An Illustrated Guide to

COMMUNITY ENERGY

Exploring the sustainable energy potential of your neighbourhood

www.guidetocommunityenergy.com

FINAL VERSION | May 2013

Reference:
Barron, S, TR Tooke, S Cote, SRJ Sheppard, R Kellett, K Zhang, L Holy, M Sherriff, M vanderLaan (2013). An Illustrated Guide to Community Energy. The Collaborative for Advanced Landscape Planning (CALP).

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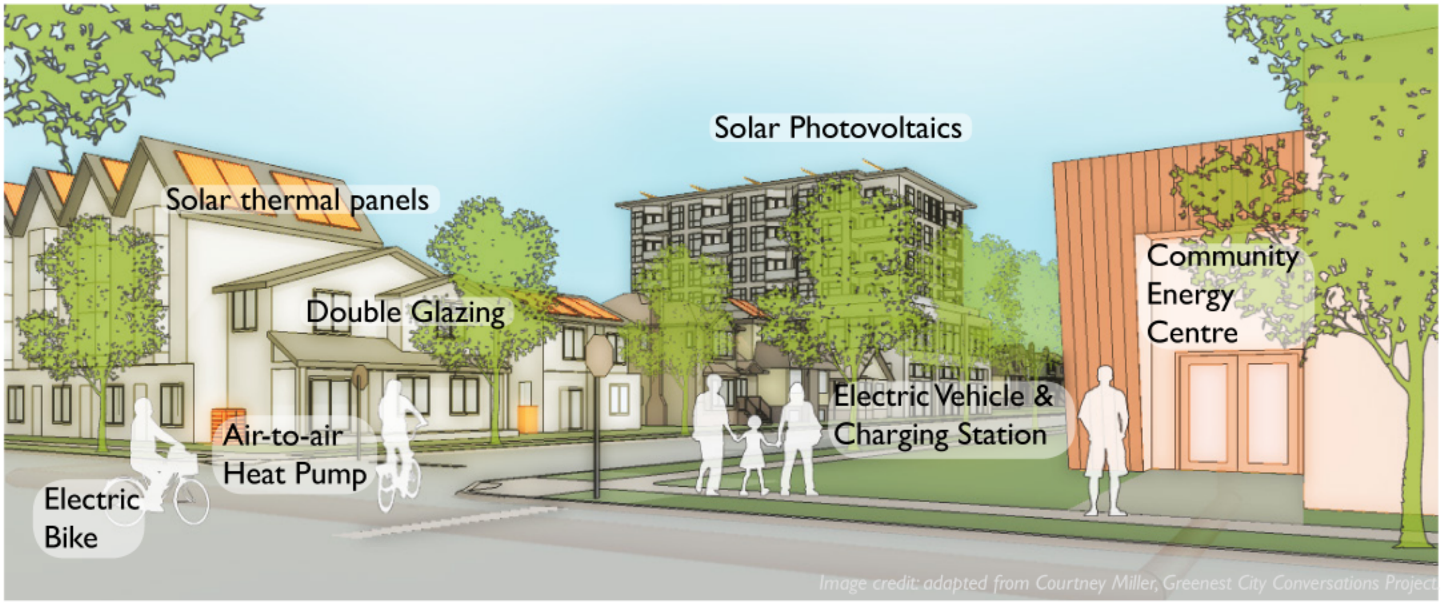
GEOIDE

With additional support from: Richmond; City of Surrey the future lives here.

An Illustrated Guide to Community Energy

With clear and compelling visuals of Metro Vancouver case studies, and new information on regional and local energy resources, this Guide aims to inform citizens about unfamiliar energy options, and stimulate discussion about the energy choices that each community will face.



Orange elements in the image above generate energy to heat and power the community. A community energy centre (at the right) is powered by a renewable energy source.

Imagine a neighbourhood where our homes generate energy and excess energy is shared with the community or is sold to the grid as a source of revenue.

What if Metro Vancouver used sustainable regional renewable energy resources instead of fossil fuels that contribute to global warming?

Imagine neighbours working together to share skills, improve energy efficiency, & reduce energy costs through neighbourhood retrofits.

This guide shows how local involvement in community energy systems can promote more sustainable and secure energy futures, while reducing carbon emissions that contribute to global warming. The guide explains the idea of community energy, which is becoming an important topic for every municipality in British Columbia. Change is coming to neighbourhoods as municipalities try to reduce community-wide carbon footprints and manage rising energy prices, while maintaining their citizens' quality of life.

1.0 Why Do We Need an Illustrated Guide?

1. So citizens can develop more informed opinions on possible energy transformations in our neighbourhoods.
2. For practitioners and community groups to use in their public engagement activities.

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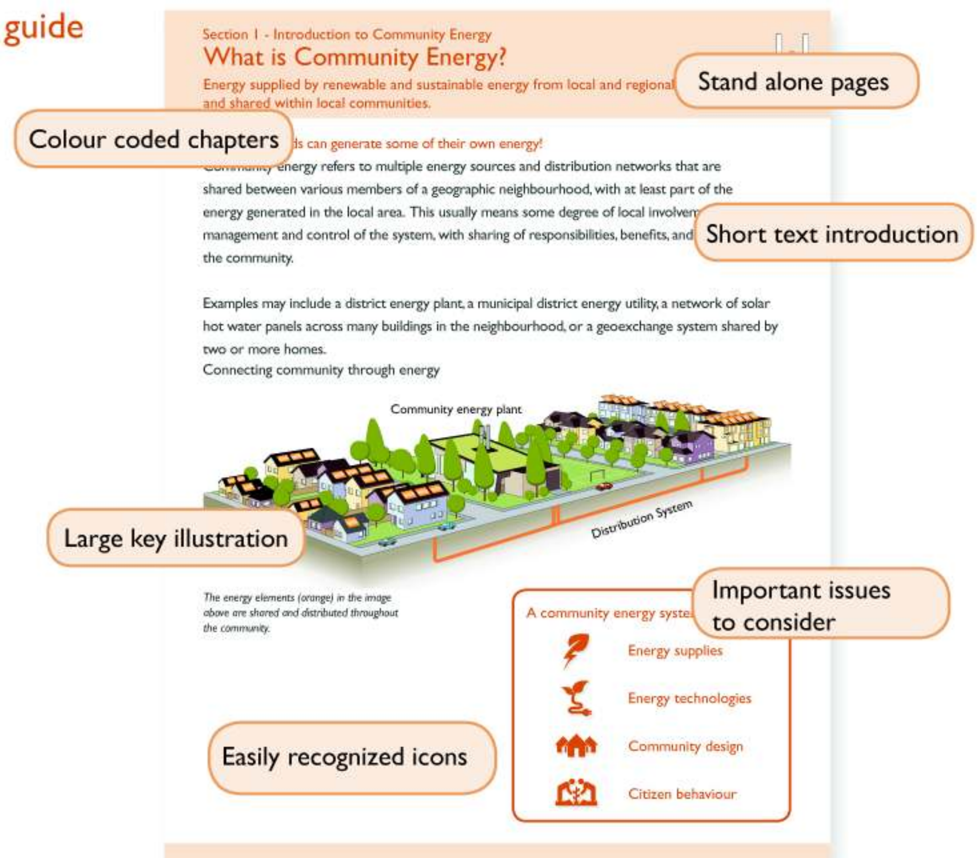
How to use this guide



What is Community Energy?

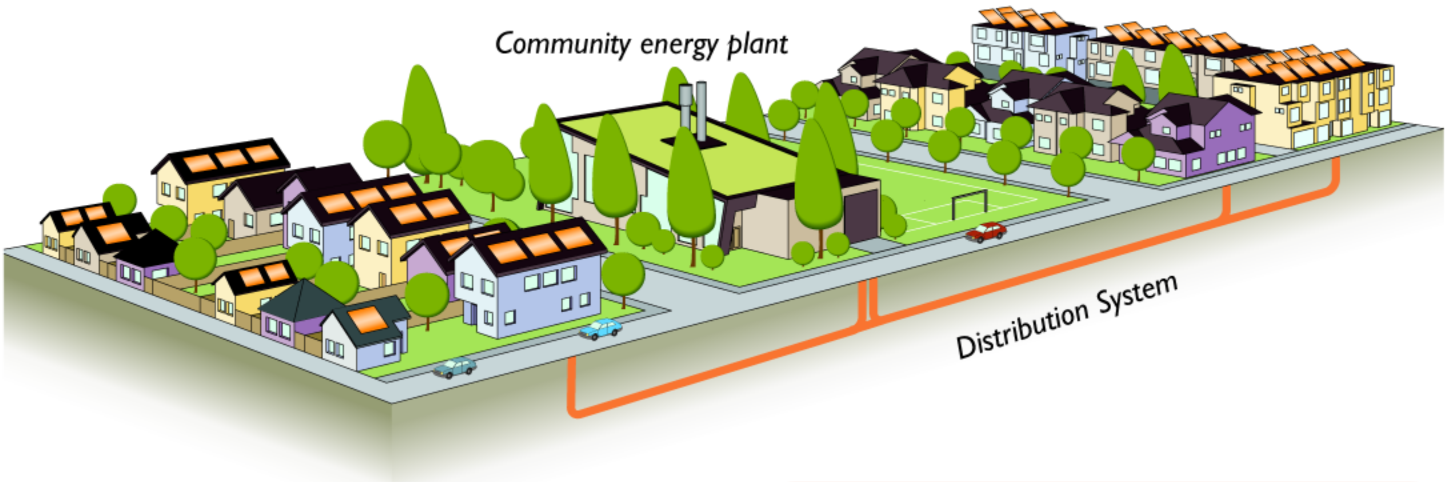
Energy supplied by renewable and sustainable energy from local and regional sources and shared within local communities.

Neighbourhoods can generate energy.

Community energy refers to multiple energy sources and distribution networks that are shared between various members of a geographic neighbourhood, with at least part of the energy generated in the local area. This usually means some degree of local involvement in the management and control of the system, with sharing of responsibilities, benefits, and impacts among the community.

Examples may include:

- a district energy plant run by a local utility, municipality or citizen co-operative
- a network of solar hot water panels installed on many buildings in the neighbourhood
- a geoexchange system shared by a few homes



The energy elements (orange) in the image above are shared and distributed throughout the community..

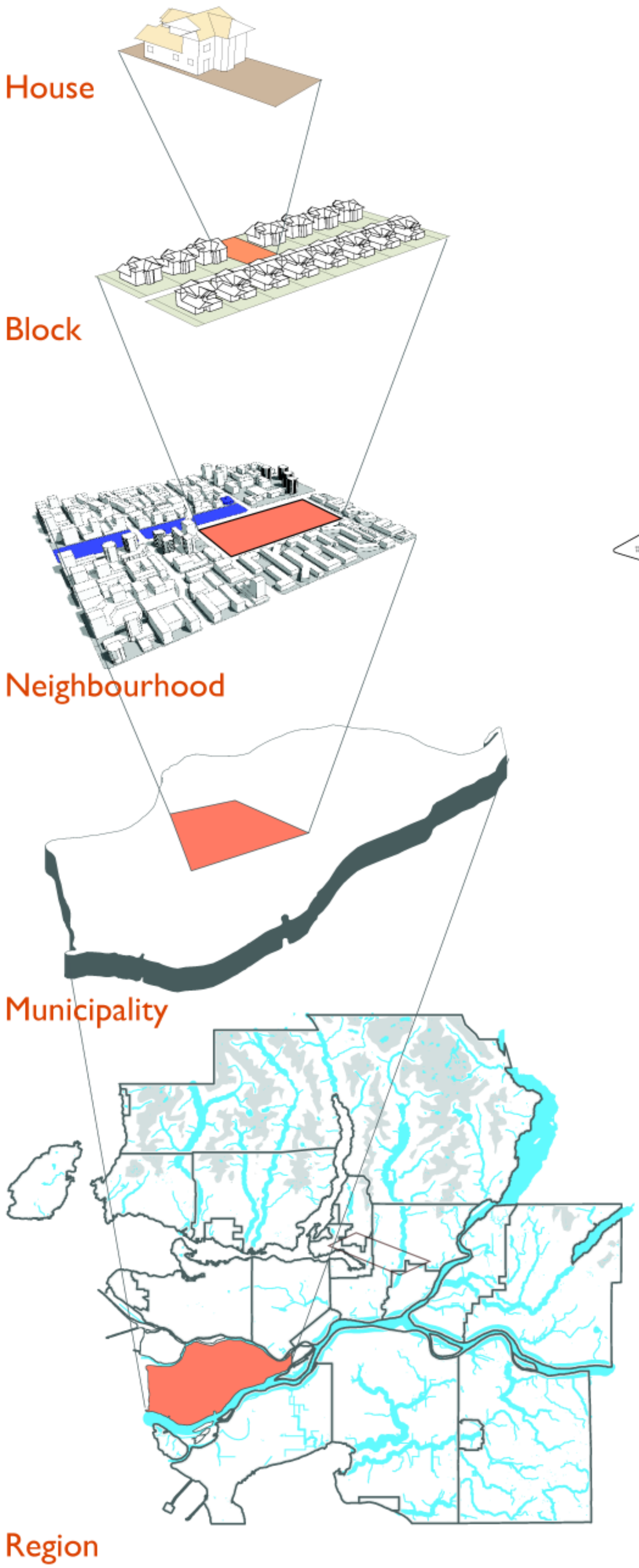
Transportation uses a significant amount of energy, and contributes over half of our regional greenhouse gas emissions. Transportation is not the focus of this guide, but should be integrated into community energy planning and engagement.

A Community Energy System Includes:

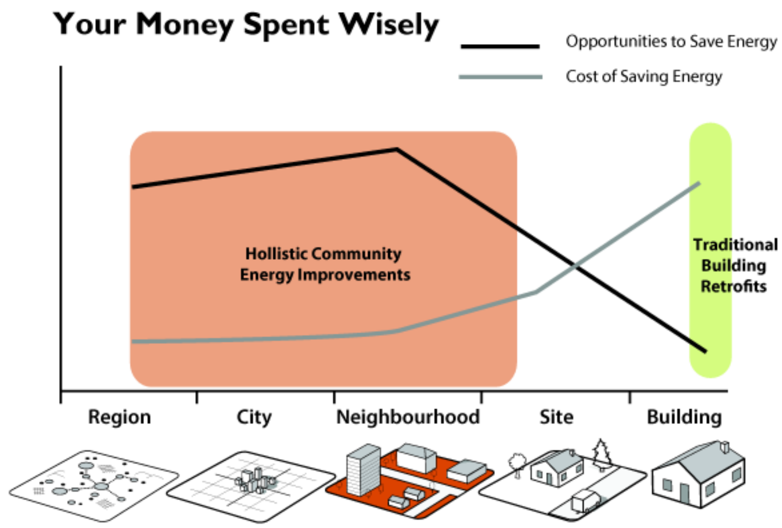
- Energy Technologies
- Community Design
- Citzen Behaviour

1.2 Layers of Community

Community Energy applies to a range of scales, from a small collection of houses, to a region providing local renewable energy resources.



This guide focuses on the region, neighbourhood, & block scales.



Various Scales of Community Energy:

Energy is a community concern. As the graph above shows, the neighbourhood scale has the highest opportunity, and lowest cost to save energy.

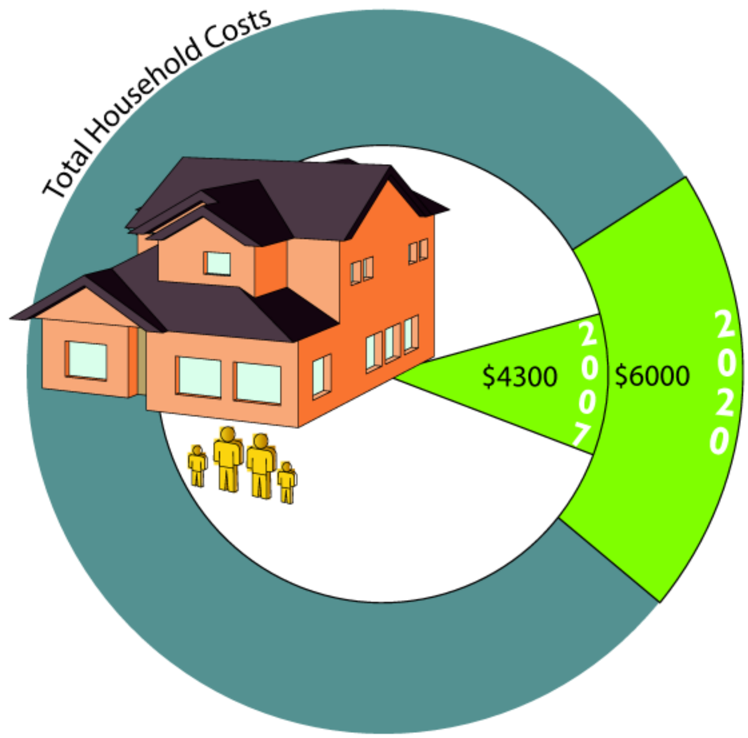
Source: adapted from Community Energy Planning 'a tool to combat climate change,' presentation by Paul Bouman, BC Hydro

Why is scale important?

- Transmission Losses
- Energy Security
- Environmental Accountability

Local Economy

A community energy system based on renewables can be less vulnerable to global energy markets, because after the initial investment operation costs remain generally low.



Projected increase in household energy costs by 2020.

Citizens of Surrey could collectively spend more than $1.3 billion on household energy by the 2020.

What if this money stayed in the community?

One dollar spent locally

can provide local economic benefits 2-5 times the original amount.

Source: communityenergy.org

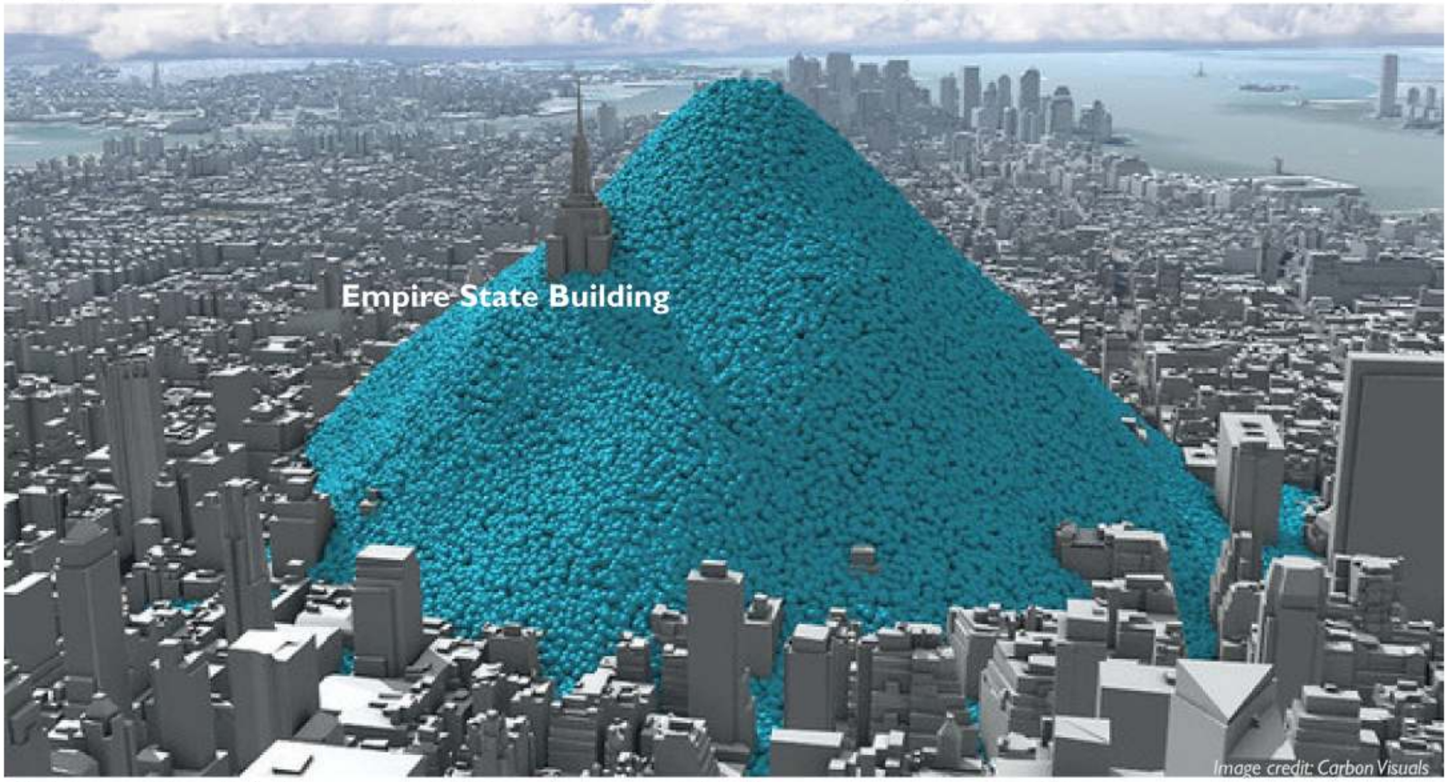
Why is community energy important for the local economy?

- Stable Energy Prices
- Control of Local Energy Supply
- Local Economic Benefits

1.4 Climate Change

Fossil-fuel energy resources release greenhouse gases that cause global warming and endanger current and future generations.

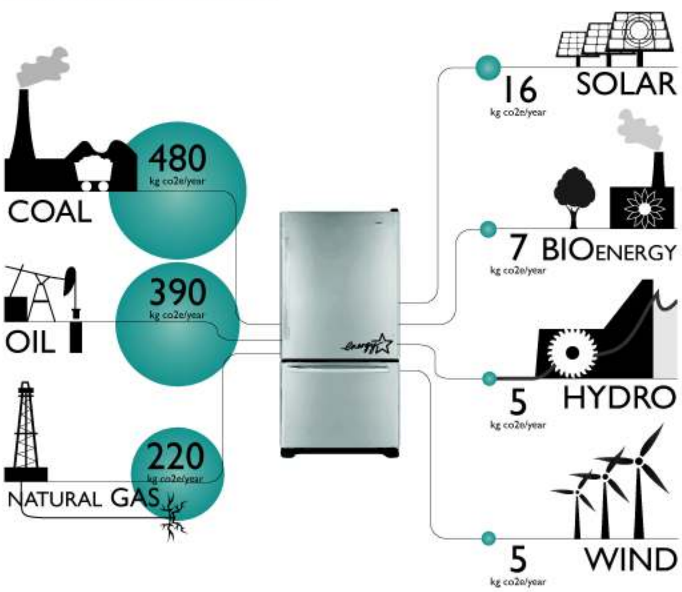
Imagine if we could see the CO_2 a community produces in a day.



This image of New York shows one day's CO_2 production - each bubble represents one tonne of CO_2.

We can work together to mitigate climate change by making more efficient use of community energy and switching to renewable sources to reduce carbon emissions. Most municipalities in BC have pledged to reduce their community-wide carbon footprints by up to 80% by 2050.

How much greenhouse gas emissions is your fridge responsible for?



Sources of greenhouse gas emissions in your city:

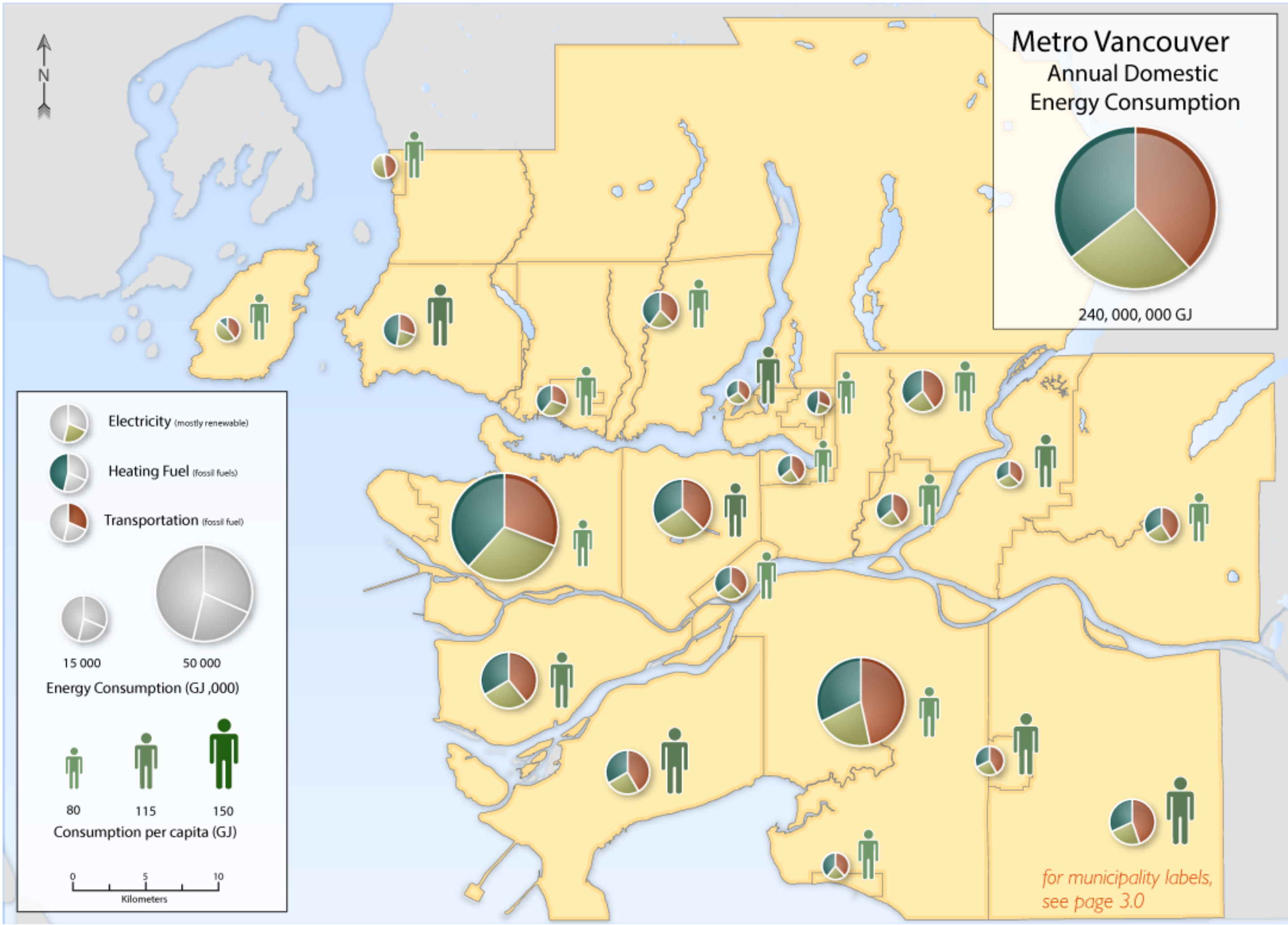
Burning Fossil Fuels

Agriculture

Waste & Landfills

How Does our Region Use Energy?

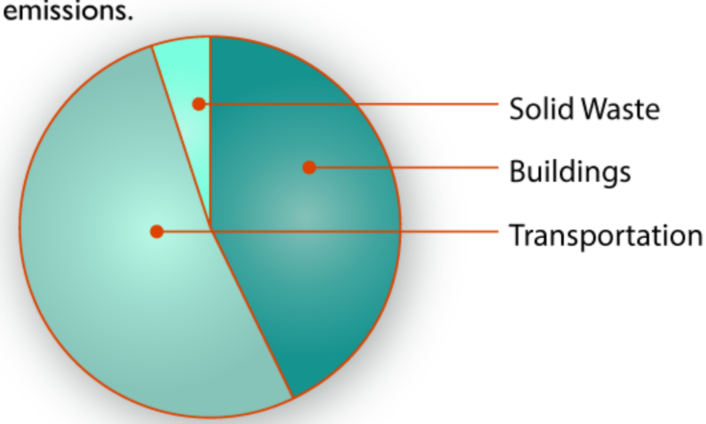
Communities across the region use different total amounts of energy for electricity, heating, and transportation. We also consume different amounts of energy per person across the region. How much do you use?



Municipalities with higher density and lower vehicle use tend to use less energy per person.

Regional greenhouse gas emissions sources

Buildings account for **over 40%** of regional carbon emissions.



Source: 2007 CEEI data

Why is climate change important in Metro Vancouver?

Local Impacts

Provincial and Local Reduction Targets

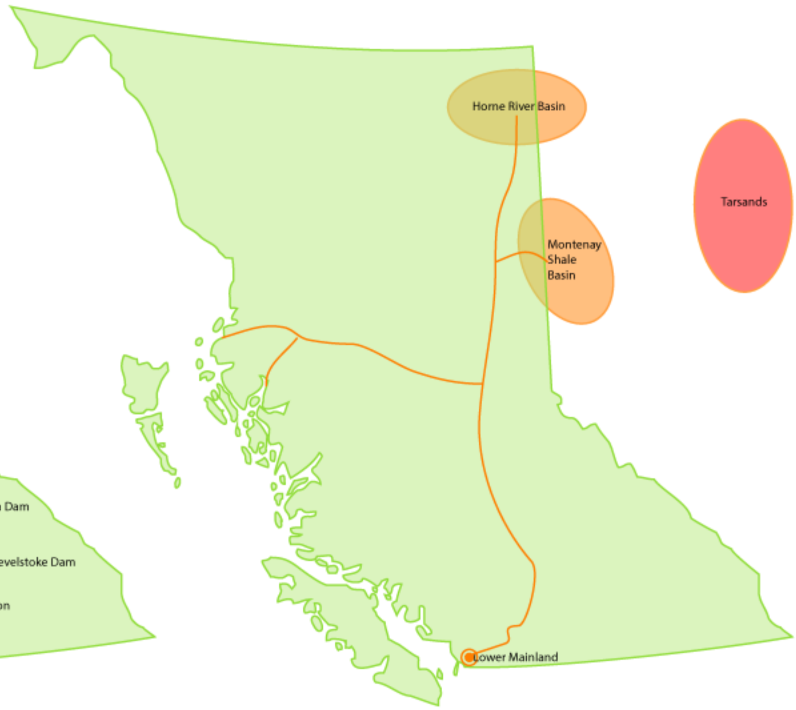
Local Solutions

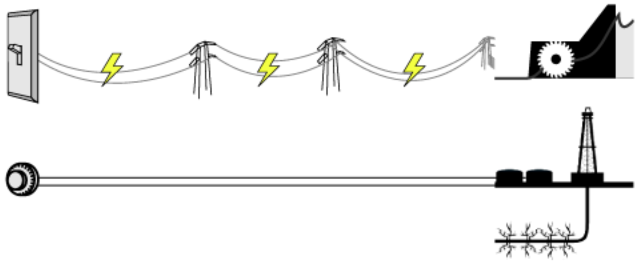
1.6 Where does Energy Come from in BC?

Much of the energy currently used in Metro Vancouver homes comes from remote suppliers in BC and Alberta, at least 400-1000 kilometers away.

Hydro Transmission

Natural Gas Routes





These long distance transmission lines and pipelines are vulnerable to losses, leaks, and disruptions that can be exacerbated from worsening climate change related events. Hydro-electricity is a renewable, low carbon energy source, but oil and gas are not.

Metro Vancouver is also crossed by railways & pipelines shipping coal & oil for export to other countries, & bringing oilsands oil for use in our vehicles.

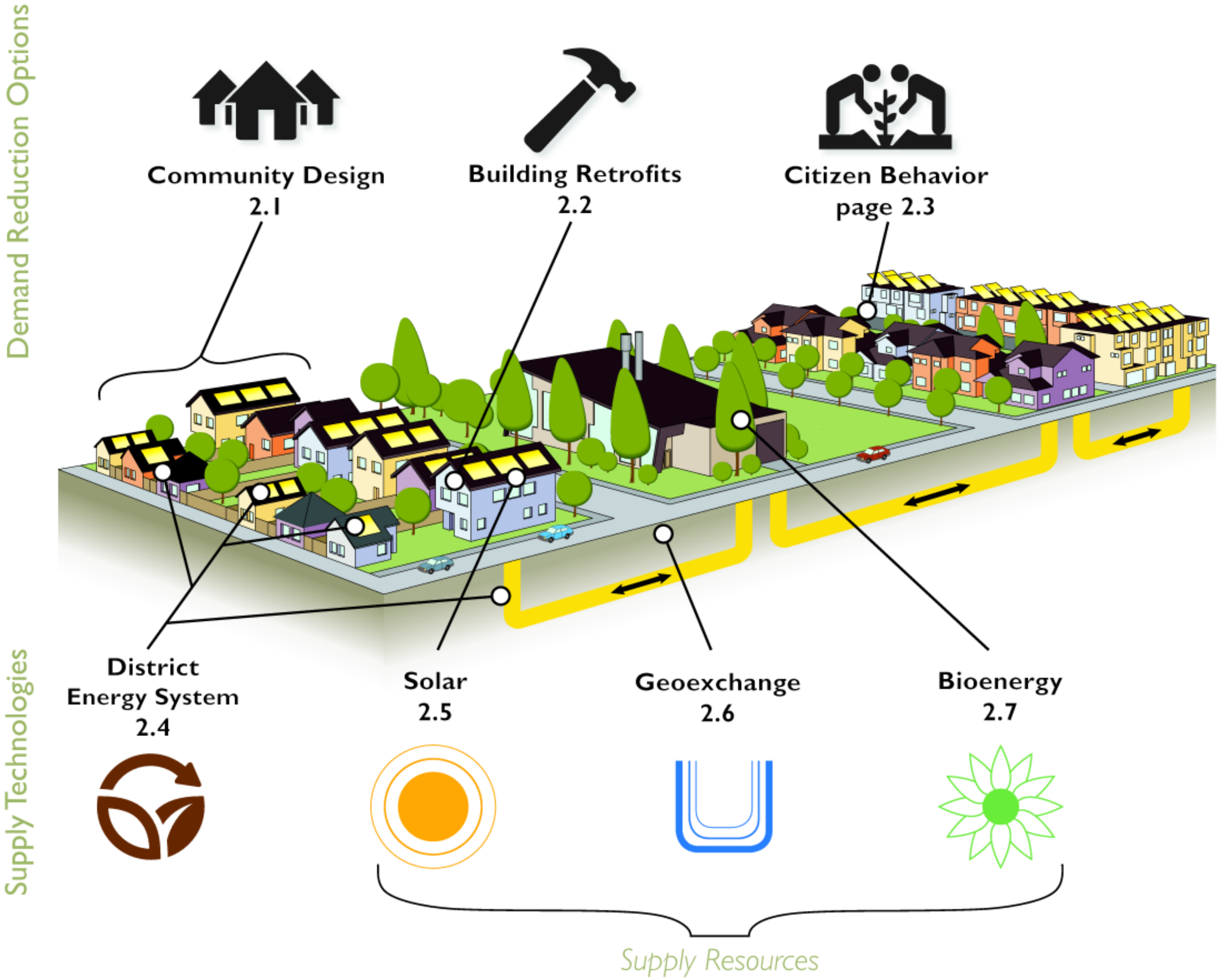
Major Current Energy Supplies in BC

- Electricity (90% Hydro)
- Natural Gas
- Oil Imports

Section 2 - Basic Concepts - A Visual Glossary

This chapter provides a visual glossary of key concepts, components, and types of Community Energy.

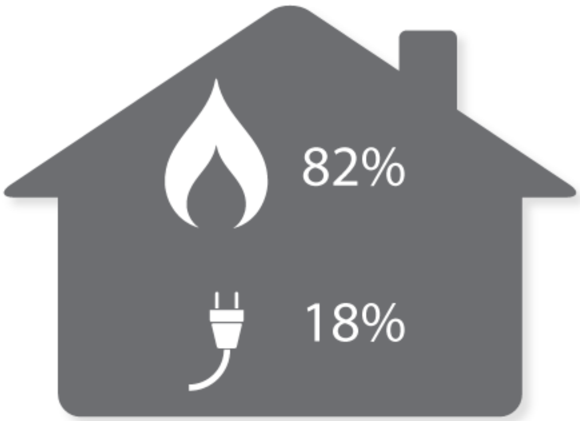
Components of a Community Energy System:



*Note: This section includes an overview of key renewable energy supplies, see **A1** for a comprehensive list of technologies.*

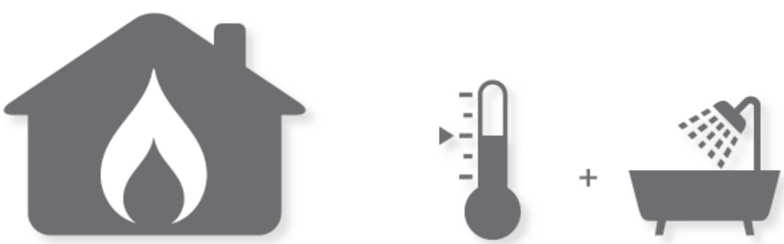
2.0b Residential Energy Demand

People use energy to provide services such as lighting, heat, cooling, and refrigeration. The energy services demanded in a typical household are shown below.



A typical household in Metro Vancouver requires about 60 megawatt hours of energy each year (electricity & thermal)

A typical household comprises 2.8 people and a floor area of 288 m^2 (>3,000 ft^2)



78% of thermal energy is used to heat space

22% of thermal energy is used to heat water

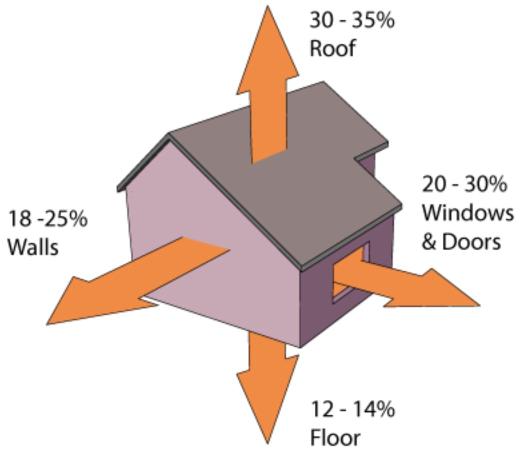
Electricity is used to power appliances, lights and devices such as electronics

Community Design

The way a community is designed has a major impact on the amount of energy it uses & its carbon footprint.

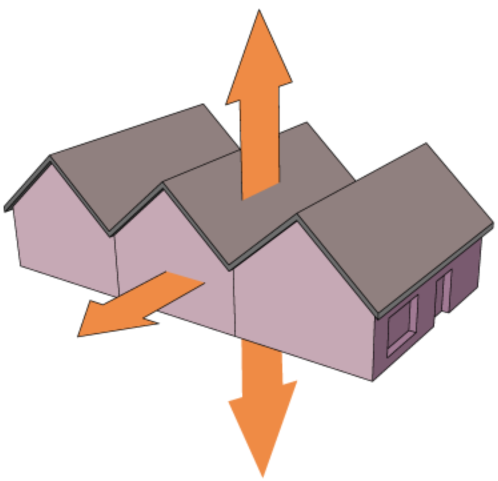
Conserving heat in our communities depends on design factors such as building density, building size, orientation, and amount of windows.

Reducing Energy Loss Through Shared Walls



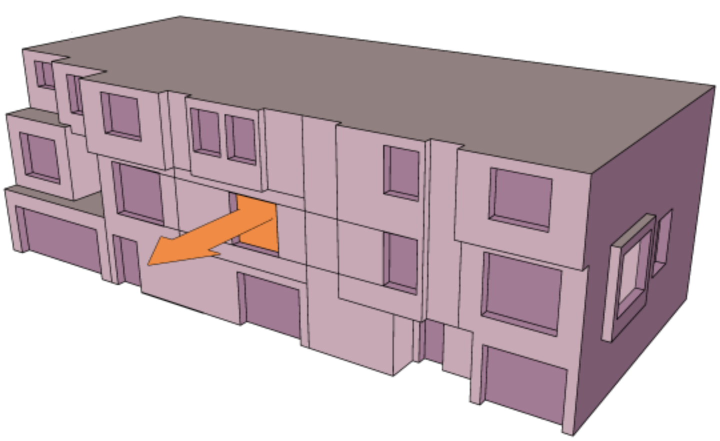
Detached buildings

- Often one family in a large space
- Many exposed walls (large surface area)



Attached buildings

- More shared walls
- Multiple families sharing heat
- Compact surface area



Issues to Consider:

- Density
- Dwelling Size
- Transit Access
- Landscape

Sketch of what the City of North Vancouver could look like in 100 years with greatly reduced greenhouse gas emissions.

Workshop participants discuss future visions for the city.

City of North Vancouver 100 Year Vision

The City of North Vancouver and the University of British Columbia Design Centre for Sustainability (UBC-DCS) teamed up to prepare a 100 Year Sustainability Vision for the City.

The plan looks at challenges and opportunities for promoting sustainable future development. This long-range vision aims to guide the City's community design toward carbon-neutral status by 2107, the City's 200th anniversary.

The visioning process addressed community design issues such as:

- compact, complete neighbourhoods
- 5 minute walking distances
- location of district energy plants
- mixed residential and commercial uses
- jobs/housing balance
- per capita carbon emissions

Learn more:
cnv.org/server.aspx?c=3&i=541

Density

Increased density has many benefits. For example, more people have access to transit, live in attached buildings with shared walls and district energy systems become more cost effective.

Dwelling Size

Smaller dwelling units generally use less energy to heat and operate.

Access to Transit

With increased density, more people can live close to transit, which in turn supports increased transit options and availability.

Landscape

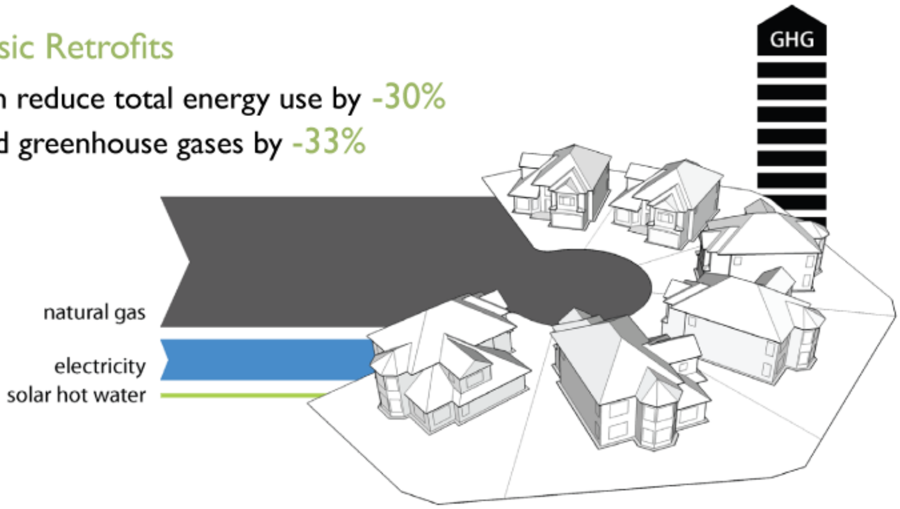
The way we design our landscape can affect the energy performance of our buildings. For example, trees along the south facade of a house can help cool buildings in the summer.

Retrofits

Much energy can be saved by bringing existing buildings up to new, more efficient standards.

Basic Retrofits

can reduce total energy use by -30%
and greenhouse gases by -33%



Key strategies used to achieve energy reductions

- increase insulation
- reduce air infiltration
- upgrade furnace
- switch to solar or on-demand hot water
- energy efficient appliances
- compact fluorescent/LED lighting

Major Retrofits

can reduce total energy use by -75%
and greenhouse gases by -80%

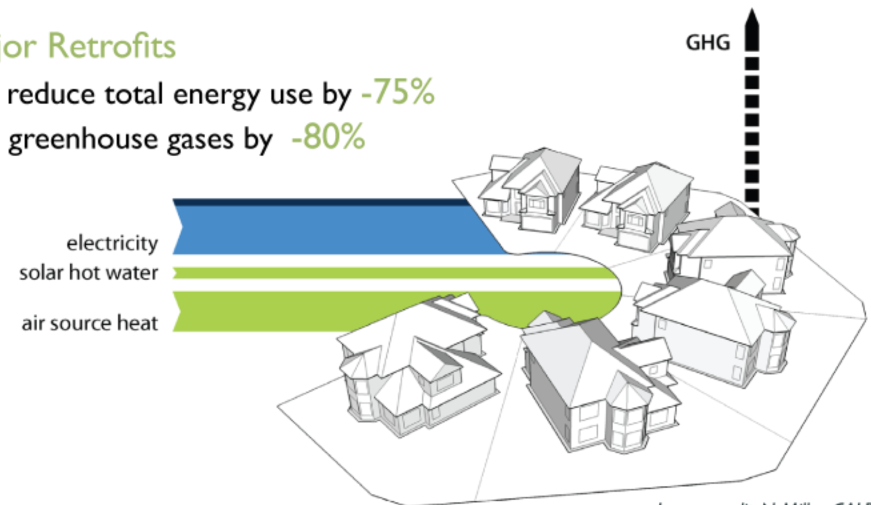


Image credit: N Miller, CALP

Key strategies used to achieve energy reductions

- major insulation increase
- heat recovery ventilator
- window upgrades
- upgrade to super high efficiency furnace or heat pump
- solar hot water or an on-demand system
- energy efficient appliances
- compact fluorescent lighting

Most of the buildings that will be here in 2050 already exist.

Issues to consider:

- Costs
- Practicality
- Livability
- Community Support

All information on this page is from the following report:
http://calp.forestry.ubc.ca/files/2010/02/CALP_REIBC_Retrofit-Challenge_Final_Report.pdf
Authors: Ellen Pond, Duncan Cavens, Nicole Miller, and Stephen Sheppard

2.2b

Retrofits

Case Studies


Image credit: Palace Realty Inc.

Residences on Eagle Island

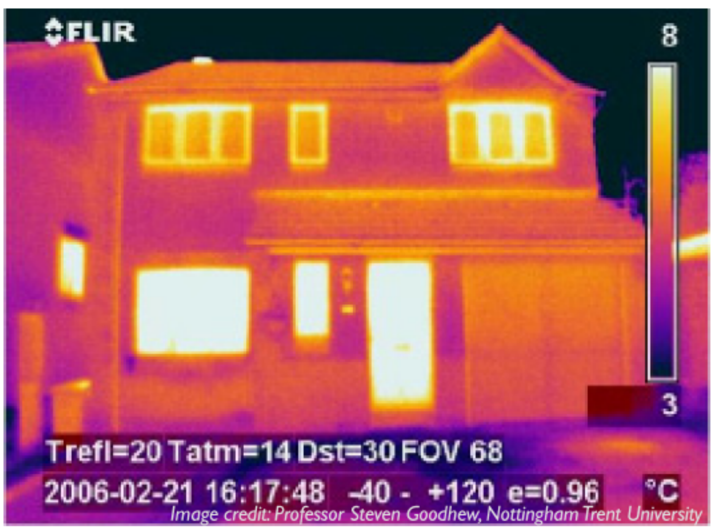


Image credit: Professor Steven Goodhew, Nottingham Trent University

Thermal image taken outside of home revealing locations of heat loss in the home.

Eagle Island Community Retrofit Project

is an example of how action on climate change can become more achievable and scale up when conducted at the neighbourhood level. Eagle Island is a community of 30 homes, located within the District of West Vancouver. A community champion led the neighbourhood through a retrofitting process, encouraging every neighbour to undergo a home energy audit, and then follow through with making their homes more energy efficient through such measures as adding better insulation, updating furnaces and draft proofing.

By making the activities fun (hosting parties and dinner meetings), using thermal imaging in the audit, and working as a group rather than as individuals, the residents of Eagle Island managed to increase the efficiency of 26 homes on the island. Spill-over from this initiative has residents considering more options for reducing their carbon footprint, such as switching from diesel-power to electric boats (main method of transportation to the island). The success of this initiative was supported by the District of West Vancouver & local businesses, and has grown into the "Cool Neighbourhoods" movement, carrying out similar programs in other North Shore communities (notably Blueridge and Horseshoe Bay).

Learn more:

mc-3.ca/eagle-island

http://www.townsfortomorrow.gov.bc.ca/

Pacific Institute for Climate Solutions White Paper on Thermal Imaging. (Cote et al., 2013)

Cost

Retrofits come at a range of costs, from a few hundred dollars for basic retrofits such as increasing insulation, to thousands of dollars for major retrofits, such as upgrading windows. Various rebate schemes are available to reduce costs.

Practicality

Some retrofits do not require major changes to buildings, while others require modifications to the building walls and roof structure.

Livability

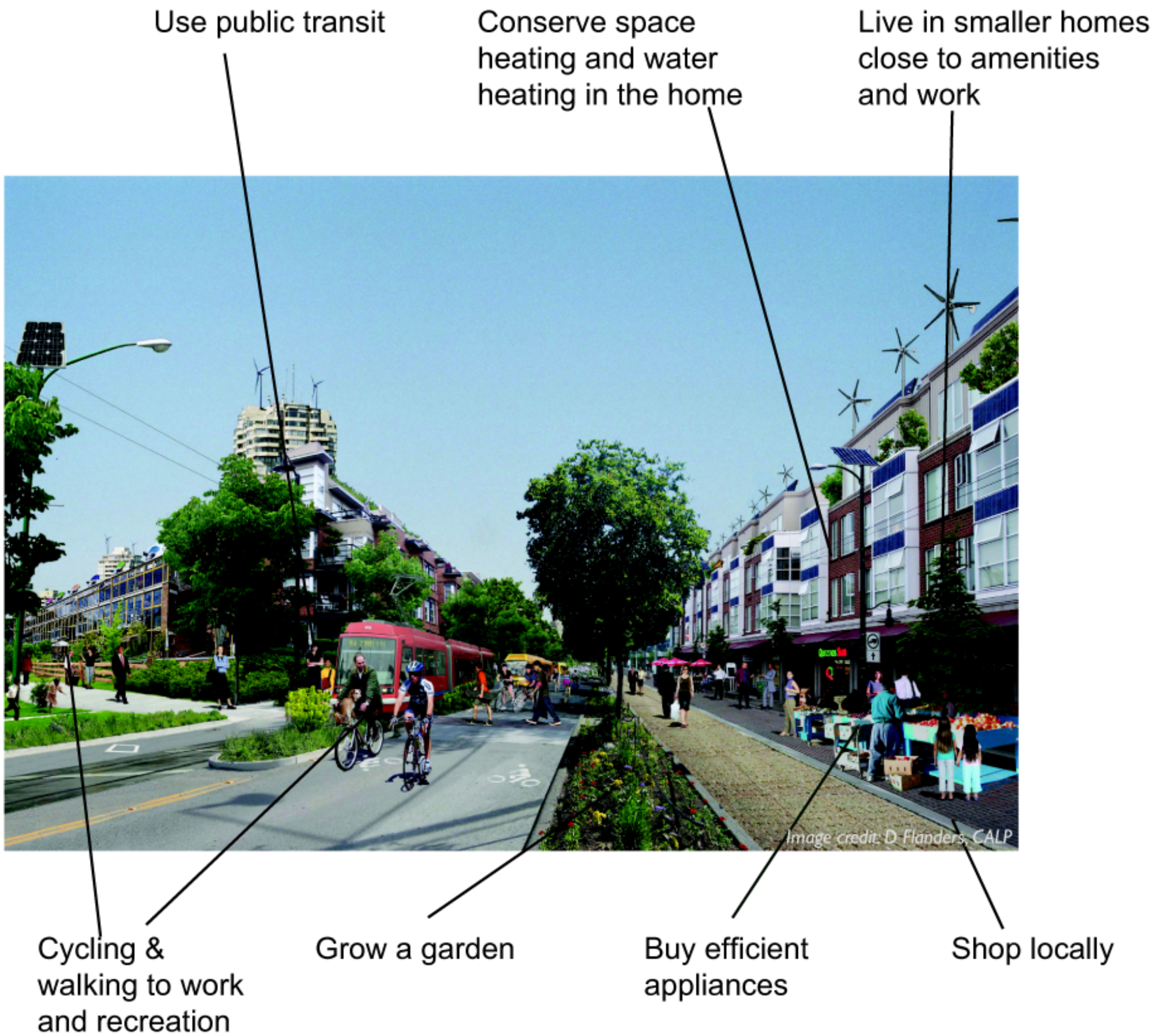
While all retrofits will make the building more livable, construction during retrofitting impacts building residents and neighbours.

Community Support

It helps to see other neighbours retrofitting their properties and to share expertise, tools, & materials. Some neighbourhoods form "buyers clubs" to negotiate bulk discounts from local building suppliers

Citizen Behaviour

What can we do as citizens and neighbourhoods to conserve energy and support good, climate friendly, community design?



Conserving energy is just as important as where we source our energy from. Above are some suggestions about where we might be able to reduce energy use. What else can we do as a community in our homes, at work, at school and at play?

Learn More:

More guides and tips, go to:
http://www.bchydro.com/guides-tips.html
http://www.bchydro.com/news/conservation/2012/energy-future-conservation-vision.html
http://www.toolkit.bc.ca/

Issues to Consider:

- Costs
- Feedback
- Making Time

2.3b

Citizen Behaviour

Case Studies

REaDY Summit at Steveston-London Secondary School April 2012

Logo designed by students for the summit.

Richmond Earth Day Youth Summit (REaDY)

On April 21st 2012, the Richmond Student Green Teams, with support from the School Board and Richmond City staff, led and facilitated the Richmond Earth Day Youth Summit (REaDY) at Steveston-London Secondary School. Winnie Hwo of the David Suzuki Foundation writes, "[it]…was more than just a way to celebrate the 42nd Earth Day, it was also a time for REaDY Summit participants to learn and talk about what the future holds for our environment. Their conclusion — the Earth is in worse shape today than 42 years ago and the time to take action is now!"

This collaboration between youth, NGO and municipal representatives reveals the importance of working together as a community towards raising support, momentum and awareness for sustainability issues. For example, Ian Bruce, of the DSF's Climate Change and Clean Energy Team led a group visioning session about what a sustainable neighbourhood and transportation future might encompass.

Learn More:

davidsuzuki.org/blogs/climate-blog/2012/02/richmond-earth-day-youth-summit-2012/

Costs

According to BC Hydro, energy efficiency and conservation measures cost as little as one-fifth to one-eighth the cost of other new clean resource options, on average.

Feedback

When people can actually see the energy they are using, they tend to use less. Easy to see monitoring displays help people understand how they are using energy, enabling them to make decisions on how to conserve.

Making Time

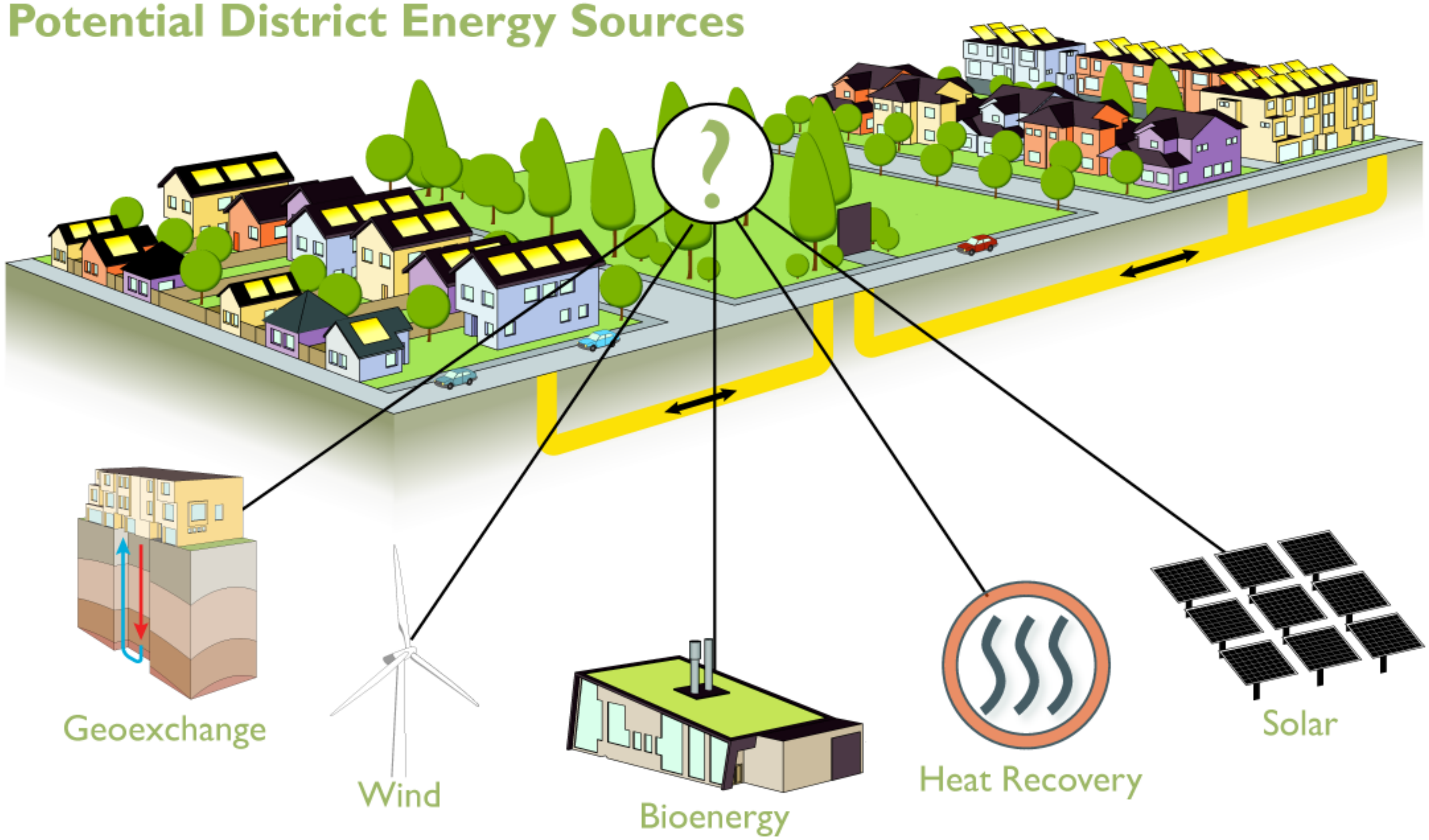
Creativity is needed for scheduling time together with busy members of the family & neighbourhood to discuss how they can conserve energy and reduce carbon footprints … try combining the energy saving conversations with other fun social activities

District Energy Systems

A district energy system generates heat and sometimes electricity for distribution to local users (homes and businesses).

District energy is more energy efficient than using individual building furnaces for neighbourhood with adequate density, and therefore reduces greenhouse gas emissions, especially when using renewable supplies.

Potential District Energy Sources



District Energy can provide both

Heating

&

Electricity

District Energy uses piping or a micro grid to distribute heat or power from a central neighbourhood plant or dispersed network. A micro grid is a local system of electricity generation, energy storage, and users that is also connected to the traditional large-scale grid.

Issues to Consider:

- Aesthetics
- Air Pollution
- Health
- Costs & Revenues

2.4b District Energy Systems

Case Study

Image credit: Google Street View


Image credit: NR Can

Drake Landing Solar Community

is a 52-house neighbourhood in Okotoks, Alberta. It is heated by a district system designed to store solar energy underground during the summer months and distribute the energy to each home for space and water heating needs during winter months. Solar energy is captured all year by an 800-panel garage mounted array.

The system fulfils 90% of each home's space heating requirements from solar energy, which means they rely much less on fossil fuels. The reduction in greenhouse gas (GHG) emissions has been calculated to be approximately 5 tonnes per home per year.

District Energy Systems range in size from serving a single apartment complex or multiple single family homes, to serving a whole neighbourhood (such as the Lonsdale Energy Corporation in the City of North Vancouver).

Learn more:
dlsc.ca/

Aesthetics

Citizens are often concerned with how a new District Energy plant or rooftop facilities will look in their neighbourhood. Many local examples show that good design can result in a community feature, rather than an eyesore.

Air Pollution

Air pollution from some renewable fuel supplies can be of concern to local residents. Strict industry standards & regional restrictions are in place to ensure that air pollution & reduced visibility is not a major issue.

Health

Perceived health effects from air pollution, noise, night lighting, or other irritants can be reduced through good design, but should be monitored. Educational campaigns about these issues should be implemented when District Energy is proposed.

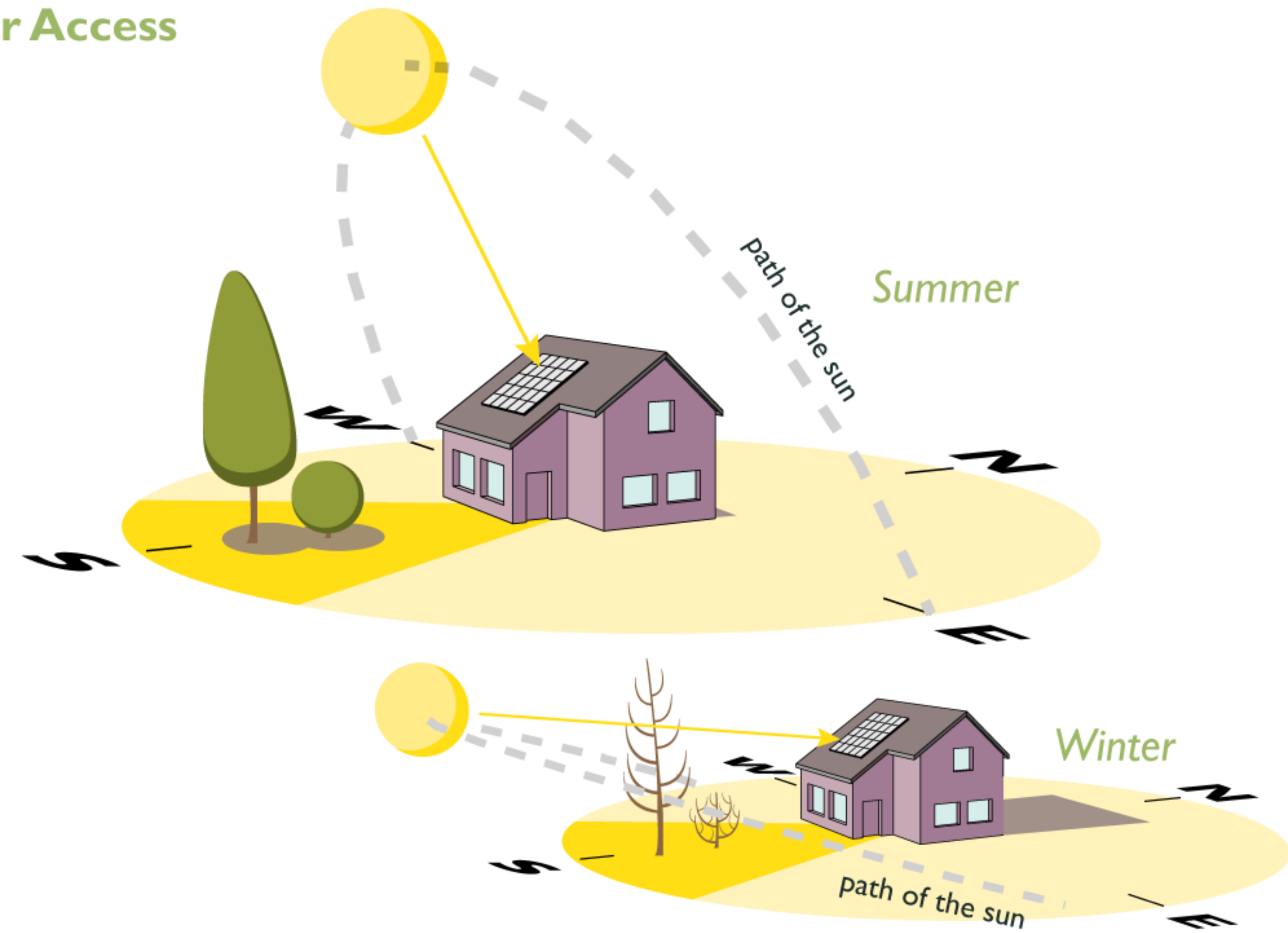
Costs

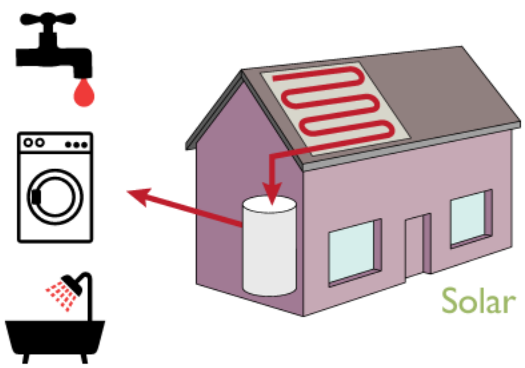
District Energy systems come in a range of costs. Much of the costs are up-front costs for new buildings and infrastructure. Actual energy supply costs are often low. Some cities are building District Energy utilities to provide long-term revenue.

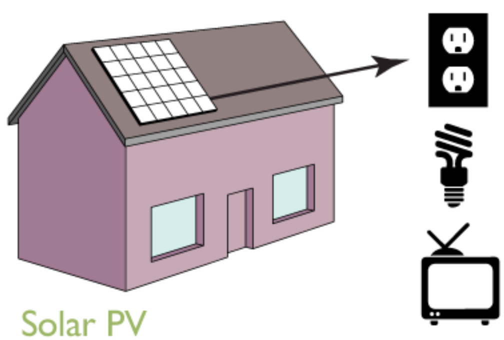
What Is Solar Energy?

Solar (energy from the sun) can provide energy to buildings using proven systems such as Solar Photovoltaic (PV) and Solar Thermal Energy.

Solar Access







Issues to Consider:

- Costs/Savings
- Cloudy Weather
- Shade
- Maintenance

2.5 Solar Energy

Case Studies

Sum-SHA-Thut, Sooke, British Columbia


Image credit: Green Muze


Image credit: turtleisland.org

The T'Sou-ke Nation is a small First Nation community located on the very southern tip of Vancouver Island. The community has completed a 75-kilowatt solar power installation, which is the largest in B.C. to date. The project is called Sum-SHA-Thut, the Sencoten term for "sunshine".

The T'Sou-ke solar power installation generates electricity from photovoltaic panels. They have also installed solar thermal panels on 37 (out of 86) homes to pre-heat hot water, further reducing energy consumption and their carbon emissions.

Learn more:

greenmuze.com/climate/energy/1315-tsou-ke-nation-solar-project-.html
turtleisland.org

See also:

District of North Vancouver Solar Calculator
http://geoweb.dnv.org/applications/solarapp/

SolarBC
http://www.solarbc.ca/

Costs

Costs per kilowatt hour range from:
11-23¢ for a solar farm,
19-38¢ for rooftop hot water,
30-45¢ for rooftop photovoltaic

Current BC Hydro prices are about 7¢ per kWh.

Intermittency

The energy produced by a solar panel changes throughout the day and year depending on sun angles and cloud cover. A large uptake of solar technologies would require careful management of the energy system.

Shade

Shade from trees and buildings will affect the energy produced from a solar panel. To ensure the maximum energy output of a solar installation some jurisdictions in California have laws that prohibit shading of neighbouring solar panels.

Maintenance

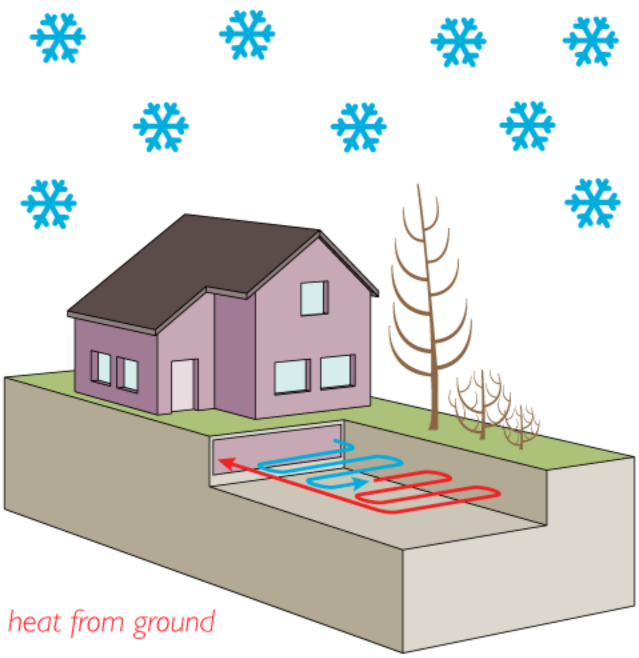
Solar panels require some maintenance for removing dust and snow. If the panels are not maintained, the energy output of the technologies can be reduced and economic viability can be compromised.

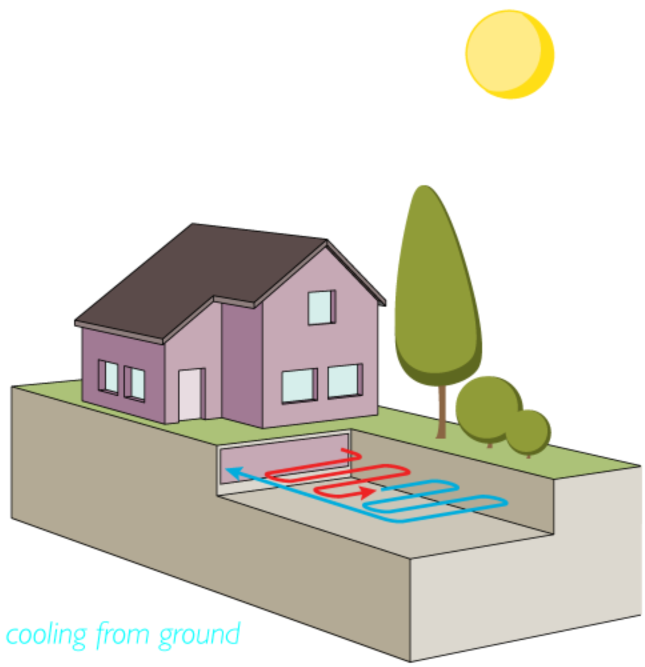
What Is Geoexchange?

Geoexchange takes advantage of the relatively stable temperature just below ground to provide heating or cooling in buildings using similar technology as your refrigerator.

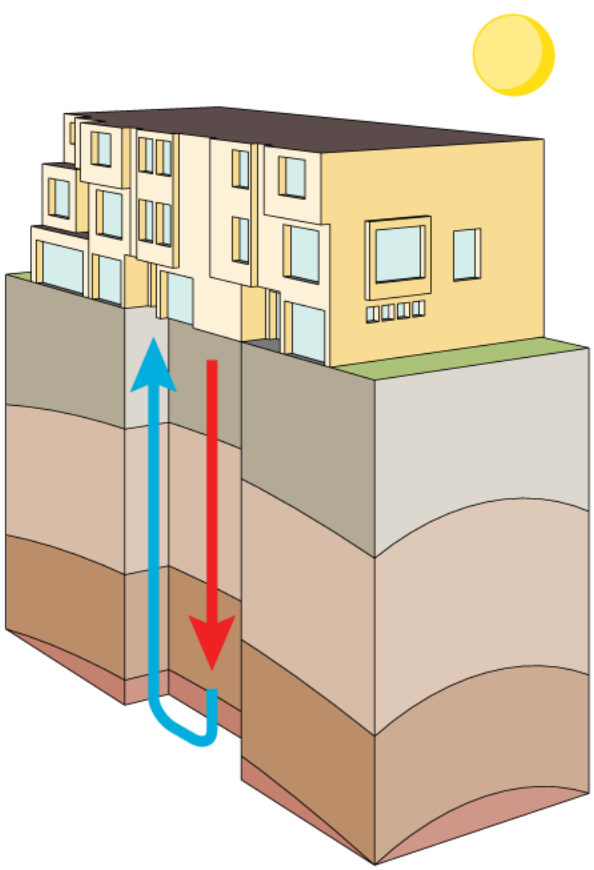
Heat in Winter, Cool in Summer

Horizontal System





Vertical System



Horizontal vs. Vertical systems

Pipes can be laid horizontally (above) to provide heating/cooling to homes with space around them, or can be drilled vertically into the ground (below), where space is more limited. Note that geoexchange requires electricity to work.

Issues to consider:

- Costs/Savings
- Scale
- Retrofits

What Is Geoexchange?

Case Studies

Interior of Energy Centre building

The City of Richmond has constructed its first city-owned district energy utility with a vertical geoexchange system. The first phase, developed in partnership with Oris Geo Energy Ltd., uses thermal energy from the ground to heat and cool new residential units currently being built in Richmond's West Cambie neighbourhood. It could cut local production of greenhouse gas emissions by 200 to 600 tonnes annually.

The first phase is expected to cost $3.5 million to construct and $80,000 to operate annually at full capacity. All of these costs will be recovered over time through user rates, and will place no burden on Richmond taxpayers who are not serviced by the utility.

Laying the pipes in the ground

Learn more:

richmond.ca/news/city/districtenergy.htm
http://gibsons.ca/geoexchange-district-energy-utility

Costs

Vertical systems are more expensive, but can become cost effective at higher building densities. Both systems reduce or eliminate costs & price fluctuations of natural gas or other non-renewable heat sources.

Scale

Geoexchange works at a range of scales, from the household to the neighbourhood.

Retrofits

Horizontal geoexchange fields can take up a lot of space, so may be difficult to install in areas that are already developed and have mature trees. Existing home heating systems must also be compatible with the geoexchange heat pumps.

What Is Bioenergy?

Bioenergy describes the energy contained in biological material, such as wood, crops, manure and garbage.

BC has large natural biomass resources that can be used to produce energy at the individual level (eg. high-efficiency wood stoves), farm level (eg. biogas), or in district energy plants.

Bioenergy Plant

Biofuel sources

Bioethanol: Fermentation of starch crops
Biodiesel:Vegetable oils and animal fats
Biogas: Methane from anaerobic digestion of organic waste or syngas from wood.

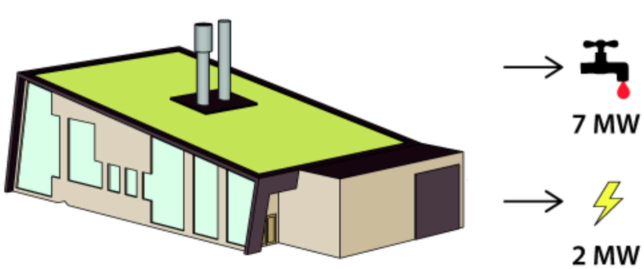
Biomass sources

Forestry waste
Construction wood waste
Fuel crops, dried manure & stemwood
Garbage
Charcoal, Biochar

The difference between bioenergy and fossil fuels:

Burning bioenergy releases carbon that has been sequestered from the atmosphere, and therefore can be considered carbon neutral. In contrast, burning fossil fuels releases carbon that has been buried beneath the earth for millions of years, releasing additional carbon into the atmosphere.

Bioenergy can produce heat and/or electricity



Building architecture and energy output in the example above are modelled after UBC's bioenergy plant.

Issues to Consider:

- Costs/Savings
- Air Pollution
- Fuel Source Quality
- Increased Traffic

2.7b

What Is Bioenergy?

Case Studies

Image Credit: Northern Development BC

Baldy Hughes Therapeutic Community, near Prince George, BC

When the therapeutic community began operations at their current site, it soon became apparent that meeting their heating requirements with propane would be costly - both in monthly fuel costs and carbon taxes.

In response, the community pursued funding for installation of a community bioenergy heating system. This $1.3 million project, replaced the propane boilers with a biomass system that uses wood pellets as fuel. The wood pellets are made from low-cost carbon-neutral wood by-products available in the area.

The system has exceeded their expectations reducing heating costs by 75%.

Image Credit: John Newcom

Dockside Green, Victoria, BC

A wood-fired combined heat and power plant will provide heat and hot water to the entire development. This, along with the hydropower-based electricity, will reduce the carbon footprint of the development.

Learn more:

seatoskygreenguide.ca
northerndevelopment.bc.ca/explore-our-region/success-stories/baldy-hughes-invests-in-a-community-bioenergy-heating-system/
nexterra.ca/files/pdf/Project Profile_UBC 20120912_EMAIL.pdf

Costs/Savings

Costs per kilowatt hour range from:
9-13¢ for a biomass plant,
15-50¢ for biogas plant

Current natural gas prices are about 9¢ per kWh.

Air pollution

Metro Vancouver has very strict air quality standards, that must be met when installing a bioenergy plant. UBC's Nexterra bioenergy plant filters out virtually all particulate matter.

Fuel Source Quality

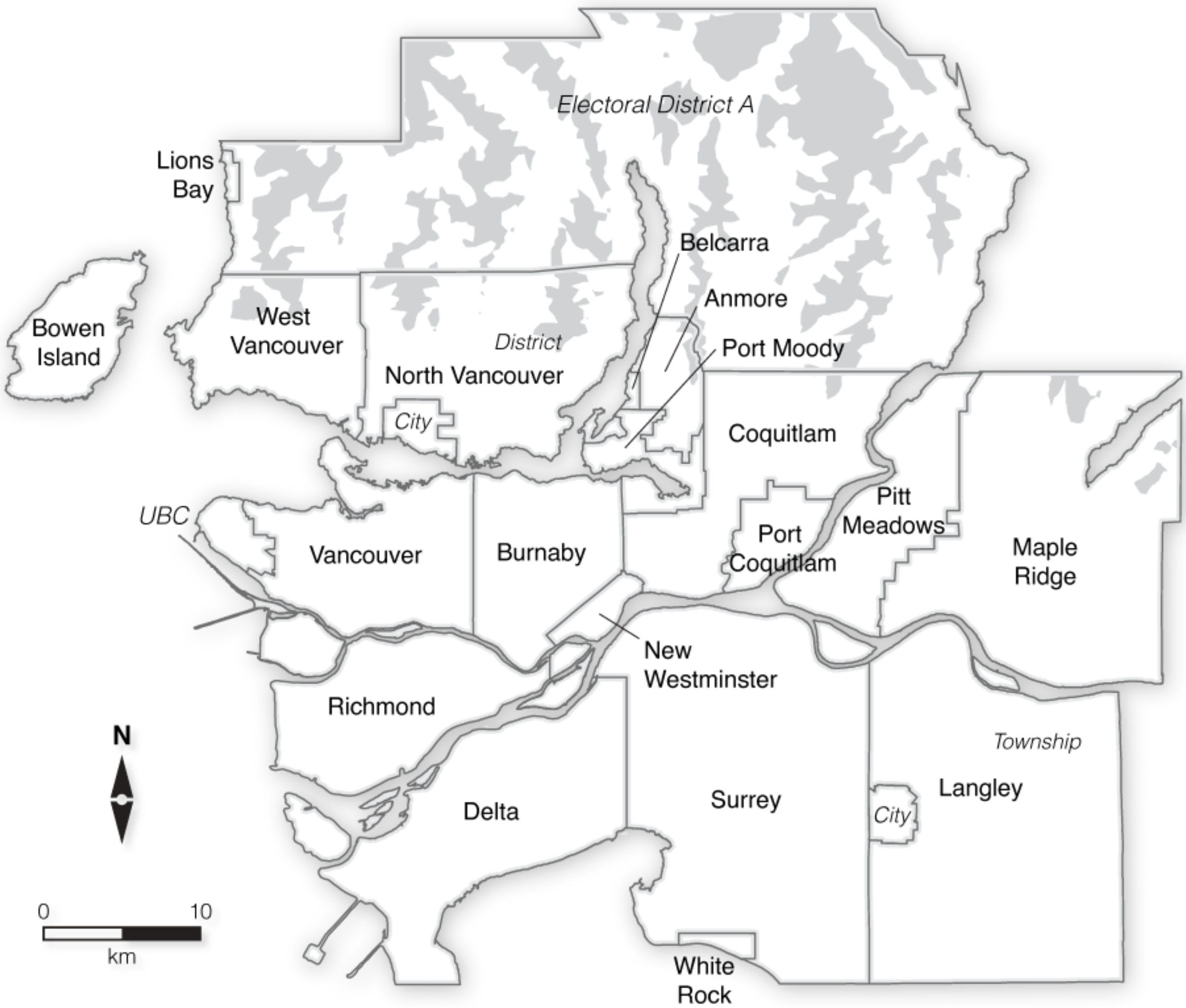
The fuel source must be free from contaminants, & be of consistent low moisture content, etc.

Increased Traffic

A medium-sized district energy plant is supplied by two trucks per day. This requires careful siting to avoid quiet residential streets.

Section 3 - Regional Renewable Energy Resources

This chapter provides an inventory of the potential capacity of select renewable energy resources across the region, and describes issues arising from the associated technologies.



The region of Metro Vancouver comprises 22 municipalities, one electoral area, and one treaty First Nation.

The resources inventoried in this section provide an overall snapshot of the physical potential for renewable energy generation in Metro Vancouver. They do not reflect constraints of economic viability, social acceptability or current regulations. Existing data from various sources are analyzed and mapped using new techniques suitable to communicating energy resources at the regional scale.

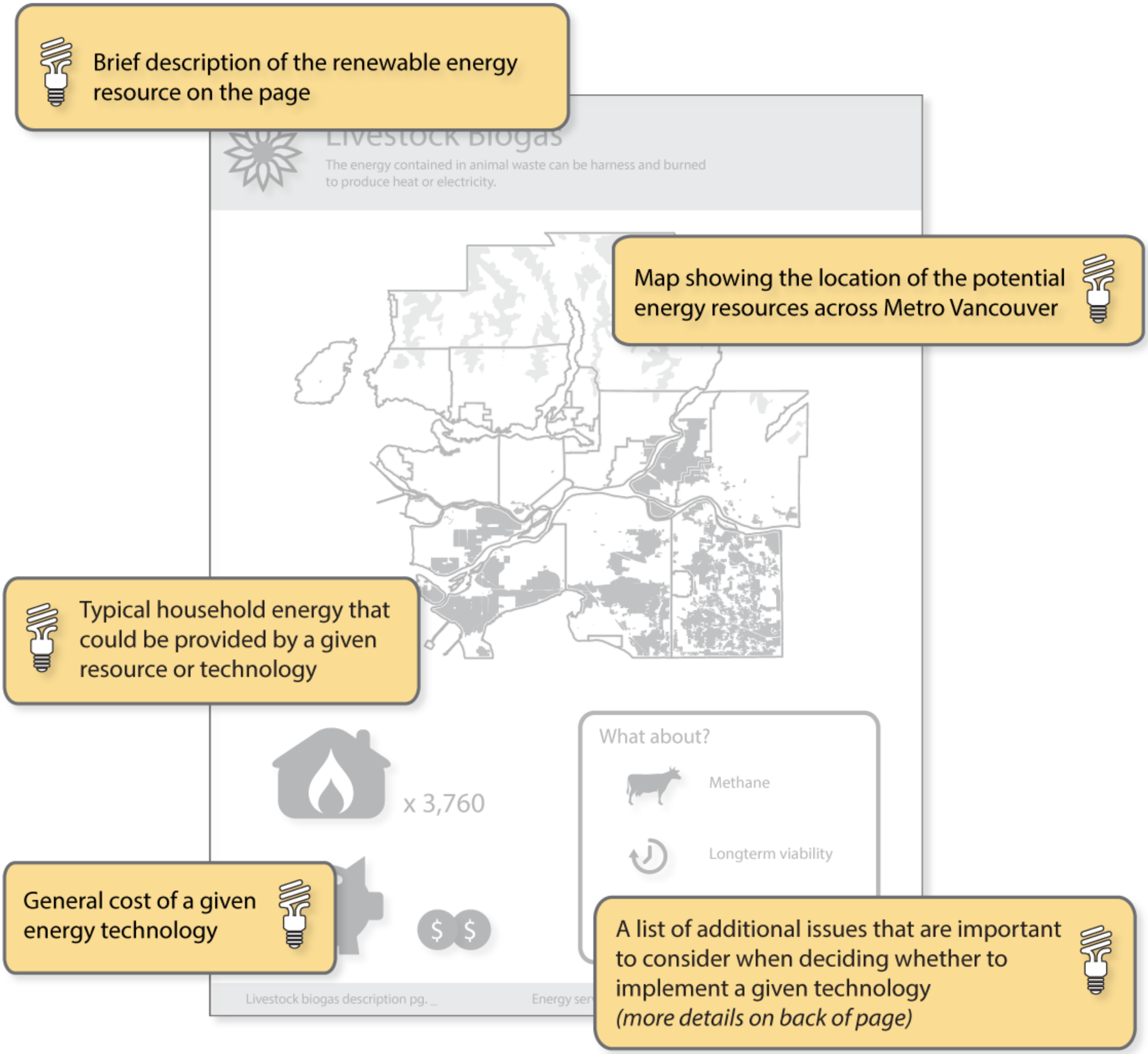
Energy Resources Inventoried

- Rooftop Solar
- Run-of-River Hydro
- Industrial Recovery
- Livestock Biogas
- Sustainable Forest Biomass

3.0b

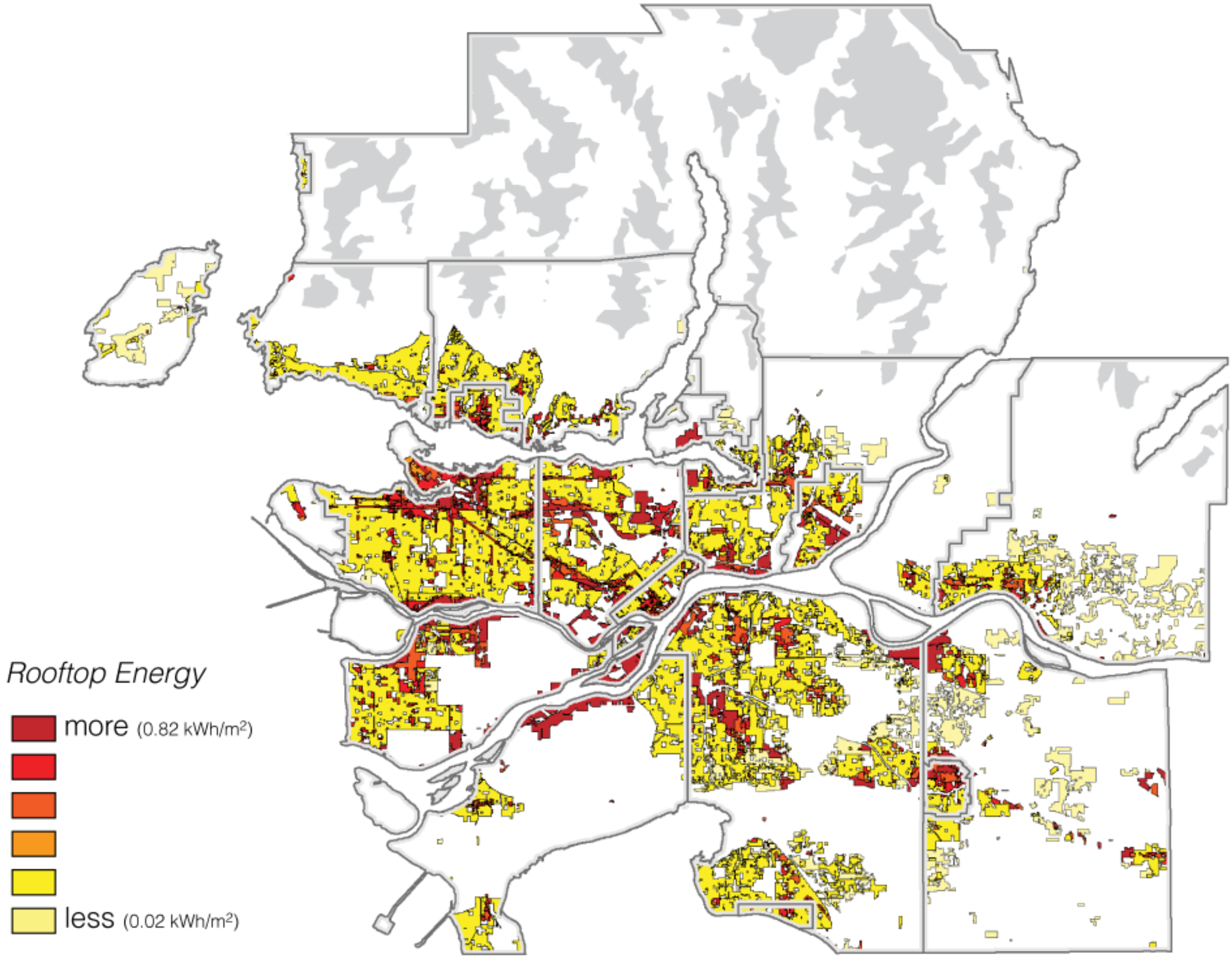
How To Use This Section

Outlined below is a general description of the layout of this chapter and how to think about the information.



Rooftop Solar

Solar energy can be collected using panels to produce hot water or electricity. Here the energy on the south-facing (or flat) portion of exisiting roofs is assessed.



for municipality labels see page 3.0

could heat up to
650,000
typical households

or

could power up to
900,000
typical households

costs range between
19 - 45 ¢
per kWh

Issues to Consider

Intermittency

Shade

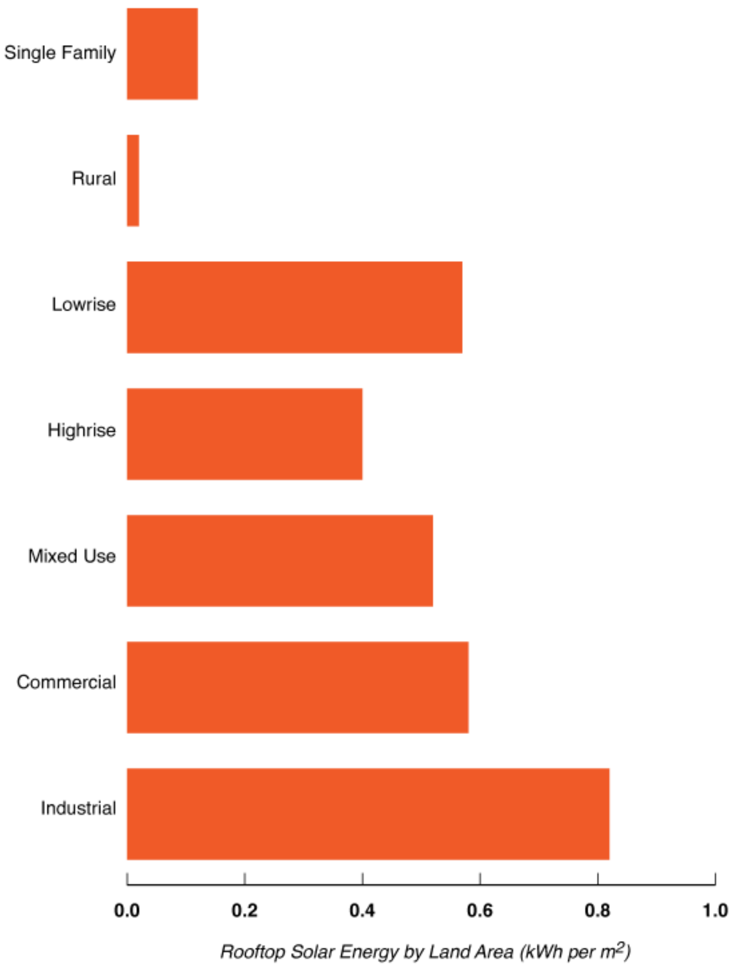
Maintenance

see over

3.1b ...More Information

Source: University of British Columbia
Rooftop solar energy was assessed using the typical built form found in Land Use Classes across Metro Vancouver. The analysis considers roof shading, orientation and atmospheric effects.

South-Facing Rooftop Solar Energy by Land Use Type



Local Example

Vancouver Airport's Solar Hot Water System

In 2003, the Vancouver Airport installed 100 solar panels on the roof of the domestic terminal building. The system uses evacuated tube solar collectors to absorb solar energy and transfer the heat to water.

The panels heat over 3000 liters of water every hour, which has led to a 25% decrease of natural gas use in the terminal.

The cost of the project was about $500,000 and the airport reports energy saving of more than $100,000 a year. Furthermore, by reducing natural gas use, the airport has also managed to lower its carbon emissions.

Intermittency

The energy produced by a solar panel changes throughout the day and year depending on sun angles and cloud cover. This intermittency in energy output requires consideration of additional energy technologies to supply energy when the sun is not shining.

Shade

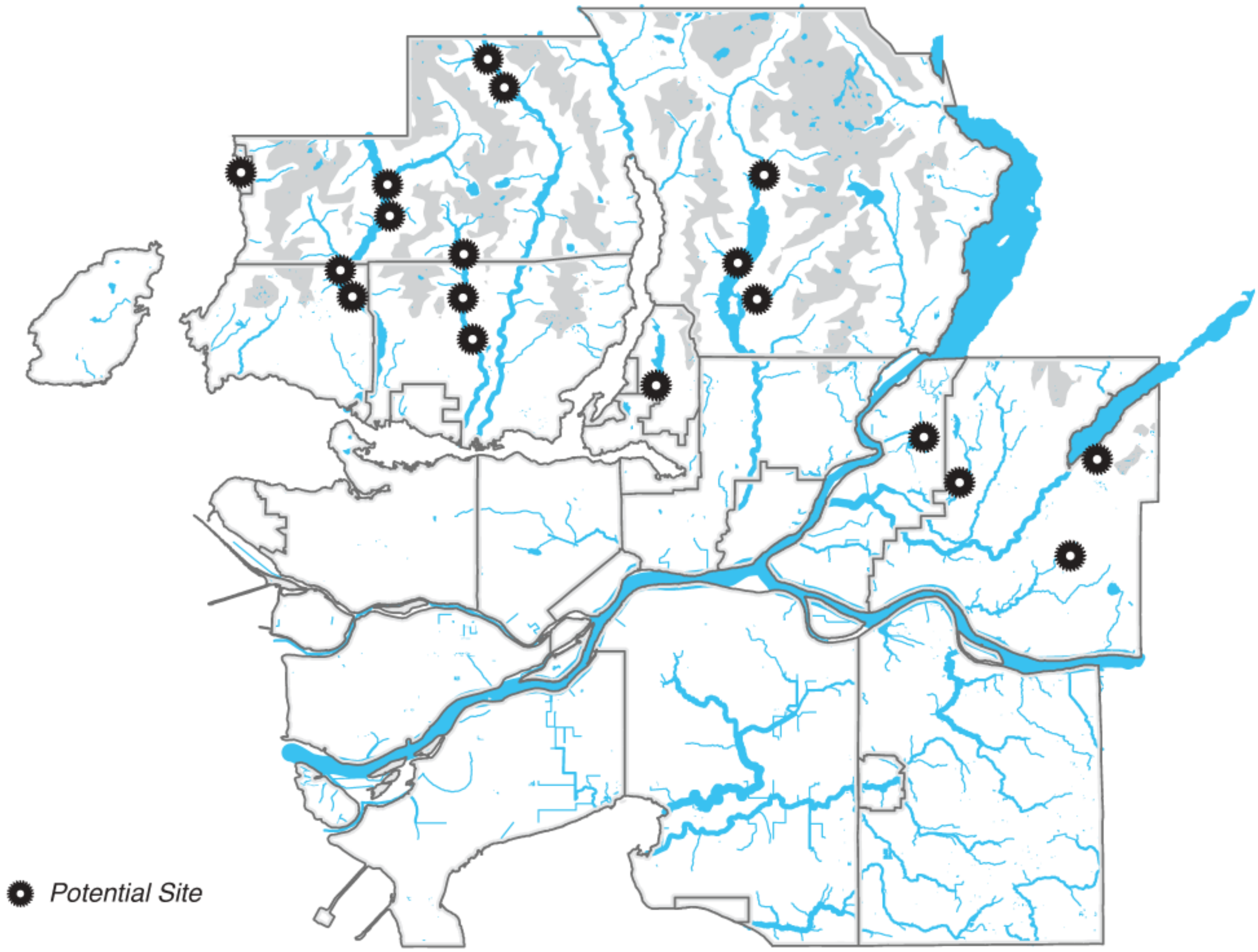
Shade from trees and buildings will affect the energy produced from a solar panel. To ensure the maximum energy output of a solar installation some jurisdictions in California have laws that prohibit shading of neighbouring solar panels.

Maintenance

Solar panels require some maintenance for removing dust and snow. If the panels are not maintained, the energy output of the technologies can be reduced and economic viability can be compromised.

Run-of-River Hydro

Run-of-river technologies generate electricity by harnessing the energy from water flows in streams and rivers, without the use of large dams.



for municipality labels see page 3.0

could power up to

7,500

typical households

costs range between

6 - 14 ¢

per kWh

Issues to Consider

Fish Bearing Streams

Protected Areas

Recreation

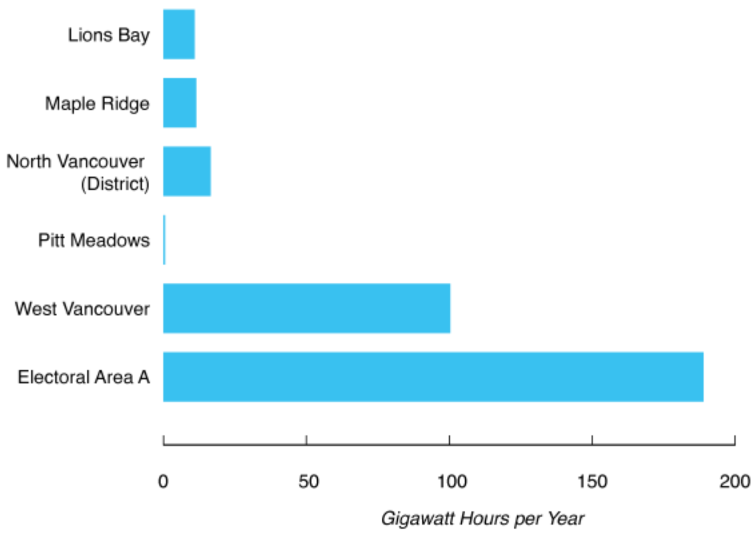
see over

Note: Potential Run-of-River sites were provided by BC Hydro

3.2b ...More Information

Source: BC Hydro
Potential Run-of-River Hydro locations and electricity generation potential were gathered from the BC Hydro Resource Options Mapping (ROMAP) database

Potential Run-of-River Hydro Energy by Municipality



Local Example

Fitzsimmons Creek Run-of-River Project

The Run-of-River facility at Fitzsimmons Creek in Whistler began generating electricity in January 2011.

The Run-of-River project diverts water flow from the creek to run a turbine that produces electricity, before returning the water to the creek.

The project has the ability to produce over 33 GWh of energy per year, which is enough to power Whistler Blackcomb's summer and winter operations.

The length of stream where the project was installed is not a fish bearing area of the creek, and the weir was constructed to maintain minimum water levels.

Fish Bearing Streams

To minimze impacts on native fish populations, Run-of-River projects can be installed upstream of fish bearing reaches. The assessment of potential sites in Metro Vancouver accounts for known fish bearing streams.

Protected Areas

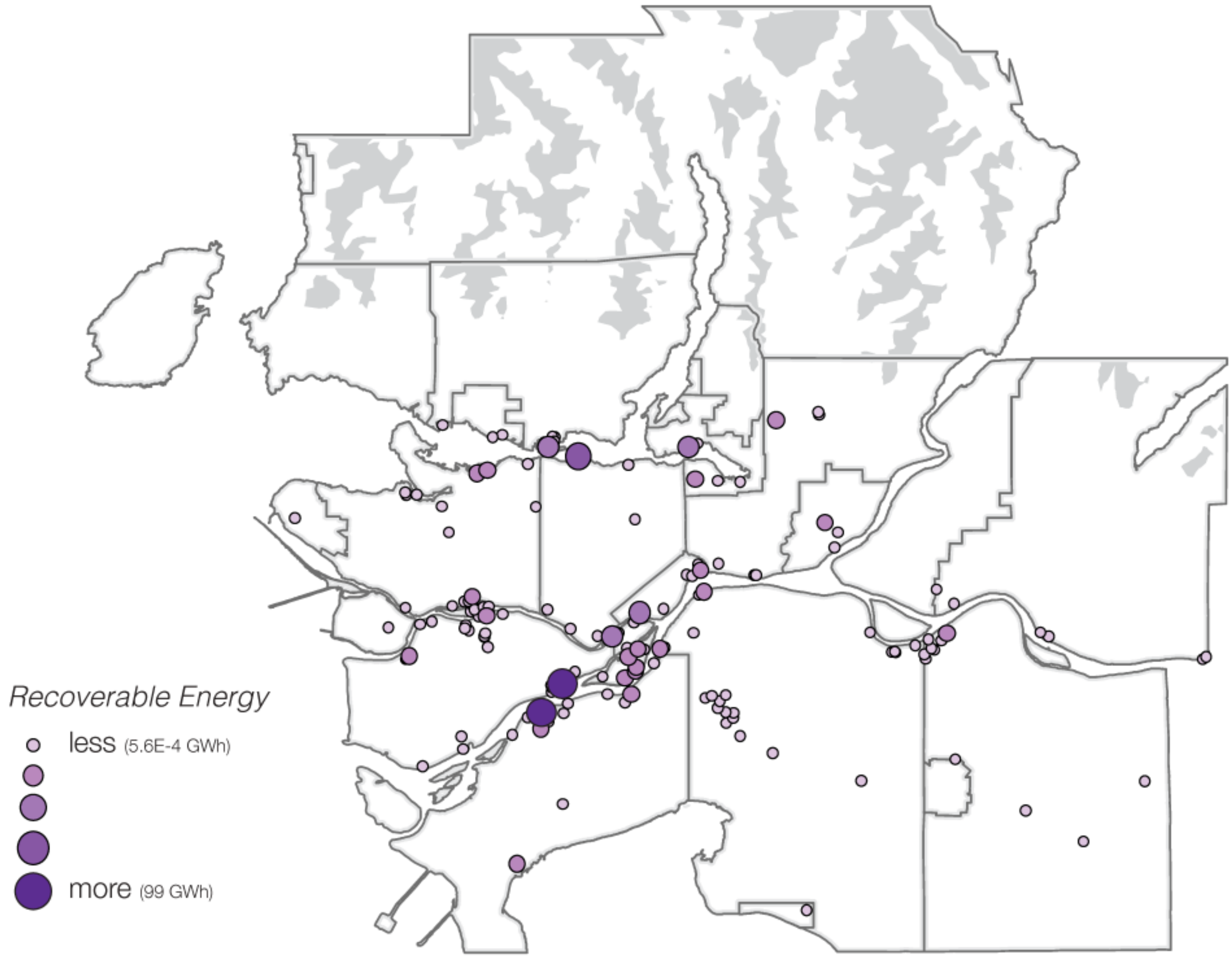
Many of the potential run of river sites in Metro Vancouver are located in protected areas, designated as watersheds for drinking water or recreational areas; this raises key policy and public acceptance issues.

Recreation

Many recreationists enjoy using creeks and rivers for activities such as kayaking, canoeing and fishing. However, there are opportunities for recreation and energy production to co-exist on the same stream. Various conditions are often negiotiated during project planning.

Industrial Energy Recovery

Energy generated during industrial processes can be captured and reused, or shared with nearby buildings.



for municipality labels see page 3.0

could heat up to

7,500

typical households

costs are variable, many technologies generate revenue

Issues to Consider

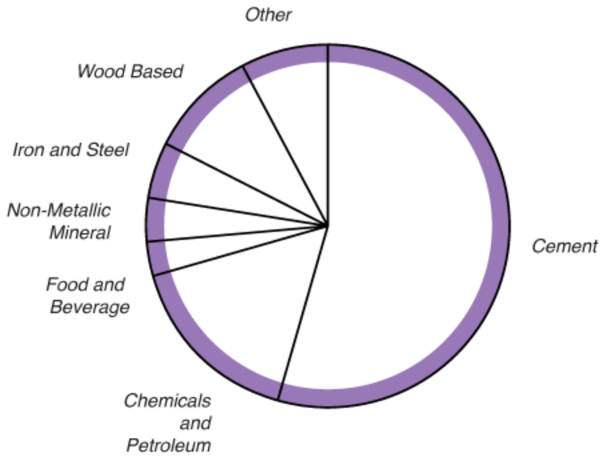
- Air Quality
- Longterm Viability
- Siting & Infrastructure

see over

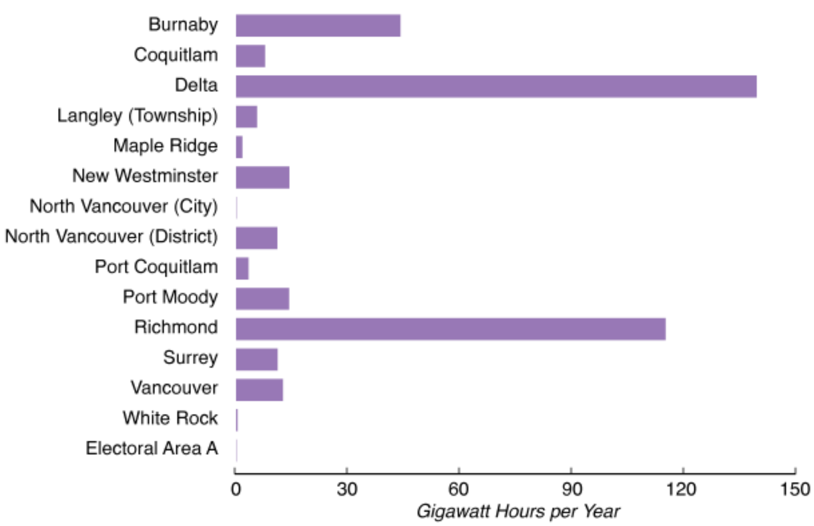
3.3b ...More Information

Source: University of British Columbia
Industrial heat recovery was assessed using major gas consuming industries in Metro Vancouver and their associated NAICS class as a reference for published heat recovery factors.

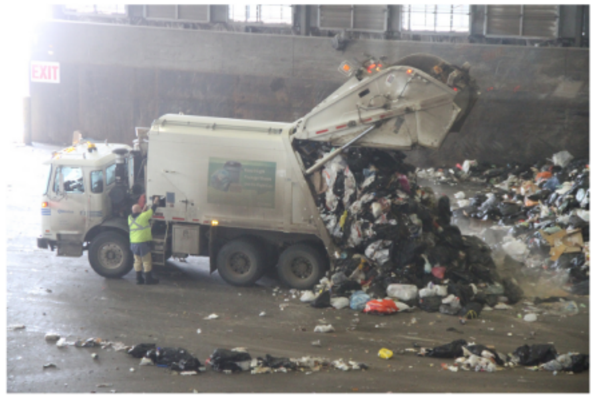
Potential Regional Heat Recovery by Industry



Potential Heat Recovery by Municipality



Local Example



Metro Vancouver's Waste-to-Energy Facility

In 1988 Metro Vancouver installed a Waste-to-Energy Facility in Burnaby, BC. The facility takes 25% of the region's garbage (285,000 tonnes) and turns it into heat and electricity.

The energy provided from the facility generates enough energy to power 16,000 households.

Since the incoming garbage is burned to produce energy, its volume is reduced by more than 75%. Much of this waste can then be recycled or reused, resulting in a total of about 4% of the initial volume of garbage ending up in a landfill.

Note: Additional waste-to-energy facilities were not considered in the estimate of industrial recovery potential.

Air Quality

Recovering waste heat has little to no air quality impacts. Converting waste to electricity requires burning, but modern technologies remove most of the pollutants before they enter the atmosphere.

Longterm Viability

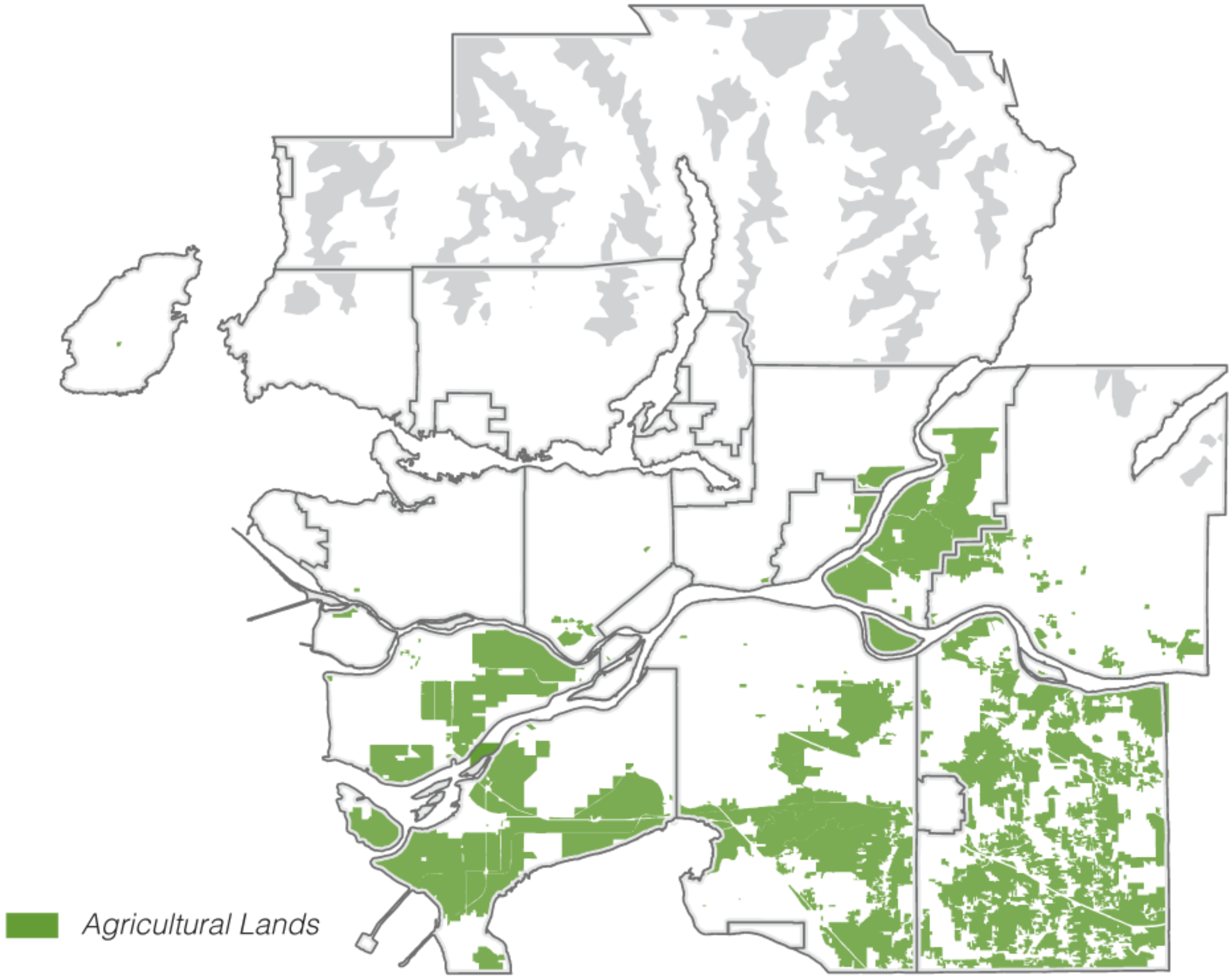
The implementation of energy technologies that use waste heat or waste materials must consider potentially competing waste reduction initiatives that may limit the availability of waste fuels over long periods of time.

Siting & Infrastructure

Delivering waste industrial heat to buildings requires the construction of new infrastructure such as underground pipes. Since heat dissipates quickly, the proximity of the buildings to the industrial heat source must also be considered.

Livestock Biogas

The energy contained in animal waste can be harnessed and burned to produce heat or electricity.



for municipality labels see page 3.0

could heat up to
3,500
typical households

or

could power up to
17,000
typical households

costs range between
15 - 50 ¢
per kWh

Issues to Consider

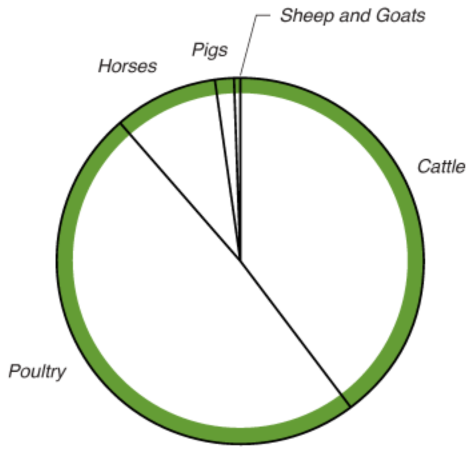
- Methane
- Longterm Viability
- Infrastructure

see over

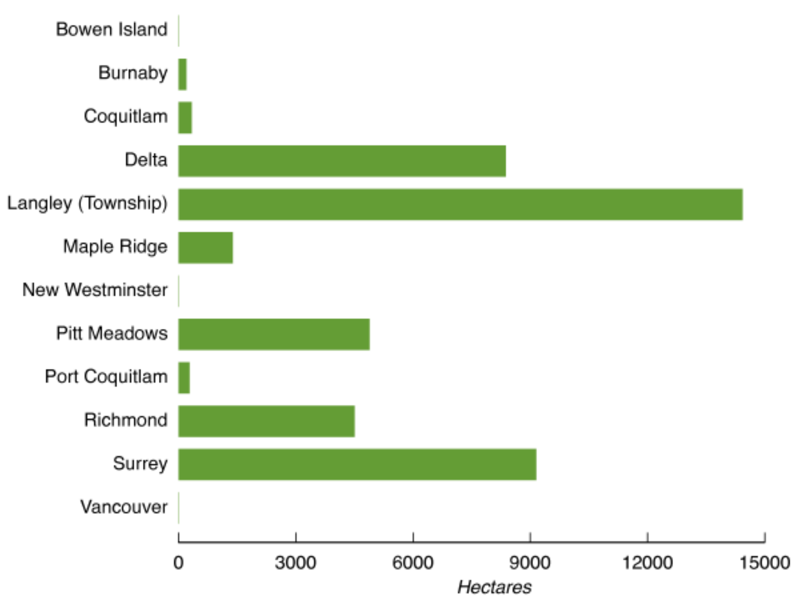
3.4b ...More Information

Source: University of British Columbia
Livestock biogas energy was assessed using livestock headcounts from the Canadian Agricultural Census with published manure mass and methane recovery factors by livestock type.

Biogas by Livestock Type



Agriculture Land by Municipality



Local Example

Bakerview EcoDairy's Anaerobic Digester

In 2011 Bakerview EcoDairy in Abbotsford, BC installed a small-scale on-farm anaerobic digester that converts cow manure into electricity. The digester can generate 60,000 kWh of electricity per year, enough to power more than 5 typical households in Metro Vancouver.

In addition to the electricity that the digester generates, the system also provides heat, fertilizer and cow bedding for use on the farm.

Further benefits of the digester include reductions of water pollution, odours and methane emissions (a potent greenhouse gas).

Methane

Livestock manure contains high amounts of methane, a greenhouse gas with over 20 times the warming potential of CO_2. By capturing the methane from manure and burning it produce it energy, global warming impacts can be reduced, since the methane is converted to CO_2 before being released to the atmosphere.

Longterm Viability

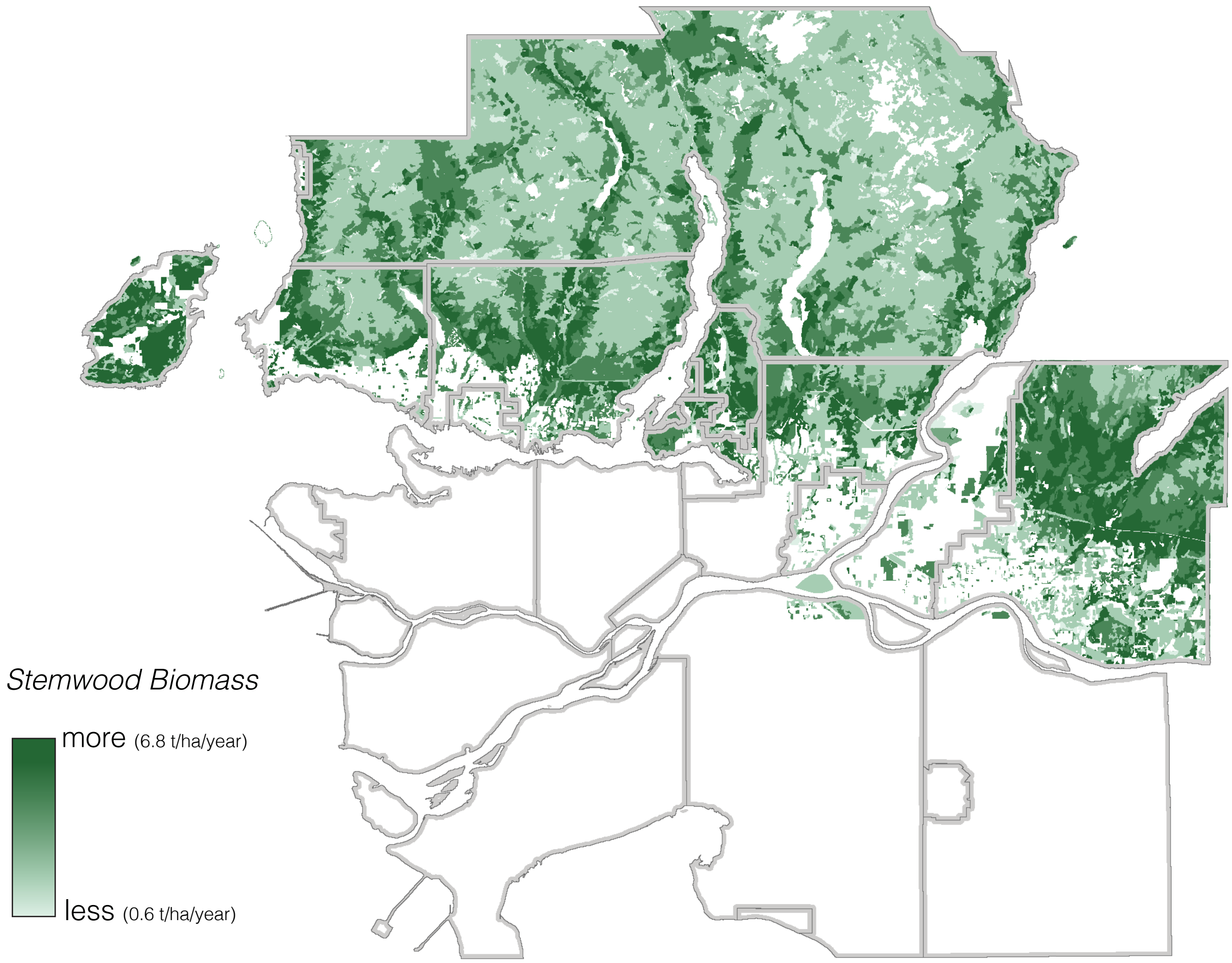
The implementation of energy technologies that use animal waste must consider future changes to agricultural lands and livestock husbandry to ensure an adequate availability of manure fuels.

Infrastructure

Generating and delivering gas and electricity from livestock wastes requires consideration of new transmission infrastructure such as underground pipes and electric lines, as well as transportation of manure to the energy generating or processing facility.

Sustainable Forest Biomass

Sustainably harvested forest biomass can be used as a fuel for generating heat or electricity.



for municipality labels see page 3.0

could heat up to
24,000
typical households

or

could power up to
26,000
typical households

costs range between
6 - 14 ¢
per kWh

Issues to Consider

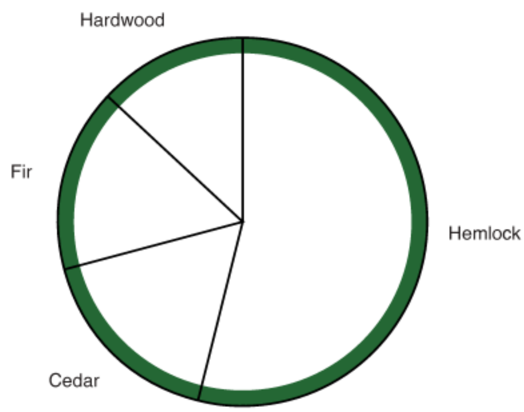
- Protected Areas
- Views
- Sustainable Harvests

see over

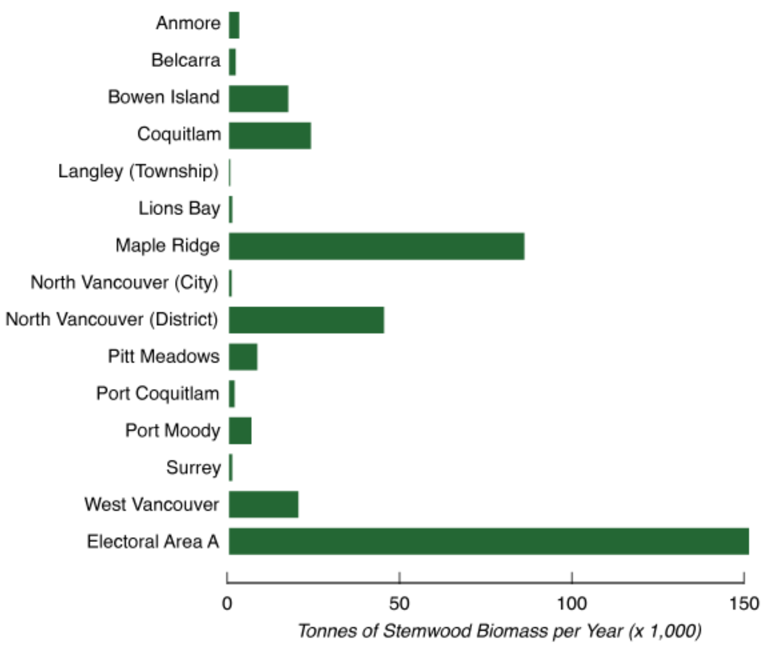
3.5b ...More Information

Source: University of British Columbia
Sustainable forest biomass was assessed using the FORECAST model. A selection harvest of stemwood on a 50 year rotation was selected to maintain the quality of the existing forests.

Regional Biomass by Tree Types



Potential Forest Biomass by Municipality



Local Example

University of British Columbia's Biomass Power Plant

In 2012 the University of British Columbia installed a biomass power plant that uses waste wood from regional sawmills to produce heat and electricity.

The plant can produce enough electricity to power over 1,500 households. The heat from the plant is used to provide thermal energy to nearby buildings on the university campus, reducing UBC's natural gas consumption by 12%.

Other biomass sources used to run biomass plants could be gathered from park trimmings, fire fuel removal, wood wastes from logging activities, clean construction wastes and stemwood from fast-growing plantations.

Protected Areas

Much of the potential timber in Metro Vancouver is located in protected areas, designated as watersheds for drinking water or recreational areas. This raises key policy and public acceptance issues.

Views

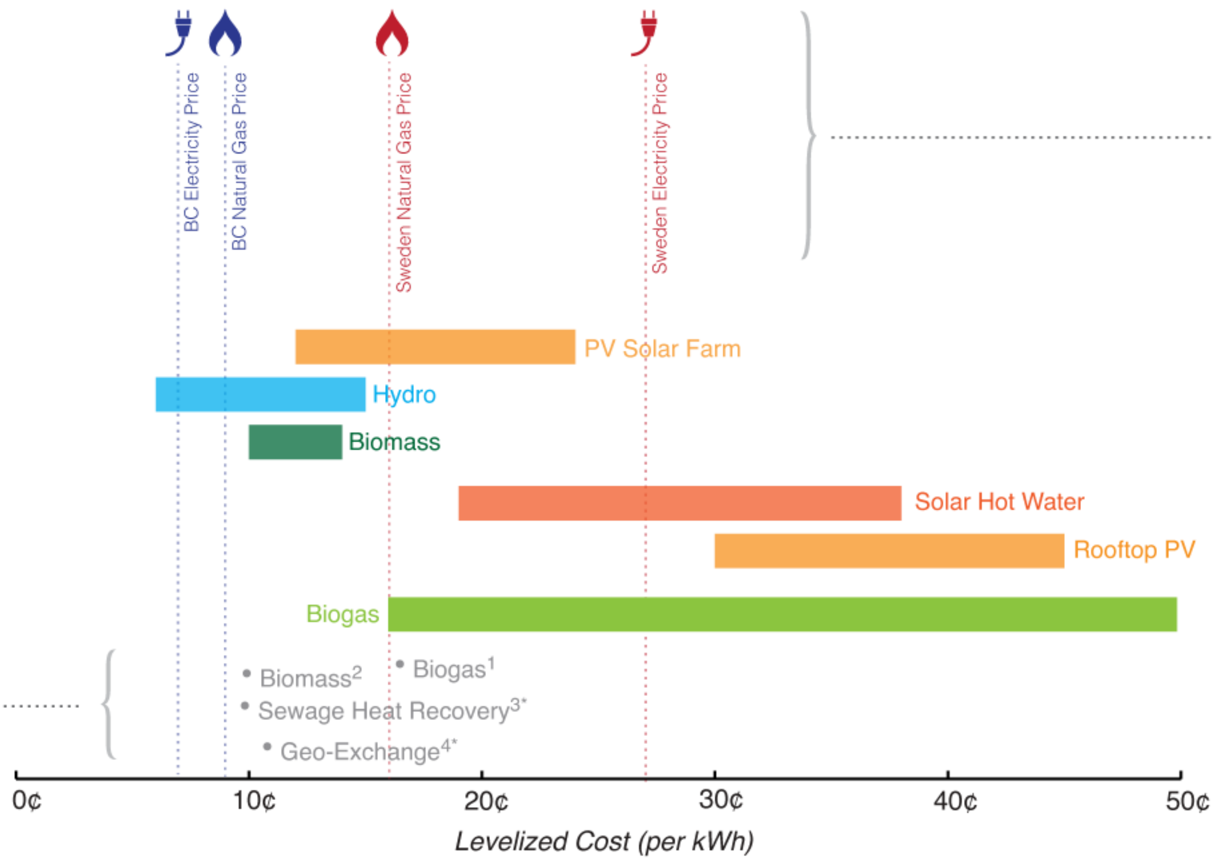
Harvesting trees to provide biomass energy resources could have an impact on the view of forests in Metro Vancouver. However, partial cutting techniques and good design can mimize these visual impacts.

Sustainable Harvests

Harvesting can be designed to maintain soil quality and carbon, local habitats and ecosystem services. The assessment of biomass here assumes selection harvesting of stemwood on a 50 year rotation, which could be coordinated with fire protection strategies.

Energy Costing

The Levelized Cost of Energy estimates technology lifetime costs including capital, labour and financing, relative to the total energy they will generate.



Local Examples

1 In 2011 **Bakerview EcoDairy** in Abbotsford, BC installed an anaerobic digester to convert cow manure into electricity.

2 In 2012 the **University of British Columbia** installed a biomass power plant that uses clean wood waste from regional sawmills to produce heat and electricity.

3* The **South-East False Creek** neighbourhood utility in Vancouver recovers heat from sewage, which is used to provide hot water to local residents.

4* The **PCI Marine Gateway** neighbourhood utility has been proposed to provide heating and cooling for residents of the Marine Gateway Development in Vancouver. The system will heat and cool buildings using a closed-loop geo-exchange system (with natural gas backup).

** Utility rate used as cost*

Pricing Energy & Carbon

The price paid for energy in British Columbia reflects technology installed long ago, such as our hydroelectric dams. Various policies including our carbon tax and clean energy requirement also affect energy prices.

Aging infrastructure and new procurement to meet increased demand will require that we pay more for our electricity.

Although natural gas prices are currently low in North America, they are likely to increase and adding a price to carbon emissions in order to account for the costs of global warming will impact gas prices.

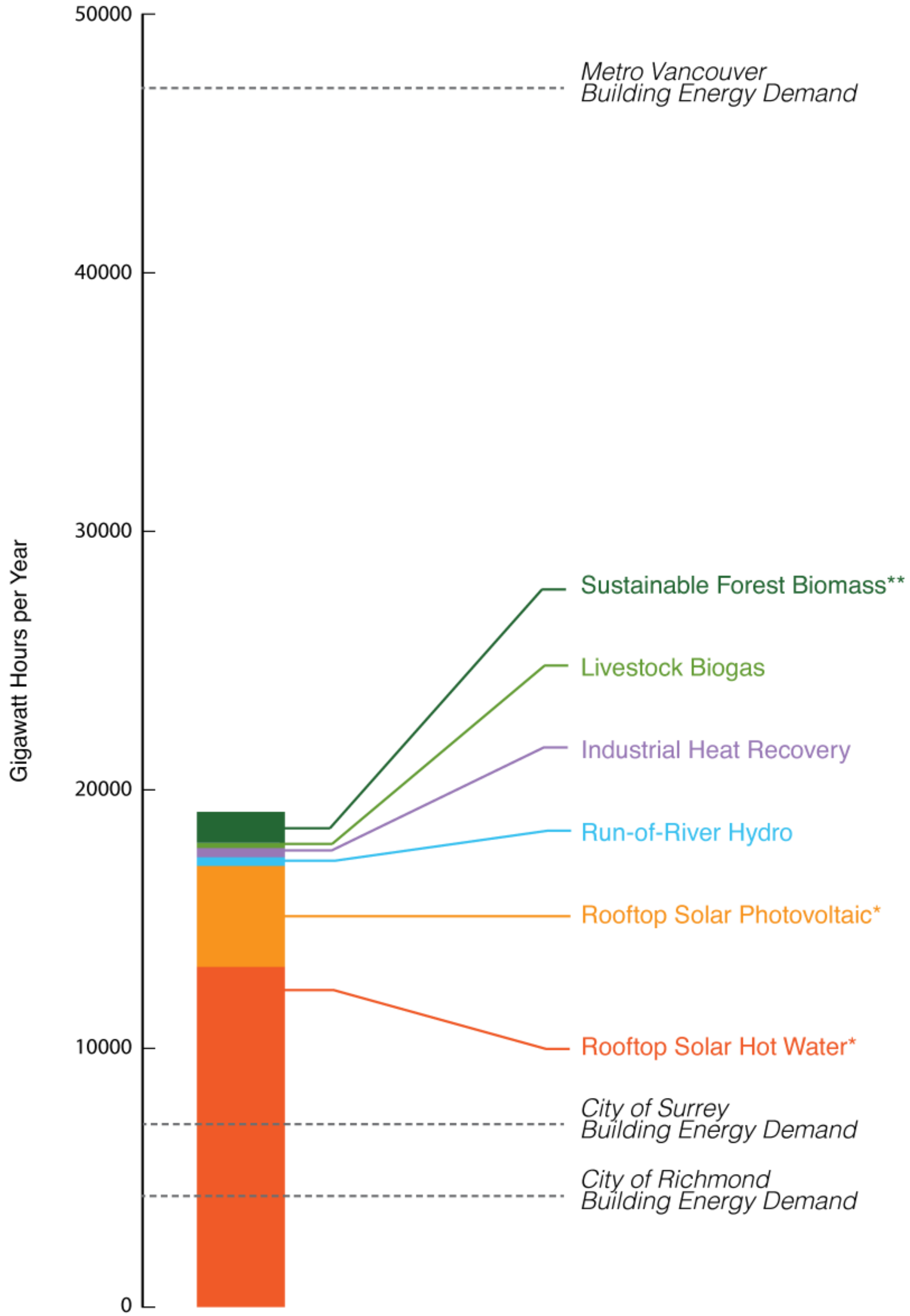
British Columbia currently has a carbon tax of $30 per ton. In comparison, Sweden, with a similar climate, hydroelectric infrastructure and biomass resource pays $150 per ton.

Since Sweden implemented its carbon tax in 1991, carbon emissions have gone down but their economy has grown more than 50%.

3.6b

Energy Resources Compared

The graph below compares the assessed sustainable energy resources in Metro Vancouver (bars) against building energy demand (lines)



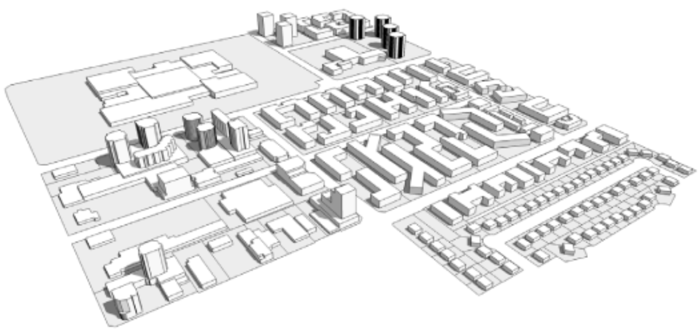
* Rooftop solar assessment makes a simple assumption that of half of south facing roof space is used for photovoltaic and the other half for solar hot water

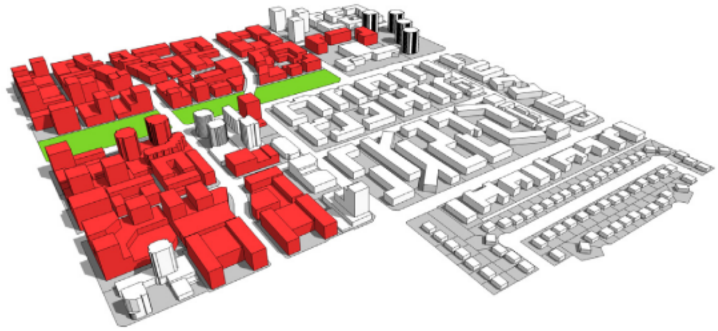
** Biomass potential considers heat energy. Electrical energy would be about 290 Gigawatt Hours per Year

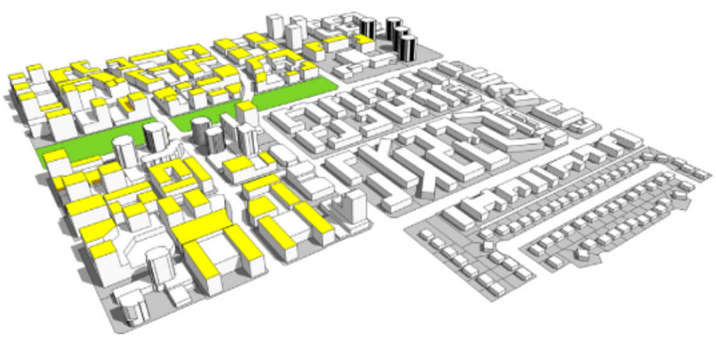
Section 4 - Urban Neighbourhood Energy Scenarios 4.0

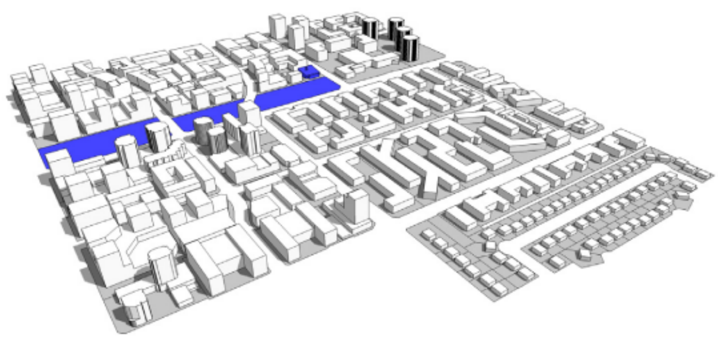
Richmond Case Study

This Case Study explores some generic options for reducing energy consumption and greenhouse gas emissions in a neighbourhood redevelopment situation such as Lansdowne Mall in Richmond BC.









How can a city centre neighbourhood transition to a community that uses less energy and supplies most of its energy from local renewable sources?

Location of study site, Richmond, BC.

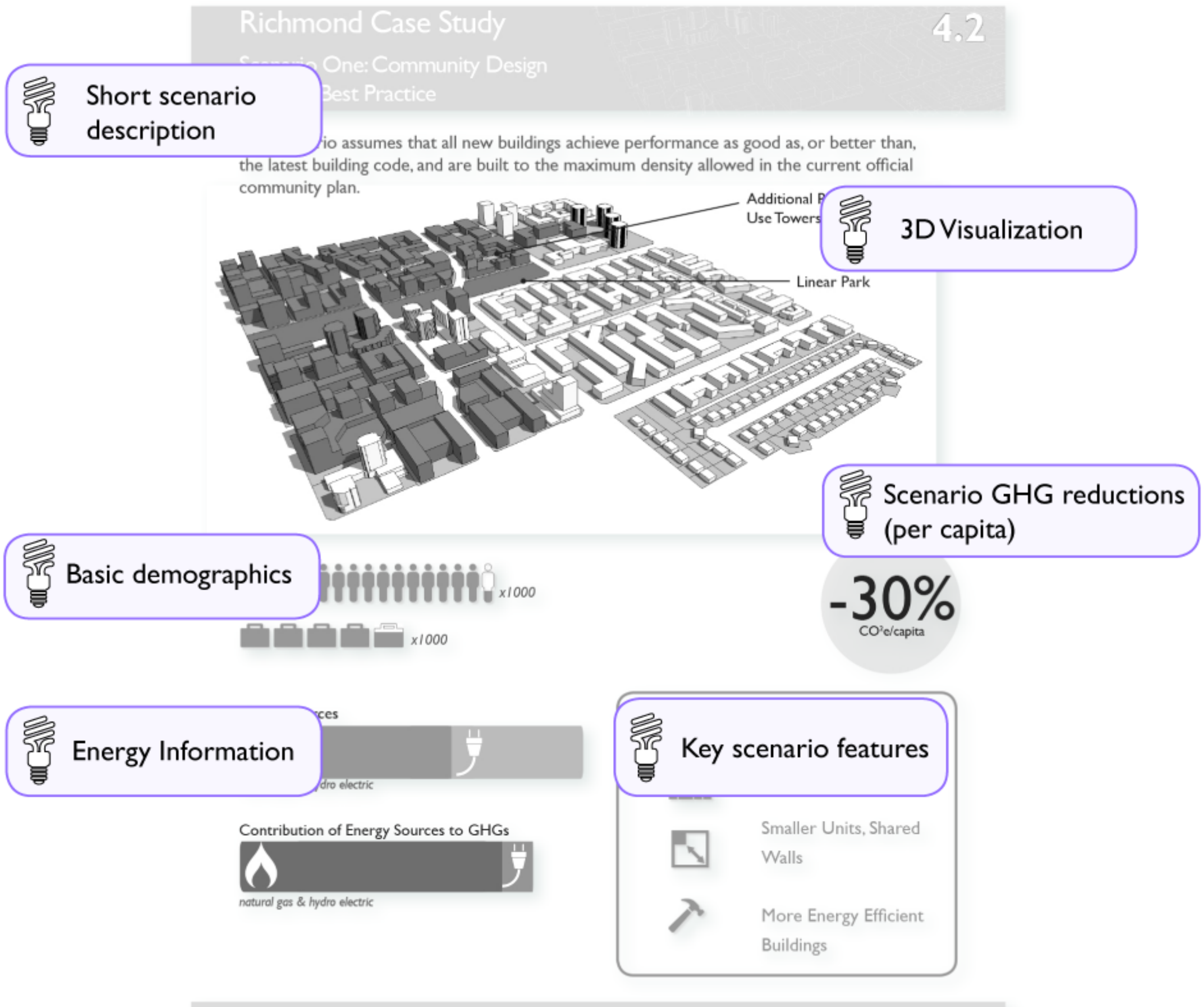
Scenarios:

Existing Conditions	**0.77** CO_2eT/person/yr
Current Best Practice	**-30%** per capita residential GHG
+ Building-Level Renewables (Solar)	**-38%** per capita residential GHG
+ Shared Energy	**-72%** per capita residential GHG

Per capita greenhouse gas reductions estimated for the scenarios based on energy modelling by UBC.

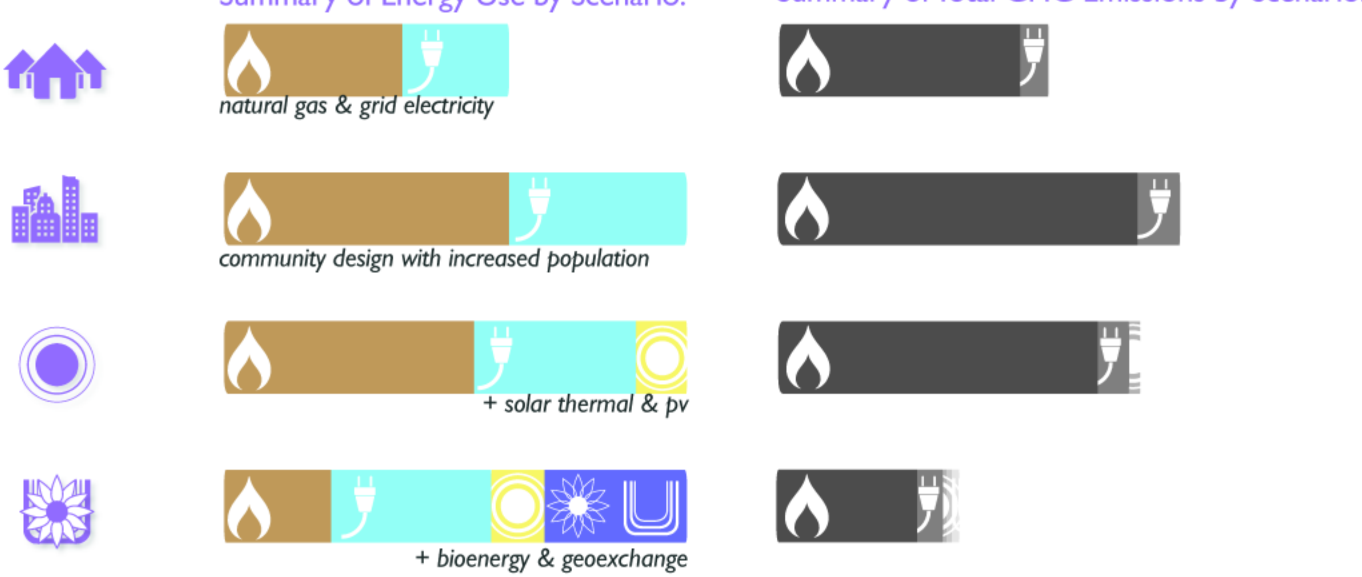
4.0b How to Use this Section

Outlined below is a general description of the layout of this chapter and how to explore the information.



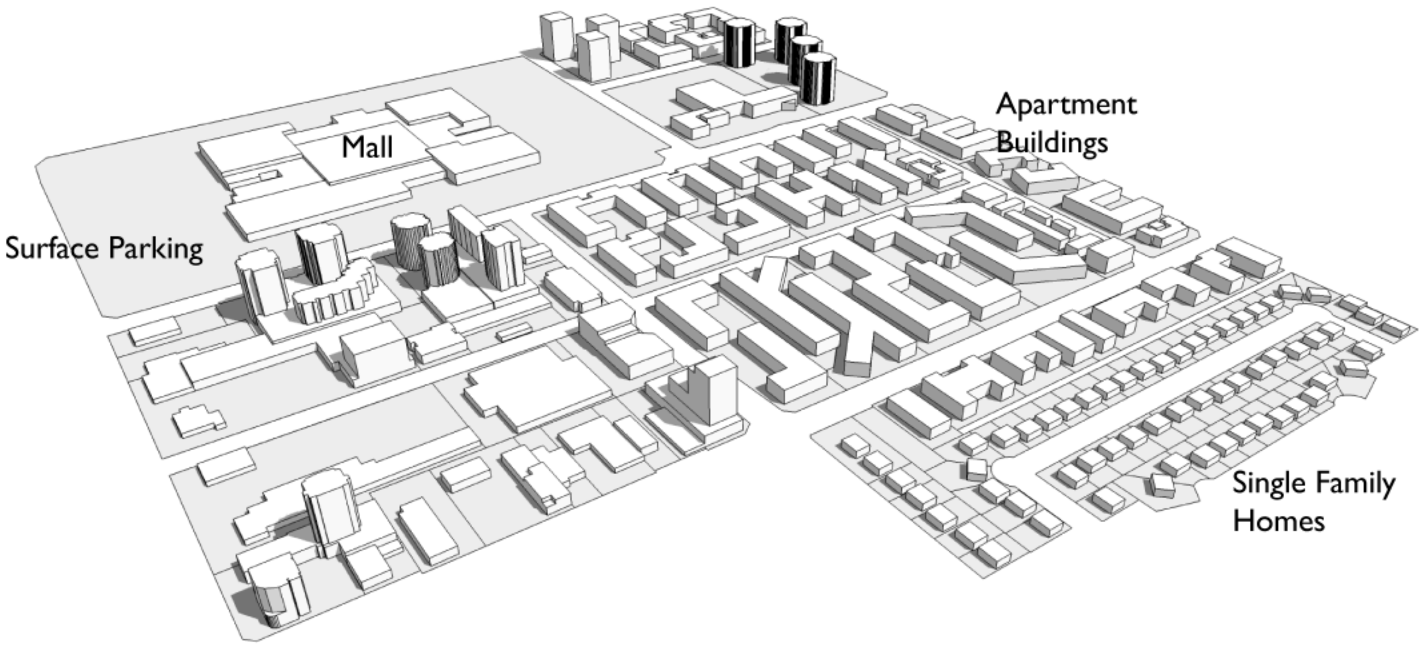
Summary of Energy Use by Scenario:

Summary of Total GHG Emissions by Scenario:



Richmond Case Study

Existing Conditions



Population
x1000

Jobs
x1000

0.77
CO_2eT/person

Energy Sources

natural gas & grid electricity

Contribution of Energy Sources to GHGs

natural gas & grid electricity

Existing Conditions:

- Extensive Surface Parking
- Low Density
- Many Buildings with Low Energy Efficiency

4.1b Richmond Case Study

Current Conditions

This neighbourhood is centred around an existing mall with large surface parking lots. Residential density is relatively low for an urban neighbourhood, and existing buildings are not energy efficient.

Total Residential Energy Consumption

164,000 GJ/yr

108,000 GJ/yr + 56,000GJ/yr

Total Residential Greenhouse Gas Emissions

5,900 tonnes CO_2e

Existing Conditions:

Extensive Surface Parking
Large surface parking lots do not provide any energy benefits and contribute to heating the neighbourhood in the summer.

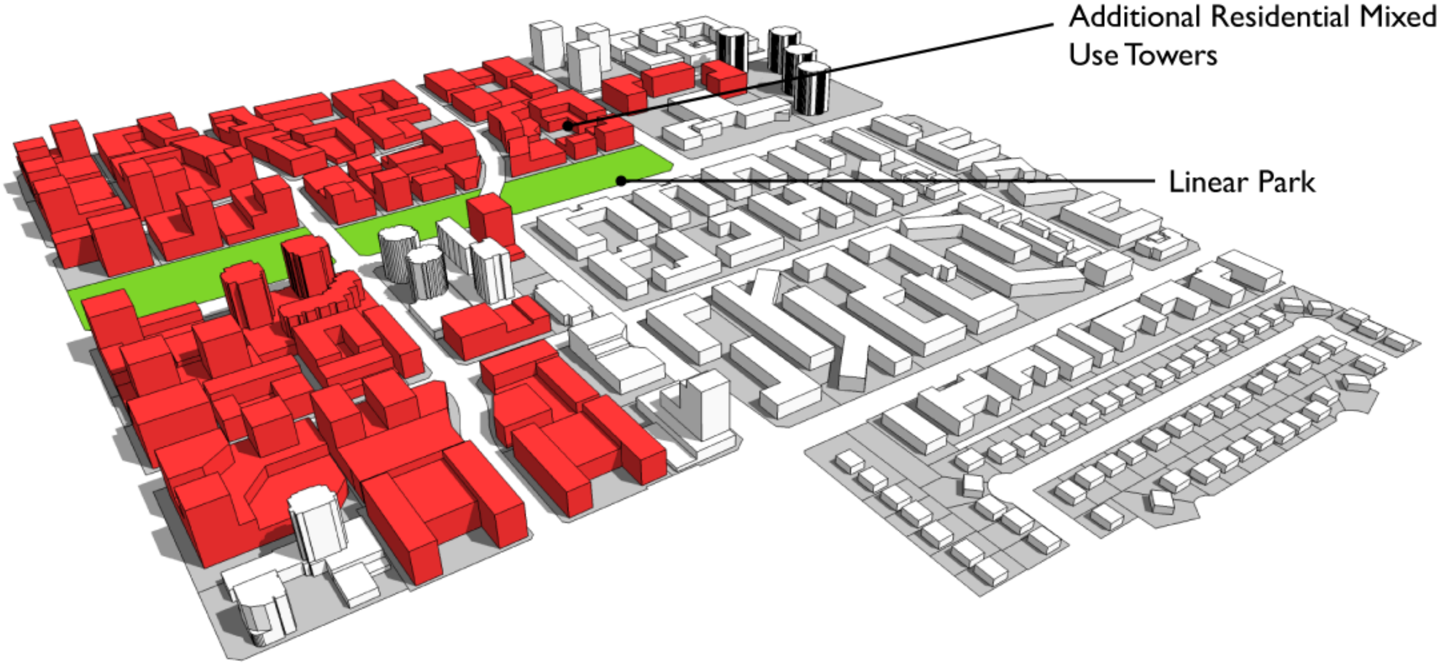
Low Density
The area has low residential density compared to other urban areas in Richmond.

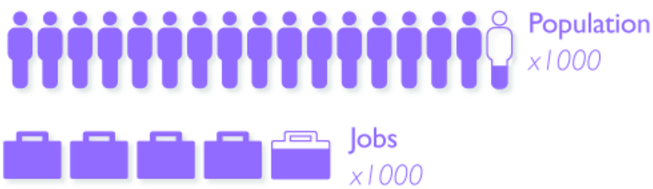
Many Buildings with Low Energy Efficiency
Many buildings are older with less insulation, lower efficiency furnaces and windows.

Richmond Case Study

Scenario 1: Community Design Current Best Practice

This scenario assumes that all new buildings achieve performance equal to the latest building code, and are built to the maximum density allowed in the current official community plan.





Scenario 1 Key Moves:

- Add Buildings
- Smaller Units, Shared Walls
- More Energy Efficient Buildings

Energy Sources

natural gas & grid electricity

Contribution of Energy Sources to GHGs

natural gas & grid electricity

4.2b Richmond Case Study

Scenario 1: Community Design

This neighbourhood develops to become compact and complete, with extensive mid-rise mixed use buildings complemented by a new large park. More jobs locate within the neighbourhood, and it is more walkable for residents. All of these changes greatly reduce per capita carbon emissions.

0.54
CO_2eT/person

Total Residential Energy Consumption

256,000 GJ/yr

160,000 GJ/yr + 96,000GJ/yr

Total Residential Greenhouse Gas Emissions

8,800 tonnes CO_2e

Scenario 1 Key Moves:

Add Buildings
Under utilized land is developed at the maximum allowed density.

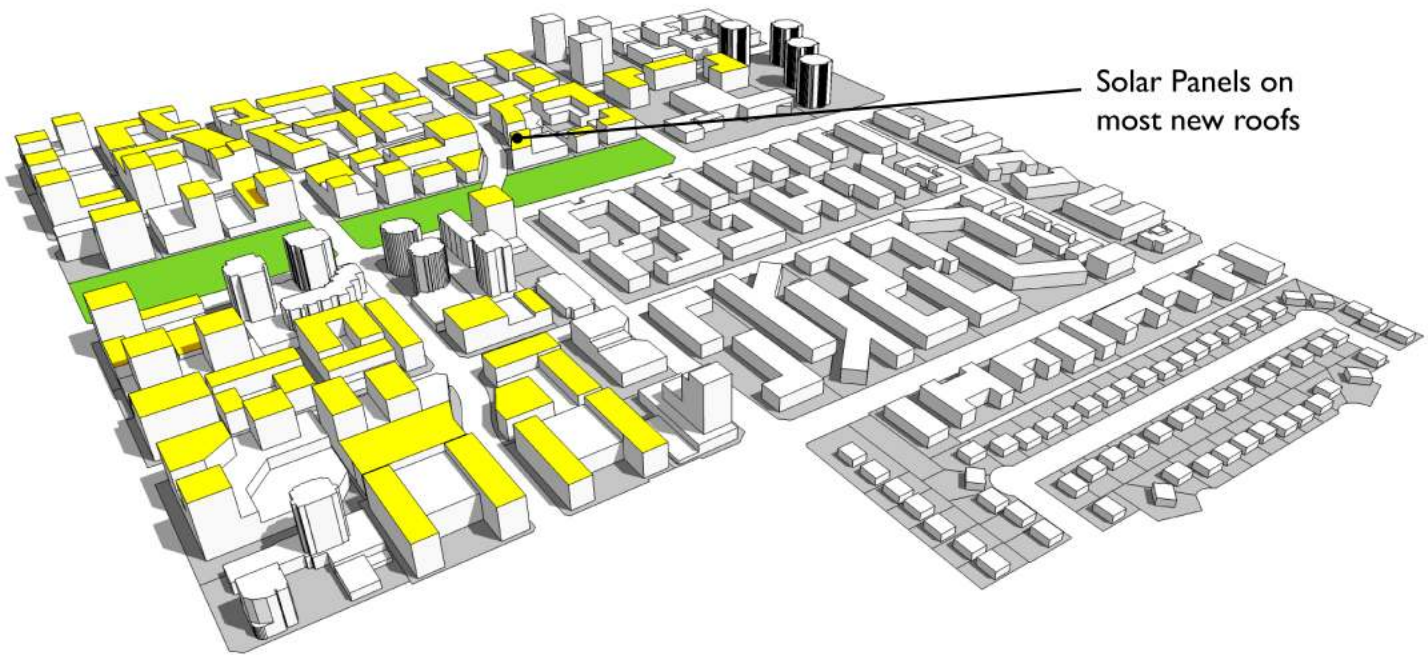
Smaller units, shared walls
New units are in highrise buildings and are smaller on average than current units in the study area.

More efficient buildings
New buildings achieve more energy efficient building standards, such as ASHRAE 90.1

Richmond Case Study

Scenario 2: Building-level Renewables

This scenario shows the opportunity for individual buildings to supply renewable energy. Solar energy technologies were selected because of the amount of available roof space.



Population
x1000

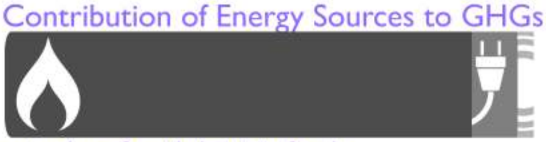
Jobs
x1000

-38%
CO_2e/capita

Energy Sources

natural gas & grid electricity & solar

Contribution of Energy Sources to GHGs



natural gas & grid electricity & solar

Scenario 2 Key Moves:

- Add Rooftop Solar
- 50% Solar Hot Water
- 50% Photovoltaic

4.3b Richmond Case Study

Scenario 2: Building-level Renewables

Solar panels can be integrated with the design of new buildings to reduce visual impact from ground-level and minimize shading from nearby buildings. Using solar energy further reduces per capita carbon emissions.

0.48
CO_2eT/person

Total Residential Energy Consumption

256,000 GJ/yr

141,000 GJ/yr + 92,000GJ/yr + 22,000GJ/yr

Total Residential Greenhouse Gas Emissions

7,800 tonnes CO_2e

Scenario 2 Key Moves:

Rooftop Solar
Solar panels cover 90% of all new roofs, which is 25% of the roof space of the study area

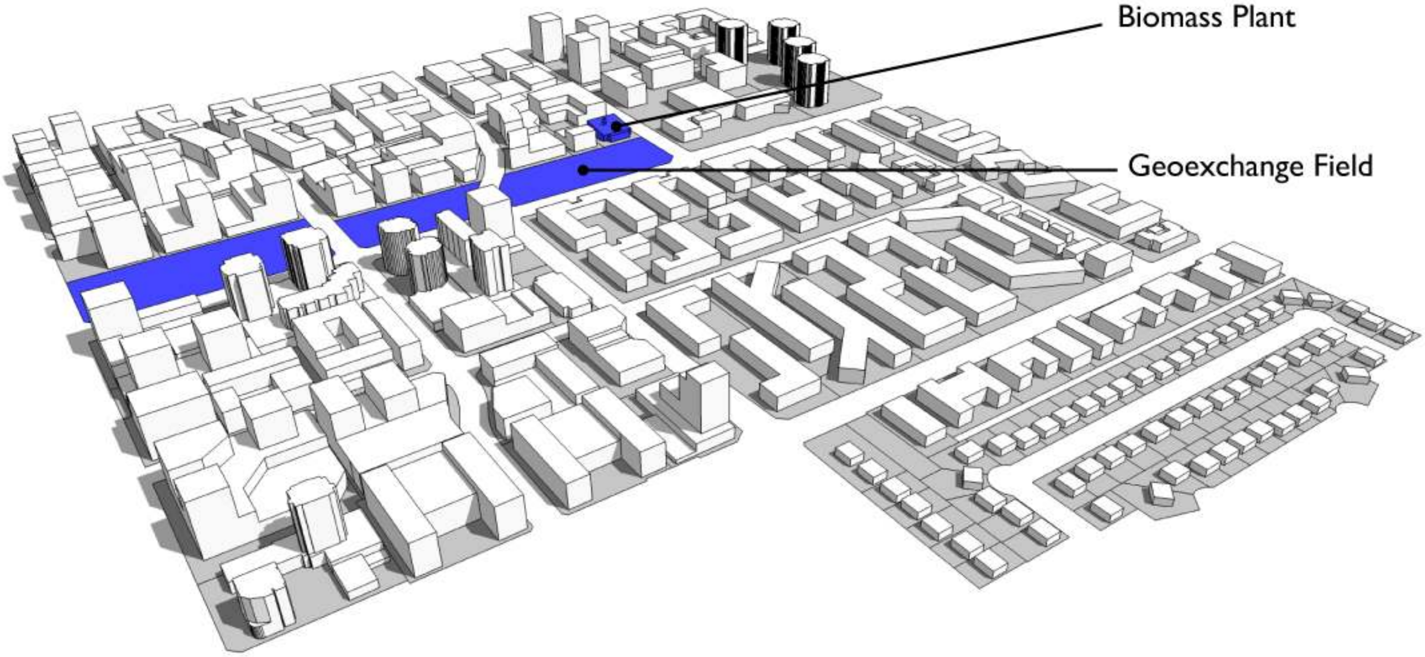
50% Solar Hot Water
Solar thermal produces 18,000 gigajoules per year

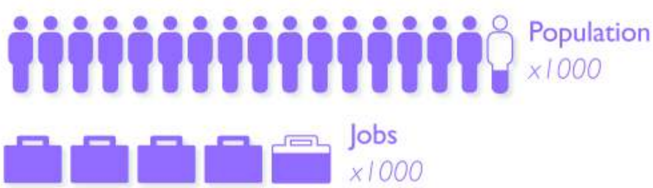
50% Photovoltaic
Solar photovoltaic produces 4,600 gigajoules per year

Richmond Case Study

Scenario 3: Shared Energy

This scenario shows the opportunity for community renewable energy systems. Geoexchange locates in the linear park, and a bioenergy district energy plant locates within the community.





Energy Sources

natural gas & grid electricity & solar & bioenergy & geoexchange

Contribution of Energy Sources to GHGs

natural gas & grid electricity & solar & bioenergy & geoexchange

Scenario 3 Key Moves:

Geoexchange added

Biomass Plant added

4.4b Richmond Case Study

Scenario 3: Community Options

Geoexchange is located underground and out of sight in the linear park. A bioenergy plant is located within the community on a major street for access and can be integrated with surrounding building design. This scenario greatly reduces per capita and total carbon emissions.

0.21
CO_2eT/person

Total Residential Energy Consumption

256,000 GJ/yr

56,000 GJ/yr + 92,000 GJ/yr + 22,000 GJ/yr + 40,000 GJ/yr + 43,000 GJ/yr

Total Residential Greenhouse Gas Emissions

3,400 tonnes CO_2e

Scenario 3 Key Moves:

Geoexchange
The geoexchange provides 76,000 GJ of energy per year, half of which goes to residential uses.

Biomass Plant
The biomass plant provides 85000 GJ of energy per year, half of which goes to residential uses

Section 5 - Suburban Block Energy Scenarios

Surrey Case Study

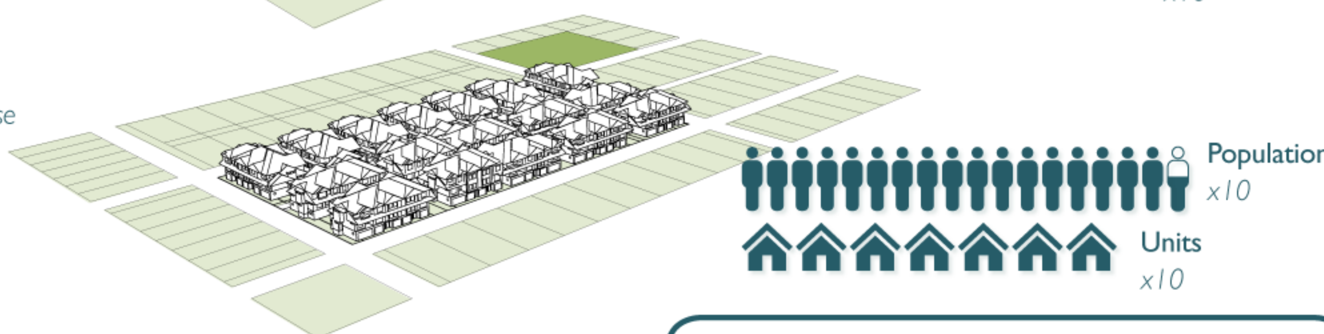
This case study explores reducing energy consumption and greenhouse gas emissions using different community designs and addition of renewable energy resources for a residential block in Surrey BC.

Housing Types

Large lot single family

Small lot single family

Rowhouse



The same block is compared using three different housing types. Each housing type is modeled to determine its current energy use and greenhouse gas emissions. Feasible renewable technologies are then modeled for each housing type to determine their potential energy supply and greenhouse gas emissions reductions:

- solar for roofs which are solar ready
- geoexchange and district energy in nearby parks or rights-of-way.

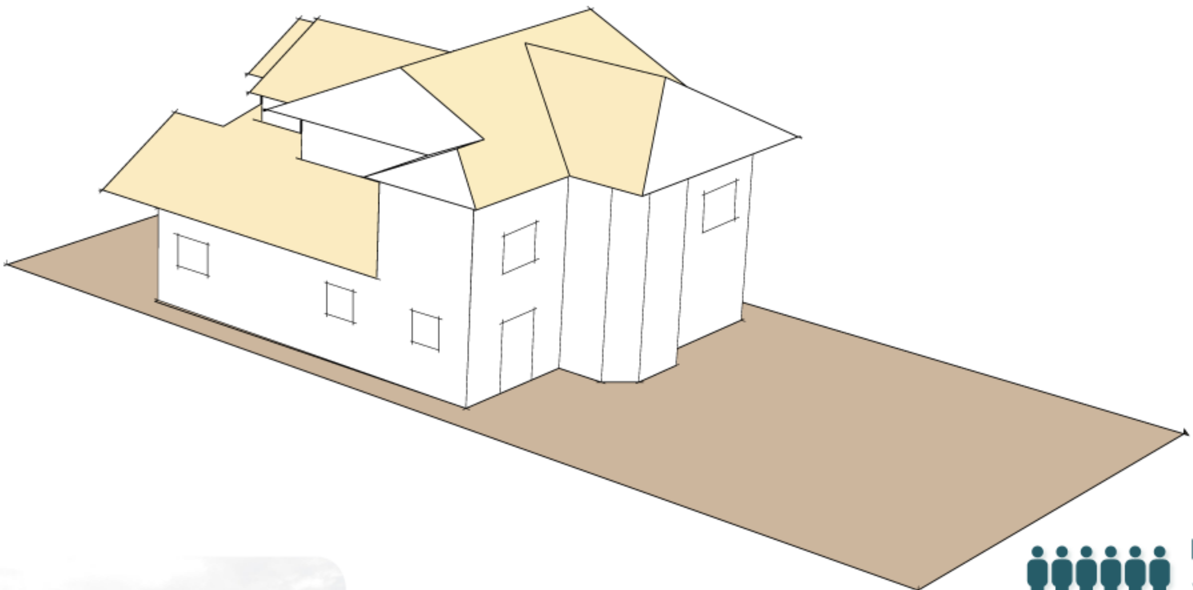
Three housing types:

- Large Lot Single Family
- Small Lot Single Family
- Rowhouse

5.1 Surrey Case Study

Large Lot Single Family

A typical large lot single family home in Surrey could reduce its reliance on external energy sources by incorporating solar photovoltaic and solar hot water panels.



Population
x10

Units
x10

105 *GJ/household/yr*

2,200 *GJ/block/yr*

Greenhouse Gas Emissions

Current Emissions

0.98
CO_2eT/capita/year

Emissions with Solar Panels

0.67
CO_2eT/capita/year

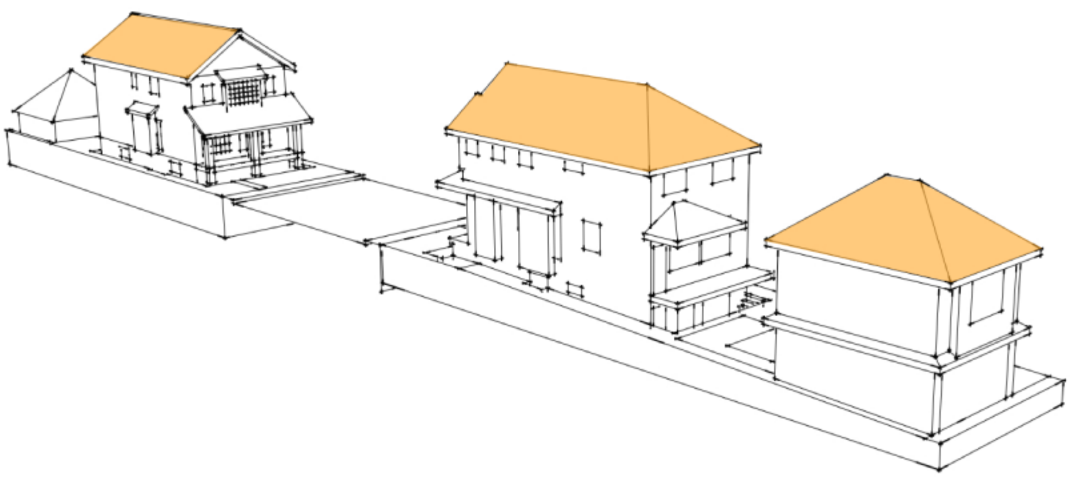
32%
reduction

Issues to Consider:

- Roof Design + Area for Solar
- No Shared Walls
- Large Building Size for Space Heating

Surrey Case Study
Small Lot Single Family

A typical small lot single family home could reduce its reliance on external energy sources by incorporating solar photovoltaic and hot water panels and a community geoexchange system.



Population x10

Units x10

67 *GJ/household/yr*

4,000 *GJ/block/yr*

Greenhouse Gas Emissions

Current Emissions

0.80 CO_2eT/capita/year

Emissions with Solar Panels

0.27 CO_2eT/capita/year

58% reduction

Emissions with Solar Panels + Geoexchange

0.09 CO_2eT/capita/year

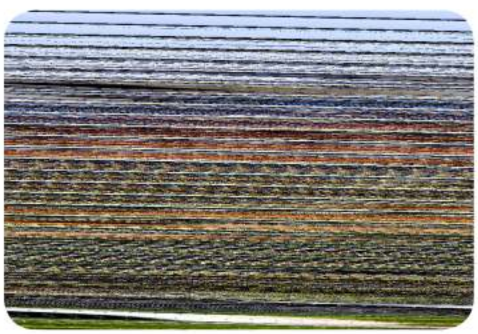
89% reduction

Issues to Consider:

- Roof Design + Area for Solar
- Smaller Buildings + Suites
- Adequate Density to Support Shared Geoexchange System

5.3 Surrey Case Study
Rowhouse

A typical rowhouse in Surrey could reduce its reliance on external energy sources by incorporating solar photovoltaic and hot water panels and connecting to a community geoexchange system.



87 *GJ/household/yr*

6,000 *GJ/block/yr*

Greenhouse Gas Emissions

Current Emissions

0.75 CO_2eT/capita/year

Emissions with Solar Panels

0.32 CO_2eT/capita/year

58% reduction

Emissions with Solar Panels + Geoexchange

0.09 CO_2eT/capita/year

88% reduction

Issues to Consider:

- More Shared Walls
- Roof Design & Area for Solar
- Adequate Density to Support Shared Geoexchange System

Surrey Case Study

Housing types compared

Housing Type | Energy Supply | Greenhouse Gas Emissions

Large lot single family

block population 60

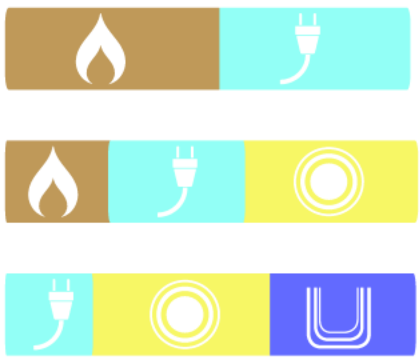
0.98 tonnes CO_2e/capita/year

32% reduction

40.2 *tonnes CO^2e/block/year*

Small lot single family

block population 135



0.80 tonnes CO_2e/capita/year

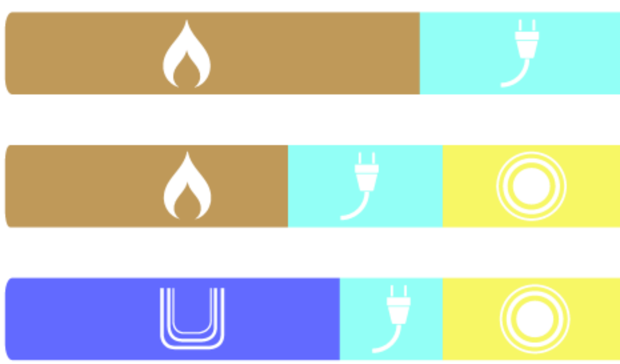
58% reduction

89% reduction

12.2 *tonnes CO^2e/block/year*

Rowhouse

block population 175



0.75 tonnes CO_2e/capita/year

58% reduction

88% reduction

15.8 *tonnes CO^2e/block/year*

These scenarios show that:

- Large lot single family homes are much less energy efficient than smaller homes and higher density neighbourhoods.
- Per capita carbon emissions are lowest with rowhouse designs
- Solar energy can substantially reduce carbon emissions with all building types,
- Shared energy systems such as geoexchange can almost eliminate carbon emissions (both per capita and total) with higher density community designs, sufficient to meet BC's community-wide GHG emission reduction targets.

6.0 Links and Resources

Where does the guide go next?

If the possibilities visualized here for community energy are to be realized, co-operation between various levels of government, citizens and businesses will be required. Important issues such as the economics of renewable energy installation and home retrofitting, and the feasibility of developing local energy resources, need more analysis and policy development. The next version of the Guide will address some of these issues, as well as other renewable energy sources not yet covered. It will also go online to become more accessible and interactive, as the **iWISE (interactive Web-Interface for Sustainability Energy)** project. This will give municipalities, neighbourhoods, and citizens more visual learning tools with which to explore, animate and query regional energy information, as well as more visualization examples for practitioners to use in community engagement and planning on energy projects.

Links and Resources:

General website resources:

- Community Energy Association | http://www.communityenergy.bc.ca
- Livesmart BC | http://www.livesmartbc.ca
- Fraser Basin Council | http://www.fraserbasin.bc.ca/spc_home.html
- Climate Action Secretariat (CEEI) | http://www.env.gov.bc.ca/cas/mitigation/ceei/
- BC Hydro | http://www.bchydro.com/powersmart/local_government_district.html
- Collaborative for Advanced Landscape Planning (CALP) | http://calp.forestry.ubc.ca/
- ElementsDB | http://elementsdb.sala.ubc.ca/

Community energy references:

- The Rough Guide to Community Energy. Clark, D. & M. Chadwick (2011) Rough Guides Ltd., UK. http://www.roughguide.to/communityenergy/
- Sustainable Energy – Without the Hot Air. MacKay, D.J.C. (2009) UIT Cambridge, UK. http://www.inference.phy.cam.ac.uk/sustainable/book/tex/cft.pdfv

Community engagement references:

- Having the Climate Conversation. ICLEI (2012) Canada http://www.icleicanada.org/programs/adaptation/item/4-having-the-climate-conversation
- Local Climate Change Visioning and Landscape Visualizations: Guidance Manual. (Pond, E., et al. 2010) UBC http://calp.forestry.ubc.ca/viz-guidance-manual/
- Visualizing Climate Change: A Guide to Visual Communication of Climate Change and Developing Local Solutions. Sheppard, S.R.J. (2012) Routledge, UK. http://www.routledge.com/books/details/9781844078202/

Conclusion and Next Steps

6.1

What should I know about community energy?

This Guide has tried to explain what Community Energy means, what it looks like, and why we should care about it, including:

- its importance in reducing our dependency on fossil fuel supplies that contribute to global warming
- improving local energy security and reducing longterm energy costs
- enhancing quality of life
- meeting adopted municipal sustainability targets
- sharing the responsibilities of energy production, benefits and costs locally

Every community in BC needs to do its share if we are to transition to a safer, more sustainable future.

What can I do in my community?

- Use the Guide and its compelling graphics to help build energy literacy among your own family, friends, and neighbours. Talk about what it might mean to your neighbourhood if you worked together (see the Eagle Island story on page 2.2b).
- Get involved in the urgent decisions to be made on local energy issues that will affect you and your kids. Take part in an informed dialogue within neighbourhood, municipal, and regional planning processes.
- Give us feedback on the guide:

  Email: Rory Tooke, Project Manager | *trtooke@alumni.ubc.ca*

  Web: Guide Blog | *www.guidetocommunityenergy.com*

Clean Technologies

A wide range of technologies are available to produce energy or to help reduce its use.

GENERATION

SOLAR
Concentrating Solar Thermal
★☆ Photovoltaic
★☆ Domestic Hot Water

HYDRO
Storage Hydro
★ Run-of-River Hydro
Pico Hydro

BIOMASS
★ Timber
Crop
★ Manure

WASTE
★ Industrial Recovery
Waste-to-Energy
Sewage Heat Recovery

GEOTHERMAL
Natural Convection Systems
Enhanced Geothermal Systems

ACTIVE HEAT TRANSFER
☆ Ground-Source
Air-Source
Water-Source

WIND
Turbine

OCEAN
Tidal
Wave
Current
Thermal
Osmotic

NUCLEAR

CONSERVATION

BUILDING MATERIALS
Insulation
Windows
Ventilation

ENERGY DEVICES
Compact Fluorescent Lighting
Programmable Thermostats
Energy Efficient Appliances

DESIGN
Passivhaus
Shared Walls
Shade Trees

BEHAVIOUR

★ Assessed for the region in chapter 3

☆ Assessed for case studies in chapters 3 & 4

Glossary

Joule (J)- is a derived unit of energy, work, or amount of heat in the International System of Units. The other popular unit of power is the "horsepower". The conversion is that one horsepower = 756 Watts. A 100-HP car would be able to turn a 75,600 - Watt electrical generator, or 75.6 kilowatts.

Gigajoule (GJ)- is a metric term used for measuring energy use. It is equal to one billion (109) joules. Six gigajoules is about the amount of potential chemical energy in a barrel of oil, when combusted.

Watt- is a derived unit of power in the International System of Units, named after the Scottish engineer James Watt. The unit, defined as one joule per second, measures the rate of energy conversion or transfer.

Kilowatt hours (kWh)- a unit of energy equal to the work done by a power of 1000 watts operating for one hour.

Megawatt hour (Mwh)- A megawatt is a unit for measuring power that is equivalent to one million watts. A megawatt hour is equal to 1,000 Kilowatt hours (Kwh). It is equal to 1,000 kilowatts of electricity used continuously for one hour.

EV Charging Station- The facility that provides battery charging for EVs (electric vehicles). Many new installations provide electricity from wind and solar sources.

Greenhouse Gas (GHG)- is a gas in the Earth's atmosphere that absorbs and emits radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. The primary greenhouse gases in the Earth's atmosphere are water vapour, carbon dioxide, methane, nitrous oxide, and ozone.

Greenhouse Effect- A popular term used to describe the heating effect due to the trapping of long wave (length) radiation by greenhouse gases produced from natural and human sources.

Carbon Dioxide Equivalent (CO_2e)- a measure for describing how much global warming a given type and amount of greenhouse gas may cause, using the functionally equivalent amount or concentration of carbon dioxide (CO2) as the reference.

Conversions:

1 J = 0.0003 Wh

1 Wh = 3600 J

Sources

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Images

Chapter One:
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Chapter Two:
Lukas Holy, Rory Tooke, Design Centre for Sustainability, CALP REIBC team (Ellen Pond, Duncan Cavens, Nicole Miller, Stephen Sheppard), Stephen Sheppard, David Flanders, David Suzuki Foundation, Google Street View, Natural Resources Canada, Green Muze, Turtle Island, City of Richmond, City of Gibsons, Northern Development BC, John Newcom

Chapter Three:
Rory Tooke, David Dodge: Green Energy Futures

Chapter Four:
Kevin Jingyi Zhang, Sara Barron, Lukas Holy

Chapter Five:
Mesa Sherriff, Sara Barron, City of Surrey