Making Data Decision-Ready for the Intelligent Enterprise

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Overview

- From Data to “Decision Ready” Data
- New ***Uses*** for and ***Users*** of PI System Data
- Enabling Analytics for Operational Intelligence
  - Descriptive, Predictive and Multidimensional (BI)
- Driving Continuous Improvement
- Summary and Wrap Up

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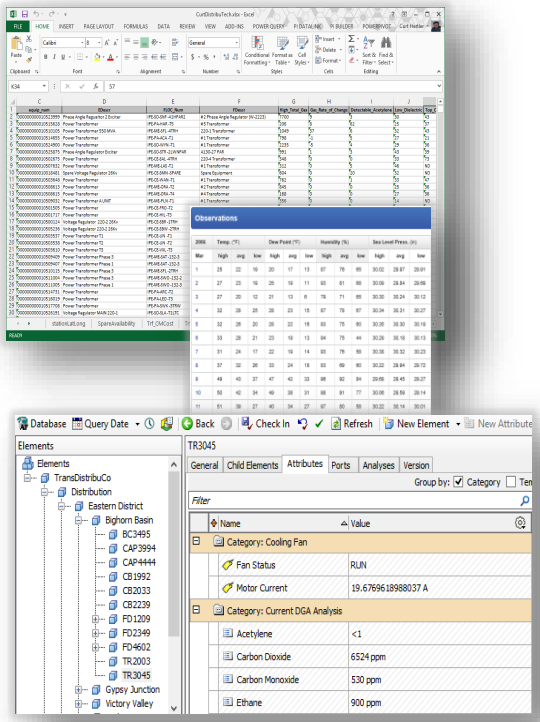
From Data to “Decision Ready” Data

Data



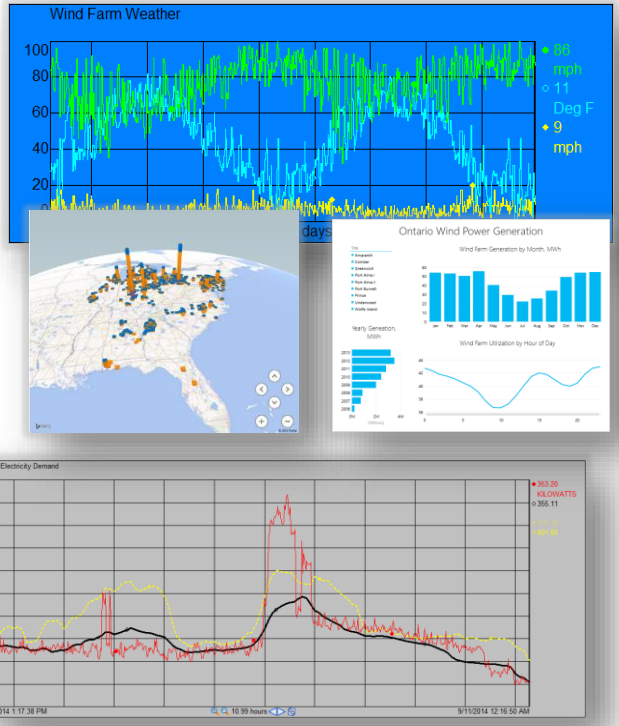
Accessible for investigation and analysis

Data integration capabilities

Anywhere access and socialization

Data mining and predictive analytics

“Decision Ready” Data



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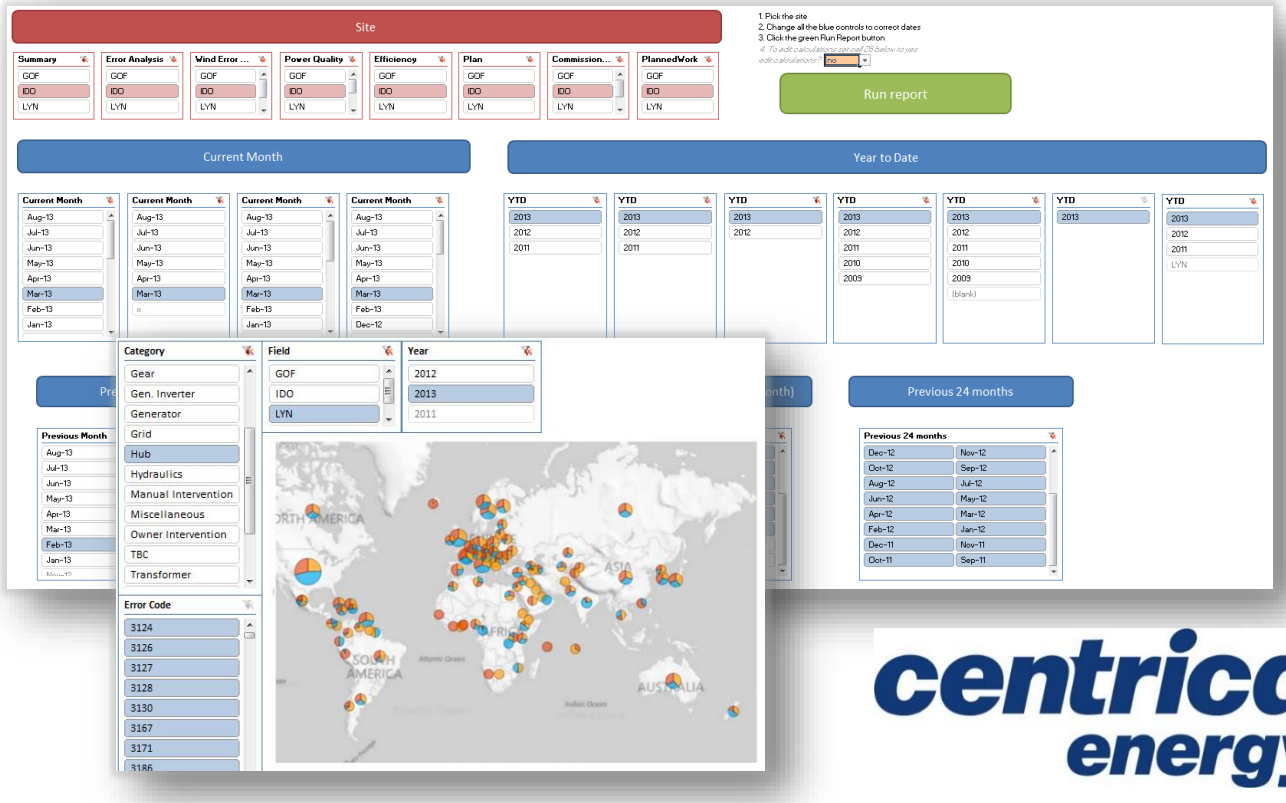
Scalable “Decision Ready” Reporting

Centrica Energy

Asset Performance

- Expanding wind business by 10 fold.
- Configured concise, scalable reports based on PI AF using PowerPivot for Excel.
- Eliminated 199,000 custom calculations in Excel.



centrica energy

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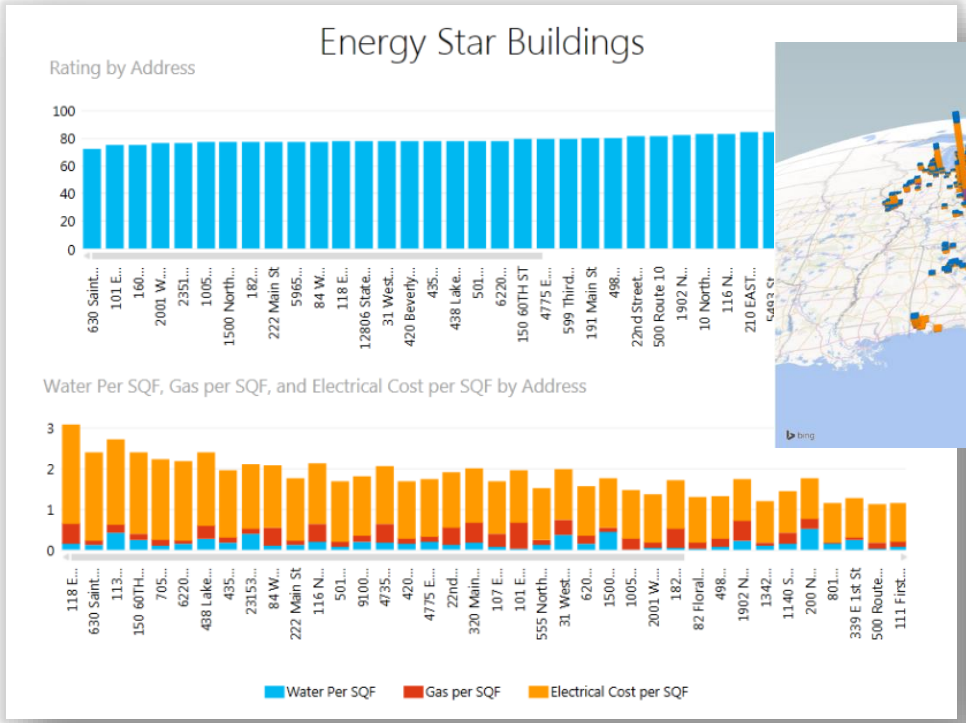
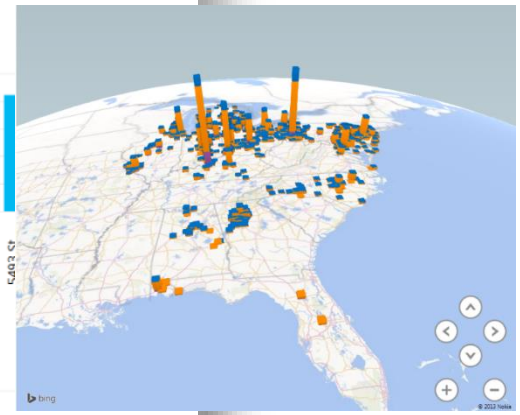
Rapid “Decision Ready” Analysis

Carnegie Mellon University – School of Architecture

Asset Management

- Utility usage and costs for 1600 branch offices.
- Rapid delivery of analytical reporting.
- Increased the value of the data.





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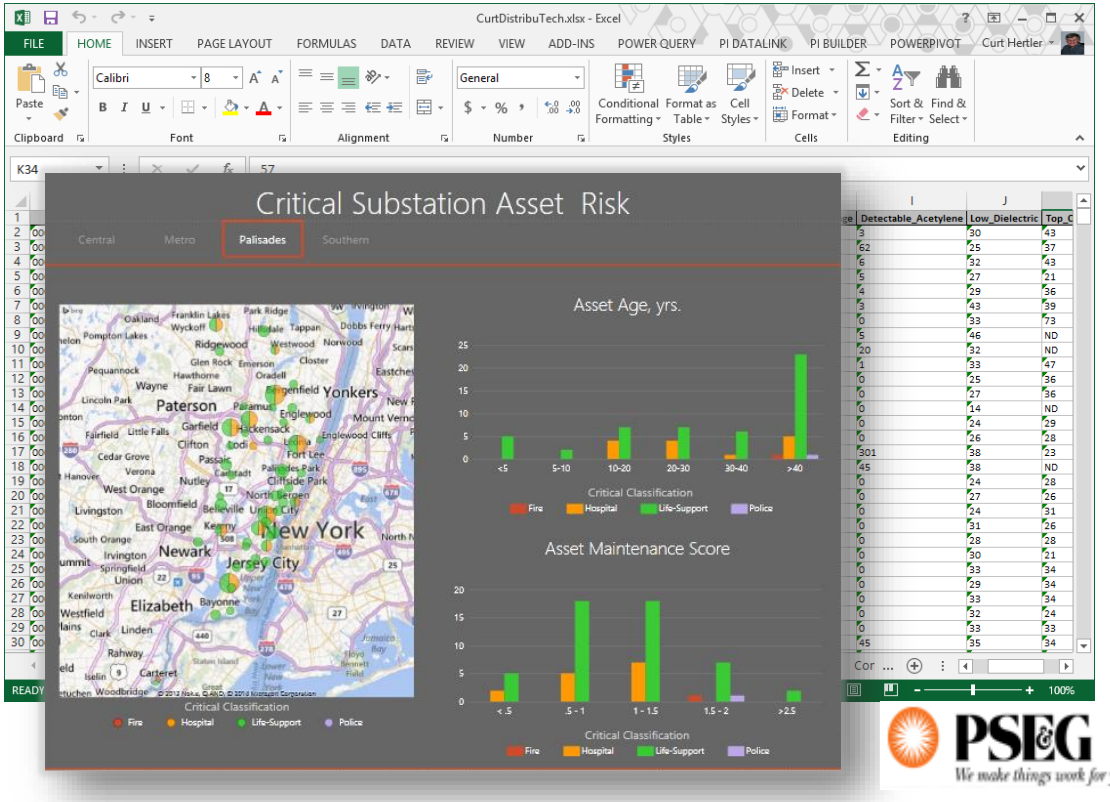
Integrated “Decision Ready” Assessment

PSE&G

Asset Risk Assessment

Data integration from;

- Operations
- Maintenance
- Service Demographics
- Geospatial Sources



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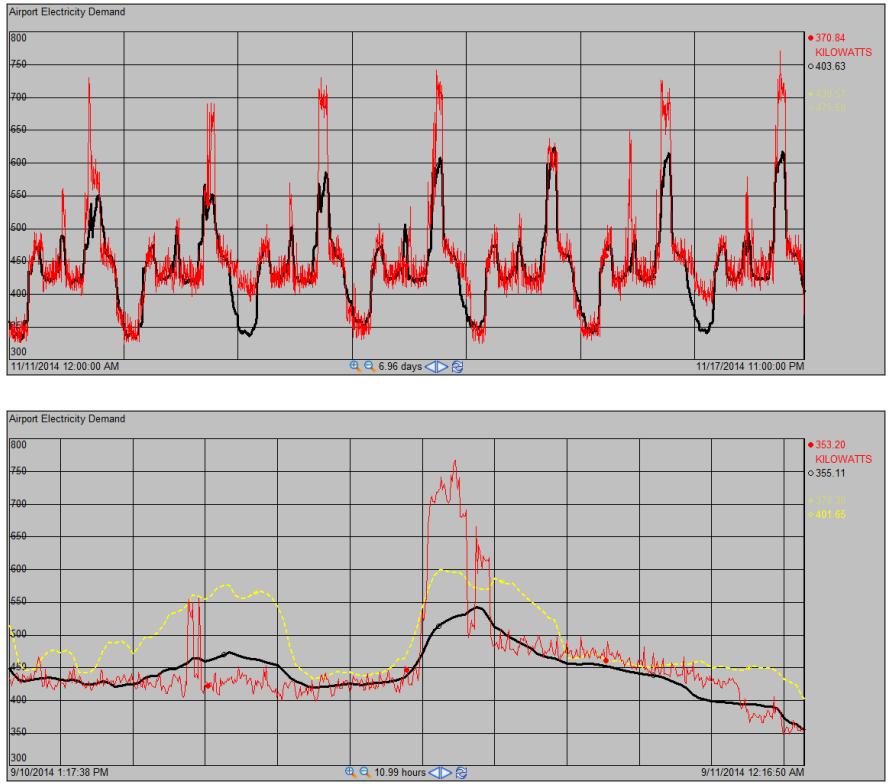
Opportune “Decision Ready” Prediction

San Diego Airport

Develop a model to predict energy use at San Diego Airport. This model can be used for capacity planning, and abnormal spike detection and notification.



Actual Energy Use

Predicted Energy Use

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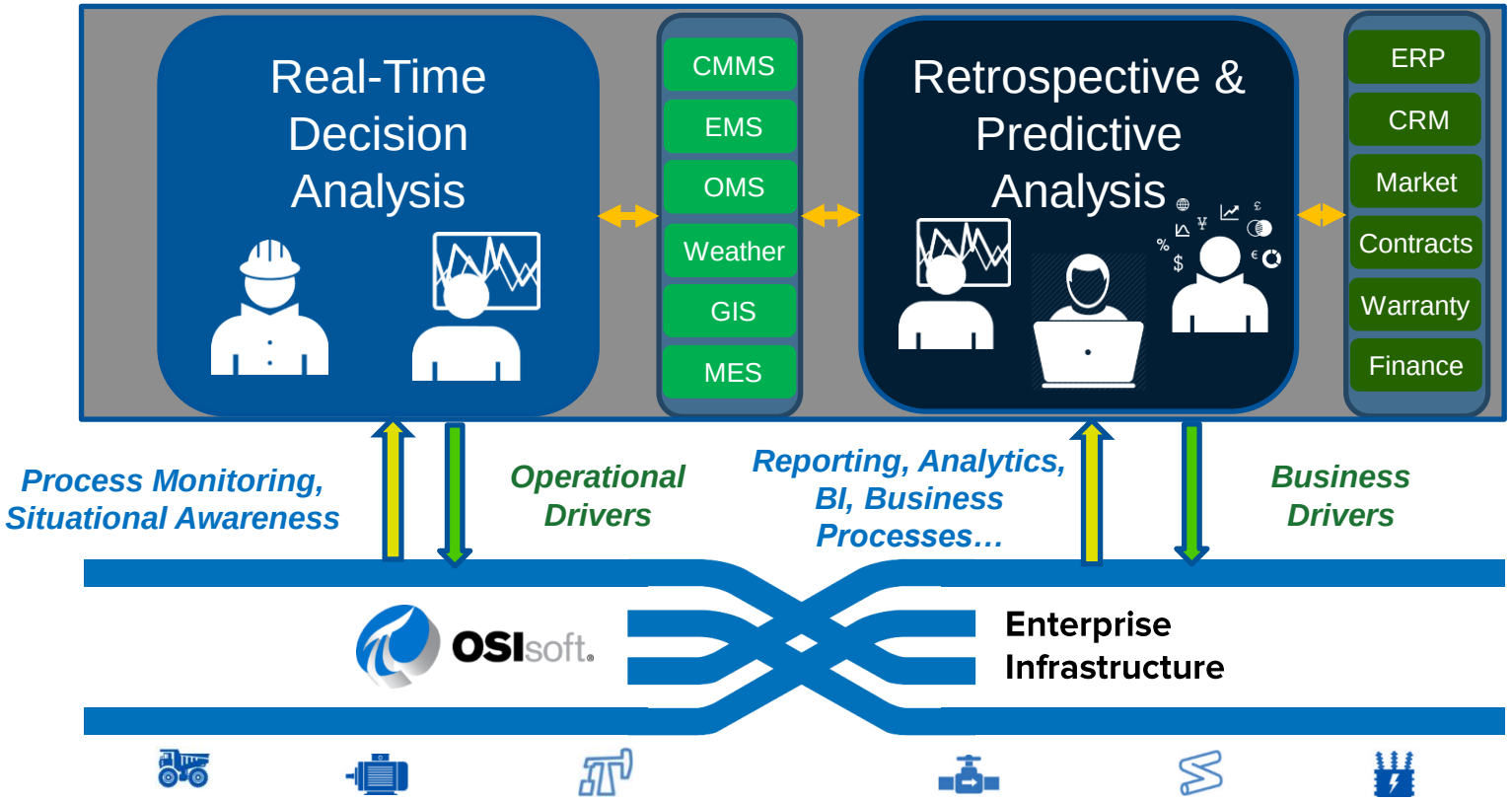
New ***Uses*** for and ***Users*** of PI System Data



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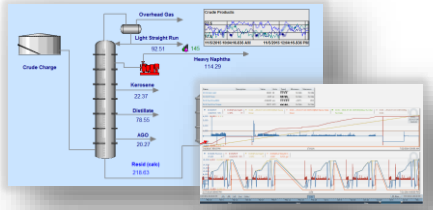
Enabling Analytics for Operational Intelligence

Real-Time Decision Analysis



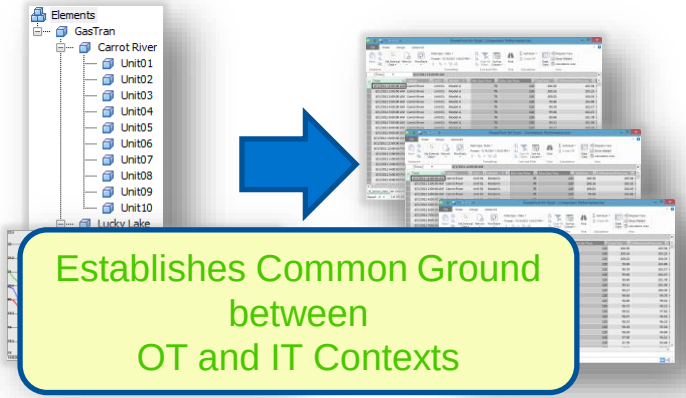
Time and Event
Trending & Awareness

Specialized Models
Simulation & Optimization

$$Q = \frac{\Delta P_{DD} * kh}{141.2 \mu B_0 \left\{ ln \frac{r_e}{r_w} - \frac{3}{4} + S \right\}}$$

Descriptive
Performance
& Condition

PI Integrator for
Business Analytics



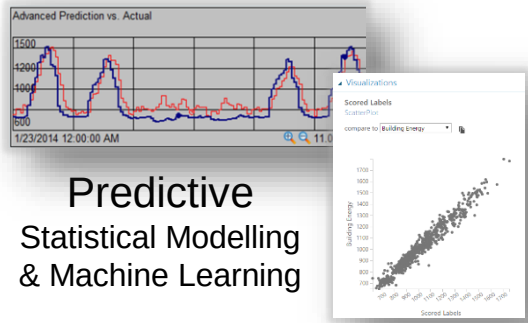
Establishes Common Ground
between
OT and IT Contexts

Time, Event
and Asset
Context

Tabular
Context

Retrospective & Predictive Analysis

Multidimensional
Business Intelligence
& Dashboards



Predictive
Statistical Modelling
& Machine Learning

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Descriptive Analytics - *Performance & Condition*

- First Principles Relationships ***always*** exists between process measurements
- Time synchronized observations for meaningful results
- Enables real-time decision making only when visible, i.e. not performed in spreadsheets

Daniel Bernoulli
(1700 – 1782)

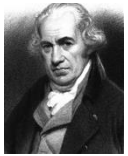
$$H = z + \frac{p}{\rho g} + \frac{v^2}{2g} = h + \frac{v^2}{2g}$$

Benoît Clapeyron
(1799 – 1864)

$$Q = \frac{\Delta P_{DD} * kh}{141.2 \mu B_0 \left\{ ln \frac{r_e}{r_w} - \frac{3}{4} + S \right\}}$$

$$PV = nRT$$

$$F = \frac{(R+1)^{1/2} \text{ x ln } ((1-SR)/(1-S))}{(1-R) \text{ x ln } \left\{ \frac{2-S(R+1-(R+1)^{1/2})}{2-S(R+1+(R+1)^{1/2})} \right\}}$$



James Watt
(1736–1819)

$$P = IV = I^2R = \frac{V^2}{R}$$

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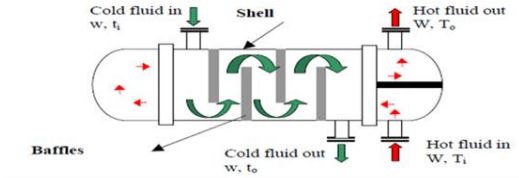
Descriptive Analytics - *PI Asset Analytics*

- *Configure* calculations at scale
- Math, statistical, logical and steam table functions
- Supports simple predictive analytics
- Supports future data for forecasting
- Backfill ! Backfill ! Backfill !



Heat Exchanger Key Performance Indicator:

Overall heat transfer coefficient

$$U = \frac{Q}{A \times \text{Corrected LMTD}}$$

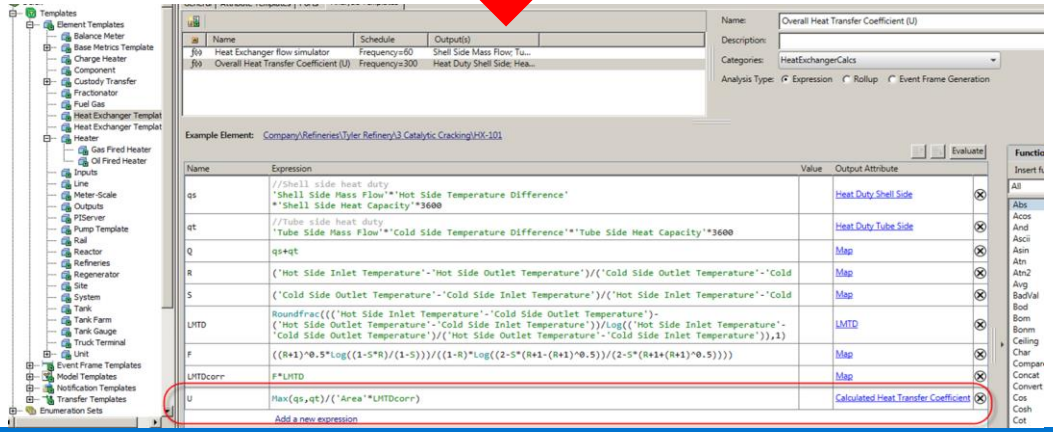
RULE: *IF the heat transfer coefficient is decreasing, THEN the* ***Heat Exchanger FOULING*** *!!! Cleaining is required!*

Calculation Steps:

1. Heat Duty, $Q = q_s + q_t$
   $q_s = W \times C_{ph} \times (T_i - T_o)/1000/3600$
   $q_s = w \times C_{pc} \times (t_o - t_i)/1000/3600$
2. Hot Fluid Pressure Drop, $\Delta P_h = P_i - P_o$
3. Cold fluid pressure drop, $\Delta P_c = p_i - p_o$
4. Temperature range hot fluid, $\Delta T = T_i - T_o$
5. Temperature range cold fluid, $\Delta t = t_o - t_i$
6. Capacity ratio, $R = W \times C_{Ph} / w \times C_{pc}$ (or) $(T_i - T_o) / (t_o - t_i)$
7. Effectiveness, $S = (t_o - t_i) / (T_i - t_i)$
8. LMTD
   LMTD Counter current Flow = $((T_i - t_o) - (T_o - t_i)) / \ln ((T_i - t_o)/(T_o - t_i))$
   LMTD Co current Flow = $((T_i - t_i) - (T_o - t_o)) / \ln ((T_i - t_i)/(T_o - t_o))$
   Correction factor for LMTD to account for Cross flow

$$F = \frac{(R+1)^{1/2} \times \ln((1-SR)/(1-S))}{(1-R) \times \ln\left\{\frac{2-S(R+1-(R+1)^{1/2})}{2-S(R+1+(R+1)^{1/2})}\right\}}$$

9. Corrected LMTD = F x LMTD



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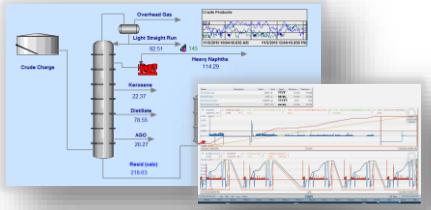
Enabling Analytics for Operational Intelligence

Real-Time Decision Analysis



Time and Event
Trending & Awareness

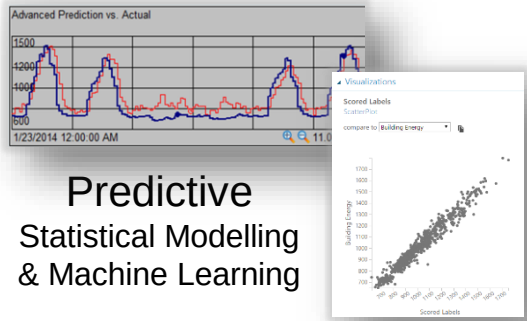
Specialized Models
Simulation & Optimization

$$Q = \frac{\Delta P_{DD} * kh}{141.2 \mu B_0 \left\{ ln \frac{r_e}{r_w} - \frac{3}{4} + S \right\}}$$

Descriptive
Performance
& Condition

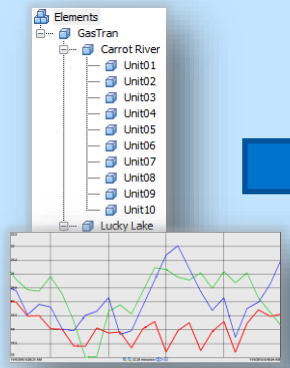
Retrospective & Predictive Analysis

Multidimensional
Business Intelligence
& Dashboards

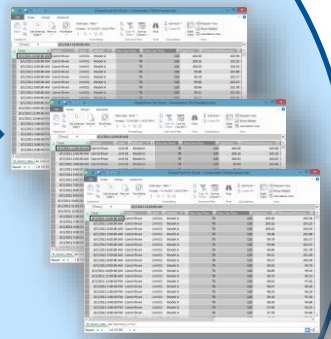


Predictive
Statistical Modelling
& Machine Learning

PI Integrator for Business Analytics



Time, Event and Asset Context



Tabular Context

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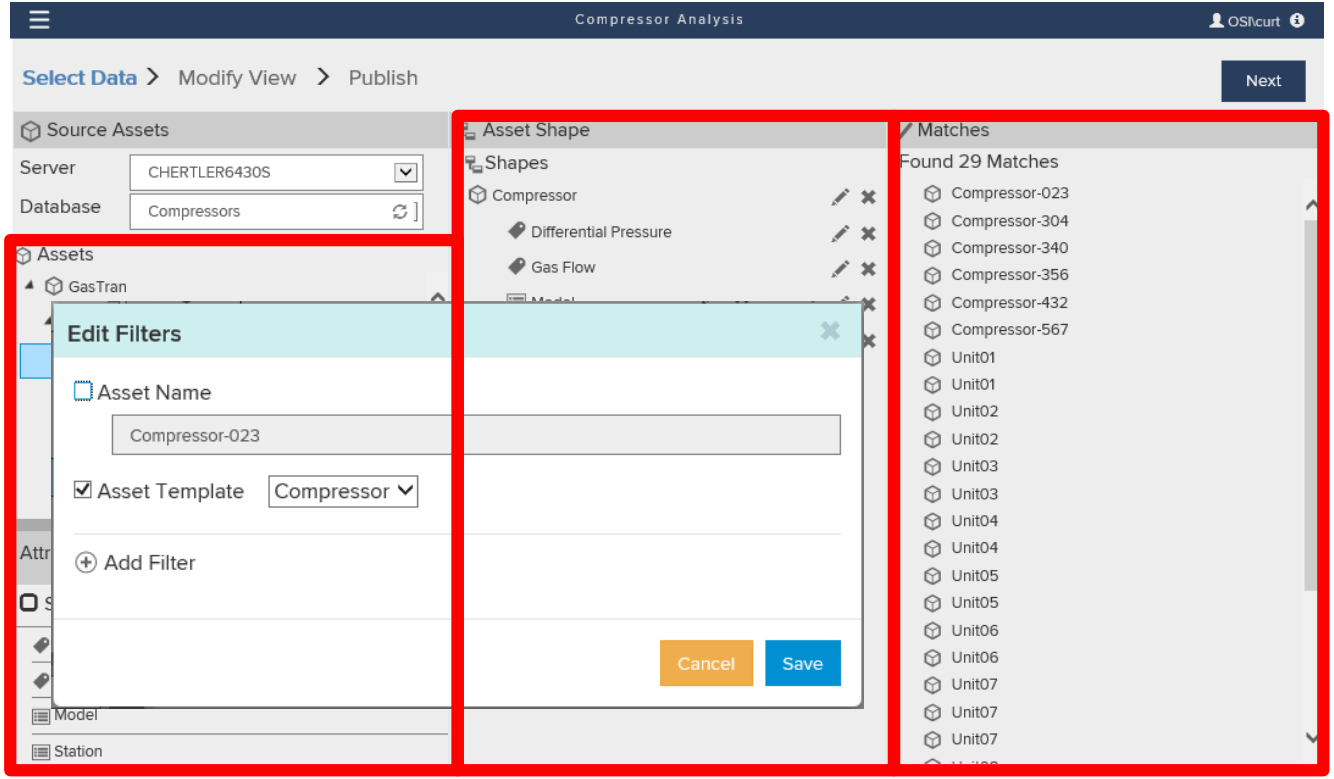
PI Integrator for Business Analytics - *"Select Data"*

- Intuitive way to create tabular content in "PI Views"
- Requires AF Hierarchy
- Select AF Elements and Attributes
- Scale up leveraging name, hierarchy, or category



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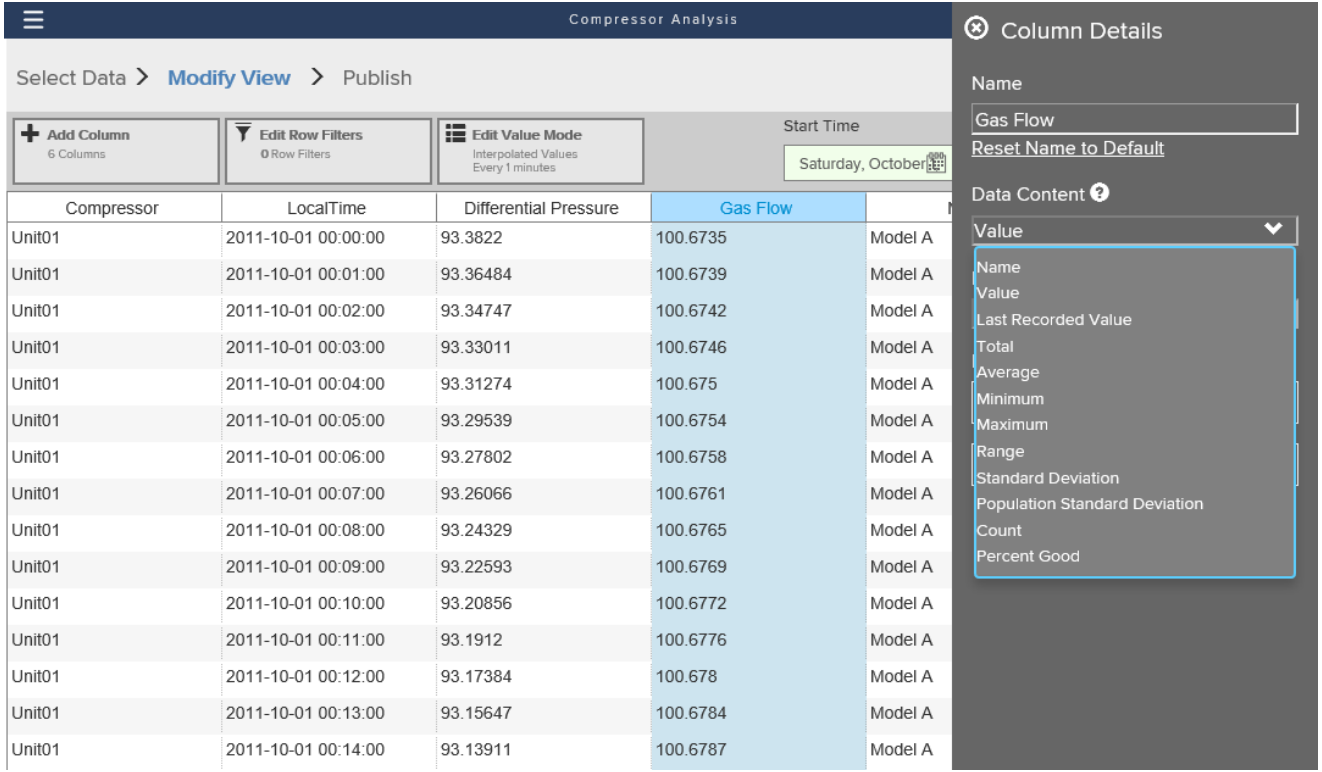
PI Integrator for Business Analytics - *"Modify View"*

- Select any time range and interval
- Add columns for <u>proper</u> aggregating PI System data
- Add columns for common time and date functions



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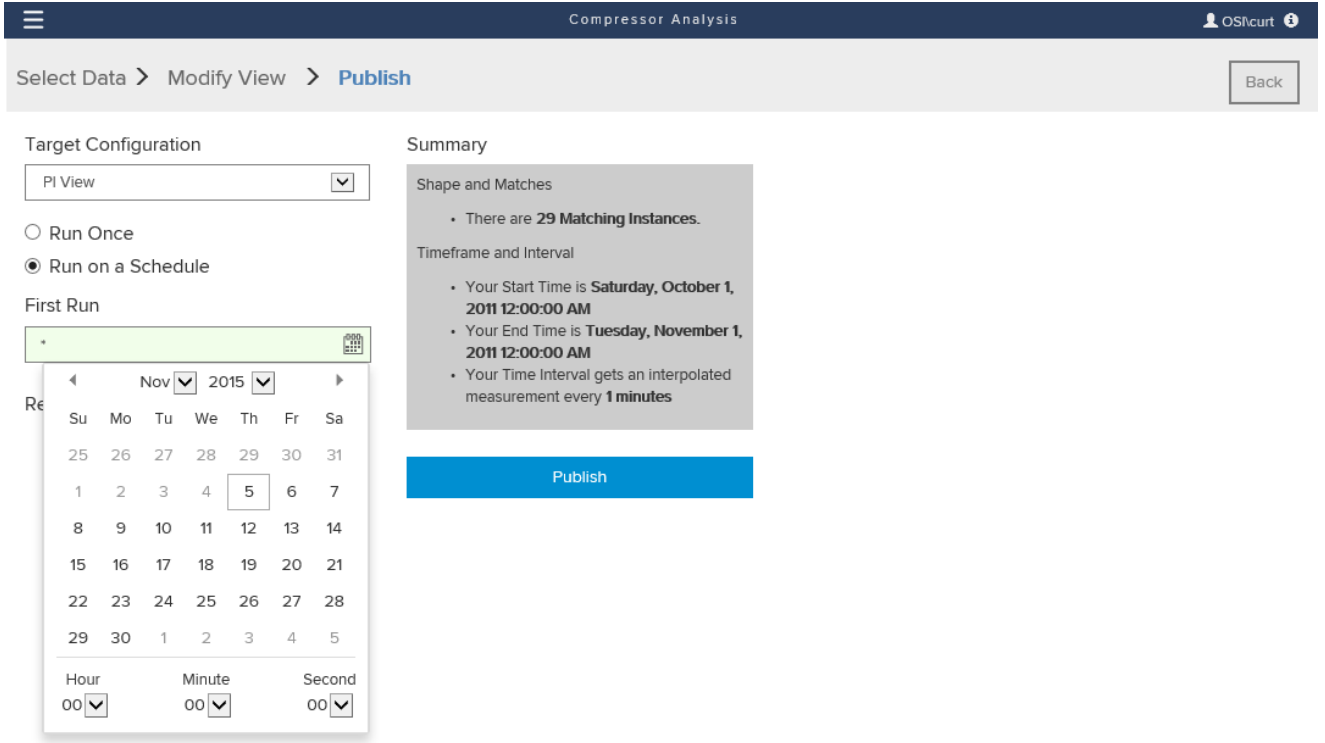
PI Integrator for Business Analytics - *"Publish"*

- Select targeted endpoint "PI View", MS SQL, File, more to come….
- Publish once or on a scheduled bases



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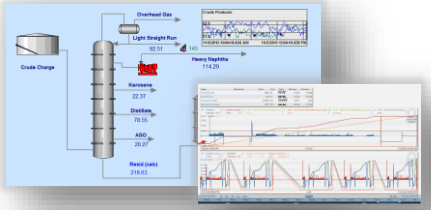
Enabling Analytics for Operational Intelligence

Real-Time Decision Analysis



Time and Event
Trending & Awareness

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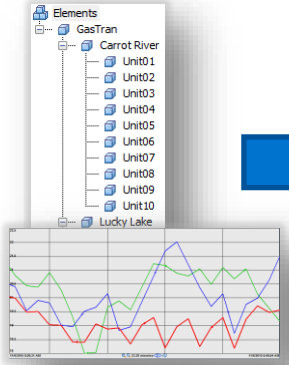
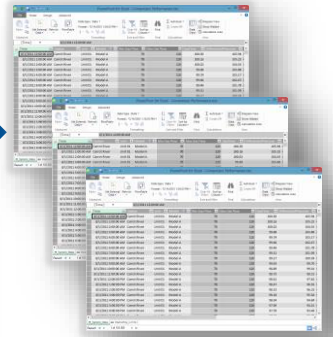
Descriptive
Performance
& Condition

PI Integrator for
Business Analytics



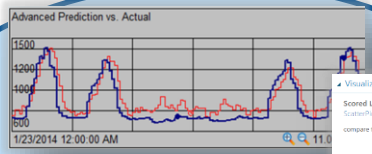
Time, Event
and Asset
Context

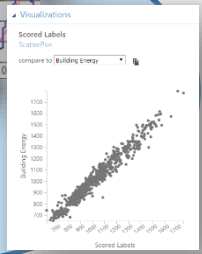


Tabular
Context

Retrospective & Predictive Analysis

Multidimensional
Business Intelligence
& Dashboards





Predictive
Statistical Modelling
& Machine Learning

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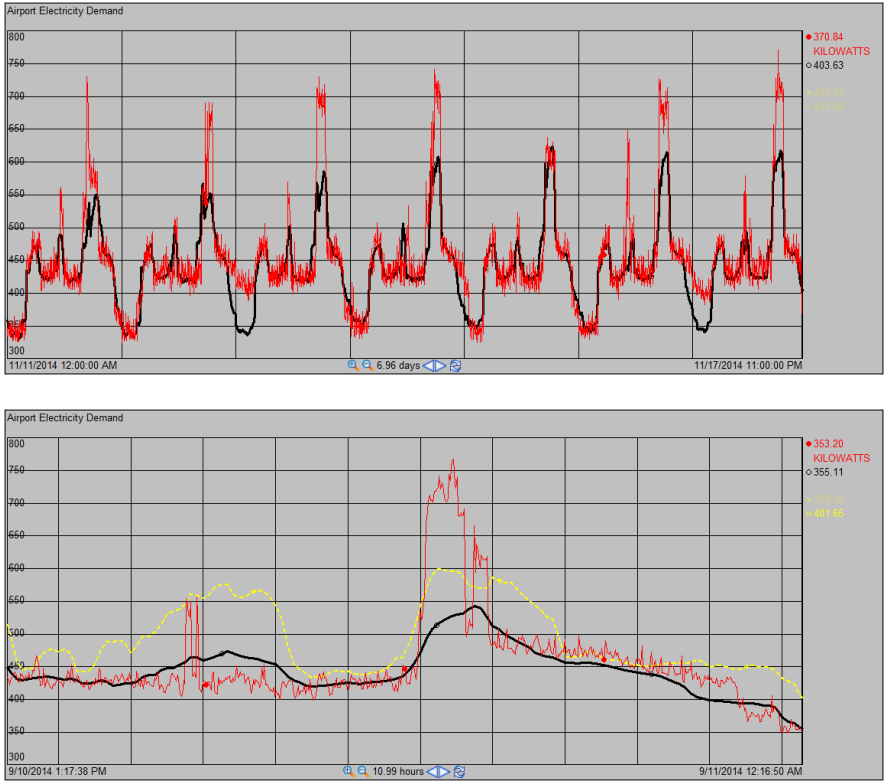
Scenario: “Predict Airport Energy Use”

Develop a model to predict energy use at San Diego Airport. This model can be used for capacity planning, and abnormal spike detection and notification.



Actual Energy Use

Predicted Energy Use

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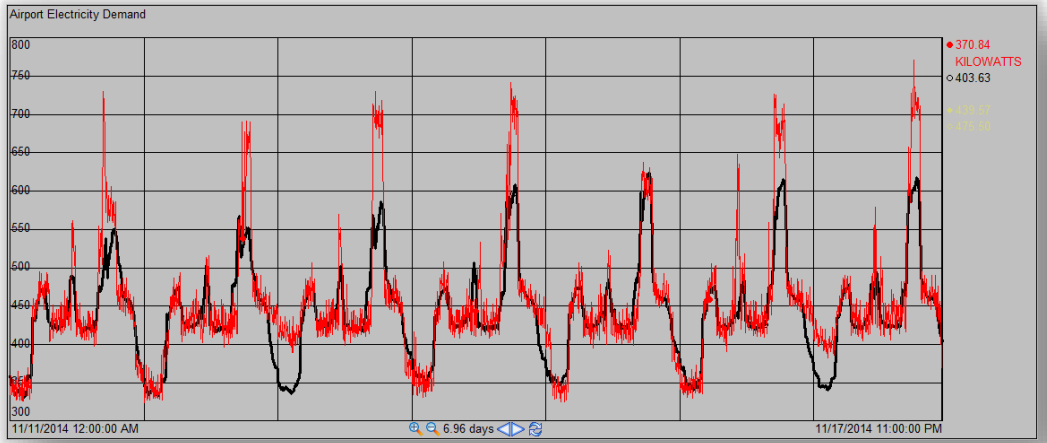
Statistical Analytics - *Example: Energy Prediction*

Predicted Power = 0.2324 * Average(**Actual Power**, 1 day ago, +/- 5 min) +
0.1421 * Average(**Actual Power**, 2 days ago, +/- 5 min) +
…….(terms for 3-13 days ago)……
0.0435 * Average(**Actual Power**, 14 days ago, +/- 5 min)

- Statistically derived equation with coefficients and time relative averages
- Configurable in PI AF with backfill to assess
- Schedule in PI AF to provide forecast - PI future data



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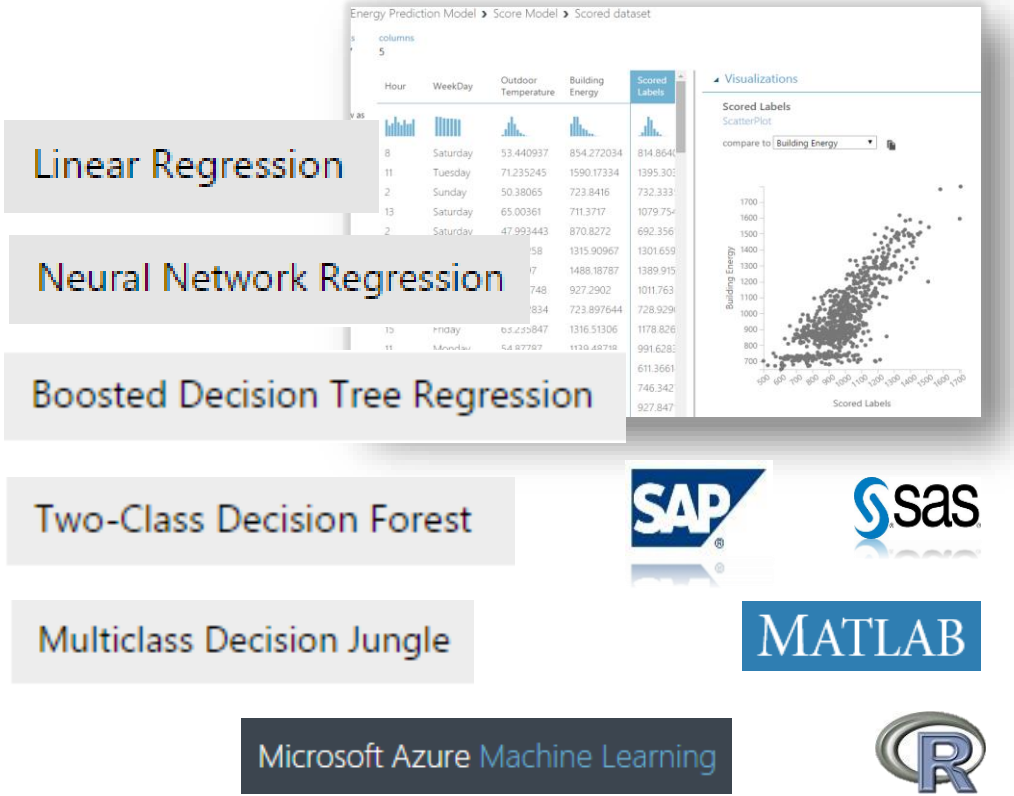
Statistical Analytics - Predictive Modelling & Machine Learning

- Complex systems where first principles equations interact or don't exist
- Empirical or "fitted" models generated from time, event and asset data in tabular context
- Predicts outcome, e.g. equipment failure, unmeasured or forecasted quantities
- Model continuously improves or "learns" with additional data



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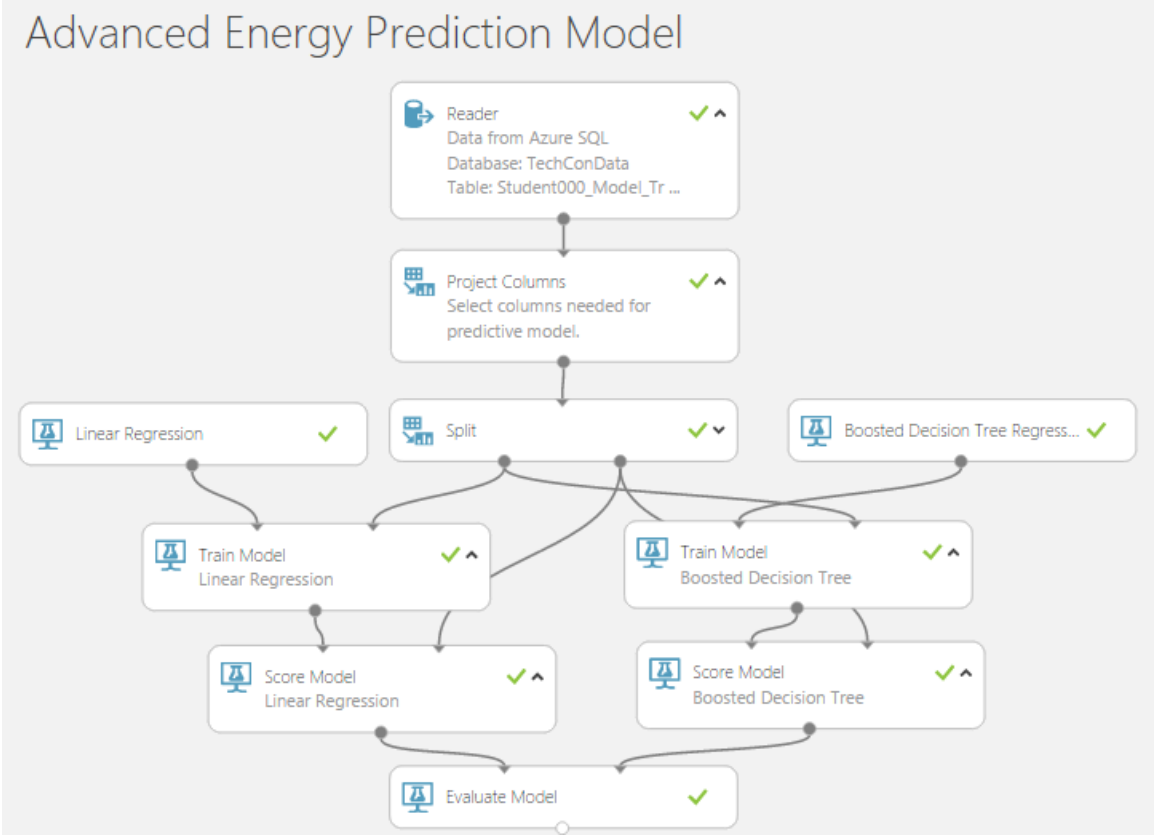
Microsoft Azure ML Studio

- Self-service data science
- Experimentation to find “best fit” prediction models
- Publish finalized models as accessible web service
- Pay as you go



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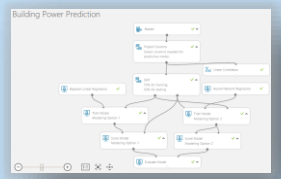
Predictive Modelling Process

Cloud Services

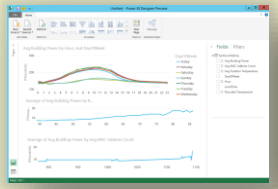
DayOfWeek	Hour	Avg Building Power	Avg MAC Address Count	Avg Outdoor Temperature
Thursday	0	1131.59375	897	76.699997
Thursday	1	1131.59375	897	76.699997
Thursday	2	1131.59375	897	76.699997
Thursday	3	1131.59375	897	76.699997
Thursday	4	1131.59375	897	76.699997

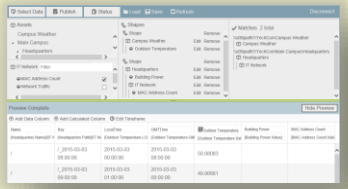


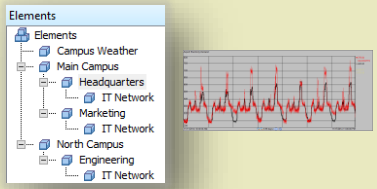
Azure SQL Database

Azure ML Studio

On Premise Applications







Power BI Designer

PI Integrator for BA
(internal Alpha)

PI System 2015

Facilities

Weather Station

IT Network

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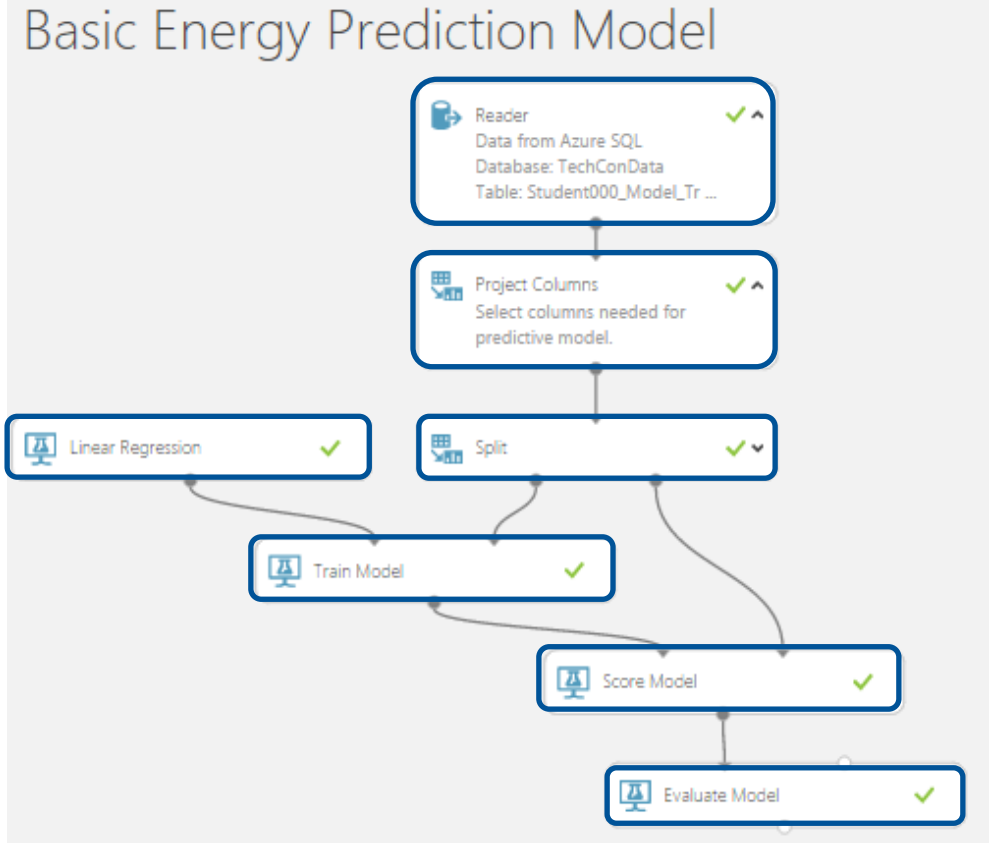
“Basic” Energy Prediction Model Experiment

- Read data from Azure SQL table
- Select model input variables
- Split data for training and testing
- Train model using a selected algorithm
- Score (Test) model
- Evaluate model



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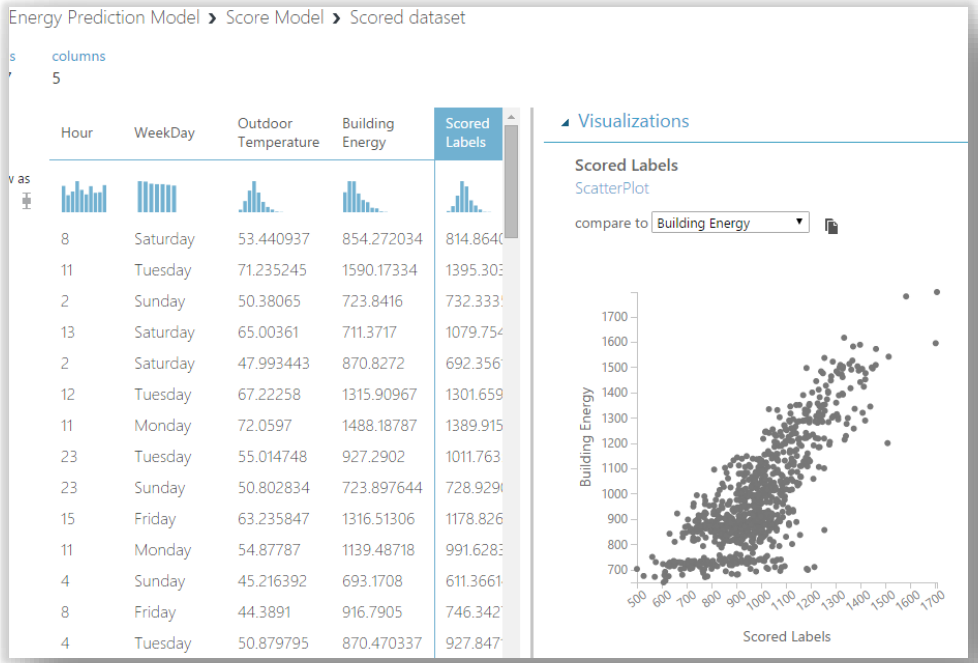
“Basic” Energy Prediction Model Evaluation Results

- Visual and Statistical Analysis of Model Scoring
- “Coefficient of Determination” a.k.a. R-Squared = 0.63

Mean Absolute Error	Root Mean Squared Error	Relative Absolute Error	Relative Squared Error	Coefficient of Determination
102.021831	126.771506	0.610971	0.37002	0.62998



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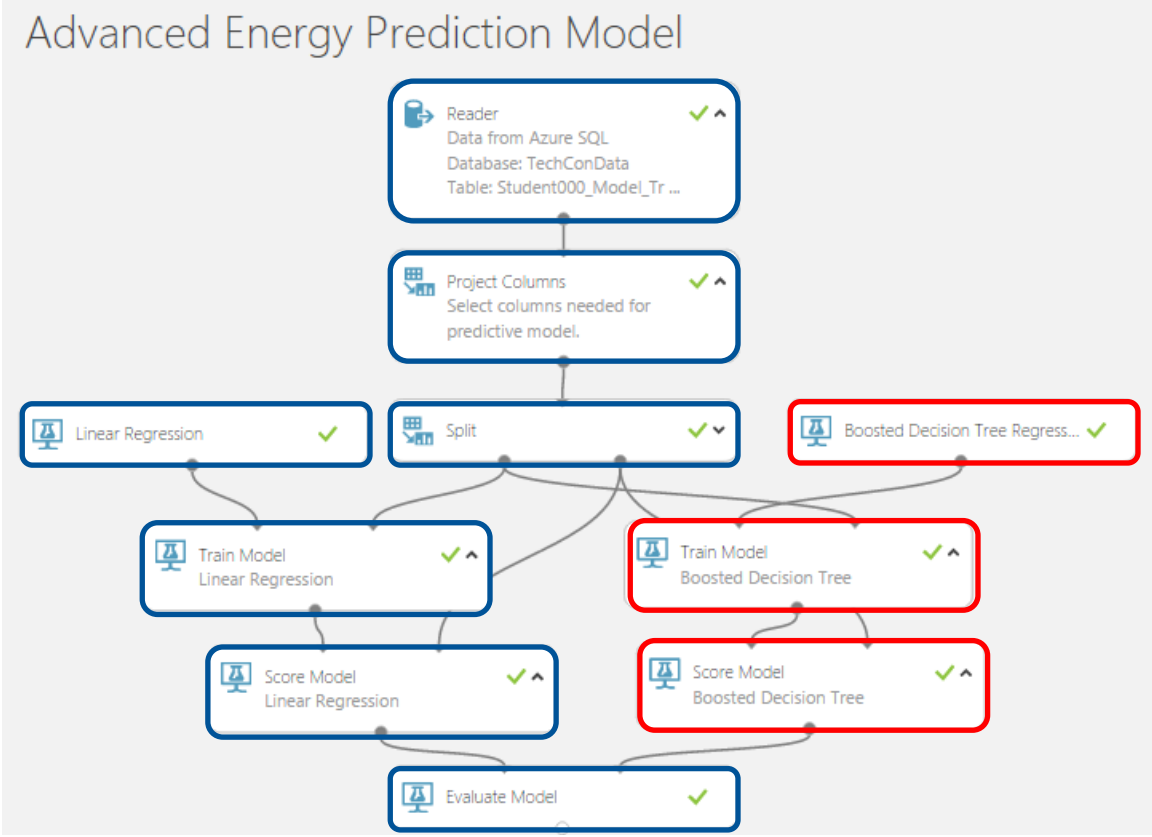
“Advanced” Energy Prediction Model Experiment

- Copy “Basic” Model
- Add “Boosted Decision Tree Regression” algorithm
- Train both algorithms with Training Dataset
- Score both models with Scoring Dataset
- Evaluate algorithms



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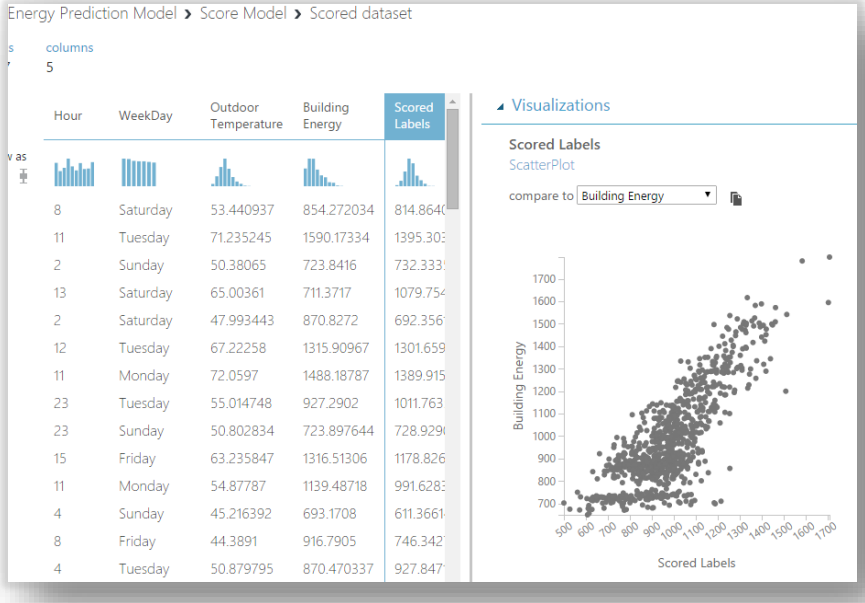
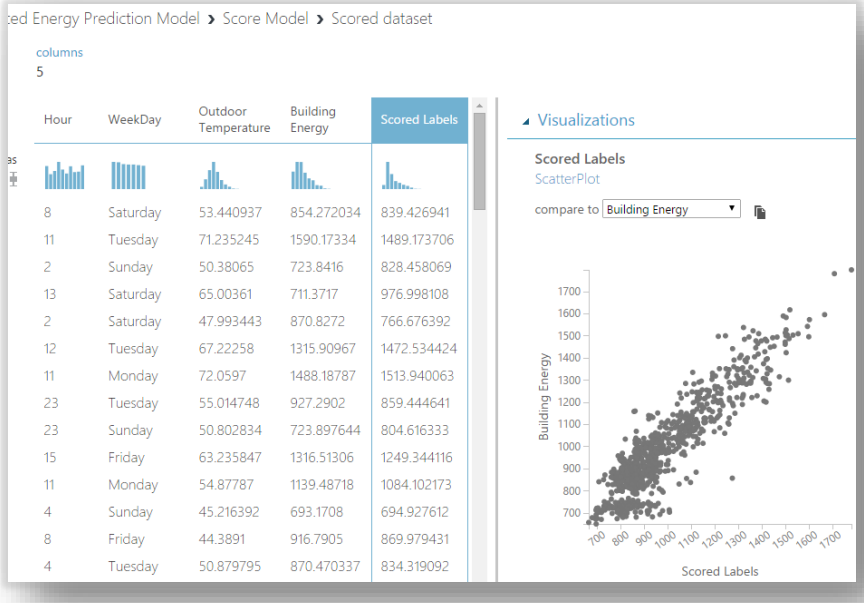
“Advanced” Energy Prediction Model Evaluation Results

“Linear Regression”
R-Squared = 0.63



“Boosted Decision Tree Regression”
R-Squared = 0.83



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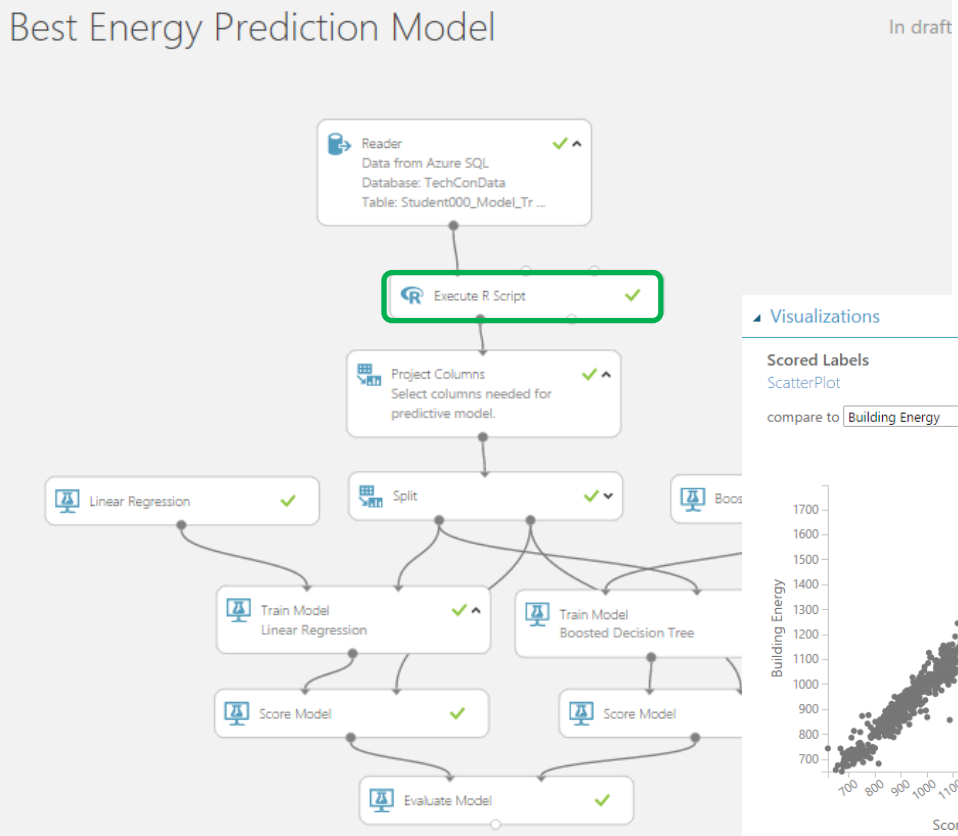
“Best” Energy Prediction Model

- Consider Seasonal Effect on Building Energy Demand
- Added feature, “Week Number” of the Year
- Insert “R” Script to “Week of Year” column
- R-Squared 0.96



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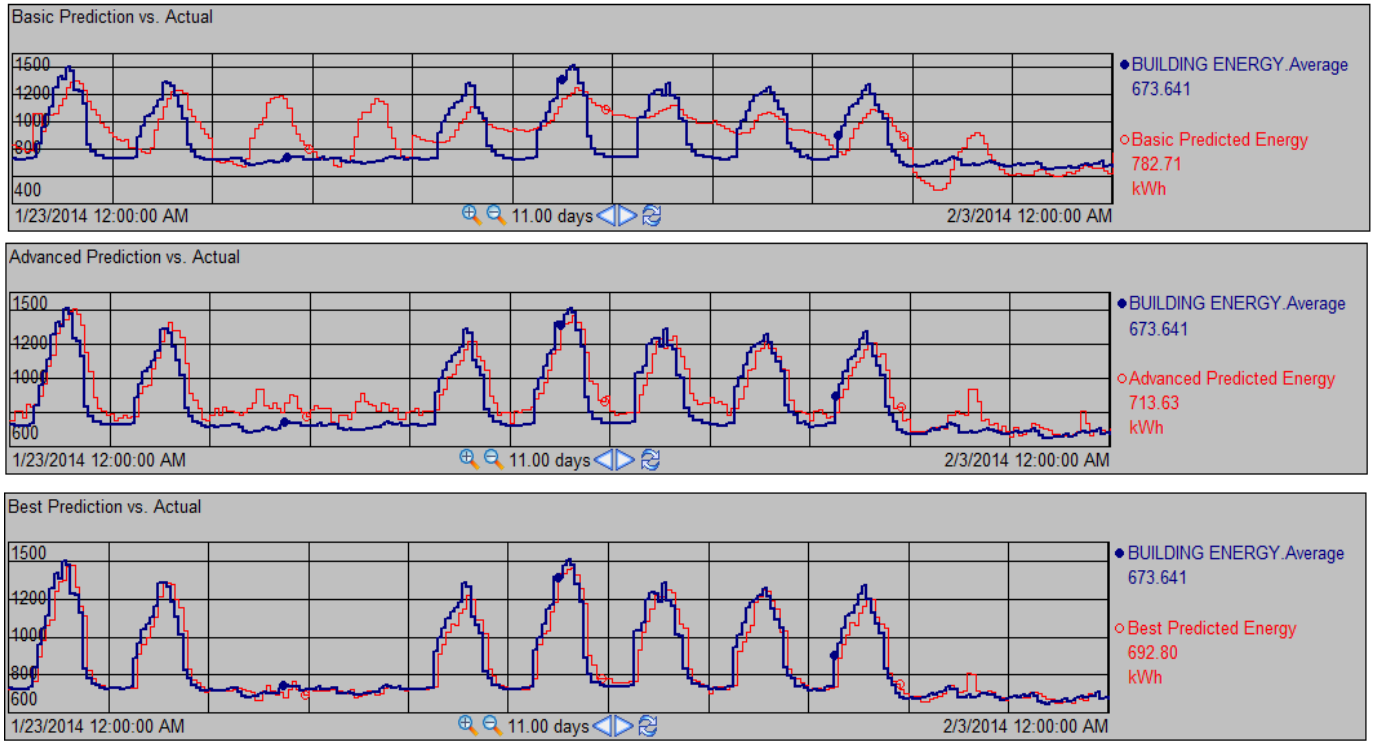
Energy Predictions in PI System 2015



R Squared
0.63

R Squared
0.83

R Squared
0.96

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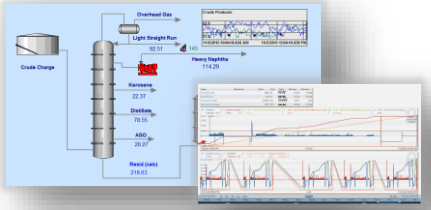
Enabling Analytics for Operational Intelligence

Real-Time Decision Analysis



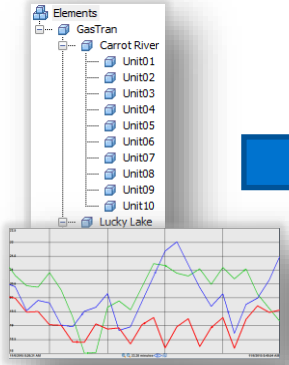
Time and Event
Trending & Awareness

Specialized Models
Simulation & Optimization

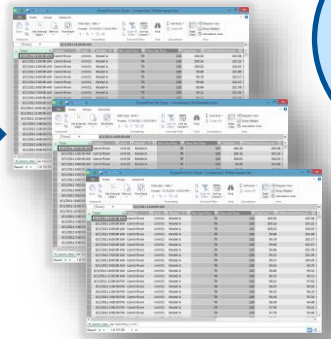
$$Q = \frac{\Delta P_{DD} * kh}{141.2 \mu B_0 \left\{ ln \frac{r_e}{r_w} - \frac{3}{4} + S \right\}}$$

Descriptive
Performance
& Condition

PI Integrator for
Business Analytics



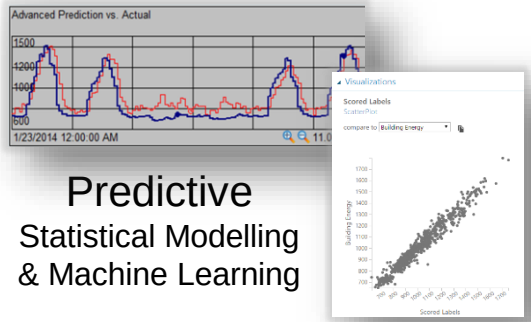
Time, Event
and Asset
Context



Tabular
Context

Retrospective & Predictive Analysis

Multidimensional
Business Intelligence
& Dashboards



Predictive
Statistical Modelling
& Machine Learning

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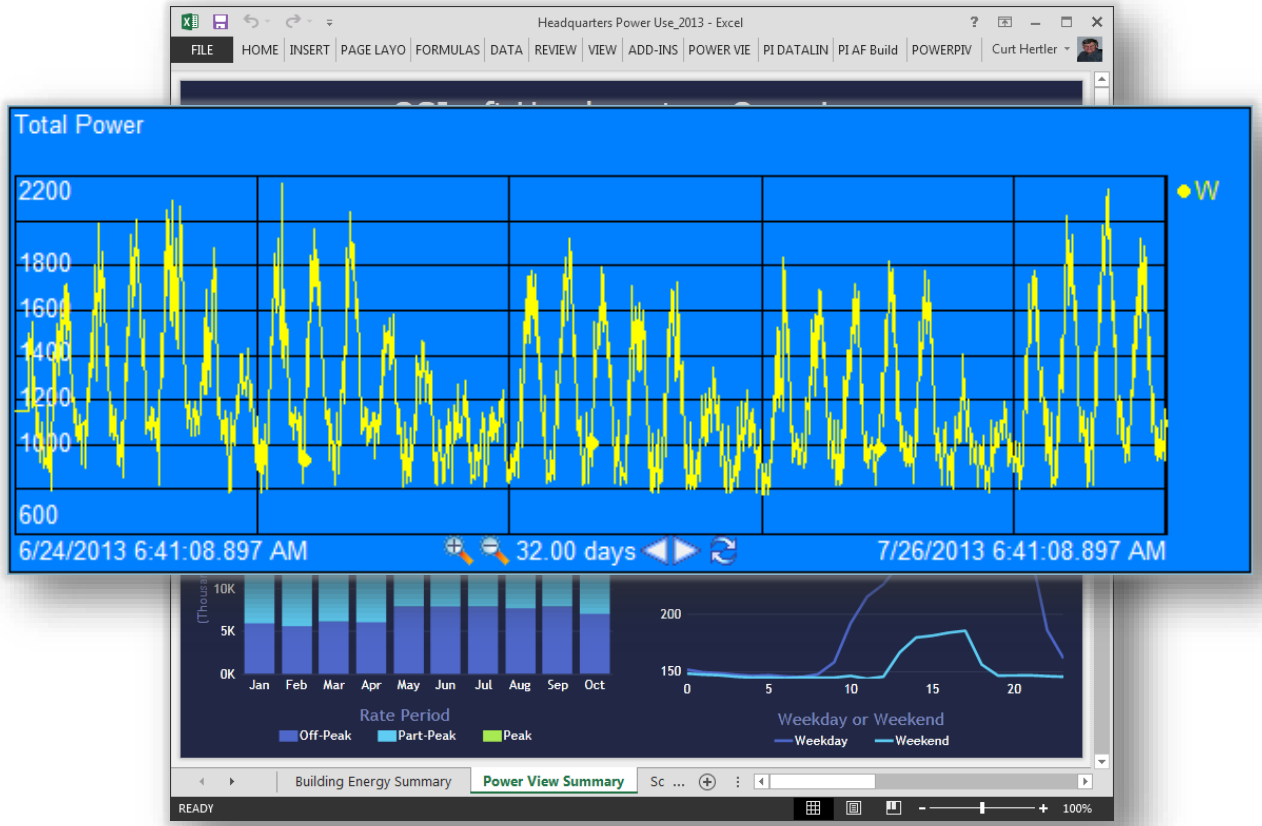
Ad Hoc Multidimensional Analysis

Power Use at OSIsoft Headquarters



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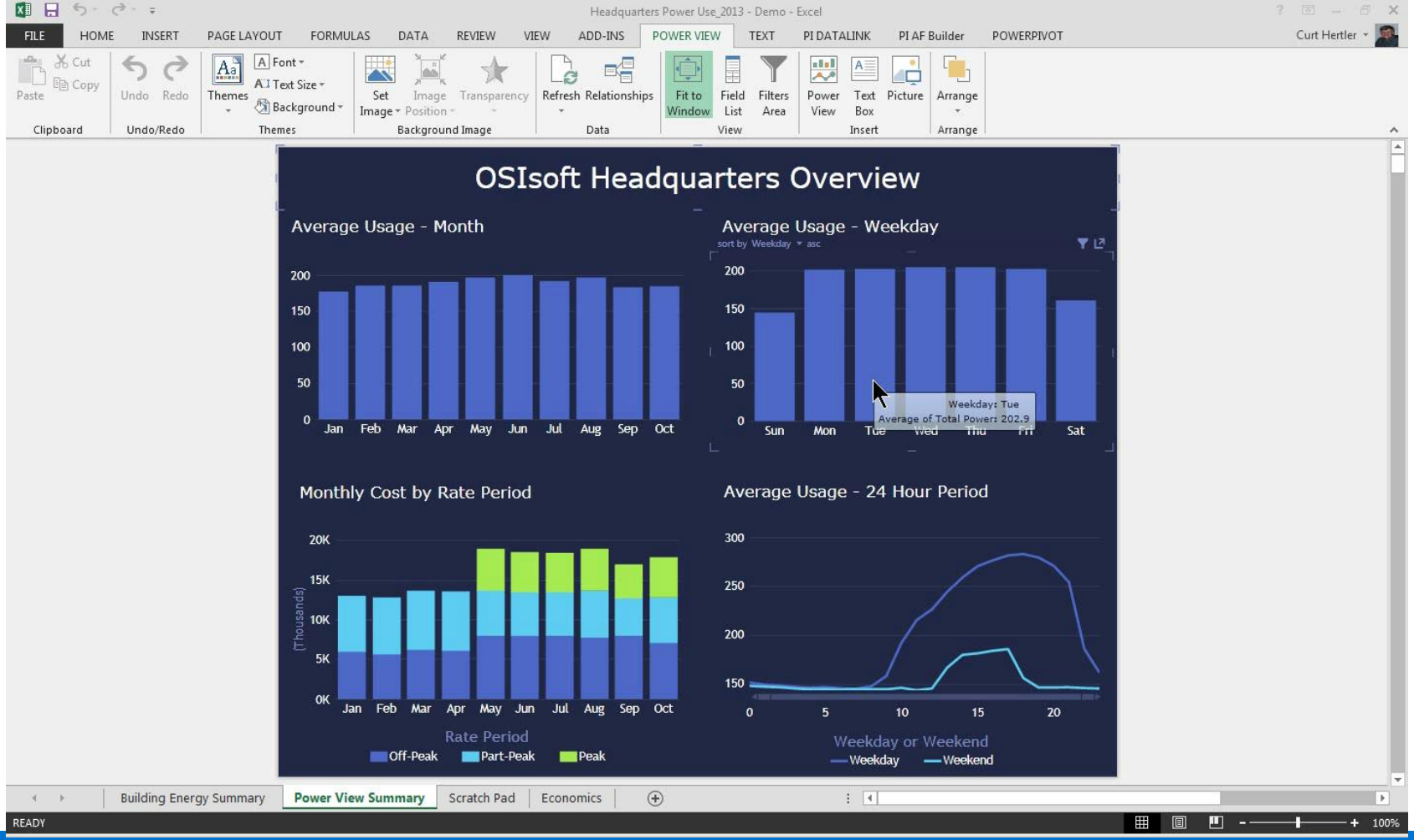

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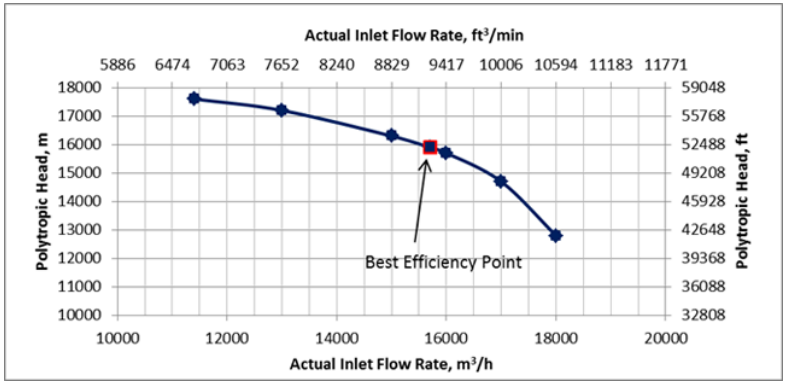
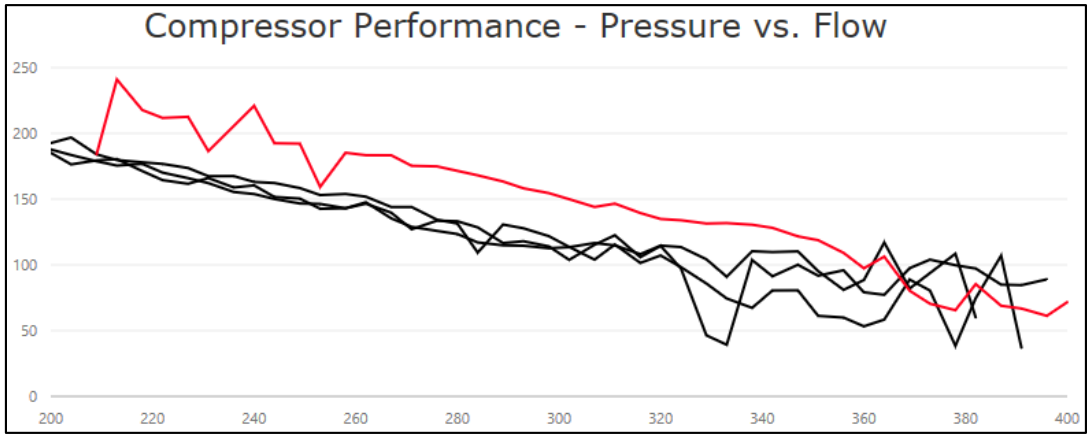
Multidimensional Analytics – Operational Intelligence

- Ad hoc, visual analysis of a table or related tables of data
- Columns aggregated for selected rows, presenting results in a variety of ways
- Excellent tools for personal analysis and enterprise reporting and dashboards





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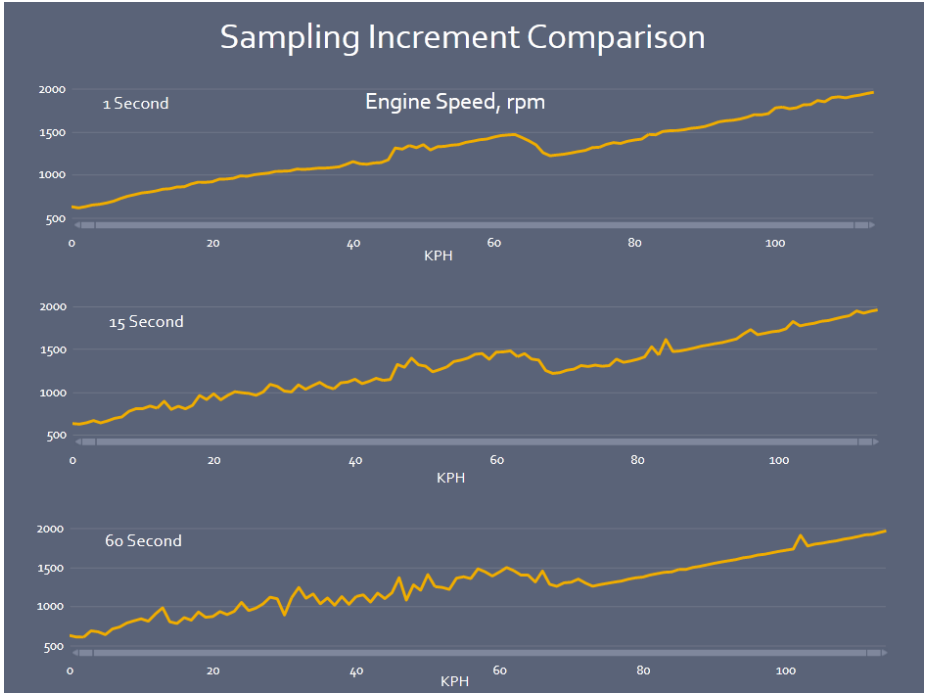
Multidimensional Analytics – Time Contextualization

Flexible, repeatable access to high fidelity operational data

- Time relative aggregations and statistics at any interval
- Juxtaposition of values - published rows can contain previous row's value.
- Backfill First Principle facts as best practice



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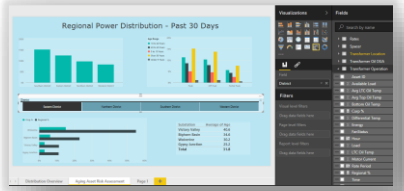
Driving Continuous Improvement

Content

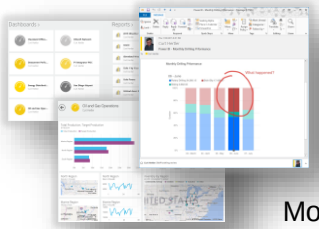
Organizational Insight

Access



Personal Analytics & Assessment

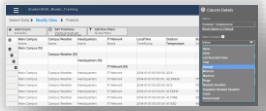
Collaborative Intelligence



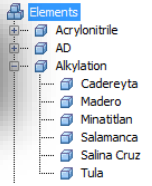
Mobility & Socialization

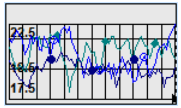
Data with Context

Operational Awareness



PI Integrator for BA





PI System

Action

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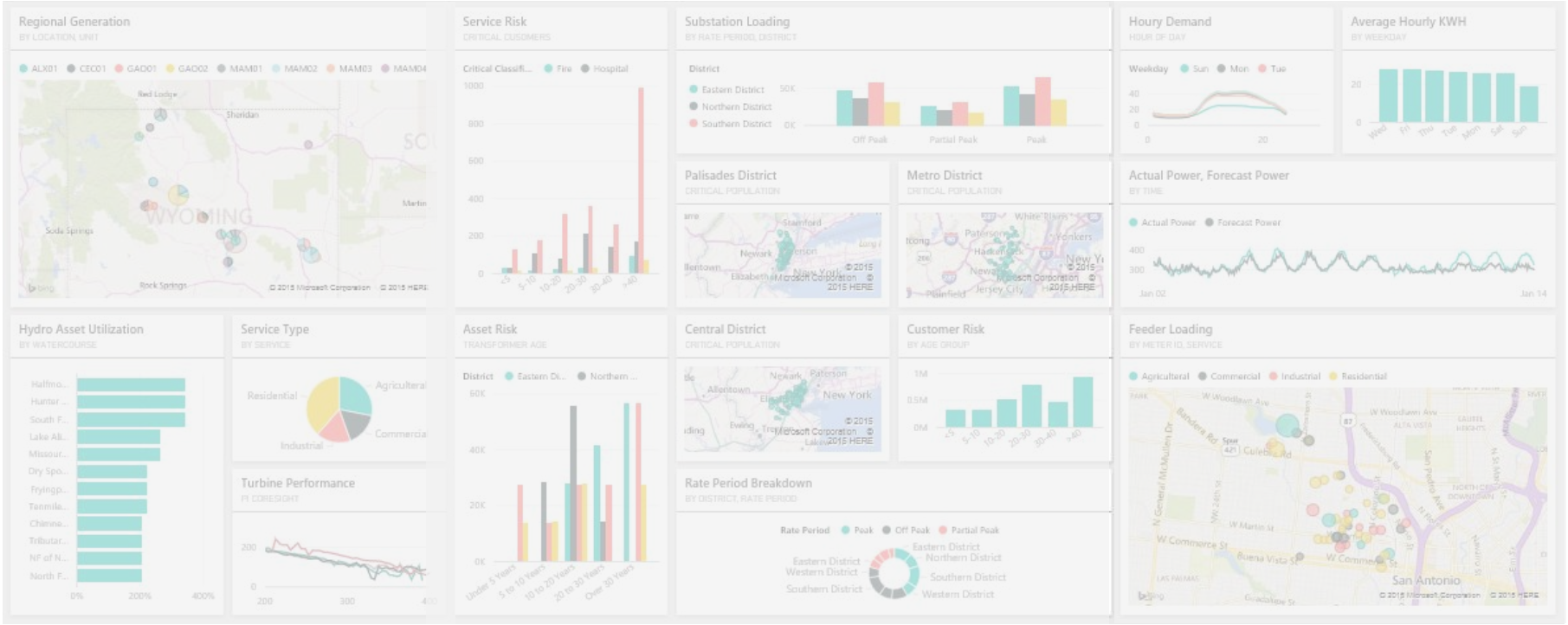
Enterprise Performance Summary



Generation | Substations | Distribution

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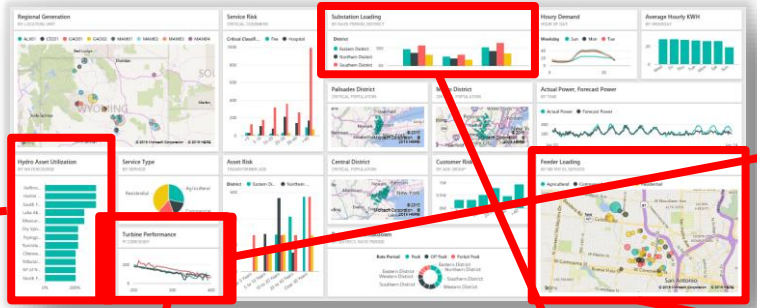
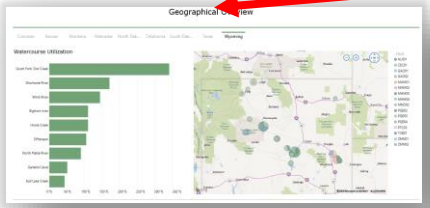
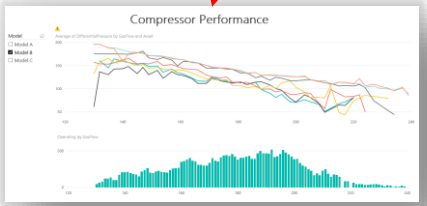
Detailed Reporting and Analytics

Dashboard drilldown to detailed reports

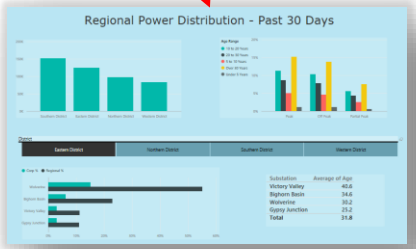




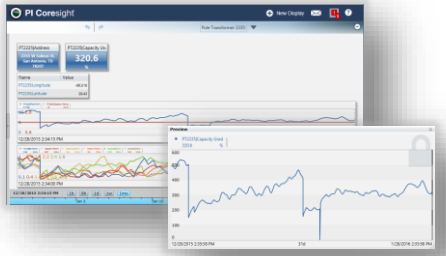
Generation Demographics



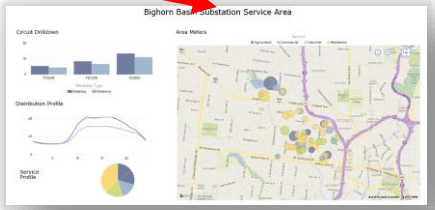
Asset Performance



Substation Performance



PI Coresight



Feeder Loading

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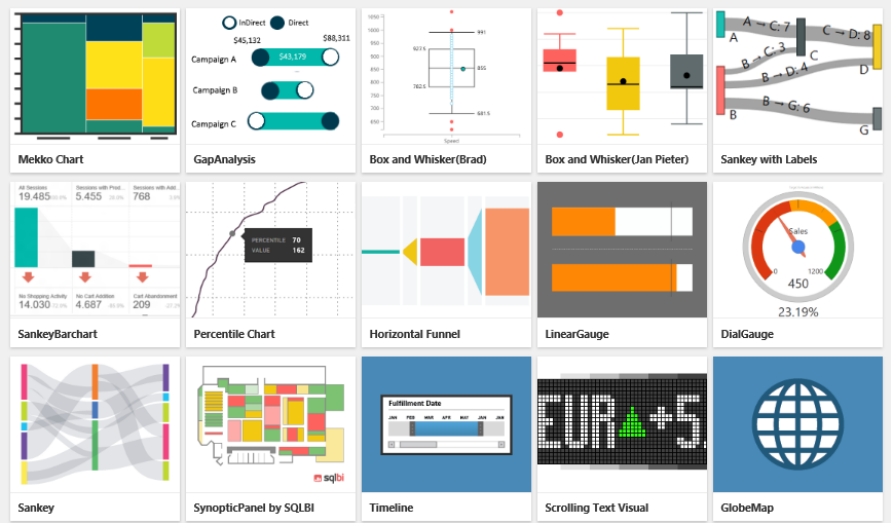
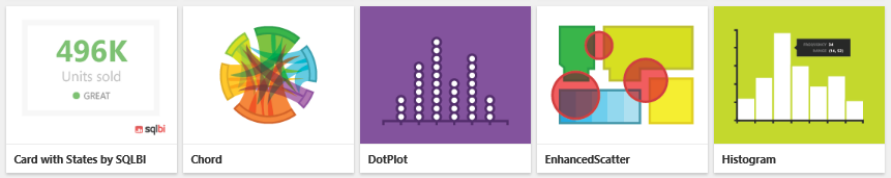
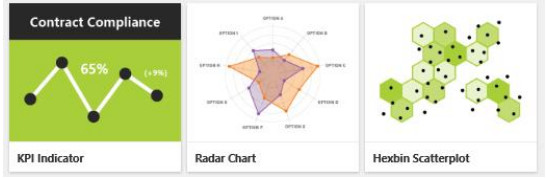
Custom Visuals Gallery







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Summary and Wrap Up

- The PI System enables all types of operational analytics by providing time-related data supported by the essential foundation provided by PI Asset Framework.

- Look holistically when selecting an analytical method or methods. PI Analytics is very capable of performing equation-base analytics for performance and conditions assessment, as well as, certain types of predictive analytics.

- The PI Integrator for BA establishes “Common Ground” between OT and IT contextualization for enabling the Intelligence enterprise.

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Resources

- OSIsoft Learning Channel on YouTube - “PI Integrator for Business Analytics”
- PI Square Community – “Asset Based PI Example Kit”
  - https://pisquare.osisoft.com
- Azure Machine Learning
  - https://studio.azureml.net
- Power BI Desktop
  - https://powerbi.microsoft.com/desktop
- Power BI Desktop Visuals Gallery
  - https://app.powerbi.com/visuals
- On-Line Courses
  - https://www.edx.org

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Questions

Please wait for the **microphone** before asking your questions

State your **name & company**

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Thank You