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# EEBHub Navy Yard Sankey Diagram Energy Analysis Final Report

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**EEBHUB NAVY YARD SANKEY DIAGRAM ENERGY ANALYSIS**

**FINAL REPORT**

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## Executive Summary

The Energy Efficient Buildings Hub (EEBHub) uses Sankey diagrams to visually analyze energy uses among buildings within the Navy Yard. This report describes the preliminary steps taken to incorporate multiple buildings in a district energy analysis, which can eventually be expanded to the Greater Philadelphia Region.

The Navy Yard analysis incorporates ~170 buildings, with energy flows and data broken down to building type and end use based on Energy Information Administration (EIA) commercial data for buildings. The electricity and natural gas consumption is provided by EEBHub. The largest end uses of fuel consumption are space heating (~140 MBtu) and lighting (~72 MBtu). The natural gas consumption is heavily used in the service areas (~120 MBtu) mainly for space heating. The electricity consumption is more evenly spread out among building type with the largest uses in office space and other (description in Appendix B).

As the Navy Yard data gets updated, there are opportunities to analyze the Navy Yard in other formats. The results of this preliminary analysis are to identify large sources of energy consumption, recognize gaps in data, and use Sankey visualizations to address the goals of the EEBHub.

## Introduction

The Energy Efficient Buildings Hub (EEBHub) requested visualization of energy flows in Sankey format for buildings in the Navy Yard. These diagrams provide a compact representation of quantitative information from multiple sources of data. This work will lay the groundwork for visualizing building energy use within the Greater Philadelphia Region, which is instrumental to demonstrating the success of EEBHub. A quantitative understanding of inter-related energy flows helps to identify opportunities to deploy energy saving technologies.

The Sankey diagrams address several objectives identified by EEBHub

- Integrate design, construction, commissioning, and operation of buildings
- Integrate energy saving technologies for whole building system solutions at the Navy Yard and elsewhere in the region
- Inform, train, and educate people (i.e. policy makers, community, workforce) about proven energy saving strategies and technologies

This report describes a preliminary analysis of energy usage and flows among buildings in the Navy Yard. The starting point of this project was to sketch a qualitative Sankey diagram that identifies important sources of energy consumption. We chose to analyze data by building primary use type to estimate end use consumption of the buildings. Details of the analysis are described in Appendix A.

The two sources of data used in this analysis are:

- Energy Information Administration (EIA) tables that list major components of energy consumption for commercial buildings as displayed in Tables A2 and A3.
- Navy Yard data that includes building use type of 528 entities, annual electricity usage for 89 buildings, and annual natural gas usage for 48 buildings.

As the understanding of the Navy Yard energy use is updated and refined, Sankey diagrams can be updated and modified.

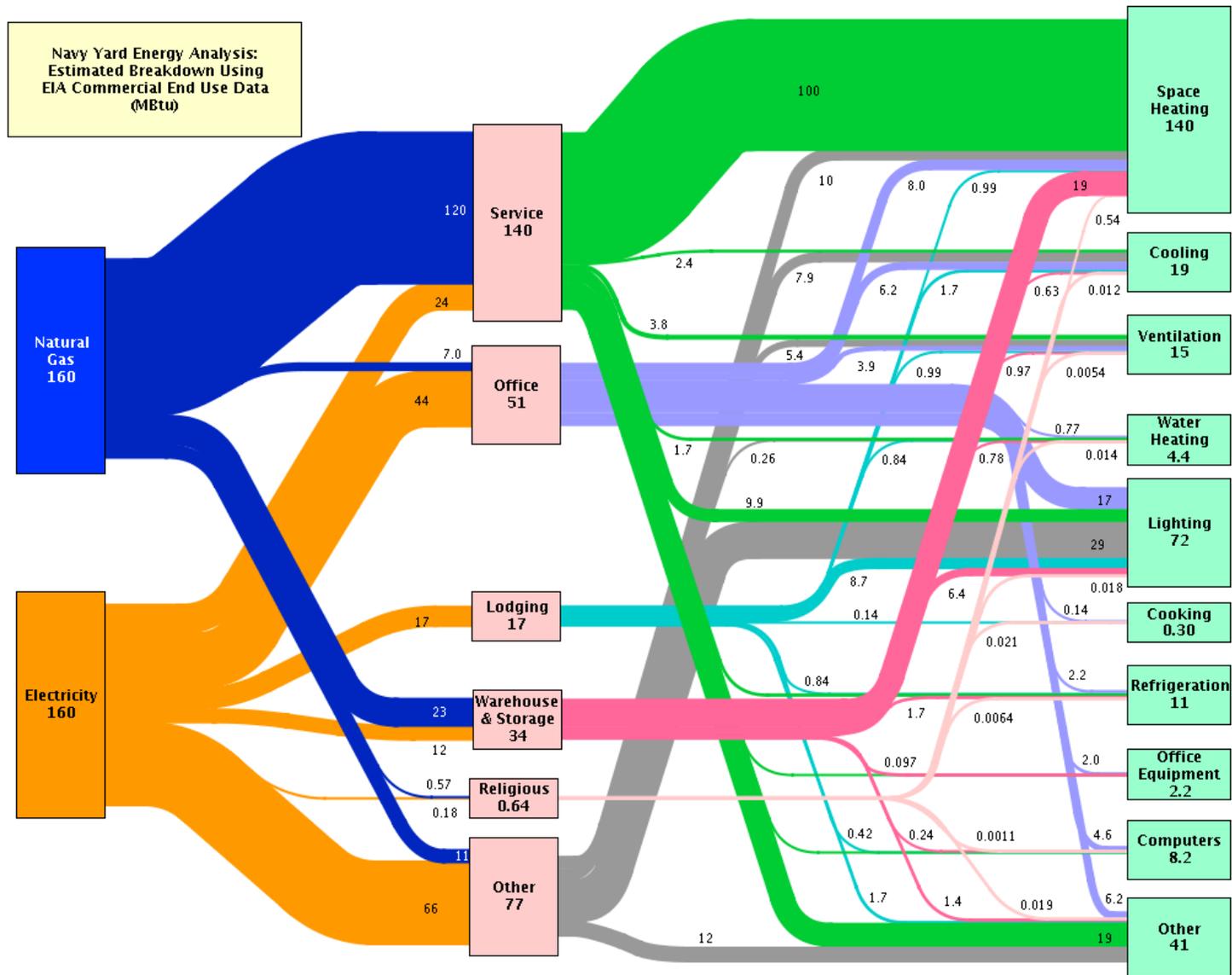


Figure 1 Navy Yard Energy Analysis: Estimated using EIA Commercial End Use Data (MBtu).

## Analysis

The starting point for this analysis was the 1/2010 – 12/2011 energy consumption data for all Navy Yard buildings collected by the electric and gas utilities that serve the Navy Yard. These data were organized into a single spreadsheet containing electricity and natural gas use for ~170 existing buildings. Of these buildings, ~100 consume metered electricity, and ~60 consume natural gas. Such a large number of buildings cannot be individually depicted (each with its own “box” for energy use) on a single Sankey Diagram. Therefore, we chose to aggregate the buildings in the Navy Yard by usage type (lodging, office, warehouse, etc.)

Because most of the buildings at the Navy Yard are not sub-metered, we needed a way to estimate the fractions of electricity and gas that are put to various end-uses (heating, lighting, etc.) in each building. We chose to use EIA’s 2003 Commercial Buildings Energy Consumption Survey data to estimate the end-use energy loads in each building.

For each building at the Navy Yard, we multiplied the quantity of natural gas consumed (as metered) by the EIA-estimated fraction of natural gas energy applied to each end use in that building type. Similarly, we multiplied the quantity of electricity consumed (as metered) by the EIA-estimated fraction of electricity applied to each end use in the building’s type. See Appendix A for the fractions of consumption applied.

We then combined these flows (2 energy types used in 10 end-uses each) into a maximum of 10 flows from each building type to the end uses. In this way, the total energy consumed for each end use can be compared with the total energy consumed for each type of building.

It should be noted, however, that this visualization is a draft, and based on preliminary energy consumption data provided by the utilities that serve the Navy Yard. While all data have been normalized to reflect annual energy use, the data are from the most recent time period available, and are not based on a statistically representative sample of historical values.

## Conclusions

The Navy Yard Sankey diagrams depict estimated energy flows based on end uses of commercial buildings. The estimated end use values are preliminary, so they are not specific to Philadelphia or the Navy Yard.

The Sankey diagram does, however, provide a framework in which to discuss future sub-metering efforts at EEBHub. When a majority of the buildings are instrumented, this diagram will transition from an estimate of energy consumption to a compact form of energy use reporting.

Specific actions may be taken to speed this transition. For example, the Hub may want to focus on a specific building class (e.g. office buildings), and could choose to focus its efforts on the specific subset of buildings belonging to that class. Alternatively, the Hub might choose to focus on the largest end uses of energy: heating and lighting.

If available, the Hub might also choose to analyze historical data and compare year-over-year energy use, or depict the evolution of the Navy Yard's energy distribution systems (transition from steam to gas heating, for example.)

Ultimately, this preliminary graphic serves as a strawman template for a regional energy dashboard, whose key attributes will be defined by EEBHub personnel and other stakeholders.

### **References:**

Energy Information Administration. 2003 Commercial Buildings Energy Consumption Survey: Energy End-Use Consumption Tables. Table E3 and E7.

## Appendix A: Energy Component Data for Navy Yard Sankey Diagrams

A breakdown of energy data by commercial building type and end use is published by the Energy Information Administration (EIA)<sup>1</sup>. The data is separated into seven categories of principal building activity (i.e. food sales, lodging, office, religious worship, service, warehouse and storage, and other). The EIA data also breaks down major fuel consumption to end use (Table A1).

Data for the Navy Yard buildings includes the primary building type and estimated electricity and natural gas consumption<sup>2</sup>, and is currently being updated by collaborators in the EEBHub. Older versions of the data may have significant uncertainties associated with the data. Possible reasons include: buildings have changed from steam to natural gas for heating, and permission for data collection is still needed for some buildings.

The steps taken to evaluate the building data:

- 1) From the EIA tables, calculate the fraction of end use type for each building type (i.e. lighting end use takes ~ 53% of the total electricity consumption for lodging building type). Table A1 lists building and end use type used in the Navy Yard analysis. Table A2 and Table A3 show the fraction of consumption by each end use type.
- 2) The Navy Yard data is separated into building type, shown in Table A4. The electricity and natural gas data are broken down into end use by making them proportional to EIA end use data calculated in step 1. These estimates of fuel use are shown in Table A5.

**Table A1** Building type and End Use categories used for the Sankey Diagram

<b>Building Type</b>	<b>Electricity Consumption End Use</b>	<b>Natural Gas Consumption End Use</b>
food sales	Space heating	Space heating
lodging	Water heating	Water heating
office	Cooking	Cooking
religious worship	Other	Other
service	Cooling	
warehouse & storage	Ventilation	
other (incl. non-categorized)	Lighting	
	Refrigeration	
	Office Equipment	
	Computers	

<sup>1</sup> source: *EIA Major Fuel Consumption (Btu) by End Use for Non-Mall Buildings, 2003*

<sup>2</sup> [Navy Yard data was taken from the file provided in email from Robert Leicht to A.J. Simon "NavyYardData\_UTRC\_29Mar.xlsx", 9/19/12]

**Table A2** End Use Fraction of Total Natural Gas Consumption for Building Type, Modified from EIA Table E7: Natural Gas Consumption (Btu) by End Use for Non-Mall Buildings, 2003.

	Space heating	Water heating	Cooking	Other
Food Sales	0.69	0.05	0.21	Q <sup>3</sup>
Lodging	0.30	0.58	0.07	Q
Retail	0.92	0.03	0.03	0.02
Office	0.86	0.05	0.01	0.09
Religious Worship	0.94	0.02	0.04	Q
Service	0.86	0.01	Q	0.12
Warehouse & Storage	0.84	0.03	Q	Q
Other	0.83	0.02	Q	0.14
Vacant	0.93	Q	Q	Q

**Table A3** End Use Fraction of Total Electricity Consumption for Building Type, modified from EIA Table E3: Electricity Consumption (Btu) by End Use for Non-Mall Buildings, 2003

	Space heating	Cooling	Ventilation	Water heating	Lighting	Cooking	Refrigeration	Office Equipment	Computers	Other
Food Sales	0.03	0.06	0.03	Q	0.22	0.01	0.57	0.01	0.01	0.05
Lodging	0.06	0.10	0.06	0.05	0.53	0.01	0.05	Q	0.03	0.10
Retail	0.03	0.12	0.08	0.01	0.53	(*) <sup>4</sup>	0.10	0.01	0.02	0.10
Office	0.05	0.14	0.09	0.01	0.39	0.001	0.05	0.04	0.10	0.13
Religious Worship	0.05	0.18	0.08	(*)	0.27	(*)	0.10	(*)	0.02	0.29
Service	0.04	0.10	0.16	(*)	0.42	Q	0.06	0.01	0.02	0.19
Warehouse & Storage	0.02	0.05	0.08	0.01	0.54	Q	0.15	0.01	0.02	0.12
Other	0.02	0.12	0.08	Q	0.44	Q	0.08	Q	0.04	0.17
Vacant	0.07	0.13	0.07	Q	0.27	Q	(*)	Q	(*)	0.47

<sup>3</sup> Q=Data withheld because fewer than 20 buildings were sampled for any cell, or because the Relative Standard Error (RSE) was greater than 50 percent for a cell in the "Total" column.

<sup>4</sup> (\*)=Value rounds to zero in the units displayed.

**Table A4** Navy Yard Building Number, Primary Use, Electricity, and Natural Gas Annual Use

Index	Description	Primary Building Use	Annual Electric Use (kWh)	Annual NG Use (CCF)
1	B1	Office	0	0
3	3	Office	171,837	25,203
4	B4	Office	2,344,250	58
6	B6	Office	388,838	18,150
7	B7	Office	3,871,650	0
9	9	Service	0	0
10	B10	Nonrefrigerated warehouse	598,939	0
11	B11	Office	1,461,081	0
12	B12	Service	0	0
14	14	Service	15,271	0
15	B15	Office	0	0
16	B16	Service	1,227,113	0
17	17	Service	83,550	0
18	18	Service	0	0
19	19	Service	0	0
20	B20	Service	0	30,021
21	21	Other	0	0
22	B22	Service	0	0
23	B23	Service	22,380	1,050,786
25	B25	Service	0	0
26	B26	Nonrefrigerated warehouse	968,941	5,947
29	29	Other	0	899
40	40	Other	0	0
41	B41	Service	38,693	0
44	B44	Service	0	1,868
47	47	Other	0	0
49	B49	Office	0	0
56	B56	Service	224,605	4,254
57	B57	Service	360,555	0
68	B68	Service	45,183	0
69	B69	Service	35,542	1,868
77	77	Other	6,458,232	105,537
80	80	Other	0	0
82	82	Other	0	0
83	83	Office	0	0
84	84	Nonrefrigerated warehouse	252,800	0
87	B87	Service	0	39,599
93	93	Other	577,625	0
94	B94	Service	0	0

95	B95	Nonrefrigerated warehouse	0	0
96	B96	Service	0	0
100	B100	Office	408,570	8,522
101	B101	Office	877,824	16,525
104	104	Other	0	0
120	120	Nonrefrigerated warehouse	180,000	0
121	B121	Office	85,543	0
122	B122	Nonrefrigerated warehouse	0	0
139	B139	Service	0	0
455	455	Other	0	0
480	B480	Office	53,077	0
483	483	Other	0	0
487	487	Other	14,585	0
489	489	Other	0	0
500	500	Office	0	0
501	B501	Office	0	0
519	519	Other	0	0
520	520	Service	0	0
526	B526	Service	0	0
529	529	Service	19,609	0
530	530	Service	0	0
531	531	Service	0	0
542	B542	Nonrefrigerated warehouse	638,100	33,761
543	B543	Nonrefrigerated warehouse	0	0
545	B545	Service	78,824	0
546	B546	Service	0	0
549	549	Other	829,000	0
567	B567	Nonrefrigerated warehouse	46,166	0
574	574	Other	50,801	0
590	590	Other	0	0
592	B592	Service	626,400	0
602	602	Other	8,638,424	0
603	603	Nonrefrigerated warehouse	0	0
605	B605	Nonrefrigerated warehouse	25,420	0
608	608	Office	0	0
611	B611	Nonrefrigerated warehouse	16,096	0
613	B613	Refrigerated warehouse	45,600	0
615	B615	Office	56,343	0
616	616	Other	0	0
618	618	Other	0	0
620	B620	Nonrefrigerated warehouse	0	136,386

621	621	Other	0	0
622	622	Other	0	0
623	B623	Service	44,648	3,877
624	624	Office	0	0
626	626	Other	0	0
633	633	Other	1,964,131	2,194
634	B634	Nonrefrigerated warehouse	0	0
636	636	Office	0	0
640	640	Office	0	0
643	B643	Service	6,832	0
649	B649	Religious worship	19,485	5,626
653	B653	Nonrefrigerated warehouse	7,701	0
661	661	Other	0	0
662	662	Other	0	0
664	664	Other	27,548	0
666	666	Other	0	0
668	668	Service	0	0
669	B669	Service	0	0
670	670	Other	0	0
677	677	Other	4,800	0
679	B679	Service	35,560	0
685	685	Other	0	0
694	694	Nonrefrigerated warehouse	166,282	17,357
712	B712	Service	182,310	0
731	731	Other	0	0
733	B733	Service	0	0
738	B738	Service	0	0
739	739	Other	135,402	0
744	744	Other	0	0
745	745	Other	0	0
753	753	Nonrefrigerated warehouse	242,700	27,894
754	B754	Service	0	0
756	756	Service	0	0
763	B763	Nonrefrigerated warehouse	264,838	0
766	766	Other	0	0
770	770	Other	0	0
771	771	Other	0	0
772	B772	Service	87,250	5,993
776	776		0	0
778	778	Service	219,260	0
793	793	Other	0	0

796	796	Other	55,196	0
811	811	Other	0	0
824	824	Other	0	0
830	B830	Service	13,878	0
842	842		0	0
910	910	Other	0	0
919	919		0	0
920	920		0	0
921	921		0	0
922	B922	Service	0	0
923	B923	Service	0	0
990	B990	Service	296,790	23,426
994	B994	Service	372,923	0
998	998	Food sales	0	0
999	999	Other	0	0
1000	B1000	Office	3,300,000	0
1028	B1028	Service	34,927	0
1029	B1029	Service	2,817,600	0
1031	1031	Lodging	0	0
1032	1032	Other	68,300	1,896
1036	1036	Other	0	0
1070	1070	Other	0	0
1081	1081		129,040	0
1082	1082		316,775	0
1085	1085		0	0
5001	AKER	Lodging	0	0
5002	APPTEC	Lodging	0	0
5003	CRESCENT 1	Lodging	1,328,550	0
5004	CRESCENT 3	Lodging	2,762,550	0
5005	Crescent 5	Lodging	76,704	0
5008	QUARTERS A	Lodging	23,064	0
5009	QUARTERS B	Lodging	19,820	0
5010	QUARTERS C	Lodging	58,360	0
5011	QUARTERS K	Lodging	40,340	0
5012	QUARTERS L	Lodging	30,407	0
5013	QUARTERS M	Lodging	201,149	0
5014	QUARTERS M1	Lodging	48,593	0
5015	QUARTERS M2	Lodging	12,049	0
5016	QUARTERS M3	Lodging	6,850	0
5017	QUARTERS M4	Lodging	7,349	0
5018	QUARTERS M5	Lodging	4,808	0

5019	QUARTERS M6	Lodging	13,049	0
5020	QUARTERS M7	Lodging	118,600	0
5021	QUARTERS N	Lodging	22,313	0
5022	QUARTERS O	Lodging	74,180	0
5028	STOCK EXCHANGE BLDG.	Service	0	0
5029	TASTYKAKE	Service	0	0
5030	UNIQUE	Service	0	0

**Table A5** Estimated Electric and Natural Gas use of the Navy Yard by Principal Building Activity

	annual Electric use (kWh)	annual Electric use (MBtu)	annual Natural Gas use (CCF)	annual Natural Gas use (MBtu)	<i>Total Electric and Natural Gas (MBtu)</i>
food sales	0.0E+00	0.0	0.0E+00	0.0	0.0
lodging	4.8E+06	16.5	0.0E+00	0.0	16.5
office	1.3E+07	44.4	6.8E+04	7.0	51.4
religious worship	1.9E+04	0.1	5.6E+03	0.6	0.6
service	6.9E+06	23.5	1.2E+06	118.5	142.0
warehouse & storage	3.5E+06	11.8	2.2E+05	22.6	34.4
other (incl. non-categorized)	1.9E+07	65.8	1.1E+05	11.3	77.0
<i>Total</i>	<i>4.8E+07</i>	<i>162.1</i>	<i>1.6E+06</i>	<i>159.9</i>	<i>322.0</i>

## Appendix B: Building Type Definitions

[http://www.eia.gov/emeu/cbecs/building\\_types.html](http://www.eia.gov/emeu/cbecs/building_types.html)]

Building Type	Definition	Includes These Sub-Categories from 2003 CBECS Questionnaire
Lodging	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	motel or inn
		hotel
		dormitory, fraternity, or sorority
		retirement home
		nursing home, assisted living, or other residential care
		convent or monastery
		shelter, orphanage, or children's home
		halfway house
Office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	administrative or professional office
		government office
		mixed-use office
		bank or other financial institution
		medical office (see previous column)
		sales office
		contractor's office (e.g. construction, plumbing, HVAC)
		non-profit or social services
		research and development
		city hall or city center
		religious office
		call center
Religious Worship	Buildings in which people gather for religious activities, (such as chapels, churches, mosques, synagogues, and temples).	No subcategories collected.

Service	Buildings in which some type of service is provided, other than food service or retail sales of goods	vehicle service or vehicle repair shop
		vehicle storage/ maintenance (car barn)
		repair shop
		dry cleaner or laundromat
		post office or postal center
		car wash
		gas station
		photo processing shop
		beauty parlor or barber shop
		tanning salon
		copy center or printing shop
		kennel
Warehouse and Storage	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	refrigerated warehouse
		non-refrigerated warehouse
		distribution or shipping center
Other	Buildings that are industrial or agricultural with some retail space; buildings having several different commercial activities that, together, comprise 50 percent or more of the floorspace, but whose largest single activity is agricultural, industrial/ manufacturing, or residential; and all other miscellaneous buildings that do not fit into any other category.	airplane hangar
		crematorium
		laboratory
		telephone switching
		agricultural with some retail space
		manufacturing or industrial with some retail space
		data center or server farm