Building the FirstLight house: 
Applied research in sustainability

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ABSTRACT: Sitting on the junction between theory and practice, the design and construction of sustainable buildings has become one of the major growth areas of architecture over the past decade. The growth of ‘green’ ESD buildings is also providing impetus and direction for the growing field of sustainability in building science.

The aim of this paper is to chart the progress to date of the FirstLight House, an entry in the United States Department of Energy Solar Decathlon 2011 competition. This entry was initiated by a student-led design competition, which realised theory through the actual construction of a full sized experimental dwelling, to be constructed and deconstructed as a working laboratory.

As the project is ongoing, the paper addresses issues that have been resolved, and future issues to be faced in the coming months. The project bridges the gap between the theory and practicalities of architecture. Outcomes are being used to inform both teaching and practice within the School of Architecture at Victoria University, New Zealand.

Keywords: Sustainability, Construction technology, Design Education

INTRODUCTION

The Solar Decathlon is a competition run by the US Department of Energy (DoE), every two years, for the last decade. The aim is for 20 university teams of students to each design, build, and run a solar-powered house for a week-long competition. The competition is called a Decathlon as there are 10 key competitions in the project that are judged or assessed.

In 2009, a final year student team from Victoria University in Wellington (VUW) undertook the project from a University assignment, submitted their design and became the first team ever from the southern hemisphere to be selected for the competition, along with the rest of the world’s best. By 2011, the graduate students involved (Farrow, A; Jagersma, B; Nuttall, E; Officer, N) are planning - and VUW are contractually obliged - to have a house built, shipped to the US and erected on site in the Mall in Washington, and to run the house completely on solar power during the course of the competition.

To say this is no small task is an understatement. The task ahead is enormous, but challenging for all concerned, students and staff advisors alike. The paper is written in the middle of the design phase, explores some of the issues raised in the design and construction phase that is happening during 2010, and focuses on the incorporation of the project into the building design curriculum.

1. DESIGN

1.1. Concept
The student designers of the project, strongly design-led as would be expected from a School of Architecture, have produced a striking design with both simplicity and complexity at its core. Although the design has a strong visual profile thanks to its external canopy in the form of a ‘butterfly’ roof supporting the extensive array of solar design collectors, the design of the actual house itself is relatively simple. Within, and under the external canopy, the house is a deceptively straightforward, rectangular box shape with a floor plate of around 65m² gross floor area.

1.2. Planning
Designed with the client in mind (a small house for a childless couple, set on a site in Wellington), the design draws upon the primal desire for the kitchen at the heart of a dwelling, and takes its cruciform internal planning directly from the crossing point of inside and outside. The central ‘hearth’ is the glazed central space, home to the kitchen as well as welcoming front doors. The living space crosses the hearth perpendicularly, and the sole bedroom and bathroom extend off the central space. There is an aligned storage area that also houses the extensive mechanical equipment needed to run the house. As per the competition aims, the house is to be run completely from solar power: this is an entirely logical conclusion to the Vale’s dictum, that: “For the designer of buildings, solar energy is the most suitable renewable source for exploitation.” (Vale 1991:54). The cruciform planning within the rectangular outline enables a
thermal buffer to be planned at the north-facing wall to suit the northern hemisphere competition. The house would, of course, be flipped on site when ‘at home’ in its southern hemisphere condition.

1.3. Branding
The solar powered house, now being branded and marketed as the FirstLight House by the students, will be one of the more technologically advanced relocatable homes in New Zealand when it is completed in 2011. The design of the building relates well to the aims of sustainable architecture – although, as Finlay observes, “As yet nothing is truly sustainable. Things are just more or less efficient.” (Finlay 2008:167). The design is planned to be as sustainable as possible (in terms of solar-powered energy self-sufficiency), and to adhere to the roots of the design concept, while also aiming efficiently and firmly at the central goal of winning the competition.

2. LOGISTICS

2.1. Shipping
In the course of the design phase, it rapidly became apparent that despite any preconceived ideas about how to construct and export a standard timber dwelling to the USA, this project design would be constricted and largely governed by shipping restrictions. Initial examinations assumed completely knocked down (CKD) construction, with the shipping of flat panel assemblies to the US in standard 12.2m (40’) ISO containers. Detailed examination of the practicalities involved have largely ruled out flat-packing as a preferred approach: while there are some potential cost savings in the shipping of the house if flat-packing is used, this appears to be outweighed by additional costs in the US for the subsequent assembly phase there.

2.2. Trucking
While only 4 of the teams have to contend with shipping via sea (16 of the 20 teams selected for the competition are from mainland USA), all teams have also to contend with how to transport the homes by road. The house as designed is too wide to be carried fully built up for any distance without causing severe traffic disruption, and so still needs to be carried a certain distance in pieces to site. The use of standard width containers will remove road-width restrictions likely to be faced in the US. Some of the other entrants have coped with these issues by making their entries no wider than a standard truck body, or even basing their design on the incorporation of the truck chassis as a permanent structural element. This approach has not been adopted by the FirstLight team, as it was felt this would compromise the intended ‘off-road’ site features of the design (ie suiting possibly hilly Wellington topography), as well as requiring early sponsorship by a trucking firm willing to incorporate one of their trailers into the project for a reasonably substantial period of time.

2.3. Assembly
Assembly of the project on site will be a crucial phase of the project. Owing to the delicate political nature of the site in the centre of the Mall in Washington, teams are only given a limited time (120 hours) in which to arrive on site, set up, unload and assemble the solar house, with testing of integrated systems up and running within a mere 72 hours. As far as time limits go, this is extremely brief, even for the most experienced house assembly team, let alone for an inexperienced student team.

Analysis of previous entries (available on the Solar Decathlon website — the aim is for all to learn from previous successes and mistakes: Solar Decathlon, 2010) revealed that there were a number of alternative construction and shipping possibilities. The decision made during July 2010 by the student / staff design team was to look at shipping partially assembled modules, fitting them within standard width containers – albeit over-height. This will allow for pre-assembly and full testing in New Zealand prior to shipping, a vital step in minimising on-site risk.

The recent adoption of the Solar Decathlon competition by the European Union (planned to run every alternate year to the US competition) has been recently run in Madrid (June 2010) and Team NZ sent observers to site to watch the European erection procedures, which has reinforced key design and logistics decisions made.

3. CURRICULUM

3.1. Student involvement
A key part of the success of this project will be the degree to which the University partakes in this project. So far, at time of writing, the response from the institution has been excellent. Victoria University realised the opportunities this gave for not only the students concerned but also the School of Architecture and indeed the University as a whole (VUW, 2009). As a real life project the building gives students an opportunity to put theory to the test, and put action into practice. The core student members were encouraged to persevere with their design work through the summer vacation period, and this resulted in the successful acceptance of the New Zealand entry at the Schematic Design phase.

The continued presence of the four leading students has been made possible by their enrolment in a Master of Architecture degree, where the design, fabrication, assembly, and running of the building during the site will contribute substantially to the research in the M Arch itself. There is also an understandably steep learning curve for all the students concerned: something that, while hard work during the University semester, will produce highly skilled graduates with additional knowledge and hence enhanced desirability for future employers.

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3.2. Team Build-up
Acceptance of the proposed project was based upon the ‘Technical Proposal’ submitted by the University, which incorporated the student work into the wider submission by Victoria University (VUW 2009). The Technical Proposal set out the project planning and organisation of the project within the University, as well as the extent of involvement sought from outside the University. The document sets out that while the project will be headed by the School of Architecture, input will also be sought from the associated Centre for Building Performance Research (CBPR), the School of Design, New Zealand Climate Change Research Institute (NZCCRI), and the Media Studies department, amongst many others.

At the start of the 2010 university year, with acceptance confirmed, the project fund-raising began. Major sponsors have been approached, and continue to be sought at the time of writing. Flow-on effects of the project were assessed: the student team would need to be enlarged, so that more students could benefit from the increased flow of practical knowledge application. Staff members have also been added to the team as experienced advisors, allowed as Crew under the extensive Solar Decathlon rules, but not able to work directly on the project when on site. Addition of extra students and staff would ease the workload on the four primary students involved: in some other university teams, several Universities or Technical colleges have banded together.

3.3. Team breadth
The project is not judged solely on ‘architecture’ – indeed, architecture is only one of the 10 competitions. Other criteria include judged performance of engineering, market appeal, communications, affordability, and measured performance / compliance with comfort zone, hot water, appliances, home entertainment, and energy balance. In addition, other aspects are closely monitored, including health and safety on site, hydraulics, electrics (especially photo-voltaic energy flows) and adherence to regulations etc. This presents both an obstacle to running this project completely within the architecture school alone, as well as an opportunity to broaden the appeal of the project and involve other University departments as well. The inclusion of the Building Science (BBSc) program at Victoria has allowed several key cross-overs with BBSc students into this Solar Decathlon project, with BBSc students working alongside Architectural Studies (BAS) students to design and test the thermal envelope and the mechanical systems.

3.4. Standard courses
Several of the lecturers involved in the teaching of the standard program of Architecture have taken the opportunity of converting their courses so that the syllabus directly reflects the needs and requirements of this particular project. This way a larger number of students can be encompassed to work on the project, as well as allowing variations on design concepts to be explored in parallel via a non-critical path approach.

Second year construction students were assigned to draw up plans and details for the FirstLight House, and were permitted and even encouraged to explore alternative methods of construction – an approach which has paid off already, as the alternative construction method is now the preferred and adopted solution. Third year construction students are also examining construction techniques and their relevance to the commercialisation of the house to see how it can be adapted to future possible scenarios.

Similarly, courses in Cost Planning, Sustainable Engineering Systems Design, and Furniture Design have been altered to permit the testing of alternative construction, detailing, and thermal analysis. Care has been taken to ensure that all teaching and learning objectives are still valid despite the refocusing of the courses involved. Media Studies department have also been tasked with using the house as a test bed on which to run communication and media studies.

3.5. Special courses
In addition to standard courses being altered where possible to suit the project, special papers have been set up to permit working on the house as an elective. At least two special papers are offered: one on the developed design phase, and one of the construction phase. Solar Decathlon rules set out strict criteria regarding the student representatives on the projects, and this necessitates student involvement in some key positions that run through to an on-site position during the Mall assembly phase in 2011. The incorporation of special courses for phases such as Construction and Assembly gives enrolling students a chance to follow the project through from simple sketch drawings, all the way to a completed and fully functional solar-powered laboratory on site in the USA.

Students undertaking the first special topic paper have been assigned to produce reports on their selected area of the building, e.g. exploration of alternative foundation systems, or reporting on which New Zealand based window systems would be the most suitable for the project.

At the stage of writing, every design decision is being tested against the feasibility of shipping to and from the USA: this would not be such an issue of the design was focused and solely marketed within New Zealand. At the same time however, material selection and product suppliers are also being evaluated, tempering any material design decisions against a backdrop of practical evaluation of finances: any product in the hand is worth two in the metaphorical bush (free donation of goods or services may take preference over goods that would otherwise have to be paid for). Research for the product selection is being driven by these student reports.

3.6. Building Science
The advantages of undertaking this project for real are obvious and substantial; as opposed to a more typical architectural school project where practicality and reality can be temporarily placed on hold. Building Science students are strongly involved – and we hope that this aspect continues to gain momentum. With the background
knowledge that this project is to be constructed, a strong sense of practicality is being imbued into the project. In parallel however, the fact of this project being the student’s own responsibility – and that the ultimate client of this project is the students themselves, still allows the project to explore innovations to as full an extent as possible. Any decisions made on the project are made by the students themselves, answerable primarily only to a set of (admittedly strict) rules laid down in Washington. Innovation on this project is of course encouraged, and points awarded accordingly, but this is tempered by the knowledge that too much untested innovation may result in the project failing – if, for instance, the temperature results fall outside the standard (extremely narrow) temperature range required by the competition.

The project is being tested at three times or more: at least once by means of virtual simulation (testing different material / elemental scenarios), again when the building undergoes a test assembly in Wellington, and finally, the only one that counts: in Washington on the Mall. Data will be available both during and after the Solar Decathlon project is run: this presents an opportunity to assess how accurately virtual simulation can predict actual building performance in real world situations, although it should be remembered that with any virtual simulation: “Rather than surrogates of reality, the simulation would be best viewed as perspectives that are incomplete” (Strauch 1974). The chance for BBSc students to assess the accuracy of their data-collecting and analysing of models, still presents a golden opportunity to cross-reference the virtual with the actual. The ultimate test for validating empirical data would of course be a “comparison of simulation results with a perfectly performed empirical experiment with all simulation inputs know.” (Williamson 2010:404). However, the stark reality of the situation is also acknowledged: “because of the complexity of the built environment, such an experiment is all but impossible.” (Williamson 2010:404).

Indeed, simulation can only go so far towards providing accurate readings: “inappropriate applications of simulation may result in wrong decisions and an erroneous allocation of resources.” (Williamson 2010:401). The reasons for this are based, at high level, on the severe political issues at stake with overt reliance on simulation results that are, at best, inaccurate. For example, “the important issue of climate change is based almost entirely on the predictions of climate models and potentially these results may have a much more significant effect on design decisions than building assessment simulations per se.” (Williamson 2010:404).

4. PRACTICE

4.1. Practice similarities
The project parallels and hence replicates standard architectural decision-making dilemmas, although at a magnified level, with considerable consequences in the extra transport and technological implications involved. Issues still to be completely resolved include methods of construction and the future sites (up to five different possible sites in Wellington) – these are not typically problems that have to be addressed by a more standard building project, where the site has to be set before any design ideas are formed. However, lack of permanent site aside, the project is essentially still one of a basic construction of a timber-framed (albeit heavily modified) house, with all the ensuing issues of complying with building regulations. In this case, regulatory compliance is further complicated by the need to comply both in the home country (the New Zealand Building Code) as well as the exhibition country (in typical expansive fashion, the USA references the International Building Code) and the Solar Decathlon Building Code (SDBC) – all of which the scheme must fully comply with. As a teaching mechanism for student learning and understanding of the need to comply with regulations therefore, the project is excellent, but also considerably more confusing than a simple one-system compliance.

4.2. Prefabrication
This project has had to be designed from the ground up as a relocatable, mobile, energy-self-sufficient, prefabricated home: a state that the construction industry in New Zealand has not itself yet managed to resolve. Following the publication of Pamela Bell’s seminal and timely thesis (Bell 2009) and the subsequent highly successful initial working party of industry meeting head on with academia in Wellington (Bell 2010), the Prefab industry has only recently started to form a united front with regards to sharing intellectual property and construction issues (www.prefabnz.com). However, the coinciding of the initial industry meetings for PrefabNZ and the FirstLight project mean that there is a healthy degree of cross over with the aims of industry and the needs of the student project. It is anticipated that as the project progresses, information will flow in both directions over this subject at least: taking advice from the PrefabNZ group, and feeding back to the group over the finished product.

4.3. Practice support
So far, the project has been generally well received by the local architectural community, although there are some detractors. For example, “Is the Firstlight House illustrated a serious effort? I hesitate to comment if it is just a student sketch. If it is more than that then it is a very silly design for that environment.” (Cook 2010). More commonly however, practitioners are behind the project, and are keen to offer their assistance: “If it is of use to your team, I’m happy to donate my services…” (Huntington 2010). The ability for this project to simultaneously appeal to both industry and students alike is welcomed, although the greater question will be the ability to keep up the impetus in the long term.

4.4. Industry support
The attractions for many in the business community are proving encouraging: on the whole, businesses contacted have been vocal in their support, and perceive opportunities in participation (not solely related to the estimated half million visitors the competition will likely get on site - based on previous visitor numbers). The integration of the
construction industry with the architectural institution is closer on this project than possibly any other project in the Architectural School’s history.

These integration advantages have been noted by others: in a recent study, Wheatley, Nichols and Sailer (2010) found out that there are numerous advantages in undertaking Design Research in an Organisation (DRI), while at the same time undertaking Design Research in an Institution (DRI). These advantages include improved research skills, gaining time management skills, additional funding for seminars, and most relevant of all, that the integration of theory and practice “may well be the essential purpose of DRO [as it] helps contextualise research, resulting in more meaningful outcomes to the affected parties, and potentially more accurate results (provided the research is performed with sufficient academic rigour)” (Wheatley et al 2010). The eyes of the University will certainly be on this project to ensure that the academic results are coherently rigorous.

5. SUSTAINABILITY

5.1. Orthodoxy in sustainability

Key decisions on this project have reinforced the existing issues around designing a sustainable house. Although the team notes the irony of spending large amounts of time and money on a project to be powered by the sun, when on home territory there is plentiful hydro-electric power, perhaps making the need for solar power somewhat redundant; there is nonetheless strong allegiance to the Vale’s seminal work on sustainable housing, where it is noted that: “South-facing glazing, high mass walls and active solar collecting panels reduce energy demand by 80 per cent.” (Vale 1991:39). While the project meets the requirement for solar panels, and, being mobile, can be easily oriented towards the sun in either hemisphere (to be fully site specific), the requirement for high thermal mass walls is lacking due to the concurrent need for a lightweight, transportable building construction. Comparing the house as designed to a (reputable) sustainable building guide checklist, indicates that:

- To create a sustainable house residential developers should look at a range of features, such as:
  * Passive solar design
  * Insulation that’s several times the current standard
  * Double-glazing
  * Use of sustainable energy resources, such as solar or wind power
  * Heat pumps for air-conditioning in summer, heating in winter
  * Low-e glass for windows, using reflectivity to minimize solar heat gains in summer
  * Use of renewable and recyclable materials
  * Greywater treatment on-site for re-use to flush toilets

(Fontein 2008:142)

All of the points here have been addressed, with the exception of the grey water recycling. Storage issues exist with water in a transportable design (and the DoE rules), although this can be factored into the design if a permanent site is found. The chief factor still outstanding therefore is the ability to sustain a constant temperature. Work undertaken on other Wellington projects have indicated that the biggest factor in retaining a comfortable and stable internal temperature in this climate is the need to reduce excess sunlight from entering the building, rather than the need to provide additional heating. However, while the ability for high levels of insulation has been requested and is being addressed by the currently proposed construction methods, the key factor missing - likely to be a significant element in achieving (or not achieving) the solar performance required, is the absence of thermal mass. In the case of all recent ESD / ‘Green Star’ rated buildings constructed (or refurbished) in Wellington over the last decade, the use of exposed concrete slabs as a thermal bank over the night time period has been a major factor in the achievement of stable indoor temperatures.

The recent refurbishment of a building presented at the Wellington Sustainable Buildings 2010 Conference (SB10), although of an entirely different scale and purpose, showed that the base issues are the same. In the case of Aorangi House it was noted that there were three key factors for successful project outcome in achieving stable interior temperatures – external louvers, external insulation, and exposed thermal mass internally (Marriage and Waldhauser 2010). On a smaller commercial project, in a low rise, high profile building for Meridian Energy, the emphasis is noted as important on two fronts, namely the building envelope: “... a key element in achieving the project objectives and aims of high quality design.....” as well as the plentiful access to thermal mass: “Heat entering through the fabric of the building and generated by occupants, office equipment and lights is absorbed into the exposed building structure around the perimeter” (Barbour and Marriage 2007).

The lack of thermal mass in the design as it stands at time of writing is difficult, but not insurmountable. Concrete mass is possible, but does not help greatly with issues of transportability or site manoeuvrability. Water-filled thermal mass is an excellent option, but is a non-compliant proposal under the SDBC / DoE rules. Sandbags, the saviour of farmers during floods and families during wars, may prove once more to be the answer – light, transportable, reusable, good thermal mass and ultimately, very cheap.
CONCLUSION

Although this project is on-going, and there can be no conclusions drawn until the complete end of the project, there are a number of observations that can start to be drawn already. Firstly, that with a high quality design, and a go-getting attitude, New Zealand can enter into a playing field along with the world’s best. More importantly however, that for ongoing University architectural education to have relevance, the use of a project such as the FirstLight House can provide valuable learning opportunities for both the staff and students involved. There will be numerous outputs from the project in terms of research, both within academia but also within industry. There will be learning curves for all concerned, steep in the cases of students concerned, but also likely to be steep for academic staff concerned that may not always have been so closely associated with real life projects.

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REFERENCES