

Energy-efficient neighborhood development in Apeldoorn (NL) and Hillerød (DK), implementation and results

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Abstract

As of 31 December 2020 new buildings in the EU will have to consume 'nearly zero' energy and the energy consumed will need to be 'to a very large extent' from renewable sources produced on-site or nearby. The overall performance depends on the buildings and on an efficient local supply of energy based on renewable energy. In Apeldoorn (the Netherlands) and Hillerød (Denmark) new neighborhoods have been realized. In Apeldoorn dwellings are connected to a district heating system, running on biogas from a waste water treatment plant, with wood chip boilers to cover peak demand. In Hillerød the dwellings are connected to a low temperature district heating system, with a biomass boiler, gasifier (CHP) and solar thermal as heat sources. Whereas many studies on energy performance of efficient buildings are mostly based on small samples, in Apeldoorn 117,000 m² of buildings, mainly residential, have been constructed and monitored (hundreds of dwellings and a neighborhood services center). Besides monitoring the performance of the dwellings, the performance of the nearby installations have been monitored to determine the overall performance for each of the locations. Additionally, the satisfaction of inhabitants has been monitored, as well as potential changes in energy related behavior and attitude. This paper describes the monitoring approach, the challenges faced, the solutions applied to the challenges, and it includes results from surveys on customer satisfaction. Recommendations will be given for the realization of future energy efficient neighborhoods and the monitoring of its energy performance.

Introduction

As of 31 December 2020 new buildings in the EU will have to consume 'nearly zero' energy and the energy consumed will need be 'to a very large extent' from renewable sources produced on-site or nearby. With the energy produced nearby, the overall performance will depend on both the performance of the building itself and of the performance of the installations in the neighborhood (e.g. district heating based on renewable energy, PV fields, wind turbines) and the efficiency in distributing the generated energy to the dwellings. As the Energy-efficient Buildings Association (E2BA) Roadmap¹ indicates: "The district dimension provides new energy optimization possibilities, for instance through the connection to existing grids (electricity, heat and cooling networks), via the design and operation of a set of buildings as components of an integrated energy system, which can in turn contribute to improved peak load management." In general, it is more and more recognized that neighborhoods have the right scale when it comes to affordable energy efficiency improvements.

This approach was, on a large scale, already advocated since 2003 by the CONCERTO programme of the EU, as part of its sixth Framework Programme (FP6). A combined and integrated approach to energy-efficiency, rational use of energy and the integration of renewable energy in neighborhoods is the main target of CONCERTO, which has found a follower in the Smart Cities and Communities initiative of the seventh Framework Programme (FP7). By now, CONCERTO totals the implementation of projects in 58 cities; Apeldoorn and Hillerød, participating in the SORCER project, are two of them. The general goals of CONCERTO were stated as buildings/neighbor-

1. www.e2b-ei.eu

hoods with an energy performance of 30 % better than existing regulations for new building, and comparable to new building standards for retrofitting projects. In this paper the monitoring results of the projects in Apeldoorn and Hillerød will be described, focusing on building performance, energy performance of the districts as a whole, and consumer satisfaction.

Background

BUILDING STANDARDS (2006–2012) IN THE NETHERLANDS AND IN DENMARK

Building standards in the Netherlands

In the Netherlands, new buildings should comply with the Energy Performance Standard (EPC).

The EPC is based on the energy consumption of a building and includes for dwellings energy for heating and domestic hot water and electricity consumption for ventilation, pumping and cooling. There are minimum requirements for the performance of individual components but the EPC can be reached by a number of packages of measures, aiming at a cost-effective set of measures.

At the time the construction of the dwellings started in Zuidbroek (2006–2011), the EPC was 0.8. Therefore this stands as the standard against which the energy performance of the buildings in Zuidbroek will be compared. Since 1.1.2012, new buildings have to comply with an EPC of 0.6.

The EPC also takes into account system approaches like district heating. In that case, default values can be used to determine the EPC. As an alternative to default values, the standard allows for real savings in primary energy to be calculated using the “equivalence principle”. In Apeldoorn, the new dwellings are connected to a district heating system that is predominantly fired by biogas and by the recently installed peak woodchips boiler. This significantly reduces the fossil energy content of the district heating system and therefore the ‘equivalence principle’ calculation method is chosen. This means that the total energy performance (and thus the EPC) depends on the energy performance of the heating network. On its turn, the performance of the heating network will depend on climate conditions and weather influences, the number of dwellings connected to the grid, etc.

Building standards in the Denmark

Denmark has a very strict building code, which is based on the Energy Performance of Buildings Directive (EPBD) (2002/EC/91) and the EPBD recast (2010/31/EU). The energy performance is based on primary energy, where factors are defined for different energy carriers. The energy consumption includes energy for heating and domestic hot water and electricity consumption for ventilation, pumping and cooling. For other buildings than dwellings, such as offices, shops etc., lighting is also included. The energy consumption is calculated using a software tool developed to document the energy consumption. A set of predefined values for e.g. internal heat loads, temperature set points, use of domestic hot water etc. are to be used. All other energy consumption such as household electricity consumption is not included in the energy frame, it is only to be added to the calculation as an internal heat load.

In addition to the energy performance there are minimum requirements for U-values of building components, thermal bridging and specific fan power of the ventilation system, as well as the overall average U-value of the building envelope except for windows and doors.

The building code has had three different energy performance levels;

- a minimum requirement for fulfilling the building code
- a low energy performance which is the expected value for the next update of the building code or around 25 % lower than the current minimum requirements
- a low energy performance which is the expected value after two updates to the building code or around 50 % lower than the current minimum requirements.

The update interval is defined to be every five years. In the period from 2006 to 2012, Denmark has effectively had three different building codes. However, the basic principle has been the same in the entire period. The major difference is that the energy performance requirement has been tightened during the period as described above.

General project overview

MAIN PROJECT OBJECTIVES

Both the Zuidbroek project and the Hillerød project are new build, high energy-performance districts. Main objectives of the project are:

- Demonstration of low-carbon neighbourhoods based on scalable concepts.
- Feasibility of integrated approach combining energy efficiency and renewables integration.

The requirement of scalable concepts for successful replication led to both technical and socio-economic monitoring activities.

PROJECT DESCRIPTION APELDOORN ZUIDBROEK

In Zuidbroek 117,000 m² of buildings have been constructed, predominantly dwellings, but also a large community center. The neighborhood has the following characteristics:

- Energy performance coefficient of buildings (EPC – shell based) of 0.8, together with the bio-energy based district heating system, the EPC is targeted at 0.64.
- 2.65 GJ additional energy savings per dwelling per year (e.g. 400 W_p solar panels/dwelling).
- District heating Zuidbroek (2,500 dwellings).
- Sewage digester, with poultry sludge (1.5 MW_e).
- Woodchips peak boiler (2.8 MW_{th}).

Figure 1 shows the set up of the energy system of Zuidbroek. The waste water (1) of the dwellings flows into the waste water treatment plant (2) and after dewatering (3) the sludge is digested (4) and the biogas is burned in a cogeneration plant (CHP) (5) generating electricity that is used (7) for the pumps of the waste water treatment plant. The heat produced in the

CHP is used for the district heating system (6). To cover peak demand, additional boilers will be used to produce heat based on biomass chips and/or natural gas (not indicated in the picture). PV panels are not indicated in the graph, but are an integral part of the project, and are installed on dwellings as well as on the peak boiler building and the office building of the district water board (Waterschap Veluwe).

PROJECT DESCRIPTION HILLERØD

The project in Hillerød has been changed significantly during the duration of the SORCER project. Initially, the project was centered around 79,000 m² of low energy dwellings for single and multi family use in Ullerødbyen. However, this had to be changed significantly due to the financial crisis, which provoked a slump in the building activities of private homes in Hillerød as well as in Denmark in general. Against this background the project's focus was enlarged to the entire city of Hillerød and included also other building types such as office buildings. This change also led to a dramatic increase in the use of solar PV panels, which moved from around 8 kW_p to over 400 kW_p.

During the SORCER project the following has been realized in Ullerødbyen or its direct vicinity:

- Low temperature district heating network.
- Solar thermal collectors (>3,700 m²) in two fields.
- 86 Class 1 Ecobuildings (-50 % below building code requirements).
- 20 Class 2 Ecobuildings (-25 % below building code requirements).
- Biomass boiler (6 MW thermal).
- Biomass gasifier (500 kW electrical and 1 MW thermal).
- Office buildings, city college and conference centre (total 27,000 m²).
- Solar PV panels (410 kW_p).

Additionally school buildings in a different district in Hillerød have been renovated (3,000 m²).

Monitoring approach

The common approach is based upon guidelines given by the CONCERTO programme. Essentially they recommend data collection on a monthly basis, both of energy consumption and renewable energy generation, combined with information about energy costs. This paper focuses on the performance of dwellings and the neighborhood energy system. Costs will not be discussed.

MONITORING APPROACH APELDOORN ZUIDBROEK

Monitoring of the individual dwellings (EPC=0.8) is based on energy demand for space heating and domestic hot water (DHW), thus the energy provided by the district heating system. Electricity use has not been included in monitoring because no specific electricity saving measures are being implemented. Electricity generated by the PV panels is estimated on the basis of default values.

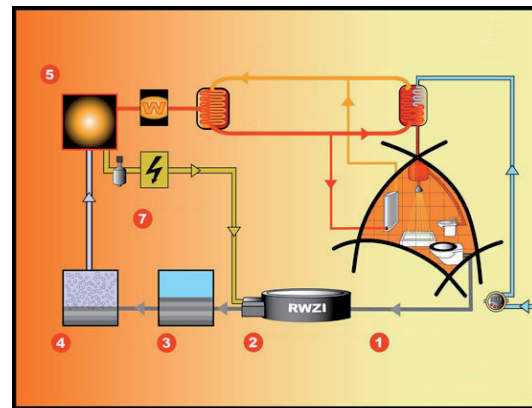


Figure 1. Zuidbroek energy system.

In the Netherlands energy consumption data can only be used for billing, unless the resident gives permission to use the data for different purposes. To overcome privacy issues, letters have been sent to the inhabitants asking them permission to use their data for analysis purposes. For the households that gave permission, energy data have been analyzed in combination with household characteristics, dwelling size, family composition etc. For the other households, heat consumption has been measured, but it is only available in an anonymised database, meaning that it cannot be ascribed to specific dwellings or households.

The district heating company has monitored the heat-use of all dwellings eight times a year, excluding the summer months. Data was collected using a car containing a radio transceiver. This for the Netherlands relatively novel way of data collection appeared to suffer from some problems, which resulted in faulty or missing data and limited the total amount of useful data. In the end, the aggregated data were available for several hundreds of dwellings. In order to assess the overall performance of the district (improving the EPC=0.8 to an EPC=0.64), we looked into more detail at the district heating system. In this context, especially the source of the heating energy is important, as well as the system losses. Three sources for heating are relevant for Zuidbroek:

- biogas from the sewage digesters
- natural gas (for peak boilers)
- biomass (in this case woodchips) for peak boilers.

In Zuidbroek, the desired 20 % better performance for dwellings is realized by having a high “equivalent generation efficiency” (EGE) for heat. This is necessary as the dwellings’ envelopes energy performance does not exceed national regulations (EPC=0.8), so the improvement needs to come from the heating system. The EGE compares the efficiency of the district heating system to that of a reference condensing boiler. Essentially it tells how much fossil energy is being used compared to the amount used in the reference boiler.

As heat is not the only component in the calculation of the energy performance of dwellings (EPC), there is a complicated relation between the EPC and the EGE. The relation is shown in Figure 2. This graph shows that the EGE of Zuidbroek needs

to be equal to 1.5 or better to establish an EPC for the dwellings of 0.64 (20 % better than 0.8).

MONITORING APPROACH HILLERØD

In Hillerød different methods have been used for monitoring. These range from yearly readings from the utility company in depersonalized data sets over monthly readings from home owners to fully automated data collection systems with resolution between minutes and hours between readings.

Figure 3 illustrates the monitoring data that are desired. In the figure, less than eight meters are considered to be sufficient. They cover monitoring of electricity, water and heating. The principle is to measure the total consumption of each carrier in a main meter (the meter used for billing the customer). The secondary meters are used for monitoring the most relevant energy and electricity flows. In practice, only the three main meters are available for monitoring.

Monitoring results: energy consumption of dwellings

Dwellings have been monitored in both the neighbourhoods of Apeldoorn Zuidbroek and Hillerød. By presenting the data in a similar way, comparison of the results is made easier.

ENERGY CONSUMPTION OF DWELLINGS IN ZUIDBROEK

The performance of the dwellings is determined based on the heat consumption as a main parameter. This is measured as kWh/m²yr final energy. Heat is supplied by the district heating company. Total system efficiency and reliance on fossil fuels per dwelling is influenced by system losses and fuel resource of the district heating respectively. In the analysis we look first at the heat consumed by the individual dwellings.

Figure 4 shows the heat consumption of about 450 dwellings built in the period 2008–2011. Key figures are the average heat demand per dwelling and the spread in the results. All data provided in Figure 4 are corrected for yearly fluctuations

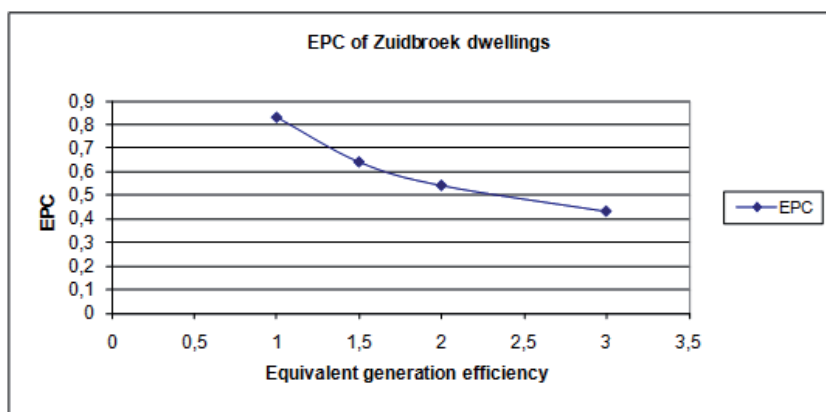


Figure 2. Relationship between EPC and EGE.

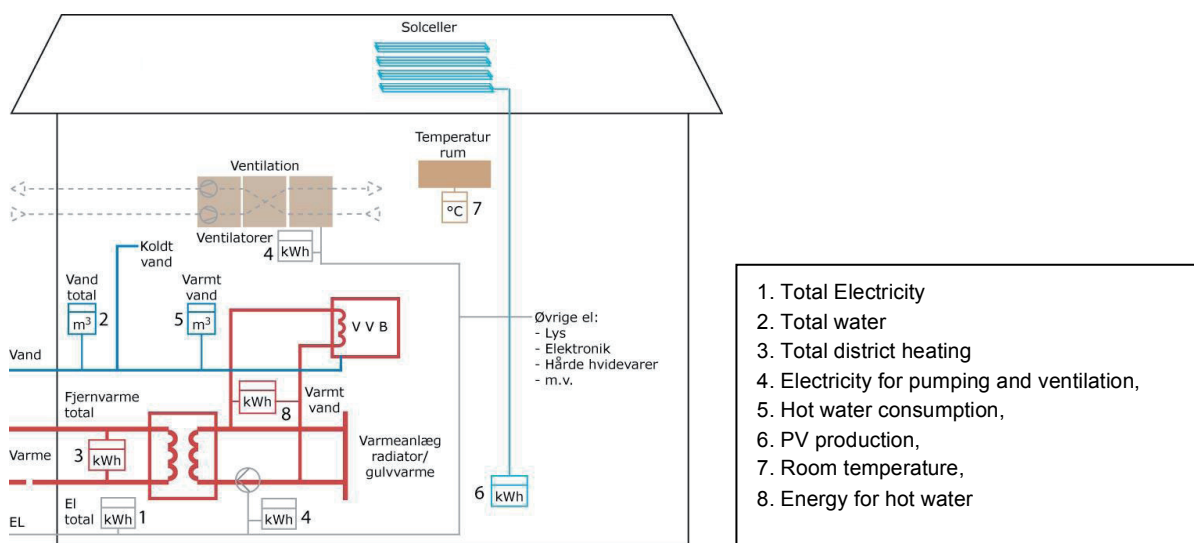


Figure 3. Hillerød monitoring concept, example for building equipped with district heating. Figure in Danish, by COWI as part of the monitoring requirements in the SORCER project.

in ambient conditions through the use of degree days, based on measurements from the nearby Deelen airport. When data were not available for exactly one year, corrections have been made based on the average yearly profile.

Each dot in Figure 4.a represents a dwelling. The average total energy consumption is 27.6 GJ/year. Energy consumption varies strongly between the dwellings. The size of the dwellings also varies (large houses have 2.5 times the gross floor area (GFA) of the smaller apartments), it does not justify the variations measured in heat consumption. Figure 4.b shows the energy consumption per square meter, for the subset of dwellings that gave permission to monitor their heat demand. As explained, all other figures are anonymous, we don't know to what dwelling (types) this consumption belongs.

The average energy consumption of the dwellings in Figure 4.b varies less than a factor 4. This is still a considerable range in energy consumption, but seems to be more reasonable than the

range shown in the previous figure. The average energy consumption per square meter is 53.4 kWh/year.

Not all dwellings were constructed in the same year. Table 1 shows how the average energy consumption for dwellings changes over time. The average consumption of dwellings constructed in the first year of monitoring seems to be more or less constant in the two succeeding years. There is no clear trend (left column: Dwellings since year 1) that the consumption in the first year of construction is considerably higher than in the years after that (while it is always said that the first year cannot be used for monitoring due to the moisture of construction still being partly in the dwelling). This conclusion is supported by the dwellings constructed one year later (dwellings since year 2), for which the average energy consumption seems to increase in the second year instead of decreasing. The last groups of dwellings (dwellings since year 3) have been monitored for only one year.

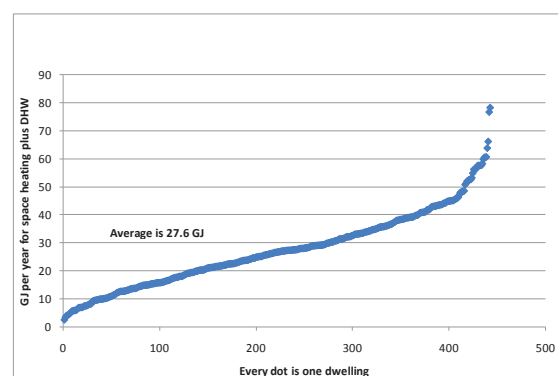


Figure 4.a. Annual heating energy consumption degree days corrected with data from airport Deelen. Consumption in GJ, sorted by increasing consumption per dwelling, May 2011–April 2012. Source: DNV KEMA 78100030-SUS 12-5063.

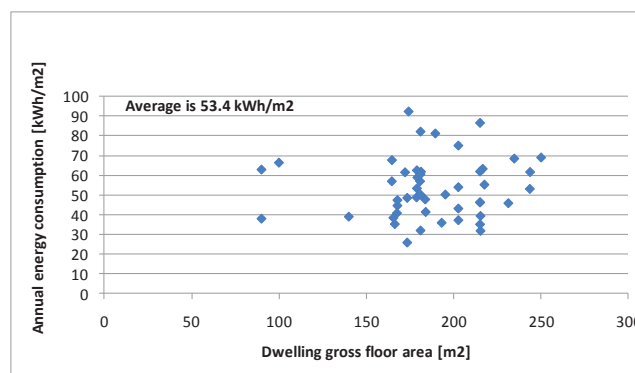


Figure 4.b. Annual heating energy consumption degree days corrected with data from airport Deelen. Consumption in kWh/m², May 2009–April 2010. Source: DNV KEMA 78100030-SUS 12-5063.

Table 1. Energy consumption for dwellings constructed in different years.

Energy consumption in kWh per square meter*year				
Heating season	Dwellings built before May 2009	Dwellings built May 2009-April 2010	Dwellings built May 2010-April 2011	Weighted av.
2009-2010	53,4			53,4
2010-2011	51,3	54,7		52,0
2011-2012	52,2	59,3	43,8	50,7
Amount of dwellings	48	13	31	total 92,0
Energy consumption per dwelling in GJ/year				
Heating season	Dwellings built before May 2009	Dwellings built May 2009-April 2010	Dwellings built May 2010-April 2011	Weighted av.
2009-2010	31,2			31,2
2010-2011	30	26,8		29,0
2011-2012	30,2	25	24,4	27,6
Amount of dwellings	223	99	123	total 445,0

Source: DNV KEMA 78100030-SUS 12-5063.

In general, a few conclusions can be drawn from the data in Table 1.

First is that over the years, more dwellings have been built and became available for inclusion in the analysis. Second is that it is difficult to observe a trend over the years.

COMPARING MONITORING RESULTS

The dwellings in Zuidbroek are constructed with a shell-based performance of EPC=0.8. The 20 % improvement compared to the standard is realized by heat supply by a district heating system (leading to a lower EPC) and by the biomass used to produce the heat (leading to an additional decrease in EPC). As the 20 % improvement is based on energy saving measures outside the dwelling, the final energy demand for space heating and hot water of the dwellings in Zuidbroek should be comparable to that of dwellings with EPC=0.8.

Reference dwellings in the Netherlands with an EPC of 0.8 have a calculated annual natural gas consumption of about 800 m³, but in reality they use 1,100 m³. One of the aims of this study is to compare the actual (monitored) consumption of the dwellings in Zuidbroek, with the actual consumption of dwellings that comply with the EPC=0.8 standard. Figure 5 shows the level of expected gas consumption in relation to the EPC value. This figure shows the nominal (and real) gas consumption of dwellings with an average GFA of about 198 m². An actual consumption of 1,100 m³ results in a specific final energy (heat) consumption of about 49 kWh/m². In Table 1 we have seen that for 2011–2012 the average heat demand for the 92 dwellings is 50.7 kWh/m². This is slightly higher than the 49 kWh/m² found in similar buildings. It can be concluded that the energy consumed in the dwellings is higher than the theoretical energy consumption, but is comparable to the actual use of other houses with EPC=0.8.

ENERGY CONSUMPTION DWELLINGS HILLERØD ULLERØDBYEN

In Figure 6 the measured consumption for heating and domestic hot water is shown for the roughly 60 single-family dwellings that were connected to the new district heating network in Ullerødbyen in the heating season of 2008–2009. The data are corrected for degree days. The monitored consumption was the consumption of the first year in the new dwellings. This value is normally expected to drop by around 20–25 % for the next year. The houses are built according to the standard building code, which has a calculated heat consumption of around 78–80 kWh/m².

As of 2012, around 250–300 dwellings have been constructed in Ullerødbyen. Data is currently being updated, but no newer data are currently available. The average energy consumption of the dwellings falls in the interval of the theoretically expected consumption. However, consumptions 50 % lower and 50 % higher also have been monitored in individual dwellings.

Figure 7 shows data from a group of 13 low-energy houses, whose nominal energy consumption is at least 25 % below the building code value. For each dwelling the energy consumption for heating, hot water and electricity for pumps and ventilation is shown. This is the consumption which is included in the building code requirements as the so-called energy frame. As it can be seen most of the dwellings have higher consumption than allowed. This is indicated by the solid line, which shows the allowed energy frame for a building 25 % below the

building code value. The data is shown as primary energy to allow for comparison to the building code. This means that all electricity consumption has been multiplied by 2.5. Four of the dwellings are heated by district heating, while the remaining are heated by heat pumps. Dwellings heated by district heating have slightly higher consumption than the dwellings heated by heat pumps. Data are still inconclusive for two houses, and therefore these are not shown.

Figure 8 presents data for the 86 low energy class 1 houses. These are heated by exhaust air heat pumps. These have unfortunately proven to be very energy inefficient and present a number of problems in terms of user satisfaction.

The figure shows that the electricity consumption for heating with heat pumps is on average 46 kWh/m². This is about twice the expected value from the design. There are a number of reasons for this, amongst which are: poor air-tightness and too small heat pumps that have to rely on the electric backup too much. While the final energy consumption for heating, domestic hot water and building operation is fairly low, which indicates that the buildings have low heat losses, the fact that the Danish building code operates using primary energy, where electricity has a factor of 2.5, means that the primary energy consumption is two to three times higher than the expected consumption based on the tool under the Danish building code requirements.

Monitoring results: energy system performance

ACTUAL PERFORMANCE ENERGY SYSTEM: APELDOORN ZUIDBROEK

The performance (EGE) of the district heating system is monitored on a monthly basis. Most recent results (month 1–month 12 in 2012 and January 2013) are shown in Figure 9.

The EGE should be equal or better than the desired value of 1.5. This value can be reached with sufficient heat generation from biomass sources and limited energy losses. Until September 2012, the month in which the woodchips boiler became operational, this value had not been reached yet. The October 2012–January 2013 performance concerning the situation with the two 1.4 MW woodchips boilers is as desired. Actual performance depends on weather conditions in general, more specific on heat buffer size, variability of the temperature and wind. Biomass peak boilers with a capacity to cover all conditions are oversized most of the time and therefore not economical.

ACTUAL PERFORMANCE ENERGY SYSTEM: HILLERØD

There are to date no monitoring data available to determine the overall energy performance of the district in Hillerød.

Socio-economic analysis and satisfaction

APELDOORN

A survey (S1) was launched at the start of the project, when people entered their new homes. The main aim of this survey was to determine the households' situation before they moved to their new homes and their expectations for their new homes and the SORCER area. Also, the characteristics of the households were collected. A second survey (S2) was held when people had lived in their homes for one year or more. With this

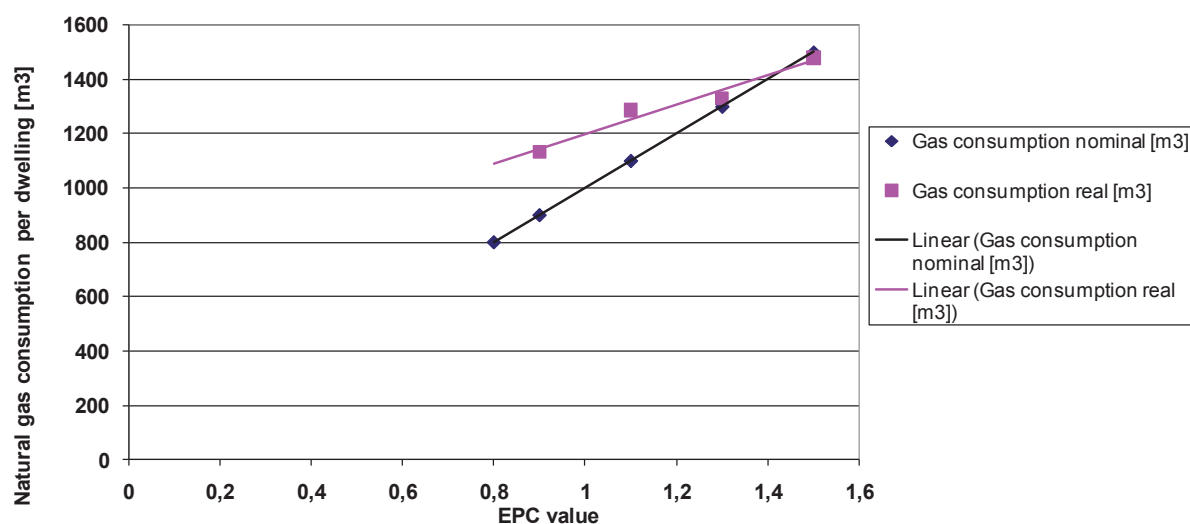


Figure 5. Evolution of natural gas consumption per dwelling in The Netherlands (heating and DHW) versus EPC. Source: DNV KEMA, based on figures from (Ecofys 2004).

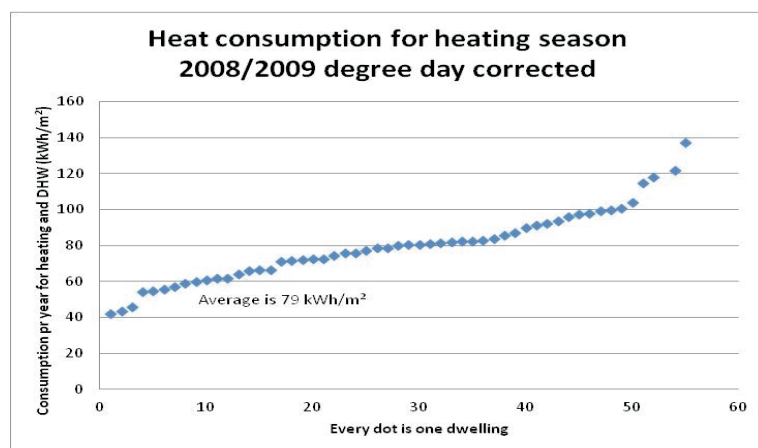


Figure 6. Heat consumption in standard dwellings in Ullerød. First year of operation shown, final data expected to be much lower.

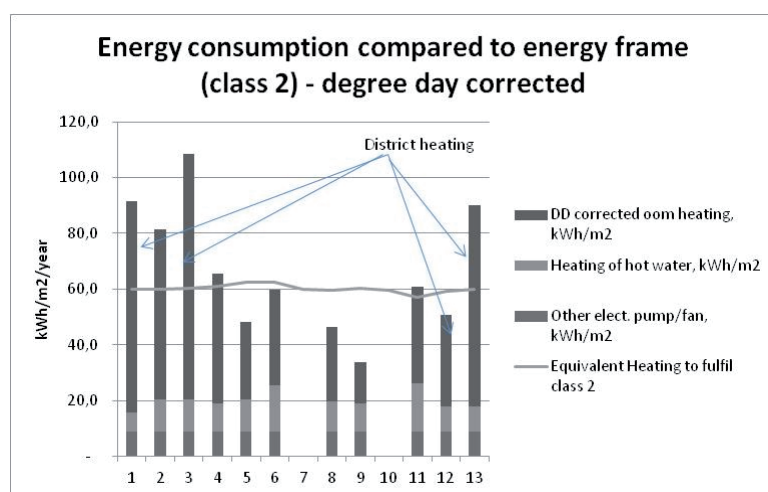


Figure 7. Heat consumption in low energy houses.

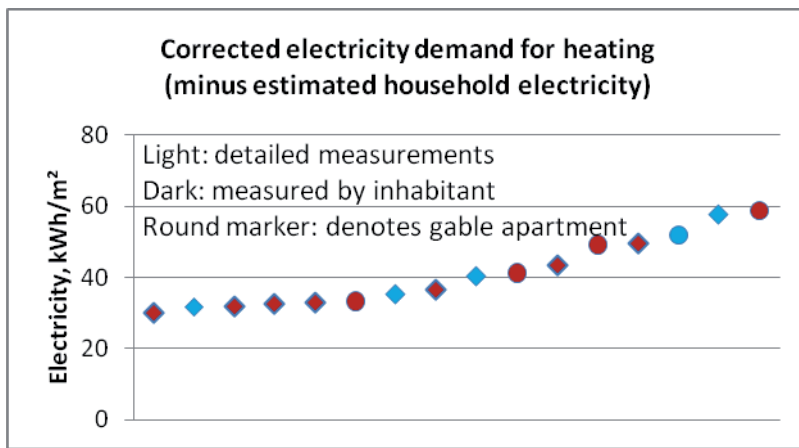


Figure 8. Heat consumption in low energy class 1 dwellings heated by an exhaust air heat pump.

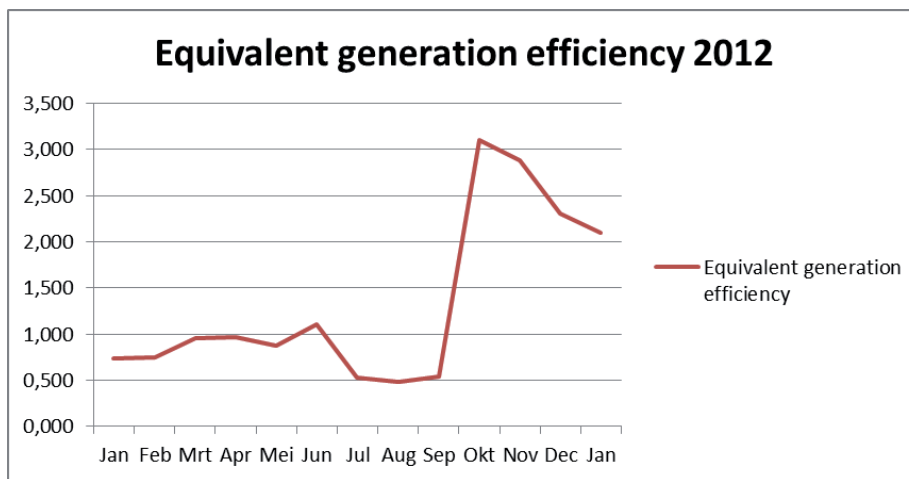


Figure 9. EGE of the district heating system.

survey the impact of the SORCER project were determined. In addition this survey was used to evaluate the Energy Conservation Stimulation program in Apeldoorn.

For a group of 91 households that gave permission to use their energy data and filled in the questionnaires, the data on heat demand was linked to the survey data. Their average heat demand (from May 2009 to April 2010) was 33 (+29) GJ. This figure is higher than the average consumption of each of the three construction periods indicated in Table 1.

Within this group of 91 households, 41 households answered the questions whether they are satisfied with the energy costs, living comfort and indoor climate in their new house.

A significant correlation was found between “heat demand and satisfaction with energy costs” ($r=-0.58$) and between “heat demand and living comfort” ($r=0.36$). The negative sign of the correlation between satisfaction with “energy costs and heat demand” makes sense, as it shows that people are more satisfied with energy costs when their heat demand is low. The other correlation shows that people become more satisfied with the living comfort when the heat demand is high.

Between “heat demand and energy attitude” and “heat demand and energy behavior” no significant correlations were found.

Within this group of 91 households, 27 gave information about the amount of natural gas they used in their previous houses. For these 27 households the average heat demand in Zuidbroek was 33 GJ, i.e. as far as heat demand is concerned they are representative for the group of 91 households. The average heat demand in the previous house was 43 (+28) GJ. For these 27 households it can thus be concluded that on average the heat demand in the Zuidbroek is 23 % lower than the heat demand in their previous houses. However, no information was available about the size (m^2 or m^3) of their previous houses. In Figure 10, the heat demand in the previous houses is compared to the heat demand in the Zuidbroek dwellings, for these 27 households. It is interesting to see that the households show less spread in heat demand in the Zuidbroek dwellings than in their previous houses.

In a further step, the individual change in heat demand, i.e. the difference between heat demand in the previous house and

the Zuidbroek house was calculated and related to the satisfaction with energy costs, living comfort and indoor climate in the Zuidbroek house.

The individual “energy saving” only shows a significant correlation ($n=15$, $r=0.62$) with the satisfaction with energy costs. Figure 11 shows the relation between satisfaction with energy costs and energy saving (compared to the previous house)

It is interesting to see that people who rent (1) are saving energy and are satisfied with the energy costs, whereas people who own their house are using more energy and are not satisfied. They probably have bought a larger house than their previous one. Although it is more energy efficient it apparently uses more energy.

Figure 12 is based on survey S2 and shows that the inhabitants of Zuidbroek were on average more satisfied with certain aspects than with others. Especially living costs and energy costs scored on average lower. Aspects regarding the house scored on average somewhat higher; e.g. the house itself.

SOCIO-ECONOMIC ANALYSIS ULLERØDBYEN

In Ullerød it was decided not to perform a general survey of the entire area as in the case for Apeldoorn. Instead two surveys were conducted in the low energy class 1 houses. This was due to the fact that it quickly proved that the inhabitants had problems concerning their satisfaction with the dwellings.

Figure 13 shows data from the first survey. There is a high satisfaction with daylight conditions, indoor air quality and apartment standard. However, both space heating and domestic hot water has a high score of dissatisfaction. The comments of the residents with respect to space heating and domestic hot water revealed that if it was cold outside, the heat pump could not maintain 20 °C indoors. And also that it took a long time to heat the dwelling. Concerning domestic hot water there simply was too little hot water for large families.

A second survey conducted one year later showed the same general trend, but fewer respondents were very dissatisfied with the space heating.

The survey also contained two questions concerning the experienced consumption/cost of electricity together with the actual stated consumption.

In Figure 14 ideally the persons with low actual consumption should perceive that they have low costs/consumption. However it can be seen that there are a number of respondents who have a low consumption, but consider it to be very high. It should be noted that the consumption is based on the stated values in the survey and not actual consumption data, so there may be inaccuracies in the consumption data. A reason for the findings could be that many of the inhabitants came from a dwelling where they paid heating and electricity separately. In fact in most cases the heating was paid as a part of the rent in

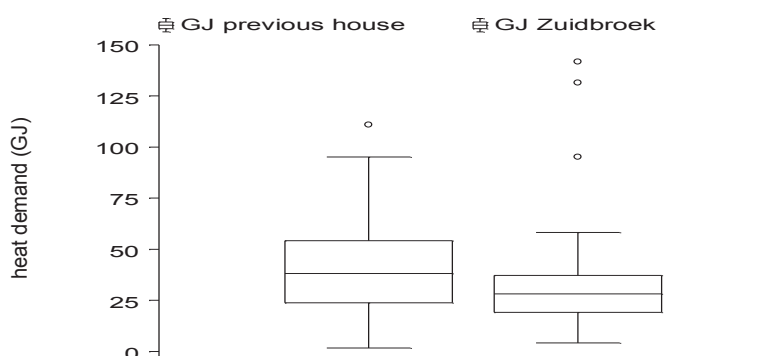


Figure 10. Box plots of the heat demand in previous houses and Zuidbroek dwellings, for 27 households.

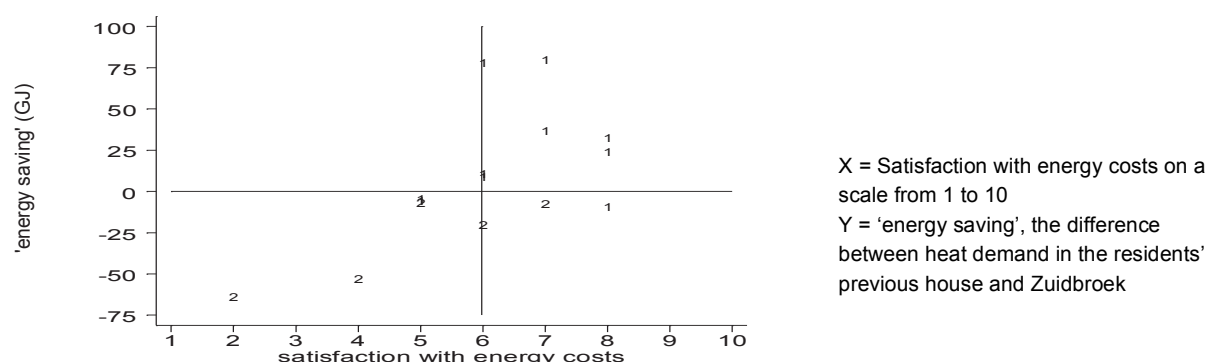


Figure 11. Scatter plot of the savings in heat demand against satisfaction with energy costs, for people who rent (1) and house owners (2).

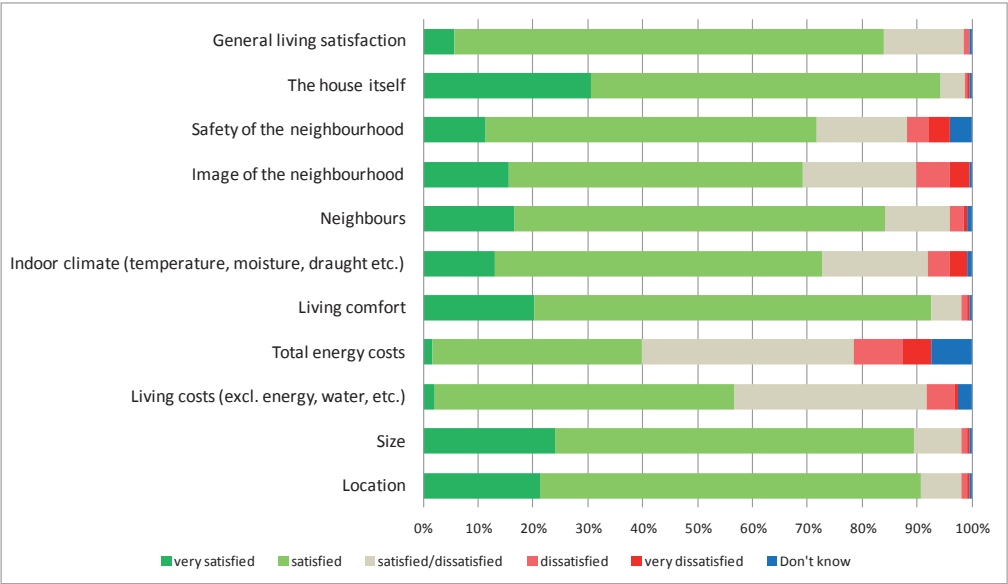


Figure 12. Living satisfaction in Zuidbroek (n=243).

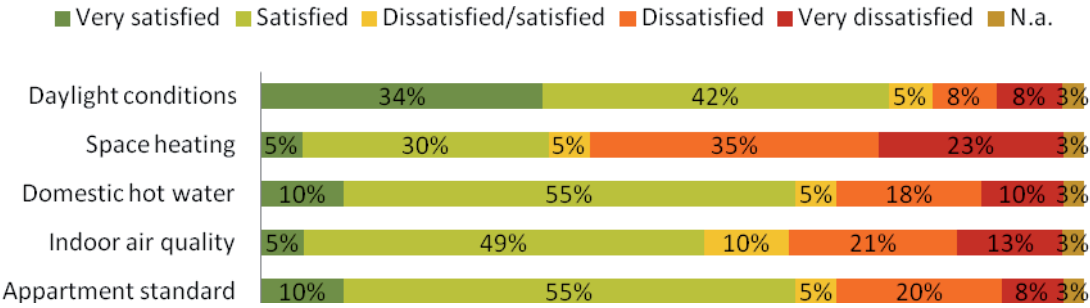


Figure 13. User satisfaction in low energy class 1 apartments in Ullerød Q1 2010 (n=24 or 28 %).

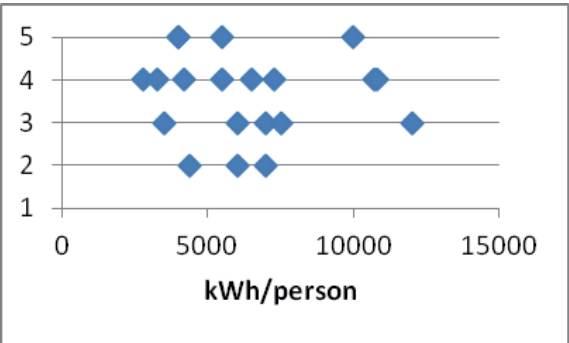


Figure 14. Assessment of actual electricity consumption vs. perceived (stated) consumption (scale 1–5, 1=very low, 5=very high).

their previous apartments. Now they pay separately for electricity consumption, which has increased to a much larger consumption, as it also includes heating. This may lead to a feeling that the consumption is in fact higher than it really is.

Conclusions and recommendations

First of all, both projects show that the district dimension indeed provides new energy optimization possibilities, such as connection to a district heating system, (partly) running on renewable energy. However, a more integrated approach is also more difficult to realize when circumstances require project changes. Therefore it is recommended to work with solutions that can be realized in phases. Furthermore, the energy performance of the dwellings (use of fossil fuels) depends in the case of an integrated approach on system efficiency, such as distribution losses in case of a district heating system.

In both projects the new dwellings lead to higher average energy consumption than expected from calculations. However, this is not surprising, as it is also found in other projects, especially projects with more efficient dwellings (Boerakker et al. 2012). The actual energy consumption for dwellings in Zuidbroek (without taking into account system efficiency) turns out to be similar to that of other dwellings with an EPC of 0.8. Together with the district heating performance now the wood chip boilers are operational, the desired EPC of 0.64 is met.

The socio-economic analysis in Zuidbroek shows that people are more satisfied with energy costs when their heat demand is low. The analysis in Hillerød shows that there is no clear link between perceived level of electricity consumption and actual consumptions (households with low consumption levels still consider consumption to be high). Additionally, the satisfaction surveys in both towns show that residents show higher levels of dissatisfaction on energy (energy costs in Apeldoorn

and space heating in Hillerød) than on any other items. Overall it can be concluded that it is important to inform residents well about what energy consumption they may expect (not just based on calculations, but realistic consumption based on similar dwellings). On the other hand it is important that in new efficient dwellings lessons from other similar projects are taken into account, to prevent mistakes such as too small capacity of heating systems.

Overall one could say that the SORCER project delivered, apart from showcasing several approaches to low-carbon neighbourhoods:

- Better insight into the critical parameters of popular approaches to low-carbon heating, i.e. district heating and air to air heat pumps.
- Improved understanding of residents perception of energy cost.

References

- Ecofys, 2004. "Evaluation climate policy built environment 1995–2002".
- Boerakker, Y., and Stoops, J. (2012). "Building Energy Standards Can Fail to Deliver Expected Savings".

Glossary

CHP	Combined Heat and Power
E2BA	Energy-efficient Buildings Association
EBPD	Energy Performance of Buildings Directive
EGE	Equivalent Generation Efficiency
EPC	Energy Performance Coefficient
DH	District Heating
FP	Framework Programme
PV	Photo-Voltaics