# OUTDOOR ELECTRIC LIGHTING AND THE SMALLER DECEPTIVELY INSIGNIFICANT ELEMENTS OF OUR BIOSPHERE

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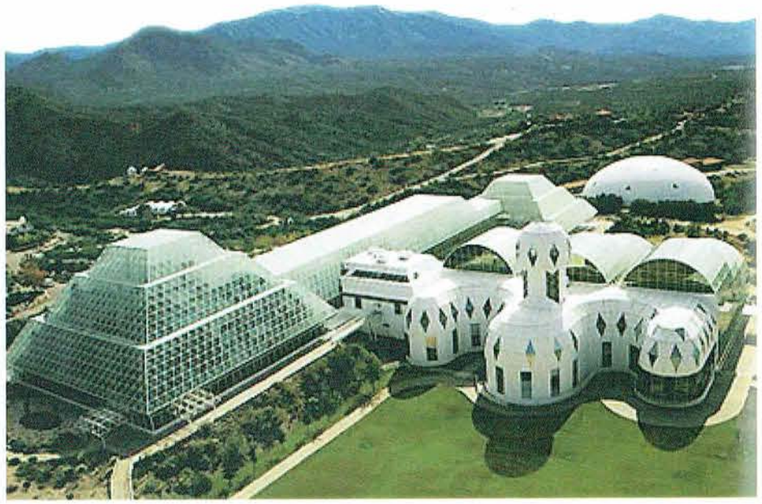

**FIGURE 1**
*Biosphere II (ref 3)*

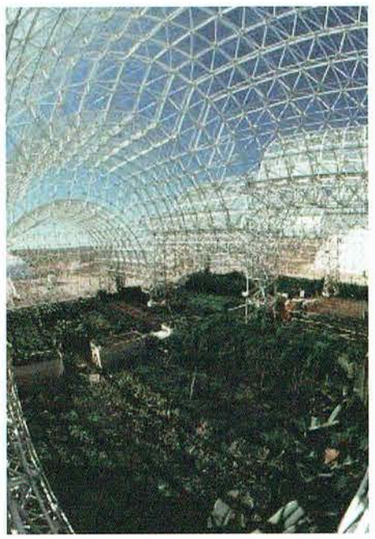

**FIGURE 2**
*Inside agricultural biome (ref 1)*

## Introduction

Holes in the ozone layer, global warming, climate change, violent storms, drought, water restrictions, soil salinity, and population pressure are current news items raising public awareness of our reliance on environmental conditions to sustain human life. Increasing life-style expectations, availability of wealth and expansion of energy distribution networks and the proliferation of lighting are rapidly changing the global night-time environment. Have we reached a situation where the on-going natural changes and adjustments within the environment are unable to accommodate the increasing rate of increase of the detrimental aspects of human activities?

An interesting experiment was constructed in Tucson (USA) in the late 1980's; Biosphere II (Biosphere I being the Earth). This was an attempt to build and live in a completely sealed and self sustaining environment for a protracted period of time. Eight adults were sealed in this biosphere for a period of two years commencing September 26th 1991. Despite the best of research and rigorous training in the preceding years and US$200 million funding the experiment failed in its primary objective of being self-sustaining. Information can be found on the internet (ref 1, 2, 3, 12).

**Briefly, Biosphere II:**

- Was built between 1987 and 1989.
- The man-made design closed-ecological system covered 1.27 hectares consisting of five biomes (that is a section of forest, savannah, desert, ocean and marsh) plus an intensive agriculture biome (farm) and a human habitat area.
- The biosphere system was a sealed system with "lungs" housed in a connected dome structure to accommodate air expansion and contraction with diurnal heating and cooling and alleviate the enormous pressures applied to the biosphere structures.
- 3,800 species of plants and animals were carefully chosen and placed in the biosphere. Some of the savannah plants were from Australia. Soils were enriched with organic nutrients.
- Eight adults entered Biosphere II on 26th Sept 1991 and left the biosphere 26th Sept 1993.
- Oxygen levels started to fall from the moment the environment was sealed and vital oxygen had to be pumped into the biosphere after 18 months. The level of oxygen was very low, equivalent to an altitude over 5,180m making physical effort difficult. Microbes in the over-enriched organic materials in the rainforest and savannah biomes metabolized the material at a much higher rate than expected thus consuming more oxygen and producing more carbon dioxide than expected.
- The $CO_2$ excess from the nutrient material breakdown could have been converted to oxygen by photosynthesis; however, concrete (calcium hydroxide ($Ca(OH)_2$) used in the construction combined with the $CO_2$ forming a layer of calcium carbonate ($CaCO_3$) on the inside face of all of Stray • Was built between 1987 and 1989.
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- Abnormally long periods of overcast weather (much longer than had been anticipated) combined with more solid structural elements than had been anticipated initially produced extra shading; all contributed to less photosynthesis.
- Levels of dinitrogen oxide became dangerously high creating a reduction in synthesis of vitamin B12 with the risk of brain damage.
- The water system became polluted with too many nutrients.
- 19 of the 25 small vertebrate species died out during those two years.

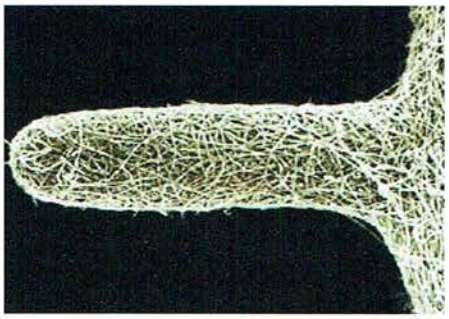

**FIGURE 3**
*Mycorrhyzae – 3 m of hypae per cm of plant root (ie 300 X more effective)*

- Virtually all of the insect species became extinct, including those that had been introduced to pollinate plants. Therefore the plants could no longer self propagate.
- Cockroaches, katydids (crickets etc) and crazy ants (local ants not deliberately introduced but found their own way into this sealed environment) ran rampant.
- Vines such as morning glory threatened to choke every other kind of plant.

A biosphere of supposedly known content (and supposedly known interaction of those contents) lost its atmospheric human habitability, lost the majority of its animal and insect species and hence lost the ability for plants to self propagate in less than two years.

Suzuki and Dressel (ref 14 page 14) quote Edward O Wilson, professor of ecology at Harvard and an expert on biodiversity indicating that while the extinction of Homo Sapiens may well be beneficial to the earth as forests would re-grow, almost extinct species revive and the whole system re-generate; the extinction of creatures such as ants would have major consequences. Without ants, some other species would disappear and parts of ecosystems would collapse as ants help aerate the soil, are predators to other insects and break up and remove 90 percent of any small dead creatures such that they become part of the biogeochemical (nutrient) cycle; that is, the cyclical movement of elements such as oxygen, carbon, nitrogen, sulphur and phosphorous between living organisms and their non-living surroundings (ref 7, page 71). Plants use and process these elements as an important function of our biosphere in providing a continued human friendly environment.

Another experiment in the 1990's; a company announced a break-through in genetic engineering with a common soil bacteria that could convert rotting crop waste into ethanol. Mycorrhysae (ref 5 and Figure 3) is an association of fungi (hypae) on plant roots that keep plants healthy and selectively absorb minerals that plants need to survive. The genetically engineered bacteria, Klebsiella planticula, produced ethanol but also interfered with and killed mycorrhysae, a potentially catastrophic side effect discovered by accident (ref 14, pp 120-121) - no plants ultimately means no oxygen.

The point being emphasized is that it is the small and deceptively insignificant components of an ecosystem that would appear to have the greatest potential to impact the health of our biosphere (ref 13) for human habitation. Is the proliferation of electric lighting contributing to the extinction of species and habitats and consequently an atmosphere not able to support life as we know it?

The first practical application of carbon arc electric lighting in main squares and thoroughfares was in Paris (ref 6, pg 13) 128 years ago (1878). In New South Wales the first small carbon arc public lighting system was ( ref 15) switched on in Tamworth on the 9th of November 1988, followed by an installation in Young in April 1989 and the centre of Sydney 8th July 1904. Electric lighting has proliferated not only as a result of lamp technology advances and manufacturing efficiencies but particularly with the availability of electricity supply and that is more recent. The NASA image titled Earth at Night (ref 4) with Image 4 being a copy of the latest composite image available, October 1, 2006 showing the proliferation of electric lighting around the world. This proliferation has occurred essentially during the last 100 years.

At the 2006 National IESANZ and IDA combined conferences, there was a much greater focus on the importance of environmental awareness and the global impact of electric light. One of the papers presented, listed a reference Ecological Consequences of Artificial Night Lighting. This book, published in 2006, is a useful collection of information from a number of authors around the world. It has six parts covering mammals, birds, reptiles and amphibians, fish, invertebrates and also plants. The recommended use of illuminances in the order of 10-6 lux is very questionable, however, in principle, the book is a useful step forward and acknowledges the lack of detailed information on the subject and that much more research is required to be species-specific and to provide the kind of pragmatic results similar to the research associated with loggerhead, leatherback and green turtle hatchlings. Phrases such as "it would be logical to conclude" throughout the various papers are used when there is no evidence but the authors express an opinion to overcome the gap. Investigation of the detrimental effects of electric lighting on different species is receiving more attention than 20 years ago.

Road lighting is often targeted (ref 9) as a significant contributor to light pollution.

**FIGURE 4**
*NASA Composite Image of the Earth at Night October 1, 2006*

According to Kenny and Fisher (ref 11) road lighting design is about as efficient as it can be without exceeding the maximum threshold increment limit (Ti) and becoming excessively glaring to motorists. The new revised Australian Standard AS/ANZ1158 for road lighting, in particular category V, is restricted to the use of high pressure sodium (HPS) unless in town and city centres or close to retail, commercial or entertainment precincts where metal halide is the alternative for whiter light (not high pressure mercury, HPM) to promote the efficient use of electrical energy. Eisenbeis (ref 8) indicates that use of HPS as a light source reduced the catch rate of insects in field studies by 55 percent compared to HPM although an HPM lamp with a UV filter attracted less insects than an HPS lamp. According to Frank (ref 10) some species of moth fly towards light and others rarely do. The quantity of insects trapped was highest during new moon (dark night period) and warm temperatures compared to either full moon and/or cool night temperatures. Other papers (ref 12) discuss the attraction of spiders, frogs, bats and birds to public lighting, feeding on insects and prey/predator relationships, disruption to circadian rhythms, potential interruption to mating cycles and the potential impact on species as a result of electric light throughout the night period. Whilst Fisher (ref 9) indicates that late night switch out would not benefit "significant traffic" late night and early morning, it is interesting to recall the removal of category V road lighting from Southern Cross Drive (between Kensington and Eastlakes – Sydney) and the exclusion of category V road lighting from the Burnt Bridge Creek Deviation from Seaforth to Manly Vale (Sydney) in the late 1980's which at first was unusual but 20 years later neither have been changed. Is our demand for services throughout the night an unsustainable and an unnecessary expectation? Do country villages and towns have "significant traffic" late night and early morning or could they become dark zones with only strategic intersections lit?

In Europe the option to step switch some HID lamps down to 50 percent late at night has been available for many years. Some recent advances in technology in Australia may provide some further options. Sylvania is marketing some new control gear, "the Active Reactor", made by The Active Reactor Company Pty Ltd that will reduce unnecessary light resulting from the usual provision for lumen depreciation of HID lamps with standard iron-core control gear. In Europe, the option to step switch some HID lamps down to 50 percent late at night has been available for many years. Some recent advances in technology in Australia may provide some further options. Sylvania is marketing some new control gear, "Environ system", made by Ultratech. That will reduce unnecessary light resulting from the usual provision for lumen depreciation of HID lamps with standard iron-core control gear. LED is becoming an option. Advance Lighting are marketing a luminaire developed by RUUD that is applicable to category P lighting and is capable of providing V2 and V3 lighting although no trials have been conducted at this time. At the moment the energy benefits are borderline, however, the rapid developments and improvements in LED technology may well see that benefit become more favourable in the foreseeable future. The claim that white LED emits no ultra-violet light may provide some advantages if it reduces insect attraction. General area, public lighting and local sports lighting could use fixed luminaires with nil direct ULOR (upward light output ratio) and adjustable luminaires have a sufficiently asymmetric intensity distribution that when installed correctly the intended application is lit appropriately but there is nil direct ULOR unless otherwise approved by the local authority for the application. Is the cheapest luminaire on the shortest (cheapest) pole the correct cost for our survival?

There seems to be some doubt that any minor improvements in light pollution control (ref 9) will be sufficient to counteract population growth and resultant urbanization increase complete with associated electric lighting and this may well prove to be true if we continue with the same mind-set.

It is quite clear from experiments such as Biosphere II and Klebsiella planticula that ecosystems are not necessarily comprehensively understood and that considerable research is required to more clearly understand some of the effects of the proliferation of electric light and our life-style expectations on the ecosystems and the health of our biosphere. Considering the estimates on the number of species of life on earth is unclear ranging from 2 to 100 million with an expectation that it might be closer to 10 million (ref 14): also considering that something like only 1.4 million species are currently named, obtaining research and knowing the effect of the proliferation of electric light on each of these known species and also on the yet to be discovered species is unlikely in the near future or perhaps the next 100 years.

If we knew today that in 20 years time we would be unable to breathe easily or that potable water would be scarce as a result of our current actions challenging our environment, would we change what we do today? If it were 5 years instead of 20 would that be sufficient motivation? It took only 1.5 years in Biosphere II. It takes a long time to correct the direction of a large ship. Is it paranoia or is a paradigm shift in expectations and 'duty of care' required by anyone associated with or wanting outdoor lighting as well as by all involved in the process of bringing that need to fruition?


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