Resilience Gaps & Clean Energy Solutions at State-Owned Medical & Residential Care Facilities

NESEA Boston - March 2019

Agenda

- Intro
- Policy landscape
- Study overview
- Task 1: Energy resilience gap analysis
- Task 2: Clean energy technology screening
- Task 3: Clean energy system modeling
- Technology examples
- Results
- Keys for success
- Next steps

The Leading by Example Program (LBE) works collaboratively with state agencies and public colleges and universities to advance clean energy and sustainable practices that reduce the environmental impacts of state government operations

We are an independent firm of designers, engineers, architects, planners, consultants and technical specialists working across every aspect of today's built environment.

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Director of Leading by Example
MA Department of Energy Resources

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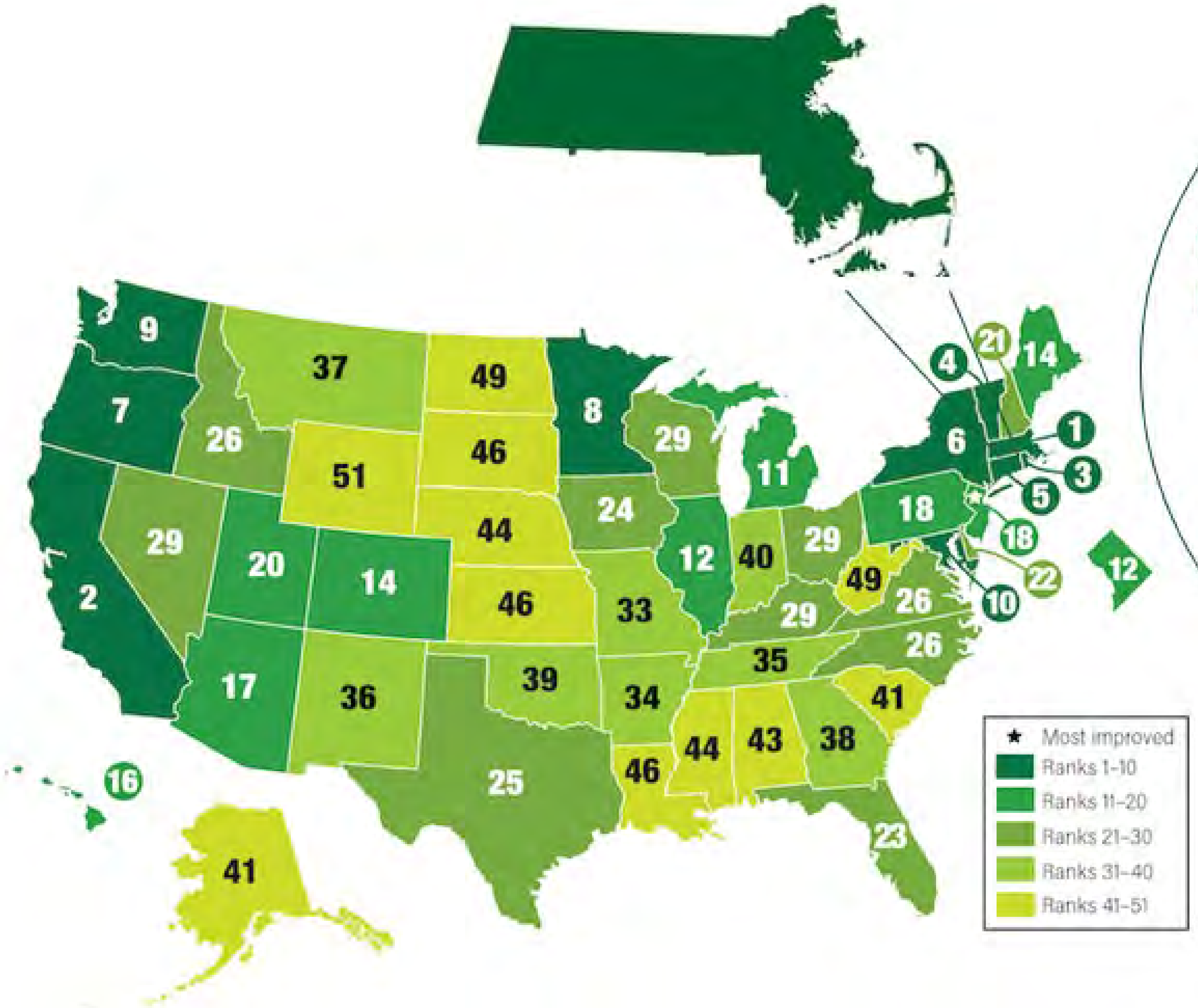
Learning objectives

- Explain common resilience gaps and threats affecting medical & residential care facilities
- Define potential clean energy technologies for mitigating resilience gaps, including CHP, solar, & batteries
- Discuss challenges with meeting resiliency and environmental goals while maintaining cost effectiveness
- Understand opportunities and hurdles associated with specific clean energy strategies designed to enhance energy resiliency

Policy Landscape



RANKED
No. 1

8th Year in a Row in Energy Efficiency

Why do we need to be resilient?

The New York Times

Nursing Home Deaths in Florida Heighten Scrutiny of Disaster Planning

Tampa Bay Times

Following deaths from Irma, Florida looks to new rules for keeping nursing homes cool after outages

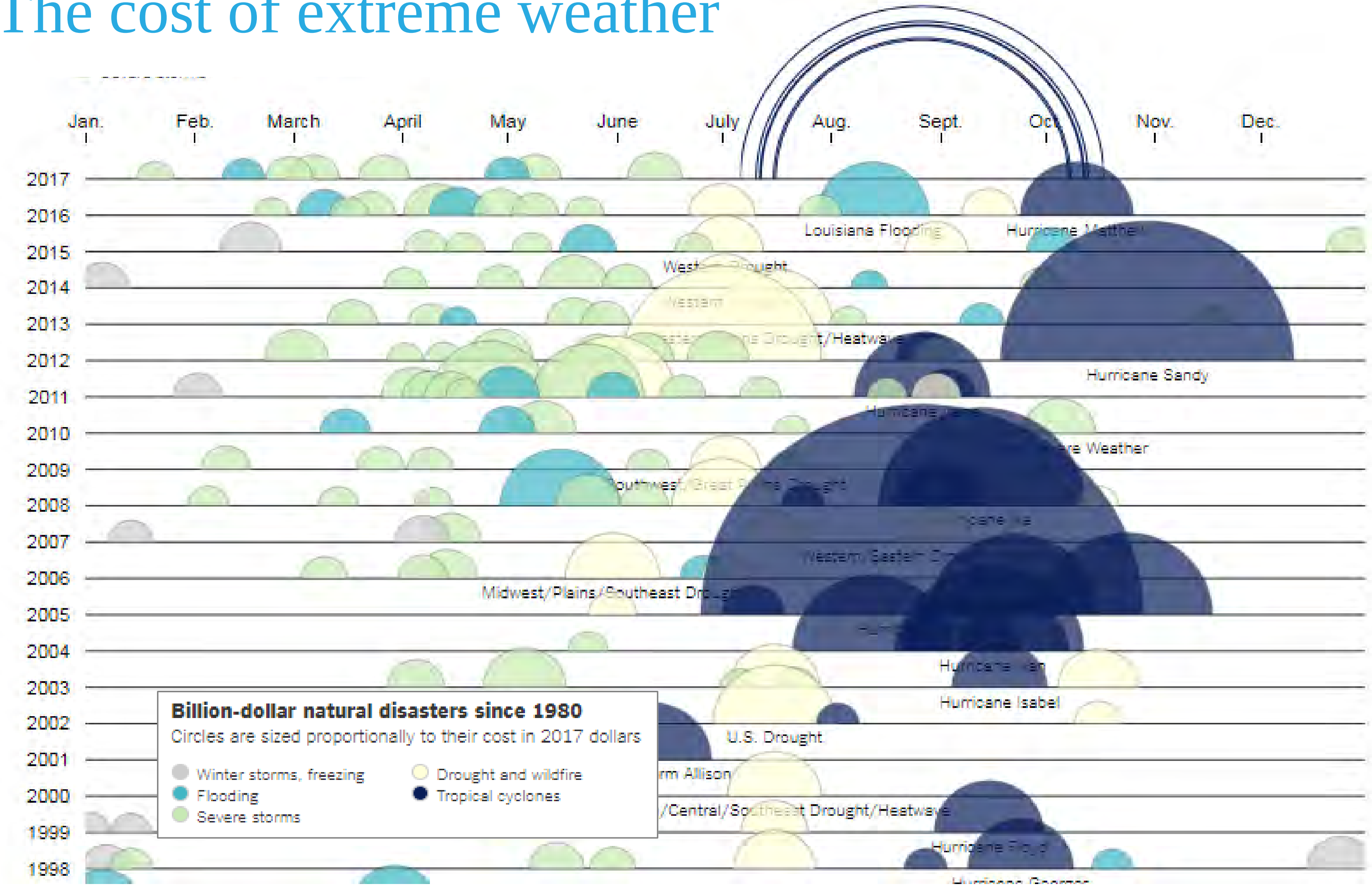
Some hospitals hang on as others close amid Harvey's floods

By Jen Christensen, CNN

Updated 12:29 AM ET, Thu August 31, 2017

CNN

The cost of extreme weather



https://www.nytimes.com/interactive/2017/09/01/upshot/cost-of-hurricane-harvey-only-one-storm-comes-close.html

Cost to US GDP

$3.9

trillion by 2025

Lost Business Sales

$7

trillion by 20205

Lost Jobs

2.5

million jobs in 2025

Cost to Families

$3,400

per year

http://www.asce.org/failuretoact/

Massachusetts Resiliency Context and Policy Drivers

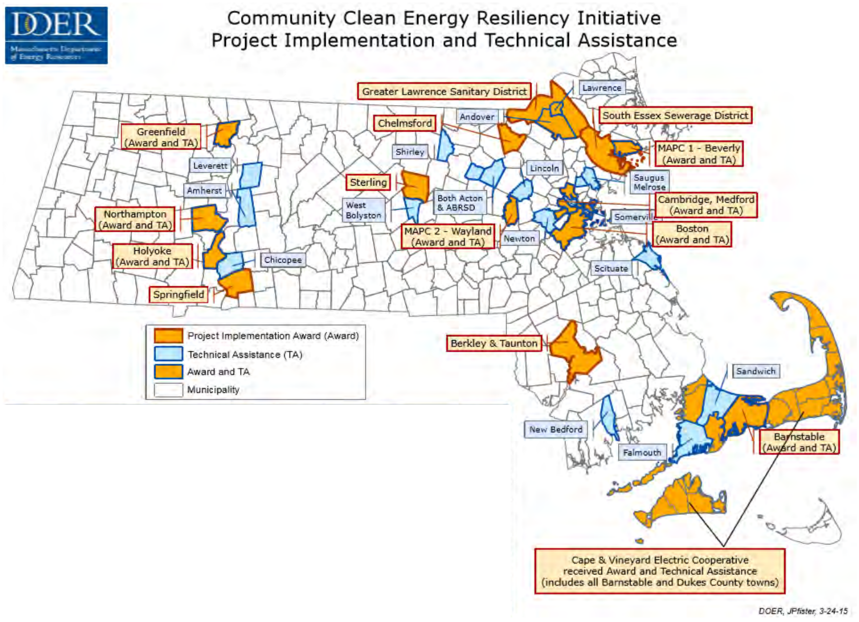
Executive Order 569: Establishing an Integrated Climate Change Strategy for the Commonwealth (2016)

- Establish GHG emissions reduction targets for 2030 & 2040
- Develop Commonwealth Climate Adaptation Plan, including vulnerability assessments and adaptation options for state government, cities and towns

Community Clean Energy Resiliency Initiative (CCERI)

- $26 million awarded to 19 municipal resiliency projects
- $11.5 million awarded to 10 hospitals for resiliency

$2.4 Billion in Proposed Governor and Legislative Resiliency Initiatives



Massachusetts Clean Energy Context and Policy Drivers

Global Warming Solutions Act (2008)

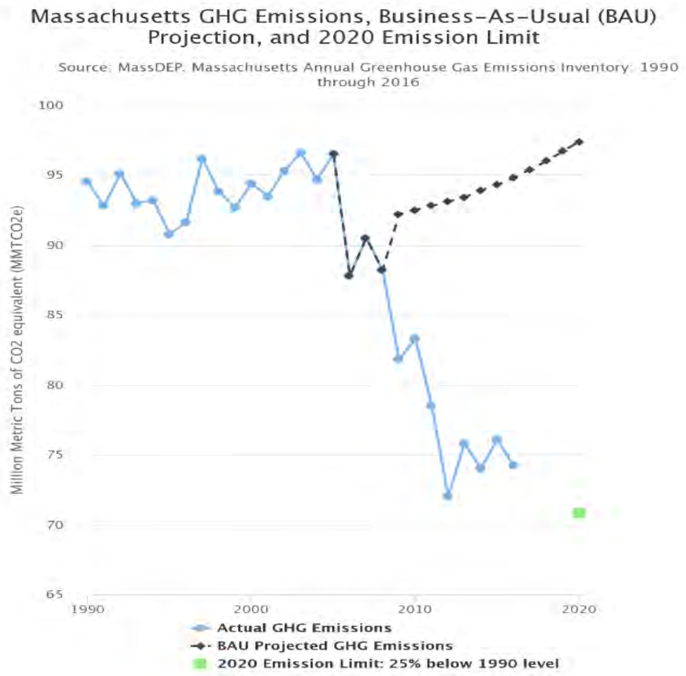
- 2020 GHG reduction Goal: 25% reduction over 1990 levels
- 2050 GHG reduction Goal: 80% reduction over 1990 levels

Leading by Example Program

- 2020 & 2050 GHG reduction goals: 40% & 80% over 2002 baseline
- Energy Use Intensity reduction goal: 35% over 2004 baseline
- Renewable energy goal: 30% of electricity consumption

Renewables

- Portfolio standard requires 1%/ year increase in Class I renewables until 2020 & 2%/ year increase until 2029
- Current 1600 MW solar goal on top of existing 2000 MW
- Legislative mandate for 1600 MW of wind by 2027



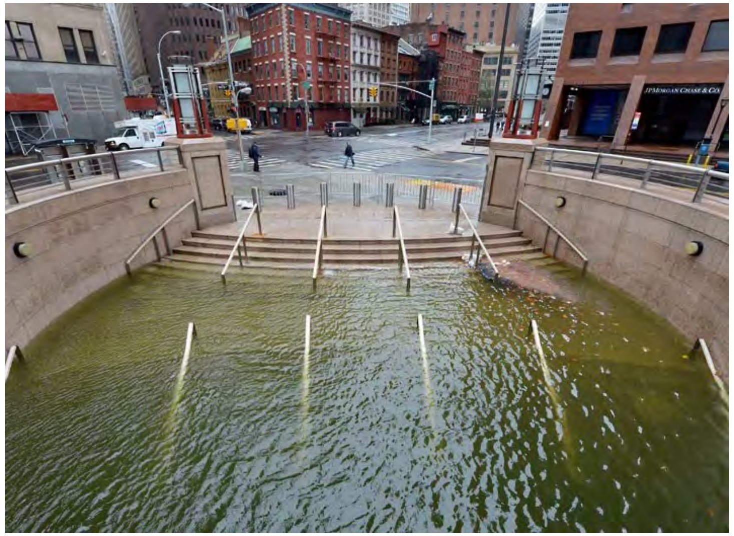
What is resilience?

Resilience is the capacity to maintain services, increase flexibility, and continue to thrive despite shocks and stressors.

Key is to focus on the **CRITICAL FUNCTIONALITY** of systems, not simply restoring the system itself

Why do we need to be resilient?

Enhanced resilience:



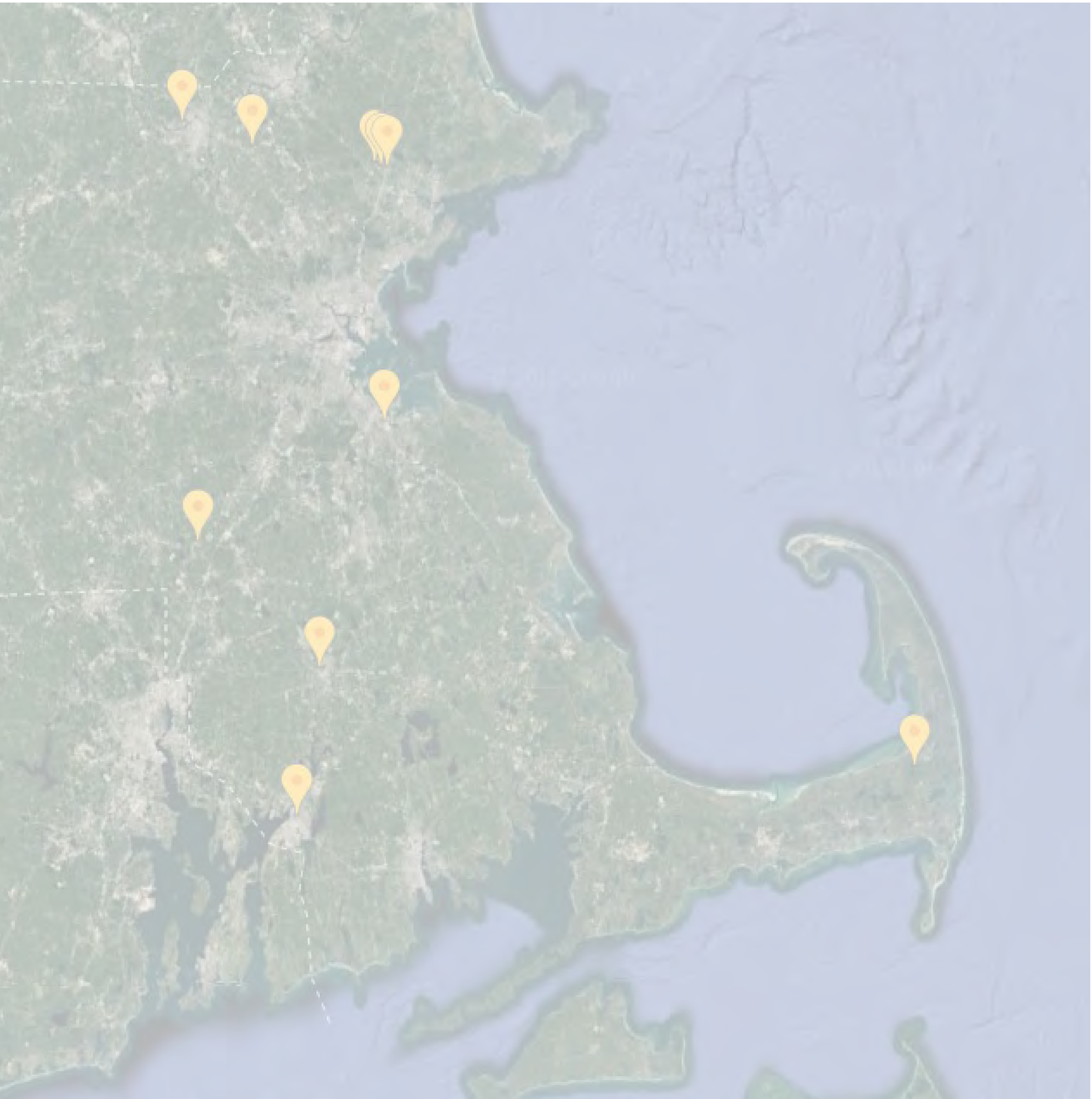
- Increases public and patient safety
- Avoids evacuations
- Protects vulnerable populations
- Reduces burden on emergency management personnel
- Reduces costs associated with crisis management

Study overview

Overview: Resiliency Study Goals

Purpose of Study	**“Identify opportunities to utilize clean energy technologies to increase the energy resiliency of each facility, thereby reducing the likelihood of prolonged outages during extreme weather events”**
Resilience Goals	• Increase length of time the site is able to maintain facility-wide or critical load operations during grid outage
	• Increase number of ancillary services or facility square footage with backup generation in the event of grid outage
	• Increase the redundancy of the existing backup generation
Clean Energy Objectives	• Replace or supplement fossil fuel back up power to increase facility operational capabilities during power outage
	• Provide diversity of fuel sources to increase reliability by removing reliance on a single fuel and on fuel transport
	• Reduce GHG emissions, reliance on fossil fuels

Project Overview: Background on Site Selection



Consulted with key agencies

- Emergency management, DCAMM, public safety
- identified health and human services facilities where emergency resources would be substantially taxed during widespread power outages

Rationale for site selection

- State-owned facilities providing 24/7 residential & medical care
- Vulnerable populations
- Difficult to evacuate during emergency
- Facility diversity and geographic distribution

Project Overview: Sites Selected

- 12 Health & Human Services facilities
- 12,000 - 1,000,000 square feet
- 10-350 person capacity
- Various building ages (majority 30+ years old)

Primary Purpose	Size (SF)	Capacity	Year Built
Community Mental Health Center	61,000	16	1967
Community Mental Health Center	12,000	12	1950s
Community Mental Health Center	67,000	28	1982
Community Mental Health Center	86,000	25	1976
Hospital	301,061	218	1899-1999
Hospital	1,036,982	350	1890s
Hospital	179,112	102	1937
Intermediate Care Facility	314,385	138	1963-70
Long-term Care Facility	233,000	270	1950-70s
Long-term Care Facility	609,427	270	1920-30s
Youth Services Center	70,000	45	2016
Youth Services Center	23,390	10	1978

Project Overview: Tasks 1-4

Task 1: **Existing Conditions Assessments**	• Evaluate energy systems, emergency preparedness, critical & non-critical loads • Summarize energy resiliency gaps
Task 2: **Preliminary Review of Energy Resiliency Strategies**	• Identify potential clean energy technologies & strategies • Select 3 technologies per site for in-depth analysis
Task 3: **Feasibility Studies**	• Technical feasibility of technologies & strategies • Cost/Benefit Analysis
Task 4: **Energy Resilience Guidance Documents for State Agencies**	• Guidance document with energy resiliency benefits & strategies • Site assessment guide to assist agencies in identifying key energy resiliency gaps at their facilities

Task 1
Energy resilience gap assessment

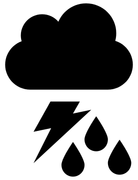
Site investigation

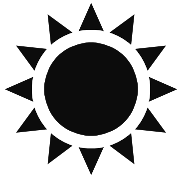
Guided interview and site walk

- Are any sites particularly vulnerable to projected climate change impacts?
- Are any sites more susceptible to outages or operational failures?
- Are certain facility operations more vulnerable to outages than others?
- Are any of those operations critical?
- What types of resilience is needed for each site?
- How much would adding clean energy resiliency cost?

Shocks and stressors


Flooding & Sea Level Rise


Precipitation


Temperature
(Extreme heat and extreme cold)


Wildfire

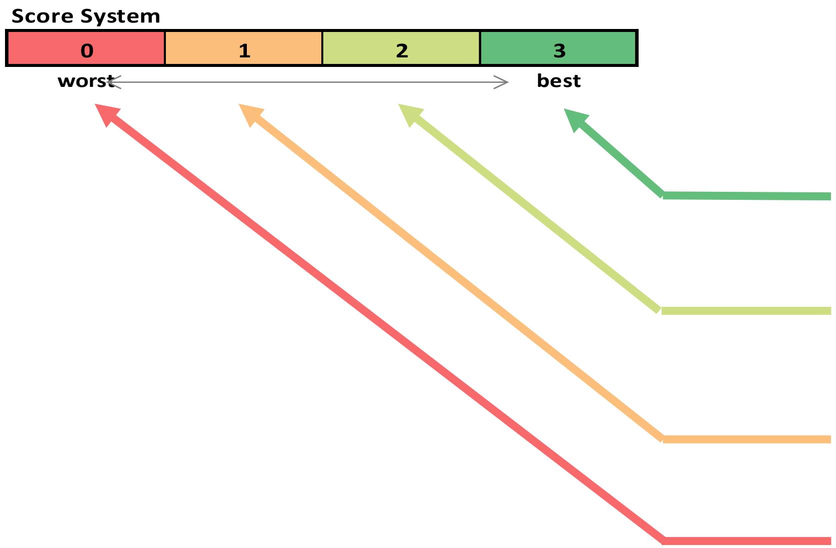

Manmade Hazards


Wind


Earthquakes


Winter Storms

Site score card



Sufficient for current needs with significant redundancy

Sufficient for current needs with some redundancy

Sufficient for current needs, but lacks redundancy

Insufficient for current needs

Assessment Categories			
Systems Resilience			
Electrical			
Normal Power	Utility Service	2	1.5
	System Resilience	1	
	System Capacity	2	
	Equipment Age/ Condition	1	
Backup Power	System Resilience	1	1.5
	On-site Generation Capacity	2	
	On-site Fuel Storage Capacity	2	
	Equipment Age/ Condition	1	
HVAC			
Heating	System Resilience	2	2
	System Capacity	2	
	On-site Fuel Storage Capacity	2	
	System Backup Power/ Supply	2	
	Equipment Age/ Condition	2	
Cooling	System Resilience	2	0
	System Capacity	2	
	System Backup Power/ Supply	0	
	Equipment Age/ Condition	3	
Miscellaneous Systems			
Medical Records		2	2.0
Security/ Access Control System		2	
Elevators/ Patient Transport		3	
Domestic Water		2	
Sanitary/ Wastewater		1	
Telecom		2	
	Systems Resilience Average		1.4
Operational Resilience			
Emergency Mgmt. Plan			0
Staff Accessibility			2
Staff Accommodations			1
Operational Redundancy/ Access to Nearby Facilities			2
Foodservice			0
Pharmacy/ Drug Storage			2
Flooding Risk			2
Sensitivity to Extreme Heat or Cold			1
Sensitivity to Extreme Wind			2
Seismic Risk			2
	Operational Resilience Average		1.4

Energy resilience

Electrical

- Normal and emergency power system

HVAC

- Heating and cooling systems

Miscellaneous Systems

- Medical records
- Security/Access control
- Elevators/Patient Transport
- Domestic Water
- Sanitary/Wastewater
- Telecom/IT

Assessment Categories			
Systems Resilience			
Electrical			
Normal Power	Utility Service	2	1.5
	System Resilience	1	
	System Capacity	2	
	Equipment Age/ Condition	1	
Backup Power	System Resilience	1	1.5
	On-site Generation Capacity	2	
	On-site Fuel Storage Capacity	2	
	Equipment Age/ Condition	1	
HVAC			
Heating	System Resilience	2	2
	System Capacity	2	
	On-site Fuel Storage Capacity	2	
	System Backup Power/ Supply	2	
	Equipment Age/ Condition	2	
Cooling	System Resilience	2	0
	System Capacity	2	
	System Backup Power/ Supply	0	
	Equipment Age/ Condition	3	
Miscellaneous Systems			
Medical Records		2	2.0
Security/ Access Control System		2	
Elevators/ Patient Transport		3	
Domestic Water		2	
Sanitary/ Wastewater		1	
Telecom		2	
	Systems Resilience Average		1.4

Operational resilience

Operational Resilience	
Emergency Mgmt. Plan	0
Staff Accessibility	2
Staff Accommodations	1
Operational Redundancy/ Access to Nearby Facilities	2
Foodservice	0
Pharmacy/ Drug Storage	2
Flooding Risk	2
Sensitivity to Extreme Heat or Cold	1
Sensitivity to Extreme Wind	2
Seismic Risk	2
Operational Resilience Average	1.4

Emergency Mgmt. Plan

Staff Accessibility

Staff Accommodations

Operational Redundancy/ Access to Nearby Facilities

Foodservice

Pharmacy/ Drug Storage

Flooding Risk

Sensitivity to Extreme Heat or Cold

Sensitivity to Extreme Wind

Seismic Risk

Portfolio score card

Systems Resilience Average	Electrical: Normal Power	Electrical: Backup Power	HVAC: Heating	HVAC: Cooling	Misc. Systems
1.4	1.5	1.3	2.2	0	2.0
1.3	1.8	1	2	0	1.8
0.7	1.8	0	0	0	1.5
1.4	2	1.5	2	0	2.0
1.4	1.5	1.5	2.2	0	2.0
1.6	2	1.8	2	0	2.2
2.0	2	1.8	2.2	1.8	2.0
2.2	1.5	2.8	2.4	2.3	2.2
2.2	1.8	2.5	2.4	2	2.3
2.0	1.5	2.3	2	1.8	2.2
1.8	1.5	2	1.6	2	1.8
1.8	2.3	2.3	2.2	0	2.0
1.6	1.7	1.7	1.9	0.8	2.0

Systems Resilience Summary

Score System

0	1	2	3
worst			best

Operational Resilience Average	Emergency Mgmt. Plan	Staff Accessibility	Staff Accommodations	Operational Redundancy/ Access to Nearby Facilities	Foodservice	Pharmacy/ Drug Storage	Flooding Risk	Sensitivity to Extreme Heat or Cold	Sensitivity to Extreme Wind	Seismic Risk
1.8	2	2	1	2	3	2	2	1	2	1
2.1	3	1	2	3	3	2	2	1	2	2
1.7	2	2	3	2	0	2	2	1	1	2
1.4	0	2	1	2	0	2	2	1	2	2
1.8	2	2	1	2	2	2	2	1	2	2
1.6	2	2	1	2	2	2	2	1	1	1
1.7	2	2	1	2	1	2	2	1	2	2
2.1	2	3	2	3	3	2	2	2	1	1
2.1	2	3	2	2	3	3	2	2	1	1
1.8	2	2	1	2	2	2	2	1	2	2
2.1	2	3	2	2	3	2	2	2	1	2
1.8	2	2	1	2	2	2	2	1	2	2
1.8	1.9	2.2	1.5	2.2	2.0	2.1	2.0	1.3	1.6	1.7

Operational Resilience

Key portfolio Resilience Gaps

Lack of backup power for cooling – 7 sites
Generator failure during an extended utility outage – 4 sites
Lack of backup power for food service – 2 sites
Emergency preparedness planning – 1 site

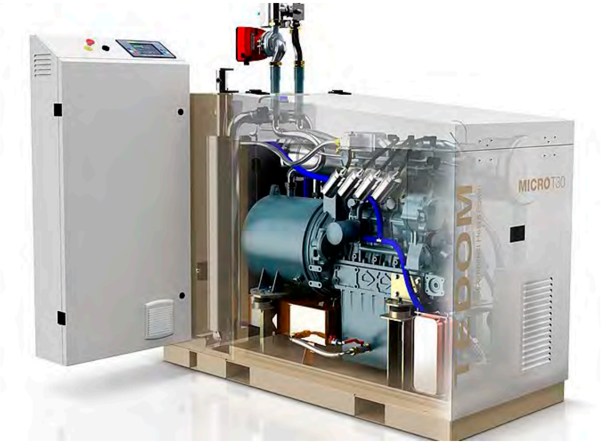
Also identified several resilience “quick hits”
which do not require a clean energy solution

Task 2
Clean energy technology screening

Solar photovoltaics

Battery energy storage

Solar thermal

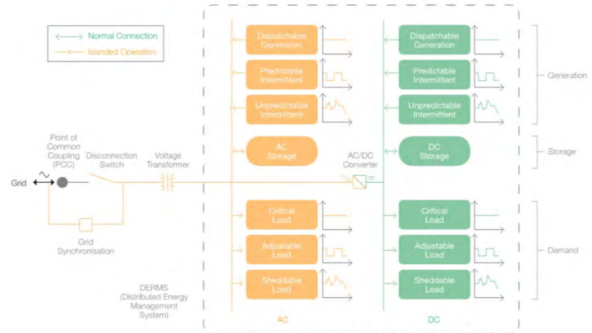


Combined heat and power

High efficiency fuel cells

Thermal energy storage

Wind power

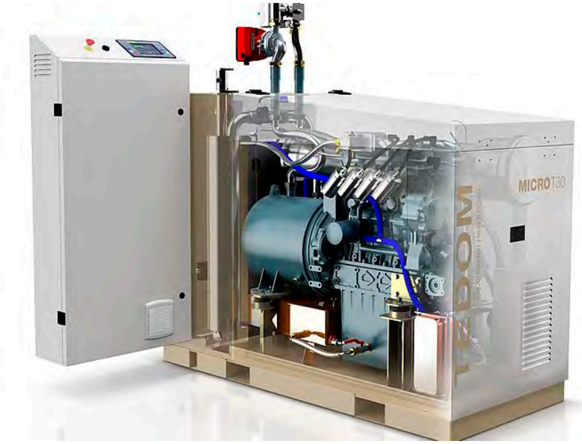


Microgrids

Solar photovoltaics

Battery energy storage

Solar thermal



Combined heat and power

High efficiency fuel cells

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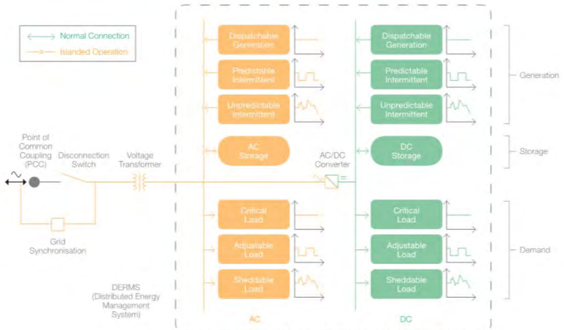
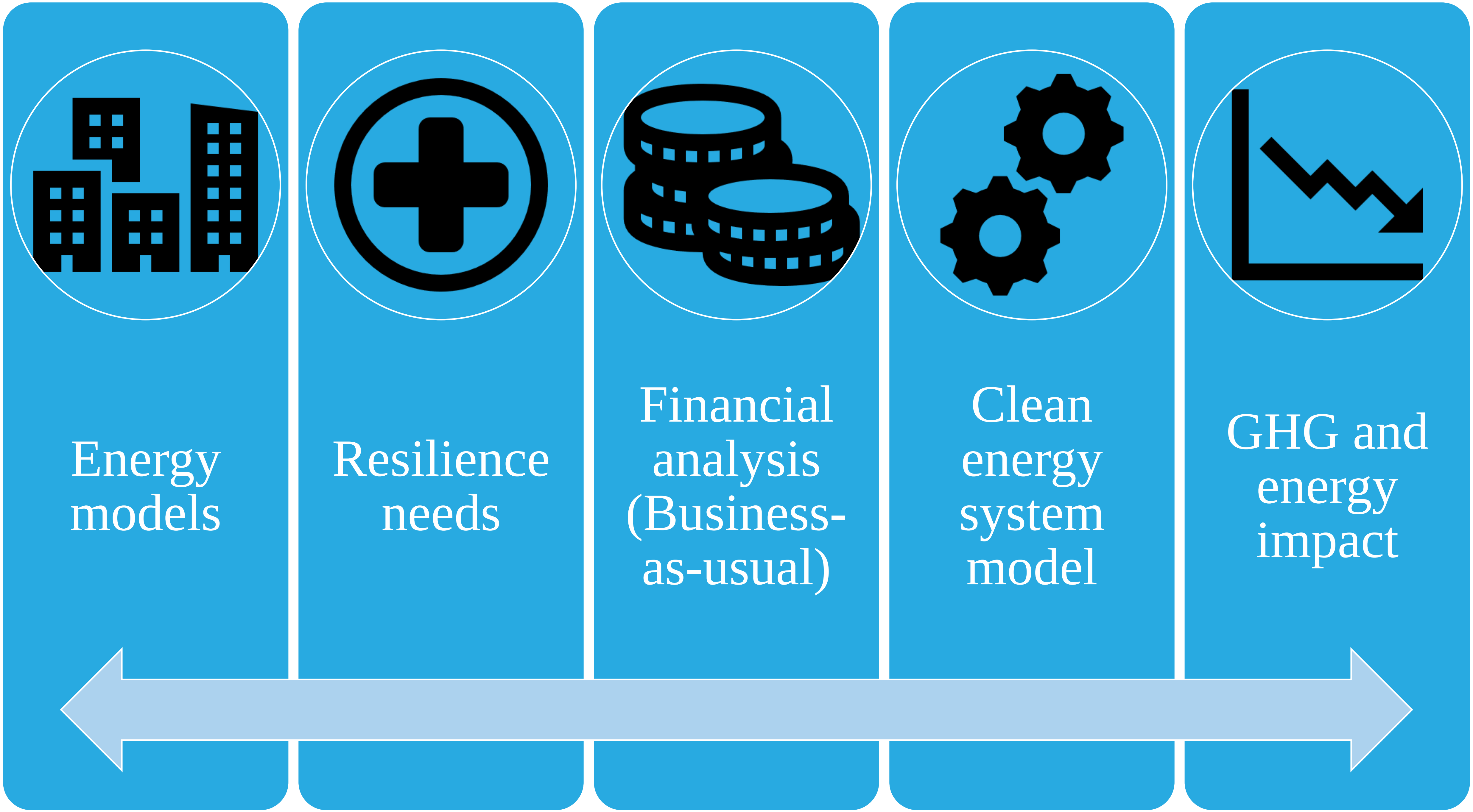
Wind power



Microgrids

Task 3
Clean energy system modeling

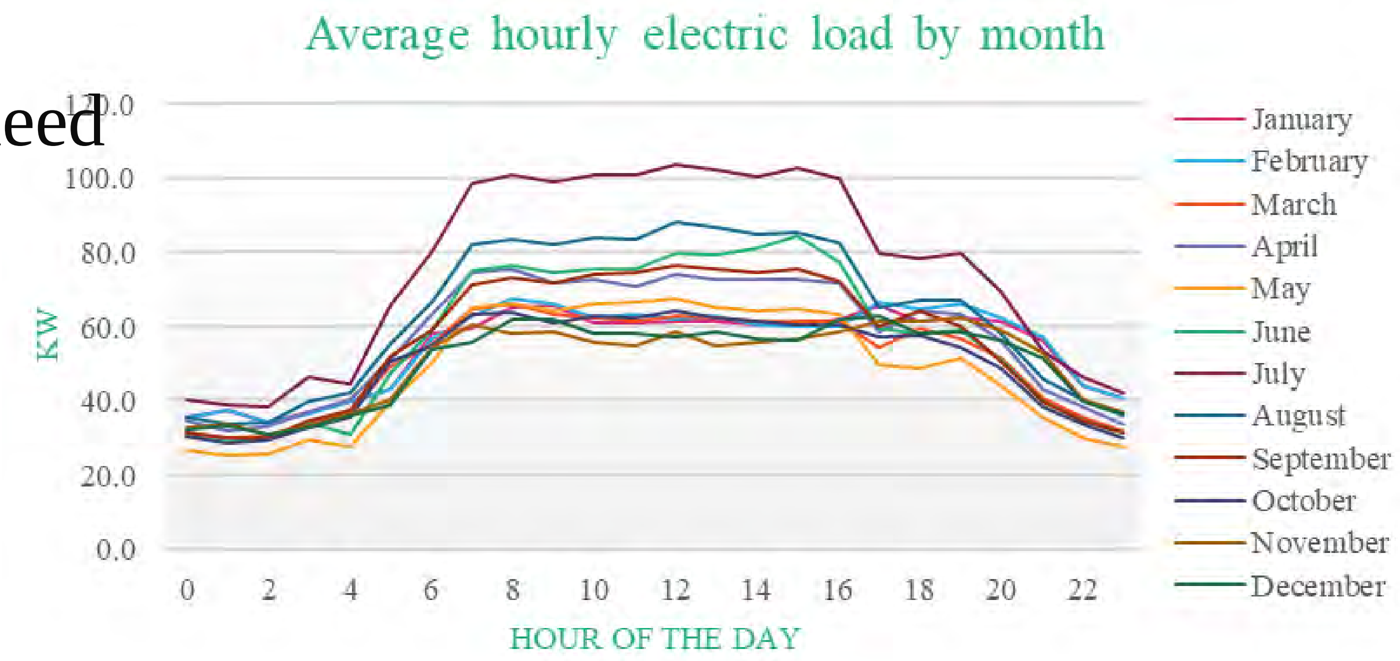

Energy models
Resilience needs
Financial analysis (Business-as-usual)
Clean energy system model
GHG and energy impact

Energy models

Inputs:
- Existing use data
- ASHRAE benchmark data
  Energy efficiency measures

Outputs:
- Annual load profiles
- Typical daily load profiles

Key challenge:
Limited hourly data resulted in the need to estimate energy profiles



Resilience needs

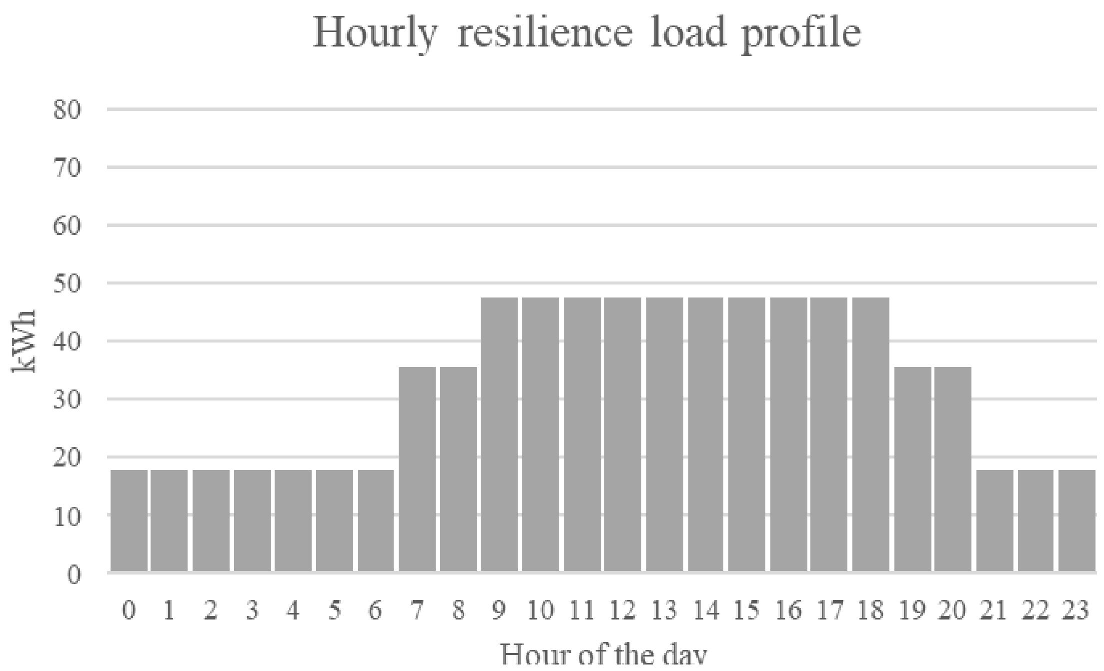
Inputs:

- Determined needs based on resilience gap analysis
- Estimated loads based on site data and equipment nameplates
- Estimated daily load profile during power loss event

Output:

- Daily load profile of critical systems

Key challenge:
Limited sub-metered data required high-level estimate to determine load profile



Financial analysis

First costs:

Conservative cost estimates
Mass Save CHP incentive
LBE incentive

Annual savings/costs:

Energy cost savings
Demand charge savings
SMART
AECs/RECs
Clean energy system O+M costs
Fuel costs

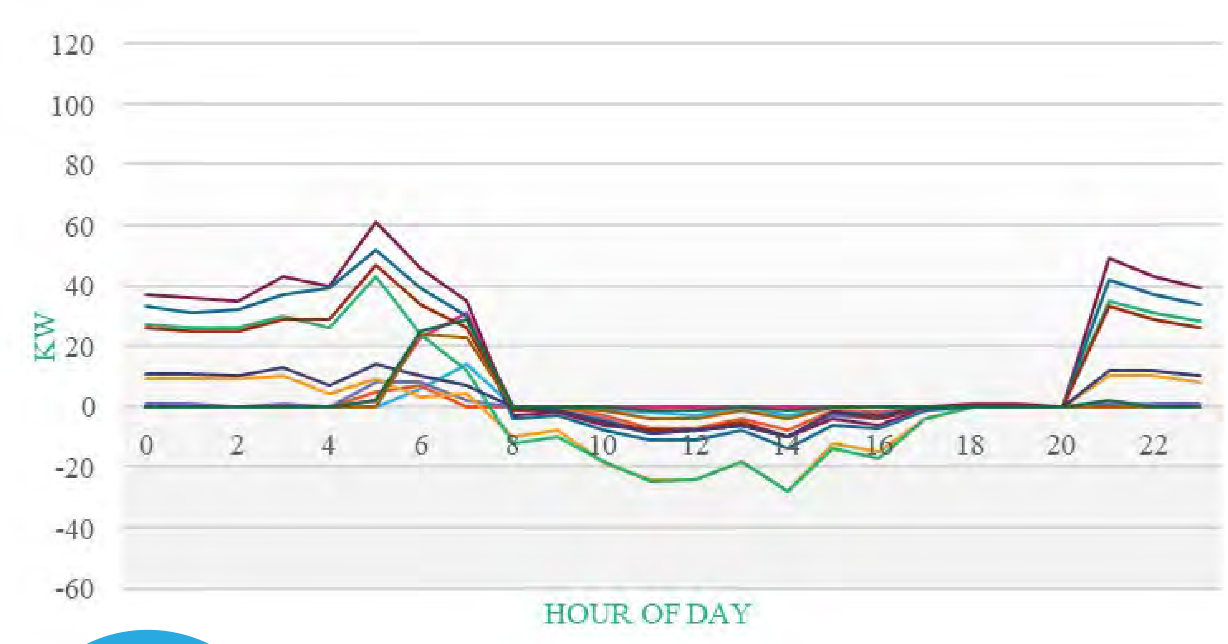
Did not include financial benefits from resilience

	Baseline	*65 kW CHP*	*65 kW CHP w/ 200 kW PV inside*	*65 kW CHP w/ 200 kW PV and 120 kWh battery*	*200 kW solar PV and 302 kWh battery*
First costs ($)					
Installed cost	N/A	(215,000)	(1,315,000)	(1,448,000)	(1,435,000)
Mass Save CHP program incent.	N/A	27,100	16,900	15,800	-
LBE incentive	N/A	-	330,000	354,000	390,400
Net installed cost	*N/A*	*(187,300)*	*(968,100)*	*(1,078,200)*	*(1,044,600)*
Annual costs ($)					
Utility electric supply cost	(45,700)	(16,500)	(5,000)	(6,200)	(22,900)
Utility electric T&D cost	(25,900)	(9,400)	(2,900)	(3,500)	(13,000)
Utility electric demand cost	(11,000)	(4,400)	(1,800)	(100)	(4,800)
Utility thermal energy cost	(31,800)	(13,200)	(19,200)	(19,400)	(31,800)
Proposed clean energy system maintenance cost	N/A	(3,260)	(2,000)	(1,900)	-
Proposed clean energy system fuel cost	N/A	(40,940)	(25,000)	(23,300)	-
Annualized overhaul cost	N/A	(2,600)	(2,600)	(5,300)	(6,700)
SMART incentive	N/A	-	24,300	32,500	37,800
AEC incentive	-	8,000	5,700	5,700	-
Net annual cost	(114,400)	(82,300)	(28,500)	(21,500)	(41,400)
Net annual incentives	**N/A**	**8,000**	**30,000**	**38,200**	**37,800**
Annual savings compared to baseline	*N/A*	*32,100*	*85,900*	*92,900*	*73,000*
Summary					
Payback period (simple payback, years)	**N/A**	**5.8**	**11.3**	**11.6**	**14.3**
30-yr NPV ($)	N/A	*375,000*	*527,000*	*544,000*	*316,000*

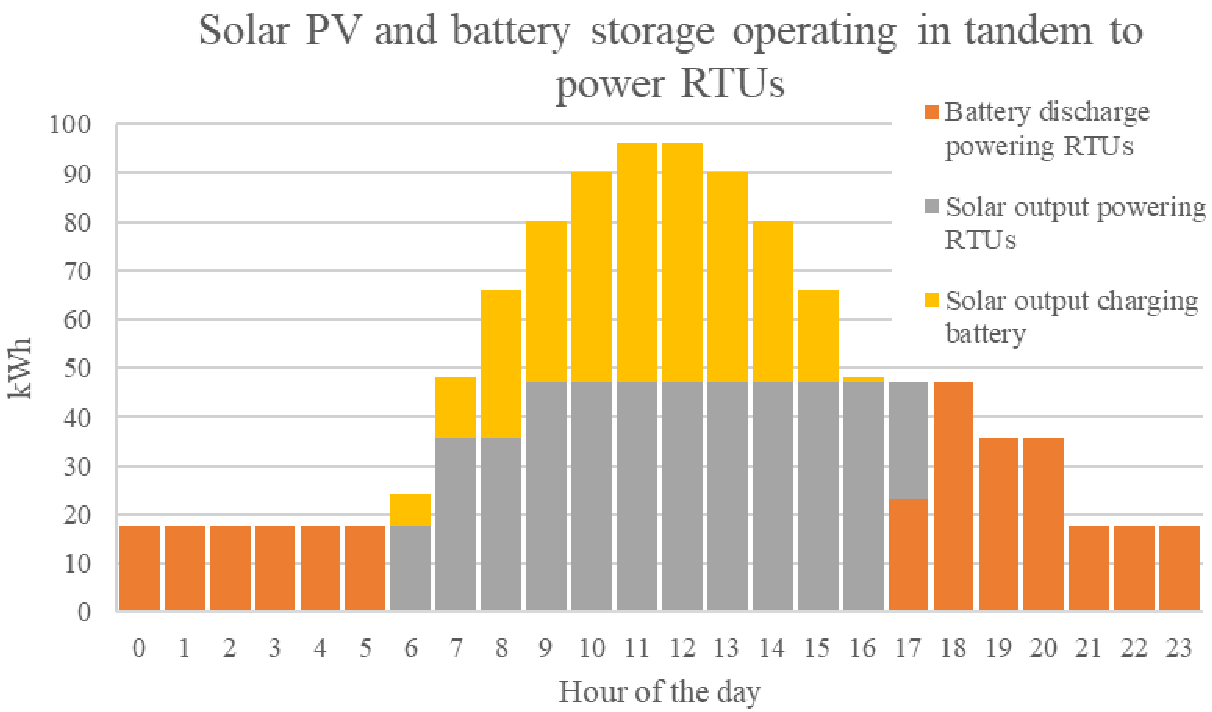
Clean energy system model

Two scenarios:

Sized to optimize ROI

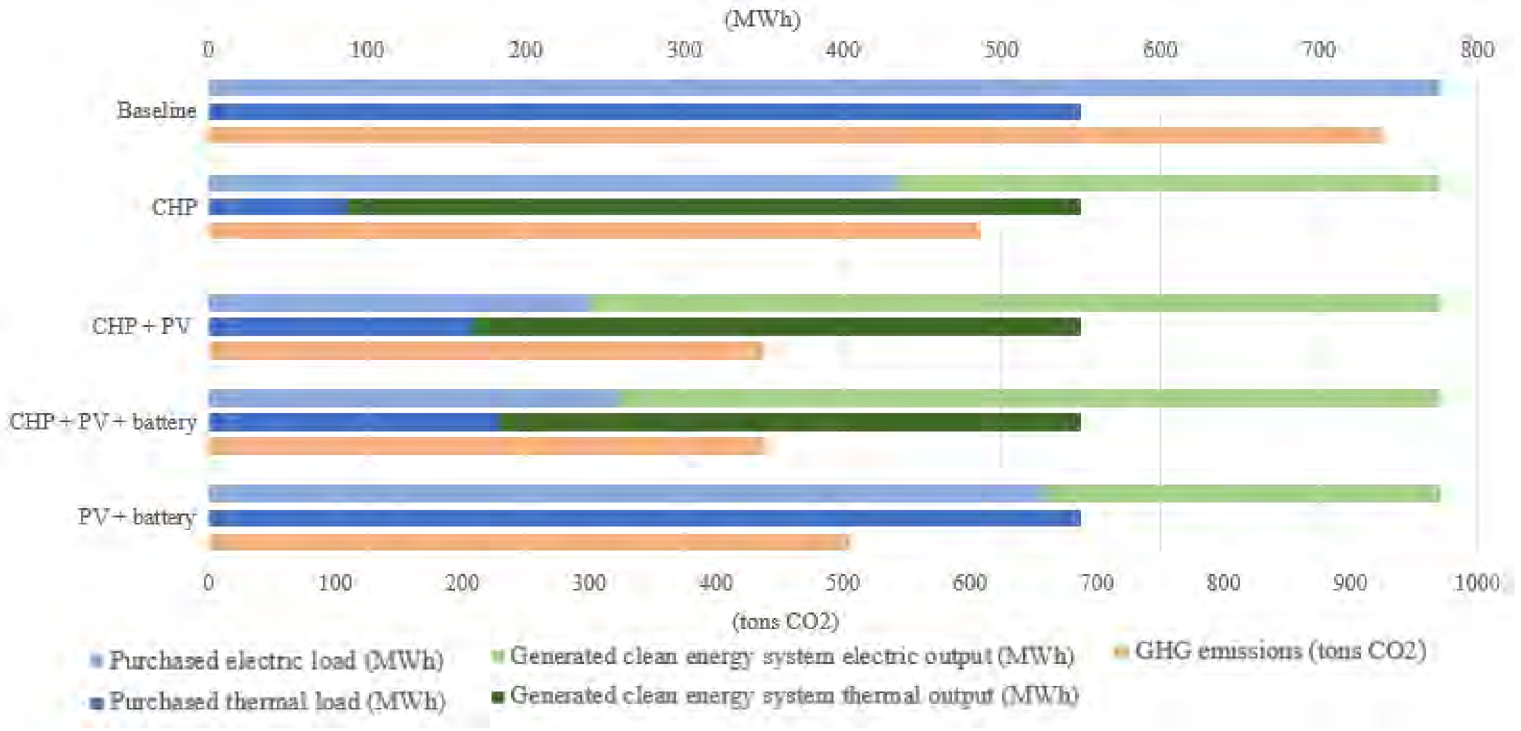


Sized to meet resilience needs



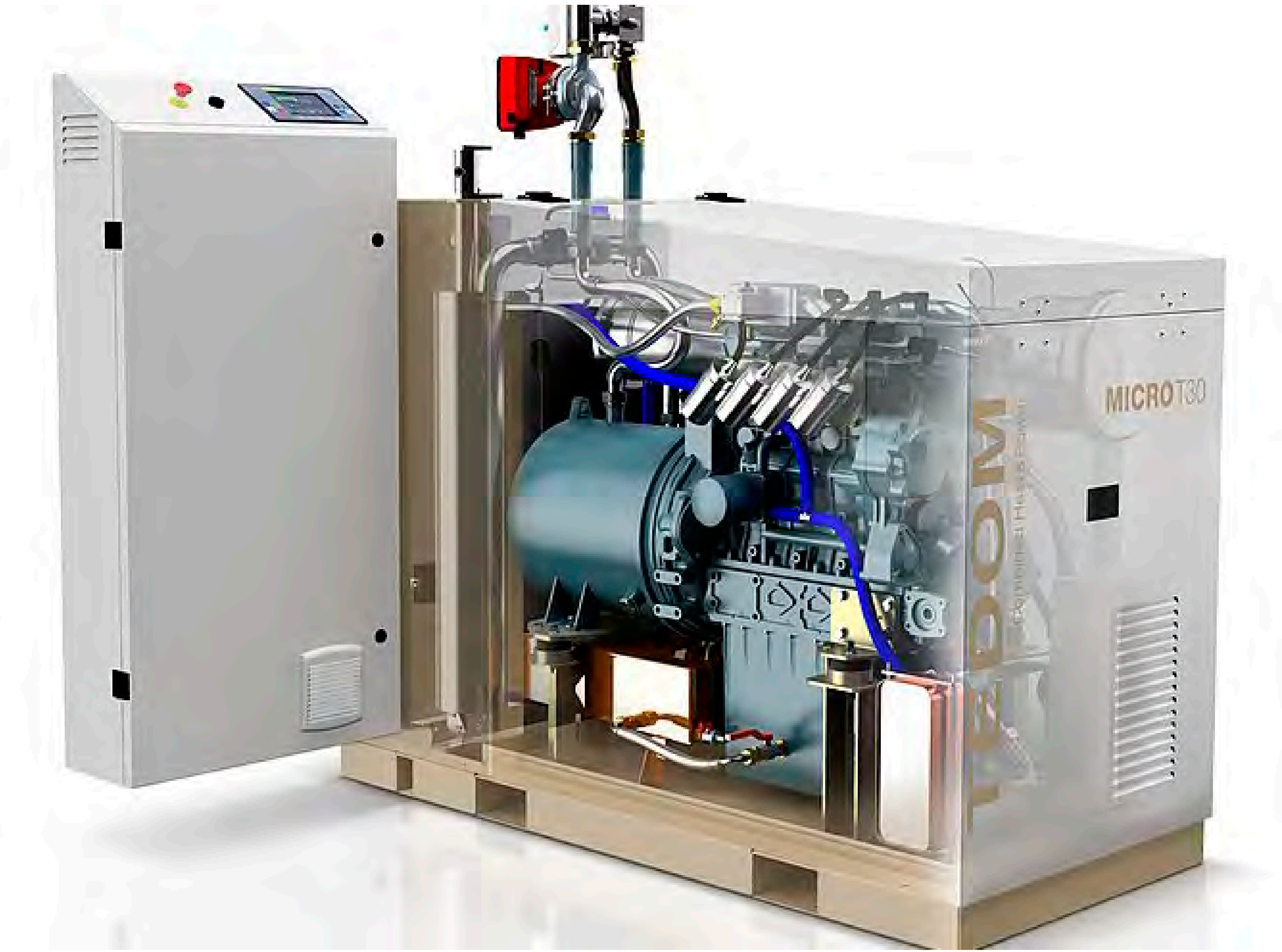
Greenhouse gas and energy impact

Confirmed overall GHG reductions for each option as well as reduction in purchased energy



Technology Examples

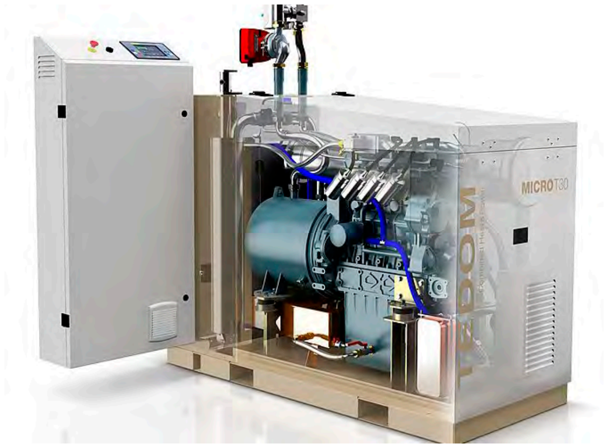
CHP example



CHP basics

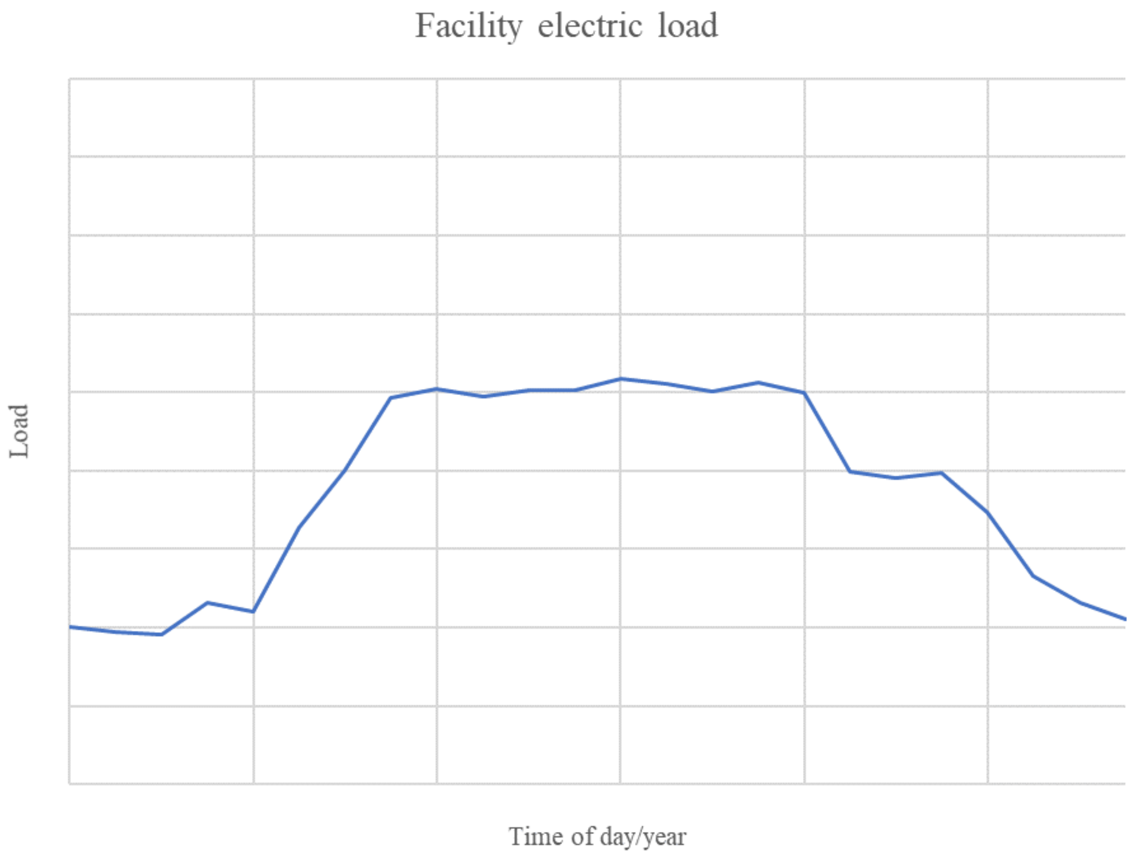
CHP systems convert natural gas to electricity and thermal energy (heat)
Prefer to operate at a consistent output
Maximum efficiency when both electrical and thermal energy can be used

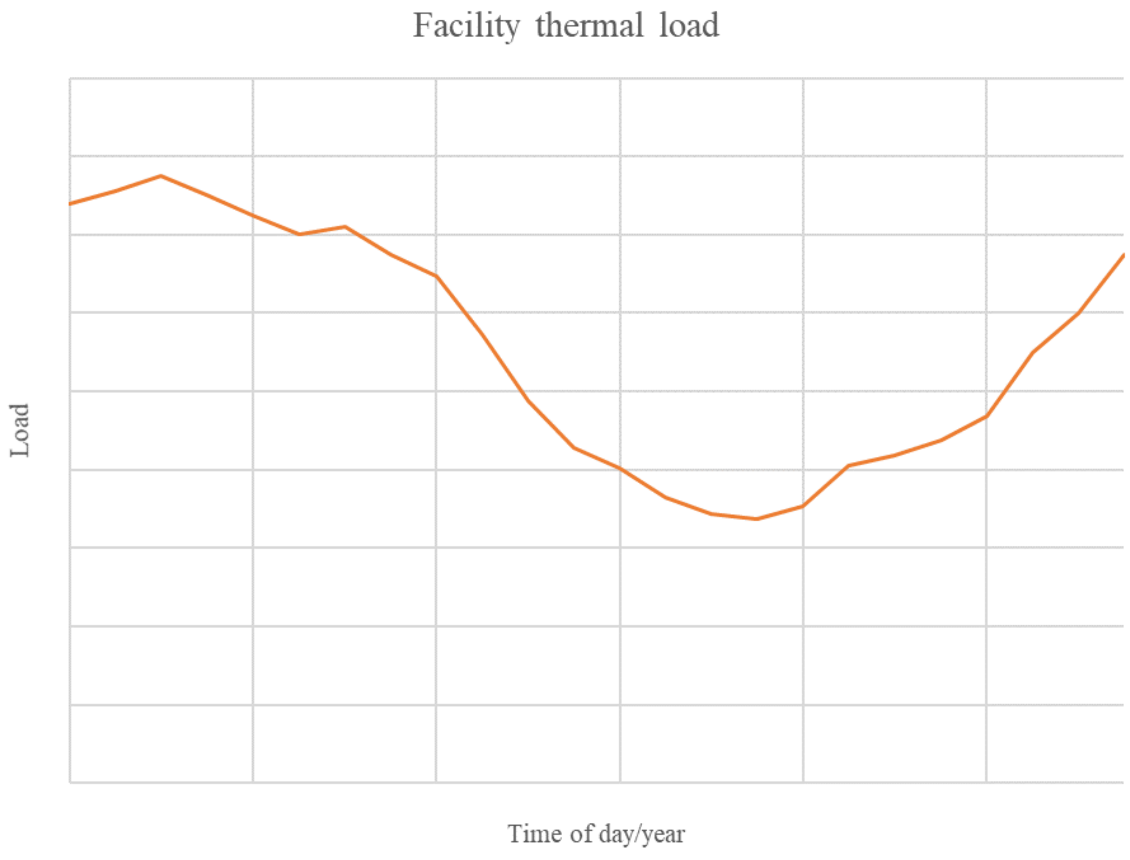
“Set-it-and-forget-it”



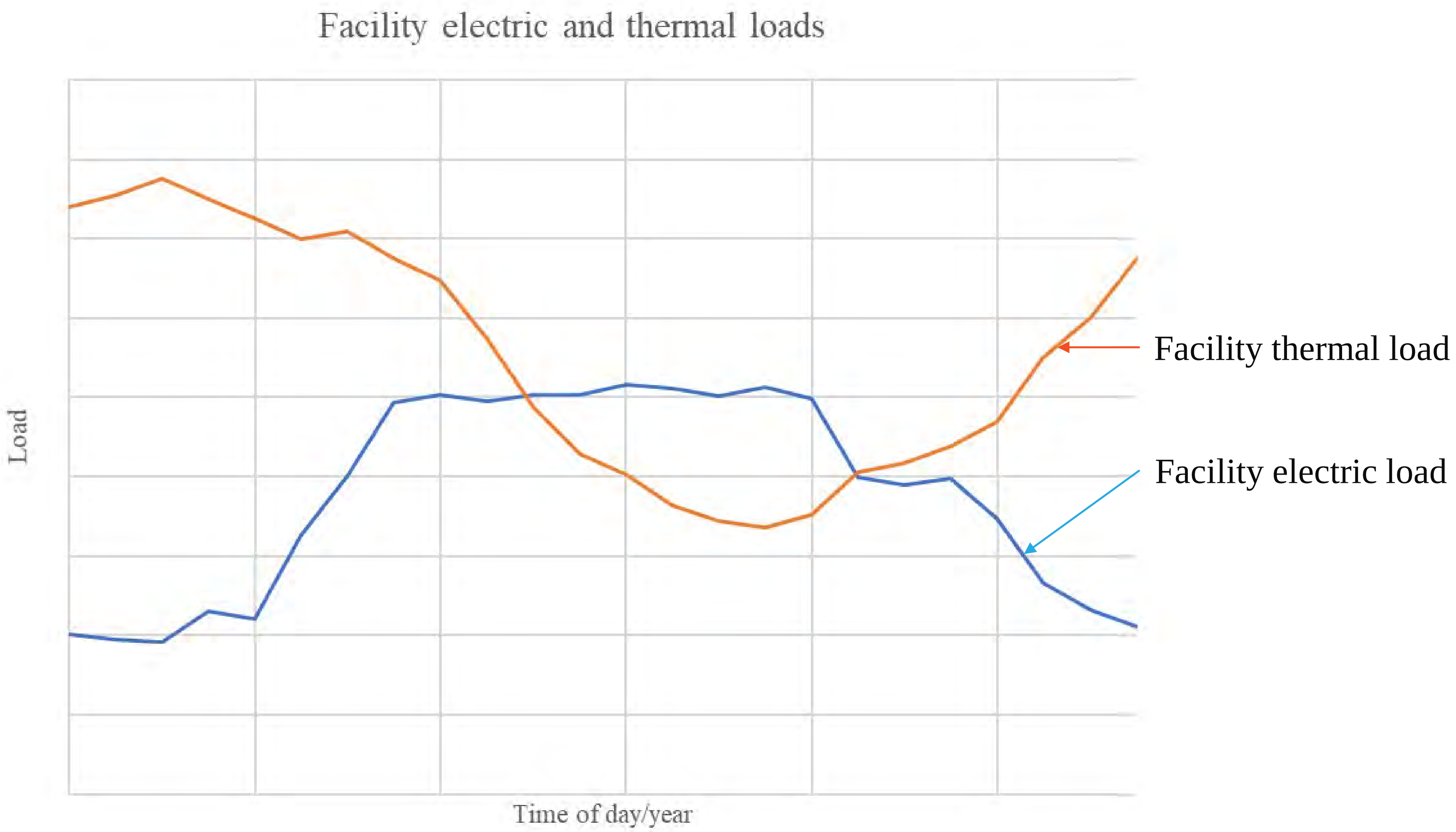
CHP system sizing

Need to consider both electric and thermal load profiles

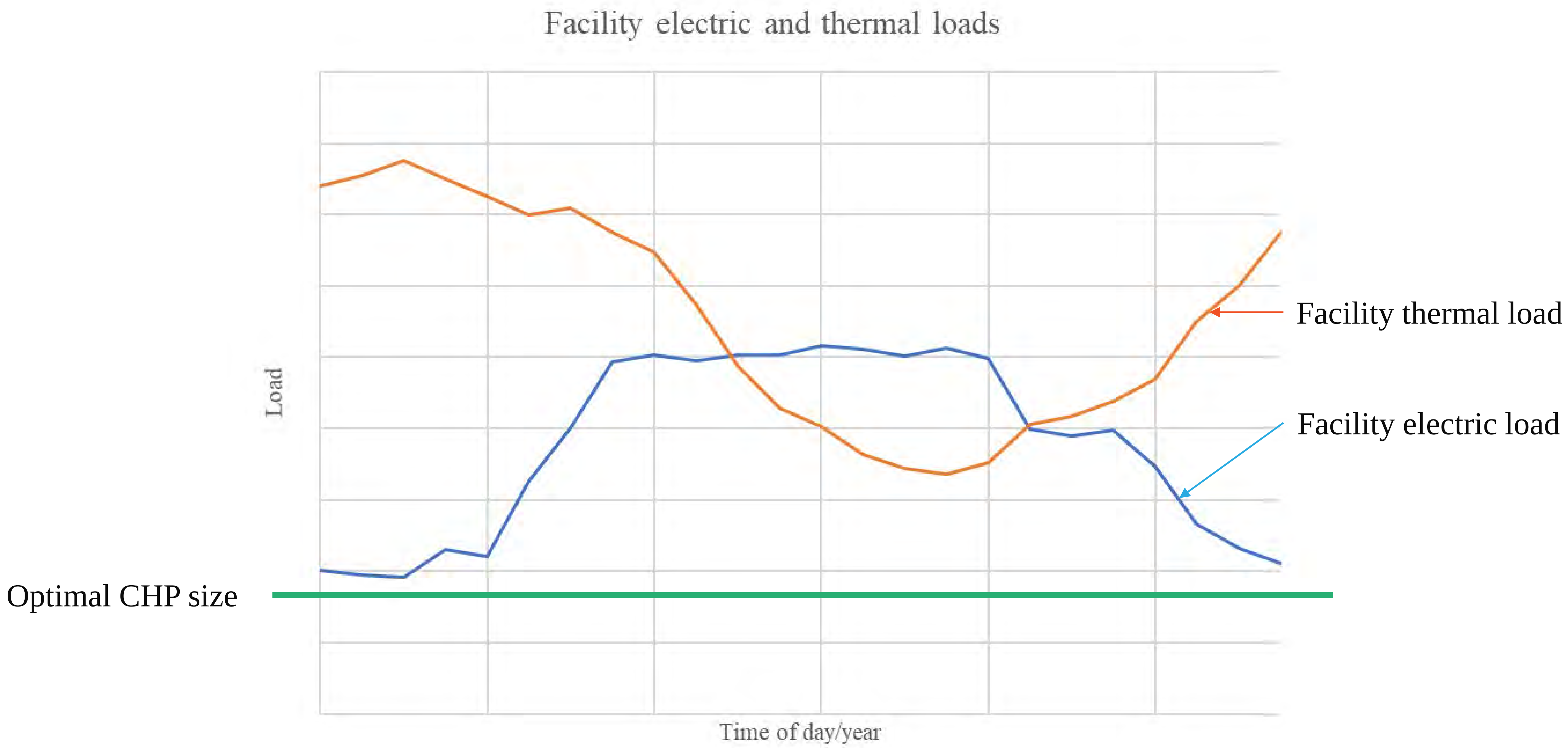




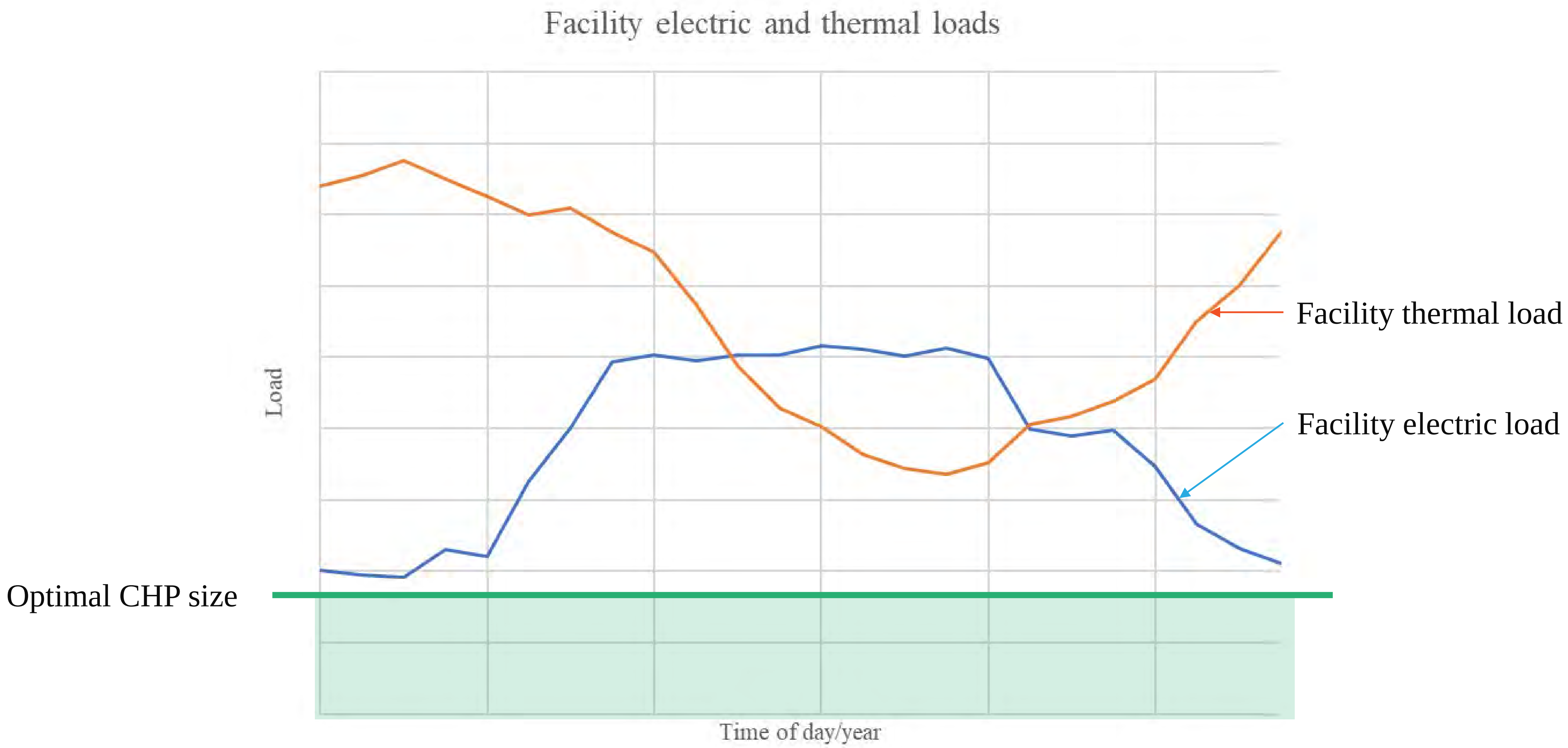
CHP system sizing



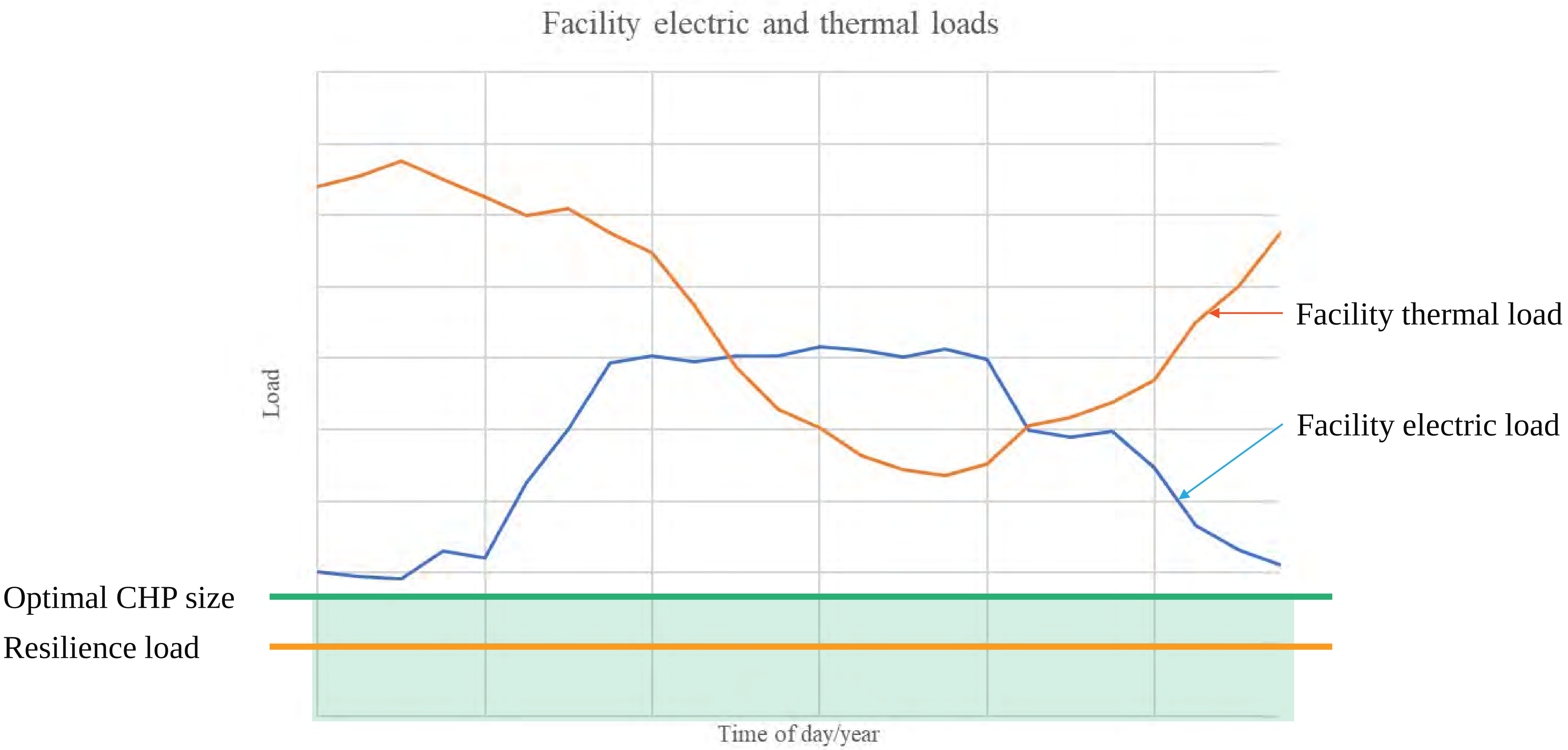
CHP system sizing



CHP system sizing



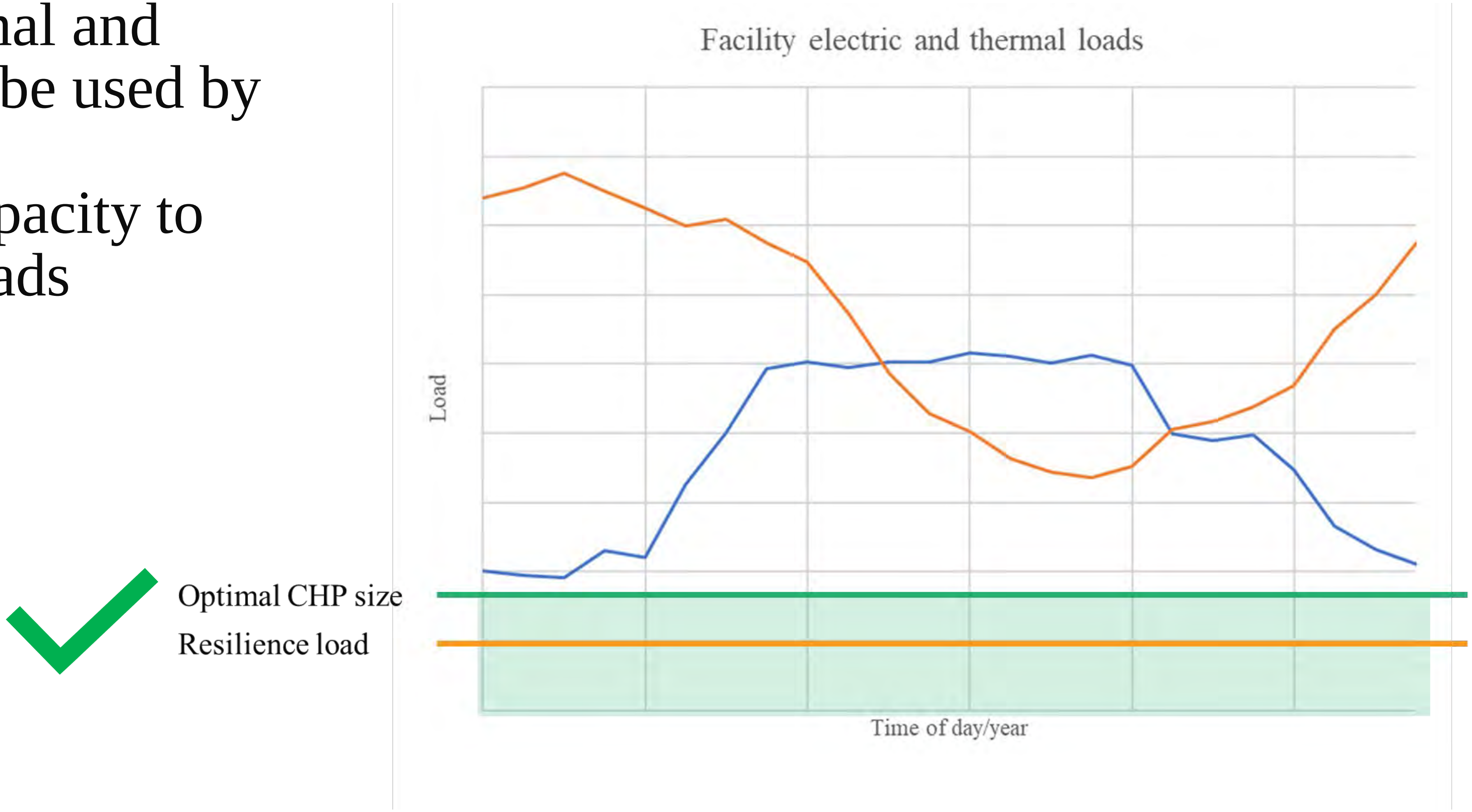
CHP system sizing

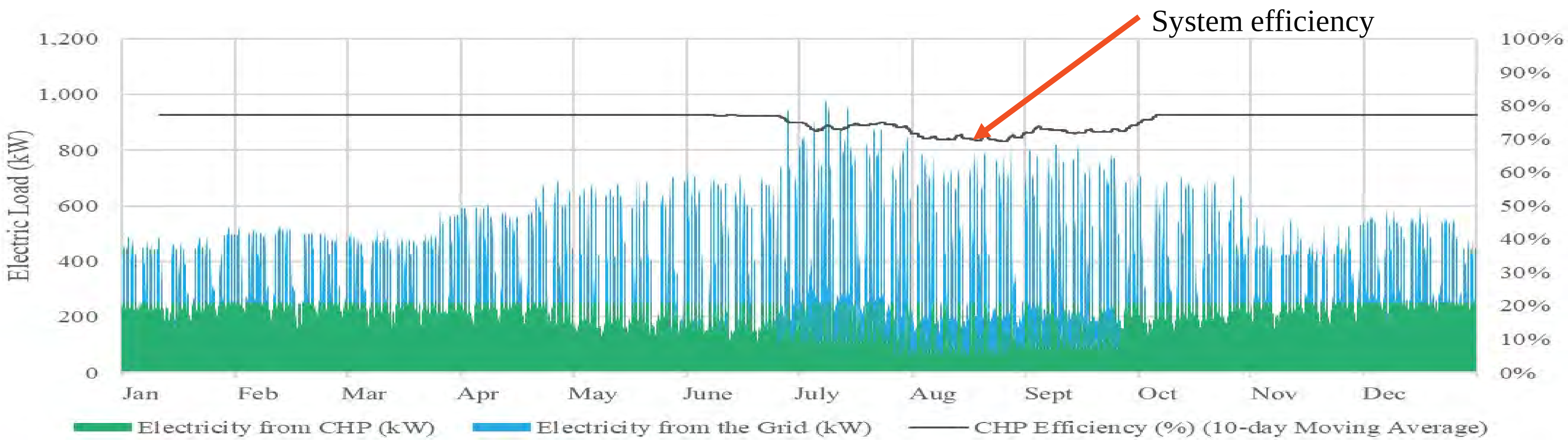


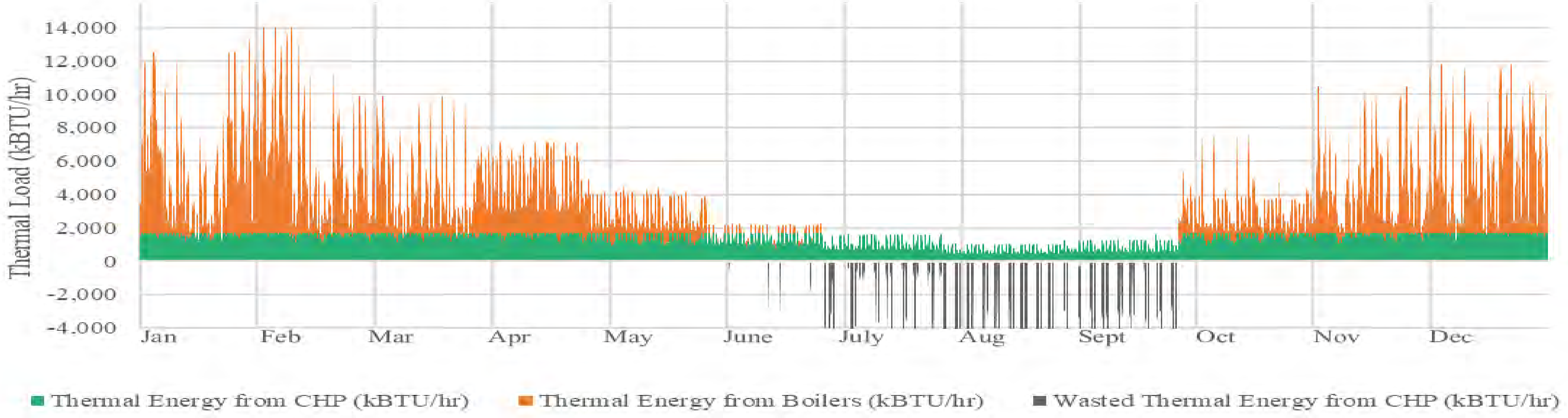
CHP system sizing

When optimal CHP size is larger than the resilience need

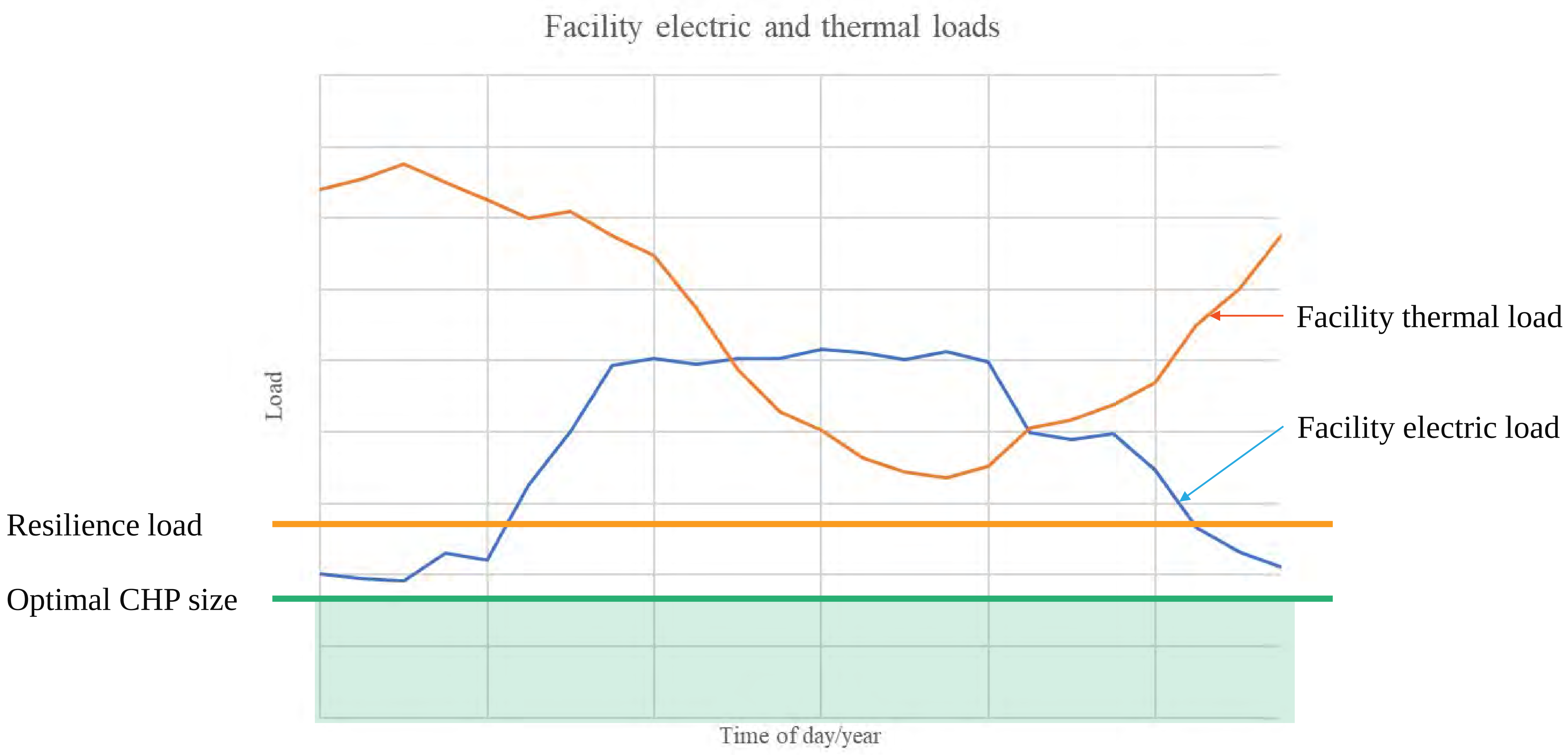
- CHP system operates at maximum efficiency
- All generated thermal and electric energy can be used by the facility
- CHP system has capacity to power resilience loads




System efficiency
Electric Load (kW)
1,200
1,000
800
600
400
200
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Electricity from CHP (kW)
Electricity from the Grid (kW)
CHP Efficiency (%) (10-day Moving Average)


Thermal Load (kBTU/hr)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Thermal Energy from CHP (kBTU/hr)
Thermal Energy from Boilers (kBTU/hr)
Wasted Thermal Energy from CHP (kBTU/hr)

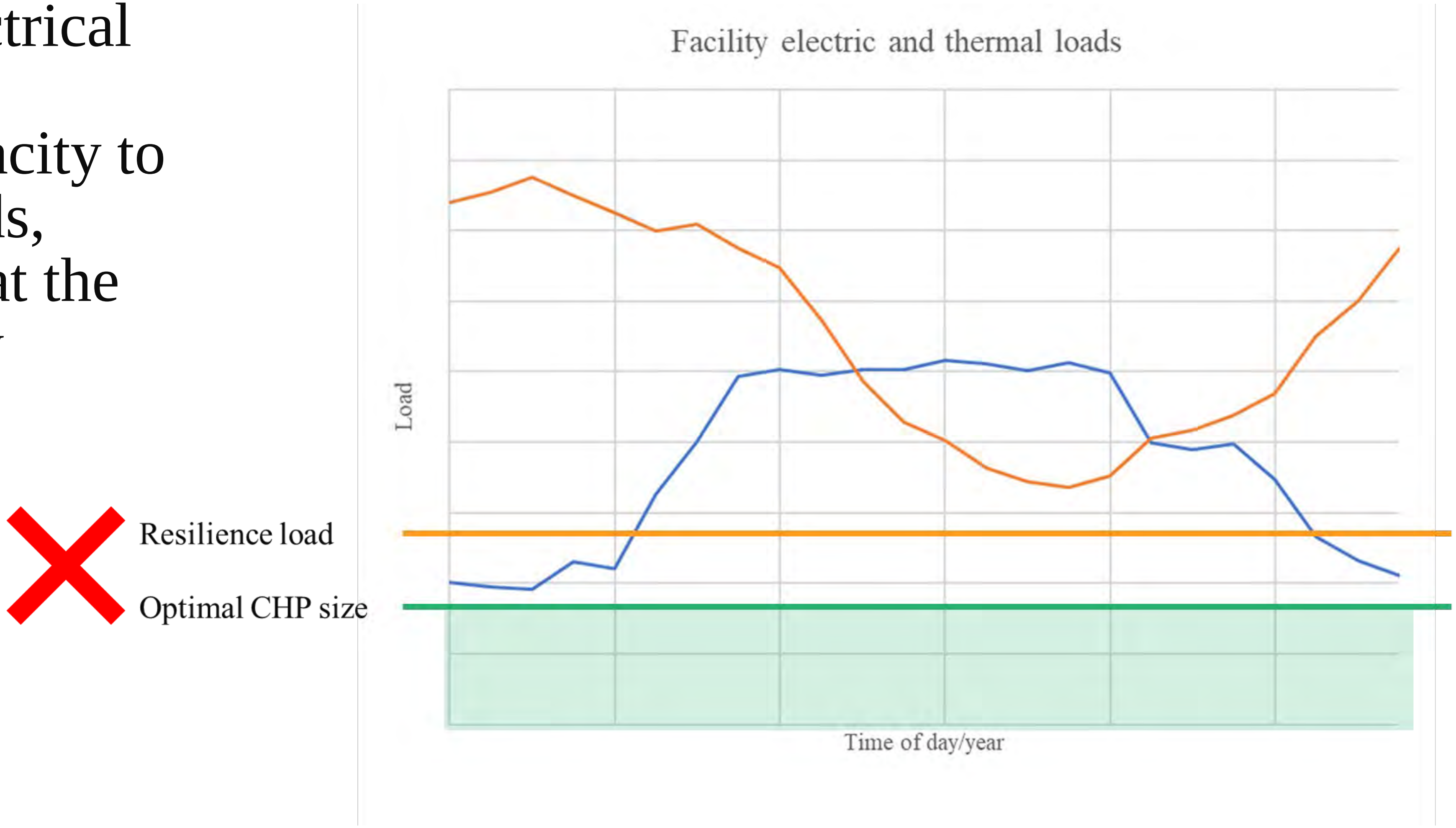
CHP system sizing



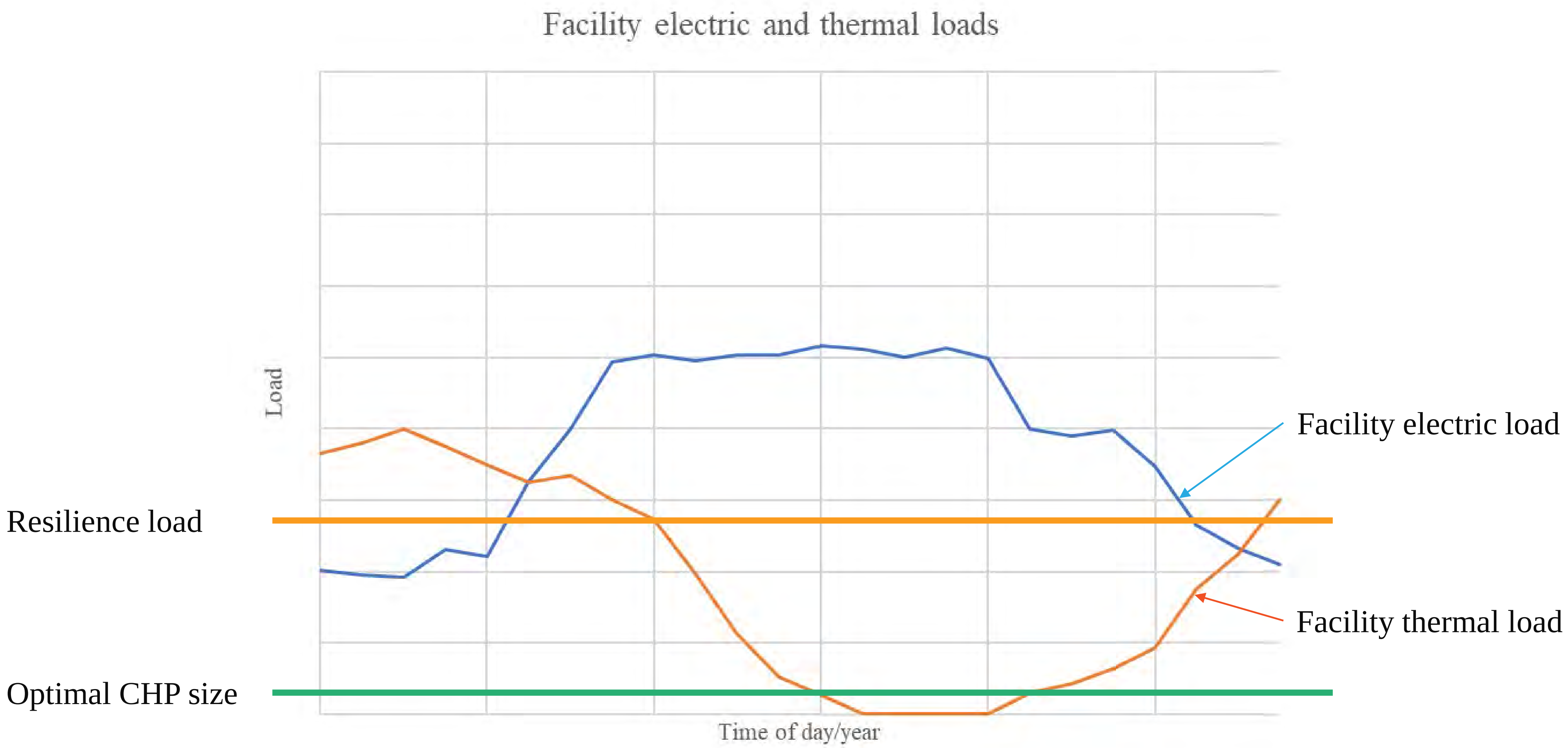
CHP system sizing

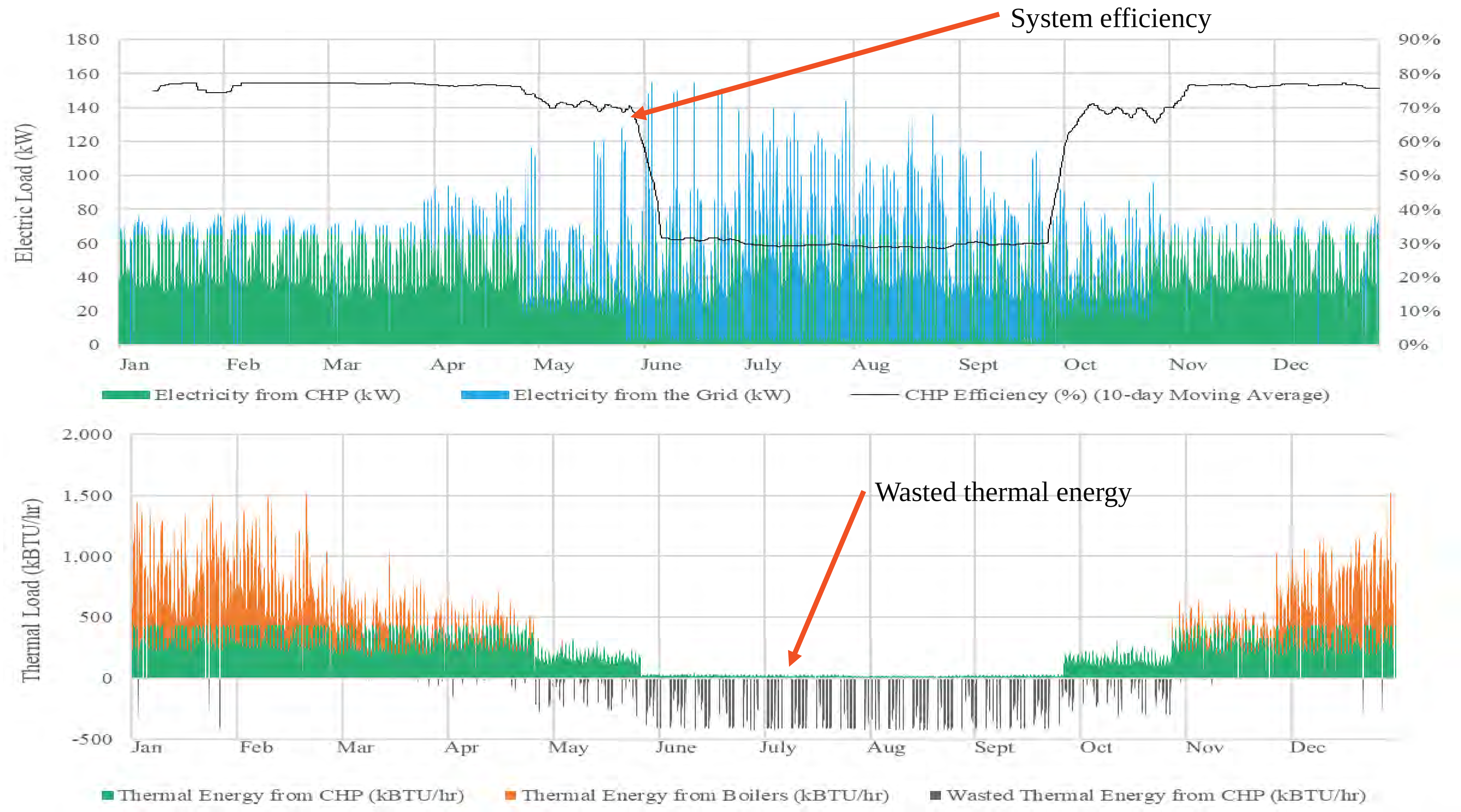
When optimal CHP size is smaller than the resilience need

- CHP system operates at reduced efficiency
- Some thermal or electrical energy is wasted
- CHP system has capacity to power resilience loads, however this comes at the expense of efficiency



CHP system sizing



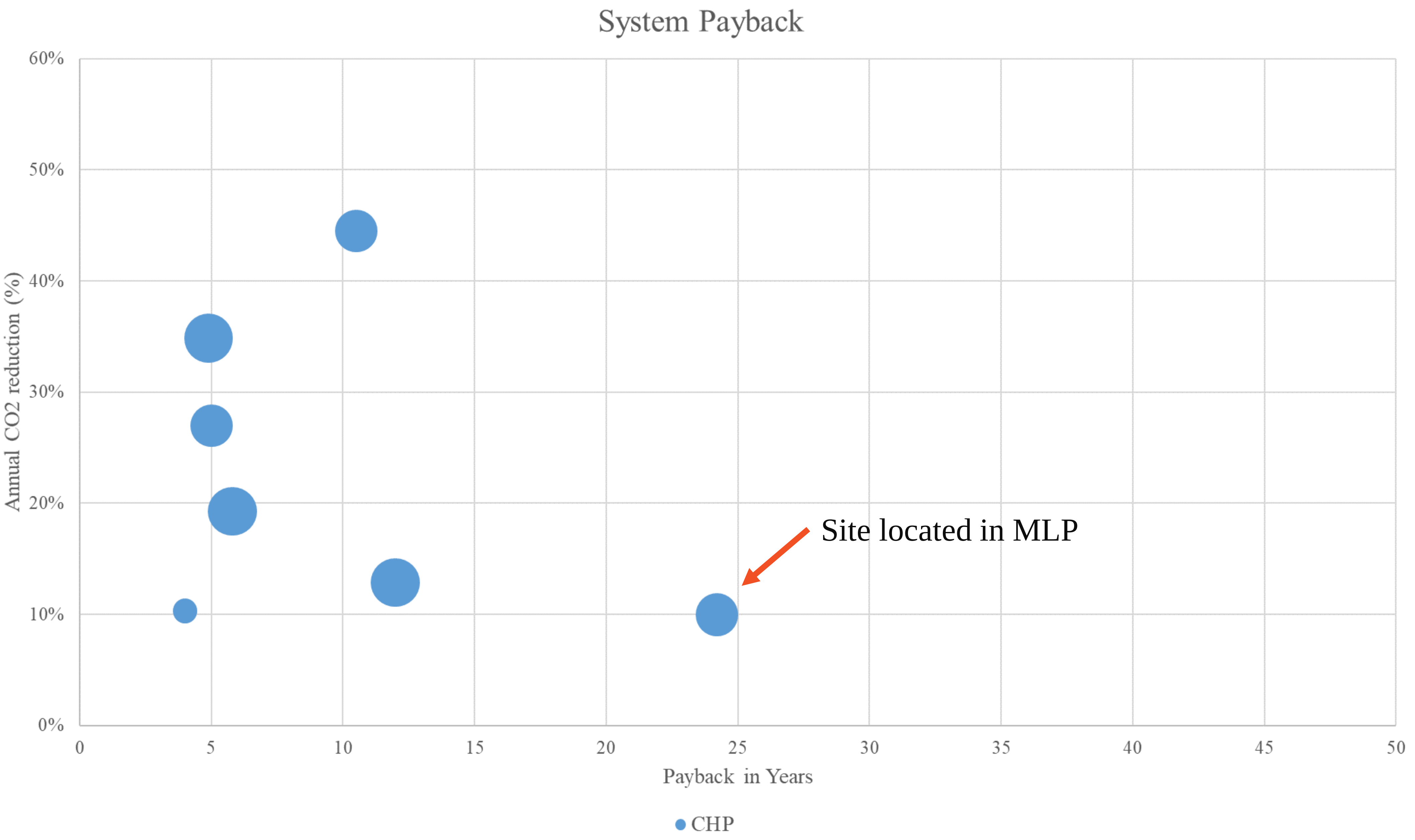

System efficiency
Electric Load (kW)
180
160
140
120
100
80
60
40
20
0
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Electricity from CHP (kW)
Electricity from the Grid (kW)
CHP Efficiency (%) (10-day Moving Average)
Wasted thermal energy
Thermal Load (kBTU/hr)
2,000
1,500
1,000
500
0
-500
Thermal Energy from CHP (kBTU/hr)
Thermal Energy from Boilers (kBTU/hr)
Wasted Thermal Energy from CHP (kBTU/hr)

CHP

Optimal system operation

- Electrical and thermal loads are closely matched
- Baseloads are consistent year round
- High energy costs which can be offset by onsite energy generation
- Resilience need is less than baseload and CHP system can load follow during utility outage

CHP payback results



Solar + Storage example

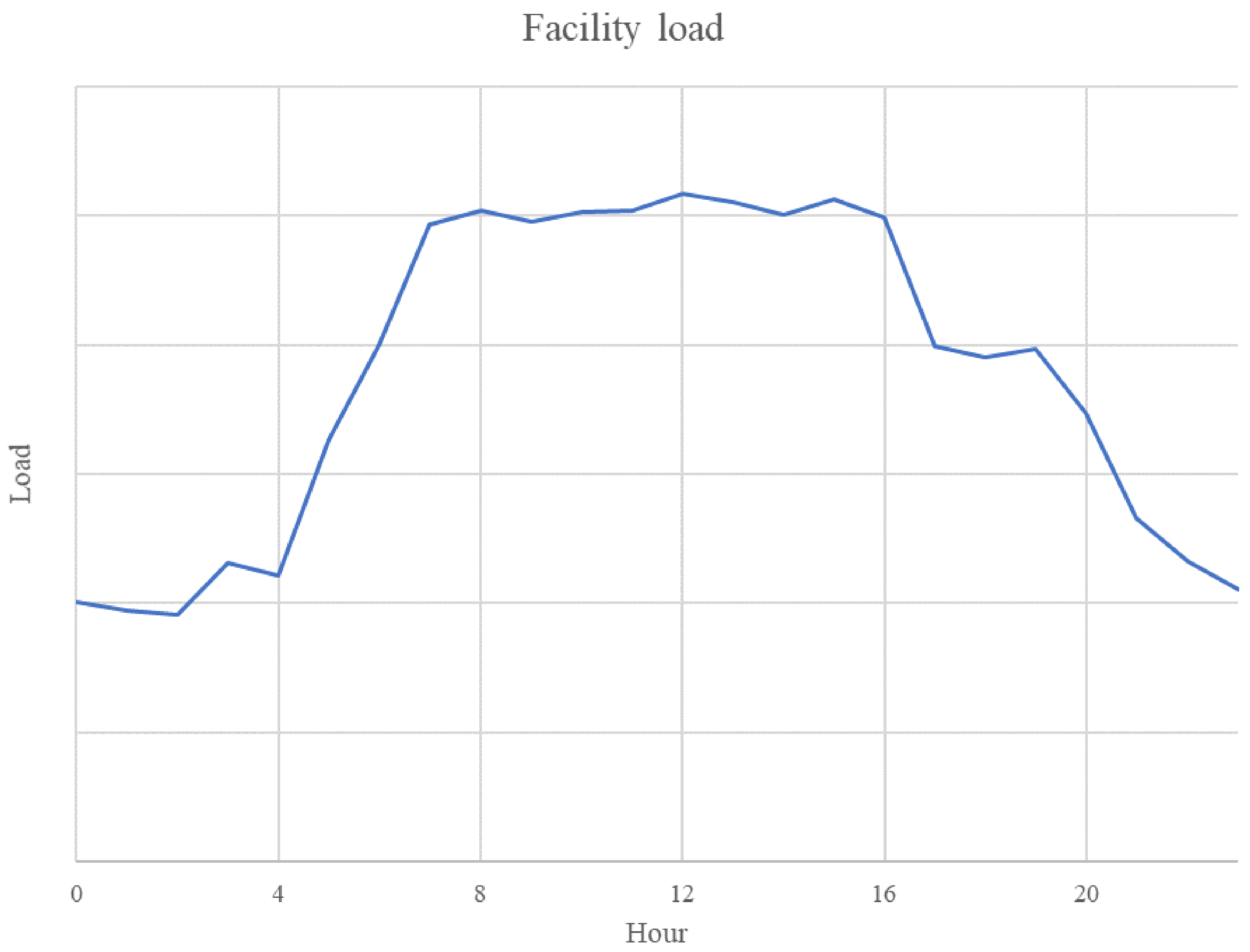
Solar + storage basics

Maximize ROI (Business-as-usual):
Size solar to maximize ROI by minimizing export of PV energy
Size storage to reduce any remaining peak demand
Frequent charge/discharge cycles required to maximize revenue from energy storage

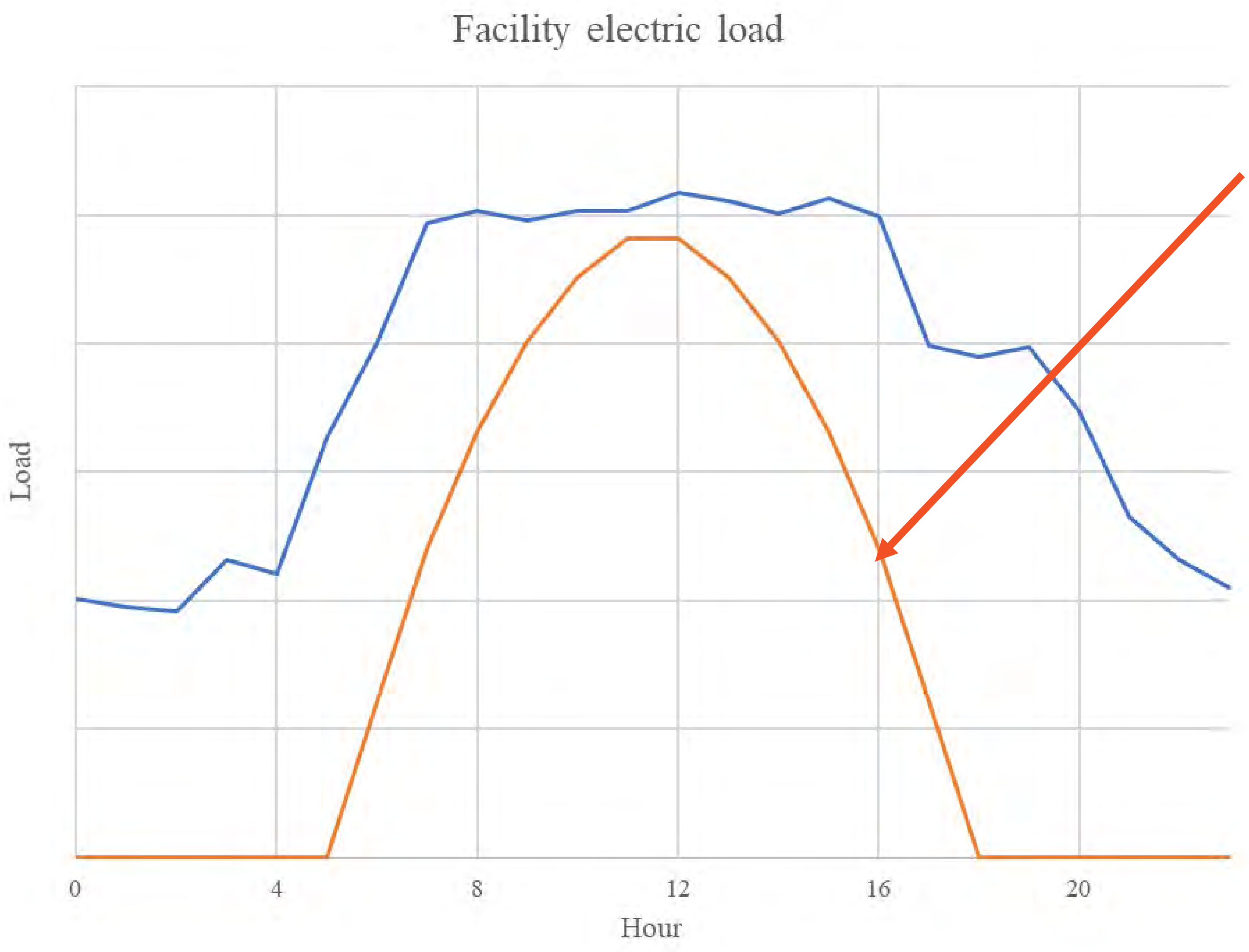
Maximize resilience:
Size solar to produce energy required for 24-hour operation of resilience loads
Size storage to power resilience loads once PV system is no longer generating energy

Solar + storage system sizing

Maximize ROI



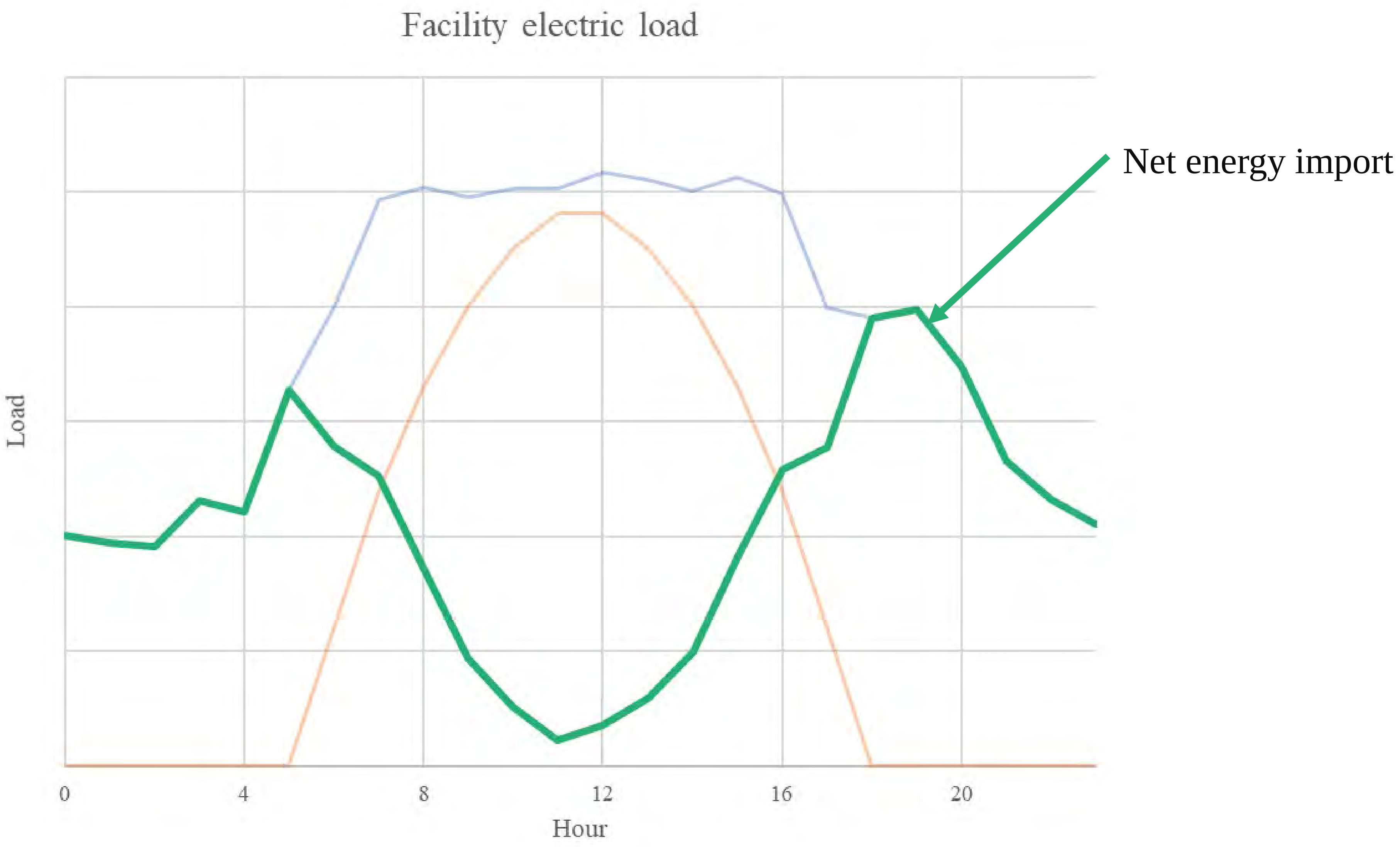
Solar + storage system sizing
Maximize ROI



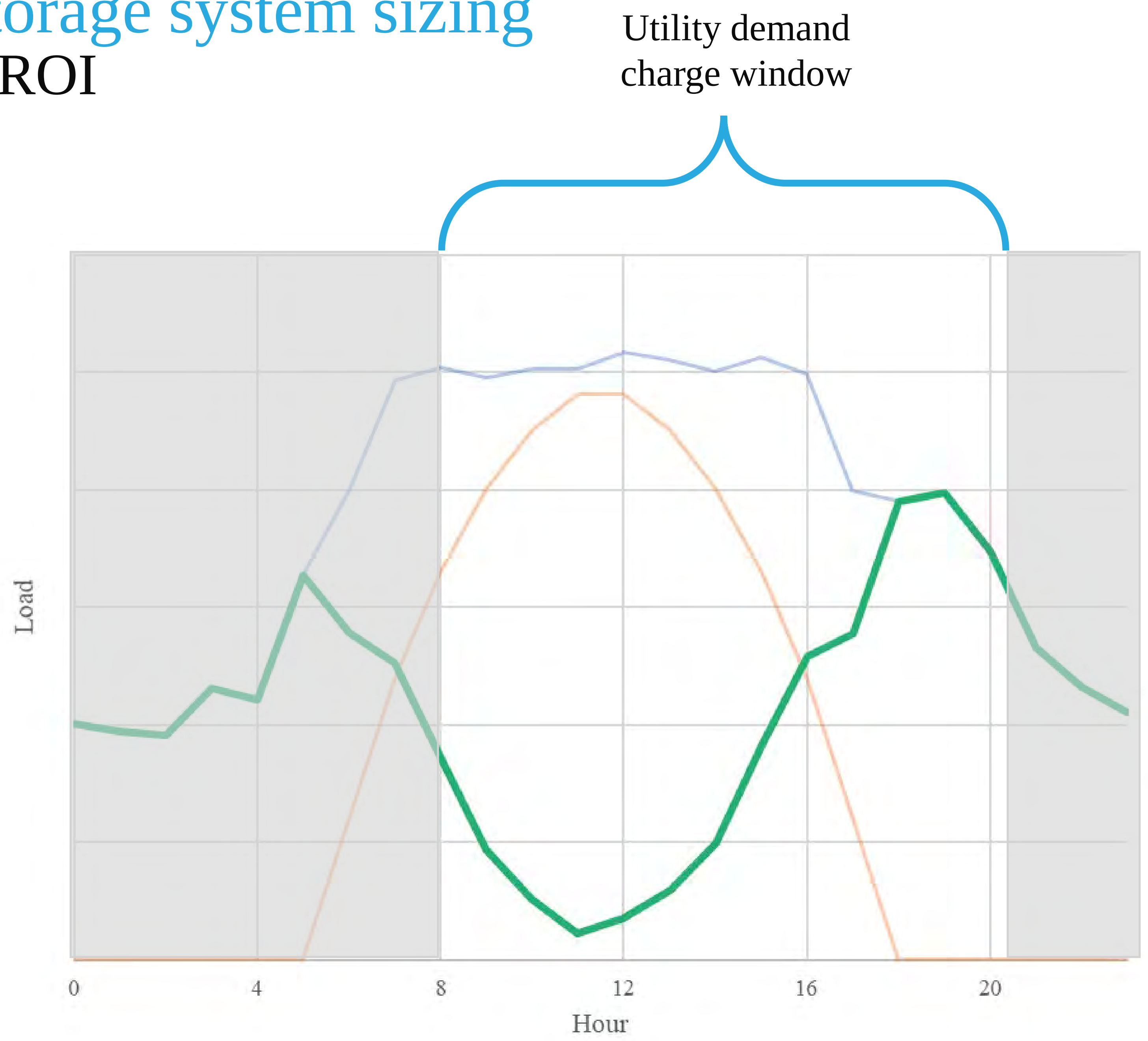
PV system sized to ensure all energy is used on-site

Solar + storage system sizing

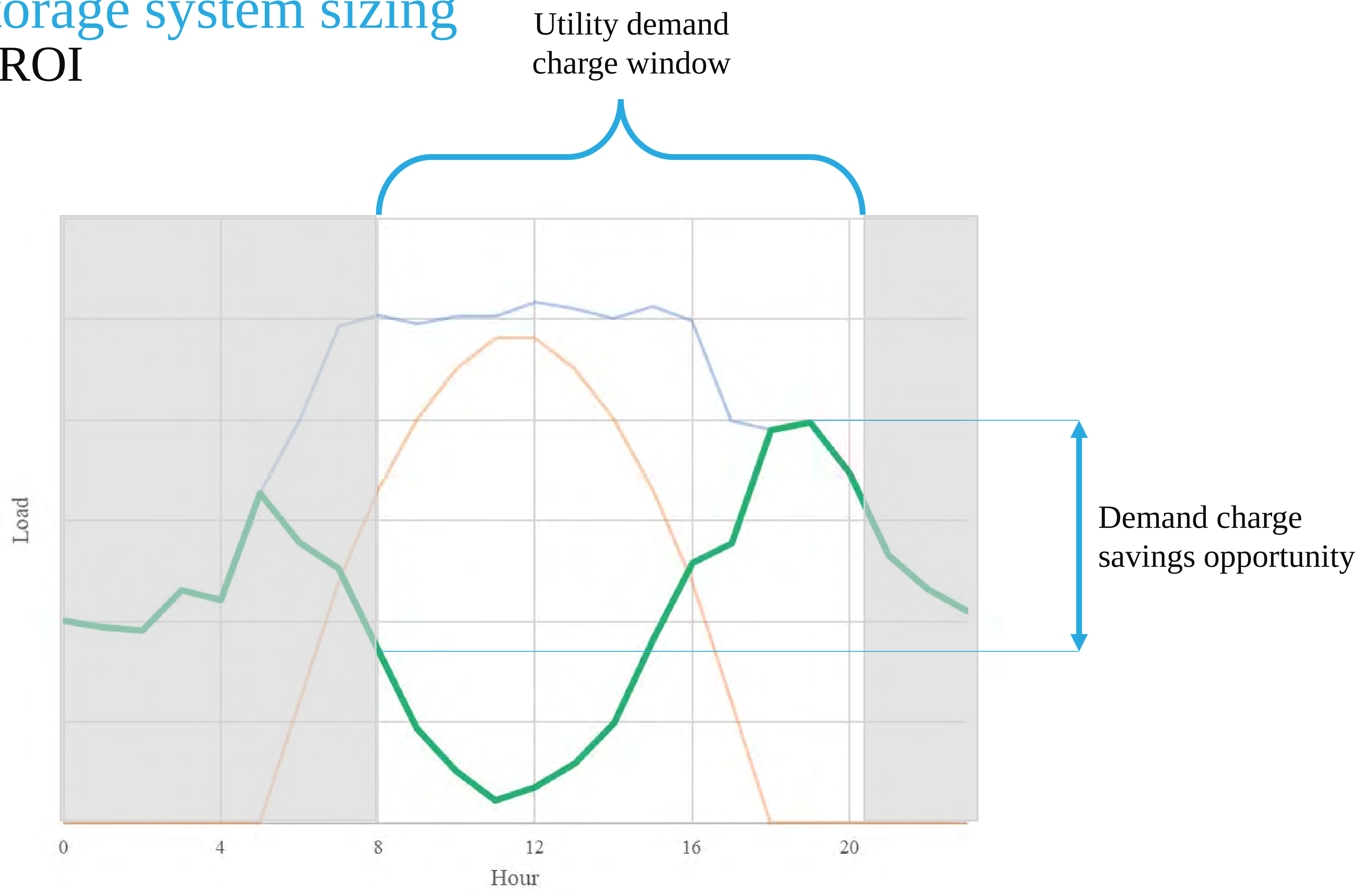
Maximize ROI



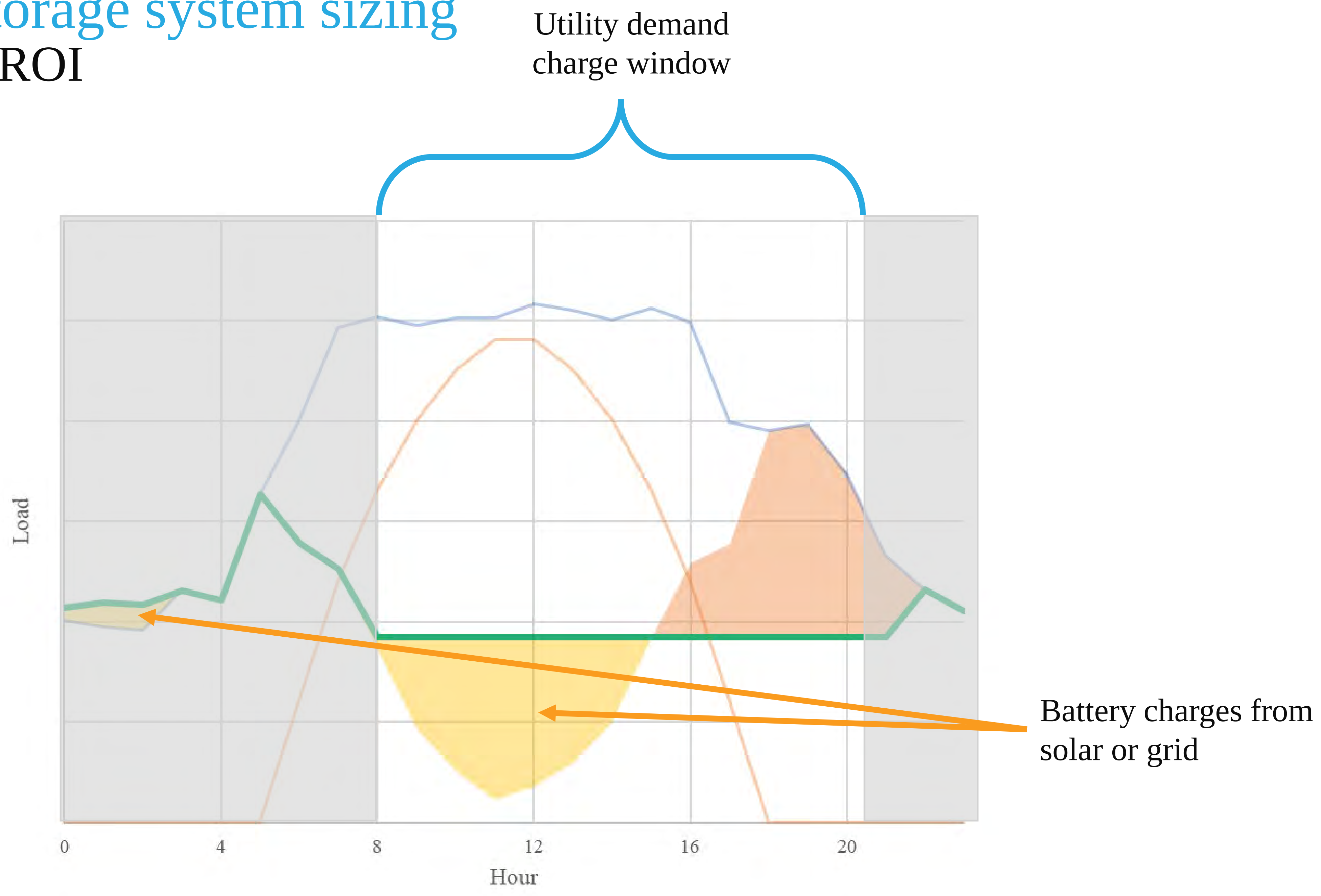
Solar + storage system sizing
Maximize ROI



Solar + storage system sizing
Maximize ROI

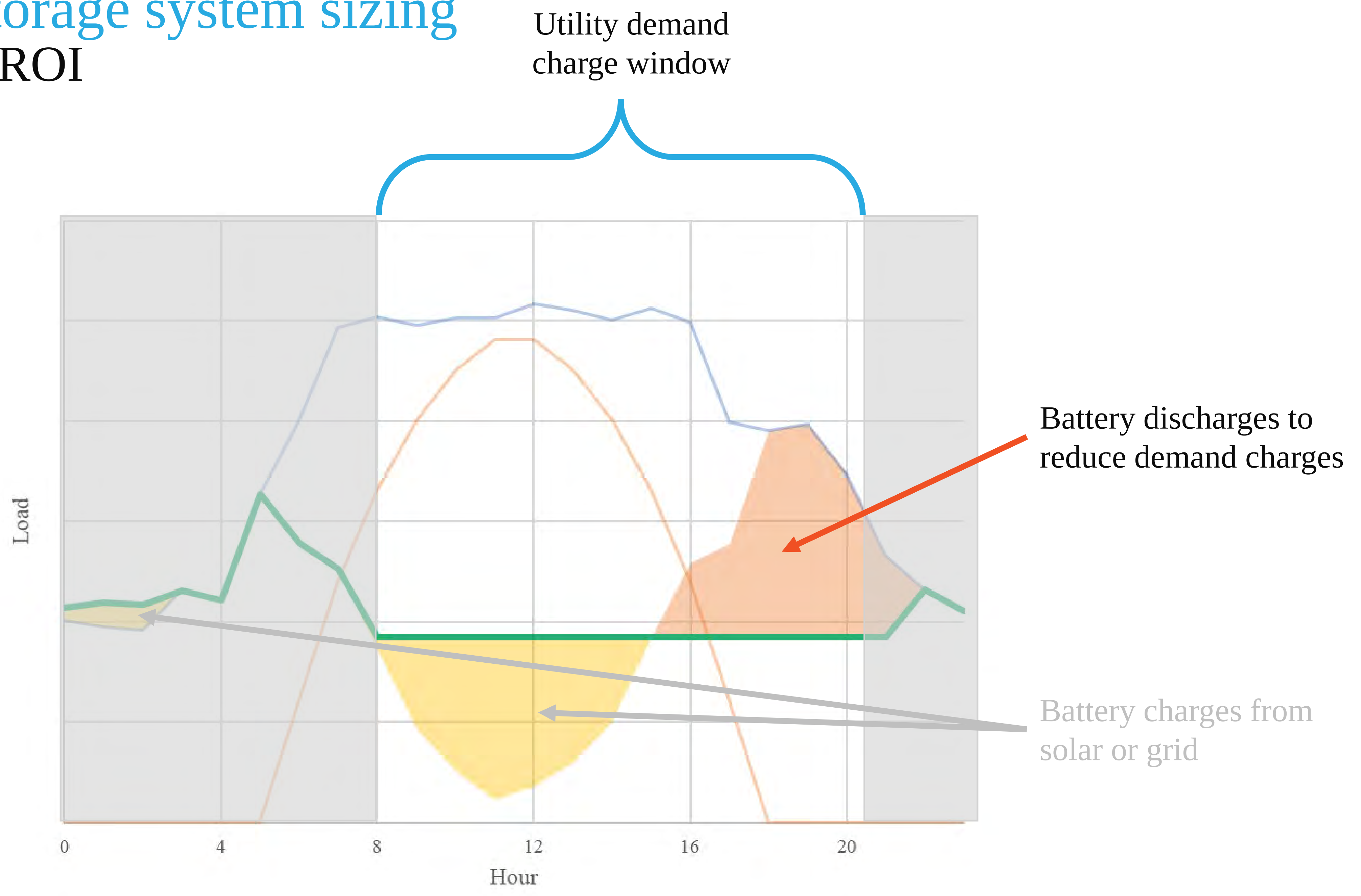


Solar + storage system sizing
Maximize ROI

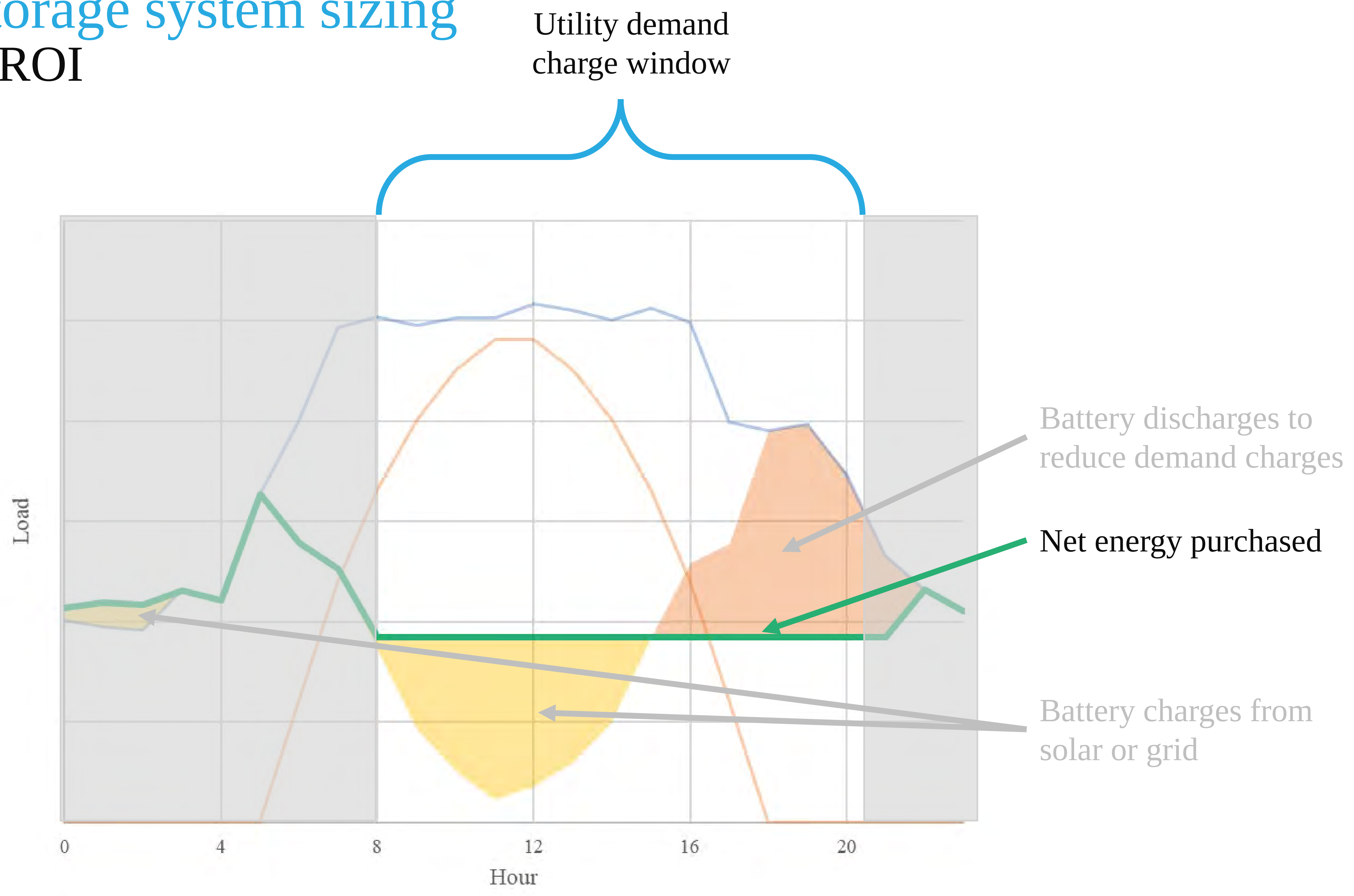


Solar + storage system sizing

Maximize ROI

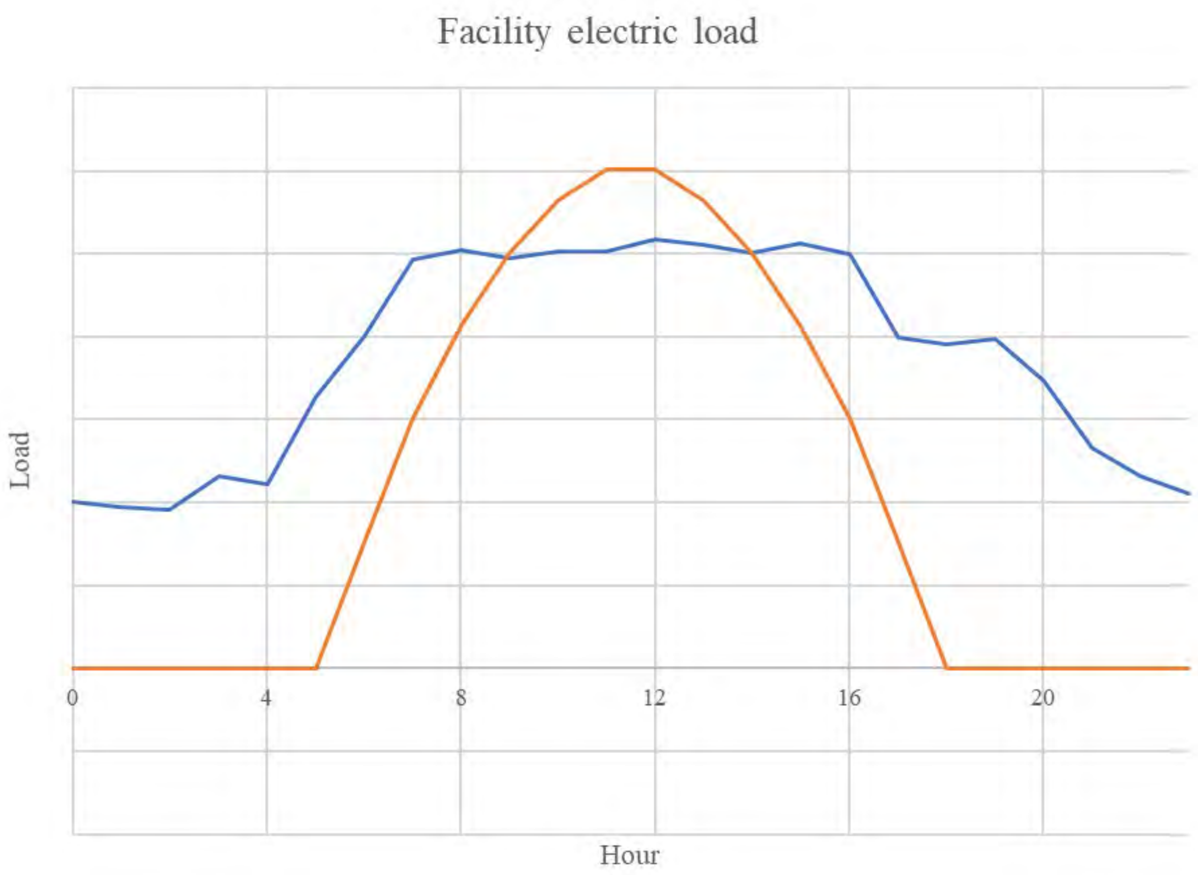


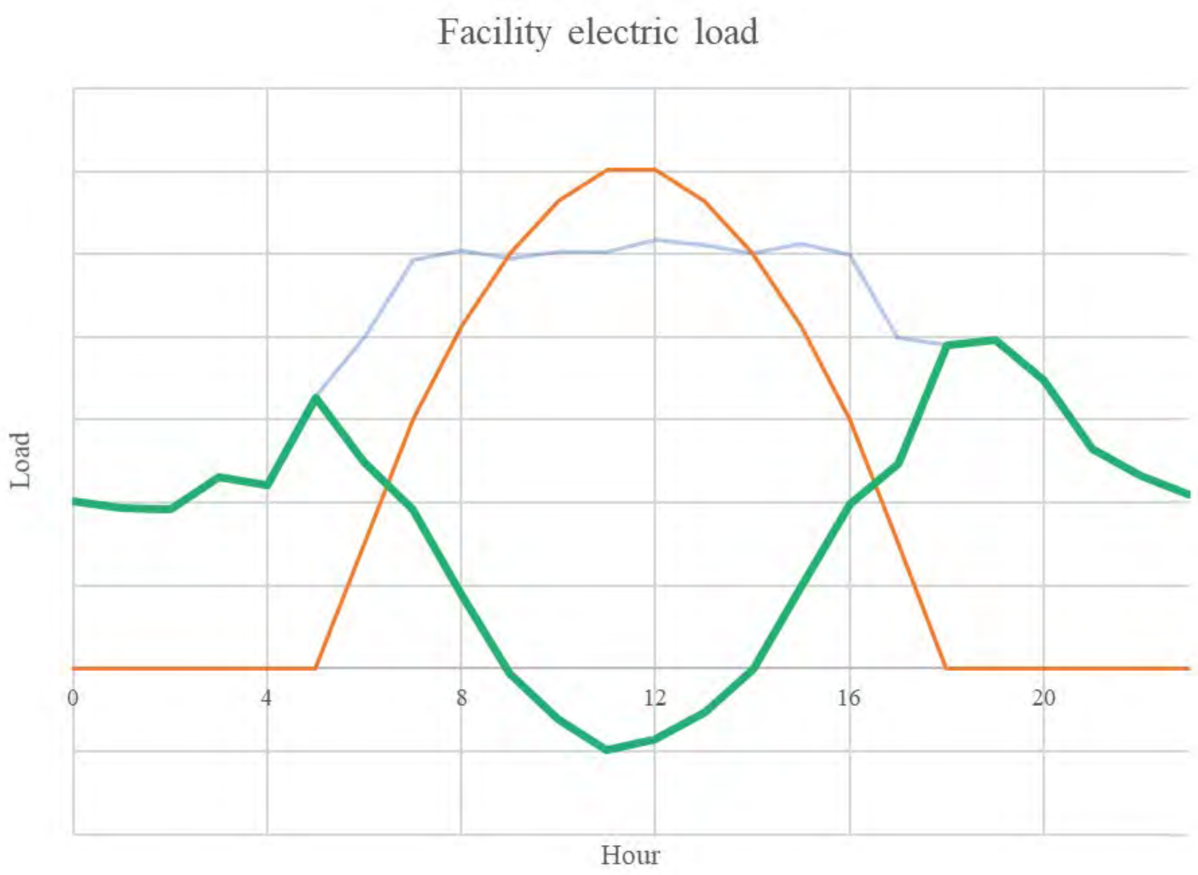
Solar + storage system sizing
Maximize ROI



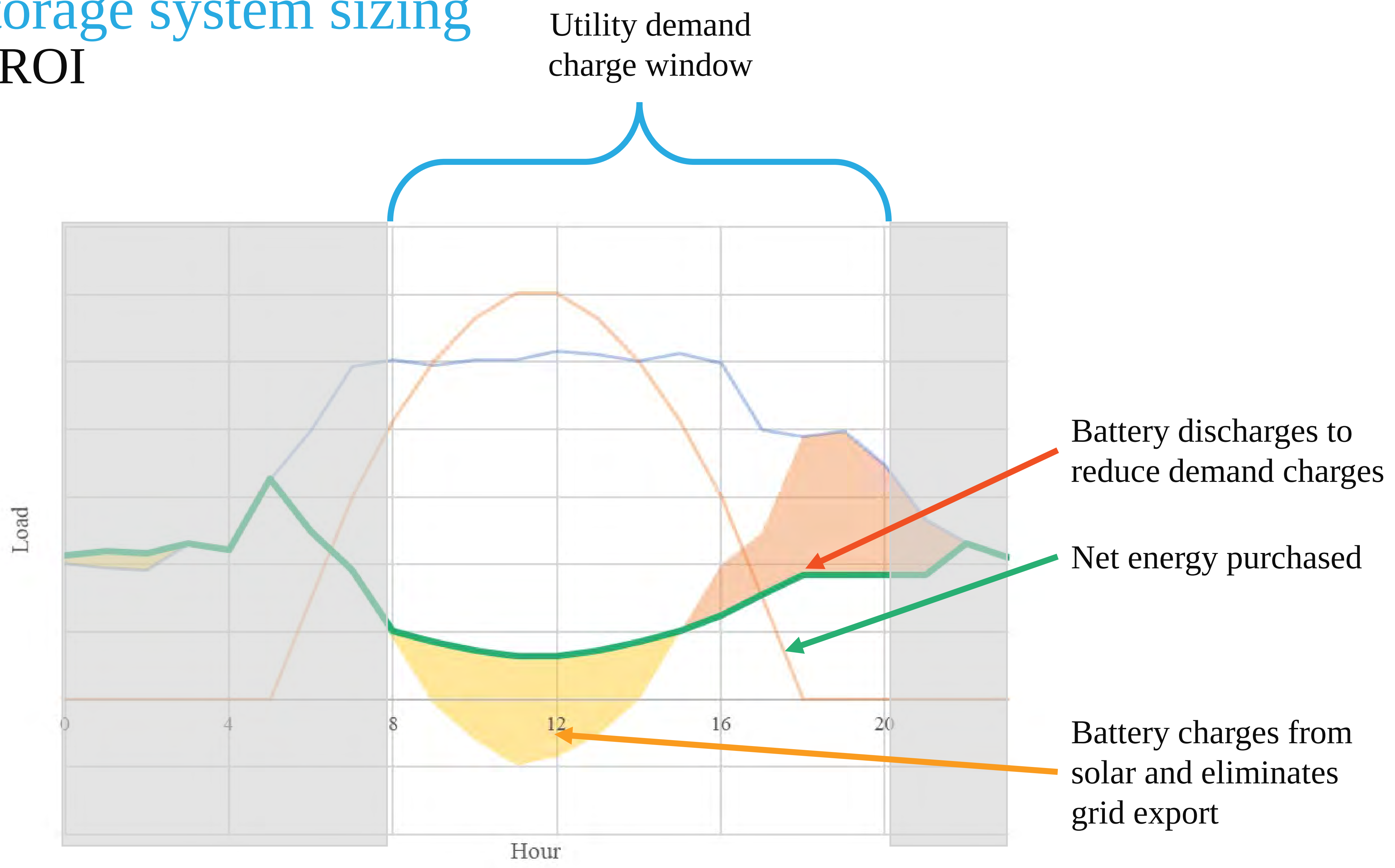
Solar + storage system sizing

Maximize ROI – Batteries allow larger PV system sizes



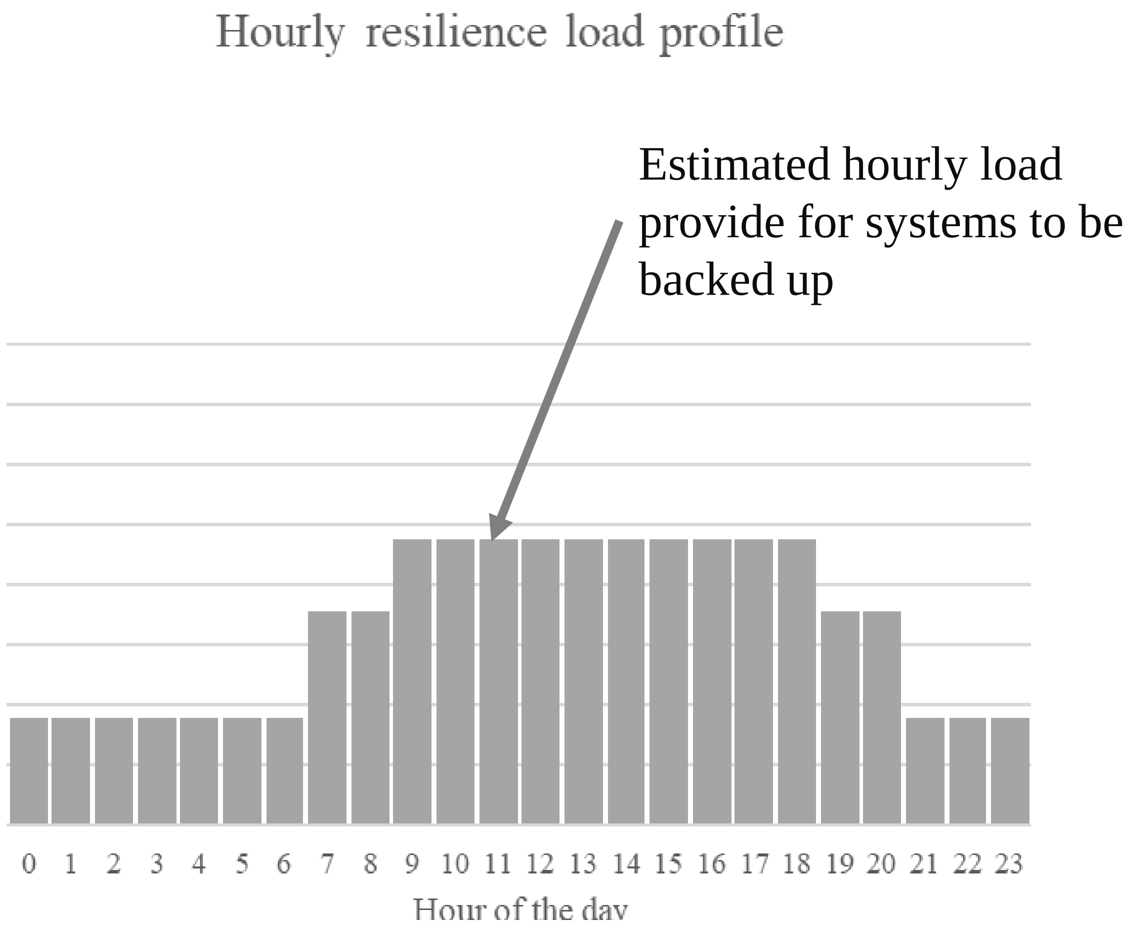


Solar + storage system sizing
Maximize ROI



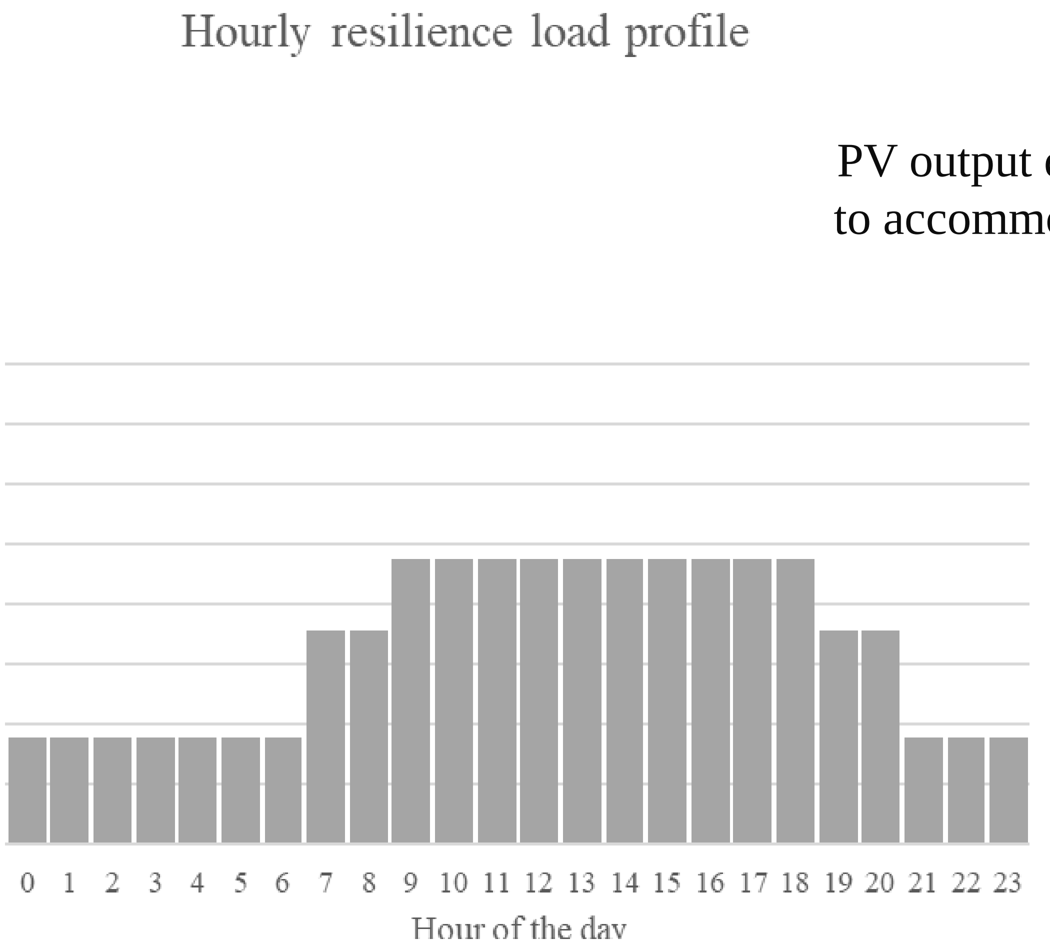
Solar + storage system sizing

Resilience scenario - When utility power is not available

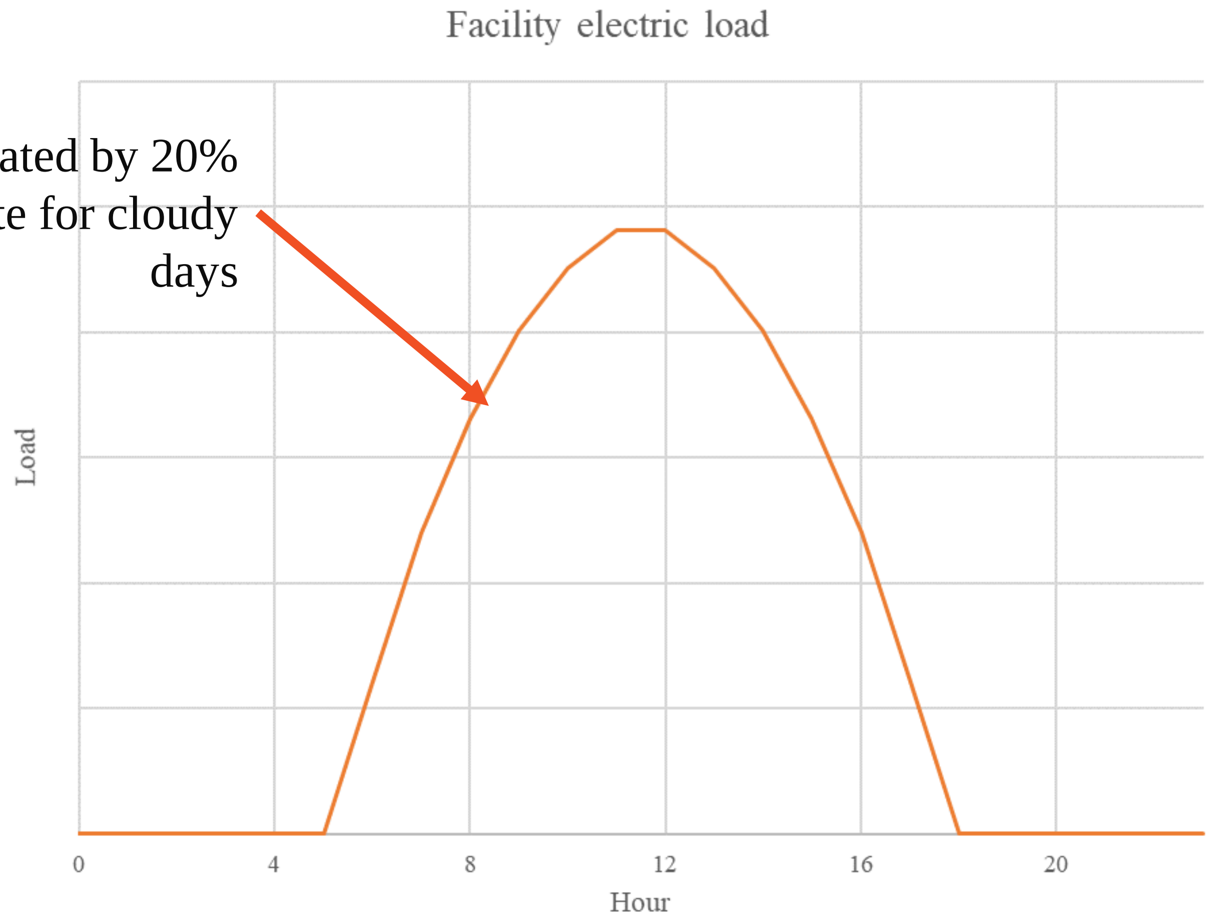


Solar + storage system sizing

Resilience scenario - When utility power is not available

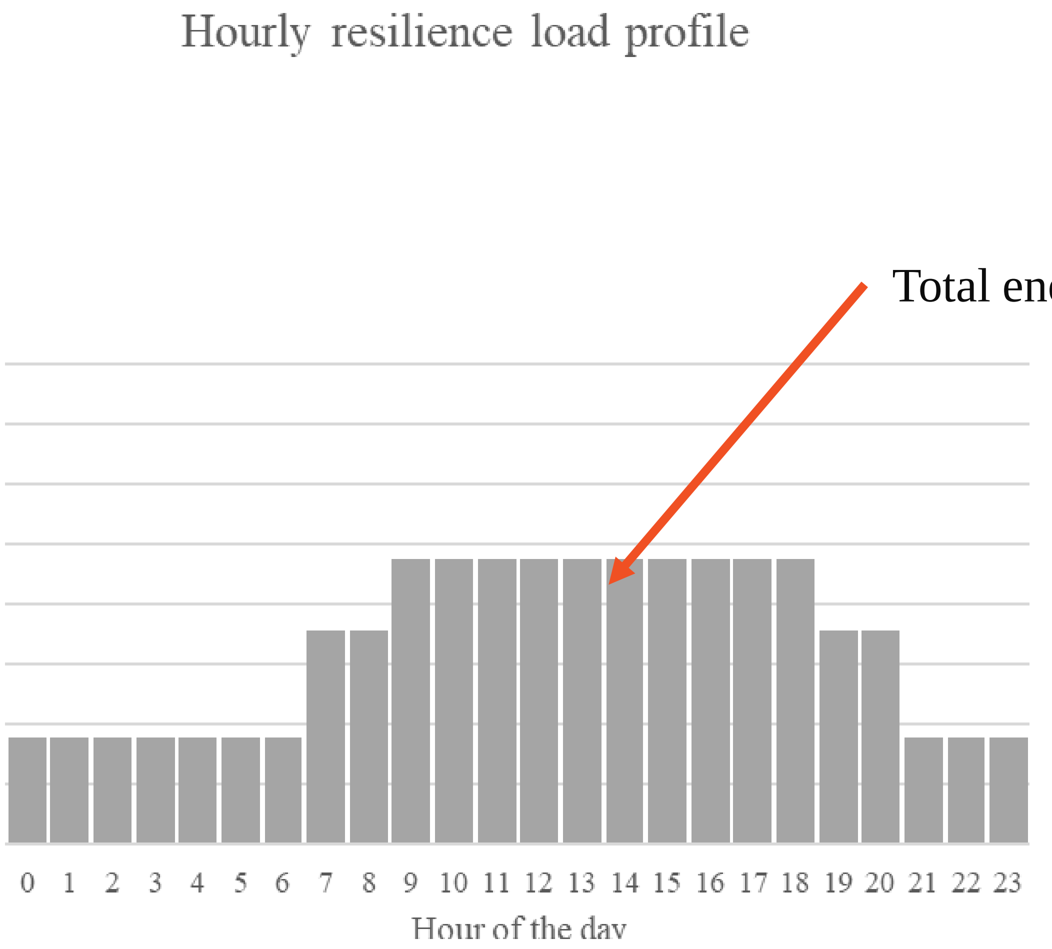


PV output de-rated by 20% to accommodate for cloudy days

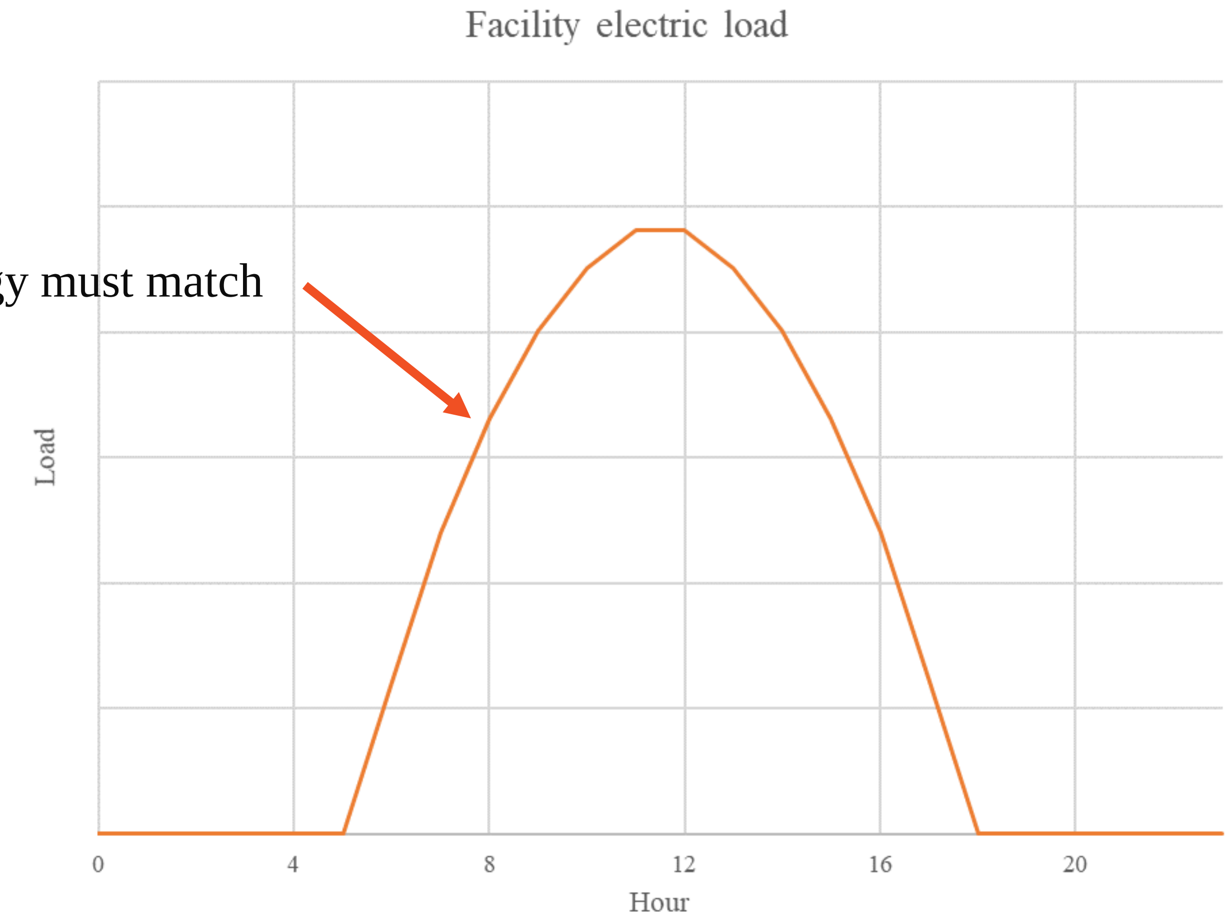


Solar + storage system sizing

Resilience scenario - When utility power is not available

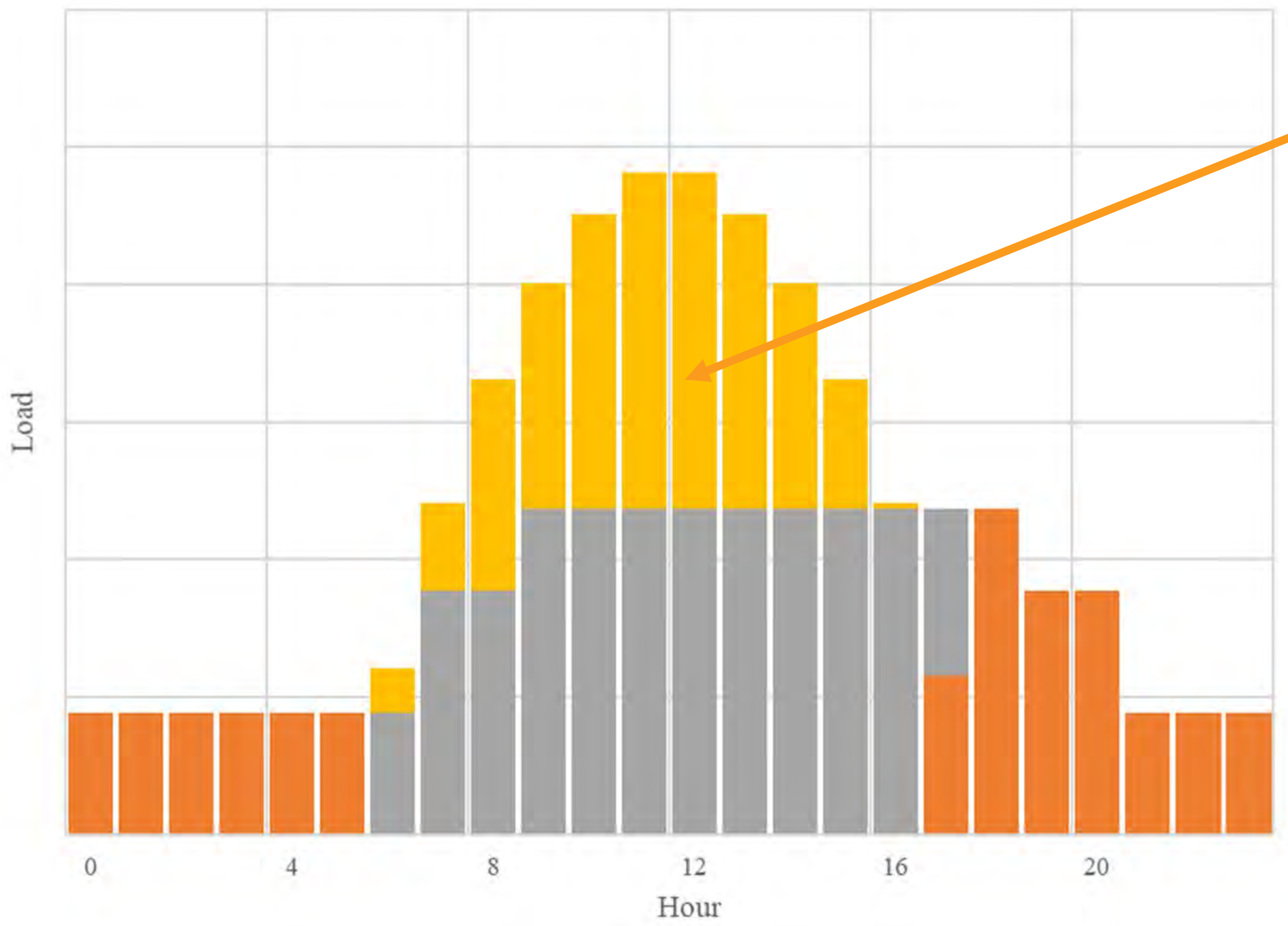


Total energy must match



Solar + storage system sizing

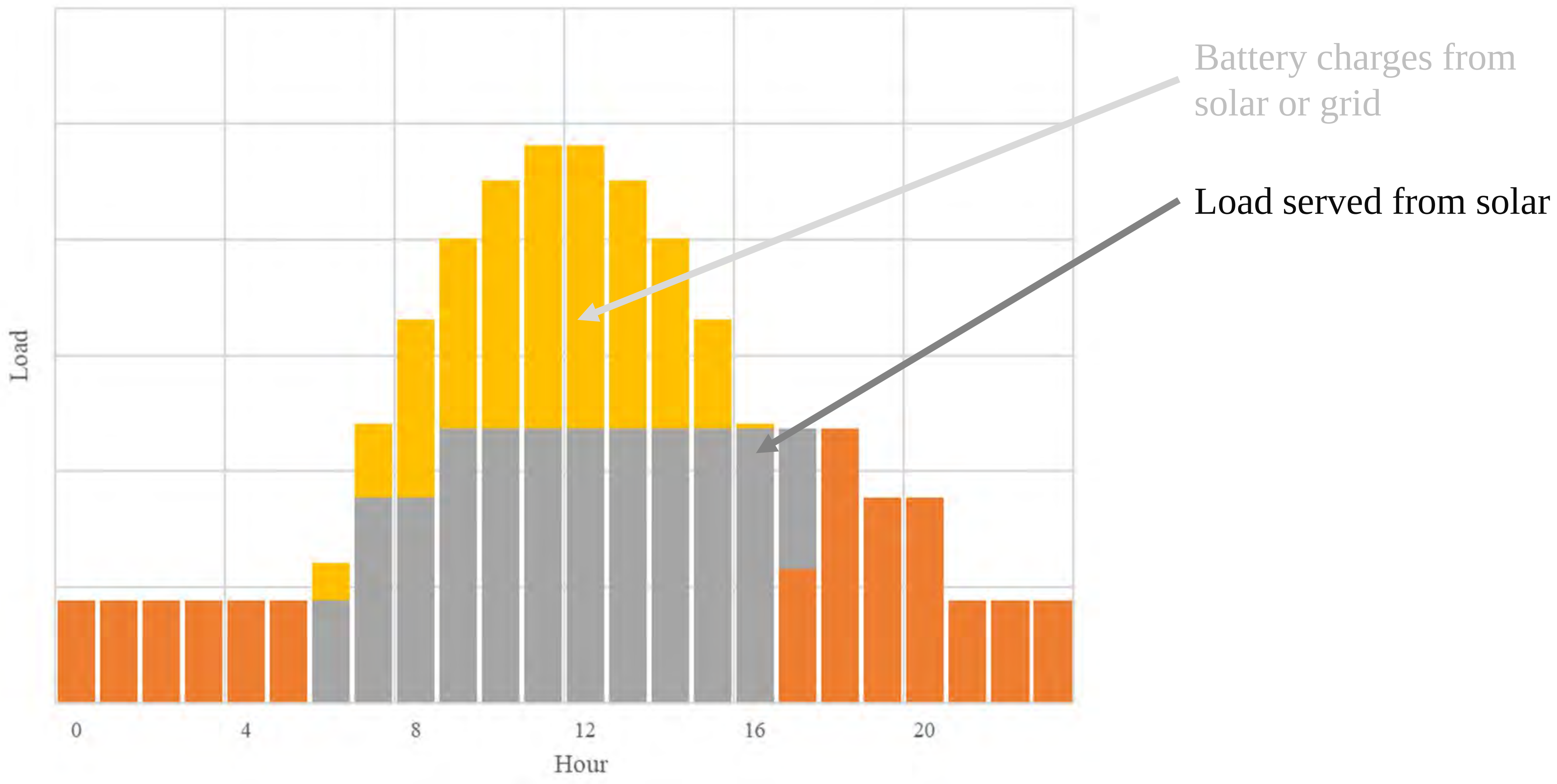
Resilience scenario - When utility power is not available



Battery charges from solar

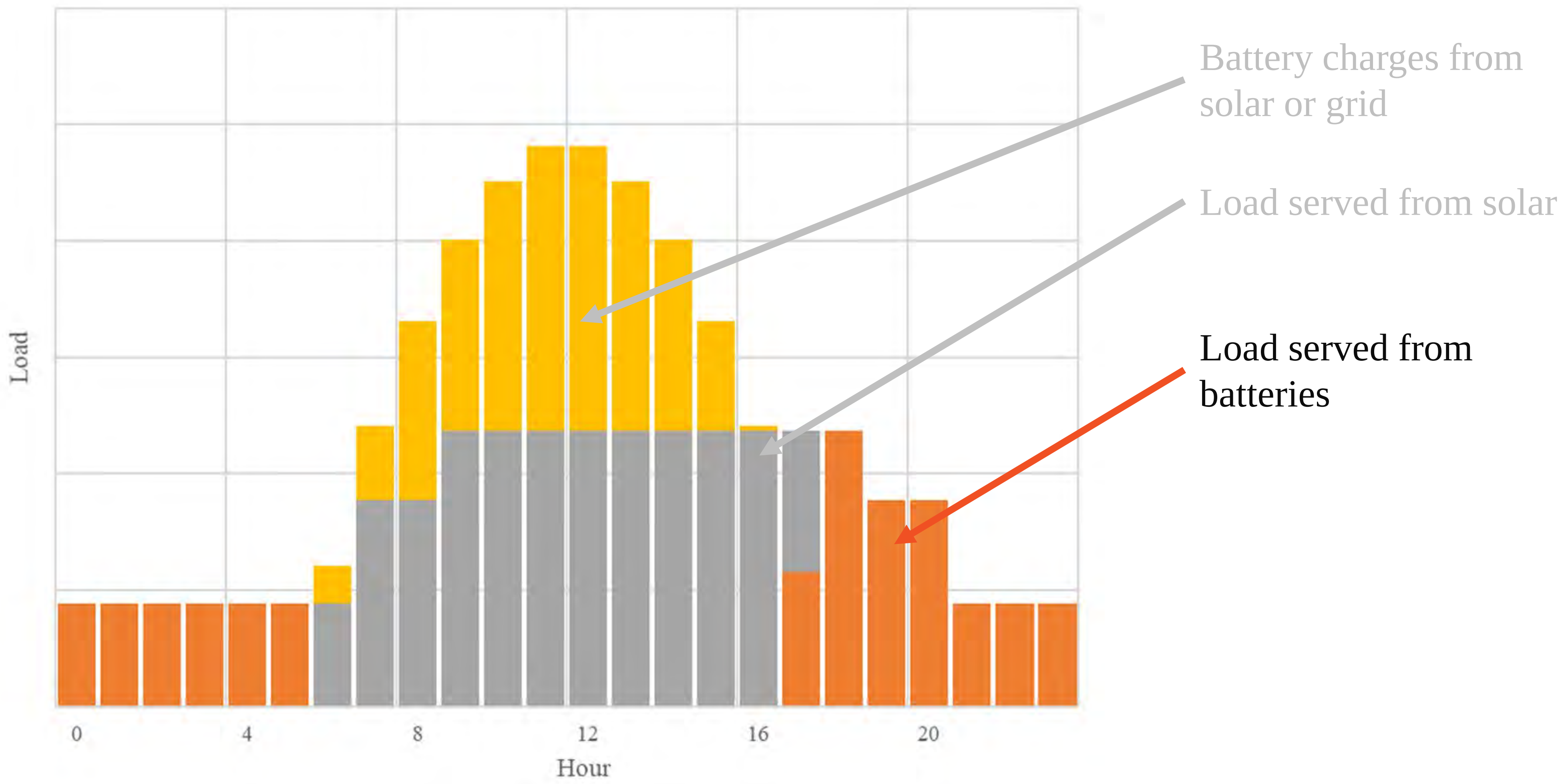
Solar + storage system sizing

Resilience scenario - When utility power is not available



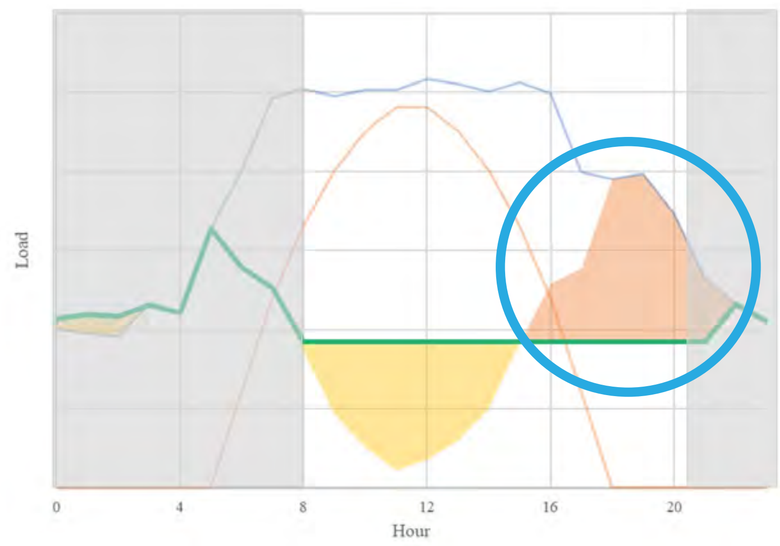
Solar + storage system sizing

Resilience scenario - When utility power is not available

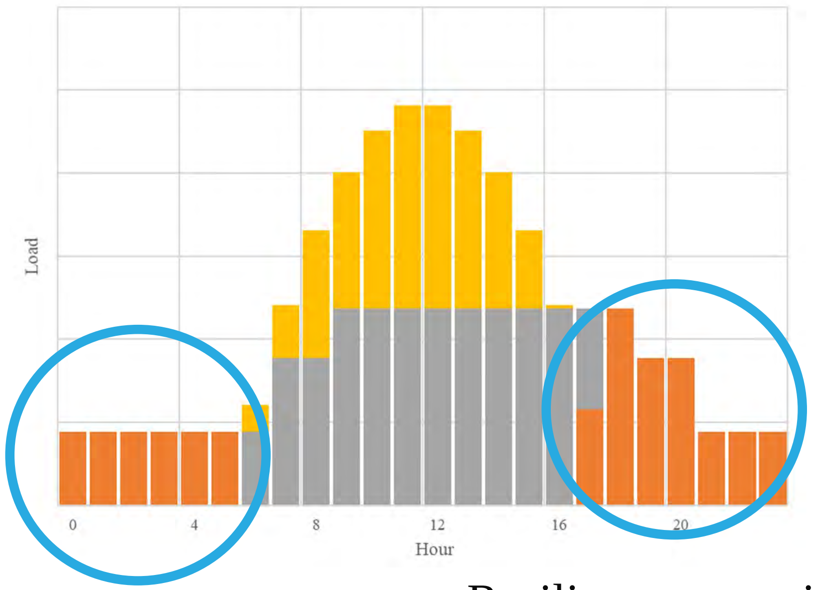


Solar + storage system sizing
Challenge

If energy required for resilience is higher than that required to maximize ROI, system will not fully monetize installed battery capacity



Maximize ROI

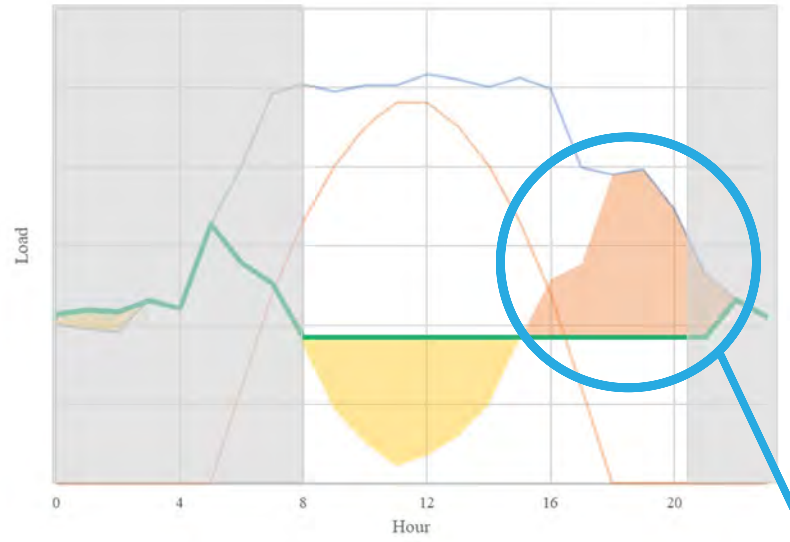


Resilience scenario

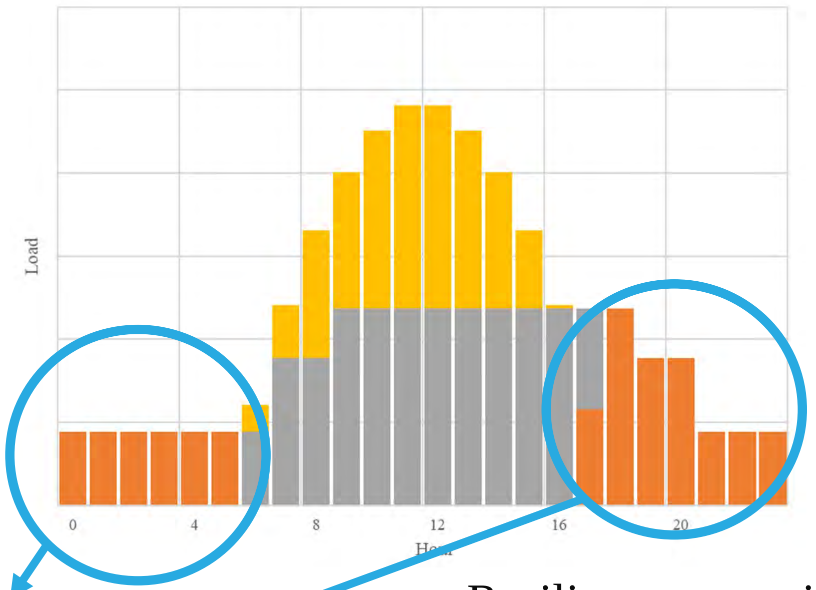
Solar + storage system sizing

Challenge

If energy required for resilience is higher than that required to maximize ROI, system will not fully monetize installed battery capacity



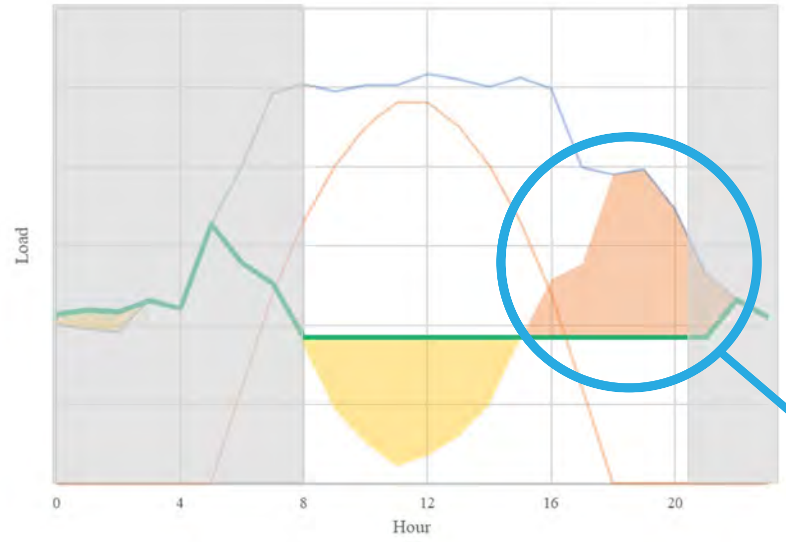
Maximize ROI



Resilience scenario

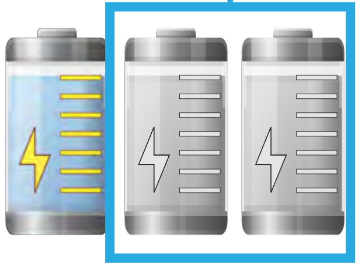
Solar + storage system sizing
Challenge

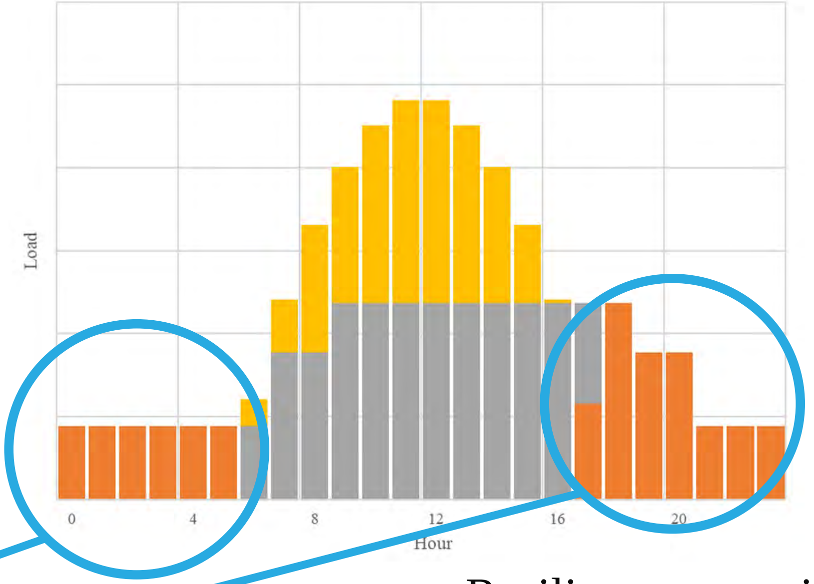
If energy required for resilience is higher than that required to maximize ROI, system will not fully monetize installed battery capacity



Maximize ROI

Batteries do not generate revenue





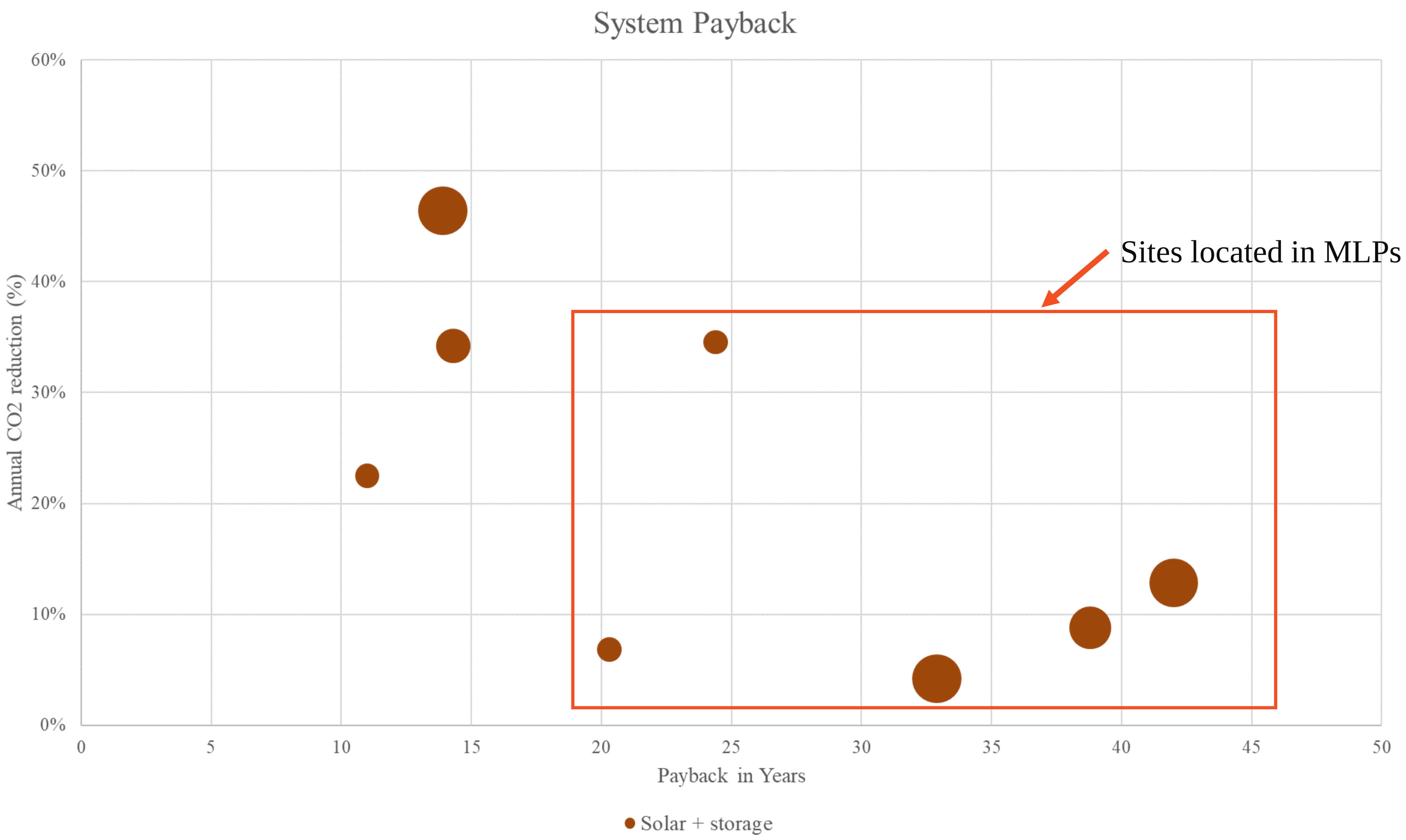
Resilience scenario

Solar + storage

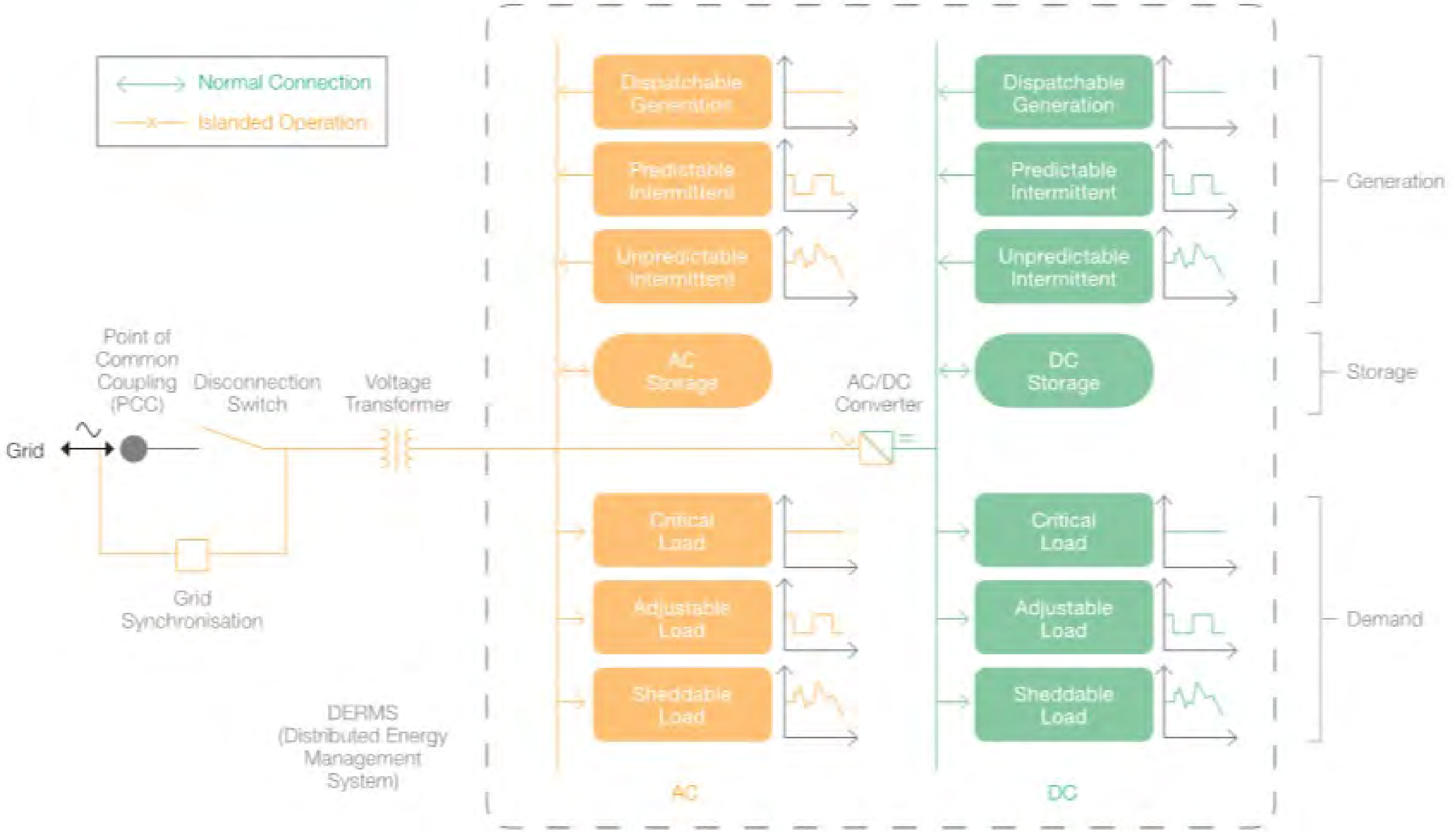
Optimal system operation

- Electrical load is high enough that a cost-effective solar system can be installed
- Resultant peak demand is of short enough duration that a cost-effective energy storage solution can be installed
- High energy costs which can be offset by onsite energy generation
- Resilience need is less than optimal storage system size, or resilience load can be biased towards daylight hours

Solar + storage payback results



Microgrid example

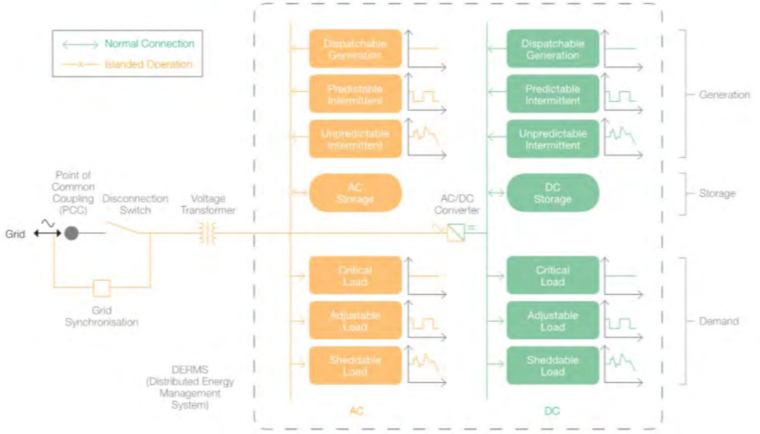


Microgrids

Basics:
- No common definition of a microgrid
- Typically have several distributed energy resources and can run isolated (islanded) from utility power

Use case:
- Used when combining several distributed generation assets
- Typically deployed on campus projects, however some of the smaller projects with several resources can be considered microgrids

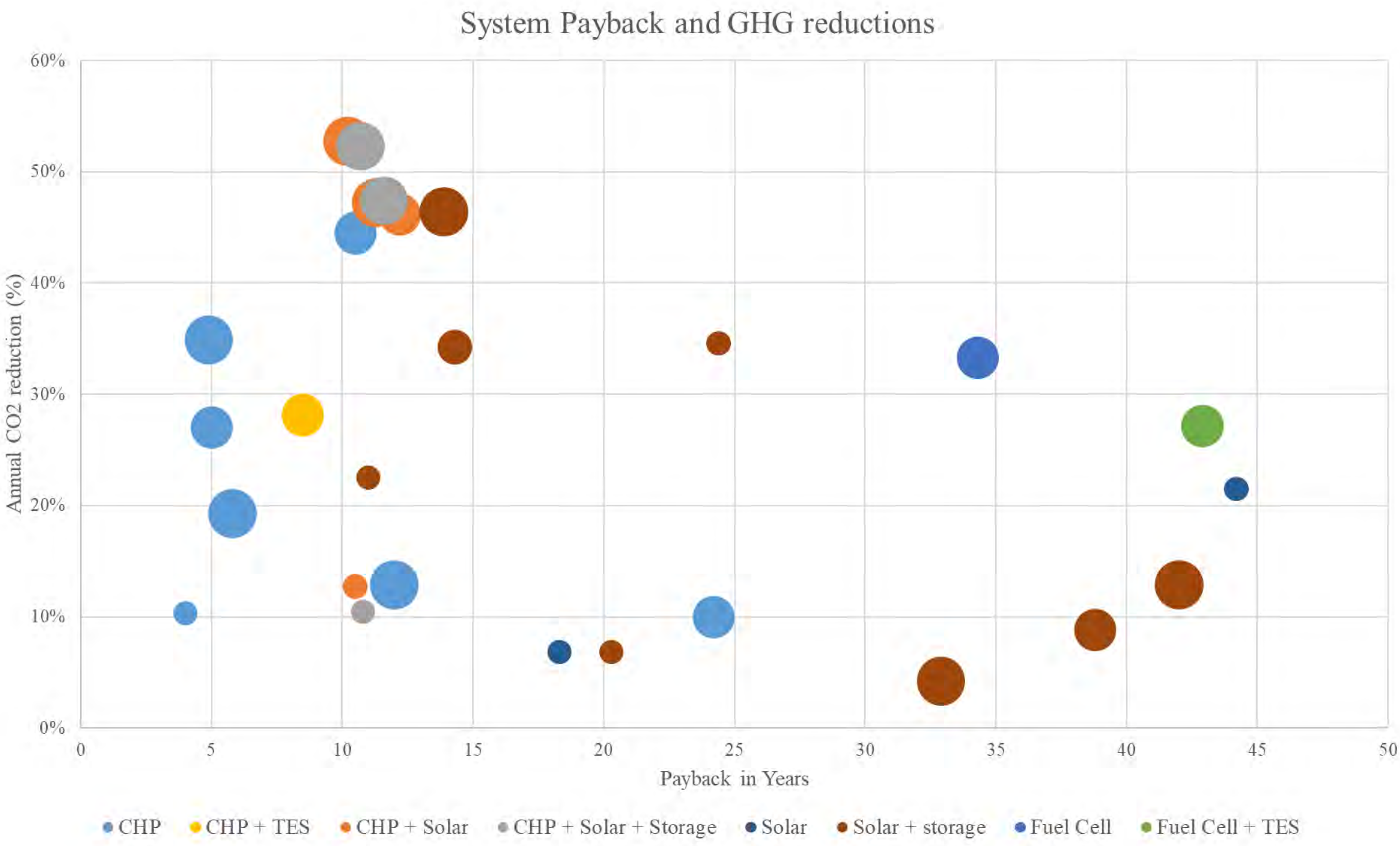
Challenge:
- Does not provide an ROI by itself but can increase resilience and reduce reliance on human operators



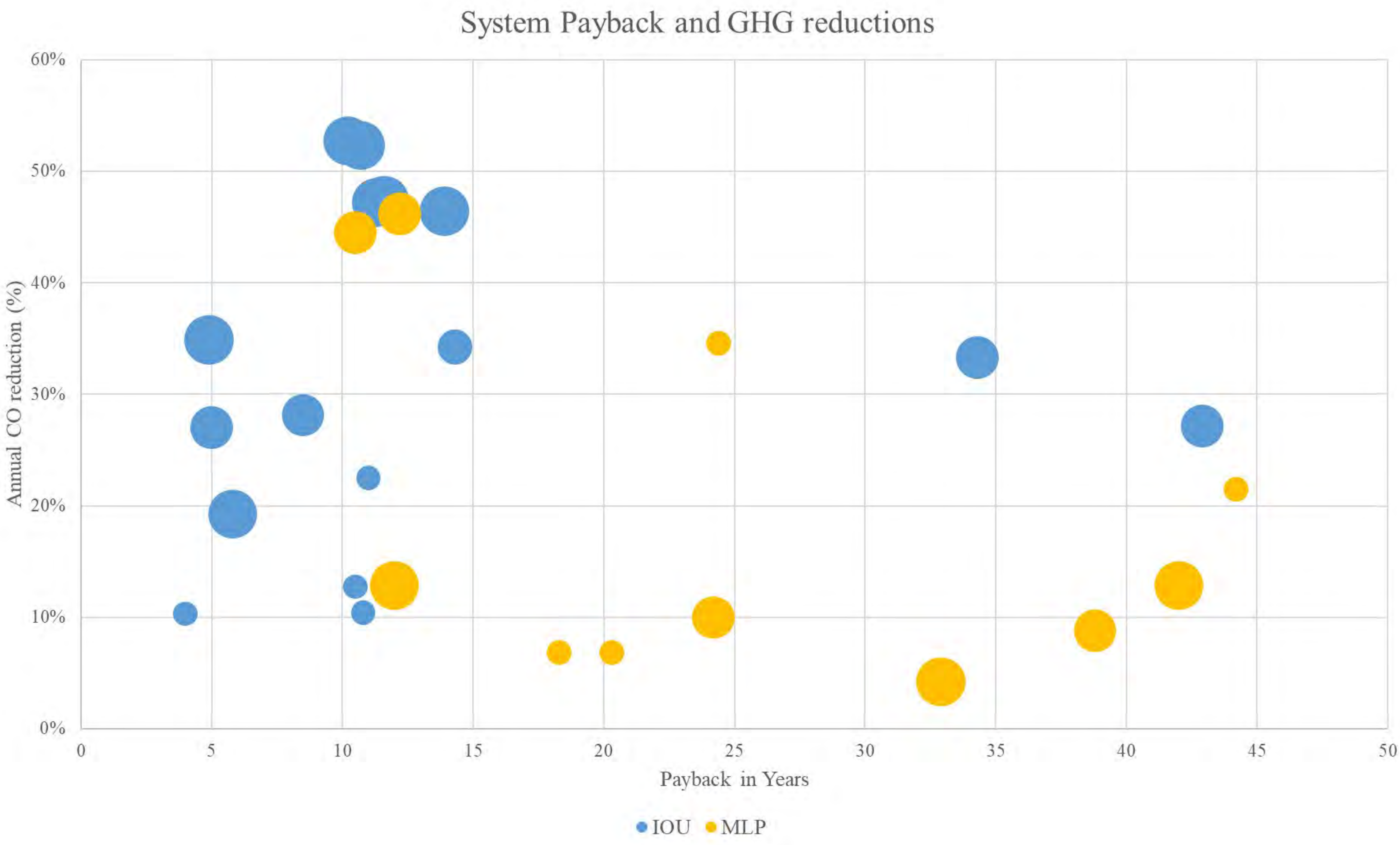
Results

	Utility	CHP	CHP + TES	CHP + PV	CHP + PV + BES	PV	PV + BESS	Fuel Cell	Fuel Cell + TES	Wind	uG
Site 1	IOU	✓	✓					✓	✓		
Site 2	MLP	✓					✓				
Site 3	IOU	✓		✓	✓		✓				
Site 4	IOU	✓		✓	✓		✓				✓
Site 5a	MLP						✓				
Site 5b	IOU						✓				
Site 6	MLP	✓					✓				
Site 7	MLP					✓	✓				
Site 8	IOU	✓		✓	✓		✓				
Site 9	MLP	✓				✓	✓			✓	
Site 10	MLP	✓		✓			✓				✓
Site 11	IOU										✓

	Utility	CHP	CHP + TES	CHP + PV	CHP + PV + BES	PV	PV + BESS	Fuel Cell	Fuel Cell + TES	Wind	uG
Site 1	IOU	✓	✓ (grey)					✓ (grey)	✓ (grey)		
Site 2	MLP	✓ (grey)					✓ (grey)				
Site 3	IOU	✓		✓	✓		✓				
Site 4	IOU	✓		✓	✓		✓				✓
Site 5a	MLP						✓ (grey)				
Site 5b	IOU						✓ (grey)				
Site 6	MLP	✓					✓ (grey)				
Site 7	MLP					✓ (grey)	✓ (grey)				
Site 8	IOU	✓		✓	✓		✓				
Site 9	MLP	✓ (grey)				✓ (grey)	✓ (grey)			✓ (grey)	
Site 10	MLP	✓		✓			✓ (grey)				✓
Site 11	IOU										✓



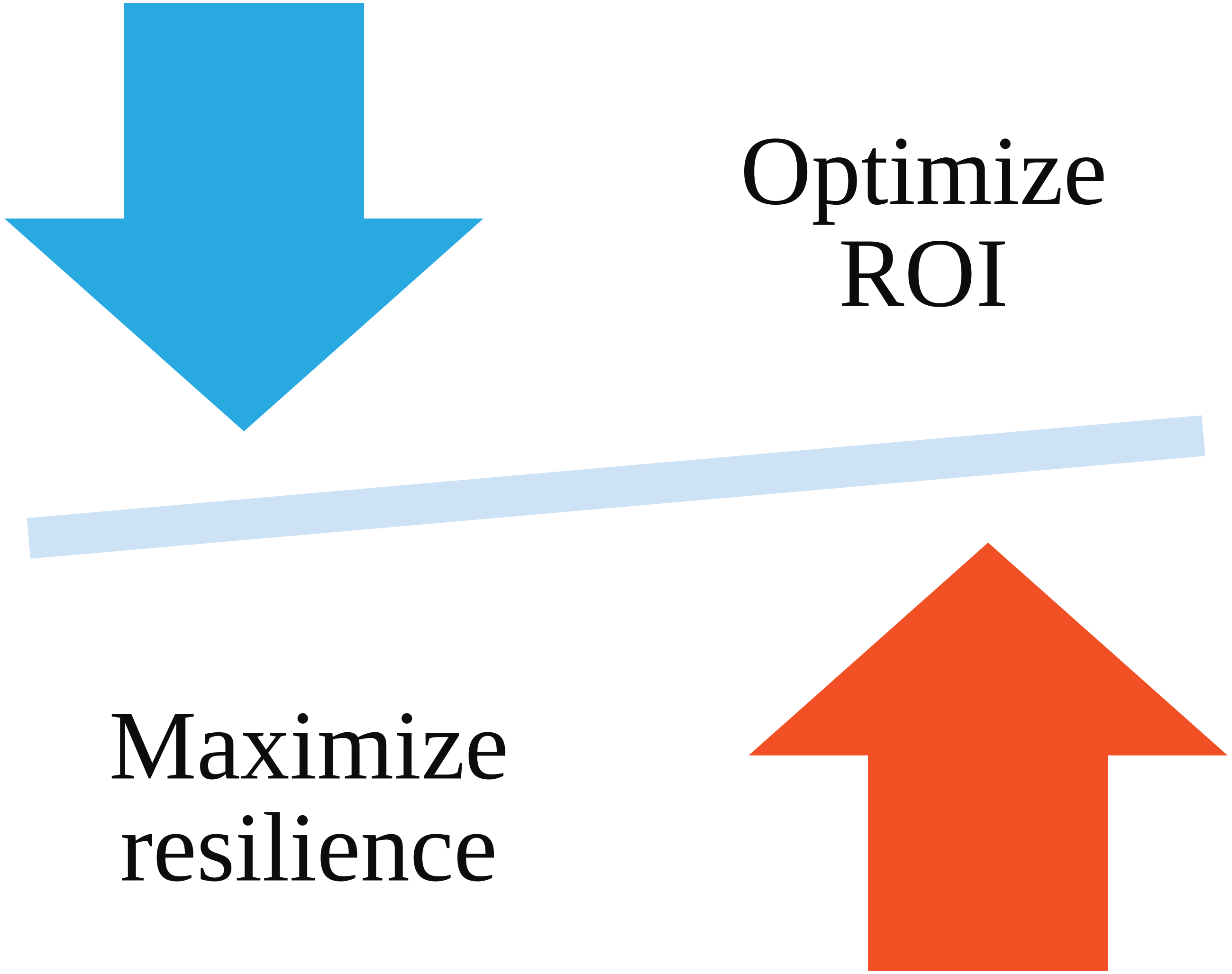
System Payback and GHG reductions
Annual CO2 reduction (%)
60%
50%
40%
30%
20%
10%
0%
0
5
10
15
20
25
30
35
40
45
50
Payback in Years
CHP
CHP + TES
CHP + Solar
CHP + Solar + Storage
Solar
Solar + storage
Fuel Cell
Fuel Cell + TES


System Payback and GHG reductions
Annual CO reduction (%)
60%
50%
40%
30%
20%
10%
0%
0
5
10
15
20
25
30
35
40
45
50
Payback in Years
IOU
MLP

Top-down, bottom-up

Size system to maximize revenue and then determine resilience benefit which can be provided

Need to balance revenue operations with resilience needs



Lessons learned & keys for success

Understanding your existing buildings and operations

Understanding how overall and individual energy systems work is critical to the development of strategies that can complement business-as-usual operations and enhance resiliency

Accurate facility data

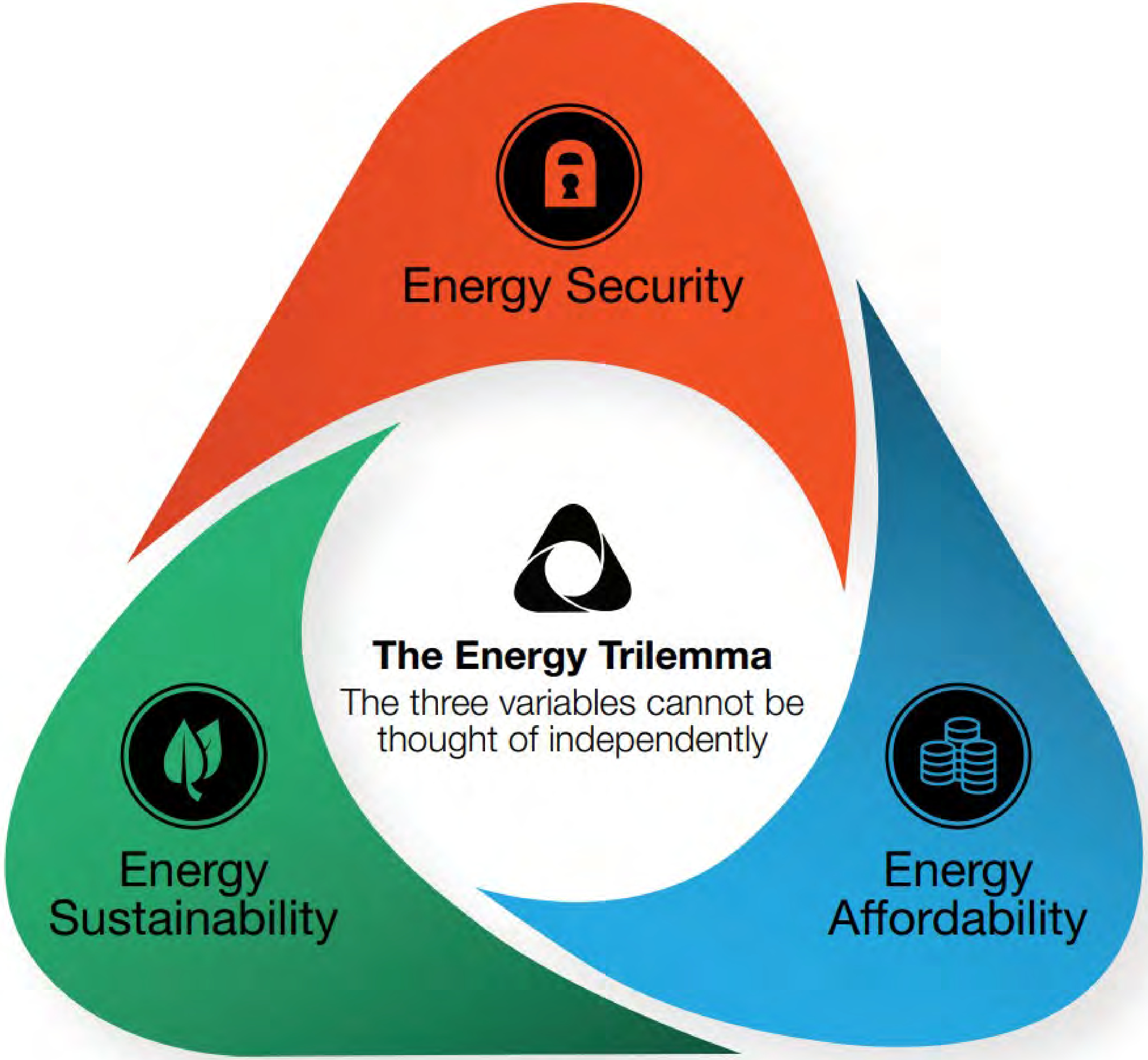
The better the data, the more accurate and potentially viable the solution

Recognize the pros and cons of a volatile market

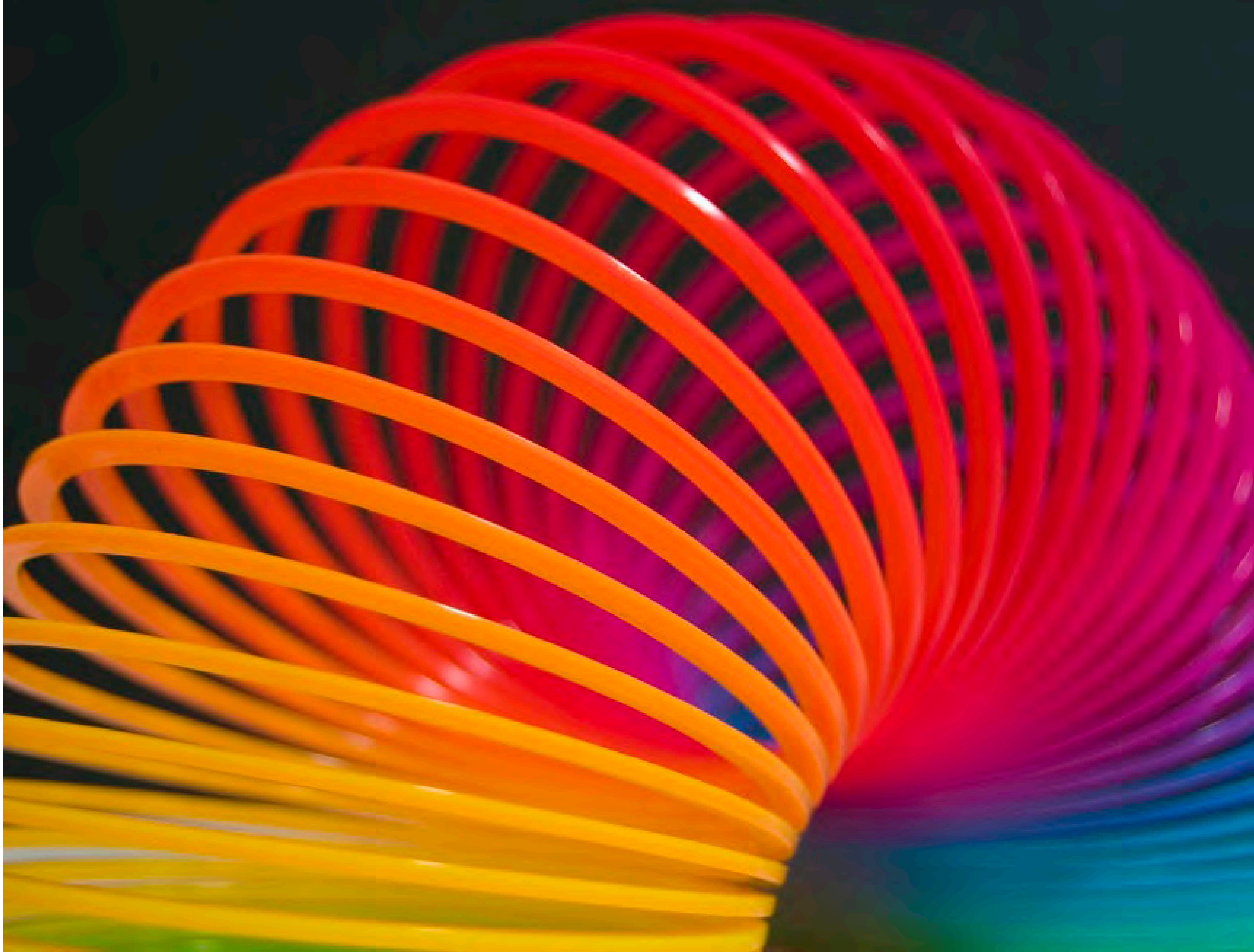
Project economics is a moving targets given changing technology costs and changing incentives

Identify priorities

Successful strategies will vary depending on how you prioritize your objectives



Be flexible



Some resiliency is better than none

Resiliency can address a range of challenges leading to multiple strategies

Next Steps