Abstract

A sustainable Energy Use Plan with special emphasis on historic preservation by the example Iphofen

Options for a central district heating network including the restoration of listed historic buildings in urban districts

Research by order of BBR Forschungsinitiative Zukunft Bau
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Figure 1: viewing levels for the creation of energy-use plans of historic neighbourhoods - community - Quarter - Typical building

1.1. Introduction

The Federal Government aims to achieve a climate-neutral building stock supplied with renewable energy by 2050. The current building renovation rate has totalled 1% for the last two years and is continuously declining. According to the German Bundestag the renovation rate should be raised to 2% per year in order to achieve this climate goal (see [Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2012]). The Climate-Sensitive Urban Redevelopment will be a significant step towards the implementation of the turnaround in energy policy. As 75% of the German building stock was built before 1975 (cf. [Erhorn et al., 2007]) they must be renovated anyway. Although the share of listed buildings is quite low: 3-5% of the total housing stock [vdld, 2005], it is rather a question of preservation of important architecture and of strengthening regions with a high proportion of historic buildings.

Maintaining the stock also plays an important role in the context of demographic change and a declining population. A recent trend is a migration towards the city leading to the depopulation of rural areas. This has to do with demographic change on the one hand and with the lower cost of living together in the city on the other hand (cf. [Weeber et al., 2005]). This phenomenon often happens to whole neighbourhoods characterized by a high proportion of older buildings. Municipalities with a high proportion of historic buildings have difficulties in marketing them. These buildings must be occupied and maintained in order to preserve this valuable existing building stock. Vacant buildings run the risk of decay. Therefore contemporary solutions are needed to increase the attractiveness for buyers and tenants to live in a historic building.

Strategies for climate-friendly urban redevelopment are required in order to maintain the architectural culture of our past, while ensuring a timely and comfortable habitability. New approaches for the design, construction and renovation of buildings are needed to achieve these goals.

Particular historic buildings and neighbourhoods have their strength in the ensemble. Buildings are always integrated into an overall structure - the urban structure, which has a big impact on the potential energy saving and the use of renewable energies. In the future, our vision should not be limited to the individual building but should extend to the district and the municipality. The focus is not on individual restoration and on the implementation of individual measures in the district, but we should strive a global vision at an urban planning level. The energy issues should not be limited to single buildings but should extend to the energetic design of districts and even at the municipal level (□ Fig. 1).

This approach paves the way for new holistic approaches for historic districts. It allows us to find out the energy potential, to exploit synergies and local energy resources and to develop energy and restoration concepts responding to the individual site and strengthening the value chain. There are no standard solutions - but we provide individual solutions for a specific place. This requires an intensive examination of the historical buildings and ensembles, local energy potentials, energy user structures and infrastructures.

The use of appropriate planning tools is necessary to implement energy saving measures, to reach an increased energy efficiency, to use renewable energies on a municipal level and to match these measures. An energy use plan * (ENP) is an informal design tool that allows the linking of complex questions on energy (see [Hausladen et al., 2011]) (□ Fig. 2). In the context of urban planning and urban renewal, it is an important instrument to coordinate the sub-field of energy efficiency.

* An energy use plan is an informal planning tool on the energy issue for municipalities. The Energy Use Plan (like the land use plan in the spatial planning sector) lays down holistic energy concepts and planning targets.

1.2. Summary

The result of the research shows that the energetic rehabilitation of historic city quarters - with holistic solutions is possible. Here, the holistic approach plays an important role at urban and municipal level. The architectural and urban characteristics of the city's historical quarters allow a wide range of energy efficient solutions to be developed.

In the past, various individual measures have been developed and implemented in the field of renewable energy supply. Most planed and implemented projects tend to be characterized by individual measures without any overall co-ordination. The narrowness of the regenerative and economic resources and the necessity of increasing the energy efficiency, make a global co-ordination compulsory for these individual efforts.

The City of Iphofen has set itself a goal to implement a long-term energy use plan aiming to improve energy efficiency in the municipal area. The City's highest commitment is saving energy. The following criteria have to be examined in order to provide an energy use plan: the existing and future consumer structure, existing energy potential and energy networks, as well as strategies for the future use of energy. This allows us to bundle existing energy concepts and synergies to achieve an optimized energy use.

The historical town of Iphofen presents a particular challenge because, given their situation, there are special requirements listed. The high proportion of historic timber-framed and solid building predominantly from the 17th and 18 Century is characteristic for Iphofen.

The question about sustainable energy concepts, with the specific task of the integration of historic buildings is not only for the city of Iphofen of interest. In Germany there are a variety of urban, historic neighbourhoods that require solutions fulfilling the complex requirements of climate protection and the preservation of architectural culture. Therefore it was the aim of the research project "energy plan with special emphasis on historic preservation by the example Iphofen _ Options for a central district heating network including the restoration of listed historic buildings in urban districts " to show how small communities with a high proportion of historic buildings can become energy efficient and be supplied with a high proportion of renewable energy sources.

The project is embedded in the research area "energy use plan _ municipal energy concepts". In contrast, the main research focused on individual neighborhoods with a high stock of historic buildings, which are characterized by the following features:

- Efficient use of renewable energy sources is often limited due to the conservation provisions and urban realities. In this Research Project, therefore paths are shown how their use can nevertheless be ensured efficiently.
- Historic buildings and districts allow only a limited amount of energy refurbishment. In terms of building construction, rehabilitation and technical retrofit opportunities are identified to ensure the development of efficient supply opportunities.
- In addition, the districts usually characterized by a high density of buildings - which leads to a long-term high energy density of such settlements.

Figure 2: of an Energy Use Plan (map sections)

Comment on the figure

Analysis of site-specific heat demand density (1) - the infrastructure (2) and the renewable energy potential (3). Based on this analysis, energy concepts (4) are developed that respond to the individual site and strengthen it.

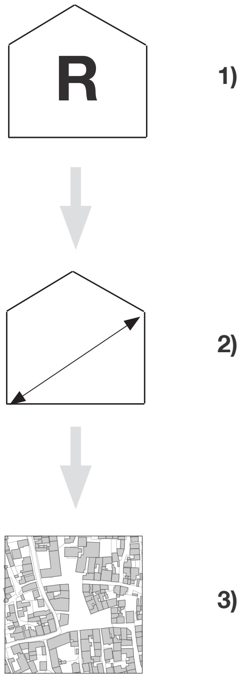


Figure 3: reference building process in accordance with GemEB (municipal energy balancing software)

Comment on the Figure
1) reference building
The specific heating requirement of the Historical and Energetic Building Typology (HEGT) are based on exemplary calculations of typical historic buildings. These buildings are also included in GemEB 2.0 as reference buildings.
2) Geometric adjustment
As the influence of the size of the building has a decisive influence on the heating demand, the reference buildings are geometrically adjusted to the existing buildings in accordance with the Historical and Energetic Building Typology (HEGT). This adjustment is made by energy balancing software GemEB 2.0.
3) Location-based heating demand values
This process allows the specific identification of heat demand densities, taking into account the factor of individual development structure and sizes of buildings on site.

New methods and approaches were needed to allow the incorporation of Iphofens' historic buildings in a municipal energy concept. An iterative research approach and application of the results allow us to deliver general recommendations, instructions to the work process, parameters and important background knowledge. These are documented in the form of a universal guide.

The main areas of research are divided into three major components:

- Development of a methodology for the identification of the heat demand of historical quarters (→ Section 1.2.1)
- Identification of remediation and potential savings historic districts (→ section 1.2.2)
- Statements on central supply solutions and uses of renewable energies (→ section 1.2.3)

Each aspect of the most important results has been summarized.

1.2.1. Method used to determine the heat requirement of historic neighbourhoods

The determination of the local energy needs in neighbourhoods is the basis for the development of energy concepts. Therefore the current and future heat requirement (→ Point 1.2.2) and its spatial distribution in the municipality (heat demand density) have to be calculated and presented in map. While determining the structures of the heat requirement for historic districts, we have to consider several factors which make an enhanced approach and an adjustment of the previous methods necessary. These factors are: the use of existing materials and regionally grown and dense urban structures. A Historical and Energetic Building Typology (HEGT) (→ Fig. 4) has been developed in order to take these points into account. The Historical and Energetic Building Typology (HEGT) enables us to identify heat demand densities, independent of construction year categories and of historical classifications. The typology builds on energy relevant criteria, on the compactness of buildings/housing and on the thermal quality of the construction, which is regionally defined.

Studies on typology have shown that the compactness of buildings/houses exerts the most decisive influence on the heat demand. Compactness depends on the density of construction and on the number of floors. Block perimeter development have 50% less heat requirement than stand alone buildings or detached houses. Secondly, the thermal quality of the construction is relevant for energy. The more compact a building is, the lower is the influence on the thermal quality of construction.
Construction classes have been created in order to map the thermal quality of the constructions of a typical building in Iphofen. These design classes can be applied to a wide variety of buildings on a regional level. The construction class can be adapted if necessary.

The local heating requirements necessary to determine heat density maps can be identified with software support. For this, the Historical and Energetic Building Typology flows as a reference building process in the energy balancing software GemEB. This software helps to calculate the heat and hot water needs based on the geometrically matched reference building. This allows us to identify heat demand values for customized urban structures (→ Fig. 3).

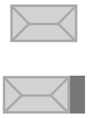
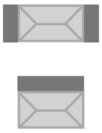
HEGT			Floor	Construction Class **A** Q_h [kWh/(m$^2_{Wohnfläche}$*a)]	Constructionclass **B** Q_h [kWh/(m$^2_{Wohnfläche}$*a)]
1 compactness		 	1	227	278
		 	2-4	176	230
2 compactness		 	1	202	239
		 	2-4	149	188
3 compactness		 	1	167	182
			2-4	110	127

Figure 4: Historical and Energetic Building Typology HEGT

W/(m²K) ... 1,4 1,9 2,4 ....

A B

Referenz-gebäude Referenz-gebäude

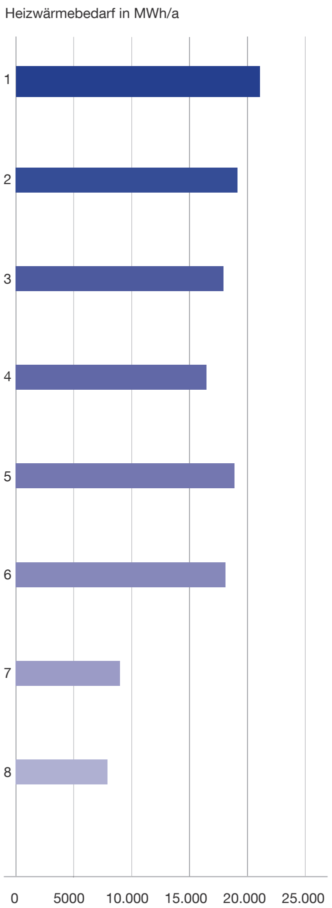
Comment on the figure:
The heating needs can easily be assessed on the basis of the Historical and Energetic Building Typology (HEGT) on the criteria of the compactness and the construction class. The Historical and Energetic Building Typology table shows a first tendency of the heat demand of the building. The heating demand depends on the compactness of the building 1 (standing alone buildings or detached houses), 2 (semi-detached houses), 3 (block perimeter development), and on the number of storeys. Compact buildings have lower heating demand. The construction class is energy-relevant.
Two typical construction classes have been defined for Iphofen. These classes can apply to a wide variety of buildings in the region. The construction class can be interpolated and adapted if necessary.

Construction Class A
e.g. Timbered walls with clay frames, and massive stone walls with low density, such as Brick walls, these walls have a thermal tendency of U = 1.40 W/(m² K)

Construction Class B
e.g. Trusses with stone frames, massive natural stone walls of sandstone, shell limestone, quarry stones, trusses with rubble masonry stone or Lessstein / boulders, trusses with mudbrick frameworks, depending on wall thickness, these walls have a thermal bias of U = 2.40 W/(m² K)

The demand can be geometrically adapted and adjusted to the respective building structures thanks to the GemEB energy balancing software. Thus this allows us to calculate the heat demand density for specific quarters. GemEB relies on the reference buildings of the Historical and Energetic Building Typology HEGT (→ Fig. 3).

Table 1: future scenarios 1 (Iphofen)



comment on Table:

1 current heat demand

2 Renovation rate not historical (NH) 1.5% each year - historical (H) 0.5% Renovation rate

3 (NH) 1.5% - (H) 1.0% Renovation rate

4 (NH) 1.5% - (H) 1.5%

5 renovation rate (NH) 1.5% - (H) insulation of any ceilings

6 renovation rate (NH) 1.5% - (H) insulation of all backyard facades and floors

7 renovation rate (NH) 100% - (H) insulation of backyard and street facades, floors (comparative scenario)

8 renovation rate (NH) 100% - (H) insulation of backyard and street facades, floors, and floor panels (comparative scenario)

1.2.2. Rehabilitation of historic neighbourhoods and savings

In addition to the analysis of the current structure of energy use, the analysis of future heat consumption is crucial. Because the heat demand density is closely related to the centralized or decentralized use of renewable energy. Therefore energy saving potential for historic and non-historic buildings has to be examined over a longer period.

An important issue for the sensitive restoration of historic quarters, is to what extent energy rehabilitation measures are to be regarded as historically acceptable and what energy savings can be achieved.

Basically, the investigations and the interviews with experts have shown can be energy-efficiently refurbished in a very cautious way. The energy saving potential does not necessarily depend on the conservation classification. High energy savings maintaining the historical character of buildings or districts can be achieved via well-matched rehabilitation packages. This approach requires an extensive examination of the location. The analysis of the urban structure, characterized by the density of buildings and the typical historic building forms the most important basis for the development of remediation strategies. An approach is needed that takes into account the aspects of physics, the energetic relevance, heritage protection and the formative effect of energy rehabilitation measures. On this basis, restoration concepts are being developed that are tailored to a neighbourhood and designed to strengthen this.

In order to determine the redevelopment strategies needed for the typical neighbourhood buildings, it is important to know the energetic relevance of different remedial measures. Therefore, a remediation matrix, showing the trends of energy-saving potential, has been developed to support the process. This builds on the Historical and Energetic Building Typology (HEGT) and considers the aspects of compactness of buildings and the thermal quality of the construction. Matching the impacts of these remedial measures on the historical quarters with the energy savings potential allows us to make a first assessment as to which remedial measures are appropriate respectively which measures are historically-compatible for a neighbourhood.

The determination of potential rehabilitation measures for a district on this basis enables us to define remediation scenarios and savings potentials. The calculations can be made via the energy balancing software GemEB. Several remediation options have been identified for Iphofen (→ Tab. 1). Should we strive a refurbishment rate of 1,5% in Iphofen, approx. 5 buildings per year would have to be refurbished in a historical compatible way. Achieving this ambitious target would allow us to reduce the demand for energy by 23% (or 4,800 MWh) by 2035. The energy demand would total 16400 MWh.

Another important result is that historic neighbourhoods with a high building density are favourable for implementing economic energy rehabilitation measures. This can be attributed to the following: The lower the portion of the outer wall in relation to the heated volume, the lower the investment cost per square meter. The lower the thermal quality of the building envelope, the shorter the payback period, and the more economical the energetic measures will become.

* A Historically-sound remediation means that depending on building the top ceilings, interior insulation and / or possibly in semi-detached houses and block perimeter development the courtyard facades are insulated. The calculation using the GemEB tool is carried out according to monument classification and probabilities stored in the data base.

1.2.3. Central supply and renewable energy solutions

Refurbishment measures enable us to envisage new supply structures. Inner-city historic neighbourhoods highly benefit from the implementation of centralized networks.

This is due to the high density of the energy supply system and the improved capacity utilization with decentralized heating systems. The change from a decentralized to a centralized energy supply also provides economic benefits to the community, especially if municipal buildings are involved. Moreover, this will result in complying with using the legally required percentage of renewable energy, which can be problematic due to the historic preservation and downtown locations. Historic Buildings can achieve quite good primary energy levels and fulfil the legal requirements, such as the Energy Saving Ordinance (EnEV).

The successful implementation of centralized heating systems is dependent on the energy saving potential through future redevelopment and the expected rates of connection. This is being mainly associated with the urban structure (⍰ Fig. 5).

It can be summarized as two main results:

- For settlements with a high building density the efficiency of a heating network is not closely linked with the expected level of connection and the future development of the energy-related renovation. The influence of energy provision prevails.
- The efficiency of a heating network depends on settlement areas with a low building density from a significant degree from the expected level of connection, the future development of the energy-related renovation and from energy supply.

Figure 5: Options for central heating networks in accordance with the urban structure, future restoration and connection rate

Districts that have been deemed suitable for centralized solutions upon rough estimation are colour coded. It has been supposed that the historically-compatible energetic refurbishment totals 1,5 % p.a. and the connection rate 70%. The potential central supply solutions highly depend on the urban structure. Moreover, the renovation rate and the reduction of energy demand in neighbourhoods are closely linked to the potential to use renewable energy centrally or locally. Thus, the restoration scenarios can also be seen as an upper limiting value for the central utility networks. If a quarter is densely built the connection rates and the renovations will have a low impact on the feasibility of central solutions. It can be concluded that districts with high building density highly favour central supply options, taking into account historical-friendly renovations and realistic rates of connection. However, in areas with low building density, commercial applications are quite limited.

Source & Information:

[bmu, 2012] http://www.bmu.de/energiewende/beschluesse_und_massnahmen/doc/46507.php [Stand 27.09.2012]

[Erhorn et al., 2007] Erhorn, H., Erhorn-Kluttig, H., Hauser, G., Sager, C., Weber, H., co2online gemeinnützige GmbH; Friedrich, M., Becker, D., Grondey, G., Laskowski, F.: CO2 Gebäudereport 2007, (Hrsg.) Bundesministerium für Verkehr, Bau und Stadtentwicklung, Fraunhofer-Institut für Bauphysik, Berlin, 2007

[VdLd, 2005] Vereinigung der Landesdenkmalpfleger in der Bundesrepublik Deutschland: Arbeitsblatt 25 Stellungnahme zur Energieeinsparverordnung (EnEV) und zum Energiepass, Wiesbaden, 2005

[Weeber et al., 2005] Weeber H., Weeber R., Fritz A., Dörrie A.: Besser Wohnen in der Stadt. Konzepte und Beispiele für Familienwohnungen, Fraunhofer IRB Verlag, 2005

[Hausladen et al., 2011] Hausladen, G., Wagner, T., Schmid, T., Bonnet, C., Hamacher, T., Tzscheutschler, P., Burhenne, R.: Leitfaden Energienutzungsplan, (Hrsg.) Bayerisches Staatsministerium für Umwelt und Gesundheit StMUG, Bayerisches Staatsministeriums für Wirtschaft, Infrastruktur, Verkehr und Technologie (StMWIVT), Oberste Baubehörde im Bayerischen Staatsministerium des Innern (OBB), München, 2011

[EnEV, 2009] Verordnung über energiesparenden Wärmeschutz und energiesparende Anlagentechnik bei Gebäuden von 29. April 2009, Bundesgesetzblatt, 2009