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The Challenges of Designing and Building a Net Zero Energy Home in a Cold High-Latitude Climate

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Abstract

Edmonton, Canada is far from the equator at 53°34' N latitude – closer to the pole than Tasmania – with winter design temperatures of -32°C and a winter solstice with only 7.5 hours of daylight. This presented significant technical challenges to an interdisciplinary group working at designing a 'net-zero' energy house, a house that produces as much energy as it consumes over a year. Though there is an abundance of solar energy in the spring and summer, the key design challenges come in winter with cold temperatures, the greatest demands for space and water heating and domestic electricity, and short days with sun angles within 13° of the horizon.

A number of systemic challenges and barriers to the wide-spread implementation of solar and energy efficiency technologies in residential, commercial and industrial sectors exist that are related to municipal, provincial and national policies. These barriers will be similar in other Canadian cities and cities around the world. Examples include subsidised utility energy prices, little value given to environmental benefits, building code restrictions, planning restrictions, lack of simple access to the electrical grid, lack of qualified design professionals, technicians and trades, lack of expertise in an integrated design process, lack of appropriate design software, lack of building-integrated solar products, untested energy efficient products and processes, and products focussed on buildings with large energy consumption.

This paper provides an overview of how the technical challenges in designing and building the Riverdale NetZero house, which will be completed and operational by 2008 April, were overcome. It will also provide an overview of the policy barriers that are being encountered in the implementation of net zero energy technologies including recommendations to mitigate or remove those barriers.

1. INTRODUCTION

A net zero energy (NZE) house produces as much heat and electricity as it consumes on an annual basis. Such a house has never been built before in an urban setting in Canada. "Near zero" and "net zero ready" house concepts are also being developed. "Near zero" recognises when a house's purchased energy is very low and is thus close to the net zero target. "Net zero ready" recognises when the house's infrastructure and building envelope are developed to facilitate the addition of suitably sized solar energy technologies post construction. The decision to add solar technologies could be, for example, as solar prices decline, as fossil fuel prices rise, and as concerns with fossil fuel resource depletion and environmental degradation continue to grow.

The net zero energy goal is achieved by employing a combination of technologies that reduce house energy requirements and use on-site renewable energy systems. Specifically a net zero energy strategy:

1. reduces domestic electricity consumption through energy efficient appliances and lighting;
2. reduces household water heating requirements through water efficient appliances;
3. reduces space heating and cooling energy using an energy efficient building envelope; and
4. uses appropriate site-based renewable energy systems to supply heat and electricity (typically only solar-based and geothermal technologies would be used in an urban setting).

This paper is written from the perspective of the environmental, governance and regulatory climates in the province of Alberta in Canada.

1.1. Canada and Net Zero Energy Houses

In 2006, the Canadian government's housing agency, Canada Mortgage and Housing Corporation (CMHC), organised a net zero energy healthy house pilot initiative based on five guiding principles for sustainable design: Health, Energy, Resources, Environment, and Affordability. This initiative, now branded as "EQuilibrium Housing",[1] is seen as a model for sustainable housing with low/no housing related environmental impacts on water, land and air. The long-term goals of EQuilibrium housing are for community scale demonstrations of 1500 EQuilibrium houses to be underway by 2010, and all new housing to be EQuilibrium housing by 2030. Since this will present significant challenges, it is important to find out what these are.

As the first step in reaching their goal, CMHC set up a design-build competition to attract 12 builders from across the country to each design and construct a net zero energy healthy house in their local area. It elicited a huge response, with over 600 builders asking for information on the initiative and 72 builders organising design/build teams. This interest is continuing to grow. Both builders and homeowners are seeing the options for reducing house energy and emissions broadened considerably, and are now developing plans to build both customised and mass produced net zero energy houses.

The proposals in the competition were assessed on their responses in the following areas:

1. Health – indoor air quality, emissions, thermal comfort, moisture, particle control, ventilation, daylighting, noise, water quality;
2. Energy – annual energy consumption, renewable energy strategy, peak electricity demand, embodied energy strategy;
3. Resources – sustainable materials, durability, material efficiency, water conservation, adaptability / flexibility;
4. Environment – land use planning, sediment and erosion control, storm water management, waste water management, solid waste management, air pollution emissions; and
5. Affordability – financing, marketability.

1.2. Riverdale NetZero (RNZ) Energy House (www.riverdalenetzero.ca)

A net zero energy house is a complex concept. Though the consumption and supply of domestic electricity in a house is relatively simple due to the reliability and energy absorption ability of the electrical distribution grid, the consumption and supply of heat is very complex. Its complexity arises from the diurnal and annual interplay of solar radiation, thermal mass, heat gains from occupants, domestic electricity use and equipment standby losses, and the varying personal-taste and activity-based requirements for thermal comfort in a home.

This paper discusses the challenges being faced and managed in constructing the Riverdale NetZero Project, one of the 12 winners of the EQuilibrium competition. The house is a duplex, 165 m^2 above grade, two-storey, with three-bedrooms per side (illustrated in Figure 1). It will be finished construction at the end of April 2008 in Edmonton, Alberta. One side of it will be sold immediately, and the other will be open as a show home for at least six months. The project team for the house consists of 45 specialists in design, energy, water, construction, financing, marketing, communication and technology transfer. The project's three proponents are Peter Amerongen of Habitat Studio & Workshop (designer, builder, developer), Andy Smith of Solnorth Engineering (structural engineer, passive solar heating) and Gordon Howell of Howell-Mayhew Engineering (electrical engineer, solar electricity).

In following the nascent strategy for developing a net zero energy house in Canada, the energy features of the house include (for each side of the duplex):

1. Reduction in domestic electricity consumption: highly energy efficient appliances, motors, equipment, lighting; task-focussed lighting; solar illumination; controls on selected phantom electrical loads;
2. Reduction in water consumption and water heating energy: highly water efficient appliances; drain water heat recovery unit;
3. Reduction in space heating energy consumption:
   a) Double-2x4 stud wooden walls insulated to RSI 9.86 (R-56) with 400 mm of cellulose fibre;
   b) Ceilings insulated to RSI 17.6 (R-100) with 690 mm of cellulose fibre insulation;
   c) Basement walls insulated to RSI 9.51 (R-54) with expanded polystyrene, isocyanurate and cellufibre;
   d) Basement floor insulated to RSI 4.2 (R-24) with extruded polystyrene insulation;

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[1] Information on EQuilibrium Housing can be found at <www.cmhc-schl.gc.ca/en/inpr/su/eqho/index.cfm>.

e) Windows with soft low-emissivity coatings, argon gas fill, low conduction glazing spacers, and insulated fibreglass frames;
   1) south and east/west triple-glazed windows with a centre-of-glass thermal resistance of RSI 1.3 and 1.5 (USI 0.8 and USI 0.68, R-7.3 and R-8.3);
   2) north quadruple-glazed windows with a thermal resistance of RSI 1.8 (USI 0.57, R-10);

f) Envelope air tightness expected to be 0.5 air changes per hour at a rated 50 Pascals pressure difference using common reference test methods;

g) Highly efficient (80%) heat recovery ventilation system;

4. Integrated passive solar heating system using south-facing windows equal to 10% of the floor area, plus 20 000 kg of distributed concrete thermal mass;
5. Active solar heating system using 21 m^2 of collectors in a drainback configuration supplying a 300 litre storage tank for household water heating and a 17 000 litre concrete storage tank for house space heating;
6. Low-speed forced-air heating/ventilating system based on a fan coil and using centre-of-house ducts;
7. Grid-dependent solar photovoltaic (PV) system with 5.6 kW of 17% efficient PV modules at 53° tilt;
8. Passive summer cooling strategies include opening windows, fixed south window shading, low solar heat gain coefficient on the east-west windows; and optionally, the circulation of water through piping loops under the garage and next to the foundation. Edmonton has a mild and short cooling season.

Figure 1. SketchUp™ rendering of the Riverdale NetZero Project

House energy consumption and production was modelled using HOT2000[2] and RETScreen[3], though no software is available that specifically is intended for net zero energy houses. If the house were built using current best practices in Edmonton, the house's heat loss would be 15.3 kW at -32°C design temperatures, the annual space heat consumption would be 35 600 kWh, and the fuel used for space heating would be 23 000 kWh (net of useable internal heat gains and passive solar heat gains). The Edmonton house space heating average is 29 000 kWh. For the net zero house, the envelope components described in item #3 above reduce the design heat loss to 6.5 kW, equivalent to the heat produced by four 4-slice toasters or 6 hair dryers, and the space heat consumption to 10 860 kWh. Useable internal heat gains of 3030 kWh and passive solar gains of 4370 kWh reduce the space heating consumption to 3460 kWh. Active solar supplies 2240 kWh and solar PV supplies 1220 kWh to reach net zero energy space heating.

Water efficiency and heat recovery reduces water heat consumption from 4800 kWh to 1980 kWh (Edmonton's average is 8300 kWh). Active solar supplies 1910 kWh of this and solar PV supplies 70 kWh to reach net zero energy water heating.

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[2] Information on HOT2000™ can be found at http://www.sbc.nrcan.gc.ca/software_and_tools/hot2000_e.asp.

[3] Information on RETScreen® can be found at www.retscreen.net.

The house's electricity efficient features reduce its annual domestic electricity consumption from 9060 kWh with conventional construction standards to 4500 kWh. Edmonton household average is 6600 kWh. Solar PV then supplies 4930 kWh to yield a surplus of 430 kWh.

These energy features are listed for the reader to appreciate the technical extent that is needed to achieve a net zero energy house in Edmonton's location. These levels of energy efficiency, solar heating and solar electricity are unheard of in a house and are causing significant interest and also scepticism from the public and builders.

2. CHALLENGES – OPPORTUNITIES FOR BUSINESS DEVELOPMENT

The significant challenges to net zero energy houses can be categorised into two basic areas, ones that have technology as their solution, and ones that have solutions in how society organises itself:

1. **Technical:** the outdoor temperature and the renewable energy resources of the location in which it is constructed, which leads to large amounts of technology-based construction and equipment, and significant additional capital costs.

   These challenges generically relate to the existence of technologies and how well they perform. They increase in cold high-latitude climates due to the need to extensively use energy efficiency, water efficiency and renewable energy.
2. **Organisational,** into which can be included:
   a) Financial – the economics (costs and benefits) of the technologies employed.

   These challenges are related somewhat to technology performance, and strongly to market size and to corporate and government policies on financing.

   b) Policy – the municipal, provincial and national government policies that reduce fossil fuel prices to facilitate industrial development, international trade, and societal services.

   Such policies were accepted for the development of society in the past 100 years, but are now being strongly questioned because of their environmental effects.

   c) Training – the deficit of integrated expertise amongst the design team (these houses have never been built before in our climate) and the stakeholders (implied in the barrier lists in Section 2.2) in whose jurisdictions the house challenges their decision-making basis.

   Whether stakeholders have sufficient training relates to a technology's market size at present and how they see the market changing in the future.[4]

These challenges are all readily seen in Alberta, Canada's prominent oil and gas-based province, of which Edmonton is its capital. The challenges in building net zero energy houses here, at 53°32' N latitude, include (with comparisons to Adelaide in parentheses):

- a winter-time solar energy resource of 1.3 sun-hour per day (kWh/m^2/day) on a horizontal surface (2.6);
- a long cold 5589 kelvin-day heating season (919), with summer cooling requirements of 476 Kd (2392);
- in a location where governing jurisdictions struggle to develop effective policies and programmes on climate change, greenhouse gas emission reduction, and energy efficiency and renewable energy;
- in a city that currently has minimal planning policies and no programmes that support solar energy;
- in a province:
  - that subsidies fossil fuel prices (*e.g.*, a 23% average subsidy on residential natural gas in 2006);
  - where environmental policies and laws do not value the environmental benefits of energy efficiency and solar energy;
  - with no currently policies for energy efficiency, renewable energy and bio-energy;
  - where the building code for insulation has not been updated for over 11 years;
  - where the model national energy code was never adopted; and

[4] History holds many good examples that show how stakeholders respond to "disruptive" technologies and other changes in markets. If the future is seen as an opportunity, then stakeholder responses include jostling for market position and making business strategies that welcome, facilitate, and lobby for it. If the future is seen as a threat, an entrenching of paradigms and positions happens with business strategies that deny, dismiss, dispute, and lobby against it. Microcomputers, renewable energy, and climate change are great examples of this. Lobbying influences government policies and affects its unbiased leadership in how society organises itself to face the future. Lobbying against the future leads society away from preparing to meet it.

- where national and provincial economic development policies value rapid growth in fossil fuel production over the short- and long-term value in adequately protecting land, air, water and habitat resources during the industrial fossil fuel cycle: exploration, production, consumption and reclamation.[5]

2.1. Challenges that have Technical Solutions

Net zero energy housing in an urban setting will need to consider and evaluate the technologies shown in Table 1. These are listed from least expensive to most expensive technologies, and include brief comments on opportunities and challenges to their utilisation, how the Riverdale NetZero Project team dealt with them, their preliminary costs for the house as known at this time, and their nominal energy reduction or supply contribution to the house shown in kWh of energy and % of the house electrical and heating needs.

Though the major house technologies used in net zero energy houses are off-the-shelf, the challenge is how to design and integrate various combinations of them to achieve the net zero energy goal.

Table 1. Energy and Water Options to be considered in a Net Zero Energy House – showing the choices for the Riverdale NetZero house

#	Energy/ Water Option	Comments	Opportunities (O), Challenges (C), Solutions (S), Nominal Added Cost ($), Energy or Water Supply to RNZ house (E/W)
1.	Highly energy efficient electrical fixtures and appliances	Lighting, stove, range, fridge, clothes dryer, clothes washer, dish washer, air circulating fans, pump motors	O: Reduce electricity use. Low added cost, short-term payback, independent of house design. C: Finding appliances that are sufficiently energy efficient. S: Selected appliances from the national EnerGuide appliance list (www.oee.nrcan.gc.ca/energuide), which was as good as could be found. Higher efficiency appliances are needed. $: Nominally $2000 added cost. Could end up being less. E: Reduces house domestic electricity use by 4700 kWh or 52% of the original house heating energy.
2.	Highly water efficient fixtures and appliances	Clothes washer, dish washer, shower heads, faucets, dual-flush “Aussie-type” toilets	O: Reduce use of water and water heating energy. Low added cost, short-term payback, independent of house design. C: Finding appliances that are sufficiently water efficient, and that also provide acceptable and comfortable water services. S: Selected appliances from the national EnerGuide appliance list and from the internet. $: Nominally $2000 added cost. Could end up being less. W: Reduces household hot water volumes from 225 L/day down to 101 L/day, or 58% of average water heating energy. E: Reduces water heating energy from a typical household of 4800 kWh down to 2200 kWh depending on choice of fixtures.
3.	Drain water heat recovery	From shower grey water only	O: Reduces water heating loads. Can be retrofitted if house design accommodates it. C: Newly commercialised technology; needs to be planned into house design; performance not well known or substantiated; marketing claims not fully reliable. S: Selected one of the units and hoped it works well. $: Nominally $700 installed. E: Expected to reduce water heating energy by between 200 and 700 kWh, an additional 4% to 14% reduction in water heating.

[5] Alberta has huge coal (estimated at a 400+ year supply), oil (2nd biggest reserves in the world), and natural gas reserves (20 years remaining at most). See Alberta Energy and Utilities Board (2005) and (2007), and BP (2007). Alberta’s government is widely influenced by the corporations that develop these resources, and so creates policies and regulations that protect these reserves and business interests.

#	Energy/ Water Option	Comments	Opportunities (O), Challenges (C), Solutions (S), Nominal Added Cost ($), Energy or Water Supply to RNZ house (E/W)
4.	Grey water recycling	Using bathroom and laundry wash water as source of water in toilets and landscaping. Stores warm grey water in a tank in the house. Water in tank feeds toilets or is drained into sewer by new waste water.	O: Reduction of water use for toilets and landscaping, plus allow residual heat in waste water to cool down inside house. C: Plumbing codes across Canada consider grey water to be black water (as from toilets) and so is not permitted for irrigation. S: Declined for RNZ due to plumbing code issues, and low house water use due to water efficient appliances, minimal-water landscaping, harvesting rain water for landscaping, and house location in a 6-month landscaping-dormant climate. $: $2400 if house is ready for grey water. Up to $3300 as retrofit. W: Toilet supply: 70 L/d savings. $60 annual savings at Edmonton's combined water-sewage price of $2.28/m^3. W: Landscaping irrigation: not known. E: Could reduce space heating energy up to 600 kWh or ~6% of gross space heating.
5.	Rainwater harvesting	For landscaping not drinking	O: Reduce water consumption for landscaping. Rainwater harvesting is employed with the house, but is not discussed in this paper.
6.	High efficiency building envelope	Ceiling, walls, floor, windows, doors, and air-tightness, including house ventilation and air heat recovery	O: Can reduce space heating loads by 50%. Least expensive way to reduce space heating and cooling loads. C: Choosing from a large number of competing wall construction methods and marketing claims that may not be fully reliable. Need well-done case studies on costs and performance results. S: Used many years of personal experience with construction methods and costs to choose building envelope method. $: Nominally $25 000 added cost. Could end up being less. E: Reduces house heat consumption by 24 600 kWh or 69% from the RNZ house built with conventional construction techniques.
7.	Passive solar space heating	Typically employing equator-facing windows, integrated thermal mass, fixed window solar shading	O: Built into house design and features. Nil operating costs. C: Needs specialised design professionals to properly assess heating, cooling, comfort and visual considerations and energy performance. Proper site orientation and solar access required to optimise it. Risk of overheating not well quantified. Need well-done case studies on costs and performance results as well as performance modelling software. S: Used professional expertise of a team member and hoped it works well. $: Added costs shared with house envelope and features, and are not yet known in detail. E: Estimated to supply a further 4400 kWh or 40% of gross space heating (acknowledging increased window area and losses).
8.	Solar thermal for household water heating	Includes active and passive systems as appropriate for the climate	O: Highly appealing to the public. Low operating costs. C: Choosing from a large number of competing products and technologies. Some marketing claims don't appear to be fully reliable. Supply chain not well developed. S: Used professional expertise of a team member. $: Nominally $9 600 added costs for 3 collectors plus components. E: Supplies 1900 kWh or 83% of gross water heating.

#	Energy/ Water Option	Comments	Opportunities (O), Challenges (C), Solutions (S), Nominal Added Cost ($), Energy or Water Supply to RNZ house (E/W)
9.	Active solar space heating	Can include water, glycol, and air heating technologies. Only water-based configurations were considered.	O: Highly appealing to the public. Low operating costs. C: Rarely employed due to high costs, low operating efficiencies, short operating season, complex installation, few qualified design professionals, supply chain not well developed, and limited availability of modelling data. S: Used professional expertise of team members. Some gaps in expertise remained unfilled. $: Nominally $17 500 added costs for 4 collectors, storage tank and components. E: Supplies house with 2200 kWh or 21% of gross space heating.
10.	Solar assist heat pump for space heating	Using the solar heat storage tank as its source.	O: Could increase the efficiency of the solar heating collectors and extract more heat from solar storage tank. C: Design choices/performance not well known in this application. S: May consider a ¾ tonne heat pump (size of a large fridge) but need detailed modelling to quantify performance and benefits. $: Nominal $3 000 added cost. E: Could supply at least 500 kWh not including operating energy.
11.	Geothermal heat pump	Primarily for space heating and cooling. Can provide household water heating. Typically 2/3 of heat comes from the ground; 1/3 from electricity.	O: Highly appealing to the public. Can provide all heating energy. C: Some marketing claims about performance, costs and environmental benefits are not reliable. High electrical energy consumption and costs (source of electricity is a factor). S: Did consider 2T heat pump. Declined for lack of information. $: Nominal cost of $16 000 for heat pump and components. E: Could supply between 4% and 100% of house heating depending on the other house heating options selected.
12.	Solar photovoltaic (PV) electricity	Grid-dependent, usually with no battery bank for electrical energy storage	O: Highly appealing to the public. Can supply complete electrical and heating loads. Costs are declining, efficiencies improving. Supply chain improving. Very simple to design and install. Performance well known. C: Traditionally extremely expensive. Low system efficiency. Should only be used after ultra high energy efficiency is employed to reduce loads. Issues with complex provincial electrical industry grid-connection and regulatory policies. S: Have no option but to use this technology to reach urban NZE. Design of whole house is optimised to minimise its size. $: Approximate installed cost $43 000. E: Supplies 5700 kWh, or 106% of the electrical energy for domestic use plus water and space heating deficits. Supplies more than 100% to account for small additional energy deficits due to component performance or occupant choices.
13.	Sustainable materials	Choices of construction and finishing materials	O: Reduce energy used in manufacture and transport of construction and finishing materials; reduce off-gassing of pollutants that affect interior air quality; increase the sustainable harvesting of natural materials. This paper does not discuss the choices in sustainable materials.

Many other technologies could also be considered including combined solar PV/solar thermal, combined solar heating/geothermal, active and passive solar cooling, innovative control systems, motorised blinds and shutters, microwind, microhydro, and wood heating, although the latter three are likely not suitable for urban locations due to practical zoning restrictions and a lack of on-site energy resources. New energy technologies are rapidly being developed and commercialised. The initial challenges with choosing them largely relate to whether marketing claims of economics, performance and durability are reliable.

2.2. Challenges that have Organisational Solutions

Work on the house and its design and construction plus analysis of the technology performance and costs has shown that it is challenges that have economic solutions and not challenges that have technical solutions that are the most significant.

Financial, policy, and training challenges in effect relate to how society organises itself and establishes its priorities. This level of organisation and priorities largely stem from government leadership and its resulting policies. Policies are "answers to commonly asked questions". They tell us where we are heading. They either hinder or help society in making changes necessary to prepare for the future. Today the future includes much uncertainty regarding energy pricing, climate change and other extreme environmental issues. Indeed, though signs are now showing that the planet is fast approaching the point where its people may need to become frenetic in their work at implementing diligent responses to environmental issues [6], many influential governments remain intransigently opposed to providing the requisite leadership, citing various fears and platitudes instead of looking for its opportunities.

Integrating different energy options and managing different types of energy loads is both a business opportunity and a challenge. Integration of energy technologies is significantly affected from a lack of system performance information and professional design skills. These challenges arise from a lack of market demand, which in turn result from low fossil-fuel energy prices and policies that don't facilitate non-fossil fuel resources.[7]

Nodelman & Howell (1997) suggest that only about 5% of any solution to an environmental issue is based on technical components. They go on to describe how the balance of 95% is related to legal, ethical and social relationships, which also include ecological, educational, financial, psychological, political, and territorial ones. When applying these comments to evaluating the effort to achieve environmental goals, we see that though large financial resources are spent on research into and development of the sustainable energy and environmental technologies needed to achieve a significant reduction in humanity's environmental footprint, far less is spent on the relationships (internal and between groups) needed to facilitate the timely adoption of these technologies. The major block to these technologies is found to be relational, not technical.

The challenges and barriers to achieving any goal can be assessed by answering the question "Why have we not achieved our goal?". In an unpublished paper written to plan business development opportunities arising from barriers, Howell (2006) provides an outline identifying answers to this question as they pertain to net zero energy housing. It outlines the barriers and the key stakeholders that hold them, as organised into categories of:

1. Education (related to awareness, understanding, and expressions of fear);
2. Relationships (related to leadership, trust, credibility, ownership, competition, inertia, communication, contracts, covenants, liability, and experience);
3. Industry infrastructure (related to training and certification, codes, standards, insurance, supply chain development, financing, marketing, and business models);
4. Financial risk (related to system performance, energy pricing, value of benefits, competition, access to capital and financing, and taxes);
5. Site suitability (related to permitting, zoning, land, site infrastructure, solar access, design); and
6. Technology (related to the technologies and their performance).

The document shows that by far, the solutions to the barriers are based on relationships and not technology or economics. Relationships are a result of how we humans organise our society. As more renewable- and efficiency-based energy systems are added to and change the existing fossil-fuel-based infrastructure, however, these barriers will increase as businesses comprising the existing infrastructure move to strengthen the

[6] "We … are confronting a planetary emergency — a threat to the survival of our civilization …", "We must quickly mobilize our civilization with the urgency and resolve that has previously been seen only when nations mobilized for war", Gore (2007) on receiving his Nobel Peace Prize. There are many other internet references now to climate change being a planetary emergency.

[7] In practical terms, fossil fuel prices in many provinces and countries are strongly affected by government energy and environment policies that haven't considered or implemented full-cost accounting and the effect of those policies' implicit and explicit fossil fuel price subsidies. These policies are sometimes contentious. See also Marsden (2007).

relationships that protect their financial territory and business models. Organisational changes need to be made to our relationship structures in order to facilitate these emerging technologies, especially as they are now becoming critical to the planet's future, so that they do not face such large, overriding and often intractable impediments.

Opportunities arise from challenges and barriers because they can result in the development of organisations and businesses, both to resolve them and to thrive within the new structures. The questions really are then 'How do we want to organise ourselves in order to achieve the goals?" and "How well are we organising ourselves to resolve the barriers?'. The key is that these can be resolved only where there is a will amongst the stakeholders to resolve them. Governments and their policies have a significant role to play in leading this re-organisation. They can to a large extent provide solutions to resolve organisational challenges. Making policies to capitalise on these challenges and opportunities takes a political will that overcomes its own fears.

The task of resolving the organisational challenges facing energy efficiency and renewable energy increase where political will focuses on financial capital (*e.g.* gross domestic product, GDP), and ignores the other two pillars of sustainable development: environmental capital and social capital. This political will is shown by policies that ignore the environmental damage caused by the development and use of fossil fuel energy resources; that facilitate and subsidise existing strong industrial-scale fossil fuels over fledgling and vulnerable small-scale renewable energy; that dismiss the value of energy efficiency; and that overlook the will of its citizens to live in a compatible way with the environment.

In calling these challenges "organisational", we are not meaning that they do not exist – they do indeed exist, however their solutions lie in the way that society organises itself rather than whether a technology has been developed or how well a technology is working. It is important to identify the breadth and significance of challenges that have organisational solutions because the primary efforts in meeting the energy and environment issues of our times need to consider that, largely, we already have the technology at hand to meet these issues. What we have not been wilful and diligent in working on is the relationship-based 95% portion of the solution [8]. Instead much effort is spent on the technically interesting technology-based 5% portion, even though that effort alone is likely not going to quickly get us to where we need to be.

van Mierlo (1999) summarises many non-technical barriers for building integrated solar PV systems. Howell *et. al.* (1996) describes the barriers encountered in Canada's first grid-connected PV system west of Toronto and the 12th one in the country. Though written in 1996, many barriers remain unresolved today. Table 2 lists an updated summary of those barriers and as applied to net zero energy houses.

Table 2. Barriers to Net Zero Energy Houses that have Organisational Solutions

1. Development permits – land-use bylaws, looks, neighbourhood architectural covenants, prohibition against selling electricity in residential zoning
2. Building permits – roof loading, mechanical fastening of solar systems
3. Safety codes – updating electrical, plumbing and building codes for new products, techniques, and their installation (energy efficiency, water efficiency and renewable energy), electric utility company policies for private residential micropower
4. Insufficient training – building design (optimisation and integration of systems, solar thermal operation and installation), trades not being qualified or interested in learning (electrical, plumbing, framing, insulating, heating/ventilating), inspectors (electrical, plumbing, building), knowledge by electric utility company personnel of PV inverter safety and power quality standards, property insurance and taxation personnel
5. Electrical metering – policies and regulations not set up for residential micropower
6. Processes – complexity of modelling solar thermal systems, complexity of micropower grid-connection approvals, provincial electric industry regulations and laws (regulatory boards, electric system operator)
7. Tax policies – industrial property tax for PV, residential property tax for NZE houses
8. Costs – capital, financing, mortgage interest, grid-connection fees, permitting fees.

[8] This is elegantly stated by Mahatma Mohandas Karamchand Gandhi from India in his quote: "The difference between what we do and what we are capable of doing would suffice to solve most of the world's problems."

Each of these references to barriers can be expanded to illustrate their details. They are directly related to society's organisational structure and hence can be resolved through organisational changes. Standards are a good example of this. Enhanced mandatory product and design standards are a direct and outcome of appropriate organisational policies. They set the parameters for society's continued development and make consumer choices mandatory by their nature (for example, no inefficient fridges are available for purchase because all fridges must meet standards of high efficiency). Standards facilitate international trade, cause diverse elements in society to be in synch with each other, and cause society to pull together in a common direction. Standards would mitigate many of the PV challenges, for example, that we are seeing from electric utility companies, industry regulators and municipalities. Many of these organisations do not fully understand solar PV technologies, and so apply regulations, processes and policies (and thus costs) to house-sized PV systems but that were intended for large industrial power generators. Price subsidies and low environment standards have enabled low fossil fuel prices, which have limited the development of the energy efficiency and solar energy markets and the processes (regulatory, standards, codes, permits) that are needed to facilitate them. These processes take a long time to develop, and yet now they are needed immediately to help deal with environmental issues.

For the RNZ house, its capital cost threatens to be its major block. Many of the other barriers listed above added to the complexity of its design and construction. Trades training can be a significant issue for builders. Training was a significant barrier for the RNZ solar thermal system design, but not for PV system design and framing of the envelope due to the previous experience of RNZ team members. The builder has been involved in energy efficient housing for the past 25 years and its framing crews were already suitably trained.

Organisational challenges are not immovable ones imposed by the environment, lack of scientific knowledge, or the performance of materials or systems; instead they are volitional – our decisions impose these challenges upon ourselves, even if we have not valued their full consequences. The solutions to organisational challenges, however, are significant and require many disparate and vested interest groups to agree to meet, listen, understand, and relinquish some of their territory, power and control, and perhaps change their business models, perhaps for the primary good of society rather than the primary good of themselves.

Many organisational challenges can be overcome by their stakeholders being aware of the financial, social and survival challenges facing society as it deals with climate change, and the likely coming call for everyone to participate fully in doing their part to deal with them. When the reality of climate change is then faced, education, training and demonstration programmes help develop the market pull and the product standards, which in turn spawn the required technologies, design skills and supply chain. The lack of these programmes is largely the result of the way that society makes priorities. Governments have a great opportunity to provide considerable leadership in achieving these goals because they represent the will of the population.

2.3. Organisational Challenges (masked as Financial Challenges)

The economics challenge to changes in the way that society organises itself relates to the cost of the change, the value that is placed on the perceived results of the change, and the value that is placed on the perceived consequences of not changing. This is clearly the case with a net zero energy house. Its major economics challenge arises from the very high incremental cost of the house, and the generally unrecognised and low value that is placed on the energy and the environmental effects that the house's technologies mitigate. These economic barriers arise both from the higher cost of new technologies (because they are not mature and not as widely produced) and how current government policies direct society's values on the energy that the house saves and produces.

To achieve the net zero energy goal, large amounts of renewable energy must be employed when houses consume large amounts of energy. As increasing energy efficiency measures are employed in a house to reduce its energy consumption, then smaller amounts of renewable energy are required. This is illustrated in concept in Figure 2. The concept of diminishing economic returns with increasing amounts of energy efficiency is well known. At high levels of energy consumption, it is easy to see that energy efficiency is cheaper than renewable energy. There is an optimum point, as yet not well understood, where, for the same reduction in energy purchased from the utility grids, it becomes more costly to increase the amount of energy efficiency than to increase the amount of renewable energy supply. In designing the Riverdale NetZero house, the design team grappled with this concept, organised spreadsheets, and used preliminary values of "technology cost per annual kWh of energy reduced or supplied" to help answer it. Further design, modelling and monitoring experience will provide additional data for these curves.

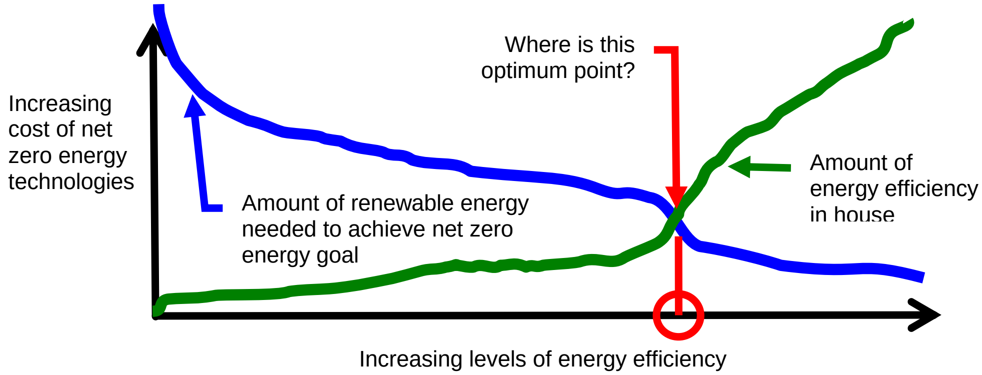

Figure 2. Illustration of Optimum Point for Choosing between Employing Additional Energy Efficiency or Employing Additional Renewable Energy

Table 3 and Table 4 show preliminary added construction cost data and annual energy consumption and utility bills from an options-analysis spreadsheet used to assess design options. The added construction cost of the house is shown on Line 9 summed for the cost of various energy options as selected by an "x". This analysis was performed after the house construction started, when construction costs started to become known, and as more time was spent in understanding the house following the flurry of activity undertaken to submit the design's competitive proposal to CMHC. This spreadsheet will be modified and the optimum point more clearly understood as the house performance and the technology costs become more fully known. These tables show that the most important first steps in reaching net zero energy are a significant reduction of the amount of energy consumed, far before considering the source of any energy for the house.

While Table 3 only shows technologies that reduce the utility energy bills, Table 4 shows a number of technologies that allow the house to reach the net zero energy goal. Note that while each of these technologies operates independently of the others, their aggregated performance is not the sum of their individual performance. This arises because a house is a system of interconnected components. The performance of one component affects the performance of several others.

It is well known that all energy efficiency and renewable energy technologies compete against each other to reach their maximum economic value. As greater numbers of net zero energy houses are developed and evaluated, these tables need to be further developed, rigorously evaluated and then made into documents that are readily available to builders. These costs will change considerably as the energy configuration options begin competing vigorously for market share, and as prices of solar PV systems continue to decrease. The price of solar PV is decreasing at a rate of about 20% for every doubling in market size (which has been growing at 50% per year for the last 13 years). This is rapidly changing the economic choices for net zero energy houses. As shown in columns A to D of Table 4, solar PV is now starting to compete heavily with solar space heating in economics and in simplicity, and is a competitor with geothermal in energy efficient houses.

Many of the challenges arising from its incremental costs would become far less significant if the true cost of fossil fuel-based energy were realised by internalising fossil energy's environmental costs [9] and by eliminating fossil energy's subsidises (*e.g.* the costs to the health care systems of air and greenhouse gas emissions, the costs of habitat destruction, infrastructure investments, *etc.*). These would then cause the price of fossil fuel to rise to the value that society is paying for already in ways that are obscured from general view. This would also reduce the need (which is largely unfulfilled in Canada) to provide similar subsidies to the renewable energy sector.

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[9] Drummond *et. al.* (2007) says that "externalities occur when organisations take actions that benefit themselves while forcing unwanted costs onto other people". When the environmental costs of fossil fuels are "internalised", it does not mean that the costs to the producer appear from no-where; rather it means that the producers of the costs pay for them instead the costs being paid by groups external to the producers. Current payers of "externalised" costs are those who have voices that are weaker than the producers: the public, the poor, the unorganised, the isolated, the unborn generations and the environment. These voices need to become much stronger in order to resist unfairly being forced to pay the "externalised" costs.

Table 3. Riverdale NetZero House Energy Efficiency and Solar Heating Options – without achieving the net zero energy goal

#	Energy Option	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1.	Appliance electrical energy efficiency		x	x	x		x	x	x	x
2.	Appliance water efficiency			x	x		x	x	x	x
3.	Drain water heat recovery				x		x	x	x	x
4.	Building envelope efficiency						x	x	x	x
5.	Passive solar space heating						x	x	x	x
6.	Active solar household water heating							x		x
7.	Active solar space heating									x
8.	Geothermal heat pump (rated heating capacity)					x 7 T			x 2 T	
9.	Additional house cost with selected options [10]	$0	$2k	$4k	$4.7k	$26k	$30k	$39k	$46k	$57k
10.	Energy services used by house and occupants	41 300 kWh	37 500 kWh	34 800 kWh	34 800 kWh	41 300 kWh	13 800 kWh	14 000 kWh	13 800 kWh	14 000 kWh
11.	Electricity purchased for household & heating	9060 kWh	4100 kWh	4100 kWh	4100 kWh	16 800 kWh	9400 kWh	7600 kWh	6000 kWh	5400 kWh
12.	Natural gas purchased for water, space heating	114 GJ	119 GJ	101.3 GJ	100.7 GJ	0 GJ	0 GJ	0 GJ	0 GJ	0 GJ
13.	Annual energy bill [11]	$2570	$2060	$1910	$1900	$2090	$1260	$1060	$890	$810
14.	Simple return on investment (ROI)	base case	26%	16%	14%	1.9%	4%	3.8%	3.7%	3.1%
15.	GHG emissions [kg]	16 160	12 420	11 100	11 050	13 970	7 800	6 300	5 000	4 500

Notes on Table 3:

1. The options listed are for the size and floor plan of the Riverdale NetZero house.
2. Column A represents standard 2007 construction practices in Edmonton.
3. Line 9: The additional capital costs do not include the team's *pro-bono* charrette, design, and consulting fees estimated at $200k for this first net zero energy house. Additional design fees for subsequent houses shouldn't be more than $20k.
4. Lines 10 to 15 are annual values.
5. Line 10: The annual amount of energy used from all sources to provide the house's heating and electrical energy services.
6. All supplemental space & water heating is from natural gas for columns showing a non-zero amount for natural gas heating on Line 12; otherwise all supplemental heating is from electricity.
7. Line 15: Alberta's energy-based greenhouse gas emission rates are 0.833 kg/kWh for electricity (64% coal-fired, 31% natural gas-fired) and 0.272 kg/kWh for natural gas.
8. Line 14 is the simple payback only (equals Line 9 divided by the savings in energy bills compared with the base case). It does not include the cost of mortgage interest, which is a huge factor.

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[10] All monetary numbers are in Canadian dollars. At time of writing, CAD 1 = AUD 1.05; 1 CAD = 0.687 €.

[11] 2007 average energy price in Edmonton was 11.17 ¢/kWh for electricity and $8.73 /GJ for natural gas. This residential natural gas price is further reduced by 23% through a government subsidy programme.

Table 4. Riverdale NetZero House Energy Efficiency and Solar Energy Options – achieving net zero energy

#	Energy Option	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1.	Appliance electrical energy efficiency	x	x	**x**	x	x		x	
2.	Appliance water efficiency	x	x	**x**	x	x		x	
3.	Drain water heat recovery	x	x	**x**	x	x		x	
4.	Building envelope efficiency	x	x	**x**	x	x			
5.	Passive solar space heating	x	x	**x**	x	x			
6.	Active solar household water heating		x	**x**		x			
7.	Active solar space heating			**x**		x			
8.	Geothermal heat pump (rated heating capacity)	x 2 T	x 2 T			x 2 T	x 7 T		
9.	Solar PV electricity (rated capacity, PV array area)	x 6 kW, 35 m^2	x 5.5 kW 32 m^2	**x 5.6 kW 33 m^2**	x 9.3 kW 55 m^2	x 4.7 kW 28 m^2	x 17 kW 98 m^2	x 25 kW 149 m^2	x 32 kW 187 m^2
10.	Additional house cost with selected options	$92k	$98k	**$101k**	$102k	$110k	$155k	$201k	$247k
11.	Energy services used by house and occupants	13 800 kWh	14 000 kWh	**14 000 kWh**	13 830 0 kWh	14 000 kWh	41 300 kWh	34 800 kWh	41 300 kWh
12.	Electricity purchased for household & heating	0 kWh	0 kWh	**-300 kWh**	0 kWh	0 kWh	0 kWh	0 kWh	0 kWh
13.	Annual energy bill	$214	$214	**$180**	$214	$214	$214	$214	$214
14.	Simple ROI	2.6%	2.4%	**2.4%**	2.3%	2.1%	1.5%	1.2%	1.0%
15.	GHG emissions [kg]	0	0	**-250**	0	0	0	0	0

Notes on Table 4:

1. The PV array area is for the use of 17% efficient PV modules, one of the most efficient modules commercially available for terrestrial use.
2. Lines 11, 12, 13, 14, and 15 are annual values.
3. Columns A, B, C, D, and E represent several competing energy supply configurations that have roughly similar costs and varying degrees of technical simplicity.
4. Column C represents the options employed in the Riverdale NetZero house.
5. Columns D, G and H readily illustrate the immediate value of incorporating energy efficiency before employing solar energy sources. The expenditure of $4.8k for appliance electrical and water efficiency and heat recovery in Column G saves $46k (Line 10) in energy system costs over Column H. An additional expenditure of $25k for building envelope energy efficiency in Column D saves an additional $99k over Column G.
6. Line 9 in Columns F, G, and H show that the area of the PV array is too large for an average house and thus urban net zero energy is not generally possible without envelope energy efficiency.
7. The annual energy bill (Line #13) is shown as always being $214. This is the annual charge for connecting to the electricity grid in Edmonton (it ranges up to $400 with other Alberta electric utility companies). This does not include fees for electricity purchases because the annual net electricity purchase is zero. The RNZ house is not connected to natural gas delivery services.
8. Line 14 is the simple payback only (equals Line 10 divided by the savings in energy bills compared with the base case). They do not include the policy costs illustrated in Table 5.

2.4. Organisational Challenges (masked as Return-on-Investment Challenges)

A famous quote is relevant to the organisational challenges facing net zero energy houses: "If you really want to do something you will find a way, if you really don't want to do something you will find excuses". Although the economic barriers to net zero energy housing may appear to be enormous and perhaps impossible to overcome, they are really "just" related to how society organises itself. Finding a solution to them depends on how strongly people want to find a way to achieve their goals. It depends on what society values and what it does not value.

The economic barriers for the Riverdale NetZero house are summarised in Table 5. They are separated into two vertical sections: Columns A, B, C, and D that show how current government policies value the house's reduction in fossil fuel energy and emissions; and parallel Columns E, F, G and H that show the effect of policies that would facilitate net zero energy houses. Such policies use similar economic development goals that have previously facilitated the historic growth and economic well-being of Alberta based on the development of fossil-fuel energy's industrial capacity.

The resulting differences in the accumulating net benefits (Columns D and H) progressing from Line 1 to Line 16 are significant. The net result is a negative 4% return on investment (ROI) based on current policies and a positive 6% ROI with new policies. It illustrates how single policies add or subtract small amounts to the value of energy, and cumulatively how large differences are the result. The economic effects of the current policies referenced in Table 5 have readily been seen with a number of other solar PV and microwind electricity systems installed in the last few years in Alberta, leaving the owner with very little economic benefit. This is in contrast with fossil-fuel policies that provide large subsidise to corporations even in profitable times and don't consider increasingly destructive and un-moderated environmental and health costs. Taylor (2006) shows how the Genuine Progress Indicator (GPI) evaluates the economic well-being of Alberta based on all the consequences of choices. The Genuine Progress Indicator has the depth and scope to track the change in the economic health of Alberta arising from the development of net zero energy houses. It is expected that other benefits of net zero energy house not covered in this paper, such as reduced threat to heat and electricity supply under extreme weather conditions, reduced resource depletion, local employment, and balance of payment issues arising from resource depletion would be tracked by GPI and add to the value of net zero energy housing. Energy efficiency and renewable energy likely would not need to have any subsidies if the actual costs of fossil fuels were known.

Note the implications behind the current and new policies, the stakeholders affected by them, and how the changes from the current policy to a new policy are organisational in nature. Most of these policy changes have zero net societal costs to them. Instead they transfer already-existing costs from one group (usually weaker and without a co-ordinated voice) to another (usually more powerful, well-connected and entrenched in resisting such changes). It is these cost transfers that then set the stage for the organisational difficulties in changing policies that direct which group pays the costs and thus how commodity price signals are provided to consumers to cause the changes to their energy choices. The resistance to such cost transfers can be readily seen in considering how the externalised costs of fossil fuels could ever be internalised. Since maximum profits for a corporation are achieved when all its costs are externalised (or socialised, which means paid for by groups external to the corporation) and when all its benefits are internalised within the corporation and since most CEOs are mandated by their shareholders to achieve this goal, then it is not surprising that the environment is not being valued and that these externalised costs are not being paid for by the corporations that produce them.

The most significant barrier described in Table 5 is the effect of mortgage interest in Line 14. It is widely seen that loan interest payments effectively nullify many otherwise highly worthwhile renewable energy and energy efficiency measures, and this, at the time when such measures are strongly needed to help mitigate environment issues. Ultra-low interest "green" loans supported by government banking policies need to be developed to overcome this barrier. Anielski (2004) describes the JAK Bank in Sweden (http://jak.aventus.nu) that has developed a banking system that helps to overcome loan interest issues.

Table 5. Economic Barriers to the Riverdale NetZero House – How Current Policies Create Them and How New Policies Can Resolve Them

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Current Policy	**Comments on Current Policy**	**Value of Current Policy for RNZ**	**Cumulative Value of Current Policies**	**Recommended New Policy**	**Comments on Recommended New Policy**	**Est. Value of New Policy for RNZ**	**Cumulative Value of New Policies**
1.	Consumer electricity prices are only credited to the 20% of solar electricity directly used by the house and not to the 80% that is exported. See Note 1.	11.17 ¢/kWh is the 2007 regulated residential price of delivered electricity as billed, including all kWh-based fees and taxes.	$127 per year, = 11.17 ¢/kWh x 5700 kWh x 20%	Value of $127 per year (equals the value in table Cell C1)	Apply full consumer electricity price to all solar electricity by using equal-rate net billing See Note 3.	An equal-rate net billing policy is equivalent from the viewpoint of the consumer to net metering.	Credit of $637 per year, = 11.17 ¢/kWh x 5700 kWh	Value of $637 per year (equals Cell G1)
2.	Exported solar electricity is valued at the market's marginal price at noon on the last day of the month.	The average exported price of electricity in 2006 was 8.6 ¢/kWh. The credit = 8.6 ¢/kWh x 5700 kWh x 80%.	Credit of $391 per year	Value of $518 per year (equals Cell D1 + C2)	Same as Cell E1.	The full consumer electricity price is already included in the value of the solar electricity in Cell G1.	Already included	Value of $637 per year (equals Cell H1 + G2)
3.	Charges of $263 per year levied by the Alberta Electric System Operator (AESO) to sell any amount of electricity into Alberta's industrial-scale electricity market.	This fee is 67% of the value of the PV electricity sold into the market. For much smaller PV systems, this fee is 200% of the value of the sold electricity.	Fee of $263 per year to become an electricity market participant	Value of $256 per year (equals Cell D2 – C3. C3 is subtracted because C3 is a fee.)	Eliminate the AESO electricity market participant fees for micropower generators. See Note 3.	The elimination of this fee needs to be part of the overall goal to simplify Alberta's 60 paperwork step process of approvals for connecting solar PV systems to the grid. (Howell *et. al.*, 2004)	Fee of $0 per year	Value of $637 per year (equals Cell H2 – G3)
4.	Electric utility company fees ranging from $0 to $250 per year to operate a safety disconnect switch because they do not consider PV inverters to be safe for their line workers.	The fees arise because electric utility companies have not evaluated the internationally recognised safety provisions of grid-dependent PV inverters.	Fee of $0 per year in Edmonton for safety disconnect	Value of $256 per year (equals Cell D3 – C4)	Change the Electric Utilities Code and the Canadian Electrical Code to mandate that utility companies accept certified inverters without added safety precautions.	If safety were a real issue with these inverters, they would not be used in a million solar PV systems every year.	Fee of $0 per year throughout Alberta	Value of $637 per year (equals Cell H3 – G4)

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Current Policy	**Comments on Current Policy**	**Value of Current Policy for RNZ**	**Cumulative Value of Current Policies**	**Recommended New Policy**	**Comments on Recommended New Policy**	**Est. Value of New Policy for RNZ**	**Cumulative Value of New Policies**
5.	Electric utility companies have fees ranging from $0 to $289 per month to read the electricity export meter.	Electric utility companies are prohibited from adding into their rate base, the cost for reading export meters for micropower systems, though some do so anyway.	Fee of $0 per year in Edmonton to read export meter	Value of $256 per year (equals Cell D4 – C5)	Mandate that the costs for reading the export meters for micropower systems be added to the electric utility company's rate base. See Note 3.		Fee of $0 per year throughout Alberta	Value of $637 per year (equals Cell H4 – G5)
6.	Service charges for connecting a house to the electrical grid range from $200 to $400 per year in 2007 depending on electric utility company policies. EPCOR's 2007 connection fees are $214 per year. These fees are paid regardless of whether or not the house has a PV system.	These are valid fees that pay for maintenance on the electrical distribution system, electric utility company profits and billing administration. In effect, the $214 per year fee is the fee for using the grid as a giant well-maintained reliable battery bank.	Grid-connection fee is not included because it would be paid for regardless of house construc-tion.	Value of $256 per year (equals Cell D5 – C6)	Eliminate the connection fees and require them to be wrapped into electrical commodity prices. The increase in prices equals 3.2 ¢/kWh. This is calculated from Cell A6 ($214) divided by the average annual residential electricity consumption of 6600 kWh.	This gives a more appropriate price signal for the environmental strategies that are required today. It does not affect the bill of the average consumer. It increases the bill of heavy-use consumers and decreases the bill of thrifty consumers.	Value of $185 per year = 5700 kWh/year x 3.2 c/kWh	Value of $772 per year (equals Cell H5 + G6)
7.	Alberta government rebate on natural gas fuel price in the winter amounted to an annual average of 23% in 2006. The 2007 regulated price of residential natural gas was $8.73 /GJ.	This only applies to natural gas. Its effect encourages heavy-use consumers and discourages thrifty consumers.	Credit of $0 per year on the amount of natural gas used by RNZ (=0)	Value of $256 per year (equals Cell D6 + C7)	Apply the 23% subsidy to the amount of natural gas that a NZE home would have used if it was built according to conventional construction standards. For the RNZ house, this is 114 GJ, from Table 3, Cell A12.	This is a no-cost option to the government. They would have had to pay it anyways if the homeowner had not decided to use her own capital to become energy efficient.	Credit of $229 per year, = 114 GJ x $8.73/GJ x 23%.	Value of $1051 per year (equals Cell H6 + G7)

	(A) Current Policy	(B) Comments on Current Policy	(C) Value of Current Policy for RNZ	(D) Cumulative Value of Current Policies	(E) Recommended New Policy	(F) Comments on Recommended New Policy	(G) Est. Value of New Policy for RNZ	(H) Cumulative Value of New Policies
8.	Ignores the effects caused by the emissions from coal-generated electricity on the health of Albertans and that are paid for by Alberta Health Care premiums	DSS Management Consultants and RWDI Air (2005) reported that the generating costs of coal-fired electricity in Ontario were 3.7 ¢/kWh. However the costs of the damage that this causes to health and the environment increases the total cost of this electricity to 16.4 ¢/kWh. The difference is 12.7 ¢/kWh.	Credit of $0 per year No credit for reduced health care and environ-mental damages.	Value of $256 per year (equals Cell D7 + C8)	Determine the full health care damages from the air, water and land emissions from coal-generated and natural gas-generated electricity and its associated exploration and production activities, increase electricity prices by this amount and decrease the health care premiums by the same amount.	This example uses the price of 8.1 ¢/kWh calculated from 12.7 ¢/kWh x 64% of Alberta's electricity that is from coal. This policy shifts the pollution costs onto the sectors that cause them so that price signals appropriate to the energy source are given.	Credit of $736 per year, = 8.1 ¢/kWh x 9060 kWh of electrical energy the RNZ house would have used with no energy efficiency or solar PV	Value of $1794 per year (equals Cell H7 + G8)
9.	Does not place a value on the development of Alberta's industrial capacity in solar and energy efficiency technologies to help meet the world's urgent need for reducing GHG emissions.	Alberta has previously implemented effective policies to facilitate the industrial development of its oil, gas and tar sands industries with widely prosperous results.	Credit of $0 per year	Value of $256 per year (equals Cell D8 + C9)	Develop a solar PV feed-in tariff to value the electricity production costs of solar photovoltaic technologies in order to facilitate a home-grown world-scale industry similar to oil and gas.	Ontario's feed-in tariff is 42 ¢/kWh. Several countries in Europe have feed-in tariffs ranging up to 85 ¢/kWh.	Credit of $1915 per year, = 42 ¢/kWh x 5700 kWh/year x 80% exported.	Value of $3702 per year (equals Cell H8 + G9)
10.	Does not place a value on the release of fossil fuel-bound carbon to the atmosphere.		Credit of $0 per year	Value of $256 per year (equals Cell D9 + C10)	Place an environmental fee on the value of carbon released. Use $43 per tonne, which is the social cost of carbon as reported by the Intergovernmental Panel on Climate Change and the British Treasury.	The RNZ house reduces the emission of 16.2 T of greenhouse gases per year from what it would have emitted if it was built with standard construction practices.	Credit of $697 per year, = 16.2 T x $43/T	Value of $4399 per year (equals Cell H9 + G10)

	(A) Current Policy	(B) Comments on Current Policy	(C) Value of Current Policy for RNZ	(D) Cumulative Value of Current Policies	(E) Recommended New Policy	(F) Comments on Recommended New Policy	(G) Est. Value of New Policy for RNZ	(H) Cumulative Value of New Policies
11.	Solar PV systems in Alberta are required to pay an industrial property tax, typically amounting to 2.9% of its capital value.	This tax has never been levied, even though the law requires it to be so.	This fee would be $1260 per year if levied.	Value of $256 per year (equals Cell D10 – C11)	Remove this tax from the laws. See Note 3.		Credit of $0 per year	Value of $4399 per year (equals Cell H10 + G11)
12.	Increased residential property tax	Edmonton's residential property taxes are typically based on common features not unique ones.	Unknown fee	Value of $256 per year (equals Cell D11 – C12)	Pass a bylaw to exempt residential renewable energy and energy efficiency measures from taxation.	This City measure would provide highly visible encouragement to people to choose responsibly.	Fee of $0 per year	Value of $4399 per year (equals Cell H11 – G12)
13.	Increased house insurance premiums to insure the increased house construction costs	Premiums will likely be higher than necessary because of a lack of experience in the insurance industry.	Fee estimated at $81 per year	Value of $175 per year (equals Cell D12 – C13)	Develop training to ensure that insurance companies have the training to value NZE houses properly.	Training also applies to many sectors, not just insurance.	Fee estimated at $81 per year	Value of $3945 per year (equals Cell H12 – G13)
14.	Mortgage interest on additional construction cost of house	The estimated value is based on a 6% interest rate and a $101k incremental cost for the house.	Fee of $6060 per year	Value of negative $5885 /year (equals Cell D13 – C14)	Develop zero interest mortgages on energy efficiency and renewable energy additions to new and existing houses.	Interest payments effectively nullify many otherwise highly worthwhile renewable energy and energy efficiency projects.	Fee of $0 per year	Value of $4318 per year (equals Cell H13 – G14)
15.	(This line isn't a policy, rather it adds in the rest of the energy bill savings.)	Savings in energy bills due to energy efficiency and solar heating	Savings of $1756 per year	Value of minus $4129 per year (= D14+C15)		Savings in energy bills due to energy efficiency & solar heating	Savings of $1756 per year	Value of $6074 per year (= cell H14 + G15)
16.	Regulatory approval fees amount to $1300	Return on capital costs of $101k + 1.3k:	= cell D15 / B16	minus 4.0% per year	No additional regulatory fees	Return on capital costs of $101k:	= cell H15 / F16	6.0% per year

Notes on Table 5:

1. It is estimated that at least 80% of the 5700 kWh of electricity that the RNZ solar PV system will generate per year will be immediately exported to the grid at the time of its production since the system has no battery bank (which is the configuration of 99% of grid-connected solar PV systems), and since the house is electrically very energy efficient.
2. Many of these policy barriers pertain only to solar PV and other house-based electricity generating systems because such systems are connected into the electric utility infrastructure and its associated safety, power quality, cost and metering relationships. Similar barriers are not found with solar heating, geothermal heat pump, and energy efficiency because they are stand-alone technologies.
3. Several policy changes will largely be resolved through Alberta's new microgeneration policy now intending to be in place sometime in 2008, specifically those in Lines 1 (partially), 3, and 5.
4. In addition to the items in Table 5 are policies that need to:
   a) eliminate the electric utility company grid-connection application fees that range up to $1400;
   b) drastically simplify the industrially-complex micropower grid-connection process that now effectively requires homeowners to engage a consultant at fees of $1300 (for solar PV) to $3000 (for microwind) to obtain the required regulatory approvals for grid connection; and
   c) eliminate electric utility company requirements for additional safety equipment (up to $200).
5. Additional net-zero-cost policies need to be developed to place a monetary value on:
   a) the health, emissions, infrastructure, and energy saving benefits of reduced water consumption;
   b) the reduced health care costs of much better household indoor air quality;
   c) the infrastructure benefits of reduced construction waste; and
   d) as in Line #8, the full health care damages from the air, water and land emissions from natural gas- and oil-based heating and transportation fuels and their associated exploration and production activities, that can then be prorated and credited to the account of net zero energy houses and other houses were people construct and operate them at less than the municipal averages.
6. Likely as more experience is gained with net zero energy houses, further benefits (and perhaps some costs) will be experienced, understood and valued.

3. CONCLUSIONS

Canada Mortgage and Housing Corporation's EQuilibrium housing initiative and the resulting net zero energy houses are demonstrating their role as part of the solution to the planet's environmental issues. By constructing the Riverdale NetZero house, its team is identifying barriers to the implementation of the house's innovative technologies and integrated design process, and opportunities for profitable business based on the development of appropriate technologies, training, and policies. The house offers CMHC, the house team and its stakeholders the opportunity to provide significant leadership in reducing the environment impact of residential housing.

From the experience with the Riverdale NetZero house, the team found that the technical challenges in designing and building a net zero energy house in a cold high-latitude climate included availability of components, equipment and systems:

- that had a high-enough energy efficiency (electrical appliances and consumer equipment, solar PV and solar heating equipment, heat pumps, circulating pumps and fans, lighting, windows, doors, insulation);
- that could easily be integrated into building structures (solar PV, window shutters, variable window shading); and
- that had independently-verified performance claims (solar heating, heat pumps, heat recovery units, window shutters).

The key challenges with net zero energy technologies are in how these technologies are integrated to provide the greatest reduction in energy use and make the production of on-site energy most effective.

The team found that the challenges that had organisational solutions were more significant than the technical challenges, particularly relating to how monetary values were assessed to the environmental effects of energy sources. This affects how the reduction in fossil fuel consumption is valued.

These organisational challenges included:

- training and awareness (in integrated design, performance modelling, trades, marketing, grid-connection, plumbing codes, land-use bylaws, solar access laws, equipment performance standards);
- lack of community design standards to allow for solar access and infrastructure to support distributed electricity generating and heat producing systems; and
- government policies on financing, support for fossil fuels, energy efficiency, renewable energy, and the environment. Current government policies have historically had the effect of facilitating and increasing the production and consumption of fossil fuels, and not decreasing it. A wholesale change is required in the focus of energy policies.

Net zero energy homes are economically viable and feasible under the following conditions:

a) when fossil fuel energy is not subsidised; and instead when their pricing pays for the full costs of their effects on clean air, clean water, clean land, habitat, and on public infrastructure such as health care;

b) when all the benefits of energy efficiency and renewable energy are valued (such as emissions, weather security, reduced resource depletion, local employment) in addition to its energy value; and

c) when energy is sold and delivered on a pure commodity basis in line with other commonly purchased commodities, where all energy and delivery costs are bundled into energy prices and not increasingly into time-based connection fees.

With policies developed to address today's environment issues, energy efficiency and solar energy would be so strongly valued that net zero energy houses could easily find their essential place in the increasing need to make fundamental changes to society's sources of energy. Net zero energy homes would then not have financial challenges and wholesale changes in new house construction could begin, followed by the much more difficult renovation of existing housing stock.

The biggest challenge is in developing the required organisational solutions to overcome the financial, policy and training barriers. A question to this end is "Who is going to step up to the plate to provide society with the leadership that the environment is requiring of society?" [12]

4. RECOMMENDATIONS

This paper highlights the challenges to net zero energy housing and how they largely relate to current policies and their economic consequences. Equitable changes need to be made to them.

Love (2007) makes 12 exemplary recommendations for action that identify barriers to and opportunities for conservation to move the Canadian province of Ontario Canada towards a "culture of conservation". These recommendations highlight organisational solutions to achieve their goals.

Drummond *et. al.* (2007) describes market-based solutions to protect the environment. The report recognises that "The existence of externalities and market failures has long been one of the key rationales for government intervention in the economy".[13] The report recommends environmental taxation and policies that change the price structure of pollution.

As a result of the work on the Riverdale NetZero Project, we recommend that:

1. Governments develop sustainable development and sustainable energy policies and strategies to eliminate the barriers to net zero energy housing;
2. Governments develop ultra low-interest "green" loan policies and programmes to promote the use of energy efficiency and renewable energy measures;

[12] The future does not belong to those who are content with today, fearful in the face of new ideas and bold projects. It will belong to those with a personal commitment. Quote: Robert Kennedy, 1966

[13] "Socialism collapsed because it did not allow the market to tell the economic truth. Capitalism [is heading in the direction of collapsing] because it [is not allowing] the market to tell the ecological truth."
Quote paraphrased from Øystein Dahle, retired VP of Exxon Norway.

3. Governments establish programmes to work with industry and academic institutions to design, develop and demonstrate net zero energy housing and its integrated design and product development infrastructure in order to rapidly gain credibility, identify further barriers and develop solutions;

4. Governments, in consultation with appropriate stakeholders, develop policies to implement Table 5, column E, lines 1 to 14 as applicable to their own jurisdiction, and to have a common nation-wide grid-connection approvals process for solar PV systems;[14]

5. Governments develop policies that use utility energy price signals to facilitate realistic economic returns for the reduction in greenhouse gas emissions, and the use of energy efficiency and renewable energy measures;

6. Governments develop policies that provide ways for utility companies to profit by the introduction of energy efficiency and renewable energy technologies; and

7. Governments prepare for net zero energy housing by using full-cost accounting methods and by developing and revising land-use bylaws, solar access laws, building codes, energy codes and product standards to reflect the societal cost of energy use.

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