Optimal Building—how far can energy optimization be pushed

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SINCE 1973 an extensive research and development program has been pursued in Sweden in the field of energy production and energy saving. Even the usually inert building sector has been strongly influenced. Energy considerations attained a completely new import, and the result was a rapidly expanding flow of products.

At first the flood was of single products, most being touted as ultimate solutions for all current and future energy problems. But then products began to get integrated into "energy systems," with even higher pretensions.

With time, the situation has improved a little. But not long ago, anyone visiting a technical fair or building exhibition could see that the market in energy products was greatly plagued by both confusion and fortune hunting.

Often the products offered were of dubious design or benefit, but sometimes there also appeared energy concepts which could be classified as "over-optimized." Many fine components had gone into the baking of a splendid technological cake; but the result was too specialized, too redundant, and too expensive to have reasonable application for a normal residential Scandinavian house. Such systems were the result of 1) smart marketing, 2) poor system analysis, and 3) sheer panic at the prospect of an imminent energy catastrophe.

But for residential application, the perspective must be one of economics; that is, one which takes into account building expenses, projected life span of the structure, and future working costs of the energy system.

Prof. Bjorn Karlsson, at the Institute of Technology at Linkoping's University in Sweden, is one of the world's leading experts in this field. His research, very promising at both theoretical and practical levels, is a guide to radically diminished energy consumption in the future.

The professor insists on the importance of sizing efficiency. With an arrogance born of expertise he declares that the use of heat pumps as energy saving systems in small houses ought to end absolutely, although he then notes a possible exception in the case of old houses which are difficult to renovate and which involve very high heat expenditure.

His argument is that a typical Scandinavian climate with sudden and very steep temperature declines postulates a disproportionately large sizing efficiency. Using a heat pump as the only source of heat means that it has to be dimensioned for the peak load periods. This involves very high costs in the investment phase. (A heating system that exploits natural solar heat from a lake, from subsoil water, or from surface earth, requires extensive and expensive installations.) But in general circumstances the use of the heat pump's large capacity will be quite low. While the heat factor of the pump may seem impressive, and the gains during full operation of the pump will be large the use of the pump will probably violate economic efficiency. This is especially true in the case of a modern, comparatively well-insulated and energy-efficient dwelling.

A technologist by training, Karlsson seems in spirit an economist. Not only is he skeptical about the use of the heat pump as a heat source, but he considers it lunacy when the heat pump is furthermore combined with extra installations, such as sensors and traducers that direct the heat flow. These systems may be justifiable in special buildings with extreme claims upon micro-climate and security, but are not economically sound for normal domestic houses.

This energy-economical orientation can perhaps be traced to the time when Karlsson was a member of ELAK (Committee for the Application of Electricity). His task was to develop arguments for the total prohibition of the use of electric power for the heating of living quarters. But the findings of the investigations were that direct electric resistance heating turned out to be the most viable, economical (long-term), and, from a national perspective, reasonable method—provided important basic criteria were met.

Out of this work came the idea of the Optimal Energy House (OEC). The model aims at a system of optimization with a high degree of general applicability.

In very simple terms the basis of Karlsson's building ideas is: inverted proportionality between the building costs and the investment in the heating system. If it is to be economically reasonable, a structure should be designed so that a high initial investment expenditure will be offset by low operating costs.

This idea can of course be converted into an equation. Uncertain variables, such as future energy expenses, can be included in the form of maximum/minimum parameters. The purchaser can then get a solid idea of what it will all cost.

Karlsson is primarily a building engineer, and his starting point is the envelope of the house. This, he contends, is what will finally determine the total economy of the construction. In the optimal energy house, the body will be the important investment against which the remaining expenses will have to be weighed. Also, the envelope will be the most constant part of the building, while other installations will probably have to be renewed, improved, or replaced.

Consequently, Karlsson believes that, in the beginning, insulation is the key. Its thickness and quality will determine the k-value of the envelope. Karlsson has some strong criticism for current building technology and practice in this area.

Karlsson himself has been accused of over-insulating his houses, but his response is powerful: new constructions have a quality related to an energy price of 8–9 cents/kwh. The price of oil/electricity is at least three times as high. Why do we not then calculate the real level of costs when we build houses today?

According to Karlsson, the insulation should consist of 24–30 cm mineral wool,* which should provide a basic k-value of 0.16 $w/m^2 K$. Rockwool, a company that has taken part in this development work, offers an "insulation beam" that has almost double the heat resistance of a normal wooden beam, so that the cold bridges of the wall are considerably diminished.

Because hot air rises, the roof should be given an extra thick layer of insulating material; Karlsson recommends up to 50 cm of mineral wool.

In terms of insulation, windows have always been considered a problem, but it must be remembered that heat leaks both ways through windows, so that traditional k-values may be misleading. "Equipment" or "efficient" k-value is a new measurement, according to which the heat losses of a modern, energy-efficient window are

*Calculation correlated to the relatively rough climate of middle Sweden.

extremely low, and in some cases become negative (more heat passes in than leaks out). It is in fact possible to install windows with better k-value than the facade. Unless the glass area is very large relative to the area of the facade, this is a good example of over-optimization. The ideal is equivalent effective k-values for both facade and window.

In the OEH, the window is of triple or quadruple Kappa glass with argon-filled panes. The glass is sophisticated and expensive, but permits the achievement of the ideal equilibrium between the thermal transmission properties of the walls and those of the windows.

An OEH will not only be very well insulated but will be relatively air tight. Traditionally, air tightness has been thought to lead to entrapment of moisture, but today excess moisture in the house can be viewed as a ventilation problem as opposed to a structural one.

In the OEH the majority of the heating requirement should be met by solar heat radiation, indoor human activities, lighting, and heat from the use of household utensils. The heat will be recycled again and again, and the almost negligible need for additional heat is met by a 4-kw electric cartridge.

Karlsson recommends an air-conditioning/heating system designed by Huskvarna. The system is based on the managing of heat and ventilation in one unit, and it's extremely simple. Used warm air is ventilated away by means of a small fan (0.5 air changes/h), and the heat is recovered by a heat exchanger connected to the system. The heating cartridge is built into the heat exchanger.

What are the expenses for a house built according to the above rules? A one-family house with a total living area of 120 m^2 will cost about 5 percent less to build than an equivalent building based on the SBN 80 (Swedish Building Standard—1980). The lower building cost is primarily the result of the radically simplified heating system.

And what about operating expenses? Expected annual heating costs is about 250 Sw crowns (about $30 American), based on energy prices of mid-1985. It is therefore not surprising that Karlsson no longer feels that electric heating should be forbidden.

The Swedish market for small houses is currently somewhat limited, but there is a considerable need, particularly in the southernmost part of Sweden, for renovation. There are now plans to bring some of Karlsson's building ideas to this application. The town furthest along in its plans is Malmo.

Renovation poses its own set of problems, and Karlsson's concepts will naturally have to be modified. His OEH called for an extremely light building shell, but the blocks of flats to which his ideas will be applied are of bricks and concrete. The emphasis, however, will be the same: what is the heat transmission of the existing structure, and how much insulation should be added to achieve an ideal result?

Where an OEH is practically air tight, making a tall block of flats air tight may not be wise. There is a serious risk of "chimney effects," *i.e.* rapid upward movements of accumulating heat. Therefore, thick insulation of the roof may not be warranted, while a more energy-demanding system for the transportation of heated air may be. This implies that a considerably more sophisticated solution may be needed than that of the simple air heating of the one-family house.

As for windows, the Kappa glass of the OEH has the disadvantage of markedly muffling entering light. In the case of existing structures, the decrease in light cannot be easily or cheaply mitigated by increasing window area. In comfort or expense, some compromise will have to be struck.

The OEH has an exciting potential. Because the building sector in Sweden is currently inert, a great part of the potential looks to be in its exportability. On the international market there is a great interest in Swedish small house quality, and it seems as though, for example, West Germany and the USA may become profitable markets for Karlsson's ideas. This will be doubly true if application of the ideas to renovation can be mastered.

But from a more domestic viewpoint, Karlsson's ideas point the way to the potential solution of Sweden's energy problems. Today every Swede stands before the political decision to eliminate the use of nuclear power. The Government bill presented in January 1985 sticks firmly to the line once established by the plebiscite: no nuclear power after the year 2010.

In the use of electric power for heat, large savings can be achieved in the future. The model developed at the Institute of Technology in Linkoping could become the guiding principle for a long-term project to radically reduce total energy consumption for heating purposes. By this means valuable electric power could be transferred from house heating to industrial use, and the need for electro-specific energy could thus be satisfied.

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Methane Gas Recovery*

IN ONE important respect, wastewater treatment plants can become producers of an alternative energy source. This through the generation of methane, a flammable gas which is a by-product of the decomposition of the bacteria in sewage sludge.

"Sludge" is the term used by sanitary engineers to describe the semisolid residue which is separated from wastewater as a result of the treatment stages. The decomposition of sludge into an inert and harmless dry mass has always been a very important part of wastewater treatment engineering. The production of methane gas is therefore not a new phenomenon. However, only in recent years has it become worthwhile to try to optimize the gas production process, and to try to find good ways to put this valuable energy resource to work.

The results can be impressive. For example, in 1981, the Milwaukee Metropolitan Sewerage District reported a saving of over one million dollars as a result of methane gas recovery at the City's 120 mgd South Shore Wastewater Treatment Plant. Methane gas in the Milwaukee facility is used to operate aeration blowers, generate electricity, preheat sludge, and heat buildings. Milwaukee's impressive results represent a five-year effort to maximize methane gas production and use.

Recovery of methane gas is also cost-effective in small wastewater treatment plants. For example, the 2.4 mgd wastewater treatment plant in Big Rapids, Michigan saves approximately $1,800 annually by preheating sludge with digester gas rather than using natural gas.

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