# An Innovative Integrated Approach to Plant Management using Dynamic KPIs and Automated Root Cause Analysis

## Executive Summary

KPIs (Key Performance Indicators, also known as Key Success Indicators) are measurements of the performance of a system. In industry, they are used to study engineering processes, to see whether the output is in line with what was intended. An organization may use KPIs to evaluate its success, for diagnosis purposes and as communication and management tools.

KPI management can cover design through deviation diagnosis and corrective actions advisory. KPI design consists in defining KPIs and their attributes, categories and procedures. Implementation includes targeting, deviation detection and user interface. KPI targeting relies on determining baseline performance which can be either static or dynamic. If it is dynamic, models should be built to describe the relationship between the KPI and its primary drivers. The final step is to build information displays using the data collected and models created. These displays should include high-level KPI views to give a general performance indication, as well as detailed drill-downs for a deeper diagnosis of the deviations and more targeted corrective actions.

Emerson has built an Energy KPI System for Saudi Aramco's Abqaiq plants to help Abqaiq stakeholders get insights to successfully drive the plant's energy performance. The system retrieves real-time data from a data source, and performs data validation, KPI calculations, KPI monitoring and dynamic targeting, automated Root Cause Analysis, and complex event detection. It stores results into a database and publishes via a customized web application.

## Table of Contents

# KPI Definition and Benefits

## KPI Definition

KPIs (Key Performance Indicators) are measurements of the performance of an individual, group, organization, system or component. They are a part of the performance measurement process that includes collecting, analyzing and reporting information regarding performance. In the industry, they are used to study engineering processes, to see whether the output is in line with what was intended or should have been achieved.

## KPIs Use and Benefits

An organization may use KPIs to evaluate its success, or to evaluate the success of a particular activity in which it is engaged. In case of failure to achieve targets, KPIs and associated models can be used as diagnostic tools: analyzing historical values may help in understanding the reasons for that deviation and in making plans to improve the performance. During periods when performance is better than target, this should also drive investigation to figure out why, so that the improvement can be duplicated going forward. This is why KPIs are routinely associated with “performance improvement” initiatives.

Because they summarize information, KPIs can also be an important tool of communication, be it external or internal. In external communications, on-target KPIs attract customers and reassure partners. In internal communications, good KPIs have an impact on motivation: they make the long-term vision concrete by providing direction and a way to measure progress.

# KPIs for Plant Management

Managing KPIs involves a set of tasks that go from design to root cause analysis, including KPIs targeting, deviation detection, and drilldowns.

## KPI Design

### KPI Definition

Each KPI must be clearly defined if it is to be an effective management tool. The definition includes a description of what is being measured and why. The “why” component makes the business case for the KPI (why it is important and how it is tied to the organization’s strategic goals). The definition also describes how making progress toward or achieving a goal will affect the customer, team, department or organization, along with any associated risks.

A well-known principle to help guide people in selecting KPI is the S.M.A.R.T criteria. Ideally speaking, each corporate, department, and section objective should be S.M.A.R.T:

- ***S**pecific* – target a specific area for improvement.
- ***M**easurable* – quantify or at least suggest an indicator of progress.
- ***A**ssignable* – specify who will do it.
- ***R**ealistic* – state what results can realistically be achieved, given available resources.
- ***T**ime-related* – specify when the result(s) can be achieved.

Another well-known approach is the use of a “strategy map”. A strategy map is a diagram used to document the primary strategic goals being pursued by an organization or management team. It can be used in KPI design to link corporate goals to specific KPIs in several general areas. An example of a generic strategy map is shown in the figure below. Many KPIs might be associated with each box.

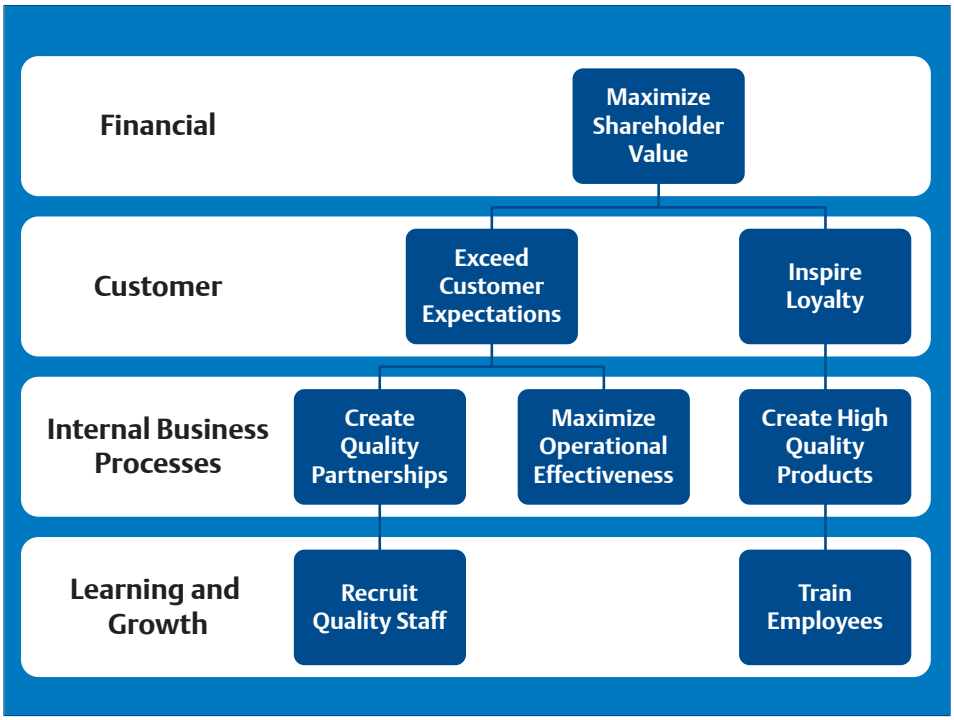


*Figure 1 : A generic strategy map*

**Attributes**

KPIs include a number of attributes that must be identified and documented, including the start and end dates, unit of measurement and formula, and data sources for the KPI. The attributes include the KPI sponsor, the position or person responsible for tracking it and those who will benefit from it.

**Procedure**

Organizational KPIs are determined by senior management, while departments and teams develop their own, which are aligned with organizational KPIs. The KPI procedure begins by identifying the indicators linked to strategic goals and initiatives. Data elements and resources are identified, along with collection and reporting methods. A formula is developed that summarizes the KPI; for example, the Mean Time to Repair is the total corrective maintenance time for failures divided by the total number of corrective maintenance actions for failures. A reporting or display method, such as a dashboard or chart, is developed for each KPI and the results are evaluated each month by the team, department or management to identify problems and opportunities for improvement.

## Data Collection

The next step is to determine how the required data will be collected. Using a KPI approach, only the data required to accomplish the primary goals is captured. This data tends to fall into one of two main categories:

- **Static:** e.g. equipment ratings typically collected during an initial audit and used to normalize measurements for benchmark comparisons.
- **Dynamic:** e.g. process data, temperatures and pressures, production volume. This data tends to be more expensive to manage because continuous effort is involved in acquiring and processing it, and because it takes up the vast majority of storage space. If the data collection is too expensive or difficult, an alternative KPI should be considered.

## KPI Targeting

When setting targets for KPIs, data is the critical ingredient. Baseline performance is the starting point in KPI targeting. Developing targets and tracking success is one of the most challenging aspects of implementing a KPI system.

### Static Targeting

This is defined by using a range which defines the highest acceptable value and the lowest acceptable value of the process, as shown in figure below. Any result within these “acceptable” or “expected” ranges is considered to be a normal value: the process is under control, no action is required and attention should be focused elsewhere. However when results fall outside these ranges, actions must be taken.

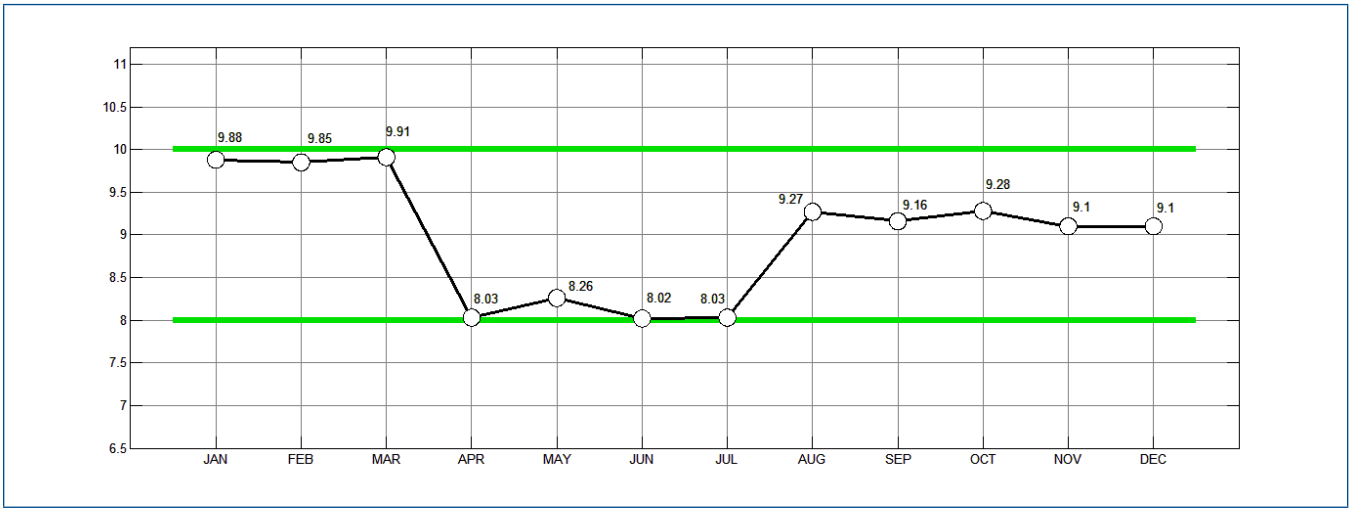


*Figure 2 : Example of static targets. The green lines correspond to the highest and the lowest acceptable values*

### Dynamic Targeting

Dynamic targeting consists in building models that describe the relationship between the KPI and its primary drivers. The four-step process of building models, illustrated in the figure below, involves selecting a baseline dataset, creating and testing a baseline model, and generating one or more target models to track performance.

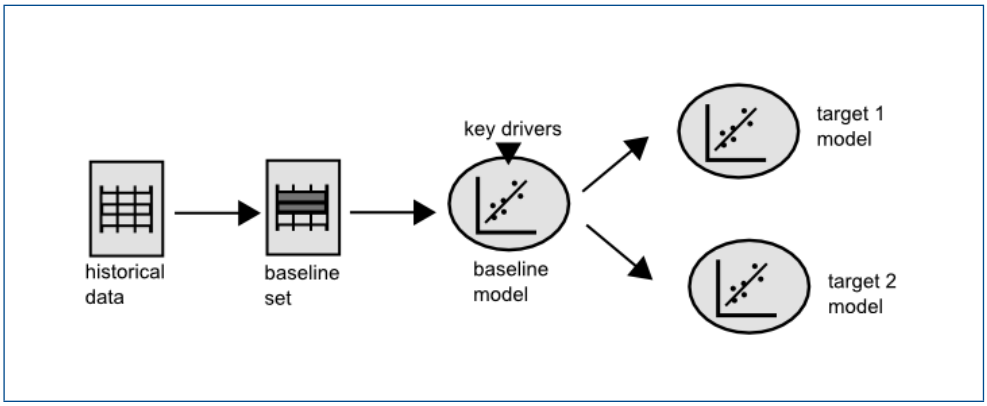


*Figure 3: Steps in building baseline and target models*

**The Baseline Dataset**

The baseline dataset is created by choosing a dataset selected over a defined length of time to capture the behavior of the KPI. Data normally consists of the KPI and the associated primary drivers over a common time interval, such as daily.

To be accurate, the dataset used to create the baseline model should reflect the “normal” behavior of the KPI: shutdown/ unavailability periods should be discarded, points corresponding to outliers and abnormal conditions should be removed. The dataset period should encompass the time needed for the process to cycle through its entire operating range.

**The Baseline Model**

The baseline model is created using a correlation table or a correlation graph highlighting an often strong relationship between the KPI and the primary drivers. In some cases there may be a strong linear relationship between the KPI and its primary drivers. Figure 4 shows an example where the considered KPI is the energy consumption plotted against one primary driver which is the production volume.

When the relationship between the KPI and the primary drivers is not linear, technical resources are available to help interpret results and develop appropriate baselines. An interesting case of non-linearity arises when the scatter plot consists of several clusters corresponding to different behaviors of the process. This happens when the process switches between two or more operating modes or process scenarios. Clustering algorithms and identification techniques should be used accordingly to create separate datasets and generate different baseline models, one for each cluster. An example of clustered scatter plot is shown in figure 5.

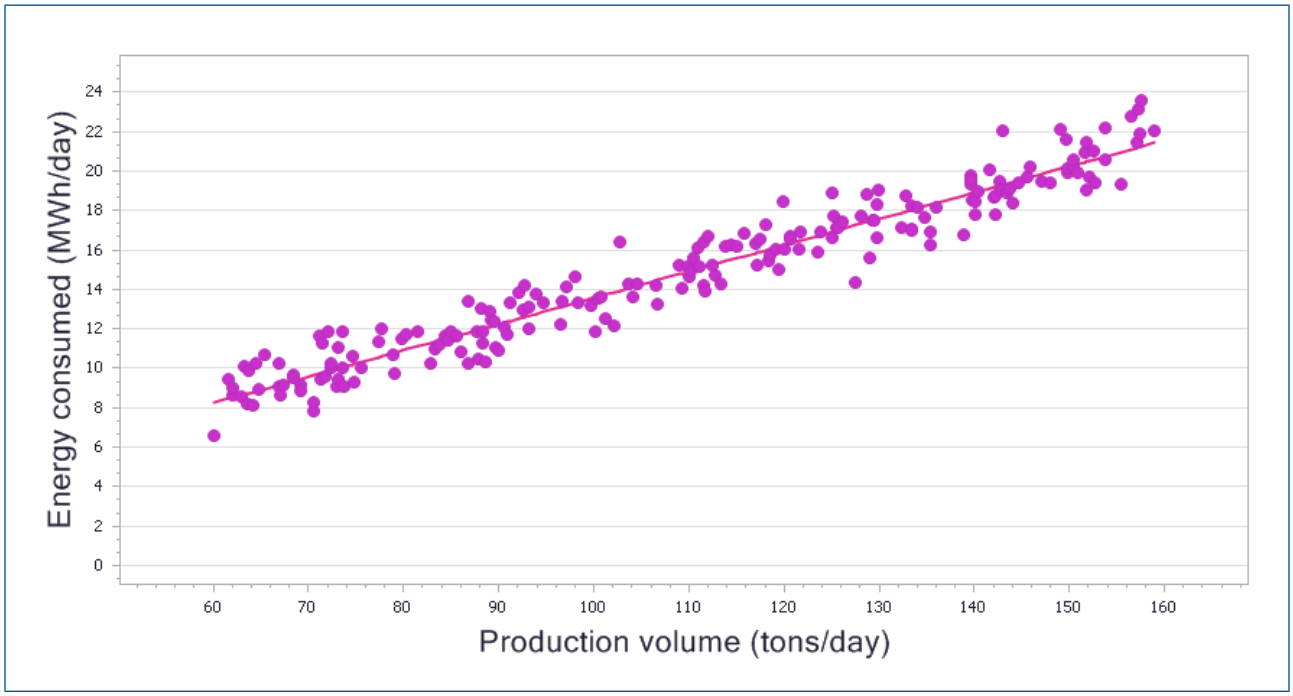


*Figure 4: Scatter plot of energy consumption versus production volume, showing “best fit” baseline model*

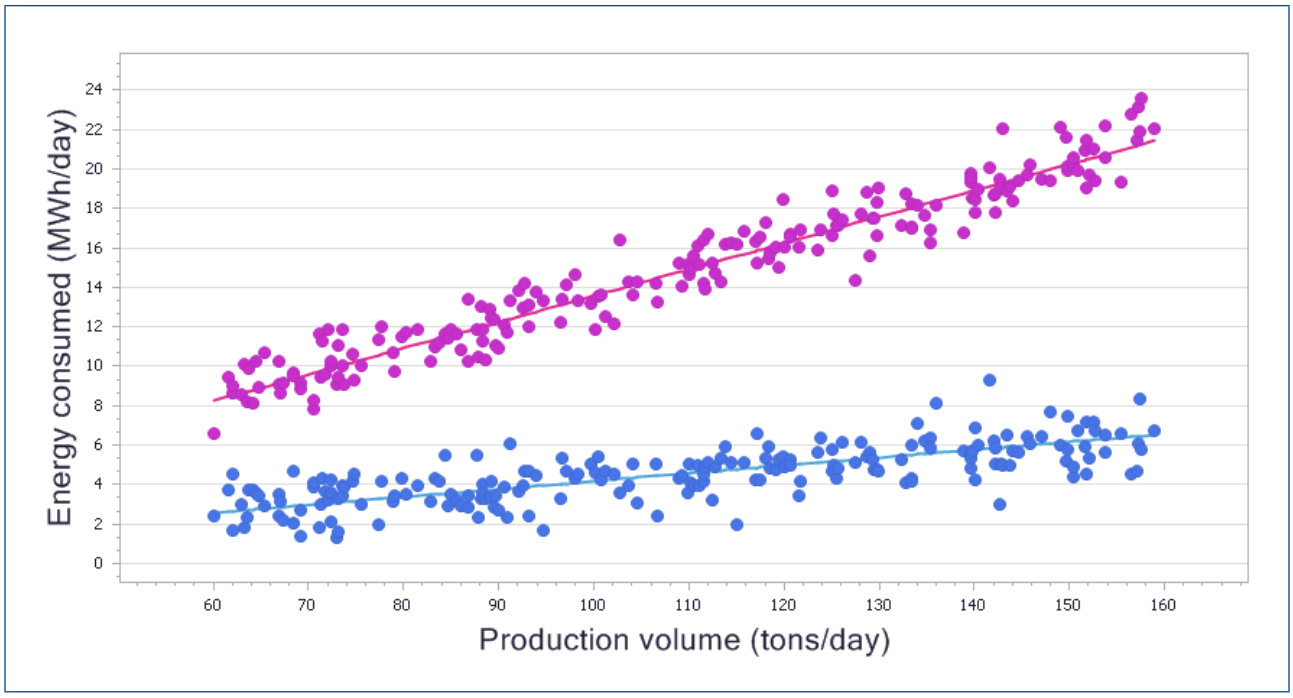


*Figure 5: Example of clustered scatter plot with a best-fit line for each cluster*

Over time, new operating modes will occur, for which there was previously no data. When this happens, there should be procedures in place to add models for the new clusters corresponding to the new operating mode.

**Target Modeling**

The next step, target modeling, provides the benchmarks by which the success of the management activities will be measured. Target models are constructed by applying the key goals, embedded in the performance metrics, against the baseline model to generate the reference model that ongoing measurements will be compared against. For example, you can arbitrarily decide that this year's target is 80% of last year's target. More likely, you might target the best performance that you've proven achievable at least, say, 20% of the time, so that each year the targets get tougher, yet within proven abilities.

## Online Performance Tracking

Information displays are an important part of the process. These displays should include high-level KPI views to give a general indication of performance, as well as detailed drill-downs to help understand why a plan might be starting to go off-track. The best choice of format for each will depend on what information is being conveyed and how it will be used.

For more details, a time-series chart provides a view of the data behind the high-level KPI. In the example below, after identifying that measured energy consumption exceeded the target on July 4th, the more detailed times series chart reveals that the deviations from the goal occurred around 12:00pm and 3:00pm.

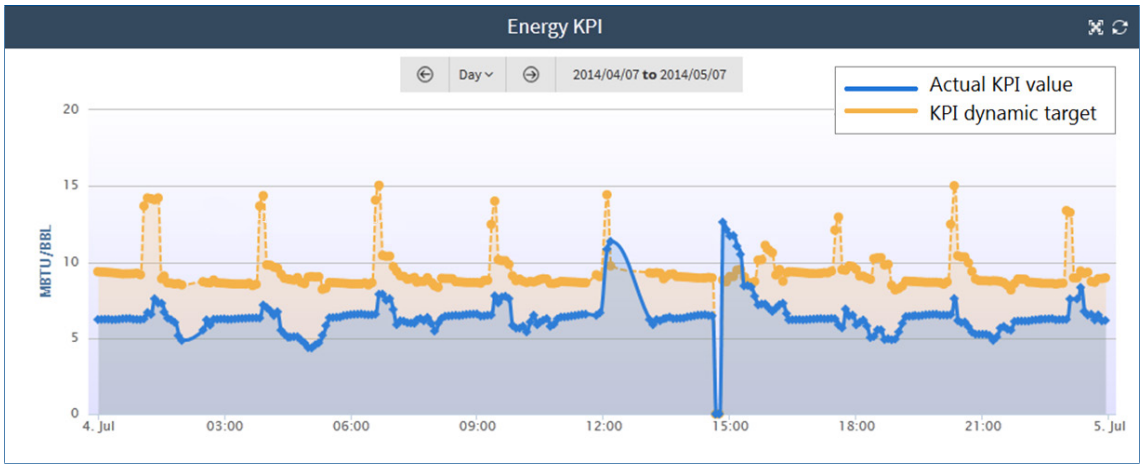


*Figure 6: Times series chart of an energy KPI used to detect deviations with respect to target*

There will typically be different audiences within an organization for the different information displays described above. All stakeholders will be interested in the high-level KPIs, while the specific teams will be the primary audience for detailed drill-down views. For instance, an energy manager will likely make use of both the high-level KPIs as well as some selected detailed views when presenting updates to executives.

## Drilldowns

The definition of a KPI could be further expanded to allow a manager to keep things on track by “drilling down” to richer details regarding what behaviors might be causing deviations from the plan. The figure below shows an example of an energy KPI where electricity and gas consumption can be broken down to each major consuming category and by shorter daily or even hourly intervals.

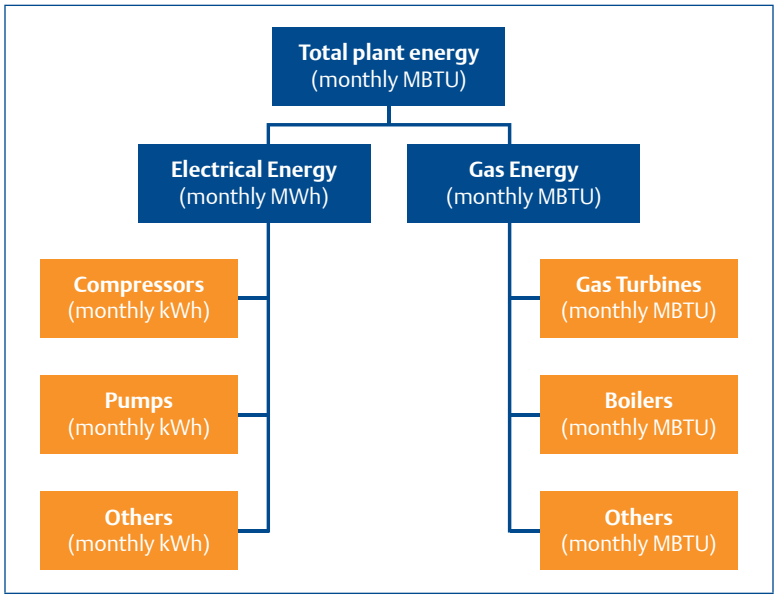


*Figure 7: Expanded KPI breakdown for energy consumption*

A user can review high-level KPIs first and drill down into details only when there are deviations from target goals. This is called “Management by exception” and can help the user avoid searching though thousands of data points to find the few that are of interest. However, it is possible that lower-level KPIs are off-target even when their top level KPI is within tolerance. This is why it is important to have displays that show the real statuses of KPIs and sub-KPIs independently of any hierarchy.

## Emerson’s KPI System for Abqaiq Plants

Emerson built an Energy KPI System for Saudi Aramco’s Abqaiq plants to help Abqaiq stakeholders get insights to successfully drive the plant’s energy performance. The system provides the following major functionalities:

- Define energy key performance indicators from equipment level up to the plants-wide level,
- Dynamically adjust energy performance targets based on operating modes, equipment availability and product feed,
- Monitor and detect energy performance deviations from their corresponding targets
- Validate data
- Diagnose the reasons behind the performance deviations using automatic root cause analysis
- Analyze trends to predict impending problems
- Present data and warnings in a user-friendly web-based interface

Because it can accommodate Abqaiq plants concerns and challenges, Plantweb Optics Analytics was chosen for this project. Plantweb Optics Analytics is an intelligent application framework designed to manage, analyze and improve plant performance visibility. Plantweb Optics Analytics gathers the right data and information, and intelligently integrates knowledge scattered in the many islands of automation.

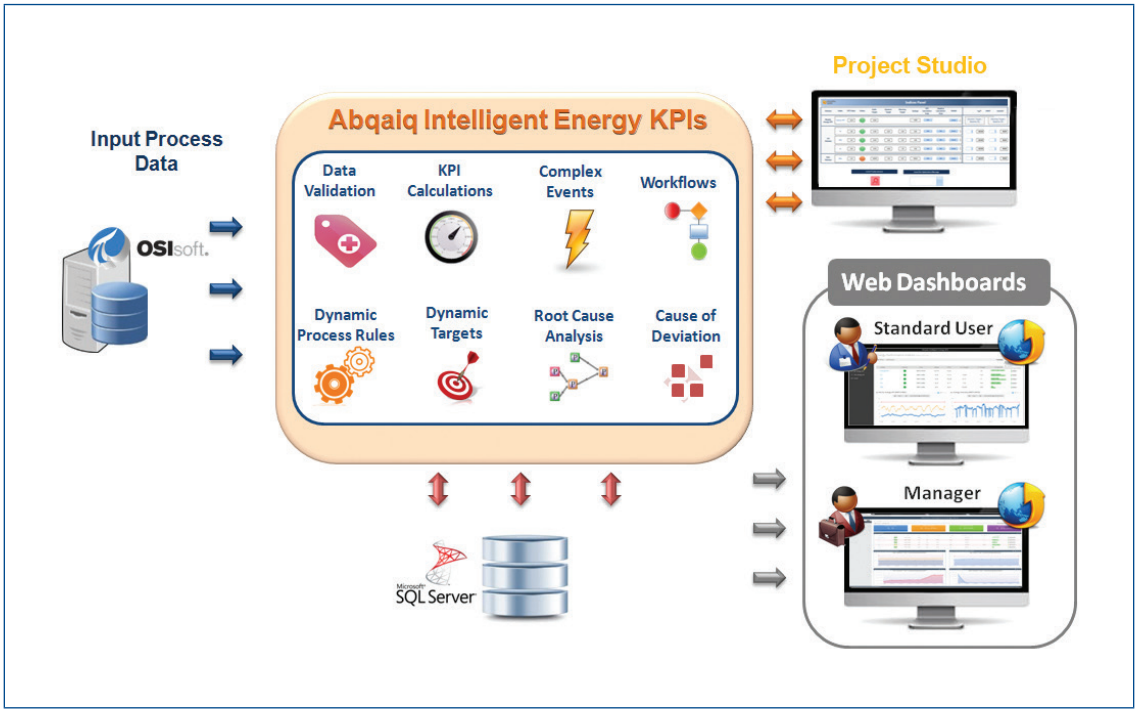


*Figure 8: Data flows through Abqaiq KPI intelligent application*

# An Innovative Integrated Approach to Plant Management using Dynamic KPIs and Automated Root Cause Analysis

**White Paper**
December 2020

Data analysis tasks used in Plantweb Optics Analytics, an out of the box software application package designed to help engineers and operations in the manufacturing to transform their massive and unstructured data into knowledge and actionable decisions. Plantweb Optics Analytics helped in:

- Analyzing and investigating the plant process behavior and states
- Building models for KPI dynamic targeting
- Predicting abnormal conditions
- Identifying opportunities to increase operational efficiency and reliability

The innovative part of the Abqaiq application consists in tying KPI presentation to automatically-detected operations modes and using different regressions for different data regions to determine dynamic targets. But another innovation is simply bringing in different technologies such as RCA as well as the statistical tools like clustering and regression, all in the service of managing with KPIs.

With Intelligent Energy KPIs in place at Abqaiq plants, the cycle time and efforts to detect and diagnose energy consumption performance gaps were significantly reduced and energy savings were estimated to over 20M$ for a period of 1 year.

## Related Documents

**White paper** – **From Data to Knowledge: the Process of Knowledge Discovery**

**Success Story** – **Saudi Aramco Abqaiq Plants goes beyond Business Intelligence**

## Keywords

- Key Performance Indicator
- KPI management
- Performance monitoring
- Performance improvement
- Dynamic targeting
- Root cause analysis
- Drill-down



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