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Tools for Sustainable Building

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ABSTRACT: The Web represents a particularly important innovation by offering access to text-based information, searchable databases, photographs, sound recordings, and video images. For energy professionals, the Web is more than a place to post one's favourite paper-based reports; it's a venue for one-on-one as well as group communications, tracking down detailed energy data, acquiring software, running dynamic on-line calculations, and even collecting energy data from remote sites. Tools and software that incorporate environmental cost and considerations could be a valuable help to take well-informed decisions on environmental management and cost.

Efforts to develop tools and methodologies have increased. Industry consultants and companies are developing new software systems and tools. Even if numerous initiatives still in experimental phase, the engagement of important government agencies (DOE - U.S. Department Of Energy, EPA - U.S. Environmental Protection Agency) in the putting to point of some of these instruments indicates concrete possibilities for their dissemination in times not excessive long.

The aim of this relation is to provide information to users of existing tools and software available on the Internet. Elementary rules, guides, handbooks, guidelines, database and software are first examined; then LCA based systems, rating systems and web-based tools are focused.

The web-based approach is the most promising: regardless of the computing resources they have available, users have access to powerful computational engines residing on the host server and tools are accessible regardless of platform. Finally, the Web provides immediate access to all the other relevant information that is constantly evolving on the Internet.

KEYWORDS Sustainable Building Design, Guidelines, Software, Handbooks, Web-based Tools

1. INTRODUCTION

The trend towards environmental protection is gaining momentum. Social and political forces are bringing additional pressure for more environmentally-sound technological decisions. Companies and facilities also recognize that initiatives such as proper materials and waste management, efficient process and product design, energy efficiency, and recycling can be both profitable and environmentally preferable. In addition, new standards and mandates are encouraging companies to manage their environmental costs and considerations better. International standards¹ are now requiring companies to develop environmental management systems.

The construction and use of buildings causes environmental damage at many levels. Thus, for example, carbon dioxide emissions from the consumption of fossil fuels contribute to the global greenhouse effect; tall buildings can produce dangerous winds in the neighborhood; and many buildings suffer from sick building syndrome. These are but three examples from a long list of environmental effects.

Therefore, many building design professionals, now involved in "green building design" or "sustainable design", initiate "environmentally-responsible" design based on their own recognition of the need to reduce human impact on the environment - local and global.

Very often a designer can assess environmental effects without making in-depth analysis; elementary rules can be used in most circumstances [1]:

- do not think natural materials are always better (Plastic can be recycled, wood ...not always);
- do not forget energy consumption (focusing the attention on material selection is not always justified, because one product could use energy during its life cycle);
- increase product lifetime (a designer can try to make it more durable from a technical point of view, or he can make it upgradable; more important, he can try to design the product in such a way people will feel attached to it: many products are not thrown away because they do not work, but because people get bored with them);
- do not design products but services (people do not always want a product: they want solutions for their problems);
- use a minimum of material (very often it is possible to reduce the amount of material by critically looking at dimensions, required strength and production techniques);

¹ For example, the International Organization for Standardization (ISO) is creating a series of voluntary environmental management standards entitled ISO 14000. Compliance with ISO 14001 standard, the Environmental Management System (EMS) specification document, has strong potential for becoming a de-facto requirement for conducting trade.

- use recycled materials (if recycled materials are used, demand for such materials will be created; if there is demand, supply will certainly follow);
- make your product recyclable (only those products that can be easily disassembled into many pieces will be recycled in future);
- ask stupid questions (very often design decisions are based on common practice, traditions² and "we have always done it in this way and it worked").

To date, efforts to implement green design practices have largely consisted of adoption or eclectic adaptation of various technologies and solutions to perceived environmental problems. Some examples of common sustainable building features [2] are listed in table 1.

Energy conservation (insulation, efficient lights and mechanical equipment)
Solar energy utilization (passive space heating, cooling; water heating; photovoltaic electricity generation)
Use of recycled (content) materials
Water conservation (low consumption fixtures)
Good indoor air quality (low emitting material selection and ventilation)
Reduced building construction waste and re-sourcing waste products
Habitat-sensitive site development (run-off control, small footprint, preservation of water courses, natural vegetation and habitats)
On-site wastewater treatment
Reduced or eliminated O ₃ -depleting compounds
Life cycle assessment of materials and building systems
(Formal) environmental impact assessment
Built-in recycling provisions for occupants

Table 1: Common Green Building Features

The practical conditions for sustainable building [3] are:

- the preparedness of the client to present requirements concerning the environmental impact of the project, in addition to economic and functional requirements;
- the preparedness of the designer to present a well-argued solution corresponding to the requirements;
- the preparedness of producers to provide information about the environmental qualities of their products.

Adequate knowledge of the environmental impact of different solutions as well as abilities and resources to utilize systems and tools of information acquisition and use are conditions of sustainable development.

2. TOOLS FOR SUSTAINABLE BUILDING

2.1 GUIDES AND HANDBOOKS

The Internet represents a rich mine of manuals and handbooks. But on-line and downloadable examples are very few, since most guides are only available for purchase.

AIA's 'Environmental Resource Guide' [4] offers concise but constantly updated and authoritative information on the environmental impacts of conventional building materials. In particular, the effects in terms of natural resources and energy consumption, production waste generation, indoor air quality are considered, together with practical suggestions for designers and indications on future trends in the fields of research and production.

Although it does not allow further information, it can act as a starting point for the consideration of the consequences of design decisions – and then as a means of stimulation – preliminary to the search for sustainable building materials.

CMHC's 'Building Materials for the Environmentally Hypersensitive' [5] contains hints for materials selection, based on information gathered from residential demonstration projects. It is organized in product sheets containing – for each product – common product names, typical uses, a short description, considerations on installation or application, chemical composition, health risks deriving from installation and use and comments on the suitability for a sensitive environment. Unfortunately, excerpts were not found on-line.

Among purchasable handbooks, the 'Local Government Sustainable Buildings Sourcebook' [6], edited by PTI and US Green Building Challenge and supported by EPA, contains construction and renewal strategies for municipal buildings, with indications about recent sustainable plans and projects.

Two special kinds of manual, that are not expressly addressed to designers, but to different users should be added to the list. The 'Global Energy Efficiency Initiative's Sustainable Energy Guide' [7] is conceived to support individuals and organizations in developing countries to find resources and contacts for projects based on energy efficiency and

² Traditionally rainwater pipings have a diameter of 80 mm in Holland; after a deeper analysis of the building regulations, the diameter was reduced to 30 mm. due to a simple optimisation of the hydraulic properties of the water inlet.

renewable energy use. It aims at giving advice on financing opportunities, general information, technical assistance, professional training and exchange, available for public and private institutions.

DOE's 'Energy Savers' [8] offers the average user on-line information on efficient residential energy use. The guide contains practical, clear and detailed solutions, but the enormous amount of information and its sequential reading mode are perhaps not perfectly suited for a quick consultation by an average user, generally not provided with specialistic interests or knowledge.

The 'Green Builder Sourcebook On-line' [9] is conceived as a support tool for Austin's 'Green Builder Program'. In order to foster the application of the program's recommendations, it offers practical information on legislative issues, instructions for the adoption of techniques and materials, references to technical assistance services, commercial profiles of different technologies. As pointed out in the presentation, the user's knowledge of technical terminology constitutes a pre-requisite. The guide provides – for each material - the classification number assigned by the CSI (Construction Specification Institute) in order to allow cost-analysis with special manuals, a definition, observations on properties and performance characteristics and a matrix summarizing the global commercial profile (level of technological development, availability of local suppliers, cost) and implementation issues (financing opportunities, public acceptance, regulatory aspects).

2.2 GUIDELINES

In the range of websites examined, these tools reflect the different interpretations of the concept of sustainability in the building sector. In some cases, guidelines (frequently referred to as 'checklists', which leads to a misunderstanding of their function as a final check of the design decisions' correctness) just point out specific issues, such as recycling and re-use practices and the adoption of local materials [10]. Other cases reflect the effort to set out a more comprehensive tool, considering every implication, in coherence with an 'integrated approach' to building design. Such a perspective lays itself open to the risk of formulating a compendium of all possible alternatives, and ultimately leaving the designer alone in front of a wide range of solutions, each – singularly – appreciable and worth considering.

Very few examples seem to consider such risk; in particular, the British Columbia Ministry of Education's Guidelines [11], still strongly suggesting an integrated approach, point out potential conflicts and synergies resulting from the combination of different technologies.

Another interesting feature is their structure, coupling an extensive description with a table in which each sustainability sub-goal is connected with the related code norm and the applicable technologies or strategies, with a distinction between 'advanced' and 'innovative' solutions.

This could obviously allow the user to take into due consideration different realities - with different technical and economical feasibility, clients' expectations and requests - as well as the building's actual future re-use perspectives. Thanks to its flexibility, such a tool can be of great help for designers. Other examples of design guidelines available on-line reach a higher detail level; this is the case of tools drawn up for actual interventions in specific contexts, which explains their prescriptive formulation [12]. But previous to the use of such tools other considerations should be made. Environmental goals are generally complex and, often, conflicting: local, regional and global objectives can be incompatible; moreover, even in a given context, different problems have different degrees of importance. It becomes, then, necessary to have criteria for the evaluation of the building's total environmental impact at disposal, taking the possible trade-offs between single objectives into account.

2.3 DATABASES

The experiences in the field of building construction found in the Internet show an appreciable progress towards the achievement of sustainability. The efforts of researchers and governments offer valuable and differentiated patterns of actions in the different stages of the design-construction-operation process, through the now enhanced availability of knowledge useful to designers and builders as well as to homeowners and occupants.

At the moment, it is possible to point out considerable advances in specific fields, such as sustainable building materials and technologies. Researchers have been focused attention on alternative building materials, whose behavior and performance under different conditions have been comprehensively explored. In addition, the environmental impact of conventional building materials - concrete, steel, wood, etc. - has been carefully considered as well as materials with recycled content. In all these cases, the Internet represents by now a precious source of information.

The current level of knowledge available therefore allows a more practical approach and a shift from the stage of research and investigation towards a subsequent one of actual application. News and information concerning urban development and building initiatives, extensively reported in the Internet, represent a rich mine of hints and starting points for designers and developers, as well as for the general public.

It could be said more generally that the ultimate problem is not where to identify concrete possibilities and patterns of intervention or how to make them feasible, but rather how to speed up their implementation and widen their extent. Basically what constitutes an obstacle in this direction is not the lack of knowledge, but rather the inadequate availability of databases organized and structured so as to be easily accessible by their potential users.

Therefore, databases can be very useful tools. A wide range of databases is offered in the Internet; nevertheless, finding one's bearings among them and the right information is often not so immediate. Although the term 'database' is generally given a unique and precise meaning, in sustainable building there seems to be less clarity. From our recent survey on the Internet, some difference in the interpretation of this word has emerged.

Building materials and technologies databases are particularly numerous. Mostly, these are structured as actual catalogs or simple listings of materials and components, searchable by category, product name or manufacturer. Effective and interesting examples are the 'Green Building Products and Materials Directory' [13], the 'Green Seal Products Directory' [14], the 'On-line Catalog of the Environmental Home website' [15] and the 'Sustainable Building Sourcebook' [16]. The result of the search session offers, in general, a set of synthetic cards, with key-data about the product. There are also databases in which materials are presented exclusively through textual description; they deal with environmental as well as technical issues, in the design, construction and operation phases [17].

Undoubtedly both types of structure present useful features; but, if adopted separately, they can result insufficient, and compel users (designers in particular) to explore other databases in order to widen their knowledge. Similar problems can arise in the case of databases that, although effectively coupling synthetic information on the product technical and environmental performances with details on its use [18], do not offer lists of local producers. Commercial issues do not represent a negligible point in the organization of a database.

Although mention of specific firms may be specifically connected to commercial interests, the setting up of databases intentionally rejecting any form of advertising probably goes to the detriment of an organic design process, because it forces the user to invest time and energy searching for local retailers. In addition, coordination problems can arise when investigating further, in the design stage, a specific material (or technology) in a database: it is impossible to locate in other databases a material with equal characteristics, or with proven code compliance, or simply locally marketed.

As regards optimization of time invested in finding information and, more generally, in the design stage, databases that couple each item with the corresponding code number for cost [19], or linked to energy performance, simulation programs [20] are to be considered as precious.

Our survey clearly points out that databases of materials and/or building techniques are efficient only when the user is well-targeted and the goal is building design. Although the high level of environmental awareness is testified [21] together with the positive effect of raising the issue of sustainable buildings, two questions still remain unsolved. The first one concerns the impossibility for the building customer to enter into the detail of the building process and to understand the peculiarities of its various phases (planning, construction and management). The second one is tied to the possibility, for the customer, to search the Internet, as an example, before purchasing a building, or contacting the planners³.

Demonstration projects carried out by numerous research institutes, or constructions by enterprises engaged in sustainability might be more impressive, since they offer the customer a real example of living in sustainable buildings. It would be more useful to address databases to professionals rather than to anyone interested; the attention of the final customer could be captured by designers. An excellent example of the application of this principle is the Residential Energy Efficiency Database - REED [22]. The database structure, following construction phases, is useful for the designer; information about maintenance and cost savings in building management can be utilized also to make the user more aware of sustainable practices. For example, electrical power costs for some electrical equipment in different operating conditions contribute to this goal. Lists of sustainable building products and materials are also supplied.

The total involvement of the designer in taking care of the customer's interests is however fully in line with the current evolution of Project Management.

Designers are obviously not the only actors in achieving more sustainable buildings; governments and decision makers equally have an important role especially in a responsible (and therefore informed) decision process and in favoring contacts between the public and professionals [23]. 'Consultant database' lists professionals engaged in sustainable design, and can be of remarkable support in such an action.

At the moment, this kind of database is not widely present, and only few data (name, specialization and activity geographical area) are often supplied. Only the DJC Online Consultant Database [24] supplies also web sites or emails to contact professionals involved in sustainability. Professional advice is available in a lot of web sites:

- Enermodal provides assistance and direction to ensure that a building project meets strictly standards for energy and resource efficiency [25];
- EcoDesign supports a list of Practitioners [26];
- Architettura&Natura - in Italy - keeps designers up to date about all the relevant themes, especially with the help of a Documentation Center, open only to members [27].

No doubt, more information on realized works or on how some specific aspects have been faced could be of aid in guiding choices. However, local governments pressed by economic problems, cannot allocate resources of any kind to sustainable building research. In such a context, the availability of best practices for similar environmental problems can greatly contribute to achieving sustainability.

Sharing knowledge on sustainable buildings beyond local contexts is therefore very important.

Networking and exchange of expertise and experiences as in Surban, the database on good practice in urban development hosted by the European Academy of Urban Environment [28], or some interactive database for the exchange of recycled materials, such as California Integrated Waste Management Board's - CALMAX [29] or Maui Recycling Group's - HIMEX [30], can enormously contribute to the construction of a collective knowledge-base on sustainability.

³ The problem is: right information at the right site. Do citizens search for a web site devoted to sustainable building, hosted by research institutes, or do they surf around home agencies?

2.4 SOFTWARE

Sustainability implementation strategies often privilege the goal of energy consumption reduction. The production of energy performance simulation software tools has achieved remarkable levels.

SOLAR 5.4 [31] conceived in the UCLA laboratories, carries out the model of the environmental performance of the building connected with different solutions – with different values of windows surface and global thermal mass – examining their effects on indoor climate and temperature. Its use is essentially related to passive design features.

ENERPASS [32], a widespread simulation program, presents greater potentialities, due to the optimization of the combined use of passive solar design techniques and other energy efficient technologies, and to the effective dimensioning of HVAC systems. It is structured for a fast data entry and performs the hourly calculation of building temperature, energy consumption, peak demand loads and daylighting parameters. Additional advantages are connected with the automatic check for data errors and the possibility to customize the program for special applications. Its ease of use is particularly pointed out in the ENERMODAL website [25].

PowerDOE [33] is an analytical design tool that accepts as input the physical description of a building, occupancy patterns, climate data, etc., and provides as output the building's energy performance.

BDA (Building Design Advisor), developed at the Lawrence Berkeley National Laboratory, uses PowerDOE as a simulation engine. BDA is conceived to support preliminary design phases through the comparison of alternative solutions, based on descriptive performance parameters. A 'Schematic Graphic Editor' allows geometrical data entry, while other parameters are given 'intelligent' default values, modifiable by a Browser. All data are analysed by the program to perform a representation of the values obtainable – based on the different data sets corresponding to the different solutions – for the parameters chosen by the user. The 'Decision Desktop' supports their comparison through 2D and 3D distributions, images and sound. BDA 2.0 is available free on the Internet [34].

Likewise, ENERGY 10, developed at the National Renewable Energy Laboratory, [35] supports the user in the selection of the best combination of energy efficient strategies in the pre-design stage. The system generates two descriptions of the building, one with the general architectural characteristics and one with a set of energy efficient strategies chosen by the user, functioning as 'reference case'. Through a simulation of the building's energy performance, factors with the highest influence on consumption levels are identified and new strategies, with different performance levels, are defined. As a consequence, the designer can correctly tackle preliminary design, after the presentation and discussion of results with the client and the determination of desired performance goals. Preliminary design will then require adjustments on the reference case until the agreed performance level is reached, in an iterative process. The system has different graphic outputs; those regarding annual energy consumption and economic savings obtainable are particularly interesting for the communication between designer and client. In its complex, the program presents several advantages: its iterative sequence correctly matches the design process; besides correct consideration of cooperation between designers and users of buildings is coherent with the new contents that sustainability demands from the design process. Finally, the specific destination of this tool to the preliminary phases, when all the building's requisites – also environmental ones – should be considered, is particularly relevant. Such a tool enables the designer to approach the following design stages on the basis of clear decisions on technical elements. This avoids subsequent forced adjustments, inevitable when having to reconcile technical or plant-related issues - generally put off to the final phases – within a general frame, defined by architectural or structural choices.

The ideation of buildings with given requisites of energy efficiency can also be pursued through the immediate assessment of energy code compliance.

Actually, many simulation programs and databases available are linked to codes: CATALOGUE [36], a computer program for the selection of energy efficient doors and windows, is linked to the Canadian National Building Code compliance assessment software. It enables the user to search a database of commercial products, identify the ones with the desired thermal characteristics – also through further searches for specific technical features – and carry out the final choice through a comparison of other information available for the selected products.

MecCHECK, developed by the U.S. Department of Energy (DOE), performs the Model Energy Code compliance assessment for new residential buildings in different modalities. With the 'prescriptive approach', a comparison is carried out between the building's characteristics and solutions characterized by different combinations of efficient technologies, in compliance with the code. The 'trade-off approach' allows the variation of some of the characteristics of the project (thermal isolation features, windows surface, glazing and door U-values) until the global UA-value of the project meets code prescriptions. MecCHECK is available free on the Internet [37].

A list of energy related software tools for buildings, with an emphasis on using renewable energy and achieving energy efficiency and sustainability in buildings is available at [38]; a guide for software incorporating environmental costs and considerations is available at [39].

3. INNOVATIVE SYSTEMS

A whole series of tools to assist designers and clients have been developed. One of the shortcomings of these tools is that they are not integrated in the planning process. A more comprehensive assessment should ideally follow the

principles of a life cycle approach - LCA⁴, but a number of adaptations must be developed for the building industry⁵, due to the lack of a coherent database with building materials and building processes data.

3.1 LCA-BASED TOOLS

Eco-Quantum [40] assess the environmental burden of a complete building on the basis of LCA, including the impact of energy use, maintenance, differences in durability of building components and product reuse and renovation.

ATHENA [41] performs the environmental impact assessment of structural elements, from the extraction of natural resources up to the complete execution, in connection with the Canadian Raw Material Database, containing the environmental profiles of a great number of constituent materials. It must be pointed out, again, that the assessment of the environmental performance of materials, components and complex products through their whole life span is neither simple nor immediate; major problems are linked to the impossibility of determining the global impact of any product. Although environmental consequences of single features (greenhouse effect, natural resources consumption, etc.) can be easily estimated, more general information requires the mutual weighting of the different effects.

ECO-INDICATOR 95, initially conceived for industrial design, takes this issue into account by including a weighting procedure, thus determining the total environmental impact of materials and processes through the 'eco-indicator' parameter. Data obtained can be used as input for the calculation of the environmental burden of the final product. Information regarding similar programs expressly formulated for the building sector was not found in the Internet, but the principles described can obviously be easily transferred in this field.

Consideration of effects from the combination of different materials and components in a building project is the core of DFE, Design For the Environment [42], that offers, in addition, suggestions on alternative solutions that can reduce the global impact; the information available is, also in this case, not widely detailed.

An effort to establish the relative importance of various environmental problems is at the basis of an international comparative risk assessment completed at Harvard by Norberg-Bohm, called SEABEP - Systematic Evaluation and Assessment of Building Environmental Performance [43].

According to early sensitivity studies, the performance of buildings has the same importance for designers' and occupants' behavior. It is thus essential to make occupants aware of the environmental consequences of their choices. A simple software, ECOPROFILE, has been developed for an exhibition at La Villette Museum in Paris: visitors can click on choices on the screen, and an environmental profile is displayed on the right side by comparison with standard values.

3.2 RATING SYSTEMS

A key role is played by rating systems: assigning stars is simple but clear information. In rating systems, scoring is usually implicit or explicit in terms of a small number of discrete environmental goals. No apparent effort is made to assess the trade-offs among various environmental objectives. This approach, used most notably by Building Research Establishment Environmental Assessment Method - BREEAM [44], and Building Environmental Performance Assessment Criteria - BEPAC, provides some guidance to those lacking any other basis for choosing less environmentally harmful building technologies. BREEAM is an example of an environmental quality standard which has proved to add value and to provide market benefits for its user. BREEAM is now specified for all new buildings commissioned by the UK Government (the benefits of buildings with a BREEAM compliance are better known and more quantifiable). However, it is an inadequate basis to determine whether a particular design element is environmentally benign or beneficial from a comprehensive building environmental performance perspective.

LEED (Leadership in Energy and Environmental Design), a priority program of the U.S. Green Building Council, is closely linked to performance based standards for US commercial buildings. It is a voluntary, consensus-based, market-driven building rating system based on existing proven technology. It evaluates environmental performance from a 'whole building' perspective. Different levels of green building certification are awarded (platinum to bronze) based on the total credits earned. A wide range of issues are evaluated to include energy and water use, indoor health, recycling for occupants, access to mass transit, material impacts, landscaping, construction waste management, building siting and maintenance [45].

EPA's Energy Star Residential Program sums up the energy efficiency characteristics of buildings by assigning them an adequate number of stars [46].

⁴ The complete LCA method has 5 steps : definition of the objectives of the study, inventory (quantification of mass and energy balances of the system), classification (quantification of environmental indicators e.g. global warming potential), evaluation (comparison of results with a reference case) and improvement (identification of the possibilities of reducing impacts).

⁵ LCA was mainly developed for industrial products with current life times of weeks and months; on the contrary, buildings are produced as one-of-a-kind products, their lifetime may be up to hundreds of years, they include a large and still growing number of materials, and their design process is complex, involving many actors with often contradicting targets.

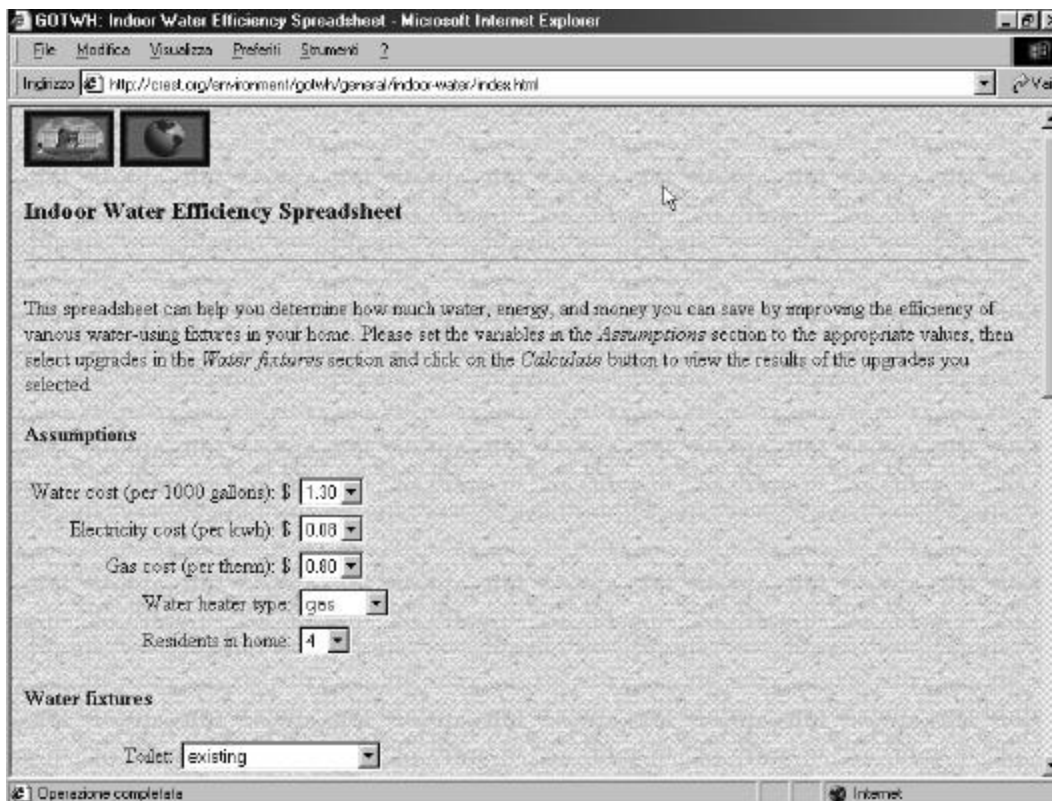
3.3 ON-LINE TOOLS

The Internet is an important new resource for information about energy efficiency. While many applications amount to little more than reformatting static text into Web pages, the Internet shows its true potential when it enables users interactively to obtain customized information.

A Web-based approach has several distinct advantages over the traditional software production and distribution process. First, given the sophistication of Web development tools, the user interface can be designed (and subsequently modified) with considerably less effort (and thus lower cost) than with traditional methods. Second, the cost to distribute the product is minimal. Furthermore, future refinements or additions to the program do not require physical redistribution or reinstallation of the software or documentation. Changes need only to be made to the master version (located on the home server) for all users to have the benefit of those changes. Any user with a forms-enabled Web browser sees a seamless interface free of most hardware and software compatibility and installation problems. Regardless of the computing resources they have locally available, users have access to powerful computational engines residing on the host server. Another advantage is that users of any Web browser can access the tool regardless of platform, and the Web provides immediate access to all the other relevant information that is constantly evolving on the Internet.

A little example of this potentiality is available in [47], where the user can take a “House Tour” to learn about saving (energy, water, materials, and money), reducing waste and pollution, and making a healthier home. A floor plan drawing provides a guide to jump room by room and see how to manage homes in more sustainable ways using not only text, photos and sketches for how the demonstration house works, but also a spreadsheet. This spreadsheet [48] can help to determine how much water, energy, and money can be saved by improving the efficiency of various water-using fixtures in a home (fig.1).

An innovative Internet-based tool for residential energy analysis is the “Home Energy Saver” [49]. This tool calculates residential building's energy use based on default values or detailed assumptions specified by the user (fig.2). Within the tool's interface, links to lists of energy-efficient appliances and vendors of energy-efficient software and products make the tool's interface unlike any traditional disk-based product.



The screenshot shows a web browser window titled "GOTWH: Indoor Water Efficiency Spreadsheet - Microsoft Internet Explorer". The address bar shows the URL "http://celest.org/environment/gotwh/general/indoor-water/index.html". The page content includes a title "Indoor Water Efficiency Spreadsheet" and a paragraph explaining the tool's purpose: "This spreadsheet can help you determine how much water, energy, and money you can save by improving the efficiency of various water-using fixtures in your home. Please set the variables in the *ASSUMPTIONS* section to the appropriate values, then select upgrades in the *Water fixtures* section and click on the *Calculate* button to view the results of the upgrades you selected."

The "Assumptions" section contains the following input fields:

- Water cost (per 1000 gallons): \$ 1.30
- Electricity cost (per kwh): \$ 0.08
- Gas cost (per therm): \$ 0.60
- Water heater type: gas
- Residents at home: 4

The "Water fixtures" section contains the following input field:

- Toilet: existing

The browser's status bar at the bottom shows "Operazione completata" and "Internet".

Figure 1: Indoor Water Efficiency Spreadsheet

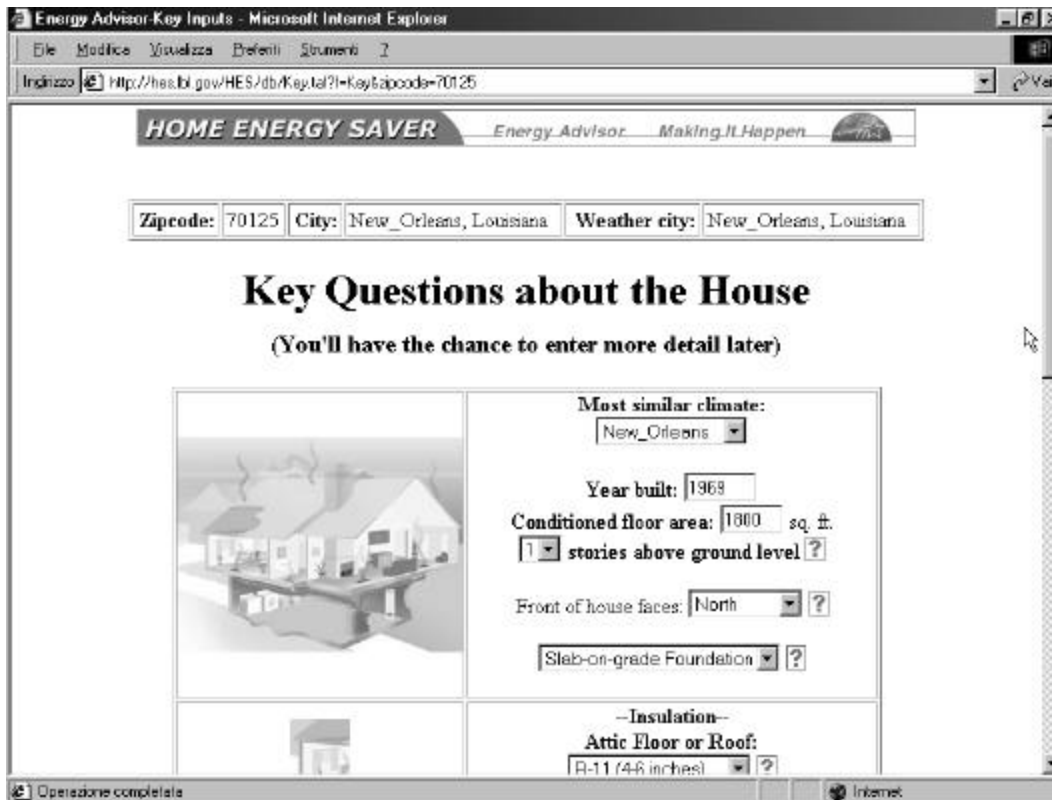


Figure 2: Home Energy Saver

4. DISCUSSION

Decision-makers rely everyday on tools and software systems to help them make decisions. When these decision-support products incorporate environmental costs and considerations, they can save money while simultaneously protecting the environment. However, if environmental cost information remains hidden and unaccounted for in the decision-making process, well-informed decisions on environmental management and investments cannot be made.

Present procedures seems to be inadequate, incomplete and poorly embedded in a framework for integrated sustainability assessment. Diversifying these tools for different actors, stakeholders and system boundaries is important. Both short- and long-term solutions are needed for incorporating environmental costs into decision-making. Elementary rules, guides, handbooks, guidelines, database and software are widely available on the Internet, while LCA based systems, rating systems and web-based tools are hardly present at all.

The web-based approach is the most promising, due to several advantages as illustrated in this paper.

5. ACKNOWLEDGEMENTS

This paper refers to a project supported by the National Research Council of Italy. N. Maiellaro (research manager) is the author of paragraphs 1., 3. And 4.; A. Lerario is the author of paragraphs 2.

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