AFFORDABLE NET ZERO ENERGY BUILDINGS

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1. Key Drivers for Innovation in the Solar Industry

Since the early beginnings of the solar exploration, three major drivers have constantly shaped and improved the industry. Firstly, a significant amount of research and development conducted by a variety of disciplines aimed to either generate electrical power, or to utilize thermal connectivity. Since early inventions made by Edmond Becquerel, efforts led to a multitude of solar related energy applications and also contributed to the field of material science. R&D often leads to system designs that can be tested and benchmarked against other technologies in development or on the market. This points towards the second driver for innovations in the field of solar energy, the re-engineering and improvement of already existing system designs. By employing superior material properties or by modifying component configurations, higher energy yields can be gained. While R&D and the optimization of prevalent systems concern major parts of the solar industry, architects and planners are predominantly interested in applied solutions, opportunity costs and life expectancies of solar technologies. To gain a competitive advantage, cost efficiencies have been the third driver for innovation and progress for some time. Over the years, individual manufacturers were able to achieve significant price drops, sometimes of to up to 80% from one product generation to the next. While this can positively impact on supply and demand of the market, it does not guarantee that designers are encouraged to investigate system designs in regard to cost saving potentials.

Looking the case study of a net Zero Energy Building designed and build by Victoria University of Wellington to compete in the Solar Decathlon 2011, this paper illustrates how architectural design decisions can be based on these three drivers.

2. The New Zealand Entry to the Solar Decathlon 2011

In recent years the desire and need for net Zero Energy Buildings (ZEBs) has been identified by government agencies around the world and as a consequence, legal frameworks have been developed and financial incentives have sometimes been established. This led to a significant pressure on the solar industries to satisfy political agendas as well as market demands. Both, solar and building industry, have realised that they need to work collaboratively to cater for these novel situations.

While what may or may not constitute a net ZEB is still under discussion, several governments around the world already defined time frames for the implementation of new legislations. To date principles of net ZEBs include but are not limited to the boundary condition, net zero balance, life-cycle-analysis (Fay 2000), crediting systems, temporal energy match and monitoring procedure (Sartori et al. 2010). While these terms have been discussed extensively in recent years in relation to their meaning for architecture, it has also been remarked that correlations and dependencies for design decision-making has not sufficiently been explored (Torcelli et al. 2006, Voss 2008).

2.1 Setting the Scene

The 2012 Solar Decathlon competition is in this regard it is of particular interest as it introduced a new competition contest that is closer aligned with consumer interests. The Solar Decathlon is organised by the US Department of Energy and underwent an evolutionary development process not unlike to the developments of the solar industry itself. The competition asks 20 collegial university teams from around the world to design and build solar-powered houses that compete in ten individual categories. Some of the contests are judged others are measured under pre-defined competition criteria. All sub-contests are designed to simulate real-life situations. While the first competitions focused predominantly on technical innovations, a second set of competitions emphasised on the optimisation of existing technologies. Houses were rewarded points in accordance to their capability to produce as much energy as possible in accordance with competition rules. As a result, teams provided design solutions that fulfilled this request by installing as many PV panels as possible, which resulted in buildings that often failed market demands. For the 2011 competition, the organisers modified the rules and competition criteria by including affordability as one of the ten contests. The abundance of energy is no longer rewarded, leading to design decision have to consider costs.

2.2 Design Principals

While the question of what may or may not constitute a Net Zero Energy house can almost be seen as philosophical query, it was instrumental for the recruitment of students that dare to compete in Washington DC. While each student has a personal agenda for entering the solar design competition as part of a university team, a set of common aims and objectives was relatively easy to establish. It was agreed that the building is supposed to have a net Zero Energy balance over a daily as well as over an annual period of time. The team decided that while being a competition is held in the US, the house has to perform in local climate conditions in New Zealand as well as in the United States. Embodied energies of materials and global warming potential are supposed to be either zero or have energy surplus over the lifetime of the building. Furthermore, solar passive and active design features must not impact negatively on user lifestyles. The last point on the design agenda is the avoidance of toxic or harmful materials.

2.3 Design Process

This set of design principles required a pre-defined design process that enabled the incorporation of the outlined objectives. It also meant that consistant performance modelling would be essential to determin the energy requirements and to enable the team to make informed decisions and to progress the design. A further challenge of the competition is the obligation to comply with three different building codes, comprising of the International Building Code, and Solar Decathlon Building Code and the local, in our case the New Zealand Building Code. The obligation to meet these three different standards is of relevance in regard to the selection of environmentally sound building materials. Life cycle assessment tools have been used to aid the selection of building materials.

Any net ZEB project demands comprehensive considerations in regard to active and passive energy use and generation. Difficulties may arise when transforming early assumptions on energy demands into validated energy load profiles. It was found that in order to efficiently progress New Zealand's entry to the Solar Decathlon 2011, a five-step progress would be beneficial. The five interlinked phases comprise:

- Development of an Architectural Design and User Profile
- Definition of Baseline Model
- Comparative Study of Specific Building Materials
- Performance Simulation of each individual Building Element in comparison to the Baseline Model
- Final selection of Building Components and Elements

Fig. 1: Rendering of House with Canopy Structure

The development of architecture always includes the exploration of design variations and alternatives. Parameters for the New Zealand design entry include the requirement for the building to be re-locatable by road and sea. Furthermore, it has been found that building management systems (BMS) are not intuitive for most users. Hence a particular emphasise has been put on user-friendly, inclusive design solutions.

As an overall design idea, the position of services and other serving spaces including the bathroom and the dressing room have been located strategically as a buffer zone on the sun averted side of the building.

2.3.1 Development of Architectural Design Ideas and User Profile

It was also established that the solar array should be detached from the building itself. Besides being considered an aesthetic design feature of the architecture, there are two practical reasons. Firstly, by detaching the canopy from the roof structure, a penetration of the waterproofing membrane can be avoided. Secondly, a canopy structure allows for a natural ventilation of PVs and as well as it provides shade for the underlying roof structure (Fig. 1). These two design features became instrumental in the development of a preliminary energy profile.

The design process has been shaped by a variety of objectives and these preliminary design intentions made obvious that a defined design methodology would be of benefit for the development of the design. Figure 2 (Fig. 2) describes the decision-making matrix that has been developed in more detail. Design Ideas have been analysed in regard to their aesthetic and performance values as well as place and context specific merit. These considerations were than compared and evaluated in regard to their fulfilment of specific demands for each building component. As soon as feasibility was given, a comparative study of material properties took place. In this phase net ZEB values have been indirectly and directly explored and compared. In a next step, cost options were considered. As soon as Design Idea, Demands of each Building Component, Energy Performance, Life-Cycle performance and Cost Evaluation were made, the Baseline Model has been updated.

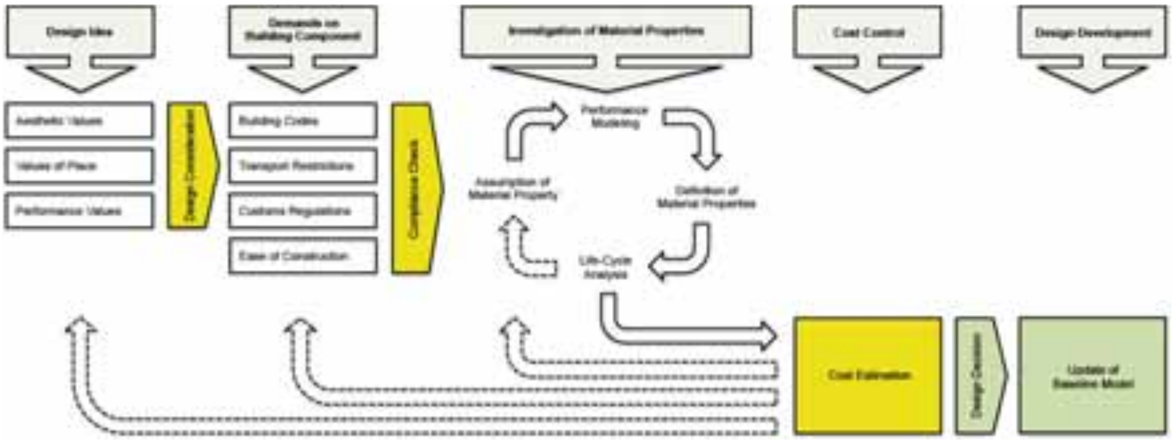

Fig. 2: Design Process

2.3.2 Definition of a Baseline Model

A comparative study of different building configurations, including opening sizes of wall penetrations, as well as the determination of appropriate canopy overhangs, helped to define a baseline model. In this phase it was of importance to consider how the building would maintain heat and how heat gains might impact on the overall energy balance. As in every building project, aim was to avoid overheating as well as finding a way to cater for heat dissipation. Questions in regard to natural and mechanical ventilation were pondered, as well as the efficient use of daylight artificial lighting has been simulated. Calculations were essential to commit to both, the overall architectural appearance as well as energy demands. Adding complexity to the baseline model has aslo been a part in this phase (Fig. 3).

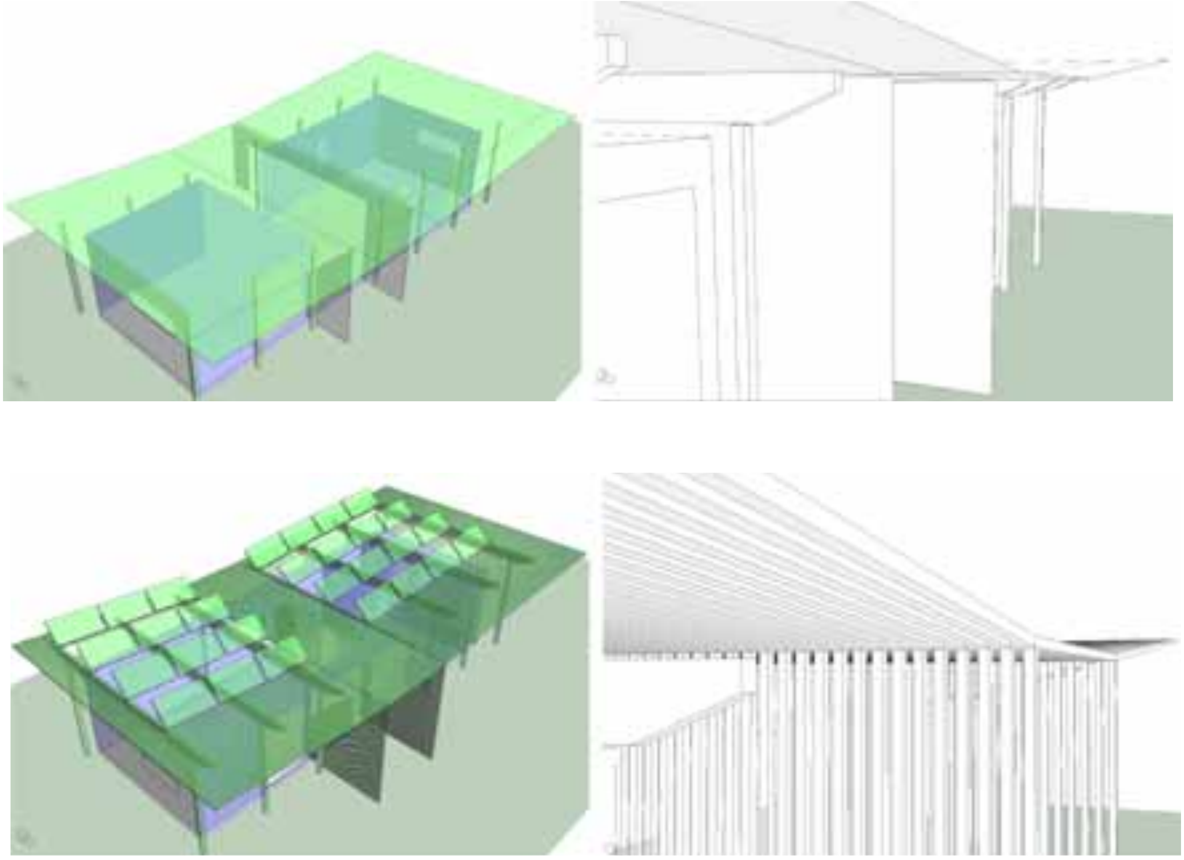

Fig. 3: Adding Complexity into the Baseline Model

Comparative Study of Specific Building Materials

At this phase of the project, considerations around the use of solar active and passive energy strategies gained particular importance. In order to establish how much energy would be consumed to power the house while maintaining comfortable living standards, worst-case scenarios have been simulated. The selection of material qualities and quantities took place under consideration of costs and performance values. Insulation levels for all envelope components (Tab. 1) have been researched in this part of the project. Initial findings suggested that the installation of a concrete slab would help to mitigate peak loads significantly and might allow downsizing the HVAC system. General considerations have been pondered and tested in this phase of the competition as well. Part of the enquiries considered the utilisation of steel versus timber frames, or the use of Structural Insulated Panels (SIPs). While SIPs are uncommon in New Zealand, export of timber can be challenging considering that New Zealand predominantly uses arsenic treatment methods that are banned in many countries.

Tab. 1: R-Value of Building Components

Building Element	U-value (W m^{-2} K^{-1})
Roof	0.154
Wall	0.173
Concrete Floor	0.183
Timber Floor	0.170
Glazing, Doors and Skylight	0.901

Performance Simulation of each individual Building Element in comparison to the Baseline Model

While for most components of the building the cost-benefit analysis was fairly simple. And yet, the team had lengthy discussions around the skylight in the central part of the building. Glazing and framing types have been compared extensively, tinted foils have been added to increase the reflectivity of the windows, as well as the installation of internal and external blinds have been simulated. As a result it was found that the additional electrical energy produced on a hot summer day would exceed the energy required to cool the space mechanically. As a consequence, the team decided against the installation of external blinds.

Another point of discussion was the installation of evacuated tubes for the generation of solar hot water. While flat plate collectors would have been the preferred choice for a variety of reasons, only evacuated tubes allow us to comply with the pre-defined energy load profile.

Sheep wool has been selected as insulation material mainly for health reasons. It came as a surprise that the global warming potential (GWP) of natural wool fibre is immense. ¾ of the total GWP in the building are created by sheep wool (Drysdale, Danielmeier 2011). While that might have been conflict of interest from a Life Cycle Analysis point of view, it was also found that the house would produce more energy than it uses, including all embodied energy – aligning it with the aims and objectives set by the team.

Final Selection of Building Components and Elements

While building projects are usually driven by costs, a solar decathlon competition entry encourages teams to design the most energy efficient design solutions. Most teams have welcomed the move by the organisers to consider costs as part of the competition. Saving potentials for the New Zealand design exceeded the investment that would have been necessary to commission a building scientist to carry out the additional work. Given that energy prices are rising globally, a better approach to planning should be welcomed by all parties involved in a building process.

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