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CEATI INTERNATIONAL Inc.
1010 Sherbrooke Street West, Suite 2500
Montreal, Quebec, Canada H3A 2R7
www.ceati.com

DEMAND SIDE ENERGY MANAGEMENT PROGRAM (DSMP)

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ENERGY MANAGEMENT BEST PRACTICES FOR CANNABIS GREENHOUSES AND WAREHOUSES

Prepared by:
Posterity Group
Cultivate Energy Optimization
D+R

Principal Investigators:
Alex Tiessen
Erika Aruja
Sonja Dods
Joe Sullivan
Eric Stern
John Morris
Jenna Winer

Sponsored by:
BC Hydro
Enbridge
FortisBC
Independent Electricity System Operator
NRECA

Technical Advisor:
Eric Mazzi

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ABSTRACT

The legalization of recreational cannabis in Canada and some US states has generated a new sector with significant energy needs. This budding industry is creating a need for policymakers and utilities to better understand the energy requirements of the sector and find ways to manage demands on energy systems.

The objectives of the study are twofold: to assess and document baseline consumption of electricity and natural gas for cannabis warehouse and greenhouse operations, and to document best practices, available technologies, and implementation costs for saving energy in both warehouse and greenhouse facilities. The outcome of this work will form an important base of industry knowledge and bridge the gap to provide up to date and comprehensive information regarding energy use in cannabis facilities, from which future conservation activities might be developed.

This report presents results including estimated energy consumption from 2019 to 2024 in British Columbia, Ontario, Colorado, Oregon, and Washington; energy saving measures applicable to the indoor cannabis sector and considerations for interactive effects; technical and economic savings potential by measure for greenhouse and warehouse facilities in each region; energy management strategies used in the cannabis sector today including codes and standards and demand side management (DSM) programs; common barriers to DSM programs seeking to target the cannabis industry, and suggested program design approaches and tools that program provides can use to help engage the cannabis sector in DSM programming.

Keywords:

Energy Management for Cannabis, Cannabis Greenhouse, Cannabis Warehouse, Energy Saving Measures, Energy Savings Potential, Demand Side Management, Market Characterization.

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EXECUTIVE SUMMARY

Background

The legalization of recreational cannabis in Canada and some US states has generated a new sector with significant energy needs. This budding industry is creating a need for policymakers and utilities to better understand the energy requirements of the sector and find ways to manage demands on energy systems.

The objectives of the study are twofold: to assess and document baseline consumption of electricity and natural gas for cannabis warehouse and greenhouse operations, and to document best practices, available technologies, and implementation costs for saving energy in both warehouse and greenhouse facilities. The outcome of this work will form an important base of industry knowledge and bridge the gap to provide up to date and comprehensive information regarding energy use in cannabis facilities, from which future conservation activities might be developed.

This study will benefit the industry by helping to demonstrate the business case for energy efficiency in the commercial cannabis cultivation industry and provide a comprehensive, independent source of energy consumption and conservation potential information.

Summary

Study Scope

The study:

- Estimates energy use in the indoor commercial cannabis sector, including greenhouse and warehouse facility types. The geographic scope encompasses five regions in North America: British Columbia, Colorado, Ontario, Oregon, and Washington. The study begins with a base year of 2019 and conducts a forecast from 2020-2024. The impact of the COVID-19 pandemic is not captured or assessed in this study.
- Characterizes energy saving measures applicable to greenhouse and/or warehouse cannabis production facilities and assesses the potential energy savings (technical and economic) from applying these measures.
- Profiles energy management strategies used in the cannabis sector today including codes and standards and demand side management (DSM) programs.
- Outlines common barriers to DSM programs seeking to target the cannabis industry.
- Provides suggested design approach and tools to help DSM programs achieve success.

Footprint of the Sector in 2019 and Projections to 2024

Using the best available public data, the study team researched the footprint of the sector in 2019 and forecasted to 2024. A summary of the findings of this work include:

- Greenhouse operations are more numerous relative to warehouse facilities in British Columbia and Ontario, while the opposite is true in Colorado, Oregon, and Washington.
- An increase in energy consumption from cannabis production is expected in British Columbia and Ontario over the forecast period because production is expected to expand within existing facilities as these markets mature. However, there is little to no increase expected in new facilities in these provinces.

- More facilities are expected to join the indoor cannabis markets in Colorado and Oregon, as moderate historical growth in cannabis production and supply is expected to continue to 2024. Energy consumption is expected to also increase as more facilities are used for cannabis production.
- Washington is a unique region in this study because the state is not providing new licenses for producers. Therefore, it is assumed the number of cannabis facilities will remain constant, and so will the sector's energy consumption over the study period.

How Energy Is Used in Cannabis Producing Facilities

Natural gas and electricity are the most common fuels used by the cannabis sector in the regions included in this study. Electricity is primarily used for lighting and ventilation in both greenhouses and warehouses, and for space cooling and dehumidification in warehouses. Natural gas is primarily used for space heating in greenhouses (however, fuel shares vary by region).

Energy is used differently in greenhouses and warehouses:

- Energy use in greenhouses tends to be mainly for lighting and space heating. Dehumidification consumption is negligible because most greenhouses do not have mechanical dehumidification and some dehumidification may be occurring through ventilation.
- Energy use in warehouses tends to be for lighting and space cooling. Energy use for space heating tends to be minimal due to the high internal heat gains; most of the heating load is associated with dehumidification re-heat. Due to high internal heat gains, the space cooling load is highest during the summer and shoulder seasons.

Non-Energy Impacts and Interactive Effects from Energy Saving Measures

Equipment used to produce cannabis in indoor environments comprises complex systems that are used to create ideal growing conditions. Control and growth environment setpoint changes that aim to optimize plant growth conditions while reducing energy inputs can have significant impacts on energy consumption, energy peak demand, and plant growth. Until further research is undertaken, including test/pilot cases documenting proven results for blueprints (grow strategies coupled with system designed parameters), we need to rely on a more simplistic approach to quantify measure opportunities and economic savings potential within different jurisdictions. This explains why measure opportunities outlined in this study are focused on equipment replacement opportunities.

If we assume equipment is operating properly to achieve the desired effect in the grow environment, then replacing a single piece of equipment with a more efficient model will not lead to significant interactive effects or cause non-energy impacts. The one major exception to this is LED grow lighting.

LED Grow Lights

There will be significant interactive effects if a change is made to the lighting source in indoor cannabis facilities. When HPS lighting systems are replaced with LED fixtures, the lighting energy balance changes drastically. Overall, less lighting electricity is required, but at the same time less overall heat is transferred to the air. This new environment must be managed differently by cooling, heating, and dehumidification systems to achieve a cultivator's desired plant growth environment.

In heating dominated jurisdictions, like the regions covered by this study, the reduction in heat transfer needs to be replaced by another source of heating.

In greenhouses, the result is essentially a partial fuel switching measure; in broad strokes, the difference in convective and radiative heat transfer needs to be provided by the facilities' gas heating systems (i.e., electricity savings will occur, but gas consumption will increase). In warehouses, which have high internal heat gains and predominately meet dehumidification reheat load with electric heat, the extreme outcome is almost a complete offset of lighting electricity savings with an increase in electric heating load. If facilities are taking advantage of heat recovery to address reheat load, some of this additional heating load could be met through heat recovery, lessening the impact of the heating interactive effect.

For this study, the following HVAC interactive effects were considered for the LED measure:

- Cooling Interactive Effects – 90% of the value of the lighting savings is removed from the cooling load, since additional heat from lighting is no longer being added to the facility. The cooling interactive effects occur for 5 months of the year and assumes that the cooling system has a COP of 3.5.
- Heating Interactive Effects – 90% of the value of the lighting savings is added to the heating load, since additional heat from lighting is no longer being added to the facility. The heating interactive effects occur for 7 months of the year and assume that the heating system has a COP of 3.0.

Energy Saving Measures & Potential

Thirteen measures were analyzed for this study. Technical and economic savings potentials[1] were estimated for each region by facility type. A key result is that LED lighting offered the most technical energy savings potential for both greenhouse and warehouse facilities in all regions, even with HVAC interactive effects considered. Measures that passed the economic screen vary by region and facility type and are summarized in the table which follows.

[1] Technical potential is the theoretical maximum amount of energy use that could be displaced by the measures, only considering technical constraints. Economic potential is the subset of the technical potential that is economically cost-effective to the end-user such that the reduction in fuel costs is greater than the costs of the measure (capital costs and incremental operation and maintenance costs.)

	British Columba	Ontario	Colorado	Oregon	Washington
Greenhouses	Condensing Boilers; Condensing Unit heaters; Energy Curtains.	Energy Curtains; VFD on Supply/Exhaust Fan; Condensing Boiler; Condensing Unit Heater	Energy Curtains; VFD on Supply /Exhaust Fan; Greenhouse LED Lighting; Condensing Boiler; Condensing Unit Heater	Energy Curtains; VFD on Supply Fan/Exhaust Fan; Greenhouse LED Lighting; Condensing Boiler; Condensing Unit Heater	Energy Curtains; Condensing Boiler; Condensing Unit Heater
Warehouses	Chiller - Air-Cooled; Dehumidifier; DX Unit Gas Heating; DX Unit Heat Pump	Chiller - Air-Cooled; Chiller - Water-Cooled; Dehumidifier; DX Unit Gas Heating; DX Unit Heat Pump; Warehouse LED Lighting; Waterside Economizer	Chiller - Air-Cooled; Chiller - Water-Cooled; Dehumidifier; DX Unit Heat Pump; Waterside Economizer; Warehouse LED Lighting	Chiller - Air-Cooled; Chiller - Water-Cooled; Dehumidifier; DX Unit Gas Heating; DX Unit Heat Pump; Waterside Economizer; Warehouse LED Lighting	Chiller - Air-Cooled; Dehumidifier; DX Unit Heat Pump

Energy Management for the Cannabis Sector

As legal recreational cannabis markets develop in North America, there is an increasing awareness of the energy requirements to grow cannabis, particularly in warehouses. In response, some jurisdictions have implemented regulations to reduce the energy consumption and environmental impact of cannabis production. Currently, most regulations for energy consumption by cannabis facilities focus on lighting and HVAC.

California has proposed updates to the state's Energy Efficiency Building Standards to include controlled environmental horticulture comprising warehouses and greenhouses that grow cannabis. The proposed code changes apply to horticultural lighting minimum efficacy, efficient dehumidification and reuse of transpired water, and greenhouse envelope standards. In addition to energy efficiency requirements, some jurisdictions in California have requirements for use of renewable sources for energy in cannabis and/or indoor agriculture facilities.

The DesignLights Consortium (DLC) is a non-profit organization focused on achieving energy efficiency. In 2018, the DLC launched the Horticultural Lighting Program, expanding upon the Solid-

State Lighting program that had been in effect for many years. The Horticultural Lighting Program provides a suite of tools and resources to help foster the adoption of energy-efficient LED technology throughout the horticultural lighting industry. The Horticultural Lighting Program sets specifications via its Technical Requirements, and routinely, via established revision cycles, updates the Technical Requirements to keep pace with the advancements in LED technology. DLC's Qualified Products List is used by some regulators, such as the State of Illinois, to enforce energy efficiency requirements for grow lighting in cannabis operations.

Demand Side Management Programming

Although indoor agriculture utility customers are encouraged to participate in most utility demand-side management (DSM) programs, few North American utilities have established standalone controlled-environment DSM specific offerings. The project team researched existing programs in five regions – Colorado, Oregon, Northwest, Massachusetts, and Ontario – and found many programs applicable to indoor cannabis facilities.

However, there are several barriers that should be addressed when designing DSM programs specific to the cannabis cultivation industry. The following table summarizes these barriers, program design approaches to help overcome these barriers, and tools utilities can use to successfully delivery cannabis-focused DSM programs.

Common Barriers to DSM Programs	DSM Program Design Approaches	DSM Program Tools
1. Outreach/limited access to ownership 2. Lack of awareness/unfamiliarity with DSM 3. Lack of awareness of energy use, rates, & costs 4. Preference for privacy 5. Traditional efficiency/return on investment (ROI) discussion not relevant 6. Every site is unique 7. Interaction of measures 8. Traditional energy metrics are not applicable 9. Traditional trade partners are not applicable 10. Long upgrade timelines	1. Align DSM program requirements with local/state regulations 2. Extend pre-approval notifications for up to 18 months 3. Use non-disclosure agreements (NDAs) by on-site implementers 4. Place program restrictions on walking multiple sites per day to reduce contamination risk 5. Earmark 5-10% percent of commercial custom program rebate amounts for indoor agriculture 6. Conduct active account management 7. Conduct specialized outreach and events 8. Work with specially marked trade partners	1. Dedicate specific web pages for indoor cannabis program details 2. Leverage industry specifications to ensure that growers are exposed to appropriate technology and best practices 3. Participate in industry training 4. Use field hardware

Conclusion

Standard practices for energy management are currently limited for the indoor cannabis sector because:

- Of its newness as an industry in many jurisdictions in North America
- Every facility is unique
- There are currently no unifying standards or protocols for cannabis growers that provide a 360-degree perspective on the optimal combination of equipment and control strategy.

Despite these conditions, there is information and resources that policymakers, utilities, and growers can use to reduce the energy footprint from indoor cannabis production. Key insights from this study include:

- Greenhouses tend to use the most energy for lighting, ventilation, and space heating, while warehouses typically need energy for lighting, ventilation, space cooling, and dehumidification.
- There are many energy efficient measures applicable to warehouse and greenhouse facilities that can save energy, including many that are cost effective. LED lights offer large opportunities for technical potential savings in both facilities type and all regions. Measures that are cost-effective to the user vary by facility type and region.
- Energy curtains offer the highest opportunity for gas savings in greenhouses in all regions.
- Other measures with high opportunities for economic energy savings include efficient dehumidifiers, DX unit heat pumps, and VFDs on supply/exhaust fans.
- Codes and standards do exist in some jurisdictions, with more under development to regulate energy consumption by indoor cannabis facilities. Currently, most regulations focus on energy efficiency from lighting and HVAC equipment.
- There are DSM programs in-market that focus on indoor agriculture, with limited programs tailored to cannabis specifically. However, indoor cannabis facilities may be eligible to participate in many of these existing programs. While there are common barriers that may impede the success of a DSM program targeted at cannabis, there are tools that program designers and administrators can use to overcome these barriers to ensure DSM programs targeted at the indoor cannabis market can be successful.

Recommendations

Recommendations related to DSM program design approaches and tools are specific suggestions for the program administrators provided in this report.

Through the process of conducting this study, it was found that energy management for the indoor cannabis sector field would benefit from:

- More investment – research and pilot work is needed to prove out blueprints on optimized cannabis grow strategies and system design parameters.
- Research specifically focused on quantifying interactive effects for lighting under different grow strategies and facility system design characteristics would be helpful to better understand the effects of the LED lighting measure.

This study contributes to the growing body of research and literature to support energy management for the indoor cannabis sector.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

1.0 ABOUT THE STUDY

This section provides a brief introduction to the study.

1.1 Purpose and Objectives

The objectives of the study are twofold: to assess and document baseline consumption of electricity and natural gas for cannabis warehouse and greenhouse operations, and to document best practices, available technologies, and implementation costs for saving energy in both warehouse and greenhouse facilities. The outcome of this work will form an important base of industry knowledge and bridge the gap to provide up to date and comprehensive information regarding energy use in cannabis facilities, from which future conservation activities might be developed.

Benefits from this work include providing a comprehensive picture of best practices for the cannabis sector, including energy consumption data, baseline technologies, and technological solutions to advance load forecasting and insight into potential demand side management (DSM) program development. Strategic research has been undertaken to develop a comprehensive picture of best practices for cannabis sector technology, including LED grow lighting and specific HVAC opportunities in the regions of interest.

This study will benefit the industry in general by helping to demonstrate the business case for energy efficiency in the commercial cannabis cultivation industry, and providing a comprehensive, independent source of energy consumption and conservation potential information.

1.2 Scope

The following key items frame the scope of the study.

1.2.1 Segments

This study focuses on greenhouse and warehouse facilities that cultivate cannabis in an indoor or controlled environment commercial setting. Field production of cannabis and production of hemp is excluded from the scope.

1.2.2 Energy Consumption

This study focuses on annual energy consumption. Demand and peak analysis are excluded from the scope.

1.2.3 Timing

The study uses a 2019 base year and develops a five-year (2020-2024) reference case forecast.

1.2.4 Regions & Climate Zones

The study encompasses five regions, which provide the regional scope for the study:

Table 1-1: Regions and Climate Zones

Sponsor	Region	Applicable ASHRAE Climate Zones
FortisBC Electric	British Columbia (BC)	4 & 5
BC Hydro		
Enbridge	Ontario (ON)	5 & 6
Independent Electricity System Operator (IESO)		
National Rural Electric Cooperative Association (NRECA)	Washington (WA), Oregon (OR), and Colorado (CO)	4, 5 & 6

Regions are used to define applicable laws and regulations related to cannabis production and energy use (i.e., energy costs, codes).

1.2.5 End Uses

The following end uses are in scope for the study:

- Lighting
- Space Heating
- Space Cooling
- Ventilation
- Dehumidification
- Irrigation and Circulation Pumps
- Other Electricity
- Other Gas

This study focuses on energy and space used for the production of cannabis plants, while energy and space used for processing of cannabis are excluded. For production facilities that also have a small part of the facility dedicated to processing, we have treated this as an "other" end-use and have not researched specific opportunities.

1.2.6 Fuels

Fuels included in the study are grid-generated electricity, natural gas, and propane. Cogeneration (on-site electricity and cogeneration heat) and water consumption are excluded.

2.0 THE CANNABIS SECTOR TODAY AND TOMORROW: BASE YEAR AND REFERENCE CASE

This section provides an overview of the cannabis industry in each of the five regions covered by the study and presents the energy profile of the sector in the base year (2019) and forecasted years included in the reference case (2020-2024).

2.1 Warehouse versus Greenhouse Operations

Cannabis is typically produced in a warehouse facility using only artificial light, a greenhouse using a mixture of artificial light and sunlight, or outdoors in a field using only sunlight. This study focuses on warehouse and greenhouse facilities, as they are more energy intensive compared to outdoor field operations.

Relative to greenhouse operations (particularly those with passive ventilation), warehouses can provide a higher degree of environmental control: grow rooms are sealed from the outdoor environment and provide plants with artificial light, mechanical cooling, and dehumidification to deliver optimal growing conditions. Warehouse facilities tend to have high construction and operating costs relative to greenhouse operations [1].

Energy use for warehouse and greenhouse cannabis cultivation varies; the end-uses that tend to use the most energy in greenhouses are lighting, space heating, and ventilation, while energy-intensive end-uses in warehouses include space cooling, dehumidification, and lighting.

2.2 Cannabis in Canada

In Canada, producers licensed by Health Canada have been able to grow marijuana for medicinal purposes since 2014. Cannabis was federally legalized for recreational use for adults 18 years of age of older in the fall of 2018. Production of cannabis is regulated at the federal level while the sale of cannabis is regulated at the provincial level [2].

2.2.1 British Columbia

2.2.1.1 Profile of the Sector: 2019

In 2019, there were an estimated 56 indoor cannabis facilities operating in BC, of which about 20% were warehouses and 70% were greenhouses [3], [6], [7], [8]. Figure 2-1 provides the estimated number of indoor cannabis facilities by subsector in 2019.

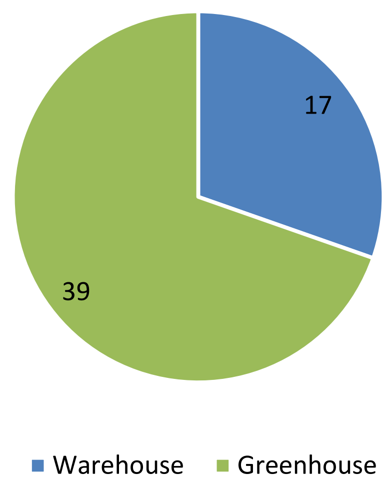

Figure 2-1: Number of Indoor Cannabis Facilities by Sub-sector in 2019, BC

As illustrated in Figure 2-2, an estimated 6.3 million square feet of indoor space was used to produce cannabis in 2019 in BC.

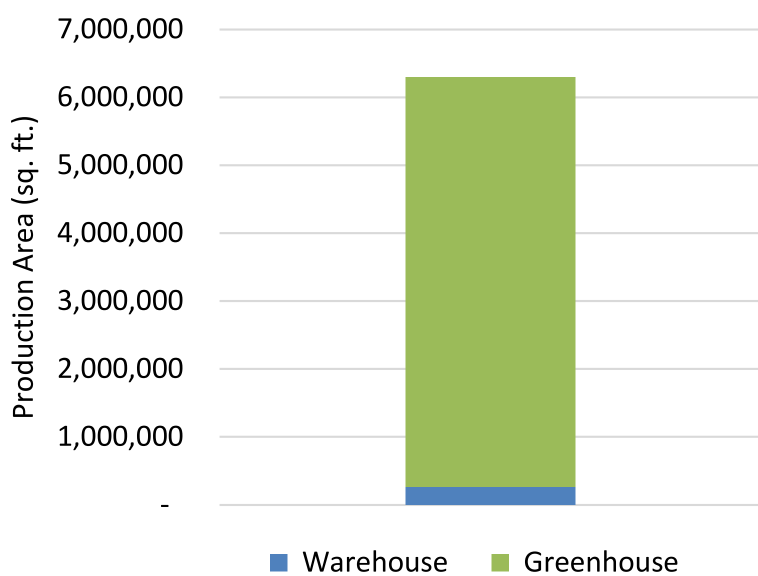

Figure 2-2 : Production Area (sq. ft.) of Indoor Cannabis Facilities in 2019, BC

Research suggests that many cultivators were only able to use a portion of their facility for production when they began to produce cannabis indoors for the recreational market. It is assumed that production of other products does not occur in the balance area of those facilities because of the risk of contamination. As cultivators are able to optimize their systems and cultivation approach over time, it is expected that production will scale up to use existing area [4], [5], [6], [7], [8].

2.2.1.2 Energy Use

The following assumptions were made to estimate energy consumption for the sector in BC:

- Most greenhouses do not have mechanical dehumidification; rather, they typically use natural or passive ventilation to control humidity.
- Warehouses use a limited amount of space heating due to high internal heat gain; the majority of heating load is associated with re-heat of conditioned air for dehumidification.
- All end uses are supplied 100% by electricity, except space heating. The fuel share for space heating is assumed to be 50% natural gas and 50% electricity for warehouses, and 85% natural gas and 15% electricity in greenhouses.

Figure 2-3 presents estimated energy consumption (eMWh) for 2019 by subsector and fuel in BC. The majority of consumption was for electricity, which covers end uses such as lighting, ventilation for both greenhouses and warehouses, and space cooling and dehumidification in warehouses. The natural gas consumption represents space heating in greenhouses.

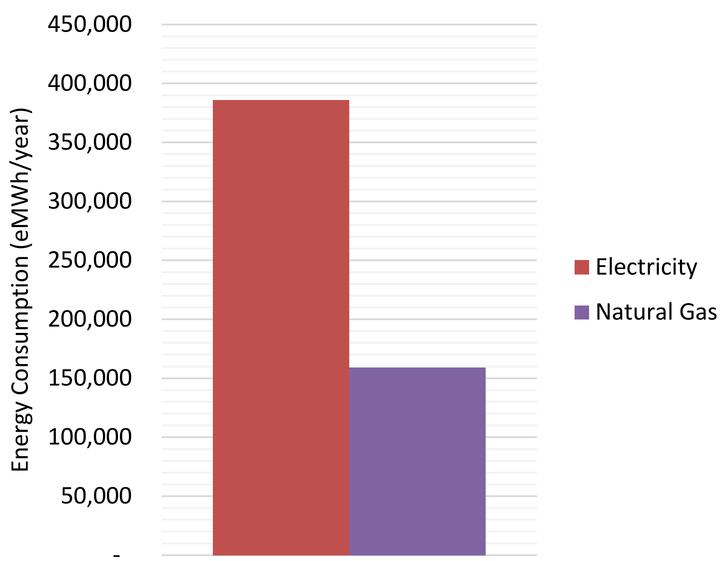

Figure 2-3: 2019 Energy Use (eMWh) by Subsector and Fuel, BC

Figure 2-4 illustrates the share of consumption by end use in a cannabis greenhouse in BC. The majority of consumption is for lighting and space heating. Dehumidification consumption is negligible because most greenhouses do not have mechanical dehumidification and some dehumidification may be occurring through ventilation.

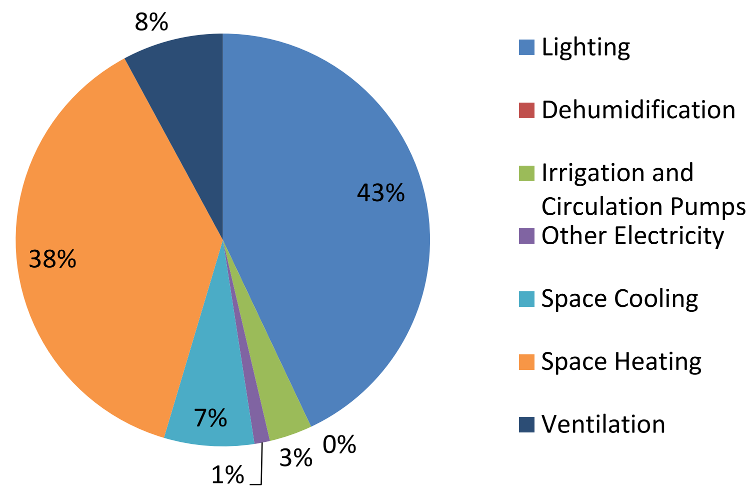

Figure 2-4: Greenhouse - Share of Consumption by End Use, BC

Figure 2-5 illustrates the share of consumption by end use in a cannabis warehouse in BC. The majority of energy use is for lighting, followed by space cooling. Energy use for space heating is minimal due to the high internal heat gains; most of the heating load is associated with dehumidification re-heat. Due to high internal heat gains, the space cooling load is highest during the summer and shoulder seasons.

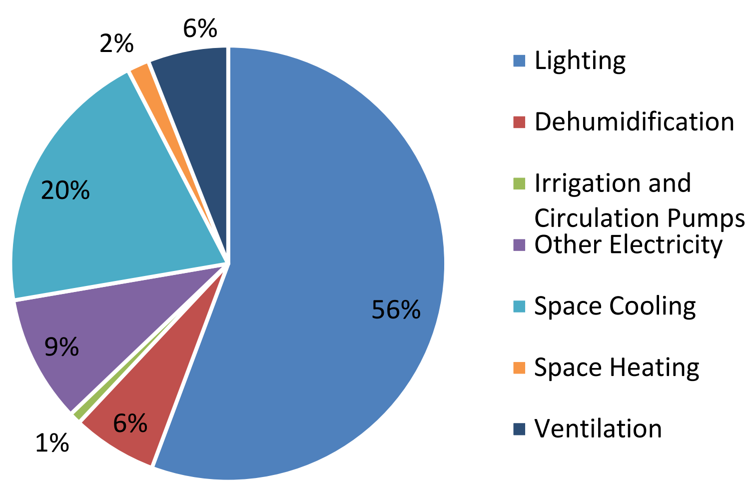

Figure 2-5: Warehouse - Share of Consumption by End Use, BC

2.2.1.3 Profile of the Sector: 2020-2024

Two greenhouse facilities were assumed to be removed from the BC cannabis industry based on public announcements of the closure of two BC Tweed facilities: one 1.7 million sq. ft. facility in Delta (climate zone 5C) and one 1.3 million sq. ft. facility in Aldergrove (climate zone 4C) [9], [10], [11]. We assume no other changes in the number of facilities over the forecast period[2].

The share of existing space being used for production is expected to increase as cannabis operations scale production to use more area of existing facilities [8].

Figure 2-6 illustrates the forecasted change in area of the indoor cannabis sector in BC. This exhibit reflects both the changes in number of accounts and increased use of existing area for production. It also shows greenhouse area declining in 2020 with the closure of two large facilities before increasing as the portion of existing area used for production in other facilities increases. Warehouse area is significantly less than greenhouse area because there are fewer warehouse facilities, and they have a smaller average size compared to greenhouses.

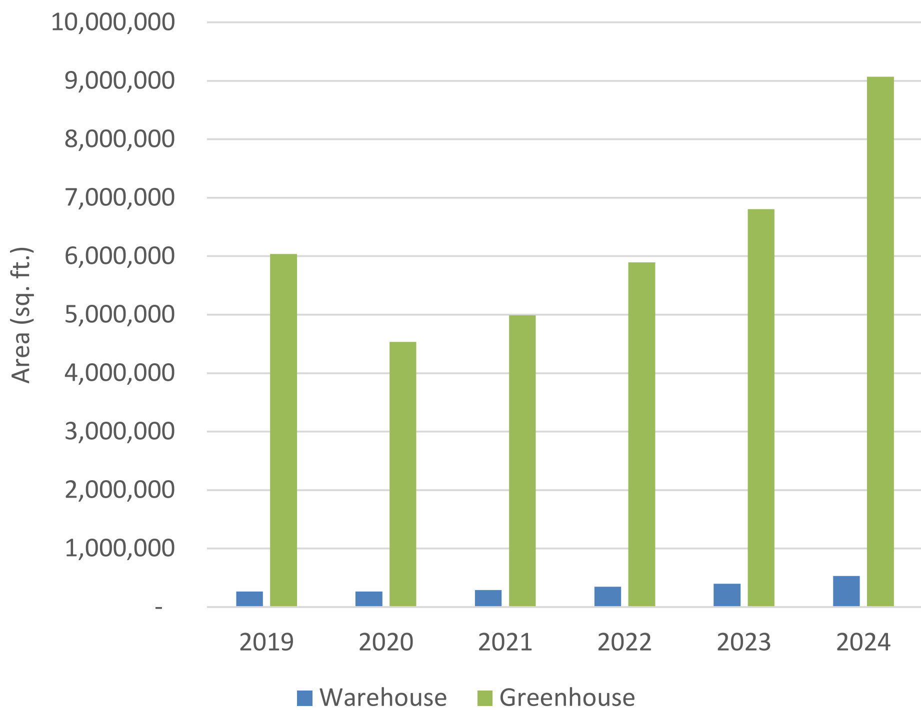

Figure 2-6: Forecast Production Area (sq. ft.), BC

Figure 2-7 presents the forecasted annual energy consumption (eMWh) for BC by fuel. The increase in energy consumption is primarily due to the expected increase in area used for production in existing facilities. Natural gas is a smaller portion of consumption because that fuel is only used for space heating, while all other end uses use electricity.

[2] There is mixed information about the future of the cannabis industry in BC, and Canada in general. While there have been announcements of facility closures, there is also continued speculation about growth in the industry. Due to the conflicting information, accounts are held constant from 2021-2024.

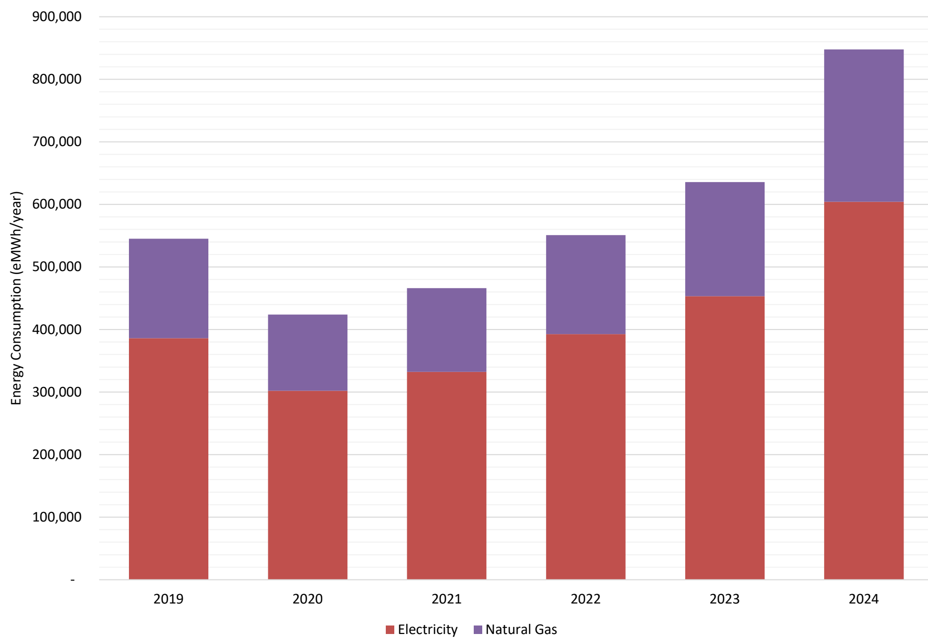

Figure 2-7: Forecasted Annual Energy Consumption (eMWh) by Fuel, BC

2.2.2 Ontario

2.2.2.1 Profile of the Sector: 2019

In 2019, there were an estimated 396 indoor cannabis facilities operating in Ontario, of which about 90% were greenhouses and 10% were warehouses [12], [3], [13]. Figure 2-8 provides the estimated number of indoor cannabis facilities by subsector in 2019.

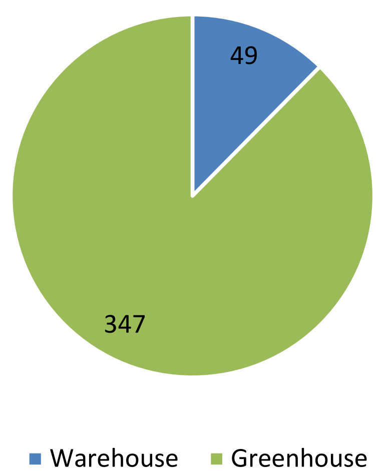

Figure 2-8: Number of Indoor Cannabis Facilities by Sub-sector in 2019, ON

As illustrated in Figure 2-9, an estimated 5.2 million square feet of cannabis facilities were in production in Ontario in 2019.

Figure 2-9: Production Area (sq. ft.) of Indoor Cannabis Facilities in 2019, ON

Research with market actors in Ontario suggests that many facilities were only using a portion of area for production when operations started late 2018. In the balance area of those facilities, no production of other plant products occurs because of the risk of contamination. As growers refine their cultivation methods, it is expected that that production with scale up quickly such that all existing area is being used [4].

2.2.2.2 Energy Use

The following assumptions were made to estimate energy consumption for the sector in Ontario:

- Most greenhouses do not have mechanical dehumidification; rather, they typically use natural or passive ventilation to control humidity.
- Warehouses use a limited amount of space heating due to high internal heat gain; the majority of heating load is associated with re-heat of conditioned air for dehumidification.
- All end uses are supplied 100% by electricity, except space heating. The fuel share for space heating is assumed to be 50% natural gas and 50% electricity for warehouses, and 85% natural gas and 15% electricity in greenhouses.

Figure 2-10 presents estimated energy consumption (eMWh) for 2019 by subsector and fuel in Ontario. The majority of consumption was for electricity, which covers end uses such as lighting, ventilation for both greenhouses and warehouses, as well as space cooling and dehumidification in warehouses. The natural gas consumption represents space heating in greenhouses.

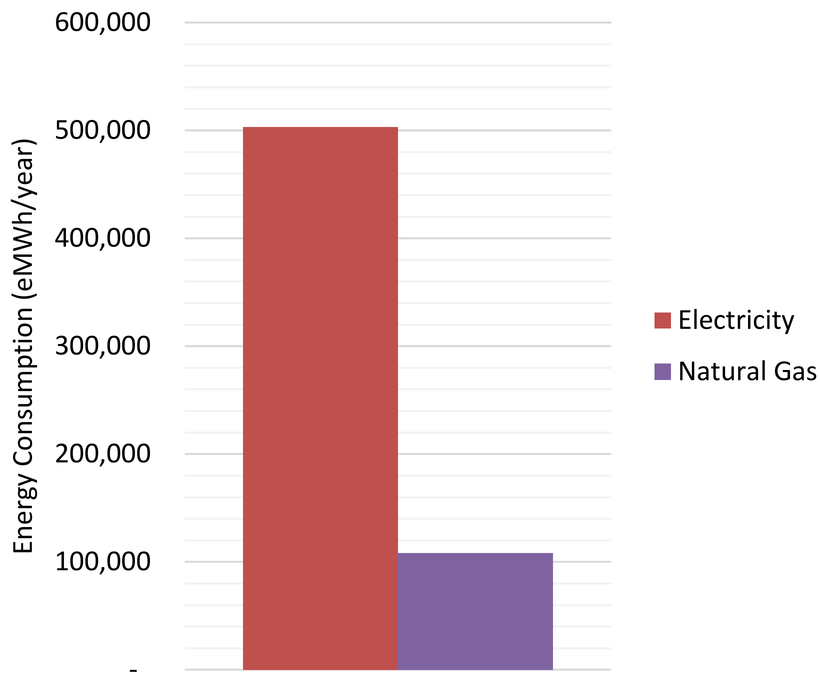

Figure 2-10: 2019 Energy Use (eMWh) by Subsector and Fuel, ON

Figure 2-11 illustrates the share of consumption by end use in a cannabis greenhouse in Ontario. The majority of consumption is for lighting and space heating. Dehumidification consumption is negligible because most greenhouses do not have mechanical dehumidification and some dehumidification occur through ventilation.

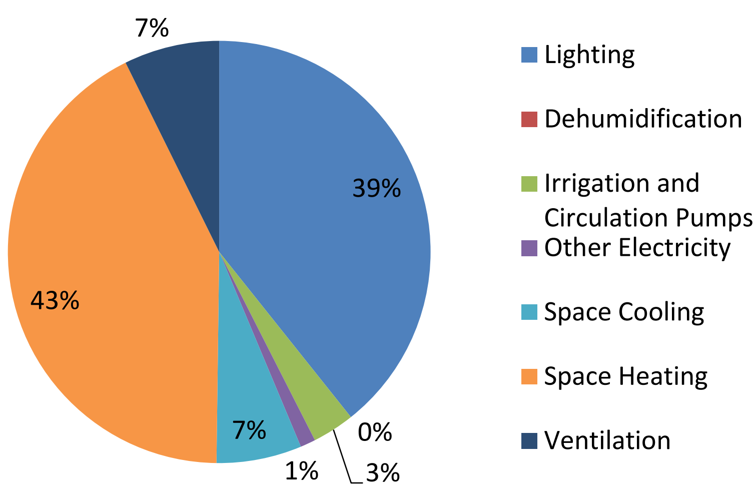

Figure 2-11: Greenhouse - Share of Consumption by End Use, ON

Figure 2-12 illustrates the share of consumption by end use in a cannabis warehouse in Ontario. The majority of energy use is for lighting, followed by space cooling. Energy use for space heating is minimal due to the high internal heat gains; most of the heating load is associated with dehumidification re-heat. Due to high internal heat gains, the space cooling load is highest during the summer and shoulder seasons.

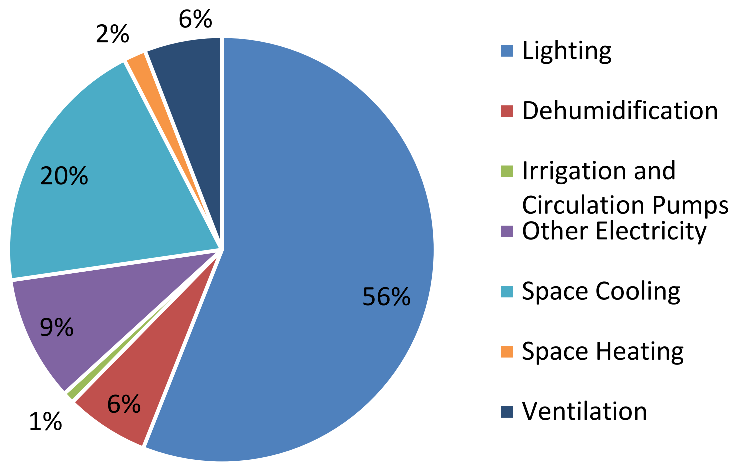

Figure 2-12: Warehouse - Share of Consumption by End Use, ON

2.2.2.3 Profile of the Sector: 2020-2024

Figure 2-13 illustrates the forecasted increase in area used for production in Ontario for warehouses and greenhouses. This exhibit reflects both the changes in number of accounts and increased use of existing area for production.

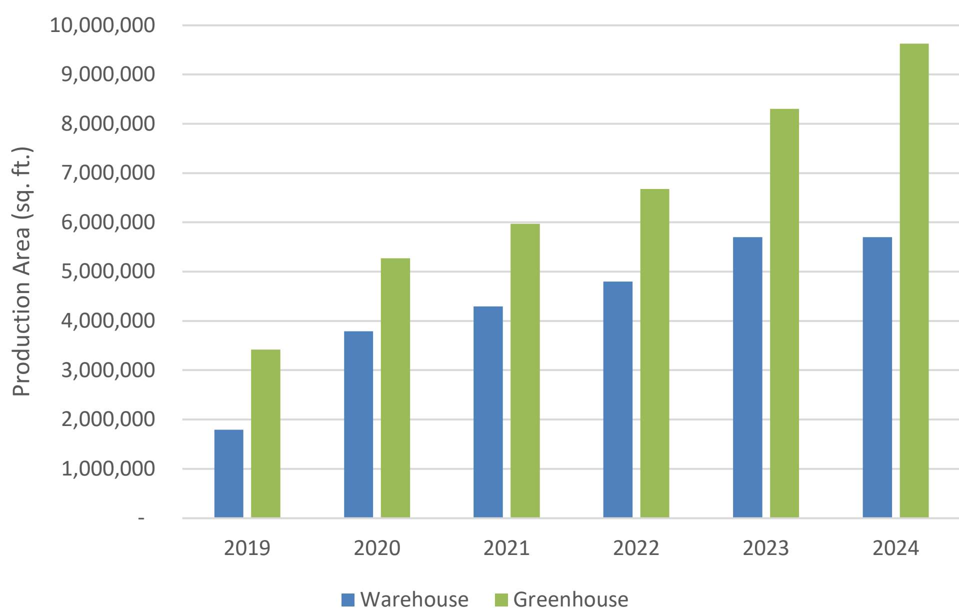

Figure 2-13: Forecasted Production Area (sq. ft.), ON

We estimate that the number of greenhouse accounts will grow by approximately 15% per year. New warehouse facilities are not expected over the forecast period, except for one large facility set to open in 2020 [4].

Figure 2-14 presents the forecasted annual energy consumption (eMWh) for Ontario by fuel. The increase in energy consumption is primarily due to the expected increase in area used for production in existing facilities. The increase in energy use is also due to an increase in number of facilities. Natural gas is a smaller portion of consumption because that fuel is only used for space heating, while all other end uses use electricity.

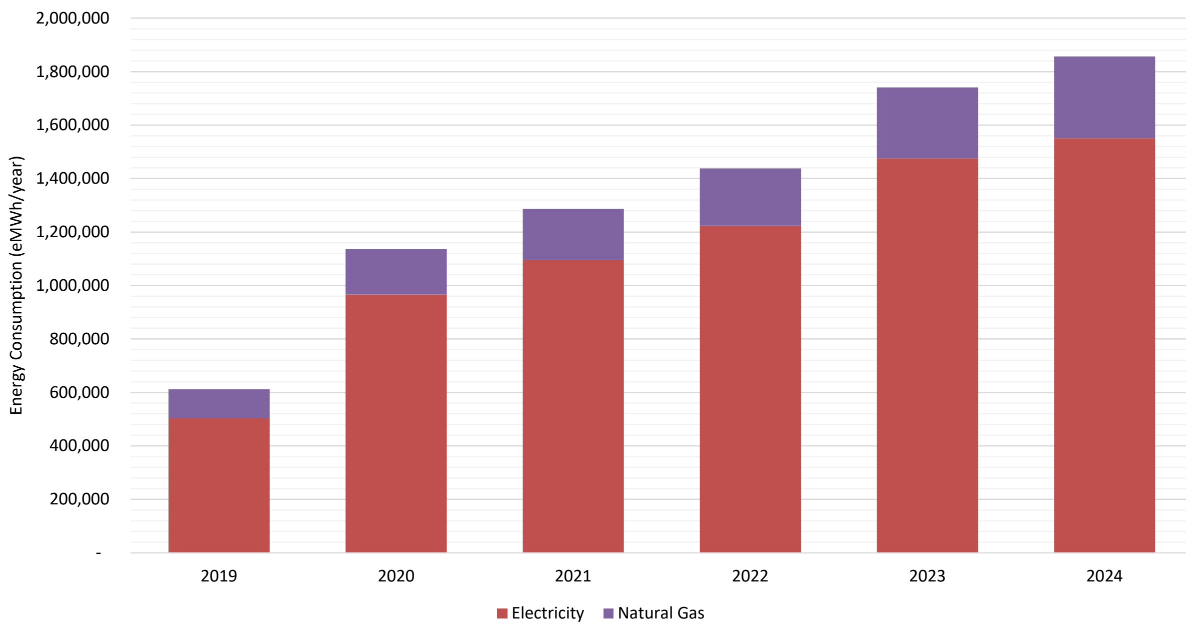

Figure 2-14: Forecasted Annual Energy Consumption (eMWh) by Fuel, ON

2.3 Cannabis in the US

Unlike Canada, production and sale of recreational cannabis in the US is under state jurisdiction and is currently illegal at the federal level.

2.3.1 Colorado

2.3.1.1 Profile of the Sector: 2019

In 2019, there were an estimated 861 indoor cannabis facilities operating in Colorado, of which about 80% were warehouses and 20% were greenhouses [14]. Figure 2-15 provides the estimated number of indoor cannabis facilities by subsector in 2019.

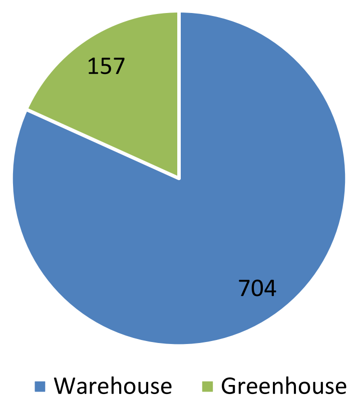

Figure 2-15: Number of Indoor Cannabis Facilities by Sub-sector in 2019, CO

As illustrated in Figure 2-16, the total area of the cannabis sector in Colorado is estimated to be about 10.6 million square feet in 2019.

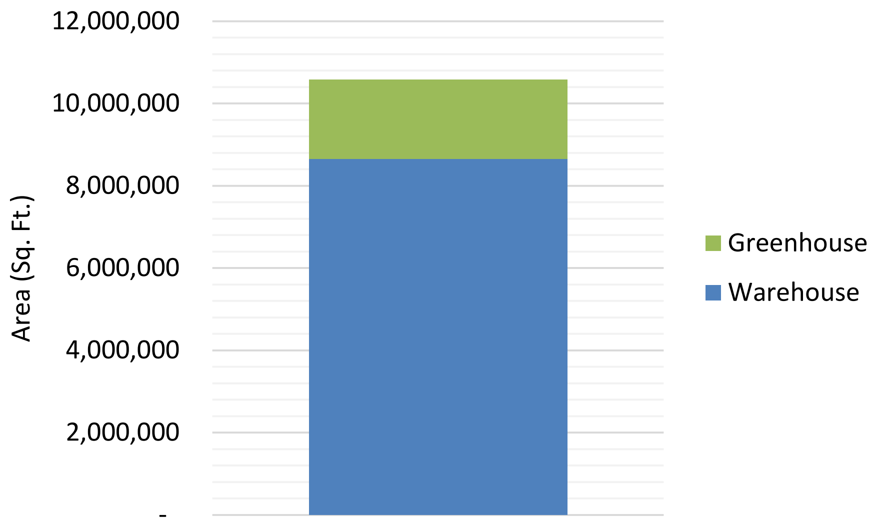

Figure 2-16: Total Area (sq. ft.) of Indoor Cannabis Facilities, CO

Unlike the Canadian provinces included in this study, it is assumed that all existing area is used for production due to the maturity of the legal cannabis market in Colorado.

2.3.1.2 Energy Use

The following assumptions were made to estimate energy consumption for the sector in Colorado:

– Most greenhouses do not have mechanical dehumidification; rather, they are using ventilation to control humidity.

- Warehouses use a limited amount of space heating due to high internal heat gain; the majority of heating load is associated with dehumidification re-heat.
- In warehouses, all end uses are supplied 100% by electricity.
- In greenhouses, all end uses are supplied 100% by electricity except space heating, which has a fuel share of 66% natural gas and 33% propane.

Figure 2-17 presents estimated energy consumption (eMWh) for 2019 by subsector and fuel in Colorado. Electricity is the primary fuel source, largely because warehouses are assumed to be fully electric and are a larger portion of the sector's footprint in Colorado compared to greenhouses.

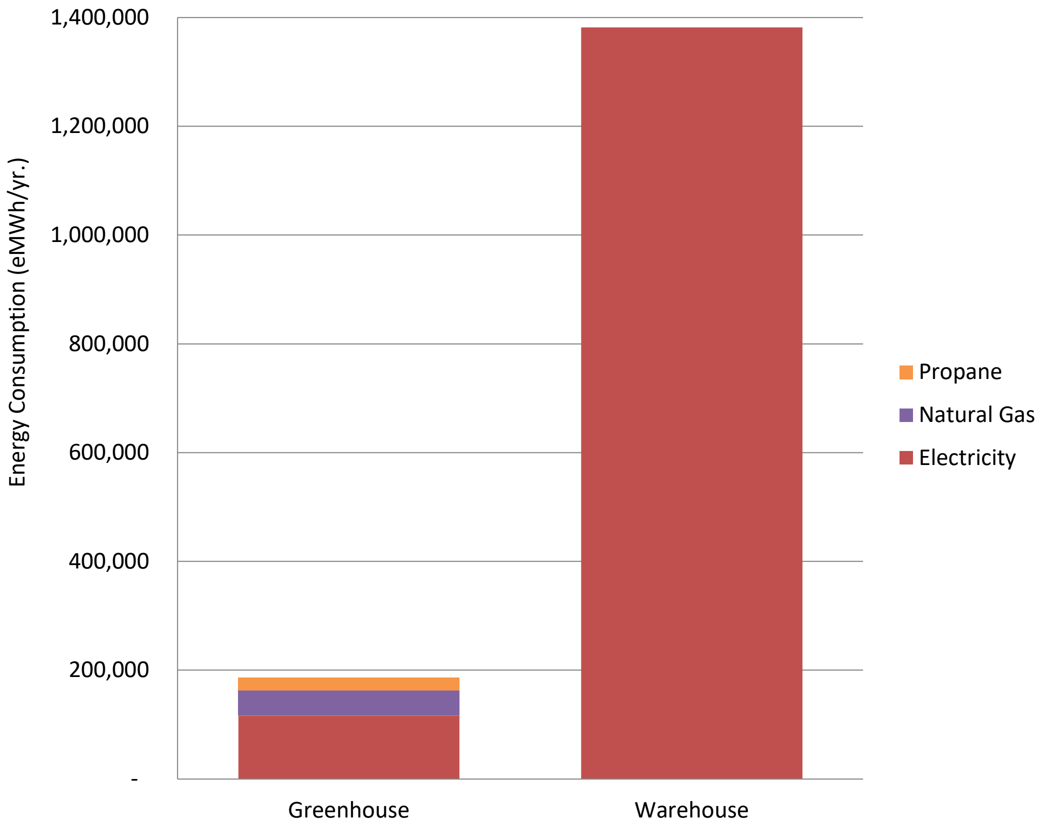

Figure 2-17: 2019 Energy Use (eMWh) by Subsector and Fuel, CO

Figure 2-18 illustrates the share of consumption by end use in a cannabis greenhouse in Colorado. The majority of consumption is for lighting and space heating. Dehumidification consumption is negligible because most greenhouses do not have mechanical dehumidification and some dehumidification may be occurring through ventilation.

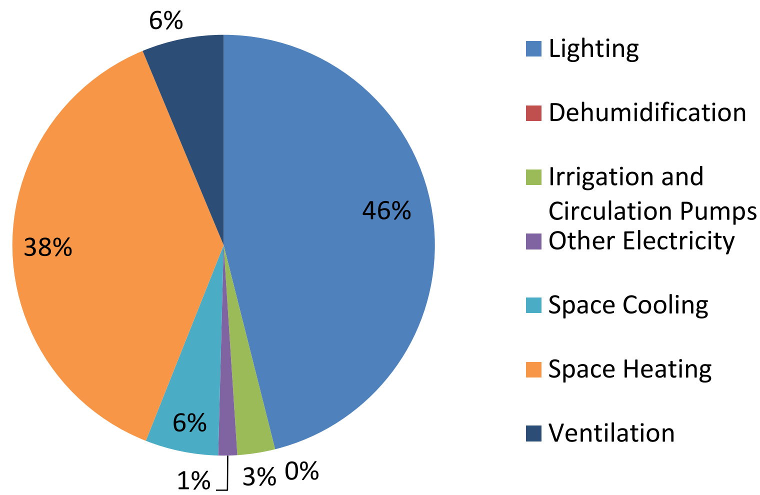

Figure 2-18: Greenhouse - Share of Consumption by End Use, CO

Figure 2-19 illustrates the share of consumption by end use in a cannabis warehouse in Colorado. The majority of energy use is for lighting, followed by space cooling. Energy use for space heating is minimal due to the high internal heat gains; most of the heating load is associated with dehumidification re-heat. Due to high internal heat gains, the space cooling load is highest during the summer and shoulder seasons.

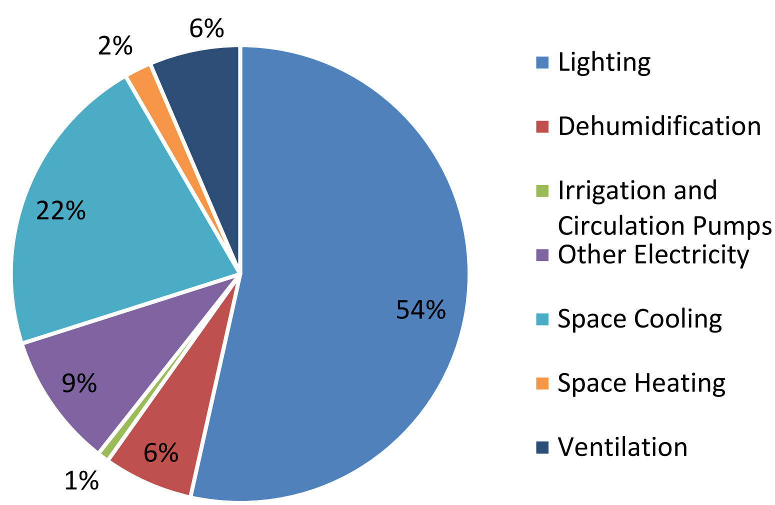

Figure 2-19: Warehouse - Share of Consumption by End Use, CO

2.3.1.3 Profile of the Sector: 2020-2024

Figure 2-20 presents the forecasted increase in indoor area used to produce cannabis in Colorado. Average historical sales data from 2014 to 2020 reported by the State of Colorado shows that cannabis production and supply has increased 7.5% year over year [15]. We assume that a similar level of growth in the industry will continue, therefore the number of facilities increases by 7.5% each year in the reference case. The total area of the sector is assumed to grow in lockstep with the number of accounts.

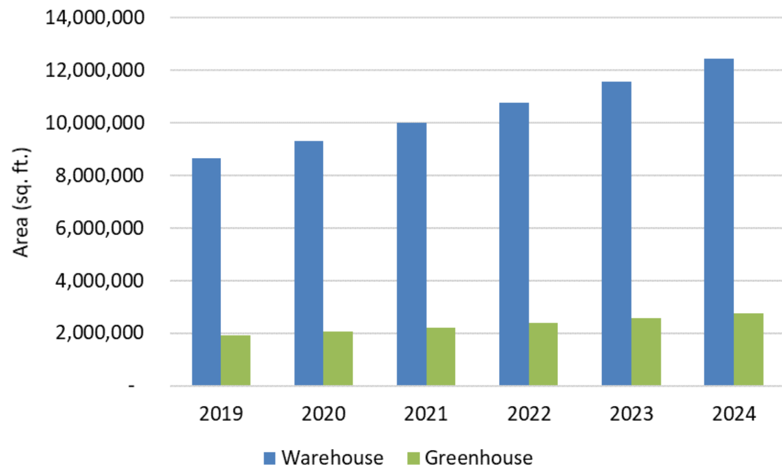

Figure 2-20: Forecasted Production Area (sq. ft.), CO

Figure 2-21 presents the forecasted annual energy consumption (eMWh) for Colorado by fuel. The increase is due to the expected increase in the number of facilities. Natural gas and propane are a smaller portion of consumption because those fuels are only used for space heating, while all other end uses use electricity.

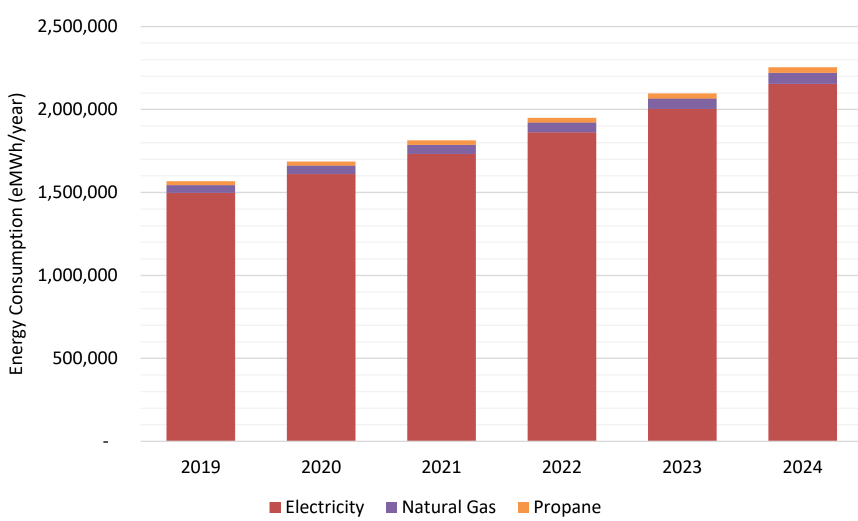

Figure 2-21: Forecasted Annual Energy Consumption (eMWh) by Fuel, CO

2.3.2 Oregon

2.3.2.1 Profile of the Sector: 2019

In 2019, there were an estimated 917 indoor cannabis facilities operating in Oregon, of which about 60% were warehouses and 40% were greenhouses. Figure 2-22 below provides the estimated number of indoor cannabis facilities by subsector in 2019.

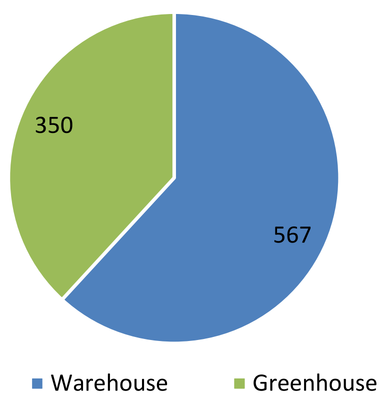

Figure 2-22: Number of Indoor Cannabis Facilities by Sub-sector in 2019, OR

As illustrated in Figure 2-23, the total area of the cannabis sector in Oregon is estimated to be about 7.4 million square feet in 2019.

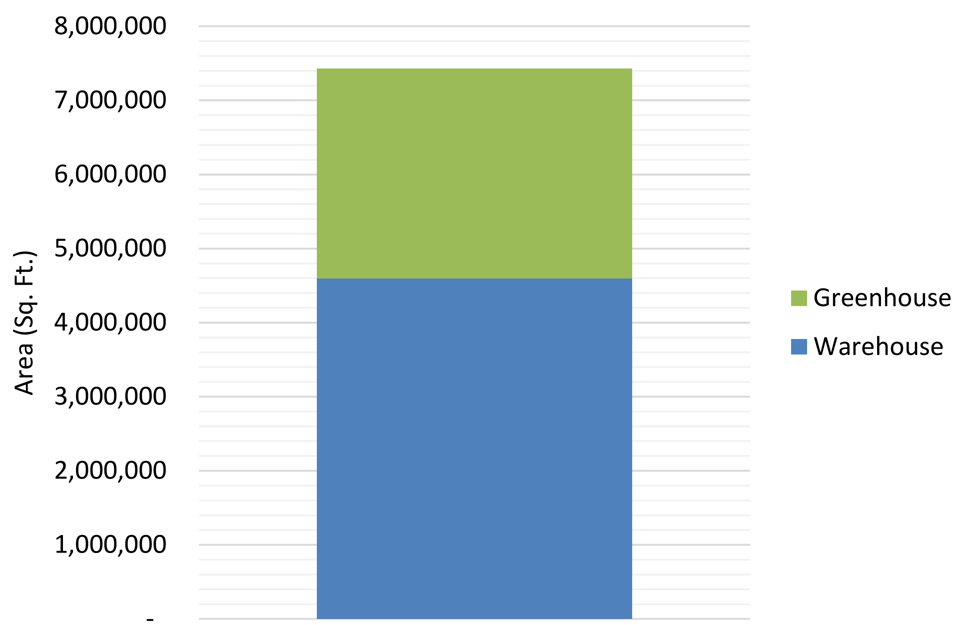

Figure 2-23: Total Area (sq. ft.) of Indoor Cannabis Facilities in 2019, OR

Unlike the Canadian provinces included in this study, it is assumed that all existing area is used for production due to the maturity of the legal cannabis market in Oregon [15].

2.3.2.2 Energy Use

The following assumptions were made to estimate energy consumption for the sector in Oregon:

- Most greenhouses do not have mechanical dehumidification; rather, they are using ventilation to control humidity.
- Warehouses use a limited amount of space heating due to high internal heat gain; the majority of heating load is associated with dehumidification re-heat.
- In warehouses, all end uses are supplied 100% by electricity.
- In greenhouses, all end uses are supplied 100% by electricity except space heating, which has a fuel share of 66% natural gas and 33% propane.
- Figure 2-24 presents estimated energy consumption (eMWh) for 2019 by subsector and fuel in Oregon. Electricity is the primary fuel source, largely because warehouses are assumed to be fully electric and warehouses are a larger portion of the sector's footprint in Oregon compared to greenhouses.

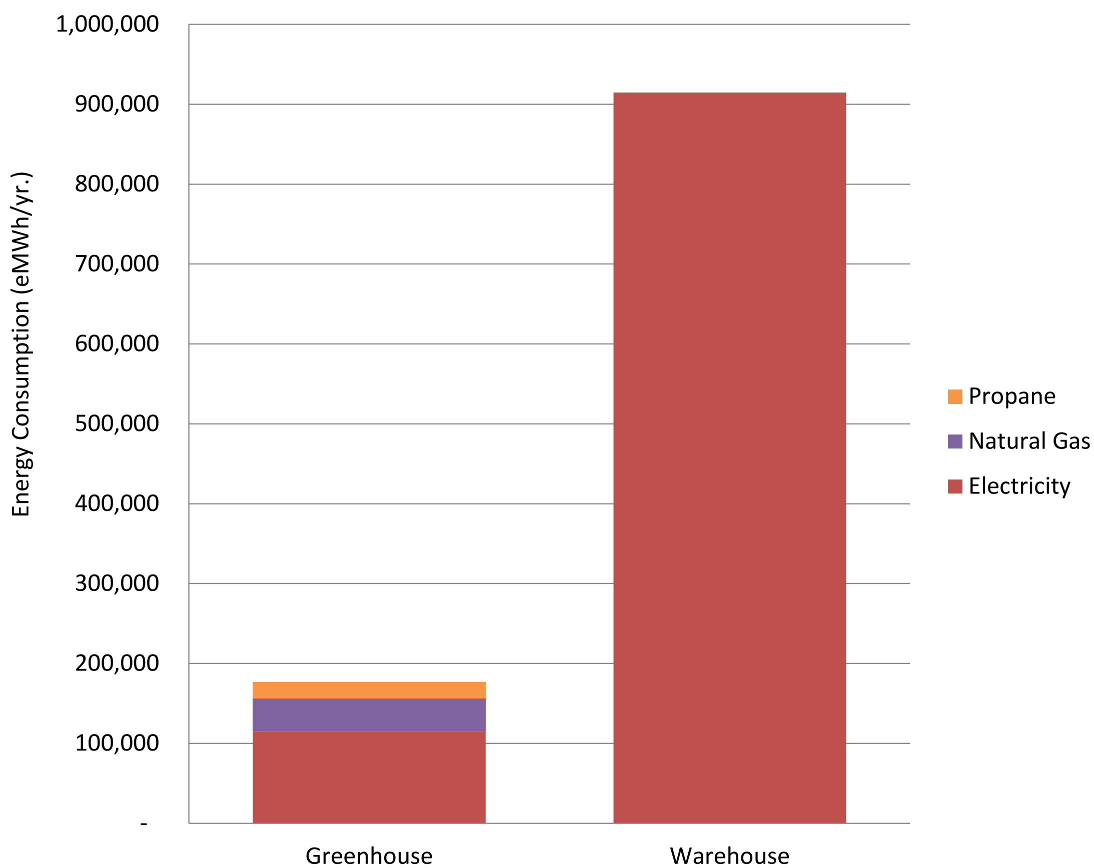

Figure 2-24: 2019 Energy Use (eMWh) by Subsector and Fuel, OR

Figure 2-25 illustrates the share of consumption by end use in a cannabis greenhouse in Oregon. The majority of consumption is for lighting and space heating. Dehumidification consumption is negligible because most greenhouses do not have mechanical dehumidification and some dehumidification may be occurring through ventilation.

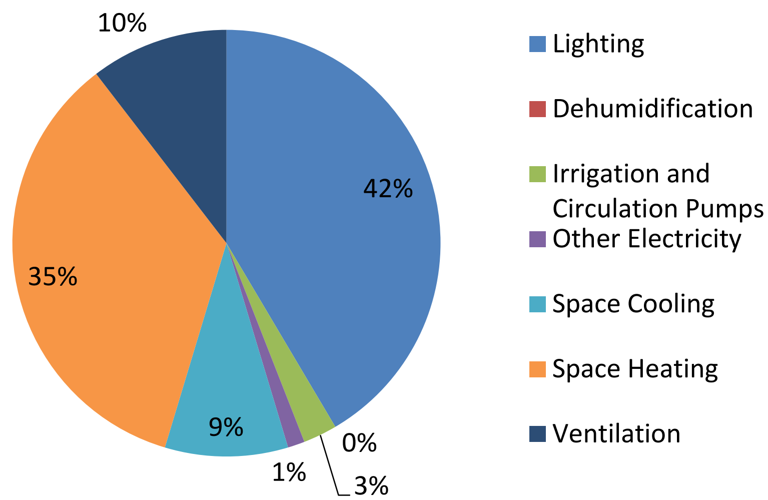

Figure 2-25: Greenhouse - Share of Consumption by End Use, OR

Figure 2-26 illustrates the share of consumption by end use in a cannabis warehouse in Oregon. The majority of energy use is for lighting, followed by space cooling. Energy use for space heating is minimal due to the high internal heat gains; most of the heating load is associated with dehumidification re-heat. Due to high internal heat gains, the space cooling load is highest during the summer and shoulder seasons.

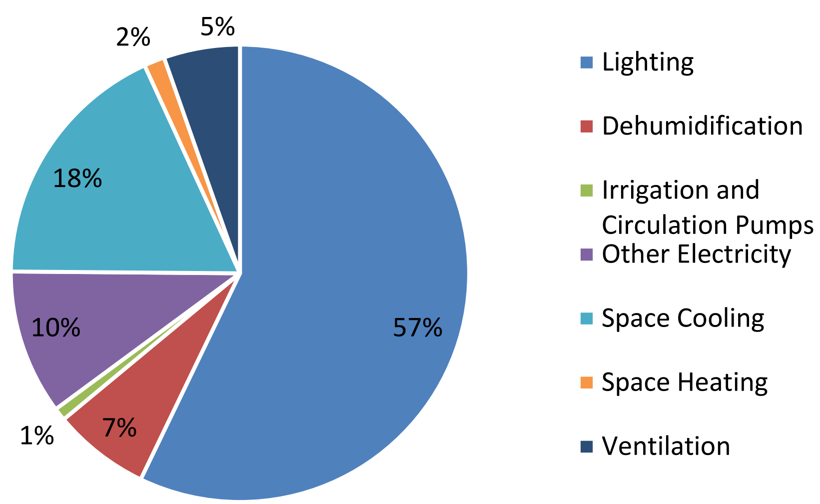

Figure 2-26: Warehouse - Share of Consumption by End Use, OR

2.3.2.3 Profile of the Sector: 2020-2024

Figure 2-27 presents the forecasted increase in indoor area used to produce cannabis in Oregon. The State of Oregon reported an average of 2.6% increase in monthly cannabis sales tax year over year from 2016 to 2020 [16], [17]. The increase in cannabis sales tax is used as a proxy for product demand, therefore the number of accounts is assumed to grow by 2.6% year over year. The total area of the sector is assumed to grow in lockstep with the number of accounts.

Figure 2-27: Forecasted Production Area (sq. ft.), OR

Figure 2-28 presents the forecasted annual energy consumption (eMWh) for Oregon by fuel. The increase is due to the expected increase in the number of facilities. Natural gas and propane are a smaller portion of consumption because those fuels are only used for space heating, while all other end uses use electricity.

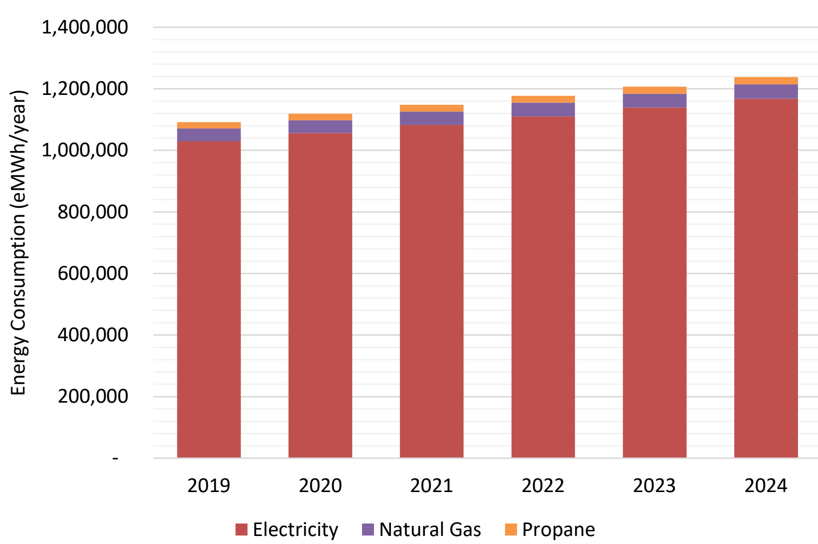

Figure 2-28: Forecasted Annual Energy Consumption (eMWh) by Fuel, OR

2.3.3 Washington

2.3.3.1 Profile of the Sector: 2019

In 2019, there were an estimated 499 indoor cannabis facilities operating in Washington, of which about 70% were warehouses and 30% were greenhouses [14]. Figure 2-29 provides the estimated number of indoor cannabis facilities by subsector in 2019.

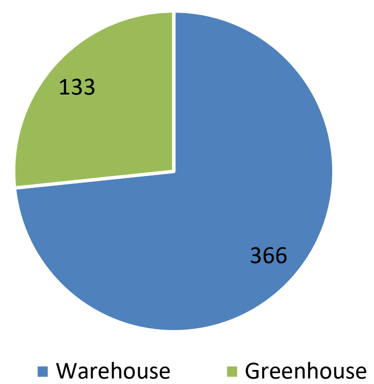

Figure 2-29: Number of Indoor Cannabis Facilities by Sub-sector in 2019, WA

As illustrated in Figure 2-30, the total area of the cannabis sector in Washington is estimated to be almost 5 million square feet in 2019.

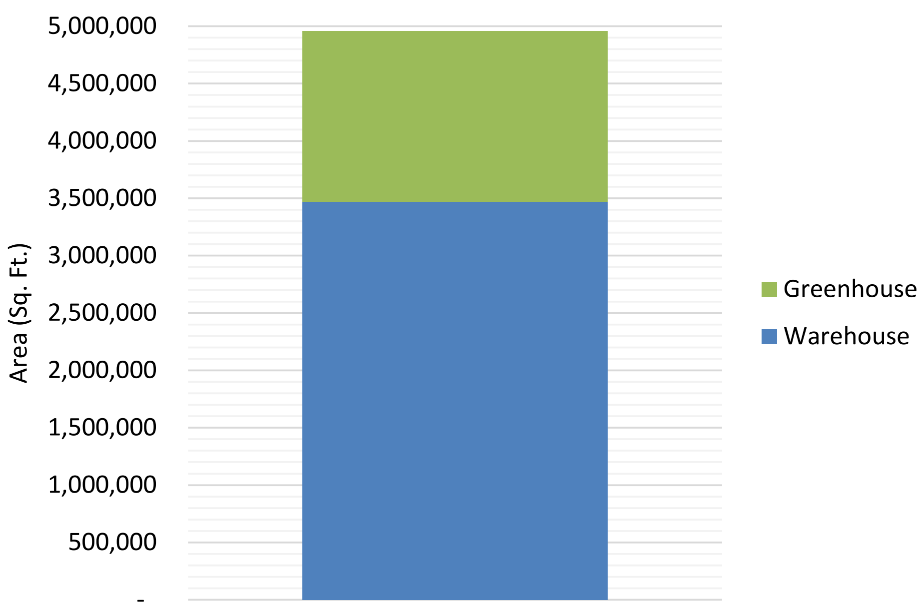

Figure 2-30: Total Area (sq. ft.) of Indoor Cannabis Facilities in 2019, WA

Unlike the Canadian provinces included in this study, it is assumed that all existing area is used for production due to the maturity of the legal cannabis market in Washington [15].

2.3.3.2 Energy Use

The following assumptions were made to estimate energy consumption for the sector in Washington:

– Most greenhouses do not have mechanical dehumidification; rather, they are using ventilation to control humidity.
– Warehouses use a limited amount of space heating due to high internal heat gain; the majority of heating load is associated with dehumidification re-heat.
– In warehouses, all end uses are supplied 100% by electricity.
– In greenhouses, all end uses are supplied 100% by electricity except space heating, which has a fuel share of 66% natural gas and 33% propane.

Figure 2-31 presents estimated energy consumption (eMWh) for 2019 by subsector and fuel in Washington. Electricity is the primary fuel source, largely because warehouses are assumed to be fully electric and warehouses are a larger portion of the sector's footprint in Washington compared to greenhouses.

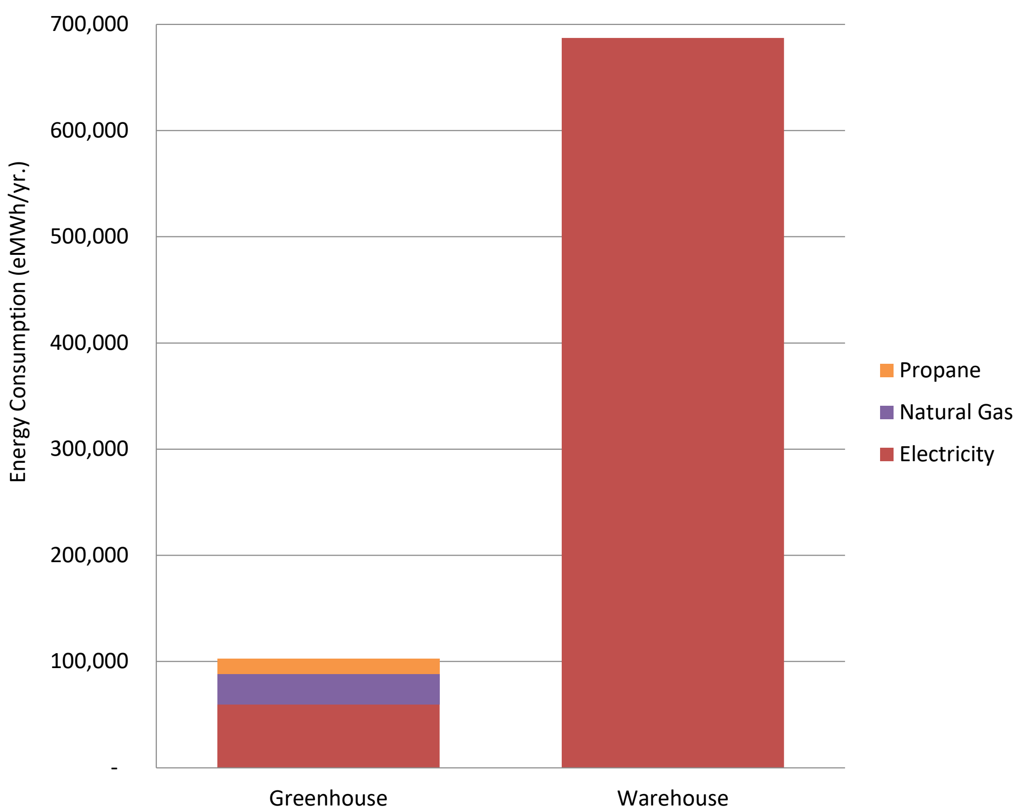

Figure 2-31: 2019 Energy Use (eMWh) by Subsector and Fuel, WA

Figure 2-32 illustrates the share of consumption by end use in a cannabis greenhouse in Washington. The majority of consumption is for lighting and space heating. Dehumidification consumption is negligible because most greenhouses do not have mechanical dehumidification and some dehumidification may be occurring through ventilation.

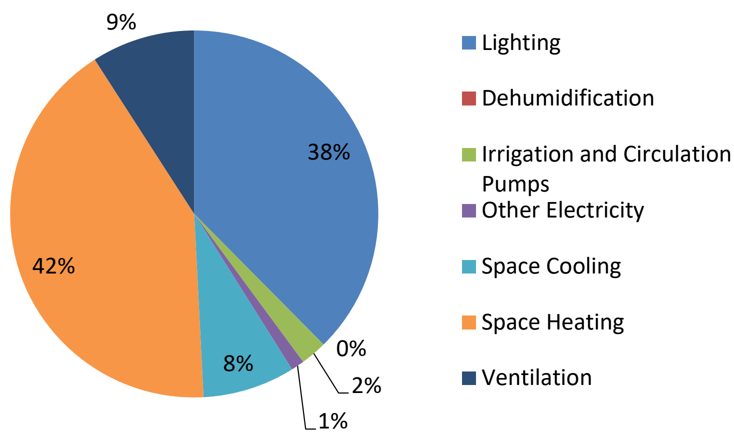

Figure 2-32: Greenhouse - Share of Consumption by End Use, WA

Figure 2-33 illustrates the share of consumption by end use in a cannabis warehouse in Washington. The majority of energy use is for lighting, followed by space cooling. Energy use for space heating is minimal due to the high internal heat gains; most of the heating load is associated with dehumidification re-heat. Due to high internal heat gains, the space cooling load is highest during the summer and shoulder seasons.

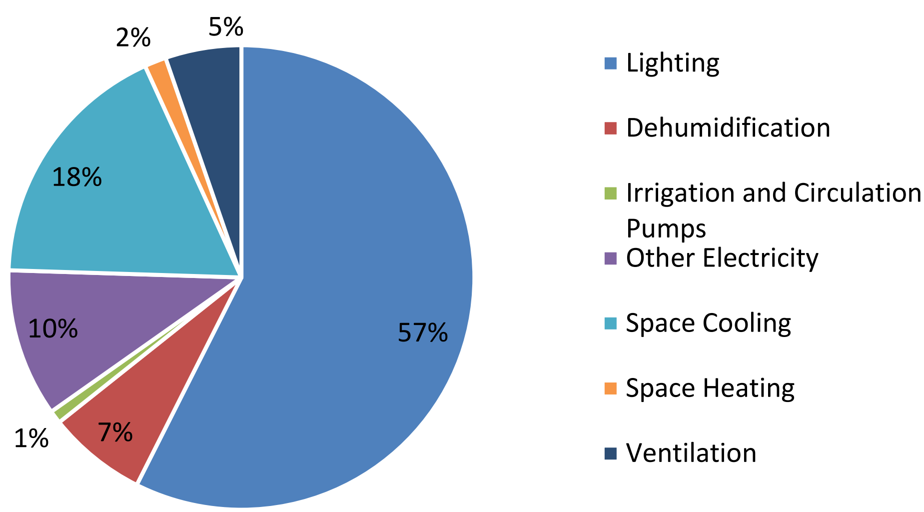

Figure 2-33: Warehouse - Share of Consumption by End Use, WA

2.3.3.3 Profile of the Sector: 2020-2024

As of June 2018, the Washington Liquor and Cannabis Board is no longer accepting new license applications for producers. As no licenses are expected to be granted, it is assumed there is no growth in the number of accounts. Therefore, the total area of the sector remains constant throughout the forecast period, as illustrated in Figure 2-34.

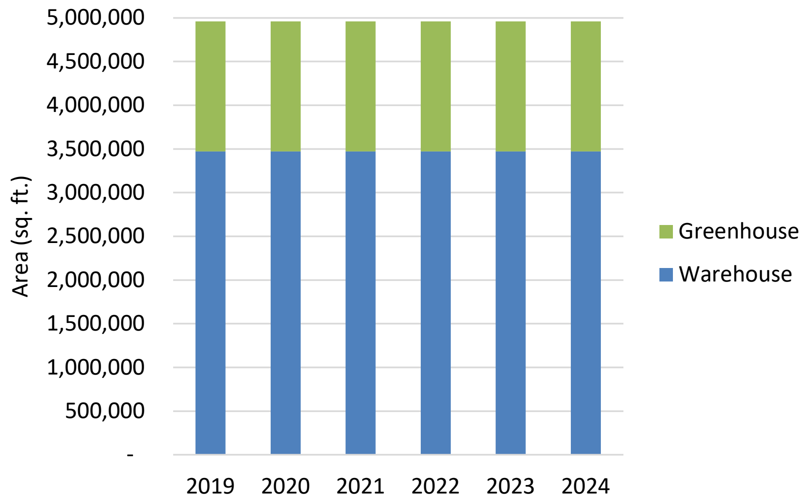

Figure 2-34: Forecasted Production Area (sq. ft.), WA

Figure 2-35 presents the forecasted annual energy consumption (eMWh) for Washington by fuel. As the number of facilities and total square footage are assumed not to change over the forecast period, energy consumption is also expected to stay constant.

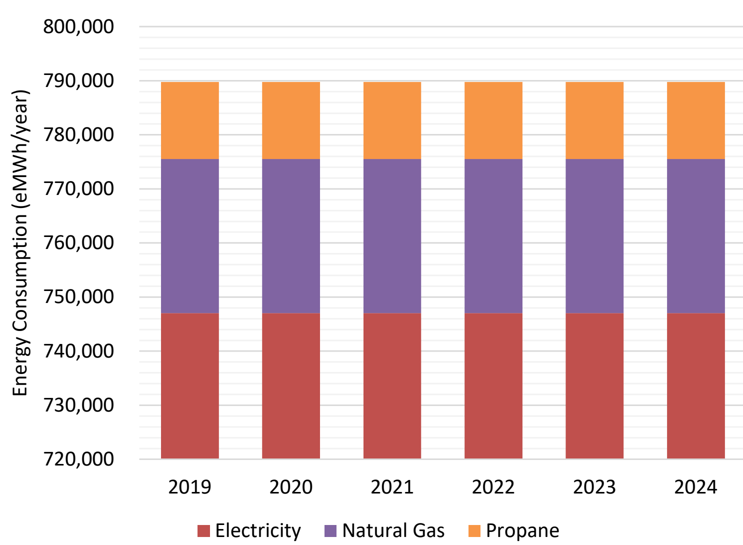

Figure 2-35: Forecasted Annual Energy Consumption (eMWh) by Fuel, WA

3.0 ENERGY SAVING MEASURES

3.1 List of Measures included in the Savings Potential Analysis

We have identified best practices for saving energy in warehouse and greenhouse facilities based on industry experience, internal site data from cultivator facilities, and vendor/cultivator input. It was agreed the study would focus on specific measure categories, while excluding other categories that were either a lower priority for study sponsors or were out of scope. For example, cogeneration, fuel-switching and envelope opportunities were excluded.

Table 3-1 provides a brief description of the energy saving measures included in the savings potential analysis and a justification for inclusion in the study.

Table 3-1: Energy Saving Measures Analyzed

Measure Category	Measure Name	Measure Description	Applicable Segments/Fuels	Justification for Inclusion
LED lighting	LED lighting	Replace lighting in plant production areas w/ LED fixtures	Warehouses/electricity	Lighting accounts for the highest energy end-use in warehouse facilities.
LED lighting	LED lighting	Replace lighting in plant production areas w/ LED fixtures	Greenhouses/electricity	Lighting is one of the two highest energy uses in greenhouse grows.
Space cooling	Air-cooled chiller	Install new air-cooled chiller	Warehouses & greenhouses that have mechanical cooling/electricity	Provides the ability to cool multiple zones separately on a large scale.
Space cooling	Water-cooled chiller	Install new water-cooled chiller	Warehouses/electricity	Provides the ability to cool multiple zones separately on a large scale.
Space cooling	DX AC	Install new DX unit with gas heating	Warehouses/electricity & gas	High efficiency option for standard practice cooling system.

Measure Category	Measure Name	Measure Description	Applicable Segments/Fuels	Justification for Inclusion
Space cooling	DX HP	Install new DX heat pump	Warehouses/electricity	High efficiency option for standard practice cooling system.
Space heating	Condensing Unit Heater	Install new condensing unit heater	Greenhouses/gas	High efficiency option for standard practice heating system in smaller greenhouses.
Space heating	Condensing Boiler	Install new condensing boiler	Greenhouses/gas	High efficiency option for standard practice heating system in large greenhouses. Boilers are typically used to provide root zone heating in greenhouses, which help to heat plants instead of surrounding air.
Space cooling	Waterside Economizer	Install waterside economizer	Warehouses/electricity	Air-to-air economizers are not typically used in cannabis production because outside air creates biosecurity concerns. Waterside economizers are able to provide the benefits of supply air economization without mixing outside air with supply air.

Measure Category	Measure Name	Measure Description	Applicable Segments/Fuels	Justification for Inclusion
Ventilation	VFD on supply /exhaust fan	Install VFD on HVAC and greenhouse fans	Greenhouses/electricity	VFDs help to modulate air flow and provide precise temperature and humidity.
Dehumidification	Dehumidifier	Install efficient stand-alone dehumidifier	Warehouses/electricity	High efficiency option for standard practice dehumidification system in warehouses.
Dehumidification	HVAC with energy recovery	Install HVAC system with energy recovery	Warehouses/electricity/ gas	Reheat for dehumidification is necessary to avoid overcooling. Heat recovered from the facility HVAC system can reduce the reheat load (gas or electric).
Energy curtains	Energy curtains	Add energy curtains	Greenhouses/gas	Minimizes heat loss during colder periods at night or in the winter.

The measure input assumption workbook is provided as a separate document (see Appendix A), and contains detailed measure input assumptions. With this workbook, readers will be able to find the following information for each measure:

- Applicable end-uses and facility types
- Incremental measure costs, including incremental operations and maintenance costs
- Current measure saturation within sponsor jurisdictions
- Baseline and upgrade consumption, percent savings, and supporting savings calculations and methodologies
- Measure lifetime

3.2 Measure Options that Were Assessed but Excluded from Analysis

The following measures were discussed as options and excluded from the potential analysis. Table 3-2 lists these measures and provides a brief explanation as to why they were excluded.

Table 3-2: Measure Options Excluded from the Study

Measure Category	Measure Option	Justification for Exclusion
Space Cooling	Gas heat-pumps for cooling	Not standard practice in cannabis production.
Horticultural Production Approaches	Rootzone heating	This measure is covered under the condensing boiler category.

Measure Category	Measure Option	Justification for Exclusion
LED Lighting	Intra canopy lighting	Intra canopy lighting is not a standard practice in cannabis production. Based on experience with over 100 grow operations, zero have used intra canopy lighting. That does not mean it is not being used or is not viable, rather, it is just extremely rare. We have extensively researched standard practice and baseline lighting technology while developing California's Title 24 Controlled Environment Horticulture Codes and Standards. We interviewed dozens of growers and horticulture lighting experts, and intra canopy lighting was not mentioned. A few reasons why cannabis growers don't typically use intra canopy lighting: – Typically, cannabis growers remove (or prune) leaves from the bottom 1/3 of plants so energy can be focused on budding or THC/cannabinoid production which happens at the top half of the plant. Since intra canopy lighting is focused on parts of the plant that are typically removed, the additional light would have a diminished return. – Growers typically move plants from one area of the facility to the next as they mature from one growth stage to another (e.g., transition from vegetative to flower stage). Intra canopy lighting is not aligned well with this strategy because it would make it difficult to move the plants. – Even with traditional top lighting, growers still struggle to manage microclimates (or hotspots). Prior to LEDs, when fluorescent lighting was the only option, the additional heat emitted by fluorescent intra lighting would increase the incidence of microclimates within a plant canopy, which growers wanted to avoid. Because standard practice for cannabis is top-lighting (HID or fluorescent depending on the plant growth phase), top-lighting is the most realistic baseline definition for growers experimenting with intra canopy lighting. However, it is complicated to compare top-lighting to intra canopy lighting. To ensure a proper "apples to apples" comparison, the top-lighting baseline needs to provide a similar amount of light, photosynthetic photon flux density (PPFD), to the lower areas of the plant canopy; measurement and verification is likely required to verify savings. Although not standard practice for cannabis, a fluorescent intra canopy baseline would be easier to use to estimate savings. Fluorescent intra lighting is being used as a baseline for other crops (e.g., vertical farming) [22]. The DesignLights Consortium (DLC) does not currently categorize horticulture fixtures based on mounting variations. However, DLC is proposing sub-family categories, which include mounting variations, in the Horticultural Technical Requirements V2.0, recently published on September 14, 2020, with an effective date of March 2021 [23].

Measure Category	Measure Option	Justification for Exclusion
Horticultural Production Approaches	Vertical stacking	Multiple levels of plant canopy require the same amount of environmental inputs and subsequently energy use per canopy sq. ft. as a single level canopy. Thus, there will be negligible energy savings when utilizing a vertical stack configuration vs. traditional (single-level) canopy.
Horticultural Production Approaches	Load factor optimization	In our experience, this is a behavioral measure. We have not found there to be any horticulture specific controls available in the market to manage demand on a facility or equipment level.
Dehumidification	Desiccant	In our experience, desiccant dehumidification is best utilized in spaces that require a very low RH and dew point temperature, which is out of the standard range of environmental requirements for cannabis plant production.

4.0 ENERGY SAVING POTENTIAL

This section of the report presents the energy savings potential of the measures described in Section 3.0 over the study period of 2019-2024. The reference case energy consumption is provided in Section 2.0. This section is organized as follows:

- Section 4.1 describes the modelling approach used
- Section 4.2 presents the energy savings potential in British Columbia
- Section 4.3 presents the energy savings potential in Ontario
- Section 4.4 presents the energy savings potential in Colorado
- Section 4.5 presents the energy savings potential in Oregon
- Section 4.6 presents the energy savings potential in Washington

4.1 Modelling Approach

Energy potential modelling was completed using the Posterity Group Navigator Energy and Emissions Simulations Suite. Base year and reference case energy use was developed using the information presented in Section 2.0 of this report, for a base year of 2019.

Energy savings can be estimated as either the technical potential or the economic potential, which are defined as follows:

Technical Potential - Technical Potential is the theoretical maximum amount of energy use that could be displaced by the measures, only considering technical constraints. Non-technical constraints such as cost-effectiveness and the willingness of end-users to adopt the efficiency measures are not considered.

Economic Potential - Economic Potential is the subset of the technical potential that is economically cost-effective to the end-user[3]. To calculate the economic potential of the measures, a benefit cost ratio test was applied. To pass the benefit cost ratio test, the ratio of the total benefits of the measure over its lifetime to its total lifetime costs must be greater than one. The benefits in this test are the energy cost savings, from the facility's perspective. The costs are the total costs of implementing the measure.

In this analysis a flat rate of electricity was used for each region, and it was assumed the cost does not differ based on time of use. In practice, an end-user may see different energy savings depending on what time of day they reduce their load.

Adding Measures to the Model

Measures are introduced to the model on either a full cost basis, at the beginning of the study period, or at the end of their useful life, on an incremental cost basis. In this study, most measures are introduced on an incremental cost basis, when the existing equipment needs to be replaced. The

[3] An economic screen from the customers' perspective differs from the total resource cost (TRC) test that uses a local avoided cost assumption. This study used an economic screen from the customers' perspective to be consistent in the analysis approach across the regions. Depending on the jurisdiction and local conditions, a TRC test may yield different economic potential results.

following measures are an exception and are introduced on a full cost basis: energy curtains, waterside economizer, VFD on supply fan/exhaust fan.

Measures are added to the model one by one. For a given measure, the maximum savings are what remains after previous measures have been applied. The feature of modelling is called cascading, and it ensures that savings are not double counted. Measures were added to the model in the following order:

Table 4-1: Order of Adding Measures to Model (Cascade Feature)

End Use	Measure Order
Lighting	• LED Lighting
Space Heating	• HVAC w/ Energy Recovery • Energy Curtains • Condensing Unit Heater • Condensing Boiler • Interactive Effects from LED Lighting
Space Cooling	• DX Unit with Gas Heating • DX Unit Heat Pump • Chiller - Air-Cooled • Chiller - Water-Cooled • Waterside Economizer • Interactive Effects from LED Lighting
Ventilation	• VFD on Supply Fan/Exhaust Fan
Dehumidification	• Efficient Dehumidifier

Lighting HVAC Interactive Effects

Installing LED lighting can lead to indirect effects on HVAC energy usage. The decline in heat emitted from high efficiency LED lighting can lead to an increase in the heating load and a decrease in cooling load of a facility [24]. The lighting savings potential analysis includes a high-level, coarse estimate of interactive effects for both heating and cooling end-uses. The estimate is by nature incorrect to the difficulty associated with trying to accurately model a very complex interaction. As discussed in Section 3.1, every facility has a different blueprint of system design and control parameters and therefore requires a different approach to quantify interactive effects, making the simplification and estimation at a jurisdictional level futile. However, not carrying a coarse estimate would be arguably more incorrect, so we made the following simplifying assumptions for the modelling:

- Cooling Interactive Effects - 90% of the value of the lighting savings is removed from the cooling load, since additional heat from lighting is no longer being added to the facility. The cooling interactive effects occur for 5 months of the year and assume that the cooling system has a COP of 3.5.
- Heating Interactive Effects - 90% of the value of the lighting savings is added to the heating load, since additional heat from lighting is no longer being added to the facility. The heating interactive effects occur for 7 months of the year and assume that the heating system has a COP of 3.0.

4.2 Energy Savings Potential – British Columbia

This section presents the energy savings results for both greenhouses and warehouses in British Columbia.

4.2.1 Greenhouse Results

Table 4-2 and Figure 4-1 show the technical and economic consumption and savings from 2019-2024, for all fuels. More detailed results by measure and fuel type are shown below.

Table 4-2: Total Forecasted Annual Energy Consumption and Savings (eMWh), BC Greenhouses

Year	Reference Consumption	Technical Potential Consumption	Technical Potential Savings	% Savings	Economic Potential Consumption	Economic Potential Savings	% Savings
2019	497,920	465,920	32,000	6.4%	469,610	28,310	5.7%
2020	376,520	349,780	26,750	7.1%	354,670	21,860	5.8%
2021	414,190	382,250	31,930	7.7%	389,910	24,280	5.9%
2022	489,480	448,810	40,670	8.3%	460,500	28,980	5.9%
2023	564,790	514,450	50,350	8.9%	531,030	33,760	6.0%
2024	753,060	681,450	71,610	9.5%	707,610	45,450	6.0%

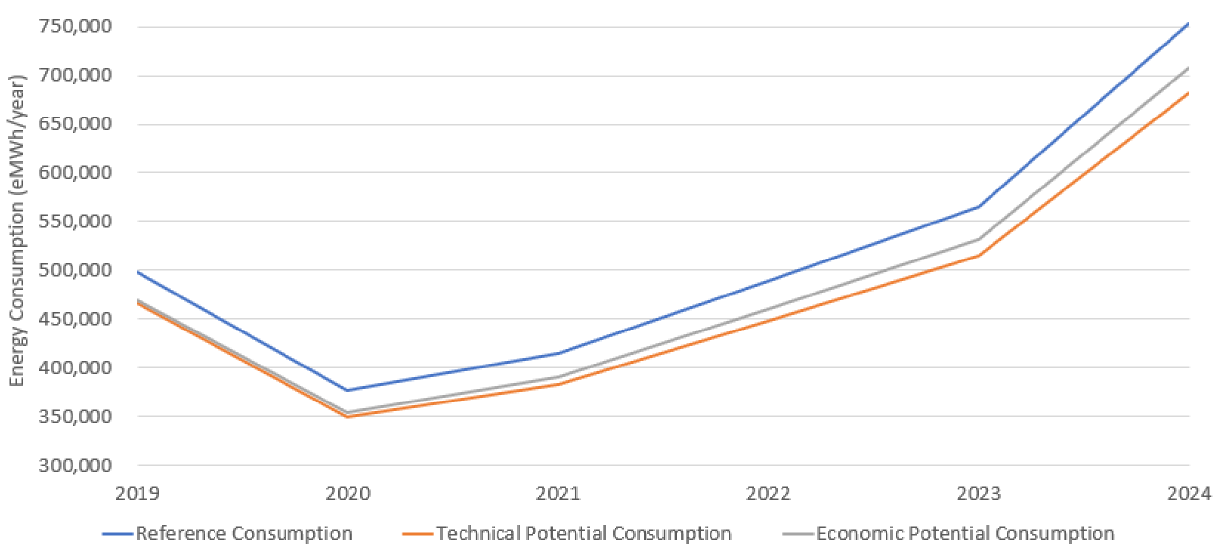

Figure 4-1: Forecasted Annual Energy Consumption (eMWh), BC Greenhouses

4.2.1.1 Technical Savings by Measure and Fuel

Table 4-3 shows the annual technical savings potential of measures for greenhouses in BC, separated by fuel. Figure 4-2 and Figure 4-3 illustrate the savings for all electric and gas measures respectively, except lighting. Lighting savings, along with the HVAC interactive effects, are shown separately in Figure 4-4, since the scale of these savings is much larger, and the lighting measure impacts both gas and electricity use.

Overall, the biggest potential for electric savings LED lighting, even with interactive effects taken into consideration. The biggest potential for gas savings is with energy curtains.

Table 4-3: Technical Potential Savings by Measure and Fuel (eMWh/yr), BC Greenhouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Energy Curtains	4,230	3,240	3,570	4,230	4,900	6,550
	VFD on Supply Fan/Exhaust Fan	860	640	640	640	640	640
	Greenhouse LED Lighting	2,940	4,420	7,290	11,490	16,570	26,510
	LED HVAC Interaction (Elec Heating & Cooling)	240	360	590	930	1,340	2,140
Natural Gas	Energy Curtains	23,900	18,320	20,210	23,960	27,740	37,100
	Condensing Boiler	100	160	260	410	590	940
	Condensing Unit Heater	250	390	640	1,020	1,470	2,360
	LED HVAC Interaction (Gas Heating)	-510	-770	-1,280	-2,010	-2,900	-4,640
Electricity & Natural Gas	Net Lighting Savings	2,670	4,010	6,600	10,410	15,010	24,010

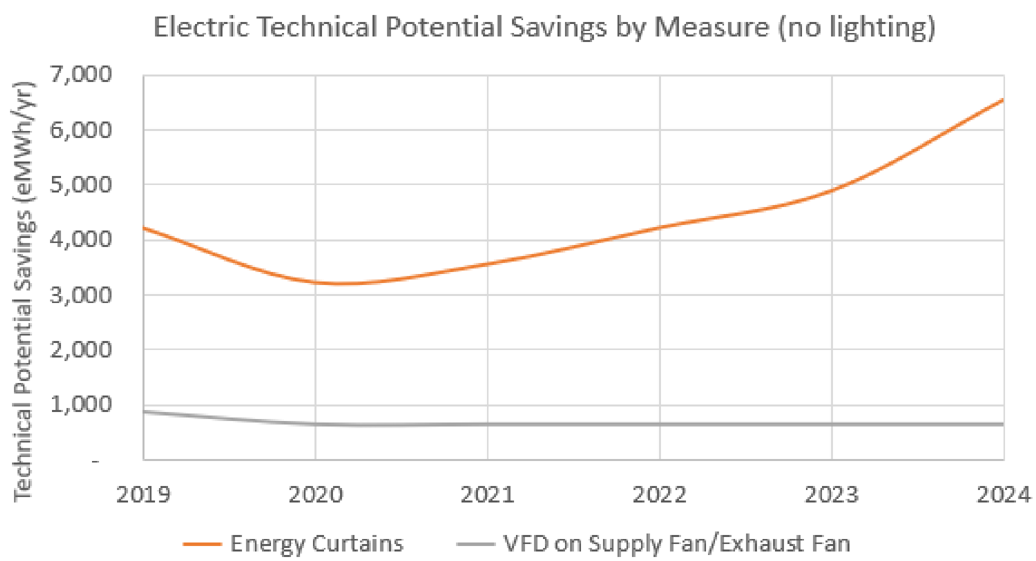

Figure 4-2: Electric Technical Potential Savings by Measure (eMWh/yr), BC Greenhouses, Excluding Lighting

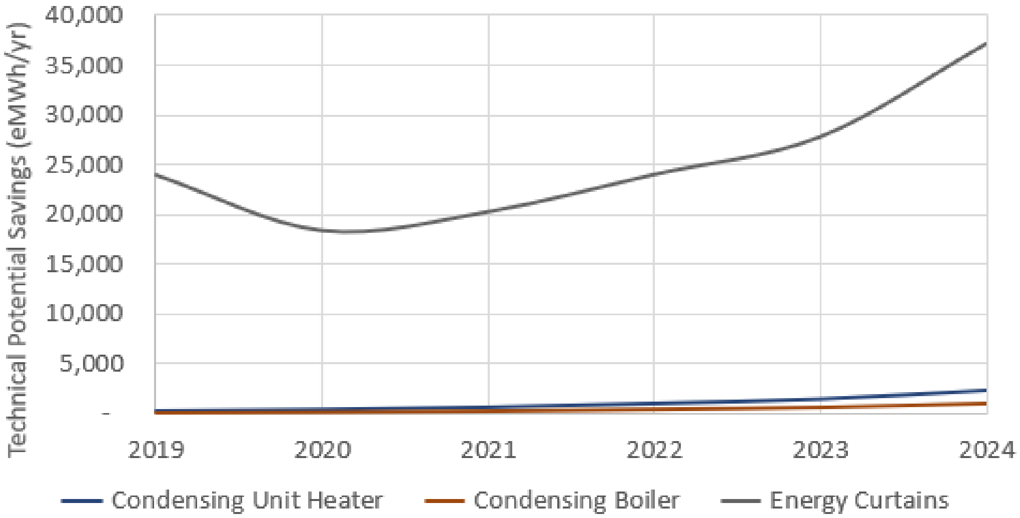

Figure 4-3: Natural Gas Technical Potential Savings by Measure (eMWh/yr), BC Greenhouses, Excluding Lighting

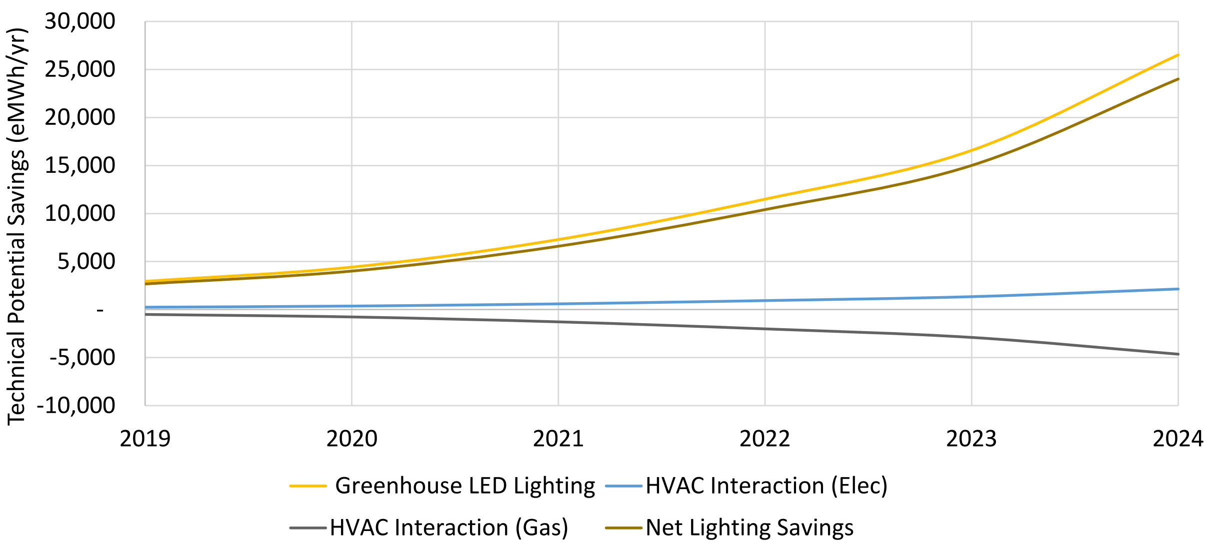

Figure 4-4: Technical Potential Savings (eMWh/yr), BC Greenhouses, LED Lighting with Interactive HVAC Effects, BC Greenhouses

4.2.1.2 Economic Savings by Measure

Table 4-4 and Figure 4-5 show the economic savings potential of measures in greenhouses in BC by fuel. Only three measures pass the economic screen: condensing boilers, unit heaters and energy curtains.

Table 4-4: Economic Potential Savings by Measure (eMWh/yr), BC Greenhouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Energy Curtains	4,210	3,220	3,540	4,190	4,830	6,440
Natural Gas	Energy Curtains	23,820	18,200	20,020	23,660	27,300	36,400
	Condensing Boiler	80	120	210	320	470	750
	Condensing Unit Heater	200	310	510	810	1,170	1,860

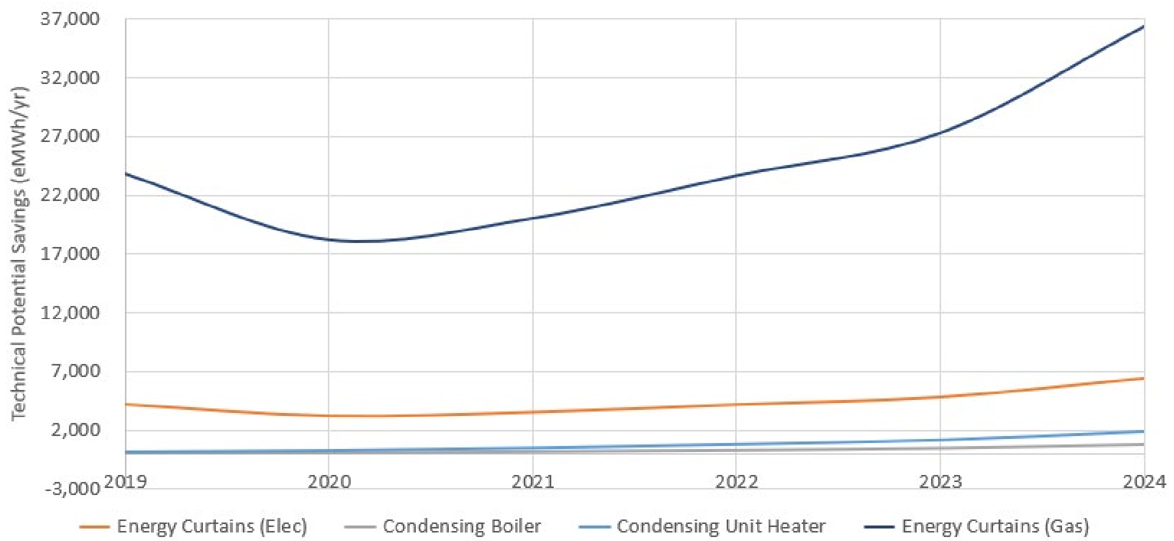

Figure 4-5: Economic Potential Savings by Measure (eMWh/yr), BC Greenhouses

4.2.2 Warehouse Results

Table 4-5 and Figure 4-1 show the technical and economic consumption and savings from 2019-2024, for all fuels. More detailed results by measure and fuel type are shown below.

Table 4-5: Forecasted Annual Energy Consumption and Savings (eMWh), BC Warehouses

Year	Reference Consumption	Technical Potential Consumption	Technical Potential Savings	% Savings	Economic Potential Consumption	Economic Potential Savings	% Savings
2019	47,300	46,500	800	1.7%	47,220	80	0.2%
2020	47,300	45,730	1,570	3.3%	47,130	170	0.4%
2021	52,030	49,450	2,580	5.0%	51,750	280	0.5%
2022	61,490	57,430	4,060	6.6%	61,050	440	0.7%
2023	70,950	65,080	5,870	8.3%	70,320	630	0.9%
2024	94,600	85,200	9,400	9.9%	93,580	1,020	1.1%

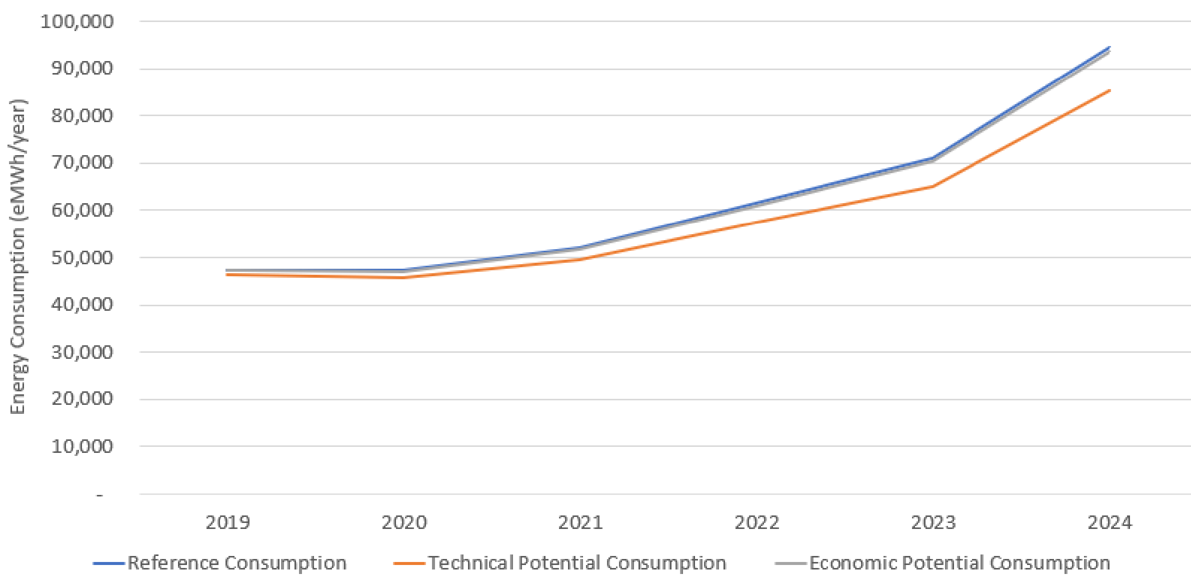

Figure 4-6: Forecasted Annual Energy Consumption (eMWh), BC Warehouses

4.2.2.1 Technical Savings by Measure and Fuel

Table 4-6 shows the annual technical savings potential of measures for warehouses in BC, separated by fuel. Figure 4-7 illustrates the savings for all measures for all electric and gas measures respectively, except lighting. Lighting savings, along with the HVAC interactive effects, are shown separately in Figure 4-9, since the scale of these savings is much larger, and that measure impacts both gas and electricity use.

Overall, the biggest potential for savings is LED lighting, even with interactive effects taken into consideration.

Table 4-6: Technical Potential Savings by Measure and Fuel (eMWh/yr), BC Warehouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Chiller - Air-Cooled	5	9	15	24	34	54
	Chiller - Water-Cooled	11	8	12	18	26	35
	Dehumidifier	52	104	172	271	391	626
	DX Unit Gas Heating	17	34	56	88	126	199
	DX Unit Heat Pump	10	20	33	51	73	116
	Waterside Economizer	18	18	18	18	18	18
	Warehouse LED Lighting	728	1,455	2,401	3,784	5,457	8,732
	LED HVAC Interaction (Elec Heating & Cooling)	14	29	47	74	107	172
Natural Gas	HVAC w Energy Recovery	16	36	69	121	194	341
	LED HVAC Interaction (Gas Heating)	-75	-150	-247	-390	-562	-899
Electricity & Natural Gas	Net Lighting Savings	667	1,334	2,201	3,469	5,003	8,004

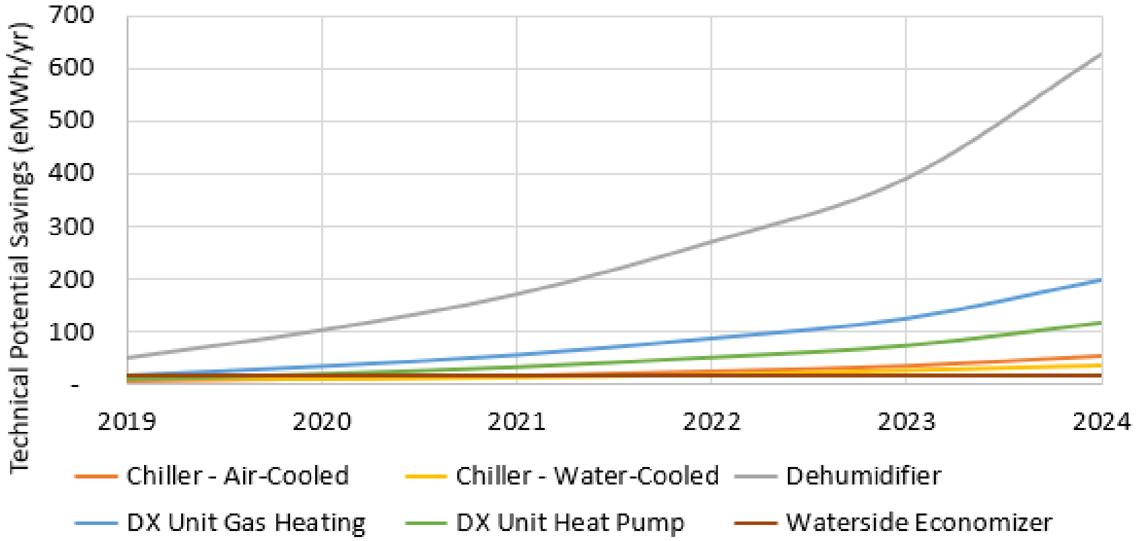

Figure 4-7: Electric Technical Potential Savings by Measure (eMWh/yr), Excluding Lighting, BC Warehouses

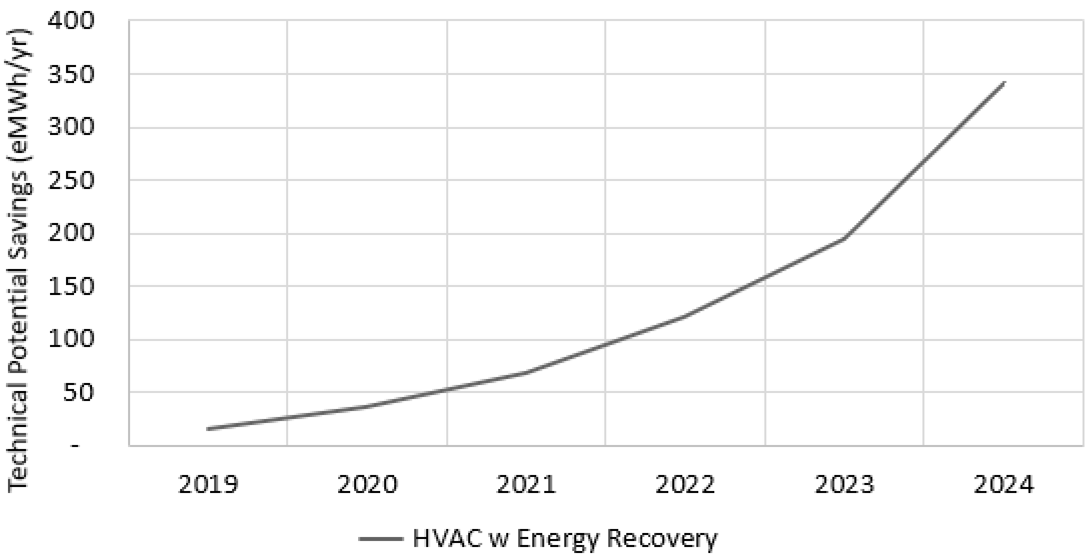

Figure 4-8: Gas Technical Potential Savings by Measure (eMWh/yr), Excluding Lighting, BC Warehouses

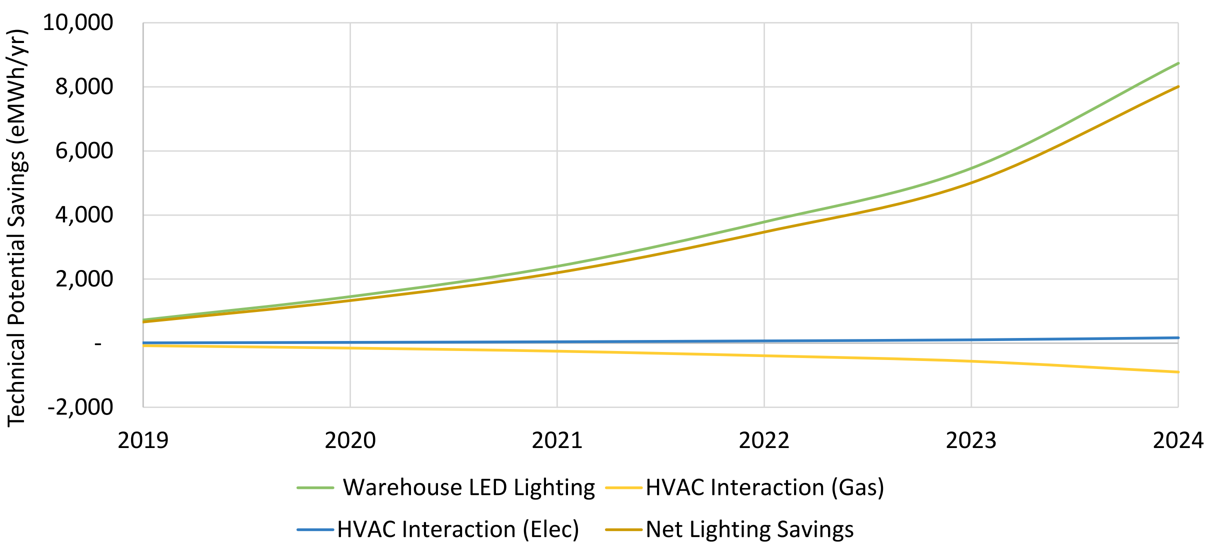

Figure 4-9: Technical Potential Savings by Measure (eMWh/yr), Lighting with Interactive HVAC Effects, BC Warehouses

4.2.2.2 Economic Savings by Measure

Table 4-7 and Figure 4-10 show the economic savings potential of measures in warehouses in BC. Four measures pass the economic screen, all of which are electric.

Table 4-7: Economic Potential Savings by Measure (eMWh/yr), BC Warehouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Chiller - Air-Cooled	5	10	16	25	36	57
	Dehumidifier	52	104	172	271	391	626
	DX Unit Gas Heating	17	35	58	91	131	210
	DX Unit Heat Pump	10	20	34	53	76	122

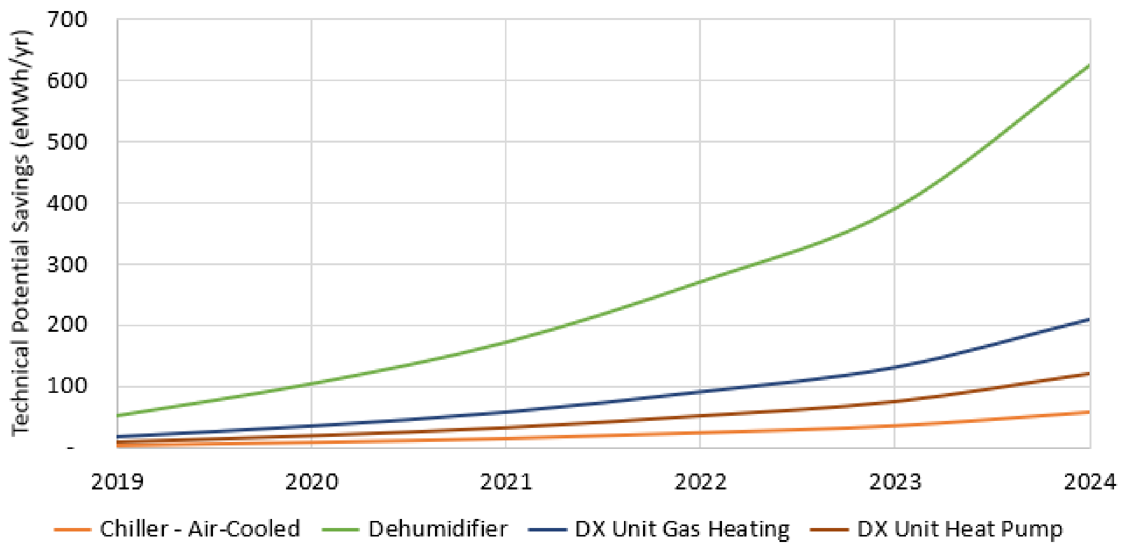

Figure 4-10: Economic Potential Savings by Measure (eMWh/yr), BC Warehouses

4.3 Energy Savings Potential – Ontario

This section presents the energy savings results for both greenhouses and warehouses in Ontario.

4.3.1 Greenhouse Results

Table 4-8 and Figure 4-11 show the technical and economic consumption and savings from 2019-2024, for all fuels. More detailed results by measure and fuel type are shown below.

Table 4-8: Total Forecasted Annual Energy Consumption and Savings (eMWh), Ontario Greenhouses

Year	Reference Consumption	Technical Potential Consumption	Technical Potential Savings	% Savings	Economic Potential Consumption	Economic Potential Savings	% Savings
2019	292,957	272,067	20,890	7.1%	273,778	19,179	6.5%
2020	461,196	424,091	37,105	8.0%	429,343	31,853	6.9%
2021	522,693	477,431	45,262	8.7%	486,429	36,264	6.9%
2022	584,176	529,969	54,207	9.3%	543,432	40,744	7.0%
2023	726,544	637,234	89,310	12.3%	654,994	71,550	9.8%
2024	842,296	717,422	124,874	14.8%	738,773	103,523	12.3%

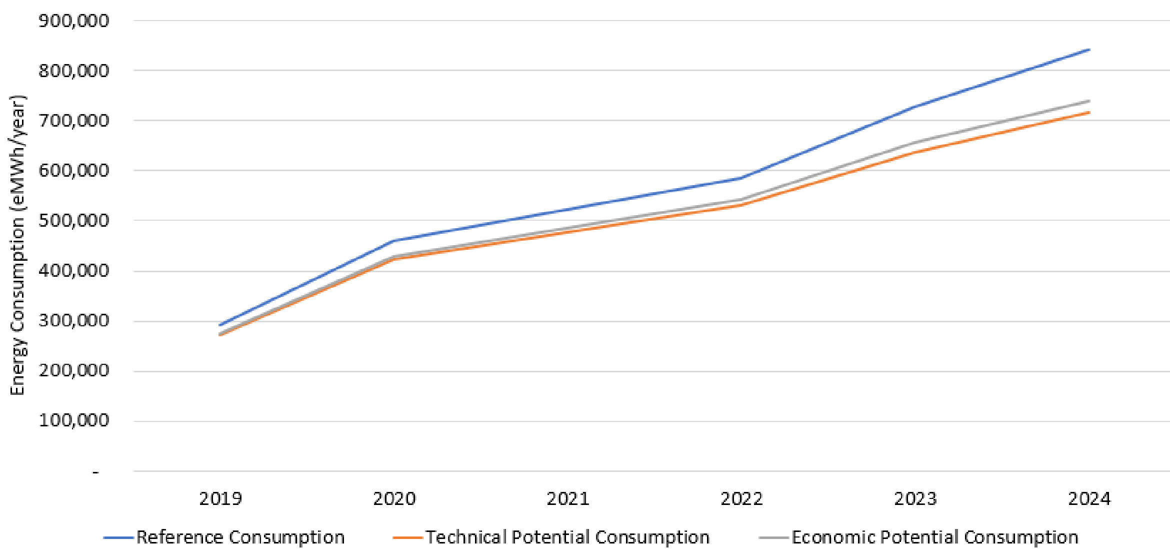

Figure 4-11: Forecasted Annual Energy Consumption (eMWh), Ontario Greenhouses

4.3.1.1 Technical Savings by Measure and Fuel

Overall, the biggest potential for electric savings LED lighting, even with interactive effects taken into consideration. The biggest potential for gas savings is with energy curtains.

Table 4-9 shows the annual technical savings potential of measures for greenhouses in Ontario, separated by fuel. Figure 4-12 and Figure 4-13 illustrate the savings for all electric and gas measures respectively, except lighting. Lighting savings, along with the HVAC interactive effects, are shown separately in Figure 4-14, since the scale of these savings is much larger, and the lighting measure impacts both gas and electricity use.

Overall, the biggest potential for electric savings LED lighting, even with interactive effects taken into consideration. The biggest potential for gas savings is with energy curtains.

Table 4-9: Technical Potential Savings by Measure and Fuel (eMWh/yr), Ontario Greenhouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Energy Curtains	2,818	4,629	5,261	5,895	9,723	13,399
	VFD on Supply Fan/Exhaust Fan	485	956	956	956	3,967	7,074
	Greenhouse LED Lighting	1,582	5,068	8,798	13,246	19,263	26,372
	LED HVAC Interaction (Elec Heating & Cooling)	128	410	712	1,072	1,558	2,133
Natural Gas	Energy Curtains	15,917	26,168	29,751	33,356	55,083	75,979
	Condensing Boiler	68	217	378	572	882	1,295
	Condensing Unit Heater	169	543	946	1,429	2,205	3,237
	LED HVAC Interaction (Gas Heating)	-277	-887	-1,540	-2,318	-3,371	-4,615
Electricity & Natural Gas	Net Lighting Savings	1,434	4,478	7,713	11,568	15,844	20,094

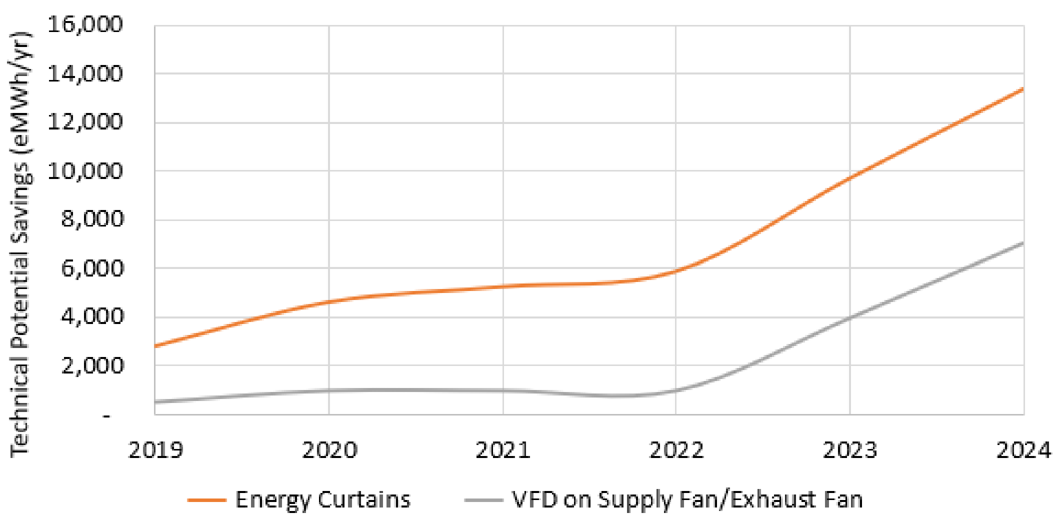

Figure 4-12: Electric Technical Potential Savings by Measure (eMWh/yr), Ontario Greenhouses, Excluding Lighting

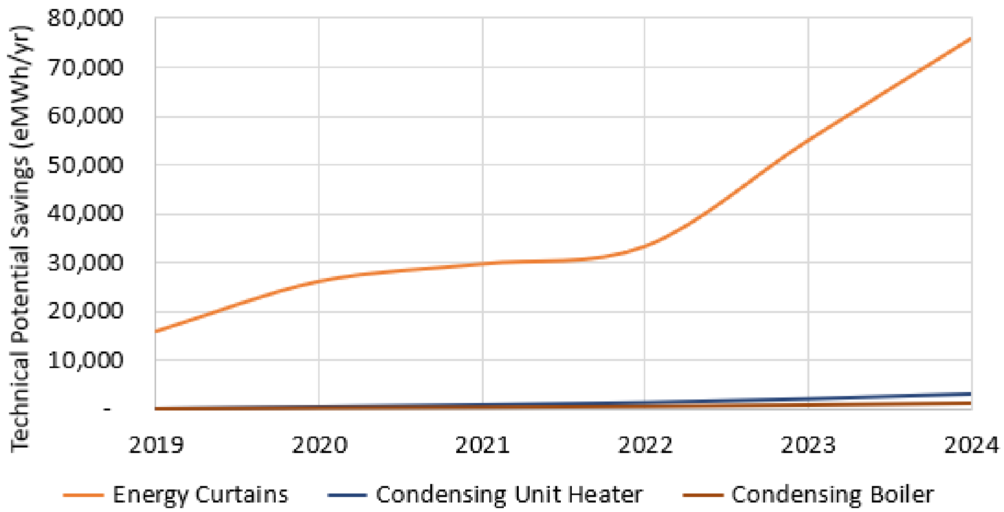

Figure 4-13: Natural Gas Technical Potential Savings by Measure (eMWh/yr), Ontario Greenhouses, Excluding Lighting

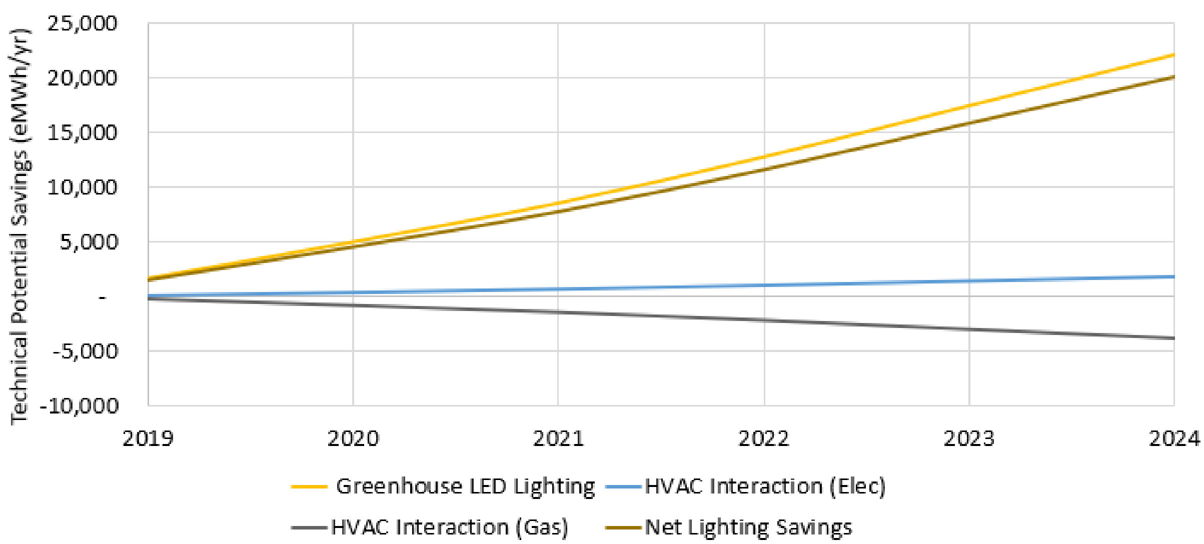

Figure 4-14: Technical Potential Savings (eMWh/yr), Ontario Greenhouses, LED Lighting with Interactive HVAC Effects

4.3.1.2 Economic Savings by Measure

Table 4-10 shows the economic savings potential of measures in greenhouses in Ontario by fuel. Figure 4-15 and Figure 4-16 show the economic potential of electric and gas measures, respectively.

Table 4-10: Economic Potential Savings by Measure (eMWh/yr), Ontario Greenhouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Energy Curtains	2,812	4,610	5,228	5,846	9,658	13,321
	VFD on Supply Fan/Exhaust Fan	485	956	956	956	3,967	7,074
	Greenhouse LED Lighting	-	196	444	745	2,772	6,549
	LED HVAC Interaction (Elec Heating & Cooling)	-	16	36	60	224	530
Natural Gas	Condensing Boiler	7	34	66	105	267	554
	Condensing Unit Heater	0	35	79	134	497	1,182
	Energy Curtains	15,875	26,040	29,532	33,028	54,650	75,459
	HVAC Interaction (Gas Heating)	-	-34	-78	-130	-485	-1,146
Electricity & Natural Gas	Net Lighting Savings	-	178	403	675	2,511	5,933

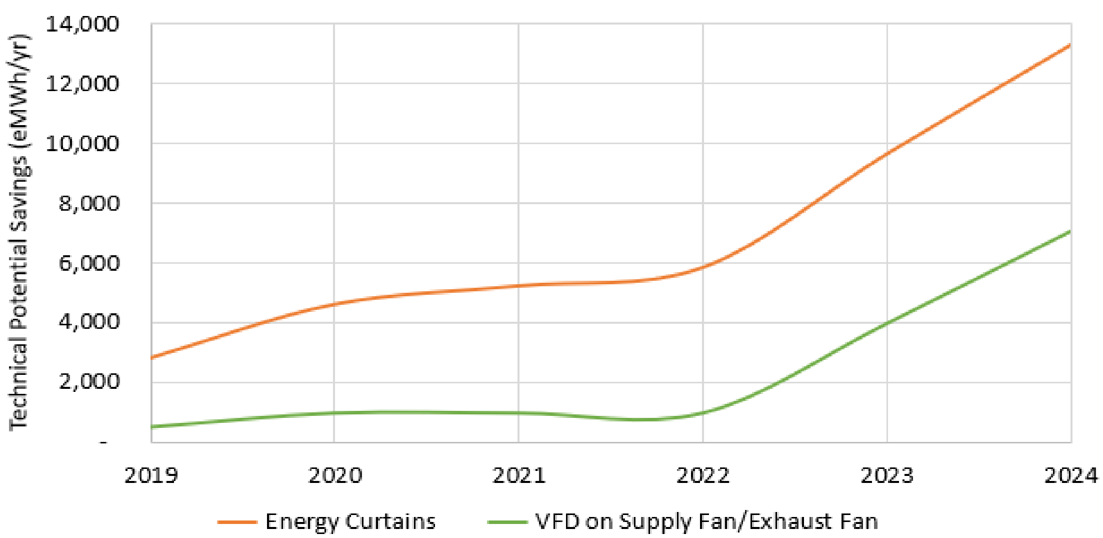

Figure 4-15: Electric Economic Potential Savings by Measure (eMWh/yr), Ontario Greenhouses

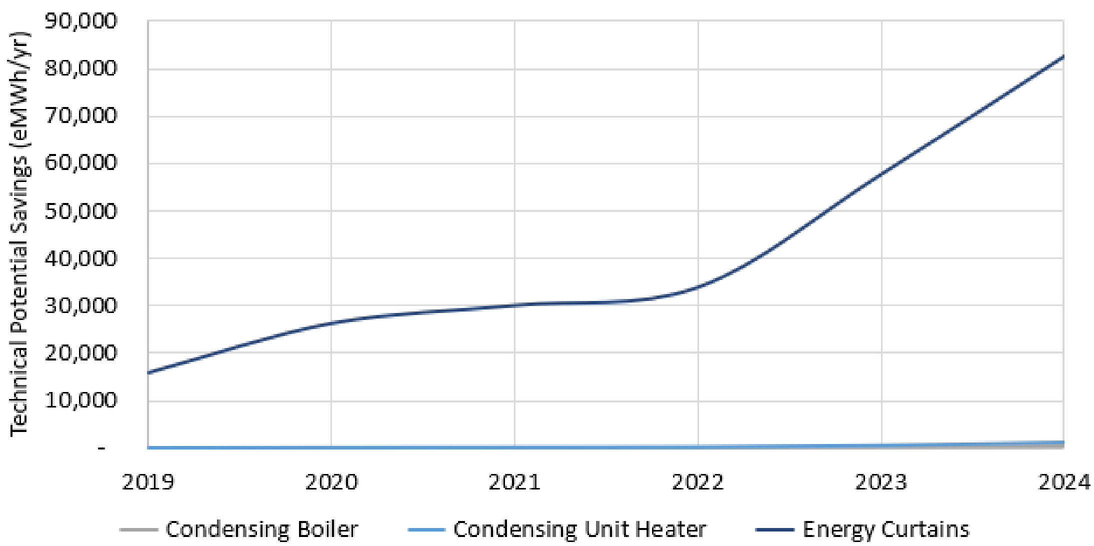

Figure 4-16: Gas Economic Potential Savings by Measure (eMWh/yr), Ontario Greenhouses

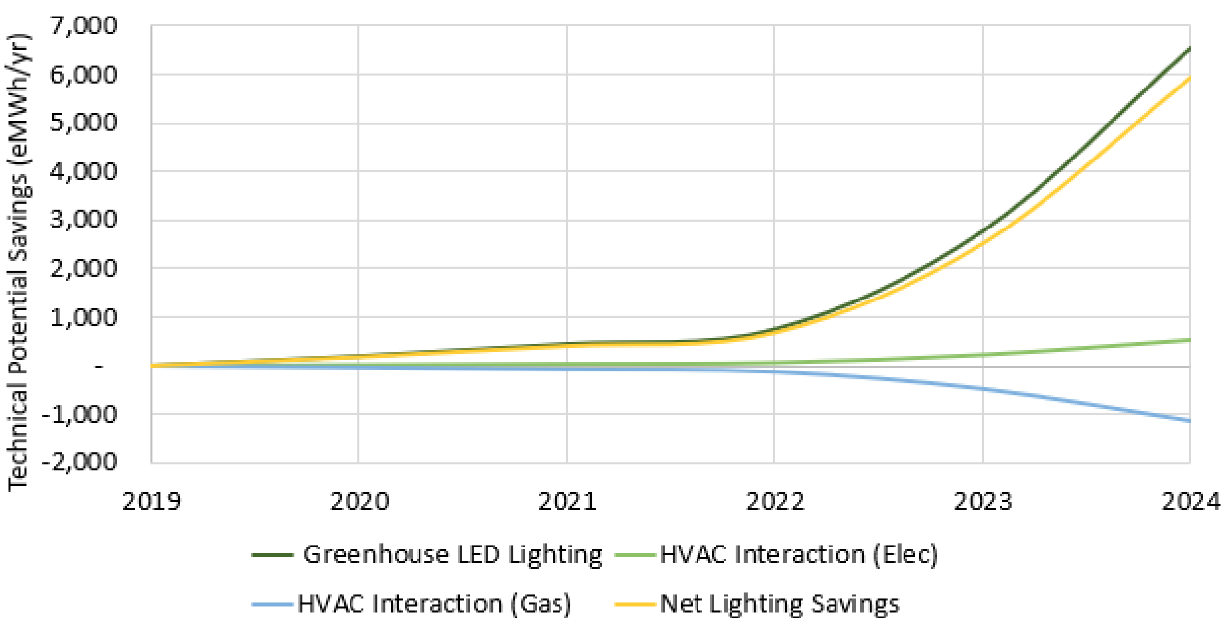

Figure 4-17: Economic Potential Savings (eMWh/yr), Ontario Greenhouses, LED Lighting with Interactive HVAC Effects

4.3.2 Warehouse Results

Table 4-11 and Figure 4-18 show the technical and economic consumption and savings in Ontario warehouses from 2019-2024, for all fuels. More detailed results by measure and fuel type are shown below.

Table 4-11: Forecasted Annual Energy Consumption and Savings (eMWh), Ontario Warehouses

Year	Reference Consumption	Technical Potential Consumption	Technical Potential Savings	% Savings	Economic Potential Consumption	Economic Potential Savings	% Savings
2019	318,706	313,331	5,376	1.7%	318,134	572	0.2%
2020	674,317	647,242	27,076	4.0%	661,420	12,897	1.9%
2021	764,229	713,554	50,675	6.6%	737,883	26,346	3.4%
2022	854,131	774,510	79,620	9.3%	811,075	43,055	5.0%
2023	1,014,906	900,805	114,101	11.2%	949,267	65,639	6.5%
2024	1,014,906	869,817	145,089	14.3%	928,688	86,218	8.5%

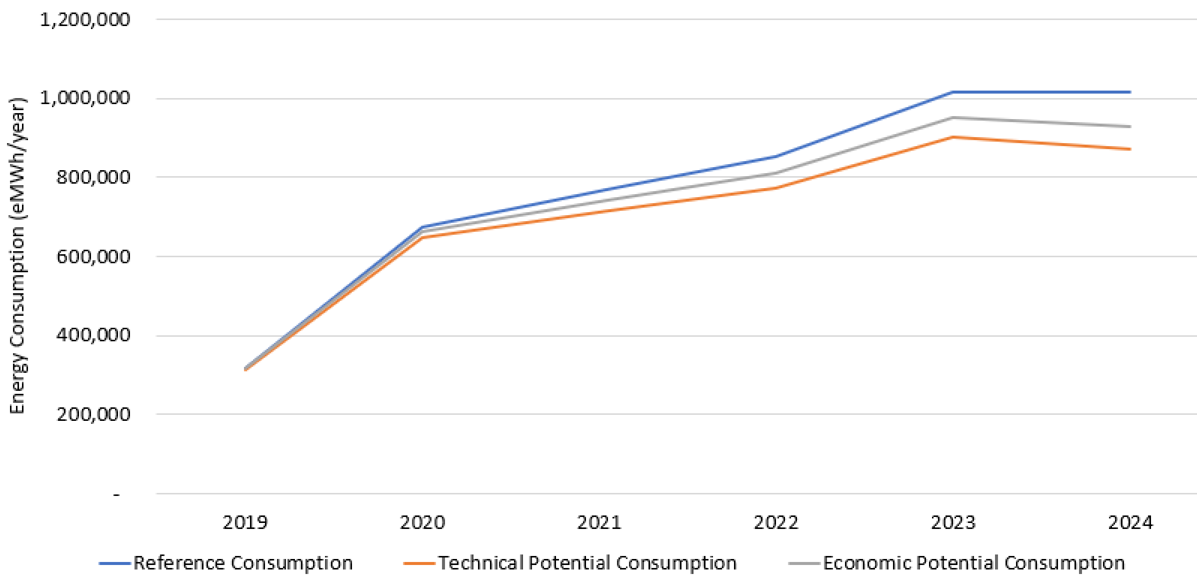

Figure 4-18: Forecasted Annual Energy Consumption (eMWh), Ontario Warehouses

4.3.2.1 Technical Savings by Measure and Fuel

Table 4-12 shows the annual technical savings potential of measures for warehouses in Ontario, separated by fuel. Figure 4-19 and Figure 4-20 illustrate the savings for all measures for all electric and gas measures respectively, except lighting. Lighting savings, along with the HVAC interactive effects, are shown separately in Figure 4-21, since the scale of these savings is much larger, and that measure impacts both gas and electricity use.

Overall, the biggest potential for savings is LED lighting, even with interactive effects taken into consideration.

Table 4-12: Technical Potential Savings by Measure and Fuel (eMWh/yr), Ontario Warehouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Chiller - Air-Cooled	31	307	631	1,007	1,509	1,919
	Chiller - Water-Cooled	38	681	561	909	1,075	1,941
	Dehumidifier	354	1,834	3,556	5,625	8,116	10,310
	DX Unit Gas Heating	115	932	1,883	2,989	4,437	5,620
	DX Unit Heat Pump	67	790	1,643	2,635	3,975	5,071
	Waterside Economizer	144	768	768	768	1,044	1,044
	Warehouse LED Lighting	4,930	23,177	44,154	69,339	98,982	124,975
	LED HVAC Interaction (Elec Heating & Cooling)	97	455	867	1,362	1,944	2,455
Natural Gas	HVAC w Energy Recovery	109	518	1,158	2,122	3,208	4,619
	LED HVAC Interaction (Gas Heating)	-507	-2,386	-4,545	-7,138	-10,189	-12,865
Electricity & Natural Gas	Net Lighting Savings	4,519	21,246	40,476	63,564	90,737	114,565

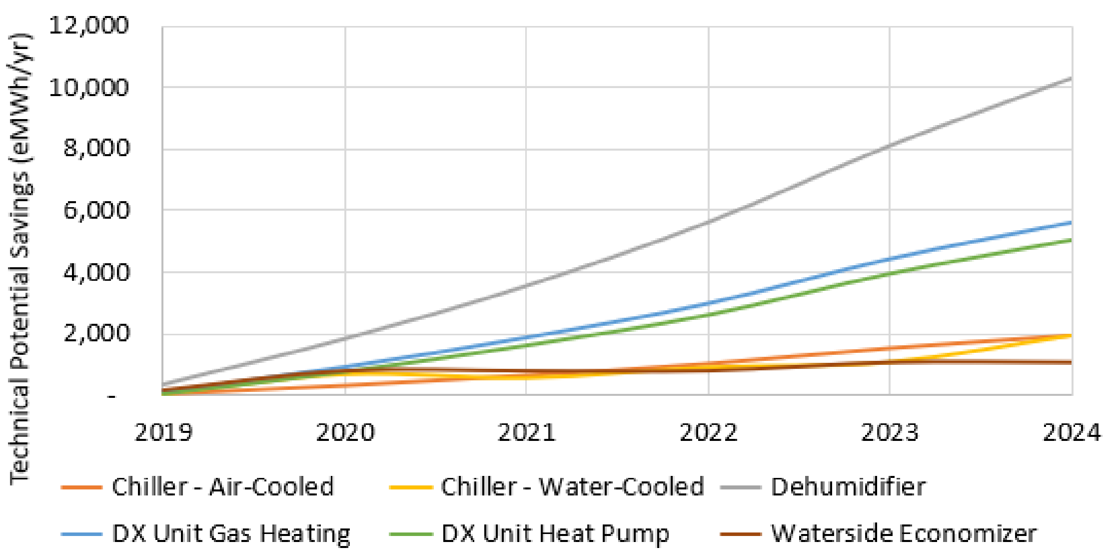

Figure 4-19: Electric Technical Potential Savings by Measure (eMWh/yr), Excluding Lighting, Ontario Warehouses

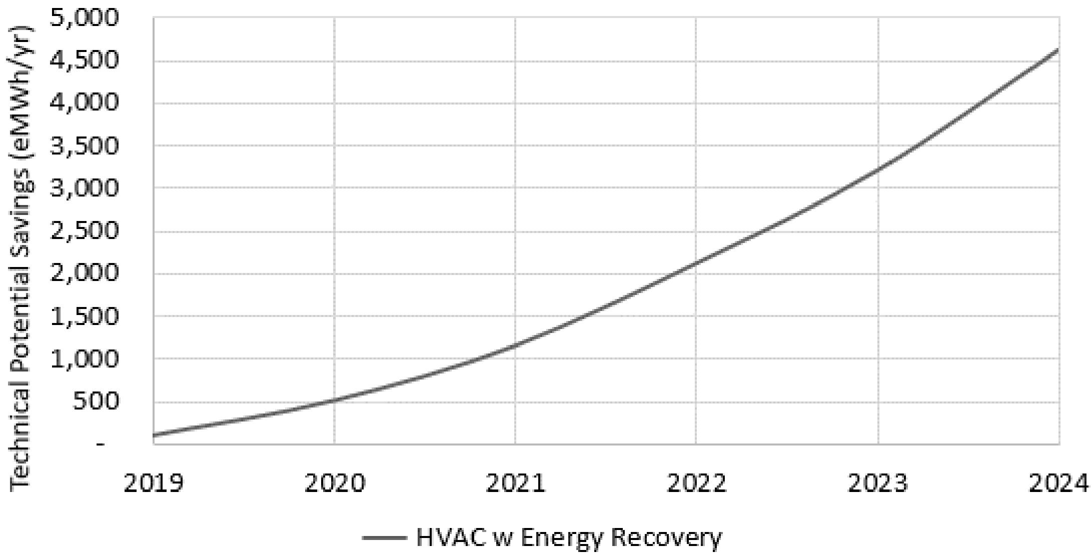

Figure 4-20: Gas Technical Potential Savings by Measure (eMWh/yr), Excluding Lighting, Ontario Warehouses

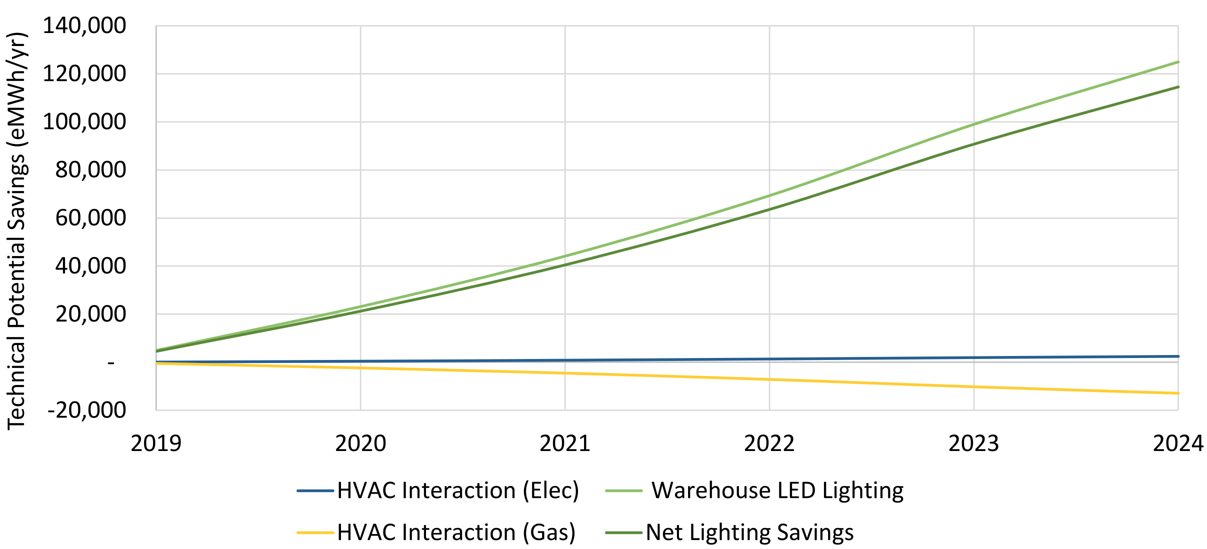

Figure 4-21: Technical Potential Savings by Measure (eMWh/yr), Lighting with Interactive HVAC Effects, Ontario Warehouses

4.3.2.2 Economic Savings by Measure

Table 4-13 and Figure 4-22 show the economic savings potential of measures in warehouses in Ontario, excluding lighting. Lighting savings with interactive effects are shown in Figure 4-23. Seven measures, including lighting, pass the economic screen.

Table 4-13: Economic Potential Savings by Measure (eMWh/yr), Ontario Warehouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Chiller - Air-Cooled	31	309	635	1,015	1,522	1,938
	Chiller - Water-Cooled	4	710	554	901	1,065	1,931
	Dehumidifier	354	1,834	3,556	5,625	8,116	10,310
	DX Unit Gas Heating	116	938	1,898	3,019	4,486	5,690
	DX Unit Heat Pump	67	793	1,652	2,653	4,004	5,112
	Warehouse LED Lighting	-	8,388	19,013	31,874	49,686	65,820
	Waterside Economizer	-	624	624	624	900	900
	LED HVAC Interaction (Elec Heating & Cooling)	-	165	373	626	976	1,293
Natural Gas	HVAC Interaction (Gas Heating)	-	-863	-1,957	-3,281	-5,115	-6,776
Electricity & Natural Gas	Net Lighting Savings	-	7,689	17,429	29,219	45,547	60,337

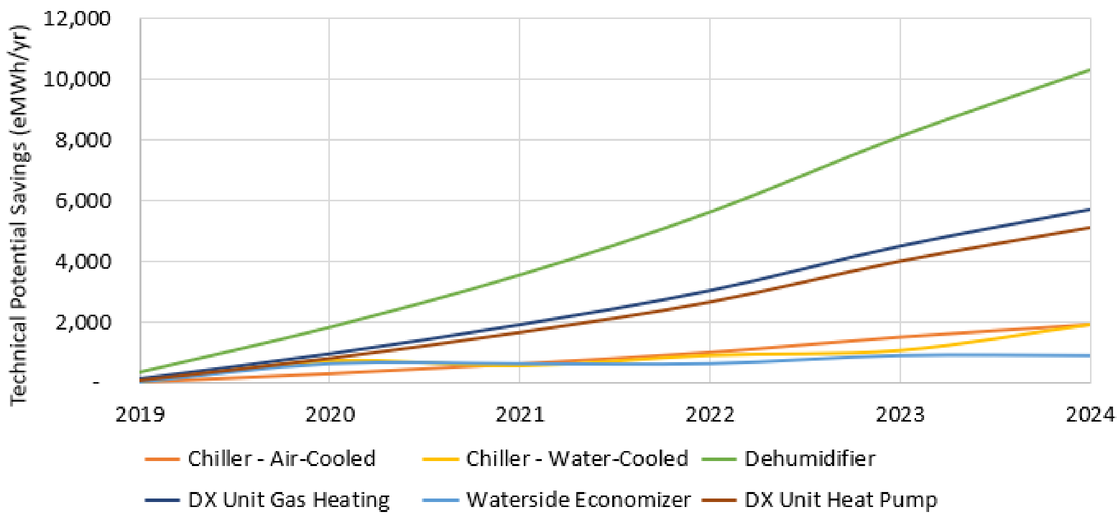

Figure 4-22: Electric Economic Potential Savings by Measure (eMWh/yr), Ontario Warehouses

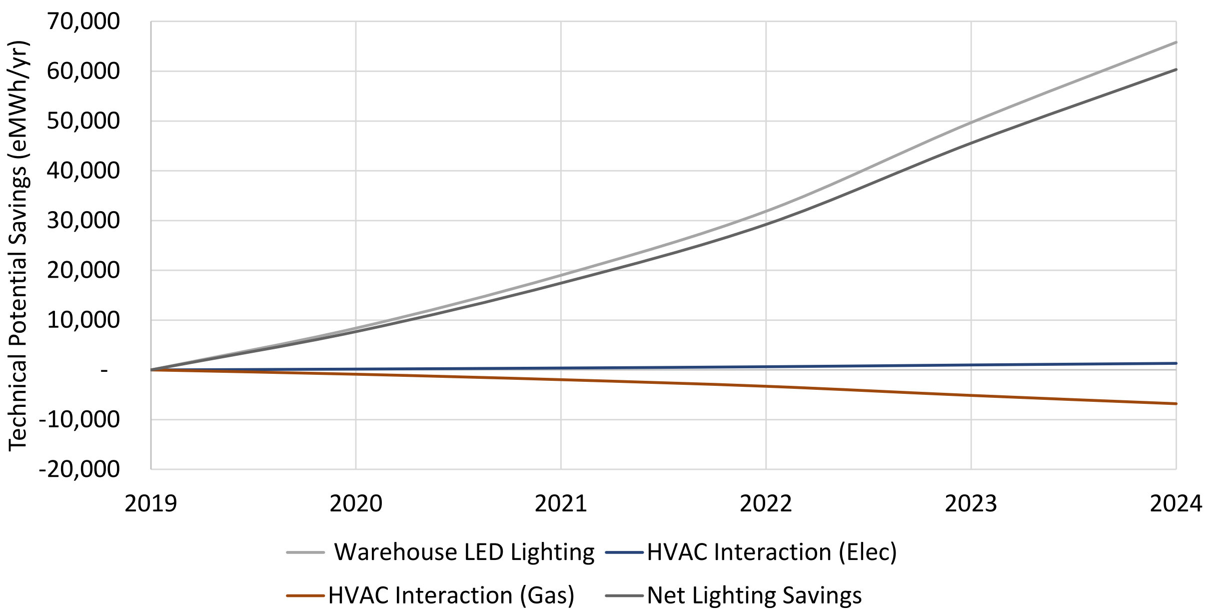

Figure 4-23: Economic Potential Savings (eMWh/yr), Ontario Warehouses, LED Lighting with Interactive HVAC Effects

4.4 Energy Savings Potential – Colorado

This section presents the energy savings results for both greenhouses and warehouses in Colorado.

4.4.1 Greenhouse Results

Table 4-14 and Figure 4-24 show the technical and economic consumption and savings in Colorado greenhouses from 2019-2024, for all fuels. More detailed results by measure and fuel type are shown below.

Table 4-14: Total Forecasted Annual Energy Consumption and Savings (eMWh), Colorado Greenhouses

Year	Reference Consumption	Technical Potential Consumption	Technical Potential Savings	% Savings	Economic Potential Consumption	Economic Potential Savings	% Savings
2019	186,574	174,672	11,902	6.4%	175,911	10,663	5.7%
2020	200,623	183,917	16,706	8.3%	186,259	14,365	7.2%
2021	215,730	193,660	22,070	10.2%	197,106	18,625	8.6%
2022	231,975	203,939	28,035	12.1%	208,489	23,486	10.1%
2023	249,442	214,794	34,648	13.9%	220,449	28,994	11.6%
2024	268,225	226,267	41,958	15.6%	233,028	35,198	13.1%

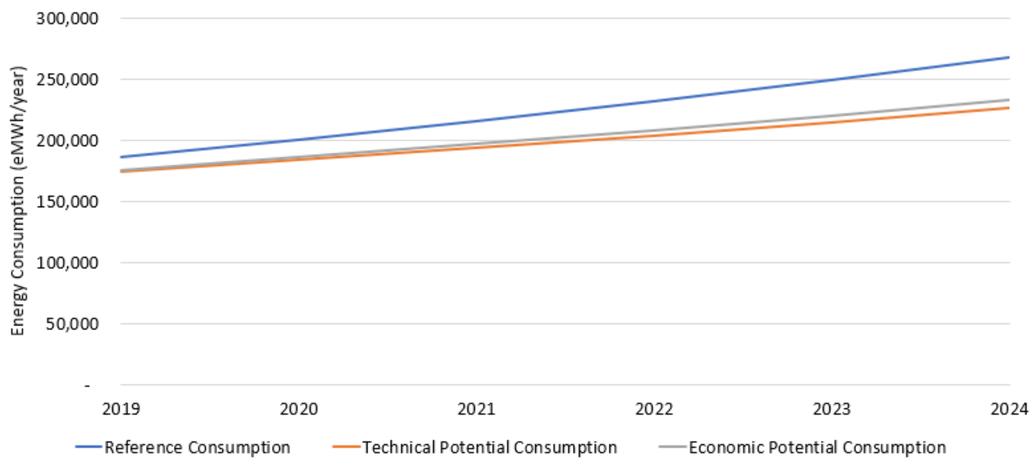

Figure 4-24: Forecasted Annual Energy Consumption (eMWh), Colorado Greenhouses

4.4.1.1 Technical Savings by Measure and Fuel

Overall, the biggest potential for electric savings LED lighting, even with interactive effects taken into consideration. The biggest potential for gas savings is with energy curtains.

Table 4 15 shows the annual technical savings potential of measures for greenhouses in Colorado, separated by fuel. Figure 4-25 illustrates the savings for all electric and gas measures, except lighting. Lighting savings, along with the HVAC interactive effects, are shown separately in Figure 4-26, since the scale of these savings is much larger.

Overall, the biggest potential for electric savings LED lighting, even with interactive effects taken into consideration. The biggest potential for gas savings is with energy curtains.

Table 4-15: Technical Potential Savings by Measure and Fuel (eMWh/yr), Colorado Greenhouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	VFD on Supply Fan/Exhaust Fan	136	797	1,506	2,270	3,090	3,973
	Greenhouse LED Lighting	1,181	2,609	4,303	6,282	8,568	11,185
	LED HVAC Interaction (Elec Heating & Cooling)	127	280	461	673	918	1,198
Natural Gas	Energy Curtains	7,065	8,873	10,833	12,955	15,252	17,737
	Condensing Boiler	30	71	125	192	274	371
	Condensing Unit Heater	75	178	313	481	685	929
	LED HVAC Interaction (Heating)	-162	-358	-591	-862	-1,176	-1,535
Electricity & Natural Gas	Net Lighting Savings	1,145	2,530	4,173	6,093	8,310	10,848

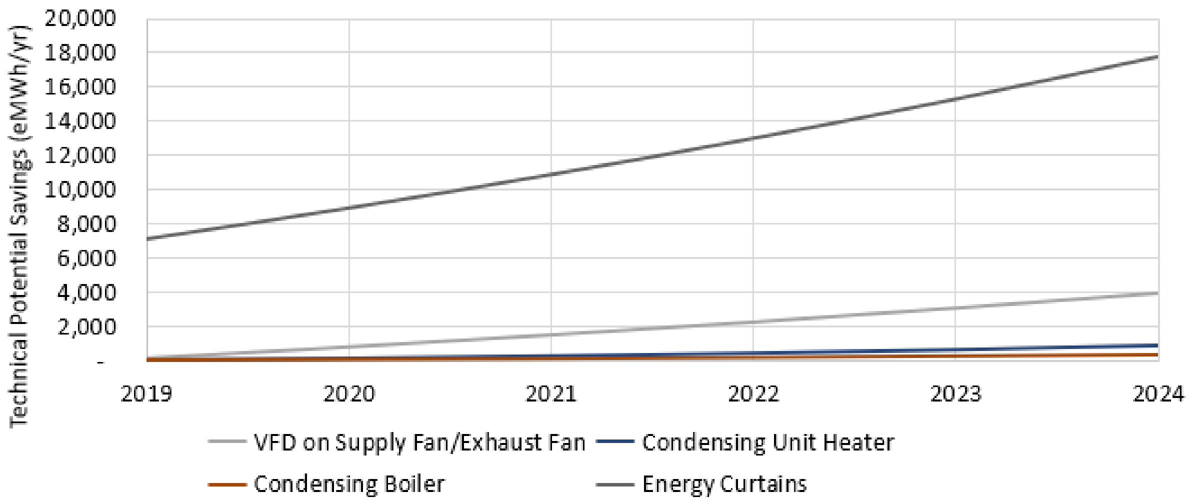

Figure 4-25: Technical Potential Savings by Measure (eMWh/yr), Colorado Greenhouses, Excluding Lighting

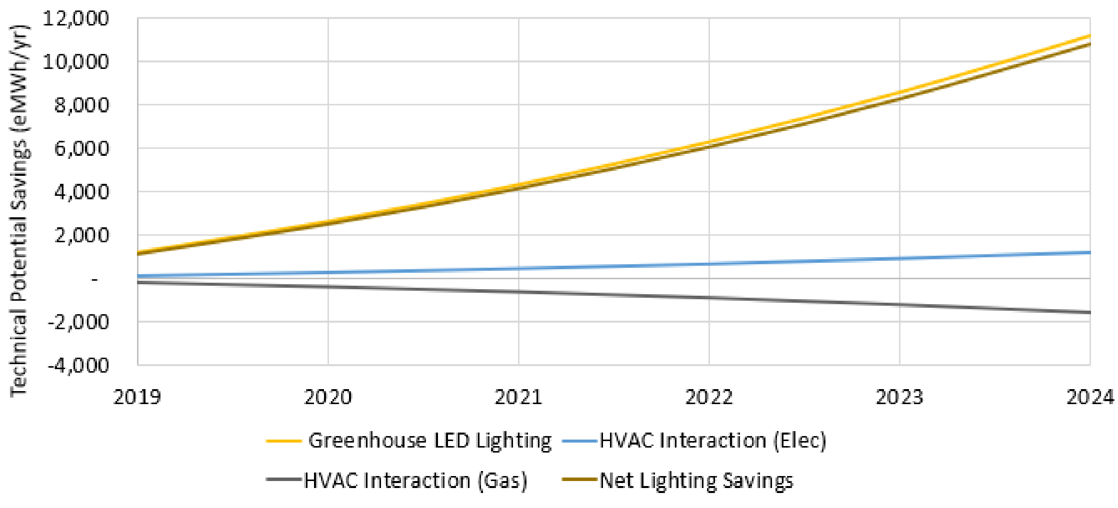

Figure 4-26: Technical Potential Savings (eMWh/yr), Colorado Greenhouses, LED Lighting with Interactive HVAC Effects

4.4.1.2 Economic Savings by Measure

Table 4-16 shows the economic savings potential of measures in greenhouses in Colorado by fuel. Figure 4-27 show the economic potential of both electric and gas measures. LED lighting economic savings are shown separately, in Figure 4-28.

Table 4-16: Economic Potential Savings by Measure (eMWh/yr), Colorado Greenhouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	VFD on Supply Fan/Exhaust Fan	-	660	1,370	2,133	2,954	3,837
	Greenhouse LED Lighting	-	247	760	1,558	2,664	4,099
	LED HVAC Interaction (Elec Heating & Cooling)	-	26	81	167	285	439
Natural Gas	Energy Curtains	7,041	8,824	10,760	12,858	15,130	17,591
	Condensing Boiler	30	70	123	189	270	366
	Condensing Unit Heater	74	176	308	474	675	915
	LED HVAC Interaction (Heating)	-162	-358	-591	-862	-1,176	-1,535
Electricity & Natural Gas	Net Lighting Savings	-162	-85	251	863	1,773	3,003

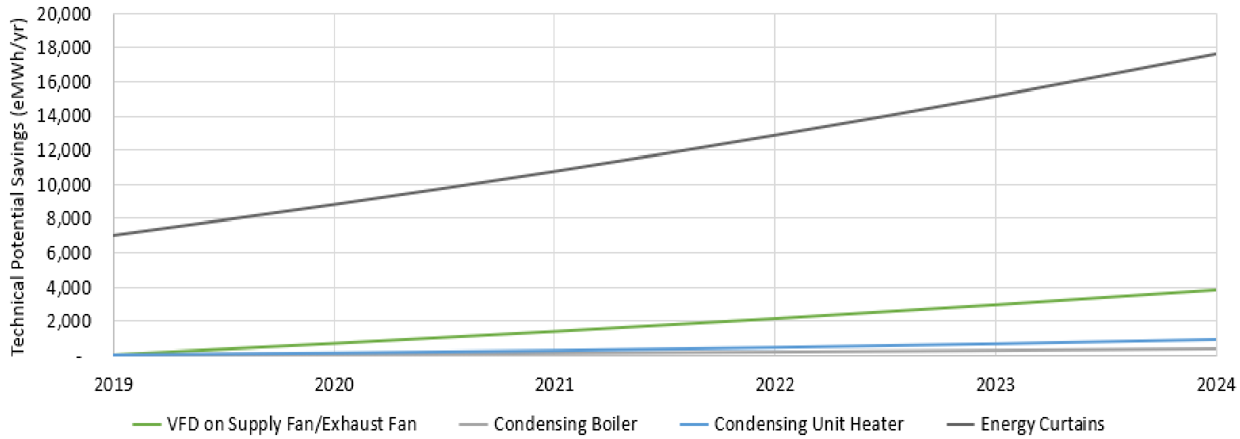

Figure 4-27: Economic Potential Savings by Measure (eMWh/yr), Colorado Greenhouses

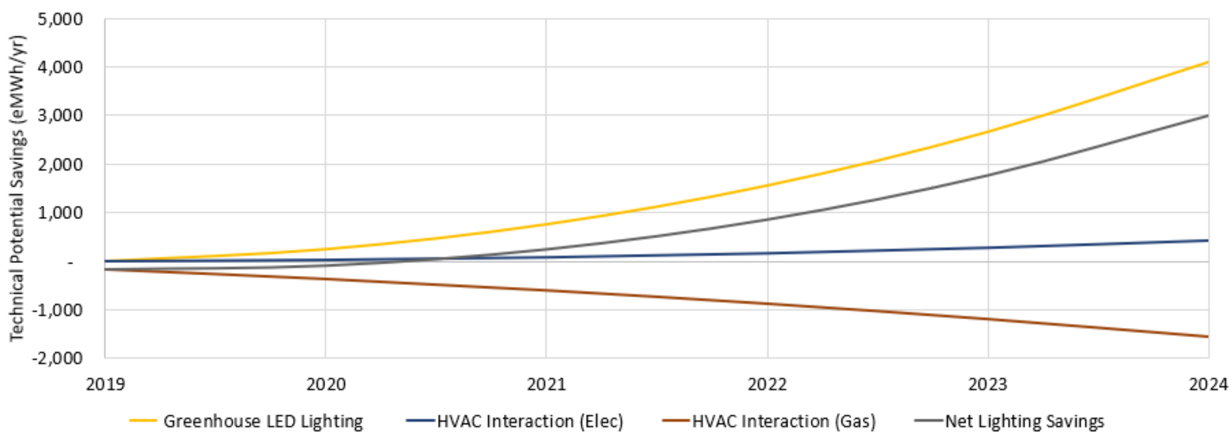

Figure 4-28: Economic Potential Savings (eMWh/yr), Colorado Greenhouses, LED Lighting with Interactive HVAC Effects

4.4.2 Warehouse Results

Table 4-17 and Figure 4-29 show the technical and economic consumption and savings in Colorado warehouses from 2019-2024, for all fuels. More detailed results by measure and fuel type are shown as well.

Table 4-17: Forecasted Annual Energy Consumption and Savings (eMWh), Colorado Warehouses

Year	Reference Consumption	Technical Potential Consumption	Technical Potential Savings	% Savings	Economic Potential Consumption	Economic Potential Savings	% Savings
2019	1,381,932	1,360,220	21,712	1.6%	1,379,356	2,576	0.2%
2020	1,485,991	1,434,774	51,217	3.4%	1,473,079	12,912	0.9%
2021	1,597,887	1,515,280	82,606	5.2%	1,572,651	25,235	1.6%
2022	1,718,207	1,595,765	122,442	7.1%	1,672,111	46,097	2.7%
2023	1,847,588	1,678,573	169,015	9.1%	1,773,877	73,712	4.0%
2024	1,986,712	1,763,891	222,821	11.2%	1,878,136	108,576	5.5%

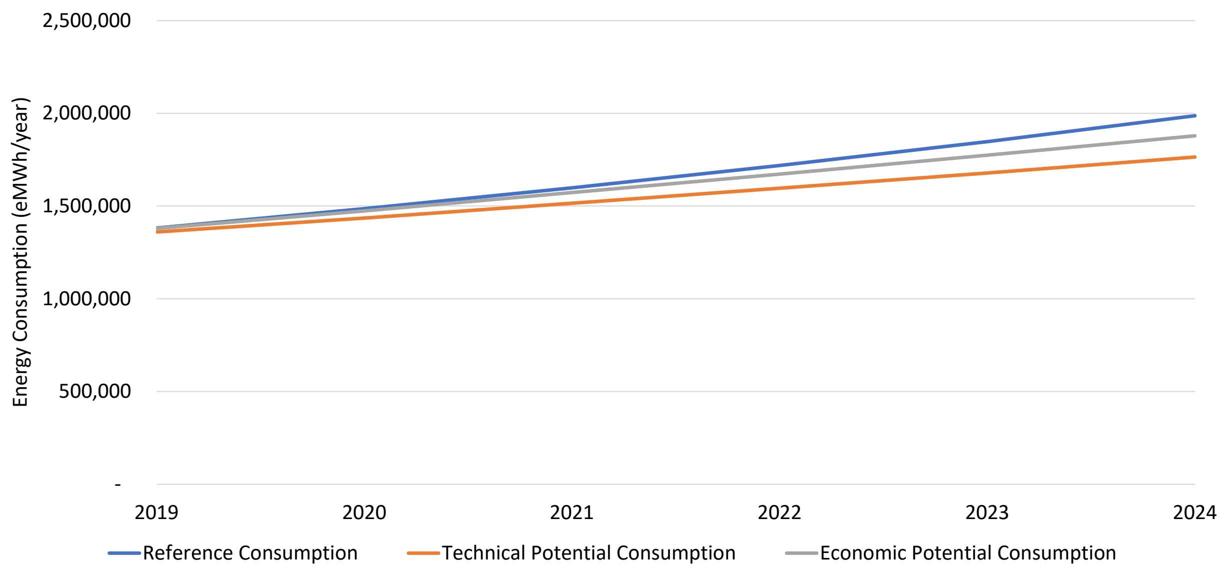

Figure 4-29: Forecasted Annual Energy Consumption (eMWh), Colorado Warehouses

4.4.2.1 Technical Savings by Measure and Fuel

Table 4-18 shows the annual technical savings potential of measures for warehouses in Colorado. For warehouses in Colorado, all heating is electric, so only electric savings are present. Figure 4-30 illustrates the savings for all measures, except lighting. Lighting savings, along with the HVAC interactive effects, are shown separately in Figure 4-31, since the scale of these savings is much larger.

Overall, the biggest potential for savings is LED lighting, even with interactive effects taken into consideration.

Table 4-18: Technical Potential Savings by Measure and Fuel (eMWh/yr), Colorado Warehouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Chiller - Air-Cooled	148	416	810	1,336	1,999	2,807
	Chiller - Water-Cooled	62	1,880	618	1,068	1,643	2,353
	Dehumidifier	1,530	3,471	5,855	8,714	12,085	16,006
	DX Unit Heat Pump	829	2,525	5,127	8,679	13,226	18,821
	Waterside Economizer	111	881	857	1,408	1,977	2,577
	Warehouse LED Lighting	20,417	45,106	74,387	108,607	148,138	193,379
	LED HVAC Interaction (Elec Heating & Cooling)	-1,385	-3,061	-5,048	-7,370	-10,052	-13,122
	Net Lighting Savings	19,032	42,045	69,339	101,237	138,085	180,256

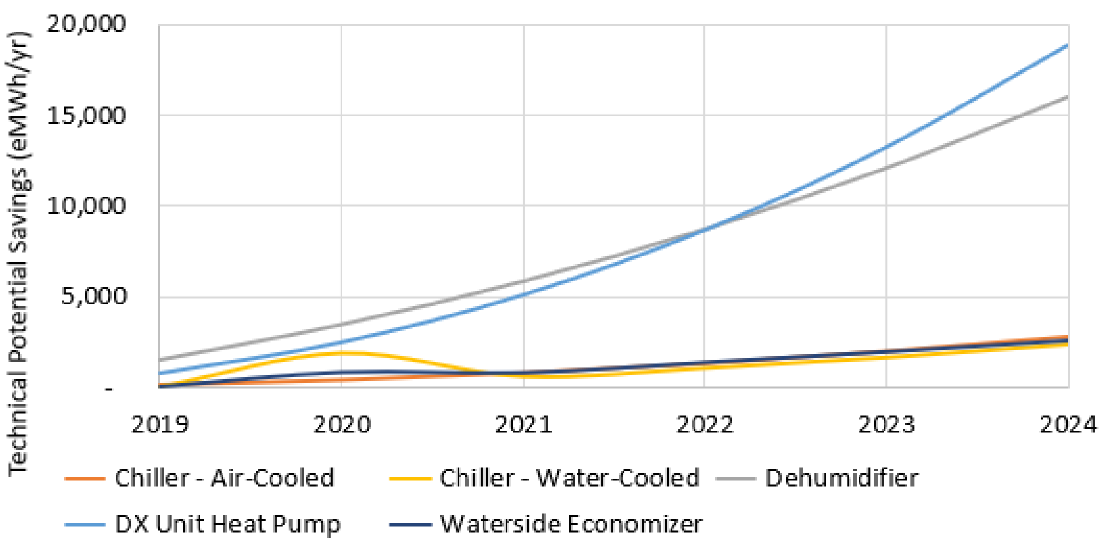

Figure 4-30: Electric Technical Potential Savings by Measure (eMWh/yr), Excluding Lighting, Colorado Warehouses

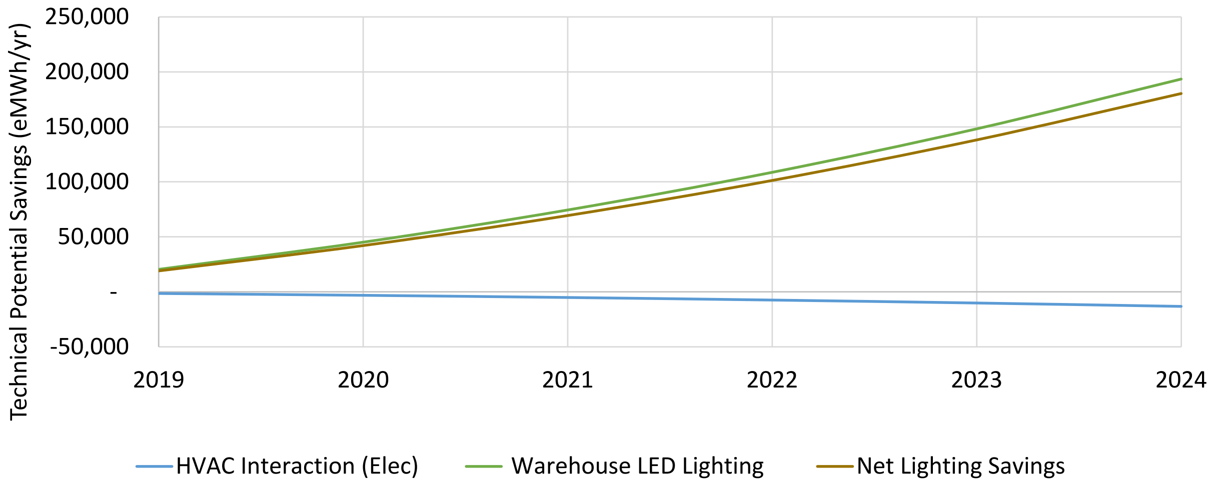

Figure 4-31: Technical Potential Savings by Measure (eMWh/yr), Lighting with Interactive HVAC Effects, Colorado Warehouses

4.4.2.2 Economic Savings by Measure

Table 4-19 and Figure 4-32 show the economic savings potential of measures in warehouses in Colorado, excluding lighting. Lighting savings with interactive effects are shown in Figure 4-33. Six measures, including lighting, pass the economic screen.

Table 4-19: Economic Potential Savings by Measure (eMWh/yr), Colorado Warehouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Chiller - Air-Cooled	149	421	820	1,353	2,026	2,847
	Chiller - Water-Cooled	62	1,957	625	1,082	1,666	2,387
	Dehumidifier	1,530	3,471	5,855	8,714	12,085	16,006
	DX Unit Heat Pump	835	2,549	5,182	8,777	13,380	19,041
	Waterside Economizer	-	533	510	1,061	1,629	2,230
	Warehouse LED Lighting	-	4,271	13,135	26,938	46,051	70,874
	HVAC Interaction (Elec Heating & Cooling)	-	-290	-891	-1,828	-3,125	-4,809
	Net Lighting Savings	-	3,981	12,244	25,110	42,926	66,065

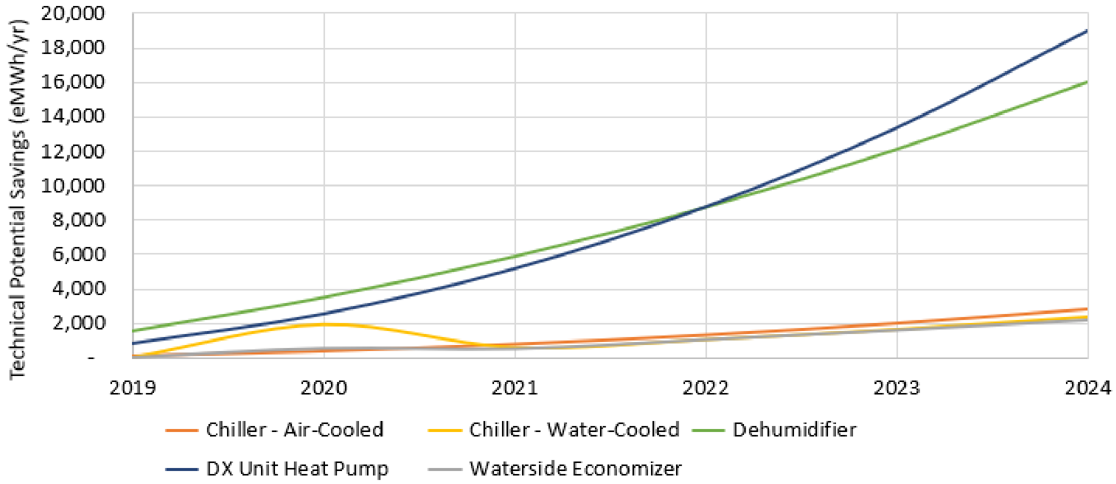

Figure 4-32: Economic Potential Savings by Measure (eMWh/yr), Colorado Warehouses

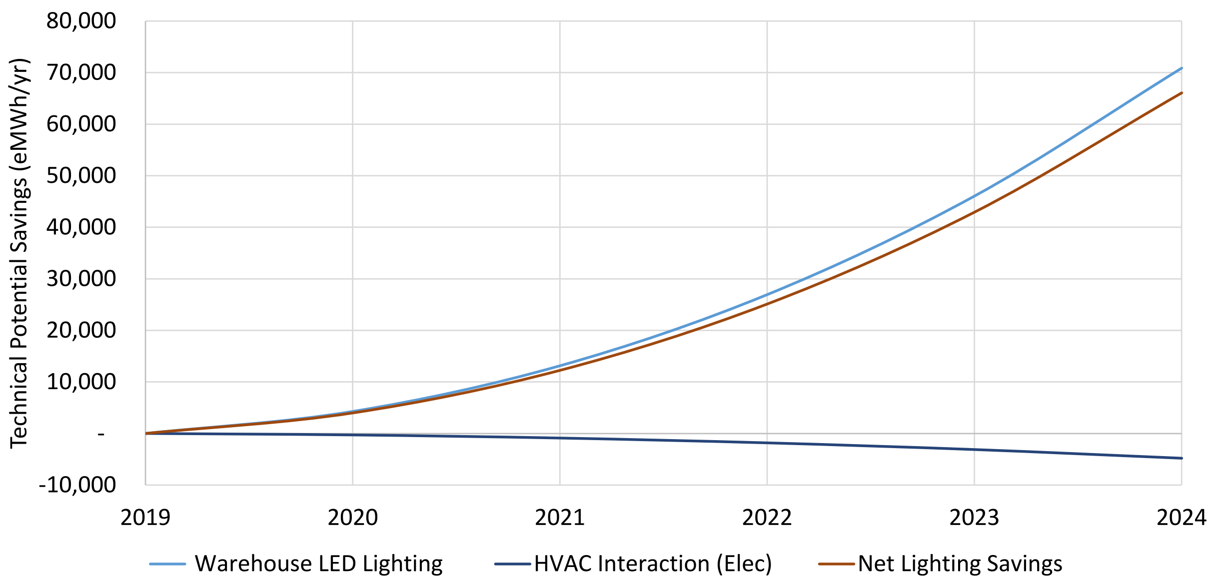

Figure 4-33: Economic Potential Savings (eMWh/yr), Colorado Warehouses, LED Lighting with Interactive HVAC Effects

4.5 Energy Savings Potential – Oregon

This section presents the energy savings results for both greenhouses and warehouses in Oregon.

4.5.1 Greenhouse Results

Table 4-20 and Figure 4-34 show the technical and economic consumption and savings in Oregon greenhouses from 2019-2024, for all fuels. More detailed results by measure and fuel type are shown.

Table 4-20: Total Forecasted Annual Energy Consumption and Savings (eMWh), Oregon Greenhouses

Year	Reference Consumption	Technical Potential Consumption	Technical Potential Savings	% Savings	Economic Potential Consumption	Economic Potential Savings	% Savings
2019	177,013	166,503	10,510	5.9%	167,737	9,276	5.2%
2020	181,527	168,759	12,768	7.0%	171,026	10,501	5.8%
2021	186,156	171,015	15,141	8.1%	174,316	11,840	6.4%
2022	190,903	173,270	17,633	9.2%	177,606	13,297	7.0%
2023	195,771	175,525	20,246	10.3%	180,896	14,875	7.6%
2024	200,763	177,779	22,984	11.4%	184,185	16,578	8.3%

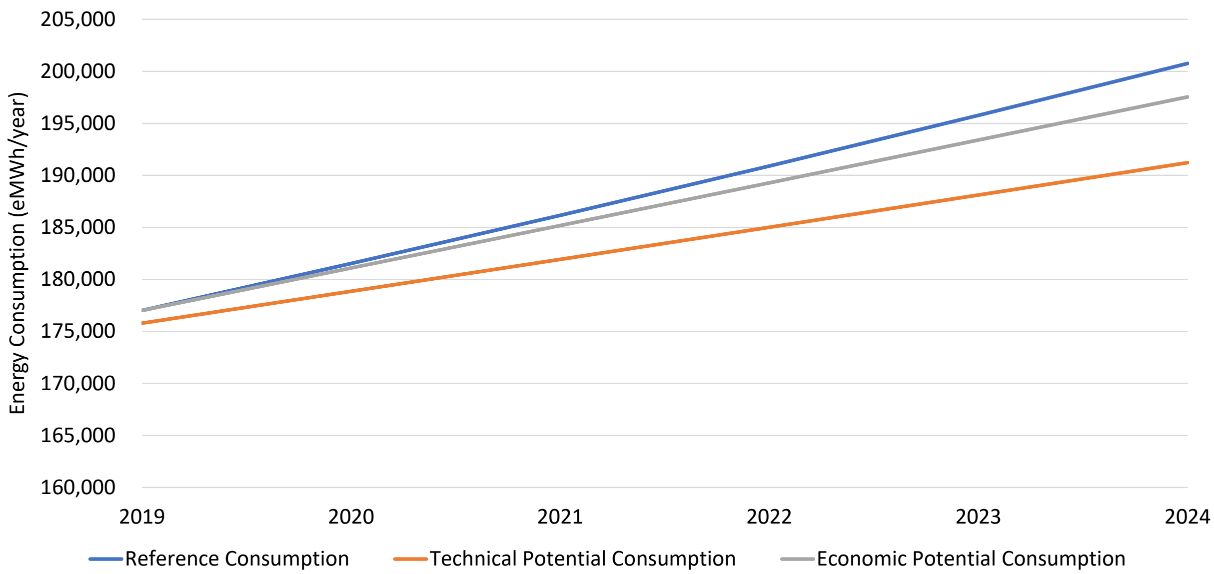

Figure 4-34: Forecasted Annual Energy Consumption (eMWh), Oregon Greenhouses

4.5.1.1 Technical Savings by Measure and Fuel

Overall, the biggest potential for electric savings LED lighting, even with interactive effects taken into consideration. The biggest potential for gas savings is with energy curtains.

Table 4-21 shows the annual technical savings potential of measures for greenhouses in Oregon, separated by fuel. Figure 4-35 illustrates the savings for all electric and gas measures, except lighting. Lighting savings, along with the HVAC interactive effects, are shown separately in Figure 4-26, since the scale of these savings is much larger.

Overall, the biggest potential for electric savings LED lighting, even with interactive effects taken into consideration. The biggest potential for gas savings is with energy curtains.

Table 4-21: Technical Potential Savings by Measure and Fuel (eMWh/yr), Oregon Greenhouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	VFD on Supply Fan/Exhaust Fan	201	554	916	1,286	1,667	2,057
	Greenhouse LED Lighting	1,009	2,089	3,243	4,472	5,778	7,163
	LED HVAC Interaction (Elec Heating & Cooling)	108	224	347	479	619	767
Natural Gas	Energy Curtains	6,206	6,758	7,327	7,916	8,524	9,152
	Condensing Boiler	26	56	90	127	168	213
	Condensing Unit Heater	66	140	224	317	420	533
	LED HVAC Interaction (Heating)	-138	-287	-445	-614	-793	-983
Electricity & Natural Gas	Net Lighting Savings	979	2,026	3,145	4,337	5,604	6,947

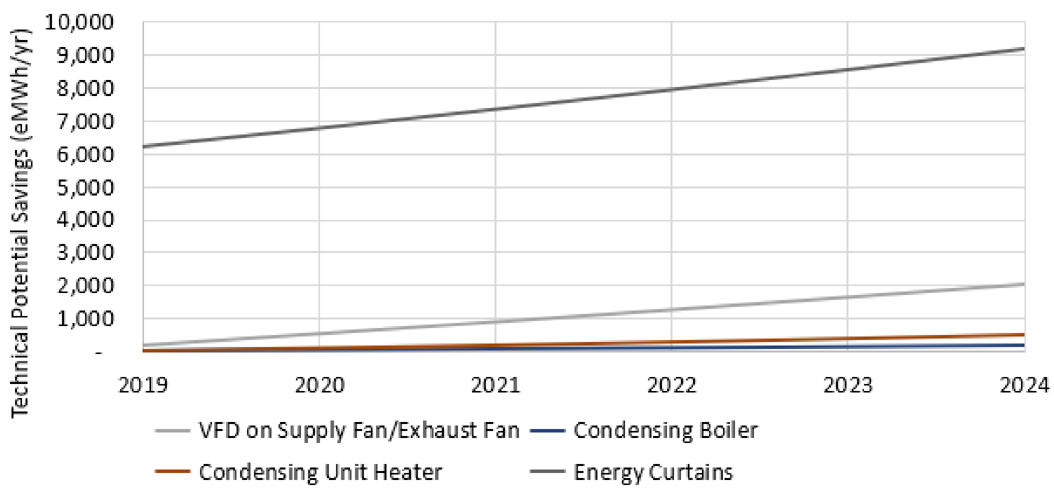

Figure 4-35: Technical Potential Savings by Measure (eMWh/yr), Oregon Greenhouses, Excluding Lighting

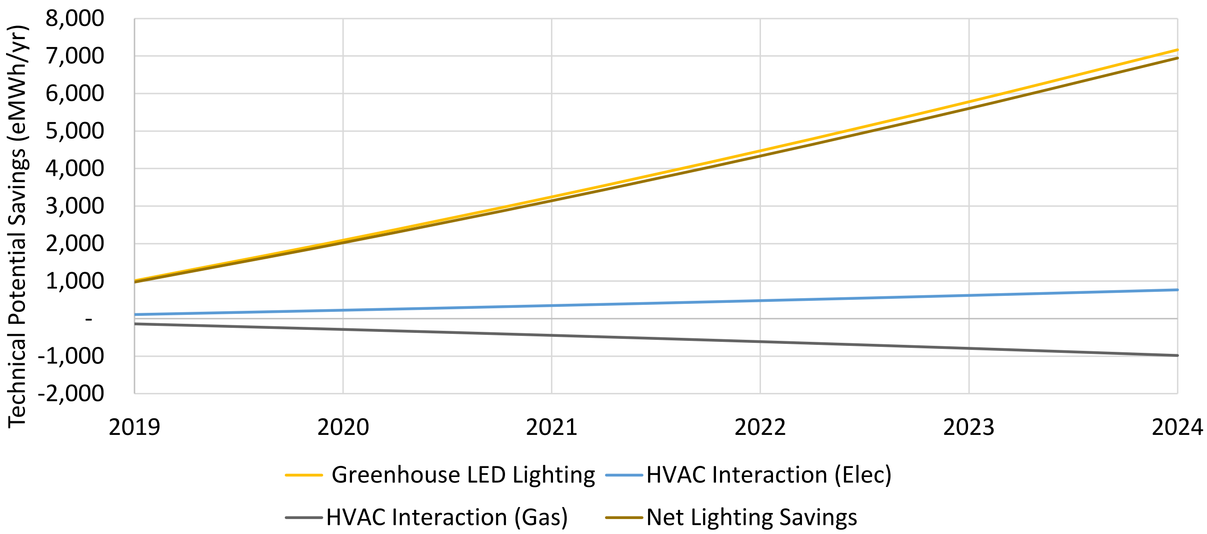

Figure 4-36: Technical Potential Savings (eMWh/yr), Oregon Greenhouses, LED Lighting with Interactive HVAC Effects

4.5.1.2 Economic Savings by Measure

Table 4-22 shows the economic savings potential of measures in greenhouses in Oregon by fuel. Figure 4-37 show the economic potential of both electric and gas measures, except for lighting. LED lighting economic savings are shown separately, in Figure 4-38.

Table 4-22: Economic Potential Savings by Measure (eMWh/yr), Oregon Greenhouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	VFD on Supply Fan/Exhaust Fan	-	353	714	1,085	1,465	1,855
	Greenhouse LED Lighting	-	71	216	436	733	1,110
	LED HVAC Interaction (Elec Heating & Cooling)	-	8	23	47	79	119
Natural Gas	Energy Curtains	6,186	6,716	7,265	7,833	8,420	9,027
	Condensing Boiler	-	3	10	20	34	52
	Condensing Unit Heater	-	8	25	51	86	131
	LED HVAC Interaction (Heating)	-	-10	-30	-60	-101	-152
Electricity & Natural Gas	Net Lighting Savings	-	69	210	423	711	1,076

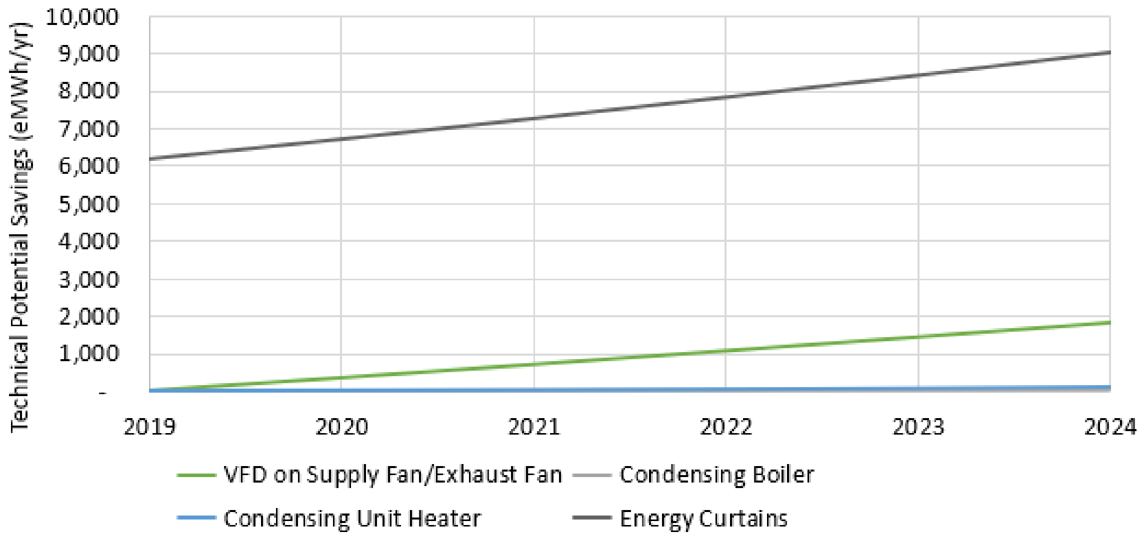

Figure 4-37: Economic Potential Savings by Measure (eMWh/yr), Oregon Greenhouses, Excluding Lighting

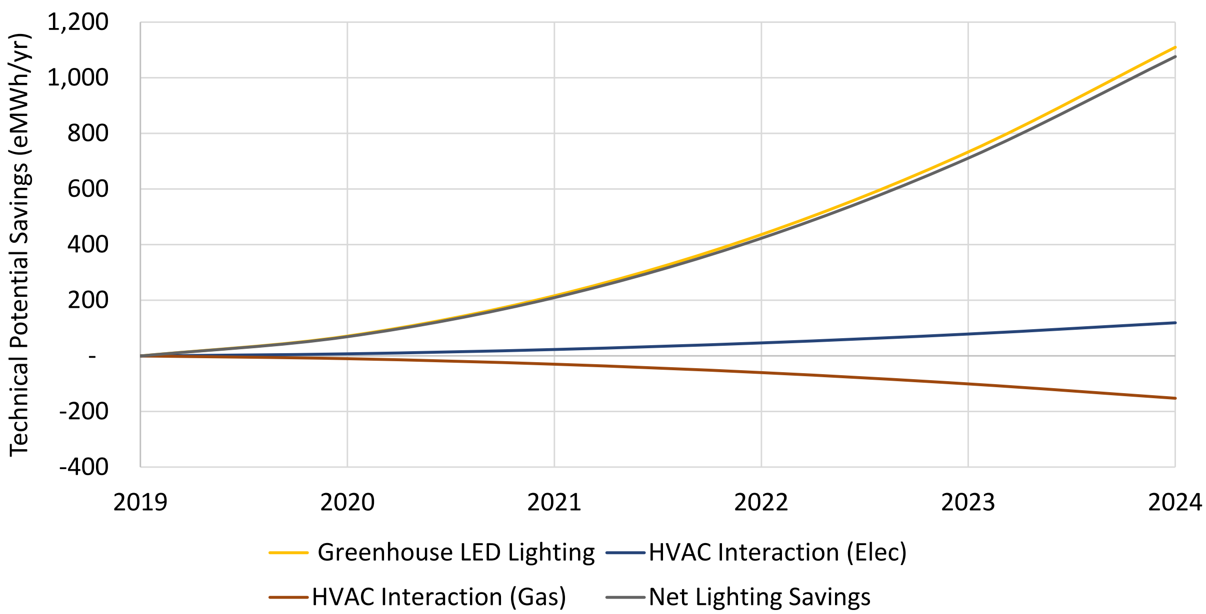

Figure 4-38: Technical Potential Savings (eMWh/yr), Oregon Greenhouses, LED Lighting with Interactive HVAC Effects

4.5.2 Warehouse Results

Table 4-23 and Figure 4-39 show the technical and economic consumption and savings in Oregon warehouses from 2019-2024, for all fuels. More detailed results by measure and fuel type are shown.

Table 4-23: Forecasted Annual Energy Consumption and Savings (eMWh), Oregon Warehouses

Year	Reference Consumption	Technical Potential Consumption	Technical Potential Savings	% Savings	Economic Potential Consumption	Economic Potential Savings	% Savings
2019	914,512	898,982	15,530	1.7%	912,558	1,954	0.2%
2020	937,832	904,455	33,376	3.6%	931,463	6,369	0.7%
2021	961,746	911,143	50,603	5.3%	951,615	10,131	1.1%
2022	986,271	916,119	70,152	7.1%	969,985	16,286	1.7%
2023	1,011,421	920,345	91,075	9.0%	987,588	23,833	2.4%
2024	1,037,212	923,810	113,402	10.9%	1,004,412	32,800	3.2%

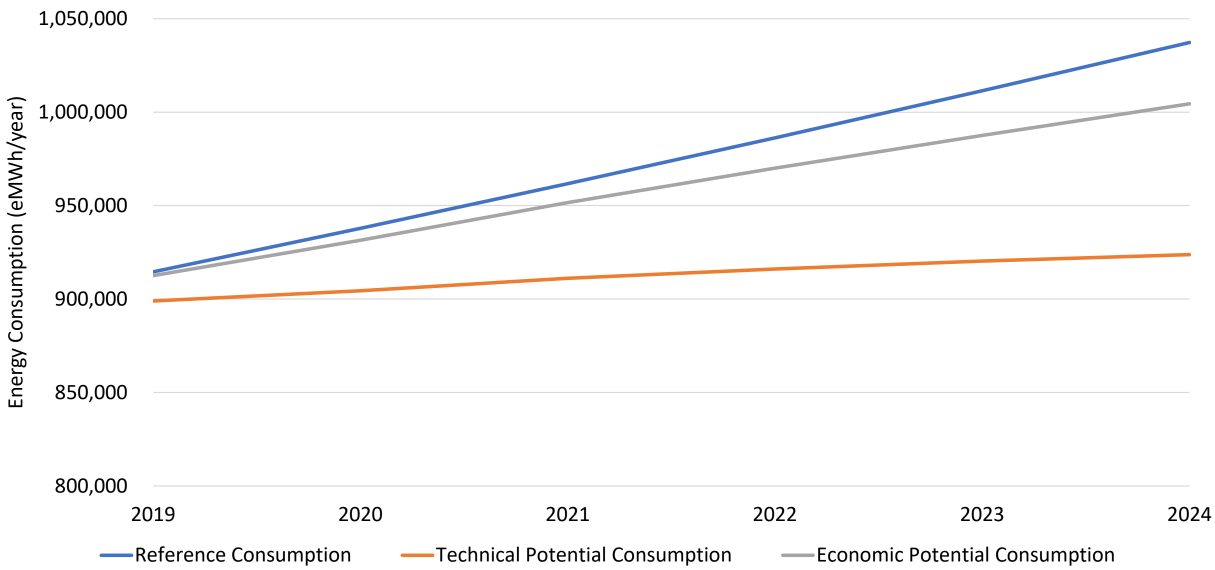

Figure 4-39: Forecasted Annual Energy Consumption (eMWh), Oregon Warehouses

4.5.2.1 Technical Savings by Measure and Fuel

Table 4-24 shows the annual technical savings potential of measures for warehouses in Oregon. For warehouses in Oregon, all heating is electric, so only electric savings are present. Figure 4-40 illustrates the savings for all measures, except lighting. Lighting savings, along with the HVAC interactive effects, are shown separately in Figure 4-41, since the scale of these savings is much larger.

Overall, the biggest potential for savings is LED lighting, even with interactive effects taken into consideration.

Table 4-24: Technical Potential Savings by Measure and Fuel (eMWh/yr), Oregon Warehouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Chiller - Air-Cooled	82	185	309	453	618	803
	Chiller - Water-Cooled	12	1,029	276	410	563	735
	Dehumidifier	1,094	2,287	3,583	4,983	6,490	8,108
	DX Unit Gas Heating	301	659	1,073	1,542	2,066	2,643
	DX Unit Heat Pump	458	1,070	1,836	2,752	3,817	5,027
	Waterside Economizer	129	284	279	377	471	566
	Warehouse LED Lighting	14,434	29,890	46,395	63,976	82,659	102,472
	LED HVAC Interaction (Elec Heating & Cooling)	-979	-2,028	-3,148	-4,341	-5,609	-6,953
	Net Lighting Savings	13,455	27,862	43,247	59,634	77,050	95,519

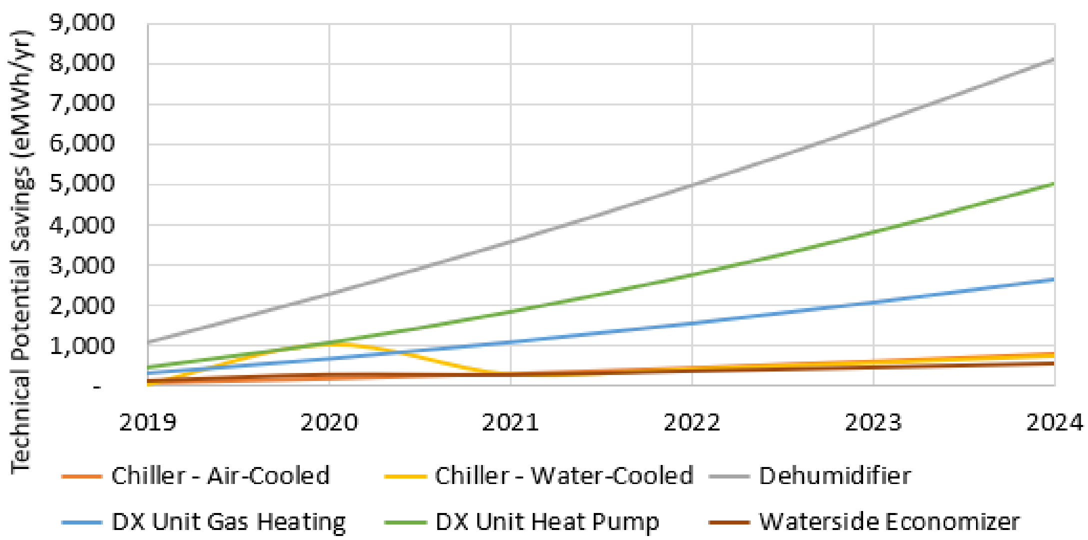

Figure 4-40: Electric Technical Potential Savings by Measure (eMWh/yr), Excluding Lighting, Oregon Warehouses

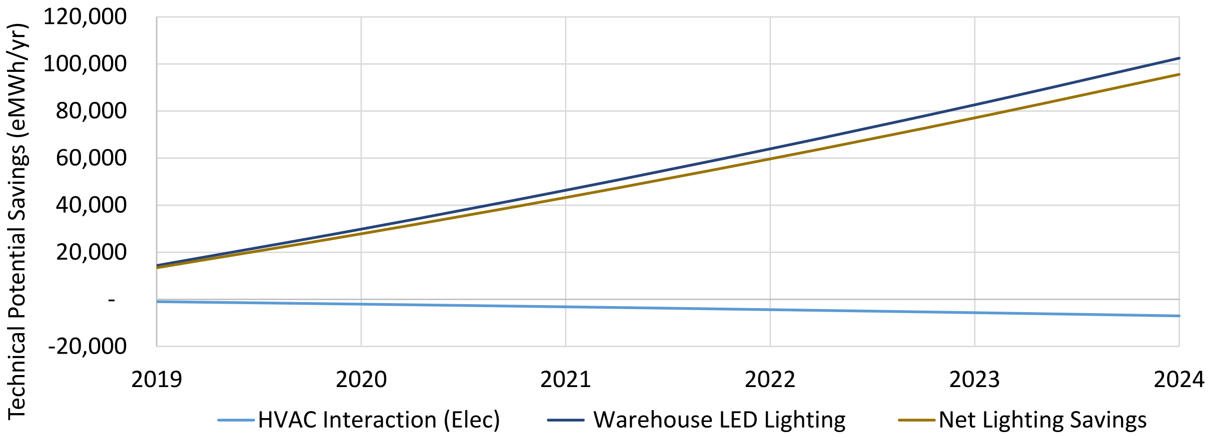

Figure 4-41: Technical Potential Savings by Measure (eMWh/yr), Lighting with Interactive HVAC Effects, Oregon Warehouses

4.5.2.2 Economic Savings by Measure

Table 4-25 and Figure 4-42 show the economic savings potential of measures in warehouses in Oregon, excluding lighting. Lighting savings with interactive effects are shown in Figure 4-33. Six measures, including lighting, pass the economic screen.

Table 4-25: Economic Potential Savings by Measure (eMWh/yr), Oregon Warehouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Chiller - Air-Cooled	83	188	316	466	638	831
	Chiller - Water-Cooled	12	1,083	281	420	579	759
	Dehumidifier	1,094	2,287	3,583	4,983	6,490	8,108
	DX Unit Gas Heating	304	670	1,098	1,588	2,137	2,746
	DX Unit Heat Pump	462	1,088	1,875	2,822	3,925	5,183
	Waterside Economizer	-	100	95	192	287	382
	Warehouse LED Lighting	-	1,022	3,093	6,240	10,489	15,868
	HVAC Interaction (Elec Heating & Cooling)	-	-69	-210	-423	-712	-1,077
	Net Lighting Savings	-	953	2,884	5,816	9,777	14,792

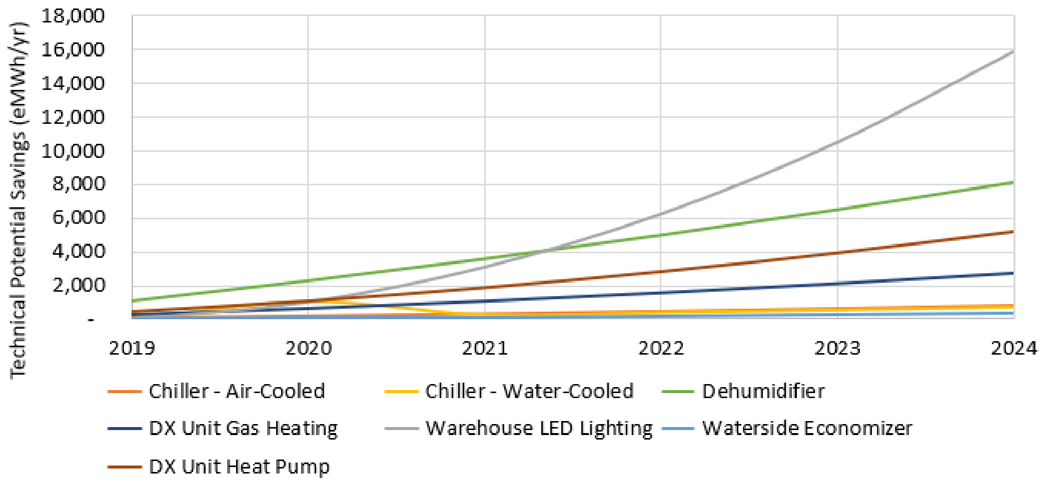

Figure 4-42: Economic Potential Savings by Measure (eMWh/yr), Oregon Warehouses

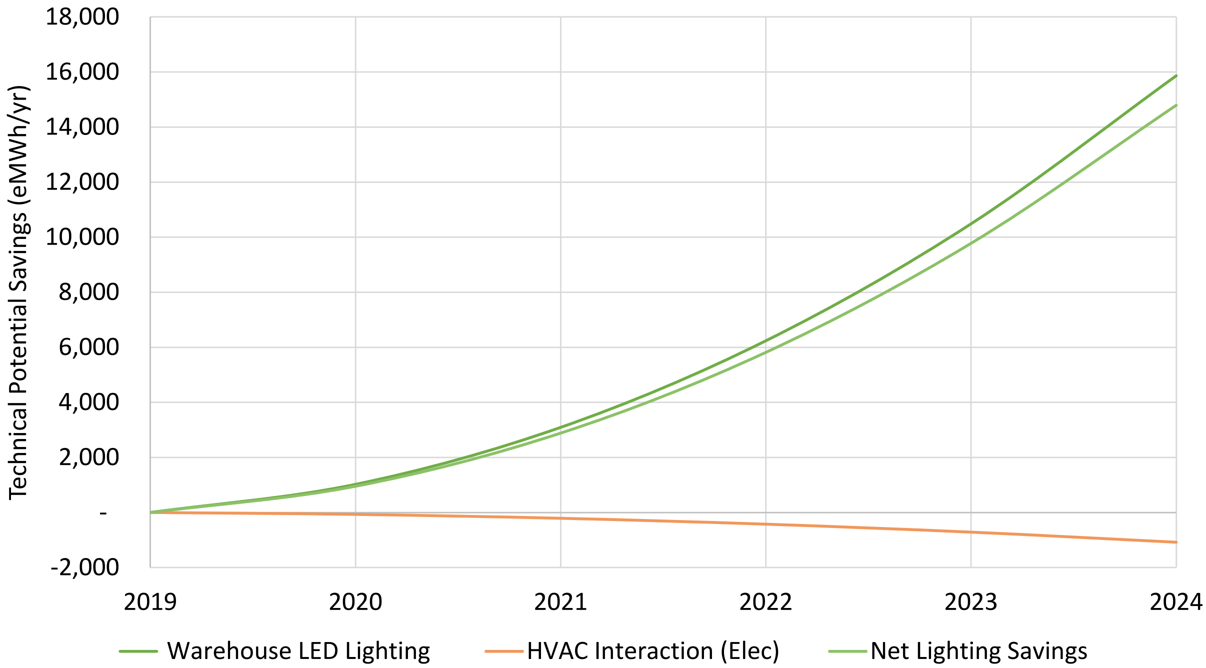

Figure 4-43: Economic Potential Savings (eMWh/yr), Oregon Warehouses, LED Lighting with Interactive HVAC Effects

4.6 Energy Savings Potential – Washington

This section presents the energy savings results for both greenhouses and warehouses in Washington.

4.6.1 Greenhouse Results

Table 4-26 and Figure 4-44 show the technical and economic consumption and savings in Washington greenhouses from 2019-2024, for all fuels. More detailed results by measure and fuel type are shown below.

Table 4-26: Total Forecasted Annual Energy Consumption and Savings (eMWh), Washington Greenhouses

Year	Reference Consumption	Technical Potential Consumption	Technical Potential Savings	% Savings	Economic Potential Consumption	Economic Potential Savings	% Savings
2019	102,466	95,392	7,074	6.9%	96,015	6,451	6.3%
2020	102,466	94,835	7,631	7.4%	95,975	6,491	6.3%
2021	102,466	94,278	8,188	8.0%	95,935	6,531	6.4%
2022	102,466	93,720	8,746	8.5%	95,895	6,571	6.4%
2023	102,466	93,162	9,304	9.1%	95,855	6,610	6.5%
2024	102,466	92,603	9,863	9.6%	95,816	6,650	6.5%

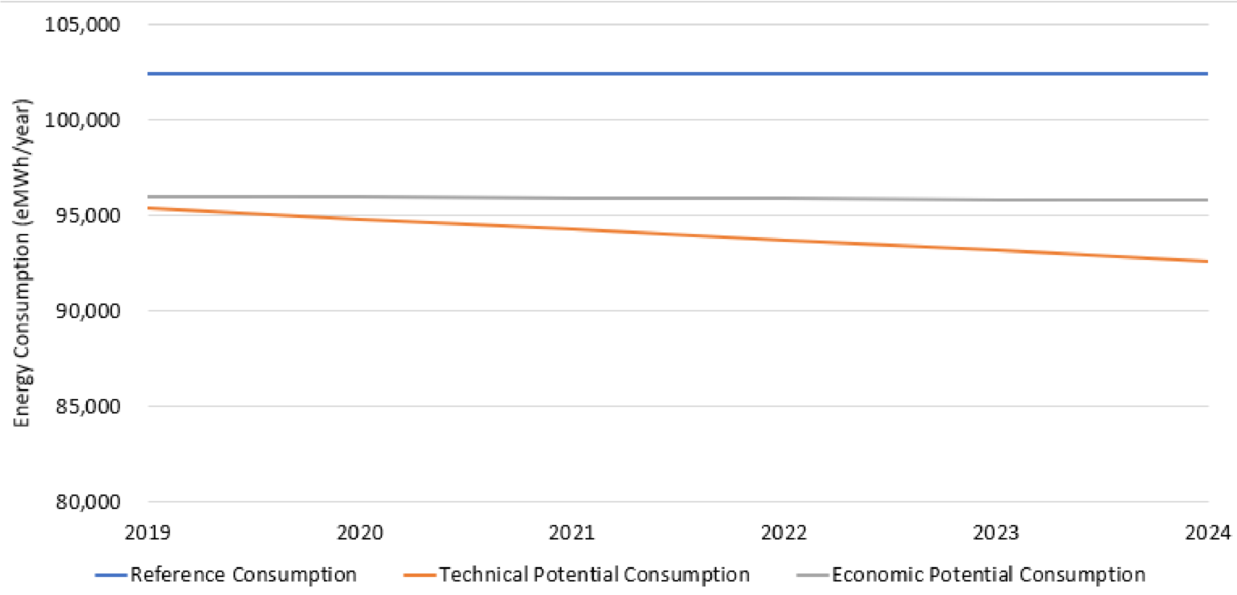

Figure 4-44: Forecasted Annual Energy Consumption (eMWh), Washington Greenhouses

4.6.1.1 Technical Savings by Measure and Fuel

Table 4 27shows the annual technical savings potential of measures for greenhouses in Washington, separated by fuel. Figure 4-45 illustrates the savings for all electric and gas measures, except lighting. Lighting savings, along with the HVAC interactive effects, are shown separately in Figure 4-46, since the scale of these savings is much larger.

Overall, the biggest potential for electric savings LED lighting, even with interactive effects taken into consideration. The biggest potential for gas savings is with energy curtains.

Table 4-27: Technical Potential Savings by Measure and Fuel (eMWh/yr), Washington Greenhouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	VFD on Supply Fan/Exhaust Fan	106	106	106	106	106	106
	Greenhouse LED Lighting	529	1,058	1,587	2,116	2,645	3,174
	LED HVAC Interaction (Elec Heating & Cooling)	57	113	170	227	283	340
Natural Gas	Energy Curtains	4,286	4,297	4,308	4,318	4,329	4,340
	Condensing Boiler	18	36	55	73	92	111
	Condensing Unit Heater	45	91	137	183	230	276
	LED HVAC Interaction (Heating)	-73	-145	-218	-290	-363	-436
Electricity & Natural Gas	Net Lighting Savings	513	1,026	1,539	2,052	2,566	3,079

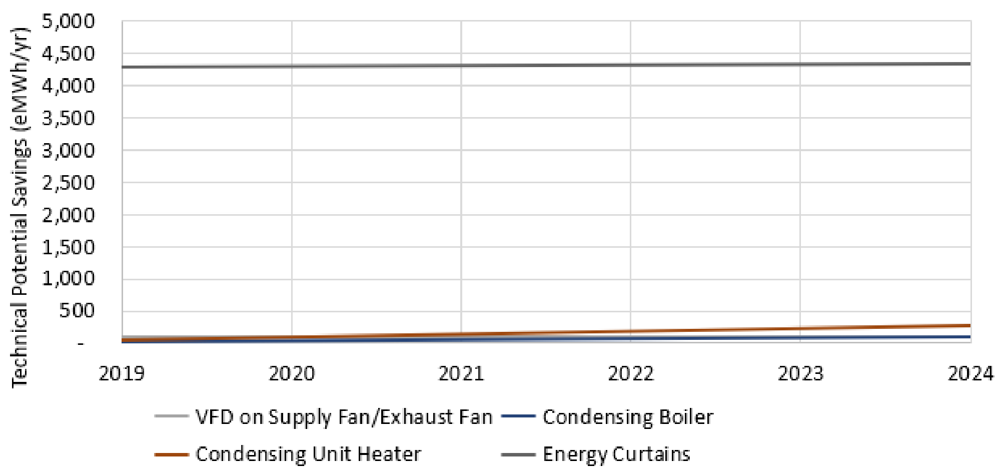

Figure 4-45: Technical Potential Savings by Measure (eMWh/yr), Washington Greenhouses, Excluding Lighting

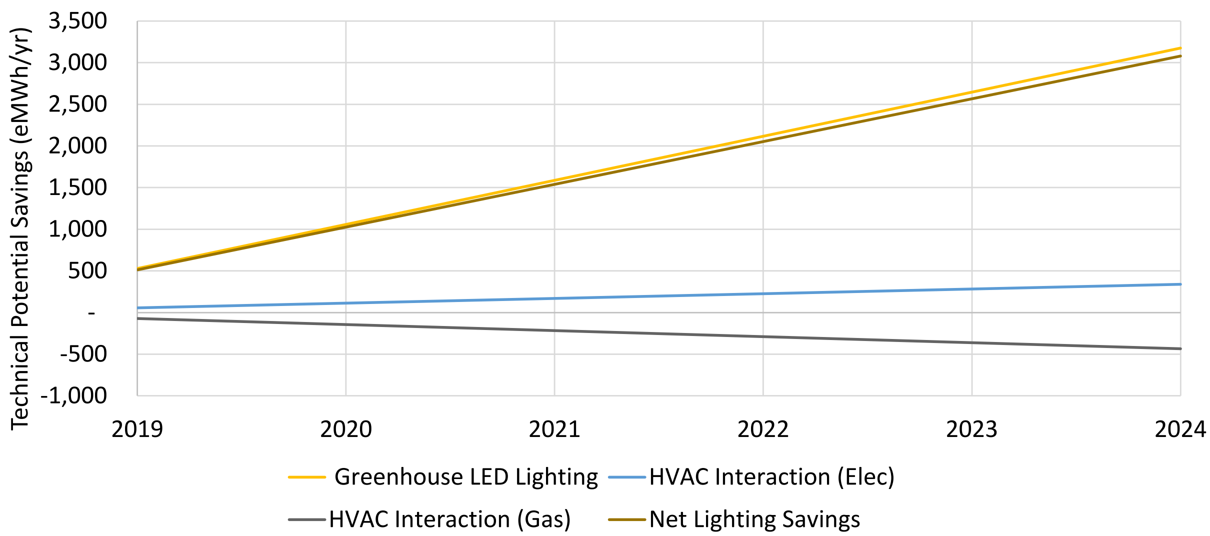

Figure 4-46: Technical Potential Savings (eMWh/yr), Washington Greenhouses, LED Lighting with Interactive HVAC Effects

4.6.1.2 Economic Savings by Measure

Table 4-28 shows the economic savings potential of measures in greenhouses in Washington. Figure 4-37 show the economic potential of measures. In this segment, only two measures pass the economic screen, both of which are gas measures.

Table 4-28: Economic Potential Savings by Measure (eMWh/yr), Washington Greenhouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Natural Gas	Energy Curtains	4,275	4,275	4,275	4,275	4,275	4,275
	Condensing Boiler	11	23	34	45	57	68
	Condensing Unit Heater	28	57	85	114	142	171

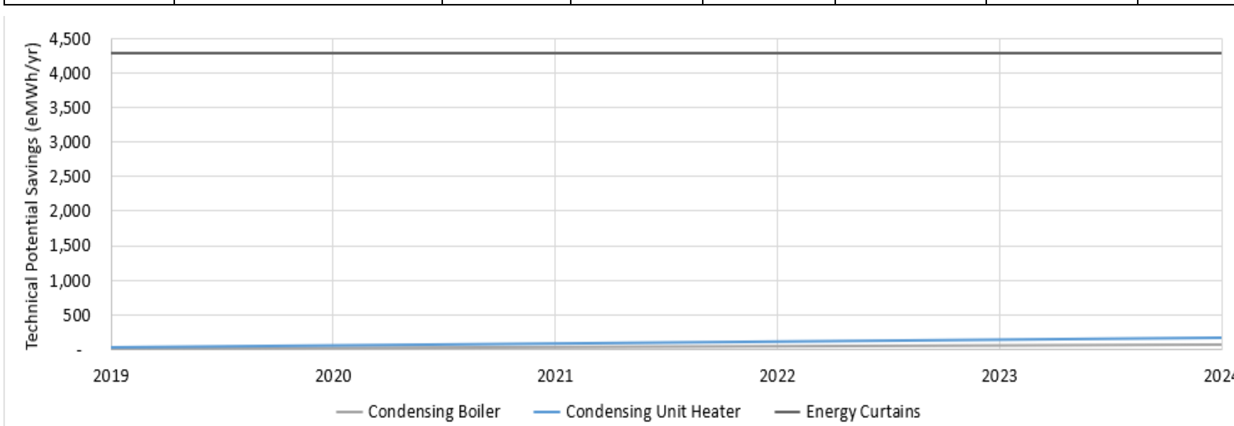

Figure 4-47: Economic Potential Savings by Measure (eMWh/yr), Washington Greenhouses

4.6.2 Warehouse Results

Table 4-29 and Figure 4-48 show the technical and economic consumption and savings in Washington warehouses from 2019-2024, for all fuels. More detailed results by measure and fuel type are shown below.

Table 4-29: Forecasted Annual Energy Consumption and Savings (eMWh), Washington Warehouses

Year	Reference Consumption	Technical Potential Consumption	Technical Potential Savings	% Savings	Economic Potential Consumption	Economic Potential Savings	% Savings
2019	687,299	675,762	11,536	1.7%	686,071	1,228	0.2%
2020	687,299	664,275	23,024	3.3%	684,843	2,456	0.4%
2021	687,299	652,846	34,453	5.0%	683,615	3,684	0.5%
2022	687,299	641,426	45,873	6.7%	682,387	4,912	0.7%
2023	687,299	630,015	57,284	8.3%	681,159	6,140	0.9%
2024	687,299	618,613	68,686	10.0%	679,931	7,368	1.1%

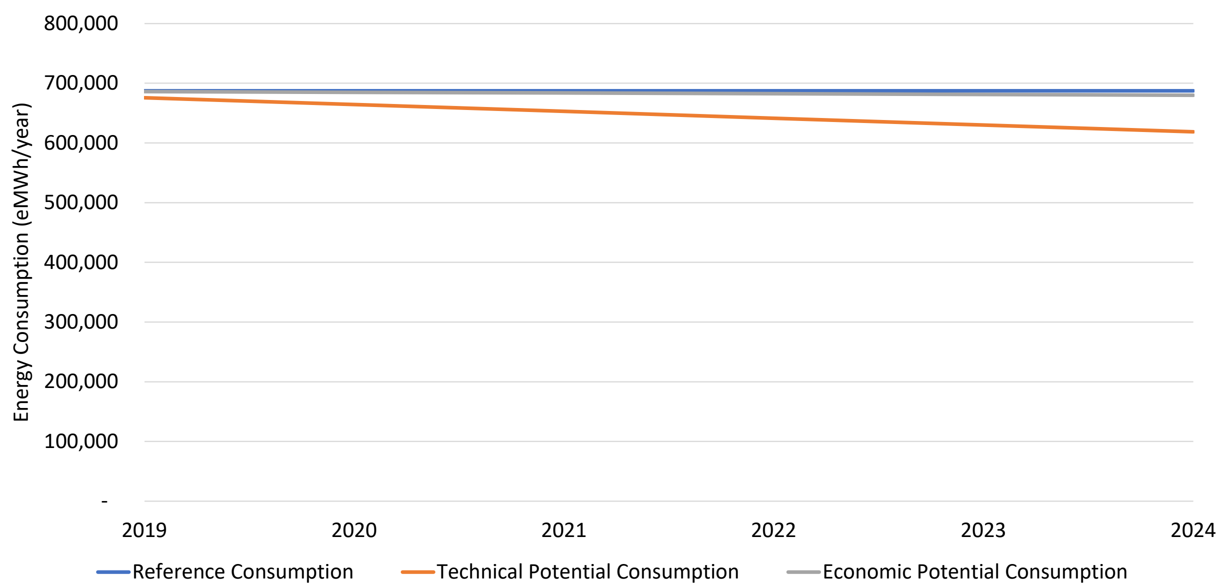

Figure 4-48: Forecasted Annual Energy Consumption (eMWh), Washington Warehouses

4.6.2.1 Technical Savings by Measure and Fuel

Table 4-30 shows the annual technical savings potential of measures for warehouses in Washington. For warehouses in Washington, all heating is electric, so only electric savings are present. Figure 4-49 illustrates the savings for all measures, except lighting. Lighting savings, along with the HVAC interactive effects, are shown separately in Figure 4-50, since the scale of these savings is much larger.

Overall, the biggest potential for savings is LED lighting, even with interactive effects taken into consideration.

Table 4-30: Technical Potential Savings by Measure and Fuel (eMWh/yr), Washington Warehouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Chiller - Air-Cooled	60	120	178	234	290	345
	Chiller - Water-Cooled	54	121	179	237	293	348
	Dehumidifier	826	1,652	2,478	3,304	4,130	4,956
	DX Unit Heat Pump	338	669	993	1,311	1,623	1,928
	Waterside Economizer	96	139	139	139	139	139
	Warehouse LED Lighting	10,901	21,803	32,704	43,606	54,507	65,409
	LED HVAC Interaction (Elec Heating & Cooling)	-740	-1,479	-2,219	-2,959	-3,699	-4,438
	Net Lighting Savings	10,162	20,323	30,485	40,647	50,808	60,970

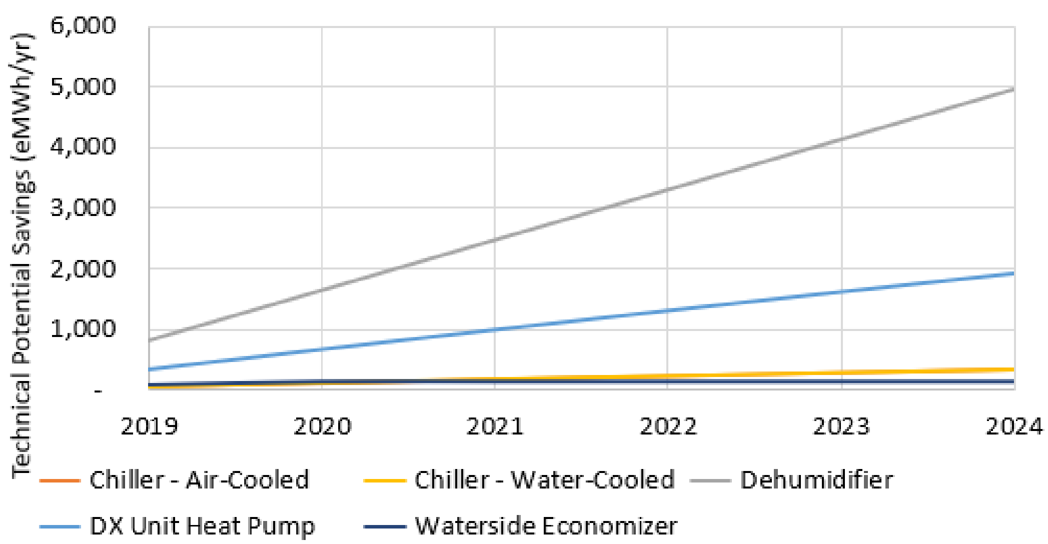

Figure 4-49: Electric Technical Potential Savings by Measure (eMWh/yr), Excluding Lighting, Washington Warehouses

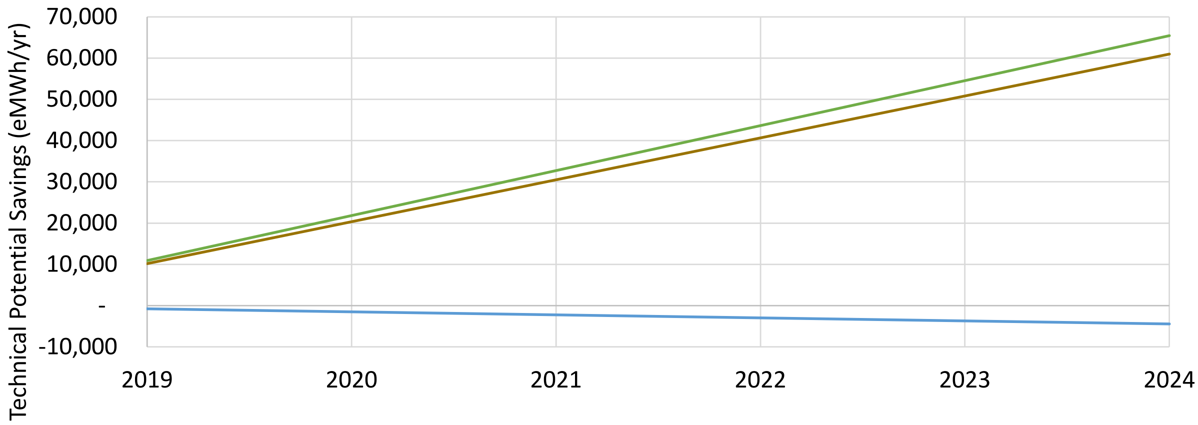

Figure 4-50: Technical Potential Savings by Measure (eMWh/yr), Lighting with Interactive HVAC Effects, Washington Warehouses

4.6.2.2 Economic Savings by Measure

Table 4-31 and Figure 4-51 show the economic savings potential of measures in warehouses in Washington, excluding lighting. Lighting savings with interactive effects are shown in Figure 4-33. Only three measures pass the economic screen.

Table 4-31: Economic Potential Savings by Measure (eMWh/yr), Washington Warehouses

Fuel	Measure	2019	2020	2021	2022	2023	2024
Electricity	Chiller - Air-Cooled	61	122	183	244	305	366
	Dehumidifier	826	1,652	2,478	3,304	4,130	4,956
	DX Unit Heat Pump	341	682	1,023	1,364	1,705	2,046

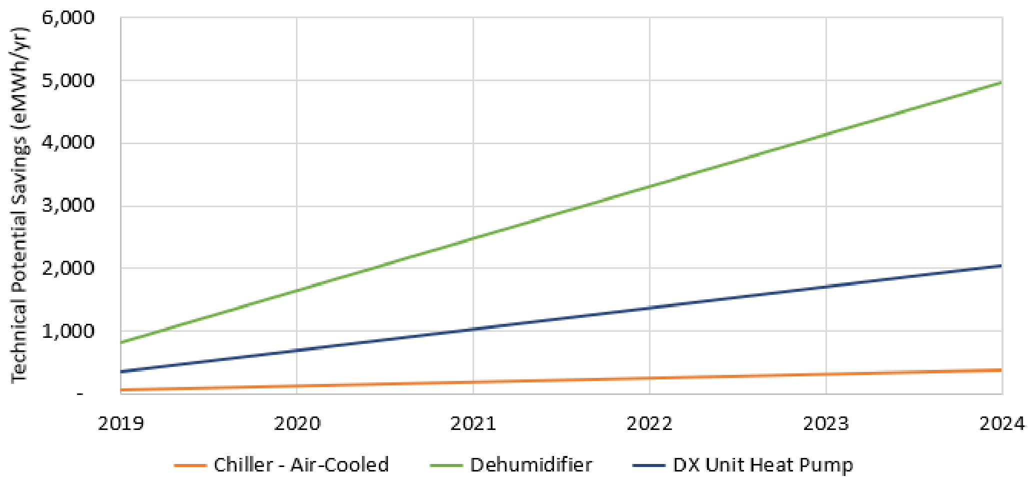

Figure 4-51: Economic Potential Savings by Measure (eMWh/yr), Washington Warehouses

5.0 ENERGY MANAGEMENT IN THE CANNABIS TODAY AND TOMORROW

This section focuses on energy management in the cannabis sector aside from the measures discussed in Section 3.0. It contains information about current codes and standards and demand side management (DSM) programs relevant to the indoor cannabis industry. It also discusses common barriers inhibiting the success of DSM programs for the indoor cannabis sector and provides design approaches and tools that utilities and regulators can use to help overcome the barriers specific to this industry.

5.1 Codes and Standards

This section highlights codes and standards that exist, or are under development, to manage energy use in the cannabis industry from select regions.

As legal recreational cannabis markets develop in North America, there is an increasing awareness of the energy requirements to grow cannabis, particularly in warehouses. In response, some jurisdictions have implemented regulations to reduce the energy consumption and environmental impact of cannabis production. In the US, local jurisdictions within states that have legalized cannabis can create regulations for medical and recreational cultivation.

5.1.1 Energy Efficiency Regulations

Currently, most regulations for energy consumption by cannabis facilities focus on lighting and HVAC. Table 5-1 provides an overview of some of the regulatory approaches jurisdictions in the US are taking to require and encourage energy efficiency in cannabis operations.[4]

[4] As of January 2020.

Table 5-1: Summary of Select Energy Regulations for the Indoor Cannabis Sector

Jurisdiction & Applicable Regulations	Requirements
State of Massachusetts 935 CMR 500: Adult Use of Marijuana (2019) **[25]**	– Regulations require cannabis cultivators to meet minimum energy efficiency and equipment standards. – Cultivator applicants must submit an energy compliance letter with the application that demonstrates how the grower will reduce energy consumption, particularly electric demand, engage in efficiency programs, and consider renewable energy generation – Cultivators must submit 12-months of energy and water usage when renewing their license [25] Lighting-specific requirements: – Limit on power density: Horticulture lighting must not exceed 36 watts per square foot, except for Tier 1 and Tier 2, which must not exceed 50 watts per square foot; or, horticultural lighting must be from a list approved by the Cannabis Control Commission; or, must be a fixture on the DLC's Horticultural Qualified Product List that are 15% more efficient than the minimum efficacy requirement [25] HVAC-specific requirements: – HVAC and dehumidification systems must meet Massachusetts Building Code and must provide that the systems have been sized for the loads of the facility [25] These requirements will be waived if an indoor cultivator is generating 80% or more of the total annual on-site energy use for all fuels from an onsite clean or renewable generating source [25].

Jurisdiction & Applicable Regulations	Requirements
State of Illinois Cannabis Regulation and Tax Act, Public Act 101-0027 (2019) **[26]**	– Cultivation license applications require: "energy needs, including estimates of monthly electricity and gas usage, to what extent it will procure energy from a local utility or from on-site generation, and if it has or will adopt a sustainable energy use and energy conservation policy" [26] – "A cannabis cultivation facility commits to use resources efficiently, including energy and water" [26] Lighting-specific requirements: – "The Lighting Power Densities for cultivation space commits to not exceed an average of 36 watts per gross square foot of active and growing space canopy, or all installed lighting technology shall meet a photosynthetic photon efficacy of no less than 2.2 micromoles per joule fixture and shall be featured on the DesignLights Consortium Horticultural Specification Qualified Products List" [26] HVAC-specific requirements: – "For cannabis grow operations with less than 6,000 square feet of canopy, the licensee commits that all HVAC units will be high-efficiency ductless split HVAC units, or other more energy efficient equipment – "For cannabis grow operations with 6,000 square feet of canopy or more, the licensee commits that all HVAC units will be variable refrigerant flow HVAC units, or other more energy efficient equipment" [26]
State of Washington Washington State Liquor and Cannabis Board **[27]**	The Washington State Liquor and Cannabis Board limits the size of the canopy per license and limits the number of licenses each company can own. The largest tier – Tier 3 – has a limit of 30,000 square feet of canopy and each company can own a maximum of 3 licenses [27]
City of Seattle, Washington Seattle Energy Code, Chapter 4, Commercial Energy Efficiency **[28]**	– "Lighting for plant growth must have a PPE per watt of no less than 1.20 micromoles per joule – "Lighting for plant growth must be controlled by a dedicated control that is independent of controls used for other lighting" [28]
Bay City, Michigan Medical Marijuana Ordinance **[29]**	"Applicants for medical marijuana licenses must submit electrical plans to Bay City Electric Light & Power so a load study can be conducted. Electric service may be denied if the applicant fails the load acceptance review or if the load requirements are not conducive to the location" [29]

Jurisdiction & Applicable Regulations	Requirements
Boulder, Colorado Boulder Colorado Municipal Code, Chapter 16 – Recreational Marijuana **[30]**	"Cultivation facilities are required to: – "Report Energy Use to the City of Boulder; – "Comply with the Renewable Energy Requirements; – "To offset 100 percent of their electricity use "To comply with these regulations, cannabis facility owners must provide: – "Proof of records confirming electricity use must be provided using the Environmental Protection Agency's ENERGY STAR Portfolio Manager tool "Proof of records showing how 100% of the facility's electricity use is offset" [30]
City of Denver, Colorado 2019 Denver Building and Fire Code **[31]**	– "Energy efficiency requirements for space cooling equipment for indoor plant grow operations (please see section C403.13 for additional details) – "Dehumidification system requirements (growers can choose from options) – "No less than 80% of total watts from lighting in canopy areas must be provided by lights with PPE of at least 1.6 μmol/J" [31]

5.1.1.1 *California's Codes and Standards Enhancement Initiative for Controlled Environment Horticulture*

California has proposed updates to the state's Energy Efficiency Building Standards to include controlled environmental horticulture (CEH), which includes warehouses and greenhouses that grow cannabis. The proposed code changes include three submeasures applicable to CEH facilities:

- Horticultural lighting minimum efficacy
- Efficient dehumidification and reuse of transpired water
- Greenhouse envelope standards [32]

Information on each submeasure has been taken from [32]. More details about the proposed code changes are available online via the referenced sources [33].

> ***Horticultural Lighting Minimum Efficacy:*** *The horticultural lighting minimum efficacy submeasure proposes a mandatory requirement for minimum photosynthetic photon efficacy (PPE) of 2.1 micromoles per joule (µMol/J) for luminaires used for plant growth and maintenance in indoor growing facilities with more than 1,000 ft2 of canopy and a minimum PPE of 1.7 µMol/J in greenhouses with more than 1,000 ft2 of canopy. The submeasure requires time-switch controls and multilevel lighting controls in both types of CEH facilities. The submeasure applies to new construction, additions to CEH facilities, alterations that change the occupancy classification of a building (for example, a warehouse converted to a CEH facility), and alterations that involve replacing 10 percent or more of the luminaires serving an enclosed space.*

Efficient Dehumidification and Reuse of Transpired Water: *The efficient dehumidification and reuse of transpired water submeasure mandates the use of one of the following dehumidification systems in indoor growing facilities:*

- *Integrated HVAC system with on-site heat recovery for reheating dehumidified air; or*
- *Chilled water system with on-site heat recovery for reheating dehumidified air; or*
- *Solid or liquid desiccant dehumidification system.*

Facilities with less than 2,000 ft2 of canopy in combined CEH spaces are permitted to use stand-alone dehumidification units with a minimum energy factor of 1.9 liters per kWh (L/kWh). The submeasure requires the on-site heat recovery system to be designed to fulfill at least 60 percent of the facility's dehumidification needs during peak dehumidification periods. Furthermore, under this submeasure, dehumidification equipment must have the capability to reuse transpired water for irrigation in indoor growing facilities. This submeasure exempts CEH facilities from the prescriptive requirement to install an air-side economizer when carbon dioxide (CO2) enrichment is used as a strategy to promote plant growth. The proposed submeasure applies to newly constructed facilities and newly installed HVAC and dehumidification systems in existing facilities.

Greenhouse Envelope Standards*: The greenhouse envelope standards submeasure is a code cleanup measure that proposes the following envelope requirements specific to conditioned greenhouses:*

- *Opaque wall and roof assemblies must meet the existing insulation and building*
- *Non-opaque walls assemblies must have a weighted average U-factor of 0.7 or less; and*
- *Non-opaque roof assemblies must have a weighted average U-factor of 0.5 or less.*

The submeasure also exempts greenhouses from existing prescriptive building envelope requirements for window wall ratio, skylight roof ratio, and daylighting requirements for large enclosed spaces. The proposed submeasure applies to newly constructed greenhouses and to greenhouses being converted from unconditioned to conditioned. Since this submeasure is a code cleanup effort, there are no associated savings or incremental costs.

5.1.2 Renewable Energy Requirements

Some jurisdictions in California have requirements for use of renewable sources for energy in cannabis and/or indoor agriculture facilities. Examples include:

- Humboldt County, California: Electricity must be provided either a) grid power from 100% renewable energy sources, b) on-site renewable system with 20% net non-renewable energy use, or c) grid power partially supplied by a non-renewable source with purchase of offset credits [34].
- Monterey County, California: Onsite renewable energy generation is required for all indoor cultivation activities. Renewable energy systems must be designed to have a generation potential equal to or greater than half of the anticipated energy demand [35].
- Sonoma County, California: Energy must be 100% powered by renewable sources or carbon offsets must be purchased (generators are prohibited) [36].

5.1.3 DesignLights Consortium's Horticultural Lighting Program

The DesignLights Consortium (DLC) is a non-profit organization focused on achieving energy efficiency through interconnected solutions focused on quality for people and the environment. In 2018, the DLC launched the Horticultural Lighting Program, expanding upon the Solid-State Lighting program that had been in effect for many years. The Horticultural Lighting Program provides a suite of tools and resources to help foster the adoption of energy-efficient LED technology throughout the horticultural lighting industry. The Horticultural Lighting Program sets specifications via its Technical Requirements, and routinely, via established revision cycles, updates the Technical Requirements to keep pace with the advancements in LED technology. DLC's Qualified Products List is used by some regulators, such as the State of Illinois, to enforce energy efficiency requirements for grow lighting in cannabis operations.

Manufacturers of horticultural lighting products may submit applications for eligible products for inclusion on the DLC Horticultural Lighting Qualified Products List (DLC Horticultural QPL). DLC members (utility energy efficiency organizations or other energy efficiency advocacy groups) rely on the DLC Horticultural QPL for verified product performance, and members provide expertise into DLC policy and specification development. Additionally, the DLC Horticultural Lighting program provides all stakeholders with horticultural lighting resources including guides of topics of interest in horticultural lighting to introduce and summarize key horticultural topics.

To date, there are over 100 horticultural lighting products qualified on the DLC Horticultural QPL, and the public comment period for draft specifications for Technical Requirements V2.0 wrapped up in June 2020. Technical Requirements V2.0 has a proposed effective date of March 2021 and contains updates to add additional reporting options for efficacy, alignment with ASABE terminology, alignment with UL 8800, require TM-33-18 reporting, and introduction of family grouping and private labeling applications.

5.2 Demand Side Management Programs Applicable to the Cannabis Sector

This section focuses on demand side management (DSM) programs in terms of existing program activity related to the cannabis sector in select regions, common barriers to DSM programs to deploying successful programs for the cannabis industry, and design approaches and tools to overcome these barriers.

5.2.1 Summary of DSM Program Activity

This section provides an overview of existing DSM programs for the cannabis/indoor agriculture sector in select regions.

Although indoor agriculture (indoor ag.) utility customers are encouraged to participate in most utility DSM programs, few North American utilities have established stand-alone controlled-environment DSM specific offerings. The project team researched existing programs in five regions: Colorado, Oregon, Northwest, Massachusetts, and Ontario. Findings are summarized in Table 5-2 to 5-5, with one table per region. Information is current as of summer 2020.

Table 5-2: DSM Programs in Colorado

Utility	Program Description	Incentive Structure
Colorado Electric Cooperatives **(various)**	The Colorado Energy Office sponsored the Rural Cannabis Energy Management Program in partnership with multiple Colorado cooperatives. The Energy Office focused on providing no-cost on-site energy use assessments to 15 individual cannabis cultivators located in the 5 rural territories, and advised the cooperative on how best to assist their indoor agriculture customers with EE and RE upgrades. The program operated from 10/2019 to 06/2020. Several of the cooperatives now offer EE rebates to indoor agriculture customers.	Holy Cross will rebate $120/LED to indoor ag. customers as part of its commercial lighting program. La Plata Electric Association will rebate $125/horticultural LED for retrofit and new construction applications within its commercial LED lighting program. San Isabel Electric Association will rebate $150/horticultural LED for retrofit and new construction applications within its commercial LED lighting program. Rebate will cover a maximum of $20,000/project or 50% of invoiced fixture cost. Pre-approval is required for its lighting rebate program. Colorado Spring Utilities will rebate horticultural LEDs through their Business Lighting rebate program. Pre-approval is required for all projects. Projects with 30 or more fixtures require pre-inspections. Other rebates include $60/ECM motor under 1/2 hp and $100/ECM motor for those larger. Custom efficiency rebates are also available for energy savings projects, pre-approval and M&V is required.

Utility	Program Description	Incentive Structure
Colorado Electric Cooperatives **(various)**	The Colorado Energy Office sponsored the Rural Cannabis Energy Management Program in partnership with multiple Colorado cooperatives. The Energy Office focused on providing no-cost on-site energy use assessments to 15 individual cannabis cultivators located in the 5 rural territories and advised the cooperative on how best to assist their indoor agriculture customers with EE and RE upgrades. The program operated from 10/2019 to 06/2020. Several of the cooperatives now offer EE rebates to indoor agriculture customers.	
Efficiency Works Colorado **(partnership between Platte River Power Authority and Colorado Municipal Utilities - Longmont, Loveland, Fort Collins & Estes Park)Utility**	Launched in July 2019, the Efficiency Works Indoor Agriculture Program offers free technical assistance to 50 cannabis cultivators and targets more than 2.0 GWh in potential energy savings over multiple calendar years.	Efficiency Works offers free energy advising and assessments to all indoor ag. customers. Indoor ag. customers qualify for both prescriptive and custom rebates. Prescriptive Rebates: – Cooling – Lighting – VFDs – Building envelope Custom Rebates ($0.10/kWh or $500/kW): – Lighting & EMS Controls – Dehumidification – Efficient fans & motors

Utility	Program Description	Incentive Structure
Colorado Investor Owned Utilities (Black Hills Energy & Xcel Energy), Utility Efficiency Works Colorado (partnership between Platte River Power Authority and Colorado Municipal Utilities - Longmont, Loveland, Fort Collins & Estes Park)	Black Hills Energy introduced an on-site assessment offer in 2020 called the Cannabis Industry Audit Program. The Cannabis Industry Audit Program is a new proposed pilot program for legal and licensed commercial cannabis related indoor agriculture customers. The program will provide technical services to customers to better understand energy consumption through targeted specialized engagement with cannabis indoor facilities. In addition, the program will connect customers with qualified horticultural product and service contractors through eligible measures such as LED lighting, HVAC, commercial insulation upgrades, high efficiency fan replacements, pump system upgrades, and motor replacements. The program plans for the delivery of 29 on-site assessments and 1.3 GWh in Net savings in 2020.	Xcel Energy – Prescriptive rebates for recommissioning, efficient motors ($75 - $125/motor), VFDs (dollar amount based on motor HP and type), hot water boilers ($400 - $700/BTUh), water heaters ($400/100,000 BTUh), and unit heaters ($50 - %150/ 100,000 BTUh). – Horticulture LED lighting is rebated through Custom Efficiency and eligible for up to $500/kW saved. Pre-approval is required for all Custom Efficiency projects. – Dehumidification, lighting and environmental controls, fan upgrades, and envelope measures are also covered under the Custom Efficiency program, with projects eligible for up to $500/kW saved for system peak savings and $4/Dth. – Cooling rebates for indoor ag. are available through their Midstream Cooling program. High load facilities such as indoor ag. qualify for bonus rebates up to 2 times the prescribed amount. Black Hill Energy – Offers free energy assessments for licensed cannabis customers with electric service. – Cannabis customers are eligible to receive prescriptive rebates for heating and cooling systems (DX, heat-pump, and chiller units) and A/C system tune-ups. – All other energy savings measures, including horticultural LEDs, dehumidification, envelope, and motors are eligible for a commercial customer rebate. Projects require pre-approval with incentives ranging from $0.10/kWh - $0.30/kWh based on total project savings.

Table 5-3: DSM Programs in Oregon/Northwest US

Utility	Program Description	Incentive Structure
Energy Trust of Oregon	Free technical services and cash incentives for licensed cannabis and hemp growers. Available for indoor, outdoor and greenhouse production modes. Indoor Cannabis Grow Operations: – Lighting and Lighting Controls – Insulation – Dehumidifiers Greenhouse and Outdoor Cannabis and Hemp Grow Operations: – Lighting and Lighting Controls – Irrigation System Upgrades – Greenhouse Upgrades – Heating and Cooling	Standard Energy Solutions: – High Efficiency Lighting and Controls o Maximum 50% of total eligible measure cost • Not to exceed $0.25 annual kWh saved – Dehumidification: o $9 per pint per day o Minimum energy factor of 2.8 L/kWh o Available for new portable or stand-alone dehumidifiers replacing existing working portable or standalone dehumidifiers o Greenhouse installations not eligible – Insulation: – Incentives vary – Final incentive based on estimated savings – Only eligible to indoor grow operations Custom EE Projects: – High Efficiency Lighting and lighting controls – Technical studies to identify energy efficiency opportunities for HVAC, insulation, and other improvements. For qualified projects, Energy Trust pays 100% of the cost of the study Incentive Process: 1. Check business eligibility (must be customer of Pacific Power, PGE, Avista, NW Natural, or Cascade Natural Gas) 2. Find a trade ally contractor 3. Submit documentation 4. Get pre-approval from Energy Trust prior to ordering materials or installation 5. Install equipment 6. Submit final project 7. Receive incentive

Utility	Program Description	Incentive Structure
Snohomish PUD	Limited time offer where Snohomish PUD accepts bid-packages for the program, and Snohomish PUD staff provide technical assistance to complete the bid-package. All projects must be pre-approved. Incentives may not exceed 75% of total material costs, and all incentives capped at $150,000. Incentive rates may change and funding is limited.	Lighting Requirements: – LED lamp or fixture products – UL or ETL listed – Power Factor 0.9 or above – 5-year warranty Non-Lighting Requirements: – AHRI, ANSI/ASHRAE/IES Certification – 1-year warranty
Emerald PUD	Emerald's Energy Services provides lighting surveys, technical assistance with project development, and incentives to encourage building owners and operators to make the switch to more energy-efficient lighting systems for non-residential buildings. Applications must be submitted using the BPA Commercial/Industrial lighting calculator. Measure eligibility is based on BPA list of incentives for lighting retrofits.	Incentives are limited to 50% of a project's eligible upgrade costs. A completed lighting calculator is required for all projects. Incentive Process: – Confirm eligibility and get free lighting assessment – Contact vendor from Trade Ally Northwest to develop lighting project proposal – Receive rebate proposal from Emerald PUD – Submit project application – Emerald will conduct final inspection

Utility	Program Description	Incentive Structure
Seattle City Light	Seattle City Light's Commercial and Industrial Retrofit Program encourages small, medium and large commercial and industrial customers to undertake energy retrofits of existing buildings and equipment. The program includes: – Building controls and HVAC system upgrades – Industrial process improvements – Water heating – LED Lighting conversions including new fixtures, retrofit kits and networked lighting controls Eligibility: – Must have a commercial account with SCL – Equipment cannot be purchased until project has been reviewed and approved by SCL	Seattle City Light's retrofit incentives are paid based on calculated annual energy savings or on a per-unit basis as indicated in your contract. Retrofit incentive rates are published online. Incentives are capped so that Seattle City Light does not pay more than 70% of the incremental project cost. For any lighting product to receive an incentive, all products must meet one of the following requirements: 1. The product is listed on a Seattle City Light-recognized Qualified Product List (QPL): o DLC lighting fixtures o DLC QPL for Networked Lighting Controls (NLC) o ENERGY STAR o DLC Horticultural QPL (see Indoor Horticulture section for additional specifications) 2. Ad-hoc approval by Seattle City Light staff with the following product documentation requirements: o Product LM-79 test results o Other documentation, as requested

Utility	Program Description	Incentive Structure
Puget Sound Energy (PSE)	PSE provides incentives for qualifying new construction and retrofit projects for indoor cannabis growth. Equipment requirements: – Fixtures must be LED. – Fixtures must have a minimum Photosynthetic Photon Efficacy (PPE) of 1.9 micromoles/Joule, as published by the manufacturer – Fixtures must be covered under a manufacturer-provided 5 year warranty – Fixtures must be UL certified (or equivalent). – All fixtures installed over a specific illuminated canopy area must be of the same make and model; all lighting must be installed in a homogenous array or row with no inter-array or inter-row installations of other lighting models – Light fixtures must be approved by Puget Sound Energy. Additional information on how PSE will measure the Illuminated Canopy Area for Indoor Cannabis projects is made available online.	PSE can provide up to $25 per square foot of Illuminated Canopy Area for qualifying LED light fixtures. Incentives are available for qualifying new construction and retrofit projects for indoor cannabis growth. Incentive Process: 1. Submit application documentation 2. PSE engineer will contact customer and begin working on project is application is applicable 3. Engineer may meet with business owner/manager to review project and discuss lighting layout 4. Upon approval, PSE will send grant agreement 5. Final inspection

Utility	Program Description	Incentive Structure
Pacific Gas & Electric (PG&E)	PG&E provides rebates to indoor ag. customers through their Agriculture and Food Processing Efficiency Program. Funding for this program is limited and available on a first-come-first-serve basis until allocated funds are exhausted or the program ends. Energy audits are available for any agriculture customers. PG&E provides energy and rebate advising through their Agriculture Customer Service Center. Prescriptive and custom Incentives for the Agriculture and Food Processing Program: – Irrigation and pumping efficiency – VFDs and ag. ventilation fans – Pipe insulation – LED Lighting Cannabis and indoor ag. customers are also eligible for traditional business rebates. – HVAC – VFDs – Controls – Recommissioning – Custom efficiency	Equipment must meet or exceed California Building Standards Code (Title 24). Prescriptive rebates vary based on equipment type. Custom rebates, including horticultural lighting, require pre-approval and qualify for \$75/kW - \$200/kW, \$0.06/kWh - \$0.12/kWh, and/or \$0.50/therm - \$1.74/therm. Projects must demonstrate energy savings that earn an incentive of at least \$5,000 to qualify.

Utility	Program Description	Incentive Structure
Sacramento Municipal Utility District (SMUD)	SMUD offers Business Energy Efficiency rebates for: – Horticultural LED lighting – HVAC – Controls – Heat-pump water heaters – Custom efficiency Options are available for self-direct (prescriptive), complete energy solutions (free assessment and install from qualified service provider), and integrated design solutions (new construction).	Rebates are available for new and existing cannabis facilities. Prescriptive Rebates: – Up to $20,000 per project for prescriptive rebates. – Prescriptive rebates larger than $5,000 require pre-approval. – Rebates are based on equipment type. Custom Rebates: – Pre-approval is required before construction and/or installation of measure begins. – Incentives are calculated and are dependent on annual energy savings – A peak-demand reduction incentive (kW) is also available for most non-lighting projects

Table 5-4: DSM Programs in Massachusetts

Utility	Program Description	Incentive Structure
National Grid via MassSave	National Grid offers energy efficiency incentives for: – Retrofit lighting on existing facilities – Custom incentives on new construction and major renovations – Lighting systems for new construction projects – Discount pricing on energy-efficient lamps and fixtures	Incentive Rules: 1. All applications for incentives under the custom application process require sound documentation of the proposed cost, projected electricity savings, and related non-energy savings 2. Check with program administrator to determine eligibility of the proposed project and to establish requirement for detailed savings projections and cost estimates 3. Information will be submitted to the program administrator's technical representative for review and evaluation of potential incentives. 4. The technical representative will develop a minimum requirements document which describes minimum equipment specifications and operational requirements of the proposed system, and the customer will be required to sign it 5. After successful review, the program administrator will notify customer in writing of the project approval, the incentive amount and terms and conditions to receive final incentive payment

Utility	Program Description	Incentive Structure
Massachusetts Municipal Wholesale Electric Company (Serving: Ashburnham Municipal Light Plant, Chicopee Electric Light Department, Holden Municipal Light Department, Ipswich Municipal Light Department, Peabody Municipal Light Plant, South Hadley Electric Light Department, Shrewsbury Electric and Cable Operations, Sterling Municipal Light Department, West Boylston Municipal Light Plant)	The Green Opportunity (GO) Program assists Massachusetts municipal utilities in developing and delivering energy efficiency services to their commercial and industrial customers [37]	"The Prescriptive GO Program is designed to expedite the processing and installation of typical energy efficiency opportunities in commercial, industrial and non-residential buildings. "Incentives are offered to promote the installation of premium efficiency equipment and offset the incremental cost of such equipment over standard replacements. – "All incentives capped at 50% of Installed Project Costs" [37] – Currently the program offers incentives for: o Lighting o HVAC
Unitil	Commercial & Industrial New Equipment and Construction Program [38] Offers financial and technical services to commercial, industrial and institutional customers building a new facility, undergoing a major renovation, or replacing failed equipment [38]	Prescriptive and custom incentives are available to cover the lesser of a one-year payback or 75% of the incremental cost of the efficient over standard equipment [38]. Unitil provides detailed plan reviews, including assessments of specific energy efficiency projects and equipment and building commissioning.

Table 5-5: DSM Programs in Ontario

Utility	Program Description	Incentive Structure
Save on Energy (IESO)	New Construction: Incentives available for eligible prescriptive energy savings equipment. Must provide sustainable, measurable, and verifiable reductions in electric peak demand and electricity consumption. Building must be connected to the electricity grid when the application is pre-approved. Retrofits: Retrofit Program: Prescriptive track: projects must be pre-approved. Small projects must be worth a minimum incentive of $500.	New Construction: Incentive capped at %50 of eligible project costs, up to $1 million. Retrofits: Fixed incentive levels for prescriptive projects on a per unit basis. Incentive capped at %50 of eligible project costs, up to $1 million.

5.2.2 DSM Programs: Common Barriers

Based on experience and publicly available literature, there are several barriers that should be addressed when designing DSM programs specific to the cannabis cultivation industry. These barriers are presented as follows:

1. **Outreach/Limited Access to Ownership**
   Due in part to the competitive nature of the business, combined with the security and privacy regulations that the industry must adhere to, access to ownership and the ability to perform outreach directly to decision makers within cannabis customer organizations is challenging and presents significant barriers to generating participation in traditional DSM programs.
2. **Lack of Awareness/Unfamiliarity of DSM**
   Unlike other industries such as healthcare and business, the cannabis cultivation industry is, for the most part, unfamiliar with DSM programs and offerings from their local utilities. Often, the industry's initial interactions with their electric utility is related to simply gaining access to adequate power and, as a result, it does not seek out assistance or support from the utility related to energy management and incentive opportunities as other industries typically do.
3. **Lack of Awareness of Energy Use, Rates, & Costs**
   As with other industries, cannabis cultivation is often unable to associate energy use and the resulting costs with production. This occurs because energy costs are accounted for through accounts payable and the production metrics are tracked via the head grower; the two departments rarely connect. Since the energy use per production ratio is not tracked, it is difficult to justify energy efficiency investments and opportunities given the lack of a baseline or comparison tool. Additionally, the industry often has limited understanding of cost breakdowns resulting from

either energy use or demand charges which also impacts the ability to make the business case for energy efficiency upgrade investments.

4. **Preference for Privacy**
   The cannabis industry is competitive, with a preference for privacy. Industry groups and associations are few and limited, and best practices related to energy management are rarely (if at all) shared. The industry is hesitant to allow non-employees access to facilities and prefers to limit understanding and access to its operating procedures to employees and known individuals.
5. **Traditional Efficiency/Return on Investment (ROI) Discussion Not Relevant**
   Traditional energy engineering and DSM programs position their value proposition using basic ROI calculations. Unfortunately, given that the a cannabis facility is a manufacturing site, traditional energy savings from ROI formulas are not applicable. As an example, if a cannabis cultivator uses (X) kWh over a given cycle to produce (Y) kg of product, and an energy efficiency upgrade will change the result to (X-0.1X) kWh needed per cycle and a production yield of (Y-0.05Y) kg. of product, a simple ROI from the upgrade doesn't convey the total value.
6. **Every Site is Unique**
   Although classified as the same business type, cannabis cultivation facilities can be operated in spaces less than 1,000 square feet to as large as 300,000 square feet. They can be located in warehouses, barns, greenhouses, personal residences, and custom hybrid locations. There are few, if any, codes and standards that must be followed. Due to this, creating appropriate baselines and one-size fits all DSM incentive offers remains challenging for this specific customer segment.
7. **Interaction of Measures**
   More so for this industry than others, when upgrading/changing one energy efficiency measure, (such as lighting), there is significant impact on the building's humidity, temperature, and other conditions, resulting in interactive effects related to HVAC and other operational equipment. When looking to address a single measure, a DSM program must also be prepared to account of the interaction and impact it will have on other dependent energy systems.
8. **Traditional Energy Metrics Are Not Applicable**
   As discussed, energy use per square-foot and other common benchmarking energy metrics are not directly applicable to the cannabis cultivation industry, thus making it difficult to determine baselines and efficiency standards for a DSM program sponsor.
9. **Traditional Trade Partners Aren't Applicable**
   Most DSM programs utilize the same network of trade partners, be it lighting, HVAC, or other. However, for cannabis customers seeking EE upgrades, a specialized network of qualified trade partners is needed as the majority of vendors operating within the current network likely do not have the specific horticulture products, nor understanding needed to satisfy the unique requirements of this customer segment.
10. **Long Upgrade Timelines**
    EE upgrades for the industry can take roughly 12 to 18 months to fully install from the date of first engagement. This extended timeline typically goes beyond the calendar year and makes it challenging for program administrators and regulators to track and verify savings.

5.2.3 DSM Programs: Design Approaches

The barriers presented in Section 5.2.2 can often be addressed through specific DSM program design approaches made prior to the beginning of implementation. The following program design approaches are suggested:

1. **Align DSM program requirements with local/state regulations.**
   Designing a utility DSM program for the cannabis cultivation industry that works in close alignment and in support of local and state regulations is critical to success. This may include allowing utility energy assessments to also serve as acceptable compliance checks or ensuring the offered utility rebates also provide a path for participants to install equipment that meets or exceeds all local and state codes.
2. **Extend pre-approval notifications for up to 18 months.**
   Designing to allow for a pre-approval to be valid/used for up to 18 months by an indoor agriculture customer participating in a utility DSM program will allow the participant to first make a single room and smaller upgrade, thoroughly test the results through several cycles, and stagger upgrades to their facility over the 18-month period.
3. **Use Non-Disclosure Agreements (NDAs) by on-site implementers.**
   Designing (or potentially requiring) for the use of NDAs for the benefit of participants prior to walking indoor agriculture sites.
4. **Place program restrictions on walking multiple sites per day.**
   To prevent the potential for contamination, an effective DSM program can be designed to limit any individuals from walking more than one site per day.
5. **Earmark 5-10% percent of commercial custom program rebate amounts for indoor ag.**
   Although new rebates are often not needed by the indoor agriculture industry, reserving a percentage of the commercial custom budget specifically for these customers is beneficial.
6. **Conduct active account management.**
   Unlike other commercial customers, a dedicated account management function must be allocated to each indoor agriculture customer to help them navigate the DSM process from beginning to end. The account management function will include scheduling site assessments, identifying potential trade partners, and providing assistance in completing rebate forms – a concierge, for lack of a better term.
7. **Conduct specialized outreach and events.**
   Since indoor agriculture customers will rarely (if ever) attend or participate in utility DSM events and workshops, the utility must design DSM activities that include seeking out opportunities to meet with indoor agriculture customers in their preferred settings. This may include the identification of cannabis industry conferences, hosting organized workshops specific to indoor agriculture and other related activities.
8. **Look for specially marked trade partners.**
   To help identify which utility DSM trade partners are qualified to sell horticulture-specific energy efficiency solutions, a specialty mark or indication should be included to help easily identify applicable options when viewing a list of lighting, HVAC, and other trade contractors.

5.2.4 Demand Side Management Program Tools

The following tools can be used by utilities to help successfully deliver cannabis-focused DSM programs:

Utility Program Websites

Utilities can and should dedicate specific web pages for indoor cannabis program details that are no more than one or two clicks from the utility home page. After reviewing a number of utility websites across North America, we found that very few utilities made it easy for growers to learn more about utility program offerings. Once program details were found, they were arduous and complex worksheets that would most likely turn away prospective program participants. Powerful program tools would include case studies and savings calculators to help growers see how much they can save if they participate in a local utility DSM program.

Horticulture Industry Specifications

DSM programs should leverage industry specifications to ensure that growers are exposed to appropriate technology and best practices. We found that a number of utilities were providing links to the DLC website for lights that are eligible for rebates. However, utilities can and should also highlight the DLC Horticulture Standard for growers looking to produce indoor crops as efficiently as possible.

DSM programs can also leverage best practice guidelines from the Resource Innovation Institute which are developed by the grower industry, for the grower industry. The Resource Innovation Institute PowerScore tool can help growers understand the energy impacts of their grow facilities and show growers how they rank in relation to other growers who have registered their grow data. The default setting compares growers to national averages for each cultivation method including indoor/outdoor/mixed light.

Industry Trainings

Resource Innovation Institute also delivers local trainings for utilities that want help facilitating best practices for their growers/customers. The Efficient Yields Cultivation Workshops cover a wide array of topics, including:

- LED Lighting
- Controls & Automation
- HVAC

Field Hardware

Tools to assess cannabis facilities include PAR light meters, infrared gun for leaf temperature readings, anemometer for air flow measurements, and thermo-hygrometer to measure air temperature and humidity.

- Specialty light meters known a PAR meters measure light levels of photosynthetically active radiation, which is used by plants. Standard commercial light meters that measure lumens or lux cannot be used to measure light for plant growth. Additionally, PAR meters that include spectroradiometer capabilities are recommended to analyze light quality.
- Environmental measurement equipment is utilized to identify existing growth conditions and analyze equipment functionality. Leaf temperature, air temperature, relative humidity, and air flow are recorded using an array of different instruments.
- Tyvek suits are recommended for site assessments to ensure no cross contamination between plant-production facilities occurs.
- Energy analysis tools should be developed and customized for indoor agriculture and program incentives.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Standard practices for energy management are currently limited for the indoor cannabis sector because:

- Of its newness as an industry in many jurisdictions in North America
- Every facility is unique
- There are currently no unifying standards or protocols for cannabis growers that provide a 360-degree perspective on the optimal combination of equipment and control strategy

Despite these conditions, there are information and resources that policymakers, utilities, and growers can use to reduce the energy footprint from indoor cannabis production. Key insights from this study include:

- Greenhouses tend to use the most energy for lighting, ventilation, and space heating, while warehouses typically need energy for lighting, ventilation, space cooling, and dehumidification.
- There are many energy efficient measures applicable to warehouse and greenhouse facilities that can save energy, including many that are cost effective. LED lights offer large opportunities for technical potential savings in both facilities type and all regions. Measures that are cost-effective to the user vary by facility type and region.
- Energy curtains offer the highest opportunity for gas savings in greenhouses in all regions.
- Other measures with high opportunities for economic energy savings include efficient dehumidifiers, DX unit heat pumps, and VFDs on supply/exhaust fans.
- Codes and standards do exist in some jurisdictions – with more under development – to regulate energy consumption by indoor cannabis facilities. Currently, most regulations focus on energy efficiency from lighting and HVAC equipment.
- There are DSM programs in-market that focus on indoor agriculture, with limited programs tailored to cannabis specifically. However, indoor cannabis facilities may be eligible to participate in many of these existing programs. While there are common barriers that may impede the success of a DSM program targeted at cannabis, there are tools that program designers and administrators can use to overcome these barriers to ensure DSM programs targeted at the indoor cannabis market can be successful.

Recommendations related to DSM program design approaches and tools are specific suggestions for program administrators provided in this report.

Through the process of conducting this study, we found that energy management for the indoor cannabis sector field would benefit from:

- More investment, research, and pilot work to prove out blueprints on optimized cannabis grow strategies and system design parameters.
- Research specifically focused on quantifying by measurement and verification (M&V) the interactive effects for lighting under different grow strategies and facility system design characteristics would be helpful to better understand the effects of the LED lighting measure

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APPENDIX A. ESTIMATES FOR CANNABIS MEASURE INPUTS

Available for download at my.ceati.com

APPENDIX B. QUANTIFYING INTERACTIVE EFFECTS FROM LED LIGHTING

This appendix presents two methods to quantify interactive heating and cooling effects associated with LED lighting energy conservation measures in cannabis greenhouses and warehouses:

- A broadly applicable method energy management practitioners can use as a starting point to guide their facility specific analysis
- The method used in this study to model the results on a jurisdiction wide basis

B.1 Broadly Applicable Method

Although not directly applied in our jurisdictional analysis, a slightly more granular (and broadly applicable) method for quantifying interactive heating and cooling effects associated with LED lighting energy conservation measures in cannabis greenhouses and warehouses is presented. In practice, lighting interactive effects will vary considerably depending on the facility grow strategy, system design, and control parameters, and savings should be modelled (or, preferably, measured) on a facility-specific basis.

These savings equations are meant to serve as a starting point, and prior to use in any specific application, they should be modified (and expanded on) to ensure they are suitable for the actual grow strategy and system design blueprint. They:

- Represent a simplified system design where a facility is using dedicated equipment for space cooling (which serves the cooling load and part of the dehumidification load) and separate dedicated equipment for dehumidification (which serves the remaining dehumidification load).
- Assume cooling savings occur when either a space cooling load or a space cooling + space cooling dehumidification load is present.
- Assume heating savings occur when either a space heating, space heating + dehumidification reheat, or dehumidification reheat (without space cooling) load is present. Many warehouses (which have high internal heat gains) do not have space heating loads and only have dehumidification reheat loads.

This method does not explicitly consider:

- Baseline or LED upgrade lighting systems integrated with heat recovery (and/or directly reject heat to the outdoors)
- Cooling systems with heat recovery
- Impacts resulting from changes to humidity setpoints and impacts to dehumidification rates due to space temperature changes
- Changes to length of growth cycles at the clone, flower, and vegetative stages due to the introduction of LED lighting

Because every facility will have a custom blueprint, these sample equations are not recommended for use in a prescriptive program, or within a utility technical reference manual.

$$Cooling\ Savings = \frac{Cooling\ Interaction\ Factor * Lighting\ Savings * \sum(\frac{Coolings\ Hours}{8760})}{Cooling\ System\ Efficiency}$$

Where:
- Cooling Interaction Factor = to be determined by energy model or (preferably) measurements. In the absence of detailed model or measurements, use 0.9 for facilities with mechanical cooling and use 0 for facilities without mechanical cooling.
- Cooling System Efficiency = actual cooling system efficiency. In the absence of system-specific efficiency, use 3.5 based on typical value for COP of cooling systems.

$$Heating/Reheat\ Savings = \frac{Heating\ Interaction\ Factor * Lighting\ Savings * \sum(\frac{Heating/Reheat\ Hours}{12})}{Heating\ System\ Efficiency}$$

Where:
- Heating Interaction Factor = to be determined by energy model or (preferably) measurements. In the absence of detailed model or measurements, use -0.9 for facilities with mechanical heating systems.
- Heating System Efficiency = in the absence of system-specific efficiency, use 0.8 for conventional gas heating, 0.9 for gas condensing heating, 3.0 for electric heat pump, or 1.0 for electric resistance reheat.

The suggested formulas could be illustrated as daily hours such as: Σ (cooling days/365). Also, other variables could vary hourly or daily, as well and be moved inside the time summations – for example, if lighting savings varied by the hour or day.

B.2 Method for Modelling Results on a Jurisdiction Wide Basis

For the purpose of modelling the results on a jurisdiction wide basis, simplifying assumptions were made about HVAC system efficiencies and interaction factors.

In the energy savings potential modelling analysis, cooling and heating savings associated with the LED lighting measure are calculated as follows:

$$Cooling\ Savings = \frac{Cooling\ Interaction\ Factor * Lighting\ Savings * (\frac{Coolings\ Months}{12})}{Cooling\ System\ Efficiency}$$

Where:
- Cooling Interaction Factor = 0.9 for warehouses; 0 for greenhouses[5]
- Cooling Months = 5
- Cooling System Efficiency = COP of 3.5

$$Heating/Reheat\ Savings = \frac{Heating\ Interaction\ Factor * Lighting\ Savings * (\frac{Heating\ Months}{12})}{Heating\ System\ Efficiency}$$

[5] Majority of greenhouses in the study jurisdictions do not have mechanical cooling

Where:

- Heating Interaction Factor = -0.9 for warehouses and greenhouses
- Heating Months = 7
- Heating System Efficiency = COP of 3.0 for electric heating, efficiency of 0.80 for gas heating[6]

The magnitude of heating and cooling savings associated with the LED lighting measure varies significantly based on the lighting energy use intensity of the facility. An example calculation applying this jurisdictional scale method to a typical cannabis warehouse facility (with electric reheat), is provided below:

- Baseline Lighting Consumption = 258.6 kWh/ft^2
- Upgrade Lighting Consumption = 164.8 kWh/ft^2
- Lighting Savings = 93.80 kWh/ft^2

$$Cooling\ Savings = \frac{0.9 * 93.8\ \frac{kWh}{ft^2} * (\frac{5}{12})}{3.5} = 10.05 \frac{kWh}{ft^2}$$

$$Heating/Reheat\ Savings = \frac{-0.9 * 93.8\ \frac{kWh}{ft^2} * (\frac{7}{12})}{3.0} = -16.42 \frac{kWh}{ft^2}$$

[6] Warehouse heating systems are predominantly split system heat pumps in the study jurisdictions; Greenhouse heating systems are predominantly natural gas based in the study jurisdictions (units heater or central boilers); As a simplifying assumption in the potential modelling, a COP of 3.0 for heating was used for all fuel segments.

APPENDIX C. KEY DATA SOURCES BY REGION

To complement the bibliography, this appendix provides the key data sources used to develop the inputs and assumptions for each region.

C.1 British Columbia

- Health Canada's list of Licensed Cannabis Cultivators [3] which provided the total number of licensed cannabis cultivators in BC
- Data from FortisBC and BC Hydro about the number of cannabis production facilities in their service territory [40], [41] and estimated energy consumption from this customer segment [42]
- Websites of cannabis companies operating in BC used to inform estimates of facility type (greenhouse vs warehouse) and size (square footage) of facilities[7]
- The 2019 Greenhouse Energy Profile Study for Ontario [4], which provided assumptions for end use breakdown and unit energy consumption

C.2 Ontario

- Statistics Canada's 2016 Census of Agriculture, for greenhouse products and mushrooms [12]
- Health Canada's list of Licensed Cannabis Cultivators [3]
- The 2019 Greenhouse Energy Profile Study for Ontario [13]

C.3 Colorado

- To develop UEC estimates and facility energy use for cannabis greenhouses and warehouses, the study team drew on information from cannabis facilities in Colorado collected via 15 grower surveys administered on-line and 30 on-site facility assessments that included equipment analysis, square footage measurements, historical electric utility bill reports, and 13 facilities with electric monitoring devices on individual equipment [43]
- Facility stock for the base year was estimated based on the State of Colorado's license tracking reports [14] which include location, account name, and license type (medical or recreational) and applied to facility level data
- Historical annual sales reports published by the Colorado Department of Revenue [15] provide the basis for industry growth forecasts

C.4 Oregon

- Oregon Liquor Control Commission, Approved Marijuana Licensed Retailer list [44]
- D+R's PowerScore data set which includes energy use data and surveys from 87 warehouse and greenhouse cannabis cultivators in Oregon [45]
- Cultivate Energy Optimization's (CultivateEO) database of cannabis facility assessments, which includes detailed equipment and energy use information collected from 43 sites, 13 of which have electric monitoring devices on individual equipment [43]
- Interviews with cannabis growers utilizing both warehouse and greenhouse facilities [46]

[7] Communication with the BC Ministry of Agriculture and Agricultural Land Commission confirmed that, at this time, there is no publicly available dataset that provides facility-type or square footage information for licensed cannabis production operations in BC.

C.5 Washington

- Washington Liquor and Cannabis Board, Licensed Producer list which includes all licensed cannabis cultivators in the state of Washington [47]
- D+R's PowerScore data set which includes energy use data and surveys from 8 warehouse and 1 greenhouse cannabis cultivators in Washington [45]
- Cultivate Energy Optimization's (CultivateEO) database of cannabis facility assessments which includes detailed equipment and energy use information collected from 43 sites, 13 of which have electric monitoring devices on individual equipment [43]
- Interviews with cannabis growers utilizing both warehouse and greenhouse facilities [46]

APPENDIX D. MODELLING METHOD

A model for this project was developed using the Navigator Energy and Emissions Simulation Suite.

D.1 Model Parameters

There are six key parameters required for this model, presented in Table D-1. Data for each of these parameters is fed into the model to calculate energy consumption over the study period.

Table D-1: Model Parameters for the Energy Management for Cannabis Sector Study

Parameter	Definition	Units
Accounts	Number of facilities	# of facilities
Building Units	Total square footage of facilities	sq. ft.
Area Built Out and Operating (%)	Primarily used for cannabis facilities, this parameter indicates the amount of square footage in an existing facility that is fully operational, as opposed to square footage that is currently not being used for production	%
Saturation	The portion of total units that use a specific end-use	%
Fuel Share	The percentage of the energy end-use that is supplied by each fuel	%
Unit Energy Consumption (UEC)	The amount of energy used by each end-use per unit.	$\frac{eMWh}{sq.ft.}$

D.2 Model Segments

Energy consumption in this study will be broken down based on the following segments:

Table D-2: Model Segments for the Energy Management for Cannabis Sector Study

Regions	Sub-Sectors	End-Uses	Fuels
– Ontario – British Columbia – Washington – Colorado – Washington – Oregon	– Greenhouses – Warehouses	– Lighting – Space Heating – Space Cooling – Ventilation – Dehumidification – Irrigation and Circulation Pumps – Other Electricity – Other Gas	– Electricity – Natural Gas – Propane – Oil – Biomass

The region segments are also broken down further into climate zone segments, as follows:

Table D-3: Climate Zones by Region

Region	Climate Zones
British Columbia	– BC-4C – BC-5A – BC-5B – BC-5C
Colorado	– CO-4B – CO-5B – CO-6B – CO-7B
Ontario	– ON-5A – ON-6A
Oregon	– OR-4C – OR-5B
Washington	– WA-4C – WA-5B – WA-5C – WA-6B