UC DAVIS
FACILITIES MANAGEMENT

Solar Thermal Optimization for District Hot Water through Energy Modeling

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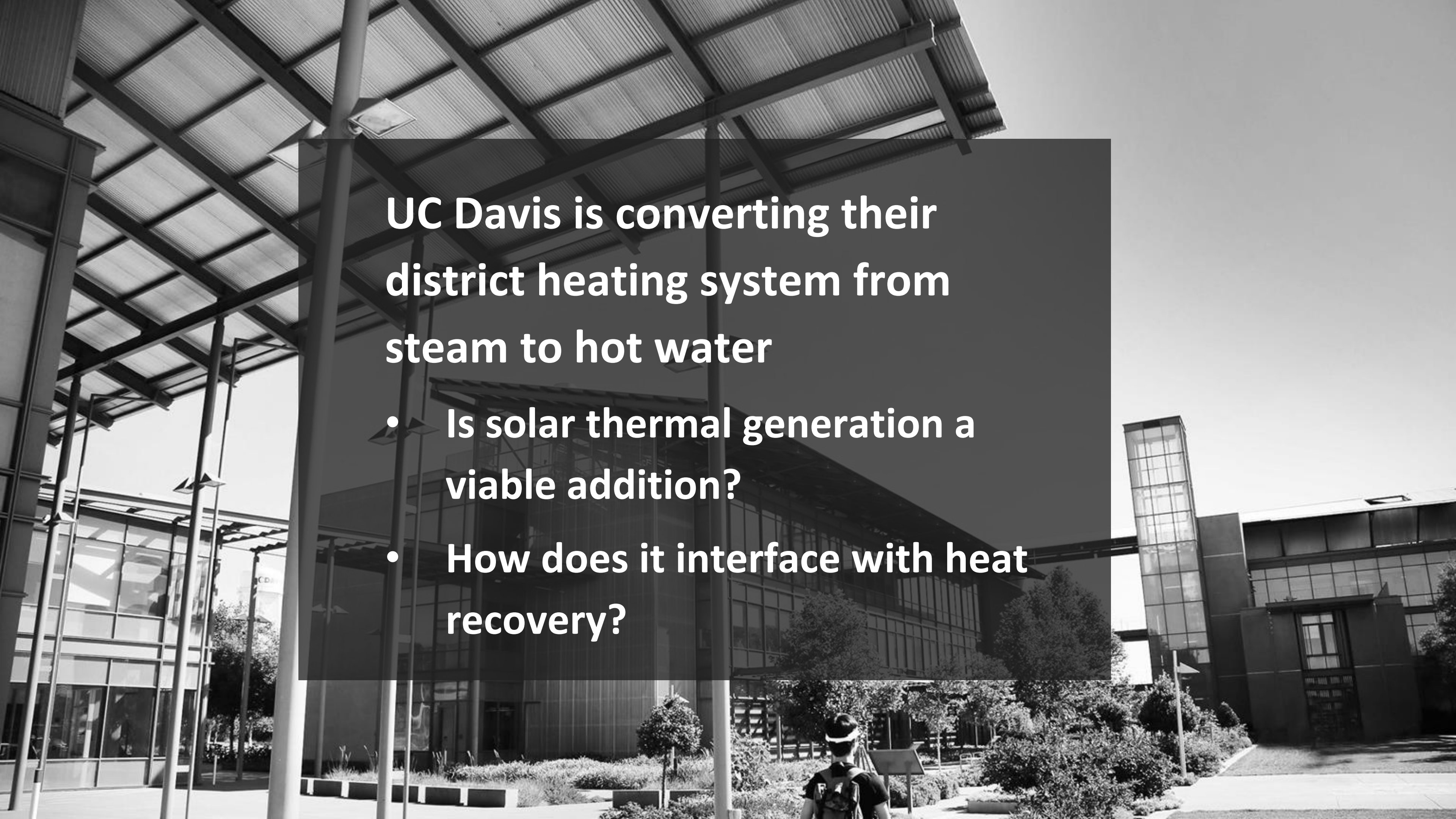
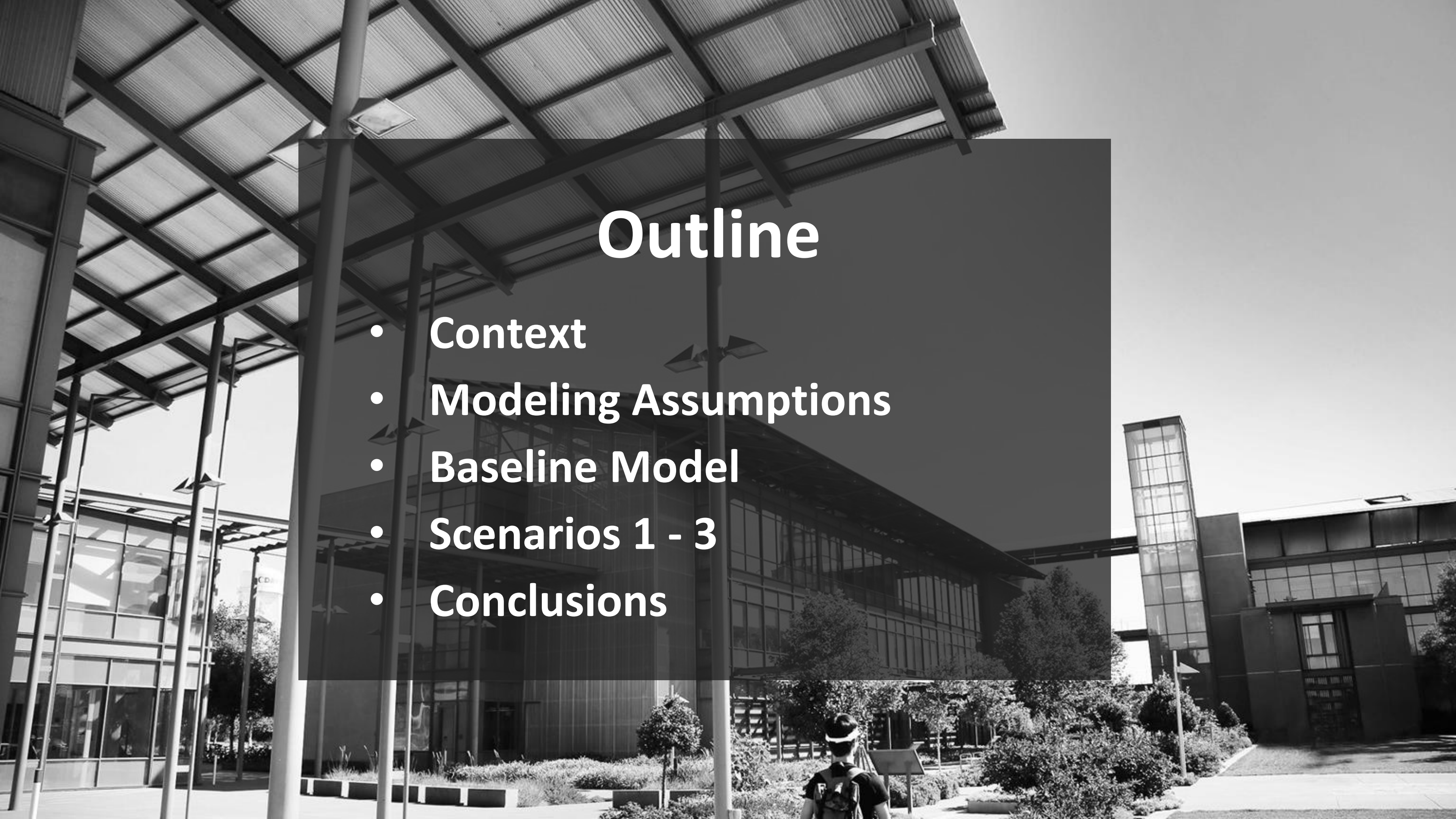
energy conservation office



UC Davis is converting their district heating system from steam to hot water

- Is solar thermal generation a viable addition?
- How does it interface with heat recovery?



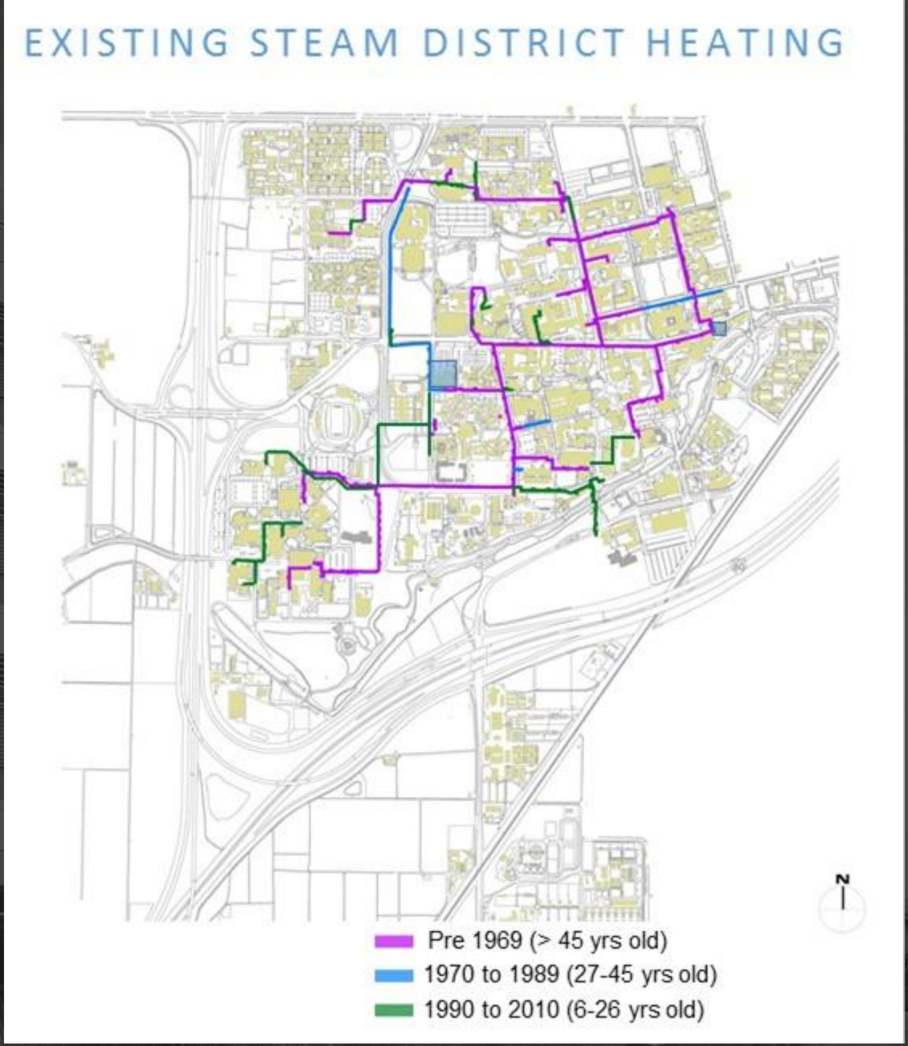
Outline

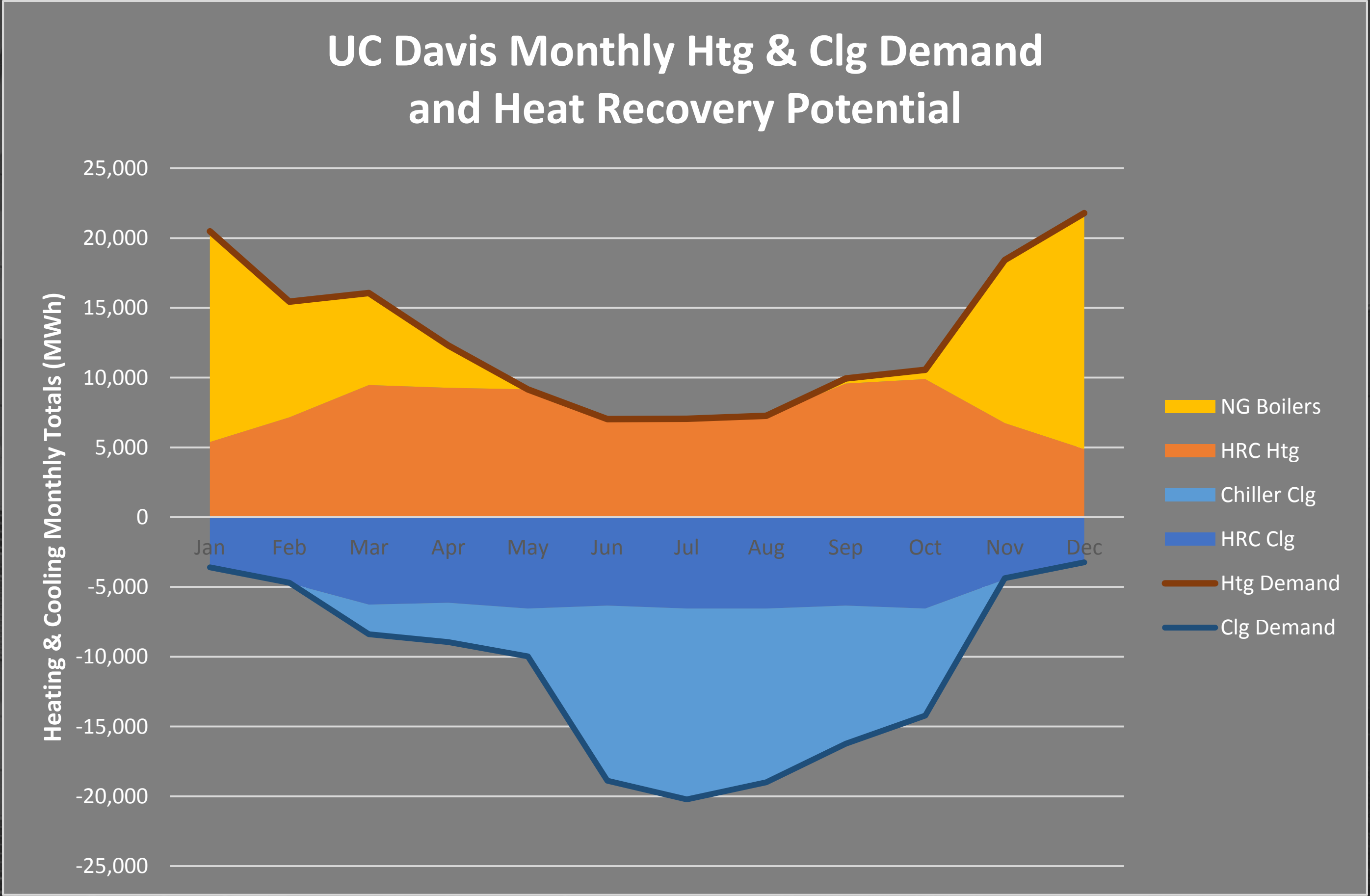
- Context
- Modeling Assumptions
- Baseline Model
- Scenarios 1 - 3
- Conclusions

Context

Aging steam DH system

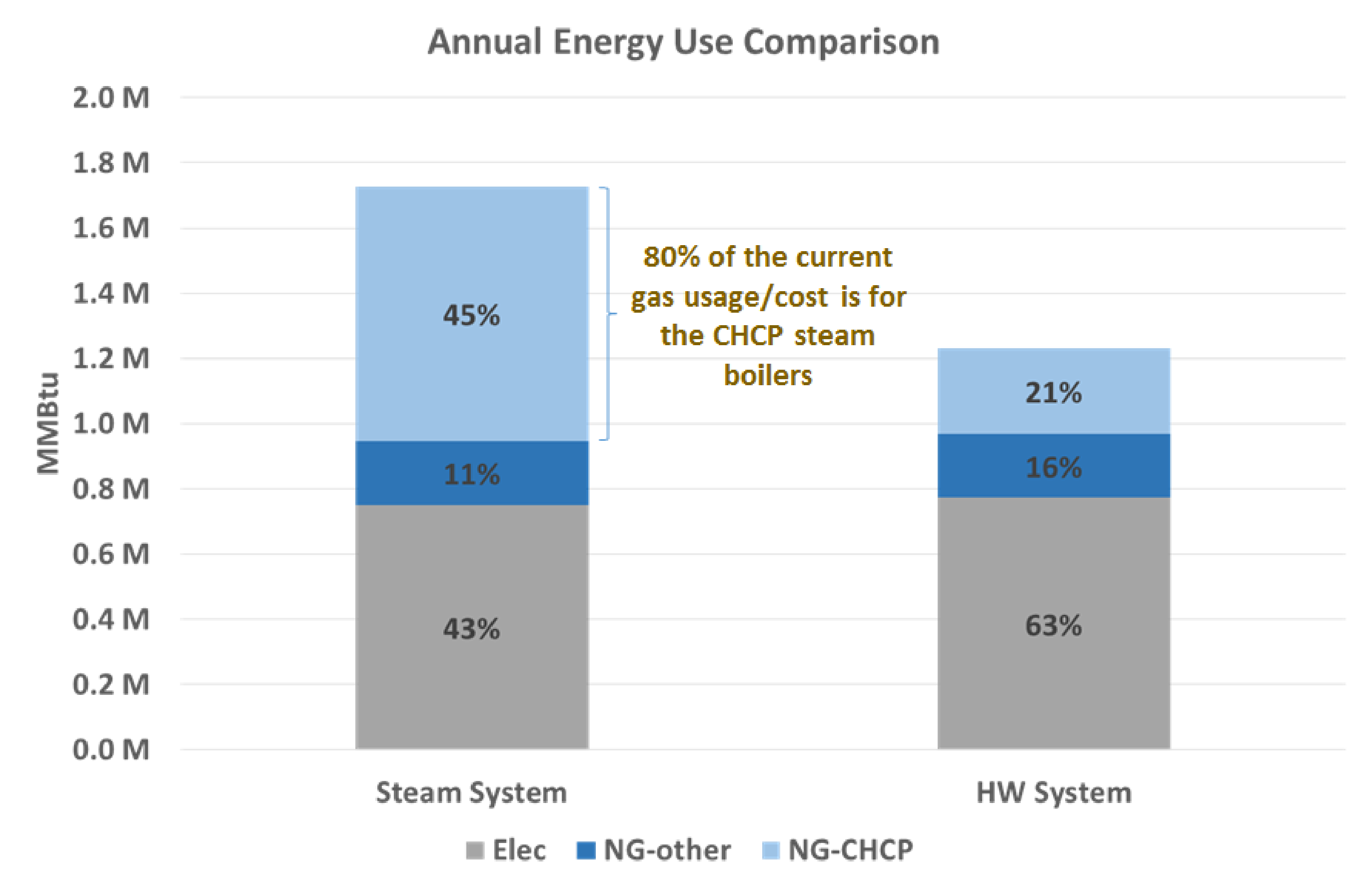
- Boiler capacity issue
- Piping & insulation failures
- Building leaks
- Cost of maintenance
- 30-50% distribution losses





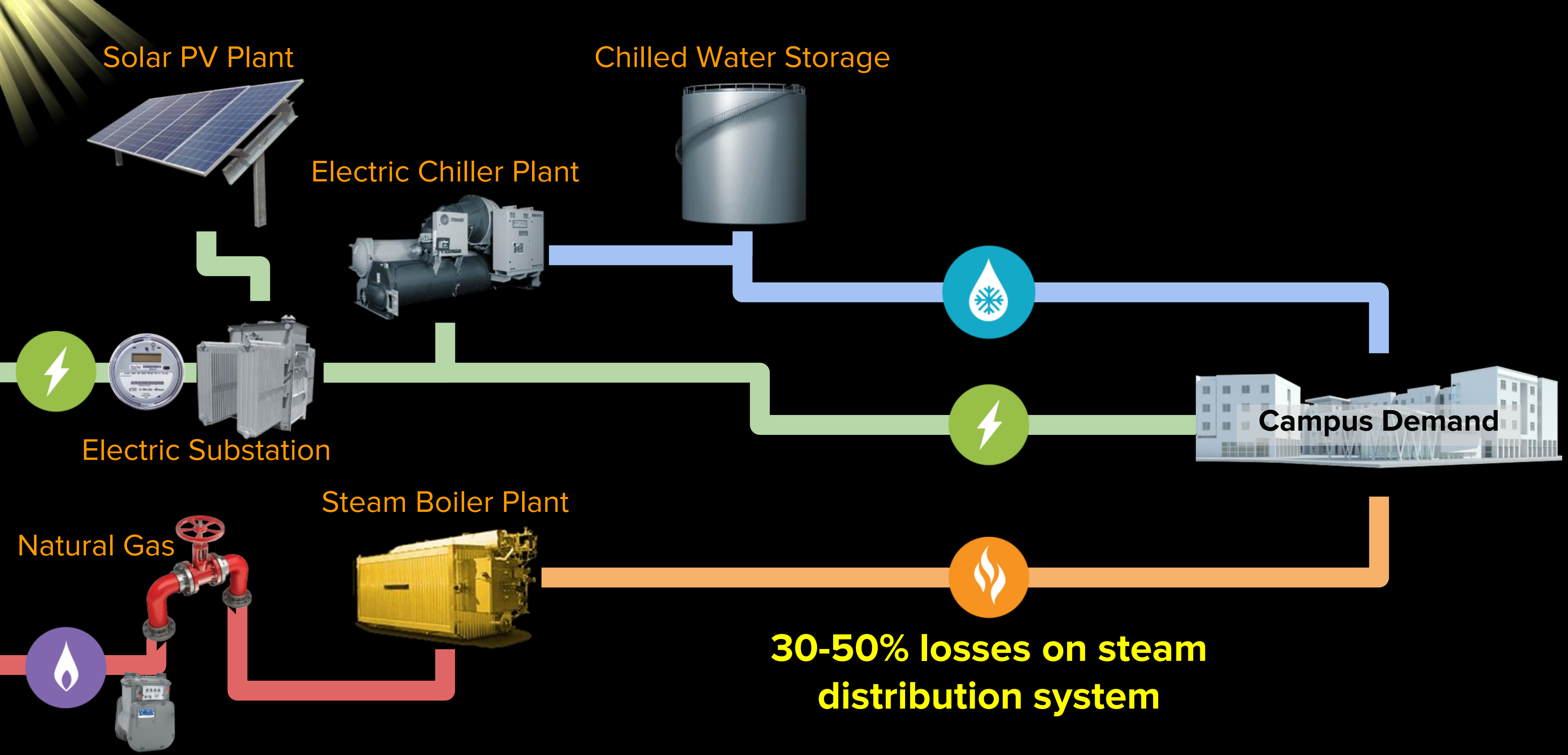
Context

Opportunity for Heat Recovery

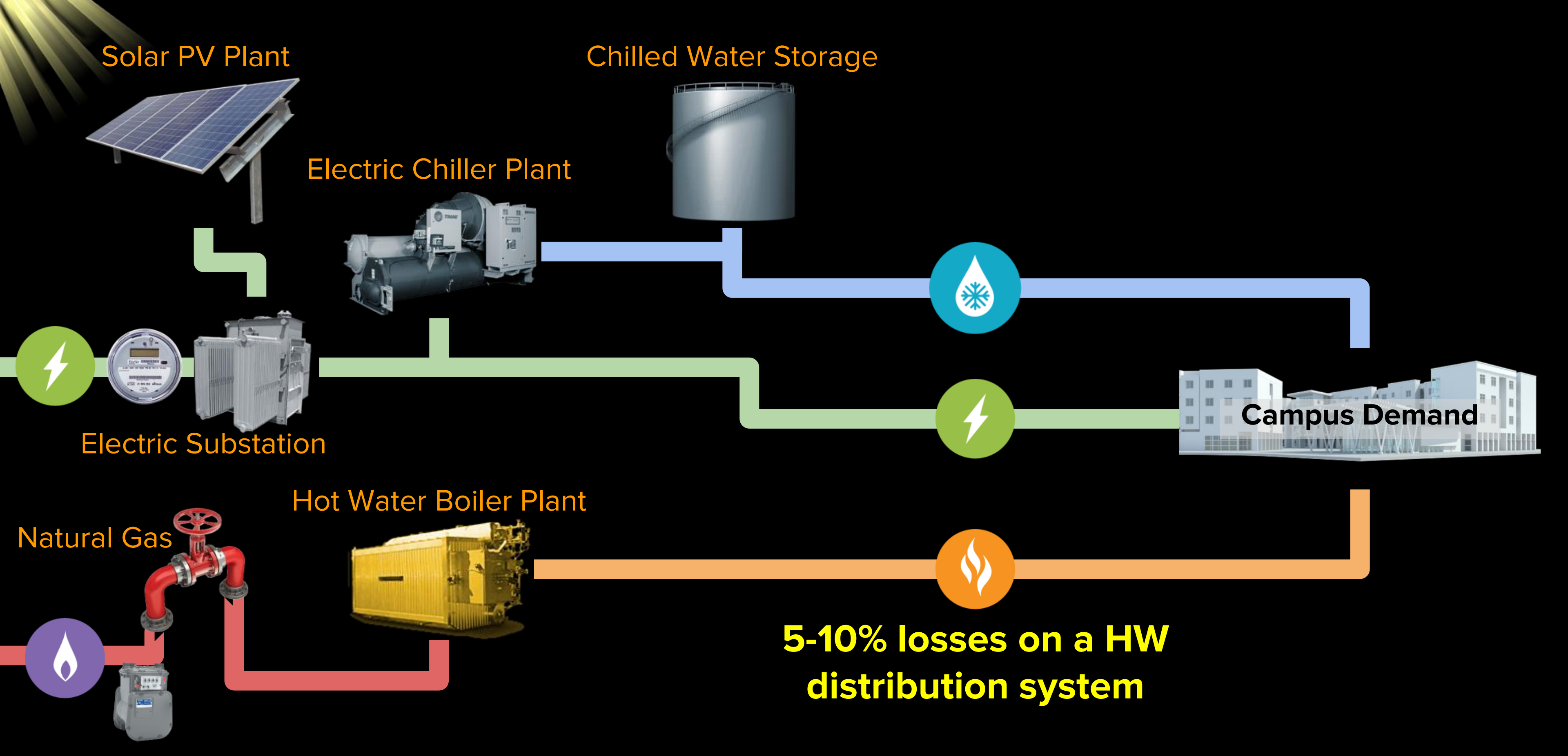


Context

Carbon Neutral by 2025

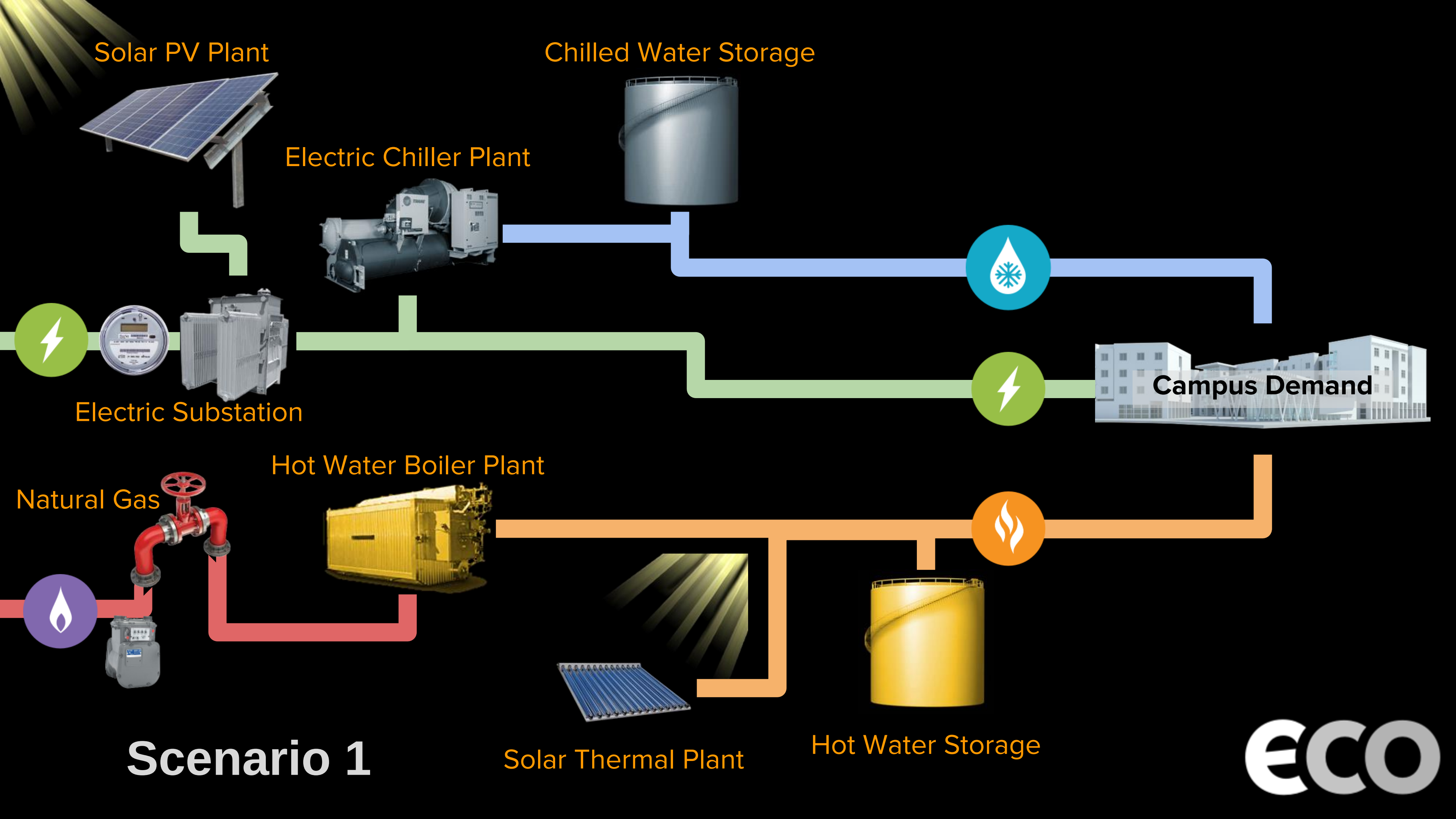


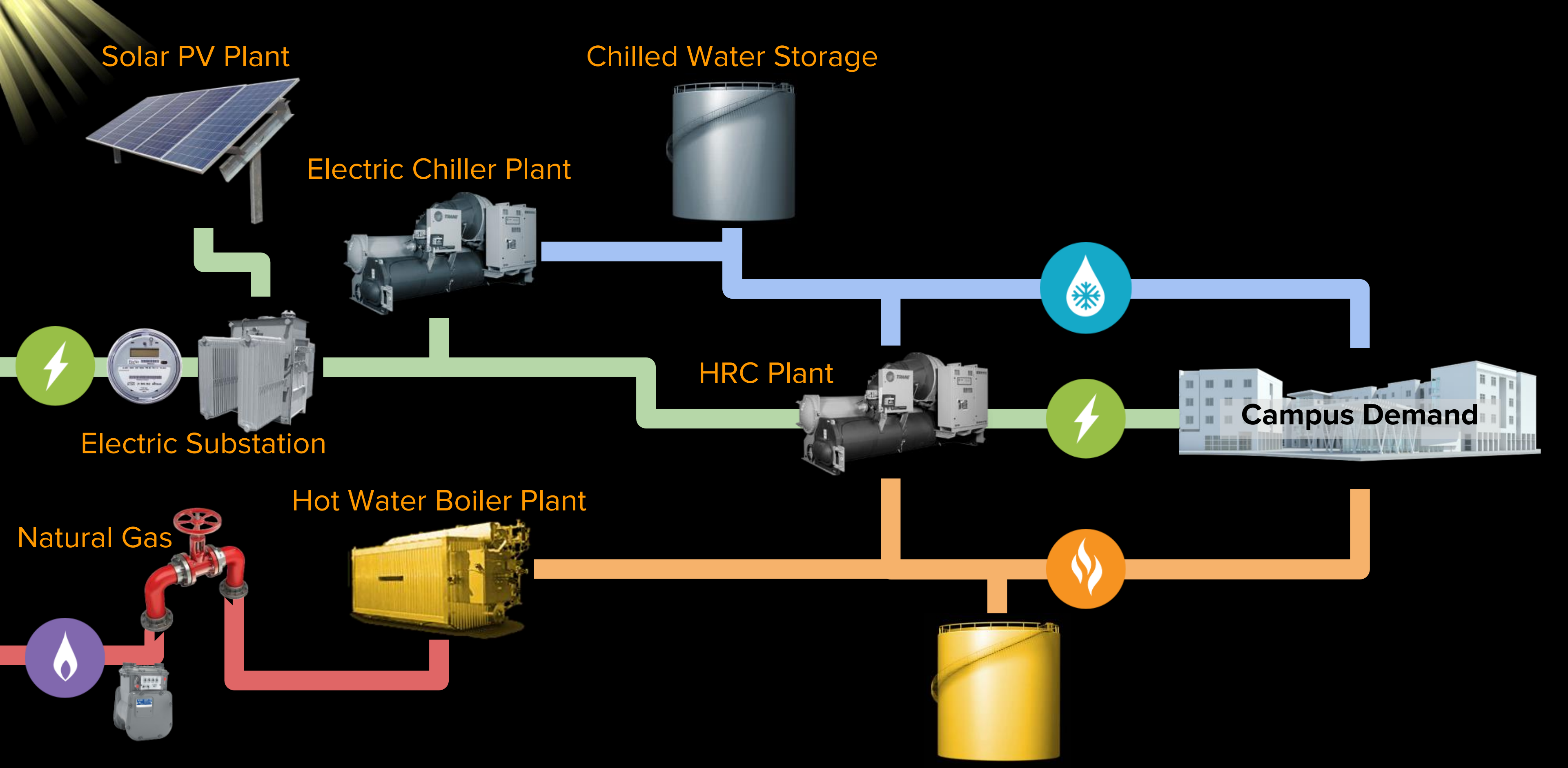
Current Campus Systems



Baseline model (HW district heating)

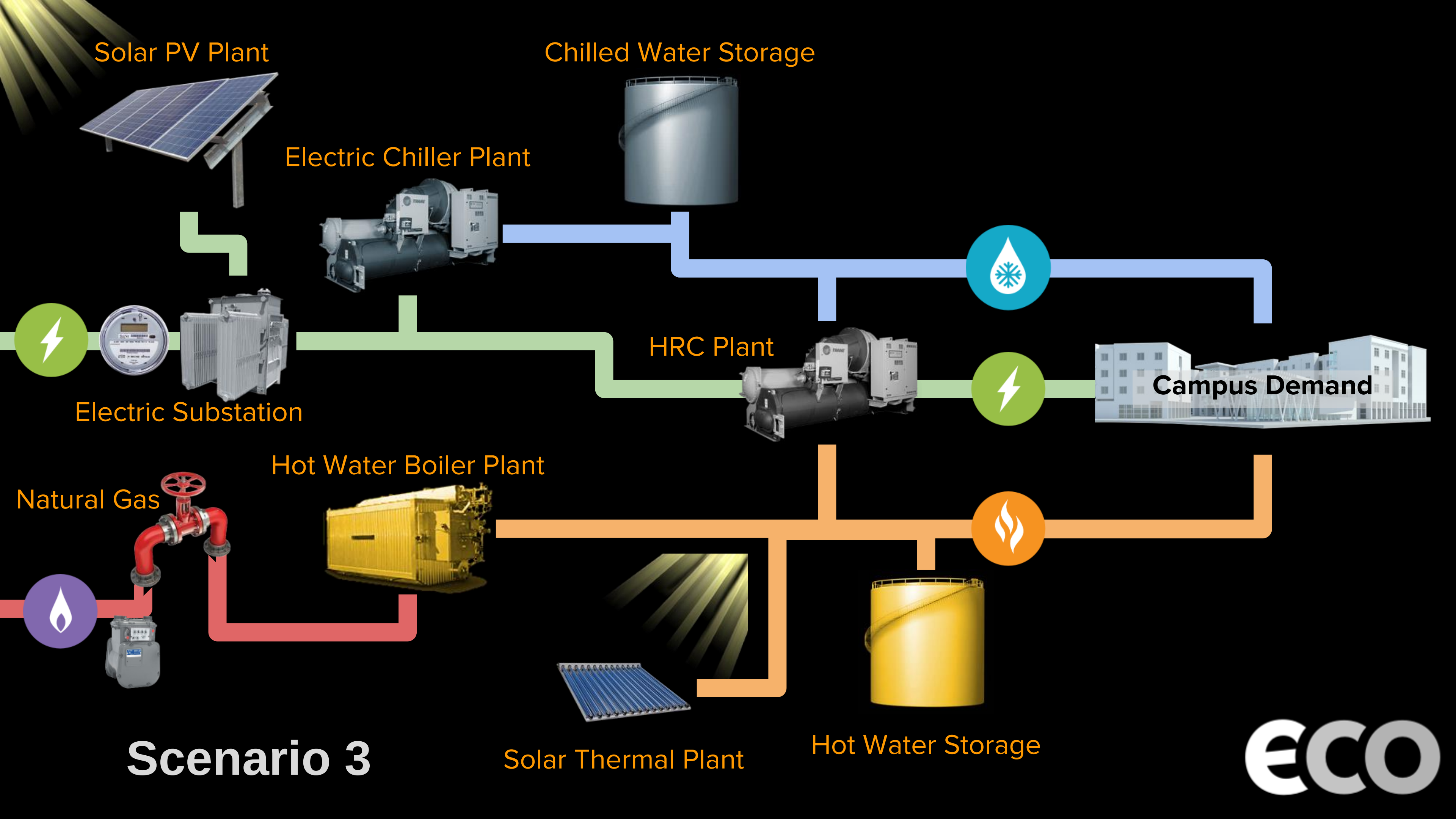
ECO


Solar PV Plant
Chilled Water Storage
Electric Chiller Plant
Electric Substation
Campus Demand
Hot Water Boiler Plant
Natural Gas
Solar Thermal Plant
Hot Water Storage
Scenario 1
ECO



Solar PV Plant
Chilled Water Storage
Electric Chiller Plant
HRC Plant
Campus Demand
Electric Substation
Hot Water Boiler Plant
Natural Gas
Hot Water Storage

Scenario 2



Solar PV Plant
Chilled Water Storage
Electric Chiller Plant
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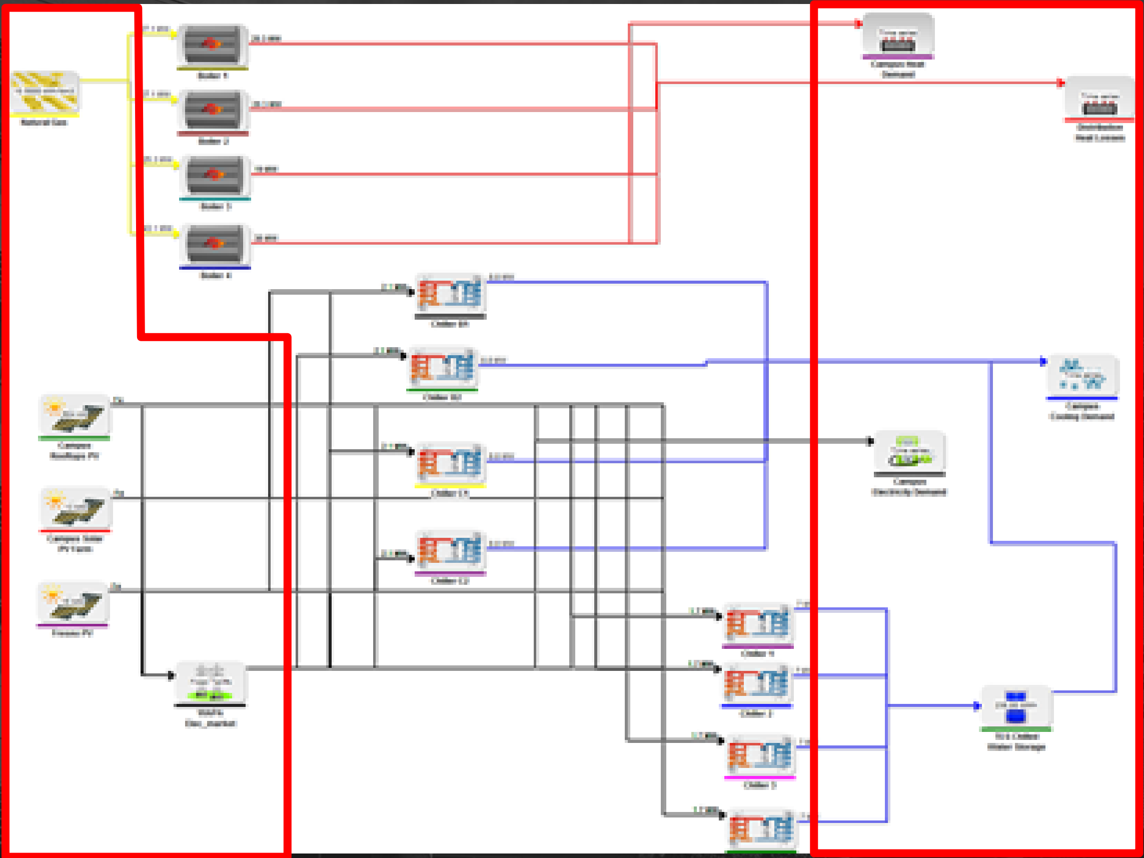
Natural Gas
Solar Thermal Plant
Hot Water Storage
Scenario 3

Energy Conversion Units

Energy Sources



Energy Demands

Campus Energy Model

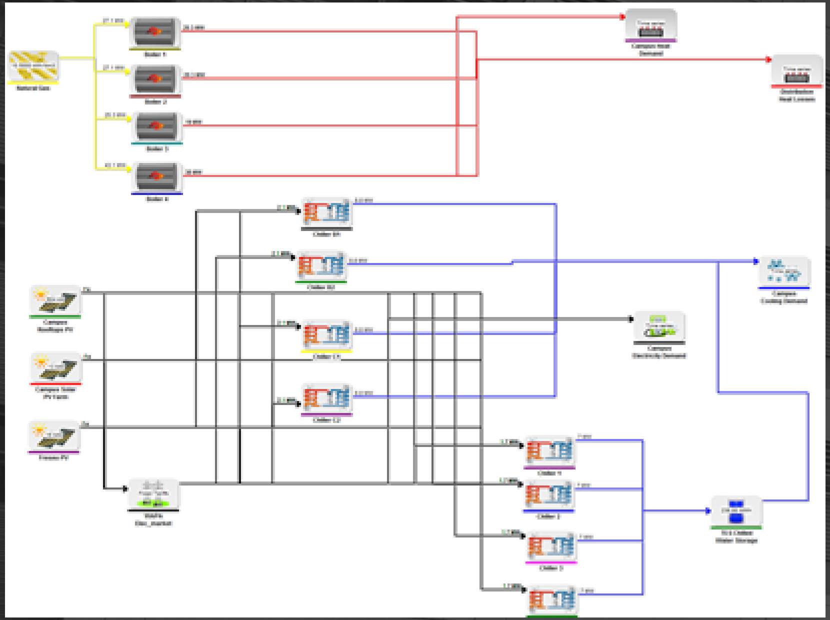
Using energyPRO (emd.dk)

Campus Energy Model

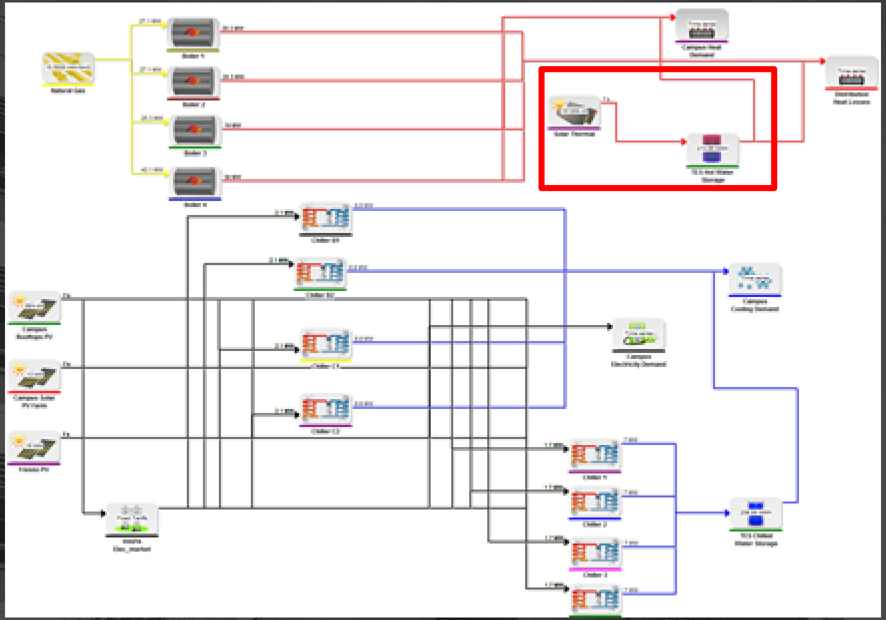
- 77 MW (305 pph) steam boiler plant
- 63 MW (18,000 tons) electric chiller plant
- 5 Mgal CHW TES Tank
- 30 MW solar PV plant

Unit	Primary fuel	Primary output	Output Capacity	Efficiency	Function	Inst. year	Condition
District heating supply							
Boiler 1	Natural Gas	Saturated Steam	20.3 MWth 80,000 pph steam	-	None	1967	Non-operational
Boiler 2			20.3 MWth 80,000 pph steam	75%	Back-up	1967	Poor
Boiler 3			19 MWth 75,000 pph steam	75%	Summer baseload and	1994	Good
Boiler 4			38 MWth 150,000 pph steam	88%	Baseload	2009	Good
District cooling supply							
Chiller B1	Electricity	Chilled Water	8.8 MWth 2,500 ton Refrigeration	COP 4.25 0.83kW/Ton refrigeration	Baseload in summer	2004	Good
Chiller B2			8.8 MWth 2,500 ton Refrigeration			2004	Good
Chiller C1			8.8 MWth 2,500 ton Refrigeration			2010	Good
Chiller C2			8.8 MWth 2,500 ton Refrigeration			2013	Good
TES Chiller 1			7MWth 2,000 ton Refrigeration		Baseload + providing to cold TES	2000	Good
TES Chiller 2			7MWth 2,000 ton Refrigeration			2000	Good
TES Chiller 3			7MWth 2,000 ton Refrigeration			2004	Good
TES Chiller 4			7MWth 2,000 ton Refrigeration			2004	Good
Power Supply							
Fresno	Irradiance	Electricity	16 MWe AC 20 MWe DC	-	RE contribution	2017	Good
Solar PV Farm			13 MWe AC 16.3 MWe DC			2015	Good
Rooftop PV			604 kWe AC 757 kWe DC			2012	Good

Hot Water District Heating



With Solar Thermal Plant



Campus Energy Model

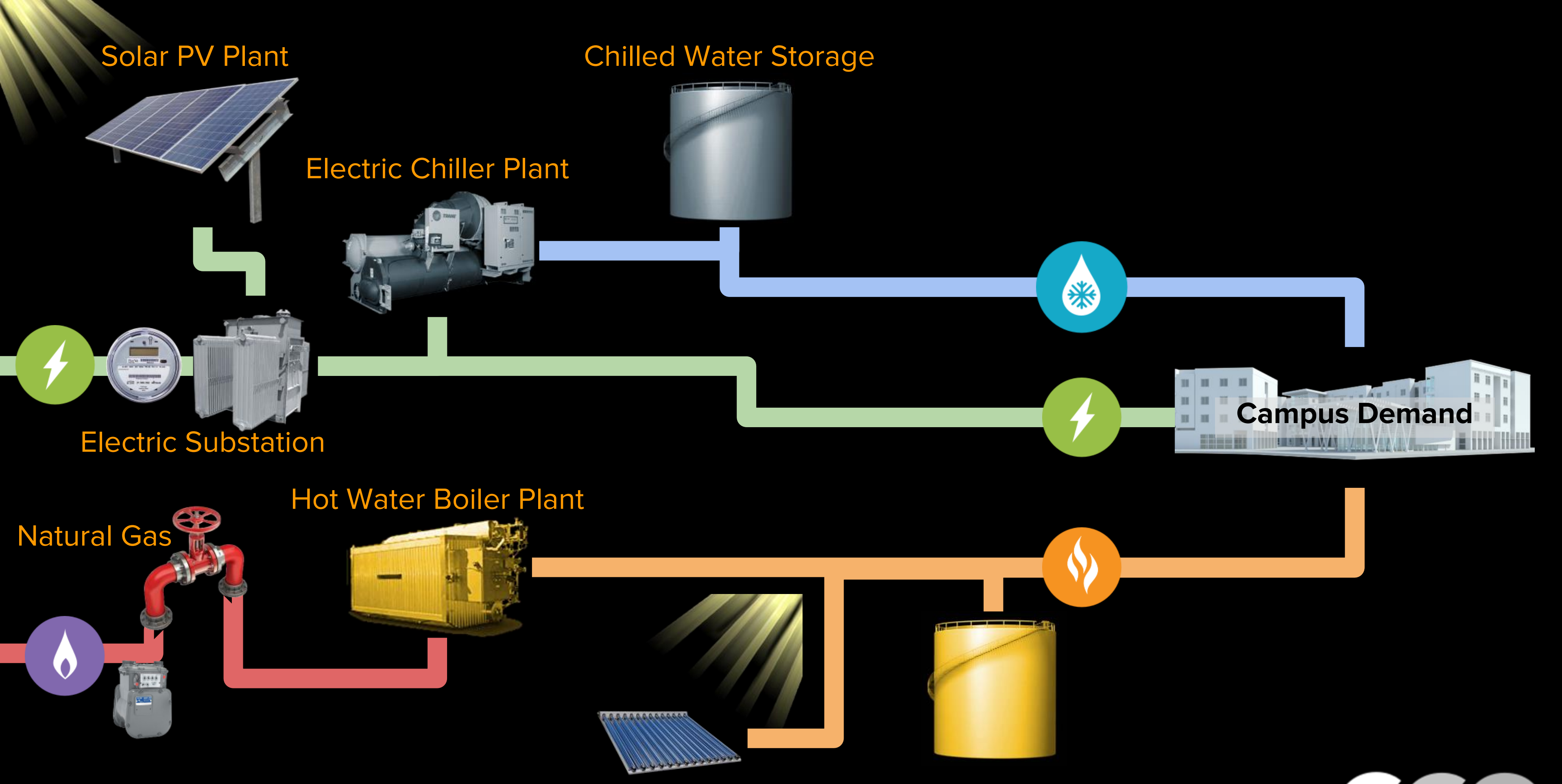
Using energyPRO (emd.dk)

HW Modeling Scenarios

1. 25 acre (100k m2) Solar Thermal (ST) plant
2. One 2,500 ton Heat Recovery Chiller (HRC)
3. One 2,500 ton HRC + ST + seasonal storage

Scenario Assumptions

- 20 year model (2017-2036)
- 1.25 MGal HW TES for daily storage
- 31% steam distribution losses (assuming actual heating demand is 69% of measured heating demand)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Hot Water Boiler Plant
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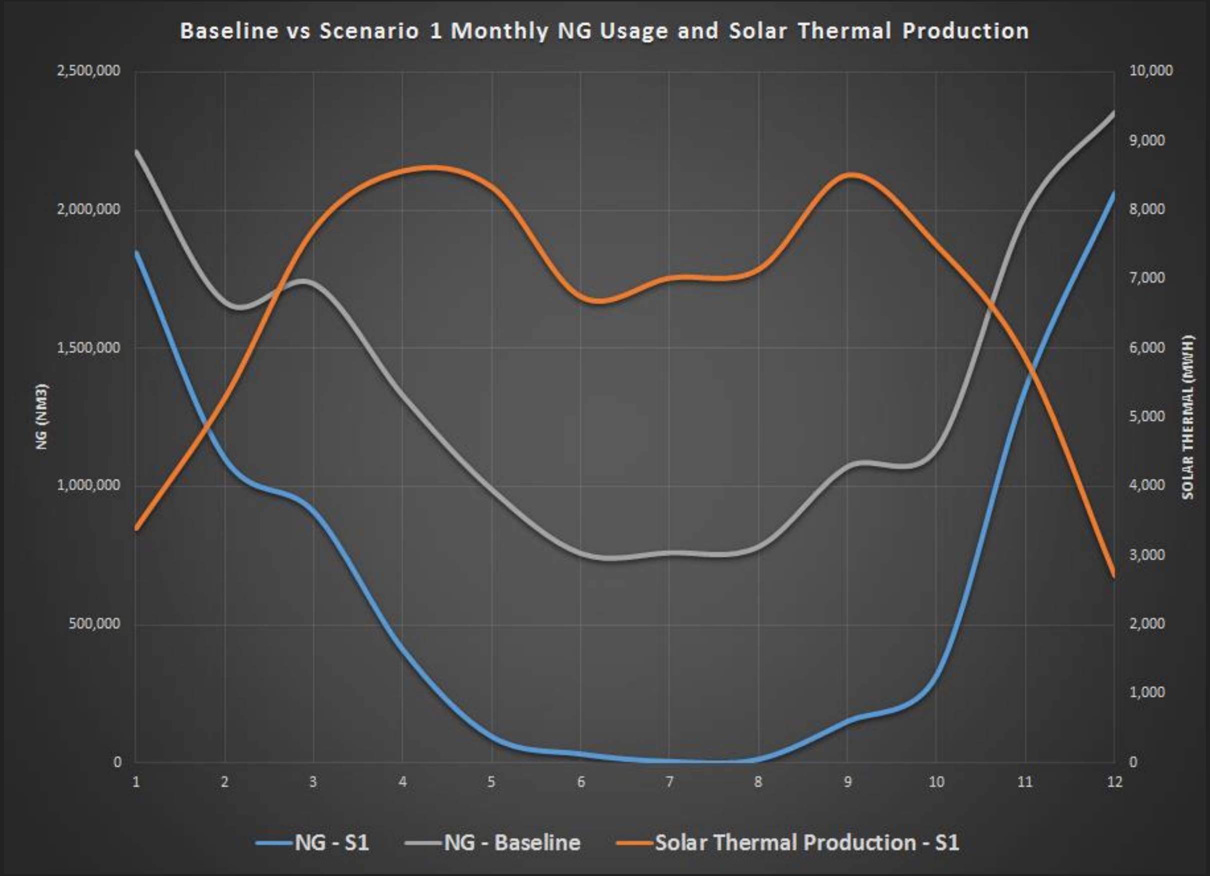
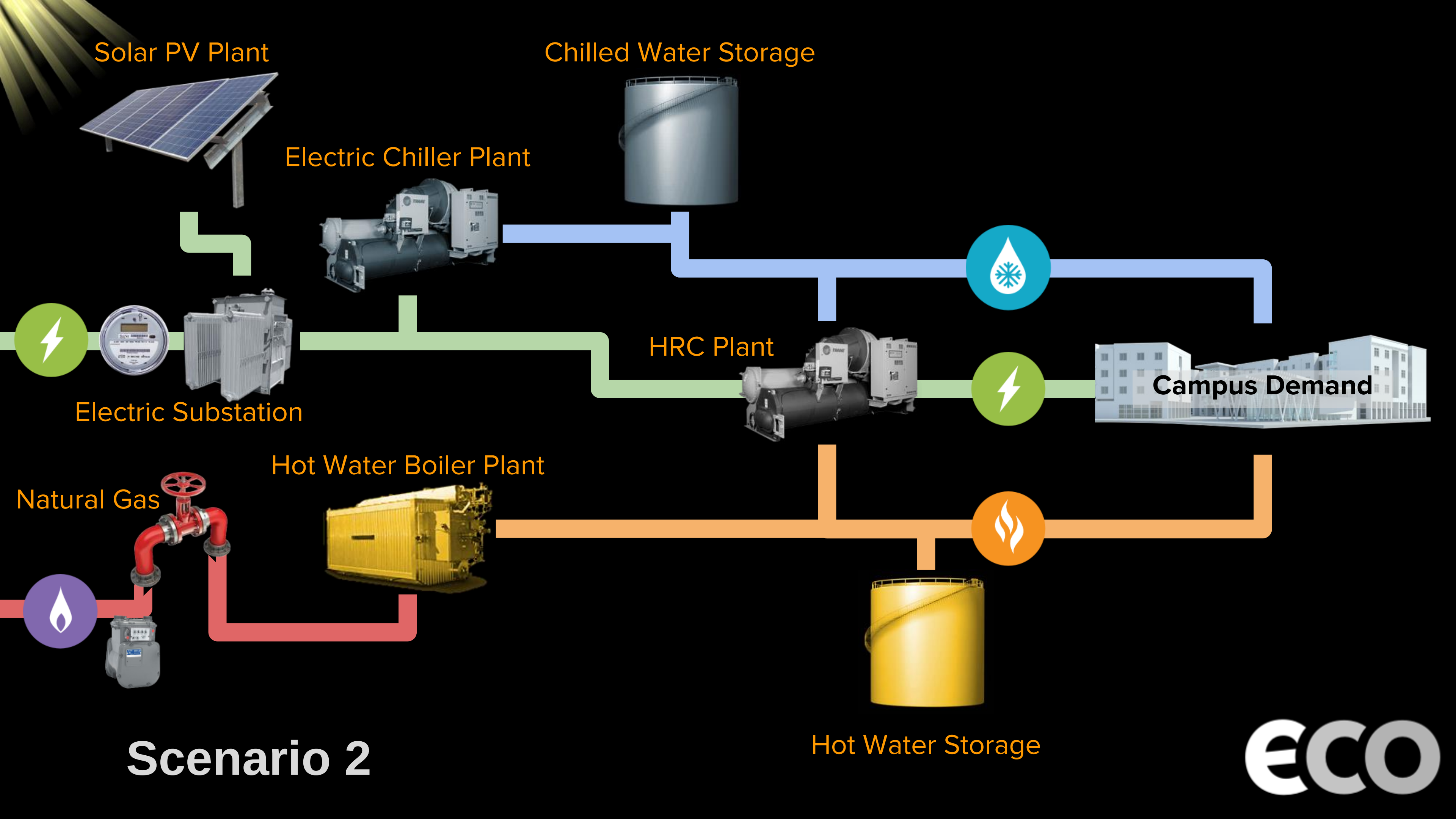
Scenario 1

Scenario 1 Results

ST Production drives **Scenario 1 NG Usage** to zero in summer but has less impact in winter (compared to **Baseline NG Usage**).



Scenario 1 HW with ST	Baseline HW (NG Boilers)	HW District with ST
% Boilers	100	49
% Solar Thermal	0	51
NG (m3/yr)	16,800,000	8,300,000
Elect (MWh/yr)	32,000	32,000
mtCO2e/year	80,000	64,000
Cost Savings/year	0	$1M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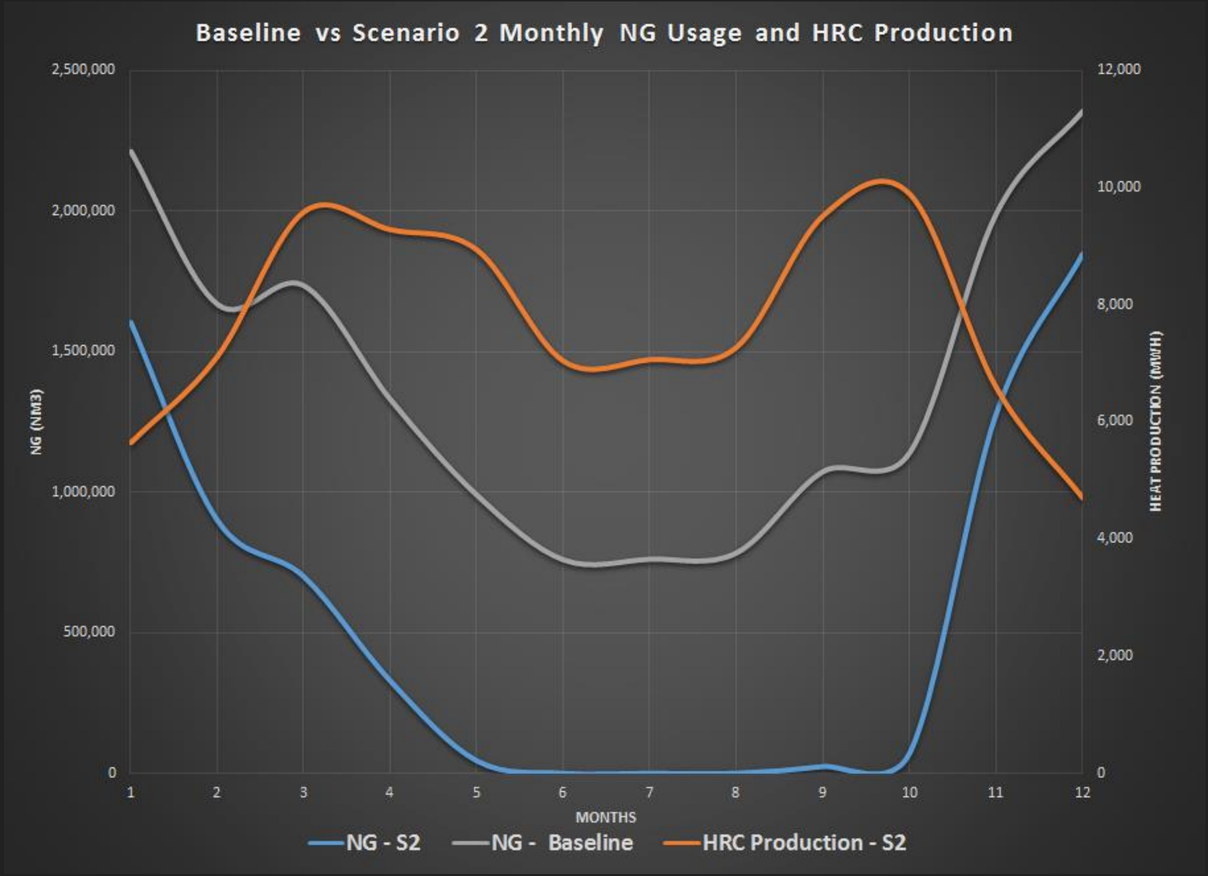
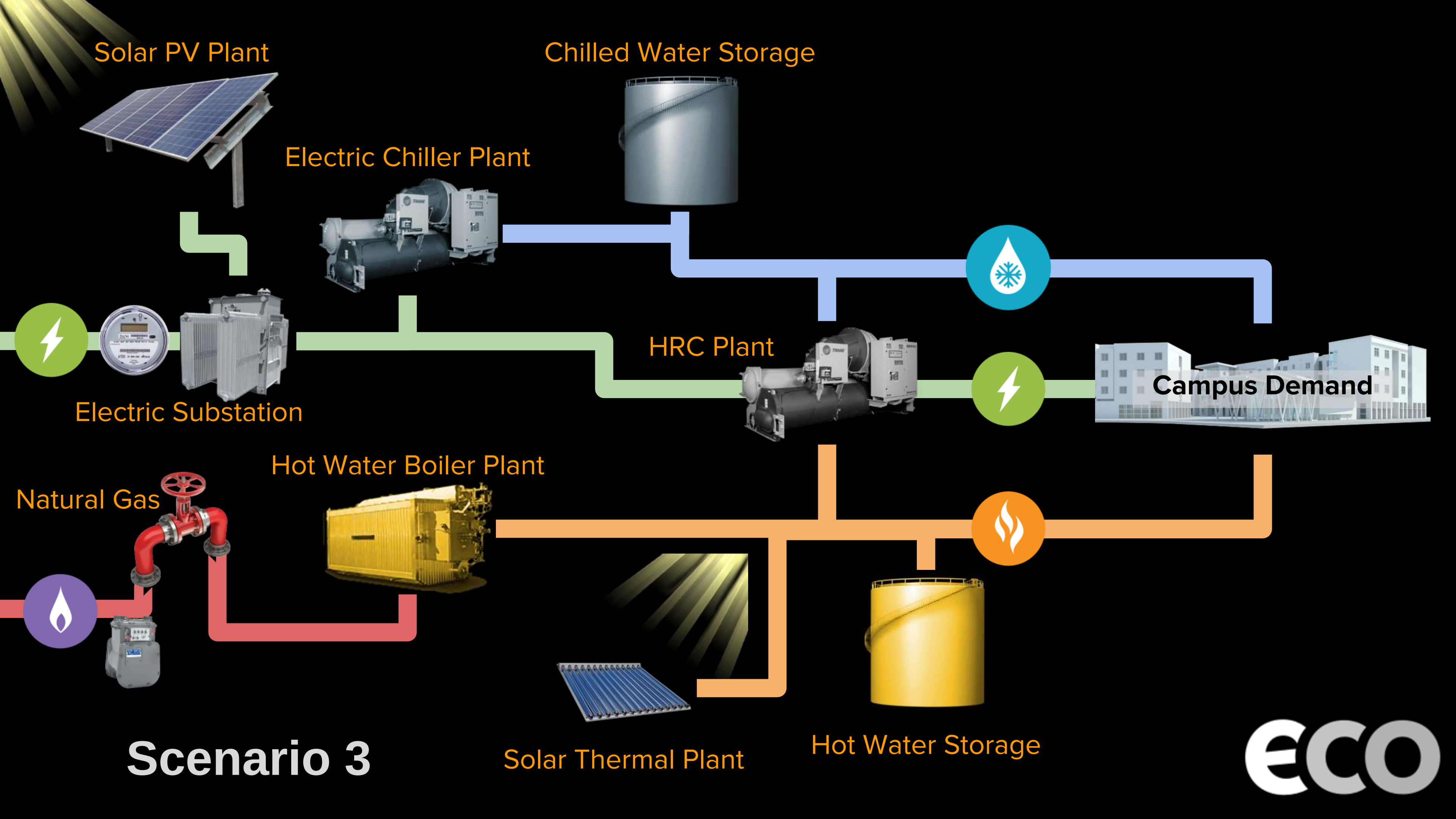
HRC Plant
Campus Demand
Electric Substation
Hot Water Boiler Plant
Natural Gas
Hot Water Storage
Scenario 2
ECO

Scenario 2 Results

HRC HW Production drives **Scenario 2 NG Usage** to zero in summer but has less impact in winter (compared to **Baseline NG Usage**).



Scenario 2 HW with HRC	Baseline HW (NG Boilers)	HW District with HRC
% Boilers	100	40
% HRC	0	60
NG (m3/yr)	16,800,000	6,800,000
Elect (MWh/yr)	32,000	48,000
mtCO2e/year	80,000	66,000
Cost Savings/year	0	$90k



Solar PV Plant
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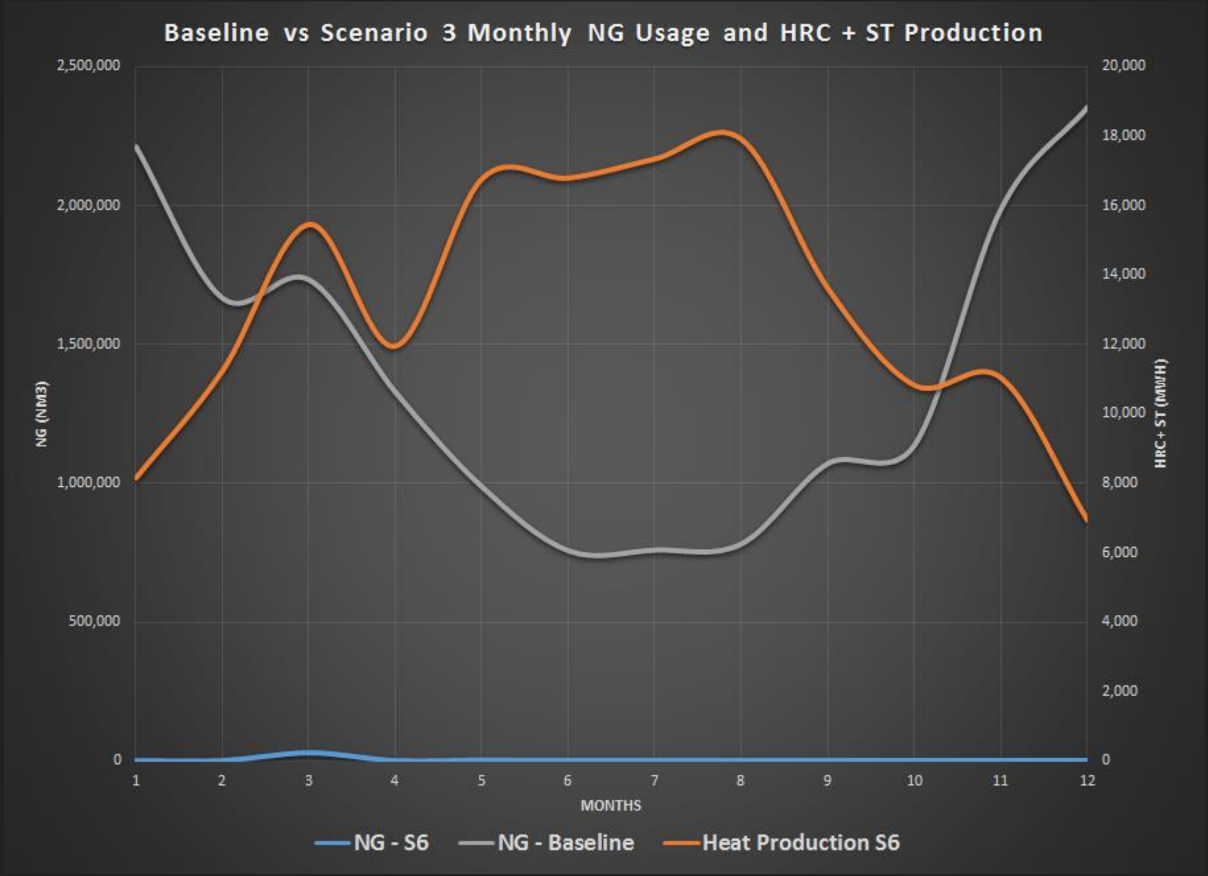
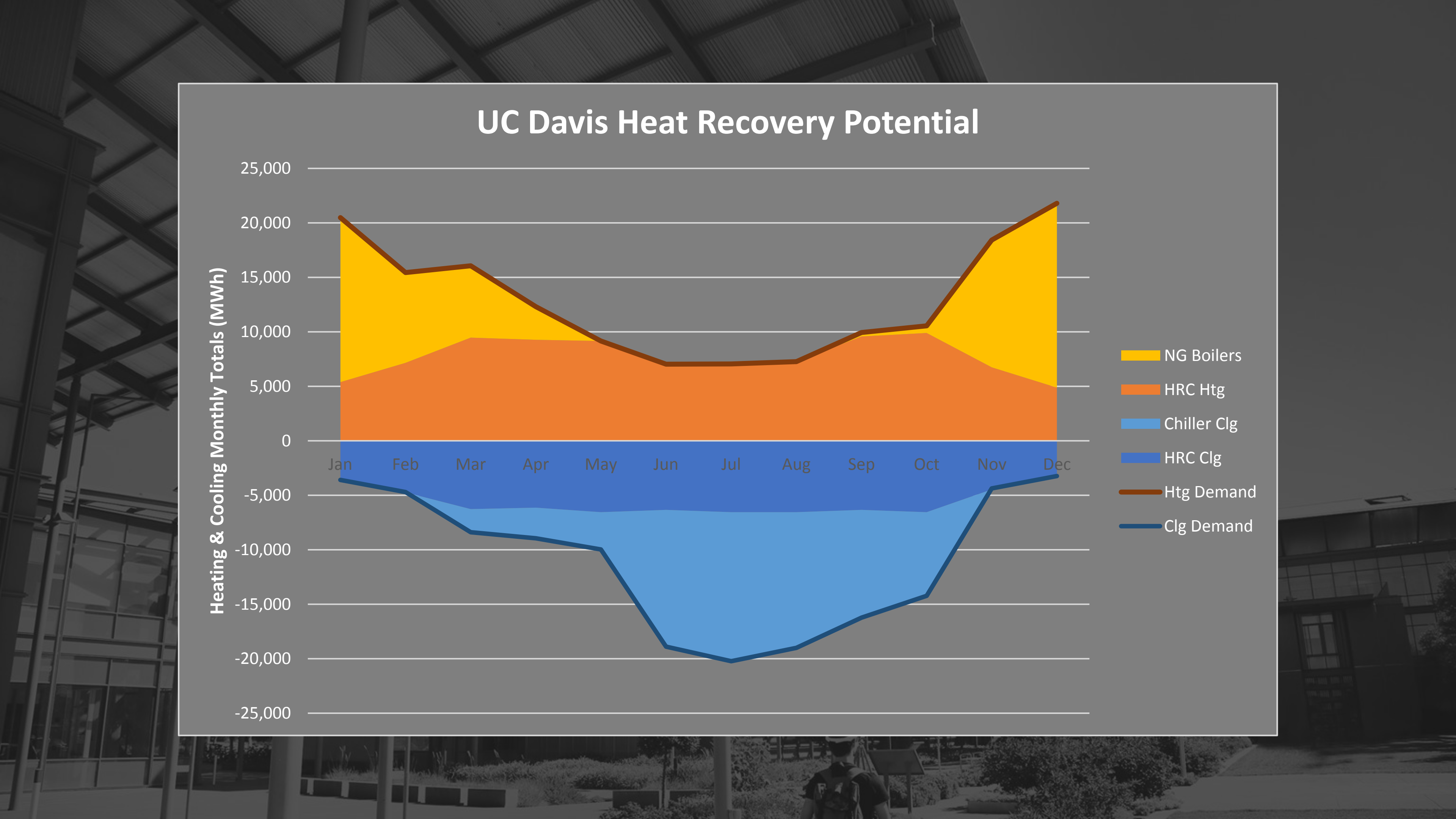
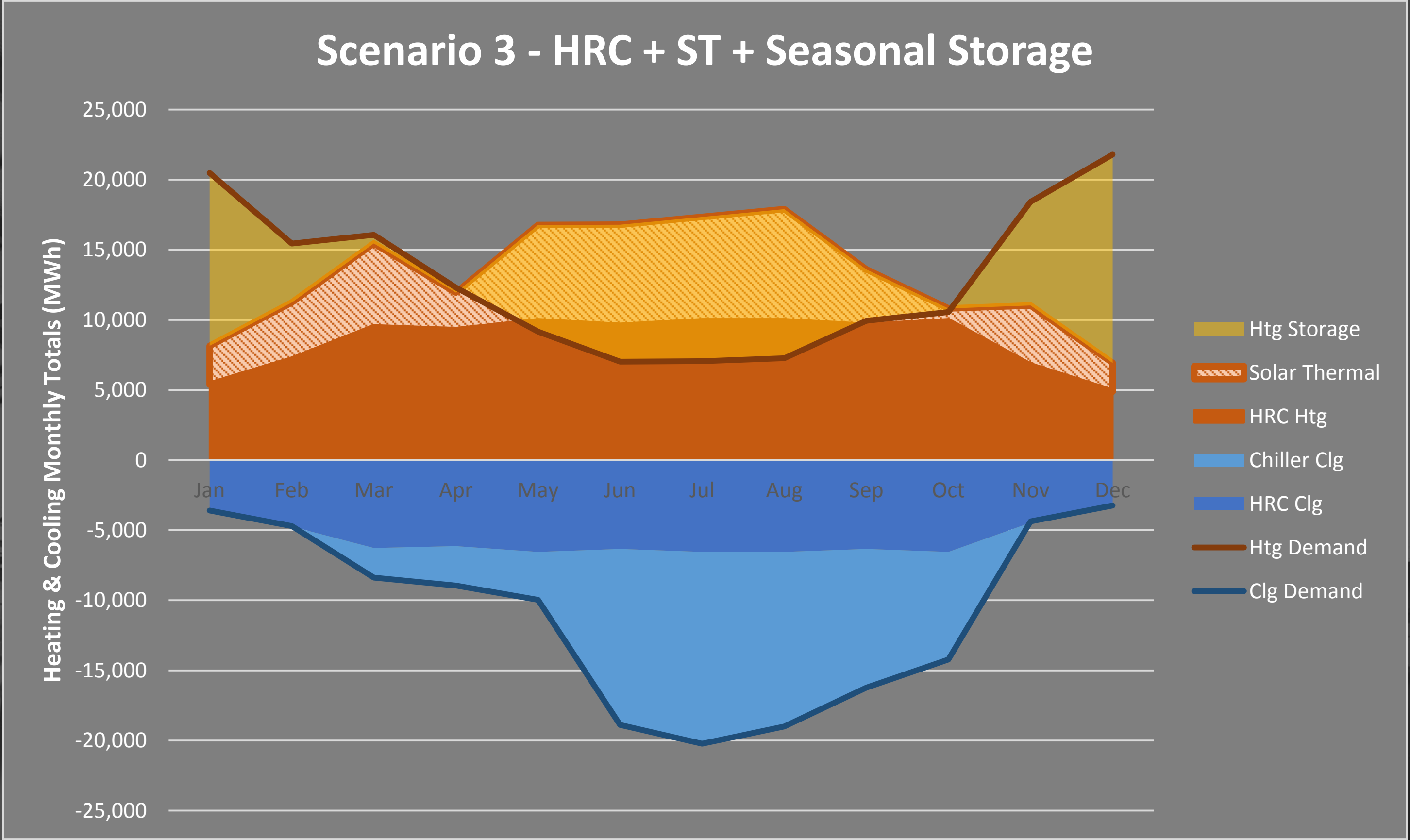
Electric Chiller Plant
HRC Plant
Campus Demand
Electric Substation
Hot Water Boiler Plant
Natural Gas
Scenario 3
Solar Thermal Plant
Hot Water Storage

Scenario 3 Results

HRC + ST Production drives **Scenario 3 NG Usage** to zero year-round (compared to **Baseline NG Usage**).




UC Davis Heat Recovery Potential
Heating & Cooling Monthly Totals (MWh)
25,000
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
-25,000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
NG Boilers
HRC Htg
Chiller Clg
HRC Clg
Htg Demand
Clg Demand


Scenario 3 - HRC + ST + Seasonal Storage
Heating & Cooling Monthly Totals (MWh)
25,000
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
-25,000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Htg Storage
Solar Thermal
HRC Htg
Chiller Clg
HRC Clg
Htg Demand
Clg Demand

Scenario 3 HW with HRC + ST + Seasonal storage	Baseline HW (NG Boilers)	HW District with HRC + ST + Seasonal storage
% Boilers	100	0
% HRC + ST	0	100
NG (m3/yr)	16,800,000	0
Elect (MWh/yr)	32,000	50,000
mtCO2e/year	80,000	53,500
Cost Savings/year	0	$780k

Seasonal storage for the UC Davis district heating system would be 4.5x larger than the world's largest thermal storage pit (Vojens, Denmark)

https://stateofgreen.com/en/profiles/ramboll/solutions/world-largest-thermal-pit-storage-in-vojens

Conclusions

- Solar Thermal is ideal where Heat Recovery options are limited
- Heat Recovery can limit Solar Thermal potential
- Both are limited by summer heating loads and storage size
- Seasonal storage is required to leverage both Heat Recovery and Solar Thermal to their full extent