Novel Concept and Technologies of Sustainable Building Design

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Abstract:

*"What are the current digital and / or innovations driving sustainable architecture?
What could be the suggestions for a more holistic approach?"*

The more individual approaches of esteemed experts should be digitally linked together for a synergetic approach. It is believed that this combined effort could be more productive than addressing the issues individually. Sustainable design parameters may be visualized as the genetic code of a building's specific performance requirement – similar to the DNA of all living entities. This "Building DNA" could provide comprehensive "Performance" parameters, further could be programmed to be SMART – Sensible, Meaningful, Adaptive, Realistic and Time-cost effective.
Way back in 2001, a highly networked, expertise-orientated, integrated design strategy of "Form Follows Performance" was coined in our workspaces and research in Germany, India, and Sri Lanka, primarily for the complex industrial projects and passive housing. In planning process, "Virtual Twins" apply the state of the art of 3D- BIM modeling for architecture, structure and utilities integrated with dynamic climatic simulations and CFD analysis, sustainable parameters, and cradle to grave life-cycle systems.
Furthermore, it is needless to mention that Programming has become an all-important task, as specific parameters of geography, climate, topography, culture, process, technology, and logistics are key forces driving innovative and integrated architecture from a preliminary stage. While we are shaping out "Passive" sustainable design solutions for site, volume, structure, envelope, interiors, we are minimizing the need for "Active" utilities, if and where necessary.
In a nutshell, it is believed that it is vital that the ecological responsibility lies in designing sailboats and not motorboats in architecture. The German government BMBF, Federal Ministry of Education and Research, and DAAD, German Academic Exchange Service, funded program will culminate in a web-portal and app climatehub.online Holistic design strategies and academic research will create a broader audience, a collaborative and deeper understanding of the topics on hand and a one-of-a-kind E- Learning Platform - Program.

Keywords:

BIM modeling virtual twin, Dynamic climatical simulation, Dynamic CFD simulation, Changeability of building volumes, Sustainability benchmarks, Performance based design, High mass vs Low mass, Envelope dependent forms , Low energy buildings, Building design for adaptive comfort, Cradle to grave lifecycle, Active utilities in sustainable building, Programming, Building DNA, Academic E- Learning

Part 1 shall be roughly outlining the global needs for sustainability, problems with traditional planning of buildings, development from first steps of the Digital Factory to proposed new holistic digital strategy BSM/ Building Sustainability Modeling

Sustainability, problems with building as custom productions, Digital Factory

In 1972 the book “Limits of Growth” first drew attention to the foreseeable extinction of natural resources on earth and triggered a debate that continues to this day [01]. Forty years later, its predictions for the most part have regrettably been confirmed [02]. The authors’ findings have triggered world-wide efforts not only to reduce the consumption of energy, but also to protect the environment as a holistic approach and to establish rules for the responsible utilization of its resources. In 1987 this subject was addressed in a report from the UN World Commission on Environment and Development entitled “Our Common Future”. This document included the fundamental definition of sustainability as recognized today: “Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs”. The report led to the UN Conference “On Environment and Development” in Rio de Janeiro in 1992 and the program for action referred to as “Agenda 21”. Then in 1997, the World Climate Summit held in Kyoto was aimed at setting binding targets for greenhouse gas emissions in industrialized countries. Finally, in 2002, the World Summit on Sustainable Development (WSSD) was held in Johannesburg.
However, in the eyes of many observers, it failed to create effective governmental policies regarding sustainability targets (http://www.worldsummit2002.org/).

Figure 1.01 illustrates the problems of global ecological footprint and human development, with currently due to accelerated Global Warming even much more urgent consequences [03]. The actual worldwide ecological footprint data of 2018, with specific calculations of continents and countries, are available in [04].

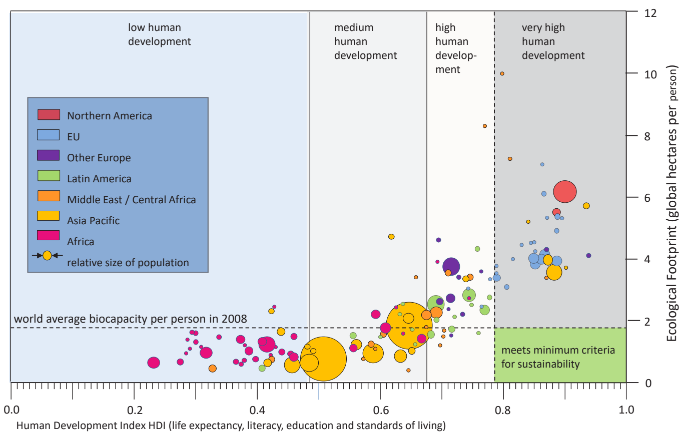
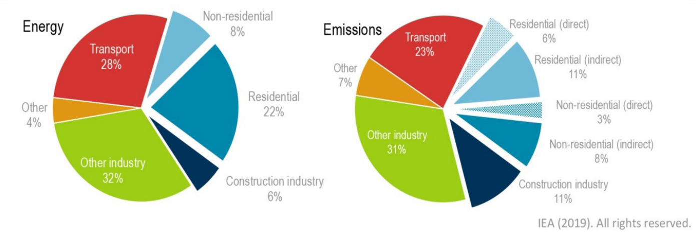


Figure 1.01: Ecological Footprint and Human Development (source: Global Footprint Report 2010)

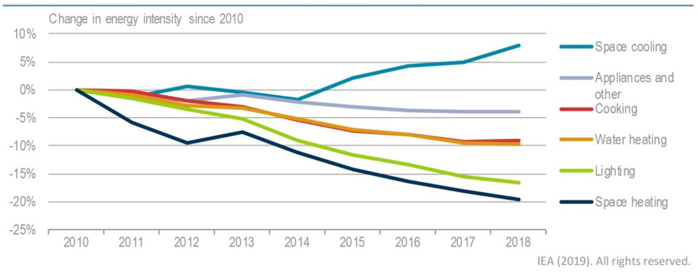
According, these compilations, measured (gha) in billions of global hectares ecological footprint, particularly in the Asia- Pacific region merely doubled the emissions during past 25 years. Generic discussion on Climate Change and Global Warming issue, displaying the scientific background and the possible climate strategies are pointed out in official U.S.NASA website [05]. Narrowing down further to buildings’ contributions is described in UN 2019 source [06], initiating as an introduction for further analysis of building sectors and types: “Decarbonising the buildings and construction sector is critical to achieve the Paris Agreement commitment and the United Nations (UN) Sustainable Developments Goals (SDGs): responsible for almost 40% of energy- and process-related emissions, taking climate action in buildings and construction is among the most cost-effective. Yet, this 2019 Global Status Report on buildings and construction tells us that the sector is not on track with the level of climate action necessary. On the contrary, final energy demand in buildings in 2018 rose 1% from 2017, and 7% from 2010.” According to this UN 2019 analysis of different building types such as residential, non-residential and industrial contribute to 8%, 22%, and 32 % respectively to overall energy intensities, whereas the industrial sector is moreover responsible for 31% of auxiliary emissions.
Thus, industrial sector is responsible for roughly one third of all global emissions (Fig. 1.02).



Notes: *Construction industry* is the portion (estimated) of overall industry devoted to manufacturing building construction materials such as steel, cement and glass. Indirect emissions are emissions from power generation for electricity and commercial heat.
Sources: Adapted from IEA (2019a), *World Energy Statistics and Balances* (database), www.iea.org/statistics and IEA (2019b), *Energy Technology Perspectives*, buildings model, www.iea.org/buildings.

Figure 1.02: Global share of buildingd and construction final energy emissions, 2018 (source: Global Footprint Report 2010)

During years 2013 to 2018 energy intensities for cooling raised up to 9 %, whereas intensities for heating and lighting declined to 12% and 9% (Fig. 1.03). Assumptions of interpretation might result in accelerated global warming as the reason for difference in cooling and heating, encouraging LED technologies for lighting. Thus, in the sector of industrial buildings as a whole, cooling especially in tropical countries, and the consumption of electrical power still for lighting seem to offer the neglected sustainable potentials for global warming delay.
In planning of buildings, due to different investors, financial expectations and user needs, sociological and technological embeddings, available building materials and environmental conditions, every project is a fairly unique “custom production”, usually barely driven by issues in line with aims of sustainability. Typically, with



Notes: *Energy intensity* is final energy used per unit of floor area. *Appliances and other* includes household appliances (e.g. refrigerators, washers and televisions), smaller plug loads (e.g. laptops, phones and other electronic devices) and other service equipment.

Sources: Adapted from IEA (2019a), *World Energy Statistics and Balances* (database), www.iea.org/statistics and IEA (2019b), *Energy Technology Perspectives*, buildings model, www.iea.org/buildings.

Figure 1.03: Global buildings sector final intensity changes by end use, 2018 - 2018 (source: Global Footprint Report 2010)

conventional planning approaches, academic education and building execution traditions create more or less isolated solutions related to site, building structures, building utilities and processes of special use, resulting in a lot of unpleasant symptoms as depicted in Fig.1.04 [07].

During whole period of usage this common practice leads to more than just missed deadlines and overrun budgets. It also produces unsatisfactory lifelong planning outcomes which will be reflected in functional and qualitative defects, poor performance in building components and insufficient adaptability during the

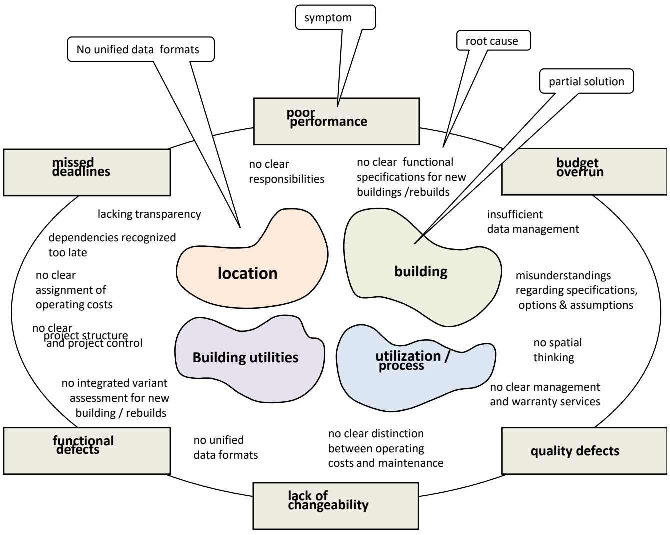


Figure 1.04: Typical consequences of partial solutions in Building Planning (source: RMA Architects)

lifecycle operating phase. As pointed out before industrial buildings are the most responsible for global emissions, moreover due to higher degree of planning and execution complexity building typologies of industrial architecture have proven as forerunners towards various efficiency potentials as well as aesthetical demands. Hence thorough analysis of historical and current state of the art industrial building construction typologies could stimulate the overall building world in terms of sustainability. As in industrial load bearing structures, utilities and envelope systems which are often modular, prefabricated and offer dismantling mechanisms, these aspects of lifecycle adaptability should be of more special interest for sustainability, and should be be transferred to other building sectors. Parameters for specific project discussion of "foreseen" degrees of adaptability are discussed in [08]. In times of Global Warming the engineering of thermal comfort, energy efficiency, carbon and other emissions evolves far more complex and ignores considerable potentials for detailed discussion on sustainability criteria.

In focusing on general building construction, strict separation between load bearing structures, envelopes, interiors, utilities with choice of adequate materials would be more favorable for sustainability. Idea of the preferred components in building structure assembly leads to a paragon of a "Building Kit", as proposed for wooden structures in Fig.1.05 [09, 10].

Same principle would apply for steel, concrete, or composite structures. The outline of historical development in Germany, and the general criteria for design and engineering process of industrial steel structures are pointed out in [11], example of a development of a modular wide span steel structure, with special reference to 3D-

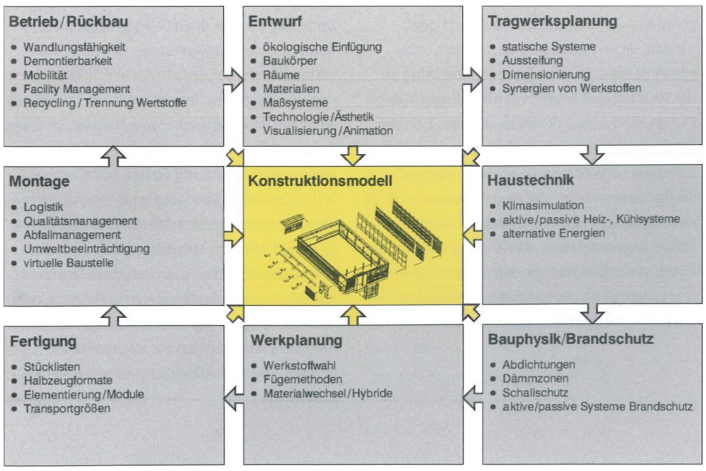


Figure 1.05: Planning , Construction and Operation Cycle of a seperate componets assembly „Building Kit",
(source: Reichardt,J., Industrie- und Gewerbebau in Holz, Der Bausatz als Integrales Konstruktionsmodell, 66- 79)

transference of 3D- architectural to finite elements is quoted in [12]. In this context an interesting example in terms of building technology and engineering is avant-garde U.S. industrial architecture of Albert Kahn, architect of Henry Ford. Exemplary were the adaptability aspects of wide span structures, integration of modular utility plants, expertise in daylight, natural ventilation and thermal comfort of workspace, as well as holistic design, engineering and project management approach[13], some projects are shown in Fig.1.06. Many of his more than 1500 "less is more" engineered factories served as blueprints for modern architecture at beginning of 20th century. Moreover, are the noticeable aesthetic root of German Bauhaus movement to Louis Sullivan recalling credo "Form Follows Function" [14, 15].

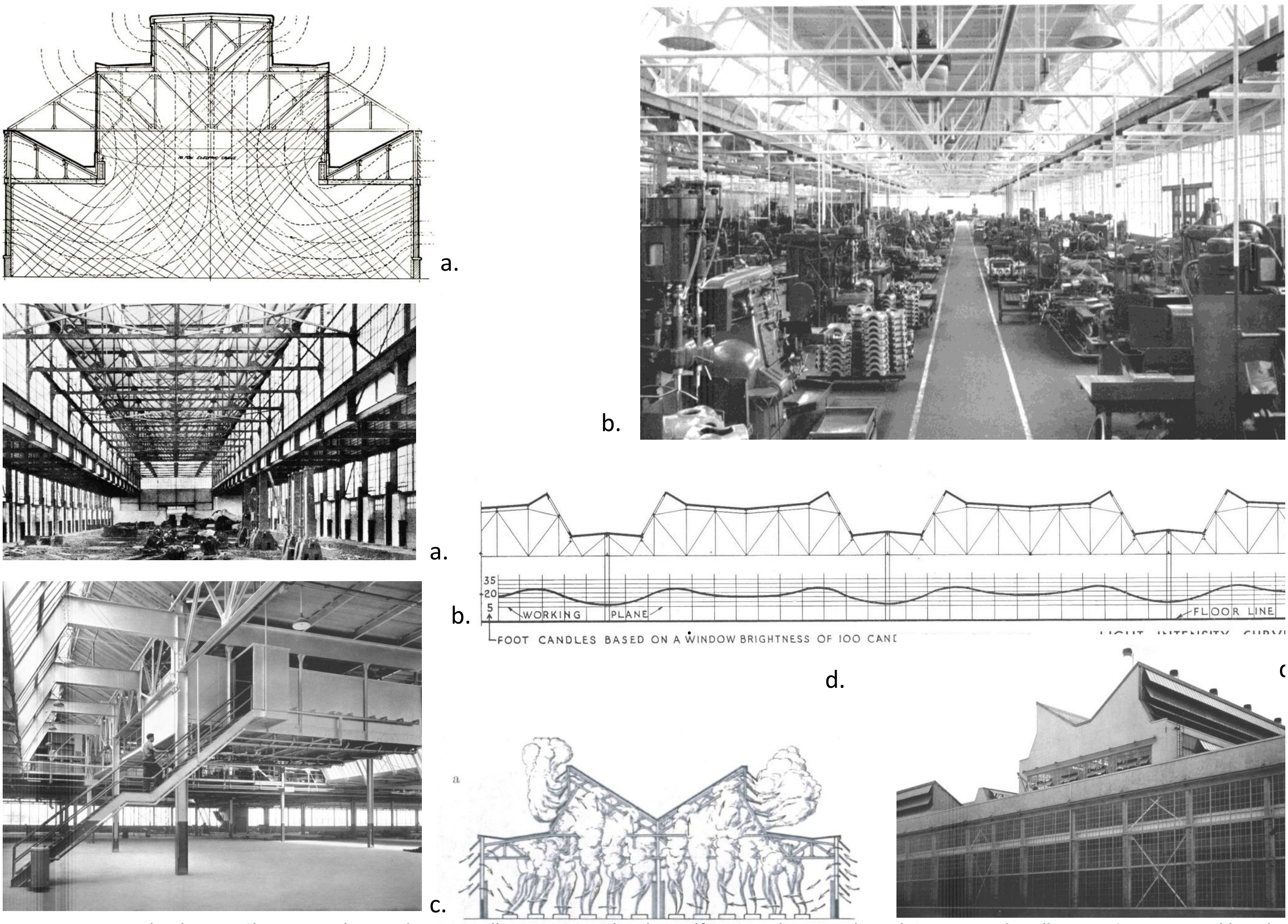


Figure 1.06: a. Packard Forge Shop, 1910; b. Hamilton Propellers, 1936; c. Chrysler Half Ton Truck, 1938; d. Ford Open Hearth Mills, 1924 (source: Buerklin, Th., Reichardt, J., Albert Kahns Industrial Architecture)

A Variety of interesting and more modern industrial architecture with emphasis on design and engineering process is pointed out in [16]. In the field of digital building planning more sophistic efforts are evident since the 1980sdue to the extensive amount of risk and finances involved, pioneers in the digital planning were U.S. (military) aircraft, shipyard, and automotive industries. These approaches were first aiming at digital model planning of the production facilities exclusively. In order to predict their behavior as realistic as possible, these approaches can be regarded as further development of CIM (Computer Integrated Manufacturing), the term Digital Factory was established in [17, 18].
The German VDI guideline VDI4449 is defined as follows: “The Digital Factory is the generic term for a comprehensive network of digital models, methods and tools - among others simulation and three dimensional visualization - which are integrated by an integral data management.. Its goal is the holistic planning, evaluation and continuous improvement of all relevant structures, processes and resources of the real factory in connection with the product”. In the following years aspects of the building structure, envelope and utilities became more interesting digital planning , an example for a pioneer application in lean management and integral digital planning of an automotive factory in Germany is described in [19, 20].
In the rest of the industrial sectors, including residential and non-residential typologies, because of more small or medium scale project structures and extensive preparatory work and investment, there is only gradual development in this direction. Other barrier is still the lack of interoperability of models used, complicating the exchange of data on the different levels.

BIM/ Building Information Modeling

In building construction, approaches that correspond to CIM and Digital Factory, are still relatively premature, In Europe, also due to more conscious political support, United Kingdom and Scandinavian countries seem to be a few of years digitally ahead. Main goal is the better integration of all individual projects of building construction objects and the reflection of their results during the project in a digital model. For this purpose, the term Building Information Modeling (BIM) has been established since about 15 - 20 years [21,22,23]. The technical basis for this is the standardized 3D-CAD interface IFC (Industry Foundation Classes), an open standard for digital description of building models (www.ifcwiki.org/). IFC is supported by a union of numerous CAD software manufacturers to enhance interoperability. On basis of a soft-ware system during the design process of a building created a precise, three-dimensional building model. In addition to the object geometry the BIM techniques a central database collects and networks to the project team at a central location all data for the creation and production, analysis, and optimization as well as relevant for the subsequent operation. All parties involved in planning and construction, such as users, professional planners for structural, building, utilities, process, and logistics engaged in all planning and life cycle phases ¬in the central building information model may use the information relevant to them. The variations during the planning phase shall inevitably be reflected in all affected areas and all „classical“ planning documents such as floor plans, sections, since updating is in real time, redundancies are avoided. Moreover, since the liable data for parallel Project Management and Facility Management, as mass calculations for cost estimations and tenders, are extracted out of the actual 3D- BIM database, traditional planning errors in cost and time schedules will be avoided. Fig. 1.07 depicts a wishful synergetical planning coupling of BIM “process” and “space” data structure for a factory project. The various advantages of central data modeling for owners, users, managers, architects, engineers, and entrepreneurs are explained in terms of possible BIM applications in planning in [24], Project Management [25] and Facility Management [26]. The distinct and urging issue of cost savings potentials in residential buildings on basis of BIM organization planned and prefabricated structures is proposed in [27].

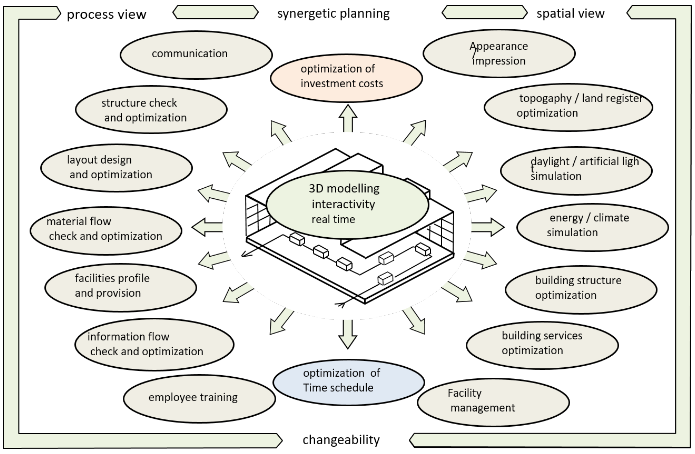


Figure 1.07: Potentials of simulatenious engineering, Digital Factory/ BIM (source: RMA Architects)

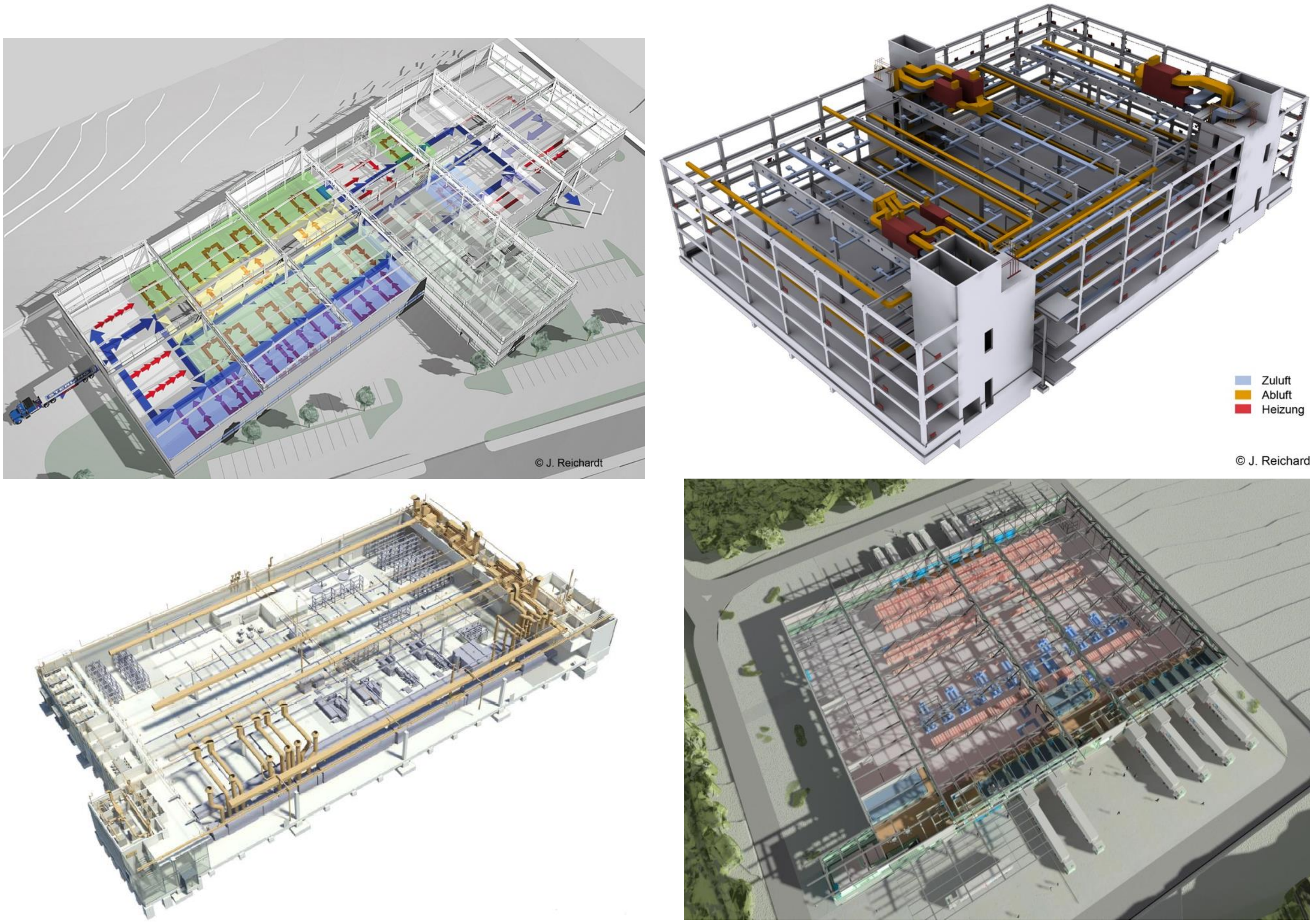
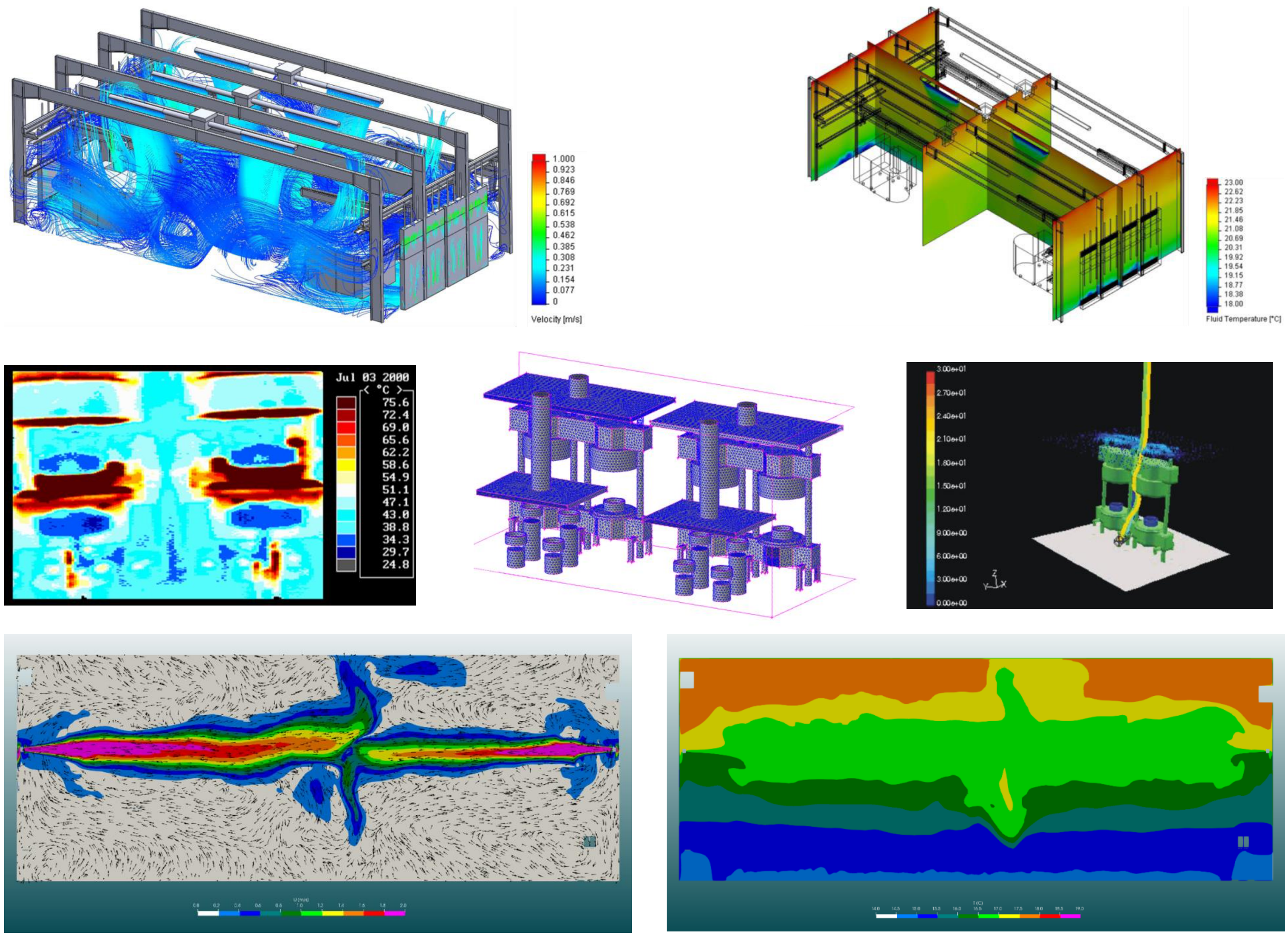


Figure 1.08: Examples of 3D- BIM integration of structure, material flow, ventilation utilities,CFD analysis of temperature and air velocity (sources: a.Pump plant, b.Earphone manufacturing, c. cooler manufacturings, RMA Architects; Handbook Factory Planning, 318, 420, 464, 307)

The following example will illustrate the possibilities and the interaction of the various professional planners using the BIM approach for a factory planning project in more detail : The architect, in consultation with the factory and logistics planners for the facilities layout, develops a spatial concept for a new building.
After concluding the preliminary building planning building structure skeleton is transferred to the structural engineer, who derives a static analysis model. As the project progresses, the structural engineer may refine and detail the analysis model and dimensions of all components of structure. When any amendments are needed he consults to the architect, who in turn manages the prevailing 3D model without any redundancies. The building utilities services engineer then utilizes the overall three-dimensional building model as generated by architect and monitored by structural engineer for employing technical plants and services pipe routings. The architect, due to over layering the partial models of structural, the building utilities and process facilities, surveys collision points of the production facilities it prevents errors in the overall planning. Therefore, reduces the conflicts between the technical as well as expensive alterations during the construction period due to previous coordination inaccuracies can thus be reduced to a minimum. Thus, specific construction phases, but also complex construction processes can be simulated, and 3D visualized with virtual walk through before the groundbreaking. Materials patching, color and shades are standard visualization tools of current state of the art BIM models, allow users a very vivid impression of the virtual model during the design stage. Project management referring BIM data, is relevant for overall cost budgets, tender phase mass determination and building site time scheduling. Facility management referring BIM data are respective of operation timeline for building, utilities and process components, particularly defect liability warranties adaptability and flexibility due to changes in use. Examples for RMA Architects 3D- integration of structure, process and utilities are shown in Fig. 1.08, for dynamic thermal analysis, CFD air velocity and temperature analysis in Fig. 1.09. The different evaluations of the same 3D- digital REVIT model for building structure, process, utilities, thermal simulation analysis and photorealistic visualization for a watch manufacturing plant are depicted in Fig.1.10. The multidisciplinary digital AEC (Architecture, Engineering, Construction) expert team strategies are pointed out in [28]and special Synergetical Factory Planning is quoted in [29, 30].



a.

b.

c.

Figure 1.09: Examples of 3D- BEM analysis of process heat emission, , CFD analysis of temperature and air velocity in manufacturing plants (source: a. Mechanical precision plant, ifes, Handbook Factory Planning, 299; b. Tire Factory; c. Chocolate bar high rack storage, RMA Architects

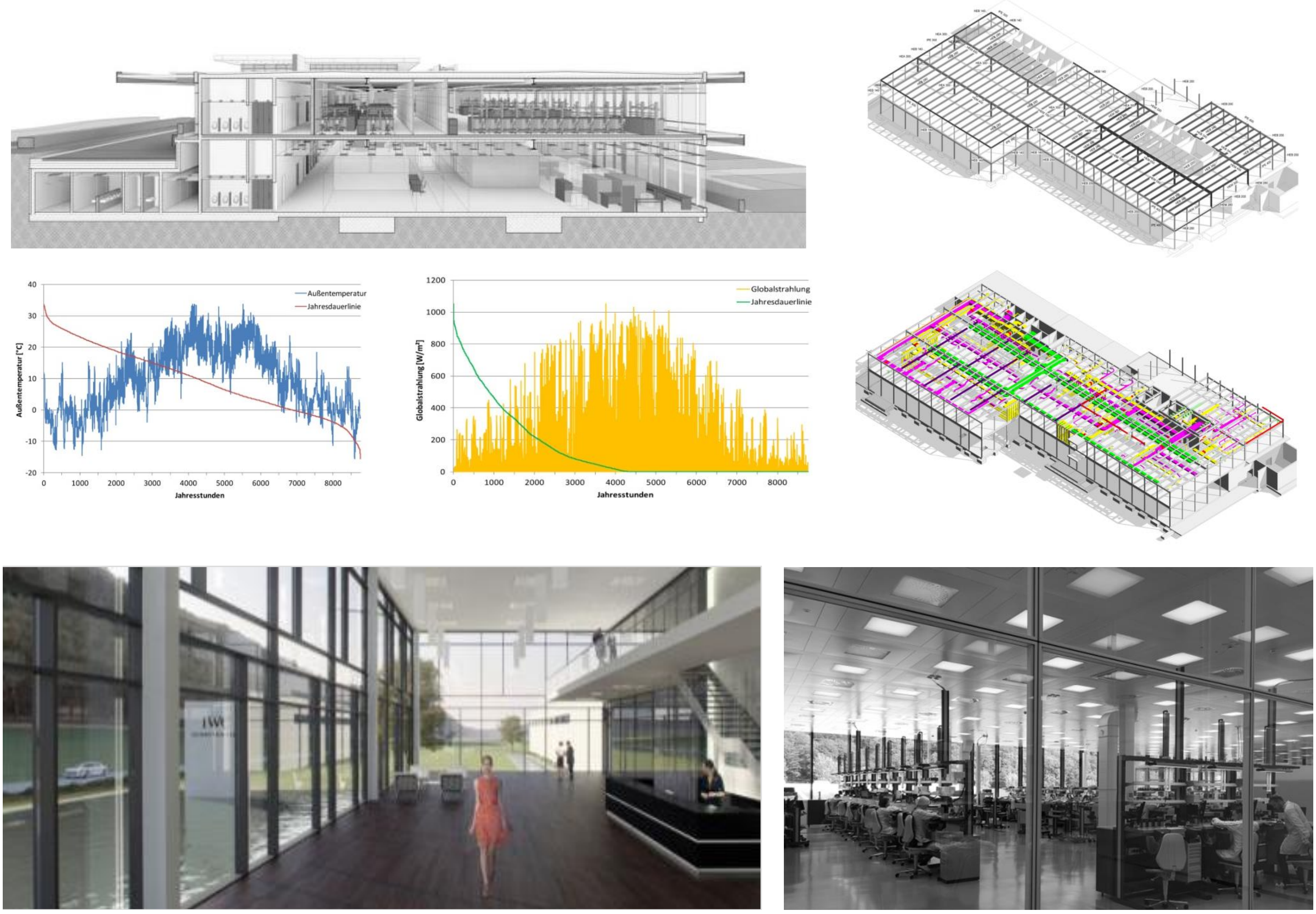


Figure 1.10: 3D- BIM modeling integration of architecture, structure, utiliities, thermal comfort, visualization, impression of built project (source: Watch Manufacturing plant, Switzerland, RMA Architects)

Energy Efficiency, BEM/ Building Energy Modeling

Since the mid-1990s and recently further accelerated due to the severe discussions about global warming, there has been a change in attitude within industry and society, in particular due to radical environmental changes and rapidly rising energy prices. The technological leaders attempt, on the one hand, to manage tighter cost situations with energy efficiency programs and on the other hand, in an increased awareness of their social responsibility, to mitigate the threat of global warning by comprehensively reducing CO2 emissions. Relevant areas for increasing energy efficiency and reducing CO2 primarily include industrial production processes, transportation logistics for supply chains, the energetic quality of buildings and the efficiency of the building services. An important example is European ISO 14000, which presents a series of international standards for managing energy (http://www.iso.org/). The underlying idea is "a management tool that allows organizations of all sizes: to identify and control the environmental impact of their activities, products and services, to continually improve their environmental performance and to introduce a systematic approach to setting and achieving environmental objectives, to attain them and to show that they have been attained."
ISO is working on a new standard for the carbon footprint of products, for quantifying and communicating greenhouse gas emissions (GHG) produced through the work associated with the production of goods and services. A carbon footprint is defined as the total greenhouse gas emissions that are generated by a person, organization event or product (http://www.carbontrust.co.uk/). The new norm is extensively based on ISO 14040/44 and ISO 14025. These additional constraints create relatively new aspects of enhanced attention. Currently more and more urging conscience towards global warming and sustainability are often "lost" even in the programming and concept phase, and moreover it seems that building industry is still much reluctant to introduce digital state in traditional "building" practice.

A critical study reveals the grave differences particularly in comparison to rapid digital changes with Industry 4.0 and IOT (Internet of Things) engineering methods used in advanced industries [31, 32]. The mere concentration on single project issues prevents editing potentials of the sub-projects when viewed holistically.

As already mentioned before, regrettably site, buildings, buildings utilities and processes are still often planned more sequentially compared to a simultaneous parallel engineering approach, resulting in poor ecological considerations. These potentials must play a much more important role now, during planning, construction, and operation (e.g., for grey energy and waste materials emissions) as well as with utilities and processes in operation (e.g., for energy consumption, CO2 emissions caused by cooling and heating, hazardous substances). The technology related energy savings potentials in the industrial sector can be highly rated (e.g., lighting, compressed air generation, pumping systems, cooling systems, heating supply and ventilation systems), according to national and international Energy Conservation Codes [33] a range of some possible measures in terms of avoiding energy wasting for factories as well as general projects are listed in [34, 35, 36].
The goal of energy efficiency is only one of many aspects of a comprehensive sustainable engineering. Against the background of constantly ascending energy prices an increasing number of legal obligations concerning resource efficiency, and particularly issues of prevention of global warming, it is imperative to consider the buildings processes more strongly and more comprehensively both from an economical (e.g., operating costs, lifecycle costs) and an ecological perspective (e.g., space consumption, recycling, changeability, CO2 emissions). In the field of industrial architecture IFA, Institute for Factory Facilities, University of Hannover, and MSA, Muenster School of Architecture, combined research analysed daylight, energy, and comfort issues (Fig.1.11).

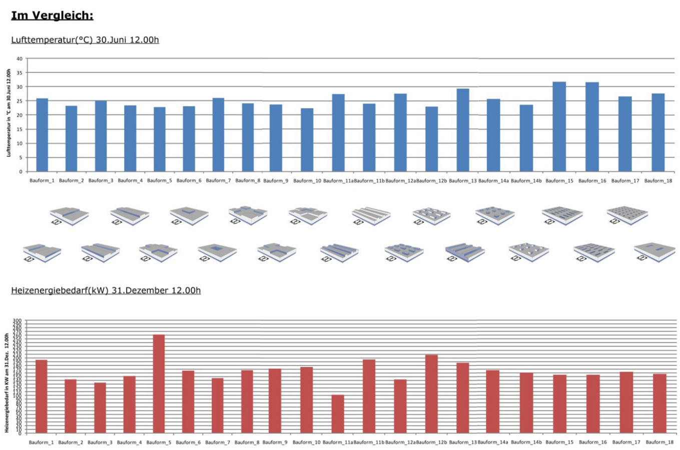


Figure 1.11: Daylight, comfort and energy IES simulationof same footprint model factory hall variants structures (source: Reichardt, combined research project IFA Hannover, MSA Muenster)

The approach of comparing equal footprint with different roof profiles section in dynamic 3D- IES energy model, particularly with sustainability aspect of natural daylight availability is noteworthy. As electricity consumption for lighting fixtures might be minimized over whole life period of operation, less favorable positioning of roof openings might result in undesirable solar heat, leading to more cooling demands. [37, 38] point out examples for rooftop daylight provisions, interaction, and manipulation of 3D- BIM volumes and distribution of daylight, and references to European and International EN, ISO and ASHRAE workspace specifications. Together with the German BMWI, Federal Ministry of Economic Affairs and Energy funding IFA/ MSA ECO Fabrik webtool method analyzed energy- efficiency potentials for factories in operation. Method was 2 step coarse scan and further detailed detecting of single measures. Fig. 1.12 and Fig. 1.13 visualize, list, and balance such areas and measures of potentials in terms of sites, processes, buildings, utilities and organization parameters.

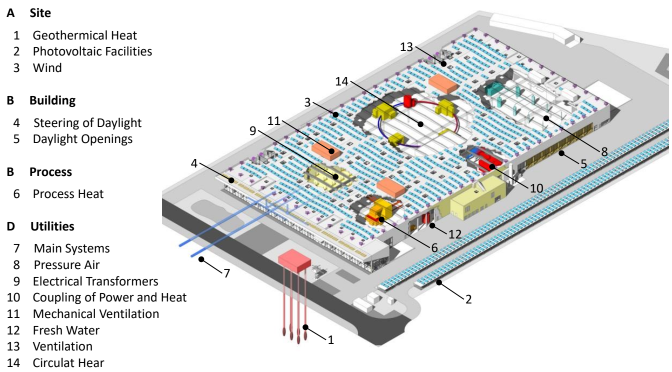


Figure 1.12: Diagram illustrating areas and objects potentials for energy savings in a factory plant (source: Wiendahl, Reichardt, Nyhuis,Handbuch Fabrikplanung, Hanser 2014, 523)

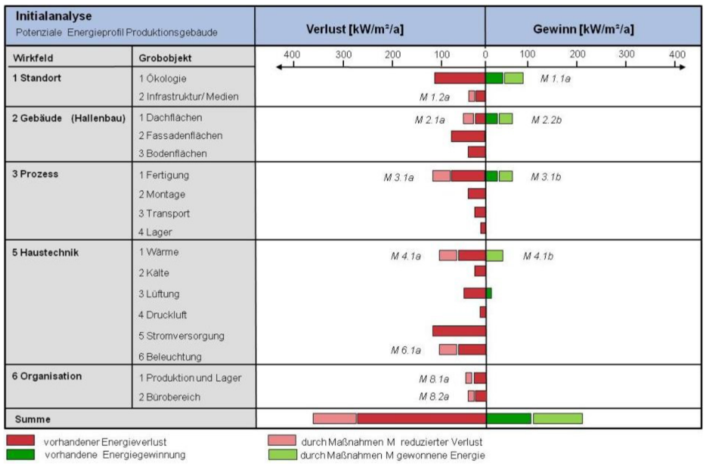


Figure 1.13: Balance of summing up areas and objects of energy loss and savings potentials of a factory plant (source: Wiendahl, Reichardt, Nyhuis,Handbuch Fabrikplanung, Hanser 2014, 526)

In summary energy losses and gains to zero in terms of 100 % self-sufficiency would be ecologically best [39, 40]. State of the Art for energy and comfort optimizing tools in digital planning are 3D- dynamic simulation programs. Possibilities and applications of these energy, comfort, and light aspects out of 3D- modeling optimizing software tools are summarized in BIM wording analogy BEM Building Energy Modeling. The main strive is for an early and precise creation of meaningful variants simulation for various optimization scenarios. Vast digital technology field is still the lossless data "coupling" wish wishful complete data transference of 3D- geometric BIM data including attributed information into BEM modeling and back, questions of adequate LOD Level of Development of 3D-modeling in different phases of planning have to be solved. Level from rough to fine are defined with LOD 100 to LOD 600 [41]. BIM modeling often are created in e.g., REVIT, ARCHICAD, MICROSRATION, whilst BEM dynamic 3D- Energy modeling often occur in e.g. IES, TAS, ENERGY PLUS, DESIGN BUILDER. The purposes simulations might be analyses of daylight, solar harvesting, heating, cooling, ventilation, thermal user comfort, as well as specific proofing of building physics detail problems, as e.g., materials cold bridges or acoustical noise disturbance. Exemplary state of the art BIM/ BEM interaction research, experiences with different combinations of BIM/ BEM specific software data coupling are discussed in [42, 43, 44, 45]. Special attention must be attained to local climatic situation, with specific embedding to topography, temperatures, sun, wind, rain offered "passive energy" potentials.

Green Buildings, Sutainability Certification Assessments

These sustainability potentials of simultaneous planning and assembly of building structures, so far more outlined on exemplary of forerunning industrial architecture, apply to other sectors of buildings, too. Residential, office, commercial and educational projects offer manifold potentials for BIM/ BEM simultaneous team design and engineering, energy efficiency is politically demanded, as quoted e.g., for California, U.S. in [46]. In history of architecture regrettably after first world war new "International Style" movement generated more climate uncommitted aesthetics. European avantgarde architects as Le Corbusier in France and W. Gropius in Germany, propagated cardboard like, climatically neutral esthetic vision of "white box", after New York MoMA exhibition in 1932 spreading as "International Style" all over the world. Hence specific vernacular regional climate, building design, material, as well as sociological roots seemed less important. Only few, as F.L. Wright with his concept of "Organic Architecture" and "The Natural House" opposed a strong plea for more sensibility towards site, nature, and material: "…The first condition of homeliness, so it seems to me, is that any building which is built should love the ground on which it stands….Garden and building may now be one. In any good organic architecture it is difficult to say where the garden ends and where the house begins or the house end and the garden begins…" [47, 48]. B. Rudowsky`s "Architecture Without Architects: A Short Introduction to Non-Pedigreed Architecture " is a book originally published in 1964, following a New York City MoMA exhibition of the same name. It provides a demonstration of the artistic, functional, and cultural richness of vernacular architecture [49].

"Operating Manual For Spaceship Earth", a bright parable of the earth as spaceship with finite amount of resources that cannot be resupplied, was first published by thought leader R. Buckminster Fuller in 1969 [50]. Presently the rising awareness for these resilience aspects recall early as 1962 ad 1973 forerunners in warm climate architectural sustainability V. Oligay [51] and O. Koenigsberger [52]. S. V. Szokolay was Cassandra like visionary pioneers for more more bioclimatic architecture, titling his 1992 book "Architecture and Climate change", with "Introduction to Architectural Science he thoroughly further analyzed environmental aspects for architectural design [53, 54]. On this roots R. Hyde researched further on innovative and bioclimatic designs in moderate and hot humid climates climate [55]. A spectrum of more international examples of sustainability of vernacular traditions in Egypt and Sri Lanka are pointed out in [56, 57]. A variety of solutions towards "Green" or "Eco" residential projects with BEM climate and energy analysis for warm climates of Egypt, Chile, Africa, India, and Vietnam is shown in [58, 59, 60, 61, 62], whereas more general design guides and "tool kits" for green building are quoted in [63, 64, 65, 66, 67]. Further projects typological studies for energy saving strategies for offices, commercials, as well as schools and residentials renovation and retrofit analysis are pointed out in [68, 69, 70, 71]. Fig.1.14 shows an example of an as early as 1994 "coupling" of MICROSTATION 3D- architectural and TAS 3D- energy modeling for a private home and studio in Essen, Germany.

Potentials of specific slope topography for cooling and heating comfort, extensive green roof and solar thermal passive energy were considered in 3D dynamic simulation. More measures towards ecology and energy efficiency project were minimizing site surfaces sealing, grey water recycling and modular prefabricated steel, wood and glass composite structure with dismantling ability [72, 73]. For northern and central Europe heating has been identified responsible for major carbon footprint in residential buildings. The Idea of highly insulated Passive Housing [74] emerged about 35 years ago in Scandinavian countries and is meanwhile an established international standard in energy efficiency The Passive House Institute (PHI) has played an especially crucial role in the development of the Passive House concept. The first German pilot project (Kranichstein Passive House, Darmstadt, 1990) was Europe‘s first inhabited multi-family house to achieve a documented heating energy consumption of below 10 kWh/(m²a), confirmed through years of detailed monitoring.

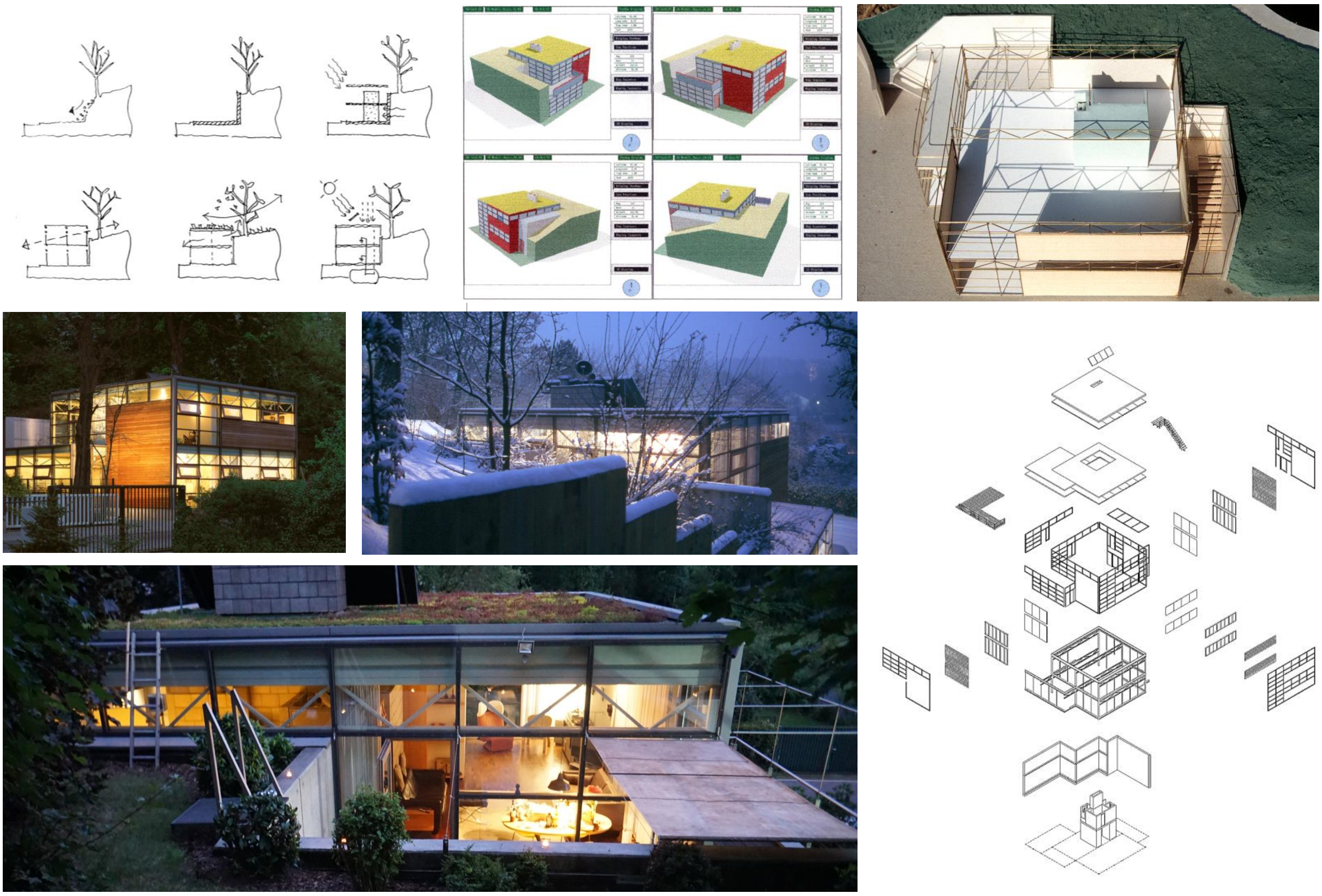
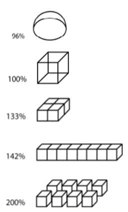


Figure 1.14: 3D- site design scetches, architectural model, TAS climate and energy simulation , prefabricated steel structure, impressions (source: Home and Studio Essen, Germany, RMA Architects)

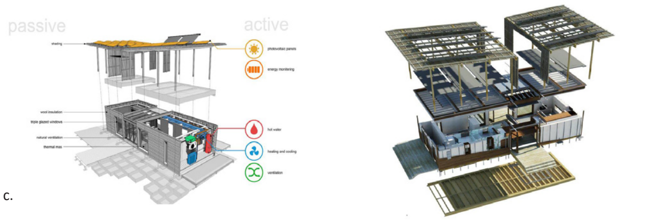
Fig. 1.15 analyses building volumes within winter favorable minimum area of envelope (A) to maximum volume (V) ratios, as well as daylight harvesting potentials for different volumes in reference to sun angles and building shapes, climatical context of MSA research in passive housing design is Muenster, Germany [75].
The five main principles of Passive Housing, high quality insulation, heat control and robust windows, airtight construction, heat recovery ventilation, thermal bridge free design also partly apply to warmer climate green building, too, but may lead to more complex designs. Academic cooperation of University of Wellington, NZ and MSA Muenster launched BIM/ BEM design and engineering of New Zealand award winning entry in worldwide Solar Decathlon Competition 2011 (Fig.1.15). Mobile wooden building structure, envelope, interiors, and all facilities components were prefabricated in N.Z., shipped and assembled at U.S. Washington Mall, shipped again back and assembled 2nd time in NZ. House was maintained completely with own solar energy harvesting, and local data monitoring, as mandatory 10 sustainability assessment goals benchmarking[76]. As the climate conditions vary with each unique site, a thorough climate analysis, followed by variant scenarios of climate strategies, is mandatory in commencing a project . Digital climatical database is available for sites all over the world and is imported into the BEM software packages prior to simulations. Forwarded engineering demands open minds for different climatical embeddings, as researched in international academic network between Muenster, Colombo, Sri Lanka and Bangalore, India. In part 2, case study 2, more detailed building characteristics and typologies for warm humid climates will be discussed.



a.

Bauform	-	A	B	C	D	E	F	G	H
Nettofläche	[m²]	77,44	77,44	77,44	77,44	77,44	77,44	77,44	77,44
Bruttofläche	[m²]	92,16	92,37	92,88	93,63	96,77	99	91,73	102,94
Höhe	[m]	6	6	6	6	6	6	6	6
Volumen	[m³]	552,96	554,22	557,28	561,78	580,62	594	550,38	617,64
Umriss	[m]	38,4	38,93	40,2	42,06	49,92	53	37,12	63,77
Hüllfläche	[m²]	414,72	418,32	426,96	439,62	493,06	516	406,18	588,5
A/V	[1/m]	0,750	0,755	0,766	0,783	0,849	0,869	0,738	0,953
Solareintrag									
Jahr	[kWh/(m²a)]	106.731,98	103.903,27	103.831,60	105.615,04	118.245,87	144.365,38	102.782,81	169.771,00
West		39.638,76	33.611,14	29.305,70	25.861,35	18.972,64	57.951,35	36.503,80	61.318,75
Ost		26.838,13	22.757,02	19.841,95	17.509,89	12.845,77	41.459,13	24.715,55	44.493,49
Süd		40.255,09	47.535,11	54.683,95	62.243,81	86.427,46	44.954,90	41.563,46	63.958,76
Sommer		69.892,81	67.214,35	66.457,21	66.457,21	73.292,68	95.251,28	67.275,44	112.713,16
West		27.515,07	23.331,03	20.342,43	17.951,54	13.169,78	39.593,40	25.338,96	42.731,69
Ost		18.498,37	15.685,44	13.676,20	12.068,82	8.854,04	28.421,69	17.035,37	30.681,14
Süd		23.879,36	28.197,88	32.438,58	36.923,09	51.268,86	27.236,19	24.901,12	39.300,33
Winter		36.839,17	36.688,93	37.374,39	38.671,59	44.953,19	49.114,10	35.507,37	57.057,83
West		12.123,69	10.280,11	8.963,28	7.909,81	5.802,87	18.357,95	11.164,85	18.587,06
Ost		8.339,76	7.071,58	6.165,74	5.441,07	3.991,73	13.037,44	7.680,18	13.812,34
Süd		16.375,73	19.337,23	22.245,37	25.320,71	35.158,60	17.718,70	16.662,34	24.658,43

b.



c.

Figure 1.15: a. A/V area to volume ratios, b. energy analysis of Passive House volumes, c. 2011 Solar Decathlon Entry University Wellington, NZ (source: Reichardt, MSA Future Passive House research project, Danielmeier, University of Wellington , 2011 Solar Decathlon Project)

As introduced with Solar Decathlon project, "proofing" sustainability with benchmarking criteria has some tradition. Historically triggered in project development marketing, since the 1990s arouse sustainability certifying assessments. BREEAM (Building Research Establishment Environmental Assessment Method) was first established in Great Britain. It provides a point system for the project quality in 8 categories including management processes, energy, water use, ecology, health, transportation, material and pollution Since then, according to BREEAM, over 595.000 buildings world-wide have been certified, 2.315.000 buildings regarded in 89 countries. The assessments extend to a scale ranging from excellent to very good, good and average [77]. LEED (Leadership in Energy and Environmental Design) was designed by the US Green Building Council in 1998 based on BREEAM. The categories that are assessed here include the sustainability of the site and earth, water efficiency, energy and atmosphere, materials and resources, quality of internal spaces, as well as innovation and design processes. The projects assessed are certified as silver, gold, platinum [78]. IGBC (India Green Building Council) was developed in India in 2006 based on LEED and is especially designed for buildings in industrial projects. In particular, it takes into consideration the aspects of energy efficiency and sustainability which are particular to the hot climate regions of India. The definition states: "a green building is one which uses less water, optimizes energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants than a conventional building" [79].The German Sustainable Building Council (DGNB) was introduced in Germany in 2007 and has now spread internationally. Its aim is to provide a certification system that can be adapted to local conditions, but which makes buildings in different countries directly comparable.. Six categories are defined with which the ecological, economic, socio-cultural, functional, technical, process and site quality are assessed; weighting is project specific (Fig.1.16). An auditing system moderates the points received during the planning and execution of the project. Therefore, depending on the criteria met, following some relaunches, ratings of bronze, silver, gold and platinum are possible. It is noteworthy that term "DNA" as proposed by authors with RMA GENEering™ [125] meanwhile was also adopted in DGNB wording. The current system comprises more than 60 criteria and moreover specific validations for 46 building types, which makes it fairly elaborate for all participants [80].

Main criteria group	Criteria group	Criteria	Main criteria group	Criteria group	Criteria	Main criteria group	Criteria group	Criteria
Ecological quality	*Life cycle analysis*	Global warming potential			Visual comfort			Ease of dismantling and recycling
		Ozone depletion potential			User control possibilities	**Process quality**	*Planing quality*	Quality of project preparation
		Photochemical ozone creation potential			Quality of outdoor spaces			Integral planning
		Acidification potential			Safety and risk of hazardous incidents			Optimization and complexity of planning method
		Eutrophication potential		*Functionality*	Handicapped accessibility			Evidence of sustainable aspects in call for and awarding of tenders
	Effect on the global and local environment	Risks to the local environment			Space efficiency			Creation of conditions for optimal use and management
		Other effects on the local environment			Suitability for conversion		*Construction quality*	Construction site / construction process
		Sustainable use of resources / wood			Public access			Quality of contractors / prequalification
		Microclimate			Bicycling convenience			Quality assurance for construction
	Ressource consumption and waste generation	Nonrenewable primary energy demand			Social integration			Commissioning
		Total primary energy demand and proportion of renewable primary energy		*Design quality*	Assurance of design and urban development quality in a competition		*Management quality*	Controlling
		Other uses of non-renewable resources			Percent for art			Management
		Waste by category			Quality features of use profile			Systematic inspection, maintenance, and servicing
		Drinking water demand and volume of waste water	**Technical quality**	*Technical performance quality*	Fire prevention			Qualification of operating staff
		Space demand			Sound insulation	**Site quality**	*Site quality*	Risks in the micro-environment
Economic quality	*Life cycle costs*	Building related life-cycle costs			Quality of building envelope with regard to heat and humidity			Conditions in the micro-environment
	Performance	Suitability for third-party use			Building services' backup ability			Public image and condition state of site and neighbourhood
		Marketable			Building services' ease of use			Access to transportation
Sociocultural and functional quality	*Healthiness, comfort and user satisfaction*	Thermal comfort in the winter			Building services' equipment quality			Proximity to use-specific facilities
		Thermal comfort in the summer			Durability			Connections to public services (utilities)
		Interior air hygiene			Ease of cleaning and maintenance			Legal situation for planning
		Acoustic comfort			Resistance to hail, storms, and flooding			Extension options / reserves

Figure 1.16: DGNB Certificate of Sustainable Building, Hierarchy of Evaluation Critria (source: Wiendahl, Reichardt, Nyhuis, Handdbook of Factory Planning, 425)

Green Cities

It is even more demanding than single buildings are larger area resilient Green city agglomerations, as so far outlined strategies of sustainability planning multiply. The more complexity at the moment comprehends e.g., financial development, cultural, sociological, traffic, water and waste management, natural ventilation and recreation green corridors, health pollution or urban heat island aspects. Key lessons might be learnt of three different Eco city case studies, Auroville, Singapur and Masdar. The roots of Auroville go back to 1966, when visionary couple Mira Alfassa and Sri Aurobindo succeded in acquiring UNESCO support for development of 210 acres (985.000 m²) desert land in Pondicherry, South India. Land purchase began in 1968, with idealistic multinational founders out of 121 nations and 23 Indian states. Then due to intelligent low tech ecological water management and alternative ways of living, former dry desert land flourished into a lush green oasis radial green belt around central spiritual of Matrimondir chapel.

Low tech buildings structures are till today locally researched with international experts, and constructed in own experimental workshops, avoiding mechanical AC utilities support. Central cooking facility is passive energy solar driven [81]. Singapore aims to be the world's greenest city. After independence more than 70 years a crowded unpleasant high density town state developed into a clean sustainable garden city, with political supported green measures as green roofs, cascading vertical gardens, verdant walls, smart water management system, and rainforests amidst skyscrapers [82]. New town Masdar in Abu Dhabi, Saud Arabia, reflects future Arabian "Ecotopia" high tech vision for green times after decay of crude oil wealth. It was appraised first carbon neutral city development started in 2008, with plans for 600 hectars of 15 degrees cooler city space than surrounding desert, 1500 green businesses, 110.000 inhabitants, 10 megawatt solar plant 45 m wind cooling tower. A critical look reveals that rapid profit expectations were not in full line with longer term resilience goals [83]. Current international concepts for "green" or "eco" city environmental management are pointed out in [84, 85], specific climate influence of wind and rain in[86, 87], shadowing volumes and envelopes in [88, 89].

Biotechnological possibilities for urban green green and water bodies are quoted in [90], an example of retrofitting green developments for German city of Francfort is referenced in [91]. Two larger scale projects with some green city ideas authors were engaged in Germany will be roughly outlined.

Fig. 1.17 depicts ideas for a 250 hectars (2.500.000 m²) total area for a new industrial, science and residential "ECO Parc" at motorway exit to Nuremberg, Germany, project was awarded 1st prize in an international competition. Basic sustainability idea was a free of building curved landscaped ventilation and waterbody corridor for pedestrians, bicycles, solar individual taxis, and solar logistics, serving as spatial and traffic connection of central public transport to perimeter existing localities. Moreover, green ideas were combination of individual traffic hidden under soil covered landscaped "hill" with 1800 cars central public transport under technology center, modular flexible zonings for industrial, science and residential developments, and overall intensive use of green roofs and solar energies. The project was proposed with 3D- models for all building structures [92]. Regrettably the landowners resisted the project, as they felt that proposed green landscaped corridor land sale would be less profitable than their expected sales for building sites.

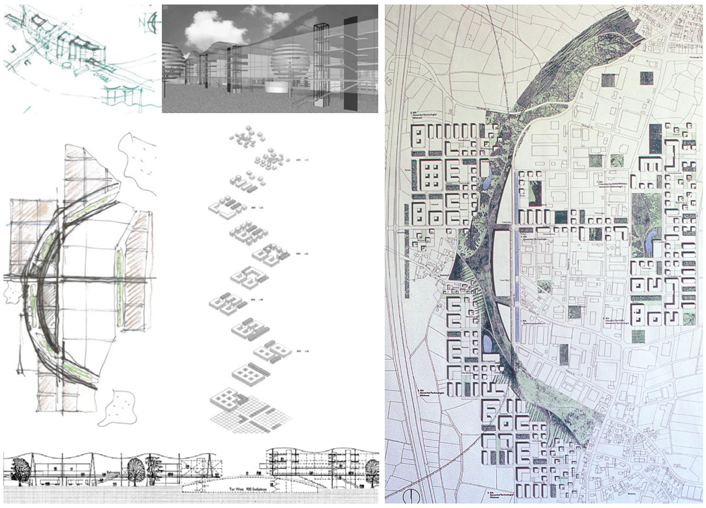


Figure 1.17: ECO Parc 2.500.000 m² research, industry and residental area development, sustainable green landscaped corridor (source: Reichardt, RMA Architects)

Fig. 1.18 shows a conversion "2nd life project" for an abandoned fenced 45 hectars (450.000 m²) industrial wasteland area amidst German town of Essen. In Years 1925 to 1970 M1 area was formerly used by KRUPP company for manufacturing heavy weight mechanical parts. New Ideas for temporarily abandoned polluted soil and criminal area were building back existing vast industrial steel structures, replacing, and cleaning up polluted soil, inserting landscaped park area open to public, organizing new traffic and infrastructure and offering modular sites for 2nd life light industrial and offices development.

The project was developed fully in digital town 3D-modeling, energy modeling for some projects, and with own City of Essen webpage web support for development management in marketing of sites and attributed site information data base. During 8 years of RMA Architects artistic direction of development, potential

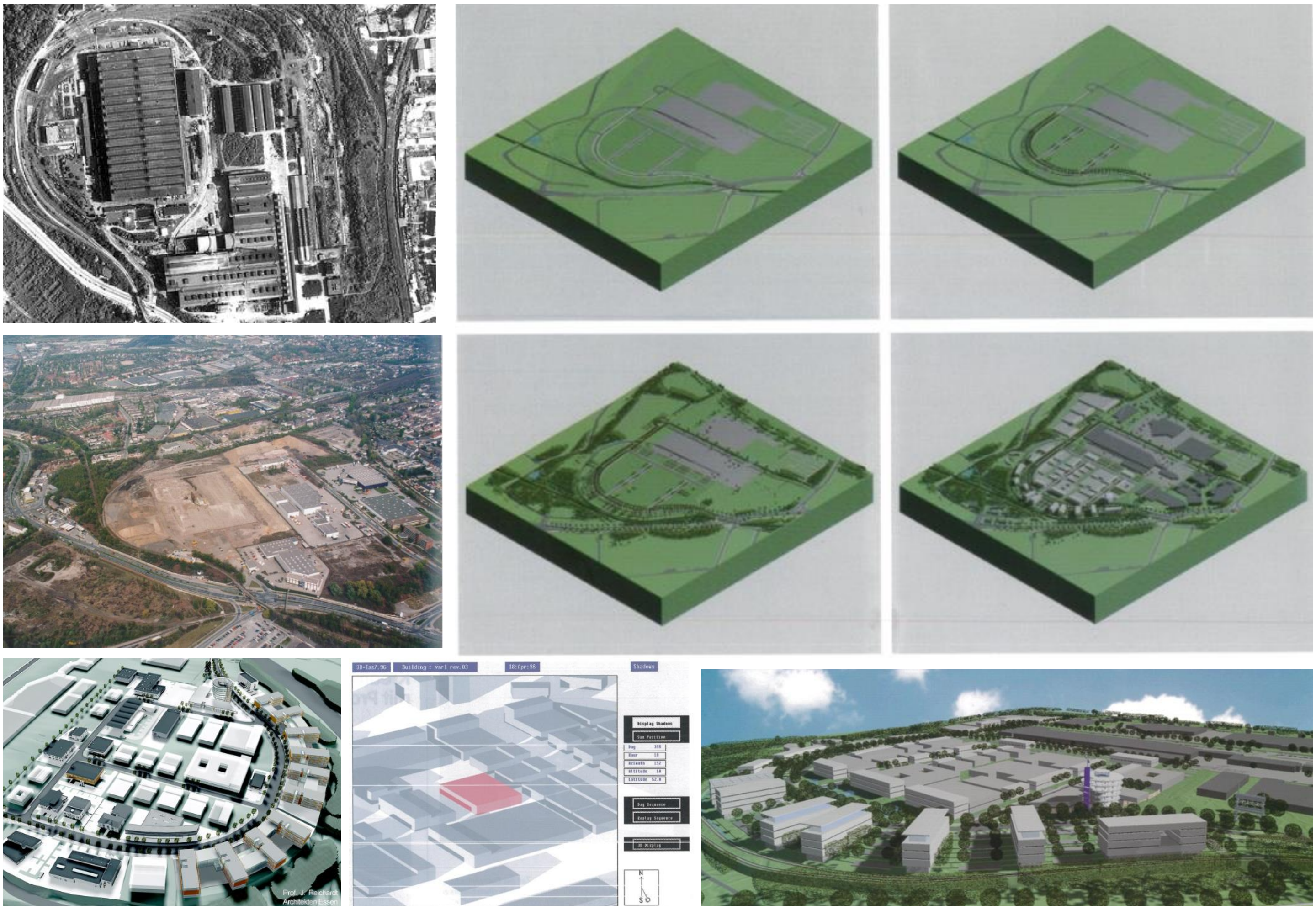


Figure 1.18 M1 Essen 450.000 m^2 area industrial waste land conversion 2nd life industry, offices development, 3D- town, energy modeling (source: Reichardt, RMA Architects)

investors ideas were 3D- twin modeled and "virtually inserted" into digital embedding of overall modeling, with control of volumes, heights, and envelope materials. In time frame of 8 years nearly 2000 new jobs were created [93]. In more detail shown case study 1, Solar Bakery (Fig. 2.01 to 2.05) was further "Form Follows Performance" designed and engineered on that larger scale basis.

Cradle to Cradle, Lifecycle, Health

Along with the immense acceleration due to current global CORONA pandemic, even more ecological based health aspects arouse as matters of research, quality of planning and sales marketing. Overall world- wide aims and consequently not only cover energy consumption, but also protecting more sensibly environment and developing rules for an overall responsible and healthy building approach. Already in 2002, in their highly acclaimed book "Cradle to Cradle" Braungart and McDonough pointed to the – at the time still minimally considered – side effects of industrial societies such as contaminants in products, unresolved waste disposal or irreplaceable resources [94]. Hence cradle to cradle, urban mining recycling aspects of building and utilities materials, urban farming, moreover a strong plea for architectural and engineering favorable health aspects are new demands for more overall efficiency and resilience of buildings and cities. Building materials "hidden" grey energy and waste has been widely recognized as major contributions to global warming, hence optimization of these aspects is mandatory. As all building and utilities geometry and material components are already coined out in 3D- BIM modeling, specific grey energy and recycling material BIM attributes may be compared and benchmarked. The evaluation of variants for envelope materials equivalent CO2 tons of carbon footprint with reference to 3D- BIM modeling are analyzed in [95, 96], specific grey energy validations, recycling ability comparisons and life expectancies of of building and utilities components are quoted in [97, 98, 99], as well as an exemplary for campus buildings lifecycle analysis in [100]. For new trend of "Urban Mining" reuse of materials components specific grey energy validations are important. Analysis of in reference to wood sustainably minor favorable cements and steel are shown in [101, 102], analysis and engineering possibilities for innovative new material as fiber reinforced cement for high rises and vernacular traditional material for bermed earth shelters are pointed out in [103, 104], references of Industry 4.0 and circular economy in [105]. In terms of comfort and health utmost important will be avoiding of heat islands in city agglomerations, simulations of supporting favorable wind and rain simulations might avoid urban heat islands, decreasing hot temperature in high density sealed cities. State of the art CFD (Computational Fluid Dynamics) simulations allow for more precise data of wind temperatures and velocities [106, 107].

Utilities Sustainability

Furthermore issues of larger scale are closer sustainability driven looks on all utility systems. Replacement of temporarily inefficient or inadequate utilities, installation of additional mechanical ventilations in closed rooms, as well as the comprehensive improvements of new and existing mechanical ventilation utilities, particularly towards more sustainable cooling and additional HEPA filter devices will be dominant future tasks. At this juncture, it would be important to point out two issues highlighted by Authors Grondzik, Walter T., et. al in the preface of their book [108]. The authors pointed out that the society has slowly moved from systems that centralize the provision of heating, cooling, water, and electricity toward those that encourage more localized production and control. Increased sophistication of digital control systems has encouraged this trend. Further, the authors point out that encouragement comes from more multipurpose buildings whose schedules of occupancy are fragmented and from corporations with varying work schedules that result in partial occupancy on weekends. Another factor in this move to decentralization is the worker satisfaction; there is growing evidence that productivity increases with a sense of individual control of one's work environment. In [109] authors Ma, Liu and Shang propose more beneficial use of BIM model for developing artificial neural networks (compare [124], Building DNA). Examples for efficiency potentials with radiant cooling and retrofit of existing facilities are shown in [110, 111], a summary of aspects of utilities operational costs in [112]. As responsible Architects, Engineers & Town-planners it is important to stress upon 'passive' utilities, improving whole lifecycle of systems, so as to achieve same level of comfort but consuming lesser energy and at an optimum cost. Facility Management web based systems might be advisable for centralized monitoring steering [113, 114], future generation of systems will have fully integrated 3D- BIM and BEM philosophy [115]. In part 2, case study 3 will more elaborate on a utilities conversion project in Bangalore, India embedding.

Form Follows Performance Strategy, DNA, Virtual Twin, communication, summing up to holistic BSM/ Building Sustainability Modeling

The time schedule phases and milestones of a synergetic approach in complex building planning are described in [116]. Data cloud with beehive "ins" and "outs" is steadily growing from coarse to fine, and should be open and transparent to all team participants. The integrated expert engineering team approach includes evaluation of variants and optimization measures, as well as support of 3D- model BIM, BEM simulations of sustainability potentials. The resulting digital virtual twin data cloud should prove sustainability performance abilities, also avoiding unforeseen later cost and time defects in construction site erection "1:1 life modeling". The credo Form Follows Performance, for such all phases steadily quality assuring strategy of expert team approach, was first coined in 2001 [117], and is meanwhile widely acknowledged for design and engineering issues of energy [118], and building construction in terms of load bearing structure, envelope, and interiors [119, 120, 121, 122]. It is crucial for whole lifecycle sustainability are manifold performance talents, as created in phase 1 "birth" programming of a project, e.g., in terms of utilities example, conscious and clear separation between "passive" and "active "measures. Utmost important is preliminary research, which should end with a specification book for all site, building, utilities, and process parameters [123]. Proven workshop method for achieving a holistic programming is GENEering™. The term – which linguistically combines 'gene' of a living organism with 'engineering' features– indicates this method is concerned with developing a Building DNA code [124], but from the perspective of object planning. This method combines settings of "hard" and more "soft" decision areas, further defining the structural forming parameters in the project's future lifecycle performance. These are described with 8 factors, which will be visualized in further steps through expressive images visualizing these "talents" (Fig.1.19). Initially these are not directly related to the project construction, but rather are meant to trigger new associations for workshop participants. Secondly, the factors are reviewed in a similar nature however this time are oriented on examples. Each individual factor is broken down once more into three sub-concepts and examined from internal and external company perspectives. Each of the sub-concepts are designated an importance, whose value can be between 1 (not important) and 10 (extremely important). GENEering™ gains particular importance in the discussion on sustainability measures. For example, in terms of sustainability possible future changes in use or climate conditions need demands of a thorough

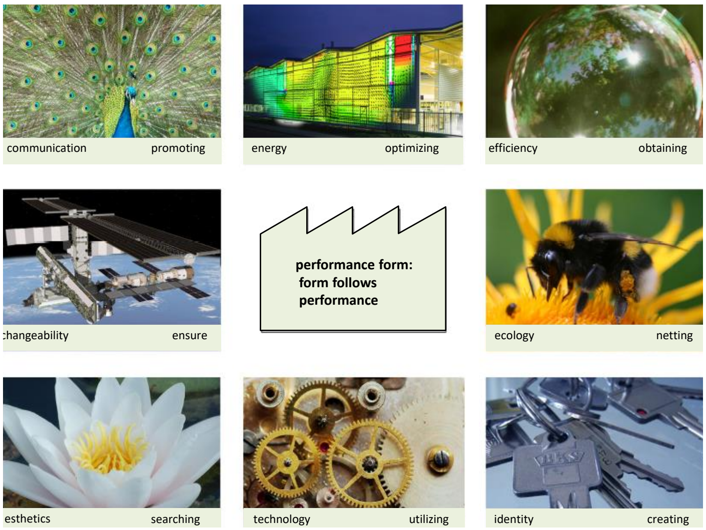


Figure 1.19: Programming workshop method GENEering™ DNA talents of project (source: Wiendahl, Reichardt, Nyhuis, Handbook Factory Planning, Springer 2014, 383)

discussion of wishful aspects of changeability, as the involved building, utility and process parameters will be utmost decisive for possible period of overall usage life period of project. Fig. 1.20, 1.21 point out GENeering™ aspects with first rough benchmarks, Fig.1.20 shows more detailed parameters and specific project components evaluation of changeability [125, 126].

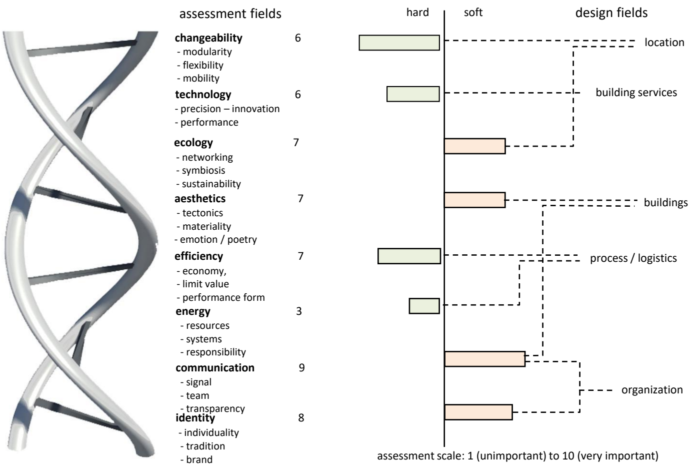


Figure 1.20: Programming workshop method GENEering™, benchmarking of assessment fields (source: Wiendahl, Reichardt, Nyhuis, Handbook Factory Planning, Springer 2014, 385)

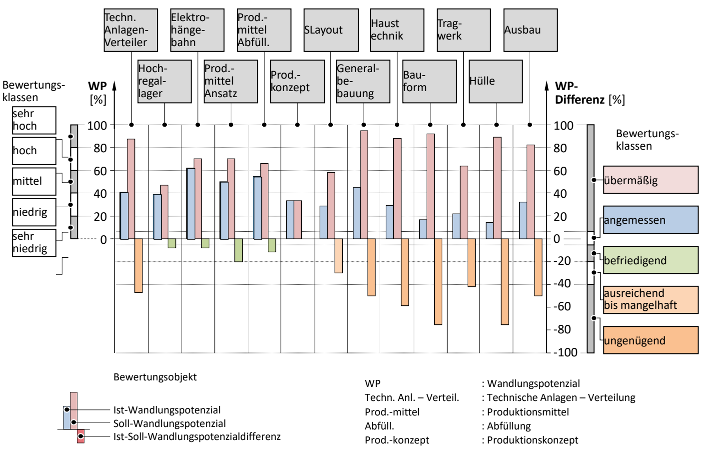


Figure 1.21: Programming workshop method GENEering™, project example of specific evaluation of assessment fields of changebility (source: Wiendahl, IFA University of Hannover, Reichardt, RMA Architects)

In regard to the communication current planning team Video conferences and Data Cloud management systems are recommendable, as saving communication time and various emissions and traffic emissions connected with alternate travelling. A high degree of flexibility and system openness is achieved with the establishment of a separate website for a building. Due to differentiated accesses to specific information levels, authorized users can influence portions of digitally available information of location, buildings, utilities, and further facilities. In addition, through mobile PDA devices, laptops, and mobile phones, for example, reading data of aggregates can be entered directly online. Hence advantages are: Duplication and errors are reduced, plans can be reviewed and commented online, considerable saving of time in the assessment and approval processes, risks of losing important files are eliminated.
Special CAFM system web-based edits are also a cost-effective alternative against providing complete hardware and software installation for each user instead in individual office. Free viewer systems allow the editing of numerical, 2D, 3D data drawings without the need of installing the complete software with the individual user, Examples for CAFM system Archibus and website digital project management Conject are shown in [127, 128].
As a summary of thoughts authors propose to unite so far more isolated created aspects of data of BIM, BEM, Sustainability and Health, DNA Programming and Form Follows Performance Strategies, in ONE comprehensive digital team planning approach, with, holistic data management towards

BSM Building Sustainability Modeling

Fig. 1.22 illustrates phases, areas, aspects, and quality assuring milestones of BSM, Building Sustainability Modeling. Information collecting and planning opimisation is from top to down, coarse to fine, digital island knowledge not transferable into other programs should be avoided.
Parable for data cloud would be “Beehive” with no bees lost, no blossom dust, no honey nectar produced wasted. Due to the central just in time overall database, variants are transparently performed, results automatically based for following planning options. This saves considerable time and maintains all questionable data in the project consistent. The aspects mentioned might be arranged in terms of individual “checklists” for different issues, synergies should lead to sustainably more responsible project. In vertical direction, from top to down, are proposed 6 phases of project development, staring with programming, ending with completion of

life cycle operation. Each planning phase is finalized with a defined "milestone", as conclusion of past phase summarizing data for "entrance gate" to next phase. In horizontal direction interlocking of (left side) listed special sustainability aspects and (right side) aspects of building evolving process are visualized. Interlocking in between, with visualization of "Curved Line" indicates that planning process will not be linear, variants have to be discussed in constant assimilation between "left side" and "right side" issues. Purposes of conflicts are manifold, just mentioning cost and time, resulting in constant dialogue upon sustainability issues.

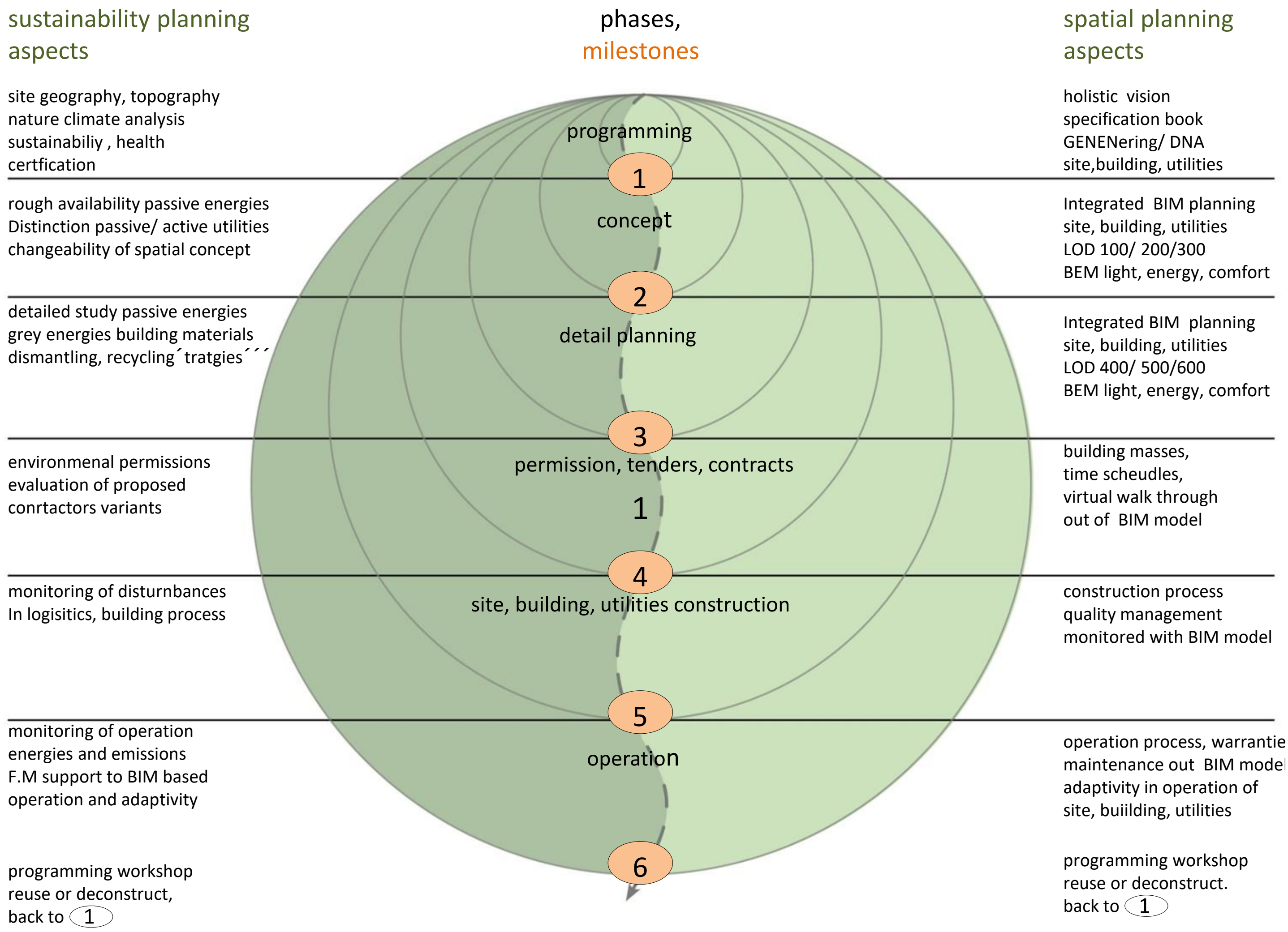


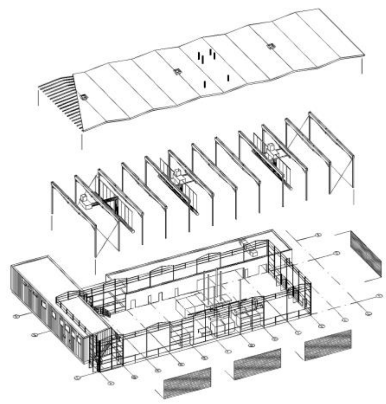
Figure 1.22: BSM, Building Sustainability Modeling,„Beehive" Process Diagram of Phases, Milestones, Aspects, Data Cloud (source: MSA Muenster School of Architecture, RMA Architects)

On basis of in part 1 roughly proposed aspects of design, engineering and construction of sustainability, in part 2 shall be discussed in more detail three specific climate and technology embedded case studies of a solar bakery in Germany, Climate Responsive Simulation research in Colombo, and reconversion of existing utilities in Bangalore, India. In part 3 shall be outlined roots and issues of existing international academic cooperations, ideas towards further international research networking, as well as development of website, app and E-Learning desk climatehub.online

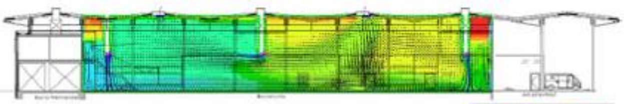
Case Study 1:
Solar Manufacturing Plant for Baked Goods in Essen, Germany
Prof. J. Reichardt, RMA Ass. Architects Essen, Germany

Phase 1, 1998

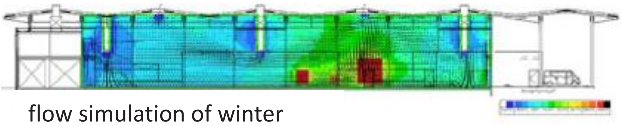
Modern bakeries are characterized by the highly technicised use of heating and cooling units. In Fig. 2.01 conceptualization of the first construction phase for a plant in 1998, the optimized combination of the building structure, technology and energy expenditure was sought using state of the art 3D simulation technology [129]. By means of simultaneous engineering, the interdisciplinary planning team was able to attain the goal of an efficient and energy-saving production facility under the banner of sustainability. The planning team participants jointly set the conditions for a holistically optimized new construction including: the bakery specific production processes, the workplace design, the building structure as well as the supply and removal system. Traditionally, cooling and heating loads are calculated using static models. However, in this project, the building and system simulation program TAS was used to calculate the thermal currents and temperature distributions. The integrated energy and production planning lead to an annual energy requirement of 31 kWh/m² for heating and approximately 450 kWh/m² for cooling. Even in 2021, these are still excellent benchmark values for bakeries.



modular prefabricated building structure



flow simulation of summer



flow simulation of winter

Figure 2.01: 3D- architecture, modular structure, TAS energy and climate simulation, interior Impression (source: Peter Bakery Essen, Germany, Phase 1 , RMA Architects)

The, to most degree recyclable, building structure was designed as a highly flexible steel and wood skeleton structure, completely modular roof and wall construction made of the renewable resource wood. By intelligently networking the process and air conditioning technology as well as realizing the building shell in a passive house standard with an insulation strength of 30 cm, the room air could for the most part be sufficiently conditioned by the process waste heat. Fig. 2.02 depicts the combined location of Phase 1, an existing hall used for baskets cleaning facilities and Phase 2 of the new project.

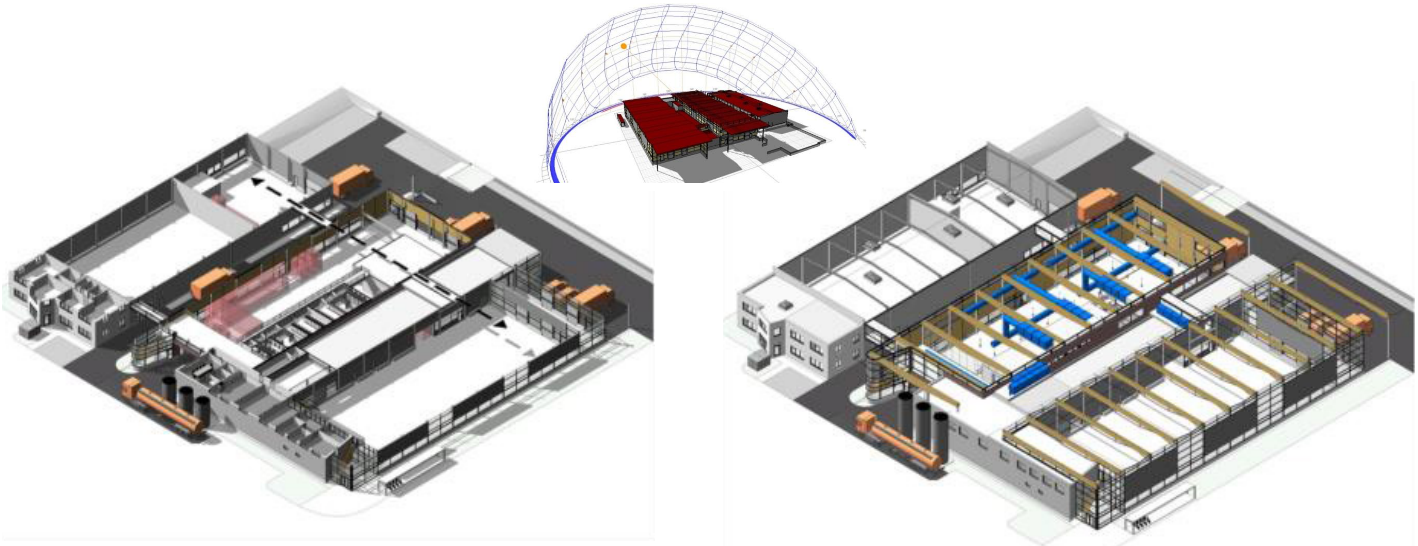


Figure 2.02: 3D- Aerial View of site Plan, daylight and solar analysis, process flow, modular wooden structure, utilities systems (source: Peter Bakery Essen, Germany, Phase1 + 2, RMA Architects)

Phase 2, 2011

In phase 2 BIM modeling of architecture, process facilities, wooden structure and envelope, and utilities were intensified. In deepening the energetic and building climate strategies from Phase 1, the GENEering process was implemented in the expansion project to meet the client's demands in particular for continuing to reduce CO_2 levels also in the supply chain and increasing the overall energy efficiency. Consequently in the approximately 1500 m^2 hall, heat recovery technology from baking steam and room air is comprehensively used. In addition, for the first time in the German baking trade, the high global warning potential (GWP) of conventional refrigerant R 4404a was avoided through a two stage cascaded compression refrigeration system. Cascades work with separate refrigerant circuits so that the evaporator temperature decreases considerably from stage to stage. An energy-saving of 45% compared to Phase 1 was achieved with double the space to cool (i.e. cooling volume). In a future expansion stage, warm water is supplied to the washing machines from the systems' thermal discharge. Furthermore, for the first time in a bakery, an energetic high efficiency and innovative lighting system (in comparison to conventional systems) is developed using LED high bay lighting, which due to the specific design of the prism plates and heat sinks, is suitable for the flour loaded atmosphere in bakeries. Networked together with a daylight dependent control, the system is highly sensitive. The building materials and technology systems used were selected in view of holistic biogeochemical cycles and holistically optimized using 3D building information modeling.

Solar Bakery, Solar Logistics

In the final stage, the in total 2,200 m^2 roof area from Phase 1 and Phase 2 were completely equipped with photovoltaic panels. In a first step, on the approximately 1,100 m^2 roof from Phase 2, 123,00 KWh of solar yield is directly fed into the bun baking process as well as in the fueling of the company's zero emission delivery fleet (5 ton delivery trucks with solar energy drive electric motors) for the retail outlets. In supplying retail outlets in urban areas, with a mileage of approximately 300,000 km/year and approximately 36,000 liters of diesel fuel, approximately 100 tons of CO_2 is saved per year. After drawing off the 54,000kWh/year required for the delivery fleet, approximately 69,000 kWh/year of solar energy can still be directly fed into the bakery's lighting and electrical processes. The approximately 60 outlets distributed around the entire city of Essen thus become "sustainability ambassadors" of a forward thinking supply chain strategy.

DGNB Gold Assessment

The planning of the layout and logistics, buildings and building services was facilitated during the entire project duration by a certification according to DGNB gold standard. Fig. 2.03 shows the criteria for the main category 'ecological quality' for this case study as well as recycling modularity of completely prefabricated building structure and envelope components. The main category is further divided into three sub-groups with a total of 12 individual criteria. Each criterion can achieve a maximum of 10 points. The achieved number of points is multiplied by a weighting factor and where needed an adjustment factor. This value is then divided by the maximal attainable weighted point value and results in a performance index. The sum of all the weighted point values is set in relationship to the maximal attainable number of points resulting in the group performance indicator, which in this case is 81% for the ecological quality. The group value has a weight of 22.5% in the overall evaluation, overall sustainbale benchmark was 85,2%, equivalent DGNB gold standard [130].

As part of the „Energy Efficient Building 2011“ contest ran by the German Federal Ministry of Economics and Technology (BMWi) submitted project was analyzed and evaluated according to energy consumption in kWh / m². Fig. 2.04 shows the energy consumptions of the utility and office areas for the baked goods project, Fig. 2.05 impressions of solar roof and architecture. The project was awarded by BMWI, won the city of Essen's environmental prize in 2012, received international attention for energy efficiency, moreover was acclaimed for Solar Logistics and Bio- architecture [131, 132, 133].

energy balance

heat load in the hall	Demand [kW]	waste heat [%]	heat load [kW]
dough preparation			
- mix, weigh	2	0.22	0.44
- knead	30	0.09	2.70
dough processing			
- roll plant	11.5	0.13	1.50
- press	1	0.28	0.28
- dough separation	2	0.22	0.44
- dough separation	5.5	0.15	0.83
boiling pastries	10	0.5	5.00
fine bakery	10	0.5	1.25
various	5	0.25	2.50
fermenting room	5	0.5	0.5
sum [kW]			19.93
- area [m²]	816		
- simultaneity	0.8		
sum energy [W/m²]			19.54

optimized annual energy requirement

	heating		ventilation	
	Load [kw]	ann. Demand [kWh/a·m²]	Load [kW]	ann. Demand [kWh/a·m²]
initial situation	90	32	192	576
optimized situation	34	31	117	449
improvement [%]	62	4	39	22

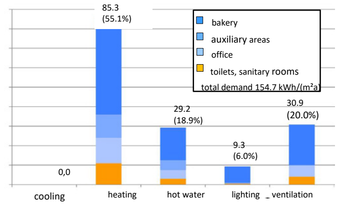
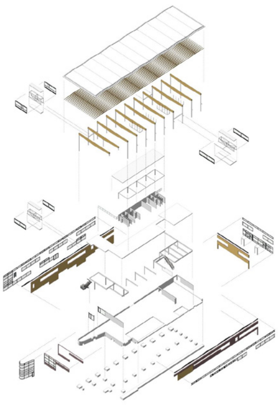


Figure 2.03: Energy values of bakeries areas, comparison of initial and optimized situation (source: Peter Bakery Essen, Germany, Phase 2, RMA Architects)



MAINCRITERIA GROUP	CRITERIA GROUP	CRITERIA	SCORE MAXIMUM	CRITERIA POINTS ACHIEVED	CRITERIA POINTS MAX. POSSIBLE	WEIGHTING FACTOR	ADAPTATION FACTOR	WEIGHTED POINTS ACHIVED	WEIGHTED POINTS MAX.	PERFORMANCE INDEX	GROUP POINTS ACHIEVED	GROUP POINTS MAX. POSSIBLE	GROUP PERFORMANCE	GROUP WEIGHT	TOTAL PERFORMANCE INDEX
ECOLOGICAL QUALITY	LIFE CYCLE	Global warming potential	10	8,0	10,0	3,0	1	24,0	30	80,0%					
		Ozone depletion potential	10	10,0	10,0	1,0	1	10,0	10	100,0%					
		Photochemical ozone creation potential	10	10,0	10,0	1,0	1	10,0	10	100,0%					
		Acidification potential	10	8,0	10,0	1,0	1	8,0	10	80,0%					
		Eutrophication potential	10	9,0	10,0	1,0	1	9,0	10	90,0%					
	EFFECT ON THE GLOBAL AND LOCAL ENVIRONMENT	Local environmental impact	10	7,5	10,0	3,0	1	22,5	30	75,0%					
		Suytainable use of resources/wood	10	10,0	10,0	1,0	1	10,0	10	100,0%	173,5	215,0	81%	22,5%	85,2%
		Microclimate	10	1,0	10,0	0,5	1	0,5	5	10,0%					
	RESSOURCE CONSUMPTION AND WASTE GENERATION	Nonrenewable primary energy demand	10	7,0	10,0	3,0	1	21,0	30	70,0%					
		Total primary energy demand and share of renewable primary energy	10	10,0	10,0	3,0	1	30,0	30	100,0%					
		Drinking water demand and volume of waste water	10	6,0	10,0	1,0	1	6,0	10	60,0%					
		Land demand	10	7,5	10,0	3,0	1	22,5	30	75,0%					

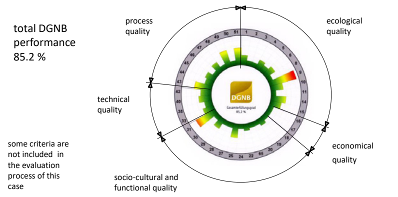


Figure 2.04: Explosion view of Modular recycling ability structure and envelope,DGNB sustainability benchmark, gold award (source: Peter Bakery Essen, Germany, Phase 2, RMA Architects)

Figure 2.05: Architctural impressions wooden structure and envelope, solar roofing (source: Peter Bakery Essen, Germany, Phase 2, RMA Architects)

Case Study 2:
Simulation research and climate responsive design teaching

Dr. U. Rajapaksha, University of Moratuwa, Colombo, Sri Lanka

Building characteristics of architectural design are significant physical parameters that affect climate reponsiveness and thus energy use behaviour of a building. The effort to understand performance characteristics of buildings mandates the need for recognising a building type or a geometry that distinguishes a group of buildings, and a typology, the study of building types.

Early studies of performance characteristics highlights that heat transfer between indoor environment and outdoor climate is significant through the fenestration of facade. Three ways of environmental and internal load transfer were considered – conduction through the opaque surface, conduction through glazed areas and radiation through the glazed area. Lam's [134] study using a DOE simulation based on a generic model across 146 existing high rise commercial buildings in Hong Kong suggested following as major "design aspects" that affect building cooling load specially in warm climates.

1. Building design inlcuding envelope
2. Indoor design conditions
3. Internal loads and enironmental loads
4. Mechanical systems including heating ventilation and air-conditioning (HVAC).

Adapting buildings to extreme temperatures in present and the future to prevent indoor overheating due to environmental heat gain and promote passive cooling in tropics is a priority in the process of achieving Net Zero Emission Buildings. Since the roof is the main contributor in environmental heat gain in low rise buildings, facades are considered equally important as the main heat gain contributor in multi-level or high rise buildings. The "geometry" of the building design in respect to design decisions i.e. its own microclimate, form, and the envelope properties of the structure regulates the thermal performance of the building and thus the outdoor – indoor thermal balance between the building and surrounding environment [53, 55].

Amidst extreme climatic scenarios, optimizing the four main design decisions of the building in maintaining the thermal balance to its contribution to cooling, thermal comfort and reducing energy need for maintaining the indoor environment shall in turn provide a useful contribution for reducing carbon emission. Further, on the basis of potential relationship between building and climate, characteristics of buildings are seen with a wider approach. Dascalaki et al [135] have seen building design higher performance purpose in different types in respect to the degree of exposure, thermal mass, skin dependence and internal structure, thus office buildings can be:

1. Free standing or enclosed, based on their location in the urban context
2. Heavy or light, depending on the structure and material of construction
3. Skin or core dependant, according to the relative importance of the outer envelope and the installed active systems in their energy performance
4. Open plan, consisting of large spaces and minimum partitioning or cellular, consisting of small spaces (Dascalaki et al, [135])

Passive system through bioclimatic influence of buildings

Bioclimatic design of buildings [51] is seen as an appropriate basis for climate responsive design which involves the way buildings filter the climate for occupants' comforts involving four equally important interlocking variables i.e. climate, biology, technology and architecture. In this process, the building envelope, section and form are main "bioclimatic drivers" that foster interventions to reduce the negative impacts of outdoor air temperature, summer heat gain, winter heat loss, optimise daylight efficiency and increase internal heat loss in summer thus the appropriate solar control.

Use of appropriate microclimatic concerns are faciliators for other interlocking design variables. This influence can be effective in skin dependant buildings because of the potential interaction between climate, buildings and occupants. Ken Yeang's work on new high rise buildings can be seen with bioclimatic influence but empirical evidence of the effectiveness of these interventions is less visible. Integration of bioclimatic influence in retrofitting is deserved in the context of environmental sustainability.

Work of Steemers, K., [136], Capeluto I.G., [88], Wagner et al, [137], Voss. K et al [138], Gratia E., et al [89] and Li Denny H. W., & Tsang E. K. W., [139] on retrofitting medium and low rise existing buildings illustrates evidence of utilising this effect in various forms of interventions in achieving energy saving targets primarily in cold climates. The challenge for further research however will be to define interventions that foster bioclimatic influence with reduced energy use potential in high rise commercial buildings in warm climates.

Climate responsive design teaching

Memorandum of understanding (MOU) between University of Moratuwa and Munster University of Applied Science is facilitating student and staff exchange programs since 2006. One of the key objectives of this corporation is to promote teaching, learning and research on climate responsive architecture. Since Sri Lanka is having a warm humid tropical climate, studies on global warming, heat stress and their effects on architecture and indoor environments are commonplace. In this context, a teaching module was designed to provide students from both Munster University and University of Moratuwa sills in understanding of indoor overheating potential of buildings, measures to minimize this overheating through architectural interventions and explore both theoretical and design knowledge to address global climate emergencies. Another design based module requested students carry out a design exercise on an identified location in Colombo in exploring social life of selected communities in the area and gather information of climate as well. The specific modules designed to explore climate responsive architecture paved way for the following:

1. Reviewing of selected research papers on indoor overheating and present a five to ten page document. Identify a clear direction of an argument in respect to the main theme of the papers (overheating). The structuring of the paper should include an abstract, introduction, literature review with a discussion, conclusion and a list of references.
2. Assessing a given three dimensional form for energy efficiency with the given climate of Colombo, a typical tropical climate. Students were required to carry out a DesignBuilder simulations for several alternative options of plan form, sectional forms, envelope characteristics. Options for simulations were given.

In this process, the building envelope, section and form were considered main "bioclimatic drivers" that foster interventions to reduce the negative impacts of outdoor air temperature, summer heat gain, winter heat loss, optimize daylight efficiency and increase internal heat loss in summer thus the appropriate solar control. Use of appropriate microclimatic concerns was facilitators for other interlocking design variables (Fig. 2.06)

Location	Colombo Elevation 1000m/6.9271^{0} N, 79.8612^{0} E
Orientation	Shorter facades of a rectangular form facing East and West
Floor area and plan size	96 ^{m2} and 6m X 16m
Building height and type	4m and non-domestic
External walls	2 mm plaster (light weight) + 4 mm cement mortar + 225 mm thick burnt single brick layer + 4 mm cement mortar +2mm plaster (light weight)
Window to wall Ratio	Facing East and West – 0%, facing North and South 25 %
Roof	Clay half round tiles with timber ceiling and resistive insulation with aluminium foil to consider the heat gain from roof as zero U = 0.239
Windows	5 mm normal clear glass/(U) = 6.121 W/m^2 K,
Lighting and equipment	Zero – to consider that there is no internal gains
Occupancy	Zero – to consider that there is no internal gains

Figure 2.06: Characteristics of the generic building form with climate for Designbuilder simulation (source: Rajapksha,U., Department of Architecture, University of Moratuwa, Colombo, Sri Lanka)

Research methodology

Research methodology consisted of two phase as shown in Fig. 2.07-2.09. The work started with a collection of research evidence from previous studies for setting a hierarchical order of design decisions with regard to addressing indoor overheating potential of building design. This first Phase involved research evidence by others and original field investigations carried out by the lecturer (Upendra Rajapaksha) contributing to justify that a conceptual rectangular form with shorter facades facing east and west orientations work better in climate response in tropics (Figure 2.06). The second Phase investigated further alternative options to this rectangular form with improvements to four design decisions i.e. microclimate, plan form, sectional form and the envelope using a 3D simulation program. The framework for simulations was provided by the lecturer and simulation task was partially carried out by students from Munster University (Ilka Drixelius and Jan Goldbach) for the main research developed by Upendra Rajapaksha of University of Moratuwa to look the air temperature behavior. Further work is underway to look at energy performance behavior of each alternative option by Upendra Rajapaksha. Due to the dynamic capacities of simulation programs, modeling yield performance assessment outcomes that reproduce the real world phenomena [Fig. 2.06]. DesignBuilder computer based simulation program with graphical utility interface for EnergyPlus was used for performance assessment of the generic model and other models. Performance assessment was aimed at evaluating effects of selected design interventions of the models on indoor climate. The accuracy of the performance assessment depends on proper input data on how the building is designed, operated, managed and used by occupants [Fig. 2.07, 2.09]. Thermal simulation process of this research followed the following stages in order to maintain prediction accuracy;

a. Development of the base case model of a rectangular building form, massing and orientation of the building and its context. Performance predictions were started with this base case which was developed to represent conceptually developed physical and operational conditions of this rectangular building form,

b. Input of more detailed data in respect to climatic elements of the building location by uploading EnergyPlus Weather (EPW) File using data of Colombo, building characteristics in terms of alternative plan forms, sectional forms, orientation, thermal properties of the envelope and opening sizes and types in the building form.
c. Modelling the base case (Fig. 2.07) and the comparison of the predicted results of the alternatives options of the base case to ascertain a mapping of design interventions to microclimate, plan form, sectional form and envelope.

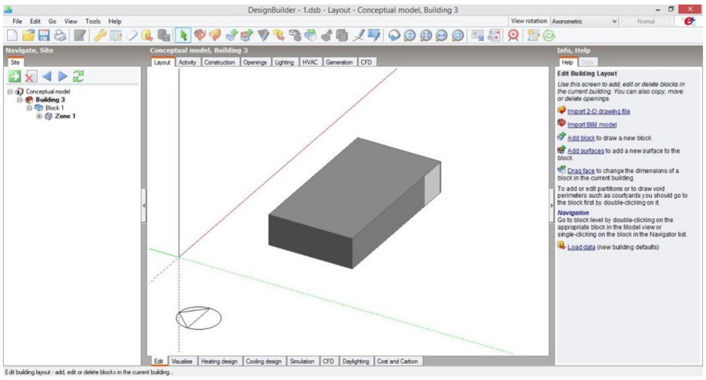


Figure 2.07: simulated base case of the conceptual rectangular plan form (source: Rajapksha,U., Department of Architecture, University of Moratuwa, Colombo, Sri Lanka)

Simulation of the model

Considering the holistic effect of design and physical characteristics and expected performance outcome, a generic rectangular building form is conceptualized. Shorter facades are orientated to east and west to minimize direct solar access on facades. The building form in the aspects of thermal performance and indoor air temperature were investigated using DesignBuilder/ EnergyPlus program initially with an insulated flat roof with which zero transmittance of solar gain, making the assessment of solar gain through building facades more prominent and easier. The generic rectangular form was developed into a detailed rectangular building with several bioclimatic interventions aiming at minimizing environmental hat gain through facades.

1. Generic rectangular model in FOUR different orientations with shorter facades facing i) East-West (Fig. 2.08), ii). North-South, iii). North West-South East and iv). North East- South West in single skin facades with an insulated flat roof. Ventilation was provided during the daytime
2. Improved model of the Generic Form 1 with double skin shorter and solid facades to East and West with flat roof
3. Next improved model to the above with a sloping from high end roof to the East (Figure 2.09)
4. Next improved model to the above with a cool pool and a courtyard created inside on east and west. Cavity in the double skin is filled with water and night ventilation and daytime ventilation throughout. (Fig. 2.09)
5. Improved model to the Generic Model 2 with glass double skin facades to East and West and shorter solid walls to North and South
6. Further improvement to the above model by adding solid double skin walls to East and West
7. Improved model to the model 2A by adding a sloping roof towards West
8. Improved Model to the Model 2B by adding double skin solid walls to the East and West. Cavity inside the double skin wall is filled with water. A cool pool and a courtyard are added with night ventilation as well.

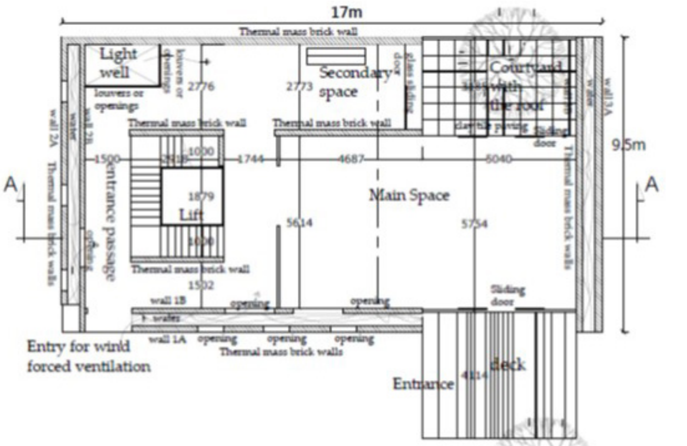


Figure 2.08: Conceptual improved rectangular building form, shorter facades orientated E/O, double skin envelopes, openings for night ventilation (source: Rajapksha,U., Department of Architecture, University of Moratuwa, Sri Lanka)

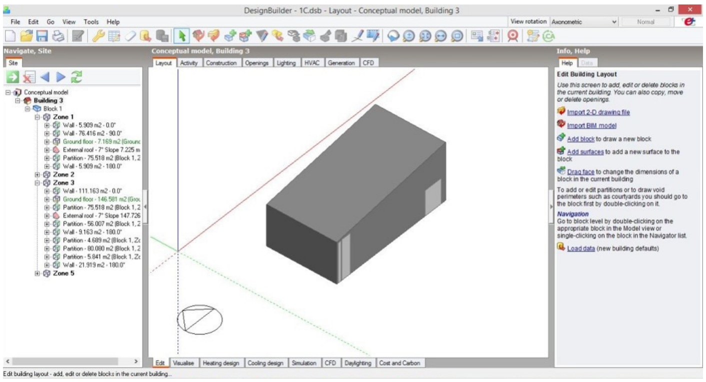


Figure 2.09: Improved version of the base Case to have a sloping roof and higher internal volume on the easterly leeward side (source: Rajapksha,U., Department of Architecture, University of Moratuwa, Sri Lanka)

Objective of the simulations was to investigate the level of climate modification with regard to Operative, indoor air and mean radiant temperatures. Since the rectangular form was considered as perfect from the literature review, any attempt in assessing changes in plan form on indoor air was not within the context of the work but the effects of microclimate, sectional form and envelope configurations and properties were aimed at assessing. This work is underway and detailed results will be published elsewhere

Case Study 3:
Reconversion of existing utilities facilities, for a new research, manufacturing and sales company in Bangalore, India

Adj. Prof. I. Bhattacharya, Technical Advisor, BRAE Consulting Services Pvt. Ltd., Bangalore, India

Around 2006, a German Company proposed to set-up its India Campus on the out-skirts of Bengaluru, in the state of Karnataka. India. Their aim was to collate their existing research, development, manufacturing, sales, marketing and servicing divisions at one already "built" location to increase their overall operational efficiency, optimize time- costs and plans for future expansions in a holistic manner. Bengaluru has a tropical wet and dry/ savanna climate, according to Köppen-Geiger [140] classification is Aw, with a pronounced dry season in the low-sun months, no cold season, wet season is in the high-sun months. Further, Bengaluru is situated in or near the subtropical dry forest biome Holdridge [141] life zones system of bioclimatic classification. In following description main phases of project in terms of utilities choices, construction, as well as changes in attitude of management during operation, shall be roughly pointed out. It would be prudent to start this discussion with an excerpt - 'Efficiency, after all, is the economic equivalent of a free lunch. Greater efficiency means consumers can enjoy the same level of comfort but use less energy. And when it comes to efficiency, improvements in buildings offer the most cost-effective way to reduce energy use and greenhouse gas emissions. The McKinsey Global Institute, which has studied the issue on a worldwide basis, estimates that four of the five most cost-effective measures taken to reduce greenhouse-gas emissions involve building efficiency. (`"The measures are building insulation, lighting systems, air conditioning and water heating...."）
The said excerpt can be easily related to Building Utilities.

Selection of Site (Mar – July 2006):

The Architects and Construction Project Managers were called in to evaluate short-listed sites considering current and future needs of the Company. After careful analysis of the available site areas, accessibility, site-orientation, topography, infrastructure and utilities, the Team recommended a site measuring about 40,700 sq.m. out of which 40% was built and the balance was left untouched. The existing buildings having a total floor area of 3,500 sq.m. were about 8 years old, well maintained and could cater to some of immediate needs of the Company. Fig. 2.10, left side, shows the status of the Site as on 2006, courtesy Google Earth. Existing Building No.1 (measuring 800 sq.m.), could be used to house the sales – marketing - administrative facilities. Existing Building No. 2 (measuring 2000 sq.m.) had a Clean Room Facility and could be used to house the Research – Development and others. Existing Building No. 3 (measuring 280 sq.m.) was a warehousing facility. Utility Buildings (measuring 420 sq.m.) provided necessary utilities including raw water, RO water, clean steam, electrical, fire-fighting systems, data, LAN, others. Figure 2.11 gives a glimpse of the various utilities under discussion, for extension, reconversion, or replacement.

Figure 2.10: Comparative Site Images 2006, 2021 (Source: Google Earth, BRAE Consulting Services Pvt. Ltd.)

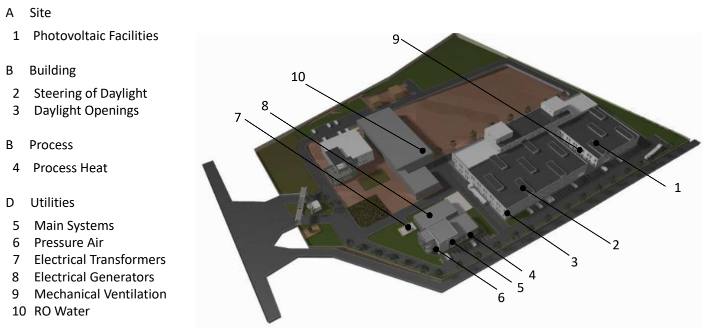


Figure 2.11:-Diagram illustrating various utilities in the Project under discussion (source: BRAE Consulting Services Pvt. Ltd.)

Programming – Concept Development – Detailed Engineering (Aug 2006 – Mar 2007):

One of the most important steps towards sustainable design and engineering would be 'Programming' and establishment of the DNA of the Project along with the Client. A GENEering™ Workshop (refer to Fig. 1.18, 1.19) was conducted by Prof. Juergen Reichardt & Reichardt-Maas-Ass. Architekten GmbH & Co. KG to understand the present and future requirements and visions of the Company. The headcount as on Aug 2006 was around 225. The Workshop resulted in the following findings:

- Optimise hard-surfaces and built-up areas to leave maximum space for rest - relaxation and future expansions.
- New Building No. 1 (measuring 10,000 sq.m.) would provide for manufacturing facilities (measuring 6,000 sq.m.) in the Ground Floor, offices (measuring 2,650 sq.m.) in the First Floor and Dining Hall, Recreational Facilities along with Spaces for Future Expansion at the 2nd Floor.
- New Building No. 2 (measuring 900 sq.m.) would provide for additional Utilities (RO water, clean steam, electrical, fire-fighting systems, others) required for the new manufacturing systems and facilities.

'Passive' sustainable design solutions for site, volume, structure, envelope, interiors:

- The Manufacturing Facilities (measuring 6,000 sq.m.) was conceived as a rectangle having sides of approximately 112 m x 55 m at the Ground Floor with cut-outs and expansion joints. A structural grid of 12.80 m x 12.80 m was chosen to provide maximum freedom to plan / change manufacturing systems in line with the concepts of 'future – proof' production planning.
- The long axis (112 m) of the building faced North – North East reducing the overall thermal load on the building. The Offices located along 112 m. length on the First Floor received Day-Light and had views towards a Landscaped Garden.
- The double height manufacturing halls were located towards the South - South West. A system of skylight not only brought in north light but also helped to remove hot air thereby setting up convective currents. Fig. 2.12 shows the conceptual sections through the manufacturing halls along with the skylights.
- RCC Construction with 200 mm block masonry was adopted to buffer the offices, dining hall, recreation areas, others from the 'noisy' manufacturing spaces.
- The windows sizes have been optimized to provide for natural light and ventilation, avoiding unnecessary glare. The glass area is appropriately protected with shading devices. Structural Glazing is limited only for the Staircase which is naturally ventilated and faces North / North East.

Figure 2.12: Conceptual Sections of the Manufacturing Halls (source: BRAE Consulting Services Pvt. Ltd.)

'Active Utilities':

- The Electrical Systems were upgraded to handle 2250 kVA since the manufacturing systems alone were to consume 1500 kVA as per the available data. Existing generators were planned as a back-up in case of failure of the supply grid.
- The Artificial Lighting System was based on combination of CFL's for office areas and HID's for manufacturing areas.
- A 160 – TR Variable Refrigerant Flow (VRF) System was planned for 1,900 sq.m. of carpet areas for the First Floor Offices. The same translates to a mere 0.08 TR of Air Conditioning Load per sq.m. of office area.
- On-site 30 m3/day Sewage Treatment Plant was generating enough recycled water for flushing toilets and urinals. The rain water collected from the 6,000 sq.m. roof area was used for re-charging of Ground Water Table.

Fig. 2.13 shows some photographs of the completed project which was handed over around Oct 2009.

Figure 2.13: Images of the completed Project (Source: BRAE Consulting Services Pvt. Ltd.)

Facilities Management:

International Facility Management Association [100] defines 'Facility management is a profession that encompasses multiple disciplines to ensure functionality, comfort, safety and efficiency of the built environment by integrating people, place, process and technology'. Facility Management includes, but are not limited to, the following areas: Building Operations, Space Planning, Workplace Strategy, Sustainability, Project Management, Real Estate Management and others. Effective Facility Management is considered to be one of the most cost-effective methods for ensuring reliability, safety and operational efficiency of a physical asset. Good Engineering Practices can generate substantial savings and should be considered a resource for the future generation. Finally, Facility Management is not only responsible for comfort, but also the health and safety of the occupants. Till March 2016 the Campus was operated and maintained by the on-site Facility Management Team.

Electrical Systems:

- The on-site Facilities Team carefully monitored the electrical consumption on a day-to-day basis. Studies revealed that the actual energy consumption of the manufacturing systems was much less than the originally assumed 'diversity factors'.
- An informed decision was taken to downgrade the incoming feeder line thereby cutting down power wastage and unwarranted electrical tariffs.

Water Systems:

- The on-site Facilities Team were continuously looking for options to reduce – recycle water for various domestic and manufacturing uses.

Fig. 2.10, right side, shows the status of the Site as on date, courtesy Google Earth. The total headcount on site has almost doubled to 520 people

Reduce – Reuse – Recycle: Electrical Systems

- CFL's & HID's were replaced with LED's to reduce total Lighting Load further.
- In line with UN Sustainable Development Goals the Company currently proposes to generate energy from renewable sources and systematically cut down its reliance upon non-renewable ones. Simulations of the proposed Solar PV installations were conducted using various software including 'The Solar Lab' (https://thesolarlabs.com/) to arrive at various scenarios. Figures 2.14 shows screenshots from 'The Solar Lab' analysis.

Figure 2.14: Screenshots of the proposed PV Installtion using,The Solar Lab'. (Source:Others)

- Fig. 2.15 gives a glimpse of the Technical Analysis of the proposed systems. Calculations show that a 475 kW Solar PV System would mitigate 15,375 tons of CO2 and can pay-back the initial cost of investment comfortably within 5 years. Fig. 2.16 shows the proposed Power Consumption from Non-Renewable Sources over the years.

Technical Analysis of the proposed Solar PV Systems

Parameters		Vendor A	Vendor B
Assumed Global Horizontal Irradiance	kWh / m2 / year	1969	1830 - 2011
Module **Orientation**		**South facing** with 25 deg azimuth	**Dual Orientation:** East West orientation
Module **Inclination**		10 Deg	
Expected No. of Modules		1390+	1360+
Module Technology		Monocrystalline Silicon Technology	Monocrystalline Silicon Technology
Total Expected Generation - **DC**	Kilowatt-Peak (kWp)	528	600
Total Expected Generation - **AC**	**KW**	430	489
	W	4,30,000	4,88,636
Performance Ratio (%)		77.60%	78.40%
Solar PV modules			
Performance Warranty		25 years as per data sheet	25 years as per data sheet
Solar Inverter		5 years from Date of Supply.	5 years from Date of Supply.

Figure 2.15:Technical Analysis of the proposed Solar PV Systems (Source:BRAE Consulating Services Pvt. Ltd.)

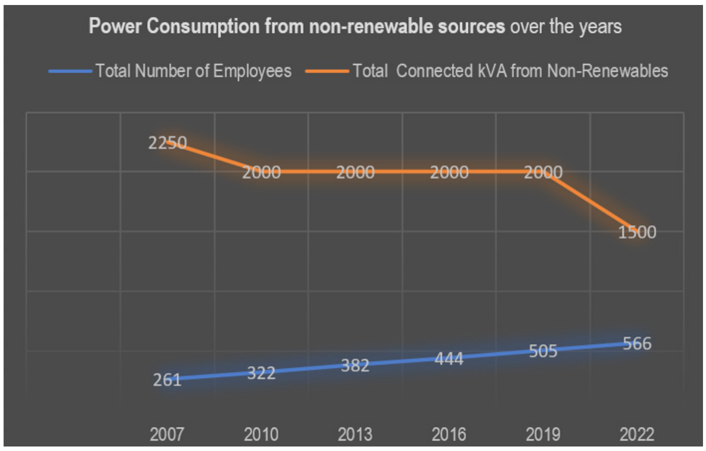


Figure 2.16: Power consumption over the years. (Source: BRAE Consulting Services Pvt. Ltd.)

Reduce – Reuse – Recycle: Water Systems

- The entire plumbing system was retro-fitted with low-flow flushing tanks, sensor-based water taps for wash basins, water-less urinals and others. This has brought down total water consumption by 14 m3/day. There is also an attempt to recycle filter backwash and RO reject water to additionally save 8 m3/day.

- An ambitious plan has been floated to store rain-water which was being originally used for ground water re-charge. Theoretical estimates suggest about 10,000 m3 of water / year can be generated in this manner. Fig. 2.17 shows the Water Consumption over the years.

The above project exemplifies the fact that 'programming', 'facility management', 'adaptability', 're-engineering' and others would be important terms for sustainable future for all. It also goes to prove that if Clients, Consultants & Contracting Partners join hands to rethink - reduce – reuse – recycle it is definitely possible to slowdown the impact of climate change one brick / building at a time.

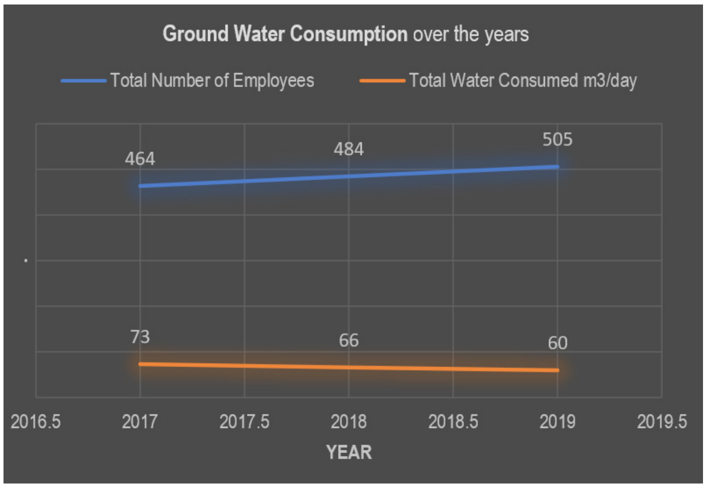


Figure 2.17: Ground Water consumption over the years (Source: BRAE Consulting Services Pvt. Ltd.)

In part 3 shall be outlined roots and issues of existing international academic cooperations, ideas towards further international research networking, as well as development of website, app and E-Learning desk "climatehub.online"

International Cooperation Program "Climate Responsive Architecture"

Idea of International Student Master Module Cooperation Program "Climate Responsive Architecture" was developed between Universities of University of Applied Sciences, MSA, Muenster School of Architecture, Muenster, Germany, Moratuwa University, Department of Architecture, Colombo, Sri Lanka, and RV College of Engineering, Bangalore, India, from 2005 onwards till today. A series of official and private programs for academic cooperation in the field of energy efficient and sustainable, as well as student and staff exchange were partly funded by German BMBF Federal Ministry of Education and Research, and DAAD German Academic Exchange Service. General focus is on developing architectural strategies against global warming, main objectives are building up and maintaining international academic partnership, as well as synchronizing study structures and curriculums. Due to worldwide Corona problem invitation of students to Muenster University was regrettably subject of cancellation in March 2020.

The international student program was continued via weekly zoom video conferences. Even more emphasis and effort now flowed into new ideas towards more digital based E- Learning approach, with elaborate development of English language app and web portal "climatehub.online" Basic knowledge with climate responsive architecture, as worldwide vernacular as well as contemporary built and student projects, seminars, research papers and auxiliary planning tools, as well as separate E- Learning Desk will be maintained and constantly actualized. These thoughts have been woven into MSA, Muenster School of Architecture, in summer 2021 offered international masterstudio. Moreover in 2020 University of Applied Sciences Münster, MSA, Münster School of Architecture, decided to offer from winter 2021 onwards a post MA PHD program in Architecture, with main emphasis on sustainable architecture. This program shall be accessible to international students, too.

1 Development of web, app "climatehub.online"

The overall approach is to sensitize building planning professionals in terms of climate issues for architecture, and moreover especially in international education of students of architecture. There is no claim for academic state of the art University driven research, as deliberately maintained and collected in International Research Networks as e.g. Applied Sciences, MDPI, ELSEVIER or academia.edu. The Idea is to stimulate architectural students in bachelor and master study with Mission in terms of more climate conscience in designing projects. Double effort was taken in programming for parallel use as desktop and smart phone version, hoping that students might have more fun with informal "thumb playing" through the content. Here is hope that students from international Universities might enjoy surfing through the vernacular and more modern "built" Exemplary projects, as well looking at student projects developed in different academic embeddings.

Google Earth variant scale possibilities were exploited to "situate" the exemplary projects in their "real" neighborhoods, thus specific urban and topographical surroundings might be visualized as well. Auditorial Board elected projects, on basis of a grammar of 10 possible sustainability aspects, are characterized with aim of "on one glance". In Research tools chapter one might pursuit with one or a series of catchphrases more available projects or expert papers, courtesy of open access academic networks as well as student seminars, in the app "library", filtering linkage will select and display results. Several special digital programs, as helpful for e.g. climate analysis, BIM, BEM simulations, or moreover digital thermal camera support, are introduced in the Additives section with suppliers manuals or more experienced student tutorials. In the E- Learning desk is gathered all relevant specific student project briefing information, time schedules, action plan roadmaps and international academic expert E- lectures modules for international student academic video teaching, (e.g. summer 2021 MSA International Masterstudio "2nd life conversion Grugabad Essen, Germany"). Finally Network is mostly important for the further success of the overall app effort, looking for more international academic partners, feeding in their passion and expertise with critical discussion, proposing more and brighter exemplary projects, research papers, tools. The information available in climatehub.online has been gathered mainly by students of architecture. Organization of available information has been organizes in two levels: A "top of the iceberg" small open to public web package of projects and papers, and a "hidden underneath" larger package, only accessible when being registered as Academic networking partner. There is hope that this might encourage international partners to be part of the "underwater team".

2 Mission, Rethink, Reduce, Refuse, Reuse, Recycle

Referring to app
https://www.climatehub.online/

Combined building and construction sector is now responsible for most part of global CO2- emissions. In Germany alone, for example, the average living space per person has more than doubled since the 1960s. The growing desire for space is increasingly becoming a luxury good, which every citizen is nevertheless happy to pay for. But we should fundamentally question consumer policy and ask ourselves whether everything always has to be bigger, higher, faster, further, as we are often sold every day. The question of the usefulness of something is fundamentally divided into the categories of use and consumption, whereby the term consumption is less common than use, due to its negative undertone. Sustainability also requires a balance between the ecology, the economy and the social. Unfortunately, this balance is notoriously difficult to maintain in practice - the balance between the use and regeneration of resources seems increasingly distant [142]. In respect to responsibility academic profession T. Bürklin, M, Peterek, and J. Reichardt have summarized outlook towards education of Rethink, Reduce, Refuse, Reuse and Recycle in: „A Plea for an Architecture of Responsibility"[143].

Rethink:
Rethink means to become aware of one's own actions and to learn to know and assess the consequences of one's own deeds, may be learning to say „no" sometimes. To ask oneself whether one's own intentions are in the best interest of society or whether in the end - once again - one only wants to satisfy oneself. At least for the short term, until something new comes along.

Refuse:
Especially in the construction industry, one should think about the use or even non-use of materials. The CO2 emissions mentioned, for example, are largely due to concrete, which consists of cement, among other things, and has to be extracted using a lot of energy. Only to withstand perhaps 50 years and then to be distributed crushed on the ground so that we can drive on it with our individual traffic. Or the thermal insulation industry. Or the plastics industry. Or, or, or.

Reduce:
Reduce speaks of general efficiency in architectural organization. It is about the above-mentioned question of space requirements, not senseless use of space. Above all, construction and materiality play a major role in architecture. It decides already in the early planning process which fundamental path we take with a conversion or new building. In addition, the building envelope, the furnishings and the technology are of decisive substance, because they are so present in our everyday lives and smart lobbies always want to sell only „the best".

Reuse/ repair:
But sometimes it doesn't seem economically or aesthetically feasible to act in the way that would make the most sense ecologically and sustainably. In this case, before throwing away, we should talk more about reusing things. On a larger scale, such as architecture, the goal of reuse often requires explaining in advance which building materials to choose. Just like reusing things, so is the effect of repairing. The conditions that must come together for most people here are that the object used (whether small or large scale), has the same

quality as the original object. Very often it turns out that not everything has to be new to work. Repairing is becoming more and more a real alternative.

Recycle:
One of the final parameters in the fight for greater sustainability is recycling. If none of the aforementioned methods have been used, as is the case with most things these days, then the only option left is to break an object down into its component parts and, with a great deal of labor and energy, make it into exactly the same objects - only new. Wood seems to be most ecological material, but rarely ma be used again, Compared to concrete, steel, for example, offers a good prerequisite for being used in a new construction project. Either as the steel beams already exist, for example (modular construction), or in a modified form, without much effort.

3 A "grammar" of 10 climate responsive architectural parameters

Referring to app:
https://www.climatehub.online/

The proposed "form follows performance" strategy aims to integrate 10 component parameters towards climate responsibility through a holistic design and engineering approach. The focus widens from individual requirements of a single building / structure to agglomeration of building structures, influenced by specific local climate and site surrounding factors, requiring a synergetical approach for the whole project life cycle. This "grammar" includes aspects of planning, construction detailing, execution on site, operation, maintenance, renovation, reuse and others. The Authors strongly believe that the proposed 10 parameters must be programmed, creatively designed, engineered, balanced and optimized from the very beginning and systematically followed through the whole planning, building and life cycle process. Hence these aspects might used as a individually arranged "checklist", too. The holistic aim is to achieve an overall optimized solution which is practical, climate responsive and sustainable. Finally, the overall grammar of the project should result in minimum amount of disturbance to the existing ecology as well as minimize the carbon footprint based upon a rigorous yet sensitive check-list. Further listings are very rough headings concerning 10 parameters (Fig. 3.01)
The Authors strongly believe that the role of the Expert Team is quite similar to that of a juggler who is trying to juggle well balanced 'expert-knowledge' balls.

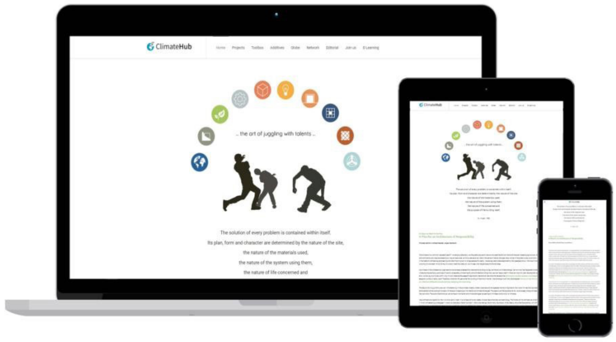


Figure 3.01: Landing page & 10 parameters (source: website climatehub.online editorial team, MSA, Muenster School of Architecture, Germany)

Geography:
Projects (both at urban / city planning scale and as well as on individual building level) should respond to the local climatic conditions. Each climate zone has developed its own construction systems and methods, which is best suited for the said climatic conditions based upon experience knowledge passed down generations. As a thumb rule, locally available building materials were used which was sensible both in terms of ecology as well as economy. Over time, building techniques improved to such an extent that structures that combined minimum effort with maximum benefit became the universal standard. Traditional building types today may not meet the current functional and energy requirements; however, they nevertheless provide invaluable insights into energy-conscious construction methods. The climatic zones were further classified to bring out subtle differences, often leading to unique building / construction typologies based upon positive experiences of the locals.

Ecology:
The goal as Architects, Engineers and Town-planners should be to plan for peaceful co-existence with nature and not 'over' protection from 'hostile' site conditions. The proposed development should attempt to minimize its ecological foot-print on earth, to support favorable habitat for species, esp. insects and birds, to minimize additional resource requirements to plan – operate – maintain, and to minimize waste (solid, liquid, gases as well as noise) generated during construction and post-occupancy. One should avoid 'sealing' of towns and buildings. Further, one should attempt to make a sound analysis of the available bounties of nature in terms of sun – wind – rain - others in order to strengthen the 'passive' utilities and energies of the project.

Technology:
The available construction systems and technologies

vary a lot due to the climatic, geological and even site-specific conditions as well as our socio-cultural backgrounds and religious beliefs. In terms of sustainability, local building materials should be preferred, to avoid unwarranted logistical challenges and additional carbon emissions associated with mining, manufacturing, transportation and disposal at the end of the life-cycle. Senseful sustainable ratios between “high tech” and “low tech” have to be considered not only for building structure, shell and interiors, but for the utilities as well. One should focus of strengthening the ‘passive’ utilities to reduce dependence on the ‘active’ utilities and systems. New possibilities of smart building digital process seem to arise in on site CNC production manufacturing, esp. with wiki knowledge spreading construction and material knowledge.

Volume:

The sun is a constant source of ‘free’ energy and plays a crucial role in our overall health and well-being. Orienting the proposed built volume keeping in mind the diurnal and seasonal movement of the sun increases the overall energy efficiency of a project and should be considered as a basic planning requirement. The overall energy and daylight gains from the sun depend on the latitude, angle of incidence, the associated hours of sunshine, the radiation power and the local time of day and season. There should be clear strategy towards shading by neighboring built volumes in terms of catching or reducing thermal energy gains. In west European latitudes, the following building orientation would make sense: For winter, the solar gains can be optimized by orienting the main living spaces towards the south. The adjoining rooms, which need less or no heating, are oriented more to the north. In summer, with higher angle of sun, harmful glare and excessive room heating must be avoided by adequate shading facilities.

Energy:

As explained earlier, buildings are predestined to generate solar energy if their overall built volumes and specifically the roof surfaces are oriented correctly. Typically, solar photo-voltaic or thermal collectors mounted on a south-facing roof can make optimal use of the sun‘s rays to generate ‘green’ energy for the project. Ideally, the required residual energy can be provided by an active solar or wind-based energy generation system. At present, both solar as well as wind-based technologies are widely established across the world. Project sites blessed with solar, wind, water or geo-thermal sources can make best use of the same to reduce operation and maintenance costs and their carbon footprint. On the whole, authors propose more ‘sail-boat’ strategies, making use of the prevailing conditions, rather than ‘motor-boat’ utilities, causing more carbon footprint and global warming. It is needless to mention that in the long run ‘low-tech - passive’ systems are more economical to design, execute, operate and maintain than their ‘high-tech active’ counterparts.

Envelope:

The building envelope serves as protection against wind, rain, moisture, solar radiation and temperature-specific influences. In addition to the overall aesthetics, the energy consumption of a building depends on the envelope detailing too. The building envelope requires a fine balance between the following goals: The low and incident angle of the sun, ensuing passive energy gains, if any. Daylighting for the interiors and glare. The heat-insulating properties of glass, wall and other peripheral surfaces. Durability, operation and maintenance challenges, if any of the proposed material/s and technologies. The life – cycle analysis of the proposed system and materials.The aim of an energy-efficient building envelope is to ensure a sustainable and desired indoor climatic condition. A reduction in energy demand can be achieved by integrating solar technologies on to the building envelope. Green roofs, green walls, facades which are able to generate energy as well as control noise and others are being widely accepted and integrated into the holistic planning process.

Floor plan/Section zoning:

Floor plan and sectional zoning determines internal spacing of volume, but also areas of specific usage in line with the functional requirements and programming of the building. Architects need to look into ‘flexible’ or ‘changeable’ spaces ideally both in plan as well as section in order to arrive at a now and in future ‘sustainable’ solution. The harvesting of energy (specifically solar energy) is essential for the health and well-being of the occupants and to minimize energy losses while shading devices are important to minimize glare and overheating. The following needs to be kept in mind in order to arrive at a sustainable solution: sun orientation with reference to floor plan and section, coherence of inner heat load depending on use to sun orientation, fixed or moveable spatial / structural divisions. In cold climates, the aim is to store a lot of energy in order to minimize losses, whereas in hot climates, storage of energy in buffer materials / spaces should be avoided. Intermediate climate attic rooms were originally used as drying rooms and acted as a buffer.

Material:

The thermal properties of a building depend to a large extent on the choice of materials and their associated properties. Heat can be transported through transmission, radiation and convection. In this context, the heat transfer of a material is specified with the thermal conductivity (W/mK). The following points need to be kept in mind: 'Grey' or 'embodied' energy needed for producing / manufacturing the material. Locally availability. Ease of construction, replacement and maintenance. Durability. The material / finishes should not be injurious to health (humans as well as domestic animals / pets). Physical properties – like expansion / shrinkages should not affect the durability of the structure. Ease of disposal at the end of its life – cycle. One should look into the 'cradle to cradle' philosophy for all the preferred materials and technologies in order to plan a truly sustainable building.

Ventilation:
Ventilation is an effective tool for passive cooling, especially if temperatures are cooler outdoors than indoors. Natural ventilation is caused by thermal and / or pressure differentials. Favorable volume design, floor plan, section design and envelope design can increase natural ventilation by using one or more of the following techniques: Courtyard and atrium design enabling night and day air movement merits. Orienting the building / openings towards prevailing wind conditions. Floor & section planning to permit cross ventilation air movement. Strategically introducing wind catchers, nozzle devices, solar chimneys and other specific measures.

4 Exemplary projects

Referring to app:
https://www.climatehub.online/projects/category/project

To convey the holistic design and engineering approach more accessible for academics, students and architects, climatehub.online provides a huge growing database of built best practice projects around the globe mastering the juggling with the 'expert-knowledge' juggling balls. Moreover, out of the box thinking student projects are shown for inspiration. The projects can be explored playfully via an interactive map, by entering a catchphrase term, filtering the projects or simply by browsing (Fig.3.02). The two examples selected below, picked from more than hundred in website, show that we can learn interesting "climate responsive grammar" aspects not only from contemporary projects but also from historic and vernacular examples.

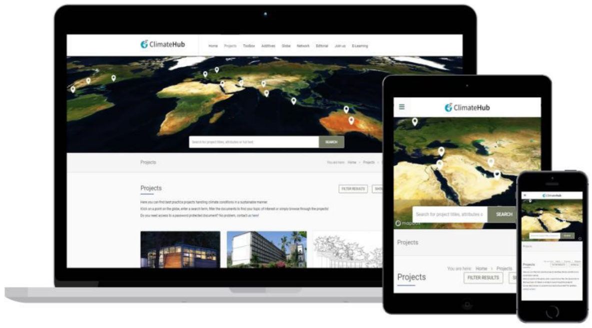


Figure 3.02: Exemplary projects locatetd on world map
(source: website climatehub.online editorial team, MSA, Muenster School of Architecture, Germany)

Project example 1:
First Light House, New Zealand, 2011, Solar Decathlon Team, New Zealand, Prof.Tobias Danielmeier

This contemporary project stands out with its well-considered usage of nearly all presented parameters like volume, zoning, geography, topography, building shell, shadow, ventilation, material, construction, technology, energy and active utilities (Fig. 3.03, First Light House).
Project Example 2:
Roman Atrium House, Pompeji, Italy, around 200 A.C, anonymous

This historic example from the Roman residential atrium houses shows how building tradition highly successful integrated parameters like zoning, geography, volume, envelope, material, technology and ventilation many hundreds of years ago, reacting effectively to their surrounding conditions without our days modern technology (Fig. 3.04, Roman Pompeji Atrium House, Italy).

5 Research tools

Referring to app:
https://www.climatehub.online/projects/category/toolbox
https://www.climatehub.online/projects/category/additive

Next to the Exemplary projects database, climatehub.online offers further sources of information. In the toolbox area one can find fact sheets, research papers, articles, presentations and more explaining architectural tools. Auxiliaries, like simulation programs, special websites and literature, courtesy of open access academic networks, may be explored with users in the additives area. By entering a catchphrase term, individually filtering documents for topic of interest, or simply by browsing, the user may find specific information on his


First Light House

Waimārama | New Zealand

Tobias Danielmeier . Solar Decthlon Team New Zealand

Aspects geography | Topography | Vegetation

Exposed costal climate.

Building volume | Zoning

Sun orientation of main living space. Serving spaces (bathroom, laundary, utilities and services) act as thermal buffer. HVAC as single zone with mutliple outlets and heat recovery system.

Building shell | Shadow | Ventilation

Modular construction for easy transport. Detached canopy roof that houses the solar active technologies. Timber frame structure with cedar cladding, air tightness and extensive insulation for passive climate control.

Material | Construction | Building techniques

The First Light house has been designed using environmentally sustainable design principles. Use of materials that use recycled timber, as well as used locally sourced, low cost, low energy materials that a non-toxic.

Sustainability | Energy | Ecology

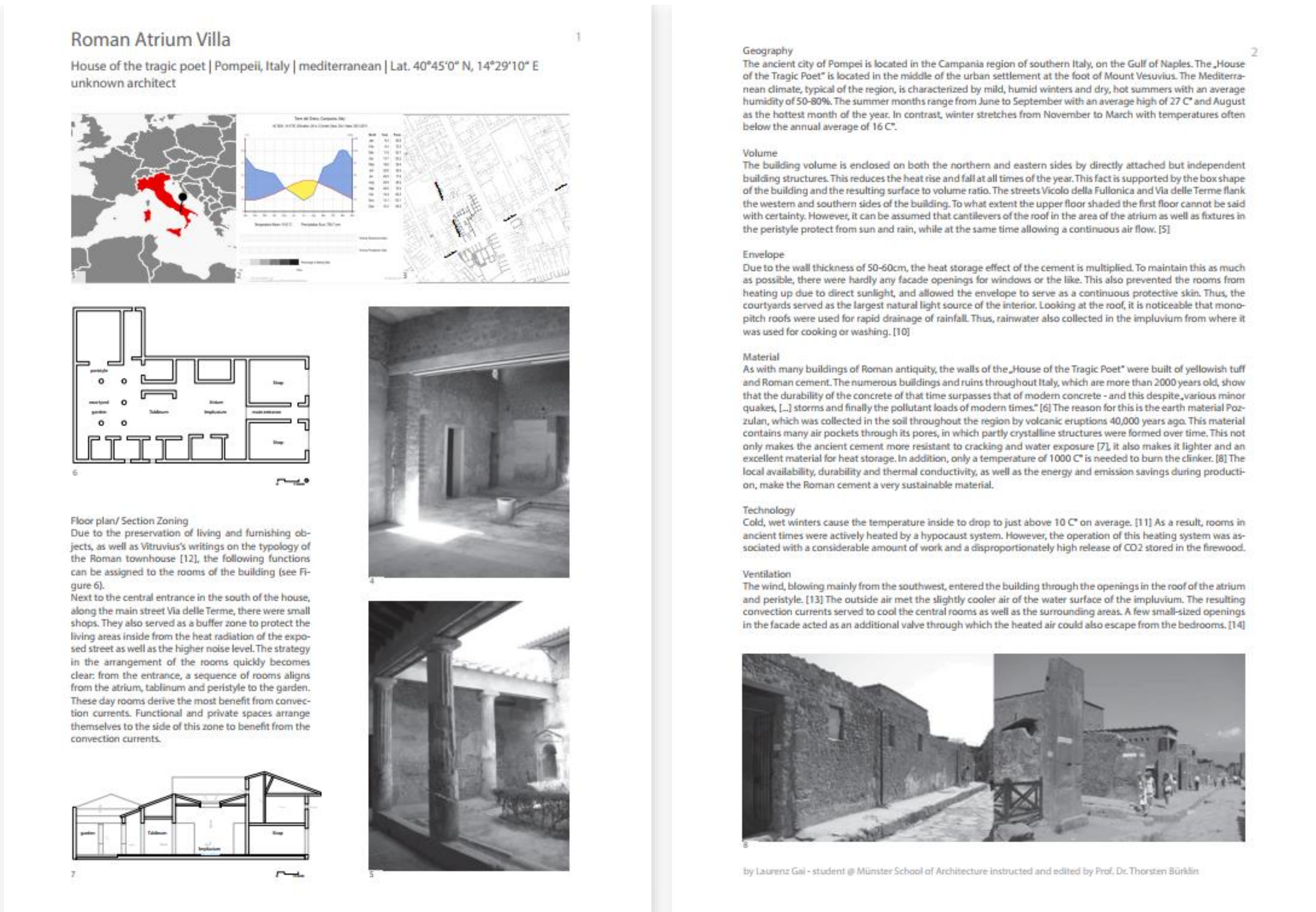
Net-Zero enery house that utelises a range of passive and active solar stratgies. The house has a 6.3kilowatt solar array with 28 polycrystalline photovoltaic panels, as well as evacuated tubes for water heating.

Utilities

Building managment system that monitors and controls all aspect of the house and gained the house first price in the Solar Decathlon Engineering comptition.

by Tobias Danielmeier - associate professor @ Otago Polytechnic

Figure 3.03: First Light House, NZ Solar Decathlon Project (source: Danielmeier, T,, University of Wellington, NZ, website climatehub.online editorial team, MSA, Muenster School of Architecture, Germany)


Roman Atrium Villa

House of the tragic poet | Pompeii, Italy | mediterranean | Lat. 40°45'0" N, 14°29'10" E

unknown architect

Floor plan/ Section Zoning

Due to the preservation of living and furnishing objects, as well as Vitruvius's writings on the typology of the Roman townhouse [12], the following functions can be assigned to the rooms of the building (see Figure 6).

Next to the central entrance in the south of the house, along the main street Via delle Terme, there were small shops. They also served as a buffer zone to protect the living areas inside from the heat radiation of the exposed street as well as the higher noise level. The strategy in the arrangement of the rooms quickly becomes clear: from the entrance, a sequence of rooms aligns from the atrium, tablinum and peristyle to the garden. These day rooms derive the most benefit from convection currents. Functional and private spaces arrange themselves to the side of this zone to benefit from the convection currents.

Geography

The ancient city of Pompei is located in the Campania region of southern Italy, on the Gulf of Naples. The „House of the Tragic Poet" is located in the middle of the urban settlement at the foot of Mount Vesuvius. The Mediterranean climate, typical of the region, is characterized by mild, humid winters and dry, hot summers with an average humidity of 50-80%. The summer months range from June to September with an average high of 27 C° and August as the hottest month of the year. In contrast, winter stretches from November to March with temperatures often below the annual average of 16 C°.

Volume

The building volume is enclosed on both the northern and eastern sides by directly attached but independent building structures. This reduces the heat rise and fall at all times of the year. This fact is supported by the box shape of the building and the resulting surface to volume ratio. The streets Vicolo della Fullonica and Via delle Terme flank the western and southern sides of the building. To what extent the upper floor shaded the first floor cannot be said with certainty. However, it can be assumed that cantilevers of the roof in the area of the atrium as well as fixtures in the peristyle protect from sun and rain, while at the same time allowing a continuous air flow. [5]

Envelope

Due to the wall thickness of 50-60cm, the heat storage effect of the cement is multiplied. To maintain this as much as possible, there were hardly any facade openings for windows or the like. This also prevented the rooms from heating up due to direct sunlight, and allowed the envelope to serve as a continuous protective skin. Thus, the courtyards served as the largest natural light source of the interior. Looking at the roof, it is noticeable that monopitch roofs were used for rapid drainage of rainfall. Thus, rainwater also collected in the impluvium from where it was used for cooking or washing. [10]

Material

As with many buildings of Roman antiquity, the walls of the „House of the Tragic Poet" were built of yellowish tuff and Roman cement. The numerous buildings and ruins throughout Italy, which are more than 2000 years old, show that the durability of the concrete of that time surpasses that of modern concrete - and this despite „various minor quakes, [...] storms and finally the pollutant loads of modern times." [6] The reason for this is the earth material Pozzulan, which was collected in the soil throughout the region by volcanic eruptions 40,000 years ago. This material contains many air pockets through its pores, in which partly crystalline structures were formed over time. This not only makes the ancient cement more resistant to cracking and water exposure [7], it also makes it lighter and an excellent material for heat storage. In addition, only a temperature of 1000 C° is needed to burn the clinker. [8] The local availability, durability and thermal conductivity, as well as the energy and emission savings during production, make the Roman cement a very sustainable material.

Technology

Cold, wet winters cause the temperature inside to drop to just above 10 C° on average. [11] As a result, rooms in ancient times were actively heated by a hypocaust system. However, the operation of this heating system was associated with a considerable amount of work and a disproportionately high release of CO2 stored in the firewood.

Ventilation

The wind, blowing mainly from the southwest, entered the building through the openings in the roof of the atrium and peristyle. [13] The outside air met the slightly cooler air of the water surface of the impluvium. The resulting convection currents served to cool the central rooms as well as the surrounding areas. A few small-sized openings in the facade acted as an additional valve through which the heated air could also escape from the bedrooms. [14]

by Laurenz Gai - student @ Münster School of Architecture instructed and edited by Prof. Dr. Thorsten Bürklin

Figure 3.04: Roman Pompeji Atrium House, Italy (source: Laurenz Gai, Buerlin, Th., department of Architectural Theory, Website editorial team MSA, Muenster School of Architecture, Germany)

individual way of creating own climate responsive architecture. There is a clear distinction between an open accessible and (e.g. in terms of only academic use figures copyrights) password protected information area. A major concern was to create an on-point search tool to allow the user to find exactly the information needed. To achieve that, each project, research paper, etc. on climatehub.online is connected to a wider variety of parameters and keywords. A search filter (Fig. 3.05) allows to combine these parameters to a specific search request, example is given for finding more searched information for project example of First Solar House (Fig. 3.03).

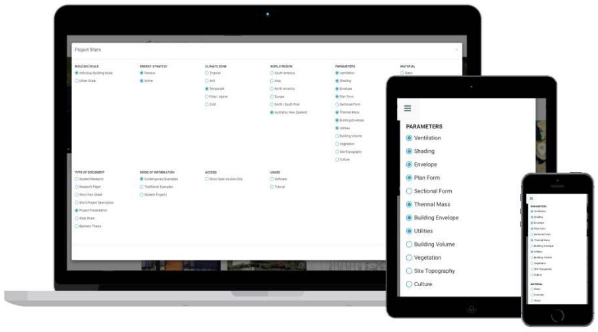


Figure 3.05 : Catchphrase request (source: website climatehub.online editorial team, MSA, Muenster School of Architecture, Germany)

6 E- Learning desk

Referring to app:
https://www.climatehub.online/e-learning

Another major component of climatehub.online is the a one-of-a-kind E-Learning program. It offers a wide variety of online E- lectures about Climate Responsive Architecture from international experts in the field, accessible for registered students scattered around the world (Fig. 3.06). Moreover, students can find information about their ongoing classes, seminars, lectures, events, roadmaps and so on. Fundamental content can be shared easily and target oriented. This allows for a bundled up, simplified, international synchronized and thus more efficient teaching with all information, knowledge and facts in one place. Moreover individual international student networks are favored.

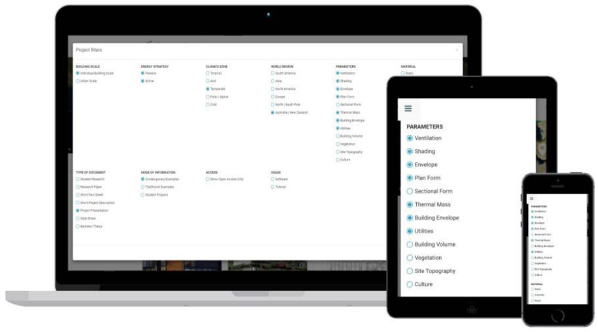


Figure 3.06: E-Learning desk, timeschedule roadmap (source: website climatehub.online editorial team, MSA, Muenster School of Architecture, Germany)

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