EnergyFlowVis: Interactive Sankey diagram for visualizing real-time and/or simulation-derived energy

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Abstract

This paper presents EnergyFlowVis, an interactive web-based Sankey diagram generator for energy data. The tool is aimed at researchers and energy managers to visualize energy flows on the University of British Columbia (UBC) campus. This tool will allow the users to manipulate the Sankey diagram in real-time to filter by building type, dates or individual buildings. The application works at two levels where it gives an overview of the consumption at the campus level and details on the individual building's end-uses. The user can use the individual building view to compare the actual data to simulation data.

Key Innovations

- Effective and rapid visualization of energy flows
- Bridges the gap between web-based data visualization and simulation or building management system-derived building data
- Removes the need for practitioners to understand web programming language (i.e. Javascript) to produce interactive web-based tool.

Practical Implications

The level of data literacy amongst different stakeholders in the building development and operation process can vary significantly. This proposed tool enables a user to investigate actual and simulated energy supply systems data using a well-known and easily interpretable visual archetype: a Sankey diagram. As an open-source tool, this tool's main practical implication is that it will provide greater capability among building simulation professionals and building managers to visualize interactive data in a manner that is also easily interpretable by non-experts. The tool will be made available one month before the conference through the web and a github repository.

Introduction

As UBC keeps adding buildings and students while putting forward a desire to be one of the greenest university campuses in Canada and the world, energy management (UBC Energy & Water Services, 2020) and decision-making toward energy become a major issue. The decision-makers need access to relevant information in a timely matter. This is an issue that not only UBC faces but many institutions and district energy systems globally. This paper presents a new data analysis tool for visualizing district energy flows at varying scales, in real-time, via an interactive Sankey energy flow diagram. In the pilot application, the tool uses UBC's energy and water services (EWS) data collected with smart meters across the university's portfolio of over 150 buildings. The visualization tool allows users to inspect individual building energy use, by end-use.

Methods

Sankey diagrams have been a common way to visualize flows of information. From economic flows (Bakenne, Nuttall, & Kzantzis, 2016) to energy sources (Cullen & Allwood, 2010) these charts have been able to help decision-makers better understand the relationship between dynamic systems driven by the flow of resources from source to end-use. Sankey diagrams have been used for similar use cases but were produced as images for one-time analysis (Abdelalim, O'Brien, & Shi, 2017).

Studies have shown that decision-makers can improve overall building performance diagnostics with better visualization without having to resort or rely on building automation systems. Sankey diagrams can provide transparent carbon accounting of building energy use across end uses, building types, and time. Sankey diagrams also make access to measured building performance data more accessible, which can support practitioners seeking to calibrate building energy models. (Coakley, Raftery, & Keane, 2014). Though representing energy flows via a Sankey diagram is not new, we argue that an interactive Sankey diagram that is connected to a real-time building metering database, or a synthetic simulation-derived database, can improve one's understanding of measured and/or predicted building performance.

Results

The resulting application has two different functions. The first one gives the user and overview of the campus' consumption and the ability to narrow down the building and building groups. This enables users to easily and dynamically explore the campus's energy consumption

and evolution over time without programming or data analytics skills.

The second function is around individual building, where the user can see detailed consumption. In this proof of concept, we are comparing the consumption per end use with the building's simulation. The Sankey diagram is broken down between the actual data and the consumption error. The red bars will represent negative error and green positive. Therefore, the user will be able to troubleshoot his simulation results by focusing by the main contributor of error.

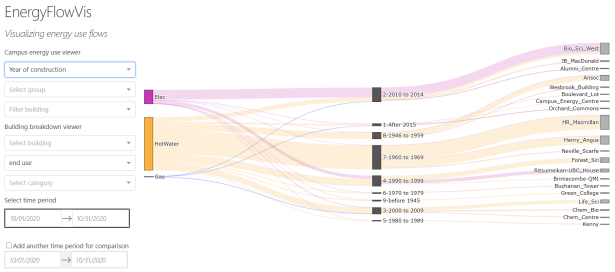

Figure 1 Campus overview for energy flow vis. Colors represent the type of energy used.

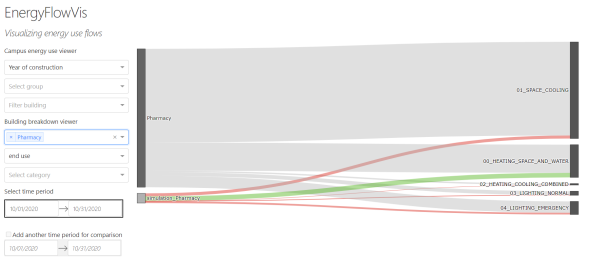

Figure 2 Detailed energy use vs actual consumption for pharmacy building.

Implementation

EnergyFlowVis was implemented using the Dash framework from Plotly (Dash, 2020), with all backend programming in Python. The decision to use a python web framework was taken because researchers in building science generally have more experience in python than other web programming language. The current application architecture serves as a prototype for proof of concept.

The data is stored in an Influx database. This type of database specializes in the storage of time series data; the resampling queries are optimized compared to using a typical relational database, which allowed us to increase our application's reactiveness. The application is hosted in the Compute Canada cloud environment as it is a free resource for researchers to use. For the building metadata, we stored the data in comma-separated text files (CSVs) loaded to memory whenever the user loads the page. We filter for buildings using this data frame and filter the dates at the database level.

Discussions

Sankey diagram allows the users to have a better view of the direction energy takes. However, those graphics will be biased toward elements that are bigger than others. As we can see in Figure 2, the user will be inclined to look only at the top consumer.

We are also limited by data availability; this application is dependent on labelled data. Currently, the data available to campus-level consumption is widely available. However, to get to a lower level, there's a need for additional labelling work. The adoption of frameworks like Project Haystack and Brick could help that effort to identify how the different sensors are used clearly.

Conclusion

This paper presented EnergyFlowVis as a Sankey Diagram generator for energy use flows on UBC campus. It serves as an effective way to get an overview of how the energy use is distributed amongst buildings and the sources from which the energy originates. It also allows comparison between groups of buildings as well as user-defined time periods. The application is a prototype that will be used as an input for a longer-term solution to help researchers and energy managers make better decisions to improve campus energy efficiency. The results show great potential and are a noticeable improvement over the current visualization options. The next step is to conduct structured user studies and improve the tool's capabilities to extend the energy flow diagrams to include higher-level sources and lower-level end-uses. Also, including direct input from a simulation tool would benefit wider adoption by the research community.

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Appendix

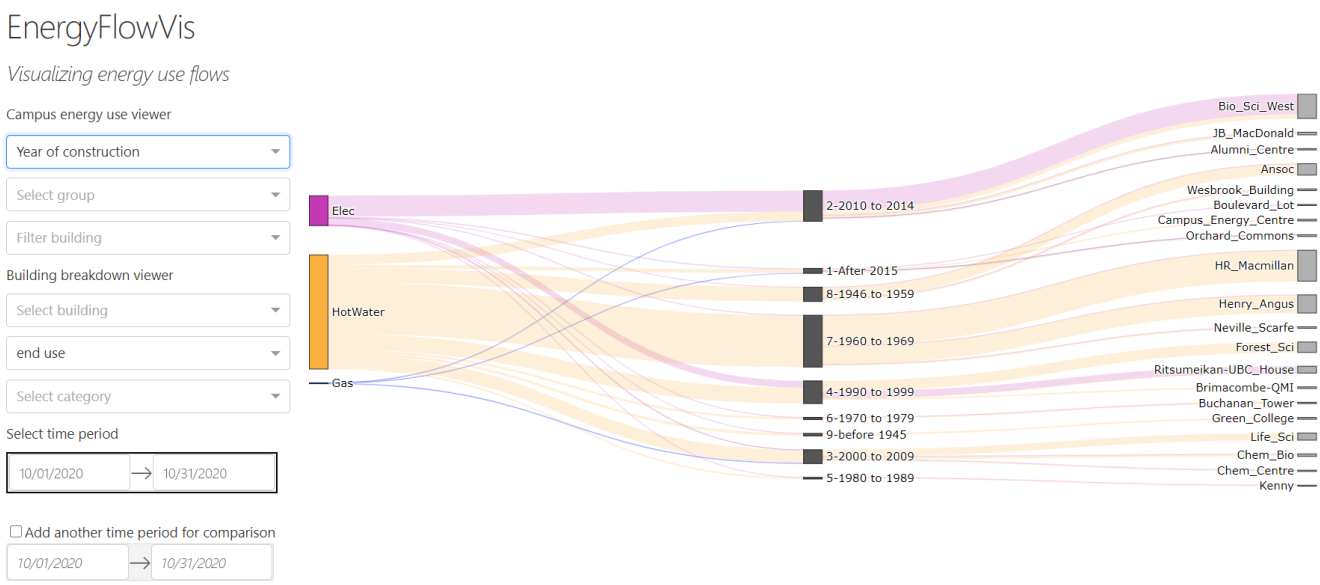

Figure 3 Zoomed figure 1 for more details

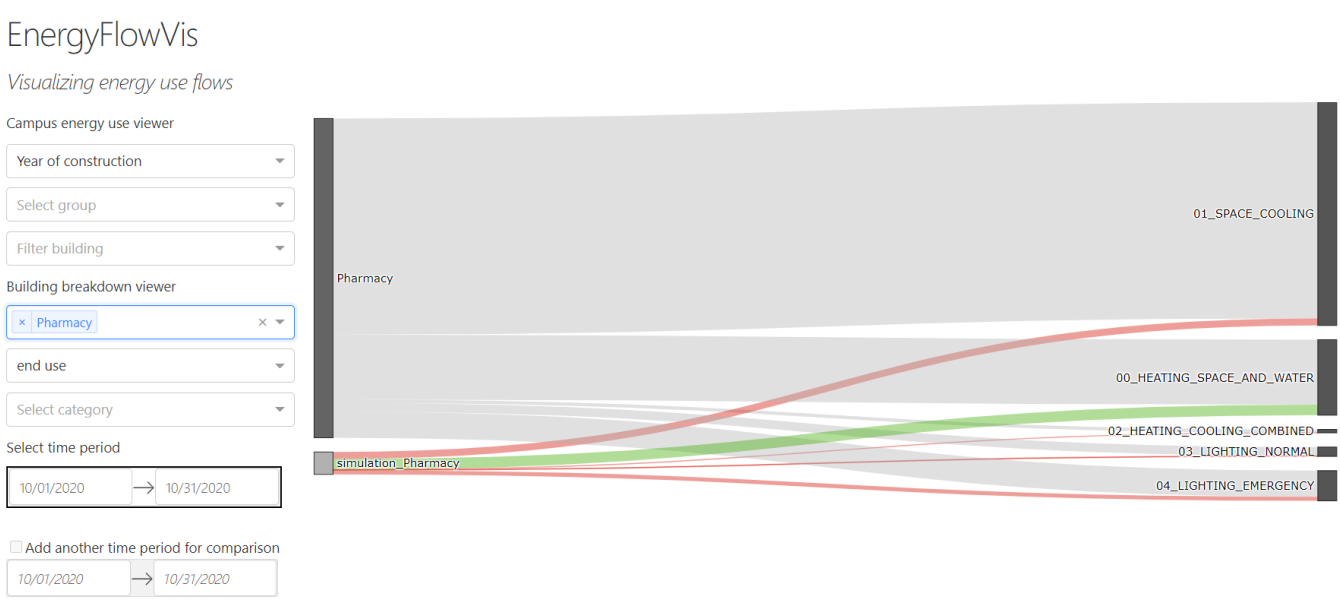

Figure 4 Zoomed figure 2 for more details