Energy neutral living in Amsterdam, Lyon and Helsingborg: practical results and household assessment

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Abstract

In anticipation of the 2020 target in the EU Energy Performance of Buildings Directive, several European cities are experimenting with 'nearly zero energy' (NZE) buildings in newly developed city districts. As stipulated by earlier research, such plans include a combination of well insulated dwellings, smart local grids and local production of renewable energy. In the EU 'Next-buildings' research project, NZE building examples from Amsterdam (the Netherlands), Lyon (France) and Helsingborg (Sweden) are brought together and compared.

Common to the three building projects are high insulation standards and solar PV as source of local renewable energy. Amsterdam 'Blok 0' and Helsingborg Kvarteret Isbanan are connected to local district heating, while the Lyon 'Hikari' building has a rapeseed boiler and includes an advanced energy management system. Special features are district cooling in Amsterdam and a façade PV system in Lyon. The first residents arrived in 2015 in Hikari and the first lots of Amsterdam, while full occupation was reached by mid-2016.

As part of the Next-buildings project, we are monitoring the energy use of residents and investigate their experiences. Monitoring includes both total energy use and net energy use, including renewable production in/on the building. Reported residents' experiences relate to motivations to move into the new neighbourhoods, their perceptions about positive and negative qualities of their new dwellings, and whether they make active use of smart energy devices. This information is collected through surveys and focus group meetings.

The paper describes the results of the monitoring exercises in the three city districts, the challenges faced and resident's proposals for improvement. We conclude with lessons learned, presenting good practices for future city planning. The EU requirement is the development of buildings with a final energy use of less than 60 kWh/m^{2}yr (building bound energy, this is space heating + domestic hot water +fixed value for electricity. This may differ slightly for the various countries). Helsingborg and Amsterdam show results of about 32 and 43 kWh/m^{2}yr, respectively. For Lyon, this value is 37 kWh/m^{2}yr for dwellings (space heating, DHW) and 24 kWh/m^{2}yr for offices (space heating and cooling).

Introduction and background

Europe is heading for energy-neutral new build by 2020. In order to achieve this ambitious goal, several support and research programmes have been set up. Concerto (http://smartcities-infosystem.eu/concerto/concerto-archive) projects from 2005-2013 aimed at improving the energy performance of refurbishment projects as well as new build above the national building standards and the European Performance of Buildings Directive set the stage for gradual improvement of national standards for new build in parallel. In response to the building and financial crisis from 2008, within FP7, a Public Private Partnership approach has been set up. Under this approach the EU has defined, together with the construction sector, programs in various areas. These range from e.g. smart façade development to refurbishment of listed (historical) buildings.

The NEXT-Buildings project has been set up in response to an EU call for demonstration of very low energy buildings and started on 1 January 2012. This project brought together examples from Amsterdam (The Netherlands), Lyon (France) and Helsingborg (Sweden) and compared them. Similar projects from the same call are Direction (www.direction-fp7.eu), NEED4B (www.need4b.eu) and Buildsmart (www.buildsmart-energy.eu).

- Direction focuses on the demonstration of very innovative technologies
- NEED4B focuses on the design process
- Buildsmart focuses on exploitation and market deployment of the solutions
- NEXT-Buildings focuses on the affordability of the solutions

The paper is structured as follows. First, it explains the technical approaches to nearly zero energy buildings that have been chosen at the three locations. Second, it presents the results of the technical monitoring, Third, it reports on the experiences of the residents in the new dwellings. The final section presents conclusions.

Technical approach to very low energy buildings (NZEB)

COMMON APPROACH

The EU required for the demonstration project an energy consumption (building bound) that is better than 60 kWh/m^{2}yr (final energy). In addition to a high energy performance, the EU was looking for affordable and replicable solutions. The three demo sites joined forces yet they have their local solution for the energy and affordability goal. The case studies will show how the approaches turned out in reality, with respect to performance and user appreciation.

AMSTERDAM HOUTHAVEN BLOK 0

The target for building-bound energy consumption was set at about 25 kWh/m^{2}yr. Not entirely climate neutral, as will be the target for the future parts of the Houthaven, but ambitious enough to be challenging. In order to provide freedom of choice for inhabitants in their selection of energy saving measures, the municipality developed a "menu" from which future inhabitants could choose. See the picture in Figure 1.

This approach led to a situation that different combinations of measures could lead to the desired ambition level. (The result should lead to an energy consumption that is less than 50 % of what is in the building regulations of that time. Among the choices residents could select were:

- Triple glazing (U<0.7)
- Shower heat recovery system
- Solar panels
- Low temperature district heating
- Hot fill connection
- CO_2 controlled ventilation/Heat recovery ventilation
- A heat flux resistance of Rc 6 to Rc 8 m^{2}K/W

HELSINGBORG KVARTERET ISBANAN

Kv. Isbanan contains a wide range of technologies and measures that are all an environmental initiative for the area and the project. Kv. Isbanan is a low energy project with a building-bound energy requirement of less than 43 kWh/m².

The project, comprising of 111 apartments in three buildings, have windows with a U-value of 0.9 W/m^2°C. This is significantly lower than the current standard (1.2 W/m^2°C). The buildings are also equipped with solar cells (148 m^2), solar thermal collectors (60 m^2) and collective heat exchangers on downpipes located in basements for heat recovery from wastewater from kitchens and bathrooms. To reduce water consumption, low-flow fixtures have been installed. This should lead to an annual water saving of 34 % compared to traditional installations (product information sheet[1]). For ventilation, a fan aggregate with an SFP of 1.23 kW/(m^3/s) and heat recovery is installed. Only one unit per apartment building is needed. An elevator has been installed that complies with the best energy class. While all appliances are classified for its attention to the environment, Kv. Isbanan uses appliances which almost all are certified as "Green Technology Inside".

To assist the existing area with innovation and to help solving a maintenance problem, the block has been equipped with a new waste system with nine different fractions for a wide range of waste separation. The system fractions are available from the public area and continues underground in large containers in order to reduce emptying.

LYON CONFLUENCE HIKARI

Based on the feasibility study (see ref. Herzog & de Meuron) on a piece of land of 3.380 m^2 referenced P block, the public company in charge of the Lyon-Confluence urban project, set up the environmental and energy targets of a 12.000 m^2 building composed of dwellings, office places and shops. Thanks to the financial support expected within the NEXT-Buildings project, the energy performance requirements of this building has been improved compared to what has been achieved for recent buildings of this area and was set at a very ambitious level: make this building a positive energy building.

More precisely, this objective was defined as the following: the positive energy balance of the plot over the year shall consider the whole energy consumption and not the heating consumption only and shall be calculated with the yearly primary energy consumption and the yearly primary energy produced by this building. See Figure 2.

This energy performance target and the primary energy factors to be used have been included in the environmental guidelines used for the international competition that took place in 2011 to select a developer for the design and the construction of this building. The winner of this international competition was the proposal called HIKARI (see ref. Bouygues Immobili-

1. http://www.moraarmatur.se/vara-produkter/koksblandare/mora-mmix/mora-mmix-k2/mora-mmix-k2/

Menukaart Klimaatneutrale Zelfbouw

Wil je met me bouwen?

Omcirkel het aantal punten dat overeenkomt met uw antwoord, één antwoord per vraag mogelijk

Vraag	Antwoord	Punten	Score
1. Isolatie	Standaard: Rc < 5	0	
Hoe goed isoleert u uw huis in vergelijking met een	Iets beter: Rc ≥ 5	5	
standaard nieuwbouwwoning?	Veel beter: Rc ≥ 6	6	
Het gaat om de minimale Rc-waarde (zie toelichting), waaraan	Zeer veel beter: Rc ≥ 7	7	
zowel gevel, dak als vloer voldoen.	Bijzonder veel beter: Rc ≥ 8	8	
2. Glas	Dubbelglas met U > 1,0	0	
Welk soort glas past u toe?	Dubbelglas met U ≤ 1,0	2	
Het gaat om de maximale U-waarde (zie toelichting).	Drievoudig glas met U ≤ 0,7	4	
3. Ventilatie	nee	0	
Past u CO2-gestuurde ventilatie toe en/of WarmteTerugWinning balansventilatie?	ja	4	
4. Verwarming	nee	0	
Brengt u voor uw hoofdverblijven in de woning vloerverwarming en/of wandverwarming aan in combinatie met stadswarmte of warmtepomp?	ja	6	

Figure 1. Amsterdam Houthaven Climate neutral building menu.

er) lead by an association from Japan. In order to reach the positive energy target, this team decided to:

- Build a low energy consumption building with a high-performance envelope,
- Use PV to generate renewable power on-site (PV façade and roof-top) (see ref. HIKARI),
- Use a rapeseed oil CHP system to provide renewable heat and power on-site,
- To use many other design techniques and systems to reduce the energy consumption of this building (like phase change materials for heat storage).

Monitoring results

COMMON APPROACH AND LIMITATIONS

The common approach is based upon guidelines given by SCIS (Smart Cities Information systems, http://smartcities-infosystem.eu/), that assists with dissemination of results from smart cities and energy-efficient buildings programmes. Essentially, they recommend data collection on a monthly basis, both of energy consumption and renewable energy generation, combined with information about energy cost. Minimum envisaged monitoring period is one year to ensure the buildings are monitored during all seasons. It is recognized that in general, buildings perform better after the initial couple of months is which evaporation of residual water in the construction material consumes a significant amount of energy. Energy consumption may therefore decline in future years. This paper focuses on the performance of dwellings and the neighborhood energy system. Costs will not be the focus of this paper.

AMSTERDAM HOUTHAVEN

Technical monitoring

Equipment and Process

Monitoring of the individual dwellings (being designed as climate neutral according to the approach of Amsterdam) is based on energy demand for space heating and domestic hot water (DHW), this energy is provided by the district heating system in the area. Electricity use has also been included in the monitoring. Detailed electricity production by the PV panels is based on data from a selected number of houses. These households have the panels connected to their dwellings "behind the meter". For other blocks, aggregate values of larger systems are collected from another supplier. Based on earlier experience, see e.g. eceee paper 3-060-13, the method of choice for data collection is based on making use of the available smart meters in this new-built area. Heat poses a particular challenge, as commonly used meters do not have a remote readout.

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. The response was sufficient, about 60 households out of 232 indicated their willingness to participate. For the households that gave permission, energy data have been analyzed in combination with household characteristics, dwelling size, family composition etc.

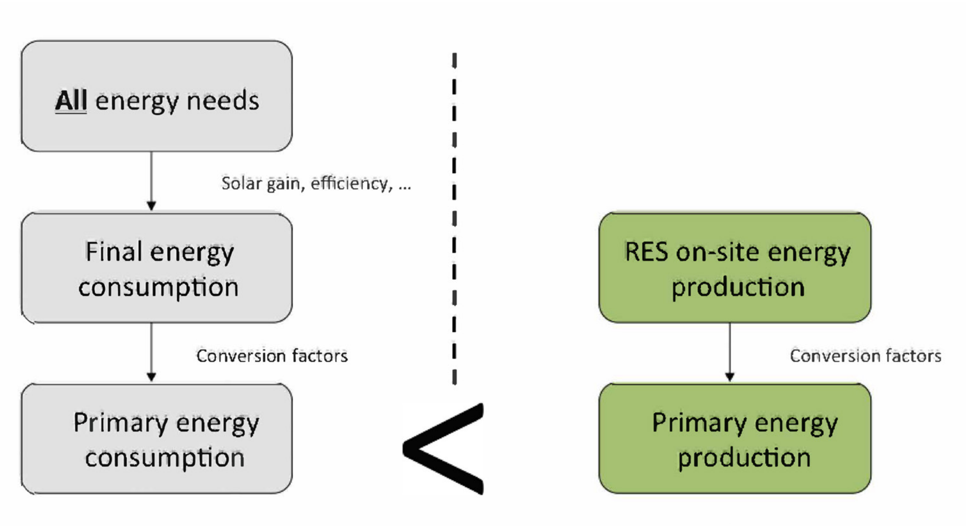


Figure 2. Definition of the positive energy target.

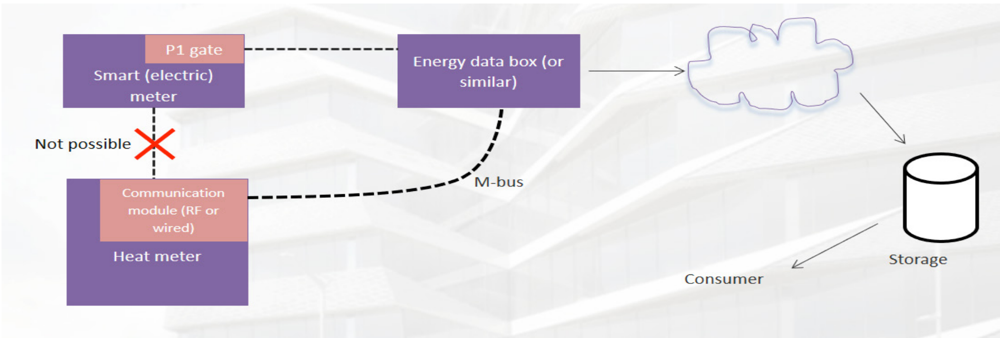


Figure 3. Approach for Amsterdam Houthaven household energy consumption data collection.

The various constraints led to an approach where participating households receive an internet-connected energy data box (EDB). This device is connected to the P1 port of the smart meter and via M-bus to the heat meters. The solution is graphically shown in Figure 3. PV output is directly measured by the EDB. Through cost and organizational issues, eventually, 30 households were equipped with this solution in 3 batches of 10 (November 2015, May 2016 and October 2016). In this paper focus is on the first and second batch.

Apart from the data logging capabilities, inhabitants can also make use of the device through an app, that enables to monitor their electricity consumption near real-time (10s refreshment rate). This enables them to easily learn about the energy consumption of their appliances.

Results

Envisaged monitoring time for the buildings is at least one year. A full year of monitoring is reached for the "Pakhuis" and "My Loft" lots in Blok 0. For these, monitoring started December 2015. The monthly heat and net electricity consumption data that are shown in Figure 4 (anonymous), reflect the actual metered values in kWh final energy. The electricity consumption graph includes the data for the second batch of monitored dwellings starting from June 2016, but no final conclusions for these dwellings are yet possible. The graph clearly shows that for larger dwellings the electricity consumption is also higher. For monthly heat consumption, the data are presented in a graph with degree days on the horizontal axis.

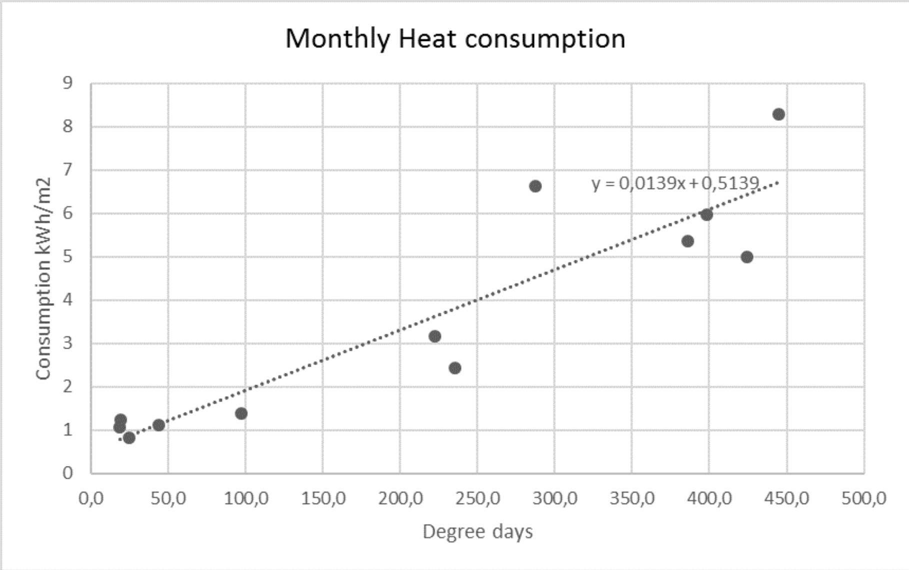
In this way it is possible to separate DHW consumption from space heating. (The slope of the curve represents the thermal performance of the dwellings related to space heating. The vertical axis cut-off is an estimate of the DHW energy consumption).

A few conclusions can be drawn for the Pakhuis and MyLoft dwellings:

- Building bound energy consumption: 43 kWh/m^2 (heating+50 % of electricity[2] , degree days corrected).
- DHW energy consumption: about 25 % of total heat consumption.
- Electricity consumption is rather flat over the year. If PV is connected behind the meter, a clear reduction in electricity demand can be observed in summer.

These results show that the building bound energy consumption is higher than originally envisaged, but significantly lower than the energy consumption of dwellings built to building standards. It is further to be noted that the heat is produced by a CHP from the waste incineration facility of Amsterdam.

2. The 50 % of electricity is the common estimation for building bound electricity in The Netherlands.



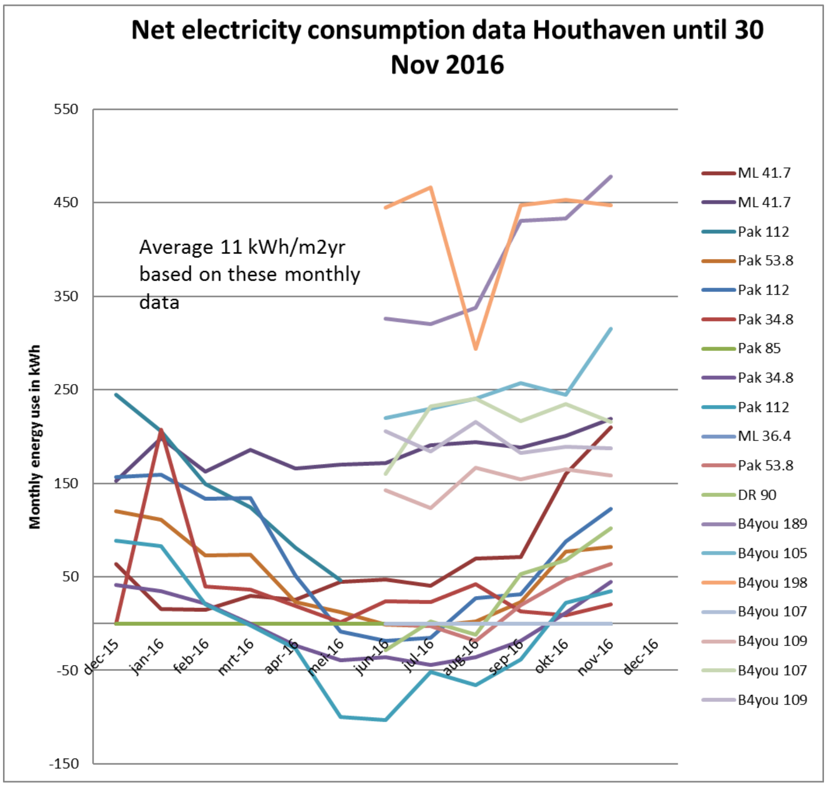


Figure 4. Heat and net electricity consumption for Blok 0, lots are ML (My Loft), Pak (Pakhuis), DR (De Rede) and B4you (Building4You). The figure behind the building indication in the legend shows the gross floor area in m^2.

Their fuel is regarded as 50 % organic which means a significant saving on fossil energy use.

For a limited number of dwellings in Pakhuis, the PV production was measured on an individual household level. The results are shown in Figure 5. It shows the common yearly curve. The particularly cloudy month June can be observed. Overall yearly yield of the Pakhuis solar panels is 630 kWh/kW$_p$. This relatively low figure can be explained by the fact that the design has maximized the total production of solar electricity rather than optimization of the production per panel. 36 kW$_p$ has been installed on a projected horizontal surface of 256 m^2. This is 140 W$_p$/m^2 of roof surface!

HELSINGBORG KVARTERET ISBANAN

Technical monitoring

Equipment and Process

The energy consumption in Kvarteret Isbanan is monitored for the three buildings separately. The meters have remote readout and an energy management system.

Moreover, the indoor air temperatures are monitored in the staircases, the roof apartments and in every apartment of the buildings. The temperature of the fluid in the wastewater heat recovery unit before and after the heat recovery is also measured.

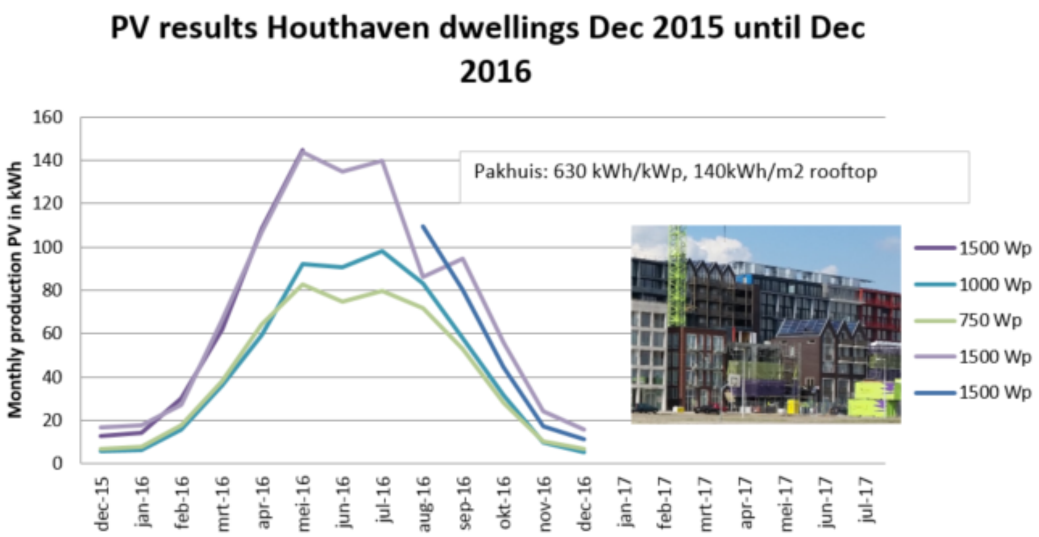


Figure 5. PV production of individually measured dwellings with different PV capacity.

Table 1. Overview of monitored parameters in Kvarteret Isbanan.

Building 14	Building 15	Building 16
Space heating (actual and climate normalised), kWh	**Space heating (actual and climate normalised), kWh**	**Space heating (actual and climate normalised), kWh**
Electricity, kWh • Common installations • Pumps etc. • Ventilation • Households	Electricity, kWh • Common installations • Pumps etc. • Ventilation • Households	Electricity, kWh • Common installations • Pumps etc. • Ventilation • Households • PV production and export • Lift
Water • Total hot water, m³ • District heating for hot water, kWh • Solar heating production, kWh • Waste water heat recovery, kWh • Circulation loss, kWh	Water • Total hot water, m³ • District heating for hot water, kWh • Solar heating production, kWh • Waste water heat recovery, kWh	Water • Total hot water, m³ • District heating for hot water, kWh • Waste water heat recovery, kWh

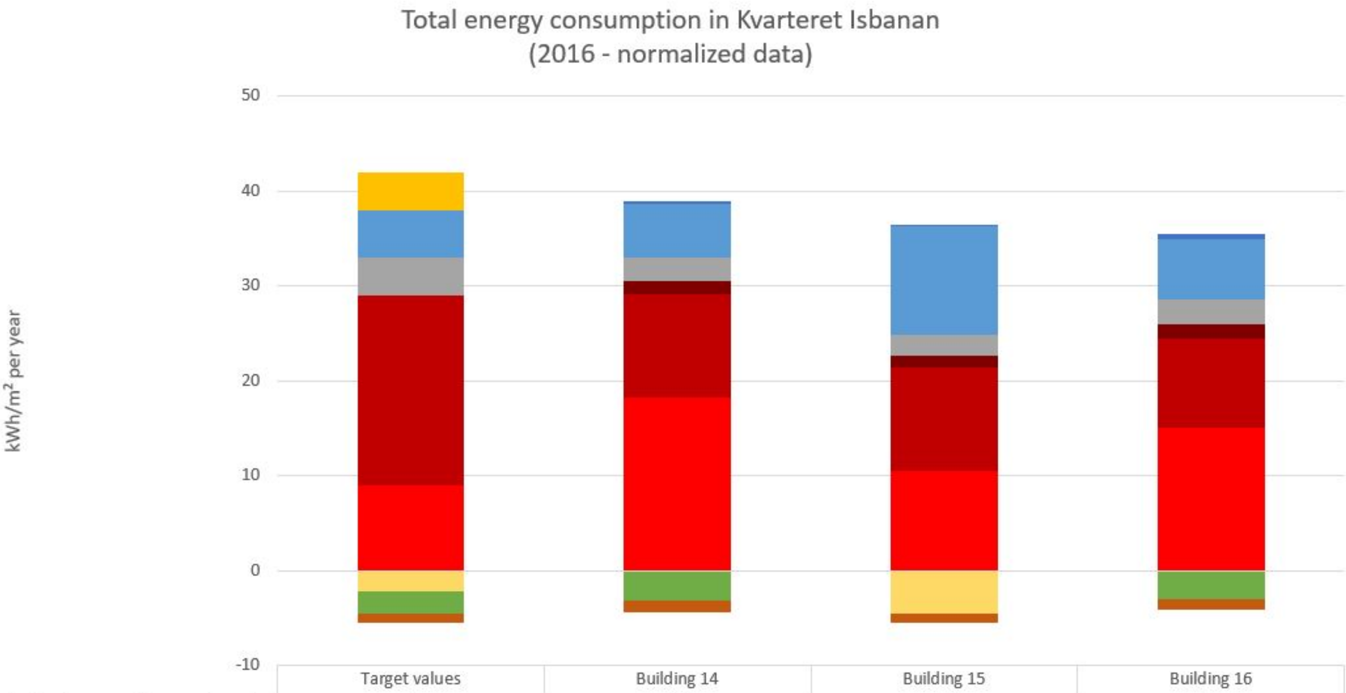
The housing company has decided not to charge the inhabitants for space heating in the first year of the rental period because of commissioning. When the system is complete, the inhabitants are supposed to pay for the space heating according to the indoor air temperature that they are keeping. Included in the rent is an indoor air temperature of 21 °C and if the resident keeps a lower temperature, money will be returned and if the resident keeps a higher temperature an additional charge is added.

Results

The first inhabitants moved into building 14 in December 2015 and into building 15 and 16 in March 2016. Monitoring has been ongoing since. Collected data are for the three buildings complete until and including December 2016. A complete year is therefore at present not yet available, but a forecast has been made for January and February 2016.

In general, the total annual energy consumption in the three buildings in Kvarteret Isbanan is below the target (design) consumption of the EU-project which is 42 kWh/m² before subtraction of energy from renewables. The buildings energy consumption range from 35.4 kWh/m² to 38.9 kWh/m². The space heating consumption is slightly higher than expected, which might be caused by the drying out of the constructions combined with the preliminary billing procedure which gives the tenants less incitement to save on their heating consumption. The consumption of domestic hot water is in all buildings significantly lower than expected, in average 10.3 kWh/m² (excluding contribution from waste water heat recovery and solar heating), which is almost half of the expected. The wastewater heat recovery unit performs as expected, which is approximately 1.1 kWh/m². The electricity consumption is in average lower (8.2 kWh/m²) than the project requirements (13 kWh/m²). All in all, the houses perform exceptionally.

It is emphasized that the consumption for January-February 2016 for apartment building 15 and 16 is a forecast and the results therefore must be considered as preliminary. However, it



	Target values	Building 14	Building 15	Building 16
Heat recovery from waste water	-1	-1,2	-1,0	-1,1
Solar thermal - flat plate	-2,3	-3,2	0,0	-3,1
PV installation	-2,2	0,0	-4,5	0,0
Lighting	4	0,0	0,0	0,0
Pumps	0	0,3	0,2	0,4
Common electricity	5	5,7	11,4	6,4
Ventilation	4	2,4	2,2	2,6
Pipe heat losses	0	1,5	1,3	1,5
Domestic hot water	20	10,8	10,8	9,4
Space heating	9	18,3	10,5	15,0

Figure 6. Overview of the energy consumption in the monitored houses.

is based on 10 months of real data and estimated out from actual degree days, so the uncertainty is very low.

The local district heating company delivers heat based on 90 % renewables consisting of waste incineration and biomass. In Figure 6, the renewable energy contributions are shown as negative numbers.

LYON CONFLUENCE HIKARI

Technical monitoring

Equipment and Process

A comprehensive Building Energy Management System (BEMS) is used to control the operation of all energy systems and devices and to monitor many parameters in order to check the energy performance of the HIKARI building.

This BEMS is designed to optimise the indoor comfort of users and is connected to more than 10.000 sensors such as image based motion sensors, temperature, CO_2 and humidity sensors, see Figure 7. It is also connected to one Home Energy Management System (HEMS) per dwelling used to control the indoor comfort and to provide energy feedback to inhabitants in order to help them to make energy savings.

Results

The first monitoring period of HIKARI goes from August 2015 to July 2016. The 100 kW CHP powered with rapeseed oil did not operate at optimal yield during this period and required the help of the manufacturer to solve technical problems. Also, the PV system was commissioned late on April 2016 due to a delay to connect it to the distribution grid and it did not produce as much energy as expected during this first period. Finally, the Building Energy Management System did not operate optimally during this first year of monitoring with 2 consequences: some consumption values where not accurate and have been corrected and the consumption values, even if still acceptable, are higher than expected and should be better for the second monitoring period.

During year one of operation 985 MWh of heat and 257 MWh of electricity have been produced on site. The share of renewable energy sources is 28,4 % for the heat (from rapeseed oil) and 100 % for electricity (26 % from PV and 74 % from rapeseed oil), see Figure 8.

Out of the 985 MWh of heat produced, 878 MWh have been measured after storage and before distribution to the several heat usages of the building. Therefore, the storage losses were of approx. 11 %.

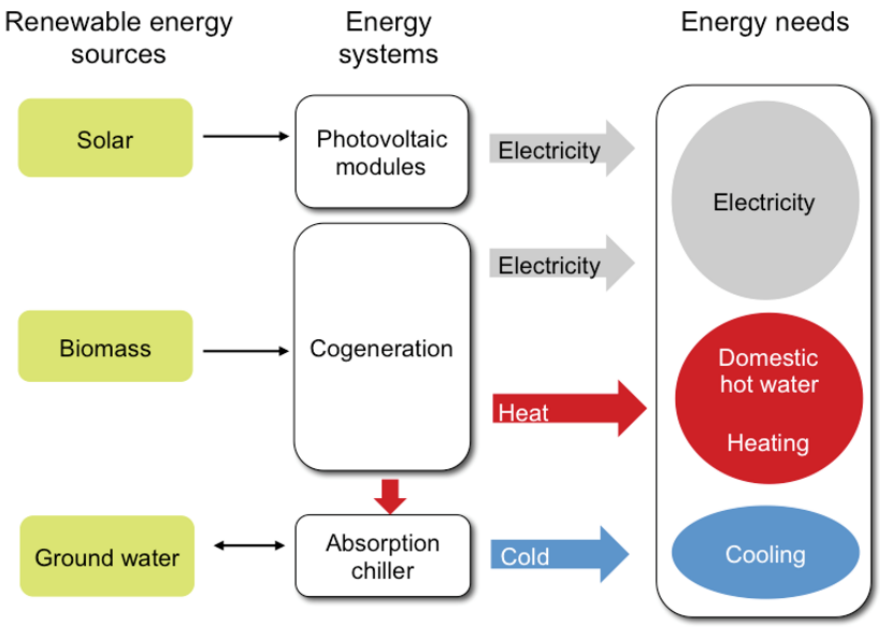


Figure 7. Overview of the energy system design monitored by the BEMS.

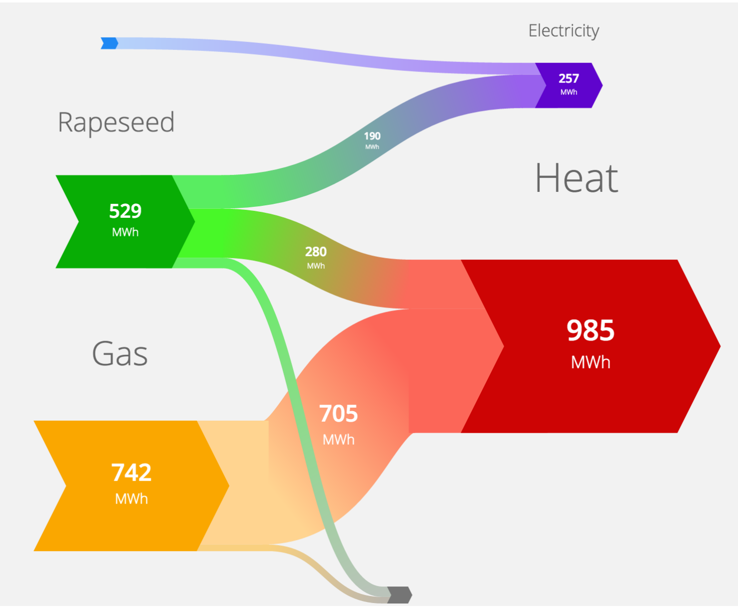


Figure 8. Energy produced on site during year 1 of operation.

The following consumption values where measured before distribution, see Figure 9:

- Heat to dwellings: 178 MWh (20 % of the heat available before distribution),
- Heat to offices: 429 MWh (49 %),
- Heat to retailed shops and restaurant: 206 MWh (23 %),
- Lost heat due to wrong installation of some devices and identified as "technical losses": 65 MWh (7 %).

For the dwellings, the specific energy consumptions with distribution losses for the first year of operation are:

- Heat consumption: 28,7 kWh/m^2/year,
- DHW consumption: 21,6 kWh/m^2/year.

And for offices, the specific energy consumptions with distribution losses are:

- Heat consumption: 31,7 kWh/m^2/year.

Although much better than the energy consumption of similar new buildings built in France, consumption values for the first year of operation of HIKARI are higher than expected. With the help of the detailed Building Energy Management System, sources of unexpectedly high-energy consumption have been detected and corrected. Thus, energy consumption values for the second year of operation should be closer to the expected values.

Table 2. Energy produced on site during year 1 of operation.

MWh	Gas	Rapeseed	PV	Total
Heat	705	280	0	**985**
Electricity	0	190	67	**257**
Production losses	37	59	0	**96**
Total	**742**	**529**	**67**	

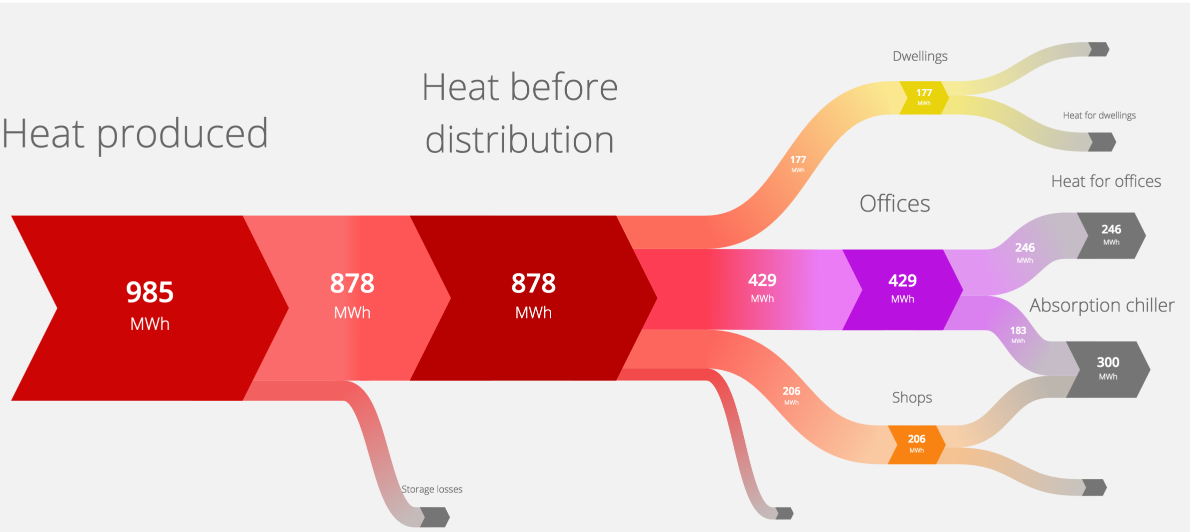


Figure 9. Heat produced and heat available before distribution.

Table 3. Heat produced and heat available before distribution.

MWh	Dwellings	Offices	Shops	Other	Total
Heating	101	246	89		**436**
DHW	76				**76**
Absorption chiller		183	117		**300**
Technical losses				65	**65**
Total	**178**	**429**	**206**	**65**	**878**

Household assessment of the new dwellings

A COMMON APPROACH, BUT WITH DIFFERENCES IN IMPLEMENTATION

As part of the Next-buildings project, we investigated experiences of new residents through surveys and focus groups. Core questions were:

1. Why did you choose your climate neutral house?
2. Are you satisfied with your climate neutral house?
3. Do you actively use energy saving appliances?
4. Are you interested to participate in new energy projects with your neighbours?

In Helsingborg and Lyon, the house developers included the Next-buildings questions in a user satisfaction survey, which is standard procedure half a year after moving in. The response in Helsingborg amounted to 69 out of 96 and in Lyon 9 out of 36.

In Amsterdam, we decided to discuss the questionnaire with the 12 residents participating in the focus groups. All information was gathered in 2016.

RESULTS

Below we present answers to the four core questions. For Helsingborg and Lyon, numerical results predominate. The Amsterdam results are based on discussions in the focus group.

1. *Why did you choose your climate neutral house?* As shown in Table 4, location is the dominant argument. Quality of the house, being new, plays an additional role. Climate neutrality is important in Lyon, but plays a limited role in Helsingborg. The Amsterdam focus group gave similar answers. Location was dominant by far, climate neutrality was considered a welcome extra. A noticeable remark was that real estate agents, trying to sell the Amsterdam apartments, hardly mentioned the low energy use in their brochures.

Table 4. Arguments to choose for a climate neutral house.

Reasons	Amsterdam	Helsingborg	Lyon
Location	100 %	55 %	100 %
Neighborhood	40 %	32 %	–
Newly built	40 %	48 %	–
Quality of the house	40 %	26 %	44 %
Climate neutral	40 %	16 %	66 %

Table 5. Helsingborg energy saving measures.

Measure	Percentage
Turn off lamps in empty rooms	63 %
Careful waste separation	69 %
Take a shower of 5 minutes maximum	35 %
An extra pullover instead of extra heating	38 %
Travel more on bike	28 %
Buy eco-products	30 %

2. *Are you satisfied with your climate neutral house?* In Helsingborg 75 % of the respondents were (very) positive about their apartment, 15 % neutral and 10 % negative. In Lyon, thermal comfort was under criticism: While 67 % of the respondents showed satisfied, 33 % found it too cold. According to the developers, the reason was a disfunctioning of the heating system in Hikari in the first months of operation. This has now been fixed. In Amsterdam, the focus group assigned a 9 for satisfaction (on a 1–10 scale). Interestingly, this positive judgment went along with a number of complaints about bad workmanship of the builders (a score of 6), too high temperatures in the house and lack of information on proper use of installations and appliances (e.g. floor heating). It took the residents one year to find out themselves.
3. *Do you actively use energy saving appliances?* In Sweden, indoor temperatures are traditionally regulated by the housing association. Therefore, occupants can only focus on equipment and behavior. Table 5 shows self-reported behavior. Most actions are low profile, not implying changes in lifestyle.

The inhabitant in Lyon mentioned measures related to both individual equipment and changes in behavior. Ownership of energy saving appliances is remarkably high. This could be linked to the fact that most people in the Hikari building belong to higher-income groups. As for behavior, results are less obvious. It seems that the Hikari inhabitants focus primarily on technical solutions.

In Amsterdam, 40 % of the participants in the focus group had given permission to install an *Energy Data Box,* a device to get detailed information about actual energy use. As an active user stated later: “After two weeks it gets boring, because by then you know the few ‘big users’ to look after”. A limited number of people planned to buy *hot-fill* washing machines and dishwashers. Some residents are very conscious about their energy use, however most of them rely on convenient, technical solutions (e.g. LED-lighting, A+ dishwashers).

4. *Are you interested to participate in new energy projects with your neighbours?* We asked all participants whether they want to compare their energy use with neighbours. As Table 7 shows, interest in Amsterdam and Helsingborg is limited. In Lyon, more people show interest.

Is there any interest to develop common energy projects in the neighbourhood? Sweden traditionally develops communal projects, backed by municipalities and/or housing associations, but not by individual households. Lyon and Amsterdam inhabitants showed little interest to invest in extra production of sustainable energy (solar PV, wind, biomass), as a means to make their district fully climate neutral. A few of the Amsterdam house-owner-groups intend to get involved in climate neutral transport (e.g. electric cars, a shared boat).

LESSONS LEARNED

What can we learn from the outcomes of the household questionnaire? Because of the limited number of respondents, only tentative conclusions are possible. However, we discover striking similarities in the three cities:

- Location and quality of the apartment are dominant motives to move in;
- Climate neutrality plays an additional role, but is not dominant;
- Most people focus on small scale, mainly technical, energy improvements, that do not demand major changes in behaviour;
- There is limited interest in future actions together with neighbours.

We conclude that most residents in Amsterdam, Helsingborg and Lyon have chosen a house that fits their, already developed, demands and lifestyle. Climate-neutrality is welcome, but has not been decisive for their decisions.

Table 6. Lyon energy saving measures.

Buy energy saving appliances?	%	Changes in behavior?	%
Green label washing machine	89 %	Turn off lamps in empty rooms	55 %
Energy saving lamps (LED etc)	78 %	Lowering temperature in winter	33 %
Green label dishwasher	89 %	Check energy use of housemates	22 %
Stand-by killer of electricity use	–		
Refrigerator A+	89 %		

Table 7. Do you want to compare your energy use with neighbours?

Answer	Amsterdam	Helsingborg	Lyon
Yes	40 %	30 %	55 %
No	60 %	57 %	22 %
Do not know	–	13 %	22 %

Table 8. Summary of the energy consumption results.

	EU Target	Amsterdam Houthaven	Helsingborg Kvarteret Isbanan	Lyon Hikari dwellings*	Lyon Hikari offices*
Gross building energy consumption kWh/m²yr final energy	n.a.	53	36,9	51	32
On-site renewable energy production kWh/m²yr	n.a.	10	4,7	14	8
Net building energy consumption kWh/ m²yr (average of buildings)	60	43	32,2	37	24

** For Hikari, these figures relate to heat only. On-site renewable electricity production is 19 kWh/m2yr for both dwellings and offices based on an equal amount per square meter.*

Overall conclusions

Three demo sites have different paths to very low energy buildings. In France, the building relies heavily on a CHP on rapeseed oil. In Helsingborgshem and Amsterdam, the heat provision is from sources with partially renewable fuels (waste in Amsterdam and waste/biomass combined in Helsingborg). All building utilize waste heat recovery systems, heavy insulation and renewables on-site (PV and solar thermal). Table 8 shows a summary of the energy consumption results in the three sites. On average, the final energy consumption of all buildings (measured in the first year of operation) is of the order of 40 kWh/m²yr. The ambitious local goals of energy neutrality are only approached by a significant amount of renewable heat (50% in Amsterdam, 90% in Helsingborg, 100 % in Lyon (given proper operation of the CHP)) and 4–19 kWh/m²yr contribution of renewable electricity/solar thermal.

The monitoring activities reveal that attention to proper craftsmanship (insulation, draughtproofing) is essential for low energy buildings and that control settings heavily influence energy consumption. General opinion is that the energy consumption goes down in the second year as the result of solving teething troubles in installations and drying of the buildings.

Most inhabitants of the new dwellings have not been attracted by climate neutrality as such, but by newly built apartments in attractive locations. They do not show specific lifestyles, and focus on small scale, mainly technical, improvements in energy use.

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