Resources From Waste:
A Guide to Integrated Resource Recovery

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Resources from Waste : A Guide to Integrated Resource Recovery.

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Foreword

This guide to Integrated Resource Recovery (IRR) emerged from an independent report released by the Government of British Columbia in May 2008. That report, entitled *Resources from Waste: Integrated Resource Management Study* examined approaches local governments across British Columbia might consider in using solid and liquid waste to create energy, reduce greenhouse gas emissions, conserve water, and recover nutrients. The document was composed of the report by a study team, the comments of a technical advisory committee and comments of four peer reviewers. The report illustrated that there is broad agreement that integrated resource recovery could aid local governments in reducing greenhouses gas emissions, diverting waste from landfills, and generating revenue from infrastructure.

This IRR Guide is intended for those who plan, design, and fund infrastructure - including water, wastewater, transportation, energy, and solid waste. Although it is technical in nature, it is also intended to be a resource for the broader community which uses this infrastructure. It offers suggestions for making municipal infrastructure, and the communities served by the infrastructure, more economically, environmentally, and socially sustainable by extracting value from the resources in waste.

The Ministry of Community Development would like to acknowledge the complementary work and contribution of the Community Energy Association (CEA). The Community Energy Association supports municipalities, regional districts and First Nations to tackle energy issues and climate change at the local level. CEA is a collaboration of the Province of British Columbia, Union of B.C. Municipalities, local government members, transit and energy service providers and professional organizations, and has been serving the needs of local governments for 15 years. CEA has a comprehensive Community Energy Planning toolkit, funding guide (updated quarterly on the CEA website), and renewable energy guide, comprised of four modules: *Heating Our Communities*, *Powering Our Communities*, *Utilities and Financing*, and *Policy and Governance Tools*. This guide is intended to complement CEA's publications which can be found on the web at: *www.communityenergy.bc.ca*

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1.0 Introduction

Integrated Resource Recovery is a new way of thinking about waste. Rather than viewing waste as something to be disposed of, IRR views waste as a resource that can continually provide value and add to the inventory of opportunities available for use by communities. Outputs from human and industrial processes are considered as inputs into other processes to enhance the natural environment.

Such a system can provide economic, environmental and social benefits as outlined below:

Environmental:

- reduction of greenhouse gas emissions;
- provision of carbon-neutral forms of energy;
- reduced requirements for new energy sources;
- reduction of water pollution methane emissions from landfills; and
- reduction of use of high quality, potable water for non-potable purposes.

Social:

- flexible infrastructure that matches the growth of the community; and
- provision of local, sustainable employment in new industries based on recovering resources such as biofuels from waste.

Economic:

- production of new sources of revenue for communities to offset infrastructure cost;
- reduction of the life-cycle cost of infrastructure to taxpayers; and
- reduction of costs when compared managing each waste stream individually.

This guide introduces many techniques for recovering resources from waste including: aerobic composting of organic waste; anaerobic digestion to create fuel for heating or for vehicles; combustion or gasification of wood waste to create fuel; cogeneration of electricity and heat; district heating systems; reclamation of heat and cold from wastewater using heat pumps; water reuse through at sewage treatment plants; and extraction of nutrients from wastewater for use as fertilizer.

This guide focuses on tools for dealing with the benefits of integrating the management of energy, water and waste, and the tools for recovering and reusing the resources in waste.

Implementing these techniques requires planning beyond traditional "silos" such as engineering and planning departments, and liquid and solid waste divisions. It also involves partnerships beyond sectors that traditionally have operated separate waste management systems, such as local governments, agriculture, forestry, and transportation.

2.0 Setting the Context

2.1 Challenges With Current Waste Management Approaches

2.1.1 Inefficiencies, Cost and Lost Opportunities

The goal of conventional waste management is to protect people and the environment from pollution at reasonable cost and dispose of waste safely. While successful in making waste seemingly disappear, this approach overlooks the valuable resources embodied in waste. It also results in costs from greenhouse gas emissions, environmental degradation, and the over-consumption of energy, water, and minerals.

In addition, the costs of building and maintaining conventional waste disposal infrastructure are increasing at a time when this infrastructure in many communities is ageing and in need of replacement.

Finally, the availability of land for conventional disposal practices such as landfills is decreasing.

These pressures make it worthwhile to look for new ways to reduce costs and recover revenues from waste.

2.1.2 Administrative "Dis-integration"

"Silos", or individual departments in government can present a barrier to recognizing the value in waste. Departments which manage solid waste, liquid waste, potable water, transportation, land use planning, and greenhouse gas reduction strategies naturally focus on their own areas of responsibility. Other agencies, such as those responsible for the supply of electricity and fuels may not develop their strategic plans in coordination with local governments. This "dis-integration" of responsibilities makes it difficult for those heading these departments to see the cumulative impacts of their separate decisions.

"*When we try to pick out anything by itself, we find it attached to everything else in the universe.*"

- John Muir,
American Naturalist, 1892

However, if a broader, more integrated approach was taken to the planning, investment and implementation of infrastructure, individual departments could work in a more synchronized fashion. For example, organic waste could be diverted to produce biofuels for vehicles. An expanded wastewater treatment system could be designed to reduce demand for potable water and also provide heat for buildings. While the initial investment may be higher, long-term benefits may pay for those initial costs and more. This approach, referred to as "tunnelling through the cost barrier"[1] can result in lower overall costs and higher overall benefits.

Since organic material, water, energy, and climate change are connected in nature, it makes sense to integrate planning for these areas as well.

2.2 Relationships Between Climate, Energy, Water and Waste

Awareness of the impacts of energy, water and waste management systems on the climate is increasing, this was clearly outlined in B.C.'s Living Water Smart and Energy Plans, released in 2008. Knowledge of the connections among these systems is also increasing. In the current waste management system, energy, water and waste are connected in the following ways.

First, when organic waste is disposed in landfills it produces methane, a potent greenhouse gas that contributes to climate change. Further, disposal of organic matter in landfills makes it unavailable for reuse as fuel or as a source of nutrients.

Second, water is a key element of waste management. Large amounts of high quality potable water are consumed by moving and treating drinking water, storm water, and wastewater. This in turn consumes a considerable amount of energy. The production of this energy in turn requires large amounts of water - either directly through hydro-electric plants, or indirectly in cooling thermal generating plants.

In agriculture, too, pollution and water consumption are a result of this "once-through" approach. Producing artificial fertilizers for agriculture consumes fossil energy, and gives rise to greenhouse gas emissions. Runoff from agriculture carries artificial and mineral fertilizers away from fields into nearby waterways, resulting in water pollution. Much of farming depends on irrigation with surface water, or "fossil water" from ground sources which are not being adequately replenished.

Even solutions that have provided alternative energy sources to fossil fuels have unintended consequences on resources. For example, the production of biofuels is placing pressure on land availability and food prices, as land that was once used to grow food crops is converted to land to grow fuel crops.

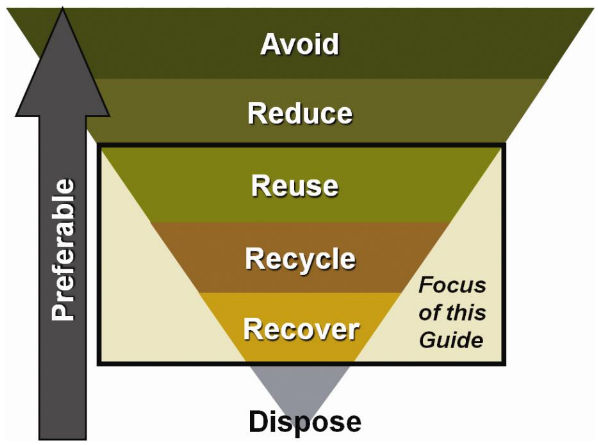
Underpinning this entire cycle is the decreasing availability of water from drought and changing rainfall patterns as a result of climate change.

If the connections among all of these elements – climate, energy, water and waste - were more fully understood and a new approach to waste management was adopted, there would be environmental, economic and social benefits for communities.

2.3 Viewing Waste as a Resource

2.3.1 Preventing and Reducing Waste

While the 3Rs of waste management have historically been known as “reduce, reuse, and recycle", new trends in the industry see this model evolving to 5Rs: "reduce, reuse, recycle, recover resources, and residual management (disposal)”.



Pollution Prevention Hierarchy

This guide focuses on the “reuse, recycle, recover” components of the Pollution Prevention Hierarchy. However, this does not mean that “avoid” and “reduce” through conservation are not still fundamental components of pollution prevention.

2.4 Asking Different Questions

One option for increasing integration is to bridge several functions in local government. While many regional governments maintain separate committees for solid waste, liquid waste, potable water, urban planning, and the environment, others are integrating them. For example, Metro Vancouver has integrated its planning for solid and liquid waste under a single "Waste Management Committee".

An integrated committee or an integrated department can ask better questions such as:

- What if planning for a solid and liquid waste was combined in order to minimize expenditures on infrastructure and maximize revenues from resources?
- What if plans were devised for potable water, liquid waste, and piping infrastructure to minimize life-cycle costs of all three?
- What if waste-to-energy facilities were planned in cooperation with other agencies such as the gas or electricity utility?
- What if *all* costs and benefits were taken into account, the economics of recovering resources from waste are evaluated, such as the:
    - value of electricity and heat consumed by buildings and vehicles, which could be displaced by energy recovered from waste;
    - value of surplus electricity which could be sold to BC Hydro;
    - value of surplus heat or biofuels which could be sold;
    - reduction in the cost of conventional waste disposal;
    - reduction in the cost of purchased greenhouse gas offsets required to meet regulations;
    - value of surplus greenhouse gas credits which can be sold; and
    - value of residues such as fertilizer or compost which can be sold.
- What if less quantifiable benefits were considered, such as the:
    - value of reduced pollution of air, land, and water;
    - value of local, sustainable employment;
    - value of using land for higher purposes than garbage disposal; and
    - opportunities for eco-municipal tourism and educational workshops based on resource recovery and opportunities to teach the next generation about the value of sustainability.

3.0 What is Integrated Resource Recovery (IRR)?

Integrated Resource Recovery begins when waste is viewed as a potential resource – not something to be disposed of. In an IRR approach, plans for municipal infrastructure are developed in an integrated and holistic manner to maximize the recovery of "value" from waste resource streams. This approach mimics the closed-loop cycles present in all ecosystems, provides local sources of energy, water and other resources, and reduces demand from external or new sources. As in nature, water, carbon, and nutrients are treated as renewable resources and continually recycled: nature has no waste.

Comparison of Conventional Waste Management and Integrated Resource Recovery

Resource	When is it Waste?	Conventional Approach	IRR Approach
Storm Water	When reaching drainage systems	Collect and discharge to receiving environment	• Collect, treat, and reuse on-site; • Divert to ecological uses; reduce amount of impermeable surfaces through water sensitive urban design; and • Follow natural drainage and hydrology.
Waste Water	When reaching collection systems	Collect, treat, and discharge to receiving environment	• Collect, treat, and reuse water for regulator-approved non-potable purposes.
Biosolids	When produced by wastewater treatment plants	Collect and landfill, or apply to Industrial Landscaping	• Collect and divert to composting or anaerobic digestion to produce biomethane; and • Recover nutrients through regulator-approved use of residuals.
Wet Organic Waste (e.g. food waste, agricultural waste)	When produced by farming as well as processing, retailing, preparation and consumption of food	Collect and landfill	• Collect and divert to composting or anaerobic digestion to produce biomethane; and • Recover nutrients through regulatory-approved use of residuals.
Dry Organic Waste (e.g. Yard waste, wood residuals, nonrecyclable paper)	After initial use	Collect and landfill	• Collect and divert to composting or to energy production; and • Recover nutrients through regulator-approved use of residuals.

4.0 Why Undertake Integrated Resource Recovery?

4.1 Benefits For Communities

An integrated approach to planning and managing energy, water and waste infrastructure can offer many synergies and benefits to a community. These include reduced greenhouse gas emissions, water consumption, infrastructure requirements, and infrastructure costs.

4.1.1 Reduced Greenhouse Gas Emissions

Greenhouse gas emissions contribute to climate change. Many local governments across British Columbia have committed to reducing greenhouse gas emissions and taking action to address climate change. Integrated Resource Recovery can significantly reduce greenhouse gas emissions and aid local governments in achieving these goals.

As of February 2009, over 170 local governments had signed on to the Climate Action Charter. The Charter is a voluntary initiative between the Provincial Government, Union of British Columbia Municipalities and signatory local governments.

By signing on to the Charter, local governments agree to the goals of:

- being carbon neutral in respect of their corporate operations by 2012, recognizing that solid waste facilities regulated under the *Environmental Management Act* are not included in operations for the purposes of the Charter;
- measuring and reporting on their community's greenhouse gas emissions profile; and
- developing compact communities.

Local governments who have signed the Climate Action Charter are eligible for the new Climate Action Revenue Incentive Program (CARIP) grant through the Ministry of Community Development. Under CARIP each eligible local government receives a grant equal to 100 percent of the carbon tax paid as a direct expenditure.

Another economic incentive is the *Greenhouse Gas Reduction* (*Cap and Trade*) *Act* (Bill 18). Under this legislation, greenhouse gas-neutral fuels, such as biofuels produced from IRR, are exempt from B.C.'s carbon tax. The result is that biofuels will likely become less expensive relative to fossil fuels over time.

Other relevant Provincial Government legislation includes the *Local Government* (*Green Communities) Statutes Amendment Act* (often referred to as Bill 27) which requires local governments to set greenhouse gas reduction targets, polices, and actions in their Official Community Plans by May 31, 2010 and Regional Growth Strategies by May 31, 2011.

4.1.2 Reduced Water Consumption

Demand for potable water can be reduced by reusing wastewater from sewage treatment processes, or by treating storm water. This water can then be used to serve the non-potable water needs of B.C.'s communities, such as for irrigation or water features. Reusing water saves money and resources by reducing the demand for new water sources. It also helps to protect the environment by reducing the need to tap pristine watersheds as additional water sources.

4.1.3 Reduced Infrastructure Requirements

Integrated Resource Recovery reduces the need for new waste management infrastructure such as landfills, pipes, and sewage treatment plants. Integrating the planning of wastewater collection and treatment systems reduces the combined physical infrastructure requirements, reduces the treatment plant's capacity requirements and therefore plant size and life cycle cost. Integrated planning may also lead to building smaller, distributed treatment plants which can be tailored to meet the needs of the region in which it resides.

4.1.4 Reduced Infrastructure Costs

Integrated Resource Recovery involves a broader geographical (e.g. the entire community rather than a single waste management facility) and time scale (e.g. considering the costs and benefits over several generations). This wider perspective provides the opportunity to look at infrastructure needs in an integrated way.

Integrating waste infrastructure with resource recovery, public transit, and energy utility planning can provide uses for the recovered resources, offer new partnership opportunities, and provide sources of revenue to offset infrastructure investment. For example, upgraded biogas may be used as fuel for vehicles, or it may be injected into a natural gas pipeline as a carbon-neutral source of methane.

Additionally, the needs of major energy and water consumers in a community (e.g. hospitals, and universities) can be taken into account when locating new wastewater treatment or waste-to-energy facilities. These institutions can then use the heat or fuel from these facilities at a lower cost. The fees that are paid for the heat or fuel can then be used to offset the cost of infrastructure and operations.

The benefits of integrated resource recovery will vary widely between each community. However, based on the independent study *Resources from Waste: Integrated Resource Management Study*, commissioned by the Provincial Government in 2008 a region with a population of approximately 350,000, could achieve the following savings[2]:

- greenhouse gas emissions reduction of 20-25%;
- energy recovered from waste to heat the equivalent of 30% of the community's homes;
- electricity recovered from waste to power 10% or more of the community's homes; and
- biofuels recovered from waste to run 10% or more of the vehicles in a community.

Integrating the planning of community waste infrastructure with local industrial and agricultural needs can also result in lower costs and greater benefits for all parties. The Revelstoke Community Energy Corporation, wholly owned by the City of Revelstoke, derives heat from a low-emitting wood residue burner located at a local sawmill to provide heating for several buildings in the community.

The anaerobic digester in Kristianstad, Sweden relies on waste from the community, food factories and farms, which converts the waste to biogas and to nutrient-rich fertilizer for farms.

4.2 Guiding Principles

Design with Nature: Designing infrastructure to work with, rather than against, nature is more efficient and sustainable. For example, directing storm water to permeable surfaces or bioswales rather than to waterways through pipes and pumps requires less infrastructure, less energy, and helps to recharge groundwater.

Integrate Land Use Planning and Infrastructure Decisions: Much of the infrastructure in B.C.'s communities is ageing and requires replacement or upgrading. This provides a unique opportunity to rethink traditional modes of land use and infrastructure planning. Local governments can ensure appropriate zoning is in place for an IRR approach, and also consider spatial requirements for IRR when Official Community Plans or Regional Growth Strategies are being revised.

Move Upstream to Prevent Waste: If waste resources can be recovered for the benefit of the community which produced them, then the cost of transportation to a central facility can be avoided. For example, wastewater in the City of Victoria's Dockside Green development is treated to the point where it can be used for non-potable purposes on the site. As a result, the development's *consumption* of fresh water and *production* of wastewater are both significantly reduced. This reduction is in addition to water conservation measures, which are first taken to reduce consumption.

Every Waste is a Potential Resource: Almost all waste is a potential resource. For example, organic waste in landfills decomposes to produce methane, a potent greenhouse gas. If this waste is diverted to an energy facility such as an anaerobic digester, the methane becomes a source of renewable energy instead of a pollutant.

Use Each Resource More Than Once: Resource streams can provide multiple benefits. At the Dockside Green development in Victoria, fresh water is used first for potable purposes, then again for non-potable uses. In a waste-to-energy facility, this solution not only provides a renewable energy source; it can produce a nutrient-rich residual that may be used as a replacement for artificial fertilizer.

Resource Recovery Generates Revenues: Just as it is economically beneficial to recycle metals than to pay for them to be buried in a landfill, it is also more profitable to recover usable resources from waste than to landfill them.

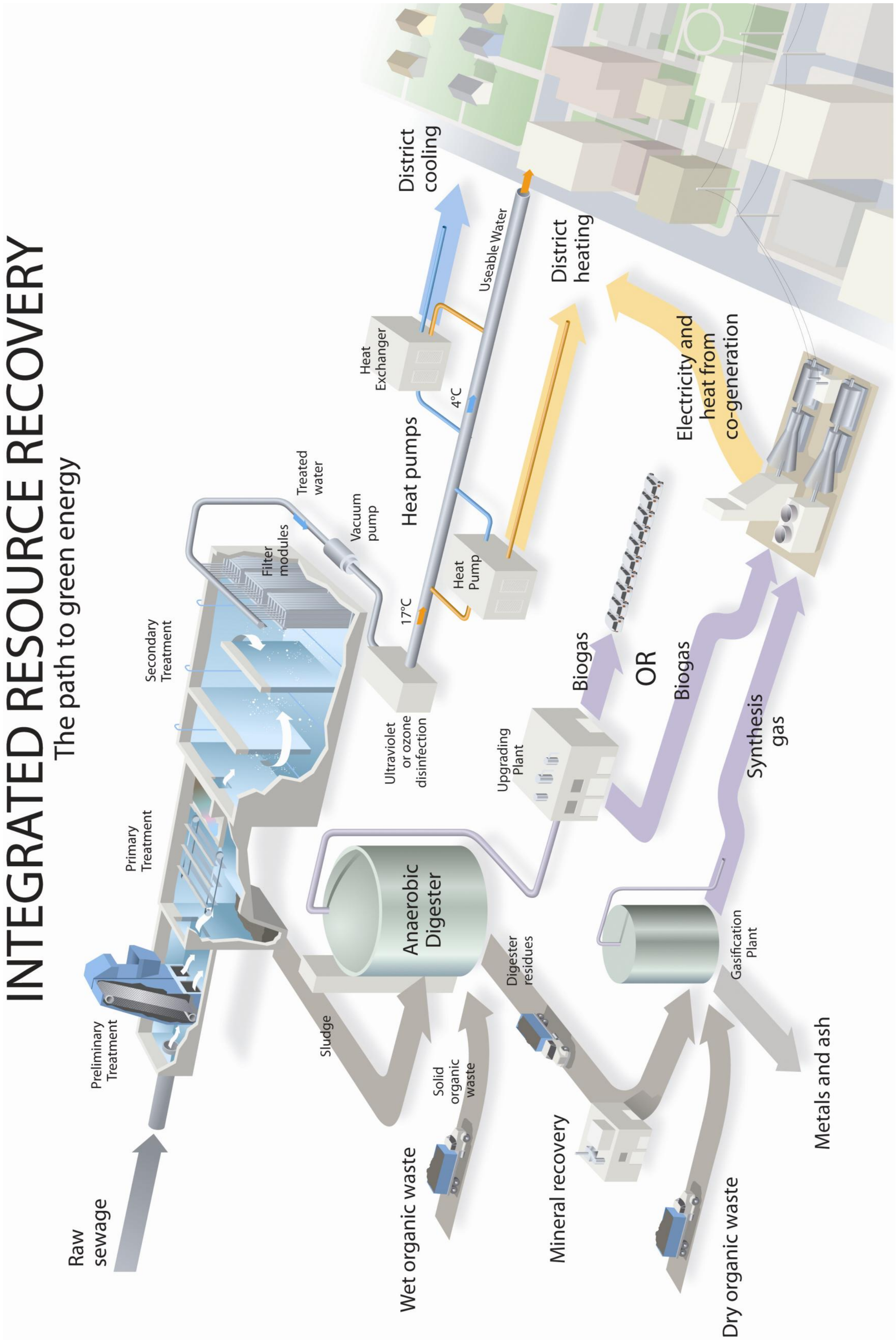
Integration of System Boundaries: Options for waste management increase significantly when system boundaries are viewed more broadly than they have been traditionally. For example, in the City of Revelstoke, the local sawmill is the site for a wood residue burner that provides heat for the sawmill, as well as for nearby buildings in the community.

Use Each Resource for its Highest Value: Waste can be recycled (e.g. metal cans back into cans), down-cycled (e.g. glass used as road base) or up-cycled (e.g. kitchen waste digested to biomethane). The value gained from each of these processes should be analyzed to determine which is most appropriate.

Evaluate Revenues First, Costs Second: Innovative models are emerging that consider not only the cost of infrastructure, but also the potential revenue that it could generate. For example, the Quesnel Community and Economic Development Corporation (owned by the City of Quesnel) is in the process of establishing a "Municipal Energy and Resource Corporation" (MERC) to take advantage of opportunities for resource recovery infrastructure such as community energy networks to be jointly owned with industrial or commercial entities.

New ways to recover revenues can be developed by looking at:

- potential markets for recovered resources (e.g. electricity and heat from co-generation);
- costs which can be avoided or reduced (e.g. lower waste disposal costs);
- cost sharing capitalization (i.e. Joint ownership of an anaerobic digester by a food processor and a community);
- existing infrastructure which could be used to produce resources (e.g. a wastewater plant);
- analyzing the total life cycle cost (economic, environmental, social) of new infrastructure;
- whether this infrastructure be located within existing assets (e.g. a wastewater plant); and
- infrastructure financing (e.g. via industrial partners or grants for sustainable infrastructure).



INTEGRATED RESOURCE RECOVERY
The path to green energy
Raw sewage
Preliminary Treatment
Primary Treatment
Secondary Treatment
Filter modules
Treated water
Vacuum pump
Ultraviolet or ozone disinfection
17°C
Heat Pump
Heat pumps
4°C
Heat Exchanger
Useable Water
District cooling
District heating
Sludge
Wet organic waste
Solid organic waste
Anaerobic Digester
Digester residues
Upgrading Plant
Biogas
OR
Biogas
Mineral recovery
Gasification Plant
Synthesis gas
Electricity and heat from co-generation
Dry organic waste
Metals and ash

5.0 Tools, Techniques and Methods of Integrated Resource Recovery

Integrated Resource Recovery includes many tools, techniques and methods of turning waste into resources which are illustrated in the diagram on the previous page. The particular solution which individual communities adopt will depend on the available waste resources and the community's needs.

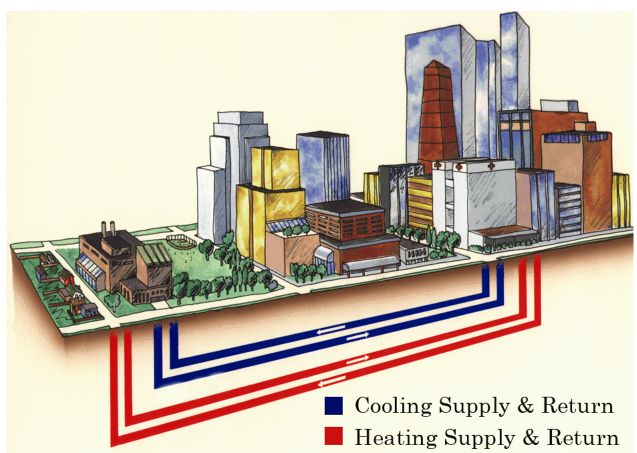
5.1 District Energy Systems for Heating and Cooling

In district energy systems, heat is transported from one or more sources to customers by means of insulated hot water pipes. These pipes provide energy for space heating and domestic hot water. A similar system can provide district cooling by supplying cold water to replace conventional air conditioning.

Other sources of heat can include:

- natural gas;
- industrial waste materials;
- industrial waste heat;
- cogeneration plants;
- heat pumps; and
- waste heat emitted from buildings.

One of the benefits of district energy systems is that they can simultaneously accept heat from several sources, which makes them flexible and robust.



District Heating and Cooling Scheme

District cooling systems pump chilled water (from heat pumps) through the piped network to provide cooling to customers. This reduces the need for electricity to run air conditioning and refrigeration equipment.

Cost Considerations

District heating and cooling pipes are insulated, buried, and include leak detection technology. Depending on the type and capacity of the pipes used, the installed costs range from $1-$2 million per kilometre. Maintenance of district heating and cooling pipes is technically uncomplicated, and the pipes are designed to last up to fifty years.

In order to connect to the district energy system, heat exchangers which transfer the heat (or cold) to the building's heating system are required. If the building relies on a hydronic system (e.g. hot water baseboards or hot water radiant heating), then conversion costs are relatively low. If the building uses a forced air heating system, then a "fan coil" (similar in function to a car's radiator) would have to be installed to transfer heat or cold from the community energy system to the building's ducts.

In the cases where electric baseboard heaters are required, these would need to be replaced with either a hydronic or a forced air system.

Local governments can support potential future district heating systems by encouraging the installation of hot water heating in new buildings.

Environmental Benefits

District energy systems can use larger sources of heat energy which are more energy efficient than the many small heating sources they replace. Since these systems can use non-conventional sources of heat (e.g. industrial waste heat, cogeneration heat) their energy costs can be lower than competing fossil or electrical sources, and their greenhouse gas emissions can be lower.

In the case of the Revelstoke Community Energy Corporation in the City of Revelstoke, the district energy system is heated by clean combustion of sawmill wood residues. Since these residues were diverted from a conventional wood waste burner, air pollution in the community was reduced.

Economic Benefits

District energy systems result in energy price stability because the heating system is not dependent on fluctuating fossil fuel prices. For example, customers of the Revelstoke Community Energy Corporation pay 5% less than propane heating, and are guaranteed that the rate will increase only at the rate of general inflation.

Social Benefits

As communities learn about district energy systems and their risks and benefits, a sense of autonomy can be gained. These systems create local sustainable jobs, and the revenues from these systems generally stay in the community. For example, the Revelstoke Community Energy Corporation is locally-owned, and provides a non-tax source of revenue to the City of Revelstoke. These funds can then be used to offset costs of other social programs.

Considerations

District energy systems are less expensive to implement when they are planned before new developments are built, or if the piping can be installed alongside other infrastructure. In Sweden, community energy companies cooperate with other utilities by sharing trench space set aside for infrastructure. If a telephone company plans to extend its fibre optic network into a community, or the sewage utility needs to repair a length of pipe, the community energy company is offered the chance to extend its network of district heating and cooling pipes at the same time.

Existing buildings that are heated conventionally will require investments in heat exchangers to make use of this heat source.

District Heating Pipes in Gothenburg, Sweden.

Organizations in B.C. which sell energy are regulated by the B.C. Utilities Commission. Local governments are exempt; if a local government establishes an energy utility the local government is the regulator, not the B.C. Utilities Commission[3]. This can be an

Where is it Done?

District energy systems are currently in operation in the cities of Revelstoke, Vancouver and North Vancouver, Whistler, and Victoria. They are being developed or considered in many other B.C. communities.

District Heating Pipes in Revelstoke

In Southeast False Creek in Vancouver, a Neighbourhood Energy Utility is being created to provide space heating and domestic hot water to 16,000 residents in the Southeast False Creek and Olympic Village sustainable community development. The first phase, expected to be completed by 2010, will recover heat directly from the municipal sewer system. It will also utilize heat from rooftop solar modules on three Olympic Village buildings. The project will receive $8.47 million from the federal Gas Tax fund.

The Capital Regional District will receive $2.98 million in funding from the federal Gas Tax fund to recover thermal energy from effluent at the Saanich Peninsula Wastewater Treatment Plant. This energy will be used to provide hot water and space heating in the plant and adjacent facilities, including the Panorama Recreation Centre, the Centre for Plant Health, and nearby elementary school.

Sweden

In Gothenburg, Sweden, waste heat from a refinery, wastewater-source heat pumps, and municipal waste-to-energy facilities are used as heat sources for nearby buildings. This municipally-owned energy utility (Göteborg Energi), employs approximately one thousand people in the business of recovering and distributing energy from waste sources. It sells heat to clients at a rate below the cost of fossil fuels. After a new client has subscribed to the service, the utility upgrades the insulation and glazing in the client's building to reduce the amount of energy drawn by that building. The investment to reduce the client's energy losses improves the energy utility's revenues, since more energy will then be left in the system to sell to future clients. In this case, the economic interests of the client and the utility are aligned with the community's interests in protecting the environment. The result is that energy is sold as as a service, rather than a commodity.

Getting Started

1. Local governments can investigate their opportunities to recover waste energy from industrial or municipal sources, and to connect those sources to clients through district energy systems.

2. Local governments can consider planning for providing district heating to major energy users such as factories, residential developments, government buildings, hospitals and educational and recreational facilities.

3. Communities can investigate the possibility of extending existing systems (e.g. those in place at universities) to serve other clients.

4. Communities can encourage the construction of district energy systems through their Regional Growth Strategies and Official Community Plans, and through the development permit approval process.

5. Communities can encourage the installation of hydronic heating systems in new developments which may be served by future district heating systems.

6. Communities can consider the benefits of mixed ownership of district energy infrastructure. For example, if a source of energy will be industrial wood residues, it may make sense for the wood-fired boiler to be owned by the industrial source, and for the district heating piping to be owned by a "Municipal Energy and Resource Company" with access to financing at favourable long-term rates.

7. Local government councils and staff can visit communities which operate district energy systems, in order to better understand the costs and benefits.

8. Communities can contact the Community Energy Association (www.communityenergy.bc.ca), the Canadian District Energy Association (www.cdea.ca), or Natural Resources Canada for more information about the feasibility of implementing a community energy system in their region.

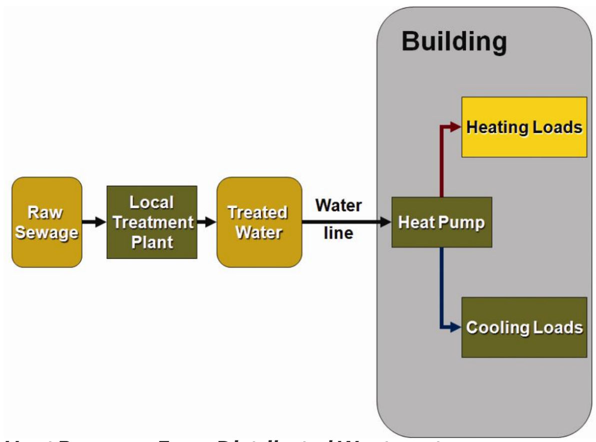
District Energy Summary

Resources Consumed	• Waste heat from cogeneration; • Heat recovered from wastewater through heat pumps; and • Electricity required to pump hot or cold water through the district energy pipes.
Resources Produced	• Heating for space heating and domestic hot water; and • Cooling for refrigeration and air conditioning.
Residuals Produced	• None. Residuals may be produced by the source of energy for the community energy system such as a gasifier or wood burner, but not by the community energy system itself.
GHG Reductions	• Avoided emissions from fossil fuels which are displaced by community energy; and • Avoided emissions from production of electricity displaced by district cooling which would otherwise be required to run refrigeration and air conditioning equipment.
Pollution Avoided	• Air pollution from combustion of fossil fuels for heating, and from production of electricity for refrigeration and air conditioning.
Other Benefits	• Local sustainable employment; and • Increased energy independence.

5.2 Reclaiming Heat and Cold from Wastewater Using Heat Pumps

How it Works

Heat pumps use electricity to recover low temperature heat, and to make this heat available at suitable temperatures for heating and for hot water systems. For every unit of electricity consumed by heat pumps, they typically produce three to four units of higher temperature heat.



Heat Recovery From Distributed Wastewater Treatment Plants

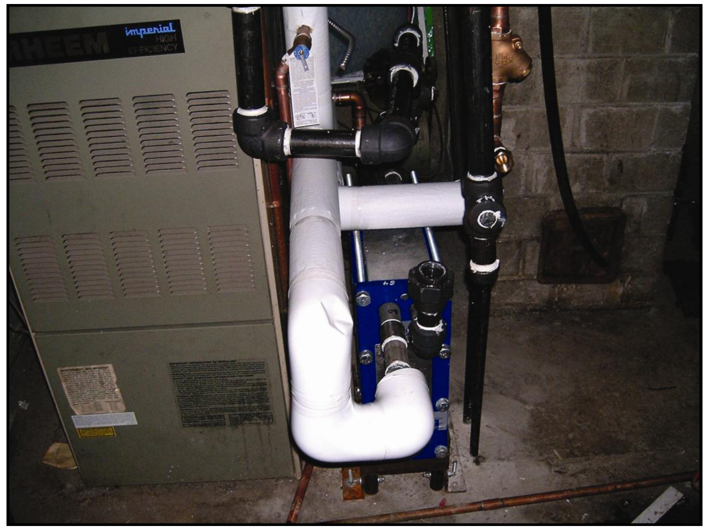
As treated wastewater is significantly warmer than other sources of energy for heat pumps (e.g. air during the winter, ground-sources, lakes or the ocean), energy can be recovered from wastewater more efficiently. This approach has the further advantage of avoiding the expense of the underground piping fields which are required by ground-source heat pumps. After the heat has been extracted from treated wastewater, the water is cold enough to be used for air conditioning or refrigeration through a district cooling network. This results in less demand for electricity for air conditioning or refrigeration.

Unlike their European counterparts, most Canadian cities do not have extensive networks of insulated district heating pipes. However, treated wastewater from local plants can be delivered through ordinary pipes to heat pumps located in buildings near treatment plants. If the needs of buildings for energy and reclaimed water are taken into account when communities plan for wastewater treatment infrastructure, then treatment plants can be sized and located to deliver the greatest amount of energy (and even reclaimed water) to the greatest number of buildings. This approach tends to favour a network of distributed small treatment plants over the more traditional option of large centralized plants.

Although it is possible to recover heat from untreated sewage, the cost is higher and the amount of heat recovered is lower when compared to recovering heat from treated wastewater. Additionally, if untreated sewage is cooled significantly by the extraction of heat from sewer collection pipes in advance of the wastewater treatment plant, then the efficiency of the biological treatment processes in the plant will be reduced.

Cost Considerations

Heating systems in buildings would need to be adapted to use this form of energy. Conversion costs would include the capital and operating costs of the heat pumps, heat exchangers, and any necessary modifications to the building's heating system. Heat pumps normally require replacement every twenty years.



Revelstoke District Heating Heat Exchanger

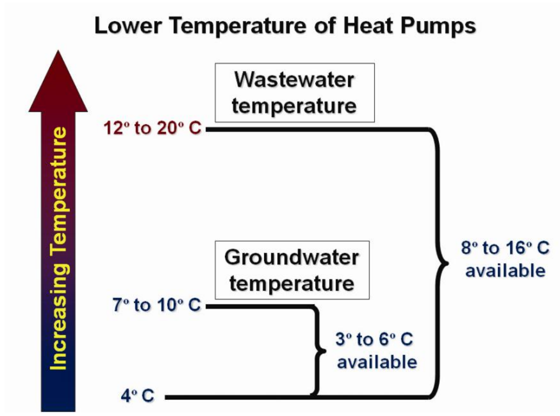
Either the community or a local energy company could pay for the cost of infrastructure such as the un-insulated water piping required to deliver the treated water to heat pumps. Building owners would pay less for this source of energy than subscribers of higher-temperature district energy systems which distribute hot water from cogeneration plants, since subscribers would carry the cost of operating the heat pumps required to recover the energy.

Environmental Benefits

Although the heat pumps consume electricity, the net greenhouse gas reductions achieved by replacing natural gas with heat recovered from treated wastewater or sewer lines are significant. Heat pumps cause no direct emissions, but are responsible for the upstream (or "indirect") pollution associated with the generation of the electricity they consume.

Economic Benefits

- The cost of wastewater treatment can be offset by revenues from energy subscribers paying for heat provided by the wastewater treatment plant.
- On a lifecycle basis, heat pumps cost less than other sources of heat, such as electric baseboard heating or fossil fuels, provided the buildings to be heated are located within a reasonable distance of the wastewater treatment plant (e.g. 1-2 kilometres).
- The price of energy from wastewater generally will not increase at the same rate as fossil fuels.
- Operating heat pumps during hours when electricity demand is lower can result in potential savings. The heated water can then be stored for use during peak heating demand hours.



Relative Temperatures of Sources for Heat Pumps

Social Benefits

Heat pumps produce no emissions and have no implications for climate change or public health.

Source Temperature and Heat Pump Performance

	Air-Source	Ground Source	Wastewater Source
Source Temperature	0ºC	7-10ºC	12-20ºC
Relative Efficiency[4]	3.3	3.7	4.3

Considerations

In older buildings where the heating system was designed for higher temperatures, other sources of heat will be needed to boost the heating system temperature on the coldest days.

Locating decentralized wastewater treatment plants near to clients for heat energy will require a different approach to planning on the part of local governments than the current system of fewer, centralized plants.

Existing buildings will require investments in heat exchangers in order to make use of this heat source.

The economics of heat pumps are strongly affected by the temperature of the heat source. The higher the temperature, the lower the capital and operating costs, as the heat pumps can be smaller in size. With rising temperatures, more heat is also available.

Where is it Done?

Okanagan College in Kelowna uses heat pumps to heat the campus from treated wastewater from the Kelowna Wastewater Treatment Plant. The system meets the entire college heating load when the outdoor temperature is above freezing, and meets 80% of the total heating requirements of the campus[5]. This arrangement saves the college $300,000 per year, while reducing its greenhouse gas emissions.

Okanagan College Heat Pumps

Wastewater-source heat pumps are common in Europe. For example in Stockholm, Sweden this source of energy provides heat to the equivalent of 80,000 homes (equal to one in five homes). In Stockholm, the Henricksdals wastewater plant is paid for this energy by the local energy company: these payments help offset the cost of wastewater treatment to taxpayers.

Getting Started

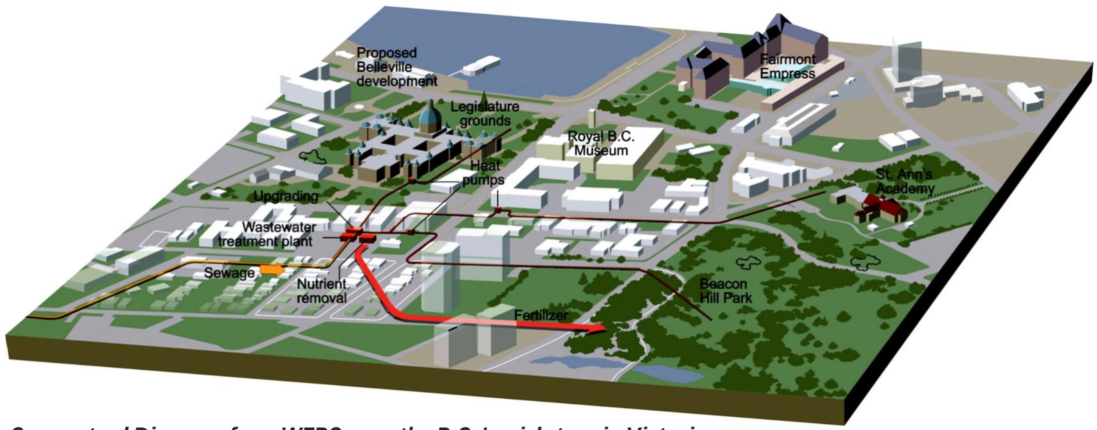
1. Heating systems which are designed to accept low-temperature heat can be designed into new buildings.

2. Communities could consider the costs and benefits of building wastewater treatment facilities which will minimize heat loss during treatment. Enclosed wastewater treatment facilities for example will lose less heat during the winter than facilities which use open tanks and lagoons. The temperature of wastewater can even increase as it is processed in small, enclosed wastewater treatment plants.

3. Communities can look for opportunities to locate small, decentralized wastewater treatment facilities near to users of heat energy, such as a residential development. Ideally, the development would also be able to use highly treated wastewater for non-potable purposes on the site. In this way, treated wastewater delivered through one pipe could help displace fossil fuels for heat, electricity for air conditioning, and potable water for irrigation.

Conceptual Case Study: Heating and Cooling From Wastewater Using Heat Pumps

The illustration below provides a conceptual example of a water and resource recovery "cell" (WERC) for the neighbourhood of James Bay in Victoria.



Conceptual Diagram for a WERC near the B.C. Legislature in Victoria

Conceptually, wastewater from the James Bay area of Victoria could be processed in a small treatment plant in the vicinity of the Provincial Legislature. Using modern technology, the plant could be small enough to be incorporated into an existing government-owned building near the Legislature. The plant would be designed to produce highly-treated water, which would meet regulatory standards allowing "unlimited human contact", and used for irrigation. Highly-treated wastewater would be carried in un-insulated water pipes (the red lines) to heat pumps in neighbouring buildings.

The Provincial Legislature, the Royal B.C. Museum, government buildings, the Fairmont Empress, other nearby hotels, the James Bay Community School, and the planned Belleville Development could all be potential customers for heating and cooling their building through heat pumps.

Once the highly-treated water has passed through the heat pumps, it could either be used for irrigation or discharged through a water feature. The Legislature grounds (including the water fountain), Beacon Hill Park, and St. Ann's Academy would be potential clients for reclaimed irrigation.

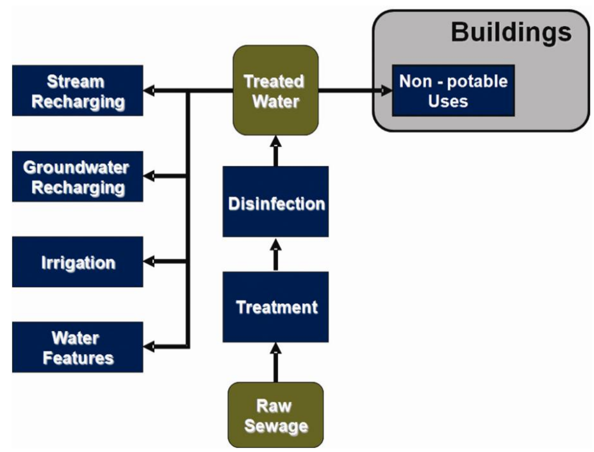
Wastewater Heat Pump Summary

Resources Consumed	• Electricity to operate the heat pumps.
Resources Produced	• Heat for space heating and domestic hot water; and • Cooling for refrigeration and air conditioning.
Residuals Produced	• None.
GHG Reduction	• Avoided greenhouse gas emissions which would otherwise have been produced from burning fossil fuels for heat; and • Avoided greenhouse gas emissions from the production of electricity which would otherwise be consumed for cooling and refrigeration.
Pollution Avoided	• Air pollution from combustion of fossil fuels for heating, and from production of electricity for refrigeration and air conditioning.
Other Benefits	• Local sustainable employment; and • Increased energy independence with respect to fossil fuels.

5.3 Reclaiming Wastewater

How it Works

Wastewater can be treated to the extent required for any re-use purpose. This is consistent with the principles of "highest and best use". Wastewater can even be brought to potable standards through appropriate processes of treatment and disinfection. Water recovered from wastewater is commonly referred to as "reclaimed" or "renovated" water.



Wastewater Reclamation Schematic

Cost Considerations

Costs for reclaimed water increase with the degree of treatment used. Taking an integrated approach, it is possible for the extra cost to be offset by reduced infrastructure costs and increased value in the community.

If potable water demand can be reduced by using reclaimed water for non-potable purposes (such as irrigation or street cleaning), local governments can delay an expansion of potable water supplies and distribution systems. Additional savings can result from the reduced pumping costs for potable water and wastewater.

Environmental Benefits

Reclaimed water can be put to many environmental uses. It can be used to recharge groundwater supplies, to augment stream flows during dry periods for fish protection and generally to reduce the consumption of potable water.

Economic Benefits

Reduced demand on potable water sources and systems delays investment in new infrastructure. Additional benefits include both capital and operating cost savings over the lifecycle of the infrastructure.

Social Benefits

Reclaimed water can be used to create water features which provide amenity and can serve as meeting places. Green spaces irrigated by reclaimed water can enhance healthy, active communities. The green spaces will not only have social and ecological value, but can serve as natural cooling cells in the summer months. These cooling cells can reduce the energy consumed for air conditioning in adjacent buildings.

Considerations

To fully explore the costs and benefits of water reclamation and reuse, an integrated, long-term approach must be taken. The capital and operating costs of potable water infrastructure and treatment, wastewater infrastructure and treatment, and the benefits of re-use must all be included in the analysis. For example, if highly-treated wastewater can be reused, the analysis would need to account for the cost savings of the reduced demand on potable water infrastructure and reduced demand on sewer infrastructure.

Public health concerns may be a perceived barrier and consultation must be fully explored. Treated water must comply with applicable regulations, including the *B.C. Building Code*, the *Drinking Water Protection Act* and the Code of Practice for the Use of Reclaimed Water (2001) under the *Municipal Sewage Regulation* and the *Environmental Management Act*.

Where is it Done?

The City of Sequim in Washington State (U.S.A.) treats all wastewater to the level where it can be used for non-potable purposes including irrigation. The City of Vernon uses highly-treated wastewater for irrigation. In Victoria, two commercial enterprises, the mixed use development Dockside Green, as well as Sooke Harbour House hotel treat wastewater on-site and use the reclaimed water for toilet flushing, irrigation, and water features.

Sequim, Washington

The City of San Diego (U.S.A.) treats wastewater to potable water standards, and returns the water to the city's potable water reservoir. At Metro Vancouver's Annacis Island Wastewater Treatment Plant, a portion of the treated wastewater undergoes additional treatment before being used to wash vehicles.

Getting Started

Local governments can integrate planning for water and wastewater to seize opportunities to reduce demand on potable (drinking) water sources by using reclaimed water for non-potable purposes.

Councillors and local government staff can visit communities which already use recycled water, in order to understand the implications of such a system in their own jurisdiction.

Local governments can take a holistic approach to assigning value to water, by including ecology and valuation in their planning processes. For example, what is the value to society of creating water features or improving fish habitat with reclaimed water?

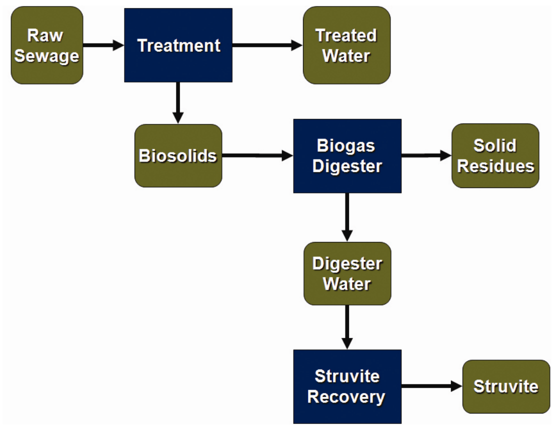
Reclaimed Wastewater Summary

Resources Consumed	• Energy to treat wastewater and electricity to operate the pumps to move the water to users.
Resources Produced	• Reclaimed water for non-potable purposes.
Residuals Produced	• None.
GHG Reductions	• Reduced GHG emissions associated with lower consumption of energy for pumping water; and • Lower energy consumption for cooling.
Pollution Avoided	• Exploitation of new watersheds; and • Depletion of groundwater.
Other Benefits	• Environmental benefits of recharging streams and groundwater; • Social benefits of amenity and beautification of water features which could not otherwise have been developed; and • Economic benefits of using lower-cost reclaimed water for non-potable purposes, and savings in potable water treatment infrastructure.

5.4 Reclaiming Nutrients from Wastewater

How it Works

Nutrients can be recovered from wastewater in several ways. In Europe, residues from biogas digesters, which process clean food waste, are safely applied to farmland[7]. In Canada, biosolids from wastewater treatment plants have been applied to land, but concerns over soil and groundwater contamination and odour tend to limit the scope of land applications.



Nutrient Recovery Schematic

Since sewage biosolids can be dewatered and used as a feed stock in a biogas plant or gasification plant, its highest and best use and value may be for energy.

A more innovative approach to recovering nutrients from wastewater is to extract nutrients in crystalline form. Fertilizer in crystal form can be recovered from wastewater treatment plants which have biogas digesters, using a technology developed at the University of British Columbia and commercialized by Ostara Nutrient Recovery Technologies in Vancouver.

Cost Considerations

Ostara Technologies has installed its equipment in the City of Edmonton, Alberta's Gold Bar wastewater treatment plant. The capital expenditure is expected to be recovered in approximately five years through lower maintenance costs and sales of a slow-release recovered fertilizer called "Crystal Green™" or "struvite".

Struvite fertilizer from Ostara Technologies

Environmental Benefits

Slow-release fertilizers result in less surface runoff to nearby water bodies, thereby causing less water pollution and eutrophication. Artificial and mineral fertilizer production accounts for 1.2% of global greenhouse gas emissions[8]; replacing artificial and mineral fertilizer with fertilizer recovered from the wastewater treatment process can help reduce greenhouse gas emissions.

Finally, phosphorous is essential to plant growth, and sources of this element are limited.

Economic Benefits

Sales of struvite also offset the capital and operating costs of the recovery equipment. Removing struvite from wastewater plants prevents it from accumulating in pipes, thereby reducing maintenance costs.

Social Benefits

Public acceptance of crystalline fertilizer applications to farmland is likely to be higher than it would be for applications of wastewater treatment plant biosolids.

Where is it Done?

Ostara Technologies equipment is installed in the City of Edmonton, Alberta, at the Gold Bar wastewater treatment plant.

Reclaimed Nutrient Summary

Resources Consumed	• Treated wastewater, and electricity to operate the recovery process, process chemicals.
Resources Produced	• Slow-release fertilizer.
Residuals Produced	• None.
GHG Reductions	• Reduction in emissions associated with the manufacture of artificial and mineral fertilizer.
Pollution Avoided	• Reduced eutrophication of water bodies caused by runoff of artificial and mineral fertilizer.
Other Benefits	• Reduced wastewater treatment plant maintenance costs.

5.5 Anaerobic Digestion of Wet Organic Waste

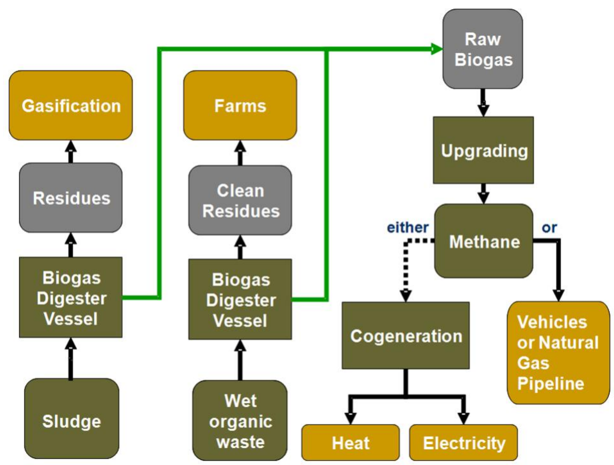
How it Works

Aerobic Versus Anaerobic Composting

Aerobic composting of wet organic waste (including residential kitchen waste, restaurant waste, food processing waste, wastewater treatment plant biosolids, and manure) is a common practice and considered a traditional method of resource recovery.

Aerobic composting can result in a significant reduction in greenhouse gas emissions (methane) from landfills[9]. Composting also recovers nutrients and soil-building materials for agriculture.

In aerobic composting, micro-organisms digest the organic materials, giving off metabolic heat and carbon dioxide (CO_2). Since the CO_2 is from atmospheric rather than fossil sources, it is considered greenhouse gas-neutral. The goal in composting is to expose organic materials to air as effectively as possible, in order to accelerate the decomposition process and to prevent anaerobic decomposition.



Biogas Production Process Schematic

However, a new type of composting with environmental advantages is emerging - *anaerobic* composting. In aerobic composting, chemical energy in the organic matter is lost as heat in the process. If instead waste is decomposed without oxygen in an *anaerobic* digester, the nutrients are still concentrated in the residues, but bacteria convert the waste into "biogas". Biogas is rich in methane which can be captured and used for fuel for vehicles, or to generate heat and electricity. Because the carbon in this methane (sometimes called biomethane) comes from food waste rather than fossil sources, this fuel is greenhouse-gas neutral.

Digester designs are tailored for the types of material they process (e.g. food waste, sewage biosolids, manure), and fall into two main categories. *Mesophilic* digesters operate at approximately 35ºC, and *thermophilic* digesters operate at the 55ºC range. Although mesophilic digesters are common, thermophilic digesters have the advantages of higher biogas yields, faster processing time, and pasteurization of pathogens.

Yields from the digester can be increased by making the organic material more available for decomposition by the digester's micro-organisms. Techniques include chopping the waste into smaller pieces and using high pressure, ultrasound, hydrolysis, or heat to make the organic material more digestible. The increased costs of preparation processes are offset by higher gas yields and smaller volumes of residues.

Yields of biogas from organic waste depend on a large number of factors including moisture content, composition of the waste, the method used to prepare the waste for digestion, and the type of digestion process used. Fortunately, biogas digesters operate more efficiently on a "mixed diet", in which the ratio of carbon to nitrogen are balanced.

Nutrients

Communities could consider that they have two options for recovering nutrients from organic waste: aerobic composting or anaerobic digestion. Aerobic and anaerobic digestion both recover nutrients and divert organic waste away from landfills; anaerobic digestion has the added benefit of providing greenhouse gas-neutral energy. The digestate from anaerobic digestion typically takes the form of wet slurry, while the residuals from composting contain less water and are therefore less costly to dewater and transport.

Cost Considerations

Capital costs depend on the technology, size of digester, and the extent of odour control measures required. If less than 10,000 tonnes/year of feed stock is available, then anaerobic digesters are not economically viable. Another cost consideration is that to achieve adequate inputs for a digester, curb-side collection of organic waste will likely be necessary.[10]

In Kristianstad, Sweden, farmers provide manure to the local biogas digester, and in turn receive the digester's residues (also known as "digestate"). The digestate is used to fertilize farmland, and farmers benefit from the fact that the digestate they receive contains a higher concentration of nutrients than the manure they supply to the digester. Farmers are not charged to drop off manure or to pick up the residues.

Environmental Benefits

Diverting wet organic waste from landfills reduces emissions of methane, landfill leachate, and the area of land needed for landfills. Common landfill gas capture systems recover only a fraction of methane produced (and only a fraction is captured), and the escaping portion is twenty-one times more potent for climate change than carbon dioxide. Further, biogas digesters produce a greenhouse gas-neutral fuel which can be used in vehicles or burned in a cogeneration plant to produce electricity and heat. Finally, if the feed stock is uncontaminated, digestate can be applied to farmland: the environmental benefits of doing so include reduced runoff from artificial and mineral fertilizers, as well as reduced greenhouse gas emissions produced during the manufacture of artificial and mineral fertilizers.

When compared to aerobic composting, the advantages of anaerobic composting include:

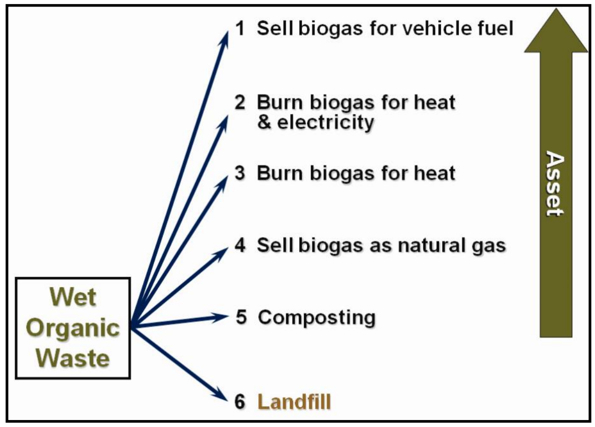
- production of a greenhouse gas – neutral energy;
- fewer odours;
- fewer greenhouse gas emissions;
- better inactivation of weed seeds (thermophilic digestion only); and
- better availability of nutrients in residues (especially nitrogen) for plants.

Economic Benefits

There are many uses for biogas and communities will need to assess the "highest and best use and value" for this resource based on their needs and means. As illustrated on the following page, the highest and best use for biogas is to sell it as biofuel.

A biogas plant generates revenue through tipping fees, sales of methane, and greenhouse gas credits. Biogas can be burned in cogeneration plants for electricity and heat, or upgraded to natural gas quality for use as a greenhouse gas-neutral vehicle fuel. Methane is also a building block molecule from which hydrogen, alcohols, and more complex hydrocarbons can be produced. It is even possible to convert the methane from biogas into synthetic jet fuels (kerosene) though gas-to-liquid (GTL) technologies[11].

Revenues generated from a biogas plant generally remain within the community and can be used to fund other sustainable initiatives.



Highest and Best Use and Value for Organic Waste and Biogas

Social Benefits

Biogas generation can be part of an overall energy program that moves a community towards energy independence. The United Nations Development Program recognizes anaerobic digestion as a source of decentralized energy supply[12].

Further, biogas engines are quieter, requires less maintenance, last longer and produce lower emissions of particulates and other pollutants than diesel or gasoline engines.

Considerations

Biogas plants must be designed to minimize odour through careful siting, and the use of building enclosures and biofilters. Locating biogas digesters within wastewater treatment plants is useful, since the digester can accept biosolids from the wastewater plant, and the wastewater plant can accept residual water from the digester.

Raw biogas contains hydrogen sulphide (H_2S) and sulphur dioxide (SO_2) which pose serious hazards to humans. Biogas plants must be designed to minimize the risk of raw biogas leaks, and to minimize the risk of exposure to leaks. These sulphur compounds can be removed by "scrubbing" the gas before it is used.

The methane in biogas is explosive, and the design and operating precautions which apply to installations which handle natural gas will also apply to biogas plants.

Anaerobic digestion is a biological process, which is sensitive to changes in the feed stock or "diet". Skill is required on the part of biogas plant operators to ensure the plants operate within optimal conditions such as temperature, carbon/nitrogen ratios, and moisture content.

If metals are present in the digester feed stocks, they will also be present in the residues. In Sweden, residues from digesters which only accept food waste and manure without heavy metals are provided to farmers at no cost, while residues from wastewater treatment plant digesters are only used for industrial landscaping.

Finally, operators of biogas plants need secure supplies of feed stock, and ensure that truck delivery traffic is no more disruptive to the community than garbage truck traffic.

Where is it Done?

In North America, it is common for larger wastewater treatment plants to use mesophilic digesters to produce biogas from sewage biosolids and to use the gas to produce heat and electricity for the plants. Metro Vancouver's Annacis Island Wastewater Treatment Plant incorporates thermophilic anaerobic digestion of the wastewater treatment biosolids.

Community Biogas Plant in Kristianstad, Sweden[13]

In Europe, over 4,000 biogas digesters are in operation, where the gas is used to produce electricity and heat, and as fuel for buses, cars, and trucks.

In Stockholm, Sweden a wastewater treatment plant co-digests kitchen waste with biosolids to produce enough biogas for 50 city buses, the number of buses using biogas will increase to 200 by 2010. In Kristianstad, Sweden, the biogas plant converts household compostable waste, food factory waste, and manure into biogas, a greenhouse gas-neutral source of methane.

Getting Started

Anaerobic digesters that create biogas are beginning to be constructed in B.C. For example, Metro Vancouver has been awarded 2.4 million dollars in federal grant funding under the Gas Tax program to proceed with the "B.C. Bioenergy from Biogas" project. This project will increase the biogas output of the Lulu Island wastewater treatment plant, clean the biogas and provide advanced co-generation to produce electricity and heat. Other communities can begin by undertaking the following actions.

Biogas Powered Car in Kristianstad

- Completing an inventory of waste streams, such as all organic solid waste from homes, food factories, and agriculture.
- An analysis of resource needs could then be undertaken, such as a need for greenhouse gas-neutral transit fuel. This information could then be used to develop business cases for the infrastructure required to recover waste from resources.
- A local government could increase the productivity or capacity of its wastewater treatment plant digestion process, and could also divert organic solid waste from landfills by undertaking anaerobic digestion in separate vessels at the wastewater treatment plant.
- If the community does not have a biogas digester, it could study the costs and benefits of building one. Existing municipal land and assets, as well as industrial sites, could be considered as locations for a new biogas digester.

The Fraser Valley is potentially a suitable location for one or more new biogas digesters, since it could intercept source-separated organic waste from Metro Vancouver, as well as agricultural waste, food factory waste, and manure from farms in the area[14]. Residues from the digester are similar to compost since they are rich in inorganic nutrients, and could be used by local farms to reduce their dependence on artificial and mineral fertilizers. The biogas produced could either be burned for cogeneration (if the heat from cogeneration can be used), or the gas could be upgraded and sold as vehicle fuel or injected into a gas distribution network.

Summary of Biogas

Resources Consumed	• Kitchen waste; • Restaurant waste; • Food processing waste; • Wastewater treatment plant biosolids; and • Manure.
Resources Produced	• Vehicle fuel or electricity and heat from a greenhouse gas-neutral source; and • Natural fertilizer as a replacement for artificial and mineral fertilizer.
Residuals Produced	• Residuals, or digestate, from clean organic waste can be returned to farmland; and • Residuals from wastewater treatment plant biosolids can be used for industrial landscaping. If the digestate is not suitable for application to land, it could be dewatered and included in the feedstock for a thermal process such as gasification.
GHG Reductions	• Reduced methane emissions from landfills, from the displacement of fossil fuels by biogas, and from the reduction in then need for artificial and mineral fertilizers.
Pollution Avoided	• Reduced leachate soil contamination, methane emissions, and land consumption from landfills; • Reduced upstream impacts of energy production (e.g. exploration, extraction, refining, and transportation); • Reduced particulate pollution from engines fuelled with biogas compared with fossil fuels; and • Reduced water pollution caused by runoff from artificial and mineral fertilizers.
Social and Economic Benefits	• Local sustainable employment; • Lower waste disposal costs for the community; • Revenues for community; and • Increased energy independence.

5.6 Combustion of Dry Organic Waste

The low moisture content of dry organic waste makes this resource less suitable for "biological" treatment such as aerobic composting or anaerobic digestion, and more suitable for "thermal" treatment through the application of heat. There are three methods of dealing with dry organic waste through heat: combustion of wood residues; incineration; and gasification.

5.6.1 Combustion of Wood Residues to Produce Heat

In 2004, the City of Revelstoke completed a heat-only community energy project which takes wood residues from a local sawmill and uses it as the source of fuel for producing heat. The system is operated by the Revelstoke Community Energy Corporation, which is owned by the City of Revelstoke. Since the wood residue burner produces lower air emissions than an old industrial beehive burner, this project helped improve air quality in Revelstoke.

Wood Residue Burner for Community Energy in Revelstoke, B.C. [15]

Customers of the district heating system include an arena, community centre, school, aquatics centre, and hotels. They are served by two kilometres of district energy piping. The burner is located on land owned by the local sawmill, which processes heat from the system for a drying kiln; the sawmill and provides operations personnel to monitor the burner.

Funding for the $5.6 million project was provided by the Federation of Canadian Municipalities Green Municipal Investment Fund ($1.35 million in loans, and $1.35 million in grants), the City of Revelstoke, and the Revelstoke Credit Union.

This project has many positive outcomes, such as:

- reducing use of the old wood residue burner;
- improving air quality (the burner incorporates pollution control equipment in the form of an electrostatic precipitator);
- reducing greenhouse gas emissions;
- replacing propane as a source of fuel; and
- providing a non-tax source of revenue for the City of Revelstoke.

5.6.2 Incineration Of Municipal Waste

Incineration of municipal waste has traditionally been a commonly used method of solid waste disposal in B.C. Although incineration historically does not recover resources, there are new technologies which enable resource recovery. Incineration of sorted dry organic waste (e.g. wood residues, paper and cardboard which cannot be recycled) can now occur in a way which maximizes resource recovery and minimizes pollution.

One example is the City of Burnaby, which is home to a municipal waste incinerator that produces electricity as well as heat for a nearby paper recycling facility[16]. This waste-to-energy facility more than covers its costs.

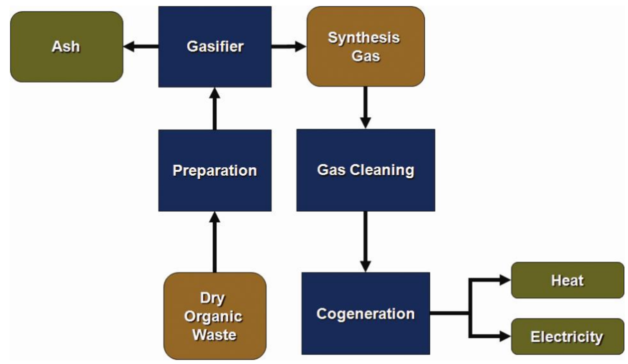
In Sweden, there are over thirty municipal waste incinerators which produce electricity and heat for district energy systems. Because of the source separation of burnable materials and advanced pollution control systems, the Swedish EPA reports that its incinerators emit a total of less than one gram of dioxins per year[17]. By contrast, a number of municipal waste incinerators in Canada emit as much as 1 to 4 grams of dioxins per year each[18]. In Sweden, a tax has recently been applied to incineration in an effort to steer more materials toward recycling. This is a good example of ensuring that waste resources are used for their highest value.

Although the environmental impact of incineration is being reduced through new technologies, the reduction of solid waste through diversion programs remains the preferred approach and the highest on the pollution prevention hierarchy.

5.7 Gasification of Dry Waste to Synthesis Gas

How it Works

Another IRR approach to dry organic waste (defined as wood residues with a moisture content below 50% such as yard and garden trimmings, and construction and demolition waste) is gasification.



Gasification Schematic

Gasification has been practiced for hundreds of years – since 1699 - originally to produce gas from coal. During gasification, the waste is heated in a vessel with limited amounts of oxygen. The waste decomposes to ash and "synthesis gas", a mixture of hydrogen, carbon monoxide, carbon dioxide, methane, and more complex hydrocarbons. Synthesis gas can be burned in a boiler for heat, or in a cogeneration plant to produce heat and electricity. It is not suitable for transmission through natural gas networks.

Gasification is a cleaner process than traditional incineration, since the process can be more tightly controlled and since it presents two opportunities for removing contaminants: first from the synthesis gas stream between the gasifier and the cogeneration engine or boiler, and again from the exhaust stream from the cogeneration engine or boiler to heat or electricity.

Nutrients

If the wood residues are free of contaminants then the ash could be used as fertilizer. If the ash contains metals it could be included with ore at a smelter in order to recover those metals. Because smelters have the necessary pollution control equipment to remove heavy metals, this option could be the safest use for contaminated ash. One pulp mill in Chetwynd, British Columbia sends the ash from its waste-to-energy plant to a mine, where the ash is blended with ore for recovery of the metals in a smelter.

Cost Considerations

Gasification and cogeneration plants can be economically viable down to sizes of 10,000 tonnes/year (equivalent to the dry organic waste from approximately 50,000 people). The economic viability depends on whether the plant receives tipping fees for waste; whether the energy can be sold via cogeneration of electricity and heat; and whether the greenhouse gas credits are sold. Land costs can also be reduced since gasification plants require relatively less space than biogas plants.

Environmental Benefits

Diverting dry organic waste from landfills reduces land consumption; lowers emissions of methane from decomposing waste; and reduces landfill leachate. Diverting construction and demolition waste away from uncontrolled incineration (e.g. a "waste burner") reduces air pollution. Gasification is also a cleaner process than conventional combustion of wood residues. Further, synthesis gas is a greenhouse gas-neutral fuel which can be burned in a cogeneration plant to produce electricity and heat. Finally, if the ash from thermal processes such as gasification is free of contaminants, it can be added to feed stocks for composting. In this way, the inorganic nutrients which were contained in the dry organic waste can be recovered and returned to the ecosystem.

Economic Benefits

A gasification and cogeneration plant can offset costs and produce revenue from tipping fees, sales of electricity and heat, and the sale of greenhouse gas credits.

Social Benefits

Revenues generated through gasification and cogeneration plants generally stay within the community. In addition, air quality and public health improves when wood residues are diverted to gasification.

Considerations

A waste-to-energy installation would need a secure and steady supply of feed stock. The availability of industrial wood residues is affected by industrial demand, since wood residues are also a source of energy for pulp mills and saw mills. On the other hand, the supply of dry organic waste from the community (e.g. yard and garden waste, construction and demolition waste) is relatively more reliable.

Wood residues would need to be source-separated to remove contaminants such as plastics.

When the moisture content of stockpiles of wood residues is high enough, spontaneous combustion caused by biological activity can occur. These risks can be reduced by minimizing the amount of wood residue stored on site.

Local governments need to ensure that truck delivery traffic is not disruptive to the community.

Where is it Done?

Gasifier installations are in place at the Tolko veneer mill in Hefly Creek and at the University of South Carolina, U.S.A., where electricity and heat are provided to the campus through gasification of wood residues. In Victoria, the Dockside Green gasification plant will be located in the heart of the development, and is expected to begin producing heat from wood residues in 2009.

Gasification installation at the University of South Carolina

Getting Started

Communities with wood residues which are not suitable for other uses could consider including this source with dry organic waste from the community (e.g. paper and cardboard products which cannot be recycled) as feed stock for a gasification and cogeneration plant. If the plant could be located on an existing industrial site, then capital and operating costs could be reduced by sharing operating and maintenance personnel.

Gasification Summary

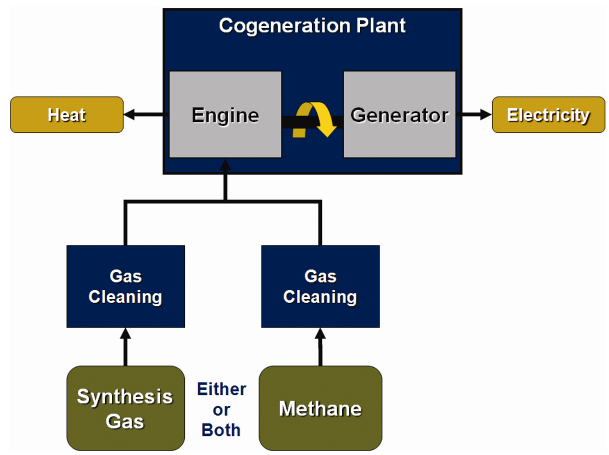
Resources Consumed	• Wood residues; • Cardboard and paper which cannot be recycled; • Yard and garden trimmings; • Construction and demolition waste.
Resources Produced	• Fuel which can be burned for heat, or for electricity and heat in a cogeneration plant.
Residuals Produced	• Ash, which could be used as fertilizer, as a component of cement production, or included with ore to allow recovery of metals.
GHG Reductions	• Avoided methane emissions from landfills; and • Avoided emissions from production of electricity and from combustion of fossil fuels which are displaced by heat from a cogeneration plant or gasification plant.
Pollution Avoided	• If wood waste is incinerated, air pollution, potentially including dioxins, from burning of unsorted construction and demolition waste; • If wood waste is buried, landfill leachate soil contamination, landfill methane emissions, land consumption; and • Upstream impacts of energy production (e.g. exploration, extraction, refining, and transportation).
Other Benefits	• Local sustainable employment; • Lower waste disposal costs for the community;. • Revenues for the community; and • Increased energy independence.

5.8 Cogeneration of Electricity and Heat

How it Works

Cogeneration refers to the process of fuel being burned in a steam plant, a reciprocating engine, a gas turbine, or fuel cell to produce electricity and heat. Heat can be recovered from the engine through heat exchangers and used as a source of heat for buildings or greenhouses.

Cogeneration plants can provide high-grade heat, at 100ºC or even higher (in the case of gas turbines), which is suitable for heating older buildings in cold climates. Cogeneration can also provide low-grade heat, at 70ºC to 80ºC, which can serve buildings which are designed to take advantage of lower-temperature sources of heat. Heat can be provided to clients through insulated underground district heating pipes.



Cogeneration Plant Schematic

Cogeneration plants are the link between sources of greenhouse gas-neutral fuels such as biogas digesters and gasification plants, and the district heating networks which can distribute the heat produced through cogeneration.

Cost Considerations

Locating cogeneration equipment in the same facility as biogas digesters or gasification plants reduces the capital and operating costs of cogeneration. Cogeneration plants using internal combustion engines can be economically viable in capacities below one megawatt, provided the heat can be sold.

Environmental Benefits

- When electricity is transmitted from central generating stations such as hydroelectric dams, to cities, approximately 10% of the electricity is lost during transmission. If on the other hand, electricity is produced locally from small, decentralized cogeneration plants, such transmission losses are minimized.
- If the source of fuel for the local cogeneration plant is greenhouse gas-neutral, then the electricity produced will have a low environmental impacts.
- Particulate emissions from cogeneration plants that burn biogas are 80% lower[20].

Economic Benefits

The rates offered by BC Hydro for energy from sustainable sources have trended upwards in recent years, and B.C.'s carbon tax has also improved the economic viability of cogeneration. Locally-produced electricity can generate revenues for local governments, while supporting Provincial and BC Hydro initiatives to generate all electricity from greenhouse gas-neutral sources. Organizations which produce electricity are able to realize the value either by reducing their own electricity costs (for example through BC Hydro's Net Metering program) or by selling electricity directly to BC Hydro.

Social Benefits

Revenues from cogeneration can remain within the community and be put toward social sustainability programs.

Electrical Requirements and Production Types

Source	Electrical Power (Megawatts)
Revelstoke Dam	1,700
Williams Lake Biomass Plant	60
Solid Waste from Greater Victoria, B.C.[19]	20
Commercial Windmill	2
Requirement for One Home	0.001

Considerations

Prices for sustainable electricity are rising, but the value of heat from a cogeneration plant can provide a significant proportion of a plant's revenues. For this reason, the full benefit of cogeneration can only be realized if the plants are located close to potential users of heat.

Cogeneration plants produce air emissions which must be minimized through the use of processes to clean the fuel (e.g. cleaning and upgrading processes for synthesis gas and biogas), and through pollution control equipment after combustion.

Cogeneration plants produce noise, the impacts of which can be minimized by the careful choice of location, and by enclosing the plant inside a secure building.

Where is it Done?

Larger wastewater treatment facilities such as Metro Vancouver's Annacis Island and Lulu Island plants generate electricity and heat for the operation through cogeneration. The engines in these treatment facilities burn biogas produced from biosolids in the plant's anaerobic digesters.

The Municipal / Private Landfill Gas Utilization Project in the Lower Mainland provides an example of developing a unique approach to local governance in order to achieve community goals such as clean air and healthy cities.

This twenty–year green energy project involves a partnership between two local governments, The Corporation of Delta, and the City of Vancouver; and two private organizations, CanAgro Produce Limited and Maxim Power Corp. The project consists of beneficially utilizing landfill gas from the City of Vancouver's Vancouver Landfill in a co-generation application, to generate electricity and heat. The electricity is sold to BC Hydro as "green" power and the heat is used to replace natural gas in the CanAgro Produce Limited South Delta greenhouse.

Cogeneration at the Iona Wastewater Treatment Plant

The project's substantial commitment in infrastructure is financed by the private sector, while both municipalities will receive environmental, social and economic benefits from the co-generation plant. Maxim Power Corp will provide the $8.5 million financing required for the 2.5 kilometre pipelines and cogeneration plant. In return for providing the LFG, the City of Vancouver will receive between $250,000 to $300,000 annually, while Delta will receive between $80,000 and $110,000 in new tax revenue. CanAgro Produce Limited will receive a secure, low-cost heating source from the cogeneration plant located on its property. BC Hydro will purchase all of the electricity under its Green Energy Program.

Replacing fossil fuels with methane from LFG to heat CanAgro's greenhouse will reduce carbon-dioxide emissions by an estimated 30,000 tonnes a year, equivalent to taking Translink's fleet of 1,100 diesel buses off the road for two months. Energy from the project is equivalent to providing the annual energy requirements to approximately 5,000 homes.

Another example of cogeneration is from the United States, where the University of South Carolina operates an integrated gasification and cogeneration plant which produces electricity and heat for the campus from wood residues. Additionally, the Wastewater Division of the King County (Seattle, U.S.A.) Department of Natural Resources has installed a 1 MW fuel cell alongside two 3.5 MW turbine generators to convert biogas into electricity and heat. [21]

Getting Started

1. Biogas digesters in existing wastewater treatment plants can be upgraded to improve their efficiency, and renovated to accept clean organic waste from the community for digestion in separate vessels beside existing facilities for digesting treatment plant biosolids.

2. Cogeneration can be incorporated into new waste-to-energy plants, which could be located close to potential users of the heat.

3. District heating networks can be used to deliver heat from the cogeneration plant to clients.

Cogeneration Summary

Resources Consumed	• Cleaned synthesis gas from gasification, or biogas from anaerobic digestion.
Resources Produced	• Electricity and heat from a greenhouse gas neutral source.
Residuals Produced	• Exhaust emissions.
GHG Reductions	• Reduced greenhouse gas emissions from the production of electricity and from the combustion of fossil fuels which are displaced by heat from the cogeneration plant.
Pollution Avoided	• Reduced upstream impacts of energy production (e.g. exploration, extraction, refining, and transportation); and • Emissions from biogas engines are cleaner than emissions from diesel and gasoline powered engines, since they contain lower levels of pollutants such as particulates.
Other Benefits	• Local sustainable employment; and • Increased energy independence.

5.9 Other Recovery Process

Biodiesel

Biodiesel is vegetable oil which has been converted into a form which can be used in diesel engines. The conversion is a chemical process called "esterification" which consumes methanol and sodium hydroxide, and produces glycerine.

Waste restaurant oil is the conventional feedstock for conversion into biodiesel, however, fat, oil and grease (FOG) from grease traps and wastewater treatment plants can also be converted[22]. Fat, oil, and grease can also be converted to biogas in a biogas digester. In New Zealand, strains of algae which contain up to 40% oil are grown in wastewater treatment ponds, and the oil is recovered for conversion to biodiesel. Ideally biodiesel production will be integrated with other resource recovery processes. For example, the glycerine by-product of biodiesel production is a resource for pharmaceutical manufacturing, and can also become a feed stock for anaerobic digestion.

Liquid Fuels

Biodiesel and aircraft fuel can be produced from biomethane (from anaerobic digestion) or synthesis gas (from gasification) through a catalytic conversion process (Fischer-Tropsch).

Cellulosic Ethanol

Cellulosic Ethanol is ethanol produced from woody material rather than from food crops. The cellulose in wood and paper residues can be converted into ethanol in at least two ways. First, residues can be gasified and the resulting synthesis gas can be reformed into liquid fuels, including ethanol. Second, cellulose can be converted to sugars through hydrolysis, allowing the sugars in turn to be fermented to ethanol. Research into both approaches is substantial in North America and Europe, and a number of pilot stage facilities have been built.

Microbial Fuel Cells

Microbial fuel cells are being developed by researchers at Washington University in St. Louis. These cells utilize bacteria to produce electricity while digesting organic materials in wastewater. Since 2005, the technology has been improved to produce ten times more electricity. Once another tenfold improvement in yield is achieved, the technology will be commercially viable for treating wastewater. This technology holds the potential to make wastewater treatment plants net energy producers.

Hydrogen

Hydrogen is produced during one of the natural stages of anaerobic digestion. Research is underway to alter the behaviour of the bacterial processes at work, in order to recover hydrogen rather than methane from anaerobic digestion[23]. This source of hydrogen would have a lower ecological footprint than hydrogen produced with electricity through hydrolysis, since most North American electricity comes from non-renewable sources.

6.0 How Communities Can Implement Integrated Resource Recovery

6.1 Overcoming the Barriers

All of the processes which have been described in this Guide are well-established and commercially available, yet many of them are more common in industrial rather than municipal processes. Below are some of the barriers local governments may experience when implementing IRR.

Staff Capacity Few local governments have direct experience with waste-to-energy infrastructure or greenhouse gas modelling, since these areas have not typically been part of their core operations. Local governments could consider holding joint training workshops with staff from experienced jurisdictions.

Conservatism and Risk Management A certain level of risk aversion in the design and planning of infrastructure is both necessary and responsible. Although resource recovery facilities may entail a greater degree of economic and social risk than conventional infrastructure water pipes, local governments can learn from other communities which have already encountered these issues. Many communities in Europe, for example, can be looked to for advice on risk mitigation.

Regulatory Environment Many communities have implemented elements of resource recovery and have worked through the regulations which applied to their initiatives. No regulatory barriers to Integrated Resource Recovery exist per se: communities which are determined to take a truly integrated approach will deal with the many regulations which apply to the environment, water, and energy as a matter of course. It will be helpful if these regulations are not weakened, but are coordinated by regulators to facilitate an integrated approach to resource recovery.

Community Acceptance Closing the ecological loops by recovering resources from waste means that new facilities will be built within city limits and near residential areas. However, when a facility to recover resources from waste is proposed for a community, there may be resistance from residents. Local governments will need to engage citizens about the environmental, social, and economic costs of current waste management approaches, and the benefits of resource recovery.

Dis-integration There are many organizations which need to be involved to implement IRR projects. These include those managing solid waste, liquid waste, potable water, transportation, land use planning, greenhouse gas reduction strategies, public transit and the supply of electricity and fuels. They are seldom integrated, however. These divisions occur not only in local and senior governments, but also in the consulting firms which serve them. One consultant may be asked to prepare plans for greenhouse gas reductions, while another prepares plans for upgrading wastewater treatment facilities, and yet another prepares a report on managing organic waste. Thus, education concerning IRR needs to cross both public and private sectors.

6.2 Policies that Support Integrated Resource Recovery

Integrated Resource Recovery requires a major shift in approaches to waste management. Despite the relatively few projects "on the ground" in British Columbia, communities can begin this shift with the following actions:

- introduce resource recovery into their Regional Growth Strategies, Official Community Plans, Community Energy Plans, and Sustainability Plans;
- ensure the processes for revising Liquid Waste Management Plans, Solid Waste Management Plans, development permit processes, building codes, zoning processes, bylaws, tax incentives, and financial grant programs encourage rather than hinder resource recovery;
- complete an audit and inventory of waste resources available and markets for energy, reclaimed water, and nutrients to identify resource recovery opportunities. The audit could include waste resources from the community as well as industry, and could identify:
    - opportunities to reduce energy and water consumption in the community;
    - liquid waste flows and their potential for energy recovery and water reuse;
    - solid waste flows and their potential for diversion to composting or energy production;
    - trends in water supply, including drought management plans;
    - streams whose environmental function could be improved with additional water;
    - industries which can provide waste or receive recovered resources; and

  - new developments which could provide waste or receive recovered resources.

- identify and remove policy barriers. For example, do regulations and local policies make it easier or harder for communities and developments to be sustainable, treat sewage on-site, or to recover resources from waste? Do building codes and related bylaws make it easier or harder to implement community energy systems?

- identify and pursue funding from the Provincial and Federal agencies for sustainable infrastructure, green electricity, and greenhouse gas reduction initiatives.

7.0 Related Provincial Government Plans, Programs and Legislation

Related plans, legislation, and programs are outlined in the table below. A table outlining funding programs is on the following page.

Provincial Plans & Goals Potentially Assisted by IRR

***Greenhouse Gas Reduction Targets Act* (Bill 44)**	• Requirement to reduce GHG emissions by 33% below 2007 levels by 2020.
Landfill Gas Management Regulation	• Under the *Greenhouse Gas Reduction (Emissions Standards) Statutes Amendment Act; and* • Establishes province-wide criteria for landfill gas capture from municipal solid waste landfills.
BC Energy Plan	• Reduce greenhouse gas emissions from energy production; and • Meet new energy needs through conservation and from sustainable sources.
BC Air Action Plan	• Reduce air pollution, including pollution from energy production and use.
BC Bioenergy Strategy	• Biofuel production to meet 50% or more of the province's renewable fuel requirements by 2020.
Living Water Smart Plan	• Reduce municipal water use by 50%; and • Improve the health of streams.
***Local Government (Green Communities) Statutes Amendment Act* (Bill 27)**	• To require local governments to set greenhouse gas emission targets, policies and actions in Official Community Plans by May 31, 2010 and Regional Growth Strategies by May 31, 2011; and • There are also new Development Cost Charges and Development Permit Area authorities.
BC Agriculture Plan	• Minimize the agriculture industry's impact on climate change.

Funding Programs for Integrated Resource Recovery Projects

Provincial	Website
Infrastructure Planning Grant Program	http://www.cd.gov.bc.ca/lgd/infra/infrastructure_grants/index.htm
Towns for Tomorrow	http://www.townsfortomorrow.gov.bc.ca
Innovative Clean Energy Fund	http://www.tted.gov.bc.ca/ICEFund
Smart Development Partnerships (for innovative land use planning)	http://www.cd.gov.bc.ca/lgd/intergov_relations/index.htm
Provincial / Federal	
Building Canada Fund: Communities Component	http://www.cd.gov.bc.ca/infra/infrastructure_grants/index.htm
Federal	
Federation of Canadian Municipalities Green Municipal Fund	http://www.sustainablecommunities.fcm.ca/home
Western Economic Diversification Canada	http://www.wd.gc.ca/eng/16.asp
Sustainable Development Technology Canada	http://www.sdtc.ca

8.0 Links to Additional Information

Provincial	Website
BC Hydro	http://www.bchydro.com
BC Ministry of Agriculture and Lands	http://www.cd.gov.bc.ca/al
BC Ministry of Community Development	http://www.gov.bc.ca/cd
BC Ministry of Energy, Mines and Petroleum Resources	http://www.gov.bc.ca/empr
BC Sustainable Energy Association	http://www.bcsea.org
Federal	
Natural Resources Canada—Sustainable Buildings and Communities	http://www.sbc.nrcan.gc.ca
Other	
Canada Green Building Council	http://www.cagbc.org
Canadian Biogas Association	http://www.biogas.ca
Canadian District Energy Association	http://www.communityenergy.bc.ca
Danish Biogas Association	http://www.biogasbranchen.dk
The Natural Step	http://www.naturalstep.ca
Swedish Environmental Protection Agency	http://wwww.naturvardsverket.se/en/In-English

9.0 Glossary

Biogas	Biogas is a product of anaerobic digestion of organic waste. Raw biogas is composed of approximately 2/3 methane, 1/3 carbon dioxide, and trace amounts of hydrogen sulphide and sulphur dioxide. The sulphur compounds are removed before biogas is used for cogeneration, and the carbon dioxide is removed before the gas is used for vehicle fuel.
Biofuels	Fuels produced from biomass such as ethanol from corn or sugar cane, as well as fuels produced from waste materials such as kitchen waste and biosolids from wastewater treatment plants.
Dry Organic Waste	Wood residues, yard and garden trimmings, and construction and demolition waste. Plastics which can be safely gasified (e.g. those which do not contain chlorine) could be included, provided a better use such as recycling is not possible. In this guide, Dry Organic Waste does not include unsorted municipal solid waste.
Extended Producer Responsibility	Under EPR, manufacturers of products and packaging are required to take responsibility for the environmental costs associated with the use and disposal of their products over the product's life cycle. The Organization for Economic Co-operation and Development (OECD) defines EPR as "an environmental policy approach in which a producer's responsibility, physical and/or financial, for a product is extended to the post-consumer stage of a product's life cycle."
GHG	Greenhouse gas
Global Warming Potential	An indicator of the extent to which a given amount of a greenhouse gas contributes to global warming. Carbon dioxide has a Global Warming Potential of 1 by definition, while methane has a Global Warming Potential of 21. In other words 1 tonne of methane is equivalent to 21 tonnes of carbon dioxide in terms of the potential of methane to cause global warming.
GJ	A gigajoule is a unit of energy, equal to one billion joules. A typical Canadian home consumes approximately 130 GJ of energy for heating and hot water per year.
GW	A gigawatt is a unit of power, equal to one billion watts.

Glossary Continued...

GWh	A gigawatt hour is a unit of energy, equal to one gigawatt of power supplied over one hour.
MW	A megawatt is a unit of power, equal to one million watts.
MWh	A megawatt hour is a unit of energy, equal to one million watts of power supplied over one hour. A typical Canadian home consumes approximately 10 MWh of electricity per year.
Struvite	A slow-release fertilizer recovered from wastewater treatment plants which have biogas digesters - magnesium ammonium phosphate (MgNH3PO4·6H2O).
Synthesis Gas	The product of heating dry organic waste with little or no air. Synthesis gas is composed of hydrogen, carbon dioxide, carbon monoxide, methane, and higher hydrocarbons.
WERC	Water and Resource Recovery Cell - an alternative name for a small, decentralized wastewater treatment plant which has been sited primarily to take advantage of the heat available in wastewater, and to take advantage of reclaimed water.
Wet Organic Waste	Kitchen waste, restaurant waste, food factory waste, wastewater treatment plant biosolids, manure and others.

10.0 Endnotes

1. Hawken, P., Lovins, A., Lovins, L. 1999. Little, Brown and Company, Natural Capitalism. 396 pages.

2. Corps GC, Salter SJ, Lucey WP, and O'Riordan J. Resources From Waste: Integrated Resource Management Study Phase 1 Report. February 29, 2008. 181 pages.

3. Utilities Commission Act RSB.C. 1996, Part 1

4. Efficiency of heat pumps is measured in terms of Coefficient of Performance, which is the ratio of high-temperature heat available per unit of electricity consumed.

5. Community Energy Association. 2007. Heating Our Communities: A module of the Renewable Energy Guide for Local Governments in British Columbia. 44 pages.

6. Source: City of San Diego

7. Swedish Environmental Protection Agency

8. Kongshaug, G. 1998. Energy Consumption and Greenhouse Gas Emissions in Fertilizer Production. IFA Technical Conference, Marrakech, Morocco, 28 September-1 October, 1998. 18 pages.

9. Björklund, A. et al. Evaluating a municipal waste management plan using ORWARE. 1999. Journal of Cleaner Production, vol. 7 pp 271-280.

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11. Aviation. Kjelgaard, C. 2007. Qatar Leads New Research into Cleaner Jet Fuel.

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13. Source: Municipality of Kristianstad

14. Electrigaz Technologies. 2007. Feasibility Study – Anaerobic Digester and Gas Processing Facility in the Fraser Valley, British Columbia. Prepared for the B.C. BioProducts Association. 105 pages.

15. Source: Revelstoke Community Energy Corporation

16. Metro Vancouver. 2006. Waste-to-Energy Facility.

17. Swedish Environmental Protection Agency

Endnotes Continued…

18. Environment Canada's National Pollutant Release Inventory

19. Assuming all solid waste is used to produce electricity through cogeneration.

20. Westport Innovations Inc.

21. US Department of Energy. 2005. Wastewater Treatment Gas to Energy for Federal Facilities: Biomass and Alternative Methane Fuels. 4 pages.

22. East Bay Municipal Utility District, Oakland California

23. Jeong Ok Kim et al. 2006. Enhancing continuous hydrogen gas production by the addition of nitrate into an anaerobic reactor. Process Biochemistry. Volume 41, Issue 5, May 2006, Pages 1208-1212.