“Rationalization of What and Where” for Advanced Analytics in an IIOT and Big Data World

Curt Hertler, Global Solutions Architect, OSIsoft

Teradata - *Data Warehouse*

- 1976–1979: concept of Teradata grows from research at ***California Institute of Technology*** (Caltech) and from the discussions of ***Citibank's*** advanced technology group.
- 1984: Teradata releases the world's ***first parallel data warehouses and data marts***.
- 1986: Fortune Magazine names Teradata ***"Product of the Year."***
- 1992: Teradata creates the first system over ***1 terabyte***, which goes live at ***Wal-Mart***.
- 1997: Teradata customer creates world's largest production database at ***24 terabytes***.
- 1999: Teradata customer has world's largest database with ***130 terabytes***.
- 2014: Teradata acquires Rainstor, a company specializing in online ***big data archiving on Hadoop***.

https://en.wikipedia.org/wiki/Teradata#History

Hadoop - *Wide Search of Everything*

- The genesis of Hadoop came from the ***Google*** File System paper that was published in ***October 2003***.

- This paper spawned another research paper from Google – MapReduce: Simplified Data Processing on Large Clusters.

- Development started in the Apache Nutch project, but was moved to the new Hadoop subproject in January 2006. Doug Cutting, who was working at ***Yahoo!*** at the time, ***named it after his son's toy elephant***.

https://en.wikipedia.org/wiki/Apache_Hadoop#History

In-Memory Columnar processing - *Tabular based analytics*

Company	Product	Description
IBM	Informix	Supports Dynamic In-memory (***in-memory columnar processing***) Parallel Vector Processing, Actionable Compression, and Data Skipping technologies, collectively called "Blink Technology" by IBM. Released: March 2011.
IBM	DB2 BLU	IBM DB2 for Linux, UNIX and Windows supports dynamic in-memory (***in-memory columnar processing***) parallel vector processing, actionable compression, and data-skipping technologies, collectively called IBM BLU Acceleration by IBM.
Microsoft	SQL Server	SQL Server 2012 included an ***in-memory*** technology called xVelocity ***column-store*** indexes targeted for data-warehouse workloads.
SAP	HANA	Short for 'High Performance Analytic Appliance' is an ***in-memory, column-oriented***, relational database management system written in C, C++.

https://en.wikipedia.org/wiki/List_of_in-memory_databases

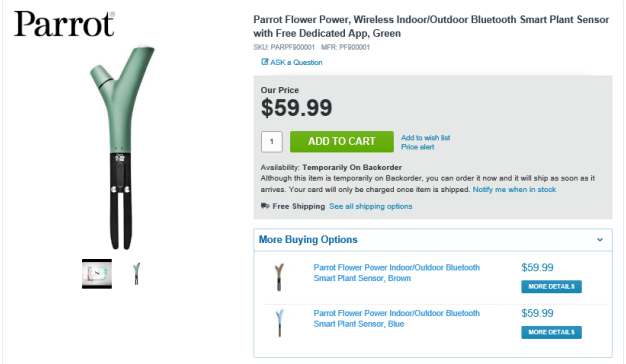
Power Pivot for Excel - *Self Service, Large Data Analytics*

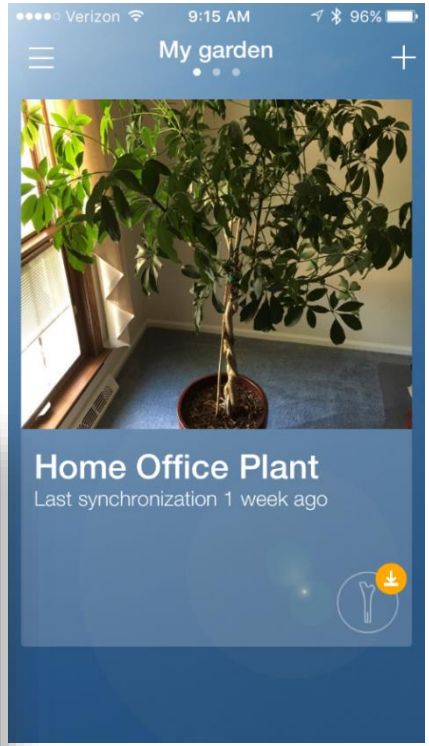
Power Pivot is a feature of Microsoft Excel. It is ***available as an add-in in Excel 2010 and 2013, and is included natively in Excel 2016***. PowerPivot extends a local instance of Microsoft Analysis Services Tabular that is embedded directly into an Excel Workbook.

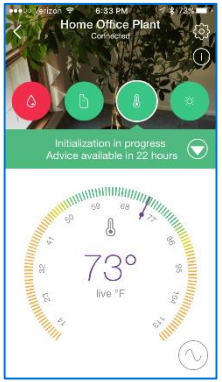
PowerPivot uses the SSAS Vertipaq compression engine to hold the data model ***in memory on the client computer***. Practically, this means that PowerPivot is acting as an ***Analysis Services Server instance on the local workstation***.

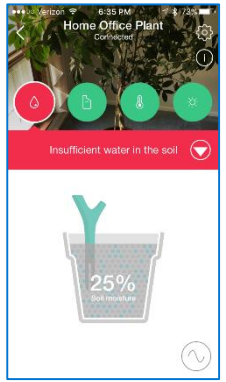
https://en.wikipedia.org/wiki/Power_Pivot

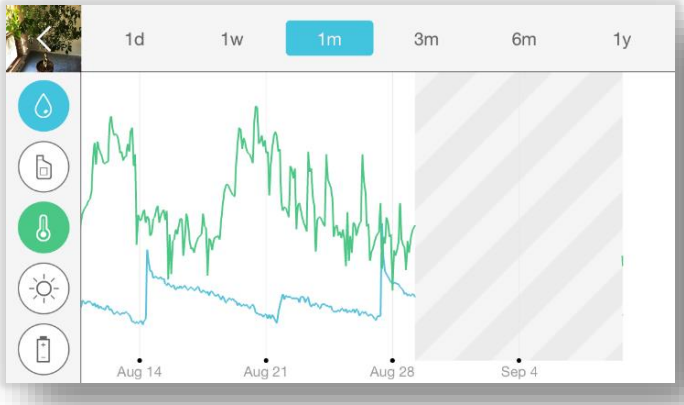
Internet of Things - *This means all things!*

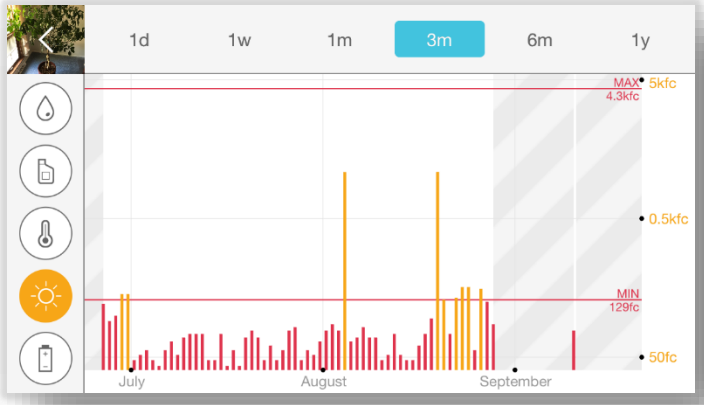






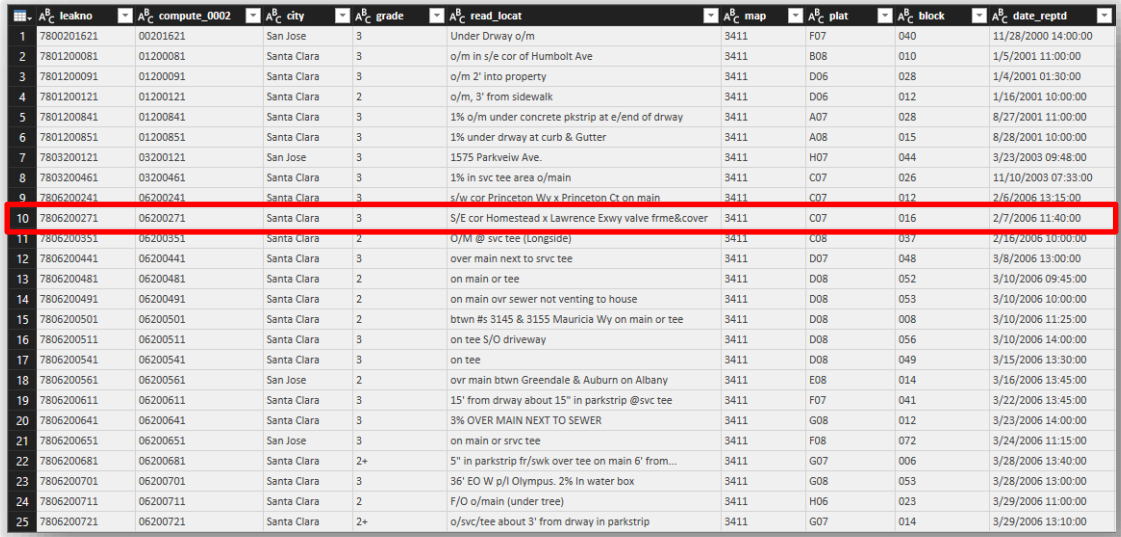






Real Time Data is Different

- Transactional data is recorded in a tabular format with values associated by columns in each row.



	leakno	compute_0002	city	grade	read_locat	map	plat	block	date_reptd
1	7800201621	00201621	San Jose	3	Under Drway o/m	3411	F07	040	11/28/2000 14:00:00
2	7801200081	01200081	Santa Clara	3	o/m in s/e cor of Humbolt Ave	3411	B08	010	1/5/2001 11:00:00
3	7801200091	01200091	Santa Clara	3	o/m 2' into property	3411	D06	028	1/4/2001 01:30:00
4	7801200121	01200121	Santa Clara	2	o/m, 3' from sidewalk	3411	D06	012	1/16/2001 10:00:00
5	7801200841	01200841	Santa Clara	3	1% o/m under concrete pkstrip at e/end of drway	3411	A07	028	8/27/2001 11:00:00
6	7801200851	01200851	Santa Clara	3	1% under drway at curb & Gutter	3411	A08	015	8/28/2001 10:00:00
7	7803200121	03200121	San Jose	3	1575 Parkveiw Ave.	3411	H07	044	3/23/2003 09:48:00
8	7803200461	03200461	Santa Clara	3	1% in svc tee area o/main	3411	C07	026	11/10/2003 07:33:00
9	7806200241	06200241	Santa Clara	3	s/w cor Princeton Wy x Princeton Ct on main	3411	C07	012	2/6/2006 13:15:00
10	7806200271	06200271	Santa Clara	3	S/E cor Homestead x Lawrence Exwy valve frme&cover	3411	C07	016	2/7/2006 11:40:00
11	7806200351	06200351	Santa Clara	2	O/M @ svc tee (Longside)	3411	C08	037	2/16/2006 10:00:00
12	7806200441	06200441	Santa Clara	3	over main next to srvc tee	3411	D07	048	3/8/2006 13:00:00
13	7806200481	06200481	Santa Clara	2	on main or tee	3411	D08	052	3/10/2006 09:45:00
14	7806200491	06200491	Santa Clara	2	on main ovr sewer not venting to house	3411	D08	053	3/10/2006 10:00:00
15	7806200501	06200501	Santa Clara	2	btwn #s 3145 & 3155 Mauricia Wy on main or tee	3411	D08	008	3/10/2006 11:25:00
16	7806200511	06200511	Santa Clara	3	on tee S/O driveway	3411	D08	056	3/10/2006 14:00:00
17	7806200541	06200541	Santa Clara	3	on tee	3411	D08	049	3/15/2006 13:30:00
18	7806200561	06200561	San Jose	2	ovr main btwn Greendale & Auburn on Albany	3411	E08	014	3/16/2006 13:45:00
19	7806200611	06200611	Santa Clara	3	15' from drway about 15" in parkstrip @svc tee	3411	F07	041	3/22/2006 13:45:00
20	7806200641	06200641	Santa Clara	3	3% OVER MAIN NEXT TO SEWER	3411	G08	012	3/23/2006 14:00:00
21	7806200651	06200651	San Jose	3	on main or srvc tee	3411	F08	072	3/24/2006 11:15:00
22	7806200681	06200681	Santa Clara	2+	5" in parkstrip fr/swk over tee on main 6' from...	3411	G07	006	3/28/2006 13:40:00
23	7806200701	06200701	Santa Clara	3	36' EO W p/l Olympus. 2% In water box	3411	G08	053	3/28/2006 13:00:00
24	7806200711	06200711	Santa Clara	2	F/O o/main (under tree)	3411	H06	023	3/29/2006 11:00:00
25	7806200721	06200721	Santa Clara	2+	o/svc/tee about 3' from drway in parkstrip	3411	G07	014	3/29/2006 13:10:00

- Real-time data is recorded with only time context, i.e. value and timestamp.

56.902 03-SEP-2016 11:23 AM

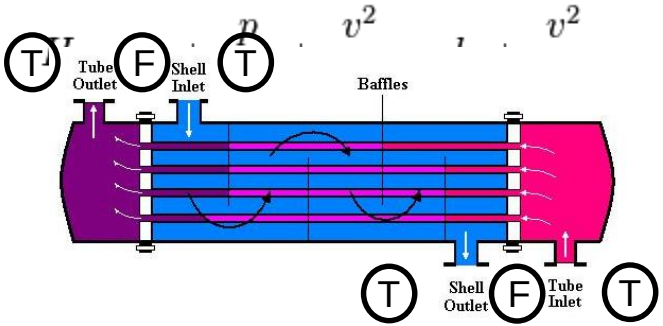
Real-time Data Requires Context

Time

63.781 03-SEP-2016 11:19 AM → 56.902 03-SEP-2016 11:23 AM → 58.341 03-SEP-2016 11:41 AM

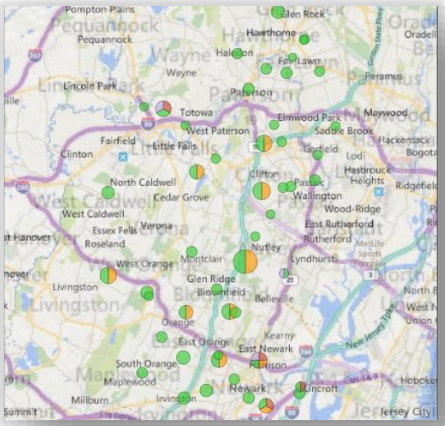
Asset

Scientific Fact



Daniel Bernoulli
(1700 – 1782)

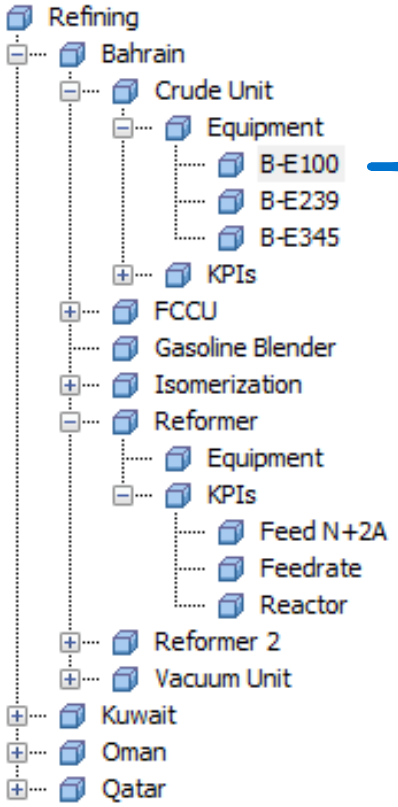
Location



PI AF Supplies Required Context

Asset Hierarchy

- Plant
- Process
- Assets
- Process Context
- Location
- Specifications



Process Context

Category: Process Data	
Cold Side Inlet Temperature	77.1157989501953 °F
Cold Side Outlet Temperature	131.192291259766 °F
Hot Side Inlet Temperature	374.601501464844 °F
Hot Side Outlet Temperature	292.926361083984 °F

Location

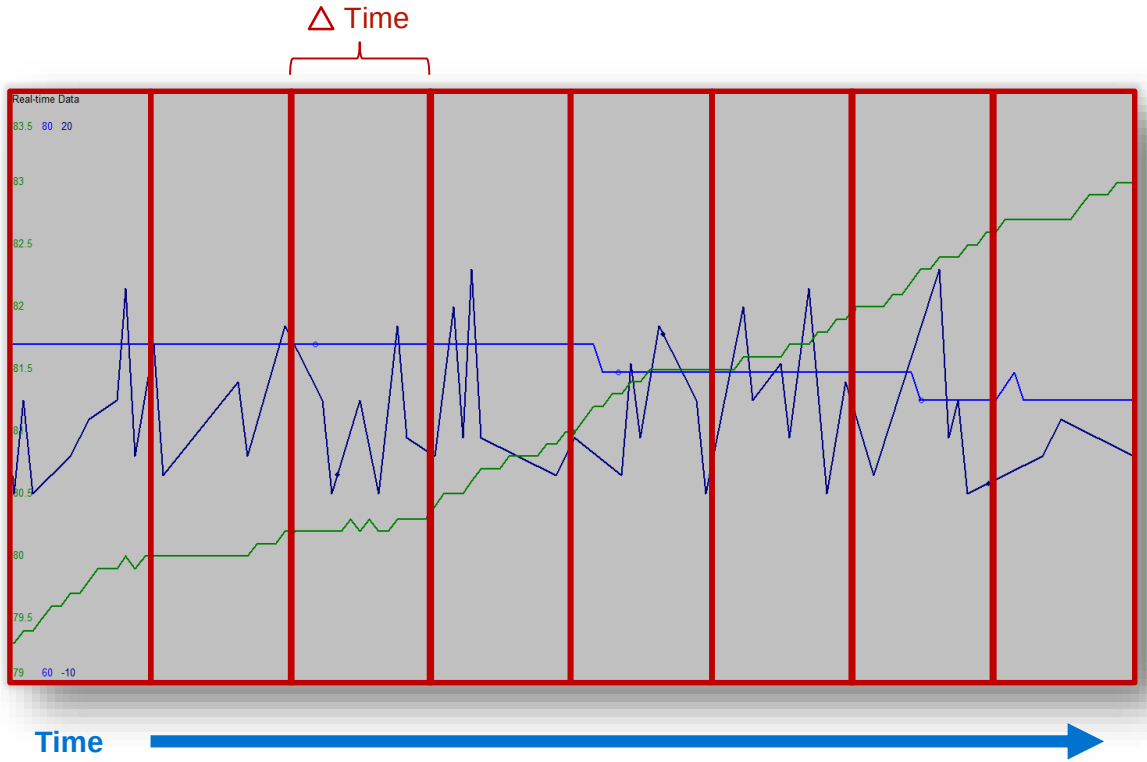
Category: Location	
Address	2265 W Salinas St, San ...
Latitude	29.43027
Longitude	-98.518172

Specifications

Category: Specifications	
Area	1200 ft2
Coefficient	75.66 BTU per F ft2 Hr
Service	Crude vs. Naphtha

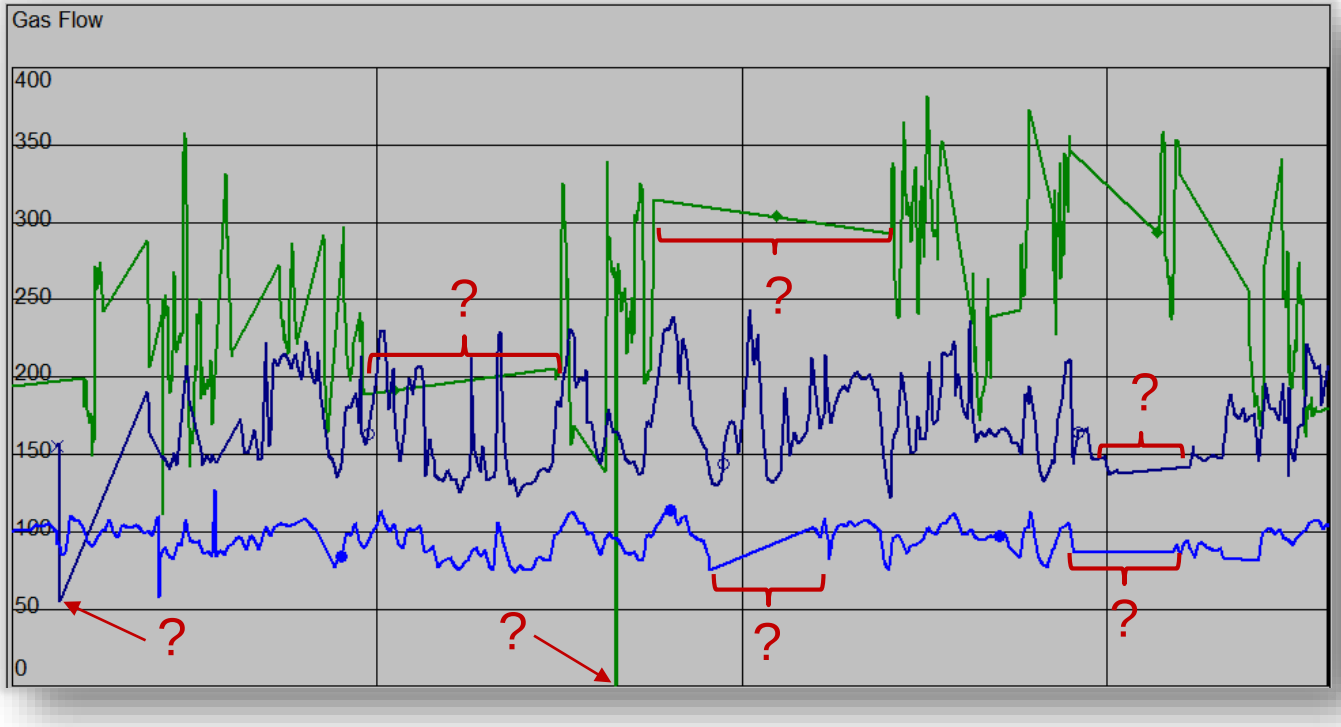
Real-time Data Requires Proper Aggregation

- Optimized for Operations, along the time-dimension for agile performance and access.
- Interpolations and time-weighted aggregations are required to fit tabular formatting requirements.



Real-time Data Never Stops

- Equipment failure ?
- Sensor failure ?
- Process upset ?

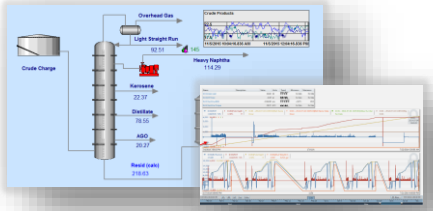


Enabling Analytics for Operational Intelligence

Real-Time Decision Analysis

Retrospective & Predictive Analysis

PI Integrator for Business Analytics

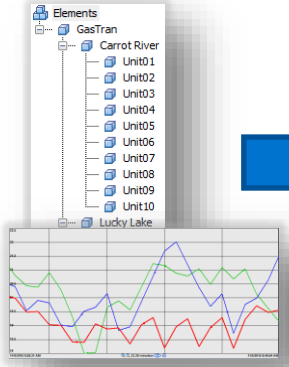


Time and Event
Trending & Awareness

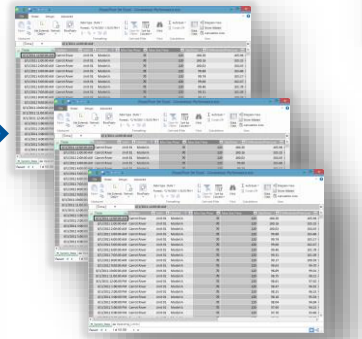
Specialized Models
Simulation & Optimization

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

Descriptive
Condition & Performance

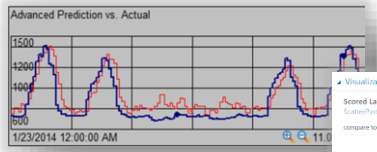


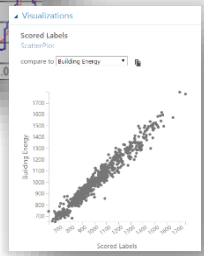
Time, Event and Asset Context



Tabular Context

Visual
Dashboards &
Multidimensional Assessment





Predictive
Statistical Modelling
& Machine Learning

Common Ground between Technological Contexts

Descriptive Analytics – Condition & *Performance*

- First Principle Relationships that ***always*** exists between process measurements.
- Enables real-time decision making only when visible, i.e. not performed in spreadsheets.
- Operations ownership requires transparency of methods, assumptions, and frequency.

Daniel Bernoulli
(1700 – 1782)

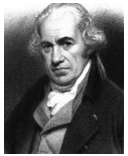
$$H = z + \frac{p}{\rho g} + \frac{v^2}{2g} = h + \frac{v^2}{2g}$$

Benoît Clapeyron
(1799 – 1864)

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

$$PV = nRT$$

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

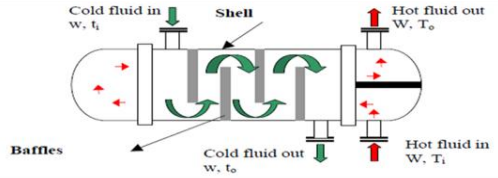


James Watt
(1736–1819)

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

First Principles Analytics - *PI Asset Analytics*

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



Heat Exchanger Key Performance Indicator:

Overall heat transfer coefficient

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

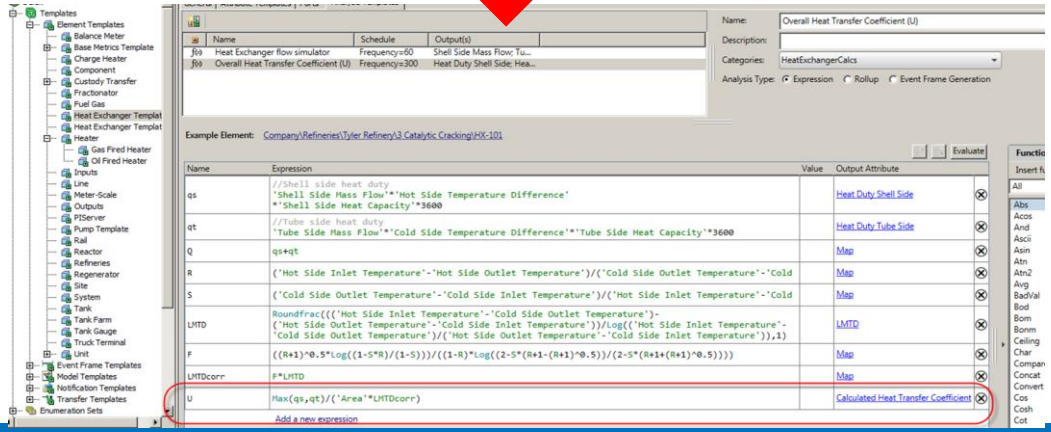
RULE: *IF the heat transfer coefficient is decreasing, THEN the* ***Heat Exchanger FOULING*** *!!! Cleaining is required!*

Calculation Steps:

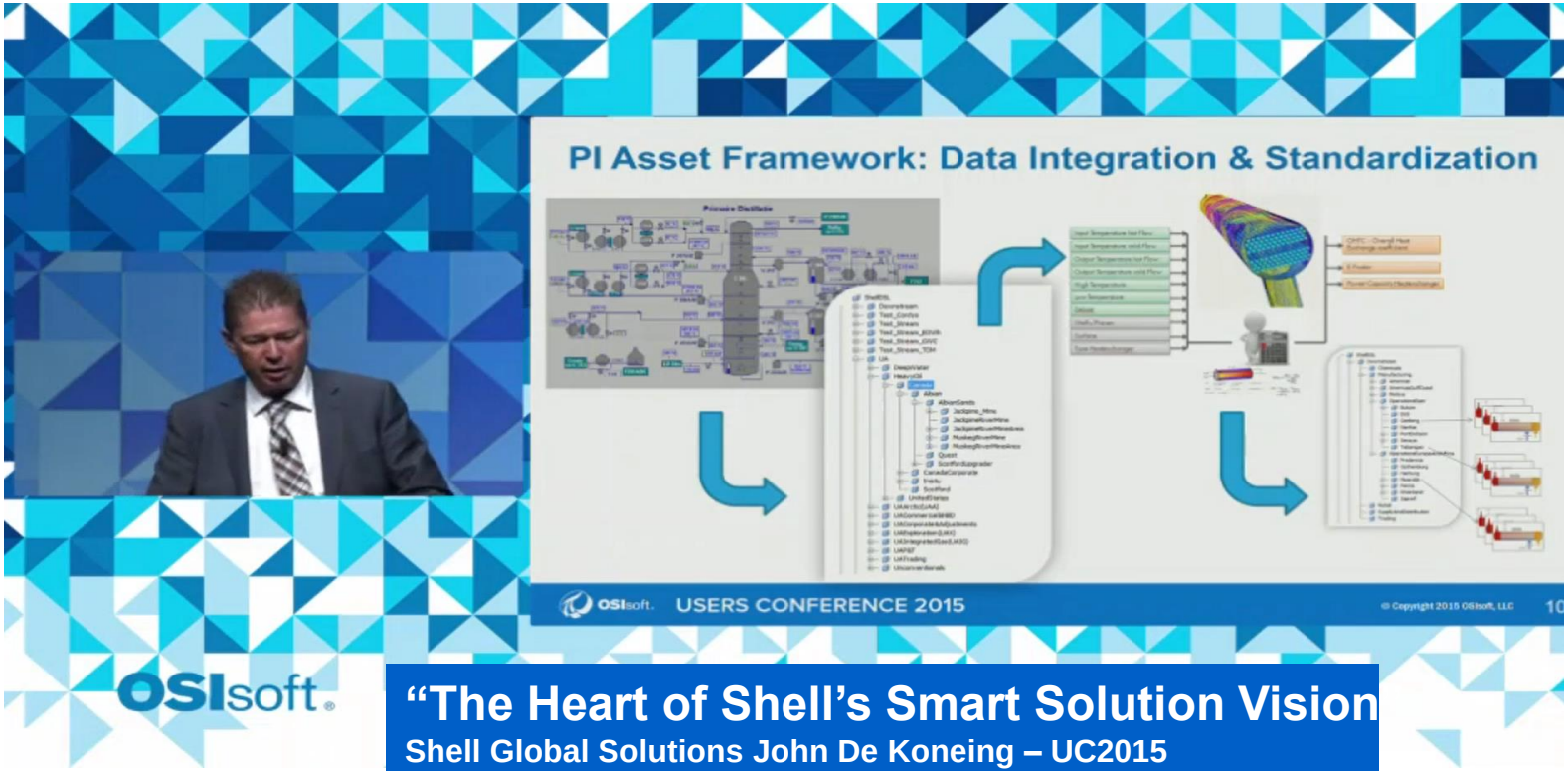
1. Heat Duty, $Q = q_s + q_t$
   $q_s = W \times C_{ph} \times (T_i - T_o)/1000/3600$
   $q_s = w \times C_{pc} \times (t_o - t_i)/1000/3600$
2. Hot Fluid Pressure Drop, $\Delta P_h = P_i - P_o$
3. Cold fluid pressure drop, $\Delta P_c = p_i - p_o$
4. Temperature range hot fluid, $\Delta T = T_i - T_o$
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

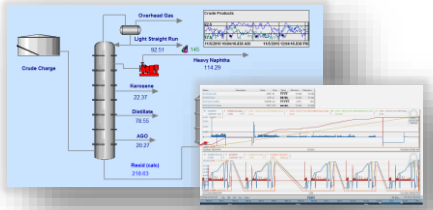


500 PI AF Templates “Smart Asset” Templates



Enabling Analytics for Operational Intelligence

Real-Time Decision Analysis



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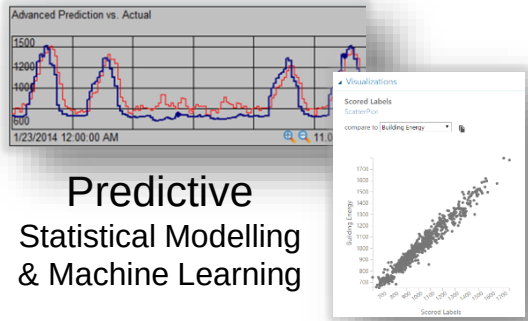

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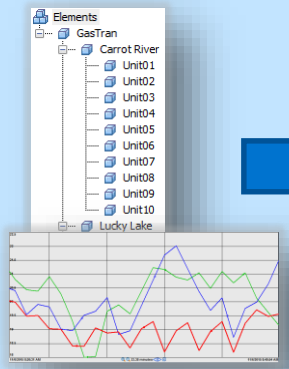

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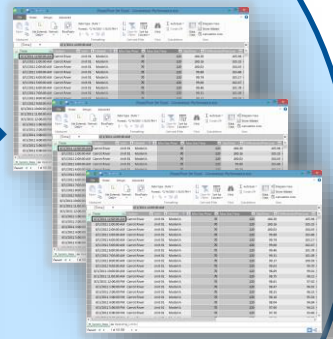
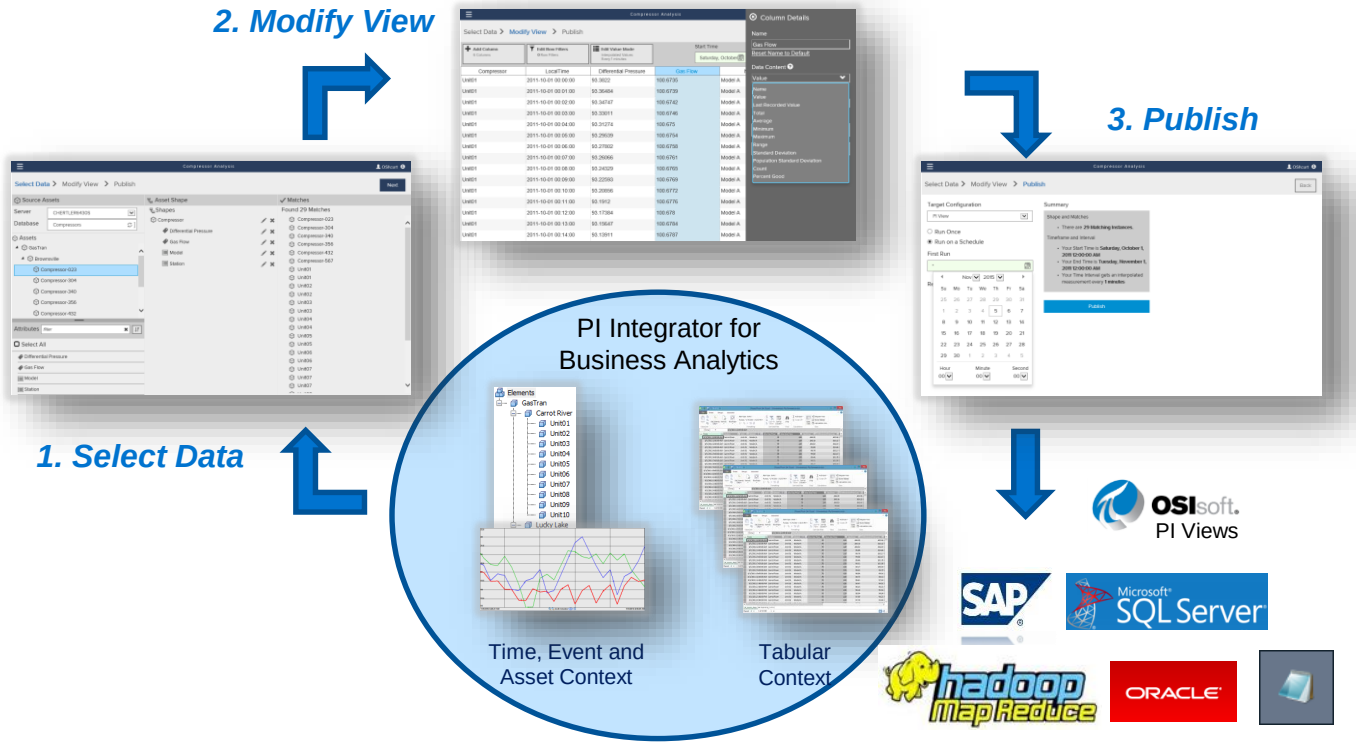


Tabular Context

PI Integrator for Business Analytics

Easy, scalable way for users to create contextualized views of operational data.

- **Select** assets and their attributes from an AF hierarchy.
- **Modify View** by setting time range, row interval, and column aggregations. Add filtering rules to “cleanse” data.
- **Publish** once or on a scheduled bases.



PI Integrator for Microsoft Azure – *Coming Soon!*

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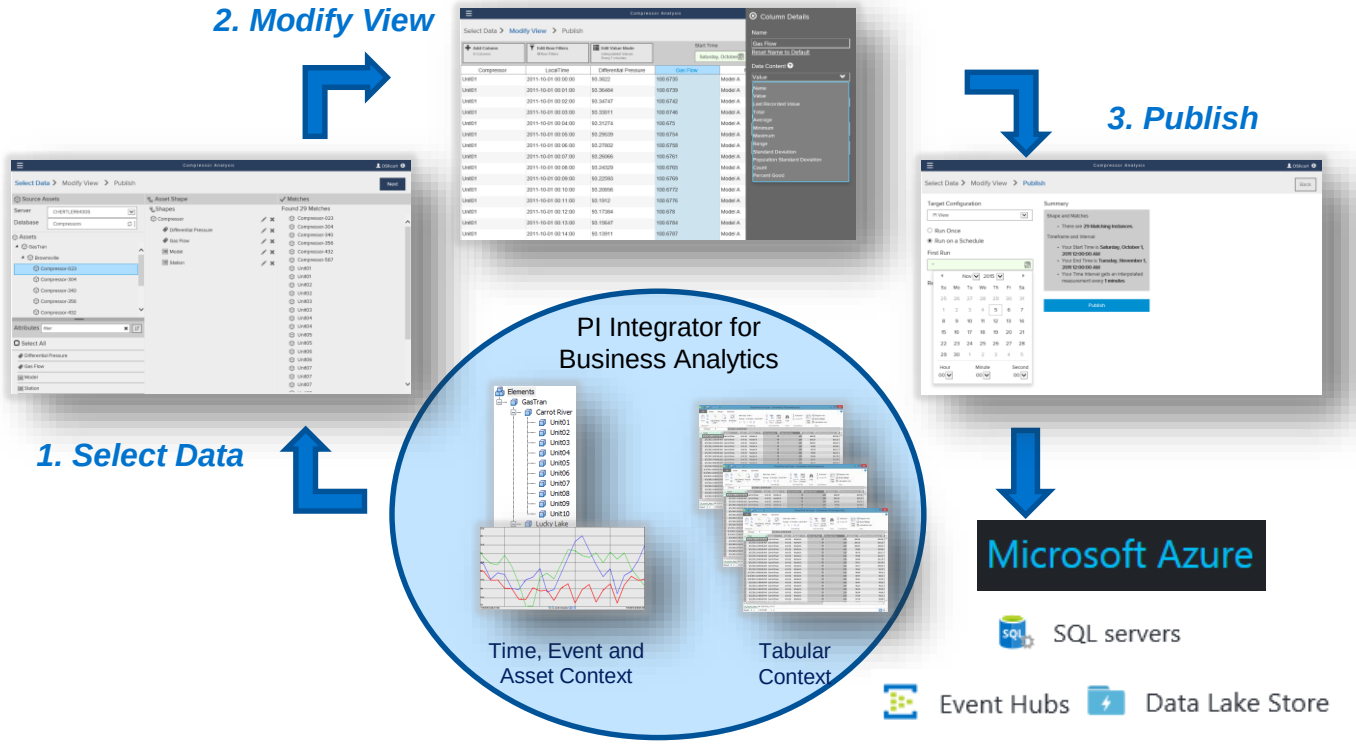

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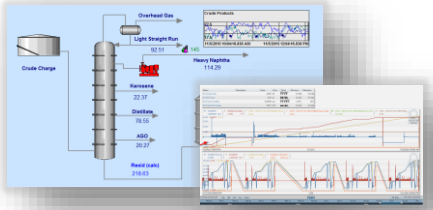

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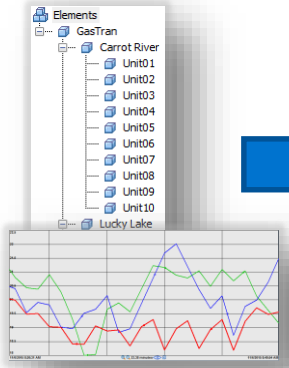

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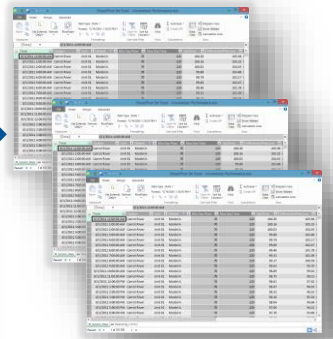

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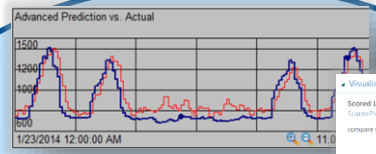
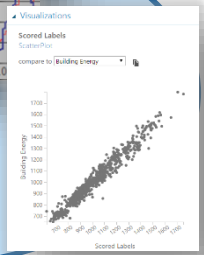
Dashboards & Multidimensional Assessment



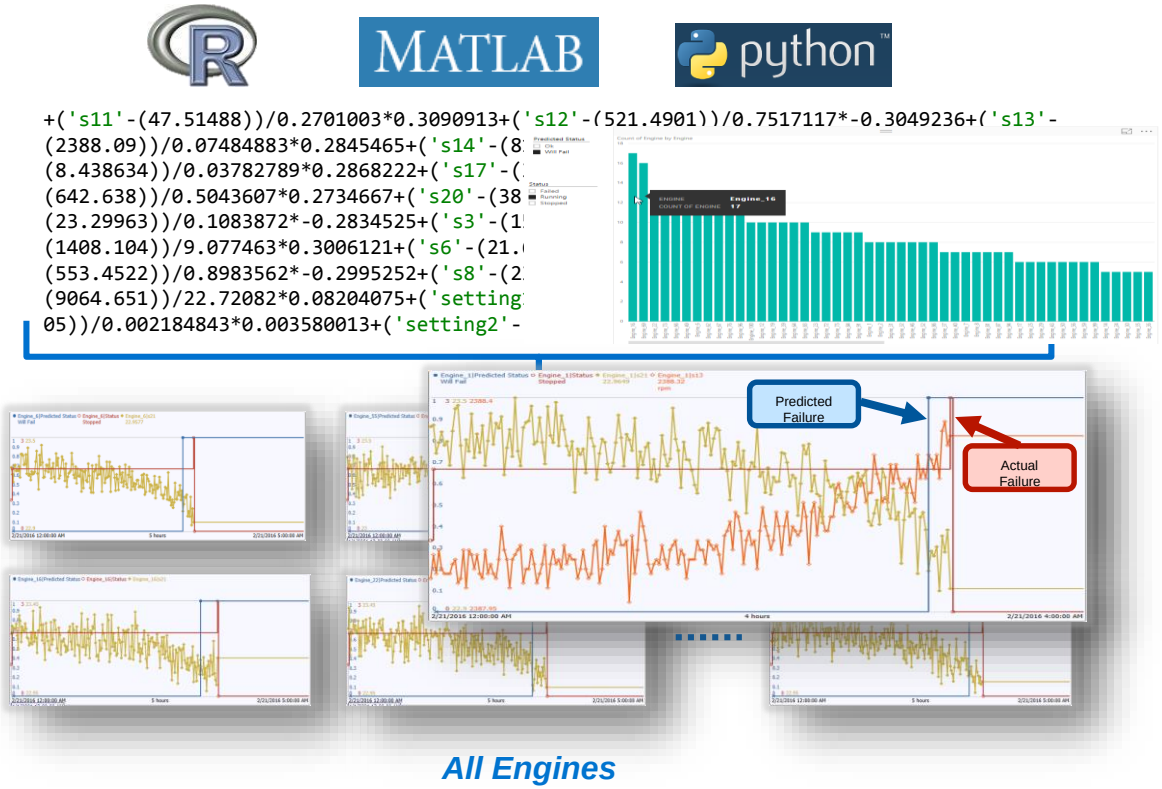


Predictive
Statistical Modelling & Machine Learning

Statistical Modelling - *Predict Asset Failure*

Complex systems descriptive equations are too numerous and interrelated.

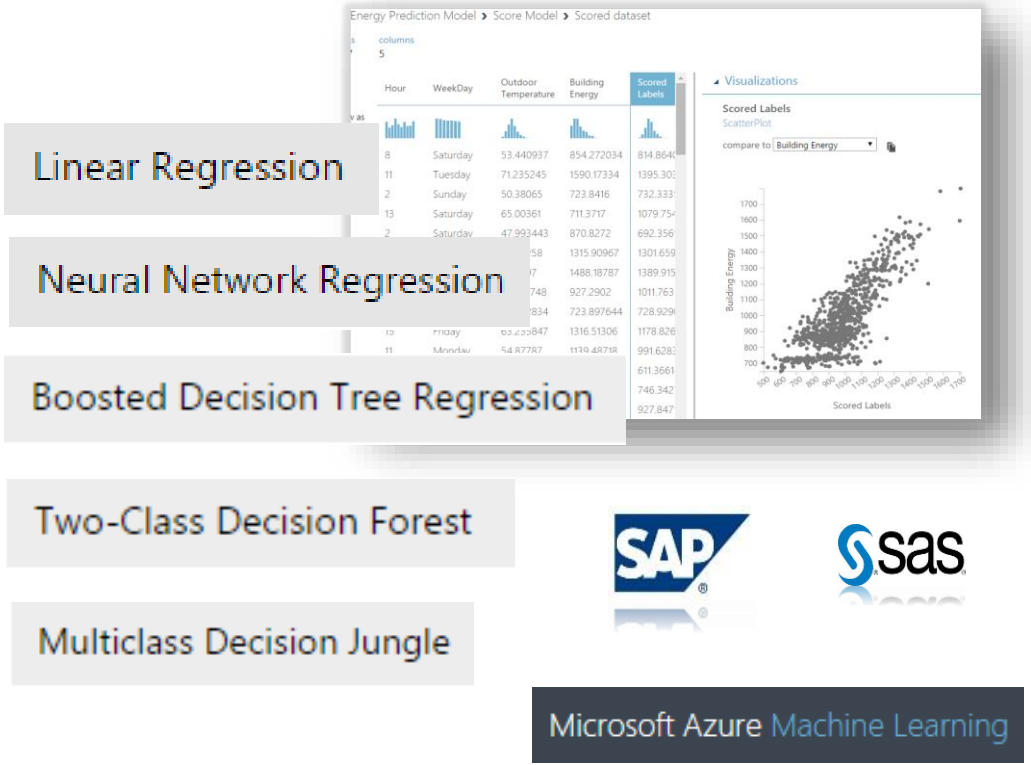
- Create an operationalized model to reduce unplanned downtime for 100 engines.
- ***PI Integrator for BA*** used to extract data for 2,300 sensors leading up to engine failures.
- Developed a statistical model using R for predicting failure.
- Tested and operationalized using PI Analytics for all engines.



Predictive Analytics - *Machine Learning*

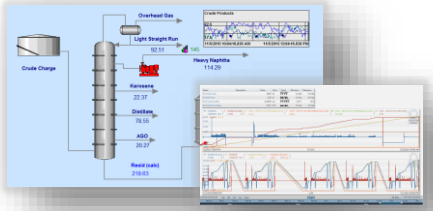
Machine learning improves statistical model by “learning” from additional operating data.

- OSIsoft Partners provide statistical applications and data science services.
- Gain business insights from datasets coming from many sources, e.g. data warehouse.
- **Operationalization supported by scheduled publication from PI Integrator for Business Analytics.**



Enabling Analytics for Operational Intelligence

Real-Time Decision Analysis



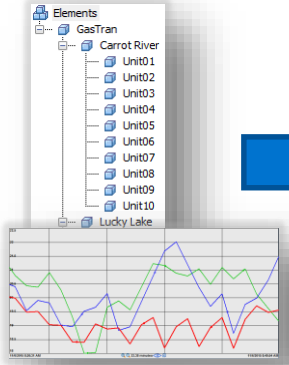
Time and Event
Trending & Awareness

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
Condition & Performance

PI Integrator for Business Analytics



Time, Event and Asset Context

Tabular Context

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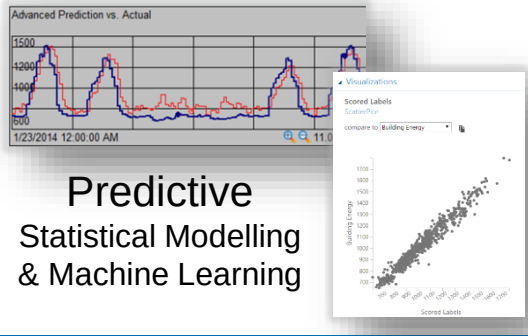
Visual
Dashboards & Multidimensional Assessment



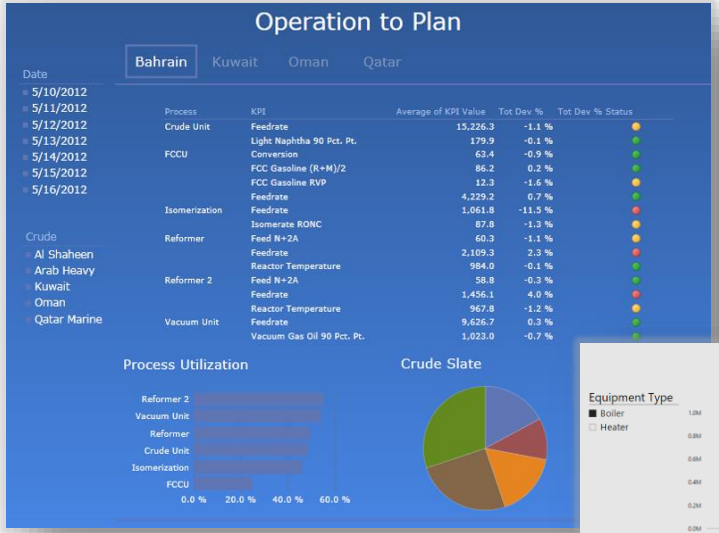
Predictive
Statistical Modelling & Machine Learning

Visual Analytics - Dashboarding & Reporting

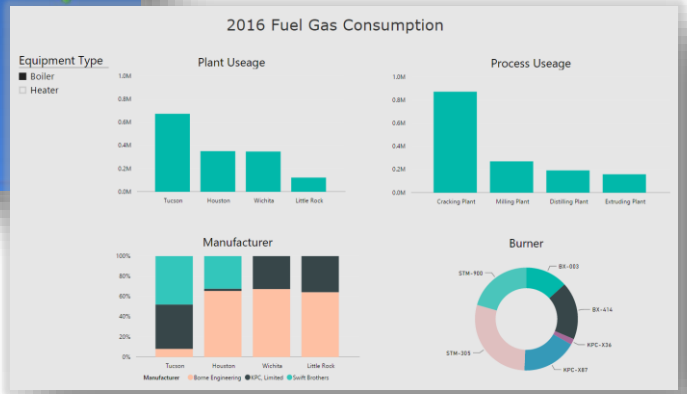
Dashboards and reports for performance assessment or accountability.

- Cross filtering charts for ad hoc investigation.
- **“What is shown in the report, stays in the report.”**
- Important aggregations can be permanently recorded in PI using AF Analytics.

Enterprise Scorecard



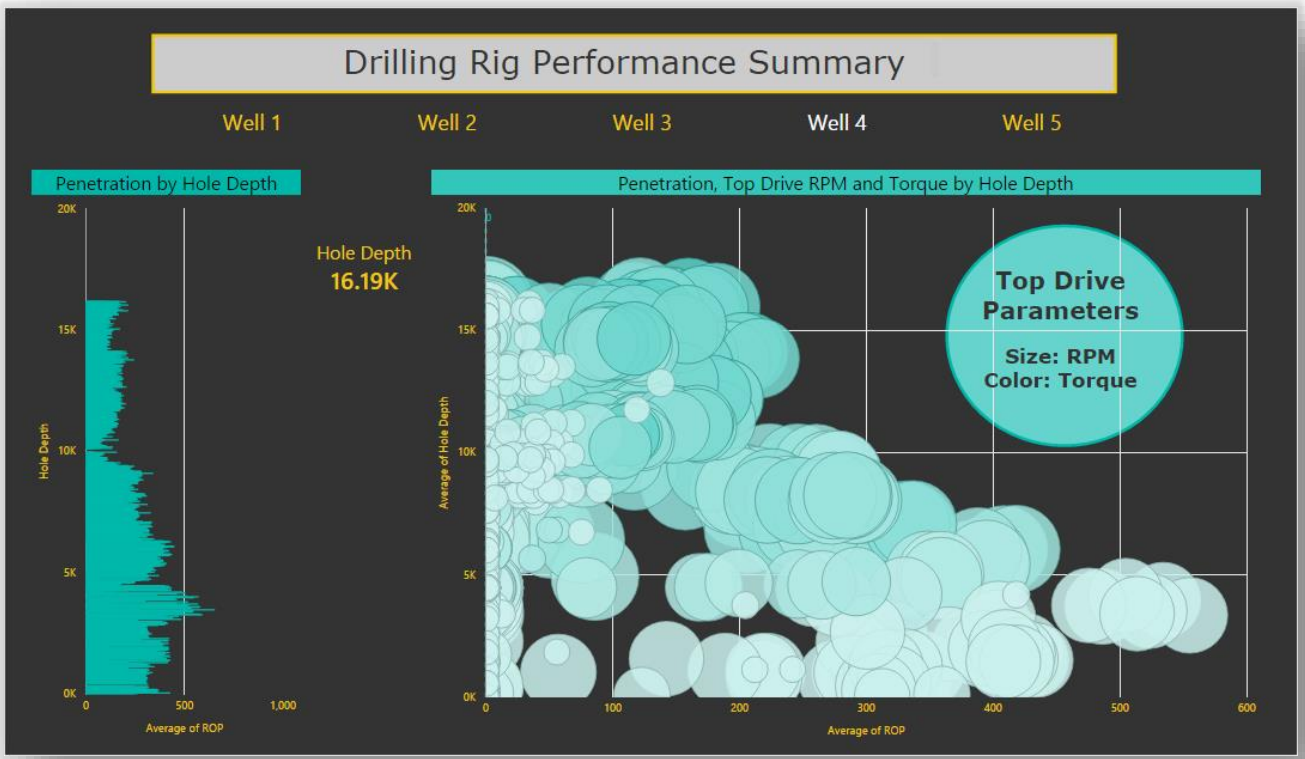
Energy Accounting



Visual Analytics - Multidimensional Assessment

Data collected to manage drilling operation is used to gain insights about formation geology.

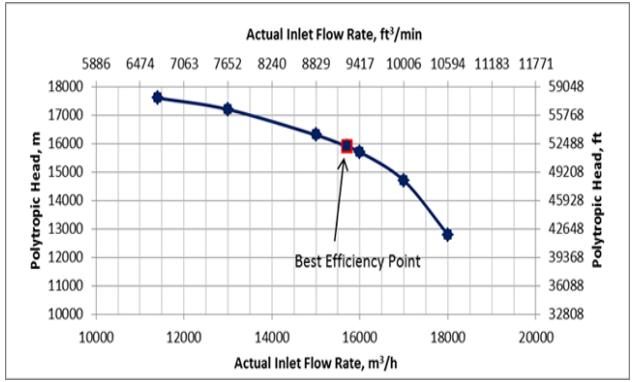
- Ad hoc analysis on any dimension, well depth, drilling rate, rpm and torque.
- Wide variety of charting objects available.

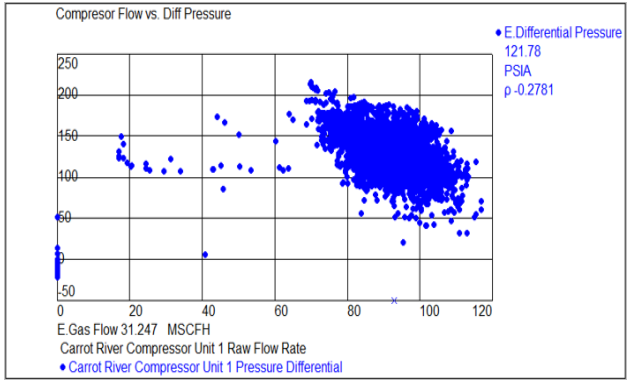


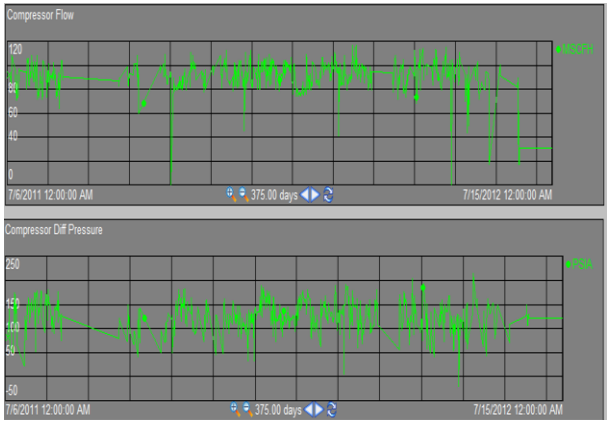
Visual Analytics – Asset Benchmarking

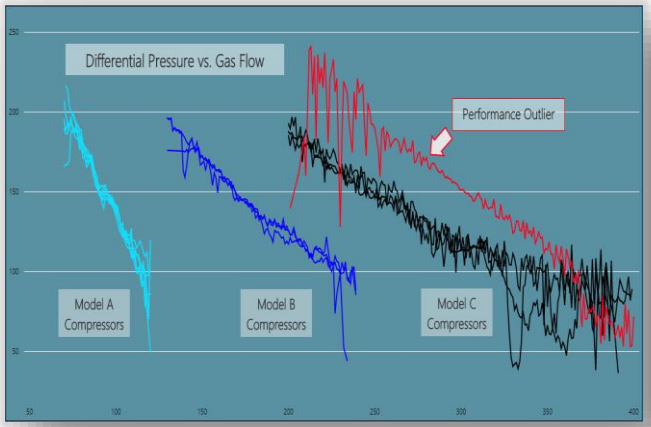
Benchmark similar assets against know performance characteristics.

- Real-time view is essential for current operation.
- Different tools required to analyze groups of assets.
- Summarize months of actual operations exposing actual performance profile.





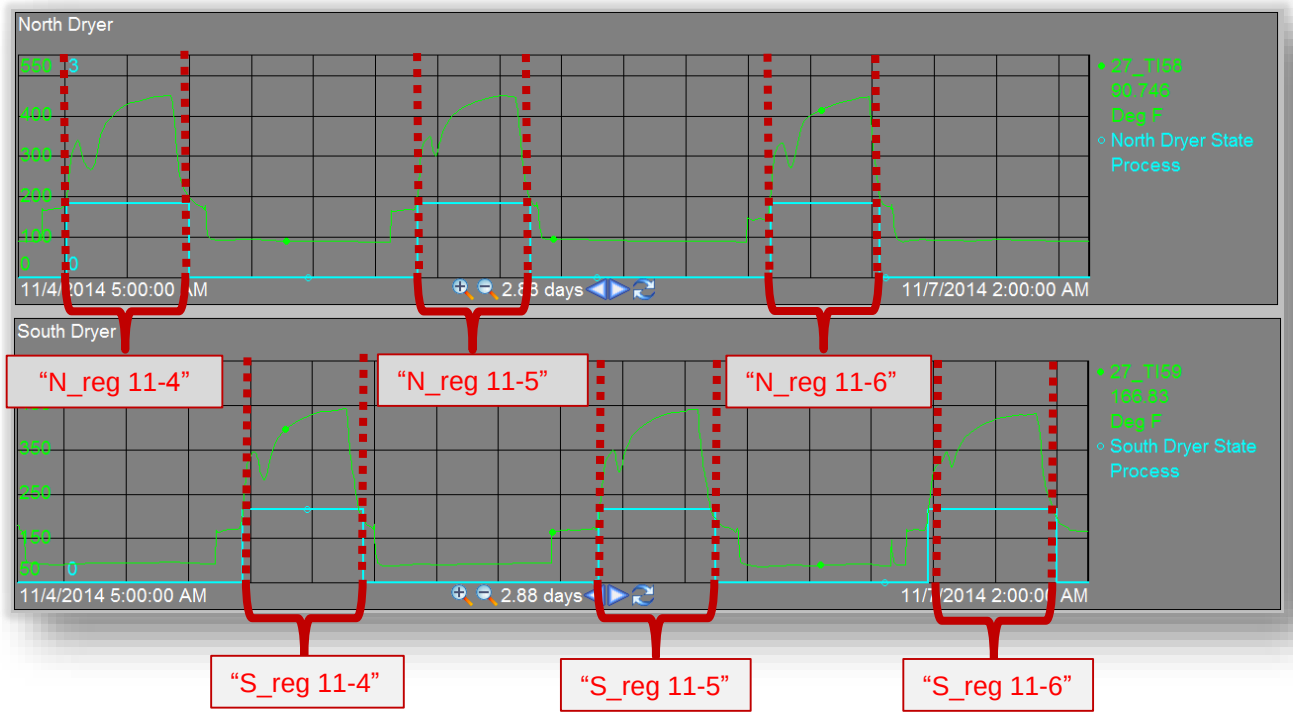




Event Frames – Feed Dryer Regeneration Cycles

PI Event Frames identify and record interesting periods of process operation for further analysis.

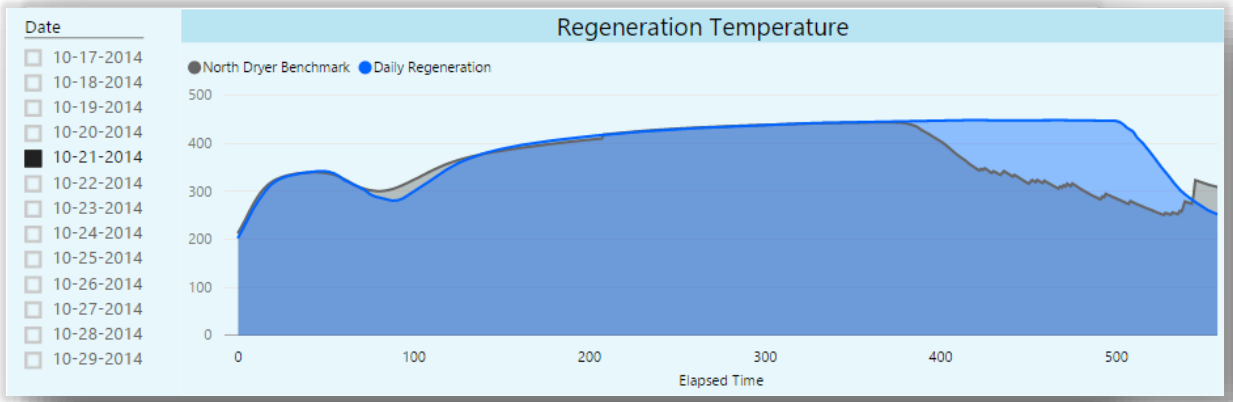
- Dryers cycle between processing and regeneration modes.
- PI Event Frames define regeneration cycles for each feed dryer.

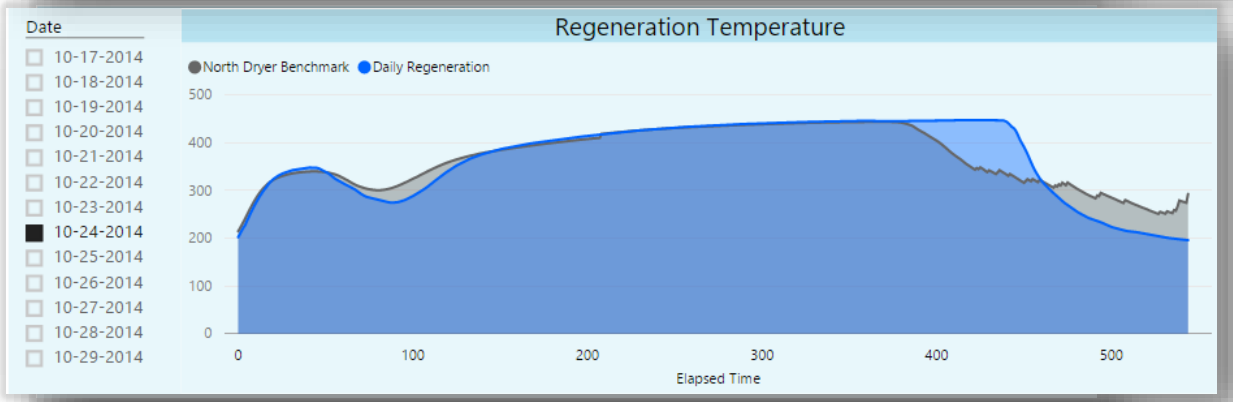


Visual Analytics - Conditional Profiling of Process Events

Feed dryer regeneration profile comparing two identical assets.

- PI Event Views can contain sampled process values throughout event.
- Profiled view of operation based on elapsed time.
- Conditional filtering of profile against benchmark or norm.





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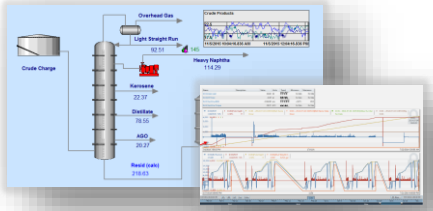

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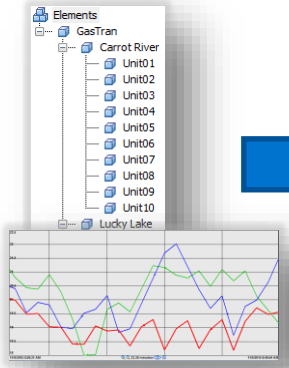

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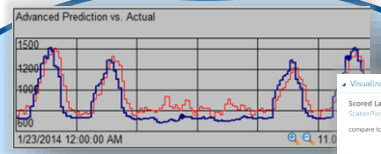
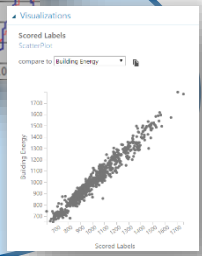




Predictive
Statistical Modelling & Machine Learning

Integration with R Open Source Visuals

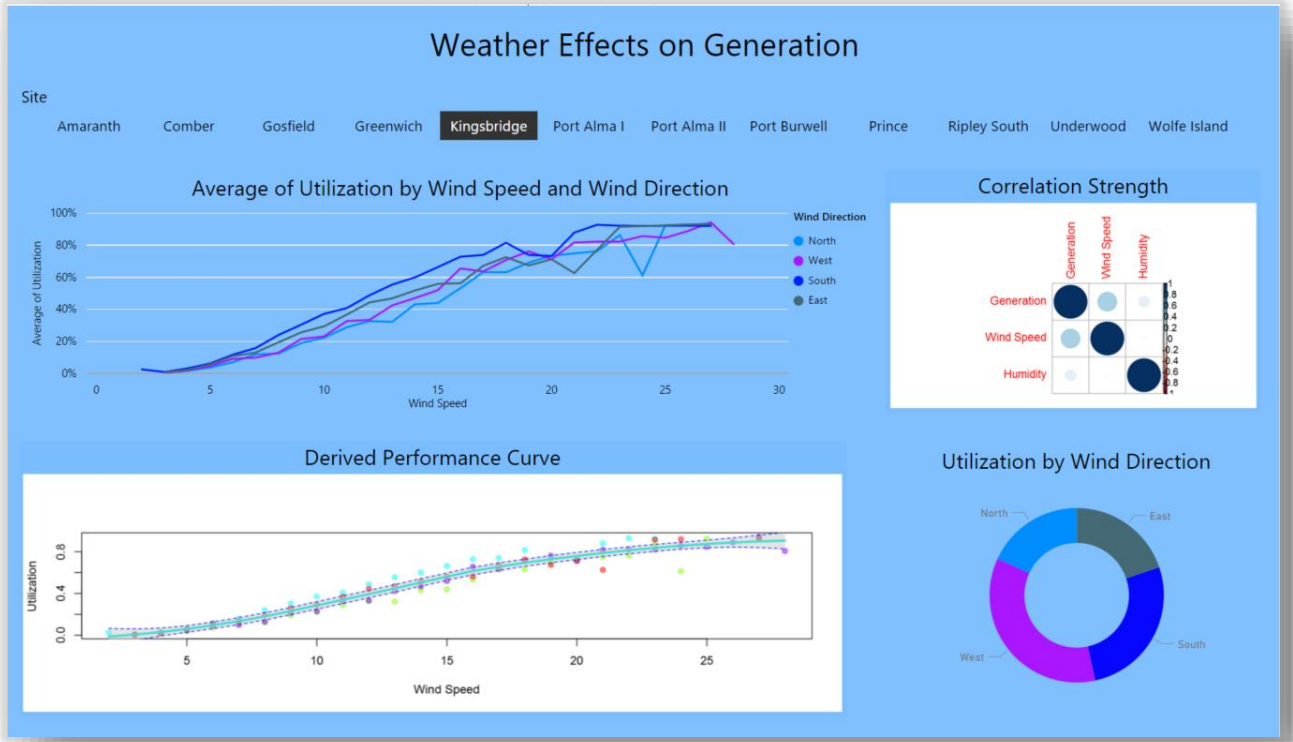
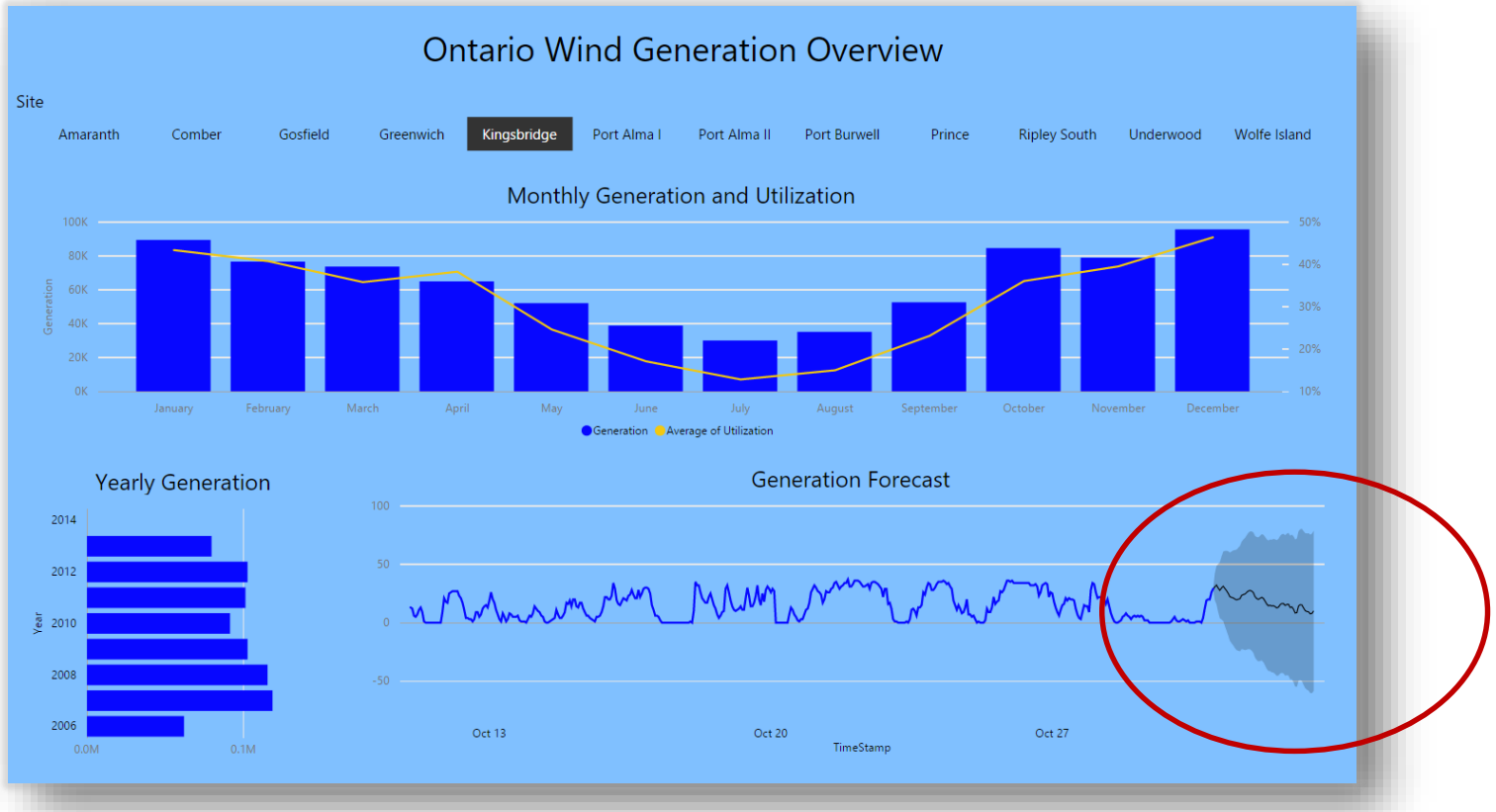
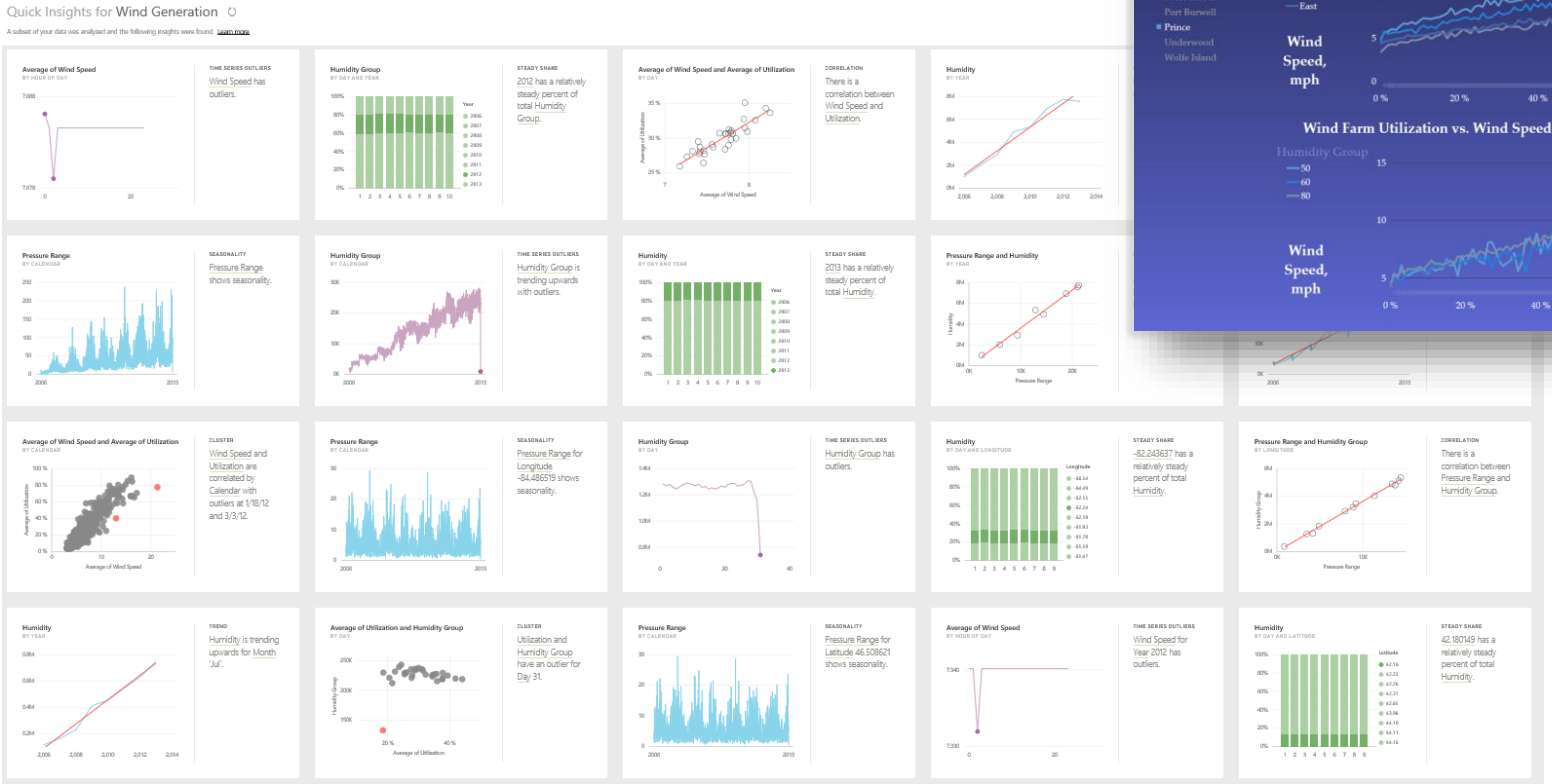
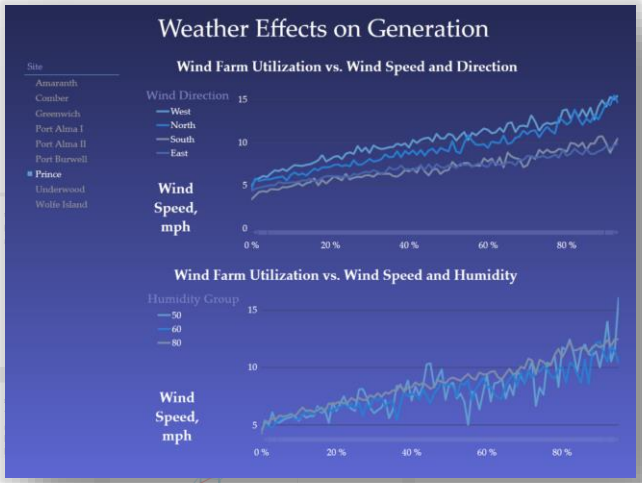


Chart-Embedded Analytics



Quick Insights for Report Data





Summary and Wrap Up

- Real time data is different. The PI System Infrastructure can supply required context, proper aggregation and configurable cleansing rules needed to prepare operational data for advanced analytics.

- 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 contextual “Common Ground” enabling organizations to leverage emerging technologies for Operational Intelligence.

Thank You

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