Chapter 19
Resource Efficiency in the Building Sector

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Abstract Endeavours towards resource-efficient and climate friendly construction seem to be reaching their limits. The current approaches, which focus on continual reductions in heating energy consumption, are leading to increasingly elaborate insulation measures and complex air-tight buildings. Further improvements can only be realized in the scope of the building's lifecycle. Factor X offers a pragmatic approach by reducing the consumption of non-renewable raw materials, non-renewable energy and the emission of greenhouse gases throughout the building's entire life cycle, resulting in significant improvements in comparison with other strategies employed to date. This concept has already been put into practice in two small residential areas in Inden and Eschweiler (North Rhine-Westphalia, Germany), and the first positive experiences with building contractors and related companies have been gathered.

Keywords Building sector • Residential areas • Energy Saving Ordinance • Construction costs • Marginal costs • Life cycle • Marginal energy savings • Ecological rucksacks • Factor 4 house • Resource-efficient construction • Klimaexpo NRW • Faktor X Agentur

19.1 Background

Building and habitation result in the highest rate of material exchange between nature and the anthroposphere worldwide, cf. UNEP (2011), Herczeg et al. (2014). Raw materials are extracted, transported and processed to make construction materials. During the extraction process the natural environment is destroyed, energy is consumed and waste products are expelled to the environment. Green spaces are converted into residential areas and energy is consumed when the buildings are inhabited.

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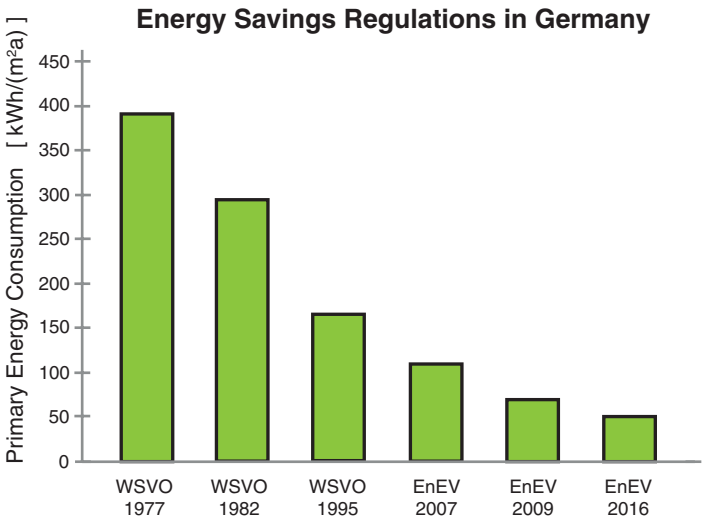

Fig. 19.1 Energy conservation regulations in Germany since 1977 (Source: Author)

Reducing building energy consumption in the building sector has been a goal of in German politics for some time.

The first thermal insulation regulations in Germany (Wärmeschutzverordnung, WSVO) came into force as early as 1977. This saw the first capping of energy consumption specifically for the building's use phase. Since then the permissible upper consumption limits have been continually adjusted. The latest Energy Saving Ordinance (*Energieeinsparverordnung, EnEV*) from 2016 reduces the required energy consumption during the building's use phase by almost 87% of the theoretical maximum reduction (cf. Fig. 19.1). The European Unions (EU) directives on Energy Efficiency and Energy Performance of Buildings Directive have a similar goal, cf. EU (2010), EU (2012).

However, in view of the material expenditure involved in sufficiently insulating the outer shell of a building in order to reach this goal, the continual reduction of energy consumption limits proves to be inefficient. At approximately half of the theoretically possible energy savings, the insulation effort required increases disproportionally to the benefits. The marginal energy savings from each centimetre of additional insulation begin to decrease drastically above an insulation thickness of 5 cm (cf. Fig. 19.2).

Furthermore, the construction costs increase dramatically for reaching this degree of insulation in the building. The necessary thermal insulation can only be reached by installing mechanical ventilation systems and only if the building is planned and built to be completely air tight. The actual behaviour of the user also plays a crucial role as windows must not be opened during the heating phase.

In this context a further tightening of building energy consumption requirements should be viewed extremely critically. In other words: if buildings are to reach

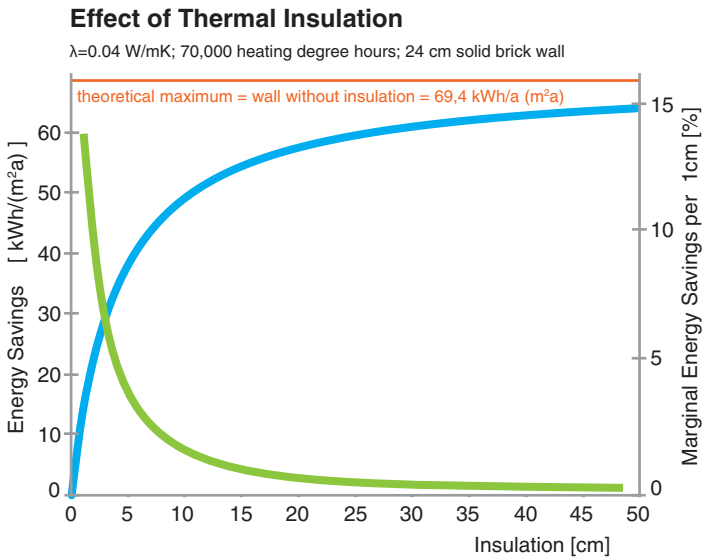

Fig. 19.2 Theoretical energy savings of thermal insulation (Source: Author)

energy savings beyond those currently attainable in new buildings, other potential sources of energy savings must be unlocked.

In addition to reductions in energy consumption, the production of renewable energy through photovoltaic or solar-thermal collectors can also be pursued. The current energy saving regulations only consider these energy sources in terms of the energy balance. The energy produced is deducted from the building's annual energy consumption. However, this does not reflect the actual energy flow. During the sunnier periods, from April to September, the building's energy requirement can be sustained by the energy yielded from photovoltaic or solar-thermal collectors. Surplus energy is produced but this cannot yet be stored to any significant extent for the low-radiation times of the year. External energy sources are thus required for heating and warm water in the low radiation months from October to March. It is therefore possible for an energy neutral or even a plus energy house on the balance sheet to still require an additional energy supply in low-radiation months. This fact is largely ignored in current legislation (Fig. 19.3).

Measures to improve energy efficiency currently only consider the building's use phase. But before the building is put into use, building materials need to be produced which requires the extraction, transport and manufacturing of raw materials into construction materials, which subsequently need to be transported to the construction site. In modern buildings this phase of a building's life cycle uses 30–75% of the total energy consumed during the building's entire life span. If the building needs to be renovated due to a change in its intended use or a defect technology needs to be replaced, the energy expenditure is even higher. At the end of the life cycle the building may be demolished, which also requires energy.

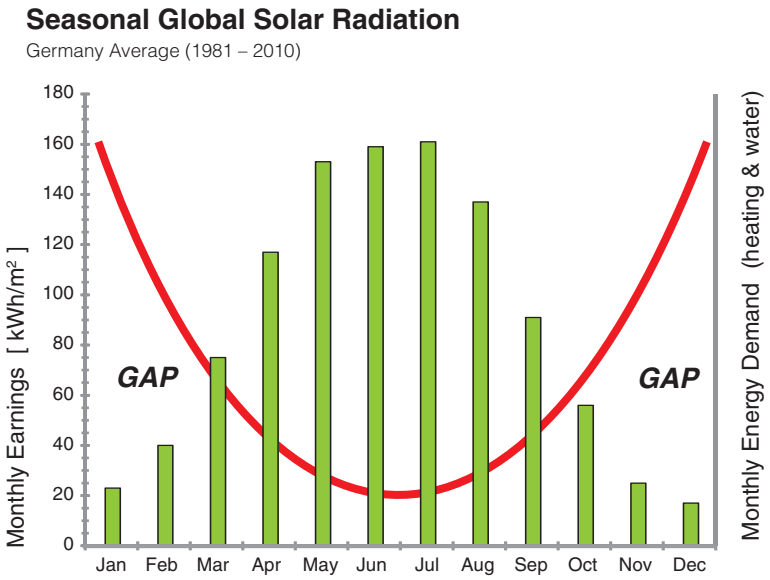

Fig. 19.3 Seasonal global solar radiation in Germany (Source: Modified after DWD (2016))

19.2 The Factor X Approach

The decreasing marginal energy savings associated with additional insulation measures and the lack of options for storing surplus energy in high-radiation periods indicate that it is necessary to develop and utilize other potential methods of climate protection. If construction work and the renovation of existing buildings are to contribute to improved climate protection, then the consumption of non-renewable energy, the emission of greenhouse gases and the consumption of non-renewable raw material must be reduced over the complete building life cycle. As only low marginal energy savings result from improvements during the building's use phase, the boundaries of the system must be are widened considerably (cf. Fig. 19.4).

The Energy Saving Ordinance considers only the use phase of the building. Factor X extends the system boundaries to include energy production, the production of construction materials, the construction phase, maintenance, repairs and renovation as well as building demolition and all related transportation.

Within the extended system boundaries, non-renewable primary energy, greenhouse gas emissions and the consumption of non-renewable raw materials as well the related ecological rucksacks are considered.

In order this extension of the system boundaries to be widely applied, the system needs to be easily accessible for users from the construction industry. It is crucial to consider reductions in resource consumption early on in the planning process. Due to the high amount of effort involved in assessing a building's environmental

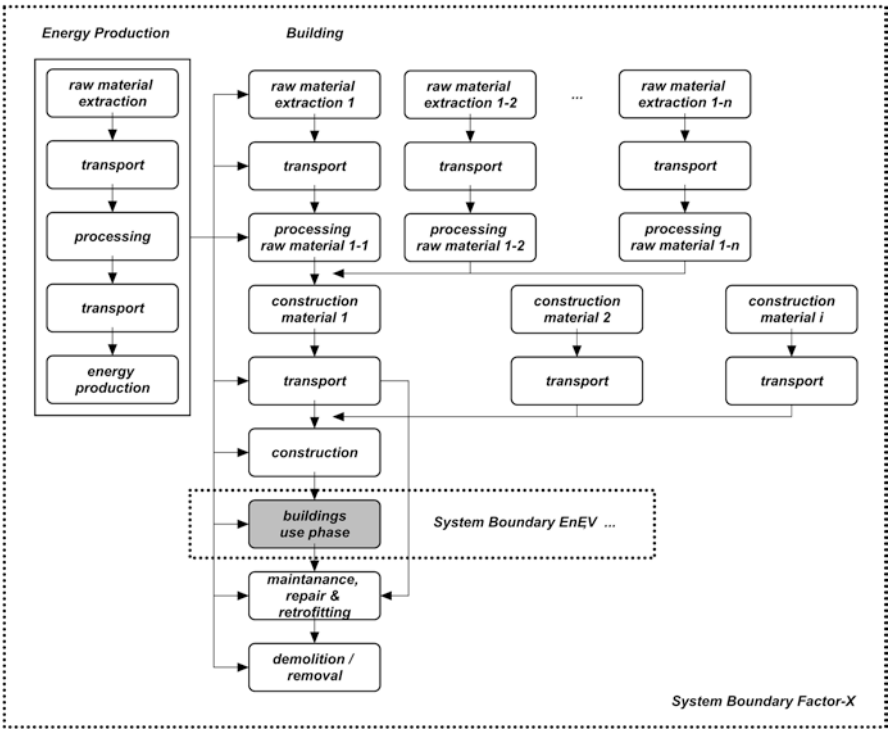

Fig. 19.4 System boundary of factor-x (Source: Author)

balance—as required by the sustainable building process of the Deutschen Gesellschaft Nachhaltiges Bauen (DGNB) (German Society of Sustainable Construction) or the German Federal Institute for Research on Building, Urban Affairs and Spatial Development—an assessment is generally not drawn up until finalising the planning details or after the building work has been completed for the purpose of applying for a sustainability certificate.

Since the summer of 2016, the Factor X approach has been tested in two new build residential areas between Aachen and Düren. In Inden-Seeviertel and Eschweiler-Dürwiß two building sites each with approximately 40 structures are currently under construction. The only criteria (apart from the 2016 legally applicable Energy Saving Ordinance) is the application of a Factor 2. Over a defined time period of 50 years, the buildings may only consume 50% of the non-renewable energy and non-renewable resources and may only emit 50% of the greenhouse gases compared to conventional construction. The system boundaries were extended as shown in Fig. 19.4.

In order to make this method accessible to a wide user group, ranging from architects to interested building contractors, an Excel tool was developed to help estimate resource consumption involved in the main features of the house at a very early stage in the planning.

Fig. 19.5 Factor 4 House in Inden, Architecture by Prof. Jörg Wollenweber, Düsseldorf (Source: Jörg Wollenweber, unpublished illustration)

A Factor 4 house was also constructed. In the three resource categories non-renewable embodied energy, non-renewable raw material and greenhouse gases, this optimised building achieves a maximum consumption of 25% compared to a similar conventional building. The fundamental principles for resource-efficient construction, such as lightweight construction, abstaining from concrete materials, recycling-oriented building, the use of renewable construction materials and allowances for easy changes in usage through a modular and marketable design, were all implemented (Fig. 19.5).

All three projects have been or are being considered for an award from the Klimaexpo NRW (www.klimaexpo.nrw.de) as pioneering climate protection projects.

From January 2017 the Faktor X Agentur located at the indeland Entwicklungsgesellschaft in Düren will focus on promoting this holistic approach to climate and resource conservation on a regional and national scale.

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