

Integrating Combined Heat and Power with thermal energy storage for optimizing building energy efficiency



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The Navy Yard

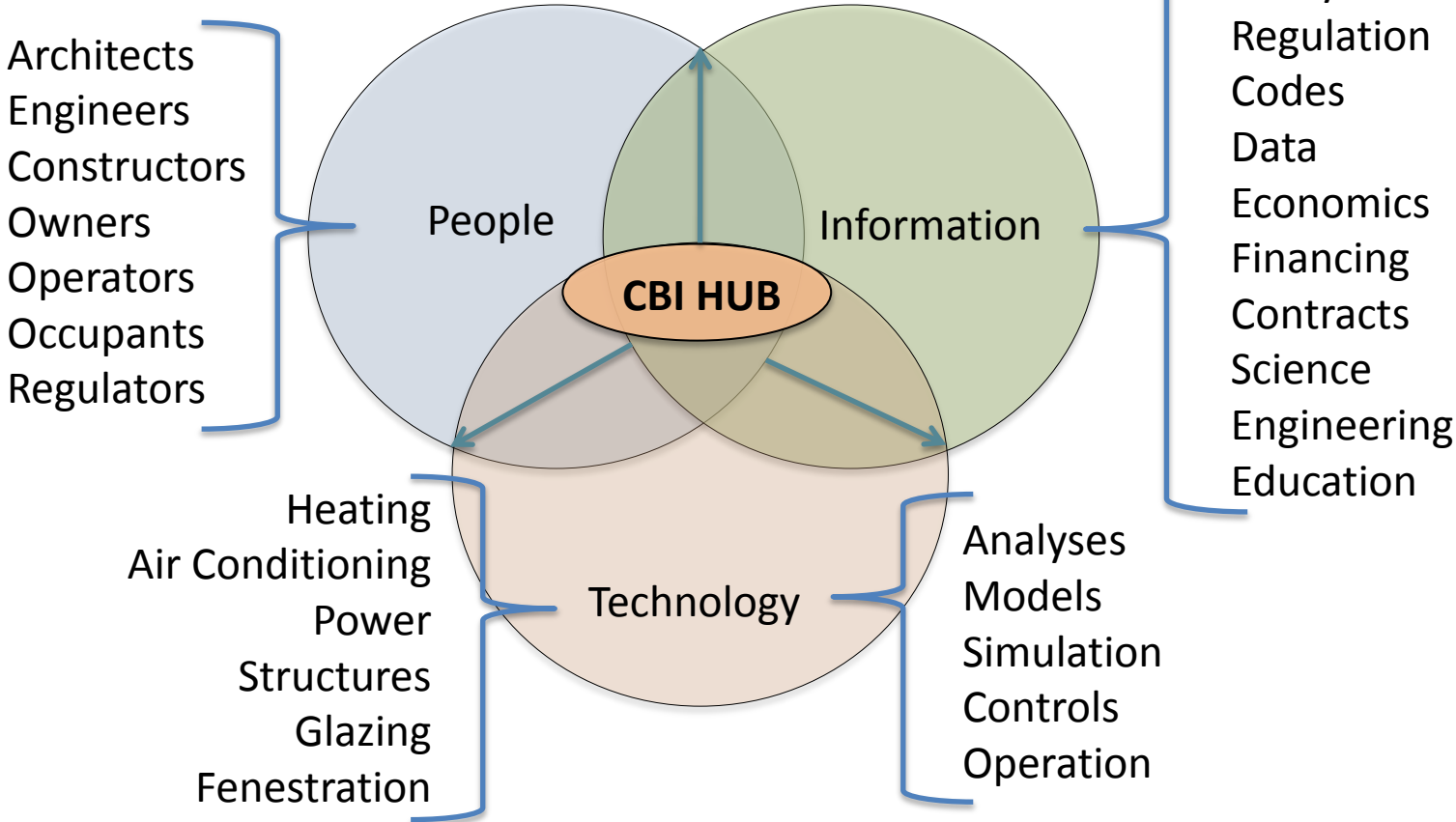
- Redevelopment project of regional and national significance
- Test bed for energy research and demonstration
 - Independent unregulated micro-grid
 - 270 buildings
 - Early 19th Century to new construction
 - Most occupied and some awaiting redevelopment,
 - Mix of industrial, commercial and government uses
- Multiple US Dept. of Energy Centers
 - Mid-Atlantic Clean Energy Applications Center
 - Northern Mid-Atlantic Solar Training Center
 - GridSTAR Smart Grid Training Center
 - **Consortium for Building Energy Innovation**



Consortium for Building Energy Innovation:

1. **Develop and deploy** to the building industry **state-of-the-art modeling tools** to support integrated design, construction, commissioning, and operation.
2. **Demonstrate the market viability of** integrating energy saving technologies for **whole building system solutions** at the Philadelphia Navy Yard and elsewhere in the region.
3. **Identify policies that accelerate market adoption of energy efficient retrofits of commercial buildings** and support policy makers in the development of supporting standards, codes and financial models.
4. **Inform, train, and educate people** about proven energy saving strategies and technologies whether they design, own, construct, maintain, or occupy buildings.
5. **Help launch business ventures** that will exploit market opportunities for providing whole building energy saving solutions.

The Challenge: Adoption



Combined Heat and Power (CHP)

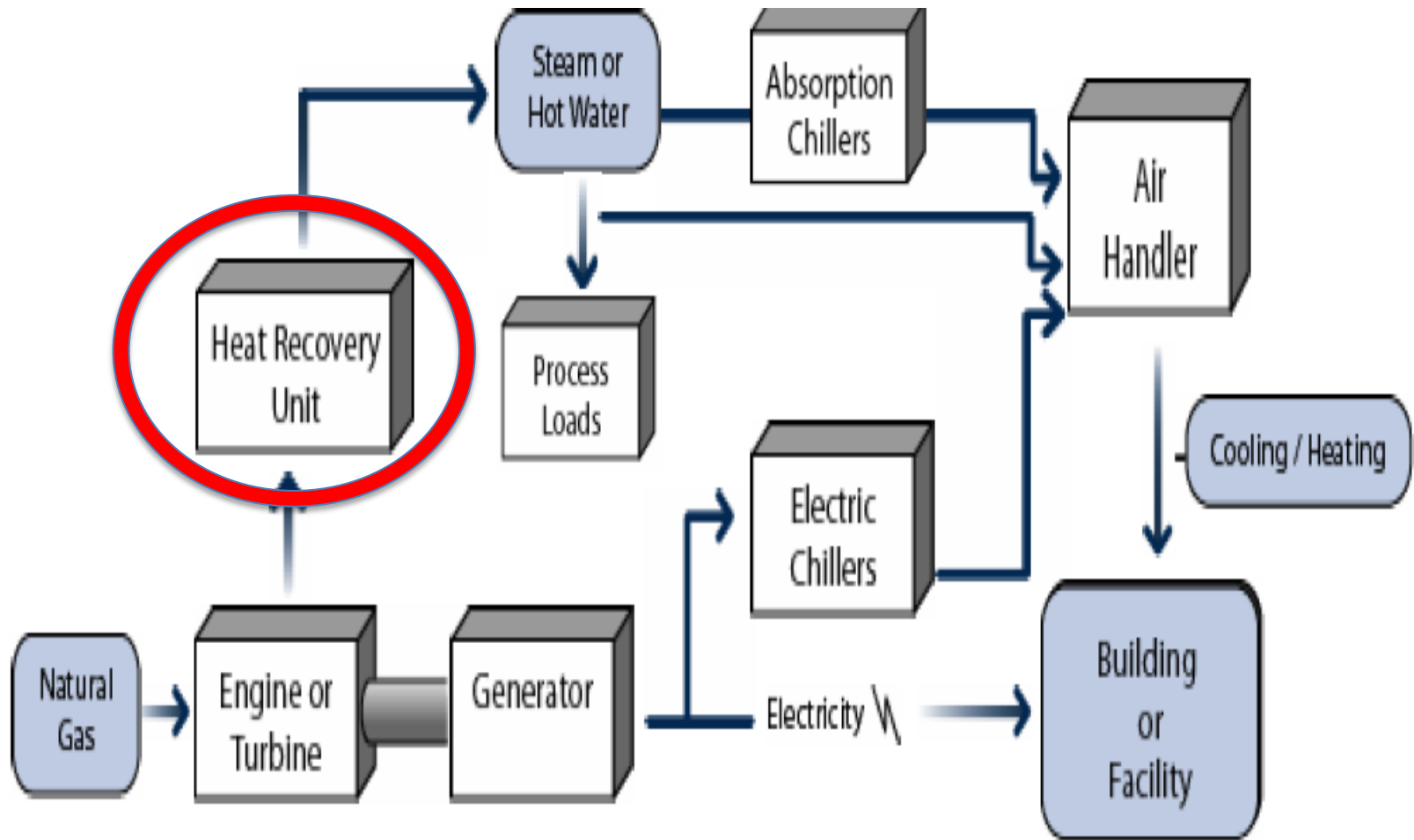
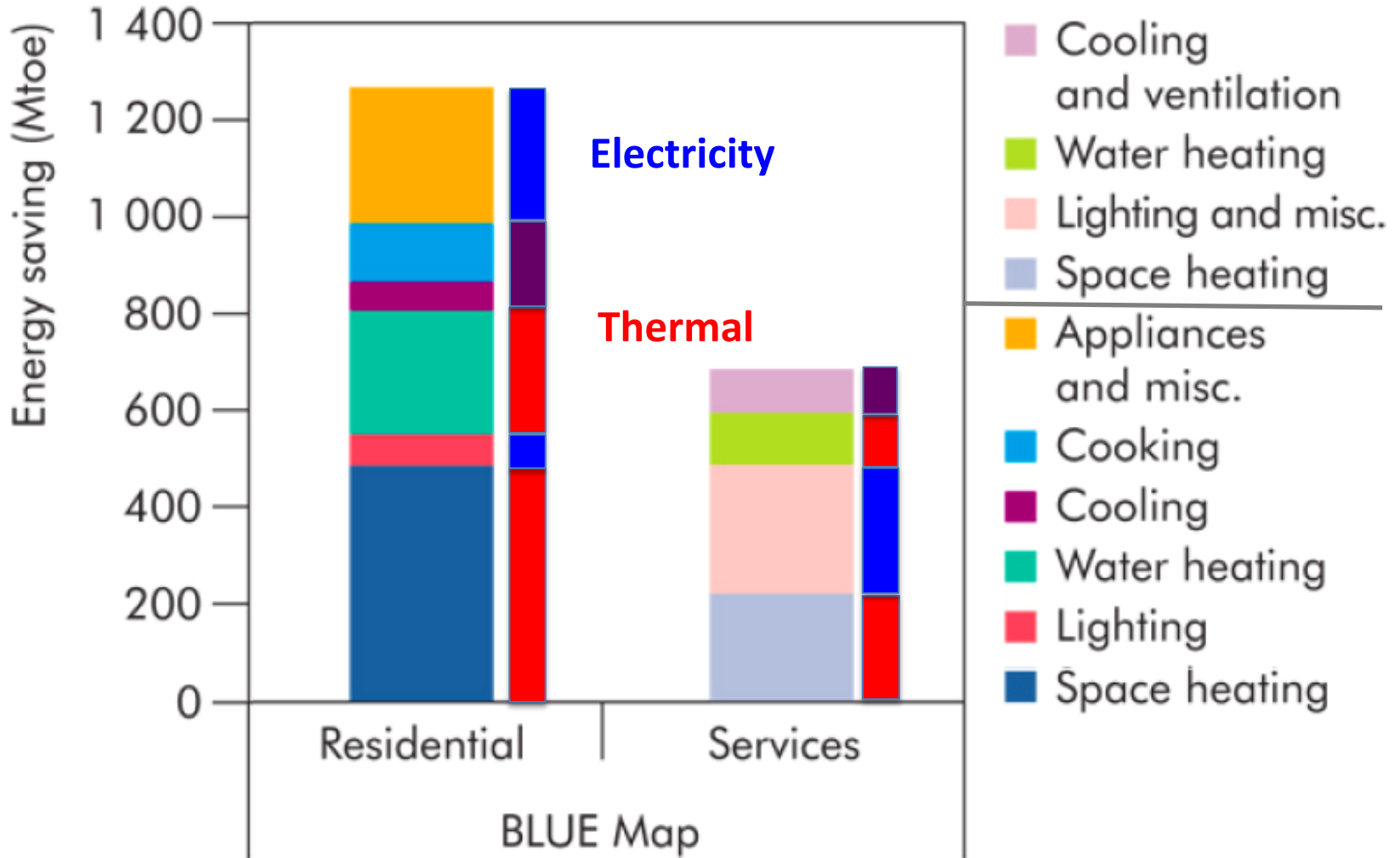


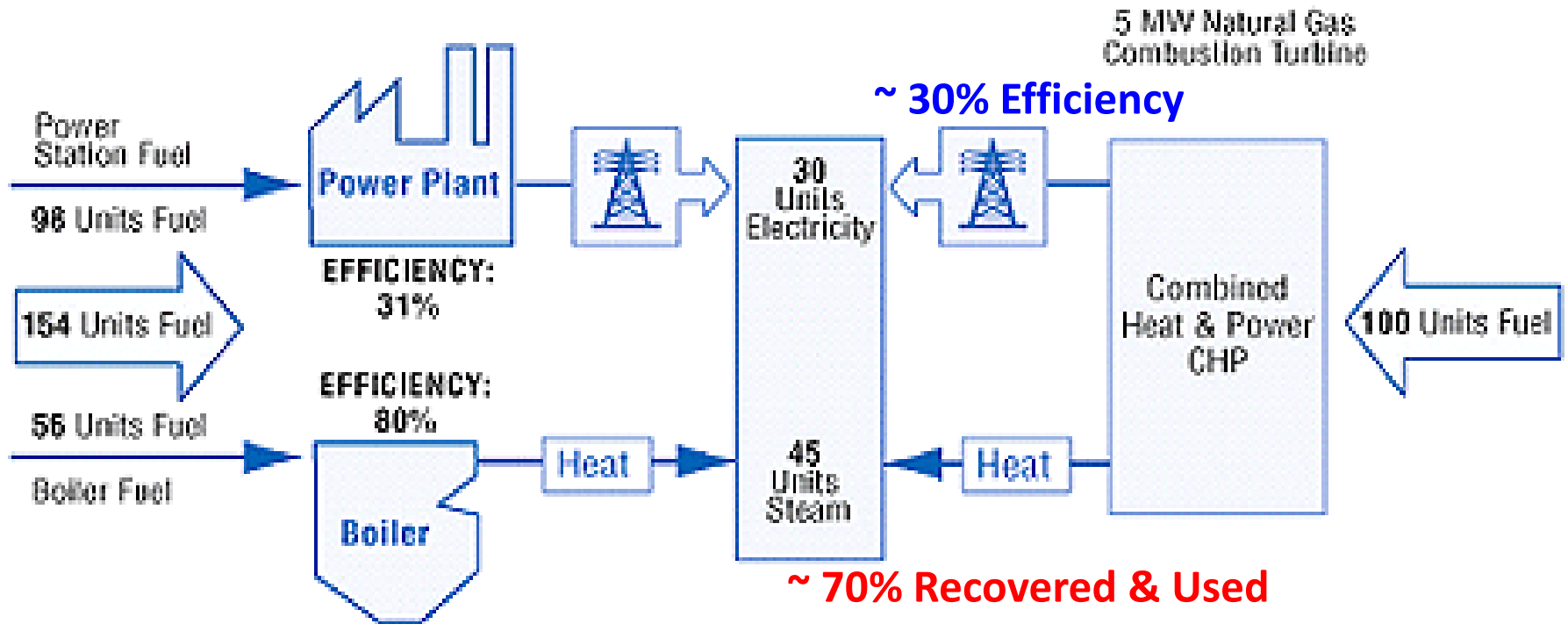
Figure 1-1 Conceptual Schematic Flow Diagram of a CHP System



International Energy Agency: Energy Technology Perspectives 2008

Separate Heat & Power (SHP)

vs Combined Heat & Power (CHP)



49% OVERALL EFFICIENCY

75% OVERALL EFFICIENCY

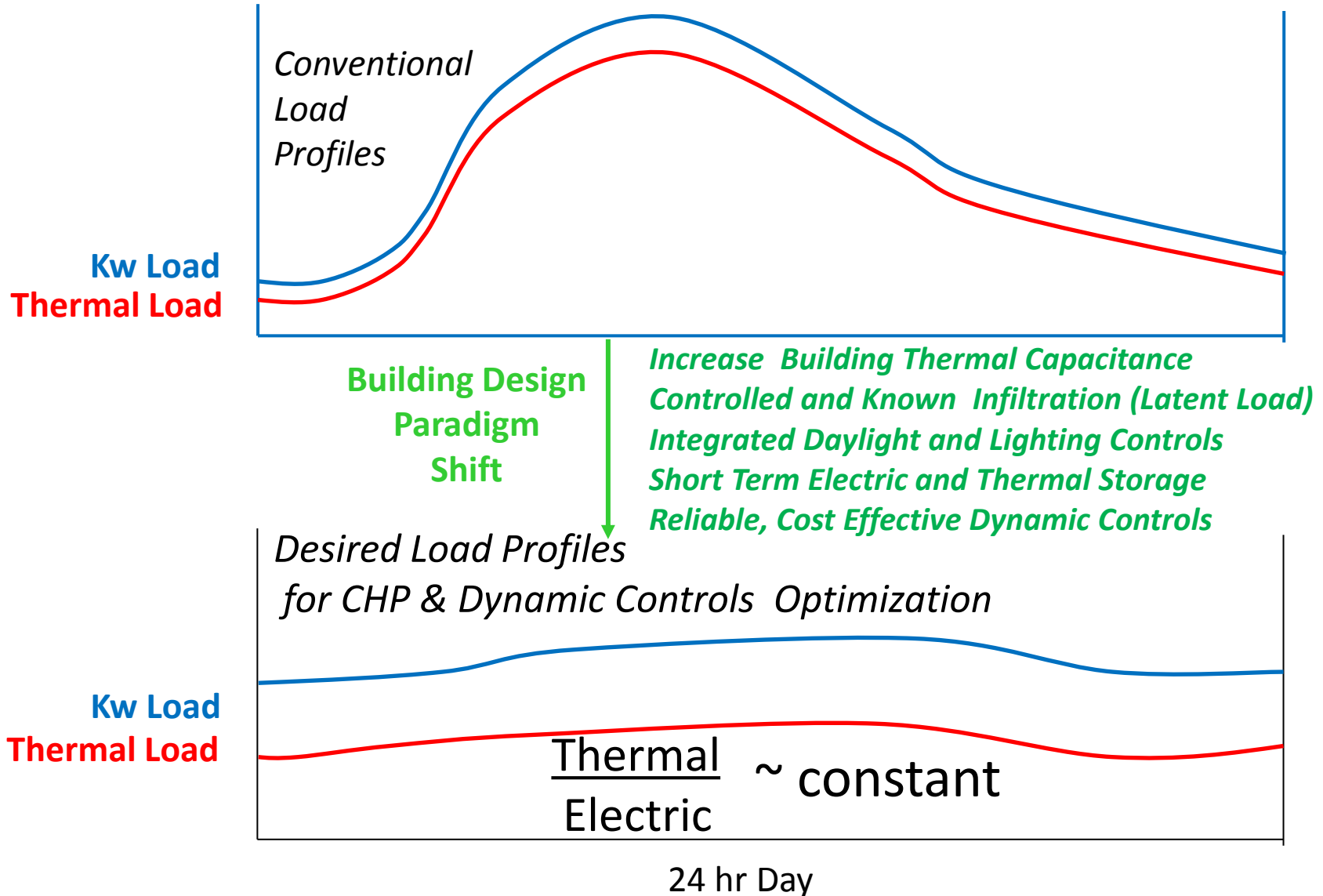
$$\lambda_U = \frac{\text{Heat}}{\text{Power}} = 1.5$$

*Lower emissions
Higher reliability
Lower Life Cycle costs?*

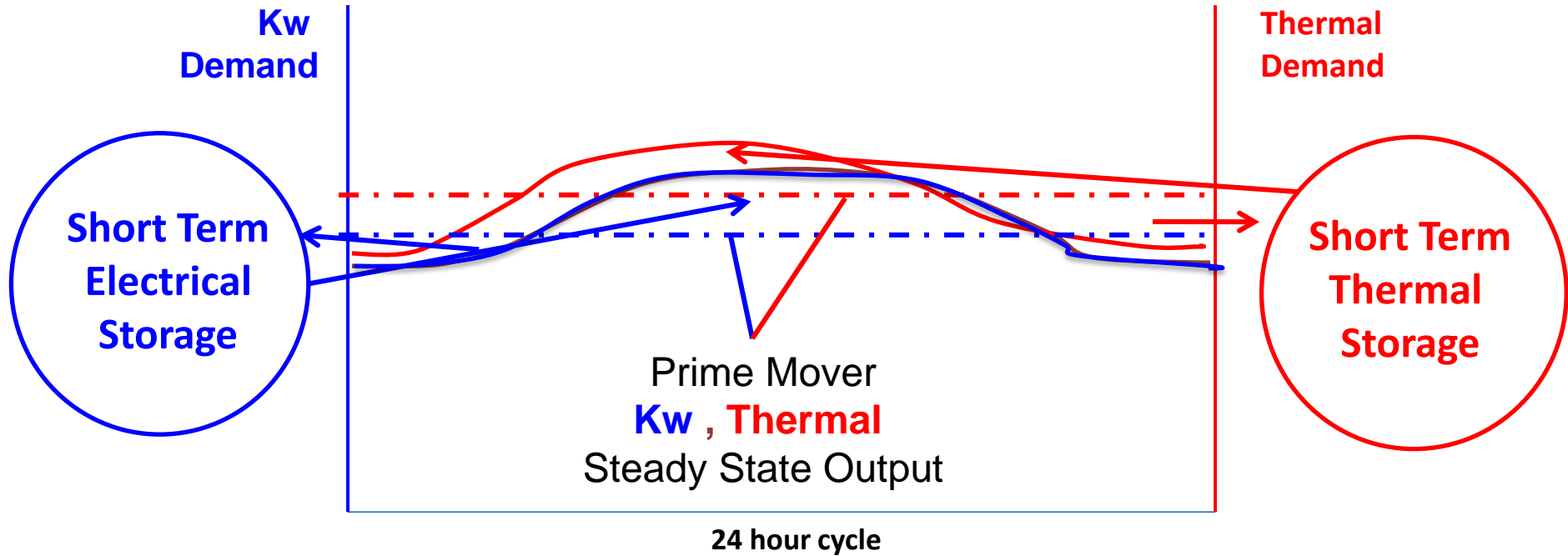
CHP (w/CH₄) Value Proposition

Category	10 MW CHP	10 MW PV	10 MW Wind	Combined Cycle (10 MW Portion)
Annual Capacity Factor	85%	25%	34%	87%
Annual Electricity	74,446 MWh	21,900 MWh	29,784 MWh	76,212 MWh
Annual Useful Heat	103,417 MWh _t	None	None	None
Footprint Required	6,000 sq ft	1,740,000 sq ft	76,000 sq ft	N/A
Capital Cost	\$20 million	\$15 million	\$24.4 million	\$10 million
Cost of Power	7.6 ¢/kWh	5.8 ¢/kWh	7.5 ¢/kWh	5.8 ¢/kWh
Annual Energy Savings	316,218 MMBtu	225,640 MMBtu	306,871 MMBtu	203,486 MMBtu
Annual CO₂ Savings	42,506 Tons	20,254 Tons	27,546 Tons	35,090 Tons
Annual NOx Savings	87.8 Tons	26.8 Tons	36.4 Tons	76.9 Tons

Putting Principles into Practice



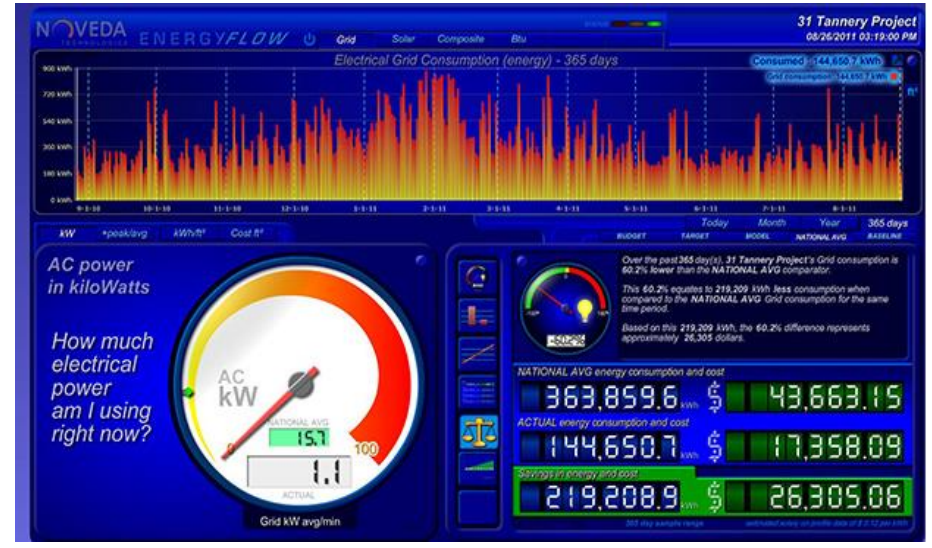
Flattening Loads, Coupling with Storage



And all this for \$X00/ft²
compared to \$X,000/ft²automobiles
\$X00,000/ft²aircraft
with no significant rebuilds or breakdowns in 20 years!

It's not rocket science, it's a lot more difficult!

Smart Buildings



Southface **Eco Office**

60 occupants

LEED Platinum

Homepage Green Features Solar

CAMPUS Hamilton **Kirner-Johnson** Find buildings

Electricity Solar PV Water Natural Gas

210 occupants **4th**

Total Electricity Use (kWh)

Day	SUN	MON	TUE	WED	THU	FRI	SAT
Usage	~130	~170	~200	~150	~240	~110	~100

22 kilowatt hours **104** Kilo watt hours so far this week

TOTAL PER PERSON TODAY WEEK MONTH YEAR kWh CO₂ \$

Homepage Comparisons Competitions

Green Roof & Solar Array

One hundred photovoltaic panels gather energy from the sun and cool the building. Next to the array is a turf roof, an emerging technology that Europe and some American cities. Turf roofs insulate, limit storm-water footprint that was displaced during construction.

LEED v2.0, Energy and Landscape

The majority of solar heat gain comes through windows, glazing the building itself allows it gain into the building can be minimized by using Low-E coatings on the windows.

Electricity Budget Tracker MENU

JAN 1 → JAN 31

January

1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18
19	20	21	22	23	24	25	26	27
28	29	30	31					

Goal: **\$250 or less**

So far this period: **\$188**

How are we doing? **7% too high**

8 Better than average days **5** Average days **8** Worse than average days

\$6.50 or less Around \$8.00 \$9.50 or more

Electricity End Use Breakdown MENU

12:00 AM - 8:30 PM

HVAC	LIGHTS	PLUGS	SERVERS	OTHER
40%	21%	28%	7%	4%

NOW HOUR TODAY WEEK MONTH YEAR

What are you doing to conserve? Submit

Also post on Facebook

Wilson Hall is hosting a Power Off event tomorrow night!
Tamara Klein, Jan 16 at 4:30pm Comment

Remember: phantom power is constantly used by plugged-in devices, even if they aren't on!
Sarah White, 12 minutes ago

That means turn off those lava lamps, too! :)
Abhay Saha, 2 hours ago

Lowes

Adam Joseph Lewis Center
Lewis-Maker Hall
Lewis Place

670 gal/day

24,090 Gallons so far this week

Comparisons Competitions

Your Buildings

37% reduction

35%

34%

30%

27%

27%

Dascomb
This building used 23 kWh yesterday, or 15% below baseline consumption.

REAL-TIME DATA

250 occupants

20,000 SQUARE FEET

CHANGING RANK

16 Jul 12

Clinton, NY MENU

Mostly sunny **72°F**

Humidity: 13% Pressure: 29.00 in Hg Wind: **10W 26 mph**

Sunrise: 8:05 am Sunset: 8:20 pm

Lucid Design Group

Energy Flows

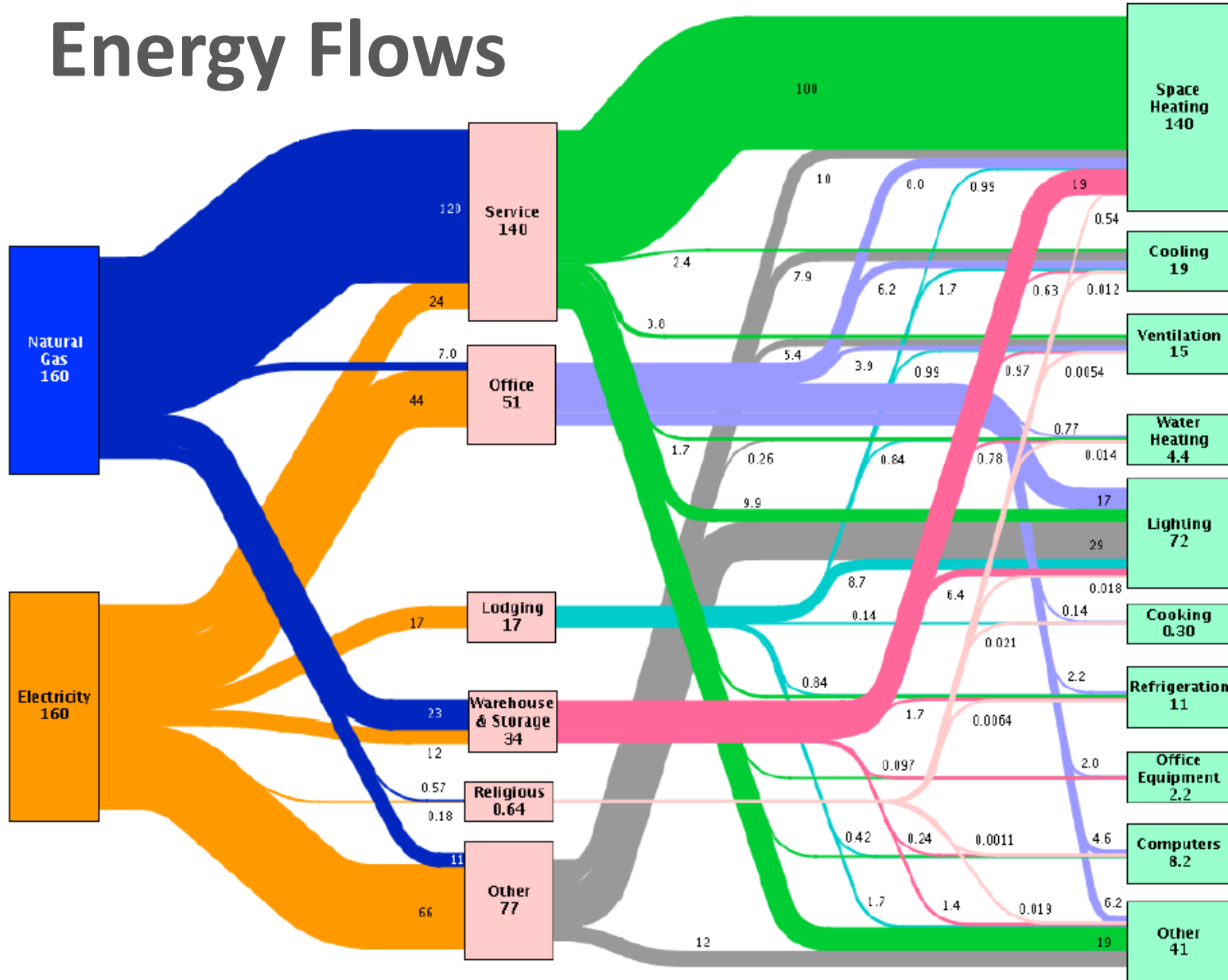
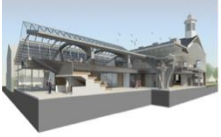


Figure 1 Navy Yard Energy Analysis: Estimated using EIA Commercial End Use Data (MBtu).

Singer and Simon, 2013. LLNL-TR-613594

The Navy Yard: Living Lab and Education Center



EAST FACADE



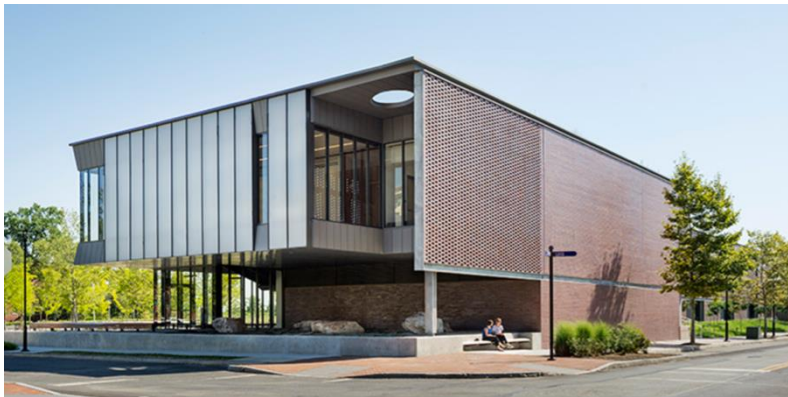
S.W. CORNER



GYM INTERIOR



ROOF & PARKING LOT



Consortium for Building Energy
Innovation

Advanced Energy Retrofit

Living CBEI Laboratory

Permanent CBEI Headquarters

