A market overview of erected low-energy buildings in Sweden

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Introduction

The recently revised directive on the energy performance of buildings (2010/31/EU) contains requirements that all new-build public buildings must meet the requirements for *"near zero-energy buildings"* by 1st January 2019, and that the same will apply to all buildings with effect from 1st January 2021. The definition of exactly what *"near zero-energy buildings"* means is left to each member state to decide for its buildings. If this performance is to be achieved, it will require a number of support measures and a tightening up of regulations relating to new building work and renovation work. Developing a strategy for near zero-energy buildings and deciding which and where resources should be set in requires updated information on the present market status of low-energy buildings.

The LÅGAN programme *(name derived from the Swedish for buildings with very low energy use)* is one of the national initiatives that assist improvement of energy use in buildings. Its objective is to increase the rate of construction of low-energy buildings. Two market surveys of low-energy buildings in Sweden have been performed as part of the work of LÅGAN. The first is a web-based market overview (www.laganbygg.se), for which detailed data on about 50 buildings has been collected and quality-assessed. The second survey, described in this article, aims to provide an overview of various categories of low-energy buildings that have been built in Sweden, and does not go into details of the technologies used or similar aspects. It has been performed partly in the form of a search of the literature and partly by direct contact with persons involved in the sector, in the form of an e-mail enquiry to which over 70 persons in the sector responded. The information that they gave in respect of energy performance, costs, energy classifications etc. has been used without further checking, which means that the results from this investigation must therefore be regarded only as an overview.

The overview contains information on erected buildings having an energy use that is at least 25% less than the requirements in the applicable building regulations. It does not include information on buildings that are at the design stage.

The Swedish building regulations

The most recent edition of the building regulations published by the National Board of Housing, Building and Planning dates from 2006. It sets out the requirements for energy performance of buildings. Further restrictions for electrically heated buildings were published in 2009. The requirements specify not only maximum permitted energy use per square meter, but also the permitted installed electric power for heating, and a mean coefficient of thermal transmittance of the building envelope. In addition, the new building code specifies that energy performance must be verified by measurements within 24 months of completion of the building.

The requirements are described in terms of specific energy use (kWh/m² A_{temp}), and are shown in **Table 1**. A_{temp}, the temperature area, is defined as the area bounded by the inside of the building envelope, on all floors, that is supposed to be heated to more than 10°C.

The building's energy use is defined as the energy that needs to be delivered to the building *(often called "purchased energy")*, in normal use and during a normal year, for heating, comfort cooling, domestic hot water, and electricity for operation of the building's services systems. This means that the delivered electricity for buildings heated with heat pumps is included while the heat from ground sources are not. Electricity for domestic purposes or business activities is not included.

Construction of low-energy residential buildings beats all records

The market for low-energy buildings initially grew only very slowly, but has begun to take off in recent years. In total, over 100 detached houses and over 3200 apartments (in 72 apartment buildings) have been built as low-energy buildings. Over 60% of them have been built in the

Table 1. Requirements for specific energy use in the national building code (kWh/m² A_{temp}).

Type of building	Climate zone		
	I (north Sweden)	II (middle Sweden)	III (south Sweden)
Residential buildings with heating systems other than electric heating	150	130	110
Residential buildings with electric heating	95	75	55
Commercial and similar premises with heating systems other than electric heating	140 + 110 · (*q*–0,35)	120 + 95 · (*q*–0,35)	100 + 70 · (*q*–0,35)
Commercial and similar premises with electric heating	95 + 65 · (*q* – 0,35)	75 + 55 · (*q*–0,35)	55 + 45 · (*q*–0,35)

q is the average specific outdoor air ventilation flow rate during the heating season (l/(s,m²) and is an addition that must be included when the outdoor air flow exceeds 0.35 l/(s,m²) in order to maintain required hygienic air quality in temperature-controlled areas. Its maximum permissible value is 1.00 l/(s, m²).

last two years (**Figure 1**). Most of them have been built in Climate Zone 3, distributed as follows: western Sweden 54%, Småland 18%, Greater Stockholm 11%, and southern Sweden 9%.

Numbers beat all records in 2010, when the proportion of low-energy apartments accounted for 11.2% of total apartment new-build numbers, and the proportion of detached houses amounted to about 1%.

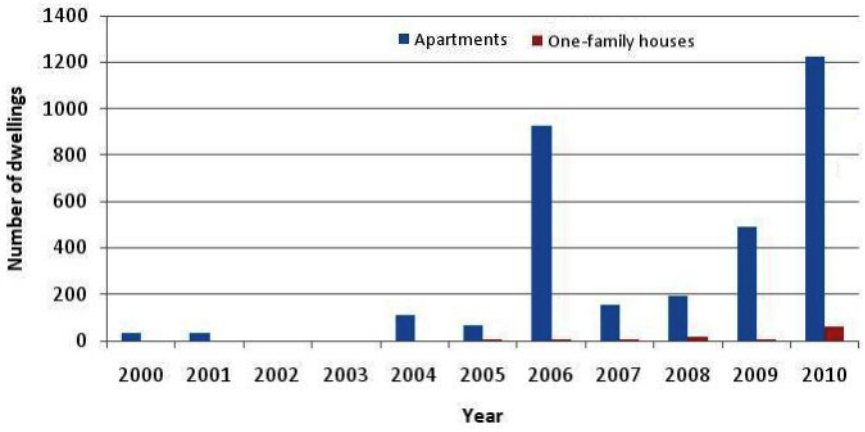

Figure 1. Numbers of residential dwelling units constructed per year.

The large number of buildings that were built in 2006 are mostly "electrically heated", complying with the building regulations of the time, which did not impose particular requirements on electrically heated buildings, and giving a total of 523 apartments. They cannot be classed as low-energy buildings under the present building regulations requirements for "electrically heated" buildings.

Table 2 shows the spread of energy performance in residential buildings for those of them that fall into the "heating other than by electricity" category. Where possible, the metered energy use is shown: if this is not available, then the expected *(i.e. as expected in the design work)* energy use is shown. It has been assumed that buildings with heat pumps fall into the "electrically heated" category , while other buildings fall into the "heating other than by electricity" category.

E_{BBR} is the requirement in accordance with the current building regulations (January 2011). E_{use} is the building's

Table 2. Energy performance for residential buildings in the "heating other than by electricity" category.

Energy use, E_{use} (kWh/m² A_{temp})	No. of det. houses	Proportion (%) of detached houses	No. of apartments	Proportion (%) of apartments
$E_{use} < E_{BBR}$	-	-	80	4
$E_{use} \leq 0.75 \cdot E_{BBR}$	17	22	1012	52
$E_{use} \leq 0.5 \cdot E_{BBR}$	37	47	800	41
$E_{use} \leq 0.25 \cdot E_{BBR}$	24	31	68	3

metered or expected energy use (excluding energy for domestic purposes). The 80 apartments having an energy use higher than 75% of that specified in the current building regulations have design values that are less than 75% of the building regulations values, but did not achieve this performance during the first year of metering.

Five detached houses and 658 apartments use heat pumps for heating, and are therefore classified as electrically heated, they are not included in **Table 2**. Under present-day building regulations, many of them fail the classification of low-energy buildings as their energy consumptions are well over 75% of permissible values in the applicable building regulations. However, it must be pointed out that they were built in accordance with the building regulations at the time, which did not include special requirements for electrically heated buildings. Their energy use values lie in the range of 41-75% of the energy requirements for buildings with heating systems other than electric heating.

Energy performance of commercial and similar premises improving, too

The market for low-energy buildings in the commercial and similar premises sector is similar to the residential buildings market. Development has been very slow, and has started to improve only during the last few years. A total of 700 000 m² of commercial and similar premises has been built as low-energy buildings, in 78 construction projects.

Most of the low-energy commercial and similar premises have been built in the last three years: **Figure 2**. As with residential buildings, most of them have been built in Climate Zone 3, with the distribution as follows: western Sweden, 36%; Greater Stockholm, 31%; southern Sweden, 12%; and northern central Sweden, 8%. Over 400 000 m² of office premises have been built, with half of them being in Greater Stockholm.

2009 and 2010 beat all records, with the proportion of commercial and similar premises built as low-energy premises amounting to 8% of the total area.

76% of these buildings have an energy performance that is 25-50% better than required by the current building regulations, while 20% are 50% better than required by the regulations.

Much more extensive valuation data needed

As by far the majority of the buildings have been built in the last two years, there are no high-quality post-construction measurements or assessments. Several such follow-up projects are in progress, but many more are needed. In the residential buildings, less than half of them have had their energy performance measured. More extensive measurements of airtightness of the building envelope, and follow-up in the form of questionnaires to occupants or interviews asking about the indoor climate have been carried out in a quarter of the apartments and in only three detached houses.

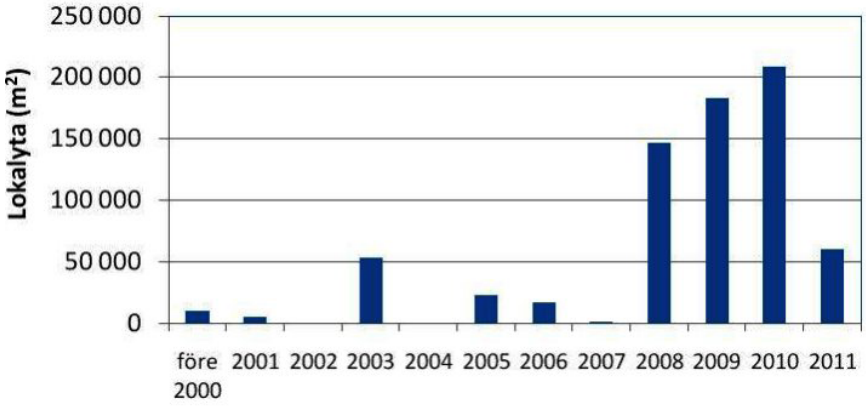

Figure 2. Low-energy commercial and similar premises, construction per year.

Table 3. Energy performance in new commercial and similar premises.

Energy use, E_{use}, (kWh/m² A_{temp})	Infant schools	Schools	Universities	Office	Care services, hotels	Sport, industry	Retail	Total number	Proportion (%)
$E_{use} < E_{BBR}$	1		1		1	0	0	3	4
$E_{use} \leq 0.75 \cdot E_{BBR}$	12	6	5	27	3	2	4	59	76
$E_{use} \leq 0.5 \cdot E_{BBR}$	7	3		2	1	1	1	15	19
$E_{use} \leq 0.25 \cdot E_{BBR}$		1			0	0	0	1	1
Total	**20**	**10**	**6**	**29**	**5**	**3**	**5**	**78**	

Hamnhuset, a residential low energy building by Älvstranden Utveckling in Göteborg. The tenants moved in 2008.

Among the commercial and similar premises, follow-up of energy use and evaluation of other properties and characteristics of the buildings is even more deficient than for the residential sector. Support for monitoring their performance will be important for many years into the future, in order to collect experience and develop the necessary appropriate technical design and system improvements.

The Swedish building code requires that energy performance must be verified by measurements within 24 months of completion of the building and the building´s energy certificate will normally be based on the monitored energy performance. Exceptions are if the building is sold within the first 24 months. In that case the energy certificate will be based on calculated energy performance.

Voluntary initiatives

Changes can be seen in the construction and property sectors, with several developers, contractors and local authorities already having clearly enunciated targets for constructing buildings having lower energy use than as specified in the applicable building regulations.

Interviews have shown that several of the parties have their own high performance requirements for all future work – and this in a sector that has previously been regarded as conservative. Project development company JM AB has, for example, decided to build only residential buildings with an annual energy use not exceeding 75 kWh/m² in Climate Zone 3, or 45 kWh/m² for electrically heated buildings. Contractors Skanska Residential Development Nordic and NCC Boende Sverige have also set the requirement of 75 kWh/m² in Climate Zone 3.

Public property owners are also setting performance requirements for new buildings. Göteborg Property Department, which builds schools, infant schools and residential property for the elderly, has set its performance requirement for maximum permissible energy use as 45 kWh/m². Västfastigheter, which builds health care premises, has set its maximum permissible annual en-

ergy use level at 100 kWh/m², including electricity for operational requirements.

Developers Skanska Commercial Development Nordic and NCC Property Development have committed themselves to ensuring that, in all projects where they have some form of purchasing role, and are therefore in a position to influence energy performance, such performance shall be at least 25% lower as required by the applicable regulations.

Since 2009, Göteborg has applied stricter requirements than in the Building Regulations when granting planning permission for buildings. For apartment buildings, the city requires a maximum heating energy not exceeding 60 kWh/m² (or 45 kWh/m² for 'electrically heated' buildings). For detached houses, the figures are 55 kWh/m² (or 40 kWh/m² for 'electrically heated' buildings) respectively. In December 2010, Stockholm City Council announced that all residential buildings and commercial and similar premises to be built on the city's land must be passive buildings.

Växjö, Malmö, Jönköping, Västerås and Linköping also set stricter standards as a condition for planning permission, ranging between 70 and 85 kWh/m², year. However, the setting of specific local energy requirements can make industrial-scale building and renovation more difficult.

Driving forces

The Västra Götaland region in particular has favourable experience of construction of apartment buildings as low-energy buildings, with the proportion of low-energy apartments being as high as 24% of total new building in 2010. This is of course due to a range of factors. The region has had several proponents of such development, who have pushed development, while the Environmental Department has supported a multi-year programme for energy-efficient buildings, under which such developments as the passive house sector in Alingsås have been carried out. Another contributory reason can be that there is a tradition of interdepartmental cooperation in the region between land use planning, purchasers, administrators, contractors, energy utilities etc.

The purpose of energy labelling certification schemes is to support development. In the commercial and similar premises sector, almost half of the buildings have obtained GreenBuilding certification, which indicates that this labelling has provided an important impetus. This is particularly noticeable for development in the Stockholm area, which has accelerated since establishment of the GreenBuilding scheme.

The establishment of performance specifications for passive houses may also be one of the factors that has assisted development of most of the residential properties, with an energy use less than half that of the applicable building regulations.

A new low energy office built by Husvärden in Göteborg, Sweden. The consultant company Bengt Dahlgren moved in December 2010.

Investment costs

Information on additional costs is very difficult to estimate, with what they are based on being dependent on who has prepared the cost estimates and what system solution has been taken as the comparison case for a building designed and constructed in accordance with the relevant building regulations. The additional costs given are for the particular building or project concerned, which is often the first energy-efficient building that the organisation has built. This means that the additional cost probably includes an element of learning costs which, in a more efficient construction process with greater volumes and numbers, could be expected to fall as the number of buildings increases.

Based on information from ten detached houses investment costs amount to SEK 19 500/m² on average. Data for three of them indicates that the additional investment for energy efficiency is about 10%. Based on information from 34 of the apartment buildings investment costs amount to SEK 17 000/m² on average. The average additional investment for energy efficiency is stated as about 7%, but varies between 0 - 17%.

Based on information from 13 infant schools investment costs amount to SEK 27 000/m² on average. The additional investment for energy efficiency is stated as about 3% on average, but varies between 0-10%. Based on information from seven schools investment costs amount to SEK 23 000/m² on average. The additional investment for energy efficiency is stated as about 2% on average, but varies between 0-5%.

Cost information is available for seven of the newly built offices. The average investment cost amounts to SEK 22 000/m². The average additional cost for energy has been given for only one building, for which it is stated to be "negligible".

Are the target levels of the NNE strategy reasonable?

During 2010, the Swedish Energy Agency has been working on preparation of a strategy to implement the requirements for *"near zero-energy buildings"*. The preliminary strategy proposes halving the maximum specific energy use allowed in the present building regulations in the "heating other than electric heating" category by 2020.

This review identifies a relatively large number of residential buildings that have shown that it is technically possible to meet a performance requirement of only 50% of the energy use specified in the applicable building regulations. Practice from calculation of profitability shows that it is not viable to build low-energy apartment buildings if the additional investment cost exceeds 7%. Viability requires the process to be improved so that the additional cost at least go halves.

Stadsskogen in Alingsås built 2008.
A kindergarten built with passive house technique.

For infant schools and primary schools, it is technically possible to construct buildings having an energy use of only 50% of that given in the applicable building regulations, but that several empirical follow-ups are needed to measure both energy performance and other technical parameters and properties.

Practice from calculation of profitability shows that it may be viable to build low-energy infant schools and schools if the additional investment cost is of the order of 2-3%, i.e. these energy efficiency improvement measures can already be viable.

This review shows that it is today technically possible to build office premises having an energy use 25% less than in the applicable building regulations. The additional cost for higher energy efficiency is stated as being negligible for an office, but was also without exception regarded as negligible in interviews with a number of contractors.

At present there are not sufficient material available from existing and monitored buildings that clearly shows the technical and economic potentials for low-energy buildings in each category of building. However, for commercial and similar buildings as a common group, there is an indication that it is technically possible to produce buildings having energy use 25% less than as given in the applicable building regulations.