Alternative Fuel Use in Cement Manufacturing

Implications, opportunities and barriers in Ontario

White paper for

Workshop on Alternative Fuels in Cement Kilns
Updated for Follow up Meeting, May 23, 2014

Written by

The Pembina Institute and Environmental Defence

Funding provided by

Cement Association of Canada and Holcim (Canada) Inc.

Alternative Fuel Use in Cement Manufacturing

Implications, opportunities and barriers in Ontario

Contents

List of tables

Executive summary

Tackling climate change by reducing greenhouse gas (GHG) emissions is an urgent global priority. Ontario's cement sector is looking to do its part to help by seeking opportunities to reduce their GHG emissions.

Cement manufacturing is a very emissions-intensive process. Approximately half of the emissions come from the chemical reaction that converts limestone into clinker, the active component in cement. Another 40% comes from burning fuel, and the final 10% is split between transportation and electricity. The energy required for the chemical reaction, which occurs at temperatures above 1,400˚C, is typically provided by burning coal or petroleum coke, two of the most carbon-intensive fossil fuels.

There are three key levers for reducing emissions from cement manufacturing in the short term: improving thermal and electric energy efficiency, reducing the clinker-to-cement ratio by blending with mineral substitutes, and using lower-carbon alternative fuels to fire the kiln.

Canada's cement industry has made progress over past two decades in each of these areas. Energy intensity improved by 21% between 1990 and 2010. There have also been improvements in the clinker-to-cement ratio and the use of alternative fuels is growing. As a result, the overall GHG intensity of cement manufacturing in Canada has decreased by 13%.

However, the immediate opportunities for further progress on efficiency are limited. Improvements to the clinker-to-cement ratio are largely tied to standards and building codes, which are outside of the industry's control.

Replacing coal and petroleum coke with lower-carbon alternative fuels is the most substantial short-term opportunity to reduce GHG emissions from Ontario's cement sector. Alternative fuels have been successfully used in many other jurisdictions for more than 20 years. Success stories include Quebec and Germany, where substitution rates exceed 30% and 60% respectively.

Increasing fuel substitution in Ontario requires action to address key regulatory barriers and community concerns. To justify the cost associated with modifying a cement facility for use of alternative fuels, Ontario's regulatory framework needs to provide more clarity on the application process and regulatory requirements.

Individuals, communities and stakeholder organizations are often skeptical of fuel substitution due to community and environmental concerns. Updating the regulatory framework can also give communities greater confidence that these concerns are being addressed.

This white paper seeks to respond to common concerns about fuel substitution, demonstrate its environmental value and open a dialogue on how to move forward in Ontario.

1. Mitigation options in Ontario's cement sector

1.1 Ontario's climate context

Deep reductions in global greenhouse gas emissions are required in order to stay below the agreed threshold of 2˚C of global warming. Ontario intends to play its part, and has pledged to reduce greenhouse gas emissions by 80% below 1990 levels by 2050. Meeting this ambitious goal will require a vast transformation in all sectors, including cement.

Concrete is an essential ingredient of our infrastructure, and it plays a critical role in building more sustainable and resilient cities, buildings and power systems. However, cement production is also one of the most emissions-intensive industries in Ontario. This is driven by the high thermal energy requirements and chemical process required to produce clinker, the active component in cement.

The difference between cement and concrete

Although the terms cement and concrete are often used interchangeably, cement is actually an ingredient of concrete. Concrete is a mixture of aggregates and paste. The aggregates are sand and gravel or crushed stone; the paste is water and cement. Cement comprises from 10% to 15% of the concrete mix, by volume.

The cement sector is responsible for roughly 5% of global GHG emissions from human activity each year. In Canada, cement manufacturing accounts for 1.4% of total emissions.[1]

Environment Canada is currently developing GHG performance standards for the sector.[2] Ontario is also considering an alternative emissions trading approach that would cover the cement sector along with other major emitters.[3]

Addressing this climate challenge will require the cement sector to make the most of the solutions available today while continuing to support innovation, as transformative technologies are necessary for the sector to continue contributing to climate mitigation in the future.

[1] Environment Canada, *National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada* (2013). http://www.ec.gc.ca/Publications/A07ADAA2-E349-481A-860F-9E2064F34822%5CNationalInventoryReportGreenhouseGasSourcesAndSinksInCanada19902011.pdf

[2] Environment Canada, *Canada's Sixth National Report on Climate Change: Actions to Meet Commitments Under the United Nations Framework Convention on Climate Change* (2013). http://unfccc.int/files/national_reports/non-annex_i_natcom/submitted_natcom/application/pdf/final_nc_br_dec20,_2013%5B1%5D.pdf

[3] Ontario Ministry of the Environment, *Greenhouse Gas Emissions Reductions in Ontario: A Discussion Paper* (2013). http://www.ebr.gov.on.ca/ERS-WEB-External/displaynoticecontent.do?noticeId=MTE4MzMy&statusId=MTc3MDg5

1.2 Emissions from cement production

More than 50% of the total CO_2 from cement production results from the chemical reaction that converts limestone into clinker, the active ingredient in cement. This chemical reaction accounts for approximately 540 kg CO_2 per tonne of clinker.[4] The next 40% of emissions result from burning fuel, and the final 10% are from transportation and electricity.[5]

Clinker is made by heating limestone, clay, bauxite and iron at temperatures of more than 1,400˚C in a long rotary kiln. It is then interground with gypsum and other cementitious materials to produce cement. Producing the high temperatures necessary to drive the reaction requires a great deal of energy. Kiln fuel accounts for roughly 86% of all energy required in the production process.[6] Carbon-intensive coal and petcoke are the most commonly used fuels, and their combustion accounts for the majority of energy-related emissions.

According to Getting the Numbers Right, a global project organized by the Cement Sustainability Initiative, producing one tonne of clinker emits an average of 825 kg of CO_2, excluding emissions from electricity generation. The best-performing plants have emissions in the range of 650 kg CO_2 per tonne of clinker. In Canada, the average is 855 kg CO_2/t.[7] It should be noted that the data includes all companies who are members of the initiative, but membership is voluntary. The global average value may therefore underestimate the true global average.

Ontario's six plants produce approximately six million tonnes of cement per year — nearly half of Canadian production. In 2011, these facilities reported on-site GHG emissions of 4.36 Mt CO_2e, or 2.5% of Ontario's total emissions of 171 Mt.[8]

Approximately 60% of the sector's emissions came from industrial processes (2.6 Mt of direct emissions from the calcination of limestone into clinker),[9] with the remainder coming from fuel combustion.

Nationally, the cement sector reduced its CO_2 emissions intensity by 13% from 1990 to 2010. This reduction was driven by improvements in the clinker-to-cement ratio, an increase in the thermal energy substitution rate, and a 21% improvement in overall energy intensity.

---

[4] Ali Hasanbeigi, Hongyou Lu, Christopher Williams and Lynn Price, *International Best Practices for Pre-Processing and Co-Processing Municipal Solid Waste and Sewage Sludge in the Cement Industry* (Lawrence Berkeley National Laboratory, 2012). http://eetd.lbl.gov/sites/all/files/publications/co-processing.pdf

[5] Cement Sustainability Initiative, *Guidelines for the Selection and Use of Fuels and Raw Materials in the Cement Manufacturing Process* (World Business Council for Sustainable Development, 2005). http://www.wbcsdcement.org/pdf/tf2_guidelines.pdf

[6] Natural Resources Canada, *Canadian Cement Industry Energy Benchmarking Summary Report* (2009). https://www.nrcan.gc.ca/energy/publications/efficiency/industrial/6003

[7] World Business Council for Sustainable Development Cement Sustainability Initiative, "GNR Project Reporting CO2," database. http://www.wbcsdcement.org/GNR-2011/ (accessed February 2014)

[8] Ontario Ministry of the Environment, "Facility Greenhouse Gas Emissions," spreadsheet, 2011. http://www.ontario.ca/sites/default/files/moe_mapping/downloads/1Air/GHG_by_year/GHG2011.xls

[9] *National Inventory Report 1990-2011*.

1.3 Mitigation options

In the short term, there are three critical levers for reducing the emissions intensity of cement production: improving energy efficiency throughout the process, reducing the clinker content of cement with mineral substitutes, and replacing coal and petcoke with lower-carbon alternative fuels.

As will be shown in the following sections, the cement industry has already pursued improvements in energy efficiency and reductions in clinker content. Substituting alternative fuels for coal and petcoke therefore provides the best opportunity for emissions reductions.

1.3.1 Improving energy efficiency

As noted, cement production is extremely energy intensive. Energy inputs can account for nearly 40% of the annual operating costs of a cement plant.[10] Improvements in thermal and electric efficiency can yield significant reductions in both GHGs and operating costs.

The biggest determinant of energy efficiency is plant design. The least efficient processes — wet- and long-dry kilns — are gradually being phased out around the world and replaced by newer, more efficient plants.[11] This trend has also been a significant factor behind the 21% reduction in energy intensity over the past two decades in the Canadian cement sector.[12]

A dry process with both a preheater and a precalciner is the current state of the art.[13] All Ontario plants use a dry process with preheaters, and most have precalciners, so there is limited opportunity for major short-term gains.

Due to the high costs of energy, operating efficiency tends to be well-optimized. However, a 2009 benchmarking study of the Canadian cement industry found that there is still significant potential for further improvement, particularly in terms of electricity use.[14] However, it should be noted that due to the phase out of coal power in Ontario, reducing electricity consumption produces a relatively small benefit from an emissions standpoint.

1.3.2 Reducing clinker content with mineral substitutes

Cement is produced by blending clinker with other mineral components like gypsum, and then grinding the mixture into a powder. Clinker production accounts for the vast majority of emissions from cement. Accordingly, reducing the amount of clinker in blended cements can have a significant impact on their emissions intensity.

---

[10] *Canadian Cement Industry Energy Benchmarking Summary Report.*

[11] International Energy Association and World Business Council for Sustainable Development, *Cement Technology Roadmap 2009: Carbon emissions reductions up to 2050* (2009). https://www.iea.org/publications/freepublications/publication/Cement.pdf

[12] Cement Association of Canada, *2010 Canadian Cement Industry Sustainability Report* (2010). http://www.cement.ca/images/stories/ENGLISH%20FINAL%202010%20SD%20Report%20Mar17.pdf

[13] *Cement Technology Roadmap 2009.*

[14] *Canadian Cement Industry Energy Benchmarking Summary Report.*

Conventional Ordinary Portland Cement contains up to 95% clinker and 5% gypsum or limestone. Replacement materials used in blended cements include natural minerals or waste-derived silica-rich materials such as fly ash (from coal power generation), silica fume (from microchip production) or blast furnace slag (from steel production).

The recent introduction to Canada of Portland-Limestone Cement (PLC) marketed under the name Contempra allows for an additional 10% of the clinker to be replaced with limestone, resulting in a proportional reduction in GHG intensity. European standards allow PLC to contain up to 35% limestone.[15]

In 2011, the clinker-cement ratio in Canada was 82% (down from 91% in 1990). By comparison, the global weighted average was 76%.

The appropriateness of clinker replacements depends to a high degree on the requirements of the application, as well as the local availability of these materials. For example, the closure of coal-fired power generation in Ontario will have an impact on the volumes of fly ash available.

In addition, increasing the substitution rate above what is approved for Contempra would involve modifications to Canada's building codes, which again limits the future emissions reductions that can be made through mineral substitution.

1.3.3 Substituting coal and petcoke with alternative fuels

Coal and petcoke, two of the most carbon-intensive fuels, are typically used to heat cement kilns. The Carbon War Room[16] estimates that substituting coal with lower-carbon fuels offers the greatest short-term potential to reduce CO_2 emissions in the industry.[17]

Most alternative fuels have a lower carbon intensity than coal or petcoke. According to the International Energy Association, these mixed fuels can be 20 to 25% less carbon-intensive than traditional fossil fuels.[18] Using alternatives to coal and petcoke as replacement fuels in a cement kiln can significantly reduce greenhouse gas emissions, and in some cases other air pollutants.

The Carbon War Room suggests that the cement industry should aim for a coal replacement rate of 50% by 2020 as part of its CO_2 emission reduction strategy. This compares with a current replacement rate of 30% in Quebec, which has successfully used lower-carbon fuels in cement kilns for more than 20 years, and the national average replacement rate of 10%.

Canada's cement industry has a lower substitution rate than many other countries, and it falls below the global average. In 2011, Canadian cement producers derived 90% of thermal energy

---

[15] Cement Association of Canada, *Backgrounder: Portland-Limestone Cement* (2011). http://www.lafarge-na.com/portland-limestone_cement_fact_sheet.pdf

[16] The Carbon War Room is an international non-governmental organization and think tank seeking the acceleration of the adoption of business solutions that reduce carbon emissions at gigatonne scale and advance the low-carbon economy.

[17] Arjun Gupta, David Colt and Zeeshan Feerasta, *Gigaton Analysis of the Cement Industry: The Case for Rapid Adoption of Proven Technology* (Carbon War Room, 2011). http://www.carbonwarroom.com/sites/default/files/reports/Carbon%20War%20Room-%20Cement%20Report_1.pdf

[18] *Cement Technology Roadmap 2009.*

for production from conventional fuels, compared to a global average of 87%.[19] By comparison, cement producers in the European Union derived 66% of thermal energy from conventional fossil fuels, with rates as low as 34% in Austria and 38% in Germany. In the United States, the average in 2011 was 84%.

Ontario has banned the use of coal for electricity generation, phasing out over 7,000 MW of capacity since 2005. This is the single largest GHG reduction measure in Canada, and it has already reduced the emissions intensity of Ontario's electricity generation by more than half.

Allowing Ontario's cement producers to use appropriate, lower-carbon alternative fuels is the largest short-term opportunity for improved carbon performance in the sector.

1.3.4 Other and "emerging" opportunities

While the three levers outlined above offer important short-term options for reducing emissions, meeting Ontario's longer-term emissions target of 80% below 1990 levels will require additional GHG controls in the cement sector.

Carbon capture and storage (CCS) plays a major role in technology roadmaps, including the IEA's, but has yet to be deployed at a commercial scale in the cement sector. Studies have indicated that CCS should be feasible in the sector, but the primary issue at this stage is cost.[20] Initial projects will likely require innovative financing mechanisms to proceed.

Several pilot projects are currently underway in the cement sector, including a test of four different post-combustion CCS methods at the Norcem plant in Brevik, Norway.[21]

In late 2013, Skyonic began the construction of a commercial-scale capture project at the Capitol Aggregates cement plant in San Antonio, Texas. The project, which is scheduled for completion in 2014, is expected to capture 75,000 tonnes of CO_2 per year from the flue and mineralize it into marketable products like baking soda, bleach and hydrochloric acid.[22]

Pond Biofuels is piloting a system at the St. Mary's cement plant in Ontario that diverts a portion of flue gases to grow algae, which can in turn be converted to biodiesel and residual biomass that can be used as an alternative kiln fuel.[23] Technologies like these could be particularly relevant to Ontario, where the geological storage capacity for CO_2 may be limited.

Further innovations will be critical not just on the production side, but also for buyers and users of cement. The right policy framework must be in place to enable, support and reward the

---

[19] "GNR Project Reporting CO2."

[20] European Cement Research Academy, *ECRA CCS Project: Report on Phase III*, TR-ECRA-119/2012 (2012). http://www.ecra-online.org/fileadmin/redaktion/files/pdf/ECRA_Technical_Report_CCS_Phase_III.pdf

[21] Dennis Van Puyvelde, "Capturing CO2 from the Norwegian cement industry," *Global CCS Institute*, September 20, 2013. http://www.globalccsinstitute.com/insights/authors/dennisvanpuyvelde/2013/09/20/capturing-co2-norwegian-cement-industry

[22] Skyonic Corporation, "Skyonic Begins Construction on Nation's First Commercial-Scale Carbon Capture and Mineralization Plant," news release, September 30, 2013. http://skyonic.com/wp-content/uploads/2010/02/Skyonic-Groundbreaking-Release-September-30-2013.pdf

[23] Hank Daniszewski, "Slime today, fuel tomorrow," *London Free Press*, June 29, 2012. http://www.lfpress.com/news/london/2012/06/29/19936146.html

innovative production and application of greener cements. In addition, stronger codes and standards for buildings and other infrastructure are needed to ensure that we are maximizing the longevity of these materials.

The price of carbon pollution — be it explicit or implied — will only grow over time, making improvements in performance increasingly profitable. Moreover, the challenge of reducing emissions from cement production is a global one; any solutions developed in Ontario will have global market opportunities.

2. The case for alternative fuels in cement kilns

As has been described above, substituting alternative lower-carbon fuels for coal and petcoke in cement manufacturing is one of the most promising options for reducing GHG emissions from cement production. It's also an approach that is readily under the control of the cement manufacturers.

Alternative fuels have been used in cement manufacturing since the 1970s. While total substitution rates globally are about 13%, individual countries have achieved substitution rates in excess of 80%.[24]

Most alternative fuels are waste or byproducts from industrial, agricultural and other processes. They are traditionally managed through landfills, treatment or incineration. The use of waste and byproducts as alternative fuels in cement production allows for a decrease in GHG emissions, as well as reducing the demand for fossil fuels, while providing a productive use for these materials at the end of their life.

This chapter discusses what types of fuels are suitable for substitution, provides information on various emissions performance metrics for alternative fuels and reviews the current regulatory framework in Ontario and other jurisdictions.

2.1 What materials are suitable for fuel substitution?

The cement manufacturing process requires a well-defined and controllable balance of four major components: calcium, iron, aluminum and silica. The final product must also meet strict building standards. As a result, the manufacturing process must be closely monitored and controlled, with regular testing of fuels, additives and products.[25]

Because of the manufacturing controls required when producing cement, not all materials are suitable for fuel substitution. Suitable fuels are those with a high calorific value, a known and consistent chemical make-up, and predictable availability. The risks and impacts of transporting, unloading and storing fuels are also relevant considerations. And finally, the impact of fuels on clinker production and facility emissions must be assessed.[26]

Alternative fuels have been used in cement kilns for more than 20 years, and the practice is prevalent in the U.S., Japan and the EU.[27] According to reports from the IEA[28] and the European

[24] Hasanbeigi et al., *International Best Practices for Pre-Processing and Co-Processing.*

[25] *Guidelines for the Selection and Use of Fuels and Raw Materials in the Cement Manufacturing Process.*

[26] GTZ–Holcim Public Private Partnership, *Guidelines on Co-Processing Waste Materials in Cement Production* (2006). http://www.coprocem.com/trainingkit/documents/diverse/guideline_coprocem_v06-06.pdf

[27] Hasanbeigi et al., *International Best Practices for Pre-Processing and Co-Processing*.

Commission,[29] typical alternative fuels used by the cement industry include pre-treated industrial and municipal wastes, waste oil, solvents, non-recyclable plastics, textiles and paper residues, as well as biomass such as animal meal, wood chips, waste wood, rice husk, sawdust and sewage sludge. Unrecyclable tires from abandoned dumps have also been used successfully in many jurisdictions. Construction and demolition wastes such as old asphalt shingles, demolition wood and used carpets are also commonly used as lower-carbon alternative fuels.

2.1.1 GHG performance of fuels

As shown in Table 1, potential alternative fuels have a range of CO_2 emission factors. However, it is difficult to find any that have greater GHG emissions than coal or petcoke (certain types of carpet waste are a known exception).

Table 1: GHG performance of typical alternative fuels

Fuel type	Net CO_2 emission factor (kg CO_2/GJ)
Petcoke	101
Coal	96
Natural Gas	54.2
Tires	85
Waste oil	74
Plastic	75
MSW	8.7
Animal meal	0
Waste wood	0

Adapted from Albino et al.[30]

Potential GHG savings in Ontario

While it is unclear what mix of alternative fuels would be used in Ontario, we can establish a range of possibilities based on the available information. We will assume a 30% substitution rate, which is comparable to current practice in Quebec. This results in GHG savings for the sector

[28] *Cement Technology Roadmap 2009.*

[29] European Integrated Pollution Prevention and Control Bureau, *Best Available Techniques Reference Document for the Production of Cement, Lime and Magnesium Oxide* (2013). http://eippcb.jrc.ec.europa.eu/reference/BREF/CLM_30042013_DEF.pdf

[30] Vito Albino, Rosa Maria Dangelico, Angelo Natalicchio and Devrim Murat Yazan, *Alternative Energy Sources in Cement Manufacturing: A Systematic Review of the Body of Knowledge* (Network for Business Sustainability, 2011). http://nbs.net/wp-content/uploads/NBS-Systematic-Review-Cement-Manufacturing.pdf

ranging from 12% (0.49 Mt) when using carbon-neutral biomass exclusively, down to 1% (0.06 Mt) when using tires.

This range of savings is equivalent to the annual emissions from 12,580 to 102,083 passenger vehicles, or the amount of CO_2 sequestered each year by 49,180 to 401,639 acres of forest.[31]

Table 2 shows the breakdown of alternative fuels used in Canada for 2005, based on the PCA North American Cement Industry Annual Yearbook.

Table 2: Alternative fuel use in Canada for 2005

Alternative fuel	Percentage use
Scrap tires	37%
Used oil	15%
Waste solvent	16%
Other solid waste-derived fuel	4%
Miscellaneous waste	21%

Adapted from Venta[32]

Using this breakdown provides a fuel source that is 36% less GHG intensive than coal, resulting in a 4% or 0.175 Mt reduction in the Ontario cement sector's total GHGs. This is equivalent to taking more than 36,458 cars off the road, or the amount of CO_2 sequestered by 143,443 acres of forest. This does not account for potential avoided emissions from other disposal methods, such as methane from landfill decomposition or emissions from incineration.

2.2 Performance of other air emissions

A number of meta-studies have been conducted to summarize the published data on the performance of alternative fuels in cement manufacturing. Below we provide information from two such studies:

- *International Best Practices for Pre-Processing and Co-Processing Municipal Solid Waste and Sewage Sludge in the Cement Industry*; written by the Lawrence Berkeley Laboratory (LBL) for the U.S. Environmental Protection Agency
- *Alternative Energy Sources in Cement Manufacturing: A Systemic Review of the Body of Knowledge*; commissioned by the Network for Business Sustainability (NBS).

[31] Calculated using the U.S. Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator, available at http://www.epa.gov/cleanenergy/energy-resources/calculator.html

[32] George J. Venta, *Use of alternative fuels in the Canadian and U.S. Cement Industry: Opportunities and barriers* (Cement Association of Canada, 2007). http://www.docstoc.com/docs/47625552/Use-of-alternative-fuels-in-the-Canadian-and-US

2.2.1 Lawrence Berkeley Laboratory study

Section 4.5 of the Lawrence Berkeley Laboratory study specifically addresses the emissions and air pollution associated with the use of alternative fuels. It found that the impact of using alternative fuels on emissions from cement manufacturing is relatively minor when done in compliance with strict regulations.[33] For specific compounds, the study draws the following conclusions:

- **Sulphur dioxide:** The concentration of sulphur in substitute fuels (0.1–0.2%) is generally much lower than the reference value in conventional fossil fuels (3–5%). In addition, the alkaline matrix of the clinker traps much of the sulphur, thus keeping sulphur emissions below critical levels. There is still the possibility that sulphur may react with different metals in raw meal, so metal and sulphur content in fuels must be monitored closely.
- **Nitrogen oxides:** In general, the formation of NO_x is related to the amount of nitrogen in the fuel, the temperatures in the kiln, the residence times and the types of burners. Overall, alternative fuels do not lead to higher NO_x emissions. Ensuring proper kiln operation also helps to limit NO_x emissions.
- **Chlorine:** Chlorine-related concerns are the same whether alternative or conventional fossil fuels are being used. These concerns include both direct and indirect impacts on cement kiln emissions and performance. Chlorine in feed materials can lead to the formation of acid gases, and there is a risk of increased corrosion if these gases build up on the kiln surface. Provided that chlorine content stays below 0.5%, these risks are minimal. If the chlorine content of the fuel rises above that level, it may be necessary to operate a bypass on the flue gas to limit the chloride concentration in clinker.
- **Heavy metals:** Heavy metal concerns are essentially the same for both alternative fuels and traditional fossil fuels. Non-volatile heavy metals are effectively incorporated in the clinker, while semi-volatile metals are captured in the clinker stream or dust. Highly volatile metals such as mercury and cadmium are an exception: the best approach is to limit their concentration in raw materials and fuels.
- **Dioxins and furans:** The formation of dioxins and furans is a recognized concern for cement manufacturing regardless of the fuel used. The high temperatures and long residence time typical of cement kilns can repress formation of these compounds, as they form more readily at lower temperatures. Limiting the concentration of organics in raw materials and quickly cooling the exhaust gases in the kilns also reduces formation. Numerous studies comparing dioxin formation rates between alternative fuels and traditional fuels in cement manufacturing have found no significant difference in emissions.

For other emissions, the European Commission summarized assumed impacts of waste co-processing as follows:

- Dust emissions and carbon monoxide are largely unaffected by co-processing wastes.
- The alkaline kiln environment removes hydrogen chloride and hydrogen fluoride produced during firing.

[33] Hasanbeigi et al., *International Best Practices for Pre-Processing and Co-Processing*.

- There is no correlation between the use of alternative fuels and total organic compound emissions levels.

As is show in Table 3, the use of waste-derived fuels in a cement kiln can cause some shifts to the emissions profile, but allows for a reduction in GHG emissions.

Table 3: Example of profile from a cement kiln using waste-derived fuels

Parameter	Measure	Individual measurements		Change
		No use of wastes	Use of wastes	
Total Particulate	mg/m3	2.8 – 12.90	12.0 – 15.900	Increase
HCl	mg/m3	0.88 – 5.93	0.87 – 1.320	Decrease
SOx	mg/m3	714 – 878.00	311 – 328.000	Decrease
HF	mg/m3	0.13 – 0.23	0.02 – 0.040	Decrease
NOx	mg/m3	789 – 835.00	406 – 560.000	Decrease
Total Carbon	mg/m3	11.7 – 23.20	5.7 – 7.100	Decrease
Polycyclic aromatic hydrocarbon	mg/m3	–	0.003	Increase
Benzene	mg/m3	0.27 – 0.540	0.45 – 0.550	Increase
Cd	mg/m3	<0.005	<0.007	Increase
Tl	mg/m3	<0.005	<0.005	No change
Hg	mg/m3	0.014 – 0.044	0.003 – 0.006	Decrease
Sum of Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn	mg/m3	<0.300	<0.500	Increase
PCDD/PCDF, I-TEQ	mg/m3	0.001 – 0.002	0.005 – 0.006	Increase
Total Particulate	mg/m3	2.8 – 12.90	12.0 – 15.900	Increase

Adapted from Hasanbeigi et al.[34]

2.2.2 Network for Business Sustainability systemic review

The NBS review sought to answer two questions. First, what are the environmental, human health, social and economic implications of using alternative fuels as opposed to fossil fuels in

[34] Hasanbeigi et al., *International Best Practices for Pre-Processing and Co-Processing.*

cement manufacturing? Second, how does the use of alterative fuels for cement manufacturing compare with other end-of-life and waste-management options?[35]

Similar to the Lawrence Berkeley Laboratory research, the NBS study found that "the use of alternative fuels in cement manufacturing was found generally to lead to a reduction in greenhouse gasses and criteria air contaminants compared to the use of fossil fuels. Results varied by type of alternative fuel for hazardous air pollutants and heavy metal emissions."[36]

2.3 Ontario's regulatory framework

Ontario has not developed specific regulations around the use of alternative fuels in cement manufacturing, but it is clear that the provisions of Ontario's Environmental Protection Act would apply. It would also be necessary to apply for an Environmental Compliance Approval (ECA) in order to process, store and use alternative fuels.

The most directly applicable piece of regulation is Guideline A-7, *Air Pollution Control, Design and Operation Guidelines for Municipal Waste Thermal Treatment Facilities*. It introduced specific air emission limits for cement or lime kilns that use municipal waste as fuel. In particular, it states that "In accordance with Regulation 347, burning or co-incineration of waste in cement kilns is considered thermal treatment of waste."[37] A cement plant co-processing waste would therefore be regulated similarly to a waste treatment facility. The document also mentions that the use of biomass-type waste as an alternative fuel would be permitted on a case-by-case basis during the application process for an ECA.

It is unclear which fuels would be classified as wastes, and thus which regulatory framework would apply. This lack of clarity around the use of alternative fuels makes it difficult for a proponent to proceed with an application for an ECA or another type of approval. It is also difficult for stakeholders to evaluate the merit and completeness of such applications.

For example, used asphalt shingles that are removed following repairs to a building would fall under the definition of a waste. Would shredded and processed shingles still be considered waste, especially in the case of virgin shingles? Or would they be considered a fuel, as with the use of petcoke?

If a facility is successful in obtaining an ECA for the use of alternative fuels, it is typically for a pilot project or a demonstration burn. The process for moving from the pilot stage to continuous use is not defined.

Taken together, all of these issues produce uncertainty around regulatory requirements such as testing, monitoring, the injection point, storage, controls and demonstrating compliance. To justify the cost associated with modifying a cement facility for use of alternative fuels, proponents need clarity around the regulatory process.

---

[35] Albino et al., *Alternative Energy Sources in Cement Manufacturing*.

[36] Ibid.

[37] Ontario Ministry of the Environment, *Guideline A-7: Air Pollution Control, Design and Operation Guidelines for Municipal Waste Thermal Treatment Facilities* (2010). http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/std01_078349.pdf

2.4 Secondary barriers

Converting a cement manufacturing facility to allow for the use of alternative fuels could result in improved greenhouse gas performance, but it requires a substantial capital investment. Because most Canadian cement manufacturers are multinational corporations, the choice to make capital expenditures will always be considered in the context of multiple jurisdictions.

2.4.1 Regulatory uncertainty for greenhouse gases

As mentioned earlier, Environment Canada is currently developing GHG performance standards for the sector.[38] Ontario is also considering an alternative emissions trading approach that would cover the cement sector along with other major emitters.[39] Without a stable and clear regulatory framework for GHGs in Ontario, companies may lack the necessary incentives to make the required investment.

2.4.2 Fuel availability

The availability of fuel varies for many reasons. These include seasonal variations (shingles are available in the summer, when most roof replacements are done), technological changes (tires are now more recyclable, so only the nylon fluff is available for use as fuel) and insufficient sorting (most auto-recycling waste is unsuitable because the content is not consistent enough). These all impact a potential fuel's value and suitability for use in cement manufacturing. Having a well-established recycling and waste collection sector increases the dependability of fuel availability.

[38] *Canada's Sixth National Report on Climate Change*.

[39] *Greenhouse Gas Emissions Reductions in Ontario*.

3. Frequently asked questions

Individuals, communities and organizations are often skeptical of fuel substitution due to concerns about hazardous fuels, air pollution, impacts on local communities and impacts on waste management and recycling. There is also a perception that allowing fuel substitution in cement manufacturing would open the door to waste incineration.

These are all valid concerns, and will need to be addressed specifically by any facility seeking to use alternative fuels. However, experience in many other jurisdictions that have been using fuel substitution for decades shows that it is possible to reap numerous benefits by using alternative fuels in cement production while managing negative impacts.

3.1 Common concerns

3.1.1 How is the use of alternative fuels in cement production different from waste incineration or waste-to-energy?

Co-processing waste as an alternative fuel in cement production is different from incineration in a number of ways. The high temperatures and longer residence time of cement kilns allows for a more complete combustion of fuel, thus reducing air emissions. Unlike incineration, the cement manufacturing process produces limited residual waste, as nearly all non-combusted material is incorporated into the clinker.

The impacts on waste management and recycling are also different from incineration. The capital-intensive construction of new incinerators or energy generation facilities requires a steady, long-term supply of waste in order to be economically viable. Cement kilns, on the other hand, are existing infrastructure and can adapt to changing conditions.

Since waste-derived alternative fuels are typically non-recyclable, they do not impact the incentives to maximize waste reduction and recycling. Using existing infrastructure also prevents the creation of a new point source for emissions.

Since cement production is a manufacturing process with specific input requirements, operators must carefully select and monitor fuel inputs to ensure proper operation of the kiln. This limits the range of fuels that are suitable for substitution.

Many of these issues are addressed further in the questions below.

3.1.2 Why don't cement producers switch to natural gas?

While using natural gas instead of coal or petcoke would have a significant GHG benefit, gas-fired kilns can also significantly increase NO_x due to their higher flame temperatures. Modern pre-heater, pre-calciner kiln systems fuelled by coal have a range of 1.35 to 1.95 kg NO_x per tonne of clinker, compared to 1.7 to 3 kg NO_x/t for natural gas.[40] NO_x is an important contributor to smog formation and has direct local public health implications.

In Ontario, industrial emissions of air pollutants like NO_x are controlled through Regulation 194/05, which imposes a target emission level based on Best Available Technology (BAT) performance for the cement sector. The increase in NO_x from a switch to gas would exceed the ability of most, if not all, of Ontario's plants to meet the regulatory limit even when using BAT.

3.1.3 Will this remove or reduce incentives for recycling?

Fuel substitution will not reduce incentives for recycling. A European Commission study of the role of energy recovery in waste management found that waste-derived fuels did not negatively impact recycling rates.

On the contrary, it concluded that the use of waste-derived fuels could be a strategic component of an integrated waste management system, helping to achieve high diversion rates by using non-recyclable waste streams as a fuel. In particular, the use of these fuels in industrial processes like cement was found to be more flexible than incineration, as it involves less of a long-term commitment should new recycling programs be introduced in future.[41]

Waste recovery can also serve as a financial support for recycling activities which otherwise may not have been economically viable. The recycler can receive compensation for the additional processing required to create value around recycling residues, which often represent significant volumes, instead of having to pay for their ultimate disposal.

3.1.4 What alternative fuels are most likely to be used in Ontario?

It is hard to predict which specific alternative fuels would be used as there are many factors influencing these decisions. Any potential alternative fuel needs to meet essential manufacturing criteria for the four major components of cement: calcium, iron, aluminum and silica. Other important factors include availability, price, incentives and regulatory constraints.

In other jurisdictions, the primary fuels used to substitute for coal and petcoke are materials at the end of their usable or recyclable lifespan. These can include post-consumer materials such as carpets, shingles, wood and recycling residues, or manufacturing byproducts such as packaging materials, process rejects and even biomass of different origins.

Cement producers will often use a series of alternative fuels and materials to meet the requirements of the manufacturing process. The fuels being considered in Ontario include the following:

[40] U.S. Environmental Protection Agency, *Alternative Control Techniques Document Update: NO_x emissions from New Cement Kilns*, EPA-453/R-07-006 (2007). http://www.epa.gov/ttncatc1/dir1/cement_updt_1107.pdf

[41] Directorate General Environment, *Refuse Derived Fuel, Current Practice and Perspectives* (European Commission, 2003). http://ec.europa.eu/environment/waste/studies/pdf/rdf.pdf

- **Cellulose shingles:** A growing number of these are being sent to landfills both as a result of housing renovations, and because they are being phased out and replaced with fiberglass shingles. The sand is removed from the shingles when they are processed for fuel (it is used in producing asphalt) which leaves paper and heavy oil, two known quantities in cement manufacturing.
- **Railroad ties and telephone poles:** In most cases, this waste wood is rotting in the ground and producing methane, a potent GHG. They are unsuitable for most conventional disposal as the preservatives — copper or organic compounds — present a contamination risk. When used as a fuel in cement manufacturing, the copper is non-volatile and the organics are fully combusted. Queen's University is currently studying the use of these fuels in cement kilns in partnership with Lafarge at their Bath, Ontario plant.[42]
- **Non-recyclable or composite plastics:** This waste stream is a byproduct of recycling centres. At present it is mostly directed to landfills.
- **Tire recycling fluff:** Ontario has a robust tire-recycling program that diverts 95% of the tires in the province.[43] Tire recycling results in two byproducts: steel and nylon (referred to as tire fluff). The steel can be reused in metal production, but the fluff is typically sent to landfills and could be used in cement production.
- **Municipal solid waste:** This type of waste has been used in many other jurisdictions. Provided that the supply is sorted and that its composition is known, it could be considered in Ontario.
- **Off-specification products:** Factories occasionally produce batches of products that do not meet specifications and cannot be sold to consumers. If these products cannot be reused, sold at a discount or recycled, they may provide a suitable fuel source for cement manufacturing.

3.1.5 Will cement producers burn tires?

As noted above, due to the well-established tire recycling market in Ontario, 95% of tires in the province are currently recycled. As a result, cement producers are unlikely to seek permits for their use. There are some byproducts of this process that cannot be recycled, such as the nylon tire fluff, which are suitable for use as alternative fuels. Tires are likely to continue being used as alternative fuel in other jurisdiction due to less robust recycling programs and existing stockpiles of discarded tires.

3.1.6 What is the role of fuel substitution in a zero-waste society?

End-of-life use as an alternative fuel source is the best use for some products. For streams of waste that cannot be reused or recycled, fuel substitution can be a high-value use. Fuel substitution can result in downward pressure on virgin resources (e.g. iron, aluminum) because some of the physical material in the fuel becomes an active ingredient of the clinker, and less

---

[42] Carbon Management Canada, "Low carbon fuels for Canada's cement production," news release, May 7, 2013. http://www.cmc-nce.ca/combusting-construction-and-demolition-waste-shingles-poles-and-railway-ties-to-fuel-canadas-cement-production/

[43] Ontario Tire Stewardship, "About Us." http://www.rethinktires.ca (accessed February 2014)

coal needs to be mined for combustion. The resulting concrete can be recycled at the end of its life.

While the ultimate waste management goal would certainly be to design all products so that no residue remains, Ontario has a long way to go to achieve that goal. In the interim, cement kilns offer an alternative to landfilling or dedicated incinerators for these residual wastes. No matter which economic or regulatory instrument is chosen by Ontario as part of its waste diversion review, a large volume of waste will invariably end up in landfills due to technical limitations.

3.1.7 What are the potential safety concerns? How will they be addressed?

The potential safety concerns with fuel substitution depend on the fuels being used. However, common areas of concern are the impact on air pollution and issues around fuel handling.

Fuel handling (including transportation, storage and processing) is an important concern for some alternative fuels. Potential issues with transportation — such as odours, dust or run-off, and the proper handling of hazardous materials — must be addressed through facility design, the application of best practices, community engagement and regulatory controls.

Emissions for most alternative fuels are similar to or lower than those of conventional fuels, and they are subject to regulated limits. For certain fuels, regular chemical analysis and testing prior to use may be required in order to minimize the content of chlorine or volatile heavy metals like mercury and cadmium. This is already undertaken for traditional fossil fuels.

Under Ontario's *Emissions Trading and NO_x and SO_2 Emissions Limits for Ontario's Electricity Sector,* cement plants in Ontario are required to install continuous emission monitoring equipment.[44] These monitoring units can also be used to monitor carbon monoxide, carbon dioxide, opacity and particulates. Some pollutants, including metals and dioxins, cannot be monitored continuously. For those compounds, stack tests are performed annually or more frequently to ensure that environmental regulations are respected. Ontario cement plants will need to comply with a series of regulations: Guideline A-7, the Air Quality Management System Federal limits for NO_x and SO_2, and specific limits found in their Environmental Compliance Approvals.

[44] Ontario Ministry of the Environment, *Emissions Trading and NOx and SO2 Emissions Limits for Ontario's Electricity Sector* (2002). http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_080107.pdf

4. Learning from experience and best practices

4.1 Experiences in other jurisdictions

The use of waste as an alternative energy source varies widely across regions and countries. The main influences on its adoption are the level of development of waste legislation, law enforcement, waste collection infrastructure and local environmental awareness.

Alternative fuels have successfully been used in cement manufacturing in many other jurisdictions, in some cases for up to 20 years. Below is a brief overview of some of their experiences.

4.1.1 Canada

In Canada, environmental legislative, regulatory and certification standards — as well as plant operating permitting process — are all handled at a provincial level. This leads to a fragmented approach that varies significantly from province to province.

In 2011, alternative fuels accounted for an average of 10% of fuels consumed in cement production nationwide. Quebec has the most experience with using alternative fuels in cement manufacturing, having achieved fuel substitution rates of more than 30% over the last 20 years. In addition, Lafarge's St. Constant plant is the only facility in Canada where waste-derived fuels are the primary fuel source.[45]

Across Canada, most cement manufacturing facilities have permits that allow for the use of alternative fuels in processing. These permits generally require an environmental assessment and are issued for a specific subset of fuels. In some cases they require burn demonstrations to assess kiln emissions.[46]

The Canadian Council of Ministers of the Environment (CCME) has guidelines for cement kilns that suggest the following limits, with continuous monitoring for NO_x and SO_2:

Table 4: CCME guidelines for priority emissions

Criteria emission	Limit
NO_x	2.3 kg/t clinker
Particulate (from stack)	0.2 kg/t clinker
Particulate (from cooling system)	0.1 kg/t clinker

[45] Venta, *Use of alternative fuels in the Canadian and U.S. Cement Industry*.

[46] Ibid.

SO_2 and CO	Minimize while keeping NO_x under the limit

Canadian Council of Ministers of the Environment[47]

As described in section 2.3, Ontario has not created a regulatory framework specifically for alternative fuel use in cement. In addition, Ontario's Waste Reduction Act does not engage with the possibility of fuel substitution for materials at end of life.

4.1.2 United States

The use of alternative fuels in cement kilns in the U.S. is primarily regulated by the Environmental Protection Agency as directed by the Clean Air Act. The act establishes emissions limits for nine pollutants: cadmium, CO, dioxins and furans, hydrogen chloride, lead, mercury, NO_x, particulate matter and SO_2.

A Maximum Achievable Control Technology (MACT) is established for these nine pollutants. In the case of cement, it is known as the Portland Cement Kiln MACT. It seeks to establish the maximum reduction in emissions, while taking into account cost, energy requirements, and health and environmental impacts unrelated to air quality.

4.1.3 European Union

In the EU, the use of alternative fuels has been increasing quickly. The fuel substitution rate was 3% in 1990, yet by 2007 it had reached 17%.[48] The rate ranges widely between member states, from almost zero use up to 80% in the Netherlands.[49]

The EU has a suite of policies, known as directives, which address waste management and pollution prevention. The Waste Framework Directive (2008/98EC) establishes a clear waste management hierarchy. It prioritizes waste prevention first, reuse or recycling second, recovery in the form of energy third, and disposal by landfilling as a last resort. This directly encourages fuel substitution. The directive also provides recycling and recovery targets to support the top of the waste management hierarchy. These include reuse and recycling targets of 50% for households, and 70% for construction and demolition waste, by 2020.

To ensure that fuel substitution respects social and environmental constraints, the Waste Incineration Directive (2000/76/EC) addresses the incineration of waste. It specifies permitting requirements, emissions limits and operating conditions, as well as monitoring and reporting requirements. There are also further directives covering the incineration of hazardous wastes, as well as integrated pollution prevention and control.

---

[47] Canadian Council of Ministers of the Environment, *National Emission Guidelines for Cement Kilns* (1998). http://www.ccme.ca/assets/pdf/pn_1284_e.pdf

[48] European Integrated Pollution Prevention and Control Bureau, *Best Available Techniques Reference Document for the Production of Cement, Lime and Magnesium Oxide* (2013). http://eippcb.jrc.ec.europa.eu/reference/BREF/CLM_30042013_DEF.pdf

[49] Unless noted otherwise, all information in this section is based on: Hasanbeigi et al., *International Best Practices for Pre-Processing and Co-Processing.*

These directives are typically combined with country-specific regulations and laws to establish the process for permitting and using alternative fuels in cement manufacturing in a given member state.

For example, in Germany the use of alternative fuels is governed through the German Federal Pollution Control Act and EU regulations such as the Waste Incineration Directive. Germany's waste management policy provides a clear waste hierarchy. The highest priority is accorded to the avoidance of waste, followed by recovery and then disposal. Disposal options include landfill, fuel substitution and incineration if appropriate.

Manufacturers are also required to design products to minimize waste during production and use, and to facilitate recovery and disposal at the end of life. This is known as Extended Producer Responsibility. Within this regulatory framework, Germany is achieving 60% use of alternative fuels for cement manufacturing.[50]

4.2 Key takeaways

The best practices and experiences of other jurisdictions have been documented in a number of places. These resources could provide a road map for Ontario if it considers moving forward with alternative fuels in cement manufacturing.

If alternative fuels are used according to stringent environmental and emissions standards and regulations, they do not present any additional health and environmental risks compared to coal or petcoke. [51] The use of alternative fuels also presents a concrete opportunity for reducing GHG emissions.

[50] "GNR Project Reporting CO2."

[51] Hasanbeigi et al., *International Best Practices for Pre-Processing and Co-Processing.*

5. The path forward

The use of alternative fuels presents a readily available lever to reduce the GHG emissions associated with cement manufacturing and further Ontario's action to phase out coal. Alternative fuels should be used in an environmentally sound manner. This involves the proper sorting and pretreatment of waste, clearly defining acceptance criteria, ensuring quality control of waste inputs, implementing clear regulations with enforcement to prevent pollution, and maintaining rigorous systems for site selection and permitting. [52]

In Ontario, the regulatory framework needs more clarity and controls. This will allow stakeholders to be confident that alternative fuels are being appropriately controlled. In addition, cement manufacturers are lacking a clear path to approval. That uncertainty will delay investment and adoption by the industry.

[52] Hasanbeigi et al., *International Best Practices for Pre-Processing and Co-Processing.*

Appendix A. Relevant publications

Ali Hasanbeigi, Hongyou Lu, Christopher Williams and Lynn Price, *International Best Practices for Pre-Processing and Co-Processing Municipal Solid Waste and Sewage Sludge in the Cement Industry* (Lawrence Berkeley National Laboratory, 2012). http://eetd.lbl.gov/sites/all/files/publications/co-processing.pdf

Arjun Gupta, David Colt and Zeeshan Feerasta, *Gigaton Analysis of the Cement Industry: The Case for Rapid Adoption of Proven Technology* (Carbon War Room, 2011). http://www.carbonwarroom.com/sites/default/files/reports/Carbon%20War%20Room-%20Cement%20Report_1.pdf

Cement Sustainability Initiative, *Guidelines for the Selection and Use of Fuels and Raw Materials in the Cement Manufacturing Process* (World Business Council for Sustainable Development, 2005). http://www.wbcsdcement.org/pdf/tf2_guidelines.pdf

Committee on the Medical Effects of Air Pollutants, *Statement on the use of Substitute Fuels in Cement Kilns*, (European Union, 2009). http://www.comeap.org.uk/documents/statements/39-page/linking/78-substitute-fuels-in-cement-kilns

European Integrated Pollution Prevention and Control Bureau, *Best Available Techniques Reference Document for the Production of Cement, Lime and Magnesium Oxide* (2013). http://eippcb.jrc.ec.europa.eu/reference/BREF/CLM_30042013_DEF.pdf

International Energy Agency and World Business Council for Sustainable Development, *Cement Technology Roadmap 2009: Carbon emissions reductions up to 2050* (2009). https://www.iea.org/publications/freepublications/publication/Cement.pdf

GTZ–Holcim Public Private Partnership, *Guidelines on Co-Processing Waste Materials in Cement Production* (2006). http://www.coprocem.com/trainingkit/documents/diverse/guideline_coprocem_v06-06.pdf

Nicolas Müller and Jochen Harnisch, *A blueprint for a climate friendly cement industry*, (WWF International, 2008). http://awsassets.panda.org/downloads/englishsummary__lr_pdf.pdf

Secretariat of the Basel Convention, *Technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns*, (United Nations, 2009). http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-GUID-PUB-CementKilns.English.pdf

Vito Albino, Rosa Maria Dangelico, Angelo Natalicchio and Devrim Murat Yazan, *Alternative Energy Sources in Cement Manufacturing: A Systematic Review of the Body of Knowledge* (Network for Business Sustainability, 2011). http://nbs.net/wp-content/uploads/NBS-Systematic-Review-Cement-Manufacturing.pdf

Karstensen K.H., *Formation and Release of POPs in the Cement Industry, Second edition* (World Business Council for Sustainable Development/SINTEF, 2006). http://www.wbcsdcement.org/pdf/formation_release_pops_second_edition.pdf

Appendix B. Continuous emissions monitoring systems

The use of Continuous Emissions Monitoring Systems (CEMS) is required at all cement plants in Ontario due to the NO_x and SO_2 cap-and-trade regulations in Ontario.[53] This is also a requirement of the Cement Sustainability Initiative.[54]

In a typical facility in Ontario, the following criteria air contaminants would be monitored: NO_x, SO_2, PM or opacity, CO, HCl, VOC and CO_2. Compounds that cannot be measured continuously are normally measured at least annually, and often more frequently. This would include some heavy metals and dioxins.

Facilities typically conduct annual stack tests for the list of air contaminants recommended by the CSI, and more depending on the fuels used. Tests would be conducted more often when significant modifications to the process are made, or when demonstration tests for new fuels are being conducted.

Limits would be twofold. Provincial or federal limits when they exist, such as those for dioxins or found in the A-7 guideline. Plant specific, which would be found in the respective Certificate of Approval and Environmental Compliance Approval. Facilities are also required to do modelling to ensure compliance with ambient air quality limits at the property boundary, as laid out in regulation 419/05.[55]

Typical facilities manage emissions using the regulatory limit adjusted by a "safety factor" that varies depending upon the compound. Depending on the air contaminant being discussed, the limits may be monthly or annual. Few compounds have instantaneous limits.

These limits are programmed in to an operating system that can control the conditions within the kiln. The facility manager can then control the system to ensure the facility stays under the established limit regardless of the fuel mix being used.

---

[53] http://www.epa.gov/usca/docs/feasstudy.pdf

[54] http://www.wbcsdcement.org/pdf/CSI_Guidelines%20for%20Emissions%20Monitoring%20and%20Reporting%20in%20the%20Cement%20Industry_v2_Mar%202012.pdf

[55] http://www.torontowestcaer.com/speakers_files/presentation_reg_419_092607_final.pdf

Appendix C. Potential fuels for Ontario

Below is a list of the alternative fuels currently under consideration in Ontario provided by the Cement Association of Canada (CAC). This is purely an illustrative list, and the market for alternative fuels is dynamic. Cement manufacturers may get unforeseen access to viable fuels, or need to change the mix of fuels to preserve the integrity of the chemical process in the kiln.

The sections of this appendix following the list address each fuel in more detail.

C.1 Alternative fuels being considered in Ontario

List of fuels provided by CAC	Categorization in this memo
Construction and demolition	
Asphalt shingles	Asphalt shingles
Railway ties	Railway ties
Telephone poles	Waste wood or railway ties
Other combustible C&D waste (e.g. wood)	Waste wood
Pre-consumer / post-diversion	•
End cuts from manufacturing (wood, plastics, carpet)	Carpet, plastic, waste wood
Used filter paper	•
Cardboard rolls (with plastic, non-recyclable)	Plastic
Off-spec diesel	•
Post-consumer / post-diversion	
Non-recyclable plastics / contaminated plastics (e.g. oil containers)	Plastic
Composite packaging or recycling residues (from multi-layer packaging)	Plastic
Soiled / used carpets	Carpet
Plasticized cardboard boxes (e.g. taped portion of cardboard boxes sorted from recycling stream)	Plastic

Wax paper cups (coffee cups)	•
Pulp and paper by-products	•
Other recycling residues (e.g. MRF residuals)	•
Other Biomass	
Wood waste	Waste wood
Agricultural byproducts (e.g. bone meal, fats, grease and other designated animal wastes)	Sewage sludge and biosolids
Biodiesel	•
Biosolids (not viable without significant investment to process and therefore not likely without strong municipal and community support)	Sewage sludge and biosolids

C.1.1 Alternative fuels not being considered in Ontario

- Unsorted municipal solid waste
- Whole tires
- Batteries
- Medical waste
- Radioactive waste

C.2 Available data for alternative fuels

C.2.1 Asphalt shingles

- 1.25 million scrap asphalt and saturated-felt shingles are generated from Canadian residential asphalt tear-off (reroofing) shingles, new construction scrap and related organic-felt scrap quantities. Pages 20–21. http://www.athenasmi.org/wp-content/uploads/2012/01/Athena_Roofing_Study_EN.pdf
- "the organic fractions (e.g., asphalt cement, cellulose felt) are combusted as a fuel supplement. The non-combustible, inorganic portion of the shingles (e.g., mineral filler aggregates, surface granules, talc dust, fiberglass, any remaining nails or other metals) remains in the kiln and becomes part of the kiln's end product, typically referred to as clinker. The inorganic materials from the shingles become part of the useful ingredients needed for cement production including: limestone, dolomite, silica, calcium, magnesium, aluminum, and/or iron." Page 34. https://www.shinglerecycling.org/sites/www.shinglerecycling.org/files/shingle_PDF/ShingleRecycling-BPG-DFK-3-22-2010.pdf
- A reported concern with using asphalt shingles as a fuel supplement has been the release of asbestos at combustion temperatures below 1,800 F (982 C). Asbestos has not been used in the manufacturing of shingles since the 1970s, so most shingles from that period would have

been replaced by now. In addition, kiln temperatures are approximately 1400 C. Page 11. http://infohouse.p2ric.org/ref/42/41583.pdf

- Energy value of shingles is 6,000 to 7,200 per pound. Page 11. http://infohouse.p2ric.org/ref/42/41583.pdf
- Avoided emissions from combustion of Asphalt Shingles in a cement kiln: 1.05 MT CO_2e / short ton Asphalt Shingles. Page 9. http://www.epa.gov/climatechange/wycd/waste/downloads/asphalt-shingles10-28-10.pdf

C.2.2 Railway ties

- "No significant adverse environmental impacts could be observed when shredded scrap ties have been used as alternative fuel during clinker production in cement works" "There was no increase in flue gas emissions and also no impairment of operating conditions and product quality" http://www.ccaresearch.org/ccaconference/pre/pdf/poster_lorber.pdf
  - This is just an abstract of a poster presentation, so further details aren't available at this time.
- *Guidelines for the Safe and Beneficial Use of Mixed Fossil & Biomass Fuels Sources in the Cement Industry, with a Focus on Railroad Ties* http://www.cement2020.org/download/file/fid/191%E2%80%8E
  - This paper reviews available burn data for creosote treated wood. They found comparable or decreased emissions for criteria air contaminants for any combustion above 920 C. Because this is less than cement kiln operating temperatures they expect the same or better performance. Table 3 on page 38.

C.2.3 Waste Wood

- Generally viewed as carbon neutral – but this is dependent on sourcing.
- No change in CO, particulate matter, metals, NO_x, SO_2 or HCl. Decrease in CO_2. Metals content can be a problem if not limited at the source. Page 27. http://nbs.net/wp-content/uploads/NBS-Systematic-Review-Cement-Manufacturing.pdf
  - Supported by benchmarking for permit change by Castle Cement. Page 13. http://www.heidelbergcement.com/NR/rdonlyres/ED7EF16C-7623-4265-8A07-953816701FA4/0/Wood_Application.pdf

C.2.4 Carpet

- Nylon Carpet can increase NO_x emissions due to having 4-5% nitrogen content versus the 1% typical in coal. But SO_2, CO_2 emissions were decreased. http://www.ncbi.nlm.nih.gov/pubmed/18720656
- No change to dioxin and furan emissions. Decreased metals, organic compounds, and particulate emissions. Page 23. http://nbs.net/wp-content/uploads/NBS-Systematic-Review-Cement-Manufacturing.pdf

C.2.5 Plastic

- The chlorine content of plastics can be the cause of HCl emissions (Heidelberg, 2007b). Because chlorine content is a known concern, cement manufacturers test and control for it at the inlet.
- Under certain conditions, chlorine content can influence the formation of precursors of dioxins and furans. Page 92. http://www.wbcsdcement.org/pdf/formation_release_pops_second_edition.pdf
- This can be managed at the operations level through rapid cooling of exhaust gases or the presence of sulphur.

C.2.6 Sewage sludge and biosolids

- Not viable without significant investment to process, and therefore not likely without strong municipal and community support (from CAC/Holcim).
- Some studies consider this to be carbon-neutral. Emissions for metals and hazardous air pollutants are uncertain, and likely dependent on composition. Page 25. http://nbs.net/wp-content/uploads/NBS-Systematic-Review-Cement-Manufacturing.pdf
- NO_x emissions are lower. Page 49. http://www.epa.gov/composting/pubs/biosolid.pdf
- One study has shown SO_2 emissions increased, but this is dependent on whether it is raw or digested. http://pubs.acs.org/doi/pdfplus/10.1021/es052181g

C.3 Summary of findings from NBS paper

The Network for Business Sustainability conducted a systemic review of the research available on the use of alternative fuels in cement manufacturing. As discussed in the white paper, they found that "the use of alternative fuels in cement manufacturing was found generally to lead to a reduction in greenhouse gasses and criteria air contaminants compared to the use of fossil fuels. Results varied by type of alternative fuel for hazardous air pollutants and heavy metal emissions."[56]

Below is a summary table of their findings. The direction of the arrows represents positive or negative findings, size of arrows represents the number of papers with positive versus negative findings. The color (light versus dark) represents the total number of papers discussing that type of fuel, where light means there were two or fewer papers.

The table can be found in the NBS paper on page 47, and the legend for the symbols is on page 45.

[56] http://nbs.net/wp-content/uploads/NBS-Systematic-Review-Cement-Manufacturing.pdf

	General alternative fuel	Municipal solid waste	Industrial, commercial and institutional residues	Plastics	Sewage sludge	Animal and bone meal	Waste wood	Used Tires	Biomass	Hazardous waste
Resource consumption/ conservation	↑	↑	↑		↑	↑	↑	↑	↑	↑
Global Warming	↑	↑	—	↑	↑	↑	↑	↑	↑	↑
CACs/Non hazardous air pollutant	↑	↑	↑		—	↑		↓	↑	
Metals & HAPs	↑	↓	↓	—	↓	—	—	↓	↑	↑
Operations Waste	↑	↑	↑	↑	↑	↑	↑	↑	↑	
Other Social Impact	↑				—	↑	—	↑	↑	
Environmental impact	↑	↑	↑		↑	—	↑	↑	↑	—

Appendix D. Air emission data

D.1 Ontario specific data

St. Mary's Cement conducted an alternative fuel demonstration project in 2011. Table 2-2 below provides data on a number of key air emissions before, during and after the demonstration. There is an overall emissions summary table available in the full report that includes many more pollutants.

The fuel in use consisted of shredded and dried post-composting residual plastic film sourced from Orgaworld Canada in London, Ontario. During the test they achieved a fuel substitution rate of 23%, with the rest of the fuel being provided by conventional sources. It is worth noting that at this level of substitution, the alternative fuel only represented 1.5% of all kiln material throughput.

Table 2-2: Performance Objective Table, Averaged Results

Parameter	Units	Emission Limit	Baseline	Alternative Fuel	Post
			Concentration		
Particulate Matter	mg/Rm^3	50	9.2	7.0	7.7
Dioxins and Furans	$pg\ ITEQ/Rm^3$	80	Below Limit of Quantification		
Hydrochloric Acid (HCl)	mg/Rm^3	27	10	13	10
Cadmium	$\mu g/Rm^3$	14	0.52	0.45	0.32
Lead	$\mu g/Rm^3$	142	10	8.5	13
Mercury	$\mu g/Rm^3$	20	13	11	15

R - Reference flue gas conditions, defined as; 25C, 101.3kPa, 11% oxygen, dry conditions

D.2 Dioxins and Furans emissions data

Formation and Release of POPs in the Cement Industry compiles data on the status of Persistent Organic Pollutant (POPs) emissions from the cement industry.
http://www.wbcsdcement.org/pdf/formation_release_pops_second_edition.pdf

The paper found that the co-processing of alternative fuels and raw materials does not appear to influence or change the emissions of POPs.

The table below summarizes the emissions of dioxins and furans from cement kilns using various combinations of alternative fuels (page 99 in the above referenced paper). All measurements are below the commonly used limit of 100 pg TEQ/Nm^3.

Plant	Year	Type of alternative fuel	PCDD/PCDF emissions in ng I-TEQ/Nm^3
1	2002	Animal meal, plastics and textiles	0.0025
2	2002	Animal meal and impregnated sawdust	0.0033
3	2002	Coal, plastic and tires	0.0021 & 0.0041
4	2002	Tires	0.002 & 0.006
5	2002	Petcoke, plastic and waste oil	0.001
6	2002	Petcoke, sunflower shells and waste oil	0.012
7	2002	Tire chips	0.004 & 0.021
8	2002	Solvents	0.07
9	2002	Impregnated saw dust and solvents	0.00003 & 0.00145
10	2002	Solvents	0.00029 & 0.00057
11	2002	Sludge	<0.011
12	2002	Car waste and sludge	0.0036 & 0.07 & 0.0032

Appendix E. Ontario waste and recycling regulations

The Canadian Institute for Environmental Law and Policy published *A Brief History of Waste Diversion in* Ontario in November 2008, which provides an excellent overview of Ontario's waste and recycling regulations.[57]

In 1994 the 3Rs Regulations were introduced under the *Environmental Protection Act* to support the goals of the Waste Reduction Action Plan. There were four regulations applying to non-hazardous waste:

- Ontario Regulation 101/94: Recycling and Composting of Municipal Waste
- Ontario Regulation 102/94: Waste Audits and Waste Reduction Workplans
- Ontario Regulation 103/94: Industrial, Commercial and Institutional Source Separation Programs
- Ontario Regulation 104/94: Packaging Audits and Packaging Reduction Workplans

To address some of the concerns and challenges with the 3Rs regulations, the *Waste Diversion Act* was introduced in 2002. It provides the framework and processes under which waste diversion programs are implemented and operated in Ontario. In addition it established Waste Diversion Ontario as the primary institution for managing these programs.[58]

The following materials that need to be source separated for recycling under the Industrial, Commercial and Institutional Source Separation Programs (regulation 103/94):[59]

- Aluminum food and beverage cans
- Cardboard (corrugated)
- Fine paper
- Glass food and beverage bottles/jars
- Newsprint
- Steel food and beverage cans
- Brick and Portland cement concrete
- Drywall (unpainted)
- Steel
- Wood (not including painted, treated or laminated wood)
- P.E.T. plastic bottles for food and beverage
- Aluminum

[57] http://www.cielap.org/pdf/WDA_BriefHistory.pdf

[58] http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_02w06_e.htm#BK0

[59] https://dr6j45jk9xcmk.cloudfront.net/documents/1353/226-source-separation-of-recyclable-materials-en.pdf

- Glass
- HDPE plastic jugs, pails, crates, totes, drums
- LDPE film plastic
- Polystyrene expanded foam
- Rigid polystyrene trays/reels/spools

Municipalities with populations of more than 5,000 must collect all Basic Blue Box Waste (aluminum food or beverage cans, glass bottles and jars, newsprint, PETE, steel food or beverage cans) and at least two categories of materials from the Supplementary Blue Box Waste list:

- Aluminum foil
- Boxboard and paperboard
- Cardboard (corrugated)
- Expanded polystyrene food or beverage containers and packing materials
- Fine paper
- Magazines
- Paper cups and plates
- Plastic film
- Rigid plastic containers
- Telephone directories
- Textiles (not including fibreglass or carpet)
- Polycoat paperboard containers

The Ontario government has proposed an update to the Waste Diversion Act through Bill 91.[60] This bill died on the order paper in May when the provincial general election was called. If it had been passed, one of the bill's key goals was to "increase the diversion of a wider range of wastes."[61] This process would have included stakeholder consultations to identify additional wastes that could be designated under the proposed act.

While this bill is no longer before the legislature, there were a number of groups concerned that the proposed changes would not improve the current system.[62][63]

---

[60] http://www.ontla.on.ca/web/bills/bills_detail.do?locale=en&Intranet=&BillID=2818

[61] http://www.downloads.ene.gov.on.ca/envision/env_reg/er/documents/2013/011-9262.pdf page 29

[62] http://blog.solidwastemag.com/is-ontarios-waste-reduction-act-beyond-saving/

[63] http://www.stewardshipontario.ca/news/stewardship-ontario-responds-to-the-ontario-governments-proposed-bill-91-the-waste-reduction-act-2013/

Appendix F. Potential fuel acceptance criteria

Some possible suggestions for acceptance criteria in fuel substitution are presented below. This list is provided as a starting point for a conversation, and should not be viewed as a finished set of suggestions or recommendations.

Suitability criteria:

- Not a hazardous waste
- Not unsorted municipal waste (i.e. garbage)
- Provides a greenhouse gas benefit
- Respects emissions limits and other environmental limits
- Improvement in mercury level compared with coal
- Non-recyclable

Defining what is or is not recyclable is a moving target, as changes in technology and market demand will change the list over time. The following are some possible criteria for non-recyclable materials:

- Physical or chemical properties make recycling impossible
- Material contamination or mixing
- Composite materials that cannot be separated or processed
- Already a recycling reject
- No market solution exists in the area
- Recyclers cannot handle the available volume

The goal of the non-recyclable criteria should be to avoid sending materials to landfills when they could be effective substitutes for coal.