

AIR QUALITY ASSESSMENT

A Report on the

Potential Air Quality Impacts  
for the  
Environmental Screening Study

of the

REMASCO Project  
Kingsville, Ontario

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2011

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## AIR QUALITY ASPECTS of the REMASCO PROJECT

### **PREFACE**

REMASCO has initiated the Environmental Screening Process (ESP) in accordance with Ontario Regulation 101/07 under the *Environmental Assessment Act* (EAA). This regulation addresses the use of thermal treatment facilities on industrial sites when the energy is used on the site where the energy is generated. Such projects are deemed exempt from Part II of the EAA if the environmental screening process is completed. The ESP is intended to determine the feasibility of expanding the existing REMASCO energy facility at Southshore to include a co-generation facility that will heat and power the greenhouses and to install a REMASCO energy facility to heat the Agriville greenhouse facility.

The Regulation requires that the proponent consider all aspects of the interaction of the proposed project with the environment during the screening process. One aspect of the environment identified in the ESP Guidelines issued by the MoE is air quality.

During preliminary discussions with local government agencies and members of the public various people expressed interest about the air quality effects arising from the project. Furthermore, it was suggested that the existing operations in the community might be exacerbated by the implementation of the REMASCO project. The results of sampling the emissions from the REMASCO pilot plant, as mandated by the MoE pilot project approval, indicated that the system, with some improvements, would be capable of meeting the province's guidelines for emissions from facilities treating waste materials. Putting these emissions into context with the existing emissions in the Kingsville area, and assessing the ambient air burdens of both the REMASCO facilities alone and in combination with the existing facilities is the purpose of this report. Moreover, the projections of local air quality generated in this report serve as an input to a Human Health Risk Assessment [HHRA] commissioned by REMASCO. The HHRA is available as a separate volume.

This report documents the emissions measured at the REMASCO facility during the operation of the gasifiers between 2008 and 2010.

The existing air quality in the community is a function of local sources that release contaminants to the atmosphere and more distant sources that contribute to the long range transport of air pollutants. Air monitoring conducted by government agencies provides some of the information necessary to characterise air quality in the province. In areas with extensive commercial and industrial emission sources such monitoring data serves as the baseline to define the effects of adding new sources. In industrialized areas where monitoring data is not available it is necessary to estimate the effects of existing sources. It is known that various fuels are used for heating greenhouses in the Kingsville area. All the greenhouses have similar energy needs so it is possible to estimate the amount of fuel that must be consumed to heat these facilities, and from that information and published emission

factors associated with specific fuels, it is possible to develop estimates of the emissions from the existing greenhouses. This report discusses the ambient air quality data available in southwestern Ontario, and how that data can be combined with the estimates of emissions from the greenhouses to develop an understanding of air quality in the Kingsville area.

Mathematical models are frequently used to predict the impacts of stack emissions. Using local meteorology and advanced algorithms that describe the dispersion of materials leaving a source, these models are accepted as a good tool for estimating existing air quality conditions, and by extension, predicting how those conditions might change if the source emissions are altered. That approach was used to address the questions about the cumulative impact of the REMASCO project and the existing greenhouse emissions and is described in this report.

## **1.0 INTRODUCTION**

### **1.1 *The Screening Environmental Assessment Process***

The REMASCO gasifiers have been operating at the Southshore Greenhouse for over 2 years under a Certificate of Approval [CofA] issued by the Ontario Ministry of the Environment [MoE]. That Approval covered a pilot program to build and test the technology to ensure that it could meet environmental standards and operate in a cost effective manner while delivering the heat required by the greenhouse complex.

It was recently announced that REMASCO was undertaking a screening environmental assessment of expanding the process. The environmental assessment is a necessary step to allow the facility to obtain full operational approval for an expanded boiler house at Southshore. Also included in the assessment is the use of the same technology and fuel to provide the energy for a co-generation system at Southshore and the replacement of the existing wood fired boilers at the Agriville greenhouse site with a REMASCO developed system.

### **1.2 *Purpose of This Report***

This report entitled *AIR QUALITY ASSESSMENT – Technical Study Report* was prepared to assess the potential air quality related effects associated with REMASCO project at the Southshore and Agriville sites in the Kingsville area. The report identifies current contributors to air contaminant levels in the Kingsville area and assesses changes that might occur due to the project. This report forms part of the supporting documentation for the Screening Environmental Assessment.

### **1.3 *Overview of Report Contents***

This report describes the existing air quality conditions in the Kingsville area and how these conditions may be affected by the proposed project. The Report analyses the net effects of the proposed project on the air quality in the area and proposes a set of monitoring requirements for the facilities. The key components of the Report are:

- Study methodology;
- Review of Baseline Ambient Air Quality;
- Emission Inventory for the Study Area;
- Review of existing REMASCO monitoring data to define emission estimates;
- Description of dispersion modelling procedures; and,
- Comparison of model predictions with applicable air quality criteria.

## 2.0 Study Methodology

When REMASCO announced that it was commencing an Environmental Screening Process for the Project, questions were raised about the potential effects of the project. Air emissions were a major concern for those that commented on the project. This is not surprising because it is generally agreed that one of the primary ways for contaminants to reach human and ecologic receptors is through their release into the atmosphere, airborne dispersion and deposition to the ground surrounding the site. To address these concerns, the key objectives of this study were to provide:

- the data necessary to assess the potential environmental effects of the Project on air quality and cumulative effects in the project vicinity; and,
- concentration and deposition data to the HHRA study team.

The assessment relies upon dispersion modelling to predict downwind concentrations of air contaminants from both the REMASCO facilities and the existing greenhouse operations in the Kingsville area. The predictions are compared to regulatory standards and objectives for both the existing and proposed situations. The most important consideration in conducting a dispersion study is characterising the sources of contaminants that might be released to the atmosphere, both in terms of the nature and mass of the contaminants, but also the temporal nature of those emissions.

The assessment of the air quality effects related to the Project consisted of:

- compiling emission inventories for the REMASCO facilities and other greenhouses in their immediate vicinity;
- determining the baseline ambient air quality conditions for selected contaminants from published air quality data, and through modelling of the existing emissions;
- modelling of the dispersion of contaminants released from the REMASCO facilities to provide both ambient air concentrations and deposition data for the HHRA study; and,
- comparing the predictions to ambient air quality criteria and to the existing situation to define incremental changes that could be associated with the Project.

It should be noted that any new project in the province that releases emissions to the atmosphere must obtain approval from the MoE. When seeking approval the proponent must estimate the quantity of contaminants that might be released from the facility. Secondly, using air dispersion models, the proponent must determine the resulting concentrations of those contaminants in the community. These concentration estimates are then compared to the Point of Impingement [POI] criteria values set by the MoE. If the estimated concentrations are reasonable compared to the standards, the facility is normally approved, albeit in the case of waste management facilities with extensive requirements for continuous monitoring of these processes and emissions. This study thus also provides the information needed for the formal application procedure for approval of the new facilities.



## **2.1 Methodology for Analysis of Potential Environmental Effects**

While the general environmental assessment framework considers the physical, biological, social and economic environments as well as examining human health and ecological risk issues, this Report concentrates on:

- ambient air quality criteria, objectives and standards;
- facility emission limits; and,
- incremental changes in emissions likely to occur upon implementation of the Project.

These aspects should be considered in terms of a project life span and include the potential effects of Construction; Operation; and De-Commissioning of the Facilities.

Activities related to construction vary according to the various components of the Project. Adding an additional gasifier in the existing boiler house at Southshore is mainly an equipment erection and installation process with potential replacement of existing fans and air pollution control systems. This phase will be on the order of two months in duration, and has little potential to create air emissions during the construction. The Agriville installation is a replacement of existing equipment inside an existing building therefore it will be similar to the Southshore boiler addition process except for the addition of the baghouse and fuel storage silos. Being a larger installation involving the removal of existing equipment, this construction phase will be longer, possibly 6 – 8 months but it will occur indoors with limited potential for air emissions. The construction of the new power plant at Southshore will involve constructing a building and erecting additional fuel storage silos and the air pollution control equipment on site. This construction phase could take one year to complete, however after the building is constructed most of the construction takes place inside as the equipment is installed. During building construction there is a potential to generate emissions of dust and criteria air contaminants related to diesel powered equipment used during construction.

Operational emissions are addressed in terms of the seasonal requirements for heating later in this document.

De-commissioning of the gasifiers and associated equipment will involve the removal of equipment, and its replacement with alternative heating equipment. The emissions associated with these activities are anticipated to be less than the initial construction emissions.

## **2.2 Assessment Focus**

As noted earlier, the air quality issues were evaluated with respect to emissions from REMASCO operations and other existing industrial emission sources in the study area in the context of the regulatory framework. In Ontario the framework is a combination of ambient air quality criteria are identified for a wide range of contaminants and certain sources are subject to limitations on the concentration of contaminants that they can release to the atmosphere. In addition, there are provincial, federal and international considerations for greenhouse gas emissions.

## **2.3 Study Area**

For the purposes of this Report, the study area was defined to the portion of Kingsville south of County Road 18 stretching from the Kingsville Town Line in the east to County Road 29 in the west. Specific attention was paid to industrial emission sources in the area bounded by the eastern Town Line, County Road 34 to the north, Jasperson Road to the west and the lake. This latter area is approximately 13 square kilometres and within these bounds is the highest concentration of greenhouse facilities.

## **2.4 Contaminants of Concern**

For REMASCO, the provincially issued Certificate of Approval required repeated monitoring of the eight contaminants listed in Guideline A-7. Coincident with the required measurement of cadmium, lead and mercury, the concentrations of another 41 trace metals were measured on each occasion. In addition, a wide range of volatile organic compounds and semi-volatile organics compounds were measured on one occasion. This report uses the results of the May 2010 testing of the evolved gasifier fired with the latest pellets produced by the fuel processing system. These data were supplemented by emissions for 3 specific VOC and SVOC compounds developed in the 2008 testing program. These substances, vinyl chloride monomer, benzene and benzo(a)pyrene are of interest for the human health risk assessment study that is being completed as part of the environmental assessment.

One substance excluded from the list is carbon monoxide [CO]. This contaminant is monitored on a continuous basis at the facility. All test data collected at the facility shows that operating conditions the CO levels at the facility are much less than the A-7 guideline of 35 ppm. Recognizing that there is significant dilution from the stack to the point of impingement it was concluded that under no circumstance would CO levels approach the one hour limits of O.Reg. 419/05, 6,000 ug/m<sup>3</sup> (single source limit) nor the ambient criteria level of 30 ppm so the substance was excluded from the list.

For the purposes of calculating greenhouse gas emissions, carbon dioxide, methane and nitrous oxide concentrations were considered.

## 3.0 EXISTING AIR QUALITY

### 3.1 Source Apportionment and Categorisation

Local air quality will depend largely upon the emission sources in a region although in certain areas upwind sources can also influence the amount of contaminants found in the atmosphere. Many of the sources in the province have been characterized as to their emissions and the MoE has divided these sources into groups based upon types of activities. Each source group has been assigned a portion of the overall provincial emissions profile as noted in Table 1<sup>1</sup>.

Table 1 Summary of Percentage of Annual Emissions By Sector and Criteria Contaminant

Sector	Oxide of Nitrogen [NO <sub>x</sub> ]	Fine Particulate [PM <sub>2.5</sub> ]	Carbon Monoxide [CO]	Sulphur Dioxide [SO <sub>2</sub> ]
Road Vehicles	27	3	46	Combined 4
Other Transport	41	20	41	
Cement/Concrete	5	5		6
Petroleum				10
Smelters	2	10	3	45
Other Industry	8	19	3	8
Utilities	10			24
Residential		37	Combined 7	
Miscellaneous	7	6		3

The groups in Table 1 include the transportation sector: road vehicles, trains, airplanes, and ships. This sector contributes the majority of the NO<sub>x</sub> and CO released in the province. Residential sources are responsible for the highest percentage of fine particulate matter released, while smelters and utilities account for nearly 70% of the SO<sub>2</sub> emitted.

The MoE's ambient air quality reports provide the data on the levels of the criteria pollutants such as oxides of nitrogen [NO<sub>x</sub>], sulphur dioxide [SO<sub>2</sub>], fine particulate matter [PM<sub>2.5</sub>], and carbon dioxide [CO] monitored in the province. The MoE operate two full air quality monitoring stations in Windsor, and one station in Chatham where they measure ozone, O<sub>3</sub>; fine particulate matter, PM<sub>2.5</sub>; nitrogen dioxide, NO<sub>2</sub>; carbon monoxide, CO; and sulphur dioxide, SO<sub>2</sub>. The Province also conducts limited sampling for O<sub>3</sub> and PM<sub>2.5</sub> in Port Stanley. The data in this report comes from 2008 monitoring data for these stations. This is the latest data available.

The "criteria" pollutants are of particular interest because their release to the atmosphere from large sources is regulated to meet human health-based and/or environmental based criteria (science-based guidelines) which define permissible levels. The limits based on human health are called primary

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<sup>1</sup> Ministry of Environment Ontario, 2010. Air Quality in Ontario. 2008 Report. Available on the MoE website as PB7356e.pdf

standards. A secondary set of standards limit emissions to prevent environmental and property damage.

The extent to which sources contribute to local air quality levels depends upon the nature of the release. For instance, contaminants released from vehicles or residential heating systems are generally released at low elevations and do not get transported far from the sources. Smelters and fossil fuelled power plants have high stacks and their releases rise into the atmosphere and can travel long distances before returning to ground level. Thus, one could anticipate that NO<sub>x</sub> and CO levels will be higher in areas where there are higher numbers of vehicles, or low level releases. The influence of distant power plants and smelters can be seen in some areas of the province under specific atmospheric conditions. For instance power plants in the Ohio River valley are on occasion associated with poorer air quality in south western Ontario.

### 3.2 *PM<sub>2.5</sub> Levels in Study Area*

A simplistic assignment of sources for different contaminants is not possible because some contaminants change their form when they are released to the atmosphere. For instance, additional fine particulate matter [PM<sub>2.5</sub>] can be created by chemical reactions in the atmosphere and this would add to that released from stacks. The MoE suggests that the secondary formation and trans-boundary movement of fine particulate matter is responsible for the high levels of PM<sub>2.5</sub> occasionally found in some parts of the province. Table 2, fine particulate monitoring results, shows however that higher levels were found nearer the larger population centre listed in the table.

Table 2      PM<sub>2.5</sub> [ug/m<sup>3</sup>] South Western Ontario 2008 from MoE

Location	24-hr Mean	24-hr 90 <sup>th</sup> Percentile	Maximum 24 Hour	Number of Days Value > 30 ug/m <sup>3</sup>
Windsor Downtown	8.3	17	34	4
Windsor West	8.9	18	28	4
Chatham	7.3	16	32	3
Port Stanley	6.7	14	29	0

### 3.3 *Ozone Levels in Study Area*

The trans-boundary influence of contaminant movement is evident in the ozone data, (Table 3). While not directly released from combustion sources, ozone is influenced by releases of volatile organic compounds [VOC] and NO<sub>x</sub> to the atmosphere. The MoE notes that both the formation and the transport of ground-level ozone are strongly dependent on meteorological conditions. In most areas ozone levels are elevated on hot and sunny days.

Vehicular traffic is responsible for a large portion of the NO<sub>x</sub> released into the atmosphere. Oxides of nitrogen, NO<sub>x</sub>, are the collective term used to describe emissions of combustion related nitrogen compounds to the atmosphere. These emissions are defined as the sum of nitrogen dioxide [NO<sub>2</sub>] and nitric oxide [NO]. Emissions of NO<sub>x</sub> from internal combustion engines consist mainly of NO, with some NO<sub>2</sub>. When released, NO emissions convert to NO<sub>2</sub> which has adverse health effects at a lower level than NO. One of the chemicals that NO reacts with to form NO<sub>2</sub> is the ozone present in the atmosphere. Thus, vehicular emissions in the morning rush hour can result in a decrease in ambient

Table 3 Ozone [ppb] Monitoring Data South Western Ontario 2008 from MoE

Location	Annual Mean	1-hr 90 <sup>th</sup> Percentile	Maximum 1 Hour	Number of Hours Value > 80 ppb
Windsor Downtown	26.9	49	93	27
Windsor West	25.9	48	93	15
Chatham	30.9	50	94	25
Port Stanley	34.3	54	95	36

ozone levels as the NO scavenges the ozone from the atmosphere. The production of ground level ozone continues throughout the day peaking in mid-afternoon when the sunlight is at its most intense level. Hourly values show that ozone levels start to decrease after the sun sets. In areas with lower vehicular related emissions one might expect to see higher ozone levels, particularly if it originates from areas upwind of the monitoring station. This combination of influences likely explains the higher ozone levels in Chatham and Port Stanley.

### 3.4 Carbon Monoxide Levels in Study Area

Table 1 indicates that the predominant sources of CO are related to transportation. Typically CO is monitored in areas with higher vehicular traffic levels. The data in Table 4 suggests that while the annual means in Windsor and Chatham are similar, the higher concentration levels are less frequent in Chatham than in Windsor, thus the lower 90<sup>th</sup> percentile value in Chatham. Over a longer period, 24 hours, the average level is much lower in Chatham. In no case do the levels approach the ambient air quality criteria levels.

Table 4 Carbon Monoxide [ppm] South Western Ontario 2008 from MoE

Location	Annual Mean	1-hr 90 <sup>th</sup> Percentile	1-hr Maximum	Number of times 1-hr >30 ppm	8-hr Maximum	Number of times 8-hr >13 ppm
Windsor Downtown	0.19	0.35	1.29	0	1.02	0
Chatham	0.18	0.27	1.52	0	0.58	0

### 3.5 Sulphur Dioxide Levels in Study Area

Table 5 provides a summary of the sulphur dioxide data collected in 2008. SO<sub>2</sub> levels are only monitored in Windsor and Chatham. The levels in Chatham are much lower. This is likely due to higher emissions of sulphur compounds from sources in the Windsor area.

Table 5 Sulphur Dioxide [ppb] South Western Ontario 2008 from MoE

Location	Annual Mean	1-hr 90 <sup>th</sup> Percentile	1 hour Average		24 hour Average	
			Maximum	Times >250 ppb	Maximum	Times >100 ppb
Windsor Downtown	4.5	11	57	0	20	0
Windsor West	4.7	13	65	0	20	0
Chatham	2.0	5	54	0	12	0

### 3.6 Oxides of Nitrogen Levels in Study Area

Table 6 summarizes the NO<sub>2</sub> monitoring results. Ambient standards for oxides of nitrogen are based upon the NO<sub>2</sub> concentrations in the atmosphere because, as noted earlier, this compound creates more adverse health effects. The levels monitored in Windsor are much higher than those seen in Chatham. For the purposes of this report, the ppb concentration data for NO<sub>2</sub> has been converted to the form that results from modelling studies, concentration per volume [ug/m<sup>3</sup>] in the lower half of the table.

Table 6 Nitrogen Dioxide NO<sub>2</sub> [ppb] South Western Ontario 2008 from MoE

Location	Annual Mean	1-hr 90 <sup>th</sup> Percentile	1 hour Average		24 hour Average	
			Maximum	Times >200 ppb	Maximum	Times >100 ppb
Windsor Downtown	15.2	28	64	0	39	0
Windsor West	16.2	28	66	0	36	0
Chatham	7.0	14	42	0	24	0
	[ug/m <sup>3</sup> ]	[ug/m <sup>3</sup> ]	[ug/m <sup>3</sup> ]		[ug/m <sup>3</sup> ]	
Windsor Downtown	29.0	53	122		74	
Windsor West	30.9	53	126		69	
Chatham	13.4	27	80		46	

### **3.7 *Ambient Air Quality Criteria***

The monitoring data discussed above can be judged against a number of criteria or standards. While the Canada Wide Standards for Ozone and PM<sub>2.5</sub> have already been presented, a number of other criteria are summarized in Table 7. In all cases these criteria are set to protect the general community.

The ambient air contaminant levels shown in the preceding tables would generally be classified as low compared to the standards. It should be noted that monitoring has historically been conducted in areas where there are known to be higher levels of air contaminants. This approach seeks to ensure that levels do not exceed the appropriate standards, while identifying areas of concern and allowing regulators to target facilities that contribute to the high levels. The MoE note that, for the most part, provincial levels of criteria contaminants have been decreasing as a result of the lowering of emission standards for vehicles and other sources.

The ambient data from the MoE's monitoring stations provide a benchmark of levels in south western Ontario. They are not specific to Kingsville, but they can at least serve as a basis for comparison of the effects of operating boiler facilities at greenhouses in the area.

Table 7 Ambient Air Quality Objectives

<b>NO<sub>x</sub> [ug/m<sup>3</sup>]</b>	<b>Level</b>	<b>1-Hour</b>	<b>24-Hour</b>	<b>Annual</b>
National	Maximum Desirable	-	-	60
	Maximum Acceptable	400	200	100
	Maximum Tolerable	1100	300	-
Provincial		400 [200 ppb]	200 [100 ppb]	
World Health Organization	Proposed Guideline	200		
<b>CO [mg/m<sup>3</sup>]</b>	<b>Level</b>	<b>1-Hour</b>	<b>8-Hour</b>	
National	Maximum Desirable	15	6	
	Maximum Acceptable	35	15	
	Maximum Tolerable	-	20	
Provincial		36 [30 ppm]	16 [13 ppm]	
World Health Organization	Proposed Guideline	30	10	
<b>Particulate Matter [ug/m<sup>3</sup>]</b>	<b>Level</b>		<b>24-Hour</b>	<b>Annual</b>
National [TSP total]	Maximum Desirable		-	
	Maximum Acceptable		120	
	Maximum Tolerable		400	
CWS PM2.5	National Target		30	
Provincial [SPM <44 um]	AAQC		120	60
	PM10 Target Interim		50	
<b>Ozone [ppb]</b>	<b>Level</b>	<b>1-Hour</b>	<b>24-Hour</b>	<b>Annual</b>
National	Maximum Desirable	100	30	
	Maximum Acceptable	100	50	30
			4th Highest 8-Hour Avg.	
CWS Ozone National Target			65	
Provincial CWS Adopted			65	



## 4.0 Emission Inventory

### 4.1 REMASCO Facility Description

Every greenhouse in the Kingsville area has a boiler plant to supply heat to the facility. The boiler plants to be built by REMASCO are no different. Essentially the boilers are housed in structures that are separated from the greenhouse areas. Like the greenhouses they have concrete floors. Unlike the greenhouses, the structures housing the boilers are not heated, are not enclosed with glass and, generally have a lower roof height than the peak of the surrounding greenhouses. The fuel used in the other boiler plants can vary from wood, to coal, to bunker oil but natural gas is the preferred fuel if the price of the gas is appropriate.

Other than gas fired boilers, all other facilities must provide fuel storage facilities on site. Coal piles, wood piles, or oil tanks are typically utilized. Wood may be stored outside the building typically in open piles, or in areas surrounded by berms to contain the materials. Coal is typically stored in storage bins or silos. The REMASCO facilities utilize vertical fuel storage silos.

The flue gases from all boilers are exhausted through stacks to the atmosphere. The configuration of these stacks varies by facility, however, conventional boiler plants have no air pollution control facilities to clean the gas being exhausted from the boilers. The REMASCO facilities will be equipped with systems that will inject reagents into the gas stream to assist with the control and removal of various contaminants and fabric filter particulate control devices to remove contaminants and reaction products from the gases before they are released to the atmosphere through stacks.

This project description outlines:

- the activities that will be required to install the gasifiers, boilers, steam turbine, and air pollution control systems at the various sites;
- the nature of the gasifiers, their operation, emission control systems and anticipated releases to the atmosphere during the operation; and,
- the steps that would be taken in the future should the gasifiers need to be retired from service.

Included are descriptions of the buildings that will house the equipment, and their construction.

#### 4.1.1 Site Locations and Equipment Overview

The proponent will be seeking approval for gasifier installations at two greenhouse sites in the Kingsville area:

- Southshore, 1746 Seacliff Drive E, Kingsville, N9Y 2M6; and,
- Agriville, 1600 Kratz Road, Kingsville, N9Y 0A1.

The Southshore facility and adjacent greenhouses (Mucci farms and the 10 acres on the south side of Seaciff Dr.) currently cover 52 acres. Plans are in place to expand these facilities by 60 acres before the end of 2012. The Southshore greenhouse is currently heated by two REMASCO gasifiers with a total installed capacity of 800 boiler horsepower and a combination of natural gas and oil fired boilers. When expanded to 112 acres the greenhouse will require approximately 30 boiler HP of REMASCO gasification capacity per acre to meet the peak demand, even with an expanded heat storage system similar to the current facility. The near constant electrical requirement of the greenhouses is approximately 10 kW per acre so the greenhouses at Southshore will require 1.2 MWe. The gasifiers consume approximately 100 kWe of electricity per boiler and 7 boilers will require 0.7 MWe. In the co-generation mode three 500 HP high pressure boilers/gasifiers will be required to provide the electrical needs of the complex, 2 MWe. A total of four high pressure units will be installed in a new 30 m by 60 m building to be constructed north of the existing REMASCO boiler house. The fourth boiler will provide back-up to the high pressure steam supply system, thereby allowing a unit to be taken off line without reducing the amount of power being produced. The fourth boiler will also provide thermal energy to meet the peak heating needs of the facility. The exhaust from pairs of boilers in the new building will be combined and exhausted through fabric filter particulate control device, an induced draft fan, and a stack. Each fabric filter installation measuring approximately 5.5 m in diameter will be installed outside the building. The two fabric filters and two stacks will be constructed adjacent to the new boiler building. The existing REMASCO boiler plant will accommodate an additional 500 HP low pressure boiler without any need to change the building footprint. This installation will bring the total capacity of the lower pressure gasifiers/boilers on site to 1,300 HP. Expansion of the boiler capacity in the existing REMASCO boiler house will require that the fabric filter in that facility be upgraded to meet the needs of the boilers and the new unit will be similar in size to those at the new boiler house. The two existing fuel storage silos on the site will be augmented by two new silos of similar size located next to the existing ones. The storage silos will be interconnected to serve all 7 gasifiers installed on the site.

At the Agriville site, greenhouses currently cover 40 acres. Plans are in place to expand these facilities by 20 acres before the end of 2012. The Agriville facility is currently heated by wood fired boilers that deliver 1,200 HP at peak load. These are connected to the hot water heat storage system. The wood fired boilers require high maintenance efforts. Consuming wood to heat the greenhouses has several drawbacks. Wood supplies are limited, and the volume of wood required means that an outside storage area of 0.6 acres as well as inside storage area that measures 50 m by 30 m is required to contain and handle the fuel. The need to store wood outside precludes approximately 5 acres of land on the site from being converted to greenhouse thus lowering the overall efficiency of the site. The expanded size of the greenhouses will bring to total projected thermal heating needs for the site to 1,800 HP. To reduce the area required for fuel storage, lower maintenance costs and raise performance efficiencies, this heating requirement will be met by four 500 HP low pressure REMASCO gasifiers/boilers matched to 2 air pollution control trains and stacks similar to those discussed above. The current plan is to install these gasifiers/boilers in the existing buildings that house the wood boilers and the inside wood chip handling equipment. Pellets could be stored in 4 new silos installed adjacent to the boiler building or in the existing wood storage building, depending upon development plans.

#### **4.1.2 Construction Activities and Emissions**

##### **Agriville**

The space necessary to house the gasifiers and boilers to be installed at the Agriville site is currently erected. Modifications will be required inside the building to accommodate the new gasifiers/boilers, fuel handling and ash handling equipment. The new air pollution control systems and the new fuel storage silos will need to be erected outside the facility. Construction outside the buildings will require minor excavation to install the footing for the equipment and concrete pads below the silos should they be required, and for the fabric filters baghouses and the stacks.

The areas where the pads will be constructed are currently used as traffic routes and outside storage areas for the Agriville operation. The fabric filters will require two pads each measuring approximately 7 m square. The silos are approximately 16 m in diameter and 17 m high. A truck unloading area, suitable for handling a tractor trailer combination and sheltering the unloading operation from the elements will be constructed along side the silos. Overall the fuel storage silo pad will measure approximately 80 m by 20 m with the adjacent truck unloading area being an additional 8 m wide and extending the length of the silo pad.

##### **Southshore**

The existing REMASCO gasifier/boiler house measures 34 m by 31 m and has sufficient space to house 3 gasifier/boiler units, the two existing 400 hp boilers and a new 500 hp low pressure boiler. The existing installation includes two existing baghouses and a stack that takes the flow from the two baghouses. There are two existing fuel storage silos with a covered truck unloading area. No work will be required on the existing building, however the existing baghouses will be supplemented with a third, larger baghouse which will be sized to accommodate 120% of the anticipated flow from the 500 hp third unit. The new baghouse will be over-sized to relief the loads on the two existing baghouses which currently restrict the capacity the existing gasifiers. The three baghouses will manage the flow from the boilers when they are producing a total of 1300 hp. A new stack will be erected to accommodate the expanded flow. These elements will be located close to where the existing systems are located.

A new REMASCO boiler building on the Southshore site will have to be constructed to house four 500 hp high pressure gasifier/boiler units and the power island that will consist of steam turbine/generator combination. The new building will be similar in construction to the existing REMASCO building, a steel frame construction with steel siding built on a concrete pad with a minimal slope on the roof. Construction will involve excavating to accommodate footings for the building walls and a poured concrete floor slab that will support all the equipment. The turbine/generator will be built on a pedestal that will be isolated from the rest of the building. After the slab has cured the columns are installed, the purlins are added to the space between the columns and the siding is installed. The roof is installed in a similar manner with the joists being installed on the top of the columns, the perlines added and the roof deck fastened to the structure. Inside the building, the gasifier/boilers, the power island and the control room will be separated by concrete block walls.

The new boiler building will be equipped with a shower/washroom for the staff and water will be directed to the sanitary sewers that serve the site. Rainwater collected from the roof of the building will be diverted to the existing rainwater handling system operating on the site.

Outside the building, two new fabric filter baghouses and stacks will be constructed. Each will serve a pair of the gasifiers. They will be located adjacent to the boiler end of the facility on the west side of the building, relatively close to each other. Fuel for the new boilers will be stored in silos similar to those currently located on site. It is anticipated that the new silos will be located in line with the existing silos on the east side of those silos so the various silos can be loaded from one unloading system. As with the silos at Agriville, a concrete pad will be built to support the silos and their contents. The pad for the silos will be approximately 35 m by 18 m in size.

Like all other slabs and footings, the construction will involve some excavation to install foundations followed by pouring equipment supports and the floor slab.

### **4.1.3 Equipment Descriptions**

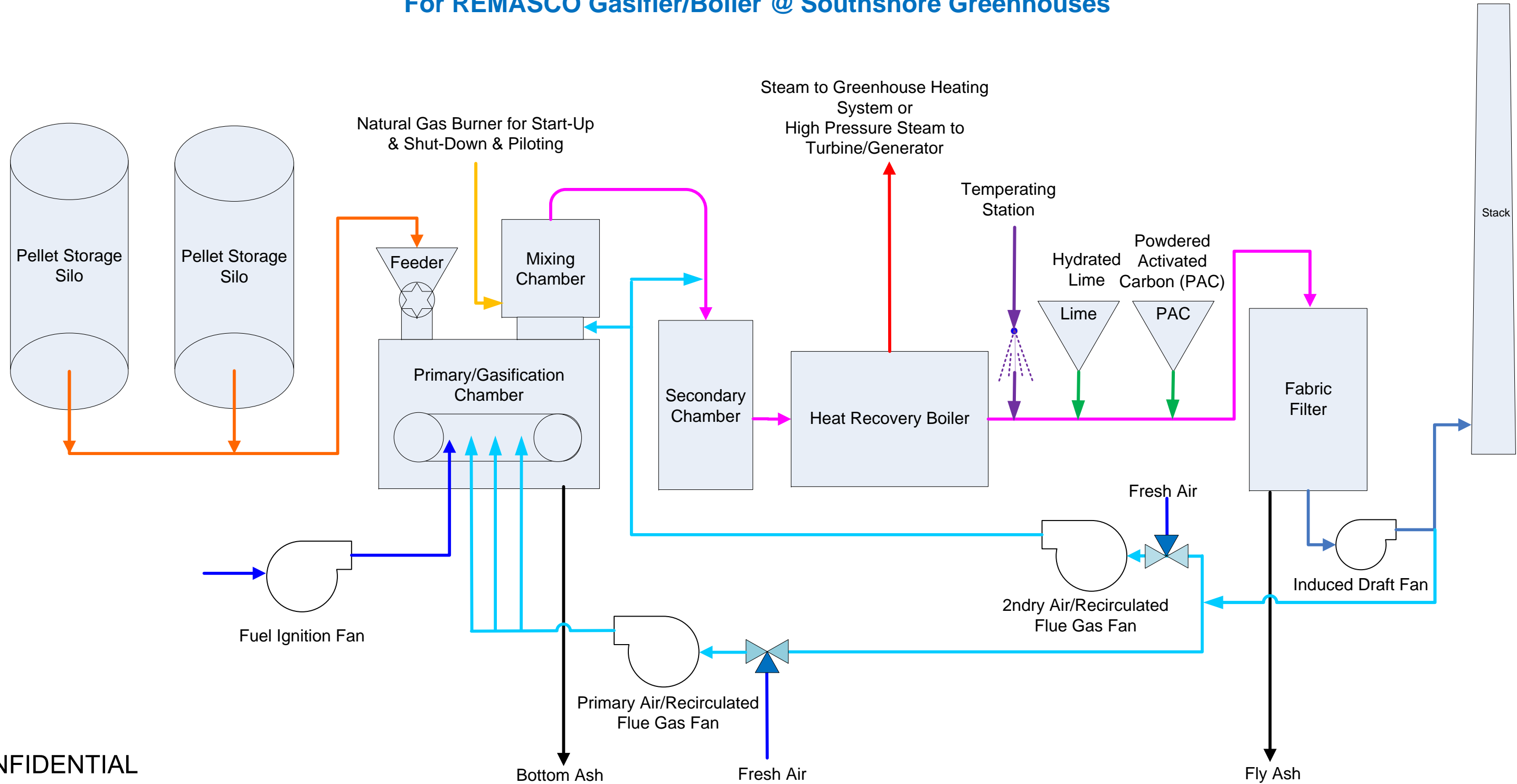
The preceding sections suggest that the equipment list at the various sites will be very similar. The general process flow diagram for a single gasifier is shown in Figure 4-1. The components included in the equipment installed at any site can be divided by function:

1. Fuel Storage and Handling;
2. Gasifiers and Boilers;
3. Residue Handling Systems;
4. Air Pollution Control Systems;
5. Control and Monitoring Equipment; and,
6. Steam Turbine and Electricity Generator.

The seven gasifier/boiler units situated at Southshore are virtually identical with the exception that the two existing gasifiers are smaller, 400 HP versus the 500 HP units that will be installed in the future. The four boilers in the power house will be high pressure steam generators with superheaters, as opposed to the low pressure steam systems installed at the other locations. The Air Pollution Control systems will be similar, with the two systems at Agriville and the two systems associated with the power house being identical. Of the three baghouses that will eventually be installed for the existing Southshore boiler house one will be the same design as those at the power house and Agriville. The two APC existing units are smaller as they were each sized for a 400hp gasifier. The power island, steam turbine and electricity generator will be unique to the power plant portion of the installation, and because these components add more complexity to the facilities, the controls associated with the turbine generator will be unique compared to the other boiler houses.

The individual components of the systems are described below with differences between the installations being identified as appropriate. This approach provides the reader with an

Figure 1 PROCESS FLOW DIAGRAM  
For REMASCO Gasifier/Boiler @ Southshore Greenhouses



CONFIDENTIAL

COLOUR KEY

- |                                |                       |                                |
|--------------------------------|-----------------------|--------------------------------|
| Pellet Storage and Feed System | Gasifier Exhaust Flow | Air Pollution Control Reagents |
| Fresh Air Supply               | Cleaned Exhaust Flow  | Water                          |
| Recirculated Flue Gas          | Residue Streams       | Steam                          |
|                                |                       | Natural Gas                    |

understanding of how the components are employed in the system, but avoids the redundancy of describing all the components in each of the three installations separately.

### **Fuel Storage and Handling**

Pellets shipped to REMASCO are transported in walking floor trailers. At site the trailer is unloaded into a storage silos adjacent to the boiler house. As noted elsewhere there are two silos associated with the existing REMASCO boiler house. Two more silos will be added at the Southshore site and 4 silos will be installed at the Agriville site. These silos are typical of the type of equipment used to store various materials at agricultural facilities.

Each silo holds approximately 1,200 Mg of pellets (48 ft diameter x 54 ft peak x 35 lbs/ft<sup>3</sup>). Upon arrival at site, the trailer will be driven over a covered unloading pit where pellets will be discharged. Pellets will be transported from the pit to the silos using a 110 ft high bucket elevator. At the head of the bucket elevator pellets can be diverted to the appropriate storage silo. Materials will move through the silos on a first in first out basis suggesting that one silo will be emptied as the other is being filled and when the second silo is full, fresh pellets will be diverted to the partially empty silo. Each silo is capable of holding sufficient pellets for approximately 48 gasifier days of operation at full load.

The existing pellet transport system transfers pellets from the bottom of the active silo to an intermediate day hopper mounted near the roof of the building. This feeds the fuel metering bin hoppers on top of each gasifier. The existing roof bin stores approximately 8 Mg of pellets, thereby requiring a refill every 4-6 hours to supply two 400 hp gasifiers. On start up or shutdown of a unit the feed system can operate with the roof bin empty and its bottom slide-gate open, thereby allowing different fuels to be fed into different units simultaneously. In this case, each metering bin calls for its fuel directly from the source fuel bin and the bucket elevator operates each time a metering bin is calling for fuel. The control of this system is governed by level controls on the metering hoppers. The metering bin hoppers regulate the feed of pellets to the gasifier. Each metering bin hopper holds approximately 1 m<sup>3</sup> or 500 kg of pellets. The roof bin hopper accepts approximately 7 m<sup>3</sup> of fuel thus buffering the material flow from the storage silos to the gasifier metering bins. The roof bin minimizes the wear and tear on the bucket elevator because it does not have to start and stop frequently. These systems are totally enclosed and no air emissions are associated with the transport of fuel.

The metering bins are equipped with a rotary airlock at the bottom of the bin. This rotary air lock transfers fuel from the bottom of the metering bin and drops it directly onto the chain grate of the gasifier. The speed of the rotary airlock is controlled and synchronized with the speed of the grate.

### **Solid Fuel Gasifier/Boiler Installation**

The REMASCO solid fuel systems are basically biomass gasifiers that are connected to a heat recovery boiler that produces hot water or steam at a pressure required for downstream equipment. Low pressure steam can be used for process heating, or high pressure steam can be used to drive a steam turbine to generate electricity. The principal source of fuel for the gasifier will be ENERPAX pellets,



although waste wood pellets or wood chips are used during start-up and shut down of the units and can be substituted for the ENERPAX pellets if necessary.

A REMASCO Commercial Gasifier/Boiler unit will be rated at 500 HP output capacity, or 24 GJ/h input capacity. The gasifier is designed with systems to supply fuel to the bed, control how that fuel is processed and how the residues of ash are removed. Downstream of the gasifier, a boiler is used for heat recovery. Two 400 HP variants of these systems are currently installed in the REMASCO building at Southshore.

### **Gasification System**

The gasifier is a refractory lined chamber with a moving grate installed in the lower portion of the chamber. The cast alloy chain grate rotates around the underfired air plenum. A water-cooled, 24" drive pulley driven by a variable speed controlled electric motor is mounted at the ash discharge end of the gasifier to move the grate at the appropriate speed.

As noted in the previous section, fuel is added to the grate from the metering bin. Once the fuel is deposited on the moving grate, it takes approximately 1.5 to 2 hours to travel through the unit. The grate does not tumble or turn the fuel bed, rather the fluidising air flow stirs the material exposing fresh surfaces. At the feed end of the grate, fuel is added at a rate that maintains an even fuel distribution. The thickness of the bed decreases as the materials move towards the discharge end of the grate. At the end of the grate, the bed is fully consumed, containing minimal unburned material.

The ash created on the grate drops into a water-cooled ash auger sump at the end of the grate. The ash auger then discharges the ash through a rotary airlock that provides the vacuum seal between the gasification process and atmosphere. The hot ash is deposited into a covered drag chain which contains strategically placed spray nozzles to cool the ash and minimize dust generation. The ash drag conveys the ash to a 20 m<sup>3</sup> lugger bin for haulage to disposal. Large ash particles are discharged off the end of the conveyor, while fine ash particles, siftings, pass through the chain and are pushed along the gasifier floor into the ash sump with a light drag chain conveyor.

A combination of recirculated flue gas and fresh combustion air is blown up through the grate and fuel bed. The grate system has been designed with four independently controlled combustion zones. The first zone utilizes fresh air only while a combination of recirculated flue gas and fresh air is supplied to the balance of the zones. The mix of fresh and recirculated flue gas controls the amount of oxygen in the underfired combustion air and serves to control the temperature within the gasification chamber.

The gases produced in the gasifier chamber exit through the Mixing Chamber and Hot Gas Ducting (HGD) to the secondary combustion chamber. Secondary and tertiary combustion air is injected into this region through nozzles tangentially mounted on the ducts. This air is a mix of fresh air and recirculated flue gas to control the temperature and amount of oxides of nitrogen produced in the system. Temperatures in the HGD mid-section and Secondary Chamber exhaust are measured as a control parameter for fresh air addition.

Gases entering the secondary chamber are in excess of 1,000°C and remain in the secondary chamber for a minimum of 1 second prior to exiting the chamber. Gas velocity is reduced in the secondary chamber to allow large particulate matter to settle to the floor of the chamber.

### **Heat Recovery**

The basic single pass low pressure steam boilers installed for heat recovery at Agriville and Southshore are manufactured by the Johnson Boiler Co. The boilers are positioned in a way that allows quick and easy access to the tubes for periodic cleaning. A positive on-line cleaning system is installed in each boiler. This system is used to remove any ash building up on the boiler tubes providing better operating conditions and reduced contaminant generation. The gas exhaust temperature from a clean boiler will be in the range of 325 - 350°F and will increase by approximately 50 °F as the boiler tubes begin to foul.

Heat produced by the boiler is either sent directly to the greenhouse or to a heat exchanger to heat water to be stored in large, outdoor hot water storage tanks currently installed on the properties.

The high pressure steam boilers required for the power plant on the Southshore property will be of water tube construction complete with a superheater and economizer section for maximum recovery of energy. The gas exhaust temperature from the boiler will be in the range of 325-350°F, but to ensure that the temperatures do not exceed the operating range of the fabric filter baghouses, water is added to the flue gas stream ahead of the APC section. Steam produced by the boilers will be sent to the steam turbine/generator set for conversion to electricity.

### **Steam Turbine and Generator (Power Island)**

The power island will consist of a 50,000 lb/hr, 3 stage, 450 psi back-pressure steam turbine coupled to a 4160V, 3 phase synchronous generator. Currently the capacity of the generator will be limited to 1.8 MWe. The generator will be connected to at least two of the three greenhouse facilities, as a separate source of supply to each of their existing backup generator systems. The transfer from grid power to island power for each of the three services will be manual. This means that a brief power outage will occur during the transfer from one source of supply to another.

The turbine is referred to as a “back-pressure” unit because, unlike installations where electricity generation is the major consideration and the turbine extracts the maximum energy from the steam by discharging to a vacuum, the steam exiting the turbine will only be brought down to 15psig. To utilize the balance of the energy in the steam, a desuperheating/pressure-reducing station will allow any unused steam to be sent directly to greenhouse heating, either through a heat exchanger or for direct use as low pressure steam.

Of the 1.8 MWe generated in the power plant, the REMASCO gasifier/boiler loads will total approximately 600kW and the greenhouses will consume approximately 10kW/acre or 1.1mW for 110 acres.



### **Air Emissions Abatement System**

The exhaust from a pair of boilers passes to the emission control system which includes the recirculated flue gas systems and the induced draft fan that discharges gases to the stack after they go through the fabric filters. Several methods are used to control emissions from the gasifiers. Aside from good combustion control measures ensuring high organic compound destruction rates, and the use of flue gas recirculation to reduce the production of oxides of nitrogen, the main control measure is introducing various sorbents into the flue gas stream and removing the resulting reaction products in particulate control devices.

To prevent equipment deterioration and optimize the operation of the gasifier/boiler system, the recirculated flue gas is treated and polished to the same extent as the final effluent, before being mixed with fresh air to achieve the desired recirculated gas quality and before reintroduction into the gasification system.

In the existing facility, provisions have been made to inject lime and powdered activated carbon [PAC] into the duct that carries the gas stream to the fabric filter. Both reagents are injected using separate small, volumetric metering screw. The lime feed rate can be adjusted to achieve the desired outlet concentrations of HCl and SO<sub>2</sub>. PAC injection rates are typically on the order of 1 lb/hr per operating unit, sufficient to reduce mercury and PCDD/F emissions to well below the regulatory levels. Typically duct sorbent injection systems such as the one that is currently used have a higher reagent injection rate than would be required when better mixing of the reagent with the gas stream can be accomplished and when longer reaction times are available. To overcome these limitations, the new systems will incorporate a spray dry absorber [SDA] ahead of the baghouse.

The spray dry absorber will utilize a lime slurry to deliver the reagent to the gas stream for removal of HCl and other acid gases and PAC to remove PCDD/F and mercury. Since a slurry is used for injection, sufficient time must be allowed for the moisture in the slurry to evaporate into the gas stream. It is anticipated that a residence time on the order of 12 seconds is required at the REMASCO sites. Essentially, the spray dry absorber is an enlarged section of duct where the gas velocity can be slowed and any particulate matter that is not transported with the gas stream can settle. The SDA is connected to the baghouse where the majority of the reaction products are removed.

The SDA/baghouses used at the REMASCO sites will be identical in most cases, although a slightly larger system will be required for control of the 1300 HP of boilers installed in the existing REMASCO building on the Southshore site. The fabric filters will be modular, walk-in plenum style units designed to provide 3,300 ft<sup>2</sup> of filter area. With a design flow of 10,000 cfm this equates to an air to cloth ratio of 3.01:1. The filters will be standard fibreglas bags. A pulse air cleaning system is used to periodically clean the bags. The resulting APC residue, consisting mainly of spent lime and ash is expelled into an air-tight 2 m<sup>3</sup> or larger bin.

Gases will exit each baghouse through a 56 kW induced draft fan and expelled through a 0.81 m diameter stack. The stack associated with the existing REMASCO boiler house will be 0.91 m

diameter to maintain a similar exhaust gas flow rate from the larger system. The speed of the ID fan will be varied to control draft within the primary gasification chamber.

### **Controls, Data Acquisition & Continuous Emission Monitoring Systems**

The process control and data acquisition system for the REMASCO commercial test system is an ethernet capable, Siemens S7-300 process controller (PLC) complete with a PC based supervisory control and data acquisition system. This system is capable of monitoring and providing long term storage for all discrete and analog process parameters measured and controlled by the PLC. Such parameters will include major equipment on/off status, all temperatures, pressures, flows and all required Continuous Emission Monitoring parameters. Two oxygen measurements are used for process control purposes. These sensors will be installed as permanent instruments complete with sampling probes, sample conditioning systems and daily calibration capability. Any additional continuous gas measurements that may be deemed necessary for processing the Enerpax pellets will be installed as required.

The control system, including the PLC and SCADA PC will be protected from power surges and backouts using an uninterruptible power supply. In addition, the South Shore Greenhouses Inc. 600VAC emergency power system will protect the entire REMASCO pilot facility from local electrical grid power failures.

### **Start-up and Shutdown Operations and Upsets**

Aside from the operating flexibility that allows the REMASCO gasifier to operate at high combustion efficiency across a broader firing range than a typical mass burn waste incinerator, there are other benefits related to the design of these units. Being smaller than conventional mass burn units, it is easier to control the start up and shut down of the system, thus minimizing the potential for increased emissions during these operational phases.

The secondary chamber of the gasifier is raised to 1,000°C before any ENERPAX pellets are introduced into the gasifier. This is accomplished by operating a natural gas burner that fires into the mixing chamber. This raises the temperature in the zones downstream of the mixing chamber: secondary chamber, heat recovery boiler, and fabric filter. When the secondary chamber reaches the appropriate temperature, the ENERPAX pellets start to be introduced into the gasifier. They are ignited by a second gas burner.

As noted in the equipment descriptions, the grate in the gasifier has multiple zones where air is added to the system. Pellets are deposited and ignited on the feed end of the grate and are moved towards the outlet end of the gasifier as they sit on the grate. The air added under the grate provides agitation of the pellets, but it is only introduced when the grate in that zone is covered with pellets.

The gasification of the pellets raises the operating temperatures in the system even further, so that the firing rate of the natural gas burner can be reduced as the quantity of pellets on the hearth increases. The firing rate of the gas burner in the mixing chamber is adjusted to maintain the appropriate

secondary temperature. When the pellets on the bed maintain the secondary temperature without the help of the burner, the burner can be shutdown.

All gases leaving the secondary chamber pass through the boiler, and the fabric filter, with some of this flow being returned to the system and the rest being discharged to the atmosphere. There are no bypasses around the system and any particulate matter released from the combustion system is trapped in the fabric filter. Lower flow rates during start-up ensure that the fabric filter system operates at optimal levels at all times.

When it comes time to shut the gasifier down, the process is repeated in the reverse order. The feed to the gasifier is stopped and the first zone of the grate is slowly uncovered as the pellets are transported towards the discharge end of the chamber. As the temperature drops due to lowering input the mixing chamber burner comes on to maintain the appropriate temperature. When the majority of the first section of the grate is emptied, the air to that section is turned off. The grate continues to move pellets down the length of the gasifier, and since much of the pellet is consumed on the early section of the grate, the burner firing rate must increase to maintain temperature. When the 3<sup>rd</sup> zone is empty the air to that section is reduced, and the burner ramps up even higher. The burner maintains the operating temperature in the secondary chamber until all the ash is discharged from the grate. At that time the burner can be shut off and air continues to be introduced to cool the components. When the temperature drops to the appropriate point, the fans can be shut off and the gasifier doors are opened to allow further cooling.

The steady increase in firing rate and decline as the waste feed is shut off reduces rapid transitions in the system, and limits startup and shutdown emissions. Operating experience suggests that the grate can be fully charged with pellets within about 2 hours of introducing the first pellets. Shutdown is typically accomplished within 1 hour from the cessation of pellet feed. This operation is unlike the typical mass burn incinerator which is much larger. The size of these units makes it difficult to achieve reasonable operating temperatures before waste is added to the grate. This contributes to potential start up and shut down emissions from such units, but these conditions can be circumvented in the REMASCO gasifier.

The other potential upset scenario is a failure in the Air Pollution Control system. The performance of baghouses, their ability to remove particulate matter from the gas stream, does deteriorate over time, typically between 24 and 36 months. Single bags may fail when a hole is ripped in them due to cleaning operations, or a failure in the material. Such failures can be identified by a rapid increase in opacity in the stack gases. An opacity monitor is installed in each stack for the purposes of identifying sudden failures, or the long term degradation in performance. When the base opacity reading slowly increases after each successive cleaning it is a fairly good indicator that the bags need replacing. A sudden increase indicates a bag failure, and the system can be taken into shutdown so the offending bag can be identified and blocked off. If 10% of the bags in the fabric filter are blocked off the operator should consider scheduling an outage to replace all the bags.

## **4.2 Facility Emissions**

### **4.2.1 Stack Sampling Results**

The data used to describe the stack emissions from the REMASCO facilities was obtained from the results of the stack tests completed at the Southshore facility as part of the requirements of the Pilot Facility Certificate of Approval. Typically stack sampling requires 3 tests each lasting 2 to 4 hours. For most sources, these tests would be conducted over a 2-3 day period when the facility was operating at nominal production rates. Such sampling reports the stack gas flow and emission data from the test period. As such both the emission concentration and the emission rate can be determined for contaminants of interest.

Table 8 presents the emission data values for metallic species emissions<sup>2</sup> based upon the tests conducted while the gasifier was processed the most recent pellets manufactured at the DONGARA Pellet Plant. The results were taken from the report submitted to the MoE as part of the requirements in the Approval. The data represent the operation of one 400 HP boiler at 100% load.

Table 9 presents the emission data for dioxins and furans [PCDD/F] emissions bases upon the same 2010 testing program.

Table 10 presents the criteria air contaminants emission data (NO<sub>x</sub>; SO<sub>2</sub>) and Chlorine and Hydrogen Chloride reported in the 2010 testing report. This table also contains emission data for total suspended particulate matter from the 2009 testing program<sup>3</sup> because this parameter was not quantified in the 2010 testing. In addition, three organic species, vinyl chloride, benzene and benzo(a)pyrene are listed. These contaminants were considered in the HHRA and the only emissions data available was from the 2008<sup>4</sup> test report.

In all cases the data in the three tables referenced in the previous paragraphs represent the average of the emission test data for the April 2010 test series. Testing was conducted according to a pre-test plan approved by the MoE prior to the field work, and the sampling was observed by staff of the MoE to ensure that it was done in a manner consistent with the pre-test plan. When using test data it is common practice to average the emission test results to determine if they comply with emission criteria such as those outlined in Guideline A-7<sup>5</sup>. The same procedure was used to define emission rates for this study since experience suggests that for full scale operating facilities the results of year over year testing lie within a relatively narrow range that is reasonably approximated by the average of the test series.

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<sup>2</sup> AMEC, 2010. 2010 COMPLIANCE SOURCE TESTING SOLID WASTE INCINERATOR UNIT 2 KINGSVILLE, ONTARIO A report prepared by AMEC Earth and Environmental Report # TC101705.2000 June 21, 2010

<sup>3</sup> AMEC, 2009. 2009 COMPLIANCE SOURCE TESTING SOLID WASTE INCINERATOR UNITS 1&2 KINGSVILLE, ONTARIO A report prepared by AMEC Earth and Environmental Report # TC91712 July 28, 2009

<sup>4</sup> AMEC, 2008. 2008 COMPLIANCE SOURCE TESTING SOLID WASTE INCINERATOR KINGSVILLE, ONTARIO A report prepared by AMEC Earth and Environmental Report # TC81727, October 27 2008

<sup>5</sup> MoE, 2010. GUIDELINE A-7, Air Pollution Control, Design and Operation Guidelines for Municipal Waste Thermal Treatment Facilities. Ontario Ministry of the Environmental, October.

Table 8

Table 8 Metals Species Emission Testing Results REMASCO 2010

METAL SPECIES	Concentration					Emission Rate
Compound	Met 7	Met 8	Met 9	Average	Average Corrected	[400 lb/hr]
	[ug/Rm3]	[ug/Rm3]	[ug/Rm3]	[ug/Rm3]	[ug/Rm3 @ 11% O2]	[g/s]
Aluminum	12.51	10.33	11.31	11.38	8.6	2.27E-05
Antimony	0.71	0.40	0.64	0.58	0.4	1.08E-06
Arsenic	0.37	0.40	0.39	0.38	0.3	8.90E-07
Barium	1.47	1.56	1.70	1.58	1.2	3.07E-06
Beryllium	0.07	0.08	0.08	0.08	0.1	1.54E-07
Bismuth	0.15	0.11	0.08	0.11	0.1	2.22E-07
Boron	292.86	326.71	321.94	313.84	237.8	6.30E-04
Cadmium	1.23	0.42	0.62	0.76	0.6	1.52E-06
Calcium	136.87	134.08	136.18	135.71	102.8	2.73E-04
Chromium	13.25	15.05	20.17	16.15	12.2	3.24E-05
Cobalt	0.49	0.53	0.51	0.51	0.4	1.01E-06
Copper	5.86	5.17	5.96	5.66	4.3	1.14E-05
Germanium	0.74	0.79	0.77	0.77	0.6	1.54E-06
Gold	0.37	0.40	0.39	0.38	0.3	7.70E-07
Indium	0.37	0.40	0.39	0.38	0.3	7.70E-07
Iridium	0.37	0.40	0.39	0.38	0.3	7.70E-07
Iron	184.20	228.67	192.45	201.77	152.9	4.04E-04
Lead	1.69	1.51	1.75	1.65	1.3	3.30E-06
Magnesium	13.49	14.04	15.16	14.23	10.8	2.84E-05
Manganese	8.76	7.45	7.09	7.76	5.9	1.56E-05
Mercury	0.31	0.19	0.18	0.23	0.2	4.11E-06
Molybdenum	0.86	1.32	1.59	1.26	1.0	2.51E-06
Nickel	31.30	29.33	29.93	30.19	22.9	6.12E-05
Palladium	0.07	0.08	0.08	0.08	0.1	1.54E-07
Phosphorus	4.49	5.33	5.55	5.12	3.9	1.02E-05
Platinum	0.37	0.40	0.39	0.38	0.3	7.70E-07
Potassium	20.60	18.55	19.27	19.47	14.8	3.90E-05
Rhodium	0.37	0.40	0.39	0.38	0.3	7.70E-07
Rubidium	0.74	0.79	0.77	0.77	0.6	1.54E-06
Selenium	1.08	0.56	0.39	0.67	0.5	1.36E-06
Silicon	32.13	40.01	34.17	35.44	26.8	7.10E-05
Silver	4.73	2.15	2.18	3.02	2.3	6.13E-06
Sodium	189.11	191.57	158.02	179.57	136.0	3.61E-04
Strontium	0.69	1.19	35.46	12.45	9.4	1.96E-06
Sulphur	16462	13832	12033	14109	10690	2.84E-02
Tellurium	0.49	0.48	0.51	0.49	0.4	9.89E-07
Thallium	0.37	0.40	0.39	0.38	0.3	7.70E-07
Tin	35.07	34.53	35.46	35.02	26.5	7.04E-05
Titanium	0.61	0.61	0.77	0.66	0.5	1.32E-06
Tungsten	0.37	0.40	1.13	0.63	0.5	1.27E-06
Uranium	0.37	0.40	0.39	0.38	0.3	7.70E-07
Vanadium	0.07	0.08	0.10	0.09	0.1	1.63E-07
Zinc	13.64	11.18	11.69	12.17	9.2	2.45E-05
Zirconium	0.20	0.13	0.15	0.16	0.1	3.18E-07

Table 9

## Dioxin and Furan Emission Testing Results REMASCO 2010

PCDD/F	ORG 7 [pg]	ORG-7 TEQ [pg TEQ]	ORG 8 [pg]	ORG-8 TEQ [pg TEQ]	ORG 9 [pg]	ORG-9 TEQ [pg TEQ]	Average
2378 TCDD	3.1	3.1	4.2	4.2	4.8	4.8	
12378 PCDD	6.4	3.2	7.4	3.7	6.7	3.35	
123478 HxCDD	10.7	1.07	9.4	0.94	6.2	0.62	
123678 HxCDD	41	4.1	32.7	3.27	24.3	2.43	
123789 HxCDD	24.2	2.42	21.6	2.16	8.5	0.85	
1234678 HpCDD	175	1.75	163	1.63	100	1	
OCDD	231	0.231	229	0.229	127	0.127	
2378 TCDF	407	40.7	330	33	240	24	
12378 PCDF	77	3.85	59	2.95	43	2.15	
23478 PCDF	95	47.5	84	42	64	32	
123478 HxCDF	100	10	80	8	63	6.3	
123678 HxCDF	89	8.9	78	7.8	51	5.1	
234678 HxCDF	115	11.5	95	9.5	63	6.3	
123789 HxCDF	7.3	0.73	7.2	0.72	4.6	0.46	
1234678 HpCDD	314	3.14	260	2.6	150	1.5	
1234789 HpCDD	52	0.52	47	0.47	26.3	0.263	
OCDD	197	0.197	206	0.206	100	0.1	
TOTAL [pg TEQ]		142.908		123.375		91.35	119.21
Sample Vol [DRm3]		3.878		3.804		4.023	
Concentration [pg/Rm3]		36.85		32.43		22.71	30.66
Oxygen [%] Concentration [pg/Rm3 @11%O2]		7.90		8.00		7.60	
Stack Flow [DRm3/s]		28.06		24.89		16.90	23.29
Emission Rate [pg/s]		1.98		1.97		2.06	
		72.96		63.89		46.78	61.21

Table 10

Other Emission Testing Results REMASCO 2010 and Previous Years

Contaminant	Units	Test 1	Test 2	Test 3	Average
<b>Sulphur Dioxide</b>	[ppmd]	10.6	6.35	8.75	8.57
	[mg/DRm3]	27.9	16.75	22.9	22.52
	[ppmd @ 11% Oxygen]	8.1	4.9	6.5	6.50
	Emission Rate [g/s]	0.058	0.0335	0.0475	4.63E-02
<b>Oxides of Nitrogen</b>	[ppmd]	175.25	128.25	139.8	148
	[mg/DRm3]	330	239	263	277
	[ppmd @ 11% Oxygen]	123	96	106	108
	Emission Rate [g/s]	6.60E-01	4.67E-01	5.31E-01	5.53E-01
<b>Chlorine</b>	[mg/DRm3]	0.332	0.298	0.241	0.29
	[mg/DRm3 @ 11% O2]	0.234	0.225	0.183	0.21
	Emission Rate [g/s]	6.68E-04	6.25E-04	4.86E-04	5.93E-04
<b>Hydrogen Chloride</b>	[mg/DRm3]	62.9	72.5	58.3	64.57
	[mg/DRm3 @ 11% O2]	44.2	54.6	44.3	47.70
	Emission Rate [g/s]	0.126	0.152	0.118	1.32E-01
<b>Total Suspended Particulate</b>	[mg/DRm3]	16.4	22.8	9.71	16.30
	[mg/DRm3 @ 11% O2]	10.9	14.2	6.14	10.41
	Emission Rate [g/s]	3.29E-02	4.78E-02	1.97E-02	3.34E-02
<b>Vinyl Chloride Monomer</b>	[ug/DRm3]	3.26E+00	3.26E+00	3.26E+00	3.26E+00
	Emission Rate [g/s]	6.62E-06	6.62E-06	6.62E-06	6.62E-06
<b>Benz(a)pyrene</b>	[ug/DRm3]	2.66E-01	3.41E-01	6.51E-01	4.19E-01
	[ug/DRm3 @ 11% O2]	1.80E-01	2.29E-01	4.56E-01	2.88E-01
	Emission Rate [g/s]	3.65E-07	4.65E-07	9.26E-07	5.85E-07
<b>Benzene</b>	[ug/DRm3]	8.14E+00	1.34E+01	4.23E+00	8.57E+00
	Emission Rate [g/s]	1.65E-05	2.71E-05	8.59E-06	1.74E-05

Tables 8 to 10 provide both concentration and emission rate data. Concentrations are expressed as [mass/Rm<sup>3</sup>] which can be multiplied by the stack flow to determine the rate at which the contaminant is released [mass/second]. The dispersion model described later uses the rate information to describe the emissions from the facility. These emission rates are based upon the gasifier operating at full rated load feeding the maximum amount of fuel the unit was designed to consume. As such, this is the maximum possible emission rate from the gasifier.

The gasifiers will not operate at full load year round rather they are operated at a rate that maximizes the energy production efficiency while meeting the heating needs of the facility. Since dispersion conditions change throughout the year, mainly on a seasonal basis, it was considered appropriate to define the maximum expected operating condition for the boilers on a monthly basis so that when the emissions were modelled using hourly operating data they would reflect a conservative assessment of the combined effects of the operating state of the facilities and the dispersion characteristics of the atmosphere. At some times in the year the ambient temperatures might be such that the boiler plant in the greenhouse does not need to operate. The operating scenario for the REMASCO facilities is described in the next section.

#### **4.2.2 Operating Scenario REMASCO Facilities**

In the full scale operation, as described in the project description, REMASCO intend to install five 500 HP boilers on the Southshore Greenhouse site, and four 500 HP boilers on the Agriville site in addition to the two 400 HP boilers currently on the Southshore site. The new units on the Southshore site will be divided into two groups:

- The existing building with one 500 HP and the existing two 400 HP boilers and one stack;
- The new power plant building with four 500 HP boilers and two stacks; and,
- The Agriville site with four 500 HP boilers and two stacks.

Three of the boilers in the power house will be equipped with high pressure boilers to generate steam to drive the turbine, and they will supply heat to the storage system when they operate. These units will run year round to generate power. The amount of heat provided by the high pressure boilers will be sufficient to maintain operating temperatures in the heat storage system during the warmer months of the year. This means that the low pressure boilers will not need to operate during some months. Furthermore, since the plants in the greenhouse benefit from elevated levels of CO<sub>2</sub> during part of their growth cycle, gas fired boilers in the greenhouses are run to produce heat and their exhaust, containing CO<sub>2</sub> is discharged into the greenhouse. This further reduces the heating load on the low pressure boilers.

The basic emission parameters for the stacks, when operated at full load, are shown in Table 11. Any time the load is reduced on a boiler the stack gas flow decreases because less fuel is fed to the gasifier and less air is introduced to the system. Reducing the flow reduces the velocity at the exit of the stack and influences the plume rise of the gases leaving the stack. These issues are discussed in the following sections.



Table 11 Basic REMASCO Stack Characteristics (full load flow data)

Source ID	Description	Stack Characteristics						
		Volumetric Flow [Am <sup>3</sup> /s]	Temperature [°C]	Inner Diameter [m]	Height above Grade [m]	Height above Roof [m]	UTM Coordinates of Location [m]	
							E	N
SS1	Existing SS	11.21	142	0.91	21.34	12.8	362,344.6	4,656,145.2
SS21	Co-gen 1	8.63	142	0.81	21.34	12.8	358,393.0	4,656,586.2
SS22	Co-gen 2	8.63	142	0.81	21.34	12.8	362,394.7	4,656,586.1
AG1	Agriville1	8.09	142	0.81	21.34	12.8	362,342.1	4,656,232.1
AG2	Agriville2	8.09	142	0.81	21.34	12.8	362,344.3	4,656,226.7

### *Emissions under Reduced Input*

The REMASCO gasifiers are different than conventional mass burner waste incinerators in that they are smaller, were designed with multiple stage combustion that have higher velocity inside the ducts to promote a high level of turbulence and hence better mixing to promote good combustion. These characteristics allow the gasifiers to be operated with good combustion efficiency at higher turndown ratios than most mass burner incinerators.

In the typical mass burn furnace reducing the total air supplied to the system reduces the penetration of the combustion air into the main combustion gas area in the furnace leading to some of the combustion gases bypassing the air being added. This results in an increase in the amount of products of incomplete combustion leaving the system.

While the typical mass burn furnace operates as 9 – 10% oxygen levels, 70-90% excess air, the REMASCO gasifier operates at approximately 20% excess air with oxygen levels in the 3 -5% range in the gasifier rising slightly as the gas moves downstream. Reducing the flow to match the firing rate in the REMASCO unit thus has less effect on the total air flow than it would in the mass burn furnace. Unfortunately, reducing flow under reduced loads decreases turbulence and the mixing in a combustion system even though the effective residence time increases. It has been demonstrated in furnaces that the more the turbulence is reduced the poorer the combustion efficiency. This has been attributed to gases bypassing the main flame and high temperature zones and not being affected by the combustion reactions. This is typical of any combustion device; however, with high internal velocity, and less excess air the design features of the REMASCO unit make it less susceptible to reduced combustion efficiency at lower throughput.

The REMASCO mixing chamber throat is only 0.6 m in diameter and is equipped with a series of air jets around the circumference that induce a swirling motion to the gases as the extra air is injected. Before the gases enter the secondary chamber, there is a third stage of air addition. In both cases, the scale of the system limits the impact of reduced throughput.

Carbon monoxide levels in exhaust gas streams are frequently used as a marker of combustion performance. Low CO levels indicate good combustion. CO levels in excess of 100 ppm have been associated with the increased production of products of incomplete combustion, ie poor combustion

performance. In the REMASCO system the drop off in combustion efficiency occurring when the oxygen level gets below 2.5% is marked by an increase in CO levels. Over the range of operating conditions that the units have been tested at the CO level seldom exceeds 4 ppm and the typical values recorded by the facility instrumentation are 1 ppm or less. The 4 hour average CO upper limit that the MoE considers acceptable is 35 ppm as listed in Guideline A-7. The other indicator of combustion performance that the MoE use is total hydrocarbon level expressed as methane. The criteria for this parameter is 50 ppm in a ten minute average. Measurements of THC recorded during testing at the REMASCO facility are consistently below 8 ppm.

Combustion engineers frequently associate temperature of the gas stream, the level of turbulence in that stream, and duration that the gases are at the high temperature as being the factors that lead to good combustion efficiency. Should the temperatures be maintained at a level in excess of 1,000°C, a decreasing the flow would raise the residence time and should result in a greater reduction in the concentration of the products of incomplete combustion. This is not always the case since turbulence levels must be maintained to ensure good mixing, or more materials will bypass the reaction zone and be left in the exhaust stream. This relationship holds throughout the active combustion zones. After the gases leave these zones, the destruction reactions cease, and the residual products of incomplete combustion are released. Hence, with poor destruction CO, the most refractory of all the contaminants, can be found at substantially higher concentrations.

There is one reaction however that does not benefit from increased residence time in the areas of the combustion system where the temperature is in the 250 – 450°C range, the *de novo* reactions that are responsible to the reformation of PCDD/F downstream of the combustion zone. At temperatures in this range the literature indicates that the *de novo* synthesis reactions will create more PCDD/F as the residence time is extended. Below this temperature range the reaction is very, very slow, and above this range more PCDD/F is destroyed than created. This temperature range is usually found in the waste heat recovery boiler on waste incineration facilities. It is recommended in several references that operators attempt to transition this temperature range as fast as possible to minimize the *de novo* reactions. To limit the potential for increased *de novo* reactions in the REMASCO system during lower firing rates, REMASCO is currently developing a modification for the boiler that will allow the full load residence time to be maintained regardless of the firing rate, and this system will be tested later in 2011.

One more difference between a typical waste incinerator and the REMASCO system is the nature of the fuel. The ENERPAX fuel pellets are an engineered fuel produced from residual MSW. As such they have a very uniform composition, and they burn at a very uniform rate. In a typical waste incinerator the waste is a highly variable with any specific sample containing a different mixture of the major carbon bearing components such as plastics, paper, and food scraps as well as water. These variations mean that some waste must be dried before it burns and some wastes flash almost instantaneously to a mixture of combustible gases. The ENERPAX pellets are dense and uniform in size so they are consumed at a relatively steady rate and do not overload the combustion system at one moment and result in more excess air than necessary being in the system the next minute. This

uniform reaction rate lends itself to a very stable process that does not suffer wide fluctuations that can be exacerbated by reducing the fuel firing rate.

Experience suggests that the assumption made about the reduction of emissions during turndown operations is appropriate.

### *Operating Scenario Selection*

The scenarios for heating greenhouses in the Kingsville area are well understood by the operators and these are the basis for all the operating scenarios presented in the report. The boiler plants in these facilities must be adequate to provide heat for a wide range of weather conditions. But they also need to be sized in a cost effective manner.

The general operating parameter is that 30 boiler horsepower is sufficient to provide the heating needs of the facilities on all but a prolonged spell of days that are colder than the climatic history would suggest. Most greenhouses are equipped with natural gas fired boilers for providing CO<sub>2</sub> to the greenhouses, and these units can be used to supplement the main heating boilers should there be a need for more heat.

Tables 12 and 13 were based upon the average boiler loads by month for the Southshore facility's existing boilers. This load is shown in the 2<sup>nd</sup> column of the table.

The development of a co-generation facility at Southshore results in the co-generation system producing heat year-round as part of the electricity generation process. That heat offsets some of the heating required at Southshore and results in the operating loads at Southshore being split between the existing gasifier facility and the co-generation facility, thus there are 2 scenarios for Southshore in Table 13, but the sum of both is sufficient to meet the heating profile for the site.

Considering the Agriville site, it was anticipated that 4 units would be installed in the final configuration. The average load for the facility in column 2 can thus be distributed to the 4 gasifiers to provide individual operating scenarios for the units. Some assumptions must be made concerning how the load should be proportioned between the units.

A solid fuel fired boiler is best operated in the base load mode, ie it runs at a steady rate taking as much of the load as reasonable. Should the load increase beyond the capability of all the base loaded solid fuel boilers, that increase is best absorbed by operating one or more of the gas fired boilers. Should the load decrease, solid fuel boilers can be taken off line. The cost effective way to design and operate a boiler plant with a wide range of potential loads is to install multiple units and operate them at as close to the full firing rate as possible because this is the point where maximum thermal efficiency is achieved. Should the load reduce and a unit be taken off line, the balance of the on-line units would meet the load by operating at as high a capacity as possible. The ultimate flexibility would be to install many units so the incremental change in load can be absorbed by changing the status of one boiler. In reality, this would require too many small boilers thus some nominal turndown capacity should be installed for each boiler. Setting an appropriate turndown ratio is done

on the basis of cost and expected load variations, while considering when the boiler's operation may become unstable. It is recognized that thermal performance will generally suffer at lower firing rates.

For this evaluation, the maximum turndown was set at 65% load. It was further assumed that all the gasifiers on line at any time would be operated at the same reduced load. When the load drops to 75% at Agriville, one of the units could be shutdown, and the remaining load would be provided by the other three units. When three units drop to 66% another unit can be shutdown and the two remaining units can absorb the load. Recognizing that lower flue gas flows reduce the effective plume rise the other operating assumption included in the report was to maintain the stack gas flow as high as possible at any time. Thus, the shutdown sequence attempts to maintain the throughput through one pair as high as possible until 2 of the 4 units are shut down.

The approach in the assessment was developed as a reasonable estimate of operational status that maximized the use of the gasifiers year round.

The model allows the emissions to be varied on a temporal basis, in any time frame from hourly to seasonally. However, varying the emissions in the model does not vary the stack flow conditions. Since those conditions can influence dispersion, it was considered necessary that the model account for different operating conditions, ie different loads on boilers and different stack flow rates. To do this the monthly energy requirements, both for heat and electricity, were evaluated to establish how much fuel had to be burned. This was calculated based upon certain assumptions:

- 32 acres of greenhouse requires approximately 1,000 HP of boiler capacity during the coldest part of the year,
- the steam turbines/boiler would be operated continuously, and,
- the gas boilers were needed during certain periods to supply CO<sub>2</sub> to the greenhouse.

The total heating load from the low pressure boilers at Southshore was determined, and from that the monthly variation in load was determined. A similar calculation was completed for the Agriville facility however in this case there was no base load from the power plant, and the low pressure boilers and gas fired CO<sub>2</sub> boilers were assumed to meet the energy needs.

Table 12 shows the operating scenario for Agriville. This shows that during some months only one boiler is discharging to a specific stack, and in the summer the second stack will be inoperative. Looking at the average flows by month in stack #1 eight different flow rates can be identified. For stack #2, four unique monthly average flow rates are provided, and 7 months have no flow.

Table 13 shows the co-generation operating scenario for the Southshore Greenhouse installations. Three stacks are included on this site: the existing building stack and the two on the new building. The top half of the table shows the operation of the high pressure boilers in the co-generation facility separate from the required loads for the low pressure heating boilers which is shown in the bottom half. Except for July and August, the co-generation facility operates at levels in excess of 95% load which results in only 4 unique flow situations for stack #2 which will serve two of the high pressure

boilers associated with the co-generation building. Stack #3, serving the other pair of boilers in the co-generation facility, operates with the remaining high pressure boiler on line at a monthly average load similar to the boilers served by stack #2, however during the heating months the low pressure boiler in the co-generation building operates at the same average rate as the low pressure boilers in the existing building. This results in 8 unique monthly average flow situations for stack #3.

The low pressure boilers on the Southshore site augment the heat provided by the co-generation boilers and are operated to supply heat during periods of higher demand. As such, when the average load for the 3 boilers in the existing building falls below 80% a boiler is shut down in an attempt to maintain both the highest efficiency and the highest flow from the stack for that operating condition. Because of the desire to maintain stack flows, a preference is given for operating the low pressure boiler in the co-generation building over the equipment in the boiler plant as this creates more flow in stack #3 at the co-generation plant. Stack #3's flow is a combination of the high pressure boiler and the low pressure boiler. The one operating situation that leads to low flows is the low requirement for heating in October. On a monthly basis, one 400 HP boiler would only need to be operated at 41% of its capacity. Since this is too low, the likely operating scenario would be to bring that unit on line on October 19<sup>th</sup> and run it at the rated capacity for the balance of the month. Stack #1 has 5 unique flow situations, with no flow for 5 months, and October which could be said to be similar to May, but only operating 40% of the month.

To allow for the varying stack flow situations, separate sources were developed for each stack's unique flow characteristics and emission characteristics, and given the ability to vary emissions, the stacks were either on or off for the appropriate flow in any given month. Since it is inappropriate to run a boiler at any input below 65%, in October rather than having the existing stack [E1] operating at the low input, the overall use in the month was reduced to 40% assuming it was on line at full flow. The Emission Rate Factor shown in the tables is effectively the ratio of the average calculated flow in the stack divided by the flow for the test condition of 19.127 MMBtu/h [3.45 Am<sup>3</sup>/s]. This assumes that the concentration of contaminants in the exhaust from the boilers will not vary with load.

Table 12 Anticipated Operating Conditions for Agriville REMASCO Facility  
 Dispersion Case Operating Strategy - Equal Turndown all Boilers

Month	% Max Load	Total Load [HP]	Units On Line	Total # of Full Load Boilers Req'd	# of Boilers On-line in Stack AG1	Average Load	Average Flow per Stack [Am3/s]	Average Velocity [m/s]	Emission Rate Factor Stack AG1	# of Boilers On-line in Stack AG2	Average Load	Average Flow per Stack [Am3/s]	Average Velocity [m/s]	Emission Rate Factor Stack AG2
January	100	1875	4	3.75	2	94	8.09	15.69	2.34	2	94	8.09	15.69	2.34
February	100	1875	4	3.75	2	94	8.09	15.69	2.34	2	94	8.09	15.69	2.34
March	82	1538	3	3.08	2	103	8.84	17.16	2.56	1	103	4.42	8.58	1.28
April	63	1181	3	2.36	2	79	6.79	13.18	1.97	1	79	3.40	6.59	0.98
May	48	900	2	1.80	2	90	7.76	15.06	2.25	0	90	0.00	0.00	0.00
June	35	656	2	1.31	2	66	5.66	10.98	1.64	0	66	0.00	0.00	0.00
July	27	506	1	1.01	1	101	4.37	8.47	1.27	0	101	0.00	0.00	0.00
August	27	506	1	1.01	1	101	4.37	8.47	1.27	0	101	0.00	0.00	0.00
September	35	656	2	1.31	2	66	5.66	10.98	1.64	0	66	0.00	0.00	0.00
October	41	769	2	1.54	2	77	6.63	12.87	1.92	0	77	0.00	0.00	0.00
November	50	938	2	1.88	2	94	8.09	15.69	2.34	0	94	0.00	0.00	0.00
December	68	1275	3	2.55	2	85	7.33	14.23	2.13	1	85	3.67	7.11	1.06

Table 13 Southshore Greenhouse Operating Alternatives

a) Dispersion Case Operating Strategy - Co-generation - Power Generation Portion - Optimize for Highest Flow through Stacks - Even Load across Boilers

Month	% Max Load	Co-Gen Load [HP]	500 HP Units on Line	400 HP Units on Line	Average Load	# of Boilers On-line in Stack SS1	Total Output in Stack [HP]	Average Flow per Stack [Am3/s]	Average Velocity [m/s]	Emission Rate Factor Stack SS1	# of Boilers On-line in Stack SS21	Average Flow per Stack [Am3/s]	Average Velocity [m/s]	Emission Rate Factor Stack SS21	# of Steam Boilers On-line in Stack SS22	Average Flow per Stack [Am3/s]	Average Velocity [m/s]	Emission Rate Factor Stack SS22
January	100%	1500	3	0	100%	0	0	0.00	0.00	0.00	2	8.63	16.74	2.50	1			
February	100%	1500	3	0	100%	0	0	0.00	0.00	0.00	2	8.63	16.74	2.50	1			
March	100%	1500	3	0	100%	0	0	0.00	0.00	0.00	2	8.63	16.74	2.50	1			
April	100%	1500	3	0	100%	0	0	0.00	0.00	0.00	2	8.63	16.74	2.50	1	Details for this operation is shown in the columns below		
May	98%	1469	3	0	98%	0	0	0.00	0.00	0.00	2	8.45	16.39	2.45	1			
June	95%	1421	3	0	95%	0	0	0.00	0.00	0.00	2	8.17	15.86	2.37	1			
July	72%	1080	3	0	72%	0	0	0.00	0.00	0.00	2	6.21	12.05	1.80	1			
August	72%	1080	3	0	72%	0	0	0.00	0.00	0.00	2	6.21	12.05	1.80	1			
September	95%	1421	3	0	95%	0	0	0.00	0.00	0.00	2	8.17	15.86	2.37	1			
October	98%	1469	3	0	98%	0	0	0.00	0.00	0.00	2	8.45	16.39	2.45	1			
November	98%	1469	3	0	98%	0	0	0.00	0.00	0.00	2	8.45	16.39	2.45	1			
December	100%	1500	3	0	100%	0	0	0.00	0.00	0.00	2	8.63	16.74	2.50	1			

b) Dispersion Case Operating Strategy – Co-generation – Heating Portion – Optimize for Highest Flow through Stacks – Even Load across all Boilers

Month	% Max Load	Co-Gen Load [HP]	500 HP Units on Line	400 HP Units on Line	Average Load	# of Boilers On-line in Stack SS1	Total Output in Stack [HP]	Average Flow per Stack [Am3/s]	Average Velocity [m/s]	Emission Rate Factor Stack SS1	# of Boilers On-line in Stack SS21	Average Flow per Stack [Am3/s]	Average Velocity [m/s]	Emission Rate Factor Stack SS21	# of Htg. Boilers On-line in Stack SS22	Combined Flow Stack SS22 [Am3/s]	Average Velocity [m/s]	Emission Rate Factor Stack SS22
January	100%	1800	2	2	100%	3	1300	11.21	17.24	3.25	0	0.00	0.00	0.00	1	8.63	16.74	2.50
February	100%	1800	2	2	100%	3	1300	11.21	17.24	3.25	0	0.00	0.00	0.00	1	8.63	16.74	2.50
March	87%	1560	2	2	87%	3	1127	9.72	14.94	2.82	0	0.00	0.00	0.00	1	8.05	15.62	2.33
April	51%	921	2	0	92%	1	461	3.97	6.11	1.15	0	0.00	0.00	0.00	1	8.29	16.08	2.40
May	22%	401	0	1	100%	1	401	3.46	5.32	1.00	0	0.00	0.00	0.00	0	4.22	8.20	1.22
June	0%	0	0	0		0	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	4.09	7.93	1.18
July	0%	0	0	0		0	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	3.10	6.02	0.90
August	0%	0	0	0		0	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	3.10	6.02	0.90
September	0%	0	0	0		0	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0	4.09	7.93	1.18
October	9%	164	0	1	41%	1	164	1.41	2.17	0.41	0	0.00	0.00	0.00	0	4.22	8.20	1.22
November	25%	456	1	0	91%	0	0	0.00	0.00	0.00	0	0.00	0.00	0.00	1	8.16	15.83	2.36
December	60%	1088	1	2	84%	2	669	5.77	8.88	1.67	0	0.00	0.00	0.00	1	7.92	15.37	2.30



### **Start-up and Shutdown Operations and Upsets**

Aside from the operating flexibility that allows the REMASCO gasifier to operate at high combustion efficiency across a broader firing range than a typical mass burn waste incinerator, there are other benefits related to the design of these units. Being smaller than conventional mass burn units, it is easier to control the start up and shut down of the system, thus minimizing the potential for increased emissions during these operational phases.

The secondary chamber of the gasifier is raised to 1,000°C before any ENERPAX pellets are introduced into the gasifier. This is accomplished by operating a natural gas burner that fires into the mixing chamber. This raises the temperature in the zones downstream of the mixing chamber: secondary chamber, heat recovery boiler, and fabric filter. When the secondary chamber reaches the appropriate temperature, the ENERPAX pellets start to be introduced into the gasifier. They are ignited by a second gas burner.

As noted in the equipment descriptions, the grate in the gasifier has multiple zones where air is added to the system. Pellets are deposited and ignited on the feed end of the grate and are moved towards the outlet end of the gasifier as they sit on the grate. The air added under the grate provides agitation of the pellets, but it is only introduced when the grate in that zone is covered with pellets.

The gasification of the pellets raises the operating temperatures in the system even further, so that the firing rate of the natural gas burner can be reduced as the quantity of pellets on the hearth increases. The firing rate of the gas burner in the mixing chamber is adjusted to maintain the appropriate secondary temperature. When the pellets on the bed maintain the secondary temperature without the help of the burner, the burner can be shutdown.

All gases leaving the secondary chamber pass through the boiler, and the fabric filter, with some of this flow being returned to the system and the rest being discharged to the atmosphere. There are no bypasses around the system and any particulate matter released from the combustion system is trapped in the fabric filter. Lower flow rates during start-up ensure that the fabric filter system operates at optimal levels at all times.

When it comes time to shut the gasifier down, the process is repeated in the reverse order. The feed to the gasifier is stopped and the first zone of the grate is slowly uncovered as the pellets are transported towards the discharge end of the chamber. As the temperature drops due to lowering input the mixing chamber burner comes on to maintain the appropriate temperature. When the majority of the first section of the grate is emptied, the air to that section is turned off. The grate continues to move pellets down the length of the gasifier, and since much of the pellet is consumed on the early section of the grate, the burner firing rate must increase to maintain temperature. When the 3<sup>rd</sup> zone is empty the air to that section is reduced, and the burner ramps up even higher. The burner maintains the operating temperature in the secondary chamber until all the ash is discharged from the grate. At that time the burner can be shut off and air continues to be introduced to cool the



components. When the temperature drops to the appropriate point, the fans can be shut off and the gasifier doors are opened to allow further cooling.

The steady increase in firing rate and decline as the waste feed is shut off reduces rapid transitions in the system, and limits startup and shutdown emissions. Operating experience suggests that the grate can be fully charged with pellets within about 2 hours of introducing the first pellets. Shutdown is typically accomplished within 1 hour from the cessation of pellet feed. This operation is unlike the typical mass burn incinerator which is much larger. The large size of mass burn units makes it difficult to achieve reasonable operating temperatures before waste is added to their burning grate. This contributes to potential start up and shut down emissions from such units, but these conditions can be circumvented in the REMASCO gasifier.

The other potential upset scenario is a failure in the Air Pollution Control system. The performance of baghouses, their ability to remove particulate matter from the gas stream, does deteriorate over time, typically between 24 and 36 months. Single bags may fail when a hole is ripped in them due to cleaning operations, or a failure in the material. Such failures can be identified by a rapid increase in opacity in the stack gases. An opacity monitor is installed in each stack for the purposes of identifying sudden failures, or the long term degradation in performance. When the base opacity reading slowly increases after each successive cleaning it is a fairly good indicator that the bags need replacing. A sudden increase indicates a bag failure, and the system can be taken into shutdown so the offending bag can be identified and blocked off. If 10% of the bags in the fabric filter are blocked off the operator should consider scheduling an outage to replace all the bags.

To address these situations, process upsets were evaluated. There is little data to assess the emissions that could occur under any of these transitory situations, however, to model the potential upset conditions the study team followed the approach suggested by the California Air Resources Board<sup>6</sup> as recommended by the US EPA<sup>7</sup>.

***Estimating Emissions from Process Upsets:*** To represent stack emission rates during process upsets, multiply the emission rate developed from the trial burn data by 2.8 for organics and 1.45 for metals. These factors are derived by assuming that emissions during process upsets are 10 times greater than emissions measured during the trial burn. Since the unit doesn't operate under upset conditions continually, the factor is adjusted to account for only the period of time, on an annual basis that the unit operates under upset conditions. For organic compounds, the facility is assumed to operate as measured during the trial burn 80 percent of the year and operate under upset conditions 20 percent of the year  $[(0.80)(1)+(0.20)(10)=2.8]$ . For metals, the combustor is assumed to operate as measured during the trial burn 95 percent of the year and operate under upset conditions the remaining 5 percent of the year  $[(0.95)(1)+(0.05)(10)=1.45]$ .

This approach addresses upsets from hazardous waste incinerators which are different from the REMASCO gasifier since the fuel is different. Note the US EPA state:

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<sup>6</sup> California Air Resources Board. 1990. "Health Risk Assessment Guidelines for Nonhazardous Waste Incinerators." Prepared by the Stationary Source Division of the Air Resources Board and the California Department of Health Services.

<sup>7</sup> US EPA, 2005. Human Health Risk Assessment for Hazardous Waste Combustion Facilities Final Sept. Chapter 2, <http://www.epa.gov/epawaste/hazard/tsd/td/combust/finalmact/ssra/05hhrap2.pdf>

It is possible for unburned hazardous waste to be emitted through the stack as a result of various process upsets, such as start-ups, shutdowns, and malfunctions of the combustion unit or APCS. Emissions can also be caused by operating upsets in other areas of the facility (e.g., an upset in a reactor which vents gases to a boiler burning hazardous waste could trigger a process upset in the boiler, resulting in increased emissions). U.S. EPA (1994i) indicates that upsets aren't generally expected to significantly increase stack emissions over the lifetime of the facility.

The burning of hazardous waste, particularly liquid hazardous waste with high calorific value, or for that matter with extremely low calorific value is significantly different than any solid waste incinerator where the major issue is the calorific value of the plastics introduced and their propensity to flash upon charging to the hot incinerator. Burning a consistent fuel such as the ENERPAX pellets results in a process that is not easily upset.

That said, the potential for upsets was considered following the CARB recommendations, however these were modified recognizing that a solid waste incinerator has different combustion characteristics than a hazardous liquid waste incinerator. For all but the criteria air contaminants, oxides of nitrogen, sulphur dioxide and hydrogen chloride the 1 hour maximum due to upsets, the factor of 10 was employed. For the daily and annual values, no distinction was made between organic and inorganic contaminants and the 2.8 factor was employed for all but the above listed criteria air contaminants. Since the CARB recommendation is silent on the approach for the 24 hour upset factor, the operational aspects of the REMASCO facility were reviewed to determine if it should be treated in a manner similar to CARB's approach to the annual upset factor. It was determined that if there was an upset that would force the facility to be shutdown this could be accomplished within 1 hour from the time it was determined that there was a need to shut down. During a shutdown, fuel feed is curtailed and the emissions would be anticipated to drop as soon as shutdown commenced. To err on the side of caution, it was assumed that it would take 4.8 hours to shut the facility down so during any 24 hour period 20% of the period would be spent operating at the 10 times emission factor. Applying the CARB proportional approach this converts to a factor of  $(0.2 \times 10 + 0.8) = 2.8$  for the 24 hour average concentration.

Some consideration must be given to how these factors are applied to the REMASCO facility that is configured with multiple gasifiers and stacks. The CARB recommendations for addressing potential upsets at hazardous waste incinerators recognize that changes in the nature of the waste, or in the quantity of waste fed to the incinerator, are likely to create combustion related upsets. Intermittent changes in the calorific value of the waste can upset the combustion system very easily because there is a need to closely match air flow to changing calorific values. A plug in one of the nozzles delivering waste to the incinerator would be enough to upset the system. Of course there could be other failures, such as those related to the APC systems which would create increases in trace metal emissions, but they are less likely to occur at the hazardous waste facility a fact recognized by the differentiation between metallic and organic upset conditions.

The failure scenarios at REMASCO are most likely to be associated with the APC systems. The nature of ENERPAX pellets makes it much less likely that significant upsets will occur in the combustion

system at REMASCO. The pellets are a dense uniform, man-made fuel that has a uniform energy value and an even burning characteristic, as evidenced by the stable combustion conditions achieved at the existing facility. Fuel feed issues are very unlikely. On occasion, there may need to be a non-normal shutdown of a system due to a boiler leak. These must be done quickly to protect the rest of the systems downstream of the boiler, and can lead to upsets, but these are typically handled very quickly. The normal shutdown procedures that allow the bed to be cleared are dispensed with and more residue is shipped to disposal to ensure that the system integrity can be maintained.

It is much easier to conceive of failures in parts of the APC system downstream of the combustion zones. No lime feed for acid gas control, a condition that is experienced at many facilities that handle powdered lime for addition to gas stream. Powdered activated carbon addition could also be disrupted. Fabric filter bags wear with time, and must be replaced every few years. More importantly, many factors can lead to the premature failure of one or more bags in the system leading to an increase in emissions.

These failures scenarios have an extremely low probability of occurring simultaneously on all 3 of the process streams at the Southshore site. There are three independent APC systems, ie. three stacks connected to pairs of boilers systems, or, in the case of the existing facility at Southshore, 3 boilers systems. It is unlikely that boiler tube failures would occur simultaneously in both boilers, so at worst only half or a third of the flow to one stack might be affected by a combustion system upset. Each of the stacks have an associated APC system, but it is equally unlikely to experience simultaneous failures on the APC systems connected to two stacks, let alone all three.

It is not hard to suggest that there could be an upset on one gasifier system, say one in the group of three at Southshore that would be required to be shutdown. Moreover, the APC system could fail in one of the ways outlined above that would result in an increased release. Since the highest potential emissions are from the existing stack at Southshore, it was assumed for the purposes of the evaluating upsets that this system went into upset with emissions increasing to 10 times their normal level over the hour. The remaining systems were assumed to continue to run at normal levels during this situation. Since the emission rates are different for the systems these conditions were run for one hour with the 10 times higher emissions from the original stack at Southshore and normal at the other sources. The model was also run with the 2.8 times emissions from the existing stack to determine the 24 hour average and the annual average.

With respect to the criteria air contaminants the 10 times factor for the one hour situation was considered to be overly conservative. Test data from the facility, general literature data, and specific emission test data from the Brampton solid waste incinerator were considered in setting conservative estimates of emissions for NO<sub>x</sub> and SO<sub>2</sub>.

For NO<sub>x</sub> the upper bound on emissions is a function of the combustion system because all control of NO<sub>x</sub> is provided by controlling the combustion characteristics. Data on NO<sub>x</sub> emissions from waste

incinerators is available in the CCME Guidelines<sup>8</sup> shows the mean uncontrolled NO<sub>x</sub> value measured during 377 tests was 142 ppm @ 11% O<sub>2</sub>. The testing data from the Brampton MSW incinerator before the implementation of NO<sub>x</sub> control used for the environmental assessment for the expansion of that facility produced an upper confidence estimate of the NO<sub>x</sub> emissions of 246 ppm @ 11% O<sub>2</sub>. The maximum emission value recorded at the REMASCO facility during the various test programs conducted during the Pilot Project was 160 ppm @ 11% O<sub>2</sub>. Based upon these data, a multiplier of 2.15 times the normal operating level was used for the 1 hour upset NO<sub>x</sub> level for the REMASCO facility. The modelled value equates to an emission level of 247 ppm @ 11% O<sub>2</sub>.

For sulphur dioxide emissions the maximum that can be released from the facility is limited by the amount of sulphur in the fuel. Analytical data for the ENERPAX pellets has reported sulphur concentrations ranging from 0.07 percent by weight to 0.2 percent by weight and averages approximately 0.1%. The original guarantee offered by the pellet manufacturer suggested that the sulphur content would be less than 0.05%. The nature of the sulphur found in the pellets also influences the release of sulphur during the gasification process. The IAWG report<sup>9</sup> suggests that approximately 35% of the sulphur in the feed will report to the bottom ash in the incinerator. Data from early testing at the REMASCO facility<sup>10</sup> showed that sulphur in the pellets was 0.08% while the average ratio of sulphates in the bottom ash compared to the pellets was 0.37 which agrees with the IAWG data that suggests sulphur will be retained in the bottom ash. This suggests that the uncontrolled sulphur emissions will be on the order of 0.065% of the feed sulphur rate. Assuming that a 400 boiler HP gasifier consumed 862 kg/hour of pellets, the estimated uncontrolled sulphur release rate would be 0.56 kg/h or 0.16 g/s sulphur, which translates to 0.32 g/s of SO<sub>2</sub>. This value is approximately 7 times the emission rate used for normal operation. The multiplier for SO<sub>2</sub> used for upset operation is 7 times.

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<sup>8</sup> CCME, 1988. Supporting Technical Appendix for the Canadian Operating and Emission Guidelines for MSW Incinerators. October. Published by CCME at IP-95 in May, 1989.

<sup>9</sup> IAWG, 1997. Municipal Solid Waste Incinerator Residues. Published by Elsevier ISBN 0-444-82563-0

<sup>10</sup> I. Coyle, F. Preto and R. Dureau, 2008. Emissions Testing at a Novel Waste-to-Energy Converter. A report prepared by the Industrial Innovation Group, CANMET Energy Technology Centre – Ottawa under the auspices of Natural Resources Canada.

### **4.3 Existing Facilities**

In order to assess the cumulative effects of the REMASCO development on air quality in the community it is necessary to examine emissions from other sources that could release air contaminants. One source of such data is the National Pollutant Release Inventory [NPRI] data base which publishes annual inventory data by community. There is only one Kingsville area industrial source included in that data list. While there are a number of sources in Leamington their size and the fact that they were some distance from the main study area suggest that these data are of little use in a comparison. Discussions with members of the local community identified that greenhouse heating systems occasionally create local air quality concerns. Given this information, and the fact that REMASCO will be replacing some existing greenhouse heating systems, it was considered appropriate to limit this review to the emissions associated with greenhouse heating. This is not to preclude other sources in the community, residential heating systems or transportation sources however it was assumed that background measurements of ambient air quality will account for these sources.

Without published emissions data for each of the greenhouse operations located in the area it was necessary to develop an estimate of potential emissions from these sources.

#### **4.3.1 The Effects of Fuel Burning**

REMASCO are proposing to their technology combined with an alternate fuel for heating greenhouses. As such the REMASCO project will replace fuels that are currently being used for this purpose. However, burning of any fuel results in the release of energy and associated air emissions.

At a very simple level, the process of burning natural gas results in combining one mole of methane, [CH<sub>4</sub>], with 2 moles of oxygen, [O<sub>2</sub>], and releasing one mole of carbon dioxide, [CO<sub>2</sub>], and two molecules of water vapour, [H<sub>2</sub>O]. Unfortunately, this may be too simple a description since natural gas is not exclusively methane and can contain higher level organic compounds that may not be totally converted to CO<sub>2</sub> and H<sub>2</sub>O. Indeed, even the burning process might not go to completion as many natural gas fired appliances release trace quantities of methane during combustion.

Secondly, as a result of the combustion reactions other contaminants can be created. The air that supplies the oxygen needed for combustion contains 79% nitrogen and when this nitrogen combines with oxygen at high temperatures oxides of nitrogen, NO<sub>2</sub> and NO, are created. Similarly, the sulphur in the natural gas converts to SO<sub>2</sub> or SO<sub>3</sub> depending upon the nature of the combustion process. There is data suggesting that gas combustion can lead to the release of metallic species albeit at low levels. Since it is unlikely that these materials originate in the gas, the most plausible explanation for these results is that surfaces inside the boiler and the exhaust ducts deteriorate due to corrosion and other chemical reactions.

Unlike natural gas, most other fossil fuels contain trace metals at varying concentrations. Burning these fuels will result in the vaporization of the more volatile metals. The more stable metals can be

released with the particulate matter carryover in the combustion system. As the level of impurities increases in the fuel, the potential for elevated contaminant releases rises. Some examples of impurities include the various nutrients and metals that trees absorb from the soil when they grow. Potassium emissions occur when wood is burned. Coals typically contain a wide variety of elements in addition to carbon and hydrogen. Sulphur is frequently found in coal. The concentrations of trace metallic species found in coal vary with geological conditions in the area where the coal was mined. The release mechanisms for sulphur and the other elements present in coal are the same as found in other fuels. Liquid fuels, oil, also contain impurities such as sulphur and vanadium. As with other fuels these impurities are released during combustion.

The mechanisms responsible for the release of various elements are complicated. Elements in the fuel recombine in the combustion system as a result of complicated chemical reactions driven by concentration gradients, oxidation state, and the operating temperature. The presence of halogens in the fuel can change the nature of some metals making them more prone to being released as fumes.

Table 1 shows a high proportion of sulphur dioxide is released from power plant stacks. This relates to sulphur levels in the coal or oil being burned. Recognizing that SO<sub>2</sub> contributes to health and environmental affects, regulators have imposed restrictions on the amount of SO<sub>2</sub> that can be released from power plants. These facilities are now equipped with air pollution control systems that remove the sulphur compounds from the exhaust gases, or they can use fuels with very low sulphur content. The choice is typically based upon economics.

Some industrial and commercial processes are also equipped with air pollution control systems to reduce the rate at which they release contaminants to the atmosphere. One such set of sources are facilities that burn waste materials, particularly municipal solid waste, biomedical waste or hazardous wastes. In many jurisdictions these types of facilities have to meet very strict emission release standards. In Ontario, the A-7 guideline imposes some of the most stringent emission standards on this category. Furthermore, facilities subject to A-7 are required to monitor their operation on a routine basis, and their emissions are measured on a frequent basis. Such measurement campaigns allow the emissions from these facilities to be characterized. The REMASCO facility has undergone such extensive testing and as discussed in the previous section emission factors for the facilities are based upon this testing data. These emissions can be compared with emissions from other fuel burning systems based upon emissions data documented by the US EPA and other regulatory bodies. Typically, such data are referred to as emission factors.

### 4.3.2 Emission Factor Documentation

The US EPA has developed emission factor data for many processes<sup>11</sup> to assist states in determining if emissions in their jurisdiction meet federal standards. The referenced report suggests that emission factors form the cornerstone of air quality management decisions and are important for states when

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<sup>11</sup> US EPA, 2010. AP 42, Fifth Edition *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*. Available at <http://www.epa.gov/ttnchie1/ap42/>



they try to define how they might improve air quality in their region. The emissions factor documentation is divided into a number of sections each of which deals with a specific type of process. The first chapter documents emission factors from external combustion sources: steam/electric generating plants, industrial boilers, and commercial and domestic combustion units. That chapter is further divided into sections that relate to the type of fuel being burned: coal, fuel oil, and natural gas. Chapter 1.1 addresses emissions from boilers firing sub-bituminous and bituminous coals. Chapter 1.3 addresses various types of fuel oil fired boilers. Chapter 1.4 deals with natural gas fired boilers and furnaces. Wood residue fired boilers are covered in Chapter 1.6. In addition to different factors for equipment and fuels, the data also address the influence of equipment size on emissions, and where applicable the influence of control systems on reducing emissions.

Emission factors cover more than just the criteria pollutants discussed earlier. They include factors for the release of the trace metallic and trace organic species as well as halogens measured at the REMASCO facility. The number of emission contaminants listed varies by fuel. For oil or gas fired boilers approximately 50 contaminants are listed whereas close to 100 are listed for coal or wood fired systems. Since the emission factors were derived from research work done for various purposes, the list of substances is not consistent across the range of fuels, or equipment.

While emission factors can be used to compare typical emissions from a variety of equipment and fuels, the comparisons must be conducted on a standard basis. Since solid fuels require that more air be introduced into the system than might be used for gaseous or liquid fuels, a simple comparison of emission concentrations could be misleading. To overcome this limitation, the emissions can be expressed as a mass emission rate [g/s or lb/hr]; however, since larger boilers would be expected to emit more contaminants than smaller units comparing emissions in [g/s] from different sized facilities would be misleading. By describing the emissions as the quantity of emissions released per unit of heat input into the device the comparisons can be made without these biases. Emission factors expressed as lb/MMBtu or g/GJ of energy input are used for this comparison.

The US EPA emission factors are expressed on the basis of common usage for different fuels such as – lb/ton of coal; lb/10<sup>6</sup> scf of gas; lb/1000 gallons of oil; or for wood, lb/MMBtu. Even these units are not used consistently since trace metal emissions for coal are expressed as lb/10<sup>12</sup> Btu input, which is comparable to 1x10<sup>-6</sup> lb/MMBtu.

It should be noted that in all cases the emissions of oxides of nitrogen are reported as NO<sub>x</sub> the combined total of NO and NO<sub>2</sub> released from the sources. The US EPA<sup>12</sup> discusses the treatment of such releases when they are being modelled to assess cumulative impacts from sources. That document provides data for default ratios of NO/NO<sub>2</sub> in the absence of site specific data so that models can be used to assess the NO<sub>2</sub> levels in the environment. More details are provided later in this report.

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<sup>12</sup> US EPA, 2011. Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO<sub>2</sub>, National Ambient Air Quality Standard. Memo from Air Modeling Group, Air Quality Planning and Standards Division, US EPA to Regional Directors.

Explanations of the source and limitations on the emission factors for the various fuels are provided in the following paragraphs.

### **Emission Factors for Coal Use**

The emission factors for coal use were taken from the US EPA AP-42 publication, Chapter 1.1. The report provides emission factors for 3 different boiler types, 4 different heat transfer surface arrangements and 3 firing configurations as well as providing data on the effectiveness of air pollution control equipment. The data are further sub-divided to address the type of coal fired in the system.

The US EPA notes that small, coal-fired boilers and furnaces are found in industrial, commercial, institutional, or residential applications. These are generally firetube boilers with a horizontal return tubular, Scotch, or vertical configuration. In a firetube boiler the hot gases are inside the tubes that separate the water from the hot gases. These units typically employ stoker type grates where the coal is fed onto a moving surface that carries the fuel into and through the furnace discharging ash at the end of the grate. For the most part these smaller systems do not have emission control systems. This type of boiler would be expected to be typical of coal burning systems employed to heat greenhouses and thus their emission factors were used in this report.

The emission rate for the release of criteria contaminants from stoker type furnaces varies by stoker type. The values for spreader stokers firing sub-bituminous coal were used for this comparison. The spreader stoker uses a mechanical device to spread the fuel across the grate. Sub-bituminous coal is more economical than other coals and it was assumed to be the coal of choice for the area.

Emission factors for sulphur dioxide are a function of the sulphur content of the coal being used. The report lists SO<sub>2</sub> emission factors that range from 31 to 38 times the sulphur content of the coal. The sub-bituminous multiplier is listed as 35. The average sulphur content of sub-bituminous coal was obtained from a B&W reference<sup>13</sup> which provides an average of 0.65% sulphur.

For NO<sub>x</sub> the emission factors range from 7.5 – 9.5 lb/ton and the sub-bituminous value of 8.8 lb/ton was selected.

For CO the sub-bituminous value is at the low end of the range, 5 – 11 lb/ton.

When selecting a factor for filterable particulate matter emissions, it was assumed that the furnace had multiple cyclones for dust control and the listed factor of 12 lb/ton was used. This configuration has a PM<sub>10</sub> emission factor of 7.8 lb/ton.

For organic contaminants the only data available was from pulverized coal fired boilers with dry bottoms or cyclone furnaces equipped with air pollution control systems. Thus the organic emission factors used for this comparison may be lower than would be found if spreader stokers with minimal

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<sup>13</sup> Babcock & Wilcox Company, 1984. Useful tables for engineers and steam users. 14th edition.



air pollution control systems were tested. HCl and HF emission factors are the same for all types of coal fired systems.

AP-42 emission factors for metals are a function of the particulate matter release rate [PM] expressed as [lb/MMBtu], and the coal's ash [A] and trace element concentration [C]. The concentration of the metal in the coal, [C], is expressed as parts per million [ppm] on a weight basis. The weight fraction of ash in the coal [A] is expressed as a decimal value ie. 10% ash implies A=0.1. The emission factors are equations defining the statistical correlations between these factors. They represent the most reliable estimates for metals estimates, provided the ash and trace metal content data are available. The equation takes the form of:  $[\text{constant} \times (\text{C/A} \times \text{PM})^x]$  where the constant and x, the power, depend upon the element being considered. There is no factor of this form for mercury emissions. Mercury from a spreader stoker is quantified in another set of values that could be used if the inputs to the emission factor equations are not available.

To determine the metal emissions it is necessary to estimate the ash content and the trace element content of the coal that might be used. The ash content of sub-bituminous from the B&W reference averages 5.7%. The trace metal concentrations for numerous US coals are listed in a USGS report<sup>14</sup>. These values were used for the calculations.

The coal emission factors must be adjusted to develop the lb/MMBtu emission factors required for this study. Such a conversion must be based upon the heating value of the coal. For sub-bituminous coal, the heating value of coal was assumed to be 10,300 Btu/lb<sup>15</sup>. The total input from a ton of coal would thus be 20.6 MMBtu. Thus AP-42 coal emission factors [lb/ton] must be divided by 20.6 to convert them to [lb/MMBtu].

One of the 8 substances listed in A-7 is PCDD/F, polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans. A single number is used to represent the quantity of this family of substances released from a source, the International Toxic Equivalents [ITEQ] and expressed as [mass ITEQ/Rm<sup>3</sup>]. The ITEQ value is the sum of the 17 most toxic isomers times a toxicity weighting factor specific to the isomer, ITEF. The ITEF values, which range from 0.001 to 1. The ITEQ factors were designed to be applied to the congener quantities for the various 2,3,7,8 species at different chlorination levels, but in the absence of sufficient data, they can be applied to the homologue totals. The US EPA PCDD/F emission factor data does not include ITEQ values, rather they report the homologue totals by chlorination level for both dioxins and furans. The US legislation does not reference the TEQ value, rather it is based upon total PCDD/F so there has been little need to use the alternative form. It is possible to use the homologue data with the ITEF factors appropriate for that homologue to calculate the sum product and provide an estimated ITEQ emission factor for coal. Applying this approach the emission factor would be  $1.73 \times 10^{-11}$  lb/MMBtu.

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<sup>14</sup> Stricker, G.D., Flores, R.M., Trippi, M.H., Ellis, M.S., Olson, C.M., Sullivan, J.E., and Takahashi, K.I., 2007, Coal quality and major, minor, and trace elements in the Powder River, Green River, and Williston basins, Wyoming and North Dakota: U.S. Geological Survey Open-File Report 2007-1116. Available on the Web as OF07-1116Report\_508 on the USGS web site.

<sup>15</sup> Babcock & Wilcox Company, 1984. Useful tables for engineers and steam users. 14<sup>th</sup> edition.

Another published emission factor for PCDD/F is available. The United Nations Environment Programme [UNEP] developed default emission factors for PCDD/F emissions from numerous sources in an attempt to standardize world wide inventories of dioxin and furan releases<sup>16</sup>. That report provides PCDD/F emission factor estimates [ug/TJ] for coal combustion in a range of applications as well as for oil and natural gas boilers and wood waste boilers. The UNEP factors expressly assume that the boiler is reasonably well-operated and maintained as well as being run to maximize power output. These emission factors [ug/TJ] must be converted to the standard form [lb/MMBtu]. The conversion is as follows:

$$1 \text{ ug/TJ} = 10^{-6} \text{ g/} 10^{12} \text{ J} = 10^{-18} \text{ g/J.}$$

$$1 \text{ MMBtu} = 1.0551 \times 10^9 \text{ J so multiplying } 10^{-18} \text{ g/J} \times 1.0551 \times 10^9 \text{ J/MMBtu} = 1.0551 \times 10^{-9} \text{ g/MMBtu.}$$

$$1 \text{ lb} = 453.6 \text{ g so dividing } 1.0551 \times 10^{-9} \text{ g/MMBtu} / 453.6 \text{ g/lb} = 2.33 \times 10^{-12} \text{ lb/MMBtu.}$$

$$1 \text{ ug/TJ} = 2.33 \times 10^{-12} \text{ lb/MMBtu.}$$

The UNEP estimate for PCDD/F emissions from coal is 10 ug TEQ/TJ which converts to  $2.33 \times 10^{-11}$  lb TEQ/MMBtu about 35% higher than the US EPA estimate.

### **Emission Factors for Oil Use**

The US EPA Chapter 1.3 for oil fired boilers covers fire tube boilers typically used for heating systems fired with a range of different quality oil from distillates, #1 and #2 fuel oil down to residuals #5 and #6 or Bunker C fuel oils. For the purposes of this comparison the residual fuel oil emission factors were used. Bunker C is the lowest cost fuel oil available.

The report contains emission data for three different sizes of equipment, boilers greater than 100 MMBtu/hr input; those smaller than 100 MMBtu/hr input but larger than typical residential size units, and for residential size units of less than 1 MMBtu/hr. The data for boilers smaller than 100 MMBtu/hr were used for this study. This represents boilers that will produce approximately 2,250 Boiler HP at 75% thermal efficiency, larger than any system that would be needed greenhouses in the Kingsville area. Typically, the boiler installations at greenhouses are not single large systems but multiple smaller systems so the maximum operating efficiency from the systems can be achieved by matching demand to capacity.

The oil emission factors [lb/1000 gallons] are provided in the AP-42 compilation. To convert these values to the standard emission factor form [lb/MMBtu] one needs to define an average heating value for a gallon of #6 fuel oil. The B&W document referenced earlier suggests that #6 fuel oil weighs 8.1 lb/gallon and provides 18,200 Btu/lb of fuel burned. This implies that 1,000 gallons will provide an input of 147.4 MMBtu. To express the lb/gallon emission factors in lb/MMBtu they must be divided by 147.4.

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<sup>16</sup> UNITED NATIONS ENVIRONMENT PROGRAMME, 2005. Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases. 2nd edition prepared by UNEP Chemicals, Geneva.

The US EPA compilation has no PCDD/F emission factor for oil combustion. The UNEP value for oil is 2.5 ug TEQ/TJ which translates to  $5.83 \times 10^{-12}$  lb TEQ/MMBtu, one quarter of the value reported for coal fired boilers. This number represents the median of a range for values that ranged from  $2.33 \times 10^{-12}$  to  $9.32 \times 10^{-12}$  lb TEQ/MMBtu.

### **Emission Factors for Natural Gas Use**

Chapter 1.4 in the AP-42 compilation provides emission factors for natural gas fired boilers. In practice these boilers are very similar to those used for fuel oil firing, essentially package fire tube boilers. These units are fabricated in the manufacturer's facility and shipped complete to the site. It is not unknown to have such boilers fired with both fuel using different burners in the same boiler.

Similar to the oil fired situation, natural gas emission factors are divided into 3 broad categories with larger boilers split into two capacities larger and smaller than 100 MMBtu/hr input and the very small residential units. Newer boilers can be fitted with low NO<sub>x</sub> boilers, and emission factors reflecting these systems are available; however these were not used for this study.

The emission factors [lb/10<sup>6</sup> scf of natural gas] are provided in the AP-42 compilation. To convert these values to the standard emission factor form [lb/MMBtu] one needs to define an average heating value for natural gas, 1,020 Btu/scf. The conversion in this case is simply a matter of dividing by the calorific value.

The US EPA compilation has no PCDD/F emission factor for natural gas combustion. The UNEP value for natural gas is 0.5 ug TEQ/TJ which translates to  $1.17 \times 10^{-12}$  lb TEQ/MMBtu, one twentieth of the value reported for coal fired boilers. This number represents the average of data reported by various agencies that ranged up to  $3.5 \times 10^{-12}$  lb TEQ/MMBtu.

### **Emission Factors for Wood Use**

The AP-42 compilation addresses wood combustion in Chapter 1.6. The report suggests the burning of wood residue in boilers is mostly confined to those industries where it is available as a byproduct. It is burned both to obtain heat energy and to alleviate possible solid residue disposal problems. When used in boilers the wood residue is normally hogged wood, bark, sawdust, shavings, chips, mill rejects, sander dust, or even wood trim. Hogged wood consists of wood chips approximately 5 cm across by 10 cm long created from the parts of the tree that cannot be converted to uses other than fuel.

The firing method most commonly employed for wood-fired boilers is some form of spreader stoker. The wood enters the furnace through a fuel chute and is spread across the furnace on a stationary or moving grate. This type of boiler has a fast response to load changes, has improved combustion control, and can be operated with multiple wood types. Natural gas, oil, and/or coal, are often fired in spreader stoker boilers as auxiliary fuels. Although spreader stokers are the most common stokers among larger wood-fired boilers, overfeed and underfeed stokers are also utilized for smaller units.

Emission factors for criteria contaminants are listed in the compilation for different types of units, and fuels, with the major distinction being whether the exhaust system includes multiple cyclones to control the release of particulate matter or not. It has been assumed that any wood residue boiler in a greenhouse would be equipped with cyclones. The balance of the emission factors represent the average of data collected from various facilities and is said to adequately represent expected emissions from a wide range of boilers, fuel types, and systems with limited air pollution control equipment.

The wood fuel used in most greenhouse operations is obtained from suppliers in chip form. Chips can be stored in external piles or internal storage areas and transported into the boiler house with conventional front end loaders. The heating value for wood residue ranges from 4,500 British thermal units/pound (Btu/lb) of fuel on a wet, as-fired basis, to about 8,000 Btu/lb for dry wood. Emission factors in the compilation are expressed in the form chosen for this comparison [lb/MMBtu].

As was the case for the coal fired boilers, the US EPA compilation has PCDD/F emission factor data in the form of homologue totals. Applying the TEQ factors to the homologue data produces an emission factor estimate of  $1.62 \times 10^{-7}$  lb/MMBtu. The UNEP report distinguishes between mixed agriculturally derived biomass fired boilers which can include straw and poultry bedding amongst other components of the fuel and wood waste boilers. The emission values for mixed biomass fired units 500 ug TEQ/TJ whereas the emission factor for clean wood is 50 ug TEQ/TJ. The latter value translates to a value of  $1.17 \times 10^{-10}$  lb TEQ/MMBtu. This number represents the average of data reported by various agencies assuming that the calorific value of the wood was in the range of 12-15 MJ/kg. The individual homologue values in the EPA data list HxCDD at  $1.6 \times 10^{-6}$  lb/MMBtu, significantly, 100 to 1000 times, higher than balance of the homologue factors. Given this apparent anomaly in the data, the UNEP values were used for this comparison.

### **REMASCO Emissions Data**

The REMASCO stack testing emission data was reported earlier on a concentration basis [g/Rm<sup>3</sup> @ 11% oxygen] to allow comparison with the standards in A-7. For the most part these data formed the basis of the emissions from the REMASCO units. One adjustment was made to these data, the value for hydrogen chloride emissions. As a regulated contaminant in Guideline A-7, the HCl emission concentration is limited to 27 mg/Rm<sup>3</sup> @ 11% O<sub>2</sub>. This value was substituted into all the calculations for predicted ambient HCl concentrations that are presented in this report. REMASCO recognizes that this limit must be met for the REMASCO units to remain in operation after the formal approval process, and is confident that, with some modifications to the fabric filters used at the site, this standard can be met and in fact anticipate that operating emissions will be lower than the regulated concentration. For the comparison of emissions discussed in this section the existing measured emission data are used although, as noted later, Table 14 includes the emission rate data based upon both the actual test data and the A-7 Guideline value for each of the contaminants.

Using the measured stack gas flow expressed as Rm<sup>3</sup> @ 11% O<sub>2</sub>/second, the emission concentration data can be reported as a mass emission rate [g/s]. The conversion of this value to an emission factor

[mass/MMBtu] is discussed in this section. To convert these data to the reference base for this comparison one needs to determine the input for the gasifier.

The testing was done with the gasifier operating at the full input rate producing 400 Boiler HP. Since the emission factors in this report are expressed in lb/MMBtu the output, Boiler HP needs to be converted to Btu. The conversion factor is 33,472 Btu/hr per Boiler HP, so the output of the boiler is 13.4 MMBtu/hr. Calculations suggest that the system operates at about 70% thermal efficiency, that is for every million Btu of fuel used, 700,000 Btu of energy is recovered. Dividing the output by the efficiency raises the input to  $13.4/0.70 = 19.13$  MMBtu/hr.

The emission rate [g/s] should be converted to an hourly rate [g/hr = g/s x 3600 s/hr] before dividing by the input rate [MMBtu/hr] to get [g/MMBtu]. The final step is to divide by 453.6 [g/lb] to express the emission factor from the tests in the chosen form for this comparison [lb/MMBtu].

Data listed in Table 10 that was not collected in 2010 were expressed on a concentration basis, [g/Rm<sup>3</sup> @ 11% O<sub>2</sub>], and converted to emission rate assuming the concentration would be the same regardless of firing rate.

#### 4.3.4 Comparison of Emission Factors

Emission factors for all the specific fuel sources discussed in the preceding sections were entered into a spreadsheet with the contaminant name and the emission factor in the basic units from the US EPA compilation. The conversion factors discussed above were applied to the US EPA or UNEP emission factor data to create [lb/MMBtu] emission factors for each fuel and contaminant.

Since there were different contaminants listed in each of the compilations, the lists were merged into one sheet based upon the list of contaminants that the REMASCO Certificate of Approval required to be tested. This list was reduced by limiting the contaminants to those that, for the most part, had emission factors for at least 3 different fuels. The reduced list provides emission factors for a total of 30 contaminants as listed in Table 14. The list includes the ITEQ emission factor values for PCDD/F from the UNEP report as discussed earlier. The highlighted values in the table denote the lowest emission factor for each contaminant. In most cases either natural gas or the REMASCO data have the lowest emission factor.

For comparison purposes the A-7 emissions standards that the REMASCO facility must meet are included in the last column of Table 14 in the [lb/MMBtu] form based upon the 2010 testing flow rates. It is important to recognize that the REMASCO emission data from the spring 2010 testing showed that NO<sub>x</sub> and HCl emission levels expressed in the form shown in the table were greater than the required emissions in the A-7 column. Subsequent testing conducted later in 2010 demonstrated that the facility can meet these standards, but the evaluation was based upon the May test results.

For ease of comparison three graphs were prepared. The data in Table 14 was separated into the following groups: Metals; PCDD/F ITEQ; and, Other Contaminants (the Criteria Contaminants, HCl,

volatile organic compounds [VOC] and semi-volatile organic compounds [SVOC]) emission factors. In each case, where there is an A-7 emission standard, the derived emission factor related to that factors is plotted.

For the metals a number of elements were dropped from Figure 2 to simply the figure. The elements removed were emissions factors that were only common to wood use and the REMASCO data. If there is no square or column shown for a particular fuel and contaminant combination, there is no data for that particular combination. Emission factors based upon the REMASCO test data, which represents a controlled source, are some of the lowest values shown in the graph. Elements that can be taken up by the wood as it grows and are released from an essentially uncontrolled source have some of the highest emission factors. It should be remembered that the metals emissions factors for coal are a function of the chosen trace metal concentrations in the coal and actual values could vary.

Figure 3 shows the PCDD/F emissions comparison for the REMASCO facility versus the data listed in the UNEP report. It is important to note that the comparison data from UNEP were based upon default factors for large, well maintained power plants. The same report suggests that for small coal fired boilers/stoves used for heating the emission factor can release up to seven (7) times more PCDD/F than listed for the power plant application. It is suggested that this behaviour results from poorer combustion controls in smaller units. Natural gas emissions are the lowest, due in part to more complete combustion in these systems.

A wide group of contaminants, the Other Contaminants in Figure 4 include the Criteria Contaminants and HCl as well as SVOC species included in the HHRA. Controlling NO<sub>x</sub> in the REMASCO gasifier leads to these units having lower emission factors than the uncontrolled systems. The fabric filter in the APC systems at REMASCO lowers particulate matter emissions. Natural gas which does not form significant particulates during combustion has the lowest factor. Sulphur dioxide emissions are related to the assumed concentration of sulphur in the fuel. The typical sulphur content of sub-bituminous coals are at least half of those found in bituminous coals and SO<sub>2</sub> emissions could be higher from high sulphur coals. Some control of SO<sub>2</sub> is affected by the APC system at REMASCO and since the pellets have a low sulphur concentration, the REMASCO facility produces low emission values. The HCl values are comparable for coal and REMASCO; however, REMASCO emissions are controlled versus the uncontrolled coal emissions. The SVOC/VOC data, although hard to see at the scale in Figure 3, shows that wood has the highest emission factor of any of the fuels, in most cases at least 100 times higher than the next closest fuel. These SVOC/VOC compounds reflect products of incomplete combustion and the high factors for wood combustion suggests that the nature of the fuel, and possibly its variable moisture levels, can lead to limitations in the combustion characteristics of the systems.

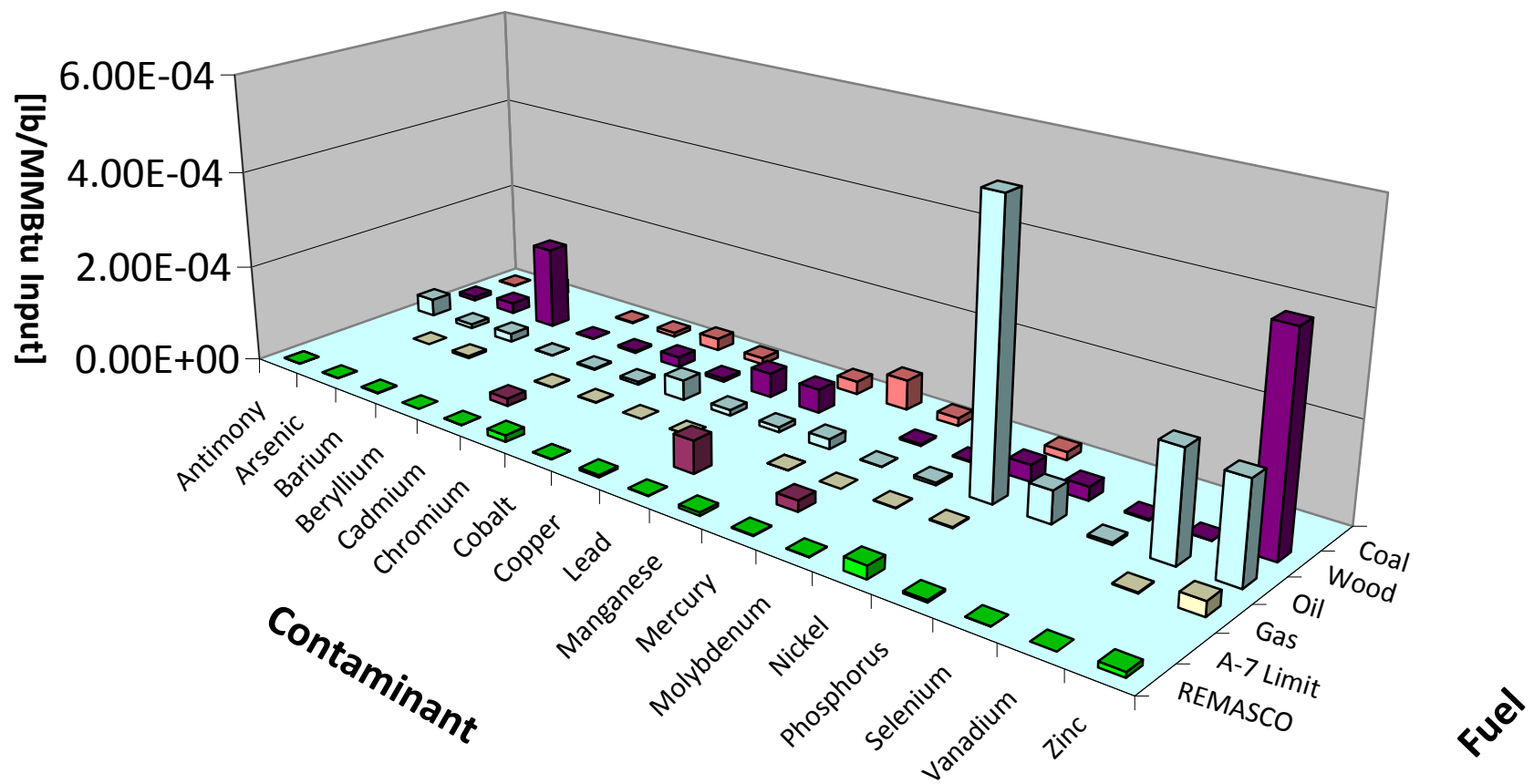
As noted, Table 14 shows REMASCO emission factors to be amongst the lowest for all the fuels considered.



Table 14 Emission Factors [lb/MMBtu] for Different Fuels

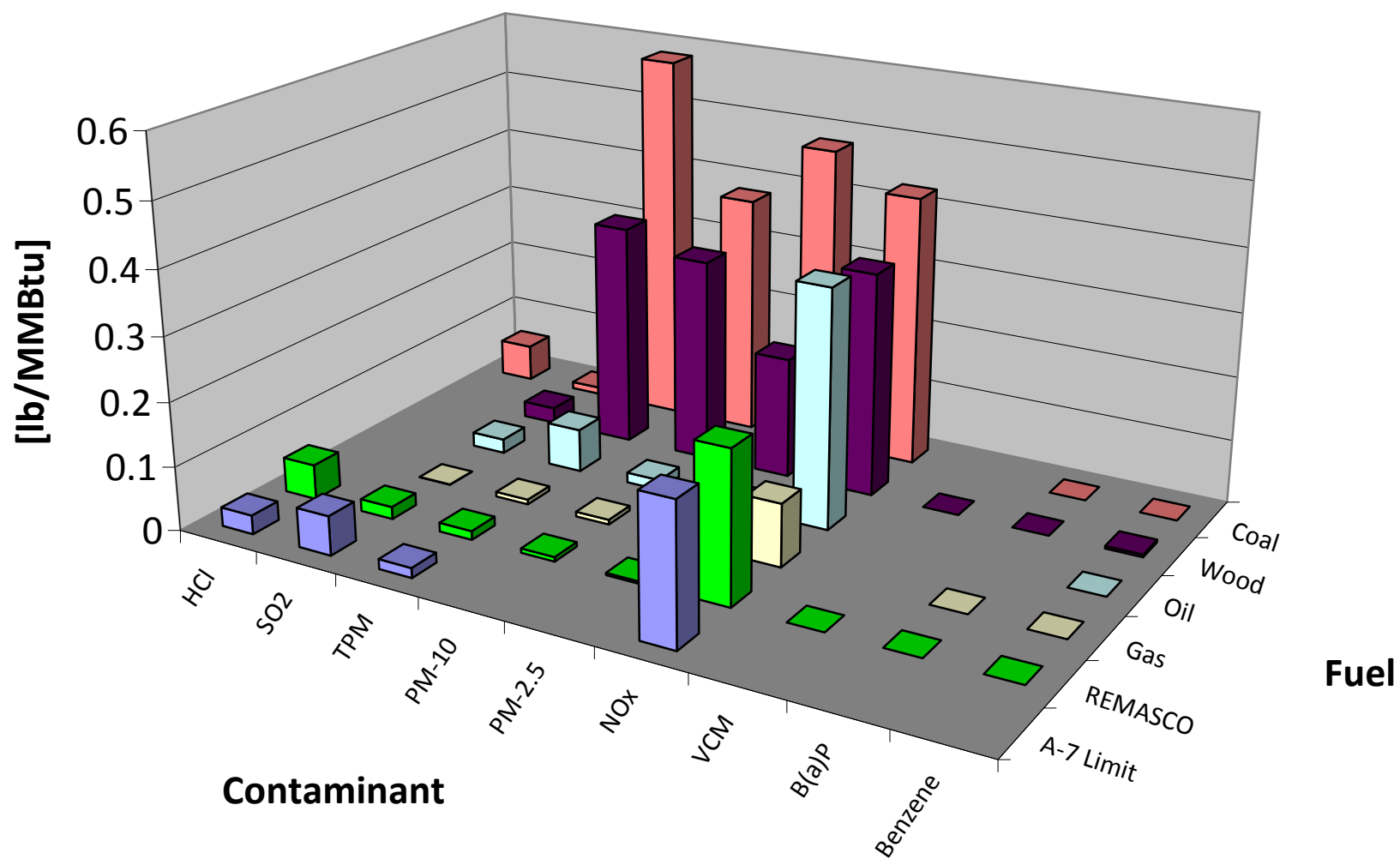
Compound	FUEL TYPE					A-7 Limit as EF
	Coal	Oil	Wood	Gas	REMASCO	
Antimony	9.33E-07	3.56E-05	7.90E-06		4.48E-07	
Arsenic	2.98E-05	8.95E-06	2.20E-05	1.96E-07	3.69E-07	
Barium		1.74E-05	1.70E-04	4.31E-06	1.27E-06	
Beryllium	2.35E-06	1.89E-07	1.10E-06		6.39E-08	
Cadmium	8.17E-06	2.70E-06	4.10E-06	1.08E-06	6.31E-07	1.53E-05
Chromium	2.48E-05	5.73E-06	2.10E-05	1.37E-06	1.34E-05	
Cobalt	1.32E-05	4.08E-05	6.50E-06	8.24E-08	4.19E-07	
Copper		1.19E-05	4.90E-05	8.33E-07	4.73E-06	
Lead	2.61E-05	1.02E-05	4.80E-05		1.37E-06	6.57E-05
Manganese	6.10E-05	2.04E-05	1.60E-03	3.73E-07	6.47E-06	
Mercury	1.60E-05	7.67E-07	3.50E-06	2.55E-07	1.71E-06	2.19E-05
Molybdenum		5.34E-06	2.10E-06	1.08E-06	1.04E-06	
Nickel	1.63E-05	5.73E-04	3.30E-05	2.06E-06	2.54E-05	
Phosphorus		6.42E-05	2.70E-05		4.23E-06	
Selenium		4.63E-06	2.80E-06		5.64E-07	
Silver			1.70E-03		2.54E-06	
Sodium			3.60E-04		1.50E-04	
Strontium			1.00E-05		8.13E-07	
Tin			2.30E-05		2.92E-05	
Titanium			2.00E-05		5.48E-07	
Vanadium		2.16E-04	9.80E-07	2.25E-06	6.76E-08	
Zinc		1.97E-04	4.20E-04	2.84E-05	1.02E-05	
PCDD/F TEQ [UNEP Default]	2.34E-11	5.82E-12	1.17E-10	1.16E-12	2.54E-11	8.76E-11
Hydrogen Chloride	5.83E-02				5.48E-02	2.96E-02
Sulphur Dioxide	1.10E-02	2.24E-02	2.50E-02	5.88E-04	1.92E-02	6.13E-02
Total Particulate Matter	5.83E-01	6.8E-02	3.50E-01	7.45E-03	1.39E-02	1.53E-02
PM-10	3.79E-01	1.6E-02	3.20E-01	7.45E-03	6.93E-03	
PM-2.5	4.80E-01	1.2E-02	1.90E-01	7.45E-03	3.46E-03	
Oxides of Nitrogen	4.27E-01	3.73E-01	3.50E-01	9.80E-02	2.34E-01	2.17E-01
Vinyl Chloride Monomer			1.80E-05		3.78E-07	
Benzo(a)pyrene	1.84E-09		2.60E-06	1.18E-09	4.98E-08	
Benzene	6.31E-05	1.45E-06	4.20E-03	2.06E-06	9.96E-07	

**Figure 2 Metal Emission Factor by Fuel**

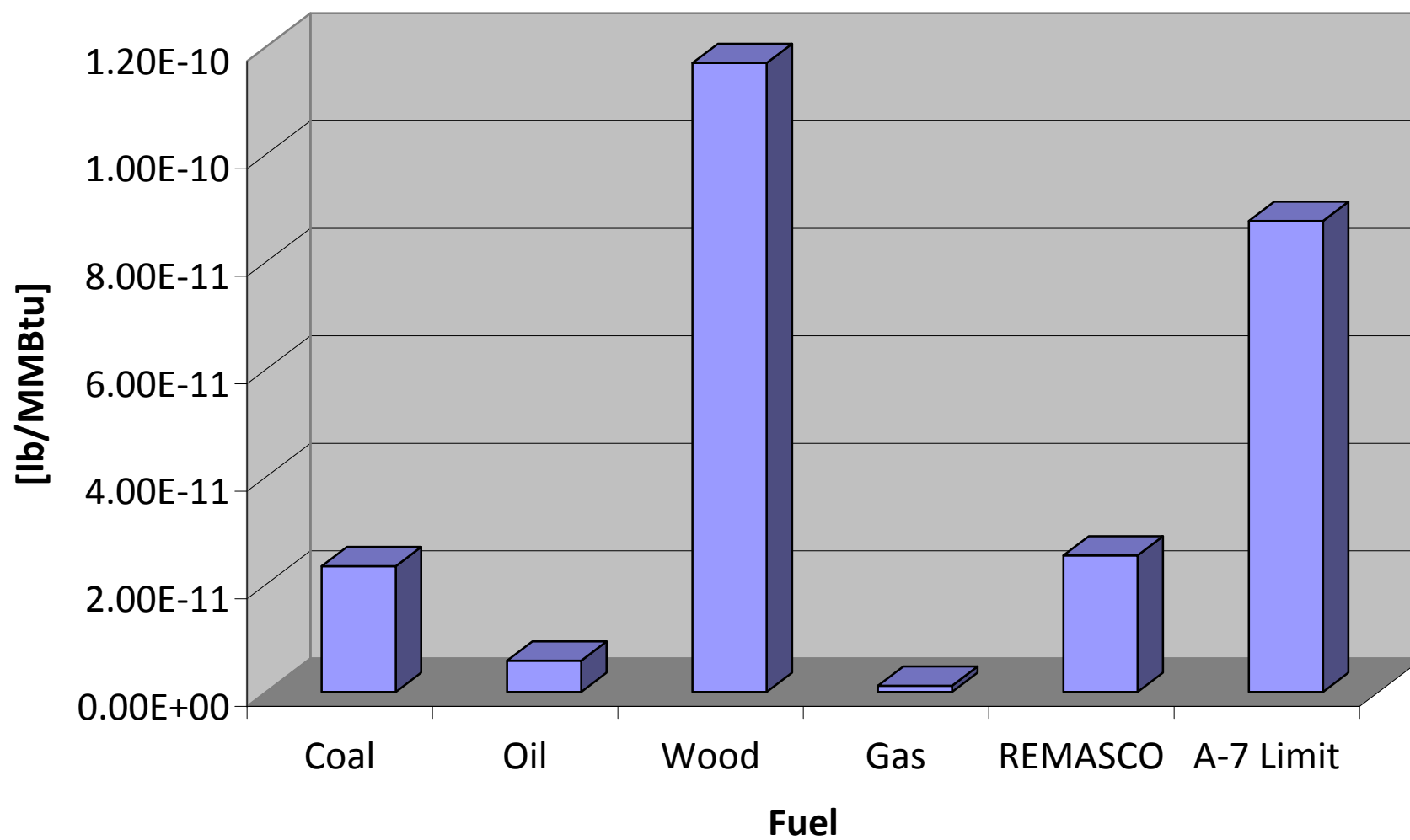




### Figure 4 Other Emission Factors by Fuel



**Figure 3 PCDD/F Emission Factors by Fuel**



#### **4.3.5 Using Emissions Factors to Define Air Emissions in the Kingsville Area**

There are numerous greenhouse operations in the Kingsville area. For this project consideration was restricted to the effects from the greenhouse operations situated south of 4,657,000 N and between the 364,000 W and 357,500 W. These UTM co-ordinates roughly equate to Townline Road S or 31 in the east, the lake on the south, Jasperson Lane in the west, and south of County Road 34 in the north. The only greenhouses located north of Road 2 E are those on Lot 1851 and Lot 1669. The western boundary includes the facility on the west side of Kratz Road. There are a total of 25 facilities within the area designated.

The Kingsville Internet Mapping Framework<sup>17</sup> was used to establish the locations of each of the facilities, and to estimate the area of each greenhouse facility. For the purpose of identification a 250 m grid was applied on the map, from 357,500 W to a line 6.5 km east and from 4,657,000 N south for 2 km. This covers the area outlined above. The grid was assigned letter designations in the N/S direction and numbers in the E/W direction from the upper left hand square. The sources were numbered A1 – A25, but to facilitate further identification they were labelled according to the grid square in which the southwest corner of the facility was located. Thus, Agriville was labelled C2 and main Southshore complex F19. See Figures 5 and 6 for the study area and the grid locations.

It was assumed that the emissions associated with heating the greenhouses were proportional to the area of the greenhouses as determined from the Kingsville mapping site. The total greenhouse area shown on the 2008 air photo version of the map is approximately 117 ha, or 289 acres.

To estimate emissions from each site it was assumed that the typical boiler operating rate was 30 BHP per acre of area covered. Given a 75% thermal efficiency, this translates to 1.34 MMBtu/hr/acre [3.31 MMBtu/hr/ha] input to the boilers. Using that factor, and the greenhouse area the total input can be defined and from that the emissions in terms of MMBtu/hr can be determined. It remained to make an assumption about the types of fuels used in the greenhouses so the appropriate emission factor from Table 14 could be applied.

In almost every large greenhouse there are some gas fired boilers used to provide CO<sub>2</sub> for the plants, and heating. These units are typically operated during the day when the heating load is lowest, and the heat they generate is transferred to the water storage systems. At night, when it is colder different boilers can be employed to provide sufficient heat to optimize the use of stored heat and the instantaneous heat from the boiler systems. As the weather gets colder, some of the main heat boilers are brought on line and operate 24 hours per day to cover both the extra daytime heat requirements and ensure that there is sufficient heat at night. The main heat generating boilers use different fuels, oil, wood, coal, or natural gas. Their combustion products are discharged to the atmosphere because some of these fuels are not as clean as natural gas, and CO<sub>2</sub> is not required at night.

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<sup>17</sup> <http://gisweb.countyofessex.on.ca/Geocortex/Essentials/Kingsville/Web/Viewer.aspx?Site=PublicKingsville#>





Figure 5 Western Portion of Study Area with Grid





Figure 6 Eastern Portion of Study Area with Grid



Local knowledge or observation of operations can identify the predominant fuel type used at some of the greenhouses and thus the area of greenhouses in the study area that are heated with a particular fuel can be quantified. Allowing that some percentage of the fuel used at most of the large greenhouses will be the natural gas, for CO<sub>2</sub> production, it was necessary to determine how much of the other fuels might be used. While the predominant fuel used at each of the greenhouses can be identified, circumstances can change and the fuel mix could be altered because a cheaper fuel is available. Recognizing that the purpose of the cumulative assessment was to estimate background levels, it was considered inappropriate to assign a specific fuel to a specific facility. Rather, it was decided that all the greenhouses would be modelled with a composite mix of the fuels.

The mix was based upon the greenhouse area that was known to be associated with a specific fuel type. The area of the greenhouse was compared to the total area and the fuels divided based upon that area. The results of the estimates were that 30% of the acreage was fuelled by wood; 25% by coal; 30% was allocated to natural gas including that portion of the large greenhouses that have CO<sub>2</sub> generating boilers, and the balance, 15%, was assumed to be fuelled by oil. At any specific time this mix can change due to opportunities to purchase cheaper fuels, but in the long term this proportion should be reflective of fuel use and can be used for modelling.

Multiplying the appropriate fuel emission factors [lb/MMBtu] by the decimal fraction of the use of that fuel and summing the value for each of the fuels provides an average emission rate for the existing greenhouses under consideration. The average emission factor [lb/MMBtu] can be multiplied by the required fuel input [MMBtu/h] based upon the facility's size to get an emission rate in [lb/hr] which can be converted to [g/s] for use in modelling. The emission rates are shown in Table 15 expressed as [g/s/ha] so the individual emission rates for any facility can be obtained by multiplying these values by the area of the greenhouse.

Table 15 Emission Factors for Fuel Blend

Contaminant	Emission Rate [g/s/ha]	
	Fuel Mix	REMASCO
Antimony	2.07E-05	1.17E-06
Arsenic	4.02E-05	9.62E-07
Barium	1.43E-04	3.32E-06
Beryllium	2.46E-06	1.66E-07
Cadmium	1.04E-05	1.64E-06
Chromium	3.59E-05	3.50E-05
Cobalt	2.97E-05	1.09E-06
Copper	4.36E-05	1.23E-05
Lead	5.85E-05	3.57E-06
Manganese	1.30E-03	1.69E-05
Mercury	1.37E-05	4.44E-06
Molybdenum	4.57E-06	2.71E-06
Nickel	2.62E-04	6.61E-05
Phosphorus	4.62E-05	1.10E-05
Selenium	4.00E-06	1.47E-06
Silver	1.33E-03	6.63E-06
Sodium	2.81E-04	3.90E-04
Strontium	7.98E-06	2.12E-06
Tin	1.80E-05	7.61E-05
Titanium	1.56E-05	1.43E-06
Vanadium	8.68E-05	1.76E-07
Zinc	4.28E-04	2.65E-05
PCDD/F TEQ [UNEP Default]	1.10E-10	6.61E-11
Hydrogen Chloride [REMASCO@ A7 Default]	3.79E-02	7.13E-02
Sulphur Dioxide	3.59E-02	4.99E-02
Total Particulate Matter	6.85E-01	3.62E-02
PM10	5.09E-01	1.81E-02
PM2.5	3.11E-01	9.05E-03
Oxides of Nitrogen	7.74E-01	6.11E-01
Vinyl Chloride Monomer	1.41E-05	9.84E-07
Benzo(a)pyrene	2.03E-06	1.30E-07
Benzene	3.33E-03	2.59E-06

#### **4.4 Other Emissions Associated with Project**

For completeness it is appropriate to document other potential sources of air emissions associated with the REMASCO operations. These include:

- vehicular traffic: pellet delivery; residue shipments; staff vehicles;
- construction activities; and,
- decommissioning and closure of the facility.

These activities are addressed in this section.

##### **4.4.1 Traffic related to Operations**

Pellets are delivered in standard size tractor trailers. These vehicles are licensed to carry up to 40 Mg of materials in any load. On the Southshore site the maximum consumption of pellets is estimated at 175 Mg/day. At Agriville the consumption would be 106 Mg/day. To keep up with the demand, approximately 280 Mg/day of pellets must be received at the sites. This would require a total of 7 trucks per day. In reality, it is more likely that shipments will be received 5 days per week between 7 am and 7 pm, bringing the maximum number of shipments to 10 per day.

It is anticipated that, at most, 2 trucks per day will be required to remove residues from the two buildings on the Southshore site and 1 truck would be required for the same activity at Agriville.

The employees at the two sites will likely arrive for work in their own vehicles. A total staff complement of 6 will be required at Southshore and 4 at Agriville. Since the Southshore facility will require manning around the clock when the co-generation facility is in operation, the employee traffic will be distributed throughout the day according to shift changes.

In total, less than 20 vehicle movements into and out of the Southshore site are anticipated daily. At Agriville the total estimated vehicle movements associated with the REMASCO project would be on the order of 10 vehicles.

Traffic data from Essex County reveals that the average daily traffic on County Road 20 [Seacliff Drive] is in excess of 10,000 vehicles at points east and west of the Southshore site. Data is not available for the roads in the Agriville area, however it should be noted that the existing wood fuelled boilers require shipments of wood and hauling of residues at rates similar, or even higher than will result from the REMASCO operation.

Given the relatively small number of vehicles associated with the Southshore operation, when compared to the overall traffic movement on County Road 20, no further consideration of traffic associated air emissions was completed for that site. Since the traffic associated with the Agriville site, will not change, and in fact might be reduced when wood is no longer used on site, no further consideration of air emissions associated with vehicles was conducted for that site.



#### **4.4.2 Construction Activities**

At the Agriville Site construction activities will be limited to the installation of the silo base and the pellet unloading system. At Southshore, new silos will need to be installed along with the construction of the new co-generation facility. REMASCO constructed the existing building on the Southshore site in approximately 10 weeks. Much of this time was spent erecting steel, covering the steel and dealing with the roof and roof penetrations to accommodate the various pieces of equipment installed in the building. The actual construction of the foundations and the floor slab that required site clearing and compaction to carry the various loads was accomplished over a 2 week period.

It is anticipated that the co-generation building will take 3 months to construct, during which the high activity period that has a potential to generate dust emissions will be less than 4 weeks. At Agriville the unloading pad construction will likely require 2 weeks to complete.

Dust emissions during construction activities could have a temporary effect on local air quality. These emissions are associated with land clearing, excavation and equipment travel on site. When estimating emissions from such activities it is generally accepted that emissions will be proportion to the disturbed land area and the level of construction activity. Furthermore, such activities occur during normal work days, and are limited to daylight hours. Such emissions depend largely upon the nature of the soil in the area, and the amount of precipitation that occurs during the construction period. Should dust generation lead to offsite dust impacts, REMASCO will undertake to employ wet suppression measures to limit dust levels.

Given that much of the land in the area of both sites is crop land, local fugitive dust sources are anticipated to create periods of high dust loadings to the atmosphere.

Vehicles associated with construction activities will produce exhaust emissions from fuel combustion. Some construction activities, welding and surface finishing, can affect air quality in the construction area but these effects are unlikely to be noticed off site. Limiting periods of long term idling and ensuring the contractor's equipment has been properly maintained goes a long way towards minimising any construction related impacts.

Given that the construction activities are not anticipated to be of long duration, nor would they be any different than other construction activities in the community, the minor, transitory nature of their associated emissions were not modelled. Under O.Reg. 524/98 emissions from construction activities are exempt from the Ontario Certificate of Approval process.

#### **4.4.3 Decommissioning of the Site**

Boilers housed in buildings at greenhouse facilities would typically be refurbished with new equipment at the end of the boilers effective life. Typical equipment life would be expected to be on the order of 20 – 25 years with appropriate maintenance activities. As such it is unlikely that the boiler facilities would be decommissioned until such time that the greenhouses were no longer viable operations. At that time decommissioning of the REMASCO facilities would involve equipment and

building removal and redevelopment of the sites. The portion of these activities associated with the REMASCO facilities that cover a very small portion of the greenhouse sites is considered insignificant compared to the large scale rehabilitation of a 120 acre greenhouse area and thus are not considered any further in this study.

## 5.0 Facility Design and Mitigation Measures

### 5.1 Construction Emission Control

Emissions from construction and demolition activities are covered by Ontario Regulation 419/05, Section 37 as follows:

37. Except for heat, sound, vibration or radiation, no person shall,
- (a) construct, alter, demolish, drill, blast, crush or screen anything or cause or permit the construction, alteration, demolition, drilling, blasting, crushing or screening of anything so that a contaminant is carried beyond the limits of the property on which the construction, alteration, demolition, drilling, blasting, crushing or screening is being carried out; or
  - (b) sandblast or permit the sandblasting of anything so that a contaminant is emitted into the air, to an extent or degree greater than that which would result if every step necessary to control the emission of the contaminant were implemented. O.Reg. 419/05, s.37.

The important part of this legislation is the *“carrying of contaminants beyond the limits of the property”* and dust clearly fits the definition of a contaminant in O.Reg. 419/05.

The contractor will be responsible for ensuring that visible dust emissions do not leave site, and that material tracked from the site does not create significant dust emissions. Typically, the Owners include environmental controls practices in their construction contracts. With respect to air contamination these contract documents include measures that are aimed at limiting the amount of dust released during these activities. Contracts can include requirements to undertake air monitoring studies to address issue of particular concern with respect to worker health and safety. Any measures that will be applied during such contracts would be addressed in an Environmental Controls and Methods Plan that would be required to be developed by the contractor before any construction activities commence. Elements that could be included in such plans are discussed in the following paragraphs. Several references for such controls are available, but the material was drawn largely from a report prepared for Environment Canada<sup>18</sup>.

Watering areas of the site in order to minimize fugitive dust generation from vehicular traffic is considered to be the first measure that should be considered. The application of water to open soil will provide at least a 50 percent reduction in fugitive dust emissions from unpaved roads. Vehicle speeds on such roads should be controlled to further limit the amount of dust liberated.

Whenever feasible, contractors should consider seeding and mulching of construction areas when work in the vicinity of the areas is completed.

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<sup>18</sup> Cheminfo Services Inc., 2005. Best Practices for the Reduction of Air Emissions From Construction and Demolition Activities. A report prepared for Environment Canada, Transboundary Issues Branch in conjunction with the Construction and Demolition Multi-stakeholder Working Group. Available at: <http://www.bieapfrempp.org/Toolbox%20pdfs/EC%20-%20Final%20Code%20of%20Practice%20-%20Construction%20%20Demolition.pdf>

Particular attention must be paid to limiting the amount of material tracked off site. Techniques include removing material from truck underbodies and tires prior to leaving the site and removing mud/dirt trackout/carryout from paved streets at the access point(s). There are a number of alternatives for limiting track out. These start with the design of roads leaving the construction areas. By either paving or constructing gravel strips for ingress and egress from the sites, tracking can be reduced. Anywhere on site that extensive haul distances are contemplated for some duration these surfaces should be treated in the same manner. These design features will limit mud and dirt deposits on public paved roads because the tires will be self cleaned before vehicles move onto paved public roads. The referenced report suggests that the paved surface should extend at least 30 meters into the site and be at least 7 meters wide (23 feet wide).

Mud and dirt deposits accumulating on paved interior roads should be removed often but at least once per workday, to prevent carryout and trackout onto paved public roads. If a gravel bed is to be used it should consist of washed gravel, rock, crushed rock or other low silt (<5%) content material, that is at least 2.5 cm in size, but 7.5 cm diameter material would be preferred. The gravel bed should cover the full width of the unpaved exit surface and be at least 7 meters wide and at least 15 meters long and a minimum of 6 inches deep. To maintain the effectiveness of the gravel bed, it should be re-screened and washed periodically followed by regarding so at least the top 15 cm do not contain significant soil.

Operating restrictions on the site can further minimize trackout/carryout. Such measures include:

1. confining load-in/load-out procedures to leeward (downwind) side of the material;
2. designating a single site entrance and exit; and
3. ensuring that vehicles stay on established traffic routes within the construction site.

Regardless of how well controlled the site is, there is likely to be material tracked out on to public roads. Any accumulation of mud, dirt or similar debris on these roads should be removed daily. Cleaning should be initiated immediately if the trackout/carryout extends more than 10 metres onto the paved public road. Mud and dirt accumulated on on-site paved roads should be removed frequently to limit trackout/carryout onto the paved public roadway. Any vehicle waiting areas on site should also be kept clean.

Street cleaning should be accomplished with a motorized rotary brush or broom accompanied with or preceded by sufficient wetting; or by vacuum sweeping. If wet systems are used, the runoff should be controlled so it does not saturate the surface of the adjacent unpaved haul road. The report recommends that street sweeping technology be selected to minimize water use while maximizing dust collection. It is suggested that because vacuum sweepers are more effective in removing smaller, finer soil particles, they are replacing conventional broom sweeping technology.

There is a potential for wind erosion to liberate dust from the site. Large areas of exposed soil can be scoured by the wind and dust will be entrained into the moving across the site. To minimize this, porous wind breaks that act to reduce wind velocity and allow the particles to settle before moving

off site can be installed. Furthermore, where possible the contractor can create wind breaks where appropriate.

The guidelines should also include guidelines to minimize the potential for minimizing impacts from diesel powered construction equipment such as:

1. Selecting construction equipment to be used on site based upon low emission factors and high energy efficiency.
2. Ensuring that all construction equipment is tuned and maintained in accordance with the manufacturer's specifications.
3. Using only ultra low sulphur fuel for diesel engines and ensuring that such equipment is equipped with diesel particulate matter traps to reduce particulate matter emissions.
4. Utilizing electric or diesel powered equipment, in lieu of gasoline powered engines, where feasible.
5. Ensuring that construction plans include a statement that work crews will shut off equipment when it is not in use.
6. During smog alerts (May through October), measures should be taken to ensure that diesel equipment use is optimized to reduce the emissions of smog forming substances.
7. Whenever possible, time the construction activities so as to not interfere with peak hour traffic and minimize obstruction of through traffic lanes adjacent to the site; if necessary, a flagperson shall be retained to maintain safety adjacent to existing roadways.
8. Support and encourage ride sharing for the construction crew.

## **5.2 Operations Emissions Control**

The facility will be designed, constructed and operated in accordance with good engineering practice, generally accepted industry standards and currently applicable codes and regulations. The nature of the facility, including the use of flue gas recirculation to minimise emissions, requires that the flue gas be cleaned to an acceptable level for re-use in the combustion system. Since dust and contaminants in the flue gases could be detrimental to fans, nozzles and other components in the combustion system, the fabric filter employed before the stack exhaust will reduce particulate loads to below the level specified in Guideline A-7. Similarly, since the facility must meet A-7 during operation, other contaminants such as hydrogen chloride, acid gases, and PCDD/F will be controlled.

Control is achieved through a combination of combustion control, the staged combustion zones that are unique to the REMASCO system, the addition of reagents to control acid gases and PCDD/F emissions, and the use of a fabric filter to control particulate matter in the gas stream. This system is described in the §4.1.3 of this report. The furnace exposes the flue gases to temperatures in excess of 1,000°C for at least 1 second. This is an operating condition that is maintained during all ENERPAX pellet feeding.

As noted elsewhere monitoring requirements are typically a part of any Certificate of Approval issued by the MoE. Moreover, for facilities that burn waste materials the monitoring requirements are typically more stringent. Process monitoring installed as part of each system is described in the

process description in the section referenced above. In addition, REMASCO currently undertake daily testing for NO<sub>x</sub>, HCl, and SO<sub>2</sub> using approved monitoring systems. REMASCO propose to continue to monitor NO<sub>x</sub> and HCl using the same procedures, but are proposing to the MoE that since the sulphur content of the pellets is consistent, and the HCl monitoring tracks the performance of the acid gas control system that SO<sub>2</sub> monitoring be removed from the requirements. The sampling equipment and procedures will continued to be used to monitor flue gases in the five stacks that will be in operation when the full system is completed. Personnel will be assigned to collect these data on a regular schedule.

In some operations fugitive emissions from material handling operations can create impacts. Typically these emissions would occur from fuel and residue handling operations.

The pellets contain little loose material, and are not friable which limits the potential for unloading operations to create dust emissions. The unloading areas are enclosed to limit the potential for wind to pick up and scatter any dust from the pellets. All pellet transfer operations are enclosed.

Residue from the gasifier is water quenched limiting the potential for dust emissions from this source. It is transferred, inside the building, to a lugger bin that carries the material to the disposal site. The bin is covered during transfer operations.

The APC system residue is a fine powdered of spent reagents and particulate matter removed in the fabric filter. The dust is removed from the bags as necessary and transferred to an air-tight lugger bin thereby minimising any dust release from the fabric filter and APC residue handling system. The bin carries the materials to the disposal site.

## **6.0 Modelling the Release of Contaminants into the Atmosphere**

### **6.1 *Background and Introduction to Air Modelling***

Any time fuel is burned, contaminants are released to the atmosphere. These releases add to the amount of materials that is present in the environment. The contaminants disperse as they move downwind and eventually settle to the ground.

If you observe the plume from a stack, you will see it move downwind and spread both vertically and horizontally along the plume centerline. Much of what we see is water vapour which eventually evaporates into the atmosphere and is no longer visible. If the plume contains a great deal of particulate matter, the plume will persist for much longer but will appear to get less dense as the plume spreads. The degree of spread depends upon the speed of the wind which stretches the plume in the downwind direction. A highly turbulent atmosphere will cause the plume to be mixed with the surrounding air in the vertical and across plume direction. The spreading reduces the concentration of contaminants in the plume and the plume becomes invisible. The speed of the wind and the amount of mixing are a function of atmospheric conditions, wind speed, wind direction, the amount of solar energy hitting the surface, and the amount of turbulence present in the atmosphere.

Other factors limit the plume spread. The vertical spread can be limited by a layer of stable air above the ground surface which has little of the inherent turbulence needed to promote mixing. While the plume continues to be stretched in the downwind direction, vertical spread is limited and the contaminants have a higher concentration than would occur if the vertical mixing were stronger. Most of the time though, there is little practical limit to the vertical mixing, particularly with relative low stacks.

Low stacks also bring other factors into play and these affect the plume's behaviour. As the wind moves over a building, areas of recirculation can be set up downwind of the building, and materials can be trapped in this recirculation zone and increase in concentration. If the stack is not high enough, the plume can get trapped in this recirculation zone. Eventually, the materials in this downwind zone settle on the ground as, for the most part, they are influenced by gravity.

Based upon detailed study of the behaviour of plumes, scientists have developed mathematical models that predict the distribution of contaminants released for a source. These models use historic weather data for the area where the source is located to define the downwind, cross-wind and vertical mixing that dilute the concentrations in the plume. Typically the models assume that there are no removal or conversion processes in the atmosphere, however some models include algorithms describing these effects. If there are no removal or conversion reactions, the output concentration data from the model is proportional to the emission rate from the source. If all the sources being considered have similar emission rates, it is possible to run the model for a typical emission rate and calculate the concentration for any contaminant by using the ratio of the modeled release rate to that of the contaminant of interest. Using this approach, and assuming that the emission conditions: stack height, stack gas exit velocity, and stack gas temperature are the same regardless of the fuel used, the



ambient concentration of the contaminants listed in Table 15 would be proportional to the ratio between the different emission factors.

Typically the models are used to estimate the ambient concentrations of contaminants associated with new sources. These are generally referred to as point of impingement [POI] values. In Ontario, the MoE has developed a set of standards for different contaminants based upon these POI values. These are listed in various tables in O.Reg. 419/05, sub-titled Air Pollution - Local Air Quality. If the model predicts values that exceed the POI values, the proponent has to take measures to reduce the rate at which contaminants are released from the stack. Values lower than the standards are generally judged to be acceptable, provided the emission estimates are conservative, or unlikely to be exceeded for any substantial period of time. POI estimates that are very low compared to the standards are assumed to indicate that there is little possibility of effects from the contaminant.

As part of the studies being conducted for the REMASCO facilities, the emissions from the stacks associated with the two sites were modelled with an advanced algorithm approved by the MoE. The objective of the modelling was to determine annual deposition levels for contaminants that could be emitted from the stacks at the two facilities as well as providing point of impingement estimates for comparison to the O.Reg. 419/05 criteria. Deposition modelling requires consideration of the local terrain and meteorological conditions as well as characterisation of the particles that are released from the sources. Modelling was completed using the US EPA approved AERMOD model.

The model will also form part of the application REMASCO must file with the MoE to obtain approval to build the facility. The detailed modelled results are discussed later in this report, and their interpretation as part of the Health Risk Assessment is presented in a separate report.

The modelling results considered by the Health Risk Assessment identified that NO<sub>x</sub> and particulate matter are the contaminants that the modelling shows produce values that are closest to their applicable limits. Since NO<sub>x</sub> emissions will occur at some level from all combustion devices the modelling runs were extended to examine the effects of the existing boilers installed in the Kingsville area, and the changes that are anticipated to occur when the REMASCO facilities replace the existing boilers at the Southshore, Mucci, and Agriville facilities. The assumptions and methods used to these comparisons are discussed in this section of the report.

## **6.2 AERMOD Algorithm Overview**

Simulating the mixing and dispersion of exhaust gases released to the atmosphere involves describing these processes by way of parameters developed from laboratory and field experiments. The majority of dispersion occurs in the Planetary Boundary Layer of the atmosphere. This is the zone of turbulent air next to the earth's surface that is influenced by surface heating and the nature of the surface. This layer is also affected by the presence of stable air masses above it. Motion in this region is governed by surface roughness which creates friction in the lower layer and increases atmospheric turbulence. This turbulence increases the mixing of the plume with the atmosphere thereby reducing the concentrations of contaminants as the plume moves downwind. Increased turbulence can cause



materials to remain suspended in the atmosphere for longer periods of time but in some circumstances the nature of the surface can deplete the materials at a faster rate.

The height of the planetary boundary layer varies depending upon the time of day, 1 to 2 km during the day and a few hundred meters at night. The movement in the atmosphere can be described in terms of a convective boundary layer and a stable boundary layer. The convective layer has a vertical structure and turbulence scales that were defined through experiments earlier than were the factors that describe the stable boundary layer. Both conditions are incorporated into the latest dispersion modelling algorithms.

The algorithms use eddy-diffusion techniques to describe surface releases, statistical theory and planetary boundary layer scaling for dispersion parameter estimation, and a probability density function to describe motion in the convective boundary layer. These factors are related to meteorological variables (e.g., surface heat flux) that govern turbulence parameters and simple techniques have been developed to describe these factors.

As the general level of knowledge advanced there were opportunities to improve the dispersion model and the AERMOD algorithm represents current state of the art for such models. It was developed under the direction of the American Meteorological Society and the US EPA. It contains improvements in the description of the planetary boundary layer turbulence, plume interaction with the terrain, building downwash and dispersion over urban areas. The AERMOD model addresses short-range dispersion for industrial sources. It replaces the older Industrial Source Complex model that had been used as the regulatory standard model for many years.

Relative to the older ISC3 model, AERMOD contains new or improved algorithms for:

1. dispersion in both the convective and stable boundary layers;
2. plume rise and buoyancy;
3. plume penetration into elevated inversions;
4. computation of vertical profiles of wind, turbulence, and temperature;
5. the urban night time boundary layer;
6. the treatment of receptors on all types of terrain from the surface up to and above the plume height;
7. the treatment of building wake effects;
8. an improved approach for characterizing the fundamental boundary layer parameters; and
9. the treatment of plume meander.

AERMOD is a modelling system that consists of two pre-processors and the dispersion model. A pre-processor for the meteorological data (AERMET) generates the data necessary to characterise the planetary boundary layer while the terrain pre-processor (AERMAP) is used to provide the surface characteristics that the model requires and to develop the receptor grids used by the model.

AERMET uses meteorological data and surface characteristics to calculate boundary layer parameters (e.g. mixing height, friction velocity, etc.) needed by AERMOD. This data, whether measured off-site or on-site, must be representative of the meteorology in the area being considered. AERMAP uses

gridded terrain data for the modeling area to calculate a representative terrain-influence height associated with each receptor location.

While for most locations in the United States, this data can be derived from the Digital Elevation Model (DEM) data produced by the United States Geological Survey (USGS 1994), similar data is not readily available for the Kingsville area. These parameters were defined as part of this project, as described later in this report. The terrain pre-processor computes elevations for both discrete receptors and receptor grids.

AERMOD requires certain data to describe the system that needs to be modelled. Inputs include:

- Emission characteristics;
- Deposition parameters;
- Building information;
- Meteorological data; and,
- Terrain characteristics.

Each of these aspects is addressed in the following sections with specific reference to this project.

### **Emissions**

**REMASCO** - The model allows one to specify the type of sources (point, area, volume). The REMASCO stacks were defined as point sources.

Point sources are defined in terms of the size of the stack (diameter, height); the stack gas characteristics (volumetric flow, and temperature); and, the rate of release of different contaminants in grams per second. As discussed in §4.2, the emissions data for the facilities was developed from the stack sampling conducted according to MoE direction.

The flow and emission data from the 2010 testing program formed the basis of the emission characteristics entered into the model, except as pointed out earlier for HCl where the A-7 emission limit was used for the modelling. The heating output of the boiler during testing was 400 Boiler HP and the actual stack flow rate was 3.45 m<sup>3</sup>/s. Assuming the stack flow is proportional to the boiler output, the flow can be adjusted by pro-rating the test value to the actual operating rate required for the month as described in the Operating Scenarios in §4.2.2. Table 13 lists the stack gas volumetric flow for the different months at the Southshore facility, and Table 12 provides the same data for Agriville.

As noted in the discussion of Tables 12 and 13 earlier in the report, the characterisation of the stacks was associated with the monthly operating scenarios. That is, for each month of the year, the operating conditions in each of the 7 stacks associated with the REMASCO operations were determined, and the stack was modelled as operating at that rate for the complete month. Thus the flow from the stacks was assumed to vary on a monthly basis and with that the velocity of the gases exiting the stack were assumed vary. The flows and velocities are shown in Tables 12 and 13 by

month based upon all stacks being 0.81 m in diameter with the exception of the stack for the three low pressure units at Southshore which was 0.91 m in diameter. All REMASCO stacks were modelled with a height of 21.34 m above grade. The stack exit temperature under all operating conditions was assumed to be 142°C or 288°F, typical of stack gas temperatures during testing.

The emission data in Tables 8, 9 and 10 represent the various contaminant emission rates derived from the operation of one 400 HP boiler at 100% load [19.127 MMBtu/hr input and 3.45 Am<sup>3</sup>/s flow]. The emission concentration measured during the testing was assumed to be representative of the performance of the systems regardless of the load on the gasifier. This implies that the emission rate will vary as the exhaust flow changes because the emission rate is the product of the flow and the concentration. While the approach discussed in the paragraphs above accounts for the changes in dispersion induced by different stack flow rates but does not address the changes in emission rate.

The emission rate variations are proportional to the flow based upon the assumption of constant concentration, thus for each stack operating condition a specific emission rate can be calculated based upon the flow from the 400 boiler HP load situation.

The mathematics of the dispersion model directly link the predicted concentrations to the emission rate. That is, if the emission rate were to double, the model would predict that the concentration at the receptors would be twice as high. This relationship allows the modeller to undertake a single model run and simply multiply the output by the ratio of the emission rate to the modelled emission rate. When modelling multiple sources though one must be careful to use the appropriate unit emission rate in the model. In this case, the unit emission rate was assumed to be that of one 400 boiler HP gasifier and all the operations were related to this situation. For a stack with two 500 boiler HP gasifiers on line, the unit emission rate was 2.5 – simply the ratio of the installed capacity to the base capacity (1000/400=2.5). As the flow varies, the unit emission rate was reduced to reflect this relationship. The unit emission rate of 2.5 was applied to the co-generation stacks at Southshore and the stacks at Agriville. The unit emission rate for the full load at the existing Southshore facility is 3.25 since the total capacity is 1300 boiler HP. This was simply adjusted for each flow situation.

To allow the predicted concentrations for all the contaminants to be calculated the values resulting from the unit emission rate were multiplied by the actual emission rate in Tables 8, 9 and 10 to determine the point of impingement values for each contaminant.

**Existing Greenhouses** – For the assessment of the cumulative effects for NO<sub>x</sub> and particulate matter particularly PM<sub>2.5</sub> it is necessary to establish emission rates for the existing greenhouses. The emission rate [g/s/ha] developed in Table 14 can be combined with the area of the greenhouses under consideration to develop gram per second emission rates. These emission rates are shown in Table 15. However since the results of this modelling were combined with those of the REMASCO stack, the unit emission rate could not be used for the REMASCO stacks under the different monthly scenarios. For the REMASCO sources, the cumulative assessment model used the actual emission rate for each REMASCO stack under that operating condition.

It was assumed, for the purposes of modelling, that the existing greenhouse stacks were located in the centre of a square that circumscribed most of the greenhouse space of the associated stack. Since the actual configuration for each stack was not available, the stacks were assumed to be free standing with no building surrounding them. The height of the stack was assumed to be 16 m above grade. Based upon an inspection of the various greenhouses it was estimated that the stacks on the facilities that were burning wood or coal were about twice the height of their associated greenhouses. Typically, the peak of the greenhouses is approximately 7 m above grade. Without the exact details of the various greenhouses, they were not introduced into the model and the effects of the buildings on the plume were not considered for any greenhouses other than the existing REMASCO systems.

For all the facilities, the exhausts were approximated by large diameter, low velocity discharges typical of gas and oil fired systems. This approach compensates for the presence of caps on the stack. Most gas fired boilers have stacks that are equipped with a cap to eliminate rain water entering the stack. Oil furnaces may also have caps to reduce the chance of rain entering the flue. Such caps reduce the velocity of the gases leaving the stack and the plume's momentum; however the heat of the gases is maintained so that thermal buoyancy is still a factor in the plume's rise. The model uses the stack gas exit velocity and temperature to define plume rise. To address the effect of the caps, the MoE recommends that the exit velocity be entered as 0.01 m/s so there is a limited momentum effect. To determine the size of the stack, it is necessary to estimate the flow from the boiler.

The approximate stack diameter was estimated based upon the selected exit velocity and the volumetric flow rate in the stack at actual conditions. This was calculated as follows. It is accepted that 10 ft<sup>3</sup> of air are required to release 1000 Btu. Translated to the typical 3.31 MMBtu/hr/ha of greenhouse this would be 33,100 ft<sup>3</sup> air/hour. However, this relationship holds only for stoichiometric combustion when the air is perfectly matched to the amount of fuel burned. Typically boilers operate somewhere in the range of 70% excess air [8.5 to 9.5% CO<sub>2</sub>] or 1.7 times more air than determined by the stoichiometry. Furthermore, these volumes are at standard conditions and the volume must be adjusted for gas temperatures different than the standard condition of 15.56°C. This is accomplished based upon the ratio of the absolute temperatures, ie

$$\text{Temperature correction} = (T_{\text{exit}} + 273.15)/(273.15 + 15.56)$$

If the flue gas temperature is assumed to be 180°C for all the heating equipment, the standard condition flow needs to be increased by 1.5697 times to get an actual flow rate. In effect, this brings the actual stack gas flow to 88,327 ft<sup>3</sup>/hr or 0.695 m<sup>3</sup>/s/ha. The total flow from a greenhouse complex can be assumed to be released from one stack for the purposes of this evaluation. Thus the number of hectares of greenhouse associated with any site can be multiplied by the factor above to estimate the exhaust gas flow rate.

Given that the exit velocity was specified, dividing the flow rate [m<sup>3</sup>/s] by the exit velocity, 0.01 m/s, defines the area of the stack [m<sup>2</sup>]. The stack diameter can be calculated by taking the square root of the volumetric flow rate divided by the assumed exit velocity and multiplying it by 4/π. The result is shown in the last column of Table 16. For the large facilities, the calculated stack diameter exceeds the

maximum allowed by the model, 30.48 m or 100 ft. The exit velocity from those facilities was increased to maintain the maximum stack diameter.

As discussed for Agriville and Southshore, the greenhouse heating systems in the other facilities are not expected to operate at full load the year round. The operating scenarios developed for Agriville and Southshore, based upon heating demand records at Southshore, were used for the other greenhouses too. This scenario assumes that over the 12 months of the year the output from the boilers can be varied to meet load requirements. In January and February they run at 100% of the installed load and this decreases to 27% in July and August. For each month it was assumed that the boilers in all the facilities would operate at the load capacity for the whole month regardless of the changes in ambient conditions. This represents close to the worst case condition. There might be occasions when extra capacity in the greenhouses might need to be operated, however these are short term situations, typically at night when it is colder and the thermal momentum of the plumes will be greater. It was assumed that this extra online capacity would have little effect on the maximum estimated POI values.

Table 16 Emission Summary (NO<sub>x</sub> and Particulate Matter) for Existing Greenhouses

Source	Label	UTM Coordinates of Centre of Greenhouse Complex		Stack Height [m]	Greenhouse Area [ha]	Stack Flow [m <sup>3</sup> /s]	Exit Diam. 0.01 m/s Velocity [m]	NO <sub>x</sub> ER [g/s]	PM ER [g/s]	PM10 ER [g/s]	PM2.5 ER [g/s]
		X	Y								
A1	E1	357700	4656075	16	7.257	5.06	25.38	5.62E+00	4.97E+00	3.69E+00	2.25E+00
A2	E2	358000	4656025	16	4.007	2.79	18.86	3.10E+00	2.75E+00	2.04E+00	1.24E+00
A3	C2	358250	4656500	16	17.44	12.16	39.34	1.35E+01	1.19E+01	8.87E+00	5.42E+00
A4	B5	358660	4656725	16	1.8	1.25	12.64	1.39E+00	1.23E+00	9.16E-01	5.59E-01
A5	G6	358900	4655375	16	1.4	0.98	11.15	1.08E+00	9.59E-01	7.12E-01	4.35E-01
A6	G8	359350	4655675	16	7.14	4.98	25.17	5.53E+00	4.89E+00	3.63E+00	2.22E+00
A7	E8	359550	4656175	16	7.06	4.92	25.03	5.47E+00	4.84E+00	3.59E+00	2.19E+00
A8	E10	359825	4655825	16	1.8	1.25	12.64	1.39E+00	1.23E+00	9.16E-01	5.59E-01
A9	B14	360950	4656875	16	3.94	2.75	18.70	3.05E+00	2.70E+00	2.00E+00	1.22E+00
A10	C14	360975	4656550	16	8.72	6.08	27.82	6.75E+00	5.97E+00	4.44E+00	2.71E+00
A11	D14	361075	4656150	16	3.24	2.26	16.96	2.51E+00	2.22E+00	1.65E+00	1.01E+00
A12	E14	361050	4655900	16	3.5	2.44	17.62	2.71E+00	2.40E+00	1.78E+00	1.09E+00
A13	F14	361000	4655675	16	3	2.09	16.32	2.32E+00	2.06E+00	1.53E+00	9.32E-01
A14	F16	361425	4655700	16	1.89	1.32	12.95	1.46E+00	1.29E+00	9.61E-01	5.87E-01
A15	E17	361750	4656010	16	3.71	2.59	18.15	2.87E+00	2.54E+00	1.89E+00	1.15E+00
A16	H18	362060	4655350	16	4.1	2.86	19.07	3.17E+00	2.81E+00	2.09E+00	1.27E+00
A17	F19	362250	4655850	16	12.42	8.66	33.20	9.61E+00	8.51E+00	6.32E+00	3.86E+00
A18	H21	362650	4655325	16	6.38	4.45	23.79	4.94E+00	4.37E+00	3.25E+00	1.98E+00
A19	F21	362675	4655675	16	4.14	2.89	19.17	3.20E+00	2.84E+00	2.11E+00	1.29E+00
A20	E22	363050	4656010	16	1.85	1.29	12.81	1.43E+00	1.27E+00	9.41E-01	5.75E-01
A21	F23	363200	4655650	16	1.34	0.93	10.90	1.04E+00	9.18E-01	6.82E-01	4.16E-01
A22	F24	363425	4655615	16	3.4	2.37	17.37	2.63E+00	2.33E+00	1.73E+00	1.06E+00
A23	F25	363740	4655625	16	3.764	2.62	18.28	2.91E+00	2.58E+00	1.91E+00	1.17E+00
A24	E26	363800	4655850	16	2.34	1.63	14.41	1.81E+00	1.60E+00	1.19E+00	7.27E-01
A25	A24	363450	4656850	16	1.2	0.84	10.32	9.29E-01	8.22E-01	6.10E-01	3.73E-01

Highlighted sources will be replaced by the REMASCO facilities.

### **Deposition Parameters**

The model considers the particle size distribution of the emissions during the deposition modelling. The fate of various contaminants that are emitted in particulate form from the facility were the focus of this study. To model their release it was necessary to make assumptions about the nature of the emissions of these contaminants.

AERMOD provides estimates for both dry and wet deposition using either a well defined particle size distribution, or applying an assumption that the contaminant of interest is predominantly emitted as particles that are smaller than 10 microns. The AERMOD guides suggest that the second method be used when less than 10% of the particulate matter is greater than 10 microns in size. There was no specific test data for particle size distributions from the fabric filter dust control system used by REMASCO. However, the use of fabric filters in the APC systems will result in predominantly fine particulate matter being released from the stacks. Moreover, combustion in the system occurs in stages providing more opportunity to reduce the size of unburned particles. This conclusion prompted the decision to use Method 2 for this study.

Method 2 models dry deposition by using a deposition velocity for the fine fraction <2.5 microns and the coarse fraction <10 microns and >2.5 microns. For the fine fraction, the velocity is based upon parameters derived from sulphate dry deposition studies. For the coarse fraction, a representative settling velocity is applied. The results of deposition calculations are combined in proportion to the mass of the contaminant in both size ranges. Representative mass median diameters for use in AERMOD are listed in a reference document cited by the AERMOD guidance documents<sup>19</sup>. Wet deposition is accounted for by a washout ratio that is proportional to the mass median diameter of the particulate size splits.

The reference provides the particle size information for selected hazardous air pollutants based upon measurement of these contaminants in the atmosphere. Numerous references are cited and preferred values are identified in the list. In summary, the fine particulate matter mass and the mass median diameter for different contaminants are listed in Table 17.

Table 17                      Summary of Particulate Characteristics

Contaminant	Fine Particle Mass [%]	Mass Median Diameter [um]
Antimony, Nickel, Chlorides	60	1
Arsenic, Lead, Cobalt	75	0.5
Cadmium	70	0.6
Chromium	55	1.2
Manganese	45	1.8
Mercury	80	0.4
PAH	93	0.1
PCDD/F	90	0.1

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<sup>19</sup> Wesley, M.L., P.V. Doskey and J.D. Shannon, 2002. Deposition Parameterizations for the Industrial Source Complex (ISC3) Model. ANL/ER?TR-01/003. <http://www.epa.gov/ttn/scram/7thconf/aermod/driscdep.zip>



### **Buildings**

Depending upon the height of the stacks and the buildings the winds moving over the building can change the nature of the plume dispersion close to the stack. Typically this occurs in situations where the plume becomes trapped in the zones of recirculation that occur on the roof of buildings, or on the downwind side of buildings. In most cases these interferences are limited if the stack is high enough above the top of the building. The AERMOD model incorporates the Building Profile Input Program [BPIP] which addresses these issues.

The BPIP uses the Good Engineering Practice [GEP] formulations to determine whether or not a stack will be subjected to wake effects from a structure or structures. The GEP stack height, related Building Height [BH] and Projected Building Width [PBW] is used to define the interaction between the plume and building wake effects are determined first part of BPIP. A second part re-calculates building downwash BH's and PBW's if a stack is being influenced by structure wake effects. Output from BPIP is used as an input for the building downwash algorithms used in AERMOD.

The inputs to BPIP are the relative location and height of various structures around the REMASCO sites. Buildings that are basically rectangular boxes of a certain height are described by the coordinates of the corners and the height of the building. Since the predominant buildings adjacent to the stacks are greenhouses, these were simply input at rectangular buildings with flat roofs.

The building areas were developed from the Kingsville Interactive Map as described in §4.3.

### **Meteorological Data**

The AERMOD model requires meteorological data to describe the atmospheric conditions governing dispersion. Typically these data are based upon information collected at an official weather station in the vicinity of the project, or from a weather station erected at the site. On site meteorological data was not available for the site, and considering that it is typical to run the model with 5 years of hourly data, it could not be collected for this study. The MoE provide "typical" meteorological data sets for different areas of the province and these can be used in the model. For southwestern Ontario the MoE's "typical" site is based upon London data. Along with the meteorological data the MoE data sets also provide default factors for surface roughness, albedo and Bowen Ratio for the area. These factors are discussed later in this section.

Recognizing that the presence of the lake in close proximity to the site will influence the wind direction and speed at the site, it was considered appropriate to examine whether the London data was suitable for the site. Since the nearest weather station to the site was Windsor, that data was used for comparison to the wind direction and speed data for London. The data are summarized in Table 18. The data are taken from the Environment Canada Climate Normals.

Table 18 Comparison of Wind Speed and Direction Data from the Climate Normals

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
London													
Avg Speed	18.5	16.7	17.3	16.6	14.3	12.5	10.9	9.9	11.5	13.8	16.3	17	14.6
Direction	SW	W	E	W	W	W	W	W	NW	W	W	SW	W
Windsor													
Avg Speed	19.3	18.1	18.8	18	15.6	14.2	12.6	11.6	15.3	17.4	17.5	17.5	16
Direction	SW	S	S	S	S	S	S	S	S	S	SW	SW	S

The predominant wind direction in London is different from that of Windsor. The average wind speed in London is slightly lower than the Windsor values. While it is not known how much effect this would have on the resulting predictions it was considered more appropriate to use data more reflective of the Kingsville area.

Lakes Environmental supplied site specific Surface and Upper Air data for AERMET processed from MM5 data. MM5 [5th-generation Mesoscale Model] is a prognostic meteorology model developed by Pennsylvania State University and the U.S. National Center for Atmospheric Research [NCAR]. The model is a limited-area, non-hydrostatic model designed to simulate or predict mesoscale and regional-scale atmospheric circulation. The model uses "objective analysis" from the Global model, which incorporates meteorological data assimilated from conventional airport stations and satellite observations. Objective analysis is a process of analyzing the observed data and outputting it to a specified grid. The meteorological field is "balanced" to account for the energy and momentum equations of the atmosphere. These objective analyses are products of global models, which are maintained by national weather centers or federal agencies such as UKMO (United Kingdom Meteorological Office) or NCEP (National Center for Environmental Protection).

Lakes Environmental uses MM5 to produce hourly surface data files and upper air data files in a form suitable for input into the AERMET model that is a pre-processor for AERMOD. The centre of the 12 km by 12 km grid that was used for the MM5 calculations was centred at 360471.1 E and 4656246.7 N which is a point midway along a straight line joining the stack locations at the Southshore and Agriville greenhouse facilities. The data period included January 1, 2005 to December 31, 2009.

MM5 approach uses a nested grid for calculation purposes. In this way, an area of interest can be modeled without the penalty of excessive run times created by having a fine grid over the entire modeling domain. Lakes Environmental employs a 12 km grid for the AERMOD model although a finer grid can be provided for other models. The inner nested grid has 12 km spacing with 31 points in each direction (covers a 360 km x 360 km zone), the second level has 36 km spacing with 31 points in each direction (1,080 km in each direction) and the 3<sup>rd</sup> level has 108 km spacing with 23 points in each direction (2,378 km in each direction).

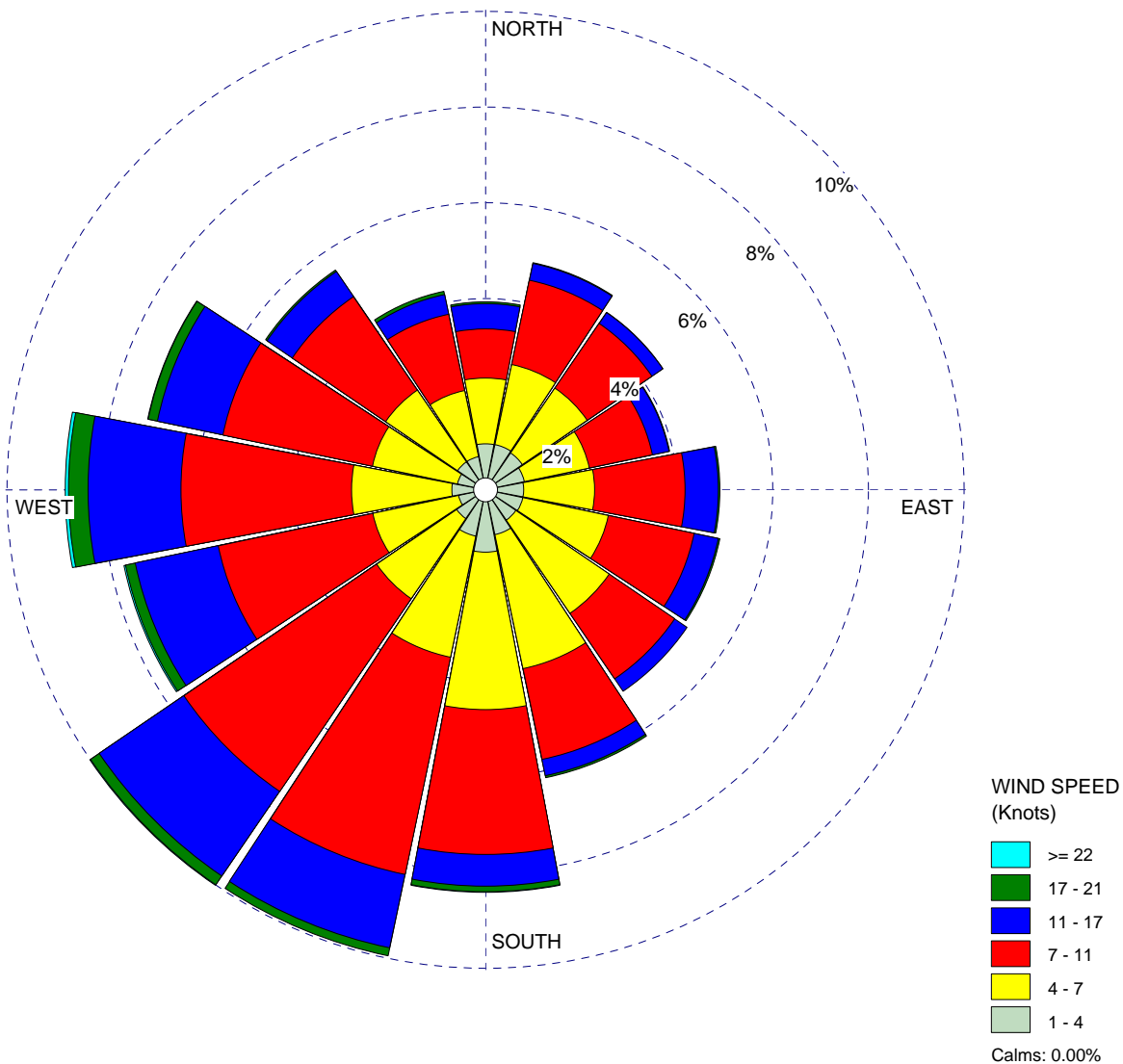
Precipitation data is created from the same data sets in the same manner. A wind rose created from the MM5 results is shown in Figure 7.

WIND ROSE PLOT:

**Figure 7 Site Specific Meteorology**  
**REMASCO Kingsville**

DISPLAY:

**Wind Speed**  
**Direction (blowing from)**



## COMMENTS:

MoE Revised Surface Wind Data  
 with 1 m/s minimum and 4.3 m/s  
 average

## DATA PERIOD:

**Start Date: 01/01/2005 - 00:00**  
**End Date: 31/12/2009 - 23:00**

## COMPANY NAME:

## MODELER:

## CALM WINDS:

**0.00%**

## TOTAL COUNT:

**43824 hrs.**

## AVG. WIND SPEED:

**7.72 Knots**

## DATE:

**30/06/2011**

## PROJECT NO.:

### **Terrain Characteristics**

AERMET requires that Surface Parameters be specified for the area around the sources. These are specified in terms of appropriate values for three surface characteristics: surface roughness length [ $z_0$ ], albedo [ $r$ ], and Bowen ratio [ $Bo$ ]. The values developed for the study are shown in Table 19.

The surface roughness length is related to the height of obstacles to the wind flow and represents the height at which the mean horizontal wind speed is zero based on a logarithmic profile. The surface roughness length influences the surface shear stress and influences the magnitude of mechanical turbulence and the stability of the boundary layer. The albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption. The daytime Bowen ratio, an indicator of surface moisture, is the ratio of sensible heat flux to latent heat flux and is used for determining planetary boundary layer parameters for convective conditions driven by the surface sensible heat flux.

The AERMOD guidance suggests that there are several sources of data for determining appropriate surface characteristics. This may include printed topographic and land use, land cover (LULC) maps, aerial photos from web-based services, site visits and/or site photographs, and digitized databases of land use and land cover data. For this study, the aerial photos from the Kingsville Interactive Maps were used.

Each of the different land uses have surface characteristics that vary by season. The MoE guidance document provides 21 different land use categories for which they provide seasonal factors for each of the characteristics. The review of the aerial photographs supplemented by some local site visits reduced the list to 8 categories: mixed forest was used because the exact nature of the trees in the wooded areas was not known; orchards/vineyards, row crops and small grains were used for the agricultural areas; the greenhouses were classified as commercial/industrial not at airports; the residential as low intensity; recreational/urban grasses was used to cover the ball diamonds west of Agriville and the lake was assumed to have open water except in the winter when the ice characteristics were substituted.

The methods employed to calculate the appropriate values for each parameter are outlined in the following paragraphs:

The determination of the surface roughness length was based upon an inverse distance weighted geometric mean for an upwind distance of 3.2 kilometer relative to the meteorological site.

The determination of the Bowen ratio was based upon a simple unweighted geometric mean (i.e., no direction or distance dependency) for a representative domain, with a default domain defined by a 3.2 km radius centered on the measurement site.

The determination of the albedo was based upon a simple unweighted arithmetic mean (i.e., no direction or distance dependency) for the same representative domain as defined for

Bowen ratio, with a default domain defined by a 3.2 km radius centered on the measurement site.

The land use was estimated on the basis of the characteristics in twelve sectors each 30 degrees wide, and for seven 470 m equally spaced zones out from the origin.

Seasons are divided into Spring; Summer; Autumn; and Winter. The seasons are not related to a particular group of months but rather relate to latitude and annual vegetative growth cycles. Spring is when the vegetation is emerging and partially green, and can be defined by the 1 – 2 month period after the last killing frost. For Kingsville the last below zero temperature readings occur in March so spring would be considered April and May. Autumn is the period with freezing temperatures after the leaves have dropped and the crops have been harvested but before snow cover is present. There is snow cover on the ground from December through February in Kingsville/Windsor, and in October the daily minimum temperature is just above freezing so October and November were defined as Autumn. June, July, August, and September were defined as Summer and December through the end of March as Winter.

As noted earlier, the airphotos on the Kingsville interactive map site were used to define the land use. In each sector the portion covered by different land uses was estimated from the aerial photo. There are numerous areas in the aerial photo that look to have plants growing in well defined rows. Site visits determined these areas were orchards or vineyards and in some cases there are some limited cedar hedges used as wind breaks.

The determinations of land use, and the calculations for each of these parameters result in the values listed in Table 19. These were introduced into AERMET in a matrix that lists the average value per sector for each of the three parameters for each month of the year.

Table 19 Surface Data used in the AERMET Program

Albedo

Sector	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
30	0.1007	0.1007	0.1007	0.0306	0.0306	0.0379	0.0379	0.0379	0.0379	0.0379	0.0379	0.1007
60	0.0986	0.0986	0.0986	0.0305	0.0305	0.0361	0.0361	0.0361	0.0361	0.0361	0.0361	0.0986
90	0.1098	0.1098	0.1098	0.0291	0.0291	0.0377	0.0377	0.0377	0.0377	0.0377	0.0377	0.1098
120	0.0857	0.0857	0.0857	0.0244	0.0244	0.0270	0.0270	0.0270	0.0270	0.0270	0.0270	0.0857
150	0.1692	0.1692	0.1692	0.0263	0.0263	0.0266	0.0266	0.0266	0.0266	0.0266	0.0266	0.1692
180	0.2296	0.2296	0.2296	0.0342	0.0342	0.0344	0.0344	0.0344	0.0344	0.0344	0.0344	0.2296
210	0.2263	0.2263	0.2263	0.0349	0.0349	0.0353	0.0353	0.0353	0.0353	0.0353	0.0353	0.2263
240	0.1084	0.1084	0.1084	0.0188	0.0188	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.1084
270	0.1073	0.1073	0.1073	0.0294	0.0294	0.0358	0.0358	0.0358	0.0358	0.0358	0.0358	0.1073
300	0.0903	0.0903	0.0903	0.0249	0.0249	0.0315	0.0315	0.0315	0.0315	0.0315	0.0315	0.0903
330	0.1172	0.1172	0.1172	0.0282	0.0282	0.0392	0.0392	0.0392	0.0392	0.0392	0.0392	0.1172
360	0.1096	0.1096	0.1096	0.0287	0.0287	0.0377	0.0377	0.0377	0.0377	0.0377	0.0377	0.1096

Bowen Ratio

Sector	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
30	0.5000	0.5000	0.5000	0.6128	0.6128	0.7942	0.7942	0.7942	0.7942	0.9784	0.9784	0.5000
60	0.5000	0.5000	0.5000	0.5036	0.5036	0.6416	0.6416	0.6416	0.6416	0.8818	0.8818	0.5000
90	0.5000	0.5000	0.5000	0.3560	0.3560	0.5260	0.5260	0.5260	0.5260	0.7522	0.7522	0.5000
120	0.5000	0.5000	0.5000	0.3668	0.3668	0.4616	0.4616	0.4616	0.4616	0.5796	0.5796	0.5000
150	0.5000	0.5000	0.5000	0.1160	0.1160	0.1202	0.1202	0.1202	0.1202	0.1231	0.1231	0.5000
180	0.5000	0.5000	0.5000	0.1092	0.1092	0.1107	0.1107	0.1107	0.1107	0.1117	0.1117	0.5000
210	0.5000	0.5000	0.5000	0.1155	0.1155	0.1192	0.1192	0.1192	0.1192	0.1217	0.1217	0.5000
240	0.5000	0.5000	0.5000	0.1344	0.1344	0.1496	0.1496	0.1496	0.1496	0.1632	0.1632	0.5000
270	0.5000	0.5000	0.5000	0.3290	0.3290	0.4941	0.4941	0.4941	0.4941	0.6645	0.6645	0.5000
300	0.5000	0.5000	0.5000	0.4439	0.4439	0.6360	0.6360	0.6360	0.6360	0.8344	0.8344	0.5000
330	0.5000	0.5000	0.5000	0.3148	0.3148	0.4937	0.4937	0.4937	0.4937	0.7116	0.7116	0.5000
360	0.5000	0.5000	0.5000	0.4231	0.4231	0.5510	0.5510	0.5510	0.5510	0.8084	0.8084	0.5000

Surface Roughness

Sector	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
30	0.0577	0.0577	0.0577	0.1320	0.1320	0.3014	0.3014	0.3014	0.3014	0.3014	0.3014	0.0577
60	0.0906	0.0906	0.0906	0.1680	0.1680	0.3452	0.3452	0.3452	0.3452	0.3452	0.3452	0.0906
90	0.0408	0.0408	0.0408	0.0912	0.0912	0.2550	0.2550	0.2550	0.2550	0.2550	0.2550	0.0408
120	0.0854	0.0854	0.0854	0.1140	0.1140	0.1747	0.1747	0.1747	0.1747	0.1747	0.1747	0.0854
150	0.0058	0.0058	0.0058	0.0040	0.0040	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0058
180	0.0039	0.0039	0.0039	0.0025	0.0025	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0039
210	0.0051	0.0051	0.0051	0.0035	0.0035	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0051
240	0.0095	0.0095	0.0095	0.0079	0.0079	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0095
270	0.0388	0.0388	0.0388	0.0743	0.0743	0.1999	0.1999	0.1999	0.1999	0.1999	0.1999	0.0388
300	0.0301	0.0301	0.0301	0.0699	0.0699	0.2075	0.2075	0.2075	0.2075	0.2043	0.2043	0.0301
330	0.0182	0.0182	0.0182	0.0490	0.0490	0.1950	0.1950	0.1950	0.1950	0.1950	0.1950	0.0182
360	0.0281	0.0281	0.0281	0.0728	0.0728	0.2355	0.2355	0.2355	0.2355	0.2355	0.2355	0.0281

### **Receptors Used for Modelling**

The model was set up with a uniform 100 m x 100 m receptor spacing extending south from 4661000 and east from 356000. This represents a 10 km x 10 km modelling area centred on the point between the Southshore and Agriville sites. This extends about 4.5 km north of the northern boundary of the area where the majority of the greenhouses are found and well out into the lake on the south. The area extends from west of County Road 29 to nearly 2 km east of County Road 31.

This receptor pattern is different than the MoE typically require for a air approval application. In those documents it is recommended that the nested receptor grid have 20 m, 50 m, 100 m, 200 m and 500 m separation at distances of 200 m, 500 m, 1000 m, 2000 m, and 5000 m from the source box. Since the REMASCO sources are on properties that measure in excess of 400 m in both directions, and the sources are close together, in very few instances would the 20 m spacing be required beyond the property line. Furthermore, the 500 m spacing was viewed as being too wide for the area between the two source locations that are approximately 4.2 km apart. Most importantly, with the presence of numerous existing greenhouse sources in the area, a tighter spacing was determined to be capable of providing a better understanding of the variations in levels in the community. The specific modelling for the REMASCO sources was completed with 20 m spacing within 40 m of the property line around both of the sites. A total of 11,327 receptors were evaluated by the model.

After preliminary modelling runs were completed, 13 locations on the grid were designated as special receptors. These receptors represent what might be classified as sensitive receptors, locations where air contaminants could affect people who may be more susceptible to air pollution. In Ontario, sensitive receptors are generally associated with schools, day care centres, recreation centres, or amusement areas where children may be exposed; hospitals and seniors' residences where people's health may be more fragile; and residential areas where children might be exposed. The schools, recreation centre, and seniors' residences in the area were defined based upon their location. In the case of residential receptors, the residential properties that were estimated to have the highest concentrations were selected, along with locations where some concerns had been expressed about the potential for air contamination. In the case of clusters of houses in the same general area, the receptors were located in the zones with the highest predicted concentrations for that area. Since the health risk assessment also considered ingestion impacts, the special receptors included areas where crops are grown: an asparagus field; an apple orchard; and a vineyard. Table 20 lists the specific receptors selected, and the approximate distances from the nearest REMASCO stack. These receptors are shown in Figure 7 which combines Figures 4 and 5 into a single aerial photograph of the study area. The modelling results for these receptors were extracted from the posting produced by AERMOD. The posting file allows the values at each of the receptors to be seen in the output to as many significant figures as deemed necessary. When the posting data was reviewed, the highest value at receptors in the vicinity of the X shown for each receptor and each averaging period were extracted for further analysis. In most cases, the high values were found within 100 m of the X shown in Figure 8, however in some cases the maximum value occurred further from the X location.



PROJECT TITLE:  
**REMASCO Environmental Assessment**  
**Sources and Receptors**



COMMENTS:  
Figure 8  
Airphoto showing source locations and location of special receptors

SOURCES:

55

RECEPTORS:

10000

COMPANY NAME:

MODELER:

DATE:  
30/06/2011

SCALE: 1:25,000  
0 0.5 km

PROJECT NO.:



Using the AERMAP module in the program, and terrain elevations downloaded from the WEBGis site, the elevation of all the receptors, buildings, and sources were determined before the model was run in the elevated terrain mode.

Table 20 List of Designated Special Receptors for the Study

Number	Description	Location		
		Distance from Closest REMASCO Stack	Easting	Northing
1	School on Road 3	2650	356300	4658400
2	Seniors Centre Kingsville	2140	356200	4656850
3	Residential Area Kingsville	1310	357200	4655900
4	Recreation Centre	780	357400	4656700
5	Residence close to Agriville	320	358300	4656900
6	Asparagus Field	680	358500	4655900
7	Apple Orchard	1750	360500	4655900
8	Vineyard	2160	360200	4657800
9	Colisanti Complex	2220	361300	4658100
10	Owner's Residence	1370	361200	4655400
11	Residence north of Southshore	410	362000	4656500
12	Ruthven School	730	362300	4657000
13	Residence south of Southshore	600	362420	4655570

### 6.3 Modelling Runs Completed

The model was run for three different situations:

1. REMASCO associated sources were modelled in both the concentration and deposition mode, without plume depletion. This allows the concentrations to be compared to the O.Reg. 419/05 criteria levels. The deposition data for all particulate bound contaminants was made available to the HHRA study. The HHRA also uses the air concentration data.

The REMASCO sources were modelled for normal emission rates as noted above. The results from operation of the REMASCO facilities with the upset emission rates were also determined. In the case of the upset conditions the values were determined at the special receptors, and the highest special receptor value, regardless of location is presented in the discussion in the next chapter.

2. NO<sub>2</sub> modelling of existing greenhouses and the REMASCO emissions using NO<sub>x</sub> emission factors with a NO<sub>2</sub>/NO<sub>x</sub> ratio of 0.1, the default in AERMOD, and the Ozone Limiting Method with an average hourly background ozone concentration of 54 ppb, the 90<sup>th</sup> percentile value recorded at Port Stanley which, like Kingsville, is on the north shore of Lake Erie. While model allows hourly ozone data to be used for this calculation, in the absence of such data the model can use a representative value for ozone in the atmosphere and apply it for each hour of each year modelled. The value that was used as a conservative estimate of the annual level

was the Port Stanley 90<sup>th</sup> percentile of the hourly values reported. Port Stanley has the highest 90<sup>th</sup> percentile number for any of the ozone monitoring locations around the project area. Ozone levels have both a seasonal and diurnal variation being higher in the summer when the NO<sub>x</sub> emission levels are lower and ozone is lower in the winter season when NO<sub>x</sub> emissions are higher. The ozone levels also vary diurnally with the maximum values being found in the afternoon, while the maximum hourly concentrations from the REMASCO sources were identified to occur in the late winter evening conditions emissions would be expected to be at their highest but ozone levels would be below the peak values for the day.

This approach assesses the effects of NO<sub>x</sub> emissions from the existing sources and the REMASCO sources, separately and combined, and allows the projections to be summed with the existing NO<sub>2</sub> data to determine the likely levels in the community before and after the REMASCO project goes into operation.

3. Particulate emissions were modelled as particulate matter finer than 2.5 µm in size [PM<sub>2.5</sub>] for inclusion in the cumulative assessment through comparison with background levels measured in Chatham. No deposition was included in this evaluation. In an analysis manner similar to the NO<sub>2</sub> levels, the PM<sub>2.5</sub> monitoring data were combined with the model predictions in the evaluation.

The model was run in parallel processor mode to analyse the concentration at over 11,100 receptors for each hour of the 5 years of meteorological data. The maximum value at each receptor was saved to produce the plots of results for various averaging times: 1 hour; 24 hours; and annual. In addition, the output files were reviewed to provide maximum values and values at the 13 identified sensitive receptors. In selecting the maximum values at the identified receptors, the output of the model was reviewed and the highest reported value for the specific averaging time that was found within 200 – 300 m of the receptor location was reported.

### **Lake Breeze Effects**

The REMASCO facilities are to be located within 2,000 m of the shoreline of Lake Erie. As such, these zones are subject to the effects of on-shore breezes during certain periods of the day. The breezes are created by a temperature differential created as the land warms up more than the lake. Under these circumstances releases to the atmosphere close to the lake can be trapped in the thermally created air flow and levels can increase. This condition is frequently referred to a shoreline fumigation. To assess the potential for such effects, SCREEN3, a US EPA model approved for use by the MoE, was employed to determine if this effect could cause REMASCO emissions to be trapped. The inputs to the model include the stack height, gas exit characteristics, and the distance from the lake. The model simulates meteorological conditions including the creation of the thermal internal boundary layer in the on shore region, and determines if the plume from the stacks would be influenced under any circumstances. This model was run for both the Southshore and the Agriville sites because the distance from the shoreline is different: 1100 m for Southshore, and 1800 m for Agriville.

## 7.0 Results Analysis

The results of the modelling are presented both in tabular and graphical form. While modelling is used as a means of assessing the acceptability of new sources in the province, the emphasis in the modelling results is usually on the highest values estimated to occur around the source. For the REMASCO sources this data is presented in tabular form. The location of the maxima was on the Southshore property in the vicinity of the new greenhouse complex on the north part of the site. The maxima occurred in the night time hours in February, a time when the fresh air vents into the greenhouse are unlikely to be open, so the potential for exposing people is very limited. More important are the levels that occur in the community. As discussed in the previous chapter, in order to address values in the community 13 sensitive receptors were identified, and the maximum estimated concentrations at those receptors are presented in tabular form as well. These values can be compared to the criteria levels outlined in O.Reg. 419/05. Criteria values for both the 1 hour and 24 hour averaging periods are included in the tables.

It is important to note that the SCREEN3 results determined that the plume height from both the Agriville and Southshore sources were below the height of the Thermal Internal Boundary Layer at their respective distances from the shoreline and thus determination of shoreline fumigation was not required. The AERMOD results are thus representative of the worst case results that could be expected.

To facilitate comparison of the existing and future operations, the results of the NO<sub>2</sub> and PM<sub>2.5</sub> models were plotted, using Figure 7 as an underlay, to illustrate the concentrations estimated from the model for the following cases:

- Emissions from the existing greenhouses;
- Emissions from the REMASCO facility stacks alone; and,
- Emissions from the existing greenhouses and the new REMASCO facilities after they have replaced the existing boilers at Southshore and Agriville sites.

The results for 1 hour maximum concentrations; 24 hour maximum concentrations and annual maximum concentrations could be plotted for each of the scenarios and for both contaminants, however for illustrative purposes only the 1 hour values are presented in this report.

In order to assess the potential influence of the changes on levels in the community, tabular data that includes an allowance for the current anticipated background levels in the community is also presented. These data, at the sensitive receptors, can be used to compare the anticipated levels to the ambient air quality criteria.

## **7.1 *Estimated Concentrations from REMASCO Operations***

### **7.1.1 Maximum Point of Impingement Values**

Table 21 summarizes the maximum concentrations predicted to occur from the operation of the REMASCO facilities. Note these maxima, as expected, occur near the point where the highest emissions will occur, namely on the Southshore site. The table lists the average emission rate developed earlier in this report, and the maximum values for 1 hour, 24 hour and annual airborne concentration and the maximum value for annual deposition. Also listed in the table are the hourly and 24 hour average criteria levels for the specific contaminants as listed in O.Reg. 419/05. The percentage column simply lists the level of the estimated maxima compared to the specific criteria levels. Typically the estimated values are only a small portion of the criteria level, thus the percentage values are all less than 30% of the criteria.

Most of the metals listed in the table are predicted to have maximum values that are far less than one percent of the 24 hour criteria standard level. Cadmium, compared to the revised 24 hour standard that comes into effect in 2013 is estimated to be 0.5% of the standard, and iron is 0.81% of the standard.

Only one of the special organics at the bottom of the table has an assigned criteria level and the estimated maximum for that contaminant, vinyl chloride monomer, is approximately 0.5% of the standard. This is the same range as the chlorine value.

Since criteria contaminants dominate emissions from most sources, one might expect to see their levels elevated compared to the standards. Indeed this is the case with Oxides of Nitrogen maxima being 22.3% of the criteria while Particulate Matter at 2.2% and Sulphur Dioxide at 1.4% are lower.

Hydrogen chloride, while not a criteria contaminant, was modelled at the A-7 emission limit and the rate resulted in a level that is 28.8% of the criteria level in O.Reg. 419/05. REMASCO must operate the facility with HCl emissions at or below the A-7 limit and expect that the emission rate of this contaminant will be lower in normal operation thereby reducing the reported percentage.

Before leaving these maximum values it is important to note that the MoE recognize that the modelling process can create what are best termed as statistical anomalies in the results. These are caused by a combination of meteorological conditions that predict reduced dispersion that results in levels that are higher than would be expected. To address this issue the MoE allow the modelling data to be statistically adjusted by removing the top 8 values for each year from the 1 hour data, and the top value for each year for both the 24 hour and the annual data. This approach was not used for this study.

As noted earlier, all these values are maxima that occur on the Southshore property. The maxima predicted to occur around the sensitive receptors identified earlier in this report are presented in the next section.

### 7.1.2 Sensitive Receptors

The sensitive receptors identified for the study are locations that are outside the property boundaries of both the Southshore and Agriville facilities. Facilities closer to a stack would be expected to be exposed to potentially higher levels of air contaminants related to that source than would receptors further away. Since the Agriville and Southshore sites are separated by approximately 4 km, one would anticipate that the two sites would have only limited influence on the receptors close to the other source. As such, the concentrations at the sensitive receptors would be expected to be lower than the maximum values discussed in the previous section. The concentrations calculated for the sensitive receptors will be used in the HHRA study. Since the previous section has shown that levels at the point of maximum predicted concentration are lower than the criteria in O.Reg. and the sensitive receptor values are lower than the maxima, no attempt was made to compare the values at the sensitive receptors with the standards.

The values at the critical receptors were extracted from the model results by recording the highest value that was estimated for the unit emission rate within 200 m of the receptor points marked in Figure 6. These values were then multiplied by the emission rate shown in the 2<sup>nd</sup> column of Table 22 to provide specific values for the: 1 hour maximum air concentration estimated for each contaminant at each receptor; the 24 hour maximum air concentration for each contaminant; the annual maximum air concentration for each contaminant; and the maximum annual deposition rate for each contaminant.

For 1 hour values, modelling results will identify that receptors closer to a source have higher estimated concentrations. Of course the rate of emissions at any site will also influence this pattern. Since the Southshore site was modelled with 7 gasifiers operating, the levels around that property are higher than those around Agriville with only 4 gasifiers installed. Levels at the residence across the road from Agriville are approximately half those at the residence northwest of Southshore even though both are about the same distance from the sources. The Colisanti facility is in the same northwest direction from the Southshore stacks but being further away, 2,200 m versus 400 m from the stack, the levels are lower, about 61% of the higher values. The nature of the winds in the area also plays a role in the estimated values. The receptor south of the Southshore facility has a value that is 66% of the northwest residence, while being only about 100 m further from the stacks.

When the model averages the maximum hourly average values over longer periods the relationships can change. For instance, comparing the two closest residential sites discussed above they differ with relation to their one hour maximum results. The site north of Agriville has a 24 hour average that is about 25% of the 1 hour maximum at that site, whereas at the residence north of Southshore the 24 hour maximum is 30% of the 1 hour value. The value at the residence south of Southshore is 61% of its 1 hour value. This shows that winds from different directions and over a longer period of time, influence the concentrations found at various receptors.

As would be expected, the annual average values are much more uniform than those for the shorter periods. The highest annual averages occur at receptors 5, 11, 12, and 13. Three of these receptors are

north of the REMASCO sources. With the predominant wind directions being from the south to southwest coupled the proximity of these receptors to the sources these results are not unexpected.

Annual deposition values mirror the annual average concentrations at the receptors as would be expected because the higher the concentration over the annual period the more deposition would be expected at that location.

### **Upset Conditions**

Before leaving the discussion of levels at the special receptors that result from REMASCO operations, it is appropriate to address the impact of upset operating conditions on the levels. Since upset conditions are short term, the effects are most likely to be seen at the receptors closest the facility. To summarize the results of the upset operations, the receptor that recorded the highest concentration for each of the three averaging periods was used to calculate the impacts of upset operation shown in Table 23.

As with the table of maximum values discussed in the previous section, Table 23 compares the estimated values to the criteria levels set out in O.Reg. 419/05. In all cases the values at the residential receptor having the highest levels under upset conditions are less than the applicable O.Reg. 419/05 criteria levels. The hourly exposure for NO<sub>x</sub> under these conditions is 33% of the criteria level. The 24 hour average for HCl, modelled at 10 times the A-7 level, is estimated to be 41% of the criteria level, while NO<sub>x</sub> levels for 24 hours are 7% of the standard.

The upset results are incorporated into the human health risk assessment report where they are compared to a range of effects levels.



Table 21

Summary of Maximum POI Values

	Max POI						Max Dep		
	Average Emission	O.Reg 419 Criteria Levels 1				O.Reg 419 Criteria Levels			
Compound	Rate	1 Hour	Hour Average		24 Hour	24 Hour Average		Annual	Annual
	[g/s]	[ug/m3]	[ug/m3]	(% criteria)	[ug/m3]	[ug/m3]	(% criteria)	[ug/m3]	[g/m2]
Aluminum	2.27E-05	3.46E-03			1.83E-03			9.78E-05	1.04E-05
Antimony	1.08E-06	1.65E-04			8.71E-05	2.50E+01	0.0003%	4.65E-06	4.93E-07
Arsenic	8.90E-07	1.36E-04			7.18E-05			3.84E-06	4.06E-07
Barium	3.07E-06	4.68E-04			2.48E-04			1.32E-05	1.40E-06
Beryllium	1.54E-07	2.35E-05			1.24E-05	1.00E-02	0.1242%	6.64E-07	7.02E-08
Bismuth	2.22E-07	3.39E-05			1.79E-05			9.57E-07	1.01E-07
Boron	6.30E-04	9.61E-02			5.08E-02	1.20E+02	0.0424%	2.72E-03	2.87E-04
Cadmium	1.52E-06	2.32E-04			1.23E-04	2.50E-02	0.4905%	6.55E-06	6.93E-07
Calcium [as Ca(OH)2]	2.73E-04	4.17E-02			2.20E-02	1.35E+01	0.1632%	1.18E-03	1.24E-04
Chromium	3.24E-05	4.94E-03			2.61E-03			1.40E-04	1.48E-05
Cobalt	1.01E-06	1.54E-04			8.15E-05			4.35E-06	4.61E-07
Copper	1.14E-05	1.74E-03			9.20E-04	5.00E+01	0.0018%	4.91E-05	5.20E-06
Germanium	1.54E-06	2.35E-04			1.24E-04			6.64E-06	7.02E-07
Gold	7.70E-07	1.17E-04			6.21E-05			3.32E-06	3.51E-07
Indium	7.70E-07	1.17E-04			6.21E-05			3.32E-06	3.51E-07
Iridium	7.70E-07	1.17E-04			6.21E-05			3.32E-06	3.51E-07
Iron	4.04E-04	6.16E-02			3.26E-02	4.00E+00	0.8149%	1.74E-03	1.84E-04
Lead	3.30E-06	5.04E-04			2.66E-04	2.00E+00	0.0133%	1.42E-05	1.50E-06
Magnesium [as MgO]	2.84E-05	4.33E-03			2.29E-03	1.20E+02	0.0019%	1.22E-04	1.30E-05
Manganese	1.56E-05	2.38E-03			1.26E-03			6.72E-05	7.11E-06
Mercury	4.11E-06	6.27E-04			3.32E-04	2.00E+00	0.0166%	1.77E-05	1.87E-06
Molybdenum	2.51E-06	3.83E-04			2.03E-04			1.08E-05	1.14E-06
Nickel	6.12E-05	9.34E-03			4.94E-03	2.00E+00	0.2469%	2.64E-04	2.79E-05
Palladium	1.54E-07	2.35E-05			1.24E-05			6.64E-07	7.02E-08
Phosphorus	1.02E-05	1.56E-03			8.23E-04			4.40E-05	4.65E-06
Platinum	7.70E-07	1.17E-04			6.21E-05			3.32E-06	3.51E-07
Potassium	3.90E-05	5.95E-03			3.15E-03			1.68E-04	1.78E-05
Rhodium	7.70E-07	1.17E-04			6.21E-05			3.32E-06	3.51E-07
Rubidium	1.54E-06	2.35E-04			1.24E-04			6.64E-06	7.02E-07
Selenium	1.36E-06	2.08E-04			1.10E-04			5.86E-06	6.20E-07
Silicon	7.10E-05	1.08E-02			5.73E-03			3.06E-04	3.24E-05
Silver	6.13E-06	9.35E-04			4.95E-04	1.00E+00	0.0495%	2.64E-05	2.80E-06
Sodium	3.61E-04	5.51E-02			2.91E-02			1.56E-03	1.65E-04
Strontium	1.96E-06	2.99E-04			1.58E-04			8.45E-06	8.94E-07
Sulphur	2.84E-02	4.33E+00			2.29E+00			1.22E-01	1.30E-02
Tellurium	9.89E-07	1.51E-04			7.98E-05			4.26E-06	4.51E-07
Thallium	7.70E-07	1.17E-04			6.21E-05			3.32E-06	3.51E-07
Tin	7.04E-05	1.07E-02			5.68E-03	1.00E+01	0.0568%	3.03E-04	3.21E-05
Titanium	1.32E-06	2.01E-04			1.06E-04	1.20E+02	0.0001%	5.69E-06	6.02E-07
Tungsten	1.27E-06	1.94E-04			1.02E-04			5.47E-06	5.79E-07
Uranium	7.70E-07	1.17E-04			6.21E-05			3.32E-06	3.51E-07
Vanadium	1.63E-07	2.49E-05			1.32E-05	2.00E+00	0.0007%	7.03E-07	7.43E-08
Zinc	2.45E-05	3.74E-03			1.98E-03	1.20E+02	0.0016%	1.06E-04	1.12E-05
Zirconium	3.18E-07	4.85E-05			2.57E-05			1.37E-06	1.45E-07
TPM	3.34E-02	5.10E+00			2.69E+00	1.20E+02	2.2456%	1.44E-01	1.52E-02
PCDD/F	6.12E-11	9.34E-09			4.94E-09			2.64E-10	2.79E-11
Sulphur Dioxide	4.63E-02	7.06E+00	6.90E+02	1.02%	3.74E+00	2.75E+02	1.3584%	2.00E-01	
Oxides of Nitrogen	5.53E-01	8.44E+01	4.00E+02	21.10%	4.46E+01	2.00E+02	22.3080%	2.38E+00	
Chlorine	5.93E-04	9.05E-02			4.78E-02	1.00E+01	0.4784%	2.56E-03	
Hydrogen Chloride	7.13E-02	1.09E+01			5.75E+00	2.00E+01	28.7544%	3.07E-01	
Vinyl Chloride Monomer	6.62E-06	1.01E-03			5.34E-04	1.00E+00	0.0534%	2.85E-05	
Benz(a)pyrene	5.85E-07	8.93E-05			4.72E-05			2.52E-06	
Benzene	1.78E-05	2.72E-03			1.44E-03			7.67E-05	

Table 22 a)

## Summary of Maximum 1 Hour POI Values at Sensitive Receptors

	RECEPTOR	1	2	3	4	5	6	7	8	9	10	11	12	13
Compound	Average													
	[g/s]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]
Aluminum	2.27E-05	6.11E-04	8.03E-04	6.87E-04	1.05E-03	1.36E-03	9.62E-04	8.99E-04	9.82E-04	1.56E-03	7.93E-04	2.55E-03	1.50E-03	1.68E-03
Antimony	1.08E-06	2.91E-05	3.82E-05	3.27E-05	5.00E-05	6.48E-05	4.58E-05	4.28E-05	4.67E-05	7.42E-05	3.77E-05	1.22E-04	7.14E-05	8.01E-05
Arsenic	8.90E-07	2.40E-05	3.15E-05	2.69E-05	4.12E-05	5.34E-05	3.77E-05	3.53E-05	3.85E-05	6.11E-05	3.11E-05	1.00E-04	5.88E-05	6.60E-05
Barium	3.07E-06	8.27E-05	1.09E-04	9.29E-05	1.42E-04	1.84E-04	1.30E-04	1.22E-04	1.33E-04	2.11E-04	1.07E-04	3.45E-04	2.03E-04	2.28E-04
Beryllium	1.54E-07	4.15E-06	5.45E-06	4.66E-06	7.14E-06	9.24E-06	6.53E-06	6.10E-06	6.66E-06	1.06E-05	5.38E-06	1.73E-05	1.02E-05	1.14E-05
Bismuth	2.22E-07	5.98E-06	7.86E-06	6.72E-06	1.03E-05	1.33E-05	9.41E-06	8.80E-06	9.60E-06	1.52E-05	7.76E-06	2.50E-05	1.47E-05	1.65E-05
Boron	6.30E-04	1.70E-02	2.23E-02	1.91E-02	2.92E-02	3.78E-02	2.67E-02	2.50E-02	2.72E-02	4.33E-02	2.20E-02	7.09E-02	4.16E-02	4.67E-02
Cadmium	1.52E-06	4.09E-05	5.38E-05	4.60E-05	7.04E-05	9.12E-05	6.44E-05	6.02E-05	6.57E-05	1.04E-04	5.31E-05	1.71E-04	1.00E-04	1.13E-04
Calcium	2.73E-04	7.35E-03	9.66E-03	8.26E-03	1.27E-02	1.64E-02	1.16E-02	1.08E-02	1.18E-02	1.88E-02	9.54E-03	3.07E-02	1.80E-02	2.02E-02
Chromium	3.24E-05	8.73E-04	1.15E-03	9.81E-04	1.50E-03	1.94E-03	1.37E-03	1.28E-03	1.40E-03	2.23E-03	1.13E-03	3.65E-03	2.14E-03	2.40E-03
Cobalt	1.01E-06	2.72E-05	3.57E-05	3.06E-05	4.68E-05	6.06E-05	4.28E-05	4.00E-05	4.37E-05	6.94E-05	3.53E-05	1.14E-04	6.67E-05	7.49E-05
Copper	1.14E-05	3.07E-04	4.03E-04	3.45E-04	5.28E-04	6.84E-04	4.83E-04	4.52E-04	4.93E-04	7.83E-04	3.98E-04	1.28E-03	7.53E-04	8.45E-04
Germanium	1.54E-06	4.15E-05	5.45E-05	4.66E-05	7.14E-05	9.24E-05	6.53E-05	6.10E-05	6.66E-05	1.06E-04	5.38E-05	1.73E-04	1.02E-04	1.14E-04
Gold	7.70E-07	2.07E-05	2.73E-05	2.33E-05	3.57E-05	4.62E-05	3.26E-05	3.05E-05	3.33E-05	5.29E-05	2.69E-05	8.66E-05	5.09E-05	5.71E-05
Indium	7.70E-07	2.07E-05	2.73E-05	2.33E-05	3.57E-05	4.62E-05	3.26E-05	3.05E-05	3.33E-05	5.29E-05	2.69E-05	8.66E-05	5.09E-05	5.71E-05
Iridium	7.70E-07	2.07E-05	2.73E-05	2.33E-05	3.57E-05	4.62E-05	3.26E-05	3.05E-05	3.33E-05	5.29E-05	2.69E-05	8.66E-05	5.09E-05	5.71E-05
Iron	4.04E-04	1.09E-02	1.43E-02	1.22E-02	1.87E-02	2.42E-02	1.71E-02	1.60E-02	1.75E-02	2.78E-02	1.41E-02	4.55E-02	2.67E-02	3.00E-02
Lead	3.30E-06	8.89E-05	1.17E-04	9.99E-05	1.53E-04	1.98E-04	1.40E-04	1.31E-04	1.43E-04	2.27E-04	1.15E-04	3.71E-04	2.18E-04	2.45E-04
Magnesium	2.84E-05	7.65E-04	1.01E-03	8.60E-04	1.32E-03	1.70E-03	1.20E-03	1.13E-03	1.23E-03	1.95E-03	9.92E-04	3.20E-03	1.88E-03	2.11E-03
Manganese	1.56E-05	4.20E-04	5.52E-04	4.72E-04	7.23E-04	9.36E-04	6.61E-04	6.18E-04	6.75E-04	1.07E-03	5.45E-04	1.76E-03	1.03E-03	1.16E-03
Mercury	4.11E-06	1.11E-04	1.45E-04	1.24E-04	1.90E-04	2.47E-04	1.74E-04	1.63E-04	1.78E-04	2.82E-04	1.44E-04	4.62E-04	2.72E-04	3.05E-04
Molybdenum	2.51E-06	6.76E-05	8.88E-05	7.60E-05	1.16E-04	1.51E-04	1.06E-04	9.94E-05	1.09E-04	1.72E-04	8.77E-05	2.82E-04	1.66E-04	1.86E-04
Nickel	6.12E-05	1.65E-03	2.17E-03	1.85E-03	2.84E-03	3.67E-03	2.59E-03	2.42E-03	2.65E-03	4.20E-03	2.14E-03	6.89E-03	4.04E-03	4.54E-03
Palladium	1.54E-07	4.15E-06	5.45E-06	4.66E-06	7.14E-06	9.24E-06	6.53E-06	6.10E-06	6.66E-06	1.06E-05	5.38E-06	1.73E-05	1.02E-05	1.14E-05
Phosphorus	1.02E-05	2.75E-04	3.61E-04	3.09E-04	4.73E-04	6.12E-04	4.32E-04	4.04E-04	4.41E-04	7.01E-04	3.56E-04	1.15E-03	6.74E-04	7.56E-04
Platinum	7.70E-07	2.07E-05	2.73E-05	2.33E-05	3.57E-05	4.62E-05	3.26E-05	3.05E-05	3.33E-05	5.29E-05	2.69E-05	8.66E-05	5.09E-05	5.71E-05
Potassium	3.90E-05	1.05E-03	1.38E-03	1.18E-03	1.81E-03	2.34E-03	1.65E-03	1.55E-03	1.69E-03	2.68E-03	1.36E-03	4.39E-03	2.58E-03	2.89E-03
Rhodium	7.70E-07	2.07E-05	2.73E-05	2.33E-05	3.57E-05	4.62E-05	3.26E-05	3.05E-05	3.33E-05	5.29E-05	2.69E-05	8.66E-05	5.09E-05	5.71E-05
Rubidium	1.54E-06	4.15E-05	5.45E-05	4.66E-05	7.14E-05	9.24E-05	6.53E-05	6.10E-05	6.66E-05	1.06E-04	5.38E-05	1.73E-04	1.02E-04	1.14E-04
Selenium	1.36E-06	3.66E-05	4.81E-05	4.12E-05	6.30E-05	8.16E-05	5.77E-05	5.39E-05	5.88E-05	9.34E-05	4.75E-05	1.53E-04	8.99E-05	1.01E-04
Silicon	7.10E-05	1.91E-03	2.51E-03	2.15E-03	3.29E-03	4.26E-03	3.01E-03	2.81E-03	3.07E-03	4.88E-03	2.48E-03	7.99E-03	4.69E-03	5.27E-03
Silver	6.13E-06	1.65E-04	2.17E-04	1.86E-04	2.84E-04	3.68E-04	2.60E-04	2.43E-04	2.65E-04	4.21E-04	2.14E-04	6.90E-04	4.05E-04	4.55E-04
Sodium	3.61E-04	9.72E-03	1.28E-02	1.09E-02	1.67E-02	2.17E-02	1.53E-02	1.43E-02	1.56E-02	2.48E-02	1.26E-02	4.06E-02	2.39E-02	2.68E-02
Strontium	1.96E-06	5.28E-05	6.94E-05	5.93E-05	9.08E-05	1.18E-04	8.31E-05	7.77E-05	8.48E-05	1.35E-04	6.85E-05	2.21E-04	1.30E-04	1.45E-04

Table 22 a)

## Summary of Maximum 1 Hour POI Values at Sensitive Receptors

	RECEPTOR	1	2	3	4	5	6	7	8	9	10	11	12	13
Compound	Average													
	[g/s]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]
Sulphur	2.84E-02	7.65E-01	1.01E+00	8.60E-01	1.32E+00	1.70E+00	1.20E+00	1.13E+00	1.23E+00	1.95E+00	9.92E-01	3.20E+00	1.88E+00	2.11E+00
Tellurium	9.89E-07	2.66E-05	3.50E-05	2.99E-05	4.58E-05	5.93E-05	4.19E-05	3.92E-05	4.28E-05	6.79E-05	3.46E-05	1.11E-04	6.54E-05	7.33E-05
Thallium	7.70E-07	2.07E-05	2.73E-05	2.33E-05	3.57E-05	4.62E-05	3.26E-05	3.05E-05	3.33E-05	5.29E-05	2.69E-05	8.66E-05	5.09E-05	5.71E-05
Tin	7.04E-05	1.90E-03	2.49E-03	2.13E-03	3.26E-03	4.22E-03	2.98E-03	2.79E-03	3.04E-03	4.84E-03	2.46E-03	7.92E-03	4.65E-03	5.22E-03
Titanium	1.32E-06	3.55E-05	4.67E-05	4.00E-05	6.12E-05	7.92E-05	5.60E-05	5.23E-05	5.71E-05	9.07E-05	4.61E-05	1.49E-04	8.72E-05	9.79E-05
Tungsten	1.27E-06	3.42E-05	4.49E-05	3.84E-05	5.89E-05	7.62E-05	5.38E-05	5.03E-05	5.49E-05	8.72E-05	4.44E-05	1.43E-04	8.39E-05	9.42E-05
Uranium	7.70E-07	2.07E-05	2.73E-05	2.33E-05	3.57E-05	4.62E-05	3.26E-05	3.05E-05	3.33E-05	5.29E-05	2.69E-05	8.66E-05	5.09E-05	5.71E-05
Vanadium	1.63E-07	4.39E-06	5.77E-06	4.93E-06	7.55E-06	9.78E-06	6.91E-06	6.46E-06	7.05E-06	1.12E-05	5.70E-06	1.83E-05	1.08E-05	1.21E-05
Zinc	2.45E-05	6.60E-04	8.67E-04	7.42E-04	1.14E-03	1.47E-03	1.04E-03	9.71E-04	1.06E-03	1.68E-03	8.56E-04	2.76E-03	1.62E-03	1.82E-03
Zirconium	3.18E-07	8.56E-06	1.13E-05	9.63E-06	1.47E-05	1.91E-05	1.35E-05	1.26E-05	1.38E-05	2.18E-05	1.11E-05	3.58E-05	2.10E-05	2.36E-05
TPM	3.34E-02	8.99E-01	1.18E+00	1.01E+00	1.55E+00	2.00E+00	1.42E+00	1.32E+00	1.44E+00	2.29E+00	1.17E+00	3.76E+00	2.21E+00	2.48E+00
PCDD/F	6.12E-11	1.65E-09	2.17E-09	1.85E-09	2.84E-09	3.67E-09	2.60E-09	2.43E-09	2.65E-09	4.20E-09	2.14E-09	6.89E-09	4.04E-09	4.54E-09
Sulphur Dioxide	4.63E-02	1.25E+00	1.64E+00	1.40E+00	2.15E+00	2.78E+00	1.96E+00	1.83E+00	2.00E+00	3.18E+00	1.62E+00	5.21E+00	3.06E+00	3.43E+00
Nitrogen Dioxide	5.53E-01	1.49E+01	1.96E+01	1.67E+01	2.56E+01	3.32E+01	2.34E+01	2.19E+01	2.39E+01	3.80E+01	1.93E+01	6.22E+01	3.65E+01	4.10E+01
Chlorine	5.93E-04	1.60E-02	2.10E-02	1.80E-02	2.75E-02	3.56E-02	2.51E-02	2.35E-02	2.56E-02	4.07E-02	2.07E-02	6.67E-02	3.92E-02	4.40E-02
Hydrogen Chloride	7.13E-02	1.92E+00	2.52E+00	2.16E+00	3.30E+00	4.28E+00	3.02E+00	2.82E+00	3.08E+00	4.90E+00	2.49E+00	8.02E+00	4.71E+00	5.29E+00
Vinyl Chloride Monomer	6.62E-06	1.78E-04	2.34E-04	2.00E-04	3.07E-04	3.97E-04	2.81E-04	2.62E-04	2.86E-04	4.55E-04	2.31E-04	7.45E-04	4.37E-04	4.91E-04
Benz(a)pyrene	5.85E-07	1.58E-05	2.07E-05	1.77E-05	2.71E-05	3.51E-05	2.48E-05	2.32E-05	2.53E-05	4.02E-05	2.04E-05	6.58E-05	3.87E-05	4.34E-05
Benzene	1.78E-05	4.79E-04	6.30E-04	5.39E-04	8.25E-04	1.07E-03	7.55E-04	7.05E-04	7.70E-04	1.22E-03	6.22E-04	2.00E-03	1.18E-03	1.32E-03

Table 22 b)

## Summary of Maximum 24 Hour POI Values at Sensitive Receptors

	RECEPTOR	1	2	3	4	5	6	7	8	9	10	11	12	13
Compound	Average													
	[g/s]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]
Aluminum	2.27E-05	1.04E-04	2.24E-04	1.77E-04	6.39E-04	3.38E-04	5.80E-04	2.41E-04	1.89E-04	1.86E-04	2.79E-04	7.70E-04	3.98E-04	1.03E-03
Antimony	1.08E-06	4.94E-06	1.07E-05	8.42E-06	3.04E-05	1.61E-05	2.76E-05	1.15E-05	8.99E-06	8.86E-06	1.33E-05	3.67E-05	1.89E-05	4.92E-05
Arsenic	8.90E-07	4.07E-06	8.79E-06	6.94E-06	2.51E-05	1.32E-05	2.28E-05	9.45E-06	7.40E-06	7.30E-06	1.09E-05	3.02E-05	1.56E-05	4.06E-05
Barium	3.07E-06	1.40E-05	3.03E-05	2.39E-05	8.65E-05	4.57E-05	7.85E-05	3.26E-05	2.55E-05	2.52E-05	3.77E-05	1.04E-04	5.38E-05	1.40E-04
Beryllium	1.54E-07	7.04E-07	1.52E-06	1.20E-06	4.34E-06	2.29E-06	3.94E-06	1.64E-06	1.28E-06	1.26E-06	1.89E-06	5.23E-06	2.70E-06	7.02E-06
Bismuth	2.22E-07	1.01E-06	2.19E-06	1.73E-06	6.25E-06	3.30E-06	5.68E-06	2.36E-06	1.85E-06	1.82E-06	2.72E-06	7.53E-06	3.89E-06	1.01E-05
Boron	6.30E-04	2.88E-03	6.22E-03	4.91E-03	1.77E-02	9.37E-03	1.61E-02	6.69E-03	5.24E-03	5.17E-03	7.73E-03	2.14E-02	1.10E-02	2.87E-02
Cadmium	1.52E-06	6.95E-06	1.50E-05	1.19E-05	4.28E-05	2.26E-05	3.89E-05	1.61E-05	1.26E-05	1.25E-05	1.87E-05	5.16E-05	2.66E-05	6.93E-05
Calcium	2.73E-04	1.25E-03	2.70E-03	2.13E-03	7.69E-03	4.06E-03	6.98E-03	2.90E-03	2.27E-03	2.24E-03	3.35E-03	9.27E-03	4.79E-03	1.24E-02
Chromium	3.24E-05	1.48E-04	3.20E-04	2.53E-04	9.13E-04	4.82E-04	8.28E-04	3.44E-04	2.70E-04	2.66E-04	3.98E-04	1.10E-03	5.68E-04	1.48E-03
Cobalt	1.01E-06	4.62E-06	9.98E-06	7.88E-06	2.85E-05	1.50E-05	2.58E-05	1.07E-05	8.40E-06	8.28E-06	1.24E-05	3.43E-05	1.77E-05	4.60E-05
Copper	1.14E-05	5.21E-05	1.13E-04	8.89E-05	3.21E-04	1.70E-04	2.91E-04	1.21E-04	9.48E-05	9.35E-05	1.40E-04	3.87E-04	2.00E-04	5.20E-04
Germanium	1.54E-06	7.04E-06	1.52E-05	1.20E-05	4.34E-05	2.29E-05	3.94E-05	1.64E-05	1.28E-05	1.26E-05	1.89E-05	5.23E-05	2.70E-05	7.02E-05
Gold	7.70E-07	3.52E-06	7.61E-06	6.01E-06	2.17E-05	1.14E-05	1.97E-05	8.18E-06	6.41E-06	6.31E-06	9.45E-06	2.61E-05	1.35E-05	3.51E-05
Indium	7.70E-07	3.52E-06	7.61E-06	6.01E-06	2.17E-05	1.14E-05	1.97E-05	8.18E-06	6.41E-06	6.31E-06	9.45E-06	2.61E-05	1.35E-05	3.51E-05
Iridium	7.70E-07	3.52E-06	7.61E-06	6.01E-06	2.17E-05	1.14E-05	1.97E-05	8.18E-06	6.41E-06	6.31E-06	9.45E-06	2.61E-05	1.35E-05	3.51E-05
Iron	4.04E-04	1.85E-03	3.99E-03	3.15E-03	1.14E-02	6.01E-03	1.03E-02	4.29E-03	3.36E-03	3.31E-03	4.96E-03	1.37E-02	7.08E-03	1.84E-02
Lead	3.30E-06	1.51E-05	3.26E-05	2.57E-05	9.30E-05	4.91E-05	8.44E-05	3.50E-05	2.75E-05	2.71E-05	4.05E-05	1.12E-04	5.78E-05	1.50E-04
Magnesium	2.84E-05	1.30E-04	2.81E-04	2.22E-04	8.00E-04	4.22E-04	7.26E-04	3.02E-04	2.36E-04	2.33E-04	3.48E-04	9.64E-04	4.98E-04	1.29E-03
Manganese	1.56E-05	7.13E-05	1.54E-04	1.22E-04	4.39E-04	2.32E-04	3.99E-04	1.66E-04	1.30E-04	1.28E-04	1.91E-04	5.29E-04	2.73E-04	7.11E-04
Mercury	4.11E-06	1.88E-05	4.06E-05	3.21E-05	1.16E-04	6.11E-05	1.05E-04	4.36E-05	3.42E-05	3.37E-05	5.04E-05	1.39E-04	7.20E-05	1.87E-04
Molybdenum	2.51E-06	1.15E-05	2.48E-05	1.96E-05	7.07E-05	3.73E-05	6.42E-05	2.67E-05	2.09E-05	2.06E-05	3.08E-05	8.52E-05	4.40E-05	1.14E-04
Nickel	6.12E-05	2.80E-04	6.05E-04	4.77E-04	1.72E-03	9.10E-04	1.56E-03	6.50E-04	5.09E-04	5.02E-04	7.51E-04	2.08E-03	1.07E-03	2.79E-03
Palladium	1.54E-07	7.04E-07	1.52E-06	1.20E-06	4.34E-06	2.29E-06	3.94E-06	1.64E-06	1.28E-06	1.26E-06	1.89E-06	5.23E-06	2.70E-06	7.02E-06
Phosphorus	1.02E-05	4.66E-05	1.01E-04	7.96E-05	2.87E-04	1.52E-04	2.61E-04	1.08E-04	8.49E-05	8.36E-05	1.25E-04	3.46E-04	1.79E-04	4.65E-04
Platinum	7.70E-07	3.52E-06	7.61E-06	6.01E-06	2.17E-05	1.14E-05	1.97E-05	8.18E-06	6.41E-06	6.31E-06	9.45E-06	2.61E-05	1.35E-05	3.51E-05
Potassium	3.90E-05	1.78E-04	3.85E-04	3.04E-04	1.10E-03	5.80E-04	9.97E-04	4.14E-04	3.24E-04	3.20E-04	4.79E-04	1.32E-03	6.84E-04	1.78E-03
Rhodium	7.70E-07	3.52E-06	7.61E-06	6.01E-06	2.17E-05	1.14E-05	1.97E-05	8.18E-06	6.41E-06	6.31E-06	9.45E-06	2.61E-05	1.35E-05	3.51E-05
Rubidium	1.54E-06	7.04E-06	1.52E-05	1.20E-05	4.34E-05	2.29E-05	3.94E-05	1.64E-05	1.28E-05	1.26E-05	1.89E-05	5.23E-05	2.70E-05	7.02E-05
Selenium	1.36E-06	6.22E-06	1.34E-05	1.06E-05	3.83E-05	2.02E-05	3.48E-05	1.44E-05	1.13E-05	1.12E-05	1.67E-05	4.62E-05	2.38E-05	6.20E-05
Silicon	7.10E-05	3.24E-04	7.01E-04	5.54E-04	2.00E-03	1.06E-03	1.82E-03	7.54E-04	5.91E-04	5.82E-04	8.71E-04	2.41E-03	1.24E-03	3.24E-03
Silver	6.13E-06	2.80E-05	6.06E-05	4.78E-05	1.73E-04	9.12E-05	1.57E-04	6.51E-05	5.10E-05	5.03E-05	7.52E-05	2.08E-04	1.07E-04	2.79E-04
Sodium	3.61E-04	1.65E-03	3.57E-03	2.82E-03	1.02E-02	5.37E-03	9.23E-03	3.83E-03	3.00E-03	2.96E-03	4.43E-03	1.23E-02	6.33E-03	1.65E-02
Strontium	1.96E-06	8.96E-06	1.94E-05	1.53E-05	5.52E-05	2.91E-05	5.01E-05	2.08E-05	1.63E-05	1.61E-05	2.40E-05	6.65E-05	3.44E-05	8.94E-05

Table 22 b)

## Summary of Maximum 24 Hour POI Values at Sensitive Receptors

	RECEPTOR	1	2	3	4	5	6	7	8	9	10	11	12	13
Compound	Average													
	[g/s]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]
Sulphur	2.84E-02	1.30E-01	2.81E-01	2.22E-01	8.00E-01	4.22E-01	7.26E-01	3.02E-01	2.36E-01	2.33E-01	3.48E-01	9.64E-01	4.98E-01	1.29E+00
Tellurium	9.89E-07	4.52E-06	9.77E-06	7.71E-06	2.79E-05	1.47E-05	2.53E-05	1.05E-05	8.23E-06	8.11E-06	1.21E-05	3.36E-05	1.73E-05	4.51E-05
Thallium	7.70E-07	3.52E-06	7.61E-06	6.01E-06	2.17E-05	1.14E-05	1.97E-05	8.18E-06	6.41E-06	6.31E-06	9.45E-06	2.61E-05	1.35E-05	3.51E-05
Tin	7.04E-05	3.22E-04	6.96E-04	5.49E-04	1.98E-03	1.05E-03	1.80E-03	7.48E-04	5.86E-04	5.77E-04	8.64E-04	2.39E-03	1.23E-03	3.21E-03
Titanium	1.32E-06	6.03E-06	1.30E-05	1.03E-05	3.72E-05	1.96E-05	3.38E-05	1.40E-05	1.10E-05	1.08E-05	1.62E-05	4.48E-05	2.31E-05	6.02E-05
Tungsten	1.27E-06	5.80E-06	1.25E-05	9.91E-06	3.58E-05	1.89E-05	3.25E-05	1.35E-05	1.06E-05	1.04E-05	1.56E-05	4.31E-05	2.23E-05	5.79E-05
Uranium	7.70E-07	3.52E-06	7.61E-06	6.01E-06	2.17E-05	1.14E-05	1.97E-05	8.18E-06	6.41E-06	6.31E-06	9.45E-06	2.61E-05	1.35E-05	3.51E-05
Vanadium	1.63E-07	7.45E-07	1.61E-06	1.27E-06	4.59E-06	2.42E-06	4.17E-06	1.73E-06	1.36E-06	1.34E-06	2.00E-06	5.53E-06	2.86E-06	7.43E-06
Zinc	2.45E-05	1.12E-04	2.42E-04	1.91E-04	6.90E-04	3.64E-04	6.26E-04	2.60E-04	2.04E-04	2.01E-04	3.01E-04	8.32E-04	4.29E-04	1.12E-03
Zirconium	3.18E-07	1.45E-06	3.14E-06	2.48E-06	8.96E-06	4.73E-06	8.13E-06	3.38E-06	2.65E-06	2.61E-06	3.90E-06	1.08E-05	5.57E-06	1.45E-05
TPM	3.34E-02	1.53E-01	3.30E-01	2.61E-01	9.41E-01	4.97E-01	8.54E-01	3.55E-01	2.78E-01	2.74E-01	4.10E-01	1.13E+00	5.86E-01	1.52E+00
PCDD/F	6.12E-11	2.80E-10	6.05E-10	4.77E-10	1.72E-09	9.10E-10	1.57E-09	6.50E-10	5.09E-10	5.02E-10	7.51E-10	2.08E-09	1.07E-09	2.79E-09
Sulphur Dioxide	4.63E-02	2.12E-01	4.57E-01	3.61E-01	1.30E+00	6.88E-01	1.18E+00	4.92E-01	3.85E-01	3.80E-01	5.68E-01	1.57E+00	8.12E-01	2.11E+00
Nitrogen Dioxide	5.53E-01	2.53E+00	5.46E+00	4.31E+00	1.56E+01	8.22E+00	1.41E+01	5.87E+00	4.60E+00	4.53E+00	6.79E+00	1.88E+01	9.69E+00	2.52E+01
Chlorine	5.93E-04	2.71E-03	5.86E-03	4.63E-03	1.67E-02	8.82E-03	1.52E-02	6.30E-03	4.93E-03	4.86E-03	7.28E-03	2.01E-02	1.04E-02	2.70E-02
Hydrogen Chloride	7.13E-02	3.26E-01	7.04E-01	5.56E-01	2.01E+00	1.06E+00	1.82E+00	7.57E-01	5.93E-01	5.84E-01	8.75E-01	2.42E+00	1.25E+00	3.25E+00
Vinyl Chloride Monomer	6.62E-06	3.03E-05	6.54E-05	5.16E-05	1.86E-04	9.84E-05	1.69E-04	7.03E-05	5.51E-05	5.43E-05	8.12E-05	2.25E-04	1.16E-04	3.02E-04
Benz(a)pyrene	5.85E-07	2.67E-06	5.78E-06	4.56E-06	1.65E-05	8.70E-06	1.50E-05	6.21E-06	4.87E-06	4.80E-06	7.18E-06	1.99E-05	1.03E-05	2.67E-05
Benzene	1.78E-05	8.13E-05	1.76E-04	1.39E-04	5.01E-04	2.65E-04	4.55E-04	1.89E-04	1.48E-04	1.46E-04	2.18E-04	6.04E-04	3.12E-04	8.12E-04

Table 22 c)

## Summary of Maximum Annual POI Values at Sensitive Receptors

	RECEPTOR	1	2	3	4	5	6	7	8	9	10	11	12	13
Compound	Average													
	[g/s]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]
Aluminum	2.27E-05	4.31E-06	6.36E-06	8.85E-06	1.84E-05	2.63E-05	1.45E-05	1.59E-05	1.14E-05	9.31E-06	1.48E-05	4.38E-05	3.29E-05	2.79E-05
Antimony	1.08E-06	2.05E-07	3.02E-07	4.21E-07	8.75E-07	1.25E-06	6.91E-07	7.56E-07	5.40E-07	4.43E-07	7.02E-07	2.08E-06	1.57E-06	1.33E-06
Arsenic	8.90E-07	1.69E-07	2.49E-07	3.47E-07	7.21E-07	1.03E-06	5.70E-07	6.23E-07	4.45E-07	3.65E-07	5.79E-07	1.72E-06	1.29E-06	1.09E-06
Barium	3.07E-06	5.83E-07	8.60E-07	1.20E-06	2.49E-06	3.56E-06	1.96E-06	2.15E-06	1.54E-06	1.26E-06	2.00E-06	5.93E-06	4.45E-06	3.78E-06
Beryllium	1.54E-07	2.93E-08	4.31E-08	6.01E-08	1.25E-07	1.79E-07	9.86E-08	1.08E-07	7.70E-08	6.31E-08	1.00E-07	2.97E-07	2.23E-07	1.89E-07
Bismuth	2.22E-07	4.22E-08	6.22E-08	8.66E-08	1.80E-07	2.58E-07	1.42E-07	1.55E-07	1.11E-07	9.10E-08	1.44E-07	4.28E-07	3.22E-07	2.73E-07
Boron	6.30E-04	1.20E-04	1.76E-04	2.46E-04	5.10E-04	7.31E-04	4.03E-04	4.41E-04	3.15E-04	2.58E-04	4.10E-04	1.22E-03	9.14E-04	7.75E-04
Cadmium	1.52E-06	2.89E-07	4.26E-07	5.93E-07	1.23E-06	1.76E-06	9.73E-07	1.06E-06	7.60E-07	6.23E-07	9.88E-07	2.93E-06	2.20E-06	1.87E-06
Calcium	2.73E-04	5.19E-05	7.64E-05	1.06E-04	2.21E-04	3.17E-04	1.75E-04	1.91E-04	1.37E-04	1.12E-04	1.77E-04	5.27E-04	3.96E-04	3.36E-04
Chromium	3.24E-05	6.16E-06	9.07E-06	1.26E-05	2.62E-05	3.76E-05	2.07E-05	2.27E-05	1.62E-05	1.33E-05	2.11E-05	6.25E-05	4.70E-05	3.99E-05
Cobalt	1.01E-06	1.92E-07	2.83E-07	3.94E-07	8.18E-07	1.17E-06	6.46E-07	7.07E-07	5.05E-07	4.14E-07	6.57E-07	1.95E-06	1.46E-06	1.24E-06
Copper	1.14E-05	2.17E-06	3.19E-06	4.45E-06	9.23E-06	1.32E-05	7.30E-06	7.98E-06	5.70E-06	4.67E-06	7.41E-06	2.20E-05	1.65E-05	1.40E-05
Germanium	1.54E-06	2.93E-07	4.31E-07	6.01E-07	1.25E-06	1.79E-06	9.86E-07	1.08E-06	7.70E-07	6.31E-07	1.00E-06	2.97E-06	2.23E-06	1.89E-06
Gold	7.70E-07	1.46E-07	2.16E-07	3.00E-07	6.24E-07	8.93E-07	4.93E-07	5.39E-07	3.85E-07	3.16E-07	5.01E-07	1.49E-06	1.12E-06	9.47E-07
Indium	7.70E-07	1.46E-07	2.16E-07	3.00E-07	6.24E-07	8.93E-07	4.93E-07	5.39E-07	3.85E-07	3.16E-07	5.01E-07	1.49E-06	1.12E-06	9.47E-07
Iridium	7.70E-07	1.46E-07	2.16E-07	3.00E-07	6.24E-07	8.93E-07	4.93E-07	5.39E-07	3.85E-07	3.16E-07	5.01E-07	1.49E-06	1.12E-06	9.47E-07
Iron	4.04E-04	7.68E-05	1.13E-04	1.58E-04	3.27E-04	4.69E-04	2.59E-04	2.83E-04	2.02E-04	1.66E-04	2.63E-04	7.80E-04	5.86E-04	4.97E-04
Lead	3.30E-06	6.27E-07	9.24E-07	1.29E-06	2.67E-06	3.83E-06	2.11E-06	2.31E-06	1.65E-06	1.35E-06	2.15E-06	6.37E-06	4.79E-06	4.06E-06
Magnesium	2.84E-05	5.40E-06	7.95E-06	1.11E-05	2.30E-05	3.29E-05	1.82E-05	1.99E-05	1.42E-05	1.16E-05	1.85E-05	5.48E-05	4.12E-05	3.49E-05
Manganese	1.56E-05	2.96E-06	4.37E-06	6.08E-06	1.26E-05	1.81E-05	9.98E-06	1.09E-05	7.80E-06	6.40E-06	1.01E-05	3.01E-05	2.26E-05	1.92E-05
Mercury	4.11E-06	7.81E-07	1.15E-06	1.60E-06	3.33E-06	4.77E-06	2.63E-06	2.88E-06	2.06E-06	1.69E-06	2.67E-06	7.93E-06	5.96E-06	5.06E-06
Molybdenum	2.51E-06	4.77E-07	7.03E-07	9.79E-07	2.03E-06	2.91E-06	1.61E-06	1.76E-06	1.26E-06	1.03E-06	1.63E-06	4.84E-06	3.64E-06	3.09E-06
Nickel	6.12E-05	1.16E-05	1.71E-05	2.39E-05	4.96E-05	7.10E-05	3.92E-05	4.28E-05	3.06E-05	2.51E-05	3.98E-05	1.18E-04	8.87E-05	7.53E-05
Palladium	1.54E-07	2.93E-08	4.31E-08	6.01E-08	1.25E-07	1.79E-07	9.86E-08	1.08E-07	7.70E-08	6.31E-08	1.00E-07	2.97E-07	2.23E-07	1.89E-07
Phosphorus	1.02E-05	1.94E-06	2.86E-06	3.98E-06	8.26E-06	1.18E-05	6.53E-06	7.14E-06	5.10E-06	4.18E-06	6.63E-06	1.97E-05	1.48E-05	1.25E-05
Platinum	7.70E-07	1.46E-07	2.16E-07	3.00E-07	6.24E-07	8.93E-07	4.93E-07	5.39E-07	3.85E-07	3.16E-07	5.01E-07	1.49E-06	1.12E-06	9.47E-07
Potassium	3.90E-05	7.41E-06	1.09E-05	1.52E-05	3.16E-05	4.52E-05	2.50E-05	2.73E-05	1.95E-05	1.60E-05	2.54E-05	7.53E-05	5.66E-05	4.80E-05
Rhodium	7.70E-07	1.46E-07	2.16E-07	3.00E-07	6.24E-07	8.93E-07	4.93E-07	5.39E-07	3.85E-07	3.16E-07	5.01E-07	1.49E-06	1.12E-06	9.47E-07
Rubidium	1.54E-06	2.93E-07	4.31E-07	6.01E-07	1.25E-06	1.79E-06	9.86E-07	1.08E-06	7.70E-07	6.31E-07	1.00E-06	2.97E-06	2.23E-06	1.89E-06
Selenium	1.36E-06	2.58E-07	3.81E-07	5.30E-07	1.10E-06	1.58E-06	8.70E-07	9.52E-07	6.80E-07	5.58E-07	8.84E-07	2.62E-06	1.97E-06	1.67E-06
Silicon	7.10E-05	1.35E-05	1.99E-05	2.77E-05	5.75E-05	8.24E-05	4.54E-05	4.97E-05	3.55E-05	2.91E-05	4.62E-05	1.37E-04	1.03E-04	8.73E-05
Silver	6.13E-06	1.16E-06	1.72E-06	2.39E-06	4.97E-06	7.11E-06	3.92E-06	4.29E-06	3.07E-06	2.51E-06	3.98E-06	1.18E-05	8.89E-06	7.54E-06
Sodium	3.61E-04	6.86E-05	1.01E-04	1.41E-04	2.92E-04	4.19E-04	2.31E-04	2.53E-04	1.81E-04	1.48E-04	2.35E-04	6.97E-04	5.23E-04	4.44E-04
Strontium	1.96E-06	3.72E-07	5.49E-07	7.64E-07	1.59E-06	2.27E-06	1.25E-06	1.37E-06	9.80E-07	8.04E-07	1.27E-06	3.78E-06	2.84E-06	2.41E-06

Table 22 c)

## Summary of Maximum Annual POI Values at Sensitive Receptors

Compound	RECEPTOR	1	2	3	4	5	6	7	8	9	10	11	12	13
	Average [g/s]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]	[ug/m3]
Sulphur	2.84E-02	5.40E-03	7.95E-03	1.11E-02	2.30E-02	3.29E-02	1.82E-02	1.99E-02	1.42E-02	1.16E-02	1.85E-02	5.48E-02	4.12E-02	3.49E-02
Tellurium	9.89E-07	1.88E-07	2.77E-07	3.86E-07	8.01E-07	1.15E-06	6.33E-07	6.92E-07	4.95E-07	4.05E-07	6.43E-07	1.91E-06	1.43E-06	1.22E-06
Thallium	7.70E-07	1.46E-07	2.16E-07	3.00E-07	6.24E-07	8.93E-07	4.93E-07	5.39E-07	3.85E-07	3.16E-07	5.01E-07	1.49E-06	1.12E-06	9.47E-07
Tin	7.04E-05	1.34E-05	1.97E-05	2.75E-05	5.70E-05	8.17E-05	4.51E-05	4.93E-05	3.52E-05	2.89E-05	4.58E-05	1.36E-04	1.02E-04	8.66E-05
Titanium	1.32E-06	2.51E-07	3.70E-07	5.15E-07	1.07E-06	1.53E-06	8.45E-07	9.24E-07	6.60E-07	5.41E-07	8.58E-07	2.55E-06	1.91E-06	1.62E-06
Tungsten	1.27E-06	2.41E-07	3.56E-07	4.95E-07	1.03E-06	1.47E-06	8.13E-07	8.89E-07	6.35E-07	5.21E-07	8.26E-07	2.45E-06	1.84E-06	1.56E-06
Uranium	7.70E-07	1.46E-07	2.16E-07	3.00E-07	6.24E-07	8.93E-07	4.93E-07	5.39E-07	3.85E-07	3.16E-07	5.01E-07	1.49E-06	1.12E-06	9.47E-07
Vanadium	1.63E-07	3.10E-08	4.56E-08	6.36E-08	1.32E-07	1.89E-07	1.04E-07	1.14E-07	8.15E-08	6.68E-08	1.06E-07	3.15E-07	2.36E-07	2.00E-07
Zinc	2.45E-05	4.66E-06	6.86E-06	9.56E-06	1.98E-05	2.84E-05	1.57E-05	1.72E-05	1.23E-05	1.00E-05	1.59E-05	4.73E-05	3.55E-05	3.01E-05
Zirconium	3.18E-07	6.04E-08	8.90E-08	1.24E-07	2.58E-07	3.69E-07	2.04E-07	2.23E-07	1.59E-07	1.30E-07	2.07E-07	6.14E-07	4.61E-07	3.91E-07
TPM	3.34E-02	6.35E-03	9.35E-03	1.30E-02	2.71E-02	3.87E-02	2.14E-02	2.34E-02	1.67E-02	1.37E-02	2.17E-02	6.45E-02	4.84E-02	4.11E-02
PCDD/F	6.12E-11	1.16E-11	1.71E-11	2.39E-11	4.96E-11	7.10E-11	3.92E-11	4.28E-11	3.06E-11	2.51E-11	3.98E-11	1.18E-10	8.88E-11	7.53E-11
Sulphur Dioxide	4.63E-02	8.80E-03	1.30E-02	1.81E-02	3.75E-02	5.37E-02	2.96E-02	3.24E-02	2.32E-02	1.90E-02	3.01E-02	8.94E-02	6.71E-02	5.69E-02
Nitrogen Dioxide	5.53E-01	1.05E-01	1.55E-01	2.16E-01	4.48E-01	6.41E-01	3.54E-01	3.87E-01	2.77E-01	2.27E-01	3.59E-01	1.07E+00	8.02E-01	6.80E-01
Chlorine	5.93E-04	1.13E-04	1.66E-04	2.31E-04	4.80E-04	6.88E-04	3.80E-04	4.15E-04	2.97E-04	2.43E-04	3.85E-04	1.14E-03	8.60E-04	7.29E-04
Hydrogen Chloride	7.13E-02	1.35E-02	2.00E-02	2.78E-02	5.77E-02	8.27E-02	4.56E-02	4.99E-02	3.56E-02	2.92E-02	4.63E-02	1.38E-01	1.03E-01	8.77E-02
Vinyl Chloride Monomer	6.62E-06	1.26E-06	1.85E-06	2.58E-06	5.36E-06	7.68E-06	4.24E-06	4.63E-06	3.31E-06	2.71E-06	4.30E-06	1.28E-05	9.60E-06	8.14E-06
Benz(a)pyrene	5.85E-07	1.11E-07	1.64E-07	2.28E-07	4.74E-07	6.79E-07	3.74E-07	4.10E-07	2.93E-07	2.40E-07	3.80E-07	1.13E-06	8.48E-07	7.20E-07
Benzene	1.78E-05	3.38E-06	4.98E-06	6.94E-06	1.44E-05	2.06E-05	1.14E-05	1.25E-05	8.90E-06	7.30E-06	1.16E-05	3.44E-05	2.58E-05	2.19E-05



Table 22 d)

## Summary of Maximum Annual Deposition at Sensitive Receptors

	RECEPTOR	1	2	3	4	5	6	7	8	9	10	11	12	13
Compound	Average													
	[g/s]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]
Aluminum	2.27E-05	2.76E-07	3.61E-07	5.79E-07	1.24E-06	3.95E-06	1.64E-06	8.94E-07	6.89E-07	6.19E-07	9.18E-07	5.45E-06	4.44E-06	2.59E-06
Antimony	1.08E-06	1.31E-08	1.72E-08	2.75E-08	5.90E-08	1.88E-07	7.80E-08	4.26E-08	3.28E-08	2.94E-08	4.37E-08	2.59E-07	2.11E-07	1.23E-07
Arsenic	8.90E-07	1.08E-08	1.42E-08	2.27E-08	4.86E-08	1.55E-07	6.43E-08	3.51E-08	2.70E-08	2.43E-08	3.60E-08	2.14E-07	1.74E-07	1.02E-07
Barium	3.07E-06	3.73E-08	4.88E-08	7.83E-08	1.68E-07	5.34E-07	2.22E-07	1.21E-07	9.32E-08	8.37E-08	1.24E-07	7.37E-07	6.00E-07	3.51E-07
Beryllium	1.54E-07	1.87E-09	2.45E-09	3.93E-09	8.42E-09	2.68E-08	1.11E-08	6.07E-09	4.67E-09	4.20E-09	6.23E-09	3.70E-08	3.01E-08	1.76E-08
Bismuth	2.22E-07	2.70E-09	3.53E-09	5.66E-09	1.21E-08	3.86E-08	1.60E-08	8.75E-09	6.74E-09	6.05E-09	8.98E-09	5.33E-08	4.34E-08	2.54E-08
Boron	6.30E-04	7.66E-06	1.00E-05	1.61E-05	3.44E-05	1.10E-04	4.55E-05	2.48E-05	1.91E-05	1.72E-05	2.55E-05	1.51E-04	1.23E-04	7.20E-05
Cadmium	1.52E-06	1.85E-08	2.42E-08	3.87E-08	8.31E-08	2.65E-07	1.10E-07	5.99E-08	4.61E-08	4.14E-08	6.15E-08	3.65E-07	2.97E-07	1.74E-07
Calcium	2.73E-04	3.32E-06	4.34E-06	6.96E-06	1.49E-05	4.75E-05	1.97E-05	1.08E-05	8.29E-06	7.44E-06	1.10E-05	6.55E-05	5.34E-05	3.12E-05
Chromium	3.24E-05	3.94E-07	5.15E-07	8.26E-07	1.77E-06	5.64E-06	2.34E-06	1.28E-06	9.83E-07	8.83E-07	1.31E-06	7.78E-06	6.33E-06	3.70E-06
Cobalt	1.01E-06	1.23E-08	1.61E-08	2.57E-08	5.52E-08	1.76E-07	7.29E-08	3.98E-08	3.07E-08	2.75E-08	4.09E-08	2.43E-07	1.97E-07	1.15E-07
Copper	1.14E-05	1.39E-07	1.81E-07	2.91E-07	6.23E-07	1.98E-06	8.23E-07	4.49E-07	3.46E-07	3.11E-07	4.61E-07	2.74E-06	2.23E-06	1.30E-06
Germanium	1.54E-06	1.87E-08	2.45E-08	3.93E-08	8.42E-08	2.68E-07	1.11E-07	6.07E-08	4.67E-08	4.20E-08	6.23E-08	3.70E-07	3.01E-07	1.76E-07
Gold	7.70E-07	9.36E-09	1.22E-08	1.96E-08	4.21E-08	1.34E-07	5.56E-08	3.03E-08	2.34E-08	2.10E-08	3.11E-08	1.85E-07	1.51E-07	8.80E-08
Indium	7.70E-07	9.36E-09	1.22E-08	1.96E-08	4.21E-08	1.34E-07	5.56E-08	3.03E-08	2.34E-08	2.10E-08	3.11E-08	1.85E-07	1.51E-07	8.80E-08
Iridium	7.70E-07	9.36E-09	1.22E-08	1.96E-08	4.21E-08	1.34E-07	5.56E-08	3.03E-08	2.34E-08	2.10E-08	3.11E-08	1.85E-07	1.51E-07	8.80E-08
Iron	4.04E-04	4.91E-06	6.42E-06	1.03E-05	2.21E-05	7.03E-05	2.92E-05	1.59E-05	1.23E-05	1.10E-05	1.63E-05	9.70E-05	7.90E-05	4.62E-05
Lead	3.30E-06	4.01E-08	5.25E-08	8.41E-08	1.80E-07	5.74E-07	2.38E-07	1.30E-07	1.00E-07	8.99E-08	1.33E-07	7.92E-07	6.45E-07	3.77E-07
Magnesium	2.84E-05	3.45E-07	4.52E-07	7.24E-07	1.55E-06	4.94E-06	2.05E-06	1.12E-06	8.62E-07	7.74E-07	1.15E-06	6.82E-06	5.55E-06	3.25E-06
Manganese	1.56E-05	1.90E-07	2.48E-07	3.98E-07	8.53E-07	2.72E-06	1.13E-06	6.15E-07	4.73E-07	4.25E-07	6.31E-07	3.75E-06	3.05E-06	1.78E-06
Mercury	4.11E-06	5.00E-08	6.53E-08	1.05E-07	2.25E-07	7.15E-07	2.97E-07	1.62E-07	1.25E-07	1.12E-07	1.66E-07	9.87E-07	8.04E-07	4.70E-07
Molybdenum	2.51E-06	3.05E-08	3.99E-08	6.40E-08	1.37E-07	4.37E-07	1.81E-07	9.89E-08	7.62E-08	6.84E-08	1.02E-07	6.03E-07	4.91E-07	2.87E-07
Nickel	6.12E-05	7.44E-07	9.73E-07	1.56E-06	3.35E-06	1.07E-05	4.42E-06	2.41E-06	1.86E-06	1.67E-06	2.48E-06	1.47E-05	1.20E-05	7.00E-06
Palladium	1.54E-07	1.87E-09	2.45E-09	3.93E-09	8.42E-09	2.68E-08	1.11E-08	6.07E-09	4.67E-09	4.20E-09	6.23E-09	3.70E-08	3.01E-08	1.76E-08
Phosphorus	1.02E-05	1.24E-07	1.62E-07	2.60E-07	5.58E-07	1.78E-06	7.36E-07	4.02E-07	3.10E-07	2.78E-07	4.13E-07	2.45E-06	1.99E-06	1.17E-06
Platinum	7.70E-07	9.36E-09	1.22E-08	1.96E-08	4.21E-08	1.34E-07	5.56E-08	3.03E-08	2.34E-08	2.10E-08	3.11E-08	1.85E-07	1.51E-07	8.80E-08
Potassium	3.90E-05	4.74E-07	6.20E-07	9.94E-07	2.13E-06	6.79E-06	2.82E-06	1.54E-06	1.18E-06	1.06E-06	1.58E-06	9.36E-06	7.62E-06	4.46E-06
Rhodium	7.70E-07	9.36E-09	1.22E-08	1.96E-08	4.21E-08	1.34E-07	5.56E-08	3.03E-08	2.34E-08	2.10E-08	3.11E-08	1.85E-07	1.51E-07	8.80E-08
Rubidium	1.54E-06	1.87E-08	2.45E-08	3.93E-08	8.42E-08	2.68E-07	1.11E-07	6.07E-08	4.67E-08	4.20E-08	6.23E-08	3.70E-07	3.01E-07	1.76E-07
Selenium	1.36E-06	1.65E-08	2.16E-08	3.47E-08	7.43E-08	2.37E-07	9.82E-08	5.36E-08	4.13E-08	3.71E-08	5.50E-08	3.27E-07	2.66E-07	1.55E-07
Silicon	7.10E-05	8.63E-07	1.13E-06	1.81E-06	3.88E-06	1.24E-05	5.13E-06	2.80E-06	2.15E-06	1.93E-06	2.87E-06	1.70E-05	1.39E-05	8.12E-06
Silver	6.13E-06	7.45E-08	9.75E-08	1.56E-07	3.35E-07	1.07E-06	4.43E-07	2.42E-07	1.86E-07	1.67E-07	2.48E-07	1.47E-06	1.20E-06	7.01E-07
Sodium	3.61E-04	4.39E-06	5.74E-06	9.20E-06	1.97E-05	6.28E-05	2.61E-05	1.42E-05	1.10E-05	9.84E-06	1.46E-05	8.67E-05	7.06E-05	4.13E-05
Strontium	1.96E-06	2.38E-08	3.12E-08	5.00E-08	1.07E-07	3.41E-07	1.42E-07	7.72E-08	5.95E-08	5.34E-08	7.93E-08	4.71E-07	3.83E-07	2.24E-07

Table 22 d)

## Summary of Maximum Annual Deposition at Sensitive Receptors

	RECEPTOR	1	2	3	4	5	6	7	8	9	10	11	12	13
Compound	Average													
	[g/s]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]	[g/m <sup>2</sup> /a]
Sulphur	2.84E-02	3.45E-04	4.52E-04	7.24E-04	1.55E-03	4.94E-03	2.05E-03	1.12E-03	8.62E-04	7.74E-04	1.15E-03	6.82E-03	5.55E-03	3.25E-03
Tellurium	9.89E-07	1.20E-08	1.57E-08	2.52E-08	5.41E-08	1.72E-07	7.14E-08	3.90E-08	3.00E-08	2.70E-08	4.00E-08	2.37E-07	1.93E-07	1.13E-07
Thallium	7.70E-07	9.36E-09	1.22E-08	1.96E-08	4.21E-08	1.34E-07	5.56E-08	3.03E-08	2.34E-08	2.10E-08	3.11E-08	1.85E-07	1.51E-07	8.80E-08
Tin	7.04E-05	8.56E-07	1.12E-06	1.79E-06	3.85E-06	1.23E-05	5.08E-06	2.77E-06	2.14E-06	1.92E-06	2.85E-06	1.69E-05	1.38E-05	8.05E-06
Titanium	1.32E-06	1.61E-08	2.10E-08	3.36E-08	7.22E-08	2.30E-07	9.53E-08	5.20E-08	4.01E-08	3.60E-08	5.34E-08	3.17E-07	2.58E-07	1.51E-07
Tungsten	1.27E-06	1.54E-08	2.02E-08	3.24E-08	6.94E-08	2.21E-07	9.17E-08	5.00E-08	3.85E-08	3.46E-08	5.14E-08	3.05E-07	2.48E-07	1.45E-07
Uranium	7.70E-07	9.36E-09	1.22E-08	1.96E-08	4.21E-08	1.34E-07	5.56E-08	3.03E-08	2.34E-08	2.10E-08	3.11E-08	1.85E-07	1.51E-07	8.80E-08
Vanadium	1.63E-07	1.98E-09	2.59E-09	4.15E-09	8.91E-09	2.84E-08	1.18E-08	6.42E-09	4.95E-09	4.44E-09	6.59E-09	3.91E-08	3.19E-08	1.86E-08
Zinc	2.45E-05	2.98E-07	3.90E-07	6.25E-07	1.34E-06	4.26E-06	1.77E-06	9.65E-07	7.44E-07	6.68E-07	9.91E-07	5.88E-06	4.79E-06	2.80E-06
Zirconium	3.18E-07	3.87E-09	5.06E-09	8.11E-09	1.74E-08	5.53E-08	2.30E-08	1.25E-08	9.65E-09	8.67E-09	1.29E-08	7.64E-08	6.22E-08	3.63E-08
TPM	3.34E-02	4.06E-04	5.31E-04	8.51E-04	1.83E-03	5.81E-03	2.41E-03	1.32E-03	1.01E-03	9.10E-04	1.35E-03	8.02E-03	6.53E-03	3.82E-03
PCDD/F	6.12E-11	7.44E-13	9.73E-13	1.56E-12	3.35E-12	1.07E-11	4.42E-12	2.41E-12	1.86E-12	1.67E-12	2.48E-12	1.47E-11	1.20E-11	7.00E-12

Table 23

Summary of Maximum Residential POI Values due to Upset Operations

Compound	Average Emission		O.Reg 419 Criteria Levels 1 Hour		Max POI		O.Reg 419 Criteria Levels 24 Hour		Annual
	Rate	1 Hour	Average	24 Hour	Average	24 Hour			
	[g/s]	[ug/m3]	[ug/m3] (% criteria)	[ug/m3]	[ug/m3] (% criteria)			[ug/m3]	
Aluminum	2.27E-05	2.55E-02		2.59E-03				1.23E-04	
Antimony	1.08E-06	1.22E-03		1.23E-04	2.50E+01	0.0005%		5.84E-06	
Arsenic	8.90E-07	1.00E-03		1.01E-04				4.81E-06	
Barium	3.07E-06	3.45E-03		3.50E-04				1.66E-05	
Beryllium	1.54E-07	1.73E-04		1.76E-05	1.00E-02	0.1755%		8.32E-07	
Bismuth	2.22E-07	2.50E-04		2.53E-05				1.20E-06	
Boron	6.30E-04	7.09E-01		7.18E-02	1.20E+02	0.0598%		3.40E-03	
Cadmium	1.52E-06	1.71E-03		1.73E-04	2.50E-02	0.6930%		8.21E-06	
Calcium [as Ca(OH)2]	2.73E-04	3.07E-01		3.11E-02	1.35E+01	0.2305%		1.48E-03	
Chromium	3.24E-05	3.65E-02		3.69E-03				1.75E-04	
Cobalt	1.01E-06	1.14E-03		1.15E-04				5.46E-06	
Copper	1.14E-05	1.28E-02		1.30E-03	5.00E+01	0.0026%		6.16E-05	
Germanium	1.54E-06	1.73E-03		1.76E-04				8.32E-06	
Gold	7.70E-07	8.66E-04		8.78E-05				4.16E-06	
Indium	7.70E-07	8.66E-04		8.78E-05				4.16E-06	
Iridium	7.70E-07	8.66E-04		8.78E-05				4.16E-06	
Iron	4.04E-04	4.55E-01		4.60E-02	4.00E+00	1.1511%		2.18E-03	
Lead	3.30E-06	3.71E-03		3.76E-04	2.00E+00	0.0188%		1.78E-05	
Magnesium [as MgO]	2.84E-05	3.20E-02		3.24E-03	1.20E+02	0.0027%		1.53E-04	
Manganese	1.56E-05	1.76E-02		1.78E-03				8.43E-05	
Mercury	4.11E-06	4.62E-03		4.68E-04	2.00E+00	0.0234%		2.22E-05	
Molybdenum	2.51E-06	2.82E-03		2.86E-04				1.36E-05	
Nickel	6.12E-05	6.89E-02		6.98E-03	2.00E+00	0.3488%		3.31E-04	
Palladium	1.54E-07	1.73E-04		1.76E-05				8.32E-07	
Phosphorus	1.02E-05	1.15E-02		1.16E-03				5.51E-05	
Platinum	7.70E-07	8.66E-04		8.78E-05				4.16E-06	
Potassium	3.90E-05	4.39E-02		4.45E-03				2.11E-04	
Rhodium	7.70E-07	8.66E-04		8.78E-05				4.16E-06	
Rubidium	1.54E-06	1.73E-03		1.76E-04				8.32E-06	
Selenium	1.36E-06	1.53E-03		1.55E-04				7.35E-06	
Silicon	7.10E-05	7.99E-02		8.09E-03				3.84E-04	
Silver	6.13E-06	6.90E-03		6.99E-04	1.00E+00	0.0699%		3.31E-05	
Sodium	3.61E-04	4.06E-01		4.11E-02				1.95E-03	
Strontium	1.96E-06	2.21E-03		2.23E-04				1.06E-05	
Sulphur	2.84E-02	3.20E+01		3.24E+00				1.53E-01	
Tellurium	9.89E-07	1.11E-03		1.13E-04				5.34E-06	
Thallium	7.70E-07	8.66E-04		8.78E-05				4.16E-06	
Tin	7.04E-05	7.92E-02		8.02E-03	1.00E+01	0.0802%		3.80E-04	
Titanium	1.32E-06	1.49E-03		1.50E-04	1.20E+02	0.0001%		7.13E-06	
Tungsten	1.27E-06	1.43E-03		1.45E-04				6.86E-06	
Uranium	7.70E-07	8.66E-04		8.78E-05				4.16E-06	
Vanadium	1.63E-07	1.83E-04		1.86E-05	2.00E+00	0.0009%		8.81E-07	
Zinc	2.45E-05	2.76E-02		2.79E-03	1.20E+02	0.0023%		1.32E-04	
Zirconium	3.18E-07	3.58E-04		3.62E-05				1.72E-06	
TPM	3.34E-02	3.76E+01		3.81E+00	1.20E+02	3.1723%		1.80E-01	
PCDD/F	6.12E-11	6.89E-08		6.98E-09				3.31E-10	
Sulphur Dioxide	4.63E-02	3.67E+01	6.90E+02	3.72E+00	2.75E+02	1.3514%		1.76E-01	
Oxides of Nitrogen	5.53E-01	1.34E+02	4.00E+02	1.36E+01	2.00E+02	6.7772%		6.43E-01	
Chlorine	5.93E-04	6.67E-01		6.76E-02	1.00E+01	0.6759%		3.20E-03	
Hydrogen Chloride	7.13E-02	8.02E+01		8.12E+00	2.00E+01	40.6207%		3.85E-01	
Vinyl Chloride Monomer	6.62E-06	7.45E-03		7.55E-04	1.00E+00	0.0755%		3.58E-05	
Benz(a)pyrene	5.85E-07	6.58E-04		6.67E-05				3.16E-06	
Benzene	1.78E-05	2.00E-02		2.03E-03				9.62E-05	

## **7.2 Cumulative Effects of REMASCO Operations**

To assess the potential changes that would occur after the REMASCO equipment is used to replace existing boilers at the Southshore, Mucci, and Agriville greenhouses it is necessary to compare existing and future emissions from these greenhouses. However, these facilities are only part of the existing greenhouses in the Kingsville area and together with residential and transportation related emissions they all contribute to the existing levels of contaminants in the air. Since existing ambient air quality data is not available from the immediate vicinity, the contributions of the existing greenhouses were estimated and modelled so the results could be combined with the ambient data obtained by the MoE to represent current conditions. By using the same modelling procedures only replacing the existing Southshore, Mucci and Agriville boilers with the new REMASCO facilities, the future levels were predicted. This section presents the results of the analyses.

The emissions from the existing greenhouse operations were modelled for NO<sub>x</sub> and particulate matter. Since the ambient air quality standards for particulate matter are expressed as fine particulate, PM<sub>2.5</sub>, while Total Particulate Matter, PM<sub>10</sub>, and PM<sub>2.5</sub> were all considered, only the plots for PM<sub>2.5</sub> are presented in this section. Then PM<sub>2.5</sub> plots represent the maximum 24 hour average values for this contaminant, whereas the NO<sub>2</sub> plots are the maximum one hour values.

The figures show the modelling results as areas of the map shaded in different colours to represent the range of the maximum values recorded at the receptors. The ranges are delineated by solid lines that join points that have equal concentrations. These lines are called isopleths. The isopleths are drawn for a number of different concentrations as shown on the right hand side of the plot. The minimum value estimated to occur in the study area for a particular contaminant and averaging time is shown at the bottom of the scale of isopleths. The pattern of the isopleths shows higher levels closer to the sources. In comparing the figures, both the range on the isopleths and the area enclosed by a specific isopleth are important. Should the area stay the same, but the isopleth values change between the different situations the result of the change in operating condition would be fairly obvious. More typically the extent and the values change. These changes are discussed in the following sections.

It must be recognized that these levels do not occur simultaneously over the whole extent of the map, rather they are based upon the highest hourly, or daily average number recorded at each receptor over a 5 year period. That is the hourly values are the highest of 43,750 values calculated at that receptor and the daily averages are the highest of 1825 daily calculations at that receptor. The values depend upon the weather conditions for the hour modelled and the estimated emissions during that hour. The terrain in the area plays a role in the results because as the terrain rises, the estimated concentration increases as there is less space between the centerline of the plume and the ground.

None of the figures include the contribution from the other sources that is represented by the ambient air quality data reported by the MoE. These comparisons are presented in Table 24 where the appropriate ambient levels are added to the estimated levels at the sensitive receptors.

### 7.2.1 Oxides of Nitrogen

The results of the comparisons for hourly maximum concentrations of nitrogen dioxide are shown in Figures 9, 10 and 11. Figure 9 presents the existing situation; Figure 10 the REMASCO only results, and Figure 11 the combined effects of the existing greenhouses and the REMASCO units. These are based upon the anticipated NO<sub>2</sub> emission rate from the facilities, 10% of the total NO<sub>x</sub> released, and the influence of ambient ozone levels that will convert NO<sub>x</sub> in the atmosphere to NO<sub>2</sub> thus effectively increasing NO<sub>2</sub> levels.

Figure 9 shows the estimated existing one hour maximum NO<sub>2</sub> levels in the community from the operation of the greenhouse. The concentration outside the 145 ug/m<sup>3</sup> isopleth is 116 ug/m<sup>3</sup>. The isopleth representing 145 ug/m<sup>3</sup> concentrations of NO<sub>2</sub> enclose all the sources and tends to extend across the southern part of the study area, with the northerly area representing the effects of the 5 greenhouses west of Union. To the north of Southshore the ground rises resulting in the 145 ug/m<sup>3</sup> isopleth being extended around the higher ground further from the sources, however this also shows the effects of sources just to the east of the area on the plot. As the terrain drops towards the lake, the surface becomes further from the plume centreline and the concentration drops, thus the 145 ug/m<sup>3</sup> isopleth appears to follow the shore but slightly inland from the lake surface.

Closer to the sources additional isopleths are shown. These represent estimated concentrations of 200 ug/m<sup>3</sup> and 500 ug/m<sup>3</sup>. Not shown are even higher concentration isopleths close to the sources.

It is important to note that the modelling of the existing sources was undertaken to provide estimate of the general existing levels in the community, not for the purposes of establishing the suitability of any particular source. Without details on stack location, height, diameter, flow rate and temperature, nor precise details on the buildings surrounding the stacks, the modelling characterised emissions from a single large diameter stack with a very low exit velocity. This will give rise to higher levels close to the sources, typically on the property of the greenhouse owner. The tightly spaced isopleths around these sources are not shown around the existing Agriville and Southshore sources because the extent of the buildings on those sites was included in the model and the influence of the buildings on the dispersion results in a more fragmented isopleths pattern.

Figure 10 shows the maximum hourly ambient concentrations predicted to occur from the operation of the REMASCO sources. The outer most isopleths represents 18 ug/m<sup>3</sup> with the minimum in the study area being 6 ug/m<sup>3</sup>. The outside isopleths is about 1/8<sup>th</sup> of existing values. Inside the area higher concentrations are shown. The 18 ug/m<sup>3</sup> isopleth around Agriville is smaller than that around Southshore which would be expected since the emissions from Southshore are about 1.65 times those at Agriville. The 50 ug/m<sup>3</sup> isopleth originates from the Southshore site and shows the influence of site buildings on the plume at certain times of the year.

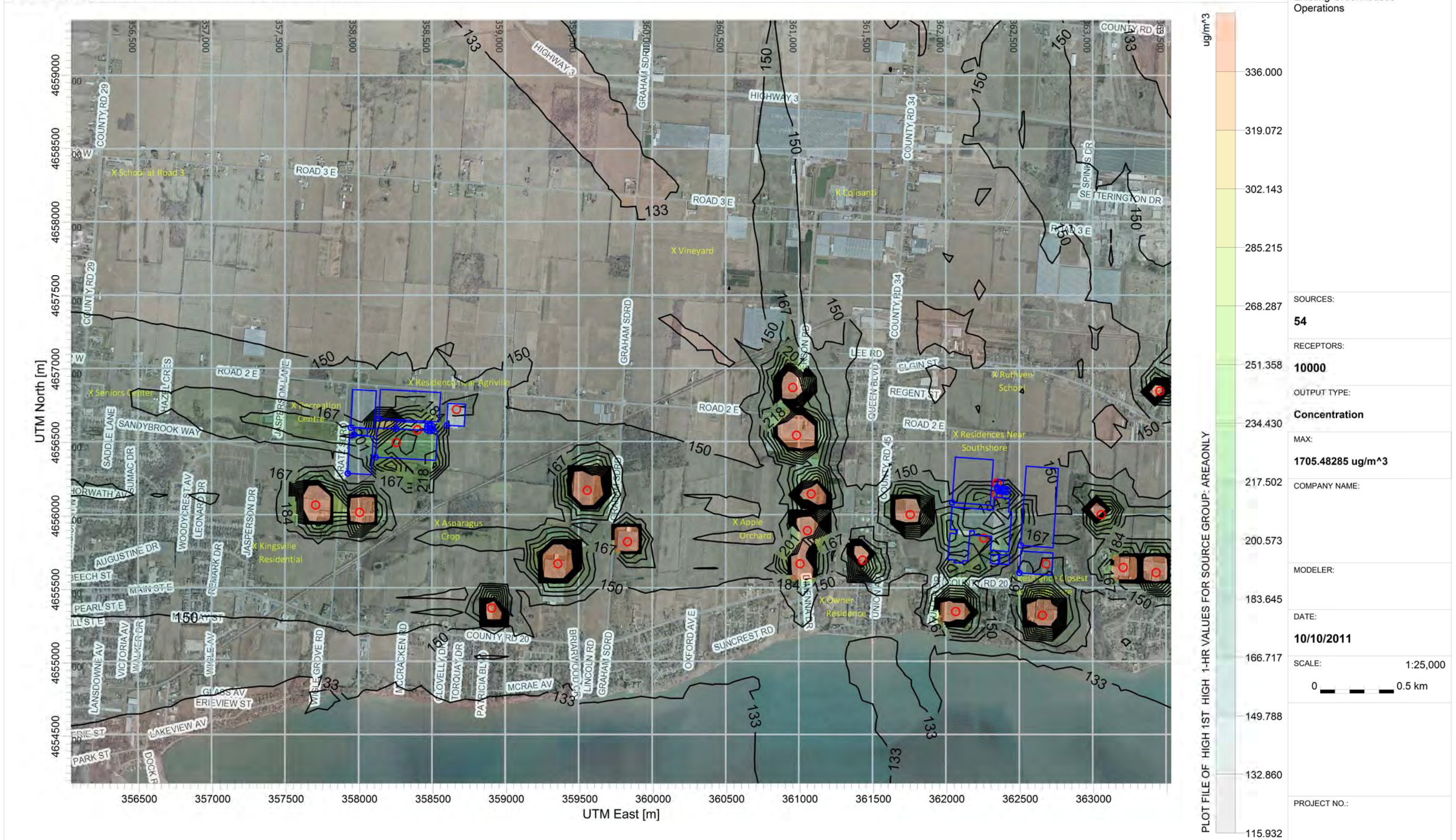
Figure 11 essentially combines the two plots above with the subtle change that the Southern and Agriville existing sources were replaced by the REMASCO sources in Figure 9. Two differences noticeable on this plot are the decrease in the outer isopleths concentration, 132 versus 145, and a decrease in the area inside that contour, at least to the west of the study area. The latter change is

likely the result of replacing the existing emissions at Agriville with the REMASCO system. However, to the north east of the study area, the area enclosed by the 132 ug/m<sup>3</sup> isopleth is more extensive than that seen for the 145 ug/m<sup>3</sup> contour in Figure 9. Looking at the pattern around Southshore in Figure 10, this change is readily understandable. The north south area in the isopleths west of Union still occurs showing the influence of the 5 sources. The terrain induced effects are still present in the north east corner of the figure. Overall, when the REMASCO facilities are at full operation, the minimum in the study area drops by 16% from the predicted existing level, and the 132 ug/m<sup>3</sup> isopleth represents a reduction of nearly 10% however, the area enclosed in the lower isopleths is approximately 20% larger.

Comparing Figures 9 and 11 shows ambient levels will generally decrease with the introduction of the REMASCO facilities.

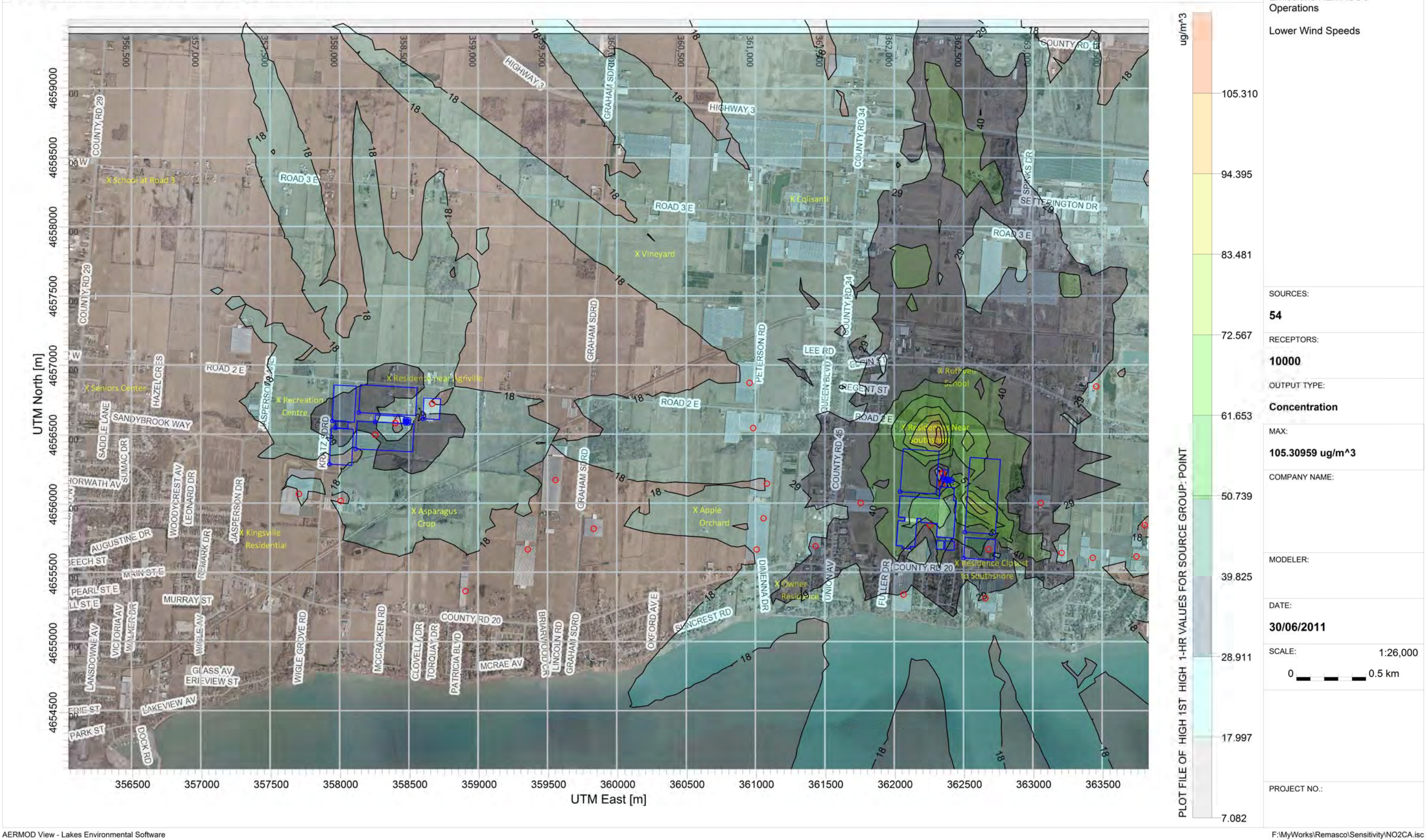


PROJECT TITLE:  
**REMASCO Environmental Assessment**  
**Existing Greenhouse Heating Impacts Nitrogen Dioxide Levels**





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**REMASCO Environmental Assessment**  
**Existing Greenhouse Heating Impacts Nitrogen Dioxide Levels**





PROJECT TITLE:  
**REMASCO Environmental Assessment**  
**Existing Greenhouse Heating Impacts Nitrogen Dioxide Levels**





### 7.2.2 PM<sub>2.5</sub> Concentration Predictions

Figures 12, 13 and 14 illustrate the maximum daily average isopleths created from modelling the PM<sub>2.5</sub> releases from the existing greenhouse sources and the REMASCO facilities. The plots and discussion are similar to those discussed in the previous section.

Figure 12, the existing situation, has a maximum daily average 32 ug/m<sup>3</sup> concentration isopleth covering most of the area. Inside that area higher zones of 64 and 128 ug/m<sup>3</sup> are shown. The north south arrangement of greenhouses results in elongated 64 ug/m<sup>3</sup> isopleths to the north and south of the center band.

Figure 13, the REMASCO only plot, shows the minimum to be 0.02 ug/m<sup>3</sup>. This is an order of magnitude lower than the minimum shown in the previous figure. Not surprisingly, the shape of the isopleths is similar to that of NO<sub>2</sub> shown in Figure 8, with a larger area with elevated concentration around the Southshore facility than around Agriville.

Figure 14, the combined situation, shows that maximum daily concentrations in the community would be reduced as the area covered by the 32 and 64 ug/m<sup>3</sup> isopleths is much smaller than in Figure 12. The minimum in the study area has dropped by 25% compared to the existing situation. After the REMASCO facilities start operating the area covered by the 64 ug/m<sup>3</sup> isopleth is approximately half of that predicted to exist at the present moment.



## REMASCO Environmental Assessment Cumulative Assessment of PM2.5 Emissions

### Existing Greenhouses

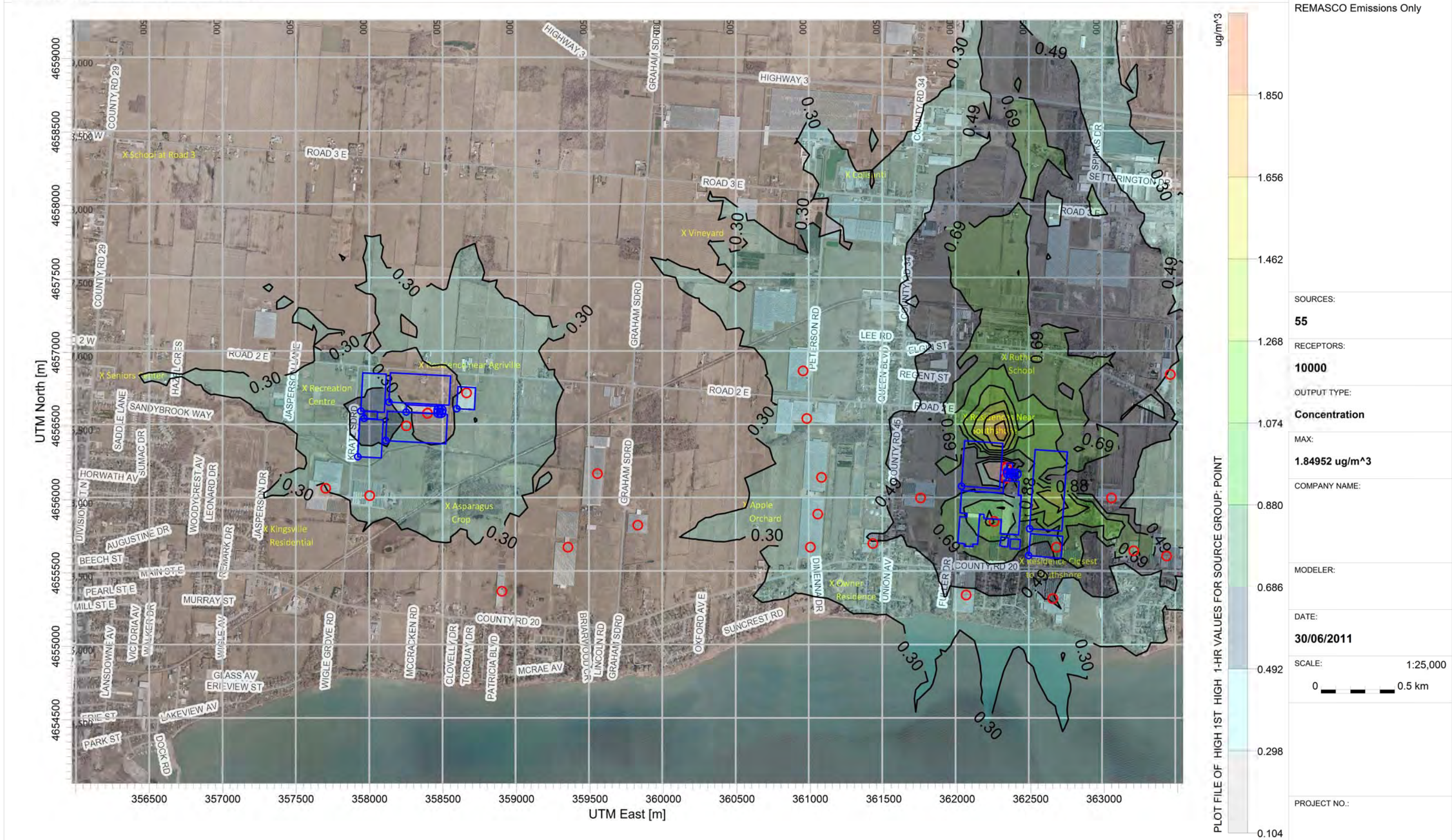


PROJECT NO.:



PROJECT TITLE:  
**REMASCO Environmental Assessment**  
**Cumulative Assessment of PM2.5 Emissions**

COMMENTS:  
Figure 13  
REMASCO Emissions Only





## REMASCO Environmental Assessment Cumulative Assessment of PM2.5 Emissions

Figure 14

**SOURCES:**

55

RECEPTORS:

OUTPUT TYPE:

### Concentration

MAX:

4064.14722 ug/m^3

COMPANY NAME:

MODELER:

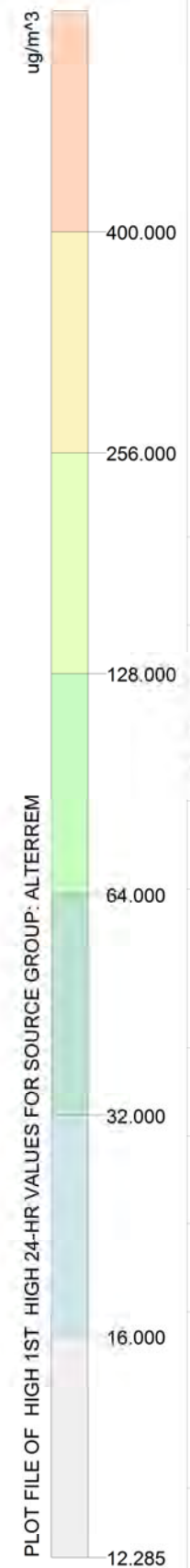
DATE:

10/10/2011

SCALE: 1:25,000

0 0.5 km

PROJECT NO.:



F:\MyWorks\Remasco\CAREPM25.isc



### 7.2.3 Comparison to Standards

While the figures discussed in the previous sections illustrate that the ambient air burden will be reduced when the REMASCO facilities are put into operation, it is important to utilize the results of the modelling to predict the levels in the community so they can be compared to standards.

Table 24 shows the estimated cumulative concentrations of NO<sub>2</sub> and PM<sub>2.5</sub> at the sensitive receptors for various averaging times. The concentrations include the contribution of other sources in the community as represented by the average values of monitored ambient concentrations reported by the MoE. These are the averages of the Chatham and Windsor data presented in Chapter 3. The averages for the two sites were assumed to be more representative than selecting either of the sites alone. The local source profiles will vary in the two communities, and while neither might be representative of the situation in Kingsville the average is more likely to be reflective of levels than either of the extremes. For NO<sub>2</sub> the hourly ambient contribution to the total is 40 ug/m<sup>3</sup>; for the daily value it is 58 ug/m<sup>3</sup>; and for the annual level it is 22.1 ug/m<sup>3</sup>. PM<sub>2.5</sub> ambient concentrations added to the modelled values were 17 ug/m<sup>3</sup> for 24 hours and 8.2 ug/m<sup>3</sup> for the annual value.

The table also contains the criteria levels that are applied to ambient data to assess acceptability.

The combination of the estimated contribution from the existing greenhouses and the ambient monitored values results in maximum 1 hour NO<sub>2</sub> values at the sensitive receptors that range from 179 – 226 ug/m<sup>3</sup>. The criteria level for NO<sub>2</sub> 1 hour concentrations is 400 ug/m<sup>3</sup>. These values are 45 – 57% of the criteria level. The assumed ambient background accounts for just under 18% of the maximum value. The range for the maximum 24 hour averages for the existing situation at the receptors is 114 – 184 ug/m<sup>3</sup>. This represents 57- 92% of the daily criteria level. The daily background absorbs 29% of the criteria level. Annually the average ranges from 25 – 50 ug/m<sup>3</sup> or 42 – 83% of the criteria level. The background value included is 36% of the criteria level.

Combining the REMASCO facilities with the existing greenhouses after replacing the boilers at REMASCO facilities lowers the NO<sub>2</sub> levels in the community. The 1 hour maxima with the background included is estimated to be 198 ug/m<sup>3</sup>. This is 12% less than the results from the existing case. The maximum daily average at the closest receptors drops from 181 to 143 ug/m<sup>3</sup> which represents a 21% reduction from the existing levels. The annual maximum at the nearby residences drops about 34% with the implementation of the new facilities.

The PM<sub>2.5</sub> standard is a 24 hour average value. Typically the MoE reports the number of days per year that the monitored values are over 30 ug/m<sup>3</sup>. As can be seen in Table 24, the maximum estimated for the existing situation at all of the sensitive receptors exceeds this value. It should be recognized that this prediction includes the background from monitoring which at 17 ug/m<sup>3</sup> is more than half the criteria level. Overall the maximum daily average value drops by 37% after the REMASCO facilities go into operation, but the data still suggest that all the sites will experience 24 hour averages that are above the 30 ug/m<sup>3</sup> criteria level.

The annual averages for PM<sub>2.5</sub> are shown in Table 24. In all cases after the REMASCO facilities commence operation the maximum annual average decreases. At the nearest receptor the decrease is nearly 40%.

#### **7.2.4 Summary of Cumulative Effects**

The results of the evaluation of cumulative effects at the sensitive receptors suggest that current levels of fine particulate matter in the area could be problematic, that is over the accepted threshold when the measured background levels from surrounding levels are added to the estimated emissions from existing greenhouses.

With the measured maximum daily PM<sub>2.5</sub> concentration value of 17 ug/m<sup>3</sup> or 57% of the criteria level there is little allowance for emissions from the sources in the area. The estimate of the effect of emissions from the greenhouses should be considered conservative that is biased high. The bias arises from the assumption that there was only limited particulate matter control on any of the coal or wood fired systems, assigning a common fuel mix, including wood and coal systems, to all the greenhouses and modelling the releases in a manner that decreases the momentum of the plume and thus the plume rise.

Improved particulate control is incorporated into the REMASCO systems. Furthermore, because the REMASCO stack characteristics are known, the emissions from these sources were modelled as proper point sources taking into account the influence of the buildings surrounding the stack. These factors suggest that the REMASCO facilities will add virtually nothing, less than 2%, to the PM<sub>2.5</sub> levels in the community. This results in the ambient levels of PM<sub>2.5</sub> decreasing after REMASCO starts operation, albeit a fairly small drop.

Existing NO<sub>2</sub> levels are below the criteria levels in all cases, and the effect of replacing boilers at some facilities with REMASCO units will be to reduce the levels, suggesting that there will be a beneficial impact from the facility.

Table 24 Cumulative Estimate of Background for Existing Situation

Existing Source Modelling Results combined with Ambient Monitoring Data						
Number	Description	NO2 1 Hr. [ug/m3]	NO2 24 hr. [ug/m3]	NO2 Ann [ug/m3]	PM2.5 24 hr [ug/m3]	PM2.5 Ann [ug/m3]
1	School on Road 3	179.61	113.66	25.23	48.71	10.24
2	Seniors Centre Kingsville	200.72	124.85	25.11	69.73	10.28
3	Residential Area Kingsville	201.32	155.33	30.11	92.05	13.05
4	Recreation Centre	214.77	146.5	31.02	101.91	13.89
5	Residence close to Agriville	197.74	183.57	41.99	129.28	20.24
6	Asparagus Field	208.13	151.53	36.69	92.96	18.29
7	Apple Orchard	193.61	159.34	38.99	114.05	19.01
8	Vineyard	178.01	122.75	31.56	72.09	14.61
9	Colisanti Complex	183.23	132.54	31.44	67.64	14.57
10	Owner's Residence	188.02	175.84	38.39	102.32	20.98
11	Residence north of Southshore	180.04	157.53	43.05	84.1	20.65
12	Ruthven School	179.01	135.02	37.23	64.96	17.34
13	Residence south of Southshore	226.12	180.67	49.94	135.25	25.59
	Criteria Levels	400	200	60	30	
Modelling Results for REMASCO Only (NO CONTRIBUTION FROM BACKGROUND)						
Number	Description	NO2 1 Hr. [ug/m3]	NO2 24 hr. [ug/m3]	NO2 Ann [ug/m3]	PM2.5 24 hr [ug/m3]	PM2.5 Ann [ug/m3]
1	School on Road 3	12.76	2.54	0.11	0.053	0.0021
2	Seniors Centre Kingsville	15.39	5.15	0.14	0.106	0.0033
3	Residential Area Kingsville	9.11	3.3	0.19	0.074	0.0011
4	Recreation Centre	24.7	11.93	0.43	0.224	0.007
5	Residence close to Agriville	33.39	8.16	0.64	0.079	0.0027
6	Asparagus Field	23.36	14.06	0.35	0.239	0.0056
7	Apple Orchard	21.96	5.89	0.37	0.121	0.0081
8	Vineyard	23.81	4.25	0.28	0.084	0.0058
9	Colisanti Complex	27.9	4.55	0.23	0.081	0.0046
10	Owner's Residence	22.52	6.29	0.36	0.123	0.008
11	Residence north of Southshore	76.27	23.96	1.22	0.799	0.0181
12	Ruthven School	44.33	14.1	1.12	0.28	0.0137
13	Residence south of Southshore	35.69	20.23	0.72	0.391	0.0143
Existing and REMASCO Source Modelling Results combined with Ambient Monitoring Data						
Number	Description	NO2 1 Hr. [ug/m3]	NO2 24 hr. [ug/m3]	NO2 Ann [ug/m3]	PM2.5 24 hr [ug/m3]	PM2.5 Ann [ug/m3]
1	School on Road 3	164.55	100.85	24.5	42.89	9.77
2	Seniors Centre Kingsville	163	113.68	24.22	59.86	9.72
3	Residential Area Kingsville	168.32	141.83	28.64	70.31	12.27
4	Recreation Centre	165.61	155.78	31.15	66.78	11.88
5	Residence close to Agriville	163.66	127.32	28.67	72.79	13.72
6	Asparagus Field	179.66	151.23	33.1	92.87	15.92
7	Apple Orchard	176.69	144.2	36.99	87.76	13.03
8	Vineyard	168.64	113.17	29.68	61.73	13.17
9	Colisanti Complex	183.19	130.65	29.49	59.45	13.22
10	Owner's Residence	187.87	175.63	35.17	102.16	16.18
11	Residence north of Southshore	178.97	128.98	33.01	76.95	16.96
12	Ruthven School	175.95	143.7	37.45	60.36	14.23
13	Residence south of Southshore	198.25	142.54	33.2	85.04	15.59
	Criteria Levels	400	200	60	30	

## 8.0 Greenhouse Gases and Climate Change

Environment Canada<sup>20</sup> defines Greenhouse gases as:

“those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. This property causes the greenhouse effect. Water vapour (H<sub>2</sub>O), carbon dioxide (CO<sub>2</sub>), nitrous oxide (N<sub>2</sub>O), methane (CH<sub>4</sub>) and ozone (O<sub>3</sub>) are the primary greenhouse gases in the earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as sulphur hexafluoride (SF<sub>6</sub>), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).”

These gases when emitted into the atmosphere can lead to climate change. Such change is an alteration of long-term weather patterns caused by natural phenomena and human activities that alter the chemical composition of the atmosphere through the build-up of greenhouse gases which trap heat and reflect it back to the earth's surface.

When calculating the effects of greenhouse gas emissions it is common practice to report such emissions in terms of how much CO<sub>2</sub> would be required to produce a similar warming effect. This is called the carbon dioxide equivalent (CO<sub>2</sub> eq) value. It is calculated by multiplying the amount of the gas by its associated global warming potential (GWP). A GWP is the time-integrated change in radiative forcing (effectiveness in absorbing outgoing infrared radiation) due to the instantaneous release of 1 kilogram (kg) of the gas expressed relative to the radiative forcing from the release of 1 kg of CO<sub>2</sub>. The concept of global warming potentials has been developed to allow scientists and policy-makers to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to CO<sub>2</sub>. For the purposes of most combustion sources the main GHG compounds are carbon dioxide [CO<sub>2</sub>], methane [CH<sub>4</sub>], and nitrous oxide [N<sub>2</sub>O]. The multipliers associated with these compounds are 1, 21 and 310 respectively. The CO<sub>2e</sub> value of emissions is thus {CO<sub>2</sub> mass + CH<sub>4</sub> mass x 21 + N<sub>2</sub>O mass x 310}.

To assisting in reporting GHG emissions, the MoE has developed a guideline for preparing such reports and provide default emission factors for MSW combustion expressed as [g/GJ of input]:

- CO<sub>2</sub> 85.6 g/GJ;
- CH<sub>4</sub> 30 g/GJ; and,
- N<sub>2</sub>O 4 g/GJ.

Using the data in Tables 11 and 12, and the number of days in each month it is possible to determine the total amount of load required for the REMASCO systems in a year. Based upon the input of 19.127 MMBtu/400 BHP, the total input of REMASCO systems is 1.38 x 10<sup>6</sup> GJ/annum. Converting the totals to CO<sub>2e</sub> the emissions from the facilities could be 2,700 tonnes per year.

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<sup>20</sup> Environment Canada, Climate Change Website. Definitions at <http://www.ec.gc.ca/ges-ghg>

Putting these numbers into perspective it is estimated that in 2010 the Canadian emissions total for GHG CO<sub>2e</sub> was 764,000,000 tonnes. Ontario is estimated to produce about 29% of this total, 220,000,000 tonnes. The REMASCO facilities would produce 0.0012% of the Ontario total. However, these are not new emissions, since the REMASCO facility will be replacing the use of existing fuels.



## **9.0 Impact Management**

The preceding assessment makes assumptions concerning certain aspects of the construction and operation of the REMASCO facilities. To ensure that these are fully recognized in the implementation of the project this chapter summarises measures that were assumed to be applicable during the evaluation.

### **9.1 Emissions Mitigation**

#### **9.1.1 Construction**

During construction of the facilities, the following mitigation measures have been assumed to be applied:

1. Entrances and exits to the sites will be controlled and maintained to minimise tracking of mud onto the surrounding roads.
2. If high quantities of mud are tracked onto the roads, sweepers will be employed to clean the roads.
3. Where necessary wind blown fugitive dust emissions from the construction site will be controlled by wetting the surface during periods of high winds.

Furthermore, it is recommended that construction contracts include clauses that:

1. Minimises unnecessary idling of vehicles on site to both limit fuel consumption and emissions.
2. Ensures that all mobile equipment used on site is properly maintained to minimise emissions during operation.
3. Develop strategies to control the unnecessary release of dust from the site during construction.

Such policies will require vigilance on the part of REMASCO to ensure that wherever possible construction related emissions are minimised.

#### **9.1.2 Operation**

The facilities were assumed to include the following emission control equipment to treat the flue gases:

1. reagent injection into the secondary chamber similar to that currently employed in the pilot facility;
2. activated carbon injection into the flue gas downstream of the boiler;
3. powdered lime injection into the flue gas downstream of the boiler for acid gas control;
4. a fabric filter baghouse to remove the solid particulate matter that result from the use of reagents for controlling contaminant emissions; and,
5. a flue gas re-circulation system to reduce the amount of NO<sub>x</sub> generated in the system.

The stack sampling data collected at the facility suggests that with these measures and appropriate operation of the control equipment the facility will meet the A-7 emission guidelines. The dispersion modelling undertaken in this study predicts that the maximum ground level concentrations of all the contaminants considered will be below the applicable regulatory criteria. Thus, additional mitigation measures are not anticipated to be required.

## **9.2.2 Monitoring**

### **Construction**

Construction contracts will include requirements that air monitoring studies be undertaken to address issues of particular concern with respect to worker health and safety and emissions of dust from the construction site. Any measures that will be applied during such contracts are to be addressed in an Environmental Controls and Methods Plan that must be developed by the contractor before any construction activities commence. In the event that monitoring suggests that there are possibilities for adverse environmental effects related to construction, the construction mitigation techniques should be reviewed and revised as necessary.

### **Operations**

Monitoring of the pilot facility's operations is a current requirement of the existing Certificate of Approval. Monitoring requirements included in the Certificate meet the intent of those outlined in Guideline A-7. The facility will also be required to file annual emissions reports with the province under O.Reg. 127. In addition, NPRI filings must be made with the federal government. To meet these requirements monitoring will be required at the facility.

The facility currently undertakes continuous monitoring for:

- baghouse outlet opacity;
- carbon monoxide;
- oxygen; and,
- temperatures both in various stages of the process and in the stack.

The facility also undertakes daily sampling for combustion gases including NO<sub>x</sub>, SO<sub>2</sub>, and HCl.

Throughput in the facility can be determined from the operation of the volumetric feeders on the gasifiers. The density of the pellets and their calorific value is very consistent and by determining the rate of feed of pellets to the gasifier the input can be determined.

Regular stack sampling is also required under the existing CofA. This testing verifies that the facility is performing in compliance with the limits of the Approval. It is anticipated that the CofA to be issued for the facility will specify the frequency of testing and the contaminants that must be quantified during the testing. These contaminants are expected to be similar to the existing list and include those contaminants listed in Tables 8 – 10.

## 10.0 Summary and Conclusions

This report has reviewed air quality aspects of the proposed REMASCO project to determine if the facility will cause adverse environmental effects on ambient air quality. This study serves as a supporting document for the Human Health Risk Assessment study that will be published under separate cover. The assessment was done by comparing the results of modelling the emissions from the proposed facilities based upon measured emissions from the pilot REMASCO facility. The results of the monitoring were compared to ambient air criteria. The assessment uses the worst case, ie highest concentration predictions, as the basis for the comparison. In addition, the concentrations were determined at a set of sensitive receptors located in the community in support of the HHRA. Given the approach used, the study should be judged to be conservative.

The key findings are as follows:

- With respect to ambient air quality criteria, objectives and standards, the study found that the downwind concentration of all contaminants from the REMASCO facilities would meet all criteria.
- With respect to facility emission limits, the testing conducted to date indicates that with proper operation the facilities will meet all emission limits set out in Guideline A-7. Such performance will continued to be monitored as part of the requirements of any future Approvals issued to REMASCO.
- With respect to potential incremental changes in ambient air quality levels, the study demonstrated that the REMASCO facilities will result in a reduction in ambient air quality levels when they replace the existing boilers at these sites.
- With respect to the incremental changes in greenhouse gas emissions, the study found that emissions could add less than 0.01% to the provincial and national inventory of CO<sub>2e</sub> emissions.