Harnessing Carleton’s Forgotten Data: Energy Analytics for Improved Campus Sustainability

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What is Energy Analytics?

▷ Data-driven tools to help institutions understand and manage their energy use
▷ Active area of research and development
Why Energy Analytics at Carleton?

Martha Larson
Director of Campus Energy and Sustainability
Why Energy Analytics at Carleton?

- By 2030: “Carleton will need to implement other aggressive carbon reduction strategies”
- Beyond 2030: “Carleton will need to implement yet to-be-determined future technologies”
Why Energy Analytics at Carleton?

- Carleton spends over $3,000,000 on energy per year
Current System

- EV.RM102.RT = 68°
- SHH.LF1.STPT = 68°
- SHH.LF1.VALV = 75%

Points!

- COA1SS = 35
- COA1ST = 12
Current System
Identified Needs

▷ Access to granular point data
▷ Three main use cases for point data analysis:
  ○ Optimization
  ○ Anomaly detection
  ○ Insights for renovation and new construction
Our Goal: Create Tools to Save Energy

- Infrastructure
- Exploration
- Automation
Architecture Overview

Infrastructure
- Value Pipeline
- Point Name Decoder

Exploration
- Database
- API
- Trends UI

Automation
- Anomaly Alerts
Infrastructure: Value Pipeline

Infrastructure

Value Pipeline

Point Name Decoder

Database

API

Exploration

Trends UI

Automation

Anomaly Alerts
The Data — Point Definitions

▷ Static

▷ Includes Information like:
  ○ Point Name: EV.RM003.RT
  ○ Descriptor: G 03 ROOM TEMP
  ○ Panel Name: EVANS.PXCM76
  ○ Engineering unit: DEG F
The Data — Reported Values

▷ Value for a point at a given time
▷ Each value logged every 15 minutes
  ○ Maximum daily potential: 9 million
  ○ Total values collected thus far: 14.2 million and counting!
Data Flow

Point → Buildings → Energy comps server → Energy comps database → API

Point Description Report → Consistently → Once → On request
Infrastructure: Point Name Decoder

Value Pipeline

Point Name Decoder

Database

API

Trends UI

Anomaly Alerts

Exploration

Automation
Decoding - Challenges

UNSTANDARDIZED

OUTDATED

UNDOCUMENTED
Decoding Challenge — Unstandardized

- Various naming conventions in the energy industry
- Carleton hasn’t reconciled the data over time

- EV.RM102.RT
- BO.1.RM149: CTL TEMP

- Evans Room 102 Room Temperature
- Boliou First Floor Room 149 Control Temperature
Decoding Challenge — Outdated

- Renovations, naming iterations
- Obsolete names in the system
  - B vs BO
  - ACDIN
Decoding Challenge — Undocumented

- WCC-AHU12.CLG-DAT
- SEV.AH3.RAT
- MCA1RV
“Decoding is the biggest challenge that’s stopping the energy industry from modernizing.”
“Microsoft spent 2 years decoding the point names on their campus.”
Decoding — Process for Determining Meaning

▷ Collected many mappings between device acronyms and device names
▷ Master decoder class + individual building decoders
▷ Built robust decoding infrastructure
Infrastructure: Database

- Infrastructure
- Exploration
- Automation

- Value Pipeline
- Point Name Decoder
- Database
- API
- Trends UI
- Anomaly Alerts
Database Design

▷ Store the information generated by decoders
▷ Be searchable
▷ Expressive structure for essential data
▷ Flexible & Extensible for the future
API

▷ Standard, controllable conduit for access to the database
▷ Tailor made interface
  ○ Does some of the work for the client application
  ○ Details of database design are hidden

▷ Problem: How to discover & specify Points to graph/analyze?
API — Standard Approach

▷ Points which measure Airflow

/points?measurement="airflow"

▷ Points in Leighton 213

/room/846/points

▷ Points tagged ‘Room Temperature’

/tag/12/points
API — Standard Approach

▷ Not good enough!
▷ Too many items
▷ Want to filter on multiple axes
API — Standard Approach

- Room Temps and Set Points on the 3rd floor of Davis and Burton
- All classrooms in Olin except for the two lecture halls 141 and 149
- The room temperatures in all residence hall doubles with windows facing West
API — Search Engine

- Room Temps and Set Points on the 3rd floor of Burton or Davis and floor = 3 and (Room Temp or Set Point)
  (@9 or @12) and floor = 3 and (#8 or #7)

- All classrooms in Olin except for the two lecture halls 141 and 149
  @22 and #42 and not ($3286 or $3292)

- The room temperatures in all residence hall doubles with windows facing West
  Room Temp and Residence and 2-Occupant and Faces West
  #8 and #38 and #246 and #801
Search Engine — Technical Details

▷ Several Regular Expressions
▷ Each token individually converted to SQL WHERE clause elements
▷ All logic and parsing are passed through to the SQL query
Search Engine — Example

@2 and :floor = 3 and :measurement 'temperature'

```
SELECT DISTINCT points.point_id
FROM points
  LEFT JOIN devices ON points.device_id = devices.device_id
  LEFT JOIN rooms ON devices.room_id = rooms.room_id
  LEFT JOIN buildings ON rooms.building_id = buildings.building_id
  LEFT JOIN value_units ON points.value_unit_id = value_units.value_unit_id
  LEFT JOIN points_tags ON points.point_id = points_tags.point_id
  LEFT JOIN devices_tags ON devices.device_id = devices_tags.device_id
  LEFT JOIN rooms_tags ON rooms.room_id = rooms_tags.room_id
  LEFT JOIN buildings_tags ON buildings.building_id = buildings_tags.building_id
WHERE buildings.building_id = 2
  AND rooms.floor = 3
  AND value_units.measurement = 'temperature'
;
SELECT points.point_id,  
    points.name
FROM devices
WHERE devices.device_id = points.device_id;

SELECT room_id, room.name
FROM rooms
WHERE rooms.room_id = devices.room_id;

SELECT building_id, building.name
FROM buildings
WHERE buildings.building_id = rooms.building_id;

(SELECT row_to_json(a)
FROM (SELECT value_type_id, type
    FROM value_types
    WHERE value_types.value_type_id = points.value_type_id
    ) a)

(SELECT row_to_json(a)
FROM (SELECT value_unit_id, measurement, unit
    FROM value_units
    WHERE value_units.value_unit_id = points.value_unit_id
    ) a)

(SELECT ARRAY(SELECT name
    FROM tags
    INNER JOIN points_tags ON tags.tag_id = points_tags.tag_id
    WHERE points_tags.point_id = points.point_id
    UNION
    SELECT name
    FROM tags
    INNER JOIN points_tags ON tags.tag_id = points_tags.tag_id
    WHERE points_tags.point_id = points.point_id
    )

AS point_name,
AS device_name,
AS room_name,
AS building_name,
AS value_type,
AS value_unit,
Exploration: Trends UI

Infrastructure

- Value Pipeline
- Point Name Decoder

Exploration

- Database
- API

Automation

- Trends UI
- Anomaly Alerts
Value of a Trend UI

▷ Aids in understanding of buildings
▷ Potential to help facilities save money
▷ Insights for renovation or new construction
Evans Renovations
Current Limitations

1. Point Selection
2. Plot

`EV.RM122.RT: INPUT REF 1`
`EV.RM102.RT`
`EV.BCP3.DRWST`
Search UI - Selecting Points

- Expose users to power of search engine
- Flexible search
- Guided exploration
How to display non-numeric data?
Trends UI — Heatmap
Automation: Anomaly Alerts

Value Pipeline → Point Name Decoder → Database → API → Trends UI → Anomaly Alerts
Value of an Anomaly Alert System

▷ Most energy loss comes from the same 10 problems
▷ Every year a window is left open during winter break
  ○ Wastes energy and money
  ○ Freezes the pipe, causes it to burst, and water gets all over the room
Implementing an Alert System

1. Determine what is anomalous
   ○ Visualize

2. Save these restrictions
   ○ Add alert rules

3. Notify facilities when something is flagged anomalous
   ○ Send an email
Visualizing Anomalies

1. Search for anomalies
2. See anomalous values in context
3. Hover for more information

Values that are less than 60 or greater than 72
Adding Alert Rules

1. Adding rules from the dashboard

2. Rule management
Email Alerts

1. Catch problems quickly
2. Avoid alert fatigue
Demo time!
What's next

▷ We have built the highway! But we only have two cars 😞
  ○ Decode other buildings

▷ Develop dashboard
  ○ Usability
  ○ More features

▷ Automated data mining analysis
  ○ Machine learning
  ○ Clustering

▷ Further interview facilities staff
  ○ Better understand their knowledge and needs
Thank You

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Any questions?