Summary:

2001 CO_2 Audit

Hannover Kronsberg

Commissioned by the City of Hannover
Environment and Urban Greenspace
Environmental Protection Division

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1 Introduction

ifeu - Institut Heidelberg GmbH was commissioned by the City of Hannover to compile CO_2 audits for the years 1999, 2000 and 2001 at the Hannover Kronsberg EXPO settlement. They show the general development in energy – and especially space heating energy – consumptions and thus the CO_2 emissions from the settlement as compared to the planned energy scenario.

One of the City of Hannover's objectives for the Hannover Kronsberg EXPO settlement was to reduce heating energy consumption by 45% and CO_2 emissions by 60% against current conventional building praxis[1]. This was to be achieved by setting appropriate conditions in the planning process, applying comprehensive quality control monitoring throughout the construction phase and informing and motivating the residents.

The ifeu - Institut Heidelberg assessments for the years 1999 – 2001 show that these extra efforts have born fruit.

In what follows the findings of the current assessment, for 2001, are summarised and interpreted. Chapter 4 contains a brief précis.

2 The Kronsberg Energy Concept

The energy concept for the Kronsberg development consists of three components: Low Energy House construction methods with quality assurance, monitoring and skilling and qualification measures, district heating provision from decentral cogeneration plants and an electricity saving programme. Together these measures should achieve 60% reductions in CO_2 emissions. The use of regenerative energy sources (wind power, solar) and innovative technology (passive houses, solar district heating, microclimate zones) contribute to further reductions in CO_2 emissions.

Illustration 1 shows the projected measures and the percentage of CO_2 potential reduction allotted to each.

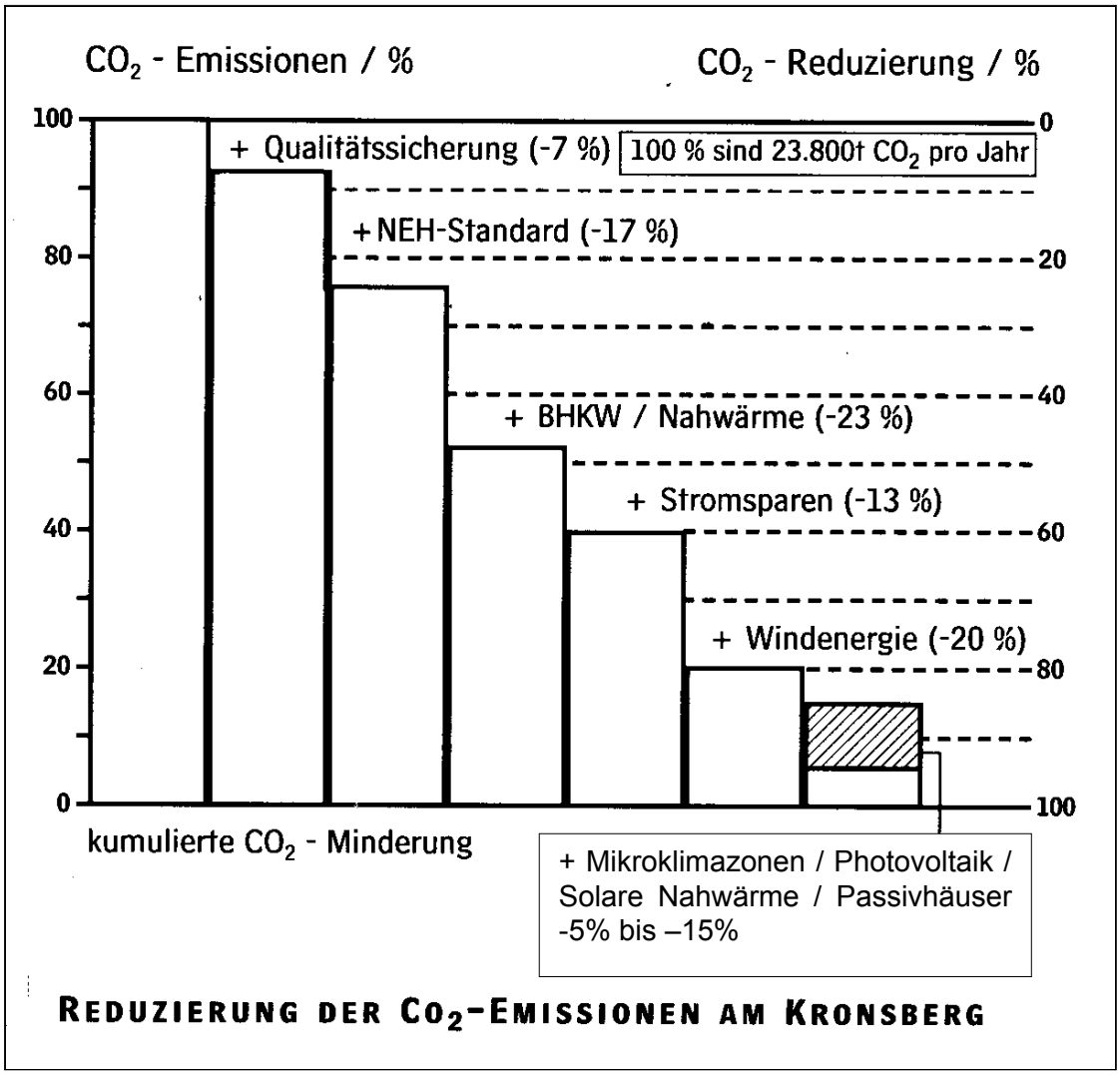
2.1 LEH Standard and Quality Assurance (QA)

Residential buildings on Kronsberg were erected according to the City of Hannover's specifications as Low Energy Houses (LEH), with a maximum heating energy demand of 50 kWh/m^2a as target value, calculated according to the 'Kronsberg-Berechnungsverfahren'. Non-residential buildings – schools, kindergartens etc. - had to achieve a maximum energy index of 30% below the 1995 statutory insulation regulations.

The entire construction process, from initial planning to handover, was supervised with the aim of guaranteeing both optimal energy efficiency and the high standards of

[1] German insulation regulations, 1995, with each building provided with heating and hot water from a gas-fuelled condensing boiler.

workmanship demanded by Low Energy construction, through to advisory services and monitoring.



Illus. 1 Reductions in CO_2 emissions on Kronsberg (from 'Hannover Kronsberg – model of a sustainable new urban community')

2.2 Decentral CHP and District Heating Provision

Energy for heating and hot water in all Kronsberg buildings is delivered from a district heating network driven by gas-powered decentral Combined Heat and Power (CHP) plants. The ca. 3,000 housing units and infrastructure so far built are supplied by two district heating networks: the smaller plant operated by GETEC mbH Hannover is located in the north of the area and supplies around 700 homes, the primary school and children's day centre, while a CHP operated by Stadtwerke Hannover AG (SWH) in the south supplies the rest of the settlement.

2.3 Electricity Saving Programme

Issuing five low-energy light bulbs and two water-saving tap fittings to each household, plus an energy saving advice service by the KUKA organisation, were components of the wide-ranging electricity saving programme to reduce electricity consumption. Purchase of energy-efficient household appliances was also subsidised.

2.4 Regenerative Energy Sources and Innovative Technologies

To achieve further reductions in CO_2 emissions and emphasise the sustainable character of the Kronsberg district, various visionary measures were implemented that went beyond the above mentioned energy efficiency optimisation framework.

Among them were use of regenerative energy sources such as solar and wind power and of innovative technologies such as passive houses, microclimate zones, photovoltaic installations and solar-powered district heating.

Passive Houses

32 Passive House Standard dwellings in four terraces were erected and occupied. The mean target (and achieved) space heating index was around 15 kWh/ m^2a. Electricity consumption is reduced by ca. 30% through use of energy-saving appliances and users' lifestyle adaptations. Thermal solar water heating makes a further contribution to reducing CO_2 emissions.

Solar District Heating Provision

106 housing units in the 'Solarcity' project draw some of their heating from solar sources. In 2001 all the homes in this development were occupied.

Photovoltaic

Photovoltaic installations producing a total output of 17 kW_p electricity were mounted on various public buildings and the SWH energy facility.

Wind Power

In 2001 three wind turbine generators were in operation: one run by the Herrmannsdorfer Landwerkstätten farm (1.8 MW), one by Stadtwerke Hannover AG (0.3 MW) and one by the Windwärts association (1.5 MW).

3 Findings of the 2001 Energy Audit

In presenting the findings we follow the structure in the step diagram (see Illustration 1). This diagram is benchmarked on preset conventional standards (100%) and presents the ambitious aim of a 60% reduction in CO_2 emissions in this model project applied to the entire settlement.

The benchmarking reference scenario assumed that:

1. all buildings would have been erected according to the 1995 insulation regulations
2. an average of 30 litres of hot water (45°C at the tap) per person per day would have been used,
3. each building would have been fitted with its own heating system powered by a gas condensation boiler
4. usually, lack of quality monitoring would have caused excess end consumption in the order of 15 %.

To see to what extent the target margins were achieved, both qualitatively and quantitatively, the findings are presented singly according to the following themes:

- Energy consumption and resultant CO_2 emissions for space heating and hot water
- Use of district heating with gas-powered decentral CHP plants
- Electricity saving programme

3.1 Only Isolated Initial High Energy Losses

The monthly heating consumption figures for 1999 and 2000 showed up significant initial energy wastage in detail.

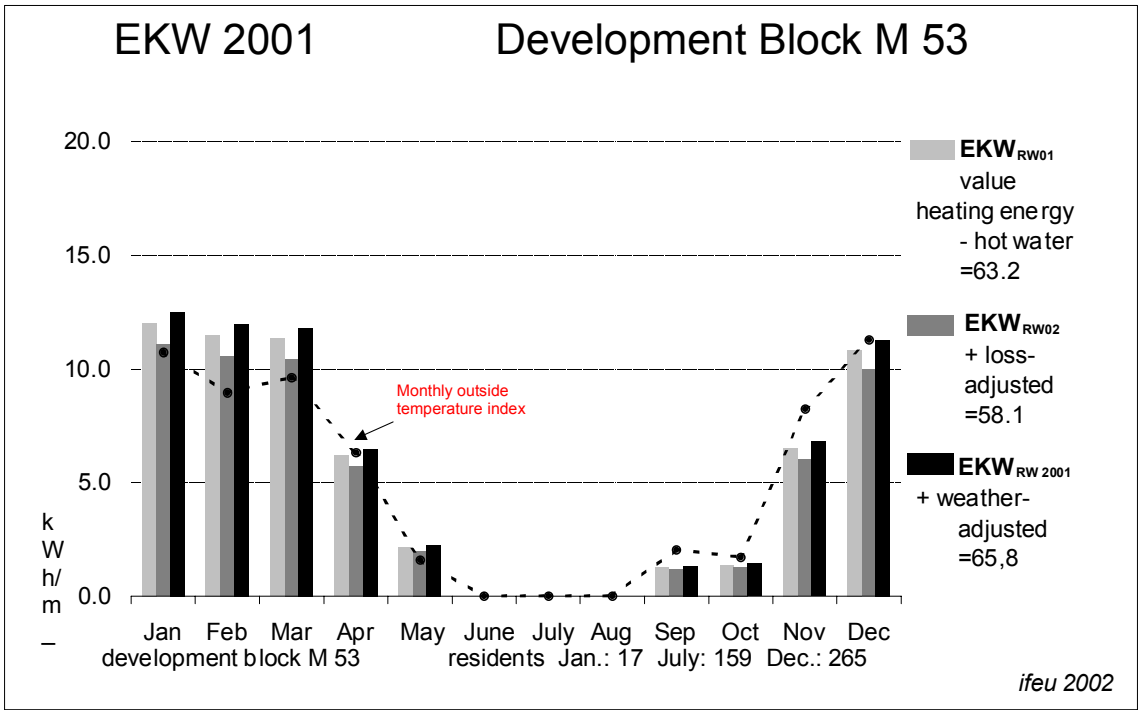
In 2001 these losses had virtually disappeared except for one development block that was only fully occupied in the course of 2001.

This block is presented here as an example.

Illustration 2 shows the month-by-month development of the block's energy consumption index through 2001. The bars show the actual consumption values less hot water consumption (light grey = 63.2 kWh/(m^2*a)), less heat loss of the building (dark grey = 58.1 kWh/(m^2*a)) and weather-adjusted (black = 65.8 kWh/(m^2*a)).

Unlike other development blocks, the indices here in the first three months of the year are noticeably above the outside temperature index. The curve in the last third of the year resembles that of other development blocks. This shows once more that energy loss is high while people are moving in (January: 17 residents) and disappears only when the block is fully occupied (December: 265 residents). For 2002 we expect that the relatively high indices for 2001 (65.8 kWh/(m^2*a)) will also fall significantly for this block.

Illus. 2 Example of high initial losses in a development block, 2001



3.2 Findings for Space Heating

To the end of 2001 the number of housing units covered by the audit rose from around 1,700 to around 2,900 when the apartments used as EXPO 2000 personnel accommodation were occupied. The total audited living space thus rose from 133,425 m^2 to 212,823 m^2. The passive houses, with a living space of 3,516 m^2, are not included.

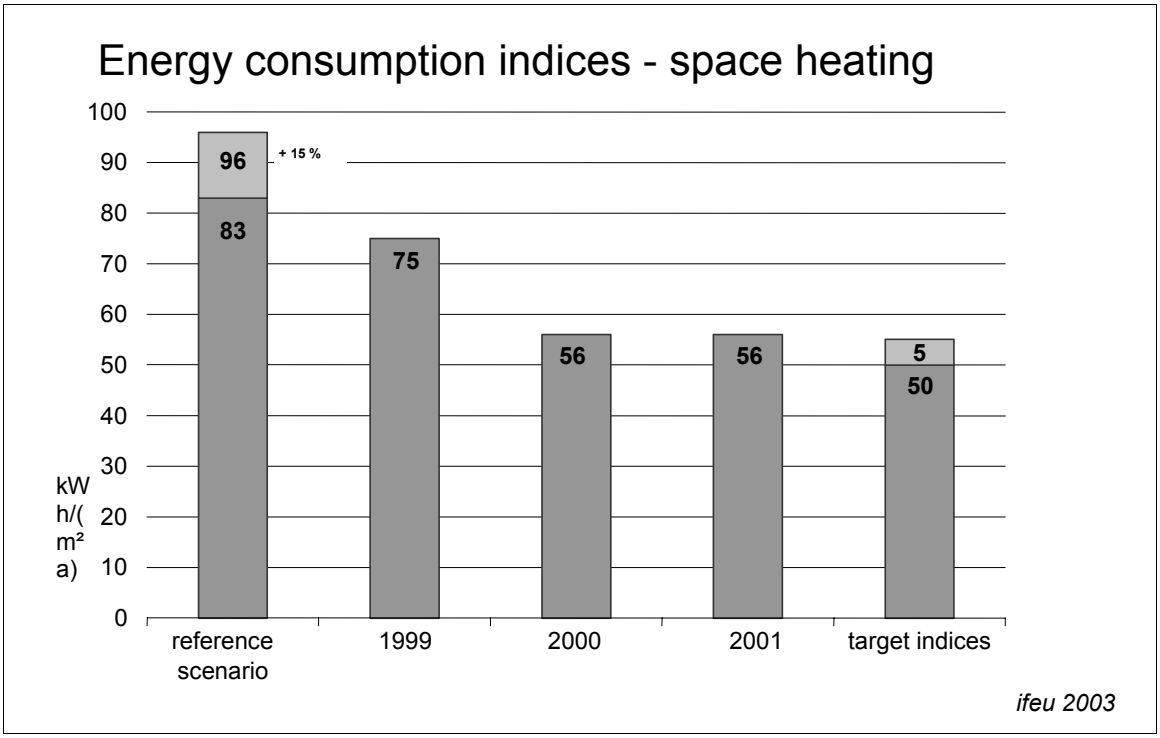
Illustration 2 presents the space heating indices for audited buildings 1999 - 2001.

The reference scenario set a mean index of 96 kWh/m^2a (+15% due to lack of quality monitoring).

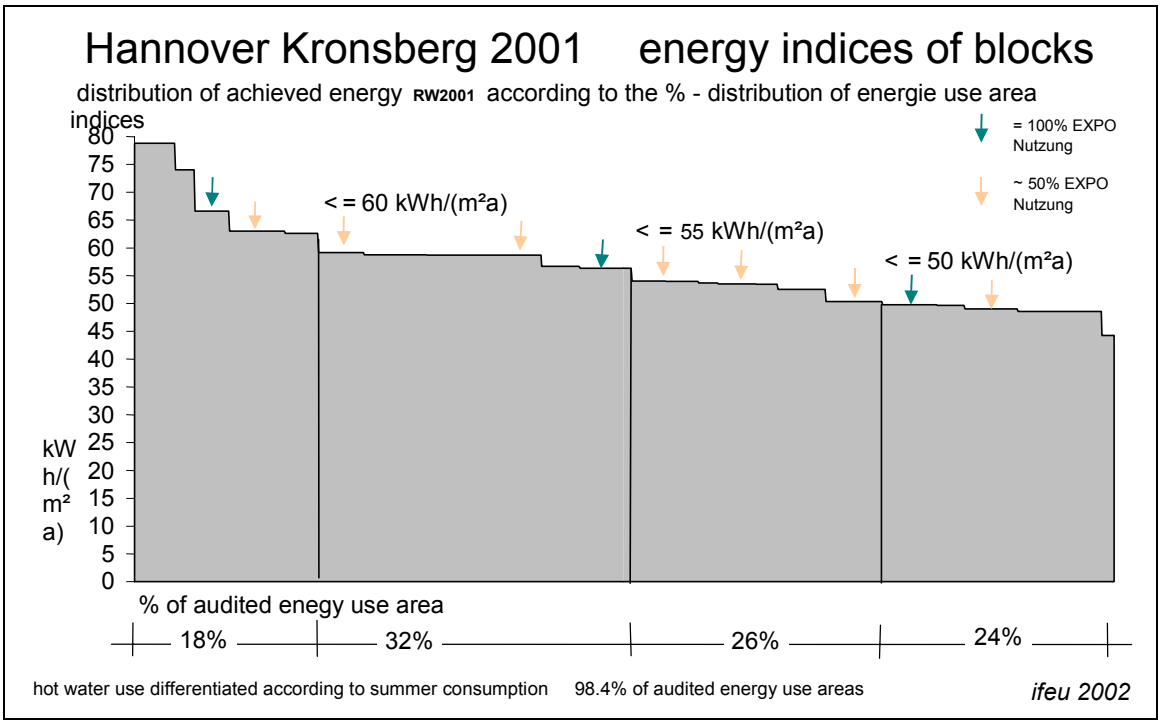
Because of excessive initial losses, in 1999 the measured weather and loss-adjusted energy consumption indices for space heating were still 75 kWh/m^2a and thus 22% below the base index. It was pleasing to note that by 2000 this value was 56 kWh/m^2a, 42% below the reference index and only just above the target range of 50-55 kWh/m^2a.

Even though the audit was extended to cover the apartments used until 2000 as EXPO accommodation, for 2001 an index of 56 kWh(m^2a was maintained.

Illus. 3 Energy consumption indices for space heating at the Hannover Kronsberg development: reference scenario, 1999, 2000, 2001 and target values



Illus. 4 Percentage distribution of energy indices achieved at all development blocks



This is also shown in illustration 4, which presents the indices achieved by each development block. 24% of apartments achieved values below 50 kWh/m^2*a, and another 26% below 55 kWh/m^2*a. No differences were perceived between buildings with and without EXPO personnel use.

The major proportion of energy savings was achieved through the exceptionally good insulation of the buildings together with quality assurance monitoring during the construction phase. The reasons for high consumption in three individual blocks could not be completely determined. Clearly they were not due to poor insulation but rather to user behaviour, which had not adapted to the accommodation, high initial losses (see above) or to high interior distribution losses.

The energy consumption indices can also be seen in Illustration 6 under space heating.

3.2.1 Hot Water Provision

The base value in the step diagram is 30 litres of water at 45°C per person per day. This produces a specific end user energy demand in the reference scenario (see also Illustration 6) of 17 kWh/m^2*a. In 1999 the specific end user consumption was around 14 kWh/(m^2*a), rising in 2000 with higher occupancy levels to 16 kWh/m^2*a.

Evaluation of hot water consumption for 2001 produces a specific end user demand of ca. 15 kWh/m^2*a. This figure meets the target scenario.

3.2.2 Heating Losses

In the reference scenario (see Illustration 6) it was assumed that each building was fitted with a separate heating system powered by a gas condensation boiler. The annual level of utilization for space heating and hot water provision was set at an assumed 80%. Included are distribution losses in the pipework that do not heat the accommodation, and the boiler and hot water only wastage for heating and hot water provision. This produces an energy index of 28 kWh/m^2*a for heat losses (reference scenario).
In 1999, however, the actual losses from heating provision system were markedly higher, at 53 kWh/m^2*a[2]. It was not until 2000 that losses decreased to around 27 kWh/m^2*a.

In 2001[3] total specific losses were recorded at the calorific meters of 24 kWh/m^2*a. They comprise losses from the district heating network pipes (8.6 kWh/m^2*a), losses from the hot water tank and pipework (10.8 kWh/m^2*a) and losses from pipework in the space heating system (4.9 kWh/(m^2*a)).

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[2] Parts of the district heating network were operating on a temporary basis, and the decentral CHP plants were not yet on stream.

[3] By end use energy is meant not the gas consumption at the heating plants but the district heat delivered by the heating plants.

A target was set for Hannover Kronsberg, along with the space heating target index (useable energy) of 50 kWh/m^2*a for hot water provision of 15 kWh/m^2*a, and reductions in heat loss (from the calorific meter at the heating plants) of 19 kWh/m^2*a.

To achieve this target, the tank and pipework losses inside the buildings would have to almost halve once again. Here, with specific measurements and optimisation of single buildings, the reasons for heat losses should be investigated.

3.2.3 Electricity Consumption

The reference scenario assumed electricity consumption of 2,500 kWh per household per annum. Related to the average living space, this produced an index of 32 kWh_{el}/m^2*a. Through savings of around 6%, this figure could be reduced in 1999 and 2000 to 30 kWh_{el}/m^2*a (see also Illustration 6).

Across all 2,678 households in the audited area, in 2001 the average saving was 5.3%. The average consumption of a household would thus be around 2,368 kWh/a, the electrical energy index around 30 kWh_{el}/m^2*a.

Only about one-fifth of the intended electricity savings of 750 kWh/a per household has thus been achieved by the end of 2001. Actual savings are far below the 30% target set for Hannover Kronsberg, which would lead to a target index of 22 kWh_{el}/m^2*a.

To clarify this large discrepancy between target and achieved index, the electricity factor was more closely examined.

The following questions were addressed:

1. Was the assumed average consumption too high?
2. Are the savings targets unrealistic?
3. Were too few savings measures carried out?

1) Compared to nationwide assumptions on average consumption in private households, the assumed reference value was completely realistic.

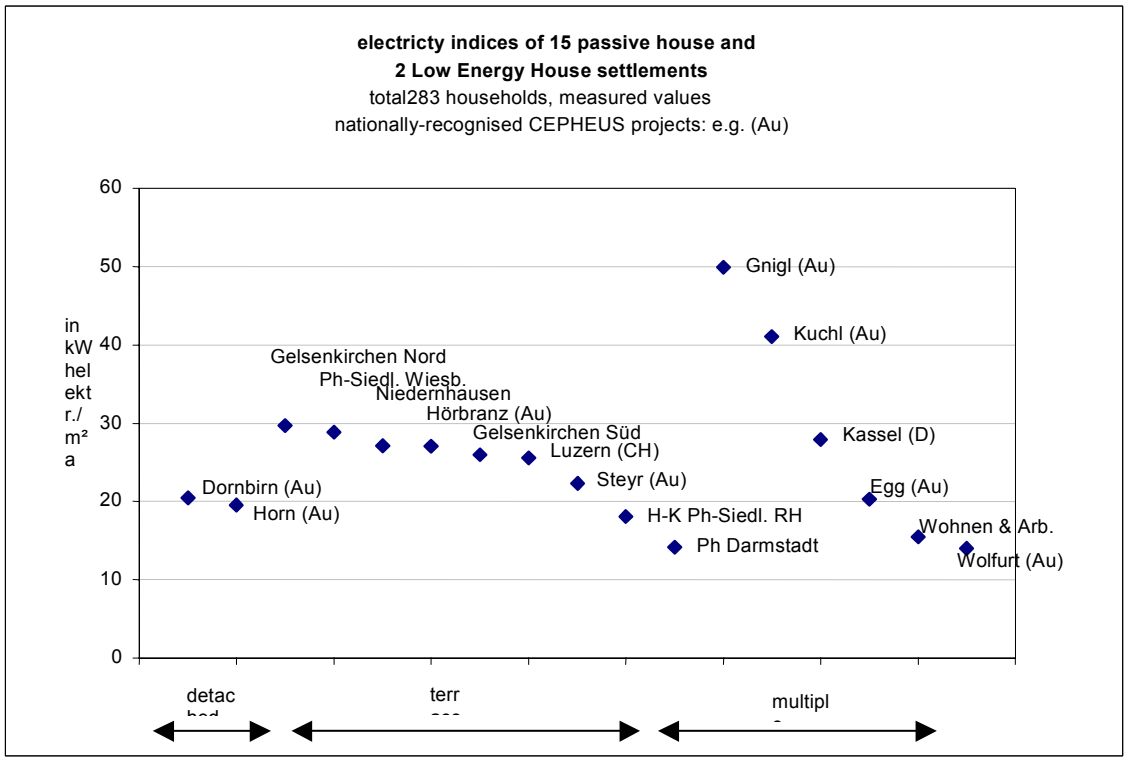
2) Compared with the electricity indices applied to other pilot projects, it can be seen that around half of them lie below the Kronsberg electricity target index of 22 kWh/m^2a (see Illustration 3). The households in the passive house development on Kronsberg could also achieve an index of 22 kWh/m^2a.

It can thus be seen that the desired savings are entirely possible.

3) Within the electricity saving programme, by the end of 2001 acquisition of the following energy-saving appliances had been subsidised:

- washing machines	77	c. 3% of households
- dishwashers	106	c. 4% of households
- refrigerators	56	c. 2% of households
- freezers	66	c. 3% of households
- low-energy light bulbs	5,600	c. 2 per household

Illus. 1 Overview of electricity indices in low-energy settlements



It is clear that only the low-energy light bulbs have been widely used. Low energy white goods were acquired by only 2-4% of households. Because only a small number of these large appliances were bought new for the move to Kronsberg, and new tenants will be moving in continually, exploiting this potential will remain a long term task.

Furthermore, we regard it as necessary to improve the database for this study. Around ten households participating in the electricity saving programme should be examined more closely and the practical savings potential studied once more. Additionally, it would make sense to record electricity consumption separately by development block with automatic meters. This would provide further reference points for target group-oriented optimisation of the electricity saving programme.

3.2.4 Trends in the Overall Energy Index

Illustration 6 shows the overall energy indices for the years 1999 to 2001.

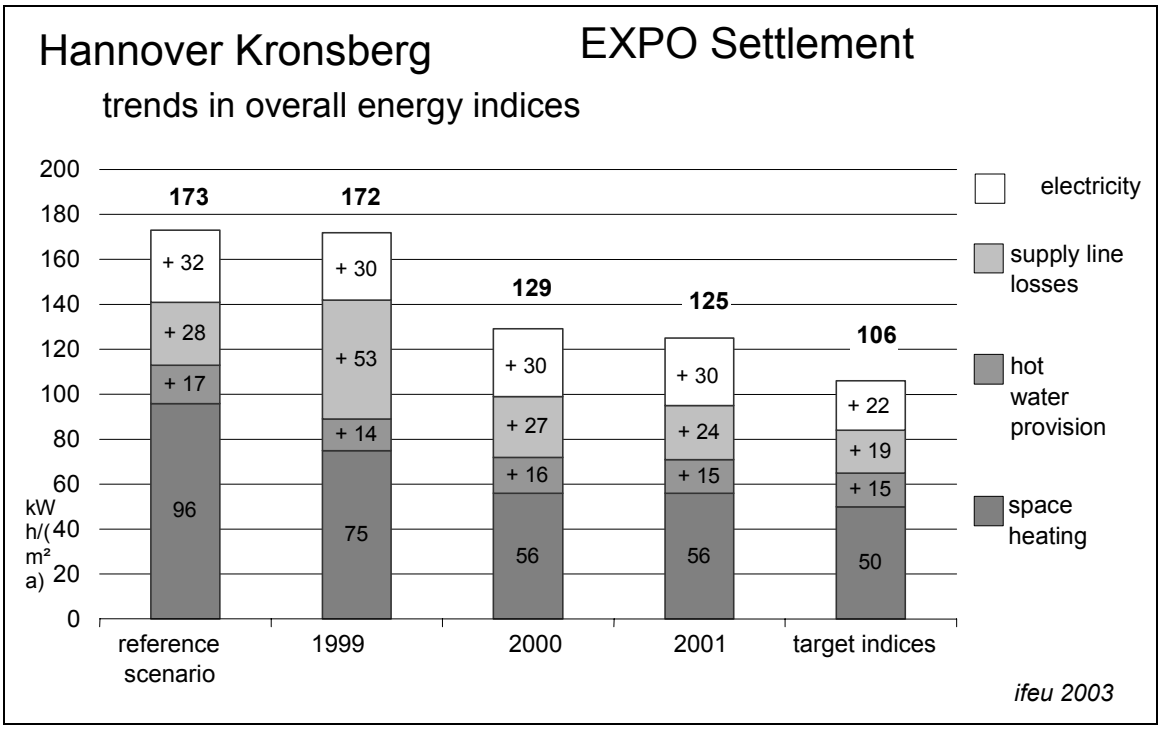
Compared to the overall energy index of the **Reference scenario** - 173 kWh/m^2*a - the values for **1999** had not changed to any practical extent. Reductions from 96 to 75 kWh/m^2*a for space heating (-22%) and of a few percent in hot water and electricity consumption were negated by higher losses in heating provision. The reasons for this lay in the construction of the district heating network with uncompleted heating plants, and temporary mobile heating without decentral CHP plants.

The year **2000** saw an overall energy index of 129 kWh/m²*a, a reduction of 25% on the reference scenario. This can be traced to the positive development in the space heating index to 56 kWh/m²*a as the initial losses disappeared. Heat losses were also halved in 2000 compared to 1999, as expected, with the almost complete construction of the district heating network, to 27 kWh/m²*a. For hot water, the expected slight increase in demand as the population rose appeared, creating an index of 16 kWh/m²*a. The electricity index was steady at 30 kWh/m²*a.

In **2001** the overall energy index fell further, to 125 kWh/m²*a, a 27% reduction compared to the reference scenario. Reasons were slightly lower hot water consumption and further reductions in heat losses (especially in the district heating network) to 24 kWh/m²*a. The electricity index remained at 30 kWh/m²*a.

The **target index** of 106 kWh/m²*a is 39% below the reference scenario.

Illus. 6 Energy consumption indices for heat and electricity at the audited Hannover Kronsberg development: reference scenario, 1999, 2000, 2001 and target indices



Future developments: To achieve the target index further efforts are needed. Savings potentials in space heating is, at the present index of 56 kWh/m²*a virtually exhausted. After the optimisation of a few development blocks with very high indices the desired overall maximum index of 55 kWh/m²*a can be achieved.

The end user energy consumption for hot water provision is, at 15 kWh/m²*a, at the top of the target value.

A heat loss index of 24 kWh/m²*a is just halfway towards the target of 19 kWh/m²*a, even though losses from the district heating network were reduced to around 9% in

2001. The question of whether losses from tanks and pipework inside the buildings (installations) can be halved by retrofitting can be answered only after more precise measurements. Measurements are currently being taken at the district arts and community centre and the kindergartens, and results are expected at the end of this year.

Overall, in 2001 a heating energy index (without electricity) of 95 kWh/m^2*a could be achieved, 13% above the target. The electricity index is the least satisfactory, 37% above the target. The high savings potential in purchasing patterns and consumer behaviour should be exploited here in the next few years.

The **overall energy index** for 2001 was, at 125 kWh/m^2*a still 18% above the target of 106 kWh/m^2*a

3.3 Trends in CO_2 emissions

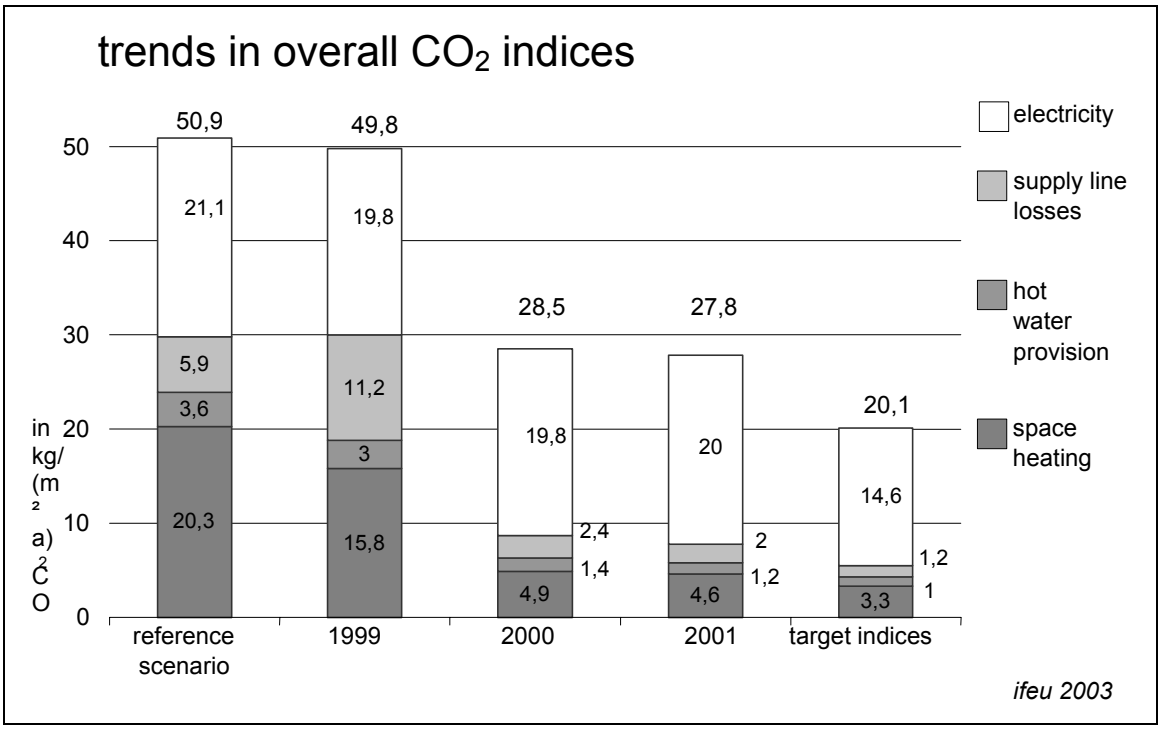
At Hannover Kronsberg electricity and heat are generated at two local power stations with gas-powered Combined Heat and Power plants. This reduces the primary energy consumption and the emissions dramatically compared to conventional power stations, where around two-thirds of the energy is released into the atmosphere as waste heat.

Illustration 7 presents the overall CO_2 emission indices, divided into applications, analogue to the end-use energies.

The emission factors are derived from a 1994 study by Stadtwerke Hannover. The CO_2 emission factor for natural gas is 211 g/kWh. For electricity, in this report a value of 660 g CO_2 / kWh was used. In considering Illustration 7 compared to the end-use energy presentation in Illustration 6 it is noticeable that the electricity bars are markedly higher. This is because CO_2 emissions specifically from electricity are higher by about a factor of 3 compared to natural gas.

The trends in CO_2 emission indices from the **reference scenario** to the **actual values for 1999** reflect trends in the energy indices. The overall CO_2 index hardly alters; reductions from 20.3 to 15.8 kg/m^2*a in space heating (-22%) and of a few percent in hot water and electricity are negated by higher losses from the heating provision system.

Illus. 7 Trends in CO_2 indices at the audited Hannover Kronsberg development: reference scenario, 1999, 2000, 2001 and target indices



With 28.5 kg/m²*a, **2000** saw significant CO_2 reductions of 44% against the reference scenario. These dramatic savings came roughly equally from end-use savings and commissioning of the decentral CHPs.

In **2001** the emission indices sank to 27.8 kg/m²*a, 45% below the reference scenario. As the decentral CHP plants were running all year, the emissions index for heating sank to 7.8 kg/m²*a. Compared to the reference scenario (heating: 29.8 kg/m²*a) this is 74% less CO_2 emissions. For electricity there was a slight increase in the emissions index to 20 kg/m²*a.

The **overall CO_2 target index of 20.1 kg/(m²*a)** is 60% below the reference scenario. Through the use of CHP plants and the saving effects, CO_2 emissions from heating are reduced from 29.8 to 5.5 kg/m²*a or by 81%. The emissions index for electricity would decrease to 14.6 kg/m²*a.

This target can essentially be achieved if the electricity savings potential can be exploited to the extent that was originally expected. If the target index of 22 kWh/m²*a and thus the CO_2 index of 14.6 kg/m²*a for electricity were achieved this would lead to an overall CO_2 index of 22.4 kg/m²*a.

4 Précis

This study shows that in 2001 the desired insulation standards were all but achieved even after the EXPO apartments were reoccupied with regular tenants. Together with the first full year of operation of the decentral CHP plants, CO_2 emissions from heat generation could also be significantly reduced. Savings in domestic electricity, however, were well below expectations. Overall, there was a 45% reduction in CO_2 emissions compared to conventional new construction standards. Applications of the originally planned measures and the actual effects on CO_2 reduction are, however, very varied between the types of energy provision.

In space heating it has been seen that the extremely high energy losses of the initial phase (in some cases double the energy consumption, on average around 20% higher) had already normalised during the first heating periods in 2000. At 56 kWh/m^2*a the achieved values for 2001 were only just above the target range of 50-55 kWh/m^2*a. It is thus plain that the aimed-for 'Kronsbergstandard' has proven its worth in reality. Including the EXPO apartments, the actual energy consumption of a total of 2,890 units with 213,000 m^2 living space was included in the evaluation.

After all the buildings had been connected to the district heating networks, in 2001 heat losses from the system also decreased, to 9%. To meet the overall heat loss targets, however, losses from tanks and pipework inside the buildings must be almost halved again. Here, with specific measurements and the optimisation of single buildings, the causes of this heat loss should be investigated.

In the area of utilities technology, in 2001 the construction target of completing Combined Heat and Power primary energy source for the first construction phase at Kronsberg was met. The electricity yield was not, however, as high as had been expected in the target scenario; after taking emission data from electricity generation into account, in 2001 specific CO_2 emissions of 82 g/kWh instead of the target 65 g/kWh were achieved. Compared to CO_2 emissions from electricity generation (660 g/kWh) and natural gas (211 g/kWh) they are still extremely good.

Concerning heat provision, application of the 'Kronsbergstandard' and full year operation of the decentral CHP plants meant that CO_2 emissions in 2001 could be reduced by 74% compared to the reference scenario of 29.8 kg/m^2*a to 7.8 kg/m^2*a.

The savings targets for electricity were unfortunately not met. Only a few households are equipped with the most efficient appliances, and because just a small proportion of white goods are bought new when moving in, and new tenants are coming to Kronsberg all the time, the exploitation of this potential will remain a long-term task.

The relatively low CO_2 emissions caused by electricity and heating generation for 2,890 homes – around 5,916 tonnes in 2001 – are complemented by the c. 3,100 tonnes of CO_2 emissions avoided by operating the 3 wind turbine generators in the Kronsberg countryside.

If one were to credit these avoided CO_2 emissions completely to the Kronsberg households the calculation would show total emissions of 2,800 tonnes of CO_2 or one tonne per household, a reduction of 74% compared to the reference scenario.

Illus. 8 Hannover-Kronsberg EXPO Project: general plan of the new city district