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Integrated energy concept for a residential neighbourhood

- Cost-optimised combinations of refurbishment measures
- New refurbishment methods and components to be tested
- Aim: to at least halve primary energy use in the neighbourhood

Fig. 1

Aerial view of the residential neighbourhood in Karlsruhe-Rintheim, Germany: The district's sustainable development is controlled by an integrated energy concept, which also takes account of urban development, housing, social and mobility aspects.

Approximately 50% of the global population lives in cities. In 2020, this figure will be more than 60%. The success of climate protections is, therefore, dependent on energy consumption and pollutant emissions in our cities and conurbations. Local councils can specify important framework conditions for implementing energy efficiency measures. Examples of this include land-use plans and specifications for supply structures based on the local council's energy concept. As a shareholder in municipal utility companies and housing associations, cities influence the development of district heating, the use of renewable energy sources and the refurbishment of residential buildings. And of course, they can act as role models when building or refurbishing their own properties. This requires action plans at city district or residential neighbourhood level. With these plans, measures can be specified and the competent parties can be appointed. Their interaction, based on defined aims and responsibilities, is the key to successful implementation.

The following model is being tested in Karlsruhe: An energy concept has been developed and implemented for a residential neighbourhood in the district of Rintheim. The aim of this concept is to achieve the best possible cost efficiencies and reduce primary energy use and CO_2 emissions by more than 80%. In addition to establishing a local heating network, buildings constructed in the 1950s and 1960s are to be cost-effectively modernised. Subsequent operation of the refurbished buildings connected to the district heating system is continuously monitored and optimised over three heating periods. Residents participate in the energy saving efforts. This research focuses on two residential buildings, in particular. They are being refurbished based on an ambitious energy concept and monitored through measurements in 2009-2010. In addition to innovations in building conceptual design, building services equipment, measurement and control technology and tenant communication, this is the first time a "low-exergy" (LowEx) approach is to be implemented for an entire residential neighbourhood. This is a pilot project of the EnEff:Stadt research initiative of the German Federal Ministry of Economics and Technology. Accompanying measures to improve local infrastructure and social integration are being promoted through the joint federal and state government programme, "Socially Integrative City". Work on the residential neighbourhood concept began in 2009. It should be completed by around 2015.

Community and neighbourhood

In 2009, an energy concept was created for the city of Karlsruhe, under the auspices of the Environmental Protection Office. It is a catalogue of energy and climate protection measures and forms the framework for urban energy and climate protection policy. The Rintheimer Feld residential neighbourhood is located in the north-east of the city. It was built in a first construction phase during the 1950s as a typical large post-war apartment complex. The resulting blocks of flats had four to five storeys and around 30 accommodation units per building. A second section followed in the late 1960s with an entirely different architecture: point blocks with up to 17 full storeys and in some cases more than 80 accommodation units per building.

Fig. 2: Housing estate profile

Residents	approx.. 2,500
Type of housing estate	mixture of high-density linear apartment blocks and high-rise apartment complexes
Utilisation type	general residential (WA)
Social infrastructure	limited amenities (mini-supermarket, hairdresser, kiosk), good public transport access (central location)
Housing estate area	250,000 m²
Floor area (according to DIN 277)	before refurbishment: 18,110 m², after refurbishment: 19,910 m²
Living area	before refurbishment: 74,970 m², after refurbishment: 81,120 m²
Number of accommodation units	before refurbishment: 1,243, after refurbishment: 1,364
Floor space index (FSI)	0.48
Heating systems: current state	gas central heating, individual gas central heating, individual coal stoves
Heating systems: planned	local heating network for residential neighbourhood (under construction)

Of the 34 residential buildings currently in the neighbourhood, four are privately owned and 30 belong to the refurbishing organisation, Volkswohnung Karlsruhe. This organisation manages the project and is the major investor. It will build an additional 4 new buildings.

EnEff:Stadt - Research for the energy efficient city

Launched in spring 2008, the German Federal Ministry of Economics and Technology's research initiative is aimed at entire neighbourhoods and city districts. Technical innovations are to be used in practice and new planning tools are to be developed as part of EnEff:Stadt. The results will be clearly documented with the aid of a consistent monitoring system. EnEff:Stadt combines research and development approaches from the construction sector (EnOB) and district/local heat use with the implementation of so-called low-exergy technologies in residential areas. This is intended to achieve measurable effects on entire neighbourhoods as well as huge improvements for individual projects. The objective of the EnEff:Stadt pilot project is to reduce primary energy use in the neighbourhood by 30 to 50%. Additional information is available at www.eneff-stadt.info.

Energy concept

With its Rintheimer Feld neighbourhood concept, Volkswohnung set itself the task of planning and deploying technical innovations in conjunction with conventional technologies and of monitoring the refurbishment in detail through measurements over at least two heating periods.
The energy concept is based on a comprehensive analysis of the residential buildings to be modernised. The six different building types at Rintheimer Feld were analysed in detail. The analysis included a status description of the building envelope and the building systems equipment. It also provides energy characteristics according to the German Energy Saving Ordinance. Based on this analysis, measures were described for energy-oriented improvement with appropriate investments, and classified according to priority. Energy balances for the whole neighbourhood and for each individual building were generated with the aid of the energy assessment and the analysis of consumption data from the municipal utility companies.

Fig. 3: Technical building typology of the neighbourhood

Typ I · 9 buildings
Linear construction
Built in 1954/56
4 to 5 storeys
Non-refurbished

U-value: 2.1 W(m²K)
Heating energy consumption: 120 kWh_{th}

Typ II · 7 buildings
High-rise buildings
Built in 1974
9 to 17 storeys
Non-refurbished

U-value: 1.1 W(m²K)
Heating energy consumption: 143 kWh_{th}

Typ III · 3 buildings
Point blocks
Built in 1956
8 storeys
Partly refurbished in 1975/2003

U-value: 0.8 W(m²K)
Heating energy consumption: 74 kWh_{th}

Typ IV · 4 buildings
Linear construction
Built in 1954
5 storeys
Fully refurbished in 1998

U-value: 0.8 W(m²K)
Heating energy consumption: 61 kWh_{th}

Typ V · 5 buildings
Linear construction
Built in 1954/55
5 storeys, fully refurbished
With solar collectors

U-value: 0.6 W(m²K)
Heating energy consumption: 50 kWh_{th}

Typ VI · 2 buildings
Forststrasse 7 / Heilbronnerstrasse 27-31
Fully refurbished in 2007/2008

U-value: 0.4 W(m²K)
Heating energy consumption: 42 kWh_{th}

Testing innovative technologies

Two demonstration buildings (a "3-litre building" and the so-called "experimental house") are to be extensively refurbished by spring or summer 2010. Both building sections with five full storeys and gable roof were built in 1956. They each have 30 apartments with a living space of 65.5 m². The apartments of each building entrance will be refurbished to different design standards and simultaneously tested. The measurements taken are compared and evaluated. This will provide recommendations for future refurbishment of this type of apartment.
Innovative technologies are to be used for the refurbishment of building envelopes, but also for heating, ventilation and hot water supply systems. These include:

- different insulation systems, including VIP panels,
- different windows materials,
- PCM ceiling panels (to increase thermal mass),
- daylight redirection systems on the exterior blinds,

- ventilation systems (in some cases, controlled exhaust air systems but also systems with heat recovery – centralised and decentralised),
- heat pumps with CO_2 borehole heat exchangers and
- different control strategies.

Buildings are heated by connecting them to the local heating system. Various heat pumps will be installed in the "experimental house". The pumps will be operated using borehole heat exchangers and air/exhaust air as a heat source. They can also be switched over to cooling. Centralised and decentralised forms of ventilation will be tested simultaneously with and without heat recovery. Decentralised heat pumps will be used throughout an individual building. The aim is to compare the energy and pump power consumption with buildings using standard equipment.

Optimum set of measures

Since a number of individual measures could be used to refurbish a building, it is difficult to find the optimum overall combination of measures. Consequently, a calculation model developed as part of an EU project was used for the buildings in the Rintheim neighbourhood. It calculates the optimum combination of measures required to achieve minimum costs or a defined savings objective. The basis for the calculation are suitable

Fig. 4: Typical transom building in original condition

Fig. 5: One of the high-rise buildings after refurbishment

cost functions and the geometry and initial state of the building. The model calculates a "cost-effective" heating energy demand of approximately 50 kWh_{th}/m^2 for the "transom buildings" in the north of the neighbourhood and 40 – 45 kWh_{th}/m^2 for the high-rise buildings in the south. The data is based on today's energy prices. Significant additional reductions in costs, primary energy and emissions are achieved by replacing the conventional gas heating with energy-efficient district heating.

Operation monitoring

The refurbishment should achieve significant energy improvements whilst keeping total rent costs constant for all tenants. At the same time, an energy management system will be installed. It will help to record energy flows to the neighbourhood, the buildings and the appartments and to develop indicators to continuously assess system performance. All building transfer stations will be equipped with so-called "smart boxes". This will allow system operation to be monitored and continuously optimised.

Tenant motivation

There are also a great deal of potential savings to be made from user behaviour. Instead of installing automatic regulation systems in individual rooms, an online "customer portal" is to motivate tenants to save energy by providing comprehensible information about their monthly consumption. The necessary technical equipment will be available in the neighbourhood after refurbishment: remote meters for recording energy consumption and transferring data.

▶ Energy-efficient use of district heating

The appartments in Rintheimer Feld are being or were heated largely with gas central heating or individual gas central heating until refurbishment. Some appartments were heated with individual coal stoves and electric continuous-flow heaters. The new supply of local heating for the neighbourhood comes from the Karlsruhe municipal utility district heating network. With an 85% share of combined heat and power and the completion of a pipeline to the MiRO refinery in 2010, around 40% of the heating requirement in the Karlsruhe district heating network will be covered by this waste heat. MiRO runs the largest refinery in Germany just to the north of the city and continuously generates significant quantities of waste heat. Rintheimer Feld is indirectly connected to the district heating network through a transfer station in order to be able to operate the local heating network in the neighbourhood at lower temperatures. The pipeline to the transfer station was built in 2008. The network and transfer station are currently being expanded and should be complete by 2012.

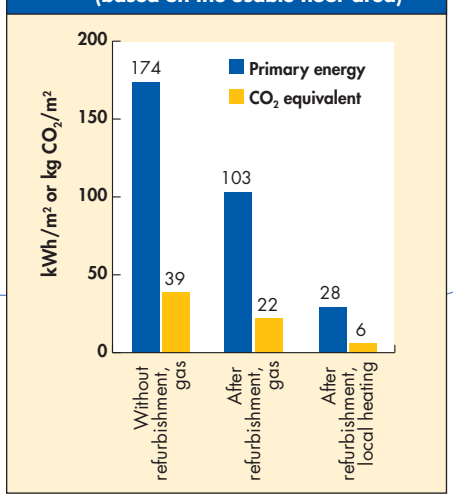
▶ Energy balance forecast

The heat requirement for heating and hot water in the entire neighbourhood will be reduced by over 50% as a result of the refurbishment programme. A higher reduction would be technically possible, but at significantly higher specific costs:
Another significant improvement is achieved by connecting to the district heating system with its very good energy characteristics ($0.39\ kWh_{PE}/kWh_{th}$ primary energy factor, supplied to end users in the neighbourhood). According to current plans, specific primary energy use and CO_2 emissions to cover heating demand will be reduced by around 84% (Fig. 7) compared to the start of refurbishment measures.

Fig. 6: Development of demand for heat in the course of the refurbishment programme

1997	14,200 MWh_{th} p.a.	entire neighbourhood before the start of refurbishment measures
2009	11,470 MWh_{th} p.a.	after refurbishment of 12 of the 30 buildings
by approx. 2015	6,200 MWh_{th} p.a.	refurbishment of Volkswohnung's remaining buildings to an average standard of 75 kWh_{th}/m^2 of residential space, incl. two school buildings in the neighbourhood

Fig. 7: Energy and CO_2 balance in the neighbourhood (based on the usable floor area)



Costs

According to the model calculation, refurbishment costs for the refurbishing company's buildings to be modernised from 2010 will total 180 to 250 euros / m² gross. This makes a total of approximately 10 to 12 million euros. Furthermore, there are network costs and costs for the new building transfer stations (a total of around 3 million euros). In addition to energy-oriented refurbishement, other modernisation and maintenance measures are required at the same time (damp rooms, sanitary fittings, electrical equipment, balconies, building entrances, etc). This will result in additional costs of around 250 euros /m². The complete refurbishment of the buildings as part of the neighbourhood concept (by approx. 2015) will total around 30 million euros. The costs will be covered by the refurbishment company. There are also additional costs for maintenance and development of the buildings' surroundings. The concept development, feasibility study and refurbishment of the two demonstration buildings and the installation of a monitoring system will be subsidised as part of the EnEff:Stadt research initiative.

Conclusion

The neighbourhood energy concept for Rintheimer Feld is now complete. Usable data for an evaluation of the project have been available since late 2009. Energy monitoring and accompanying measurements will begin in spring 2010. The feasibility study for the two demonstration buildings was completed. The first building has already been refurbished. It will be occupied again from the end of March 2010. The detailed planning of the "experimental building" with the involvement of manufacturers is almost complete. Work has started on the construction measures. Measurements for the two demonstration buildings will start in spring 2010 over a total of three testing and evaluation periods.
This pilot project develops and implements an integrated energy concept for a city district which can generally be transferred to any local government or housing estate project. It serves as a planning guideline for energy and building-related, urban development, ecological and social problem-solving and is also a testing ground for new methods and instruments. Investors, decision makers and planners of future projects are, therefore, encouraged to think in terms of systems and consequently to take networked action.

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ADDITIONAL INFORMATION

Internet
- www.eneff-stadt.info/en
- www.enob.info/en/research-areas/lowex

Picture credits
- Fig. 1-7: Volkswohnung GmbH

Service
- This Projektinfo brochure is also available as an online document at www.bine.info under Publikationen/Projektinfos. Additional information in German, such as other project addresses and links, can be found under "Service".

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