International Energy Agency

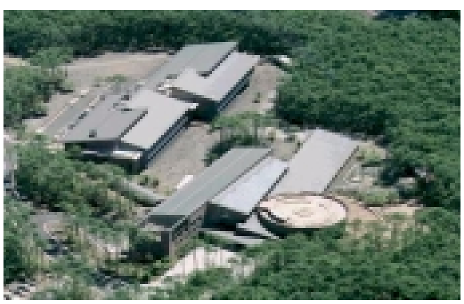
Energy Conservation in Buildings and Community Systems

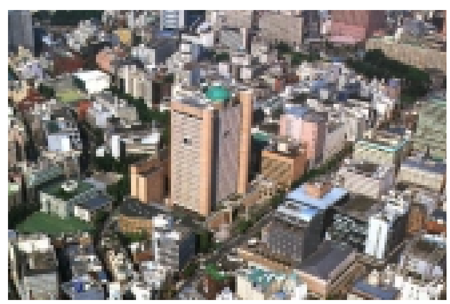
A·XXXI

ANNEX 31

CASE STUDIES

CASE STUDIES OF HOW TOOLS AFFECT DECISION-MAKING





Annex 31

Energy-Related Environmental Impact of Buildings

October 2001

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Principal Contributors

Principal author for the Case Study report is Donald Fournier, USA CERL. Authors for each Case Study are noted in the Contact Section at the end of each Case Study.

INTRODUCTION

The intent of this section is to explore how life-cycle assessment tools have had an impact on the design and environmental performance of buildings. Six countries were asked to submit case studies of building projects where tools were intentionally used to create a more efficient and environmentally friendly building or buildings stock.

CASE STUDIES

New Zealand

Waitakere City Council's 'Eco-Friendly Home'

Developer: Waitakere City Council

Commissioned: Waitakere Properties Ltd

Architects: Paul Heather, Green Design

Located: Auckland, New Zealand

Constructed: 1997

Cost: About NZ$200 000

Introduction

The Eco-Friendly Home is a three-bedroom house, built with the intention of incorporating as many sustainable design principles as practical while appealing to the mainstream market. It was intended to demonstrate that significant gains can be made in terms of healthy living and reduced impact on the environment without building a house that looks too 'alternative'. The main eco-themes are: efficient use of water and energy, healthy materials and safety conscious design.

It is being used as a display home open to the public, before being sold off to private owners.

Site and Building

The stand-alone house (see Photo #2 for the floor plan) is situated in a new low-density housing subdivision, and has panoramic views across the Waitemata Harbour to central Auckland. It is a three-bedroom design with an area is 194 m^2, with the site covering 600 m^2. The winning design was one of four tenders commissioned by Waitakere Properties Ltd. It was chosen because it best fulfilled the requirements of a healthy and environmentally friendly design and was completed within a budget comparable to homes of a similar size.

Energy Saving Elements

Energy Saving design features can be broken into three areas: the electrical system, the energy efficient appliances, and passive solar considerations.

- local area wiring (LAW) was used throughout - this controls the homes electric facilities including the lighting, heating, security system and some appliances. The LAW system is based around microprocessor intelligent circuitry, where individual elements can be programmed to be activated at specific times, and to react to various circumstances.
- energy efficient appliances include: heat pump air conditioning, heat pump hot water system, induction electric cook tops, consideration of low embodied energy materials, and compact fluorescent lamps.
- passive solar design features include: high mass, high insulation, good shading from summer sun, double-glazed windows, and natural ventilation.

Environmentally Beneficial Aspects

- asthma awareness, with no fitted carpets, reduced ledges, and a low allergen garden
- PVC free
- low formaldehyde home
- sustainably grown, treatment-free solid timber
- some incorporation of recycled materials
- low VOC paints, finishes and adhesives
- provision of outdoor clothesline
- water conservation appliances
- rainwater collection for external use
- in house recycling
- garden composting
- use of local materials
- packaging construction waste reduction

Assessment Tool

The BRANZ (Building Research Association of New Zealand) *Green Home Scheme* was applied to this home. This tool is a descriptive-based environmental auditing system for new homes, to be applied at the design stage. Fourteen environmental, safety and health issues are addressed as part of the audit system. Each issue has an associated number of credits assigned to it, according to the difficulty in achieving it and its perceived environmental importance. All requirements for each issues are above that which is currently necessary for Codes and Standards. Home designs are ranked into four environmental performance categories, reflecting the amount of credits gained. A certificate is gained for home designs that achieve a minimum amount of credits.

The designs are *Green Home Scheme* assessed by BRANZ accredited assessors, who are required to be well versed in environmental design, and have a good background in building. Workshops are held by BRANZ to train potential assessors.

The BRANZ *Green Home Scheme* is based on BREEAM, and is the only comprehensive tool that is available for this type of application in New Zealand. The *Green Home Scheme* can be applied in two ways - either to assist in the preliminary design process, or to be used as a checklist after much of the preliminary design has been finished. In this instance, the *Green Home Scheme* was used more as a checklist, with very little fine tuning necessary. In this case, the architect and the environmental consultant on the project used the Green Home Scheme.

The *Green Home Scheme* has only been available for just over a year, and so is still in its formative stages - being applied to only a handful of house designs. It has been well publicized, and a certificate displayed in this house has lifted its public image.

So far, it is difficult to tell whether there are any commercial benefits from the use of the tool, in terms of resale value and general marketability. For most of the project homes which have been Green Home Scheme assessed, the primary interest has been with the new home owner who have been interested in green ideals for ultraistic reasons.

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Photo #1: Main Entrance (from roadway)

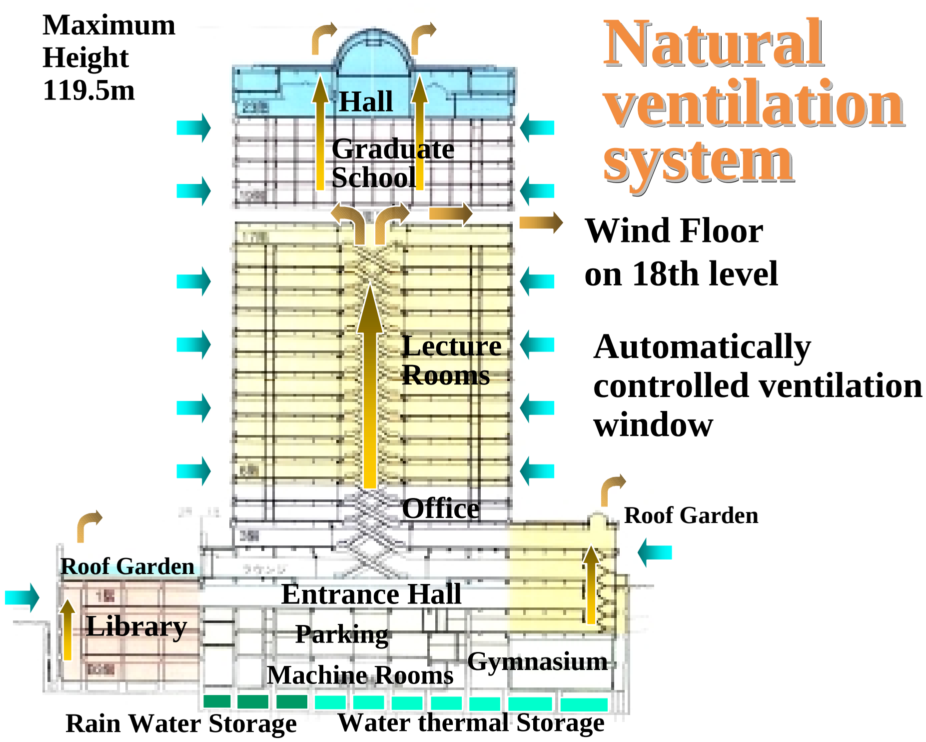
Photo #2: Floor Plan

Japan

Liberty Tower of Meiji University - Japan

Introduction

The project is the Liberty Tower of Meiji University. It is an example of natural ventilation applied in high-rise building. The building owner is Meiji University. The Architects are T.Yuizaki, H.Murayama, M.Kataoka and Y.Takagi with Structural Design by Y.Tsuneki and T.Ootake, HVAC Design by K..Matsunawa, T.Ikaga and J.Nakamura, Electrical Design by K.Fujito and K.Hara, and Environmental Engineering by T.Ikaga and T.Chikamoto, all of Nikken Sekkei Ltd. The building is a 59,001 square meter, high-rise teaching facility with lecture halls, classrooms, and a cafeteria.



Site and Building (Project) Description

Building type: Lecture room, hall and cafeteria of university
Completed: Sept. 1998 (1st phase), Ma, 2000 (2nd phase)
Site area: 11,148 m2
Gross floor area: 59,011 m2
Usable floor area: 53,000 m2
Typical building population: 8000 persons
Typical occupation hours: Mon - Sat: 0830 - 2200 hrs

Energy Saving Elements & Environmentally Beneficial Aspects

Measures taken to minimize energy loss and consumption are as follows:

- Optimization of building shape according to the requirements of solar geometry and building codes and regulations
- Insulation values (U-values in W/m2K): exterior wall (1.65); glazing (4.81); roof (0.75); basement floor and ground (0,46)
- Low energy building standard:
- Perimeter annual load(63Mcal/y/m2) :79% of Japanese codes
- Coefficient of energy consumption for air conditioning (0.78): 52% of Japanese codes
- Coefficient of energy consumption for ventilation (0.47): 52% of Japanese codes
- Coefficient of energy consumption for lighting (0.77): 77% of Japanese codes

Measures taken to optimize solar and renewable energy use are:

- Automatically controlled natural ventilation windows and wind floor (18thfloor)
- Natural lighting with automatically dimming system
- Natural lighting in staircases, elevators, machine rooms and underground rooms
- Free cooling system
- Measures concerning the treatment of structures and material
- Concrete piles made of blast furnace slag cement
- Use of wood for cafeteria floor

Measures taken to reduce construction and operating wastes are:

- Waste separation system
- Use of rain water for reclaimed water
- Basin and kitchen drain water recycling system

Measures taken to reduce the use of automobiles by building occupants consisted of locating building near subway stations in the central Tokyo.

Measures taken to improve the quality of indoor and outdoor environment are:

- Elimination of VOCs and Internal heat using automatically controlled natural ventilation windows during nighttime.
- Automatic outdoor air intake control system based on CO2 sensor.
- Roof gardening for students to improve indoor and outdoor environment.
- All electric heating and cooling system with water thermal storage (3600m3+500m3).
- Building environment and energy management system.
- Measures taken to ensure the longevity of the building are:
- To keep maximum flexibility: Floor height=4.35m, Ceiling height=3.0m, Raised floor=0.1m
- Easy to renovate: Enough vertical service shafts and machine relocation spaces

Assessment Tool(s)

The following tools were used to assess the building and evaluate the life-cycle impacts:

- Thermal dynamic simulations on natural ventilation were by STREAM. This is a popular commercial assessment tool.
- Hour by hour air conditioning system simulation was by HASP/ACLD/ACSS. This is the national tool.
- Hour by hour thermal comfort simulation was by PMV-3d. This is a private tool that I developed.
- Life Cycle CO2 and Life Cycle Cost analysis tool was by a private tool developed by Toshiharu Igaka.

The tool(s) supported optimization and improvement in the following ways:

- optimize size and amount of ventilation windows
- optimize the design of wind floor
- optimize energy saving systems
- optimize the design of sunshades and windows

The tool(s) supported the design process and were used by environmental and mechanical engineers in the schematic design phase.

Benefits and Current Usage of the Tools

The benefits of Tool Usage were to increase energy savings and decrease environmental burdens. The current usage of tool(s) for similar projects is expected to enhance marketing of the project. There are many projects and the use of assessment tools seems to enhance the performance of the design firm.

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The Yamanashi Institute of Environmental Sciences - Japan

Introduction

This project is the Yamanashi Institute of Environmental Sciences which is a research facility owned by the Yamanashi Prefecture Government. It is an example of building in a cold climate with maximum use of passive tempering techniques and coupling with the local environment. The architects are K. Matsueda, K. Ishida & A. Kitada with Energy Design by T. Ikaga, K. Niwa & J. Nakamura and HVAC Design by T. Ikaga, K. Niwa & J. Nakamura, all of Nikken Sekkei Ltd. The building is a 6,396 square meter research facility designed to harmonize with the site and preserve the local environment.

Site and Building (Project) Description

Building type: 2 buildings & 3 Annex, Reinforced Concrete & Wood
Completed: April 1997
Site area: 300,000 m2
Gross floor area: 6,396 m2
Usable floor area: 5,280 m2
Typical building population: resident 50 persons & visitor 160 persons
Typical occupation hours(Office etc.): always Sun-Sat, 9:00 - 17:00
Typical occupation hours(Laboratory): always Sun-Sat, 1:00 - 24:00

Energy Saving Elements & Environmentally Beneficial Aspects

Measures taken to minimize energy loss and consumption are as follows:

Since this location is at the altitude of 1030m, and has cold climate, high insulation values (U-values in W/m2K) were used.

- Roof: 100mm insulation board installed over RC roof (0.28)
- Wall: 100mm insulation board, air space and brick facade covering RC (0.32)
- Window panel: Low-e double glazed glass and highly insulated sash (1.70)
- Sunlight control with external light-shelves, balconies and interior blinds
- Mechanical ventilation with total heat recovery system
- high ventilation load had required for draft chambers
- rat/mice breeding system and other equipment in laboratories

Measures taken to optimize solar and renewable energy use include:

- Photovoltaic panels & solar air hybrid collector : 20kW System, 170m2
- Solar air collector (without PV panel) : 1060m2
- Cool/Heat tunnel : fresh air pre-cooling/heating using 60 meter length tunnel
- Passive solar : southern large windows allow the direct solar radiation to enter into the building in winter

Measures concerning the treatment of structures and material include:

- Use Non CFCs foamed insulation board
- Use wood for roof beam and interior finishing of entrance hall
- Use excavated igneous rocks and felled out red pine trees on site for landscaping

Measures taken to reduce construction and operating wastes are to use ground water for potable water, heat source of heat pump and reclaimed water after using as a heat source.

Measures taken to reduce the use of automobiles by building occupants include the addition of bus parking space for a party of visitors.

Measures taken to improve the quality of indoor and outdoor environment include:

- Natural ventilation: automatically controlled high-side lighting windows of natural draft chimneys in summer and mid seasons
- Hot water floor heating system is installed
- Hot water convector for windows are installed for prevention of cold-drafts
- Natural day lighting with large window and light-shelves
- Individual air conditioning and floor heating in each room
- Building shape was determined and changed several times during design and construction phase to protect the scientifically precious igneous rocks, plants and natural monuments

Measures taken to ensure the longevity of the building include:

- Insuring adequate space of utility shaft for maintenance and renewal
- BMS: gathering 400 data every 10 minutes and 400 data every 1 hour for energy management

Assessment Tool(s)

Tools used in the building assessment and design processes were:

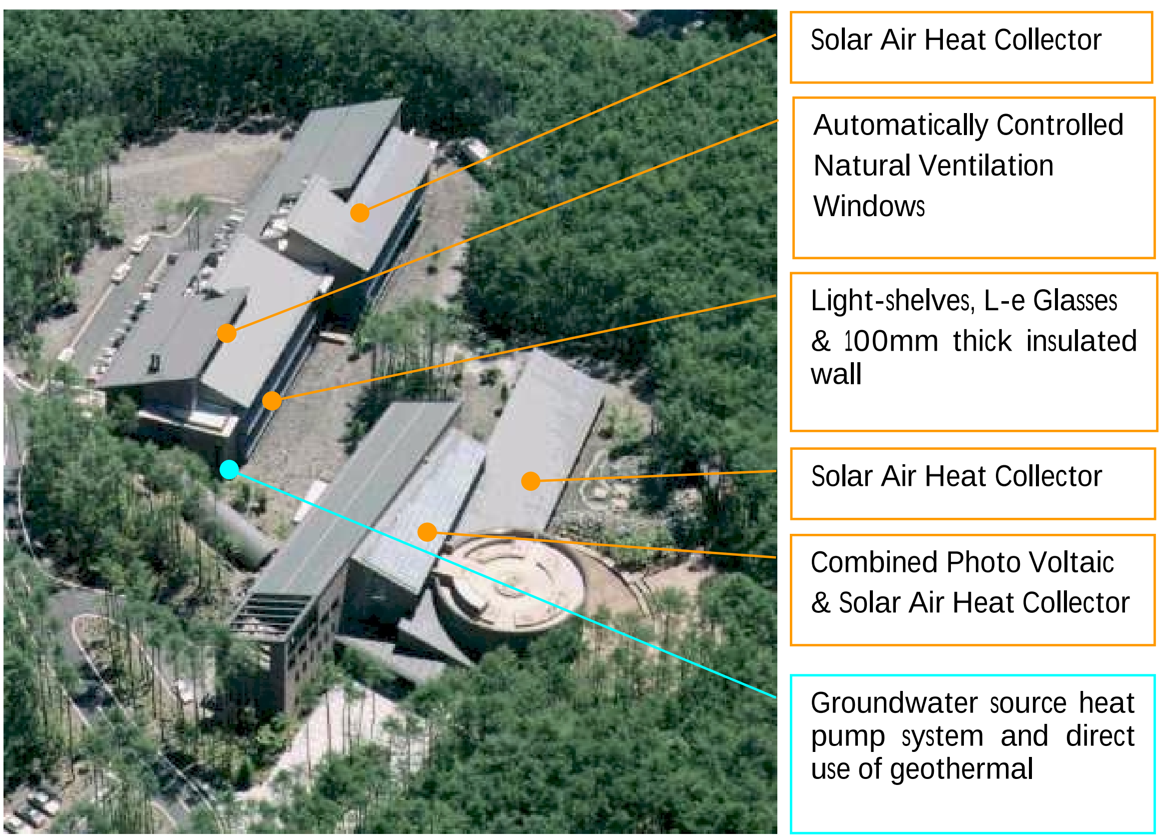
- Hour-by-hour daylighting simulation. This is a private tool.
- Hour-by-hour air conditioning system simulation by micro Peak. This is a national tool.

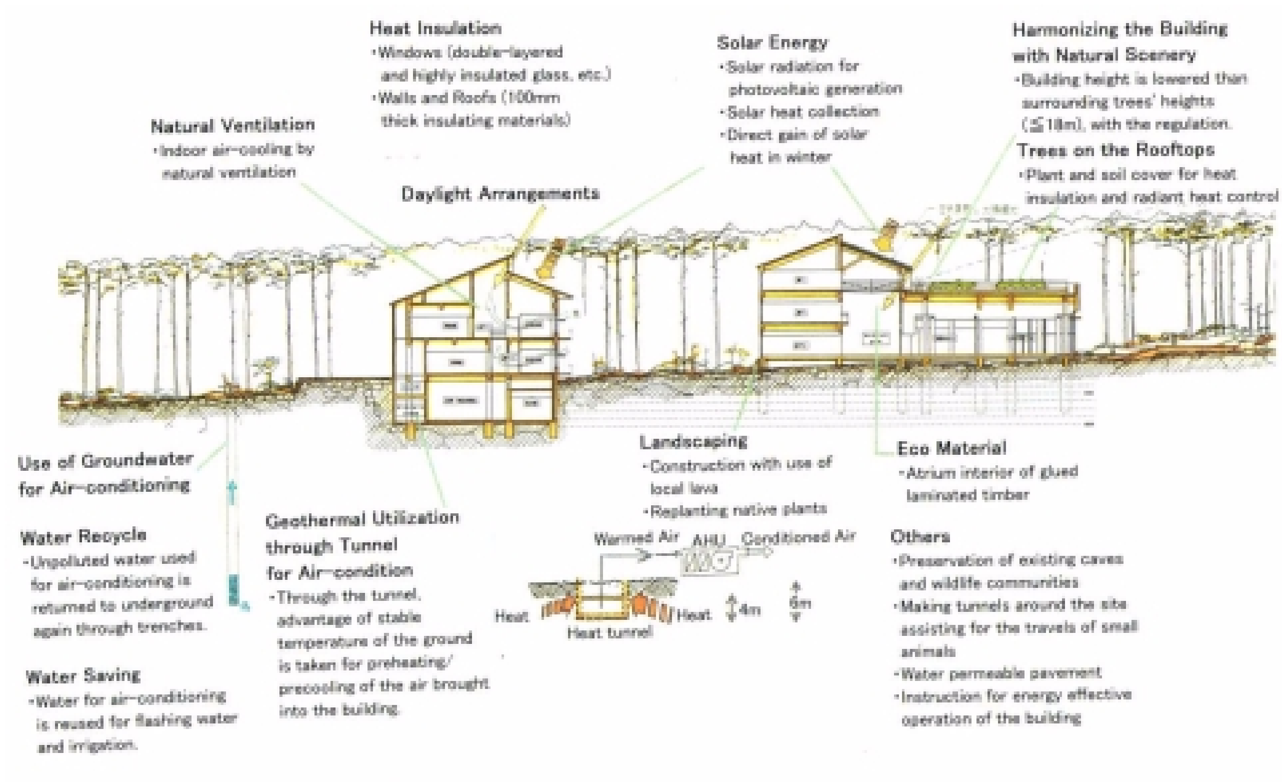
The tool(s) supported optimization (improvement) by allowing the design team to optimize the design of sunshades and windows and to optimize energy saving systems.

The tools supported the design process and were used by the environmental and mechanical engineers in the schematic design phase.

Benefits and Current Usage of the Tools

The benefits of Tool Usage were to increase energy savings and decrease environmental burdens. The current usage of tool(s) for similar projects is expected to enhance marketing of the project. There are many projects and the use of assessment tools seems to enhance the performance of the design firm.





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United States

Durant Road Middle School

Developer: City of Raleigh

Commissioned: City of Raleigh

Architects: Gary Bailey and Jill Smith of Innovative Design Raleigh, North Carolina

Located: Raleigh, North Carolina

Constructed: 1995

Cost: $12.3 million

Introduction

Durant Road Middle School in Raleigh, North Carolina is a model energy efficient school. The school met its goals for reducing costs related to energy use for lighting and cooling load; it also seems to have a positive affect on the occupants. The energy efficient design by the architects at Innovative Design in Raleigh, North Carolina came in $700,000 under budget and is expected to save $165,000 in annual energy costs. Annual energy use is projected to be half the amount of energy consumed by a comparable non-efficient school.

Site and Building

Durant Road Middle School is located in Wake County, North Carolina in the city of Raleigh. Wake County is in central North Carolina located an hour from the Atlantic Coast and an hour from the Blue Ridge Mountains. The school contains standard spaces including classrooms, gymnasiums, a cafeteria and other areas. The building is orientated lengthwise on an east/west axis to make the most of natural light.

Energy Saving Elements

Day lighting was the school design's main focus. Accounting for daylighting the design reduced the amount of energy for lighting and reduced the cooling load.

Specific elements of the efficient design include:

- South and North-facing roof monitors, which furnish daylighting to classrooms, gymnasiums, cafeteria, and other areas.
- A 30% increase in windows for daylighting. There are no windows on the east or west ends.
- Orientation is lengthwise on an east/west axis to enhance placement of the north and south facing daylighting monitors, and to reduce heat gain.
- The roof is equipped with a radiant barrier that reflects over 90% of the radiant heat.
- Low-e glazing is used throughout, including the roof monitors.
- Lighting equipment and controls are high-efficiency including motion sensors and light level sensors that automatically adjust conventional fluorescent lighting as needed.
- An energy management system is installed. The ventilation system tailors fresh air circulation to occupants of the building instead of constant operation, which is typical of school buildings.
- The reduced cooling load allowed use of a 370 ton chiller instead of the 400 ton chiller typically needed for a similar school.

Environmentally Beneficial Aspects

Reduced energy consumption and the use of natural lighting have positive impacts on both the environment and its users. Studies have shown that natural daylighting has a positive affect on student attitudes and performance. Students are inclined to be more attentive and less hyperactive in daylit classrooms. In addition to student's improved behavior, teachers have noticed an increased ability to learn. Teachers and administrators support daylit schools.

Energy efficient building has a positive affect on the environment. By reducing the dependency on power companies Durant Road Middle School is reducing the negative impacts power plants have on the environment. Some of these negative impacts include nuclear waste disposal, environmental effects of coal production, and air pollution caused by coal combustion.

Assessment Tool

The architects at Innovative Design have over 18 years experience in solar design and its benefits. Bailey and Smith used computer simulations and models to analyze and forecast the quality of lighting and energy performance of the school design. The programs they used for simulation were DOE-II and Daylite. The architects modified these programs to reflect their previous experience with schools. Innovative Design used these programs to predict overall energy as well as the lighting dynamics in individual classrooms.

Durant Road Middle School met all of the city of Raleigh's criteria for a new school building while also incorporating energy efficiency. The building uses half the energy of non-efficient schools, has an annual energy savings of $165,000 and increases the performance of its students.

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Other Sources:

American Solar Energy Society – Article November/December 1995 by: Burke Miller Thayer

U.S. Green Building Council

Switzerland

World Wildlife Funds in Geneva

Introduction

This is an illustration of how the Norwegian Ecoprofile has been used in planning of a renovation project of the World Wildlife Funds office building in Geneva. The building is more or less an ordinary office building with no special environmental aspects in excess of good environmental practice.

During a period of three years the building has been evaluated three times. One classification was carried out on the original building, the next classification was carried out before renovation and the last after the renovation was finished.

The second classification was carried out to obtain a good score due to the Ecoprofile-method, but take into account that the measures should be realistic due to the existing building. The last classification was carried out to see if there were any changes from the planned to the actual renovation.

The classifications were mainly based on information from WWF in Geneva and the consultants.

The Building and the Renovation Process

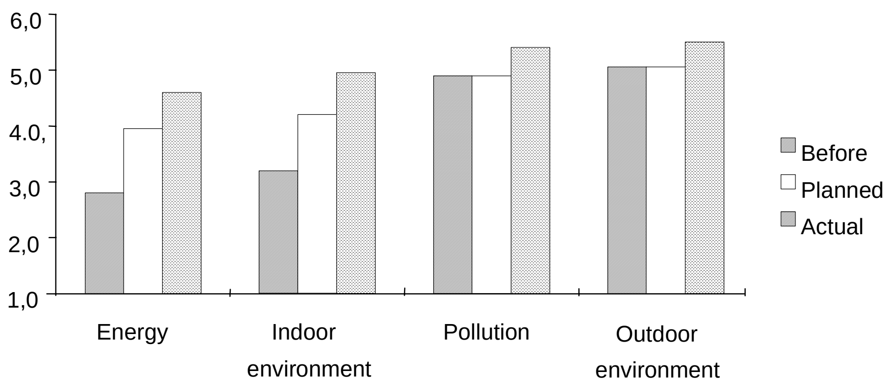
The building was built in 1978 and was renovated in 1997. It is an ordinary office building for 100 people. Total area is approximately 2400 m² divided on 4 floors. Central heating, outlet ventilation in bad conditions (very small volumes), high water consumption and original illumination system from 1978 are cues to describe the building.

Planned major measures included lower heat loss due to new windows and better tightness, a new ventilation system (balanced outlet and inlet) with significant higher volumes than originally, some cooling, reduced water consumption, an "air-infiltration-system"-wall (AIS-wall), better possibilities for temperature control, and some improved routines for cleaning.

There were some changes from the planning process to the finished building. The change of windows and the AIS with corresponding better tightness were not carried out during the renovation. The renovated building got even higher ventilation volumes than first planned and a new illumination system. Better cleaning routines were also the result.

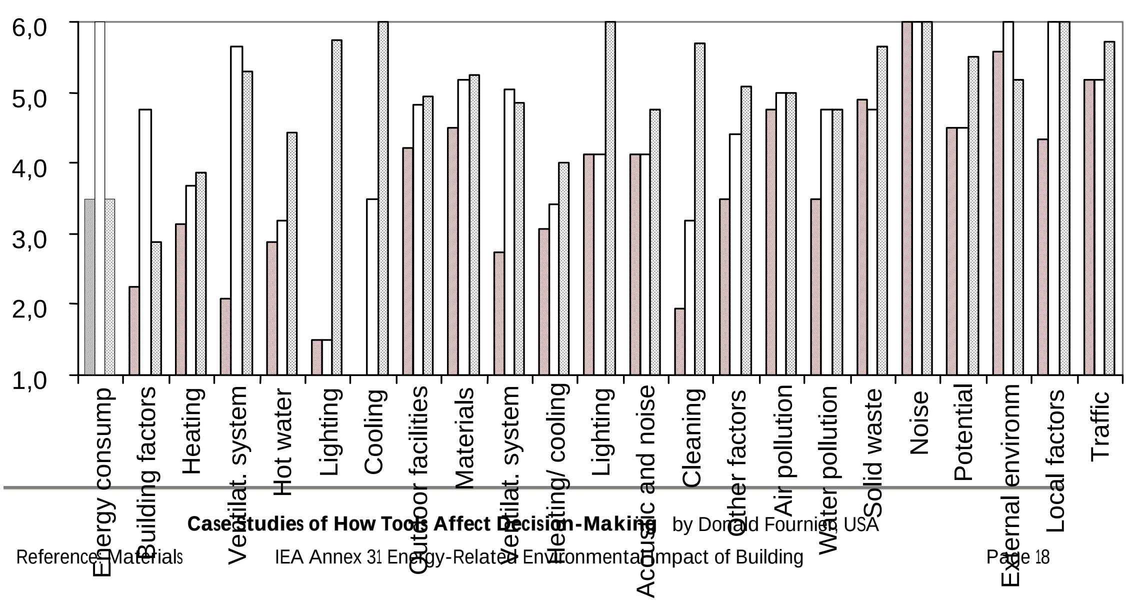
Results

The assessment results due to the four major groups in the Ecoprofile method are shown in the figure below. The higher score corresponds to lower environmental burdens, which is a positive result.



The Ecoprofile shows significant environmental improvements both from the non-renovation phase to the planned phase, and even improvements from the planned phase to the actual building. The improvements are especially within energy and the indoor environment.

Results in a more detailed level illustrate more which measures that are planned and carried out.



For some of the areas, energy consumption, building construction and ventilation are the results not so good as expected but this is compensated of significant better results for illumination and cooling than original planned.

Assessment Tool

The assessment tool is the "old" Ecoprofile used in all three classifications. The old version was used in all classifications even if the new version existed when the last classifications were done. This was made to be able to make a direct comparison. This method is somewhat different from the new method that has three main areas instead of four, which the old method had. Another major difference is that in the old version a high score represents low environmental loading while in the new Ecoprofile a low score represents high environmental loading.

The new Ecoprofile for office buildings, which now is at the Norwegian market, contains about 90 environmental parameters grouped into the three main groups, outdoor environment, resources and indoor environment. The method is only a profile of the environmental performance of the building and is no certificate due to any specific demands. The owner or the hirer of the building then decides prospective demands due to environmental performance.

Contacts

The three classifications were mainly carried out by Sverre Fossdal, Norwegian Building Research Institute. All classifications were based on information from the consultant Åke Larson Construction AS and WWF.

All results are documented in the report "Miljøklassifisering av WWF's kontorbygg i Geneve", Norwegian Research Building Institute, Oppdragsrapport O 9354, September 1998 (in Norwegian).

Netherlands

The environmental performance of Project XX (architects office built for twenty years) improved with the Dutch tool Eco-Quantum - The Netherlands

Picture 1. The wooden frame of Project XX.

Developer: Wereldhave Management Holding bv
Architect: Post Ter Avest Architecten, Jouke Post
Commissioned: BAM Rotterdam
Located: Delftechpark in Delft
Constructed: Februari 1999
Volume: 15.200 m3
Gross floor area: 2.140 m2
Costs: FL. 4.3600.000 (of which FL. 960.000 for installations)

Introduction

Re-use and recycling of the key words in Project XX in the Delftechpark in Delft in the Netherlands. The planned life of 20 years is tailored to the expected period of usage. The environmental benchmarks for this concept were contrasted with the environmental benchmarks of a standard office building using Eco-Quantum, with surprising results.

Would the environmental load of an office building be significantly reduced by tailoring its technical life to its economic life through efficient use of materials? That was the question that architect Jouke Post posed himself when designing the housing for the new office (Post Ter Avest and Jan Brouwer Associates cooperate in architectenbureau XX). He considered materials with a short life, less seasoning, renewable materials and connecting techniques that could be dismantled. W/E consultant's sustainable building set Eco-Quantum to work to answer this question. They investigated how the environmental benchmarks of Project XX, a dismantleable temporary office building, would compare with the environmental benchmarks of a reference office building.

Sustainable Building Elements

A design for short life span demands a special construction with specific details. The building must be capable of being fully dismantled and the parts must lend themselves to being reused as far as possible. Project XX has floors made of sand, cardboard air conditioning conduits, sawable columns, wooden frames and recyclable triple glazing (see table 1 and picture 1). There is a minimum of installations. The building has a good overall energy performance. The building is light in weight: 800 kg/m2 as against 1,350 kg/m2 in the reference office. The architect Post calls this light High Tech. Not because of the installations, but because of the innovative technical solutions. To restrict waste after the demolition of the building, the connecting techniques in Project XX can be dismantled, adhesion was totally banned and the concept that raw materials must be capable of being recycled was at the heart of things. There was no landfill or incineration whatsoever. Most of the materials can be reused in 20 years or will be at the end of their life. Any cycles are maintained as far as possible.

The reference building is a standard office building (see table 1). There is a concrete bearing construction, a brick and concrete front, plastic frames and double-glazing. The ground floor and the upper floors are made of concrete hollow-core slab floors. The Energy Performance Coefficient (EPC) complies with the requirements under the Building Code. The materials of the reference building are generally recycled in a low-grade manner after demolition.

Energy Saving Elements & Environmentally Beneficial Aspects

Figure 1 illustrates the differences between the two buildings measured against the four environmental aspects: the result of calculations with Eco-Quantum. The starting point is a life of 20 years, followed by demolition. The environmental benchmarks of both buildings are expressed in square metres of useful surface area per annum.

If energy consumption during the use phase is included, the environmental load of Project XX is significantly lower than that of the reference office. Depending on the environmental benchmark, the difference was no less than 51 to 64%. This is largely attributable to the good overall energy performance of XX.

If energy consumption during the management phase is excluded, a different picture emerges as illustrated in Figure 2. The environmental benchmarks for emissions and waste remain lower for Project XX. This means that the materials of XX compared to those of the reference building contribute less to such factors as reinforcing the greenhouse effect, acidification, eutrophication, ecotoxicity and depletion of the ozone layer. For example polyurethane is used as an installation material in the reference building and the water pipes are made of copper. In addition, the quantity of waste after demolition of Project XX is lower: many materials can be reused or recycled in a high-grade manner.

The environmental benchmarks for raw materials and energy by contrast are higher for XX. This results from the fact that the materials used in XX contribute more to the environmental effect of depletion of raw materials (28%) and that more energy is required for production (43%) than those for the materials of the reference building.

The environmental benchmark for raw materials breaks down into two parts: depletion of raw materials and depletion of energy carriers. The first is virtually the same for both buildings. Depletion of energy carriers is 24 per cent greater for Project XX than for the reference building. One factor is the wooden frames. Whilst the Bintangor does have an FSC hallmark, it has to be transported from a great distance to the Netherlands: this leads to depletion of energy carriers. The large triple glazed surfaces and aluminium weather drip rails are responsible for the higher energy content. The reference building is mainly made of concrete, which poses a relatively low load on the environment. A further comment to be made here is that the calculation does not include either erosion of the countryside by digging out raw materials or depletion of marl and gravel.

Assessment Tool

Project XX will not collapse and will return to dust after twenty years, as Post prosaically puts it. A longer life is very feasible. Longer life spans for both buildings were therefore calculated using Eco-Quantum. The result changes only little, as a number of components will have to be replaced after 20 years on Project XX and the reference building alike. The bearing construction and the skeleton of both buildings have a longer technical life.

Benefits & Current Usage of the Tool

Eco-Quantum was not only deployed for Project XX to compare two concepts. Eco-Quantum also helped during the design to optimise the environmental performance of Project XX. For example, aluminium frames had been selected in a previous design of the building. The environmental load of wooden frames proved to be so much lower that wooden frames with the FSC hallmark were chosen.

The use of Eco-Quantum supports the assumption that responding to developments with efficient use of materials substantially reduces the environmental load of an office building. For Project XX compared to this reference building, the potential environmental effects in terms of use of materials as a result of emissions and waste are significantly lower. Environmental experts consider the effects of the environmental benchmark for emissions such as reinforcing the greenhouse effect and depletion of the ozone layer important factors to avoid. Project XX succeeded as far as that is concerned.

When it comes to depletion of raw materials and the energy content of materials, one could look for materials closer to home (such as Northern European types of wood with FSC hallmark) to improve even further the environmental performance of this short lifespan concept over that of the reference building.

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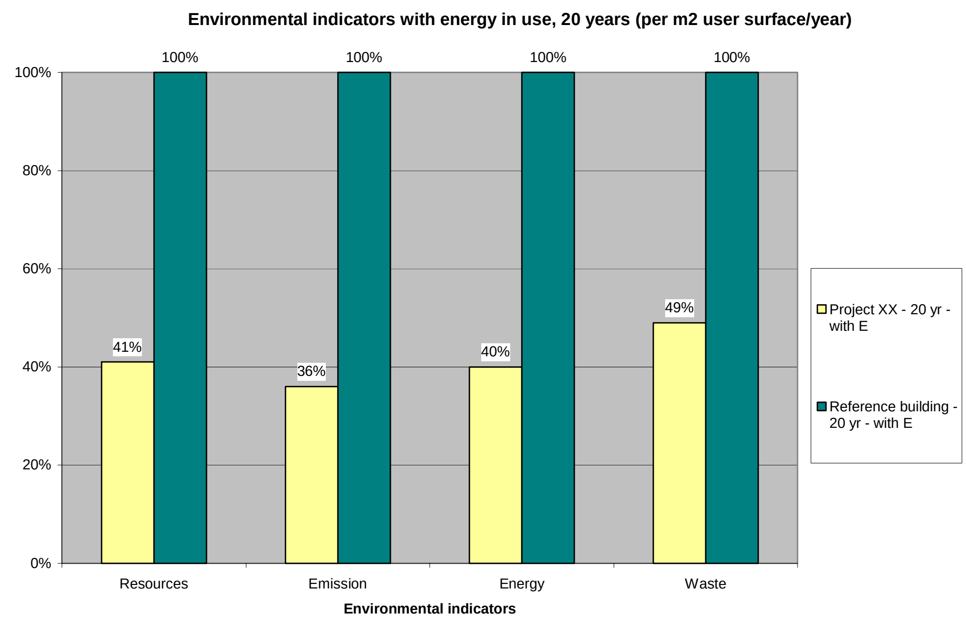
Figure 1: Environmental benchmarks of Project XX and the reference office building. Energy consumption in the management phase is part of the calculations. The life of



both buildings is 20 years. The environmental benchmarks are expressed in square metres of useful surface area per annum.

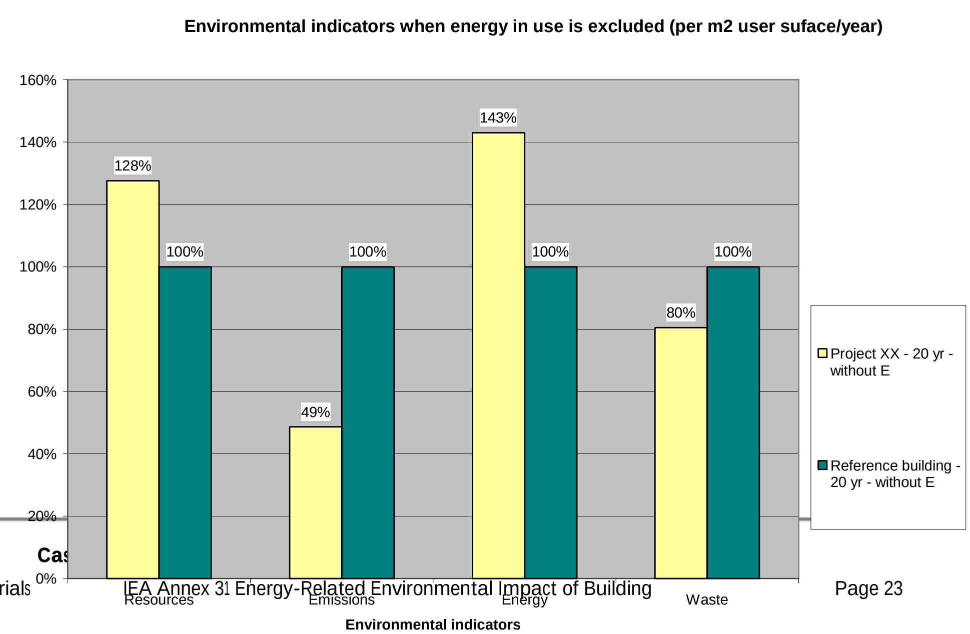


Figure 2. Environmental benchmarks of Project XX and the reference office building. Energy consumption in the management phase is not included. The life of both buildings is 20 years. The environmental benchmarks are expressed in square metres of useful surface area per annum.

Table 1. Characteristics of building XX and the reference building.

	Project XX	**Reference building**
Floor surface (m2)	2100	1500
Energy Performance Coefficient	1.0	1.9
Pile foundation	concrete, 20% regranulate as replacement of gravel	concrete
Columns	pine wood	concrete
Beams	pine wood	concrete
Ground floor floor	concrete, hollow-core, 20% regranulate as replacement of gravel	concrete, hollow-core slab floor
Exterior wall	FSC-wood with triple glazing	masonry, concrete, PVC-window frames with double glazing
Storey floor	cemented wood fibre board with sand	concrete, hollow-core slab floor
Roof construction	beams of pinewood, roof slabs of wood fibre concrete	concrete

CANADA

Town of Revelstoke, Community Energy Planning

Introduction

A planning tool named TIRA was used in the City of Revelstoke BC, Canada, to assist in preparing a Community Energy Plan. The tool used data derived from evaluations of individual building types to estimate costs and benefits for the entire building stock. This 'stock aggregation' approach permitted detailed evaluations of costs and benefits for alternative policies and systems at the community scale. TIRA was developed by the Sheltair Group; a Vancouver-based consulting firm who undertook the planning project. The Canadian government was a partner in this pilot project, providing input on the plan and financial support to the City of Revelstoke.

Site & Project Description

Revelstoke is located on the Trans-Canada Highway approximately 565 km east of Vancouver. The City is situated in the Columbia Mountains in the interior wet belt, and receives heavy snowfall in the winter months. The snow season is typically from mid-December to mid or late March. Revelstoke has an average of 4,225 heating degree-days Celsius each year. The population estimate for the City of Revelstoke as of July 1, 1996 was 8,507 (B.C. Stats 1997), with an annual growth rate of approximately 1%.

The city and residents of Revelstoke spent approximately $19 million dollars on energy in 1996, the base year of the study. On a per capita basis, energy consumption for the residential building and personal transportation sectors was about $1280 per person per year. This corresponds to 8% of the average pre-tax income. Figures 1and 2 illustrate the breakdown of energy consumption by sector and end use for Revelstoke in 1996. By providing information about how energy is being consumed, a Community Energy Plan helps decision-makers select those programs and policies most likely to reduce energy consumption and expenditures and to minimize the negative impacts on air, land and water.

Figure 1 Revelstoke's Energy Consumption by Sector (GJ)

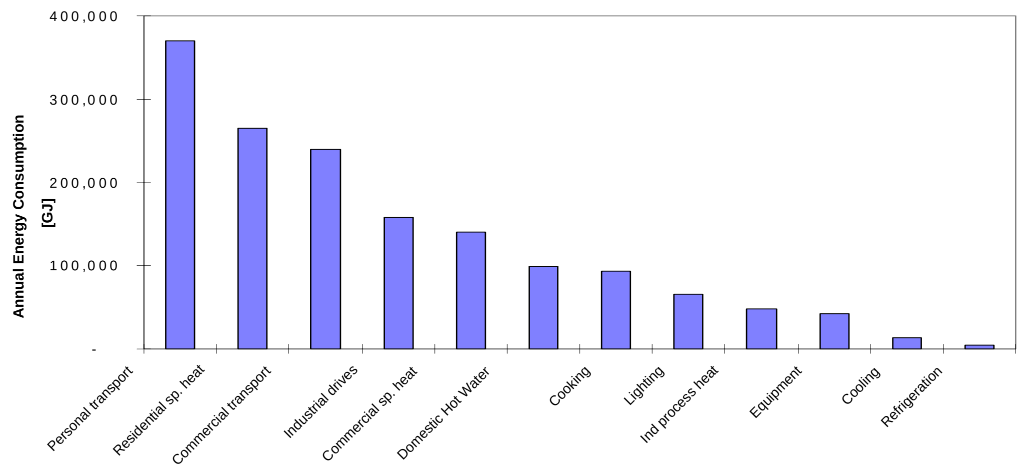
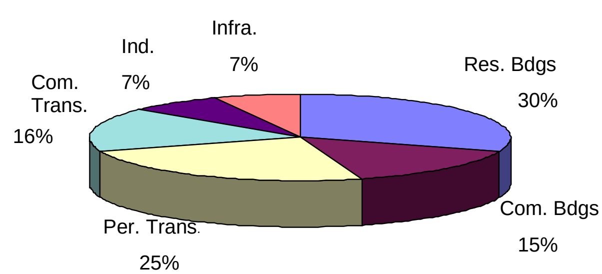


Figure 2: Energy Consumption by Sector



The project commenced in the summer of 1997, and was complete by fall, 1997. The first step was to use Revelstoke's community goals to create a logical framework for evaluating development scenarios. From the community goals, a number of objectives, targets and indicators were developed to ensure that options explored in the plan were consistent with the broader community vision. Estimates of current energy consumption were developed for buildings, transportation, industry and infrastructure. Indicators were developed including financial, economic development, CO_2 emissions, and per capita energy use. One business as usual scenario and three alternate scenarios were developed. Scenarios were developed to assess the impact of new policies and programs, including:

- A district energy system

- o The retrofit of older residential homes, and
- o ESCO activity in the local municipal and school buildings.

Assessment Tool

To analyze resource flows and develop costs of different development scenarios, the project team adopted a tool-kit approach to performing the analysis of different development alternatives for Revelstoke.

TIRA was used to create a range of development scenarios, and to analyze the associated physical resource use and lifecycle costs. The major strength of TIRA is its ability to model the resource flows and associated costs of buildings and infrastructure using a rigorous, bottom-up approach. A Geographic Information System (GIS) was also used to perform spatial queries for a range of indicators, and for developing maps for presentations. The TIRA method is presented in Figure 3.

Potential Benefits of Community Energy Planning

- saving money on energy expenditures by households, businesses, the municipality, and other large energy users in the community;
- saving money on infrastructure capital costs by the municipality and taxpayers, including the provision of new infrastructure and expansion of existing infrastructure facilities;
- creating local jobs through direct and spin-off industries of new energy-related businesses, such as energy and water retrofit businesses and new energy supply businesses;
- reducing local air pollution;
- reducing greenhouse gas emissions which contribute to global warming; and
- sustainability through greater diversity and local control of resources.

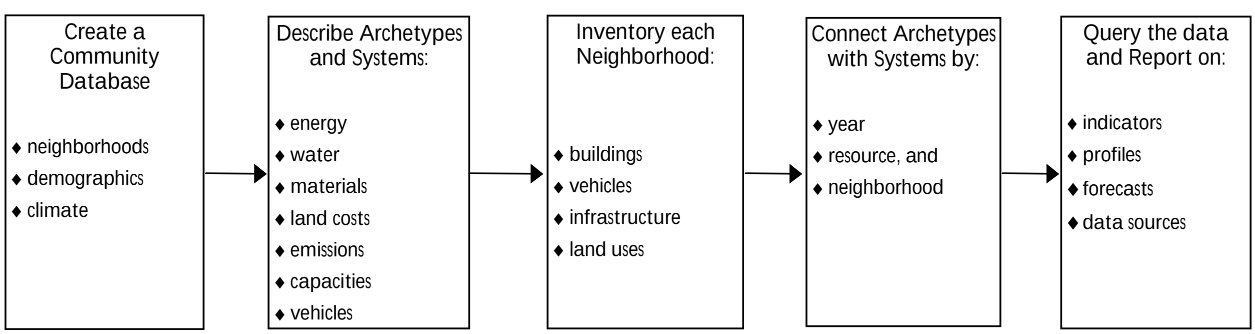


Figure 3: TIRA Method

The toolkit incorporates well-validated models to estimate resource consumption. For example, DOE 2.1 is used for commercial building energy; the Canadian government's HOT2000 is used for residential buildings. Assumptions are transparent to the user, and can be altered if necessary to reflect community concerns. TIRA uses archetypes as a convenient method to model end uses. For example, archetypes of buildings are customized by the user from a library of archetypes provided by the program.

Each building archetype statistically represents a portion of the stock, but can be accurately modeled as a single building for purposes of estimating resource consumption. The impacts of changes to individual technologies at the building level can be calculated for individual neighborhoods, or for the community as a whole. Similar archetypes exist for linear infrastructure, vehicles, and industries.

Data sources included:

- The electric and gas utilities for building energy consumption data
- The Assessment Authority and the City Building Department for building stock information
- The Motor Vehicle Branch for vehicle fleet information
- Statistics Canada and Ministry of Vital Statistics for demographic information.

Scenarios are created by changing and remodeling the archetype descriptions at milestone years, and by changing the connections between building archetypes and the various supply and processing systems available to the neighborhood or community. By modifying the default archetypes and system templates from TIRA's extensive library files, users may quickly and accurately customize TIRA to describe their community. Buildings, transportation systems, industrial processes and infrastructure components were modeled to reflect the local conditions, and the interests and objectives of the community.

Applying the TIRA methodology, the project team adopted a four step methodology used in community integrated resource planning, and briefly described below.

1. *Load the TIRA databases* with default archetypes of buildings, transportation, and infrastructure.
2. *Create a business as usual scenario for Revelstoke*, including estimates of how well the scenario performs in terms of the indicators and targets developed.
3. *Create alternate scenarios*, to examine opportunities to improve the energy efficiency, livability and sustainability of Revelstoke through the utilization of a range of land use patterns, transportation alternatives, and building technologies.
4. *Develop a preferred option*, for future development in Revelstoke, based on a portfolio analysis of the different alternatives.

A "Business As Usual Scenario" was developed to model the most likely energy consumption pattern and resulting impacts in the absence of any major new initiatives over the next 20 years.

TIRA was then used to examine how three alternative scenarios impacted energy use in Revelstoke. Scenarios are a way of describing and analyzing future conditions. By changing some variables–such as the rate of population growth or energy efficiency standards–and holding other factors constant, Revelstoke in 2016 can be described and modeled. Then, the consequences and impacts of policies and programs can be evaluated in terms of their impact on the community. In the case of Revelstoke local issues were combined with the community goals to develop the alternative scenarios examined.

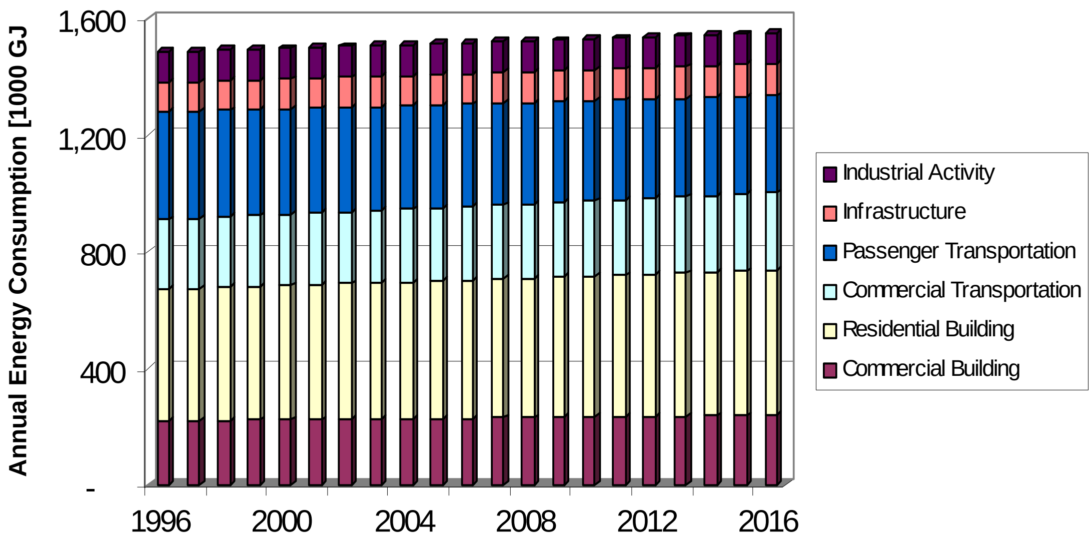


Figure 4: Energy Forecast, 1996-2016, Business as Usual

Figure 4 shows how energy consumption is likely to change over the next 20 years, assuming a "Business as Usual Scenario". Energy consumption and carbon dioxide emissions are summarized in Table 2. Total energy consumption is expected to increase from 1,480,000 GJ in 1996 to 1,550,000 GJ in 2016. Although Revelstoke's population increases by almost 11%, energy use increases by only 4.7%. This is because the new stock (buildings, vehicles, etc) adopted in the community between 1996 and 2016 is more energy efficient than the older stock that is being replaced. In addition, the older stock is becoming a smaller proportion of the overall stock.

On a per capita basis, the total annual energy use will decrease from 175 GJ in 1996 to 165 GJ by 2016. This change represents a 5.7% decrease in per capita energy consumption over twenty years. This represents a 3.1% increase in CO_2 emissions, and a 6.6% decrease in the per capita emissions.

Table 2: Energy and Green house Gas Emissions, 1996 and 2016, Business as Usual

	1996	2016	% Change
Total Energy [GJ]	1,480,000	1,550,000	4.7%
Per Capita Energy [GJ/capita]	175	165	-5.7%
CO_2 equivalent [tonnes]	74,500	76,800	3.1%
Per Capita CO_2 equiv. [tonnes/capita]	8.75	8.17	-6.6%

How the Tool supported Optimization

Three alternate scenarios were developed as part of the CEP. The alternate scenarios were developed to take advantage of local opportunities and overcome constraints identified through discussions with community decision-makers and community representatives. The scenarios are described below.

District Energy System for Revelstoke

A feasibility study was conducted for a District Energy System. The facility would to burn wood waste from local sawmills, and supply hot water for space and water heating to buildings in the downtown core, as well as process steam to industry, and heat to pasteurize water for the community. Several factors motivated the development of this scenario:

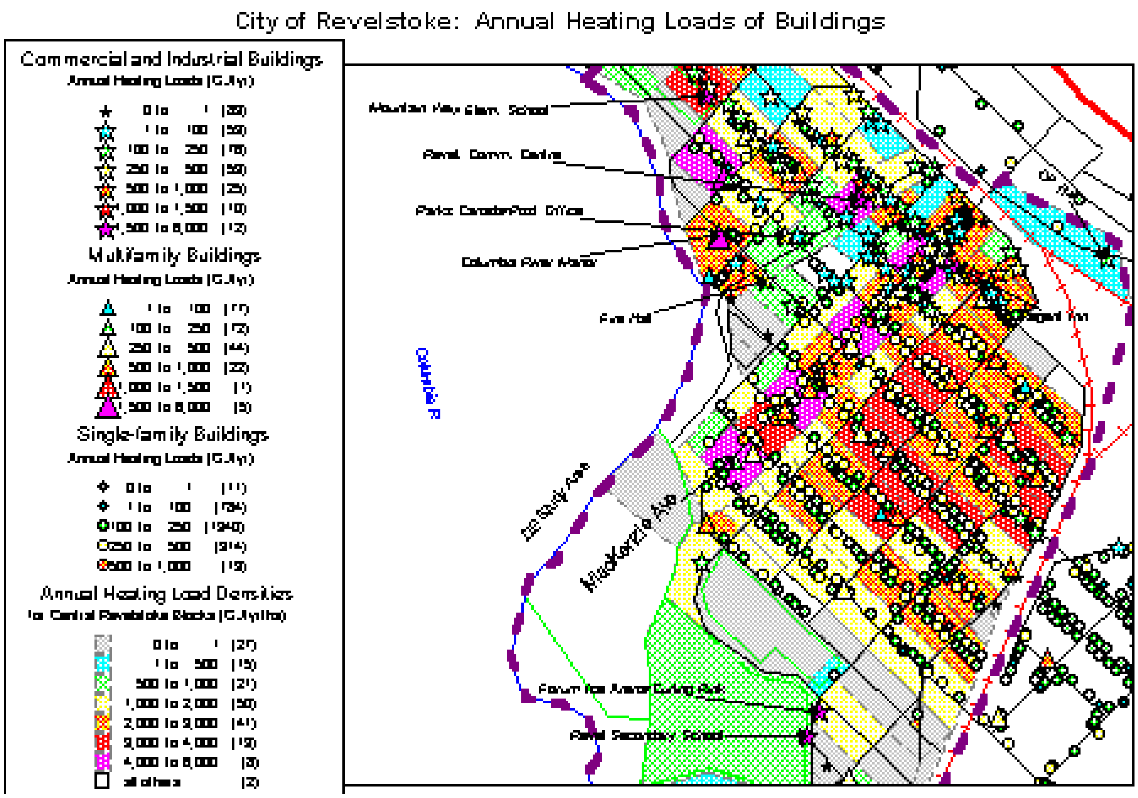
- Wood waste is available at low or negative cost from local saw mills.
- Local sawmills burn their waste wood in non-air emission compliant incinerators with limited pollution control devices, or use landfills. There is currently no heat recovery from the incineration of the wood waste. On an individual basis, these wood processors are facing significant investment decisions to meet current air pollution regulations. Analysis showed there was enough wood waste from the local logging operations to meet the energy supply requirements of the proposed District Energy System.
- Space heating for buildings in Revelstoke is one of the highest end use loads.(see Figure 2). Therefore, it offers one of the greatest opportunities for benefits from energy planning. Typically, buildings in Revelstoke are heated directly with propane, oil, electricity or wood furnaces or stoves. Consumers of fossil fuels in Revelstoke have been subject to significant price increases in recent years with limited capability of switching to alternative supplies. Those who can switch often go back to burning wood, which results in increased local air quality problems.

The investment for the district energy system, including plant, distribution system, operating and maintenance has a payback period of seven years. In addition to the financial benefits, the district energy system has a number of additional benefits that are consistent with community goals. The system would:

- consume all wood residue in the area and eliminate existing wood incinerators, open burning and landfilling of wood waste

- o reduce atmospheric particulate emissions through the use of pollution control devices, resulting in improved air quality for Revelstoke
- o utilize a currently wasted resource
- o improve visibility and environmental aesthetics
- o reduce greenhouse gas emissions by 5.5% below baseline forecasts
- o increase resiliency of the energy supply through diversification
- o increase money re-circulation inside the community
- o create 20 full time equivalent positions per year in the community

Figure 5 GIS Map of Building Heat Loads from Computerized Thermal Models



Residential Buildings Energy Retrofits

This scenario involved the development of a utility managed energy retrofit industry in Revelstoke that would retrofit older residential single-family homes. The scenario was developed to address the issues of high annual energy consumption for older buildings, as well as the unstable price for propane service in the community.

Since the local propane distributor started providing service to homes in Revelstoke in 1991, the residential price of propane has increased by about 42%. Many residents originally switched to propane due to promises of lower fuel bills and stable prices. To avoid further price increases and price instabilities, many residents are now contemplating a switch back to oil, wood or electricity for water and space heating. Based on analysis used in this study, it was found that the most cost-effective way for residents to reduce energy costs and buffer themselves against unstable energy costs is to make their homes more energy efficient.

While the local propane distributor is frequently seen as the cause of the high costs for energy, there is an opportunity to utilize a new program launched by BC Gas called "Homeworks" to address this issue of high operating costs for homeowners. The Homeworks program include:

1. A complete energy audit of a house using local contractors who are trained to perform energy audits on houses (local job creation), using sophisticated software and diagnostic tools.
2. A report showing the homeowner where energy is being consumed and the most cost-effective ways to reduce their energy bills.
3. Optional financing through the utility to pay for energy retrofits.
4. Professional installation of energy saving measures.
5. A quality assurance program.

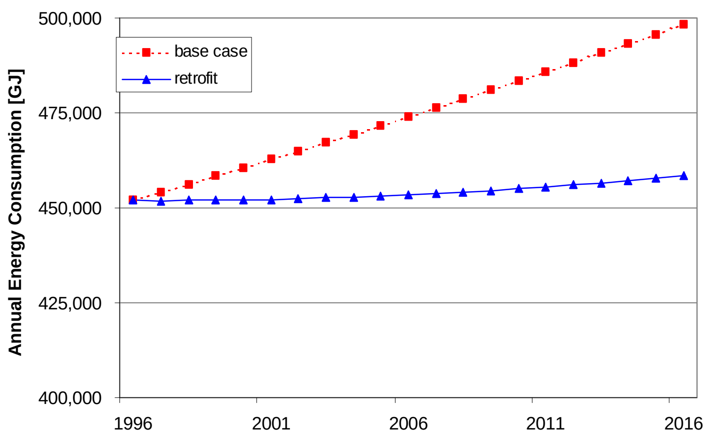


Figure 6: Potential to reduce energy consumption in homes.

Residential Buildings Energy Retrofits Scenario Benefits

Predicted energy savings from this scenario over the next 20 years are shown in Figure 6. It was found that:

- The archetypal older home in Revelstoke can achieve a 15% reduction in annual energy costs through an investment of approximately $970. This translates into a payback period of approximately 4.7 years.

- Over the next twenty years, this scenario will save the accumulated equivalent of the energy consumed by the entire residential sector in one year. This corresponds to 428,000GJ.
- The reduction in energy consumption will result in a reduction of CO2 emissions by 3% in the community, below the baseline scenario, by 2016.
- Assuming the creation of 12 jobs for every $1 million dollars spent[1] in the community, this scenario will create approximately four full time job equivalents.

Residential retrofit programs have been piloted in a number of communities in BC and are quite successful in saving energy, and reducing energy costs to homeowners. In some locations, the program has also included a water audit component, enabling communities to save both energy and water.

Retrofit of Institutional, Municipal and School Buildings

The Infrastructure and Institutional Buildings Energy Retrofit Scenario involved the implementation of energy retrofit programs for existing Municipal buildings, School District buildings, and Municipal Infrastructure. Using TIRA, Sheltair identified the retrofit of School District buildings, Municipal buildings and infrastructure as having the greatest potential for successful implementation.

Similar to the residential retrofit program explored above, there are Energy Service Companies (ESCOs) that provide energy retrofit services to larger buildings. An ESCO will:

- perform a detailed energy audit on a building,
- examine the most cost effective energy retrofit options,
- pay the cost of retrofitting the building,
- perform the work, and
- share in the savings from reduced energy bills to retrieve their initial investment.

After the ESCO has received their portion of the energy savings over a fixed time period, the building owners (the city of Revelstoke and the school board in this case) continue to keep the savings over the life of the building.

Energy Service Companies will only finance and carry out energy retrofit projects if they are of sufficiently large scale to be financially viable. Through discussions with several of the largest ESCO's working in BC, it was determined that the energy retrofit of both Municipal and School District facilities at the same time would be required to make the scenario viable.

[1] BC Energy Aware Committee, A tool-kit for Community Energy Planning in BC, Pg.11, 1997

Scenario Benefits from Retrofit of Institutional, Municipal and School Buildings

Direct benefits to the Municipal government from energy retrofits are summarized in Table 3.

Table 3: Impact of Municipal and School Retrofit

Buildings Considered	• City Hall • Community Centre • Ice/Curling Forum • Public Works Yard Firehall, Schools
Infrastructure Considered	• Sewage Treatment • Street/Traffic Lights
Current Energy Consumption	49,778 GJ/Year
Range of Energy Saving	10% - 34%
Total Energy Savings	9,000 to 12,400 GJ/Year
CO2 Reduction	184 to 266Tonnes/yr
Current Energy Costs ($/Year)	$554,000
Energy Cost Saving ($/Year)	$120,000 to $157,000
Payback Period	7 to 10 years
Net Present Value	$955,000 to $1,435,000

Benefits of Tool Usage

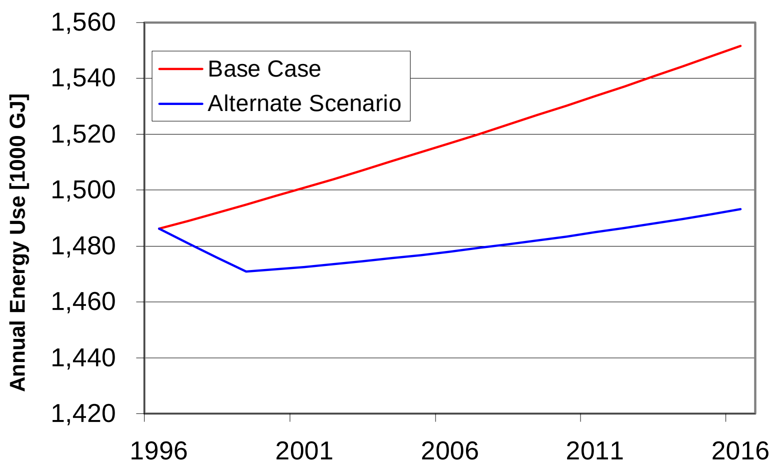
Use of TIRA allowed for a more quantified and credible estimation of benefits for alternative development scenarios in different building segments. This helped to generate political support for new energy policies, and build consensus among the stakeholders in the community. Consequently the City of Revelstoke has formally endorsed the recommendations of the CEP. As such, the City has agreed to participate in developing the District Energy System as a funding partner, and is considering the use of Energy Service Companies to reduce the cost of local infrastructure. Additional funding partners and an ownership structure are now being finalized for the District Energy System. In addition, a Residential Buildings Energy Retrofit program was established in early 1998, and is now active in the community improving the performance of the residential building stock.

Table 4 and Figure 7 highlight the projected energy savings between 1996 and 2016 from cumulative implementation of the 3 alternate scenarios developed above. Assuming all three scenarios are implemented by the year 2016 there will be an annual decrease in energy consumption of approximately 57,000 GJ per year below business as usual projections.

Table 4: Impact of Implementing Revelstoke Community Energy Plan

Indicator	1996 Baseline	Business As Usual-2016	Composite Scenarios-2016
Total energy consumed per year by community [GJ]	1,486,000	1,550,000	1,493,000
Per capita energy consumed per year (excluding industrial processes) [GJ]	162	154	147
Total tonnes of greenhouse gas emissions per year in CO2 equivalents - by community	74,500	76,800	69,900
Per capita tonnes of greenhouse gas emissions per year in CO2 equivalents	8.8	8.17	7.43
Per Capita energy operating expenditures per year in 1996 dollars - by households	$1,250	$1,260	$1,170
Net ongoing full time job equivalents resulting from implementation of the energy plan	0	0	26
Percentage of energy supplied by locally and operated energy producers	0	0	8%
Number of new industry types that are locally owned and operated resulting from energy plan	0	0	2

Figure 7: Impact of Community Energy Plan



Most noticeably, implementation of all scenarios of the Community Energy Plan will lead to:

- an average reduction of household expenditures on energy by 7%
- the creation of 26 full time jobs
- the creation of 2 new local industries
- a reduction of per capita carbon dioxide emissions by 16% below 1996 levels
- The displacement of 75,000 GJ per year of fossil fuel to renewable energy by the combustion of wood waste

In addition, the cumulative savings on energy dollars spent in the community between 1996 and 2016 are approximately $10 million dollars.

Current Use of the Tool

TIRA has been used as a proprietary tool as part of a number of similar planning exercises for communities and regional governments. Most recently the tool has been used to plan growth for regional districts and resort communities. TIRA is now being referred to as an Urban Forecasting Information System, and is undergoing development in preparation for commercial distribution.

Summary

The various case studies all demonstrate significant environmental improvements with the application of life-cycle assessment tools. By utilizing the assessment process in the design phases, it creates a positive impact on the environment and in most instances the user. In addition, the application of a stock aggregation tool measures environmental impact on a larger community wide scale. Since the current application of assessment tools has proven successful, marketing of the projects is expected to enhance the performance of projects for design firms.

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