy of the building's thermal behaviour and energy consumption in BES tools. Carrilho da Graça et al. [197] defined a procedure using CFD for airflow prediction. The results were used to establish the boundary conditions for the BES model. The following figure represents the method developed by the author.

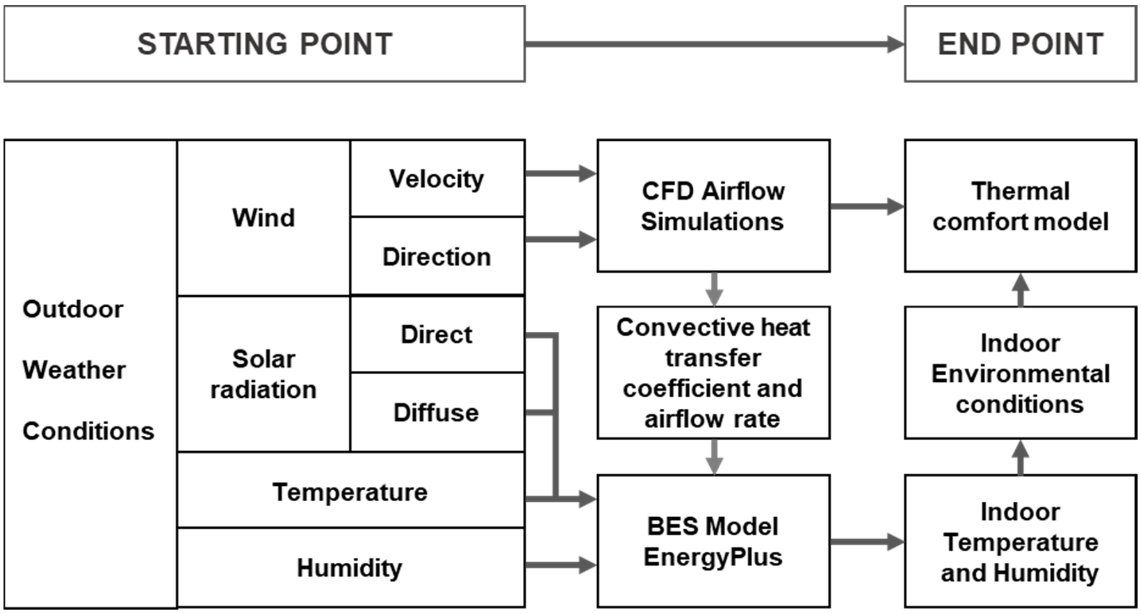


Figure 47 The structure of the BES program coupled with CFD.

10. Examples of integrated Strategies

In literature, various qualitative definitions of bioclimatic architecture can be found. A rather detailed one, for hot regions, is proposed by Givoni [8], according to whom *bioclimatic architecture* in hot regions involves architectural design and choice of materials aiming at providing comfort while minimizing the demand for energy used to cool a building.

It involves minimizing heat gain by the building, minimizing solar heating of the envelope and solar penetration through windows, providing comfort by natural ventilation, and so on.

To achieve these aims, different architectural means need to be properly designed: the layout of the building, 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 average diurnal outdoor temperature.

Givoni provides also a definition for *passive cooling systems*, which are reported as the input of cooling energy through the use of natural renewable sources to lower the indoor average temperature below the outdoor level.

Proper architectural bioclimatic design in a region with hot climate can be thus considered as a precondition for the application of passive cooling systems, and the two approaches supplement and reinforce one another.

Givoni classifies *passive cooling systems* as:

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

We offer in the following examples of application of both *bioclimatic architecture* and *passive cooling systems* through a series of examples and lessons learned.

1. MAIN STRATEGY: Solar protection (1)

Name of the strategy

2. DESCRIPTION

Among the basic strategies of Bioclimatic architecture according to Givoni there is heat avoidance though shading and light colors ,to moderate the raise of temperature in the building over external average temperature. After this step accomplished passive cooling strategies can take place to reduce indoor temperature below the external average. To be effective, shading requires an understanding of the solar geometry. The type, size and location of a shading device will, therefore, depend in part on the size of the direct, diffuse, and reflected components of the solar irradiance. External solar protections are essential to effectively control the unwanted heat gains. Internal devices convert solar radiation into thermal energy when it is already inside the building and can't escape anymore. (Alaydrus, Wizaka, & Pawata, 2021)

Short description

3. TOOLS

- https://andrewmarsh.com/apps/staging/shading-box.html
- www.sunearthtools.com
- http://suncalc.net/
- www.googleearth.com

Main implemented tools

4. MAIN SOLUTIONS SET UP

- The architect used the combined strategy of a fixed overhang which protects from mostly almost vertical solar radiation, whereas the quasi-horizontal rays are filtered by a porous skin of eucalyptus wood. As a second filter, the openings of the classrooms are equipped with a movable louver, which blocks any remaining direct light beam, while acting as a light shelf for daylighting. (Fig. 1)

- The shading strategy is firstly provided by the arrangement of the buildings. Secondly, the corridors are set as a solar barrier for the classrooms since the overhang blocks the sun penetration during the hottest hours of the year while allowing some internal gains during winter. The north façade is provided with awnings that block the sun rays from the hot season. (Fig. 2)

- The façade of the building consists of a continuous louver that blocks solar penetration towards indoor spaces, while providing good quality of daylighting through the light shelf strategy. The shading strategy is

A. EXEMPLARY CASE STUDIES

Burkina Institute of Technology	Koudougou, Burkina Faso
Name	Location

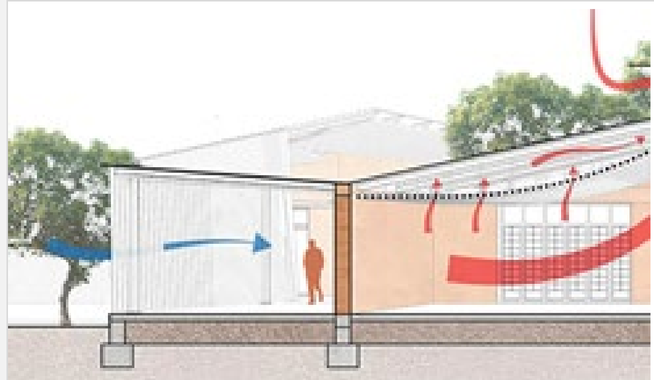


Figure 1: Cross section of the passive solutions.
Project by: Kéré Architecture

B.

Lycée Jean Mermoz	Dakar, Senegal.
Name	Location

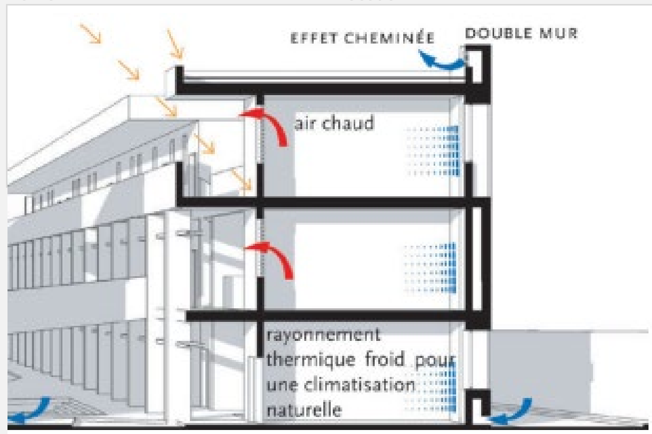
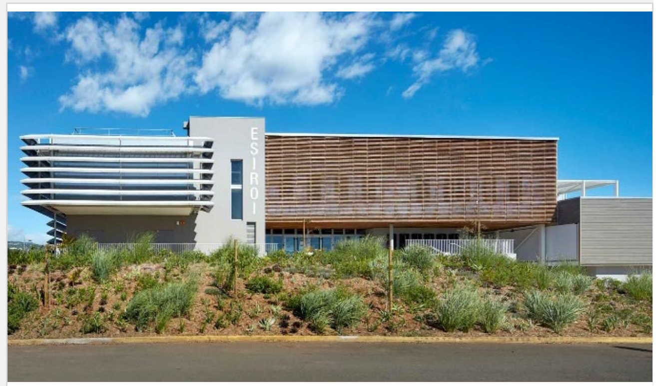


Figure 2: Section showing the shading strategy through the overhang.
Project by: Terreneuve Architects

C.

Esiroi building	Saint-Pierre, La reunion
Name	Location



used in this case as the main architectonic feature of the façade. (Fig. 3)

Short description

Figure 3: Picture of the louver facade.
Project by: LabReunion

5. COMPLEMENTARY SOLUTIONS

- In this project, the use of inner courtyards provides shadow and natural ventilation while offering additional quality spaces. In the roof, a steel Pergola covered by straw allow the use of the space during the hot hours of the day. (Fig. 4).
- A street in the medieval Medina of Fes, Morocco. Narrow streets allow shading of buildings with each other, and the wood canopy on top completes the solar protection arrangement without blocking air circulation (Fig. 5), Photo L.Pagliano

Short description

D.	Maison des Yvelines	Ourossogui, Senegal
	Name	Location

Medina of Fes Morocco

Figure 5: A street in the medieval Medina of Fes, Morocco.

6. STRENGHTS

- Passive Design
- Energy Efficiency
- Adaptability
- Reliability
- Optimal arrangement of buildings

7. WEAKNESSES

- Material’s durability

Positive facts

Negative facts

8. LESSON LEARNED AND RECOMMENDATIONS

- Burkina Institute of Technology. -The use of a combination of systems offers reliability in the most adverse orientations, such as west facing facades.
- Lycée Jean Mermoz. – When the heat avoidance concern is considered since the early phases of the design, the shading strategy can be achieved through livable spaces, such as the balconies of this school, that protect the classrooms from the sunrays while providing a space for informal social meetings.
- Burkina Institute of Technology. -The use of vegetation helps the building to control the wind and reduce the solar influence in inner spaces.
- Maison des Yvelines. – The integration of small gardens within the building plays a key role in the achievement of comfort zone. This strategy helps to considerably decrease the inner spaces temperature.
- Most of the buildings complement the solar protection strategy with other passive strategies. Considering even the urban layout or the vegetation integration.
- Burkina Institute of Technology. – The structure detachment of the roof helps to free the shape of it. This way, such an important element in the building can have the most efficient shape for the benefit of users and their comfort.

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1. MAIN STRATEGY: Solar protection (2)

Name of the strategy

2. DESCRIPTION

In a building, whether it is air-conditioned or not, one of the main goals that the designer must consider is to control direct solar radiation to ensure thermal comfort, daylight and minimization of energy consumption.

The ideal sun-shading device will block solar radiation while allowing daylight and breeze to enter the window, and an external view.

Shading is related primarily to the direct component of radiation, while the diffuse and reflected components (unless the latter is mirrored), which propagate in an almost isotropic way, are much less involved.

Short description

3. TOOLS

- http://andrewmarsh.com/software/shading-box-web/
- https://susdesign.com/overhang_annual/index.php
- www.sunearthtools.com
- www.googleearth.com

Main implemented tools

4. MAIN SOLUTIONS SET UP

- All the classrooms are shaded with venetian blinds. The light colour of the sunshades affects light and heat: in such respect they enhance the diffusion solar radiation to be transmitted decreasing also the light colour temperature, in order to have a better visual comfort. (Fig. 1)
- The choice of the shading devices materials and their color strongly affect the performance of the building: they should be characterized by light color in order to reduce their solar absorption and thus reducing the re-radiation towards the interior space. Otherwise they can be painted with low-e finishing (Fig. 2)
- The use fixed systems allows to reduce the cost if the budget is limited. However, if possible, it is better to adopt movable systems in order to allow a more efficient use of natural light and natural ventilation. The use of such devices do not hinder natural ventilation, provide security against intrusions, and allow natural ventilation at night, when required (Fig. 3).

Short description

A. EXEMPLARY CASE STUDIES

Name	Location
Secondary school	Dano, Burkina Faso

Figure 1: Open windows on the façade © Kéré Architecture

B.

Name	Location
Enerpos	Reunion island.

Figure 2: Detail of the fixed shading devices. © Jérôme Balleydier

C.

Name	Location
Lycée Schorge	Koudougou, Burkina Faso

Figure 3: Shading devices

5. COMPLEMENTARY SOLUTIONS

- The “light shelf” is a way to facilitate the penetration of light into a room, designed to provide shade, to diffuse light more evenly in the room and to protect from direct glare. Orientation, position, type and depth of a light shelf is always a compromise between the needs for natural light and sun protection (Fig. 4).
- The minimum depth of an external light shelf is determined by the shading requirements; the deeper the shelf, the better it shades the window below, preventing the penetration of direct radiation, which causes glare and solar gains.

Short description

D. Zero Energy Office (ZEO) | Malaysia

Name | Location

Figure 4: Detail of the lightshelf

6. STRENGHTS

- Visual comfort
- Energy Efficiency
- Local materials
- Avoid Glare

Positive facts

7. WEAKNESSES

- Materials’ durability
- Maintenance
- Specific design skills
- Installation cost and complexity

Negative facts

8. LESSON LEARNED AND RECOMMENDATIONS

- Dano Secondary School -The use of shading system affects not only the energy consumption but also the visual comfort for the use. They avoid glare and allow a more comfortable color temperature of the light.
- Erpos – External solar shading made of wooden strips was installed on the north and south façades of the building to prevent direct glare inside the rooms and to reduce the temperature of these walls. The use of local materials allow to reduce the energy impact of the building.
- Lycée Schorge - A secondary façade made of local eucalyptus wood wraps around the classrooms like a transparent fabric and creates a variety of shaded intermediary spaces between itself and the classrooms where students can gather informally to wait for their classes. The interior shading devices allow to manage and modulate the light entering from the outside.
- Zero Energy Office – Light shelves have a considerable impact on the architectural design of the building and must be taken into account at the early stages of the design process, because, to be effective, they also require relatively high ceilings; they should be designed specifically for each orientation of the window, room configuration and latitude. They are especially suitable for climates with high sunshine levels on windows facing south or north in near equatorial latitudes

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[2] “Kéré: Work.” Kéré | Work. Accessed April 11, 2023. https://www.kerearchitecture.com/work/building/lycee-schorge

[3] “Kéré: Work.” Kéré | Work. Accessed April 11, 2023. https://www.kerearchitecture.com/work/building/dano-secondary-school

1. MAIN STRATEGY: Comfort ventilation: natural cross ventilation / stack effect / combination of the two.

Name of the strategy

2. DESCRIPTION

When the indoor temperature, under still air conditions, seems to be too warm to occupants, it is possible to provide comfort through higher indoor air velocity, as seen in the previous chapter. This can be achieved via natural ventilation through the windows and/or other openings. This enhanced velocity, improving heat exchange by convection and evaporation form skin, can provide a direct physiological cooling effect even if outdoor air is rather warm, up to about 30 C. Hence the name of "*comfort ventilation*". It is useful to adopt this strategy only when indoor comfort can be experienced at outdoor air temperature (with acceptable indoor air speed). Alternatively, if conditions are not favourable for opening windows, increased air velocity can be provided by well-designed and positioned ceiling fans, standing fans, desk fans.

Short description

3. TOOLS

- http://coolvent.mit.edu/
- https://centerforthebuiltenvironment.github.io/fan-tool/ for dimensioning ceiling fans

Main implemented tools

4. MAIN SOLUTIONS SET UP

- All the classrooms and offices are naturally ventilated. This was made possible thanks to the design of a simple, elongated, and thin building form, the optimal orientation of the building, the general interior organization of the classrooms as well as the use of full-height glass louvers located on opposite facades, with a high porosity. (Fig. 1)
- Different passive features have been implemented in order to ensure that the interior spaces would be cooled naturally. Firstly, the louvered shutters installed on opposite facades enhance natural cross ventilation. In addition, wind-catching towers planted on top of the classrooms allow the air to flow in out of the rooms. (Fig. 2)
- The modules are placed in a staggered formation to enhance airflow in and around the building.
  The large and adjustable wood louvers present on the walls allow the buildings to be naturally ventilated. In

A. EXEMPLARY CASE STUDIES

Aime Cesaire School	Saint-Pierre, La Réunion
Name	*Location*

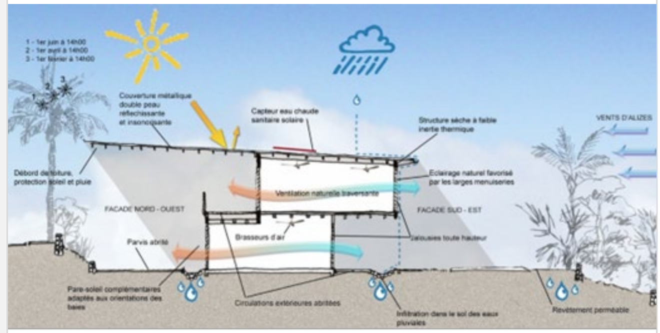

Figure 1: Cross section of the passive solutions set up for the school. Project by: Antoine PERRAU Architectures

B.

Lycée Schorge.	Koudougou, Burkina Faso.
Name	*Location*

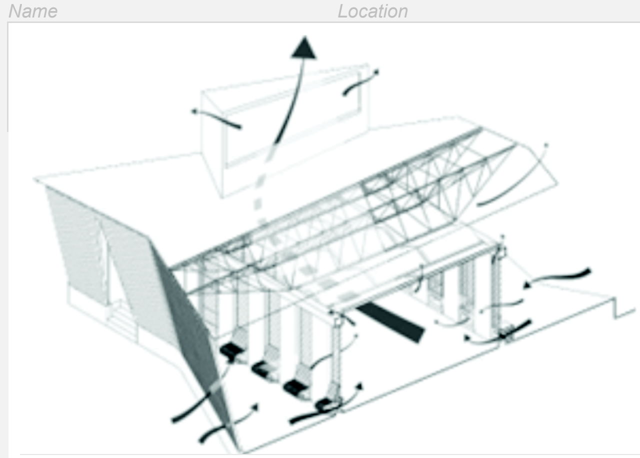

Figure 2: Climate diagram showing the natural ventilation principle. Project by: Kéré Architecture

C.

Burkina Institute of Technology	Koudougou, Burkina Faso.
Name	*Location*

addition, the rooftop openings are designed to release hot air through the stack effect. (Fig. 3)

Short description

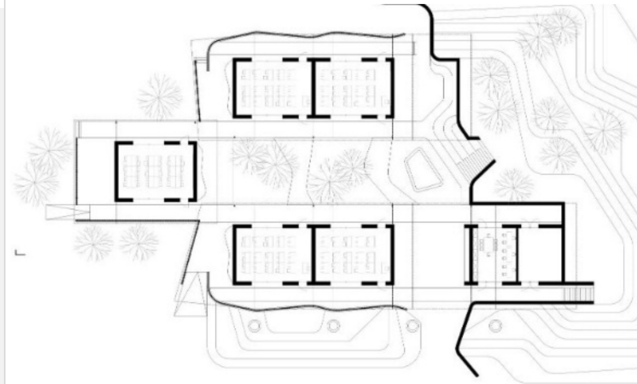

Figure 3: Section of the Burkina Institute of Technology.
Project by: Kéré Architecture

5. COMPLEMENTARY SOLUTIONS

- A total of 83 ceiling fans with a 132 cm blade diameter are installed in the offices, the classrooms, and the canteen. The use of ceiling fans guarantees additional air speed during windless days. They are used in conjunction with the natural ventilation strategy to create air movement on the skin of the occupants, increasing their comfort. The maximum power used for one ceiling fan is 70 W, with a ratio of one ceiling fan per 10-15 m². Ceiling fans have three speed levels and a maximum speed of 157 Rpm. (Fig. 4).

Short description

D. Aime Cesaire School	Saint-Pierre, La Réunion
Name	Location

Figure 4: All classrooms are naturally ventilated and equipped with efficient ceiling fans.
Project by: Antoine PERRAU Architectures

6. STRENGHTS

- Passive system
- Energy Efficiency
- Local materials
- Replicability

Positive facts

7. WEAKNESSES

- Materials' durability
- Cost of maintenance
- Building construction complexity

Negative facts

8. LESSON LEARNED AND RECOMMENDATIONS

- Lycée Schorge. -The architect showed that local materials can be successfully used within contemporary structures.
- Aime Cesaire School. – The solar shading devices are generally working well throughout the project, except for two kindergarten classrooms facing east that are exposed to direct solar radiation during the morning. Improvements should be considered to prevent morning overheating.
- Aime Cesaire School. – It is possible to use active systems for ensuring comfort zones for users. However, creating it without active systems should be a priority to avoid excessive energy consumption.
- Burkina Institute of Technology. – Although the applied strategies may seem to be complex, they can be easily applied by the local community, since it's based on basic guidelines for taking advantage of the local conditions.
- Aime Cesaire School. – The consideration of the landscape for influencing the building can be a key factor to make it work as a system in benefit of the building's energy performance.

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1. MAIN STRATEGY: Earth-Air Heat Exchanger

Name of the strategy

2. DESCRIPTION

The EAHE systems have a long history to achieve thermal comfort in an indoor environment. In general, the construction of the EAHE system consists mainly of pipes buried underground in a desirable depth where undisrupted ground temperature occurs.

Air is used as a working fluid to carry the heat and the ground serves as a heat source or sink thanks to its thermal capacity. The system has a simple working principle where active or passive means are employed to drive air into the system. As air passes through the piping system a heat transfer occurs between the air and the ground through convection and conduction, with direction depending on the season and is channeled to desired space.

Short description

3. TOOLS

- https://www.trnsys.com/index.html
- https://energyplus.net/
- Both codes include modules for modelling EAHE; the implemented code of both modules would benefit from further development and/or validation

Main implemented tools

4. MAIN SOLUTIONS SET UP

- Active or passive systems are employed to drive air into the system. In active systems, mechanical fans are employed to blow air and in passive systems wind catchers are used to drive air into the occupied zones in the building. As air passes through the piping system a heat transfer occurs between the air and the ground through convection and conduction, with direction depending on the season and is channeled to desired space.

- Pipe material is one of the parameters often discussed in literature for its effect on the heat transfer performance of the system. Initially, steel pipes were used in the system design for their high thermal conductivity. However, recent practice shows that plastic materials may offer a cheaper and long-life cycle alternative. Polypropylene (PP) is often suggested for the absence of harmful emissions and durability.

Short description

A. EXEMPLARY CASE STUDIES

EAHE system air inlet	Yukon, Canada
Name	Location

Figure 1: steel earth tube EAHE system air inlet [1]

B.

PVC pipes	Marrakesh, Morocco
Name	Location

Figure 2: PVC Earth-tubes installation [2]

C.

Aggelidis building	Athens, Greece
Name	Location

Figure 3: Point where the air from the earth tube is introduced in the building [4]

ABC21 is funded by the
EU's H2020 programme

5. COMPLEMENTARY SOLUTIONS

- The integration of EAHE systems with other passive and active systems is also common practice and it's called a hybrid EAHE system. The system can be coupled with conventional air conditioning systems, air source heat pumps, heat recovery units, evaporative cooling systems, building integrated photovoltaic systems, solar air heaters, solar chimneys, wind towers, and thermal mass or phase-changing materials.

Short description

D. Aggelidis building	Athens, Greece
Name	*Location*

Figure 4: Outdoor view of the Aggelidis paper warehouse building [4]

6. STRENGHTS

- Thermal comfort
- Energy Efficiency
- Local materials
- Space usage

Positive facts

7. WEAKNESSES

- Requires Maintenance, as other HVAC components
- Specific design skills
- Installation cost and complexity in case of renovation

Negative facts

8. LESSON LEARNED AND RECOMMENDATIONS

- Pressure drops recorded in the EAHE system can directly determine system energy demand. Determining the system pressure drop analytically in a system can be a challenging task as it accounts for every part of the system such as valves and fittings of the system.
- In EAHE system convective heat transfer phenomena play a more significant role than conduction. An increment in the length of the pipe shows, up to a certain point, a positive influence on the thermal performance of the system. Yet, the parameter required to meet constraints such as land coverage.
- Pipe diameter also has a similar effect as length where larger diameter tubes have better thermal performance. More number of pipes in parallel enhance the thermal performance of the system.
- Air velocity inside the tube, on the other hand, has a reverse relation with the thermal performance of the system. Even If the convection heat transfer coefficient of air increases with the velocity, the duration to which the system comes in contact with the pipe surface reduces. Therefore, more limited temperature rises along the tube may be obtained.

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1. MAIN STRATEGY: Natural and Hybrid Ventilation in tall buildings

Name of the strategy

2. DESCRIPTION

Natural ventilation promotes thermal comfort, health, and wellness and helps reduce operating and maintenance costs. Natural-ventilated buildings depict a broader spectrum of thermal comfort than mechanically ventilated-buildings. However, the effectiveness of natural ventilation is climate-sensitive, and incorporating this into a pre-existing project is often a complex process.

High-rise buildings are rarely designed using only natural ventilation due to the potential design risks associated with this strategy. Hence, the "mixed mode ventilation" design is more common in high-rise structures.

Geometrical features, such as building form, size, shape, and placement of windows on the facade, are central to implementing natural ventilation; hence, envelope design is crucial [1].

Short description

3. TOOLS

- http://coolvent.mit.edu/
- https://www.ohcow.on.ca/covid-19/ventilation-calculation-tool/#1636726803734-5e447b6e-34ec
- https://www.simscale.com/simulations/natural-ventilation/
- https://www.cfd-online.com/Tools/turbulence.php

Main implemented tools

4. MAIN SOLUTIONS SET UP

- The capacious terraces are engineered to ensure optimal ventilation even during the most sweltering weather conditions. The building's facade exhibits a seemingly arbitrary arrangement of square apertures; however, these openings function as windows and conduits for natural ventilation and are essential for mitigating the city's warm climate. The vegetation helps in cooling down the air before it enters the building (Fig. 1)
- The strategy for natural ventilation depends on cross-ventilation at each floor, which is caused by the stack effect in the one-meter-deep, double-skin western facade, which works as a thermal chimney. Along the east side of the building, louvers let in fresh air. Dampers at the top and bottom of the chimney make sure that the vent stays at the right temperature, which draws air out of the building. The wing roof has a big effect on the wind pattern because it generates a venturi effect and pushes the air upwards and out of the building. (Fig. 2)
- Venetian blinds control natural ventilation in a double-skin glass façade with a 1.2-m cavity. Doors and

EXEMPLARY CASE STUDIES

A. Tower 25 (White Walls) | Nicosia , Cyprus

Name | Location

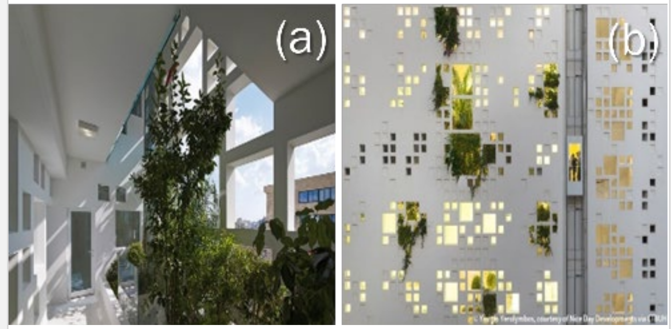


Figure 1: view of the façade perforation through openings and vegetation in the opening and balconies in Tower 25 © Keller[2]

B. GSW Headquarters | Berlin, Germany

Name | Location

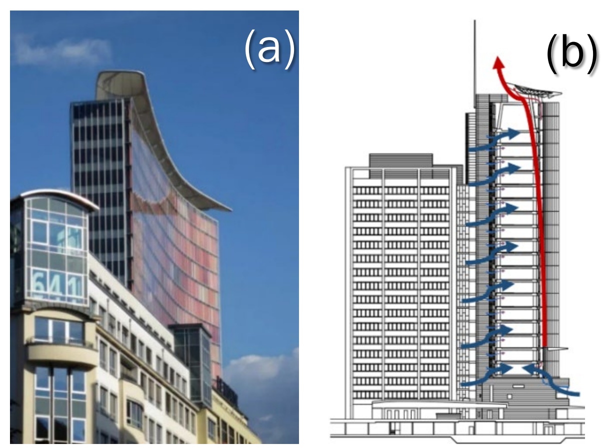
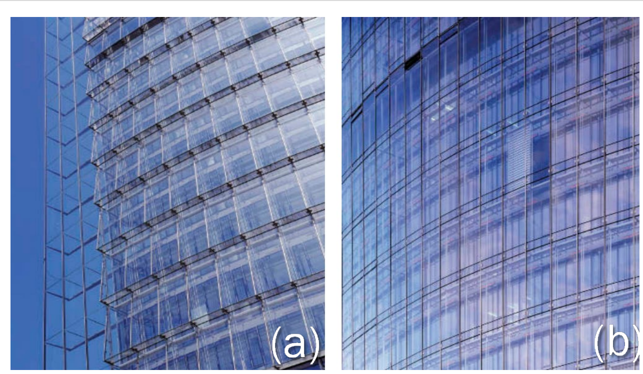


Figure 2: View of the Wing Roof which sits above the thermal flue on the west façade. © Janice Ninan, J-Space Studio[3]–[5]

C. Post Tower | Bonn, Germany

Name | Location



passageways bring air within the structure. The front north-facing windows are smooth, while the south-facing glass panes are gently sloped to improve airflow (Fig. 3). External air is pulled from the façades by a decentralised subsurface convector, conditioned, and fed back into the offices. Office air is cooled down by the Sky Gardens and is filtered out through façade flaps on the east and west sides.

- The air cavity, also called the "Pressure Ring," keeps a ring of constant positive pressure around the building. This is a unique trait of the double-skin facade. The building management system (BMS) keeps track of and controls how the coloured flaps are positioned and moved. This is how the constant positive pressure is made possible. The shape of the building was chosen to help it deal with weather, wind, and climate problems. The building's form and orientation take into account things like high wind pressure and how it works with buildings around it (Fig. 4)

Short description

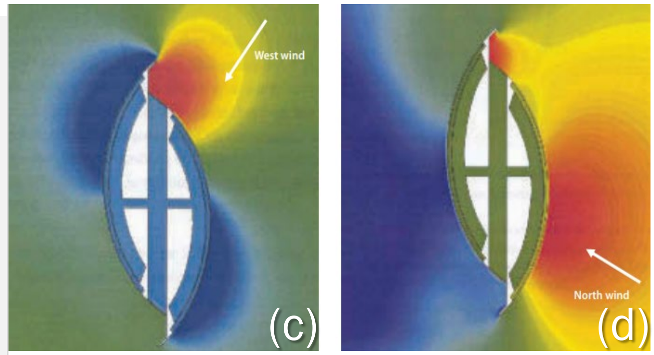


Figure 3: a) and b) View of the north facing windows which are smooth, and south windows which are slopped © Murphy/Jahn Architects
c and d)CFD model showing the effect of wing wall © Transsolar [3]

5. COMPLEMENTARY SOLUTIONS

- The facade's double-skin automatic coloured panels form a cavity for solar heat gain and natural lighting. An integrated sealing system and low-energy building technique inside the wall allow natural east-to-west cross ventilation through interior spaces and specially built corridor apertures.
- West facade louvres lower artificial heating and cooling. Colours mattered.
- A second layer of glass in west facase distributes hot, stagnant air. The double façade dampens sound and temperature (Fig. 2).
- The double-façade's outer layer extends beyond the building to create 'Wing Walls' (at the east end of the north façade and the west end of the south) that assist the building's aerodynamics and natural ventilation. CFD simulations reveal that Wing Walls produce pressure differentials across opposite sky garden façades to promote natural cross-ventilation across the atria. (Fig. 3)

Short description

D.

Kfw Westarkade	Frankfurt, Germany
Name	Location

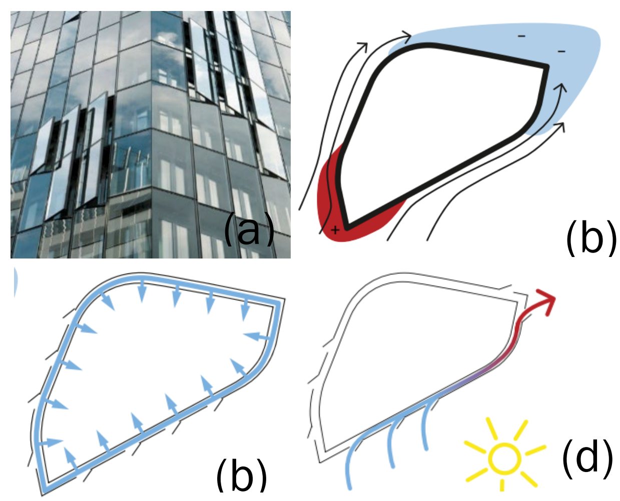


Figure 4: a)operable flaps, b) Aerodynamic shape and prevailing winds, c)aircavity making a pressure ring around the building, d) Windflow around the cavity ring in hot day ©sauerbruch hutton [6]

6. STRENGTHS

- Constant air exchange due to the natural ventilation system
- Thermal comfort
- Energy conservation
- Local and eco-friendly materials
- Water conservation
- Reuse and Recycling of materials

Positive facts

7. WEAKNESSES

- Monitoring the airstream direction
- High dependency on climatic conditions
- air contamination, insect vectors, noise, and security issues
- Maintenance of hybrid system

Negative facts

8. LESSONS LEARNED AND RECOMMENDATIONS

- **Tower 25 (White Walls)**- Certain level of perforation coupled with vegetation helps improving the natural ventilation by reducing the temperature of air and improving airflow patterns.
- **GSW Headquarters**- The "wing roof" blocks downstream wind. It channels stack effect-induced airflow out of the building.
- **Post Tower-** Wing Walls provide pressure differentials at each sky garden façade to promote natural cross ventilation in these central zones. Double-skin façades save energy by allowing natural convection process. Sky Gardens help reducing the air temperature and channelize them.
- **Kfw Westarkade-** In naturally ventilated buildings with operable windows, pressure variations on the windward and leeward sides can cause too much cross-ventilation, causing draughts and heat loss, especially in winter. The Pressure Ring in KfW Westarkade protects the tower from high wind speeds and regulates airflow into the inside, allowing residents to open their windows year-round without draughts or heat loss. Thus, offices naturally ventilate with little outside influence.

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Geometrical features, such as building form, size, shape, and placement of windows on the facade, are central to implementing natural ventilation [1].

Short description

3. TOOLS

- http://coolvent.mit.edu/
- https://www.ohcow.on.ca/covid-19/ventilation-calculation-tool/#1636726803734-5e447b6e-34ec
- https://www.simscale.com/simulations/natural-ventilation/
- https://www.cfd-online.com/Tools/turbulence.php

Main implemented tools

4. MAIN SOLUTIONS SET UP

- The façade's full-height glass curtain wall offers spectacular vistas, while the ceramic rod "veil" provides brise-soleil shading. Office levels are naturally ventilated by shading (a). The building's geometric form is capped by a sculptural mast that sits atop the tower giving it an overall aerodynamic form (b) (Fig. 1)
- By pulling heated air upwards, the tall ventilation towers organically cool the main working spaces. Meanwhile, special low-level openings bring in fresh air. The system protects campus equipment from dust and can endure high temperatures. (Fig. 2)
- The windows allow for the intake of outdoor air. The ambient temperature outdoors is characterized by a higher thermal energy content than the indoor environment, which is achieved by using wall materials with high thermal resistace values. The disparity in temperature creates a corresponding variance in pressure, which directs the movement of air in a particular direction. Meanwhile, the stale air rises up and

A. EXEMPLARY CASE STUDIES

Britam Tower	Nairobi, Kenya
Name	*Location*

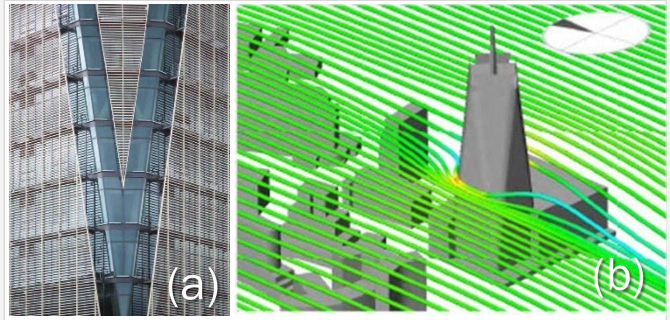

Figure 1: Britam Tower a) Veil façade and b) Aerodynamic external form © GAPP Architects and Urban Designers [2]

B.

Startup Lions ICT Campus	Lake Turkana, Kenya
Name	*Location*

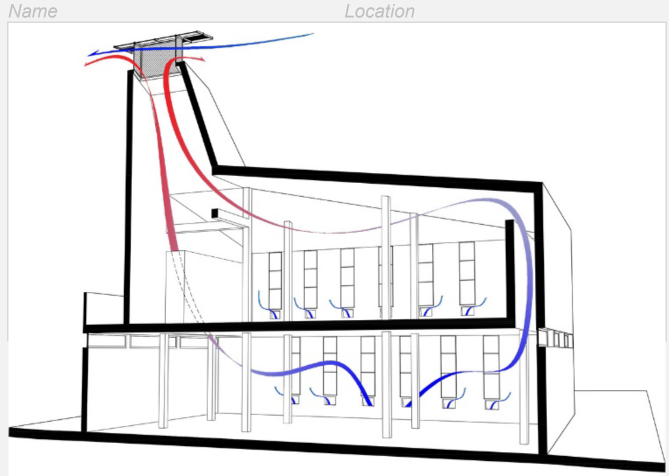

Figure 2: Three tall, ventilated towers made of terracotta. © Kéré Architecture[4]

C.

Benga, Riverside Residential Community	Tete, Mozambique
Name	*Location*

gets out through the roof opening due to the chimney effect (Fig. 3)
- The building features a 16-meter-high atrium that facilitates a chimney effect from the first floor. This mechanism draws air through six operable roof drums. The drums are programmed to commence and terminate their operation in response to the prevailing temperature conditions within the edifice. In the summer season, the operating hours of the establishment will be extended while in the winter season, it will remain closed to maintain indoor air quality[3]. (Fig. 4)

Short description

Figure 3: a) Window openings and ,b) use of insulating local material channelizing the natural ventilation c) © Kéré Architecture[5], [6]

5. COMPLEMENTARY SOLUTIONS

- Use of local eco-friendly construction materials, for instance, the use of bamboo cladding in lobbies and the application of terracotta on the façade not only provide resource efficiency and economic benefits but also act as excellent insulation materials that naturally keep cooler indoors compared to the outdoors environment by helping in movement airflow. (Fig. 1)
- Design of small openings in wall systems such as egg-crate devices (formed with the combination of fin and overhangs) are successful in lowering indoor air temperature and reducing the quanitiy of discomfort hours in hot areas [7], [8]. (Fig. 1)
- Placement of windows, such as openable windows on different floors at higher and lower levels, helps in efficient cross-ventilation [9], [10] (Fig. 1)
- A thermally activated building system (TABS) creates massive heat "sinks" in office areas by embedding water pipes into concrete soffits above workers. (Fig. 4)

Short description

D.	The Ridge, Office Building	Cape Town, South Africa
	Name	Location

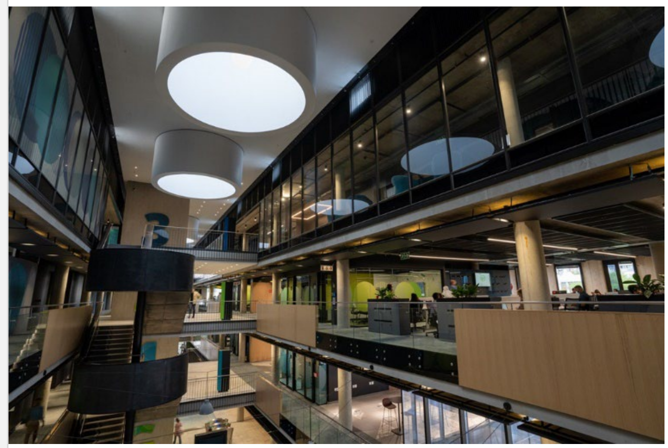

Figure 4: The central foyer of the building showing the roof drum © Kéré Architecture

6. STRENGTHS

- Constant air exchange due to the natural ventilation system
- Thermal comfort
- Energy conservation
- Local and eco-friendly materials
- Water conservation
- Reuse and Recycling of materials

Positive facts

7. WEAKNESSES

- Monitoring the airstream direction
- High dependency on climatic conditions
- Air contamination, insect vectors, noise, and security issues
- Maintenance of hybrid system

Negative facts

8. LESSONS LEARNED AND RECOMMENDATIONS

- **Britam Tower** - The ceramic rod "veil" shades the façade's full-height glass curtain wall, which gives stunning views. Shading cools offices. A sculptural pole atop the tower gives the building an aerodynamic shape which helps channel urban winds around it without causing turbulence. The building has a hybrid ventilation system to avoid risks of noise, pollution, and other microbes directly entering indoors and affecting the air quality. It is an example of a Hybrid system.

- **Startup Lions ICT Campus**-Stack effect is the best possible way for drawing the hot and used air out of the indoor spaces for this building through the four chimneys incorporated in the design.
- **Benga Riverside Residential Community-** The location, size, and quantity of apertures in the façade have a significant impact on the airflow patterns.
- **Ridge commercial office-** The first floor's 16-meter-high atrium creates a chimney effect. Six operable roof drums draw air through this mechanism. The drums start and stop depending on the building's temperature. To ensure indoor air quality, the institution will prolong its summer hours and close in winter. Mechanical air conditioning systems, passive cooling technologies, and natural ventilation work together to reduce energy usage while prioritizing occupant comfort. The fully fitted-out building is meant to function in natural ventilation mode for 81% of the year and save 64% in energy compared to a similar building of the same size and orientation.

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11. Guidelines for urban/district design

In this section we report a literature review on guidelines about urban design.

Designing sustainable cities with a focus on passive solutions at the urban scale we should consider, as suggested by the guidelines considered:

plan for compact urban forms to reduce energy consumption, minimize heat island effects, and promote efficient land use; consider the prevailing winds and solar orientation when designing the layout of buildings and streets to optimize natural ventilation and passive solar heating; develop a mixed-use urban fabric that integrates residential, commercial, and recreational spaces, reducing the need for long-distance commuting; orient buildings to maximize natural ventilation and daylighting, minimizing the need for mechanical cooling and artificial lighting; implement sustainable water management strategies, such as rainwater harvesting and graywater recycling, to reduce reliance on freshwater resources; incorporate permeable surfaces and green infrastructure to mitigate stormwater runoff and enhance groundwater recharge; design urban spaces with water features, such as ponds and fountains, to provide evaporative cooling effects and improve the microclimate; integrate green spaces throughout the city to provide shade, enhance air quality, and create microclimates; promote public awareness and education programs on the benefits of passive design strategies, bioclimatic architecture, and sustainable urban living; encourage the adoption of sustainable practices through incentives, regulations, and building codes that support passive design principles; develop an integrated and sustainable transportation system that prioritizes public transit, walking, and cycling.

By implementing these guidelines, cities can leverage passive solutions at the urban scale to minimize energy consumption, enhance thermal comfort, and create more sustainable and livable urban environments. Local context, climate conditions, and cultural factors should be considered to tailor these guidelines to the specific requirements of each city.

COMPARISON

The Literature reports of Sustainable Urban design were analysed and compared to the ABC 21 guide. Some studies follow the same direction of this reporty, while others focus on distinct themes that were not mentioned in the guideline. The next text will sum up the points that can be compared to the main guideline, but also the characteristics that could complement the current ABC21 guideline. We have already seen in previous chapters that some of the *bioclimatic* strategies and the application of *Passive cooling systems* are influenced by the urban configuration. Nocturnal ventilative cooling is favored if car traffic with its noise and pollution is limited in favor of public transport and active mobility. Heat gains to the buildings are reduced if the city has implemented green spaces and cool surfaces. An analysis of interaction between building and city level and some options that can favor bioclimatic architecture and passive systems is presented by Erba and Pagliano in [58], see Table 11.

Sufficiency Actions in Buildings→	Summer Night Ventilation and Ceiling Fans Rather Than Air Conditioning	Summer Night Ventilation Rather Than Air Conditioning	Adequate m^2 per Capita Floor Space	Adopt "Sufficient" Mobility Modes: Bicycle, Walk, Public Transport	Line Drying and Water/Hot Water Saving
In order to perform sufficiency actions, inhabitants would need→	Silence at night, clean air	External air temperature < 20 °C at night	Pleasant common indoor/outdoor spaces (shared guest rooms, music rooms, office space, playing spaces for children, etc.) to reduce the need for individual volumes	Easy access to services, schools, work and coworking spaces, equally distributed in the city; independence of movement for children and elders	Well-designed spaces for line-drying, installed water saving devices. Comfortable showers in place of bathtubs
Presently cities create constraints→	Noise, mainly from cars and motorcycles. PM10, PM2.5 pollution and other air contaminants	Asphalt, city canyons	Inhospitable districts, obligation for car parking spaces at buildings and free car parking on streets	Distance between functions, unacceptable risks for cyclists, pedestrians and persons with disabilities	Dust in air
Cities should offer enabling conditions→	Car-free residential districts and zones at 20 or 30 km/h	White/cool surfaces. Geometries facilitating air movement. Water surfaces and urban vegetation	Walkable, cyclable districts, green spaces, spaces for playing and spaces in the building for common activities	Equitable access to street space and equal access to various transportation modes	Information campaigns on water saving devices and on the high quality of drinking water from the tap
Legislation and Regulation shouldaddress→	Objective and adequate temperature and humidity set-points in regulation. Limitations to car number and to speed limits to 20–30 km/h	Mandatory white/cool surfaces, mandatory external solar protections (as, e.g., in Switzerland)	Minimum requirements of green spaces and of common spaces for meetings	EPBD (and national build codes): mandatory protected spaces inside buildings for bicycles, wheelchairs and strollers	Mandatory spaces for line drying, mandatory labeling of low-flow water devices, mandatory showers rather or in addition to bathtubs (with access at the same level of the floor for easy access by aging population)

Table 11 interactions between the building and district/city levels presented by Erba and Pagliano in [58]

The main aspects of the analysed literature that are similar to the ABC 21 plan are the use of materials construction and low-energy building design to develop a sustainable neighborhood. For instance, Glicksman and Lin [198] mentioned in their report that the use of sustainable materials will significantly improve the energy efficiency and long term durability of housing Stock. Likewise, Modeste Kameni's research [199] corroborates the importance of low-energy building design and the use of renewable energy systems. The study considers common parameters among various precedents with similar tropical climates and how their variations may impact the final outcome. Thus, as well as in ABC 21, the authors exposed how those principles can point to the net zero carbon emission goal.

On the other hand, various studies showed a new focal point of view that was not explored in the ABC 21 about sustainable urban development. Part of the supplementary targets included the implementation of diverse functionalities, people-centred approach, transit oriented development and intelligent mobility service.

To exemplify, the report of Yalcine and Karaaslan [200] encourages the implementation of mixed use, compact layouts and green networks. Considering functionality, energy efficiency and ecotechnologies usage. Additionally, the report on Jamestown also highlights the significance of a diverse urban plan. It illustrates the positive impact of a balanced mixed use development where the identity conservation was celebrated. Being flexible to new approaches, while enhancing social-ecological resilience..

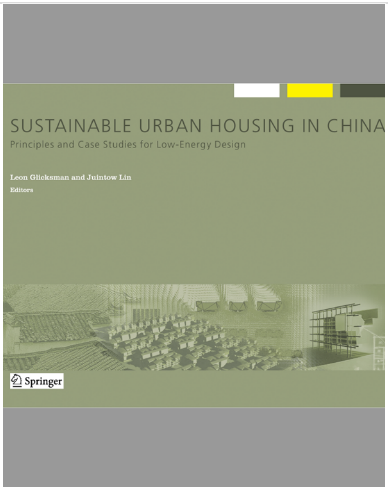
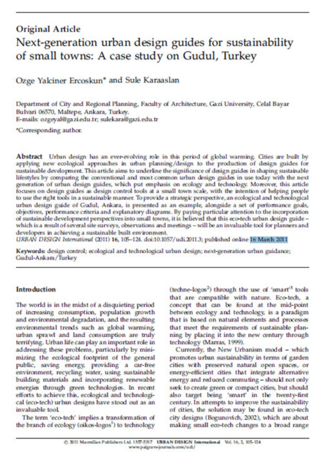
Furthermore, the guidebook "Green and Thriving neighborhoods" applies people-centred thinking and rapid emissions reduction as two pillars to design prosperous neighbourhoods [201]. It explores areas such as: compact neighbourhood, circular resources, people centred mobility, sustainable lifestyles and green base solutions.

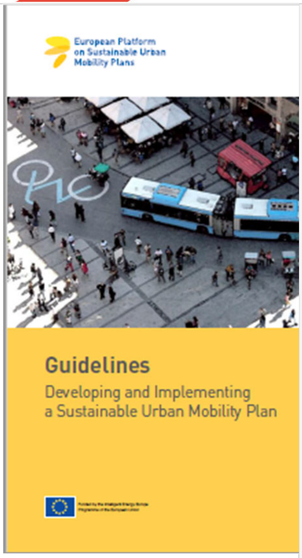
Moreover, two complementing studies emphasise the value of the Mobility service for a sustainable urban design. Firstly, Shimbash [202] proposes to focus on the intelligent mobility service and community network enhanced by the supply energy system method. Likewise, the Reedy Creek town Centre case in Australia [203] demonstrates the importance of a Transit Oriented Development (TOD) to create a pedestrian-friendly urban environment. The study proposes to connect to the landscape, incorporating green public spaces and connecting the disconnected.

To summarize, the ABC 21 guideline could be complemented to correlated studies that propose other potential principles more focused on the urban development. The use of diverse layouts, people-centred thinking and an intelligent transit mobility service are some of the plausible areas that could be examined in depth. The authors acknowledged that the principles mentioned before are essential for the sustainable design..

Table 12 lists the main sources currently available, while in Annex B we present an in-depth analysis of the references. For the freely available sources, we provide the link to download the document.

Table 12 Overview of existing guidelines at urban level

	Title	**Author/s or Publisher**	**Year of publication**
	Sustainable Hurban Housing in China	Leon Glicksman & Juintow Lin	2006
Original Article Next-generation urban design guides for sustainability of small towns: A case study on Gudul, Turkey Ozge Yalciner Ercoskun* and Sule Karaaslan Department of City and Regional Planning, Faculty of Architecture, Gazi University, Celal Bayar Bulvari 06570, Maltepe, Ankara, Turkey. E-mails: ozgeyal@gazi.edu.tr; sulekara@gazi.edu.tr *Corresponding author. **Abstract** Urban design has an ever-evolving role in this period of global warming. Cities are built by applying new ecological approaches in urban planning/design to the production of design guides for sustainable development. This article aims to underline the significance of design guides in shaping sustainable lifestyles by comparing the conventional and most common urban design guides in use today with the next generation of urban design guides, which put emphasis on ecology and technology. Moreover, this article focuses on design guides as design control tools at a small town scale, with the intention of helping people to use the right tools in a sustainable manner. To provide a strategic perspective, an ecological and technological urban design guide of Gudul, Ankara, is presented as an example, alongside a set of performance goals, objectives, performance criteria and explanatory diagrams. By paying particular attention to the incorporation of sustainable development perspectives into small towns, it is believed that this eco-tech urban design guide – which is a result of several site surveys, observations and meetings – will be an invaluable tool for planners and developers in achieving a sustainable built environment. *URBAN DESIGN International* (2011) **16,** 105–124. doi:10.1057/udi.2011.3; published online 16 March 2011 **Keywords:** design control; ecological and technological urban design; next-generation urban guidance; Gudul-Ankara/Turkey **Introduction** The world is in the midst of a disquieting period of increasing consumption, population growth and environmental degradation, and the resulting environmental trends such as global warming, urban sprawl and land consumption are truly terrifying. Urban life can play an important role in addressing these problems, particularly by minimizing the ecological footprint of the general public, saving energy, providing a car-free environment, recycling water, using sustainable building materials and incorporating renewable energies through green technologies. In recent efforts to achieve this, ecological and technological (eco-tech) urban designs have stood out as an invaluable tool. The term 'eco-tech' implies a transformation of the branch of ecology (oikos-logos[1]) to technology (techne-logos[2]) through the use of 'smart'[3] tools that are compatible with nature. Eco-tech, a concept that can be found at the mid-point between ecology and technology, is a paradigm that is based on natural elements and processes that meet the requirements of sustainable planning by placing it into the new century through technology (Marras, 1999). Currently, the New Urbanism model – which promotes urban sustainability in terms of garden cities with preserved natural open spaces, or energy-efficient cities that integrate alternative energy and reduced commuting – should not only seek to create green or compact cities, but should also target being 'smart' in the twenty-first century. In attempts to improve the sustainability of cities, the solution may be found in eco-tech city designs (Bogunovich, 2002), which are about making small eco-tech changes to a broad range © 2011 Macmillan Publishers Ltd. 1357-5317 **URBAN DESIGN International** Vol. 16, 2, 105–124 www.palgrave-journals.com/udi/	Next-generation urban design guides for sustainability of small towns: A case study in GuduL	Ozge Yalcine & Sule Karaaslan	2011
	Green and thriving neighbourhoods	Hélène Chartier, Laura Frost, Christopher Pountney	2021

	Fujisawasst Sustainable smart town Download	Higashi Shimbash	2016
	Developing and implementing a Sustainable urban mobility plan Download	Frank Wefering, Siegfried Rupprecht, Sebastian Bührmann, Susanne Böhler-Baedeker	2013
	Sustainable Urban Development in Africa Download	Un-Habitat	2015

<table>
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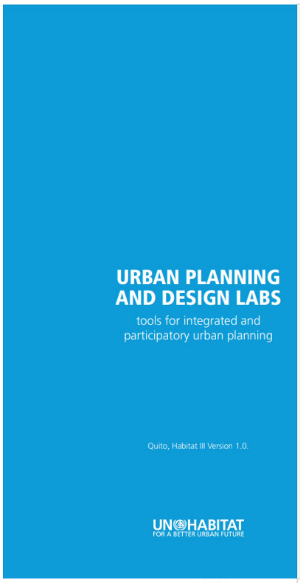
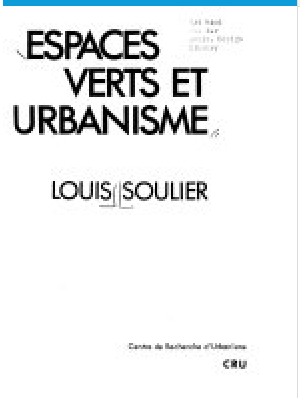
<tr><td>
</td><td>Urban Planning and Design labs

Download</td><td>Rogier van denBerg, Leonora Grcheva, Ivan Thung</td><td>2016</td></tr>
<tr><td>
</td><td>Espaces verts et urbanisme</td><td>Louis Soulier</td><td>1968</td></tr>
</table>

12. Conclusion

The present guidelines represent an effort to offer an updated view of the future of *bioclimatic architecture* (which might be *the* architecture in a climate-compatible future of humanity) and *passive systems* under the new boundary conditions of XXI century, while taking advantage of accumulated wisdom and the work of the pioneers of XX century.

As a group of partners form various places in Africa and EU, we have moved from quite different starting points, conceptually and terminologically, to a more uniform technical language and conceptual framework. And we did this during the COVID pandemic, always meeting online, apart for the final conference in Morocco. We feel it proves that quality research and application work can now take place with very little emissions connected to travelling. And that good collaboration can develop across cultures and origins, for the sake of avoiding a climate disaster.

Next steps for use of the present guidelines will include bringing even more the discussion on the need and benefits of a common technical language into the international arena, e.g. in the COP process. At the same time helping protect the wisdom accumulated in vernacular architecture and offer the information needed to update that knowledge. Bioclimatic architecture and passive systems are a key element of the future, with their evolution for taking into account the changes in climate, take profit of the improvements in local geo- and bio- based materials and the availability of totally new materials as the ones able to passively radiate more energy to the deep sky than they absorb from the sun.

We aim at promoting to university and vocational training the use of the present guidelines and other training tools (reports, simplified pre-design tools, analysis of case studies, recording of webinars,..) developed within the project. Those training activities should also be an occasion of breaking the harmful barriers between architects and engineers, with difficulties in quantitative analysis on one side and biases towards complex technologies and calculations, sometimes disconnected from user's needs and practical design, on the other side.

More work is needed, but we hope this collaboration between Africa and Europe offers suggestions for taking steps in the right direction.

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ANNEXES

A) Existing guidelines for bioclimatic buildings' design

B) Existing guidelines for urban/district design

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1. DOCUMENT TITLE:	Passive and low energy cooling of buildings - 1994	2. AUTHOR	Baruch Givoni
	Name of the document		*Name of the author(s)*

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
	X				X

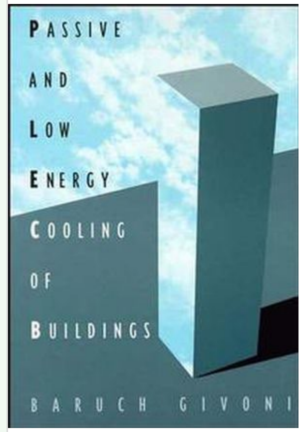
3. DESCRIPTION

Passive cooling is a key focus of this book, which explores ways of achieving it using natural energy sources or by consuming low amounts of conventional energy. The author begins by introducing the concept of the indoor and outdoor temperature differential, which is essential to understanding the true meaning of passive cooling. From there, the book goes on to examine a wide variety of passive cooling systems, each of which is tailored to meet the specific needs of a particular site location.

The goal of this book is to provide designers with a diverse range of passive cooling tools that they can use to create energy-efficient buildings. These tools range from preliminary design guidelines, such as the layout and orientation of the building, to simple techniques like comfort and nocturnal ventilation, to more sophisticated systems like radiant and evaporative cooling. By exploring the full range of passive cooling options available, this book equips designers with the knowledge they need to make informed decisions about how to achieve optimal cooling performance in their buildings while minimizing energy consumption.

Short description

4. COVER



Cover image

5. TABLE OF CONTENTS

1. Overview: The various passive cooling systems and their applicability to different climates and building types
2. Minimizing cooling needs by building design.
3. Ventilative cooling
4. Radiant cooling
5. Evaporative cooling systems
6. The earth as a cooling source of buildings
7. Cooling of attached outdoor spaces.

Main titles of table of contents

6. RELEVANT THEMATICS

- MINIMIZING COOLING NEEDS BY BUILDING DESIGN

  Minimizing the cooling needs of a building by design means lowering the heat gains during daytime. The main architectural design features that aim at lowering the indoor temperatures and enabling effective natural ventilation are building layout, orientation of main rooms and windows, window size, shading devices for windows, color of the building's envelope and vegetation near the building.

- VENTILATIVE COOLING.

  Ventilation can improve comfort in two ways. The Comfort Ventilation approach is a direct physiological effect since it raises the comfort zone temperature of the users by allowing direct ventilation right to them. This approach is adequate when the humidity level is high, as the higher air speed increases the rate of sweat evaporation from the skin. On the other hand,

7. MAIN CASE STUDIES

Name	Location
N/A	N/A

No case study present in the book

Plans / Images

More info:

Name	Location
N/A	N/A

ABC21 is funded by the
EU's H2020 programme

the Nocturnal Ventilative Cooling approach stands for keeping the building closed during the hot daytime hours and cooling the structure's mass or any other dense element at night by air circulation. The cooled mass serves during the day as a het sink. The different design options to provide mass as nocturnal cold storage are structural mass elements to be cooled by whole space ventilation, embedded air passages within the elements of the building and the use of a specialized storage with embedded air tubes, cooled by night by outdoor air.

- RADIANT COOLING.

  The chapter examines the possible applications of cooling through the exposure of elements to a long-wave radiation receptor, such as the open sky during the night. The elements of a building can act as a heat sink if their temperature is lowered by radiant heat loss during the night.

- EVAPORATIVE COOLING.
  The book explains the techniques that rely on the principle of heat loss by evaporation, which consists of the energy transfer from the ambient air or from the material over evaporation takes place. The main approaches to cooling buildings by water evaporation are basically two: Direct evaporative cooling, meaning cooling outdoor air directly through evaporation, and then introduce that air into the building; and Indirect evaporative cooling, which consists of cooling a given element of the building by evaporation.

- THE EARTH AS COOLING SOURCE FOR BUILDINGS.

  This chapter focuses on the use of earth mass under, around and above the building as a natural cooling source. The two basic approaches that are examined are: the cooling of the surface so to lower the soil temperature of the earth mass below; and the direct cooling of a large mass of the subsurface earth by increasing its cooling rate in winter relative to the heating in summer.

- COOLING OF ATTACHED OUTDOOR SPACES.

  This chapter deals with the possibilities of lowering the air and radiant temperatures in outdoor spaces adjacent to buildings, like backyards and patios.

Short description of the most relevant thematics that were addressed in the book

No case study present in the book

Plans / Images

More info:

N/A	N/A
Name	*Location*

No case study present in the book

Plans / Images

More info:

7. REMARKS

- Passive Cooling systems are becoming increasingly popular due to their ability to achieve cooling using natural energy sources or low conventional energy consumption. These systems are particularly important in countries with hot weather, where air conditioning can be a significant contributor to energy consumption and carbon emissions.

- The concept of passive cooling is discussed in-depth in the book, with a focus on the indoor and outdoor temperature differential. By understanding this concept, designers can implement a variety of passive cooling systems that are tailored to the specific needs of a given location.

- One of the key benefits of passive cooling is that many of the systems and techniques have little to no impact on construction costs. This is important in countries where cost is a significant factor in building design and where energy efficiency and comfort are still highly valued.

- In addition to being cost-effective, some of the passive cooling systems can be based on local materials instead of industrialized ones. This approach is not only sustainable but also helps to promote local industries and create jobs.

- The book provides a comprehensive overview of passive cooling tools that designers can use to create comfortable and energy-efficient buildings. These tools range from simple techniques like comfort and nocturnal ventilation to more sophisticated systems like radiant and evaporative cooling.

- By using a combination of passive cooling techniques and systems, designers can create buildings that are comfortable, energy-efficient, and sustainable. This approach not only benefits the environment but also the people who live and work in these buildings by providing a healthier and more comfortable indoor environment.

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- Publication by Van Nostrand Reinhold.

1. DOCUMENT TITLE: A manifesto for climate responsive design - 2019
Name of the document

2. AUTHOR: Peter Clegg and Isabel Sandeman
Name of the author(s)

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
	X	X			

3. DESCRIPTION

The document evolved from an Enabel conference in February 2019. This brought together expertise from across East Africa to raise awareness of climate responsive design. The conference and therefore this document, focus predominantly on single-storey community buildings in rural areas. However, we recognize that considering the rapid urbanization in East Africa, climate responsive design thinking need to be extended to higher-density, higher-rise buildings in the future.

Short description

4. COVER

Cover image

5. TABLE OF CONTENTS

8. Climate Change
9. Participatory Process
10. Sustainable Materials
11. Bioclimatic Design
12. Case Studies

Main titles of table of contents

6. RELEVANT THEMATICS

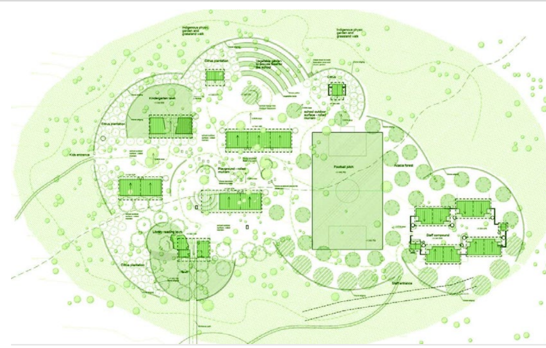
- PARTICIPATORY PROCESS
  The document emphasizes the importance of involving local communities in sustainability efforts by dividing the participatory process into two parts: Participatory Design and Participatory Construction. This social layer of analysis underscores the relevance of community engagement in sustainable development, as it ensures that the needs and concerns of the people who will be affected by the project are considered.

- SUSTAINABLE MATERIALS
  The document categorizes sustainable materials by their final functions, such as floors, walls, windows, roofs, and structures, providing a brief description of each material and its benefits and limitations. Exemplary case studies illustrate successful applications of these materials, demonstrating sustainable design in practice. This resource is useful for architects, engineers, and designers seeking to incorporate sustainable design principles into their work, providing valuable insights and inspiration for creating environmentally friendly and economically viable buildings.

- BIOCLIMATIC DESIGN
  The chapter describes several successful methods, processes, and strategies used in the territory for bioclimatic design. Each of them is

7. MAIN CASE STUDIES

AWF Primary Schools — Karamoja, Uganda.
Name — *Location*



Plans / Images
Project by: Localworks | Year: 2020
More info: In total, 21 buildings across 2 schools, each with nine classrooms reinforce AWF's vision to integrate stunning landscapes within the school. these landscapes are friendly to the environment in which they are placed and elevate preexisting perceptions of indigenous materials. Passive ventilation is completely dependent on indoor thermal comfort.

explained in detail, with practical instructions, diagrams, and short descriptions, and examples of exemplary cases are included to illustrate how they have been implemented in real-world situations. By highlighting the benefits of bioclimatic design, the document encourages readers to prioritize sustainable design strategies in their own projects.

- CASE STUDIES
  This section of the document provides an in-depth analysis of exemplary case studies found in the territory, demonstrating sustainable design principles in action. It showcases a range of real-world projects with plans, images, and diagrams that illustrate the successful application of sustainable design practices. The graphics are complemented by a detailed explanation of various aspects such as general arrangement, design strategies, implemented materials, and the project's overall impact on the community and environment. By highlighting these successful projects, the document aims to inspire readers to adopt sustainable design practices in their own work. The resource is a valuable reference for architects, engineers, and designers seeking to create environmentally friendly and economically viable buildings that benefit both the community and the planet.

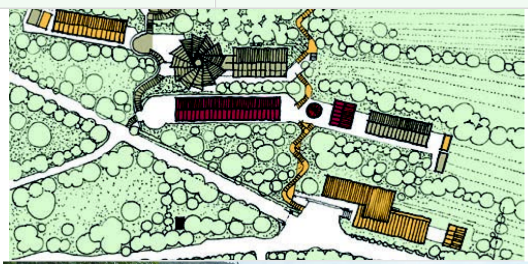
  The main purpose of this chapter is to serve as a comprehensive reference for the entire book. Sustainable materials and bioclimatic design strategies are demonstrated using color codes and numbers, making it easy to navigate and understand the information. By providing readers with a thorough understanding of these key concepts, the document aims to promote sustainable development practices and inspire future projects that prioritize the wellbeing of both people and the planet.

Short description of the most relevant themes that were addressed in the book

Ruhehe Primary School	Musanze, Rwanda
Name	*Location*

Plans / Images
Project by: Mass Design Group | Year: 2003
More info: The ADC fellows evaluated the campus and decided to demolish two old classroom blocks while renovating the other two. The newly renovated classrooms have skylights and light shelves that scatter natural light, creating a comfortable environment for reading and writing. The classrooms also have vertical woven infill windows on the sides, which can be opened to allow fresh air into the room.

Lake Bunyonyi Secondary School	Lake Bunyonyi, Uganda
Name	*Location*



Plans / Images
Project by: FeildenCleggBradleyStudios | Year: 2006
More info: The school has developed income-generating activities to achieve financial self-sufficiency. These include a beekeeping project, rabbit and goat farming, and a government-subsidized tea plantation on the school premises. The beekeeping project produces honey for sale in local markets, while rabbit and goat farming provide a source of nutrition and income.

7. REMARKS

- The document's strategic structure is designed to facilitate navigation and ensure consistency across chapters. By using color codes to classify bioclimatic design strategies and numbers to refer to sustainable materials, readers can easily find related information in the Case Studies chapter. This approach not only makes the document more accessible but also emphasizes the practical application of sustainable design concepts.

- However, the absence of external academic references, sources of information, or a bibliography may be a limitation for readers who want to delve deeper into the topic. While the document provides a wealth of practical information and case studies, it is important to acknowledge the value of citing external sources to support the claims made in the text. This could help readers better understand the context and history of sustainable design, as well as explore related research and scholarship. Without these references, the document may be seen as less credible or authoritative.

8. SIGNIFICANT REFERENCES

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1. DOCUMENT TITLE: Bioclimatic housing. Innovative designs For warm climate - 2008

Name of the document

2. AUTHOR: Richard Hyde

Name of the author(s)

2. CATEGORY:

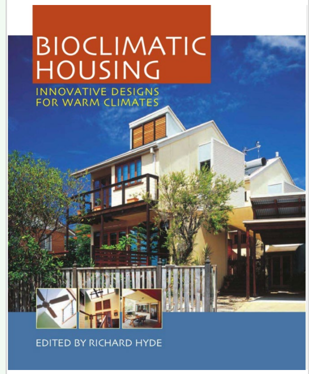
Article	Book	Report	Handbook	Guideline	Manual
	X			X	

3. DESCRIPTION

This book is a comprehensive collection of articles that address the increasingly pressing issue of maintaining comfortable indoor temperatures in the face of rising global temperatures. The articles are the result of a five-year project conducted by the International Energy Agency (IEA) Solar Heating and Cooling Program Task 28 on Solar Sustainable Housing. With a focus on countries where cooling is necessary for extended periods of time, the book delves into innovative and traditional building designs that are supported by rigorous scientific research. The articles cover a range of topics, from vernacular architecture to practical applications of sustainable design, all aimed at providing readers with real-world examples of effective strategies for staying cool in a warming world.

Short description

4. COVER



Cover image

5. TABLE OF CONTENTS

13. Overview
14. Redefining Bioclimatic Housing
15. Location, Climate Types and Building Response
16. Principles, Elements and Technologies

Main titles of table of contents

6. RELEVANT THEMATICS

- REDEFINING BIOCLIMATIC HOUSING

This section of the document is dedicated to the exploration of current definitions, concepts, and principles related to bioclimatic housing. It analyzes the evolution of sustainability and the emerging issues of the 21st century, while also examining the latest trends in solar sustainable housing design for warm climates.

- LOCATION, CLIMATE TYPES, AND BUILDING RESPONSE

Most of the document is dedicated to these three aspects: location, climate type, and building response. By framing the information in these factors, the document provides several examples that offer a detailed understanding of specific locations.

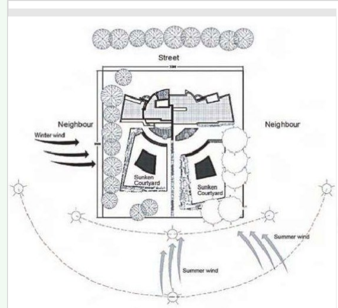
Each chapter follows the structure of location - climate - building response, with specific examples providing general information about the location, the findings of the climatic analysis, and potential solutions. The solution sets are explained in detail, including the implementation process and the composition of key elements. The information is complemented by a monitoring phase where performance is evaluated.

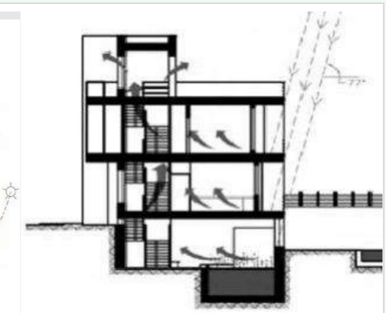
- PRINCIPLES, ELEMENTS, AND TECHNOLOGIES

The final section of the document offers general recommendations and a checklist of considerations for designing more climate-friendly housing. The summary is structured around: 1) better interpretation of location

7. MAIN CASE STUDIES

Name	Location
Akbari House	Tehran, Iran



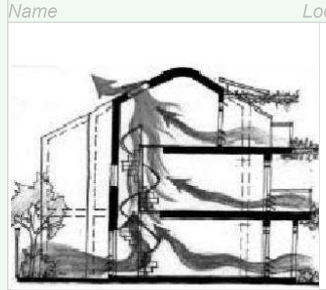


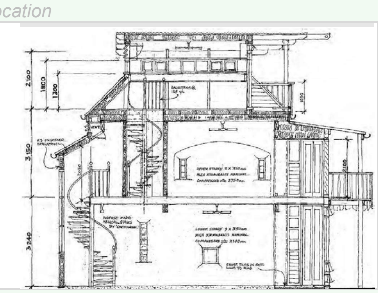
Plans / Images

Project by: Vahid Ghobadian and Neda Taghi | Year: 2008

More info: The case study focuses on two houses located in the northwestern part of Tehran. The design of these houses was based on several factors, including the use of construction methods that rely heavily on onsite labor. Additionally, the building technology available in Iran is not as advanced as in Western countries. Despite these challenges, traditional sustainable houses can still be found in Iran, particularly in hot and dry regions. As such, the design of the houses in this case study considered these traditional sustainable practices.

Name	Location
Christie Walk	South Australia





Plans / Images

Project by: Paul Downton | Year: 2006

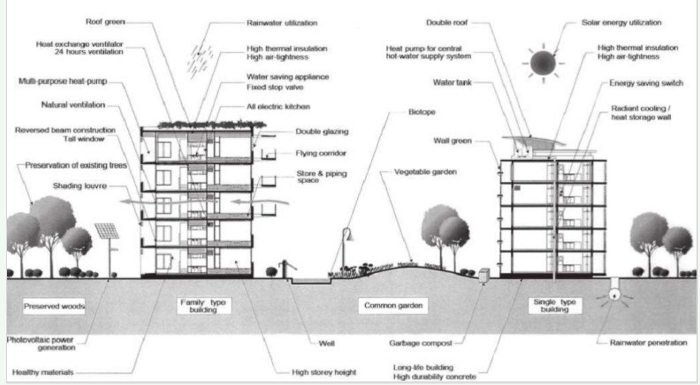
More info: Christie Walk is a community housing project in Adelaide, developed by Wirranendi Inc and Urban Ecology Australia Inc. It aims to demonstrate sustainable and climate parameters; 2) greater synthesis between building elements and local climate conditions; and 3) harmonizing passive and active cooling/heating strategies.

Furthermore, this section provides an in-depth analysis of how to improve the design outcomes of sustainable housing. It covers a variety of opportunities such as verifying predicted and operational performance, incorporating suitable green technologies, and involving users in the design and operation process. The aim is to enhance the effectiveness of sustainable housing projects and ensure that they meet the needs of both the environment and the community.

Short description of the most relevant themesthat were addressed in the book

living in cities by addressing water and energy conservation, material reuse and recycling, and healthy public spaces.

Eco-village Matsudo	Matsudo, Japan
Name	*Location*



Plans / Images

Project by: Taisei Co | Year: 2014

More info: By combining passive architectural design methods and low-energy mechanical equipment, this project achieves energy conservation and peak-load shift of electric power consumption in apartment houses. The site plan includes a family-type and a single-person-type apartment building arranged to create a courtyard and preserve the large green space in the south of the site.

7. REMARKS

- In Part II of the document, the author has done an excellent job in presenting a detailed and rigorous structure for each chapter. This structured approach not only helps the reader to navigate through the content effortlessly but also facilitates easy comparison between the different places and their climatic conditions. The well-organized format of the chapters also helps the reader to identify key points and important information easily.

- This document is a great example of how to present information in a clear and concise manner. The author has taken a data-driven approach, presented objective information and avoided personal opinions. This approach adds credibility to the arguments presented and helps the reader to understand the complexities of the issues being discussed. The document also includes a wide range of sources to support its claims, which further strengthens its validity.

- The authors have put in a lot of effort to ensure that the information presented is accurate and up to date. The inclusion of graphs, tables, and other visual aids makes the information easier to understand and helps the reader to see the data in a more comprehensive way. This is particularly important when dealing with complex topics such as climate change, where the data can be difficult to interpret.

- The document also provides an excellent framework for evaluating the proposed solutions. By presenting objective data, the author has set the foundation for a logical and reasoned approach to problem-solving. The well-structured chapters provide a clear overview of the issues at hand, and the proposed solutions are presented in a way that allows the reader to understand their potential impact.

- Overall, the document is an excellent example of how to present complex information in a clear and concise manner. The authors present objective data and propose logical solutions. The document is an invaluable resource for anyone interested in understanding the complexities of climate change and its impact on different regions of the world.

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- Occupants of the townhouse and apartment units (2003) Interview by Veronica I. Soebarto, 15 and 16 March 2003, tape recording; transcripts available at the School of Architecture, Landscape A

1. DOCUMENT TITLE: Sun Shading Catalogue. Adequate shading: Sizing overhangs and fins. -2018

Name of the document

2. AUTHOR: UNHABITAT

Name of the author(s)

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
	X				X

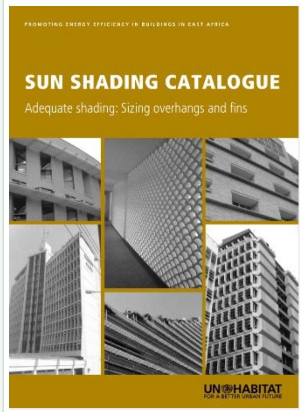
3. DESCRIPTION

The book provides comprehensive information about designing and sizing shading devices for windows in different orientations and latitudes. The book emphasizes the importance of considering factors such as the sun's position, geometry, and paths during the diagnosis and analysis stage of the shading design process. By doing so, the book provides readers with the necessary tools to create effective shading solutions that provide maximum comfort while minimizing energy consumption.

In addition to its theoretical framework, the book provides practical applications of sun shading design in exemplary buildings. These case studies serve as excellent examples of how sun shading design can be successfully implemented in real-life situations. The book's clear and concise writing style, accompanied by numerous illustrations and photographs, makes it an excellent resource for architects, engineers, and other building professionals who want to improve the energy efficiency of their buildings while enhancing occupant comfort.

Short description

4. COVER



Cover image

5. TABLE OF CONTENTS

17. Introduction
18. The Sun's Position
19. Shading Design
20. Shading Design Steps
21. Recommendations for Overhangs and Fin Sizes
22. Examples of Shading Devices

Main titles of table of contents

6. RELEVANT THEMATICS

- SUN'S POSITION
  To effectively control heat gain and provide adequate shading, it is crucial to have a comprehensive understanding of solar geometry, solar radiation, and solar energy at various times of the day and during different seasons. This knowledge is essential for designing buildings with passive heating and cooling in mind, properly orienting buildings, comprehending seasonal changes within a building and its surroundings, and creating shading devices that function optimally.
  To address this aspect, the book offers a clear explanation of the sun's behavior, utilizing three main diagrams: solar geometry, sun path, and shading protractor. These tools enable designers to better understand the movement and behavior of the sun and provide a foundation for effective shading design.

7. MAIN CASE STUDIES

Name	Location
Chandigarh College	Chandigarh, India

Plans / Images

Project by: Le Corbuiser | Year: 1961

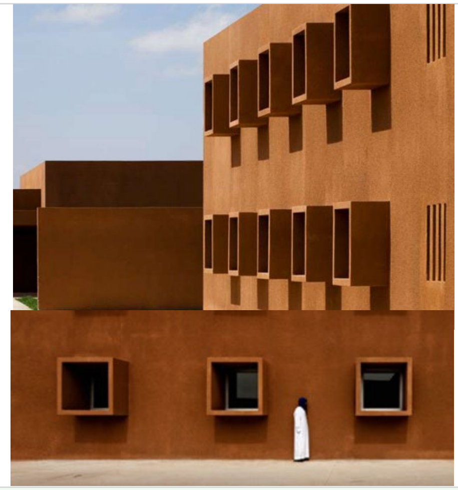
More info: Through his use of shading devices and careful consideration of the sun's path, geometry, and orientation, Le Corbusier was able to create buildings that not only provided comfortable living and working environments but also minimized energy consumption.

Name	Location
Technology School	Guelmim, Morocco.

- SHADING DESIGN
  Once designers have a good grasp of the tools for understanding the sun's behavior, the document moves onto the design stage.
  The fundamental premise of this step is the consideration of two critical shadow angles: horizontal and vertical. Understanding these angles is essential to creating effective shading devices. To gain a more precise and technical understanding of this aspect, the book provides formulas for shadow angles and shade dimensions.
  The design stage is completed with a series of steps to follow for determining the appropriate size of the shading devices, considering factors such as latitude, window orientation, and sun path.

- OVERHANGS AND FIN SIZES
  To conclude, the document includes an in-depth analysis of openings in different orientations in southern latitudes of 0, 2, 4, 6, 8, and 10, represented by the following locations: Garissa, Makindu, Mombasa, Dar es Salaam, Mbeya, and Mtwara. Projection factors are represented graphically to facilitate understanding.
  Furthermore, the technical graphs are complemented by plans and isometric drawings that provide a clear idea of the final formal outcome and its performance. The book provides designers with an extensive toolkit for designing effective shading devices that can control heat gain, reduce energy consumption, and promote comfort.

Short description of the most relevant thematics that were addressed in the book

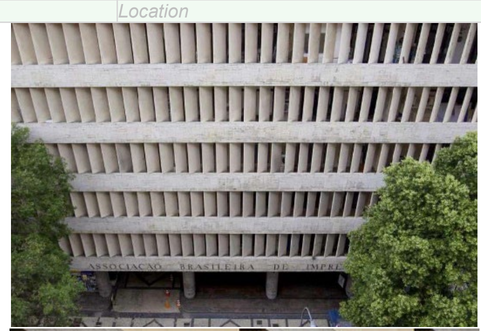


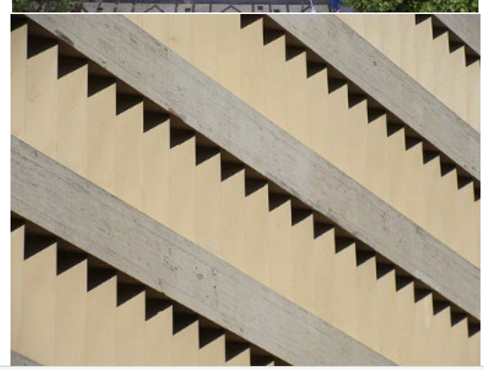
Plans / Images

Project by: Saad El Kabbaj | Year: 2011

More info: The Guelmim Technology School is made up of a collection of concrete structures that have projecting windows, louvres, and slender apertures. Canopies have been installed to provide covered pathways and seating zones, running parallel to the north-south axis, which divides the campus into two distinct areas.

ABI Headquarter	Brazil
Name	*Location*





Plans / Images

Project by: Irmaos Roberto | Year: 1936

More info: Pilotis support the building and create a partially open ground floor facing the street. The free plan is employed throughout all levels, enabling the modification of layouts on each floor. The roof features a tropical garden, while the façade is set back from the structure and features horizontal windows that run along the entire building. However, to protect against excessive sunlight, the second to eighth floor windows are shielded by a vertical Brise-Soleil.

8. REMARKS

- This document is highly specialized and specifically targets strategies for building design. It does not stray from its focused approach and concentrates solely on the topic at hand. The reader can expect to gain an in-depth understanding of various building design strategies and how to implement them in different contexts.
- The inclusion of several graphs throughout the document is a significant advantage, as it makes it easier to grasp complex concepts and data. This aspect is particularly helpful for those who may be new to the subject matter. The technical details are never compromised, ensuring that the information presented is accurate and precise.
- One of the most significant benefits of this document is that it can be used as a practical guide during the design process. The strategies presented are actionable and can be implemented to enhance the building's overall performance. This aspect makes the document a valuable resource for architects, engineers, and builders who are involved in the design and construction of buildings.
- In summary, this document is a highly focused and technical guide that provides actionable strategies for building design. The inclusion of graphs aids in the understanding of complex concepts, and the information presented is precise and accurate. Its practical nature makes it a valuable resource for professionals involved in building design and construction.

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1. DOCUMENT TITLE: Introduction to Architectural Science: The Basis of Sustainable Design - 2008
Name of the document

2. AUTHOR: Steven V. Szokolay
Name of the author(s)

2. CATEGORY:

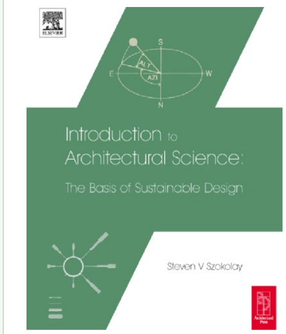
Article	Book	Report	Handbook	Guideline	Manual
	X		X		

3. DESCRIPTION

The book consists of four parts: Heat, Light, Sound, and Energy. In each part, the relevant physical principles are reviewed, followed by a discussion of their relationship to humans (comfort and human requirements). Then the control functions of the building (passive controls) are examined as well as associated installations, energy-using ‘active’ controls. The emphasis is on how these can be considered in design. The first part (Heat) is the most substantial, as the thermal behavior of a building has the greatest effect on energy use and sustainability and its design is fully the architect’s responsibility.

Short description

4. COVER



Cover image

5. TABLE OF CONTENTS

23. Introduction
24. Heat: The Thermal Environment
25. Light: The Luminous Environment
26. Sound: The Sonic Environment
27. Resources
28. Appendix

Main titles of table of contents

6. RELEVANT THEMATICS

- HEAT: THE THERMAL ENVIRONMENT
The chapter on heat provides a thorough explanation of the fundamental concepts related to thermal energy. It starts with the basic definition of heat as a form of energy and gradually introduces other crucial concepts such as temperature and heat flow through conduction, convection, and radiation. The chapter then delves deeper into the thermal comfort of buildings, examining the impact of climate on the thermal behavior of buildings. The discussion also covers the importance of thermal design and active controls to ensure energy-efficient buildings.

- LIGHT: THE LUMINOUS ENVIRONMENT
The chapter starts with the essential definition of light according to its physical properties. Later, the document introduces wider aspects like vision, daylight, and sunlight. In the final part of the luminous environment, the design methods are presented by considering fundamental techniques of design of light as the flux method.

- SOUND: THE SONIC ENVIRONMENT
The starting point is the explanation of the physics of sound. Although the explanation of this topic is less prominent than the previous ones, there are fundamental concepts accurately explained. The noise spectra and the noise control are understood as an essential aspect to deal with, to reach a successful design. The final part of the chapter explains the room acoustics and the main factor that determines the acoustic quality of each space.

- RESOURCES

7. MAIN CASE STUDIES

Name	Location
N/A	N/A

No case study present in the book.

Plans / Images

More info:

Name	Location
N/A	N/A

No case study present in the book.

Plans / Images

More info:

Name	Location
N/A	N/A

No case study present in the book.

The Resources chapter emphasizes the importance of energy and its efficient use. It discusses energy sources, conversion, storage, and practical use. The chapter also covers the critical role of water supply and its relationship with waste. The discussion of waste covers various types of waste, such as gaseous, liquid, and solid waste. Overall, this chapter provides a comprehensive overview of the importance of sustainable resource management in architecture.

Short description of the most relevant thematic that were addressed in the book

Plans / Images

More info:

7. REMARKS

- The book "Introduction to Architectural Science" by Steven V. Szokolay is a valuable resource for those seeking a comprehensive understanding of the science behind architecture. It covers a broad range of topics, including environmental design, building materials, construction methods, and structural design, providing readers with a holistic view of the field.
- One of the most significant strengths of the book is its emphasis on sustainability and energy efficiency in architecture. The author highlights the importance of designing buildings that not only look good but are also environmentally responsible. The book covers a range of sustainable design practices, such as passive solar heating, natural ventilation, and green roofs, making it an essential resource for architects and designers looking to reduce the environmental impact of their projects.
- However, while the book provides a detailed theoretical foundation, some readers may find the lack of case studies a limitation. Including ABC 21 examples that illustrate the theoretical concepts in practical scenarios could be a valuable addition, helping readers better understand how to apply the principles to real-world projects.
- Overall, "Introduction to Architectural Science" is a valuable resource for anyone interested in energy efficient building design. Its clear and concise explanations make it accessible to professionals and students alike, and its focus on sustainability makes it a timely and essential guide in today's world.

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ABC21 is funded by the EU's H2020 programme

1. DOCUMENT TITLE: Climate and Human Settlement: Integrating Climate into Urban Planning and Building Design in Africa - 1991
Name of the document

2. AUTHOR: Yinka R. Adebayo
Name of the author(s)

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
	X				

3. DESCRIPTION

The book focuses on the fact that there are still huge gaps in the actual incorporation of climatic factors in urban planning and management. The purpose of this book is to address this gap with a wealth of material on the technical and policy concerns of urban climatology through the analysis of the work of planners, architects, engineers and meteorologists presenting materials that provide the opportunity to discuss urban climatology with a strong emphasis on Africa.

Short description

4. COVER

Cover image

5. TABLE OF CONTENTS

29. Introduction
30. Data Collection and Analysis
31. Case Studies of Urban Microclimates
32. Climate, Traditional Design and Planning
33. Comfort, Cooling and Ventilation
34. Climatological Theory, Practice and Building Legislation
35. Conclusion

Main titles of table of contents

6. RELEVANT THEMATICS

- INTRODUCTION

In the introduction, the author pointed out the fact that there is technological ingenuity that has led to increased pollution and a change in the environment. This is given by the fact that although nowadays there is the knowledge needed to withstand climatic extremes, this is not always used in modern design.

Poor training, inadequate public education and cultural impediments are some of the causes of the misuses and non-uses of climatological ideas for building design and urban planning, and these overall conditions are worse in the tropical urban areas.

This volume was made to represent pioneering compilation of the efforts in this particular topic with a special reference to Africa.

- DATA COLLECTION AND ANALYSIS

7. MAIN CASE STUDIES

Name	Location
Urban Microclimates in the garden of the Institute of Green Planning and Garden Architecture	University of Hannover, Germany

Fig. 5.1: Southward exposed wall of concrete, on the right hand covered with an evergreen vine.

To make a technically correct design, the author presents as a necessary condition that the architect must take into consideration the social conditions of the place where the building will be constructed, studying social sciences, psychology and geography in addition to architecture.

For the architect, the main goal must be the physical and psychological well-being of people in buildings and cities, but to achieve this we need climate data applicable to design, that are the only way for the architect to design buildings appropriate to the climate.

- CASE STUDIES OF URBAN MICROCLIMATES

In this Section of the book, they analyze two case studies regarding the Urban Microclimates in the garden of the Institute of Green Planning and Garden Architecture of the University of Hannover and in the City of Ibadan.

- CLIMATE, TRADITIONAL DESIGN AND PLANNING

The topic of this Section concerns the effect that climate has on the design of traditional houses in tropical countries, going on to specify initially that the bioclimatic map of these places changes greatly among the various environments that are going to be analyzed.

We can draw several features from the design of traditional houses that are also useful for modern buildings, such as natural ventilation, small window sizes, and wind towers.

- COMFORT, COOLING AND VENTILATION

The main topic of this Section is about the importance of using passive control systems together with the analysis of the climatic conditions of the place where the project will be carried out, showing that in this way the energy used can be visibly reduced.

This Section analyzes the effects of environmental strain in the comfort and work performance of the students and the cooling and ventilation in Kenya.

Here they arrive to the conclusion that we cannot only take temperature into account to determine the comfort of a space, but that the sun-path pattern must also be analyzed for the organization and orientation of spaces as it is an important contributor to the heat comfort or discomfort.

- CLIMATOLOGICAL THEORY, PRACTICE AND BUILDING LEGISLATION

This Section discusses some case studies concerning the importance of climate and daylight design as

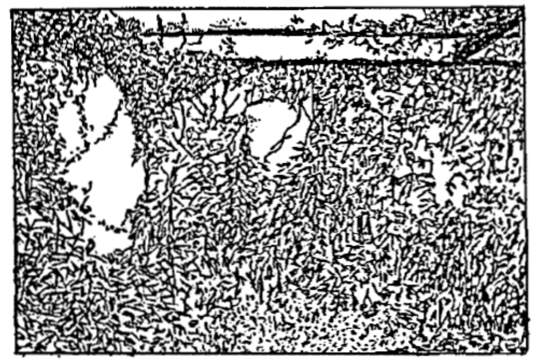

Fig. 5.2: Westward exposed wall of concrete like Fig 5.1 covered with vine and fern in front of it.

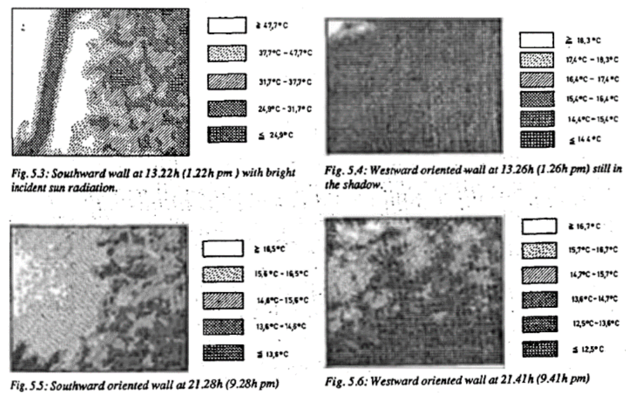

Fig. 5.3: Southward wall at 13.22h (1.22h pm) with bright incident sun radiation.

Fig. 5.4: Westward oriented wall at 13.26h (1.26h pm) still in the shadow.

Fig. 5.5: Southward oriented wall at 21.28h (9.28h pm)

Fig. 5.6: Westward oriented wall at 21.41h (9.41h pm)

Analysis Schemes
Project by: Fritz Wilmers

More info: The temperatures of the surfaces fluctuate higher or less than the air temperature. They are dependent on the energy balance, especially on the thermal conductivity below the ground and on the surface matter.
The main parameters of the microclimatic differences are the exposition to direct solar radiation, duration of radiation, thermal condition of the surface and condition of the surrounding walls.

Urban Microclimates in the City of Ibadan	Ibadan, Nigeria
Name	*Location*

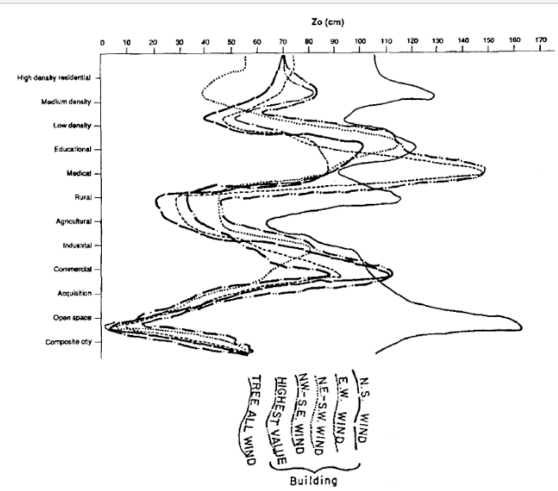

Fig. 6.1: Mean roughness of buildings and trees for major wind directions.
Source: Computed after Lettau's formula (1969). Inputs from Fieldwork (1983)

determinants of planning in Egypt, the Tropics, Middle Africa and Zambia.

- CONCLUSIONS

In conclusion, the best solution for building design and urban planning is an integrated approach, in which the climatologist plays an important role in the design. In fact, there is a need for a constant review of socioeconomic changes in the place and to prepare human settlements for long-term climate change.

Short description of the most relevant thematics that were addressed in the book

Table 6.5: Correlation Coefficient Tests Between Percentages of Urban Landuses, Selected City Surface Components and Climatic Parameters

	Q+q	Q+q	x	x	L*	L*	LE	H	T	T	RH	RH	Rn	Rn
	RA	HA	RA	HA	RA	HA	RA	RA	RA	HA	RA	HA	RA	HA
% Urban	-.80	-.90*	-.70	-.90*	-.90*	-.90*	.89*	.88*	.84	.89*	-.80	-.80	.86	.86
Building Density	-.70	-.80	-.90*	-.70	-.70	-.70	.75	.89*	.73	.75	-.70	-.70	.77	.77
Zo Building	-.40	-.50	-.54	-.54	-.54	-.54	.55	.53	.14	.55	-.49	-.54	.54	.54
Zo Tree	-.19	-.31	-.49	-.32	-.22	-.22	.20	.37	-.13	.18	-.80	-.23	.17	.17

* - Significant at 5%
% Urban - Percentage of Urban Land-Use
Zo Building - Roughness length of Building
Zo Tree - Roughness length of Tree
Q+q - Global Radiation
x - Albedo
L* - Net long wave Radiation
H - Sensible Heat Flux
T - Temperature
RH - Relative Humidity
Rn - Net Radiation
RA - Rainy season
HA - Harmattan season
LE - Latent Hert Flux

Analysis Schemes
Project by: Yinka R. Adebayo
More info: The variation in the urban climate of Ibadan is being jointly caused by both the surface components and the urban pollution veil.
It is being suggested that for an effective control of the variation in urban microclimate, effort should be concentrated on proper understanding of the links between the climatic parameters on one hand, and surface and atmospheric components on the other.

7. REMARKS

The challenges posed by urbanization problems are dynamic in nature. Consequently, the strategies to be employed can only be developed by constantly reviewing the situations that arise, based on previous experience. Just as in socio-economic spheres, physical environments are continually affected by the changing nature of human settlements.
Problems can be separated between small settlements and large polluted cities. Concerned professionals have not clearly differentiated the climatological problems of designing an isolated building, viewed as a holistic entity, from those of the urban building within the complex network of the heterogeneous urban environment.
There is a need to narrow the gap between climatologists and architects, as due to the diverse nature of the profession, the architect rarely has a thorough knowledge of urban climatology. Indeed, it is necessary for the designer to know the climatic implications of any project developed.
This brings to light the question of the appropriate use of research information for the climate-sensitive design.

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1. DOCUMENT TITLE: Sustainable building design for Tropical climate - 2015
Name of the document

2. AUTHOR: Federico M. Butera
Name of the author(s)

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
	X				

3. DESCRIPTION

Climate change and resource depletion are the main challenges that mankind has to face in the 21st century. Through its impact on ecology, rainfall, temperature and weather systems, global warming will directly affect all countries. Nobody will be immune to its consequences. However, some countries and people are more vulnerable than others. In the long term, the whole of humanity faces risks but the more immediate risks are skewed towards the world's poorest and most vulnerable people.

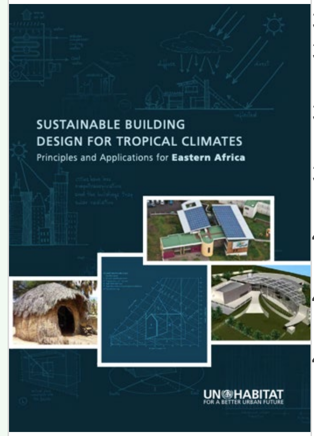
The IPCC report also says that up to 2050 substantial global emission reductions of at least 50% below 1990 levels are needed, with additional global emission reductions beyond 2050, moving towards a zero carbon economy by the end of the century. This is the only way to keep the temperature increase to 2C, which is considered to be the maximum we can afford without incurring catastrophic consequences.

Resource depletion is another critical issue. Both mineral and biological and resources are being depleted and little is going to be left for our descendants. Most essential minerals are going to last less than 40 years, because of the progressive reduction of the ore grades.

Biological resources are also being rapidly depleted: our ecological footprint is growing and the planet's biocapacity is shrinking. Since the 1970s, humanity's annual demands on the natural world have exceeded what the Earth can renew in a year. This "ecological overshoot" has continued to grow over the years, reaching a 50 per cent deficit in 2008.

Short description

4. COVER



Cover image

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38. Climate Responsive Building Design
39. Energy Efficient Building Design
40. Design at Community Scale
41. Renewable Energy Technologies
42. Net Zero Energy Buildings and Communities

Main titles of table of contents

6. RELEVANT THEMATICS

- INTRODUCTION

In 2010 the worldwide building sector was responsible for 24% of the total GHG emissions deriving from fossil fuel combustion, second only to the industrial sector (Fig. 1.2-1); but, if the embodied energy of construction materials is included, the share is far higher and the building sector becomes the prime CHG emitter. Thus, building design and construction have a significant effect on the chances of meeting the 2 °C target .

The challenge is unprecedented and will require (in fact it already requires) a radical transformation of the methods of designing and building. The reduction of CO2 emissions by reducing energy consumption is the top priority facing the construction industry today.

In developed countries, which are mostly located in cold climates, the main cause of energy consumption in buildings is heating, but the efforts to curb this consumption are being more and more frustrated by the growth of air conditioning.

In tropical climates, therefore, the challenge for containing the growth of energy consumption in buildings is not limited to a change in the mentality of architects and builders, but also in the mentality of final users.

Sustainable architecture in tropical climates is a still an unexplored field, and it is an extraordinary challenge for architects, who should be willing to integrate basic information about building physics and aesthetics, and to abandon the approach, which imitates the architecture of developed countries.

- CLIMATES AND BUILDING DESIGN

Different terms are used depending on the size of the geographical area considered. We refer to macroclimate for a large territory, meso-climate for a medium-size area, local climate and microclimate for a small area at the level of the individual or of a single confined space.

Local climate is generally related to an area ranging from a few square meters to a few hectares.

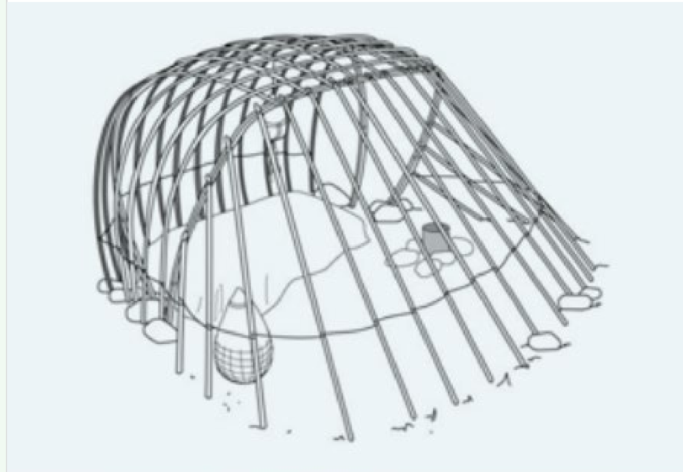
The main climatic parameters influencing the energy performance of a building are: solar radiation; air temperature; relative humidity; wind.

Solar radiation is the main driver of climate, since it influences temperature and gives rise to regional winds. The temperature at a given latitude depends on the angle of incidence of solar rays to the ground: it is highest at the equator and lowest at the poles. The higher the angle of incidence (and thus the lower the latitude) the more energy reaches the ground and the higher the air temperature.

Regional winds derive from the difference in air temperature (and thus pressure) between northern and equatorial latitudes.

7. MAIN CASE STUDIES

Min, Rendille people	Kenya
Name	*Location*



Images

More info:.The materials used to make the outer covering of the Min stop the dust and give protection from the wind, while the shape has functional and thermal purposes. The shape has the minimum surface to volume ratio and minimizes the effects of the critical environmental factors (i.e. sun, wind, heat, cold, rain).

Sukuma House, Sukuma ethnic people	Tanzania
Name	*Location*

Image
Year: 2006

- CLIMATE RESPONSIVE BUILDING DESIGN

The term “passive design” refers to a building whose architectural features are such that they take advantage of local climatic resources to provide an indoor environment which is as comfortable as possible, thus reducing energy consumption due to the need for mechanical heating or cooling.

Solar passive is a term applied to a building where solar radiation enters the interior space through windows, while solar active refers to a building where solar thermal collectors are added to the architectural envelope. It should be noted that in solar passive buildings solar energy can be used only for space heating, while in solar active buildings solar energy can be used for space heating, space cooling and hot water production.

Another term often used to define passive architecture is “Bioclimatic architecture”. More recently the term “green architecture” is also used, which includes the principles of passive or bioclimatic architecture.

A bioclimatic building is completely integrated into the cycles of nature and is able to use them without causing damage.

In passive architecture the means that the architect can use for creating a thermally and visually comfortable indoor environment are: solar radiation, wind, orientation and shape of the building, thermal mass of walls and roof, thermal transmittance and color, opening size and type of glazing.

- ENERGY EFFICENT BUILDINGS DESIGN

There are, for some types of building, periods of the year and climate zones in which thermal comfort cannot be achieved without the use of a cooling or heating system. This is common in commercial buildings, because of the significant internal loads (people, office equipment, artificial lighting), but – to a lesser extent – it also applies to residential buildings. To cope with these situations, in which a mechanical system is needed to provide comfortable conditions, openings must be designed with special care in order to minimise energy consumption. The reason for this is that openings are glazed and windows are shut during the period in which the cooling system is working, with the following consequences:

• solar gains are a more critical issue because of the greenhouse effect;

• natural lighting is a more critical issue, especially in commercial buildings;

• thermal comfort is affected by the temperature reached by the glazed surfaces.

- DESIGN AT COMMUNITY SCALE

The direct impact of the life of a city on climate change is primarily due to the production of CO_2 from the combustion of fossil fuels, i.e. from the energy system. The present urban thermodynamic system is very inefficient, as inefficient as power plants were two

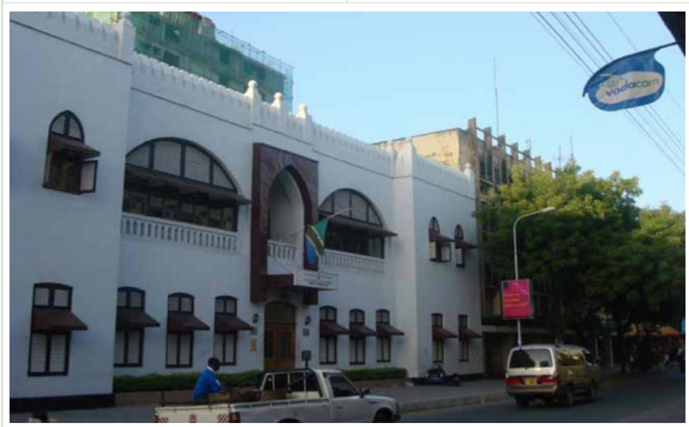
More info: Construction materials, besides bamboo, are elephant grass thatch, reeds, ropes treated with black cotton soil, and clay soil. The split or dissected bamboo is tied to the internal face of the bamboo walls and cow dung is used as plaster. The house is compact and the walls provide a limited level of insulation, as does the thatched roof, while the plaster provides some thermal mass. No finishes are provided externally apart from the decoration of the bisected bamboo pieces tied up with rope.

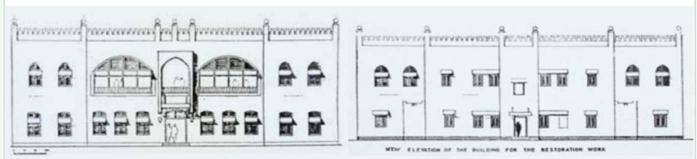
Turkana Huts	Kenya
Name	*Location*

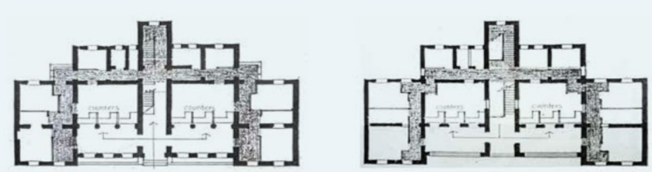
Image

More info: Nomadic communities build simple homes that are used for temporary occupation. The structure of Turkana huts depends on the availability of materials and the type of livestock owned by the family. The huts, which are mostly used during the night, are often dome shaped with the entrance opening facing away from the sun.

Mayai Building	Kakuru Linda, Tanzania
Name	*Location*







centuries ago, and for this reason we waste a very large amount of the high grade energy, or exergy that is contained in fossil fuels – as well as in solar radiation, in wind, in water heads, in biomass.

The need for sustainable urban development requires a shift from the linear to a circular metabolism and, in order to guide this transformation, it is necessary to analyse and understand present processes and their final aims, and replace them with new ones. To design a renewable built environment means, first of all, maximising its thermodynamic efficiency, i.e. minimising the amount of exergy that is used.

The main aim is to minimise primary energy consumption, more than two thirds of which is currently due to the residential, commercial and transport sectors. The fulfilment of this aim involves a combination of several actions i.e.:

- optimise the energy efficiency of the urban structure;
- minimise the energy demand of buildings;
- maximise the efficiency of energy supply;
- maximise the share of renewable energy sources.
- minimise primary water consumption and exploit the energy potential of sewage water;
- minimise the volume of waste being generated and sent for disposal, and use the energy content of waste;
- minimise transport needs and optimise transport systems;
- minimise the primary energy consumption of the means of transport;
- maximise the use of energy from renewable sources in transport.

The aim is to increase the energy efficiency of the urban structure, of individual buildings, of mobility and of energy supply systems and furthermore to maximise the proportion of energy from clean and renewable sources.

- RENEWABLE ENERGY TECHNOLOGIES

The chapter explains the characteristics of:

- Solar PV
- Solar thermal
- Solar cooling
- Wind energy
- Biomass
- Hydropower

- NET ZERO ENERGY BUILDINGS AND COMMUNITIES

In this context, the only answer consistent with the target of reducing emissions is to start to move towards zero energy buildings.

The energy performance of a ZEB (Zero Energy Building) can be defined in several ways.

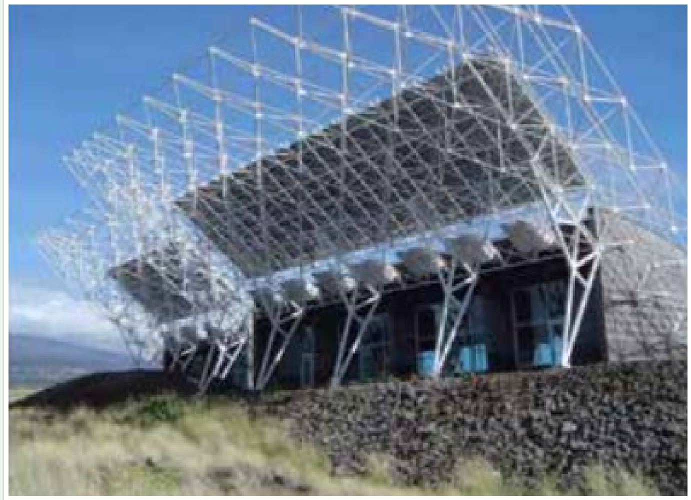
- **Net-Zero Site Energy**: a site ZEB produces at least as much Renewable Energy as it uses in a year, when accounted for at the site;

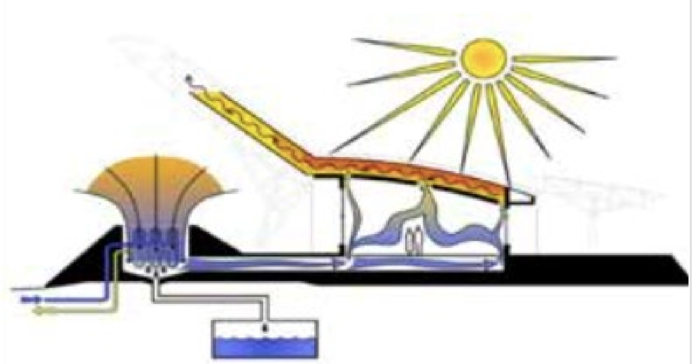
Images

Project by: Anthony B. Almeida | Year: 2011

More info: the building had compact plans in which corridors were created and the roof was restored to its original morphology. The restored building has new shading devices at all the windows to control direct sun radiation. To deal with the obvious inadequacies related to climate, substantial changes were then introduced Particular adaptations can be recognized in: widening of the windows to improve natural ventilation; double facing rooms (north/south) to adapt to the solar path in near equatorial latitudes and to favor cross ventilation; covered porches frequently used around the buildings to provide shading; buildings on studs, to avoid rising damp in the humid climate.

Hawaii Gateway Energy Center	Kona, Hawaii
Name	*Location*





Images

Project by: Ferraro Choi and Associates Ltd | Year: 1989

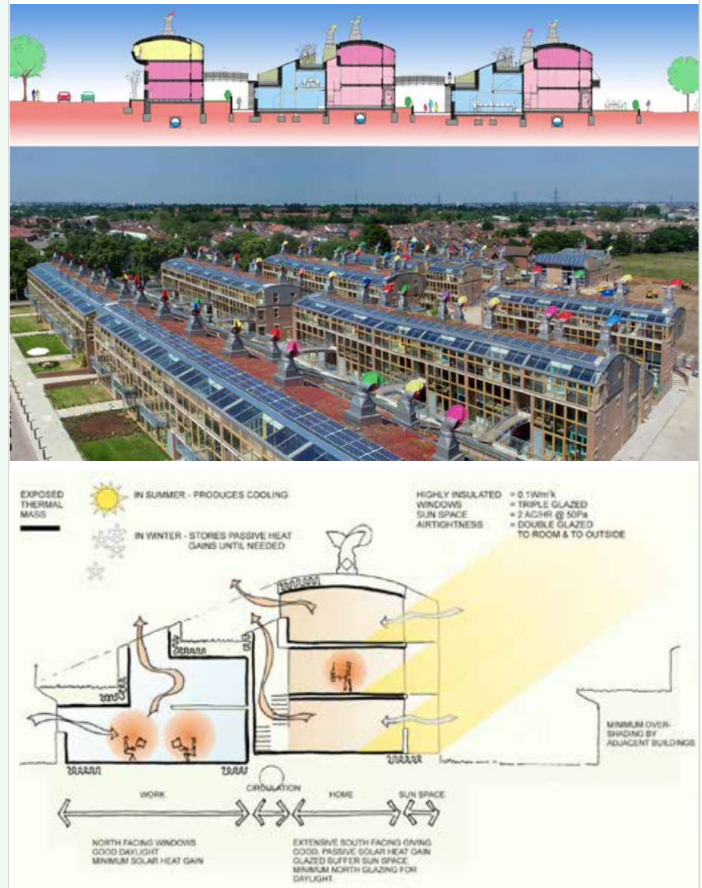
More info: the long axis of the building is oriented east-west for ideal shading and daylighting. There is no need for electric ambient lighting during daytime business hours (8:00 to 18:00 hrs) because the building is entirely daylit. The ventilation design is based on stack ventilation; cross ventilation was considered undesirable, as it would have introduced noise, wind, and dust. Passive thermal chimneys move air without mechanical equipment, allowing conventional air conditioning to be eliminated. The copper roof collects heat, which is radiated into an insulated ceiling plenum. The hot air rises up and out through actual chimneys, drawing cool replacement air into occupied space through an underfloor plenum connected to a fresh-air inlet. The cooling system uses seawater to reduce energy consumption.

- **Net-Zero Source Energy**: a source ZEB produces at least as much RE as it uses in a year, when accounted for at the source;
- **Net-Zero Energy Costs**: in a cost NZEB, the amount of money the utility pays the building owner for the RE the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year;
- **Net-Zero Emissions**: a net-zero emissions building produces (or purchases) enough emissions-free RE to offset emissions from all energy used in the building annually.

There are also two options for RE produced off-site: RE sources are produced off-site, but the energy conversion takes place on-site (as for biomass, wood pellets, ethanol, or biodiesel), or RE sources are produced and converted into useful energy off-site (as for "green purchase" of electricity produced in a distant wind or solar park).

Short description of the most relevant thematics that were addressed in the book

BedZed (Beddington Zero (fossil) Energy Development)	London
Name	Location



Images

Project by: Cortesy Bill Dunster Architects | Year: 2002

More info: The community is designed to host about 240 residents and 200 workers. BedZED is Britain's first urban carbon-neutral development. In order to minimise energy demand the houses face south to make the most of the heat from the sun. With the combination of super-insulation, heat recovery, passive solar gain stored within each flat by thermally massive floors and walls and internal gains, comfort temperature is obtained for most of the time without any need for backup heating. Moreover, wherever possible building materials have been selected from natural, renewable or recycled sources and brought from within a 55 km radius of the site. Primary energy consumption is minimised at two levels: individual building and community; in both cases renewable energy is used to power the energy efficient systems.

7. REMARKS

A basic premise of this book is that most decisions that affect a building's energy use occur during the pre- design, schematic or preliminary design stages of the project as the diagram, Front Loaded Sustainable Design indicates. Furthermore, the effort required to implement those decisions at the beginning of the design process is small compared to the effort that would be necessary later on.

Therefore, if energy issues are going to receive an appropriate level of consideration at the beginning of the design process, an effective strategy is to present them in a way that is useful to the designer and fits with other things the designer is considering at that time. The book's intention is to give only general ideas about architectural elements and their size and relationship to other elements. Precision of the information is sacrificed somewhat so that speed of use may be increased. The approximation methods are founded on certain assumptions about the elements under consideration.

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1. DOCUMENT TITLE:	Energy and resource efficient urban Neighbourohood design principles for tropical countries. Practiotioner's Guidebook - 2018	2. AUTHOR	Federico M. Butera
	Name of the document		*Name of the author(s)*

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
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3. DESCRIPTION

Roughly half of the world's population lives in urban areas, and this proportion is projected to increase to 66% by 2050, adding 2.5 billion people to the urban population. Over the next two decades, nearly all the world's net population growth is expected to occur in urban areas, with about 1.4 million people – close to the population of Stockholm – added each week (New Climate Economy 2014). With the current trend in urban density, this is equivalent to building a city the size of Greater London every month for the next 40 years (UN-Habitat 2013a). If current development trends continue, by 2030 cities in developing countries are expected to occupy triple the land area they occupied in 2005 (UN-Habitat, 2012).

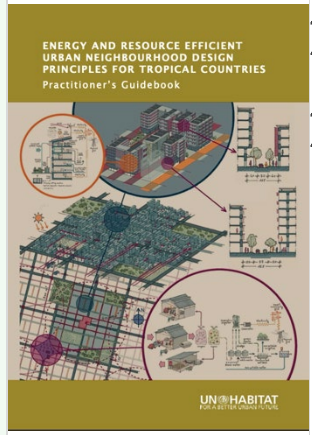
Almost 90% of the global urbanization between now and 2050 will occur in Asia and Africa (United Nations, 2014); in sub- Saharan Africa the proportion of urban dwellers is projected to increase from 37% of the total population in 2010 to nearly 60% in 2050 (OECD-FAO, 2013). Urban areas generate around 70% of global energy use and energy-related Green House Gas (GHG) emissions (IEA 2009), thus cities in the developing world, where most of the growth will take place, will have a significant impact on GHG emissions, seriously threatening any effort to reduce them – unless new urban developments are designed to minimise their impact.

Current models of human settlements are not designed to cope with the environmental challenges and are not sensitive to the rapid technological advancements from which our built environment could benefit. New real estate developments at the neighbourhood scale are producing a silent and uncontrolled urban revolution. Taken alone, small-scale housing developments might not be perceived as relevant, but if added together these new urban estates are shaping the image of the majority of megalopolises and cities in developing countries. Recent developments of new neighbourhoods and districts are here to stay and will affect energy patterns, the image of society and lifestyles for many decades.

The design of new urban developments is a key issue for coping with global warming and the quality of urban life, and, bearing in mind that urban design principles that apply to cities in tropical climates differ significantly from the principles that apply to cities in temperate climates, it is a burden shared by both developed and developing countries.

Short description

4. COVER



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5. TABLE OF CONTENTS

43. Introduction
44. Design for a sustainable neighborhood
45. Design tips and checklist
46. Best practices

Main titles of table of contents

6. RELEVANT THEMATICS

- INTRODUCTION

Urban density is a critical but controversial factor in sustainable urban design, as the issue of its impact on Green House Gas (GHG) emissions is a complex one.

On the one hand, it is recognised that urban density is inversely correlated with transport energy consumption, and CO2 emissions: the higher the density the lower the energy consumption. Density is also inversely correlated with energy consumption for space heating and cooling, because the higher the density, the lower a building's surface to volume ratio. Furthermore, density is related to land consumption, which affects CO2 emissions: the higher the density, the lower the land consumption, i.e. the lower the amount of land converted from green to built, with consequently lower emissions, because vegetation acts as a carbon sink by absorbing CO2.

On the other hand, urban density is also positively correlated to the Urban Heat Island (UHI) (Oke 1973): the higher the density, the more intense the UHI, decreasing outdoor comfort and increasing energy consumption, and CO2 emissions for space cooling.

GHG emissions in a city derive not only from the building, transport, and industry sectors, but also from solid waste, water and wastewater management. Appropriate focus on these issues is the key to designing low emission cities.

When a new urban development in a developed country is being designed, it is taken for granted that it will be connected to the existing city's electric grid, water network, sewage system, gas network, solid waste collection and disposal system, and transport system.

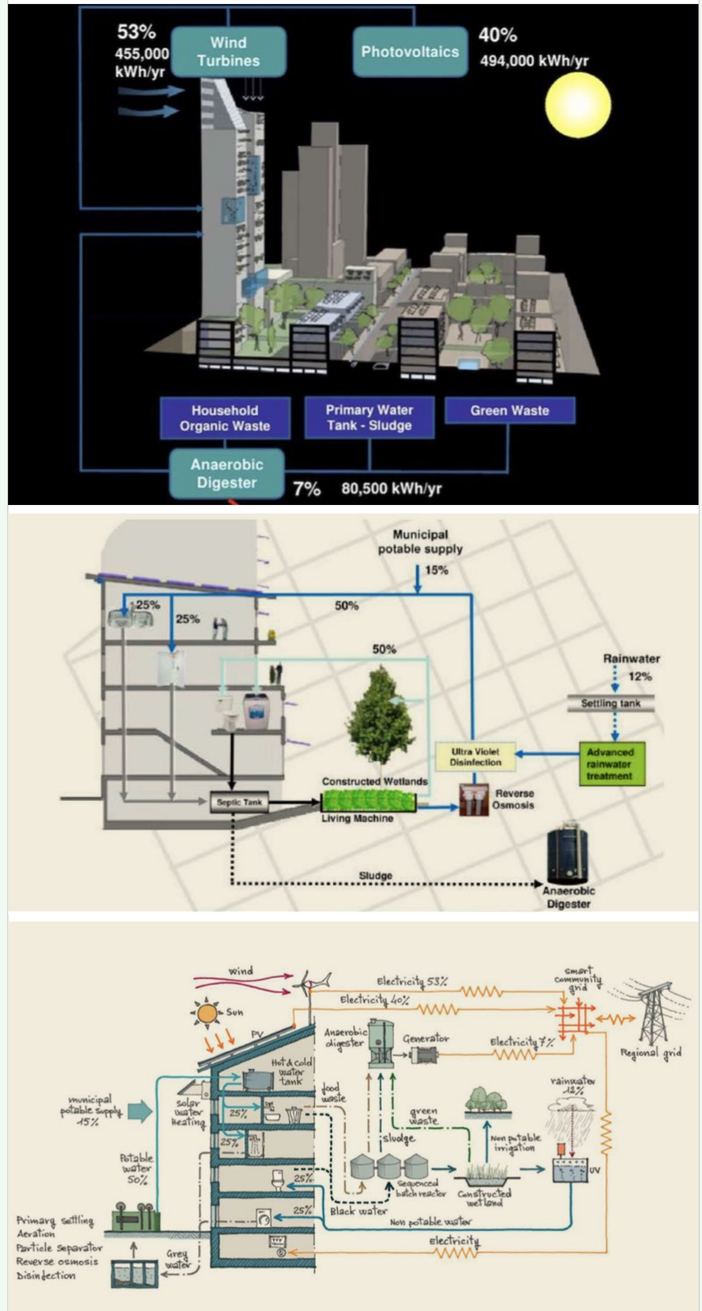
In cities in developing countries, on the other hand, these facilities are often not efficient or reliably available, or are not available at all, thus a new development should be planned and designed with these issues in mind and distributed energy generation, local water supply and local stormwater, wastewater and solid waste treatment systems should be included in the design.

In a new settlement (whether it be a planned city extension or infill development or urban transformation) located in a developing country, the new approach of distributed generation of energy, maximising the use of renewable sources and supported by smart grid technologies, is going to be a viable alternative to the centralised approach characteristic of the energy supply system of existing cities, because it may well suit rapidly expanding cities.

In the coming decades the balance between energy demand and renewable energy supply at neighbourhood or district scale will be a prerequisite

7. MAIN CASE STUDIES

Sustainable neighbourhood	Quingdao, China
Name	Location



Images
Project by: Fraker H. and UC Berkeley | Year: 2008
More info: The plan proposed an integrated system of energy generation, water conservation and supply, and waste treatment.
EcoBlocks are also semiautonomous water management/ drainage units that receive water, implement water conservation inside the structural components throughout the cluster, capture and store rainfall and stormwater, reclaim sewage for reuse, and recover biogas from organic solids.
Furthermore, at a local cluster/ecoblock scale, aquifer recharge will be accomplished by infiltration of captured stormwater by means of pervious pavements, ponds, wetlands and gardens. Such systems reduce the potential transport of stormwater pollutants, decrease the choking of storm water drains and flooding, improve the quality of ground water and also allow the storing of water that can be reused for other purposes.

for sustainable (environmentally, economically and socially) urban development both in developing and developed countries.

- DESIGN FOR A SUSTAINABLE NEIGHBORHOOD

Designing a sustainable built environment means, first of all, maximising its thermodynamic efficiency, i.e. minimising the amount of entropy generated by the urban metabolic process and enabling the reduction of the negentropy flow entering the system without impairing its functions.

The fulfilment of this aim involves several combined actions, namely:

1. Minimise energy demand of buildings;
2. Minimise energy demand for transport;
3. Maximise efficiency of energy conversion technologies;
4. Fulfil the remaining energy consumption with renewable energy sources;
5. Optimise the water cycle;
6. Enhance solid waste reuse and recycle;
7. Close energy, water and waste cycles on site;
8. Minimise indirect GHG emissions.

Control of local climate and microclimates, in turn, also affects the inhabitants' health and the neighbourhood's liveability. Given the complexity of the interactions between urban design, local climate, outdoor and indoor thermal comfort, energy consumption, environmental impact, health and liveability of outdoor spaces and the importance of local climate control, a basic knowledge of urban climatology and thermal comfort principles is necessary for the urban designer, whose task is to design the urban layout in such a way as to create comfortable outdoor conditions through an appropriate control of energy balances on three levels: building, street delimited by buildings (canyon), neighbourhood .

- DESIGN TIPS AND CHECKLIST

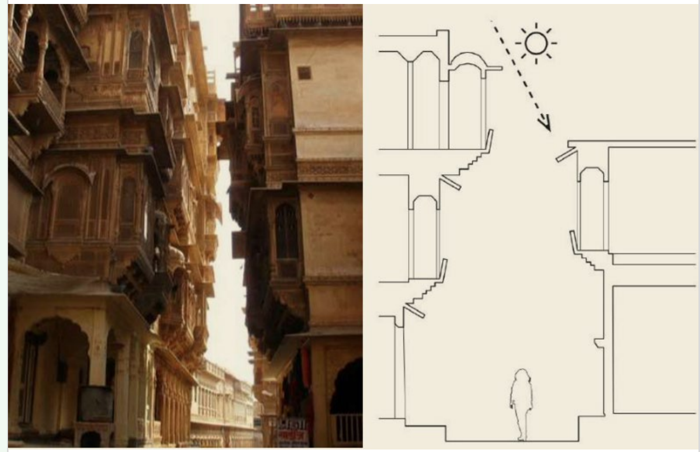
In this chapter, tips for urban design have been collected and organized to provide a synthetic guide for the design of more environment and energy-aware urban neighbourhoods in tropical climates in general and more specifically in EAC climates.

The growth of cities in developing countries is unavoidable, but it should be good growth. New developments should follow the principles of sustainability and resilience, simply because the way we build today will last for many decades and will affect the lifestyle of the citizens of the future.

The planning and design of new neighbourhoods should respond to performance requirements. Performance requirements in the built environment are mainly the following:

• Well-being, which includes physiological aspects related to human comfort, such as identity, sense of

Urban design for shade and climate attenuation, ancient city	Jaisalmer Rajasthan Jaisalmer, India
Name	Location



Images
Year: 1990
More info: The buildings in Jaisalmer employ various techniques to create a microclimate in the streets and public spaces of the city. At a large scale the streets themselves are laid out to prevent winds from entering and building up. The main streets run east-west provide protection from the primarily south-west summer winds. The streets are also narrow and winding, preventing the breezes that do enter from building up speed along their length.

Birkha Bawari	Jodhpur, India
Name	Location

belonging and safety, besides thermal and visual comfort;

• Energy efficiency and clean sources of energy;

• Environmental quality and sustainability, which involves water, sanitation and materials;

• Resilience.

The design tips address the following subjects:

• Site layout; location,

• Site layout; planning,

• Climate responsive design,

• Energy supply,

• Urban metabolism and closed cycles,

• Social and economic domains.

• BEST PRACTICES

The chapter is divided into:

• **Principles of urban climatology**: energy and water balance of an ideal volume, air movement, energy and water balance of the urban canopy layer, impact of urban geometry on albedo, impact of urban geometry on air movement.

• **Principles of outdoor thermal comfort**: components of the energy balance for outdoor comfort, thermal comfort indices for the outdoor environment.

• **Obstruction profile construction**: obstruction profile construction using a graphical method.

• **Shadowing**: evaluation of shadows, solar protection of canyon walls, shade from trees.

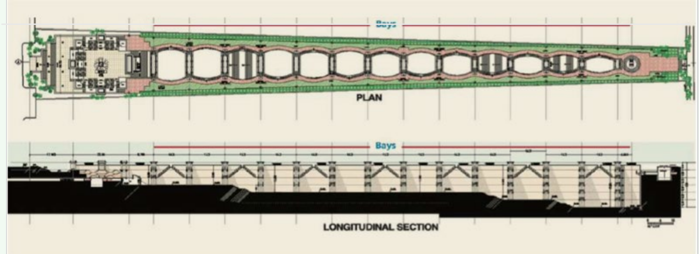
• **Polar sun charts**

• **Renewable energy technologies at neighborhood scale**: solar thermal energy, photovoltaic systems, wind energy, biomass.

• **The hydrologic cycle**.

• **Dewats components**.

Short description of the most relevant thematics that were addressed in the book

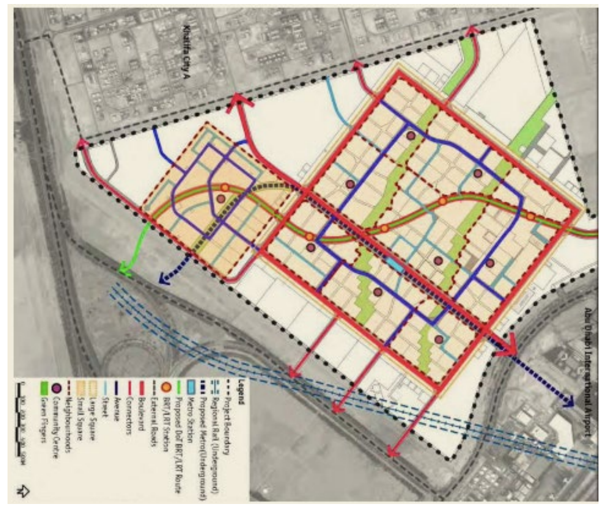


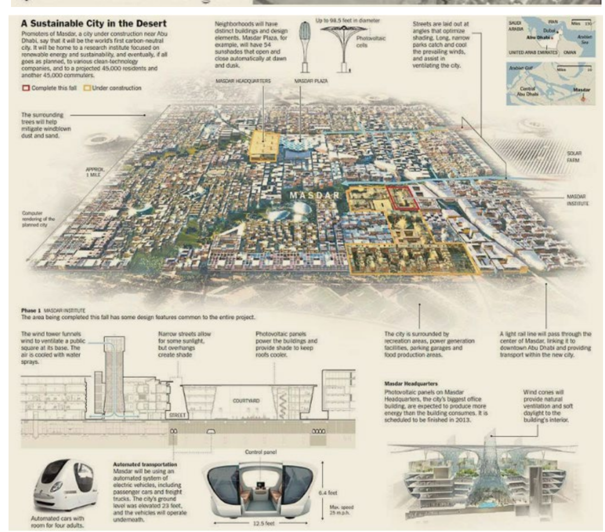
Image

Project by: Anu Mridul | Year: 2010

More info: The Birkha Bawari was designed in accordance to the vernacular architecture and the structure acts as a recreational space for inhabitants as well as storage of rainwater – and is a good example of sustainable urban development in a low rainfall region, demonstrating the value of water by conserving rainwater. The rainwater is collected from the open areas through the natural slopes as well as from the roof tops of houses which in turn are connected with the natural slope of the site through drainage conduits.

City masterplan	Masdar City, Abu Dhabi, United Arab Emirates
Name	*Location*





Images

Project by: Foster and Partners | Year: 2008

More info: he goal of Masdar City is to create a walkable, vibrant mixed-use community through the creation of interconnected neighbourhoods and public places designed to be friendly to pedestrians and cyclists. Public spaces, parks and streetscapes will be designed to encourage walking and outdoor activity throughout the day while planting, shading and water strategies will all contribute further to reducing the radiant temperature and to maximising cooling breezes to extend the time that people can spend outdoors.

7. REMARKS

The incorporation of sustainability principles in neighbourhood design becomes crucial, for several reasons. First, the neighbourhood is the basic unit of the urban organism. Second, the problems presently encountered at city level are the cumulative consequences of poor planning at the neighbourhood level. Third, neighbourhood scale development is also a relatively typical form of development, both for private real estate developers and for public interventions. Fourth, efficient and sustainable urban infrastructure, including buildings, transportation, urban vegetation, and water (i.e., water supply, wastewater, and stormwater) systems require detailed design at neighbourhood scale, not at the city scale. Fifth, decisions made at the neighbourhood scale are highly pertinent to quality of life.

According to UN-Habitat's Five Principles, a sustainable neighbourhood is characterised by:

- Adequate space for streets and an efficient street network
- High density
- Mixed land-use
- Social mix
- Limited land-use specialization

When the Five Principles are followed, the urban structure is appropriately shaped, and both the transport and the social issues are addressed. To complete the picture, features related to energy and materials, to water and waste must also be added, to encompass the metabolism of the whole neighbourhood.

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1. DOCUMENT TITLE: Stay Cool: a design guide for the built environment in hot climates - 2002
Name of the document

2. AUTHOR: Holger Koch-Nielsen
Name of the author(s)

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
			X		

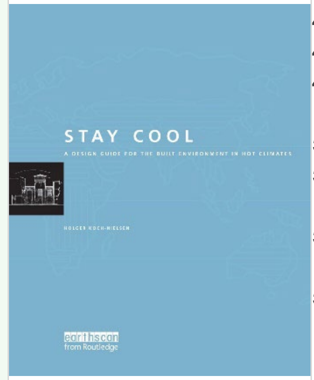
3. DESCRIPTION

This Guide aims to introduce the principles and tools for rethinking the built environment through the perspective of energy.

It will provide some ideas and present useful strategies to explain the general principles of using passive systems to achieve the comfort requirements of some specific climate characteristics.

Short description

4. COVER



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49. Thermal comfort requirements
50. The built environment
51. The external environment
52. The building envelope and its components
53. Thermal properties of building materials and elements
54. Natural ventilation and cooling

Main titles of table of contents

6. RELEVANT THEMATICS

- INTRODUCTION

7. MAIN CASE STUDIES

Name	Location
Active design building	Coventry, UK

The use of **energy-efficient solutions** may be easier in the future to meet the demand of energy in hot and warm developing countries.

Alternative energy resources may be in common use in the future, although there is no concrete information on how well renewable energies can meet current energy demand.

If future energy demand is to be sustainable and affordable in developing countries, alternative approaches that promote energy efficiency must be adopted.

To achieve indoor and outdoor comfort conditions, it is important to use **active design** by developing design solutions that make the most of passive measures.

Active design requires an integrated approach that takes into consideration different disciplines, such as architecture, planning, engineering and construction, involving them at all levels of the design process.

In this process, is imperative to do thermal evaluations during the design of the building, because the passive measures employed in the design will have a direct influence on the architecture.

- CLIMATIC ISSUES

Knowing the type of climate in a particular place is the basis for sustainable design.

The climate of a region is defined generally as the interaction of different meteorological elements:

- Solar radiation
- Air temperature
- Humidity
- Wind
- Precipitation

These data as to be collected at the beginning of the design process.

There are also other important features that influence the climate of a site and need to be examined:

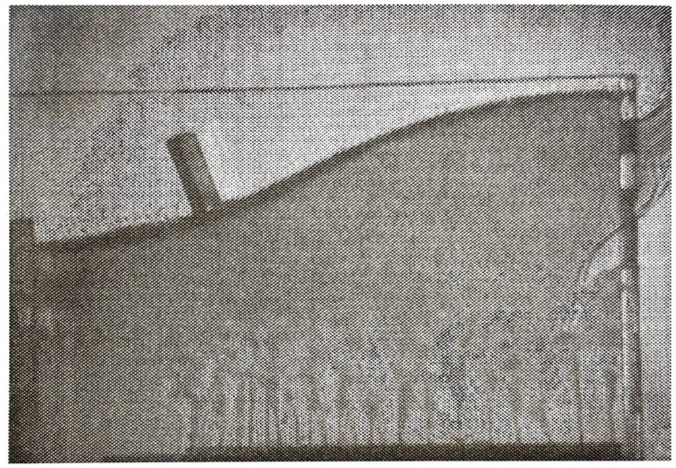
- Topography
- Ground cover and vegetation
- Water
- Building densities

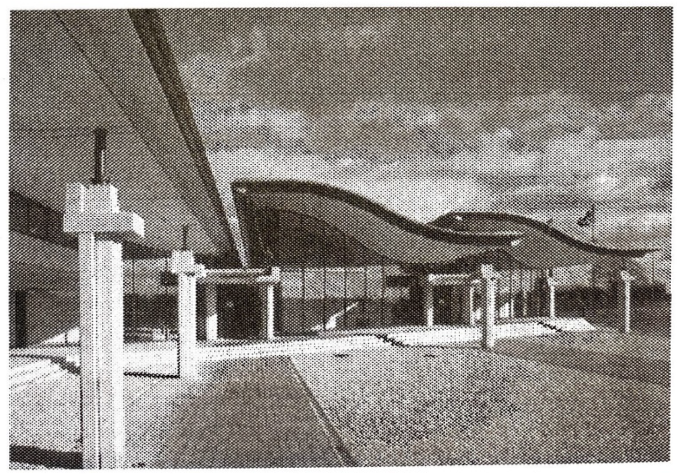
- THERMAL COMFORT REQUIREMENTS

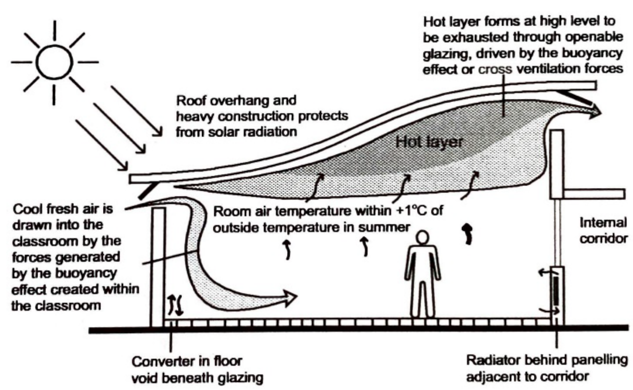
A built environment works in the right way when it provides protection from the stresses imposed by the climate.

Thermal comfort is the sensation of well-being of an individual in an environment and it varies from one individual to another. It includes both physiological and psychological aspects.

The limits for the thermal comfort vary with the level of adaptation to the climate and the psychological and social environment.







Images / Schemes

More info: active design requires that decisions made throughout the design process be rechecked and changes made accordingly.

Name	Location
Compact urban layout cities	Tunis, Tunisia (top) Yazd, Iran (below)

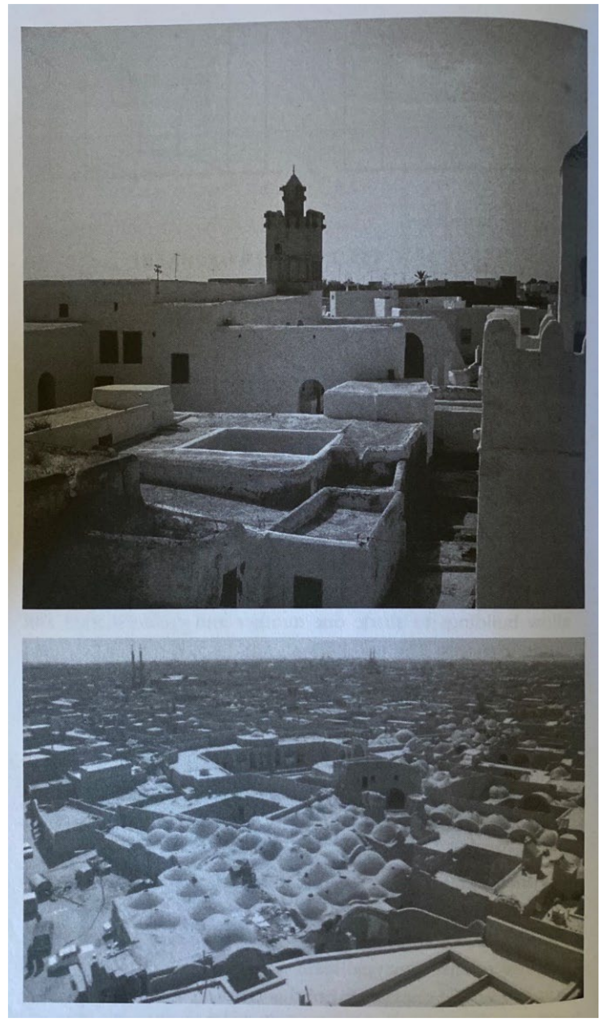
Building should be made to limit as much as possible the uncomfortable conditions through the thermal comfort conditions.

- THE BUILT ENVIRONMENT
  To design a good built environment, we should take advantage of the beneficial aspects of the climate and modify the unfavorable aspects.
  In the design process we should take into consideration not only the comfort of the internal environment but also outside the building, because green areas in the urban settlements effect the climatic condition and reduce the exterior temperature.
- THE EXTERNAL ENVIRONMENT

  As already said, an active design must take into account the surrounding space: trees and grass have a cooling effect, so they help cooling the ambient air, a shading effect and a low reflectivity.
- THE BUILDING ENVELOPE AND ITS COMPONENTS
  The building envelope is the location where there is the interrelation between the external and the internal conditions.
  The envelope needs to respond to different typologies of external conditions and, in particular for hot climates, the most important element is the solar radiation heat gain.
  The building's envelope has also to release the internal heat gains.
- THERMAL PROPERTIES OF BUILDING MATERIALS AND ELEMENTS

  The way in which the material reacts to thermal forces will be determined by its thermal properties and they will define the way the material will respond. How it:

  - Reflects heat
  - Absorbs heat
  - Emits heat
  - Reduces the flow of heat



Images

More info: the urban form should be compact to expose little to the sun except the roofs of buildings.

Botswana Technology Centre	Gaborone, Botswana
Name	*Location*

- Stores heat and releases it.

Materials will always have a combination of these five properties.

If the quality of the execution of the construction is good, it gives an important effect on the thermal values of the building elements.

- NATURAL VENTILATION AND COOLING

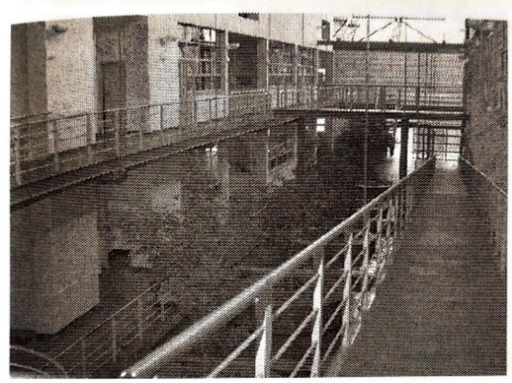
Natural ventilation can be useful for a lot of reasons: supply fresh air, remove odours, remove internal heat, cool the structure, reduce structural radiation and produce evaporative cooling of the body and the air.

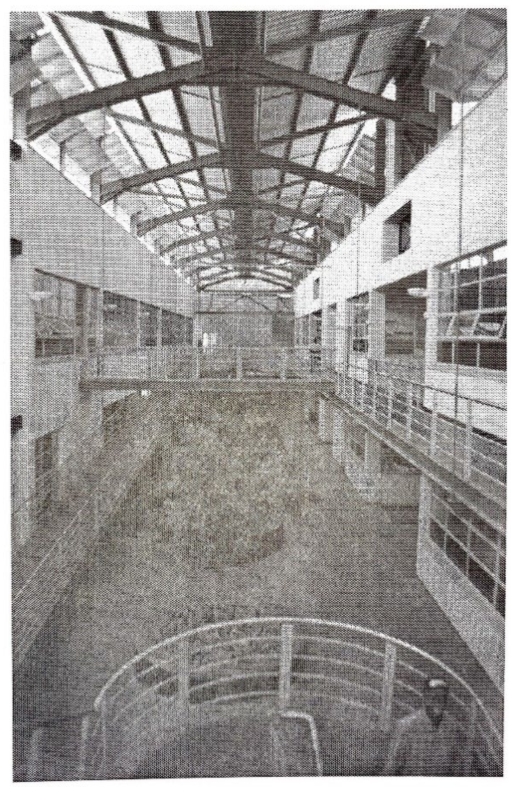
It can occur when there is:

- Wind-generated air pressure differences
- Temperature-generated air pressure differences

In hot and dry areas, natural ventilation is a mixture of vertical and horizontal air movements, while in warm and humid climates ventilation is horizontal and relies on pressure differences generated by the wind.

Short description of the most relevant thematics that were addressed in the book





Images

More info: the envelope is designed around the central space with highly placed louvered openings to the exterior creating an internal street with natural ventilation and indirect light.

7. REMARKS

There are various tools that the designer can use to check design decisions. They range from simple methods for initial designs to more complex computer modeling programs for specific design solutions.
In the simple analysis we can find:

- *Solar charts* that provide a comprehensive and easy-to-use design aid for the prediction of solar radiation exposure and shading of a building.
- *Mahoney tables* that are used to arrive at a series of performance specifications.

Are also used *Wind tunnel test models* that are physical models of buildings on a site used to examine air flow around the buildings.

In the complex analysis, we find Computer modeling, made with different computer programs: they range from rather simple calculations requiring general data input to sophisticated modeling techniques requiring a large amount of exact data.

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ABC21 is funded by the
EU's H2020 programme

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1. DOCUMENT TITLE: Bioclimatic Architecture in Warm Climates: A guide for best practices in Africa - 2019

Name of the document

2. AUTHOR: Manuel Correia Guedes, Gustavo Cantuaria

Name of the author(s)

2. CATEGORY:

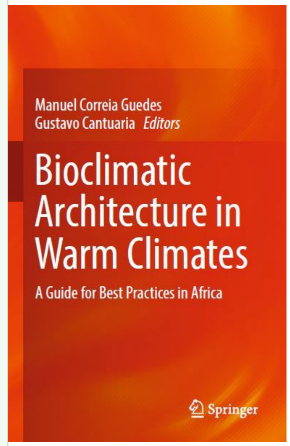
Article	Book	Report	Handbook	Guideline	Manual
	X				

3. DESCRIPTION

The book suggests basic strategies for the practice of sustainable building and urban design. It is aimed at students and professionals of architecture and civil engineering, being also accessible to the public with some technical preparation in the construction area. Considering the local climates, natural resources, and socioeconomic contexts, good practice design strategies are drawn up in a simplified way.

Short description

4. COVER



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58. Urban sustainability
59. Energy
60. Building materials
61. Water, Sanitation, and Drainage
62. Environmental Assessment Systems

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6. RELEVANT THEMATICS

- INTRODUCTION

  Much of the materials of this book is sign posted from the implemented project of SURE-Africa (Sustainable Urban Renewal: Energy Efficient Buildings for Africa). Its main aim was to deepen and disseminate existing knowledge in African countries, in the area of sustainable architecture, in particular with regard to bioclimatic design and energy efficiency in buildings, contributing to the improvement of the living conditions of the built space. It is the purpose of this work to provide valuable information on the amelioration of outdoor microclimates to achieve thermally comfortable living environments, relying on the passive interaction of the built environment with its surroundings.

- CLIMATE

  This chapter presents a brief description of various climatic regions existing in distinct locations in Africa, as examples of the starting point of the methodological process for the practice of bioclimatic architecture, of passive design. These climatic characteristics determine the level of comfort inside the buildings, as well as the appropriateness of different building design strategies.

- BIOCLIMATIC DESIGN

  The chapter presents the principals to be taken during the design process which are associated with the sun and knowing the climatic characteristics of the country. Beginning with the first steps to consider – the location, shape and orientation of buildings. In addition, the chapter highlights the role of social cohesion in

7. MAIN CASE STUDIES

Name	Location
Pancho Guedes' architecture	Maputo, Mozambique

Example: Spence e Lemos building

Example: House of Judge Camara

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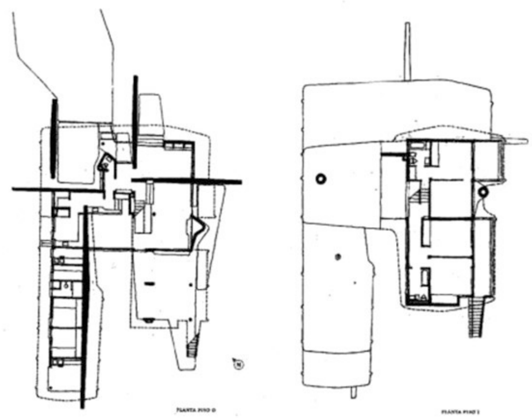
implementing pro-environmental behavior and adaptive actions to reduce the negative effects of climate change on indigenous communities of the northern Sahara. Moreover, it introduces the potential of vegetation to provide outdoor microclimates thermally more comfortable than in unvegetated places. Also, the chapter gives an overview of refined architecture solutions of shading, cross ventilation, and thermal control in Mozambique with a focus on Pancho work.

- URBAN SUSTAINABILITY
  This chapter emphasize the importance of finding operational planning mechanisms designed specifically for each of the slums' intervention cases implemented throughout history. In addition, adaptation approaches are presented throughout the chapter with the emphasize of the importance to find proactive approaches that can be a decisive factor for sustainable urban development in the context of the high rate of urban growth in the next decades. The chapter then address the key challenges in four areas: energy, water, food security, climate change, which are critical for sustainable development in rural Africa over the coming decades. It also presents the main challenges to overcome in order to have sustainable and smart cities in Africa in the future, including challenges, problems, and restrictions about social, economic, and environmental and political issues in Africa. It analyzes the main constraints of urban development on the African continent and confirms that smart cities will be possible in Africa when the current problems of sustainable development are overcome. lastly, the role of the building permit and its integration – or not – in an urban development framework is explored by using the building permit as one tool – a jigsaw – in the urban development and analyzing the need of an urban framework.
- ENERGY
  The chapter supports the opportunity for sub-Saharan countries to design low-fuel, low-carbon energy systems based on wind, geothermal and solar energy technologies as well as to use easy and efficient demand management strategies. The region has abundant fossil and renewable energy sources. The immense potential of renewable energy sources in Sub-Saharan Africa has been widely documented, and there are increasing instances of that potential to be achieved. The chapter also covers the renewable energy challenges for Sub-Saharan countries.
- BUILDING MATERIALS
  Building materials used in Africa are discussed in this chapter, mainly: Masonry, timber, and bamboo. The chapter acknowledges the predominance of structural masonry in large plan buildings in Africa, forming the external walls and sometimes some interior walls as well. One of the most common types of dwelling in Africa is based on adobe brick walls, consisting of blocks of clay-based earth mixed with sand that are

Images
Project by: Pancho Guedes | Years: 1957 (top); 1954-1956 (below)
More info:
Upper example: there's the retreat of narrow and high gaps in the northwest and northeast façades to reduce direct radiation. Together, they reveal a systematic and simultaneously creative group of solutions to design shading devices.
Lower example: were designed completely enclosed balconies with wooden mashrabiya. The use of sheds, reinforced concrete pergolas or advanced volumes on the upper floors to create shaded areas on the ground floor are solutions implemented in these small single-family dwellings.

The Plane House	Mozambique
Name	*Location*



Plans / Images
Project by: Pancho Guedes | Years: 1951-1958
More info: What characterizes this house are the soft curvature covers coated with a waterproofing mortar of lime and white stone. The raised bedrooms volume creates a living area covered by the same area of the room but without walls, a space that, along with the inner courtyard, denotes the topicalization of the architecture of the Modern Movement.

The Prometheus Building	Mozambique
Name	*Location*

molded and compacted in wooden boxes and dried in the sun. More topics like rehabilitation of masonry walls, solutions for rising dampness, use of timber in construction, traditional bamboo-based construction material and bamboo-based buildings and framing systems are discussed.

- WATER, SANITATION, AND DRAINAGE
  This chapter covers aspects related to the abstraction, treatment, reservation and distribution of water in African countries. In addition, sanitation approaches will be detailed, considering dry sanitation, faecal sludge management and conventional sanitation. Finally, some major concerns related to stormwater drainage in urban areas are presented.
- ENVIRONMENTAL ASSESSMENT SYSTEMS
  The chapter keys points are: (1) analyzes environmental assessment tools for sustainability in built environments used in Africa, (2) presents a voluntary tool to assure a built sustainable assessment tool that is LiderA and how to apply it, (3) concludes with the identification of Africa major challenges that could assure environment sustainability and the potential of using sustainable assessment systems like LiderA.

Short description of the most relevant thematics that were addressed in the book

Plans / Images
Project by: Pancho Guedes | Years: 1951-1958
More info: clarity in the structure and the use of the brise-soleil. However, it has distinct characteristics: the seven structural elements function as "trees" constituted by pillars and beams with large consoles that cross the façade of the building.

7. REMARKS

Throughout the SURE-Africa project, a number of seminars, workshops, and conferences were held, a knowledge network was established between the institutions involved in the field of sustainable urban planning and architecture, and teaching materials were produced as well as good practice manuals. These manuals provided the foundation for this book, which should be regarded as a starting point for future research work, so necessary in this area.

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1. DOCUMENT TITLE: Sustaibable Building Design for Africa 2022
Name of the document

2. AUTHOR: Prof. Federico M. Butera, Rajendra Adhikari, Niccolò Aste
Name of the author(s)

2. CATEGORY:

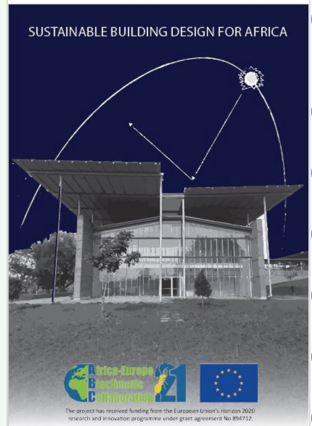
Article	Book	Report	Handbook	Guideline	Manual
			X		

3. DESCRIPTION

The handbook provides sustainable design guidelines for African countries with different climates. It presents affordable yet sustainable design solutions, starting from building form to HVAC systems, which results in achieving an energy efficient building.

Short description

4. COVER



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66. Energy efficient buildings design
67. Design at community scale
68. Renewable energy technologies
69. Net Zero Energy Buildings and Communities

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6. RELEVANT THEMATICS

- INTRODUCTION TO ENERGY EFFICIENCY AND SUSTAINABILITY IN BUILDINGS

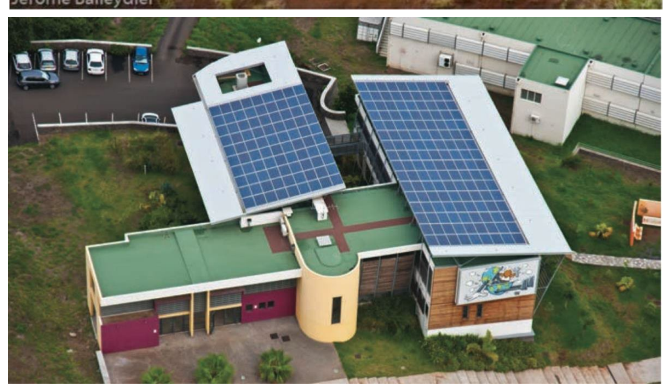
Climate change and biodiversity loss are the main challenges of the 21st Century that affect all countries, but the risks and vulnerabilities are skewed toward the world's poorest people. Resource depletion is another critical issue. The introduction explains how the building sector will require a radical transformation of the ways to design and build to reduce CO2 emission by reducing energy consumption. Thus, changing the design methodology and making use of the integrated design model that includes energy expertise is highly recommended. The combination of both a well-designed building, where solar gains are controlled and natural ventilation is exploited at best, and the adaptive comfort principles can dramatically reduce air conditioning energy consumption providing very good comfort conditions. Therefore, the task is to transform, with a sort of genetic engineering, the fossil energy-based city –into the renewable energy-based city.

- CLIMATE AND BUILDING DESIGN

Firstly, this chapter discusses the main climatic parameters influencing the energy performance of a building which are solar radiation (the main driver of climate), air temperature, relative humidity and wind. The knowledge of solar geometry and solar radiation are very important for architectural design and energy efficiency strategies as emphasized and explained by the author. Lastly, the climatic classification system and the main three classes of climates identified for African continent are introduced, mainly Group A: Hot-

7. MAIN CASE STUDIES

Name	Location
ENERPOS	Reunion Islands



Images
Project by: Thierry Faessel-Bohe | Year: 2008
More info: two-storey university building split into two parallel wings separated by a vegetated patio, underneath which there is a car park.
use of passive means and natural resources such as sun and

Humid, Group B: Arid, Group C: Temperate. Buildings, to be sustainable and low energy must be climatic responsive. Each climatic zone was characterized by a set of strategies that should be adopted to minimize energy consumption and maximize thermal comfort.

- CLIMATE RESPONSIVE BUILDING DESIGN

The chapter starts with the explanation of Passive design and the means that the architect can use for creating a thermally and visually comfortable indoor environment. Those elements are solar radiation, wind, orientation and shape of the building, thermal mass of walls and roof, thermal insulation and color, opening size and type of glazing. Then Giovani Bioclimatic charts are introduced along with its application to different African climates. Furthermore, according to African climates, design guidelines are recommended for site planning and building design. Those recommendations include the selection of urban patterns, building shape, orientation, building fabric thermal transmittance and mass, roof and wall design, openings, natural ventilation, day lighting, shading, natural cooling, and building materials.

- ENERGY EFFICIENT BUILDINGS DESIGN

Primarily, this chapter discusses how the building envelope heavily influence the building's energy performance. The envelop consists of all building components and technical elements that morphologically and functionally define the boundary between a building's interior and exterior environment. The balance between opaque and transparent surfaces, as well as them interaction with climatic factors and technical features, must be the basis of sustainable building design. Therefore, the chapter explains the properties to be considered in the opaque envelope, glazing, opening sizing, efficient energy conversion technologies, DHW production, Artificial lighting, Hybrid ventilation in new and existing buildings. Lastly, simulation tools building energy codes - energy performance certificates and green building rating systems (the most commonly used) are outlined.

- DESIGN AT COMMUNITY SCALE

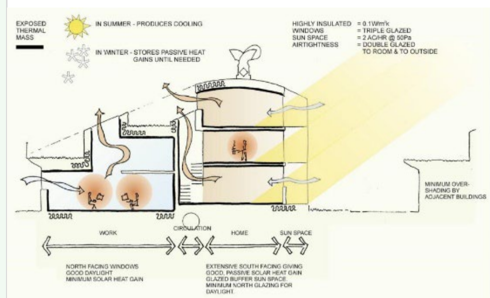
In addition to CO2 emission, emissions embodied in the flow of materials and food are a very critical issue which should not be overlooked. This chapter discusses the minimisation of fossil fuels and materials inputs; prerequisite that can be satisfied by maximising renewable energy use, energy efficiency and recycling and reuse of water and materials.

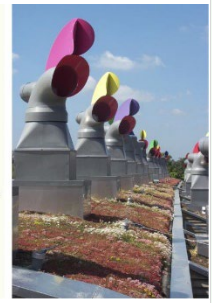
- RENEWABLE ENERGY TECHNOLOGIES

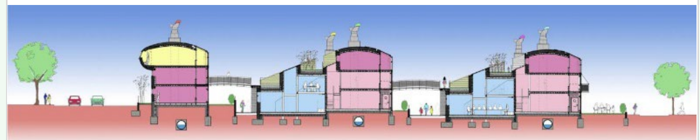
The chapter introduces Solar PV (photovoltaic systems) as a source of electricity and its architectural integration in strictly economic terms. Additionally, it

wind to achieve thermal and visual comfort.

BedZed	Surrey (UK)
Name	*Location*







Images
Project by: Bill Dunster Architects and ZEDfactory and Ove Arup & Partners
Year: 2002
More info: mixed development urban village, built by a private investor.
In order to minimize energy demand the houses face south to make the most of the heat from the sun, and are fitted with high levels of insulation, airtight triple-glazed windows and the latest energy saving appliances, including water saving devices.

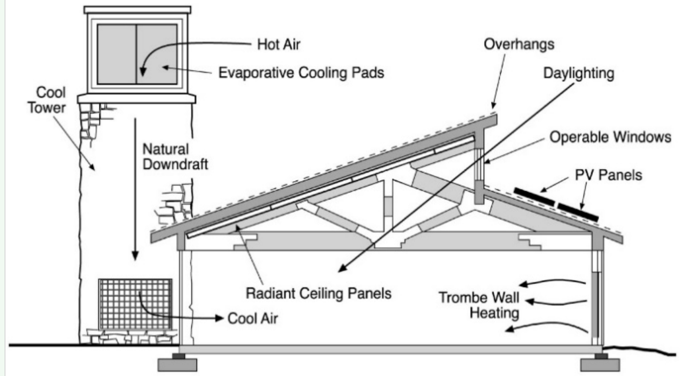
Zion National Park Visitor Center	Utah (USA)
Name	*Location*

discusses the solar thermal systems as a source of production of hot water and solar cooling. The use of Wind turbines for energy savings (stored in batteries or fed into local distribution grid) in residential buildings, hotel, commercial or manufacturing activities. In addition, Biomass represents a promising source alternative to fossil fuels, and it can be used in many applications for energy conversion, from the small stove to the big cogeneration plants. Lastly, the chapter showcases the types of Hydropower energy systems for electricity generation.

- NET ZERO ENERGY BUILDINGS AND COMMUNITIES

To answer the 2050 emissions reduction target according to IPCC, this chapter discusses and presents case studies about Net Zero-Energy Buildings (NZEB) and Net zero energy communities.

Short description of the most relevant thematics that were addressed in the book



Images / Scheme
Project by: National Park Service, Denver Service Center | Year: 2000
More info: all cooling loads are met with natural ventilation using computer-controlled clerestory windows, evaporative cooling from the cooling towers, and careful design of shading devices and daylighting apertures to minimize solar gains. The only mechanical input to the cooling system is a pump to circulate water through the evaporative media.

7. REMARKS

- The book presents a general synthesis of climate change and its implications on both urban design and architectural design.
- Comfort and climate topics are addressed to promote designing a climate responsive building.
- It provides guidelines for energy efficiency and sustainability in buildings using many techniques which help reduces the consumption of energy.

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EU's H2020 programme

1. DOCUMENT TITLE:	The Green Studio Handbook: Environmental Strategies for Schematic Design - 2006	2. AUTHOR	Walter T. Grondzik, Alison G. Kwok
	Name of the document		*Name of the author(s)*

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
			X		

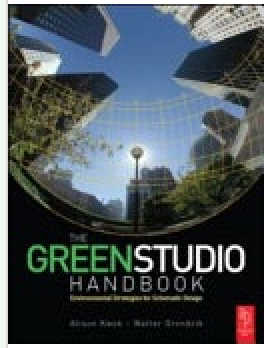
3. DESCRIPTION

This Handbook was written on the premise that there would be more green buildings if the techniques for designing them were more accessible to designers.

It presents the information needed to allow the designer to evaluate what are the appropriate strategies to follow and what are the best design decisions for green buildings.

Short description

4. COVER



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71. Design process
72. Integrated design
73. Design Strategies
74. Case Studies

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6. RELEVANT THEMATICS

- INTRODUCTION

  The purpose of this handbook is to give information regarding various green design strategies and to make the right decisions on how to use them, through a concise catalog of information.

  At the basis of this handbook there is the idea that if appropriate strategies are not included during the drafting of the schematic design phase, they will never actually be included as part of the project.

  One concept that is clarified from the start is the difference between "green" and "sustainable," as they seem synonymous but in fact are not. Green is intended as a building that is energy-efficient, water-efficient and resource-efficient, and this will contribute to sustainability.

- DESIGN PROCESS

  Design is never conventional and is simultaneously cultural, technical, formal and programmatic.

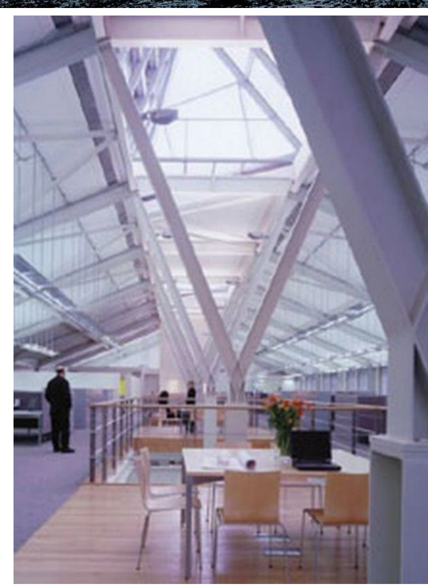
  The design process requires the architect to be an expert, transforming his role from a specialist of form to a generalist of building performance.

  The architect's work begins with defining the problem we need to address, going through data collection and site analysis and arriving at the definition of the daylighting form and passive/active strategies. After that there is the definition of the structure and envelope.

  To best use the strategies, we need to understand the basics of ecology, physics and chemistry, matching the need to the technology we are going to develop.

7. MAIN CASE STUDIES

Name	Location
Arup Campus Solihull	Solihull, UK



- INTEGRATED DESIGN

  Often, the tight timeline and sequence of the design process do not permit spending the time necessary to examine alternative options.

  Integrated design can help to achieve these goals by providing a process.

  This is a process that applies the skills and knowledge of different disciplines and the interaction of different building systems to produce more efficient buildings.

  Integrated design requires concise suggestions on how to start, and this helps in making assumptions about how a building may work.

- DESIGN STRATEGIES

  This chapter presents six major topics including the strategies that highly influence schematic design.
  These strategies describe green principles or concepts, and they help to guide the preliminary sizing of the building.
  The strategies are:
  - **Envelope**: using more efficient materials helps to conserve resources, to reduce waste and to reduce construction costs.
  - **Lighting**: controlled distribution of daylighting is at the base of the green design. It's the key to have a good energy performance and the satisfaction of the occupants.
  - **Heating**: the best and simplest way to heat a building is using the direct solar gain, letting the solar radiation to go inside the building during the heating season and conserving it in thermally massive materials.
  - **Cooling**: using climate adaptive design, we can reduce considerably the amount of energy by mechanical cooling.
  - **Energy production**: we can reduce environmental impact using on-site energy production.
  - **Water and waste**: are described some strategies for the reduction of water waste.

- CASE STUDIES

  In this chapter, are presented buildings with different geographic locations, climates, building types and strategies.

Images / Scheme
Project by: Arup Associates | Year: 2001
More info: the strategies used in this project are natural ventilation, thermal mass, exterior shading, daylighting, stormwater management, green transportation and recycling.

Beddington Zero Energy Development	Surrey, UK
Name	Location

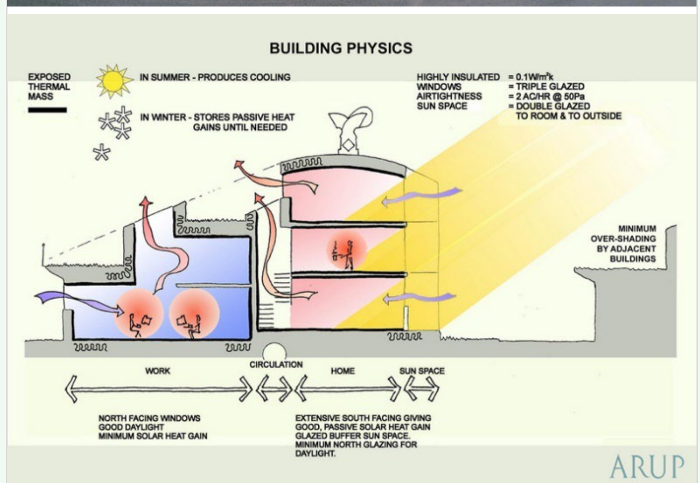
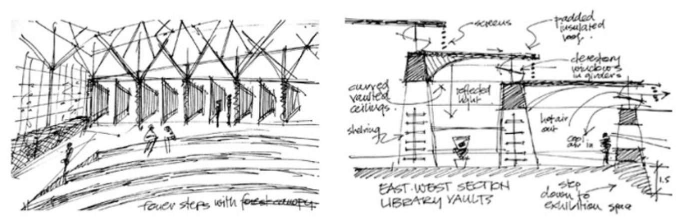


Image / Scheme
Project by: Bill Dunster Architects and ZEDfactory and Ove Arup & Partners
Year: 2002
More info: the strategies used in this project are solar access, thermal zoning, passive solar heating, exposed thermal mass, natural ventilation, high-performance windows, daylighting, photovoltaics, on-site energy generation, green roofs and water conservation.

Habitat research and development centre	Namibia, Africa
Name	*Location*



Short description of the most relevant thematics that were addressed in the book

Images / Scheme

Project by: Architect Nina Maritz | Years: 2004-2006

More info: the strategies used in this project are orientation, shading, thermal mass, daylighting, evaporative cooling, water conservation, photovoltaics, appropriate materials.

7. REMARKS

This Handbook provides the information needed to make judgments to prepare the appropriate design using green strategies and to validate design decisions related to these ones. It also provides tools for the preliminary sizing of these strategies and their components during the early stages of design.

The focus is on the design process and the better green strategies that can be used in the preparation of this design.

It’s important that architects are active participants in the shaping of green buildings, putting in their designs green strategies which have a huge impact on the final shape of the building.

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1. DOCUMENT TITLE: SUN, WIND & LIGHT
Architectural design strategies

Name of the document

2. AUTHOR: Mark DeKay and G.Z. Brown

Name of the author(s)

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
	X				

3. DESCRIPTION

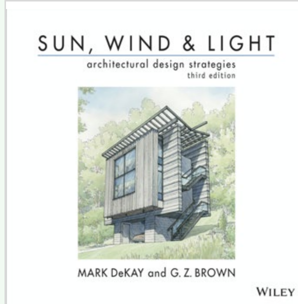
The purposes of this edition of *Sun, Wind & Light (SWL)* are aligned with those outlined in the first edition preface: to help architectural designers who are not energy experts understand the energy consequences of their most basic design decisions. With this information they can then use energy issues to generate form rather than seeing them simply as limits that must be accommodated.

Sun, Wind & Light is one of the only sources to fundamentally integrate the formal language of architectural design with the discipline of building science. Climatic forces are important in architecture because a building's response to climate is directly related to its energy consumption, and because climate is a powerful local context giving designers a means of regional expression and place making.

This edition sets out two additional purposes:
- **To map the knowledge base** of preliminary climatic design via new theoretical frameworks.
- **To provide accessible methods for net-zero energy design** with the intent of contributing to the massive effort by the building community to reduce greenhouse gas emissions from the building sector to pre-1990 levels by 2030.

Short description

4. COVER



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78. Bundles
79. Favorite design tools, condensed
80. Favorite design strategies, condensed
81. High performance buildings

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6. RELEVANT THEMATICS

- NAVIGATION

One can take any of several perspectives on the knowl- edge contained in SWL. The design strategies can be accessed in terms of name, scale, complexity, design com- ponents, energy issue or climate.

It is divided in:

- Navigation Matrix by Scale and Energy Topic
- Navigation by Design Strategy Maps
- Navigation by Climate
- USING SUN, WIND & LIGHT

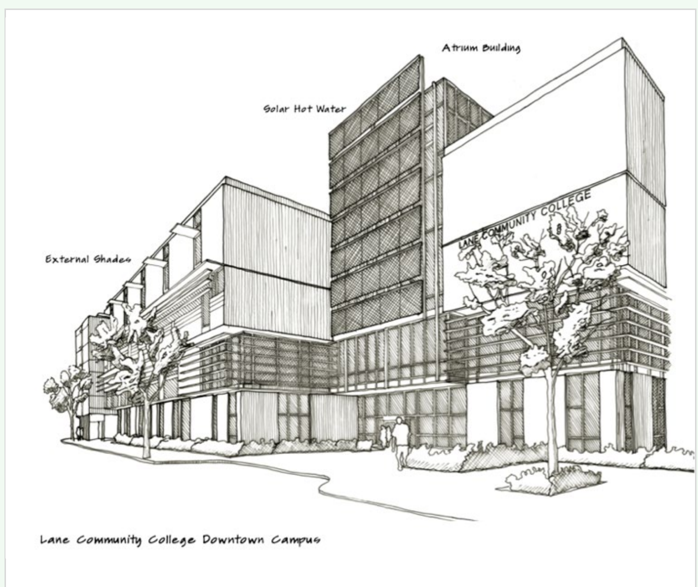
Designers seeking to produce net-zero and peak-zero, net-positive energy buildings require an understanding of what causes buildings to use energy as well as how to harness the energy design process by integrating multiple design strategies.

The first section of Part II, "Using Sun, Wind & Light," illustrates and explains the basic components and relationships of an integrated design process for "Buildings and Energy Use."

The second section introduces the Design Decision Chart for Net-Zero and Peak-Zero, Net-Positive

7. MAIN CASE STUDIES

Name	Location
Lane Community College Downtown	Eugene, Oregon



Buildings. This chart guides designers through a decision- making process that leads to seven generalized Synergies, which are in turn supported by a range of design Strategies and Bundles of strategies that can help buildings achieve maximum performance.

- SYNERGIES

This Part describes seven Synergies, or key design concepts, that if implemented properly, can help designers create net-zero and peak-zero, net-positive buildings. Each of the synergies primarily addresses one of the four aspects of integrated design: one synergy each for the Climate, Use and Systems components and four synergies for the Design component that covers the range of scales from building groups to buildings to building parts.

- BUNDLES

The first section of this part, "Bundles Explained," introduces strategy Bundles in more detail as sets of related design strategies that work together synergistically to solve common problems encountered when designing high-performance buildings. It explains the principles that define a bundle and their graphic representation in the bundle diagrams used throughout the bundle spreads in the last section, "Some Fundamental Bundles."

The second section of Part IV is "Making Your Own Bundles," which offers the reader a step-by-step process for creating customized bundles for a particular building project or for adding new bundles to the repertoire beyond those fundamental bundles presented in SWL.

The final section, "Some Fundamental Bundles," presents nine bundles: four at the L9 Neighborhoods scale, four at the L6 Whole Buildings scale and one at the L4 Rooms scale.

- FAVORITE DESIGN TOOLS condensed

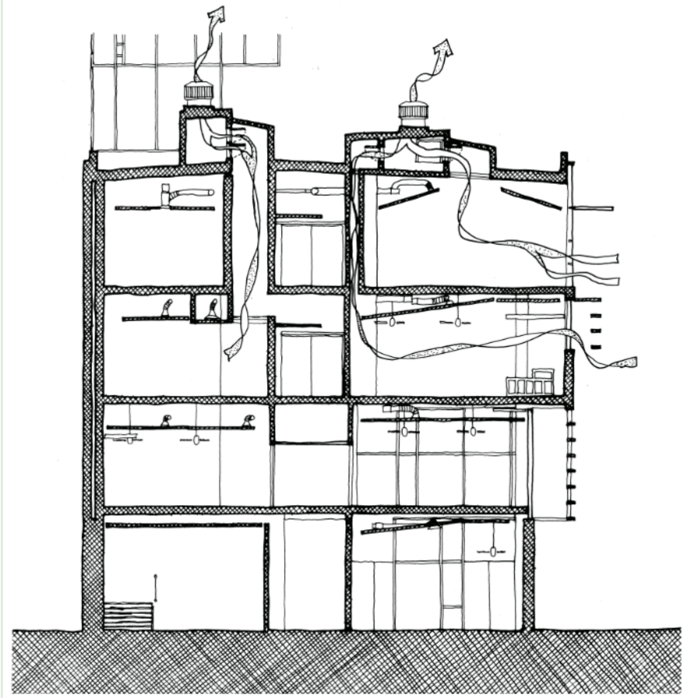
This chapter gathers useful design rules of thumb.

Part V help the designer make quick decisions early in the design process when specific information is hard to come by.

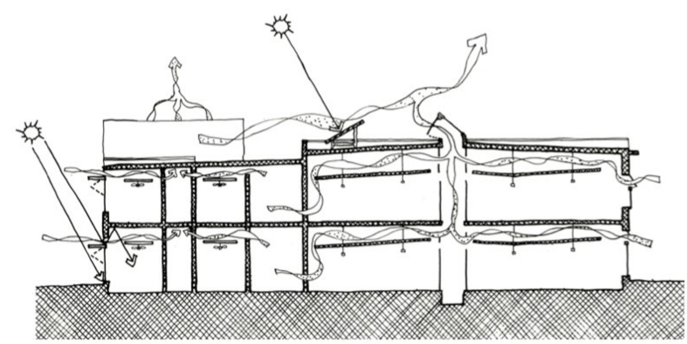
The chapter is divided in:

- **Building groups**: Daylight Spacing Angles, Building Spacing for Solar Access
- **Buildings**: Night Ventilation Potentials Map, Daylight Uniformity Rule
- **Building parts**: Insulation Recommendations, Sizing direct Thermal Storage, Passive Solar Glazing Area, Sizing Windows for Daylighting, Sizing Cross – and Stack – Ventilation, Glazing Recommendations
- FAVORITE DESIGN STRATEGIES condensed

Based on experience, some favorite design strategies have been selected, ones that come up repeatedly in



Lane Community College Downtown Campus



Lane Community College Health and Wellness Building, Eugene, Oregon, 2010, SRG Partnership

Images

Project by: Robertson Sherwood Archiects and SRG | Year: 2012

More info: The project stakeholders were committed to achieving a "net-zero-ready" building. For this project, the use of the term "net-zero-ready" indicated a desire to reduce building loads to the point that they could be met entirely by passive strategies and on-site power generation when funding for sufficient photovoltaic panels became available.

Bagsvaerd Church	Copenhagen, Denmark
Name	*Location*

practice. Buildings in extreme heating or cooling climates may not use a few of these.

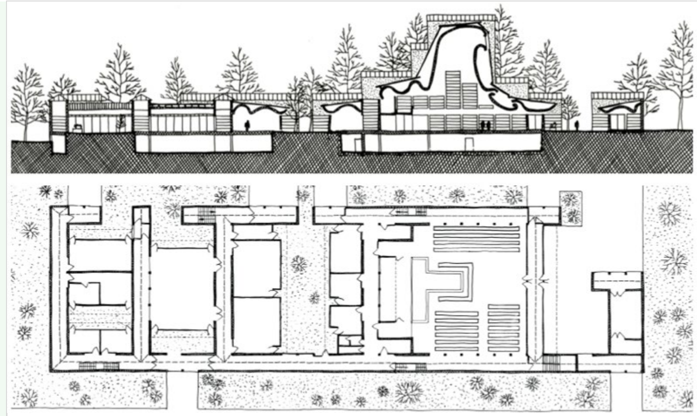
Strategies included here are those that affect form and organization to a significant degree and those that commonly come up in the fundamental bundles. These design strategies focus on the nature of the problem and its design solutions. It is divided in:

- **Unbuilt**: Energy Programming, Bioclimatic Chart
- **Building Groups**: Topographic Microclimates, Loose or Dense Urban Patterns
- **Buildings**: Migration, Cooling Zones, Heating Zones, Buffer Zones, Permeable Buildings, Locating Outdoor Rooms, Atrium Buildings, Thin Plan, Deep Sun, Daylight Zones, Room facing the Sun and Wind, Cross-Ventilation Rooms, Evaporative Cooling Towers, Direct Gain Rooms, Sunspaces, Stack-Ventilation Rooms, Night-Cooled Mass
- **Building Parts**: Mass Arrangement, Layer of Shades, Ventilation Opening Arrangement, Photovoltaic Roof and Walls, Solar Hot Water, External Shading.

- HIGH PERFORMANCE BUILDINGS

As with all tools in SWL, these targets are intended for preliminary design rather than for detailed evaluations at the design development or post-occupancy phases, when much more detail is known about the building.

- ENERGY TARGETS set goals to reduce fossil fuel consumption relative to benchmarks for the building's type and climate.
- ANNUAL ENERGY USE can be estimated to understand the energy savings of passive strategies.
- Buildings with a NET-ZERO ENERGY BALANCE produce annually renewable energy equal to the building's annual loads not met by passive design.
- Estimate the building's ENERGY USE INTENSITY (EUI) to compare its energy use to the energy target.
- EMISSIONS TARGETS set goals to reduce greenhouse gas emissions due to fossil fuel consumption, relative to benchmarks for the building's type and climate.
- CARBON NEUTRAL BUILDINGS use no greenhouse gas emitting energy to operate. Calculate the building's carbon use intensity (CUI) to compare its performance to the building's emission target.

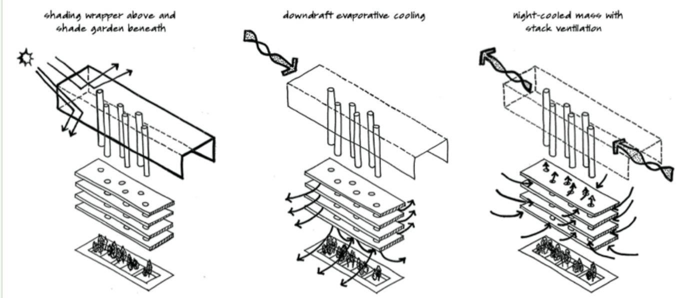


Images

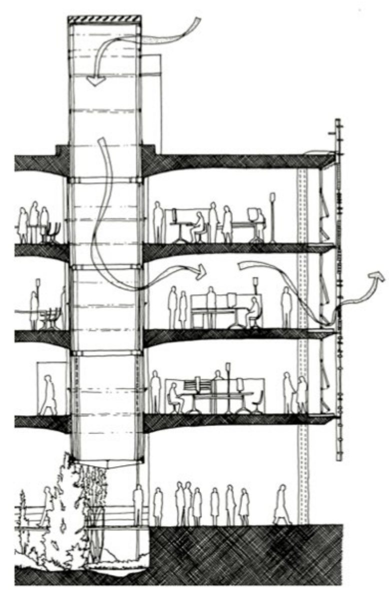
Project by: Jørn Utzon | Year: 1976

More info: this project is one of the preeminent examples of daylight design it can be understood as a single story SKYLIGHT BUILDING, as the daylight of each room is either from the top or from the side facing courts. The pattern of rooms organized around courtyards can be also seen as an ATRIUM BUILDING.

Experimental Office Building	Catania, Italy
Name	*Location*



Experimental Office Building, Catania, Sicily, Mario Cucinella Architects (MCA), 1998

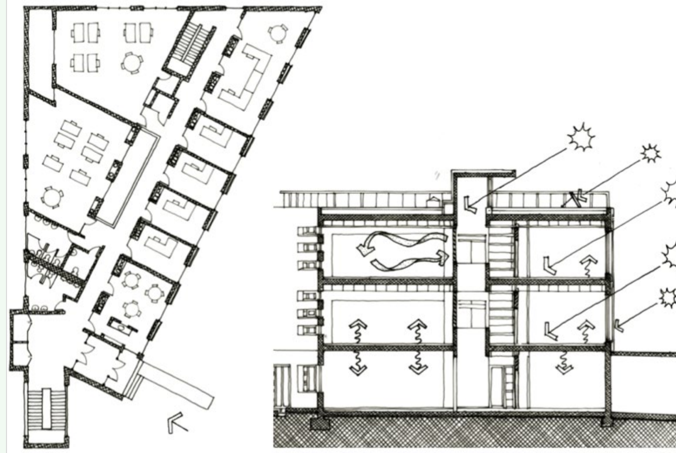


Image

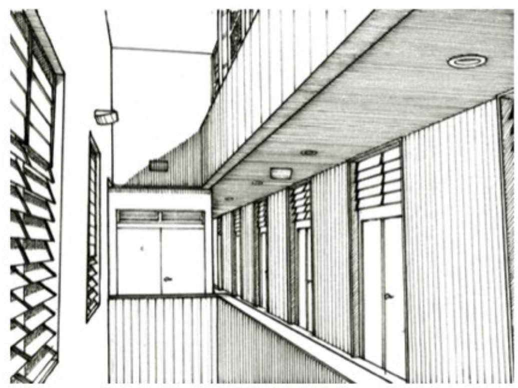
Project by: Mario Cuccinella Architects (MCA) | Year: 1998

*More info: The building is organized into cooling zones with spaces clustered around a series of central cylindrical, glazed **Downdraft Evapora- tive Cooling Towers** that function when the air is too hot outside for natural ventilation. The cooling towers can also operate as updraft shafts for STACK-VENTILATION ROOMS during the day when outside air is cooler than inside or at night while employing NIGHT-COOLED MASS.*

Edifício Solar XXI	Lisbon, Portugal
Name	*Location*



Edifício Solar XXI, National Laboratory for Energy and Geology (LNEG), Lisbon, Portugal, 2006, Pedro Cabrito and Isabel Diniz, architects



Short description of the most relevant thematics that were addressed in the book

Images

Project by: Pedro Cabrito and Isabel Diniz | Year: 2006

More info: The plan is organized according to HEATING ZONES by locating rooms that are most occupied to the south and labs that generate more heat and are less occupied to the north. The section admits DEEP SUN by raising a south-facing clerestory over a three-story light well and circulation zone (also serves as a STACK-VENTILATION ROOM). Passive CONVECTIVE LOOPS are made possible by large doors to the offices, ***interior louvers*** *at the top of the office wall, and even larger louvers in the lab walls facing the light well.*

7. REMARKS

A basic premise of this book is that most decisions that affect a building's energy use occur during the pre- design, schematic or preliminary design stages of the project as the diagram, Front Loaded Sustainable Design indicates. Furthermore, the effort required to implement those decisions at the beginning of the design process is small compared to the effort that would be necessary later on.

Therefore, if energy issues are going to receive an appropriate level of consideration at the beginning of the design process, an effective strategy is to present them in a way that is useful to the designer and fits with other things the designer is considering at that time. The book's intention is to give only general ideas about architectural elements and their size and relationship to other elements. Precision of the information is sacrificed somewhat so that speed of use may be increased. The approximation methods are founded on certain assumptions about the elements under consideration.

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1. DOCUMENT TITLE: Heating Cooling Lighting - 2015

Name of the document

2. AUTHOR: Norbert Lechner

Name of the author(s)

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
	X		X		

3. DESCRIPTION

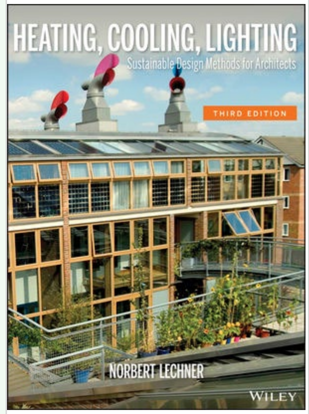
This book provides a comprehensive guide to designing buildings that prioritize human comfort while utilizing natural resources to achieve optimal energy performance. The author explores a variety of tools and techniques for analyzing and designing buildings based on local climate conditions, from heating and cooling to lighting.

The book emphasizes the importance of passive design techniques, which involve using building form and skin to optimize energy efficiency before resorting to active systems. By following this approach, designers can create buildings that are not only comfortable for occupants but also more sustainable and energy efficient.

The practical guidance and real-world case studies presented in this book make it a valuable resource for architects, engineers, and anyone interested in sustainable design practices. With its emphasis on the symbiotic relationship between architecture and natural resources, it offers a compelling vision for the future of building design.

Short description

4. COVER



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100. Checklist for designing integrated sustainable buildings

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6. RELEVANT THEMATICS

- HEATING, COOLING AND LIGHTING AS FORM-GIVERS IN ARCHITECTURE

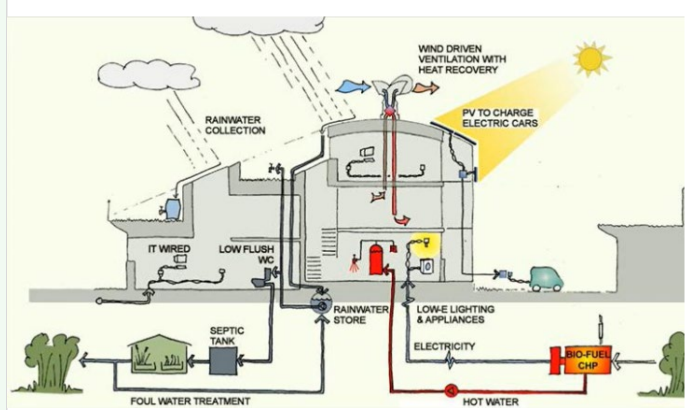
  This chapter introduces the reader to the subject of sustainable architecture, from the vernacular applications of passive techniques to the implementation of modern systems nowadays. Moreover, the author presents the "Tier" model, where the basic design of the building takes the first, the design of passive systems the second and finally the design of mechanical active systems. The principles of energy in architecture, biophilic design and resilient design are discussed.

- SUSTAINABLE DESIGN AND ENERGY RESOURCES

  This chapter addresses the issue of climate change and the urgency to change the way we build our cities. Sustainability can be achieved by implementing the four R's: reduce, reuse, recycle and regenerate. The fact that limitless growth is the opposite of

7. MAIN CASE STUDIES

Name	Location
Bedlington Zero	Bedlington



Plans / Images

Project by: Bioregional | Year: 2002

More info: It can be considered as the most ambitious effort towards achieving sustainability in a large-scale housing development. Although many aspects of it sustainability is discussed. The implementation of energy efficient buildings is crucial for sustainability, so we can reduce the reliance in fossil fuels for comfort.

- BASIC PRINCIPLES

  The basic physical phenomena related to thermal comfort in architecture are presented in this chapter. Heat, evaporative cooling, convection, transport, and radiation are explained, as well as phenomena like greenhouse effect, heat sink and heat storage.
- THERMAL COMFORT AND CLIMATE
  This chapter explains the main concepts of the human comfort, such as metabolic rate, thermal conditions, the psychrometric chart, adaptive comfort, and clothing. Also, an introduction on the principles of climate is given, such as microclimate and climatic anomalies.
- PASSIVE SOLAR AND SOLAR GEOMETRY

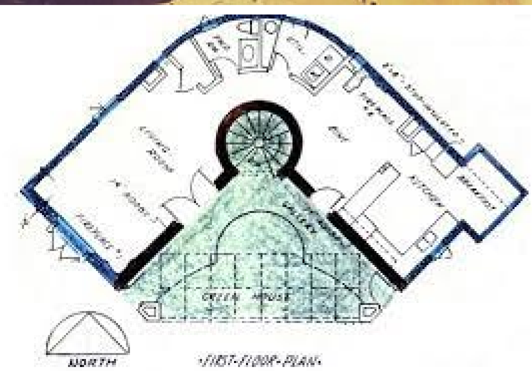
  These chapters focus on the relation between architecture and the sun. To have a better understanding of the sun's movement, the principles of solar geometry are presented, thus, openings and shading devices can be designed. As for passive solar, the book deepens about the use of sun radiation for providing internal heat gains, the main systems described are direct-gain, Trombe wall and sunspaces.
- PASSIVE COOLING, SHADING AND LIGHT COLORS
  These chapters deal, firstly, with heat avoidance in buildings. According to the author, to decrease heat gains in indoor spaces we must not let solar radiation raise temperatures, this can be achieved by using solar geometry to block sun beams. The shading devices are overhang awnings, horizontal louvers, fins, deciduous plants, exterior rollers, and egg-crate devices. As for passive cooling, the principles of fluid and ventilation are described, and then the passive cooling systems like comfort ventilation, night-flush cooling, double skin facades, radiant cooling, evaporative cooling, cool towers, earth cooling and solar chimneys.
- SITE DESIGN, COMMUNITY PLANNING AND LANDSCAPING

  This chapter focuses on the urban applications of the passive and sustainable principles. The topic is composed by site selection, solar access, shadow patterns, site planning, solar zoning, physical modeling, wind and site design, plants and vegetation, vegetated roofs, and landscaping.
- LIGHTING AND DAYLIGHTING

  This section of the book delves into the crucial role of lighting in architecture. It begins by examining the physical characteristics of light and how it impacts our perception of space. The chapter on daylighting emphasizes the importance of natural light in buildings, not only for aesthetic purposes but also to

have proven to be enduring, certain green technologies have posed adoption challenges.

Balcomb house	New Mexico
Name	*Location*

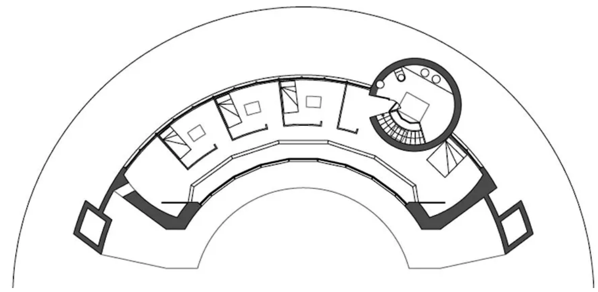


Plans / Images
Project by: William Thomas Lumpkins | Year: 1935
More info: Constructed primarily of adobe, the Balcomb House located in Santa Fe, New Mexico, exemplifies the use of passive solar heating through a sunspace. Given that Santa Fe experiences cool winters and scorching summers in a semi-arid climate, the house's design takes advantage of its location.

Jacobs II House	Wisconsin, USA.
Name	*Location*

reduce energy consumption associated with artificial lighting. The chapter outlines various strategies for daylighting, including basic approaches such as orientation and window placement through clerestories, scopes, domes, and monitors. The book also explores advanced window strategies, such as light shelves and indirect lighting, that allow for even more efficient use of natural light. Overall, this section provides a comprehensive overview of the principles and techniques that can be used to optimize lighting and daylighting in architectural design.

Short description of the most relevant themes that were addressed in the book



Plans / Images
Project by: Frank Lloyd Wright | Year: 1948
More info: The home features a circular layout with a sunken garden and concave glass window wall facing south. The northern portion is underground, shielded by the embankment and thick stone wall that offer protection against the wind while also providing warmth in winter and coolness in summer.

7. REMARKS

- The book offers a comprehensive and cohesive theoretical framework and guidelines for designing energy efficient buildings, covering the spectrum from conceptual to detailed aspects of each technique. The text is organized in a clear and logical manner, making it easy to navigate and understand.
- As a foundation for exploring passive design techniques, readers can use this text to gain a thorough understanding of the principles and practices involved in energy-efficient design. By providing a comprehensive overview of the subject matter, the book serves as a valuable resource for professionals in the field of architecture and related disciplines.
- Despite its detailed coverage of theoretical and technical topics, the book is highly accessible and easy to understand. The authors use clear and concise language, accompanied by illustrations and diagrams, to explain key concepts and techniques. This makes the text a valuable resource not only for experienced professionals, but also for students and newcomers to the field.
- By providing clear and practical guidance for incorporating energy-efficient design principles into projects, the book empowers professionals to make a positive impact on the environment. In a world where sustainability is increasingly important, this text offers valuable insights and strategies for promoting sustainable practices in the field of architecture.

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1. DOCUMENT TITLE: East Africa Climatic Data and Guidelines For Bioclimatic Architectural Design -2016

Name of the document

2. AUTHOR: Jerusha Ngungui

Name of the author(s)

2. CATEGORY:

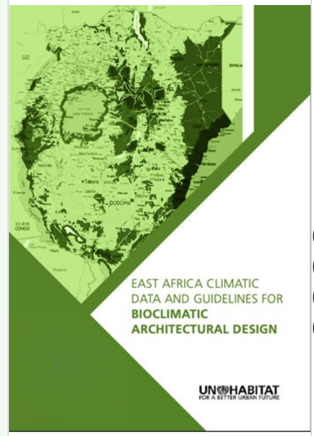
Article	Book	Report	Handbook	Guideline	Manual
		X			

3. DESCRIPTION

East Africa is divided into six unique climatic regions – hot and humid e.g. Dar es Salaam, hot-arid e.g. Garissa, hot semi-arid / savannah e.g. Dodoma, great lakes e.g. Kampala, upland e.g. Kigali and high upland e.g. Eldoret - each requiring different design strategies to minimise energy consumption and maximise indoor thermal comfort. This report presents climatic data of different regions in East Africa that was compiled within the project Promoting Energy Efficiency in Buildings in East Africa.

Short description

4. COVER



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6. RELEVANT THEMATICS

- INTRODUCTION

  In Africa, the building sector alone accounts for over 54% of primary energy. Majority of buildings in sub-Saharan Africa are replicas of buildings designed for the western world even though they are in the tropical climate. This results to heavy reliance on artificial means for cooling, heating and lighting. Additionally, tremendous energy wastage is caused by poor understanding of thermal comfort and passive building principles that leads to inefficient design as well as poor energy conscious behaviour. However, energy saving potentials can be achieved if buildings are correctly designed with passive building strategies that are according to the climate in which they are located, resource efficient appliances are provided and renewable energy technologies are adopted. Knowledge of the climatic conditions of a place is important to develop appropriate designs and consequently select suitable materials that meet climatic constraints.

- SOURCES OF CLIMATIC DATA

  Climatic data can be collected through the following ways:

  1. Government Meteorological Stations
  2. Climatic Design Publications

7. MAIN CASE STUDIES

Name	Location
Swahili Dreams House	Lamu, Kenya

Image

Project by: Urko Sanchez Architects | Year: 2014

Climatic zone: Hot and humid

More info: llightly coloured exterior surfaces reflect unwanted solar radiation, while timber shutters encourage unrestricted air movement in and out of the building while at the same time cutting out direct sunlight into the indoor spaces thus minimizing heat gain.

ABC21 is funded by the EU's H2020 programme

3. Atlases
4. Open Data Base
5. Online Sources
6. Airports

- CLIMATIC DATA PARAMETERS AND IMPACT ON DESIGN

  Designing according to the local climate is not only economically beneficial through the reduction of energy bills, but also improves indoor comfort. When designing a building for indoor comfort, the key elements to consider are; solar radiation, air temperature, relative humidity, wind (direction, frequency and velocity) and rainfall. The frequency and likely duration and nature of extreme climatic phenomenon must also be ascertained because even though they may be relatively rare and for short durations, they must be considered to ensure structural safety. Such phenomena include earthquakes, lightning, landslides, dust storms and floods.

- METHODOLOGY

  Buildings For useful energy efficiency design measures to be put in place, it is important to have hourly parameters over a 24-hour period, 1-week period, and 1-month period and so on.

  Different approaches can be used to determine passive design strategies for different climatic conditions. These include:

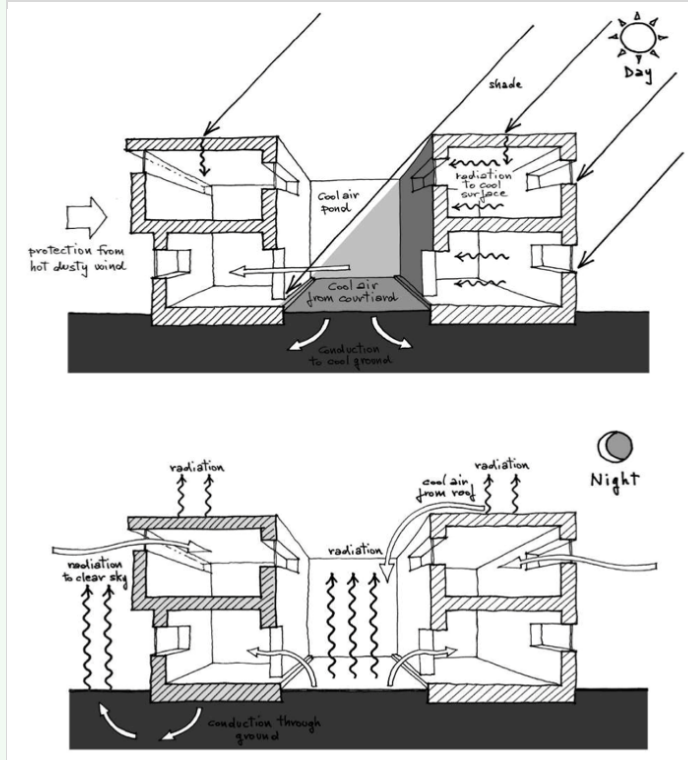
  I. Mahoney Tables: they consist of tables that use readily available climate data – temperature, relative humidity, rainfall and wind - for comparison with requirements for thermal comfort appropriate design criteria.
  II. Olgyay's bioclimatic chart: Based on dry bulb temperature and relative humidity, a point on the chart can be determined if it lies within the comfort zone. Any point that falls beyond the comfort zone region, then corrective measures are required to restore the feeling of comfort.
  III. Givoni's bioclimatic chart: it shows air temperature (represented by vertical lines) against relative humidity, (represented by curved lines) and can be used to express human thermal comfort, design strategies, and energy requirements for those strategies.

- CLIMATE CLASSIFICATION

  The Köppen-Geiger Climatic Classification System is the most widely used system to characterise the world's climatic conditions. Its categories are based on the monthly and annual averages of precipitation and temperature. According to the classification, the world is divided into 5 major climatic zones:

  - Equatorial Climate
  - Arid Climate
  - Temperate Climate
  - Cold Climate
  - Polar Climate

Courtyard	Mandera, Kenya
Name	Location



Images
Source: UN-Habitat (2015) Sustainable Building Design for Tropical Climates: Principles and Applications for Eastern Africa. Nairobi, Kenya: UN-Habitat
Year: 2015
Climatic zone: Hot arid
More info: High walls cut off the sun during the day hence providing shade to the inner walls and floor of the courtyard, preventing excessive heating. During the night, heat accumulated during the day is dissipated by re-radiation.

British high commission building	Kampala, Uganda
Name	Location

Image
Project by: Kilburn Nightingale Architects | Year: 2006
Climatic zone: Great Lakes

- MAJOR CITIES IN EAST AFRICA

Climatic data information representing 28 locations spread over the 6 climatic zones across East Africa are presented in the following sections. This information brings together data on the main climatic elements namely:

- air temperature
- relative humidity
- solar radiation
- rainfall and
- wind.

The zones:

1. **Kenya**: Eldoret, Embu, Garissa, Kakamega, Kisii, Kisumu, Kitale, Lamu, Lodwar, Makindu, Malindi, Mandera, Meru, Mombasa, Moyale, Nairobi, Nakuru, Narok, Voi
2. **Tanzania**: Dar er Salaam, Dodoma, Mbeya, Mwanza, Tabora, Tanga, Zanzibar
3. **Uganda**: Kampala

Rwanda: KigaliThis chapter focuses on the parameters to evaluate projects on their energy performance, in order to provide a framework for better building technology and cities. Energy efficiency is analyzed through different indicators, such as the Beep values as well as architectural quality.

Short description of the most relevant thematics that were addressed in the book

More info: Provision of perforated screen walls and openable windows aid in cross ventilation. Windows are shaded keeping out solar radiation thus providing cool interiors.

St. Jerome's Centre	Nakuru, Kenya
Name	Location

Images

Project by: Orkidstudio | Year: 2014

Climatic zone: Upland

More info: South West facing elevation has louvered timber openings that can be closed off during the afternoon thus minimizing unwanted heat gain during the hot afternoon. Earth bags, made from grain bags filled large quantities of soil (20% clay content) are laid like oversized bricks to create deep high thermal mass walls.

These walls are effective in absorbing heat from the sun, thus helping regulate temperatures during the cool nights.

7. REMARKS

The data was analysed and presented graphically Climate Consultant 6.0 - a graphic based climate data analysis computer program. From the analysis, it was clear that each zone requires different passive building design strategies to achieve human thermal comfort as well as minimise the energy required for heating and cooling. Some of the interventions that are suited for all the climatic zones include:

- Orientation of the building along the east – west axis with major openings facing north and south.
- Protection of all openings using appropriate sun shading devices against unwanted solar radiation.
- Provision of openings for natural ventilation and daylighting – large openings are more suitable for hot and humid climates while small openings are preferred in hot arid and hot semi-arid / savannah climates.
- Single-banked floor plans in hot humid and great lakes climate to maximise cross ventilation while double-banked building forms are desirable for uplands and high upland climates.
- Open layouts are recommended for hot humid and great lakes climates to allow maximum ventilation while compact housing layouts are preferred in hot arid and hot semi-arid / savannah climates for mutual shading and provision of cool spaces when combined with plants and water features as well as protection against hot, dry winds.
- Use of light coloured or reflective external surfaces to reflected unwanted solar radiation.

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1. DOCUMENT TITLE: Architecture bioclimatique et efficacité énergétique des bâtiments au sénégaL -2017

Name of the document

2. AUTHOR: T. Joffroy

Name of the author(s)

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
	X				

3. DESCRIPTION

One source of inspiration for this work is the scientific knowledge gained from the observation of traditional Senegalese and West African architecture. However, since the colonial era and the era of mixed-race Neo-Sudanese architecture, other protective practices have been used that can also serve as a reference for the contemporary design of comfortable and energy-efficient buildings.

This guide, produced within the framework of the PNEEB/ TYPHA programme (National Programme for the Reduction of GHG Emissions through Energy Efficiency in the Building Sector - Typha-based Thermal Insulation Materials Production Project), aims to provide information on the principles and benefits of this type of design to a wide range of professionals (political decision-makers, public and private project owners, architectural and building engineering project managers, companies, etc.)It also promotes the use of local materials, particularly those based on Typha and earth, by integrating them into an energy-efficient architectural approach that clearly prioritises bioclimatic architecture.

Short description

4. COVER

Cover image

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109. Comfort in the Tropical Zone
110. General Design Principles
111. Recommendations for building design
112. Recommendations on equipment
113. Specificities by climate zone

Main titles of table of contents

6. RELEVANT THEMATICS

- INTRODUCTION

Faced with the scarcity of fossil energy resources and the foreseeable medium-term structural increases in the price of fossil fuels, as well as the consequences of global warming which, in Senegal, will result in an increase in the average temperature and more very hot days, access to thermal comfort for all and, in particular, protection against heat in the home are essential issues.

On the African continent, the building sector (residential and tertiary) accounts for 80% of energy consumption (excluding firewood and biomass) and greenhouse gas emissions. Today, although Africa as a whole only contributes 4% of global GHG emissions, this contribution could increase significantly in the

7. MAIN CASE STUDIES

Name	Location
Centre pour femme	Rufisque, Senegal

future.The causes of this increase are population growth, massive urbanisation, the increase in GDP per capita and the rural exodus, which lead more people to use commercial fossil fuels.

It is therefore essential to control both the increase in greenhouse gas emissions and the energy bill of households, companies and the country by better controlling fossil fuel energy consumption. In anticipation of this, it is therefore essential to design buildings that consume less energy and are more comfortable. This is possible by applying common sense principles to architectural choices and construction processes.

- THE CLIMATE OF SENEGAL

Senegal has a tropical climate ranging from tropical savannah (southwestern part of the country) to tropical desert or semi-desert (rest of the country). Average monthly temperatures are above 18°C in all months of the year.

The country's climatic conditions are contrasted between the interior and the coastal region: the further away from the coast, the higher the average and maximum temperatures.

The climate is marked by two main seasons: the dry season and the rainy season, also known as the winter season. It is more abundant and lasts longer in the south.
Three main air masses, whose circulation is facilitated by a low relief, also determine the climatic conditions of the country:

- the maritime trade winds, which blow from the North/North-West to the North/North-East, and which constantly bring humidity to the country. The trade wind is most influential from November to May;
  - the harmattan, which blows from the North-East to the East/North-East, is cool at night and hot during the day, and often carries dust and fine sand. It is especially influential in the interior of the country;
  - the monsoon, which blows from the south-east and arrives in the summer period. It brings the rain. It dries up as it moves inland. It is therefore particularly influential in the south of Senegal.

Topography, and in particular altitude, influences temperature, air humidity and air pressure. Within a given climatic zone, high altitude areas are cooler than lower altitude areas. The temperature drops by about 1 °C for every 150 m of elevation gain.

- COMFORT IN THE TROPICAL ZONE

Four types of architectural response adapted to Senegal are shown on the bioclimatic diagram:

- The "basic comfort" zone: when the outdoor temperature and relative humidity under shelter are within the limits of acceptable physiological

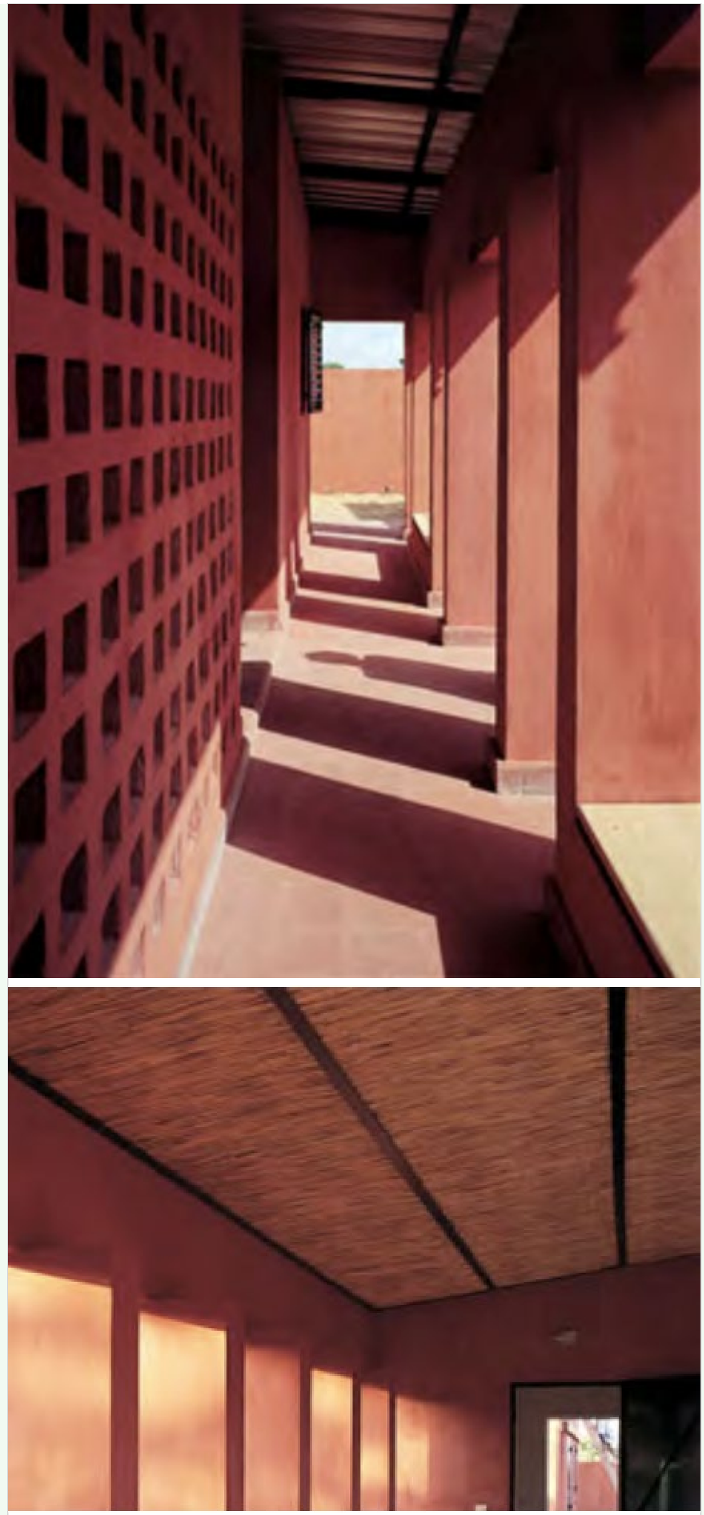

Image
Project by: Hollmen Reuter Sandman Architects I Year: 2001
More info: High-stemmed vegetation is preferred for the solar protection of the east and west walls, as the height of the sun on these walls is quite low. For the north and south walls, horizontal sun protection above the wall is preferred.
It is advisable to choose vegetation adapted to the local climate in order to limit the need for watering.
In bioclimatic buildings, however, care must be taken to ensure that the vegetation does not impede the flow of air for natural ventilation.

comfort. For these outdoor conditions, the indoor conditions should be as close as possible to these outdoor conditions;

- The "comfort zone with ventilation": where the discomfort produced by a higher temperature and humidity can be compensated for by the creation of an air velocity on the individual;
- The "high thermal inertia zone with night-time ventilation": where the architecture of the building, by storing the night-time coolness introduced by natural (or forced) ventilation in the building thanks to its high inertia and good ventilation capacity;
- The "comfort zone with internal heat gains": In this case, the ventilation of the building will be limited to the hygienic air renewal needs of the occupants so as not to dissipate these free thermal gains.

- GENERAL DESIGN PRINCIPLES

In a tropical climate, the main challenge in achieving a good level of hygrothermal comfort is to protect against heat. To achieve this, there are four complementary strategies: solar protection, ventilation, thermal inertia and insulation.

It is therefore recommended to take maximum advantage of all bioclimatic strategies, but also to complement them with artificial means where bioclimatic devices do not satisfy the occupants.

The most interesting bioclimatic design strategies for achieving thermal comfort in tropical climates are:

1. **Solar shading**: This strategy consists of good design of the ground plan, good orientation of each building and good use of vegetation.
   For daytime use of buildings, therefore, in addition to the roof, priority can be given to solar protection of the east walls, while for permanent use, the east and west walls must be protected.
2. **Ventilation**: For bioclimatic buildings, ventilation contributes to the thermal comfort of the occupants in two ways:
   - It promotes heat loss from the body by convection (air velocity) and by evaporation of sweat. Permanent ventilation is beneficial in hot and humid climates.
   - It allows the evacuation of the heat accumulated in the internal mass of the building, both for solar and internal gains. For hot and dry climates such as the Tambacounda region, this ventilation function will be used by means of night ventilation and not day ventilation.
3. **Thermal inertia**: In a climate with a high day-night thermal amplitude, walls and floors with good thermal inertia can delay the heat wave entering the building during the day, and thus protect against heat during the hottest hours.
4. **Thermal insulation**: This is of particular interest when there is a large temperature difference between the inside and outside of the building. It is essential to point out that thermal insulation in a bioclimatic building may not be an appropriate

Maison à Impluvium	Casamance, Senegal
Name	Location

Images

More info: *The intermediate spaces between the exterior spaces and the inhabited volumes, such as courtyards, verandas and loggias, are spaces that it is essential to treat with a rigorous bioclimatic approach that makes it possible to turn these transit and convivial areas into zones that are sheltered from the sun and rain, benefiting from good natural ventilation and good natural lighting.*
This design approach is essential not only for the qualitative use of these areas and their enjoyment by their occupants, but also because of the impact that their bioclimatic treatment will have on the adjacent housing.

Toiture avec combles ventilés - Ecole primaire	Gangouroubouro, Mali
Name	Location

strategy if the insulation also slows down the removal of heat from the interior of the building to the outside at night. In the case of bioclimatic buildings in hot and dry climates, it is better to use materials with high thermal inertia rather than insulation.

- RECOMMENDATIONS FOR BUILDING DESIGN

The **orientation** of a block lengthwise on the east-west axis is generally considered to be the best location for sunlight. West axis is generally considered to be the best location in relation to sunlight. This optimum orientation can vary significantly to improve natural ventilation by seeking more effective exposure to prevailing winds. It can also vary slightly to seek, for example, in certain climatic zones, a slight solar contribution for the coldest evenings (+22° rotation to the south-east). This orientation alone is not sufficient and does not replace the implementation of other bioclimatic devices (sunshades, wall colours, etc.).

In hot and dry climates, **compact** architectural and urban **morphologies** should be favoured in order to favour protection against the sun's rays. In hot and humid climates, the aim should be to promote air circulation to ventilate the buildings. In this case and if the site characteristics allow it, leaving a sufficiently large spacing between buildings will be an important design aspect of a bio-climatic strategy.

The **greening** of the building's surroundings has a beneficial effect on beneficial to the comfort of users by providing solar protection for the walls through shading, by preventing the ground surface from reflecting solar radiation towards the building, by limiting the urban heat island effect due to the mineralisation of the environment, by cooling the surrounding atmosphere through the evaporation of the water contained in the vegetation, by providing protection against dust carried by the wind and by cutting off or channelling the wind.

The **intermediate spaces** between the exterior spaces and the inhabited volumes, such as courtyards, verandas and loggias, are spaces that it is essential to treat with a rigorous bioclimatic approach that makes it possible to turn these transit and convivial areas into zones that are sheltered from the sun and rain, benefiting from good natural ventilation and good natural lighting.

- RECOMMENDATIONS ON EQUIPMENT

Air movers provide a cooling sensation for the occupants by creating an air velocity on the skin that generates heat removal by convection and evapotranspiration. Air movers can supplement insufficient or non-existent natural ventilation in a bioclimatic building, provided that the heat input is removed. This will be the case, for example, if through-ventilation is not possible for acoustic reasons or if screens slow down the ventilation rate too much. The use of these fans must of course be coupled with the

Image
Project by: LEVS Architecten I Year: 1986
More info: For good thermal and energy design, it is essential and a priority to ensure effective solar protection on the roof.

Lycée Français Jean-Mermoz	Dakar, Senegal
Name	Location

use of effective solar shading of the building and more generally with its bioclimatic design strategy.

The evaporative cooling systems are relevant for certain climatic zones in Senegal.

These systems consist of pulsing the ambient air by passing it over a humidified porous body. These systems can be used in combination with air movers. Before assessing the air conditioning requirements of a building in its design and the cooling capacity to be installed, it is important to have taken all possible measures to :

- protect the building from the sun as part of an overall solar protection strategy (roofing first, openings, then walls);
- guarantee the watertightness of the joinery and the architectural envelope and a hygienic ventilation system to ensure the renewal of air, which can be natural;
- ensuring the thermal insulation of the building for very hot and dry climates that can lead to significant temperature differences between the exterior and interior.

The indoor units must be positioned to ensure optimal air distribution in the room (as large a volume as possible) while avoiding direct blowing onto the occupants.

- SPECIFICITIES BY CLIMATE ZONE

The following devices are the most relevant for the various climates of Senegal, and depending on the climate of the region considered and the type of use of the building, they should be favoured all or part of the year:

- the **permanent ventilation strategy** which allows air to flow over the skin and creates a cooling sensation provided that the air temperature is lower than the skin temperature and that the hygrometry is not too high;
- **Thermal inertia associated with night ventilation** is a design strategy used to evacuate at night by over-ventilation the diurnal heat gains in buildings which would tend at night to be heated by the heat accumulated during the day. This strategy requires that the night temperature is sufficiently low;
- **Evaporative cooling strategy** (using an active or passive device) which uses the endothermic phenomenon of water vaporisation: the evaporation of water lowers the air temperature by taking this heat from the ambient air to change from a liquid to a gas state. This strategy requires low humidity in the ambient air.

The areas analysed are: Dakar, Saint-Louis, Linguère, Tambacounda and Ziguinchor.

Short description of the most relevant thematics that were addressed in the book

Image

Project by: Agence Terreneuve I Year: 2006

More info: Solar protection of the walls is also essential, as these walls are also exposed to direct sunlight and contribute to the heat gain in the building by absorbing solar radiation and transmitting heat to the interior. Walls facing east and west receive the most solar radiation.

Image of Pays Bassari	East of Tambacounda, Senegal
Name	*Location*

Image

7. REMARKS

This introspection on the optimisation of architectural design for various typical climates in the Senegalese region in order to best respond to the problem of the quality of the thermal environment and the search for energy performance leads, as expected, to sometimes divergent responses for the same typological case depending on the time of year when the analysis is carried out. The designers will therefore have to analyse on a case-by-case basis, for the building concerned, according to the uses and in a finer way than with the sole specification "permanent occupation" or "daytime occupation", what are the particularities of the project which may lead to making major strategic choices of envelope design on major operations, particularly in terms of inertia if the designers have the choice in terms of available materials, various technical and economic constraints or even heritage coherence.

In all the climates of Senegal there is a more or less long period of the year during which cooling is not necessary. Even in the case of air-conditioned buildings, it is necessary to give priority to an architectural design that allows for a mixed climate operation. This logic can be applied separately to different areas of the building by providing the means for active participation in energy-saving behaviour. The conceptual strategies for good thermal and energy design start with a comprehensive strategy for effective solar protection: this should combine fixed and mobile vegetation and architectural responses, as well as rigorous work on the “albedo” of the envelope, which should actively favour light colours. In addition, the buildings must be allowed to function, depending on the time of year, but also on the time of day. In conclusion, these energy-saving behaviours should be implemented and communicated in a language that the user can understand.

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1. DOCUMENT TITLE: Form Follows Energy - 2017
Name of the document

2. AUTHOR: Brian Cody
Name of the author(s)

2. CATEGORY:

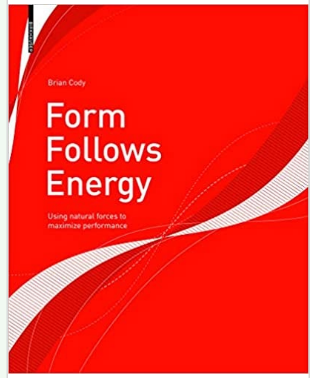
Article	Book	Report	Handbook	Guideline	Manual
	X				

3. DESCRIPTION

This book explores the connection between energy, architecture, and urban design, emphasizing the impact of the building industry on global energy consumption and the importance of sustainable design. It covers fundamental concepts related to energy and climate, principles of "energy design," and case studies from around the world. The book offers an interdisciplinary approach to the subject, providing readers with a comprehensive understanding of how design can contribute to a more sustainable future.

Short description

4. COVER



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Main titles of table of contents

6. RELEVANT THEMATICS

- ENERGY

  In this chapter, the author broadens what he calls “the energy problem”. The correlation between energy consumption, CO2 emissions and economic productivity is shown as a statement that high economic growth increases energy consumption. Based on projections, the author argues the importance of reducing the consumption of energy and still maintaining economic growth, this means making our lifestyles more efficient. To better understand this topic, the concept of energy is explained by its physical characteristics.

- THE SCIENCE OF ENERGY DESIGN.

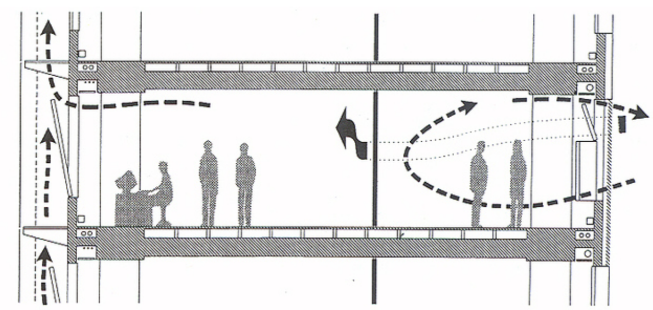
  This chapter starts by the explanation of the transference of energy, particularly the transference of heat, as it is studied in Thermodynamics, where there are sensible and latent energy. Furthermore, an introduction is made to Psychometrics, the study of humid air, which relation to human comfort can be seen through the psychometric chart. As air movement is a key factor for dehumidification though ventilation, the theory of fluid dynamics is exposed. Finally, the author presents a summary of the three methods of heat transference: thermal buoyancy or convection, such as ventilation and solar cooling; thermal conduction, as it is used in building envelopes to prevent thermal fugues; and thermal radiation, such as passive heating through thermal inversion.

- EXTERNAL AND INTERNAL ENVIRONMENTS

  Firstly, this chapter synthetizes the themes of external environment, and how the earth atmosphere behaves from one region to another. The relation of

7. MAIN CASE STUDIES

Name	Location
GSW Tower	Berlin



Plans / Images
Project by: Matthias Sauerbruch | Year: 1995
More info: The GSW headquarters in Berlin comprises five interconnected buildings that extend an office tower constructed in the 1950s. When it was built, it served as a prototype for ecological architecture and remains a prime example of this paradigm in the 21st century.

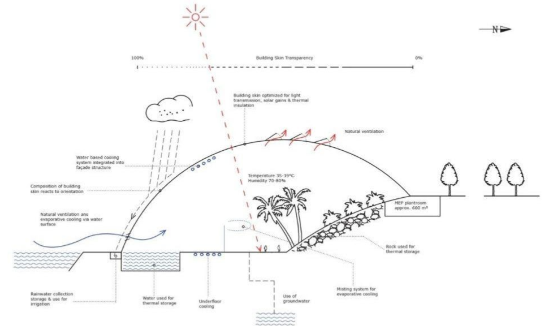
ABC21 is funded by the EU's H2020 programme

the sun radiation and air temperature gives as a result the “climatic zones”, which are categorized as tropical, subtropical, temperate, and cold. Then, the internal environment concept is explained as the thermal and physical conditions of an indoor space that affect human comfort. Human comfort is directly related to the process of thermoregulation of the human body.

- BUILDINGS AND ENERGY
  Buildings require a considerable amount of energy to be constructed, but also, they require a big amount of energy to fulfil human functions. Therefore, in this chapter the themes of heating, lighting, fan and cooling energy demand are explained as well as the energy required for humidity control. The second part of the chapter focuses on the keys for an efficient building energy performance, which are as follows: building form, building skin, climate control systems and energy supply systems.
- URBAN DESIGN AND ENERGY
  Urban design has a big implication in the energy consumption. In this chapter there is a brief introduction on the themes of the infrastructural networks of the cities, such as transport, communication, and energy supply. Then, the concept of Urban Density is addressed from the point of view of reduction of energy consumption as well as comfort and life quality. Finally, Vertical farming and energy generation in cities is explained as possible alternatives for reducing the use of energy in production and transportation of goods.
- THE ART OF ENERGY DESIGN.
  This chapter provides a comprehensive introduction to energy design, which involves optimizing resources using building form, skin, and setting. The author analyzes several case studies that demonstrate how natural forces can be harnessed to achieve energy efficiency, such as the integrated ventilation system at the Braun Headquarters in Frankfurt. By exploring the principles of energy design, readers can gain a deeper understanding of how architecture can contribute to sustainable development.
- EVALUATING ENERGY PERFORMANCE
  This chapter focuses on the evaluation of energy performance in projects, with the goal of establishing a framework for better building technology and cities. It covers various indicators for assessing energy efficiency, including the widely used Beep values, as well as architectural quality. By providing a detailed examination of the evaluation process, readers can learn how to improve the energy performance of their own projects and contribute to a more sustainable future.

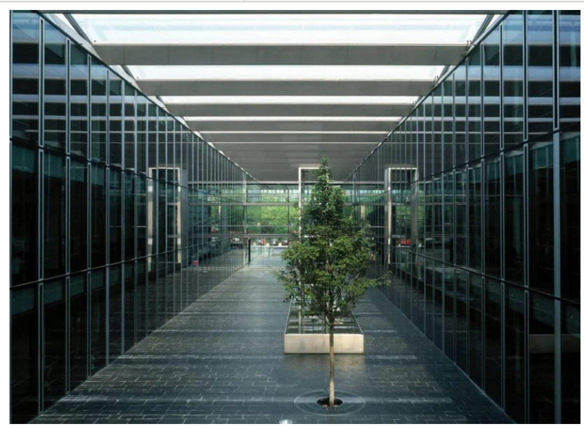
Short description of the most relevant themes that were addressed in the book

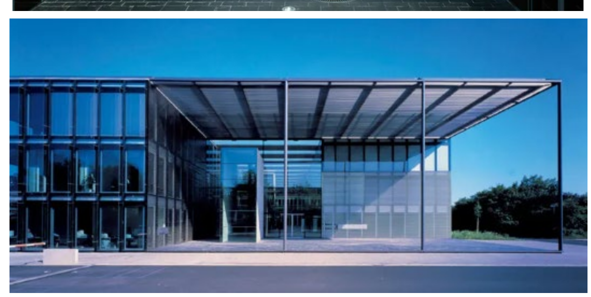
Botanical Garden	Taiyuan
Name	*Location*



Plans / Images
Project by: DMAA | Year: 2017
More info: The objective of the project was to turn an old coal-mining region into a landscape park that serves as a model for landscape design in China. Additionally, the park contains buildings that can be utilized for research and providing access to information about natural ecosystems to the public.

Braun HQ	Frankfurt
Name	*Location*





Plans / Images
Project by: schneider+schumacher | Year: 2000
More info:
The building is designed to reflect an eco-friendly attitude with a U-shaped structure and a double facade that reduces heat loss and solar gain. The facade panels can be adjusted manually to create various reflections and improve energy efficiency.

7. REMARKS

- The book provides a comprehensive and detailed examination of the complex relationship between energy and both urban and architectural design. In addition to discussing the ways in which energy usage impacts these fields, the book also explores related topics such as comfort and climate. By covering a broad range of issues, the book offers readers a thorough understanding of the importance of sustainable practices in design.

- One of the strengths of this book is its use of practical examples to illustrate theoretical concepts. The author draws on a range of case studies from both their own work and that of other architects, demonstrating how energy design principles can be successfully applied in real-world settings. By providing concrete examples, the book enables readers to better understand how to incorporate sustainable practices into their own design projects.

- Architects and urban designers seeking to incorporate sustainable practices into their work will find this book to be an invaluable resource. It offers a wealth of information on the relationship between energy and design and provides practical guidance on how to incorporate energy design principles into projects. By promoting sustainable practices, the book encourages designers to create buildings and cities that are environmentally friendly and contribute to a more sustainable future.

- The book's inclusion of both theoretical and practical information makes it a well-rounded resource for anyone interested in the intersection of energy and design. Whether you are a student, professional, or simply interested in the topic, the book offers a comprehensive examination of the ways in which energy impacts urban and architectural design. Its focus on practical examples ensures that readers are equipped with the knowledge and tools they need to create sustainable designs.

- Overall, this book offers a unique and valuable contribution to the field of energy and design. Its thorough examination of the topic, combined with practical examples and guidance, makes it an essential resource for anyone seeking to incorporate sustainable practices into their work.

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ABC21 is funded by the
EU's H2020 programme

1. DOCUMENT TITLE: Arquitectura Sustentàvel em Angola: Manual de Boas Pràticas
Name of the document

2. AUTHOR: Manuel Correia Guedes
Name of the author(s)

2. CATEGORY:

Article	Book	Report	Handbook	Guideline	Manual
					X

3. DESCRIPTION

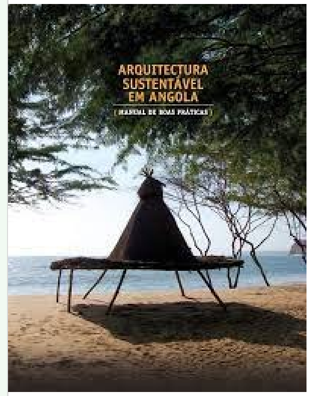
The main purpose of this manual is to suggest basic measures for the practice of sustainable architecture.

Considering the climate, natural resources, and socioeconomic context, strategies for good project practices are outlined in simplified form.

This manual is a pioneering publication that can serve as a reference not only for Portuguese-speaking countries, but also for other African countries, and are a starting point for the future.

Short description

4. COVER



Cover image

5. TABLE OF CONTENTS

122. Introduction
123. Framework
124. Sustainable architecture
125. Bioclimatic project: general principles
126. Water
127. Energy
128. Sanitation
129. Case studies

Main titles of table of contents

6. RELEVANT THEMATICS

- INTRODUCTION

  This new way of projecting consists in reformulating the programs and initiatives, taking into account the dimension of instruction and training, the relationship between scientific research and production, and the strengthening of local capacities.

  The reconstruction in the areas of human settlements will be based on the valorization and research of local materials and traditional construction techniques, the promotion of pedagogical actions, aimed at organizing and framing popular initiatives and ensuring the technical follow-up of their interventions.

  The Manual's main objective is to support the practice of sustainable construction, with emphasis on the vital area of energy efficiency in buildings, contributing to the improvement of living conditions, by increasing the habitability and environmental comfort of the built space.

- FRAMEWORK

  This manual analyses Angola, localized on the southwest coast of the African continent, bordered to the north and northeast by the Democratic Republic of Congo, to the east by Zambia and south by Namibia. To the west, it is bathed by the Atlantic Ocean.

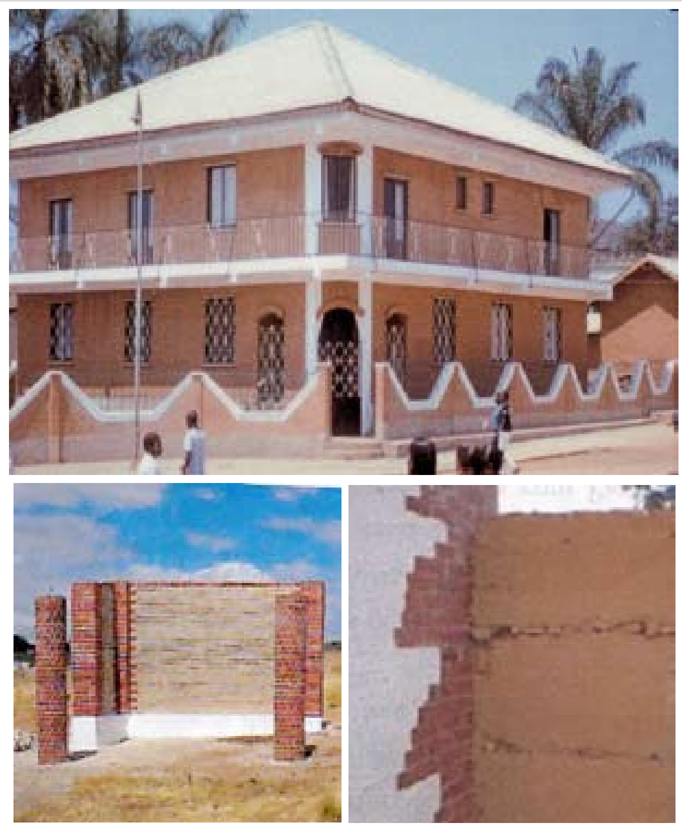
  This country still faces several problems in Health and Education, with faulty systems, despite the current development pointing to a strong improvement, especially in urban centers.

  Before getting into the theme of sustainable construction, it is fundamental to understand the state of construction in Angola.

  The types of construction are divided into:
  - Consolidated construction in urban space
  - Non-consolidated construction in urban space

7. MAIN CASE STUDIES

Name	Location
High-income housing with earth technology	Kwanza Sul Province (Gabela), Angola



Example: Earth Residential Building, in Gabela

Images

Project by: Student Francisco Amaro

More info: The primary goal is to carry out a national capacity-building plan as a strategy to effectively encourage the use of earth technology for construction and to raise everyone's awareness of the value that renewable energy plays today.

- Traditional construction.

- SUSTAINABLE ARCHITECTURE

  There are many definitions for Sustainable Architecture, but the essence of sustainability is intrinsically linked to the essence of Architecture. A good building is naturally sustainable.

  We also find sustainability practices in the vernacular, non-erudite architecture of many communities. This incorporates construction technologies that are the product of the empirical knowledge of many generations, which over centuries have developed strategies to adapt to the environment, using local resources.

  The architect, in his professional practice, in addition to the use of local materials and the introduction of renewable energy systems, must provide for priority building spaces in the design and contemplate the building as an organism that can grow, in an evolutionary spatial process that accompanies the growth of families. The evolutionary shelter that includes spaces with potential for expansion, for the growing family, is a cultural element in Africa. At the same time, the definition of priority building spaces is fundamental to the management of financial resources.

  The aim of this Handbook is to suggest basic measures for a comfortable home that respects nature and has low construction and maintenance costs. Considering climate, natural resources, and socio-economic context, good practice strategies for architectural design are outlined.

- BIOCLIMATIC PROJECT: GENERAL PRINCIPLES

  In the Angolan climatic context, it is possible to achieve a balance between building and climate by applying a range of design strategies, referred to as bioclimatic or passive design. Passive design strategies aim to provide comfortable indoor environments while reducing energy consumption. These techniques allow buildings to adapt to their environment through architectural design and the intelligent use of materials and construction elements, avoiding the use of fossil energy-consuming mechanical systems.

  In this chapter are presented the main bioclimatic design strategies:

  - Shadowing
  - Reflective coating of the enclosure
  - Insulation
  - Glazing areas and types of glass
  - Natural ventilation
  - Thermal inertia
  - Evaporative cooling
  - Internal gains control
  - Use of environmental controls
  - Passive strategies and thermal comfort criteria

- WATER

  The problems connected to water are intimately connected to health. Often, water appears contaminated by bacteria originating from organic matter of various origins: human waste, animal waste,

Secondary level hospital	Luanda, Angola
Name	*Location*

Example: Center of Bairro Palanca, in Luanda

Images

Project by: Student Venceslau Calvino Mateus

More info: are used traditional techniques that are rammed earth, adobe, CEB (compressed earth block) and wattle and daub.

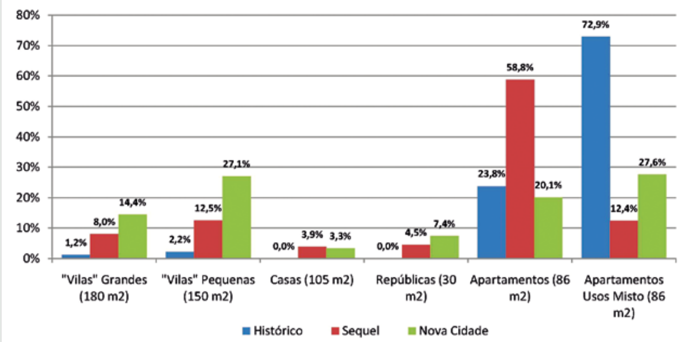
Secondary level hospital with a maximum of two floors that will be developed with two lateral blocks interconnected with the main body of easy access.

Cacuaco Esperança Project	Cacuaco, Angola
Name	*Location*

and industrial waste, causing cholera, dysentery, typhoid fever, schistosomiasis, hookworm disease, and trachoma. Contaminated water of the leading causes of death in the world. The scarcity of drinking water is a problem faced in Africa, but one that is worsening at a galloping pace throughout the world. Therefore, research in this area is now a priority, and the implementation of measures in African countries could be a potential model for the West soon.
It is necessary to create uncontaminated water supply networks, increase appropriate sanitary equipment and the collection and treatment of wastewater and sewage, contributing to the health of the population.
This chapter focuses on the description of the methods for the capture and purification of water and how to increase the supply and the methods of installation in the houses.

- ENERGY
  Considering the negative impact of the use of fossil fuels on the environment, and the increasing depletion of reserves of these fuels on a global level, it is urgent to promote the use of alternative, renewable energies, as well as the rationalization of consumption, avoiding unnecessary expenses.
  The sun and wind are the two renewable energy sources that can be harnessed the most. The movement of ocean waves and thermal differences in the ocean are other sources of energy to explore.
  In this chapter are analyzed:
  - Solar thermal energy
  - Wind energy
  - Photovoltaic energy
  - Biogas or methane gas
- SANITATION
  There is an interdependence between people's economic conditions, their hygiene habits, and the salubrity of the environments they inhabit. The system of reciprocal connection between these three elements is associated with another element which is water. The scarcity of water in certain areas and the lack of initiative to use water collection systems aggravate the lack of hygienic conditions in homes.
  A large part of Africa's population lives in rural or peripheral environments where sanitation facilities and infrastructure are scarce.
  Living in poor hygienic conditions causes disease and further aggravates the economic status of these families.
  Waste is a source of contamination of the natural environment and as such must be confined and disposed of to avoid sources of infection.
  An effective and economical response to the isolation and treatment of organic waste is the use of dry latrines.
- CASE STUDIES
  This chapter focuses on the description of case studies that best represent the previous characteristics.

Short description of the most relevant thematics that were addressed in the book



Plans / Images
Project by: multidisciplinary team including several public and private entities

ABC21 is funded by the
EU's H2020 programme

More info: The operational mode and process outlined and implemented for the Cacuaco Esperança project ensures that even in fragile areas and with scarce resources it is possible to adopt from the project phase attitudes that lead to and guarantee sustainable urban planning actions and the construction of buildings, also following the concept of sustainable construction.

7. REMARKS

Today there are several software programs for analyzing energy performance and comfort in buildings. These programs allow the measurement and quantification of indoor comfort levels and energy consumption of the building, as well as providing information on the best design strategies to implement regarding, for example, building orientation, shading, size of glazing areas, construction materials, or ventilation regimes. In addition to supporting the architectural project, which should integrate bioclimatic strategies from its initial conception (in terms of new construction and rehabilitation), these tools can be useful in deciding on standards and recommendations to be determined at the construction level in the country.

Portuguese-speaking countries in Africa have different climatic, cultural, and economic conditions, although there is much in common between them. It is possible to focus on common aspects and recognize the diversity in the fact that each solution must be adjusted and appropriate to the local context.

In many cases, there is a quantitatively significant increase in construction that has not been reflected in an increase in environmental concerns, nor in the search for efficiency in terms of energy and material consumption, thus placing on the agenda the need for a more active approach to the environmental dimension in the search for sustainability.

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1. BOOK TITLE:	Sustainable Hurban Housing in China - 2006	2. AUTHOR	Leon Glicksman & Juintow Lin
	Name of the strategy		Name of the author

2. CATEGORY:

Theoretical	Technical	Guideline	Report	Design focus	Compilation	Manual
		X				

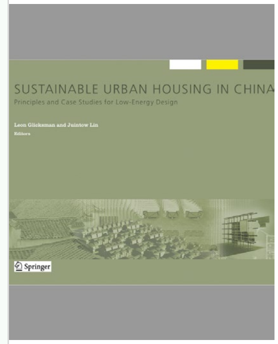
3. DESCRIPTION

This book is an outgrowth research that refers to sustainable developments as the husbanding of nonrenewable resources for future generations. The overarching goal is to preserve and improve the global environment for future generations through: the reduction in harmful emissions, conservation of nonrenewable resources such as materials and land, and improvements in the quality of life for the present generation. These goals

are particularly difficult to accomplish in areas of the world where economies and standards of living are growing rapidly like China.

Short description

4. COVER



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4. Materials and Construction for low energy buildings in China
5. Low energy Building Design
6. Wind in Building Environment design
7. Design of Natural Ventilation
8. Light and Shading
9. Case Studies

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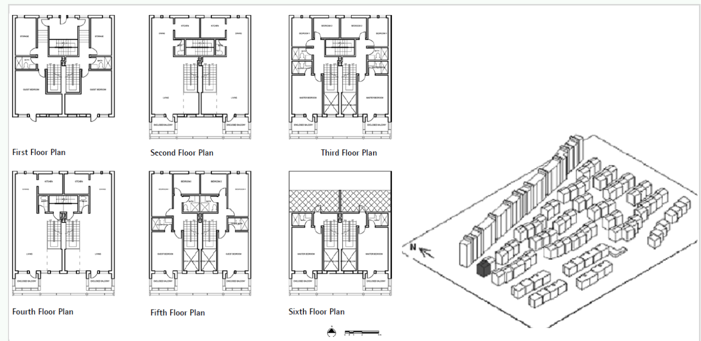
6. RELEVANT THEMATICS

1. SUSTAINABILITY AND THE BUILDING SECTOR Sustainable development also includes the husbanding of nonrenewable resources for future generations.Well-designed sustainable buildings will not only save energy, they will provide a healthier and more pleasant environment.
2. ENVIRONMENT AND CULTURE: The development of the Chinese economy encourages the demand for higher living standards in China.
3. DESIGN PRINCIPLES FOR SUSTAINABLE URBAN HOUSING IN CHINA: New urban housing in various areas of urban Chinese cities appears at first review to be relatively unsustainable. Therefore, the sustainability of housing is interpreted in multiple modes: social, technological, climatic, and urban. These are both quantitative and qualitative aspects. Some are related to better performance – an efficiency or economy of resources and energy. While others others are about quality of life and the ability of people to live together without alienation.
   The design principles are further explained at three integrated scales:
   - site design and planning (Urban Density Distribution and Urban Ventilation)
   - building form and typology
   - & building design and planning.
4. MATERIALS AND CONSTRUCTION FOR LOW ENERGY BUILDINGS IN CHINA: Improvements in both construction practices and building materials will significantly improve the energy efficiency, comfort and long-term durability of China's growing housing stock.

7. MAIN CASE STUDIES

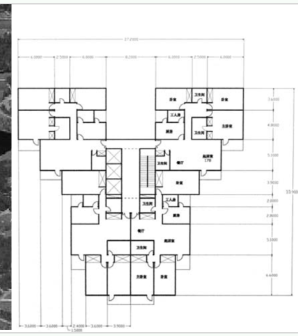
BEIJING PROTOTYPE HO	Beijing, China
Name	Location



Plans / Images

More info: *The goal was to make the house 'bioclimatic,' which would enable it to be a passive-based environmental design that was responsive to climatic forces. This would allow the housing block to use less energy through relying more on passive-based sources of environmental control and less on mechanical air-conditioning.*

Beijing Star Garden	Beijing, China
Name	Location



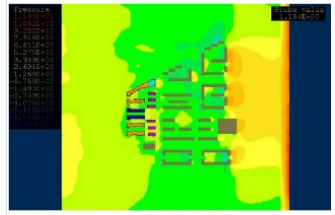
Plans / Images

More info: *an inclusively well-informed design solution based on energy simulations, CFD analyses, urban d. concepts, social considerations, etc*

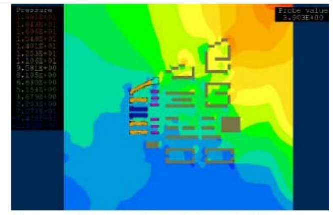
5. LOW ENERGY BUILDING DESIGN: the strategies include, Thermal Comfort, passive cooling strategies and climate data
6. WIND IN BUILDING ENVIRONMENT DESIGN: Natural ventilation studies include cross ventilation and single sided ventilation
7. DESIGN OF NATURAL VENTILATION WITH CFD Outdoor comfort and site planning
8. LIGHT AND SHADING: lighting simulations, radiosity and ray tracing methods are design tools to get advantage of daylight

Short description of the most relevant thematics that were addressed in the book

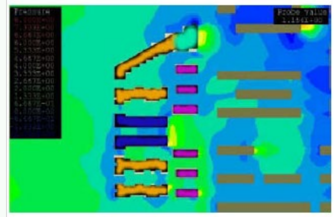
Shanghai Taidong Residential Quarter	Shangahai, China
Name	Location



Pressure - wind from east, showing the full site



Pressure - wind from northeast, showing the full site



Pressure - wind from east

Pressure - wind from northeast

Plans / Images

More info: *energy recommendations based on research of energy saving scenarios as well as urban design concepts, such as an interest in providing a variety of building and unit types.*

7. REMARKS

The book starts defining the importance of sustainability in the current scenario. It firstly describes barriers and problems present In the Chinese architecture and urban development. Then, it outilines sustainable concepts, proposes solutions through design principles strategies and how they were applied to specific cases studies in China.

Then, it emphasizes on both social and environmental sustainable objectives as important drivers for design in any context. Finally, it highlights the opportunities to create demand for energy conservation and sustainability in the housing market through policies. Having education as the main tool to incentivize people to use and understand sustainable designs

8. BIBLIOGRAPHY

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1. BOOK TITLE:	Next-generation urban design guides for sustainability of small towns: A case study in GuduL-2011	2. AUTHOR	Ozge Yalcine & Sule Karaaslan
	Name of the strategy		*Name of the author*

2. CATEGORY:

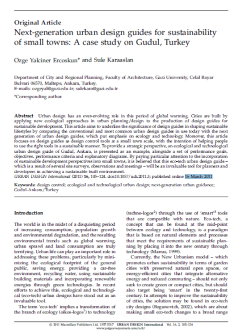
Theoretical	*Technical*	*Guideline*	*Report*	*Design focus*	*Compilation*	*Manual*
			X			

3. DESCRIPTION

The text underlines the significance of design guides in shaping sustainable lifestyles by comparing the conventional and most common urban design guides in use today with the next generation of urban design guides, which put emphasis on ecology and technology. Moreover, this article focuses on design guides as design control tools at a small town scale, with the intention of helping people to use the right tools in a sustainable manner.

Short description

4. COVER



Original Article

Next-generation urban design guides for sustainability of small towns: A case study on Gudul, Turkey

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Abstract Urban design has an ever-evolving role in this period of global warming. Cities are built by applying new ecological approaches in urban planning/design to the production of design guides for sustainable development. This article aims to underline the significance of design guides in shaping sustainable lifestyles by comparing the conventional and most common urban design guides in use today with the next generation of urban design guides, which put emphasis on ecology and technology. Moreover, this article focuses on design guides as design control tools at a small town scale, with the intention of helping people to use the right tools in a sustainable manner. To provide a strategic perspective, an ecological and technological urban design guide of Gudul, Ankara, is presented as an example, alongside a set of performance goals, objectives, performance criteria and explanatory diagrams. By paying particular attention to the incorporation of sustainable development perspectives into small towns, it is believed that this eco-tech urban design guide – which is a result of several site surveys, observations and meetings – will be an invaluable tool for planners and developers in achieving a sustainable built environment.
URBAN DESIGN International (2011) **16**, 105–124. doi:10.1057/udi.2011.3; published online 16 March 2011

Keywords: design control; ecological and technological urban design; next-generation urban guidance; Gudul-Ankara/Turkey

Introduction

The world is in the midst of a disquieting period of increasing consumption, population growth and environmental degradation, and the resulting environmental trends such as global warming, urban sprawl and land consumption are truly terrifying. Urban life can play an important role in addressing these problems, particularly by minimizing the ecological footprint of the general public, saving energy, providing a car-free environment, recycling water, using sustainable building materials and incorporating renewable energies through green technologies. In recent efforts to achieve this, ecological and technological (eco-tech) urban designs have stood out as an invaluable tool.

The term 'eco-tech' implies a transformation of the branch of ecology (oikos-logos[1]) to technology (techne-logos[2]) through the use of 'smart'[3] tools that are compatible with nature. Eco-tech, a concept that can be found at the mid-point between ecology and technology, is a paradigm that is based on natural elements and processes that meet the requirements of sustainable planning by placing it into the new century through technology (Marras, 1999).

Currently, the New Urbanism model – which promotes urban sustainability in terms of garden cities with preserved natural open spaces, or energy-efficient cities that integrate alternative energy and reduced commuting – should not only seek to create green or compact cities, but should also target being 'smart' in the twenty-first century. In attempts to improve the sustainability of cities, the solution may be found in eco-tech city designs (Bogunovich, 2002), which are about making small eco-tech changes to a broad range

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1. Introduction
2. Conventional Versus next - Generation design
3. Guides and world examples
4. Gudul Eco-Tech Urban Design Guide
5. Social Sustainability, limitations, costs and political visions on the eco-tech design
6. Conclusion
7. Notes
8. References

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6. RELEVANT THEMATICS

1. CONVENTIONAL VERSUS NEXT GENERATION DESIGN

It shows how Cities are built by applying new ecological approaches in urban planning/design to the production of design guides for sustainable development. GUIDES AND WORLD EXAMPLES.

Eco-tech, a concept that can be found at the mid-point between ecology and technology, is a paradigm that is based on natural elements and processes that meet the requirements of sustainable planning

2. GUDUL ECO TECH URBAN DESIGN GUIDE

Sustainability and comparisons with other guides: Conventional guides present certain rules about the layout and buildings in small towns, whereas next-generation guides concentrate on diverse.

Next generation guides: Promote mixed use and compact layouts, including pedestrian priority. They consider functionality, energy efficiency and recommend ecotechnologies.

They encourage local and recycled material in paving, furnishing and energy-efficient lighting. In addition, green networks with local edible plants are encouraged. Energy efficiency at home, office and in public spaces is a key point.

They mention measures for social sustainability and detail latest eco- technologies regarding waste collection, rainwater collection and alternative energy stations

3. SOCIAL SUSTAINABILITY, LIMITAIONS, COSTS AND POLITICAL VISIONS ON THE ECO TECH DESIGN OF GUDUL

It outlines the components of eco-tech design that are applicable to the Gudul area, and opens a discussion on

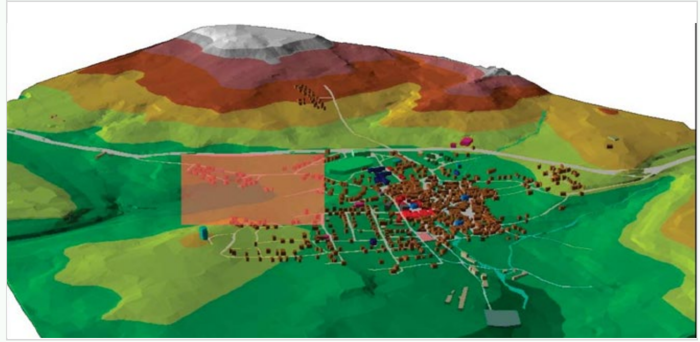
7. MAIN CASE STUDIES

GUDUL, ANKARA	Gudul, Turkey
Name	*Location*

Plans / Images

More info: *The Gudul Eco-Tech Guide includes recommendations and a framework for an eco-tech approach that is contextualized within the physical, cultural and political realities of the city.*

GUDUL, ANKARA	Gudul, Turkey
Name	*Location*



Plans / Images

ABC21 is funded by the
EU's H2020 programme

the challenges associated with the implementation of the design principles into the current social and physical context of the city of Gudul.

The performance criteria includes: Site Design, Transportation, Technology, Infrastructure, Building Design and Green Areas analysis

4. CONCLUSIONS

This article focused on the significance of eco-tech urban design guides.

The study introduced the concept of 'eco-tech' to urban design, which has not yet been widely implemented throughout the world.

This study highlights the distinction between conventional and next-generation guides, which are new in literature.

The Gudul guide that has been discussed throughout this study will be a pioneer in Turkey, and it has the potential to be listed among its global equivalents.

Short description of the most relevant thematics that were addressed in the book

Name	*Location*

Plans / Images

More info:

7. REMARKS

The study introduced the concept of 'eco-tech' through urban design guides. It focuses in Gudul, being a pioneer in Turkey, and it has the potential to be listed among its global equivalents. It shows the town potentials and limitations. This study also provides some cost information and calculations on environmental technologies that could be useful for domestic environmental technologies and governmental investments

8. BIBLIOGRAPHY

Yalciner Ercoskun, Ozge, et al. Next-Generation Urban Design Guides for Sustainability of Small Towns: A Case Study on Gudul, Turkey. 16 Mar. 2011.

ABC21 is funded by the EU's H2020 programme

1. BOOK TITLE: Green and thriving neighbourhoods 2021

Name of the strategy

2. AUTHOR: Hélène Chartier, Laura Frost, Christopher Pountney,

Name of the author

2. CATEGORY:

Theoretical	Technical	Guideline	Report	Design focus	Compilation	Manual
		X				

3. DESCRIPTION

This guidebook addresses the transition to net zero in new and existing neighbourhoods, applying people-centred thinking to deliver this in all Types of neighbourhood. It summarises the opportunities a the neighbourhood scale, then sets out the two pillars at the centre of a green an thriving neighbourhood. Ten approaches respond to the two pillars, each with actions and cases studies to exemplify from global cities

Short description

4. COVER

Cover image

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1. Introduction
2. Opportunity
3. Pillars
4. Approaches
5. Pathway
6. Scaling up
7. References

Main titles of table of contents

6. RELEVANT THEMATICS

NEIGHBOURHOOD OPPORTUNITY

The geography is analyzed based on its scale, innovation, governance, financing and communities collaboration

1. TWO PILLARS Addressing both the emissions imperative and promoting quality of life at the neighborhood scale.

a. PILLAR 1: Green net zero emissions: The neighbourhood should adopt near-term targets, driving rapid emissions reduction now: Operational emissions, embodied emissions and consumption- based emissions target.

b. PILLAR 2: Thriving: resilient, people-centred places.

This section outlines 10 APPROACHES

1. Complete neighbourhood: prioritize local life, providing a compact neighbourhood where people can access everyday needs within a short walk or bike ride from their home
2. People centred mobility: Re-prioritizing street space, good street design, tactical urbanism and zero emissions vehicles
3. Connected place: ensure strong physical and digital connectivity with other parts of the city and beyond.
4. Place for everyone: improve living standards, create better job opportunities, and enhance public and environmental health for all.
5. Clean construction: construction should be planned, designed and built for the long-term, ensuring the neighbourhood is resilient to future changes.
6. Green buildings & energy: Adopting passive design principles
7. Circular resources: using circular economy principles

7. MAIN CASE STUDIES

Name	Location
Local Government services	Buenos Aires

Plans / Images

More info: *Proximity and decentralization is encouraged to create or to consolidate a centrality in the neighbourhood, as it can attract other amenities nearby.*

Name	Location
Prioritising pedestrian and cyclists	Barcelona

Plans / Images

More info: *The superblocks programme is a transformative vision for the entire city making spaces and streets greener. It gives priority to pedestrian and cyclists by closing streets to through traffic and introducing tactical urbanism interventions.*

8. Green & Nature based solutions: proved high quality open green spaces
9. Sustainable lifestyles: supporting long term behavior change
10. Green economy

2. PATHWAY: it requires a strategic and holistic approach. Addressing the emissions imperative and promoting quality of

life will be most effective and achievable: first preparing the project, establishing a baseline, setting the vision, determining actions and planning for implementation

Remarks:

The guidebook presents 10 approaches that are grouped into three categories: the 15 minute cities, clean and green and sustainable futures. It explains what these approaches mean and provides advice on how cities can develop a pathway for implementing them, from preparing a project to planning for implementation.

3. SCALING UP: the development should be celebrated and then learning should be captured so that future neighbourhoods can refine and improve the approach.

Short description of the most relevant thematics that were addressed in the book

Comfortable neighbourhood	Sao Paulo, Brasil
Name	*Location*

Plans / Images

More info: *Digital services: Comfortable neighbourhood working spaces with good internet access will help to inject life into neighbourhood main streets and encourage people to work remotely*

7. REMARKS

The guidebook presents 10 approaches that are grouped into three categories: the 15 minute cities, clean and green and sustainable futures. It explains what these approaches mean and provides advice on how cities can develop a pathway for implementing them, from preparing a project to planning for implementation.

It is an informative for net zero masterplanning in smaller settlements, while some approaches in the guidebook work best at scale, the underlying principles can still be applied.

8. BIBLIOGRAPHY

Chartier, Helene, et al. Green and Thriving Neighbourhoods. 2021.

1. BOOK TITLE: Fujisawasst sustainable Smart Town - 2016

Name of the strategy

2. AUTHOR: Higashi Shimbash

Name of the author

2. CATEGORY:

Theoretical	Technical	Guideline	Report	Design focus	Compilation	Manual
		x				

3. DESCRIPTION

The objective is the creation of a sustainable and self-sufficient town with a low impact on the environment where two fundamental principles are united: modernity and the well-being of its people, thus giving a much more efficient and safe town to its inhabitants. The guideline proposes to focus on planned houses, commercial facilities, wellness, welfare and educational facilities, parks and zones to develop the ideal town.

Short description

4. COVER

Cover image

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2. Fujisawa Energy
3. Fujisawa Security
4. Fujisawa Mobility
5. Fujisawa Community
6. Conclusions

Main titles of table of contents

6. RELEVANT THEMATICS

1.FUJISAWA MODEL.- The main feature of this project is that we will build an actual smart town with 1,000 households.

We are not simply aiming to develop a town underpinned by advanced technology-based infrastructure, but a town based on actual lifestyles.

The main objective is to create a self-sufficient smart city based on five principles: community mobility, security, energy and wellness.

1. Energy: The objective is to create an intelligent town highly capable of self-supplying its energy needs with the implementation of solar energy and smart energy storage.
   People depend on electric power for everyday living and
   its supply should never be interrupted, even in a time of emergency. Establishing the Community Solar System, distributed renewable energy system, and other hardware throughout the town
2. Security: the use of invisible security systems such as security cameras, lighting with sensors and Security concierges to provide optimal security throughout the town.
3. Mobility: mobility sharing services, which include electric-assisted bicycles, will also contribute to the solution for this social problem of traffic gridlock. With the implementation of electric cars, electric bicycles, electric car rental and energy charging stations, they are the bases of the intelligent and sustainable movement.

7. MAIN CASE STUDIES

Fujisawa City	Fujisawa, Japan
Name	Location

Plans / Images

More info: *Achieving eco-friendly and comfortable living with the adoption of" passive design" to streets or zones of the town, delivering sunlight and breeze to the entire town*

The Fujisawa SST Square	Fujisawa, Japan
Name	Location

Plans / Images

More info: *is a site that maximizes value for town residents, neighborhood residents and companies who come to the square. Based on collaboration among a wide range of stakeholders, it is equipped with functions to" bring energy to life."*

Shonan T-Site	Fujisawa, Japan
Name	Location

4. Wellness: The objectives are to seek a balance in the implementation of quality public services integrating all citizens in a collective well-being. Social interaction helps all people associated with the town to live a physically and psychologically healthy life. For example: A “local comprehensive care system” for providing linked and seamless medical care, nursing care, elderly care, and pharmaceutical services
5. Community: A town that networks residents of the town and nearby areas and people working in the town, building a community with forward-looking values seeks to create an interconnected and socially responsible town with social and public activities for the interconnection of citizens

Short description of the most relevant thematics that were addressed in the book

Plans / Images

More info: *It 's a base for inspiring residents and visit ors to the Shon an area, nurturing new lifestyles, and making this lifestyle known to people outside the town..*

7. REMARKS

The essence of the project is based on these five fundamental pillars for a more ecological and sustainable town, which are: energy, the use of solar energy, security, the use of invisible systems for the comfort of its people, mobility with green means such as electric bicycles, community the integration of plans and strategies that allow the interaction of the community and wellness the implementation of green spaces and comfort where your community can develop healthily. First, the Fujisawa model focuses on the proposal of a smart lifestyle, then it describes the design of smart spaces and finally it proposes the creation of a smart infrastructure.

8. BIBLIOGRAPHY

Shimbashi, H. (2018) Introducing Fujisawa Sustainable Smart Town, FujisawaSST. Link. https://fujisawasst.com/EN/ (Accessed: December 15, 2022).

1. BOOK TITLE: Developing and implementing a Sustainable urban mobility plan 2013

Name of the strategy

2. AUTHOR: Frank Wefering, Siegfried Rupprecht, Sebastian Bührmann, Susanne Böhler-Baedeker

Name of the author

2. CATEGORY:

Theoretical	Technical	Guideline	Report	Design focus	Compilation	Manual
		x				

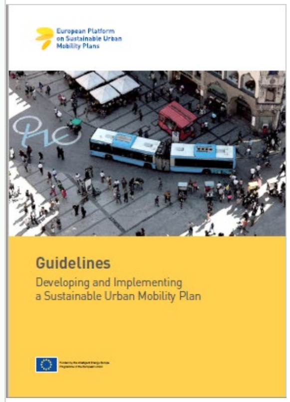
3. DESCRIPTION

T he objective of the Urban Mobility Plan is based on the exhaustive integration of a sustainable road planning where it addresses the current problems of cities and transportation routes, seeking to make them much more efficient. An urban transport plan can only call itself sustainable if certain economic, social and environmental criteria are taken into account. This guidance document on 'Developing and implementing a Sustainable Urban Mobility Plan' outlines the

main steps of defining mobility policies in the contextof a clear vision and measurable targets to address the long-term challenges of urban mobility.

Short description

4. COVER



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6. Elaborating the plan
7. Implementing the plan
8. Ensure proper management and communication
9. Identify new challenges for next SUMP generation
10. Annexes

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6. RELEVANT THEMATICS

1. URBAN MOBILITY PLAN:

Step 1: Determine your potential for a successful SUMP.- Commit to overall sustainable mobility principles, assessing the impact of regional/national framework and availability of resources.

Step 2: Define the development process and scope of plan.- Look beyond your own boundaries and responsibilities.

Step 3: Analyze the mobility situation and develop scenarios.- Develop scenarios based on the analysis of problems and opportunities

2. RATIONAL AND TRANSPARENT GOAL SETTING:

Step 4: Develop a common vision and engage citizens
Step 5: Set priorities and measurable targets.- Develop smart targets and priorities for mobility

Step 6: Develop effective packages of measures .- use synergies and create integrated packages of measures

3. ELABORATING THE PLAN

Step 7: Agree on clear responsibilities and allocate funding.- preparing an action and budget plan
Step 8: Build monitoring and <u>assessment</u> into the plan
Step 9: Adopt Sustainable Urban Mobility Plan

7. MAIN CASE STUDIES

Name	Location
Toulouse	France

Plans / Images

More info: *In the framework of the "partnership monitoring commission", all institutions, associations and mobility-related organisations meet at least once a year to discuss the progress made*

Name	Location
Aberdeen	France

4. IMPLEMENTING THE PLAN

Step 10: Ensure proper management and communication
Step 11: Learn the lessons.- identify new challenges for next SUMP generation.

Short description of the most relevant thematics that were addressed in the book

Plans / Images

Rupprect Consult	Lille PDU
Name	Location

Plans / Images

More info: *The connections between the different modes of travels, the citizens that realise them, freight transport, and the space in which transport takes place together require an integrated mobility and transport policy, articulated by the city and its citizens.*

7. REMARKS

A Sustainable Urban Mobility Plan is a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. This guidebook provides the planners with a series of principles and steps to follow in order to obtain a successful sustainable urban Mobility plan. The plant is based on 4 phases that contain 11 steps for a sustainable development.
Its concept has been designed with the best European examples in mind and it should become part of the daily planning practice in all European cities and municipalities. The guidebook outlines benefits of a sustainable urban mobility plan, it explains the guidelines methods and development. Then it illustrates the steps and activities to produce a successful sustainably urban plan. The guidelines consider potentials, aims and previous examples.

8. BIBLIOGRAPHY

Wefering, F, Rupprecht, S, et al. Developing and implementing a sustainable urban mobility plan, Brussels, Jan. 2014

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