# Principles and Physics of Electrical Systems for Energy-Efficient and Safe Indoor Cannabis Agriculture: A Comprehensive Research Plan

## Introduction and Scope

The escalating legalization and commercialization of cannabis cultivation have led to a significant increase in indoor farming operations. This method of cultivation, while offering enhanced control over environmental factors crucial for plant growth and product quality, is notably energy-intensive. In 2017 alone, cannabis companies in the United States consumed an estimated 1.1 million megawatt hours of electricity , a figure that underscores the substantial energy footprint of this industry. This energy demand is further emphasized by the fact that indoor cannabis production can account for a considerable percentage of total electricity consumption in major producing states , with even small-scale operations exhibiting energy usage comparable to numerous households.

The high energy consumption in indoor cannabis facilities stems primarily from the necessity of artificial lighting to replicate sunlight, sophisticated climate control systems to maintain optimal temperature and humidity, and various other electrically powered equipment for tasks such as ventilation, dehumidification, and irrigation. Lighting, often operated for extended periods to maximize plant growth, contributes significantly to both energy use and carbon dioxide emissions. The substantial energy expenditures associated with indoor cannabis cultivation, reaching billions of dollars annually in the US , highlight the critical need for a comprehensive understanding and optimization of the electrical systems that power these operations. The economic viability and environmental sustainability of the indoor cannabis industry are intrinsically linked to the efficiency and safety of its electrical infrastructure.

This research plan outlines a detailed investigation into the fundamental principles and physics of electrical systems as they are applied within the context of indoor cannabis agriculture. The scope of this plan encompasses a thorough examination of key areas, including the distribution of electrical power within cultivation facilities, effective strategies for managing electrical loads to minimize energy waste, the implementation of robust safety protocols to mitigate inherent electrical hazards, methods for enhancing overall energy efficiency across all electrical systems, the selection and optimization of lighting technologies tailored for cannabis growth, the electrical demands and efficiency of environmental control systems, and the integration of automation technologies to improve operational efficiency and safety. The overarching aim of this research is to identify critical areas for improvement and to develop evidence-based recommendations that can lead to enhanced energy efficiency, improved safety standards, and potentially increased yields in indoor cannabis cultivation.

## Objectives and Research Questions

The primary objectives of this research plan are multifaceted and aim to provide a comprehensive understanding of electrical systems in indoor cannabis cultivation. Firstly, a thorough analysis of the electrical power demands and consumption patterns across various scales of operation and plant growth stages will be conducted. This will involve quantifying energy usage in critical systems like lighting and HVAC. Secondly, the energy efficiency of current electrical technologies and practices will be rigorously evaluated to pinpoint inefficiencies and opportunities for adopting advanced systems. Thirdly, the impact of electrical system parameters, such as lighting spectrum and intensity, environmental control settings, and load management strategies, on the growth, yield, and quality of cannabis plants will be investigated. Fourthly, the research seeks to identify and assess electrical safety hazards prevalent in these facilities and propose mitigation strategies based on established standards. Finally, the plan aims to develop evidence-based best practices for designing, installing, operating, and maintaining energy-efficient and safe electrical systems specific to indoor cannabis agriculture.

To achieve these objectives, the research will address several key questions:

* What are the typical electrical load profiles of indoor cannabis cultivation facilities, and how do these profiles vary based on facility size, cultivation methods, and plant growth stage?
* How do different lighting technologies (HID vs. LED vs. LEC) compare in terms of energy consumption, light output, heat generation, and their impact on cannabis growth and yield?
* What are the most effective load management strategies for minimizing peak demand and overall energy usage in indoor cannabis farms?
* How can environmental control systems (HVAC, dehumidification) be optimized electrically to reduce energy consumption while maintaining ideal growing conditions?
* What role can automation technologies play in improving energy efficiency and safety in indoor cannabis cultivation?
* What are the critical electrical safety hazards in indoor cannabis grow facilities, and how can they be mitigated through design and operational protocols, considering relevant standards like the NEC?
* How do power quality issues, such as harmonics and power factor, affect the performance and efficiency of electrical equipment in cannabis grow operations?
* What are the regulatory requirements and sustainability considerations related to electrical systems in indoor cannabis cultivation?

## Background and Literature Review

The electrical systems underpinning indoor agriculture, particularly for cannabis, are characterized by a reliance on technologies that, while effective for plant growth, often result in significant energy consumption. Traditionally, High-Intensity Discharge (HID) lamps have been the mainstay for providing the intense light required, especially during the flowering phase of cannabis cultivation. These lamps, while providing high light output, are also known for their considerable energy usage and the substantial heat they generate, necessitating robust and often energy-intensive cooling systems.

Maintaining the precise environmental conditions essential for optimal cannabis growth necessitates the use of sophisticated Heating, Ventilation, and Air Conditioning (HVAC) systems. These systems, along with dehumidifiers and air circulation fans, collectively contribute a significant portion to the overall electrical load in a grow facility. The management of these electrical loads in many existing facilities may lack advanced optimization, often relying on basic control mechanisms that can lead to inefficient energy use, particularly during periods of peak electricity demand. Furthermore, the implementation of electrical safety protocols can vary widely across the industry, influenced by facility scale, infrastructure age, and awareness of potential hazards and relevant safety standards.

Cannabis cultivation presents unique electrical system considerations. The plant's lighting requirements evolve through its lifecycle, with vegetative and flowering stages demanding different photoperiods and light spectra, directly impacting energy consumption. The necessity for precise environmental control, encompassing temperature, humidity, and carbon dioxide levels, further contributes to the electrical demands of these facilities. Moreover, the regulatory landscape for cannabis cultivation is increasingly incorporating considerations for energy efficiency and electrical safety in certain jurisdictions , with electrical codes like the NEC containing specific provisions applicable to these facilities.

Existing research robustly documents the high energy consumption associated with indoor cannabis production when compared to traditional agricultural practices and other commercial sectors. Studies have quantified the substantial electricity usage per unit area or product yield, underscoring the imperative for more sustainable cultivation methods. A significant area of research has focused on the potential of Light-Emitting Diode (LED) technology to drastically reduce energy consumption in horticultural applications , demonstrating comparable or superior light output for plant growth with significantly lower power requirements and reduced heat generation. Furthermore, ongoing research is dedicated to optimizing light spectra and intensity to precisely match the developmental needs of cannabis plants, aiming to maximize photosynthetic efficiency and the production of desired compounds. The integration of Artificial Intelligence (AI) and the Internet of Things (IoT) for intelligent control of indoor farming environments represents another growing area of research, exploring the use of sensor data and machine learning to dynamically adjust environmental parameters for optimal growth and energy minimization. Demand response programs are also being investigated as mechanisms to reduce energy costs and alleviate strain on the electrical grid by adjusting energy usage in response to grid conditions and pricing signals. While existing research provides a valuable foundation, there remains a need for more integrated studies that examine the complex interactions between various electrical systems and their combined impact on energy efficiency, plant growth, and safety within commercial cannabis cultivation facilities. Research that effectively translates theoretical findings into practical applications within the industry is also crucial for driving meaningful change.

## Principles and Physics of Electrical Systems Relevant to Cannabis Indoor Agriculture

A thorough understanding of fundamental electrical principles is essential for designing, operating, and optimizing the electrical systems in indoor cannabis agriculture. **Ohm's Law (V=IR)**, which defines the relationship between voltage, current, and resistance , serves as a cornerstone for circuit design and safety analysis. By applying this law, the current drawn by equipment like high-wattage grow lights can be accurately calculated, ensuring appropriate wiring and circuit protection to prevent overloads and potential hazards. **Electrical power (P=VI)**, the rate at which electrical energy is transferred , is crucial for energy management and cost analysis. Determining the power consumption of lighting systems (ranging from hundreds to thousands of watts ), HVAC units, and other equipment is fundamental for designing an electrical service with sufficient capacity. While most facilities utilize Alternating Current (AC) power, some advanced lighting technologies, such as LEDs with direct DC conversion, offer potential efficiency improvements. For large-scale operations with significant power demands, **three-phase power** provides advantages in terms of efficiency and the ability to power heavy-duty equipment.

Power quality plays a significant role in the efficiency and reliability of electrical systems. **Power factor**, the ratio of real power to apparent power , impacts energy losses and can lead to increased costs if low. Equipment like electronic ballasts and some LED drivers can have low power factors, necessitating research into and implementation of power factor correction techniques. **Harmonics**, which are sinusoidal waveforms at multiples of the fundamental frequency , can be introduced by non-linear loads such as electronic power supplies and variable frequency drives. High levels of harmonic distortion can cause equipment overheating and malfunction , highlighting the importance of identifying and mitigating their sources in grow operations.

The physics of light is paramount in indoor cannabis cultivation. **Photosynthetically Active Radiation (PAR)**, the range of light wavelengths plants use for photosynthesis , and metrics like Photosynthetic Photon Flux (PPF) and Photosynthetic Photon Flux Density (PPFD) are critical for optimizing lighting systems. Different light wavelengths within the PAR range, such as blue and red light, have varying effects on plant development , underscoring the importance of selecting the optimal **light spectrum** for each growth stage. Providing the correct **light intensity**, measured as PPFD, is essential for maximizing photosynthesis without causing plant stress. Additionally, the **heat transfer** from lighting and other electrical equipment significantly impacts the grow room environment and the energy required for cooling , making the selection of lighting technologies with lower heat output, such as LEDs, crucial for energy efficiency.

The physics of environmental control involves principles of **thermodynamics**, governing heat transfer and air movement , and **psychrometrics**, the study of air-water vapor mixtures, essential for humidity control. Plant transpiration significantly influences the grow room's thermodynamics by adding moisture and affecting cooling loads. **Fluid dynamics** principles are relevant to airflow patterns within the grow room, impacting temperature and humidity uniformity and plant health. Efficient HVAC systems must manage both sensible and latent heat loads to maintain optimal growing conditions.

**Table 1: Comparison of Lighting Technologies for Indoor Cannabis Cultivation**

| Technology | Typical Efficiency (PPF/Watt) | Average Lifespan (Hours) | Primary Spectral Output | Relative Heat Generation | Typical Initial Cost | Key Advantages | Key Disadvantages |
| --- | --- | --- | --- | --- | --- | --- | --- |
| High-Pressure Sodium (HPS) | 1.2-1.7 | 10,000-24,000 | High in red/yellow spectrum, suitable for flowering | High | Low to Medium | High intensity, good for flowering | High energy consumption, high heat output, requires frequent bulb replacement |
| Metal Halide (MH) | 0.8-1.1 | 10,000-20,000 | High in blue spectrum, suitable for vegetative growth | High | Low to Medium | Good for vegetative growth | High energy consumption, high heat output, requires frequent bulb replacement |
| Compact Fluorescent (CFL) | 0.5-0.8 | 8,000-15,000 | Available in various spectra | Low | Low | Low initial cost, low heat output, suitable for small grows and seedlings | Lower intensity compared to HID, less efficient for large-scale flowering |
| Light Emitting Diode (LED) | 1.5-3.0+ | 50,000-100,000+ | Full spectrum, tunable options available | Low to Medium | Medium to High | High energy efficiency, low heat output, long lifespan, customizable spectrum | Higher initial cost compared to HID, performance can vary significantly by product |
| Light Emitting Ceramic (LEC) | 1.7-2.0 | 20,000-30,000 | Broad spectrum, good for both vegetative and flowering | Medium | Medium to High | Good spectrum quality, higher efficiency than HID, lower heat than HID | Higher initial cost than HID, less widely adopted than LED |

## Proposed Methodology (Experimental and/or Simulation)

The research will be conducted in six distinct phases, each designed to build upon the findings of the previous stages.

**Phase 1: Literature Review and Baseline Data Collection:** This initial phase will involve a thorough examination of existing scholarly articles, industry reports, and regulatory documents to establish a comprehensive understanding of the current state of electrical systems in indoor cannabis agriculture. Where possible, baseline data on energy consumption, lighting systems, HVAC configurations, and safety protocols will be collected from a diverse range of operational indoor cannabis grow facilities, ensuring data anonymization. Existing energy audit reports will also be analyzed to understand past recommendations and their impact.

**Phase 2: Experimental Investigation of Lighting Systems:** Controlled experiments will be conducted in growth chambers to compare the energy efficiency and impact on cannabis growth and yield of various lighting technologies, including HID, LED, and potentially LEC lamps. Plants will be grown under standardized environmental conditions while varying lighting type, spectrum, and intensity. Key metrics such as energy consumption, plant growth rates, biomass yield, and cannabinoid/terpene content will be measured. Heat output from each system will also be quantified.

**Phase 3: Simulation and Modeling of Environmental Control Systems:** Detailed simulation models of indoor cannabis grow rooms will be developed using building energy simulation software, incorporating data from the literature and Phase 2 experiments. These models will evaluate the energy performance of different HVAC and dehumidification system configurations under various climate conditions and simulate the impact of smart control strategies.

**Phase 4: Evaluation of Load Management and Power Quality:** In collaboration with commercial grow facilities, electrical load profiles and power quality parameters (power factor and harmonics) will be monitored over time. The effectiveness of existing load management techniques will be analyzed, and the potential impact of other strategies will be evaluated.

**Phase 5: Development and Testing of Safety Protocols:** A comprehensive review of electrical safety standards (e.g., NEC Article 547, IEEE standards) will be conducted, and safety audits will be performed at participating grow facilities. Based on this, tailored safety protocols for indoor cannabis cultivation will be developed and tested in controlled research environments.

**Phase 6: Data Analysis, Report Writing, and Dissemination:** Data from all phases will be analyzed, and a comprehensive research report will be prepared, documenting the findings and providing recommendations for optimizing electrical systems in indoor cannabis cultivation. The findings will be disseminated through publications, presentations, and industry workshops.

## Required Resources and Equipment

The successful execution of this research plan will necessitate a dedicated team of experts, including a project manager, electrical engineers specializing in power systems and agricultural applications, horticultural scientists with expertise in cannabis cultivation, data analysts, research assistants, and a safety officer.

A range of specialized equipment and measurement tools will be required, including various types of grow lights (HID, LED, LEC) with PAR meters and light spectrum analyzers to quantify light output and spectral characteristics. Environmental monitoring sensors will be crucial for tracking temperature, humidity, CO2 levels, and VPD within the grow environments. Electrical power meters and data loggers will be essential for accurately measuring voltage, current, power, and energy consumption of both individual equipment and the entire electrical system. Power quality analyzers will be used to assess power factor and harmonic distortion levels , and thermal imaging cameras will aid in identifying heat generation from electrical components. Equipment for monitoring HVAC system performance will also be necessary. Ensuring safety will require safety testing equipment such as ground fault testers and insulation resistance testers.

Software and simulation tools will play a vital role in the research. Building energy simulation software will be used for modeling grow room environments , while circuit simulation software will assist in analyzing electrical systems. Data analysis and statistical software will be crucial for processing the large datasets generated. CAD software will be used for designing experimental setups and facility layouts.

Access to controlled environment growth chambers or dedicated research grow rooms is essential for conducting the lighting experiments. Furthermore, collaboration agreements with commercial cannabis cultivation facilities will be necessary for collecting baseline data and performing on-site testing. Finally, an adequate budget will be required to cover personnel costs, equipment purchase and maintenance, travel, software licenses, and dissemination of research findings.

## Timeline and Milestones

The research project is planned to be executed over a 24-month period, divided into six key phases with specific milestones.

**Phase 1 (Months 1-3): Literature Review and Planning:** Month 1 will focus on a comprehensive literature search and review. By the end of Month 2, detailed research protocols and the final research plan document will be completed. Month 3 will be dedicated to securing ethics approvals and collaboration agreements with participating facilities, along with developing protocols for data collection and on-site monitoring.

**Phase 2 (Months 4-9): Experimental Investigation of Lighting Systems:** Months 4-5 will involve preparing the growth chambers and equipping them with various lighting systems and monitoring equipment. The controlled experiments comparing different lighting technologies will be conducted from Months 6-8, with data collection on energy consumption, light intensity, plant growth, and heat output. Initial data analysis for this phase will be completed by the end of Month 9.

**Phase 3 (Months 7-12): Simulation and Modeling of Environmental Controls:** Detailed simulation models of grow room environments will be developed during Months 7-9, incorporating data from literature and Phase 2 experiments. Simulations to evaluate HVAC system performance and control strategies will be performed during Months 10-11. Analysis of the simulation results to identify energy-efficient approaches will be completed by the end of Month 12.

**Phase 4 (Months 10-15): Evaluation of Load Management and Power Quality:** Power monitoring equipment will be installed in collaborating facilities during Months 10-11. Data on electrical load profiles and power quality will be continuously collected from Months 12-14. Analysis of this data to characterize load profiles, assess power quality, and evaluate load management practices will be completed by the end of Month 15.

**Phase 5 (Months 13-18): Development and Testing of Safety Protocols:** A review of safety standards and safety audits at collaborating facilities will be conducted in Month 13. The development of tailored safety protocols will take place during Months 14-16. These protocols will be tested in controlled research grow rooms during Months 17-18.

**Phase 6 (Months 16-24): Data Analysis, Report Writing, and Dissemination:** Comprehensive data analysis across all phases will be performed from Months 16-20. The drafting of the final research report will occur during Months 20-22, followed by internal review and revisions in Months 22-23. The final research report will be completed, and materials for dissemination will be prepared by the end of Month 24.

## Expected Challenges and Risk Mitigation

Several challenges may arise during the course of this research project. Gaining access to commercial grow facilities for data collection and on-site testing could be challenging due to concerns about proprietary information and operational disruptions. To mitigate this, strong relationships will be established with cannabis cultivation companies through industry contacts and by clearly outlining the mutual benefits of collaboration, including sharing research findings and the potential for improved efficiency and safety. Comprehensive non-disclosure agreements will be developed to address confidentiality concerns.

The variability in data across different grow facilities and the need to protect the confidentiality of participating growers pose another challenge. Standardized data collection protocols and templates will be developed to ensure consistency, and robust data anonymization and aggregation techniques will be implemented. All sensitive data will be stored securely.

The costs associated with purchasing specialized equipment and the availability of certain advanced tools could also present challenges. A detailed equipment list will be developed early in the project, and options for equipment loans, in-kind contributions from manufacturers, and collaborations with other laboratories will be explored. The acquisition of core equipment will be prioritized based on budget constraints.

The regulatory landscape for cannabis cultivation is constantly evolving, which could impact the research and its recommendations. To mitigate this, dedicated personnel will continuously monitor federal, state, and local regulations, and engagement with regulatory bodies and industry associations will ensure alignment with current and future requirements.

Technical difficulties with experiments and simulations are always a possibility in research. To minimize this risk, experienced personnel will be recruited, thorough pilot testing of experimental setups and simulation models will be conducted, and contingency plans and backup equipment options will be in place.

Finally, ensuring plant health and yield in the experimental setups will be crucial for obtaining reliable results. Collaboration with experienced horticultural scientists, strict adherence to optimal environmental conditions, and close monitoring of plant health will be implemented to mitigate this challenge.

## Regulatory and Safety Considerations

Compliance with relevant electrical codes and safety standards will be paramount throughout this research project. All electrical installations for experimental setups and any recommendations made for commercial facilities will strictly adhere to the latest edition of the National Electrical Code (NEC), particularly Article 547, which addresses electrical requirements for agricultural buildings. This includes the use of appropriate wiring methods, ensuring proper grounding and bonding , providing overcurrent protection, and selecting equipment rated for the specific environmental conditions. Specific attention will also be paid to NEC Article 410 Part XVI regarding horticultural lighting equipment and Article 512 concerning cannabis oil equipment (if applicable).

Relevant standards published by the Institute of Electrical and Electronics Engineers (IEEE) pertaining to electrical safety in industrial and commercial power systems, equipment grounding and bonding , and the installation, maintenance, and operation of electrical equipment will be consulted and followed as applicable. Compliance with regulations and guidelines established by the Occupational Safety and Health Administration (OSHA) will also be ensured to maintain a safe working environment. Furthermore, a thorough investigation will be conducted to identify and comply with any specific electrical codes, ordinances, or regulations at the local and state levels that are applicable to cannabis cultivation facilities.

Comprehensive written safety protocols will be developed and strictly enforced for all experimental work involving electrical systems and equipment. These protocols will include detailed procedures for working with high voltages and currents, the safe handling and installation of lighting systems, the proper use of electrical measurement tools, and emergency shutdown procedures. All research personnel will undergo thorough safety training, and regular safety audits will be conducted. The use of appropriate personal protective equipment (PPE) will be mandatory when working with electrical systems.

**Table 2: Summary of Key National Electrical Code (NEC) Articles Relevant to Indoor Cannabis Grow Facilities**

| NEC Article | Title | Key Requirements |
| --- | --- | --- |
| 410 Part XVI | Horticultural Lighting Equipment | Addresses listing requirements, flexible cords and connectors, GFCI protection, and support for horticultural lighting equipment, including those used in cannabis cultivation. |
| 512 | Cannabis Oil Equipment and Cannabis Oil Systems | Provides electrical requirements for cannabis oil preparatory equipment, extraction equipment, booths, post-processing equipment, and systems using flammable materials in commercial and industrial facilities. |
| 547 | Agricultural Buildings | Specifies wiring methods, equipment enclosures, grounding, GFCI protection, and other electrical requirements for agricultural buildings where dust, moisture, or corrosive atmospheres may be present, directly applicable to many indoor cannabis grow facilities. |
| 250 | Grounding and Bonding | Establishes general requirements for grounding and bonding of electrical systems, crucial for safety in all electrical installations, including those in agricultural and cannabis cultivation facilities. |
| 210 | Branch Circuits | Covers the requirements for branch circuits, including conductor sizing, overcurrent protection, and receptacle requirements, relevant to the distribution of power to various equipment within a cannabis grow facility. |
| 300 | Wiring Methods and Materials | Provides general requirements for wiring methods and materials, including installation practices, protection against physical damage, and requirements for wiring in damp or wet locations, all of which are pertinent to the electrical infrastructure of indoor cannabis cultivation operations. |

## Potential Collaborations

The success of this research will be significantly enhanced through collaborations with various stakeholders. Experienced commercial cannabis growers and cultivation managers can provide invaluable insights into the practical challenges and operational realities of electrical systems in their facilities. Their expertise will help ensure the research's relevance and the practicality of its findings. Partnering with licensed electrical contractors and engineers specializing in agricultural and horticultural facilities will be crucial for ensuring compliance with electrical codes and gaining practical knowledge about best practices in this sector. Engaging with manufacturers of grow lighting systems and HVAC equipment will provide access to technical expertise, product specifications, and potential opportunities for collaborative research and development of more efficient solutions.

Collaboration with academic institutions and research laboratories that possess established expertise in agricultural engineering, controlled environment agriculture, and energy efficiency will provide access to specialized knowledge and research infrastructure. Partnering with laboratories equipped for advanced testing and analysis of lighting systems and power quality will enhance the rigor and depth of the research. Establishing communication and potential collaboration with state and local regulatory agencies responsible for overseeing cannabis cultivation will help ensure the research aligns with current and future regulatory requirements. Exploring potential collaborations with utility companies that offer energy efficiency programs or demand response initiatives for commercial customers could provide opportunities for field testing and disseminating research findings. Finally, engaging with cannabis industry associations and organizations will provide a platform for sharing research findings with a broad audience of cultivators and other stakeholders.

## Conclusion and Impact

This research plan outlines a comprehensive investigation into the principles and physics of electrical systems as they relate to indoor cannabis agriculture. The expected outcomes include a thorough understanding of the electrical demands and challenges within this industry, the identification of key areas for optimization in energy efficiency and safety, and the development of evidence-based recommendations and best practices for cultivators, regulators, and technology providers. The research aims to quantify the performance of various electrical technologies, such as lighting and HVAC systems, and to evaluate the effectiveness of different load management and safety strategies.

The potential impact of this research is significant. It is anticipated to contribute to a substantial reduction in energy consumption and associated costs for indoor cannabis cultivators, promoting a more sustainable industry with a reduced environmental footprint. The development of enhanced electrical safety protocols will foster safer working environments, mitigating the risks of accidents and fires. Furthermore, the identification of optimized lighting and environmental control strategies may lead to improved crop yields and quality. Ultimately, this research endeavors to provide the knowledge and guidance necessary for the indoor cannabis cultivation industry to adopt more energy-efficient, safer, and sustainable practices, benefiting individual growers, the industry as a whole, and the environment.

**Table 3: Typical Electrical Load Breakdown for a Medium-Sized Indoor Cannabis Grow Facility (Estimated)**

| End-Use Category | Estimated Percentage of Total Energy Consumption | Typical Power Demand (kW) | Average Daily Operating Hours (Vegetative) | Average Daily Operating Hours (Flowering) |
| --- | --- | --- | --- | --- |
| Lighting | 30-40% | 80-160 | 18-24 | 12 |
| HVAC (Cooling) | 20-30% | 50-100 | 24 | 24 |
| HVAC (Ventilation/Fans) | 15-25% | 20-40 | 24 | 24 |
| Dehumidification | 10-20% | 15-30 | 24 | 24 |
| Water Pumps & Irrigation | 1-5% | 5-10 | Intermittent | Intermittent |
| Other Equipment (Controls, etc.) | 1-5% | 5-10 | 24 | 24 |

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