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?

CARBON FREE BY 2050

- 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?

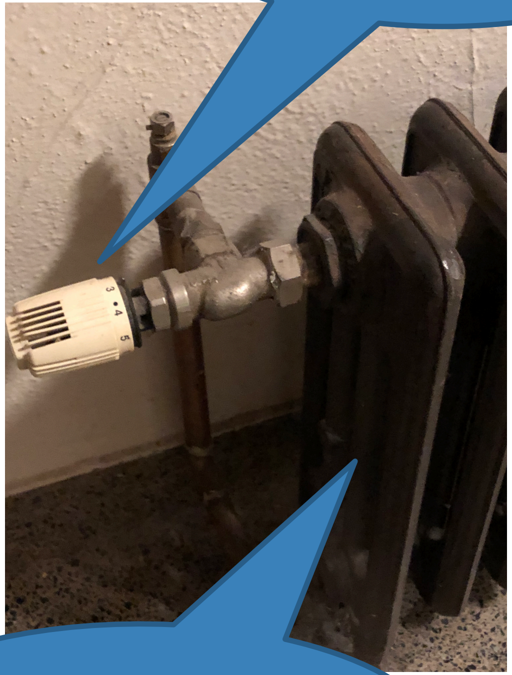
- Carleton spends over $3,000,000 on energy per year

Current System

Points!

EV.RM102.RT = 68º

SHH.LF1.STPT = 68º

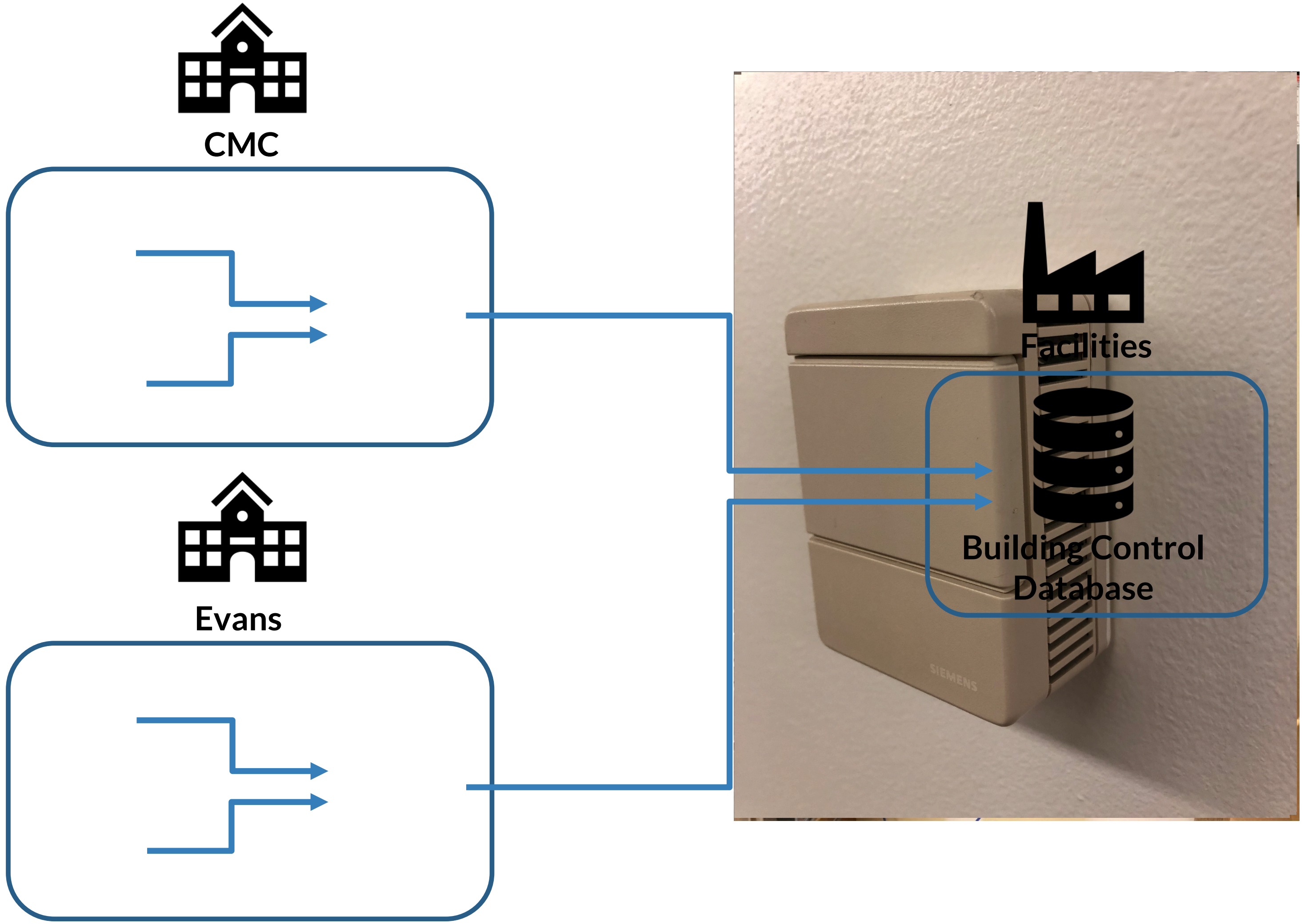


SHH.LF1.VALV = 75%

COA1SS = 35

COA1ST = 12

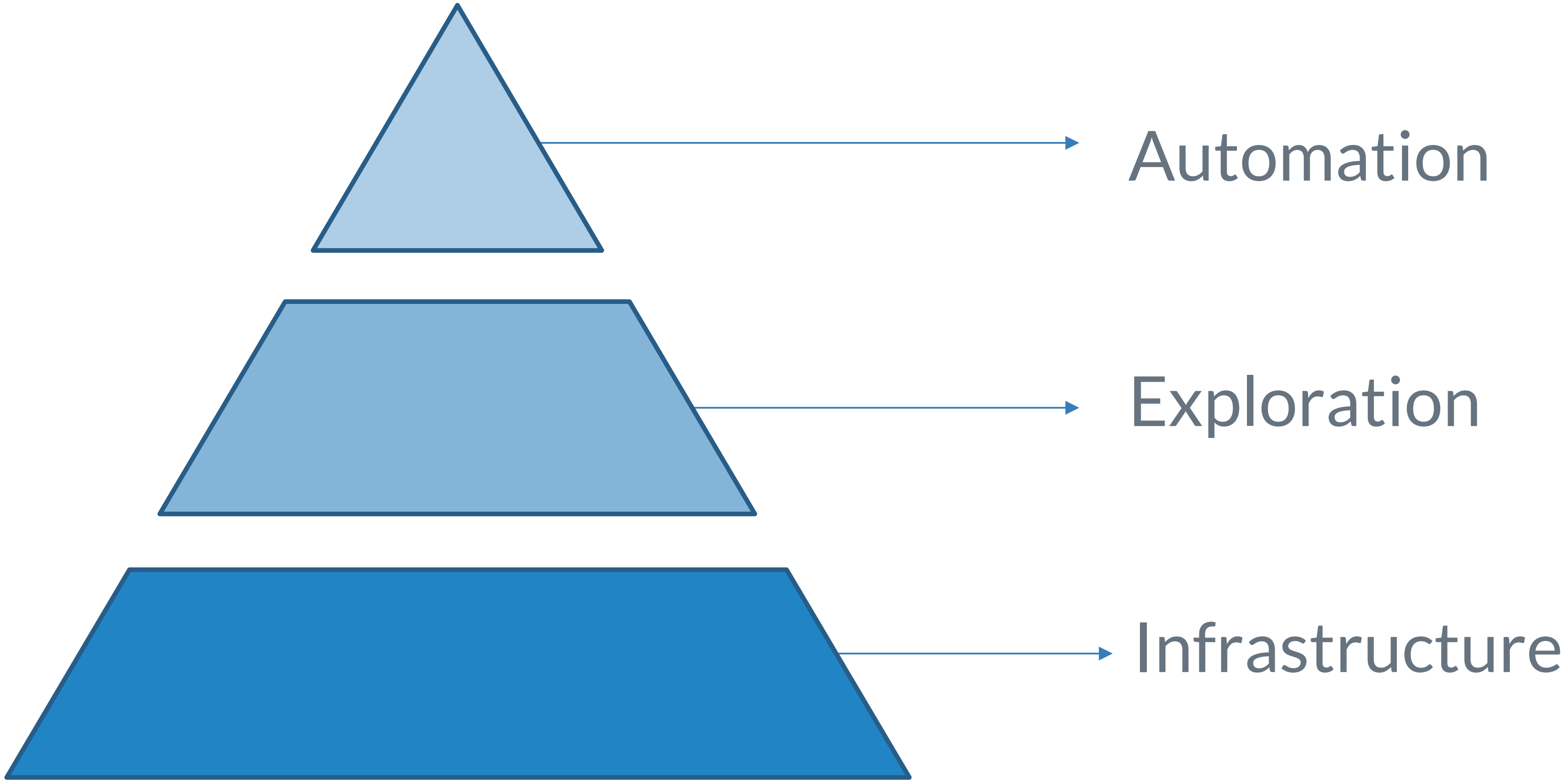
Current System



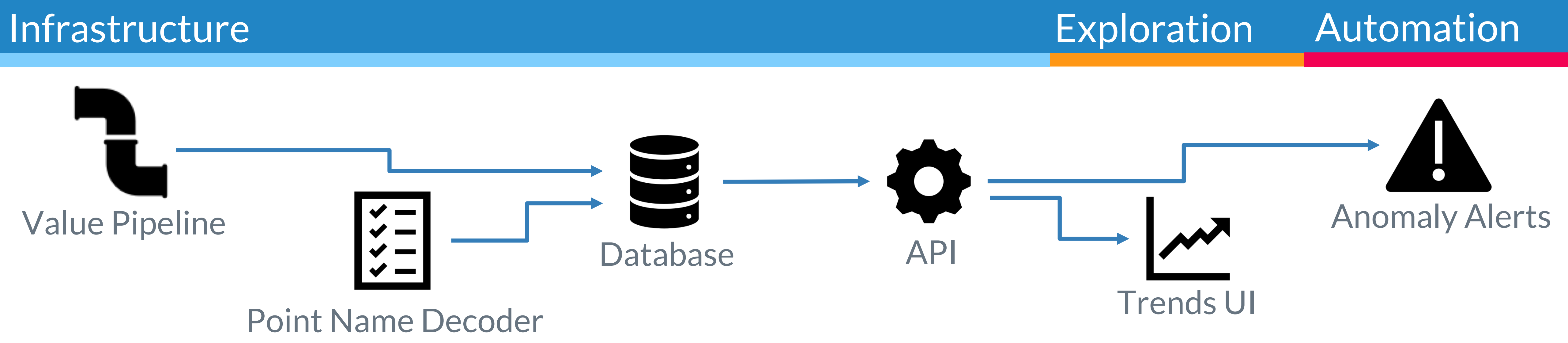
Identified Needs

- 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

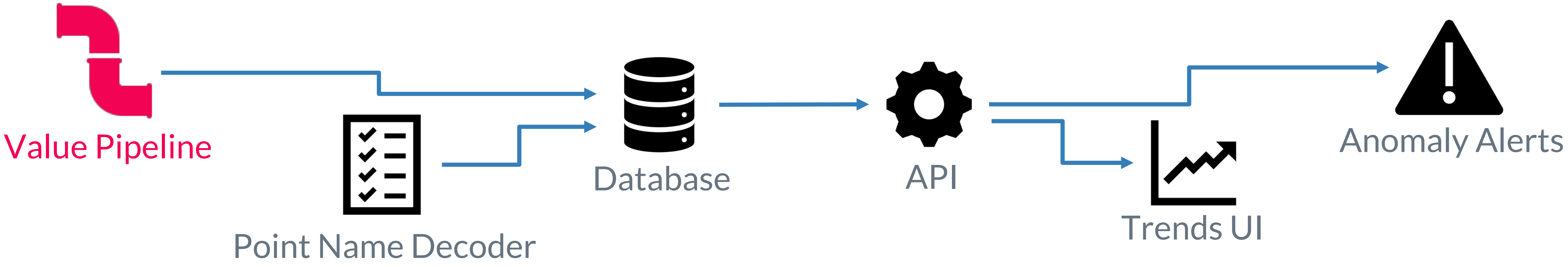


Architecture Overview



Infrastructure: Value Pipeline

Infrastructure Exploration Automation



The Data — Point Definitions

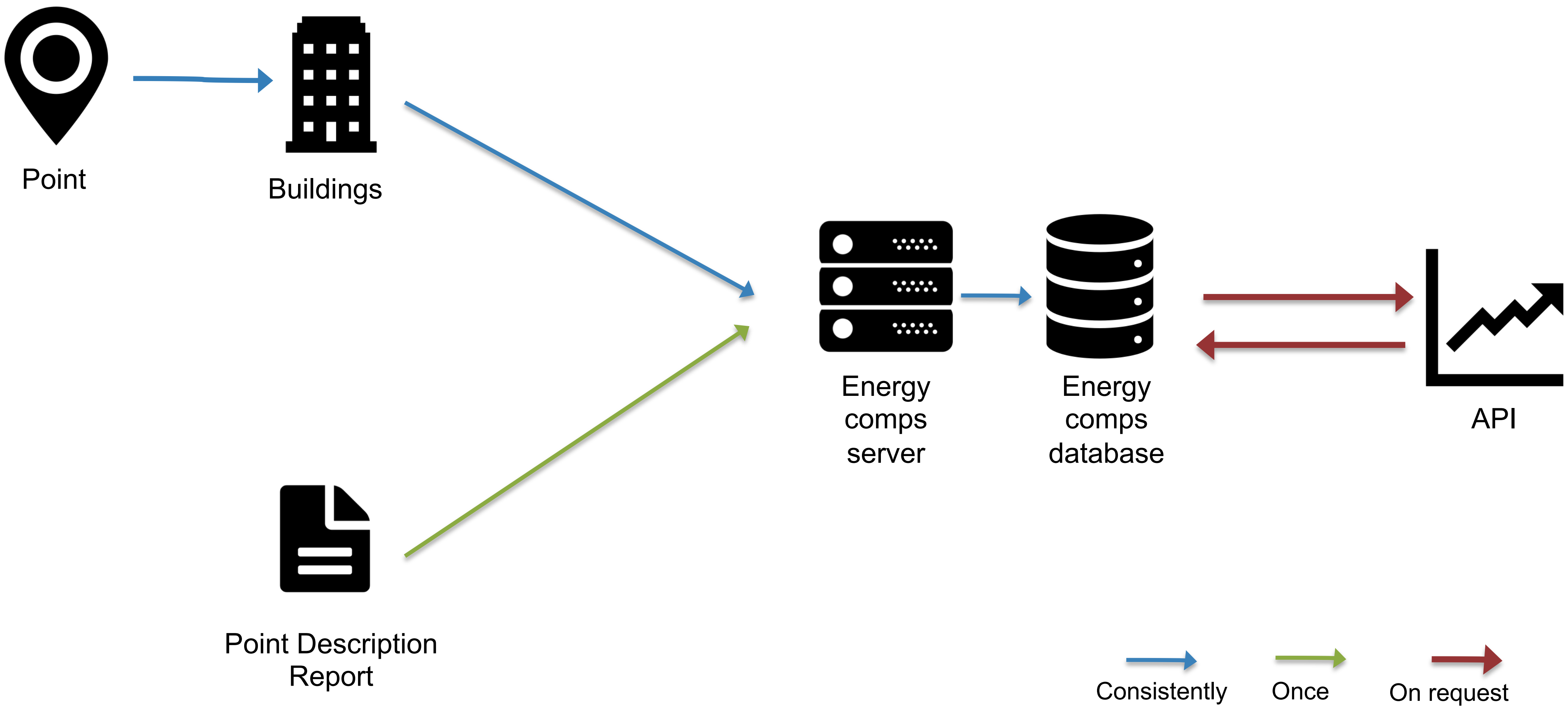
- ▷ Static
- ▷ Includes Information like:
  - Point Name: EV.RM003.RT
  - Descriptor: G 03 ROOM TEMP
  - Panel Name: EVANS.PXCM76
  - Engineering unit: DEG F

53157	Point System	EV.RM003.RT		
53158	Point Name:	EV.RM003.RT		
53159	Point Type:	LAI		
53160	Classificatior	Building Automation		
53161	Descriptor:	G 03 ROOM TEMP		
53162	Panel Name:	PXCM76	(EVANS.PXCM76)	
53163	Point Addres	FLN: 0 Drop: 22 Point: 02		
53164	Sensor Type:	MEC RTD		
53165	Slope:	1	Intercept:	-1.08913
53166	COV Limit:	1	Wire Resista	0
53167	Engineering	DEG F		
53168	Analog Repre	Float		
53169	# of decimal	2		
53170	Totalization:	None	Initial Priorit	NONE
53171	Graphic Nam	<Undefined>		
53172	Informationa	<< No Text Defined >>		
53173	Alarm Type:	Standard Alarms		
53174	Alarm Count	No		
53175	Normal ack E	Yes		
53176	Low Limit:	50	High Limit:	100
53177	Alarm Priorit	3		
53178	Print Info wit	Yes	Print Alarms	Yes

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!

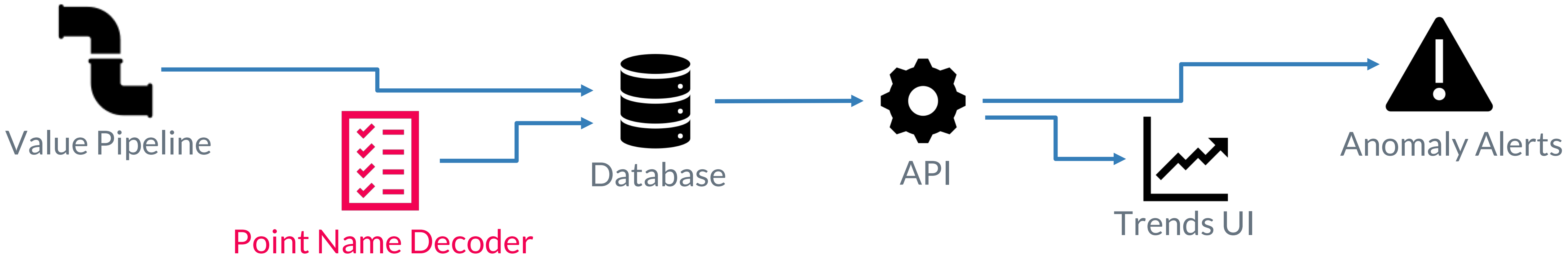
Data Flow



Point
Buildings
Point Description Report
Energy comps server
Energy comps database
API
Consistently
Once
On request

Infrastructure: Point Name Decoder

Infrastructure 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

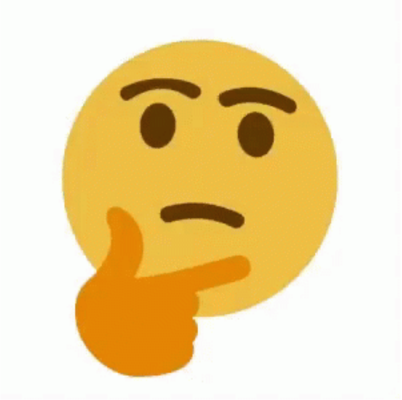
- Evans Room 102 Room Temperature
- Boliou First Floor Room 149 Control Temperature

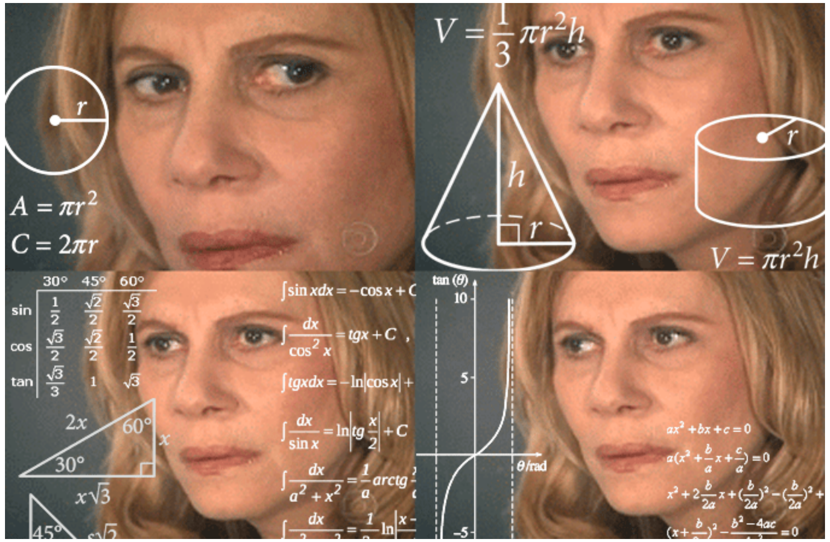
Decoding Challenge — Outdated

- Renovations, naming iterations
- Obsolete names in the system
  - B vs BO
  - ACDIN

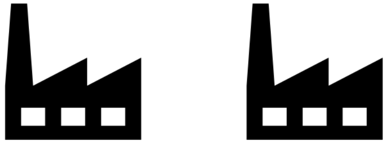
Decoding Challenge — Undocumented

- WCC-AHU12.CLG-DAT
- SEV.AH3.RAT
- MCA1RV





Decoding



“Decoding is the biggest challenge that’s stopping the energy industry from modernizing.”

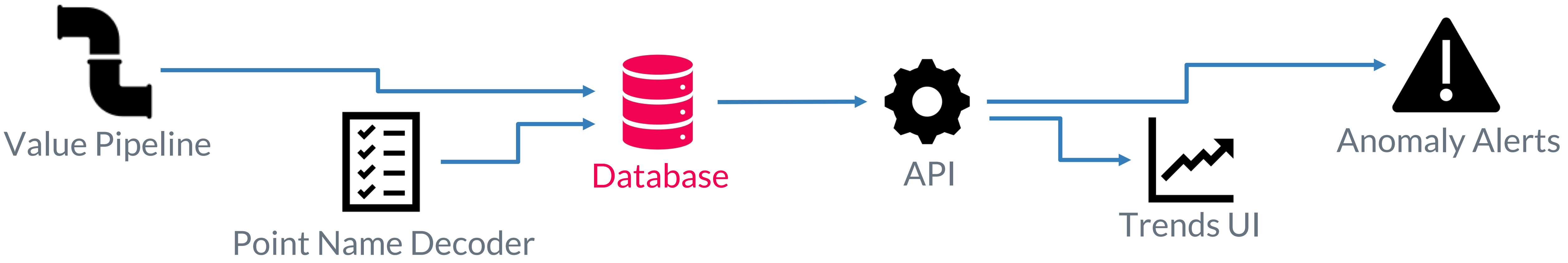
“Microsoft spent 2 years decoding the point names on their campus.”

Decoding — Process for Determining Meaning

- Collected many mappings between device acronyms and device names
- Master decoder class + individual building decoders
- Built robust decoding infrastructure

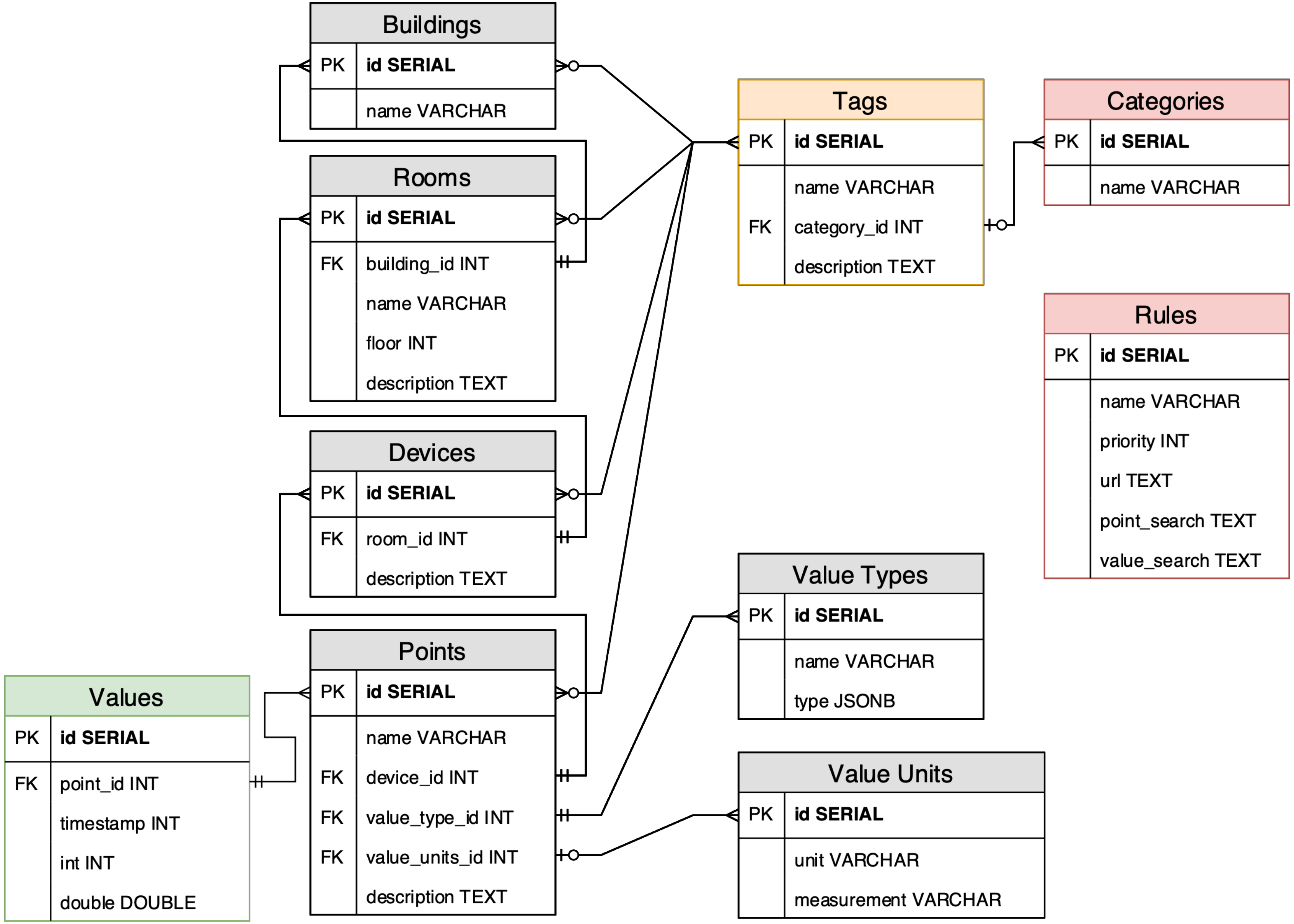
Infrastructure: Database

Infrastructure | Exploration | Automation



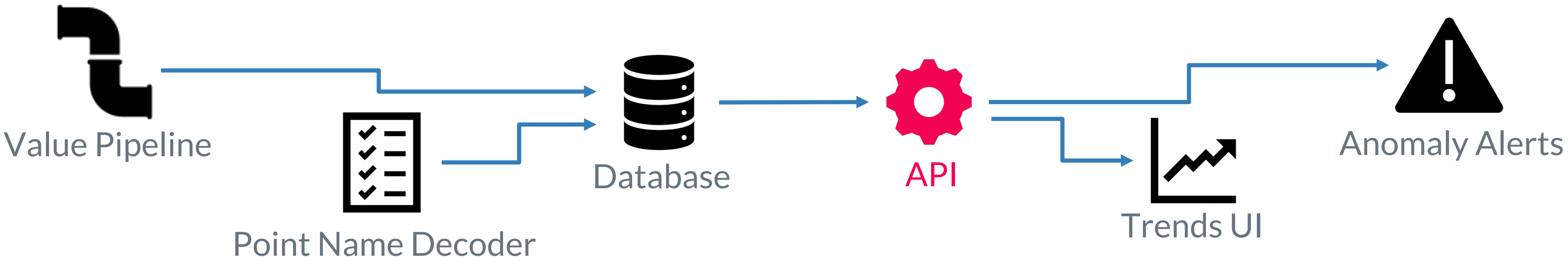
Database Design

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


Buildings
PK id SERIAL
name VARCHAR
Rooms
PK id SERIAL
FK building_id INT
name VARCHAR
floor INT
description TEXT
Devices
PK id SERIAL
FK room_id INT
description TEXT
Points
PK id SERIAL
name VARCHAR
FK device_id INT
FK value_type_id INT
FK value_units_id INT
description TEXT
Values
PK id SERIAL
FK point_id INT
timestamp INT
int INT
double DOUBLE
Tags
PK id SERIAL
name VARCHAR
FK category_id INT
description TEXT
Categories
PK id SERIAL
name VARCHAR
Rules
PK id SERIAL
name VARCHAR
priority INT
url TEXT
point_search TEXT
value_search TEXT
Value Types
PK id SERIAL
name VARCHAR
type JSONB
Value Units
PK id SERIAL
unit VARCHAR
measurement VARCHAR

Infrastructure: API

Infrastructure Exploration Automation



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

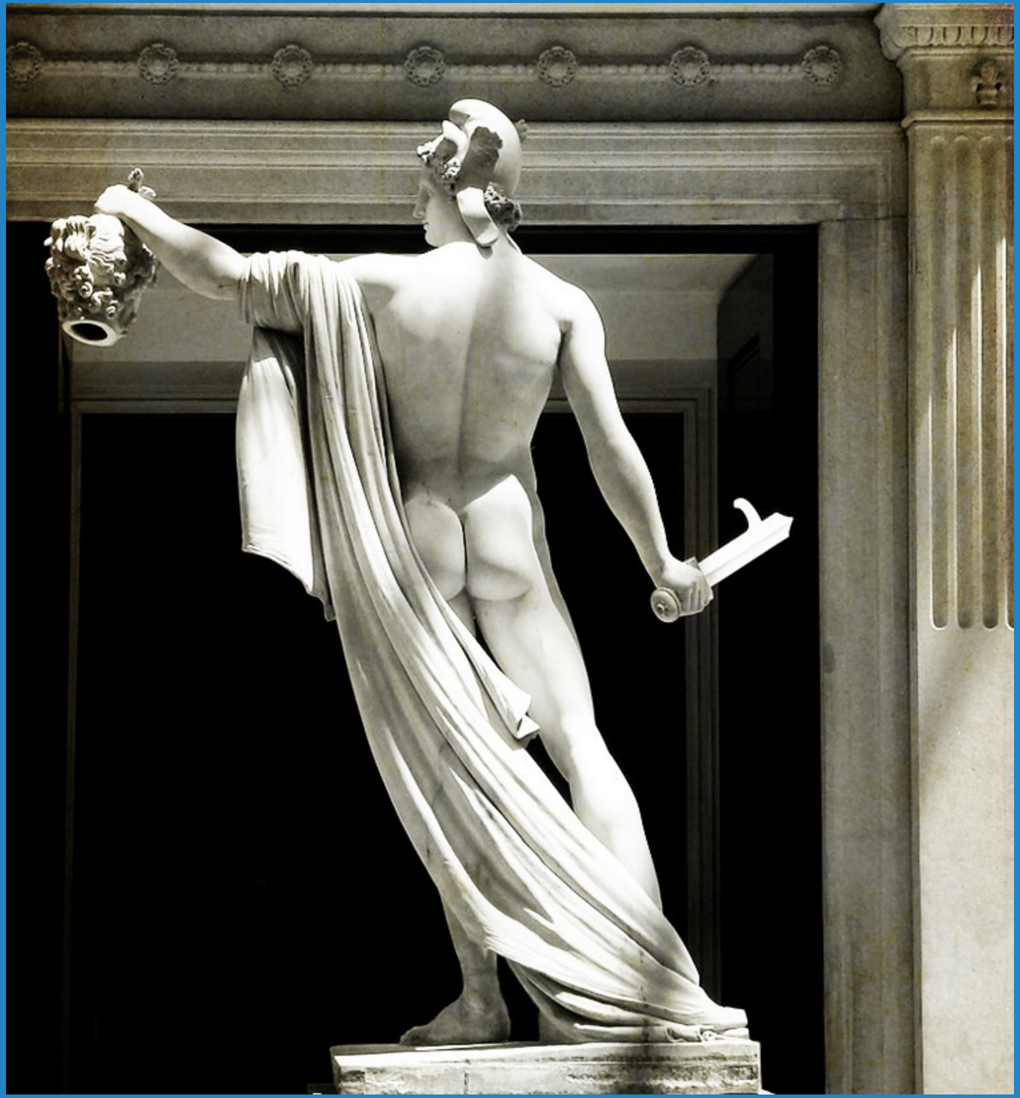
```
/points?measurement="airflow"
```

- 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 Davis and Burton

(Burton or Davis) and 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

 Olin and Classroom and not (141 or 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'
```

```sql
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'
;
```

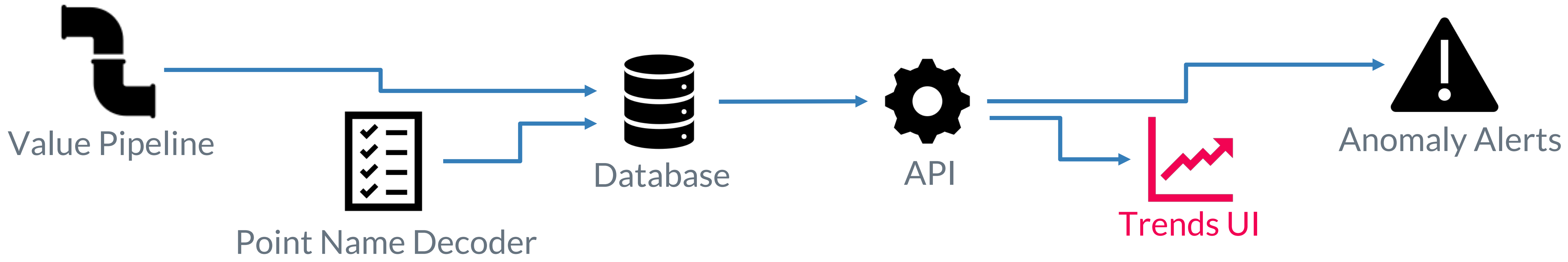
```
339, 345, 1784, 1657, 1118, 396, 1656, 67, 450, 1806, 1034, 2291, 2109, 1970, 485,
694, 1800, 1902, 2271, 2127, 742, 623, 1291, 792, 589, 2121, 1246, 880, 1344, 779,
252, 363, 238, 2235, 2370, 1965, 1052, 85, 1559, 1900, 1187, 349, 1765, 397, 374
```

Search Engine - Example

```
SELECT points.point_id,
       points.name                                                          AS point_name,
       devices.device_id,
       devices.name                                                         AS device_name,
       rooms.room_id,
       rooms.name                                                           AS room_name,
       buildings.building_id,
       buildings.name                                                       AS building_name,
       (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)                                                           AS value_type,
       (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)                                                           AS value_unit,
       (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
```

Exploration: Trends UI

Infrastructure Exploration Automation



Value of a Trend UI

- ▷ Aids in understanding of buildings
- ▷ Potential to help facilities save money
- ▷ Insights for renovation or new construction

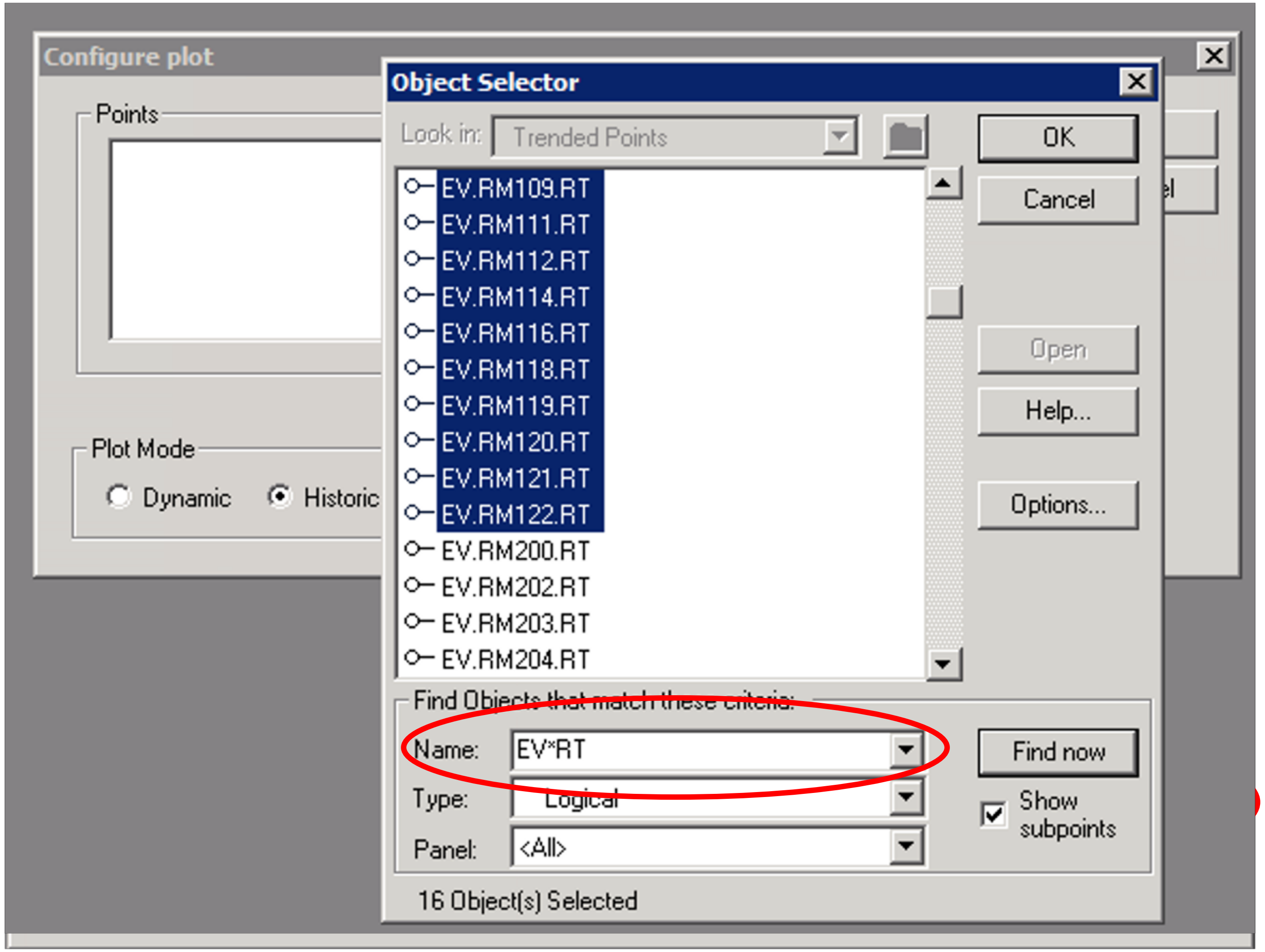
Evans Renovations

Current Limitations

1. Point Selection
2. Plot

EV.RM102.RT
EV.RM105.RT
EV.RM116.RT

EV.HWP2.VFD:INPUT REF 1
EV.HX2.V2
EV.DCP13.DHWST



Search UI - Selecting Points

- ▷ Expose users to power of search engine
- ▷ Flexible search
- ▷ Guided exploration

Firefox File Edit View History Bookmarks Tools Window Help 95% Fri 2:19 PM

Carleton College Energy Dashb

energycomps.its.carleton.edu/search

Carleton Energy Dashboard

- Trends
- Anomalies
- Points
- Rules

Trends

Point Selector

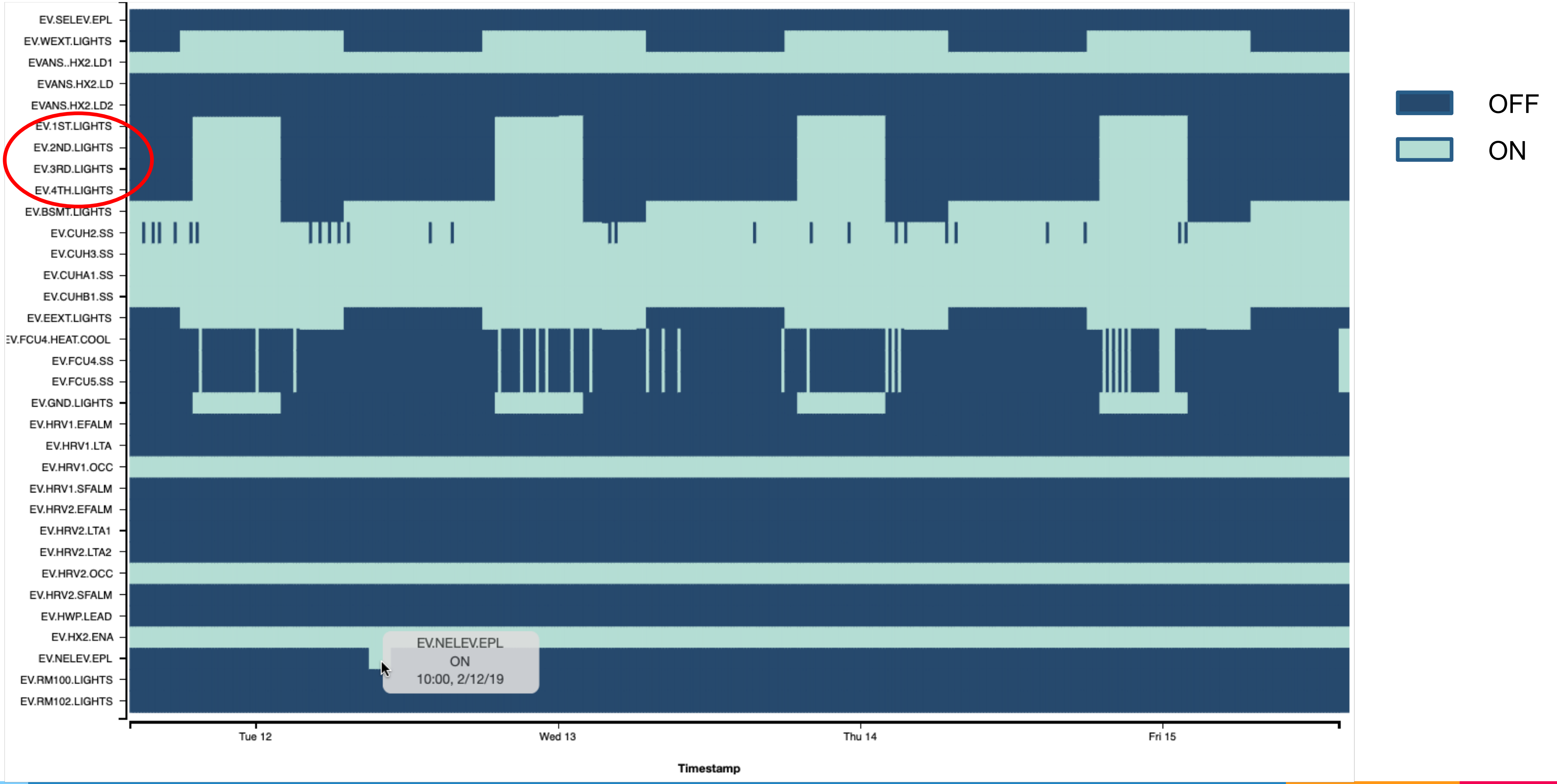
Building	Floor	Room	Point	Tag	Type
All Buildings	All Floors	All Rooms	All Points	All Tags	Numeric
Boliou	-1	003	BO.1.COMMONM:AIR VOLUM	Academic	Boolean
Evans	0	014	BO.1.COMMONM:AUX TEMP	Damper Command	Integer
UnID'd Building	1	016	BO.1.COMMONM:CLG FLOW	Room Temperature	Float
	2	020	BO.1.COMMONM:CLG FLOW	Residential	BACNET EVENT ENROL
	3	021	BO.1.COMMONM:CLG LOOP	Room Temperature Set Point	BACNET LENUM
	4	022	BO.1.COMMONM:CTL FLOW	Radiation Valve	BLEED_HOLD
	null	025	BO.1.COMMONM:CTL FLOW	Night Override	CHLR45
		030	BO.1.COMMONM:CTL STPT	Night Cooling Setpoint	CHLR_SEQ

3/03 12:00 AM - 3/07 12:00 AM

Graph

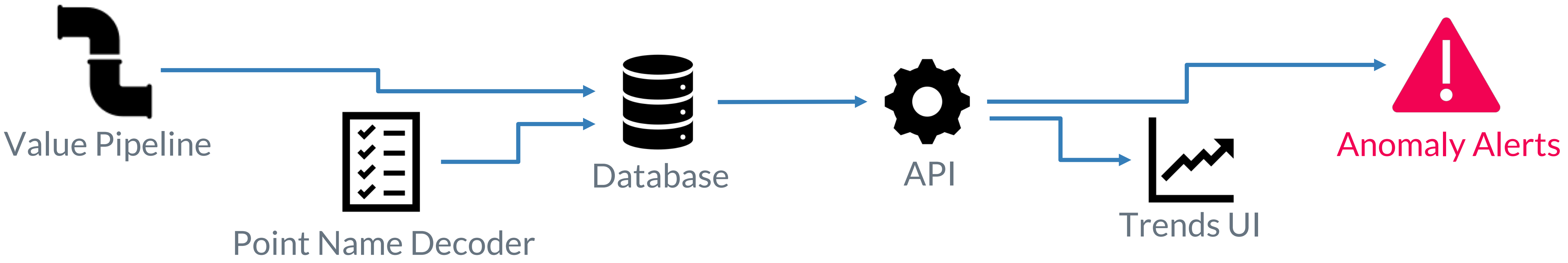
How to display non-numeric data?

Trends UI — Heatmap



Automation: Anomaly Alerts

Infrastructure Exploration Automation



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

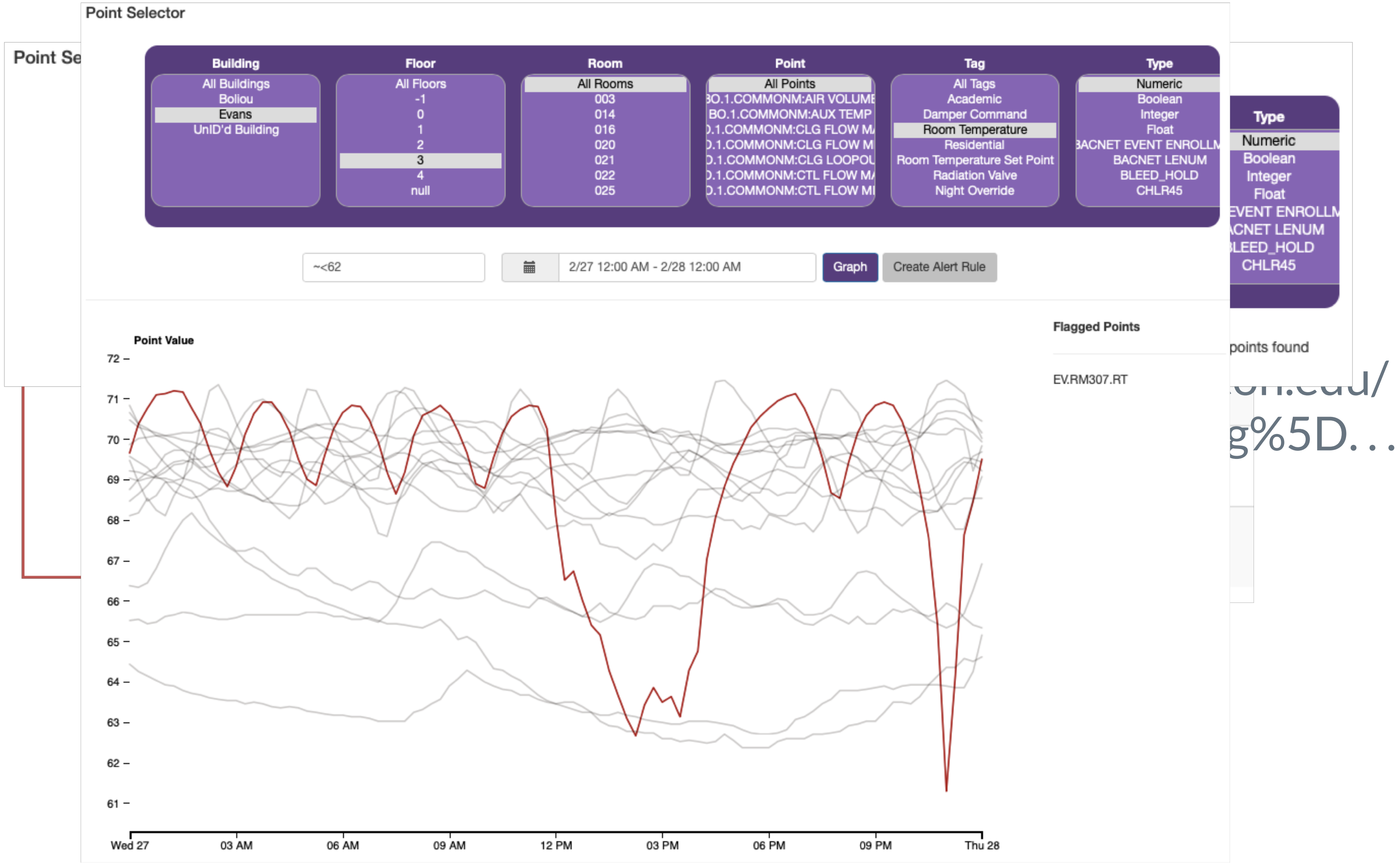
Visualizing Anomalies

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

Adding Alert Rules

1. Adding rules from the dashboard

2. Rule management



Email Alerts

Point Selector

Anomalies detected on 2019-03-06 Inbox ×

energycomps2019@gmail.com 7:55 PM (0 minutes ago)

energycomps2019 2 Anomalies detected on 2019-02-28 - The rules broken yesterday, th...

The rules broken yesterday, the number of values that flagged that rule, and the link to view more are as follows.

Rule Name	Number of Anomalous Values	Link to Dashboard
This rule rules!!!	96	view more
Set Point Rule	849	view more
Room Temperature Rule	148	view more
Evans 3rd Floor Rad Valves	20	view more

Wed 27 03 AM 06 AM 09 AM 12 PM 03 PM 06 PM 09 PM Thu 28

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

- Jeff Ondich 
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  - Kiya Govek
  - Jack Lightbody
  - Zephyr Lucas
  - Dustin Michels
  - Carolyn Ryan

Thanks!

Any questions?