Cannabis Cultivation, Energy Consumption and Sustainability 101:
Optimizing Design of Cultivation Facilities

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THE CANNABIS CONSERVANCY

Presentation Overview

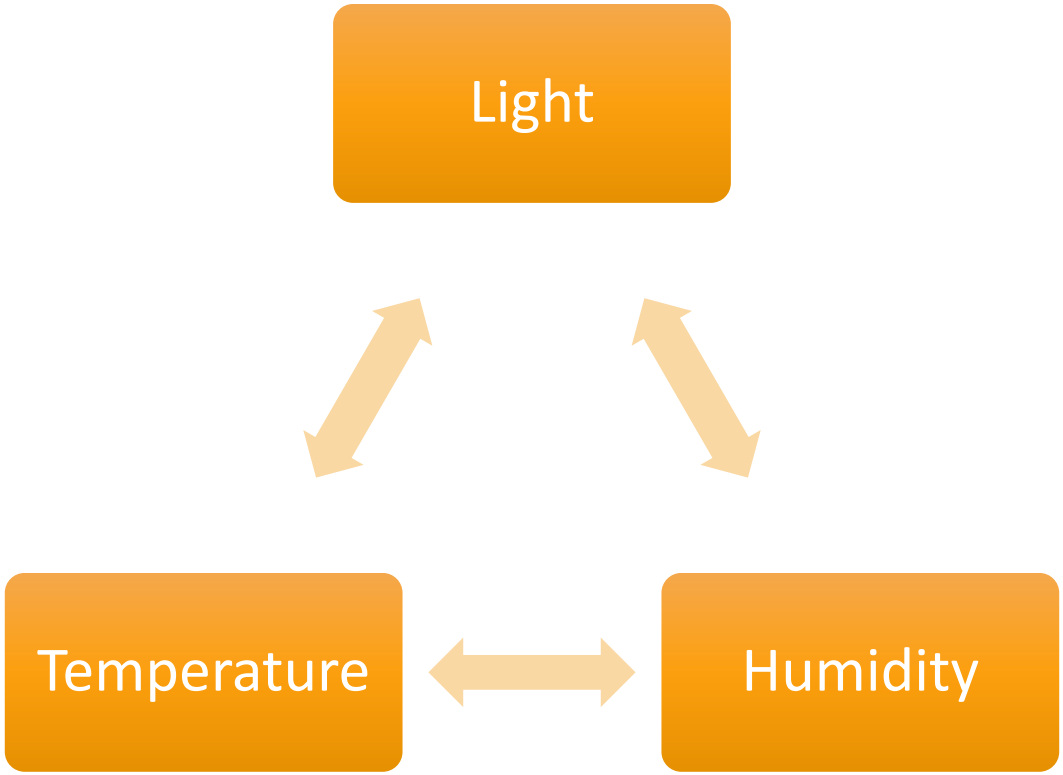
- Cultivation Overview
- Cannabis Biology
- Cultivation Methodology
- Indoor
- Greenhouse
- Sustainable Design

Direct and indirect drivers of energy use and greenhouse-gas emissions from the cannabis industry

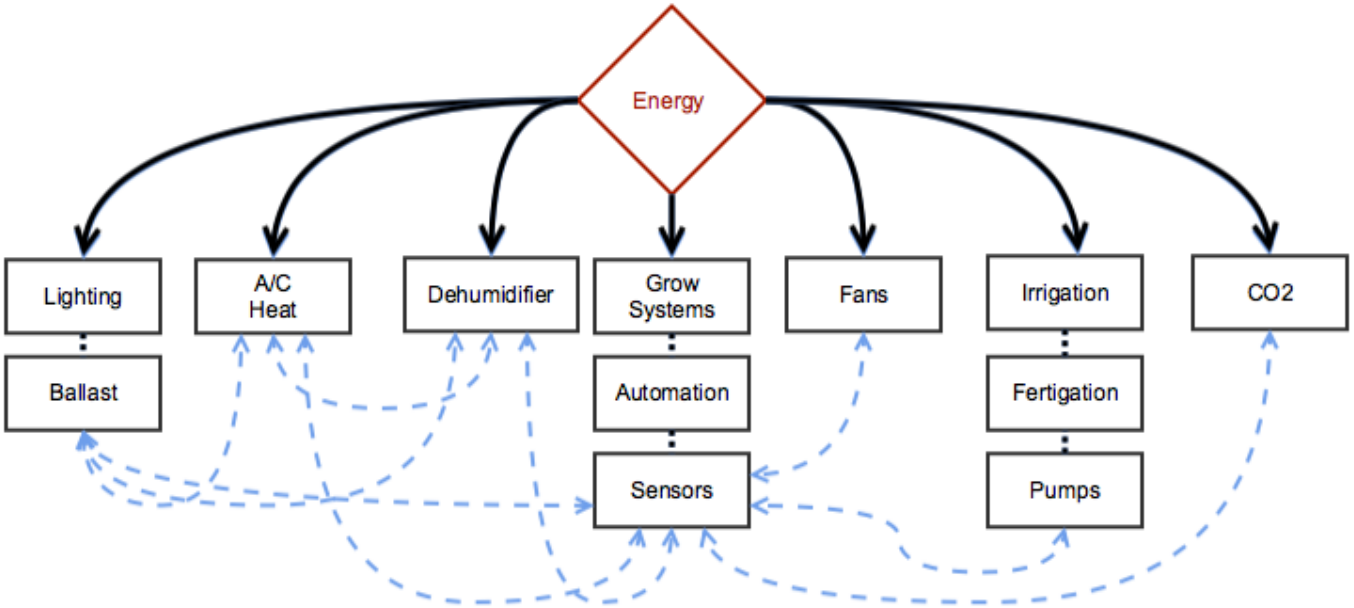
Inputs	• Energy (embodied) • Industrial CO_2* • Water production and supply • Soil, amendments, fertilizers • Artificial growing media • Pesticides, herbicides, fungicides rodenticides • Plastics (bagging, mulch, greenhouse sheeting, containers, irrigation, etc.)	  
Cultivation	• Outdoor • Small structure (windowless)* • Large structure (windowless) • Greenhouse • Energy: lighting, cooling, heating, ventilation, odor control, CO_2 generator, dehumidification, water heat, pumping, IT, plug loads*	  
Processing	• Flower drying* / freezing • Energy for producing extracts; solvents (butane, propane, ethanol, isopropyl alcohol) • Cooking/baking • Packaging • Testing labs	  
Waste	• Failed/interdicted crops • Material not passing inspection • Single-use soil or artificial growing media • Plastics • Hydroponic water effluent to waste-treatment plant • Biomass residues • Transpiration water recovery	  

Mills and Zeramby 2021. Energy Use by the Indoor Cannabis Industry

Main Cultivation Factors



Energy Use in Cultivation



Grower Considerations

- Cost
- Reliability
- Consistency
- Ease of Use
- Redundancy

Cannabis Life Cycle

Day 1

Day 30

Day 90

Propagation - Clones

Vegetative Stage

Flowering Stage

Life cycle bud week 7

Life cycle bud week 8

Life cycle bud week 9

Flowering

Ready For Harvest

Amber Trichomes

Harvesting

Curing and Storage

Why?

- Preservation
- Increase potency
- Preserve Terpenes
- Breakdown sugars, minerals

How:

- 60-70F
- 45-55% Humidity

Strain Differences

Indica vs Sativa

	Indica	Sativa
Origin	Central Asia	Equatorial
Flowering Time	45-65 Days	60-90 Days
Leaf Structure	Thick	Thin
Height	Short	Tall
Energy Needs	66 W per sq. ft.	45 W per sq. ft.

Autoflower Strains

Grow Methodology

	Clone	Vegetative	Flower
Light Hours	18-24 hours	18-24 hours	12 hours
Light Type	T-5 / LED	MH / LED	HPS / LED
Wattage	236 / 330	1000 / 330-660	1000 / 660-850
Watts/Sq. Ft (Lighting)	15-50	20-63	20-63
Length in Phase	1-3 weeks	2-7 weeks	8-10 weeks
Temperature	70-85 F	70-85 F	70-85 F
Relative Humidity	70-80%	60-70%	40-60%

Equipment By Grow Method

Equipment	Indoor	Greenhouse	Outdoor
Lighting	Primary	Supplemental	None
HVAC	RTU, Chillers, Evaporative Cooling	Passive, Evaporative, Fog, Chiller, Radiant	None
Circulation	Oscillating, Inline Fans	Ventilation, Oscillating, Inline Fans	None
Water	Filtration, Fertigation, Pumps	Filtration, Fertigation, Pumps	Pumps
Dehumidification	Stand alone, Reheat, Desiccant	Passive, Stand alone, Desiccant	None
Automation	Environmental Controls	Environmental Controls	Weather Sensors

Indoor Cultivation

- Illicit Market Legacy
- Climate Control
- Pest Pressure Control
- Consumer Preference

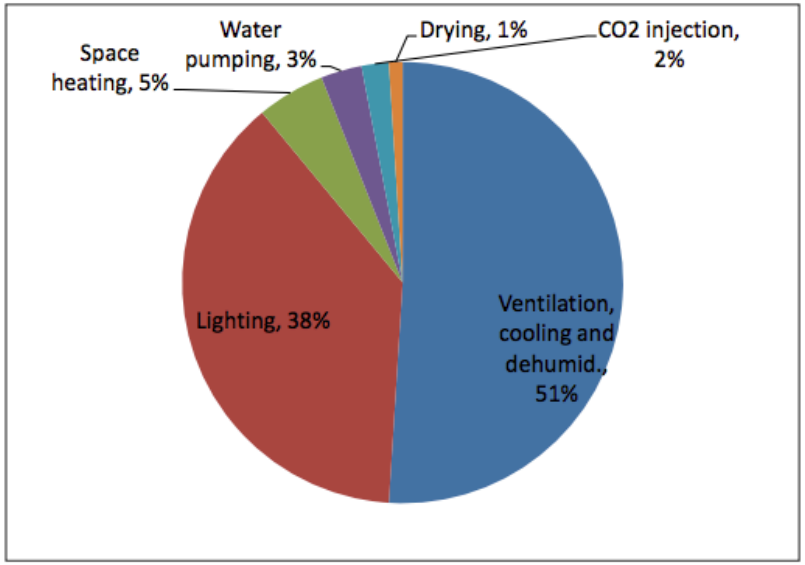
Indoor Grow Energy Usage

- Oregon Averages*
  - HVAC/Dehumidification: 40 – 50%
  - Lighting: 35 – 40%

- Colorado Averages
  - Lighting: ~60%
  - HVAC: ~30%
  - Dehumidification: ~10%

*Oregon Energy Trust

Figure 1 – Energy Use Breakdown for a Typical Indoor Cannabis Grow[9]

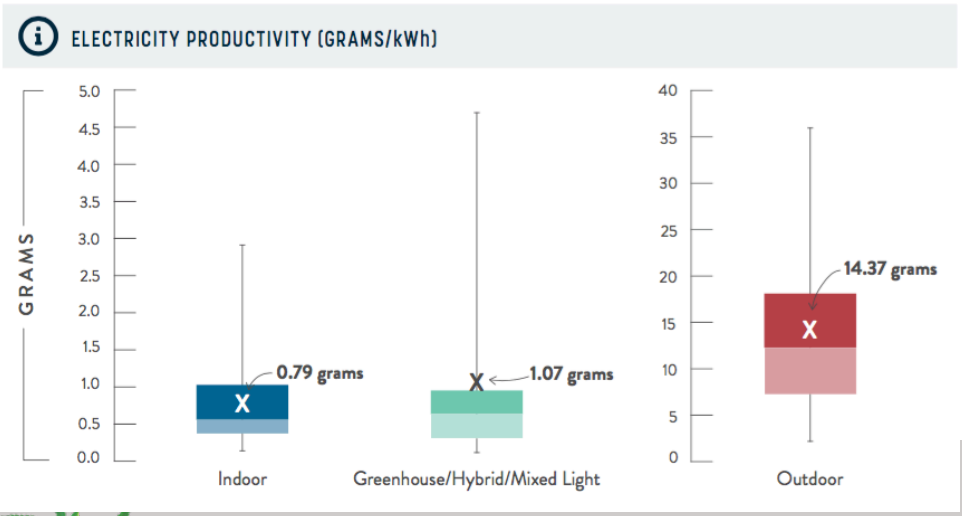


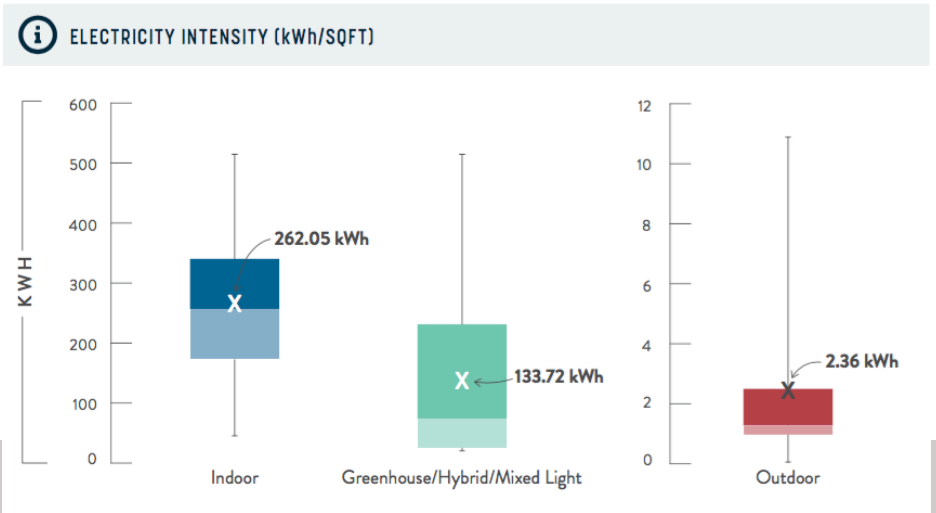
Kowley, Neil. 2017. A Budding Opportunity: Energy Efficiency best practices for cannabis grow operations. Southwest Energy Efficiency Project.

2018 Energy Benchmarks

KEY BENCHMARKS

Cultivation Type	Electricity Productivity (grams/kWh)	Electricity Intensity (kWh/sq.ft.)	Production Intensity (grams/sq.ft.)	Electricity Cost ($/gram)	Carbon Intensity (lbs.-CO_2e/gram)
Indoor	0.8	262	174	0.24	1.24
Greenhouse / Hybrid / Mixed Light	1.1	134	48	0.21	0.72
Outdoor	14.4	2	29	0.01	0.05





Lighting Considerations

- Equipment Selection
  - Photon Efficiency – Energy into PAR
  - Availability
- Design
  - Light Distribution
  - Light Intensity
  - Uniformity
- Facility
  - Space
  - Power Capacity
  - Cooling Capacity
  - Finances (Capital)

HVAC

Key Concepts

- Sensible Heat – Temperature (Lights)
- Latent Heat Load – Energy and Heat stored in Humidity (evapotranspiration)
- Poorly Designed Mechanical System increase energy use 50%

New Technology

Roof Top Units (RTU)

- Hot-Gas Reheat Forced-air System

Water Chilled Units

- Fan speed and water temp control for more efficient latent heat removal
- Water-side Economizing

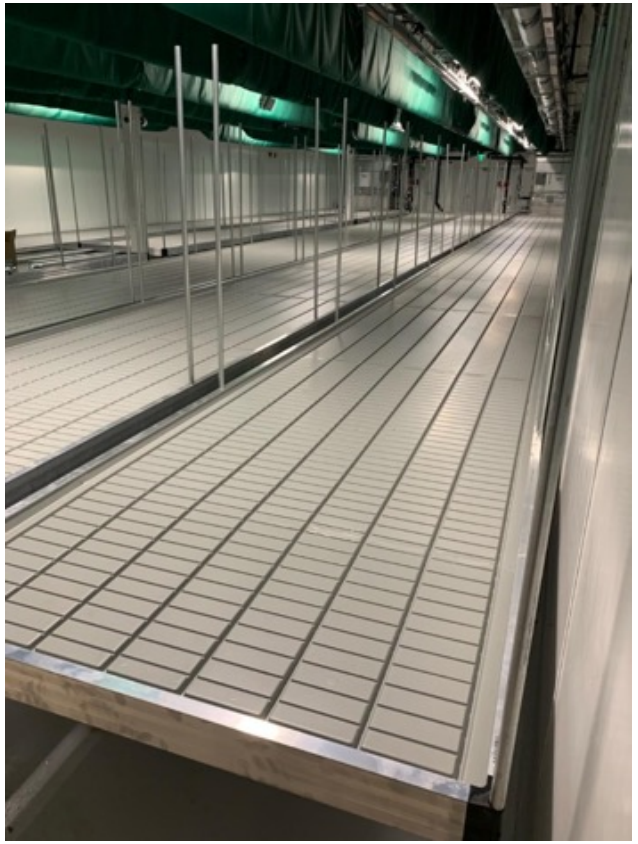
High-Efficiency Split Ductless A/C-Heat Pump

- Less Fan Energy
- Very Efficient in Heating mode

Dehumidification

- Plate Air to Air Heat Exchangers
- Hybrid Desiccant and Evaporative System

Indoor

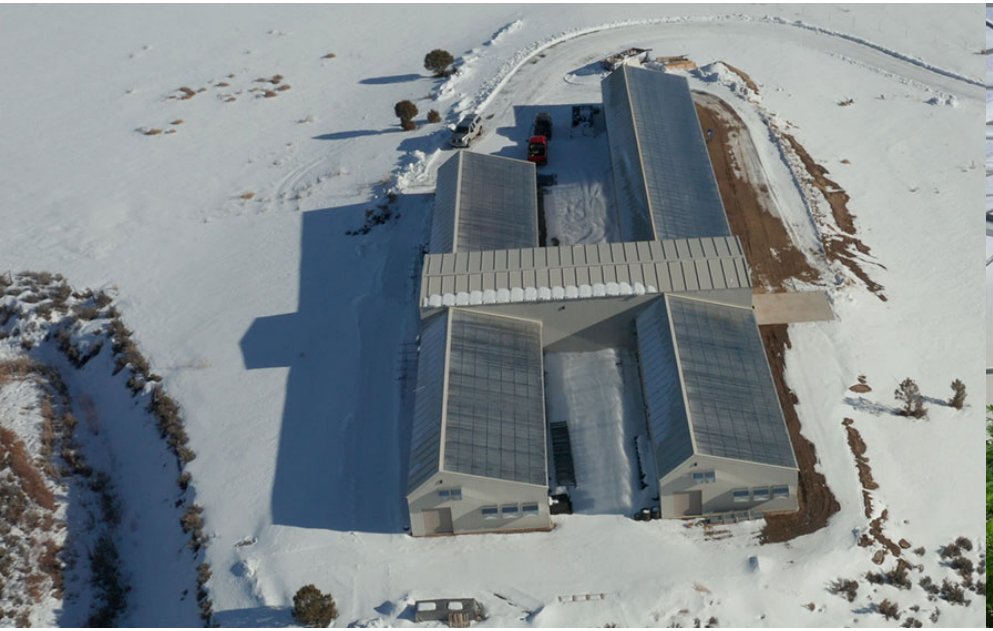


Greenhouses

Passive

Greenhouses

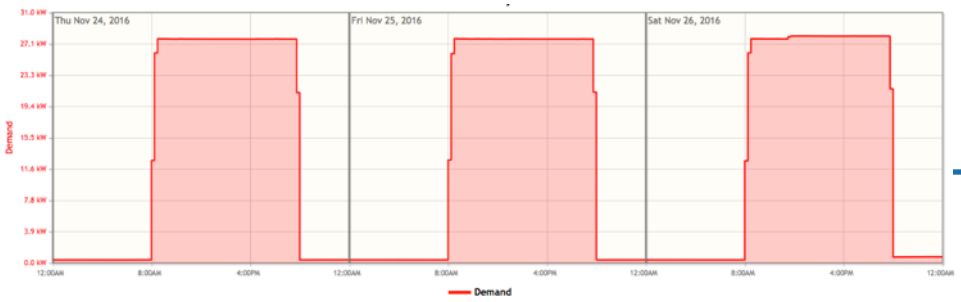
Sealed – Climate Controlled



Light Deprivation System

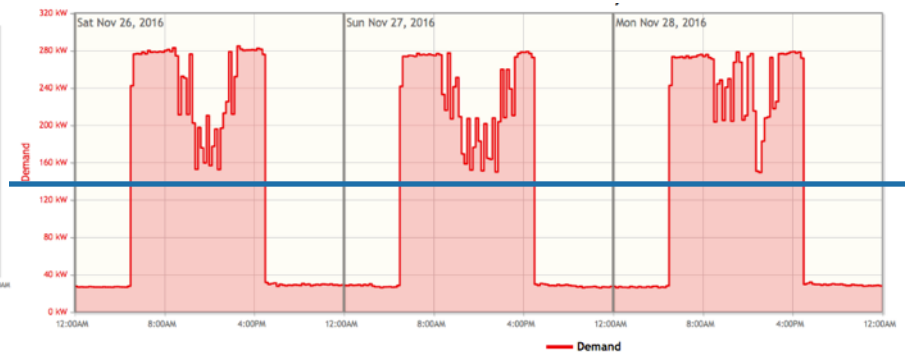
Indoor vs Greenhouse Lighting

Indoor



Max Demand	Consumption
28.1 kW	998.9 kWh
Average: 13.8 kW	
Peak Interval: 12:45 PM	

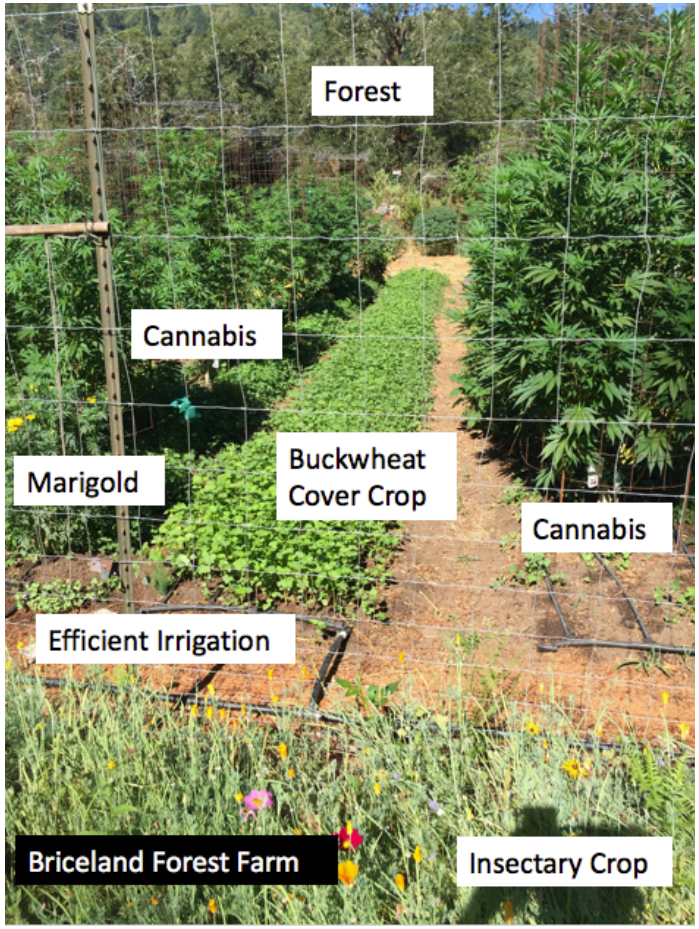
Greenhouse



Max Demand	Consumption
285 kW	9,811 kWh
Average: 136 kW	
Peak Interval: 02:30 PM	

Outdoor

Regenerative Outdoor



Environmental Set Points

- VPD
- Root Zone Temperature
- DLI
- Air Movement

Sustainable Design Trends

Focus on:

- Purpose Built Buildings
- Automation – Climate Control
- Operational Practices
- Behavioral Change
- On-going Energy Monitoring
- Sustainability as a marketing tool

Strategic Energy Management

Policy & Implementation
- Energy Conservation
- Energy Use (SOPs)
- Training Program

Energy Metrics and Benchmarks
- Total Consumption
- Production Efficiency

Infrastructure
- Building Envelope
- Insulation

Energy Management
- Annual Energy Audit
- Equipment Policies and Procedures
- Automation
- Maintenance

Equipment Systems
- Temperature and Humidity Systems
- Lighting Systems
- Air Circulation

Additional Factors
- Fuel Consumption Behavior
- Alternative Energy
- Carbon Offset

Reducing Energy Usage By Annually Increasing Stringency

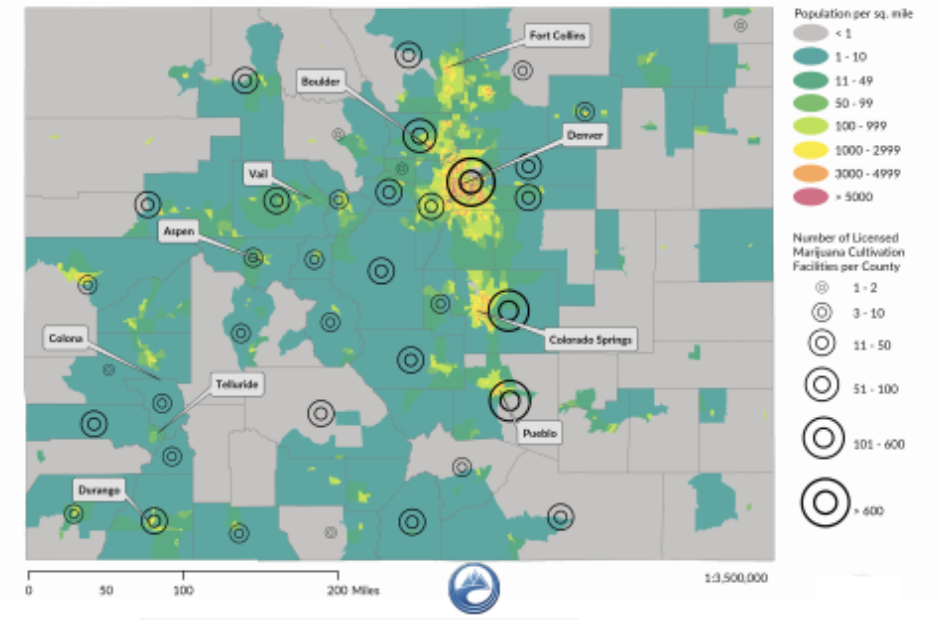
Year 1
- Benchmarking
- Recordkeeping

Year 2
- Internal Energy Policies, Trainings
- Targeted Goalsetting

Year 3
- Quantifiable Reductions
- Based on efficiency, usage, offsets

Utility Discussion

- Location
  - Clustered Urban Areas
  - Clustered by Zoning



- Client Needs
  - Utility Bill breakdown
  - Energy Audit
  - Power Upgrade Schedule
  - Rebate Guidance
- Solutions
  - Target Grower Organizations
  - Hold Public Meetings/Workshops
  - Agricultural Rates
  - Energy Offset Fund