A Time Journey through Solar Architecture
- 1900 to the Future -

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ABSTRACT

This journey from the beginning of the 20th century to the future examines the evolution of buildings making use of the sun. It begins in the USA and then follows paths in Europe and Asia. The way is marked by milestones in the forms of technological breakthroughs and political changes. Two different courses are tracked: the engineering approach using active solar and technical systems and the architectural approach where the building collects, stores and distributes solar heat. Both approaches impact aesthetics and have led to fascinating design variations from the Californian hippy solar houses of the 1970's to today's prefab, industrial design boxes. Along the journey some ways have proven to be dead-ends, some detours and some expressways. It is interesting to learn from the journey in order to make wise choices now as we proceed.

1. INTRODUCTION

We begin at the opening of the 20th century and end with a vision for tomorrow. The focus is housing and the journey has been divided into epochs defined by technical break-throughs strongly affecting solar architecture.

The trip follows several parallel routes in the USA from California, to the Southwest and then across the continent. As the solar renaissance in the USA faded in the 1980's, excited young architects in Europe took over the initiative and sought ingenious ways to adapt and improve on American ideas for their local context. Now, it appears the explosive growth in using solar is occurring in Asia, specifically China.

The author has been privileged to have directly or indirectly experience 60% of this journey through personal contact with solar pioneers such as Bucky Fuller, George Lof and many researchers of US and European national laboratories.

1. BEGINNING OF THE 20. CENTURY (1900 – 1935)

At the beginning of the 20th century American engineers began to seek practical, commercial applications for solar experiments by physicists in Europe, particularly in France. One of the first applications was the “Climax Solar Water Heater” patented by Clarence M. Kemp from Baltimore (USA). It was a quick commercial success. Previously, preparing a shallow, tepid bath entailed heating water on a stove in every conceivable kitchen container. This new wonder invention simply sat on the roof and effortlessly produced solar heated, gravity fed and free hot water for the Saturday bath. The four 30 litre galvanized steel cylinders in a black felt-paper lined pine box with a glass cover cost a mere $25 (typically a months wage). By 1900 more than 1600 Climax units were sold [Mc Donald & Bills, 2007]. However, houses equipped with these first systems, although solar, could hardly be considered architecture.

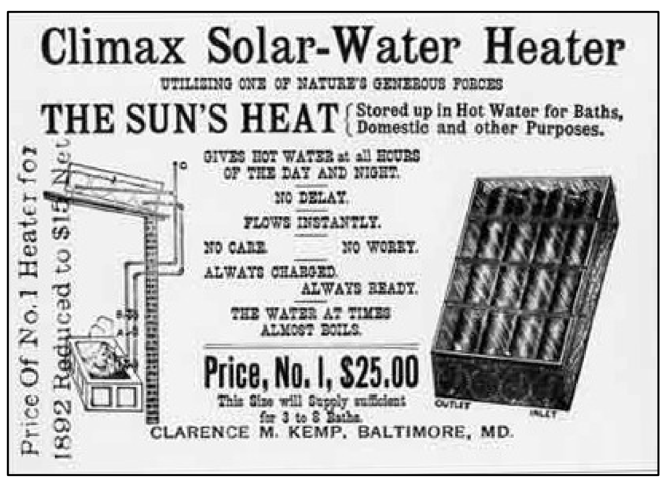

Fig. 1: An old advertisement for Climax Solar Water Heaters (Butti & Perlin 1980 / McDonald & Bills 2007).

A real estate developer, Frank Walker of Pasadena, California reacted to this shortcoming by developing a new variation in which the box was set into the roof, with the glass cover being flush with the roofing. This solution, though also very visible did not interrupt the roof profile and heat losses were greatly reduced compared to the fully exposed Climax system. [Butti & Perlin, 1980]. Further, the system was coupled to a wood stove as backup. The market for solar systems grew rapidly, especially in California, up until the 1920´s, when unfortunately for solar, vast natural gas reserves were discovered. The resulting drastic fall in energy prices doomed the prospering pioneer solar water systems industry. The solar scene moved to Florida. By the 1940´s, half the houses in Miami heated water with the sun [Mc Donald and Bills, 2007].

In this period the passive solar approach took off, thanks to new developments in glass production. Glass could now be economically produced in large sheets. Designers jumped at the opportunity to open their architecture to sun and light. Unfortunately, after sunset, these houses cooled down quickly. A positive heating balance and occupant comfort would have to await the development of better glazing.

2. <u>1935 - 1950</u>

In 1935 the Libbey-Owen-Ford introduced insulating glass, consisting of two sheets of glass with a hermetically sealed air gap. Heat losses were halved and comfort greatly improved. The architect, George Fred Keck from the Illinois (USA) began experimenting with this new product. Over the next seven years he designed and built houses with increasingly large south-facing windows. Massive room interiors stored daytime solar gains to even out temperature drops at night and roof overhangs afforded summer overheating protection. The Howard Sloan House in Chicago (1940) is a good example (Fig. 2).

Passive solar architecture had been reinvented, this time, with insulating glass. Measurements carried out on another Keck house, the Duncan House, demonstrated that, on a sunny day even with ambient temperatures as low as -20 ºC between 08:30 und 18:30, no heating was required to maintain comfort. The house was publicized as a "Solar House" sensation! [Simon, 1947]

Meanwhile, the active solar collector approach continued to fascinate experimental physicists. What if the whole south-facing roof of a house were a solar collector? In 1939 with a grant from a wealthy Bostonian, the Massachusetts Institute of Technology built the first of a series of active "M.I.T. Solar Houses". The south-facing roof incorporated 41 m^2 of "drain back" collectors. At night the collectors drained to prevent freezing. A 66 m^3 water tank under the house stored the summer excess heat production for the winter.

Solar research came to a Stop during the 2nd World War. One exception was in the area of solar air systems. George Lof, with a private grant, built and optimized a pilot house, his own, with a full roof solar air collector (Fig. 3). In a second winter a rock-bed was added to provide storage rather than directly heating rooms with the sun-warmed air.

After the war, the enormous energy infrastructure was available for the civilian energy supply. Energy prices dropped drastically, in contrast to the war years when energy was rationed. As had happened before in the 1930´s the solar industry market diminished to near non-existence. Few home-buyers were ready pay the approximate 10% added cost of a solar house. The market approach taken then was to make such houses good architecture. Several world-renowned designers, such as Louis I. Kahn of Pennsylvania (USA), promoted prototype solar houses. One of his was a direct translation of the Megaron Solar House by Socrates (469-399 B.C.).

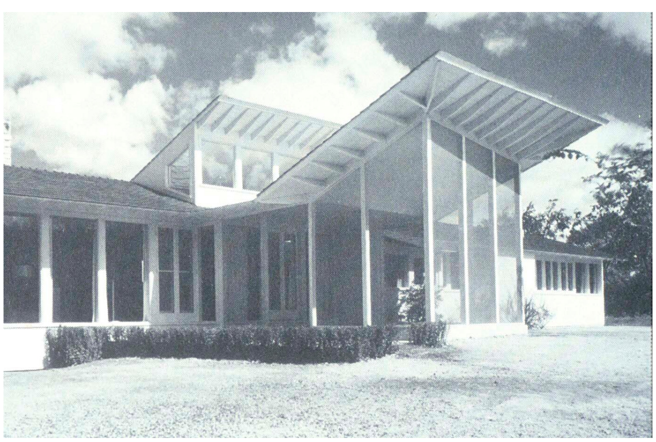

Fig. 2: The Howard Sloan House by architect, G. F. Keck (Photo: Butti & Perlin 1980)

Fig. 3: George Lof Solar Air House, Boulder Colorado ca. 1944 (USA) Photo: G. Lof

3. MIDDLE OF THE 20TH CENTURY

At the beginning of the 1950´s not only had energy supplies expanded enormously, nuclear power was introduced. People began to think that soon energy would be so plentiful it might even be free. With this view solar architecture was no longer a topic. The increasingly centralized energy suppliers with their huge infrastructure investment were driven to increase energy consumption. Another technology development had an equally negative side-effect on solar architecture: the wide-scale introduction of mechanical air conditioning. It was now possible to cool an entire building. The result was climate-insensitive design: glass skinned skyscrapers dependent on enormous electrical consumption for air conditioning - good for the utilities. Architecture reached a low point in insensitivity to the environment and indifference to squandering non-renewable resources.

In Asia, energy prices did not plummet as in North America and the solar heater industry prospered. The simple glass covered box with water tanks of the turn of the century was highly successful as were also simple plastic bag collectors resembling an air mattress but water filled. By 1969 over 4'000'000 solar collectors were installed in Japan. With introduction of super tankers and falling oil prices, the solar industry Japan suffered a setback, just as California earlier.

4. 1970'S - 90'S

1972 was a major milestone in the evolution of solar architecture: the Middle East oil embargo. The solar industry enjoyed a revival and still a further impulse by the second oil shock of 1979. In Japan annual collector sales sprang to 100'000 units finally stabilizing at 250'000 units per year through 1985. Today more than 10'000'000 Japanese homes have solar water heaters. (California, 2007).

North America, an energy glutton by the time of the oil embargo suddenly, realized the impact of oil shortages. Automobile drivers had to wait in long lines to tank their gas guzzlers, if indeed the gas stations did not run out before their turn! Overnight, conserving energy and tapping renewable energy sources had national priority. Collectors test fields and computer models served a once again prospering solar industry in their efforts to optimize performance. Public funding was plentiful for pilot projects, design tools and information dissemination. Top scientists at prestige research institutions formerly dedicated to weapons, i.e. Los Alamos, Oak Ridge and Berkeley National Labs got involved. With the new (at that time impressive) computing power it was possible to test and optimize concepts mathematically before building a prototype. Programs like BLAST, NBSLD, SERIRES, DEROB and TRNSYS were validated against measurements from specially constructed

Fig. 4: A test house with 8 test rooms at the US Nat. Bureau of Standards (1978) Architect: R. Hastings

test cabins, mostly looking like chicken coops, though there were some exceptions (fig. 4).

The passive use of solar energy by means of the building to collect, store and distribute heat had a large appeal because of its simplicity and the desire to let the light into a house. Three approaches were defined:

- Direct gain: Sunlight admitted by windows directly heats a room and its mass, providing residual warmth also for evenings. Large temperature swings had to be accepted.

- Indirect gain: Solar heat trapped in the mass of walls or roofs radiates a few hours later into the building. Two classic solutions were the Trombe-Michell mass wall

Fig. 5: Balcomb Solar House in Sante Fee NM, USA

and the Herald Hays water bag roof. Heat was trapped in the mass wall by a glass façade, in the water bags by sliding insulation panels. In summer the water bags were exposed and cooled by radiation to the night sky, then covered during the day to preserve the "cool".

- Isolated gain: Solar heat, captured outside the insulated building envelope is routed to storage and then, on demand, supplied to rooms. Solar air collectors are an example, as also are sunspaces. Attempts were made to optimize sunspaces as collectors, but these spaces are too valuable (and expensive) to compromise comfort for maximizing their heating contribution.

Solar houses made their first major reappearance since the 2nd World War in the sunny south west of the USA with a Spanish accent. As it spread to other regions of the country it adapted to the local architecture, looking Colonial in the North-East, California Modern on the west coast, but most importantly, it adapted to the regional climate situations.

In 1980 a new President slashed research and demonstration budgets and the solar lead moved to Europe. Architects back from solar pilgrimages to the USA began building their ideas. As happened in the U.S., they had to learn what worked in their specific climate and building culture.

Two paths were followed: the passive solar design approach and the high-tech approach, reminiscent of the M.I.T. Solar House series. The solar air systems promoted by George Loef during the 1940´s enjoyed a renaissance in middle Europe (fig. 6). At the other extreme, the Fraunhofer ISE built their "Zero-Energy House" (same name as an earlier generation house of the DTU in Lyngby, DK). It had high efficiency solar collectors, PV panels, energy storage in the form of hydrogen and transparent insulation walls.

5. END OF THE 20TH CENTURY

In Europe dying forests made the environment an important issue. Conservation taken to an extreme became popular. . Innovative, but too expensive solar solutions were discontinued. One very successful approach was the "Passivhaus" (fig. 7). The idea was to reduce losses and recover heat to such an extent that even on the coldest days ventilation air could transport the needed heat. Mechanical ventilation was essential to assure good air quality, but it also made no sense to build a super insulated, leaky house. Using the ventilation system to also transport heat was also economical. Important components had to be developed, however, including an efficient ventilation heat recovery system and highly insulating window glazing and frames. A compact form minimized the exterior heat-losing surface and was well suited to the contemporary "box" architecture.

Solar water heating is appealing, because all mechanical systems can be shut down in summer. Further, solar collectors can produce about 20 kWh of heat per kWh electricity for pumps and controllers; compared to at best a factor 4 for a heat pump. Some home owners increase the collector area and storage volume to provide both water and space heating. Such "combi-systems" are popular in Austria.

Whole housing developments demonstrate the commitment to such very low energy design. An example is the state program: "50 Solar Settlements of North Rhein-Westfalen (NRWF) (fig. 8).

Very pronounced in the building landscape all across Germany are roofs integrated photovoltaic panels. This is a direct response to generous buy-back laws for owners to sell electricity to the utilities. Solar use is very visible in the German built environment, even in rural farming areas.

Fig. 6: A solar air collector house
Architect: Sture Larsen (AT)

Fig. 7: The first Passivhaus built by the originator, Wolfgang Feist, Darmstadt DE

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Fig. 8: Gelsenkirchen, one of the 50 solar settlements of the NRWF

Today our present is the future we envisioned a few decades back. The solar industry is prospering. Total installed glazed and vacuum collector capacity is lead by China (>53 MW_{th}) followed by Europe (12 MW_{th}), Japan (5 MW_{th}) and North America (<2 MW_{th}) [Weis, 2007]. Also, very low-energy building is "in". There is a naming competition for design approaches, i.e.: "Minergie-P", "Klima-Aktiv" "CO2-Netural" etc. But several technologies have fallen into semi-dormancy again.

- Michel-Trombewalls, revived with the introduction of transparent insulation, have again faded into a niche market. The essential solar overheat protection makes the system too expensive.
- Solar air systems serve a niche market, i.e. keeping vacation homes dry during vacancy. Systems with rock beds are too voluminous, costly and complex and have disappeared.
- Housing developments with collectors networked to enormous central seasonal storage tanks are now in operation and under evaluation. The trend to very low energy buildings result in the network distribution heat losses being disproportionately large.

With the attention now on renovating buildings, solar technologies can be a good alternative for reducing fossil fuel consumption, where conservation options are limited. A revival of some dormant solar technologies in a new form and using new materials could occur.

7. A VIEW TO THE FUTURE

From this time journey we can observe that simple solutions tend to survive, though the underlying technologies may be highly sophisticated. Just as automobile form has been aerodynamically optimized to cut fuel consuming drag; building form has been compacted to minimize heat losing surface area. Both show a trend to sameness. Efforts to romanticize components, such as the PV "shingles", represent short detours in defining a new solar architecture.

The superior performance offered by new technologies, i.e. super windows, vacuum insulation and home automation offer more tolerance for suboptimal solutions while still being able to achieve very low energy consumption

Hopefully, clients will again demand a personalized, architecture as in past centuries. The result can be individual buildings and whole neighbourhoods which have a sense of place, personality and relate to the local climate.

This built environment must be adapted to the realities of:

- gradual and turbulent decreases in fossil fuel supplies and escalation of prices;
- less mobility making living quality at home more important, as jet-vacations become too expensive;
- more factory prefabrication of building assemblies;
- wide introduction of home-automation systems;
- aging populations demanding better comfort;
- increased recycling of materials and components as raw materials and transport become more costly;
- climate change, making summer comfort more important (no more glass architecture); and
- the need to adapt existing buildings to these realities.

The journey continues!

9. REFERENCES

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