Matthew Brehmer
@mattbrehmer
UBC

Jocelyn Ng
@JocelynNg
EnerNOC

Kevin Tate
EnerNOC

Tamara Munzner
@tamaramunzner
UBC

Matches, Mismatches, and Methods:
Multiple-View Workflows for Energy Portfolio Analysis

paper & supplemental materials:
cs.ubc.ca/labs/imager/tr/2015/MatchesMismatchesMethods/

IEEE InfoVis
October 2015

UBC

ENERNOC

CONTRIBUTIONS

Design study **success story**.

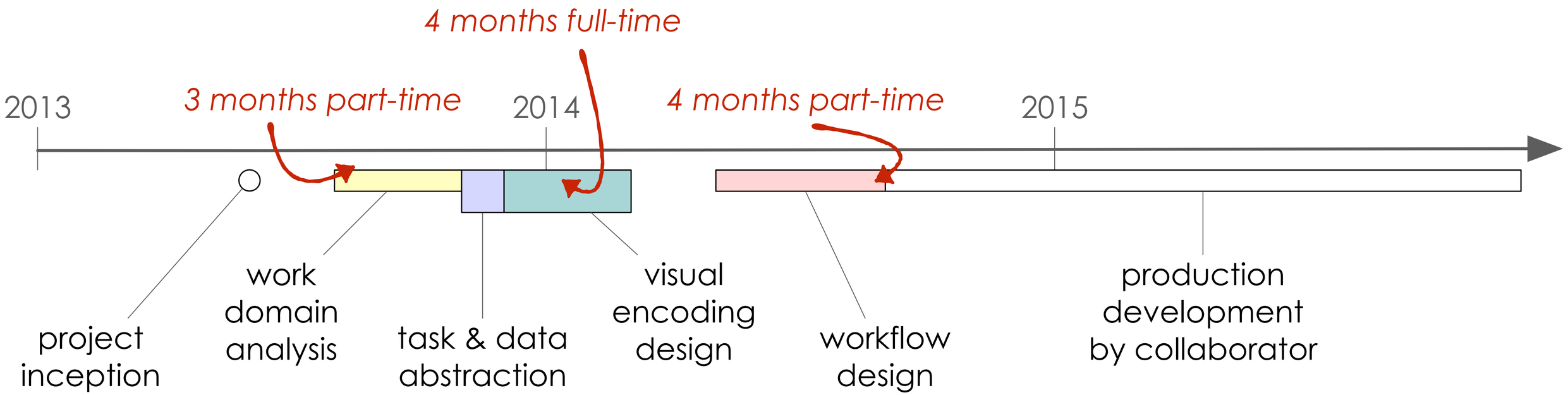
Highlighting **matches** and **mismatches:**

- task & data abstractions ←→ visual encoding & interaction design
- multiple concurrent time series

Addressing **domain convention**, **familiarity** & **trust**.

Reflecting on **methods** for visualization design studies.

DESIGN PROCESS TIMELINE



OUTLINE: DESIGN PROCESS

1. **analyzing the work domain**
   - interviews with 9 energy workers
2. identifying data and task abstractions
3. visual encoding sandbox prototyping
4. eliciting feedback on vis. encoding designs
5. prototyping workflows
6. production development by collaborator

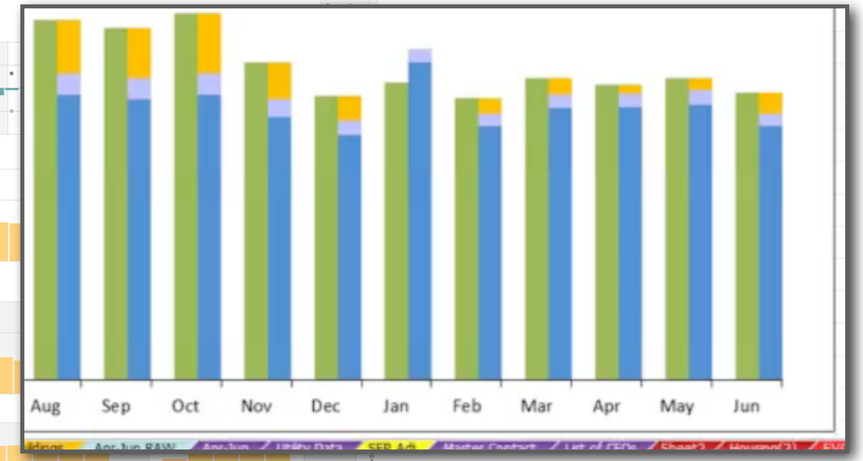
43 summary slides

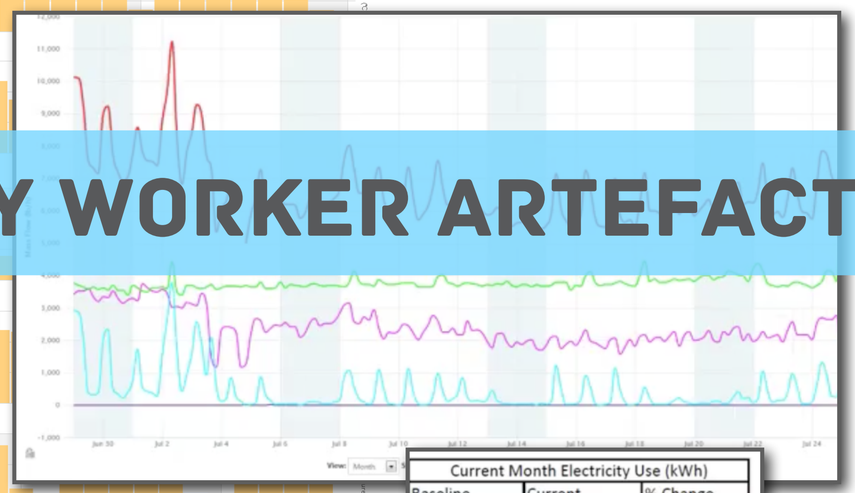
WORK DOMAIN ANALYSIS

energy workers' skill sets, goals, activities

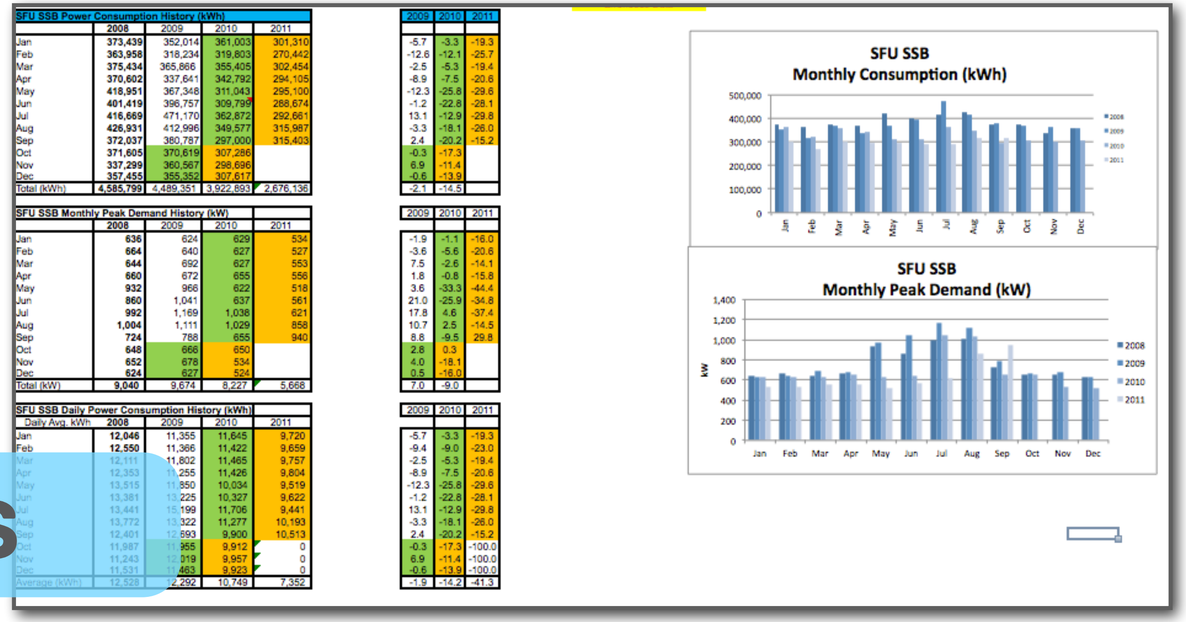
existing tools

workarounds





Current Month Electricity Use (kWh)		
Baseline	Current	% Change
1,016	907	-11%
329	1,031	214%
10,352	9,728	-6%
9,359	8,380	-10%
251	274	9%
52,131	47,532	-9%
1,257	1,190	-5%
151	214	41%
24,063	21,775	-10%
19,708	19,636	0%
1,151	1,035	-10%
15,030	12,719	-15%
-	-	#DIV/0!
1,791	1,765	-1%
20,712	20,845	1%
6,380	5,806	-9%
33,082	41,826	26%



SFU SSB Power Consumption History (kWh)

	2008	2009	2010	2011
Jan	373,439	352,014	361,003	301,310
Feb	363,958	318,234	319,803	270,442
Mar	375,434	365,866	355,405	302,454
Apr	370,602	337,641	342,792	294,105
May	418,951	367,348	311,043	295,100
Jun	401,419	396,757	309,799	288,674
Jul	416,669	471,170	362,872	292,661
Aug	426,931	412,996	349,577	315,987
Sep	372,037	360,787	297,000	315,403
Oct	371,605	370,619	307,286	
Nov	337,299	360,567	298,696	
Dec	357,455	355,352	307,617	
Total (kWh)	4,585,799	4,489,351	3,922,893	2,676,136

2009	2010	2011
-5.7	-3.3	-19.3
-12.6	-12.1	-25.7
-2.5	-5.3	-19.4
-8.9	-7.5	-20.6
-12.3	-25.8	-29.6
-1.2	-22.8	-28.1
13.1	-12.9	-29.8
-3.3	-18.1	-26.0
2.4	-20.2	-15.2
-0.3	-17.3	
6.9	-11.4	
-0.6	-13.9	
-2.1	-14.5	

SFU SSB Monthly Peak Demand History (kW)

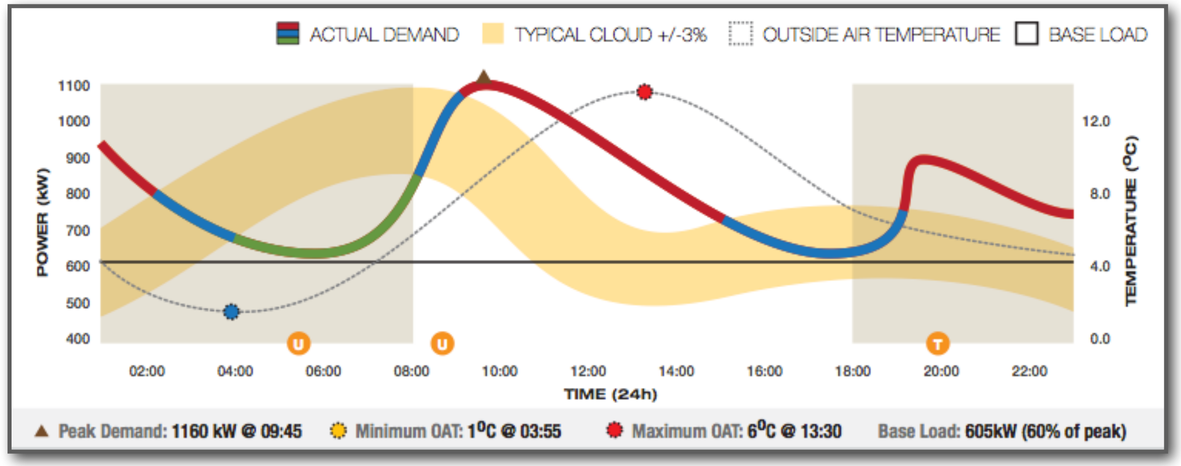
	2008	2009	2010	2011
Jan	636	624	629	534
Feb	664	640	627	527
Mar	644	692	627	553
Apr	660	672	655	556
May	932	966	622	518
Jun	860	1,041	637	561
Jul	992	1,169	1,038	621
Aug	1,004	1,111	1,029	858
Sep	724	788	655	940
Oct	648	666	650	
Nov	652	678	534	
Dec	624	627	524	
Total (kW)	9,040	9,674	8,227	5,668

2009	2010	2011
-1.9	-1.1	-16.0
-3.6	-5.6	-20.6
7.5	-2.6	-14.1
1.8	-0.8	-15.8
3.6	-33.3	-44.4
21.0	-25.9	-34.8
17.8	4.6	-37.4
10.7	2.5	-14.5
8.8	-9.5	29.8
2.8	0.3	
4.0	-18.1	
0.5	-16.0	
7.0	-9.0	

SFU SSB Daily Power Consumption History (kWh)

Daily Avg. kWh	2008	2009	2010	2011
Jan	12,046	11,355	11,645	9,720
Feb	12,550	11,366	11,422	9,659
Mar	12,111	11,802	11,465	9,757
Apr	12,353	11,255	11,426	9,804
May	13,515	11,850	10,034	9,519
Jun	13,381	13,225	10,327	9,622
Jul	13,441	15,199	11,706	9,441
Aug	13,772	13,322	11,277	10,193
Sep	12,401	12,593	9,900	10,513
Oct	11,987	11,955	9,912	0
Nov	11,243	12,319	9,957	0
Dec	11,531	11,483	9,923	0
Average (kWh)	12,528	12,292	10,749	7,352

2009	2010	2011
-5.7	-3.3	-19.3
-9.4	-9.0	-23.0
-2.5	-5.3	-19.4
-8.9	-7.5	-20.6
-12.3	-25.8	-29.6
-1.2	-22.8	-28.1
13.1	-12.9	-29.8
-3.3	-18.1	-26.0
2.4	-20.2	-15.2
-0.3	-17.3	-100.0
6.9	-11.4	-100.0
-0.6	-13.9	-100.0
-1.9	-14.2	-41.3



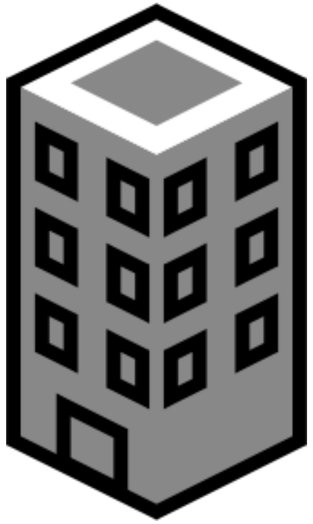
21 ENERGY WORKER ARTEFACTS

OUTLINE: DESIGN PROCESS

1. analyzing the work domain
2. **identifying data and task abstractions**
3. visual encoding sandbox prototyping
4. eliciting feedback on vis. encoding designs
5. prototyping workflows
6. production development by collaborator

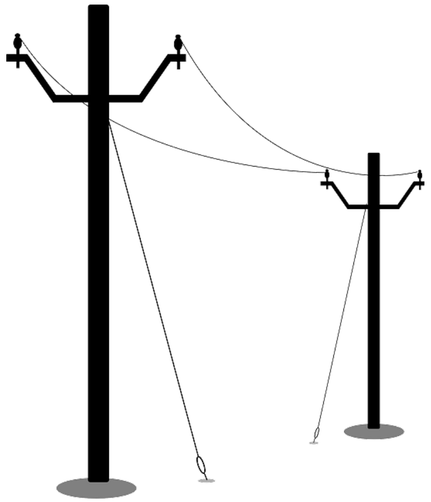
DATA ABSTRACTION

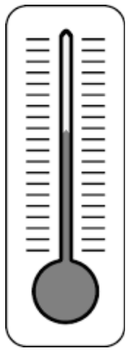
BUILDING PORTFOLIOS



Term	Abstraction	Example
Building ID	Unique categorical	#123
Building area	quantitative	450m^2
Location	spatial	49.26° N, 123.25° W
tag	categorical	*“restaurant”*

RAW TIME SERIES DATA





Term	Abstraction	Example
Energy demand	quantitative	200 kW
Outdoor temperature	quantitative	18° C

DERIVED TIME SERIES DATA

Term	Abstraction	Example
Consumption	quantitative	800 kWh
Intensity	normalized quantitative	1.78 kWh / m^2
% Savings	normalized quantitative	40%
Rank	ordinal	1st, 2nd, 3rd

Brehmer & Munzner (2013),
Munzner (2014)

TASK ABSTRACTION

Actions

Analyze

- Consume
  - Discover
  - Present
  - Enjoy
- Produce
  - Annotate
  - Record
  - Derive

Search

	Target known	Target unknown
Location known	Lookup	Browse
Location unknown	Locate	Explore

Query

- Identify
- Compare
- Summarize

Targets

All Data

- Trends
- Outliers
- Features

Attributes

- One
- Many
  - Distribution
  - Dependency
  - Correlation
  - Similarity
  - Extremes

Network Data

- Topology
  - Paths

Spatial Data

- Shape

EM Use & Frequency	Port–folio?	Portfolio Size, Organization	Task abstractions: current (not in EM)	Task abstractions: desirable	Task abstractions: possible (does data exist?)	Task abstractions: target
meta-user / power-user: frequently setting up charts, baselines for clients	YES	(Client portfolios range in size, hierarchical structure)	• **Lookup → Compare**: ranked performance (absolute and normalized) • **Lookup → Identify**: CUSUM of entire portfolio, single space	• **Locate → Compare**: portfolio performance faceted by any database field (tag, geographical location, primary use, square footage, year constructed,…) • **Locate → Identify**: space's contribution to portfolio's CUSUM • **Lookup → Compare**: multivariate ranking of portfolio performance • **Locate → Identify**: validated savings vs. unvalidated savings • **Locate → Identify**: end-use disaggregation within a space; • **Locate → Identify** contributions of parameters and events baselines (ECMs, weather, outages, holidays, other events) • **Locate → Compare** multiple baselines	• **Locate → Compare**: portfolio performance faceted by any database field (geographical location, primary use, square footage, year constructed,…), faceted by tag • **Locate → Identify**: space's contribution to portfolio's CUSUM • **Lookup → Compare**: multivariate ranking of portfolio performance	• **Locate → Compare**: portfolio performance faceted by space or by space attributes (over time) • **Locate → Identify**: contribution of individual space performance to aggregate space performance (over time) • **Lookup → Compare | Summarize**: multivariate ranking of spaces (over time)
several hours a week, additional analysis in Excel	YES	UCB campus: ~100 spaces (90% concentrated on single campus), subset in EM, departments cross-cuts spaces	• **Locate → Compare**: const mid-size spaces] • **Locate → Identify**: causes OAT • **Lookup → Compare**: rank • **Locate → Compare**: befo • **Lookup → Compare**: mo			
day-to-day monitoring	YES	2 McGill campuses, 4 zones in Downtown campus (~70 spaces), McDonald campus (~20 spaces); all in EM; JC focuses on 50 steam meters	• **Locate → Compare | Sum** two campuses; four groups • **Browse → Identify**: contrib combined consumption, an • **Lookup → Identify**: thresh			
EM for data export; analysis done in Excel, EM analysis offloaded to student volunteers	YES	~130 schools, 2 accounts, 36 in EM (Electricity, 2 submetered), 4 in EM (Natural Gas)	• **Lookup → Compare**: rank normalized) • **Browse → Identify**: anomal (consistent rankings) at ma • **Locate → Compare**: single periods • **Produce** annotations to ex			
daily email digest, follow-up in EM ~3-4 hrs / week	YES	UBC campus, ~100 spaces and 2 zones in EM, monitors about 10 spaces / week	• **Lookup → Compare**: rank • **Locate | Explore → Identif** events / alerts			
infrequent (annual, semi-annual reports)	YES	UBC campus, ~100 spaces and 2 zones in EM, LZ only interested	• **Lookup → Identify**: differential between actual and predicted performance • **Lookup → Identify**: CUSUM	• **Locate → Identify**: cause & long-term trend alerts • **Locate → Identify**: baseline precisions / uncertainty	**Locate → Compare**: performance across arbitrary time periods	**Locate → Compare**: individual performance (over time)

Task abstractions: current (not in EM)

- **Lookup → Compare**: ranked performance (absolute and normalized)
- **Lookup → Identify**: CUSUM of entire portfolio, single space

Task abstractions: desirable

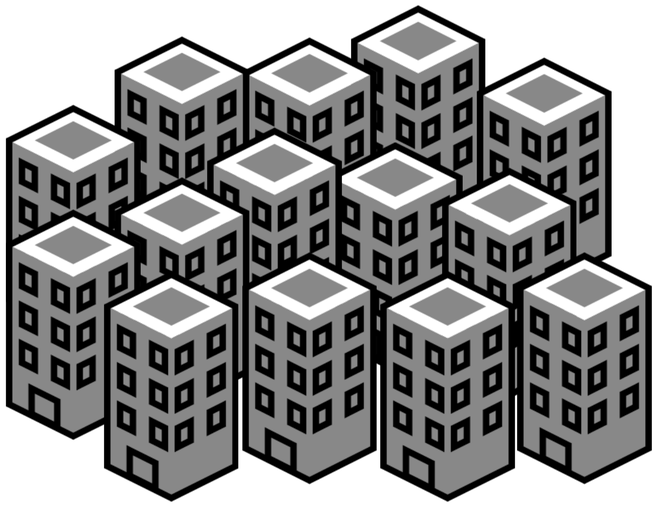
- **Locate → Compare**: portfolio performance faceted by any database field (tag, geographical location, primary use, square footage, year constructed,…)
- **Locate → Identify**: space's contribution to portfolio's CUSUM
- **Lookup → Compare**: multivariate ranking of portfolio performance
- **Locate → Identify**: validated savings vs. unvalidated savings
- **Locate → Identify**: end-use disaggregation within a space;
- **Locate → Identify** contributions of parameters and events baselines (ECMs, weather, outages, holidays, other events)
- **Locate → Compare** multiple baselines
- **Produce** aggregate baselines
- **Locate → Identify** noise / confidence / uncertainty in baseline

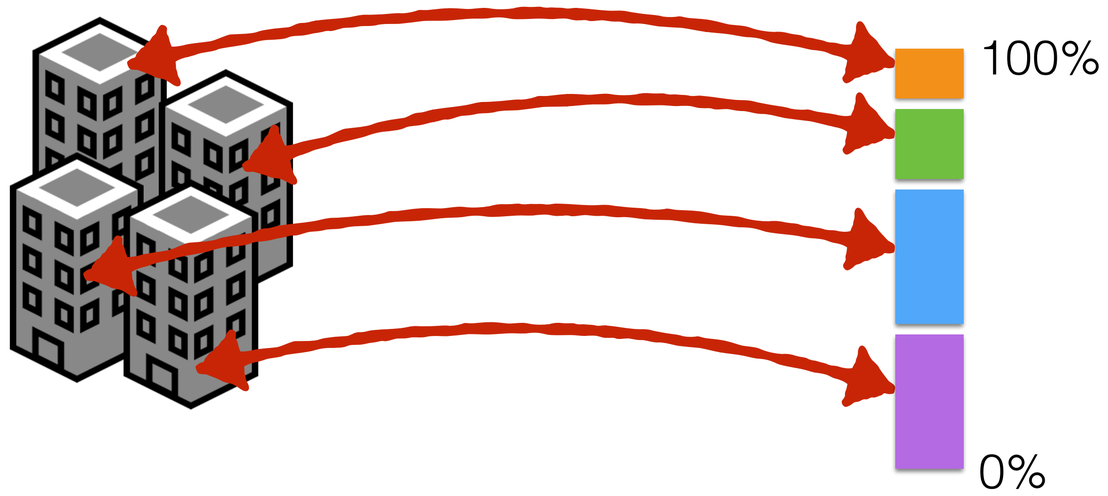
TASK ABSTRACTION

Overview

Drill Down

Roll Up





J	F	M	A	M	J	J	A	S	O	N	D

Coarse temporal granularities

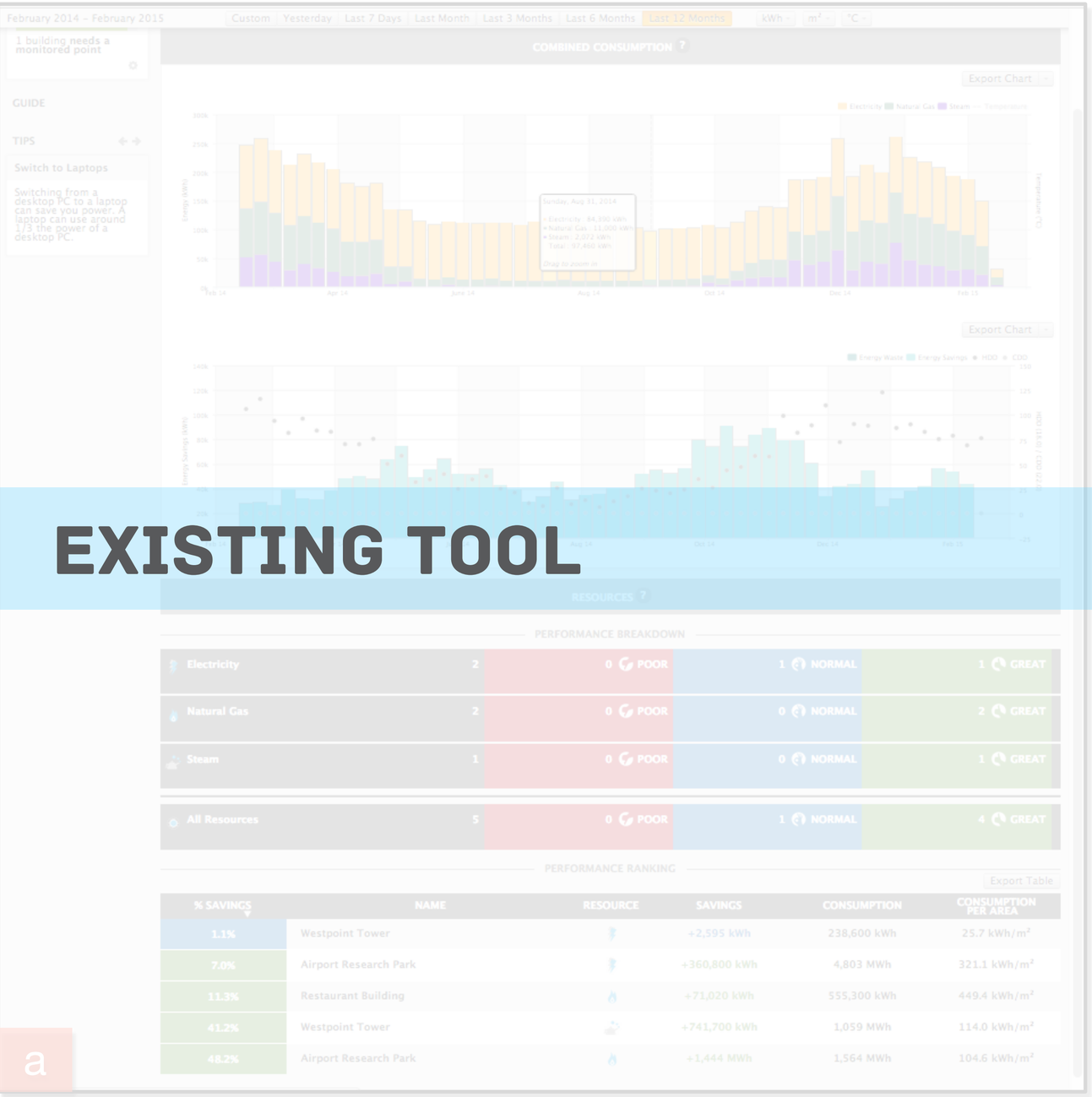
Su	Mo	Tu	We	Th	Fr	Sa

Fine temporal granularities

OUTLINE: DESIGN PROCESS

1. analyzing the work domain
2. **validating** data and task abstractions
   - checking back with 3 energy workers
   - *"did I understand your tasks correctly?"*
   - tailored design proposals
3. visual encoding sandbox prototyping
4. eliciting feedback on vis. encoding designs
5. prototyping workflows
6. production development by collaborator

EXISTING TOOL



ENERGY MANAGER

Overview

Drill Down

Roll Up

Overview too coarse

Excessive manual navigation; not scalable

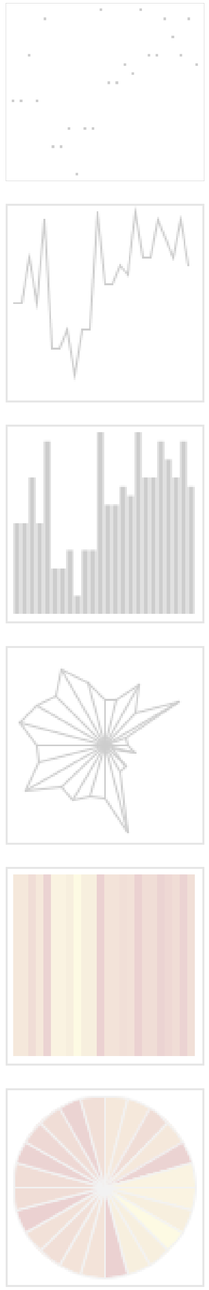
No explicit task support

J	F	M	A	M	J	J	A	S	O	N	D

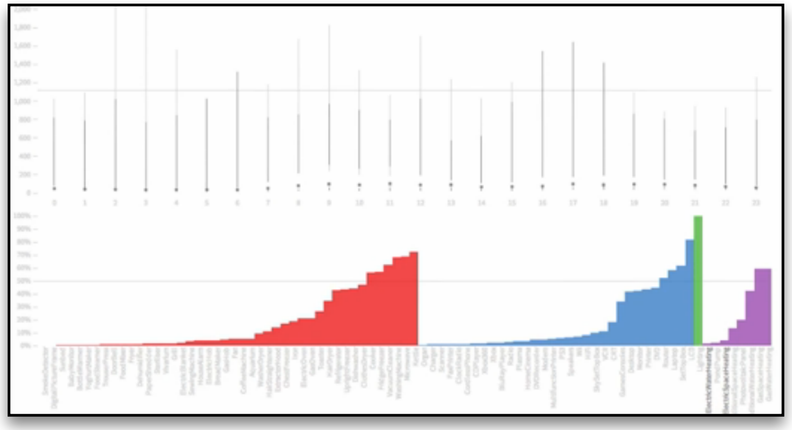
Export to Excel

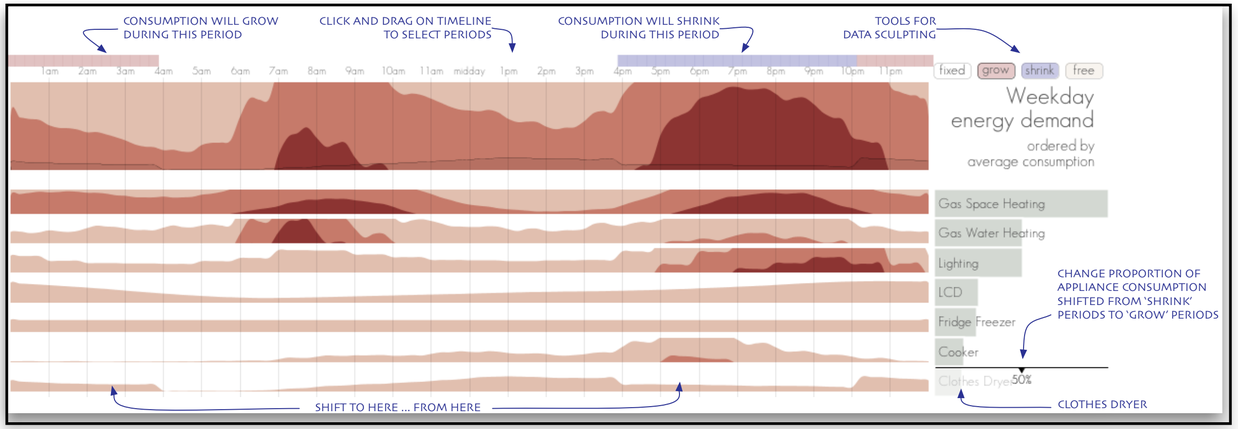
Su	Mo	Tu	We	Th	Fr	Sa

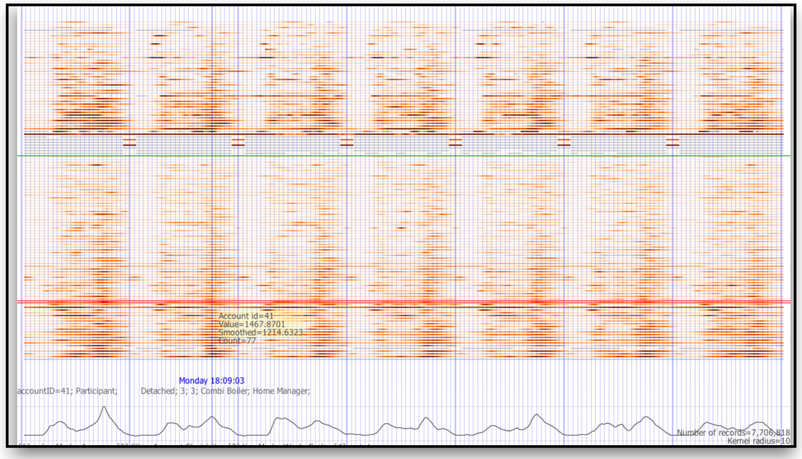
RELATED WORK

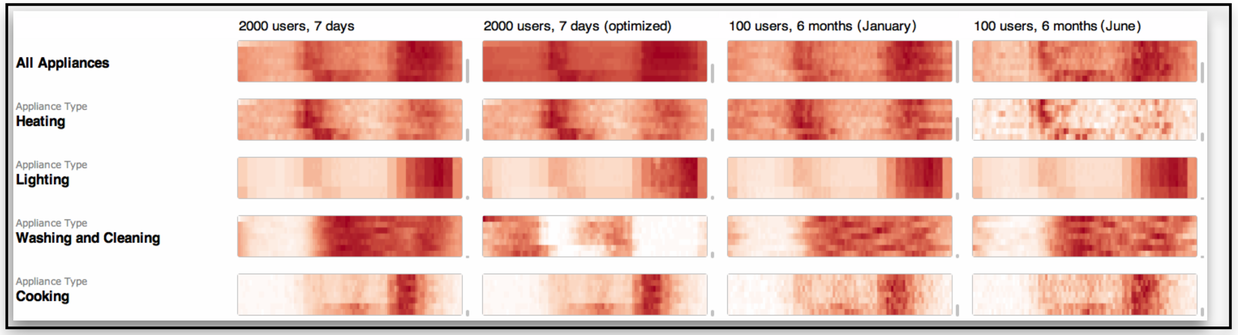


VIS IN THE ENERGY DOMAIN





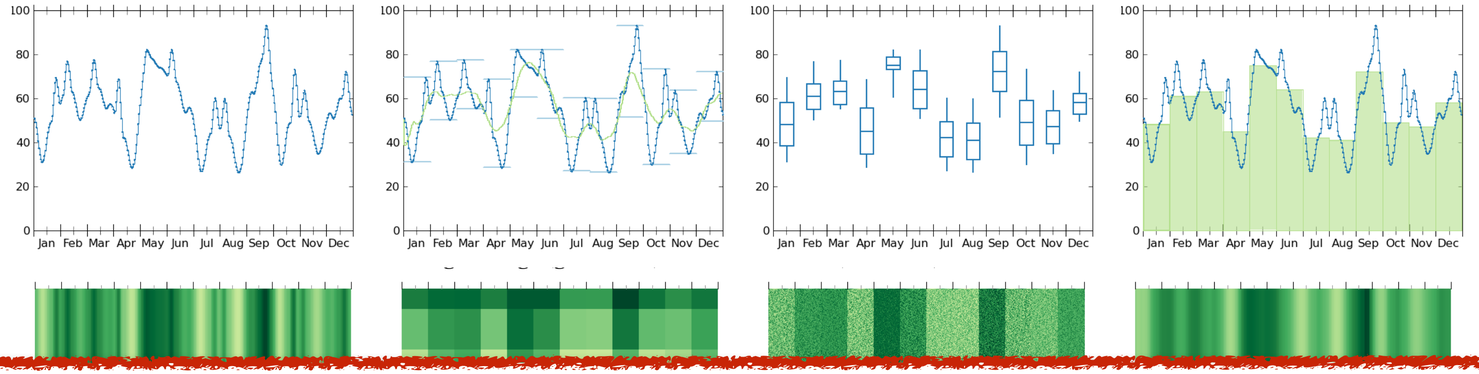




***Goodwin et al.* (2013)**: similar domain, different data, partial task overlap

VIS FOR TIME SERIES

***Aigner et al.* (2011)**: survey and framework

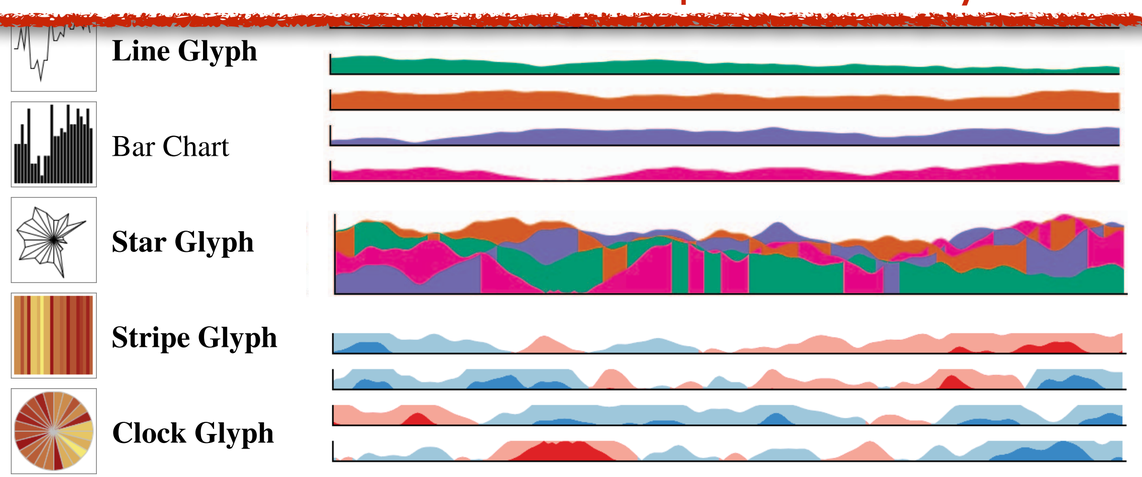


***Albers et al.* (2014)**: evaluation of multiple encodings for identifying aggregate values

Validation in the field

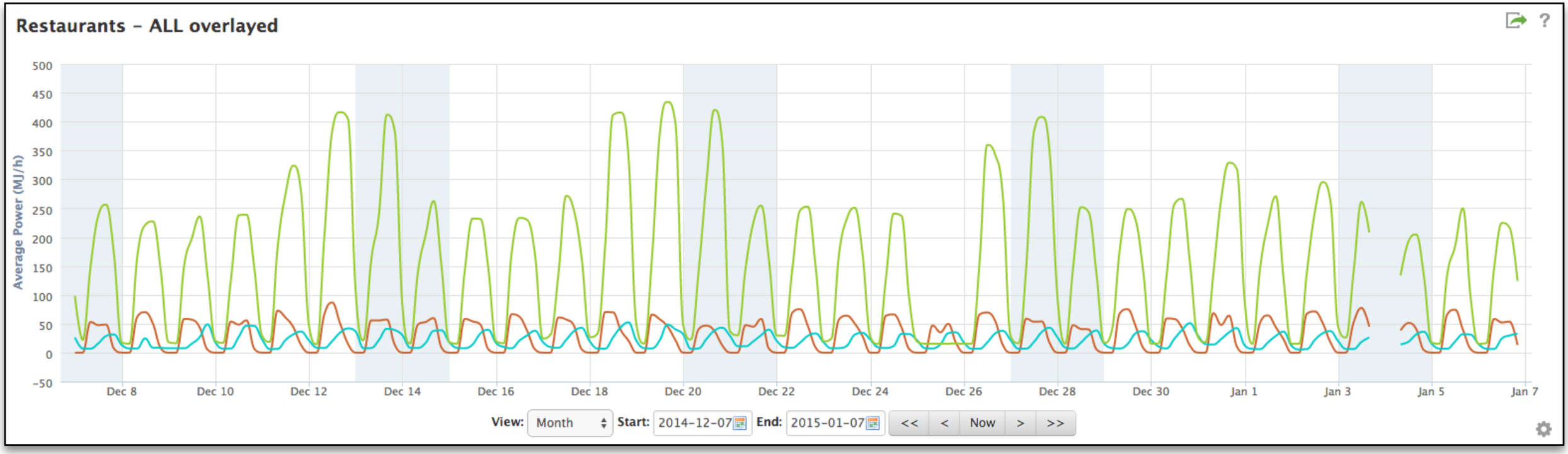
(rather than in a controlled experiment)

***Fuchs et al.* (2013)**: evaluation of multiple encodings in small multiple configurations



***Javed et al.* (2010)**: graphical perception of multiple time series

DOMAIN CONVENTION



Line charts = energy demand

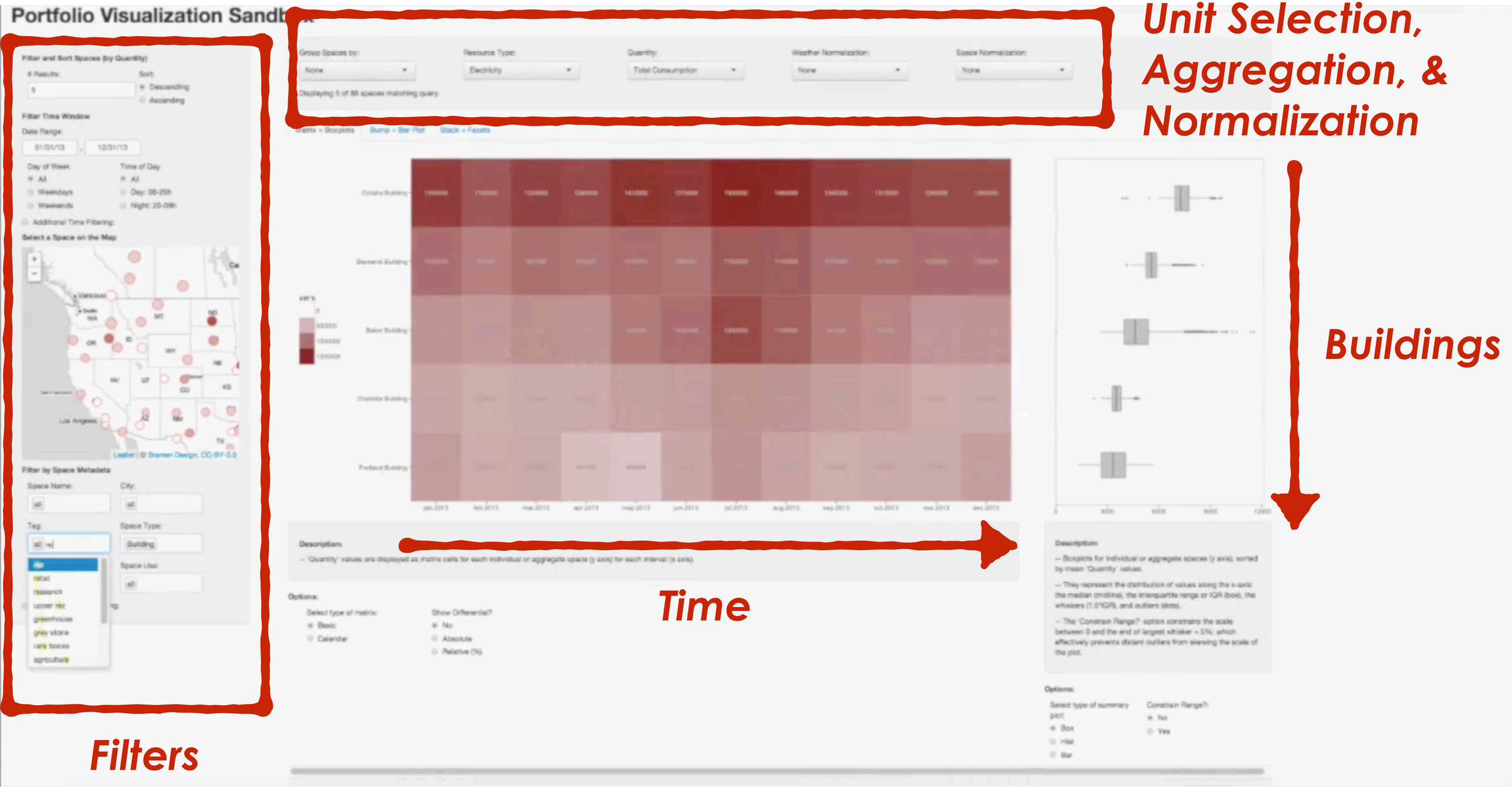
Line charts for derived data verboten!

Portfolio Visualization Sandbox

VISUALIZATION DESIGN

OUTLINE: DESIGN PROCESS

1. analyzing the work domain
2. identifying data and task abstractions
3. **visual encoding sandbox prototyping**
4. eliciting feedback on vis. encoding designs
5. prototyping workflows
6. production development by collaborator


Portfolio Visualization Sandbox
Filter and Sort Spaces (by Quantity)
Results:
5
Sort:
Descending
Ascending
Filter Time Window
Date Range:
01/01/13
12/31/13
Day of Week
All
Weekdays
Weekends
Time of Day
All
Day: 08-20h
Night: 20-08h
Additional Time Filtering:
Select a Space on the Map
Leaflet | © Stamen Design, CC-BY-3.0
Filter by Space Metadata
Space Name:
all
City:
all
Tag:
all re
Space Type:
Building
Space Use:
all
retail
research
lecture rec
greenhouse
grey stone
rare books
agriculture
Filters
Group Spaces by:
None
Resource Type:
Electricity
Quantity:
Total Consumption
Weather Normalization:
None
Space Normalization:
None
Displaying 5 of 86 spaces matching query.
Unit Selection, Aggregation, & Normalization
Matrix + Boxplots
Bump + Bar Plot
Stack + Facets
kW's
Omaha Building
Bismarck Building
Baker Building
Charlotte Building
Portland Building
jan 2013
feb 2013
mar 2013
apr 2013
may 2013
jun 2013
jul 2013
aug 2013
sep 2013
oct 2013
nov 2013
dec 2013
Buildings
Time
Description:
-- 'Quantity' values are displayed as matrix cells for each individual or aggregate space (y axis) for each interval (x axis).
Options:
Select type of matrix:
Basic
Calendar
Show Differential?
No
Absolute
Relative (%)
Description:
-- Boxplots for individual or aggregate spaces (y axis), sorted by mean 'Quantity' values.
-- They represent the distribution of values along the x-axis: the median (midline), the interquartile range or IQR (box), the whiskers (1.5*IQR), and outliers (dots).
-- The 'Constrain Range?' option constrains the scale between 0 and the end of largest whisker + 5%; which effectively prevents distant outliers from skewing the scale of the plot.
Options:
Select type of summary plot:
Box
Hist
Bar
Constrain Range?:
No
Yes

OUTLINE: DESIGN PROCESS

1. analyzing the work domain
2. identifying data and task abstractions
3. visual encoding sandbox prototyping
4. **eliciting feedback on vis. encoding designs**
   - custom tailored design specs sent in advance
   - 4 interviews (2 new energy workers)
5. prototyping workflows
6. production development by collaborator

MATCHES & MISMATCHES

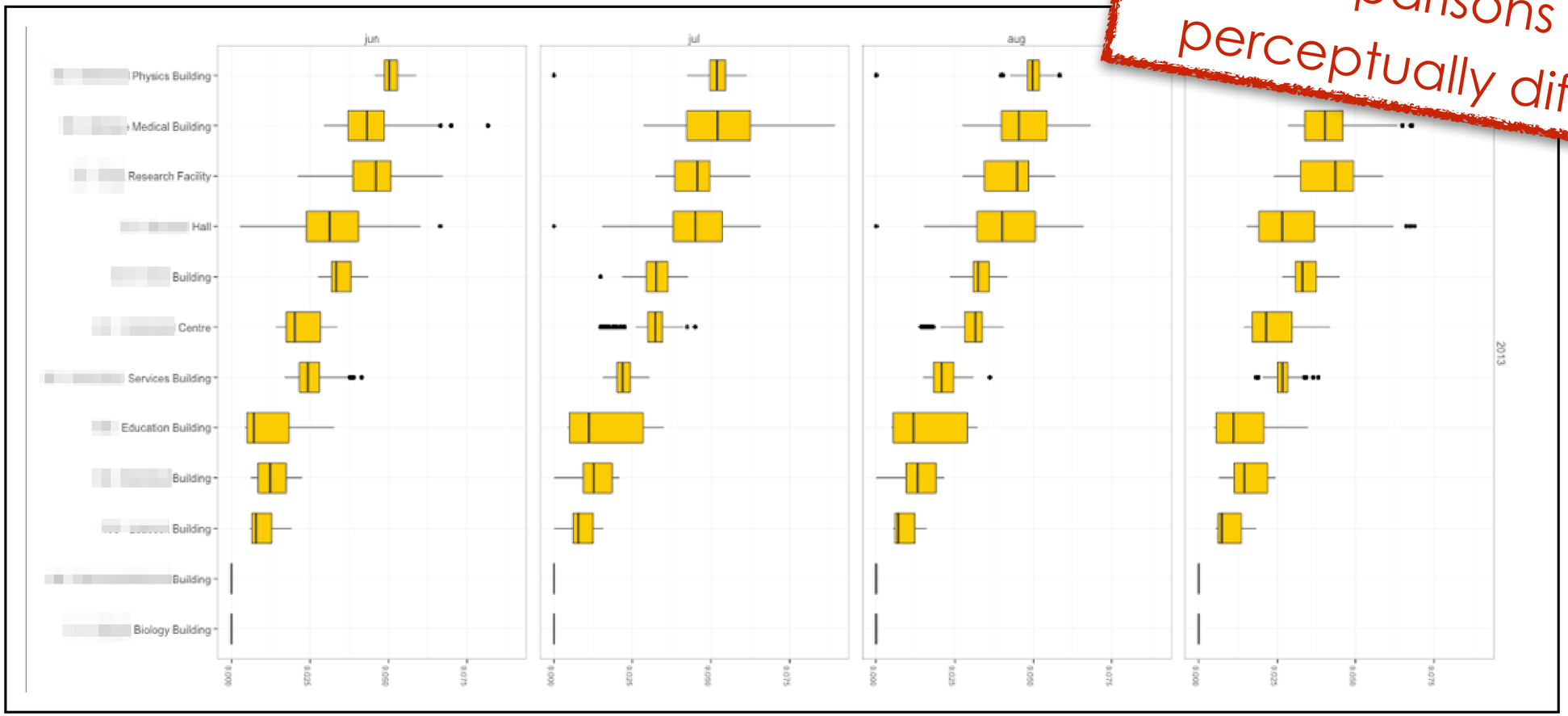
Task	Design choice	Match?
Overview	Faceted bar charts	✖
	Bump plot	✖
	Bar + bump plot	?
	Time-series matrix	?
	Map	✖
	Juxtaposed matrix and boxplots	✔
Drill Down	Faceted bar charts	✔
	Faceted boxplots	✖
	Faceted line graphs	✔
Roll Up	Stacked bar chart	✔
	Stacked area chart	✔

FACETING (SMALL MULTIPLES)

Aggregate values not trusted

Task	Design Choice	Match?
Overview	Faceted bar charts	✖
Drill Down	Faceted bar charts	✔

FACETED BOXPLOTS

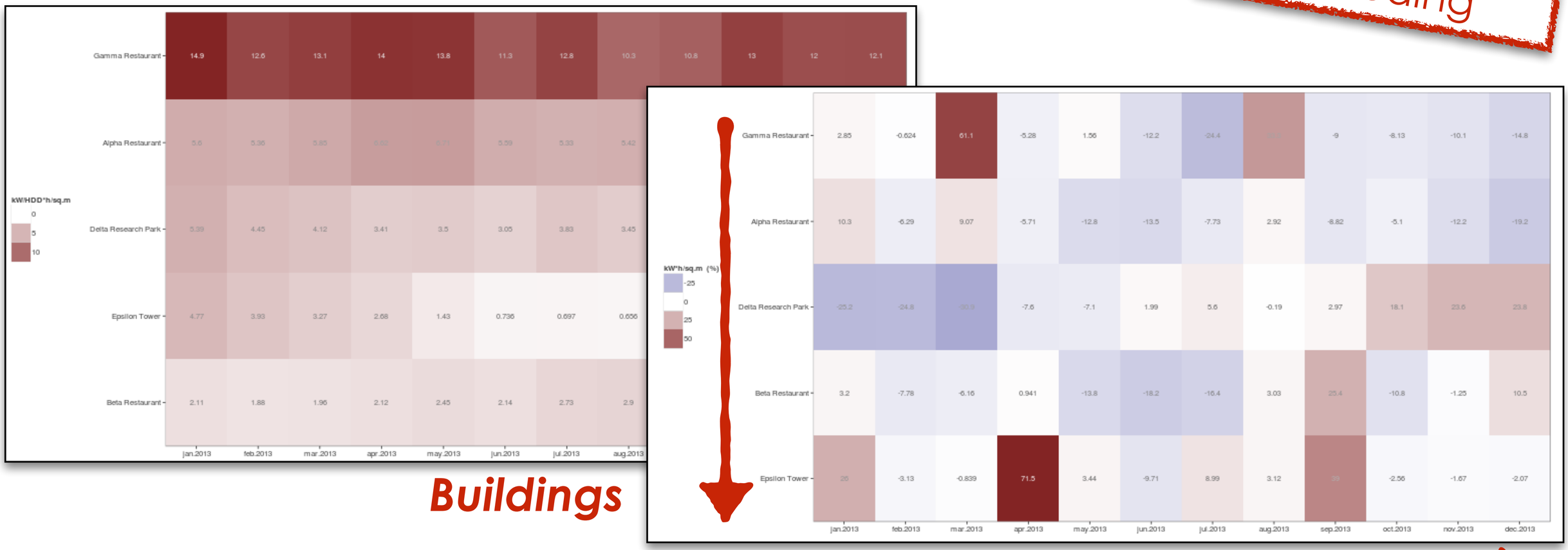


Unfamiliar encoding; comparisons are perceptually difficult

Task	Visualization Idiom	Match?
T2: Drill Down	Faceted boxplots	✖

TIME-SERIES MATRIX

Unfamiliar encoding



Buildings

Time

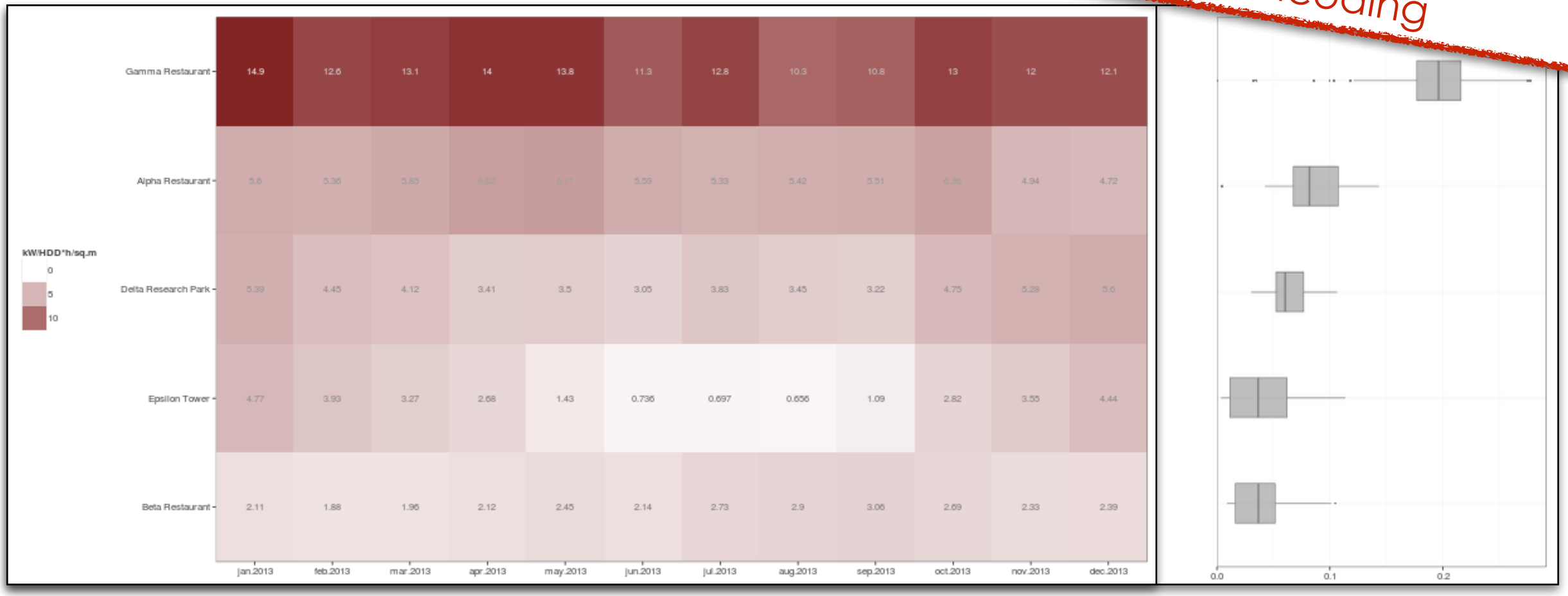
Task	Design Choice	Match?
Overview	Time-series matrix	?

OUTLINE: DESIGN PROCESS

1. analyzing the work domain
2. identifying data and task abstractions
3. visual encoding sandbox prototyping
4. eliciting feedback on vis. encoding designs
5. **prototyping workflows**
6. production development by collaborator

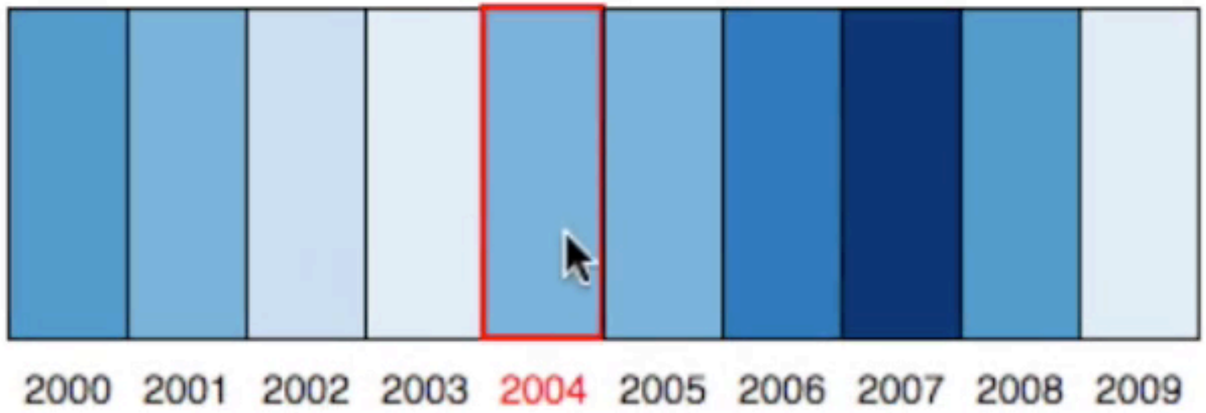
MATRIX + AUXILIARY BOXPLOTS

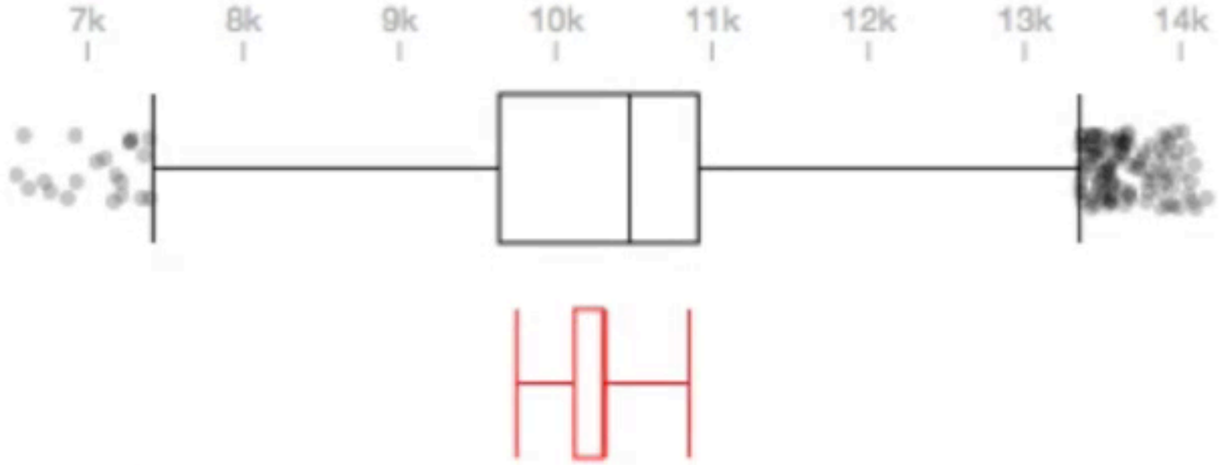
Boxplots easier to read than faceted design; reinforced by matrix encoding



Persevere despite unfamiliarity:

Positive response to juxtaposition and linking two unfamiliar encodings





Task	Design choice	Match?
Overview	Juxtaposed matrix and boxplots	✔

RESULTS

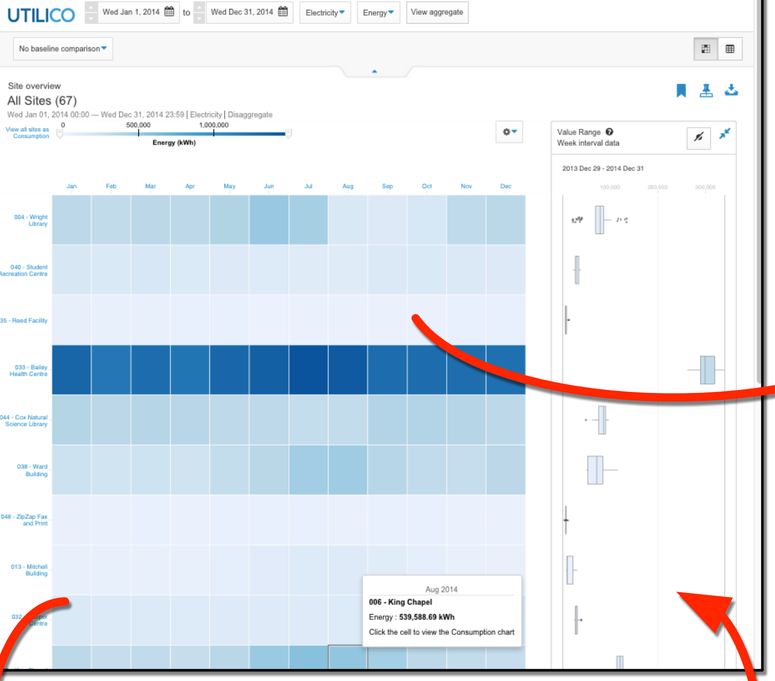
OVERVIEW (**T1**)

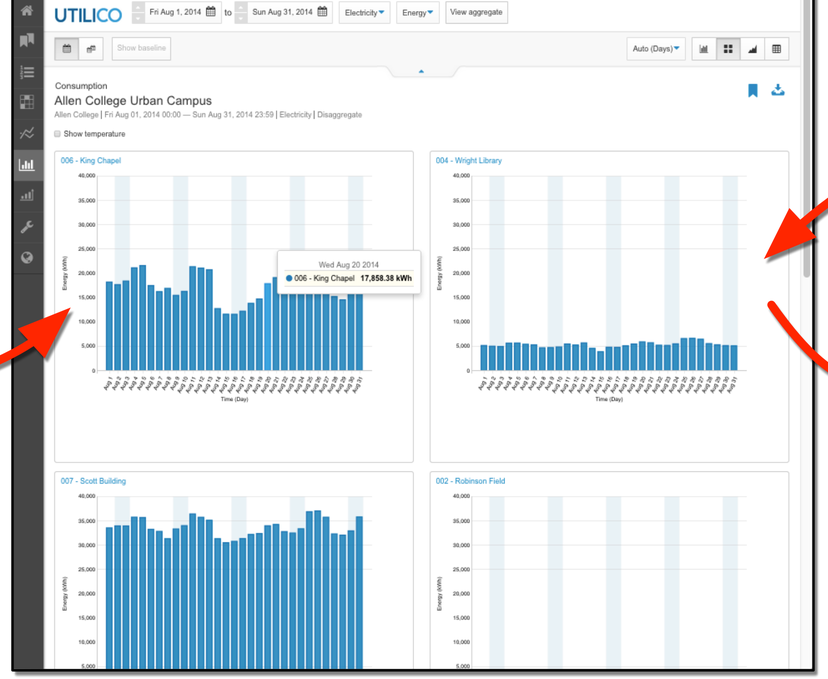
DRILL DOWN (**T2**)

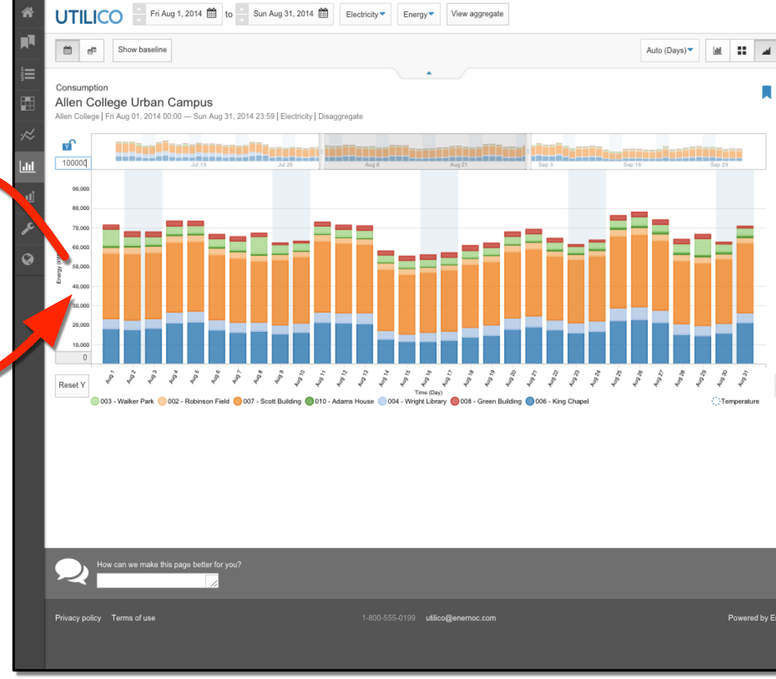
ROLL UP (**T3**)

OUTLINE: DESIGN PROCESS

1. analyzing the work domain
2. identifying data and task abstractions
3. visual encoding sandbox prototyping
4. eliciting feedback on vis. encoding designs
5. prototyping workflows
6. **production development by collaborator**
   - commitment of development resources
   - 10+ developers working on project since summer 2014



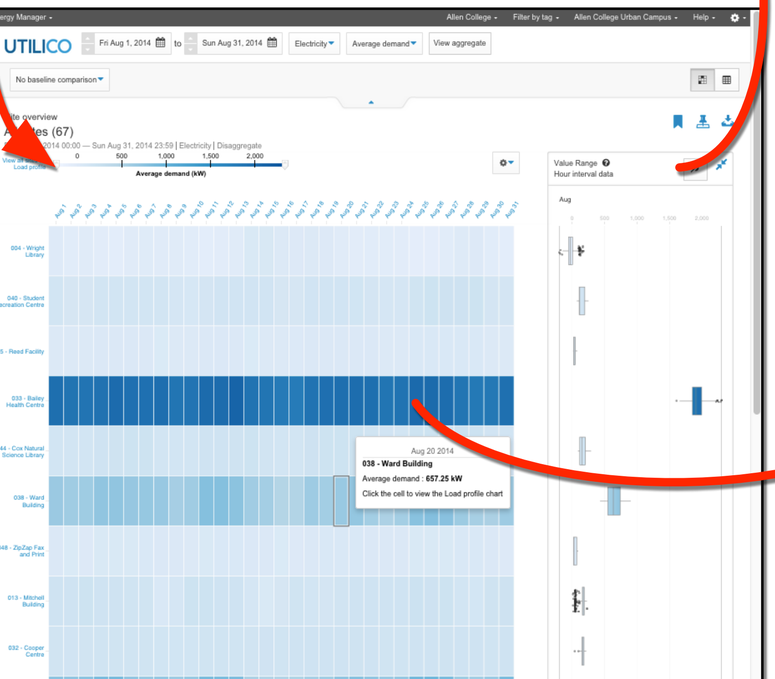


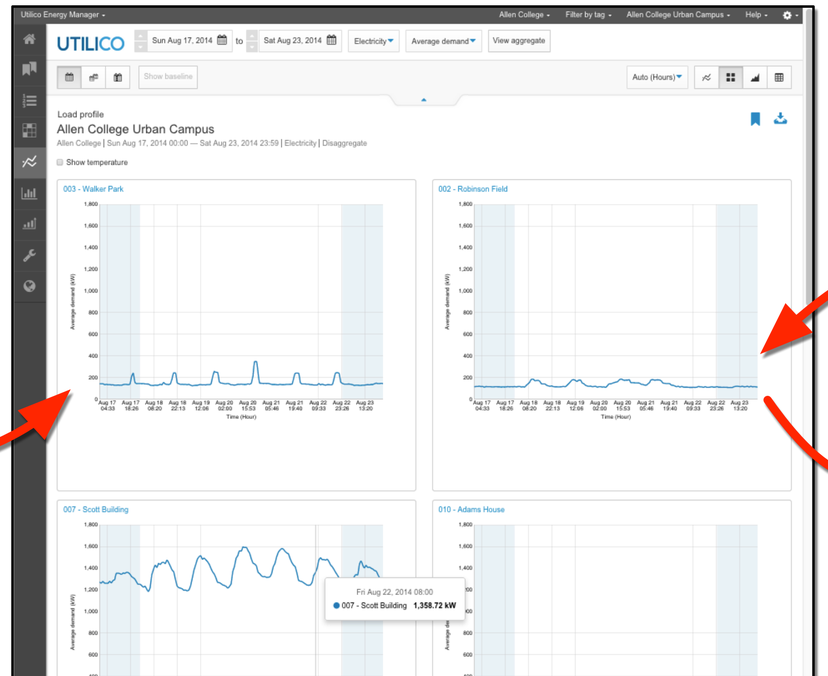


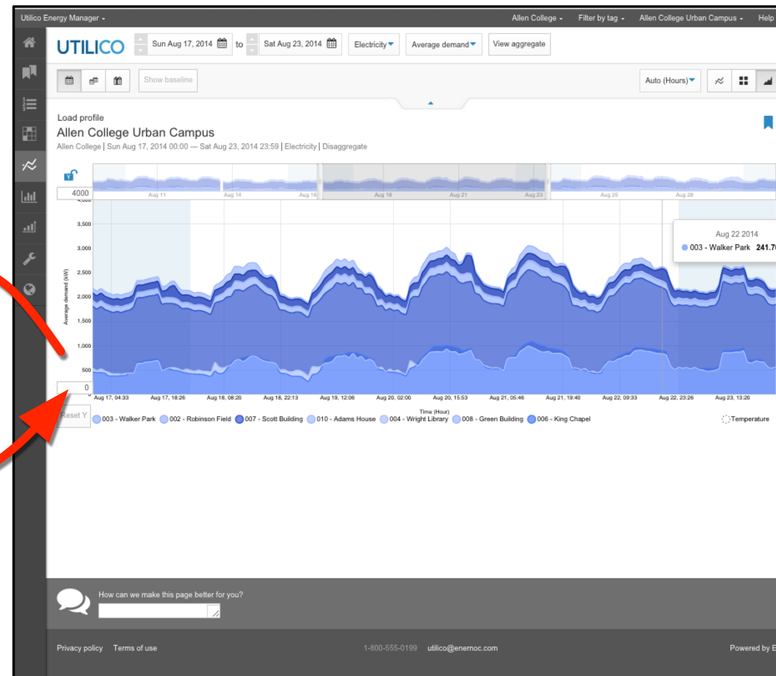
OVERVIEW (**T1**)

DRILL DOWN (**T2**)

ROLL UP (**T3**)







CONCLUSION

An industry visualization design study **success story**.

Matches and **mismatches** between task and data abstractions to visual encoding and interaction design choices.

Reflecting on **methods** for visualization design studies.

- work domain analysis + artefact collection
- custom design specs featuring real client data
- interactive sandbox for visual encoding design exploration

Matthew Brehmer
@mattbrehmer

Jocelyn Ng
@JocelynNg

Kevin Tate

Tamara Munzner
@tamaramunzner

Matches, Mismatches, and Methods:
Multiple-View Workflows for Energy Portfolio Analysis

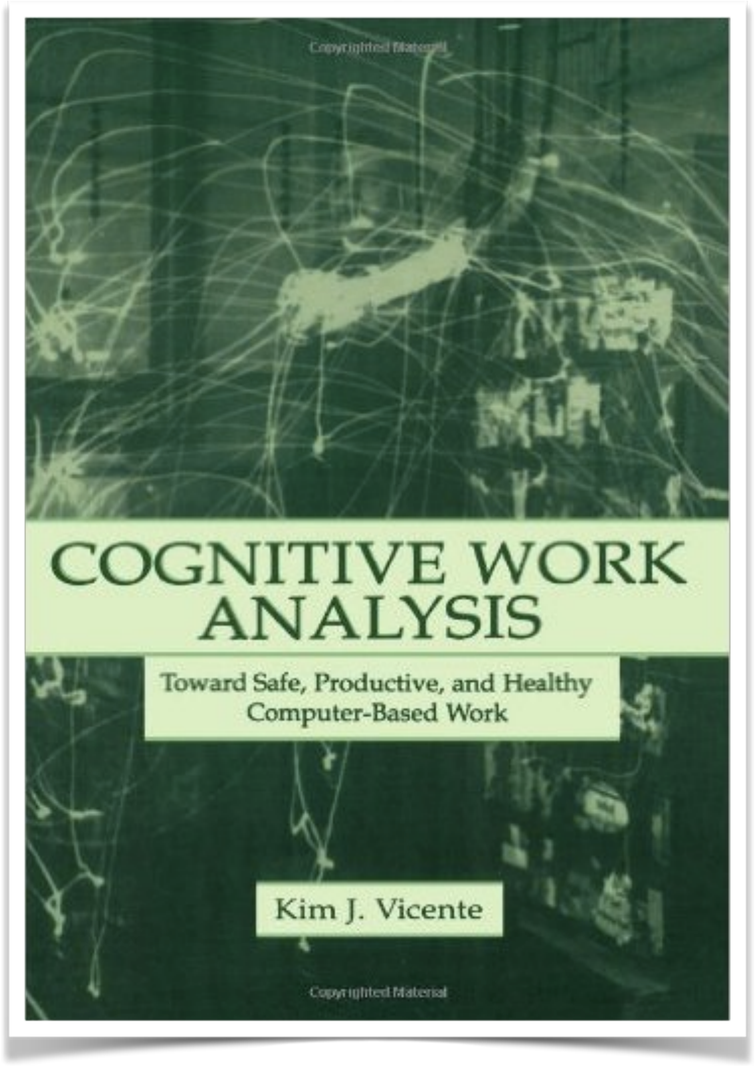
paper & supplemental materials:
cs.ubc.ca/labs/imager/tr/2015/MatchesMismatchesMethods/

- supplemental video
- high-resolution figures
- sample research artefacts + tailored design specs
- interactive sandbox design environment + git repo

thanks: Michelle Borkin, James Christopherson, Cailie Crane, Anamaria Crisan, Jessica Dawson, Johanna Fulda, Enamul Hoque, Sung-Hee Kim, Narges Mahyar, Joanna McGrenere, & UBC MUX.

SUPPLEMENTAL

WORK DOMAIN ANALYSIS



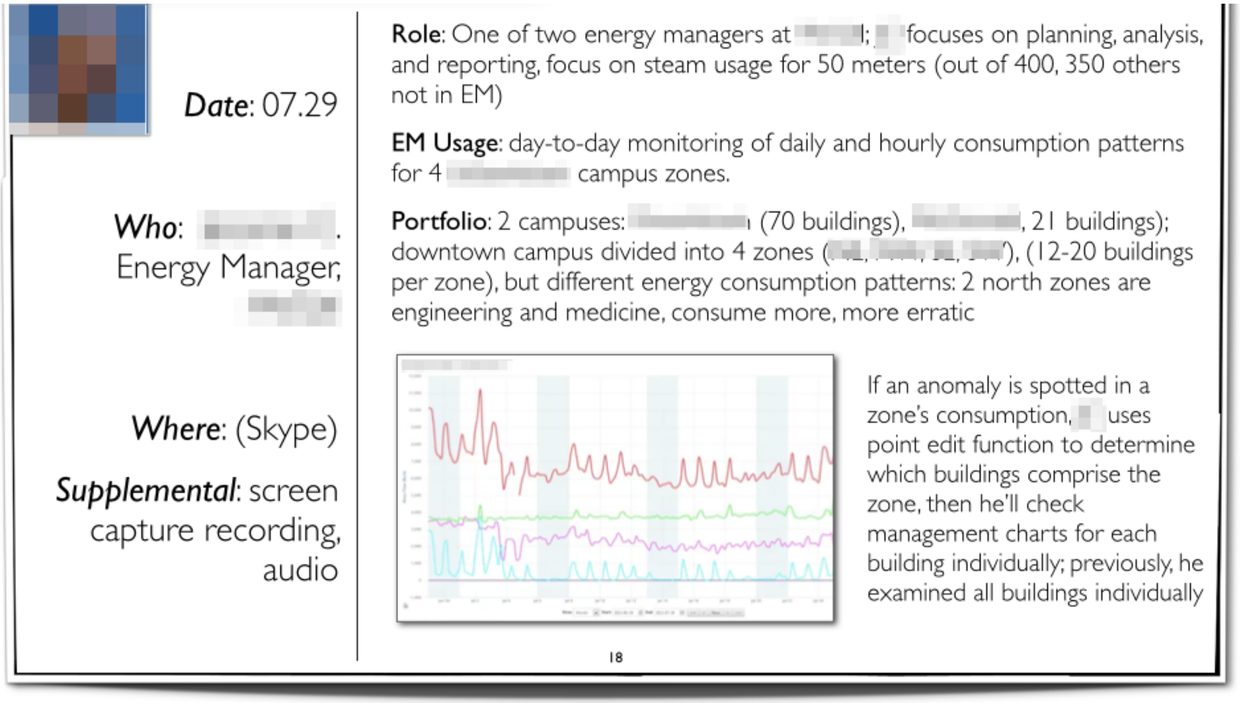
Normative, descriptive, formative perspectives. Workers' use of tools, their work context, workarounds.

Hierarchical and sequential task analysis.

Resources:

- Vicente's *Cognitive Work Analysis* (CRC, 1999)
- McNamara et al.'s VIS '14 tutorial materials.
- Brehmer et al on pre-design empiricism for InfoVis (BELIV '14)
- Winters et al. on characterizing domain problems (BELIV '14)

DESIGN DOCUMENTATION



Date: 07.29

Who: Energy Manager,

Where: (Skype)

Supplemental: screen capture recording, audio

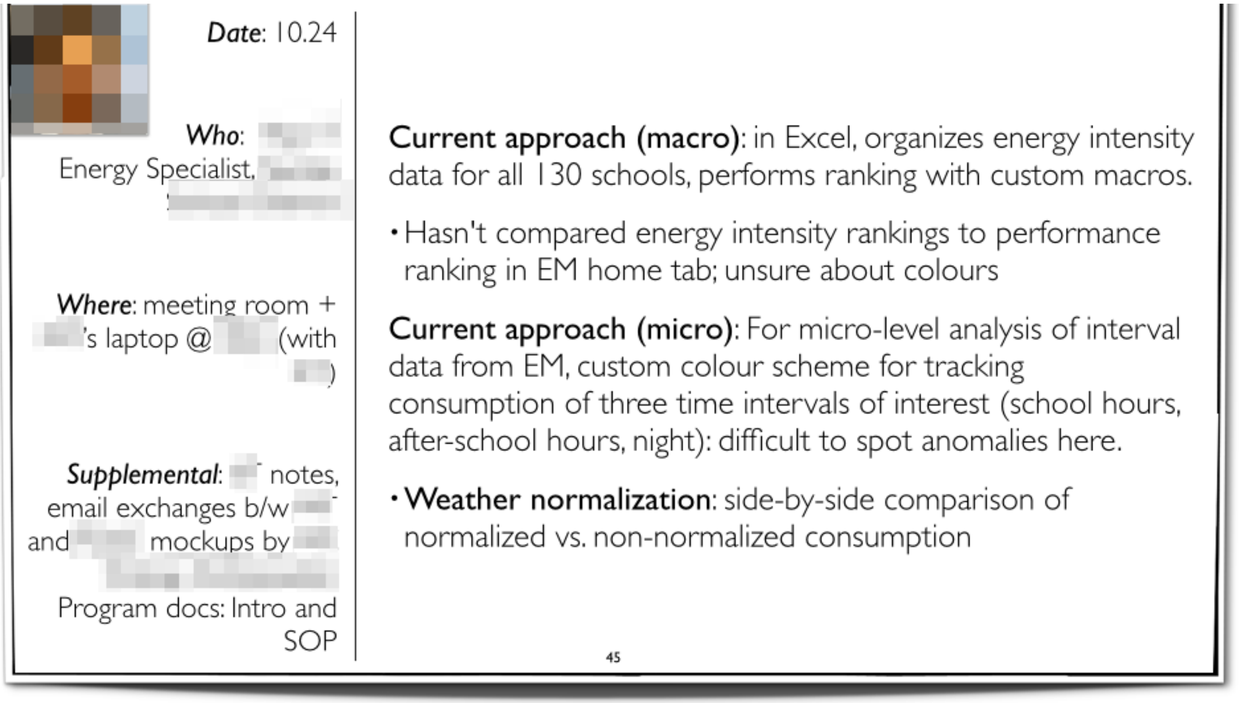
Role: One of two energy managers at ; focuses on planning, analysis, and reporting, focus on steam usage for 50 meters (out of 400, 350 others not in EM)

EM Usage: day-to-day monitoring of daily and hourly consumption patterns for 4 campus zones.

Portfolio: 2 campuses: (70 buildings), , 21 buildings); downtown campus divided into 4 zones ( ), (12-20 buildings per zone), but different energy consumption patterns: 2 north zones are engineering and medicine, consume more, more erratic

If an anomaly is spotted in a zone's consumption, uses point edit function to determine which buildings comprise the zone, then he'll check management charts for each building individually; previously, he examined all buildings individually

18



Date: 10.24

Who: Energy Specialist,

Where: meeting room + 's laptop @ (with)

Supplemental: notes, email exchanges b/w and mockups by

Program docs: Intro and SOP

Current approach (macro): in Excel, organizes energy intensity data for all 130 schools, performs ranking with custom macros.

- Hasn't compared energy intensity rankings to performance ranking in EM home tab; unsure about colours

Current approach (micro): For micro-level analysis of interval data from EM, custom colour scheme for tracking consumption of three time intervals of interest (school hours, after-school hours, night): difficult to spot anomalies here.

- **Weather normalization**: side-by-side comparison of normalized vs. non-normalized consumption

45

sample documentation slides

PORTFOLIO ENERGY ANALYSIS

Goals:
– oversee energy behaviour of portfolios of buildings
– reduce energy costs / conserve energy
– ensure comfort and safety of building occupants

Activities:
– assess behaviour following energy conservation measures
– determine which building(s) require these measures
– find (and diagnose) anomalous energy behaviour

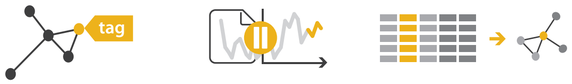
Why?

Actions

Analyze

- Consume
  - *Discover*
  - *Present*
  - *Enjoy*

- Produce
  - *Annotate*
  - *Record*
  - *Derive*

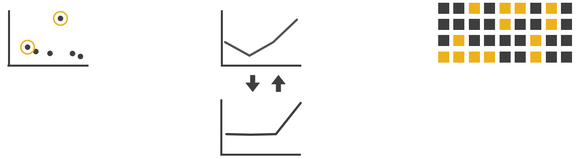


Search

	Target known	Target unknown
Location known	*Lookup*	*Browse*
Location unknown	*Locate*	*Explore*

Query

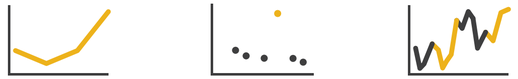
- Identify
- Compare
- Summarize



Targets

All Data

- Trends
- Outliers
- Features

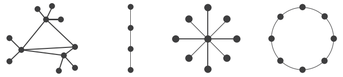


Attributes

- One
- Many
  - *Distribution*
  - *Dependency*
  - *Correlation*
  - *Similarity*
  - *Extremes*

Network Data

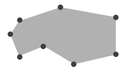
- Topology

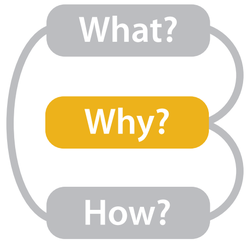


- *Paths*

Spatial Data

- Shape





TASK 1: OVERVIEW

Energy Domain Activities	Scope	Abstraction	Example Question
determine which building(s) require energy conservation measures find anomalous energy behaviour	The entire portfolio of buildings coarser time periods	discover trends, outliers lookup and summarize distributions, extremes, similarities	*"How did my building portfolio perform this past year?"*

TASK 2: DRILL DOWN

Energy Domain Activities	Scope	Abstraction	Example Question
assess behaviour following energy conservation measures diagnose anomalous energy behaviour	Groups within the portfolio of buildings finer time periods	discover, locate, and compare trends, outliers, features	*"Are my restaurants in Chicago performing better this October than they did last October?"*

TASK 3: ROLL UP

Energy Domain Activities	Scope	Abstraction	Example Question
find and diagnose anomalous energy behaviour	Groups within the portfolio of buildings finer time periods	discover, locate, and identify trends, outliers, features, dependencies	*"what proportion of a university's energy consumption is consumed by its computer science building over time?"*

Task Name	Energy Domain Activities	Abstraction	Example Question
Overview	determine which building(s) require energy conservation measures find anomalous energy behaviour	*discover* trends, outliers *lookup* and *summarize* distributions, extremes, similarities	*"How did my building portfolio perform this past year?"*
Drill Down	assess behaviour following energy conservation measures find and diagnose anomalous energy behaviour	*discover, locate, and compare* trends, outliers, features	*"Are my restaurants in Chicago performing better this October than they did last October?"*
Roll Up	find and diagnose anomalous energy behaviour	*discover, locate, and identify* trends, outliers, features, dependencies	*"what proportion of a university's energy consumption is consumed by its computer science building over time?"*

EXISTING TOOL

ANALYSIS OF ENERGY MANAGER

Limited **filtering**, no filtering items by shared attributes
"*show only restaurants*"

Limited **aggregation**, no aggregating items by shared attributes
"*all restaurants in Chicago vs. all restaurants in New York*"

No **faceting** (juxtaposed views, small multiples)

ANALYSIS OF ENERGY MANAGER

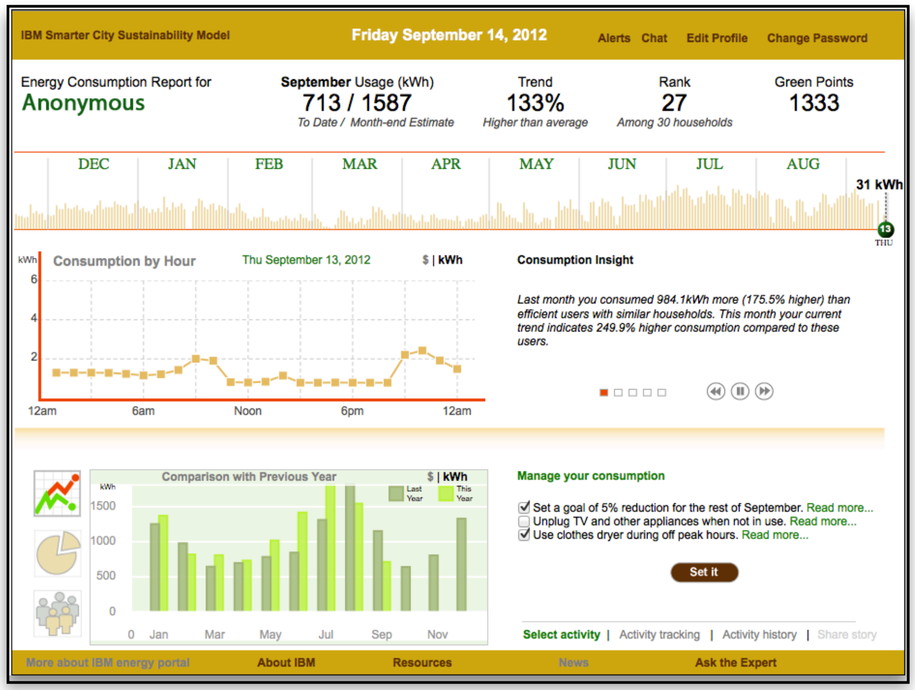
Data routinely exported and imported into Excel.

Little **trust** in predicted derived values based on statistical models. A preference for comparing against historical data.

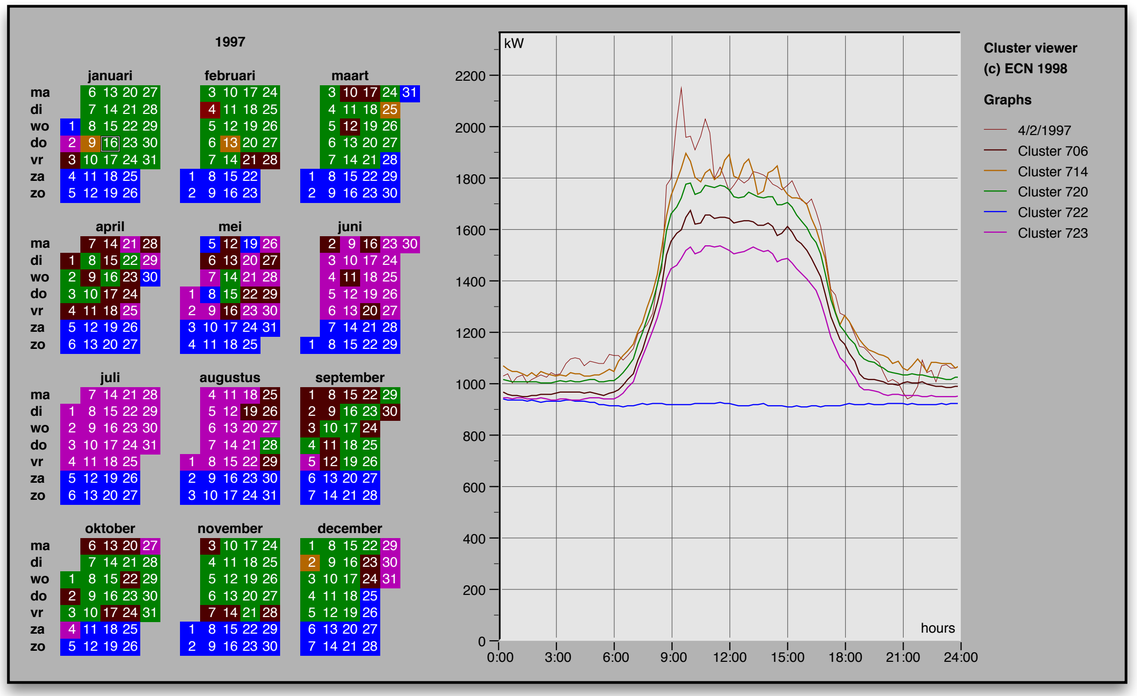
Aggregate derived values (sums, averages) too coarse (loss of detail, lack of **trust**).

RELATED WORK

VIS IN THE ENERGY DOMAIN



***Erickson et al* (2013)**: web-based residential energy report for home-owners

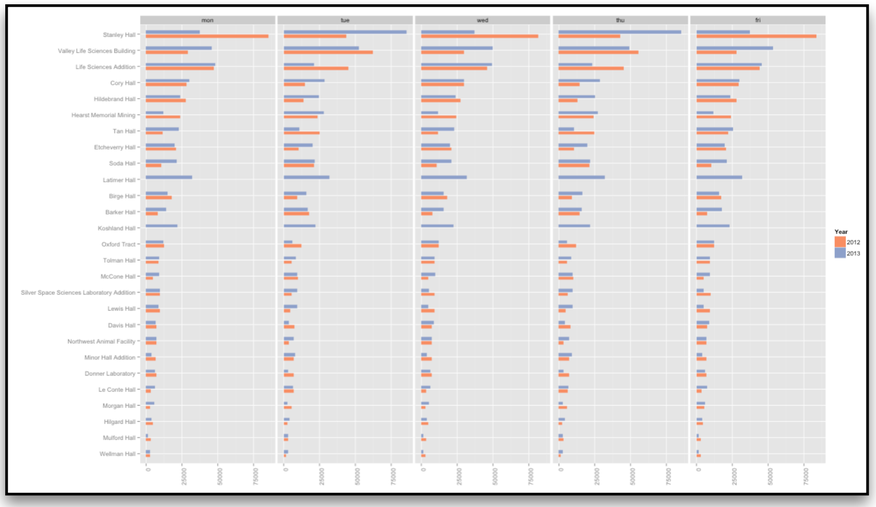


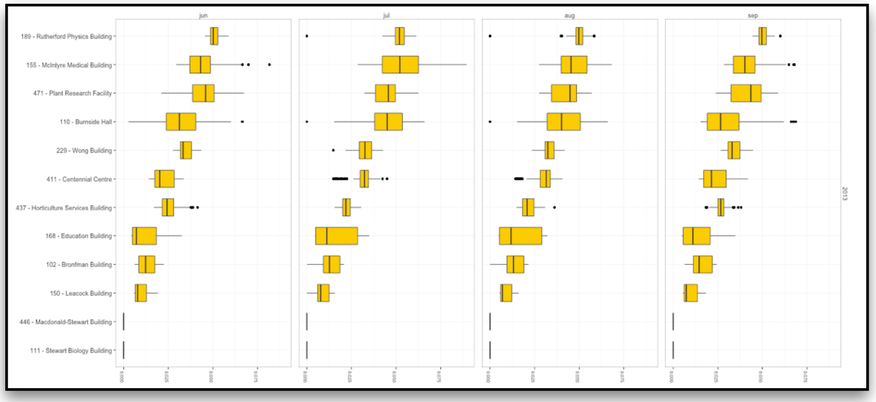
***van Wijk & van Selow* (1999)**: calendars of energy behaviour

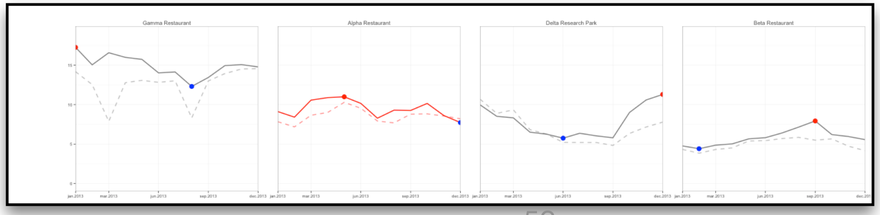
VISUAL ENCODING DESIGN

FACETING


Bear Creek Elementary - Academic 12/13 - Overview
August 2012
September 2012
October 2012
November 2012
December 2012
January 2013
February 2013
March 2013
April 2013
May 2013


mon
tue
wed
thu
fri
Stanley Hall
Valley Life Sciences Building
Life Sciences Addition
Cory Hall
Hildebrand Hall
Hearst Memorial Mining
Tan Hall
Etcheverry Hall
Soda Hall
Latimer Hall
Birge Hall
Barker Hall
Koshland Hall
Oxford Tract
Tolman Hall
McCone Hall
Silver Space Sciences Laboratory Addition
Lewis Hall
Davis Hall
Northwest Animal Facility
Minor Hall Addition
Donner Laboratory
Le Conte Hall
Morgan Hall
Hilgard Hall
Mulford Hall
Wellman Hall
Year
2012
2013

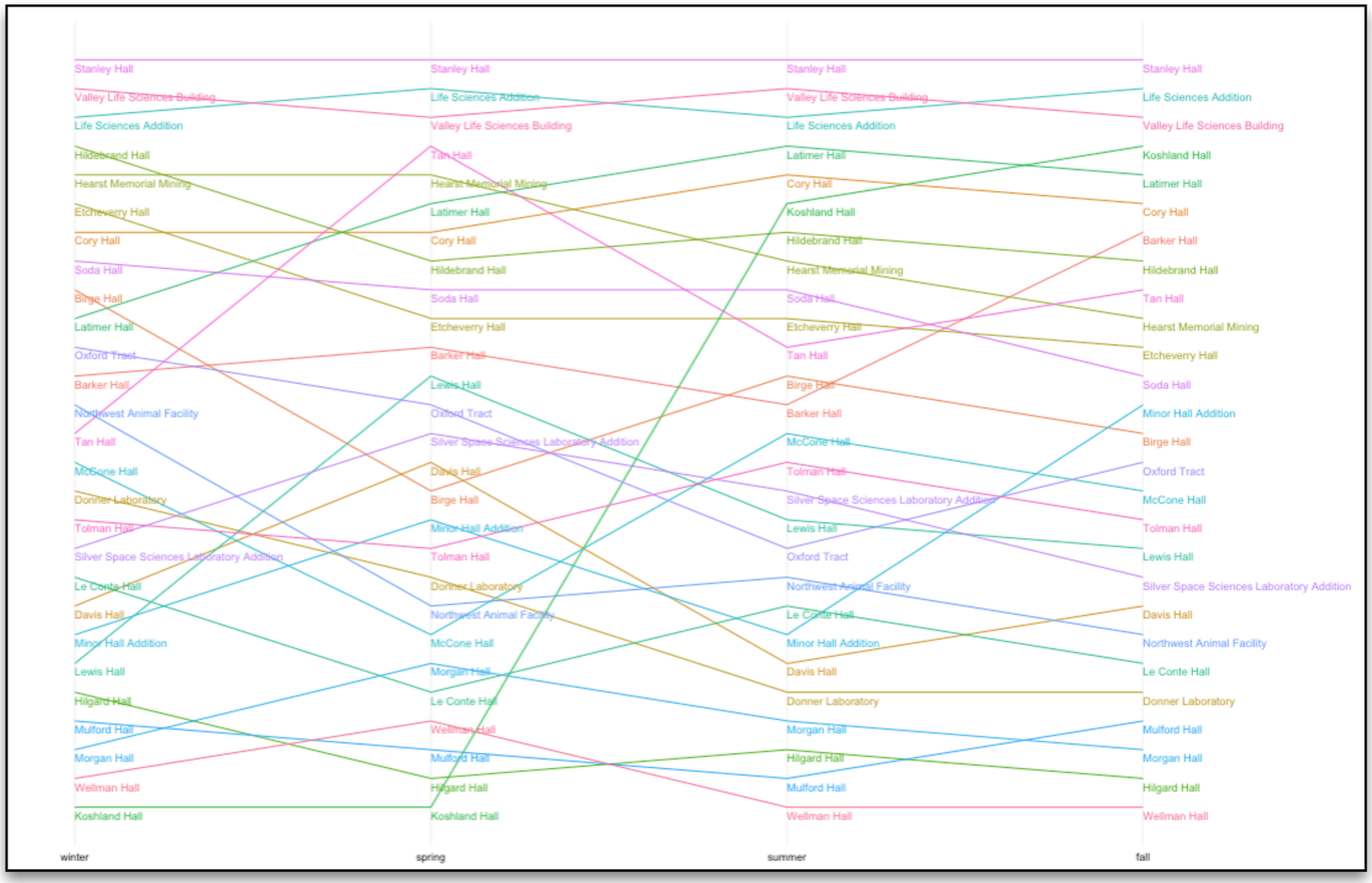

jun
jul
aug
sep
189 - Rutherford Physics Building
155 - McIntyre Medical Building
471 - Plant Research Facility
110 - Burnside Hall
229 - Wong Building
411 - Centennial Centre
437 - Horticulture Services Building
168 - Education Building
102 - Bronfman Building
150 - Leacock Building
446 - Macdonald-Stewart Building
111 - Stewart Biology Building
2013


Gamma Restaurant
Alpha Restaurant
Delta Research Park
Beta Restaurant

FACETED BAR CHARTS

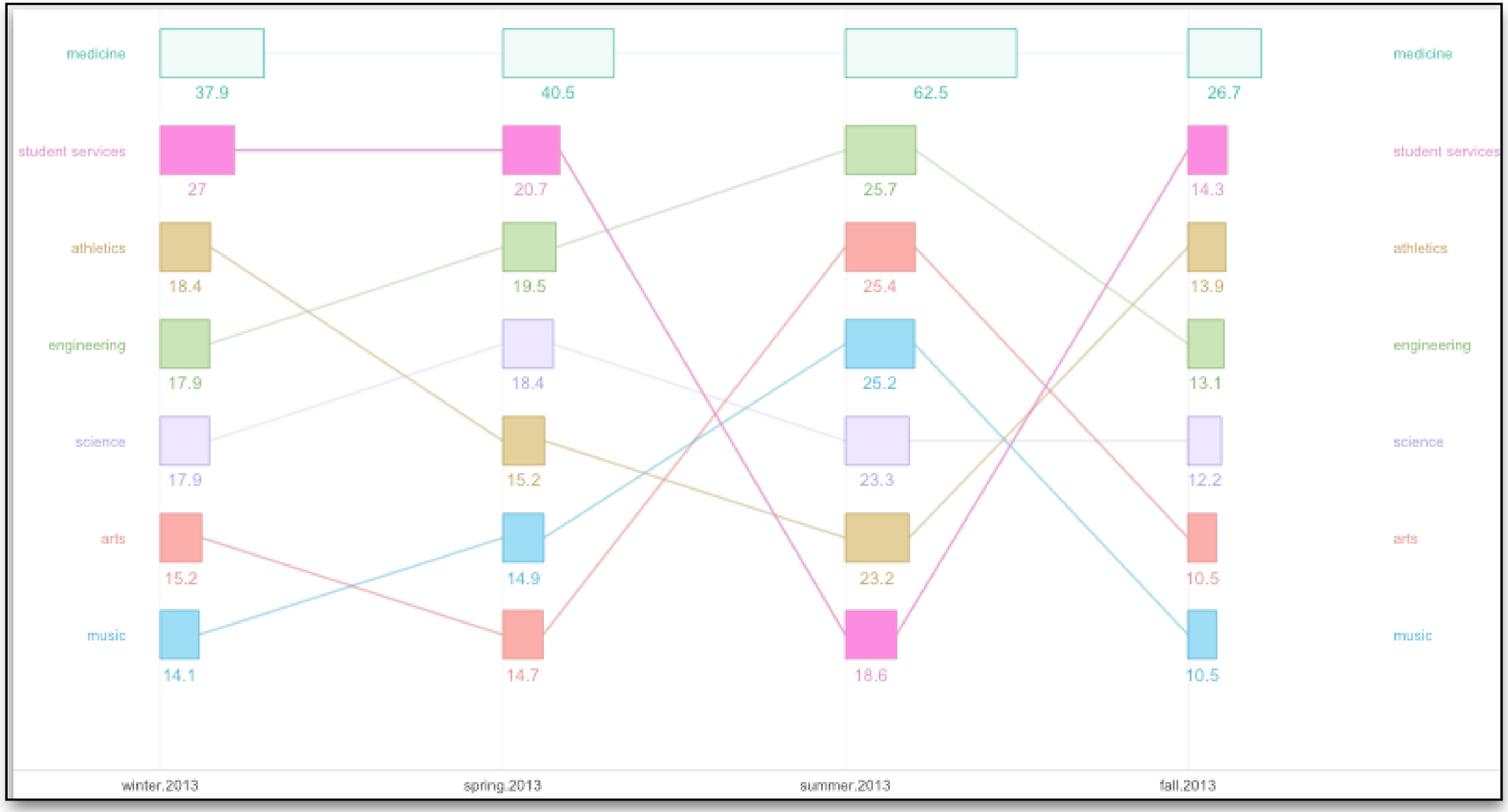
Task	Design choice	Match?
Overview	Faceted bar chart	✖
Drill Down	Faceted bar chart	✔

BUMPS PLOTS



Task	Design choice	Match?
Overview	Bump plot	✖

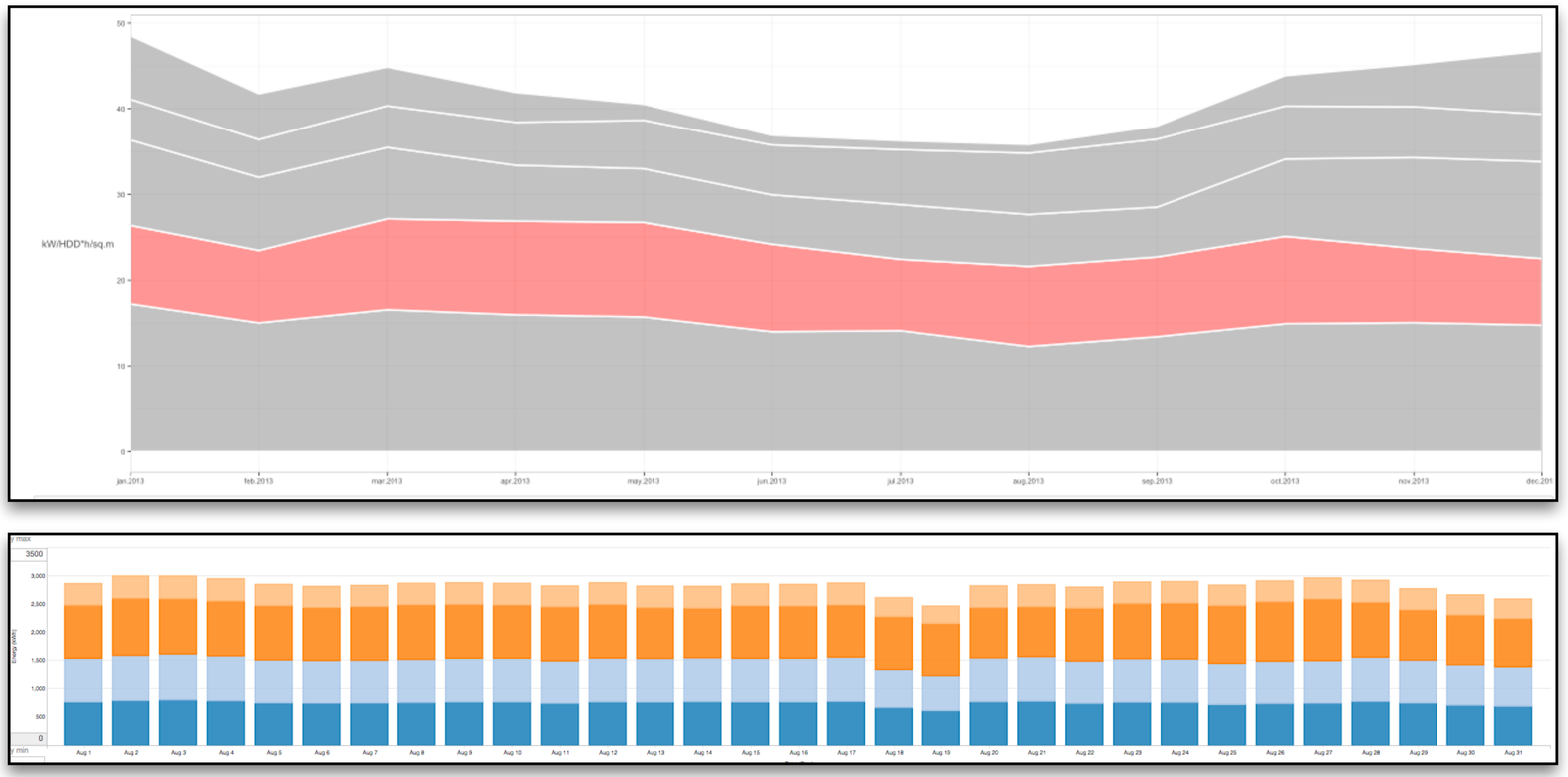
BUMPS + BARS



visual encodings that display derived rank with original quantitative value: ***Gratzl et al's LineUp* (2013), Hur et al's SimulSort (2013)**

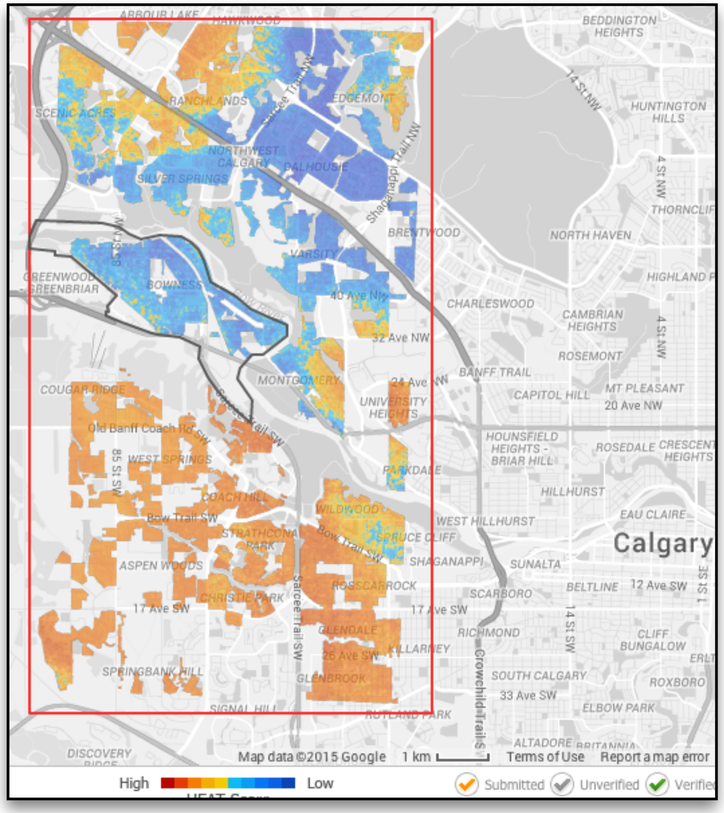
Task	Design choice	Match?
Overview	Bar + bump plot	?

STACKED AREA / BAR

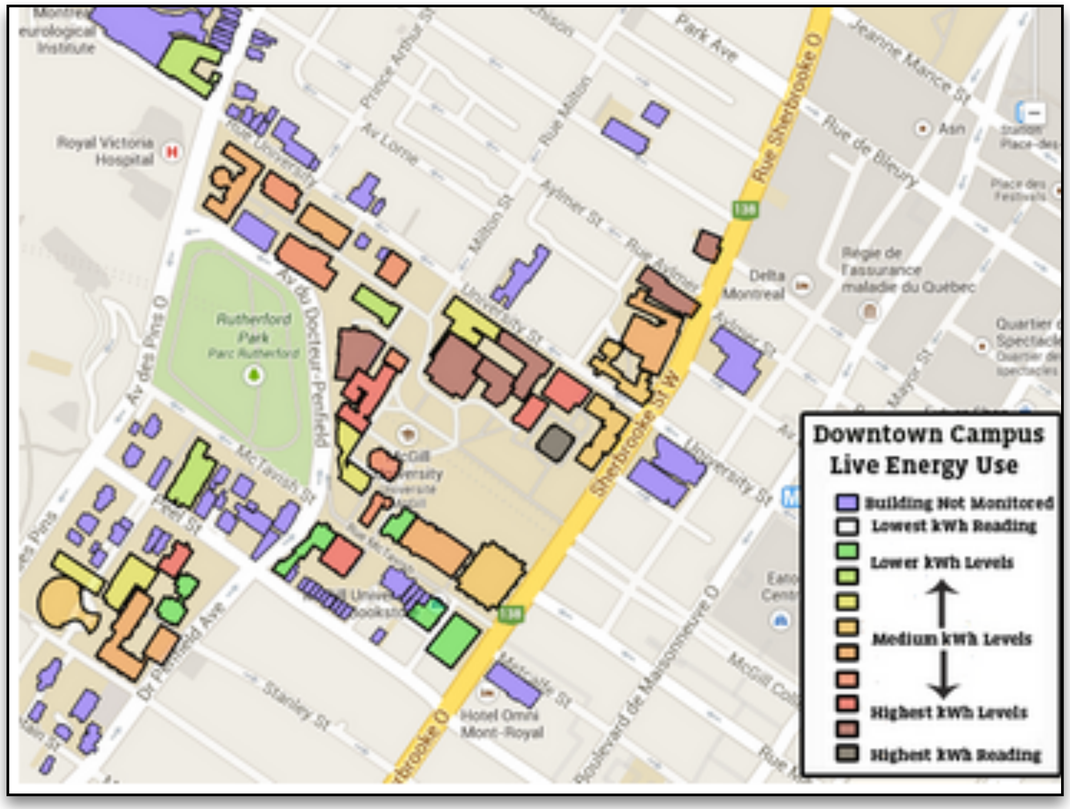


Task	Design choice	Match?
Roll up	Stacked bar chart	✔
	Stacked area chart	✔

MAPS



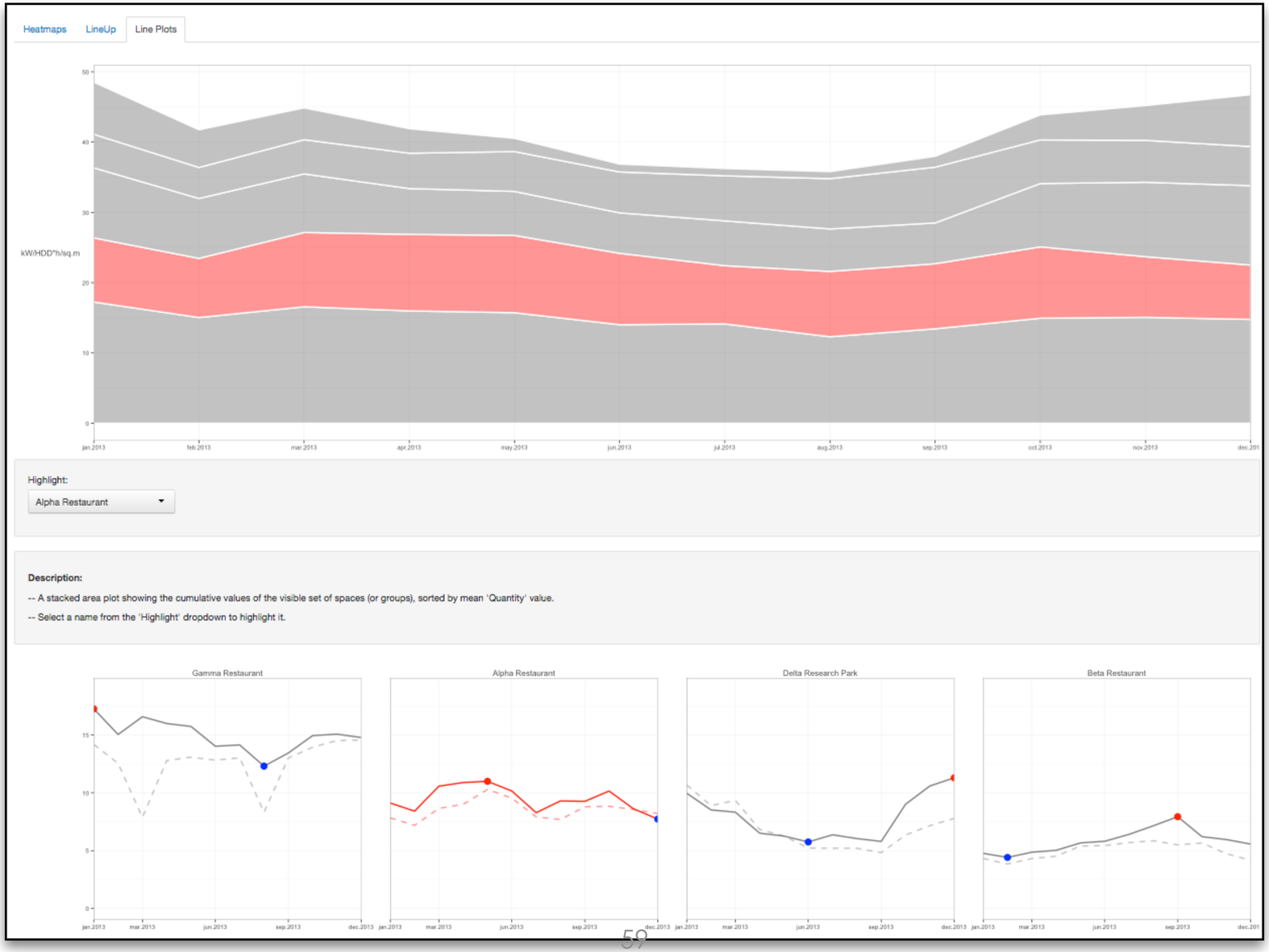
saveheat.co (2014)



McGill Energy Map (2014)

Task	Design choice	Match?
Overview	Map	✖

STACKS & FACETS, JUXTAPOSED + LINKED



ON TRUST

Auxiliary visualizations to combat information loss:
derived aggregate values hide data:
complement averages with representations of range and distribution.

ON TRUST

Promote agency over derived values: provide energy worker more agency over aggregation, unit selection, and normalization.

FUTURE WORK

Post-deployment evaluation: track usage over an extended period of time, follow-up with additional interviews and focus groups.