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Canada

R-NET

Canadian Association of Recycling Industries

RECYCLING TECHNOLOGY NEWSLETTER

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Environment Canada declared the town of Key Lake, Saskatchewan the coldest place on the planet with temperatures of -52.3 °C and -52.6 °C on January 28 and January 29, 2004, respectively. The records that were broken these days go back to 1915.

The planet Earth is currently recovering from approximately six centuries of the Little Ice Age. The ice age of the recent centuries was much shorter than the previous glaciation events and it is possible that it was interrupted by the side effects of man's activity. The Little Ice Age arrived with severe windstorms and sea floods after approximately five centuries of medieval warmth (800-1300 AD).

What was the trigger that ended over four centuries of the mild medieval warmth and brought the severe cold?

H.H. Lamb in his book "Climate, history and the modern world" (1982) warns that to develop any sound scientific and reliable system of forecasting or even just to give advice on the climate of the future, one has to first understand the causes of climatic fluctuations and change:

- Variations in the energy output of the sun (and possibly in the transparency of interplanetary or interstellar space, stellar dust).
- Astronomical variations affecting the distance of the Earth from the Sun, and the geometry of their interactions.
- Variations in the transparency of the atmosphere to either incoming solar radiation or outgoing Earth radiation arising from a multitude of sources: volcanic dust in the atmosphere, carbon dioxide concentration, cloud cover, concentrations of ozone-destroying substances, and changes in the radiation balance from effluent sulphur dioxide, hydrogen sulphide, carbon monoxide, and ammonia.
- Changes in the heat economy of the oceans and atmosphere - the Great Ocean Conveyor Belt and its ramifications. Recently a number of articles warned that human-influenced warming could bring fresh water dilution to the Atlantic Ocean resulting in the slowing or even stopping of the Great Ocean Conveyor Belt and the sudden freezing of our world.
- Changes in the absorption and re-radiation of incoming energy at and near the Earth's surface through variations in cloudiness, and changes in the nature of the surface itself: changes in the distribution of land and sea, mountains, and ice-sheets.

As confidence in the ability of models to project future climate grows, one has to remember that climate models are scientific tools and not crystal balls. Even the most sophisticated models can only approximate the system that their creators seek to understand.

Elizabeth Giziewicz
Editor-in-Chief
CANMET - Mineral Technology Branch

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Please keep writing to us with your ideas and suggestions. Share your success stories with us, do not forget to tell us about meetings and conferences that you are organizing, and be sure to let us know if you mention us in any of your publications.

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Elizabeth Giziewicz
555 Booth Street, Room 338 B
Ottawa, Ontario
Canada K1A 0G1

or send a request by e-mail to:
giziewic@nrcan.gc.ca

R-NET
Natural Resources Canada
555 Booth Street, Room 338B
Ottawa, Ontario
Canada K1A 0G1
Telephone: (613) 996-1581
Fax: (613) 996-9041
http://RNET.NRCan.gc.ca
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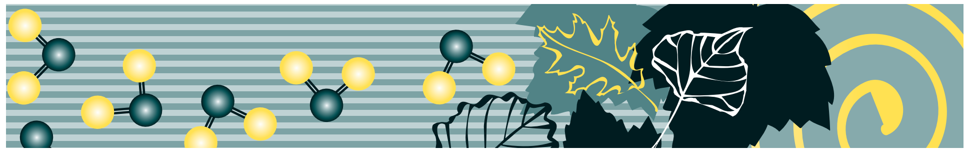

Carbon Sequestriation and Recycling

Carbon in the atmosphere

The Intergovernmental Panel on Climate Change (IPCC) (http://www.ipcc.ch/) reports that atmospheric carbon dioxide has increased by 31 percent since 1750 - mainly due to a global economy dependant upon fossil fuels - and will continue to increase as long as human activities load carbon dioxide into the atmosphere faster than it can be removed by natural sinks. The United Nations Framework Convention on Climate Change defines a sink as "any process, activity or mechanism that removes a greenhouse gas (GHG), an aerosol, or precursor of a greenhouse gas from the atmosphere." As natural sinks become saturated, the rate at which they can uptake excess atmospheric carbon dioxide is expected to diminish.

Mitigation options

To reverse the trend of rising atmospheric GHGs and maintain sustainable emission rates of carbon dioxide (rates that will not impact negatively upon natural ecosystems) one must explore all possible climate mitigation approaches. The two most common approaches are energy efficiency (reduction of overall energy consumption) and the substitution of fossil fuels with low or zero emission, renewable energy sources. A less acknowledged strategy is that of carbon sequestration. According to the IPCC, "strategies for achieving deep reductions in CO_2 emissions will be most robust if they involve all three types of mitigation options."

What is carbon sequestration?

The term carbon sequestration means removal of GHGs from the atmosphere by plants or technological measures. This term generally is used now in the context of "carbon capture and sequestration," where carbon refers to the greenhouse gas carbon dioxide. Carbon already present in the atmosphere can be sequestered via *natural pathways* (i.e., absorption by oceans and uptake of CO_2 by plant life during photosynthesis). Carbon can also be captured from a waste stream before it enters the atmosphere. In this context, sinks include oceans and geological reservoirs. While oceans offer the greatest storage capacity, some geological sinks offer commercial opportunities for "unwanted" CO_2, making this option relevant to recycling.

Geological storage

Sequestration has traditionally been applied in situations where either the captured CO_2 is a valued product for another purpose - capture for utilization in enhanced oil recovery (EOR) or enhanced coal bed methane (ECBM) production - or the removal of CO_2 enhances a process. EOR refers to the injection of CO_2 into oil and gas reservoirs to increase well productivity. According to the International Energy Agency (IEA), only 4 out of the 74 EOR projects underway worldwide use anthropogenic CO_2 in their operations. One such project is in southern

> *Canada's wealth of suitable geological formations (depleted oil and gas reservoirs), high intensity of fuel production (oil sands development) and expertise in the energy industries makes geological storage of carbon dioxide an important direction for research.*

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Saskatchewan, where EOR is expected to extend the production life of the Weyburn oilfields by 25 years. 5000 tonnes/day of CO_2 captured from a power generating station in North Dakota are delivered via pipeline to the oilfields. Researchers are currently monitoring the mobility and fate of CO_2 in the reservoir. Over its lifetime, this project is expected to store 20 million tonnes of CO_2. In ECBM production, carbon dioxide is injected into unmineable coal beds to displace adsorbed methane (coal surfaces bind CO_2 with more affinity than methane).

The International Energy Agency (IEA) Greenhouse Gas R&D Programme (http://www.ieagreen.org.uk/), based in the United Kingdom, is supported by many partner nations as well as international energy companies. Their website - http://www.co2sequestration.info/ - showcases major sequestration research initiatives underway around the world. To view descriptions of sequestration projects by the US Fossil Energy Program follow the link on http://www.ornl.gov/fossil/.

Capture and separation

The limiting factor in establishing viable carbon sequestration activities is, of course, an economic one: specifically, separating and capturing a pure stream of carbon dioxide from mixed waste streams. The transportation sector accounts for a large proportion of Canada's annual GHG emissions (190 million tonnes), however these diffuse sources of CO_2 present a challenge to cost-effective capture. Given that electricity and heat generation account for 128 million tonnes/year in GHG emissions and offer the opportunity to capture large volumes of CO_2 from fewer point sources, large power generating plants are a more cost-effective source of CO_2 capture. According to Natural Resources Canada, "costs of removing and treating CO_2 from stack gases represent probably two-thirds or more of the overall costs of capture and storage. In addition, there is an energy penalty associated with CO_2 capture that reduces overall power generation capacity."…and therefore increases energy costs.

Work is underway at the International Test Centre for CO_2 Capture (Boundary Dam power plant and the University of Regina in Saskatchewan, Canada), to test the efficacy of different solvents as part of a chemical absorption process to capture CO_2 from the stack gases of fossil-fuel power plants. The most common solvents are amine-based, however CO_2 can also be adsorbed onto activated carbon or filtered through specialized membrane systems.

Grimston et al. report that sequestration options besides ECBM production and EOR are currently more expensive than "no regret" climate change mitigation options such as forestation and fuel switching. However, the emergence of a carbon permit trading system as part of the Kyoto Protocol will help to put a price tag on carbon emitting processes and practices, thereby increasing the economic viability of sequestration.

As with all climate change issues, the avenues of discussion with respect to carbon sequestration are virtually limitless. Hopefully, this brief introduction provides a starting point for further exploration of this fascinating topic.

Carbon dioxide recycling

Carbon dioxide can be chemically transformed into marketable products. For example, the Quebec based company, CO_2 Solution, using a laboratory scale bioreactor, has perfected the dissolution of CO_2 in water followed by the enzyme-mediated transformation into bicarbonate. The company is currently focusing their research on implementing this technology in commercial settings, such as heavy industries and power stations. This requires both

Et cetera...

Energy recovery refers to the implementation of thermal conversion technologies (pyrolysis, gasification and microwave processing) to produce fuels and/or heat from biomass and/or difficult to recycle wastes. Target materials for energy recovery are generally not amenable to recycling because: a) they consist of mixed materials and cannot be economically separated; b) are available in small quantities; and c) do not have well-established or viable end-uses. Examples of potential feedstocks include rubber, low value plastics (mixed plastics, film), automotive shredder residues, organic wastes, medical waste, and household hazardous waste. In addition to producing "clean" burning fuels with high heat content, these technologies can reduce material volumes by nearly 95% and produce marketable solid residues.

There have been a number of reputable scientific investigations of the environmental consequences of **plastics incineration**. These studies indicate that even when the feed (input to an energy from waste facility) is spiked with a high proportion of plastics, contaminants of stack emissions (i.e., acid gases, dioxins and furans) and solid residues (heavy metals and trace organics) consistently meet stringent North American and European standards. In fact, it has been observed that plastics aid overall combustion of waste to yield a smaller amount of residue requiring disposal. The EPIC discussion paper, *A Review of the Role of Plastics in Energy Recovery*, available on their website (www.cpia.ca/epic) is an excellent starting point from which to explore this topic. As well, based on a life-cycle methodology of the effects of waste management activities on greenhouse gas emissions, EPIC asserts that plastics incineration, when optimized at energy efficiencies of 30% or greater, is more effective at reducing greenhouse gas emissions than recycling.

Capture and Sequestration of Greenhouse Gases in Canada
F. Mourits
Natural Resources Canada
Available online at
http://apec-egcfe.fossil.energy.gov/Thai%20Seminar_2000/F_Mourits_paper_all.pdf
The author reviews the status of CO_2 capture and storage technology in Canada.

The Capture and Storage of Carbon Dioxide Emissions: A Significant Opportunity to Help Canada Meet its Kyoto Targets
Available online at Natural Resources Canada's Office of Energy Efficiency website,
http://www2.nrcan.gc.ca/es/oerd/english/View.asp?x=649&oid=18
This report reviews the current status of CO_2 capture and storage technology development in Canada and the contribution that these technologies could make to greenhouse gas mitigation.

The European and Global Potential of Carbon Dioxide Sequestration in Tackling Climate Change
M.C. Grimston, V. Karakoussis, R. Fouquet, R. van der Vorst, P. Pearson, M. Leach
Climate Policy ***2001****, 1, 155-171 (Eng)*
Achieving a sustainable level of CO_2 emissions into the environment will require an integrated approach to carbon management that includes: more efficient production, delivery and use of energy; a shift towards the use of low-carbon or renewable fuels; and carbon sequestration. This article provides the reader a broad understanding of carbon sequestration, beginning with a description of the phases of sequestration. The report compares the cost and CO_2 reduction potentials of different seques-

developing enzymes that can withstand a broad range of environmental conditions and optimizing bioreactor performance. The company's website is http://www.co2solution.com/.

The Japanese companies Mitsubishi Chemical, Mitsubishi Chemical Engineering Corporation and Shimadzu Corporations are currently pilot plant testing a new technology converting carbon dioxide into carbon nano-fibres and water by reacting it with methane gas in the presence of a catalyst. The companies claim that the reaction uses very little energy.

Another Japanese invention is the process of "Global Carbon Dioxide Recycling". In 1996 a prototype CO_2 recycling plant was built on the roof of the Institute for Materials Research, Tohoku University in Sendai, Japan. The researchers generate electricity using solar cells that could be placed in sunny deserts. The electricity is used in the electrolytic production of hydrogen from seawater. Hydrogen is then reacted with carbon dioxide in an exothermic reaction producing methane. Methane is liquefied and used as fuel; the resulting carbon dioxide is captured and returned to react with hydrogen closing the recycling loop.

George A. Olaf, the Nobel laureate in Chemistry (1994) researched a number of carbon dioxide transformations. Unfortunately these methods are quite energy intensive and have to wait until a more abundant, inexpensive energy source becomes available. George A. Olaf working at the Loker Hydrocarbon Research Institute at the University of Southern California in Los Angeles developed methods allowing conversion of methane to higher hydrocarbons and made significant progress in conversion of carbon dioxide into methanol and hydrocarbon products.

Dimethyl carbonate (DMC) is now produced commercially from carbon dioxide. DMC is used as a solvent, as an octane booster in motor fuels and it also has very good anti-knock properties. If accepted as a gasoline additive the potential for carbon dioxide utilization will be immense. Globally, one million tonnes of carbon dioxide per year might be used in DMC production (www.ieagreen.org.uk).

An Overview of Plastic Recycling Options

While the use of plastics has contributed immeasurably to quality of life, the ever increasing volume and diversity of plastic products present a number of challenges with respect to finding economically and environmentally sound solutions for these materials when they reach their end of life.

Ultimately, about 2% of the fossil fuels produced in Canada each year are incorporated into domestically manufactured plastic products. The 15 resin manufacturers in Canada produce almost 3.5 million tonnes of various resin types each year. In 2002, about 1200 business were involved into converting plastic resins into manufactured products. According to Industry Canada, the major end-uses for plastics in Canada are: packaging (34%), construction (26%), and the automotive industry (18%).

Plastic resins are predominantly hydrocarbon polymers. These resins can be compounded with a wide range of additives to produce a plastic material with unique qualities. The ubiquity of plastics in modern society is owed to the fact that various resin and additive combinations can make a plastic product suitable for a virtually limitless number of specialized applications including electronics, textiles, packaging, building and automotive materials and other consumer goods. But when we are "finished" with these materials, should they be landfilled, recycled, incinerated or subject to chemical or thermal degradation? Depending upon the type, source and volume of plastic waste, any one of the above options could provide the greatest environmental, social and economic benefits.

According to the Environment and Plastics Industry Council (EPIC), plastics represent 7-8 percent of the Canadian municipal solid waste (MSW) stream by weight (671 000 tonnes/year), however, because of their low density, they account for a much larger proportion by volume. Packaging accounts for an overwhelming 84 percent of the plastic waste stream (564 000 tonnes) with the most prevalent materials being film (176 000 tonnes of recyclable polyethylene and 106 000 tonnes of unrecyclable mixed resin or contaminated film), bottles (179 000 tonnes of polyethylene teraphthalate (PET) and high density polyethylene (HDPE)) and polystyrene (58 000 tonnes).

Because plastics are relatively new on the scene, existing Canadian recycling infrastructure (market opportunities, collection approaches, analytical tools and communication networks) are not as well developed as those for the more traditional raw materials like wood products, metals and glass. As a result, plastic recovery rates fall far below those of materials like newspapers and aluminum cans. In Ontario, for example, overall plastic container recovery is estimated at 12% (Recycling Council of Ontario, *Ontario gets a C minus in residential recycling*, 1999). Recovery capabilities are improving as evidenced by a study of plastic waste in Ontario that reveals PET and HDPE recovery rates to be 42% and 36%, respectively (based on households with access). PET and HDPE are abundant in the waste stream, have well-established end markets and lend themselves to many uses including carpets, textiles, pallets, and composite building materials. Most Canadian municipalities, therefore, target their curbside and/or depot collection of plastics towards these resins. Uncaptured post-consumer PET and HDPE represent missed opportunities for economic and environmental benefits. A study by the American Plastics Council has shown that when consumers are asked to recycle all plastic bottles (containers with wider base than neck) rather than to identify high value plastics based on their resin type, the capture of marketable PET and HDPE plastics is favoured over less valuable tubs and lids, films and foamed plastics. Decreasing the proportion of unmarketable plastics in curbside and depot programs makes collection more economical. Read more about the "All Bottle" approach at http://www.plastics.ca/allplasticbottles/.

Some people have suggested that biodegradable plastics would solve the problem of diminishing landfill space. Modern landfills are designed to limit degradation so unless biodegradable plastics are separated from the rest of the waste stream and subject to appropriate conditions, their use in place of conventional plastics offers no advantages. Biodegradable plastics are, however, suitable for niche applications such as medical sutures and compost bags.

Most of the common plastics found in MSW are thermoplastics, meaning that they can be mechanically recycled: separated into resin types, flaked, thoroughly washed and dried and eventually formed into uniform pellets via extrusion under heat and pressure. These pellets are a marketable commodity demanded by manufacturers that use recycled plastics in their products. Most plastic recyclers process single resin streams to maximize product quality (because resins have distinct melting points), necessitating the need to cost-effectively identify and remove incompatible plastics and contaminant materials. Plastics can be sorted at a material recovery facility (MRF) by hand, which, although costly, is effective because

tration strategies. The costs of sequestration versus the costs of emitting CO_2 are discussed, with reference to carbon taxes under different emission trading scenarios. The high costs of sequestration are largely associated with the separation and removal of CO_2 from a waste stream (separation and capture phase) and vary depending upon the technology employed and the purity of the gas required. Costs are not an issue, however, in sequestration practices that enhance the recovery of hydrocarbon fuels, like the injection of CO_2 into oil and gas reservoirs and unmineable coal and coalbed methane formations. The expertise associated with these well-established practices can advance the development of other geologic storage options. The authors also introduce various approaches to ocean disposal while stating that the safety and environmental consequences of this practice require further investigation. According to the authors, ocean and geologic storage have the highest associated costs but also represent enormous emission reduction potentials. At present, carbon sequestration methods, besides enhanced hydrocarbon recovery and capture for utilization, appear to be more expensive than mitigation approaches like switching to clean energy technologies and "least regret" options like energy efficiency. The article discusses policy mechanisms most likely to be employed to encourage CO_2 emission reductions and carbon sequestration research, including taxes, credits and tradable permits. Benefits of sequestration and the barriers to well-established sequestration practices are also identified. The carbon sequestration approaches being researched in Europe are outlined and these efforts indicate a growing interest in underground sequestration. The article also includes a section on the major R&D directions taking place in both the public and private sectors internationally.

Materials for Global Carbon Dioxide Recycling

K. Hashimoto, M. Yamasaki, S. Meguro, T. Sasaki, H. Katagiri, K.Izumiya, N. Kumagai, H. Habazaki, E. Akiyama, K. Asami

Corrosion Science ***2002****, 44, 371-386 (Eng)*

The authors conceptualized, developed and tested a process of carbon dioxide recycling. Electrolysis of seawater is performed using solar cells located in deserts. An exothermic reaction between hydrogen and carbon dioxide yields methane. Methane is liquefied and transported to customers. The authors describe in detail the cathodes made of Ni-Mo, Ni-Mo-O and Ni-Fe-C alloys. They emphasize the difficulty of developing the oxygen evolving anodes. The anodes were produced from manganese oxides doped with elements, such as hexavalent tungsten or molybdenum. The reaction of CO_2 with H_2 was catalysed by Ni-Zr alloys resulting in 100% selectivity of CH_4 formation at 1 atm. The prototype plant was built on the rooftop of the Institute for Materials Research, Tohoku University in Sendai, Japan. The solar cell unit was connected with 32 electrolytic cells producing H_2. Two reactors were converting CO_2 to CH_4 by reacting it with H_2. There also was a CH_4 combustion unit combined with the CO_2 recovery unit. The authors have been awarded 3-years funding under the umbrella of the Development of Revolutional Technologies in Millennium Projects to build a pilot plant recycling CO_2. One can expect their industrial scale findings in approximately 2005. If successful, the authors claim, this system is able to supply abundant renewable energy.

Thermal Depolymerisation of Scrap Polymers

M. Newborough, D. Highgate, P. Vaughan

Applied Thermal Engineering ***2002****, 22, 1875-1883 (Eng)*

Three methods of recycling scrap polymers are mechanical processing, pyrolysis and depolymerisation.

hand sorters can become proficient at separating target plastics based on product type and brand name. Identification is also facilitated by plastic resin codes, introduced by the Society of the Plastics Industry in 1988. Recycling enterprises may employ any one of a number of available technologies to obtain a pure feedstock from heterogeneous plastic waste streams using density, spectroscopic or electrostatic techniques. The Plas-Sep electrostatic separation process, developed at the University of Western Ontario, was featured in Volume 5, Issue #1 of R-Net (January 2000).

In the midst of uncertain market opportunities, it is difficult for recycling enterprises and municipalities to invest capital in improved sorting technologies and other innovative tools. The costs of producing virgin plastic resins are highly dependant upon the price of oil. Producers of recycled resins, however, must try to remain competitive with producers of virgin resins while trying to obtain market prices for their products that will offset their fixed costs for collecting, sorting and processing post-consumer/post-industrial plastics. As such, markets for recycled resins can be unpredictable (see Corporations Supporting Recycling Price Sheet, http://www.csr.org/Publications/Jul2004_PriceSheet.pdf)

So, what about the plastics present in MSW that are not collected by your municipality? Besides PET and HDPE, the Ontario post-consumer plastic stream contains about 227 000 tonnes of other rigid plastics, film and durable goods. Post-industrial plastics are typically more homogeneous and cleaner than post-consumer plastics and therefore offer savings - in terms of collection and sorting - to recyclers. Efficient recovery programs for polystyrene and film coupled with market development in this sector would help to improve local recycling infrastructures and improve the viability of recovering lower value resins from the residential sector. In Mississauga, Ontario, the Canadian Polystyrene Recycling Association (http://www.cpra-canada.com) can recycle 3500 tonnes of polystyrene/year explaining why more than 1 million households in Ontario and Manitoba have access to polystyrene recycling. In some regions, there are markets for commingled plastic wastes including substitute lumber and other building materials.

While most plastics can be recycled in some way, economics may not favour their recovery in all regions. For products without well-developed markets, collection and processing costs outweigh any future market values. As well, the enormous amounts of energy required to recover these materials and input them back into the economy may make disposal via incineration or landfill as a mixed waste stream a more environmentally sound solution. In regions or sectors where recovery is not beneficial, low value resins could be landfilled in specialized areas so that they could be mined when market conditions or recycling capabilities improved.

There are a number of recovery obstacles associated with the use of plastics in specialized applications, including the presence of metallized coatings, paint and labels, small and intricate components, plastic composites (mixed resins) and lack of product identification. What can an environmentally conscious consumer do with their end-of-life high impact polystyrene (HIPS) and acrylonitrile butadiene styrene (ABS)? These are two of the most common plastics found in end-of-life electronics, according to the American Plastics Council. Environment Canada projects that the volume of information technology and telecommunications waste will reach 61 866 tonnes this year and that various plastics comprise roughly 23% of personal computers and monitors alone. Plastics are also becoming more and more important in automobile manufacture, for good reason. These strong and versatile materials can displace the use of metals, making vehicles lighter and more fuel-efficient. But if these materials are not recovered as resources from end-of-life vehicles during dismantling, they will ultimately end up as part of the mixed waste stream termed Automobile Shredder Residue (ASR). Each year, North America produces 3 million tonnes of ASR.

According to Alberta Environment (Government of Alberta, Canada) the energy value of HDPE is 18 700 Btu/lb and that of fuel oil is 20 900 Btu/lb.

Specialized plastics and/or mixed resin streams, such as electronic components and ASR, are excellent candidates for chemical and thermal recycling. Less common than thermoplastic resins, thermoset plastics are not amenable to mechanical recycling because, upon heating, the polymer chains become crosslinked and the plastics cannot be reformed. They can be used as fillers in other plastics but are also suited to chemical or thermal recycling. An example of chemical recycling is the depolymerisation of PET via glycolysis or methanolysis. The reclamation of monomer building blocks that can be repolymerised into "new" plastic resins, suitable for food and beverage packaging, increases the diversity of application for recycled plastics.

Thermal recycling - gasification and pyrolysis - also recovers chemical constituents of plastics, which can be used as feedstocks for new chemical products or energy sources. Because plastic have hydrocarbon backbones, they contain substantial embodied energy with calorific values approaching those of other fuels. A wide variety of gaseous, liquid and solid products can be formed depending upon operational parameters and the characteristics of the feedstock. Although costly to implement, thermal recycling technologies offer enormous potential benefits as "clean" energy sources that can displace conventional fuels associated with high greenhouse gas emissions. Overall, recycling plastics offers the benefits of conserving our fossil fuel resources and decreasing the amount of wastes that are outputted to the environment.

Addressing Gaps in Current Recovery Approaches

Waste management is under provincial/territorial jurisdiction, however it is municipal governments that must provide collection and diversion programs and waste management facilities that fulfill these provincial/territorial requirements. The resource recovery capabilities of municipalities are dictated by the local variables that make them unique, such as: population, nature of proximate industries, location and access to markets, existing infrastructure and financial resources. An overall lack of consistency among programs coupled with inconsistent reporting frameworks has resulted in uncertainty on the part of decision makers about both regional and national priorities and opportunities.

Many municipalities in Canada have waste diversion targets of 50% or greater, although according to Statistics Canada, residential diversion rates had fallen from 25% in 1998 to 23% in 2000 and diversion rates from other sectors have stalled at similar levels. This indicates that there are significant gaps in current diversion programs and as a result mountains of uncaptured resources are dumped in landfills. A broad range of awareness, communication, economic and policy issues must be addressed to facilitate economic recovery. Certain regions/groups in Canada have implemented outstanding solutions to address these challenging issues.

Systems for characterizing recycling rates and providing statistics are historically underdeveloped in Canada and a national standard reporting framework does not exist. According to Statistics Canada, these inconsistencies make it difficult to:

Depolymerisation allows the reclamation of the original monomer building blocks of plastics. There are inherent drawbacks to the commercial Clementi depolymerisation process, the most significant being associated with the use of a molten lead bath for polymer flotation. The use of molten lead causes the production of lead contaminated dross (disposal problems) and monomer products that are unsuitable for many applications. Fluidised bed processes, which do not use lead, have proven to be more energy efficient and produce relatively little solid residue. The crucial aspects of effective depolymerisation via a gas-fluidised bed (GFB) process are discussed, with particular reference to poly-methyl-methacrylate (PMMA) as the feed material. Research efforts have been focused on refining a mechanically fluidised bed process that uses a vibratory system to achieve effective depolymerisation. The commercial viability of this system is promising because it eliminates the operational problems associated with the circulating gas stream of the GFB process.

Gasification Process of Wastes Containing PVC
C. Borgianni, P. De Filippis, F. Pochetti and M. Paolucci
Fuel ***2002****, 81, 1827-1833 (Eng)*
The article presents the process of gasification of PVC, without the need for dechlorination. A bench scale two-stage reactor has been used to demonstrate a gasification process for PVC blends that yields a syngas with a chlorine content considered safe by Italian law (below 5 mg/m^3). Refuse-derived fuel (RDF) was tested as the sole reactor feed to examine the effects of various operating conditions upon the process and its products. Because chlorine slows combustion, the addition of PVC to the RDF caused an increase in the amount of unreacted material in the solid residue and a decrease in the heating value of the produced off-gas. The addition of Na_2CO_3 proved to efficiently remove chlorine. Using test

results, a thermal dynamic model was developed, the predictions of which were comparable to experimental data. This model was employed to design the optimal working conditions of a scaled up gasification system that could be used to supply electrical power or heat.

Vacuum Pyrolysis of Automobile Shredder Residues
C. Roy and A. Chaala
Resources, Conservation and Recycling ***2001****, 32, 1-27 (Eng)*
Ten different automobile shredder residue (ASR) samples from a variety of sources have been processed via vacuum pyrolysis using one of three reactor systems: a laboratory scale batch reactor, a multiple furnace process development unit and a pilot plant reactor. Thermal decomposition reduces original volumes by at least five times and produces solid, liquid and gaseous products. The proportion of each product is influenced by the amount of organic matter in the ASR and the temperature applied. The organic content of the samples in this study range from 41.3 to 82.3 wt.% and the average gross calorific value is 20 MJ/kg. Vacuum pyrolysis typically produces a large proportion of solid residue, an average of 52.5 wt.% and includes fines and recoverable metals. Oils and aqueous phase products are the second most abundant products while gaseous products make up an average of 6.6 wt.%. The composition of the gaseous phase proves to be relatively constant and is comprised of hydrogen, carbon dioxide, methane, carbon monoxide and short chain hydrocarbons. The calorific value of the gaseous phase is quite high, at an average of 24 MJ/kg (compared to the calorific value of natural gas at 56 MJ/kg).

NO_x and SO_2 Emissions from O_2/CO_2 Recycle Coal Combustion
E. Croiset and K.V. Thambimuthu
Fuel ***2001****, 80, 2117-2121 (Eng)*
Capturing and sequestering CO_2 from the stack gases of coal burning power plants could significantly reduce global

- Develop accurate and verifiable waste quantities
- Make meaningful comparisons among municipalities, provinces and industrial sectors
- Compare waste management system performance from one year to another
- Communicate the results of waste diversion programs
- Evaluate budget and grant proposals

Corporation Supporting Recycling (CSR) has developed GAP - Generally Accepted Principles for measuring municipal waste flow. This tool allows municipalities to identify what should and should not be included and excluded in records of waste generation and diversion in any municipality or jurisdiction, and to report waste flow and diversion in a consistent manner across Canada. When a **consistent reporting framework** has been established for the residential sector, similar tools can be customized for industrial, commercial and institutional (IC&I) and construction and demolition (C&D) sectors. See http://www.csr.org/CSR_National/GAP/GAP_intro.htm for more information. Strong federal guidance and support must be supplied to advantage the use and adoption of these environmentally responsible and innovative tools. See also, the Integrated Waste Management (IWM) Tool at http://www.iwm-model.uwaterloo.ca/english.html. IWM is a user-friendly computer tool that allows municipal solid waste management professionals to assess the environmental (including GHG emissions) and financial impacts of different residential waste management practices for specific product streams.

Many provincial governments regulate consumer deposit programs like beverage container and paint recycling programs in conjunction with manufacturers, independently run product return depots, retailers and consumers. The high recovery rates (beverage container program recovery rates often exceed 80%) help to illustrate "the art of the possible" when **producer responsibility** is extended to the post-consumer stage of a product's life-cycle. To view a list of provincial stewardship programs, visit the Environment Canada website *Extended Producer Responsibility (EPR) and Stewardship* at http://www.ec.gc.ca/epr/.

The Manitoba Product Stewardship Corporation uses the 2 cent levy charged on beverage containers to provide support for municipal recycling programs in the province. This support includes incentive-based funding (flat rate paid per tonne of target material recovered) as well as promotion and education materials and marketing and technical advice. The idea is to harmonize recovery approaches across the province so that circumstances are optimized for the recovery of target materials. This steady volume of quality recyclable materials contributes to establishing an **economy of scale**, an important challenge for provinces with many small, rural communities. A similar organization is Nova Scotia's Resource Recovery Fund Board.

Spending of municipalities and other government bodies providing waste management services totaled $1.4 billion in 2000 while private business spent in excess of $500 million. The Federation of Canadian Municipalities (FCM) asserts that waste management costs are under-priced due to a lack of **full-cost accounting**. Economic instruments have proven to be quite successful in communicating the true costs of wasting to Canadians. For example, over 160 Canadian cities have implemented user pay systems - whereby residents pay for collection based on the amount of waste they generate - and have noted marked reductions in disposal tonnages.

The City of Guelph (Ontario) has demonstrated the value of **source separation, social pressure**, and **visibility of waste** to diversion efforts. Guelph has adopted an innovative collection approach whereby residents are asked to separate their household wastes into three streams: dry recyclables, compost and residuals (anything that is not recyclable or compostable). Source separation results in a cleaner stream of materials arriving at the local material recovery facility (MRF). Householders deposit materials for collection at the curbside in clear bags. The clear bag concept has resulted in a participation rate of 98%, owing to social pressure and fear of sanctions for non-compliance. According to the city's local newspaper, The Guelph Tribune, residents feel that sorting has "really helped them be conscious about how much waste they generate."

Some of the most successful diversion programs in the country are attributed to the development of large **state-of-the-art facilities** that provide comprehensive resource recovery services. For example, the City of Edmonton, Alberta hopes to achieve a diversion rate of 70 percent with its facility that comprises a composting unit, MRF, sanitary landfill, dry landfill, wetland area, research and demonstration area and a biosolids lagoon (http://www.ewmce.com/). Incorporating all of these elements into one facility allows waste managers to identify potential synergies and clearly conceptualize the nature and diversity of the region's waste flows. To optimize the flow of wastes to a cutting edge facility like the Edmonton Waste Management Centre of Excellence, the future may see an emphasis upon small-scale distributed and clustered systems of specialized nodes (collection depots, transfer stations, storage and sorting facilities) whose properties can be adjusted to complement community capabilities. Read more in Green Municipalities: *A Guide to Green Infrastructure for Canadian Municipalities*, by the Federation of Canadian Municipalities (FCM, May 2001) available on their website (http://www.fcm.ca/).

The establishment of **Resource Recovery Parks** can advantage regional independence and self-sufficiency. These facilities bring together under one roof all of the actors that may make a positive community contribution through end-of-life product management. Motivated by the threat of area landfill or incinerator development, the Region of Halton Hills, north of Toronto (Ontario) established a WasteWise Community Resource Centre to demonstrate the positive effects that end-of-life materials could have on a community if treated as a resource rather than a liability. This centre houses repair, reuse, and recycling enterprises and acts as a venue for education and information about resource and waste issues. Resource Recovery Parks can catalyze the development of viable and profitable end markets for captured resources within the community, thereby reducing dependence upon government bodies and distant regions and industries for new products, waste disposal and purchase of recyclables.

Effective capture and recycling of end-of-life products is not a means to an end. At each successive stage of its life-cycle (production, distribution, use by consumers, disposal), a product will have some sort of impact (resource consumption, energy use, emissions of waste to water, air and soil). **Zero waste** is about anticipating these impacts and designing material and energy flows that will maximize value and minimize deleterious impacts at every life-cycle stage.

Concepts like **Design for Environment** (DfE) and **Design for Disassembly** (DfD) promote benign material and renewable resource inputs and that products themselves are impact neutral. Specifically, DfE products are those that incorporate the true costs (to the environment and future generations) of every life-cycle stage into product design (cost internalization). DfD means that products are designed in distinct modules with fewer materials that can be easily separated and recycled or put to another use when a product is upgraded or repaired.

Imagine if we all leased "refrigeration" rather than buying a fridge. When our orange 1970s fridge is longer stylish, we can return it to the refrigeration supplier and upgrade to a newer model without worrying about disposal. Product return systems promote zero waste because suppliers with returned products can achieve economies of scale and therefore

greenhouse gas emissions. The capture of CO_2 is facilitated when CO_2 concentrations are high compared to other stack gases like NO_x and SO_2. One method for reducing the concentrations of these stack gases is O_2/CO_2 recycle combustion. This involves burning coal in a mixture of nearly pure oxygen. The flue gas generated from this combustion has a high CO_2 concentration and thus will mitigate the high temperatures generated by pure oxygen combustion when it is recycled back to the burner. This paper presents the results of a study comparing NO_x emissions between once-through O_2/CO_2 mixtures and recycled flue gas. The authors found that higher oxygen concentrations increase NO_x emission rates. They also observed that flue gas recycling causes a 40 to 50% decrease in NO_x emission rates compared to the once-through experiments. In addition, SO_2 emission rates are examined in wet and dry recycle experiments.

Waste Management Options to Reduce Greenhouse Gas Emissions from Paper in Australia

J.G. Pickin, S.T.S. Yuen, H. Hennings

*Atmospheric Environment **2002**, 36, 741-752 (Eng)*

Greenhouse gas emissions from paper products produced and consumed in Australia accounted for approximately 2.6% of the country's annual emissions total of 460 million tonnes of carbon dioxide equivalent. The authors have provided a summary of the lifecycle assessment they employed to calculate the net greenhouse gas emissions of paper and compare the effectiveness of different waste management strategies in reducing these emissions (recycling, waste-to-energy, and recycling coupled with landfill gas recovery and composting). Included in this summary is a thorough list of the categories of emissions that were considered, the boundaries applied to each part of the lifecycle assessment and the type and source of data required for the calculations. The results of this analysis indicate that waste-to-energy is the most effective way (not including source reduction) to reduce greenhouse gas emissions from paper, by offsetting greenhouse gases from fossil fuel derived energy, however this practice is not widely employed in the country. Recycling is also effective, especially in the short-term, because this practice reduces CH_4 emissions from the degradation of paper in landfill.

Innovations in Separations Technology for the Recycling and Re-Use of Liquid Waste Streams
S.E. Kentish, G.W. Stevens
Chemical Engineering Journal ***2001****, 84, 149-159 (Eng)*
Conventional wastewater treatment processes may not be selective enough to remove certain contaminants. As well, many of these techniques result in products with little or no value. This article discusses three categories of liquid separation technologies that can be used to minimize wastes and produce recyclable or saleable products: solvent extraction; membrane technology; and ion-exchange and adsorption processes. Each technique is described in detail (i.e., how it works), including its range of popular applications and its advantages and limitations. Solvent extraction is often suitable for large-scale and concentrated waste streams, while ion exchange and adsorption are most economically applied to dilute solutions. Using membrane technologies can improve the efficacy of extraction techniques under a wide range of process conditions. Hybrid separation processes, like membranes used in concert with solvent extraction, offer many benefits and the dynamics of such systems, including different membrane designs, are explained.

A Carbon Balance Method for Paper and Wood Products
W.A. Cote, R.J. Young, K.B. Risse, A.F. Costanza, J.P. Tonelli, C. Lenocker
Environmental Pollution ***2002****, 116, S1-S6 (Eng)*
The methods used to assess the net balance of carbon (carbon storage ver-

have greater capabilities than individual consumers to recycle and reuse. The transition to this type of **service and flow economy** will encourage manufacturers and retailers to extend the life of their products by increasing durability and quality. A constant flow of end-of-life products between producers and consumers will strengthen markets for recycled materials. When manufacturers can profit from the end-of-life fate of their products they will be encouraged to invest in strategies that minimize unrecoverable waste and to design their waste streams to fulfill particular market niches.

Finally, it is necessary to advantage an economic environment that will support the above practices, through reformed legislation. This would include: increasing penalties or fees for waste disposal; developing regulations governing the design of new products; facilitating the organization of resource recovery parks; and investing in research for new recycling technologies and material recovery techniques.

CARI's Corner

Canadian Association of Recycling Industries

Anti-Recycling Myths

by Leonard Shaw

Another attack on recycling was recently launched by a group of so-called environmentalists from Sweden. They argued that waste incineration was as environmentally and economically sound as recycling. This is clearly a ridiculous and unsubstantiated position. But it does reveal ongoing anti-recycling myths. Let us examine four such myths.

All governments support sustainable development in general and activities such as recycling, reusing and reducing in particular

Although this is often their stated policy, specific actions are another story. Recycling is actually discouraged through current regulations that include recycling in waste management programs. There is no incentive to attempt to develop a system or process to take a former "waste" out of the waste stream and recycle the resources present. The extra costs needed to implement recycling do not improve the environment, but do make entrepreneurs think twice about trying to recycle these types of materials. In Canada there is a tax disadvantage to make products from recycled materials as opposed to virgin materials. There are few, if any, procurement policies that would stimulate the demand for recycled products. There is no education about the values of recycling and no product labeling requirements. Is this really support for a sustainable industry?

Recycling does not save resources

In fact, recycling saves resource materials in two ways. The actual material recycled allows conservation of natural resources that would otherwise had to be found and used. In addition, the resources required to produce the material, such as energy, are greatly reduced when recycling is employed. Not only is energy saved, but the pollution created as a result of energy production as well as the specific material production processes, is also saved. As an example, the production of a ton of steel made from recycling scrap metal in an electric arc furnace, compared to the traditional blast furnace / oxygen reduction method, reduces air pollution by 86%, water used by 40%, water pollution by 76%, and mining wastes by 97%. Compared to producing a ton of paper from virgin wood pulp, recycled paper uses 50% less water and results in 74% less air pollution and 35% less water pollution. At the other end of the process some prefer to landfill redundant materials. They ignore the fact that many landfill sites leach a host of conventional and toxic pollutants that require resources and energy to clean up. Additionally, the decomposition of some materials, such as paper, creates a variety of gaseous emissions, including methane and organic chemicals, which contribute to urban smog. Methane is a greenhouse gas and landfill sites are, according to the U.S. EPA, responsible for an estimated 36% of all methane emissions in the U.S. Recycling not only saves resources, directly and indirectly; it leads to a reduction in pollutants such as greenhouse gases.

Recycling is not cost effective

Those making this statement are often talking about a small part of recycling (blue box), and they fail to consider two things. The blue box system is relatively new and the cost benefits of a long learning curve have not yet been realised. There is also a spectrum of programs, some good and some poor. Secondly, the costs to society are not taken into consideration. The cost of producing virgin materials given above are substantial and the cost of properly disposing of materials in a landfill site, rather than recycling, are usually ignored.

But the much larger recycling world has proven to be cost effective for decades. Steel is an excellent example. The last integrated steel mill in North America was built in 1970. Since that time every new mill is based on recycling of steel and the electric arc furnace. This has occurred worldwide, not just in North America. Similarly, non-ferrous metal producers are expanding their recycling capacities. Noranda, as an example, is the world's largest processor of electronic scrap and currently produces about 20% of its copper, gold, and silver from recycled metals. There is no question that recycling is cost effective.

Recycling is nearing its maximum recovery rate

Material audits of landfill sites constantly reveal substantial amounts of recoverable recyclable materials. There are firms that are now "mining" old landfill sites to recover materials as well as prevent environmental problems. Additionally, companies are now designing products with their final means of disposal in mind. Automobile companies are leading the way. In addition to the end of life disassembly of parts, they are generating demand for recycled materials in their specifications for component parts. There is room for growth in both the amount of current materials being recycled and in the number of materials that can be recycled.

These anti-recycling myths are just that: myths. Recycling is sustainable development; it saves natural resources, it creates jobs, it saves energy, and it reduces pollution and thereby greenhouse gases. It should be actively supported. It makes sense today. It will make sense tomorrow. And it will make sense again next year and the year after that and..........

For further information regarding the above article, or for information on CARI's activities and membership, please contact Dr. Leonard Shaw. Tel.: (613) 256-8533, Fax: (613) 256-8534, Email: len.shaw-cari@on.aibn.com.

CARI's Corner

sus carbon releases to the atmosphere) associated with the forest products manufacturing stage of the carbon cycle are presented. The authors use an in-mill model to refine their carbon balance model, that allows for the consideration of 16 different accounting scenarios, and describe the derivation of many variables in the context of the pulp and paper manufacturing process. This article is suitable for those seeking an in-depth analysis and discussion of the complexities of developing a mass-balance approach for carbon flows in the paper and wood products industry.

Events

COM 2004: The Conference of Metallurgists
August 22-25, 2004
Hamilton, Ontario, Canada
Phone: (514) 939-2710, ext. 1317
Fax: (514) 939-9160
Web: www.metsoc.org

Greenhouse Gases in the Metallurgical Industries;
Policies, Abatement and Treatment
August 22-25, 2004
Hamilton, Ontario, Canada
Web: www.metsoc.org/

Sustainable Waste Management and Recycling: Challenges and Opportunities
September 14-15, 2004
London, UK
Web: strc.kingston.ac.uk/conference2004/

Be Resourceful... Compost
14th Annual National Composting Conference
September 15-17, 2004
Gatineau - Ottawa, Ontario, Canada
Web: www.compost.org/

Global Symposium on Recycling, Waste Treatment and Clean Technology (REWAS`04)
September 26-29, 2004
Madrid, Spain
Email: rsoloza@inasmet.es
Web: www.inasmet.es/rewas04/

"Mountains of Opportunity" 2004 Recycling Council of Alberta Fall Conference and AGM
October 6-8, 2004
Jasper, Alberta, Canada
Phone: (403) 834-6563
Email: info@recycle.ab.ca
Web: www.recycle.ab.ca/

Pollutec 2004
November 30-December 3, 2004
Lyon, France
Web: www.pollutec.com/

Canadian Waste & Recycling Expo
December 1-2, 2004
Toronto, Ontario, Canada
Web: www.cwre.ca/

4th International Electronics Recycling Congress
January 12-14, 2005
Basel, Switzerland
Email: info@icm.ch
Web: www.icm.ch/

5th International Automobile Recycling Congress
March 9-11, 2005
Amsterdam, Netherlands
Email: info@icm.ch
Web: www.icm.ch/

Americana 2005
The Pan-American Environmental Technology Trade Show and Conference
April 6-8, 2005
Montreal, Quebec, Canada
Web: www.americana.org/

Optimizing the uptake of atmospheric carbon by **forests**, **soils** and **wetlands** can be accomplished through a broad range of activities, including: protection of forests from pests and fire, conservation tillage of agricultural soils and wetland restoration. Canada has played an instrumental role in delineating the scope of activities that would allow Parties to the Kyoto Protocol to obtain credits for terrestrial carbon sequestration. For more information read the Intergovernmental Panel on Climate Change report on Land Use, Land Use Change and Forestry (LULUCF), available on their website (***http://www.ipcc.com/***).

Out of all possible sinks for CO_2, **oceans** have by far the greatest storage capacity, however the rate of natural absorption rates by surface waters is limited by slow ocean mixing. One proposed action to accelerate absorption is biological enrichment. CO_2 captured from point sources can also be injected into deep waters, however countries without coastal access may find transportation costs prohibitive. The 1977 discovery of hydrothermal vents and associated life forms on the ocean floor could provide an answer to excess carbon in deep waters. Chemosynthetic bacteria are able to fix carbon into organic compounds by using energy derived from the oxidation of vented hydrogen sulfide in a process parallel to photosynthesis. Research is underway to examine the effects of CO_2 injection on marine ecosystems. Read more about the role of oceans in mitigating climate change in the International Energy Agency's publication *Ocean Storage of CO_2* (March 2002), available on their website at ***http://www.ieagreen.org.uk/***.

CANMET Energy Technology Centre (***http://www.cetc-ctec.gc.ca/***), a research division of Natural Resources Canada, is studying **O_2/CO_2 combustion**. In this process oxygen is used to burn oil, coal and natural gas in boilers that also receive the evolved flue gases containing CO_2. This recycling serves to concentrate CO_2 in the flue gas up to 95% and eliminates the need for costly post-combustion separation.

There is a wealth of organizations and websites related to **zero waste**. Some great links to try are:
- Target Zero Canada: ***http://www.targetzerocanada.org/***
- Zero Waste Canada: ***http://www.zerowaste.ca/***
- Grass Roots Recycling Network (GRRN): ***http://www.grrn.org/***

A zero waste philosophy is an ideal to strive for and more and more regions and businesses around the world are up to the challenge:
- Canberra, Australia has developed a "No Waste by 2010" program. Read more about their strategy for achieving this goal at ***http://www.nowaste.act.gov.au/***.
- One third of New Zealand's local authorities have set zero waste targets. See Zero Waste New Zealand Trust for more information (***http://www.zerowaste.co.nz/***).
- Interface Flooring, based in Atlanta, is the world's largest carpet manufacturer and is world renown for their environmentally conscious practices. Interface considers anything that does not add value to their customers to be waste (***http://www.interfacesustainability.com/***).

The principles of a zero waste philosophy overlap to a large degree with the concept of eco-efficiency, described by Industry Canada as increasing the value of products and services while reducing the consumption of resources and associated environmental impacts. At Industry Canada's Eco-efficiency website you will learn the benefits of incorporating eco-efficiency into a business plan as well as profiles of progressive companies that have already done so: (***http://strategis.ic.gc.ca/sc_mangb/ecoefficiency/***).