DATA INTEGRATION FOR UTILITIES AND ENERGY

APPA INSTITUTE FOR FACILITIES MANAGEMENT

NEW ORLEANS, LA

JANUARY 10, 2024

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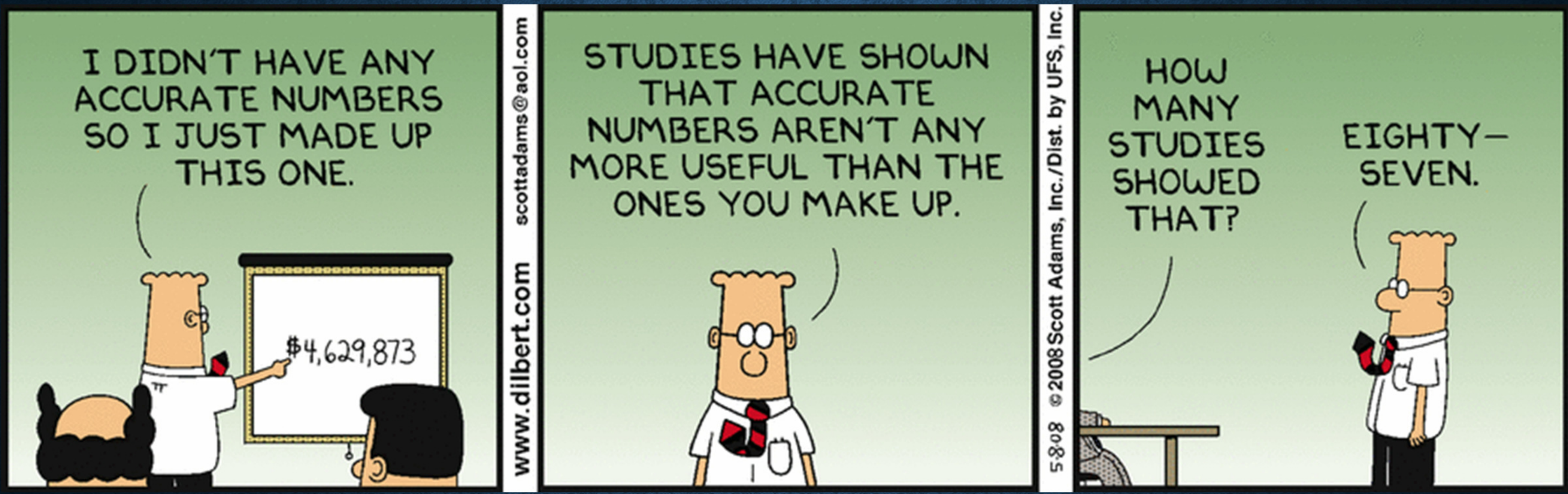
Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

PURPOSE OF TODAY'S PRESENTATION

- To provide a broad understanding of:
  - Data Warehouses/Data Marts
  - How to collect the data
  - How to convert data into information
  - Examples

WORDS OF WISDOM



If you torture the data enough, it will confess to anything.

DISCUSSION

- Create a report of energy consumption and cost for each building owned by your institution:
  - If served by a District Energy System or local system(s):
    - Chilled Water
    - Steam or Hot Water
    - Electricity
    - Water
    - Fuel-Gas/Oil/Coal
  - If served by the local utility
    - Electricity
    - Fuel-Gas/Oil/Coal
    - Water
  - This year versus last year information:
    - Consumption and cost
    - Hours used and weekly schedule
    - Average number of occupants, i.e. staff, students, faculty
    - Square footage of building including classification(s), i.e. instructional space, administrative, research, housing, etc.
    - Departmental ownership
    - Weather, e.g. average temperatures, % sun, etc.
    - HVAC system type

Building Energy Use Data

Table 1: Building Summary

Building Data			
Weather Zone	Newark, NJ	Building Name	NJ Office Building
City	Secaucus	Zip Code	07094
Year Built	1985	Floor Area (sq.ft.)	130,000
No. of Employees	390	Number of PCs	390
Weekly Operating Hours	50	Months Used	12
Percentage Heated	100%	Percentage Cooled	100%

Utility Data			
Data End Point	4/30/2012	Total Cost ($)	$471,289.89
Electricity Usage (kWh)	2,904,251	Electricity Cost ($)	$402,142.67
Natural Gas Usage (therms)	51,413	Natural Gas Cost ($)	$69,147.22
Fuel Oil Usage (gal)	N/A	Fuel Oil Cost ($)	N/A

Energy Usage			
EPA Score	39	Electric Usage (kWh/sq.ft.)	22.3
Natural Gas Usage (kBtu/sq.ft.)	39.5	Weather Adjusted Natural Gas Usage (Btu/sq.ft./HDD)	10.6
Site Energy (kBtu/sq.ft.)	115.8	Source Energy (kBtu/sq.ft.)	296.0

Environmental Impact Indicators			
Carbon Emissions			
Last Year Natural Gas $MtCO_2e$ (tons)	273.5	Last Year Total $MtCO_2e$ (tons)	1,676.7
Last Year Electricity $MtCO_2e$ (tons)	1,403.2	Efficiency Savings Over Previous Year $MtCO_2e$ (tons)	220.7

Table 2: Monthly Electricity Use & Demand

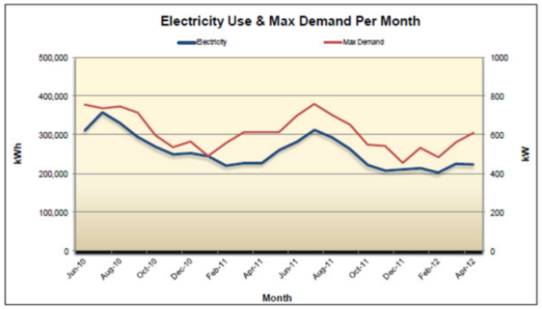
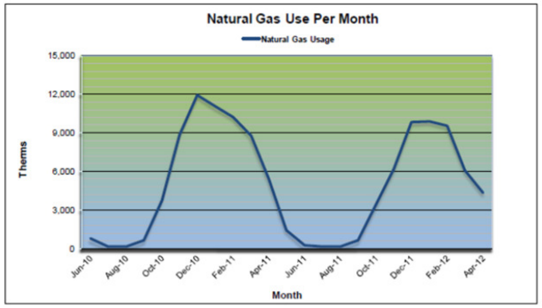


Table 3: Monthly Natural Gas Use



WHERE WOULD YOU GET THE INFORMATION TO PRODUCE THIS REPORT?

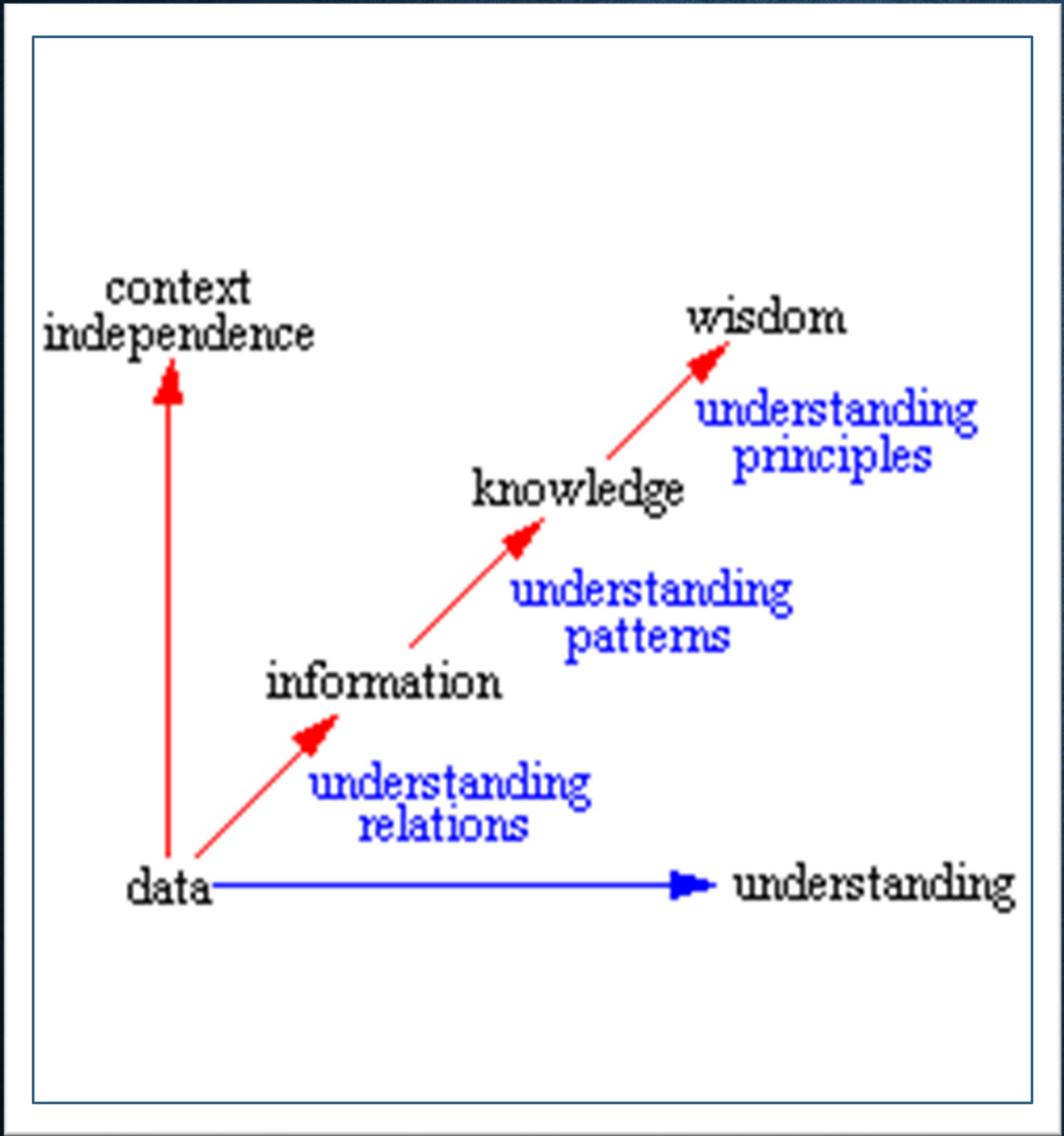
GROUP DISCUSSION

- What are our FM functions?
- What data is collected by other functions in your organization that you can/want to use?
- What data is collected institutionally that can be used to meet your needs?
- What formats does the data require, i.e. spreadsheet, dashboard, formal reports, etc.?
- Can you currently convert the data into information in the required format(s)? How?

THE DATA PROBLEM

THE PEOPLE PROBLEM

ADDING VALUE TO DATA

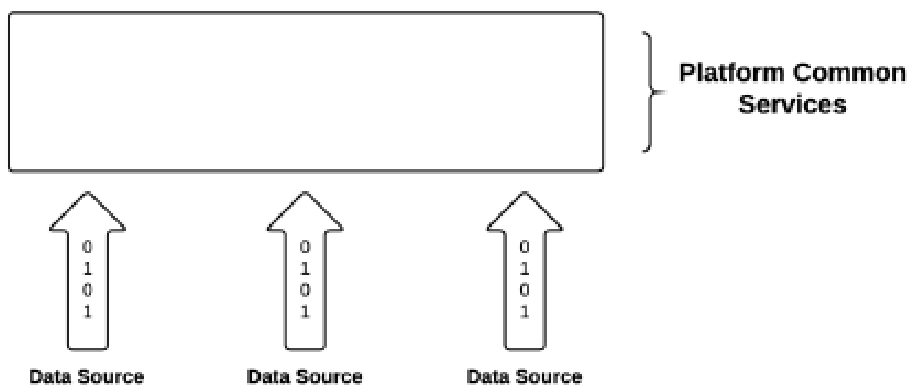


How do you get there?

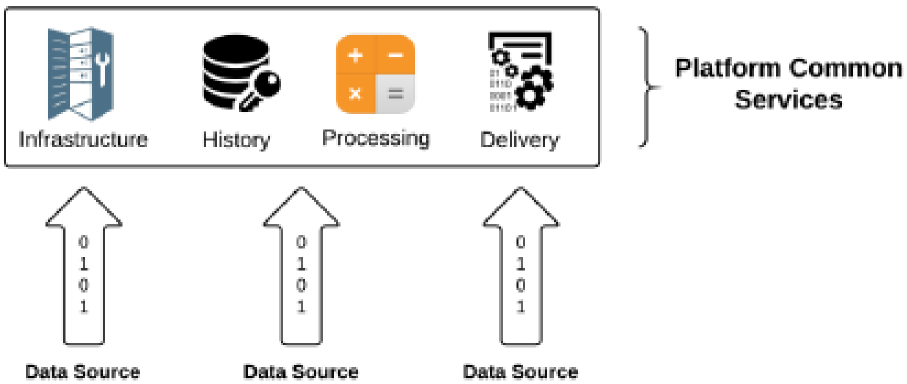
Best Practices in Data Management
Five Elements for Success

Asset Inventory	Data Access	Tools and Analytics	Organizational Structure	Engagement Communication
Comprehensive	Comprehensive	Flexible	Integrated	Targeted
Centralized	Streamlined	Secure	Centralized	Clear
Verified	Automatic	Accessible	Dedicated Staff	Transparent
Up to Date	Prompt	QA/QC	Streamlined	Mission-focused

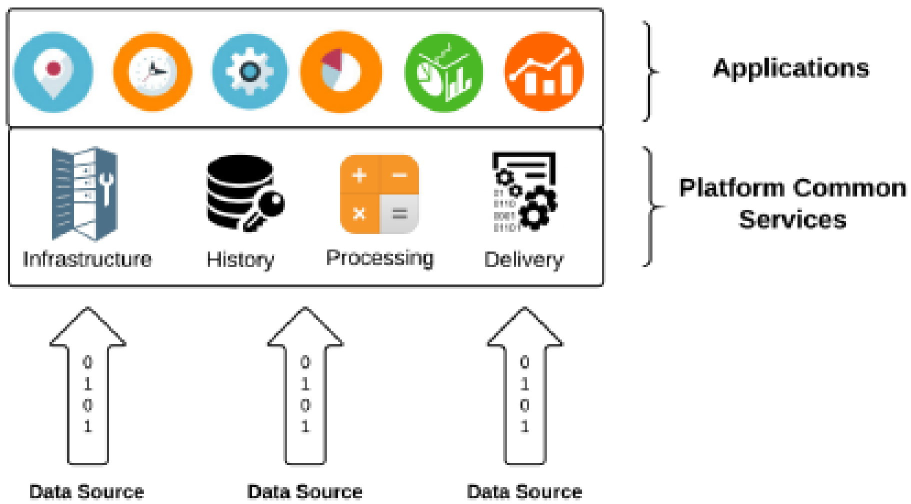
Platform Concept



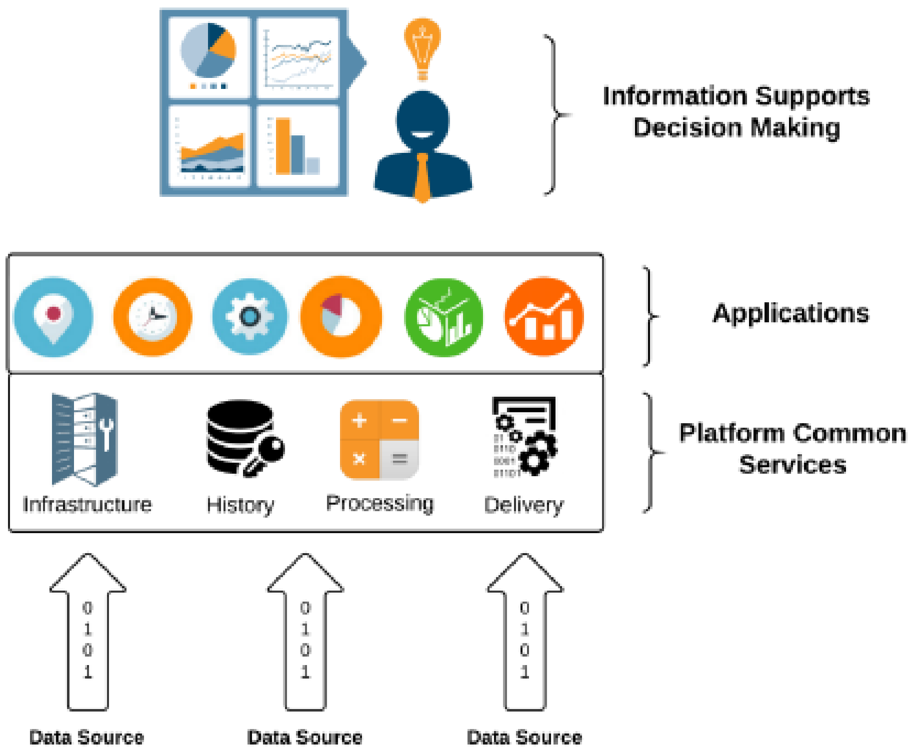
Platform Concept



Platform Concept



Platform Concept

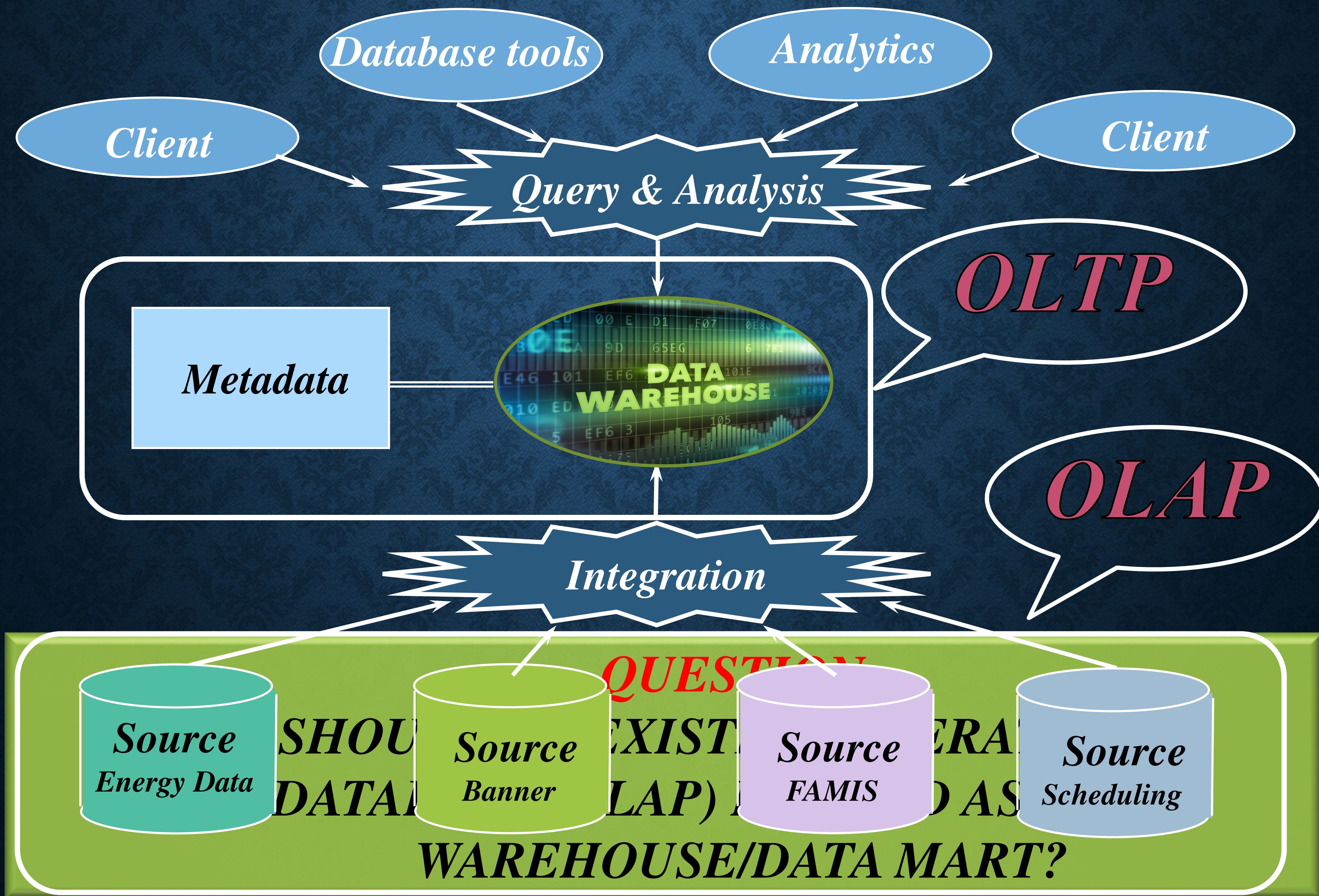


INTEGRATE THE DATA

Data Warehouse operates on an enterprise level and contains all data used for reporting and analysis, while **Data Mart** is used by a specific business department and is focused on a specific subject (business area).

- Aggregate data into a single centralized repository available to all authorized stakeholders
- Integrate the data into consistent subject categories based on how users refer to them
- Apply consistent value representation, units, and descriptors to the data

DATA WAREHOUSE/DATA MART ARCHITECTURE



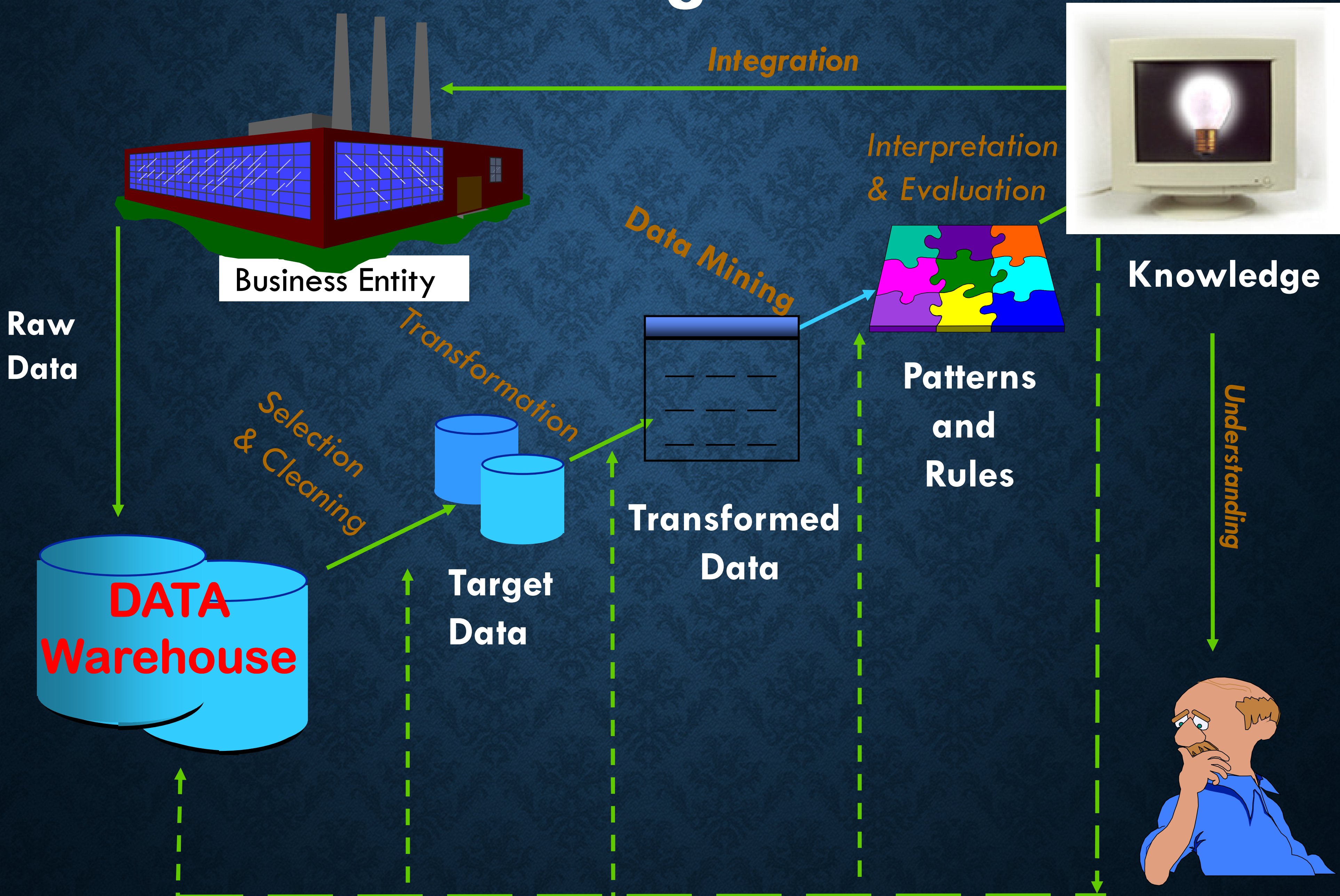
MINE THE DATA

Data mining is the

non-trivial process of identifying

- *valid*
- *novel*
- potentially *useful*
- and ultimately *understandable patterns* in data.

Data Mining Process



DATA MINING TECHNIQUES

- Classification

  The process uses predefined classes to assign to objects such as “dog”, “cat”, “hat”, etc. These classes describe the characteristics of items or represent what the data points have in common with each other. This data mining technique allows the underlying data to be more neatly categorized and summarized across similar features or product lines.

- Clustering

  Like classification, clustering identifies similarities between objects, then groups those items based on what makes them different from other items. While classification may result in groups such as "shampoo," "conditioner," "soap," and "toothpaste," clustering may identify groups such as "hair care" and "dental health."

- Regression

  A statistical method that attempts to create a mathematical relationship between one dependent variable and a series of other variables (known as independent variables).

- Association

  A simple correlation between two or more items, often of the same type to identify patterns. For example, when tracking people's buying habits, you might identify that a customer always buys cream when they buy strawberries, and therefore suggest that the next time that they buy strawberries they might also want to buy cream.

DATA MINING TECHNIQUES

- ## Prediction

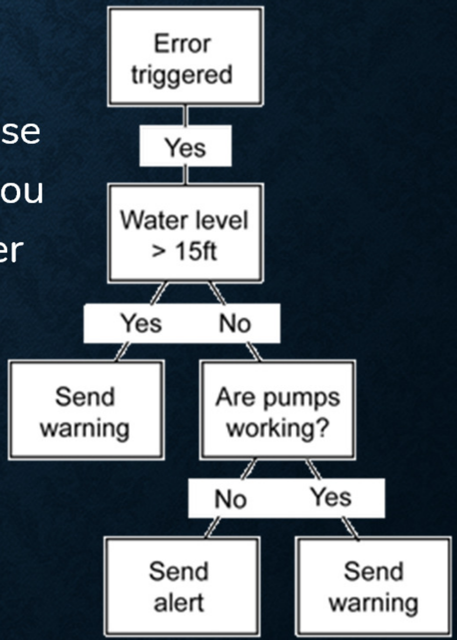
  Prediction involves analyzing trends, classification, pattern matching, and relationships. By analyzing past events or instances, you can make a prediction about an event.

- ## Sequential patterns

  Often used over longer-term data, sequential patterns are a useful method for identifying trends, or regular occurrences of similar events. For example, with customer data you can identify that customers buy a particular collection of products together at different times of the year. In a shopping basket application, you can use this information to automatically suggest that certain items be added to a basket based on their frequency and past purchasing history.

- ## Decision trees

  Related to most of the other techniques (primarily classification and prediction), the decision tree can be used either as a part of the selection criteria, or to support the use and selection of specific data within the overall structure. Within the decision tree, you start with a simple question that has two (or sometimes more) answers. Each answer leads to a further question to help classify or identify the data so that it can be categorized, or so that a prediction can be made based on each answer.



HOW IS MACHINE LEARNING RELEVANT TO FACILITIES MANAGEMENT?

Predicting Problems

When a facility manager tracks operations with machine learning, the disruptions in normal patterns are just as relevant as the consistencies. For example, if a process suddenly fails to meet its routine performance levels, it's possible to isolate and replace a failing part — before it becomes a problem. Smart technology can be programmed to set alerts when the facility displays inconsistencies, all through self-monitoring data collection.

Tracking Usage

By establishing operational patterns, it's easy for facilities managers to develop proactive system scheduling: parts ordering, cleaning, routine shutdowns, and equipment replacement can all be arranged at the most cost-effective and efficient times.

HOW IS MACHINE LEARNING RELEVANT TO FACILITIES MANAGEMENT?

Optimizing Energy Efficiency

A recent study investigated deep learning for asset optimization throughout a regular office building. The vast system of sensors tracked 35,000 measured data points per minute and drew insights on everything from prioritized elevator scheduling to kitchen odors, automated temperature adjustments, and lighting controls.

While this project proves an elaborate example, smart tech systems can outpace static programs in balancing building load. For example, most usage — even in HVAC and lighting alone — goes beyond the binary weekday/weekend or workday/holiday schedule. Weather events, holidays, and even major sporting events routinely alter attendance levels, and a smart system can mine historical performance data and respond accordingly.

Savvy Storage

In addition to predicting patterns for real-time applications, machine learning tech can also help to sort, prepare, and store data — suddenly, all this information can be significantly more useful to a manager.

For example, a tech can automatically group and sort data according to time of year, a particular machine performance, or even a type of maintenance. These analyzed, categorized data sets prepare the foundation for smart, organized action.

CONVERT DATA TO INFORMATION

- Microsoft Office
- Third party reporting tools and applications
- Analytics, AI
- Web applications

Knowing that a tomato is a fruit?
That's Data.

Knowing not to put one in a fruit salad?
That's Knowledge.

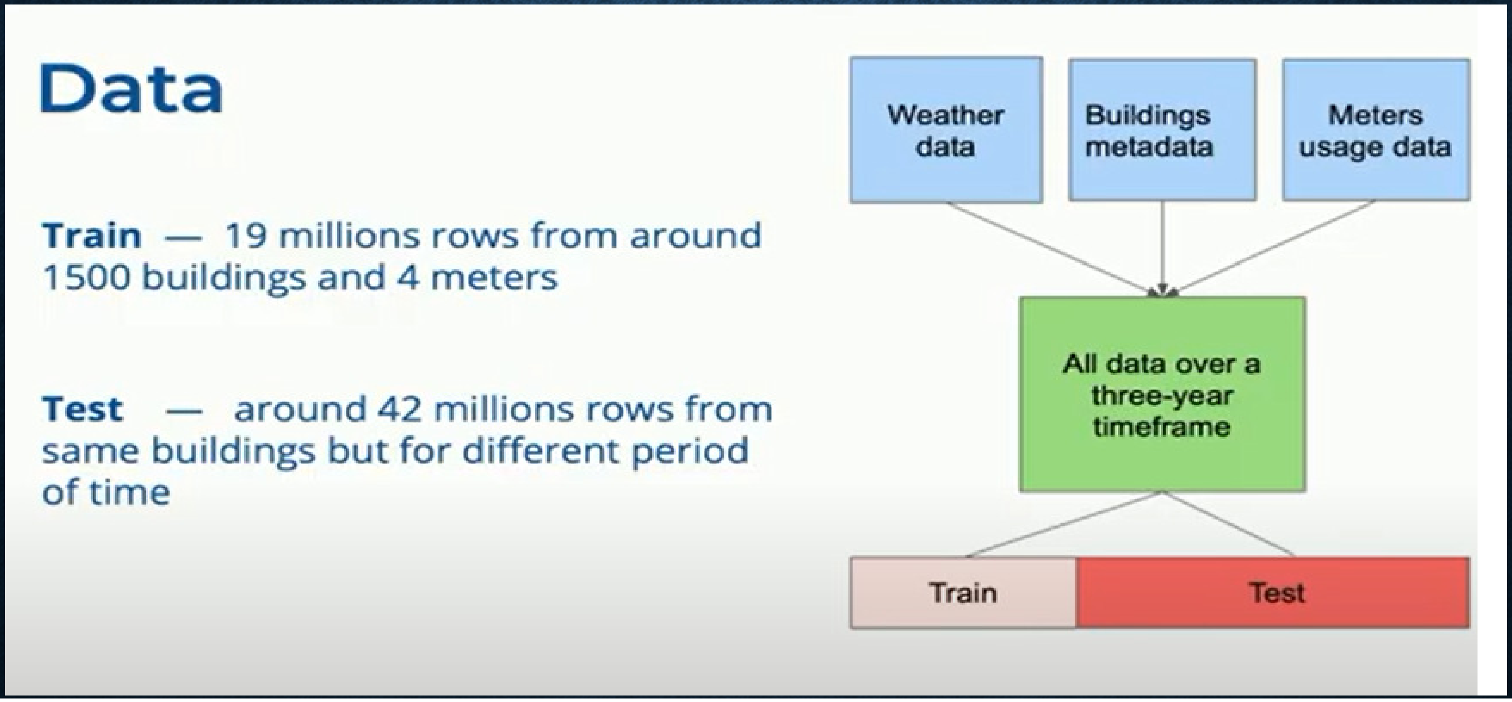
EXAMPLE APPLICATIONS

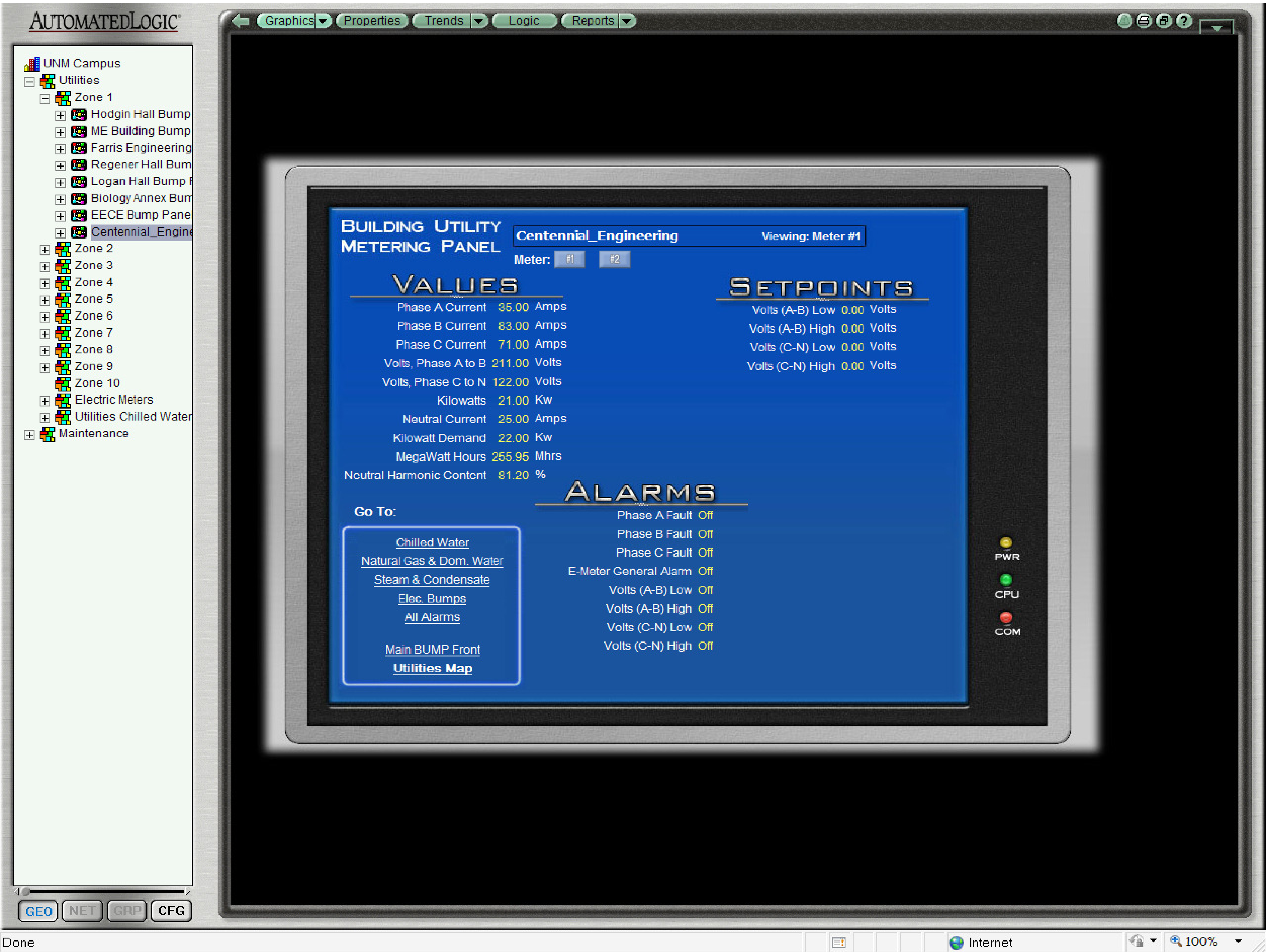
- Convert INFORMATION into KNOWLEDGE
  - Energy Management
  - Operational and Decision Support
  - Maintenance Management
  - Analytics, AI, Fault Detection
  - Reporting

ASHRAE- Great Energy Predictor III- A Machine Learning Case Study

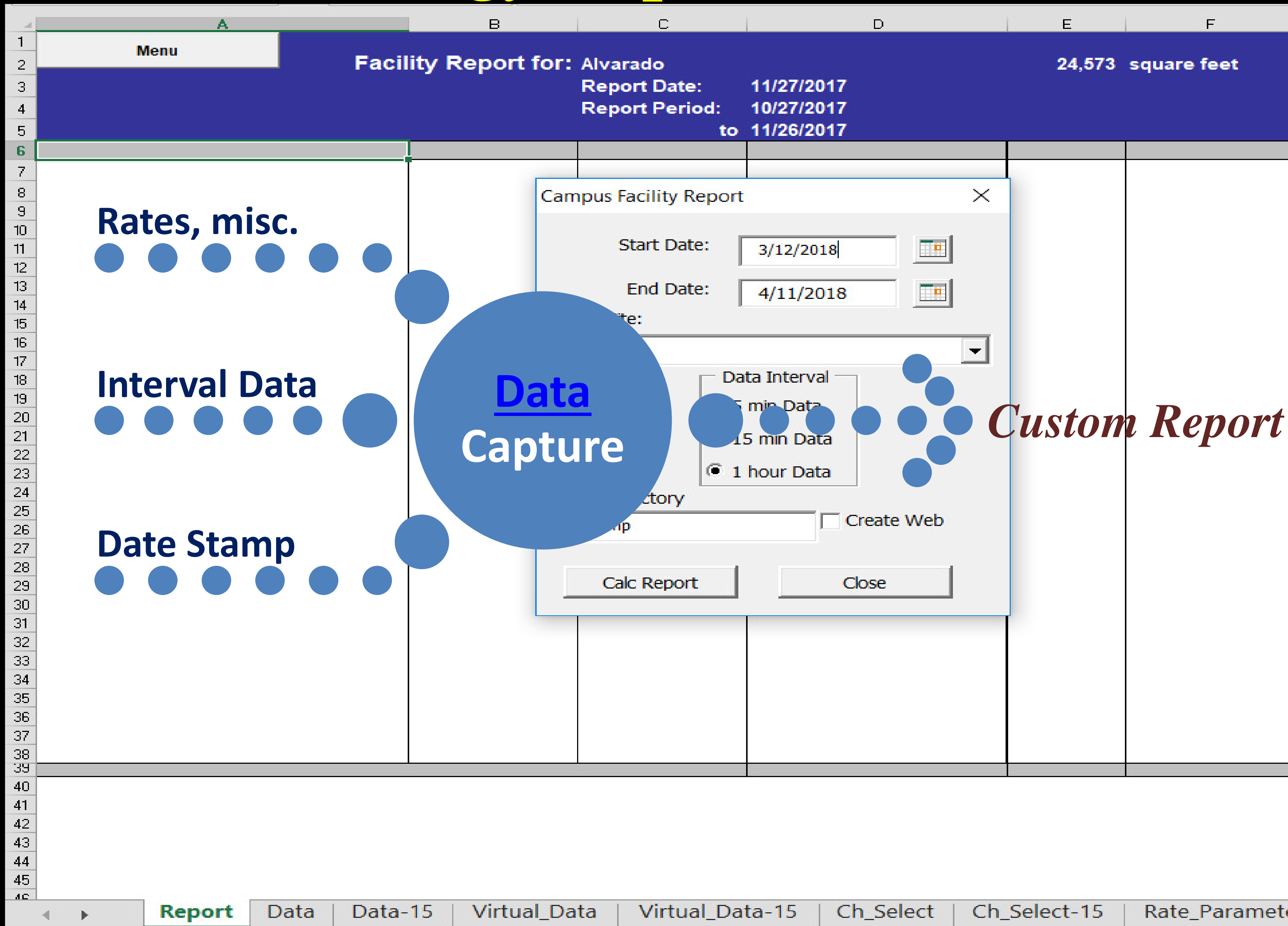
The competition focused on predicting the energy savings of a retrofit in the measurement and verification (M&V) process. Assessing the value of energy efficiency improvements can be challenging as there's no way to know how much energy a building would have used without the improvements.

Competitors were challenged to build counterfactual models across four energy types based on historic usage rates and observed weather. The dataset includes three years of hourly meter readings from over one thousand buildings, extensive characterization of the various buildings, and comprehensive weather data at over a 1,000 different sites around the world.

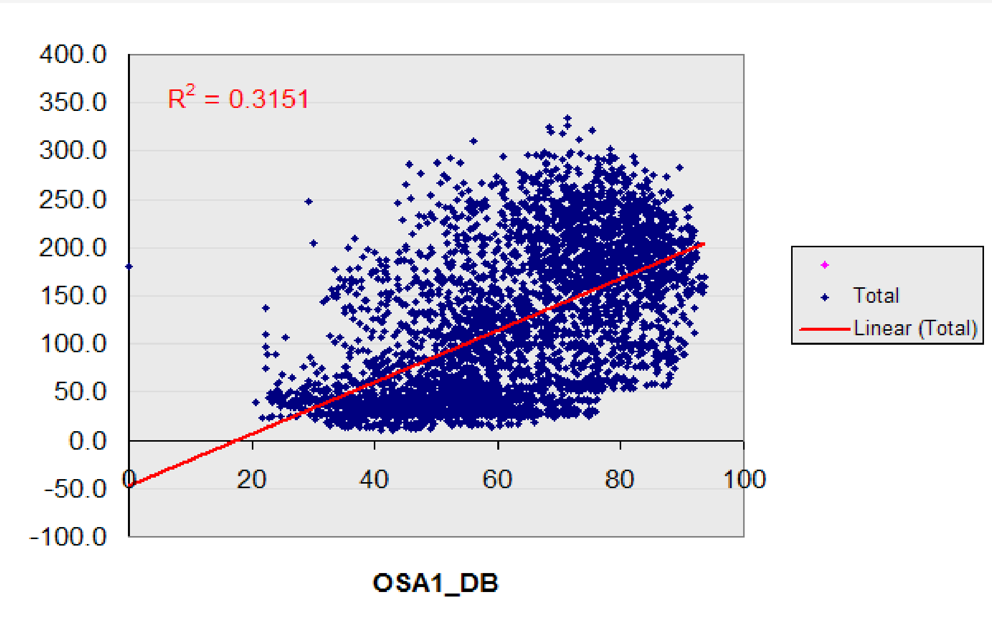


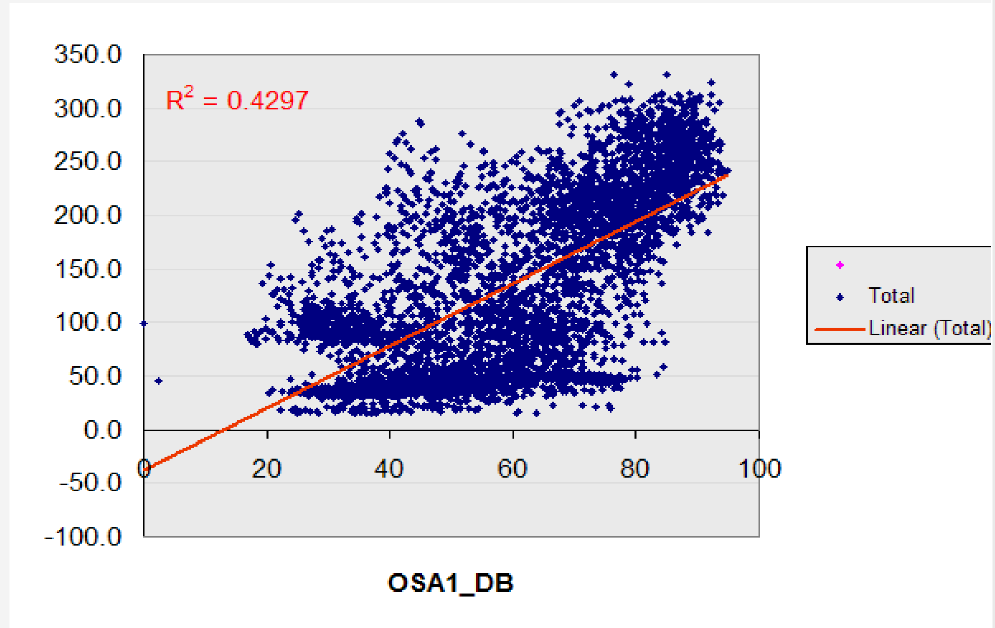

AutomatedLogic
Graphics
Properties
Trends
Logic
Reports
UNM Campus
Utilities
Zone 1
Hodgin Hall Bump
ME Building Bump
Farris Engineering
Regener Hall Bum
Logan Hall Bump F
Biology Annex Bum
EECE Bump Pane
Centennial_Engine
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
Zone 7
Zone 8
Zone 9
Zone 10
Electric Meters
Utilities Chilled Water
Maintenance
GEO
NET
GRP
CFG
Building Utility Metering Panel
Centennial_Engineering
Viewing: Meter #1
Meter: #1 #2
Values
Phase A Current 35.00 Amps
Phase B Current 83.00 Amps
Phase C Current 71.00 Amps
Volts, Phase A to B 211.00 Volts
Volts, Phase C to N 122.00 Volts
Kilowatts 21.00 Kw
Neutral Current 25.00 Amps
Kilowatt Demand 22.00 Kw
MegaWatt Hours 255.95 Mhrs
Neutral Harmonic Content 81.20 %
Setpoints
Volts (A-B) Low 0.00 Volts
Volts (A-B) High 0.00 Volts
Volts (C-N) Low 0.00 Volts
Volts (C-N) High 0.00 Volts
Alarms
Phase A Fault Off
Phase B Fault Off
Phase C Fault Off
E-Meter General Alarm Off
Volts (A-B) Low Off
Volts (A-B) High Off
Volts (C-N) Low Off
Volts (C-N) High Off
Go To:
Chilled Water
Natural Gas & Dom. Water
Steam & Condensate
Elec. Bumps
All Alarms
Main BUMP Front
Utilities Map
PWR
CPU
COM
Done
Internet
100%

Energy Report Writer



File Edit View Insert Format Tools Data Window EMetricks Workplace Help





DateRng	(All)
Year	2008
Month	(All)
MonthYr	(All)
Hour	(All)
Occupancy	**Occ**
Weekday	(All)
Daytype	(All)
Day	(All)
Holiday	(All)
5degBin	(All)
TempRng	(All)

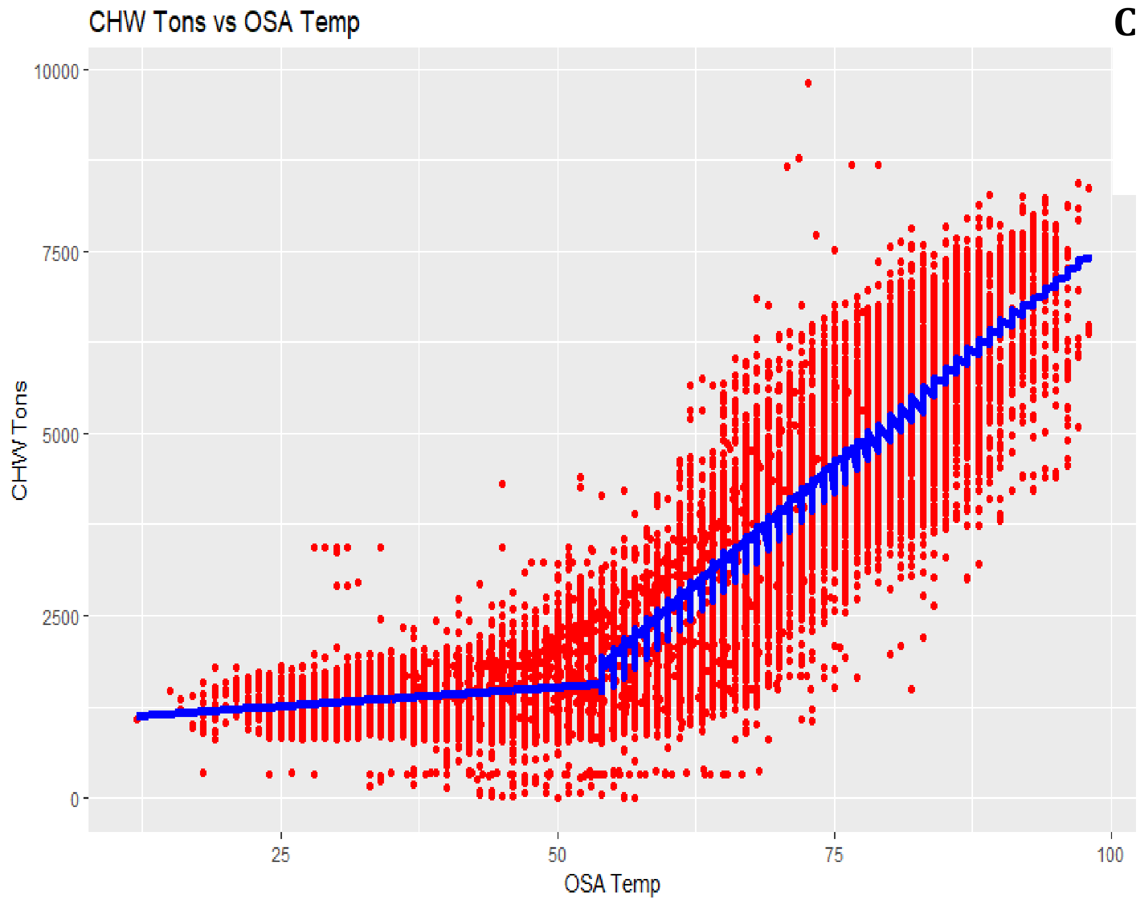
Avg ChW1_Tons	
OSA1_DB	Total
93.61581458	169.85
93.4403	159.36
93.41629938	161.52
93.25277817	152.55
92.94974775	161.15
92.78548108	169.57

DateRng	(All)
Year	2007
Month	(All)
MonthYr	(All)
Hour	(All)
Occupancy	**Occ**
Weekday	(All)
Daytype	(All)
Day	(All)
Holiday	(All)
5degBin	(All)
TempRng	(All)

Avg ChW1_Tons	
OSA1_DB	Total
94.80115045	241.35
94.17880401	238.69
94.08429039	242.23
93.97539586	218.94
93.77890126	244.64
93.70609417	266.78

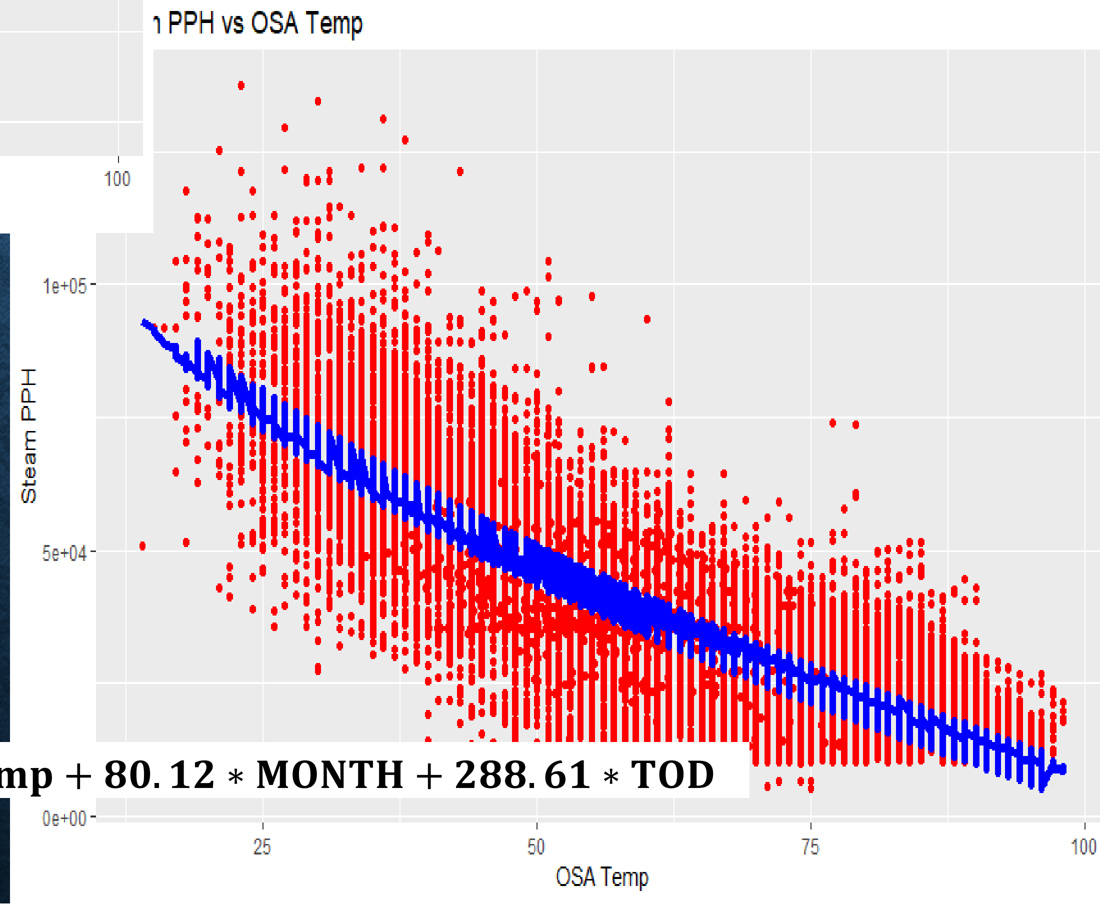
ptScatterChartDateRng / ptLPchartDaytype / ptLPchartDateRng / ptLPchartYear / ptScatterChartWeekDay / ptL

$$\text{CHW Tons} = \begin{cases} OSA.Temp < 54: \\ 1000 + 10.4 * \text{OSA.Temp} \\ OSA.Temp \geq 54: \\ -5740.44 + 131.36 * \text{OSA.Temp} + 47.08 * \text{MONTH} \end{cases}$$



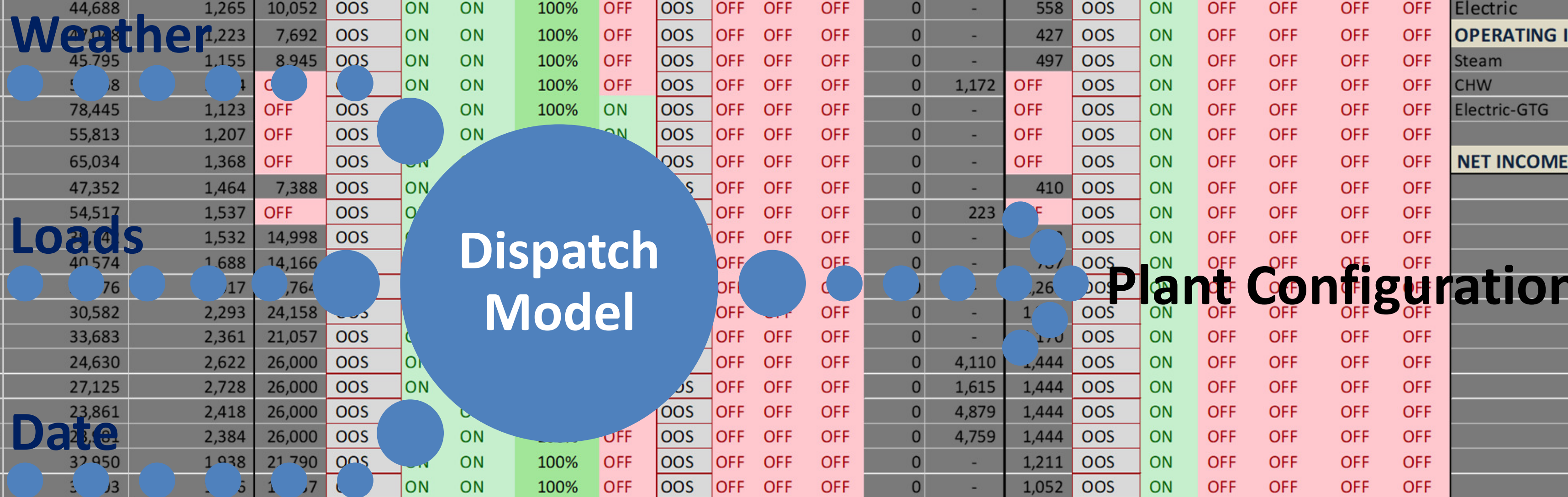
ANALYTICS

26,210 coincident campus steam and chilled water load, time-of-day, day-of-week, month, and outside temperature data points .



$$\text{Steam PPH} = 142{,}984.75 - 14{,}107.34 * \sqrt{\text{OSA.Temp}} + 80.12 * \text{MONTH} + 288.61 * \text{TOD}$$

Operational and Decision Support



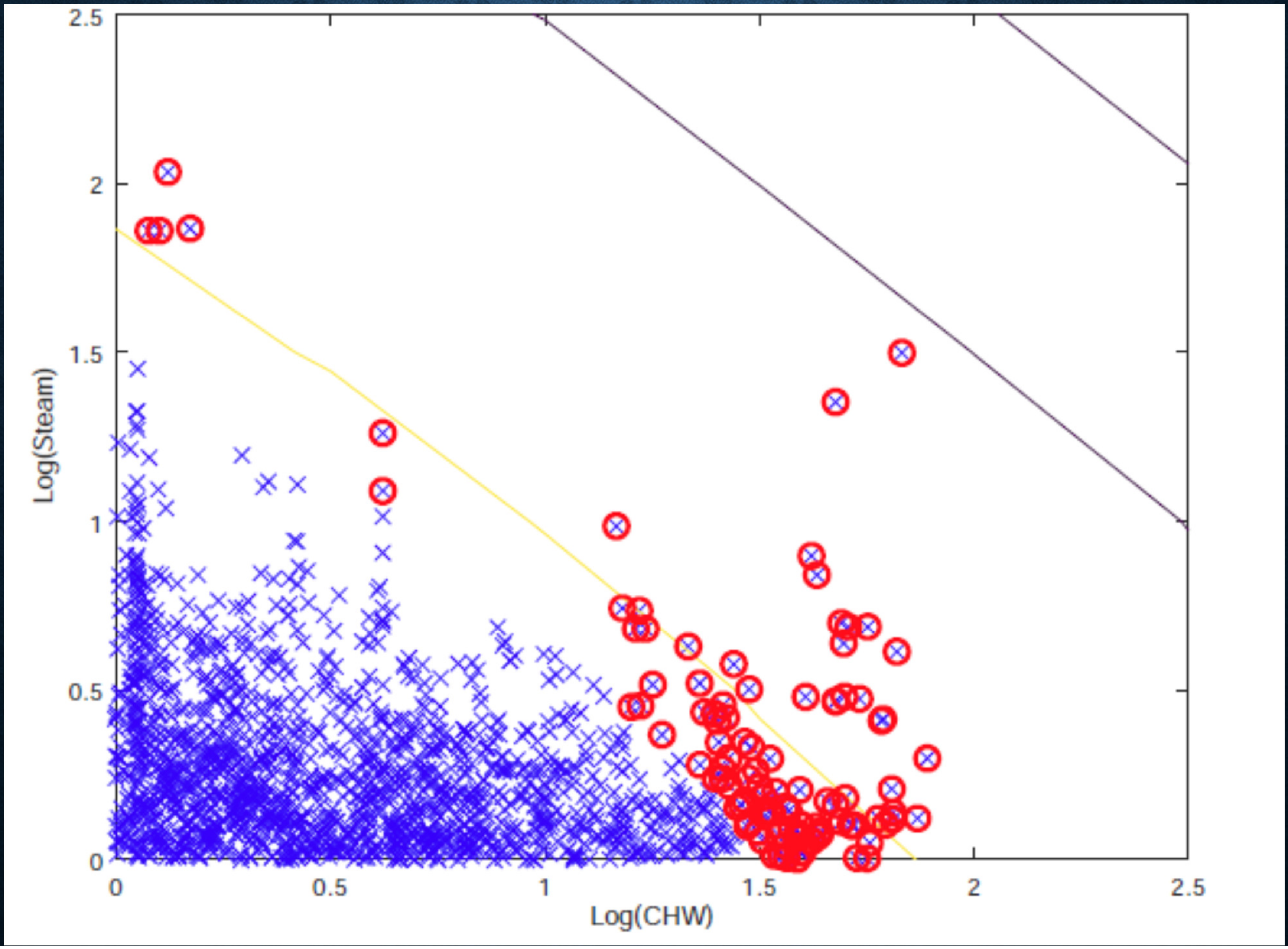
FORECAST — 09-Apr — Get Forecast — AVAILABLE =>

STEAM (☑ Free Stm) — CHILLED WATER

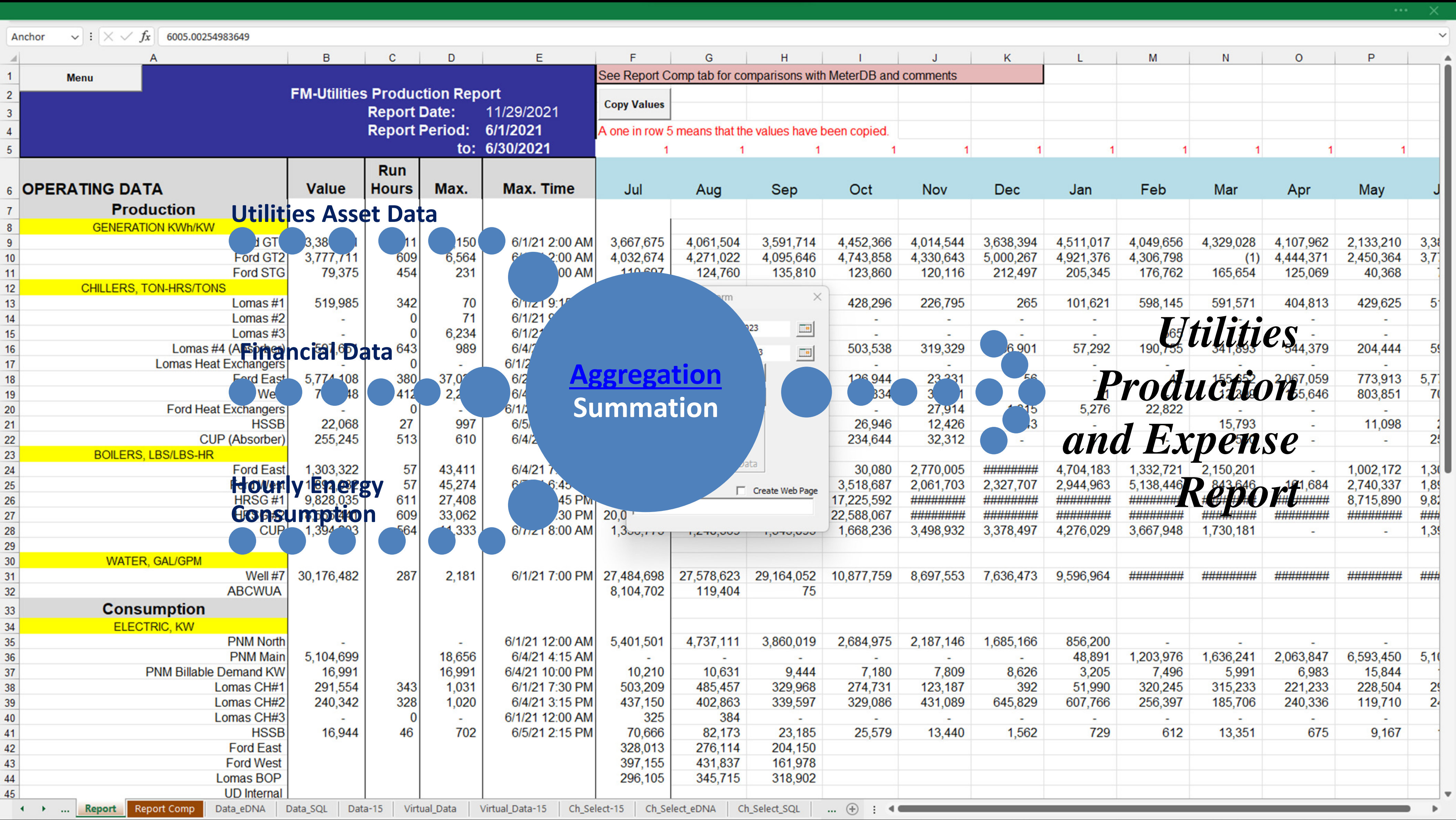
Forecast for tomorrow Hour	Temperature	Campus Steam Forecast, PPH	Campus CHW Forecast, TH	Steam: Lomas ABS	Steam: CUP ABS	HRSG #2	HRSG #1	HRSG #1 Diverted Output	East Boiler	West Boiler	CUP #1	CUP #2	CUP #3	UNMH	EXCESS STEAM	Chilled Water: Lomas ABS	Chilled Water: CUP ABS	Ford #2	Lomas #2	Lomas #3	Ford #1	Lomas #1
0:00	41	46,883	1,277	7,857	OOS	ON	ON	100%	OFF	OOS	OFF	OFF	OFF	0	-	437	OOS	ON	OFF	OFF	OFF	OFF
1:00	39	44,688	1,265	10,052	OOS	ON	ON	100%	OFF	OOS	OFF	OFF	OFF	0	-	558	OOS	ON	OFF	OFF	OFF	OFF
2:00	36	[illegible]	1,223	7,692	OOS	ON	ON	100%	OFF	OOS	OFF	OFF	OFF	0	-	427	OOS	ON	OFF	OFF	OFF	OFF
3:00	34	45,795	1,155	8,945	OOS	ON	ON	100%	OFF	OOS	OFF	OFF	OFF	0	-	497	OOS	ON	OFF	OFF	OFF	OFF
4:00	32	[illegible]	[illegible]	[illegible]	[illegible]	ON	ON	100%	OFF	OOS	OFF	OFF	OFF	0	1,172	OFF	OOS	ON	OFF	OFF	OFF	OFF
5:00	31	78,445	1,123	OFF	OOS	[illegible]	ON	100%	ON	OOS	OFF	OFF	OFF	0	-	OFF	OOS	ON	OFF	OFF	OFF	OFF
6:00	32	55,813	1,207	OFF	OOS	[illegible]	ON	[illegible]	[illegible]	OOS	OFF	OFF	OFF	0	-	OFF	OOS	ON	OFF	OFF	OFF	OFF
7:00	35	65,034	1,368	OFF	OOS	[illegible]	[illegible]	[illegible]	[illegible]	OOS	OFF	OFF	OFF	0	-	OFF	OOS	ON	OFF	OFF	OFF	OFF
8:00	40	47,352	1,464	7,388	OOS	ON	[illegible]	[illegible]	[illegible]	[illegible]	OFF	OFF	OFF	0	-	410	OOS	ON	OFF	OFF	OFF	OFF
9:00	46	54,517	1,537	OFF	OOS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OFF	OFF	OFF	0	223	[illegible]	OOS	ON	OFF	OFF	OFF	OFF
10:00	52	[illegible]	1,532	14,998	OOS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OFF	OFF	OFF	0	-	[illegible]	OOS	ON	OFF	OFF	OFF	OFF
11:00	58	40,574	1,688	14,166	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OFF	[illegible]	OFF	0	-	[illegible]	OOS	ON	OFF	OFF	OFF	OFF
12:00	62	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13:00	65	30,582	2,293	24,158	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OFF	[illegible]	OFF	0	-	[illegible]	OOS	ON	OFF	OFF	OFF	OFF
14:00	68	33,683	2,361	21,057	OOS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OFF	OFF	OFF	0	-	[illegible]	OOS	ON	OFF	OFF	OFF	OFF
15:00	69	24,630	2,622	26,000	OOS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	OFF	OFF	OFF	0	4,110	[illegible]	OOS	ON	OFF	OFF	OFF	OFF
16:00	70	27,125	2,728	26,000	OOS	ON	[illegible]	[illegible]	[illegible]	[illegible]	OFF	OFF	OFF	0	1,615	1,444	OOS	ON	OFF	OFF	OFF	OFF
17:00	69	23,861	2,418	26,000	OOS	[illegible]	[illegible]	[illegible]	[illegible]	OOS	OFF	OFF	OFF	0	4,879	1,444	OOS	ON	OFF	OFF	OFF	OFF
18:00	64	[illegible]	2,384	26,000	OOS	[illegible]	ON	[illegible]	OFF	OOS	OFF	OFF	OFF	0	4,759	1,444	OOS	ON	OFF	OFF	OFF	OFF
19:00	58	32,950	1,938	21,790	OOS	[illegible]	ON	100%	OFF	OOS	OFF	OFF	OFF	0	-	1,211	OOS	ON	OFF	OFF	OFF	OFF
20:00	53	[illegible]	[illegible]	[illegible]	[illegible]	ON	ON	100%	OFF	OOS	OFF	OFF	OFF	0	-	1,052	OOS	ON	OFF	OFF	OFF	OFF
21:00	49	45,265	1,484	9,475	OOS	ON	ON	100%	OFF	OOS	OFF	OFF	OFF	0	-	526	OOS	ON	OFF	OFF	OFF	OFF
22:00	47	49,263	1,475	OFF	OOS	ON	ON	100%	OFF	OOS	OFF	OFF	OFF	0	5,477	OFF	OOS	ON	OFF	OFF	OFF	OFF
23:00	45	51,940	1,380	OFF	OOS	ON	ON	100%	OFF	OOS	OFF	OFF	OFF	0	2,800	OFF	OOS	ON	OFF	OFF	OFF	OFF

OPERATING COST		
Gas	$	12,204
Electric	$	9,017
OPERATING INCOME		
Steam	$	16,982
CHW	$	8,239
Electric-GTG	$	27,660
NET INCOME	$	31,661

ANALYTICS
FAULT DETECTION AND DIAGNOSTICS



Operational and Decision Support



Operational and Decision Support

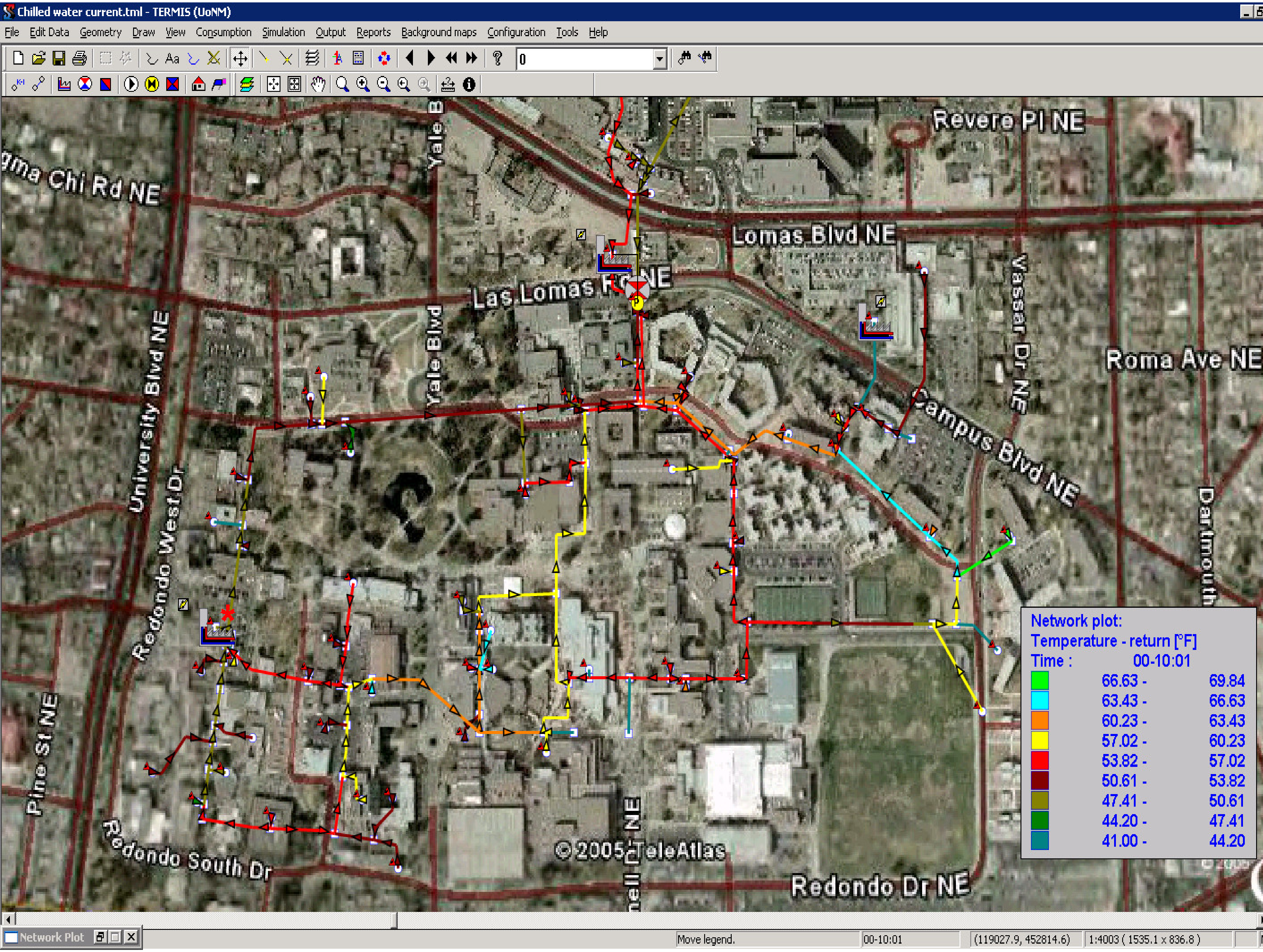
Remove Classification Tab Filter			ENERGY FACTORS					
			Ton-hrs/sq.ft.-yr	Total Tons	Sq.ft/ton	KWh/sq.ft-yr	lbs/sq.ft-yr	Total NSF
			3.45	8428.60	834.27	12.00	133.367	5,405,913
Building	Description	Year & AVG	CHW-Ton/hrs	CHW MAX Tons	CHW sq.ft/ton	ELE- KWH	STM- klbs	NSF
0002	ENGINEERING AND SCIENCE COMPUTER POD	2012						6,550.00
0002	ENGINEERING AND SCIENCE COMPUTER POD	2013						
0002	ENGINEERING AND SCIENCE COMPUTER POD	2014						
0002	ENGINEERING AND SCIENCE COMPUTER POD	2015						
0002	ENGINEERING AND SC[illegible]	2016						
0004	ELIZABETH WATERS CENTER FOR DANCE AT CARLISLE GYMNASIUM	2012				174,353.80	1,171.20	34,805.00
0004	ELIZABETH WATERS CENTER FOR DANCE AT CARLISLE GYM[illegible]	2013				179,128.00	1219.087	
0004	ELIZABETH WATERS CENTER FOR DANCE AT CARLISLE GYMN[illegible]	[illegible]				184,546.00	936.28	
0004	ELIZABETH WATERS CENTER FOR DANCE AT CARLISLE GYMNASIU[illegible]	[illegible]				186,785.00	900.057	
0004	ELIZABETH WATERS CENTER FOR DANCE AT CARLISLE GYMNAS[illegible]	[illegible]				169,471.00	238.801	
0008	BANDELIER HALL EAST	[illegible]	43331	33	2[illegible]787879	289,3[illegible].00	[illegible]3.973	8,510.00
0008	BANDELIER HALL EAST	[illegible]	[illegible]55	36	230.[illegible]888889	261,[illegible]	[illegible]	
0008	BANDELIER HALL EAST	[illegible]	[illegible]4	3[illegible]	26[illegible]75	280,657.00	191.874	
0008	BANDELIER HALL EAST	[illegible]	[illegible]345	29	29[illegible]482759	297,261.00	[illegible]	
0008	BANDELIER HALL EAST	[illegible]	37064	32	[illegible]265.9375	[illegible]	[illegible]	
0009	MARRON HALL	[illegible]				78,516.00	583.356	19,405.00
0009	MARRON HALL	[illegible]				66,610.00	653.845	
0009	MARRON HALL	[illegible]14				78,516.00	557.522	
0009	MARRON HALL	2015				75,180.00	970.978	
0009	MARRON HALL	2016				73,093.00	780.885	
0010	SCHOLES HALL	2012	101882	68	649.5441176	389,748.00	1247.431	44,169.00
0010	SCHOLES HALL	2013	103824	74	596.8783784	407,988.00	1308.659	
0010	SCHOLES HALL	2014	92628	62	712.4032258	406,453.00	1140.447	
0010	SCHOLES HALL	2015	89806	64	690.140625	417,925.00	1097.96	
0010	SCHOLES HALL	2016	86217	63	701.0952381	416,451.00	1017.526	
0011	ANTHROPOLOGY	2012	852519	156	325.8461538	882,871.00	1560.07	50,832.00
0011	ANTHROPOLOGY	2013	771147	124	409.9354839	785,637.00	1848.33	

Existing Building Data

Energy Consumption

Energy Utilization Indices

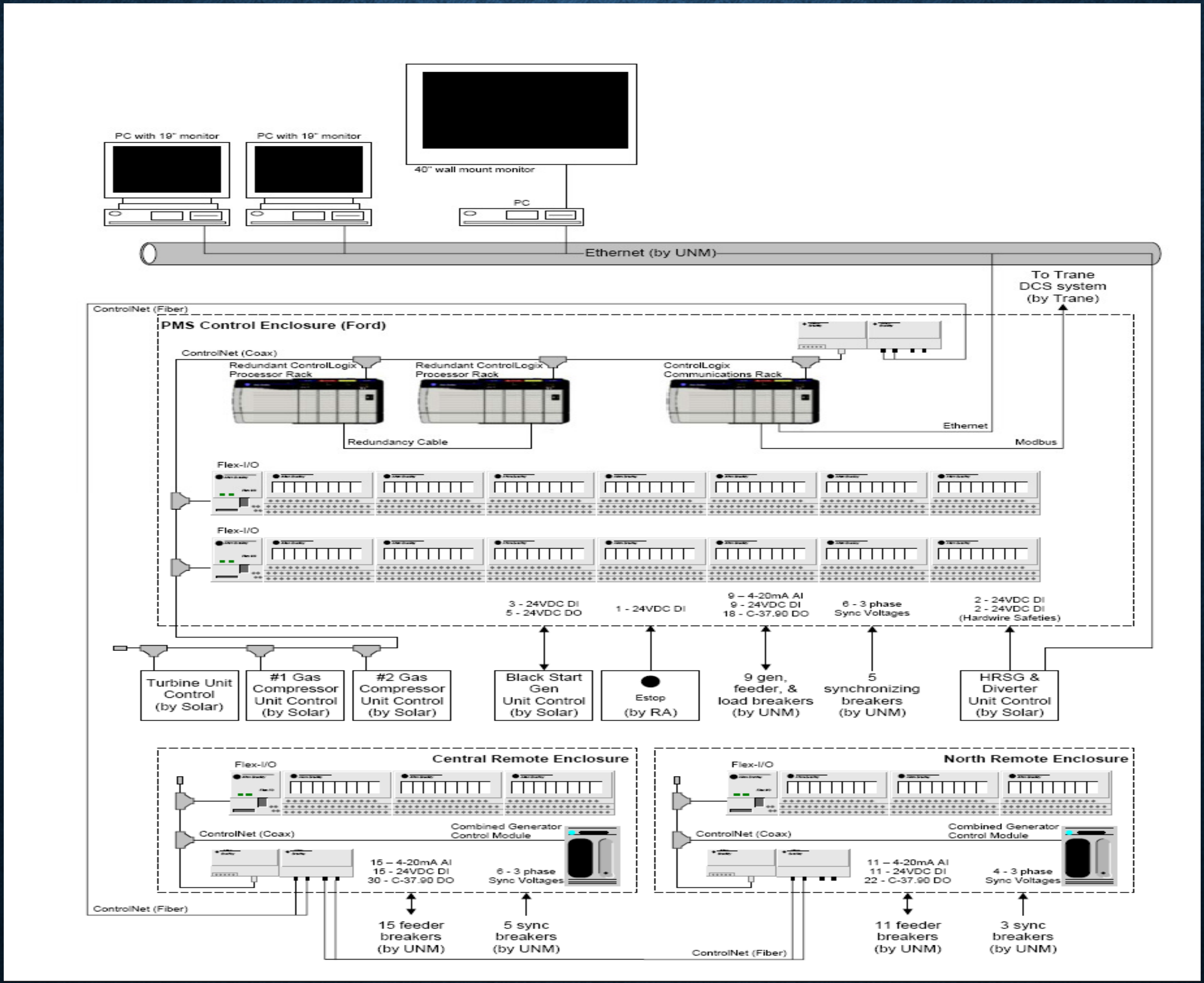
New Building Consumption



Chilled water current.tml - TERMIS (UoNM)
File Edit Data Geometry Draw View Consumption Simulation Output Reports Background maps Configuration Tools Help
Revere Pl NE
Lomas Blvd NE
Las Lomas Rd NE
Roma Ave NE
Campus Blvd NE
Vassar Dr NE
University Blvd NE
Redondo West Dr
Yale Blvd
Pine St NE
Redondo South Dr
Redondo Dr NE
© 2005 TeleAtlas
Network plot:
Temperature - return [°F]
Time : 00-10:01
66.63 - 69.84
63.43 - 66.63
60.23 - 63.43
57.02 - 60.23
53.82 - 57.02
50.61 - 53.82
47.41 - 50.61
44.20 - 47.41
41.00 - 44.20
Network Plot
Move legend.
00-10:01
(119027.9, 452814.6)
1:4003 (1535.1 x 836.8)

QUESTIONS & ANSWERS

Thank You!



THIS CONCLUDES THE AMERICAN INSTITUTE OF ARCHITECTS CONTINUING EDUCATION SYSTEMS COURSE

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