A unified tool to design and define Architectural Sustainability 2.0

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Abstract Sustainability is moving from its phase 1.0 to 2.0. There is a shift in the paradigms of sustainable design that can be recorded in the last five years. Specifically, there is a shift from a rather narrow focus on energy to a broader view of sustainability and from a technical to a qualitative and restorative approach. In addition to the classic discussion of natural flows such as wind, sun, heat, light, water, there are other quantifiable flows that are becoming key in sustainable design. In addition, there are soft and intangible aspects of sustainable design such as users' flows, views, relationships between human and building scales, democracy, habitat exchange, rights to nature, and biophilia that need to become part of the sustainability school of though. As of yet, the consideration of such factors has not been promoted (or just partially promoted) by certification systems such as LEED, BREEAM or DGNB. Given such scenario, there is a need for simple and visual tools that support an integral view of sustainable priorities on a technical level as well as operate as a set of core values. Such tools should be aimed at engaging design teams and the broader AEC industry in the present discussion that is necessary to truly understand how to solve sustainable design. The toolkit proposed here is meant to support conceptual design as well as the analysis of existing buildings. The issue of redefining the targets of sustainability in architecture was the focus of a two-week course held at the Royal Danish Academy with final-year bachelor students. 45 Danish case studies of so-claimed green design were analyzed with on-site visits, interviews of occupants and colloquiums with the architect with the goal of understanding how the buildings perform according to a wider definition of sustainability. Students have to analyze the process, products, and principles of sustainability by using a user-friendly and sketch-based toolkit: a sustainable design storytelling, a multi-scale matrix, based on the hard and soft aspects of sustainability, and an environmental section. The storytelling is a powerful time-based tool that graphically defines the "moments" that determine the sustainable design. The matrix, inspired by the Living Building Challenge standard, allows to both plan and assess the identification of sustainable design ideals inspiring project teams to reach decisions based on restorative principles. Asymmetries in the matrix show strengths and weaknesses of a project according to a holistic definition of sustainability. Finally, the environmental section visually and creatively shows the invisible flows of sustainability that go beyond the classic sections used in architectural practices to represent sustainability. They also demonstrate where quantitative and qualitative flows of sustainability overlap, thereby illustrating how design engages users and nature at the local and the global scale. Overall, the application of the toolkit to the Danish context aids to define trends in the field of green buildings and identify cases of missed opportunities of sustainability applications, which are valuable in directing future designs. As a result, the research offers a unified representation tool-kit that can be used by students and professionals in architecture in order to develop, communicate, anticipate and improve design of existing buildings toward a thoughtful sustainable design.

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An inclusive sustainability

This paper introduces a unified toolkit for the analysis and the development of sustainable design and its visualization. The aim is to support the design of a type of architecture that is performative, therefore capable of providing user comfort in a resource-efficient manner; and, expressive, therefore able to engage the user and reflect the program and its context in terms of climate, nature and culture. Perhaps because of the dominance of rating systems (i.e. LEED, BREEAM, DGNB) and of empirically based sustainability perspectives, both professionals and students of architecture often equate sustainability with technology, quantifiable energy efficiency, or its visible hardware. Conversely, the proposed toolkit promotes sustainable design that includes multiple perspectives or waves of complexity in sustainability, yielding a matrix of viewpoints and concerns. Given the exponential rate of ecological trends, it supports the question of how we, as designers, might look beyond the current limits of our approach to environmental technology and ecological design to establish a more holistic design tactic.

The issues of redefining the perspective of sustainable design and defining tools that support the design process and the analysis of sustainability were the focus of a two-week course held at the Royal Danish Academy in fall 2012. 45 Danish green buildings (or claimed Green Buildings) were analyzed with on-site visits, publications, interviews with occupants and colloquiums with the architects. Some interesting insights can be derived from this: 45% of the architects were approachable, 55% of the design cases are properly documented and published, and 80% of the buildings are "accessible". In some cases the lack of documentation, the architects' refusal to provide information and partake in interviews are found as being related to the dynamics of green washing and a fear of being scrutinized.

The goals of the research are twofold. The first is the understanding of how the recent production of "green" buildings relates (or not) to a holistic definition of sustainability that goes beyond the definition provided by norms and rating systems. The selection of case studies is based either on high certification levels reached (i.e. DGNB or LEED) or on architectural quality and their connection to nature. The second goal is the testing of the aforementioned toolkit in order to analyze the design process of the case studies and the implementation of principles of sustainability when buildings are in use. The toolkit is composed of three tools: a sustainable design process storytelling, a matrix based on a variety of principles of sustainability and an environmental section (tab.1). Such tools were conceptualized prior to the course as a way to support the design of new buildings and as well as to support the analysis of existing buildings.

The storytelling diagram	This is a powerful time-based tool that graphically defines the "moments" that determines the sustainable design.
The principles' matrix	Inspired by the Living Building Challenge standard, this tool allows the planning of sustainable design principles and ideals that inspire project teams to reach decisions based on restorative principles.
Environmental flows section	This allows to visually and creatively show the invisible flows of sustainability behind the classic sections used in architectural practices, in order to represent sustainability and where quantitative and qualitative flows of sustainability overlap, illustrating how design engages users and nature at the local and the global scale.

Tab. 1 Composition of the unified sustainable design tool-kit

The tool-kit does not reduce ecologically sustainable design to mere performance. While sustainable design is increasingly associated with performance measures (a trend that is reinforced by rating systems and regulations), sustainability in fact presents a complex reality that includes social, technological, and aesthetic values. The field of sustainability architecture

promotes the understanding of the complexity of sustainable design and places design and technology in a context of subjective perception and inter-subjective cultural meaning.

The basic premise underlying its conception is that there are "multiple natures" to designing with nature. It is clear that the 'ecological' challenges we face are not even purely physical. Many are social and spiritual as well. However, much of sustainable or "green" design, such as the approach exemplified by the U.S. Green Building Council's (USGBC) program for Leadership in Energy and Environmental Design (LEED), is based on an objective-only approach. What are missing are subjective and inter-subjective perspectives. For example, there are no LEED credits for creating experiences of beauty, none for creating or fitting to ecological order, and none for placing people into rich symbolic relationships with nature. Quality and subjectivity do not appear on this horizon. This is not to argue for a devaluation of the LEED approach, merely to point out its bias. Indeed, high-performance green approaches to building design are absolutely necessary.

The principles' matrix and green washing

Among the rating systems the broader definition of sustainability is adopted by the Living Building Challenge standard. This standard comprises seven areas of performance: site, water, energy, health, materials, equity and beauty. These are subdivided into a total of twenty imperatives, each of which focuses on a specific sphere of influence (Fig. 1).

	NEIGHBORHOOD	BUILDING	LANDSCAPE + INFRASTRUCTURE	RENOVATION	
SITE	9	10	2	9	LIMITS TO GROWTH
	2	2	2	2	URBAN AGRICULTURE
	1	1	1	1	HABITAT EXCHANGE
	2	8	1	5	CAR FREE LIVING
WATER	2	2	2	2	NET ZERO WATER
	2	2	2	2	ECOLOGICAL WATER FLOW
ENERGY	3	7	5	5	NET ZERO ENERGY
HEALTH	4	7	5	5	CIVILIZED ENVIRONMENT
	4	9	9	5	HEALTHY AIR
	4	5	3	4	BIOPHILIA
MATERIALS	4	9	8	8	RED LIST
	4	9	8	9	EMBODIED CARBON FOOTPRINT
	4	9	6	8	RESPONSIBLE INDUSTRY
	5	9	4	5	APPROPRIATE SOURCING
	4	10	5	9	CONSERVATION + REUSE
EQUITY	4	6	3	7	HUMAN SCALE + HUMANE PLACES
	4	4	4	4	DEMOCRACY + SOCIAL JUSTICE
	6	5	5	8	RIGHTS TO NATURE
BEAUTY	10	9	7	9	BEAUTY + SPIRIT
	5	5	5	5	INSPIRATION + EDUCATION

Fig. 1 The Principles' Matrix applied to the evaluation of an existing building design. In light blue are highlighted the areas of sustainability that the project is poorly approaching. In red and orange are the strengths of the project.

The standard includes both quantitative qualitative measures that relate to habitat, ecosystems, and the inspiration of people, none of which are incorporated by any other rating system. Asymmetries in the matrix show the strengths and weaknesses of a project according to the different measures impacted by the design. About half of the 45 case studies recorded asymmetries in the color of the matrix, highlighting an important issue: despite architects' claims there is not always a strong focus on sustainability. In some cases there is little focus on social

sustainability while purely quantifiable performance (i.e. energy) is used as an argument for sustainability. In other cases is the opposite.

The application of the tool-kit to the analysis of the buildings emphasizes how designers can label their buildings, especially commercial ones, as sustainable without providing the evidence to uphold such claims. This is partly due to ambiguous nomenclature employed, such as "sustainable", "bioclimatic" and "green" (Martin et al, 2011). In the majority of the case studies these labels are rarely associated with precise environmental performances and are frequently used as a substitute for hard data. It could be seen how architects often lack a scientific understanding of sustainability and therefore use these vague terms to describe their buildings in interviews, thereby proliferating confusion and misconceptions (Altomonte, 2009). In order to further a meaningful discourse of sustainability within the architectural profession, green claims need to be based on both a holistic view (i.e. the one proposed by the principles' matrix) and on hard data (i.e. the one derived by building performance simulation). The proposed tool-kit is therefore aimed to support both practices that face new design task and whoever want to look at sustainable design and previous works with more critical eyes.

The matrix and the shift from sustainability 1.0 to 2.0

Fig. 2 The shift from Sustainability 1.0 to 2.0 (students: John Phillip Edstrand, Anders Rod, Ida Bjallerbæk Pedersen, Joakim Kerrn Malmgren)

Each of the 45 analyzed buildings were tested using the principle matrix color scale in order to evaluate the influence on the building locally and globally. The comparison of matrixes allows to analyze what the trends in sustainable design are. One of the findings is that early 2000s case studies are innovative prototypes, but when monitored, they frequently do not behave as predicted. Lately, more emphasis is placed on user needs and occupier preferences than in the past (Fig. 2) (Tab. 2). People who spend their lives inside buildings now demand thermal, visual and acoustic comfort and control of their own space or workspace. There is greater appreciation that the occupiers are influenced by design variables including the degree of access to daylight, natural ventilation, natural materials and views of nature. So one big change over previous design models is the search for more natural and satisfying interior environments.

An interesting output of the use of the matrix is that "architectural energy design" is gaining more importance of "mechanical based energy design". In early 2000 the focus was mainly related to energy conservation and, in that sense, mechanical engineers could be the leader of design process. Today, there is awareness that architectural design is generally the more cost effective option: optimizing the design can reduce the energy consumption of buildings by as much as 80% (Lechner, 2000). This increasingly is the ideal sought by progressive architects and even a few demanding clients. Such understanding of the "power of Architecture" is however just recently implemented in practices, after they have started to use environmental simulation tools to predict the performance of different design options.

Finally, it is also recorded how project design is now influenced more than ever by concepts like 'cradle to cradle' (i.e. adopted by the Danish office 3XN) question the choice of materials and the life-cycle models employed (i.e. Vandkusten Architects) 'Biomimicry' has also gained a foothold in design methodology, helping to shape buildings from ecological perspectives. New knowledge has also led to an upsurge of interest in research in architectural practice- much of it

involving green issues and undertaken by the specialist sustainability divisions (i.e. Henning Larsen). It has also been recorded how the changes identified involve mainly large practices and those undertaking international projects.

Early 2000 – Sustainability 1.0	Trend After 2010 – Sustainability 2.0
Focus on the building performances	Focus on the users' performance
Mitigation is the key word	Adaptation is the key word
High Tech Solution	Low Tech – user-friendly solution
Buildings are closed and collects flows	Buildings are open to flows
Energy is the primary concern	Ecology is the main concern
External consultants and Mechanical Engineers are the main actor of Sustainability	Sustainable Design is integrated into the architectural practices
Sustainability is proposed to Clients	Clients require sustainabile design
Rating system impact was emerging	Rating systems strongly impacts the design

Tab. 2 Sustainability 1.0 vs. Sustainability 2.0

Mapping the sustainable design process

The storytelling diagram (Fig. 3) is functional for planning and understanding how sustainable design features are implemented, when and by whom (architects or external specialists) and according to which set of targets (those set by clients, local regulations or certification systems). In the course it is used in order to describe the design processes of case studies. The findings are multifold. For instance, it is clear that sustainability has begun to alter the nature of architecture and the structure of architectural offices. The huge growth in sustainable expertise coupled with the expectation that buildings will be LEED, BREEAM or LEED rated prior to construction and certified post construction, has led to the emergence of specialist sustainability teams in most medium to large architectural practices. It is recorded how these teams are often manned by architects with further degrees in energy or sustainability studies. As the need for green expertise grows, these teams assume more influence within their host company.

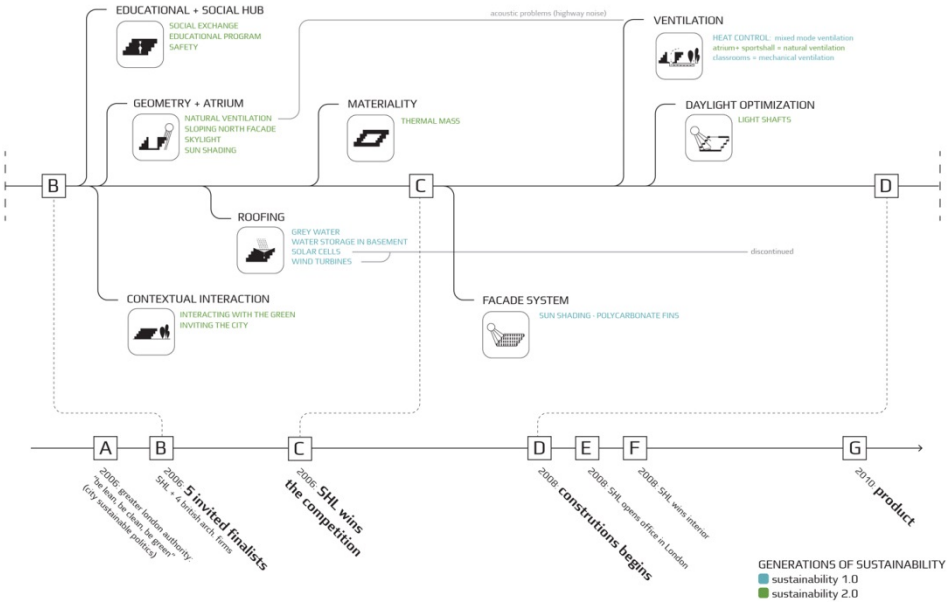

Fig. 3 Sustainable Design Process of the City of Wenminster College (students: John Phillip Edstrand, Anders Rod, Ida Bjallerbæk Pedersen, Joakim Kerrn Malmgren)

Some large architectural practices are now more than design service providers: they are green consultants undertaking project evaluation, conducting post occupation evaluation (POE), and engaged in externally funded research. The evolution of Henning Larsen and 3XN offices, two amongst the largest Danish offices, over the last twenty years, is a good example. The consequence has been to widen the knowledge base of architectural practice and bring it closer to that found in engineering offices. In fact, some big design practices now trade with engineering divisions undertaking energy modeling and parametric design. As the Danish government and corporations push ahead with zero carbon policies the nature and structure of architectural practice is changing.

Environmental section and flows

Sustainable design is a discipline that, whatever one's intentions or whatever its purpose or function is, requires the shaping of form. The sustainable principles described by the matrix and the process' map can be graphically translated into sections that include a variety of measurable and non-measurable flows (Tab. 3). Sections can guide architects to rapidly test different scenarios, which enable them to control for specific sustainable features. They can stimulate thought and serve as a reference around which the conversation on building performance is centered (Edwards, 2008). The use of sections in the conceptual phase drives a type of architecture that is receptive to soft performance, such as the integration of the natural context and the users' well-being, as well as hard performance. In this approach the architect's sensitivity and experience are valorized in closer connection to local values, priorities and microclimates. These vary seasonally and interannually (due to climate change). The environmental section reminds the designers of the big difference between urban and rural microclimates and between northern and southern cities. Apparently it seems to be an obvious consideration, but one problem with BREEAM and LEED, is the lack of subtlety with which generic assessment schemes address local climate. The section reminds designers that differential rainfall and sunshine patterns, wind speeds and air temperatures have a big impact on the economic viability of building systems (Fig. 4, Fig. 5). Attention to location allows the sustainable building of the future to express the unique ecological and climatic condition of its particular position.

Maximize Performances (Environmental Flows)	How shall we shape form? How shall we shape form to maximize performance? In this terrain, good form minimizes resource consumption and pollution while maximizing human wellbeing
Connect to Ecological Flows and Cycles	How shall we shape form to guide flow? In this terrain, good form solves for ecological pattern by creating structure in the built environment that best accommodates ecological processes through mimicry of and fitness to the context of natural ecosystems.
Manifest Relationship and Educational Value (information flows)	How shall we shape form to manifest meaning? In this terrain, good form reveals and expresses "the patterns that connect" in ways that celebrate the beauty of natural order, place inhabitants into relationship with living systems (or their idea of nature), and situate human habitation in bioregional place
Engage Users (user flows)	How shall we shape form to engender experience? In this terrain, good form orchestrates rich human experiences and creates centering places conducive to self-aware transformation, in which we can become most authentically who we are.

Tab. 3 Sustainable Flows Visualized in the Environmental Section

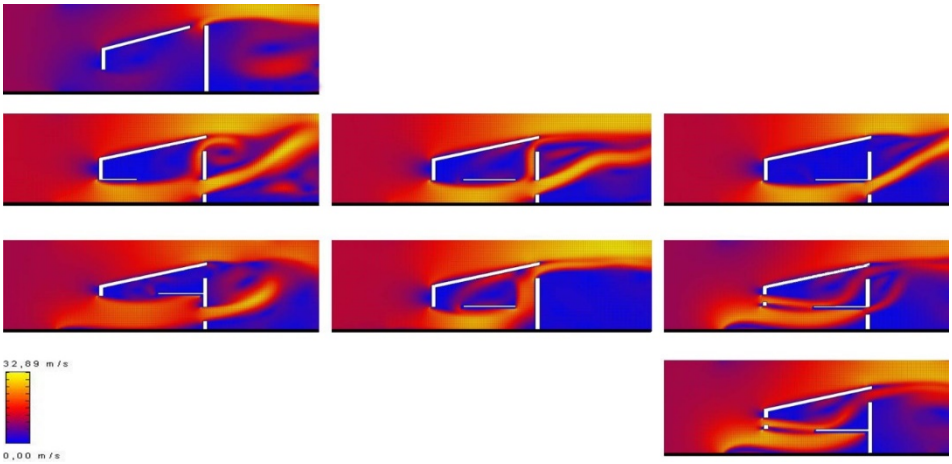

Fig. 4 CFD studies emphasize flows that can be included into environmental section (student: Francesco Tonnarelli)

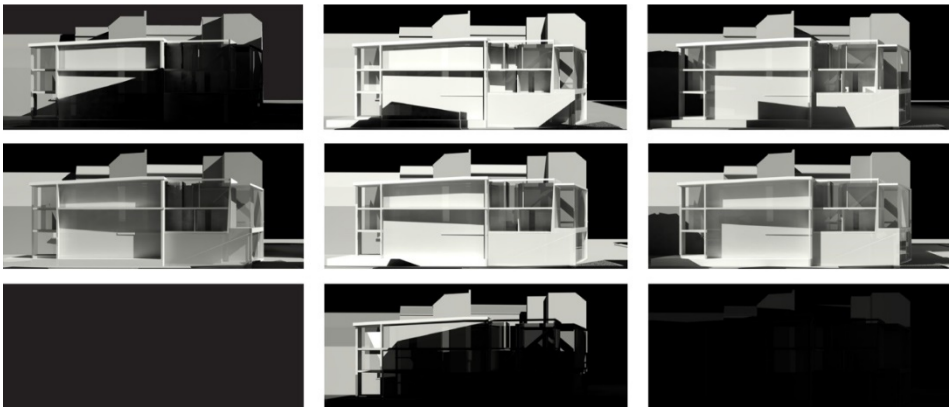

Fig. 5 Section based Shadows studies (student: Elisabet Hugrun Georgsdottir)

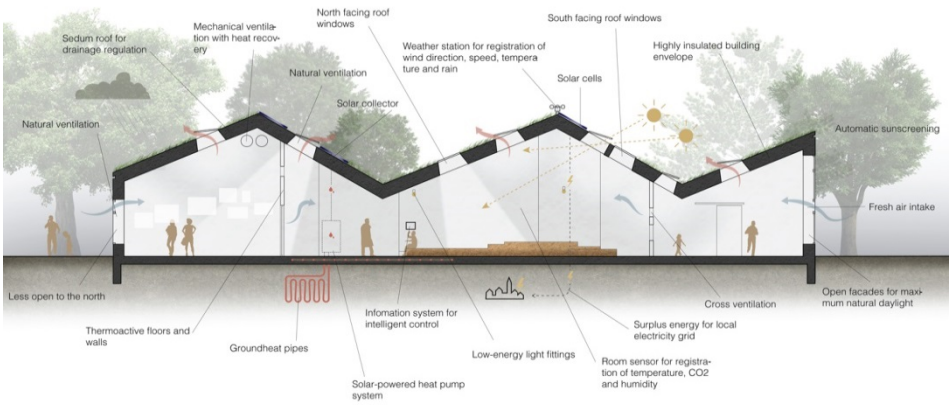

Fig. 6 Redrawn section of The Sun House Nursery in Copenaghen(students: Lou Charrier, Clara Kynne Schmidt, Simon Hald, Peter Ravnborg, Rasmus Thomas Larsen)

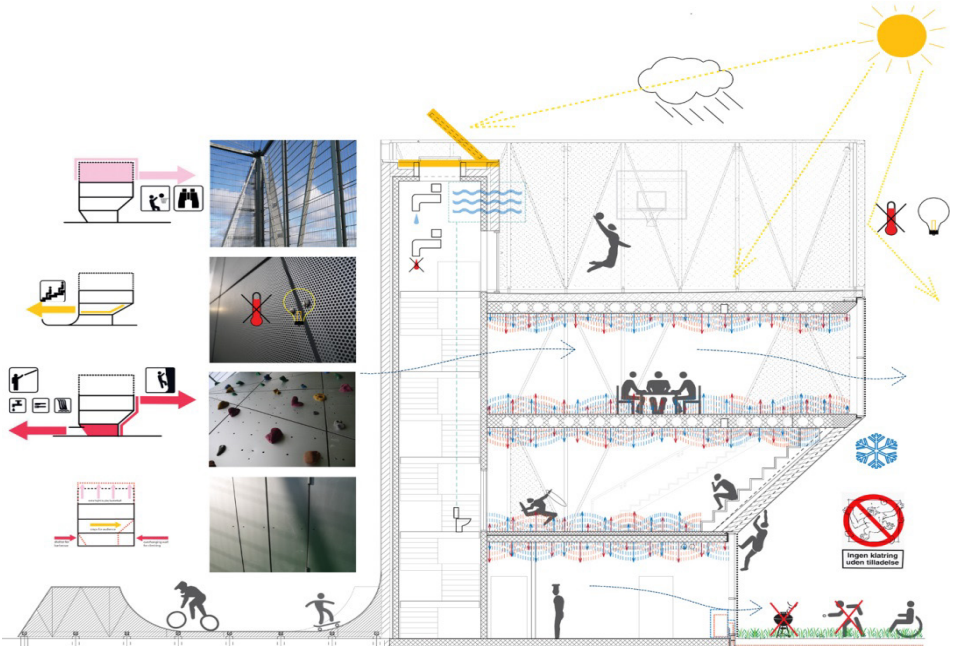

Fig. 7 Redrawn section of the Herstedlund Community Centre in Copenaghen(students: Jennifer A. Dyke, Vera Bannwart, SandrienDeroose, MargretheKabell Christensen)

The need to maximize daylight and to allow for optimizing natural ventilation has led to narrower buildings. Two common types exist: the large tall narrow floor-plate office and the suburban low to medium-rise shallow plan office. This type of office, often involving atria, is numerically the most common. It also in hybrid form is frequently used for learning and research spaces in universities. One key feature of the type is the lack of internal walls. Where partitions are required, there are low screens usually less than 1.6m in height. As such space and internal layouts are fluid thereby supporting the exchange of information as well as the sharing of daylight and natural unprocessed air. Typically this type of office is occupied by companies which value social exchange and quality of the workplace environment.

Another characteristic of the type is the degree of occupant control of the working environment. Unlike in deep planned buildings where energy systems dominate, in the shallow plan office there is more interface between the interior and exterior world, and between office space and atrium. This results in user access to the control of blinds and lights, opening windows and ventilation. Hence occupants can adjust the temperature of the workplace and decide whether views or sunshine are sought. This degree of control of the interior climate influences performance, productivity and wellbeing- and hence is of importance to employers.

One key feature of the type is the use of the stair as a point of information exchange and flow. This secondary function of the stair results in characteristic attention being paid to the size, location and design of the stair. It is often larger than necessary, sometimes contains seats on generous landings, is placed close to water or plants, has commanding views over work areas, and acts as a point of contact for many in the organization. In the offices of many media companies the stair accesses video labs, cafe and canteen areas and exhibition spaces. In universities such stairs will lead to research labs, coffee bars and teaching space.

Another key development over the past decade has been the development of active, energy generating roofs in office and educational buildings. Spurred on by pressure to exploit renewable energy sources and to use rainwater roofs have taken on particular significance in the context of green buildings.

Section and the atrium

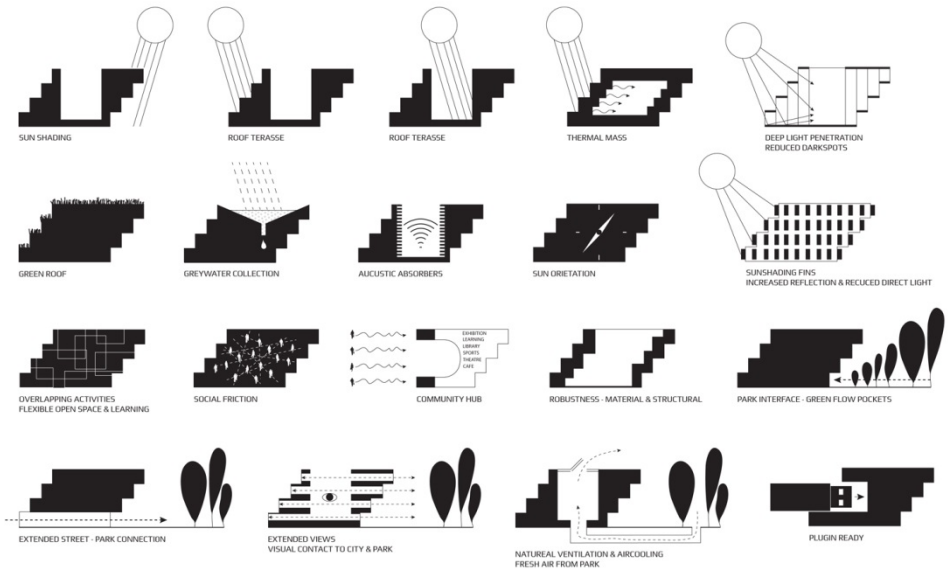

Fig. 8 Diagrammatic sections of the City of Westminster College Atrium (students: John Phillip Edstrand, Anders Rod, Ida Bjallerbæk Pedersen, JoakimKerrnMalmgren)

The most typical solution found in recent built design in Denmark is the atrium. The potential of overlapping different flows gives a special role to it (Fig. 8). It has many functions- environmental, social and organizational. It is often the shop window for a building, a place to locate the front desk, to display key advertising or directional data and to establish an appropriate image (Edwards, 2012). This is often expressed in designer furniture, art installation and interior landscape. Many atria have their design justification in energy strategy: the atrium provides essential daylight into the building core, it encourages natural ventilation using solar and incidental heat gains, and surfaces of the atrium can promote radiant night-time cooling. However, for many office workers the atrium is a place for socializing, either on the ground floor where the entrance is usually located, or on decks and bridges higher up. To the occupant of big offices the atrium is neutral space where gossip is gained, ideas shared and big vistas enjoyed. Often the atrium is also the place where office gatherings and parties take place. In educational buildings atria are designed for informal learning and for socializing between lessons.

Many office atria are generously landscaped with large trees, water features and seats. Water is a common feature of office atria because it helps give humidity to the air and when running (which is normally the case) helps mask background noise. The atrium is becoming an urban space, if not part of the landscape of the city then at least a place where office workers can gain access to a more natural and tranquil world. In busy city centers office workers increasingly have little time for perambulating around more formal city parks. Here the office atrium becomes a substitute for urban green space- a place to escape the hectic pace of the office desk. This is particularly true in hostile climates where it may be too hot or too cold to go outside for a break from work.

The atrium provides a quasi-green space within the building where coffee and sandwiches can be taken against the backcloth of foliage, flowers and trickling water. Increasingly designers see the atrium performing three inter-related functions- energy and environmental: social and cultural: health and stress. The environmental capacity of atria is well known and widely employed in

different building types and in different climate regions. The social and cultural role is also widely acknowledged with many companies creating places in atria for staff to meet either in a work capacity or more informally. Concepts of transparency and innovation support atrium usage in corporate terms with many companies valuing the exchange of knowledge, which often occurs within these lofty sunlit spaces. However, the health and stress potential of atria has only recently become appreciated. As a substitute for the under utilized external park, the office atrium assumes the role of a space for meditation and relaxation within largely green surroundings. Away from the hectic and competitive world of the open-plan office, the atrium provides a haven to stretch ones legs and reflect upon the day. Hence, the atrium has an important role if properly designed in health and stress management.

Conclusion

The three tools, the principles' matrix, the design process map and the sections are powerful tools in support of sustainable design activities and research. Students were able to gain specific experiences by analyzing design cases qualitative and quantitative performances. They have used methodologies of investigation on how spaces serve occupants' requirements in daily and seasonal cycles. The tool users developed an understanding of how sustainable architecture can be visualized, evaluated and executed effectively at different levels.

The use of the toolkit allowed for an appreciation of different concepts of sustainable development over a period of ten years. The examination illustrates how one might interpret architecture from multiple perspectives, and it reveals how a unified method can inform design. One outcome of the proposed method is that more expansive perspectives of the world and human consciousness are necessary to meet the diverse ecological, social, cultural, ethical, and technological challenges of buildings' sustainable design.

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