ReductionTech^{tm}

Municipal Air Quality, Greenhouse Gas & Sustainability Solution

Introduction

At **GC Green Carbon** we have created a proprietary ceramic that can split gases when heated, and have successfully achieved and standardized the splitting of a combined flow of pure CO_2 and oxygen to produce atomic oxygen radicals. We received nomination for a Nobel Prize in Physics for this discovery in 2012. **GC Green Carbon** has since established the production of aqueous hydroxyl radicals (OH*), which are the key to safe and effective open-air purification and greenhouse gas (GHG) reduction. This document will introduce you to the technology that we can share with potential implementers and with the public. It is technical by nature, and a layman's version will be produced for distribution shortly.

Nature has historically relied upon hydroxyl radicals (OH*) as a principal air cleanser in both natural and urban settings. But the dangerous, toxic build up of a well-mixed atmospheric brew of chemicals, smog, and heat trapping gases (GHGs) on local, regional and continental scales has now become a serious hazard to health and well-being, both human and of the biosphere in general. It threatens lives and property as seen with the increasingly frequent and severe fires, floods, and droughts spanning the globe, affecting every community.

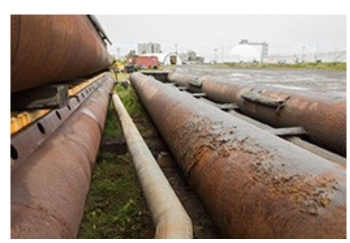
Technical ceramics are in a class of synthetic materials known for their engineered properties, like fracture toughness, strength, purity, hardness, density, thermal, gaseous and electrical conductivity, and for their use as 'molecular sieves.' They are also fundamental to **GC Green Carbon's** proprietary sustainability technology, called ***ReductionTech***^{tm}.

We are currently offering this technology to municipal governments that are already aware of the need for a solution to mitigate a) the health impacts of urban air pollution, b) a fundamental cause of climate change, the overloading of Earth's atmosphere with greenhouse gases (GHGs) like CO_2, methane, and extremely heat-trapping synthetic halogenated greenhouse gases, and c) damage to above-ground municipal infrastructure over time due the corrosive properties of GHGs.

Common Urban Problems Addressed by *ReductionTech*^{tm}

Reduce levels of toxic urban air pollution

Reduce the growing impacts of climate change



Reduce infrastructure corrosion

The Challenge

At present for nearly all major cities and municipalities of appreciable size, air quality has become a multi-dimensional problem. **Poor air quality affects the health** of citizens, pets, farm animals, wildlife, as well as trees, forests and crops. Low birth weight babies and dementia in seniors have both been traced to air pollution, as just two of the many known health problems. **Climate change** is well known to stem from the overloading of the atmospheric 'sink' for the common greenhouse gases: carbon dioxide, methane and halogenated carbon molecules used in refrigeration and industrial processes. The lesser known, but just as common urban problem is the **corrosion of infrastructure** due to the chemical activity of various components of air pollution. All three problems are reduced by introducing our proprietary **ReductionTech^{tm}**.

The atmosphere is a critical infrastructure. Due to current hazardous atmospheric loading, there is an imperative need for improving the removal of criteria air pollutants like ***PM 2.5***, ***ozone***, and ***carbon monoxide***. **Table 1** to the right indicates the most common sources and sinks for a several atmospheric radicals, including *OH and RO2 (peroxy or HOO radicals). The challenge that has arrived is that human civilization produces far more of these radicals than the natural OH* recuperative processes can handle. Hence we have overwhelmed the natural pollution sinks that have been operative for millennia.

		median rate, 10^5 molecule $cm^{-3} s^{-1}$ daily	noon	midnight
	net OH sources			
1	$HONO + h\nu \rightarrow OH + NO$	14.2	21.8	4.7
2	$H_2O_2 + h\nu \rightarrow OH + OH$	0.9	2.1	0.1
3	$O_3 + h\nu \rightarrow O(^1D) \rightarrow OH + OH$	0.3	1.7	0.0
4	$CH_3OOH + h\nu \rightarrow HO_2 + OH$	0.2	0.4	0.0
	recycling $RO_2 \rightarrow OH$			
5	$HO_2 + NO \rightarrow OH + NO_2$	8.3	11.6	2.2
6	$HO_2 + O_3 \rightarrow OH + 2O_2$	0.4	0.6	0.1
	net RO_2 sources			
7	$HCHO + h\nu \rightarrow 2HO_2 + CO$	2.1	3.7	0.4
8	$CH_3CHO + h\nu \rightarrow HO_2 + CH_3O_2 + CO$	0.9	2.1	0.2
9	$CH_3OOH + h\nu \rightarrow HO_2 + OH$	0.2	0.4	0.03
	recycling $OH \rightarrow RO_2$			
10	$CO + OH \rightarrow HO_2 + CO_2$	5.9	7.8	1.9
11	$CH_4 + OH \rightarrow CH_3O_2 + H_2O$	2.3	3.3	0.7
12	$HCHO + OH \rightarrow HO_2 + CO$	1.0	1.1	0.3
13	$CH_3CHO + OH \rightarrow CH_3CO_3$	0.8	1.1	0.3
14	$O_3 + OH \rightarrow HO_2 + O_2$	0.6	0.7	0.2
15	$H_2 + OH \rightarrow HO_2 + H_2O$	0.5	0.8	0.2
16	$CH_3OOH + OH \rightarrow CH_3O_2 + H_2O$	0.3	0.5	0.1
17	$H_2O_2 + OH \rightarrow HO_2 + H_2O$	0.1	0.3	0.0
	net radical losses			
18	$OH + NO_2 \rightarrow HNO_3$	1.9	2.2	1.1
19	$OH + NO \rightarrow HONO$	0.5	0.6	0.2
20	$OH + RO_2 \rightarrow$ products	0.4	1.0	0.0
21	$OH + RO_2NO_2 \rightarrow$ products	0.4	0.5	0.1
22	$OH + HONO \rightarrow H_2O + NO_2$	0.1	0.2	0.1
23	$OH + HNO_3 \rightarrow H_2O + NO_3$ [a]	0.0	0.0	0.0
24	$RO_2 + NO_2 \rightarrow RO_2NO_2 \rightarrow$ products	1.9	2.4	1.2
25	$RO_2 + RO_2 \rightarrow$ products	0.7	2.1	0.1
26	$RO_2 + OH \rightarrow$ products	0.4	1.0	0.0
	$\sum$ OH sources	24.2 ± 2.1 [b]	38.3 ± 3.2	7.1 ± 0.7
	$\sum$ OH losses	14.8 ± 4.6	20.3 ± 3.6	5.1 ± 1.2
	Δ	9.4 ± 5.0	17.9 ± 4.8	2.1 ± 1.4
	Δ/ OH Losses	0.6 ± 0.4	0.9 ± 0.3	0.4 ± 0.3
	$\sum RO_2$ sources	14.6 ± 1.8	21.9 ± 2.3	4.2 ± 0.9
	$\sum RO_2$ losses	11.7 ± 4.6	17.7 ± 7.2	3.5 ± 1.6
	Δ	2.9 ± 5.0	4.2 ± 7.6	0.7 ± 1.9
	Δ/ RO_2 Losses	0.25 ± 0.4	0.24 ± 0.4	0.19 ± 0.5
	$\sum RO_2$ and OH net sources	18.7 ± 0.6	32.3 ± 0.9	5.5 ± 0.1
	$\sum RO_2$ and OH net losses	6.4 ± 5.9	10.1 ± 7.1	2.7 ± 1.7
	Δ	12.3 ± 6.0	22.2 ± 7.2	2.7 ± 1.7
	Δ/net losses	1.9 ± 2	2.2 ± 1.7	1.0 ± 0.9
	$P_{pr}^{net}(OH) = \sum netOHsources - \sum netOHlosses$	12.2 ± 4.2	21.4 ± 3.0	3.4 ± 0.8
	$R_{net}(OH \rightarrow RO_2) = \sum(OH \rightarrow RO_2) - \sum(RO_2 \rightarrow OH)$	2.8 ± 2.7	3.5 ± 3.8	1.4 ± 1.1
	$P_{pr}^{net}(RO_2) = \sum netRO_2sources - \sum netRO_2losses$	0.15 ± 4.2	0.74 ± 6.6	-0.7 ± 1.5

Table 1: Global tropospheric hydroxyl distribution, budget and reactivity - Jos Lelieveld, Sergey Gromov, Andrea Pozzer, and Domenico Taraborrelli

The ReductionTech^{tm} Remedy

For every 1 ppm (part per million) increase in OH* radicals, the following reductions (Table A) are achieved where 50% treats criteria air pollutants and 50% treats GHGs: 20% of the OH* released will recycle and go on to remove more pollution so dispersing it creates a 125% enhanced steady volume, or 131 CO_2e/tonne secondary effect over 5 days. Each tonne of OH* directly offsets 530 CO_2 equivalents of atmospheric warming in addition to indicated air quality improvements, and translates to reduction of 861 tonnes of CO_2e per tonne of OH* emitted plus an estimated 27 saved lives.

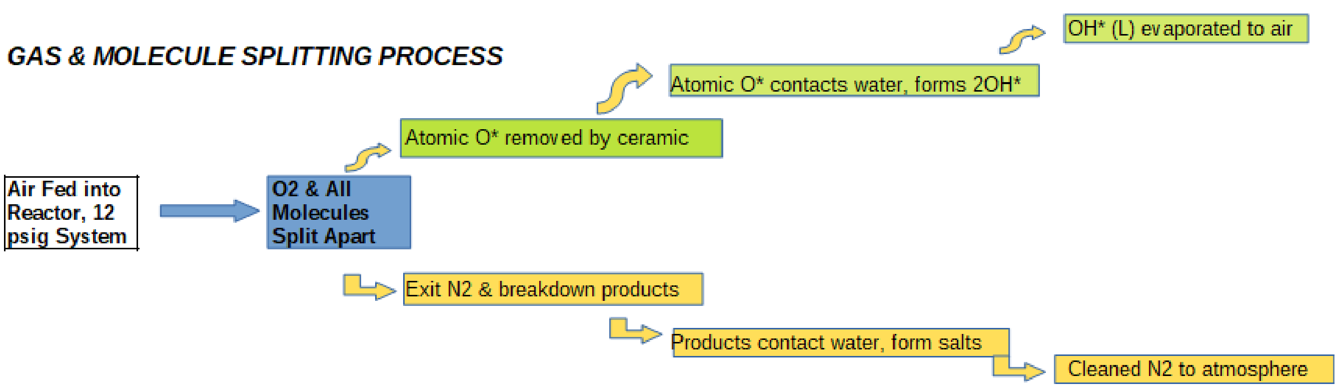
Gas or Species	Molality used	Wt % of species removed by 1 ppm OH* release	Wt % removed by thermal destruction in 20 T/Day ReductionTech System Feed Air = 200 CO2e/tonne
PM 2.5	1:1	12.5	100
O3	1:1	12.5	100
Carbon Monoxide	1:1	12.5	100
Methane	3:1	4	100
NOx	1:1	12.5	100
CO_2 buffered & removed	1:1	12.5-10 CO_2e/day	100
VOC	2:1	6.25	100
Synthetic GHGS	4:1	3	99

Table A

ReductionTech^tm Processing Facility

(Facility footprint)

Process Flow



Operation & Maintenance

The ceramic systems are housed heavy-duty stainless steel, mounted on steel skids, piped together and controlled by computer. The ceramic tubes clamp into the reactors with the removal of 8 bolts, the adjustment of 4 screws, replacement of three graphite gaskets in a turnaround time of approximately 20 minutes. The reactors weigh just less than 90 lbs. each, are serviceable in place.

The tube warranty for replacement averages one year, the heaters warranty every 2 years. This system is 8 times more cost efficient than generating OH* radicals using UV light bulbs in ambient air.

The sustainability of this technology includes recycling and reusing the ceramic material, so costs and the environment benefit. The tubular heaters' nichrome wiring can be scrapped and replaced as well. Each reactor uses approximately 700 watts of 30 amp, 110 V electricity from a green source. Water is used conservatively to make hydroxyl dispersant which is safely misted to the outdoors.

Air Shed Specifications and ReductionTech™ Value Proposition to 100,000 Urban Residents of an 8 TPD Hydroxyl Radical Air-Quality-Climate and GHG Mitigation Infrastructure

Kamloops Airshed treatment volume Km^3 1% volume (300)	3
Tonnes of Air	3,900,000
OH dispersal/day Tonnes	8
Added ppm of OH to area	2.2
Total ppm of Kamloops 3 year average PM 2.5	5
Provincial goal: 6 ppm Kamloops at 11ppm (5+6=11)	
PM 10 3 year average	6
Kamloops Deaths per year per 2.5 ppm of PM 2.5 level	22
Deaths/yr 1% with <50ppb O3/10ppb+ avg 30ppb (Cardiopulmonary Death)	30
Total empirically attributable AQ premature deaths in Kamloops/year	52
Disability adjusted Lost years attributable to air pollution	50
Monetary value of a human life USD (per US EPA)	$7,000,000
Annual cost of loss of human life value for Kamloops USD	$574,000,000
Minimum human savings for OH* dispersal per year to Kamloops USD	$57,400,000
Kamloops Methane emission cost to society at 180 kT/yr, $2900/T	$522,000,000
Value of 6% Methane footprint reduction work by 8 TPD OH*	$32,625,000
Total Annual cost of noted Criteria Pollutants to Kamloops	$1,128,625,000
Total recouped annual costs from dispersing 8TPD OH*	$90,025,000
Value of recoup in human lives: a mass casualty incident = 6 lost lives	30
Annual cost Average of a cost shared 8TPD OH* dispersal over 10 years	$10,000,000
CO2e offset impact for one year. 8T x 350 days steady flux effect included	2,410,800 Tonnes
Annual cost of OH* technology investment as % of annual 8% Recoup	11.1%
Annual cost of OH* technology investment as % of annual total losses	1.24%
Return on annual investment against annual losses	112x

Data Sources: Kamloops BCMOE, Stern Report, EPA, WHO, Schindell et. al., Physicians for the Environment Kamloops

Time Estimates

units wanted	1200
cost for them	$18,118,525
Land 20 acres	$3,000,000
total cost/unit	$22,648
total system	$27,177,788
POWER	$9,700,000
TOTLCAPEX	**$39,877,788**

The process of scaling up to a total of 1200 ***ReductionTech***tm reactors would require an estimated 2-year lead time, at a cost of $500,000.

An estimated additional three years would be required to build and commission the plant and power supply.

Potential Project Funding Structure- for Canada

Green Infrastructure Program

Project cost/100,000 People		Portion
Seed	$500,000	
Municipality	10.00%	$50,000
Province	15.00%	$75,000
Federal	25.00%	$125,000
Private	50.00%	$250,000
		$500,000
Plant	$40,000,000	
Municipality	10.00%	$4,000,000
Province	15.00%	$6,000,000
Federal	25.00%	$10,000,000
Private	50.00%	$20,000,000
		$40,000,000

The pilot program is being proposed in British Columbia in 2019.

This gives a view of the cost per 100,000 urban residents wishing to continuously upgrade and treat their air system.

Price of OH release program per citizen	
Grams/day	80
Kg per year	28
@$2.45/Kg/ye	$96.60

Offsets 2x the annual carbon footprint

Cost to Municipality: $9.60 a person/year

News & Views

HUMAN AQ STATISTICS FOR KAMLOOPS-ANNUAL

COPD/100,000 Canadian Government	1.,137
Asthma/100,000 Canadian Government	9,604
AQ Deaths WHO	50
AQ Disability WHO	52
All Cause mortality (Lancet)	301
TOTAL PER 100,000	23,094

Federal Government of Canada estimates that climate damages per capita will range from $636-$1,194/person per year.

GLOBAL METHANE INCREASE PREPARATION, February 18, 2019

What is happening as an Arctic methane release is being triggered by global industrial activity and CO_2 emissions? Communities will do better to have technology that can remove methane.

Unfortunately, the Air Quality story includes a badly deteriorating situation where Arctic methane is releasing from the terrestrial and subsea permafrost caps into the Earth's atmosphere. Methane can in turn trigger a self-amplifying feedback of Arctic warming throughout the Arctic. Scientists estimate that there are 1000 billion tonnes of methane and CO_2 at risk of leaking over the coming decades with an estimated 50 Gt release already in process. This will cause additional increased global warming of at least 2.1ºC if the entire leak happens and the methane is commercially exploited.

Table 3. Scenario B: atmospheric methane inventory (Gt), corresponding mixing ratio (ppm), radiative forcing (Wm^{-2}), and corresponding temperature increase (°C) for 2040, 2060, and 2100.

Year	Emission rate ($Tg\ yr^{-1}$)	Methane mass m CH_4 (Gt)	Mixing ratio (ppm)	Additional CH_4 radiative forcing (Wm^{-2})	Additional increase (°C)
2040	580 (2010–2040)	14.1[a]	4.9	+0.96	+0.77
2060	765 (2040–2060)	10.5	3.7	+0.64	+0.51
2100	1190 (2060–2100)	14.7	5.1	+1.01	+0.80

Source: Arctic methane, Elena Dyupina & Andre van Amstel - Journal of integrative environmental sciences.

Direct air capture of CO_2, methane removal, and synthetic greenhouse gas removal can all be done with new technologies. As municipalities move to protect community infrastructure, they are forced to look at mitigating climate damages including opportunities to remove the GHG root cause of climate damages -or never maximally secure their assets. Green infrastructure that can remove GHGs, protect and restore the atmosphere, provide lifesaving local and global air quality, begin reducing chaotic infrastructure loading are now a critical public good. Hydroxyl radicals are the best methane removal and air quality tool we have so we need reliable technology that can potentially deliver them to the atmosphere on a global scale while reducing damages.

The total warming that municipalities are confronting is 3.1'C, we have already warmed 1.1'C (IPCC). If methane and reactive GHGs are removed with technology, a 2'C cooling over the next century would help. CO_2 caused warming and other GHGs are now a combined impact. If we remove the potent GHGs we can restore the climate about 2'C over the next century and significantly reduce property damage and loss of life. The climate emergency is decadal in scale, but very large losses are already happening. The municipal damages are changing/shortening amortization schedules for infrastructure, forcing them to think about more frequent and bigger public works. Through carbon pricing, the emitter will begin to offset their impact and give emissions removal technologies at least a partial business case. Historical emissions and their role in damages have yet to be addressed.

As of February 27, 369 Local Government bodies covering over 31 million people have declared a climate emergency. https://climateemergencydeclaration.org/climate-emergency-declarations-cover-15-million-citizens/

IPCC scientists advise that we have at most 12 years to establish a forceful and sweeping combined emissions reduction protocol to get to net zero carbon emissions. If we fail, the average temperature of Earth will warm at least 2ºC over pre-industrial times, with catastrophic results. We are already at a warming of approximately 1.1ºC and the results in weather anomalies, drought and deluge, are bankrupting farmers and causing massive population migrations. ***ReductionTech**^tm* production of hydroxyl radicals is an extremely powerful intervention in this time-sensitive effort.

The more methane in the atmosphere, the fewer *OH are present to ensure air quality from other pollution sources in urban air which kills an average of 52 people per 100,000 population in Canada. Cities that are removing GHGs are also protecting themselves from the advance of climate damages by going to the root cause.

*OH is naturally variable, which means that low levels of it slows the removal of both pollutants, GHG and criteria air pollutants. At this time, communities need assurances that GHGs are being removed from the atmosphere in order to gain protection of assets and people. The way to achieve protection is with technology such as ***ReductionTech**^tm* from GC Green Carbon. Guaranteeing a steady oxidative capacity will speed the reduction of climate damages that happen.

Communities can organize in groups to secure a working ***ReductionTech**^tm* facility to help secure assets and reduce the carbon footprint that causes climate damages by maintaining safe elevated oxidation to the environment.

More information about the methane threat can be found at Professor Paul Beckwith's web site, from Dr. Peter Wadhams, IPCC, Arctic Council technical reports, peer reviewed journals and numerous public media sources.

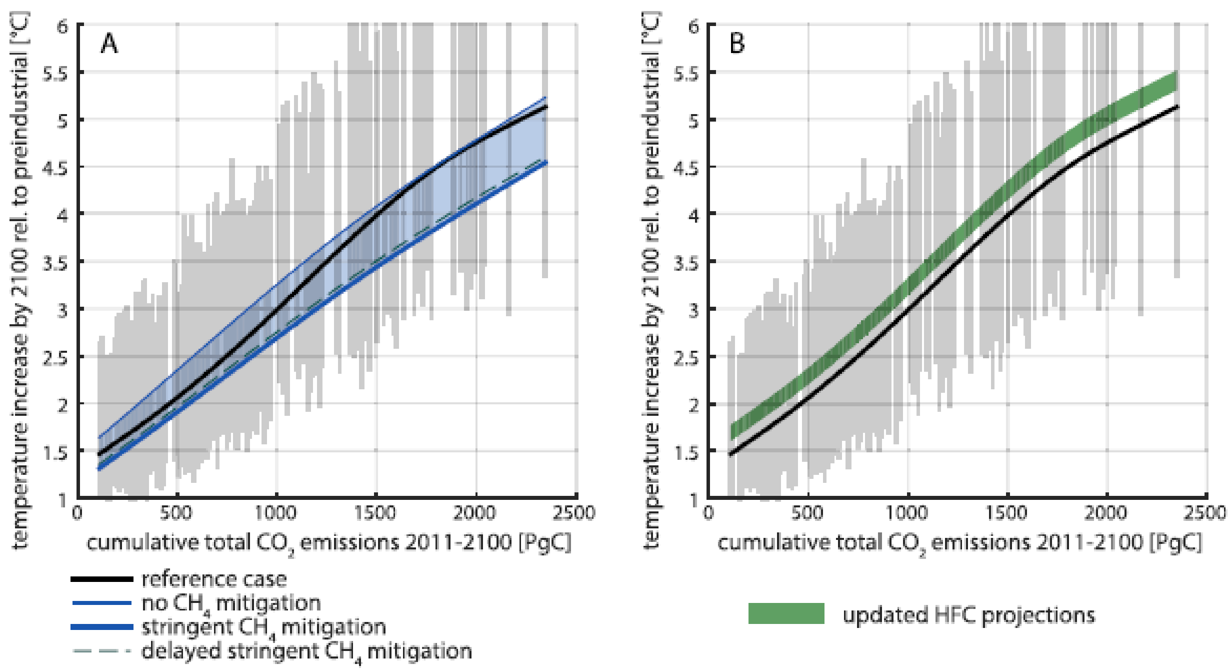


Figure 3. Dependence of carbon budgets consistent with a particular temperature limit during the 21st century. Vertical lines represent the 5th to 95th percentile range around the 'reference case' (see text). Panel A shows how the median outcome would change when assuming alternative levels of CH_4 mitigation. Panel B shows how the median outcome would change when taking into account updated baseline projections for HFCs. Note that accounting for common carbon-price signals already brings our 'reference case' at low CO_2 budgets down towards the stringent CH_4 reduction case (panel A), while at high carbon budgets the opposite is true. Not all cases are equally plausible across the various temperature levels (see section 4 in main text). Only scenarios with a temperature increase in 2100 of about 2°C and less are stabilizing temperatures by 2100. When year-2100 temperatures are higher, temperatures continue to increase past 2100 and the provided carbon budgets are thus not holding warming to below the here reported year-2100 warming in the long term.

Source: Impact of short-lived non-CO2 mitigation on carbon budgets for stabilizing global warming - Joeri Rogelj[1,2], Malte Meinshausen[3,4], Michiel Schaeffer[5,6], Reto Knutti[2] and Keywan Riahi[1,7]

Endorsements of GC Green Carbon Reduction Tech

Dr. Peter Wadhams, Professor Emeritus of Cambridge University, who said that "the science is radical and important", Andrew Ross, P Eng, Innovex Engineering, who said "exciting and technically sound", and Dr. Kingsley Donkor, Professor, Thompson Rivers University, who said "the science merits inclusion in more text books", "Relevant", Stephen Brydon, Climate Change Strategy Branch, Province of BC.

Lead Contact

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Hydroxyls are nature's silver bullet

12 million preventable AQ deaths and disabilities/yr
2'C of global food and climate security

*ReductionTech*tm

Image of utility pole with Reduction Tech mounted on it.

Frequently Asked Questions

1. Does this method really assist with outdoor air quality and greenhouse gases?

Yes. The hydroxyl radical is relied upon in nature as the #1 air quality and greenhouse gas removal compound. Its secret is that it persists in the atmosphere until it does react, meaning any enhancement of it will have an additive effect.

2. What are the methods to distribute it through a community?

There are larger facilities with a rooftop dispersal as well as local area utility pole mounted systems. These are automated and require a minimum of servicing.

3. Is the hydroxyl radical *really* overwhelmed by modern pollutants?

The highest average amount of hydroxyl is 7 ppm and about 20% recycles in the area overnight. This means that total pollutant counts above 8.60 ppm are overwhelming it and are creating a tipping point where the polluted area is now contributing to a build up of greenhouse gases and pollutants that is being exported out of the local area into neighboring regions, and contributing to accelerated global warming and climate damages.

4. Isn't the atmosphere an unlimited container?

Definitely not and only coordinated removal processes will ensure that we lower pollutant levels and protect infrastructure and lives in the mid and long term.

5. Isn't the average pollution count still acceptable in urban air?

Our statistics are based on Canadian monitoring that must include particulates and if possible, aerosol counts. The aggregate pollution count is used because hydroxyl attaches to, or breaks up aerosols and PM, so these constituents use it up just as much as the other pollutants. When they are included in urban air, even Canada's standards allow too much for the natural hydroxyl level.

6. With smart cities, can't we lower our emission levels?

It's a long journey and plant stress and plant metabolism from increased CO_2, warming and drought alone is increasing aerosol levels even in green cities. Atmospheric brown carbon and black carbon are a global issue and use up the hydroxyl reservoir and are exported to neighboring countries of developing countries that have asserted that they will peak their emissions before considering cutting down. Global emissions rose over 2% in 2018 while 18 single countries lowered emissions and viable direct removal methods like this one at *ReductionTech*^tm^ are being scaled up because the global average temperature is still rising, drought, floods and fires are projected to progress by scientists.

7. What is the individual's value proposition to use this technology?

Per Person Pollution Reductions	
PM 2.5	25%
Ozone	90%
CO	50%
CO2	6%
NO	50%
aerosols	20%
CH4	200%
SGHGs	200%
reduced deaths	30-50%
Cost Per Person Per year	
Per Person $US	8
Up to	16
OH per day grams	80-160

Based on an average Canadian Citizen's emissions profile. Other countries like the US and Asia emit more. As the hydroxyl system is outpaced, emissions are exported to other regions in an increasing cycle of inundation leading to incalculable climate damages.

Reduction Tech tm: Offering a way that communities can act scientifically and effectively for themselves, for the air, their health, and for the Earth. Even small communities can participate in community cooperatives or regional cooperatives.
Canada is officially warming at twice the pace of other countries, with the Arctic warming amplification at three times the pace.