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

Tom Richard

Jim Freihaut

Penn State University

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.

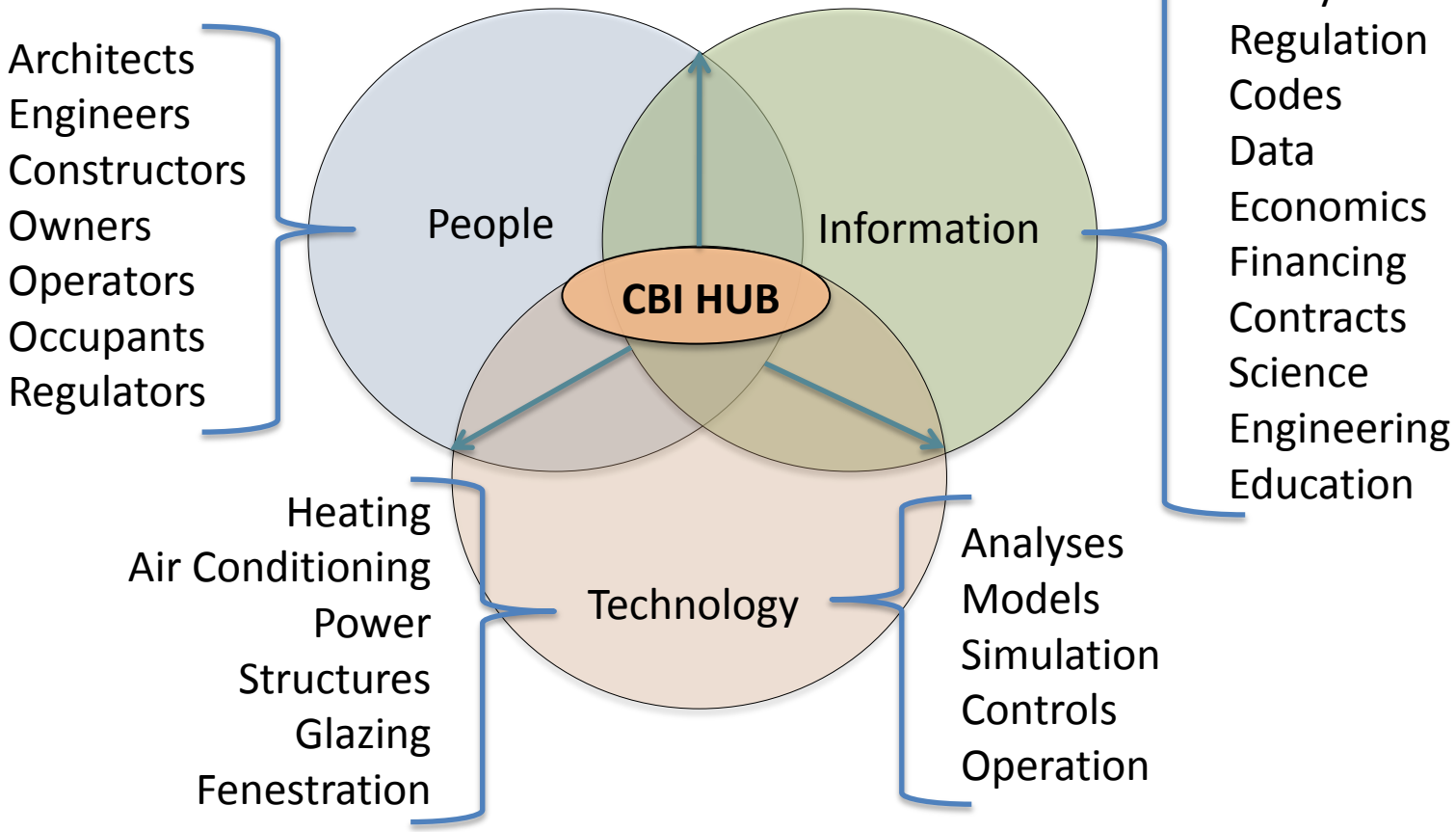
2. Demonstrate the market viability of integrating energy saving technologies for whole building system solutions at the Philadelphia Navy Yard and elsewhere in the region.

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)

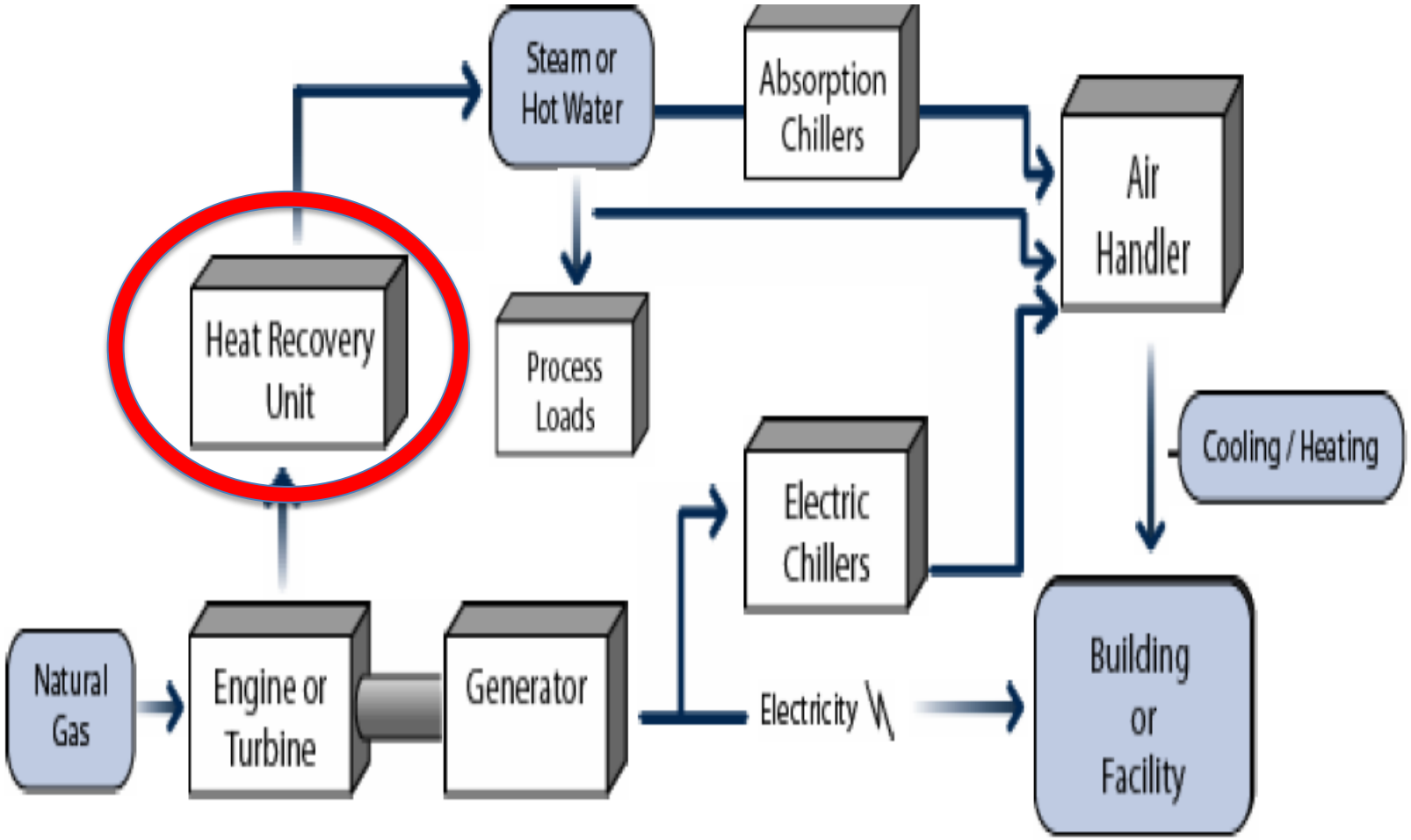
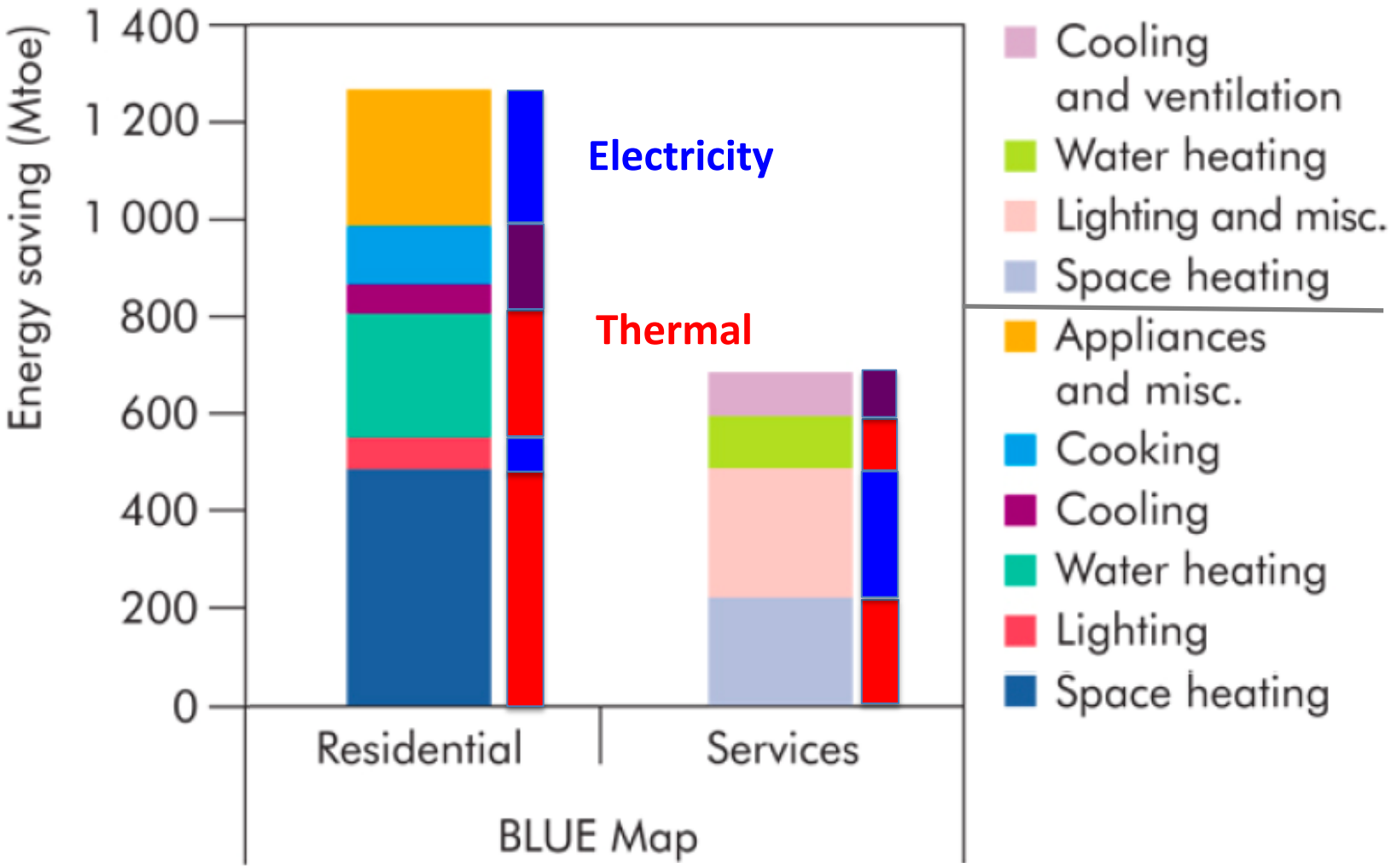
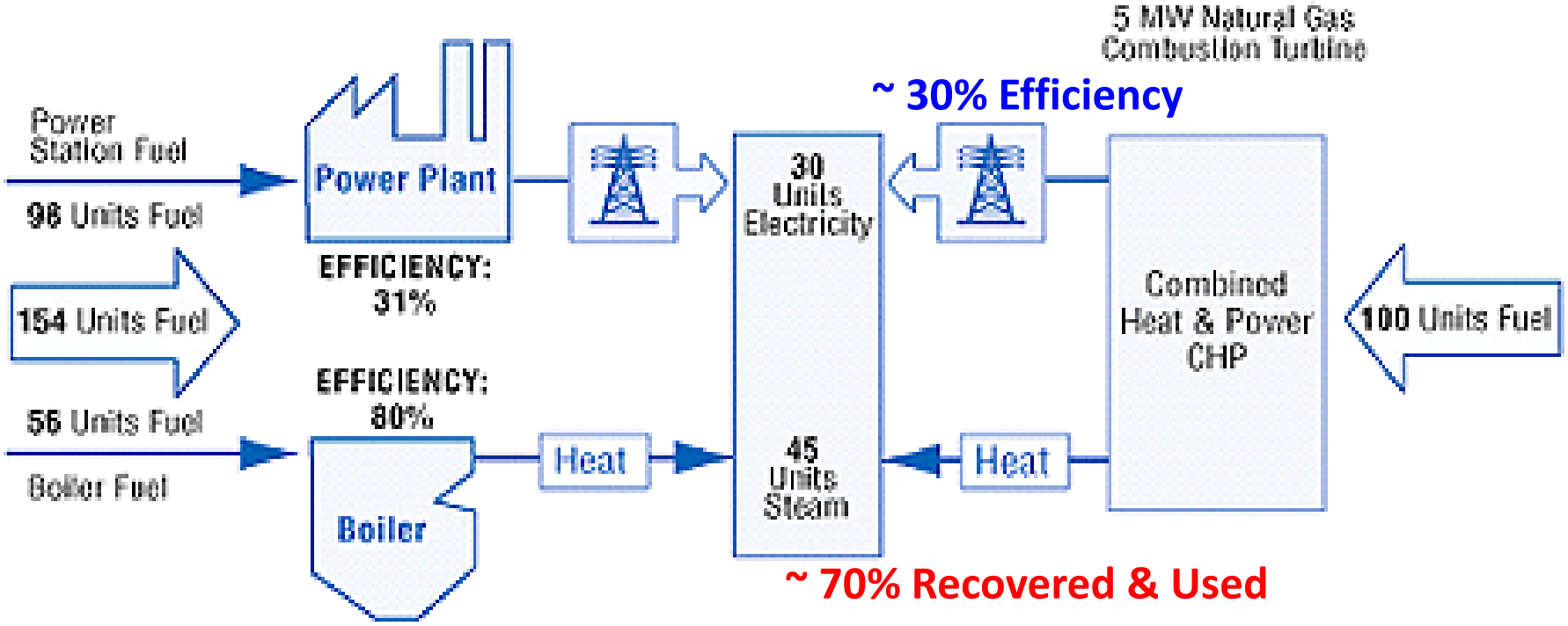


Figure 1-1 Conceptual Schematic Flow Diagram of a CHP System



International Energy Agency: Energy Technology Perspectives 2008

Separate Heat & Power (SHP) vs Combined Heat & Power (CHP)



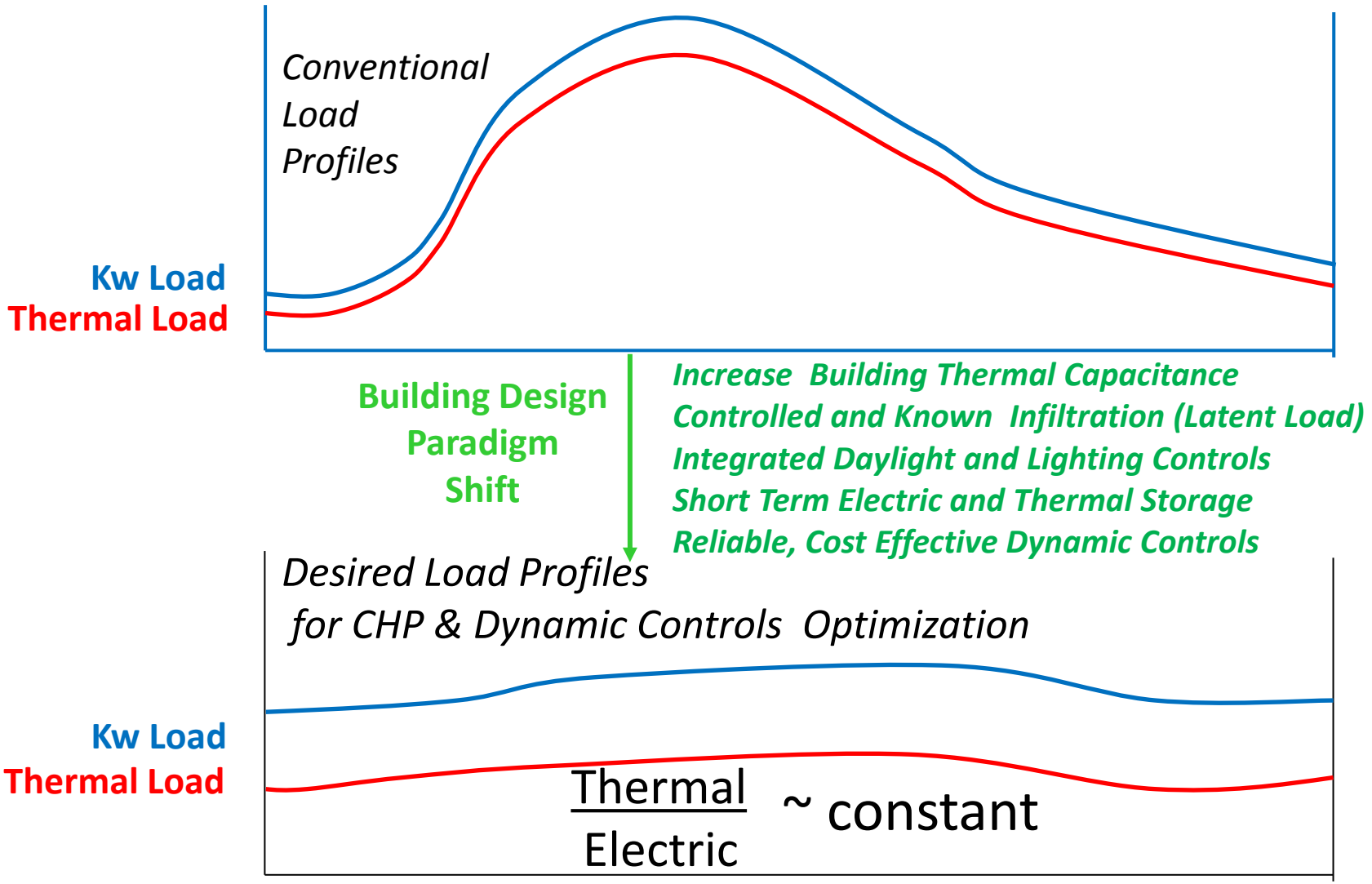
$\lambda_U = \frac{\text{Heat}}{\text{Power}} = 1.5$

Lower emissions
Higher reliability
Lower Life Cycle costs?

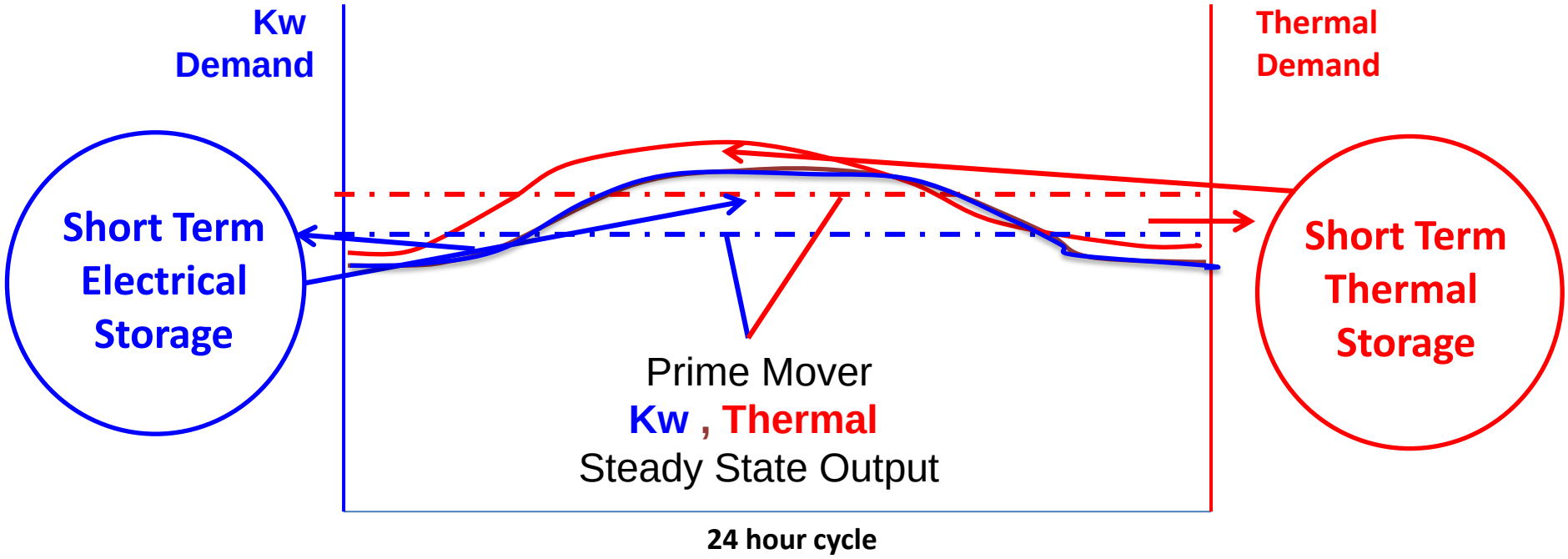
CHP (w/CH_4) Value Proposition

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 CO_2 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

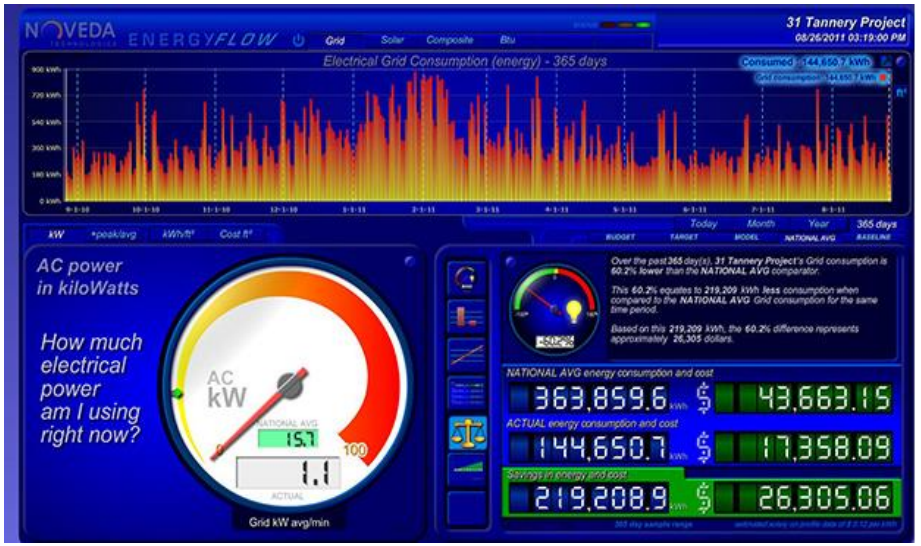
compared to **$X,000/ft² ……..automobiles**

$X00,000/ft² …….aircraft

with no significant rebuilds or breakdowns in 20 years!

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

Smart Buildings



Lucid Design Group

Energy Flows

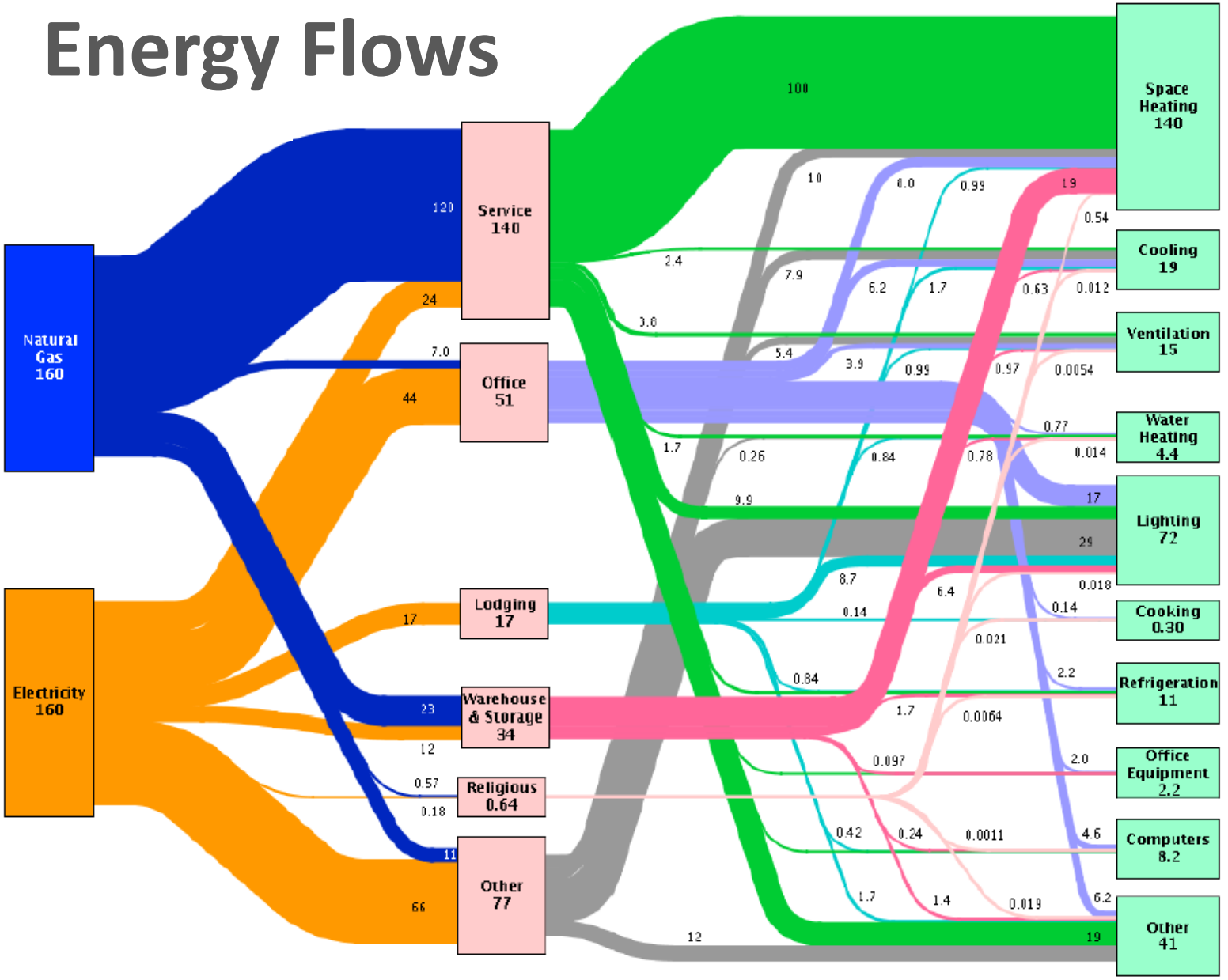
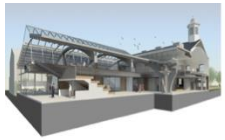


Figure 1 Navy Yard Energy Analysis: Estimated using EIA Commercial End Use Data (MBtu).

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

PennState
Institutes of Energy and the Environment