Feasibility Study –
Carbon Finance Options And Opportunities For
Companion Scrubbing Stack Technology

GC Green Carbon Inc.

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OFFSETTERS

OFFICIAL SUPPLIER

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1 Introduction

GC Green Carbon Inc. (GCI) approached Offsetters Clean Technology (OCT) to perform a feasibility study on the possibilities for the generation of carbon offsets from the use of oxide ions as a GHG destruction technology. The senior division of GCI offers remediation technology through special handling of Oxygen and Carbon that naturally and positively impacts the environment, through direct as well as oxidative destruction of toxic materials. Their technologies provide solutions for air, and water-based issues, as well as for many solid wastes. GC Green Carbon's mission is dealing with a client's CO_2 emission challenges, large and small, and to alleviate the costs incurred and provide supplementary return opportunities.

Offsetters is a leading provider of high quality carbon management solutions, based in Vancouver, British Columbia (BC), and is one of the largest, most experienced full-service carbon management teams in North America. Professor James Tansey, a specialist in the environment, business and climate change, founded the organization in 2005 at the University of British Columbia. Today, we provide a full suite of carbon management solutions for businesses and individuals, including carbon and water inventories, environmental product footprints and the development and sourcing of high-quality offset projects in Canada and around the world. Our team has grown to include experts in GHG quantification, public reporting, carbon finance, offset project development and the marketing of environmental services.

GCI has developed a technology that acts upon CO_2 emissions at their source, for example fossil fuel-powered electricity generation facilities, to oxidize CO_2 to C and O^{2-}. The technology cleaves carbon dioxide through an innovative plasma catalyst to generate carbon and oxygen ions. The oxygen ions are highly reactive, and can be used to decompose exotic greenhouse gases (GHGs) such as SF_6 to reduce the radiative forcing of the molecules. There is also a possibility to use commercial oxygen to generate oxide ions to perform the same purpose.

The technology that GCI is proposing is potentially important to two high profile areas. The first is the climate benefit associated with destruction of high global warming potential gases that have been emitted to the atmosphere. The other, which will not be the focus of this report but is an issue of critical importance, is the destruction of Ozone Depleting Substances (ODS). The company offers a novel oxidative remediation technique of O^{2-} ions applied to a closed loop of air containing ODS, which may assist in removing the ODS at ground, thereby removing the ODS loading and further destruction of the Ozone layer by intercepting these compounds with O^{2-}.

2 Technology Summary

The focus of this feasibility study is the destruction of high global warming potential (GWP) gases. These gases are measured according to a carbon dioxide referent over the 100-year time horizon, which is the convention for offset projects, and have a very high climate impact per tonne. These gases are a focus of the Intergovernmental Panel on Climate Change (IPCC), and can have a significant climate benefit even when destruction amounts are quite small. It can be seen from Table 1 below that the successful destruction of one tonne of methane derived from non-biogenic source can generate 18.55t CO_2e of emissions reductions. Using an offset proxy price of $10/tonne, destruction of one tonne of SF_6 would create $239,000 of revenue (equation 7).

There are three types of high GWP gases outside of methane and nitrous oxide. These are: sulfur hexafluoride (SF_6), other types of perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs). All of these gases contain fluorine, and fluorinated compounds have high GWP because of their long lifetime in the atmosphere and high absorption potential. Over the past two decades, PFC and HFC demand has increased because the gases are good substitutes for chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and halons—all of which are being phased out of use under the Montreal Protocol due to their adverse impacts on the ozone layer. HCFCs and CFCs were excluded from the Kyoto Protocol because the Montreal Protocol had already mandated reductions in these gases. Despite ozone benefits relative to the use of HCFCs, CFCs, and halons, HFCs and PFCs are powerful GHGs. Technologies that may be able to counteract the atmospheric concentrations of these gases could be beneficial[1].

2.1 Oxidation of High Global Warming Potential GHGs

Table 1 details the key reactions as identified by GCI. These reactions have then been analyzed using the GWP published by the IPCC in their Second Assessment Report (SAR). It should be noted here that the IPCC has updated their emissions factors in their later 4th Assessment Report (4AR); all of the GWPs were reassessed as greater than in the SAR. However, due to the principal of conservatism (see section 5) the GWP in the SAR are still used. See Appendix A2 for comparison.

[1] http://www.c2es.org/technology/factsheet/high-global-warming-potential-gas-abatement%20

Table 1 - Key Equations[2]

	Common Name	Equation	Global Warming Potential (CO_2e)		
			Inputs	Outputs	Net GWP reduction
1	Methane	$CH_4 + H_2O + 3O^{2-} \rightarrow CO_2 + 3H_2O$	1t CH_4 = GWP 21	2.44t CO_2e	18
2	Nitrous Oxide	$N_2O + 3O^{2-} + H_2O \rightarrow N_2O_4 + H_2O \rightarrow 2HNO_3 + O$	1t N_2O = GWP 310	0t CO_2e	310
3	Perflouromethane	$CF_4 + 6O^{2-} \rightarrow CO_2 + 2OF_2$	1t CF_4 = GWP 6,500	0.50t CO_2e	6,499
4	Perflouroethane	$C_2F_6 + 7O^{2-} \rightarrow 2\ CO_2 + 3OF_2$	1t C_2F_6 = GWP 9,200	0.64t CO_2e	9,199
5	Sulphur Hexaflouride	$SF_6 + 5O^{2-} \rightarrow SO_2 + 3OF_2$	1t SF_6 = GWP 23,900	0t CO_2e	23,900
6	HFC-23	$CHF_3 + 6\ O^{-2} \rightarrow CO_2 + H_2O + 2OF_2$	1t HFC -23 = GWP 11,700	0.63t CO2e	11,699
7	HFC-134a	$CHF_3CH_2F + 8\ O^{-2} \rightarrow 2CO_2 + 2OF_2 + 2H_2O$	1t HFC-134a = GWP 1,300	0.85t CO2e	1,299
8	HFC-152a	$CH_3CHF_2 + 8\ O^{-2} \rightarrow 2CO_2 + 2H_2O + OF_2$	1t HFC-152a = GWP 140	0.66t CO2e	139
9	CFC-11	$CFCl3 + 9\ O^{-2} \rightarrow CO2 + OF2 + 3CLO2$	1t CFC-11 = 3,800	0.32t CO2e	3,799
10	Nitrogen Triflouride	$2NF_3 + 6O^{2-} \rightarrow 2NO_2 + 2OF_2$	12t NF_3= GWP 12,300	0t CO_2e	12,300
11	CFC-12	$CCl_2F_2 + 5O^{2-} \rightarrow CO_2 + Cl_2 + 2OF_2$	1t CCl_2F_2 = GWP 8,100	0.36t CO_2e	8,099.64
12	CFC-13	$CF_3Cl + 6\ O^{-2} \rightarrow CO_2 + 2OF_2 + ClO_2$	1t CFC-13 = GWP 10,800	0.42t CO2e	10,799
13	CFC-113	$CF_2ClCFCl_2 + 11\ O^{-2} \rightarrow 2CO_2 + 2OF_2 + 2ClO_2$	1t CFC-113 = GWP 4,800	0.47t CO2e	4,799
14	CFC-114	$CF_2ClCF_2Cl + 10\ O^{-2} \rightarrow 2CO_2 + 2ClO_2 + 2OF_2$	1t CFC-114 = GWP 8,040	0.51t CO2e	8,049
15	CFC-115	$CF_3CF_2Cl + 9\ O^{-2} \rightarrow 2CO_2 + ClO_2, + 2OF_2$	1t CFC-115 = GWP 5,310	0.57t CO2e	5,309
16	Carbon Tetrachloride	$CCl_4 + 9\ O^{-2} \rightarrow CO_2 + 2ClO_2$	1t CCl4 = GWP 1,400	0.28t CO2e	1,399
17	Methyl Chloroform	$CH_3CCl_3 + 12\ O^{-2} \rightarrow 2CO_2 + 2H_2O, + 2ClO_2$	1t CH3CCl3 = GWP 506	0.66t CO2e	505
18	HCFC-22	$CH_3CFCl2 + 11\ O^{-2} \rightarrow 2CO_2 + 2H_2O + OF_2 + 2ClO_2$	1t HCFC – 22 =GWP 1,500	0.75t CO2e	1,499
19	HCFC-141b	$CH_2CF_2Cl + 9\ O^{-2} \rightarrow 2CO_2 + 2H_2O + OF_2 + ClO_2$	1t HCFC-141b = GWP 2,250	0.76t CO2e	2,249
20	HCFC-142b	$2CHClF_2 + 5O^{2-} \rightarrow CO_2 + ClO + OF_2 + H_2O$	1t HCFC-142b = GWP 1,800	0.25t CO2e	1,799
21	Halon-1211	$CF_3Br + 6\ O^{-2} \rightarrow CO_2 + 2OF_2 + BrO_2$	1t Halon-1211 = GWP 4,750	0.29t CO2e	4,749
22	Halon-1301	$CF_2BrCF_2Br + 10\ O^{-2} \rightarrow 2CO_2 + OF_2 + 2BrO_2$	1t Halon-1301 = GWP 5,400	0.16t CO2e	5,399
23	Halon-2402	$CF_2ClBr + 7\ O^{-2} \rightarrow CO_2 + OF_2 + ClO_2 + BrO_2$	1t Halon-2402 = GWP 3,680	0.27t CO2e	3,679

[2] Provided by GCI

3 Example applications

The technology that GCI has identified is applicable to the destruction of high GWP GHGs. This could be applied in two different ways, as detailed below.

3.1 Point Source

The technology could be used in a traditional manner as a source for destruction of high GWP GHGs specifically the class of GHGs which are known as Ozone Depleting Substances (ODS). These gases exist in refrigerants, refrigerant foam and blown insulating foam. Destruction of these substances is dealt with in a different manner depending on the region, but there is a significant opportunity in North America for the application of this technology.

3.2 Near Point Source

There is also potential application for a broad near point source emissions reduction strategy. This would entail the installation of a facility to produce oxide ions. These oxide ions would then be released to the atmosphere and act to destroy high GWP gases in the proportion which they are present in the atmosphere. This application, while potentially having a significant climate benefit, would require development of a new approach to offset quantification and has significant challenges.

4 Financial Opportunity

The carbon markets globally are continuing to grow and are currently a $176 Bn industry[3]. There is significant growth in the North American carbon markets over the near term as both California and Québec have passed the regulation to develop regulatory markets to control GHG emissions from their largest emitters.

Quebec and California have committed to a Cap and Trade carbon market commencing Jan 1st 2013 (collectively the Western Climate Initiative (WCI)). This market is expected to require 25 Mt of offsets in its first compliance period (2013-2015).

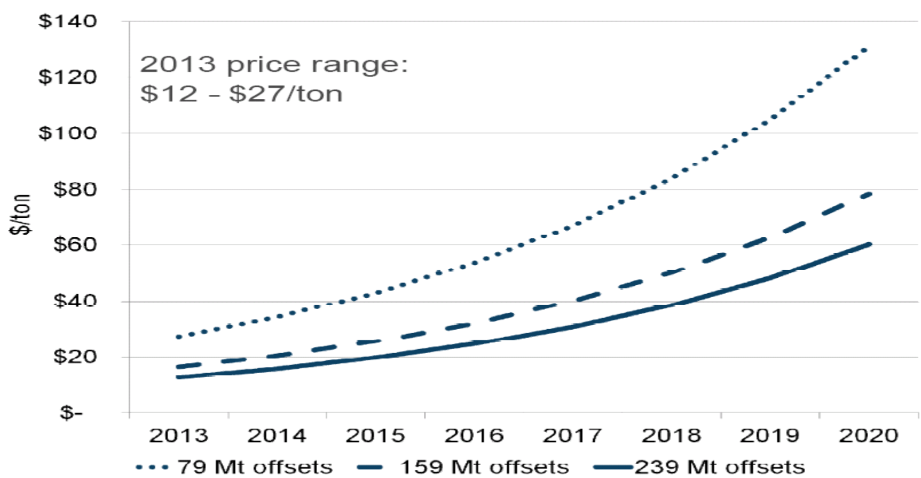

Figure 1 - Project price of allowances in the WCI under differing offset liquidity scenarios[4]

Figure 1 shows proposed pricing in the WCI under 3 different offset liquidity scenarios. Even in the "239 Mt Offsets" scenario it can be seen that the price per allowance will rise to $60 by 2020. It is not possible to predict exactly what this will mean for offset pricing, but it is reasonable to assume that the discount will not be greater than 25% from the allowance price.

[3]World Bank, State and Trends of the Carbon Market 2012, Available at http://siteresources.worldbank.org/INTCARBONFINANCE/Resources/State_and_Trends_2012_Web_Optimized_19035_Cvr&Txt_LR.pdf

[4] Source: Point Carbon

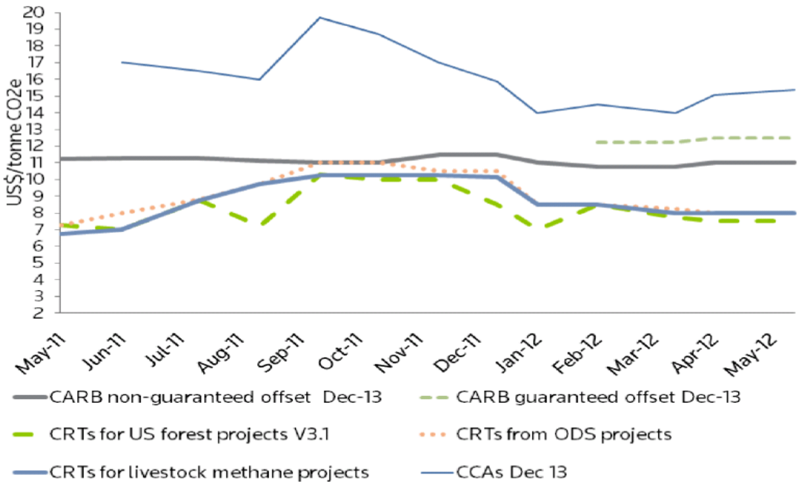

Figure 2 - Current traded price for CARB compliant instruments[5]

Figure 2 shows how prices have evolved over the 12 months from May'11 to May '12. These prices are for instruments that are expected, with a high degree of certainty, to become compliance grade instruments in California's Cap and Trade market (i.e. companies can buy these now to begin to accrue offsets to cover their future liability under the legislation). These prices demonstrate that there is a current, real market for compliance offsets, with offsets commanding prices of approximately $10 per tonne.

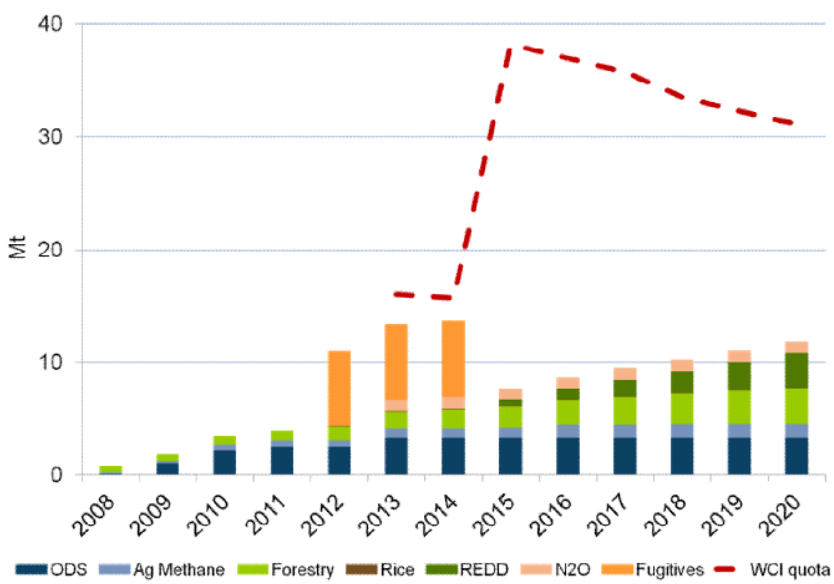

Figure 3 - Projected offset supply in the WCI out to 2020[6]

The market is expected to be significantly short offsets (as shown in Figure 3). The red line represents the projected offset requirement from the market and it can be seen that the projected supply is significantly below the projected demand. This leads to the suggestion that offset prices will be more associated with the lower offset supply scenario in figure 1. Of

[5] Source: Point Carbon
[6] Source: Point Carbon

interest to note here is the significant portion of supply that is expected to come from the destruction of ozone depleting substances.

In addition to the developing WCI, the BC Government has a commitment to purchase approximately 700kt to 1mt of emissions offset per year. This commitment is set out in the *Greenhouse Gas Reductions Target Act (GGRTA)* and the regulation for the quantification of emissions reductions projects are set out in the BC Emission Offsets Regulation. The Pacific Carbon Trust (PCT), the governments purchasing body for the offsets, has been buying offsets at an average price of approximately $10, but has been paying more for novel BC made technologies, and the GCI project would qualify for an improved price. However the PCT has a number of projects that it is already supporting and has fairly limited demand for new tonnes.

Outside of the WCI and the BC Emissions offset regulation two other markets where there is a firm price for offsets are in Europe and Alberta. Alberta is expected to have significant demand for offsets over the next 10 years, with a price for tonne of approximately $13.50. If GCI has a potential application in Alberta, there could be a solid business case for the development of offsets.

5 Quantification

At the most basic level offset quantification is based on the following equation =

Equation 1

$$GHG_{reductions} = GHG_{baseline} - GHG_{project}$$

Where:

$GHG_{reductions}$ = Number of GHG emissions reductions (tCO2e)
$GHG_{baseline}$ = Number of GHG emissions that would have occurred in the absence of the project (tCO2e)

The basic framework for all offset programs is the International Standards Organization GHG accounting standard 14064-2 *"Greenhouse gases – Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements".* This standard has 6 overarching principals that need to be considered when looking at new emissions reducing technologies and how the quantification of these emissions reductions will be designed:

1. Relevance
2. Completeness
3. Consistency
4. Accuracy
5. Transparency
6. Conservativeness

Where the quantification of reductions has an established protocol (see section 5.1 Point Source) these elements will have been taken into account in the protocol and as such will not be an issue. For the Non Point source quantification approach, these items will be critical in ensure that offsets generated are viewed as legitimate.

In addition there are some over-arching fundamental concepts of offset generation which offset projects will be required to meet regardless of the program. These are –

Additionality – the project would not have occurred in the absence of carbon funds as an incentive.

Regulatory Surplus – the project is not required by regulation.

Permanent – the project leads to permanent reductions or removals. This requirement is viewed on the same timescale as GWP, i.e. 100 years.

These requirements should not be an issue for the GCI project. The additionality case will clearly involve the use of carbon funds as this will be a key to implementation. In addition, the case can be made that the project proponent will be taking in some technology risk by adopting this technology and that will strengthen the case. With regard to Regulatory surplus, this will be dealt with in the various program quantification protocols. For example, as will be laid out below, Canada has different regulations regarding the capture and destruction of ODS that the US. In the US credit can be gained for ODS destroyed from the equipment and from the foam, but in Canada credit is only given for ODS recovered from the foam as there is already regulation governing the capture of ODS from equipment. Finally the permanence requirement is not an issue for this particular project type as the oxide ions irreversibly destroy the high GWP gases. However, for other GCI technology where Carbon Dioxide is split into Carbon and Oxygen the pathway for the Carbon will need to be considered. If it is returned to the atmosphere in less than 100 years there will be a reversal of the emissions offset.

In order for emissions reductions to be qualified as tradable financial instruments (offsets), they need to be audited by accredited third parties. The auditing requirements are dependent on the various systems but the basic requirement is that an expert auditing company (for example KPMG, PwC, Deloitte) gives an assurance on the assertion of the GHG reductions that are claimed. The validation and verification of the offsets will be the key hurdle for generating carbon funds from GCI technology.

5.1.1 Ownership

Ownership of emissions reductions is a key factor in the development of an emissions reduction program. Ownership will default to a particular party but can be transferred contractually if all parties concerned agree.

In the event of the project being a straight forward point source destruction of high GWP gases, the ownership of the environmental benefits would default to the owner of the gases that sent them to the facility to be destroyed. This could be transferred to GCI (or the owner of a GCI installed facility) either through the purchase of the gases destined for destruction or by a contract around the environmental benefits.

The broader, near point source application is more complex with regard to the ownership. These emissions reductions would occur in the common atmosphere. The logical chain of ownership for these emissions reductions would be with the owner of the facility producing the oxide ions, but at present there is no precedent for this.

5.1 Point Source

Offset projects are typically associated with reductions of emissions from a point source. There are several markets where the GCI technology might be applied and these are laid out below.

5.2 Markets and Programs

5.2.1 California Air Resources Board (CARB)

As can be seen from Figure 2, offsets generated from the destruction of Ozone Depleting Substances[7] (ODS) are generating significant interest in the run up to the California Cap and Trade market. This is one of 4 project types approved by CARB. The broad description of ODS under this regulation is:

[7] California Air Resources Board, Compliance Offset Protocol Ozone Depleting Substances Projects, Destruction of U.S. Ozone Depleting Substances Banks. Available at http://www.arb.ca.gov/cc/capandtrade/protocols/ods.pdf

"The Compliance Offset Protocol Ozone Depleting Substances Projects provides methods to quantify and report greenhouse gas (GHG) emission reductions associated with the destruction of high global warming potential ozone depleting substances (ODS) sourced from and destroyed within the U.S. that would have otherwise been released to the atmosphere. This project category includes ODS used in foam blowing agent and refrigerant applications. All destroyed ODS must be fully documented, chemically analyzed, and destroyed at a qualifying facility to be eligible for crediting under this protocol. All ODS must originate in the United States. The protocol is built off of The Climate Action Reserve's U.S. Ozone Depleting Substances Project Protocol Version 1.0 and includes the information provided in the Errata and Clarification."

The quantification methodology has several steps, the key equations are:

The equation that sets out the project emissions of CO2 from the oxidation of ODS:
Equation 2

$$ODS_{CO2} = \sum_i Q_{ODS,i} \times 0.9999 \times CR_i \times \frac{44}{12}$$

			Units
ODS_{CO2}	=	Total GHG Emissions of CO2 from ODS oxidation	tCO_2
$Q_{ODS,i}$	=	Total quantity of ODS i sent for destruction in the project	tODS
0.9999	=	Minimum destruction efficiency of the destruction facility	% (0-1)
CR_i	=	Carbon ratio of ODS i	mole C/ mole ODS
		CFC-11: 12/137	
		CFC-12: 12/121	
		CFC-113: 12/90	
		CFC-114: 24/187	
		CFC-115: 12/74	
		HCFC-22: 12/87	
		HCFC-141b: 24/117	
44/12	=	Ratio of CO_2 to C	$moleCO_2$/ Mole C

The equation that sets out the project emissions from ODS not destroyed:
Equation 3

$$ODS_{emissions} = \sum_i Q_{ODS,i} \times 0.01\% \times GWP_i$$

			Units
$ODS_{emissions}$	=	Total GHG emissions of undestroyed ODS	tCO_2e
$Q_{ODS,i}$	=	Total quantity of ODS i sent for destruction in the project	tODS
0.01%	=	Maximum allowable percent of ODS that is not destroyed	percentage
GWP_i	=	Global warming potential of ODS i (see Appendix A).	tCO_2e

The defining characteristic of the destruction methodology in this quantification methodology is a destruction efficiency of over 99.99%. This is achievable using the GCI technology by overdosing the ODS with oxide ions. The GCI technology would be able to guarantee 100% destruction of ODS, which is a significant selling point.

5.2.1.1 Challenges

There are two main requirements that would define GCI/GCIs customers developing offsets under this methodology –

1. All ODS must sourced from and destroyed within the US.
2. All ODS must be destroyed at a qualifying facility. The process for having the GCI technology certified as a recognised destruction technology would require experimental demonstration that the 99.99% destruction facility could be achieved. The currently recognised technologies are:
    a. Incinerators
        i. Rotary Kilns
        ii. Fixed hearth units
        iii. Liquid injection units
    b. Industrial furnaces
        i. Cement kilns
        ii. Lightweight aggregate kilns
    c. Plasma Technologies
        i. Argon Plasma units

5.2.2 Quebec Cap and Trade

The Quebec market has broad agreement with the California market to link. However, they are accepting different offset types and quantification methodologies. Both markets are broadly accepting offsets generated from ODS, but the Canadian protocol only allows for the destruction of ODS from foam[8]. The offset project is specified as:

> *"This offset credit protocol covers any project designed to destroy the ODS contained in insulating foam recovered from appliances in Canada or the United States. The project targets all the activities engaged in by a promoter to destroy the ODS contained in insulating foam recovered from freezing storage and refrigeration appliances in an authorized destruction facility. The ODS must be*
>
> 1. *extracted from the foam to a concentrated form under negative pressure;*
> 2. *collected, stored, and transported in hermetically sealed containers;*
> 3. *destroyed in concentrated form."*

In addition to only applying to the foam, the basket of ODS contains slightly different gases between the 2 jurisdictions:

[8] Destruction of Ozone Depleting Substances Contained in Insulating Foam Recovered from Appliances. Available at http://www.mddep.gouv.qc.ca/changements/carbone/reg-PEDE-20120608-en.pdf

Quebec regulation ODS	California regulation ODS
CFC-11 CFC-12 HCFC-22 HCFC-141b	CFC-11 CFC-12 CFC-113 CFC-114 CFC-115 HCFC-22 HCFC-141b

The quantification methodology for the destruction of ODS is consistent with that of California (see section 5.2.1) other than the broad differences detailed above.

5.2.2.1 Challenges

The challenges here are less significant than for the Californian market. Emission reductions achieved under the Quebec protocol are able to be generated across Canada, and the definition of the destruction technology is less prescriptive. However, there is only a possibility of gaining carbon offsets from ODS captured from foam, and not refrigerants themselves.

5.2.3 BC Emissions Offset Regulation

The BC EOR does not have a protocol for quantifying the emission reductions from the destruction of high GWP gases. However, the regulation does cover these gases as a GHG, and they would qualify for an emissions reduction project. This would require the development of a protocol, but, as demonstrated in earlier sections, protocols exist in several different jurisdictions that would be easily amended to be used in BC. The suggested approach would be to ensure that the technology qualifies for use under the Quebec protocol as this is already set-up with Canadian federal regulation in mind and would require the fewest number of amendments.

5.2.3.1 Challenges

Quantifying emissions reductions under the BC EOR should be a straight forward exercise. However, there are some issues that should be considered:

1. Protocol development. Additional work would be required to create an ODS protocol. This would require additional consulting services from Offsetters and would need validation by an accredited third party. The approximate cost would be $75,000.
2. Liquidity. The PCT does not have significant remaining space in their portfolio and as such they would not be able to commit to a significant purchase of ODS credits.

5.2.4 Other Potential Markets

There are two other potential markets that have significant size and liquidity and where offsets command a significant price. These are the Alberta Offset System (ABOS) and the European Union Emissions Trading Scheme (EU ETS).
ABOS currently does not have an offset protocol for the destruction of high GWP potential gases, and in order to develop offsets in this market a protocol would need to be developed and go through Alberta Environment's screening process, which takes a minimum of 18 months.

The EU ETS does have an offset protocol for the destruction of high GWP gases, but their offset system only accepts offsets that are generated from Least Developed Countries[9] and so this is unlikely to be applicable for an application of GCI technology at present.

9 http://www.unohrlls.org/en/ldc/25/

5.3 Near Point Source

GCI would like to investigate a new methodology for quantification. The basic approach is, rather than controlling the emissions destroyed on a point source basis, to have an oxide ion emitting facility close to the point sources of emissions and to allow the reactions from the oxide ions to occur in the free atmosphere. As the reaction pathways of the oxide ions are well known and the atmospheric chemistry in the area can be determined the emissions reductions generated would be, theoretically, straightforward to calculate, as the atmospheric concentrations would be used as a proxy for a defined activity level.

Table 2 - Relative atmospheric abundances of high GWP gases[10]

Common Name	Formula	Abundance (ppt)	GWP
Methane	CH_4	1,745,000	23
Nitrous Oxide	N_2O	314,000	296
Perflouromethane	CF_4	80	5,700
Perflouroethane	C_2F_6	3	11,900
Sulphur Hexaflouride	SF_6	4.2	22,200
HFC-23	CHF_3	14	12,000
HFC-134a	CF_3CH_2F	7.5	1,300
HFC-152a	CH_3CHF_2	0.5	120
CFC-11	$CFCl_3$	268	4,600
CFC-12	CF_2Cl_2	533	10,600
CFC-13	CF_3Cl	4	14,000
CFC-113	$CF_2ClCFCl_2$	84	6,000
CFC-114	CF_2ClCF_2Cl	15	9,800
CFC-115	CF_3CF_2Cl	7	7,200
Carbon Tetrachloride	CCl_4	102	1,800
Methyl Chloroform	CH_3CCl_3	69	140
HCFC-22	CHF_2Cl	132	1,700
HCFC-141b	CH_3CFCl_2	10	700
HCFC-142b	CH_3CF_2Cl	11	2,400
Halon-1211	CF_2ClBr	3.8	1,300
Halon-1301	CF_3Br	2.5	6,900
Halon-2402	CF_2BrCF_2Br	0.45	20

If the gases were present in the abundance shown here one tonne of O^{2-} applied across this basket of gases would theoretically create 97.03t CO2e of emissions reductions. This is calculated as:

Equation 4

$$\begin{aligned} &Emissions\ Reductions\ from\ application\ of\ 1\ tonne\ of\ O^{2-} \\ &= \left(\sum G_i \times Net\ GWP\ reduction_i\right) \times (Tonnes\ O^{2-}\ required) \end{aligned}$$

Where:

[10] From the IPCC Third Assessment Report (TAR). Available at http://www.grida.no/climate/ipcc_tar/wg1/pdf/TAR-04.pdf

Tonnes of Gas_i (G_i) = is the tonnage of HGWP gas type i present in the target basket calculated using equation 5.
Net GWP reduction = Global warming potential of gas type i as laid out in table 2
Tonnes O2- required = the tonnes of O2- required to destroy the basket of gases (assuming perfect mixing) as calculated in Equation 6.

Equation 5

$$Gi = \left(\frac{Relative\ abundance\ of\ Gas_i \times Atomic\ Weight\ of\ Gas_i}{\sum Relative\ abundance\ of\ Gas_i \times \sum Atomic\ Weight\ of\ Gas_i}\right) \times C$$

Where:

Relative abundance of Gas_i = The ppt of gas type i taken from Table 2.
Atomic weight of Gas_i = the atomic weight of gas type I in g/mole
c = conversion factor of grams to metric tonnes = 1,000,000

Equation 6

$$Tonnes\ O^{2-}\ required = \frac{Mole\ O^{2-}}{\sum Mole\ of\ Gas_i}$$

Where:
Mole O2- = the number of moles of oxide gas required to oxidise the basket of gas. This is established from the number of O2- ions required to oxidise each gas of type i. Oxidation of the gases is proposed by GCI to occur at 67 ions (see appendix A.4 for details).The reactions as set out in table 1 are the reactions that would occur under high temperature oxidation conditions and not what would apply under at atmospheric temperature and pressure. This is an area that requires further study, and verification by a third party in order to move forward with this approach as an offset project.

Mole of Gas_i =The number of mole of gas i calculates from equation 7.

Equation 7

$$Mole\ of\ Gas_i = G_i \times Atomic\ Weight\ of\ Gas_i$$

5.3.1 Sample financial model

Using some simple inputs a financial model was constructed for a 6 stack example plant:

Financial indicators:

Indicator	Scenario 1 – Conservative (assuming $2 per tonne of emissions reductions)	Scenario 4 – Aggressive (assuming $10 per tonne emissions reductions)
Capital Cost, including $200k to offset project development	$461k	461k

Annual operating cost	$63k	63k
Annual income	$339,993	$1,699,695
3 year IRR	$ -71%	306%
5 year IRR	$ 19%	352%

It should be noted here that this financial model is overly simplistic and does not include costs relating to permitting, site selection etcetera.

The two pricing scenarios are selected to represent the current market for compliance offsets (California and Quebec are used as the bench mark) and voluntary offsets (high quality industrial VCS is used as the bench mark).An assumption of $10 per tonne is extremely aggressive. As of today there are no purchasers either in the compliance or voluntary markets which would purchase these tonnes and there are very significant hurdles, particularly around the quantification and also regulation, before they could even be considered saleable. If the tonnes were to be intended to be sold to the voluntary market liquidity would also be a significant issue as there are a limited number of purchasers globally.[11]

5.3.2 Challenges

There are a number of significant challenges related to the monetization of credits from this application of the technology. These fall broadly into two categories; quantification and market.

5.3.2.1 Quantification

The overarching challenge with this approach is that it does not conform to the standard project-based carbon accounting approach used by offset projects. It is difficult to accurately ascertain what actual reactions took place rather than the reaction on an averaged basis. Offsetters has contacted a number of auditing bodies and broadly discussed this approach and its possible application under the current regulatory framework. The answers have overwhelmingly been negative, suggesting that any quantification would require highly accurate measuring of samples before and after in order to determine the actual destruction that has occurred. This is not a comment on the efficacy of the technology its self, but how the Near Point Source approach would fit under the current mechanism of generating offsets. The key issue a third party validator or verifier will need to assess is Materiality. Materiality for most offset standards is set at 5%. This is cumulative and if the auditor feels that it is possible for the emissions reductions claimed to be overstated by an amount equal to or over 5% they will be unable to provide the required assurance that these emissions reductions are accurately represented.
The emissions reductions will need to be verified to reasonable level of assurance and this will require the auditor to make a statement such as:

> *"Based on the process and procedures conducted, the GHG assertion*
> - *Is materially correct and is a fair representation of the GHG data and information, and*

[11] http://www.forest-trends.org/publication_details.php?publicationID=3164

- *Is prepared in accordance with the related International Standard on GHG quantification, monitoring and reporting, or to relevant national standards or practices"*

In order for an accredited third party to make an assurance statement such as the one above, the uncertainty in this Near Point source quantification methodology will need to be reduced, and this may prove impossible. Offsetters has contacted several auditing firms we have worked with for an informal opinion and will make an addition to this draft dependent on their feedback.

A further challenge to the quantification is the age of gases that are destructed. All offset quantification use 100-year GWPs. So, for example, Methane has a 100 year GWP of 23. This means that over 100 years emitting 1 tonne of Methane has the same GWPl as 25 tonnes of CO_2. There are 2 main functions of GWP, which are shown in equation 8:

Equation 8

$$GWP = \frac{\int_0^T I_{gas} M_{gas}\, dt}{\int_0^T I_{CO2} M_{CO2}\, dt}$$

Where:
Igas = instantaneous radiative forcing by gas at time t (governed by basic molecular properties and on atmospheric composition
Mgas = amount of added gas still remaining at time t (depends on the lifetime of the gas
T = Time horizon for integration (gases with lifetimes (longer/shorter) than CO_2 have GWPs (increasing/decreasing) with T).

As can be seen from this equation time is critical function in this which creates real quantification challenges for the quantification of gases that have already been emitted.

It should be noted here that GCI intends to continue the detailed study of the environmental benefits associated with Near Point source distribution of oxide ions with the intent of removing any quantification barriers. This will require large scale testing and atmospheric sampling and it is recommended that a consultancy with significant experience with atmospheric chemistry and verification and validation of offset projects is engaged to assist with this.

5.3.2.1 Market

If the quantification issues can be resolved then the issue of where these credits could be sold arises. There are two broad market types that these could be sold into, the first is the compliance market and the other is the voluntary market. In the compliance market, there is currently no market that would accept offsets generated in this way, and no market which has the flexibility to do so without significant regulatory amendment. To generate interest in this approach will be an extremely long term investment of time with no certainty of success. Regulation is slow to be established and change and this approach is so far from current approaches that there is a long time frame to adoption. There is some possibility that a voluntary purchaser could be found, but it is Offsetters professional opinion that this is unlikely, and even if a purchaser is identified the volumes are unlikely to be large enough to generate significant investment.

6 Project development roadmap

6.1 Point source

For a development of this type GCI would need to establish a supply chain of ODS and ensure that their technology and operation conforms to the requirements as laid out in the particular system they wish to pursue. The most likely would be the Quebec ODS destruction protocol. If this were the case the following budget and roadmap would be broadly applicable for the development of the project. This would need to be refined at a later date as and when there are more details related to the project.

6.1.1 Tasks

An offset project splits into two main phases: 1) project design, 2) annual monitoring and maintenance. The costs and timing described here are approximate and would be refined depending on the details of the actual project to be implemented:

Task – Project Design	Time frame
Protocol writing – may not be required depending on the project details	6-8 weeks
Protocol validation – may not be required depending on the project details	4-6 weeks
Project Design	6-8 weeks
Project Design validation	4-6 weeks

This is the initial design phase. At the end of this phase, the project would be validated and this would be the earliest stage that significant funds from a purchaser could be attracted.

Task – Monitoring and Maintenance	Time frame
Monitoring and data collection	Ongoing
Annual preparation of monitoring report	4-6 weeks
Annual verification of monitoring report	2-4 weeks
Registration and delivery of offsets	1 week

At the end of the Monitoring and Maintenance period, the project owner will have received validated and verified offsets from the project.

6.1.2 Budget

A detailed budget is difficult to lay out as there are still a large number of unknowns. However, it could be expected that the following approximate cast would apply:

Deliverable	Frequency	Cost
Validated protocol	One time	$75,000
Validated project design	One time	$60,000
Verified project report	Annual	$35,000

6.1 Near-Point Source

For a development of this type, GCI would need to establish that there is a business case for doing so, and then work with a qualified environmental science firm to establish the monitoring and maintenance requirements to create a project design with the required level of accuracy. If this is possible then Offsetters would be able to move forward on developing the offset project

6.1.1 Tasks

An offset project splits into two main phases: 1) project design, 2) annual monitoring and maintenance. The costs and timing laid out here are approximate and would be refined depending on the details of the actual project to be implemented:

Task – Project Design	Time frame
Generation of new carbon account standards to quantify this type of offset project	6 months
Protocol writing	6-8 weeks
Protocol validation	4-6 weeks
Project Design	6-8 weeks
Project Design validation	4-6 weeks

This is the initial design phase. At the end of this phase, the project would be validated and this would be the earliest stage that significant funds from a purchaser could be attracted.

Task – Monitoring and Maintenance	Time frame
Monitoring and data collection	Ongoing
Annual preparation of monitoring report	4-6 weeks
Annual verification of monitoring report	2-4 weeks
Registration and delivery of offsets	1 week

At the end of the Monitoring and Maintenance period the project owner will have received validated and verified offsets from the project.

6.1.2 Budget

A detailed budget is difficult to provide as there are still a large number of unknowns. However, it could be expected that the following approximate cast would apply:

Deliverable	Frequency	Cost
Validated protocol	One time	$200,000
Validated project design	One time	$60,000
Verified project report	Annual	$35,000

7 Conclusion and Recommendations

It is clear that GCI has a novel technology that has some significant environmental benefits. It seems that there is potential for this technology to be used as an efficient destruction mechanism for ODS, which may mean that it can generate offsets under the existing protocols for sale into existing markets as identified here and detailed under the Point Source sections of this report. Offsetters recommends that GCI explores ODS destruction opportunities with the goal of replacing existing incineration technologies as the method of destroying high GWP ODS gases.

With regards to the Non Point source application of this technology, there is definitely a theoretical climate benefit associated with the technology. Unfortunately, however, under current offset protocols and quantification approaches, Offsetters does not believe that the project can currently provide the level of accuracy necessary to obtain a reasonable level of assurance from the auditing entities, or meet current quantification requirements. In addition there is currently no market for offsets generated in this fashion and there is no plan to create one. As a result, Offsetters does not consider the project a strong candidate for satisfying the aforementioned requirements and does not deem it likely that GCI will be able to generate income from this project type under the current offsetting system. Significant changes to current regulations would be required for this project type to become feasible, which is unlikely to occur in the foreseeable future.

Appendix A – Constants

A.1 Atomic Mass

Element	Symbol	Atomic Mass
Carbon	C	12
Chlorine	Cl	35
Hydrogen	H	1
Nitrogen	N	14
Bromine	Br	80
Sulphur	S	32
Flourine	F	19
Oxygen	O	16

A.2 Global Warming Potential[12]

Common name	Chemical Formula	100 year GWP (SAR)	100 year GWP (AR4)
Carbon dioxide	CO_2	1	1
Methane	CH_4	21	25
Nitrous oxide	N_2O	310	298
CFC-11	CCl_3F	3,800	4,750
CFC-13	$CClF_3$	10,800	16,400
CFC-113	CCl_2FCClF_2	4,800	6,130
CFC-114	$CClF_2CClF_2$	8,040	8,730
CFC-115	$CClF_2CF_3$	5,310	9,990
Halon-1301	$CBrF_3$	5,400	7,140
Halon-1211	$CBrClF_2$	4,750	575
Carbon tetrachloride	CCl_4	1,400	1,400
Methyl bromide	CH_3Br	17	1
Methyl chloroform	CH_3CCl_3	506	45
HCFC-22	$CHClF_2$	1,500	1,810
HCFC-123	$CHCl_2CF_3$	90	77
HCFC-124	$CHClFCF_3$	470	609
HCFC-141b	CH_3CCl_2F	2,250	220
HCFC-142b	CH_3CClF_2	1,800	2,310
HCFC-225ca	$CHCl_2CF_2CF_3$	429	37
HCFC-225cb	$CHClFCF_2CClF_2$	2,030	181
HFC-23	CHF_3	11,700	14,800
HFC-32	CH_2F_2	650	675
HFC-125	CHF_2CF_3	2,800	3,500
HFC-134a	CH_2FCF_3	1,300	1,430
HFC-143a	CH_3CF_3	3,800	4,470

[12] http://www.climatechangeconnection.org/emissions/documents/GWP_AR4.pdf

HFC-152a	CH_3CHF_2	140	124
HFC-227ea	CF_3CHFCF_3	2,900	3,220
HFC-236fa	$CF_3CH_2CF_3$	6,300	9,810
HFC-245fa	$CHF_2CH_2CF_3$	3,380	314
Sulphur hexafluoride	SF_6	23,900	22,800
Nitrogen trifluoride	NF_3	12,300	20,700
PFC-14	CF_4	6,500	7,390
PFC-116	C_2F_6	9,200	12,200

A.3 Units

Unit	Definition
Tonnes	Metric Tonnes – 1,000 kilogrammes

A.4 Proposed reaction pathways provided by GCI

Common name	Chemical Formula	Reaction	Oxide Ion requirement
Methane	CH_4	O^{2-} + H_2O = CH_4 + 2 OH^- = H_2O + C. and + OH* from O^{2-} + H2O = 2OH-	1
Nitrous Oxide	N_2O	N_2O + 3 OH = 2 H_2O + NO_2	2
Perflouromethane	CF_4	CF_4 + 4 OH = 2 OF_2 + 2 H_2O	2
Perflouroethane	C_2F_6	C_2F_6 + 6 OH = 3 OF_2 + 3 H_2O + 2 C	3
Sulphur Hexaflouride	SF_6	SF_6 + 6 OH = 3 OF_2 + S + 3 H_2O	3
HFC-23	CHF_3	2 CHF_3 + 8 OH = 3 OF_2 + 5 H_2O + 2 C and + OH from O^{2-} + H_2O = 2OH	2
HFC-134a	CF_3CH_2F	CF_3CH_2F + 6 OH = 2 OF_2 + 4 H_2O + 2 C and + OH from O^{2-} + H_2O = 2OH	2
HFC-152a	CH_3CHF_2	CH_3CHF_2 + 6 OH = OF_2 + 5 H_2O + 2 C and + OH from O^{2-} + H_2O = 2OH	1
CFC-11	$CFCl_3$	$CFCl_3$ + 2 O_2 = OF + 3 ClO + C *O_2 is noted as 2O^{2-}	4
CFC-12	CF_2Cl_2	CF_2Cl_2 + 2 O_2 = OF_2 + 2 ClO + C *O_2 is noted as 2O^{2-}	3
CFC-13	CF_3Cl	4 CF_3Cl + 5 O_2 = 6 OF_2 + 4 ClO + 4 C *O_2 is noted as 2O^{2-}	3
CFC-113	$CF_2ClCFCl_2$	4 $CF_2ClCFCl_2$ + 9 O_2 = 6 OF_2 + 12 ClO + 8 C *O_2 is noted as 2O^{2-}	2
CFC-114	CF_2ClCF_2Cl	CF_2ClCF_2Cl + 2 O_2 = 2 OF_2 + 2 ClO + 2 C *O_2 is noted as 2O^{2-}	4
CFC-115	CF_3CF_2Cl	4 CF_3CF_2Cl + 7 O2 = 10 OF_2 + 4 ClO + 8 C *O_2 is noted as 2O^{2-}	4
Carbon Tetrachloride	CCl_4	CCl_4 + 2 O_2 = 4 ClO + C *O_2 is noted as 2O^{2-}	4
Methyl Chloroform	CH_3CCl_3	CH_3CCl_3 + 9 OH = 3 ClO + 2 C + 6 H_2O and + OH* from O^{2-} + H_2O = 2OH	4
HCFC-22	CHF_2Cl	CHF_2Cl + 5 OH = ClO + OF_2 + C + 3 H_2O and + OH* from O^{2-} + H_2O = 2OH	3
HCFC-141b	CH_3CFCl_2	2 CH_3CFCl_2 + 16 OH = 4 ClO + OF_2 + 4 C + 11 H_2O and + OH* from O^{2-} + H_2O = 2OH	5
HCFC-142b	CH_3CF_2Cl	CH_3CF_2Cl + 7 OH = ClO + OF_2 + 2 C + 5 H_2O OH* from O^{2-} + H_2O = 2OH	2
Halon-1211	CF_2ClBr	2 CF_2ClBr + 3 O_2 = 2 ClO + 2 OF_2 + 2 C + 2 BrO *O_2 is noted as 2O^{2-}	6
Halon-1301	CF_3Br	4 CF_3Br + 5 O_2 = 6 OF_2 + 4 C + 4 BrO *O_2 is noted as 2O^{2-}	3
Halon-2402	CF_2BrCF_2Br	CF_2BrCF_2Br + 2 O_2 = 2 OF_2 + 2 C + 2 BrO *O_2 is noted as 2O^{2-}	4
		Total	67