

ENERGY CONSUMPTION PARADOX (1929 AND 2002)

Designing building enclosure, one must address many different aspects of performance such as energy efficiency, durability, buildability, health and comfort of occupants, fire safety, acoustics and affordability. In this review we take energy efficiency under the magnifying glass.

The definition of the conundrum

Average energy use in large residential buildings in North America 1990 was 315 kWh /m². Since 1990 energy use in those buildings steadily declined, reaching 250 kWh /m² in 2002. Note, however, that this was equivalent to the energy use in 1920's. So, a masonry building without any insulation built 80 years ago consumed as much energy as a shiny, glass-clad building constructed today! This of course says nothing about the increased functions that modern buildings are fulfilling compared with 1920s. So our energy conundrum is why we do not use less energy than used in the 1920's and why have we from 1950 to 2000 increased emissions attributable to buildings by 300 percent.

Yet, we, as the society, have originally agreed that by year 2020 (or 2030, now 2050) we will come back to the carbon neutral new construction, last seen on this continent in the mid 19th century. To see how this can be accomplished we need to review the changes in building construction that took place over the last 60 years.

Buildings in 1920

The construction of a masonry building took a long time. As the load bearing function required thick masonry walls on lower floors that became and much lighter at the top floors, such a building had a huge thermal capacity. The floors contained steel beams and masonry blocks. The walls were airtight because of exterior and interior lime-based plasters (stucco). Lime develops strength slowly, allowing on settlement and movements of the walls. Excellent, heavy, and typically oil painted wood of double windows were integrated with the masonry walls. Windows area was small. From building physics point of view the building was airtight, massive and well integrated. Because of its inefficient and periodic heating sources, the indoor temperature varied between periods of comfort and discomfort.

Improvements of heat, air and moisture controls in the cold climates

A number of significant developments took place in decade of 1930's. Use of building paper weather barriers, as distinct from roofing materials, became standard. The building paper was placed on the external side of the wall sheathing, impeding the movement of air and rain while permitting some moisture to permeate to the outdoors. To improve thermal comfort, wall cavities were filled with insulation -- first using wood chips stabilized with lime, then shredded newsprint and eventually mineral fiber and fiberglass batts. Yet, the presence of thermal insulation in the wall cavity lowered the temperature on the outer side of the cavity, leading to condensation of moisture that, in turn, was detrimental to the durability of the wall.

Vapor barriers were introduced to reduce ingress of vapor coming from the warmer indoor environment and retardation by a wood plank was set as a practical value of resistance to vapor flow was introduced and named 1 perm (57 ng/m² s Pa).

After 1945 wood boards were replaced first by the plywood sheathing, later by wafer board and subsequently by Oriented Strand Board (OSB). Use of paper faced gypsum panels for the interior finishes emerged during this period, driven by the need to reduce construction time. Use of polyethylene vapor retarders continued this trend disallowing wall drying towards the interior. Moisture tolerance of modern walls declined. The new, more susceptible to moisture materials, still performed adequately if drying capability to the outside was sufficient.

More recent increase in levels of thermal insulation and requirements for air barriers to eliminate air leakage through the building enclosure, however, reduced the outward drying capability of walls so much so that deficiencies, such as leaks at windows or cladding penetrations, may now more easily result in moisture-originated damage.

In summary, the following major changes in wall design have taken place over the last 70 years.

- 1) Increased levels of thermal insulation
- 2) Increased level of water vapor resistance
- 3) Increased air tightness of the walls
- 4) Reduced moisture buffer capability
- 5) Introduction of more moisture sensitive materials

Each and all of these can dramatically reduce the moisture tolerance of residential walls.

Before the 1970's our society was not concerned with cost of energy. Excessive air leakage and associated heat losses were more of an inconvenience than a serious problem. Introduction of energy conservation as a means of reducing the impact of oil imports, first started in the 1970's and then accelerated in the last decade caused the requirement of mechanical ventilation in to be introduced to Canadian Building Code.

As we introduced high efficiency heating devices that eliminated the need for chimneys we introduced a new concern – the need for air circulation within the house. Now, interaction of the building enclosure with the heating, ventilation, and air circulation systems in the occupied space has become part of the builder's design framework and the phrase such as "building as the system" describes it best.

As for the large buildings, building physics tells us each floor must be separated from the others so the problems of small and large buildings are alike.

Is there a common denominator in the improvements discussed above?

From building physics point view the first common key-word for those improvements is **fragmentation**. Each of the changes, while positive in itself, produced unpredicted effects. E.g. elimination of wood strapping under exterior plaster and replacing lime with cement increased cracking and affected moisture management strategy; elimination of interior plaster or introduction of simplified methods of window mounting, both dramatically increases air leakage of the walls etc.

Increased comfort of indoor environment caused dramatic increase of the energy use; so the second key-word is **trade-off between energy use and occupant comfort**

To alleviate the problem we need to go back the integrated building systems and examine the means of retaining the comfort while reducing consumption of energy. While the American media talk glibly about using more of the renewable energy, they do not realize that renewable energy is like icing on the cake. You cannot talk about icing before you have the cake.

Renewable energy sources still represent a drop in the bucket in comparison **to the gross energy inefficiency** of today's buildings.

The need for air pressure control in buildings

As long as buildings were leaky and poorly insulated, the effect of HVAC systems on air pressure and on the durability of the enclosure was not significant. There was no need to understand air movements in the building other than providing a necessary supply of fresh air. That is not the situation today. Now we require well-insulated, airtight buildings in which potential health problems (mold/ microbial contamination) are minimized.

Today, understanding air movements in a building is a necessity. The determination of air pressure differences, however small and difficult to measure, is needed to establish the performance of the building as a system. This is probably one of the key reasons for a fundamental revision to many assumptions that have developed over the years. Air transport control is now recognized as the most critical issue in design of building enclosures. While the need for air tightness is now well recognized, achieving it in practice is still a challenge.

Air barrier systems are needed for the proper performance of building enclosures in all climates. Ensuring continuity of the air barrier plane over 100% of the surface is required. Air barrier continuity must be checked both during the design and during the construction.

Evaluation of systems not materials

It is important to place emphasis on performance of the built assemblies instead of materials. Dealing with materials is easier. Building codes and standards always ascribe a specific function to a specific material because this is the only way that a prescriptive code can work. We have water vapor retarder, air barrier, thermal barrier (fire protection), rain-screen etc, and functions are mentally coupled with materials. But some materials may have different functions, e.g. closed-cell polyurethane foam, can be insulation, rain-screen, water vapor retarder or air barrier.

The outcome of an architectural design is modified by interactions between different materials and the trades involved in installing them in an assembly. Architectural design and construction processes are holistic and involve highly specialized people – how should they collaborate during this process? This aspect of design is so important that we stress the importance on mock-up evaluation and continuous commissioning as the separate activities in the construction process. This is to ensure that the design concept is buildable and that all the trades learn what they must do to satisfy the building objectives.

Finally, we have established that the future belongs to green buildings. What are the considerations that make the complex called the “green value” of a building? Well, this topic deserves a separate essay.