

GETTING TO A NET ZERO ENERGY LIFESTYLE IN CANADA: THE ALSTONVALE NET ZERO ENERGY HOUSE

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ABSTRACT: The Government of Canada is funding the demonstration of twelve innovative homes under the Equilibrium initiative that would strive to achieve net zero energy consumption by the house, a healthy indoor environment, reduced resource consumption, particularly water, reduced deleterious impacts on the environment; affordability to the target market, and repeatability throughout Canada. This paper describes the process undertaken by one of the houses - the Alstonvale Net Zero Energy House (ANZEH), which in addition to meeting the targets of the initiative, is proposing to go one step further as it strives towards net zero energy lifestyle by integrating efficient on-site food production methods to further reduce the household's energy footprint, and incorporating, as the primary energy generation system, a 7 kW, building integrated, photovoltaic/thermal (BIPV/T) system on its roof to generate both electricity and thermal energy, and of which 1.5 kW is dedicated to balancing the local transportation needs of the household, assuming an electric drive vehicle. The design and selection of the energy systems of the house is presented and discussed with particular emphasis on its BIPV/T system, heat pumps using BIPV/T solar-heated air as source to heat a thermal storage tank, and anticipatory control to optimize heat storage and reduce peak loads.

Keywords: Net Zero Energy, photovoltaic-thermal, integrated design.

1 INTRODUCTION

Due to population and economic growth, global energy demand has risen steadily in recent history and will continue to rise under a business-as-usual or a no-policy-change world. During the last quarter-century, global energy demand increased by over 50%. An increase of another 50% is projected between now and 2030 [1]. Since the future growth in energy demand, however, builds from today's much larger base, the energy requirements as we approach 2030 will be unprecedented in scale.

There are two options available to meeting the growing demand for energy: supply more energy or improve energy productivity. Although the energy debate is disproportionately focused on expanding the supply of energy, improving energy productivity can generate dramatic and nearly immediate results with existing technologies and proven policies. Demand abatement, and boosting energy productivity can meet our energy demand more cleanly, quickly and cost-effectively than any other available supply option. Furthermore, improving energy productivity can yield these results while generating stronger financial returns than those from investments in expanding conventional or renewable energy supplies.

Simply increasing conventional energy supply is not a viable option because continued reliance on fossil fuels exacerbates energy insecurity and raises serious environmental concerns, especially related to climate change. Furthermore, simply hoping that renewable

sources can expand fast enough to keep up with an insatiable global appetite for energy is an unrealistic expectation.

Concerted global action is urgently needed to address today's daunting energy challenges. Without such action, security of energy supply and economic resilience will deteriorate, and the threat of climate change will become a devastating reality. The world's energy challenges stem naturally from welcome economic growth. But they are leading the world along an increasingly unsustainable energy path.

Facing severe energy challenges: climate, energy security, and affordability, the International Energy Agency estimates an additional 1 USD spent on efficiency avoids more than 2 USD investments in electrical supply. Without the various energy efficiency policies that have been implemented since 1973, worldwide energy consumption would be 56% higher today than it would have otherwise been [2].

Energy efficiency forms the cornerstone of the design elements of the Alstonvale Net Zero Energy House (ANZEH). The ANZEH, a grid-tied, single-family, detached house located near Montreal, Québec, is described in detail in this paper. The authors are further suggesting a path to transcend the benchmark of net zero energy houses and demonstrate the attainability of a net zero energy lifestyle

2 CANADA'S ENERGY USE BY SECTOR

Canadian total secondary energy use by sector, end-use and sub-sector in 2005 was estimated at 8,475 petajoules (PJ) (Fig. 1), resulting in 496 Mt of CO₂e greenhouse-gas (GHG) emissions¹ [3]. In 2005, Canada's buildings sector accounted for 31% (2,555 PJ) of the country's total secondary energy use and 28% (171 Mt of CO₂e) of its GHG emissions. The buildings sector consists of the residential as well as the commercial/institutional buildings sub-sectors and related energy end-use activities. The residential sub-sector accounted for 17% of total secondary energy use in Canada and 15% of its GHG emissions.

Canada's transportation sector in 2005 accounted for 30% (2,500 PJ) of the country's total secondary energy use and 34% (177 Mt of CO₂e) of its GHG emissions. The transportation sector consists of passenger or personal mobility as well as freight activity via modes such as air, water, road, rail, and pipeline. Personal Mobility includes the use of the private automobile, ride-sharing, buses, public transit, cycling and walking among others. Personal mobility accounted for over 55% of the total secondary energy consumed by the transportation sector, in 2005. This represents approximately 16% of the country's total secondary energy demand.

For the purpose of this discussion personal mobility by private automobile and light trucks alone (sport – and cross utility vehicles) represent 13% of total energy use in Canada and 15% of Canada's total GHG emissions. The energy consumed by this sub-sector is a function of kilometers traveled and vehicle fuel efficiency. These, in turn, are inextricably linked to the morphology of our communities, fuel prices and other fees, the existence of alternatives to the private automobile, personal travel propensity, and the willingness of the automobile industry to deliver increasing vehicle fuel efficiency.

Analysis of energy consumption in the agriculture and food sector in Canada in 2005, yield a total value of about 510 PJ of direct and indirect energy² consumption - a 6% of the total energy used and contributed about 6% of the total GHG emissions.

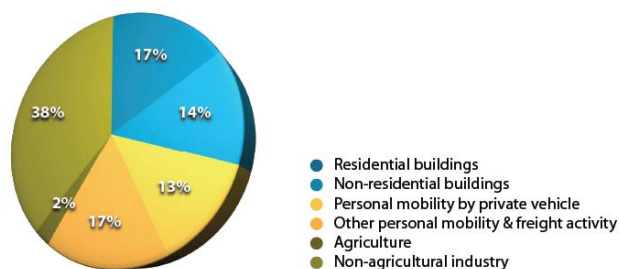


Figure 1: Canada's secondary energy use by sector and sub-sector in 2005.

3 DESCRIPTION OF THE ANZEH

3.1 The Context

In May 2006, Canada's federal housing agency, Canada Mortgage and Housing Corporation (CMHC), launched a multi-staged, nationwide, competition named EQUilibrium³ with the ultimate intention of spawning 12 housing demonstration projects across Canada. The following year CMHC announced the 12 winners of this initiative. The

Alstonvale Net Zero House was one of those selected (Fig. 2).



Figure 2: Alstonvale Net Zero Energy House.

The merits of the design proposal of the ANZEH submitted to the EQUilibrium initiative were measured on the basis of how well they achieve: (1) net zero energy consumption by the house; (2) a healthy indoor environment; (3) reduced resource consumption, particularly water; (4) reduced deleterious impacts on the environment; (5) Affordability to the target market; and (6) repeatability throughout Canada. The ANZEH was designed by an interdisciplinary team using a reiterative process and aided by computer performance simulations. The result is a house design that satisfies, in varying degrees, the six EQUilibrium objectives.

3.2 Scope of the ANZEH

Existing buildings are responsible for over 40% of the world's total primary energy consumption, and account for 24% of world CO₂ emissions (IEA, 2006). Yet, despite the proven cost-effective opportunity to reduce energy consumption, a large portion of the potential for energy efficiency in the existing residential building sector remains untapped.

The ANZEH strives towards net zero energy consumption by minimizing the energy requirement of the house through a high performance building envelope, reduced energy demand loads, and aggressive use of passive heating and passive cooling techniques, as well as generating on-site sufficient energy, through renewable resources.

Following the selection of the ANZEH, and soon into the ensuing design development phase, the ANZEH project team concluded that although the goal of net zero energy consumption by the house is excellent, it remains insufficient given the dire global energy outlook. Hence, the ANZEH team decided to expand this project's objective relating to energy consumption to encompass not just the house but the entire lifestyle of the household, by enlarging the PV system by an additional 1.5 kWp to provide power to an electric drive vehicle, and by integrating efficient on-site food production methods, at the individual household level, to displace agricultural imports and to further reduce a household's energy footprint - the principles of permaculture will permeate the landscape design.

Therefore, the scope of the ANZEH has evolved to broader and more ambitious objectives than its EQUilibrium cohorts, by attempting to demonstrate the attainability of a more encompassing "net zero energy lifestyle". In other

words, the ANZEH aims to generate all the energy required for the household's domestic as well as local transportation energy needs. By incorporating a garden, it will facilitate on-site food production in order to displace agricultural imports as much as possible. Given that slightly more one third of the total secondary energy used in Canada in 2005, as well as one third of its total GHG emission come from the three sectors (Fig. 3) that the ANZEH seeks to address, underpinning this notion of a net zero energy lifestyle is the conviction that a house is not just a home but, if designed intelligently, is the enabling backbone that supports a household's needs for shelter, mobility, and food through the sole reliance on solar and other renewable sources energy and with very minimal associated GHG emissions.



Figure 3: Secondary energy use in the residential, private transportation and agricultural sub-sectors in Canada in 2005.

4 PATH TO A NET ZERO ENERGY LIFESTYLE

4.1 The Integrated Energy System of the ANZEH

According to the Canada's secondary residential energy consumption in 2005, heating energy (space and water) accounted for 78% of total household energy consumption and electrical energy (lighting, appliances and space cooling) accounted for the remaining 22% [4].

First and foremost, the ANZEH has been designed to take advantage of passive solar heating. Triple-glazed windows (providing solar heat gains and daylighting) form 43% of the south façade and complete an air-tight building envelope with high insulating value (5.6 RSI in the walls, 12 RSI in the ceiling and 4.6 RSI in the floor). An internal masonry wall and 6-inch thick concrete floors provide large thermal inertia to the building, dampening the temperature fluctuations and storing heat from solar radiation and the HVAC system.

This house was also designed to make use of energy efficient appliances and lighting, and incorporates several measures for the rational use of domestic hot water. The design also incorporates a 7 kWp building integrated photovoltaic/thermal (BIPV/T) system on its roof. This system uses exterior air circulating in a cavity below the PV panels in order to recover heat from them, thus lowering their temperature. A glazing section, mounted on the same framing system, helps to enhance heat recovery. This can represent a large amount of energy: when there is 1000 W/m² of solar radiation on the roof (which has more than 100 m²), recovering 30% of this energy accounts for 30 kW. Since the BIPV/T is used to collect both electricity and heat, it constitutes the main energy supply system of the house [5].

There is also a solar thermal system on the overhangs of the south façade for domestic hot water production. Of the 7 kW of PV, 5.5 kW is dedicated to balancing the domestic energy needs while 1.5 kW is dedicated to balancing the

local transportation needs of the household, assuming an electric drive vehicle (EDV).

4.1.1 The Photovoltaic-Thermal Roof

As mentioned above, 1.5 kW_p of PV panels has been included to supply much of the power needed for a plug-in hybrid-electric vehicle. The consumption per charge of a hybrid-electric has been estimated to be 9 kWh, allowing the user to drive for 40 km [6]. Assuming that three charges are required per week, about 1400 kWh are needed per year. A calculation carried out in RETScreen [7] for Montréal conditions shows that 1.5 kW_p on a south-facing 45° roof generates approximately 1840 kWh of electricity per year.

The main source of space heating of the ANZEH is the roof. Choosing an appropriate framing system for the roof-integrated PV-T (BIPV/T) and the glazing was an important decision. The main considerations included ease of installation and maintenance, resistance to high temperatures (which can exceed 90 °C in the summer), capacity to withstand thermal expansion, and reasonable and affordable cost. It was finally decided that Solrif⁴ would be the framing system to be used.

In total, 40 PV panels, each with a rated power of 175 W, will be installed on the roof. The glazing section will be formed by 24 rectangular glass sheets, mounted above the PV panels (Fig. 4).

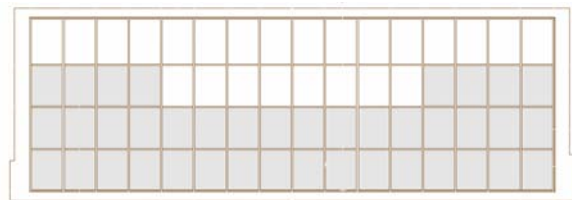


Figure 4: the PV-T system consists of PV panels (grey) and glazing (white) on the roof of the ANZEH.

The surface forming the bottom of the cavity under the panels and glazing is formed by an absorber plate.

4.1.2 Solar Collector for Domestic Hot Water (DHW)

Two evacuated tube solar collectors (AP-20), each with about 3 m² of gross area and 20 tubes, are used for domestic hot water heating. "Power-pipe", a heat exchanger that preheats the make-up water using the drain water from the shower. The size of the DHW tank is 400 L. The solar collector loop will have a heat dissipater to release the excess heat, mainly in the summer months. In addition, a motorized canopy, which can be extended over the edge of the awnings to improve the shading of the windows in summer, will be used to cover the solar collector.

4.1.3 Heat Exchanger (HX)

The ducting system coming from the BIPV/T roof was designed to use a single air-to-water heat HX for (a) direct heat transfer between the air and the water, and (b) use of BIPV/T air as a source for the heat pump. This design required a HX that had to operate in a wide range of flow and heat transfer rates. The liquid side (using a mixture of water and glycol) needed flow rates between 0.57 L/s and 1.13 L/s; the air flow rates would be between 472 L/s and over 943 L/s; the heat transfer rates would vary from 5 kW to more than 20 kW.

Naturally, this heat exchanger would have a much larger total heat transfer area than most heat exchangers

used in residential applications. The model chosen was the manufacturer-suggested by having 8-rows of coils, with 16 passes in total, 0.914 m (36 inches) by 1.27 m (50 inches), with a total face area of 1.16 m² (12.5 ft²). The small rated value of the pressure drop on the air side, varying between 15 and 42 Pa, confirmed that a bypass duct is not needed.

Considering the space limitations of the mechanical room in the basement, the HX will be located in the garage, where there is also room for smooth, rather than abrupt, duct transitions.

4.1.4 Heat Pump (HP) Configuration

The heat pump system is the most important piece of equipment of the ANZEH. The heat pump chosen had to deliver the required peak heating load (estimated at 12-13 kW). It also had to operate at partial load under varying flow rates and temperatures, with a good coefficient of performance (COP) preferably above 5. It is important to have the lower temperature limit of operation at the source side as low as possible (preferably near or below 0 °C), in order to extend the range of the HP operating conditions, as this will reduce the need for the operation of the backup system.

After evaluating the products available in the local market, it was decided to work with 2 Genesis GSW036 HPs operating in parallel. Each HP has a nominal output of 10.6 kW (36,000 BTU/hr). The Genesis series is manufactured by ClimateMaster [8]. Although they have only one stage, these HPs operate under a wide range of conditions. Simulations indicate that this system using two HPs has better overall performance than using a single, larger HP, offering a greater heat output (above 22 kW) and better COP for the same air flow rate and temperature. The configuration with two heat pumps also offered other advantages. For instance, it is possible to work with very low flow rates and temperatures by operating only one heat pump, and still delivering about 7 kW to the reservoir.⁵

4.1.5 Thermal Storage Reservoir

The heat pumps operating in parallel will transfer heat to the bottom of the 4000-L thermal energy storage (TES) tank. This volume should allow approximately one day worth of heat storage for a 6 kW heating load (close to the average) and a tank maximum temperature of 55 °C.⁶

After circulating through the heat pump(s), the water will be deposited at the top of the reservoir. This reservoir will have horizontal baffles and a vertical division to favour and maintain the thermal stratification in the reservoir, which has been estimated in between 5 to 8 °C.

Water from the tank could not be circulated directly through the air-to-water HX piping, since a water-glycol mixture is necessary to prevent freezing and bursting of pipes. A coil was added for this heat exchange. A plate heat exchanger allows heat transfer between the radiant floor heating system and the reservoir. The tank also has one additional coil (permitting heat transfer between the reservoir and the DHW tank). The heat pumps will exchange heat directly with the water in the tank, taking it from the bottom (coldest), and delivering it at the top (hottest).

4.1.6 Backup System

A support heating system is needed since at some point a sequence of cloudy days will drain the thermal energy stored in the tank and the building's thermal mass. Ethanol

burners and a wood pellet boiler were the first options considered.

Finally, since the HPs were already available in the mechanical system, the installation of a ground source loop connected to them was decided on. This only required small changes in the piping (the addition of a 3-Way valve and a pump), and extended the usefulness of the heat pumps by giving them an additional function. The wide range of temperatures that can be handled by the selected heat pumps facilitates the implementation of this dual-source system.

4.17 Control Strategies for ANZEH

An adequate control strategy is essential for the coordination of the ANZEH systems. The strategies presented below, of an exploratory nature, are intended to illustrate the effect of a predictive control strategy on the system's performance.

Two control strategies for the thermal energy storage tank were examined: (A) keeping the tank fully charged (i.e., the minimum temperature at the bottom was kept at 48.9 °C, which is the maximum tabulated temperature of the heat pumps sink side) by using the BIPV/T air; and (B) keeping the tank at a temperature which is a function of the solar radiation expected for the next day (the tank temperature setpoint could be either 35, 40, 45 or 48.9 °C).

While approach (A) is a simple control strategy that guarantees heat availability, approach (B) should save some electrical energy because the tank will not be charged unnecessarily, and the COP of the heat pumps will be higher for lower sink side (storage tank) temperatures.

The available heat in the BIPV/T air depends on the flow rate and the air temperature. In both control strategies discussed here, the air flow rate was kept constant at 755 L/s (1600 cfm). For both control strategies:

When BIPV/T air temperature is greater or equal to 46 °C (near the technical operational limit of the heat pumps), the HX is used directly;

Between 10 and 46 °C, both GSW036 heat pumps are used simultaneously. Between 3 and 10 °C, since there is less heat available, only one GSW036 heat pump is turned on (a different criterion could be established for deciding between the operation of either one or two heat pumps); and,

If the BIPV/T air temperature is below 3°C, no heat is provided to the thermal storage reservoir unless the temperature at the bottom of the tank is below 30°C (i.e. the tank is discharged). If this occurs, the backup system (i.e., one heat pump with the ground source loop) is turned on.

The expected solar radiation for any given day is also used, in both control strategies, as an input of a simple anticipatory control scheme for controlling the position of the blinds/curtains. Regulating solar heat gains helps to control indoor temperature fluctuations of the house in order to avoid overheating. If despite these measures, the operative temperature of the house still exceeds 25°C (a possible problem during the shoulder seasons) fresh-air supply is increased.

The operative temperature setpoint was kept at 21°C, with a tolerance of 2 degrees; no mechanical cooling was used. For these simulations, no linkage was made between the DHW and the reservoir, although in practice it will exist. A typical meteorological year (TMY2 file) for Montréal was used. As a simplification, these simulations do not include the interaction with the solar collector for

DHW. Table 1 shows simulation results for the heating season for both control strategies.

Savings are obtained by controlling the charge status of the tank (Strategy B). Of course, Strategy B is not optimal and there is room for improvement. In addition, the ground loop source is used more often with this strategy. It is also desirable to increase the usage of the heat exchanger for the direct recovery of heat, and to incorporate the solar radiation available at the current day in the calculation of the reservoir temperature setpoint. Other predictive control strategies will be explored and reported in future studies.

Table 1: Heating energy (kWh) using control strategies A and B

	Oct		Nov		Dec		Jan		Feb		Mar		Apr	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Heat from ground loop	0	0	486	547	1580	1796	1546	1796	344	221	84	301	1	41
Heat directly from PV/T HX	0	0	0	0	16	0	0	0	0	0	0	0	0	2
Heat from PV/T (1 HP)	124	73	432	331	326	300	218	197	232	671	209	192	279	242
Heat from PV/T (2 HPs)	158	127	634	596	850	654	928	631	1221	815	899	607	450	344
Heat supplied to reservoir	282	200	1552	1474	2772	2750	2692	2624	1797	1707	1192	1100	730	629
Heat supplied for space	134	235	1420	1421	2729	2730	2565	2583	1659	1661	1036	1039	572	571
% PV/T	100	100	66	63	40	35	50	32	78	87	93	73	100	93
HPs electrical consumption	89	54	361	344	544	597	443	597	443	399	227	255	227	156

4.1.8 Final Design of the Energy System of the ANZEH

Figure 5 shows the current status of the design of the ANZEH. Apart from the aforementioned changes, the insulating panels planned for the south facing windows have been replaced by a motorized theater-type curtain. Another addition has been the connection of a HP desuperheater to the DHW tank. The approximate distribution of the energy consumption at the ANZEH is given in Table 2.

Table 2: Planned energy consumption of the ANZEH.

Annual Energy Consumption	kWh
Heat pumps	2500
Fans and pumps	500
Domestic Hot Water	50
Ventilation	800
Lighting and appliances	3400
Electric Plug-in Vehicle	1400
Total	8650
Energy generated by PV system	8600

4.2 Net-Zero Energy Transportation

Once the benchmark of net zero energy consumption is reached for a household's domestic needs, taking the next step of achieving net zero energy transportation is surprisingly not that difficult to achieve.

For net zero energy transportation to be a viable step towards a net zero energy lifestyle, an important precondition must exist: the household's underlying lifestyle must make energy sense. In other words, a household where each member has a long, individual, daily commute to work or school, by private automobile, has a

fundamentally flawed lifestyle which is antithetical to the notion of achieving net zero. Once appropriate lifestyle decision are in place, however, achieving net zero energy transportation is surprisingly simple, particularly when starting from the baseline of a net zero energy house.

The path to achieving net zero energy transportation for the ANZEH involved integrating an additional 1.5 kW of photovoltaic over and above the 5.5 kW required to render the house net zero energy. Furthermore, two, Xantrex XW4024-120/240-60 hybrid inverterchargers were selected.

The integration of car and house offers synergies: the electric drive vehicle (EDV) may be charged by the PV/T system or base load generation. In turn, the EDV may act as an energy storage resource for the house by powering the home's critical circuits in the event of emergencies. Just as a single EDV can act as an energy storage resource for a single house, conceivably thousands of EDVs can act, collectively, as a significant energy storage resource for the entire electric grid. The ANZEH will explore this concept, known as vehicle-to-grid (V2G).

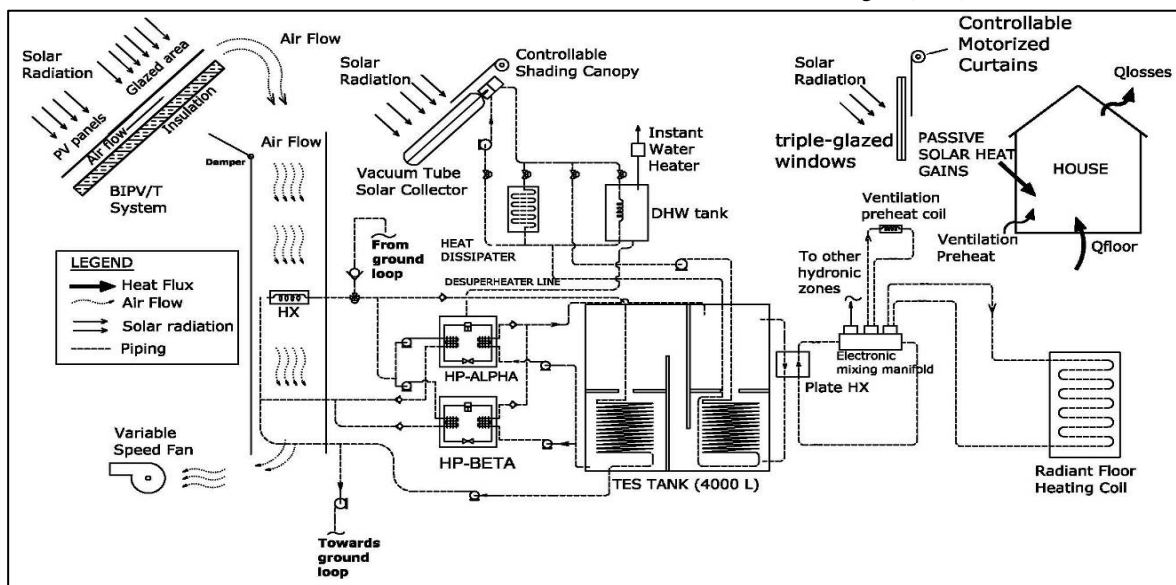


Figure 5: Final configuration of the ANZEH

A significant challenge in achieving net zero energy transportation is that the automobile industry is not present and does not yet realize that it forms an important part of the solution towards reducing energy consumption. The main hope in surmounting this obstacle rests on small manufacturers such as the Canadian-based ZENN Motor Company⁷ which manufactures the ZENN electric drive vehicle. Discussions are underway to partner with the company on this project.

Integrating an electric car with a house, as in the ANZEH, opens a fascinating landscape filled synergies: First, a home's rooftop photovoltaics may charge the battery of an EV; second, the EV battery can, in turn, be an energy storage resource for the house, known as V2H; third, many EVs can collectively be a significant energy storage resource for the grid, known as vehicle-to-grid (V2G); finally, this energy storage resource available to the grid can stabilize large-scale wind power. The requirement of a smart-grid is a significant obstacle to the deployment of V2G [Fig 6].

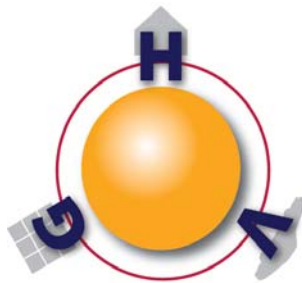


Figure 6: ANZEH's concept of integrating EDV-to-Home-to-Grid.

4.3 Net-Zero Energy Food Production

Until the turn of the century, all of the food energy available on this planet was derived from the process of photosynthesis - the energy in the food was ultimately derived from the sun. The Green Revolution following WWII radically transformed agriculture around the globe, dramatically increasing, in the process, world grain production. The success of this agricultural revolution, however, was driven by fossil fuels which yielded the synthetic nitrogen fertilizer (natural gas), the pesticides (oil), and the hydrocarbon-fueled irrigation and machinery.

Prior to the Green Revolution, one calorie of energy input produced two calories of food. A 2002 study from the John Hopkins Bloomberg School of Public Health, however, estimated that today's food system requires three calories of energy input to create one calorie of food [9]. The John Hopkins study, however, does not take into account the energy used in processing and transporting food. A subsequent study estimated that an average of 7 to 10 of energy input are required to produce each calorie of food [10]. This energy imbalance is more pronounced for grain-fed beef, which requires 35 calories of energy input for every calorie of beef.

The energy imbalance within the current industrial food system results from the inherent inefficiencies associated

with vast fields of monoculture. Fields of monoculture rely heavily on fertilizers instead of crop rotation to mitigate soil degradation [11]. Moreover, they necessitate storage, processing, and transporting foodstuffs thousands of miles between the field and the end consumer. The energy imbalance associated with monocultures is leveraged even higher when grains, produced in monocultures, are supplied to cattle feedlots and factory farms (chickens, hogs, veal calves) for industrial livestock production. This energy imbalance is leveraged because a significant amount of the energy within the grain is lost as livestock convert the grain they eat into meat. Cattle are the most inefficient in their energy conversion, requiring 7 kg of grain to produce 1 kg of beef (compared to 4:1 for pork and 2:1 for chicken) [12]. Despite this inefficiency, livestock diets have become higher in grains and lower in grasses.

A study conducted in 2000 estimates that the US food industry consumed 10% of the nation's total annual energy [13]. Comparable data is not available for Canada. However, approximately 6% (2005: 508PJ) of Canada's total annual secondary energy goes towards direct farm production, indirect fertilizer and pesticide production, as well as food and beverage processing. The amount of energy consumed by transportation within Canada's food industry is not available. However, given Canada's expansive geography and reliance on transportation, Canada's total food industry, including transportation, may indeed consume around 10% of the nation's total annual energy (about 848 PJ) in 2005.

The ANZEH will explore the notion of net zero energy food whereby architectural solutions within the house could facilitate on-site food production at the individual household scale. The objectives of this aspect within the project are to reduce the imbalance between energy input and food energy output as well as to reduce the demand on Canada's overall energy expenditure on food production.

This aspect of the project has not yet been implemented. However, starting in October 2008, a group of graduate students from McGill University's School of Environment, in Montreal, will devote an entire semester to consider possible viable approaches that would empower the family unit that will live in the ANZEH to pursue a net zero energy lifestyle in their daily living activities.

CONCLUSION

Some of the considerations used in the design of the ANZEH have been presented. The addition of 1.5 kWp, and the installation of a ground source loop as a backup system are some of the most important design adaptation. In its current state, the ANZEH is approaching zero-energy consumption attributable to its operation, along with the ability to charge an electric vehicle and on-site food production to complete the net-zero lifestyle principle.

It is possible to build houses that rely solely on solar energy. To accomplish this goal, it is important to work in guidelines for the sizing and features of thermal storage systems, such as the maximum temperature achievable by the storage medium with the available heat sources, essential to reduce the required volume.

Although this house will make use of a ground source loop as a backup heat supply, a suitable custom-designed air source heat pump capable of using very low source temperatures could eliminate the need for a backup system. Progress can be made towards simplicity in future designs through accumulated research and experience.

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ENDNOTES

¹ This figure included electricity-related GHG emission – 381 Mt CO₂e excluding electricity-related emissions.

² In this study direct energy is consumed by such activities as crop production, livestock production, poultry production, animal products production, and other farm products production. Indirect energy consists of the energy used in the manufacture, packaging and transport of fertilizers, pesticides and farm machinery. Data on the energy consumed in the transportation of farm products to the market in Canada in 2005 is not available.

³ A Net Zero Energy House is defined by CMHC as one that is tied to the utility's electric grid and draws electricity from it. It also generates electricity on site, through renewable means, and returns at least as much electricity to the grid as it draws from it. In this way, a NZEH maintains zero energy consumption balance with the grid over any twelve-month period.

⁴ <http://www.schweizer-metallbau.ch>. Retrieved on January, 2008.

⁵ The results shown in Fig. 6 are limited to temperatures between 10 and 40 °C, since this range guarantees the operation of the heat pumps for the air flow rates considered (between 472 and 850 L/s). For example, 450 L/s and 10°C, might not be adequate conditions for the operation of the heat pump. However, by maintaining higher flow rates, it is possible to work with BIPV/T air temperatures lower than 10 °C.

⁶ Naturally, the storage capacity would last longer with lower heating loads. The size selected is not necessarily optimal: sizing procedures for thermal storage are needed for the operation of solar-based heating systems.

⁷ Zero Emissions No Noise (ZENN) electric drive vehicle product website: <http://www.zenncars.com/>