

The logo for LUUNA.io is displayed in a bold, rounded, lime-green font. The letters 'L', 'U', 'U', 'A', and 'A' are connected, with the 'A's having a distinctive shape. The '.io' is separated by a period. The background is a dark blue field with a pattern of small, light blue dots that create a sense of depth and movement, resembling a starfield or a digital data stream.

LUUNA.io

IoT Optimized for Light

# **Illuminating Sustainability**

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A Comparative Analysis of Embodied and  
Operational Carbon of Lighting Systems

In an era of increasing environmental awareness, lighting systems are pivotal in reducing energy consumption and environmental impact. This report analyzes four lighting installation systems, including traditional AC/DC, low voltage DC, Power over Ethernet (PoE), and Extended PoE (X-PoE).

We explore their embodied and operational carbon footprints, considering energy efficiency and sustainability. Our aim is to provide valuable insights using the well-established TM65 method for calculating embodied carbon.

The report evaluates each system's direct energy consumption, carbon emissions, manufacturing processes, installation, and maintenance, examining their impact on resource utilization and greenhouse gas emissions over their lifecycle.

This report is intended for decision-makers, architects, and sustainability professionals, offering an objective comparison to support informed choices for more sustainable lighting solutions. Thank you to all contributors for their efforts in advancing environmentally responsible lighting technology.

**Karl Jonsson**

Co-Founder & CSO

LUUM.io

December 2023

# Airport Lobby Case Study

## Set preconditions:

1,500 sqft Space

~65lm/sqft lumen requirements

Light source: Downlights w. Reflectors, low UGR

4 Motion Zones

2 Wall Controller locations

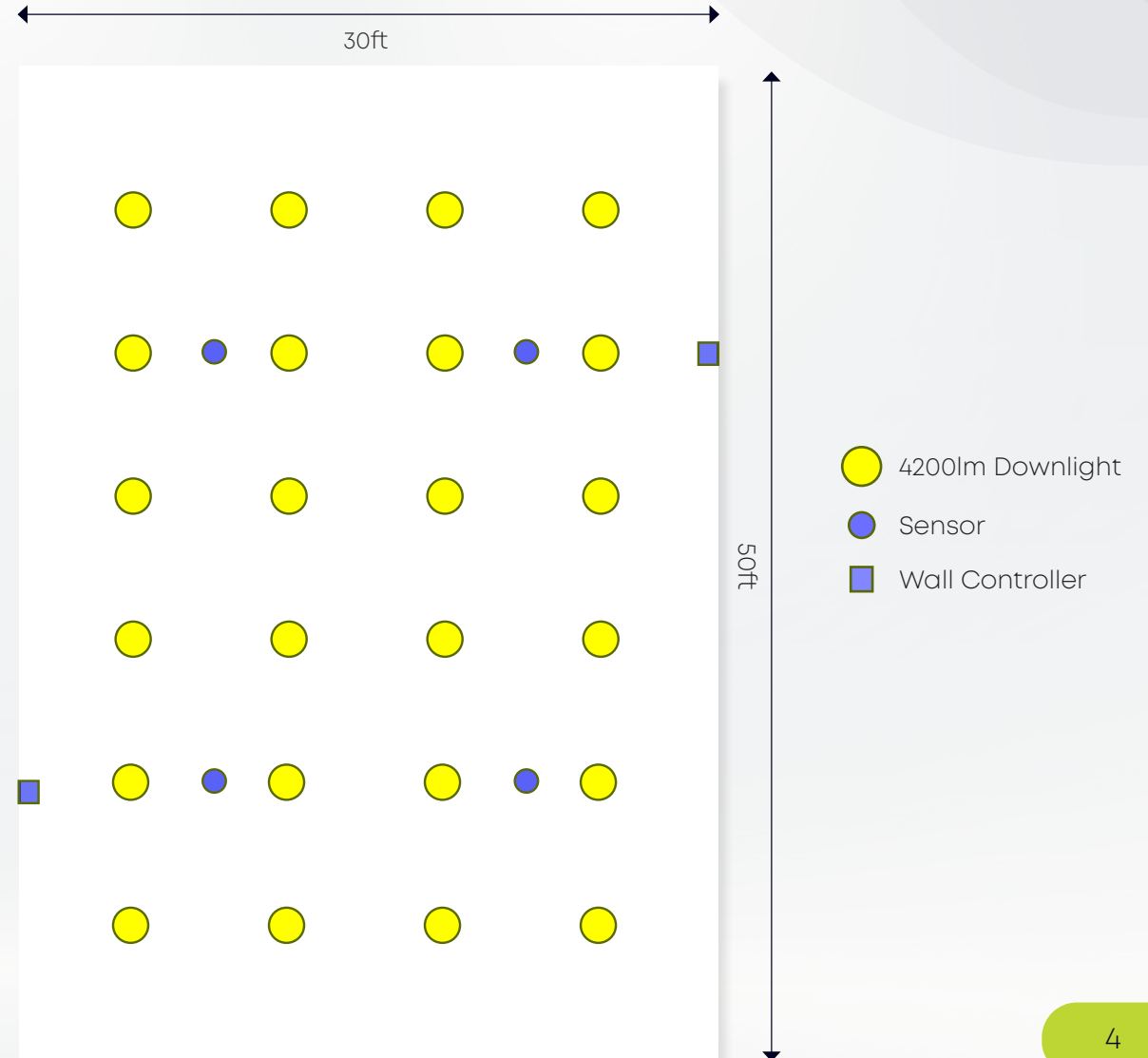
## Preconditions – operation:

16hr/365 operation

30% assumed savings on lighting controls

\$0.3/kWh Electricity price

Coal energy source@ 1.045 KgCO<sub>2</sub>e/kWh



# Case 1

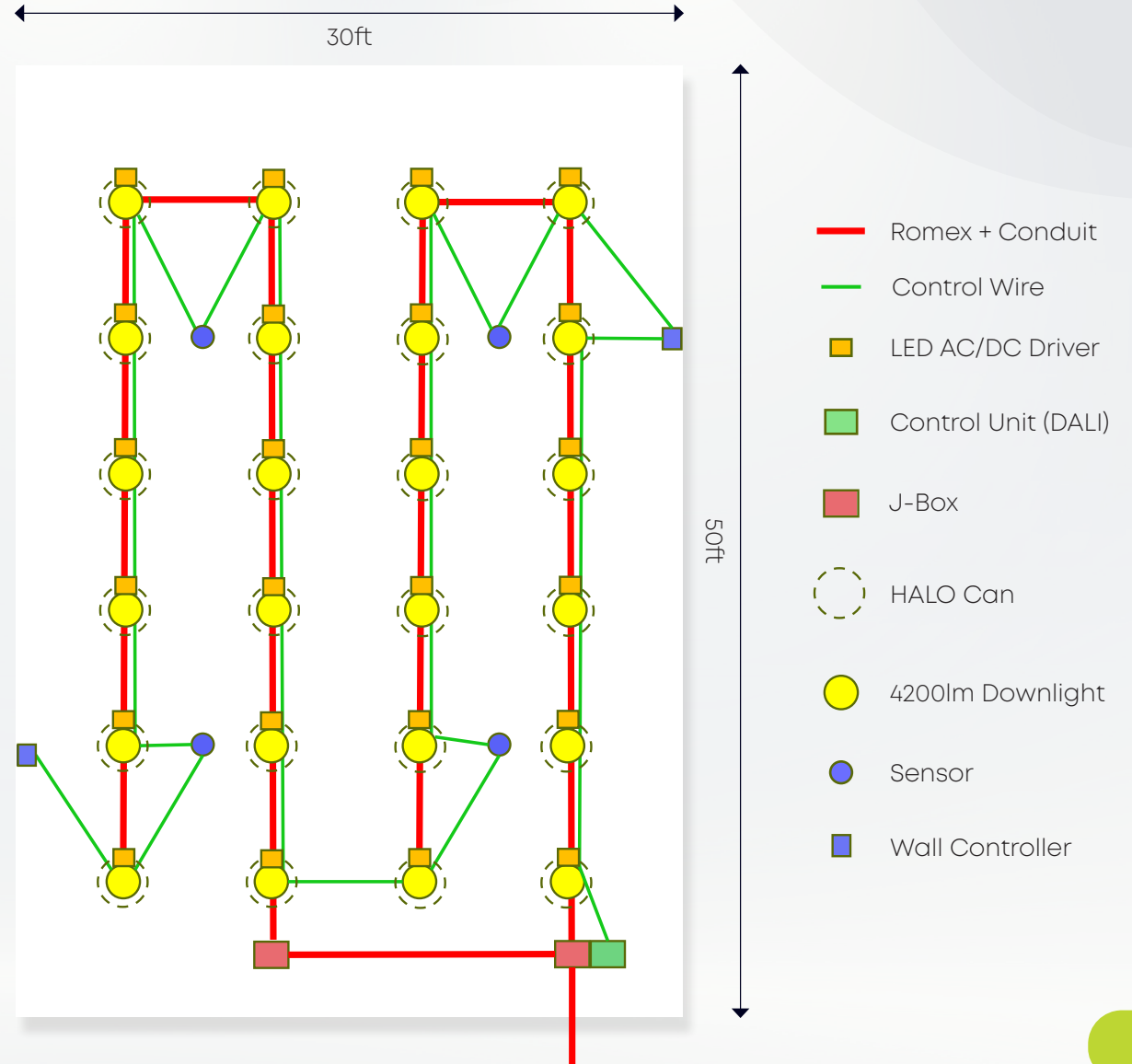
## Traditional AC/DC Installation

### Embodied Carbon:

250ft Romex	63 Kg CO <sub>2</sub> e
250ft Conduit	270 Kg CO <sub>2</sub> e
250ft Control Wire	13 Kg CO <sub>2</sub> e
24 x Halo Cans	485 Kg CO <sub>2</sub> e
24 x 4200lm Downlights	463 Kg CO <sub>2</sub> e
24 x 50W AC/DC LED Drivers	482 Kg CO <sub>2</sub> e
4x J-Boxes	41 Kg CO <sub>2</sub> e
1x DALI Master Control	% of driver incl.
4 x DALI Sensors	% of driver incl.
2 x DALI Controllers % of driver incl.	% of driver incl.
<b>Total:</b>	<b>1,817 Kg CO<sub>2</sub>e</b> (3,997 lb. CO <sub>2</sub> e)

### Operational Carbon:

• Downlight Power @ 4200lm (based on 80% Driver Efficiency)	43W (x24)
• Est. Total Controls Power	50W
Total Power:	1,082W
Annual kWh	6,319 kWh
Controls Savings (30%)	1,896 kWh
Annual kWh w. Savings	4,423 kWh
<b>Annual Energy cost</b>	<b>\$1,327</b>
<b>Annual Carbon emission</b>	<b>4,622 Kg CO<sub>2</sub>e</b> (10,168 lb. CO <sub>2</sub> e)

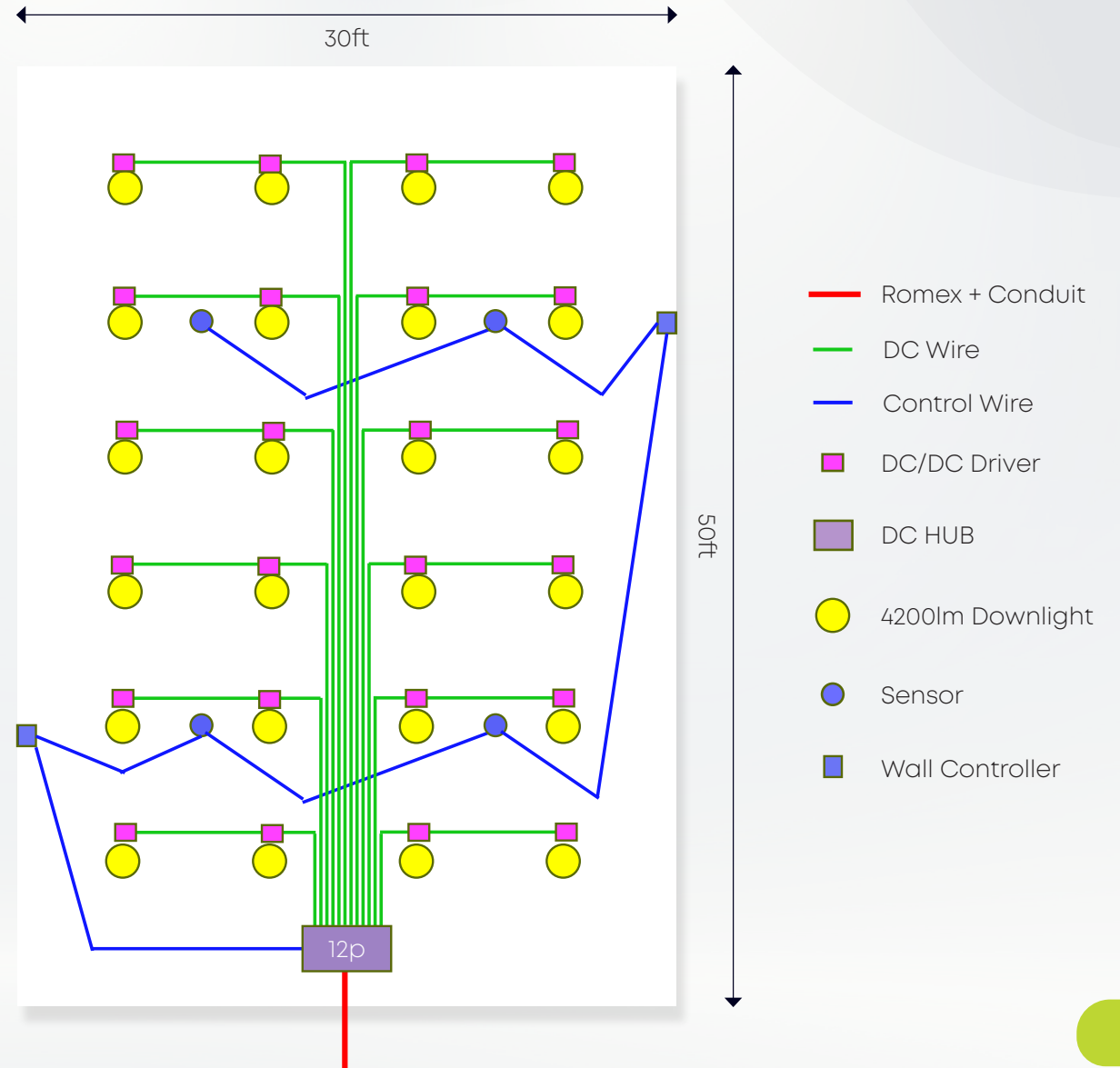


### Embodied Carbon:

10ft Romex	3 Kg CO <sub>2</sub> e
10ft Conduit	11 Kg CO <sub>2</sub> e
150ft Control Wire	8 Kg CO <sub>2</sub> e
300ft DC Wire	30 Kg CO <sub>2</sub> e
24 x 4200lm Downlights	463 Kg CO <sub>2</sub> e
24 x 50W DC/DC LED Drivers	236 Kg CO <sub>2</sub> e
1x DC HUB	939 Kg CO <sub>2</sub> e
Controls	% of driver incl.
4 x DALI Sensors	% of driver incl.
2 x DALI Controllers	% of driver incl.
<b>Total:</b>	<b>1,690 Kg CO<sub>2</sub>e</b> (3,726 lb. CO <sub>2</sub> e)

### Operational Carbon:

• Downlight Power @ 4200lm (based on 90% Driver Efficiency)	40.2W (x24)
• DC-HUB Power loss (based on 90% DC Hub Efficiency)	96W
• Est. Total Controls Power	50W
Total Power:	1,110W
Annual kWh	6,482 kWh
Controls Savings (30%)	1,945 kWh
Annual kWh w. Savings	4,537 kWh
Annual Energy cost	\$1,361
<b>Annual Carbon emission</b>	<b>4,741Kg CO<sub>2</sub>e</b> (10,430 lb. CO <sub>2</sub> e)



# Case 3

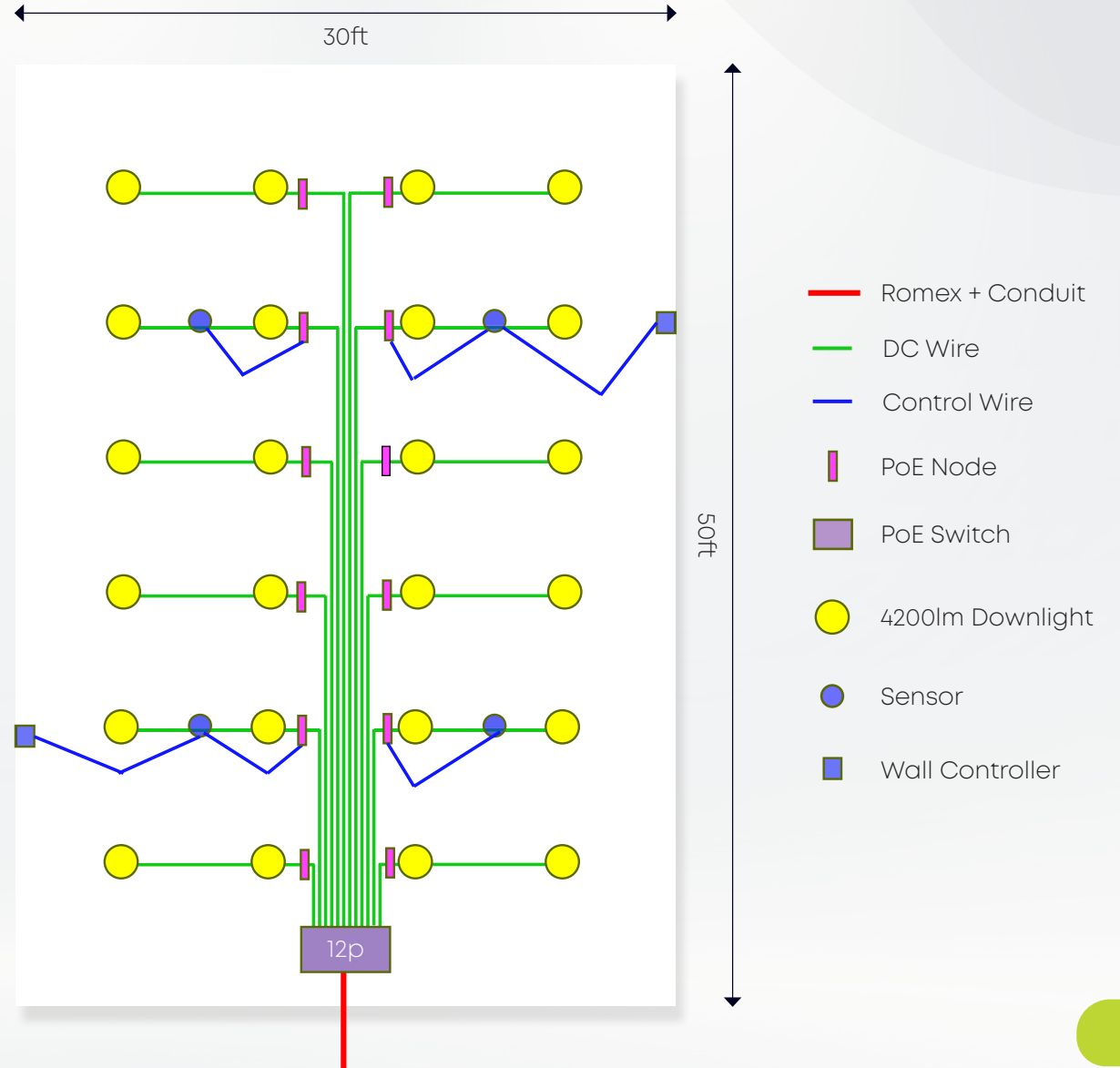
## Traditional PoE

### Embodied Carbon:

10ft Romex	3 Kg CO <sub>2</sub> e
10ft Conduit	11 Kg CO <sub>2</sub> e
350 ft Ethernet Wire	18 Kg CO <sub>2</sub> e
120ft DC Wire	12 Kg CO <sub>2</sub> e
24 x 4200lm Downlights	463 Kg CO <sub>2</sub> e
12 x 90W PoE Nodes	613 Kg CO <sub>2</sub> e
1x PoE Switch, 12p	408 Kg CO <sub>2</sub> e
1x PoE Plenum Mounting kit	56 Kg CO <sub>2</sub> e
Controls	% of PoE Node incl.
<b>Total:</b>	<b>1,584 Kg CO<sub>2</sub>e</b> (3,484 lb. CO <sub>2</sub> e)

### Operational Carbon:

• Downlight Power @ 4200lm (based on 80% PoE Node Eff.)	45W (x24)
• PoE Switch loss (based on 90% PoE Switch Eff.)	108W
Est. Total Controls Power	50W
Total Power:	1,238W
Annual kWh	7,230 kWh
Controls Savings (30%)	2,169 kWh
Annual kWh w. Savings	5,061 kWh
Annual Energy cost	\$1,518
<b>Annual Carbon emission</b>	<b>5,289 Kg CO<sub>2</sub>e</b> (11,635 lb. CO <sub>2</sub> e)



# Case 4

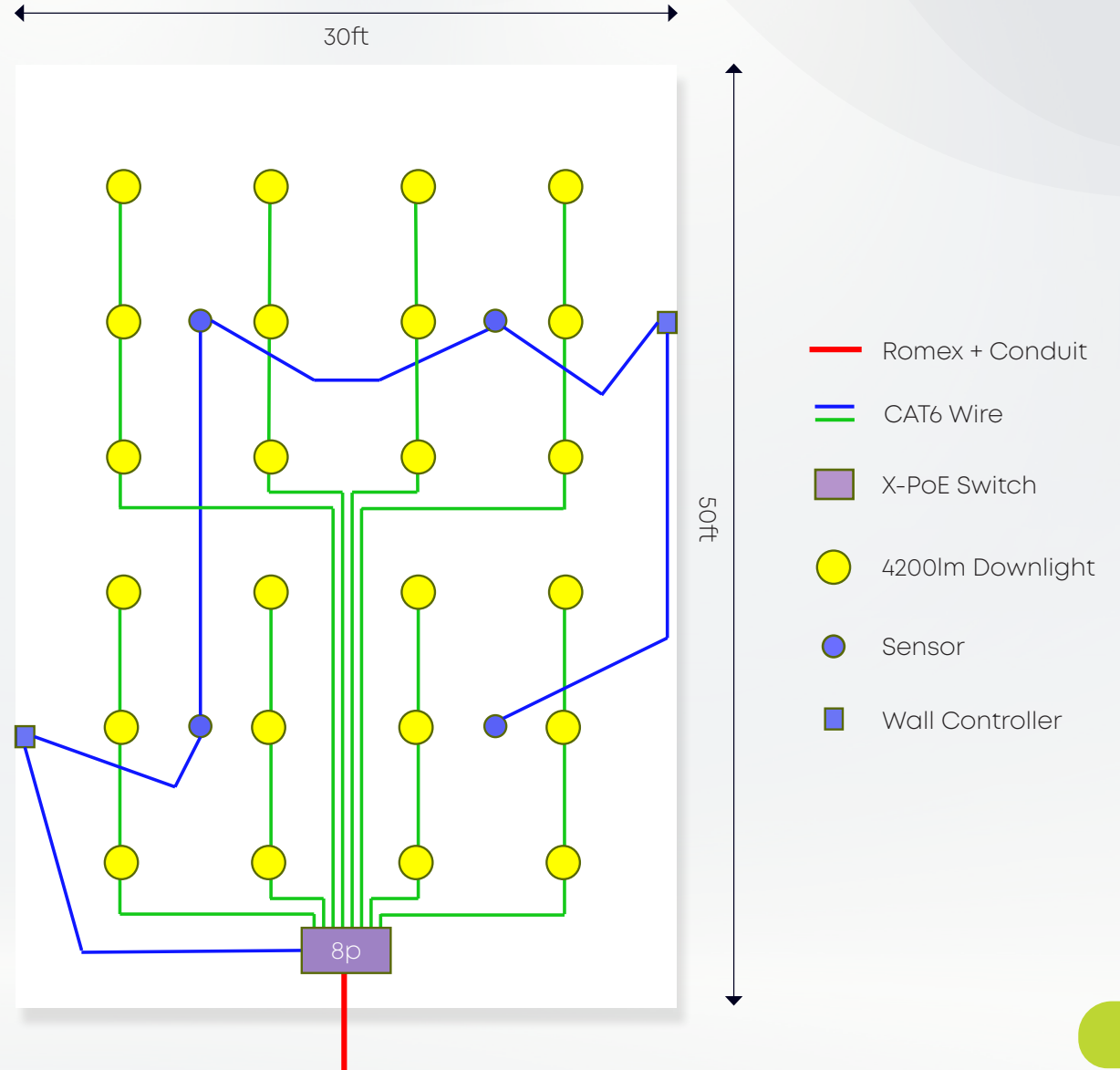
## X-PoE

### Embodied Carbon:

10ft Romex	3 Kg CO <sub>2</sub> e
10ft Conduit	11 Kg CO <sub>2</sub> e
350 ft Ethernet Wire	18 Kg CO <sub>2</sub> e
24 x 4200lm Downlights	463 Kg CO <sub>2</sub> e
1x X-PoE Switch, 8p	121 Kg CO <sub>2</sub> e
1x X-PoE GaN PSU 900W	52 Kg CO <sub>2</sub> e
1x X-PoE Plenum Mount kit	56 Kg CO <sub>2</sub> e
Controls	% of Switch incl.
<b>Total:</b>	<b>724 Kg CO<sub>2</sub>e</b> (1,593 lb. CO <sub>2</sub> e)

### Operational Carbon:

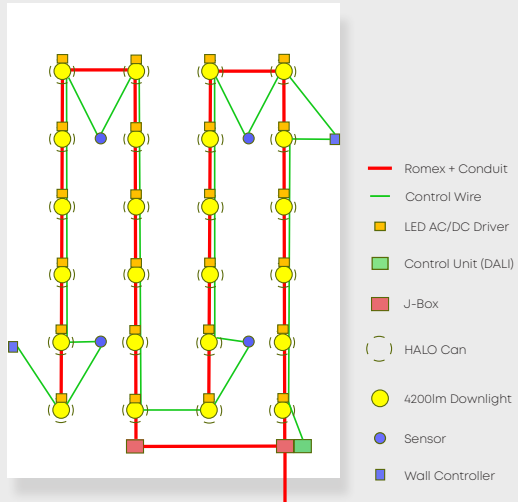
• Downlight Power @ 4200lm (based on 95% X-PoE Efficiency)	36W (x24)
• X-PoE PSU loss (based on 95% PSU Efficiency)	41W
• Est. Total Controls Power	50W
Total Power:	955W
Annual kWh	5,577 kWh
Controls Savings (30%)	1,673 kWh
Annual kWh w. Savings	3,904 kWh
Annual Energy cost	\$1,171
<b>Annual Carbon emission</b>	<b>4,079 Kg CO<sub>2</sub>e</b> (8,975 lb. CO <sub>2</sub> e)





# Summary

## AC/DC



**EMBODIED CARBON**

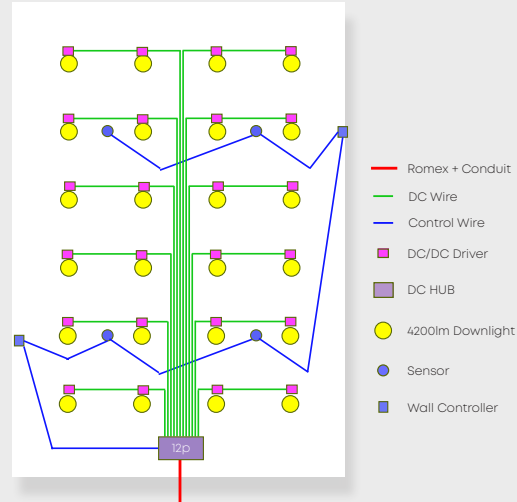
**3,997 lb. CO<sub>2</sub>e**

**ANNUAL CARBON**

**10,168 lb. CO<sub>2</sub>e**

**Cost/yr.: \$1,327**

## DC/DC



**EMBODIED CARBON**

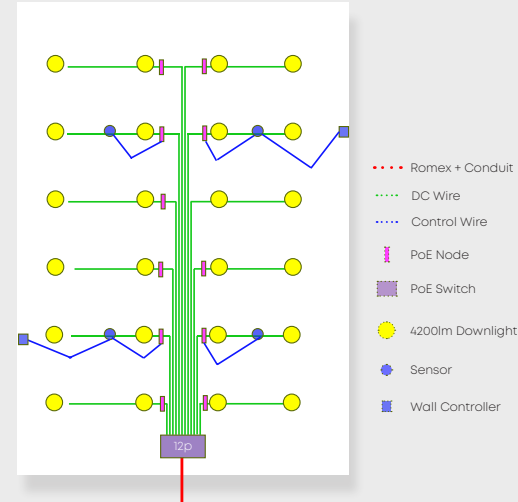
**3,726 lb. CO<sub>2</sub>e**

**ANNUAL CARBON**

**10,430 lb. CO<sub>2</sub>e**

**Cost/yr.: \$1,361**

## PoE



**EMBODIED CARBON**

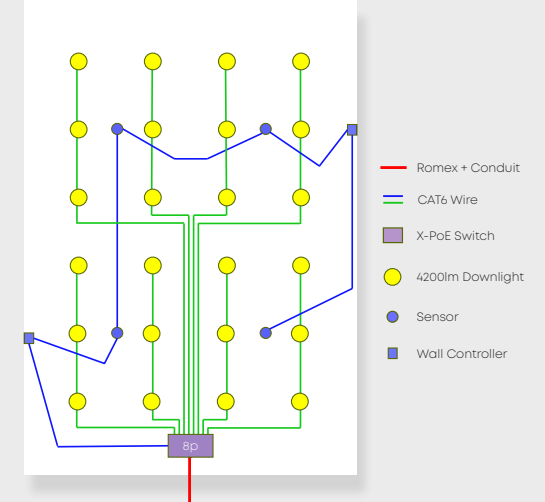
**3,484 lb. CO<sub>2</sub>e**

**ANNUAL CARBON**

**11,635 lb. CO<sub>2</sub>e**

**Cost/yr.: \$1,518**

## X-PoE



**EMBODIED CARBON**

**1,593 lb. CO<sub>2</sub>e**

**ANNUAL CARBON**

**8,975 lb. CO<sub>2</sub>e**

**Cost/yr.: \$1,171**

# Denver International Airport – example ✈️

## AC/DC

1000x

- Romex + Conduit
- Control Wire
- LED AC/DC Driver
- Control Unit (DALI)
- J-Box
- HALO Can
- 4200lm Downlight
- Sensor
- Wall Controller

**1.5M sqft**

**EMBODIED CARBON**  
**1.8 kt CO<sub>2</sub>e**

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**ANNUAL CARBON**  
**4.6 kt CO<sub>2</sub>e**  
**Cost/yr.: \$1.33M**

## DC/DC

1000x

- Romex + Conduit
- DC Wire
- Control Wire
- DC/DC Driver
- DC HUB
- 4200lm Downlight
- Sensor
- Wall Controller

**1.5M sqft**

**EMBODIED CARBON**  
**1.7 kt CO<sub>2</sub>e**

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**ANNUAL CARBON**  
**4.7 kt CO<sub>2</sub>e**  
**Cost/yr.: \$1.36M**

## PoE

1000x

- - - Romex + Conduit
- - - DC Wire
- - - Control Wire
- PoE Node
- PoE Switch
- 4200lm Downlight
- Sensor
- Wall Controller

**1.5M sqft**

**EMBODIED CARBON**  
**1.6 kt CO<sub>2</sub>e**

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**ANNUAL CARBON**  
**5.3 kt CO<sub>2</sub>e**  
**Cost/yr.: \$1.52M**

## X-PoE

1000x

- Romex + Conduit
- CAT6 Wire
- X-PoE Switch
- 4200lm Downlight
- Sensor
- Wall Controller

**1.5M sqft**

**EMBODIED CARBON**  
**0.7 kt CO<sub>2</sub>e**

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**ANNUAL CARBON**  
**4 kt CO<sub>2</sub>e**  
**Cost/yr.: \$1.17M**



X-PoE can save over 1.1 kiloton (metric) of CO<sub>2</sub>  
for lighting installation in an airport.  
Equivalent to annual emission of 240 Cars.

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Operational carbon emissions would be 600 tons less  
equivalent to annual emission of 130 cars

# Summary

The analysis using TM65 methodology combined with efficiency data shows that X-PoE lighting systems offer a lower carbon footprint and enhanced energy efficiency compared to traditional AC/DC and low voltage DC systems.

By adopting X-PoE technology, companies can significantly reduce both embodied and operational carbon emissions, directly contributing to their ESG targets.

X-PoE's efficient power management not only supports sustainability initiatives but also promises cost savings over time, reinforcing corporate commitments to environmental stewardship while maintaining financial viability.

# Appendix:

## Embodied Carbon by Product

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Individual breakdown of embodied carbon  
for products used in this case study.

# Steel Conduit / Electrical Metal Tubing (EMT)

Product SKU:	Various models - 1 ft.
Manufacturer:	Various vendors
Physical weight:	0.058 Kg / 0.128 lb. pr ft.
Material Carbon:	0.75 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	0.075 Kg CO <sub>2</sub> e (10%)
Non-Material Carbon:	0.255 Kg CO <sub>2</sub> e (+30%)
<b>Total Embodied Carbon:</b>	<b>1.08 Kg CO<sub>2</sub> per foot.</b>



Notes: Used for insulating electrical wiring in buildings.

# 12/2 Romex – Electrical Wire

Product SKU:	Various models - 1 ft.
Manufacturer:	Southwire and others
Physical weight:	0.048 Kg / 0.106 lb. pr ft.
Material Carbon:	0.17 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	0.017 Kg CO <sub>2</sub> e (10%)
Non-Material Carbon:	0.057 Kg CO <sub>2</sub> e (+30%)
<b>Total Embodied Carbon:</b>	<b>0.25 Kg CO<sub>2</sub> per foot.</b>



# 23AWG CAT6 Networking Cable

Product SKU:	Various models - 1 ft.
Manufacturer:	Southwire and others
Physical weight:	0.0095 Kg / 0.021 lb. pr ft.
Material Carbon:	0.034 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	0.003 Kg CO <sub>2</sub> e (10%)
Non-Material Carbon:	0.012 Kg CO <sub>2</sub> e (+30%)
<b>Total Embodied Carbon:</b>	<b>0.05 Kg CO<sub>2</sub> per foot.</b>



CAT6  
23/8



Control Wire  
18/4

Notes: General networking cable using 23/8 conductors. A control wire with 18/4 wires have similar carbon footprint.



# 6" HALO Can

Product SKU:	H750
Manufacturer:	HALO / Cooper
Physical weight:	0.98 Kg / 2.16 lb.
Material Carbon:	14.12 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	1.412 Kg CO <sub>2</sub> e (10%)
Non-Material Carbon:	4.66 Kg CO <sub>2</sub> e (+30%)
<b>Total Embodied Carbon:</b>	<b>20.20 Kg CO<sub>2</sub> per unit</b>



Notes: Classic HALO Can, used for insulating lights for in new construction.

# Electrical Junction Box (J-Box)

Product SKU:	Various models
Manufacturer:	Various manufacturers
Physical weight:	0.55 Kg / 1.21 lb. pr
Material Carbon:	7.2 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	0.72 Kg CO <sub>2</sub> e (10%)
Non-Material Carbon:	2.38 Kg CO <sub>2</sub> e (+30%)
<b>Total Embodied Carbon:</b>	<b>10.30 Kg CO<sub>2</sub> per unit</b>



Notes: Required for terminating electrical wires and conduit.

# Plenum mounted Rack

Product SKU:	ECB2SP and others
Manufacturer:	Legrand and others
Physical weight:	3 Kg / 6.6 lb. pr unit
Material Carbon:	39.3 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	3.9 Kg CO <sub>2</sub> e (10%)
Non-Material Carbon:	12.96 Kg CO <sub>2</sub> e (+30%)
<b>Total Embodied Carbon:</b>	<b>56.16 Kg CO<sub>2</sub> per unit</b>



Notes: Mounting for networking switches

# 50W Compact LED Driver

Product SKU 1:	SOLOdrive 561/A
Manufacturer 1:	ACUITY
Product SKU 2:	L3DA4U1UKS-HC070
Manufacturer 2:	LUTRON
Physical weight:	0.307 Kg / 0.675 lb. pr unit
Material Carbon:	10.03 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	1.0 Kg CO <sub>2</sub> e (10%)
Carbon from Control gear:	4.4 Kg CO <sub>2</sub> e (+40%)
Non-Material Carbon:	4.6 Kg CO <sub>2</sub> e (+30%)
<b>Total Embodied Carbon:</b>	<b>20.09 Kg CO<sub>2</sub> per unit</b>



Notes: Common Dimmable LED Driver

# X-PoE Switch / Lighting Controller

Product SKU:	XS-108H
Manufacturer:	LUUM.io
Physical weight:	1.9 Kg / 4.18 lb. pr unit
Material Carbon:	80.88 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	8.09 Kg CO <sub>2</sub> e (10%)
Carbon from Control gear:	35.59 Kg CO <sub>2</sub> e (+40%)
Non-Material Carbon:	37.37 Kg CO <sub>2</sub> e (+30%)
Total Embodied Carbon:	161.92 Kg CO <sub>2</sub> per unit
Number of 50W Channels:	16 (Max 60W)
<b>Embodied Carbon / ch.:</b>	<b>10.12 Kg CO<sub>2</sub> per Ch.</b>



Notes: Hybrid PoE Switch for Networking and driverless dimming of lights

# X-PoE 750W Power Supply

Product SKU:	RSP-750
Manufacturer:	Meanwell
Physical weight:	1.64 Kg / 3.61 lb. pr unit
Material Carbon:	53.67 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	5.37 Kg CO <sub>2</sub> e (10%)
Non-Material Carbon:	17.7 Kg CO <sub>2</sub> e (+30%)
Total Embodied Carbon:	76.74 Kg CO <sub>2</sub> per unit
Number of 50W Channels:	16 (Max 750W Total)
<b>Embodied Carbon / ch.:</b>	<b>4.8 Kg CO<sub>2</sub> per Ch.</b>



Notes: X-PoE External AC/DC Power Supply (not needed for Off grid X-PoE system)

# X-PoE 900W Power Supply

Product SKU:	XSP-900
Manufacturer:	LUUM.io
Physical weight:	1.12 Kg / 2.47 lb. pr unit
Material Carbon:	36.4 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	3.64Kg CO <sub>2</sub> e (10%)
Non-Material Carbon:	12 Kg CO <sub>2</sub> e (+30%)
Total Embodied Carbon:	52.05 Kg CO <sub>2</sub> per unit
Number of 50W Channels:	16 (Max 900W Total)
<b>Embodied Carbon / ch.:</b>	<b>3.25 Kg CO<sub>2</sub> per Ch.</b>



Notes: X-PoE External AC/DC Power Supply (not needed for Off grid X-PoE system)

# PoE++ Switch w. internal PSU

Product SKU:	SM24TBT2DPB
Manufacturer:	LANTRONIX
Physical weight:	6.03 Kg / 13.27 lb. pr unit
Material Carbon:	256.67 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	25.67 Kg CO <sub>2</sub> e (10%)
Non-Material Carbon:	84.7 Kg CO <sub>2</sub> e (+30%)
Total Embodied Carbon:	367.06 Kg CO <sub>2</sub> per unit
Max number of 50W outputs:	21 (1080W PSU)
<b>Embodied Carbon / ch.:</b>	<b>17.47 Kg CO<sub>2</sub> per Ch.</b>



For powering traditional PoE gear and PoE Lights using PoE Nodes/Drivers.



# PoE Node/Driver for LED Lights

Product SKU:	Linear Node
Manufacturer:	Igor
Physical weight:	0.6 Kg / 1.32 lb. pr unit
Material Carbon:	25.54 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	2.54 Kg CO <sub>2</sub> e (10%)
Carbon from Control gear:	11.24 Kg CO <sub>2</sub> e (+40%)
Non-Material Carbon:	11.89 Kg CO <sub>2</sub> e (+30%)
<b>Total Embodied Carbon:</b>	<b>51.13 Kg CO<sub>2</sub> per unit</b>



# LED DC Hubs

Product SKU 1:	DCHUB
Manufacturer 1:	ACUITY
Product SKU 2:	PHD
Manufacturer 2:	NEXTEK
Physical weight:	15.4 Kg / 33.88 lb. pr unit
Material Carbon:	656.4 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	65.6 Kg CO <sub>2</sub> e (10%)
Non-Material Carbon:	216.6 Kg CO <sub>2</sub> e (+30%)
<b>Total Embodied Carbon:</b>	<b>938.65 Kg CO<sub>2</sub> per unit</b>
Number of 90W Channels:	12
<b>Embodied Carbon / ch.:</b>	<b>78.22 Kg CO<sub>2</sub> per Ch.</b> (43.45 Kg CO <sub>2</sub> per 50W)



DCHUB



PHD

For powering and dimming LED Lights direct (PHD), or w. DC2DC Drivers (DCHUB)

# DC2DC LED Driver

Product SKU:	DC2DC Driver
Manufacturer:	ACUITY
Physical weight:	0.15 Kg / 0.33 lb. pr unit
Material Carbon:	4.9 Kg CO <sub>2</sub> e (TM65)
Repair/Replacement:	0.49 Kg CO <sub>2</sub> e (10%)
Carbon from Control gear:	2.16 Kg CO <sub>2</sub> e (+40%)
Non-Material Carbon:	2.26 Kg CO <sub>2</sub> e (+30%)
<b>Total Embodied Carbon:</b>	<b>9.83 Kg CO<sub>2</sub> per unit</b>



DC2DC LED Driver needed for DCHUB to power and dim LED lights.

# 6" 4200lm LED Downlight

Product SKU: Various

Manufacturer: Various

Physical weight: 0.91 Kg / 2 lb. pr unit

Material Carbon: 13.49 Kg CO<sub>2</sub>e (TM65)

Repair/Replacement: 1.35 Kg CO<sub>2</sub>e (10%)

Non-Material Carbon: 4.45 Kg CO<sub>2</sub>e (+30%)

**Total Embodied Carbon: 19.29 Kg CO<sub>2</sub> per unit**

