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

To appear at IEEE InfoVis '15

September 4, 2015

WHY THIS WORK MATTERS...

…contributions for an InfoVis research audience:

Data and task abstractions: identifying matches (and mismatches). Supporting task sequences.

Domain convention, familiarity, and trust.

Methodological guidance for visualization design studies.

DESIGN METHODOLOGY

DESIGN ACTIVITIES

i. analyzing the work domain
ii. identifying data and task abstractions
iii. visual encoding sandbox prototyping
iv. eliciting feedback on visual encoding designs
v. prototyping workflows
vi. production development by collaborator

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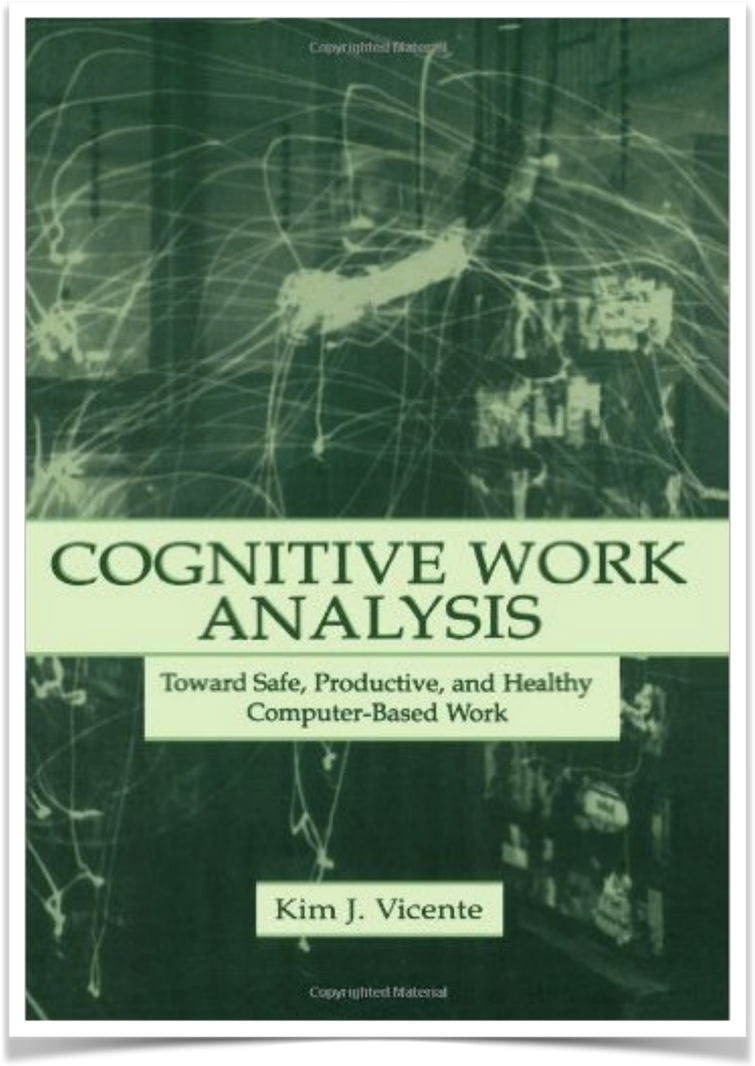
WORK DOMAIN ANALYSIS



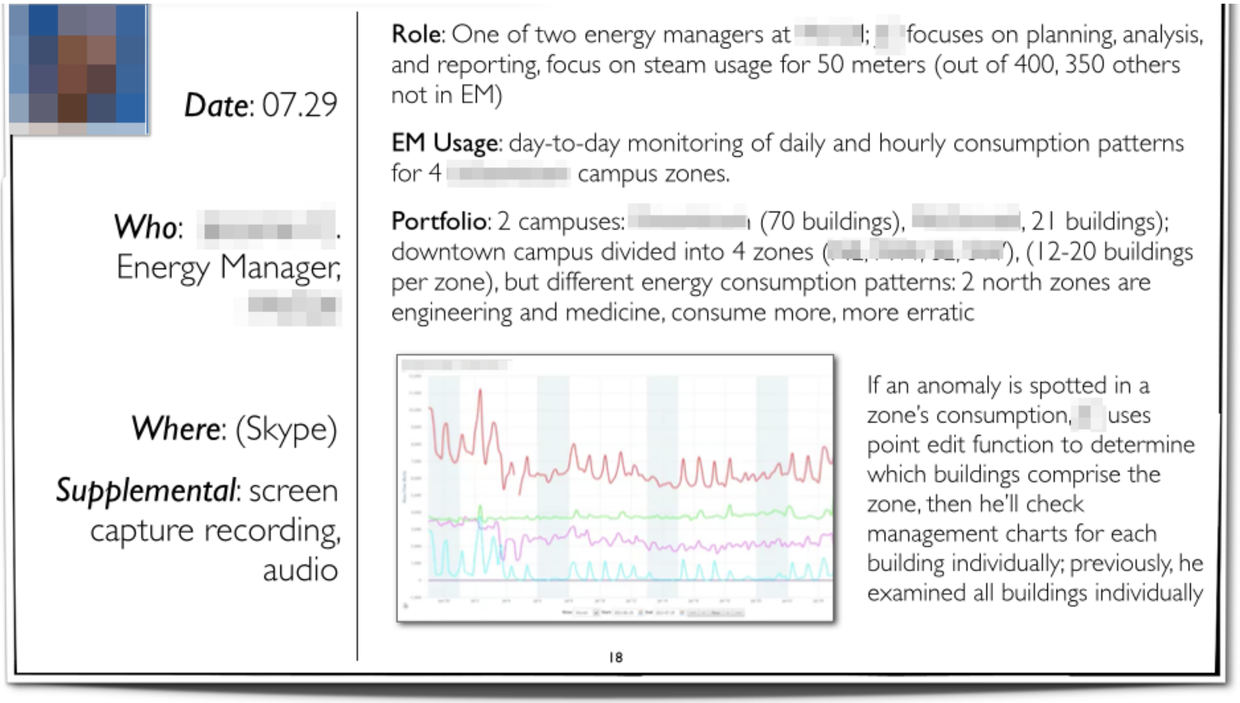
Normative, descriptive, formative perspectives. Workers' use of tools, their work context, workarounds.

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: [redacted]. Energy Manager, [redacted]

Where: (Skype)

Supplemental: screen capture recording, audio

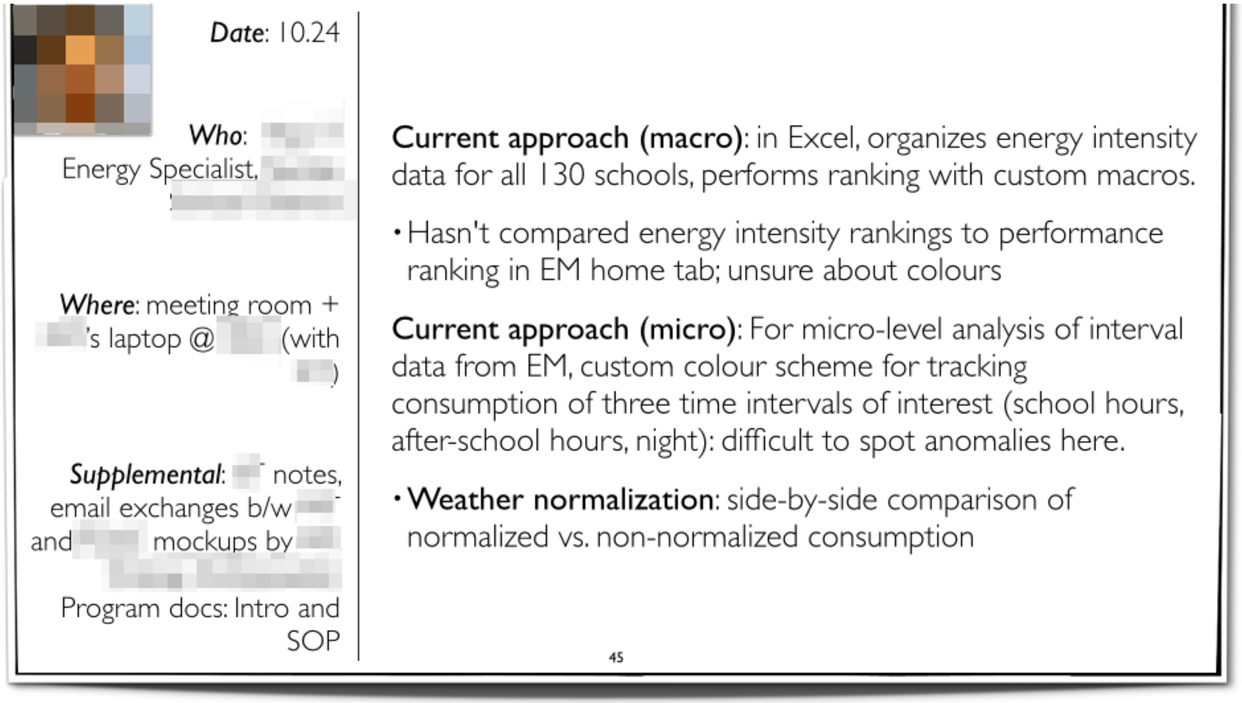
Role: One of two energy managers at [redacted]; [redacted] focuses on planning, analysis, and reporting, focus on steam usage for 50 meters (out of 400, 350 others not in EM)

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

Portfolio: 2 campuses: [redacted] (70 buildings), [redacted], 21 buildings); downtown campus divided into 4 zones ([redacted]), (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, [redacted] 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: [redacted] Energy Specialist, [redacted]

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

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

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

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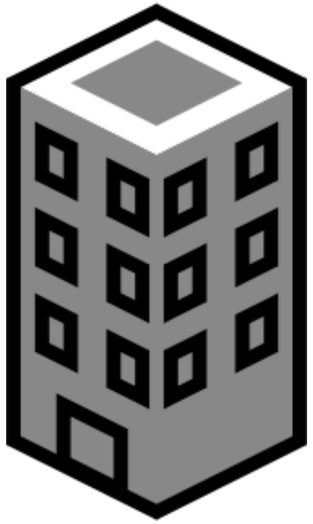
DATA ABSTRACTION

BUILDING PORTFOLIOS



Term	Abstraction	Example
	Building metadata	
Building ID	unique categorical	#123
Building area	quantitative	450 m^2
Building age	quantitative	20 years
# occupants	quantitative	50 people
Location	spatial	49.26° N, 123.25° W
Tag	categorical	*"restaurant"*

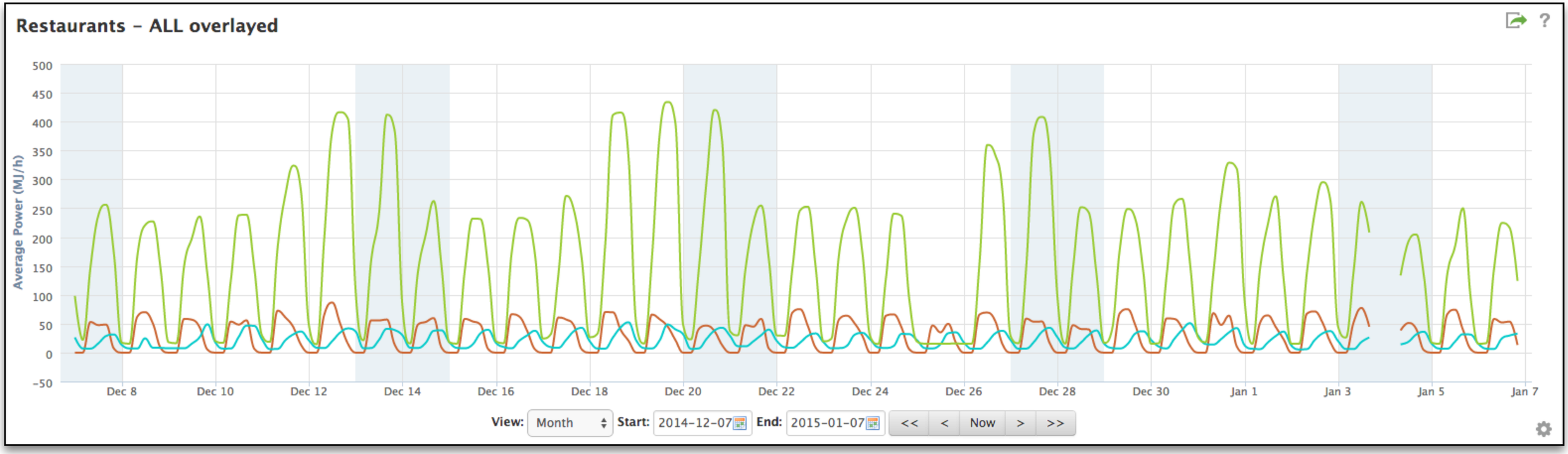
MULTIPLE TIME SERIES / BUILDING

Term	Abstraction	Example
Temporal data for each building		
Energy demand	quantitative	200 kW
Outdoor temperature	quantitative	18° C
Open / closed	categorical	Open Mon–Fri, 08-18h

DERIVED DATA

Term	Abstraction	Example
Derived temporal data for each building		
Consumption	quantitative	800 kWh
Energy intensity	normalized quantitative	1.78 kWh / m^2
Weather-independent performance	normalized quantitative	50 kWh / HDD
Predicted perform.	quantitative	190 kW
% Savings	normalized quantitative	40%
Rank	ordinal	1st, 2nd, 3rd

DOMAIN CONVENTION



line charts = energy demand

TASK ABSTRACTION

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

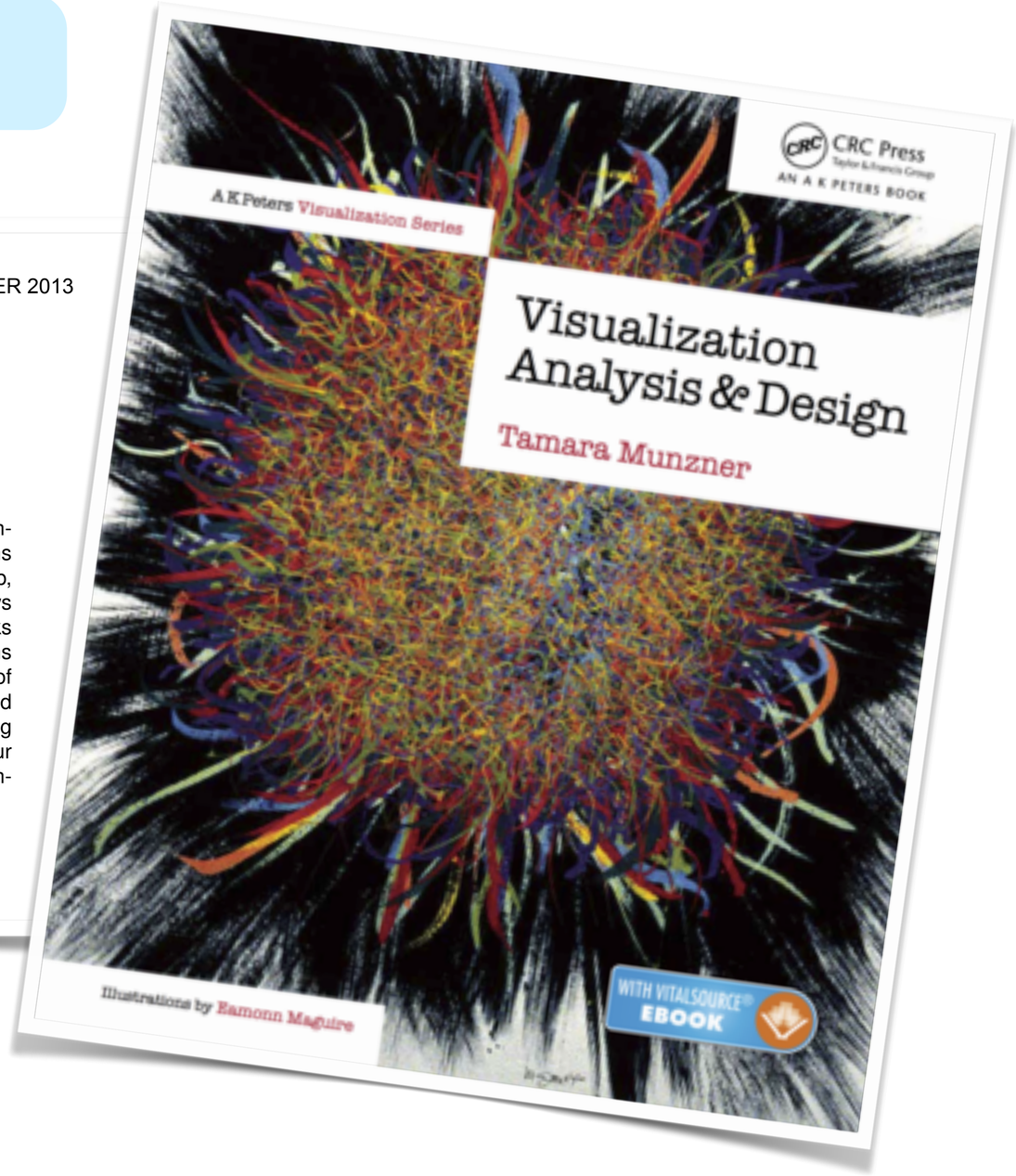
TASK ABSTRACTION

A Multi-Level Typology of Abstract Visualization Tasks

Matthew Brehmer and Tamara Munzner, *Member, IEEE*

Abstract—The considerable previous work characterizing visualization usage has focused on low-level tasks or interactions and high-level tasks, leaving a gap between them that is not addressed. This gap leads to a lack of distinction between the ends and means of a task, limiting the potential for rigorous analysis. We contribute a multi-level typology of visualization tasks to address this gap, distinguishing *why* and *how* a visualization task is performed, as well as *what* the task inputs and outputs are. Our typology allows complex tasks to be expressed as sequences of interdependent simpler tasks, resulting in concise and flexible descriptions for tasks of varying complexity and scope. It provides abstract rather than domain-specific descriptions of tasks, so that useful comparisons can be made between visualization systems targeted at different application domains. This descriptive power supports a level of analysis required for the generation of new designs, by guiding the translation of domain-specific problems into abstract tasks, and for the qualitative evaluation of visualization usage. We demonstrate the benefits of our approach in a detailed case study, comparing task descriptions from our typology to those derived from related work. We also discuss the similarities and differences between our typology and over two dozen extant classification systems and theoretical frameworks from the literatures of visualization, human-computer interaction, information retrieval, communications, and cartography.

Index Terms—Typology, visualization models, task and requirements analysis, qualitative evaluation



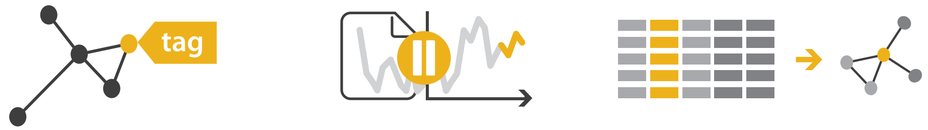
TASK ABSTRACTION

diagrams by E. Maguire

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

TASK 1: OVERVIEW

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

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

TASK 3: ROLL UP

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	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 Vancouver performing better this January than they did last January?"*
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?"*

Brehmer et al. 2015

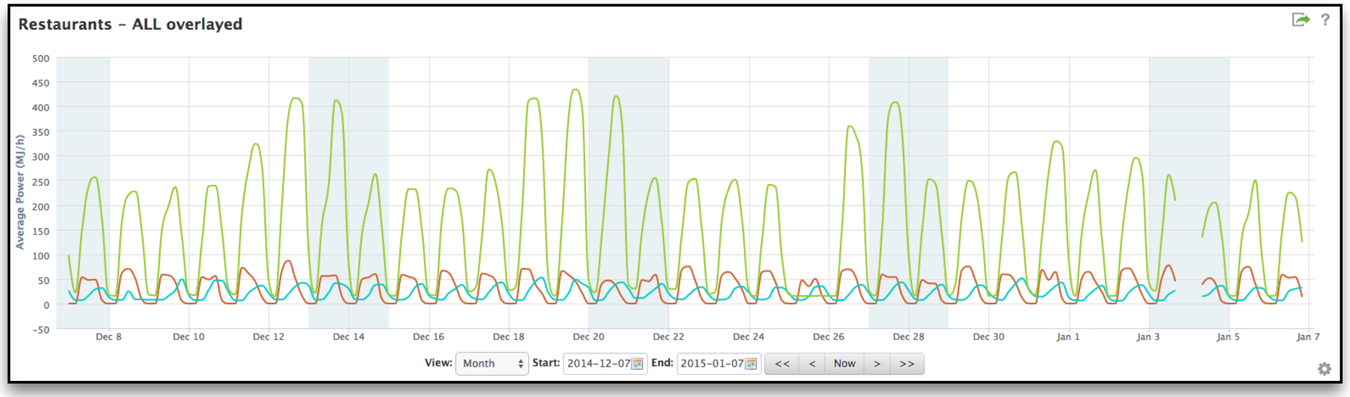
DESIGN ACTIVITIES

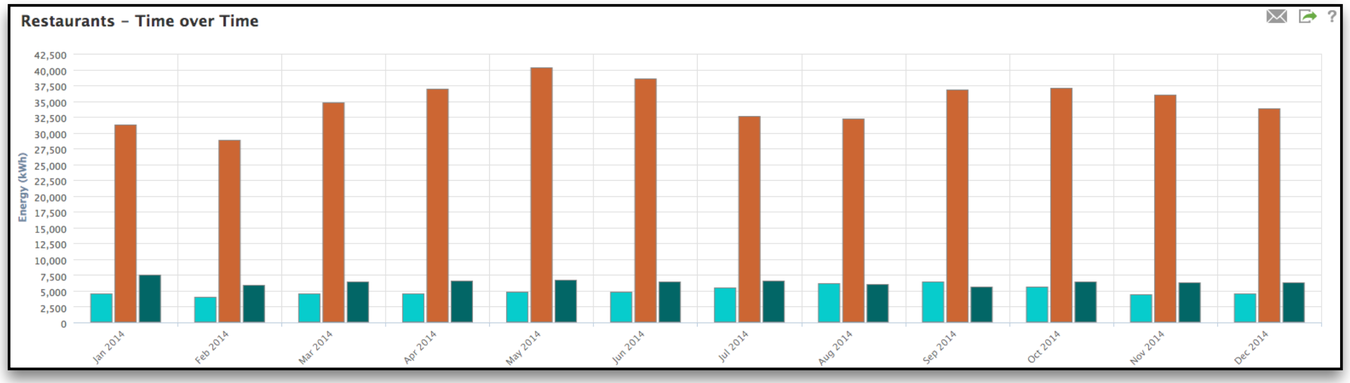
i. analyzing the work domain
ii. validating data and task abstractions
iii. sandbox prototyping
iv. eliciting feedback on visual encoding designs
v. prototyping workflows
vi. production development by collaborator

CURRENT TASK SUPPORT

the existing tool:
Energy Manager

ENERGY MANAGER

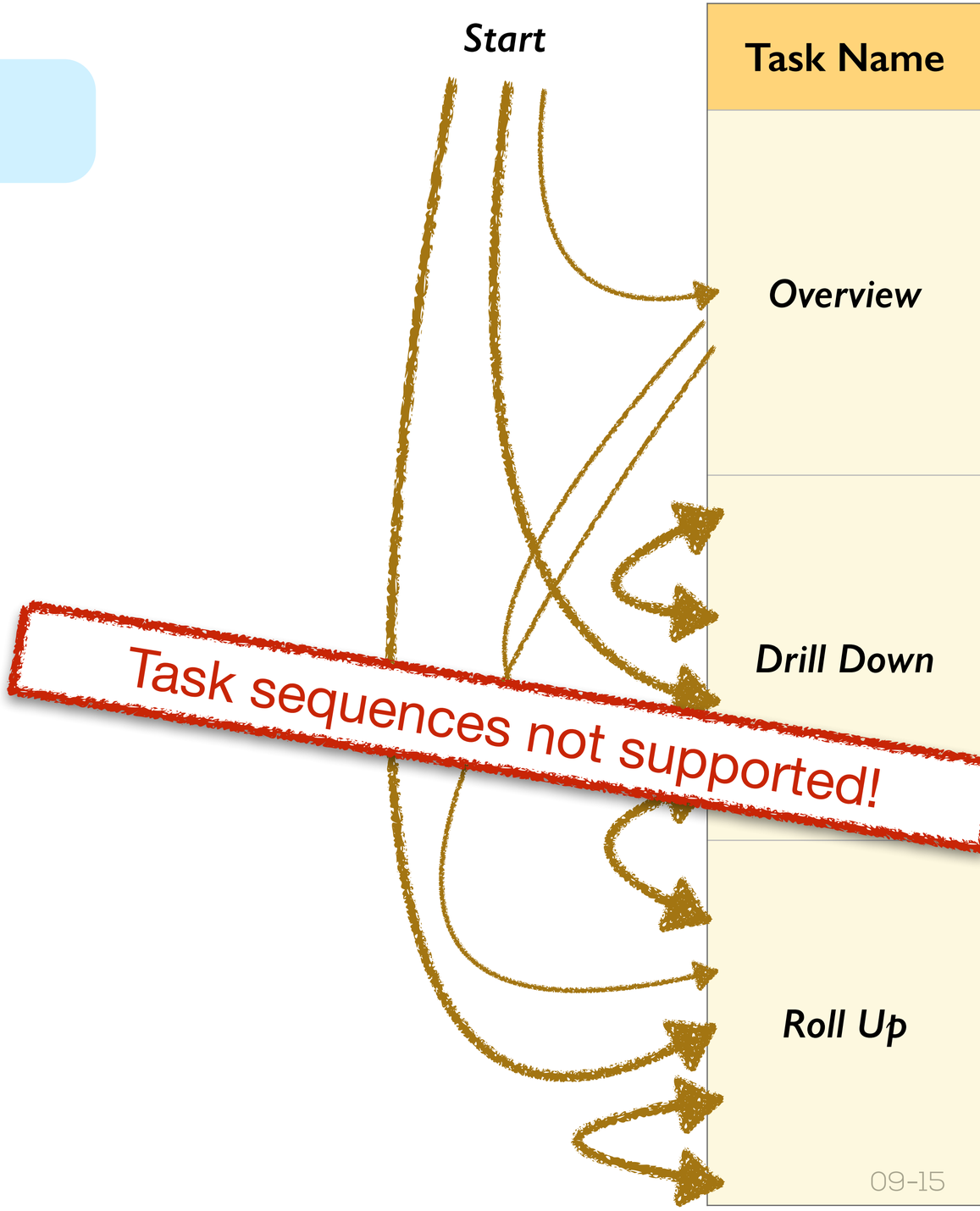




PERFORMANCE RANKING

Export Table

% SAVINGS	NAME	RESOURCE	SAVINGS	CONSUMPTION	CONSUMPTION PER AREA
1.3%	Westpoint Tower		+18,040 kWh	1,397 MWh	150.3 kWh/m²
6.0%	Restaurant Building		+118,600 kWh	1,838 MWh	1,487 kWh/m²
7.2%	Airport Research Park		+1,109 MWh	14,520 MWh	971.1 kWh/m²
37.2%	Westpoint Tower		+2,233 MWh	3,791 MWh	408.1 kWh/m²
49.0%	Airport Research Park		+4,764 MWh	4,988 MWh	333.5 kWh/m²



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 Seattle vs. all restaurants in Vancouver"

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

ANALYSIS OF ENERGY MANAGER

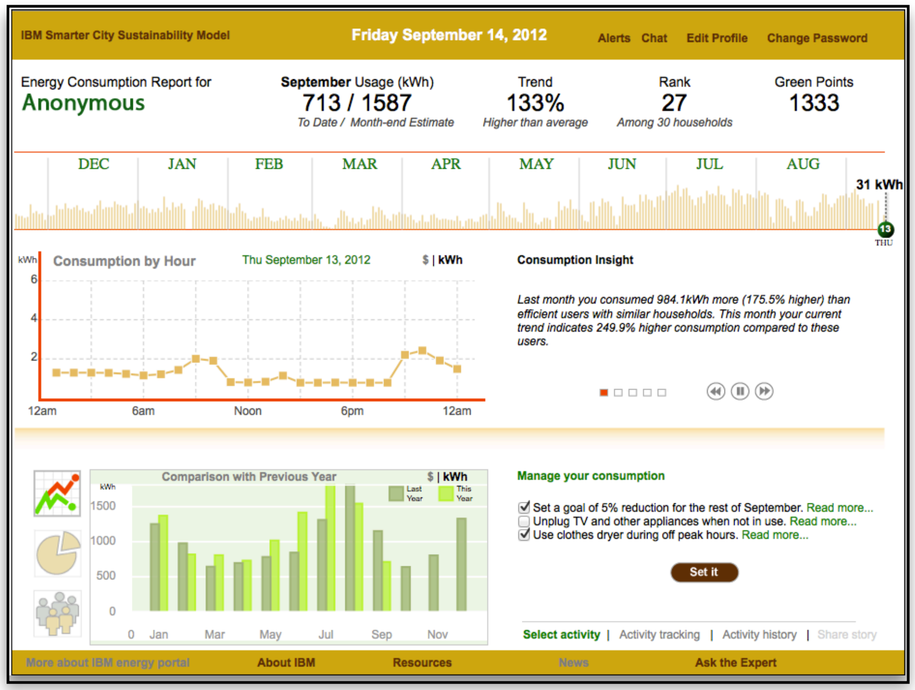
Data routinely exported and imported into Excel.

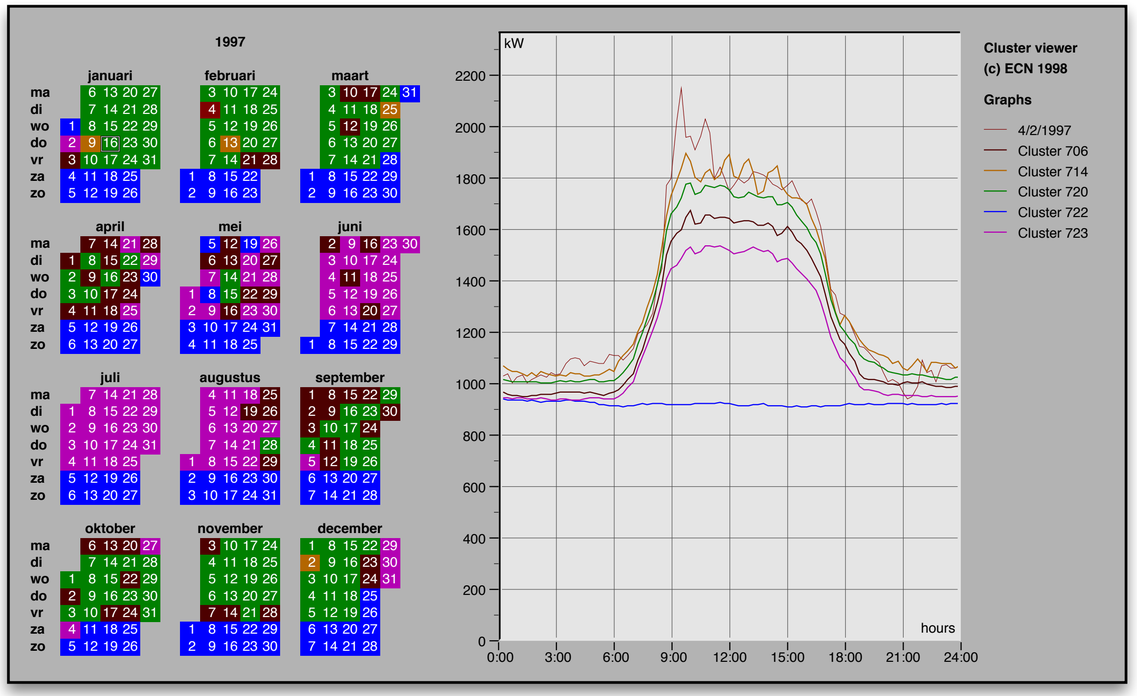
Little **trust** in predicted derived values based on statistical models. A preference for comparing against historical data.

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

RELATED WORK

VIS IN THE ENERGY DOMAIN

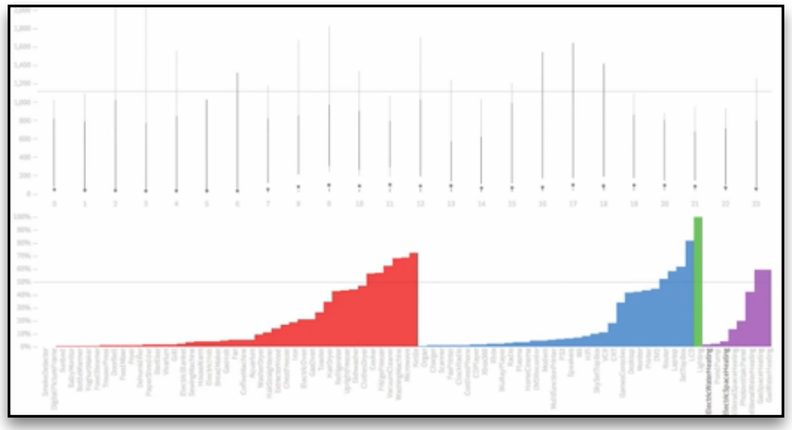


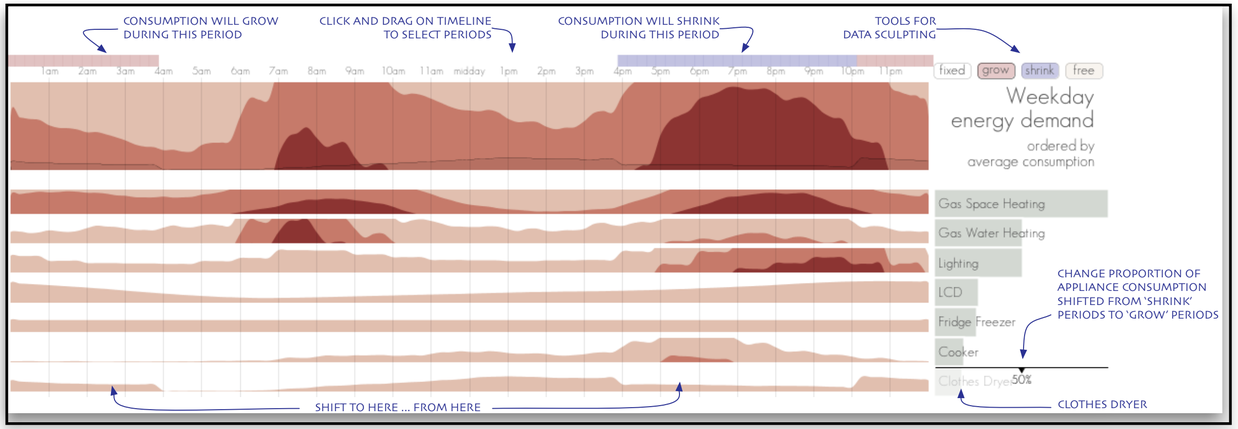


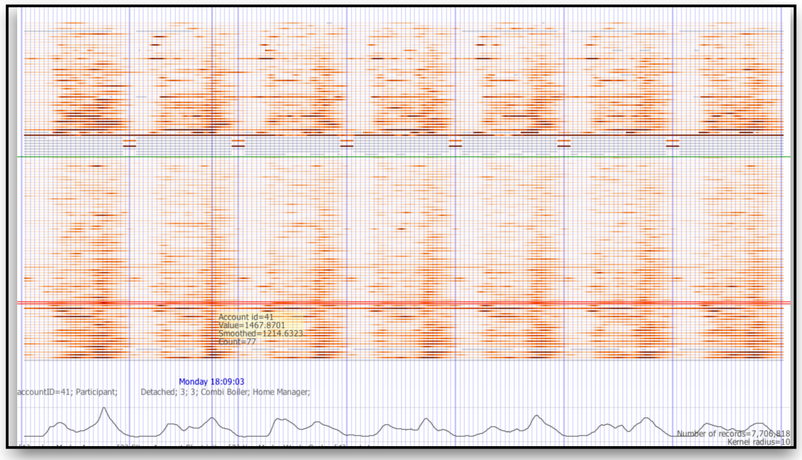
***Erickson et al* (2013)**: web-based residential energy report for home-owners

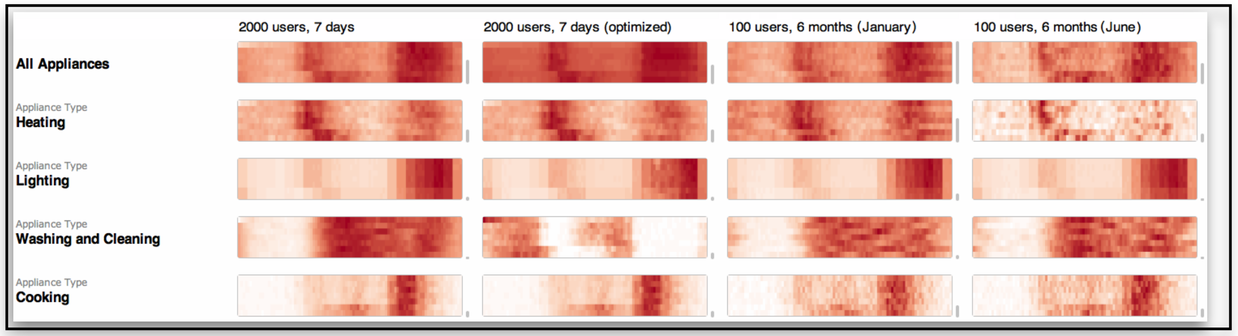
***van Wijk & van Selow* (1999)**: calendars of energy behaviour

VIS IN THE ENERGY DOMAIN





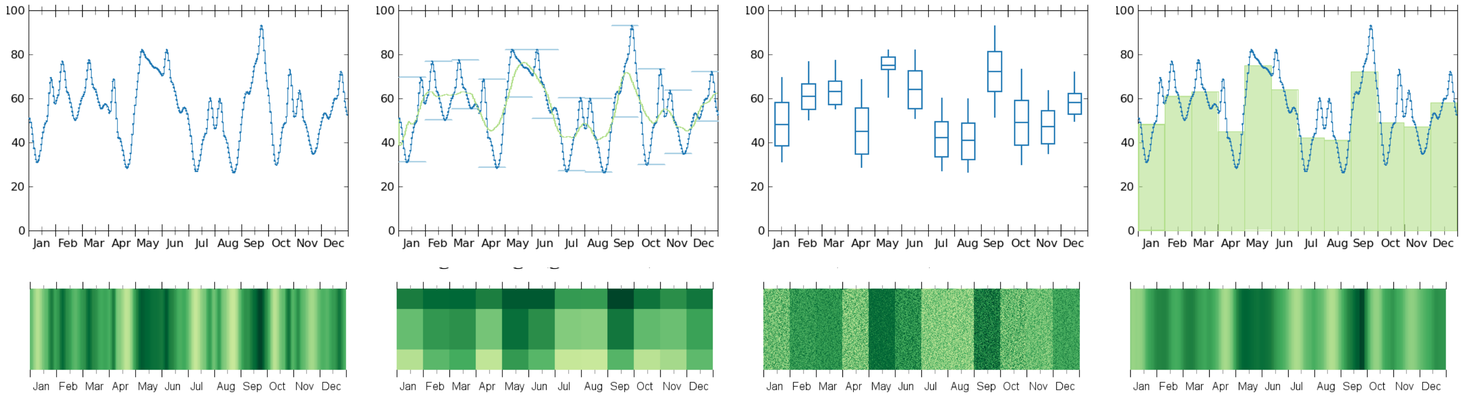




Goodwin et al (2013): similar domain, different data, partial task overlap

VIS FOR TIME SERIES

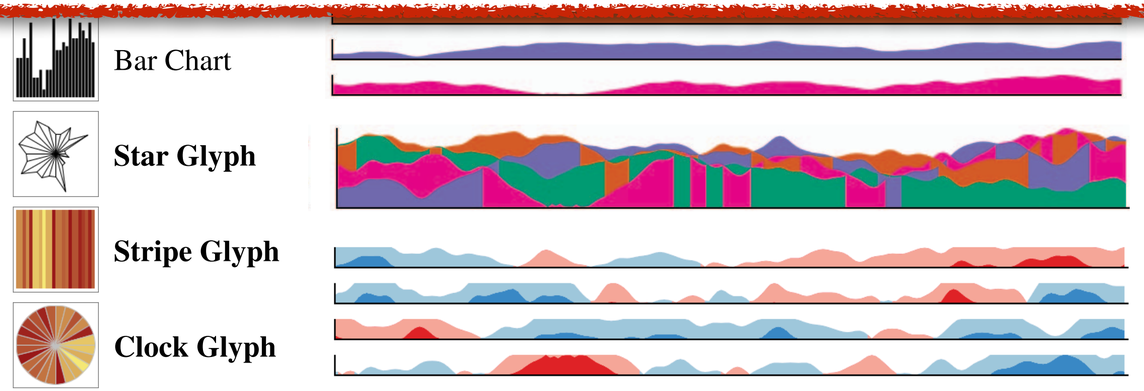
***Aigner et al* (2011)**:
survey and framework



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

line chart encodings are inappropriate
(except for displaying raw energy demand)

evaluation of multiple encodings in small multiple configurations



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

VISUAL ENCODING DESIGN

DESIGN ACTIVITIES

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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

Filter by Space Metadata

Space Name: all

City: all

Tag: all re

Space Type: Building

Space Use: all

- rbr
- retail
- research
- upper rbr
- greenhouse
- grey stone
- rare books
- agriculture

Group Spaces by: None

Resource Type: Electricity

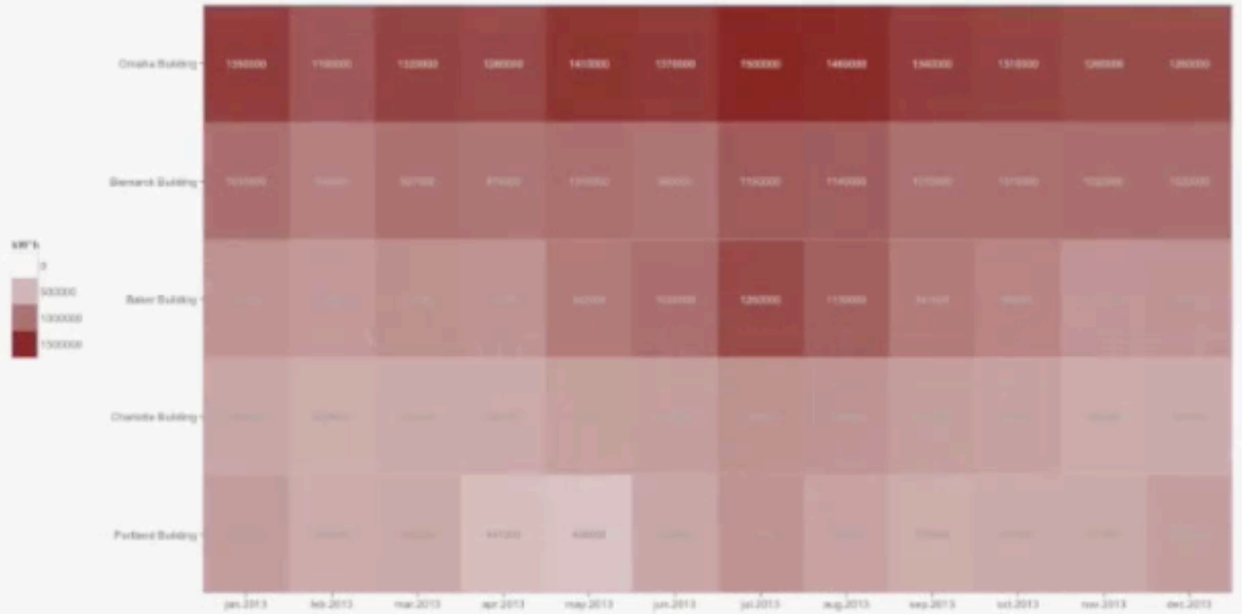
Quantity: Total Consumption

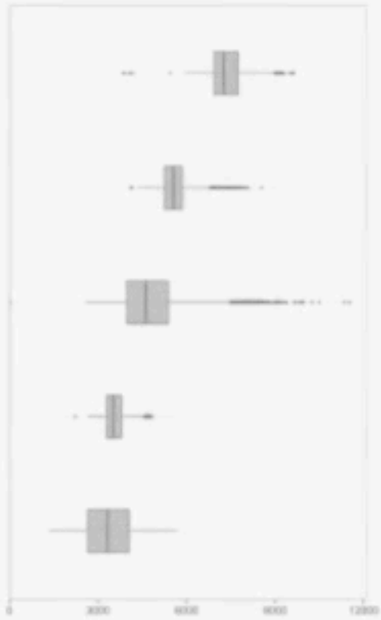
Weather Normalization: None

Space Normalization: None

Displaying 5 of 86 spaces matching query.

Matrix + Boxplots | Bump + Bar Plot | Stack + Facets





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

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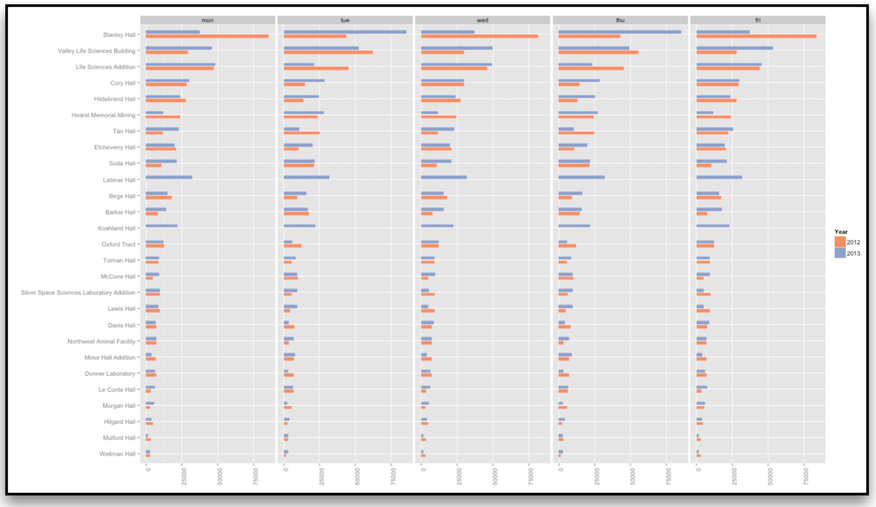
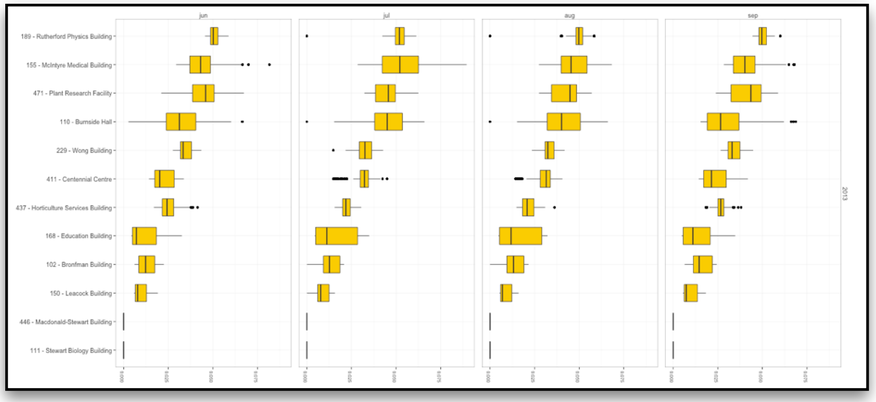
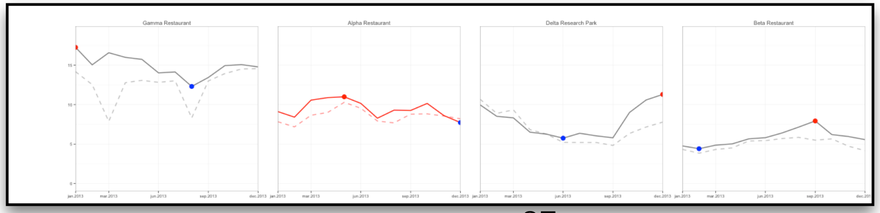
MATCHES & MISMATCHES

Task	Visualization Idiom	Match?
T1: Overview	Faceted bar chart	✖
	Bump plot	✖
	Bar + bump plot	?
	(Calendar) matrix	?
	Map	✖
	Juxtaposed matrix and boxplots	✔
T2: Drill Down	Faceted bar chart	✔
	Faceted boxplot	✖
	Faceted line graph	✔
T3: Roll Up	Stacked area graph	✔
	Stacked bar chart	✔

FACETING





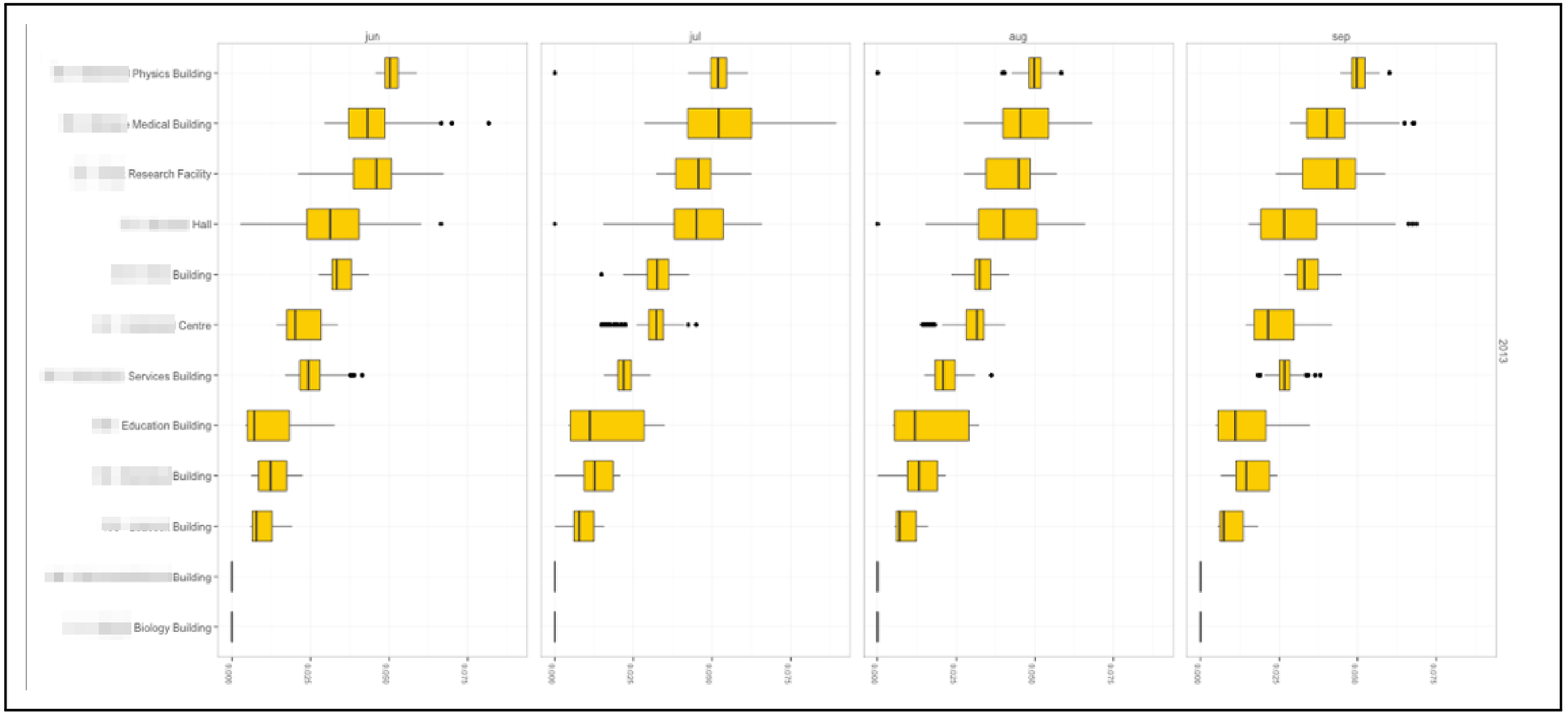


Task Name	Abstraction	Example Question
Overview	*discover* trends, outliers *lookup and summarize* distributions, extremes, similarities	*"How did my building portfolio perform this past year?"*
Drill Down	*discover, locate, and compare* trends, outliers, features	*"Are my restaurants in Seattle performing better this September than they did last September?"*

FACETED BAR CHARTS

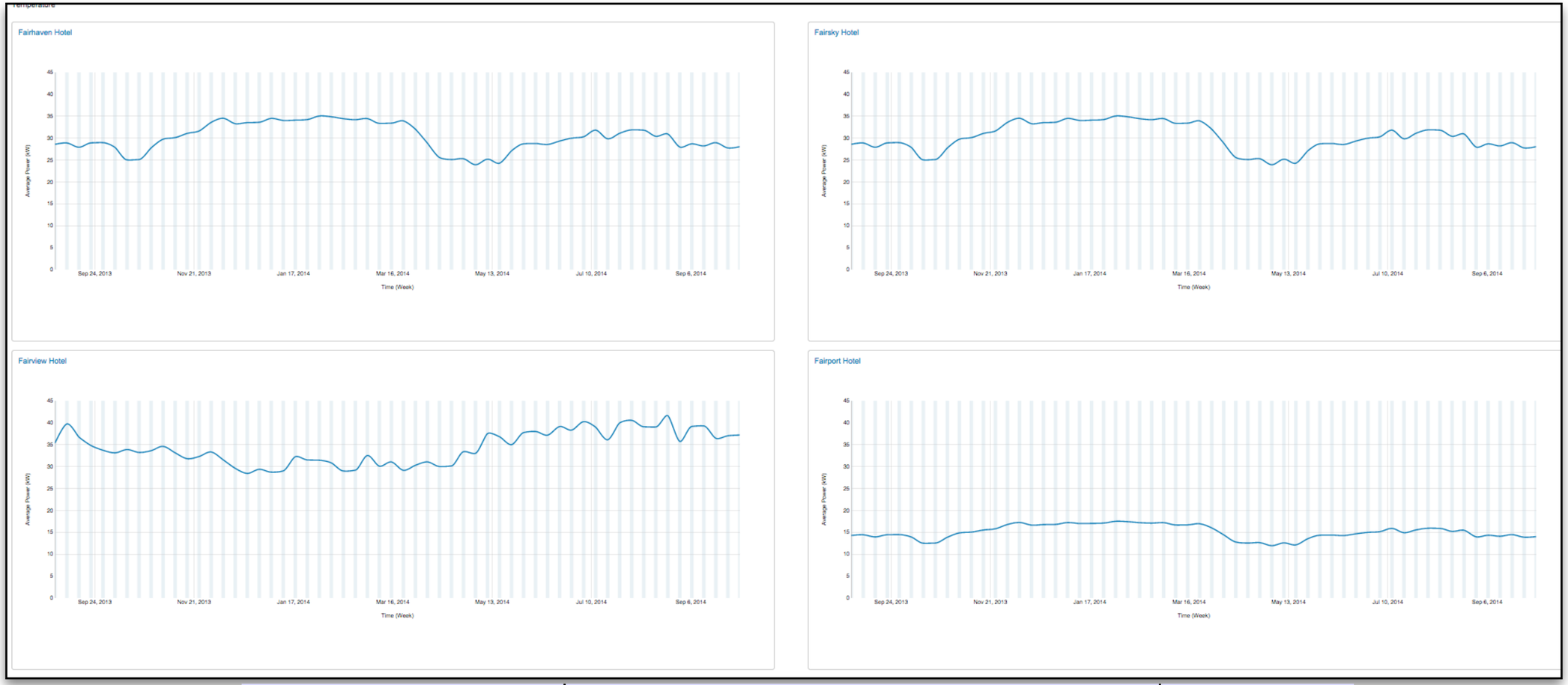
Task	Visualization Idiom	Match?
T1: Overview	Faceted bar chart	✖
T2: Drill Down	Faceted bar chart	✔

FACETED BOXPLOTS



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

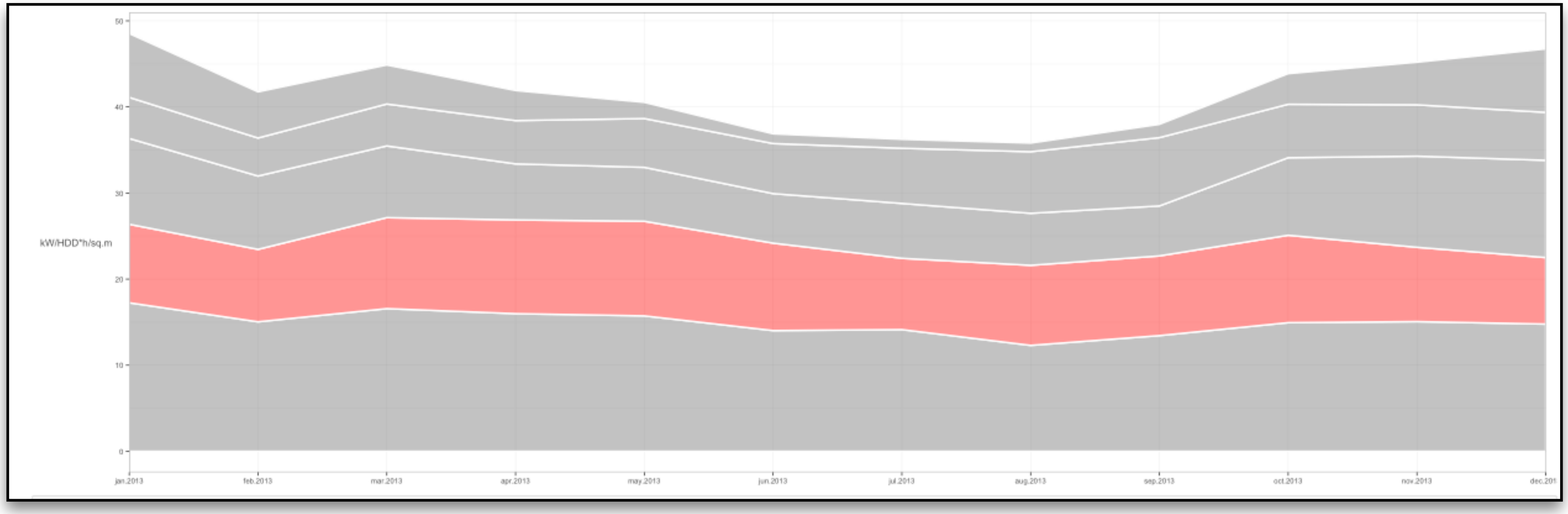
FACETED LINE CHARTS



Task	Visualization Idiom	Match?
T2: Drill Down	Faceted line graph	✔

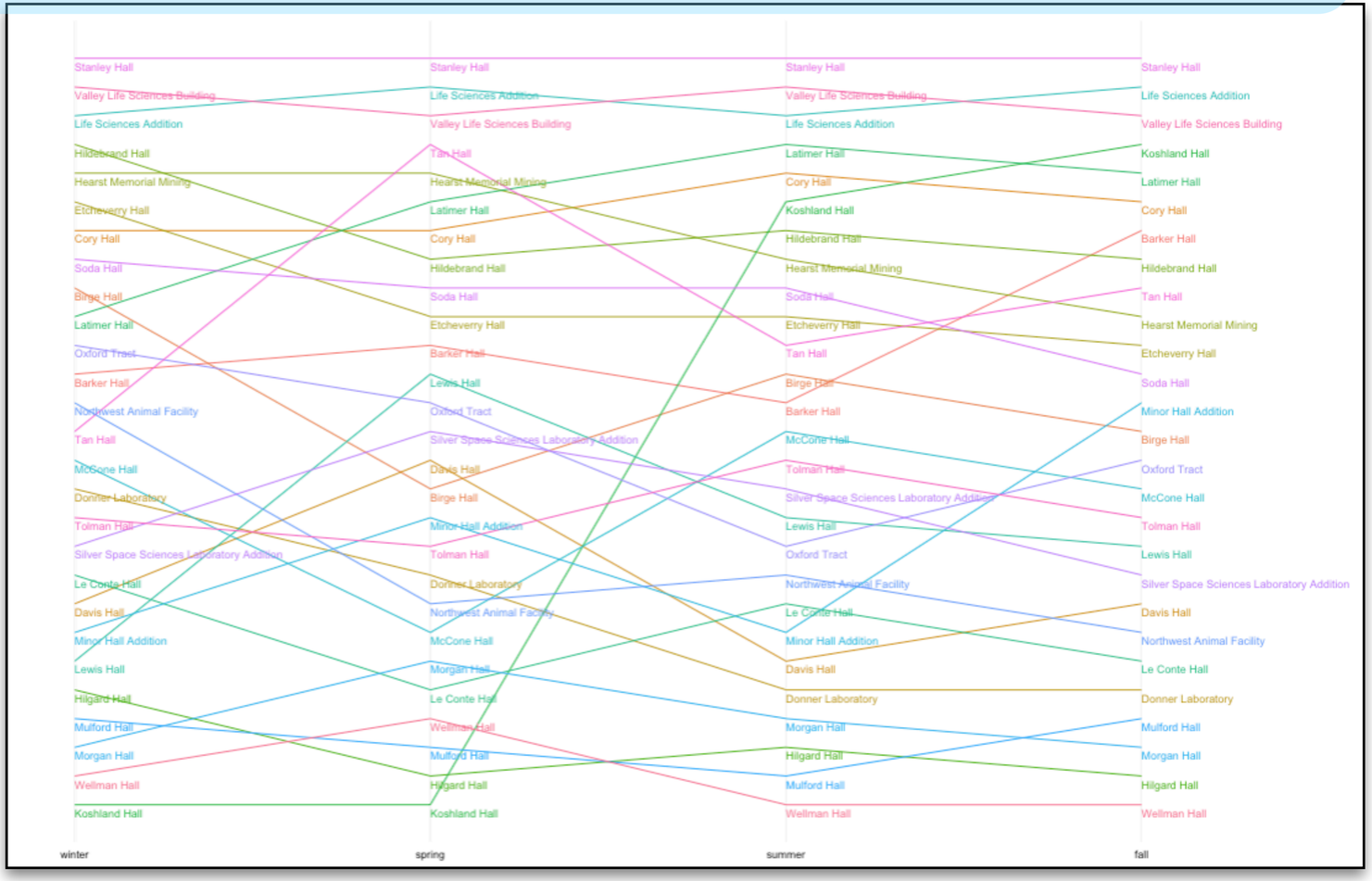
STACKED AREA / BAR

Task Name	Abstraction	Example Question
Roll Up	*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	Visualization Idiom	Match?
T3: Roll Up	Stacked area graph	✔
	Stacked bar chart	✔

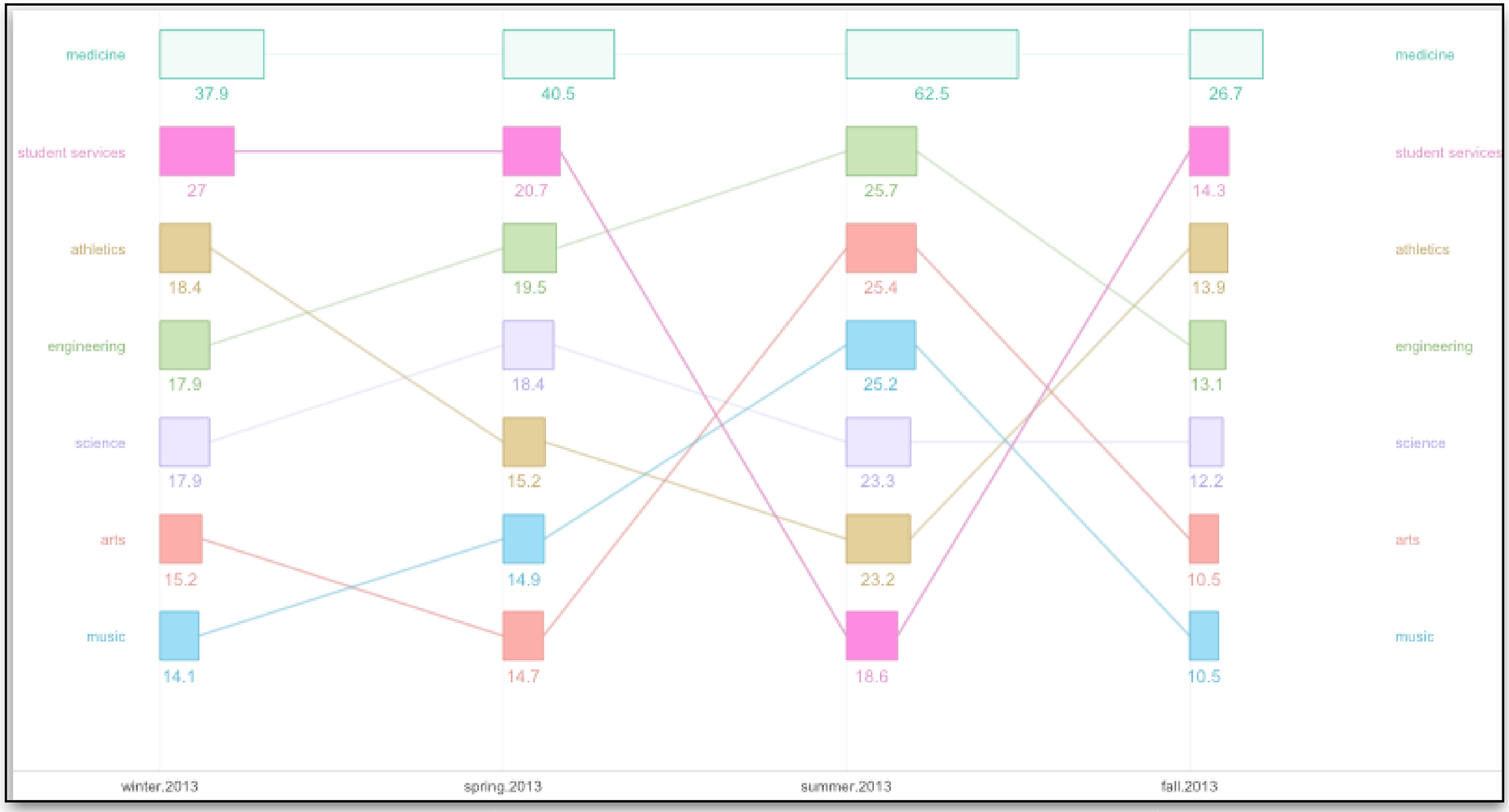
BUMPS PLOTS



Task Name	Abstraction	Example Question
Overview	*discover* trends, outliers *lookup and summarize* distributions, extremes, similarities	*"How did my building portfolio perform this past year?"*

Task	Visualization Idiom	Match?
T1: Overview	Bump plot	✖

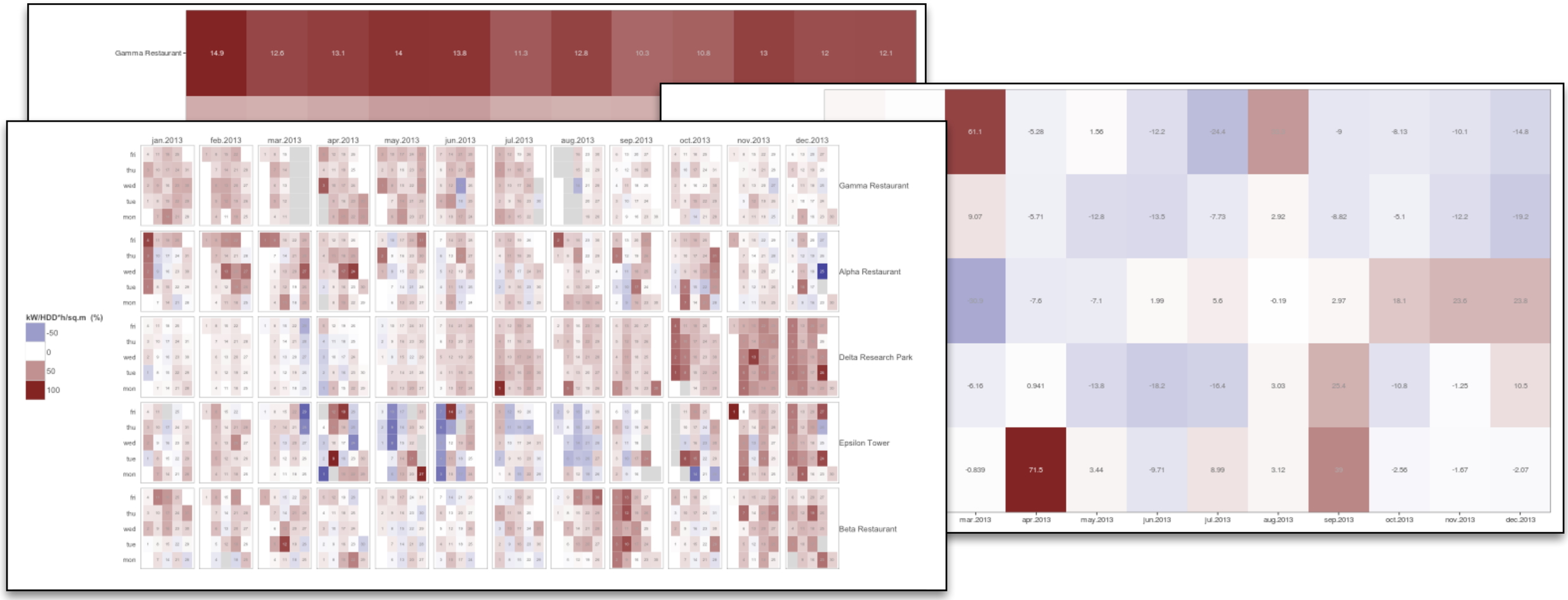
BUMPS + BARS



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

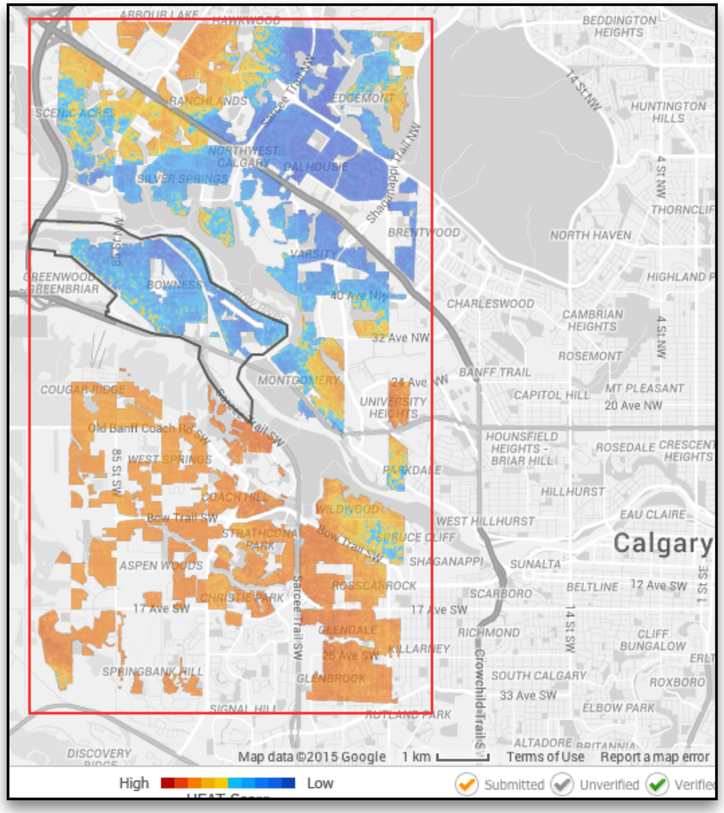
Task	Visualization Idiom	Match?
T1: Overview	Bar + bump plot	?

TIME-SERIES MATRIX

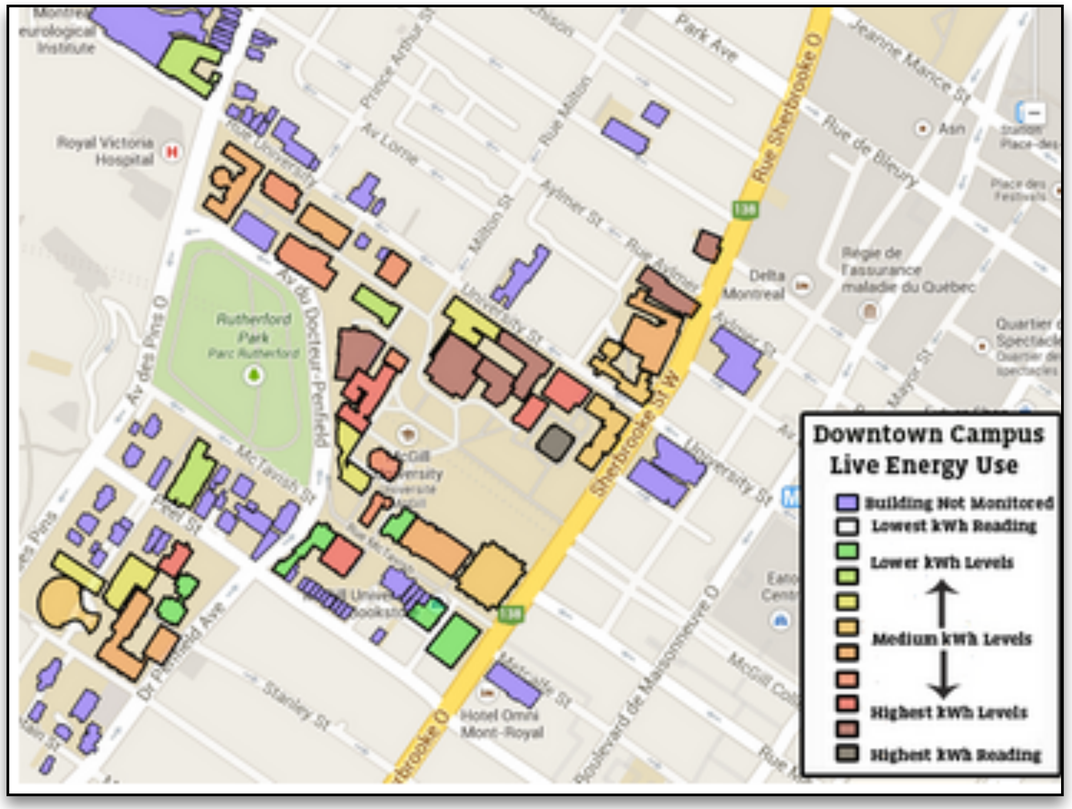


Task	Visualization Idiom	Match?
T1: Overview	(Calendar) matrix	**?**

MAPS



saveheat.co (2014)



McGill Energy Map (2014)

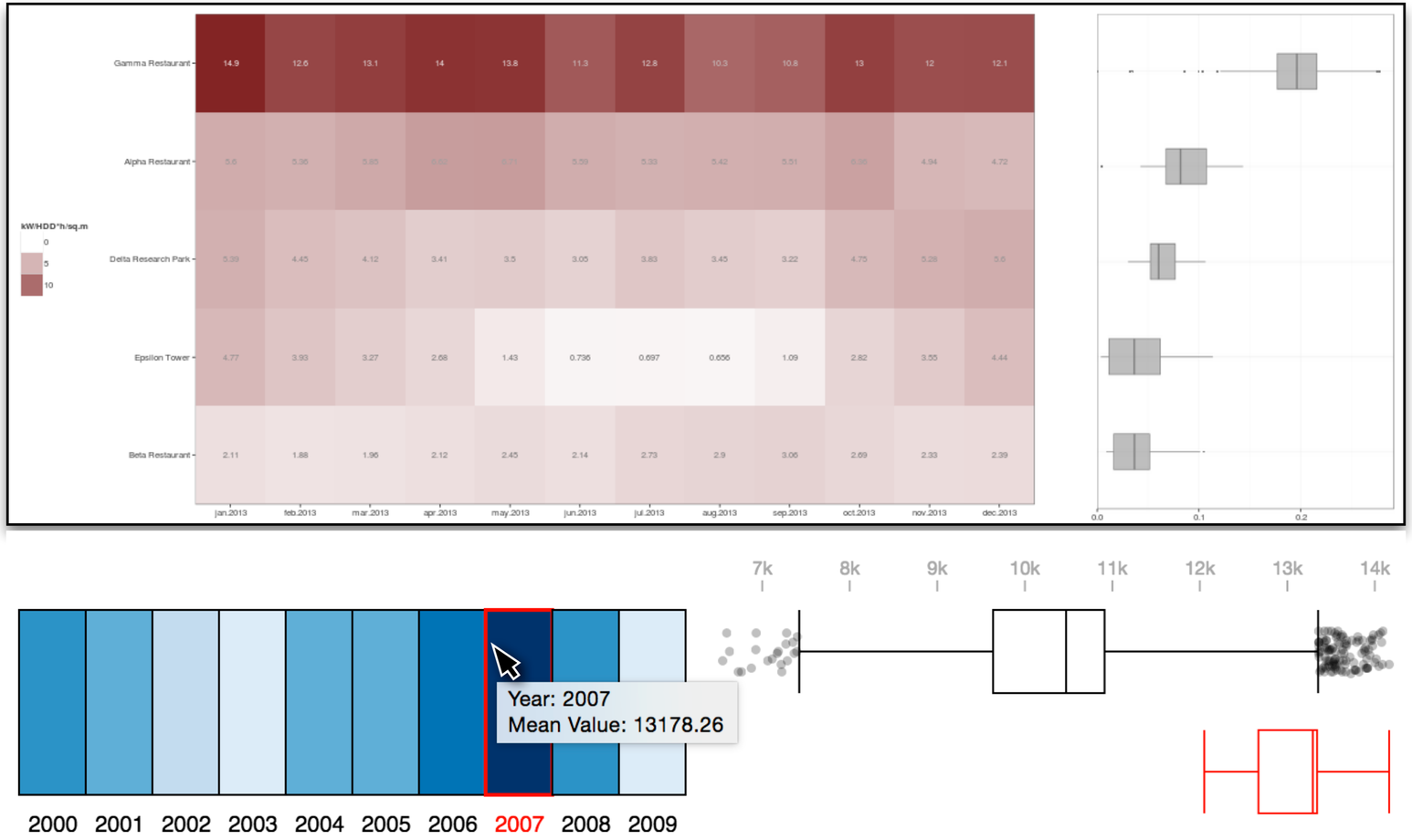
Task	Visualization Idiom	Match?
T1: Overview	Map	✖

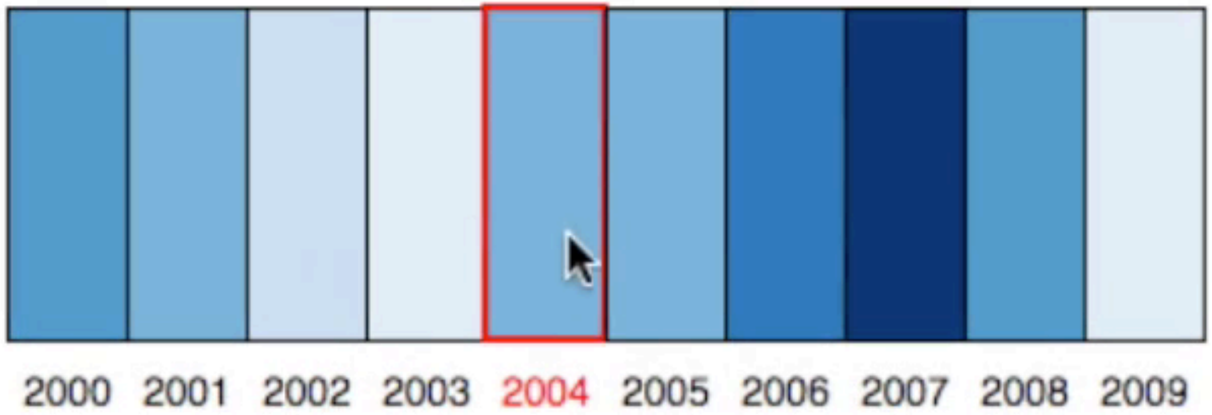
MULTIPLE VIEW WORKFLOW DESIGN

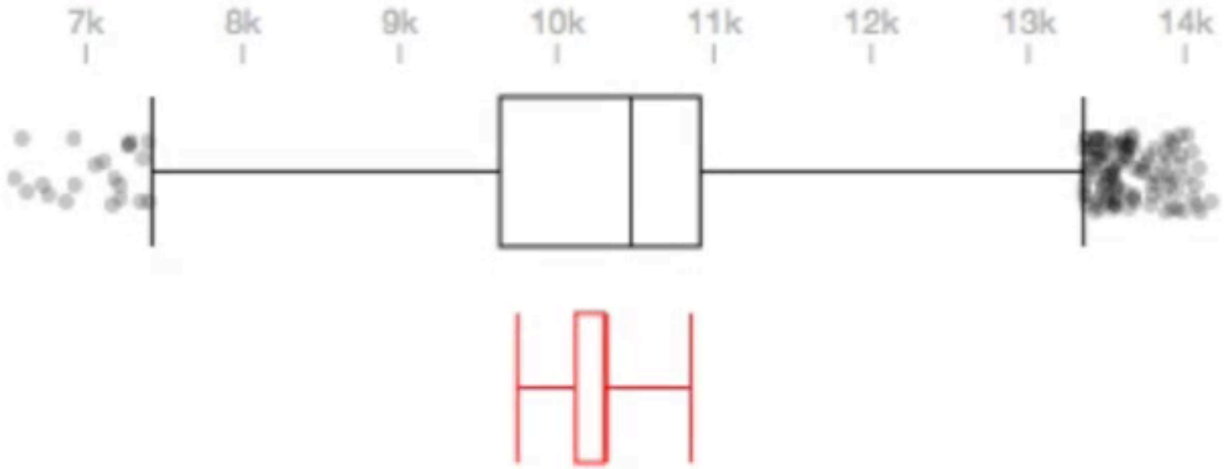
DESIGN ACTIVITIES

i. analyzing the work domain
ii. identifying data and task abstractions
iii. visual encoding sandbox prototyping
iv. eliciting feedback on visual encoding designs
v. prototyping workflows
vi. production development by collaborator

MATRIX + AUXILIARY BOXPLOTS

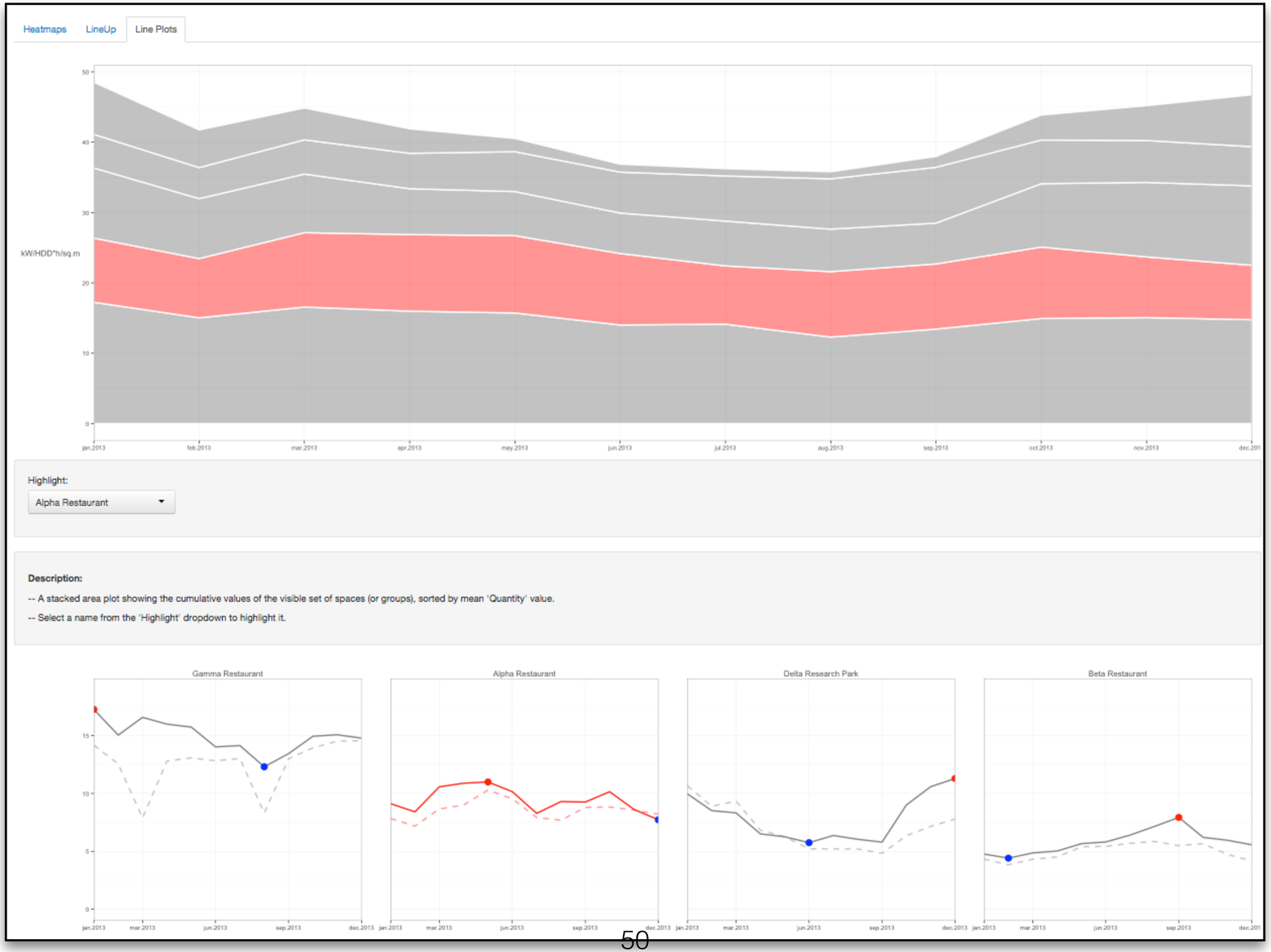




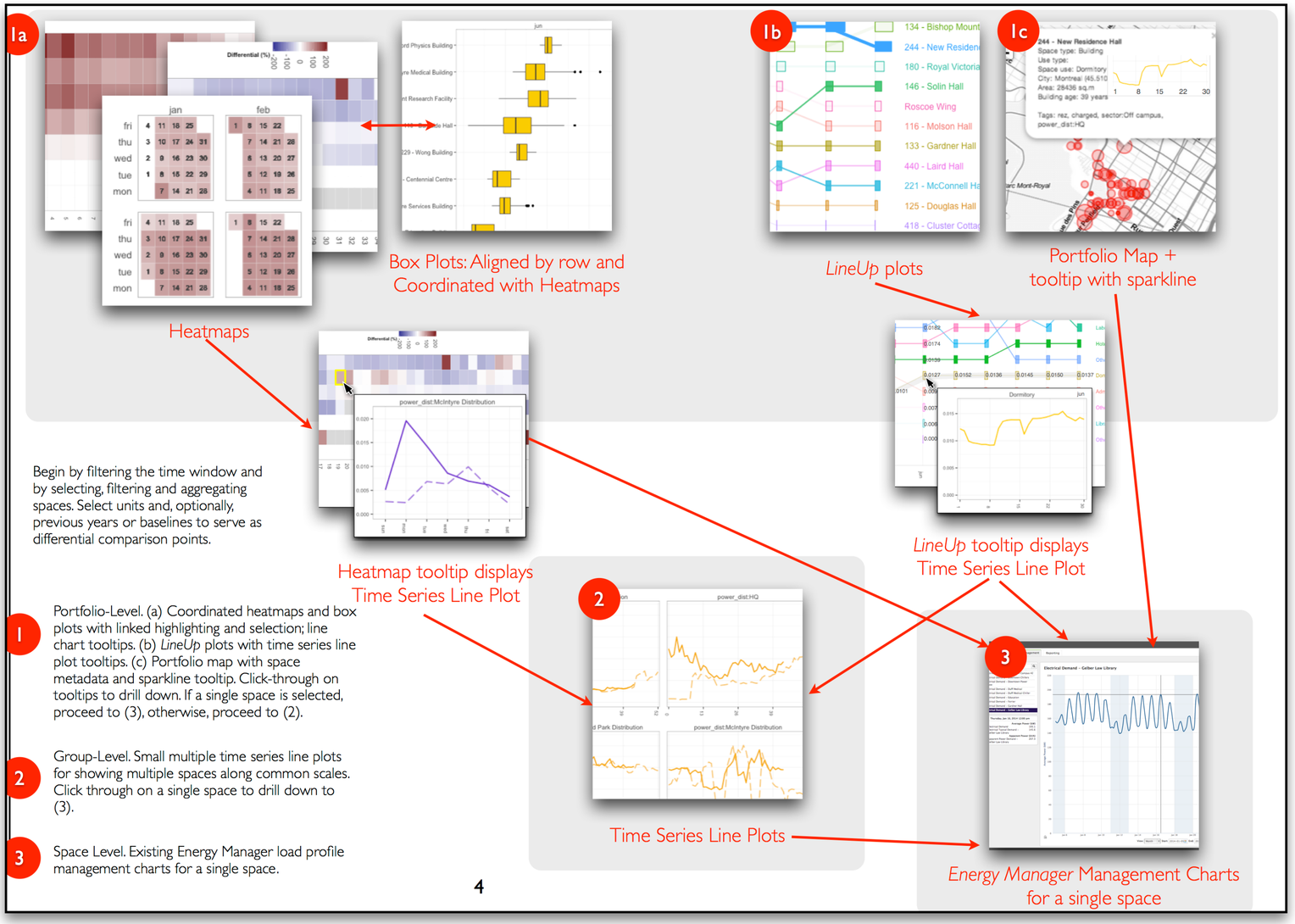


Task	Visualization Idiom	Match?
T1: Overview	Juxtaposed matrix and boxplots	✔

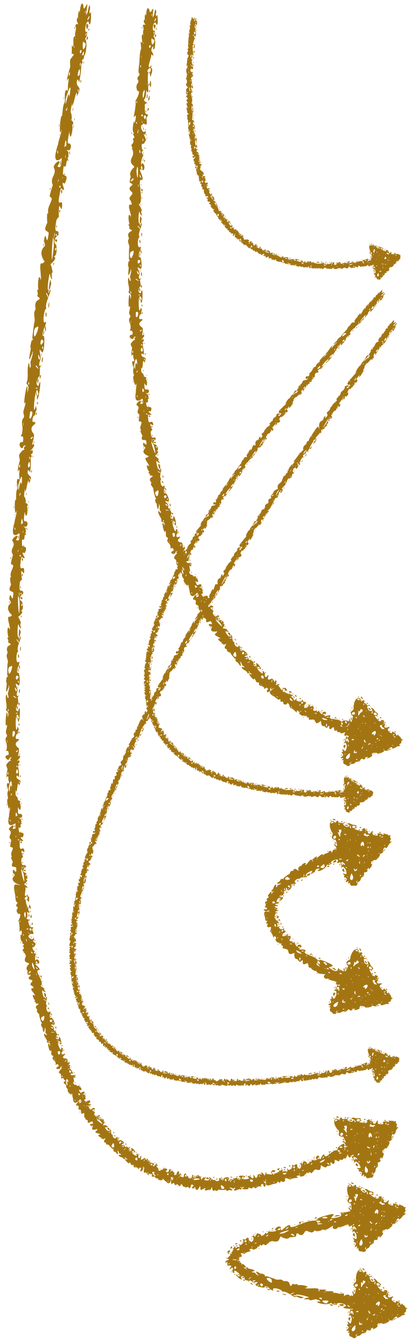
STACKS & FACETS, JUXTAPOSED + LINKED



INTERACTIVE DRILL DOWN



Brehmer et al. 2015



Task Name

Overview

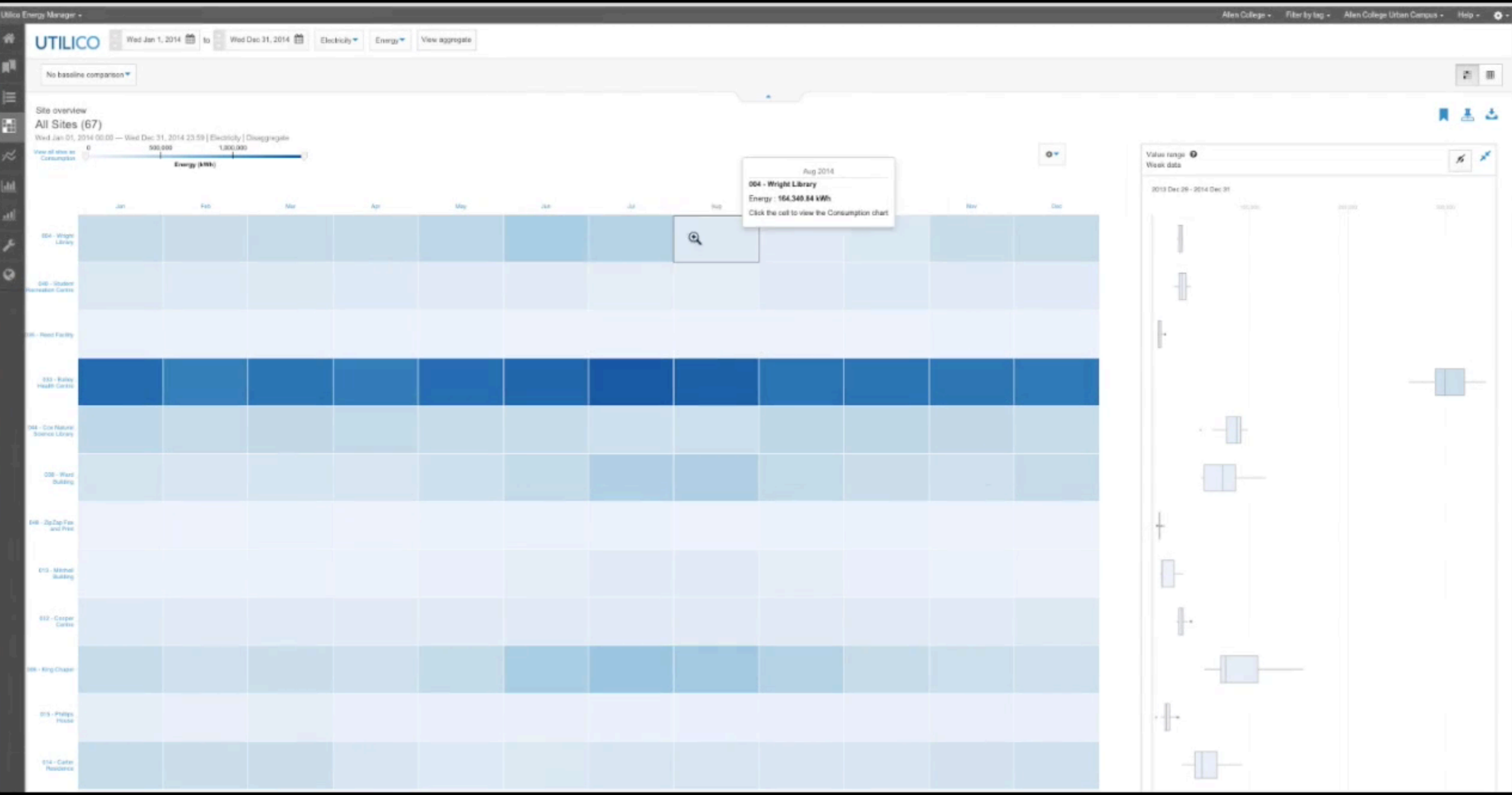
Drill Down

Roll Up

RESULTS

DESIGN ACTIVITIES

i. analyzing the work domain
ii. identifying data and task abstractions
iii. visual encoding sandbox prototyping
iv. eliciting feedback on visual encoding designs
v. prototyping workflows
vi. production development by collaborator


Utilico Energy Manager
Allen College
Filter by tag
Allen College Urban Campus
Help
UTILICO
Wed Jan 1, 2014
to
Wed Dec 31, 2014
Electricity
Energy
View aggregate
No baseline comparison
Site overview
All Sites (67)
Wed Jan 01, 2014 00:00 — Wed Dec 31, 2014 23:59 | Electricity | Disaggregate
0
500,000
1,000,000
Energy (kWh)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Nov
Dec
004 - Wright Library
Aug 2014
004 - Wright Library
Energy : 164,340.84 kWh
Click the cell to view the Consumption chart
Value range
Week data
2013 Dec 29 - 2014 Dec 31

DISCUSSION

FAMILIARITY

Persevere despite unfamiliarity: Juxtaposition of two unfamiliar encodings with coordinated interaction and highlighting.

Beware assuming familiarity: visualization names can be misleading (*"heatmap"*, *"boxplot"*)

TRUST

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

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.

CONCLUSION

Generalizable visualization design guidelines for multiple time series data, matches and mismatches between task and data abstractions to visual encoding and interaction idioms.

Higher-level guidelines with themes of familiarity & trust.

Methodological guidance for design studies in corporate contexts with internal and external stakeholders.

An industry visualization redesign study success story.

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Kevin Tate

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

paper & supplemental materials:
cs.ubc.ca/group/infovis/

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

SUPPLEMENTAL

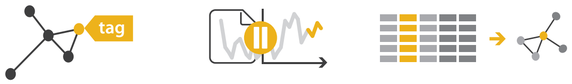
Why?

Actions

Analyze

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

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

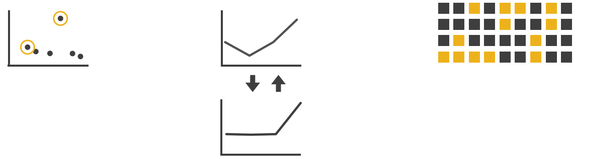


Search

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

Query

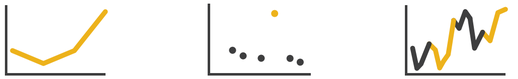
- Identify
- Compare
- Summarize



Targets

All Data

- Trends
- Outliers
- Features

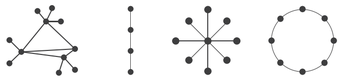


Attributes

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

Network Data

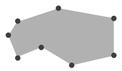
- Topology

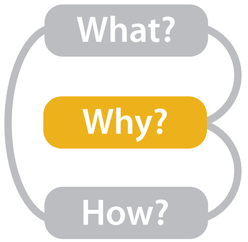


- *Paths*

Spatial Data

- Shape





ENERGY MANAGER++

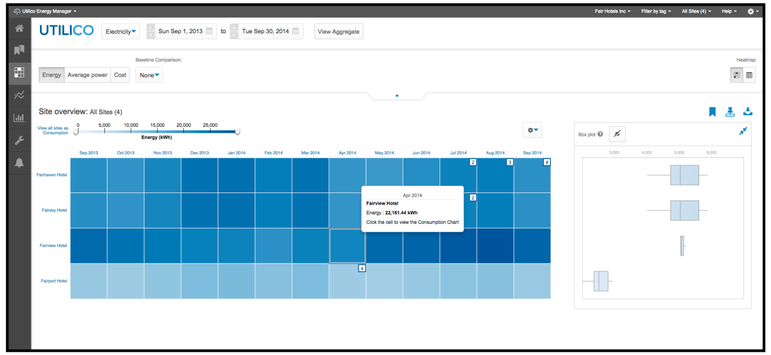
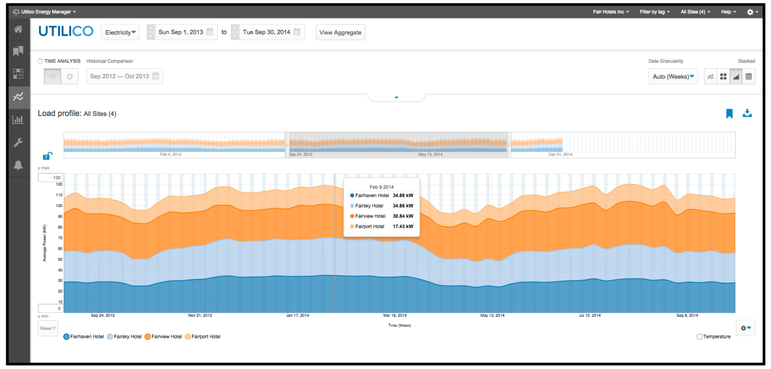
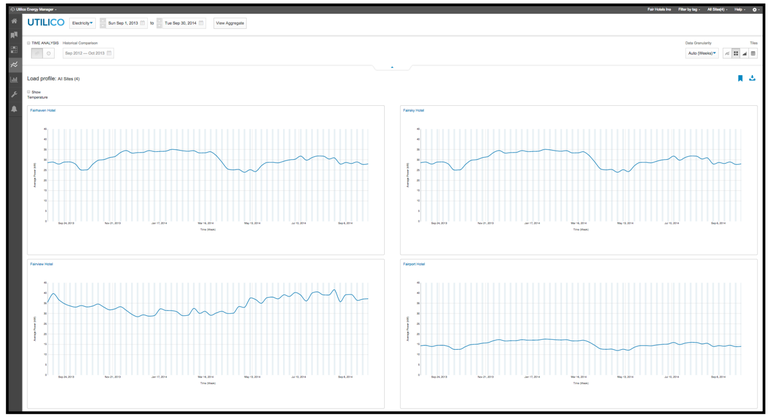
Currently **implemented** based on prototype designs and mockups:

parameterizable visualization: filtering and **aggregation** using categorical tags (normalization: not yet) (no more wizard dialogs)

matrix + **auxiliary boxplots** (top)

stacked area chart (middle), stacked bar chart

faceted line charts (bottom), faceted bar charts

navigation from matrix to other visualizations

trusted historical values instead / in addition to predicted values