Stream: Philosophy and Science of Sustainability

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Title: A systems framework for sustainability and its application to a construction project

Abstract

Developing basic principles for success from an understanding of the system, then systematically planning ahead with those principles in mind (ie. backcasting from sustainability principles), allows strategic step by step progress towards a shared vision of sustainability, without risk of wasting energy addressing symptoms or exacerbating root causes.

The framework for strategic sustainable development developed by the international non-profit organisation, The Natural Step, provides a means to understand, organise and manage impacts, as well as inform routines for what to do to avoid similar mistakes in the future. The paper will describe the framework and its use by a number of departments at the University of Canterbury, in particular by the Facilities Management Department and the School of Biological Sciences, in the context of a construction project. The framework was used in conjunction with an integrated sustainable design process to achieve a common understanding of the extent and urgency of environmental and social impacts across the design team; a common vision for the construction of new Biological Sciences buildings across the buildings' users and designers; sustainability principles to assist in selection of product and design elements; and an enormous shared enthusiasm for the task.

Introduction

There is growing acceptance that current patterns of resource use and distribution are unsustainable, and growing willingness to try to identify and take actions which will move us towards a sustainable society. However there is still much uncertainty and confusion about what are the best actions to take. Perceptions that actions which are good for the planet may be against the individual's or organisation's short term (and/or long term) economic interest can result in inaction or ineffective action. How can we decide which actions are going to be the most strategic?

Backcasting from Principles

Humanity currently faces an increasing squeeze between declining availability of life-supporting resources and increasing human demand (total population and per capita demand) – we are in effect in a funnel (see fig 1). As a result, changes in consumer preferences, environmental regulation, stakeholder concerns, and resource pricing and availability are coming thick and fast, making it hard for companies and communities to

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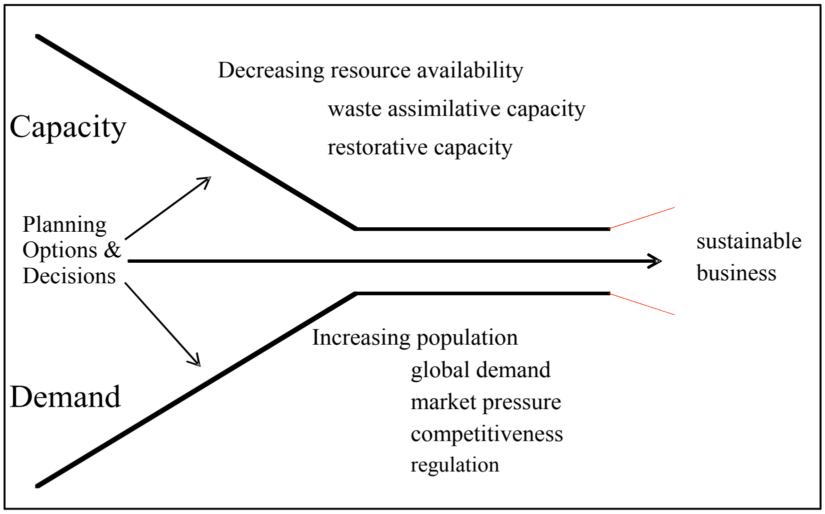

Figure 1:
The funnel

predict what is going to happen next. In such a situation, where current trends and behaviours are part of the problem and there is a need for major change, a forecasting approach, where past trends are used to decide future actions, is unhelpful – it is like driving forward looking in the rear view mirror. In such a situation, forecasting doesn't have sufficient predictive power to allow people to make sensible, profitable or sustainable choices.

An alternative approach is backcasting (Robinson, 1990; Dreborg, 1996). In backcasting, one envisages the future one desires to reach, then works back from that to today's position to work out the steps needed to reach the vision. As a planning methodology, backcasting is particularly helpful when the problems at hand are complex and when present trends are part of the problem (Dreborg, 1996). When applied in planning towards sustainability, backcasting can increase the likelihood of not only handling the ecologically complex issues in a systematic and coordinated way, but also of foreseeing certain changes in the market, and hence increases the chances of a relatively strong economic performance (Holmberg and Robèrt, 2000).

There are two main methods of backcasting – backcasting from scenarios and backcasting from a vision based on principles. Scenario planning can be very useful, particularly to help individuals think creatively and "outside the box" about alternative futures. It is a great learning tool. However, in terms of planning for sustainability, backcasting from scenarios has some challenges associated with it.

1. It is often very difficult to get a group of people to agree on the details of the future picture.
2. People are generally hesitant (rightly) to lock into a scenario based on current technology because they know new technology will come along.
3. The picture or scenario we are creating may not actually be sustainable. On what basis or using what criteria do we make such a determination? (AUMA, 2006).

To overcome some of these limitations, we need to complement backcasting from scenarios with an approach called backcasting from principles. Rather than define success in terms of putting all the pieces in place to come up with a picture like the scenario (as in a jigsaw), success is defined in broad principles (as in chess) (Cook, 2004). Checkmate is a good example of a principle-based definition of success. You can play chess 100 different times and checkmate could look different every time. Yet you know you have succeeded if you achieve the condition for checkmate - the other person's King can no longer move. Knowing that this is the principle that must be achieved to be successful, you make the strategic moves necessary through the course of the game to achieve that condition, perhaps changing strategies as the circumstances also change, but always driven by a clear understanding of the condition for success: the principle of checkmate (P. Leong, pers. comm.). Once the principles of success are determined, one can then visualise various very broad brush scenarios for our future, or that of our company, organisation or community, that satisfy these principles for success, and choose to head towards the one that resonates most.

The Natural Step Framework

The question, then, as we plan for sustainability, is what are the principles of success for sustainability? Or what is "checkmate" in the game of sustainability?

The Natural Step, an international non-profit organisation that began in Sweden in 1988, set out to answer this question, drawing on science and systems thinking. Looking at the system of the earth and the people on it, they asked "what do we know about how that system works and what is necessary for it to keep on working – to be sustained"? Drawing on the laws of thermodynamics and ecology, they identified four conditions that must be met if the biosphere/society system (and the economy which depends on these) is to be sustainable. The first three conditions describe the three main mechanisms by which humans are impairing the functioning of natural systems (on which people depend), while the fourth concerns the need for people to be able to meet their needs (Holmberg et al., 1996 ; Robèrt, 2002). These four conditions have been refined over the years and become known as The Natural Step system conditions for sustainability:

In the sustainable society, nature is not subject to systematically increasing …

1. … concentrations of substances extracted from the Earth's crust,
2. … concentrations of substances produced by society,
3. … degradation by physical means,

and people are not subject to conditions that systematically

4. … undermine their capacity to meet their needs.

These system conditions can be used as a principles-based definition of success – we will have a sustainable society when we meet these system conditions, and any organization wishing to move to sustainability can use the definition to chart their direction.

The system conditions are an integral part of a strategic planning framework developed by The Natural Step in collaboration with a network of scientists and businesses. This framework has been used by many hundreds of companies, councils and communities around the world to work out where they want to get to and how they are going to get there in a way that allows them to thrive financially, socially and environmentally. Experience has been gathered from a variety of business leaders (Electrolux, 1994; Robèrt, 1997; Anderson, 1998; Nattrass & Altomare, 1999, 2002; Broman et al., 2000; Leadbitter, 2002; Matsushita, 2002; Robèrt, 2002a, 2002b; Waage, 2003; Roberts, 2004; Cook, 2004; and case studies at www.naturalstep.org.nz) and policy makers (Cook, 2004; Robèrt et al., 2004; James & Lahti, 2004; Whistler, 2006) on applying these principles and creating a bird's-eye perspective on an array of sustainability-related problems.

Organisations usually apply the framework in four key steps.
Step A (awareness) is gaining a shared understanding of sustainability principles (system conditions), current unsustainability and the framework. Roberts (1999) discusses the motivational importance of this step in allowing staff to understand the urgency of taking action and the benefits for companies and communities of being proactive.

Step B (baseline) involves looking at where the organisation is today in relation to the definition of sustainability, asking in what ways and to what extent is the organisation currently contributing to violations of each of the system conditions. For example, how dependent is it on fossil fuels or heavy metals? Does it use any chemicals that are systematically accumulating in living systems because nature is unable to break them down at the rate humans are releasing them? And so forth.

Step C (creating a vision) – envisioning a future when the company or activity is no longer part of the problem. "How could we deliver our service in a way which does not violate the system conditions?" It is important to note that the system conditions are defined in the negative – they are not prescriptive, setting out what an organisation must do to be sustainable, but instead are more liberating, inspiring much creative thinking, by saying (in effect) you can do anything you like as long as you don't do these four things. What might we look like when we are sustainable?

Backcasting from C (where you want to be) to B (where you are today) enables you to decide the steps that are needed to reach your vision. Step D (down to action) involves designing an action programme, with both immediate steps (cost-effective easy wins – the "low hanging fruit") and longer term steps. Any proposed actions are tested against three key questions – (i) are they taking us towards our vision, (ii) are they good flexible platforms for future investments towards our vision, and (iii) do they provide good possibilities of giving a relatively fast return on investment.

Given the sometimes baffling array of sustainability-related programmes, approaches and initiatives, it can be useful to recognise that different programmes are operating at different levels. It is common that the first step organisations take when addressing sustainability is to initiate some action – a common first action is to set up a recycling scheme. As the number of these ad hoc initiatives grows, a need for tools to measure and manage the actions is recognized (e.g. a monitoring and reporting system or an environmental management system such as ISO 14001) and a need to have some coherent strategies to ensure that all the actions are heading in the same direction. Organisations wanting to be truly strategic about the suite of actions they undertake eventually decide they need to put all their actions in a bigger context and are interested in pan-organisation policies and goals that they can be confident are all heading in the same direction as, and preferably putting them ahead of, the main trend of regulations, customer preferences, investor demands etc.

The backcasting from sustainability principles framework lets five interdependent but distinct levels communicate with each other as their respective contents and relationships are explored (Robèrt, 2000; Robèrt et al., 2002):
1. *The System.* The overall principal functioning of the system, in this case the biosphere and the human society, are studied enough to arrive at a . . .
2. *Basic definition of success* within the system, in this case sustainability, which, in turn, is required for the development of . . .
3. *Strategic guidelines,* in this case a systematic step-by-step approach to comply with the definition of success (backcasting) while ensuring that financial and other resources continue to feed the process of choosing the appropriate . . .
4. *Actions*, that is, every concrete step in the transition toward sustainability, which should follow strategic guidelines, which, in turn, require . . .
5. *Tools* for systematic monitoring of the actions (4) to ensure they are strategic (3) to arrive at success (2) in the system (1).

Using The Natural Step system conditions to define the principles of success at level 2, one can then select the appropriate strategic guidelines at level 3, actions at level 4 and tools at level 5 which allow you to achieve success at level 2. Several pioneers of tools, concepts and approaches for sustainable development have already used this framework to assess how their respective tools relate to sustainability and to each other (Robèrt et al., 1997; Holmberg et al., 1999; Rowland & Sheldon, 1999; Holmberg & Robèrt, 2000; Robèrt, 2000; Robert et al., 2000; Robèrt et al., 2002; Korhonen, 2004; MacDonald, 2005; Byggeth et al., 2006; Byggeth & Horschorner, 2006, Ny et al., 2006). For example, an organisation can use The Natural Step framework to build awareness and support for a sustainability programme and to set goals and priorities, then use the environmental management system standard ISO 14001 to help them ensure that they achieve the goals they have set themselves (Burns, 1999; Rowland & Sheldon, 1999; MacDonald, 2005). Tait Electronics was the first company in New Zealand to establish an ISO14001 system based on The Natural Step framework. There is also a growing body of work on how The Natural Step system conditions can be used to identify the main sustainability aspects in a life cycle, allowing life cycle analysts to hone in on the key issues of concern, without drowning in detail or missing important impacts by falsely drawing boundaries (Byggeth, & Horschorner, 2006; Byggeth et al., 2006; Ny et al., 2006; Ny et al., 2006 in press, Ny et al, manuscript).

The Natural Step framework has been used by companies ranging from very large multinationals such as Electrolux, Ikea, Nike and Hilton (e.g. see Nattrass & Altomare, 1999, 2003) through to a half person Chess Tutor operation in Christchurch (for case study, see www.naturalstep.org.nz), and by large and small municipalities in Sweden and North America (James & Lahti 2004), Australia and New Zealand. In this example I describe its use by the University of Canterbury, Christchurch.

Applying the framework at the University of Canterbury

The University of Canterbury first explored the use of The Natural Step Framework in a pilot programme in 2004. The University already had a number of sustainability initiatives in place but was keen to move beyond isolated initiatives towards a more systemic transformation for sustainability. Staff from three departments, Geography, Continuing Education (now know as UC Opportunity) and Facilities Management, attended a two day Natural Step workshop in 2004 which went through the 4 steps described above (ABCD), exploring vision, impacts and potential actions from both departmental and university-wide perspectives. Following the workshop, the heads of the three departments each recommended that the University should give substance to the statements about environmental sustainability given in the University's ten-year charter by including sustainability in the University's strategic plans. The University's first Sustainability Plan, which was completed in 2005, is supported by a range of more detailed plans under development covering areas such as energy, transport, biodiversity, waterways restoration, materials, teaching and learning, and research.

A Sustainable Construction Project

The University of Canterbury's Facilities Management Department decided to use The Natural Step Framework for their next building project, a seven-year $60 million project for new and refurbished buildings for the School of Biological Sciences. The School's objective was to have modern, well-equipped buildings which fostered world class research and teaching and were legally compliant with the regulations covering the containment and safe use of hazardous substances and new organisms. Some of the technical performance challenges such a science building poses are:

- provision for safe use and storage of hazardous substances (including meeting legal requirements about fume cupboard venting etc);
- containment meeting legal specifications (PC2 level) for genetically modified and other organisms (including requirements for research labs at negative pressure to building, emergency water capture in pre-treatment tanks etc);
- temperature stability for animal rearing and research labs;
- housing for a wide range of equipment which give off heat and need temperature stability;
- low vibration for rooms holding scanning electron microscopes etc.

The School also wanted the layout of the buildings and the design of floors to encourage more interaction between research groups and foster collaboration and exchange of ideas. The existing buildings have a narrow footprint, a legacy from the days when research groups were small clusters based around individual academics, and co-operation between research groups was rare. To accommodate the changing nature of research, the additional requirements were therefore:

- a deep floor plan to allow teams of researchers to work together collaboratively in the same area, which creates challenges in natural lighting and ventilation;

- flexibility in floor plan because research interests and groupings change and hence different space needs emerge over time;
- a building large enough to provide an additional $2700m^2$ of additional space.

It was therefore decided to: i) create a new wider building to house the research laboratories, ii) refurbish the existing Zoology and Plant and Microbial Sciences (PAMS) buildings for office and teaching spaces, and iii) join the new research building to the Zoology building with an atrium. Creating a new separate building for the research labs and then connecting it to the existing buildings with an atrium solved several problems - it allows staff to continue to work in the existing building while construction of the new space is underway; it makes it possible to bring more natural light into people's work spaces despite the very wide footprint of the two buildings combined; it provides thermal advantages by avoiding having two building faces exposed to the elements; and it also provides a relatively design-neutral bridge between the aesthetics of the existing old Zoology building (with the narrow rectilinear slab form of most of the rest of the campus) and the new wider more modern building. A short connector building will connect the old Zoology building to the other School of Biological Sciences facilities in the adjoining PAMS block.

The University as a whole also demands a high level of accountability regarding the cost of the project– the project is funded with public money so any expenditure has to be clearly justified. However given that the developer is also the owner, a long term view can be taken – the University expects its buildings to have at least a 100 year life, so design elements that increase capital costs but reduce ongoing operational costs can be given fair consideration.

The challenge has therefore become to create a sustainable building that not only meets the demanding high technical performance criteria and needs for interaction of the building users but also satisfies tight financial controls.

The Process

The first step in the process was to give the design team a common understanding of the urgency of sustainability and a framework for addressing it. Facilities Management Director, Peter Molony, brought to the first Natural Step workshop (described above) not only Facilities management staff who would be involved in the project but also the contracted architects, mechanical and electrical engineers and the quantity surveyor. As part of a University-funded project to track the process used in the building project, videoed interviews have been held with all the key project participants. Facilities management staff commented that the first workshop had confirmed for them that they wanted to design the new buildings as sustainable buildings and that they wished to use The Natural Step framework. The architects and engineers commented in particular about the impact of Step A of the process in opening their eyes to the urgency and importance of incorporating sustainability considerations in their work, and how they were taking that heightened awareness into their work with other clients and even to their behaviour at home.

As the design process for the building progressed, Peter Molony decided to bring **all** the people involved in the project together for a second Natural Step workshop focused specifically on the building. The design team (architects, electrical, mechanical, electrical, structural, energy and fire engineers, quantity surveyor), the intended users of the building (School of Biological Sciences staff), College of Science and University Finance reps, and building maintainers and project management staff (Facilities Management, University of Canterbury) came together for two days in November 2005, facilitated by Natural Step advisers experienced in working with the construction sector.

The first part of this building workshop reviewed systems thinking, the systems conditions, the benefits of sustainable building, building life cycle issues including links to wider community and social sustainability, and how The Natural Step framework has been used in the construction sector (Step A). It also briefly reviewed the impacts of construction generally and the sustainability benefits and failings/constraints of the current and planned buildings (Step B) and brought the participants up to date on the current status of the project. Workshop participants then developed their vision for the building, beginning with an examination of what services they wanted the building to provide (including who they wanted the building to cater for and be welcoming to and what interactions they wanted it to foster), and reached agreement on what they thought success would look like (Step C). The engineers in particular have since commented on how valuable and motivating they found this session – in many projects the consulting engineers don't get to hear directly from the client about their aspirations for the building. The agreed vision - "Iconic identity for School of Biological Sciences, an enabling integrated habitat for all users, creating a healthy vibrant community, and global exemplar university building" - was supported by specific descriptors relating to issues such as energy use, environment, community, transport, building and materials, water, waste, biodiversity and landscape. Day 2 of the workshop was devoted to identifying, prioritising and assigning responsibility for the actions steps that would be needed to make this vision a reality (Step D).

The result of the two days was a really enthusiastic committed team, sharing a common vision ("we are all climbing the same mountain!" as the electrical engineer put it) and brimming with ideas. The process since then has maintained that enthusiasm. Typically most design consultants (including mechanical engineers) are paid a percentage of the capital cost of the equipment he or she specifies for the building, which does not provide much incentive to reduce the size of, or eliminate, the equipment. Indeed, for sustainable buildings this can provide a perverse incentive - design professionals can have a vested interest in bigger inefficient and more costly, rather than smaller, efficient and less costly. Molony and his team have taken a different approach and have shown that their commitment to integrated sustainable design is more than lip service by providing both the time and the funding to allow the design consultants to do adequate research to identify sustainable solutions to the issues that arise.

They also bring the design team together at regular intervals to share progress and ideas. The cross-fertilisation of ideas and skills this allows generates great innovation and new solutions to old problems and means no important options are closed off before their potential performance has been assessed, and new design features can be added before the process is too far advanced. It also means that the impact of a design decision in one part of the building on all other parts can be assessed, in an attempt to optimize decisions over the entire life cycle of the whole facility.

Integrated Sustainable Design

The University has pioneered in New Zealand an approach that has been extremely successful elsewhere, of combining use of The Natural Step sustainability framework with an integrated design approach (where all project stakeholders are involved in the design process and project delivery)[2] facilitated by Natural Step advisers.

Integrated design differs from conventional design in that it has a greater investment of time, research, brainstorming and discussion in the initial design phase and is more than simply having all the designers around a single table – it is a conscious process that is usually facilitated by an external facilitator. [3] This greater focus on getting the design right in the initial design phase (including making the building as energy and water efficient as possible) makes financial sense – by the time the first 1% of a project's up-front costs are spent, up to 70% of its life-cycle costs may already be committed; when 7% of project costs are spent, up to 85% of life-cycle costs have been committed (Romm 1994).

A recent study by McDonald (2005) on the economics of green building identified seven keys to cost effective green building – the University of Canterbury is on track to satisfy all seven:

- Get into a sustainability mindset – get all the team understanding sustainability and enthusiastic and committed to making the building sustainable;
- Establish a clear vision and define the goals;
- Integrate the design process;
- Diffuse knowledge – share the knowledge about the sustainability goals and initiatives with all the stakeholders, from the occupants to the building contractors;
- "Tunnel through the cost barrier" – challenge conventional thinking that increased energy efficiency will costs more - "saving even more energy can often 'tunnel though the cost barrier,' making the cost come *down* and the return on investment go up" (Hawken, Lovins & Lovins, 1999);
- Compensate for brains not stuff. As discussed above, eliminate the incentive to overdesign by compensating design consultants for their intellectual capital rather than a percentage of manufactured capital; reward them for their brains not how much stuff they can cram into the building (McDonald & Dale, 2004). This approach is an investment in human capital (the capacity and knowledge of

[2] An integrated design process is a holistic, systemic and comprehensive design process that brings all design professionals together, along with the building owner, the occupant, and other direct stakeholders to design the building as a team, usually helped by an external facilitator (Kobet et al, 1999; Larsson, 2002; Lewis, 2004; McLennan, 2004; NRCan, 2004; Reed & Gordon, 2000).

[3] See for example information on the Natural Resources Canada C-2000 Integrated Design Process http://www.buildingsgroup.nrcan.gc.ca/projects/idp_e.html

people) in order to reduce the depletion of and degradation of natural capital. This is a social benefit of green building, and increases the intellectual and social capital (Dale, 2001) of the community where the design professionals work and reside;

- Follow the money trail – make use of government green building incentives, e.g. to cover the energy modelling or pay for the additional design time required for a team to learn about energy efficient design. From an ecological economics perspective these incentives reward those who have taken it upon themselves to internalize some of the externalities associated with buildings.

How the approach has affected the design

The final outcome of the approach being used by the University of Canterbury in designing the new and refurbished buildings for the School of Biological Sciences will not be known for several years yet – whether it does, as intended, delight the people who work in it and visit it, foster world class research, and step lightly on the planet. So far it does appear that the decision to use of The Natural Step framework in combination with an integrated design approach is proving a winning one for the University. Over a year into the design process, the enthusiasm levels and combined team spirit still seem as high as at the end of the November workshop, the design is incorporating a wide range of best practice and innovative green features, and the cost estimate is coming in at or below original budget.

At time of writing the detailed concept drawings have just been approved and work is beginning on the detailed design. The construction will happen in three stages – a new deep plan seven story research building, an atrium connecting the new building to the existing building, and, once some staff have transferred to the new building, progressive refurbishment of the existing buildings as office and teaching spaces.

Sustainability elements that have been incorporated into the design to date include:

Efficient use of resources (mainly TNS System Condition (SC) 1):
- the most sustainable option in terms of resource use is not to build any new buildings, so a first step was a very thorough review of space usage on campus to determine how much if any new space was required. When it was determined that some additional and different type of space was needed, it was agreed to refurbish and reuse the existing Biosciences building for offices and teaching spaces, once the new research block has been completed and staff moved in there;
- infrastructure for mechanical and electrical services has been integrated into the architectural design so the layout is efficient, with two central service risers giving efficient distribution of services throughout the building (c.f. in sequential design where engineers begin work after all key design elements have been determined, the layout of service piping etc can often be quite contorted and inefficient);
- modular layout of rooms and services within rooms lowers cost and wastage;
- flexible internal layout allows rearrangement of spaces without wastage of resources. Two external concrete shear walls give more internal space, and together with internal

partitioning designed for disassembly, make it possible to rearrange internal spaces as needs change;
- existing plant, joinery and fittings will be re-used where economical and practical. Exactly what can be re-used where will be assessed in the next stage of the project;
- no installation of excess cabling but flexibility to facilitate future cabling installation if required;
- artesian water used to cool the adjoining Commerce building will be re-used as cooling water for this building, and as a water feature in the atrium, before being cooled in water gardens and returned to the adjacent Okeover stream where it helps maintain a healthy stream flow;
- a range of measures both within and outside buildings to make it easy for occupants to recycle, including provision of recesses throughout building to accommodate recycling stations; good signage; appropriately placed ramps, lifts and loading bays; screened exterior recycling stations on both the service yard and covered cycle stand; and colour coded underbench containers in kitchen and tea-making areas.
- in the context of a campus wide transport plan, the new buildings will further foster alternatives to car transport to University by removing around 120 carparks (some to accommodate new building and some for new open space – see below), providing a generous number of scooter stands (with future-proof capacity for possible solar electric re-charge facilities), installing a new secure bike facility with showers and composting toilets, and creating linkages to public transport connections and existing and potential cycle and jogging routes with attractive paths and signage.
It was hoped to re-use flyash from the University's boilers in the cement but studies unfortunately showed the ash had too high a carbon content for this to be feasible.

<u>Energy efficiency</u> (SC1):
The University of Canterbury has had a keen focus on energy efficiency for a number of years but for this building they aim to take it even further. A key element of the design process has been extensive energy modelling, which among other things has revealed that all the equipment within the research building will generate so much heat, that heat dispersal is a more important factor than heat retention. Research laboratories are notoriously energy intensive, conventionally using close to 300 kWh/m2/yr (Lawton 2004). The current modelling shows the research building will consume 238 kWh/m^2/year, but averaging across all the buildings of the School of Biological Sciences, energy use of the new and refurbished buildings will be 100.5 kWh/m^2/yr. The aim is to get the average below 100 kWh/m^2/yr. Energy efficiency measures include:
- significant use of thermal mass (concrete) to stabilise building temperatures and to assist in pre-heating and pre-cooling the fresh air;
- a wide range of energy efficiency measures that are already standard on most University of Canterbury buildings, including occupancy sensors, T5 lamp technology, electronic ballasts, high efficiency light fixtures, power factor correction and Building Management System (BMS) control of external lighting, heating, ventilation and air conditioning (HVAC) systems etc;
- daylight sensors, interfacing occupancy sensors with the BMS so not only lights but also other building services such as air conditioning are turned off in unoccupied rooms, advanced power factor correction at both the source of large mechanical loads and also

incorporated into switchboards, more energy metering and more visual display monitors of energy use, switching groups to allow only needed lights to be selected;
- increased use of natural lighting by extensively glazing the walls of the central corridor spaces allowing them to be at least partially lit by daylight from the surrounding rooms; and extensive use of glazing between office spaces and the central atrium;
- lower ambient light levels and more task lighting;
- use of high-efficiency electric motors and very high COP (co-efficient of performance) chiller and variable speed drives to minimise energy use;
- double glazed low-emission argon gas filled windows on the external faces on the research building and the new connector building. Single glazed windows on the existing old Zoology and PAMS buildings will not be changed – the large cost of installing new window systems does not justify the small energy savings, given that for most of the year these buildings need to shed heat rather than store it;
- automated shading on north east face of research building, on the north west face of PAMS and on northeast face of the connector building to prevent over-heating in non-air-conditioned spaces, and prevent over-loading of air-conditioning in air-conditioned spaces;
- ventilation systems bringing in double the outside air required by the building code, and use of outside air via motorised openings, providing better air quality and "free" cooling in mechanical systems;
- use of heat recovery from the chiller and the extract air systems;
- innovative use of solar heat gain in roof space to pre-heat air;
- use of "partial" air conditioning where appropriate, e.g. pre-cool fresh air only;
- a watching brief retained on the developments of LED lighting technology which has potential to significantly reduce electricity demand for task lighting.
- independent and audited commissioning of building services to ensure they perform to specifications.

<u>Renewable energy</u> (SC1):
The University has its own coal-fired boiler which provides very low cost hot water to all buildings, and the current price of electricity and coal is so low relative to alternatives such as photovoltaics (PV) and solar water heating that these cannot be justified under current cost scenarios. However this situation is expected to change - definitely within the life of the building and possibly even before construction is completed, so future proofing for alternative energy sources has been an important consideration. The roof is being designed to be strong enough to carry PV panels and/or solar water panels, the relative cost of PVs and solar water heating are being monitored on an ongoing basis, and a demonstration PV panel will be installed to run some of the systems e.g. pumps for rainwater harvest.

<u>Persistent chemicals</u> (SC2):
- no use of CFCs or HCFCs in the HVAC systems;
- landscaping will focus on low maintenance adapted plants that do not require pesticides and use timbers that do not require chemical treatment e.g. local plantation grown macrocarpa or *Eucalyptus saligna*;

- paints and internal fittings and finishes have not yet been addressed but sustainability will be a key consideration.

While the design of the buildings may minimise the exposure of building occupiers, workers up and downstream, and the broader environment to persistent or toxic chemicals, many hazardous substances are also used and created in research laboratories. The new field of green chemistry and green laboratories initiatives[4] present a range of alternative processes, chemicals and practices for researchers wishing to reduce their hazardous substance use. If University researchers were to adopt such practices, it would not only increase their own safety, save them money and reduce their contribution to persistent chemicals in the environment, it would also reduce the need for so many fume cupboards and the energy to run them. The University's draft Materials Plan identifies green labs as a key issue to address and the School of Biological Sciences as a potential site to pilot green lab initiatives over the next few years.

<u>Ecosystems and water</u> (SC3):
A wide range of design elements aim to integrate the buildings harmoniously with the natural ecology of the site and to minimise water use and maintain and improve stormwater quality. The following are just some of them:
- carparks between the existing building and the nearby stream will be removed and a new natural habitat, with paths, lawns, trees and an outdoor teaching and socialising area, will connect the buildings to the nearby Okeover Stream, which is being rehabilitated;
- rain water harvesting to a number of tanks at different heights inside and outside the buildings for toilets and for garden irrigation;
- possible grey-water filtration through reed beds for re-use in the building;
- composting toilets in the shower and toilet unit of the ground floor cycle sheds;
- lower pressure low flow fixtures to limit domestic hot and cold water consumption;
- stormwater treated through a water quality chain – permeable paving, rain gardens, vegetated swales, infiltration, bio-filtration, bio-retention, heavy metal and sedimentation traps – before returning it to Okeover Stream;
- timbers used in buildings will be from sustainably managed forests;
- use of plants and water in the atrium to help make it the "lungs" of the building, while providing a living demonstration of biological principles.

<u>Social sustainability</u> (SC4):
The School of Biological Sciences is a relatively new coming together of the departments of Zoology, and Plant and Microbial Sciences. Increased intellectual collaboration has followed the union, but the idea of physically sharing laboratory space, while welcomed by some staff is more of a stretch for others. One of the aspects that came through strongly at The Natural Step workshop in November 2005 was a hope and expectation from the staff that the building would make it easier for interaction between the various people in the school to happen - between researchers in related and differing disciplines; between

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[4] See for example MIT's Green Chemical Alternatives Purchasing Wizard, a tool to reduce the hazardous waste profile in research labs, an effort that ultimately saves MIT and its researchers' money, while reducing hazard potentials and the burden to our environment.
http://web.mit.edu/ENVIRONMENT/academic/purchasing.html

academic, technical and administrative staff; between staff and students; and between students. There was also a desire for the buildings to be welcoming to a wide range of community stakeholders, including local community, funders, school groups, and the full range of interested parties from 'extreme green' to commercial biotechnologists (within the constraint that for security and legal reasons some of the research laboratories needed secure access) and for the building itself to serve an educational function about biology, ecosystems and sustainability.

Architecture cannot create a community but it can assist by providing the opportunity for it to occur. The architect's preliminary design phase report of August 2006[5] summarises some of the ways this is being done:

- the atrium by its very nature offers a space readily capable of making linkages with a number of areas of the School. The various breakout spaces, generous air bridges and vertical circulation routes all provide the opportunity for a wide cross section of building users to interact with each other;
- the location of key areas such as the common room and administration either in or adjacent to the atrium ensure that this space will not become static. It will also draw into the body of the School the undergraduate students who, by virtue of the location of their laboratories, could potentially feel isolated;
- break out spaces have been provided in the atrium, maximising the opportunities for the inter-mixing of different groups in an informal setting;
- the common room provides a casual venue for both individuals and the School to meet as a whole;
- the research laboratories have been designed as group rather than individual spaces, potentially acting as a catalyst for encouraging interaction among researchers who previously did not meet owing to the separate nature of the laboratories;
- office spaces will be largely transparent, providing occupants with a visual connection to the wider School, whilst still addressing practical needs such as acoustic privacy;
- the postgraduate study area will provide individual study spaces in an open plan format which will address the competing requirements for both privacy and community.

Some ways in which the building can act as an educational tool have already been incorporated in the design (e.g. good signage about the sustainability aspects of the design, energy use meters and visual display monitors, recycling receptacles, demonstration PV units etc) but this aspect is expected to be given more consideration in the next phase e.g. use of glass window on public side of fish tank for living display, use of plants and water in atrium, displays about biology generally and about the various research programmes.

Conclusion

The Natural Step Framework is an internationally recognised strategic planning tool for incorporating consideration of sustainability principles into organisational policy and practice. Universities have key roles to play in educating for sustainable societies, both in what they teach and research and in the behaviour and practices they model. In New

[5] Courtney Architects:Designers Ltd. 2006, Architectural Sustainability Report, School of Biological Sciences, University of Canterbury.

Zealand the University of Canterbury is showing real leadership in modelling sustainable practice by applying sustainable design principles to its buildings. The approach it has adopted for the School of Biological Sciences building project of combining use of The Natural Step sustainability framework with an integrated design approach facilitated by Natural Step advisers is proving a winning one. The design team is united by a common vision and a common understanding of the importance of what they are doing, and a common set of guiding principles which can always be referred back to when discussion or thinking is getting bogged down in detail. The team has taken on, with enthusiasm, the challenge to create a sustainable building that meets the demanding high technical performance criteria of 21st century research facilities, fosters collaboration, world class research and a sense of community for the building users and also satisfies tight financial controls.

The design of the building is however only the first stage of the process. To fully achieve the goal, the construction team will also need to apply sustainable principles and practices to their work and all the users of the building will need to understand its features and work to optimise the buildings performance in practice. A clear advantage of using The Natural Step framework for the design phase is that it can be used equally well for these later stages as well, providing continuity and a common language and approach. In numerous projects in the United Kingdom, the TNS framework has been the cornerstone of construction team education and engagement programmes, and as other departments within the University and other organisations have shown, the Framework can also be used by departmental staff to set their own sustainability goals and guide their School planning and actions, including their use of the building.

A video of the sustainable building process used by the University of Canterbury will be available later this year.

Acknowledgements

Sincere thanks to all the team who have shown such commitment to realising the vision for this building, including Peter Molony, Lindsay Hampton, Rob Oudshoorn and Kate Hewson of the Facilities Management department and Prof. Paula Jameson and staff of the School of Biological Sciences at the University of Canterbury; Nick Courtney, Barry Morton and Mike Marshall of Courtney Architects:Designers Ltd; Matthew Gray and Brian Davidson of Powell Fenwick Consultants Ltd; Kees Brinkman of Enercon; William Field of Boffa Miskell; Brian Walker of Brian Walker Associates Ltd; Brady Cosgrove of Cosgrove Major Consulting; Dick Cusiel of Lovell-Smith & Cusiel; John Shipston and Ross Davidson of Shipston Davies Ltd; Brendan Harris of Woods Harris Consulting Ltd; Robert Vale of the University of Auckland who has provided external peer review of the sustainability aspects; and Peter Price-Thomas and Martin Hunt of The Natural Step UK who facilitated the November 2005 workshop, and Geoff Holgate who assisted me in facilitating the first Natural Step workshop at the University in 2004.

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