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Harmonizing Agricultural Growth and Nighttime Sky: Municipal Strategies for Mitigating Commercial Greenhouse-Related Light Pollution in Ontario, Canada

Subject keywords: agriculture; environment; planning; policymaking; public administration; value conflict

Geographical keywords: Essex County, Ontario, Canada; British Columbia, Canada; the Netherlands

MPA Major Research Report

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Abstract

This comprehensive research investigates the intricate interplay between the thriving commercial greenhouse industry and the pressing concern of nocturnal light pollution in a focussed area of Ontario, Canada, and the Netherlands. The province of British Columbia, Canada is also reviewed in this study, however it is found that the scale and magnitude of the commercial greenhouse industry in this province has not yet reached a level to warrant governmental intervention. The study addresses the multifaceted challenge of managing greenhouse-related light pollution, which emerges as an unintended consequence of employing supplementary lighting to extend growing seasons and enhance crop yields. The analysis of jurisdictional approaches reveals the complexities and the varied success achieved in addressing this issue.

In Ontario, particularly in and near the County of Essex, the response to greenhouse-related light pollution has primarily been reactive, with municipalities passing light nuisance by-laws under the province's Municipal Act. However, the lack of a comprehensive legal framework addressing greenhouse lighting in other provincial acts, such as the Planning Act and the Environmental Protection Act, has led to a fragmented approach, resulting in inconsistent outcomes. The jurisdictional scan indicates that Ontario's current approach may benefit from greater coordination and harmonization of efforts to minimize disturbances for nearby residents.

In contrast, the Netherlands has adopted a proactive and comprehensive approach, driven by decentralized policies targeting specific challenges unique to different regions. The country leverages the "Light/Dark Handbook" as a guiding resource, facilitating collaboration between provinces and stakeholders. This decentralized model allows

local authorities to implement targeted strategies, resulting in a cohesive and efficient response to light pollution concerns. Moreover, successful examples of greenhouse clusters in the Netherlands, such as Agriport A7, and which are akin to industrial parks in North America, demonstrate the effectiveness of private-public partnerships and the involvement of stakeholders in policy development.

The research highlights the importance of a coordinated and collaborative approach that aligns the interests of governmental bodies, greenhouse growers, and the public. By drawing lessons from the Netherlands' multifaceted model, Ontario can implement more cohesive efforts to combat light pollution while fostering sustainable and environmentally conscious greenhouse practices. The research underscores the significance of involving stakeholders, creating centralized guiding documents, and providing financial incentives to ensure the harmonious coexistence of agricultural productivity and environmental preservation. As awareness of light pollution's impact continues to grow, the adoption of comprehensive and integrated strategies becomes essential for balancing the needs of the greenhouse industry with the imperative of environmental stewardship.

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1. Introduction

In the rural landscape of Essex County, Ontario, nestled near the southwestern tip of the province and in close proximity to the Windsor-Detroit border, a captivating tale of transformation unfolds. This tale, set within the heart of Ontario's commercial greenhouse industry, showcases a symphony of growth and productivity that persists beyond sundown, propelled by the unyielding demand for local produce in a world grappling with the challenges of population growth and food security. However, amid this tableau of agricultural advancement, a subtle yet crucial challenge emerges—one that delicately navigates the tightrope of innovation, energy efficiency, and environmental harmony: the intricate link between the rising production of the commercial greenhouse sector and the imperative to address the potential impact of nocturnal light pollution.

Greenhouses within this region contribute indispensably to Ontario's economic and culinary landscape. Yet, as the demand for locally sourced produce gains momentum, the industry finds itself at a pivotal crossroads—where heightened productivity intersects with the delicate task of safeguarding the purity of the nighttime sky.

The adoption of new practices, such as the use of supplemental lighting techniques, emerges as a beacon of promise for extending growing seasons and augmenting yields.

These methods empower the cultivation of high-light crops even during the less illuminated periods of Canada's climate, promising to enhance agricultural output and bolster resilience against the fluctuations of nature. Recent studies, led by Hernandez and colleagues (2013, 2020), shed illuminating insights on the manifold benefits of these approaches, unveiling the positive effects of added light on essential aspects of

plant growth, including photosynthesis, fruit yield, plant structure, and overall robustness.

However, as local municipalities have embraced this industry's growth for assessment and employment purposes, with new transformative technologies in this industry, municipalities now grapple with a new pressing challenge: how can municipalities harmonize the undeniable benefits of heightened agricultural productivity with the imperative to minimize the potential impact of nocturnal light pollution, ensuring a sustainable coexistence with our environment and communities (CBC, 2019)? This inquiry propels the research topic of managing light pollution— approaches and measures implemented by governmental bodies and industry stakeholders to address the issue of "greenhouse-related light pollution" in Ontario.

Purpose and Outline

The aim of this research is to investigate the commercial greenhouse industry, with a specific focus on the increasing use of supplementary lighting to enhance crop yields. While supplementary lighting offers numerous benefits for year-round production, it also poses the potential for light pollution, impacting the night sky if not properly managed. This study aims to explore recent approaches and measures implemented by governmental bodies and industry stakeholders to address the issue of "greenhouse-related light pollution" in Ontario, Canada, and the Netherlands, as well as in other relevant regions.

The research will provide a brief background on light pollution in general, and then the commercial greenhouse industry, highlighting its significance in food production and its rapid growth in recent years, and why supplementary lighting has been employed by

greenhouse growers to optimize crop growth and meet the rising demands for produce throughout the year.

The study will then delve into the critical issue of greenhouse-related light pollution, providing a jurisdictional scan of municipalities in Ontario, and the Netherlands where the issue has come to the forefront. British Columbia is also analyzed briefly. The scan utilizes the the “NATO” classification, which offers a comprehensive lens through which to analyze the various policy tools utilized by governments. By analyzing current policies and initiatives undertaken by governmental and industry bodies in these regions, the research aims to gain insights into effective strategies to mitigate light pollution while maintaining optimal crop yields.

Following the jurisdictional scan, a range of non-greenhouse-related approaches that various regions and organizations have employed to manage light emission and address light pollution issues will be highlighted. These approaches provide important context for understanding how municipalities can potentially tackle similar challenges in the context of commercial greenhouse operations. The examples encompass a variety of strategies, including outdoor lighting regulations in urban areas, transportation industry practices, urban planning and development guidelines, measures taken by astronomical observatories, dark-sky preserves and designations, and collaborative initiatives involving multiple stakeholders. By exploring these diverse approaches, the paper underscores the importance of considering effective policies and practices to mitigate light pollution and emphasizes the need for a multifaceted and collaborative approach to ensure a balanced solution that meets the interests of various stakeholders while preserving the environment and public well-being.

Based on the findings, and the lessons that can be learned from the Netherlands, the research will provide possible policy recommendations specifically tailored to the Ontario context that can strike a balance between promoting sustainable and environmentally responsible practices in greenhouse operations and ensuring that the industry continues to thrive and meet the growing demands for food production.

Ultimately, the research seeks to provide valuable insights into greenhouse-related light pollution, offering evidence-based policy directions that can guide stakeholders, greenhouse operators, and policymakers in Ontario and other regions facing similar challenges. By addressing this issue proactively, the aim is to foster a more sustainable and responsible greenhouse industry that considers environmental impacts while contributing to food security and economic growth.

2. Background

Light Pollution – General

Light pollution has increased exponentially in the past century due to widespread implementation of electrical lighting for various purposes, including residential, commercial, sports, and agricultural (Cinzano et al., 2001). This escalation is not limited to developed nations but has become a widespread issue worldwide. According to the First Atlas of Artificial Night Sky Brightness, over 99 percent of the population in the United States and the European Union, as well as approximately 60 percent of the world's total population, reside under light-polluted skies (Cinzano et al., 2001).

Light pollution occurs during the nighttime when artificial light scatters back towards the ground due to interactions with the atmosphere, water vapor, or particulate matter

(Falchi et al., 2011). The impact of this light pollution on the night sky is not yet fully understood, as there is limited scientific research on the external light impacts of greenhouses (Barentine, 2019). Numerous studies have investigated the potential impacts of light pollution on ecology (Navara and Nelson, 2007; Longcore and Rich, 2004; Brüning et al., 2016; Moore et al., 2000), astronomical observation (Garstang, 2004; Massey and Foltz, 2000), and human health (Chepesiuk, 2009; Falchi et al., 2011; Gooley et al., 2011). However, despite these efforts, the true extent of light pollution's effects are not fully understood. According to Barentine, (2019) it is believed that the impacts could be significant especially in cold and cloudy climates where sky brightness can be amplified.

Malbon's 2013 research found that there have been various studies focused on light pollution stemming from street lighting. With the increasing adoption of LED streetlights due to their energy efficiency, cities and municipalities have been replacing traditional streetlights with LEDs. However, it was revealed by Malbon that: firstly, local governments across Canada are actively seeking more information about light pollution, indicating a growing awareness of its environmental and societal impacts; and secondly, municipalities face limitations in the tools they possess to effectively reduce light pollution, which might be hindering their efforts. Malbon's research concluded that there is a need for further research and the development of innovative solutions to address this issue effectively.

Moving to the focus of this research, the above general context mostly applies to the commercial greenhouse industry, however there are challenges to overcome in order to mitigate light pollution as will be discussed.

Why is Supplemental Lighting Necessary

In Ontario's greenhouse industry, supplemental lighting is essential due to shorter days in autumn and winter and reduced light levels on cloudy days in spring and summer (Ontario Ministry of Agriculture, Food, and Rural Affairs, 2022a). This is crucial for year-round production of high-quality crops, including vegetables, fruits, and ornamentals. Greenhouse producers use supplemental lighting for specific crop needs (OMAFRA, 2022a). Recent studies by Hernandez and colleagues (2013, 2020) found that adding extra light to greenhouses makes plants grow better in many ways, including increased photosynthesis, more fruit, improved plant shape, and overall growth.

One key purpose of supplemental light is to ensure optimal growth by increasing light exposure duration. It achieves day length extension, provided either before sunrise or after sunset. Cloudy days and sunrise/sunset periods see enhanced light intensity. For ornamental and certain cannabis plants, supplemental light controls flowering. Night interruption, a brief light period during the night, manages flowering in ornamental crops. Some cannabis species require fixed light periods for the vegetative-to-flowering transition (OMAFRA, 2022a).

The industry employs two common supplemental lighting types: high-pressure sodium (HPS) lights and energy-efficient light-emitting diodes (LEDs). While HPS lights have been prevalent, there's a shift toward LEDs due to their advantages. LEDs offer varied light spectrums for optimized plant development. They emit less heat, allowing closer placement to crops and within the canopy when appropriate (OMAFRA, 2022a).

Supplemental lighting is generally placed above the crop, suspended from greenhouse trusses. Furthermore, intracanopy lights can be applied year-round for vine vegetable

crops like tomatoes, peppers, and cucumbers, enhancing light distribution to shaded canopy areas where fruit development occurs (OMAFRA, 2022a).

Light Pollution in the Commercial Greenhouse Industry

Barantine provided that not much has changed as of 2019. The commercial greenhouse industry and the lighting industry are aware of the light pollution issue and some trade publications have started addressing the concern, however, government regulations and policies regarding greenhouse lighting remain limited. Greenhouses are often considered "indoor lighting" and not subject to provisions intended to reduce light pollution (Barentine, 2019).

Non-greenhouse related approaches are available. As noted by Baddiley (2017), proper shielding of streetlights plays a crucial role in mitigating light pollution. Similar to shielding streetlights, one common approach to prevent reflected supplemental lighting from escaping the greenhouse is to physically block the light. This can be achieved by retrofitting existing greenhouses or designing new ones with light abatement curtains. Depending on the specific conditions, light abatement or blackout curtains may offer energy-saving benefits by reducing heating requirements on cold nights, but they can also have potential drawbacks, such as trapping excess heat generated by supplemental lights, interfering with humidity management, and hindering proper air circulation and ventilation of excess humidity (Hanifin, 2019).

Regardless, and with other measures put in place, the use of light-blocking curtains or screens within the greenhouse industry is the industry-accepted standard in such light abatement, however implementing of such curtains/screens comes at a substantial additional operating cost to greenhouse operators. The focus of this research is not on

the specific technologies available to mitigate greenhouse-related light pollution, but rather the methods or approaches available to Municipalities to control/limit greenhouse-related light emissions so to ensure such methods are implemented to the widest extent possible.

The Canadian and Ontario Context

On a Canada-wide comparison, Statistics Canada notes (2019) that there was a total of 838 commercial greenhouse vegetable operations with 17.6 million square metres of production area which produced nearly 664,450 metric tons of vegetables. There has been a steady increase in greenhouse vegetable production in Canada and it is anticipated that acreages in greenhouse vegetable production will continue to grow. The acreage has increased 21% over the last five years and 48% over the last decade.

Outside of Ontario, British Columbia and Quebec represent 18% and 6% respectively of the total greenhouse vegetable production sector in Canada.

To meet the growing demands for vegetable production, the use of grow lights in greenhouses is expected to double by 2024 (Wood, 2019). In 2018 alone, the total electricity consumption for greenhouse lighting in Ontario reached 752,000 megawatt-hours, surpassing the combined electricity requirements of other greenhouse operations, which amounted to 637,000 megawatt-hours (Wood, 2019). Consequently, vegetable and fruit greenhouses in Ontario are projected to see a significant surge: compared to 2018 consumption rates, electricity requirements are forecasted to rise by 282 percent by 2024 (Wood, 2019).

As a result of the surge in electricity use in Ontario's greenhouse operations, which is expected to rise by almost 200 percent from 2019 levels by 2024 (Hanifin, 2019), the

Independent Electricity System Operator (IESO) is preparing to implement additional transmission lines to cater to regions experiencing substantial greenhouse expansion. The demand for these transmission lines is largely driven by the need to support the increasing use of supplemental lighting.

As summarized in a staff planning report to the Municipality of Chatham-Kent entitled “Planning for Large Scale Greenhouse Development” (2021), significant changes have become evident in local facilities and operations. For instance, prior to 2011, a greenhouse considered "large" would typically cover an area of 5-12 acres. However, since 2011, the definition of a "large" greenhouse has shifted considerably, encompassing structures spanning 20-50 acres built at once. This trend towards larger greenhouse sizes has resulted in farms within the region now containing commercial greenhouse developments spanning 50-200 acres as of 2021. The staff planning report also anticipated that future construction projects may surpass 100 acres at a time, leading to the establishment of extensive complexes with over 1000 acres of contiguous farmland being dedicated to greenhouse cultivation, and that these expanded greenhouses are projected to incorporate various ancillary facilities commensurate with their size, including centralized sorting, packing, storage, logistics, housing, and support services.

Classifying Policy Instruments: The NATO Framework

As the Ontario greenhouse industry continues to embrace supplemental lighting for year-round production, the issue of light pollution looms larger, raising questions about its impact on the environment and communities. Understanding the measures taken by governments to address this issue can shed light on potential solutions.

Researchers often employ classification systems to categorize the policy tools used by governments in various jurisdictions, allowing for a comprehensive comparison and analysis of their effectiveness in mitigating greenhouse-related light pollution. Scholars have developed various classification systems to describe the common policy tools used by governments. These systems include terms like "carrots, sticks, and sermons", "muscles and prayers", and "mandates, inducements, capacity-building, and system-changing" (see Bemelmans-Videc et al., 1998; Gormley, 1989; McDonnell and Elmore, 1987; respectively). Another approach conceptualizes policy instruments as "soft law" (negotiated and collaborative) or "hard law" (command and control) (Mörth, 2004).

Macdonald (2001) envisioned a continuum from self-regulation to direct government intervention, according to the degree of coercion imposed, arguing that less coercive instruments are generally more acceptable in liberal societies than more coercive ones.

The classification used for this research was developed by Christopher Hood. Known as the NATO framework, which, under this acronym, categorizes the resources available to governments as: Nodality (information); Authority (legal powers); Treasure (money); and Organization (formal organizations) (Hood, 1986; Hood and Margetts, 2007). The NATO classification offers a comprehensive lens through which to analyze the various policy tools utilized by governments. By encompassing nodality, authority, treasure, and organization, this framework provides a holistic understanding of the resources at a municipality's disposal to address this complex issue, encompassing the crucial aspects of information, legal powers, financial resources, and the structures of formal organizations (Hood, 1986; Hood and Margetts, 2007). This approach allows for a nuanced evaluation of the effectiveness of policy measures in mitigating light pollution,

offering valuable insights for sustainable and effective governance in the context of greenhouse operations.

Under this framework, governments can influence policy actors by manipulating these resources, such as providing or withholding information or money, exercising coercive powers, or directly undertaking activities. It is important to note that there is rarely a single optimal instrument for a situation, and policymakers often employ a combination of tools. The choice of instruments is influenced by factors like the political context, cultural considerations, past experiences, and the fact that policymakers build upon previous attempts to address issues or solve problems.

As it pertains to managing light emission, this framework allows for a structured evaluation of the information, legal powers, financial resources, and organizational aspects involved, and provides a comprehensive understanding of the approaches used by different jurisdictions, facilitates comparisons, and enables the identification of resource-based strategies and best practices that can be applicable to the Ontario greenhouse industry.

3. Use of a Jurisdictional Scan

To understand and address the impacts of supplemental lighting in the commercial greenhouse industry in Ontario, a jurisdiction scan has been conducted that explores approaches taken by local governments in both Ontario and the Netherlands, and to a lesser extent, British Columbia. Applying the NATO framework to these three jurisdictions provides an effective model in balancing the interests of the greenhouse industry, government regulation, and environmental concerns. Jurisdictions within the

United States were scanned, however there was little found at the local or state levels; it is postulated that the greenhouse industry there has yet grown to a scale to warrant a public policy response.

Purpose and Significance of the Jurisdictional Scan

This scan aims to provide a comprehensive overview of the current landscape of managing greenhouse-related light emission.

The purpose of the jurisdictional scan is twofold. Firstly, it seeks to identify existing policies, regulations, and initiatives specific to greenhouse-related light emission in Ontario, shedding light on the regulatory framework in place and its effectiveness. This examination enables a thorough understanding of the current measures undertaken by local municipalities in the province to manage light emission in the greenhouse industry. Secondly, the scan ventures into British Columbia and the Netherlands to explore approaches taken in those jurisdictions. This broader analysis serves to unearth valuable insights, innovative strategies, and best practices that can be adapted and applied to the Ontario context.

The significance of the jurisdictional scan lies in its ability to inform and guide the development of effective strategies and regulations for managing supplemental lighting impacts in the Ontario commercial greenhouse industry. By examining the experiences and lessons learned from other jurisdictions, the research aims to provide a deeper understanding of successful approaches and potential pitfalls. This knowledge can be leveraged to shape evidence-based recommendations and policies that are contextually relevant to the Ontario greenhouse industry. Ultimately, the jurisdictional scan contributes to the advancement of policy and regulatory practices in the management of

light emission, fostering environmental stewardship and minimizing potential negative impacts from the commercial greenhouse sector.

Scope and Methodology of the Scan

The scope and methodology of the scan, framed within Hood's NATO (Nodality, Authority, Treasure, Organization) framework, can be defined as follows:

Scope:

The scan aims to comprehensively assess the approaches taken by local governments in managing commercial greenhouse-related light emission, considering the availability and utilization of key resources outlined in the NATO framework. It encompasses a multi-dimensional analysis of policies, regulations, and other initiatives at various levels of government, including:

1. Ontario:

“Upper-Tier” Counties/Regions; and local (“Lower/Single-Tier”) municipalities, including the County of Essex and the municipalities of “Kingsville”, “Leamington”, and “Lakeshore”, together forming the region which contains the largest concentration of vegetable greenhouses in North America (IESO, 2023). Other municipalities outside of this region include “Chatham-Kent” and “Pelham”.

2. British Columbia:

The province of British Columbia (BC). In BC, the greenhouse industry is largely focused in the “Fraser Valley Regional District”, which includes the local municipalities of “Abbotsford” and “Chilliwack”.

3. International:

The Netherlands is highlighted given its large horticultural greenhouse presence focused in specific areas of the country, most notably the Westland area. Two new greenhouse “cluster” regions are identified. Jurisdictions within the United States were also scanned (Arizona, Ohio, Washington), however there was little found at the local or state levels; it is generally assumed that the greenhouse industry there has yet grown to a scale that would cause for any public policy response.

Given that the light emission issues are relatively new, the time period of the scan reviews approaches developed within the last ten (10) to fifteen (15) years.

Methodology:

The methodology will employ a qualitative comparative analysis of existing governmental “tools” used to mitigate light emissions. The research sources include academic journals, government reports, industry publications, and reputable online resources. In this research, references to various legislation and other formal actions are provided generally (e.g., “Municipal Act” as opposed to “Municipal Act, 2001, S.O. 2001, c. 25”).

The scan included academic and governmental documents. When researching the Netherlands, obtaining such documents in English was mostly possible, however municipal/provincial planning documents (i.e., official land-use & zoning) were not available in English.

From a broader international context, the scan did not venture any further into other continents, such as Asia or South America, this for two (2) reasons: the expected language barrier; and, the likely contrast, or dissimilarities in government involvement in agricultural policy making and/or practices.

The scan sought first to identify the regions/provinces/municipalities that have taken any action, e.g., implemented guiding documents, passed policy/legislation, and/or passed by-laws/regulations that seek to mitigate, or at least address, greenhouse-related light pollution. Where such was found, those governmental websites were searched to obtain such documents/policies/by-laws to see what and how such action was taken.

By applying the NATO framework to the scope and methodology, the scan ensures a comprehensive assessment of the aspects or components (nodality, authority, treasure, and organization) of various government approaches to managing greenhouse-related light emission. The 4 components contribute to a holistic understanding of the strengths and weaknesses of governmental actions, leading to more informed policy recommendations and improved decision-making processes.

Further commentary on the application of the NATO framework is as follows:

1. Nodality Assessment:

Nodality refers to the flow of information and communication within a system or organization. In the context of assessing governmental actions, nodality examines how information is gathered, disseminated, and utilized by the government to address a specific issue or problem. This includes analyzing the availability and accessibility of relevant resources, data collection methodologies,

monitoring systems, and strategies for sharing information. Nodality helps to understand how well-informed and connected the government is in managing a particular issue: in this research, greenhouse-related light emission.

2. Authority Assessment:

Authority examines the legal powers and jurisdictional control exercised by the government in addressing the issue at hand. It involves evaluating the extent to which the government possesses the necessary legal framework, regulations, and enforcement mechanisms to tackle the problem effectively. In the context of greenhouse-related light emission, authority assesses the government's ability to enact and enforce laws, regulations, and by-laws concerning light pollution in greenhouse operations. It helps identify the level of control and influence the government has in managing the issue.

3. Treasure Assessment:

Treasure pertains to the financial resources allocated by the government to tackle the identified problem. In the context of governmental actions related to greenhouse light emission, treasure assessment involves analyzing the budgetary allocations, funding programs, grants, incentives, and financial mechanisms employed to support initiatives aimed at reducing light pollution. Understanding the financial investments made by the government provides insights into the level of commitment and priority given to addressing the issue.

4. Organization Assessment:

Organization evaluates the formal structures and institutions involved in implementing and enforcing governmental actions. This includes examining

government agencies, departments, committees, greenhouse owners and growers (the “industry” and its associations), and any collaborative efforts among stakeholders. In the context of greenhouse-related light emission, organization assessment helps identify the key actors, their roles and responsibilities, as well as the coordination mechanisms and decision-making processes in place.

Understanding the organizational landscape provides insights into the efficiency and effectiveness of governmental efforts to manage light pollution in the greenhouse industry.

Organization of the Scan:

The scan is structured into the three geographic regions noted earlier: Ontario, BC, and the Netherlands. Following each noted ‘initiative’, a NATO assessment follows. Ontario involves a more in-depth review given the amount of recent municipal responses to this issue. There have been responses in BC, however not to the same extent as in Ontario. The responses taken in the Netherlands focuses on historic context, and how the country has sought to establish new greenhouse “clusters” (similar to how industrial parks are planned in North America) in different areas of that country.

4. The Jurisdictional Scan

Approaches in Ontario

As noted earlier, the Essex region, including the local municipalities of Leamington, Kingsville, and Lakeshore, contains the largest concentration of vegetable greenhouses in North America (IESO, 2023). The neighbouring municipality of Chatham-Kent is just outside of this region, however it has also responded to the increase of commercial greenhouse-related light issues.

Outside of this Essex region, there are also smaller pockets where large greenhouse operations exist. The Town of Pelham, located in Ontario's Niagara region, has also taken action on this issue, however the approach there was directed towards regulating the production of cannabis, which can be done in both indoor and outdoor settings, and both industrial and agriculturally zoned areas of that Town, and to a large extent, within large-scale greenhouses. Pelham is included within the scan, however with only a summary, noting that, as it pertains to light emissions, Pelham has taken a similar approach to the municipalities in Essex County.

In no particular order, notable governmental actions that have occurred as of the date of this research paper are detailed. Following each municipal action, an assessment against Hood's "NATO" classification is provided. As provided earlier, Hood's "NATO" classification categorizes the resources available to governments as: Nodality (information); Authority (legal powers); Treasure (money); and Organization (formal organizations) (Hood, 1986; Hood and Margetts, 2007).

1. Municipality of Leamington

The municipality first passed a by-law in December 2020 requiring the abatement of interior greenhouse light. Shortly thereafter, the Municipality received applications from several greenhouse owners filed with the province's "Normal Farm Practices Protection Board" (which will be highlighted later) seeking exemptions from this by-law.

As provided on the municipality's website:

"In June of 2022, most matters before the Board were resolved and Minutes of Settlement were executed by the parties that included changes to the

provisions of By-law 79-20. In order to have uniformity across the Municipality, Council repealed By-law 79-20 and enacted By-law 41-22 which includes provisions more in keeping with the manufacturer's specifications for "blackout" curtains and also includes the following further provisions relating to greenhouse owners who use lights (...)

"For Council, it was important to ensure a balance between supporting the economic growth from our greenhouse industry, and protecting the quality of life of our residents," said Mayor Hilda MacDonald. "I believe this new By-law will allow us to accomplish that balance."

Upon this new by-law, those greenhouse owners who had not already installed curtains were required to (by October 1, 2022): a) submit evidence that such would be installed on or before October 1, 2023; or b) submit a declaration that the greenhouse lights would be shut off and remain off (HortiDaily.com, 2023). As of early 2023, only two (2) owners have submitted evidence related to a planned curtain installation, and no (0) owners have submitted a declaration (HortiDaily.com, 2023).

Since November 2022, Leamington by-law enforcement officers have engaged in a patrol of the municipality for the purpose of gathering evidence of greenhouse owners operating in contravention of the by-law, having laid 88 charges under Part III of the Provincial Offences Act upon 12 individual Greenhouse Owners. The charges reflect numerous contraventions across many calendar days. According to the municipality, it is important to note that the matters will not be heard by the courts for several months (HortiDaily.com, 2023).

NATO Assessment - Leamington

- a) Nodality (information): Leamington's approach demonstrates a moderate level of Nodality. The municipality passed a by-law requiring the abatement of interior greenhouse light, which indicates they have access to relevant information about the issue. They also engaged in negotiations with greenhouse owners and monitored compliance through patrols. However, it is not clear if the municipality has gathered comprehensive data on the extent of light pollution and its impact on the environment and residents.
- b) Authority (legal powers): Leamington's approach shows a high level of Authority. They passed and repealed by-laws related to greenhouse lighting and enforced the by-law by laying charges under the Provincial Offences Act. This indicates a strong exercise of legal powers to address the issue.
- c) Treasure (money): The information provided does not specifically mention financial resources allocated for mitigating greenhouse-related light pollution. Therefore, it is not possible to assess the level of Treasure (money) devoted to this approach from the available information. It is noted that Leamington has imposed fines into the by-law, as opposed to exploring the incentive-based approach.
- d) Organization (formal organizations): Leamington's approach exhibits a high level of Organization. Municipal by-law enforcement officers are responsible for administering (i.e., investigating and laying fines) the by-law, indicating a structured approach to decision-making and enforcement.

Overall, the Municipality of Leamington's approach to mitigating greenhouse-related light pollution appears to be strong in terms of Authority and Organization. They have enacted by-laws and enforced them through legal means. However, there may be room for improvement in terms of gathering more comprehensive information (Nodality) and ensuring financial resources (Treasure) are allocated to support the ongoing efforts effectively.

2. Town of Kingsville

The Town of Kingsville, located beside and to the west of Leamington, adopted a similar by-law as Leamington's in October 2020. To ensure compliance with the by-law, a town hall meeting was organized, attended by over thirty greenhouse owners.

In Kingsville, it has been observed that most greenhouse growers are collaborating with the municipality to comply with the by-law, showing a willingness to align with the regulations. However, similar to Leamington, there are instances of growers who haven't yet sought compliance, and the full implementation of the by-law's dark skies requirement might take a few years to visibly materialize. The requirement of 100 percent light abatement has sparked debates, particularly because it may restrict essential venting for greenhouse operations. Concerns have been raised by the Growers' organization ("OGVG"), suggesting that the by-laws could prove challenging to implement, especially in the context of Canadian winters, where additional light and heat are vital for plant growth, a challenge magnified during the COVID-19 pandemic when local produce is crucial.

NATO Assessment – Kingsville

- a) Nodality: Kingsville's approach shows a moderate level of Nodality. The town passed a similar by-law to Leamington's, indicating they have access to relevant information about the issue. They also held a town hall meeting where over thirty greenhouse owners attended, demonstrating efforts to gather information and engage stakeholders. However, it is not clear if the town has conducted comprehensive studies or assessments on the extent of light pollution and its impacts. Efforts to persuade growers to comply would also fall under nodality.
- b) Authority: Kingsville's actions exhibit a medium level of Authority. Kingsville passed a by-law similar to Leamington's, indicating a use of legal powers to address the issue. However, the information provided suggests that enforcement may take time before visible results are achieved, which could indicate some limitations in its authority or enforcement mechanisms.
- c) Treasure: Fines have been written into Kingsville's by-law, however beyond this, the information provided does not specifically mention financial resources allocated for mitigating greenhouse-related light pollution. Therefore, it is not difficult to assess the level of financial resources devoted to this approach from the available information.
- d) Organization: The Town shows a medium level of Organization. In the same manner as Leamington, Kingsville staff, including by-law enforcement responsible for administering the by-law, demonstrates a structured approach to implementation. However, the information provided does not mention

extensive collaboration with formal organizations beyond the town hall meeting.

Overall, the Town's approach appears to be moderate in terms of Nodality, Authority, and Organization. They have enacted a by-law and engaged with stakeholders through the town hall meeting. However, there may be room for improvement in terms of gathering more comprehensive information (Nodality), ensuring effective enforcement of the by-law (Authority), and potentially seeking collaboration with formal organizations for ongoing efforts.

3. Municipality of Lakeshore

The Municipality of Lakeshore is located in the County of Essex to the north of both Leamington and Kingsville, and to the west of Chatham-Kent (which is outside of Essex County). This municipality has not experienced the same level of greenhouse development as its neighbours to the south, however did elect to take proactive measures given its close proximity. Lakeshore's response was more broadly encompassing, looking at greenhouses from all aspects, including their use for marijuana/cannabis production facilities, which the federal government had passed legislation for.

The municipality started in late 2019, directing its staff to bring a report regarding a light pollution by-law related to greenhouses. Following that, a local planning consultant was retained to prepare a "Lakeshore Greenhouse Study". A final report was presented to the municipality in late 2022 (Storey, T. 2022). The final study provided four (4) options, including a "do nothing" option, and an option that would prohibit large-scale greenhouses (although this option was specifically

not recommended by the consultant). Generally, the municipality and the report recommendations sought to take a permissive, but also regulatory approach to such greenhouses, and ultimately (March, 2023), amendments to the municipality's official plan and implementing zoning by-law were passed that sought to impose stringent regulations, including:

“(commercial greenhouse farms) shall be designed to eliminate any impact resulting from the use of supplementary grow lighting;”

In the passing of an official plan amendment, it is noted that such amendment is required to be ratified by the County of Essex, as the upper-tier authority, before taking effect. At the time of finalizing this research the County of Essex has not yet issued a final decision (i.e., an approval) to the amendment.

NATO Assessment – Lakeshore

- a) Nodality: Lakeshore's approach demonstrates a high level of Nodality. The municipality started addressing the issue in late 2019 by directing staff to bring a report regarding a light pollution by-law related to greenhouses. They retained a local planning consultant to prepare a comprehensive "Lakeshore Greenhouse Study," and a final report was presented in late 2022. The study provided multiple options and recommendations, indicating a thorough gathering of information and a proactive approach to understanding the issue.
- b) Authority: Their approach exhibits a high level of Authority. They passed amendments to the official plan and implementing zoning by-law to impose stringent regulations, requiring commercial greenhouse farms to be designed

to eliminate any impact resulting from the use of supplementary grow lighting.
This demonstrates a strong exercise of legal powers to address the issue.

- c) **Treasure:** The information available does not signify that the Town is allocating financial resources for mitigating greenhouse-related light pollution.
- d) **Organization:** The Municipality of Lakeshore shows a high level of Organization. They directed staff to prepare a report, retained a planning consultant for a study, and passed amendments to the official plan and zoning by-law, indicating a structured and organized approach to decision-making. The mention of requiring ratification by the County of Essex further suggests collaboration with formal organizations.

Overall, the Municipality of Lakeshore's approach appears to be strong in terms of Nodality, Authority, and Organization. They have conducted a comprehensive study, utilized legal powers to pass regulations, and collaborated with formal organizations. However, similar to previous assessments, it is important to note that the information provided does not mention specific financial resources (Treasure) allocated to support the implementation of the regulations.

4. Municipality of Chatham-Kent

Responding to actions taken by the municipalities of Leamington and Kingsville regarding lighting issues from the commercial greenhouse industry, municipal staff were directed to prepare an informational report. Such report was presented in April, 2021 by the municipality's planning director recommending that Council pass an "Interim Control By-law", under the province's Planning Act. Such by-

laws provide a municipality the ability to effectively pause specified development, in this case, both large and small greenhouses as defined in the municipality's zoning by-law so that a review or study can be undertaken. The interim control by-law was recommended to be applied to the settlement (i.e., urban, or non-agricultural) areas of the municipality only, and the areas immediately adjacent thereto. Greenhouses, if proposed, could still be developed outside of these areas while the interim control by-law was in effect.

The interim control by-law remained for nearly two years (the maximum time frame allowed under the Planning Act for such by-laws), with the municipality ultimately enacting a new by-law similar to Leamington and Kingsville's, being a Municipal Act by-law entitled "Greenhouse Lighting Abatement By-law", and which includes a multi-tiered enforcement system that includes a set fine schedule along with a reference to the Municipality's ability to apply to the Superior Court of Justice for an order to cease greenhouse operations for up to 2 years in the unlikely event of a repeated and/or particularly egregious By-law contravention (Municipality of Chatham-Kent Community Development Planning Services, 2023).

The by-law requires the installation of curtains on the sidewalls, end walls, and ceilings of lit greenhouses. The curtains will be used between the hours of sunset to sunrise. The development of Chatham-Kent's by-law involved discussions with representatives of the Ontario Greenhouse Vegetable Growers Association, which gave a deputation in support, and several local greenhouse operators

(Municipality of Chatham-Kent Community Development Planning Services, 2023; Chatham Daily News, 2023).

It is noted in the 2023 planning report of municipal staff that the by-law was carefully crafted following the enactment, and any legal responses to same, of the similar by-laws in Leamington and Kingsville so to address all factors.

NATO Assessment – Chatham-Kent

- a) Nodality: The approach shows a moderate level of Nodality. The municipality prepared an informational report and engaged in discussions with representatives of the Ontario Greenhouse Vegetable Growers Association and several local greenhouse operators. They used this information to craft a new by-law similar to Leamington and Kingsville's, addressing all factors. However, there may be room for improvement in terms of gathering comprehensive data on the extent of light pollution and its impact on the environment and residents.
- b) Authority: The approach demonstrates a high level of Authority. They passed an "Interim Control By-law" under the province's Planning Act, effectively pausing specified development of both large and small greenhouses in certain areas for a period of almost two years. Subsequently, the municipality enacted a new by-law, the "Greenhouse Lighting Abatement By-law," which includes a multi-tiered enforcement system, including set fines and the ability to seek court orders to cease greenhouse operations in case of repeated or egregious contraventions. This robust approach indicates a strong exercise of legal powers to address the issue.

- c) Treasure: Like Leamington and Kingsville, fines are included in Chatham-Kent's by-law, however incentives for growers are not apparent.
- d) Organization: The Municipality shows a high level of Organization. The planning process involved municipal staff, including the planning director, and they engaged in discussions with formal organizations such as the Ontario Greenhouse Vegetable Growers Association. This demonstrates a structured and organized approach to decision-making and collaboration with stakeholders.

Overall, the Municipality of Chatham-Kent's approach to mitigating commercial greenhouse-related light pollution appears to be strong in terms of Authority and Organization. It effectively utilized legal powers to enact by-laws and engaged with formal organizations for input and collaboration. However, there may be room for improvement in terms of gathering more comprehensive information (Nodality) and ensuring financial resources (Treasure) are allocated to support the implementation of the by-law effectively.

5. Town of Essex and Town of Pelham

A summary of these two municipalities is not provided given:

- a) Although the Town of Essex does contain some commercial greenhouses within its boundaries, the Town has not taken any notable action against mitigating light pollution; and,

- b) The Town of Pelham, located in the Region of Niagara, ultimately passed a light abatement by-law similar to the municipalities in Essex County. Similar to Chatham-Kent and Lakeshore, it imposed moratoriums on greenhouse construction and expansion while the municipality works to balance increasing resident concerns over light pollution and odour (esp. cannabis greenhouses) with the crop production requirements of greenhouse operators (Ligaya, 2019)

Accordingly, a NATO assessment of these two municipalities has not been conducted.

Summary: Approaches in Ontario

The Essex County municipalities of Leamington, Kingsville, and Lakeshore, as well as the neighbouring municipality of Chatham-Kent, have taken various approaches in order to address the issue of commercial greenhouse-related light pollution. These municipalities have demonstrated a commitment to finding a balance between the economic benefits of the greenhouse industry and the well-being of their residents, but with varying levels of emphasis on different aspects of governance as outlined in Hood's "NATO" classification.

Leamington and Kingsville have enacted by-laws that require greenhouse owners to implement light abatement measures, showcasing a strong exercise of legal powers (Authority). While most growers in these municipalities are collaborating and showing willingness to comply, the requirement of 100 percent light abatement has sparked debates, and full compliance may take time to achieve (Nodality). Chatham-Kent, on the

other hand, utilized a similar approach with an interim control by-law and subsequently enacted a comprehensive "Greenhouse Lighting Abatement By-law." This approach displays a structured and organized decision-making process, involving discussions with industry representatives and consideration of similar by-laws enacted in neighboring municipalities (Organization).

Lakeshore took a broader approach by conducting a "Lakeshore Greenhouse Study" and considering multiple options, ultimately leading to stringent regulations in their official plan and zoning by-law. The municipality demonstrated a high level of Nodality, engaging in a proactive and comprehensive study to inform their decisions.

Collaborative efforts with formal organizations were also evident in Lakeshore's approach, indicating a structured and organized approach (Organization).

Overall, these municipalities in Essex County have taken steps to mitigate greenhouse-related light pollution, with varying degrees of emphasis on Nodality, Authority, and Organization. While there may be room for improvement in areas such as comprehensive data gathering and allocation of financial resources, their approaches show a commitment to addressing the issue and finding a balanced solution that respects both the greenhouse industry and the community's quality of life.

Before moving beyond Ontario, it is important to highlight the province's "Farming and Food Production Protection Act".

"Farming and Food Production Protection Act"

While the above-highlighted municipalities have passed light abatement by-laws under the Municipal Act as a means to address commercial greenhouse-related light pollution,

it is important to recognize the legal framework within which these by-laws operate. The "Farming and Food Production Protection Act" (FFPPA) holds a significant role in shaping the jurisdictional scope and restrictions that municipalities can impose on agricultural activities, including greenhouse operations.

The FFPPA, a legislation aimed at safeguarding and promoting agricultural activities, has a key provision that specifically prohibits municipal by-laws that restrict normal farm practices (Ontario Ministry of Agriculture, Food and Rural Affairs, 2019a; and Ontario Ministry of Agriculture, Food and Rural Affairs, 2019b). This prohibition raises questions about the enforceability of certain land-use planning restrictions, especially those that might impact core agricultural practices such as cultivation on farmlands.

The act's intention, aligned with the importance of the agricultural industry for food production and the economy, ensures that farmers have the freedom to conduct their activities without unnecessary hindrances (Ontario Ministry of Agriculture, Food and Rural Affairs, 2019; and Farming and Food Production Protection Act, 1998). Legal cases, such as Ontario (Attorney General) v. Hamilton (City), have further solidified the supremacy of the FFPPA over municipal by-laws that seek to restrict normal farm practices, establishing a robust protection for farmers (Ontario Ministry of Agriculture, Food and Rural Affairs, 2019).

Lakeshore's approach is notable. It has taken a unique approach by adopting both a light abatement by-law under the Municipal Act, as well as greenhouse-specific official plan policies and zoning regulations under the Planning Act. This "belt-and-suspenders" approach reflects Lakeshore's commitment to addressing the issue of light pollution from commercial greenhouses while considering both the Municipal Act and the

Planning Act, given the specific context and needs of their municipality. However, it is noteworthy that the County of Essex has yet to finalize its decision on Lakeshore's official plan amendment, indicating the complexity of navigating local regulations while aligning with provincial legislation.

Approaches in British Columbia (“BC”)

According to the BC Ministry of Agriculture (2014), BC's commercial greenhouse industry is largely focused in the Fraser Valley region, which is located north of the U.S. border and east of Greater Vancouver. Greenhouses typically span from two to four hectares, with some larger establishments surpassing 20 hectares. Often, multiple greenhouses are found on a single farm property, with a yield of 15 to 20 times more produce compared to an equivalent field area (BC Ministry of Agriculture, 2014).

In BC, the regulation for the commercial greenhouse industry regarding supplemental lighting and light pollution fall under the purview of both the local municipal and provincial governments.

At the municipal level, local municipalities have the authority to regulate land use and development within their jurisdiction. This includes setting zoning by-laws that may specify the conditions under which commercial greenhouses can operate. These by-laws can address issues such as setbacks from residential areas, noise restrictions, and possibly even light pollution. However, the specific regulations related to supplemental lighting and light pollution may vary from one municipality to another in BC.

A scan of municipal zoning by-laws within the Fraser Valley (City of Abbotsford Zoning By-law No. 2400-2014; City of Chilliwack Zoning By-law 2020, No. 5000; Fraser Valley

Regional District Zoning By-law No. 1638, 2021) finds that there is a lack of, or essentially no comprehensive provisions that aim to tackle light abatement in the commercial greenhouse industry. While they cover general aspects of land use, such as maximum lot coverage of a lot and migrant worker housing, they do not address the specialized lighting requirements of greenhouse operations. Outside of the Fraser Valley, the City of Delta, the municipality at the south-limit of Greater Vancouver and adjacent to the Georgia Strait, also contains some large-scale commercial greenhouses, but similarly does not regulate greenhouse-related lighting.

Outside of zoning by-laws, the City of Abbotsford completed an “Official Community Plan” (OCP), being the over-arching land-use planning policy document. The OCP was completed in 2016, and although it does not contain any policies specific to greenhouses or greenhouse-related light pollution, it does contain policies for mitigating light pollution in new urban (i.e., residential, commercial, mixed-use, and industrial) development.

It is also noted that the City of Abbotsford is currently in the process of developing a new zoning by-law, and there does not appear to be any new regulations as they would pertain to the commercial greenhouse industry and/or light abatement. Regulations for “cannabis production facilities” have been contemplated for the proposed new zoning by-law.

Greenhouse-related light pollution policies are also not included in the corresponding policy documents for Chilliwack and the Fraser Valley Regional District. This is not to suggest that these municipalities should have such policies and/or regulations, but

rather, perhaps the specific issue of greenhouse-related light pollution has not yet become a municipal concern in this area.

Although greenhouse-related nuisances are largely silent in the local municipal planning documents, the BC Ministry of Agriculture, Food and Fisheries oversees policies and regulations related to agricultural practices in the province and provides guidelines and best practices for sustainable agricultural operations. This Ministry also provides a regularly updated “British Columbia Environmental Farm Plan Reference Guide”. Its primary purpose is to assist producers in assessing environmental risk on their farms, and include guiding recommendations as opposed to enforceable regulations.

With regard to greenhouse farming, the guidelines list “emissions from greenhouse lights that result in light pollution” as a primary environmental concern, among other concerns including energy use and greenhouse gas emissions of the industry; greenhouse operations are among the most energy-intensive agricultural operations in BC.

NATO Assessment – British Columbia

- a) Nodality: The BC Ministry of Agriculture provides valuable information and guidelines on agricultural practices, including greenhouse farming and its environmental impacts. The Ministry's "British Columbia Environmental Farm Plan Reference Guide" assesses environmental risks and lists light pollution from greenhouse lights as a primary concern. This indicates a strong emphasis on Nodality, as the government provides relevant information to stakeholders to understand the issue and its potential impact on the environment.

- b) Authority: At the provincial level, the BC Ministry of Agriculture, Food and Fisheries has the authority to oversee policies and regulations related to agricultural practices in the province. While the Ministry provides guidelines and recommendations for sustainable agricultural operations, there seem to be no enforceable regulations specifically targeting greenhouse-related light pollution. This suggests a potential gap in legal powers (Authority) to directly regulate and enforce measures to mitigate light pollution from greenhouses.
- c) Treasure: budgetary allocations or financial incentives dedicated to addressing greenhouse-related light pollution were not found. It is not clear if there are specific financial resources allocated to support initiatives aimed at reducing light pollution in the commercial greenhouse industry.
- d) Organization: The regulation for the commercial greenhouse industry in BC falls under the purview of both local municipalities and the provincial government. At the municipal level, local municipalities have the authority to regulate land use and development, including setting zoning by-laws that may address greenhouse operations. However, the scan of municipal zoning by-laws within the Fraser Valley shows a lack of comprehensive provisions for tackling light abatement in the commercial greenhouse industry. This indicates a potential gap in organized efforts (Organization) at the municipal level to address greenhouse-related light pollution.

Overall, BC's approach to mitigating commercial greenhouse-related light pollution shows a significant emphasis on Nodality (information) through providing guidelines and information on environmental concerns, including light

pollution from greenhouse lights. However, there appears to be a lack of enforceable regulations and comprehensive provisions at the municipal level, indicating potential gaps in Authority and Organization aspects of the approach. Information on budgetary allocations and financial resources (Treasure) to support initiatives related to greenhouse-related light pollution is not provided, making it difficult to assess this aspect of the approach.

The relatively limited growth of the greenhouse industry in BC that has yet to trigger significant public policy responses regarding light pollution could be attributed to several speculative factors. One potential reason is the geographic concentration of commercial greenhouses primarily in the Fraser Valley region. This concentrated location might limit the widespread impact of greenhouse-related light pollution, making it a localized concern rather than a broader issue. Additionally, the relatively smaller scale of individual greenhouse operations in the region, often spanning two to four hectares, could contribute to lower light emissions compared to larger-scale operations, mitigating the urgency for specific policy measures. Furthermore, the absence of enforceable regulations for greenhouse-related light pollution in municipal by-laws might reflect a lack of public awareness or perceived importance of the issue, leading to the absence of responsive policy actions at this point.

Approaches in The Netherlands

According to information provided by the Netherlands Ministry of Health, Welfare, and Sport (2023), there is no national policy concerning nocturnal lighting and dark sky protection. However, several provinces and municipalities have implemented decentralized policies. Typically, the motivation for creating policies regarding nocturnal

light is energy conservation. In the Netherlands, policies aimed at protecting dark skies serve a dual purpose. They not only focus on energy conservation but also play a crucial role in safeguarding “Natura 2000” areas. These areas are an extensive network of protected natural spaces across the European Union, chosen for their significance in supporting and preserving Europe's most valuable and threatened species and habitats. The policies on dark sky protection ensure that these critical ecological zones are shielded from the negative impacts of light pollution, allowing the ecosystems within Natura 2000 areas to remain undisturbed and providing a more suitable environment for the survival and well-being of these important species.

In the Netherlands, the “Environmental Act” governs the protection and use of the physical environment. Under this act, provinces and municipalities can develop policies and regulations related to nocturnal lighting and dark sky protection. In order to limit the disturbance caused by greenhouse lighting and other similar large-scale uses such as sport/stadium lighting, there are existing or in-progress regulations (The Netherlands Ministry of Health, Welfare, and Sport, 2023).

From a provincial/upper-level government approach, the “Light/Dark Handbook” (not available in English) was published in 2010 by The Association of Provinces of the Netherlands (Dutch: Interprovinciaal Overleg, or ‘IPO’, being the association of the twelve provinces of the Netherlands). The handbook is a guiding document that compiles basic information on light pollution and dark sky protection and provides policy and implementation building blocks related to this topic. It addresses various policy fields such as spatial planning, environment, public lighting, nature, and health (The Netherlands Ministry of Health, Welfare, and Sport, 2023).

Unlike its counterpart legislation in Canada, being the Environmental Protection Act, the “Environmental Activities Decree” (Rijkswaterstaat Environment, 2023) does specifically address and provide regulations for greenhouse horticulture lighting, aiming to reduce nuisance in residential areas caused by greenhouse-related lighting. Categorized as an environmentally harmful activity, greenhouse crop cultivation must follow rules for assimilation (i.e., supplemental) lighting. Similarly, activities in other sectors, such as industry and tourism, must consider environmental impacts and take appropriate measures to prevent or minimize adverse effects.

At a local/municipal level, it is apparent that the commercial greenhouse sector in the Netherlands has largely been focused in two predominant areas: the area between Rotterdam and The Hague (known as the Westland), and southeast of Amsterdam around Aalsmeer (Needham, 2014).

As noted by Needham, land-use planning policies in the Netherlands have been framed so that its agricultural land base is planned and used for its maximum food-producing efficiency (Needham, 2014). Agricultural land-use policies since the Second World War stayed away from directing how agricultural practices could occur, but rather ensured nothing else got in the way of agriculture. This was the practice of Dutch policy up until intervening policies were needed for, first, tackling the swine fever outbreak in the late 1990s as a result of overly concentrated and intensive pig farms, and then later, the dispersion of greenhouses from the two mass concentrations of such structures in the two above-noted predominant areas (the Westland and southeast of Amsterdam around Aalsmeer).

In his graduate thesis which researched the special clustering of the Dutch horticultural sector, Martijn Barendse sought to identify the characteristics of such greenhouse clusters, with special emphasis on those characteristics that can be addressed by land use planning. Barendse performed case studies on two new cluster regions: the “Agriport” greenhouse cluster located in the village of Middenmeer (Municipality of Hollands Kroon) in the Dutch province of North Holland; and the “Bergerden” cluster in the province of Gelderland (Municipality of Lingewaard) in the eastern Netherlands.

Barendse’s research (2017) focused on why one region, “Agriport”, had become “well-developed”, and why the other, “Bergerden”, had not. Although Barendse’s research did not focus specifically on greenhouse-related light pollution, it did provide, through various interviews, that the Agriport cluster was able to become established through in-depth consultation with the public, the growers, and government agencies, and where an environment-first focus was brought. The Bergerden cluster, however, experienced more turbulence given that in the municipality’s land-use plan, there is no specific regulation for the reduction of light pollution, but there is mentioned that growers should apply screens on the side walls.

Barendse’s research found that constructive collaboration between public and private actors provides stronger developments and catalyzes growth of the cluster. The quality of this collaboration grows when greenhouse growers are involved in the content of the land use plan.

Interestingly, Barendse’s research (2017) concluded that in the development of greenhouse clusters, another small greenhouse area in Northern Holland was in a decline, however with the help of restructuring and spatial (i.e., zoning) regulations, the

area has been given “new spirit from governmental initiative”. Also, Barendse provides that “(l)ocal governments with the ambition to support continued growth, could use the characteristics of the well-developed cluster as a guideline, but should not immediately copy the governmental strategy.”

NATO Assessment – Netherlands

- a) Nodality: The Netherlands lacks a national policy on nocturnal lighting and dark sky protection. However, information from the Ministry of Health, Welfare, and Sport indicates that several provinces and municipalities have implemented decentralized policies to address the issue. The motivations for creating these policies are energy conservation and the protection of Natura 2000 areas, which are crucial for safeguarding valuable and threatened species and habitats. Further, the Netherland's "Light/Dark Handbook," published by The Association of Provinces of the Netherlands (IPO), offers a guiding document with policy and implementation building blocks related to light pollution and dark sky protection. Although not available in English, this handbook addresses various policy fields, including spatial planning, environment, public lighting, nature, and health, indicating a financial commitment to the issue.
- b) Authority: The "Environmental Act" governs the protection and use of the country's physical environment, granting provinces and municipalities the authority to develop policies and regulations concerning nocturnal lighting and dark sky protection. Existing or ongoing regulations aim to limit disturbances caused by greenhouse lighting and other large-scale uses, such as sport/stadium lighting.

c) **Treasure:** It was found that there was financial support provided in the Agriport cluster noted. "Agriport A7", a private corporation, provided financial support to greenhouse growers, stimulating investments and expansion plans. This private-public partnership fostered greenhouse growth while ensuring sustainable practices.

Otherwise, the context of the Netherlands' treasure approach to light pollution mitigation is challenging because detailed information about the allocation and specific financial resources devoted to this issue, both at the national and local levels, is often not readily available in public sources. Additionally, the actual financial investments and budgets related to dark sky preservation and enforcement of regulations may vary across municipalities and regions within the country, making it difficult to provide a comprehensive and standardized evaluation of the financial commitment to addressing light pollution.

d) **Organization:** The Dutch government has exhibited structured and organized efforts to address greenhouse-related light pollution through the implementation of the "Environmental Activities Decree." This decree serves as a significant framework that categorizes greenhouse horticulture lighting as an environmentally harmful activity, underlining the government's recognition of the potential negative impacts on the environment and residential areas. The specific regulations within the decree, notably those related to assimilation lighting, are indicative of the government's systematic approach to minimizing nuisance and light pollution caused by greenhouse operations. Through these regulatory measures, the Dutch government actively demonstrates its commitment to

organized environmental management and the protection of both the natural environment and the quality of life for residents affected by light pollution.

Overall, the Netherlands' approach to mitigating greenhouse-related light pollution demonstrates a well-informed and coordinated strategy, combining legal powers, available resources, and collaboration between governmental and private actors to address the issue effectively.

Interestingly, the Netherlands has taken the industrial land-use approach to regulating where and how commercial greenhouses can be situated. Particularly, greenhouses are to be clustered in assigned areas akin to industrial parks. Also, and not highlighted in this research, an unrelated (and especially, non-agricultural) land-use, being the large, corporate data centers are also permitted amongst these clusters. These data centers are similar in the scale and architecture of greenhouses, being sprawling buildings far from resembling typical residential and commercial buildings.

In the Netherlands, although the government still lacks a centralized national policy, decentralized policies, and the specific regulations contained within the "Environmental Activities Decree" have been implemented at the provincial and municipal levels. The motivations of energy conservation and the protection of Natura 2000 areas indicate a commitment to environmental preservation.

5. Non-Greenhouse-Related Approaches to Managing Light Emission

Transitioning from the jurisdictional scan focused on greenhouse-related policies, it's important to recognize that addressing light pollution involves a broader perspective beyond the commercial greenhouse sector. As we delve into non-greenhouse-related approaches, we gain valuable insights from diverse strategies employed globally,

underscoring the need for comprehensive, adaptable measures that consider both environmental impact and collaborative efforts across various stakeholders and sectors. Below are examples, in no particular order or fashion, of how light-related nuisances are approached from a non-commercial greenhouse perspective:

1. Outdoor Lighting Regulations:

Similar to how the Essex County municipalities passed light abatement by-laws under the Municipal Act, the following are urban examples of similar by-laws (City of Brampton, 2021):

- City of Mississauga: Nuisance Lighting By-Law section 4(4.1) (c) states: “No direct lighting or indirect lighting shall be used so that an unusual quantity or type of light creates a glare or light trespass upon the land of others so as to be or to cause a Nuisance to the public generally or to others residing or carrying on a business or trade in the vicinity.”
- City of Vaughan: Property Standards By-law 231-2011 specifically prohibits lighting fixtures from directing light directly onto abutting properties. Section 5.7 of The Property Standards By-Law 231-2011 states: “Exterior lighting fixtures shall be directed in a manner as to prevent the light source from shining directly onto abutting properties.”
- City of Toronto: Toronto Municipal Code Chapter 629 (Property Standards) Section 17 states: “(A property that) because of its use, occupancy or other reasons, creates a nuisance to other properties in the neighbourhood shall be buffered from these properties so as to minimize the effect of the nuisance by the provision and maintenance of:

A barrier or deflectors to prevent lighting and vehicle headlights from shining directly into a dwelling unit.”

2. Transportation Industry Practices:

Port of Vancouver's Lighting Practices (BC, Canada). The port has adopted shielded lighting fixtures, dimming lights during off-peak hours, and the use of adaptive lighting technologies to minimize light emission (Government of Canada and Vancouver Fraser Port Authority, 2015).

3. Urban Planning and Development Guidelines:

Outdoor Lighting Ordinance (California, United States). Such ordinances regulate lighting design, fixture types, and placement to reduce light spillage and glare.

Las Vegas Lighting Ordinance (Nevada, United States). The lighting ordinance in regulates outdoor lighting to preserve the city's iconic skyline while minimizing light pollution and energy waste. The ordinance focuses on controlling light direction, intensity, color, and glare, as well as restricting unnecessary lighting during specific hours. It applies to public spaces, commercial areas, and iconic landmarks, ensuring both aesthetic appeal and minimal light pollution, and was established following collaboration between the city's planning department, lighting professionals, and stakeholders to ensure compliance with the lighting ordinance.

4. Astronomical Research and Observatories:

McDonald Observatory Lighting Guidelines: These guidelines pertain to this observatory in Texas, U.S.A., and ensure minimal light pollution to protect

astronomical observations, and include regulations and lighting practices followed by the observatory (McDonald Observatory, n.d.).

5. Dark-Sky Preserves and Designations:

Dark Sky Preserves exist globally, and as of 2022 there are 27 of such sites across Canada alone (Royal Astronomical Society of Canada, 2023). Such preserves follow stringent measures to minimize light pollution and protect the night sky. Strategies employed include lighting restrictions and the use of specialized fixtures.

The UK has more certified international dark-sky places than any other country outside the USA and has some of the largest areas of dark sky in Europe (Hyde et al., 2019). The Commission for Dark Skies (run by the British Astronomical Association) has played its part in supporting these initiatives. Separately, the Dark Sky Discovery Partnership's growing network of Dark Sky Discovery Sites presents the best spots in rural and urban areas to see the night sky. The town of Moffat in Scotland is titled as Europe's very first Dark Sky Town (Dalglish et al., 2021).

6. Collaborative Initiatives:

The Night Light Interreg EU project (Interreg Europe, 2023) involves regional authorities from several European countries, including the Netherlands, working together to combat light pollution and preserve night skies. This project seeks to enhance local policies and measures related to light pollution reduction.

SEEING STARS (Studio Roosegaarde, 2021) exemplifies a site-specific exhibition in the city of Franeker, Friesland, where a controlled switching-off of city lights and non-essential lighting occurred. A collaborative effort involving UNESCO Netherlands, Studio Roosegaarde, residents, government, and businesses, this project exemplifies a commitment to addressing light pollution in a concerted manner.

The non-greenhouse-related approaches presented in this section offer valuable insights into the multifaceted strategies employed to manage light pollution. These examples span a spectrum of measures, from municipal by-laws regulating outdoor lighting to the innovative use of shielded fixtures and collaborative initiatives involving local authorities, organizations, and communities. The focus on energy-efficient lighting, preserving the night sky for astronomical research, and enhancing urban aesthetics underscores the importance of comprehensive policies. While these approaches serve as effective models for various contexts, it's essential to adapt and tailor solutions to the unique challenges posed by commercial greenhouse operations. By understanding the successful integration of multiple stakeholders, stringent lighting regulations, and specialized designations, municipalities can develop holistic approaches that mitigate light pollution while fostering a sustainable balance between greenhouse growth and environmental protection.

6. Recommendations

Planning for Greenhouses in Land-Use Plans

The establishment of new “cluster” areas (like the North American industrial park) in the Netherlands is compelling. What the Westlands were in The Netherlands is what

portions of Essex County are in Ontario. From a practical and traditional land-use planning perspective, Dutch governments are essentially managing the greenhouse industry as if it is a traditional industrial use, requiring operations to be grouped together. It is not to say that such clusters do not pose concerns from a land-use compatibility perspective, however the government acknowledges and has consciously weighed the pros and cons, whereby notwithstanding the nuisance created, the efficient production of food is necessary for the country's population and economy.

To that end, an approach in the Ontario context should at least be explored further, and this would go beyond the Agroport example. The Netherlands has specifically identified and defined large-scale greenhouse farming into its policy documents (the “Environmental Act” and “Environmental Activities Decree”), and the Ontario provincial government could explore a similar approach that would assist local municipalities and greenhouse growers themselves.

Financial Mechanisms

Further research on this topic could focus on financial mechanisms to address the issue, especially with existing “un-curtained” greenhouses, and/or in supporting new operations being appropriately equipped for light abatement. In the jurisdictional scan, finding financial approaches (subsidies, etc.) proved difficult.

The Ontario provincial government has provided funding for initiatives that support innovation and economic growth, including approximately \$19 million from the province to support projects that develop and adapt technologies that advance the competitiveness of Ontario's commercial greenhouse sector (Harrison, 2017). With this

support, does there now need to be a shift in how government (including OMAFRA) provides support in this industry, perhaps towards reducing the nuisances created?

Zoning Regulations /Building Permits

With regard to regulations, the research has found that, due to the “Farming and Food Production Protection Act” (FFPPA) and “Normal Farm Practices”, the Ontario municipalities scanned determined that they legally couldn’t impose specific requirements, such as setbacks or light abatement curtains.

However, in Ontario, there is already a similar approach used relating to livestock farming. The "Minimum Distance Separation (MDS) formulae" is a set of guidelines and regulations that aim to ensure the appropriate siting and separation of livestock operations from sensitive land uses, such as residential areas, schools, and hospitals. MDS is designed to mitigate potential conflicts between livestock operations and nearby communities, considering factors like odors, noise, and other environmental impacts (Ontario Ministry of Agriculture, Food, and Rural Affairs, 2022b). Further, unlike typical guidelines which are usually voluntary in nature, the MDS guidelines are written into the province’s planning policy statement as guidelines that must be followed.

In the context of greenhouse-related light pollution, the provincial government could develop similar mandatory guidelines or standards, including encouraging the adoption of energy-efficient lighting technologies and sustainable lighting practices that minimize light pollution.

7. Conclusion

Summary of key findings from the jurisdictional scan

Light pollution, a global concern affecting both natural ecosystems and human well-being, demands a proactive response from governments worldwide. As found in this research, both Ontario, Canada, and the Netherlands have grappled with the challenge of mitigating light pollution caused by commercial greenhouse activities and other sources. While each region has developed unique approaches, a comparative analysis reveals that the Netherlands' multifaceted approach strikes a more successful balance between governmental interests, greenhouse growers, and public concerns.

In Ontario, light pollution mitigation efforts have primarily been reactive, whereby municipalities have passed light nuisance by-laws under the province's Municipal Act, given that there is a lack of specific authority and/or regulations addressing greenhouse lighting in other provincial acts, such as the Planning Act and the Environmental Protection Act, resulting in a fragmented approach to tackling the issue. Greenhouse-related light pollution remains unaddressed within a comprehensive legal framework, leading to inconsistent outcomes and potential challenges in minimizing disturbances for nearby residents.

In contrast, the Netherlands has adopted a more comprehensive and proactive approach. While lacking a centralized national policy, the country has implemented decentralized policies to address light pollution effectively. Motivated by energy conservation and the protection of Natura 2000 areas, various provinces and municipalities have developed tailored strategies to combat nocturnal lighting issues.

This decentralized model enables local authorities to target specific challenges unique to their regions, fostering a more efficient and targeted response.

A central resource in the Netherlands' approach is the "Light/Dark Handbook," a guiding document published by The Association of Provinces of the Netherlands (IPO). This handbook compiles essential information on light pollution and dark sky protection, offering policy and implementation building blocks for various fields, including spatial planning, environment, public lighting, nature, and health. This centralized resource facilitates collaboration between provinces and stakeholders, ensuring a cohesive effort in addressing light pollution.

Comparing greenhouse clustering in specified regions further highlights the effectiveness of the Netherlands' approach. Although Ontario's greenhouse sector is largely focused, or as one could suggest, "clustered" in the Leamington and Kingsville area, such has arisen before there had been any coordination among growers and municipal authorities, resulting in challenges in implementing collective measures to combat light pollution, leading to a patchwork of individual efforts with varying levels of success.

Conversely, the Netherlands' greenhouse sector (especially some of the new clusters) has proactively been planned into clusters much like the traditional industrial park in North American land-use planning, and as exemplified by the Agriport and Bergerden clusters. The development of the Agriport cluster stands out as a success story, driven by constructive collaboration between public and private actors. In-depth consultation with the public, growers, and government agencies, alongside a strong focus on environmental considerations, has led to a well-developed cluster. This exemplifies how

involving stakeholders from various sectors can result in an effective and harmonious approach to light pollution mitigation.

Another critical difference lies in financial support. In the Netherlands, Agriport A7, a private corporation, provides financial support to greenhouse growers, actively stimulating investments and expansion plans. This private-public partnership fosters greenhouse growth while ensuring sustainable practices. In Ontario, financial support mechanisms for greenhouse growers to adopt light pollution mitigation measures are less evident, potentially limiting their willingness to invest in such changes.

The Dutch approach, with its emphasis on collaboration, organization, and a tailored decentralized response, demonstrates a more successful balance between governmental interests, greenhouse growers, and public concerns. By involving stakeholders in policy development, creating centralized guiding documents, and providing financial incentives, the Netherlands has fostered a cooperative environment that benefits all parties involved.

In conclusion, the Netherlands' multifaceted approach to mitigating light pollution, particularly concerning greenhouse activities, sets a positive example for other regions, including Ontario. By addressing the issue at both national and local levels (or “Unitary” v. “federal” systems), involving stakeholders, and providing financial support, the Netherlands has created a comprehensive strategy that achieves a harmonious balance between environmental protection and greenhouse development. Ontario could draw valuable lessons from the Dutch model, implementing coordinated efforts to combat light pollution while safeguarding the interests of greenhouse growers and the public. As

awareness of light pollution's impact grows, collaborative and holistic approaches will be vital in creating sustainable and environmentally conscious practices worldwide.

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