Chapter 2
Building and Sustainable Development

Abstract This section explains the concept of sustainable development in terms of a building. Multiple sources for environmental indices imply the need for a thorough qualitative analysis on the basis of established criteria. The first part lays the background and the second specifies the indicators and associated data to measure performance. The next part presents different assessment tools or guides that improve performance. Finally, the fourth and last part presents and analyses the scientific literature.

Keywords Building • Tools • Sustainable development • Assessment

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2.1 Background

The importance and impact of the negative effects of the growth of industrial activities at a global level have led to the development of the concept of "sustainable development". It has rapidly become a long-term concern for buildings. There exist several definitions of sustainable development. While not opposing and often complementary, these definitions are vague in nature, especially when the analysis focuses on the consequences they entail, both at individual and collective levels.

M. Méquignon and H. Ait Haddou, *Lifetime Environmental Impact of Buildings*, SpringerBriefs in Applied Sciences and Technology, DOI: 10.1007/978-3-319-06641-7_2,

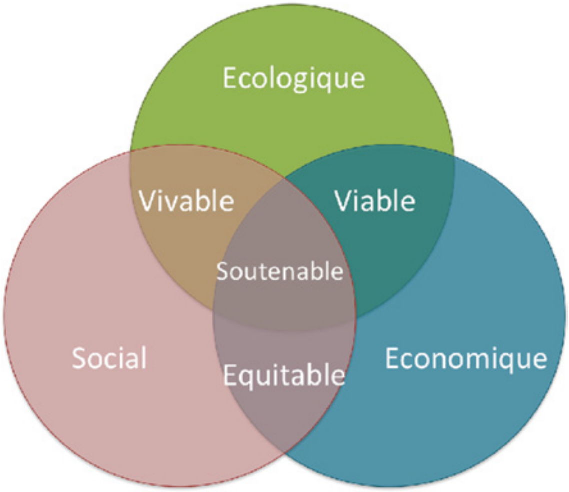

Fig. 2.1 Model Jacobs and Sadler (Boothroyd 1990)

2.1.1 *Definitions*

The following relatively accurate definition allows us to address the essential issue of sustainable development. It was put forth by the World Commission on Environment and Development:

"Sustainable development seeks to meet the development needs of present generations without compromising the ability of future generations to meet their own need" (WCED 1987). This definition seems to have a relative consensus among most of the people interested in the subject (Fig. 2.1).

At the Copenhagen summit in 1995, it was recognized that sustainable development should be characterized by three dimensions that would give it a fuller and more accurate content. These are social, economic and ecological dimensions. This characterization is illustrated by the above model of Jacobs and Sadler (Boothroyd 1990).

The originality of sustainable development lies in the systemic or structural connection between economy, the environment and society. It is understood as a development that meets the basic needs of one generation without compromising the needs of other generations.

The economic aspect reflects the search for sustainable development focussing on growth and economic efficiency. This approach must address the need to develop the economy and the society, particularly in the case of developing countries seeking an adequate standard of living.

The social approach expresses the fact that sustainable development must be based on human needs and therefore aim for social equity. The individual positioned at the centre of the action can meet this necessity. Recalling the intra-generational and intergenerational links, the Brundtland Report has positioned man at the centre of the objective; this approach involves health, hygiene and cultural aspects. In terms of the intergenerational aspect, the report also set the goal in relation to time.

The ecological approach stresses the fact that action has to preserve, improve and enhance the environment and make it fit for life. Action must conserve resources on the long term and favour regeneration rather than exhaustion. The approach also includes the reduction of climate impacts caused by human actions.

The different features of the concept are:

- A relationship between the environmental, social and economic aspects;
- A transverse and systemic approach;
- Harmonization between short term and long term, based on the precautionary principle;
- A motto of "think global, act local";
- Solidarity between rich and poor countries, with an inter-generational component;
- A new form of governance for strengthening democracy.

The question of the role of culture arises through the definition. Can we ignore the approach to issues of the built environment? In its Opinion No. 2002–2007 of April 2002, the French CSD questioned the lack of reference to culture in the work on sustainable development. In this text, the Committee puts man at the centre of the device and reminds the specificity of the species in its relation to culture. She emphasizes "the need to complete the approach to sustainable development by integrating the cultural dimension as well as economic, social and ecological dimensions." The actions undertaken in the framework of a sustainable development approach must necessarily integrate the cultural specificities of each human group. Cultural diversity, as well as natural heritage must be protected and enhanced in order to be transmitted to future generations.

2.1.2 Principle: Analysis of Life Cycle

According to ISO 14040:2006 standards Series: Environmental management—Life cycle assessment—Principles and framework, the analysis lifecycle or "LCA" assesses the environmental impact of a product or system considering all stages of its life cycle.

The objective of this principle allows, firstly, to identify the points on which a system can be improved and secondly, to obtain a complete record of the essential part of a performance comparison of different solutions. According to the attached diagram extracted from the ISO 14040 standard, the method consists of four main phases (Fig. 2.2):

These are:

- Define the objectives and define the system;
- Create the emissions inventory. This is the quantitative description of the different flows that cross system boundaries. The inventory should consider recycled or reused elements and shall be deducted from the global value;

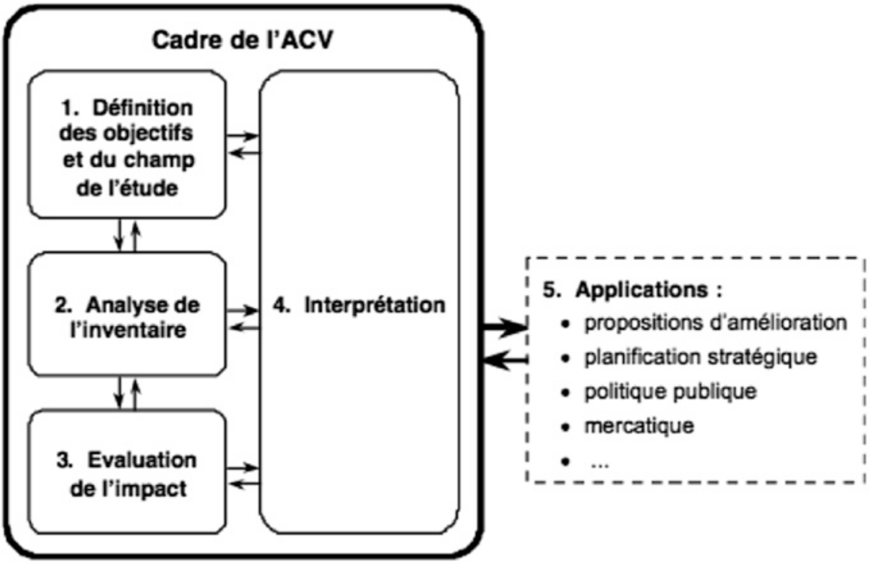

Fig. 2.2 ACV steps—ISO 14040-2006

- Make an interpretation;
- Analyse the impact: they may fall within human toxicity, noise, creating oxidant, the depletion of the ozone layer, global warming, acidification, eutrophication, eco-toxicity, land use and loss of habitat, dispersion of species and organisms, the usage of natural resources, soil erosion, salinization of soils, … (Curran 2006).

In brief, products or systems must be evaluated in their life cycle, which means taking into account the phases of design, production, use and demolition. Only the life cycle analysis of products used to compare different solutions in the context of an assessment of environmental, economic and social impact.

2.1.3 Eco-Design and Eco-Building Materials

Architecture compatible with sustainable development therefore results from a subtle balance between the requirements of the society, economy and environment.

The building includes several functions to meet many needs. The functional response can be established through numerous solutions. These responses are established at a level of environmental, social and economic quality. The study of ecological quality is the most thorough approach. The environmental quality of buildings includes the quality of indoor environments and reducing impacts on the environment. Eco-design includes the choice of materials and the system consisting of assembly, as regards the impact they induce on the inside and outside environment. This analysis assesses the degree of performance of the choice of materials as eco-materials (Peuportier 2001a, b).

2.1.3.1 Definitions

Eco-materials are materials classified according to their environmental and health impact, according to their performance and comfort based on the lowest overall cost. Therefore, the materials are classed by their performance levels.

Eco-design of a building take into account the environmental impact and atmosphere through the morphology and organization of interior spaces for the lowest overall cost (Peuportier 2001a).

2.1.3.2 The Criteria for Eco-Materials

The criteria mentioned in the French standard NF P01-010 impacts the choice of eco-materials are introduced implies that performance in the following terms (Table 2.1):

Table 2.1 Eco-materials properties

Specifications	Units	Definition (Sacadura 1993)
Density	–	Ratio of the mass of material and the mass of same volume of water at the temperature of 3,98 °C.
Thermal Conductivity	W/m.K	Heat flow in watts running through thick 1 m materials on a surface of 1 m^2 with a temperature of 1 °C or K between the two sides
Thermal capacity	$Wh/m^{3*}K$	Ability of the material stored heat. It measures the amount of heat required to raise 1 °C, 1 m^3 of material.
Phase shift	h	Speed of the heat wave to pass through a material
Thermal effusivity	$J^{*}K.m^{-2}.s^{-1/2}$	Coefficient that characterizes the speed with which the temperature of a material is heated
Thermal diffusivity	m^2/s	Physical quantity which characterizes the ability of a material in the penetration and the alleviation of a thermal wave in a medium
Porosity	–	Ratio of the volumes of voids on the volume of the materials
Hygroscopic	%	Ability to hold water and interact with the environment
Sound reduction	dB	Ability to absorb sound waves

2.1.3.3 The Criteria for Eco-Design

The impact criteria mentioned in the previous paragraph, an eco-design will aggregate other analysis such points:

- Land use;
- Surrounding cover;
- The winds;
- Sunlight causing overheating in summer and glare;
- Ambient light that will change the lighting and energy, and liveability;

- The luminance of a light source is the ratio of the intensity of the source on a surface in a direction of the projected area of the source;
- Colors and surface conditions;
- Noise;
- Air, its renewal, its speed and relative humidity;
- The energy sensors;
- Leakage and radiation.

Bernstein et al. (2006), Liébard and De Herde (2006), Déoux and Déoux (2004).

The response to the program of the client, must be a consensus in the consideration of various constraints so that the impact on the environment is as low as possible and the indoor environment most habitable. This optimal response must result from an equilibrium having a minimum overall cost.

Finally, as recommended by the 2nd target of the 2008 version of the HQE®, Bruno Peuportier evokes the "sustainability" within the meaning of lifespan in his general analysis of buildings (Peuportier 2001b). It presents rehabilitation of old buildings obtaining a very satisfactory performance in terms of energy but does not evaluate the gains in other criterion of sustainable development nor those obtained by extending the lifespan. Lifespan of products, components built using these products and building itself has an impact on the environment. None of the other works that have been consulted involve the question of the lifespan of products or buildings and their influence in performance.

2.2 Indicators and Sustainable Development Data

2.2.1 Indicators and Indices

In this section, indicators and indices are defined in the sense of Boulanger (2004). Thus, an indicator is an observable variable used to reflect the status of a non-observable reality. For example, it may be the amount of greenhouse gas emitted by the manufacture of a product, the unit being kg of CO_2. An index refers to a synthetic indicator constructed by aggregating so-called basic indicators.

The process of construction of indicators is identified by Lazarsfeld in 1958 according to the following scheme:

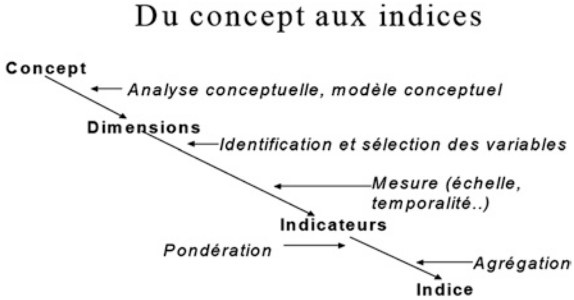

Table 2.2 List of polluting emissions

Consumption of non-energy natural resources
Antimony (Sb), Silver (Ag), Clay, Arsenic (As), Bauxite (Al_2O_3), Bentonite, Bismuth (Bi), boron (B), Cadmium (Cd), Limestone, Sodium Carbonate (Na_2CO_3), Chloride potasium (KCl), Sodium chloride (NaCl), Chromium (Cr), Cobalt (Co), Copper (Cu), Dolomite, Tin (Sn), Feldspar, Iron (Fe), Fluorite (CaF_2), Gravel, Lithium (Li), Kaolin (Al_2O_3, $2SiO_2$, $2H_2O$), Magnesium (Mg), Manganese (Mn), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Gold (Au), Palladium (Pd), Platinum (Pt), Lead (Pb), Rhodium (Rh), Rutile (TiO_2), Sand, silica (SiO_2), Sulfur (S), Barium sulfate ($BaSO_4$), Titanium (Ti), Tungsten (W), Vanadium (V) Zinc (Zn), Zirconium (Zr)
Emissions in air
GHG and acidification Nitrogen oxides
GHG: Carbon dioxide (CO_2), Methane (CH_4), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulfur hexafluoride ($SF_{6)}$
Sulfur dioxide
Greenhouse eutrophication Ammonia (NH_3)
Hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOC), Carbon monoxide (CO), Nitrous oxide (N_2O), Sulfur oxides, Sulfur Hydrogen, Hydrogen cyanide acid, chlorinated organic compounds, inorganic chlorine compounds, chlorinated compounds not specified, fluorinated organic compounds, inorganic fluorine compounds, halogenated compounds, fluorine compounds unspecified Cadmium and its compounds, Chromium and its compounds, Cobalt and its compounds, Copper, Tin and its compounds, Manganese, Mercury, Nickel and its compounds, lead and its compounds, Selenium, Tellurium Zinc, Vanadium Silicon
Emissions in water
COD (Chemical Oxygen Demand), BOD5 (Biochemical Oxygen Demand in 5 days), Suspended Matter (SPM) AOX (adsorbable organic halogens compounds), hydrocarbons, phosphorus compounds

This aggregation of heterogeneous indicators requires a multi-criteria approach which is made to establish conversions to homogeneous units on the basis of the chosen relative importance.

The list of product emissions in the building sector is accurate cf. Table 2.2. It allowed the establishment of estimating emissions of products based on the French standard NF P01-010, itself supported on ISO 14040 series of analytical life cycle (Life Cycle Impact Assessment). The objective is the evaluation of an entire life cycle, from product emissions in the building sector.

In these programs, you must add the evaluation of water consumption and the inventory of recycled materials.

On the depletion of natural resources, the index used is the Abiotic Depletion Potential (ADP). This indicator takes into account the consumption of energy and non-energy resources (except water) by weighting each resource by a coefficient corresponding to a Rarity (antimony has a value of 1 by convention) (Clift 2004). In ESFD base INIES, a value greater than 1 for UF of a product indicates that we are consuming a resource that's rarer than antimony. The resources whose value on the indicator is very low (less than 0.001) are considered non-exhaustible on a human scale. This principle is stated in the standard NF P01-010.

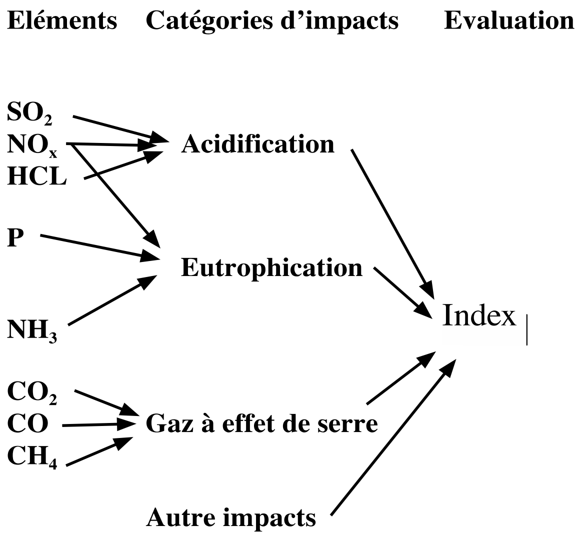

Fig. 2.3 Diagram of constituting an index of environmental impact (Oberg 2005)

The formula for calculating the depletion of natural resources is as follows (Habert et al. 2010a, b):

With DRi (kg/year) extraction rate of resource i

Drsb is the extraction rate of antimony which is equal to 6.06×10^7 kg/year and Ri is the stock of resource i in kg

RSb equal to 4.63×1015 natural resources stock of antimony (Sb).

For example: The maximum stock of cement in France

$$\text{R cement} = 2.49 \times 1012\,\text{kg}$$

$$\text{DR cement} = 2.48 \times 1010\,\text{kg/year}$$

$$\text{ADP cement} = 1.41 \times 10^9\,\text{kg eq Sb}$$

In conclusion of this example, the calculation performed for UF, is well below 1. These results present the cement as weakly exhaustible. Nevertheless, discussions and oppositions may appear on the available resources to the extent that the rate of extraction and resources are located.

On the establishment of an index globalising environmental impacts, work has been completed. The logic is shown schematically in the figure below provided by Oberg (2005), Osso (1996) (Fig. 2.3).

Then, the difficulty lies in choosing the relative impacts. On the basis of the previous diagram, proposed constitution of indices were performed as illustrated in the Table 2.3.

One can sense the difficulty of consensus in the rapid analysis of proposed distributions of impacts. For example, contradictions are evident in the proportions of nitrogen compounds and sulphur dioxide in SIKA and EPS systems. Also, only a few impacts such air and energy used are taken into account. For example, impacts such as water emissions or resource depletion are omitted. Integration of

Table 2.3 Proposed key distribution impacts (Oberg 2005)

Sytem	Units	Emission in air			Energy used	
		CO_2	NO_x	SO_2	Fossil	Electricity
SIKA[a]	Euro	0.088	6.8	2.3		
EPS[b]	ELU	0.108	2.1	3.3	0.0094	0.0009
ET[c]	–	36.5	3,970	3,770	2.94	2.78

[a]SIKA (2002)
[b]EPS 2000 (Stenn 1999)
[c]Baumann and Tillmann (2004)

all impacts, would require a consensus on these impact factors, their consequences and the importance of their relative impact.

In summary, on environmental indicators, there is no consensus on the creation of an index. The lack of consensus is not about impact indicators taken into account but the relativity of impacts between themselves. The aggregation of indicators was not successful and, in fact, the production of a consensus index is not performed.

2.2.2 Emissions from the Sector and Its Products

Ecological context includes many factors. The high profile highlighting the risks of climate change and depletion of natural resources, is not new. The risk of global warming associated with the greenhouse effect had been identified by Arrhénus in 1896 (Dufresne et al. 2006). The fear of depletion of coal resources was raised by Jevons in (1866). However, consumption and impacts resulting from rapid population growth, have imposed awareness. So at the Earth Summit in Rio de Janeiro, Brazil that the international community has truly become aware of the issue in terms of global warming, climate change, resource depletion, and destruction of flora and fauna.

Although vitiated by many uncertainties (Lorius 2003; Le Treut et al. 2008) and sometimes even disputes (Enghoff and Svensmark 2008), a number of climatic effects are accepted by the entire scientific community. In 1999, Michel Petit listed, changes in temperature, atmospheric carbon dioxide concentration, the influence of water vapour and rising sea level as certifiable phenomena.

At international level, the United Nations established in 1988, the Intergovernmental Panel on Climate Change (IPCC), whose mission is to study the issue of climate change. While in its first report in 1988, the IPCC still hesitated to hold man responsible for global warming, the fourth report in 2007 leaves no doubt on the issue.

For example, in France, the building sector is the largest consumer of energy among all economic sectors, with the equivalent of 65.35 million tonnes of oil in 2009, or 43.88 % of the total final energy (Source: energy Statistics France, March 2005—Ministry of Ecology, Sustainable Development, Transport and Housing—all metropolitan areas).

This energy consumed annually results in the emission of 120 million tonnes of CO_2 (Source: Inventory of air pollutant emissions in France, February 2010)—CITEPA (Inter-professional Technical Centre for the Study of Air Pollution), representing between 23 and 25 % of national emissions (Source ADEME: Agency for Environment and Energy Management). It is still responsible for 466 million tons of minerals extracted for construction which represents nearly 75 % of global consumption ("stats.environnement.developpement-outenable.gouv.fr"). Regarding waste, the construction sector accounted for 343 million tonnes in 2004 (Source ADEME—waste figures) which is the largest generator of waste, ahead of household garbage with 26 million tonnes.

The construction of buildings is responsible for several important impacts on the environment. Through the scientific literature, a consensus about the causes of environmental impacts has taken place. The main pillars of ecological field to be evaluated are set within ISO 14044: 2006 Environmental management—Life cycle assessment—Requirements and guidelines. Pollutants to assess relate to acidification, eutrophication, photochemical pollution, greenhouse gas emissions, contamination by heavy metals, contamination by persistent organic pollutants and suspended particles.

CITEPA (Inter-professional Technical Centre for the Study of atmospheric pollution) is responsible for the implementation of the emissions inventory in France.

It follows that the only residential and tertiary sectors in France are the source of air emissions in 2008 in the following proportions (Source: CITEPA/CORALIE/FORMAT SECTEN—Update April 2010) (Table 2.4).

Note that for many emissions, significant percentages often apply to quantities in sharp decline since the 1990s. For example, SO_2 emissions decreased by 74 %, 63 % PAHs or PCBs 28 % for all sectors. However, a large part of the emissions are generated by the residential sector. Improved technologies using more biomass explains the overall reduction in emissions from the sector. These reductions in emissions are important because they apply to an annual production increase of nearly 45 % of housing between 1990 and 2007. Housing units have a surface increase of nearly 6 % over the period (Source INSEE) These "structural" changes in the sector, combined with the increase of 7.3 % of the population, largely explain the 22 % increase in greenhouse gas emissions measured between 1990 and 2004.

At the scale of the building itself and on the impacts described above, the phases of the life cycle do not have the same magnitudes in the impact assessment. For example, the work of researchers such as Liu and Pulselli showed that at least in some areas of the building in terms of energy consumption and environmental impact, the usage phase of the building was much larger than construction, maintenance and demolition. However, large differences appear from one item to another. Mr. Liu shows that 70–80 % of the energy and environmental impacts are attached to the use of 50-year phase (Liu et al. 2010) while Pulselli estimated at 49 %, the manufacturing phase, 35 % of the maintenance and 15 % using (Pulselli et al. 2007). The proportions of impacts on which these statements are based probably see some of their differences because of the different places the studies have taken place, the city of Chongqing in China for the first, Italy for the second.

Table 2.4 Emissions from the residential and tertiary sectors in 2008

Substances causing acidification, eutrophication, photochemical pollution				
9 % du SO_2	8 % du NO_x	31 % de COVNM		32 % du CO
Substances for increasing the greenhouse gas				
23% of carbon dioxide (CO_2)	3 % de methane (CH_4)	2 % of nitrous oxide (N_2O)	52 % des hydrofluorocarbons (HFCs)	1 % de sulfur hexafluoride (SF_6)
Substances for contamination by heavy metals				
15 % of arsenic (As)	6 % cadmium (Cd)	25 % of chromium (Cr)	3 % copper (Cu)	5 % of mercury (Hg)
7 % of nickel (Ni)	15 % of lead (Pb)	9 % dof selenium (Se)	25 % of zinc (Zn)	
Substances related to contamination by persistent organic pollutants				
17 % of dioxins and furans (PCDD-F)	68 % of polycyclic aromatic hydrocarbons (PAHs)		20 % of polychlorinated biphenyls (PCBs)	20 % of polychlorinated biphenyls (PCBs)
Suspended particles				
10 % des TSP	60 % de $PM_{1,0}$	34 % de $PM_{2,5}$	22 % de PM_{10}	

Table 2.5 List of groups of environmental impacts in the building

Total primary energy (MJ)	Renewable energy (MJ)	Non-renewal energy (MJ)
Primary energy process (MJ)	GHG (kg éq CO_2)	Reused waste (kg)
Hazardous waste (kg)	Non-hazardous waste (kg)	Inert waste (kg)
Radioactive waste (kg)	Air pollution ($m^{3)}$	Water pollution ($m^{3)}$
Acidification (kg éq SO_2)	Resource depletion (sb)	Water (L)
Photochemical ozone formation (kg ethylene eq)		
Destruction of the stratospheric ozone layer (kg eq)		

This observation implies that it is necessary to distinguish the impact of different phases, for the comparison of technical solutions which take into consideration the issue of lifespan.

On the scale of construction products, Standard NF P01-010 (NF P01-010-2004 Environmental quality of construction products—Environmental Statement and health of construction products), established from the ISO 14040 series of standards (ISO 14040—Environmental Management—life Cycle analysis) based on the principle of life-cycle analysis, and taking all of the inventory prepared by the ISO 14025 standard (ISO 14025—environmental labels and declarations—Type III environmental declarations) led to the establishment of reporting environmental and health records (EPD). This Standard applies to the presentation of different impacts of products used in the building. Different impacts are grouped under the headings of the following indicators whose definitions are provided in the Table 2.5.

Work on the environmental impact of human activities mainly address the issue of climate change. On the depletion of natural resources, we take the Life Cycle Impact Assessment Method (LCIA) develops an indicator for resource depletion (Habert et al. 2010a, b). For the measurement, the principle applied is that of the pressure on stocks of antimony. However, G. Habert highlights the importance of the local level to take into account the depletion of natural resources. Based on a study of the Paris region, it shows how the availability of resources can be calculated and attempts to measure the forecast error associated with economic or technologically complex social situations (Habert et al. 2010a, b).

In summary, the DU10 indicators seem to be a standard for the evaluation and measurement of the environmental impacts of an anthropogenic origin.

2.2.3 The Characteristics of the Data and Data Sources

Evaluate performance and simulate behaviours implies the use of data. On environmental indices of products used in the building, some organizations have undertaken the creation of databases. The most serious and known organisations publish the specific protocols for the preparation of the databases. These databases are listed and briefly analyzed in the Table 2.6.

Table 2.6 Database of sustainable development

	Sectors	Nature et specialities	Qualities	Défects
ECOINVENT Switzerland www.ecoinvent.org	All	Database co-managed by government agencies and professional Environmental database of materials and systems for the building	Tool inventory comprehensive information lifecycle data global warming, acidification, primary energy, renewable, non-renewable, eutrophication To facilitate environmental claims of products, life cycle analysis, the management lifecycle and design for environmental Very often used in assessment tools	The high cost of license
KBOB Switzerland www.bbl.admin.ch	Building	Coordination conference construction services and building master public authority KBOB	Database which provides for the elements constituting the primary energy consumption and GHG emissions of the solutions building Evaluation based on data ECOINVENT Free	Do not provide information on primary energy and GHG
≪Baubook≫ Austria www.baubook.at/zentrale	Materials and building system	Energy		Source of data and protocol difficult to obtain
≪ELCD Database≫ EU http://lct.jrc.ec.europa.eu	All	Database co-managed by government agencies and professional	Willingness to harmonize the index values of environmental impacts of products across Europe	Base in preparation poorly documented Data from professional associations whose control is difficult to implement
		Environmental impacts	Free database	Go to face the opposition of approach to wood-based materials

(continued)

Table 2.6 (continued)

	Sectors	Nature et specialities	Qualities	Défects
INIES France www.inies.fr	Building	Database co-managed by government agencies and professional Environmental and health impacts	Based on the NF P01-010 standards established itself on the ISO 14040 series for inventory evaluation in life cycle and ISO 14020 for environmental labelling Provides data for global warming, acidification, primary energy, renewable, non-renewable, eutrophication Operation based on a specific protocol between government agencies and professionals under the control of the Ministry	The participation of the industrial producer leaves doubt on the objectivity of the information
ICE- UK www.bath.ac.uk/mech-eng/sert/embodied/	Building	Process enrgy and GHG	Compiles information internationally a number of sources such as government agencies or private companies Conducted within the University of Bath	Difficulty of control analysis and objectivity of the data
IBO Autriche www.ibo.at	Building	As a non-profit environmental impacts	Provides the primary data of global warming, acidification, energy, renewable, non-renewable, eutrophication, ecological index	Data based on the declaration of manufacturers with verification test

For ecological data, the necessity to provide values over the full life cycle as defined in ISO 14040 is accepted by all databases. It is also important to have the emission values for each phase of the life cycle.

2.2.3.1 Conclusion

The environmental field is documented accurately. Information is available and accessible. Multiple sources for environmental indices imply the need for a thorough qualitative analysis on the basis of established criteria.

2.3 Tools for Ecological Performance

2.3.1 Standards and Guides

Following the awareness of the impact of human activities on the environment and more generally on sustainable development, the need for decision support tools has ben revealed. This section summarizes the existing tools.

2.3.1.1 Standards

The ISO standards 14040—Environmental Management—Life Cycle Analysis (ISO 14040, 1997) appeared in 1997. They define the founding principles of the standards and tools whose objectives are impact measurements. This series of standards is based on two fundamental principles. The first is based on the fact that evaluation is meaningful only if it takes into account the entire life cycle. This principle, accepted by all stakeholders, has a recent and clear progress in the development of other standards and evaluation tools. The life cycle is defined as "cradle to grave" for all impacts related to the production, use and disposal. The second principle is the necessary inventory of impact elements based on the notion of delimitation of the system. This principle guarantees the exhaustivity of the impacts.

A wide methodology and framework, the ISO 15392:2008 standard—Sustainability in building construction—General principles—clarifies the application of the concept of level of sustainable development in buildings. It contains three main aspects, namely, the environment, the economy and society. Also at this level, with a methodological lens, ISO/TS 21929-1—Sustainable development in construction, provides a common frame of reference which will allow a better consideration of the performance of buildings with regard to sustainable development. It provides recommendations and guidelines for the development and selection of appropriate indicators of sustainable development for the building. Sustainability in building construction—Sustainable Development Indicators—ISO 21929-2 standard Part 2: Framework for the development of indicators for civil engineering is being developed and will be published in 2013.

In the scale of the building, the ISO 21931-1—Sustainability in building construction—Methodological framework for assessing the environmental performance of construction works—Part 1: Buildings, provides a set of criteria and reference principles. It proposes a framework for building owners and designers that will enable them to evaluate the performance of their projects.

EN 15643-1, 2: 2010—Contribution of construction to Sustainable Development—Evaluation of the contribution to sustainable development of buildings—presents general principles and requirements for the assessment of buildings in terms of environmental, social and economic performance. This evaluation aims to quantify the contribution to sustainable development by construction works. It clarifies again the definitions of the principle including the very interesting concept of functional equivalent. It is stated that « comparisons between the results of assessments of buildings or assembled systems (part of the work), when designing or whenever the results are used, should only be made with reference to the functional equivalent of building. This requires that the main functional requirements are described with the intended use and the relevant specific technical requirements. This description is used to determine the functional equivalence of different options and types of construction and forms the basis for a transparent and reasonable comparison. » For each phase, the conditions for an approach to sustainable development are described. EN 15643-3—Contribution of construction works to Sustainable Development—Evaluation of buildings—Part 3: Framework for the assessment of social performance is being validated. It will be published in March 2012.

ISO 21930 : 2007—Buildings and built structures—Sustainability in building construction—Environmental declaration of building products incorporates the principles of the standard NF P01-010 for construction products internationally. It establishes a clear set of indicators to quantify the production, implementation, use and demolition of building products. Prior to this and based on this standard, NF P01-010: 2004 Environmental quality of construction products—Environmental Statement and health of construction products (NF P01-010, 2004) has enabled the establishment environmental and health reporting sheets on the basis of the inventory of impacts, considered over the entire life cycle. This standard allows the establishment of true environmental and health hazard identity card of building products. The principles of business are specifically described in Appendix 3.

2.3.1.2 Benchmarks

There are numerous benchmarks in the building industry. Some of the major ones are HQE, LEED, BREEAM, CASBEE…. Detailed analysis of the main benchmarks is presented in Appendix 1. The summary of this analysis can show the shallowness of taking into account the economic dimension, probably due to the difficulty of its establishment. Furthermore, taking into account the lifespan is rare.

In France, the HQE certification has been analysed in detail (Hetzel 2009). The objective of benchmarks is to set a common set of rules to guide designers and builders. Eventually, this can result in a certification Benchmarks are also performance evaluation and diagnostic tools. It is only recently, in its 2008 version that the HQE Benchmark for environmental quality of buildings, encourages consideration of adaptability on short, medium and long terms up until 100 years. For other standards, when the latter is taken into account, it ranges from 30 to 90 years.

2.3.2 The Analytical Tools for Evaluating the Performance

The performance assessment tools are those involved in the category of tools that assist decision making. They are used at an advanced stage in design projects or at the diagnostic stage for existing projects. They quantify phenomena and thus identify and compare the performance of solutions. As there are numerous assessment tools, a comprehensive analysis was not possible. However, a detailed description for the most popular tools has been provided in Appendix 2.

In 2002, a state-of-the-art survey by the HQE2R group mentioned the extreme diversity of indicators using existing tools. The conclusion is that it is not feasible to have a selection of indicators which is common to the whole European community, and that a systematic adaption of the tools is therefore necessary.

In 2006, following careful analysis of existing tools, Ness B concluded that all the evaluation tools focus on the environment (Ness 2006). There are no tools addressing the social and economic aspect other than those dealing with costs. Indicators are not integrated and evaluations are conducted on local or national scales. Moreover, their analysis reveals an extreme simplification when taking into account the lifetimes of products or buildings evaluated. Furthermore, lifetimes considered are relatively short since the longest is 80 years, and none of these tools actually assess the impact of lifetime. Another observation emphasizes the scarce use of economic indicators.

Concerning the state of the art in tools that evaluate performance in terms of sustainable development, Haapio carefully describes their conditions (Haapio and Viitaniemi 2008). In summary, the researcher points out that the comparison of the tools is difficult or impossible. Tools mainly concern ecological evaluation. The overall assessment of the performance in terms of sustainable development seems unattainable.

Concerning tools assisting decision making for property management, only ASCOTT and APOGEE—PERIGEE models deal with overall costs and the economic aspect in detail. The decision-assisting tool BEES and repository BREEAM briefly evoke discounting. It seems that for the latter, no development is introduced as regards the causes and consequences of the choice of rate, which leaves the users to their own expertise. Other tools include no economic module.

The analysis of these tools suggests two conclusions. First, no integrated assessment tool exists. Evaluations are essentially ecological and except for the issue of costs, no tool addresses the social and economic aspects. Second, evaluations are conducted on national or local levels. At the building level, the assessment tools deal with thermal and environmental aspects.

2.3.3 The Models

In 2001, Voglander proposed the Eco-cost Value Ratio (EVR). This is a model which aims at the optimization of the design on the basis of efficiency (Vogtländer et al. 2001). The assessment of environmental costs and the fight against these costs as part of a response to a specific need provide, according to the author, the most effective approach in terms of sustainable development. This is an approach linking economic and environmental impacts. It has the distinction of introducing the concept of full costs by taking into account the costs of externalities. This workable model in all sectors therefore proposes to establish a ratio EVR = Ecocosts/Value. The Ecocost is the sum of the costs of toxic emissions, energy consumption resources, depreciation of equipment and human labor. Its value is that of the goods produced. This is a model of efficiency, with the object of taking into account and reducing environmental impacts. Lifeitme is indirectly integrated through the value of the goods.

Zhang has developed an evaluation model of the environmental performance of buildings, BEPAS (Zhang 2005). After listing and weighing the overall environmental impact of a building, the model makes an aggregate of its relative impact and supplies a final score. Again, the lifetime for the evaluation is fixed a priori—in this case 50 years.

Alwaer furthers the study of taking multiple criteria into account by looking at the distribution of key indices in an approach to evaluate the performance of sustainable development (Alwaer and Clements-Croome 2010). There is no reference to the inclusion of lifetime in the choice of appropriate indicators.

N. Banaitiene presents a multicriteria evaluation method in the complete life cycle of the building (Banaitiene et al. 2008). The method at no time refers to the potential impact the life of the building—neither to the selection criteria, nor to the consequences of the latter.

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