IBO

OI3-INDIKATOR

IBO-Leitfaden für die Berechnung von Ökokennzahlen für Gebäude

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IBO - Österreichisches Institut für Baubiologie und -ökologie GmbH
A-1090 Wien, Alserbachstr. 5/8,
fon+43/1/3192005-32, fax DW 50
www.ibo.at

LEITFADEN ZUR BERECHNUNG VON ÖKOKENNZAHLEN FÜR GEBÄUDE

GUIDELINES TO CALCULATING ENVIRONMENTAL INDICATORS FOR BUILDINGS - Calculating the $OI3_{BGx}$ indicators

1. PURPOSE OF THESE GUIDELINES

These Guidelines to Calculating Environmental Indicators for Buildings have been drawn up by the Austrian Institute for Healthy and Ecological Building (IBO) with the purpose of harmonising the ways in which environmental indicators for buildings (specifically, the $OI3_{BGx}$ indicators) are calculated.

They describe the structural elements of the building to be considered in the calculation in terms of a hierarchical envelope boundary concept (BGx, x standing for a figure between 0 and 6), in which the original envelope boundary TGH (the thermal building envelope plus the intermediary floors) represents an envelope boundary of 0 (BG0).

The Guidelines explain the procedure for calculating the following environmental indicator values:

- Environmental indicator $OI3_{BGx}$ of the thermal building envelope
- Environmental indicator $OI3_{BGX,lc}$
- Environmental indicator $OI3_{BGX,BGF}$
- Environmental indicator $OI3S_{BGX}$ for rehabilitated buildings

The calculation methods used here are based on the environmental indicators contained in the IBO building materials database. You can download this as an Excel table or PDF file free of charge from the IBO home page, or load it into your calculation programme from the baubook database (www.baubook.at) via the xml interface.

2. BASES FOR RATING THE ENVIRONMENTAL QUALITY OF BUILDING MATERIALS

2.1 Introduction

During their life cycle, building materials have a widely differing impact on a wide variety of environmental and health areas. Environmental optimisation means finding the best solutions while taking into account as many of these areas and impacts. This affects the life cycle phases of

- Production,
- Use
- Dismantling, recycling and disposal

The choice of environmentally compatible building materials should be made as far as possible on the basis of scientific, or at least reproducible, findings. A good basis for comparing building materials as objectively as possible is a quantitative method, such as that of impact-focused classification, which produces environmental indicators such as greenhouse gas or acidification potential. However, we have to keep in mind the fact that these environmental impact categories only cover one part of the life cycle and impacts of a building material. To be able to estimate aspects such as the impact on health of integrating materials into a building and using them over time, further information and methods are required (see Qualitative evaluation of building materials).

2.2 Quantitative evaluation of building materials

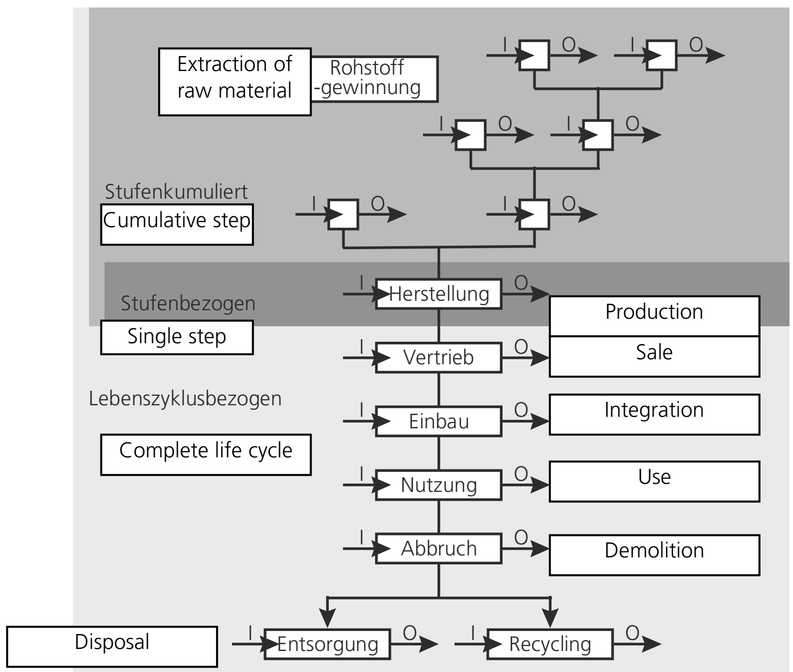
2.2.1 Environment model

Quantitative evaluations of building materials are based on a simplified environment model:
The system to be analysed is delimited by a precisely defined model (assessment model). In this assessment model, processes take place independently of inputs and outputs of materials and energy. In the first step, analysis focuses on the material and energy flows which can be clearly assigned to one cause and which are measurable and quantifiable (life cycle inventory). The inputs here are the raw materials and energy requirement and the outputs the emissions into air, water and soil, as well as waste.

Environmental effects are ascribed to each input and output, which are then used in the second step for evaluation and weighting purposes.

2.2.2 Assessment model

The assessment model will usually contain a number of processes which are interlinked and all concern energy and material flows:



Simplified chart of the life cycle of a building material. The single-step approach is part of the cumulative step, which is in turn part of the complete life cycle.

Depending on the assessment model, one of the following three types of approach is conducted:

Single-step – based solely on flows for a product during one step (without taking previous and subsequent steps into account).

Cumulative steps – based on all flows up to a defined point in time or a defined state, usually until the end product is ready for shipping.

Complete life cycle – encompasses all the phases in a defined life cycle of the product. In this type of assessment, different scenarios of use and disposal have to be defined, as inputs and pollution downstream of the manufacturing process have to be taken into account. The longer the life, the more difficult prediction becomes.

2.2.3 Life cycle inventory

The capture and documentation of the energy and material flows in a data set is called a life cycle inventory or input/output analysis and is, in principle, identical for all known environmental evaluation procedures.
A standard data set is structured as follows:
1. General information
2. Inputs
3. Outputs
The general information section contains the information which is required to precisely define the object of study.

2.2.4 Databases

Given the vast scope of Life Cycle Assessments, it is helpful to divide them up into sets of tasks:
The production data are linked with base data from databases. The base data encompass the LCA results of general processes, such as energy systems, transportation systems, waste disposal systems and packaging materials, as well as existing product LCAs which have been built on these results.
The following databases form the basis for the IBO building materials database, or have been used by IBO for assessing building materials.

- Ökoinventare und Wirkungsbilanzen von Baumaterialien [Weibel 95]
- Ökoinventare von Energiesystemen [Frischknecht 96]
- Ökoinventare Transporte [Maibach 95]
- Ökoinventare von Entsorgungssystemen [Zimmermann 96]
- Ökoinventare für Verpackungen [BUWAL 96]
- Baustoffdaten - Ökoinventare [Kohler 95]

2.2.5 Impact assessment

The impact assessment assigns impacts to the material and energy flows noted in the life cycle inventory. From the scientific point of view, the impact assessment presents the greatest challenge. The basic principle is that the objective is to draw scientific conclusions, not set political thresholds, for example.
Heijungs proposed the method of impact-focused classification [CML 1992], of which a new, updated edition has since been published [CML 2001]. The impact assessment procedure is made up of two steps:

1. Classification
2. Quantification

Classification consists of assigning the results of a life cycle inventory to a concise number of environment categories. In the second step, the substances that have been assigned to environment categories are quantified and weighted). Of the multitude of environment categories, the IBO currently uses the following:

- Global Warming Potential (100 years in relation to 1994)
- Acidification potential
- Non-renewable energy resource[1] requirement

2.2.6 Global warming potential (GWP)

More and more greenhouse gases are being injected into the atmosphere by human activity. This is causing a larger proportion of the thermal radiation being emitted by the earth to be absorbed, altering the earth's radiation balance (anthropogenic greenhouse effect). This will result in global climate changes. The most important greenhouse gas in terms of quantity is carbon dioxide. For the most frequently occurring greenhouse gases, a parameter is defined in relation to the principal greenhouse gas, carbon dioxide (CO_2), and this is expressed as GWP (Global Warming Potential). The global warming potential describes the contribution of a gas to the greenhouse effect in relation to that of an identical quantity of carbon dioxide. For each greenhouse gas, an equivalent amount of carbon dioxide is therefore calculated in kilograms. This enables their direct impact on global warming to be expressed as a single impact figure in which the global warming potential of an emitted gas i (GWP_i) is multiplied by the mass of the gas m_i in kilograms:

$$GWP = \sum_i GWP_i \cdot m_i$$

Global warming potential can be determined for various time horizons (20, 100 or 500 years). A shorter integration period of 20 years is crucial for predicting short-term changes due to an exacerbated greenhouse effect, as is to be expected for a continental land mass. This means that it can be used

[1] The non-renewable energy resource requirement, expressed as primary energy content, does not fall within Heijungs' impact classification as it is a material quantity (cause).

when the temperature rise is to be limited to 0.1℃ per decade, for example. By contrast, the use of longer integration periods of 100 and 500 years is appropriate for evaluating the long-term rise in ocean levels and serves, for example, to weight the greenhouse gases by limiting the total anthropogenous temperature rise to, say, 2℃.

2.2.7 Acidification potential (AP)

Acidification is caused mainly by the interaction of nitrogen oxides (NO_x) and sulphur dioxides (SO_2) with other constituents of air, such as the hydroxyl radicals. This can cause these gases to be converted in the space of just a few days into nitric acid (HNO_3) and sulphuric acid (H_2SO_4) – both substances which are instantaneously soluble in water. The acidified water droplets then precipitate as acid rain. Unlike the greenhouse effect, acidification is a regional, not a global, phenomenon.

Sulphuric and nitric acid may also be deposited in dry form. There is increasing evidence that dry deposits cause the same, major environmental problems as wet ones.

Knowledge of the impact of acidification is still only fragmentary. One of the clearly attributed consequences is the acidification of lakes, rivers and streams, which is decimating fish stocks in terms both of quantity and diversity. Acidification can have the effect of mobilising heavy metals, which then become available to plants and trees. Moreover, acid deposits may play a role in the damage to forests which we are seeing. Over-acidification of the soil can impact the solubility and thus the availability to plants of nutrients and trace elements. Corrosion on buildings and outdoor art works is another consequence of acidification.

The unit of measurement for the tendency of a constituent to acidify is the acidification potential, AP. For each acid-forming gas, this is expressed in relation to the acidification potential of sulphur dioxide.

2.2.8 Non-renewable energy resource requirement (PEC n.r. – non-renewable primary energy content)

The primary energy content is the overall consumption of energy resources required to manufacture a product or a service. It is divided into renewable and non-renewable energy resources. The non-renewable energy resources are oil, natural gas, lignite and coal, and uranium. The renewable energy resources are wood, water power, solar energy and wind energy. For the

purposes of this project, only the non-renewable energy resources were evaluated.
The “non-renewable primary energy content” is calculated from the highest calorific value of all the non-renewable energy resources which were used during the production chain of the product.
Strictly speaking, the primary energy content is not an impact category, but a material quantity, but it is frequently spoken of on a par with the other environmental impact categories.

2.2.9 Interpretation

The interpretation is carried out at the end of this procedure. Basically, there are two different approaches:

- The low-level aggregation method (conflation into an environmental profile)
- The high-level aggregation method (conflation into one or a small number of key figures)
- Descriptive interpretation

3. BUILDING MATERIAL ASSESSMENT AND BUILDING MATERIAL DATABASE

3.1 Building material assessment

The building materials are assessed by means of a cumulative-step life cycle assessment up to the “ex-factory” point in time. This means that all the processes are taken into account upstream of the point when the product is ready for shipment. For each step in the process, the material, transportation and energy inputs, as well as the emissions into the air, soil and water, and waste, are calculated. The downstream stages (sale, integration into buildings, etc.) are not assessed, as these depend on the place of sale, place of use and the chosen structure. Also, the disposal and recycling scenarios and reliable data as to the useful life of the products are lacking.
The building material data are taken from the following sources:

- Scientific publications
- Manufacturer or distributor specifications
- Information from experts

The system boundaries of the building materials assessed by the IBO are based on the linked-in databases as far as possible (cf. 2.2.4 Databases). You will find more details on the methods applied in the IBO benchmarks [IBO-Richtwerte 2009].

3.2 IBO building material benchmarks database

The IBO building material benchmarks database contains environmental key figures for many of the building materials used to construct shells. They include global warming potential, acidification potential and the primary energy content in terms of non-renewable energy resources which were gathered from representative or average factory assessments of building materials. The origins of the IBO reference database lie in the “Ökologischer Bauteilkatalog” (Catalogue of Environmentally Compatible Structural Elements, BTK 1999), for which environmental data on building materials were gathered from 1994 onward and have been continually updated ever since. Manufacturer figures and data from the literature are the sources. From the literature, only figures which date from less than ten years ago are used. The current IBO reference database (September 2006) was drawn up

as part of the “Passivhaus-Bauteilkatalog” (Catalogue of Passive-Energy House Construction Components, BTK 2008).
The IBO reference database on building materials is used:
as a sub-criterion in an all-encompassing (qualitative) life cycle analysis of building materials:
to provide benchmark values for the product database at www.baubook.at (the öbox and ixbau.at databases combined) and for building physics programmes:
to calculate key figures for buildings (assessment of environmental impacts of the construction of a building) in the context of building certification or housing subsidy programmes).

4. OI3 BASE INDICATORS

The OI3 base indicators are:

- Environmental indicator $OI3_{KON}$ for one square metre of a structure or building material
- Environmental indicator ΔOI3 for one layer of building material

The $OI3_{KON}$ indicator is relative to 1m² of a structure and all the OI3 indicators described below are based on it. This means that it is also the base indicator for assessing buildings.
The ΔOI3 (pronounced delta OI3) indicator for building material layers indicates by how many OI3 points that layer of building materials raises the $OI3_{KON}$ of a structure. This OI3 indicator is extremely helpful for optimising structures.

4.1 Environmental indicator $OI3_{KON}$ of a structure.

A structure’s $OI3_{KON}$ environmental indicator (for 1m² of a structure) encompasses OI_{PECnr} (environmental indicator of non-renewable primary energy content, PEC n.r.), OI_{GWP} (environmental indicator of global warming potential GWP), and OI_{AP} (environmental indicator of acidification potential AP), in proportions of one-third each. This is calculated as shown below:

$$OI3_{KON} = 1/3\ OI_{PECnr} + 1/3\ OI_{GWP} + 1/3\ OI_{AP}$$

A datasheet for calculating the $OI3_{KON}$ will contain the following information:

- All the layers of the structural elements of a structure
- Gross density of the structural element layers
- Thickness of the structural element layers

- Percentage (in the case of inhomogenous layers)
- Building material key figures from the IBO benchmark database on building materials

4.2 Calculating the sub-indicators OI_{PECnr}, OI_{GWP}, OI_{AP}

As mentioned above, before calculating the $OI3_{KON}$, the following indicators concerning production of the structure must be calculated:

- OI_{PECnr} concerning consumption of energy resources
- OI_{GWP} concerning the global warming potential
- OI_{AP} concerning the acidification potential

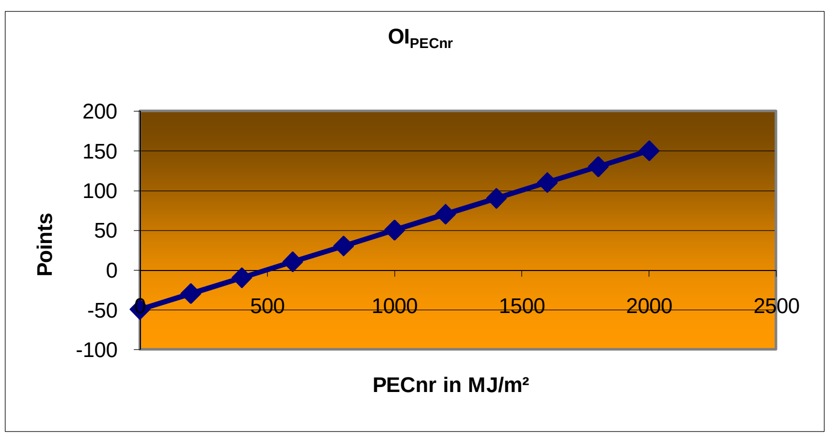
The scale of each indicator ranges from 0 – 100 points for conventional structures.

To calculate the sub-indicators OI_{PECnr} , OI_{GWP} und OI_{AP}, the respective key figures for all the layers and structural elements are added together and reduced to a scale of, typically, 0-100 points using the functions described below:

4.2.1 OI_{PECnr}

To calculate the OI_{PECnr} the following line chart was drawn on the basis of actual structural and building data:

To convert the MJ per 1 m² of structure into OI_{PECnr} points, the linear function f(x) = 1/10*(x-500) is used.

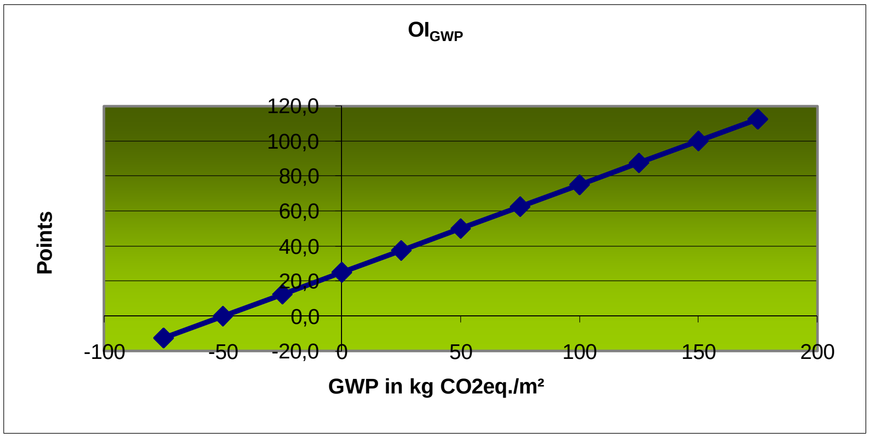


Conversion of PECnr in MJ/m² into OI_{PECnr} points

4.2.2 OI_{GWP}

To calculate the OI_{GWP}, the following line chart was drawn on the basis of actual structural and building data:

To convert the kg CO_2 eq. per 1 m² of structure into OI_{GWP} points, the linear function f(x) = 1/2*(x+50) is used.

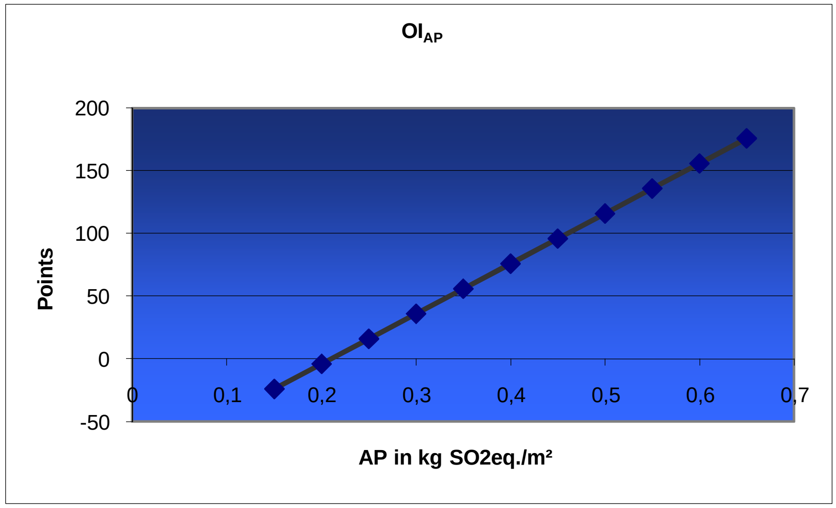


Conversion of GWP in kg CO_2 eq. into OI_{GWP} points

4.2.3 OI_{AP}

To calculate the OI_{AP}, the following line chart was drawn on the basis of actual structural and building data:

To convert the kg SO_2 eq. per 1 m² of structure into OI_{GWP} points, the linear function f(x) = 100/0.25*(x+0.21) is used.



Conversion of AP in kg SO_2 eq. into OI_{AP} points

4.2.4 Scale of values of the $OI3_{KON}$ indicator

The environmental quality of conventional structures is shown by the environmental indicator $OI3_{KON}$ on a scale of 0 to 100 points. For example, an outside wall with an $OI3_{KON}$ of 70 is typical of a standard structure without any environmental optimisations; an $OI3_{KON}$ of 15 or less can only be attained by means of environmental optimisation or by a very light structural design.

4.2.5 ΔOI3 – the OI3 indicator for one layer of building material

The ΔOI3 (pronounced delta OI3) indicator for one building material layer indicates by how many OI3 points that layer of building materials raises the $OI3_{KON}$ of a structure. In other words, if you eliminate one layer from a structure, the $OI3_{KON}$ of the structure will sink by $\Delta OI3_{BS}$ points (BS stands for *Bauteilschicht*, layer of a structural element).

This ΔOI3 indicator is extremely helpful in terms of structure optimisation, as the "environmental heavyweights" in a structure are easy to recognise by virtue of their high $\Delta OI3_{BS}$ scores. The formula for calculating the $\Delta OI3_{BS}$ points of a layer of a structural element is as follows:

$$\Delta OI3_{BS} = \frac{1}{3} \cdot \left[\frac{1}{10} \cdot (PECnr)_{BS} + \frac{1}{2} (GWP)_{BS} + \frac{100}{0.25} (AP)_{BS} \right]$$

$(PECnr)_{BS}$….non-renewable primary energy consumption of the structural element layer (BS) in MJ/m²

$(GWP)_{BS}$….global warming potential of the structural element layer in kg CO_2 eq./m²
$(AP)_{BS}$….acidification potential of the structural element layer kg SO_2 eq./m²

Adding together all the ΔOI3 points of a structure does not provide the $OI3_{KON}$ value of the structure, but a value which is higher by 109/3 (the OI3 points are zero offset so that buildings with an envelope boundary BG0 (TGH) can be represented within a range of 0-100 $OI3_{BG0}$ points.

5. FLEXIBLE ENVELOPE BOUNDARIES

Buildings are made up of a multitude of different structures. The direct way to calculate the OI3 points of a building is to work out the weighted mean values of the OI3 points of all the structures contained in it. In theory, all the structures and elements in a building would have to be captured and included in the calculation; in practical terms, however, the task of capturing all these data would take far too long. Moreover, the uncertainties of the values of the principal structural elements are already higher, in some cases, than the absolute values of the lesser elements.

The OI3 of a building was so far calculated mainly in terms of the THG (thermal building envelope), the local THG boundary encompassing the structures or elements of the thermal building envelope including the intermediary layers (this envelope boundary is referred to below as BG0).

Experiences so far with the spatial thermal envelope boundary TGH have shown that successfully extending the boundary beyond the TGH with the aid of a flexible envelope boundary concept has the greatest chance of being accepted in actual practice.

This is why the following envelope boundary concept (spatial and temporal) has been designed, in the interests of helping the OI3 indicator to evolve:

- BG0 (old TGH boundary): structures of the thermal building envelope + intermediary floors – roof cladding – damp-proofing – rear-ventilated façade elements.
- BG1: Thermal building envelope (all structures) + intermediary floors (all structures)
- BG2: BG1 + inside walls (dividing elements)
- BG3: BG2 + complete basement

- BG4: BG3 + direct accesses (stairways, covered walkways, etc.)
- BG5: BG4 + HT (housing technology)
- BG6: BG5 + all accesses + adjoining buildings

From boundary BG2, the temporal boundary may already include useful life. From boundary BG3, the useful life of the structural element layers must be included, as the basement – especially in detached houses – is “overvalued” in environmental terms.

Envelope boundary BG5 covers a building in its entirety. Envelope boundary BG6 refers to building complexes.

6. $OI3_{BGX,Y}$ – ENVIRONMENTAL INDICATORS FOR BUILDINGS

The following OI3 indicators for buildings have been defined:

- Indicator $OI3_{BGX}$ of a building, which depends on the chosen BGx envelope boundary (area-weighted $OI3_{KON}$ indicator of the area of the structural elements considered)
- Indicator $OI3_{BGx,lc}$ (area-weighted $OI3_{KON}$ of the building, in which the corresponding BGx envelope boundary is corrected to take into account the typical length of the building)
- Indicator $OI3_{BGx,BGF}$ (area-weighted $OI3_{KON}$ of the building, in which the corresponding BGx envelope boundary is corrected to take into account the gross surface area of a storey)
- Indicator $OI3S_{TGH}$ for rehabilitated buildings (depreciation model for the environmental pollution caused by production)

6.1 Calculating $OI3_{BGX}$

$OI3_{BGX}$ is the area-weighted mean of the $OI3_{KON}$ values of all the structures contained within the envelope boundary.

$$OI3_{BGX} = \frac{\sum_{i=1}^{N} A_i \cdot OI3_{KON,i}}{\sum_{i=1}^{N} A_i}$$

$$A_i \; ...Areas\ of\ the\ structures\ in\ m^2$$

$$OI3_{KON,i} \; ...OI3_{KON}\ of\ the\ i-th\ structure$$

$$\sum_{i=1}^{N} A_i \; ...Structure\ area\ (KOF)$$

6.2 Calculating $OI3_{BGX,lc}$

To allow the $OI3_{BGX}$ indicator to take into account the environmental pollution caused by ill-chosen ratios of surface area to volume, the key figure $OI3_{BGX,lc}$ is defined as follows:

$$OI3_{BGX,lc} = 3^* OI3_{BGX}/(2+l_c)$$

in which lc is the typical length of the building.
lc = VG/AG
VG… Volume of building, AG.....Surface area of building.
Lc is calculated according to the OIB guidelines RL6 on how to calculate energy key figures [OIB Guidelines].

6.3 Calculating $OI3_{BGX,BGF}$

To allow the $OI3_{BGX,BGF}$ indicator to take into account the environmental pollution per m² of gross area of one storey, it is defined as follows:

$$OI3_{BGX,BGF} = \frac{\sum_{i=1}^{N} A_i \cdot OI3_{KON,i}}{BGF}$$

$$A_i \; ...Area\ of\ the\ structures\ in\ m^2$$

$$OI3_{KON,i} \; ...OI3_{KON}\ of\ the\ i-th\ structure$$

$$BGF \; ...Gross\ surface\ area\ of\ storey\ in\ m^2$$

The BGF is calculated according to the OIB guidelines RL6 on how to calculate energy key figures for buildings.

6.4 Functional unit of the $OI3_{BGX}$ indicators

The basic functional unit chosen for the $OI3_{BGX}$ indicators was an area of 1 square metre of structure. The structure area is the sum of all the areas of the different structural elements taken into consideration in calculating the $OI3_{BGX}$. Thus, the $OI3_{BGX}$ indicators represent an area-weighted mean value of the environmental pollution of the structural elements included in the calculation.

6.5 Scale of values of the $OI3_{BGX}$ indicators

The environmental quality of a building is indicated by means of these key figures and the envelope boundary BG0 on a scale of 0 to 100 points; that is, 100 points means that the building envelope is highly polluting, while 0 points can only be attained by extremely optimised structures.
In this, the $OI3_{BG0}$ points are similar to the figures for heating requirements: low heating requirements of 15 kWh/m²a are regarded as excellent, as are buildings and structures with fewer than 15 $OI3_{BG0}$ points.
The $OI3_{BG1}$ points for buildings are around 10 points higher than the $OI3_{BG0}$ points.

6.6 Calculating the $OI3S_{BGX}$ indicators

Building rehabilitation is set to be a crucial factor in construction in the next few years.
The environmental quality of the rehabilitation of the thermal building envelope can be judged with the aid of the environmental indicator $OI3S_{BG1}$. The $OI3S_{BG1}$ is calculated in the same way as the $OI3_{BG1}$, except that the age of the structure of building is taken into account by means of a simple depreciation model. The $OI3_{BG1}$ value is the starting point. The environmental pollution of a new structure or building is depreciated in a linear fashion over a period of 80 years, starting after five years, to 25% of the starting value. In other words, after 80 years, a building has an $OI3_{BGX}$ value which is only 25% of the value when new. The base value of 25% of the value when new is retained to take into account the disposal of the structure or building. The fact that depreciation starts after 5 years is to cover at least the construction time. The OI3 value depreciated over the years is called $OI3S_{BG1}$.
The OI3S is calculated as follows:

1. The age of the layer, structure or building is determined.

2. The key figures PEC n.r./m² and AP/m² are then determined. These key figures as such represent the correct values for calculating the OI3S if the layer is younger than 5 years. If the age of the layer is more than 5 years, their value has to be multiplied by a factor of 0.75*(1- "age of layer minus 5"/75) and the base value of 0.25*PEC n.r/m² added on. If the “age of layer” is higher than 80 years, the base value represents the value of the key figure.
3. Precisely the same method is applied to determine the GWP/m², except that the base value is 0 kg/CO_2 eq./m². Positive and negative GWP values of layers are multiplied by the factor (1- "age of layer minus 5"/75) if the layers are older than 5 years. This depreciates the effect of the CO_2 stored up over the fictive life of 80 years.

   From the PEC n.r./m², GWP/m² and AP/m² values thus calculated, the methods described above are used to calculate the indicators $OI_{BG1,PECnr}$, $OI_{BG1,GWP}$ and $OI_{BG1,AP}$, and on the basis of these, the indicator

   $$OI3S_{BG1} = 1/3\ OI_{BG1,PECnr} + 1/3\ OI_{BG1,GWP} + 1/3\ OI_{BG1,AP}$$

   is found.
4. The two environmental indicators $OI3S_{BG1,lc}$ and $OI3S_{BG1,BGF}$ are calculated using the method described above.

Thus, the environmental indicator $OI3S_{BG1}$ takes the life of a structure or building into account in a simple manner. The life of each and every layer is taken into account, which means that due consideration is given to thermal rehabilitation work.

The environmental indicator $OI3S_{BG1}$ ascribes very low environmental pollution to long-lasting structures or layers. Rehabilitation or re-use of layers is rewarded with low $OI3S_{BG1}$ values. In this model, the use of new structures or new layers generates the maximum amount of environmental pollution, that is, the highest possible amount of $OI3S_{BG1}$ points.

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7. LITERATUR

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