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CONCEPT OF THE NEW PHYSICAL-ENERGY QUANTIFICATION OF BUILDINGS IN THE DEVELOPMENT OF TECHNOLOGY IN ARCHITECTURE FOR SUSTAINABLE SOCIETY

KONCEPCJA NOWEJ FIZYKO-ENERGETYCZNEJ OCENY BUDYNKÓW W ROZWOJU TECHNOLOGICZNYM ARCHITEKTURY DLA ZRÓWNOWAŻONEGO SPOŁECZEŃSTWA

Abstract

Renewable energy sources as a conditioning factor of fundamental concept changes of energy quantification of buildings. 1st generation of low energy buildings. 2nd generation of low energy buildings. Green buildings with zero heat balance of the network – buildings with nearly zero energy balance of the network. Sustainable buildings with zero energy balance of the network. Sustainable building with an active energy balance in relation to distribution networks.

Keywords: *renewable energy sources*, *low energy buildings*, *green buildings*, *sustainable buildings*

Streszczenie

Źródła energii odnawialnej jako kluczowy czynnik fundamentalnych zmian w ocenie energetycznej budynków. Pierwsza generacja budynków niskoenergetycznych. Druga generacja budynków niskoenergetycznych. Zielone budynki niskoenergetyczne – budynki niemal zeroenergetyczne. Budynki zrównoważone zeroenergetyczne. Budynki zrównoważone z aktywnym bilansem energetycznym w stosunku do sieci dystrybucyjnych.

Słowa kluczowe: *odnawialne źródła energii*, *budynki niskoenergetyczne*, *budynki zielone*, *budynki zrównoważone*

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1. Introduction

Two separate but closely connected categories are expressed by the term new physical--energy quantification of buildings:

- physical quantification particularly of envelope constructions of buildings, which are in global relations expressed by the weighted average coefficient of the thermal transmittance U_m (W/(m^2.K)) and
- energy quantification of a building which is expressed by the specific energy demand for heating, ventilation, cooling, (hot water preparation) Q_H (kWh/(m^2·a)), (kWh/(m^3·a)).

A very close connection of these two categories can be seen in existing design solutions of buildings with purposeful energy saving where the reduction of energy demand of the buildings is in principal solved by an increase of the physical quantification of their envelope constructions. The new physical-energy quantification of buildings is also about the change of relations of these two categories. It is going to be about the optimization of the physical quantification of envelope constructions of buildings in economic relations to energy of renewable sources and the technology of their conversion.

The economic costs connected with the increase of physical quantification of envelope constructions until they reach the point of economic reversal, become inefficient from the investment point of view (U_m < 0.4 W/(m^2·K)). On the contrary, investment and operational costs into renewable energy sources with in situ conversion might be of such parameters that even higher level of energy demand for acquiring the state of zero energy demand in relation to the distribution network might be economically profitable and therefore justifiable.

It is more convenient to set an interval of specific energy demand which allows the investors to determine the optimal mix of technologies, ensuring the energy efficiency of the energy conversion and the required return on investment.

The part of the concept of a new physical-energy quantification of a building is also the principle to measure separately the energy demand in a building for:

- heating, ventilation, cooling, (preparation of domestic hot water), which is converted from the primary energy source to the heat and separately to,
- lighting, appliances, motor drives, (possibly the preparation of domestic hot water), which is optimally converted from the primary energy source to the form of electric energy.

Electric distribution network represents a strategic task for the development of the infrastructure for a transformed society based on renewable energy sources.

2. Common Characteristics of Zero Energy Buildings in Relation to the Energy Distribution Networks

It is necessary to seek a balance of a new physical-energy quantification of buildings in the applied ratio of:

- energy from ecologically clean renewable sources and ecologically clean conversion of the energy in local facilities, optimally in situ (without energy losses from the distribution) and

– energy from fossil fuels and conversion of the energy in centralized facilities which is characterized by the production of emissions of greenhouse type and is distributed by the energy networks (with energy losses from the distribution).

The ratio of these two ecologically significantly different types of energy in buildings is possible to measure quantitatively. It is therefore possible to define buildings on the physical and economic principles in the form of "Net Zero Energy Buildings" in their three basic modifications [9] (Fig. 1):

1. Nearly Net Zero Energy Buildings. These are the buildings that have practically zero energy demand (heating, ventilation, cooling (hot water preparation) from the distribution network, from which only take energy (electrical lighting, electrical appliances, electric motor drives).
2. Net Zero Energy Buildings. These are the buildings that have zero energy demand and zero electric energy demand from the distribution networks.
3. Net Plus Energy Buildings. These are the buildings that have higher energy conversion in situ than their annual demand in real time.

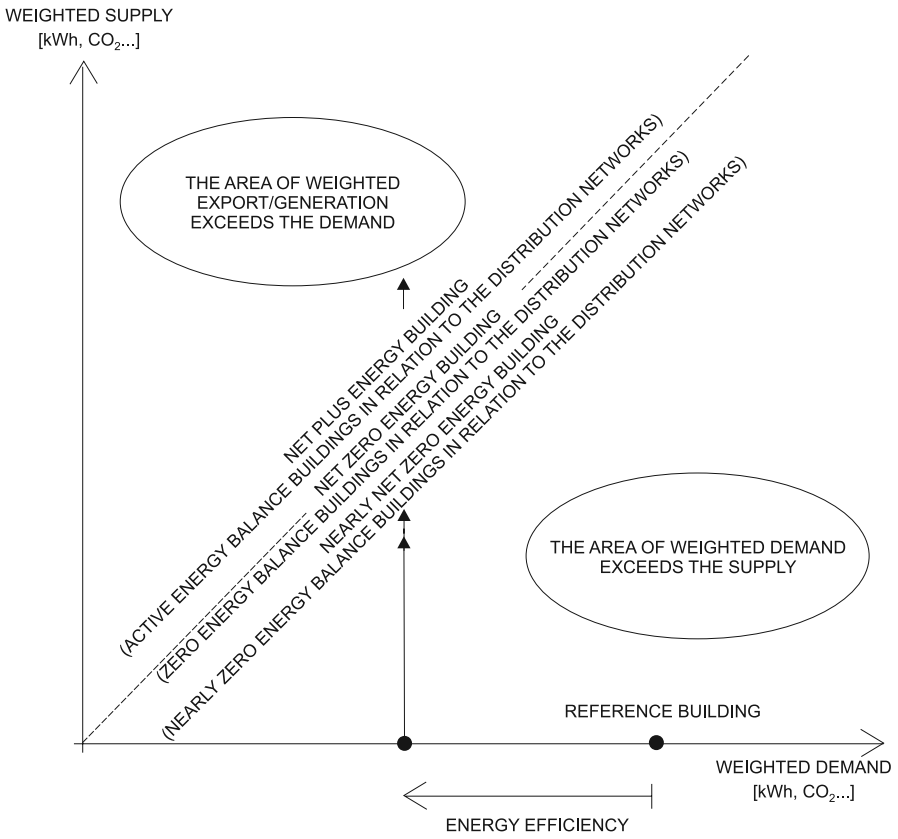


Fig. 1. Scheme of graphic dependence representing a way towards zero energy buildings in relation to the distribution network with alternatives "nearly" and "active"

Zero energy buildings are characterized by:

– the concept of application of the construction design of the theory of low energy house, based on the system relation BUILDING – CLIMATE – ENERGY [7], which defines requirements on all the elements of the building (Fig. 2), influencing its overall annual energy demand,
– the concept of application of ecologically clean local renewable energy sources which are optimally renewed by the power of nature for the economic processes of man,
– the concept of application of ecologically clean conversion of this energy in small technology devices in situ. The buildings of this concept are generally only connected to the electric distribution network (the demand of motor energy eventually the storage of energy in real time). The distribution network of electric energy represents a strategic task for the development of the infrastructure of the transformed society,

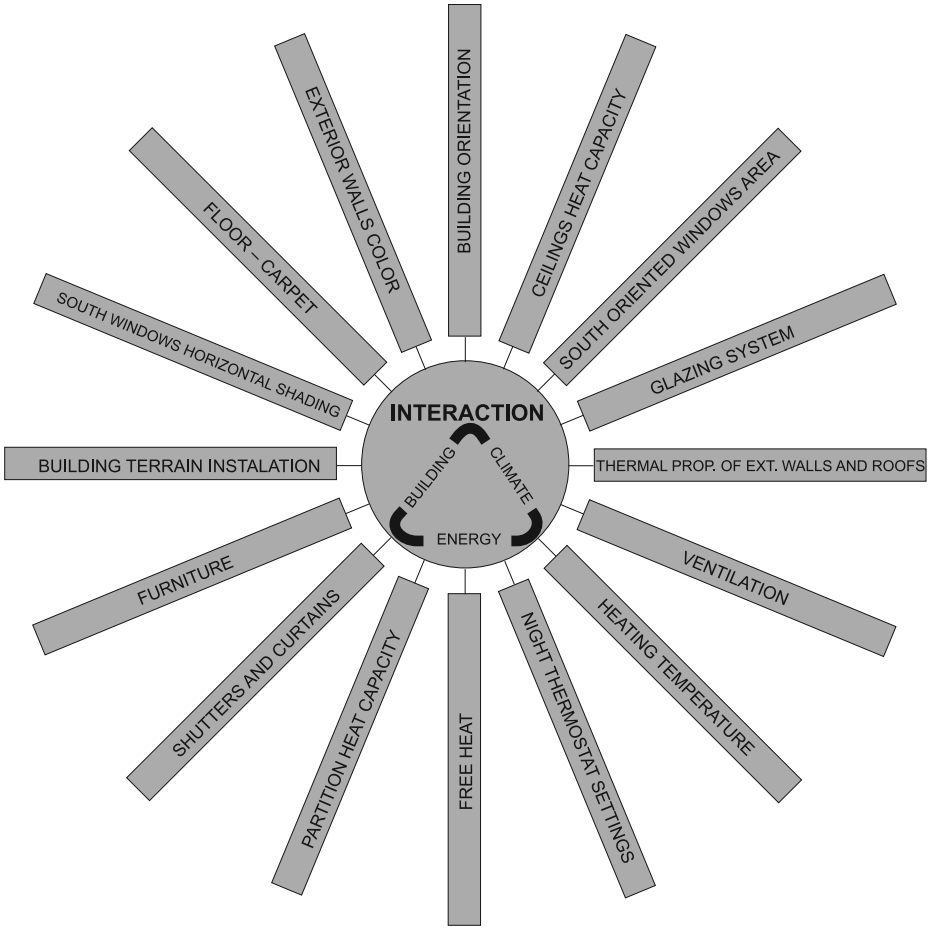


Fig. 2. Building in the system building – climate – energy is defined by the subsystem factors influencing its annual energy consumption

– the concept of a systematic decrease of production of emissions and not only by the change of energy source (from fossil to a renewable one), but also by the orientation to the application of ecologically clean building materials and their ecologically clean manufacture,
– the concept of the transformation of buildings from "a passive model of a consumer" of energy taken from the energy distribution network to "a dynamic model of collection and conversion of renewable energy and to its consumer at the same time" in situ, eventually to a supplier of energy into the distribution network.

3. New Physical-Energy Quantification of Buildings in the Development of Technology in Architecture for Sustainable Society

New physical-energy quantification of buildings must continuously build on the existing development of the energy demand of buildings. We determined its beginning by defining a building before the process of purposeful energy saving in buildings. The initial state (≈ year 1990) represents COMMON BUILDING (A) – Table 1.

3.1. 1st generation of low energy buildings

Among buildings of purposeful energy saving type belong low energy buildings of 1st generation. These include ENERGY EFFICIENT BUILDING (B) – Table 1. It is represented by a new or significantly refurbished building, designed and realized in accordance with the theory of construction design of low energy buildings in the system relation BUILDING – CLIMATE – ENERGY [7]. Energy demand of this building is in full range acquired from the distribution energy networks, i.e. the energy on the basis of fossil fuels. The only element of this building, utilizing the renewable source of solar radiation is a transparent construction (window, glass wall).

A higher level of low energy building of 1st generation represents LOW ENERGY SOLAR BUILDING (C) – Table 1. In essence, it is a building of category (B), with the additional application of renewable energy sources in the form of simple, mainly solar systems (passive solar systems, hybrid and active solar systems e.g. collectors etc.) with photothermal conversion of energy in situ. This category of buildings is also classified by the term SOLAR BUILDING with a shape-expression elements of solar architecture.

The buildings of category (A), (B), (C) – Table 1, are characterized by the fact that the physical quantification of their envelope constructions was the main criterion for reduction of their energy demand for heating, ventilation and cooling. This situation, unfortunately, in some cases, persists to this day. The increase of physical quantification of the buildings envelope for reduction of specific heat in the building, as experience has shown, is limited. The increase of physical quantification of the envelope constructions lower than the value of weighted average coefficient of the thermal transmittance $U_m < 0{,}4$ W/(m^2·K) is economically inefficient, with long energy return on investment (≈ 40 years). Moreover, buildings with high physical quantification of their envelope constructions necessarily require mechanical cooling connected with an additional energy demand (high temperatures of indoor climate in summer period). These significantly reduce the energy savings from the physical quantification of their envelope constructions (in winter period).

Tabela 1

Classification and approximate new physical-energy quantification of buildings in accordance with the development of technology in architecture for a sustainable society

Categories of building: – Residential buildings			Informative weighted aver. coefficient of the thermal transmittance of the envelope constructions	Informative specific heat use for: – Heating – Ventilation – Cooling – DHW		Informative specific energy use for: – Electric lighting – Electrical appliances – Motorized power – (DHW)	
Basic Classification of Buildings			U_m	Q_H		Q_E	
			[W/m²·K]	[kWh/(m²· a)]		[kWh/(m²· a)]	
				From power distribution network based on fossil fuels	From the local renewable sources with the conversion of energy in situ	From power distribution network based on fossil fuels	From the local renewable sources with the conversion of energy in situ
Buildings before systematic energy saving	A	Common building	0.80–0.85	100	0	15	0
Low energy huildings of 1st generation	B	Energy efficient building	0.55–0.65	70	0	15	0
	C	Low energy building – solar	0.45–0.55	50	5–10	15	0
Low energy buildings of 2st generation	D	Green building, with nearly zero energy balance in relation to the distribution networks	0.40–0.45	5–7	35–40	13	0
	E	Sustainable building, with zero energy balance in relation to the distribution networks	0.40–0.45	0	30–35	0	15–18
	F	Sustainable building – Plus, with an active energy balance in relation to the distribution networks	0.40–0.45	0	30–35	0	15–18

3.2. 2nd generation of low energy buildings

The dominant production technology of the natural capital in the form of renewable energy sources fundamentally changes the point of view to the energy quantification of buildings in the development of the technology in architecture for a sustainable society. The trend of buildings with purposeful energy saving is represented here by LOW ENERGY BUILDINGS of 2nd generation (D), (E), (F) – Table 1. Essentially, it is about a building of category (C) with the optimized application of renewable energy sources in the widest sense.

Among low energy buildings of 2nd generation belongs GREEN BUILDING (D) – Table 1, with nearly zero energy balance in relation to the distribution networks (nearly Net Zero Energy Building). The energy demand for heating, ventilation, cooling and domestic hot water preparation is covered by the local renewable sources, with the conversion of energy in situ. It is thus a building, which for the creation of an artificial living – architectural environment, has nearly zero energy balance – without the requirements for energy demand from the distribution energy network – Table 1, with the exception of energy for motor drives and the energy for regulation, or a reserve (Fig. 3). Thus is defined nearly Net Zero Energy Building, characterized by the tendency to save energy and reduce production of emissions, possess system features of green architecture, product of which is GREEN BUILDING [2].

A higher level of low energy buildings of 2nd generation represents SUSTAINABLE BUILDING (E) – Table 1, with zero energy balance in relation to the distribution networks (Net Zero Energy Building). The energy demand for heating, ventilation, cooling and domestic

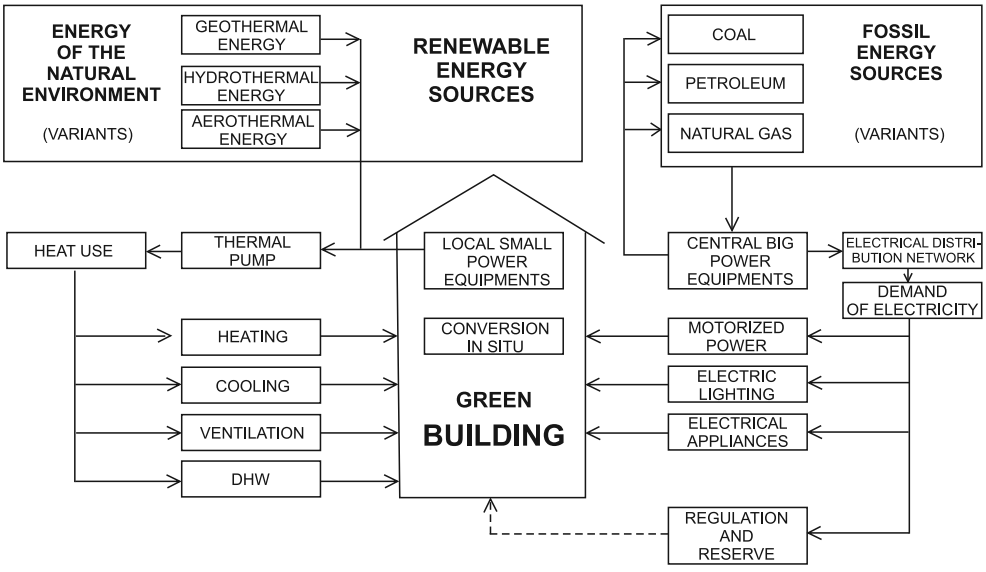


Fig. 3. Scheme of green building with nearly zero energy balance in relation to the distribution networks (nearly net zero energy green building). It has zero requirements of the energy demand for heating, cooling, ventilation and domestic hot water preparation from the distribution energy network

hot water preparation and also the energy demand for artificial electric lighting, electric appliances and motor drives are covered by the local renewable sources with the conversion of energy in situ (Table 1, Fig. 4). Nature with its processes ensures the renewal of these energy inputs, namely:

– in real time of the economic activity of man (geothermal, hydrothermal and aerothermal energy of the natural environment etc.) (Figs. 3, 4) or
– not entirely in real time of the economic activity of man (solar energy, wind energy etc.) – Fig. 4. These sources require additional technologies enabling the conversion of this energy from unpredictable form to the energy of standard quality, suitable for the economic utilization in real time (e.g. in connection with the distribution network of electric energy etc.).

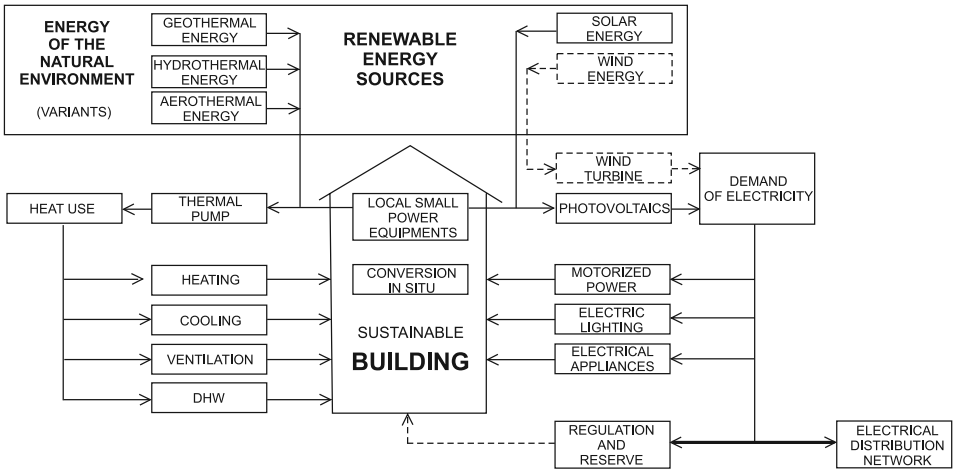


Fig. 4. Scheme of sustainable building with zero energy balance in relation to the distribution networks (net zero energy sustainable building). It has zero requirements of the energy demand for heating, cooling, ventilation and domestic hot water preparation and also zero requirements of the energy for motor drives, electric lighting and appliances. It is, in terms of the regulation and the reserve, always connected to the distribution network of electric energy

It is thus a building, which not only for the creation of the climate of artificial living – architectural environment, but also for other operation technologies has zero energy balance – has no requirements for energy from distribution energy networks, with the exception of energy for regulation or reserve (Fig. 4). Thus is defined Net Zero Energy Building, characterized by the rational utilization of energy and an optimal reduction of emissions (to the extent of the coverage by the ecosystems of the locality, region or state), possess system features of sustainable architecture, product of which is SUSTAINABLE BUILDING [2].

The highest level of low energy buildings of 2nd generation represents SUSTAINABLE BUILDING – PLUS (F) – Table 1, with an active energy balance in relation to the distribution networks (Net Plus Energy Building).

It can be seen that zero energy buildings or plus energy buildings in the final perception of sustainable buildings must also utilize the renewable energy source of solar radiation, namely at photovoltaic conversion it is a direct conversion to the electric energy (Fig. 4).

Low energy buildings of 2nd generation of type (D), (E), (F) are always connected to the distribution network of electric energy fulfilling the function of the regulation and the reserve (Figs. 3, 4). For the building of type (F) fulfills the distribution network also the function of a supplier – storage – electric energy consumer.

4. Conditioning Factors and Time Relations of Energy Transformation of the Society Towards Renewable Energy Sources

The process of the transformation towards renewable energy sources (the transformation of buildings from passive energy consumer to a dynamic system of energy collection and conversion) might be economically efficient only under the conditions of an anti discriminatory approach to all the energy sources (fossil and renewable), i.e. under the conditions of the united energy market based on the economic fundamentals [8]. Their principle comprises built-in motivation, but also repressive factors, declaring a new value system of the energy with reduced impact of emissions of greenhouse type on the atmosphere of the planet. This new economic value, which enters into the organization of the energy market, is a social value of the emissions of greenhouse type. It represents additional costs that the society must pay to prevent the creation of emissions.

Determination of the social value of CO_2 emissions in the range of ≈ 85 USD/1 tonne [6] or 65 to 75 EUR/1 tonne [8], represents a rational approach in the current period. The amount represents the costs that a company must pay additionally to produce 1 MWh of electric energy without 1 tonne of CO_2 emissions.

The transformation of the energy market thus requires transformation costs. It is possible to measure them – quantify them with the index of CO_2 emissions for each particular type of energy source and the technology of conversion of the energy. This enables the selection between the technologies or energy sources which is provided by the knowledge curve of emissions – Fig. 5. Utilizing it can optimize the order of relevant technologies, i.e. create a strategy of a logical economical allocation of the capital for investments in renewable energy sources [8].

The knowledge curve in Fig. 5 shows the fact that some technologies have not yet reached the parameters within the range of the reversal point to ensure investment returns. The necessary technological development of a new generation of photovoltaic panels and devices for storage of electricity allows us to consider such a situation of the utilization of solar energy until sometime between 2020–2025.

Therefore, in the current period, in the field of low energy buildings of 2nd generation it is realistic to have a green building with nearly zero energy balance in relation to the distribution networks, i.e. a net zero energy building. The energy is thus supplied from the renewable energy sources of natural environment (geothermal, hydrothermal and aerothermal energy) with the conversion in situ by the utilization of heat pumps according to the scheme in Fig. 3. Sustainable building according to the scheme in Fig. 4 with zero

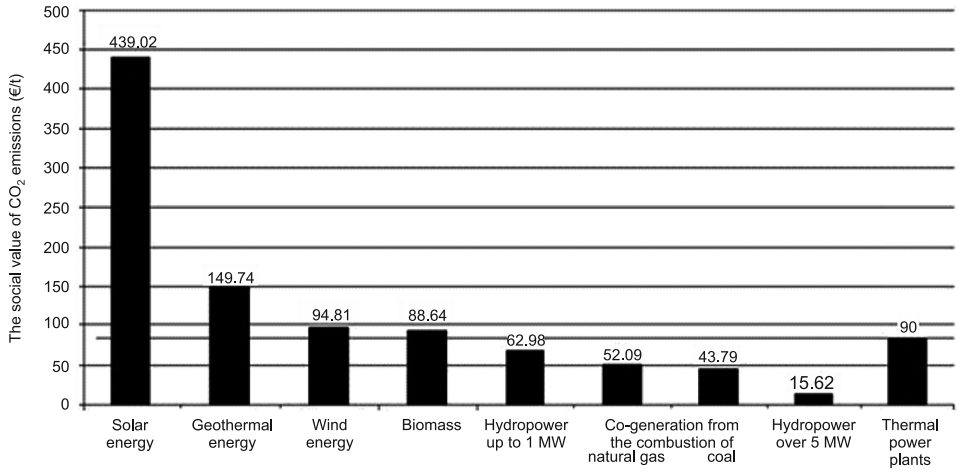


Fig. 5. Knowledge curve of CO_2 emissions in the production of electricity

energy balance in relation to the distribution networks in accordance with the development of the technology in architecture seems to be realistic after the year ≈ 2020.

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