# RAISING THE ROOF: MAKING CONTEMPORARY HOUSING DEVELOPMENTS SOLAR READY

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A Major Research Paper presented to Ryerson University

in partial fulfillment of the requirements

for the degree of Master of Building Science

Department of Architectural Science

**Toronto, Ontario, Canada, 2015**

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## Abstract

Raising the Roof: Making Contemporary Housing Developments Solar Ready

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With a growing population and the inevitable increase in demand for energy, cities planners and developers need to design communities that are sustainable and resilient to meet the ever growing challenges of the 21$^{st}$ century. Solar energy is a viable attribute to our current energy production and, as this research indicates, provides an opportunity to move towards a renewable energy system. Solar ready homes can help bridge the transition from non-renewable to renewable energy sources, by provide infrastructure that has the ability to exploit solar resources

The overall objective of this research is to quantify the potential solar energy generated from roofs in a typical contemporary housing development built in southern Ontario through simulations. Further analysis showed that small simplified modification to the original roof typography can increase solar electrical production in some cases as high as 47%. Furthermore, by pooling the solar electrical production of a cluster of homes that represent a block in a typical contemporary neighbourhood, simulation were conducted and showed that significantly portion of the blocks electrical consumption could be offset through roof top solar generation.

## Acknowledgements

This research and the production of this paper could not have been done without the support and encouragement of many individuals in my life. I like to acknowledge the huge support I have had from my family and in particular my mother Jane Riddell and father Rob Riddell and the continues support from my brother and sister, Jessica and Luke Riddell

I like to thank my professors Miljana Horvat and Mark Gorgolewski for the guidance and support that they provided me and the inspiration to complete this research paper.

Finally, I'd like to thank all my friends that have listened to my ranting over the year about my research and their support for editing and never doubting me.

Charles

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**Abbreviations**

AC – Alternate Current
BIPV – Building Integrated Photovoltaic
CanSIA – The Canadian Solar Industries Association
DC – Direct
EAA – Environmental Assessment Act
EPA – Environmental Protections Act
EPBT – Energy Payback Time
FIT – Feed in Tariff
GEA – Green Energy Act
GEGEA – Green energy and Green Economy Act
GHG – Greenhouse gas
GTA – Greater Toronto Area
HVAC – Heat Ventilation and Air Conditioning
IEA – International Energy Agency
IESO – Independent Electricity Systems Operator
IMF – International Monetary Fund
IPCC – Intergovernmental Panel on Climate Change
kW – Kilowatt
kWh – Kilowatt hours
kWh/m2 – Kilowatts hours per meter square
MOE – Ministry of Energy
MW – Megawatt
NRCan – Natural Resources Canada
NREL – National Renewable Energy Laboratory
NZEH – Net zero Energy House
NZEN – Net zero Energy Neighbourhood
OPA – Ontario Power Authority
PH – Passive House
PV – Photovoltaic
REA – Renewable Energy Approvals Regulation
SI – Solar Irradiation
SRH – Solar Ready Homes
W – Watt

# 1. Introduction

In the developed and developing world, buildings occupy much of the urban landscape. This reality demands that developers, architects, and city planners consider the potential energy benefits when designing, implementing and creating urban and suburban developments. With a growing population and the inevitable increase in demand for energy, cities planners and developers need to design communities that are sustainable and resilient to meet the ever growing challenges of the 21st century. Along with this growth and energy demand, new sources and fresh approaches need to be considered in order to obtain the energy that is needed to power urban centers. Current energy is mainly generated through the use of centralized power plants, such as nuclear, coal, natural gas and hydro electrical. These energy sources are transmitted often from long distances to larger grid networks, and ultimately to the end consumer. Centralized power stations could be inefficient, costly, and environmentally damaging which is amplified through climactic and or anthropological events.

This research investigates renewable means of energy, in particular solar, through roof designs, which could benefit the consumer, the environment and society as whole. Solar energy gathered through rooftops, in particularly in the context of solar neighbourhoods could be a viable alternative to our current energy production and, as this research will indicate, could present an opportunity to make positive strides in moving toward a renewable energy system. Solar energy can be captured through thermal heating in a variety applications, such as hot water, space heating, preheated air, pool heating and industrial processing. Solar energy can also be converted into electricity, in which this focus of this paper will be on.

Extreme weather events have substantial effects on communities and their energy needs. As illustrated by the Intergovernmental Panel on Climate Change (IPCC), “Climate change, whether driven by natural or human forces, can lead to changes in the likelihood of the occurrence or strength of extreme weather and climate events or both” (Intergovernmental Panel on Climate Change, 2013). Proper preparation on an infrastructural level for such events helps maintain the stability and functionality of a society as extreme weather events occur. Conversely, a lack of preparedness results in quite the opposite as is evident through an analysis of The Great Ice Storm of 1998 in Quebec. This storm left millions of homes in Eastern Canada without electricity for weeks, resulting in at least 25 deaths, with a total economic cost estimated between $5 and $7 billion (Mayer, 2015).

From a global climate change perspective Thomas Stocker, Co-Chair of IPCC Working group, illustrated in a short IPCC film 3 key messages:

- *"The warming in the climate system is unequivocal, that is based on the observations at multiple lines of independent evidence*
- *Human influence on the climate system is clear, and this is a result from the combination of model simulations with the observed climate change*
- *Continue greenhouse gas emission cause further climate change and constituent multi-century commitment in the future".*

Therefore, IPCC concludes that limiting climate change requires extensive and continual reduction in greenhouse gas emissions (Change, 2013). These statements also suggest that a commitment to reducing GHG emissions is not only a necessity for our current times, but an obligation for future generations to consider. Figure 1, exemplifies the dramatic increase of weather related power outages in the U.S in the 2000s.

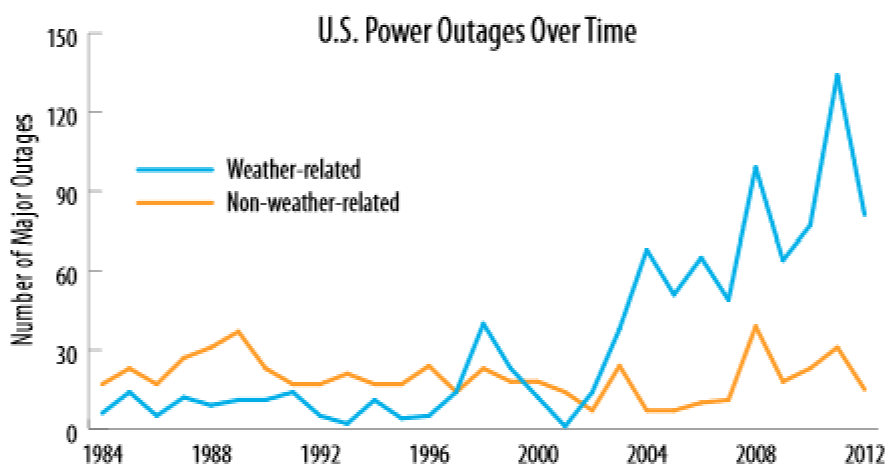



**Figure 1: Major weather related power outages that affect >50,000 customers (National Renewable Energy Laboratory, 2014)**

According to ICF International, the United States' "emergency management strategies were primarily focused on preparedness and response – namely, what happens at the moment of an emergency and in the minutes, hours, days, and weeks thereafter" (ICF International, 2013). It was not until the year following the events of September 11th 2001, that infrastructure resiliency became apparent for future emergencies. "This ability to maintain operation despite a devastating event has become a key principle in disaster preparedness" (ICF International, 2013). This illustrates a clear shift from preparedness to prevention at the infrastructure level. Whether this was due to a terrorist attack or a climatic event, the concept mitigation proves paramount.

As more and more people move to cities, urban development spreads across the land, resulting in an increased demand for energy. The use of fossil fuels to sublimate this increase in energy demand is not only finite, but unsustainable for the overall health of the planet and therefore society. Thus, the focus needs to shift to the energy conservation of buildings and the decentralization of energy distribution. One source of energy, with a seemingly endless supply, is the sun. This all empowering resource is being underestimated by developer and city planners for energy generation. Solar energy can help create a decentralized energy system. A decentralized energy system can use the same interconnected grid network as a centralized energy system (i.e. power plants), however, its distribution is fundamentally different. A solar network would result in usable energy, acquired at many individual scales and eventually dispersed widely across the network (Clesle, 2010). Photovoltaic panels, for example, can be utilized at the local and individual levels. By decentralizing energy, localized energy generation can be achieved. This creates energy security at a community and individual level. This energy security allows community to become more resilient to climate change, contribute to the decrease of greenhouse gas emissions and protect the end user from increases in energy costs.

Much of today's society has become increasingly disconnected from their energy sources, resulting in a misguided idea of their consumption behaviours. Producing energy in and around the area that is consuming it re-establishes a conscious consumer connection with the energy being both produced and consumed. This can influence how society and how individuals value energy and help creates awareness that allows for more conscience energy choices. By creating energy based infrastructures, local energy security can be established, which can help avoid relying on centralized stations, creating a more democratized energy distribution sector.

*Solar Ready Homes* (SRH) can contribute to energy infrastructure resiliency by allowing for the installation of photovoltaic panels (PV), solar domestic hot water (SDHW) and space heating. This simple and cost effective building consideration aids in the pursuit of sustained GHG reductions and creates clean renewable local energy sources, all the while democratizing energy distribution by giving the individuals and communities the option to generate and make conscience energy choices.

This research will investigate the solar potential that can be achieved in subdivisions and how solar ready homes and planned energy infrastructure can be achieved with minimal changes to current home and site plan design. This study will demonstrate the potential for harvesting solar energy from roofs in a contemporary residential subdivision currently built in Southern Ontario. Further investigation will be conducted to see what simplified changes can be introduced in order to increase solar potential and make newly built houses solar ready. With solar consideration in the design phase, developer and urban planners can begin to work with roof layouts and establish concrete approaches for localized solar strategies. As Clesle indicates, “emphasis on solar consideration in the design process from the beginning can only help improve the quality of solar architecture procedure and allow the possibility of new technologies and design innovations to grow” (Clesle, 2010).

# 2. Literature Review

## 2.1 Solar Ready Building

According to the National Renewable Energy Laboratory (NREL) a *solar ready* building is defined as being designed and built, “to enable installation of solar photovoltaic and heating systems sometime after the building is constructed” (Lisell L. T., 2009). A solar ready design building essentially allows the incorporation of a solar energy system without having to significantly change the roof structure, open walls for conduits and electrical cables, create a location for electric components, as well as storage tanks components (Lunning Wende Associates, Inc, 2010).

Solar Ready in this research refers to the physical “rough-in” requirements that PV or SDHW need to have for installation. That includes: conduits that provide access to electrical or storage tank locations in the house, structurally sound roof surface, ideally facing south or east and west. These surfaces are free of plumbing stakes or and roof vents. Furthermore, an assumption has been made that legislation and regulation (or certifications) that pertain to these requirements have been acquired and approved.

The installation of a solar energy system on an existing home can face considerable barriers. The most obvious one is the fact that the original roof structure was not designed to house a solar system. This lack of solar consideration at the design phase results in issues with roof structure (i.e. loads), building orientation, choice on mechanical systems and design element (i.e. vents, plumbing stacks, lines, peaks and valley of a roof). These issues often make the retro-fit process more complicated and expensive. According to (Lunning Wende Associates, Inc, 2010), the solar ready building idea treats buildings as infrastructure, multi-generational investment that consider not only today’s market, but provide flexibility to meet the next generation’s needs. This ensures that solar energy systems can be installed easily, allowing owners to invest in solar energy at any point in the future (Lunning Wende

Associates, Inc, 2010). Making homes solar ready is similar to the roughing in a central vacuum system. If installed during construction the cost is far less than to have it retroactively installed later post construction. These rough-in packages are a standard option with most builders, often not showing up as a budget line in some cases. Furthermore, studies in California have indicated that a solar ready house will have a higher resale value than similar houses in a given neighbourhood (Solar Nova Scotia, 2009). However, some of these requirements create barriers that are hindering the process for solar ready to be mandatory on production home development. This will be discussed in section 8, Barriers.

### 2.2 Ontario's Population Increase

Ontario's population is projected to increase from 13.5 million in 2013 to 17.8 million in 2041 (Ontario Ministry of Finance, 2015). The majority of growth will occur in the Greater Toronto Area (GTA) and is projected to be the fastest growing region in the province. This region's population anticipates an increase of almost 3 million, or 45.8 percent, reaching over 9.4 million by 2041. Furthermore, the GTA's share of the provincial population is projected to rise from 47.6 percent to in 2013 to 52.9 percent in 2041 (Ontario Ministry of Finance, 2015). With the ever increasing population, cities and towns will need to build communities that not only house people but meet the energy demands that will accompany increased growth. An approach that anticipates the energy needs for future energy generation

### 2.3 Energy Supply Systems

To gain a truer representation of a building's energy consumption, an understanding of the difference between *site energy* versus *source/primary energy* is crucial. According to Straube, failing to account for this difference will result in an apples-to-oranges comparison, given that the difference between 'site' and 'source' energy can be so great. 'Site' energy is all the energy one consumes at the meter. What is not included however, is the actual process of generating that electricity and the losses that that process incurs. Source energy, one the other hand, is a measure that accounts for the total energy consumed on site and the energy consumed during generation and transmission in supplying energy to that specific site (Straube J. &., 2010). These losses are enough that for every unit of electricity at the plug, it might be necessary to "burn" about 3 times that amount of energy (coal, gas, nuclear, etc.) at the power plant (Straube J. &., 2010). Source energy is much more important than site energy if the concern is environmental performance. These losses can be reduced with better technology and will be reduced even further in the future by distributed power generation (i.e., the Smart Grid), especially if power is generated reasonably close to where it is being consumed. Overall, it can be said that "the grid" is "~30 percent efficient": with majority of the losses taking place at the power plant (Straube J. &.,

2010). In Canada 'source' to 'site' ratio for electricity purchased from the grid, is more efficient than in the U.S. This is mainly due to the difference in power generation. The efficiency of secondary energy production, such as electricity, depends on the types of primary fuels that are consumed and the particular equipment being used (U.S Environmental Protection Agency , 2013). On average, in Canada, the mix of electrical production is approximately 23 % fossil fuels, 16% nuclear and 61% renewables (hydro electrical, biomass, solar, wind, geothermal) (U.S Environmental Protection Agency , 2013), although there are considerable variations between regions and provinces. Hydro electrical power accounts for 59% of Canada's total electrical generation (Government of Canada, 2014). The US mixed electrical production, on the other hand, is approximately 66% fossil fuel, 21% nuclear and 13% renewable (U.S Environmental Protection Agency , 2013). According to U.S Environmental Protection Agency, "Source energy traces the heat and electricity requirements of the building back to the raw fuel input, thereby accounting for any losses and enabling a complete thermodynamic assessment" (U.S Environmental Protection Agency , 2013)  Because the US consumes more fossil fuels for electrical production, a significant portion of conversion losses such as energy in the form of heat can be attributed to the burning of fossil fuels, resulting in a 'source' to 'site' ratio of 3.14, for electricity purchased from the grid. This means for every 1 unit of energy consumed on 'site', 3.14 units of energy are consumed at 'source', (includes transmission and distribution losses) (U.S Environmental Protection Agency , 2013). Canada in contrast obtains a large portion of its electricity from hydro power, where heat energy losses from direct electrical production is not a factor, resulting in a 2.05 'source' to 'site' ratio  (U.S Environmental Protection Agency , 2013).

Transmission losses add to roughly 10 percent inefficiency to the electrical grid, according to (Straube J. &., 2010) and can be as high as 20 percent (City of Toronto, 2007). The transportation of electricity from power plant to cities requires high-voltage lines that are carried via massive transmission towers. These towers are susceptible to climate change and the frequency and intensification of storms. A scenario seen in 1998 Ice Storm, in which 300 of these transmission towers collapsed in Quebec and an additional 50 in Eastern Ontario (Mayer, 2015) see figure 2. This, though a telling example, is not an isolated event.

Figure 2: Collapsed high voltage transmission towers. Hydro Quebec/via Google images

The other aspect of the grid that is affected by storms is the low voltage lines that move from street level utility poles to individual homes. These lines are usually damaged via fallen tree limbs. Recommendation to protect these lines from such events is to bury them underground. This is easily achieved in new housing developments, where lines can be laid at the same time as sewer, water and natural gas lines (Mayer, 2015). However, retrofitting the high voltage power lines or an entire city such as Toronto would require enormous investments. The U.S Energy Information Administration estimates that underground power lines can cost up to 10 times more than overhead distribution lines (Mayer, 2015). Furthermore, burying power lines by no means is a cure-all solution, they are still subject to flooding and with regards to general equipment failure, it may be hard to identify and repair when problems do occur (Mayer, 2015).

Considering the inefficiency and vulnerabilities of a centralized energy system, decentralizing energy systems and the advantages of renewable energy (i.e. PV) is their ability to be installed close to where energy is demanded. This reduces distribution costs, increase efficiency through mitigation of transmission losses and provides a more reliable cleaner energy supply.  Also, the multiple points of entry reduce the number of fail points that potentially impact large sections of the grid.  According to the City of Toronto 98% of Canadian power outages originate in the transmission and distribution grid (City of Toronto, 2007).  On-site solar energy production is a secondary form of energy, in which there are no conversion losses, because electricity derived from the sun is not considered discrete organic fuels, such as fossil fuels. Furthermore, with electricity being converted on-site there is no transmission or distribution, resulting in a source to site of 1.0, for on-site solar electricity (U.S Environmental Protection Agency , 2013).

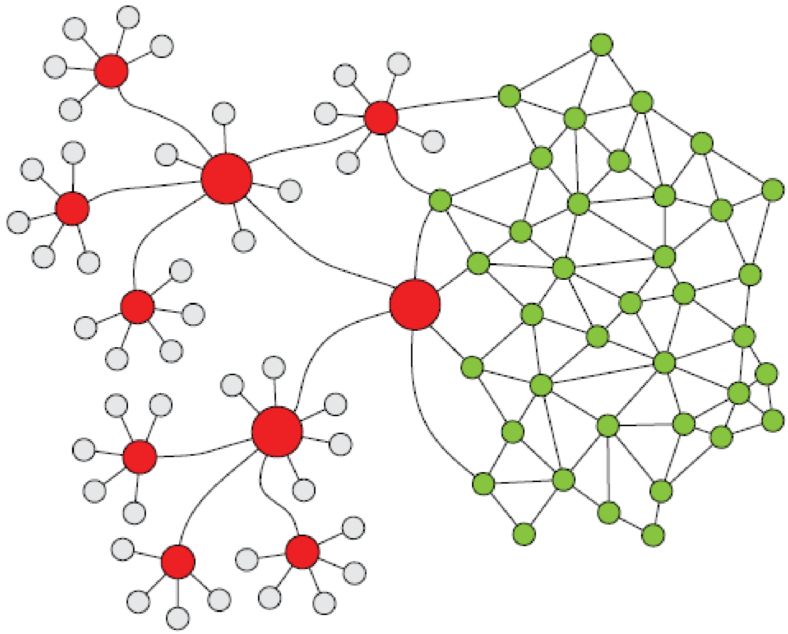


**Figure 3: Centralized System (Left) versus Decentralized System (Right) (Clesle, 2010)**

It is important to note that decentralized infrastructure may use the same interconnected grid network; however additional connections would be needed throughout the grid to connect the dispersion of power generation plants together. This will result in a necessary upgrade in the grid infrastructure. Ontario however, has begun to update its distribution network and implement smart grid technologies (Ontario Government , 2012).

## 2.4 Smart Grid and Distribution Networks

As a first step, the Ontario Government describes their *Long Term Energy Plan* as; "moving toward a modern, smart electricity system that will help consumers have greater control over their energy usage – even when they're not home… and make it easier for consumers to produce their own power" (Ontario Government , 2012).

Smart distribution networks are being introduced by distributors to replace the aging infrastructure with new technologies that are being described as the Smart Grid. The Smart Grid utilizes computers, sensors, automation, digital communication and monitoring to add intelligence to networks that have not substantially changed their architectures since the beginning of the 20th century (Ontario Government , 2012). Local Distributor Companies (LDCs), have, for decades been a passive player in the electricity sector acting merely as brokers for delivering electricity in a one-way flow where energy is generated elsewhere. As mentioned, traditionally, electricity has been produced at a central generation station using: hydroelectric, coal, natural gas, nuclear energy, where it would then be transmitted, often over long distances, to local communities and then distributed to costumers (Ontario Government , 2012). Smart Grid technology, on the other hand, provides the consumer more control over their electricity usage. A smart grid is defined by the Independent Electricity Systems Operator (IESO), formally the Ontario Power Authority (OPA) as a “two-way system that monitors and automatically optimizes the operation of the interconnected elements of the power high-voltage network and distribution system, to end-use consumers and their thermostats, appliances and other household devices.” (Environmental Commissioner of Ontario, 2010).

The Smart Grid allows for the integration of the variable output that comes from renewable energy sources and also accommodates the charging of electrical vehicles, which can also be used as storage devices. Furthermore, once energy storage devices become commercially viable, the ‘smart’ distribution network will be able to handle that as well (Ontario Government , 2012). The Ontario Government suggests that the first phase of this new world for energy consumers is occurring at the home. The installation of smart meters in virtually all homes and business in Ontario is the beginning of a so-called ‘smart home’. This introduction of smart metering on a Smart Grid has allowed for homes and business to apply for and received Feed in Tariff (FIT) or microFIT contracts that allow them to install solar panels and wind turbines to feed electricity back into the grid (Ontario Government , 2012). This very concept of creating smart metering on Smart Grid infrastructure that many Ontarians have access to, should entice architects and developers to take full advantage of this ability to generate one’s own power and send it back to the grid.  ‘Solar Ready’ should be considered at the design phase for developers, as well as putting emphasis on the fact their homes are now far more future ready for new technology and integration, then their competitors..

### 2.5 Electricity Consumption

Canadian households consumed 520,250 TJ of electricity in 2007, with an average electricity consumption of 40 GJ per household (Government of Canada, 2012). In Ontario, electricity accounts for roughly 30 percent of the total energy consumption, while in comparison, Quebec’s electrical consumption is 61 percent of the total energy consumption (Government of Canada, 2012). Electrical consumption in Quebec is higher due to its use for space heat and domestic hot water, while the majority Ontario’s residential sector uses natural gas to heat these appliances.

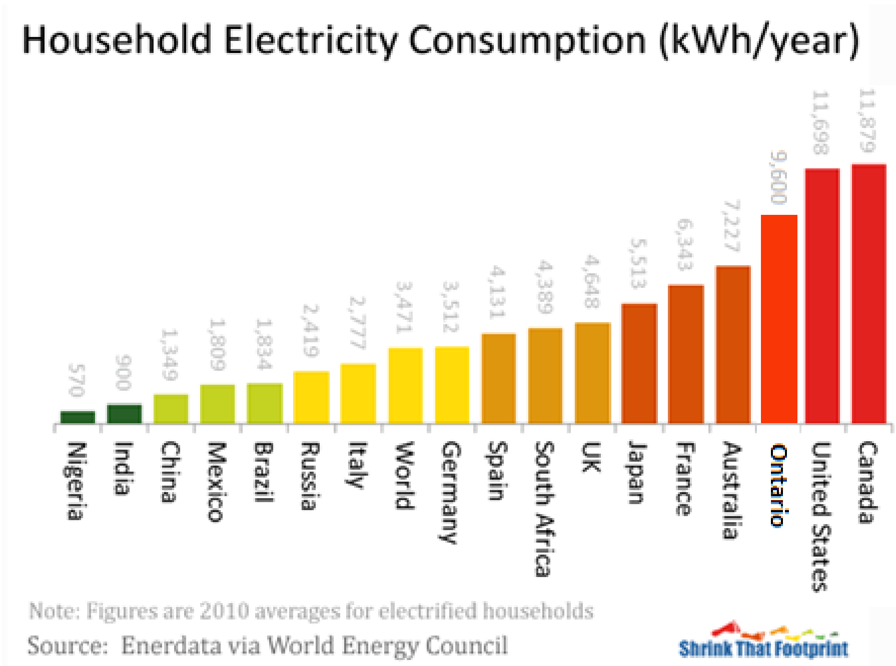



**Figure 4: World Household Electricity Consumption comparison (Shrink that Footprint, 2010) (Modified by Author)**

The above graph reflects Canada and Ontario's electrical consumption compared to other nations around the world. The current Ontario Government strongly believes that conservation should be the first priority in energy planning, an important concept because with the reduction in consumption, becoming electrically net zero is easier to achieve. Electrically net zero is defined in this research as a building or neighbourhood that produces as much electricity on –site as it consumes during the course of a year. Electricity consumption in Ontario per average household has decreased from just over 12,000 kWh in 1990 to 9,600 kWh in 2013 (Ontario Ministry of Energy, 2014). This decrease illustrates that electricity conservation works. The importance of the above graph is a good illustration of how Canadians compare to the rest of the world, in which we consume far more than many developed nations. In Ontario, electrical consumption is nearly double that of what a Japanese household consumes and nearly two thirds of what a German household consumes. This consumption statistic is crucial because it shows that consumption levels can be diminished while maintaining the quality of life that a developed nation enjoys. If Ontario continues to conserve electricity, while simultaneously creating onsite renewable electrical generation, such as solar, a net or near net zero electrical consumption for a house or neighbourhood becomes more achievable.

## 2.6 Ontario Green Energy Policies

In May 2009, the Ontario Government passed the *Green energy and Green Economy Act, (GEGEA)* which enacted the *Green Energy Act (GEA)*. Based on two main goals of stimulating the economy and the reduction of greenhouse gas emissions, the GEA states along with enhanced energy conservation, the government's commitment to "fostering the growth of renewable energy projects, which uses cleaner sources of energy, and to removing barriers to and promoting opportunities for renewable energy project…" (Environmental Commissioner of Ontario, 2010) This, along with the smart gridding of the infrastructure and the Feed-in Tariffs programs, indicates that there is a willingness and desire from the top decisions makers in the province to create a more renewable and greener economy.

The GEA was to assist in the removal of barriers and to promote opportunities for renewable generation facilities (Environmental Commissioner of Ontario, 2011). The amendment of the *Environmental Protection Act (EPA)* by the GEGEA introduced a new course of approvals for renewable energy projects, and thus the *Renewable Energy Approvals Regulation* (REA Regulations) was formed under the *EPA.* This established a new streamline process that would be followed in order for a renewable energy project to be approved. This approval process was created by integrating all former Ministry of the Environment (MOE) regulatory approval requirements into a single process base on a "one window, one permit" approach (Environmental Commissioner of Ontario, 2011). Most electricity projects were subject to onerous official plan amendments and or zoning by-law amendments as required by municipalities, prior to REA regulation coming into force, greatly slowing down both approval and implementation. Furthermore, these projects had to go through environmental screening by the EAA and had to receive a certificate of approval under the EPA. This resulted in a long bureaucratic processes that were often complex, time consuming and expensive (Environmental Commissioner of Ontario, 2011). This burdensome process would have been a deterrent for investors.

The government exempted most renewable energy projects which produced electricity from the requirements of the *Environmental Assessment Act (EAA).* At the same time, GEGEA made amendments to the Planning Act which allowed for most planning approval requirements no longer apply to renewable energy projects (Environmental Commissioner of Ontario, 2011). This may have a significant importance to the process in creating solar ready homes on a neighbourhood scale.

## 2.7 Why Solar?

The Earth receives an astonishing amount of energy in the form of radiation from the sun. The amount of energy works out to be 1 x $10^{18}$ kWh/a, which is equivalent to around 10,000 times the world's energy requirements. Of this, only 0.01 per cent of the sunlight's energy would need to be harnessed to cover humankind's total energy needs (German Solar Society , 2013 ). The sun provides an endless supply of clean renewable energy, an energy that is tangible, quantifiable and usable. Given that many of Ontarians receive electricity from non GHG emitters, such nuclear and hydroelectric power, both sources of energy nonetheless have a plethora of negative attributes. Hydroelectric power can cause habitat and land loss due to damming. Nuclear power has concerns with radioactive waste disposal, a problem that has yet to be solved anywhere in the world. This of course can become an economic burden or an environmental disaster. In fact, according to Behling, construction cost for nuclear power plants rose from £250 ($510 CAD, current exchange rate) per kWh in 1971 to £2,000 ($4,090 CAD, current exchange rate) per kWh in 1985, reflecting the risk factor involved (Behling, 2000). Catastrophic events such as a meltdown are also of paramount concerns: Fukushima, Japan, being a perfect example of the dangers of nuclear power and how the effects can be felt on a global scale (i.e. the radioactive contamination of the Pacific Ocean). Furthermore, majority of these centralized energy facilities are far from urban centres. In a scenario where these facilities or transmission lines are damaged, whether from a climatic, geological or human made event, these incidences can have an effect on the distribution and reliability of electricity. Localized energy production, like solar PV on the other hand, can help alleviate energy losses and help manage the electrical grid during peak hours with safer and cleaner energy production. The generation of solar PV at peak demand periods "can be used to reduce the need for investment in large peak generation capacity and improve the overall power system's ability to meet peak demand (CanSIA, 2013).

In order to utilize the grid and meet these energy and distribution needs, as well as create resiliency among communities, building construction should be built with the anticipation of integration of new technology, the increasing cost of energy, and the need for reduction in carbon and GHG emissions. Solar ready homes, in combination with solar technologies, will support future installation for individual homes and in turn provide a large contribution to energy security for neighbourhoods and communities as a whole. The application of solar access principles in the design of new neighbourhoods and the improvement of energy efficiencies of buildings can form the bases to meet net zero or near net zero energy (Hachem, Fazio, & Athienitis, 2013). Considering the complexity of creating a net zero or near net zero energy community in an MRP format, the research will focus on the solar potential that a new housing development has and the contribution that it can provide to the formulation of a net zero community.

Solar ready homes built at a community/neighbourhood level, could prove invaluable in the future when extreme weather events occur, providing homes the ability generate and consume energy onsite. Moreover, with solar ready consideration, homeowners may take a co-operative approach on the neighbourhood scale, creating a method that helps facilitate more involvement and a better purchasing power for homeowners. Co-operative practices can help homeowners be part of a collective energy source that all members benefit financially while at the same time providing energy security. The collective use of equipment and technologies may include, but is not limited to: inverters, panels, energy storage technologies, grid connectivity, smart grid technologies, and an awareness of future technologies that can be incorporated with the existing systems. However, this topic unto itself will need further research to understand the viability and importance of this approach.

As Morley suggests, “solar energy is a community resource and should, therefore, be treated as such” (Morley, 2014). When local plans and regulations fail to explicitly address solar energy production and its use, significant hurdles to adoption and implementation of solar technology are created (Morley, 2014). Every community in the U.S and Canada have solar resources, however “very few are utilizing this resource at the community level where planning and development decisions affect the future availability of local solar resources and or opportunities for the private-sector solar development” (Morley, 2014).

There is a plethora of environmental, social, and economic benefits for communities that develop local solar energy generation. Solar energy is a carbon-free, emission-free, and local fuel, which can help communities meet goals for greenhouse gas reduction, energy security, local job creation, and encourage the population to be involved in their electricity generation (Morley, 2014). This involvement can help bridge the disconnect between consumer and the energy sources by creating an awareness that individuals and society as a whole can begin to make educated energy choices and be conscience of their energy consumption. The very concept of knowing how much energy one produces at an individual level will undoubtedly push these individuals to try and balance and offset each other, particularly when financial merit is evident. These benefits transcend jurisdictional borders and other direct environmental benefits outside the community. These benefits include decreased emissions from centralized fossil-fuel power plants, thus slowing the expansion of fossil fuel mining or drilling operation and reduced water consumption for cooling towers at power plants (Morley, 2014) .

The concept of conventional energy reserves, such as a nation's oil, gas or coal is well understood by most planners (Morley, 2014). However, the concept of solar energy as a local resource and thus a "reserve" has been ignored in the planning and development of communities. As Morley illustrates, planners at the local level "regularly assess their communities' economic, natural and social (or human) resources in order to set priorities that help plan and making development decisions" (Morley, 2014). However, in many communities' solar resources are overlooked. Without the consideration of solar resources at the planning and development stages, a community may find it very difficult to adapt to future energy needs in a post fossil fuel world. Solar ready homes can help bridge the transition from non-renewable to renewable energy sources, by provide infrastructure that has the ability to exploit solar resources. Solar ready homes on a large development scale could be seen as a communities' solar energy "reserve".

## 2.8 Solar Energy

Solar irradiance, or solar radiation, refers to the electromagnetic energy emanated from the sun (Morley, 2014). Morley proposes that since solar radiation can be harnessed by producing either heat or electricity an approach of resource management should be applied to it. Every location on Earth receives some amount of solar radiation, however a number of variables affect the quantity and quality of the solar resource. These variables range from temporal, atmospheric and geographical conditions, such as the season and time of day, cloud cover and pollution, latitude and local landscape topography (Morley, 2014). In the northern hemisphere, south roof exposure is optimal for solar energy production, see figure 5.

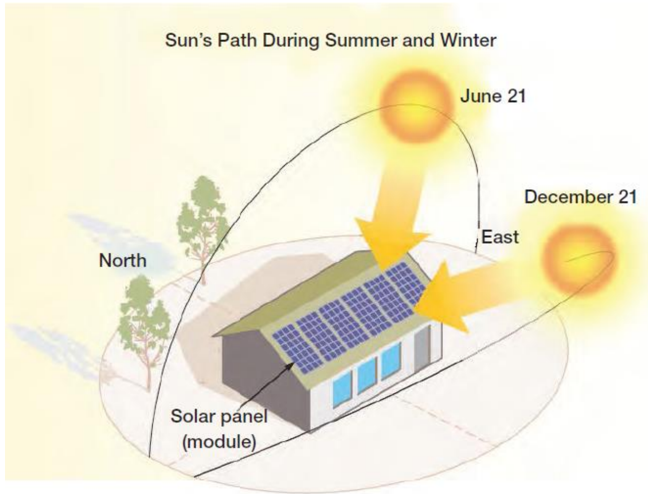



Figure 5: Sun's path during the summer and winter in the northern hemisphere

Germany is the leader in solar renewable technology and has installed more than 1000 times more solar energy capacity than that of Canada, even though it has a lower annual solar irradiance average level than most Canadian cities (Clesle, 2010). Compared to Berlin, Toronto receives 35% more solar radiation per unit of surface area. These solar radiation levels are similar to cities like Milan, however Toronto's installed photovoltaic capacity per capita is roughly 3% that of Germany (Clesle, 2010). Figure 6, illustrates a comparison of Toronto and Berlin's latitudinal position on the Earth and the solar photovoltaic potential of Ontario.

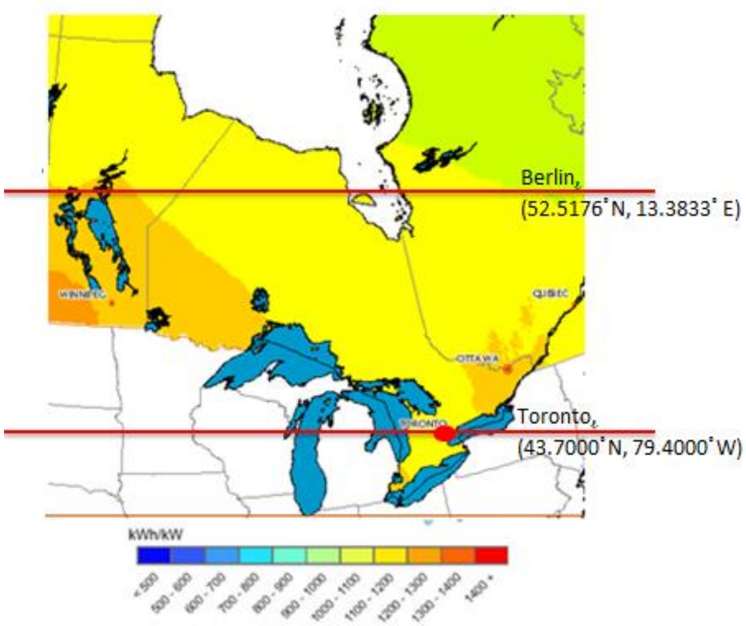



Figure 6: Solar PV potential across Ontario and Toronto and Berlin's global coordinates (Natural Resources Canada, 2013)

The above map illustrates the solar potential of different region in Ontario. The Toronto region has the solar potential of approximately 1100-1200 kWh/kW annually. These figures suggest that there is a significant amount of solar potential in southern Ontario that can be contributed to solar electrical harvesting.

## 3. Benefits of Solar

There are many benefits that accompany solar power implantation. The Canadian Solar Industries Association (CanSIA) prepared a report: *Revising Ontario's Long-Term Energy Plan* for submission to the Ontario Ministry of Energy (MOE). In this comprehensive report CanSIA reveals, policy recommendation, projected forecasts and illustrates the surplus of benefits that solar technology has for society, for the environment, and for the electrical distribution. Solar technology has the highest support of any other form of electrical generation, with 98 per cent Ontarians approval rate (CanSIA, 2013). Benefits of solar deployment include, but are not limited to; empowerment of consumers, is greenest form of energy, continues to decrease in costs, has the capability to alleviate peak demands, it can defer transmission and distribution investments and has long term predictable costs, unlike fossil fuels. CanSIA *Revising Ontario's Long-Term Energy Plan* report demonstrates in far more detailed information the benefits that are accompanied through solar technology.

## 3.1 Job Creation

Further benefits to solar energy adoption include job creation: Ontario has 925 megawatts (MW) installed as of September 2013, making it the leading North American jurisdiction in solar energy capacity. Ontario has 3,000 clean-tech firms and employs 65,000 people in the clean-tech sector, generating annual revenues of more than $8 billion (Ontario Government, 2015).

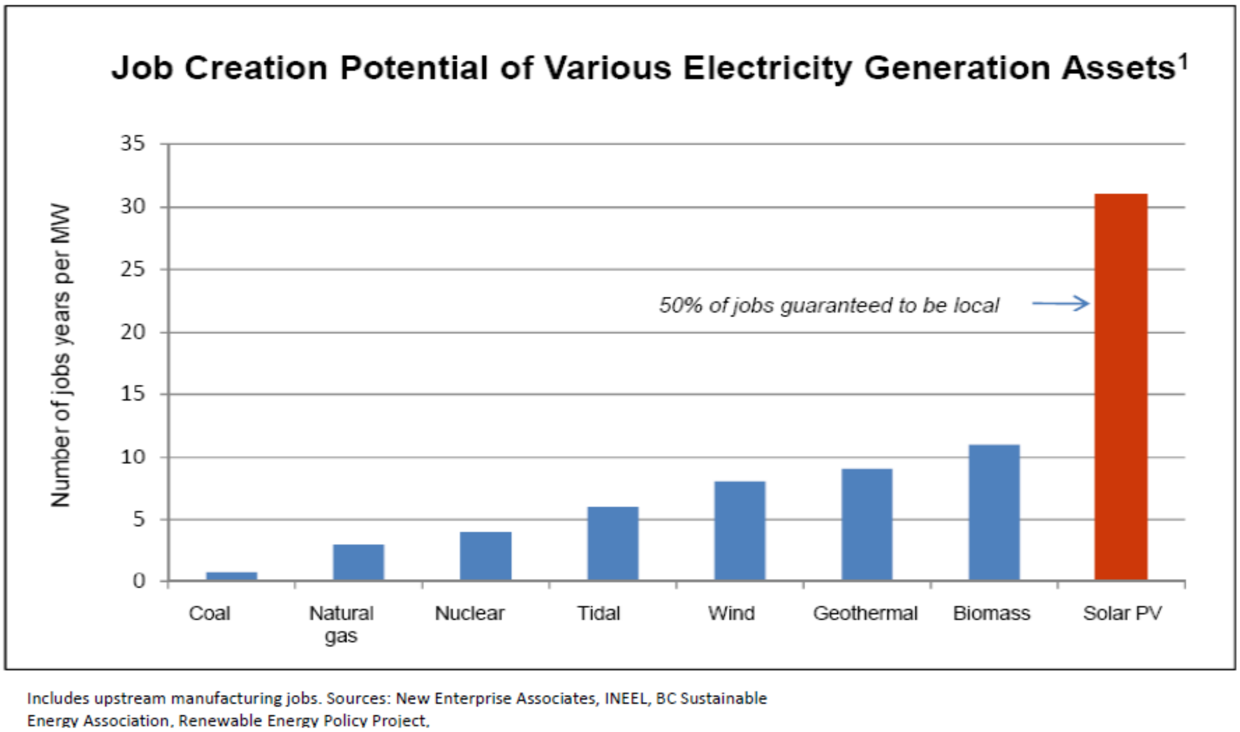



**Figure 7: Potential Job Creation of Various Electricity Generation Assets (CanSIA, 2013)**

Worldwide photovoltaic has increased dramatically. The International Energy Agency (IEA) has indicated "that there is a technology revolution under way and widespread deployments of low-carbon technologies that not only will help address climate change but also enhance energy security and economic development" (Environment Canada, 2012). At 103 MW in 1992, the cumulative PV power capacity worldwide has grown to 34,953 MW in 2010. Considering this huge influx in growth, PV systems currently contribute only 0.1% of the world wide electricity supply.

Internationally, the cumulative installed PV capacity has had an astounding growth of 68% from 2009 to 2010. In Canada, the PV sector grew by more than 22% annually between 1993 and 2009 and currently employs over 5000 people. It has a business value of more than $1 billion (Environment Canada, 2012)

# 4. Photovoltaic System Application

There are two general applications for PV systems, the first being grid-connected application in which PV systems are connected to a centralized electricity. The second application is off-grid or stand-alone systems, in which storage capabilities are necessary (Environment Canada, 2012).

## 4.1 Off-Grid and Stand-alone Applications

Photovoltaic technologies were historically developed for off-grid application in niche markets. These niche markets were created when a location was far from the electricity grid or when electricity means are modest. There are particular scenarios where it often cost less to use onsite generation technology than grid extension (Environment Canada, 2012). Furthermore, PV systems require minimal maintenance and thus are attractive technologies in remote unmanned sites. A variety of remote application, such as telecommunication stations, navigational aids, water pumps, highway signs, lighting and water treatment plants can be powered using PV system (Environment Canada, 2012). However, in many stand-alone PV systems, energy storage is required, such as batteries.  This inherently increases the cost of the system itself. The most common batteries used in stand-alone systems are rechargeable lead-acid batteries. These batteries can handle large and small charging currents with efficiency and are the most cost effective (German Solar Society , 2013 ). However, new lithium ion technologies are emerging, from companies such Tesla. Home energy batteries could be charged via solar and mounted to the wall of a home. Such battery systems can provide security against power outages and could provide independence from the power grid (Tesla, 2015).

The average home uses the majority of it electricity during the morning and the evening hours of the day, as seen in figure 8. During midday hours, solar energy is plentiful and usage is low, this surplus of energy can be stored in battery packs and used when the homeowner comes from work (Tesla, 2015)

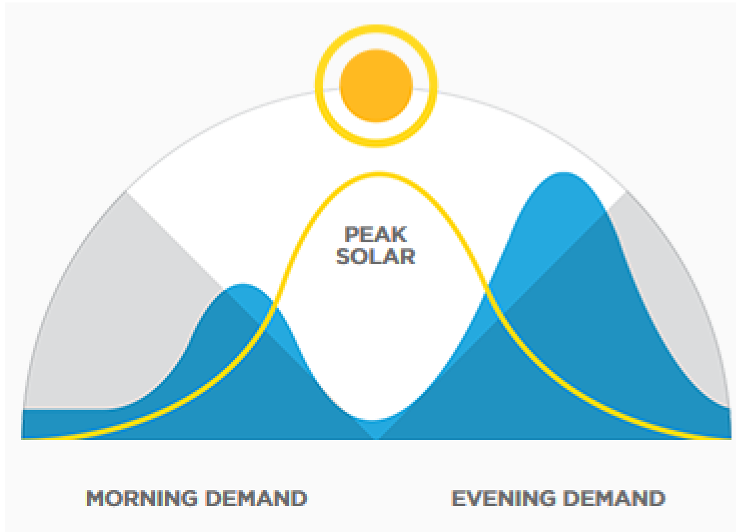



Figure 8: Solar production versus energy consumption of an average home (Tesla, 2015)

Once these storage devices become commercially viable, local distribution companies (LCD) will have to change the way they do business in order stay competitive. This may become a game changer for local distribution. If homes do not need these companies to distribute energy because homeowners can store it themselves, these LCD may loss the home energy market (Oding, 2015). Community energy storage (CES) is also gaining traction in relation to solar generation distribution. CES combine many of the benefits of customer-owned with those of utility-scale ownership and operation (National Renewable Energy Laboratory, 2014). CES is different than a storage device for individual distributed systems because CES serves all the customers connected to a particular distributed area. CES can isolate one portion of the distribution system and provide service to an entire feed if there is a power outage (National Renewable Energy Laboratory, 2014). System likes this could be community owned in which co-operative approaches could become best practice.

### 4.2 Grid-connected Application

Since electricity can be imported from the grid when needed, there is no need for storage devices for a grid-connected application. Therefore, the costs of grid-connected systems are roughly 50 percent lower than that for an off-grid system (Environment Canada, 2012). Current operating standards require grid connected PV systems to automatically disconnect when the grid endures a power outage. This is strictly done for safety purposes as unwanted electric generation on grid could injure individuals working on the system. Most systems are not designed to function as grid connected and standalone systems (National Renewable Energy Laboratory, 2014). Therefore, for solar PV to provide electricity during a power outage, the system must be designed to have the ability to standalone and isolate itself from the grid (National Renewable Energy Laboratory, 2014). Installing PV technology in accompany with energy storage, or in combination with auxiliary generating sources, or within micro grid, can provide the ability to contribute to the resiliency of a building/community by providing a localized power when the grid is down (National Renewable Energy Laboratory, 2014).

# 5. Solar Electricity

## 5.1 Photovoltaic (PV) and Building Integrated Photovoltaics (BIPV)

A photovoltaic system is made up of modules that contain cells that generate direct current (DC) when exposed to sunlight. When PV modules are grouped together, an array is created where series and parallel connected modules can produce any level of power requirements, from mere watts (W) to kilowatts (kW) and megawatts (MW) in size (CanSIA, 2011). In order for the electricity to be converted from DC to alternate current (AC) for grid conductivity, an inverter is required. (Earthscan, 2013). PV cells and modules have no moving parts, require very minimal maintenance and can last for decades (Lunning Wende Associates, Inc, 2010). There are a wide range efficiencies and configurations in today's PV systems that are available. Roof mounted and ground mounted PV systems are the most common; however the building integrated photovoltaic (BIPV) is gaining traction and is becoming more popular. BIPV system consists of integrating photovoltaic modules into the building envelope such as the building's facade or exterior weather skin or roofs such as shingles (Strong, Building Integrated Photovoltaics (BIPV), 2011).

## 5.2 Photovoltaics Technologies:

There are two basic commercial PV module technologies available on the market today:

- Thick crystal products, "which include solar cells made from crystalline silicon either as single or poly-crystalline wafers and delivers about 10-12 watts per $ft^2$ of PV array (under full sun)" (Strong, Building Integrated Photovoltaics (BIPV), 2011). However, higher efficient panels and technologies are being developed on continuous basis, in which will inevitably increase output and efficiency.
- Thin-film products," typically incorporate very thin layers of photovoltaicly active material placed on a glass superstrate or metal substrate using vacuum-deposition manufacturing techniques, which similar to the process in the coating of architectural glass. Currently, commercial thin-film materials deliver about 4-5 watts per $ft^2$ of PV area (under full sun)" (Strong, Building Integrated Photovoltaics (BIPV), 2011).

### 5.3 Building Integrated Photovoltaics (BIPV) systems

As mentioned, BIPV is the integration of photovoltaic (PV) into the building envelope in such a way that building skin outer component is replaced by PV modules. The PV modules are, therefore, bi-functional as they have a role of building skin and as power generation. As the PV modules are used as the building skin they replace conventional building envelope materials and avoid their costs (Strong, Building Integrated Photovoltaics (BIPV), 2011). According to Strong, the replacement of the conventional materials will result in the reduction in the incremental cost and thus improve its life-cycle cost (Strong, Building Integrated Photovoltaics (BIPV), 2011). This system may become highly cost effective in replacing traditional roofing shingles on a house and therefore having solar ready homes will be the first step in ensuring the best approach to integrating these systems.

**Figure 9: BIPV technology for shingles, (Lumen Solar LLC News, 2010)**

**Figure 10: BIPV technology for glazing, (Google Images)**

## 6. Assessment of PV's Life Cycle

A report conducted by Environment Canada, *Assessment of the Environmental Performance of Solar Technologies,* is a comprehensive review and evaluation that assessed the entire life cycle of PV technologies, producing a clear picture of their performance measures against key environmental indicators. Key findings are:

- PV technologies, in general, have negligible environmental impacts when compared to traditional fossil fuel based electrical production. Furthermore, many solar companies currently are either meeting or surpassing the national and international standards for handling and mitigating hazardous materials (Environment Canada, 2012)

- In recent years, the energy payback time (EPBT) has declined significantly. Considering the fuel source for solar is free ensures that the input costs will never rise. Furthermore, the increase in module efficiency, efficacy in manufacturing and the improvements in technology have all contributed to the decline in costs (Environment Canada, 2012).
- PV systems do not produce GHGs emission or air pollutants when generating electricity. The material extraction and production phases account for nearly half of all emissions in the PV life cycle. Fluorinated GHG emission is the largest concern, however the release of these gases have declined as indicated by recent trends. This could be attributed to the manufactory process and the use of alternative substances (Environment Canada, 2012).
- In the production of PV cell small amounts of heavy metals such as cadmium and lead are used, which can arise from waste created by decommissioning of the solar modules. To address the environmental challenges of decommissioning solar modules, *PV CYCLE* was created. PV CYCLE is an international PV industry program that is addressing the recycling challenges in Europe, where the first large scale dismantling facility created in 2009. North America, on the other hand has yet to construct such a facility. Recycle PV modules ensures that heavy metals, like cadmium can be reclaimed and reused in new PV models in the foreseeable future (Environment Canada, 2012)
- Water usage and the effect on water quality in the life cycle of PV technology mainly relate to the manufacturing and considered to be minimal on both.
- Ground mounted applications can have an impact on localized landscapes and ecology. However, solar technology can be deployed on brownfields and contaminated sites such exhausted mining, oil and gas exploration and other industrial sites where the land may not have any useful purpose (CanSIA, 2013). Solar can bring productivity back to otherwise lifeless land.

## 7. Solar Ready Guidelines

Natural Resource Canada (NRCan) and the Canadian Solar Industries Association (CanSIA) partnered together to create the Solar Ready Guidelines (Natural Resources Canada, 2013), in which they specify a number of design considerations and modifications that builders can make to new attached and detached homes in preparation of future solar system installations. These Guidelines are intended to be simple and cost affective to implement, while facilitating significant saving in installation cost for homeowner who choose to install a complete solar system in the future (Natural Resources Canada, 2013). Within the first iteration of the Solar Ready guidelines, these modification and design consideration include: roof space, solar domestic hot water (SDHW) and solar photovoltaic (PV) with a direct route for conduit or piping from roof to utility or mechanical area with enough room to install the balance of system for PV or SDHW i.e. inverters for PV or plumbing connections to existing hot water heater or both (Natural Resources Canada, 2013).

More complex Solar Ready guidelines or “Solar Readiness” were developed and in some municipalities, such as city of Edmonton, solar ready is incorporated into builder’s offerings through energy efficient and green building programs and standards (City of Edmonton, 2014). Aspects such as, site planning, building form and massing, space planning, mounting strategies, structure, roof pitch and many other details that would optimize the solar potential at the planning stage – details that are difficult to work around once the building is constructed (City of Edmonton, 2014).

To maximise the annual solar energy collected, SDHW and solar PV mounting angles are generally equal to the sites latitude. The optimal orientation of the roof surface is south, however west and east still provide a decent amount of solar irradiation. For example, for locations close to 45˚ latitude, the recommended roof pitch is 5/12 to 18/12, equivalent to angles between 23˚ and 56˚ above the horizontal (0˚). It should be noted that systems mounted at low angles (generally 45˚ or less) will not shed snow as well as steeper sloped roofs (Natural Resources Canada, 2013). There are however new technologies that can melt the snow from the surface of the panel in order for it be exposed to the sunlight. Scirus Technology Inc. has created heating panel that they proclaim can increase solar PV production by over 40% during the winter months by Micro Thermal Dynamics Heating Solar Photovoltaic Technology (Scirus Technologies Inc.). Losses due to snow cover are usually negligible in most cases. The fact that the winter months generally have yields due to less solar irradiation, low sun elevation and the sky is often overcast during snow fall (German Solar Society , 2013 ). This is however subject the tilt of the system.

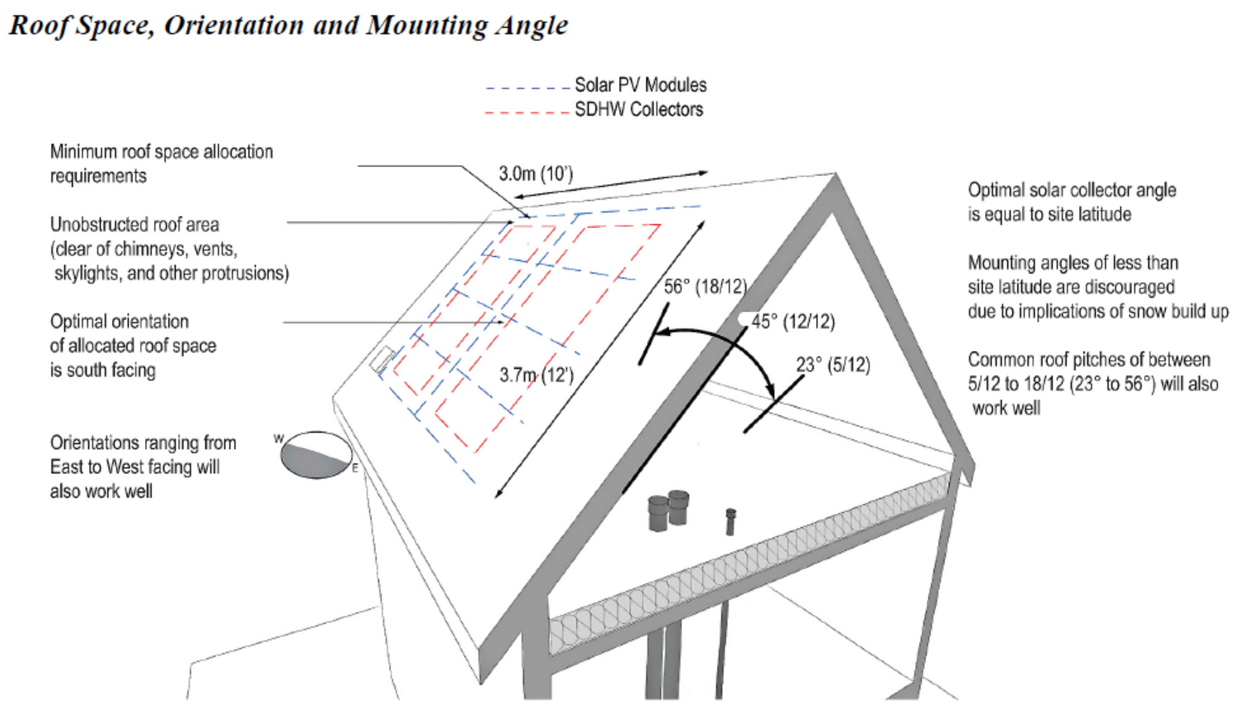



Figure 11: Solar Ready concepts (Natural Resources Canada, 2013)

For solar systems to perform at their very best in the winter or summer months, a determination of the particular solar system and site location must be made. Considering most SDHW systems tend to “over-perform” in summer and “under-perform” in the winter, builders who wish to improve the performance should allocate the roof space to a steeper slope with a modified orientation (Natural Resources Canada, 2013). The general rule for optimized winter performance for SDHW is to mount the system at an angle 10 degrees greater that site latitude and orientated slight west of due south. The more north the location site is the more pronounced the effects will be (Natural Resources Canada, 2013). With regards to PV system the same general rules apply, however since PV systems are typically intended to maximize output during the summer, and therefore a steep slope is not ideal for solar production (Natural Resources Canada, 2013). However, as Edmonton’s Energy Transition Plan report indicates, with broad base regulations to simply install solar ready components, such conduits and roof space, success will not be realized without; planning, zoning, and permitting aspects are developed concurrently or in advance of solar regulations (City of Edmonton, 2014).  Details for solar recommendations and technics and be seen in Natural Resources Canada, *Solar Ready Guidelines* (Natural Resources Canada, 2013)

Structural loading considerations are not explicitly in the Guidelines; however, there are a variety of methods for attaching solar systems to the roof structure. It is the responsibility of the installer to both select and install a solar system so that it meets the building code load requirements (Natural Resources Canada, 2013). In 2011, the Truss Plate Institute of Canada (TPIC) developed a "Solar Ready Truss Design Procedure" for solar system installed on truss based roof. The Solar Ready Truss Design focuses on a truss system that can carry the additional dead load and support typical methods of attachment currently being used by solar installers. This is one design option that builders could use if they wish to address the dead loads and methods of attachment. However, there is still discussion and disagreement on what are the best methods. A National Building Code Standing Committee is working to address the issues of installing solar systems (Natural Resources Canada, 2013). Details can be seen at the *Truss Plate Institute of Canada, Technical Bulletin # 7* (Truss Plate Institute of Canada, 2012).

# 8. Barriers

## 8.1 Financial

Upfront costs for alternative energy systems in new homes is one of the most commonly cited barriers for home buyers. The capital costs of technologies vary, but systems such as geoexchange and PV are particularly high (Environmental Commission of Ontario, 2010). Fortunately, Ontarians can take advantage of the Feed –in Tariffs (FiT) contracts, which is a fiscal tool being employed by the Ontario Government. It is currently the only system being used by a Canadian provincial government though roughly a dozen states and numerous municipalities have since implemented some form of FIT across North America. The Ontario FIT program stands as the most generous FIT policy in North America, providing a great opportunity to invest in solar technologies (World Watch Institute, 2015). Ontario's Feed in Tariff programs, which is operated by the Independent Electricity System Operator (IESO), who merged with Ontario Power Authority (OPA) on January 1$^{st}$ 2015, purchases solar electrical energy at a premium price, which can entice more homeowner/building owners to offset the cost of these systems. Ontarians have the opportunity to take advantage of home grown solar electricity production. Currently the IESO is providing for rooftop solar PV ₵38.4 for < 10 kW system, ₵34.3 for a <10 kW <100 kW system and <100 kW <500 kW systems (Independent Electricity System Operator, 2015). See appendix (A) for the full price scheduling. This is based on grid connectivity rather than off- grid/standalone systems. In Ontario, it is projected that by 2018/2019 , solar PV cost will reach "investment grid parity" which is to say that at that point it is less than or equal to the price of purchasing power from the electrical grid (CanSIA, 2013). According to CanSIA, "this will enable a sustainable net metered market to thrive, provided certain regulatory and technical challenges are overcome". These barriers will not be financial but rather technical constraints and achieving a favourable regulatory environment (CanSIA, 2013). The regulatory environment is crucial to move from fossil fuels to renewables, however energy subsidies play enormous role on the perspective that the world has on energy.

### 8.2 Energy Subsides

There appears to be a disconnect in consumer knowledge about the true costs of fossil fuel production when compared with renewable energy production. This disconnect is directly attributed to energy subsidies. According to the International Monetary Fund, energy subsidies are projected to reach US$5.3 trillion or 6.5 percent of the global GDP in 2015 (International Monetary Fund, 2015). "Most of this arises from countries setting energy taxes below levels that fully reflect the environmental damage associated with energy consumption" (International Monetary Fund, 2015). As Clesle clarifies: solar is often compared to the burning of fossil fuels, in regards to efficiency and cost, but, this comparison not only fails to take into account the numerous stages involved in the fossil production, such as extraction and transportation, but it fails to consider any environmental efficiency. The fact that the collection and generation of solar energy produces no emission waste is often overlooked (Clesle, 2010). While its intention is aimed at protecting the consumer, the IMF specifies, "energy subsidies are distorting resource allocation by encouraging excessive resource consumption, artificially promoting capital-intensive industries, reducing incentive for investment in renewable energy, and accelerating the depletion of natural resources" (International Monetary Fund , 2013). Furthermore, these subsidies reinforce inequality, because the benefits are seized by the higher-income households (International Monetary Fund , 2013)

Understanding the current extent of energy subsidies is essential for energy subsidy reform. In doing so, it highlights the potential environmental, health, fiscal and economic benefits that reform can generate (Coady, Parry, Sears, & Shang, IMF Working Paper: How Large are Global Energy Subsidies, 2015). A key factor in estimating the effects of current energy subsidies is which the definition of "subsidies" is used. Identified by (Coady, Parry, Sears, & Shang, IMF Working Paper: How Large are Global Energy Subsidies, 2015), pre-tax consumer subsidies arise when the price paid by the consumer is less than the cost of supply. Post-tax subsidies, also arise when the price paid by the consumer is less than the cost of supply but also includes an appropriate correction tax that reflects the environmental damages related with energy consumption (Coady, Parry, Sears, & Shang, IMF Working Paper: How

Large are Global Energy Subsidies, 2015). Post-tax subsidies are substantially larger than pre-tax subsidies. Rather than a lack of information on renewable energy costs, energy subsidies are misleading consumers when comparing the costs associated with fossil fuel supply chains and the cost supply chain for renewables. Subsidy reform can have huge positive impacts, to the fiscal, environmental and welfare of the world. For example, by eliminating the post-tax subsidies in 2015, the government could raise revenue by $2.9 trillion or 3.6 percent of the global GDP, $CO_2$ emissions could be cut by 20 percent globally, and premature deaths related to air pollution could be cut by more than half (Coady, Parry, Sears, & Shang, IMF Working Paper: How Large are Global Energy Subsidies, 2015). From this action, global economic welfare would rise by $1.8 trillion or 2.2 percent of the global GDP, after the higher energy costs faced by consumers is allowed (Coady, Parry, Sears, & Shang, IMF Working Paper: How Large are Global Energy Subsidies, 2015). The key findings that were determined by (Coady, Parry, Sears, & Shang, IMF Working Paper: How Large are Global Energy Subsidies, 2015), were that energy subsidies are very large and the removal would have an enormous impact on environmental, revenue and welfare gains worldwide.

| Country | Nominal GDP US$, billions | Population, millions | Post-tax subsidies in US$ billions (nominal) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Petroleum | Coal | Natural Gas | Electricity | Total |
| **Advanced** | | | | | | | |
| Australia | 1534.60 | 23.87 | 15.65 | 10.45 | 3.97 | | 30.06 |
| Austria | 448.08 | 8.56 | 1.71 | 1.11 | 1.00 | | 3.82 |
| Belgium | 536.14 | 11.24 | 5.50 | 2.58 | 2.14 | | 10.21 |
| Canada | 1873.33 | 35.88 | 30.30 | 4.92 | 10.82 | | 46.04 |
| Czech Republic | 208.87 | 10.53 | 1.27 | 15.16 | 1.15 | | 17.58 |
| Denmark | 361.33 | 5.63 | 4.28 | 0.82 | 0.69 | | 5.78 |
| Finland | 280.67 | 5.51 | 0.00 | 1.13 | 0.32 | | 1.45 |
| France | 2935.36 | 64.21 | 16.65 | 6.93 | 6.54 | | 30.12 |
| Germany | 3908.79 | 81.36 | 2.97 | 40.80 | 11.87 | | 55.64 |
| Norway | 523.19 | 5.21 | 3.57 | 0.39 | 0.68 | | 4.64 |
| United Kingdom | 3002.95 | 64.94 | 0.28 | 28.62 | 12.34 | | 41.23 |
| United States | 18286.69 | 321.24 | 406.73 | 203.37 | 89.09 | | 699.18 |

**Figure 12: Comparison of advanced countries post-tax subsidies estimated for 2015 (International Monetary Fund, 2015)**

Figure 12 shows that Canada's post-tax subsidies for petroleum is $30.3 billion and has total of $46 billion in fossil fuel subsidies. This equates to roughly 2.5 percent of Canada GDP. At the Federal level through the ecoENERGY for Renewable Power launched in April 2007, the program was designed to encourage the renewable electricity generation from energy sources such as wind, low-impact hydro, biomass, photovoltaic and geothermal energy which offer a one cent for ever kWh incentive for eligible production during their first ten years of operations (Government of Canada, 2014). As of March 31st , ecoENERGY for Renewable Power program has 104 project that are qualified which represents an investment of about $1.4 billion over 14 years and almost 4500 megawatts of renewable power capacity (Government of Canada, 2014). That equates to $100 million a year. This kind of incentive is erroneous if true renewable energy initiatives are to flourish. This is also a reflection of how the current Canadian government views renewable energy sources. To further emphasize the lack of federal contribution to renewable energy, no new contribution agreements have been signed since March 31st 2011 (Government of Canada, 2014).

Energy subsidies that support and encourage the extraction and depletion of natural resources hinder our ability to invest in renewable technologies. A culture shift that demands change needs to happen. This absence of change can be attributed to the artificially low costs of fossil fuels that Canadians experience, which is helping to reinforce the disconnect seen between the energy producer and the end user. The promotion and education on energy subsidies and the reforms that need to be implemented will have a profound impact on the cultural perspective of fossil fuels. Subsidies to the oil gas industries need to be reallocated to the renewable energy industry to help create an even playing field in which the public is offered a choice on how they access and use their energy. Creating solar 'reserves' through solar ready construction is one viable option to accomplish this. However, the perceived upfront costs of creating such neighbourhoods are deterrents for developers and communities. Ontario has the FIT and microFIT incentives that help cover the cost of the systems themselves; however there is no incentive to create an infrastructure that supports future installations of such systems. Energy subsidies need to be transferred to help facilitate developments that look to integrate future technology into an infrastructure.

### 8.3 Policy and Regulatory Barriers

With some 60,000 housing starts a year in Ontario, energy efficient houses can yield significant lifetime cost savings for home owners and society as a whole. However, if buildings and neighbourhoods are built without energy efficiency in mind, inefficiencies can be 'locked in' to the housing stock for years (Environmental Commissioner of Ontario, 2010). With so many houses being built each year, the missed opportunities for building energy efficient homes are substantial. To avoid such missed opportunities, it is important that a focus on energy efficiency is considered at the design and construction stage, further supporting the ability to adopt energy-efficient technologies, such as solar. Retrofit methods are costly and are an unnecessary approach to improving energy efficiency. According to the Environmental Commissioner of Ontario (ECO), the key barriers that are hindering the progression of alternative energy at neighbourhood and community levels are often interlinked, with regulatory, financial, and capacity consideration (Environmental Commissioner of Ontario, 2010).

Policy and regulatory barriers exist at a variety of levels, mainly due to the different agencies and levels of government involved in energy planning. These agencies include the gas and electric utilities, as well as both the provincial and municipal governments (Environmental Commissioner of Ontario, 2010). The most comprehensive solution put forth by the ECO, would be for the province to amend the Ontario Building Code (OCB) to make alternative energy systems mandatory rather than voluntary (Environmental Commissioner of Ontario, 2010). A proposal in 2010 was introduced which required that a change in the Building Code of a new homes. This proposal stated that new homes were to be built with at least one conduit to facilitate the future installation of a solar PV or SDHW systems, which would have come into force in 2017 (Environmental Commissioner of Ontario, 2010). However, by the spring of 2013, the Technical Committee at the Ontario Home Building Associate (OHBA) enhanced their effort to ensure that mandatory solar ready conduits in all new homes would not make it into the updated codes. The decision was based on the idea that they considered 'solar ready' as well as number of other potential items as 'ill-advised' (Ontario Home Building Association, Spring 2013). Why was solar considered ill advised? Through a phone interview with Andy Oding, from Ontario Home Building Association (OHBA), much of the push back was due mainly to industry. If solar ready was to be mandatory the rule for implementation would default to the 'Solar Ready Guidelines', which results in added costs for the developers, in addition to the costs of the energy efficiency requirements stipulated in the Supplementary Standards SB-12, which examines the whole energy efficiency levels of the home (Oding, 2015) (Environmental Commissioner of Ontario, 2010). The Building Code could be amended to make it easier for homes that have alternative energy systems installed to reflect the energy efficiency requirements stipulated in the Building Code. By including alternative energy systems such as solar into the "prescriptive or compliance packages" of Supplementary Standards SB-12, builders would be able to use these systems to achieve the energy efficient requirements, all the while promoting alternative energy systems (Environmental Commissioner of Ontario, 2010).

Creating a mandatory solar ready situation for developers could create incurred costs for the home buyer, who may not care to install a solar system any time in the near future or as long as they own the home (Oding, 2015). However, if the government began to look at solar ready homes as energy 'reserves' for the grid and society as whole, rather than strictly as an individual homeowner issue, subsidies could be put in place to help offset some of these costs. Other issues with solar ready are the conduits themselves. These conduits run from the basement to the attic, which can cause unwanted heat loss (via air leakage and or breaks in the thermal envelope) resulting in potential moisture entering the attic. Condensation in the attic can cause mould, decrease the effectiveness of the insulation, and over time, can cause damage to structural elements such as rafter, trusses and shingles (Pierce, 2005). If these conduits are not used strictly for solar connection but rather another purpose, such as the installation of a satellite dish for example, the builder's warranties may become null and void, leaving the homeowner to cover the damages that may incur (Oding, 2015). A very simple solution to these problems is to put the conduit on the outside of the house, therefore eliminating interior attic penetration.

Another major issue that is hindering solar ready to be considered in large housing developments is the application for access to the grid, which is determined by the LCD. According to Oding, numerous areas in Ontario have grid constrain, meaning added voltage cannot be introduced to the grid at the present moment. The developer's argument for this scenario is: 'why build solar ready if grid connectivity is not present'. This is a fair argument, considering it costs developers more to install solar ready. However, this mentality is short sighted, not only on behalf of the developers and homebuyers, but also on the utility companies, the municipality and provincial governments. However, this constraint is not necessarily a permanent issue. Access to the grid should open up as new developments are created and the energy demands increase, as well as the anticipation of new innovations, such as storages technologies.

Unfortunately, homeowners and homebuyers are yet not addressing the energy consumption aspect, nor are they addressing the future service costs of the building. As Knowles indicates, "We grow cheap and maintain expensive" (Knowles, 2003). By not considering solar ready, let alone the installation of solar technology upon construction, the ability to reduce energy consumption is lost and thus, the reduction of cost over the service life of the building is lost as well.

With Smart Grid technology available, the industry should embrace such a building code and utilize it to their advantage. Building green and creating designs that amplify electrical production via solar could be a great incentive that home buyers are looking for. This further emphasises the need for home buyers and developers to be aware of the opportunities that exist for long-term energy home investments.

## 9. Solar Design Strategies

There are a number of design strategies and opportunities that should be considered when establishing a solar community. As Hachem indicates, "at an urban level the design of energy efficient solar communities can provide opportunities for seasonal storage, implementation of smart grids for power sharing between housing units, controlling peak electricity production timing and reducing utility peak demands" (Hachem, Fazio, & Athienitis, 2013). These urban design strategies need to allow for flexibility and to increase total rooftop surface for the integration of photovoltaic systems technologies at the urban level. The current design practices do not adequately incorporate solar technology or passive design principles. Existing design guidelines are not well defined when it comes to the design parameter of buildings and neighbourhoods for solar capturing and utilization, which are largely limited to rectangular shapes (Hachem, Fazio, & Athienitis, 2013). Many of the contemporary home designs today are not rectangular but rather have various polygon shapes. With the lack of design flexibility for solar integration, architects and the public can be deterred from adapting this technology to buildings (Hachem, Fazio, & Athienitis, Solar Optimized Residential Neighborhoods: Evaluation and Design Methodolgy, 2013). There is an extensive amount of research on design strategies for residential subdivisions to maximise solar access. Considering that building orientation often depends on street and lot layouts, solar design objective should orient streets and front lot lines in new subdivisions along the east-west axis to maximise solar exposure (Morley, 2014). See figure 13

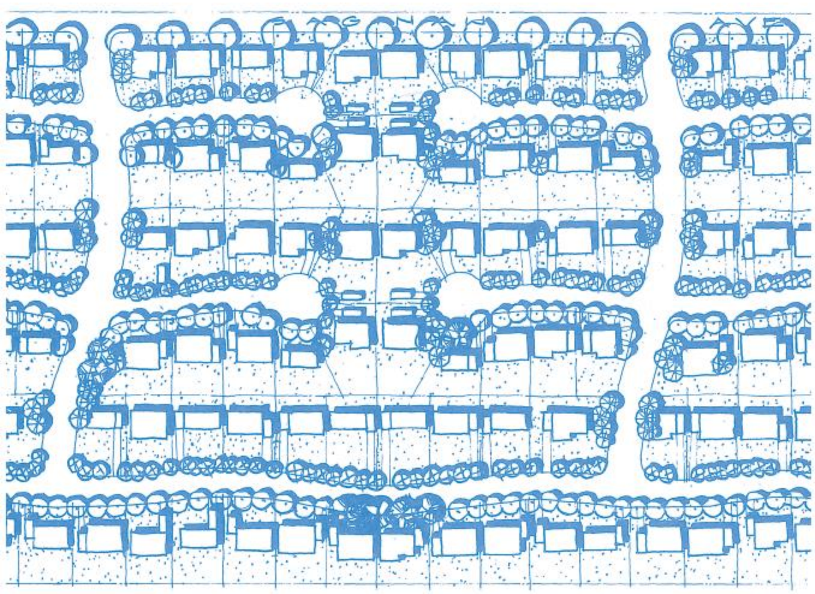


**Figure 13: Example of a site plan for residential subdivision to maximise solar access (Morley, 2014)**

Subdivisions such as the one seen in figure 13, can take advantage of passive solar gains and both PV and the thermal technologies. However, production builders are not making subdivision like this because more land is needed to acquire the benefit of passive solar design, and therefore fewer homes can be built. Furthermore, street orientations in productions develops are designed to maximize the number lots for that particular site, in turn to make east-west axis road for optimal lot orientation far more difficult.

Exemplified in (Hachem, Fazio, & Athienitis, 2013), *Solar Optimized Residential Neighbourhoods: Evaluating and Design Methodology*, geometry of building plays an important role in its potential to capture and exploit solar energy. Extensive research has been conducted to estimate the solar access in the built environment that reflects both, solar systems and passive house design. In (Hachem, Fazio, & Athienitis, 2011) *Parametric Investigation of Geometric form Effects on Solar Potential of Housing Units,* investigated the solar energy potential of two storey housing units with seven geometric shapes: square, rectangle, trapezoid (convex shapes), L, U, H and T (non-convex shapes). The location of the study was Montreal, Canada-latitude 45˚N. Using *EnergyPlus,* (2010) simulation tool, comparative analyses were done to assess the different effects of housing shapes on the solar potential, relative to a reference case (Hachem, Fazio, & Athienitis, Parametric Investigation of Geometric form Effects on Solar Potential of Housing Units, 2011). The rectangular layout was selected as the reference case, because it is generally viewed as the optimal shape for energy efficiency, for this climate location. Through examination of the shape of a site, layout of a street, distance of neighbouring building and their shapes are all elements that affect the solar access of the building in study (Hachem, Fazio, & Athienitis, Parametric Investigation of Geometric form Effects on Solar Potential of Housing Units, 2011). Shading from other building will affect the passive design strategies, while the results indicate that the number of shading facades in-self shading geometries and their relative dimension are major restrictions affecting solar incident and radiation being transmitted (Hachem, Fazio, & Athienitis, 2011). Depth ratio is the depth of the shadow-receiving façade as well as the number of shadow projecting facades. This ratio plays an important role in determining the amount of solar radiation that the shade façade and roofs receives and how much is transmitted by its windows (Hachem, Fazio, & Athienitis, 2011). Further investigation shows that manipulation of the orientation of wings in L shape units can result in increased peak electrical generation see figure 14.

Summary of results of L shape variations.

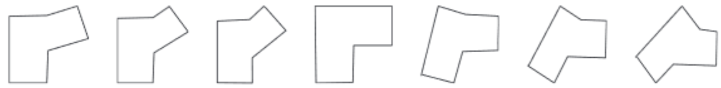
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Shapes | |  | | | | | | |
| Angle of variation | $\theta$ (°) | 15 | 30 | 45 | 0 | 0 | 0 | 0 |
| | $\beta$ (°) | 0 | 0 | 0 | 0 | 15 | 30 | 45 |
| South-facing roof area ($m^2$) | | 20.4 | 21.8 | 23.9 | 17.6 | 20.6 | 21.6 | 23.7 |
| Hip area($m^2$) | | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 | 8.1 |
| Normalized total Annual energy(kW h/$m^2$) | | 195.5 | 193.8 | 189.6 | 194.7 | 197.7 | 196.5 | 195.8 |
| Ratio of electricity generation to optimum roof | | 0.70 | 0.73 | 0.76 | 0.63 | 0.71 | 0.73 | 0.78 |

**Figure 14: Variations in L shapes (Hachem, Fazio, & Athienitis, 2011)**

These results show that with small manipulation to the orientation and design of the shape can improve solar electricity generation potential. A shift in the timing of the peak generation of about 2 hours can be reached relative to solar noon. A difference of peak of 3 hours could be observed between L variation with θ = 30˚ (Hachem, Fazio, & Athienitis, 2011). This shift in peak loads may be economically beneficial, because it is facilitating more even distribution electrical production (Hachem, Fazio, & Athienitis, 2011). This is important research because it quantifies the increase solar potential that can be generated by small manipulation to the orientation. However, these manipulations were done without necessarily taking property lines into consideration which may prevent these different variations in shape to be built on specific lots.

There is significant amount of research that suggests optimal solar exposure for homes, as well as how to create highly energy efficient building design as seen in, Charron 2006 *Design and Optimization of Net Zero Energy Solar Homes,* Knowles, 2003 *The Solar Envelope: Its Meaning for Energy and Building,* Chiras, 2002 *The Solar House: Passive heating and cooling.* Furthermore, research conducted by Hachem, 2011 *Design of Solar-Optimization Neighbourhood,* looks at how to optimize solar energy on a neighbourhood scale.

The following case studies show the potential of solar benefit that can be accompanied at a neighbourhood level if solar consideration was deliberated at the design stages.

## 9.1 Case Study: Solarsiedlung am Schlierberg

Location: Freiburg, Germany
Date: 2006
Architects / Designers: Rolf Disch Architects

Figure 15: Solarsiedlung (Google Images)

Design Strategy / Goals: The goal was to create a complex that would be energy independent. By incorporating passive design strategies, the complex utilized daylighting and thermal design to reduce energy consumption, and south facing orientation to optimize solar exposure. Natural ventilation and ventilation components in the façade served as heat recovery in the winter and cooling in the summer nights. Powered is generated be renewable energy generation through the sun, wind and biomass (Guzowski, 2010). The energy systems include: heat pumps, a heat recovery, solar hot water collectors, and photovoltaic panels. Solarsiedlung was designed to establish a community-scale sustainability plan that promotes renewable energy lifestyles that minimizes or even eliminates the dependence on fossil fuels. With Freiburg's extensive transit network, roughly 40% of residents are able to live car free (Guzowski, 2010). The site design was intended to create outdoor spaces and gardens that foster community and social connection. "The complex is an example of social and ecological sustainability that supports a sustainable lifestyle while generating more energy than it consumes by its businesses and residences" (Guzowski, 2010).

The complex consists of two major components, commercial and residential mixed-use buildings. The residential are row homes that include various models of a modular structure called Plusenergie®haus (Plus-Energy House) (Guzowski, 2010). With the complexes very low energy consumption, producing a positive surplus of energy becomes attainable. The commercial aspect of the community has a net area of 6,034m$^2$ and consumes 17 kWh/m$^2$ per year, and produces 18 kWh/m$^2$ per year. The fifty Energy Plus homes have a total area of 6,745 $m^2$. Each home consumes roughly 2200 kWh annually, which is almost one-fifth of what a typical Ontario home consumes. Each row home generates 6,280 kWh per year from their rooftop solar PV system. The electrical production of these Plus Energy Homes is nearly three times more then they consume (Guzowski, 2010). The total photovoltaic output of the complex is 445 kW, deriving 112 kW from the commercial and 333 kW from the row houses (Guzowski, 2010).

Observations: The Solarsiedlung complex design was a precognitive approach to community sustainability. This approach of sustainability in both building and lifestyle at the design stage is a crucial for energy independence and society's behavioral change towards energy. Freiburg has a relatively mild climate, with average low temperature of 2˚C in January and an average high of 20˚C in July (Guzowski, 2010). These milder conditions help such a complex succeed in achieving energy independence much easier than in climates such as Toronto, where the temperature fluctuations are more extreme throughout the year. In Toronto, the average low in January is -7.3˚C and the average high in July is 26.4˚C (The Weather Network, 2015). With a difference of nearly 9˚C and 6.5˚C respectively in the two months, Toronto will need more energy for both cooling and heating then Freiburg does. Therefore, becoming net zero energy for a building in Toronto becomes more difficult.

Looking at the electrical generation of photovoltaic systems, Toronto and in particular Southern Ontario fair quite well compared to Freiburg. Toronto's latitude is more south than Freiburg and receives on average 2066 hours of sunshine a year compared to 1740 hours that Freiburg receives annually (Current Results Nexus, 2015). Planners, developers and municipalities in Southern Ontario and in fact Canada as whole, need to begin to look at developments like Solarsiedlung, and realize that energy independence or near too, is possible at a community level. By understanding the importance of sustainability, both in lifestyle and energy at the design and planning stages, the future of the housing stock can be assured that it is capable of adapting to a post fossil fuel world. The majority of the new housing developments in Ontario are built on open green fields. Even though agricultural lands are being lost, the open fields do provide a blank slate for developers, planners, architects and municipalities to design sustainable neighbourhoods. By not taking advantage of these opportunities, there may be significant repercussions within the energy sector, which in turn affect the rest of society. These new developments and the building within it should have the ability to harvest solar energy for future needs. Solar ready homes would provide a solar 'reserve' for such communities. Of course, the emphasis on energy reduction is of paramount importance if energy independence is to become realized.

## 9.2 Case Study: Drake Landing Solar Community

Location: Okotoks, Alberta, Canada
Date: 2007
Architects / Designers: SAIC Canada and Sterling Homes

Design Strategy/Goals:


Figure 16: DLSC (Google images)

The Drake Landing Solar Community (DLSC) is a neighbourhood with 52 homes and is heated by a district system designed to store abundant solar energy underground during the summer months and distribute the energy to each home in the winter months for space heating. It is the first of its kind in North America. The solar energy system has the ability to fulfill 90 percent of each home's space heating requirements with a reduction of approximately 5 tonnes of greenhouse gas emission from each home per year. Furthermore, each home has solar domestic hot water system installed (Drake Landing Solar Community, 2014). The homes constructed to R-2000 and Built Green™ Alberta "Gold" energy efficient standards, which is 30% more efficient than conventionally built homes, before 2007.

There is an 800 solar panel array located on the garage roofs throughout the community. This can generates 1.5 mega-watts of thermal power during a typical summer day, which supplies heat to the community's Energy Centre (Drake Landing Solar Community, 2014). A glycol solution runs through insulated piping system, or collector loop which connects the arrays of solar collectors together. Once the glycol has been heated it is then transferred to the community's Energy Centre. Once at the Energy Centre, the heat is transferred in to water stored in a short term storage tank (STST), while the cool glycol solution is carried back through the loop to the solar collectors. From the STST the heated water is distributed to the Borehole Thermal Energy Storage (BTES) (Drake Landing Solar Community, 2014). The BTES is a massive underground concrete heat exchanger that extends 37 meters below the ground and is 35 meter in diameter. Drilled in the concrete are 144 boreholes, 150mm in diameter that the water filled pipes travel through. The temperatures of the storage system will reach 80 degrees Celsius by the end of the summer.  In the winter months, the heated water in the BTES passes to the STTS and is circulated through the district heating loop to the individual homes, see figure 17 (Drake Landing Solar Community, 2014). The heat is distributed throughout the house by a heat exchanger within a specially designed, low temperature air handler unit located in the homes basement (Drake Landing Solar Community, 2014).

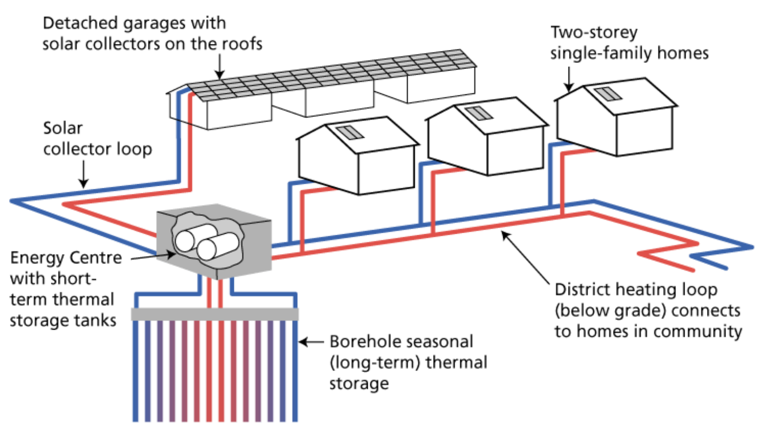



**Figure 17 Solar Seasonal Storage and District Loop (Drake Landing Solar Community, 2014)**

Observations: Drake Landing Solar Community is an excellent example of how solar technologies can be used on a community scale.  The project significantly minimizes the heating demand of the community, while reducing GHGs emissions. However, unlike the Solarsiedlung community, Drake Landing did not put any particular emphasis on how occupants use energy or sustainable lifestyle attitude shifts. There is no real attempt to curve energy consumption by the occupants or help establish a sense of sustainable lifestyle, which is exemplified by the community's dependence on cars. Rather, this project showcases technology that can help cover our energy needs, not reduce our energy demand. As Clesle exemplifies, "…it (Drake Landing) has done very little, if nothing, to promote ecologically conscious choices from its residents" (Clesle, 2010). Furthermore, doing such a development on a large production building fashion scale is not realistic or economically viable from majority of the developer's perspective. Canadian's would have to first shift their attitudes on energy consumption and lifestyles if we are to utilize renewable energy generation effectively and create neighbourhoods such as these. Nevertheless, projects like these are necessary for the public to gain confidence in solar technology and prove that the systems work.

## 10. Void in Literature

There seems to be a void in literature with regards to the solar radiation potential that current Canadian / North American contemporary neighbourhood designs and roof typographies may have. That being said, there appears to a great amount of research on the best practices for solar consideration, with a focus on achieving passive house (PH), net zero energy house (NZEH), and more importantly net zero energy neighbourhoods (NZEN). This is extremely important research because it identifies that achieving these highly efficient buildings takes a twofold approach: 1) Enhancing energy efficiency of the building and 2) optimizing active solar production using photovoltaic and thermal collectors (Hachem, Fazio, & Athienitis, 2012). NZEH and NZEN are defined in this research, as having the ability to generate as much energy through renewable sources then consumed in a year. Unfortunately, even with such informative data, large developers and municipalities in Southern Ontario and Canada as whole are not willing to take a risk to implement such design strategies in a new development. These strategies are expensive and technically savvy to implement, especially in a large development. With no legal or mandatory legislation or obligation, nor at the present moment a popular demand for it, avoiding these risks is understandable. There needs to be transition approach that provides builders an adjustment period for new technologies and perspective to become common place in the industry. This notion of popular demand may be altered if the opportunity was given and education provided. Industry and architects can sometime be the catalyst for social trends. The old saying, “if you build it, they well come” mentality can help push forward the homeowners awareness and appreciation for such designs.

For the builders, there are several benefits that accompany solar ready homes. Solar ready homes raise the green profile for a limited additional cost, while distinguishing the company from its competitors. It is a positive step toward reducing a community carbon footprint and it may limit the need for additional building permit requirements if the initial application shows location for where solar PV or thermal will be installed (Terry, 2011). These changes will help communities’ transition easier to a post fossil fuel world.

Figure 18: Doug Terry Solar Ready Home SDHW (Terry, 2011)

Considering there are 60,000 housing starts a year in Ontario alone, avoiding the opportunity to implement renewable energy and preparing communities for future energy needs seems nonsensical. Solar Ready Homes may be the catalyst needed to educate the public that they have the ability to generate and consume power that they have created on-site. With the challenges and the many more benefits stipulated throughout this paper for solar technology, the implementation of these technologies into society should not be underestimated. Solar ready homes should begin to be viewed as solar energy 'reserves'.

# 11. Research Question

The overall objective of this research is to quantify the potential solar energy generated from roofs in a typical contemporary housing development built in southern Ontario. In this research paper, the focus will be on single detached homes, where small modification to the existing roof designs can increase solar production, while keeping the home foot print and neighbourhood's layout identical.

This paper will attempt to address the four following questions:

1. What is the solar electrical potential that an existing roof layout can generate in a typical contemporary neighbourhood development?
2. What are the potential electrical gains when minor design modifications are made to the original roof design?
3. By examining the largest surface areas of the redesigned roof, how does mirroring roof layouts affect its electrical output? How much additional electricity can be generated if this was done? Mirroring of the layout will only be done if the largest roof surfaces are facing north.

4. What is the electrical output of a block of a small cluster of homes if they were to gather their electricity collectively? To investigate this, 24 homes were chosen to represents a typical block in a contemporary neighbourhood. By pooling their electrical generation, can this block of homes produce enough energy to offset their collective electrical consumption? Three scenarios will be conducted: first analysis will look at the original models in the block, the second will be the redesigned models placed in the same lots as the original, and finally how optimizing the roof surface by mirroring the models will affect the overall solar electrical production.

By understanding the solar potential of such roof and neighbourhood designs, it may be easier for production builders to shift to solar ready home designs due to minimal increases in costs and design perimeters that enable such a product to be utilized effectively. The idea behind this research will hopefully lead to solar ready home designs becoming common place and the installation of conduits as well as all other necessary requirements will be as readily available. This may be the first step to facilitate solar capabilities into new home designs on a large community scale from an initial design perspective. The hope is that the information produced through this research will enable production builders to begin the implementation solar energy at the initial design phase without having to make drastic changes to their housing designs or site plans and ultimately keeping costs to a minimum.

Solar technologies can be sold to potential buyers as an add-on option. As home buyers choose their lot location and their home design, the developer can promote and recommend best roofing design for solar harvesting for that particular lot location. Home buyers then may have the option to either buy solar at the design phase or wait until the feel the time is right; i.e. when the price of panels have decreased in costs or their financial capabilities increase. Developers should also explore the idea of creating mirrored house footprints. If the orientation is not optimal for solar exposure to largest surfaces of the roof, having the ability to mirror the house layout allows these surfaces to become optimal for solar exposure. This concept will be investigated further within the research. This method insures that the home is now solar ready for future installation and solar technology advancements. By demonstrating to developers that their current home designs have solid solar potential, even if the orientation and neighbourhood layouts are not optimal for maximum solar access, is still a very attractive selling feature for home buyers.

## 12. Current Contemporary sub-division layouts

Through the observation of a typical new neighbourhood in Southern Ontario, in particular in the Golden Horseshoe, one can see that intensification is evident, see figure 19.


Figure 19: Aerial view of a typical contemporary neighbourhood in the GTA (Google Maps)

The above topographic image is of a neighbourhood in north Oakville. As one can see there are a number of different size homes from detached, semi-detached and row homes. Through quick observation, one can see that they are built very close together with large roof surfaces and fairly small green space. Neighbourhoods like these and their design layouts are being developed across the Golden Horseshoe. This illustrates that the apparent intensification is not only happening in the big cities such Toronto, but also occurring in the suburban landscape.

## 13. Methodology

This research will analyse six roof models that were provided in collaboration with a major developer in the southern Ontario. These home models and roof designs are currently being built in a new sub-division in a southern Ontario community. The home developer provided drawings and roof typographies of a number of model types that fit into specific lots sizes. These roof models were chosen based on a number of different criteria. These criteria will be illustrated later in this section. The following methodology process was as followed:

1. Acquired AutoCAD drawing of an existing neighbourhood layout and imported it into the Vasari program.
2. Six drawings acquired from a major developer and were modelled into Revit then imported into Vasari.
3. Performed slight modifications to the original roof design, using some of the Solar Ready Guidelines and the following criteria:
    i. Creating larger roof surfaces
    ii. Decrease the number of unnecessary roof lines such as valleys and ridges
    iii. Adjusting roof angles and peaks
    iv. Eliminating “fake” decorative, unnecessary dormers
4. Investigated how many 1m x 2m panels can be installed on each roof surface regardless of orientation.
5. Established boundary conditions for solar simulations.
6. Simulated solar potential of both original and redesign model layouts in the neighbourhood setting
7. Simulated solar potential of a single house without neighbouring conditions, both original and redesigned in different orientations; North, South, East, and West.
8. Simulated mirrored model where obvious solar gains could be seen.
9. Investigated the appropriate tools and data verification.
    i. Revit
    ii. PVWatts
10. Estimated the collective solar potential of a block of 24 homes according to the three scenarios described above.

## 13.1 Neighbourhood Layout

In order to understand the current solar potential of a typical contemporary neighbourhood development, drawings needed to be acquired of homes that are being built and designed for today’s construction. A major developer provided drawings and roof plans on a number of their designs for different lot sizes. Many of these designs have been built in an existing neighbourhood located in a greater Toronto area (GTA) community.

Six roof designs were chosen to represent the solar production of a block in a typical contemporary neighbourhood. This particular subdivision has 5 different typical lot sizes; 34’ (10.4m), 38’ (11.6m), 45’ (13.7m) and 50’ (15.2m) wide and 91’ (27.3m) deep, and RTD (Row Homes). Figure 20 illustrates the development and the property lines and lot sizes that have been created to form the new development.


Figure 20: Phase 1 of the Preserve Development

For this research, three roof designs for 10.2m lot sizes were chosen and identified as; Model A, Model B and Model C. A further three more roof designs for 11.6m lot sizes were chosen and are identified as; Model D, Model E and Model F. The reasoning behind the choice of these two lot sizes was the fact that combined together they make up over half the of the lots size designations in the neighbourhood (outlined in black). There are a number of RTD (row houses, outlined in yellow) in the neighbourhood as well; however, the focus of this research is on single-family detached homes. Therefore, roughly 58% reflects the total number of detached lots within this development, see figure 20. Furthermore, intensification of neighbourhoods is assumed to persist in the future and therefore the smaller lot sizes will be more predominant in the urban landscape. Another reason for choosing the 10.2m and 11.6m lot sizes and thus the accompanied roof designs, is based on the foot print of these homes which are smaller than 13.7m and 15.2m lots and thus have a disadvantage in the roof areas in which solar panels can be installed.

## 13.2 Home/Roof Models

Based on the pdf drawings given by the developer, massing conceptual drawings for the relevant unit types were created digitally in Revit. Massing conceptual drawings are a form of digital drawings that are able to create solar simulated data on surfaces. The neighbourhood site plan was exported from AutoCAD into the Vasari program and orientated correctly to the real world development. Once the models were completed in Revit they were exported into Vasari and introduced into the site plan and positioned in lots that are designated for that particular house size. Furthermore, the houses were position on the lots according to municipal code relative distance from roads, neighbouring lots and backyard property lines, see appendix A for details.

### *13.2.1 Choosing the 10.2m Lot models*

Through observation of drawings provided by the developer, many of the footprint layouts and roof designs for homes designated to 10.2m lots have similar characteristic, (see appendix C) particularly in the back portion of the house. The front of the house, on the other hand, changes from home to home to add variety and for aesthetic appeal from street view. The 10.2m lot models came in both hip and gable style roof. For this research one gable and two hip styled roof designs were chosen. See figure 21, 22, and 23

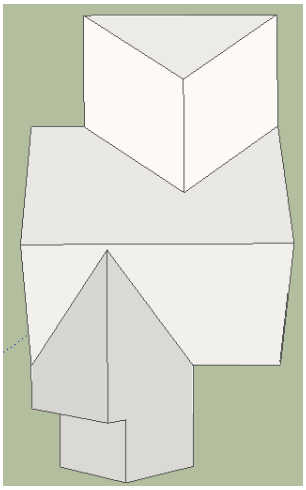


**Figure 21: Original Model A Roof Design**

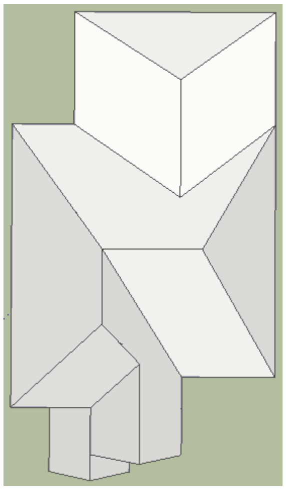


**Figure 22:Original Model B Roof Design**

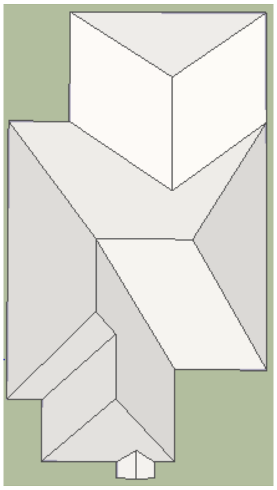


**Figure 23: Original Model C Roof Design**

Considering the 10.2m lot sizes are the smallest in the neighbourhood many models are similar. Model A with a gable roof was chosen for the obvious reason that it differs from the hip designs. Model

B and Model C, on the other hand, are both hip roofed, however their front portions/dormer differ from gable style on Model B and hip one Model C. see figure 22 and 23.

### *13.2.2 Choosing 11.6m Lot Models*

Unlike models A, B, C that were designed to fit on a 10.2m lot sizes and have similar characteristic, models D,E, and F have more flexibility to design  different foot prints and thus different roof typographies on all aspect of the homes. Because of their larger lot sizes, figure 24, 25 and 26 illustrate the dynamic difference between the three models.

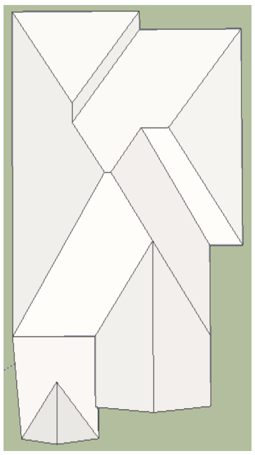


**Figure 24: Original Model D Roof Design**

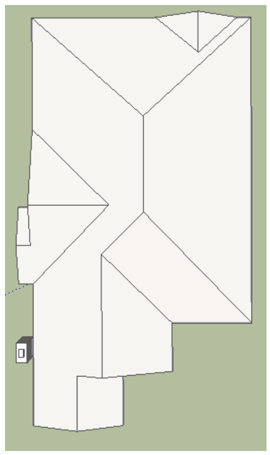


**Figure 25: Original Model E Roof Design**

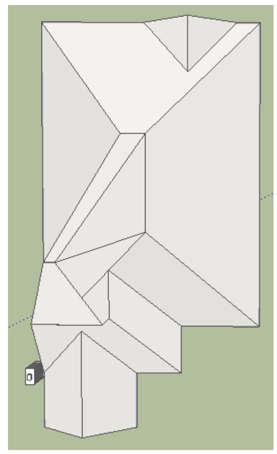


**Figure 26: Model F Roof Design**

Moreover, with the design characteristics differing in all models, a better understanding of the different challenges and solutions architects/developers may confront when designing their models for solar consideration at the design phase. One challenge in particular that needs to be addressed is the concept of “fake” decorative, unnecessary dormers, see figure 27. Majority of the roof design models provided by the developer, particularly on the larger models have these fake dormers. They affect the overall continuity of the roof surface particularly on south facing surface and thus decreasing the number of PV panels that can be install as well increase shadowing. These dormers are purely for decorative purpose.  A suggestion to help alleviate fake dormers that affect roof surface continuity, particularly for the south facing surfaces, is to eliminate them all together or provide potential home buyers with options and education them on what roof design is best suited for optimal solar harvesting for their particular lot location. Engagement with the public on such matters by the developers is crucial for a ‘solar ready’ neighbourhoods to flourish.


Figure 27: Examples of fake dormers

For this research, a focus was placed on simplifying roof topography and increasing roof surface areas, reducing roof lines such as unnecessary ridges and valleys, adjusting roof angles and peaks and eliminating fake dormers.

### 13.3 Roof Modification

The approach taken for modification was to create larger roof surfaces that were continuous. Solar Ready Guidelines were considered but were not the key decision making tool for the redesign roof layout. Without changing the floor plan, the primary goal was to eliminate certain peaks and fake dormers, decrease slop on some surfaces, and create continuous roof surfaces. This continuity allows for solar panels to be installed in a larger array while increasing the number of panels that could be installed. These principals were followed for each model. By comparing the original design with the redesign, one can see the small changes that increase the roof surface area substantially.

By analyzing the solar potential of these contemporary home designs and their correlating roof typologies, an understanding of the current solar irradiation they poses can be quantified. Once the solar irradiation and the related electricity generation potential have been established, a simplification of the roof designs was made to amplify roof surface areas. These roof design changes will not alter the footprint or change the orientation of the original home design. These changes should be minimal in costs and design perimeters, while maintaining the original aesthetic appeal. These redesigned models can be seen in section 14, simulations and results. This research will hopefully help production builders utilize this information from a practical perceptive by using developers who have a reputable construction and design methodology as well as prefabricated truss systems.

## 13.4 Estimating the number of PV panels each roof surfaces can support

The panels that were chosen to establish the electrical output from the solar irradiation were 1m x 2m in dimensions with a conservative efficiency of 15%. Technology used may vary and therefore the size and number of panels and efficacy will vary when applied to roof installation.

Figure 28, is a SketchUp drawing of the original model B. It demonstrates hypothetical number of panels on each surface regardless of orientation. Elements of a roof, such as the vents and plumbing stacks are assumed to be installed in areas where the panels are not being affected (i.e. north facing surfaces). New techniques such as roof ridge vents can be installed to ensure ample roof area surface, see figure 29.

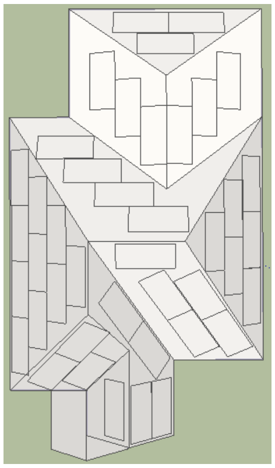


Figure 28: Example to demonstrate hypothetical number of panels on each surface regardless of orientation Original Model B


Figure 29: Ridge Roof Vents (Google Images)

### 13.5 Boundary Conditions for Solar Simulations

Each simulation conducted utilized all the same boundary conditions:

- The location: Latitude 43.4, Longitude -79.7
- Weather Data: Pearson International Airport
- Duration: January 1st 2014 through to December 31st 2014
- Time intervals: 6:00am to 9:00pm
    - 15 hours year simulation was conducted in order to insure that all potential sunlight hours were accounted for throughout the entire year.

The data collected through these simulations was averaged out for each separate roof surfaces. The data being collected is the average amount of solar irradiation that a particular roof surface receives. For example, figure 30 shows 3 distinct surfaces on the right side of the Model B home. Each surface will have their own solar irradiation average, which will be the basis for calculating the solar electrical potential (kWh per year) for each surface. Through observation it was clear that the solar irradiation varies even on the same surface, this is due to other parts of the roof casting shadows during different times of the year. This may affect the overall efficacy of an array of panels, however from a comparison perspective this can still clearly illustrate the difference between the two roof designs and their potential solar gains.

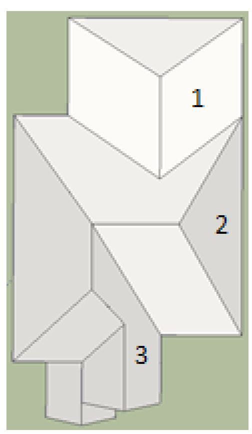



Figure 30: The numbers indicate different Surface for right side of Model B Original

## 14. Simulations and Results

In total, 80 simulations were conducted. Of these simulations, 32 of them were conducted within the neighbourhood setting, while the remaining 48 simulation were conducted in all four orientations, North, South, East and West with no neighbouring buildings present. The reasoning behind conducting all models both original and redesigned in all orientations was to establish the validity and or weaknesses of the simplifications of the roof typography and how they perform in all directions. The data that was collected describes the solar potential for the south, east and west roof surfaces. The north facing surfaces were omitted on the bases that they do not receive nearly as much solar irradiation then that of the other surface orientations in the north hemisphere. Low angled roofs facing north, however, appear to have relevance in solar production, as will be demonstrated within this paper related model A, in the result section.

Figure 31 illustrates the location in which these homes were situated within a block while figure 33 shows the location of the block within the neighbourhood. Because of the layout of this particular development many of the directions in which the homes were located were similar and therefore a conclusion was made that the solar potentials would be similar throughout the neighbourhood, within the 10.2m and 11.6m lot sizes. Also, by analysing the models in all orientations, the information acquired should be adequate enough for an overall generalization of how well the redesigned roof compares to the original roof models.

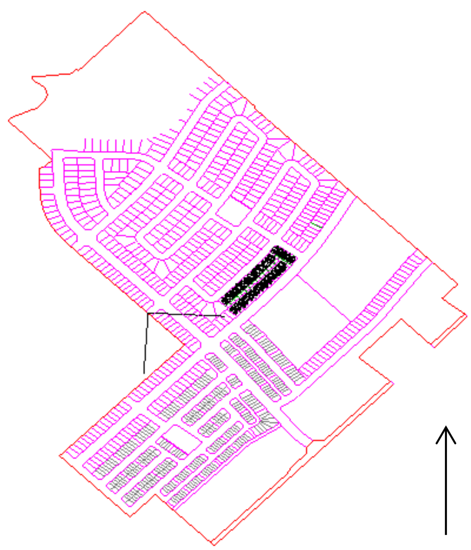


**Figure 31: Block of houses located in the neighbourhood**

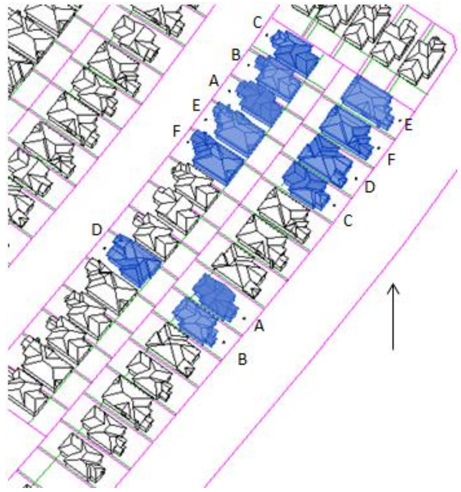



Figure 32: Location of six models with the block

In the first series of simulations, each of the six original models were simulated in which the front of the houses was orientated northwest followed by simulation with the front orientated to the southwest, see figure 32. These orientations reflect the layout in this particular block in the neighbourhood setting. Using Vasari, the solar irradiation data was estimated on each of the southwest and southeast surfaces. These homes were placed in their respective lot sizes within the block for an accurate representation and according to zoning requirements. Following the simulations and collection of data for the original models, the redesigned models were positioned in the same location as the original models, and simulated with all the same boundary conditions. This would illustrate whether the redesigned model improved or deteriorated the potential for solar irradiation on the roof surfaces in study. Moreover, the redesigned models were also simulated mirror layout to see what if any increase in solar simulation was present.

## 14.1 Simulation Data Collection

The data was collected and presented using a table generated by Excel and shows the:

- Pitches of each surface,
- The area ($m^2$) of each roof surface,
- Average yearly solar irradiation that each roof surface receives per $m^2$ (rounded to the nearest 5)
- Efficiency of the panels
- Electrical solar production kWh/year for the total roof surface area(rounded to the nearest 5)
- Percentage of area that standard PV panels can be installed and

- Total amount of electrical solar production that can be achieved on the roof surface. (rounded to the nearest 5)

Table 1, is an example of how the data was collected and evaluated for all 80 simulations.

**Table 1: Model B Northwest facing simulations**

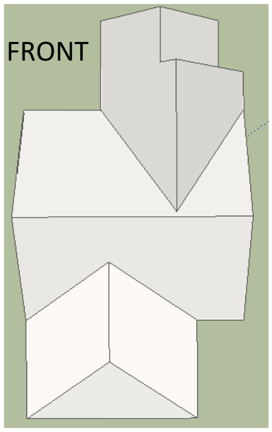
| Orientation | Pitches° | Areas per roof surface | SI* ($kWh/m^2$) Average | Total SI* kWh/yr | Efficacy % | Solar kWh/yr/produced | Area of PV coverage % | Total Solar Potential kWh/yr |
|---|---|---|---|---|---|---|---|---|
| Front (NW) | 42 | 8.7 | 500 | 4330 | 15% | 650 | 69% | 450 |
| | 32.75 | 16.6 | 590 | 9810 | 15% | 1470 | 60% | 883 |
| | | | | | | | | |
| Back (SE) | 32.75 | 20.9 | 850 | 17890 | 15% | 2685 | 38% | 1020 |
| | 32.75 | 11.1 | 860 | 9510 | 15% | 1425 | 54% | 770 |
| | | | | | | | | |
| Right (SW) | 25.45 | 15 | 905 | 13590 | 15% | 2040 | 53% | 1080 |
| | 45 | 17.8 | 770 | 13725 | 15% | 2060 | 67% | 1380 |
| | 45 | 12.4 | 855 | 10580 | 15% | 1585 | 65% | 1025 |
| | | | | | | | | |
| Left (NE) | 25.45 | 15 | 610 | 9135 | 15% | 1370 | 53% | 725 |
| | 45 | 25.4 | 430 | 10920 | 15% | 1640 | 70% | 1145 |
| | 45 | 5.4 | 380 | 2060 | 15% | 308 | 37% | 115 |
| | | | | | | | | |
| | | Usable Roof Surfaces | SE &SW | 65295 | | Usable Roof Surfaces for solar Harvesting | SE &SW (Total 42 $m^2$ of panels) | 5275 |
| | | North surfaces | NE & NW | 36255 | | North surfaces | NE & NW | 3320 |
| | | | Total | 101550 | | | Total | 8590 |

*Solar irradiation (SI)

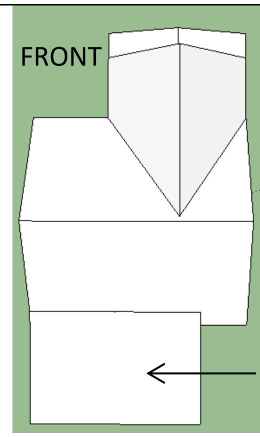
As mentioned above, simulations within the neighbourhood setting only utilized the south facing surfaces, shown in red in Table 1. For this model and location scenario, if panels were placed on all south facing surfaces they would cover $42m^2$ and generate approximately 5275 kWh/yr. Without any simplifications to the roofs' surface there is still a considerable amount of solar harvesting potential. Findings suggest that this particular model, even without simplification, can still provide a homeowner with a solid base for solar ready add-ons. Furthermore, considering that south facing surfaces were only used as a comparative to the redesigned models, it is interesting to note the amount of solar irradiation that the north surfaces of Model B in particular received and the potential solar electricity that could be generated. The above table is an example of how data is collected and interpreted in all models, in which the above model B data will be discussed in more detail.

## 14.2 Model A

**Table 2: Model A Simulation Results**




Original




Back 4˚ slope surface

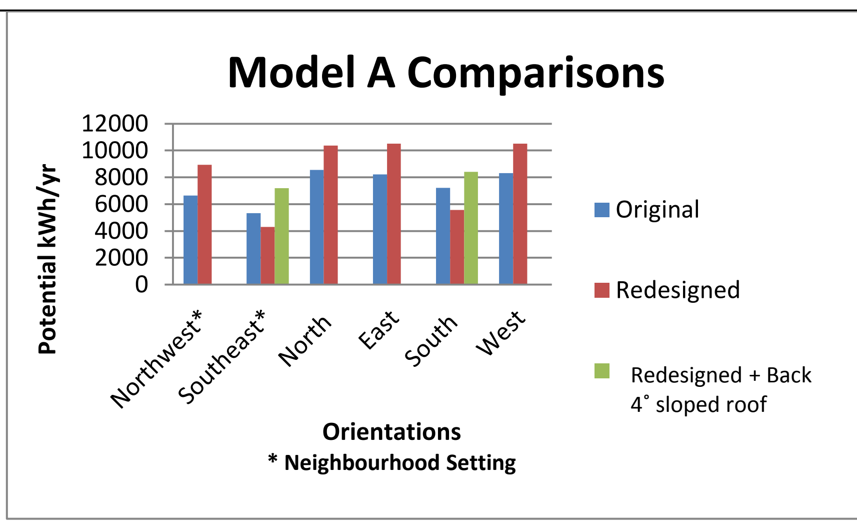
Redesigned

| Front of House Orientation | Northwest* | Southeast* | North | East | South | West |
|---|---|---|---|---|---|---|
| Solar Generating Surfaces | S.E and S.W | S.E and S.W | S, E & W | S, E & W | S, E & W | S, E & W |
| Original (kWh/yr) | 6,645 | 5,340 | 8,550 | 8,220 | 7,220 | 8,310 |
| Redesigned (kWh/yr) | 8,935 (+33%) | 4,305 (-20%) | 10,360 (+21%) | 10,500 (+22%) | 5,570 (-23%) | 10,500 (+26%) |
| Redesigned + Back 4˚ slope surface (kWh/yr) | | 7,200 (+35%) | | | 8,400 (+16%) | |
| MicroFIT $0.384/yr. original vs redesigned | $2,555 vs $3,430 | $2,050 vs $1,655 vs $2,765 | $3,285 vs $3,555** | $3,155 vs 3,600** | $2,770 vs $2,140 vs $3,225 | $3,191 vs $3,600** |

* These models have been simulated in the neighbourhood setting, with neighbouring homes present.

** Systems are greater the 10 kW. MicroFIT program : >10 kW ≤ 100kW receive$0.343

(+_ %), (-_ %) percentage of increase or decrease of the redesigned model

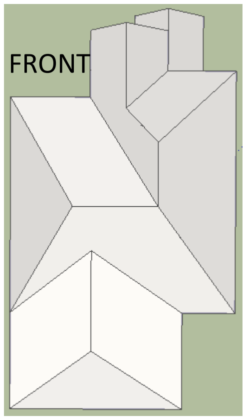


The redesign has a decreased electrical production when the house is facing southeast and east orientations this is due to two surfaces on the back portion being eliminated to make one surface. However, even though the redesign roof's back portion is facing north there is still a substantial amount of solar irradiation that the roof received. Further details of the amount of solar production will be deliberated in the discussion section.

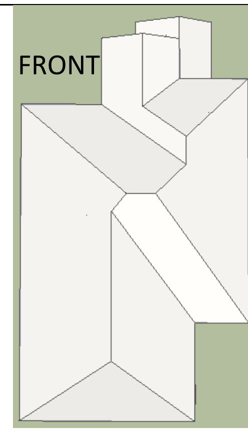
Installing a 10 kW solar system may not be in the homeowner's interest if they are concerned about the amount of income that can be generated for the Ontario's mircoFIT program. For example, when the front of Model A is orientated north, a 10 kW system can be installed and generate 10,360 kWh/yr. However, with a 10 kW system the microFIT rate decrease to $0.343 for every kWh generated, roughly totaling $3,555 annually. By removing one panel, the systems is decreased to a 9.75kW system and therefore receives $0.384 for kWh generated. If one panel was removed for example from west facing surface in the scenario where the house is facing north, the annual electrical production decreases from 10,380 kWh to  10,180 kWh/yr. a difference of only 200 kWh/yr. With the higher rate of $0.384 the homeowner could earn $3,910 a year, a difference of $355. It's important to note from a financial perspective less can sometimes be more. This evident in some other models as well.

## 14.3 Model B

**Table 3: Model B Simulation Results**



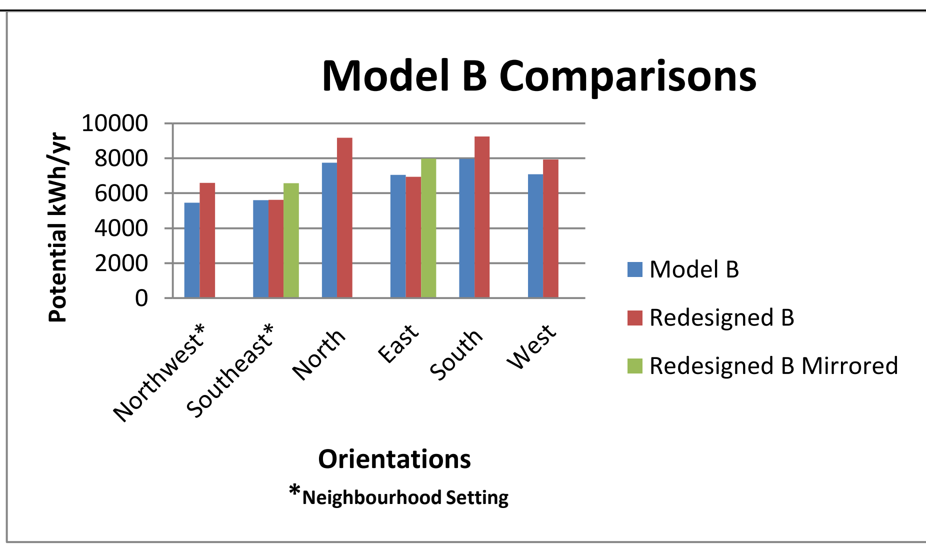

Original




Redesigned

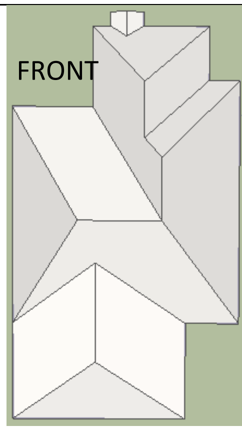
| Front of House orientation | Northwest* | Southeast* | North | East | South | West |
|---|---|---|---|---|---|---|
| Solar Generating Surfaces | S.E and S.W | S.E and S.W | S, E & W | S, E & W | S, E & W | S, E & W |
| Original (kWh/yr) | 5,460 | 5,600 | 7,740 | 7,040 | 7,970 | 7,080 |
| Redesigned (kWh/yr) | 6,590 (+21%) | 5,620 (+0.4%) | 9,180 (+19%) | 6,940 (-1.4%) | 9,250 (+16%) | 7,930 (+12%) |
| Redesigned mirrored (kWh/yr) | | 6,580 (+18%) | | 7,990 (+12%) | | |
| MicroFIT $0.384/yr. original vs redesigned vs mirrored | $2,095 vs $,2530 | $2,150 vs $2,160 vs $2,525 | $2,970 vs $3,524 vs | $2,700 vs $2,665 vs $3,070 | $3,060 vs $3,590 | $2,720 vs $3,045 |

* These models have been simulated in the neighbourhood setting, with neighbouring homes present.
(+_ %), (-_ %) percentage of increase or decrease of the redesigned model

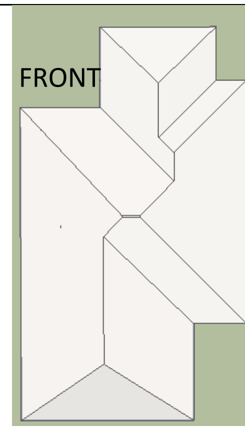


## 14.4 Model C

**Table 4: Model C Simulations Results**



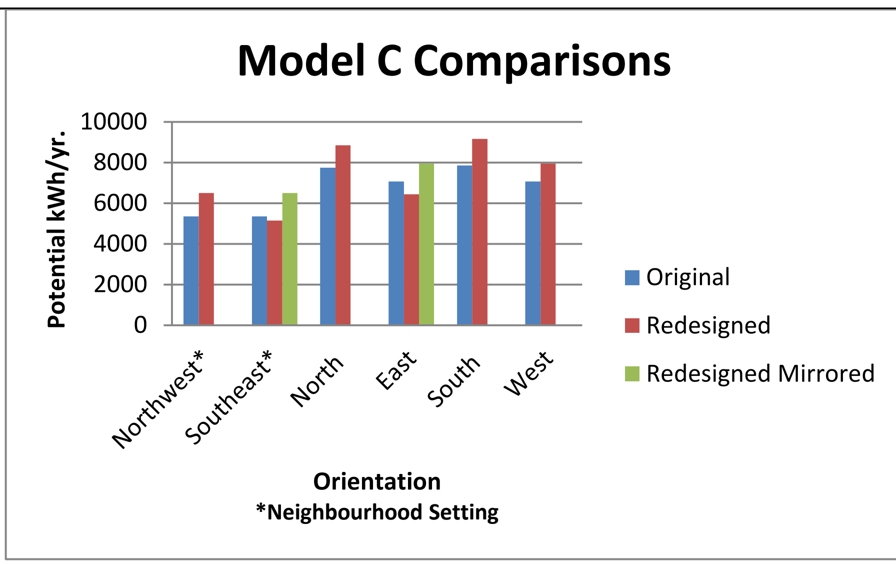

Original




Redesigned

| Front of House Orientation | Northwest* | Southeast* | North | East | South | West |
|---|---|---|---|---|---|---|
| Solar Generating Surfaces | S.E and S.W | S.E and S.W | S, E & W | S, E & W | S, E & W | S, E & W |
| Original (kWh/yr.) | 5,350 | 5,350 | 7,745 | 7,065 | 7,855 | 7,065 |
| Redesigned (kWh/yr.) | 6,505 (+22%) | 5,140 (-4%) | 8,840 (+14%) | 6,440 (-9%) | 9,165 (+17%) | 7,940 (+12%) |
| Redesigned mirrored (kWh/yr.) | | 6,500 (+21%) | | 7,940 (+12%) | | |
| MicroFIT $0.384/yr. original vs redesigned vs mirrored | $2,055 vs $2,500 | $2,055 vs $1,975 vs $2,500 | $2,975 vs $3,395 | $2,715 vs $2,475 vs $3,050 | $3,015 vs $3,520 | $2,715 vs $3,050 |

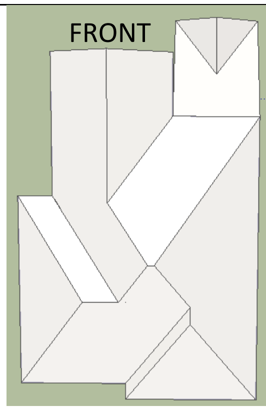
* These models have been simulated in the neighbourhood setting, with neighbouring home present.
(+_ %), (-_ %) percentage of increase or decrease of the redesigned model



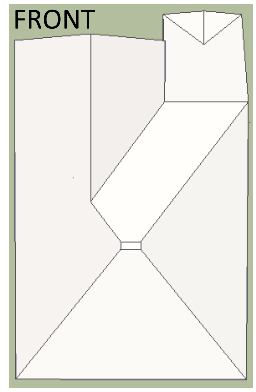
There is a slight decrease in electrical production in both B and C redesign model when facing east, this is due the fact the back surface has become slightly smaller creating the inability to install as many panels as the original. Furthermore, due to the layout, the largest roof surface area is facing north when the front of the house is facing east. For this reason, having the ability to have a mirrored roof layout provides the opportunity to have the largest roof surface facing south or in another optimized orientation.

## 14.5 Model D

**Table 5: Model D Simulation Results**




Original



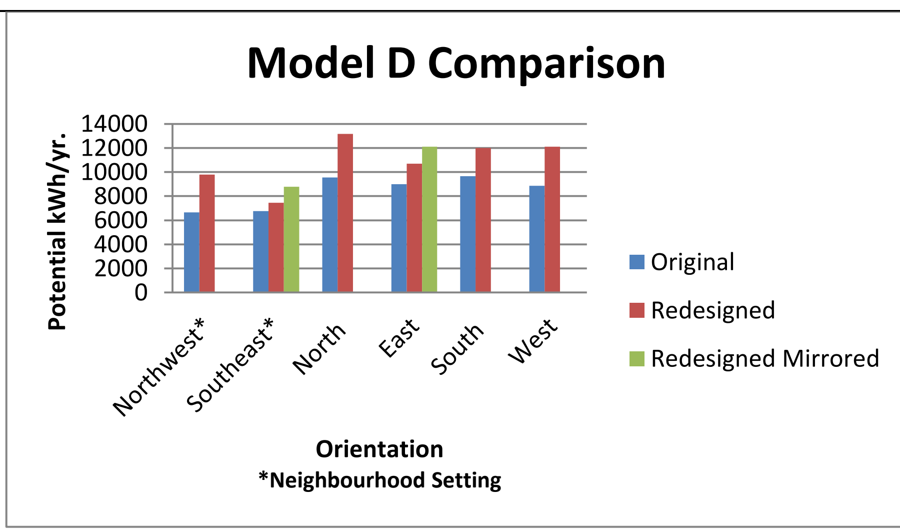

Redesigned

| | | | | | | |
|---|---|---|---|---|---|---|
| Front of House Orientation | Northwest* | Southeast* | North | East | South | West |
| Solar Generating Surfaces | S.E and S.W | S.E and S.W | S, E & W | S, E & W | S, E & W | S, E & W |
| Original (kWh/yr.) | 6,665 | 6,760 | 9,590 | 8,980 | 9,660 | 8,860 |
| Redesigned (kWh/yr.) | 9,790 (+47%) | 7,450 (+10%) | 13,160 (+37%) | 10,690 (+19%) | 12,000 (+24%) | 12,115 (+37%) |
| Redesigned mirrored (kWh/yr.) | | 8,775 (+30) | | 12,100 (+35%) | | |
| MicroFIT $0.384/yr. original vs redesigned vs mirrored | $2,560 vs $3,760 | $2,595 vs $2,860 vs $3,370 | $3,685 vs $4,515** | $3,450 vs $3,670** vs $4,150** | $3,710 vs $4,115** | $3,400 vs $4,155** |

* These models have been simulated in the neighbourhood setting, with neighbouring homes present.

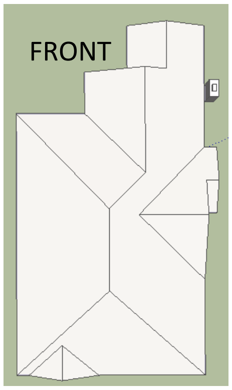
** Systems are greater the 10 kW. MicroFIT program : >10 kW ≤ 100kW receive$0.343

(+_ %), (-_ %) percentage of increase or decrease of the redesigned model

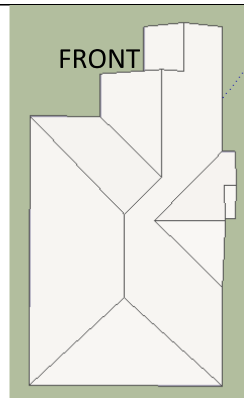


## 14.6 Model E

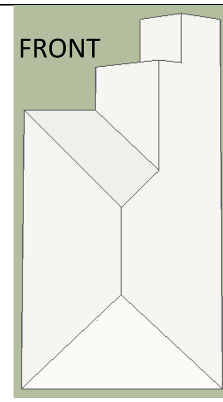
### Table 6: Model E Simulation Results



Original



Redesigned 1 (Removed back dormer and chimney)



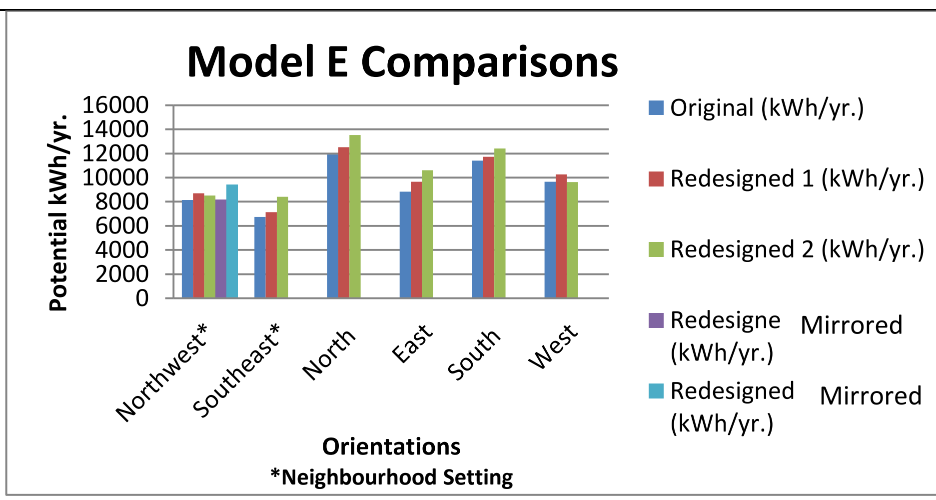
Redesigned 2 (Removed back dormer and chimney)

| Front of House orientation | Northwest* | Southeast* | North | East | South | West |
|---|---|---|---|---|---|---|
| Solar Generating Surfaces | S.E and S.W | S.E and S.W | S, E & W | S, E & W | S, E & W | S, E & W |
| Original (kWh/yr.) | 8,155 | 6,730 | 11,910 | 8,825 | 11,400 | 9,660 |
| Redesigned 1 (kWh/yr.) | 8,710 (+7%) | 7,140 (+6%) | 12,515 (+5%) | 9,660 (+9%) | 11,720 (+3%) | 10,270 (+6%) |
| Redesigned 2 (kWh/yr.) | 8,520 (+4%) | 8,405 (+25%) | 13,520 (+14%) | 10,615 (+20%) | 12,405 (+9%) | 9,620 (-0.4%) |
| Redesigned 1 mirrored (kWh/yr.) | 8,175 (+0.3%) | | | | | |
| Redesigned 2 mirrored (kWh/yr.) | 9,445 (+16%) | | | | | |
| MicroFIT $0.384/yr. original vs redesigned 1,2 vs mirrored 1,2 | $3,130 vs<br>$3,345 vs<br>$3,270 vs<br>$3,140 vs<br>$3,625 | $2,585 vs<br>$2,740 vs<br>$3,230 | $4,085** vs<br>$4,295 **vs<br>$4,640** | $3,390 vs<br>$3,710 vs<br>$3,640** | $3,910** vs<br>$4,020** vs<br>$4,255** | $3,685 vs<br>$3,525 **vs<br>$3,690 |

* These models have been simulated in the neighbourhood setting, with neighbouring homes present.

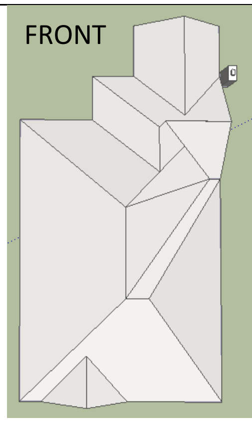
** Systems are greater the 10 kW. MicroFIT program : >10 kW ≤ 100kW receive$0.343

(+_ %), (-_ %) percentage of increase or decrease of the redesigned model

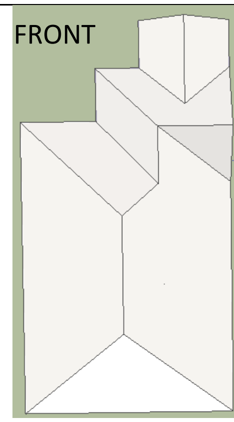


## 14.7 Model F

### Table 7: Model F Simulation Results




Original



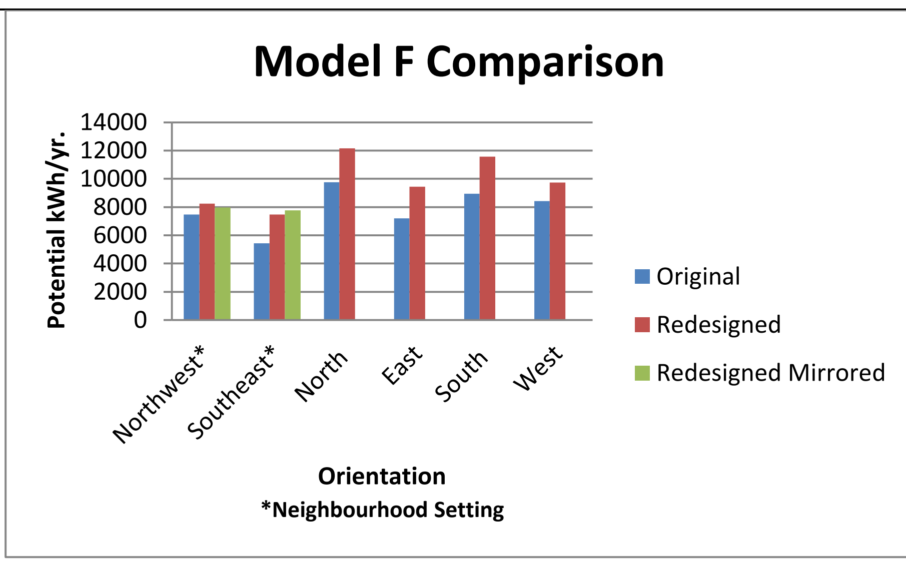

Redesigned

| Front of House Orientation | Northwest* | Southeast* | North | East | South | West |
|---|---|---|---|---|---|---|
| Solar Generating Surfaces | S.E and S.W | S.E and S.W | S, E & W | S, E & W | S, E & W | S, E & W |
| Original (kWh/yr.) | 7,470 | 5,445 | 9,760 | 7,205 | 8,940 | 8,420 |
| Redesigned (kWh/yr.) | 8,240 (+10%) | 7,475 (+37%) | 12,160 (+25%) | 9,450 (+31%) | 11,580 (+30%) | 9,745 (+16%) |
| Redesigned mirrored (kWh/yr.) | 7,980 (+7%) | 7,775 (+43%) | | | | |
| MicroFIT $0.384/yr. original vs redesigned vs mirrored | $2,870 vs $3,165 vs $3,065 | $2,090 vs $2,870 vs $2,985 | $3,750 vs $4,170** | $2,765 vs $3,630 | $3,430 vs $3,970** | $3,235 vs $3,740 |

* These models have been simulated in the neighbourhood setting, with neighbouring homes present.

** Systems are greater the 10 kW. MicroFIT program : >10 kW ≤ 100kW receive$0.343

(+_ %), (-_ %) percentage of increase or decrease of the redesigned model



An important factor to consider is that dormers on the north facing surface can increase solar production as a result of the additional roof surfaces. Furthermore, the original designs still have a substantial potential for solar harvesting.

# 15. Data Verification

The solar simulated data was collected using an Autodesk program called Vasari, with drawing created in Revit. The follow are examples for verification that the number acquired in Vasari are relevant.

## 15.1 PVWatts validation

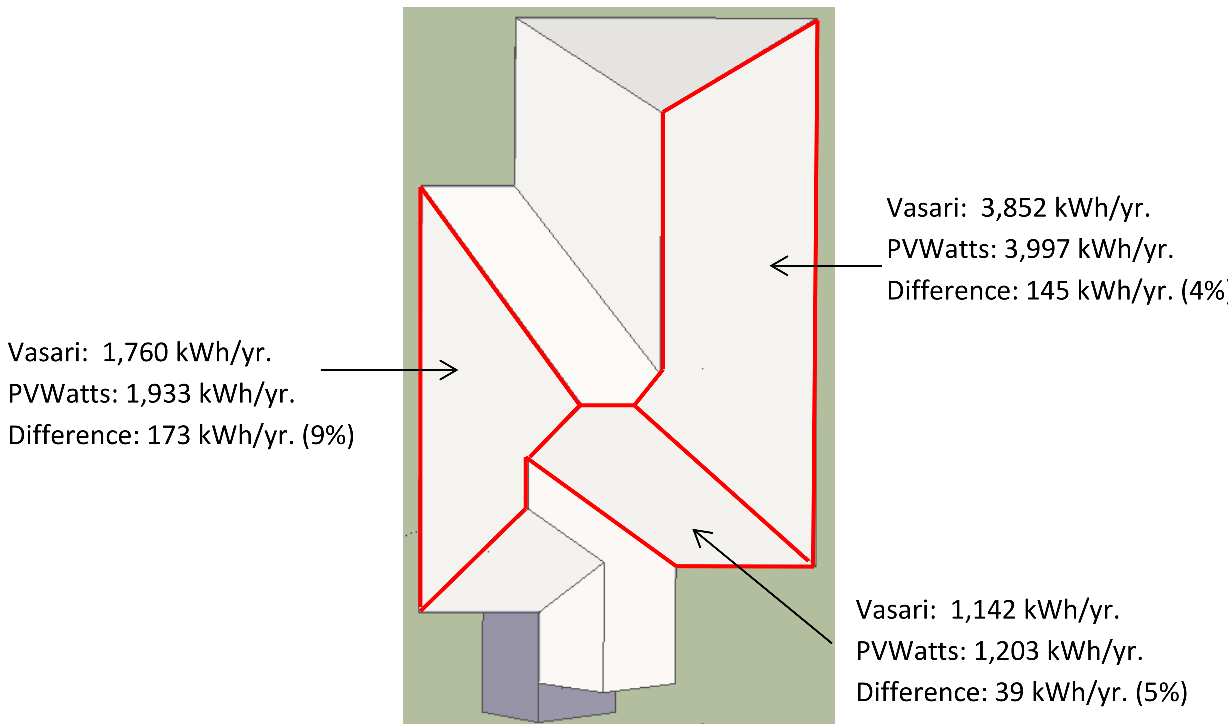



Figure 33: Surfaces used for comparison

Through the website PVWatt Calculator, three surfaces were calculated for solar irradiation. PVWatts had very similar projection for solar electrical harvesting to that of Vasari. Using PVWatts calculations, the east and south surfaces had a 4% and 5% increase of solar irradiation respectively, while the west surface had an increase of 9%.

## 15.2 Revit Validations

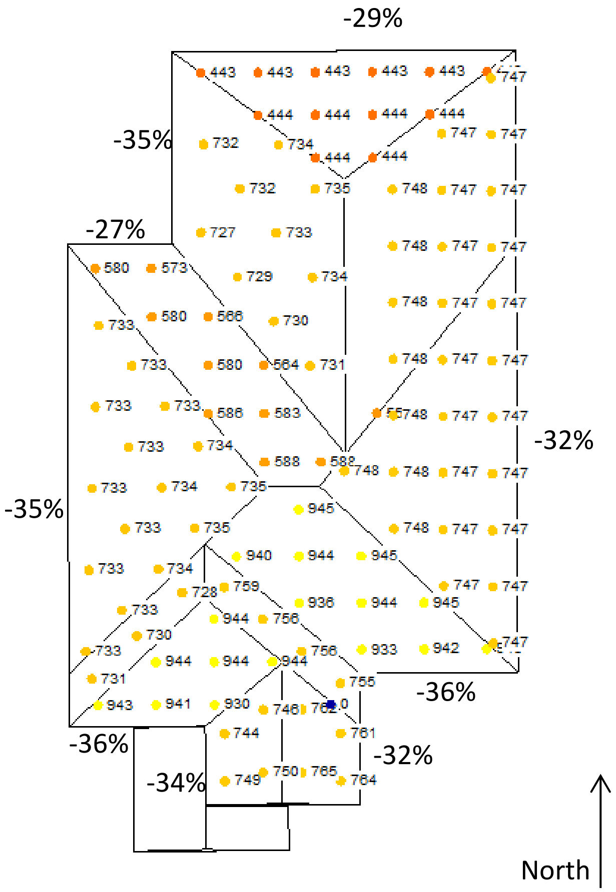



Figure 34: Vasari Solar Simulation with house orientation due South

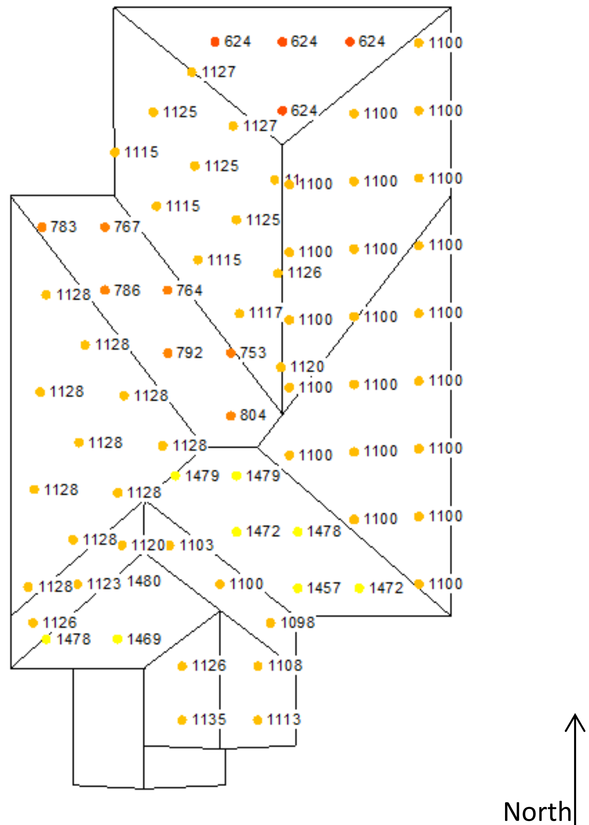



Figure 35: Revit Solar Simulation with house orientation due South

The above two figures compares the differences between Vasari solar simulation and Revit solar simulation. The data shows that in all orientation the Revit solar simulation increased solar irradiation by the following:

North: 28%

South: 36%

East: 32%

West: 35%

The South, East and West have relatively the same increases in solar irradiation on the roof surfaces when simulated in the Revit's solar analysis. Considering all three of these orientations increased at relatively the same increments, it is fair to conclude that Vasari solar analysis when compared to itself would generate roughly 35% less solar irradiation then Revit. Therefore, this demonstrates sound and consistent comparison between the two variables being analysed. North calculations are omitted. Considering that this study is conducted in the northern hemisphere, the term “south facing” is used to refer to the “equatorial facing” of roofs, facades and units. As the evidence suggests north facing sloped roofs are not ideal for solar production (Hachem, Fazio, & Athienitis, Design of roofs for increased solar potential BIPV/T systems and their applications to housing units, 2012) .

Considering Vasari shows less solar irradiation then both Revit and PVWatts, a conclusion has been made that Vasari’s solar figures may be more conservative than the other two solar simulating and therefore the data is appropriate to use in this research.

## 16. Discussion

To gain a better understanding of all the data collected, 3 simulations will be discussed later in this research paper. By selecting only a few key simulations, the data is concentrated and can illustrate that a simple modification to a roof can have significant effects on the increase of solar potential and solar electrical production. The models for discussion will be Model A, Model B and Model D.

The discussion will be broken down via model comparisons of the original and redesigned models

- Both original and redesigned Model A, Model B, Model D will be analysed and compared in the neighbourhood setting and in all orientations without neighbouring homes.
- A discussion regarding the ability to mirror a house model so that lager roof surface area can have the best solar exposure.
- Further discussion and simulation of how neighbouring homes’ shadows can affect both original and redesigned model B.
- Finally, three examinations will be conducted to see home much electricity can be produced on a neighbourhood block level of 24 homes. The first analysis will look at the original models in the block, the second analysis will be the redesigned models placed in the same lots as the original, and finally, I will examine how optimizing the roof surface by mirroring the models will affect solar electrical production.

## 16.1 Model A

The original Model A is a gable roof design with a front extension which is also a gable. The back extension, however, is a hip roof design, see figure 36. Figure 37, is the redesigned model, in which small changes can be observed. A simple but significant change can be seen on the back portion of the roof. The hip portion was eliminated and replaced with a 4˚ slope roof. For simplicity purposes, these areas are labelled as area 1 (Blue), area 2 (Red) and area 3 (Yellow).

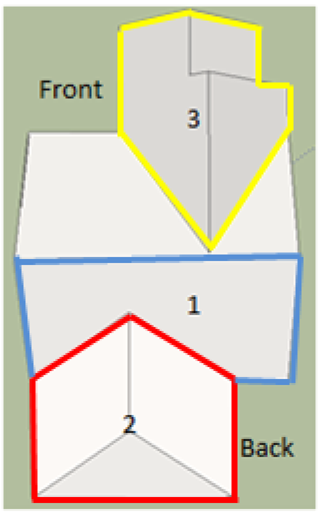


Figure 36: Original Model A

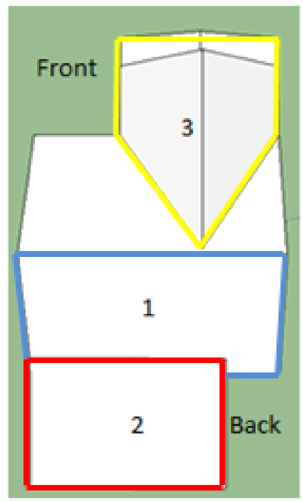


Figure 37: Redesigned Model A

The modification of the back extension (area 2 red outlined) into one surface rather than three separate surfaces, has not only created continuity of the surface, but has also increased the area of the back surface of the gable (area 1 blue outlined). This simple modification of area 2 has increased the surface area of area 1 from 33.3$m^2$ to 38.7 $m^2$, allowing 83 percent of that surface area to be covered in PV panels rather than 72 percent. This has increased solar production by 35 percent, from 3055 kWh/yr. to 4120 kWh/yr. This simple modification of the roof has eliminated the three separate surfaces that face three separate orientations in the original design. The following table and figures illustrates the comparison of the original and redesigned models of area 2, when the front of the house is orientated north.

### *16.2.1 Area 2 Comparison*

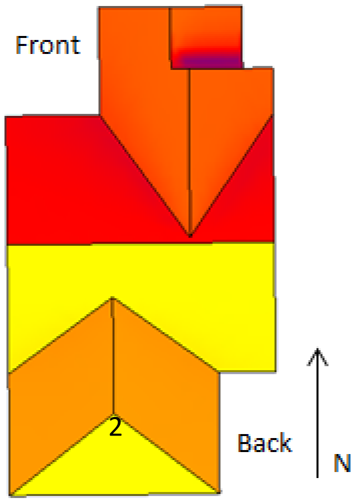



Figure 38: Original Model A Colour Scheme

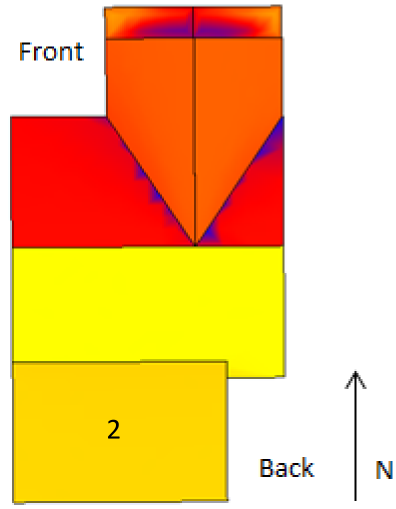



Figure 39: Redesigned Model A Colour Scheme

Table 8: Comparison of original and redesigned of area 2 in Model A

| | Orientation of surface | Pitches° | Areas per surfaces | SI (kWh/m²) Average | Total SI kWh/yr | Panel Efficacy % | Solar kWh/yr/ produced | Area of PV coverage % | Total Electrical Potential kWh/yr |
|---|---|---|---|---|---|---|---|---|---|
| Original | South | 32 | 10.5 | 951 | 9990 | 15% | 1500 | 54% | 810 |
| | East | 25.45 | 14.4 | 764 | 10930 | 15% | 1640 | 53% | 870 |
| | West | 25.45 | 14.4 | 759 | 11000 | 15% | 1650 | 53% | 875 |
| Total | | | 39.3 | | 31920 | | | | 2555 |
| | | | | | | | | | |
| Re-designed | South | 4.1 | 29.9 | 878 | 26250 | 15% | 3940 | 80% | 3150 |

Looking at the above table, we can observe that the increase of solar electrical potential is much higher in the redesigned structures. For example, when comparing to the original model A for area 2, an approximate 23 percent increase is evident. With a solar production of 3150 kWh annually, this surface area alone, has the ability for a 3 kW system to be installed on the roof, when the surface is directly south facing.  What is also interesting to note, however, is that the original area 2 receives more solar irradiation (31918 kWh/yr.) then the redesigned area 2 (26252 kWh/yr.); approximately 18 percent less. However, the redesigned area can produce nearly 23 percent more solar electrical production than the original design. The increased amount of solar irradiation on the original area 2, can be attributed to the larger area those three surfaces create when added together (39.3m²). While the redesigned area 2 is roughly 24 percent smaller ($29.9m^2$) 80 percent of the surface area can have PV panels installed. In total, twelve 2m x 1m PV panels can be installed on the redesigned surface, compared to eleven 2m x 1m PV panels on the original. Considering there is only one additional panel on the redesigned area and 18 percent less solar irradiation while increasing the solar electrical production by 23 percent, suggests continuity of surface area and orientation can play significant role in solar electrical production. Furthermore, the fact that the redesigned area 2 has a low slope (4˚) and one continues on the surface indicates that all panels can receive a substantial amount of solar irradiation in all orientations, even when facing north. See table 3.

**Table 9: Comparing orientations of Original and Redesigned Model A Area 2**

| Orientation of Area 2 | West | East | North |
|---|---|---|---|
| Original (Total of all three surfaces) | 1110+650+645 = 2405 | 1075+660+640 =2375 | 850+865+450 =2165 |
| Redesigned | 2985 kWh/yr. | 2992 kWh/yr. | 2838 kWh/yr. |

### 16.3 Simulation in the Neighbourhood Setting

When simulated with the front of the house orientated to the northwest in a neighbourhood setting, the original model A can produce roughly 6645 kWh per year; however the redesigned model A has an ability to increase solar production by roughly 33%. This is approximately 2190 kWh per year more than the original. The total amounts to roughly 8935 kWh/yr. of electrical energy and has the potential to offset the average Ontario home electricity consumer by 97%. Moreover, if a homeowner reduces their own consumption, this could create a net zero electrical scenarios as well as a surplus of electricity, in which any homeowner would be happy to acquire. Figure 40, shows the increase of solar production that the redesigned Model A gains when compared to the original Model A.

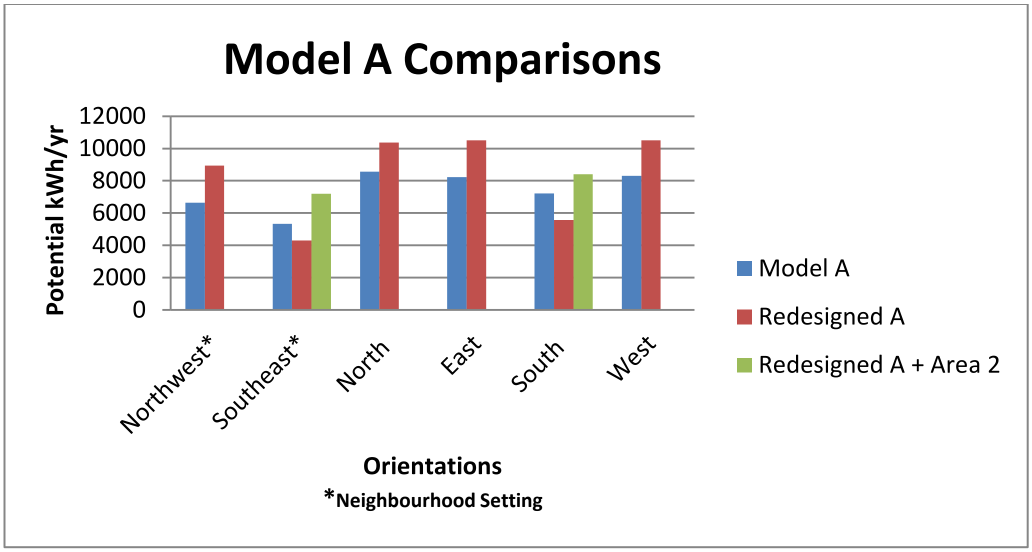



Figure 40: Model A Comparisons

From figure 40 it is evident that an overall increase of solar potential for the redesigned model A is present. An elevated solar production is apparent in all orientations except when facing south and southeast. The reason for this decline in solar production is because the back extension (area 2) does not contain east or west surfaces- only a north surface. Therefore, the east and west surfaces were not included in either orientation case. However, considering the slope is very subtle (4˚) the surface still receives a substantial amount of solar irradiation and when included into accumulation count, the solar potential increases nearly 34 percent when the front of the house is facing southeast and 16 percent south facing (represented by green bar). These surfaces can generate 2892kWh and 2838 kWh annually even when they have a north orientation. However, one drawback with a low-sloped roof is snow coverage, which may decrease the overall solar production if snow cannot be removed during the winter months. Further research and analysis on the amount of lost solar production due to snow coverage is needed to properly investigate this particular case.

The front portion (area 3) of the roof was redesigned for more continuity so that an increasing amount of panels could be installed, while avoiding unnecessary shadowing. However, through simulation, this change to the roof surfaces did very little to increase solar production. In fact, when simulated in a neighbourhood setting with the front of the house facing northwest, solar production decreased by 44.5 kWh/year. This, however, is not substantial on an annual base, which suggests that designers/architects should focus their efforts on area of the roofs that can be modified more appropriately to increase solar production in a more substantial way.

Nonetheless, these simulations illustrate that there is great potential in gable roof design as long as a substantial surface is not affected by dormers or other unnecessary lines allowing panels to have continues array. Of course, south, east and west orientations need to be available. Moreover, these simulations have suggested that even a subtle incline to the roof's surface area of 4˚ can generate substantial solar production in all orientations.

## 16.4 Model B

Model B's roof is mainly hip design, except for a small portion of the front extension. The original roof design has two distinct areas and is outlined in Blue and Red, see figure 41. These two areas are separate and therefore roof continuity and uninterrupted surface areas are lost. The redesigned roof on the other hand, connects these two areas creating 39.6m2 continues surface area with uninterrupted roof lines, see figure 42, (yellow outline and marked C). When compared to the surface areas identified in figure 41, (yellow hash and marked as A and B) with the redesigned surface of area (yellow outline marked as C in figure 42, the redesigned surface area increased nearly 19 percent.

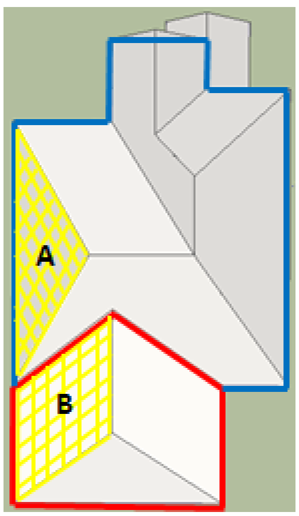



Figure 41: Original Model B

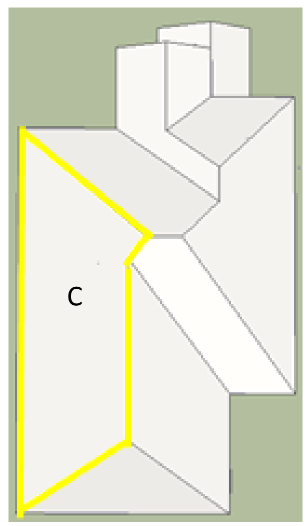



Figure 42: Redesigned Model B

When the two models are orientated northwest as seen in Figures, 41 and 42 the overall solar irradiation increase of the redesigned model is clearly illustrated with a colour scheme. By comparing and analysing these two models with all the same parameters, one can see that the redesigned roof has more consistent solar exposure. This is due to the larger area on the southwest of the home than that of the original, which ultimately enhances solar harvesting.

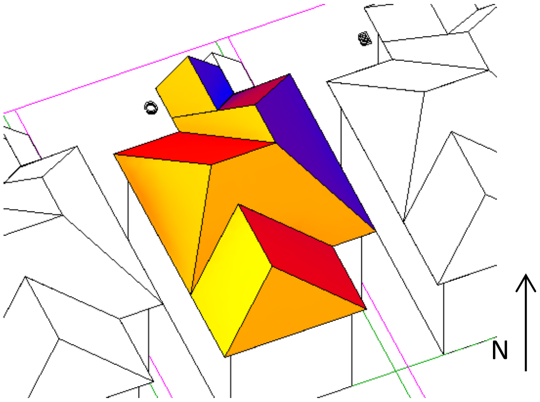



Figure 43: Original Model B colour scheme

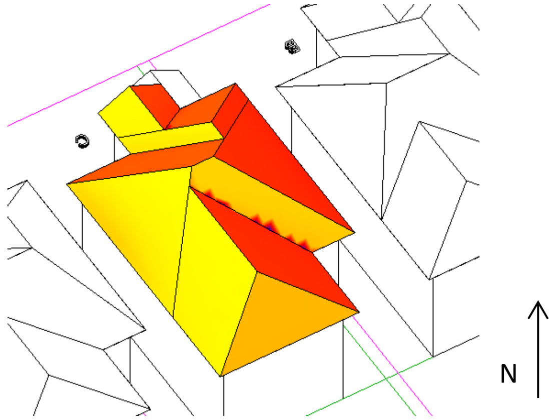



Figure 44: Redesigned Model B colour scheme

The below tables illustrates the comparison of the original two surfaces A and B, seen in figure 41 with redesigned surface C, seen in figure 42. The following simulations were conducted when the houses were facing northwest in a neighbourhood setting with the same boundary conditions, see figures 43 and 44.

Table 10: Comparison between surface C of Redesigned and surface A and B of Original Model B

| | Orientation of surface | Pitches° | Areas per surfaces | SI (kWh/m$^2$) Average | Total SI kWh/yr | Panel Efficacy % | Solar kWh/yr/ produced | Area of PV coverage % | Total Solar Potential kWh/yr |
|---|---|---|---|---|---|---|---|---|---|
| Original | Southwest - (A) | 25.45 | 14.4 | 925 | 13875 | 15% | 2081 | 53% | 1105 |
| | Southwest -(B) | 45 | 17.8 | 865 | 15360 | 15% | 2304 | 67% | 1545 |
| Total | | | 32.2 | | 29235 | | | | 2650 |
| | | | | | | | | | |
| Re-designed | Southwest (C) | 28.6 | 39.6 | 915 | 36135 | 15% | 5423 | 86% | 4665 |

The above table shows that surface C on the redesigned model B, has a 76 percent better solar production than both A and B combined. Surface C has the ability to install 16 PV panels, 1m x 2m in dimension, while surface A and B together can only install 9 of the PV solar panels, see figure 45 and 46. An increase surface area (32.2m2 to 39.6m2) and an increase of solar irradiation (29,236 kWh/yr. to 36,136 kWh/yr.) can be seen on the redesigned model B.

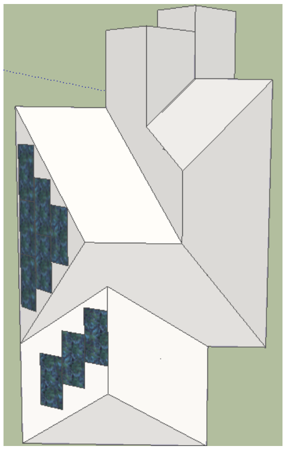


Figure 45: Original Model B, Solar panel application

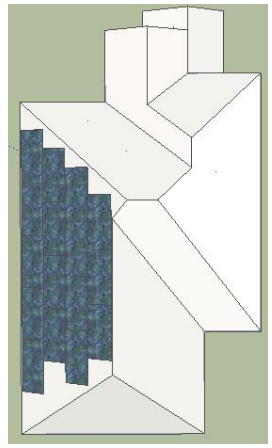


Figure 46: Redesigned Model B, Solar panel application

It is important to note that the slope of the roof's surface can have a substantial impact on the amount of solar irradiation on its surface. For example, 'A' has a slope of 25.45 ˚ while B has a slope of 45 ˚. 'A' surface receives roughly 5.5 percent more solar irradiation on average than that of B surface area. There are a number of negative aspects that accompany a steep slope on a roof. Firstly, the surface does not receive as much solar irradiation than a lesser sloped roof, as determined from above. Secondly, in order to create a steep roof surface, the height of the roof or attic space would have to, on average, be higher. For example, the 45˚ slopes that are present on the original B model have a rise of 2.9m and a run of 2.9m which suggests that the attic space is 2.9m or 9.5 feet tall. Considering that the majority of floors heights in a typical home are 8'. A 9.5' high ceiling space seems unnecessarily high for an unused truss bearing space. Of course this is assuming truss roof systems are in place and no cathedral ceilings are present. Moreover, with higher roof peaks shadowing may become an issue for neighbouring homes, this issue will be analysed and discussed further the research. With higher peaks more timber is involved which in turn means more cost are incurred. Finally, steeper slopes are more dangerous to work on, and are mainly built for pure aesthetic purposes. A taller roof makes the house look larger. This conclusion may be perspective based, but an example of this can be seen in figure 47.

Figure 47: Examples of High peaked roofs

Conversely, tall roof peaks can increase the surface area of the roof as well as steep sloped roofs can shed snow more effectively than less sloped roof, which may increase solar production in the winter months. However, these questions need more research to make any definitive conclusions.

### *16.4.1 Total Model B roof comparison*

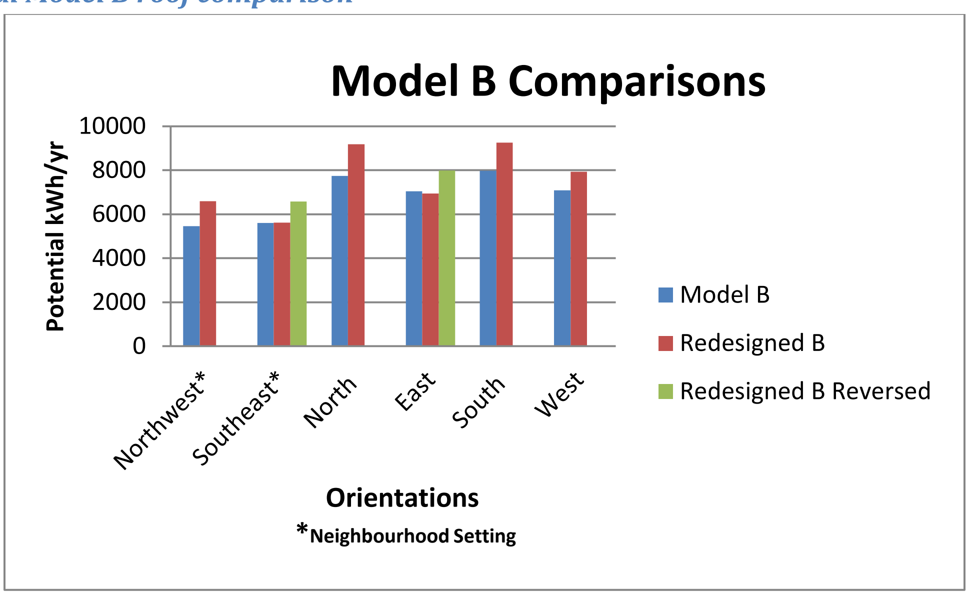



Figure 48: Model B roof comparisons

By observing the above graph and analysing the two simulations that reflect the neighbourhood setting, one can see that the when model B is orientated towards the northwest an increase of over 21 percent more electrical production can be generated in the redesigned (6590 kWh/yr.) over the original model B (5460 kWh/yr.), when PV panels are installed on the southeast and southwest roof surface areas. However, if the front of the house is orientated southeast the solar production remains relatively equal, this is because the large roof surface C that was created in the redesigned model is now facing northwest and therefore is not accounted for. However, by mirroring the house so that the large roofs surface (area C) is now facing southwest, see figure 49 solar production can be increased by 17.5 percent, from 5600 kWh/yr. to 6580 kWh/yr. These numbers suggest that if a typical household in Ontario decease electricity consumption to that of a household France of 6343 kWh annually, potentially a net zero electricity target could be achieved.

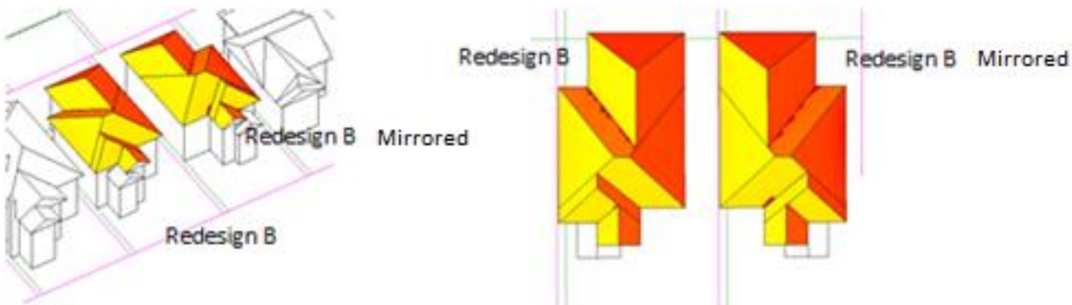



Figure 49: Comparison of mirrored redesigned model B

The concept of having a model that can be mirrored upon construction could have huge advantages when creating a solar ready home in a neighbourhood production development. This can provide the developer/builder with the same floor plans and same model, all the while having the ability to utilize the best roof surface area depending on the location and the orientation of the lot. These changes should be minimal in costs and design perimeters, while keeping with the original aesthetic appeal for the builder, the consumer and the neighbourhood. A cost comparison of material of truss system for the original and redesigned model roofs was provided by Rona Inc. Both roof model drawings and dimensions were given and the quote from their truss vendor was essentially the exact same price; $6,740 this of course does not include labour or roofing materials, such as shingles and plywood, nonetheless the redesigned B model roof truss system is in par with original B model. All models given from the developer for 10.2m lot sizes had the ability to do simple modification to the roof surface areas to enhance solar production with minimal cost to roof designs. Architects and developers need to consider these modifications at the design stages, which will enable a home to be more solar conducive and provide a homeowner with the best available roof surface areas to become solar active.

## 16.5 Neighbouring Homes Effect Solar Potential

21st century neighbourhoods are creating bigger homes on smaller lots. When it comes to solar harvesting these neighbouring home may affect the adjacent homes solar production. A series of simulations where conducted to illustrate the shadowing affect that different neighbouring homes may have on the potential solar irradiation of the model in study. The shadow simulations where conducted with models A, B and C. Figures 50, 51, and 52 shows the original models of A, B and C during the shortest and long days of the year, the emphasis however is one model B

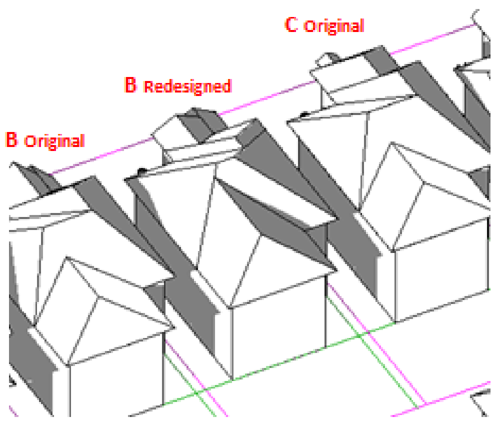



Figure 50: December 21st 12:00pm

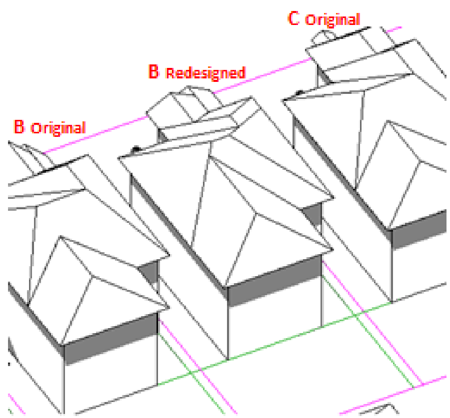



Figure 51: June 21st 12:00pm

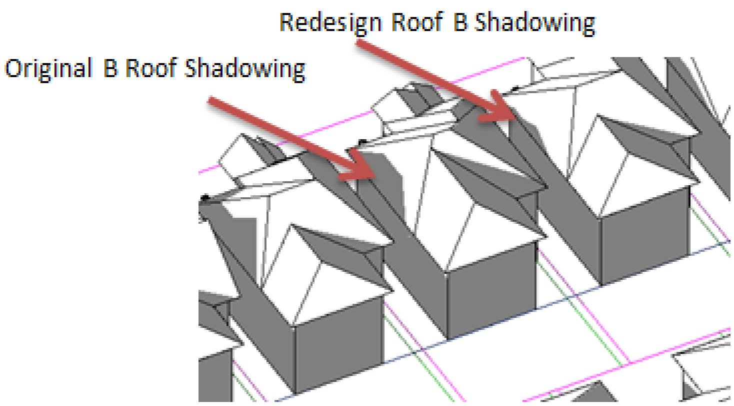



Figure 52: Comparing shadows of Original and Redesigned Model B at 2:00pm December 21st

One can see the shadow casting from original roof design onto the adjacent roof is much larger than the redesigned B roofs shadowing on to the other adjacent roof. It becomes more pronounced as the sun approaches later afternoon hours, as seen in figure 52. The Original roof is 2.9m high at its peak while the redesigned roof is 2.5m. This is not a large difference in height but would contribute roughly a

1% increase in solar irradiation and solar electrical production for the neighbouring homes on the shortest days of the year. If the redesigned roof was even shorter than what it is currently, it will only contribute further to the solar irradiation. Of course, once this occurs the roof surface area will decrease as well, resulting in a decline in the number of panels. This 1% may not seem like a whole lot, but in combination with the 10 homes that are on the same street facing the same direction, the total solar production would be far more distributed if a co-operative approach for solar generations was taken.

Once a gable roof is introduced into the neighbouring home equation the shadowing and solar irradiation becomes significantly reduced on the house of study. The below figures 53 and 54 show the shadowing that is created by the neighbouring gable roof as well as the colour scheme that illustrates the decrease in solar irradiation that hits the roof surface.

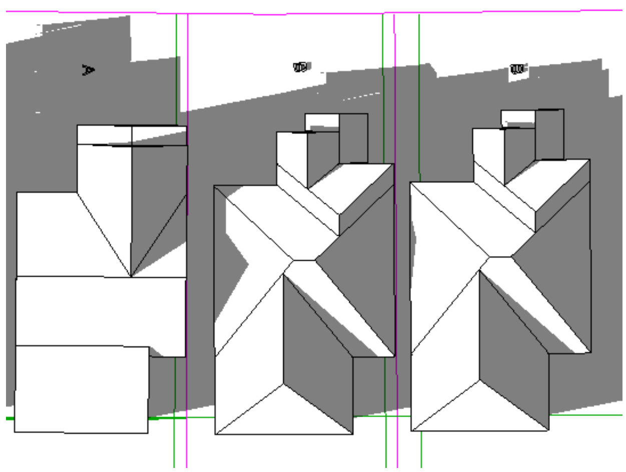


Figure 53: Shadowing of neighbouring gables at 2:00pm December 21st

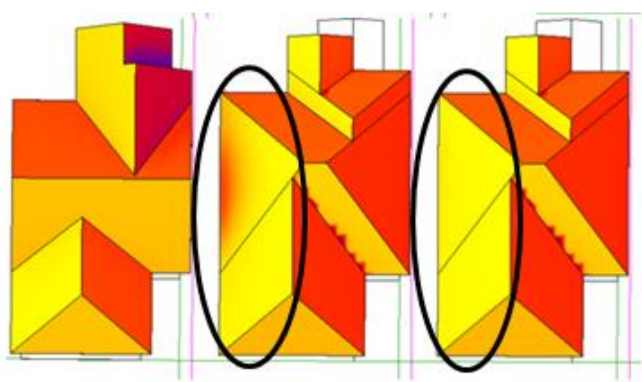


Figure 54: Circles indicating neighbouring shadow effect

These simulations illustrate that a neighbouring gable roof design on the southwest side of a house that is orientated northwest, can have a significant reduction in solar electrical potential and solar irradiation for the neighbouring house. By focusing on the surface area being affected; see area circled in figure 54 it is clear that the roof surface area, neighbouring the gables sees on average less solar irradiation then that with a neighbouring hip roof.  By comparing the average solar irradiation that the two surfaces receive, defined in the circle area, there is a reduction of 8% in solar irradiation and in solar electrical potential. This is equivalent to roughly 2495 kWh/yr. in solar irradiation and 322 kWh/yr. in electrical production and $125 a year.

This suggests that developers need to be aware that even though gable may have huge solar potential when harvesting solar energy, as seen in redesigned model A, gable roof designs need to be placed accordingly in the neighbourhood. This emphasis needs to be recognized so that a gable roof design does not impede on neighbours ability to receive sunlight.

## 17. Model D

Model D is a design that is intended to be built in the 11.6m lot sizes. As previously mentioned, the original design has unique roof lines and peaks as seen in figure 55.

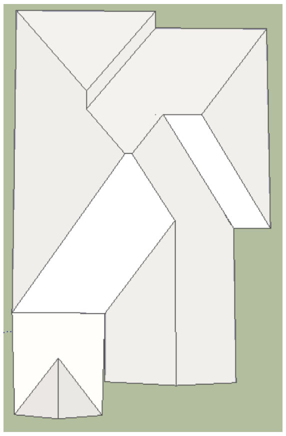


Figure 55: Original D Model

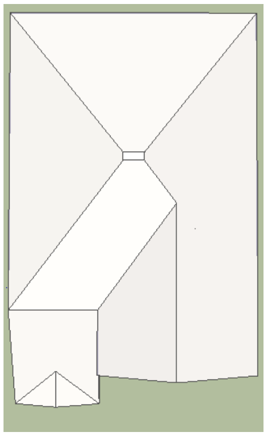


Figure 56: Redesigned D Model

Considering this roof is quite large, the hope of the redesign was to simplify and join the roof surfaces to create a continuous surface on all orientations of the roof, see figure, 56. These modifications allow for large surface areas of the roof to be created, making for a large continues array of solar panels, while keeping the same footprint of the house. However, these changes could affect the aesthetic and overall look of the home, because to connect the roof line properly the eves of the home needed to be in enlarged as seen in figure 58.

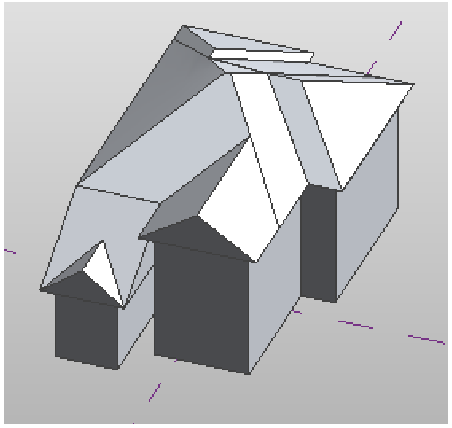


Figure 57: Original Model D

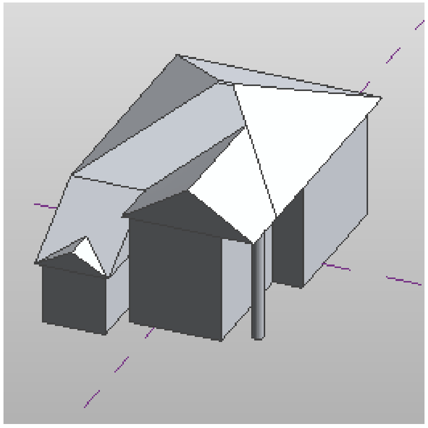


Figure 58: Redesigned Model D

By observing figures 57 and 58, one can see that a column may be needed in order to maintain roof integrity. However, architects considering these concepts at the design stages will further enable new designs and practical modification that can be utilized and delivered to homeowners with effective solar ready availability and huge solar productivity opportunities. As Clesle articulates, "with emphasis on solar consideration in the design process from the beginning, this can only help improve the quality of solar architecture procedure and allow the possibility of new technologies and design innovations to grow" (Clesle, 2010).

### *17.1 Total Model D roof comparison*

By eliminating the roof lines to allow for surfaces areas to become connected, the potential for solar electrical production increases dramatically.

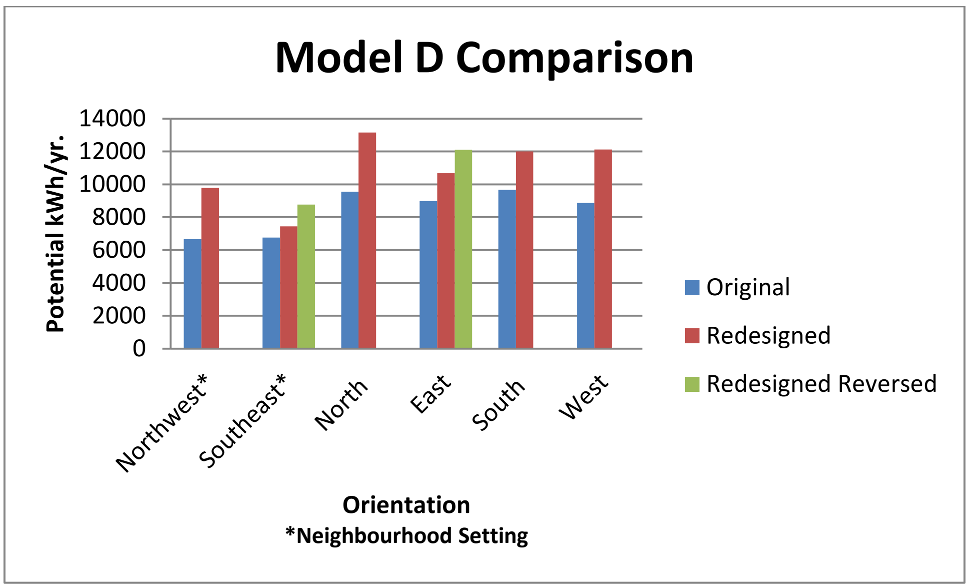



**Figure 59: Model D Comparisons**

Figure 59 show that in all orientations the redesigned model has increased the solar electrical potential by a significant margin.

Table 5 illustrates the increase solar electrical potential that the redesign has over the original when the designs are simulated in a neighbourhood setting and the orientation of the homes is facing northwest. Both the southeast and southwest surface areas are the focus of this table.

Table 11: Comparison of Original and Redesigned Model (Northwest Orientation)

| | Orientation of surface | Pitches° | Areas per surfaces | SI (kWh/m²) Ave | Total SI kWh/yr | Panel Efficacy % | Solar kWh/yr/ produced | Area of PV coverage % | Total Electrical Potential kWh/yr |
|---|---|---|---|---|---|---|---|---|---|
| Original | Southeast | 25.4 | 23.9 | 891 | 21295 | 15% | 3194 | 59% | 1869 |
| | Southeast | 25.4 | 12.5 | 884 | 11050 | 15% | 1658 | 48% | 796 |
| | Southwest | 32 | 28.9 | 891 | 25750 | 15% | 3862 | 83% | 3206 |
| | Southwest | 32 | 15.2 | 872 | 13254 | 15% | 1988 | 40% | 795 |
| Total | | | 39.3m² | | 71349 | | | | 6665 |
| | | | | | | | | | |
| Re-designed | Southwest | 24.2 | 38 | 888 | 33833 | 15% | 5075 | 73% | 3705 |
| | Southeast | 32.4 | 55 | 878 | 48290 | 15% | 7244 | 8415 | 6085 |
| Total | | | 93m² | | 82123 | | | | 9790 |

The simplification of the redesigned roof has increased the solar irradiation by just over 13 percent, while the solar electrical potential has increased by 32 percent. This significant increase can be attributed to the ability to increase PV panel installation in continues arrays. Figures 60 and 61 shows where the best places panels can be installed if the house's orientation is facing northwest for both the original and redesigned models. The blue square represent the PV panels and their location on the roof southeast and southwest surfaces.

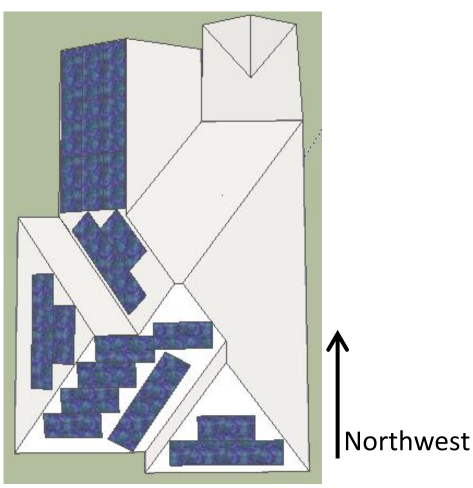



Figure 60: Original model D with solar panels

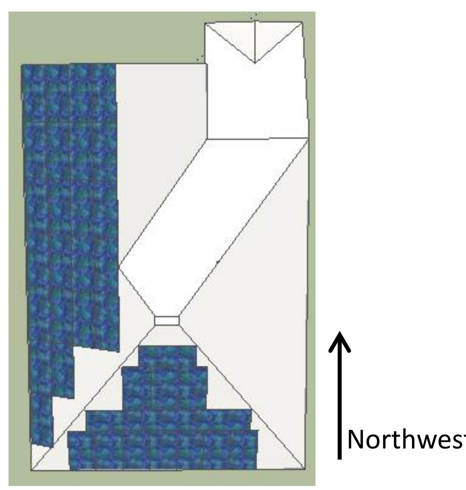



Figure 61: Redesigned model D with solar panels

What is noteworthy however, is the potential amount of solar electricity that the original roof surfaces can generate. This suggests that even without modifying the roof surface for solar consideration at the design stage, there is still a significant amount power that can be generated.

# 18. Collective Solar Potential of a Block of 24 Homes

## 18.1 Original Neighbourhood

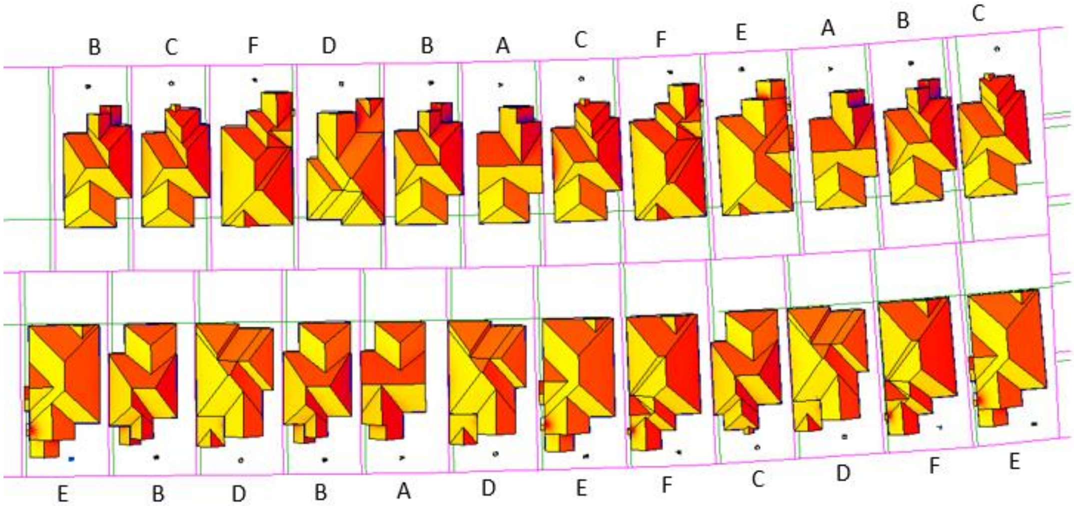



Figure 62: Original neighbourhood layout

Table 12: All six original models simulated in the neighbourhood

| | Model A | Model B | Model C | Model D | Model E | Model F | Total kWh/yr. |
|---|---|---|---|---|---|---|---|
| Northwest | 2 | 3 | 3 | 1 | 1 | 2 | |
| Southeast | 1 | 2 | 1 | 3 | 3 | 2 | |
| Total kWh/yr. Northwest | 13,300 | 16,380 | 16,050 | 6,665 | 8,155 | 14,940 | 75,490 |
| Total kWh/yr. Southeast | 5,340 | 11,240 | 5,350 | 20,280 | 20,190 | 10,890 | 73,290 |
| Total kWh/yr. production block of 24 homes | | | | | 148,780 | | |
| Average Ontario home's electrical consumption 9600 kWh/yr. x 24 homes | | | | | 230,400 | | |
| Percentage of electricity that this block of homes could potentially produce to offset the total electricity consumed by the block | | | | | 65% | | |

The original neighbour could potentially produce 65 percent of the electricity needed if solar panels were installed on the all southwest and southeast surfaces of every home in the block. This based on each home consumes 9500 kWh/yr. Considering there is no solar consideration in the original models, these figures do suggest that solar harvesting potential still has merit with the current roof design.

## 18.2 Redesigned Models

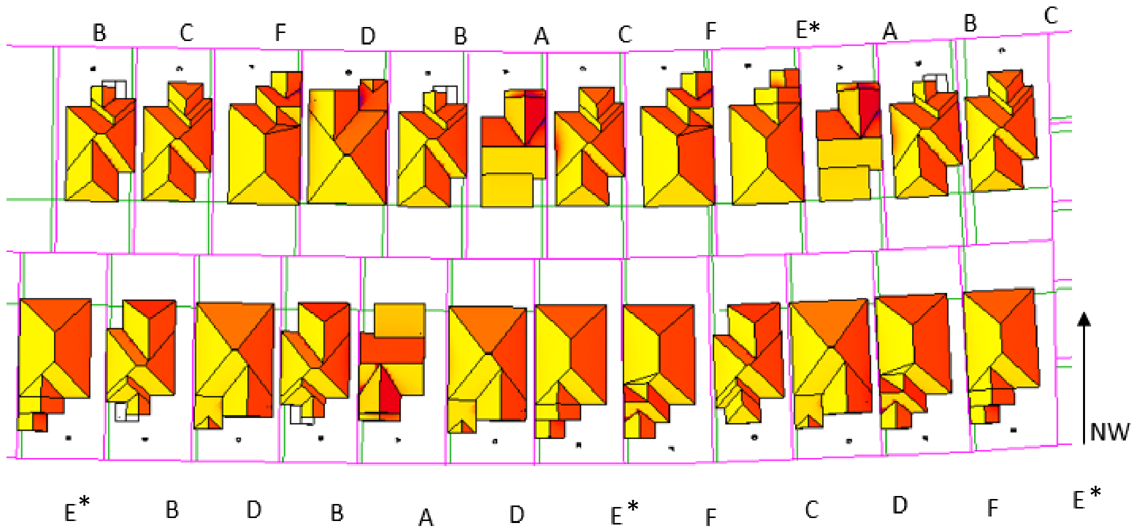



Figure 63: Redesigned neighbourhood layout

* Model E has two redesigned models and are marked as E1 and E2. Model E2 is the one seen in figure 63.

Table 13: All six redesigned models simulated in the neighbourhood

| | Model A | Model B | Model C | Model D | Model E1/E2 | Model F | Total kWh/yr |
|---|---|---|---|---|---|---|---|
| Northwest | 2 | 3 | 3 | 1 | 1 | 2 | |
| Southeast | 1 | 2 | 1 | 3 | 3 | 2 | |
| Total kWh/yr. Northwest | 17,860 | 19,770 | 19,515 | 9,790 | 8,710/8,520 | 16,480 | 92,125/ 91,935 |
| Total kWh/yr. Southeast | 7,200 | 11,240 | 5,140 | 22,350 | 21,420/ 25,215 | 14,950 | 82,300/ 86,095 |
| Total kWh/yr. production block of 24 homes | | | | | 174,425/ 178,030 | | |
| Average Ontario home's electrical consumption 9600 kWh/yr. x 24 homes | | | | | 230,400 | | |
| Percentage of electricity that this block of homes could potentially produce to offset the total electricity consumed by the block | | | | | 76%/77% | | |

## 18.3 Mirrored models to optimized southwest and southeast solar exposure

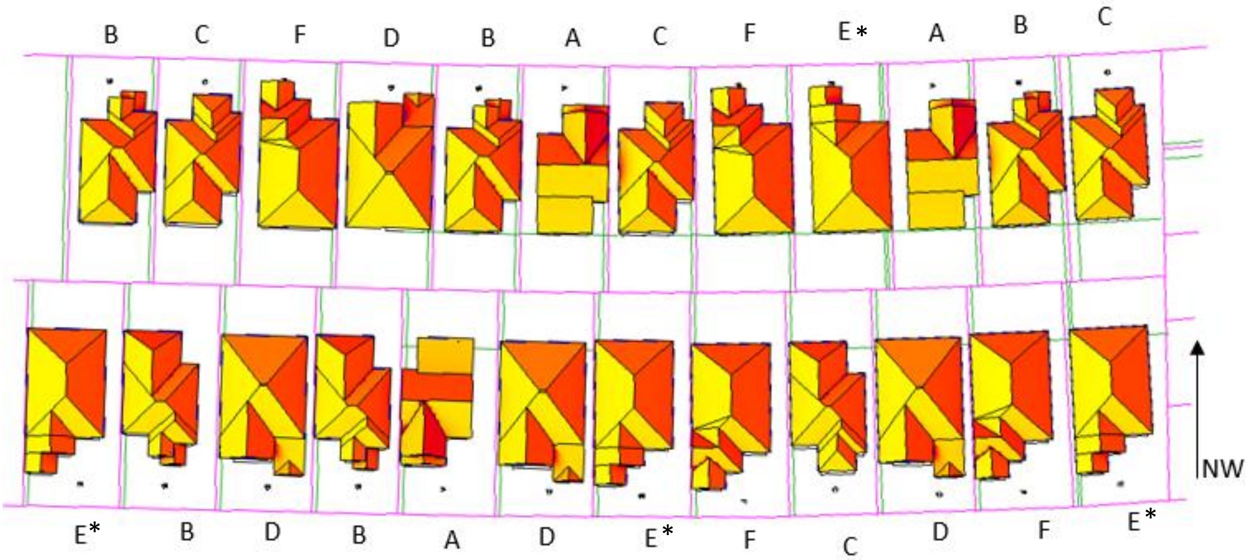



**Figure 64: Mirrored model neighbourhood layout to optimize solar exposure**

* Model E has two redesigned models and are marked as E1 and E2. Model E2 is the one seen in figure 64.

**Table 14: All six redesign models simulated in mirrored the neighbourhood**

| | Model A | Model B | Model C | Model D | Model E1/E2 | Model F | Total kWh/yr |
|---|---|---|---|---|---|---|---|
| Northwest | 2 | 3 | 3 | 1 | 1 | 2 | |
| Southeast | 1 | 2 | 1 | 3 | 3 | 2 | |
| Total kWh/yr. Northwest | 17,860 | 19,770 | 19,500 | 9,790 | 8,710/8,520 | 16,480 | 92,110/ 91,920 |
| Total kWh/yr. Southeast | 7,200 | 13,180 | 6,500 | 26,325 | 24,525/ 28,335 | 14,950 | 92,680/ 96,490 |
| Total kWh/yr. production block of 24 homes | | | | | | | 184,790/ 188,410 |
| Average Ontario home's electrical consumption 9600 kWh/yr. x 24 homes | | | | | | | 230,400 |
| Percentage of electricity that this block of homes could potentially produce to offset the total electricity consumed by the block | | | | | | | 80%/ 82% |

By mirroring the models in the southeast direction, the largest roof surfaces are now southwest facing, instead of northeast facing. By doing this, an overall increase in electrical production was 17% from that of the original neighbourhood. If developers created homes that could be mirrored or mirrored to optimize roof surface when the particular lot is not ideal for the original design, significant increases in solar electrical production could be created. This particular neighbourhood layout could potentially produce 82% of the blocks electricity. Moreover, if these homes decreased their electrical consumption from 9,500 kWh/yr. to 7500 kWh/yr. this block could become net zero at 7,500 kWh/yr. A reduction of this is achievable when looking at the average Australian home which consumes (7,227 kWh/yr.)

## 19. Limitations and Shortcomings

In order for this research to manageable, effective and have validity, boundary conditions were needed and some assumptions needed to be made. This research uses only one developer and one neighbourhood setting to represent a typical contemporary development built in southern Ontario. It should also be noted that not all production builders follow the same building methodology and therefore, this research data may vary between different developers. However, this research can be used as a general indicator of the current trends that production builders use for their home designs and neighbourhood layouts for the southern Ontario landscape. These generalizations would be attributed to: building codes, municipal planning and zoning regulations, Southern Ontario's *Planning Act* and any policies and regulations that accompany that act. The main research and data collection through simulation focuses on photovoltaic electrical production. However, solar irradiation data collected and illustrated can be used to measure solar thermal applications, such as thermal space heating and or domestic hot water. Further research will need to be conducted to see the viability and or energy production of these solar applications.

Other limitations that need to be considered are the number of models being analysed. Six models in total, varying in different designs and sizes were chosen for this research. This number was chosen because it was manageable from both simulation and modelling perspectives, but also because it allowed for a variety of different roof designs to be tested. Moreover, these simulations were all conducted in the same longitude and latitude positioning. However, these results will change in different latitudinal positions. With regards to the research on PV technologies, assumptions had to be made about their efficiency and size. Using 15% efficacy as a benchmark allowed for a conservative solar irradiation data output, which provided a more realistic outcome. Currently panels are becoming more and more efficient and thus, the electrical date collected would increase in output and therefore, reinforce the argument of the paper--that solar ready homes can produce a substantial amount of electrical power. Another factor to consider is that the panel size could change. Since there are smaller sized panels on the market, more could have been installed on the roof surfaces and therefore increase the electrical output of the data.

The use of Vasari as the solar simulation tool, can also been seen as a shortcoming. There are many solar simulating tools available and thus change to the output is inevitable. Vasari was chosen however because it gave the most conservative solar irradiation output, compared to Revit, ECOTECT, Rhino and PVWatts. In short, if the same boundary condition and simulations were conducted with any of programs mentioned, solar irradiation and solar output would increase and further reinforce the argument of the paper.

Further study needs to be conducted on the technical changes and challenges that the current grid network has and how these changes can create an environment where solar ready homes and neighbourhoods become common place. To understand the issues that hinder neighbourhoods and communities becoming energy independent, policy and regulatory research needs need to be analysed.

Seeing that southern Ontario, in particular the golden horseshoe, is experience a large development in urban development, the prospect for Solar Ready Homes (SRH) should be an important attribute to the development of the region. Unfortunately, this concept has been overlooked by many planners and major developers as they have not implemented this concept into urban planning, nor have they considered it in the home design stages. Why is this? Could it be that it is too expensive to change the roof design and installation conduits? Is it too expensive to change the layout of the neighbourhood in order to optimize solar production? Are there aesthetic and municipal deterrents for solar roof design? Is the lack of policy and legislation on the municipal, provincial and federal levels contributing to involuntary action? Is there a demand from the public even with Ontario's Feed in Tariff programs? Is there a lack education? Can the grid handle the influx of more electrical power in a photovoltaic scenario? Is there a control or monopoly for electrical generation and distribution issue? Some of these questions are out of the scope of this paper however; investigating them should shed light on issues that are hindering solar ready home production.

# 20. Conclusion

With an ever growing population and the increase in energy demand, city planners and developers need to design communities that are sustainable and resilient to meet the challenges of the 21$^{st}$ Century. To power these urban centres, new sources and approaches need to be considered in order to obtain the energy needed, all the while reducing our GHGs emissions. The sun is the ultimate power plant in our Solar System and sustains all life on Earth with huge amounts of energy. The sun provides an endless supply of clean renewable energy, an energy that is tangible, quantifiable, usable and free of charge. Energy subsidies need to be reallocated to renewables so that the true cost of fossil fuel extraction and consumption can be realized. As the natural reserves continue to be depleted, a new concept for solar energy 'reserves' should be on the forefront of all new developments.

Having solar consideration at the design phase of urban development can only improve the quality of solar architecture, creating an infrastructure that is progressive and helps avoid unwanted inefficacies that are trapped in the housing stock for generations. Solar ready homes create a positive approach to community resilience and sustainability. It allows for new technologies and the possibility of design innovations to grow. There are still challenges ahead for solar ready components to be common place in new homes. Some of these challenges and push backs are from the building industry themselves, others are technical, such as grid connectivity or upfront cost of the systems themselves. Policy and regulations can impede progress, particularly with the building codes, however Ontario has taken progressive approaches to dealing with policy and regulatory inefficiencies. These challenges albeit present are relevant; they are issues that should be overcome. Building solar ready provides the opportunity to utilize solar technology in the future when the homeowner feels the time is right. As the need for society to move towards a sustainable future, our building resiliency infrastructure should be an intricate part of the overall design of development and communities. The hope is that the information produced through this research will enable production builders to begin the implementation of solar energy at the initial design phase without having to make drastic changes to their housing designs or site plans and ultimately keeping costs to a minimum.

The overall objective of this research is to quantify the potential solar energy generated from roofs in a typical contemporary housing development built in southern Ontario. The starting point was to determine how much solar electrical potential there is with no solar consideration at the design phase. The base cases, established like this showed that the original roof models electrical production ranged as low as 5,300 kWh/yr. in model C, to as high as 11,900 kWh/yr. in model E.

With simple roof modifications solar electrical output increases substantially. For example, when model A, B and D were modeled in a neighbourhood setting and facing northwest an increase of 33%, 21% and 47% were seen respectively. These changes were simple with no changes to the homes' floor plan. In all six models, the simplified modifications to the roof increased solar electrical output. The only case in which the output actually decreased was with the redesigned Model B and C. These slight decreases in electrical production in both B and C redesign model when facing east, can be attributed to the fact the back surface has become slightly smaller creating the inability to install as many panels as the original. Furthermore, due to the layout, the largest roof surface area is facing north when the front of the house is facing east. This creates a scenario where the largest roof surface is affectively useless because of the lack of solar irradiation it would receive when north facing. For this reason, having the ability to have a mirrored roof layout provides the opportunity to have the largest roof surface facing south or in another optimized orientation. When layout was mirrored, the solar production increased up to 12% and 18% for model B and 12% and 21% respectively for model C. This proves that the simple modifications to the roof typography can increase solar production substantially without having to change street or lot orientation. A positive outcome for production builder who's large neighbourhood layout are tough to change.

Finally, it was investigated how such modification will affect the electricity production on the scale of neighbourhood. Twenty four homes were chosen to represents a typical block in a contemporary neighbourhood. Three scenarios were conducted: first analysis looked at the original models in the block, in which the data suggests that 65% of all electricity needs for the 24 home block could be achieved by solar production. The second analysis placed the redesigned models in the same lots as the original, in which a 12% increase compared to the first analysis could be seen and suggests that 77% of the electricity could be generated for this block.  Finally, by optimizing the roof surface by mirroring the models where obvious solar gains could be seen, a further 5% in electrical solar harvesting could be achieved, generating approximately 82% of the total blocks electrical consumption.

Southern Ontario has the potential to use solar energy to further our drive for sustainability. There are the political incentives, industry innovation and the know how to fully take advantage and harness the sun's energy.  However, the ability to access this solar energy affectively is still difficult from homeowners' perspective. Solar retrofitting is not cost effective nor do all homeowners have a south facing roof surface for installation.  Solar ready on the other hand provides homeowners with the tools to generate their own power on site, without optimized solar orientation. This help to decentralize the grid network and democratize energy distribution, create resiliency and energy security, all the while reducing GHGs emissions.

# Appendix A

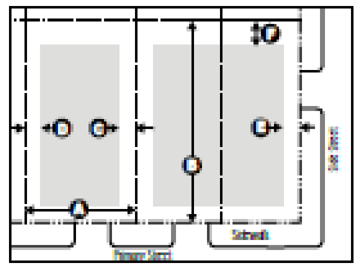


## General Urban Zone

### 7.6 General Urban (GU) Zone Regulations

### 7.6.1 Uses Permitted

See Section 6.



*The grey represents potential building area. The internal dashed line represents the maximum yard.*

**7.6.2 Building Types Permitted and Related Standard**

| Building Type | Minimum Lot Frontage (A) | Minimum Lot Depth (B) | Minimum Interior Side Yard Setback One Side (C) | Min. Interior Side Yard Setback Opposite Side (D) | Minimum Flankage Setback (E) | Minimum Rear Yard Setback (F) |
|---|---|---|---|---|---|---|
| A *single detached dwelling street* access attached *private garage* | 8.5 m | 22 m | 1.2 m | 0.6 m | 2 m | 7 m[1] |
| A *single detached dwelling street* access detached *private garage or parking pad* | 8.5 m | 22 m | 3 m | 0.6 m | 2 m | 7 m[1] |
| A *single detached dwelling* attached rear *private garage* accessed from the front or side | 9 m | 26 m | 3 m | 0.6 m | 2 m | 0.3 m |
| A *single-detached dwelling* with *lane access* | 8 m | 17 m | 1.2 m | 0.6 m | 2 m | 0.75 m |

# Appendix B

**FIT/microFIT PRICE SCHEDULE**
**(Effective September 30, 2014 for FIT and January 1, 2015 for microFIT)**

| Renewable Fuel | Project Size Tranche* | Price (¢/kWh) | Escalation Percentage** |
|---|---|---|---|
| Solar (PV) (Rooftop) | ≤ 10 kW | 38.4 | 0% |
| | > 10 kW ≤ 100 kW | 34.3 | 0% |
| | > 100 kW ≤ 500 kW | 31.6 | 0% |
| Solar (PV) (Non-Rooftop) | ≤ 10 kW | 28.9 | 0% |
| | > 10 kW ≤ 500 kW | 27.5 | 0% |
| On-Shore Wind | ≤ 500 kW | 12.8 | 20% |
| Waterpower | ≤ 500 kW | 24.6 | 20% |
| Renewable Biomass | ≤ 500 kW | 17.5 | 50% |
| On-Farm Biogas | ≤ 100 kW | 26.3 | 50% |
| | > 100 kW ≤ 250 kW | 20.4 | 50% |
| Biogas | ≤ 500 kW | 16.8 | 50% |
| Landfill Gas | ≤ 500 kW | 17.1 | 50% |

* The FIT Program is available to Projects generally ≤ 500 kW.

**Escalation Percentage based on the Consumer Price Index will be applied to eligible Renewable Fuels as calculated in the FIT Contract. The Base Date is January 1 of the year in which the Project achieves Commercial Operation, unless the Project achieves Commercial Operation in October, November, or December, in which case the Base Date is January 1 of the following year.

**FIT PRICE ADDERS**

| | Aboriginal Participation Project | | Community Participation Project | | Municipal or Public Sector Entity Participation Project | |
|---|---|---|---|---|---|---|
| Participation Level (Equity) | > 50% | ≥ 15% ≤ 50% | > 50% | ≥ 15% ≤ 50% | > 50% | ≥ 15% ≤ 50% |
| Price Adder (¢/kWh) | 1.5 | 0.75 | 1.0 | 0.5 | 1.0 | 0.5 |

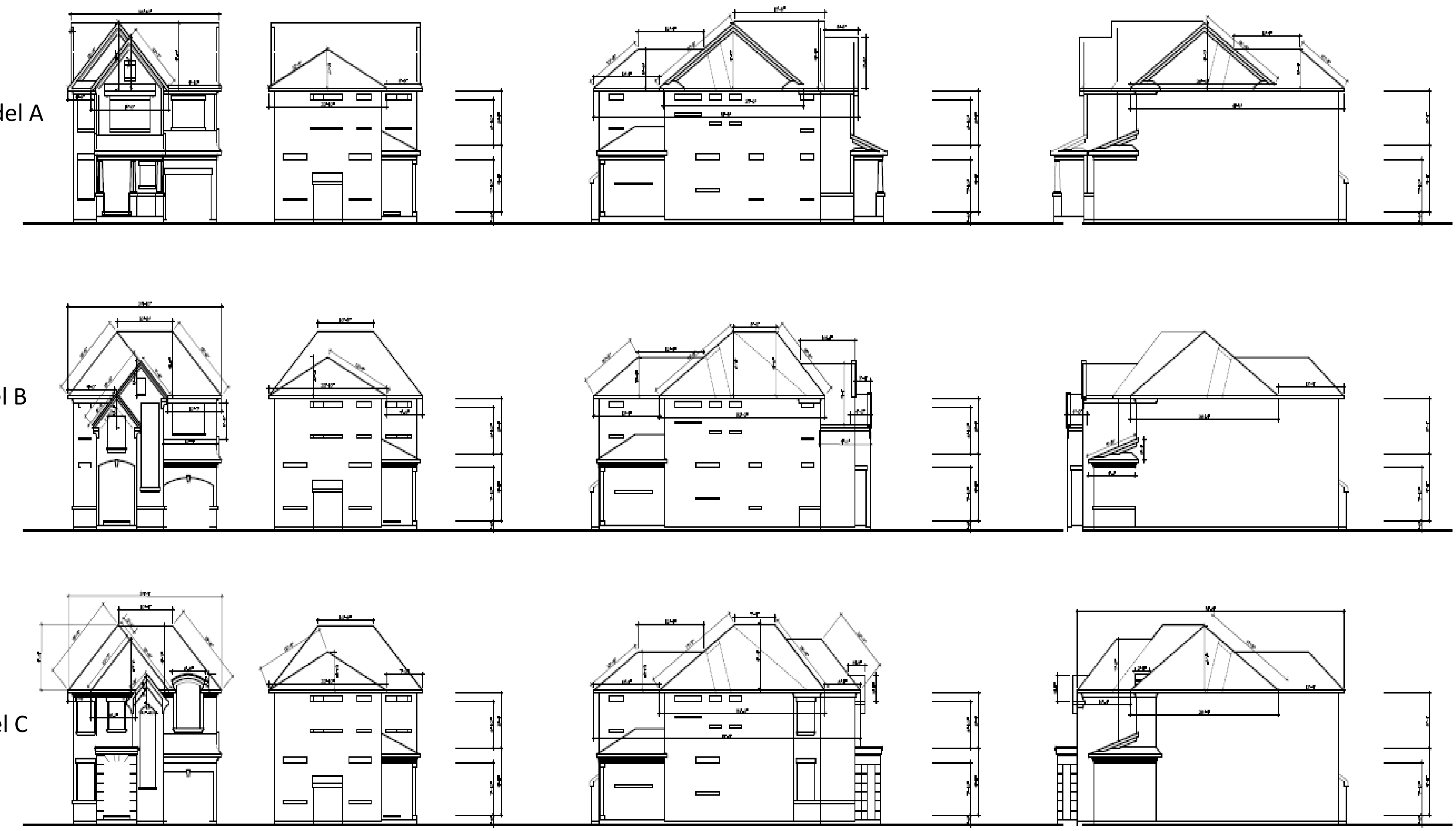
Note: The above table applies to all FIT Project sizes and all Renewable Fuels except Solar (PV) (Rooftop).

# Appendix C.1

Model A

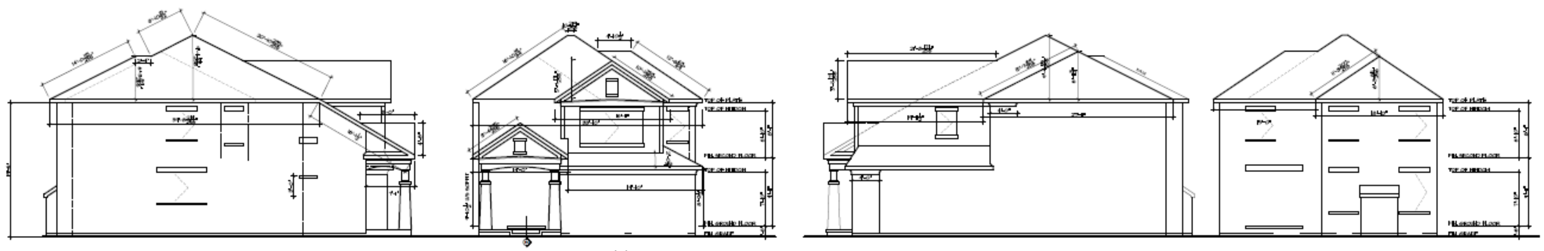
Model B

Model C



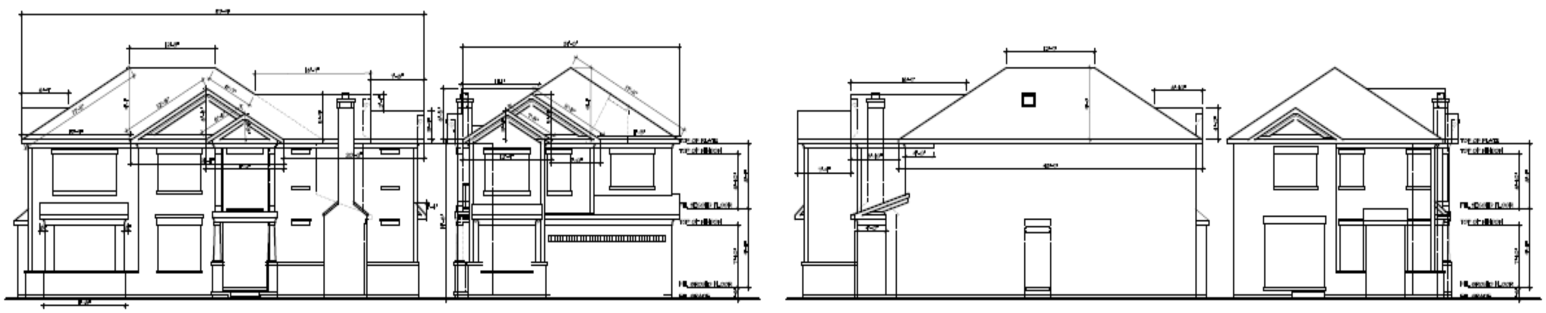
# Appendix C.2

Model D



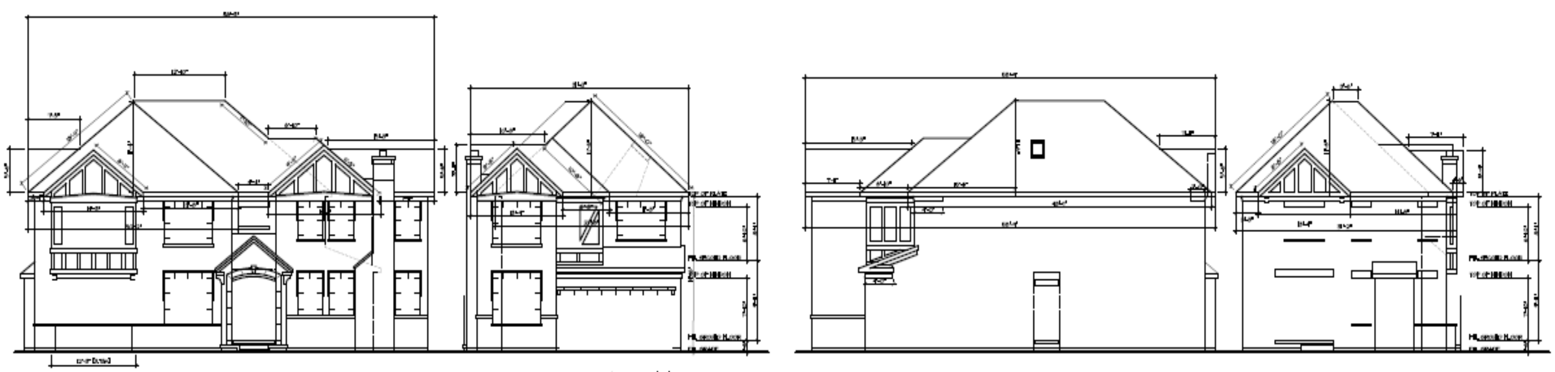
LEFT SIDE ELEVATION 'B'    FRONT ELEVATION 'B' CRAFTSMAN    RIGHT SIDE ELEVATION 'B'    REAR ELEVATION 'B'

Model E



FLANKAGE ELEVATION 'B' CRAFTSMAN    FRONT ELEVATION 'B' CRAFTSMAN    RIGHT SIDE ELEVATION 'B' CRAFTSMAN    REAR ELEVATION 'B' CRAFTSMAN

Model F



FLANKAGE ELEVATION 'C' TUDOR    FRONT ELEVATION 'C' TUDOR    RIGHT SIDE ELEVATION 'C' TUDOR    REAR ELEVATION 'C' TUDOR

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