SUMMARY REPORT
TO BC GREENHOUSE GROWERS
March 22, 2023

OPTIONS FOR GREENHOUSE GAS (GHG) EMISSIONS REDUCTION IN THE BC GREENHOUSE INDUSTRY

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Quantum Lighting

SES Consulting

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INTRODUCTION

This study emanated from an interest in the BC Government Ministry of Agriculture and Food to address government of BC interests in reducing greenhouse gas (GHG) emissions of the BC Greenhouse Growers.

The BC Greenhouse Growers are comprised of: BC Greenhouse Growers' Association, United Flower Growers Co-operative Association, and BC Landscape and Nursery Association.

The BC Greenhouse Growers are interested in complying with the BC Government GHG emissions reduction goals but are concerned with ensuring the sustainable profitability for BC's Greenhouse Growers businesses.

Process & Methods Used

The study team has consulted with stakeholders and incorporated input from stakeholders into the report.

The study has scanned extensively emerging technologies for potential long-term strategies and for shorter term implementation strategies. The study has also scanned extensively to understand what others are doing that may be relevant to the BC jurisdiction. Ultimately the study seeks to point to best practices and development of a vital context for innovation to advance the industry productivity and profitability while contributing significantly to meeting the government's GHG emissions reductions objectives.

The report development has determined that this summary report would be developed as the public version of the study work focusing on key principles for the path forward to achieving key stakeholders' objectives.

A more detailed report on the numerous subject matters studied has been prepared for the exclusive use of the greenhouse growers' with commercially sensitive information not for public distribution. This will be a living ongoing work effort to continue to research and understand the best possible options for the industry.

The process also involved visiting a number of greenhouse growers' operations and touring those operations to receive information from the growers. Key information on the industry has been provided by the BC government. In preparing the reports a number of rounds of reviews and editing with extensive impact on the reports from the stakeholders has been undertaken.

Key Objectives

Objectives of the Concept Study

Research Potential Concepts To;

1. Meet the Needs of the Greenhouse Growers, Particularly for Economics and Profitability
2. Contribute to the GHG Emissions Reductions Targets of BC & Federal Governments
3. Scan Broadly for the Approaches being Used in Other Jurisdictions
4. Scan Broadly for the Emerging Technology Solutions for BC Pilots and/or Applications
5. Enable a Practical and Achievable Path for the Short-Term and the Longer Term to deliver on Both of the Above Objectives

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Competitive Markets

The BC Greenhouse Growers grow crops which compete in the domestic market through different channels, such as marketing agencies and some direct sales. While retail prices have increased, the prices the Greenhouse Growers are receiving through the channels to the retail markets are challenging and not providing sufficient revenues to keep up with costs.

Some Greenhouse Growers compete in international markets, primarily in the US, and some compete through marketing agencies. Additionally, some compete through direct connections to retail buyers, picking up supply from points along delivery routes.

Canadian retail markets have access to supply from international competitors and these supply lines can put pressure on prices for BC Greenhouse Growers.

The competitive nature of these markets means that the BC Greenhouse Growers are price takers in the markets and not price setters. The BC Greenhouse industry has been experiencing slimmer margins and rising cost for many aspects of their businesses.

Strategies for innovating with respect to the quality of the products have enabled some access to better prices in the past; and now, abilities for product innovation to attract higher prices are more limited.

Importance of Sustainable Profitability & Capital Attraction

The requirement for a sustainable profitability for the BC Greenhouse Growers' industry is the most important element to be addressed in this study. The BC Greenhouse Growers are business entrepreneurs and have to take on a variety of risks and deliver a high level of performance to survive. They have invested considerable capital in the greenhouses and support a significant work force.

As with all sectors of the economy, it is essential for these entrepreneurs to have some degree of certainty with respect to essential elements of their business and particularly those elements that are subject to the policies and actions of governments. A competitive market with a reasonable degree of certainty is needed to attract this capital.

In the current circumstances, there is enough uncertainty about policy impacting elements of the BC Greenhouse Growers' cost structures that potential investments and expansions of the industry are on hold. In addition, to remain competitive, the Greenhouse Growers will need to keep up with evolving technologies which can support and benefit their operations.

For Greenhouse Growers to make improvements to their operations which provide benefits to the environment; substantial capital and or operating investment may be required. The government-driven changes to the business environment and related uncertainties can make capital investment and attraction difficult or nearly impossible.

The Lower Mainland of BC and the Fraser Valley are expensive places to live and work, in part, for the favourable climate and attractive cities and surroundings. This is true for employees, and workers in the business as well as for the businesses themselves. Real estate and local supplies and services are quite expensive and can exceed the costs in other competitive jurisdictions. This is another source of uncertainty for the industry.

Greenhouse Growers' Contribution to BC Economy and Communities

The BC Greenhouse Growers' industry have continually sought to reduce their costs for goods sold and lead when it comes to environmentally sustainable production. The industry is constantly looking to adopt leading technologies that can help improve their products and their operational performance.

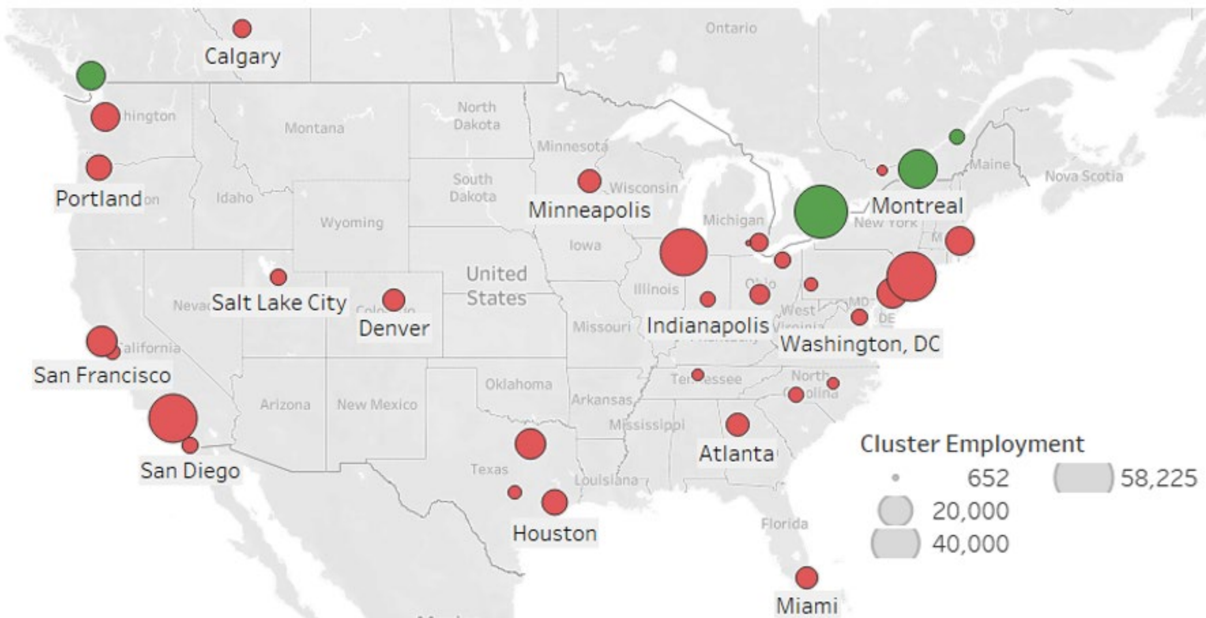
The BC Greenhouse Growers' industry is a significant contributor to the BC economy and to the quality of life in BC through food security and export revenues.

British Columbia as a Cluster Centre for Food & Beverage

The Waterloo EDC[1] has conducted analysis of cluster centers across North America, and in that process, has identified BC as a cluster center for food and beverage. If the circle is green, it's a "true" cluster. If it's red, then a cluster effect isn't evident. The circle size is representative of total cluster employment – the bigger the circle, the more employees. As you can see, a community can have high employment in a particular industry but NOT be a cluster.

FIGURE 1

NORTH AMERICAN FOOD & BEVERAGE CLUSTERS WHERE BC IS AN ACTIVE CLUSTER



Clusters are geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition. They include, for example, suppliers of specialized inputs such as components, machinery, and services, and providers of specialized infrastructure. Clusters also often extend downstream to channels and customers and laterally to manufacturers of complementary products and to companies in industries related by skills, technologies, or common inputs. Finally, many clusters include governmental and other institutions—such as universities, standards-setting agencies, think tanks, vocational training providers, and trade associations—that provide specialized training, education, information, research, and technical support.[2]

[1] Waterloo Economic Development Corporation, Website, Blog Item 14

[2] Clusters and the New Economics of Competition Michael E. Porter, Harvard Business Review November – December 1998

Natural Gas Use & Carbon Dioxide Emissions

Carbon Dioxide Equivalent Emissions for Canada by Province and for Agriculture provide the Canadian context for GHG emissions.

TABLE 1

CANADIAN GHG EMISSIONS BY PROVINCE & AGRICULTURE WITH PER CAPITA FOR BOTH

Province	GHG Emissions			Province		Agriculture
	Total *	Agriculture **	%	Population	GHG/capita	GHG/capita
	M CO_2te			#	CO_2te	CO_2te
Alberta	256	17.9	7%	4,409,899	58.2	4.1
British Columbia	62	2	3%	5,107,368	12.1	0.4
Manitoba	22	6.8	31%	1,369,952	15.8	4.9
Ontario	150	7.5	5%	14,612,471	10.2	0.5
Quebec	76	7.3	9.6%	8,548,321	8.9	0.9
Saskatchewan	66	15.8	24%	1,167,519	56.4	13.7
Rest of Canada	40	8	20%	2,599,149	15.4	3.1
	672	65.3	100%	37,814,679	17.8	1.7

* (ECCC 2020) [3]
** (Calculated)[4]
*** (Statista Report 2021)[5]

BC agriculture GHG emissions, on a per capita basis, are a little below the average for Canada and are the lowest in the country for agriculture on a per capita basis.

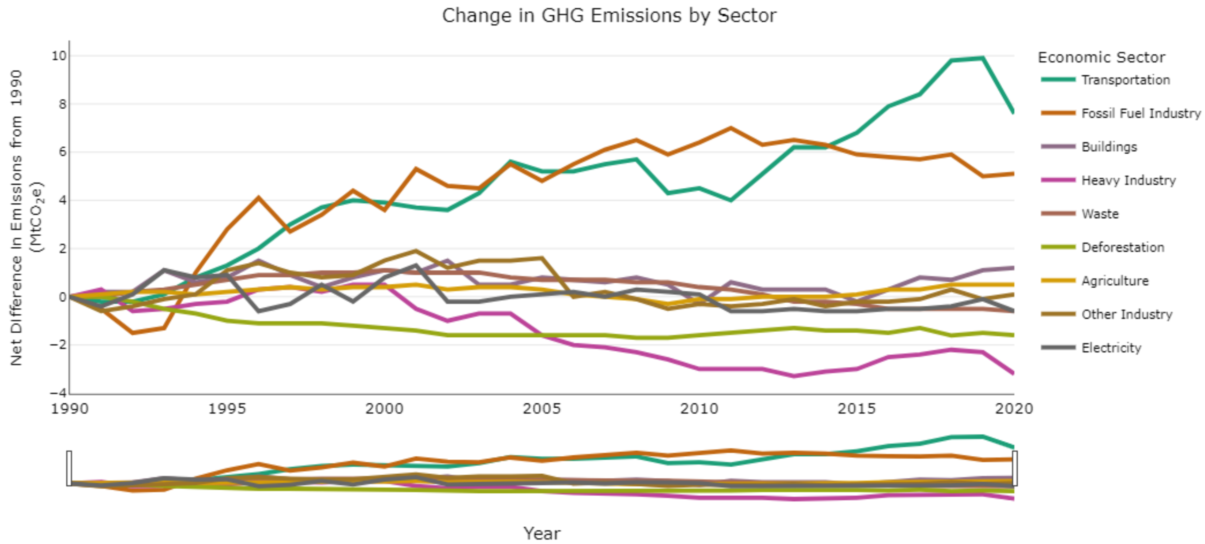
[3] Environment & Climate Change Canada, Greenhouse Gas Emissions Canadian Environmental Sustainability Indicators, Page 27 Of 28, Table A.8

[4] Greenhouse Gas Emissions from Canadian Agriculture: Policies and Reduction Measures, Ymène Fouli, Margot Hurlbert, and Roland Kröbel, Page7 Alberta 7%, Page 9 Saskatchewan 24%, Page 9 Manitoba 31%, Page 10 British Columbia 3%, Page 10 Quebec 9.6%, Page 10 Ontario 5%.

[5] Statista Report, Population Projection for Canada 2022, Adjusted back to 2020 by growth rate

FIGURE 2

BRITISH COLUMBIA GHG EMISSIONS BY SECTOR OVER TIME



[6]

BC Government Energy Objectives

The BC Government has set out its Energy Objectives in its Clean Energy Act, which includes greenhouse gas emissions reduction targets as follows; ….

British Columbia's energy objectives[7]

2 The following comprise British Columbia's energy objectives: …

(g) to reduce BC greenhouse gas emissions

(i) by 2012 and for each subsequent calendar year to at least 6% less than the level of those emissions in 2007,

(ii) by 2016 and for each subsequent calendar year to at least 18% less than the level of those emissions in 2007,

(iii) by 2020 and for each subsequent calendar year to at least 33% less than the level of those emissions in 2007,

(iv) by 2050 and for each subsequent calendar year to at least 80% less than the level of those emissions in 2007, and

(v) by such other amounts as determined under the *Climate Change Accountability Act*[8];

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[6] BC Environmental Reporting, Sustainability, Trends in Greenhouse Gas Emissions in B.C. (1990-2020)

[7] BC Clean Energy Act

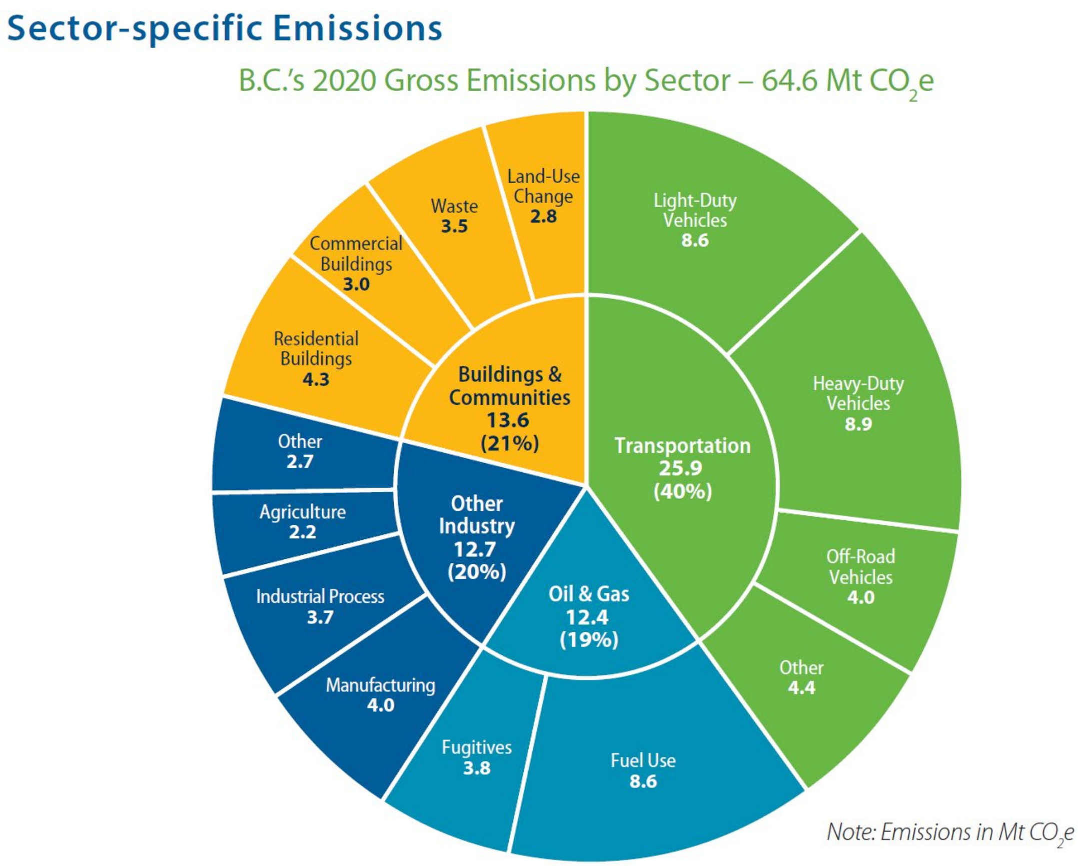
[8] BC Government Laws, www.bclaws.gov.bc.ca

Greenhouse Gas Emissions for Greenhouse Growers in BC and Economic Sectors

The base line level of GHG emissions in BC is 64.76 million tonnes (metric tons)

The sources of GHG emissions shown in the Climate Change Accountability Report[9] of the Province of BC

FIGURE 3



[10]

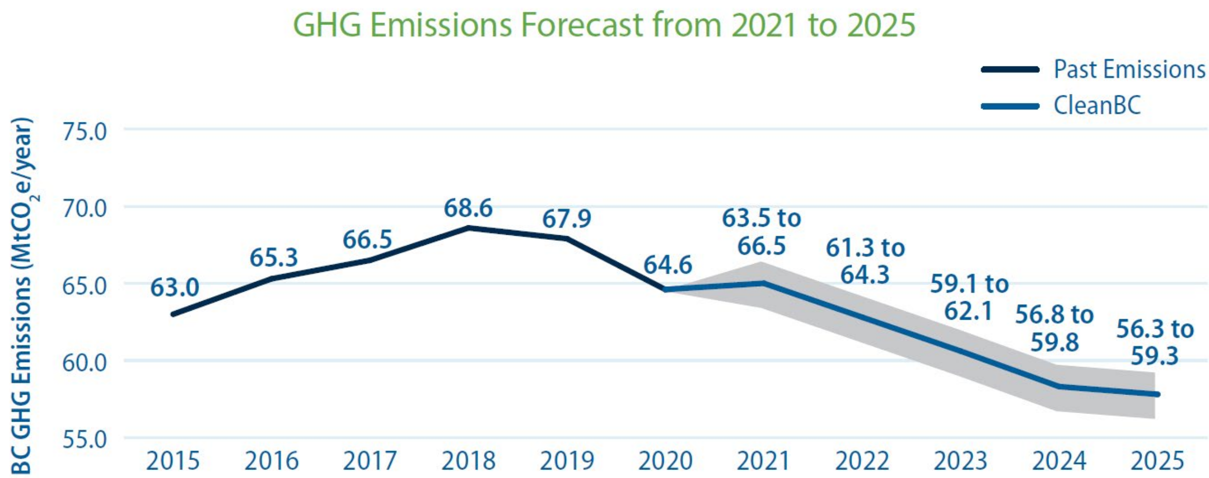
BC performance in reducing GHG emissions is as follows from the same report.

[9] 2022 Climate Change Accountability Report, www2.gov.bc.ca

[10] 2022 Climate Change Accountability Report, Page 9

FIGURE 4

BC EMISSION ESTIMATES



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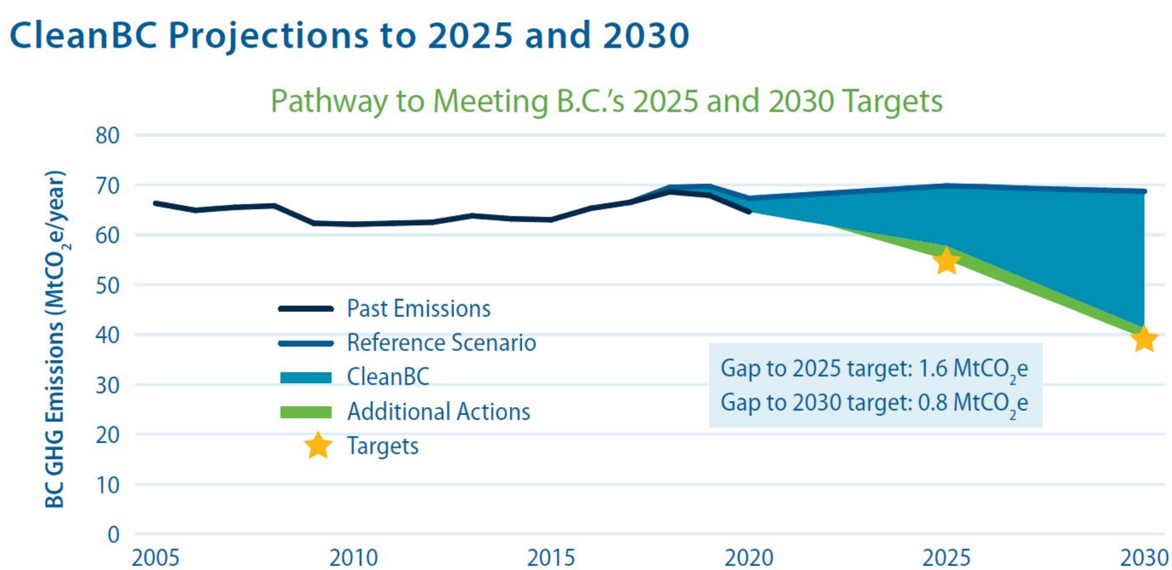
There is little change since the 2007 baseline GHG emissions. It should be remembered that 2007 was a year significantly impacted by the Great Recession and economic retraction.

The Path Forward for BC is also shown in the Climate Change Accountability Report

FIGURE 5



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[11] 2022 Climate Change Accountability Report, Page 10

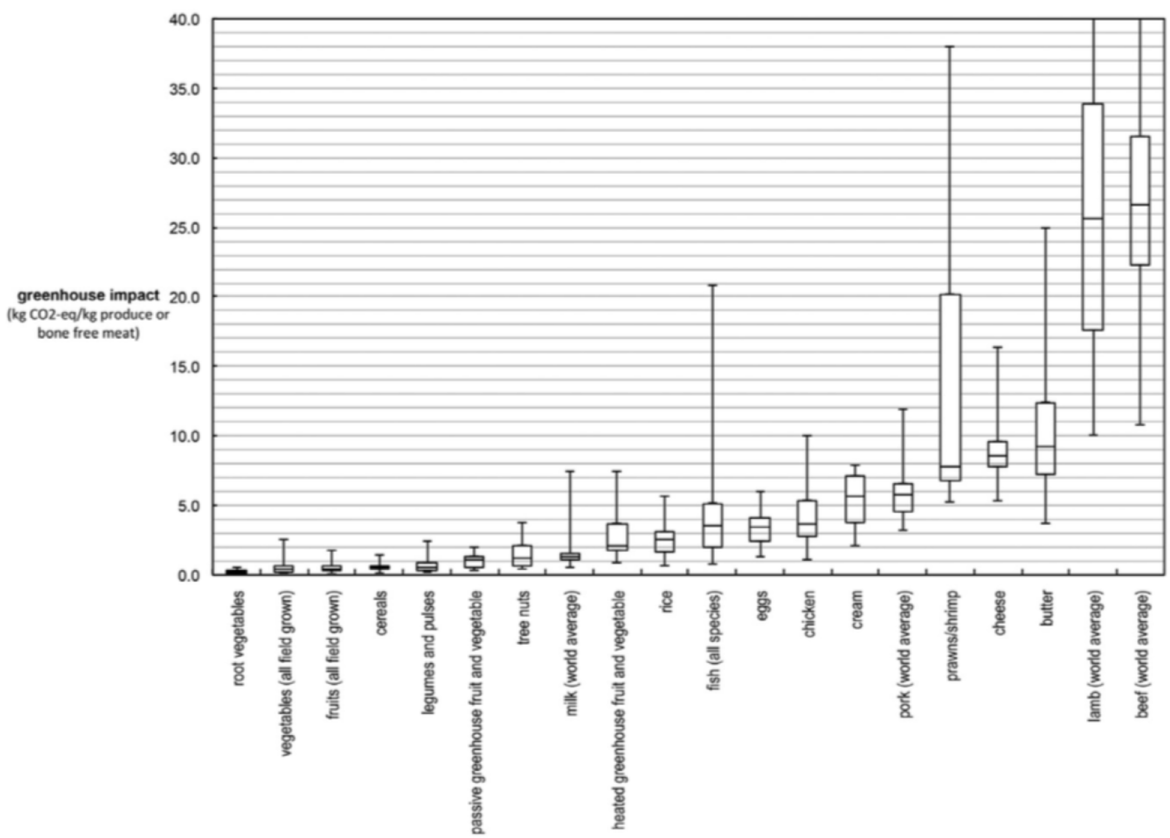
[12] 2022 Climate Change Accountability Report, Page 10

For the BC government to achieve GHG emissions reductions of 80% by 2050, from 2025 it will require GHG reductions from all emission sources of 3.1% per year. This 3.1% per year is a target for the Greenhouse Growers to model contribution, subject to having the right business context within which to do this. Greenhouse Growers' boilers are already 98% efficient[13], so the challenge will be to reduce natural gas use to improve efficiencies or offset the emissions.

Greenhouse Gas Emissions for Greenhouse Growers by Agriculture Product Sector

FIGURE 6

GREENHOUSE GAS EMISSIONS BY CATEGORY OF AGRICULTURAL PRODUCTS



[14]

The above analysis shows that heated greenhouses for fruits and vegetables have a very low contribution to greenhouse gas emissions despite using natural gas for heating to supplement

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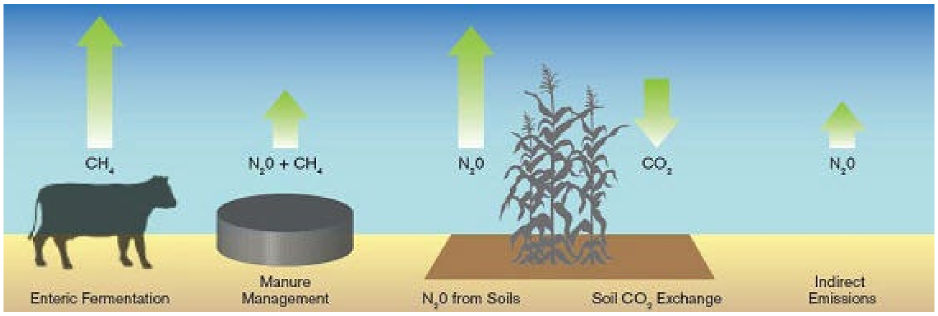
[13] www.viessmann.ca/en/products/gas-condensing-boilers.html

[14] Estimating Greenhouse Gas Emissions from Food: A Case Study on the City of Vancouver's Food Procurement Practices, Poushali Maji.

solar heat contributions through the greenhouse glass or polymer structures. Passive greenhouses for fruit and vegetables are again much lower than even the heated greenhouses.

FIGURE 7

SOURCES OF AGRIGULTURAL GHG EMISSIONS EXCLUDING ENERGY USE



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The sources of agricultural GHG emissions are substantially related to animal raising processes.

Natural Gas Use & Carbon Dioxide Emissions

The Greenhouse Growers use of natural gas and propane for 2021 were as follows;

TABLE 2

Greenhouse Growers Gas Energy Use 2021[16]		
Industry Segment	Natural Gas	Propane
Total	7,125,291 GJ	376,273 Litres
Vegetable	5,060,962 GJ	3,564 Litres
Flower & Nursery	2,064,329 GJ	372,709 Litres

The costs for natural gas to the Greenhouse Growers was approximately the following:

TABLE 3

Greenhouse Growers Gas Energy Costs 2021 @ $8.00/GJ[17]		
Industry Segment	Natural Gas	Propane
Total	$57,002,328	$489,155
Vegetable	$40,487,696	$4,633
Flower & Nursery	$16,514,632	$484,522

[15] Government of Canada, Greenhouse Gases and Agriculture

[16] BC Government Ministry of Environment Climate Change Strategy, Provided the Data

[17] Proxy Prices for Natural Gas Selected to Approximate Natural Gas Costs for the Industry

The Greenhouse Growers pay carbon tax on 20% of their natural gas use and receive relief for 80% of the carbon tax on their natural gas use. The applicable carbon tax rates for 2021 and 2022 are as follows for the Greenhouse Growers' use of natural gas and propane.

TABLE 4

Greenhouse Growers' BC Carbon Tax Rates[18]		
Value Type	2021	2021
Source	Natural Gas	Propane
Carbon Tax	\$40 CO2te	\$44 CO2te
Relief	\$32 CO2te	\$35 CO2te
Carbon Tax	\$2.31 GJ	\$2.54 GJ
Relief	\$1.85 GJ	\$2.03 GJ
Value Type	2022	2022
Carbon Tax	\$50 CO2t	\$55 CO2te
Relief	\$40 CO2t	\$44 CO2te
Carbon Tax	\$2.56 GJ	\$2.82 GJ
Relief	\$2.05 GJ	\$2.25 GJ

These carbon tax rates have resulted in the following values for relief from the carbon tax and for the specific payment for the 20% applicable carbon tax payments, shown for 2021 actual and forecast for 2022 assuming the same usage pattern.

TABLE 5

\$Value of Greenhouse Growers Relief 80% & Payment of 20% in 2021[19]			
Energy Use	NG Carbon Emissions	Propane Emissions	Total Emissions
Total	356,265 CO2te	2,206 CO2te	358,471 CO2te
Vegetable	253,048 CO2te	21 CO2te	253,069 CO2te
Flower & Nursery	103,216 CO2te	2,185 CO2te	105,402 CO2te
\$ of Relief 80%			
Total	\$11,400,466	\$77,632	\$11,478,097
Vegetable	\$8,097,539	\$735	\$8,098,275
Flower & Nursery	\$3,302,926	\$76,896	\$3,379,823
\$ for Payment 20%			
Total	\$2,850,116	\$19,408	\$2,869,524
Vegetable	\$1,619,508	\$147	\$1,619,655
Flower & Nursery	\$660,585	\$15,379	\$675,965

[18] Province of BC Carbon Tax Rates - effective relief from Carbon Tax calculated at 80%, cost/GJ calculated at 57.75 kg CO_2e for 1 GJ of natural gas and propane 10% higher GHG emissions profile than natural gas.

[19] \$ of Relief at 80% provided by the Ministry of Environment Change Strategy. Total Carbon Emissions calculated at \$ of Relief *5/4 *Carbon Tax Rate \$40/CO_2te in order to estimate CO_2te of emissions.

The total of Greenhouse Growers' emissions for 2021 was approximately 358,471 CO_2te. As a portion of BC's total emissions of 64.8 MteCO_2, the 358,471 CO_2te represents 0.55% of BC's total.

The estimated, for 2022, Greenhouse Growers' $value of carbon tax 80% relief and the 20% payment are shown in the table below.

TABLE 6

$Value of Relief 80% & Payment 20% 2022 (assuming same use as 2021)[20]			
Energy Use	NG	Propane	Total
Total	356,265 CO2te	2,206 CO2te	358,471 CO2te
Vegetable	253,048 CO2te	21 CO2te	253,069 CO2te
Flower & Nursery	103,216 CO2te	2,185 CO2te	105,402 CO2te
$ of Relief 80%			
Total	$14,250,582	$97,040	$14,347,622
Vegetable	$10,121,924	$919	$10,122,843
Flower & Nursery	$4,128,658	$96,121	$4,224,779
$ for Payment 20%			
Total	$3,562,646	$24,260	$3,586,905
Vegetable	$1,619,508	$184	$2,024,569
Flower & Nursery	$660,585	$19,224	$844,956

Note: Greenhouse Growers' cost increase 25%, from $2,869,524 to $3,586,905.

[20] $ of Relief at 80% provided by the Ministry of Environment Change Strategy for 2021 estimated on the same natural gas use as 2021 and with the 2022 Carbon Tax Rate of $50/$CO_2$te. Total Carbon Emissions calculated at $ of Relief *5/4 *Carbon Tax Rate $50/$CO_2$te in order to estimate CO_2te of emissions.

TABLE 7

BC Greenhouse Growers' Future Carbon Tax[21]					
Carbon Tax Increases for Applicable 20% or 100% Payment					
Year	Carbon Tax $/CO2te	Carbon Tax $/GJ	% increase	20% Greenhouse Growers Payments	100% Greenhouse Growers Payments
2021	40	$2.31		$2,869,524	$14,347,622
2022	50	$2.56	25%	$3,586,905	$17,934,527
2023	65	$3.24	30%	$4,539,677	$22,698,386
2024	80	$3.99	23%	$5,590,528	$27,952,642
2025	95	$4.73	19%	$6,627,368	$33,136,841
2026	110	$5.48	16%	$7,678,219	$38,391,097
2027	125	$6.23	14%	$8,729,071	$43,645,353
2028	140	$6.98	12%	$9,779,922	$48,899,609
2029	155	$7.72	11%	$10,816,762	$54,083,808
2030	170	$8.47	10%	$11,867,613	$59,338,064
Total				$72,085,590	$360,427,950

The future anticipated carbon tax payments for the Greenhouse Growers are shown above for the same levels of usage and the retention of the 20% payment requirement and for what they would be if taxed at 100%.

The withdrawal of over $72 million from the industry represents substantial levels of what might otherwise be the capital available to the industry to make investments in GHG emissions reductions or to pay for sources of equivalent energy that do not result in a carbon tax payment.

The consequence of the carbon tax rate increases from 2021 to 2030 will impose cost increases on the Greenhouse Growers' sector of the economy, of about 314% over the 9 years period. It is instructive to understand what the full carbon tax payments would otherwise be in the future if the 80% relief were not provided and there was no change in the GHG emissions reductions.

The Greenhouse Growers as an industry, if drained of this level of cash flow, would likely be crippled, because they are price takers in their markets and would be unable to pass these levels of costs through to customers without significant loss of market share. The spiral of costs and market share loss could result in loss of substantial BC local supply. Food security is a

[21] Carbon Tax Rates by Year from Province of BC, Greenhouse Growers 20% Payment calculated for same 2021 emissions levels, 358,471 CO_2te through out the table at the Carbon Tax Rate, 100% Carbon Tax is calculated to show the magnitude of the impact on the industry had relief not been provided.

distinct value to be preserved along with achieving GHG emissions reductions and ensuring the sustainable profitability of the industry.

Minimum National Carbon Price Schedule (2023-2030)

Canada's minimum national price on carbon pollution for explicit price-based systems (i.e., systems that directly set a price on emissions) is $65 per tonne of GHG emissions* calculated in carbon dioxide equivalent (CO_2e) in 2023, and increases by $15 per year to $170 per tonne CO_2e in 2030 according to the following schedule:

TABLE 8
CANADA'S MINIMUM CARBON PRICE SCHEDULE

Year	2023	2024	2025	2026	2027	2028	2029	2030
Min. Carbon Price ($ CAD/tonne CO_2e)	$65	$80	$95	$110	$125	$140	$155	$170
Min. Carbon Price. ($ CAD/GJ)	$3.24	$3.99	$4.73	$5.48	$6.23	$6.98	$7.72	$8.47

*(Please consult Schedule 3, Column 1 of the *Greenhouse Gas Pollution Pricing Act* for the complete list of greenhouse gases to which pricing must apply, to the extent they occur in the jurisdiction.)

Carbon prices on specific fuels or emissions sources must be calculated based on recognized global warming potential factors such as those used for reporting requirements under the United Nations Framework Convention on Climate Change.

As cap-and-trade systems set maximum emissions levels rather than minimum carbon prices; for these systems, the minimum carbon pollution price is translated into an equivalent cap on emissions.

Carbon Tax Relief Across Canada

TABLE 9

Canadian Provincial Emissions Reduction Programs Carbon Pricing & Carbon Tax Relief

PROVINCE	EMISSIONS REDUCTION PROGRAM	CARBON PRICE	RELIEF FOR GREENHOUSE PRODUCERS*
Alberta	Provincial carbon program	Federal Fuel Charge	Up to 80%
British Columbia	Provincial carbon program	Provincial carbon tax	Up to 80%
Manitoba	Federal Output-Based Pricing System (OBPS)	Federal Fuel Charge	Up to 80%
New Brunswick	Provincial carbon program	Provincial Fuel Charge	100% provincial offset rate on natural gas
Newfoundland/Labrador	Provincial carbon program	Provincial carbon tax	Fuel for heating is exempt unless used in generator
Nova Scotia	Provincial Cap and Trade	Cap and trade pass-through	
Ontario	Provincial OBPS	Federal Fuel Charge	Up to 80%
Prince Edward Island	Federal OBPS	Provincial carbon levy	100% exemption on marked fuels
Quebec	Provincial Cap and Trade	Cap and trade pass-through	
Saskatchewan	Federal/Provincial OBPS	Federal Fuel Charge (for greenhouse agriculture)	Up to 80%
Yukon		Federal Fuel Charge	Up to 80%
Northwest Territories		Territorial carbon tax	
Nunavut		Federal Fuel Charge	Up to 80%

[22]

Much of this relief is embedded in legislation and regulation while other relief is handled as annual budget funding. The timeframes for this relief are therefore subject to political change from time to time.

The imperative for relief is based on farm operations, including greenhouses, being price takers in very competitive produce markets; and the lack of common carbon pricing in markets trading with Canada, and in particular for this study - BC.

The relief timeframes, logically, should match the strategies and funding for reduction of greenhouse gas emissions, and implementation schedules for affordable approaches for the industry. Taxing capital out of the industry that could otherwise go to reducing GHG emissions would appear to be quite counter-productive.

[22] Greenhouse Canada Website, Navigating **C**omplex **C**arbon **P**rices**,** What greenhouse growers need to know August 16, 2022**,** By James Williams

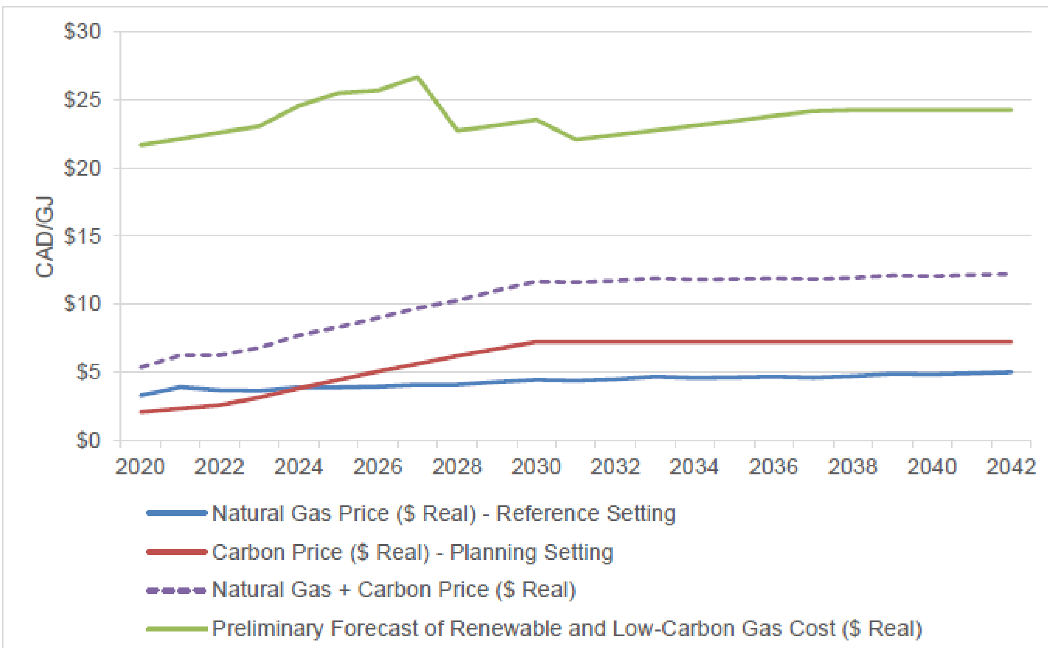
FortisBC Energy Inc. (FEI) RNG VS Natural Gas Prices

RNG supplied by FEI has declined in price somewhat from FEI's early days with RNG and is forecast by FEI in its recent long-term gas resource plan (LTGRP) to be approximately $25/GJ, while the price for natural gas commodity is estimated to be $5/GJ real price, in Canadian $.

FIGURE 8

OUTLOOK FOR ENERGY COST OF NATURAL GAS, CARBON TAX & RNG

Figure 2-3: Outlook of Energy Costs for Fuel Types Used in the Development of the LTGRP[85,86]



[23]

The carbon pricing shown in this graphic does incorporate the Federal projection for carbon taxes going to $170 CO_2te by 2030, representing about $8.47/GJ of natural gas.

The purpose of carbon taxes on natural gas is to provide an incentive to avoid the carbon tax. The cost of the RNG used to replace the fossil natural gas would be prohibitive for the Greenhouse Growers' in BC, as is the cost of the carbon tax without the BC government relief.

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[23] FortisBC Energy Inc. - Long Term Gas Resource Plan 2022, Page 2-25

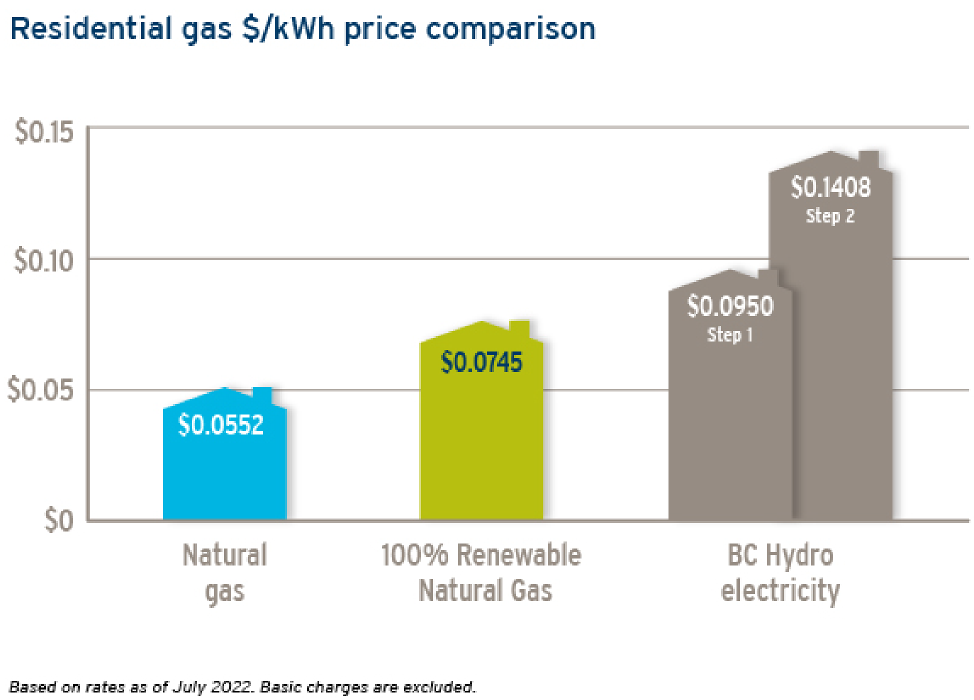
The costs for avoiding GHG emissions or paying for the alternative (carbon tax, or RNG price) is intended to be passed on by those paying the cost to the end customers for the products using the fuel.

RNG VS Electricity Prices

FEI offers residential customers an ability to select the blend of natural gas and or RNG they may choose to help avoid GHG emissions. The consequence is a greater cost for 100% RNG for heating. The FEI website promotion for this service shows the following price comparison for customers. Essentially, 100% renewable natural gas is offered for a 35% premium over the natural gas cost. This represents a 27.5% savings versus residential Step 1 electricity price.

FIGURE 9

RESIDENTIAL NATURAL GAS & RNG COMPARISON TO RESIDENTIAL ELECTRICITY PRICE



[24]

FortisBC Energy Inc. (FEI) Gas Supply Contribution

FEI is contributing to a customers' GHG reductions emissions by adding renewable natural gas (RNG) and potentially a percentage of hydrogen to their gas supply distribution system.

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[24] FortisBC Energy Inc., Website, How Much Does Renewable Natural Gas Costs, Choose your RNG Blend

The BC Utilities commission enables FEI to acquire renewable natural gas for the gas system under terms where the cost to specific customers taking RNG is discounted from the FEI cost of acquiring the RNG. The remaining cost amounts for the RNG is then covered by all customers.

FEI's RNG service also can be taken up as a percentage of the natural gas a customer uses.

BC GREENHOUSE GROWERS' ASSOCIATION & UNITED FLOWER GROWERS – MEMBER PROBLEMS & OBJECTIVES

BC Greenhouse Growers' Association members and United Flower Growers members (the "Greenhouse Growers") rely heavily on the use of natural gas for the provision of heat and plant growth, and it currently accounts for approximately 20% of the cost structure for greenhouses.

However, the current political and environmental concerns related to natural gas emissions can be expected to create significant changes in the cost-effectiveness and usefulness of this resource, and have the potential to seriously disrupt the financial viability of BC growers.

The upcoming challenges merit serious consideration to identify the most pressing concerns, the best means of mitigating these issues, and any opportunities available to preserve the financial health of the member companies, while contributing to BC government environment objectives. The following is a summary of some of the concerns, greenhouse growers face, now and or in the future, in achieving financial profitability and contributing to government environment objectives.

Carbon Tax Increases

The BC Government imposed carbon taxes of \$45/CO_2te (2021), which increased to \$50/CO_2te as of April 1, 2022. The Canadian Government Imposed Carbon Taxes will be \$170/CO_2te by 2030 resulting in a 195% increase in level of the tax affecting the cost of natural gas by 2030; and making natural gas about 30% of a business' costs, instead of the current 20% range.

Even considering the greenhouse carbon tax relief grant program, it can be expected that natural gas carbon tax costs will increase by 8% immediately, and by an additional 40% by 2030, potentially eliminating profit potential for any given business and the industry overall.

The impact of carbon taxes is that they are taken from the industry and into government revenues. These funds, in part, could be the necessary funds for the industry to work toward complying with GHG reduction targets. Even 20% of a carbon tax can remove significant funds from the industry that could be used to invest in solutions for the future.

Competitive Cost Pressures and Food Supply to BC

BC Greenhouse Growers are generally price takers, selling their produce into markets with competing local and Canadian suppliers and imported supply from US, Mexico, Central America and China, where carbon taxes are not applicable[25]. Only 14 OECD countries have carbon taxes.

Unmitigated increases in costs not only threaten the industry, but also the well-being of the citizens in BC where a strategic loss of food supply and external dependency potentially hangs in the balance.

Changes in Natural Gas Commodity

Natural gas is largely methane CH4 and is a hydrogen carrier to customer sites. Currently, hydrogen delivers about 40% of the energy and the carbon delivers about 60% of the energy per kg or m3 of natural gas[26].

FortisBC Energy Inc. (FEI) is planning to provide added hydrogen as H_2 into the natural gas stream, and will require further evaluation of the cost impacts and energy intensity implications. As FEI adds H_2 to its system and cleaner renewable natural gas (RNG), the gas delivery system will potentially become a cleaner energy supply option ensuring a green gas system for the future.

Greenhouses and Greenhouse Gas (GHG) Emissions Reductions

The *Climate Change Accountability Act* (the CCAA)[27] has set robust targets to reduce GHG emissions to 40% below 2007 levels by 2030, to 60% by 2040 and to 80% by 2050. There is an interim target of 16% below 2007 levels by 2025.

The use of CO_2 by greenhouses is flagged as a GHG emissions problem because CO_2 once released to the plants will escape the greenhouses and enter the atmosphere. While specific targets for the greenhouse sector are not yet established, greenhouses will be required to reduce their emissions. Fortunately, there are many emerging technologies for consideration for both the near and longer terms.

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[25] Our World in Data, Website ourworldindata.org/carbon-pricing, Which Countries Have Put A Price on Carbon

[26] en.wikipedia.org/wiki/Methane, CH4 contains 39 MJ per m3, Carbon Combustion Release 393.5 kJ/mole, www.toppr.com, Hydrogen H2 Combustion Releases 286/kJ/mole or 572/kJ/mole for H4, personal.utdallas.edu, Calculated % Carbon Energy 40% and % Hydrogen Energy 60% in methane.

[27] www.bclaws.gov.bc.ca

However, these are potentially costly investments or costly operating costs, which, for an industry without the flexibility to absorb costs and make uncertain investments, could leave them at risk as government policies unfold.

Electricity as an Option

While electricity is used in various aspects by the industry to improve productivity and provide cooling and power; the rate structures can result in very high costs.

The implementation of electric boilers in place of the natural gas condensing boilers introduce additional capital costs and operating costs. The operating costs of electricity could be approximately 300% greater than the cost of natural gas[28]. Although the capital costs for electric boilers is comparable to natural gas boilers the greenhouse growers already have investments in natural gas boilers. The added capital cost of new boilers would further aggravate the extreme cost differential. In addition, because the natural gas provides CO_2 as a key output, which the greenhouse growers need for their plants, the costs to replace this would add to the costs of operating the greenhouse business.

The added costs of electrification of the greenhouse boilers would drive the greenhouse businesses into bankruptcy and destroy the industry. This is not an option.

The industry finds that getting service from BC Hydro can be a very lengthy process. The grid rates are not well-matched with the needs of the greenhouse grower sector. BC Hydro is planning a number of optional rate design changes, which can hopefully assist the industry.

Using combined heat and power from a cleaner natural gas system supply may avoid electrical infrastructure timing and capacity issues. Also, this might be accomplished with carbon capture and or decarbonization creating negative carbon. Optimizing the balance of values to customers and the governments across the electric and gas utilities will be key.

Ongoing Increases in Utility Costs

The costs for both natural gas and electricity utilities will continue to face increasing cost pressures in the future for new capital investments, commodity increases (natural gas) and other regulatory and environmental pressures.

[28] Calculation of the same amount of energy provided by a natural gas condensing boiler versus an electric boiler, Electric Cost Equivalent to 1 GJ of Electricity $24.86/GJ versus Natural Gas $8.25/GJ, 300% greater.

Competitive Jurisdictions

There are numerous approaches being used in other jurisdictions to the issues around greenhouse product supply which can involve growing technology, technical, financial, regulatory & legislative policy and political realities as advantages for competitors. The BC industry must, at a minimum, keep up with its competition. Key areas for review include current state, emerging and innovative technologies and expected commercialization to ensure that BC greenhouses are at the forefront of (1) greenhouse grower competitiveness (2) meeting climate change goals as a top tier green jurisdiction (3) creating affordability of products and service for BC consumers and (4) ensuring security and safety of supply for BC's critical needs.

Objectives of the Concept Study

Research Potential Concepts To;

1. Meet the Needs of the Greenhouse Growers, Particularly for Economics and Profitability
2. Contribute to the GHG Emissions Reductions Targets of BC & Federal Governments
3. Scan Broadly for the Approaches being Used in Other Jurisdictions
4. Scan Broadly for the Emerging Technology Solutions for BC Pilots and/or Applications
5. Enable a Practically and Achievable Path for the Short-Term and the Longer Term to deliver on Both of the Above Objectives.

JURISDICTION REVIEW INFORMATION

The Canadian Greenhouse Growers[29]

The Canadian Government every 10 years does a relatively in-depth examination of the Greenhouse Growers' industry in Canada. The following data and analysis provide some of this information to understand what is happening in the Canadian and particularly the BC jurisdiction.

From Table 10 we see a Greenhouse Growers' industry that is fairly stable in terms of the number of greenhouse growers' operations.

While BC ranks third in Canada by count of the number of operations, it will be evident that BC is second only to Ontario for its contribution to Canada's greenhouse grower's contributions to the Canadian economy.

TABLE 10
NUMBER OF GREENHOUSES BY PROVINCE OVER TIME

# Greenhouses	2015	2016	2017	2018	2019
Atlantic provinces[2]	54	52	52	51	49
Quebec	242	247	250	238	235
Ontario	315	323	330	325	315
Prairie provinces[2]	100	107	101	102	94
British Columbia	150	160	154	150	145
Canada	**861**	**894**	**889**	**866**	**838**

1. Number of operations represents the number of specialized greenhouse vegetable and fruit operations and includes all other types of enclosed protection used for growing plants, such as rigid insulation, mine shafts, barns and shelters. Mixed operations (vegetables, flowers and plants) are excluded.
2. Due to confidentiality reasons, provincial breakdowns for Atlantic and Prairie provinces are not shown.

[29] Source: Statistics Canada. Table 32-10-0019-01 Estimates of specialized greenhouse operations, greenhouse area, and months of operation

Canadian Vegetable Farm Gate Values[30]

1.10. Farm gate value of greenhouse vegetables by commodity ('000s of Canadian dollars)

	2015	2016	2017	2018	2019
Tomatoes	514,251	537,032	555,196	569,574	588,519
Cucumbers	316,495	336,050	395,760	443,018	485,815
Peppers	420,539	409,980	421,873	428,451	441,680
Lettuce	28,769	27,366	32,036	33,941	35,396
Eggplants	..	7,757	11,531	11,727	10,561
Fine herbs	0	3,559	8,576	7,066	10,349
Other fruits or vegetables	15,802	7,839	6,047	7,459	7,190
Microgreens and shoots	..	..	3,585	8,384	5,684
Chinese vegetables	..	1,226	1,180	1,076	930
Sprouts	..	..	993	1,014	896
Beans (green and wax)	..	353	313	406	399
Total	**1,295,856**	**1,331,163**	**1,437,089**	**1,512,118**	**1,587,417**

.. : Not available for a specific reference period.
Source: Statistics Canada. Table 32-10-0456-01
Production and value of greenhouse vegetables

Canadian farm gate values have grown along with the harvested areas of greenhouses by about 8% over the 5 years period in line with the growth of harvested area. The Canadian population, over this same time period has grown by 6% and the Canadian dollar has maintained its value over this time period. This is a significantly inhibited level of growth compared to the worldwide annual growth of the greenhouse industry being 11.6%.

[30] Source: Statistics Canada. Table 32-10-0456-01, Production and value of greenhouse vegetables

Flower Grower Production Areas[31]

The Canadian specialized greenhouse flowers and plants business is a significant size.

1.5. Total area for production of specialized greenhouse flowers and plants by province (square metres)

	2015	2016	2017	2018	2019
Atlantic provinces	280,201	257,890	260,182	251,901	240,421
Quebec	1,220,000	1,213,584	1,181,037	1,178,262	1,239,323
Ontario	3,656,452	3,729,701	3,480,642	3,417,170	3,484,294
Prairie provinces	863,731	767,503	837,687	799,593	735,885
British Columbia	1,976,031	1,614,579	1,584,010	1,475,556	1,308,806
Canada	**7,996,415**	**7,601,836**	**7,353,127**	**7,122,483**	**7,008,729**

Source: Statistics Canada. Table 32-10-0019-01 Estimates of specialized greenhouse operations, greenhouse area, and months of operation

Flowers and plants are grown in approximately 40% less space than vegetables but have provided approximately the same total revenues as vegetables.

Canadian Ornamental Sales[32]

2.1. Ornamental sales and resales by sub-sector (millions of Canadian dollars)

	2015	2016	2017	2018	2019
Greenhouse flower and plants	1,506.0	1,510.2	1,503.9	1,555.7	1,565.8
Nursery[1]	759.5	670.5	659.5	660.8	679.6
Sod	157.0	146.8	147.3	139.8	133.6
Total	**2,422.5**	**2,327.4**	**2,310.7**	**2,356.2**	**2,379.0**

Note:

1. Operations which exclusively produce tree seedlings for reforestation are outside the scope since the 2016 survey. Prior surveys have included their production, affecting also nursery area, production, sales, labour and expenses variables.

Source: Statistics Canada. Tables 32-10-0023-01, 32-10-0032-01 and 32-10-0034-01

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31 Statistics Canada Tables 32-10-0019-01 Estimates of Specialized Greenhouse Operations Areas

32 Statistics Canada Tables 32-10-0023-01, 32-1000032-01, 32-10-0034-01

Canadian trade in vegetables is a significant part of the overall farm gate value of production and the imports are significantly smaller than the exports. The same proportions for BC are applicable to trade in vegetables. Approximately 99% of Canadian vegetables exports go to the US. About 80% of vegetable imports come from Mexico, 12.5% from the US and 3% from Spain, with the rest from other parts of the world. An almost 34% growth in exports over four years shown reflects a valuable sector of the Canadian economy.

TECHNOLOGY LESSONS FROM JURISDICTION REVIEW[33]

This information is condensed from other jurisdiction review material contained in a full report to the Greenhouse Growers.

Solid state (LED) lighting

- Solid state lighting is starting to be available for greenhouse applications as a replacement for HID lighting, but is very expensive and requires significant research and testing to be optimized for the various type of plants.
- It has the potential to save energy by dimming the light output when full light output is not needed and enhance plant growth with light spectrum tuning (from uv to ir) and reduced radiation of heat as waste.
- Moving lighting closer to plants increases crop density potential and decreases water consumption.
- LEDs play a diverse role, enabling steady lighting levels when clouds interrupt direct solar, sunrise to sunset simulation to suit plants, control of lighting level and spectrum to plant growth, optimization research driving greenhouse control strategies.
- LEDs provide reliable durable use with longer service lives, safety regarding toxic chemicals in other lighting technologies, high lighting lumen levels enhancing CO_2 uptake.

Hydroponics & Aeroponics

- Hydroponics & aeroponics with new patented concepts for supply of oxygen into the water supply to the plants has been researched. Restricted oxygen in the hydroponic supply of water and nutrients to plants limits their growth.

[33] Commercial Greenhouse Market Report – Technology Lessons Section, marketsandmarkets.com

- With adequate aeration of the water supply enabled enhanced growth and hardier crops when tested
- Research and testing have been done with strawberries, tomatoes and bell peppers.

Sensors, Data, Tracking & Controls

- Sensors, data, tracking & controls with sophistication in applying sensors, data and information, including feedback controls to optimize plant productivity is gaining positions as potential for enhancing productivity.
- Veritas, an information technology company, is experimenting with these technologies in Colorado.
- Perdue University is using imaging information (high quality data) to provide information on plant health, this will lead to research supported algorithms, controls and optimization.
- Image data can also enable plant size and growth curves monitoring leaves, stems, flowers & fruits. As well, if developed, it could include monitoring of root development and performance.

Machine to Machine (M2M) Agriculture

- Machine to machine (m2m) agriculture is a development that bypasses the human intervention and passes data to machines designed to do the analysis and build the research data based on feedback controls and optimization learning software
- Monitoring and feedback to machine learning processes can work for the supply chain into the greenhouse as well as the supply chain processes moving product to markets and end consumers, for potential for waste reduction.
- Optimization of the greenhouse land, physical structure capital, operating and maintenance costs and waste and recycling become possible.
- Greenhouse gas emissions, other environmental impacts and benefits can be tracked, and performance improved.

Drones & Unmanned Aerial Vehicles (UAV)

- Drones & unmanned aerial vehicles (UAV), whether flying machines or track mobile devices the real-time gathering of information on useful time scales can enable highly effective data profiles from which to improve greenhouse performance or for that matter farm performance too.
- Gathering data on pests, fungi, viral and bacterial disruptions to the plant growth optimum will provide a depth of protection, in addition monitoring for the precursors of these disruptions will enhance predictions and prevention.

- Monitoring of the hydroponic inputs, water quality, nutrients, pollution, water temperature, oxygen levels, air circulation, CO_2 availability, oxygen releases and other elements will further help productivity enhancement.

Greenhouses Energy Management

- Greenhouses use step controllers to regulate greenhouse climate based on solid state integrated circuits technology. Also output control equipment with present programs & or settings are used where heating & cooling is applied as needed. Accompanying this is external ambient temperature monitoring and use of area requirement delivery of heating & cooling as necessary.
- Horizontal air flow (HAF) is used with low friction losses to pick up plant canopy & root level moisture, reducing disease factors with drier environment.
- Open roof systems for greenhouse ventilation can reduce air circulation energy costs, and at times, ambient temperatures and those required by plants can be synchronized, lowering energy costs.
- Shell corn as a biofuel has been shown to be better than wood & coal as a fuel supply
- Energy curtains & shades, with curtains providing energy efficient insulation and shades blocking excess heat for cooling, can both result in cost savings.
- Reflective shades or curtains can direct light to plants, though building energy simulations are not yet common.

Energy Supply to Greenhouses

- Energy for greenhouses, with energy conservation & efficiency and or heating alternatives, can counter the rising costs for fossil fuels.
- Maintaining ideal temperatures for plant using heating & cooling systems can improve productivity of plant growth.
- Thermal insulation, solar energy, heat exchangers (air source & ground source), geothermal energy, and energy storage can lead to cost reductions.
- Geothermal energy is one of the fastest growing supply sources. 30 countries now are exploring & or adopting geothermal energy sources, an annual 10 % increase. 34 countries are using geothermal energy directly in the greenhouses.
- International energy agency (IEA) is a global energy review, and notes that long-term contracts, priority access to grid, continuous growth of renewables, (despite supply chain issues & construction delays) are leading to reduced costs.
- Greenhouse industry in agriculture has highest need for energy, so closed greenhouse with thermal storage and no open ventilation are being used to take advantage of sensible & latent heat management along with the energy storage being used.

Industry cluster development collaboration & support

- The Netherlands provides the quintessential example of an industry cluster development, where government, universities, institutions, supply businesses and the greenhouse grower collaborate to improve the productivity & performance for all.

- The Netherlands has at least nine substantial clusters featured, including Agri-foods.

OPTIONS FOR GREENHOUSE GROWERS

The Greenhouse Growers needs from their natural gas supply are for;

- heat to keep the plants from being stressed by cold or cooler temperatures (seasonally and overnight).

- CO_2 for optimizing plant growth and production productivity.

High level options for maintaining profitability in the industry and achieving GHG emissions reductions are discussed below.

Carbon Tax Relief

The BC Greenhouse Growers have found some relief from the Carbon Tax on their natural gas consumption through the BC Government's Greenhouse Carbon Tax Relief Grant Program and a more permanent relief equivalent to the 80% relief program is anticipated to be implemented at the point of sale/purchase for the natural gas.

Nevertheless, to meet the BC greenhouse gas reduction targets, the industry will need to find optimal ways to contribute to GHG reductions in the future.

The target for this contribution would be 3.1% reduction per year, starting in 2025 and continuing to 2050 thus meeting the BC Government's target of 80% reduction by 2050.

Cover Some Cost of RNG in the Natural Gas Price

One option would be to have the Greenhouse Growers' provided with renewable natural gas from FEI. This would be provided such that a BCUC approved portion of the cost of renewable natural gas would be paid to FEI by the RNG customers and the remainder would be covered in the cost of RNG charged to all customers.

Under BCUC rate setting rules, it would not be possible to get a specific low-cost rate that FEI could use to provide service to greenhouse growers, because it would be seen as discriminatory rate setting. The only way to do this would be through a government direction to the BCUC.

RNG from FortisBC Energy Inc. (FEI) is more expensive than fossil natural gas delivered through the gas delivery system. However, customers can purchase blends of natural gas and renewable natural gas. This is exactly what the Greenhouse Growers might need to do at 3.1% per year to meet the provincial GHG reduction targets.

The Greenhouse Growers would need to establish a means of financially supporting the cost of RNG over and above the cost of natural gas.

This method of ramping up the acquisition of renewable natural gas in proportional steps would be seen as proportionally and increasingly GHG emissions-free and clean as well as avoiding the carbon taxes and relieving the government from needing to provide 80% carbon tax relief.

Decarbonize Natural Gas – Use Hydrogen for Electricity and Heat

A second option would be for FEI to crack the methane delivered as natural gas at or near the greenhouse site and collect the pure carbon for sale to carbon markets while delivering pure hydrogen fuel, which would then be available for instance for combined heat and power applications.

This arrangement would enable the greenhouse growers to produce their own electricity requirements and avoid some of the BC Hydro rate structures, with their unfortunate demand charge implications for effective use of electricity.

This arrangement would need to be augmented with a means of delivering CO_2 at a reasonable price comparable to the natural gas combustion delivered CO_2, which Greenhouse Growers currently use.

Hydrogen can be produced from the decomposition of methane (also called pyrolysis). Many studies assume that this process emits few greenhouse gases (GHG) because the reaction from methane to hydrogen yields only solid carbon and no CO_2.[34]

Carbon Capture and Use

Capture of CO_2 from flue gases or cement manufacturing processes can be done cost-effectively with an off the shelf melamine powder, which costs about $40/tonne[35]. The melamine is combined with formaldehyde to form a compound which will bind to CO_2. The compound's ability to bind to CO_2 is significantly enhanced if DETA (diethylenetriamine) is used.

The addition of cyanuric acid further enhances the CO_2 capture and enables repeated reuse of the material. The resultant material can capture CO_2 at temperatures of about 40 degrees C and will release the CO_2 at a temperature of about 80 degrees C. Interestingly the release of CO_2 would occur at a typical greenhouse temperature.

Through photosynthesis, plants use sunlight to convert H_20 and $C0_2$ into sugars ($C_6H_{12}O_6$) for plant cell growth, releasing O_2 in the process.

When there is no light for photosynthesis the plants switch over to metabolizing the sugars into the plant cells, as the energy the plants need to live. They do this through breathing in oxygen O_2 and releasing CO_2 in a respiration process.

This may lead to significant ability to capture CO_2 in the ventilation and circulation of greenhouse air, effectively recycling CO_2. This CO_2 capture and reuse could be accomplished with emerging electro-swing technology[36], which could also capture CO_2 from ambient sources.

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[34] Abstract Article: Hydrogen and hydrogen-derived fuels through methane decomposition of natural gas – GHG emissions and costs by Sebastian Timmerberg a,b Martin Kaltschmitt a , Matthias Finkbeiner b

(a Hamburg University of Technology, Germany   b Technische Universität Berlin, Germany)

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[35] UCB demonstrates "incredibly cheap and easy" carbon-capture material, Loz Bain, News Atlas, August 08, 2022

[36] A new approach to carbon capture - Researchers design an effective treatment for both exhaust and ambient air, Nancy W. Stauffer, MIT News, July 9, 2020

Heat from Geothermal or Air Source Heat Pump

An option would be for air source heat pumps and or shallow geothermal loop heat pumps, which are an existing near-term technology. These could well provide heating requirements at a base level, while allowing the natural gas boiler systems to provide the more substantial heating requirements[37].

Another option would be to derive heat from a geothermal well providing heat at approximately 25 degrees C for each kilometer of depth. Well drilling technologies are developing such that substantial opportunity may exist to access greenhouse growers' heating requirements for reasonable costs. This would be a long-term future option as the technologies develop and become further proven and more cost-effective[38],[39].

Heating and Energy from the Greenhouse Property

The property upon which the greenhouses are located have substantial amounts of land which is not directly allocated to plants and growing. As well, there are significant portions of the greenhouse external walls that are not used for plant growth.

There are significant quantities of solar energy falling on the property, that are not captured and could be used to supplement greenhouse operations. The technologies for capturing these energy sources and turning them into profitable contributions to the greenhouse operations may prove very useful. Concentrated solar heat could well provide substantial contributions to heating requirements.

Heat storage and electricity storage are becoming increasingly cost effective and may play a role in ensuring use of the energy sources available and not currently being harnessed.

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[37] Josh Gabbatiss, "Heat Pumps are the Central Technology for Low Carbon Heating, Concludes IEA", https://www.carbonbrief.org/heat-pumps-are-the-central-technology-for-low-carbon-heating-concludes-iea/, Retrieved January 17, 2023

[38] Geothermal energy is poised for a big breakout – By David Roberts, Vox Media, Oct 21, 2020

[39] Massachusetts Institute of Technology News, Tapping into the million-year energy source below our feet Zach Winn | MIT News Office Publication Date: June 28, 2022

In addition to the solar energy, there is a significant amount of wind energy that may be captured through emerging technology that is now proven and available. Vancouver experiences a fairly steady level of wind energy, which might be captured and incorporated into the greenhouse power supply processes.

All of these technologies could be integrated into solutions, which could provide paths to reduced greenhouse gas emissions while at the same time enhancing the profitability and sustainability of the greenhouse operations.

Greenhouse Growers Affordability Through Efficiency and Productivity Optimization

Efficiency and Effectiveness

Investment in additional efficiency and effectiveness in the greenhouse operations may be expected to have significant costs and benefits with uncertainties that can be a challenge to evaluate.

Nevertheless, the BC Greenhouse industry is constantly looking for opportunities and evaluating options and learning from the leaders in the greenhouse industry, typically in the Netherlands.

Lighting Optimization

Lighting, in general, has a significant impact on plant growth and productivity, which can be a 1 to 1 linear relationship. Without lighting, the plants are subject to the variability of the sunlight, which varies dependent upon the time of day and year and is based on weather related cloud cover.

LED lighting can enhance plant growth & productivity, particularly tuning the light to the specific wavelengths needed by the plants. The plants can be quite responsive to red light, at times, which can enhance growth.

Since LED lighting is dimmable, lighting controls and sensors to optimize the lighting for the plants could further extend the efficiency of lighting.

Some greenhouses are looking at expansion and expansion of lighting for their crops. Energy, uncertainties facing the industry are, in part, holding back this sector of the economy.

Greenhouses interested in lighting have issues with the costs of getting access to electrical power they might need. In particular, the BC Hydro tariffs charged for both demand costs and for consumption costs can be problematic for greenhouse growers. A voluntary rate enabling more appropriate charging for greenhouse growing would be valuable.

Space Optimization

Greenhouses typically have (1) covered areas not used for plants and production but for processing, packing and shipping (2) areas on the property, which are not used for any specific kind of production (3) areas used for parking and administration as well as storage and particularly storage supply of hot water and related systems (4) vertical areas above and beside the greenhouses (5) vertical space within the greenhouses (6) isle and corridor space used for moving people, equipment and product.

Some of the greenhouse operations have pursued additional uses for such spaces to improve productivity and profitability.

Environment Attribute Optimization

For greenhouses that are looking to provide year-round utilization of the greenhouse investment, heating is an essential and most critical requirement. Through providing heating additional to the solar heating, an environment conducive to plant growth is maintained.

The greenhouse construction is primarily glass construction, though some use a polymer fabric. The insulation values and heat retention factors for the greenhouses leads to heat requirements. Greenhouses use overhead screens, overnight sometimes, to assist in retaining heat in the greenhouse. Heat losses in the process, which could be avoided, may be a source of optimization.

Heating in many greenhouses is a product of combustion of natural gas to provide CO_2 to the plants. The heat from the combustion is stored as hot water and released over time throughout the day and night to maintain temperatures conducive to the plant growth. Providing heat, particularly where and when the plants need it, can be important.

In summer season, in particular, and a few times in the shoulder seasons, the heat from the sun can become excessive for the plants. In these cases they need protection from the direct solar intensity, and particularly, the infrared spectrum of the insolation. For this, the greenhouses use movable screens for shading to protect the plants.

Venting in the roof, allowing heat to escape to the outside, is also used to control over-heating in the greenhouses; enabling a degree of cooling to assist in control and optimization of the temperature for the plants.

Humidity also needs to be controlled to provide an optimized environment for plant growth.

Optimizing heating and cooling for the greenhouses and for the produce at various stages can be an area for pursuing optimization efficiencies.

Automation Optimization

Currently, a number of greenhouses have settings on equipment that provide control over important conditions in the greenhouses. These can have varying degrees of sophistication in providing optimization.

Sensors and controls with intelligent feedback loops can lead to refined levels of optimization of the environment for the plants.

Automation of some of the functions performed by the people that operate the greenhouse, can be potential options for the application of automation. Various greenhouses are in different states of adopting different types of some of the optimization potentials.

TECHNOLOGIES REVIEWED & PRIORITIZED FOR FURTHER REVIEW

CO_2 (Emissions Reductions and Offsets)

- Direct Ocean Capture (DOC) Environmental Attributes
- Bio-pyrolysis Biochar Sequestration
- RNG subsidized
- Electro-swing capture

Heat

- Solar (normal & reflected & concentrated)
- Natural Gas
- Combined Heat & Power
- Insulation
- Heat Retention Mass

- Reflection of Infra-Red (Back into or Away from Greenhouse)
- Heat Storage Batteries
- Heat Pumps (Air Source, Geothermal Source)

Electrical

- BC Hydro supply
- Interruptible Rate supply
- Time of Use Rate supply
- Combined Heat & Power
- Wind Power (Passive & Vertical)

Light & Lighting

- Solar (normal & reflected)
- Artificial Lighting (HPS & LED)
- Optimized Utilization by Plants

Space Optimization

- Enhanced Space Use Values (growing, growth enhancement, capturing energy, processing)

Humidity

- Chillers (integrated to heating)

Sensors & Controls

- Plant (sensing & evaluating, control of environment)
- Physical Structures and Flows (sensing & evaluating, maintenance scheduling)

Automation

- Robotics (tending plants, product processing flows, tending to maintenance)

Longer term options

- Renewable deep geothermal heat and electricity based on new electromagnetic wave drilling technologies

RECOMMENDATIONS TO SET CONTEXT FOR MEETING OBJECTIVES

Collaborative Industry Cluster

The concept of economic clusters is a means of innovative development and competition to increase the productivity, performance and success of an industry cluster.

Governments and industries all over the world focus on identifying, supporting and building the collaborations that lead to significant innovation, productivity, performance and competitive edges.

The BC industry certainly has ready access to the top greenhouse cluster in the world in the Netherlands and benefits from following developments there.

In the BC context, there is a potential for much greater cluster support, particularly around the energy transition issues of energy costs and CO_2 emissions. This is important, given that BC is a leader in Canada on energy costs and GHG emissions reductions.

As a result, the best solution to achieve the emission reduction goals outlined by Government could be to explore the conceptual idea outlined below:

One conceptual idea is to establish a Greenhouse Growers Clean Energy Alliance (GGCEA) for the purpose of building the cluster of support, which may be needed to accomplish the goals for meeting GHG emissions reductions targets and remaining sustainably profitable.

A second conceptual idea is to establish a Greenhouse Growers Technical Innovation Alliance (GGTIA) for the purpose of identifying and supporting implementation of technical improvements to accomplish the goals for ensuring a sustainably profitable industry, while meeting GHG emissions reduction targets.

The target for GHG emissions reductions would be 3.1% per year from 2025 to 2050 to model the industry meeting and aligning with the 80% reduction by 2050.

Of course, making progress in advance of these targets would be expected from a strong and strengthening collaboration.

Developing the financial capacities to support is required developments to achieve these two goals will be a critical part of the 2023 and 2024 process of setting the initial conditions for success.

There are two key elements to the development of these collaborations. Everyone must recognize that the industry has been operating for a considerable period of time based on greenhouse structures, equipment and operation based on specific designs, including the use of natural gas for heating and CO_2.

This means that the industry has substantial investments based on this preceding context. Adoption of the energy transition context and the current and developing competitive context, will require a deep understanding of financial decision making in these contexts.

For instance, there are extreme challenges for industry in introducing a new form of heating and replacing investments in condensing boilers designed for use of natural gas and sized to heating the greenhouse structures as they exist. A new capital investment requires new revenues in excess of costs to be a cost-effective contribution to the industry. A replacement, adding cost but no new revenues, will degrade economic performance.

The key test will be whether the industry can attract capital investment with projects adding profitability to the industry and to the investor supporting the project. The collaboration will need to fully understand and buy in to this key principle to ensure that only cost-effective actions are planned and implemented.

GHG Emissions Target Recommended Projects – Renewable Natural Gas

The recommendation regarding GHG emissions reductions is to focus on renewable natural gas RNG from FortisBC Energy Inc. (FEI). FEI, as the utility responsible for delivering natural gas to the greenhouses, already has a developed process for providing RNG to customers and has Long Term Gas Resource Plans before the BC Utilities Commission for approval.

After setting the greenhouse gas reduction targets with the BC government and achieving financial contributions to the two cluster developments, the GGCEA & GGTIA, then the RNG adoption and GHG reductions can begin.

Adoption of RNG will need to meet a key financial test. It will need to be tested for affordability against the other options for capturing and sequestering carbon or for displacing natural gas usage and providing alternative CO_2 economically.

Also, the RNG adoption would need to fit within the model for the operation of the GGCEA & GGTIA, in terms of the amounts to be acquired.

As the RNG is adopted, the carbon taxes applicable will reduce, and the need for the governments' funding of the GGCEA & GGTIA will be paramount.

Consequently, the earlier the essential projects, required to create profitable cost reductions or additional revenues are done the sooner certainty can be developed. With the certainty, the transition to the new context can be accomplished and both parties' key goals can be on a path to being achieved.

GHG Emissions Target Recommended Projects – Heating and CO_2 Management

There are two critical issues to be managed in this context transition, heating and CO_2 management.

Heating Management

This leads to examination of potential projects that can reduce the amount of natural gas fuel-based heating requirements. Greenhouses are not highly insulated but have a substantial air mass to hold the heat.

Heating must respond to the environment, with its daily heating requirements. Solar heat declines through the evening each day, and seasonal variations occur with the winter and shoulder seasons requiring substantially more heating than the summer months.

Projects recommended for consideration, will be concentrated solar energy capture from other areas of the greenhouse growers' properties, along with storage of this thermal heat and integration into the greenhouse heat management systems to potentially lower costs.

Projects recommendations for consideration will reasonably focus on heating management, which may involve insulation and or reflection of additional infra red heat into or away from the greenhouse. Additionally, once heating levels are met, reflecting escaping heat back into the greenhouse could be considered.

In the management of heating, cooling and thermal energy management, hot water storage of heat will remain the principal technology for thermal energy storage, as this investment already exists.

Recommended for consideration, where much higher thermal temperatures are accessed, may be heat stored in the equivalent of thermal batteries. Many new designs and options for thermal storage are emerging and may become attractive in the future for thermal heat management. These can also crossover to become electricity supply at times.

The application of phase change materials is recommended for consideration as these can be installed in panels providing an artificial thermal mass and passively maintain the temperature of the growing spaces.

Geothermal exchange is also recommended for consideration, as these sources can have stable temperatures year-round. Depending upon depth, geothermal sources may be considered in the future as a source of heat derived from the earth and as a potential option for long term storage of excess heat. Offsite heat sources such as municipal sewage may be an option if available.

CO_2 Management

Also recommended are projects that look at CO_2 management in the greenhouse to avoid CO_2 not being fully used by the plants and ensuring that the quantities of CO_2 are delivered when they can be productively used by the plants. As plants use CO_2 during the day for photosynthesis and release CO_2 as respiration when they are producing plant matter over night.

A further recommendation is to examine the use of combined heat and power to offset electrical energy requirements, particularly those associated with demand charges and still provide heating and CO_2 requirements.

Low carbon heating options are also recommended for examination, particularly where paired with cold storage, as both requirements can be met with the electric energy supply. Heat recovery from chillers can be used to capture excess heat in the greenhouse and manage humidity. Capture of this heat and appropriate integration with the heat storage and heating delivery systems in the greenhouses could significantly offset heat currently provided by boilers.

Air source heat pumps in hybrid configuration with natural gas backup can provide a baseline of heating with boilers handling peak heating. This movement of air for the heating and cooling purposes might be integrated with CO_2 capture, storage and release back into the greenhouse as required.

Carbon Capture and Use technologies are emerging quickly. Commercial CO_2 capture is increasingly forecast to have lower potential costs. Among the most attractive of these, is the new electro-swing technology for CO_2 capture. As this is commercialized, it or some other competitor technology, will have the potential to cap the costs for achieving GHG emissions reductions. This may further add to the greenhouse growers' options for optimizing plant productivity as it relates to CO_2 management.

Biomass Pyrolysis, producing a biogas source for RNG and a by-product biochar with a significant potential agricultural value including its carbon sequestration values, is another recommendation to be examined. This would be particularly relevant to FortisBC Energy Inc. because of the connection with RNG.

In order to make the most effective context transitions, without incurring capital investment costs for the industry or the gas utility, it is recommended that the attachment, to natural gas use, of environmental attributes of carbon capture and sequestration be considered.

The new emerging technologies for accomplishing this cost effectively appear to be becoming increasingly attractive. One of these, based on algae growth and carbon sequestration, appears to be potentially very cost-effective.

At this time in BC, the provincial government and the BC utilities commission recognizes RNG, whether produced in BC or elsewhere around the world, to be an appropriate substitute for use of natural gas.

The BC government's Greenhouse Gas Reduction Regulations, however, do not recognize the environmental attributes of highly cost-effective carbon sequestration as an option or even a transition option. It is recommended that the industry GGCEA & GGTIA expand an outreach to other industries in the province to encourage BC to broaden the tools for meeting GHG emissions reduction targets cost effectively, particularly in transition stages, before adoption of future fuels and systems for heating greenhouses become available.

Finally, alternative sources for CO_2 as supplemental contributions to CO_2 requirements are recommended for further consideration. The advantage of dealing with emissions sources such as cement plants is that the CO_2 concentrations are orders of magnitude higher than the ambient CO_2 and therefore should be a focus of consideration.

Interestingly, cement is moving toward a number of emerging technologies which may well substantially reduce the carbon footprint of cement. Curing of cement based on absorption of CO_2 may prove to make this source an uncertainty as a longer-term solution. However, in the short term, this could well be an option.

FortisBC Energy Inc. has identified that its RNG process produces some CO_2 emissions, which could be an option for developing some temporary supplemental CO_2. This potential source of CO_2 will be worth focusing on, particularly for its potential to be a contribution to the RNG process, as well as the greenhouse growers' benefits.

Liquid CO_2 is an existing solution available now and a viable substitute to consider, although more expensive than the CO_2 that is a by product of the heating process.

Under all circumstances, the longer-term separation of the CO_2 supply for greenhouse growers from the heating supply will enable greater opportunity for optimizing both and pursuing profitable alternatives.

Light Management for Plant Growth and Avoiding Stress for the Plants

There is a potential to provide reflective surfaces to direct additional lighting into the greenhouses, and the recommendation is to include this as a priority analysis. The benefits are expected to be 1% additional growth for the plants for every 1% of additional lighting getting into the greenhouse for the plants. This is only applicable when the plants can use the additional lighting.

Reflection into the greenhouses can be a significant percentage increase when the daily sunrise and sunset angles to the greenhouses are increasingly flat. This opportunity is also enhanced when the seasonal winter and shoulder season angles of the insolation are much flatter than the summer.

Filtering solar light coming into the greenhouses is possible to reflect away infra red heat and can be beneficial to plants and energy management. In the summer, reflecting away the heat protects the plants from being overly stressed or even burned, resulting in serious plant damage. This is currently done with screen shielding but may be more effectively and profitably done with light filtering and should be considered seriously.

Electrical lighting has been shifting from a high-pressure sodium (HPS) lighting to new and emerging technology for light emitting diode (LED) lighting. HPS lighting is considerably more energy intensive than LED lighting to deliver the required lumens to the plants. Qualitative differences in the lighting with HPS delivering a broader wavelength white light, while the LED lighting is more focused on a slimmer range of wavelengths.

It is important to note that the HPS lighting has a significant electrical infrastructure supporting the lighting in the greenhouse. This investment is sunk and the replacement infrastructure is a significant change and added investment. This means that alternative lighting should be considered as additive and not replacement to HPS lighting.

The LED lighting is increasingly able to be controlled and tuned to the specific lighting needed by the plants and avoid wasting energy on lighting not needed by the plants. The emergence of this technology is still looking to find the right financial investment criteria before broader adoption. However, this opportunity is emerging more quickly now and must remain a focus for the year-round greenhouse production vision. Manufacturers Philips Horticultural Lighting and Current (GLI) Horticultural Lighting are likely partners in the GGCEA & GGTIA.

Spectral sensing and control software are emerging as lighting options allowing the lighting systems to be automatically optimized to the plants needs. Colour spectrums can be tuned to the plants' needs, and can be made responsive to the lighting levels in the greenhouses based on time of day and weather patterns of cloudiness. The right supplemental lighting can be a significant contributor to crop growth and to productivity potentials. Suntracker Technologies Ltd. may be a candidate as a GGCEA & GGTIA partner.

Solar Energy and Battery Storage for Lower Electrical Costs and Control

Emerging technologies for ultra light and thin flexible solar cells are heading toward becoming an option for consideration. As this option matures, many surfaces exposed to sunlight that is not captured into the greenhouses may become an opportunity to develop for low-cost electricity. These solar cells, like all others, would have variable performance based on the mix of direct solar light and more clouded or overcast diffuse lighting with lower energy intensities. These cells could be sufficiently thin to be transparent to much of the visible light, and yet be tuned to deliver power from the infra red spectrum. As such, these may become candidates for screening and shielding of the greenhouses in the summer.

Along with the collection of solar energy comes the potential to store that energy in some kind of battery storage device for return to the system when needed, thus providing a smooth voltage and power level delivery to the greenhouse systems. Also, with this kind of capacity, it may become more likely for greenhouses to access interruptible electrical energy supply for some uses and avoid demand charges in specific periods of time when these charges become onerous. In addition, this may at some time, enable the greenhouses to provide, for a financial benefit, a capacity supply to BC Hydro, thereby enabling access to low load hour power in the markets for the benefits of BC Hydro customers.

Liquid metal batteries have been an emerging technology for years and are in a stage of maturing in commercial stage implementation. In this stage, manufacturing costs tend to decline with volume of applications. These batteries have many attractive qualities including long life (25 to 30 years) without degradation and charging and discharging cycles without diminished performance. They are made from common materials, so there is little exposure to rare material, high cost pricing, and they are modular and easily scaled. In addition, they have very high safety characteristics. These batteries are worth consideration for what they may profitably contribute. Ambri is the manufacturer as a potential GGCEA & GGTIA partner.

Iron air electrical storage batteries are essentially based on reversible rusting of iron as it develops energy supply from the iron, based on oxidation, during battery discharge. When an electrical current is charging the battery, the oxidized iron, is returned to being iron and the oxygen is released. Form Energy is the manufacturer as a potential GGCEA & GGTIA partner.

Automation Sensors and Controls

Already, greenhouses have significant controls and sensors for some parameters, and for some levels of control over the greenhouse environment.

Emerging technologies with greater levels of granular sensing and control along with automated decision-making can likely optimize on the management of the greenhouse environment. This would be particularly true as more sophisticated approaches to plant productivity are identified and implemented.

The final recommendation in this series is to keep this as a live option because there is evidence that the enhancement of productivity may be significant, although potentially a challenge to implement.

Finally, robust automation and controls would be essential for managing electrical demand, where electrified heating sources are being utilized.

Demand management will be required to minimize the extent of electrical service and distribution upgrades that are required to support electrified systems.

GREENHOUSE GROWERS CARBON REDUCTION & PROJECT IMPROVEMENTS TO PAY FOR GHG REDUCTIONS

Minimum Requirements Analysis for Government and the Greenhouse Growers Collaboration

The Greenhouse Growers analysis of minimum requirements, being 3.1% reduction per year, for carbon reductions and the project investments that will be needed in order to pay for greenhouse gas emissions reductions and to improve the greenhouse industry performance, are based on the following assumptions.

1. The provincial carbon tax payments received from the industry (20% of the carbon tax otherwise applicable) are returned to the growers.
2. Funds returned to the growers will enable them to make payments for CO_2te reductions.
3. Funds will also enable growers to make improvements to their businesses enabling them to support payments for carbon emissions reductions.
4. Carbon emissions reductions are targeted at 3.1% per year from 2025 to 2050 to achieve the provincial target of 80% reduction by 2050.
5. The projects in which the greenhouse growers invest will be for their industry and businesses and will be designed at a minimum to achieve returns on investment comparable to the levels needed to match the cost of achieving carbon tax reductions.
6. Anything achieved over and above the plan in the way of improvements for the industry will be retained by the industry to sustain and improve their profitability.
7. The greenhouse growers' investments in projects will cover early-stage assessments and feasibility studies and collaborative undertakings.
8. Projects will be implemented by specific greenhouses as members of the industry.
9. Projects may be fully funded by a combination of external equity funding and greenhouse growers' equity where applicable.
10. Projects may also be supported by debt instruments negotiated for the projects.
11. Projects may have shared interests of the Greenhouse Growers industry and the interests of specific greenhouse growers.

Disclaimer: The Greenhouse Growers' industry must deal with many economic issues, including rising cost, increasing carbon tax costs, competitive market pricing, cost of capital increases and significant uncertainties with regard to a stable competitive environment. In addition, the Greenhouse Growers must keep up with productivity in competitive jurisdictions and elements of cost structure.

There is no commitment from government or from the BC Greenhouse Growers to any elements of this conceptual study to develop a path forward in the short term and the longer term for achieving the objectives of both parties.

The path forward will evolve through the continued collaboration of government with the Greenhouse Growers' industry making decisions, each in their own right and together on those they can agree, upon going forward.

Potential Benefits for Stakeholders

Industry

Enabling the Greenhouse Growers to receive and use the 20% carbon tax currently received by the BC government can provide some of the capital required to offset GHG emissions and support project innovation to reduce GHG emissions and contribute to Greenhouse Grower's profitability.

The creation of a collaboration with the BC Government could provide business certainty leading to expansions and accelerated investments in innovations leading to increased industry profitability.

BC Greenhouse Growers' alignment with climate change objectives could enable Climate Friendly Food branding and support industry revenues.

Government

The collaboration approach to GHG emissions reductions would be cost-effective and efficient for the Greenhouse Growers' industry and may be applicable to many others.

The collaboration could lead to greater certainty for meeting government's climate change objectives.

As the industry achieves increased profitability from implementation of project innovations, the Federal and BC Governments would receive increased income tax revenues potentially exceeding declining carbon tax revenues.

The government would be investing in a more affordable & secure local food supply.

Metro Vancouver

With increased cost-effective investment in GHG emissions reductions, the airshed quality could be improved.

Utilities (FEI, BCH)

FEI could be part of a collaborative approach with cost-effective GHG emissions reductions and existential solutions to the energy transition.

FEI from a demands side investment perspective could be making investments in opportunities to incent and accelerate more efficient and effective use of natural gas.

BC Hydro could be part of a collaborative approach to optimizing the benefits of electrical supply to customers.

Greenhouse Growers could potentially provide BC Hydro with offsetting reductions in peak demand and demand reductions minimizing future utility capital and operating costs.

BC Hydro with its electrification initiatives could contributions to cost-effective GHG emissions reductions.

Suppliers to Industry

Suppliers to the greenhouse industry could have increased opportunities for profitable engagement with whole industry as well as individual greenhouses.

Universities & Researchers

BC Universities and others could have significant opportunities for doctoral and postdoctoral research and feasibility study directed at the potential Greenhouse Growers' innovation projects.

Within the collaboration the universities would have increased opportunities to develop intellectual property of significant value to local and personal student interests as well as the public interest.

Growers’ Marketing Organization

The Greenhouse Growers’ marketing organizations would have Climate Friendly Food branding and a more profitable industry better able to compete.

BC & Export End Customer

Consumers would have year-round access to more affordable & secure local food supplies.

With strong competitive principles of cluster development and support, end consumers will benefit from a stronger BC economy.

Funding Credits

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APPENDIX D – LIST OF ACRONYMS

BCGGA – BC Greenhouse Growers' Association

BCH – BC Hydro

BCLNA - BC Landscape and Nursery Association

CAD – Canadian Dollar

CCCA – Climate Change Accountability Act (a BC law)

CO_2 – Carbon Dioxide

CO_2te – Carbon Dioxide Tonnes Equivalent (measure of GHG emissions)

DAC – Direct Air Capture (technologies for capturing CO_2 from the air)

DETA – Diethylenetriamine (A chemical which has properties that assist in carbon dioxide capture)

DOC – Direct Ocean Capture (technologies for capturing CO_2 from the ocean)

FEI – FortisBC Energy Inc.

GGCEA – Greenhouse Growers Clean Energy Alliance (a proposed organization for greenhouse growers and the BC government to support the industry cluster)

GGRR – Greenhouse Gas Reduction Regulation (a BC regulation)

GGTIA - Greenhouse Growers Technical Innovation Alliance (a proposed organization for the greenhouse growers to develop innovative project of improving their productivity and profitability)

GHG – Greenhouse Gas Emissions

GJ – Giga Joule (A Joule is measure of the amount of energy – Giga is 1,000,000,000)

HAF – Horizontal Air Flow (a form of directed air movement with greenhouse values to plants)

HID – High Intensity Discharge (a lamp providing a very bright light - electric arcing to tungsten)

HPS – High Pressure Sodium (technology for bright lighting)

H_2O – Hydrogen Oxide (Water)

IEA – International Energy Agency (Paris based 31 country organization specializing in world energy issues)

IPCC – Intergovernmental Panel on Climate Change (United Nation organization advancing scientific knowledge about anthropogenic climate change)

IR – Infra Red (a spectrum of light from the sun on the electromagnetic radiation spectrum)

KJ – Kilo Joule (A Joule is a measure of the amount of energy – Kilo is 1,000 – typically used with heat energy, such as natural gas and solar energy)

kWh – Kilowatt Hours (a watt is a measure of energy capacity and watt hour a measure of energy – typically used with electricity)

LED – Light Emitting Diode

LTGRP – Long Term Gas Resource Plan (FEI's 20 years planning document)

M2M – Machine to Machine

MCO_2te – Mega Carbon Dioxide tonnes equivalent (Mega meaning 1,000,000)

MIT – Massachusetts Institute of Technology (A university in Cambridge Massachusetts)

MJ – Mega Joule (A Joule is a measure of the amount of energy – Mega is 1,000,000)

OECD – Organization for Economic Co-operation and Development (A group of nations)

NO_2 – Nitrogen Dioxides

NOx – Nitrogen Oxides (A family of nitrogen oxides)

NREL – National Renewable Energy Laboratory (a US organization specializing in energy issues)

RNG – Renewable Natural Gas

Tonnes – Metric tons (1000 Kilograms)

UAV – Unmanned Aerial Vehicle

UCB – University of California Berkley

UFGCA - United Flower Growers Co-operative Association

USD – United States Dollar

UV – Ultraviolet (a spectrum of light from the sun on the electromagnetic radiation spectrum)