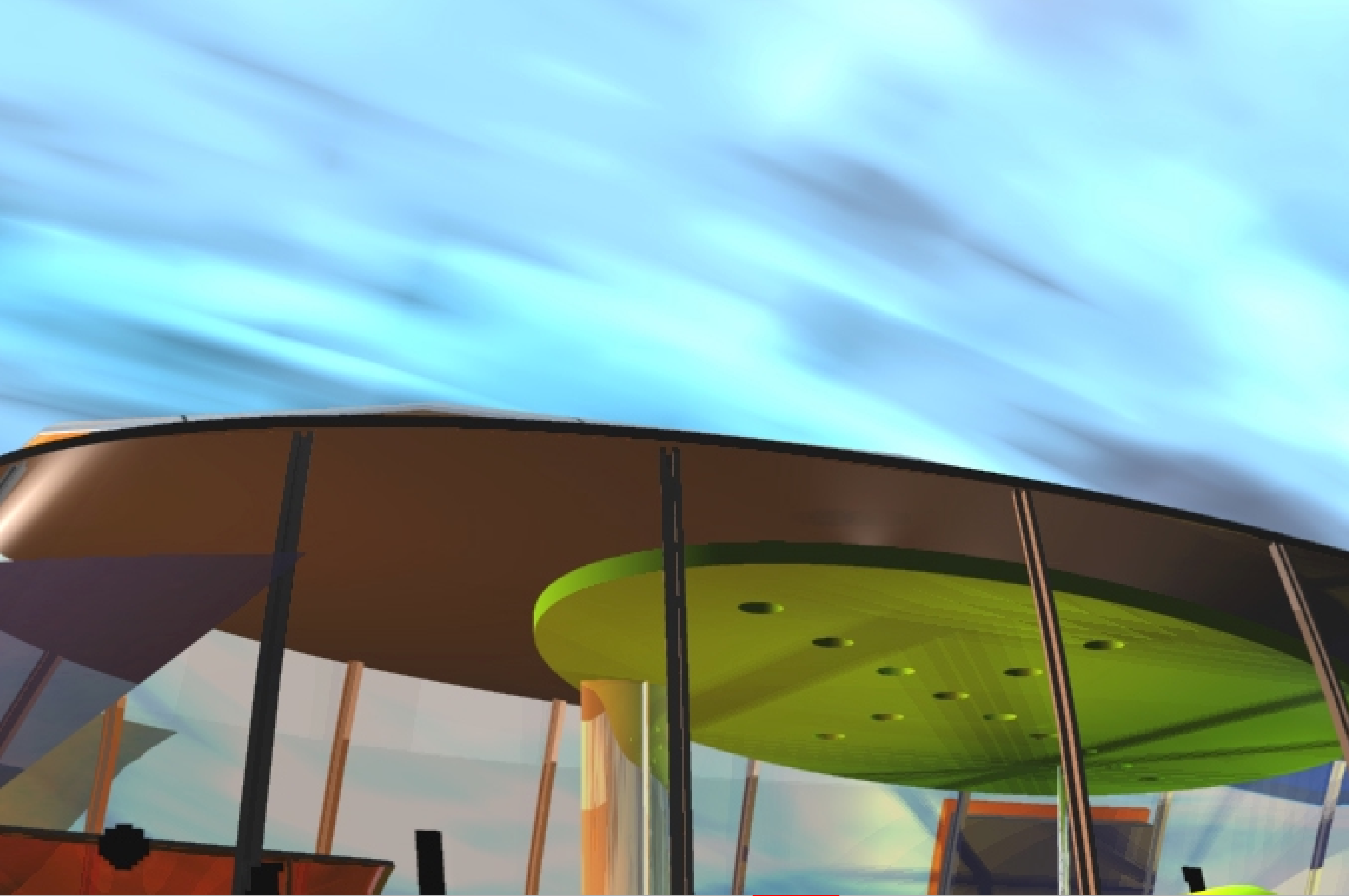



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## All tomorrows buildings

Michael Trudgeon

**audit**

In 1923 Le Corbusier in *Vers une Architecture* exhorted : ‘Industry on the grand scale must occupy itself with building, and establish the elements of the house on a mass-production basis’ In the book *Imagining tomorrow*, Brian Horrigan saw three scenarios [ for the house of tomorrow ]. In one version, architects led or inspired by the European avant-garde would transform the house into a paradigm of modern elegance. In another, engineers or would-be industrialists would clone thousands of cheap dwellings from a single proto-type. In the third scenario, the efforts of both the architect and the engineer would be eclipsed by those of the purveyors of consumer goods and gadgets.’

In engaging technological change most recorded Architectural history deals with image transfer as in the case of Le Corbusier, where there was an image transfer from ships to housing rather than technology transfer as in the case of Buckminster Fuller’s work with the *Dymaxion* houses with their transfer of aviation construction techniques to building.

The chequered evolution of the house of tomorrow and the systems technique of construction has ranged from examples like the inspired *Crystal Palace* by G. J. Paxton in 1851 and Charles Eames’ *Case study house number 9* in 1949 to the cartoonesque 1950’s American *Autorama* style futuristic dream homes, such as George Fredreck Keck’s 1934 *Crystal House* and to the purely pragmatic in Buckminster Fuller’s *Dymaxion* houses

In reality the building Industry is dominated by thousands of small businesses. It is far too fragmented to support the type of research and development carried out by either the transportation or industrial sectors and architects cant realistically charge any one single client for all the research necessary to make great leaps in technological innovation, unlike the architects to the Pharaohs or Bill Gates. The US. government and utilities spend $200 million or 0.1% of the countries annual $200 billion utility bill for building research. The steel and auto industries spend 10 times as much on their respective research. In the USA the result for the auto industry has been that from 1973 to 1987 the average new car’s fuel consumption was halved and pollution controls have seen pollution emissions drop substantially. For the manufacturing sector, since the 1973 oil embargo, the amount of energy required to produce a dollar of US. gross national product has fallen by 28%. Industrial processes account for about 40% of the energy used in the developed world. In building there has been no appreciable improvement in energy consumption in the last 25 years in the face of similar global energy concerns. Meanwhile the world's energy use rose from the equivalent of 8 million barrels a day in 1860 to 123 million barrels by 1985. Skyscrapers already employ many mass production techniques and components in their mechanical and facade systems. Ezio Manzini of the Domus academy sees industrial design as the ‘mother’ of all modern design. Through such a lens the building can potentially be viewed as an all encompassing appliance. In factory based mass production, the manufacturing environment can be carefully controlled allowing for more delicate and demanding industrial processes.

Design Audit

Demands for increased efficiency and performance require investment in research and development which is impossible to meet by scratch built or one-off construction. In the book *The machine that changed the world* James P. Womack and his research team from MIT detail how the vast research budgets necessary to develop and evolve the efficiency of new cars are amortised across large production runs of many interchangeable components to keep consumer costs competitively low.

*Consider this design audit*: 1.7 million hours of research and development time is required from clean sheet of paper to the first customer delivery for a new car. That translates into 212 people working for 4 years [assuming a 40 hour week], or 850 design person years. At $50.00 per hour the cost is 85 million dollars. With an average production run of one million cars, that design cost is amortised across the production run to come in at $85 per car, but each car has the benefit of the full 1.7 million hours of thought. At an average new car price of $20,000, the design input constitutes .4% of the purchase price [at $20,000 and weighing 1700 kilos, a car costs $11.70 dollars a kilo. That is cheaper than steak and it comes with a three year warranty].

The Sydney based industrial design company Design Resource, redesigned the Eveready *Dolphin* flashlight in 1996 for $80,000 dollars. Eveready has sold 10.5 million Dolphin flashlights valued at $189 million. The design fee accounts for 0.04% of the final purchase price.

A 40 storey fully serviced prestige office building down town will cost 110 million dollars. Architectural fees currently are likely to be $2.1%[7]. The full fee schedule including quantity surveying comes to 5.2% or $5,720,000. At $50 per hour that is only 114,400 hours of thought or 57.2 design person years [less than 7% of the time spent on the design of your car]. An architect designed 3 bedroom family home at $400,000 with a full service fee at 11%[8] will have a design input of 880 hours [at $50 per hour] or .4 design years: 22 weeks]. In these circumstances it is ridiculous to talk about *Smart houses*.

**clone**

Mass production has made substantial inroads into the building industry but through the back door. It has come with the skyscraper and with the 'homeburger'. In 1996, the Economist reported that nearly one in three new single-family homes sold in America that year were factory built. That was approximately 340,000 homes. By that year there were 9 million factory built homes in America and 18 million people, 7% of the population lived in them. At factories like that of Schult Homes in Middlebury, Indiana workers fabricate about 17 house units a day.

The typologically standardised house for the working class nuclear family was a theme that appeared as part of all international expositions at the end of the 19th Century. Modernism attempted to develop appropriate technologically perfected systems to build such homes. Almost every significant modernist architect designed a mass producable standard house and car. The idea of conveyor-belt manufacture using standardised components to produce factory made housing was influenced by the efficiency expert Fredrick Taylor and by Henry Ford's conveyer belt based system of mass production. The principles of Taylorism, which Ford used in his mass production of automobiles, were always quoted by architects as points of reference, and a goal to strive for. At the time, in the popular imagination the goods made available from mass production promised liberation from hardship and deprivation. However questions of standardisation and prefabrication became tainted by the stigma of a pragmatism and a functionalism that seemed only serve the building industry. It has never been consciously addressed in mainstream architectural thought. Invariably the spectre of a soulless uniformity and anonymity arises.

Alvar Alto observed in 1938 that the link between architecture and location and the requisite natural flexibility meant that for him mass production had to correspond to an organically flexible system, dependent on natural forces; an elastic standardisation. The development of the computer and it's role in orchestrating flexible mass production lines has initiated this key change.

**hotrod**

The solution to the danger of a numbing uniformity arising from factory based production for building is to concentrate on a system of parts that allows for an infinite number of unique combinations. An excellent example of a traditional modular building technology that achieves this is the brick. For a contemporary system careful scrutiny of the available mechanical and electronic systems is necessary to produce an integrated modular system for a diversity of solutions. Buildings should be seen as flexible systems for enabling change not as rigid and defined structures that inhibit or permanently contain choices. Narrow and traditional definitions for controlling the contributions made by the various technical disciplines greatly restricts the potential for innovation in building. Synthesised solutions integrating technologies and disciplines can produce radical leaps forward. In observing the great diversity of solutions and types that continue to evolve from the car industry, Ross Lovegrove, the English industrial designer believes that the significance of the car in urban living suggests a greater level of shared research into the co- existence of cars, buildings and urban infrastructure is essential, very much in the manner of Le Corbusier; nothing much has changed in 75 years!

**nomad**

In *Architecture and Disjunction* Bernard Tschumi observes that architecture has always been as much about the event that takes place in a space as the space itself. There is no architecture without event, without action, without activities, without functions. In today's world function is no longer fixed. Purpose, program and event change rapidly. There is a contamination of categories, substitution, superimposition and confusion of genres. Railway stations become museums and churches become nightclubs.

A single location can also give rise to many *simultaneous* events. This combination of events and spaces is charged with subversive capabilities, for it challenges both the function and the space. We find it in Tokyo, with its multiple programs scattered throughout the floors of the high-rise buildings: department-store, museum, health-club, railway-station and putting greens on the roof. And we will find it in the programs of the future, where airports are also simultaneously amusement-arcades, athletic-facilities, cinemas and shopping centres. Tschumi notes “Not only is there no simple relation between the building of spaces and the programs within them, but in our contemporary society, programs are by definition unstable. Few can decide what a school or a library should be or how electronic it should be, and perhaps fewer can agree on what a park in the twenty-first century should consist of.”

In our highly nomadic society it is the event that has become the *temporal* anchor. In *Television at the Crossroads* Francesco Morace maintains that within the home all rooms have become living rooms, where distinctions in terms of use are time based, not made by the provision of dedicated space or services. The furniture is now used to define boundaries, to create and distinguish zones in domestic space.

Responding to the pressure for denser urban life styles that are also rapidly changing, a key strategy is to make space more equipotential; i.e. to allow any range of functions in a given space, and ideally different ones at different times. The first step is to integrate all the services. Then a habitable space can be cabled and serviced in a single operation. Services can be ducted in a floor channel or along the inside of the perimeter wall at floor level or at chair rail height. The services may be contained in a single loom that is flexible and does not require joins or corner pieces like traditional plumbing etc. The loom contains sewage out, mains water in, electricity in, telephone and optical in and data through. Such a flexible system engenders longer life for a space without expensive and materially demanding renovation. It thereby indirectly contributes to environmental savings.

By such means the space is essentially characterised by a facility for connection, for change, flexibility and a long life.

**skin**

The Japanese architect Toyo Ito has said that architecture must become a media-suit to interact and mediate the information environment as clothing is an extension of our skin and the automobile is a mechanical suit or extension. Jean Nouvel believes we want a new kind of space, which is at once the most minimal in expression and the most dynamic in potential.

We must come to terms with an extraordinary interchangeability of form and function, the loss of traditional cause and effect relationships as sanctified by modernism. A constantly shifting function can not give rise to a fixed, physical generative form. Within a *physical* framework the response is to express multiple, fragmented and dislocated terrains and to separate the structure and facade or interface.

There has been some history to the evolving schism between the appearance of a building and its structure. “The triumph of the superficial”, as the author Stuart Ewen calls it in *All Consuming Images,* is not a new phenomenon, but architects have yet to understand the consequences of this separation of skin [surface] and structure. Until the nineteenth century, architecture made use of load-bearing walls that held the building up. Although it was common to apply decorations of various styles to these surfaces, the walls performed a key structural function. Often there was a connection between the type of image used and the structure of the wall. By the 1830s the connection between image, structure, and construction method had gone. New construction methods employed an inner structural frame that supported the building. Whether in the form of “balloon frame” structures covered by a skin or of “structural frames” covered by curtain walls, these new building techniques meant that walls no longer played a structural role: they became increasingly ornamental. A multiplicity of styles became possible due to the development of prefabricated panels, ready to be shaped, painted, or printed to reflect any image, any period. With a disembodied skin, the roles of engineer and architect became increasingly separate: the engineer took care of the frame, the architect the skin. Architecture was becoming a matter of appearances. Indeed , if most of architecture has become surface, an applied decoration, superficial, a paper architecture [decorated shed], what distinguishes architecture from other forms of billboard design or more ambitiously what distinguishes architecture from graphics? In fact the debate for the quest for truth in the use of materials in architecture has slipped to the facade alone.

In an attempt to deal with today’s culture of the 'dis-appearance', of unstable images [ the twenty-four-images-per-second images of cinema, video and the computer ], architecture can reveal the transience of these unstable images by the use of such devices as the digital facade, both internally and externally. With the digital facade there is no cause and effect relationship between the building and its use. Electronic facades can be both enclosure and spectacle. Bernard Tschumi argues that there can be no new Bauhaus. We are not dealing with coherent, well defined disciplines but with the disparate multiplicity of performance art, cinema, video and film production. A facade might be a media strip, a flow of projections and people, a city event, no longer a static event, but a momentary and constantly moving one.

Polyvalent or variable state membranes.

In developing such a facade the evolution in electronically controllable chemical coatings for glass makes it the ideal substrate for a polyvalent reactive building surface. Control of privacy, views, lighting and temperature can be achieved via manipulation of a glass skin. Technologies currently exist at either proof of concept or application stage to produce such a building skin. These technologies include: electrochromic, thermochromic, photovoltaic, holographic and angular selectives. They are generally applied to but not restricted to glass, control or react to heat gain, sun shading, glare, heat loss, deep sun penetration or generate electrical energy from the sunlight falling onto the glass. They allow glass to change opacity in all areas of incident radiation including infrared. Such a skin can respond to climatic changes to conserve the building interior's programmed temperature by opening or closing vents or windows to allow hot or cool air in or out, or lightening and darkening the glass surface. This skin can be controlled by a distributed array of small computers. Programmable privacy, views and surface patterns are possible. The building membrane acts as a dynamic mediator between climate and occupant. A combination of coatings applied to different surfaces of the building creates an active living skin that can vary in response to different climatic conditions and also power itself plus attendant systems such as control computers and mechanical ventilators as well as provide energy to the occupants and for other building systems, although the energy generated falls far short of making the building self sufficient. The window array is an interactive surface, an exchange of energy and information. In this way the skin can act as a chameleon like, wrap around TV screen.

Electrochromic

Sustainable Technologies Australia has developed switchable electrochromic glazing for external use that does not require continuous power to maintain its visible state. In the blue state the window transmits sufficient clear light for human comfort and visibility but rejects virtually all hot infrared radiation. In the colourless state it transmits most visible light while rejecting haze heat. Its advantages are having strong sun control in summer with full sun penetration in winter, saving cooling costs in summer and heating costs in winter. This system is double glazed using Tungsten Oxide. Commercial production began this year, 1998 with panels available up to 900mm by 1200mm.

Photovoltaic Glass

Thin film photovoltaic coatings turn windows into power sources. The window becomes a silicon cell able to generate electricity by use of a laser grooved buried grid cut into the outer surface coating. These multi layer thin film amorphous coatings can currently achieve 15% efficiency for electrical generation from incident sunlight. This compares very well with the 17% efficiency of the latest commercial solar panels. The silicon based coating is being developed by Pacific Power and the University of Sydney. The new thin film technology allows for a coating of only 20 microns thick to be applied to a glass surface. The photovoltaic surface consists of 5 layers, each one 4 microns thick. This thin film is a breakthrough in terms of cost for photovoltaic energy generation as it requires much less pure material to make it, greatly reducing the cost of manufacture. Current test samples are only 150mm square. In 2 years one metre by one metre sheets will be available. The cost of the depositing technology is so inexpensive that the key cost will be the glass. Commercial building facade construction cost currently averages out at $1,000 per square meter with an expected life span of 25 years. Photovoltaic facade production costs are already estimated to be down at $1,000 per square meter inclusive of glass and framing. B.P. Solar is also developing a range of thin oxide layer coatings to colour the glass as well.

The real cost of electric power tends to be subjective. The cost of power is currently very cheap, at 10 cents per kilowatt hour from the mains supply. To use it though you must add the infrastructural costs of establishing supply. Wiring it all up. The cost of electrical supply from batteries, like the ones in your transistor radio however is $800 per kilowatt hour. We will pay a lot for convenience. Photovoltaics allow for appliances to be screwed directly into the windows for power without the additional costs of wiring them back into the mains power grid.

**smart**

energy

36% of the moderately populated but energy intensive USA's energy is consumed by buildings. As buildings tend to last 50 to 100 years, energy related building improvements make tremendous economic sense. Such improvements should be viewed as attractive economic investments.

In commercial buildings energy costs typically consume up to 30% of the operating budget. Heating, ventilating and air-conditioning systems [HVAC] combine to constitute 30% to 50% of this. Lighting fixtures account for 30% of the energy used. Lighting also requires additional energy for cooling to compensate for the unwanted heat that it emits. This accounts for between 5% and 10% of the total energy use.

Around 75% or $3 billion of the $4 billion Australian commercial sector energy cost is associated with heating, cooling and lighting. Reductions of 30% made on HVAC and lighting energy use would net savings of $1 billion dollars each year in the commercial sector alone. Together Australian households spend around $5.8 billion each year on energy, with over $1 billion spent on heating and cooling. There are large financial and environmental benefits to be gained from saving energy. As electricity tariff structures change to penalize high energy usage at times of peak load the financial benefits from cutting HVAC and lighting energy will improve further. Energy can be saved by a number of means; reducing unwanted thermal flow or leakage, thermal storage, more efficient HVAC technologies and better energy generation technologies.

thermal storage

Studies reported in Scientific American have shown that exploiting a building's thermal storage capacity can reduce air-conditioning costs in summer from between 30% to 70%, using the building as a heat sink to soak up heat during the day and then cooling it at night ready for the following day. Conversely in winter, good insulation, collection of “free” heat generated by people, lights, office equipment and incoming sunlight and the storing this heat in the walls, floors and ceilings has allowed recently completed Swedish office buildings to become almost self sufficient, not requiring a central heating system.

Thermal storage in building has traditionally been associated with the necessity for great additional mass, often expensive, along with very fixed floor plans. Stone walls or earth mounds, water walls or burying the building, were favoured techniques. Other thermal storage techniques to reduce peak load demands in commercial buildings have included: overnight heating of ceramic rock or crushed stones for heat retrieval during the day by fan forced air, water-to-air heat exchangers used to transfer stored heat in a water tank into the building in winter and ice tanks with water-to-air heat exchangers for use in summer.

eutectic salts

The developmental work on phase-change or eutectic salts as a thermal storage medium is allowing for the possibility of more powerful and compact heat storage systems. Further, a fully integrated system will perform far more effectively than a traditional add-on or retrofit system. To develop a successful system a computer model detailing the cycle, sizes and efficiency of the system is required to show how it copes with various climatic environments and the cost savings of such a system. It is also possible to calculate at what point the system may require external power to drive any supplementary equipment such as heaters or air-conditioners.

heat pumps

Twenty five years ago when OPEC slapped an oil embargo on the United States, and triggered a giant rise in the cost of keeping buildings at a comfortable temperature, research and development into heat pumps for domestic and commercial building use began to accelerate.

A heat pump is a mechanical vapour compression unit and heat exchanger operating in a cycle similar to a domestic refrigerator. It pumps heat from one location, ideally a thermal storage source, to another, usually the habitable space. It's efficiency is dependent on the size of the temperature difference. Using stored heat or cold, or burying one of the heat exchangers in a stable temperature environment like the earth, reduces the difference between the source temperature and the desired end temperature, increasing the efficiency of the heat pump. Heat pump technology has been developing in two principle directions: water tank based systems and ground source systems. These systems can be used to supplement both heating and cooling of the building's interior.

The American Phenix THP/3 heat pump was the first commercially available heat pump for small scale use that stored heat or cold produced during off-peak times in a large insulated water tank for space conditioning later. In the summer cooling mode, Phenix extracts heat from the water tank until ice forms on its heat-exchanger coils. The water can become up to 70% ice.

In winter, heat taken from outside air is put into the tank, which can rise to a temperature of 50˚c. This chilled or heated water is then pumped into the indoor heat exchanger for space conditioning. At the end of each peak period, the micro controller establishes a target temperature or amount of ice in the thermal-storage tank for the next off-peak cycle. The target is based on the 24 hour average outside temperature, maximum outside air temperature and remaining heat or cool storage quantity. If neither cooling nor heating is needed, Phenix will just heat water. To do this the heat pump transfers heat from the air or from water in the thermal storage tank into the hot water tank.

Geothermal heat pumps

Ground source heat pumps are similar to air source units. These appliances move warmth from the soil via buried heat exchanging loops of pipe into a building for heating in winter and do the reverse in summer for cooling. In summer, the refrigerant in the geothermal heat pump evaporates at the ground-loop heat exchanger, transferring building heat to the soil. In winter the process reverses: heat in the soil is picked up by the water antifreeze loop. Inside the building the refrigerant circuit dumps this heat at a condensing coil; a fan blows the heat into the building's air to bring it to the desired temperature. Soil temperatures change more slowly and less extremely than air temperatures. In winter, soil at 7˚c has more readily extractable heat than outdoor air at -4˚c. In summer, soil at 21˚c can accept heat more easily than 35˚c outdoor air.

Until now the devices have been very costly to install, requiring the digging of very long trenches and constructing underground heat exchanger loops comprised of up to 700 meters of plastic pipe. Trenchless boring equipment and coiled ground loop configurations along with recently developed, more efficient components have halved installation costs.

cogenerators

From the middle 1980's in the United States, work progressed in the development of small scale cogeneration systems for heating and air conditioning. Cogenerators produce electricity and, in addition, make use of the inevitable by-product: heat. An internal combustion engine that runs on natural gas or propane is coupled to an alternator to produce electricity. Coolant from the engine is routed through a heat exchanger in the exhaust stack to recover some of that heat, then it goes to a heat exchanger in a tank of water where the heat is released for hot water or space heating. When the home doesn't need all of the heat, the coolant goes to an out door fan coil where the heat is dumped. If the building needs more heat than the coolant can provide, electricity from the cogenerator can power electric heaters in the water tank. The economics of cogeneration look best where natural gas or propane is cheap and the cost of electricity is high.

exothermic paint

Sections of the internal walls can be painted with exothermic paint to create large and very efficient space heaters. Exothermic paint radiates heat when a current is passed through it. It can produce temperatures from 1˚c to 1,000˚c depending on paint thickness, chemical composition and electrode placement and voltage. Electrical connections are made with silver paste or copper mesh tape. Like conventional paint, exothermic paint can be brushed or sprayed on a wide range of surfaces and shapes. It's soluble in organic solvents and dries in 20 minutes at room temperature. Rustol, a Japanese manufacturer claims that the paint can generate equivalent amounts of heat with only one third the power required by conventional resistance heaters.

**virtual**:

Paul Virillio has observed that the essence of design today lies in information. Rather than the designed physical, material form, it is the transmission of form via telecommunications that is most significant. Immediacy and impact are more important than the capacity of an object to last.

Using the language of information technology, architecture can be defined as a control system for our experiences of the world, filtering out the unwelcome and celebrating the desired. Architecture creates an artificial reality. Computer driven virtual reality achieves instant environmental transformation, substituting mass and structure for electronic simulation. Architecture can be seen as a subset of a wider field of artificial reality. The infiltration of electronics into the vocabulary of building brings with it the capacity for connection, not only of all systems within the building but also of the building itself to the surrounding world. Buildings have the potential to metamorphose into dynamic interfaces. This connection might simply be enhanced communication with other people outside the building or it can be interaction with, or a response to, the emission of data from any source or algorithm; building as dynamic topological process, a seismic boundary.

Rem Koolhaus sees architecture splitting, again, as it did in the Gothic period with the separation of painting and sculpture from building, into two streams; a seductive aesthetically adventurous virtual reality and physical, sensible, cost effective minimal and still desirable buildings. This model side-steps the challenge for built architecture to evolve with cultural and technological change

smartwalls

In *Scientific American,* April 1996, Alex Pentland of the Media Laboratory at MIT describes Smart Rooms, computer controlled environments that react 'intelligently' to the occupants, able to identify people, differentiate different facial expressions, capable of speech recognition and able to track and interpret their actions. This research is forming the basis for designing responsive interactive environments. Such environments would integrate a sensory network and the electronic communications mesh along with all the electronic appliances to feed back appropriate responses including the overall presentation of the digital and virtual environment via wall sized TV screens and a sound system. This system is driven by a network of small computers that form part of the environment, integrated into it.

**zone**:

Buckminster Fuller has described a process of technological evolution, *ephemeralization*, where doing more for less can lead to an implosion of functions, one into another, until only a single, fine, multi functional envelope takes the place of the separate cultures of structure, aesthetics and service systems. This notion was the basis of Reyner Banham's 1965 *Un-house*, 'a standard of living package' containing all the necessities of modern life [shelter, food, energy, television] contained within an environment bubble of transparent plastic, inflated by the air conditioning output.

hyperhouse

The project we have been working on is a building system with a dynamic skin that responds to climatic change and the demands of the occupants through an array of sensors connected to a loose network of small control computers. The building can store energy in the form of heat within hollow structural columns acting as thermal batteries. Such a building can be likened to a mammal in its ability to conserve its temperature by controlling the permeability of its outer skin.

The renders show *pavilion 5*, a free standing glass pavilion 7 metres wide, 14 metres long by 3.5 metres high with a hypocycloid rectangular floor plan metamorphosing into an elliptical roof plan. Two 3.5 metre long hollow cruciform polished aluminium columns [ basically oversized yacht masts, containing thermal batteries ] support the composite roof. Aluminium window mullions with integrated external drainage are suspended from the roof edge. The mullions support the glass skin, which has fully adjustable optical and thermal properties. At the South end a television image is being directly displayed from the glass skin. Also a message to the neighbours has been programmed onto the electrochromic layer of the glass skin. This could be animated. An array of small surface mounted computers [ blue biscuits mounted on the glass ], operating in concert via infrared instructions control the glass skin.

glass skin

The glass membrane may be seen as a high performance composite incorporating electronic, holographic and mechanical ventilation systems. The glazing system is modular to include: low profile evacuated, aerogel sandwich [micro porous highly transparent material with insulation properties], gas filled double glazed sandwich panels, active chromogenic glazing including electrochromic coatings [A small voltage makes the coating opaque], and thermochromic coatings [opacity controlled by temperature], passive chromogenic glazing such as photochromic coatings [opacity controlled by incident light] spectrally selective coatings [allowing the optical properties to vary with wavelength], angular dependence coatings and holographic films [allowing the optical properties to vary with the incident angle].

Variable coatings such as the electrochromic coatings work best with ‘daylighting’ or optical sensor controlled, active interior lighting in order to hold the daylight/lighting level at 320 Lux. Only the deficit is made up by the artificial lighting.

Employing Edward Freidkin's model of cellular automata a distributed array of climatically responsive computers control the performance of each window module while sensing the response and activity of the surrounding windows. The skin of the building becomes a cybernetic membrane.

Each window has a 32k Telefunken chip [$1.00] capable of limited scale decision making, based on a simple logic structure programmed into the chip and climatic sensors [for temperature, humidity etc.] and a manual override pad. Further control signals can be sent down the lighting grid. The potential complexity of the resulting behaviour has been demonstrated by the M.I.T. Mobile Robotics Lab employing a programming technique using genetic algorithms. Genetic algorithms or instructions mimic Darwinian principles of natural selection and tend to grow optimal solutions and behaviours based on feedback from previous decisions.

heat pump and arterial heat circuit

A heat pump drives a thermal cycle in the building to collect, dissipate, store and redistribute heat for year round temperature control. Heat is stored chemically within the hollow support structures. The floors and roof act as a ducted circulation system like a 'printed circuit' for heating and cooling. Air ducts are cut into composite floor and roofing material.

The floor sandwich panels consist of an upper skin of wood composite to form the floor surface, a core of light expanded foam and a lower skin to form the ceiling surface for the floor below where required. These stressed skin beams are supported by channelled edge beams spanning the columns. The floor beams are manufactured and cut to size in the factory. The air-duct circuit can be specifically designed for the demands of a particular building. The circuit plan and cutting is a computerised operation, done just prior to the glue lamination of the final upper surface.

The heat pump system is integral to the building structure in the way that blood is to the body thereby absorbing much of it’s cost, structural and space requirements. It is only visible through secondary manifestations such as intake ports on the facade of the building, the fine, tiny computer sensing arrays both inside and outside the building and the forced flow fan mountings. The visceral network of ducts and tubes, the real organisation of the heat pump system is ubiquitous but unseen.

Movable internal walls are coated with exothermic paint to create large space heaters.

integrated service loom

Two ports from the floor mounted integrated service loom [ yellow line in the floor ] are visible. This allows for the easy installation of one arterial service loop from which sewage, clean water, optical, data and telephone links can be accessed, from any point as required, to reduce to a minimum installation costs and permit maximum flexibility of use for the serviced space. Kitchen appliances are plugged into the service loom.

roof, floor and structure

The house is constructed as a discontinuous compression-tension structure. The hollow columns take all the compression loads. The roof structure is a modular composite beam, with a core of recycled plastic acting as insulating material, with the internal upper edge scolloped, to duct heated air from the roof surface so the roof can act as a thermal solar collector. This heat is sent to the thermal batteries. The upper surface of the roof is curved to shed water and matches the moment cross-section required for the span of the beam.

service pod

An externally mounted LPG powered energy and service module acts as a booster for the integral heat pump system and a cheap primary or back up generator for electricity. In placing the main heating, cooling and power assist unit externally, internal floor area is kept clear, services do not consume space within the conditioned environment. Attachment, servicing and upgrading is simplified. It can also act as a battery charger for an electric car. An aerodynamic weatherproof body protects the mechanism. The system is rented as one rents a TV or VCR. It is replaced if it malfunctions.

The service pod arrives on the back of a small truck, equipped with a simple jack to lift it into position. It is mounted onto a shock absorbing base and is located directly over self sealing quick couple connection points similar to those used in the LPG outlets at your local service station and in dialyses machines. These supply natural gas into the pod, electricity out of the pod and hot or cold air to and from the thermal storage system as required. An accessible, easy to detach module is proposed as the most effective way of packaging high technology for quick and unobtrusive repairs, as aircraft designers and airline operators around the world have found out. It is for this reason that domestic airliners have external engine pods.

The service pod contains a 10kw natural gas engine. This drives a refrigeration compressor. The pod contains a falling film evaporator, a thermo compressor and a heat exchanger for the engine. The service pod has its own active noise suppression sound system. This can be used to radiate quiet through out the house.

**Mechanical vapour recompression bathroom module**

The bathroom is a roll in, roll out module [ extrapolated from aircraft toilet modules and designed around a mechanical vapour recompression water recycling unit ] with fold out bath, toilet and hand basin. Shown is a full scale maquette.

This mobile unit uses a flexible dry-break connection system for fast plumbing. All the fittings can be folded away to allow other uses of the bathroom space.

The bathroom systems are concieved to minimise water usage. The profiles of the fittings are designed to reduce water capacity for effective use by up to 50% over traditional fittings. The designs do away with water holding space that is non functional, without sacrificing comfort.

The toilet is a dry toilet, using only 10% of the water required by a traditional toilet. The unit features a non mechanical system to liquefy solid waste for efficient disposal. Sewage plumbing cross sections can thus also be greatly reduced. The toilet pan and shower head retract into the bathroom module and the bath folds up into the shower recess.

Grey water from the shower and hand basin is distilled and purified in a mechanical vapour recompression unit. By boiling water in a vacuum, like boiling a cup of tea on the top of Mount Everest, boiling occurs at a lower temperature due to lower atmospheric pressure, requiring much less energy. MVR technology works by creating a partial vacuum to boil water with less energy. This water, now potable, is stored in a 44 gallon [ 200 litre ] holding tank for reuse in the shower and hand basin and for flushing the toilet.