AABC Commissioning Group

AIA Provider Number 50111116

Electrification of Building Energy Supply for Superior Economics & Sustainability

Course Number: CXENERGY1813

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Stanford University

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Course Description

Electrification of building heating and cooling processes, coupled with clean electricity supply, is the predominant path forward to sustainable and economic building energy supply for the long term. This presentation will explain the Stanford Energy System Innovations (SESI) project and the additional enhancements Stanford is studying to complete its full transformation to an affordable and sustainable energy system in less than 10 years.

Learning Objectives

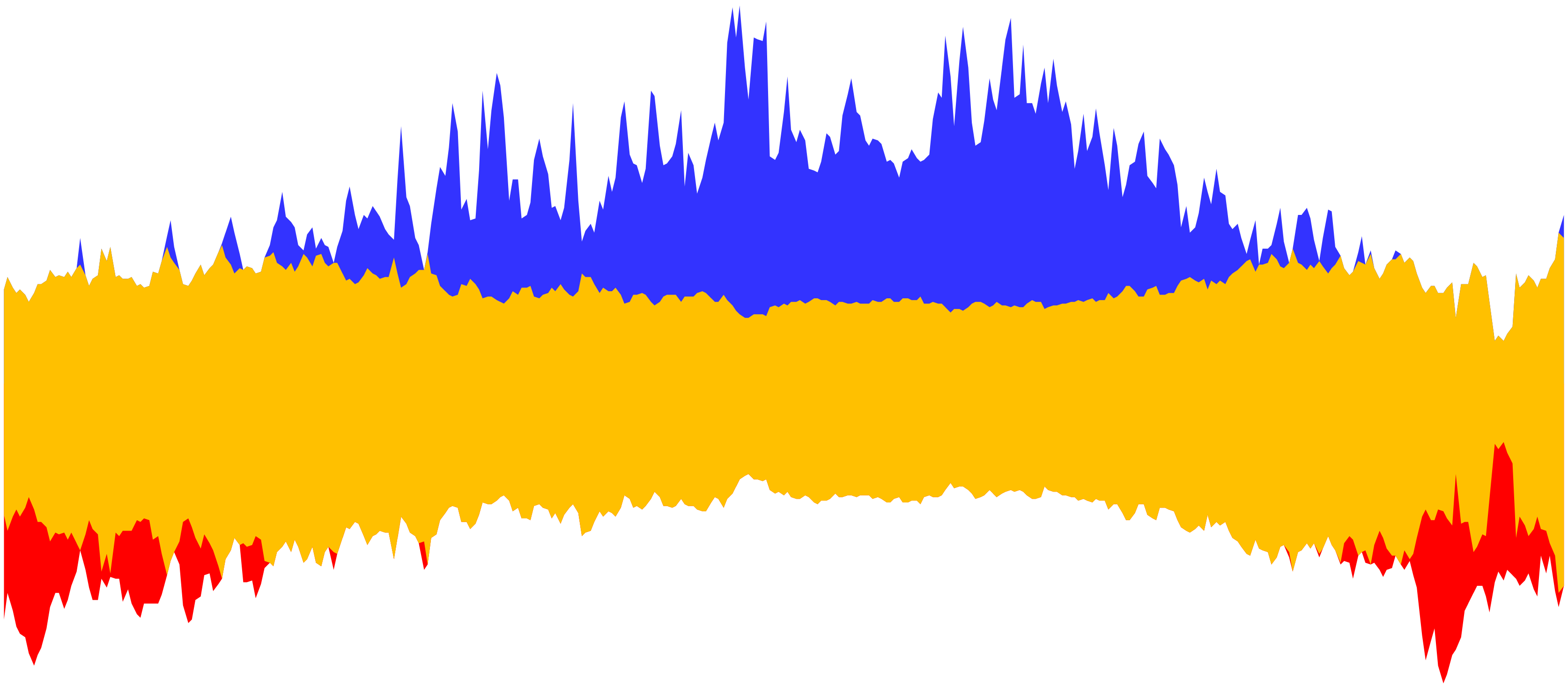
At the end of the this course, participants will be able to:

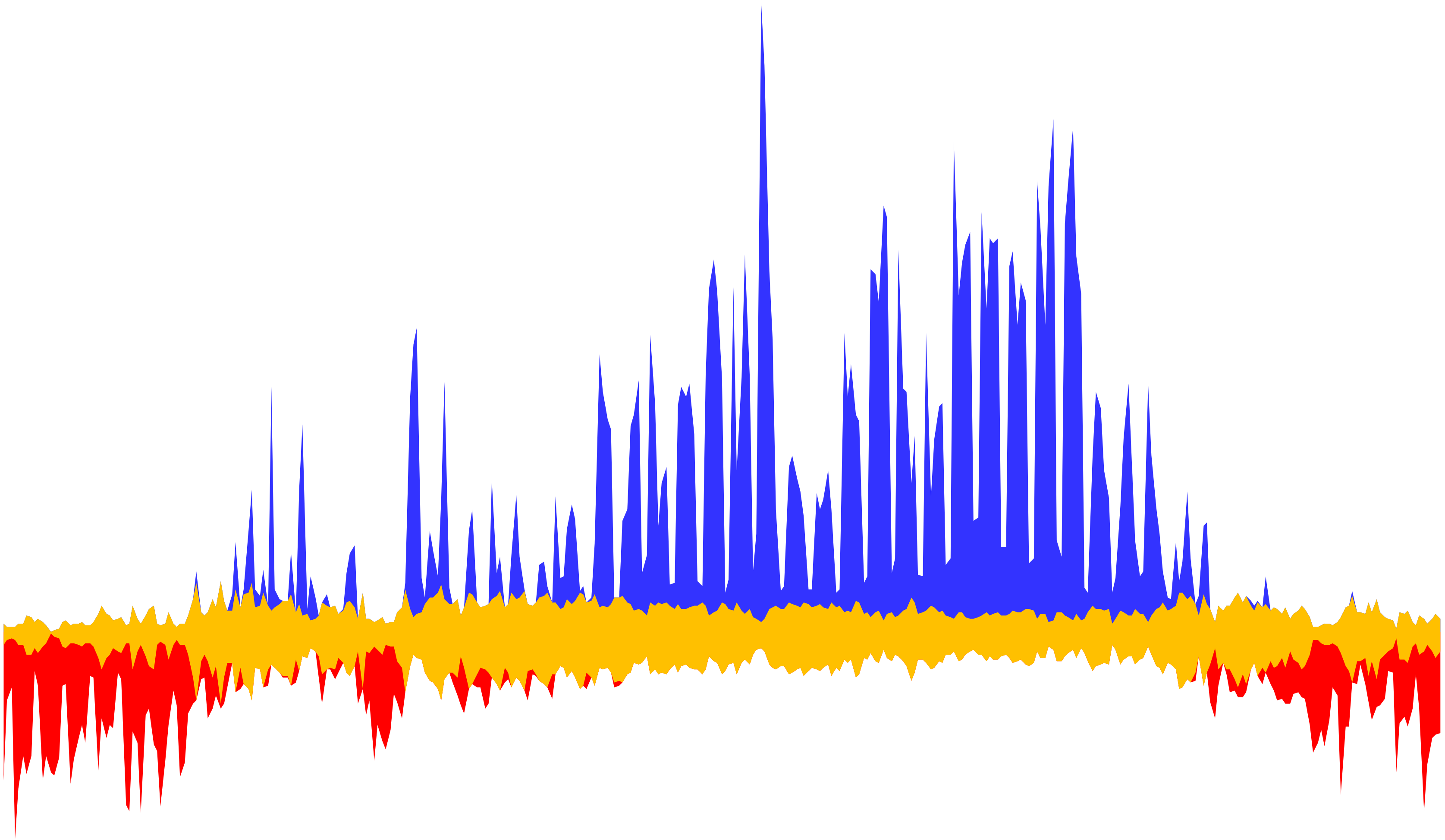
1. Learn how to electrify building heating & cooling processes efficiently and economically.

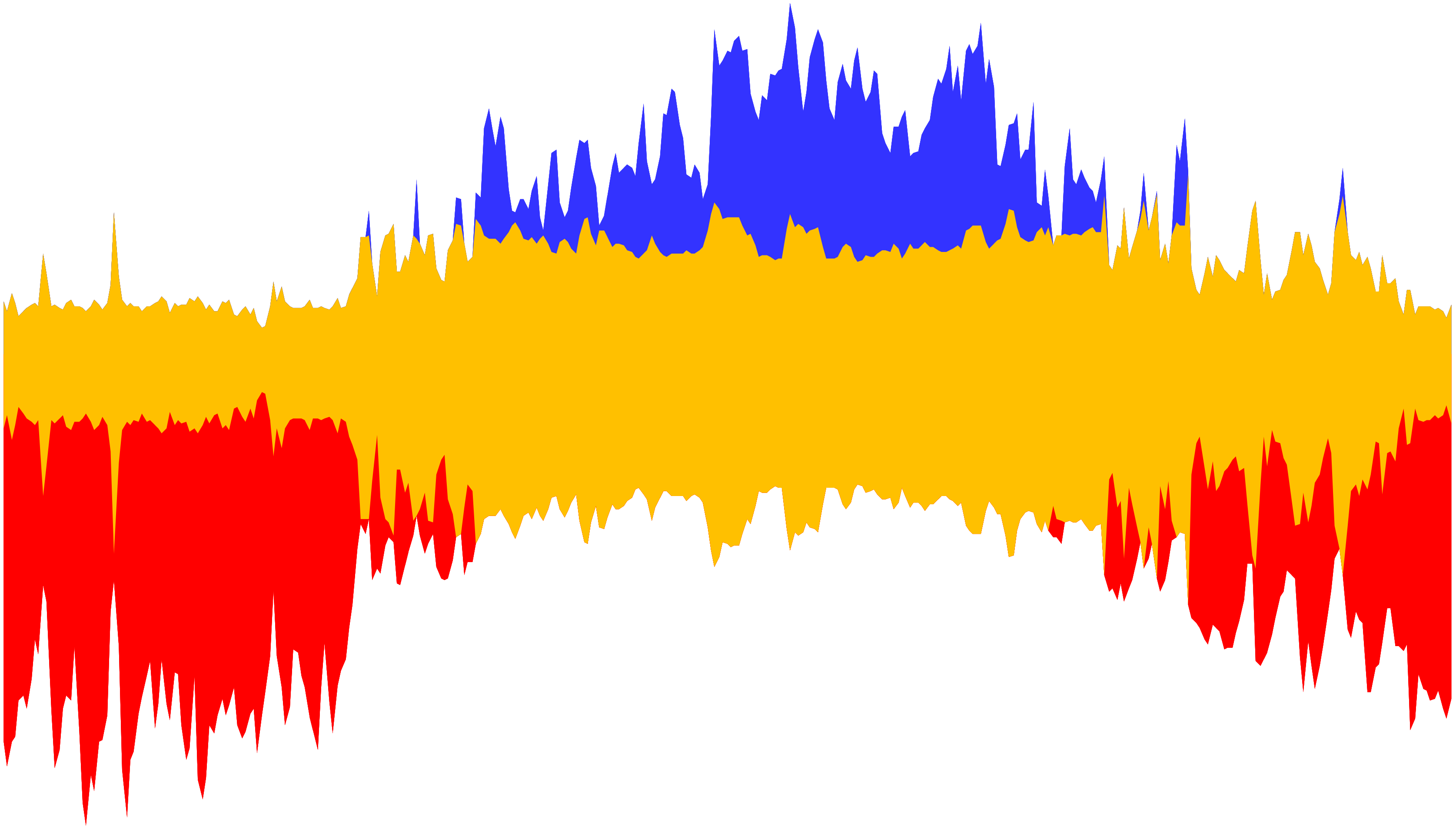
2. Learn about the benefits of both hot and cold thermal energy storage in an electrified CHC building energy scheme and how to model, design, and operate a CHC system.

3. Learn why thermal energy storage is a larger opportunity for grid electricity demand management than batteries or other forms of electricity storage.

4. Learn why all the fuss should be about Total Energy Microgrids, not Electricity Microgrids.







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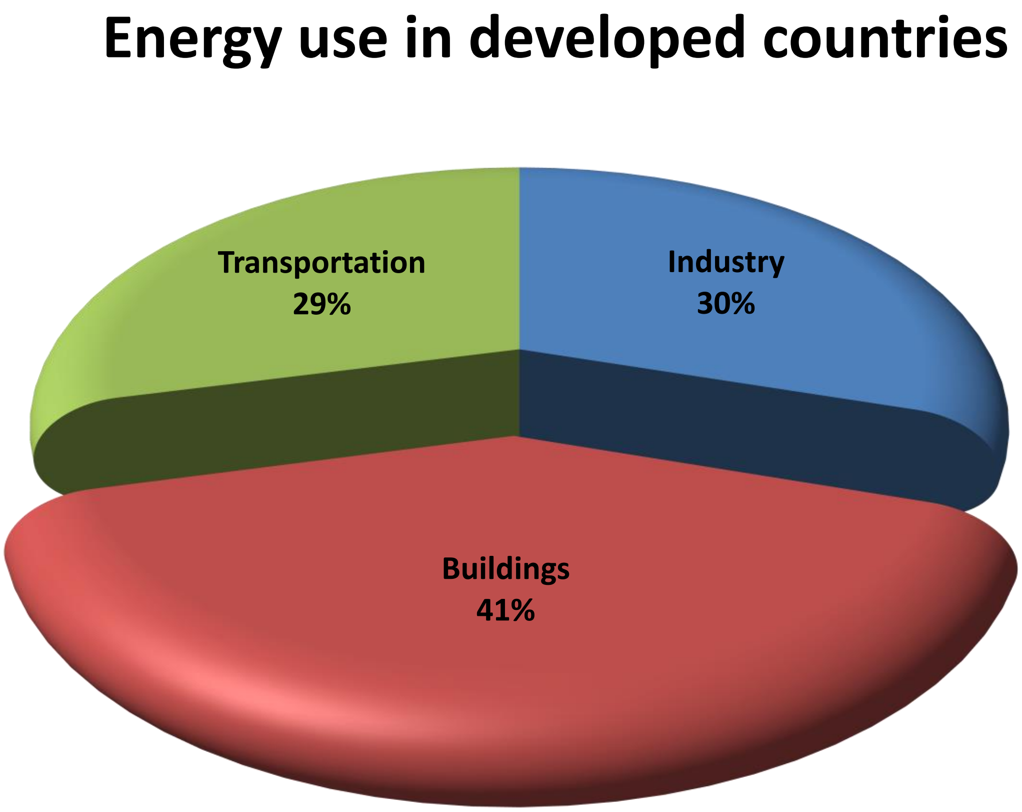
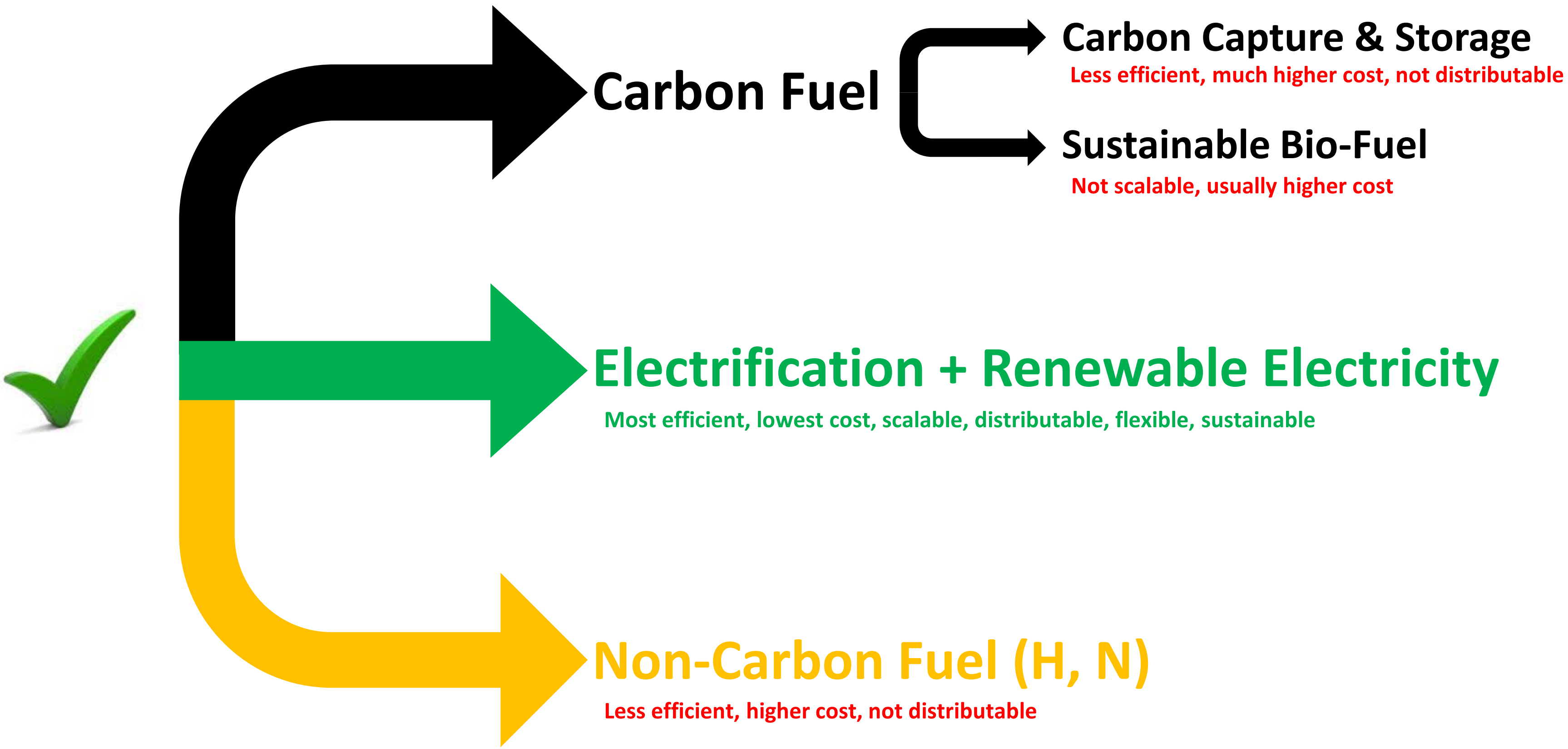
Building Energy- Scale



- Electricity, Heating, and Cooling of structures
- 40% of GHG emissions

Pathways for *Sustainable* Building Energy



Heat Pump is Key to Building Electrification

Electric Resistive

6,816 btu of gas = 1 KWH = 3,413 btu of heat
(50% efficient grid gas power plant)

Gas

4,000 btu of gas = 3,413 btu of heat
(85% efficient heater)

Electric Heat Pump

1,133 to 2,040 btu of gas = .17 (120F) to .3 (160F) KWH
= 3,413 btu of heat
(50% efficient grid gas power plant)

Assessing Heat Recovery Potential

	A	B	C	D	E	F	G
1	**Cooling Load**						
2	mmbtu						
3		0:00	1:00	2:00	3:00	4:00	5:00
4	Friday, January 1, 2016	35	35	34	34	33	33
5	Saturday, January 2, 2016	38	39	39	39	37	37
6	Sunday, January 3, 2016	38	39	39	38	37	37
7	Monday, January 4, 2016	38	38	37	37	36	36
8	Tuesday, January 5, 2016	38	38	38	37	37	37
9	Wednesday, January 6, 2016	38	37	37			
10	Thursday, January 7, 2016	38	37	37			
11	Friday, January 8, 2016	37	38	41			
12	Saturday, January 9, 2016	37	37	35			
13	Sunday, January 10, 2016	42	40	39			
221							
222	Friday, August 5, 2016	76	76	76			
223	Saturday, August 6, 2016	77	74	73			
224	Sunday, August 7, 2016	81	73	71			
225	Monday, August 8, 2016	105	93	87			
226	Tuesday, August 9, 2016	136	123	125			

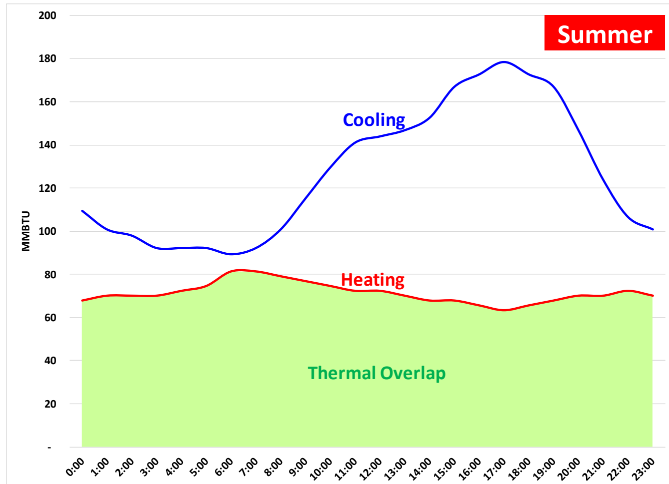
Minimum of hourly cooling or heating load = minimum 'real time' heat recovery potential

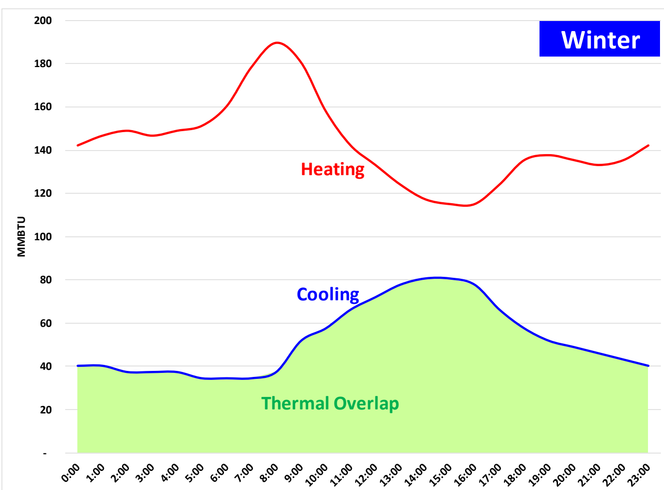
	A	B	C	D	E	F	G
1	**Heat Recovery Potential**						
2	mmbtu						
3		0:00	1:00	2:00	3:00	4:00	5:00
4	Friday, January 1, 2016	35	35	34	34	33	33
5	Saturday, January 2, 2016	38	39	39	39	37	37
6	Sunday, January 3, 2016	38	39	39	38	37	37
7	Monday, January 4, 2016	38	38	37	37	36	36
8	Tuesday, January 5, 2016	38	38	38	37	37	37
9	Wednesday, January 6, 2016	38	37	37	38	37	37
10	Thursday, January 7, 2016	38	37	37	35	10	29
11	Friday, January 8, 2016	37	38	41	33	27	23
12	Saturday, January 9, 2016	37	37	35	34	34	33
13	Sunday, January 10, 2016	42	40	39	39	39	38
221							
222	Friday, August 5, 2016	51	51	53	52	53	57
223	Saturday, August 6, 2016	51	52	53	54	54	58
224	Sunday, August 7, 2016	49	49	51	52	55	59
225	Monday, August 8, 2016	48	49	50	50	52	57
226	Tuesday, August 9, 2016	46	44	46	46	46	48

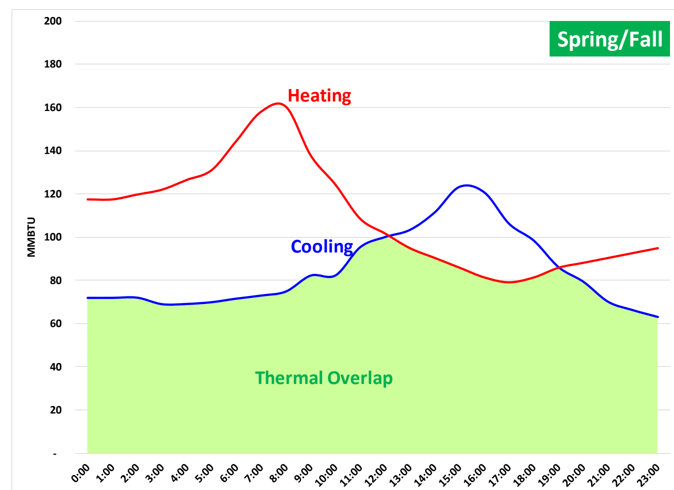
	A	B	C	D	E	F	G
1	**Heating Load**						
2	mmbtu						
3		0:00	1:00	2:00			
4	Friday, January 1, 2016	102	106	107			
5	Saturday, January 2, 2016	93	89	91			
6	Sunday, January 3, 2016	91	94	93			
7	Monday, January 4, 2016	95	103	102			
8	Tuesday, January 5, 2016	105	108	105			
9	Wednesday, January 6, 2016	110	113	111	117	118	121
10	Thursday, January 7, 2016	120	124	123	122	130	128
11	Friday, January 8, 2016	120	119	121	127	129	131
12	Saturday, January 9, 2016	122	126	125	130	128	134
13	Sunday, January 10, 2016	126	128	125	125	129	135
221							
222	Friday, August 5, 2016	51	51	53	52	53	57
223	Saturday, August 6, 2016	51	52	53	54	54	58
224	Sunday, August 7, 2016	49	49	51	52	55	59
225	Monday, August 8, 2016	48	49	50	50	52	57
226	Tuesday, August 9, 2016	46	44	46	46	46	48

More heat recovery is achievable with thermal energy storage and Model Predictive Control software

Assessing Heat Recovery Potential- Stanford Example

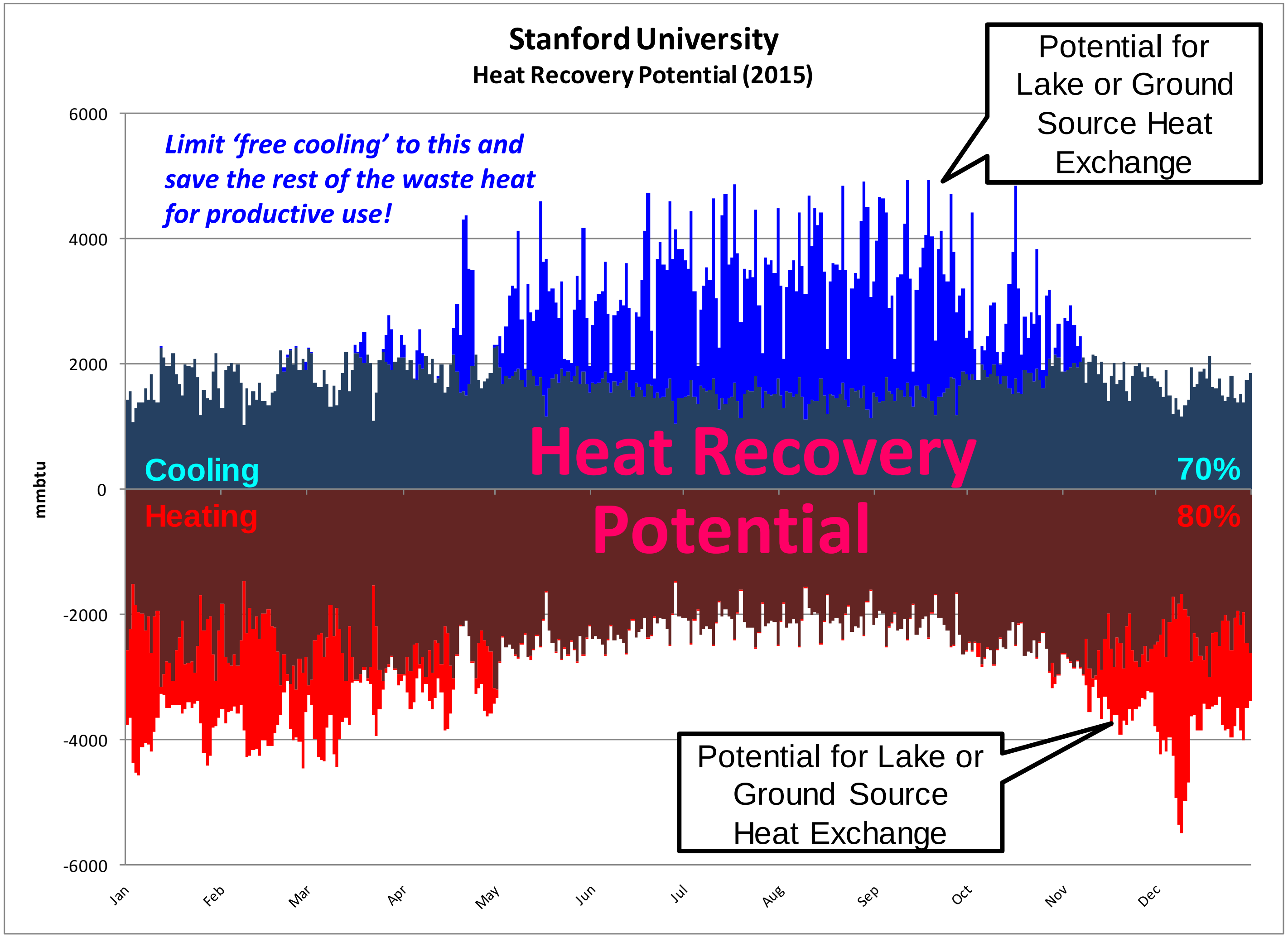




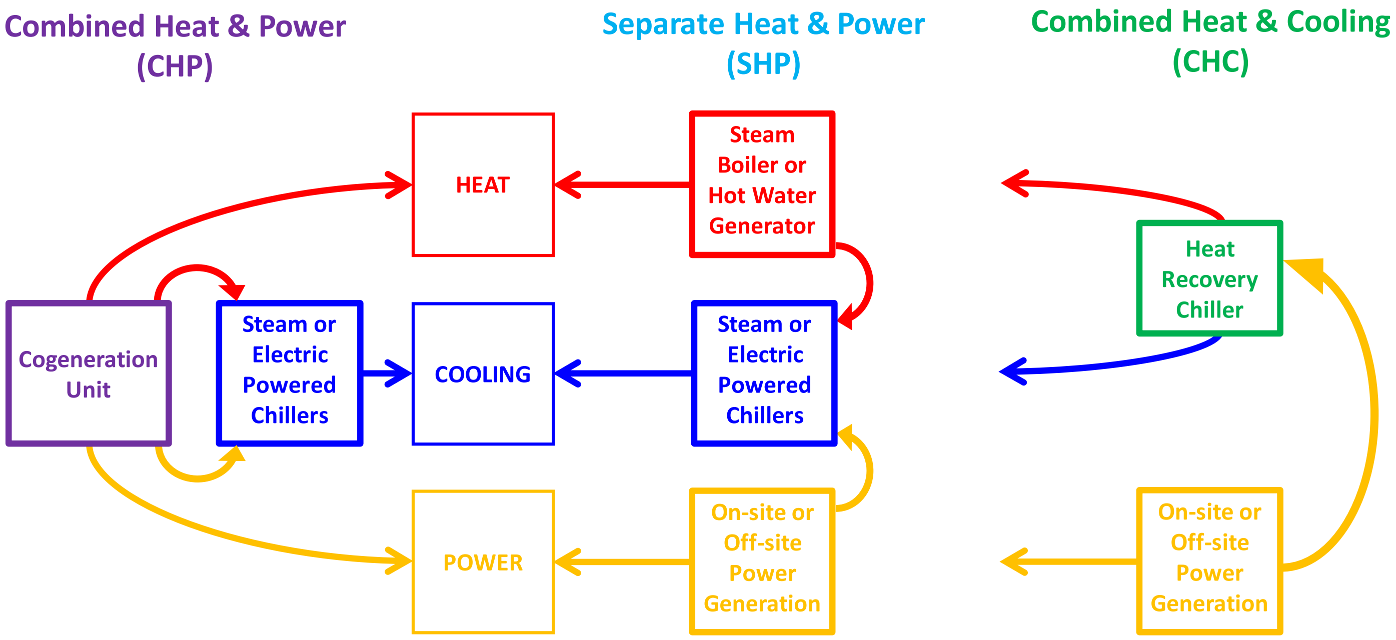


Annual Heat Recovery Potential

Use Heat Pump first for: 1) Heat Recovery, then 2) Heat Extraction from Ground or Water



Types of Building Energy Supply Systems



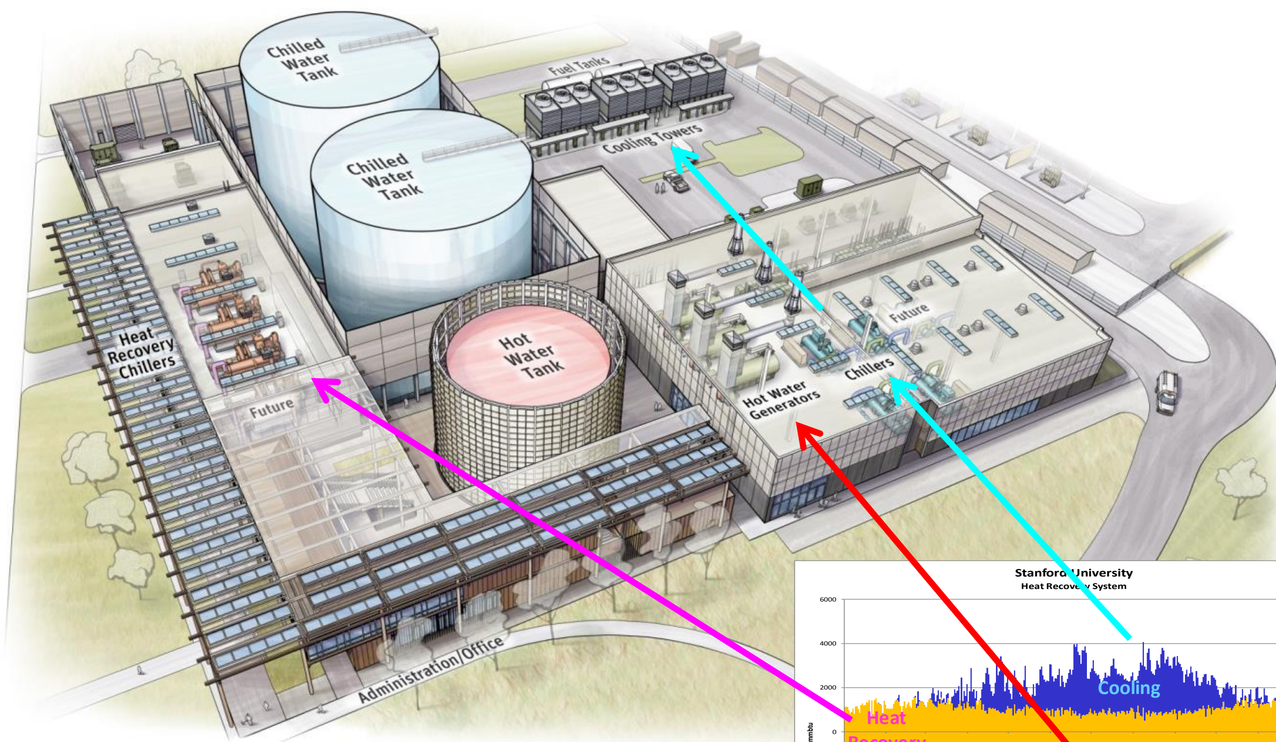
Basic Overall System Components

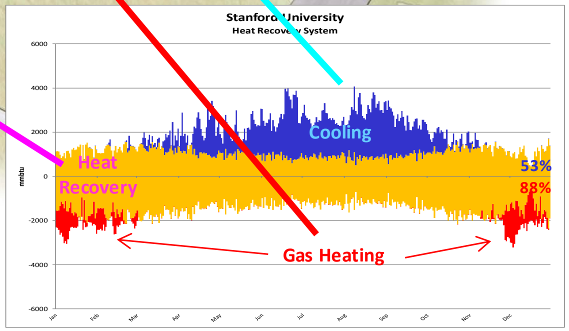
1. Heat Pump (aka Heat Recovery Chiller)
2. Chiller
3. Boiler/Hot Water Generator

<u>Optional but highly desirable and cost effective</u>

4. Hot thermal energy storage (typically water)
5. Cold thermal energy storage (typically water)
6. Model Predictive Control software for planning, design, and operation

Stanford Central Energy Facility





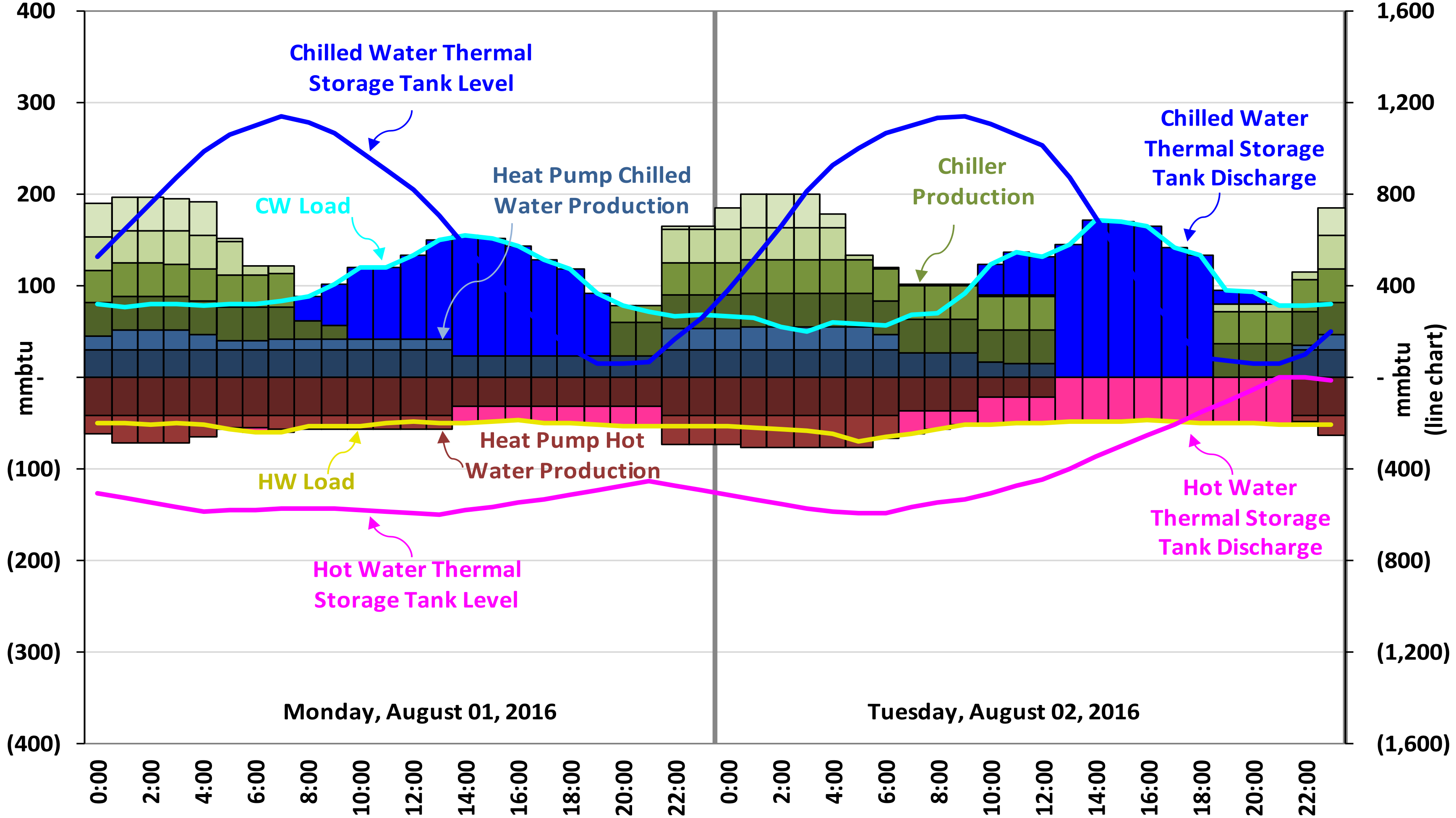
Hot and Cold Thermal Energy Storage

- Reduces Capital & O&M cost
- Increases system efficiency (6% more heat recovery)
- Reduces electricity peak demand by 17% (36 v 43 MW)
- Provides equivalent of 7 MW electricity storage

Model Predictive Control Software

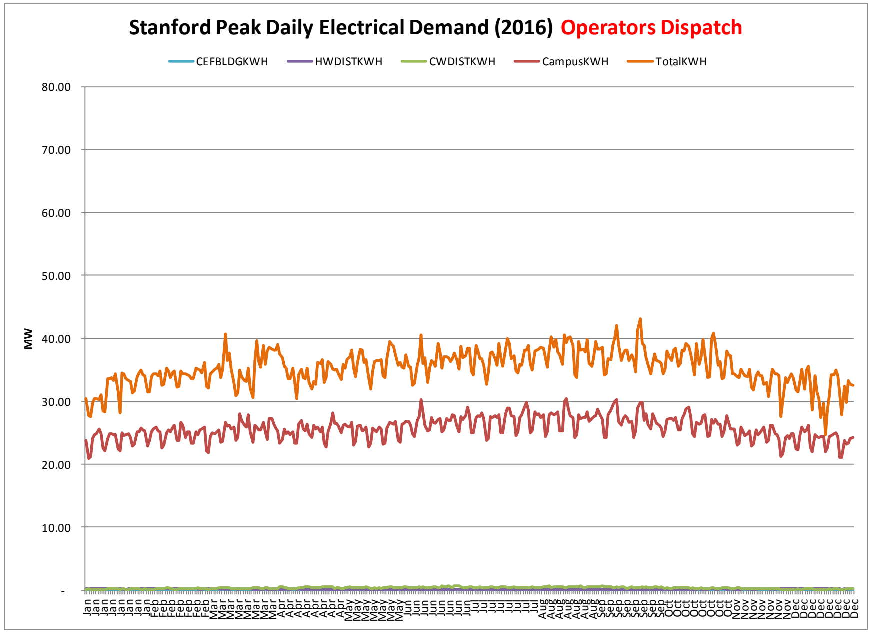
Increases system efficiency

Reduces electricity peak demand and total cost

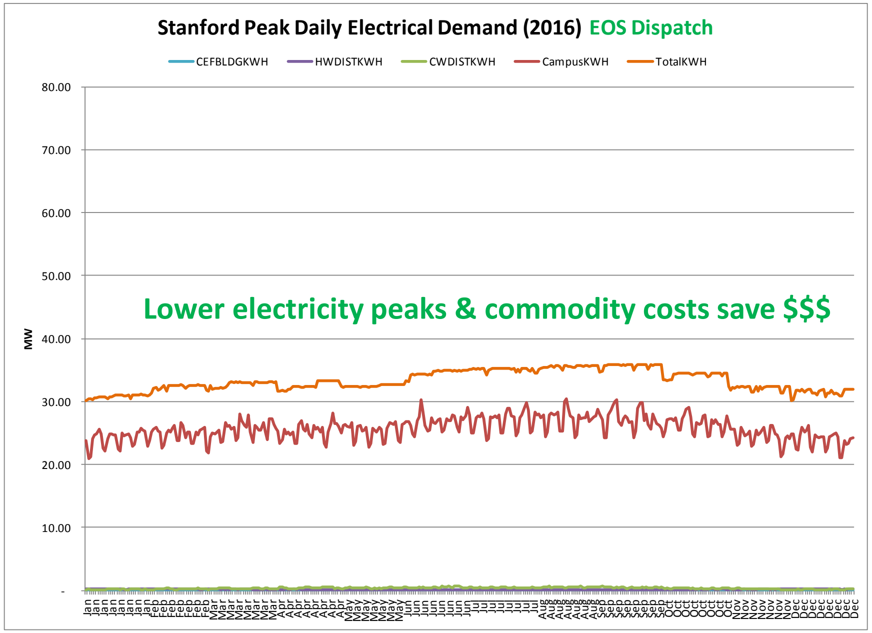


Benefits of Model Predictive Control

Manual Operation



Computer Operation



- **2016 full year Operators vs. Computer simulation conducted**
- **Benefits of computer optimization:**
  - **Reduces peak demand on grid by 7.3 MW (35.9 MW vs 43.2MW)(17%)**
  - **Saves $500,000 per year (10%) in CEF electricity cost**
  - **Functions as 'autopilot' to run CEF**

Stanford Energy System Innovations (SESI) Components

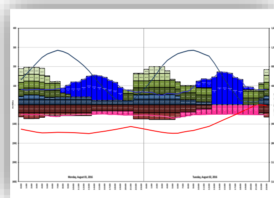
Heat Recovery
(District level application)

New thermal system
(Steam to hot water)

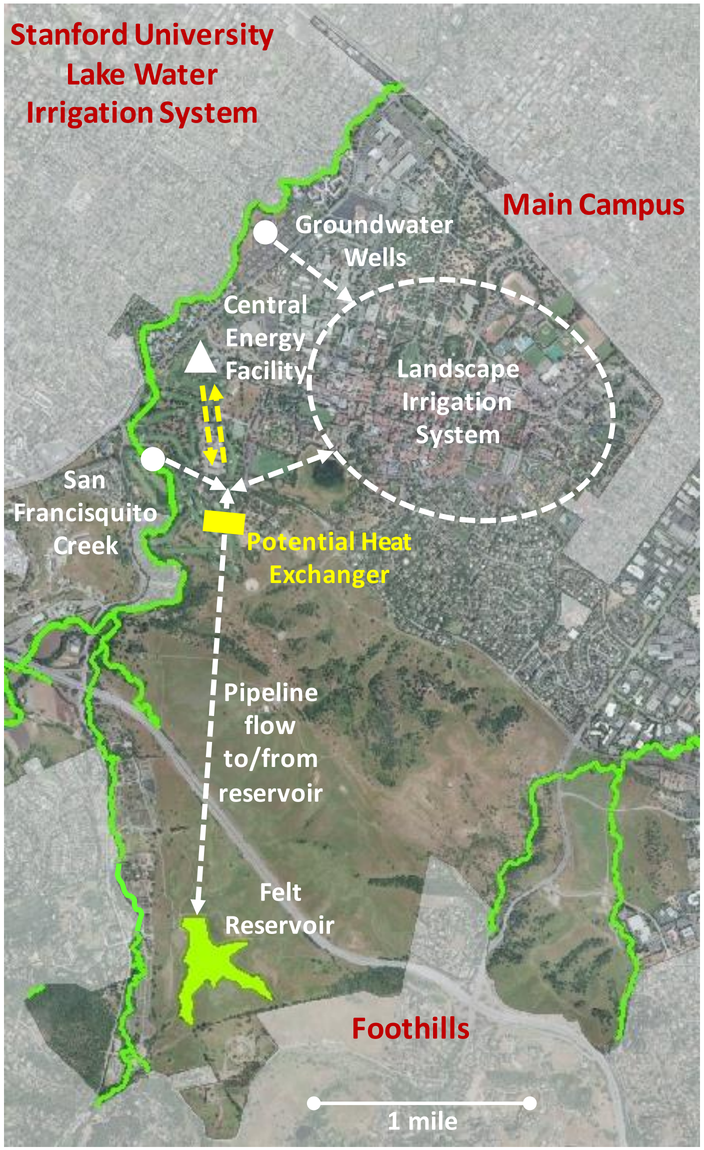
Renewable Energy Portfolio
(Purchased electricity)

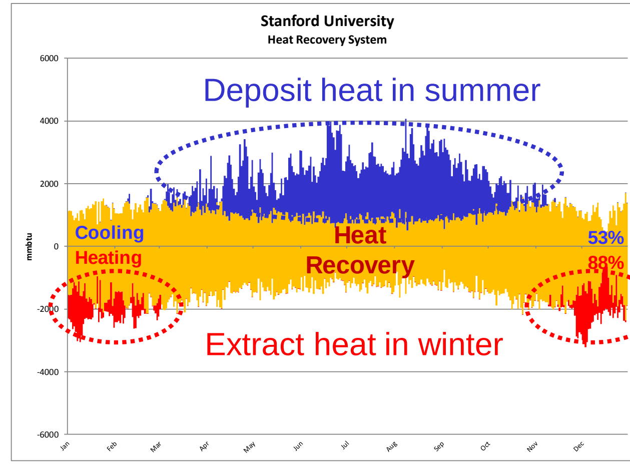
High-voltage substation
(New)

Advanced Energy Management Software
(Patented)

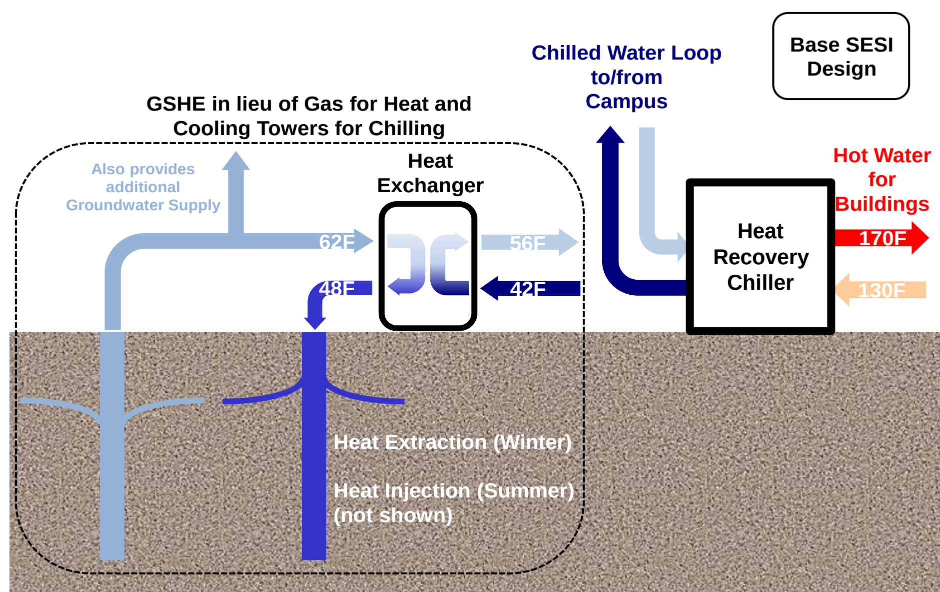


Enhancements under study





Ground Source Heat Exchange

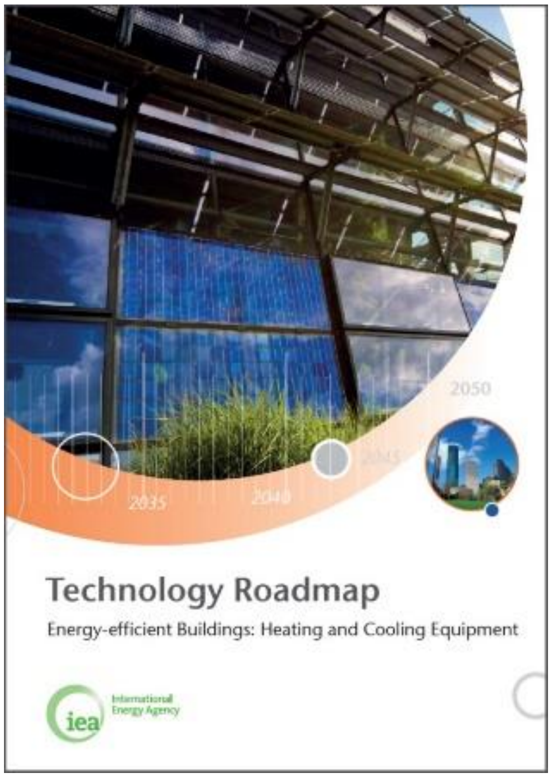


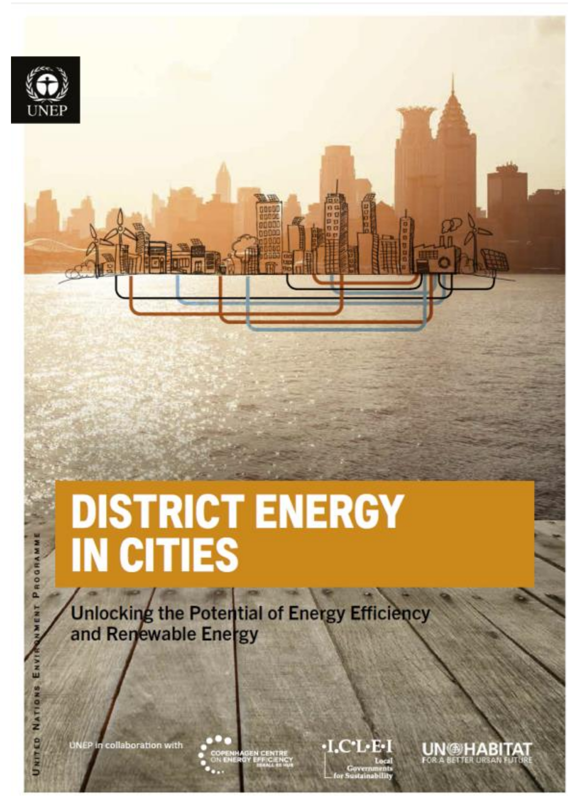
Stand Alone vs. District Energy

All concepts work at stand alone building level- residential on up

But application via District Energy even better

Application in new development even easier and more efficient

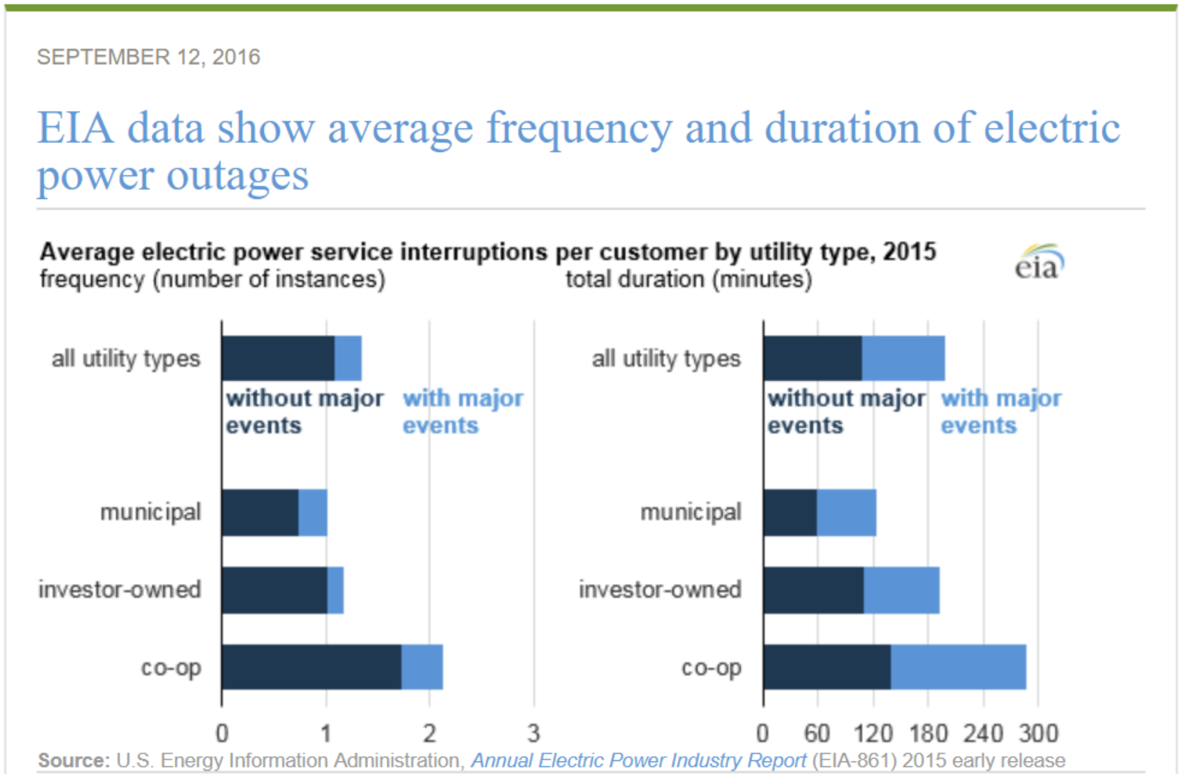




Reliability & Resiliency

"The electrical grid is far more reliable out west than back east…we have outages all the time and can't rely on the grid for something as essential as heating in winter"

"Electrification & Heat Recovery only works in mild climates like Stanford's…it won't work in cold climates like the Midwest or East"



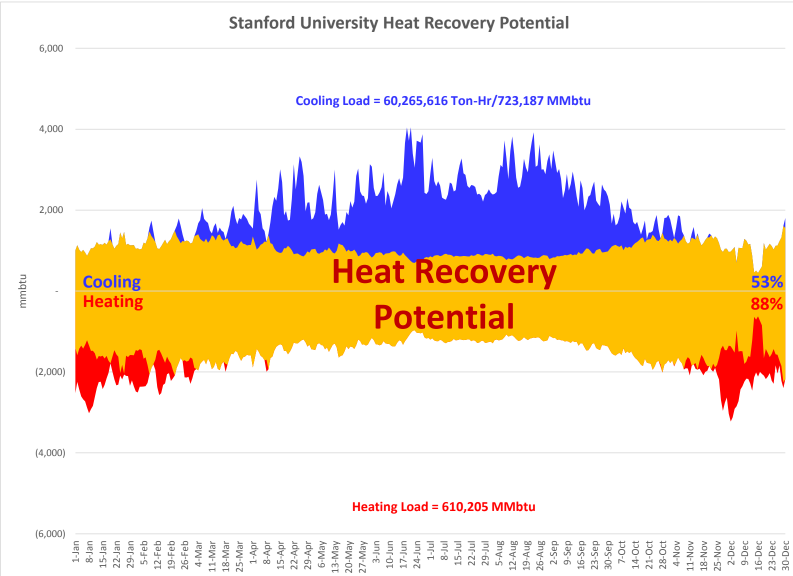
Heat Recovery (CHC) system has 4 sources of winter time heating energy:

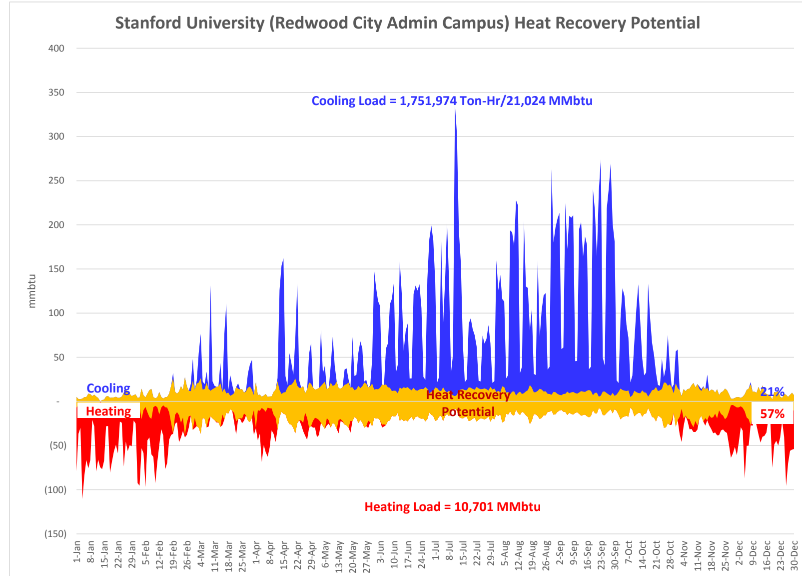
1. **Electricity (primary)**
2. **Thermal Storage (backup)**
3. **Natural Gas (backup)**
4. **Liquid Fuel (backup)**

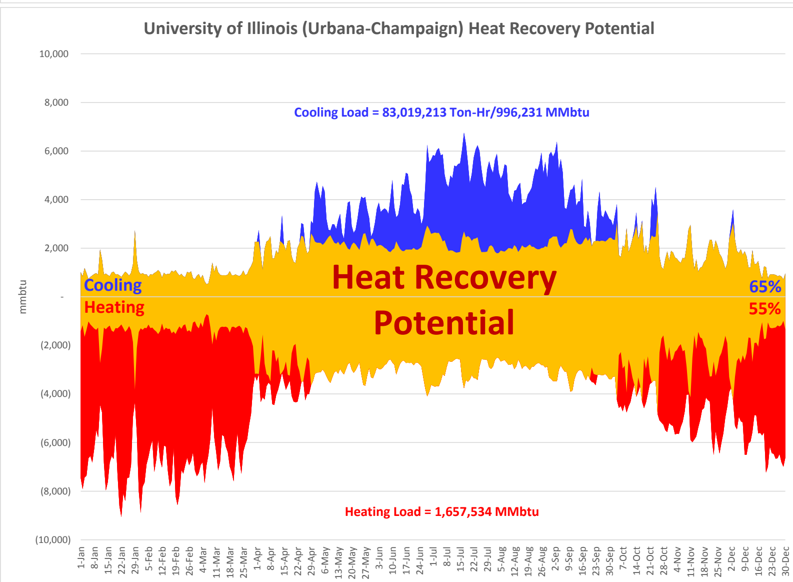
SHP and CHP systems only have 2 sources:

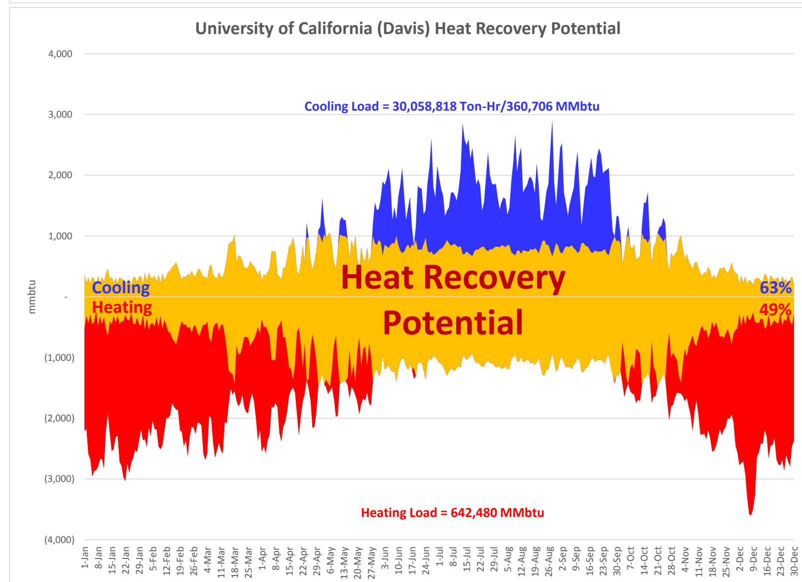
1. **Natural Gas (primary)**
2. **Liquid Fuel (backup)**

Electrification makes sense in ***all*** climates

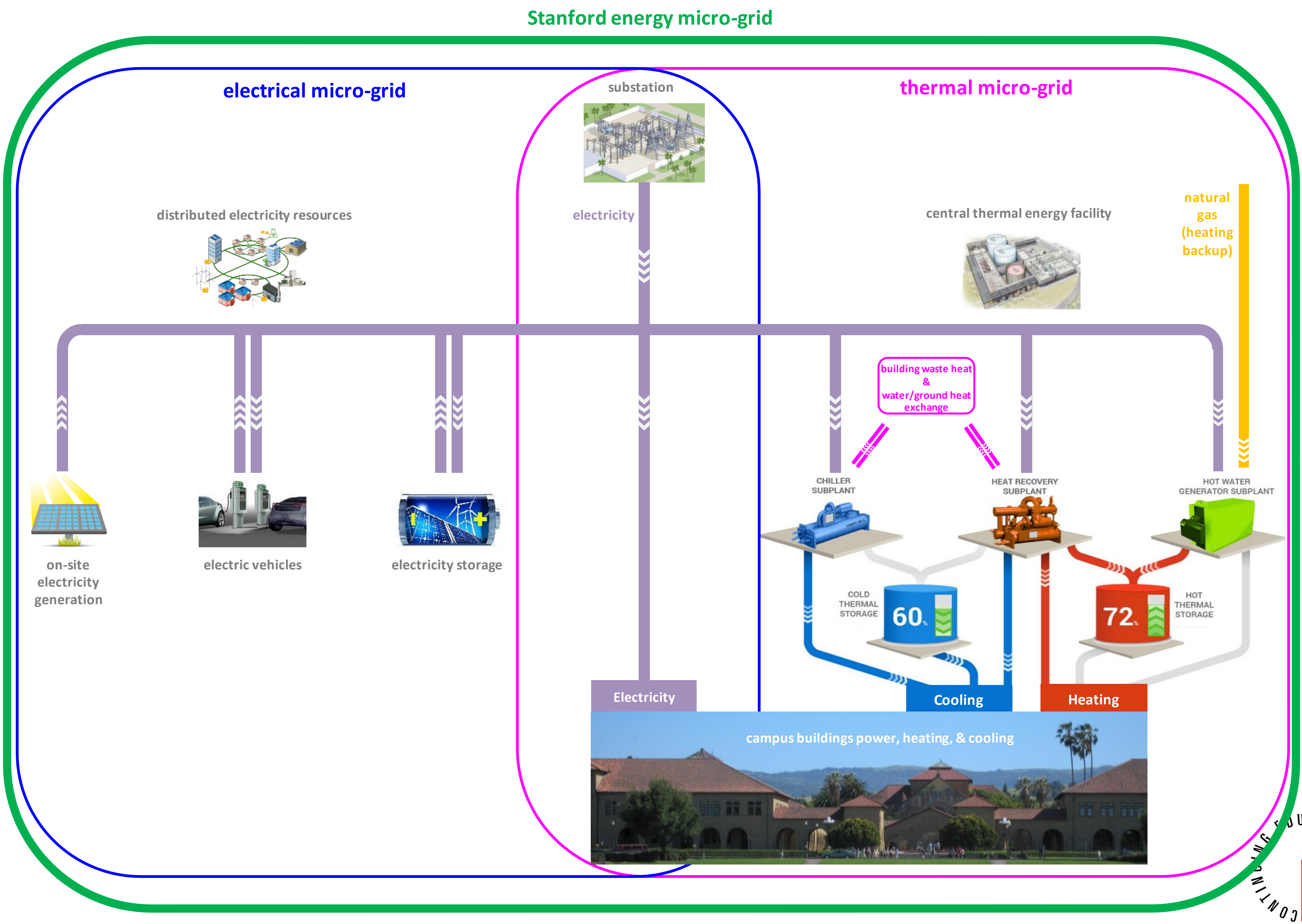








Total Energy Micro-grid...thermal before electric

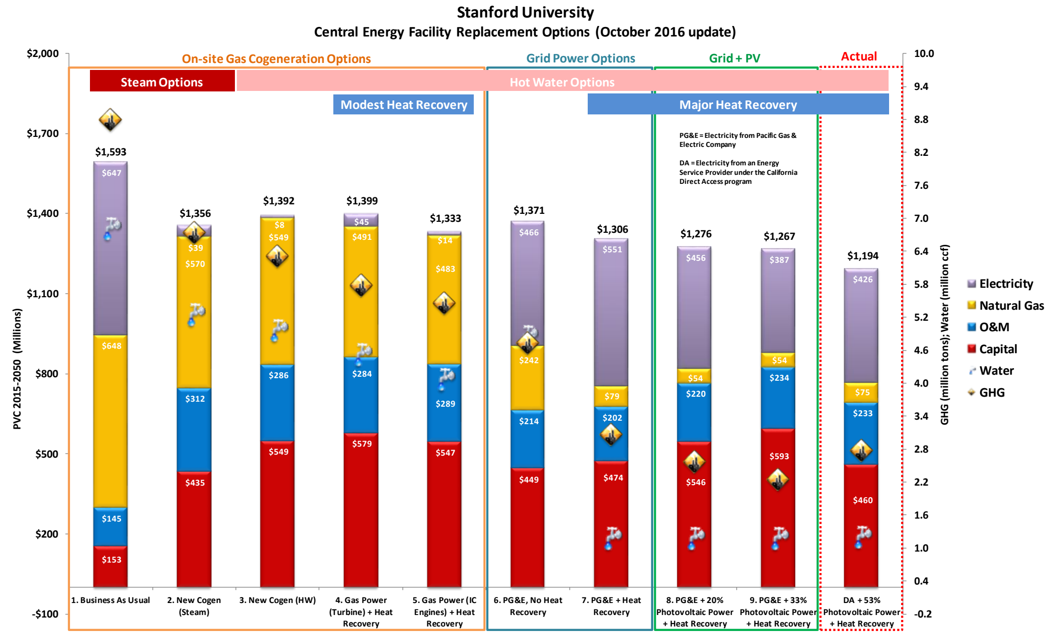


Planning for Building Electrification

1. Develop ‘8760’ tables of annual hourly estimates for building(s) electricity, heating/hot water, and cooling loads
2. Use simple ‘real time’ overlap comparison of hourly heating and cooling loads to see minimum heat recovery potential
3. Use MPC software such as Stanford’s CEPOM or JCI’s CPO for detailed planning and design of system and reveal of actual heat recovery potential, cost, GHG, water use, etc.
4. System can function without thermal energy storage and MPC but addition of these increase economics and efficiency by 20% or more
5. MPC models incorporate electricity and gas cost projection tables, grid greenhouse gas factors, and water use factors and costs to reveal total economics, efficiency, and sustainability results for different system configurations for comparison to standard HVAC systems or combined heat & power.

Other Considerations

1. Electrification not as desirable from sustainability perspective if no source of moderate to clean electricity (<800 lb/MWh GHG) is available…much of country is already there and once coal use goes down all will be there as 800 lb/MWh is about equivalent to an all-gas generation fleet
2. 100% clean electricity = 100% clean building energy
3. Electrification not as economical if gas is dirt cheap (<$3/MMBTU burner tip) and electricity is very expensive (>$100/MWh delivered)…and vice versa
4. Water savings is very substantial with heat recovery as 50% or more of current evaporative cooling tower use is eliminated
5. Compare overall long term life cycle cost of options



Sample Last Slide

This concludes The American Institute of Architects Continuing Education Systems Course

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