

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

Matthew Brehmer*, Jocelyn Ng°,
Kevin Tate°, & Tamara Munzner*

*The University of British Columbia & °EnerNOC

IEEE InfoVis Submission #106

Supplemental Material: Research Artefact Examples

Note: slides that attribute individual energy workers or depict real portfolio data have been sanitized.

- For Internal Feedback (Collaborator)
- For External Feedback (Power users)
- For External Feedback (New interviewees)



Fig. S1: 11 slide decks (302 slides) created between Nov 2013 and February 2014. Slide decks were iteratively refined research artefacts used to document the research and design process. Slides 3–12 contain sample slides from these decks.

Date: 07.29

Who: Energy Manager,

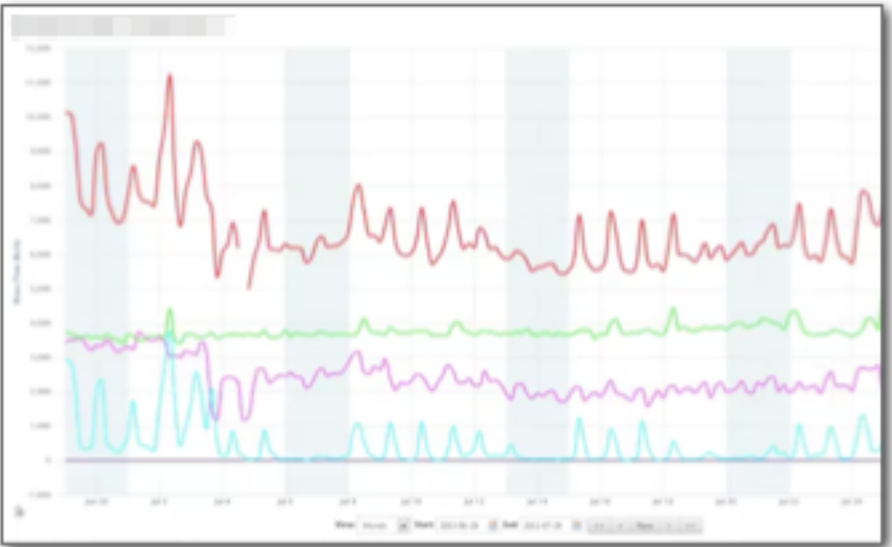
Where: (Skype)

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

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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

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Fig. S2: Partial summaries of findings from initial interviews with energy workers.

Nov
Multifaceted Comparisons and Rankings for Portfolios in Energy Manager: Task and Data Abstractions
 InfoVis @ UBC and ...
 Matt Brehmer
 Nov 15, 2013



User	Role	Affiliation	EM Use & Frequency	Portfolio?	Portfolio Size, Organization	Task abstractions: current (not in EM)	Task abstractions: desirable	Task abstractions: possible (does data exist?)	Task abstractions: target
	space automation specialist		meta-user / power-user: frequently setting up charts, baselines for clients	YES	(Client portfolios range in size, hierarchical structure)	<ul style="list-style-type: none"> Lookup → Compare: ranked performance (absolute and normalized) Lookup → Identify: CUSUM of entire portfolio, single space 	<ul style="list-style-type: none"> 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 	<ul style="list-style-type: none"> 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 	<ul style="list-style-type: none"> 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)
	energy analyst		several hours a week, additional analysis in Excel	YES	campus: ~100 spaces (90% concentrated on single campus), subset in EM; departments cross-cut spaces	<ul style="list-style-type: none"> Locate → Compare: consumption of [largest spaces, libraries, mid-size spaces] Locate → Identify: causes of threshold events in reference to OAT Lookup → Compare: ranked space performance Locate → Compare: before & after ECMs Lookup → Compare: monthly department performance 	<ul style="list-style-type: none"> Lookup → Compare: department performance at arbitrary time scales Locate → Identify: contribution of department(s) to space consumption Lookup → Compare: OAT-demand regression curves before & after ECMs Locate → Identify: end-use disaggregation within a space Lookup → Identify: changes in space sensitivity to OAT Locate → Compare: consumption of other universities Lookup → Identify: weather predictions, trends 	<ul style="list-style-type: none"> Lookup → Compare: monthly department performance Lookup → Compare: departments (arbitrary groups of spaces) performance at arbitrary time scales Locate → Identify: contribution of department(s) to space consumption (assuming assignment of tags to sq. footage, occupants within a space) Lookup → Identify: changes in space sensitivity to OAT Lookup → Identify: weather predictions, trends 	<ul style="list-style-type: none"> Locate → Compare: portfolio performance faceted by space or by space attributes (over time) Lookup → Compare Summarize: multivariate ranking of spaces (over time)
	energy manager		day-to-day monitoring	YES	campuses, 4 zones in campus (~70 spaces), campus (~20 spaces); all in EM; focuses on 50 steam meters	<ul style="list-style-type: none"> Locate → Compare Summarize: combined consumption of two campuses; four groups of spaces for main campus Browse → Identify: contribution of individual spaces to combined consumption, anomalies (spikes, surges) Lookup → Identify: threshold events 	<ul style="list-style-type: none"> Lookup → Identify: contribution of individual spaces to combined consumption, anomalies (spikes, surges) Locate → Identify: causes of threshold events in wider context Lookup → Identify: contributions of parameters to PAM baselines (weather, occupancy) 	<ul style="list-style-type: none"> Lookup → Identify: contribution of individual spaces to combined consumption, anomalies (spikes, surges) Locate → Identify: causes of threshold events in wider context 	<ul style="list-style-type: none"> 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)
	energy specialist		EM for data export: analysis done in Excel; EM analysis offloaded to student volunteers	YES	campuses, 2 accounts, 36 in EM (Electricity, 2 submetered), 4 in EM (Natural Gas)	<ul style="list-style-type: none"> Lookup → Compare: ranked performance (absolute and normalized) Browse → Identify: anomalies (jumps in rankings), trends (consistent rankings) at macro-level between spaces Locate → Compare: single-space performance across N time periods Produce: annotations to explain aspects of performance 	<ul style="list-style-type: none"> Lookup → Compare: multivariate ranking of portfolio performance Locate → Identify Compare: single space performance, within and between operating hours and between days 	<ul style="list-style-type: none"> Lookup → Identify: anomalies (jumps in rankings), trends (consistent rankings) at macro-level between spaces Locate → Compare: single-space performance across N time periods Produce: annotations to explain aspects of performance Lookup → Compare: multivariate ranking of portfolio performance Locate → Identify Compare: single space performance, within and between operating hours and between days 	<ul style="list-style-type: none"> Lookup → Compare Summarize: multivariate ranking of individuals (over time) Locate → Compare: individual performance (over time)
	head maintenance engineer, automation		daily email digest, follow-up in EM ~3-4 hrs / week	YES	campus: ~100 spaces and 2 zones in EM; monitors about 10 spaces / week	<ul style="list-style-type: none"> Lookup → Compare: ranked space performance Locate Explore → Identify: anomalies, causes of threshold events / alerts 	<ul style="list-style-type: none"> Locate → Identify: end-use disaggregation within a space Locate → Identify: contributions of parameters to PAM baselines (weather, outages, holidays, other events) 		<ul style="list-style-type: none"> Lookup → Compare Summarize: multivariate ranking of individuals (over time)
	climate and energy engineer		infrequent (annual, semi-annual reports)	YES	campus, ~100 spaces and 2 zones in EM; interested in handful of spaces	<ul style="list-style-type: none"> Lookup → Identify: differential between actual and predicted performance Lookup → Identify: CUSUM Locate → Compare: actual to baseline performance 	<ul style="list-style-type: none"> Locate → Identify: cause of long-term trend alerts Locate → Identify: baseline precision / uncertainty Locate → Compare: performance across arbitrary time periods 	<ul style="list-style-type: none"> Locate → Compare: performance across arbitrary time periods 	<ul style="list-style-type: none"> Locate → Compare: individual performance (over time)
	energy efficiency engineer (consultant)		some exploratory analysis, most analysis done in Excel	NO (small)	(single-space focus or small group of spaces (e.g. 5))	<ul style="list-style-type: none"> Explore Browse → Identify: load profile of space, anomalies Lookup Locate → Compare: within and across spaces: monthly and seasonal differences in consumption / schedule / demand; OAT vs. demand for occupied and unoccupied periods Lookup → Summarize: distribution of OAT, demand 	<ul style="list-style-type: none"> Locate → Identify: end-use disaggregation use within a space; Locate → Identify Compare: effects of simulated ECMs on space performance 	<ul style="list-style-type: none"> Lookup Locate → Compare: within and across spaces: monthly and seasonal differences in consumption / schedule / demand; OAT vs. demand for occupied and unoccupied periods Lookup → Summarize: distribution of OAT, demand 	<ul style="list-style-type: none"> Locate → Compare: individual performance (over time) Lookup → Summarize: distributions of individual's attributes (over time)
	energy efficiency engineer (consultant)		some exploratory analysis, confirmatory analysis done in Excel	NO	(single-space focus)	<ul style="list-style-type: none"> Lookup → Compare: month-to-month %Δ in consumption, peak demand; actual: baseline 	<ul style="list-style-type: none"> Locate → Identify: effects of simulated ECMs on a space based on previous success Locate → Compare: effect of ECMs between spaces 	<ul style="list-style-type: none"> Lookup → Compare: month-to-month %Δ in consumption, peak demand; actual: baseline 	<ul style="list-style-type: none"> Locate → Compare: individual performance (over time)

Fig. S3: Characterizing energy worker's activities as abstract tasks according to the typology of Brehmer and Munzner (2013, IEEE TVCG / Proc. InfoVis)

Multifaceted Comparisons and Rankings for Portfolios in Energy Manager: Task and Data Abstractions

InfoVis @ UBC and
Matt Brehmer
Nov 15, 2013



Data Abstractions: Spaces

† = not configurable in EM | [possible extensions]

- aggregate item [portfolio] [S*]**
 - (aggregate items [groups of spaces])
 - individual item [space] [S]
 - (partial item [space submeter])
 - links
 - [point 1]
 - [point 2]
 - ...
 - [point n]
 - categorical attributes
 - [primary use]
 - [space type]
 - [use_type]†
 - [weather station ID]
 - [TMY (Typical Meteorological Year) data source]
 - [floor space unit]
 - [custom descriptor tag(s)]
 - [end-use(s)]
 - spatial attributes
 - [address (location)]
 - [city]†
 - [province]†
 - [latitude]†
 - [longitude]†
 - [time zone]†
 - static quantitative attributes
 - [# occupants]
 - [# occupants subdivided by descriptor tag]
 - [year constructed (space age)]
 - [floor space]
 - [floor space subdivided by descriptor tag]
 - [# weekly operating hours]†
 - [base temperature]† (?)
 - cyclical temporal categorical attribute
 - [operating hours (e.g. open-closed, day-evening-night)]
 - [operating hours by descriptor tag]

end-use still not possible at campus level, out of scope for now

how flexible can tags be? tagging occupants, floor space, operating hours; combinatorial assignment of tags, occupants, floor space, operating hours?

where is this set? aside from linear regression points

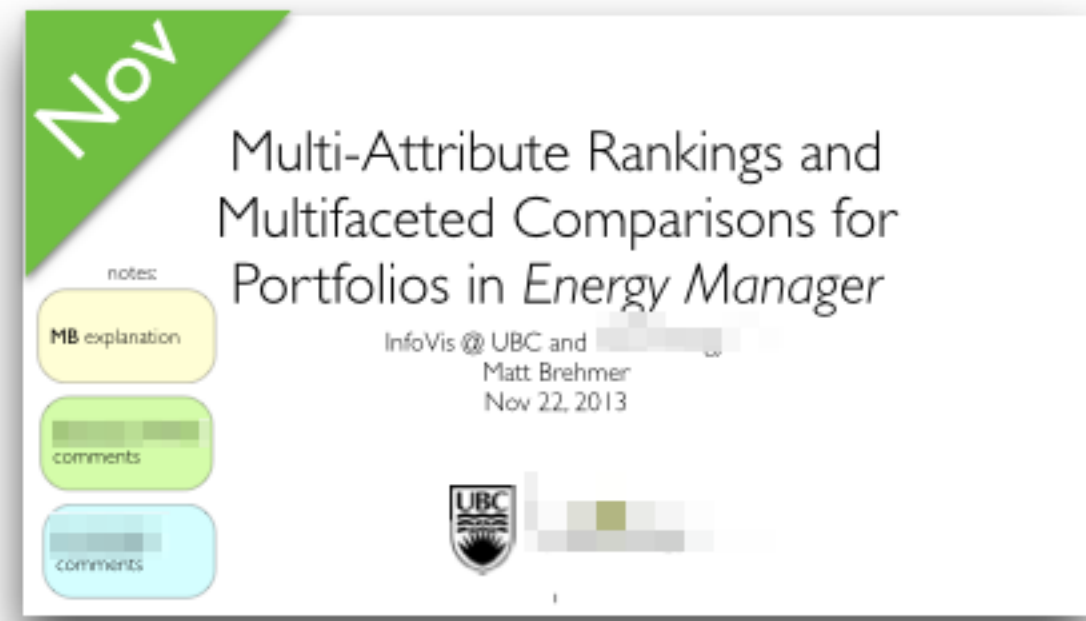
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Data Abstractions: † = not configurable in EM | [possible extensions]

- aggregate item [portfolio] [S*]**
 - (aggregate items [groups of spaces])
 - individual item [space] [S]
 - (partial item [space submeter])
 - links
 - [point 1]
 - [point 2]
 - ...
 - [point n]
 - categorical attributes
 - [primary use]
 - [space type]
 - [use_type]†
 - [weather station ID]
 - [TMY (Typical Meteorological Year) data source]
 - [floor space unit]
 - [custom descriptor tag(s)]
 - [end-use(s)]
 - spatial attributes
 - [address (location)]
 - [city]†
 - [province]†
 - [latitude]†
 - [longitude]†
 - [time zone]†
 - static quantitative attributes
 - [# occupants]
 - [# occupants subdivided by descriptor tag]
 - [year constructed (space age)]
 - [floor space]
 - [floor space subdivided by descriptor tag]
 - [# weekly operating hours]†
 - [base temperature]† (?)
 - cyclical temporal categorical attribute
 - [operating hours (e.g. open-closed, day-evening-night)]
 - [operating hours by descriptor tag]

- item [point] [P]**
- temporal quantitative attribute
 - [point value]
- categorical attributes
 - [resource] (e.g. electricity, steam)
 - [quantity] (e.g. energy, mass, avg. power)
 - [type] (e.g. monitored, conversion, baseline)
 - [unit] (e.g. kW, kWh, GJ, lb, b/h)
 - [direction] (consumption vs. generation)
- static quantitative attributes
 - [update frequency]
- links
 - [space i]
 - [datalogger j]
 - [connector k]
- item [space-point dyad] [S-P]**
- static quantitative attributes
 - [cost conversion ratio]
 - [energy conversion ratio]
 - [Green House Gas conversion ratio]
 - [normal range ±%]
 - [coarse-grained normal range ±%]
 - [fine-grained normal range ±%]
- weather [W]**
- temporal quantitative attribute
 - [OAT: outside air temperature]
 - [relative humidity]
 - [wind speed]
 - [precipitation]
 - ...
- temporal categorical attribute
 - [wind direction]
- temporal intervals [T]**
- [annual]
 - [semi-annual]
 - [quarter / season]
 - [month]
 - [week]
 - [day]
 - [operating hours]
 - [hour]
 - [1/4 hour]
- derived attributes [D1] [items [P] + temporal interval [T]]**
- quantitative attribute: average, sum, distribution, range, SD
 - [consumption]
 - [cost]
 - [average demand]
 - [peak demand]
 - [absolute savings / waste: point value 1 – point value 2]
 - [relative savings / waste: point value 1 / point value 2]
 - [cumulative savings]
- temporal quantitative attribute
 - [schedule: derivative of demand] see Excel charts
- derived attributes [D2] [item [S] + weather [W] + [T]]**
- quantitative attribute
 - [HDD: base temperature – OAT]
 - [CDD: OAT – base temperature]
- derived attributes [D3] [item [S+P] + derived attributes [D1,D2] + temporal interval [T]]**
- quantitative attribute
 - [attribute [D1] per area] (e.g. energy intensity: consumption normalized by square footage)
 - [average baseload]
 - [attribute [D1] normalized by HDDs, CDDs]
 - [attribute [D1] normalized by # occupants]
 - [attribute [D1] normalized by # operating hours]
 - [attribute [D1] faceted by schedule interval]
 - [end-use-disaggregation] out of scope for now
- derived attributes [D4] [multiple items [S+P] + [D1, D2, D3]]**
- ordinal attribute
 - ranking
- quantitative attribute
 - [contribution to aggregate derived attribute]
- derived attributes [D5] [[S+P] + ranking [D4] + N t. intervals [T]]**
- quantitative attribute
 - [change in ranking]

Fig. S4: Partial characterization of data abstractions relevant to energy workers' activities.



portfolio level: rank groups of spaces based on multiple measures of performance, sub-rank within groups. Compare changes in rank over time.

portfolio / detail level: multi-faceted comparison of portfolio performance over time.
Drill-down: split portfolio into spaces OR groups of spaces.
Roll-Up: determine contribution of spaces OR groups of spaces to overall portfolio performance.

space level: compare a single space's performance over time.

Annotations:

- #1 priority, day-to-day operations level, both Drill-down and Roll-up needed to equal degree, concerns over scalability of multi-faceted comparisons, filtering and aggregating by tag, by rank, or by value necessary.
- #1 priority, "need to have"
- #2 priority, would be less frequently used than portfolio / detail level, though helpful for generating reports and communicating to decision makers.
- #3 priority "would be nice to have"
- #3 priority, would still be used (all ideas are interesting), but not as highly prioritized as others.
- #2 priority: "need to have"

portfolio / detail level: multi-faceted comparison of portfolio performance over time.
Drill-down: split portfolio into spaces OR groups of spaces.

Annotations:

- spaces with "space_use: library"
- concern over scalability re: bandwidth. Alternative: local client?
- compare across buildings, time intervals with common scales:
 y axis: 0-300kW
 x axis: 7 days (week 45 / 52)
 linked navigation and selection
- flexibility and scalability: specify a grid and time granularity, drag-drop spaces into grid. Select rather than filter + facet.
- current workaround is to open multiple browser windows (drawback: no linked navigation / selection)
- facet by dates, or bin by #HDDs, #CDDs

Figure: A grid of line graphs showing weekly electricity demand (kW) for three libraries, faceted by space and year. The graphs are arranged in a 2x3 grid. The top row shows data for Nov 25-Dec 2 2013, and the bottom row shows data for Nov 26-Dec 3 2012. A third row is partially visible for Nov 28-Dec 5 2012. Each graph has a y-axis from 0 to 300 kW and an x-axis for 7 days. A red vertical line is present in each graph, indicating a specific time point.

Example: weekly electricity demand (kW) of 3 libraries, faceted by space and year

Fig. S5: Verifying the task and data abstractions with power user energy workers (left: summary of tasks; right: a mockup of a faceted line graph).

Portfolio Visualization Design Sketches

InfoVis @ UBC and
Matt Brehmer
Jan 14 2014



portfolio / detail level: multi-faceted comparison of portfolio performance over time.



portfolio visualization data sketch (Jan 9 screenshot)

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portfolio level: rank groups of spaces based on multiple measures of performance, sub-rank within groups. Compare changes in rank over time.



portfolio visualization data sketch (Jan 14 screenshot)

A "LineUp" chart of total monthly steam consumption for spring and summer for 2 years, normalized by aggregate area, with spaces grouped by tag and filtered to tags containing "Library".

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Fig. S6: Initial data sketches produced within the sandbox environment (left: faceted bar charts; right: an early version of the bar + bump plot).

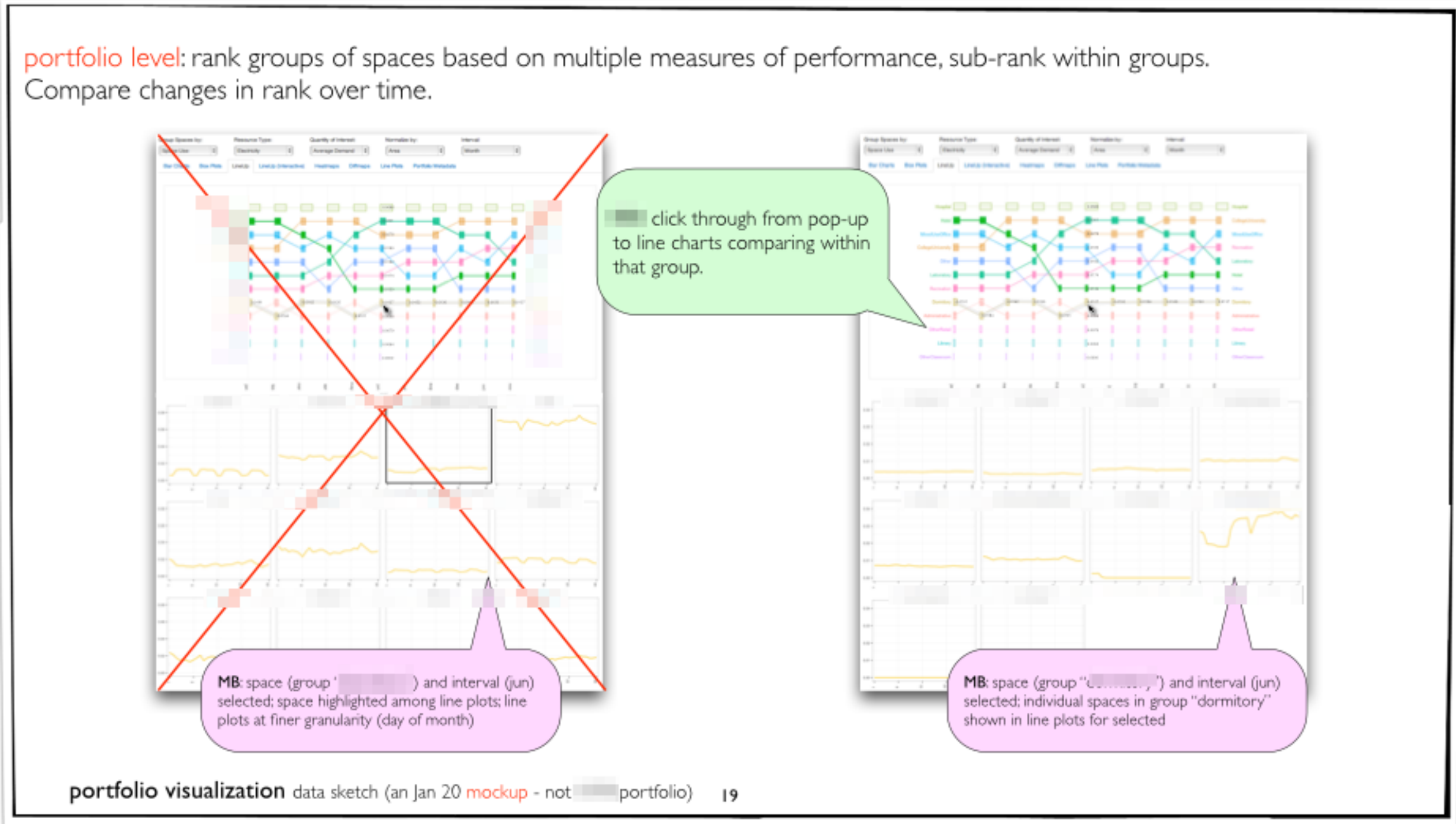
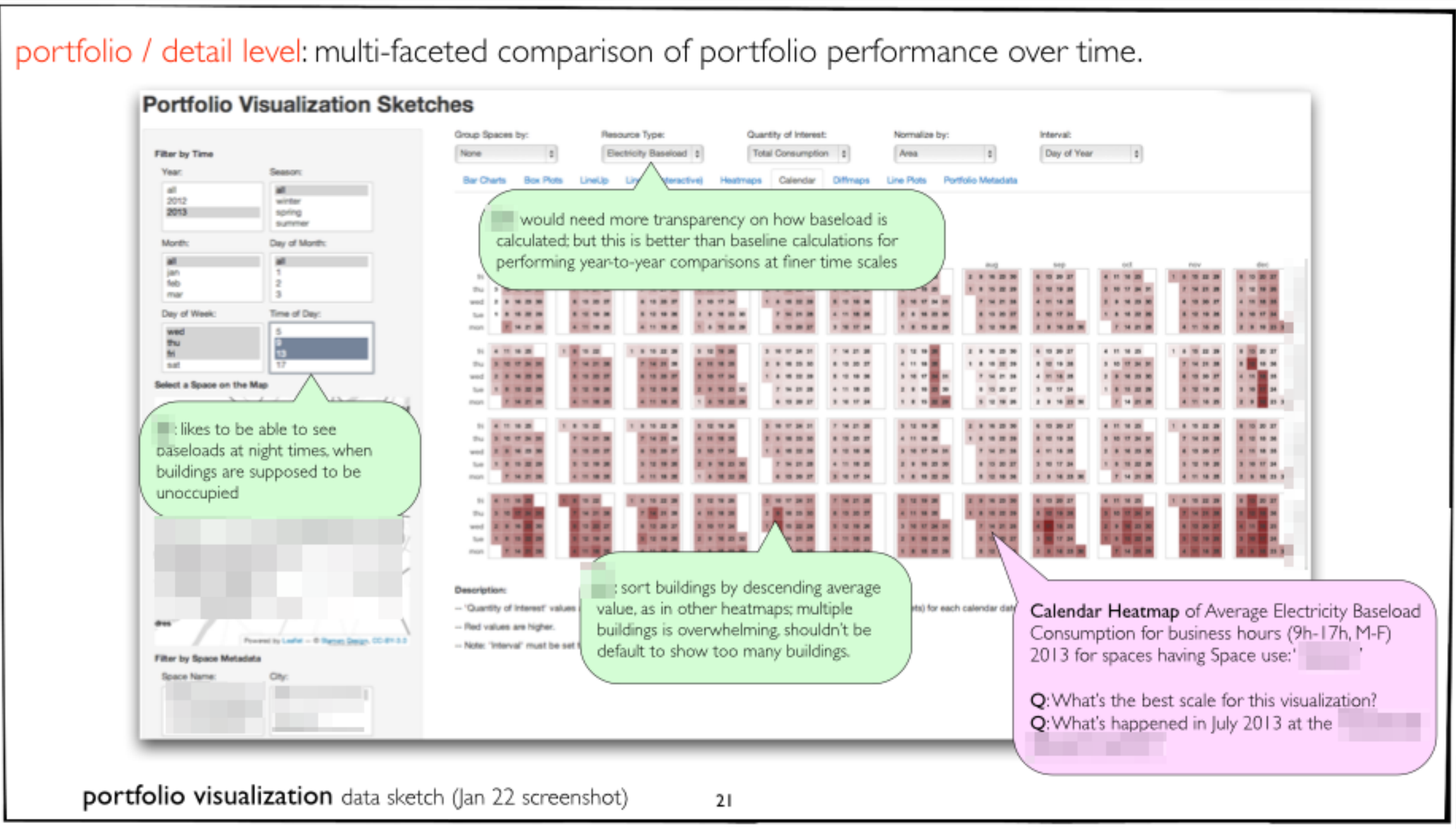
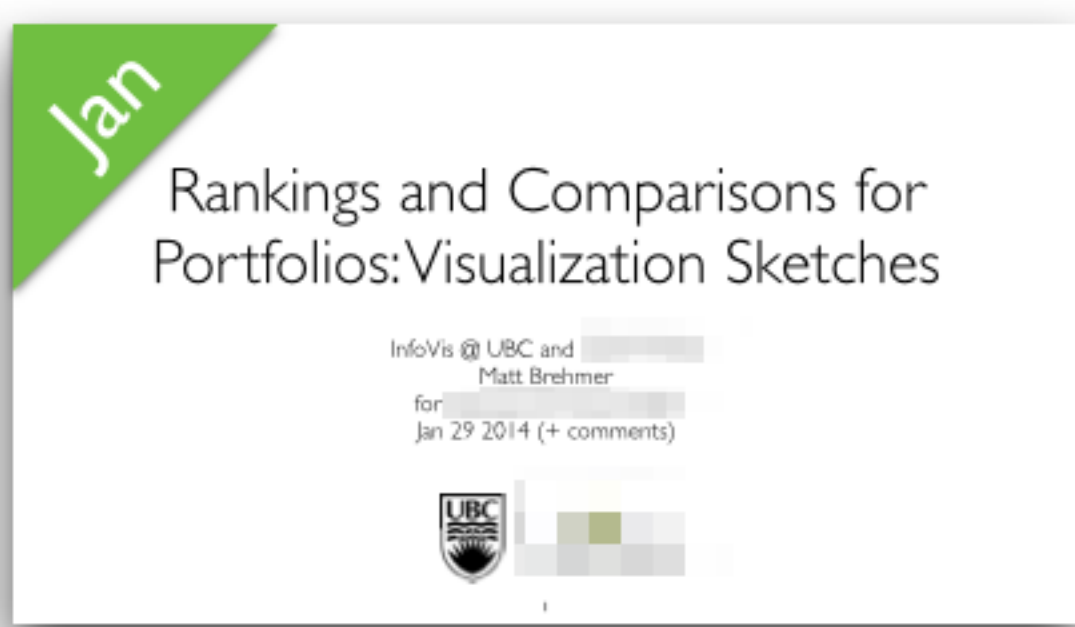
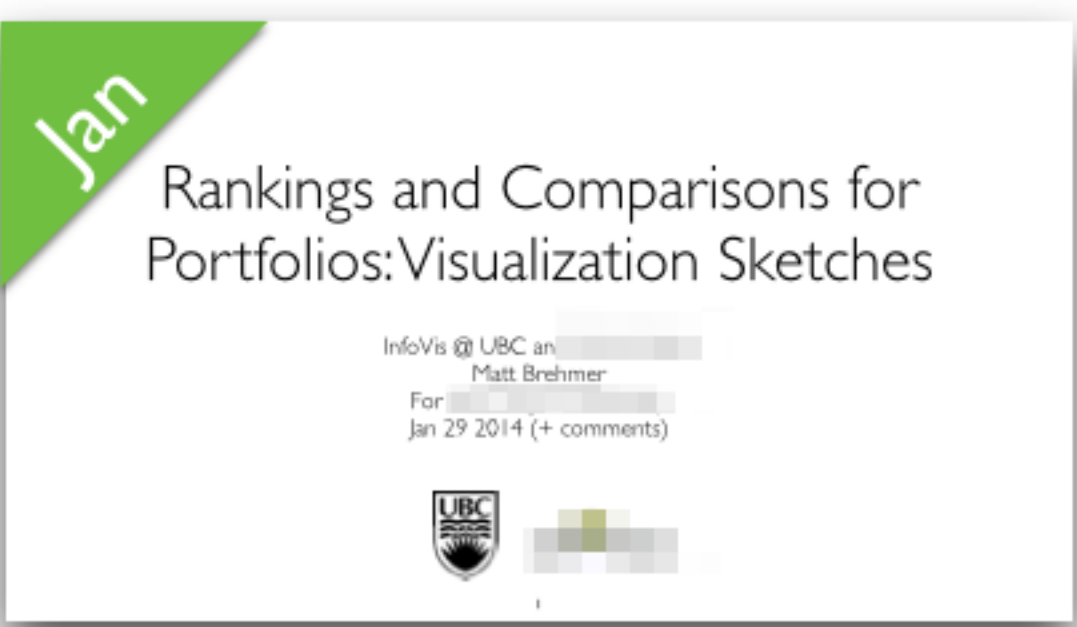


Fig. S7: Following-up with the power user energy workers with designs from our sandbox design (left: calendar-partitioned time series matrix; right: view coordination mockups).

Visualizing Portfolios in Energy Manager: Design Sketches

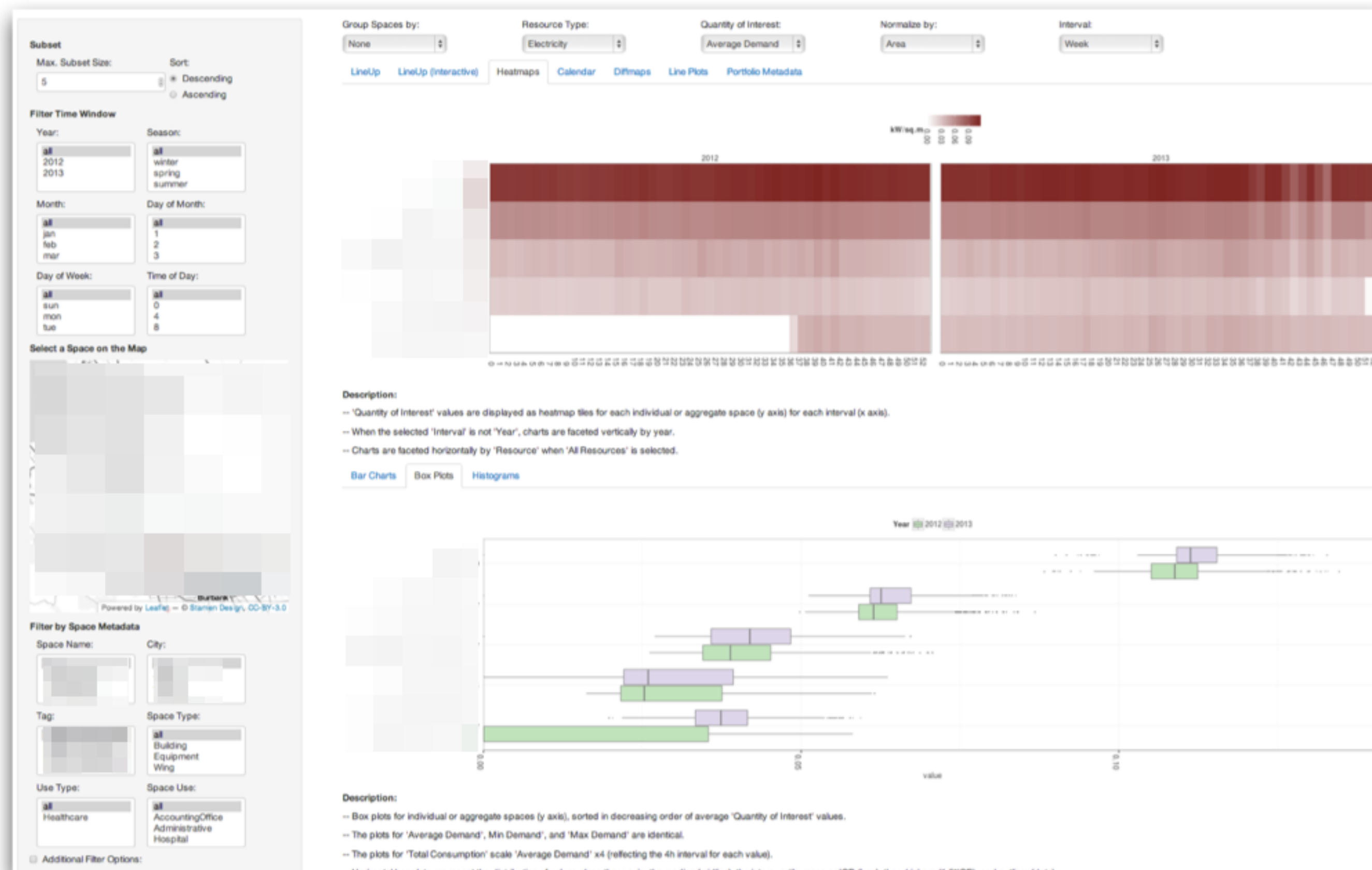
A research collaboration between InfoVis @ UBC and

Matt Brehmer (matt.brehmer@ubc.ca) | http://cs.ubc.ca/~brehmer

Feb 20 2014



portfolio visualization: sketching environment



Note: the preceding visualizations were generated in this sandbox environment, which contains controls for filtering, selection, aggregation, and normalization, as well as a map of the portfolio.

Fig. S8: Early view coordination design depicting a matrix with auxiliary boxplots.

Portfolio Visualization Design Sketches

InfoVis @ UBC and
Matt Brehmer
Jan 30 2014 (+ comments)



portfolio / detail level: multi-faceted comparison of portfolio performance over time.

MB: mouse over highlighting and tooltips needed; tooltips could include line plots at a finer time granularity

MB: show heatmaps and box plots side-by-side, on mouse-over of a tile, show placement within distribution using unidirectional brushing.

MB: include a totals row above representing the aggregate amount, as visual breadcrumb reference, reflecting what was shown before drill-down

Heatmap (a.k.a. tilemap) of Average Steam Demand for Jan-Nov 2013 at a weekly granularity for spaces grouped by tag and filtered to tags containing '...', normalized by aggregate space area. Sorted vertically in decreasing order by mean demand across all weeks.

Q: Why did ... Steam demand spike in midsummer (week 31)?

Q: What's the best scale for this visualization?

portfolio visualization data sketch (Jan 9 screenshot) 21

portfolio / detail level: multi-faceted comparison of portfolio performance over time.

MB: highlighting with tooltip display of line chart for selected space (group with tag "...") and selected interval (week 19) at finer level of granularity (day of week)

MB: same as above, tooltip shows side-by-side sparklines at 4h granularity

portfolio visualization data sketch (Jan 20 mockup) 24

Fig. S9: Another iteration of data sketches produced using the sandbox environment (left: time series matrix; right: interactivity mockups).



Generalized Workflow

Based on **feedback** collected from:

- [redacted] (Jan 22)
- [redacted] (Jan 27)
- [redacted] (Jan 28)

(throughout Jan)

For detailed [redacted] workflows, see supplemental slides

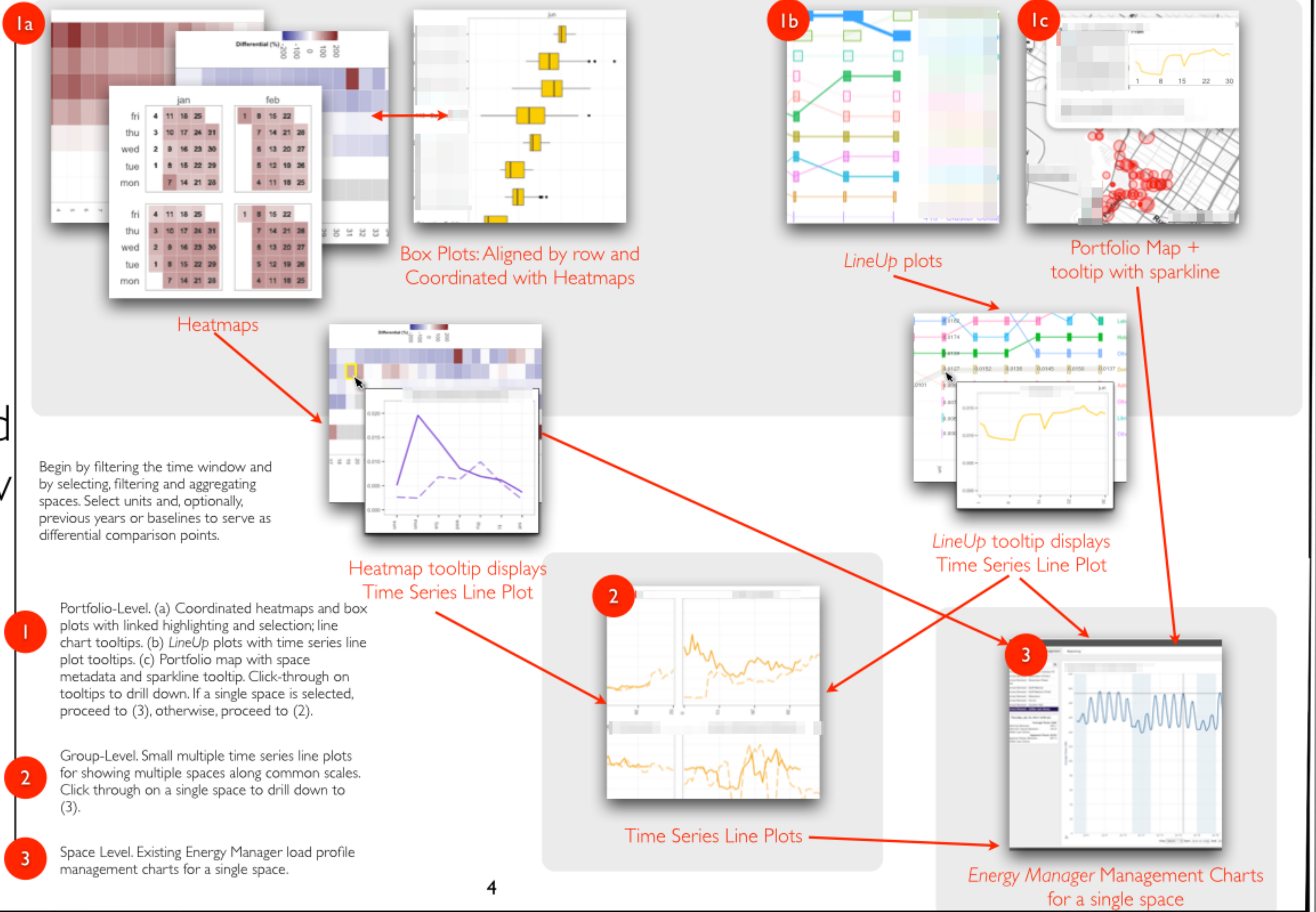


Fig. S10: Proposed workflow design involving multiple views based on consolidated feedback from energy workers.

Portfolio Visualization Design Sketches: Feedback and Workflows

InfoVis @ UBC and F
Matt Brehmer
Feb 06 2014



"Zone"-based workflow:

1. Heatmap of portfolio electricity demand in 2013 by month, spaces grouped by "Zone" tags, normalized by area. Observation: demand spike in Aug-Sep 2013 in [redacted]
2. Heatmap of [redacted] electricity demand in 2013 by month, normalized by area. Observation: % demand spike at group level in Aug-Sep 2013 caused by [redacted] being turned on?
3. Heatmap of [redacted] electricity demand in 2013 by month, normalized by area. Observation: demand spike at group level in Aug-Sep 2013 remains investigate further?
- 4a (possible). LineUp plot of [redacted] electricity demand in 2013 by month, normalized by area. Observation: Nighttime demand only. Observation: Ranks don't fluctuate much, neither do absolute values.
- 4b (possible). LineUp plot of [redacted] electricity demand in 2013 by month, normalized by area. Observation: Nighttime demand only. Observation: Ranks fluctuate a lot, but absolute values don't vary much. A false positive?
- 4bi (possible). LineUp plot of [redacted] electricity demand in July comparing 2012 and 2013, normalized by area. Observation: [redacted] shut down in Jun-Jul 2013. Observation: [redacted] increase in rank, it looks like [redacted] also gains in absolute value (bar length).
- 4c (possible). Bar charts of [redacted] electricity demand in 2013 by month, normalized by area. Observation: Nighttime demand only. Observation: absolute values don't vary much. A false positive? Some missing values apparent.
- 4 (possible). Small multiple Time Series Line Charts of baseload demand in July 2013 by 4h interval for spaces in [redacted], normalized by area. Observation: [redacted] halls removed. Observation: Not much variation. Good!
- 4i (possible). LineUp plot with tooltips and pop-up line series or sparkline. Desirable: click through to small multiple line plots.
- 5a. Small multiple Time Series Line Charts of electricity demand in July 2013 by day of week for spaces in [redacted], normalized by area. Observation: [redacted] halls removed. Observation: Not as much variation as anticipated (what happens on weekends?). Bad!
- 5b. Small multiple Time Series Line Charts of electricity demand for Fridays in July 2013 by time of day for spaces in [redacted], normalized by area. Observation: [redacted] halls removed. Observation: Not as much weekend at night time for some buildings. Bad!

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1a. Differential % Heatmap of portfolio electricity demand between 2013 and 2012 by month, spaces grouped by "Zone" tags, normalized by area. Observation: demand spike in Aug-Sep 2013 in [redacted] ? in Jan. [redacted] not as bad in Feb, Oct, investigate further.

2a. Differential % Heatmap of portfolio electricity demand between 2013 and 2012 by month, spaces in [redacted] groups, normalized by area. Observation: [redacted] shut down in Jul 2013 (explaining 100% decrease), [redacted] turned on in Jul 2013 (explaining 100% increase); next step should be to filter these two out.

3a. Differential % Heatmap of portfolio electricity demand between 2013 and 2012 by month, spaces grouped by "Zone" tags, normalized by area. Observation: [redacted] and [redacted] halls removed. Observation: [redacted] is now the worst performer, relative to last year (Again because 3 buildings were turned on in 2013). Should automatically filter out buildings where no data is available for comparison, whenever one of the values is 0?

4ii. [redacted]

4bi. [redacted]

5b. [redacted]

Workflows

based on interview recording.

Steam Workflow by Zone:

1. Faceted bar chart of portfolio steam consumption over 2 year interval spaces grouped by "Zone" tags, normalized by area. Observation: absolute value also increases for sector-NW and sector-SE groups, decreases for other groups, large decrease for [redacted].
- 1b (possible). LineUp plot of portfolio steam consumption over 2 year interval, spaces grouped by "Zone" tags, normalized by area. Observation: [redacted] group moves up in the rankings from 5th to 1st, absolute value also increases; reverse for [redacted] group.
2. Faceted Bar chart of [redacted] consumption over 2 year interval, individual spaces, normalized by area. Observation: several considerable increases; are these caused by anomalous spikes or by a gradual increase?
3. Faceted Box plot of [redacted] consumption over 2 year interval, individual spaces, normalized by area. Observation: x-axis scale is skewed by [redacted] outliers in 2012 and in 2013. Single outliers not important, especially for steam (meters are less reliable than Electricity); groups of outliers closer to whisker are more interesting. Omit single distant outliers.
4. Faceted Box plot of [redacted] steam consumption over 2 year interval, individual spaces (not including [redacted]), normalized by area (desired: still show [redacted], but omit distant outliers). Observation: what's most interesting are shifts in IQRs (e.g. Building IQR increases, median increases); prevalence of outliers is next-most-interesting, as well as combinations of these two events (e.g. [redacted] IQR increases, outliers only in 2012).
- 5i (possible). Small multiple time series line plots plot of [redacted] steam consumption over 2 year interval by month, individual spaces, normalized by area.
- 5ii (possible). Small multiple time series line plots plot of [redacted] steam consumption in May 2012, 2013 by week, individual spaces, normalized by area.
- 5a (possible). Heatmap plot of [redacted] steam consumption over 2 year interval, individual spaces, normalized by area. Observation: some IQR / median increases from step 5, such as [redacted] can be explained by observation that the building wasn't reporting any consumption in the first several weeks of 2012. [redacted] is more difficult to diagnose.
- 5b (possible). Differential % Heatmap of [redacted] steam consumption over 2 year interval, individual spaces, normalized by area. Observation: [redacted] increase in IQR / median observed earlier could be explained by non-repeating spikes in consumption throughout the year.
- 5b (possible). Differential % heatmap of [redacted] steam demand; week 19 highlighted; line plot tooltip by weekday, year-over-year comparison. Desirable: show a finer time scale than a day (requires date correction). Observation: Week 19 in the [redacted] is worse this year than last year, especially at the start of the week.
6. Time series line plots of [redacted] steam consumption in week 19 by weekday for 2 years, individual spaces, normalized by area. Desirable: show a finer time scale than a day (requires date correction). Observation: [redacted] and education buildings exhibiting different trends from one year to the next.

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Workflows

based on interview recording.

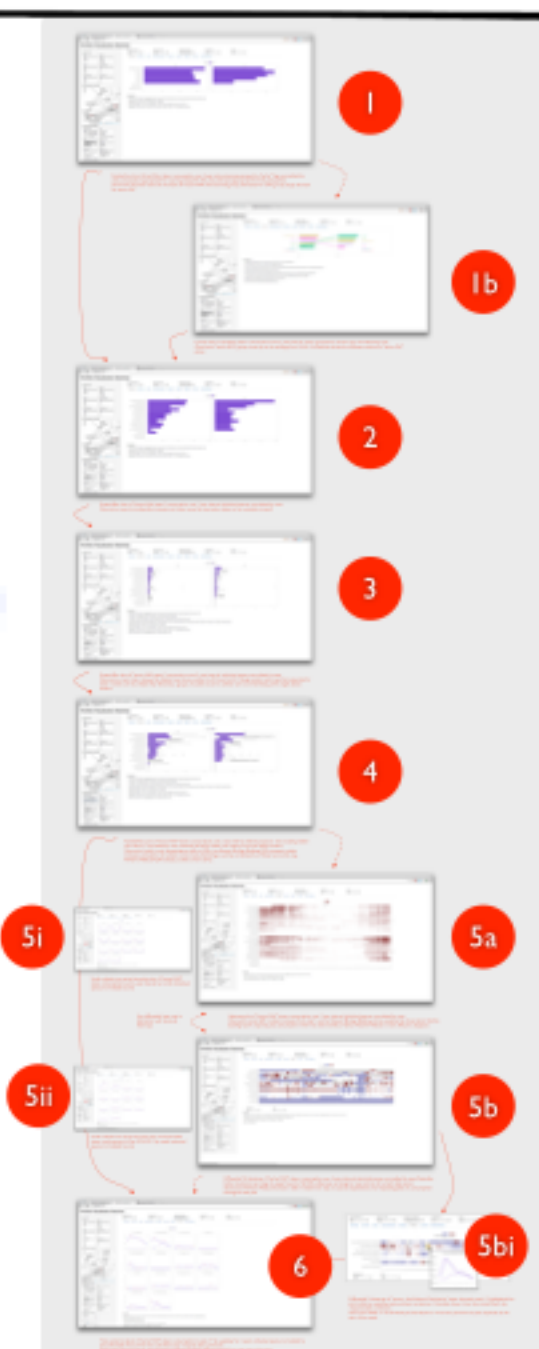


Fig. S11: Storyboards using sandbox screenshots based on power user workflows.

This slide contains screenshots of D3 prototypes developed in summer 2014 that address view coordination design.

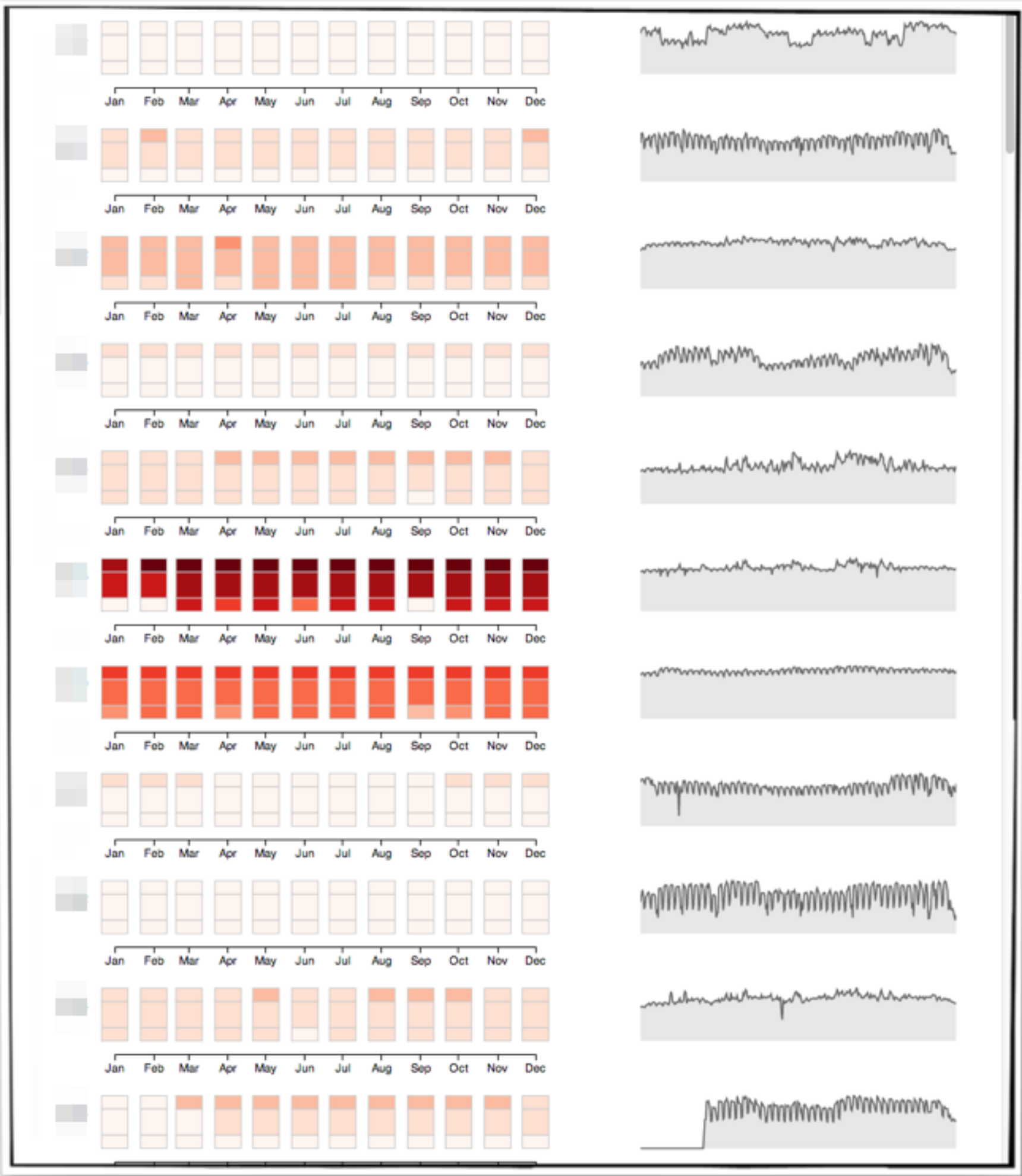


Fig. S12: color stock charts* with juxtaposed line charts as alternative to matrix with juxtaposed boxplots. (* see Albers et al, Proc. CHI 2014)

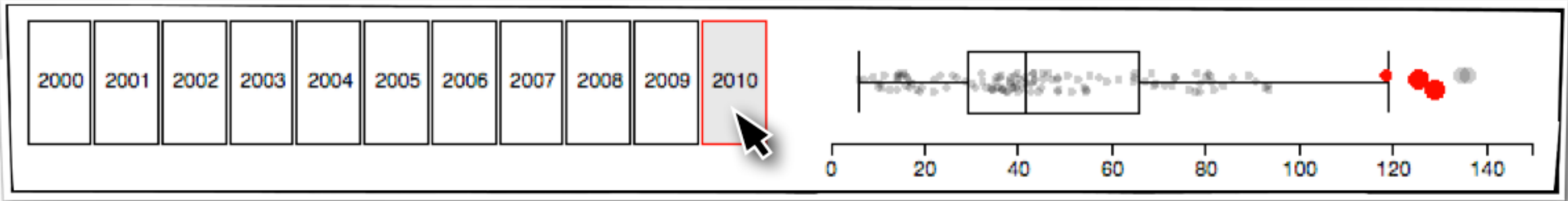


Fig. S13: Values from the brushed time period are highlighted on the juxtaposed boxplots.
<http://blocks.org/mattbrehmer/8be29724bdd7a63ff41d>

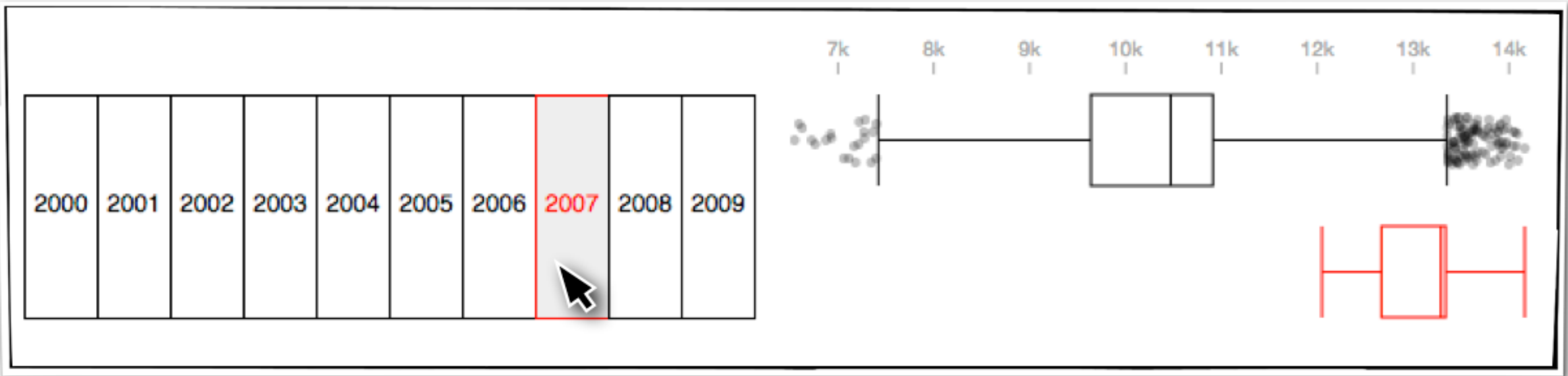


Fig. S14: boxplot for the brushed time period (red) is shown alongside the boxplot for the entire time series.
<http://blocks.org/mattbrehmer/287e44c9a12151967874>

Development on the redesigned Energy Manager continued throughout Summer 2014.

During this time, we collected feedback on the new designs from 5 energy workers at EnerNOC.

Fig. S15: An example of how this feedback was documented, using a combination of screenshots from the redesigned Energy Manager and earlier mockups.

