THE BIOTEKT BUILDING SYSTEM

A STUDY OF ENVIRONMENTAL PROPERTIES

BIOTEKT

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Sustainability has become an increasingly important focus for new construction. The high environmental cost of energy production, the carbon footprint of a product or process throughout its life-cycle, the fragility of existing ecosystems, and the impact of human life on the planet and society in general, are urgent issues which must be addressed in any new endeavor that we wish to undertake. In most areas of the world, living at a comfortable temperature is costing society and the planet more and more. Traditional construction systems which once seemed reasonable are being revalued and dissected in order to provide a real picture of their sustainability in our changing world. Everything must be taken into consideration; from the availability and ecological cost extracting the raw materials, the energy required to process and move them to the building site, through the cost of heating or cooling of a particular building, to the ultimate energy cost of maintenance and repairs or replacement of a particular building type. Other factors which are increasingly crucial are a buildings contribution to the local ecology, its interaction with the air and water surrounding it, and the protection it may offer from other undesirable outside effects, including noise, weather disruptions, and social instability.

Probably the oldest building systems of all, using the living earth as a building material, in adobe, rammed earth, and earth-sheltered construction are gaining renewed acceptance because of the need for sustainable systems of living. In particular the idea of covering a structure with living earth and plants, and using the thermal stability and security provided by the proximity to the ground, is very appealing. However, this type of construction has always been difficult and expensive to achieve, with questionable results. Achieving adequate ventilation and adequate water-proofing in this type of construction has never been easy with traditional methods, and often the result is overbuilt, requiring an extremely strong structure that does not collaborate with the earth surrounding it. The BIOTEKT system has addressed these problems in an entirely new way, using the age old methods of building with earth in conjunction with the space-age technology of composite materials. The inner shell of the buildings is very strong, light, waterproof, and modular, and the earth covering is constructed in such a way that it collaborates structurally with the shell because of its layered construction and the vaulted geometry of the system.

In comparison to other traditional materials such as concrete, brickwork, metals or wood, the total life-cycle assessment of composites contributes to their viability as green building products. When consideration is taken for the energy consumed in production and installation, composites generate a much smaller impact than other traditional materials and can be used in ways that are less energy or carbon intensive. The light weight of FRP contributes to overall savings, starting with lower transportation costs. There is no need for heavy lifting equipment and installation is faster which results in less disruption to the environment. The rigidity and structural integrity of composites as used in the BIOTEKT system means there is less dead weight and less material is required, eliminating unnecessary resource consumption and bringing down costs. By contrast, a similar product made of concrete could require up to 1000% more material to produce and would weigh far more. The process of refining cement, from extraction to fabrication, or firing brick and terracotta in high temperature ovens, generates a large amount of carbon dioxide and other gases. Composites have a life cycle that exceeds other building materials by remaining resistant to rust, rot and corrosion. By increasing the useful lifespan compared to other products, Composite materials durability reduces the need for replacement, repair or repainting. Their durability, low maintenance, and low heat transfer index, mark them as environmentally sustainable on their own. In addition to this, the BIOTEKT system is based on a lamination process that is formulated with proprietary green resins, containing up to 80% recycled material. Coupled with the multiple benefits provided by the organic earth covering, in terms of thermal inertia, as well as carbon cycling and oxygen production, and airborne pollutant removal, the BIOTEKT system has the lowest possible carbon footprint through its life-cycle and the highest sustainability of any industrialized system that we know of.

2. ENERGY EFFICIENCY IN EARTH SHELTERED CONSTRUCTION: BIOTEKT

The philosophy of Earth sheltered construction is based on three fundamental principles: energy saving, energy recovery and drawing energy from the environment, by exploiting, among other things, the building's thermal mass. Thermal Mass is different than heat transfer resistance. R-Value is heat transfer resistance only. Typical R-value for earth is 0.25 per inch; however, the thermal character of the soil mass is quite different than that of material designed and used primarily for heat transfer resistance (R-value) like polystyrene or polyurethane foam. When changing from soil to a less massive "insulating" material, you should understand the design performance with regards to heat capacity of the building and/or soil mass (K-value). A massive soil wall or roof can store heat energy to even out the temperature swings of day--lightweight insulation does not perform this way. The thermal value you get from 18 inches of soil far surpasses the 4.5 R-value (0.25 per inch). The use of earth as a large capacity heat storage makes it possible not only to reduce such buildings' demand for heating and cooling energy, but also helps to preserve the local microclimate.

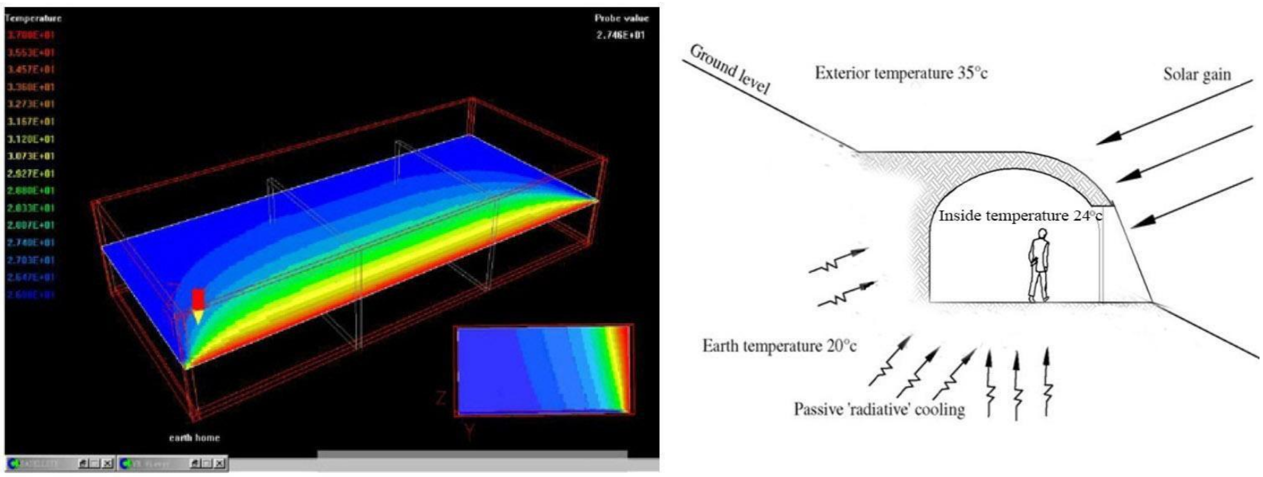
The following presentation is of a series of studies and comparisons of the Biotekt system and traditional systems in different climate regions, and are based on our own observations as well as studies and simulations done by others regarding earth sheltered buildings in general.

2A. BIOTEKT IN TEMPERATE CLIMATES

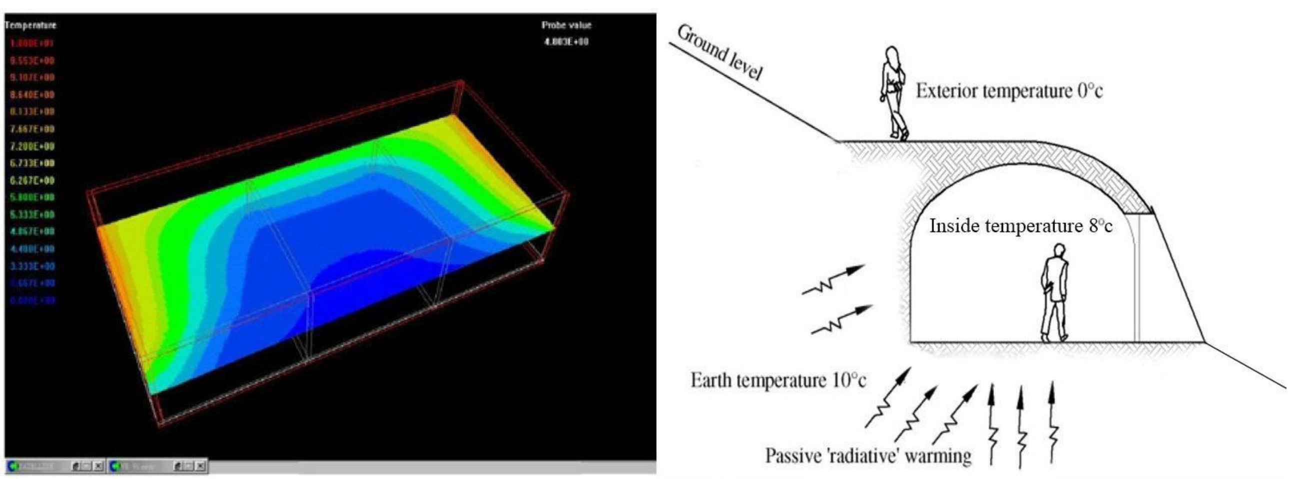
The biggest challenge to any building system is posed by the temperate and seasonal environment, (generally above 35 degrees North and 35 degrees South latitude) in which annual temperatures can fluctuate from below freezing in the winter to very hot in summer, and living spaces must be designed for comfort in a constantly changing environment. The Biotekt system of earth sheltered construction, coupled with passive solar principles, will provide energy saving solutions in this (as in other) environments. All facts and figures given in this section will apply to other climates, as they include the extremes of hot and cold conditions and their relationship to the built environment.

The concept of passive annual heat storage system (PAHS), a method of collecting heat in the summertime, by cooling the home naturally, storing it in the earth's soil naturally and then afterwards returning that heat to the contact structure(earth home) in the winter was originally introduced by Hait in his book published in 1983. It includes extensive use of natural heat flow methods, and the arrangement of building materials to direct this passive energy from the earth to the building, all without using machinery. According to this concept, there is a cooling action when one climbs down into basement structures or caves. This cooling action experienced in these enclosed environments is a result of the heat being drawn away from the body to the surrounding air which then transfers this thermal energy into the surrounding structures whose heat content is less than that of the adjacent air mass. The dynamics behind this concept is that heat always flows from a warmer system to a cooler system (as in the case mentioned above with the human body as the warm system and the surrounding air and walls as the cooler system). By this action if you are warmer than the surrounding air, the heat of the body will escape to the surrounding air until temperature equilibrium is attained. Likewise, in the case the air inside the room is warmer than the surrounding walls, heat will be drawn out of the air into the walls, thus cooling the air and warming the walls. On the other hand, if the air temperature inside the room is cooler that the surrounding walls, heat will be drawn out of the walls into the air by this warming the air and cooling the walls. Passive annual heat storage (PAHS) uses this thermodynamic principle in conjunction with bare earth to aid control of the micro-climate within the building. In the case of the earth sheltered dwelling, it utilizes the surrounding earth to regulate its temperature throughout the year. Globally, the earth receives electromagnetic radiation from the sun which is typically defined as short-wave radiation and emits it at longer wavelengths known typically as long-wave radiation. This absorption and re-emission of radiation at the earth's surface level which forms a part of the heat transfer in the earth's planetary domain yields the idea for the principle of PAHS. When averaged globally and annually, about 49% of the solar radiation striking the earth and its atmosphere is absorbed at the surface (meaning that the atmosphere absorbs 20% of the incoming radiation and the remaining 31% is reflected back to space

Effects of PAHS and passive cooling on Biotekt earth sheltered indoor space in summer- Figure 1



Effects of PAHS and passive warming on Biotekt earth sheltered indoor space in winter- Figure 2



The use of the earth's relatively stable temperature can provide occupant comfort at minimal energy costs. The earth moderates the temperature swings that occur on a daily basis and it has been determined that a time lag of approximately 133 hours occurs at a two-foot depth. The time lag occurs proportionately so that an eight or ten foot depth has a time lag of 2100 to 2200 hours or about 90 days. A reduction of 50 to 75 percent of the normal heating and cooling load requirements can be achieved due to the temperature moderation and time lag of the earth.

Temperature moderation effects on an earth sheltered house with a large thermal mass are shown schematically in Figure 3.

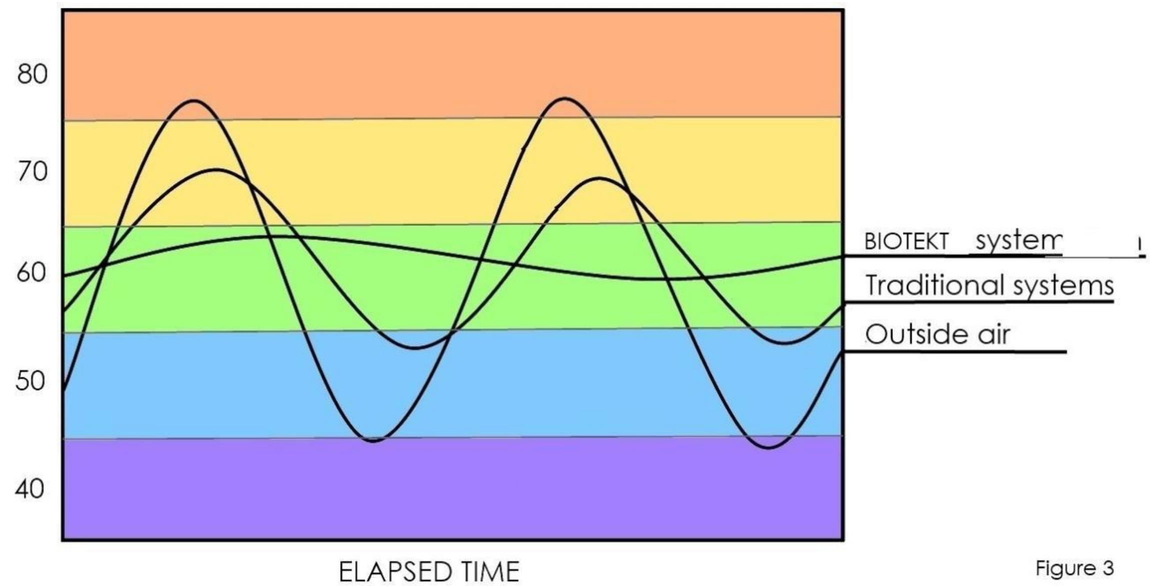


Figure 3

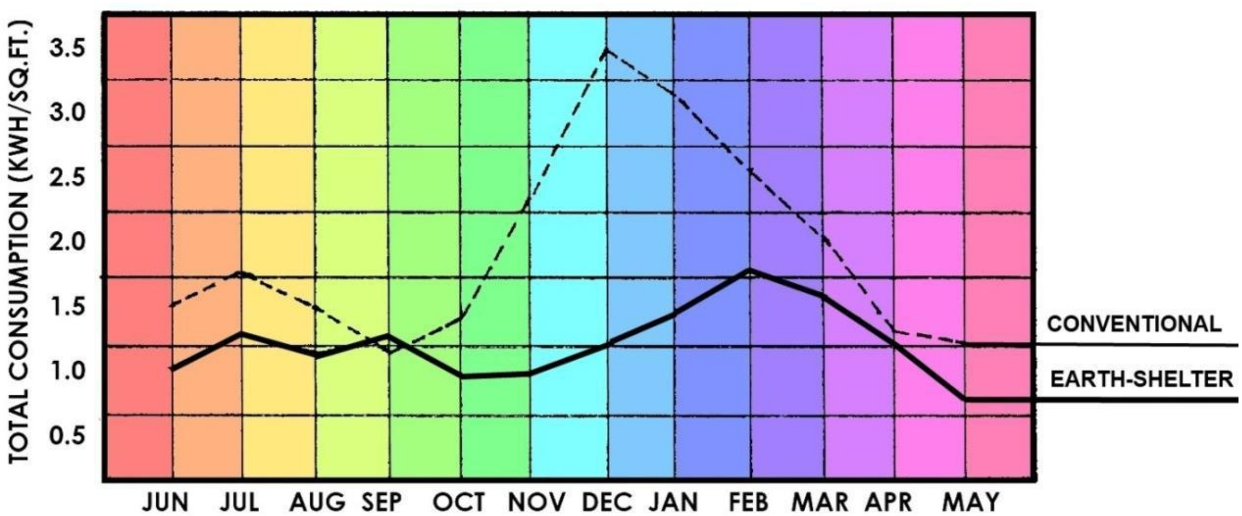
An important question is whether additional insulation is required to optimize the energy performance of the Biotekt system in a seasonal environment. In general the more insulation is added, the better the performance in winter time, and the poorer in summer. The figures are as follows:

During heating season heat losses from earth sheltered buildings are about 14 %, 8 % and 5 % smaller for: 5 cm, 10 cm and 20 cm of thermal insulation thicknesses. Increasing soil cover thickness over 0,5 m decreases heat losses about 20 to 25 % , 10 to 15 % and 5 % for 5 cm, 10 cm and 20 cm of thermal insulation. Heat gains during heating season are about 40 % higher in earth-sheltered houses than in aboveground houses. In above-ground houses heat gains are 3 % of heat losses. In earth-sheltered houses heat gains are up to about 15 % of heat losses during heating season. During cooling season heat losses from earth sheltered buildings are about 20 - 35 % greater than from above-ground buildings, while heat gains are nearly 80 % lower. In the summertime each 5 cm of thermal insulation lowers the heat losses by about 20 %. In above-ground buildings heat gains during heating season are comparable in the range of analyzed thermal insulation thicknesses. It may be concluded then, that in above-ground buildings the thickness of thermal insulation does not have a significant influence on heat gains. In the earth-sheltered houses heat gains are greater with increasing thermal insulation thickness. Each 5 cm of thermal insulation increases heat gains about 40 %. In above ground houses heat gains are 35 % of heat losses, while in earth-sheltered houses ratio of heat gains to heat losses is smaller. If heat losses are 100 % then heat gains are only 5 %. This is why earth-sheltered buildings need less cooling energy.

It can be definitely stated that the heating and cooling consumption of earth-sheltered buildings is definitively smaller that of above-ground ones. The difference between them gets smaller with the increase of the thermal insulation thickness. Earth-sheltered buildings require longer heating periods than conventional above-ground ones, while total heating loads are still smaller. This is due to the lower temperature of the soil surrounding earth sheltered houses. The cooling period is nearly the same. When analyzing the heating energy consumption it can be noticed that the largest difference in heating consumption of an above-ground building and an earth-sheltered one is noticed for 0.5 meters of soil cover. Further increasing of the soil cover thickness doesn't produce such large differences. This relation is also smaller with increasing thermal insulation thickness. The first 0.5 m of soil cover reduces heating consumption by about 25 % compared to a conventional above-ground building.

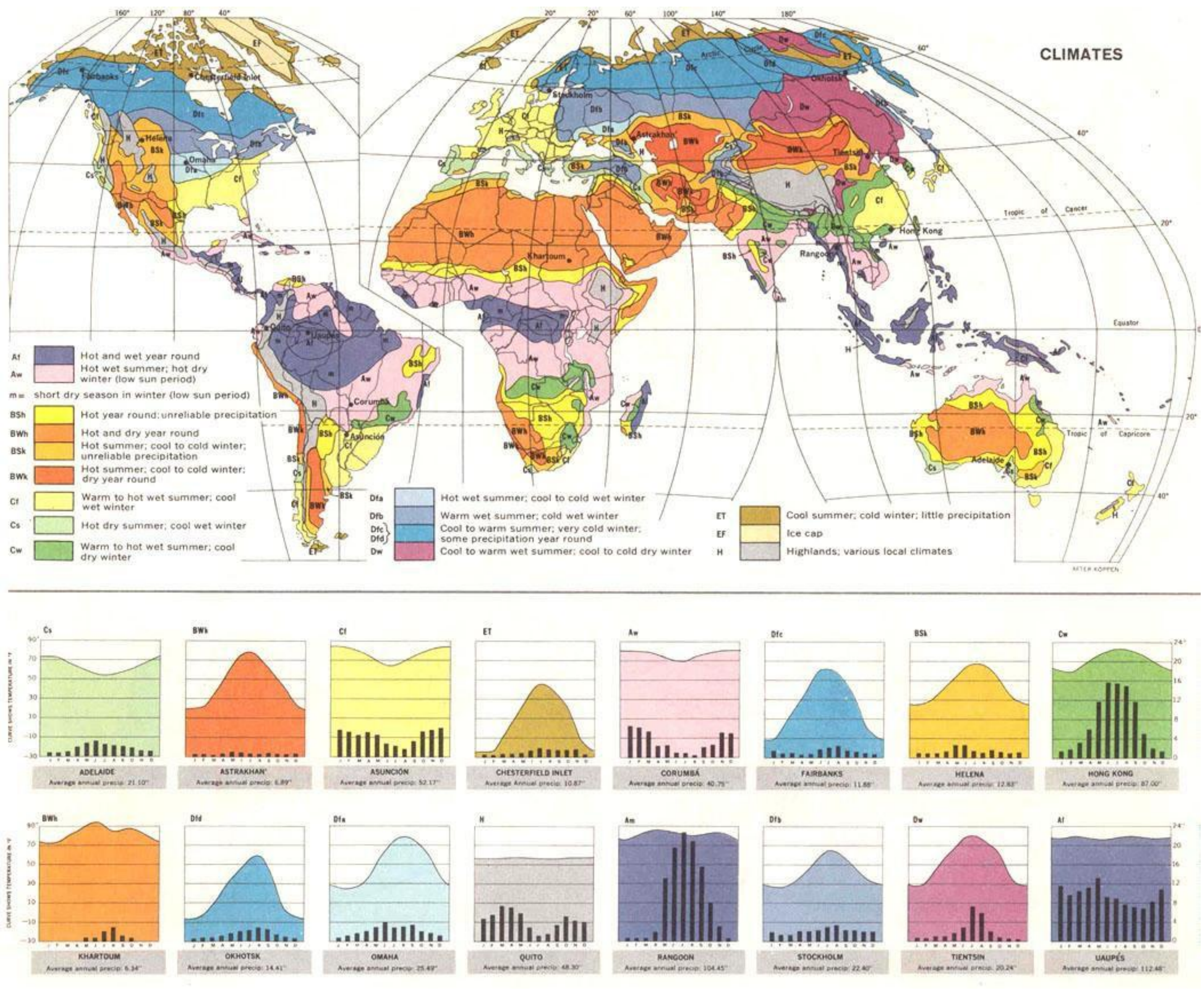
SOIL COVER THICKNESS	THERMAL INSULATION THICKNESS			
	5 CM	10 CM	20 CM	30 CM
HEATING ENERGY SAVINGS [%]				
0,5 m	24	23	24	24
1,0 m	31	28	27	27
1,5 m	36	32	31	30
2,0 m	41	36	34	33
2,5 m	44	40	37	34
COOLING ENERGY SAVINGS [%]				
All	52	36	20	15

So, the thicker the thermal insulation is, the lower heating energy savings can be obtained. It may be noticed that from the heating energy load's point of view, the thicker soil cover and insulation are, both above-ground and earth-sheltered buildings naturally consume less heating energy. But also with increasing thermal insulation thickness the influence of soil gets smaller, which causes insignificant differences between above-ground and earth sheltered buildings for large insulation thickness. For cooling loads, the soil cover thickness does not have a significant influence. Thus the thinner the thermal insulation is the greater the cooling energy savings are compared to the above-ground ones. This is due to the fact that thermal insulation acts like a coat, and during wintertime protects a building from colder outside soil temperatures but during summer does not allow the soil to naturally cool a building down.



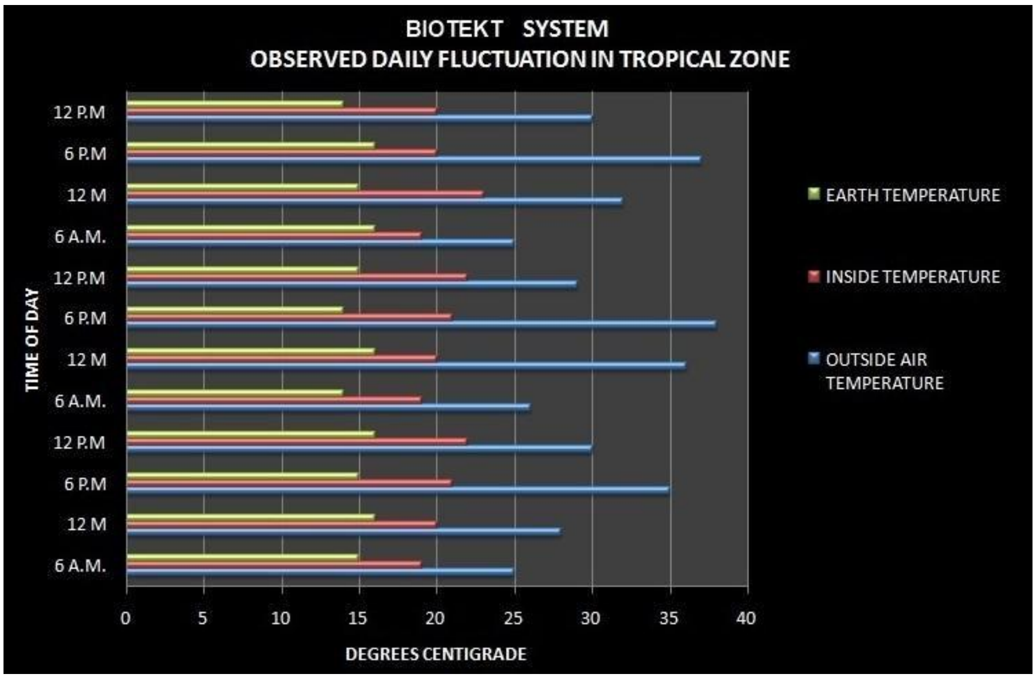
2B. BIOTEKT IN SUBTROPICAL CLIMATES

The interest in the use of earth to save energy dates back to over 5 000 years ago when in some cultures whole towns were built under the ground. The examples are: the town of Matmata in Tunisia, the Goreme Valley in Turkey and the Henan Province in Shanxi (China). Most of the ancient underground structures are located in hot countries, such as Turkey, Tunisia or northern China, which means that earth was originally used rather for cooling than heating. This is highly significant if one considers the fact that over one third of the continents (about 4.7 million km2) is situated in hot-dry climate (i.e. between 15° and 35° respectively north and south of the equator) and only 12% of the continents are situated in the temperate climates (about 1.55 million km2). Taking into account other climatic conditions, one can say that half of the continents are situated in hot climates. Thus the use of earth as the building's cooling component is of major significance, particularly considering that 15% of the world population inhabits desert and semi-arid areas.



The Biotekt system is truly ideal in these conditions. The low humidity, high temperatures in summer with little cloudiness, and moderate temperatures in winter make the Biotekt system worthy of serious consideration on a large scale. As was stated in the previous section, heat losses from earth sheltered buildings are about 20 to 35 % greater than from above-ground buildings, while heat gains are nearly 80 % lower.

In tropical regions (roughly from 15 degrees north to 15 degrees south) temperatures are more or less unchanging throughout the year, as the weather conditions are governed mainly by location and altitude. In Humid environments, an important issue that has to be taken into account with the Biotekt system (as in any other building system) is the judicious placement of windows and skylights, to ensure adequate ventilation of interior spaces. This is necessary in order to prevent condensation issues caused by the temperature differential between the cool earth covered walls and warm air.



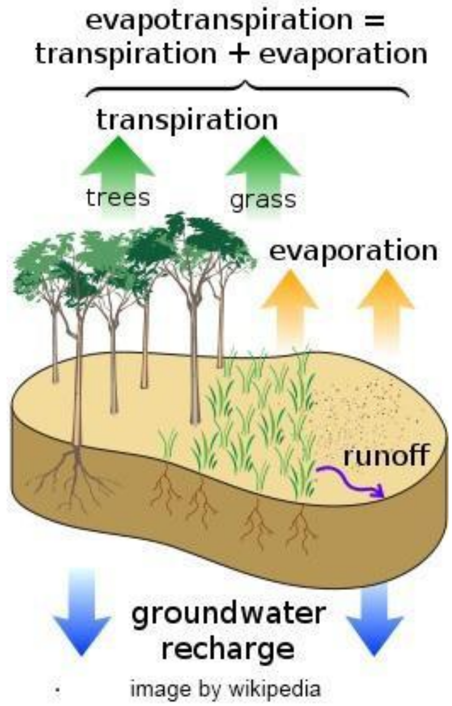
In very hot and humid areas, the most important factor in naturally achieving a comfortable inside temperature is ventilation, as heat is usually carried by the air and does not depend only on the effect of the sun. However, in these areas, the efficiency of even the smallest air conditioning system will outperform any conventional building, as it will be aided by the heat loss caused by the surrounding earth.

3. ENVIRONMENTAL QUALITY AND BIOTEKT

Year	Total world population (mid-year figures)	Ten-year growth rate (%)
1950	2,556,000,053	18.9%
1960	3,039,451,023	22.0
1970	3,706,618,163	20.2
1980	4,453,831,714	18.5
1990	5,278,639,789	15.2
2000	6,082,966,429	12.6
2010	6,848,932,929	10.7
2020	7,584,821,144	8.7
2030	8,246,619,341	7.3

The widespread use of earth sheltered and underground construction could have an enormous effect on the global environment. The effects of deforestation and the impact of urban growth on the world's atmosphere are only now beginning to be understood. In most cities, urban air temperatures are generally higher than their corresponding rural values. This phenomenon, the urban heat island, has been recognized since the turn of this century and has been well documented. Population growth in the 21st century will cause cities to grow and merge with each other, reducing even further the mitigating effects of suburban and rural vegetated areas. One key to the reduction of the negative effects of human communities on global warming, air and water pollution, and the quality of life in general, lies in technologies designed to return the natural environment to the surface level, and human habitation to an intermediate one. These technologies include green roofs and walls, rooftop and vertical urban farming systems, and earth sheltered construction with the Biotekt system.

3A. LATENT HEAT FLUX AND EVAPOTRANSPIRATION



Evaporative cooling is the process by which a local area is cooled by the energy used in the evaporation process, energy that would have otherwise heated the area's surface. It is well known that the paving over of urban areas and the clearing of forests can contribute to local warming by decreasing local evaporative cooling, but it was not understood whether this decreased evaporation would also contribute to global warming. The Earth has been getting warmer over at least the past several decades, primarily as a result of the emissions of carbon dioxide from the burning of coal, oil, and gas, as well as the clearing of forests. But because water vapor plays so many roles in the climate system, the global climate effects of changes in evaporation were not well understood. Evapotranspiration (evaporation and transpiration) from soil-vegetation systems is an effective moderator of near-surface climates, particularly in the warm and dry mid and low latitudes. Given the right conditions, evapotranspiration can create 'oases' that are 2-8°C cooler than their surroundings. In extreme oasis conditions, the latent heat flux can be so large that the sensible heat flux becomes negative, meaning that the air above vegetation and over the dry surroundings must supply sensible heat to the vegetated area and the Bowen ratio (ratio of sensible to latent heat fluxes) becomes negative. For example, in deserts, oases can develop with Bowen ratios of 0.26. In more average oasis conditions, Bowen ratios in vegetative canopies are within 0.5-2. In comparison, in urban areas ratios are typically around 5, in a desert it is in the neighborhood of 10, and over tropical oceans, it is about 0.1. Urban areas, with extensive impervious surfaces, have generally more runoff than their rural counterparts. The runoff water drains quickly and, in the long run, less surface water remains available for evapotranspiration, thus affecting the urban surface energy balance. The lower evapotranspiration rate in urban areas is a major factor in increasing daytime temperatures. Simulations indicate that a vegetative cover of 30% could produce a noontime oasis of up to 6°C in favorable conditions, and a nighttime heat island of 2°C. In conclusion, increases in vegetation in urban areas can result in some 2°C decrease in air temperatures. Under some circumstances, e.g., potentially evaporating soil-vegetation systems and favorable meteorological conditions, the localized decrease in air temperature can reach 4°C.

The long-range benefits of evapotranspiration have often been confused with the question of the Albedo effect, which is a relative measurement of the reflectivity of surfaces and of the planet itself. In general, the more reflective surfaces are (the higher the Albedo), the less radiation they absorb and the less heat they reflect back into the atmosphere. Since forests are generally attributed a low albedo, (as the majority of the ultraviolet and visible spectrum is absorbed through photosynthesis), it has been erroneously assumed that removing forests would lead to cooling on the grounds of increased albedo. Through the evapotranspiration of water, trees discharge excess heat from the forest canopy. This water vapor rises resulting in cloud cover_which also has a high albedo, thereby further increasing the net global cooling effect attributable to forests.

3B. AIR POLLUTANT REMOVAL BY VEGETATION

Vegetation in urban and suburban areas reduces air pollutants through a dry deposition process and microclimate effects. The high surface area and roughness provided by the branches, twigs, and foliage make vegetation an effective sink for air pollutants. Vegetation also has an indirect effect on pollution reduction by modifying microclimates. Plants lower the indoor air temperature through shading, thus reducing the use of electricity for air conditioning. The final result is that the emission of pollutants from power plants decreases due to reduced energy use. Vegetation also lowers the ambient air temperature by changing the albedos of urban surfaces and evapotranspiration cooling. The lowered ambient temperature then slows down photochemical reactions and leads to reduced secondary air pollutants, such as ozone.

Studies show that (in urban areas) the annual removal per hectare of green roof and grass areas is 85 kilograms and the annual removal per hectare of forest cover is 97 kilograms. In rural areas the rates would be smaller due to lower concentrations.

Observed deposition velocities of SO_2, NO_2, PM_{10}, and O_3 over different vegetation types reported in the literature

Pollutants	Vegetation (h_0 in m)	V_d Value ($cm\,s^{-1}$)	References
SO_2	Short grass (0.1)	0.2 ± 0.1–0.4 ± 0.2	Sorimachi et al. (2003)
	Grass (0.3)	0.6–0.8	Feliciano et al. (2001)
	Heathland	0.8 ± 0.4	Erisman et al. (1993)
	Grassland	1.2 ± 0.3	Erisman et al. (1993)
	Grassland (0.1–0.8)	0.4–0.7	Pio and Feliciano (1996)
	Deciduous forest	0.48 ± 0.45	Zhang et al. (2002)
	Deciduous forest (22)	0.30–1.04	Finkelstein (2001)
NO_2	Heathland	0.10–0.35	Coe and Gallagher (1992)
	Grass (0.15)	0.27 ± 0.017	Watt et al. (2004)
	Wheat	0–0.35	Pilegaard et al. (1998)
	Grassland	0.11–0.24	Hesterberg et al. (1996)
	Orchard (2.1)	0.2–0.6	Walton et al. (1997)
	Coniferous forest	0.4	Rondón et al. (1993)
O_3	Short grass (0.1)	0.2 ± 0.2–0.4 ± 0.3	Sorimachi et al. (2003)
	Grassland (0.22)	0.22–0.36	Stocker et al. (1993)
	Grass (0.1–0.8)	0.1–0.5	Pio et al. (2000)
	Mooreland	0.2–0.7	Fowler et al. (2001)
	Deciduous trees (33)	0.2–1.0	Padro (1996)
	Deciduous forest (22)	0.10–0.75	Finkelstein (2001)
PM_{10}	Grass (0.06)	0.16–0.12 ($d_p = 5$)	Chamberlain (1967)
	Nature grass (0.3–0.5)	0.22 ± 0.06	Wesely et al. (1985)
	Rye grass (0.75–1)	0.16 ± 0.072 (NGMD = 0.52)	Vong et al. (2004)
	Urban grass (0.1–0.25)	0.33–0.38 ($d_p = 0.6$–0.8)	Fowler et al. (2004)
	Urban woods (25)	0.7–1.07 ($d_p = 0.6$–0.8)	
	Deciduous trees (22)	0.1 ($d_p < 2$)	Hicks et al. (1989)
	Beach (24–25)	0.45 (NGMD[a] = 0.02–0.03)	Pryor (2006)
		0.15 (NGMD[a] = 0.06–0.07)	

Most of these studies are related to the replacement of existing roofs with green roofs, and assume a cost to benefit ratio considering other methods of pollution removal. However, if one relates these figures to the possibility of earth-sheltered communities existing with plant cover as the natural medium, where a large proportion of all construction would be relatively invisible, the implications for human health and the health of the planet itself are considerable.

4. CONCLUSIONS

There is a growing body of evidence that the visual and physical contact with the natural world provides a range of benefits to people. These include both mental benefits such as the reduction of stress, and physical benefits including the provision of cleaner air. Access to green space can bring about direct reductions in a person's heart rate and blood-pressure, and can aid general well-being. A Texan study of post-surgery recovery in hospitals demonstrated that recovery was quicker and with less chance of relapse if patients could look out onto green space. A number of American hospitals have subsequently been redesigned to bring these benefits to patients. The negative effects of 21st century life can be reduced in many ways by earth sheltered, green construction. Sound insulation of a 40 cm thick earth wall or roof with vegetation is in the neighborhood of 63 decibels, virtually sound-proofing interior spaces. The increased production of oxygen, reduction of many types of pollution, added to the reduction of energy waste, among many other benefits, are powerful arguments for the cause of earth sheltered construction.

We can envision a world where human presence is once again unobtrusive, and the negative footprint of man on the surface of the planet is reduced. The many arguments for the sustainability of earth sheltered housing cannot be denied, and the Biotekt system will solve many of the impediments to achieving this goal.

Acknowledgements and References

This document contains observations and measurements performed by Biotekt Inc. but is primarily a compendium and summary of the works of respected scientists and professionals in the fields of Biology, Earth Sciences, Architecture and others. The sources we have used are listed here, not necessarily in the order in which they are referred to.

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