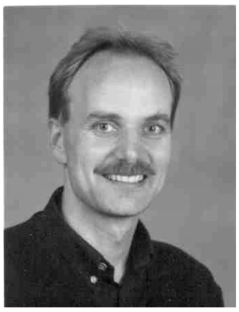
"ZERO-ENERGY/EMISSION-BUILDINGS" - TERMS, DEFINITIONS AND BUILDING PRACTICE

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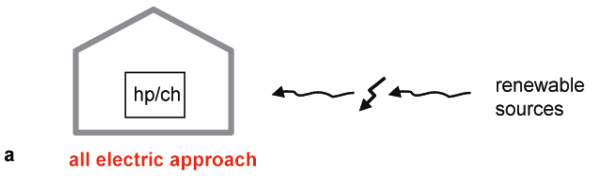
Abstract

Energy use in buildings worldwide accounts for a significant part of the primary energy use and the green house gas emissions. The ratio widely varies by country due to climate, population density, life style, building standard and use of renewable sources. Depending on the building energy standard and the fraction of the energy sources in use, buildings are more a direct (on site use of fossil fuels) or indirect source of emissions (site delivered electricity, district heating/cooling, building materials). Due to the long building lifetime energy use and emissions are dominated by the building stock. A large variety of measures to reduce energy use and emissions significantly is known and available on the market. In view of the climate change and resource shortage more is required than just increasing the energy efficiency of buildings. One vision in the current debate are so called "zero-energy" or „zero-emission" or "zero-carbon" buildings [1, 2, 3, 4].

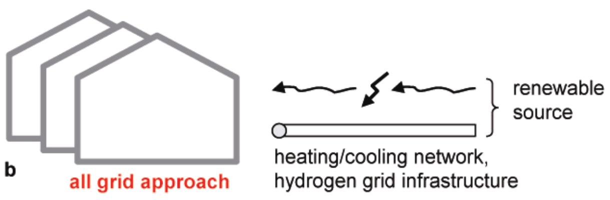
Keywords: Energy credits, cogeneration, life-cycle energy balance, emission trading

1 How to achieve "zero" in the building sector of today

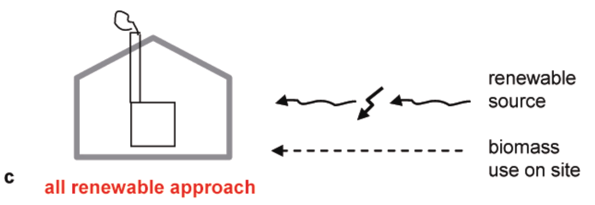
The first option is simply to avoid that a building consumes energy, that is to say to produce "nega-watts" by improving the quality of the building envelope (thanks to passive solutions such as, insulation, cross ventilation for hot humid climates etc.), the efficiency of the "active" systems (better coefficient of performance COP, better lighting efficiency, etc.) or simply replacing a fossil energy consuming system by a renewable energy driven solution (solar heating or solar cooling, etc.). Experiences from the past have demonstrated that "zero" in the interpretation of a fully autonomous energy supply for a building with locally available sources only, was found to be technical, economical and ecological not convincing in view of a wider scale application [5]. The off-grid approach causes over sizing of energy production from renewable energies to overcome the seasonal mismatch of demand and supply at most locations in the world. Excess energy cannot be used. Construction materials for seasonal storage systems embody a large amount of energy in relation to the small energy transferred over the life cycle. As a consequence gridconnection of buildings should be considered appropriate in areas with an existing energy infrastructure and minimised demands of heating/cooling should be covered by non local sources to avoid over-sizing of on site systems, e.g. of solar thermal systems. Electricity grids have the capacity to act as local and seasonal energy transmitters, but high energy efficiency on site is favourable to decrease the needs for generation, transport and storage of electricity [6].



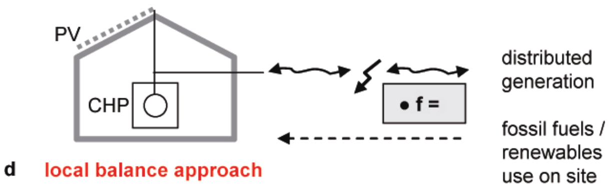
With **all-electric-buildings** direct emissions are eliminated completely. Indirect emissions can be avoided with grid electricity based 100 % on renewables as long as resources are available for rising demands (“green electricity”, example: Norway). Heating/Cooling might be based on high COP heat pumps/chillers. Depending on the national energy policy, nuclear power might be included in a zero emission scenario [7].



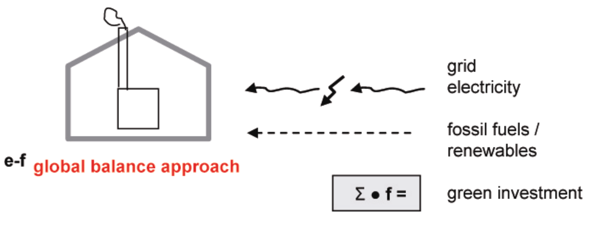
In densely populated areas the **all-grid-building** might be extended to heating/cooling supply by local or district heating/cooling plants operated with renewable energy only. Biomass co-generation is a favourable technological approach. Hydrogen generated by renewables might be delivered to buildings instead of today’s natural gas to feed burner or fuel cells in buildings.



In view of very limited resources of electricity generation by renewables and less densely populated areas in many countries, heating supply to buildings might be done CO_2-neutral by local combustion of biomass (wood chips, pellets…) in combination with solar thermal collectors for domestic hot water or space cooling and grid electricity based on renewables.



Grid connected local electricity generation with photovoltaics (PV) or building integrated cogeneration (CHP) allow balancing the mismatch and the use of non renewable sources on a primary energy or carbon emission scale over a yearly cycle by equivalent credits (**local balance building**). This approach is feasible in all countries with an electricity grid still mainly based on fossil fuels, such as Germany.



Local use of non-renewable energy or emissions are “balanced” over the lifetime of a building by additional investment in non-local renewable energy supply systems, such as wind farms (**global balance building**). The building owner acts as shareholder, making use of the energy and emission credits.

CO_2 trade in the building sector - as already established for the European power plant industry - might allow balancing the local emissions with buying certified CO_2-credits [8]. Credits may be generated by reforestation projects, building renovation (“Negawatt”), etc.

Fig. 1 Principle ways to zero energy/emission in the building sector

In principle different options exist to cut down the greenhouse gas emissions from the building sector to almost zero, **Fig. 1**. Both, direct (on site systems) and indirect emissions (from the power or district heat/cold supply systems) have to be considered. Whereas options **a** to **c** mainly focus on the responsibility for central energy systems based on renewables, option **d – the local balance building –** focuses on the building itself and the responsibility of the local investor/consumer. Option *e* is a first step to develop a CO_2 trading system. Due to existing activities in the central sector (**a**-**c**) this paper focuses on the single building scale only (option **d**) with the intention of an outlook to consider options **e** and **f** for future developments.

The **local balance building** contains the highest need for adjusting energy efficiency measures and decentralised energy production to a site-specific, appropriate level. The aim is no longer related to an energy performance index such as kWh/(m²y): A large building of the same energy performance index as a small one needs larger efforts to balance its demand. The necessary adjustment might be driven from an economic point of view by a least-cost-planning approach, searching for the set of measures to gain the lowest cost per emission or energy demand reduction (typical solution set). This approach is feasible for all types of buildings and for new buildings as well as for the existing building stock with its limitations of reduced energy consumption by improvements of the thermal envelope.

2 Energy and Emission balance: The lack of a common understanding

Setting up an energy or emission balance for a **local balance building** according to option ***d*** (**Fig. 2**) needs clear definitions of:

- **the scale:** site energy, primary energy, CO_2, CO_2-equivalents, energy cost
- **the calculation procedure:** transformation of feed-in electricity or external investments into primary energy or emission credits
- **the control volume:** energy use sectors, energy credit sectors
- **the period:** year, total time of utilization, life-cycle.

Tab. 1 Possible parts of the balancing procedure. A future definition has to set boundaries for calculations.

energy consumption / emissions	=	energy / emission credits
heating and hot water		cogeneration
auxiliary energy		solar electricity
air conditioning		green electricity
lighting		shares on green power stations
zentral services		energy contracting
appliances		national emission trading
construction materials		global emission trading

An initial literature study has shown that no common understanding exists, although many buildings are said to be zero energy or carbon neutral [10]. Many reports focus on design figures only as no monitoring was applied or data have not been analysed appropriately. Economic investigations are not published so far.

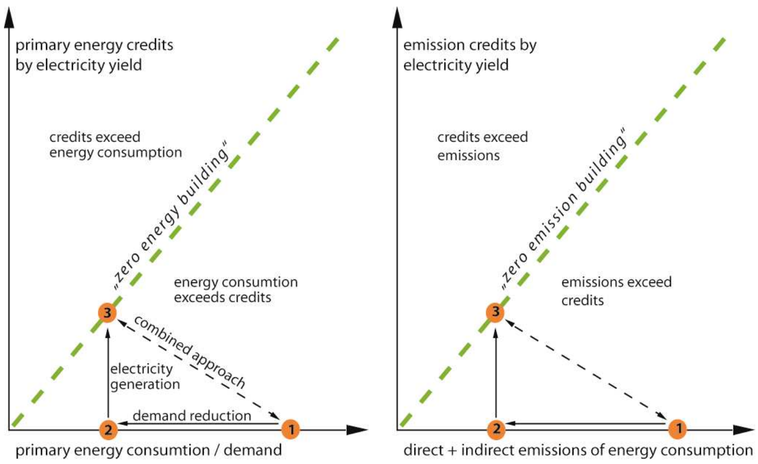


Fig. 2 Balancing energy use (left diagram) or emissions (right) of a building by credits from feed in electricity on an annual basis. "Zero energy" or "zero emission" buildings (indicated by the diagonal in the diagram) are achieved by the combination of reduced consumption (step from 1 to 2) and credits from feed in electricity (step 2 to 3). The best combination of both steps has to be determined individually by building type, country, climate, etc. (typical solution set).

Design figures mainly relate to specific energy code calculations on a national level and therefore often exclude demand sectors which are not covered by the building code (e.g. appliances). There is no common scale applied as primary energy or emission factors for grid electricity vary widely between countries and develop by-and-by [11]. These factors and specially the correlated emissions are (up to now) mostly not part of national building codes, leaving the actors free in choosing data from various sources. Credits for feed-in electricity often do not take into account energy and emissions related to the production of the alternative power supply system itself (embodied energy and related emissions). Therefore the calculated credits tend to be overestimated especially for solar power [9].

To avoid new definitions on calculation procedures and to keep a strong focus on results achieved in practical operation it is proposed to base the understanding of "zero" on measured quantities (consumption based instead of demand based). All areas of consumption should be included as splitting of sectors is difficult and requires extra metering installations (sectors 1-7, table 1). Experiences have demonstrated that appliances and user specific equipment might dominate the demand in energy optimized buildings. "Zero" should not be a label for the design but for the carbon neutral operation of buildings of all sectors. It should allow annual control of the balance on the base of metering [18].

The detailed investigation of the life cycle energy demand of low energy demonstration buildings has underlined the rising importance of the embodied energy with decreasing operation energy demand. This part might account for 20 to 50 % of the total energy use during a typical 80-year life-cycle of a building [12]. Initial countries plan to include embodied energy in the building performance standards [13]. The importance of a life-cycle approach increases with the tendency to decrease usage periods of buildings. Further investigation is needed to propose a suitable zero energy approach on a life-cycle basis.

3 Building experience

As mentioned above a variety of buildings around the world, but mainly in heating dominated climates, have been realized in a non-defined context of "zero energy/emission". Most of them belong to the residential sector and are small units.

In absence of other suitable technological solutions small houses rely on grid-connected photovoltaic power supply combined with solar low energy or so-called “passive” house designs [14]. The majority are new houses. Some use the all-electric-approach with compression heat pumps (compact units). Some examples demonstrate an up-scaling of this approach to zero energy or even “plus-energy” solar settlements [15].

For larger buildings in cold climates it will be usually difficult to balance the whole energy demand or emissions by the credits for the PV yield due to a lack of suitable oriented area. Some examples of low energy apartment buildings or settlements combine the use of natural gas or diesel driven cogeneration units and were still able to reach “zero energy” as long as the national electricity grid is mainly based on fossil fuels with a low fraction of central cogeneration (high credits). Office and production buildings follow this approach with an up-scaling of the cogeneration technology used and possible integration into a thermally driven cooling process. The case of large building in countries enduring a hot climate may be interesting to focus on. A recent study for an educational building conducted in tropical islands has shown that it is relatively easy to reach the “zero energy” goal with credits for grid connected PV [16].

4 Technological developments

In addition to significant progress in energy saving technologies progress occurred in the area of cogeneration systems in the medium and small power range. This allows future market development beside the established local or district heating sector and applications in large buildings. Intensive use of cogeneration, based on fossil fuels, doesn’t makes sense in countries where grid electricity is already mainly based on renewables (and potential for further use still exists to cover rising demands). Biomass driven cogeneration overcomes this limitation. Conventional motor generators were modified to operate with e.g. rape oil instead of diesel. Engines based on the Stirling principle for the first time allow for energy efficient cogeneration for burning of biomass in single home sizes. Progress in the range of stationary fuel cells is already made but products have only reached pilot applications so far. Developments will continue to use biogas as an energy source for fuel cells instead of natural gas.

Whereas building integrated solar power generation only depends on an area of the building fabric with suitable size and orientation, cogeneration is an integrated part of the heating system of a building. In hot climates and/or in non-residential buildings it may be the heat source for a thermally driven cooling process. This integration needs detailed knowledge on heat flows, available storage capacities and predictions of energy use for optimized operation [6]. As part of a “virtual power plant” the operation of cogeneration units has to consider the needs of an electricity grid primarily.

5 Outlook

We assume that following the strong political announcement towards zero energy or zero emission buildings, more projects will be realised in the near future, covering all climatic zones, building types and new as well as existing buildings [18, 19].

Therefore we identify a strong need for an international exchange platform of knowledge and experience. Initial steps have been made.

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