IN SEARCH OF EQUILIBRIUM IN CANADIAN HOUSING

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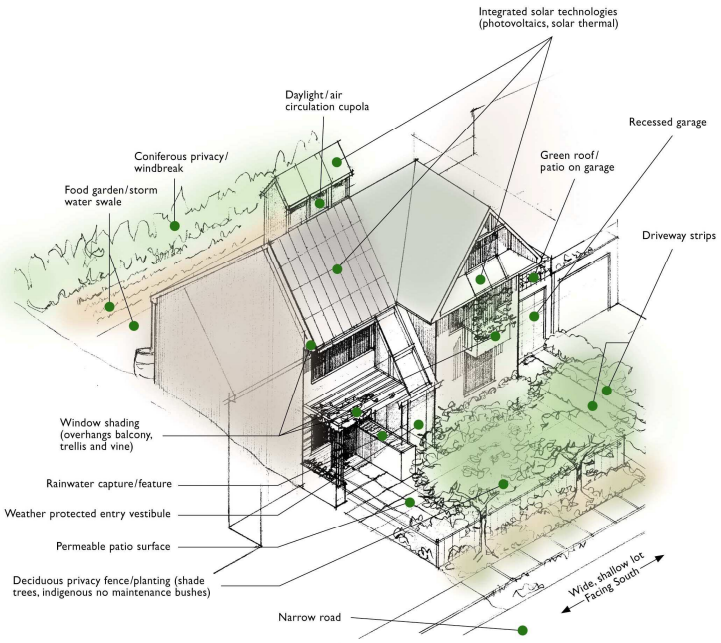
Summary

Faced with rising energy costs, a greater concern for the environment and an increased focus on the health of their families, Canadians are beginning to consider housing options that are healthy, energy-efficient, durable, environmentally friendly – and less expensive to operate and maintain. This paper is about finding the way to balance all those aspects while maintaining the sustainability principles for both housing and communities. EQuilibrium Housing is a national design and demonstration initiative, announced in July 2005 and led by Canada Mortgage and Housing Corporation (CMHC), which brings the private and public sectors together to develop zero impact sustainable homes in communities across the country.

Keywords: Net zero energy, passive solar design, sustainable housing, sustainable community, healthy housing, environmental impact, affordability



1 Introduction

Equilibrium = balance
The word "Sustainability" tells us about the possible "Equilibrium" – balance between 3 pillars / principles of sustainability: ecological, economical and societal (social, cultural, ethical etc, while social itself = health/safety, neighbourghood impact, quality of life etc.). The search was not for a good house, but for housing within community where all principles could be seen and where people could enjoy healthy lives while the impact on nature would be minimal.

We must also remember that without a culture (language, history, religion, arts, common habits, culture in general) a nation cannot have any sustainable future! **Human diversity** must be preserved just like bio-diversity. [*Tupamaki TG4*]

Fig. 1 Remastered "Girl on the Ball" by Pablo Picasso – courtesy of Wroclaw Technical University, Poland

2 Canada's performance

Climate Change in Canada has a huge impact on all aspects of life, and as Canada is the second largest country with all adverse climatic zones, it experiences such phenomena as:

- Extreme temperature and weather events
- Reduced water and food quantity & quality
- High impact on Canada's northern peoples
- Increased infectious diseases
- Poor air quality and environmental quality

It is proven that climate change happens due to human activities and a huge part is related to construction and operation of buildings and that has always been part of a "balance" we are looking for.

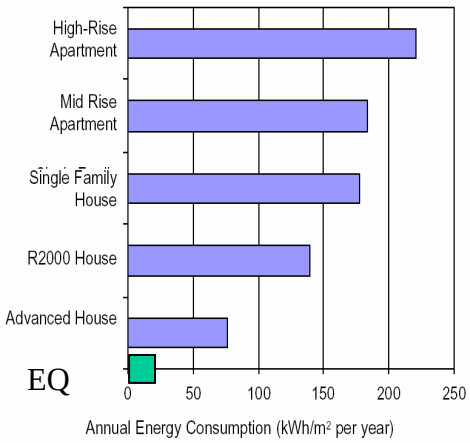


Fig. 2 Annual Energy consumption showing the Equilibrium performance (green)

Housing accounts for 17 per cent of secondary energy use in Canada and 16 per cent of the country's greenhouse gas (GHG) emissions with the following energy use per year (*Natural Resources Canada, Energy Use Data Handbook August 2006*).

The ecological footprint is the total land surface required to support (to produce and absorb the waste) a given activity or product (building being one of them).

The sad truth is that **for the entire world to live as an American or Canadian, we would need two more earths to satisfy everyone.** The average US footprint is approx 10 ha per person while there are only 2 productive ha available for each person on the planet.

Try: http://www.mec.ca/coop/communit/meccomm/ecofoot.htm

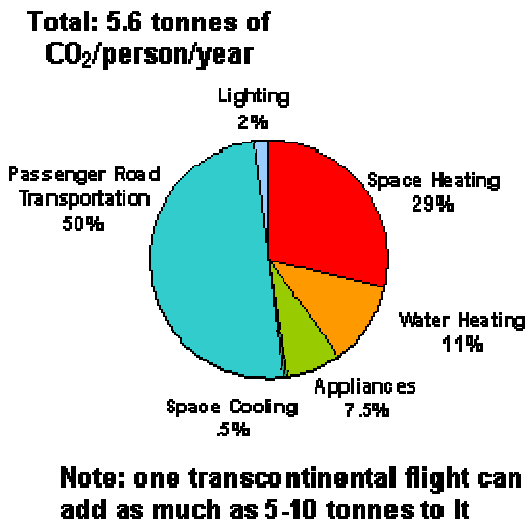


Fig. 3 Personal GHG Emissions in Canada

According to a Natural Resources Canada report on energy efficiency trends published in 2006, GHG emissions from the residential sector were up 10 per cent in 2004 (76.7 Mt) compared to 1990 (69.5 Mt).Without the energy efficiency improvements made in that time span, energy use would have risen by 31 percent.

3 EQuilibrium Housing Definition

EQuilibrium is a national housing initiative, led by Canada Mortgage and Housing Corporation (CMHC), that brings the private and public sectors together to develop homes, and eventually whole communities and that address occupant health and comfort, energy efficiency, renewable energy production, resource conservation, reduced environmental impact and affordability.

It evolved from the initial Net Zero Energy Healthy Housing initiative with a goal of developing a highly energy efficient demonstration housing that would produce as much energy on-site as they consumed on an annual basis while addressing its own 5 principles mentioned above.

EQuilibrium housing is a design and development approach that integrates the following five key principles for sustainable design: Health, Energy, Resources, Environment, and Affordability. When designed according to these five core principles, EQuilibrium homes not only help protect the environment, they also provide safe, comfortable and healthy living spaces for their occupants.

The ultimate goal is a highly energy-efficient house that provides healthy indoor living for its occupants, and produces as much power as it consumes on a yearly basis with minimal or no environmental impact on land, water and air.

From the beginning it was clear that the task to promote the challenge will be very difficult mainly due to incorrect perception in Canada that it is a Northern country, thus no solar technologies would ever work well enough. It is, however, enough to look at the globe to see that the latitude of Ottawa is close to that of Nice in France and that Canada's most populated areas along the US border enjoy much more sun that the solar leader - Germany. (PV potential and solar insolation web-based maps are at:

https://glfc.cfsnet.nfis.org/mapserver/pv/index_e.php)There was also difficulty in defining what does the Net Zero Energy really mean and the NREL publication[1] below explains why EQulibrium concept is based on the "**Net Zero Site Energy**". All other approaches would be either too difficult to measure (a site energy can be on-site

monitored, while source energy or emissions cannot be measured directly due to site-to-source factors), or could fluctuate too much such as **Net Zero Energy Costs.**

Zero-Energy Buildings (ZEBs): Definitions
A zero energy building can be defined in several ways, depending on the boundary and the metric. Different definitions may be appropriate, depending on the project goals and the values of the design team and building owner. For example, building owners typically care about energy costs. Organizations such as DOE (US Department of Energy) are concerned with national energy numbers, and are typically interested in primary or source energy. A building designer may be interested in site energy use for energy code requirements. Finally, those who are concerned about pollution from power plants and the burning of fossil fuels may be interested in reducing emissions. Four commonly used definitions are: net zero site energy, net zero source energy, net zero energy costs, and net zero energy emissions. Each definition uses the grid for net use accounting and has different applicable renewable energy sources. The definitions do apply for grid independent structures. For all definitions, supply-side option 2 can be used if this resource will be available for the life of the building. Off-site ZEBs can be achieved by purchasing renewable energy from off-site sources, or in the case of an off-site zero emissions building, purchasing emissions credits. In support of (...)research needs, the following definitions refer to ZEBs that use supply-side options available on site.

For ZEBs that have a portion of the renewable generation supplied by off-site sources, these buildings are referred to as "off-site ZEBs."

- **Net Zero Site Energy:** A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.
- **Net Zero Source Energy:** A source ZEB produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.
- **Net Zero Energy Costs:** In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.
- **Net Zero Energy Emissions:** A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources] [1].

4 Features and Advantages

The EQ initiative's teams were asked to design the best housing using passive solar principles, materials, techniques and strategies to minimize energy consumption to achieve the final goal of balancing use of energy with its production on site **and only then** use the appropriate (renewable energy) technologies.

The concept integrates a wide range of technologies, strategies, products and techniques to reduce a home's environmental impact to an absolute minimum. Equilibrium housing also features commercially available, on-site renewable energy systems to provide clean energy to help reduce annual consumption and costs.
The approach offers home buyers a wide range of benefits and advantages.

These include:

- **Lower energy bills** – net zero energy consumption annually means dramatically lower energy bills and protection from fluctuations and increases in future energy prices.
- **A reliable source of energy** – integrated on-site renewable energy systems can be designed to continue functioning even during blackouts.
- **Healthier living** – EQuilibrium homes feature better indoor air quality and non-toxic, healthy materials and finishes.
- **Greater comfort** – an energy-efficient building envelope with even temperatures, more natural light and better acoustics ensures a comfortable environment all year round.
- **Reduced pollution and CO_2 emissions** – better building design and reduced energy demand will significantly lower greenhouse gas (GHG) emissions and minimize the detrimental environmental impact of housing on water, land and air.
- **Affordable sustainable development** – The longer term vision includes vital and healthy communities characterized by efficient infrastructure, attractive green spaces and vibrant neighborhoods that combine places to work, live and play.

All of these practices have already been proven effective on their own. The difference is that EQuilibrium is a unique Canadian initiative that combines and integrates these design and building practices into practical solutions that meet the needs of both occupants and builders alike. Initially, an EQuilibrium house is expected to cost more to build than conventional housing. But this higher purchase price will be offset to some extent by the significantly lower energy and operating costs of the home.

5 12 Winning Projects

In May 2006, CMHC invited builders and developers to submit their ideas for housing that is healthy, affordable, sustainable and highly energy-efficient.

A total of 72 teams from across Canada responded to the challenge, and after an intensive two phase selection process, 12 of these teams have been chosen in January 2007 to build EQuilibrium demonstration homes in their regions while receiving technical, marketing and financial support. These builders will also acquire the experience and expertise to access new business opportunities and spread of EQuilibrium homes across the country.

Fig. 4 Abondance Montréal

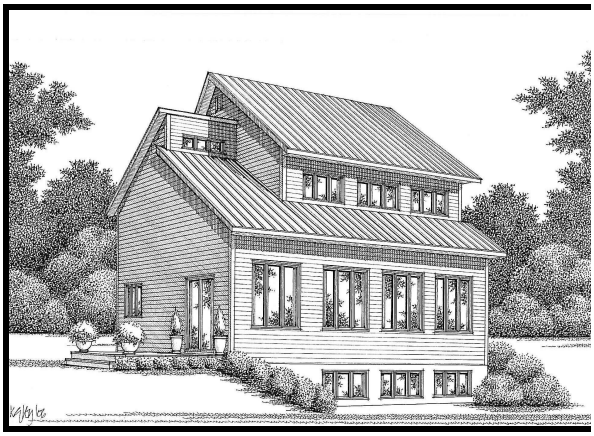


Fig. 5 Alouette Homes, Eastman, Quebec

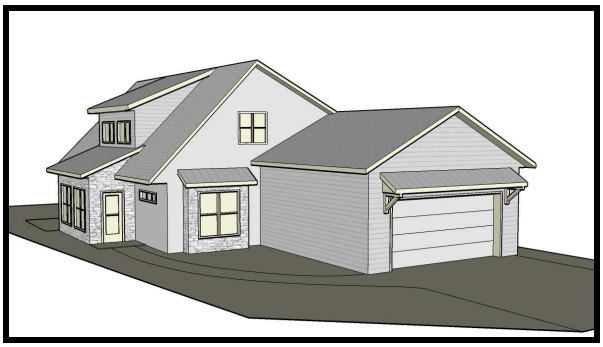


Fig. 6 Avalon Dicovery III - Red Deer, Alberta

Fig. 7 CHESS, Red Deer, Alberta

Fig. 8 Alstonvale Net Zero House, Hudson, Quebec

Fig. 9 Eco Haven, Calgary, Alberta

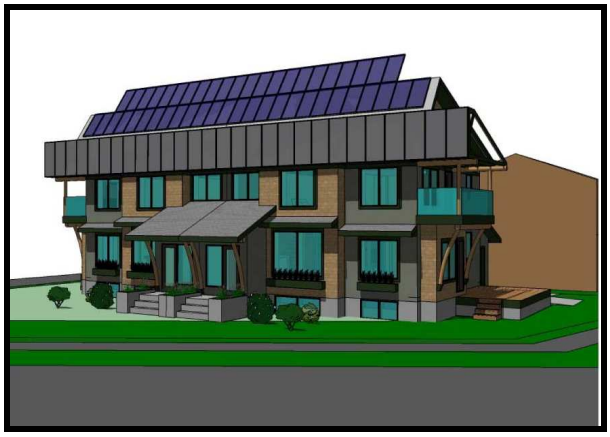


Fig. 10 Riverdale, Edmonton, Alberta

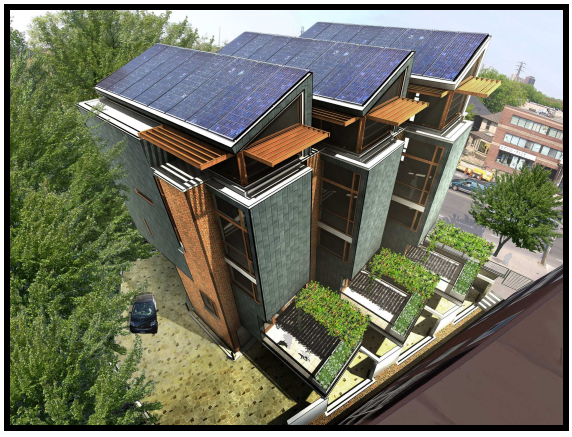


Fig. 11 Annex Townhomes, Toronto, Ontario

Fig. 12 Minto EcoHome, Ottawa, Ontario

Fig. 13 Now House™, Toronto, Ontario

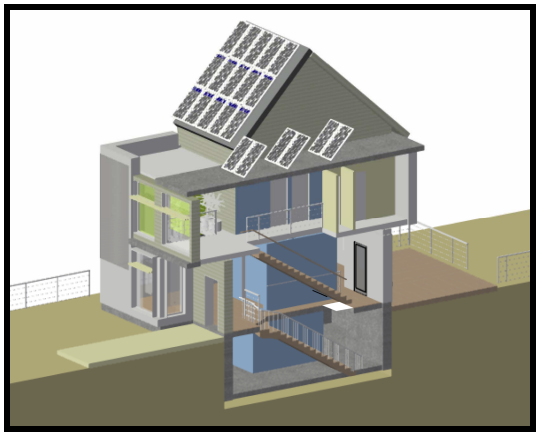


Fig. 14 Urban Ecology, Winnipeg, Manitoba

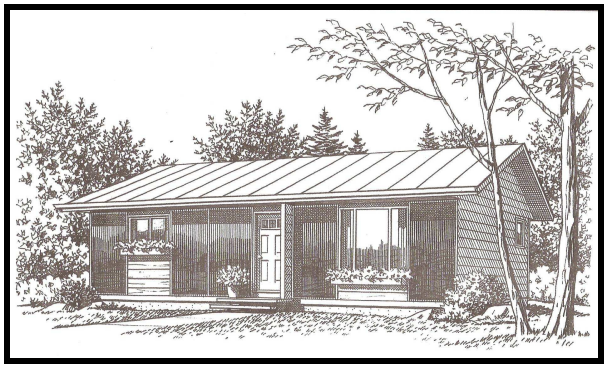


Fig. 15 YIPI!, Battleford, Saskatchewan

The data in **Fig. 16** below shows the specific approach to building envelope with very high levels of insulation in walls and roofs (shown as R value; 1 R = 0.176 RSI) despite the fact of decreasing efficiency and significant increase in cost in relation to heating energy savings. Some teams achieved the design value even of that of passive housing. On the other hand, some teams such as Alouette, shown in a detailed table, have chosen the other way, being on a lower side in comparison to others, and looking for energy efficiency and savings in other areas for example through strict passive solar design.

Average use of PVs (photovolaics) reached approximately 5.5 kW per project, which means that teams managed very well to meet the initial requirement for a very good envelope performance. The pre-requisite was to achieve a higher level of performance than current R-2000 standards, which has set the bar for many years. Only when computer simulations on HOT2000 program showed the required number above 82 in envelope (refer to **Fig. 16** – EGH envelope), the design could enter the final stage of the selection process. Last column shows the achievement of Net Zero as 100.

CMHC EQuilibrium Housing Initiative

Technical Summary: Alouette Home - Eastman, Quebec

Energy consumption (normalized by conditioned floor are

Total annual energy use:	43.57 kWh/m^2
Space heating:	9.70 kWh/m^2
Domestic water heating:	14.58 kWh/m^2
Appliances/lighting:	16.61 kWh/m^2
Mechanical ventilation:	2.68 kWh/m^2

Energy production (normalized by conditioned floor area)

Total annual energy production:	31.82 kWh/m^2
Solar thermal space and water heating:	10.87 kWh/m^2
Geothermal heat pump "desuperheater":	3.04 kWh/m^2
Greywater heat recovery:	3.04 kWh/m^2
Solar electricity:	14.87 kWh/m^2
Net annual energy balance:	-11.75 kWh/m^2

EnerGuide for Houses (EGH) Rating

EGH Rating: 85 EGH* Rating: 98

The EGH* Rating used in the EQuilibrium housing initiativ is a modification of the standard EGH Rating used in the EnerGuide for Houses program to allow for changes t standard EGH Rating procedures such as reductions in base load electricity, hot water use, and air conditioning energy.

Site

Location:	Eastman, Quebec
Site type:	Rural, new development
Site area:	10,770 m^2 (115,927 ft^2)
Altitude:	274 m (899 ft.)
Latitude:	45°29'N
Longitude:	72°32'E

Average ambient temperatures

January:	-10.4	℃	13.28	℉
April:	4.6	℃	40.28	℉
July:	19.4	℃	66.92	℉
October:	7.1	℃	44.78	℉

Design temperatures

January:	-28	℃	-18.4	℉
July:	29	℃	84.2	℉

Heating degree days (base 18℃ [64℉]):	5,242
Cooling degree days (base 18℃ [64℉]):	101

Climate

Average daily horizontal solar irradiation:	3.5 kWh/m^2
Average daily vertical solar irradiation:	3.0 kWh/m^2
Clearness index:	0.48 Kt
Precipitation:	875.5 mm (35 in.)
Wind speed:	9.4 km/h (5.8 mph)

Building Description

Type: New, 2-bedroom, single detached

Floor space:		141 m^2	1,517 sq. ft.
Building axis: East-West			
Building footprint:			
Heated volume:		671.4 m^3	23,710 cu. ft.
Heated floor area:		230 m^2	2,476 sq. ft.
Ceiling area:		87.06 m^2	937 sq. ft.
External wall area:		219.73 m^2	2,365 sq. ft.
Window area total:		33.42 m^2	360 sq. ft.
	South:	20.9 m^2	225 sq. ft.
	North:	0.65 m^2	7 sq. ft.
	West:	5.20 m^2	56 sq. ft.
	East:	6.67 m^2	72 sq. ft.

South glazing-to-floor ratio 9.1%

Airtightness: 1.0 ACH @ 50 Pa

Thermal characteristics

Roof:	RSI 9.54	(R-54.2)
Walls:	RSI 6.6	(R-37.5)
Windows:	U=1.41	(R-4.03)
Ground floor:	RSI 0.832	(R-4.73)

Space heating

Passive solar internal gains; ground source geothermal heat pump. Integrated heat recovery from behind solar PV array; back-up grid electricity.

Ventilation

Heat recovery ventilator (HRV) core with recirculation air contr ol in defrost cycle. Rate: 50 L/S

Water heating

Geothermal heat pump combined w ith heat recovery from behind solar PV array, back-up grid electri city.

Water statistics (estimated)

Annual potable water use = 134 L/day (35 gal/day)

Annual greywater use = 1206 L/day (319 gal/day)

Project	Prv	Type	Context	Bdrm	Area m2	R Roof	R wall	Energy kW/m2/y	PVk	EGH envel.	EGH
Abondance	OC	Triple	Urban	2	**77**	**70**	**45**	**61.80**	**1**	**85**	**100**
Alouette	AB	single	rural	2	**230**		**38**	**24.00**	**3**	**85**	**98**
CHESS	ON	single	urban	4	**141**	**80**	**54**	**44.50**	**3**	**88**	**100**
Discovery III	AB	single	urban	4	**234**	**86**	**72**	**58.80**	**3.**	**86**	**99**
Echo Haven	AB	single	s-	4	**209**	**10**	**60**		**7.**	**86**	**100**
Alstonvale	OC	single	rural	3	**173**	**68**	**32**	**44.50**	**5.**	**84**	**100**
Minto	ON	single	s-	3	**309**	**60**	**40**	**49.80**	**5.**	**85**	**100**
Now	ON	single	urban	2	**139**	**50**	**33**	**75.00**	**2**	**84**	**94**
Riverdale	AB	duple	urban	3	**234**	**10**	**56**	**40.70**	**5.**	**86**	**99**
Annex	ON	triplex	urban	3	**210**	**76**	**60**	**29.00**	**6.**	**84**	**101**
Urban	Mn	semi	urban	3	**162**		**57**	**29.00**	**6**	**89**	**101**
YIPI	SK	single	rural	3	**90**	**10**	**80**	**8.14**	**3.**	**86**	**94**
Average					**184**	**65**	**52**	**39.00**	**5.**	**85.6**	**98.8**

Fig. 16 Design data for all houses
Note: examplary details for Alouette Homes are shown on previous page

6 The Goals and Objectives of the EQuilibrium Housing initiative

The **goals** are to:
- Develop a clear vision and approach to achieve EQuilibrium Housing in Canada;
- Build capacity and lower the barriers for Canada's housing and renewable energy industry sectors to create high-quality EQuilibrium Housing across the country, start Community Scale demonstrations of 1500 houses by 2010
- Achieve market acceptance of highly energy-efficient healthy houses and sustainable communities.

The **objectives** are to:
- Reduce the energy intensity of our housing sector,
- Mitigate household energy cost increases,
- Foster a growing renewable energy and sustainable housing industry in Canada,
- Contribute to meeting Canada's international commitment of reducing green house gas (GHG) emissions in the Kyoto Accord and beyond, and
- Support Canada's inclusion in competitive international markets with our next generation of value added exports.

Context: **Canada has 225,300 housing starts in 2007**, which is twice the per capita as the UK and with less than half population compared to UK.**Conclusions**

The EQuilibrium housing initiative represents a significant step forward in reducing the energy intensity of Canada's housing sector, supporting our growing need for renewable energy solutions and helping Canada maintain a clean and healthy environment.

Each of these leading-edge houses demonstrates the achievement of the initiative goals to certain extent. Some are clearly winners in a design stage, but none has yet been

verified in real world. Several have already started construction, the rest is, at the time of writing this paper, still completing documentation and proceeding with final design, especially building envelope, being a critical component in each and every design. We can only expect that all, or at least most, of them will achieve a site Net Zero Energy goals and we will learn with the monitoring continued for a year after occupancy.

The huge interest from architects, builders and developers shows only that it is never too late for such endeavors to limit our impact on the nature.

> The nature, including humanity, is an ultimate source of all value. Unless it gets our consideration, the richest and most wonderful places and most of the mankind probably will not survive this century and that will be our great crime against our children and grandchildren.
>
> P. Curry – "Ecological Ethics"

Some EQuilibrium Initiative Team Websites:

- http://www.maisonalouette.com/english/
- http://www.montrealzero.ca/english/01_eng_nzehh.html
- http://www.avalonmasterbuilder.com/net_zero.html
- http://www.echohaven.ca/net-zero.html
- http://www.ecocite.ca/projects_abondance.html
- http://www.minto.com/minto/press_releases/inspiration.asp
- http://www.nowhouseproject.com/
- http://www.riverdalenetzero.ca/
- http://www.sui-toronto.com/

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[1] TORCELLINI P., PLESS S., DERU M. *Zero Energy Buildings: A Critical Look at the Definition.* ACEE Summer Study, Pacific Groove, California 2006, pp 4-5.

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[3] KUJAWSKI W. *Presentations at: Americana 07,* Montreal, March 2007.

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[5] KUJAWSKI W. *New Housing for a Changing World,* CMHC 2007, pp 1-3.

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