Reducing Carbon Emissions in Multi-Building Commercial Facilities – A Co-optimization Approach

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Outline

- Introduction and Motivation
- Research Question
- Methodology
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- Conclusions

Introduction and Motivation

In this study, a multi-building commercial facility is defined as a facility containing different buildings within a defined geographical area, operated by the same entity, serving different purposes, and containing varying equipment types

- Buildings consume 75% of electricity generated in the US and account for 39% of carbon emissions
- About 33% of all US commercial buildings are within multi-building facilities (source: US EIA)
- Energy management and emissions reduction are typically considered for each building separately (i.e., standalone optimization)

Research Question

Will considering emissions reduction and energy management for a multi-building facility as one unit (co-optimized) instead of treating each building separately (standalone optimization) produce more emissions reduction and additional energy savings?

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Methodology

Step 1
- Define representative multi-building facility

Step 2
- Develop a co-optimization strategy for the representative multi-building facility

Step 3
- Evaluate co-optimization strategy under different weather and diurnal conditions – Summer Weekday, Summer Weekend, Winter Weekday and Winter Weekend

Step 4
- Extrapolate results from step 3 to obtain additional annual emissions and energy cost reductions obtainable from the co-optimization strategy

Methodology

- What is co-optimization?

Person A, who is an expert, works on Project X in isolation

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Person B, who is also an expert, works on Project X also in isolation

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Persons A and B interact, share ideas and work together as a team on Project X

Two cohesive heads are better than one!

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Methodology

…… Well, buildings are no different either!

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Energy and emissions reduction considered for Building A in isolation

Energy and emissions reduction considered for Building B in isolation

All buildings within the facility are considered as one, capturing complementary building operation patterns

Methodology

- What does co-optimization for buildings look like mathematically?

$$\boldsymbol{minimize\ [Total\ facility\ energy\ costs + Total\ facility\ carbon\ costs]}$$

$$\textbf{subject to} \left\{ \begin{array}{c} Total\ Facility\ Power\ = Power\ for\ Building\ 1 + \cdots + Power\ for\ Building\ n \\ Total\ Facility\ Gas\ Consumption\ = Gas\ for\ Building\ 1 + \cdots + Gas\ for\ Building\ n \\ HVAC\ Equipment\ Constraints\ for\ Building\ 1\ \ldots..\ Building\ n \\ Water\ Heater\ Equipment\ Constraints\ for\ Building\ 1 \ldots..\ Building\ n \\ Solar\ PV\ constraints\ for\ Building\ 1\ \ldots..\ Building\ n \\ Battery\ Constraints\ for\ Building\ 1\ \ldots..\ Building\ n \\ EV\ Charging\ Constraints\ for\ Building\ 1\ \ldots.\ Building\ n \\ \ldots \ldots \ldots \ldots \ldots \ldots. \end{array} \right\}$$

→ Mixed Integer Quadratic Programming (MIQP) mathematical model

Case Study Parameters

- Considered a hypothetical e-commerce fulfillment facility with 3 buildings – Warehouse, Staff Office Building and External Facing Office Building

- Ran all simulations with a Python-based software package developed in collaboration with NREL

Building	Characteristics Assumption
Overall	location – Chicago; ComEd TOU electricity rates; carbon cost - $11 per ton of CO_2; natural gas price - $6.85 per term
Warehouse	500 kW maximum demand; contains HVAC, water heater, rooftop PV, batteries, plug loads and 10 EV charging stations
Staff Office Building	90 kW maximum demand; contains HVAC, water heater, plug loads and 6 EV charging stations
External Facing Office Building	120 kW maximum demand; contains HVAC, water heater, plug loads and 6 EV charging stations

Results – Carbon Costs

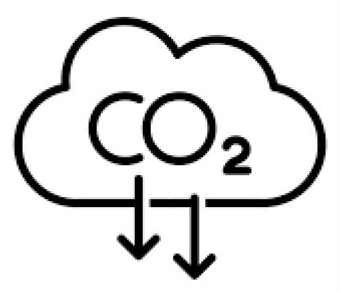
Carbon Costs ($)

	Summer Weekend	Summer Weekday	Winter Weekday	Winter Weekend
No Optimization ($)	32.87	35.04	55.55	53.85
Individually Optimized ($)	30.39	32.44	52.30	50.99
Co-optimized ($)	28.04	30.22	49.82	48.24
Additional emission reductions from co-optimization	↓ 7.7%	↓ 6.8%	↓ 4.7%	↓ 5.4%

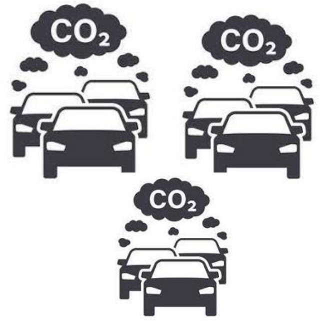
- 6.15% average additional daily reduction in CO_2 emissions
- Additional 200 kg reduction in daily CO_2 emissions
- Equivalent to removing 16 gasoline cars from the road in a day

Results – Carbon Costs

- What if we extend this to 1% of all multi-building warehouse facilities in the US?



……additional 97,820,000 kg reduction in annual CO_2 emissions



….. removing 21,440 gasoline cars from the road

………. Without extra equipment or capital investments

Results – Energy Costs

Energy Costs ($)

	Summer Weekend	Summer Weekday	Winter Weekday	Winter Weekend
No Optimization ($)	816.48	710.81	3645.6	3756.64
Individually Optimized ($)	776.99	667.12	3584.68	3707.98
Co-optimized ($)	760.17	655.83	3551.24	3670.93
Additional energy cost savings from co-optimization	↓ 2%	↓ 1.7%	↓ 0.9%	↓ 1%

- 1.4% average additional daily energy cost savings
- Equivalent to an average additional daily cost savings of $24.65 and an annual cost savings of about $9,000

Conclusions

- Co-optimizing multi-building commercial facilities does provide additional emissions reduction

- Co-optimizing multi-building commercial facilities does provide additional energy cost savings

"…… Co-optimization shall save the planet……" – A famous philosopher

Thanks!