Weatherization And Intergovernmental Programs Office

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Benchmarking Data Cleansing:

A Rite of Passage Along the Benchmarking Journey

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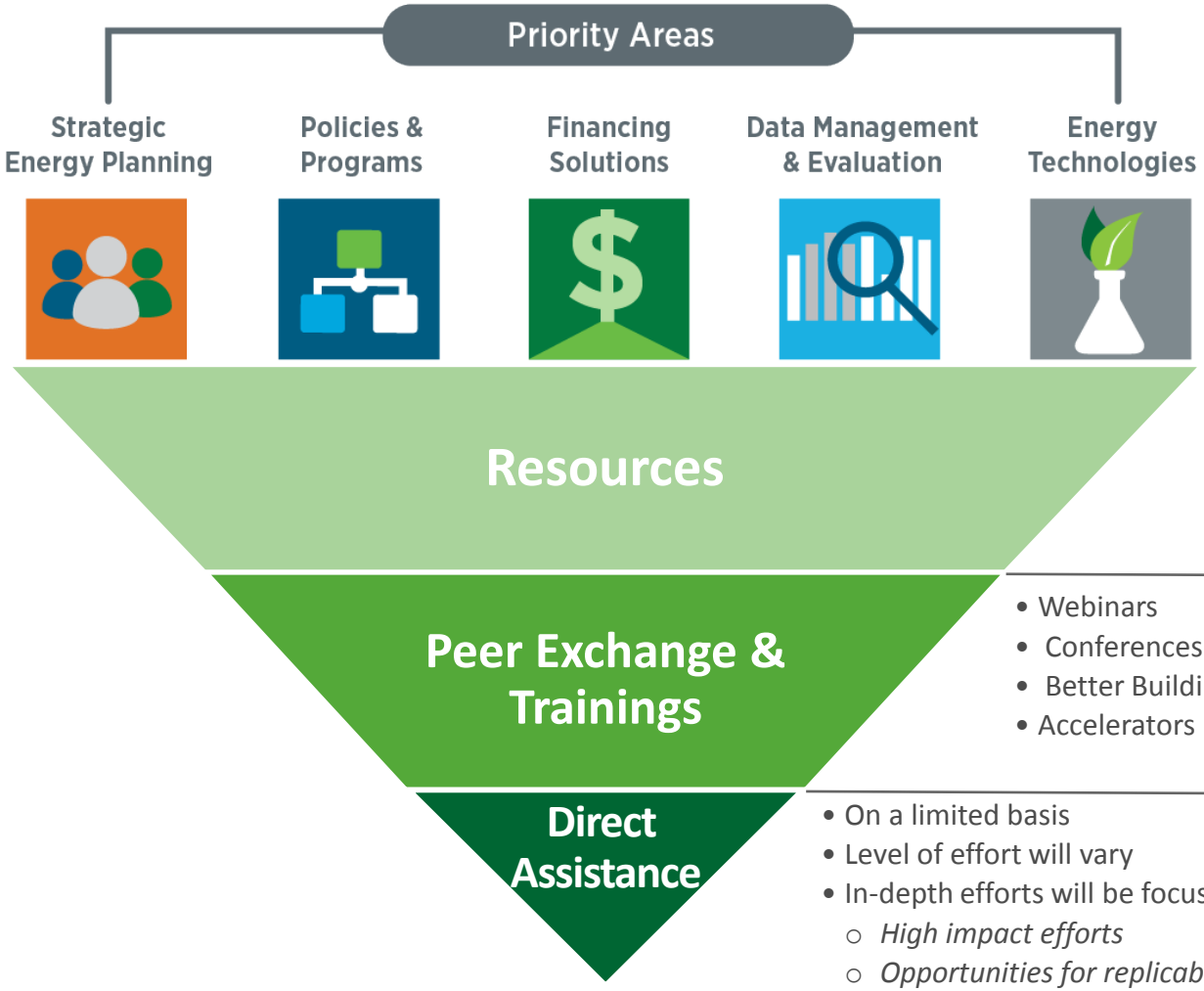


- General Education (fact sheets, 101s)
- Implementation Models (case studies)
- Research and Tools for Decision-Making
- Protocols (how-to guides, model documents)

- Webinars
- Conferences and in-person trainings
- Better Buildings Project Teams
- Accelerators

- On a limited basis
- Level of effort will vary
- In-depth efforts will be focus on:
  - *High impact efforts*
  - *Opportunities for replicability*
  - *Filling gaps in the technical assistance marketplace*

How to tap into these and other TAP offerings

- Visit the STATE AND LOCAL SOLUTION CENTER

http://energy.gov/eere/slsc/state-and-local-solution-center

- Sign up for ***TAP Alerts*** by emailing

TechnicalAssistanceProgram@ee.doe.gov

Course Outline

- Course Objectives
- Building Benchmarking
- Bad Data
  - What is it?
  - Types
  - Common Issues
- Data Cleansing
  - What it is?
  - Why do it?
- Data Cleansing Process
  - Identify/fix incorrect data types
  - Identify/fix missing or erroneous values
  - Identify/fix outliers/other inconsistencies
  - Check and fix to ensure internal consistency
- Data Cleansing on a Sample Data Set

Course Objectives

Intended Audience

Cities, communities, and states that have implemented or are considering implementing an internal or community-wide benchmarking and/or disclosure program or policy and are preparing their building energy data for analysis.

Learning Objectives

Training modules are intended to help public sector organizations:

- Identify problems associated with building energy data
- Verify data accuracy
- Clean data prior to analysis

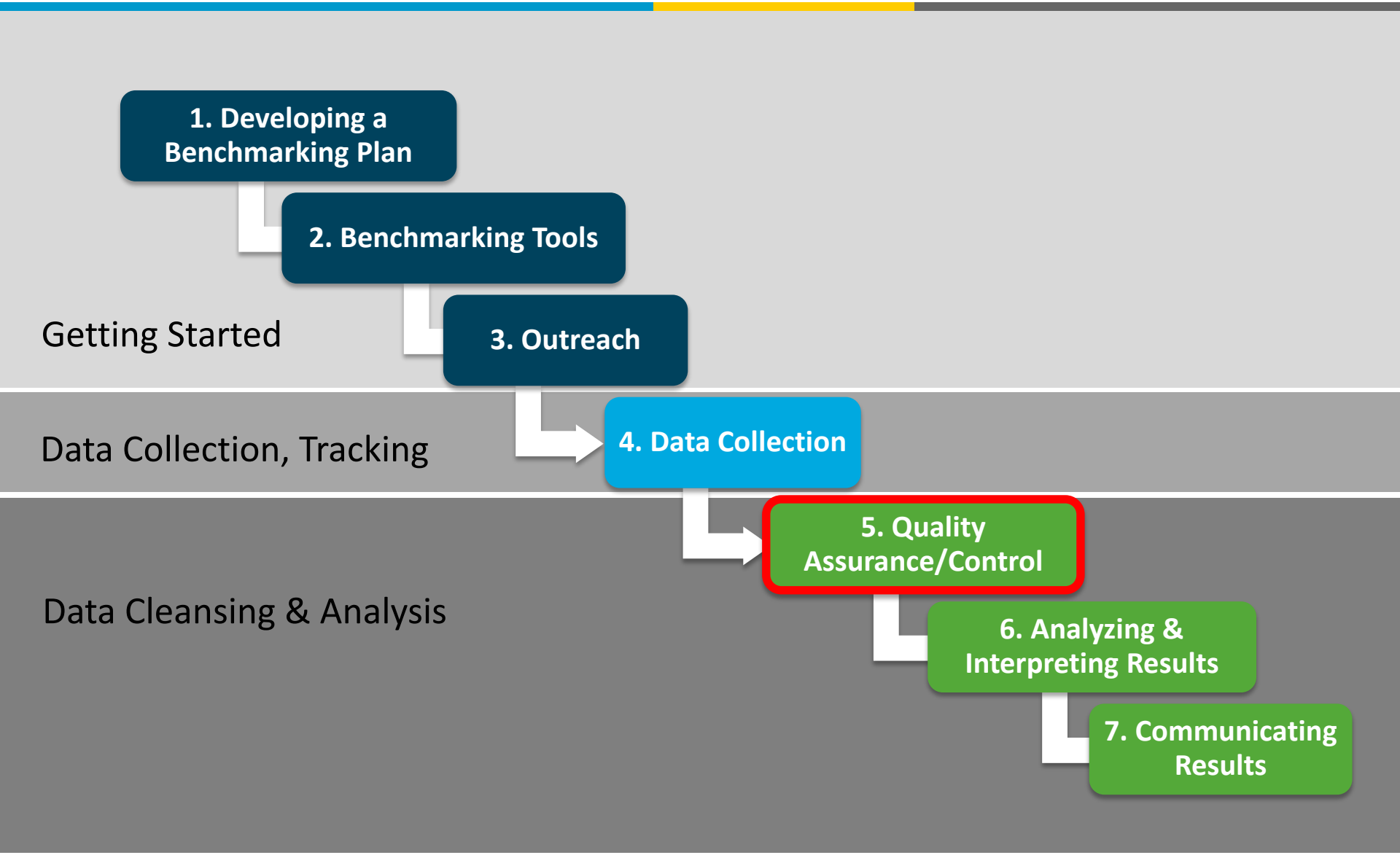
Introduction to Benchmarking

- Benchmarking compares the measured performance of a facility to itself, its peers, or established norms
- Benchmarking provides an empirical foundation for an organization's energy management strategy
- Benchmarking helps manage buildings effectively. You can't manage what you don't measure
- Benchmarking facilitates energy accounting. It assists in identifying opportunities for improvement. It can also help quantify/verify energy savings.

Benefits of Benchmarking

- Manage energy use proactively
- Assess and compare building's energy performance
- Identify billing errors and other anomalies
- Verify pre- and post-project energy use, greenhouse gas emissions, and energy costs
- Assess effectiveness of current operations, policies, and practices
- Assist in planning: set goals, targets, and timelines
- Communicate results in meaningful terms
- Participate in energy challenges or benchmarking programs

Building Benchmarking Process



Source: http://energy.gov/eere/wipo/building-energy-use-benchmarking

Benchmarking Data

ENERGY STAR® Portfolio Manager Data Fields

Collects	Reports
Property Information • Primary function • Location • Vintage **Property Type Data** • Gross floor area • Property use details (e.g., number of computers, number of occupants, operating hours) **Energy Consumption Data** • Energy data for all fuel usage	**Absolute Performance** • Total energy (kBtu) • Site and source EUI (kBtu/ft2/year) • Total GHG emissions (MtCO2e/year) **Comparative Performance** • National median site and source EUI • % difference from national median source EUI • ENERGY STAR score

Bad Data: What/Where/How?

What is it?

- Benchmarking data may be erroneous, missing, miscorrelated, estimated

Where does it come from?

- Bad data arise due to a number of issues and sources
  - Errors due to human entry and misinterpretations
  - Data errors due to incorrect translation between difference systems
  - Lack of complete information
  - Lack of a standard data dictionary

How do we identify bad data?

- Some issues may be easy to identify, such as missing values, or an energy consumption value off by a factor of a million
- Others may be quite tricky to identify
  - Errors from a building that appears to be ten times more inefficient than its peers due to a decimal error vs. a truly energy intensive building (e.g., a data center)
  - Errors due to estimations where data values are within acceptable range but is actually incorrect

Bad Data: Types

Unit conversion errors - inconsistent units of measure

- Therms of natural gas instead of million cubic feet (MCF)
- Total square feet instead of thousands of square feet

Wrong building characterization - building end use type is misidentified

- Classifying a refrigerated warehouse as non-refrigerated

Miscorrelated data - implausible value is entered into a field

- Year-to-date energy consumption instead of monthly energy consumption
- Reporting energy consumption from only one meter for a building with multiple meters

Missing data or zero values

- For example: missing building type, missing gross floor area, etc.

Alphanumeric instead of numeric – presence of units or other special characters

- 100,000 or 100K sq. ft. may not conform to a numeric data format

Estimated or default – lack of appropriate data may prompt a user to enter estimated values; users might go with the selected default values

Data Cleansing: What Is It?

- Data cleansing is a process of carefully and systematically reviewing data and removing and/or correcting suspected erroneous data before analysis
  - A screen for a variety of common erroneous or missing data
  - Identification of errors that are specific to a portfolio
- Data accuracy needs to be ensured before a detailed analysis is performed
- All data are unclean unless proven otherwise
- Everyone, no matter how small of a portfolio they have, needs to do it
- The cleansing process identifies preventative and corrective measures to be implemented for future data sets

Data Cleansing: Why Do It?

- Important to clean the data before analysis to ensure accurate results at the building level as well as to avoid skewed conclusions at the portfolio level
- Bad data "contaminates" the data set and can lead to high variances and uncertainties in the data analysis results
- Bad data creates inaccuracy in analysis, such as:
  - Comparing results of a building performance against its peers
  - Performing year-to-year trending or even
  - Gaining a firm understanding of the level of a building's performance will be inaccurate.

  This can lead to bad decisions regarding the right investment
- Bad data can lead to lack of confidence in results, potentially undermining the credibility of the underlying program or policy

Common Data Issues from BPD

- DOE's Building Performance Database (BPD) provides access to empirical data on the energy performance and physical and operational characteristics of buildings
- BPD contains data on more than 750,000 residential and commercial buildings
- Building owners submit raw building performance data to the BPD team who in turn facilitate data cleansing and entry to the system
- Data in BPD undergo rigorous mapping, cleansing, and merging steps to identify and remove suspect or erroneous values
- Common data issues identified:
  - Zero floor areas, gross floor area < net floor area
  - Building type not specified
  - Erroneous energy consumption (zero, negative, partial)
  - EUI very high or too low (1<site EUI<1000 kBtu/sft)
  - EUI not plausible for a building type (CBECS)

Data Cleansing Process

1. Identify/fix incorrect data types

Ensure data conforms with standard data schema in terms of data types and nomenclature

2. Identify/fix missing or erroneous values

Define required data fields; remove/impute records with errors or missing values in required data fields

3. Identify/fix other data inconsistencies

Remove and investigate outliers

4. Check/fix to ensure internal consistency

Identify changes in internal data to ensure consistency from year to year/Identify data trending outside of historic range

Data Cleansing on Sample Datasets

- Dataset includes benchmarking data for 2,100 buildings over 4 years
- Data fields: facility ID, city, zip code, building type, activity year, benchmarked floor area, annual building energy use, site EUI, source EUI, weather normalized site EUI, weather normalized source EUI, ENERGY STAR rating
- Dataset obtained from FEMP's Compliance Tracking System (CTS)

Additional sample dataset used:

- BPD sample dataset
- City of Seattle 2012 benchmarking data

1. Identify/fix incorrect data types

Ensure data conforms with standard data schema (nomenclature and types)

Issue: Data providers use inconsistent nomenclature and data types when submitting data

Data Cleansing Steps:

a. Convert data values to standard nomenclature
b. Convert data types to standard data types
c. Standardize data formats

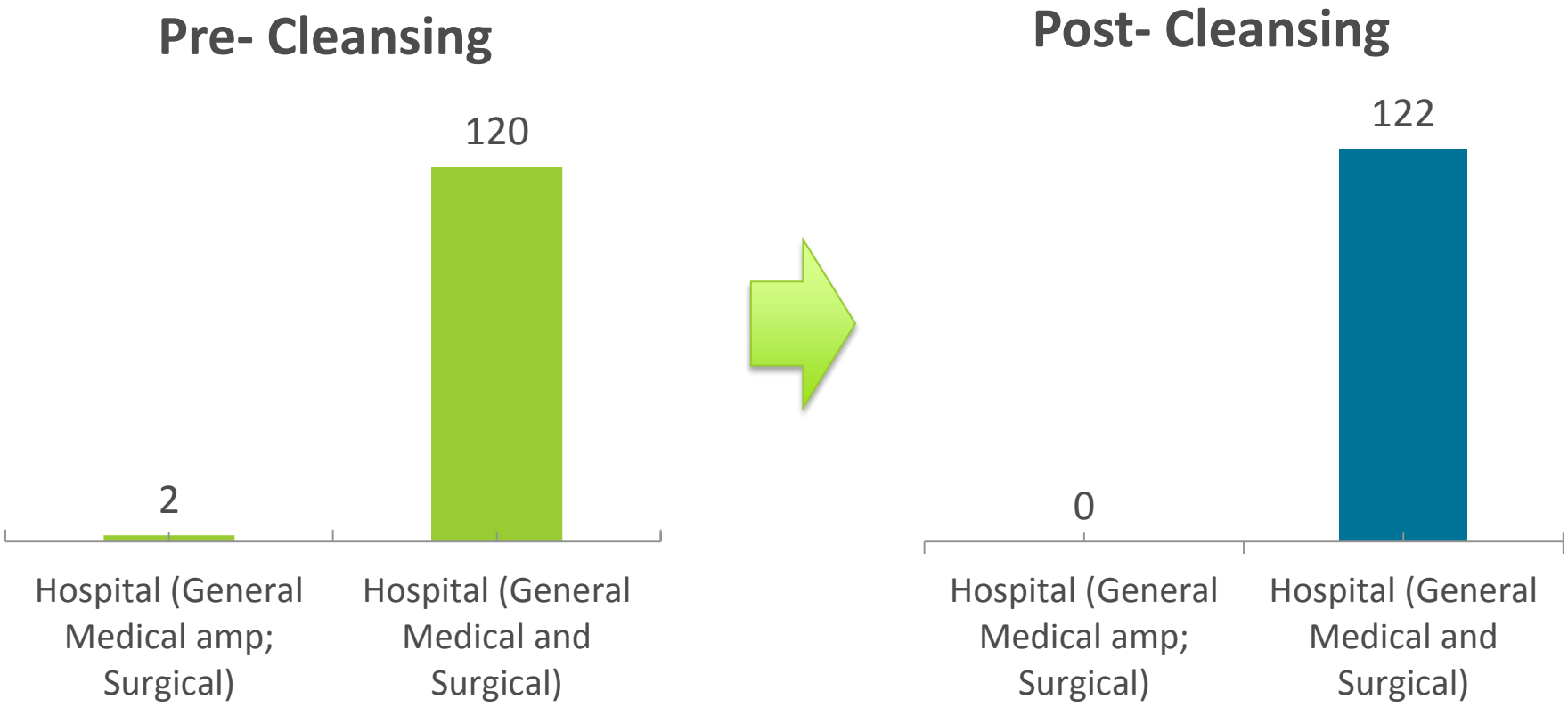
Corrective Action:

- Adopt a standard data dictionary (e.g., DOE's Building Energy Data Exchange Specification - BEDES)
- Supply data provider with a data dictionary and train data provider on correct use of data fields and possible values

1. Identify/fix incorrect data types

a. Convert data values to standard nomenclature

Source of Error: Typographical error creates two separate building types

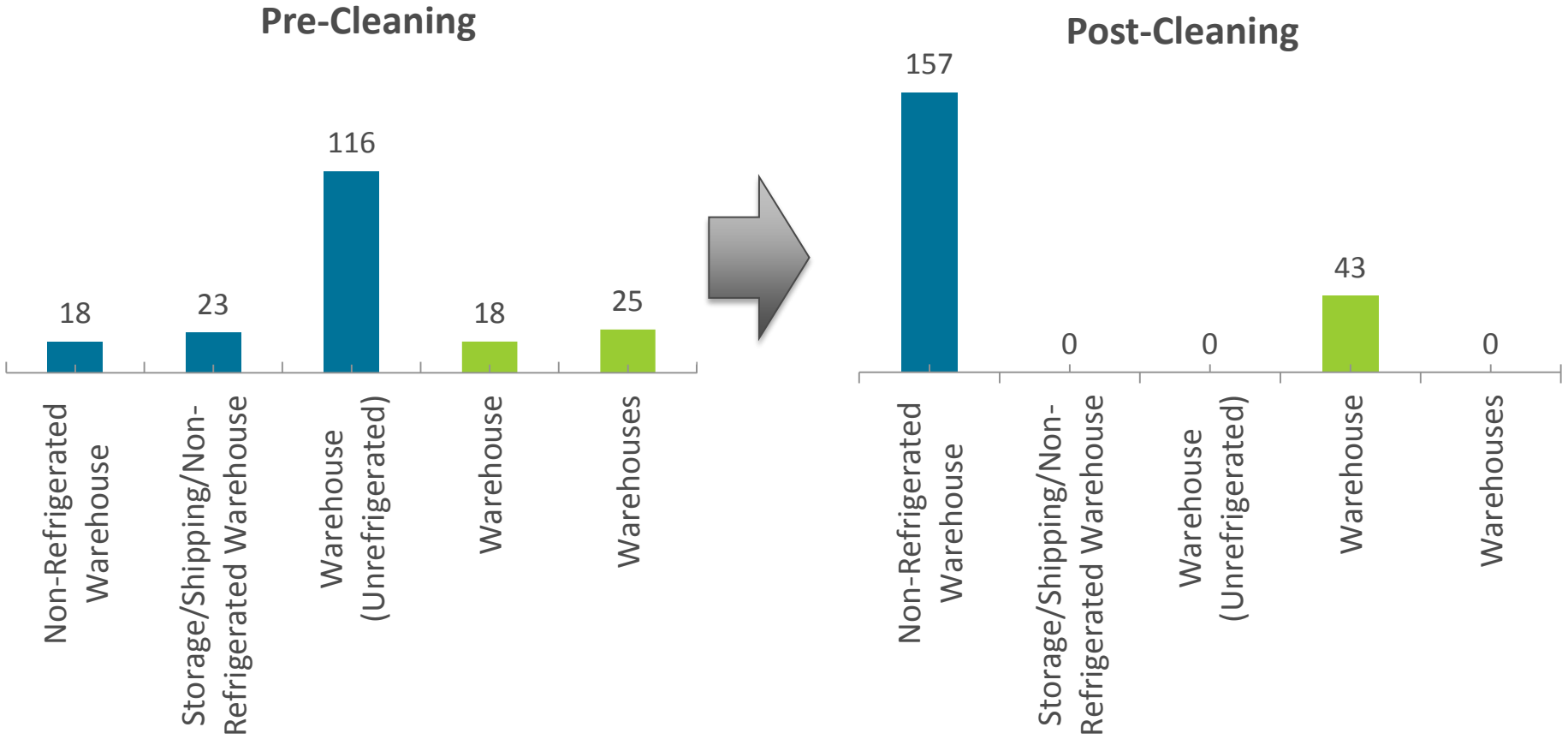


Corrective Action: Correct the building types to make them consistent with data types from the data dictionary. "Hospital (General Medical amp; Surgical)" is combined with "Hospital (General Medical and Surgical)"

1. Identify/fix incorrect data types

a. Convert data values to standard nomenclature

Source of Error: Multiple specifications for essentially the same building type



Corrective Action: Standardize building type specifications in line with data types from the dictionary. The five building types in the graph are combined to standard building types – "Non-Refrigerated Warehouse" and "Warehouse."

1. Identify/fix incorrect data types

b. Convert data types to standard data types

Source of Error: Data values are in the form of strings/text instead of a number; data from this record can not be sorted or analyzed with other records

RPUI	Year	Building Type	Benchmarking System	GSF	SiteEU	SourceEU	SiteEUI	SourceEUI	SiteEUIWN	SourceEUIWN
140320	2011	Other	ENERGY STAR Portfolio Manager	693.2	2123301.8	2383501.1	3,063.20	3,438.50	3,063.20	3,438.50

Data is represented as a string/text when expecting a number

RPUI	Year	Building Type	Benchmarking System	GSF	SiteEU	SourceEU	SiteEUI	SourceEUI	SiteEUIWN	SourceEUIWN
140320	2011	Other	ENERGY STAR Portfolio Manager	693.2	2123301.8	2383501.1	3063.2	3438.5	3063.2	3438.5

Correct format by converting the string/text into a number

Corrective Action: Correct data types to make them consistent with data types from the data dictionary. Tools such as *Openrefine* can help identify and correct these issues.

1. Identify/fix incorrect data types

c. Standardize data formats

Source of Error: Data values in an inconsistent format

Zip code	RPUI	Building Type
01432-9764	631	Hospital (General Medical and Surgical)
01432	523	Medical Office
1432	107	Other

Issue: Inconsistent representations of zip codes prevents grouping of buildings

variation 1: _1432
variation 2: 01432
variation 3: 01432-9764

Corrective Action: Correct zip code format to be consistent and match with a standard format (ABCDE)

2. Identify/fix missing or erroneous values

Remove or impute missing floor areas, EUI, building types, building IDs

Issue:

- Data sets contain errors related to data entry, default, or missing values
- Some of these values are easy to identify by reviewing or through a cursory analysis of data

Data Cleansing Steps:

- Define required fields (e.g., energy use, building type, building ID)
- Look for missing values that can be imputed by reviewing other data sources :
  - Sort for zero, empty or "N/A" values
  - E.g., the GSF or zip code for one of the years might be missing, but could be obtained from previous year's data
  - Cross check with other data sources like tax assessors data
- Flag records that may be completed through additional research
- Exclude records with missing data in the required fields; keep records with errors or missing data in non-required fields

2. Identify/fix missing or erroneous values

Remove or impute missing floor areas, EUI, building types, building IDs

Issue	Issues Identified	Remarks	Cleansed Dataset
Missing Area (GSF)	55	Reconciled 1 record for 2012 by obtaining GSF from 2011 dataset	Flagged 54 records for investigation, removed from subsequent analysis
Missing Energy Use (MMBtu)	60	Key data not available in other records	Flagged 60 records for investigation, removed from subsequent analysis
Missing Building ID (“xxxxxx”)	3	Records retained for further analysis	Flagged 3 records, included in the analysis
Missing Building Type (“N/A”)	8	Key data not available through other records	Flagged 8 records for investigation, removed from subsequent analysis
Total Records Flagged	67		A total of 67 records were flagged and excluded from analysis

Total records pre-cleansing: 3,550. Post-cleansing: **3,483**

3. Identify/fix other data inconsistencies

Remove and investigate outliers

- Establish criteria for permissible values based on the data types and realistic values
- Perform a distribution analysis to identify outliers
  - GSF
  - Site EUI
  - Site EUI by building type
- Investigate data that continue to look suspect or do not meet additional criteria

3. Identify/fix other data inconsistencies

a. Establish criteria for permissible values

BPD

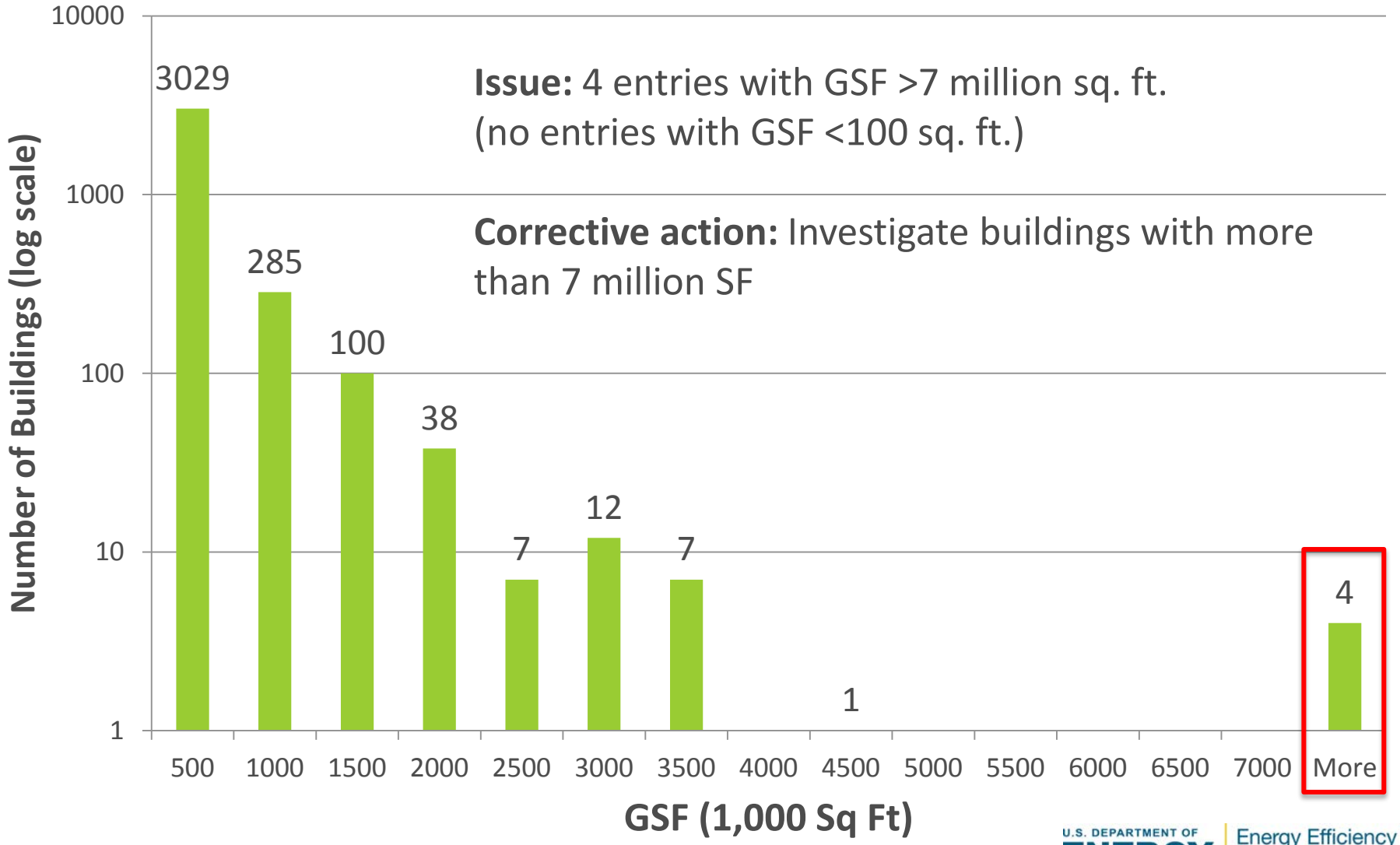
Building Performance Database

Range of Allowable Values

Field	Data Type	Allowed Values	In-range check
Year Completed	INTEGER(4)	1600 - present	
Year Occupied	INTEGER(4)	1600 - present	>= Year Completed
Benchmarking Year	INTEGER(4)	1990- present	>= Year Completed
Building Type	CONSTRAINED LIST	List	BEDES or Portfolio Manager
Gross Floor Area	DECIMAL	100 - 7 million Sq Ft	
Zip Code	INTEGER(5)	List	00210 - 99950
Site EUI	DECIMAL	1-1000	<=Source EUI

3. Identify/fix other data inconsistencies

b. Distribution analysis to identify GSF outliers



Issue: 4 entries with GSF >7 million sq. ft.
(no entries with GSF <100 sq. ft.)

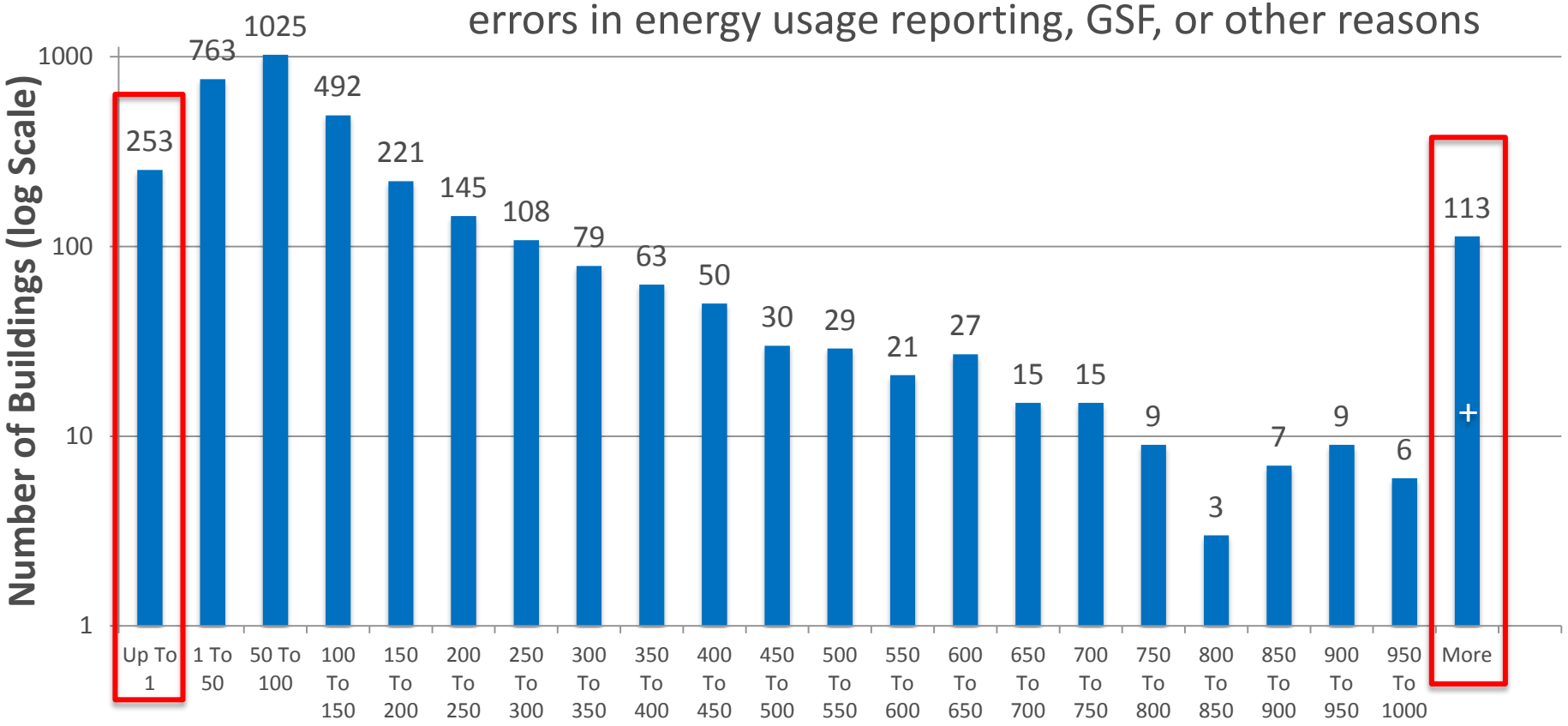
Corrective action: Investigate buildings with more than 7 million SF

3. Identify/fix other data inconsistencies

b. Distribution analysis to identify EUI outliers

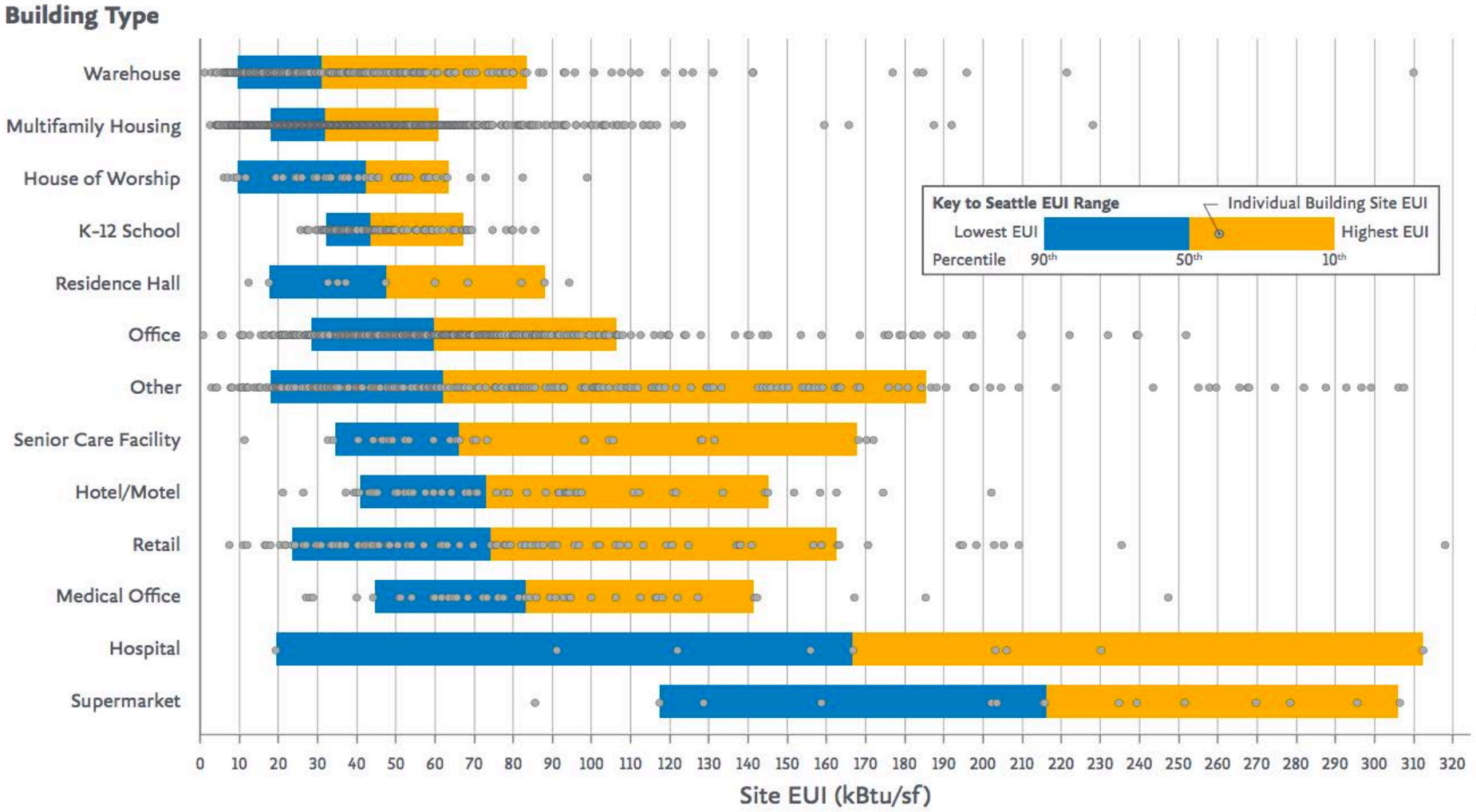
Issue: Out of range data: 253 buildings with site EUI <1 kBtu/sft; 113 buildings with site EUI >1000 kBtu/sft

Corrective Action: Investigate if anomalies are due to errors in energy usage reporting, GSF, or other reasons



3. Identify/fix other data inconsistencies

b. Distribution analysis to identify EUI outliers by building type

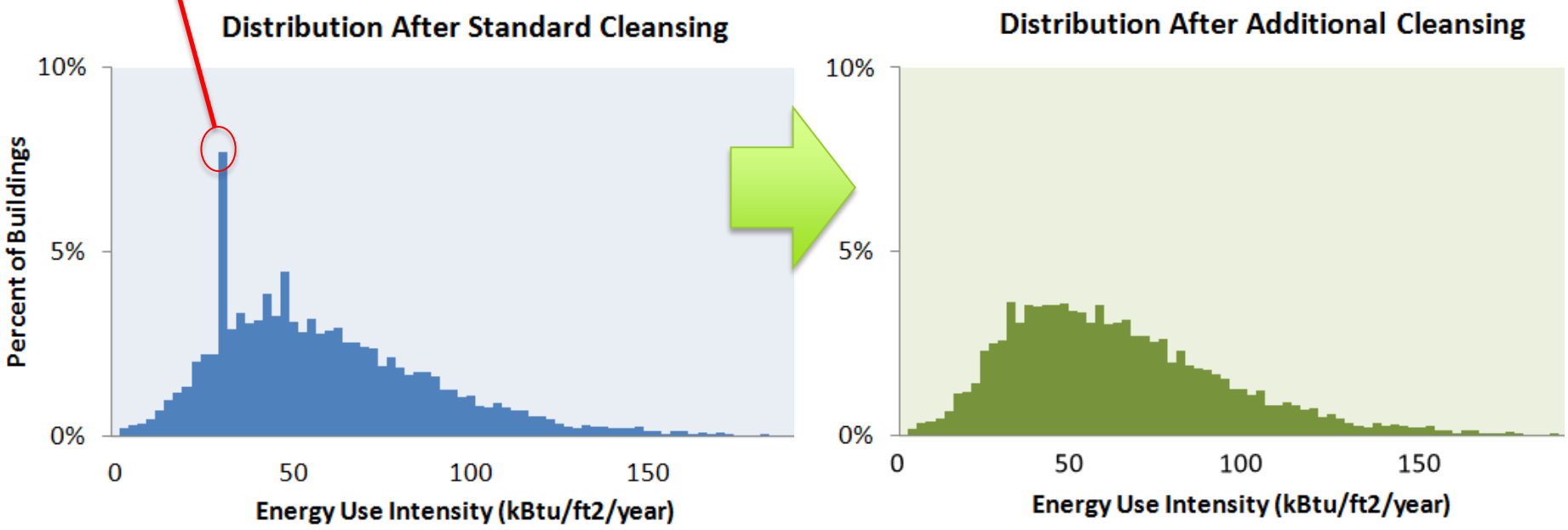


Source: 2011/2012 Seattle Building Energy Benchmarking Analysis Report

3. Identify/fix other data inconsistencies

c. Analysis to identify additional outliers/default values

8% of buildings have EUI's equal to 32 kBtu/ft2/year



Issues: A histogram of a dataset using standard cleansing rules, revealed that nearly 8% of the buildings reported EUIs equal to exactly 32 kBtu/ft^2/year

Corrective Action: Investigate suspicious data which may represent estimated values

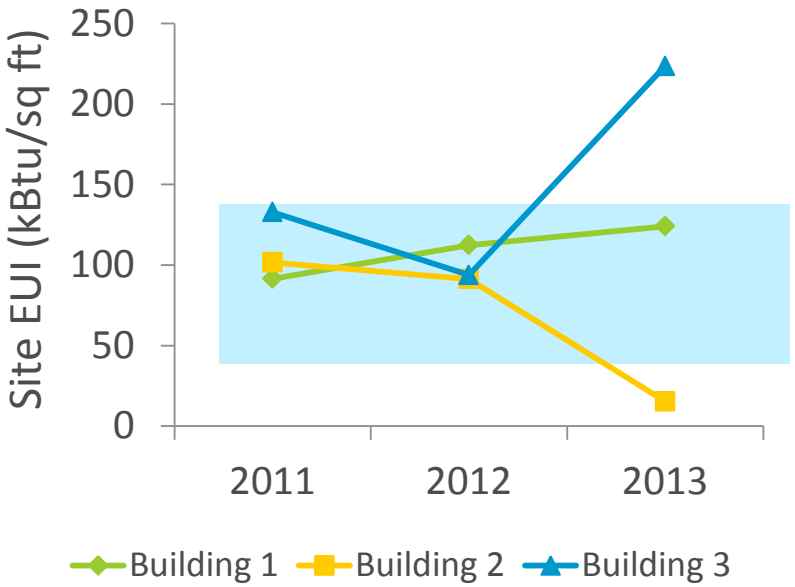
Source: Data Preparation Process for the Buildings Performance Database, LBNL, 2014

4. Check/fix to ensure internal consistency

Identify data trending outside of historic range

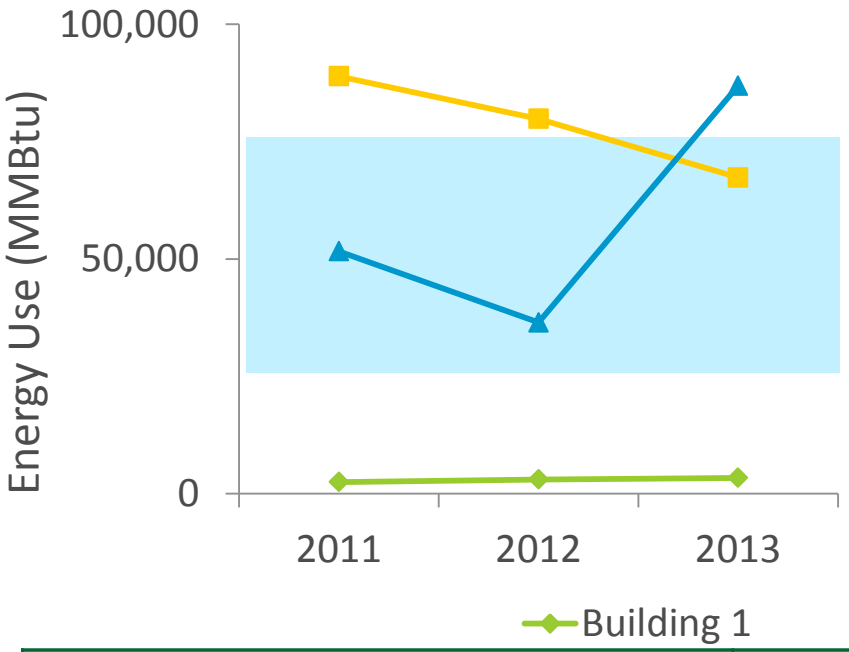
- For buildings with multiple years of benchmarking, plot EUI over time to identify variations > 50% across years
- Investigate the root cause of high variation (GSF, site energy use)
- Data with EUI variability > 50% is questionable; review on a case by case basis to identify and resolve possible data errors

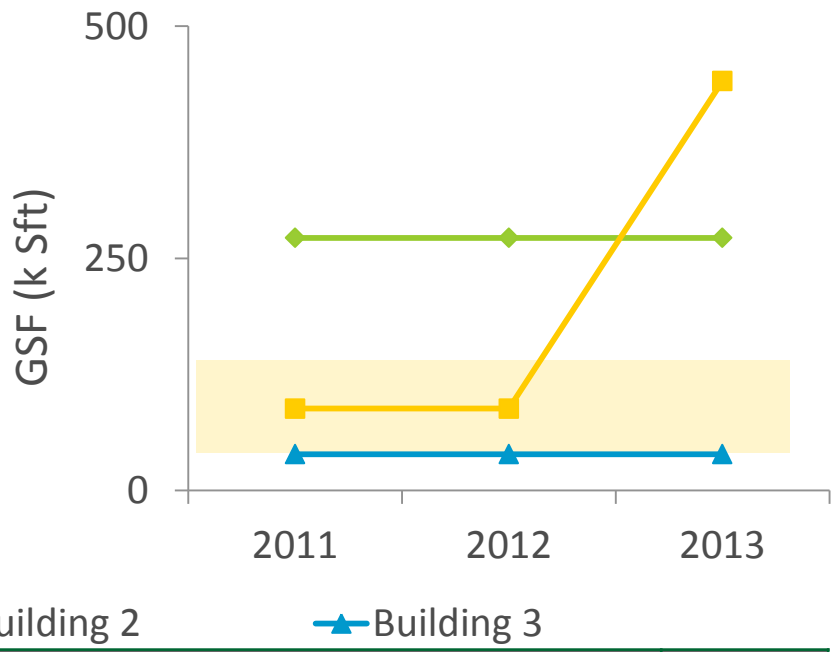
	Site EUI (kBtu/sq ft)			
Building ID	**2011**	**2012**	**2013**	**2013 vs 2011**
Building 1	91.53	112.36	124.12	+36%
Building 2	101.6	91.3	15.3	-85%
Building 3	132.8	93.8	223.5	+68%



4. Check/fix to ensure internal consistency

Identify data trending outside of historic range





Building 1 Building 2 Building 3

Building Energy Use (MMBtu)				
Building ID	**2011**	**2012**	**2013**	**% change**
Building 1	2,489	3,056	3,376	36%
Building 2	88,925	79,874	67,370	-24%
Building 3	51,636	36,492	86,902	+68%

Building GSF (k Sft)				
Building ID	**2011**	**2012**	**2013**	**% change**
Building 1	272	272	272	0%
Building 2	88	88	441	401%
Building 3	39	39	39	0%

Recommendations

- Become familiar with standard building characteristics and usage trends by major building types to help spot errors
- Learn data manipulation techniques to spot outliers
  - Sorting values
  - Identifying missing data
  - Plotting the distribution by GSF or EUI
- Perform statistical analysis to further characterize portfolio and identify additional data issues
- Use metadata to help with data cleansing and analysis
  - Part of metadata defined in BEDES is to identify the source of a data field (actual, estimated, derived, etc.). This can be very valuable to identify which data to rely on in case of discrepancies.

Results of Data Cleansing Process

	Issue	Errors	Corrections/Next Steps
1. Identify/fix incorrect data types	Zip Codes	Inconsistent data formats	Consistent data format
	Building Types anomalies	Spelling, white spaces, singular/plural, redundant building types	Fixed and merged Reduced building types from 46 to 38
2. Identify/fix missing or erroneous values	Missing Area	55	Flagged for further investigation 72
	Missing Energy Use	60	
	Missing Site EUI	60	
	Building ID =“xxxxxx”	3	
	Building Type-”N/A”	8	
3. Identify/fix other data inconsistencies	GSF outside the proposed range	4	Flagged for investigation
	Site EUI outside the proposed range	364	Flagged for investigation
4. Check/fix to ensure internal consistency	Big changes in Site EUI (~50%)	10	Flagged for investigation

Initial dataset: 3,550 Final dataset: 3,110

12% of entries removed from analysis

Summary

- Data sets are dirty until scrubbed clean
  - The BPD throws out roughly 20% of buildings provided by data contributors due to various data quality issues
  - Accurate data will strengthen confidence in final results
- Promote the use of standardized data dictionary to reduce the effort related to mapping
- Identify missing or suspicious values
  - If individual data fields seem suspect it may not be necessary to throw out the whole building record; other data fields may still be valid for analysis
  - Very similar energy uses for different building types in different locations can be an indication of default values, instead of actual values, used in either energy use or GSF

Summary

- Use ranges to identify data anomalies
  - Data cleansing may require learning about building performance characteristics to make judgments on reasonable values
  - Identify maximum and minimum gross floor areas for each of the building types from various other sources
  - Ranges of EUI can be obtained from public sources (CBECS)
- Data cleansing is one of the steps along the journey to learn about the building portfolio
- Utilizing some of the basic techniques outlined here and spending time to cleanse the data can go a long way to ensure that final analysis results are accurate and result in appropriate actions
- Automating data cleansing procedures can make this process less error prone and more efficient

Resources

- Data Preparation Process for the Buildings Performance Database, LBNL, 2014
  - http://eetd.lbl.gov/sites/all/files/data_preparation_for_bpd.pdf
- ENERGY STAR Portfolio Manager
  - http://www.energystar.gov/buildings
- OpenRefine
  - http://openrefine.org/
- Standard Energy Efficiency Data Platform (SEED)
  - http://energy.gov/eere/buildings/standard-energy-efficiency-data-platform
- Building Energy Data Exchange Specification (BEDES)
  - http://energy.gov/eere/buildings/building-energy-data-exchange-specification-bedes
- City of Seattle, 2011/2012 Seattle Building Energy Benchmarking Analysis Report, Seattle Office of Sustainability & Environment, January 2014
  - http://www.seattle.gov/Documents/Departments/OSE/EBR-2011-2012-report.pdf

Questions

Office Hours

- Thursday May 7—1 p.m. EDT
- Tuesday May 12—2 p.m. EDT

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