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Energy Optimization Steps Toward Net Zero

India's refineries are setting the pace for decarbonization

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Abstract

As much as energy transitions to renewables, green hydrogen, fuel cells etc are work in progress, energy efficiencies and improvements will always remain practical pathways not only to improve profitability of a plant's operations but also to reduce green house gas emissions. In this article a comprehensive energy optimization program is laid out, how to go about it and how digitalization enables and expedites it scientifically and in measurable manner.

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Introduction

India's announcement of ambitious plans to tackle climate change is a watershed moment for the international fight against global warming. This initiative is in response to the 21st annual Conference of Parties (COP21) held in 2015. During this conference, delegates agreed to limit global warming to 2°C and work towards zero net carbon emissions. Therefore, India's oil and gas refineries are on a transformation path to reach net zero by 2070, with most planning to meet this target between 2035 and 2050. This ambitious target will be achieved through a combination of both operating performance improvement activities and capital investments that lower capital expenditures and carbon emissions.

To reach this goal, industry leaders are taking steps to transition the energy sector to a clean energy economy. According to the leading GHG Protocol corporate standard, industrial emissions can be either direct or indirect and are categorized into three different scopes as shown in Figure 1. While Scope 1 and 2 emissions require mandatory reporting, Scope 3 is not only voluntary but also difficult to monitor and has the greatest negative impact on society. Scope 1 emissions are mainly derived from heating, which typically uses hydrocarbon combustion. However, as renewable resources become more widespread, this relationship will break down, making process heating more economically feasible. Scope 2 and 3 emissions are caused by power generation and transportation fuel, respectively. Currently, renewable electricity is displacing fossil fuels while low cost battery storage is threatening to replace liquid fuels. Overall, energy improvements could contribute to reducing emissions by 20-30% from total green house gas emissions.

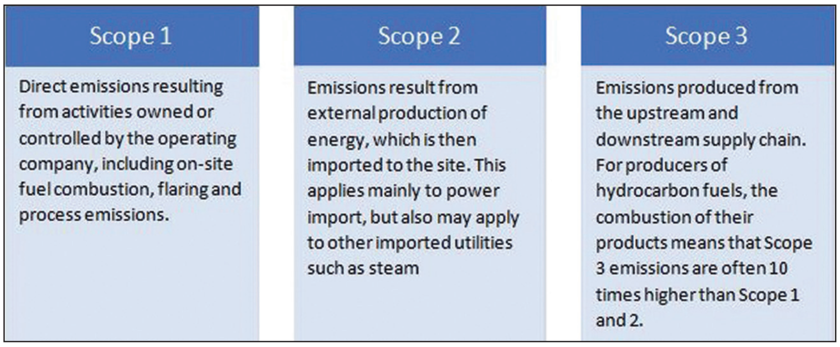

Figure 1. Three Types of Carbon Emissions

Situation

Currently, Indian refineries are concerned about energy efficiency while maintaining or increasing production volumes. Most Indian refineries have conducted benchmarking and energy optimization studies where each refinery maintains a forward-looking list of energy saving improvements. Although they have various starting points, maturity, and constraints, the common denominator includes being first-quartile performers in line with the corporate vision. However, few refineries have developed comprehensive, integrated roadmaps for energy-saving improvements. To reduce capital expenditures, the refinery needs to schedule projects according to its plan, decarbonization strategy, and budget. This strategic roadmap should be tracked digitally to ensure sufficient attention is given to the implementation of the energy improvement program.

Proven Approach

A comprehensive energy program starts with an assessment and ends with sustainable results. Launching an energy improvement program begins a strategic energy review with the refinery's management. This review helps identify challenges on the ground and align both the current and future initiatives with the vision for each asset. By analyzing yield, energy and reliability tradeoffs, the discussion contributes significant value, thereby increasing energy efficiency on the demand-side.

A holistic energy program is a fully integrated system that is able to steward the whole lifecycle process of energy improvement identification, evaluation, implementation, and sustainment. The full energy program consists of a hybrid of consulting and technology transfer using process digital twins, capital project tracking, and artificial intelligence as well as machine learning that supports strategy and organizational alignment. As shown in Figure 2, the five (5) core components of the comprehensive energy program include: (i) Opportunity Identification, (ii) Opportunity Evaluation (iii) Roadmap Development, (iv) Implementation Support, and (v) Digital Energy Management. These individual elements are described below.

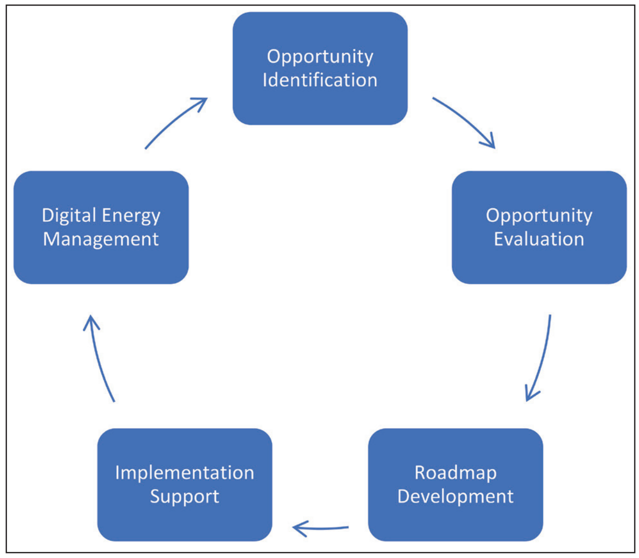

Figure 2. Comprehensive Energy Program Components

Opportunity Identification

Opportunity identification starts by using best technology methods to quantify and compare the process unit's or refinery/petrochemical plant's energy consumption to establish energy benchmarks and analyze gaps. This assessment helps align expectations and set realistic targets in subsequent phases of the process.

For refineries and petrochemical plants, fundamental analysis and design studies of individual processes lead to best technology methods. Research has shown that a newly built grass roots plant can achieve 100% best technology energy performance. Such a plant has an economically justifiable level of energy efficiency and is supported by a highly efficient steam and power system.

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Best technology performance is based on the following high efficiency features:

- Fired heater efficiency of up to

94%

- R-curve analysis determines all power generated internally at an optimum fuel-to-power efficiency
- Highly efficient steam/power system with 100 bar (1,500 psig) high-pressure boilers and steam let down to lower pressures through turbines
- All rotating equipment operating at high efficiency
- Heat exchanger networks designed using pinch technology with optimum approach temperatures
- Optimised, energy-efficient process configurations
- Yield efficiency

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Benchmarking

Benchmarking is an effective tool to identify areas to immediately improve energy performance. Since best technology calculation accounts for site-specific energy pricing structures and limitations, it is directly indicative of the energy improvement potential and emission reductions.

Benchmarking begins by establishing an energy baseline for the refinery's energy optimization study. The site operating data from the previous three months is screened to identify a time (typically 2 – 5 days) when consistent operations were achieved. This time period, and the resulting site energy consumption, is considered the energy benchmark for the remainder of the study.

Site utility models are constructed using simulation software and based on the energy benchmark and pinch analysis. Any changes made to the plant after the deadline are considered separately and excluded from the energy benchmark. Likewise, all identified energy-saving opportunities are compared and valued based on the energy benchmark.

Gap Analysis

The best technology analysis forms the basis of a gap analysis that identifies four areas for improvement, specifically 1) Fired Heater Efficiency, 2) Heat Integration Effectiveness, 3) Power Generation Efficiency, and 4) Process Configuration. Each of these four areas is described below.

- **Fired Heater Efficiency** - A proprietary fired heater model is used to compare actual performance against best practices for all furnaces and boilers. Based on the results of this analysis, recommendations are made to improve operations and, where appropriate, investment projects to enhance the energy efficiency of fired heaters.
- **Heat Integration Effectiveness** - The existing pinch analysis models are reviewed or developed as needed based on a cold-eyes review of the current level of heat integration in the various process units at the site.
- **Power Generation Efficiency** - An analysis of the utility system's efficiency is conducted using simulator software. The model examines the steam, fuel and power system where the heat balances serve as inputs for each process unit. Results are evaluated to identify the potential for additional power generation and to optimize steam supply.
- **Process Configuration** - Process flow diagram (PFD) reviews are conducted during review meetings. The PFD reviews note anticipated changes to process units, such as unit revamps. These improvement opportunities range from operational adjustments to short-term and long-term retrofit projects that require capital expenditures. This list is based on the findings gathered from the PFD reviews, benchmarking and gap analysis tasks, simulation and pinch analysis of the CDU / VDU / SGU units, and the energy audit of the equipment.

Opportunity Evaluation

Each opportunity requires a detailed analysis to evaluate key metrics related to the costs, benefits, and associated risks. This evaluation includes the following:

- Impacts on equipment and systems within the process unit
- Calculated economics based on the site energy balance
- Estimated capital costs
- Condition of operations (complexity, interactions between systems, control, reliability)
- State of implementation issues (e.g. plant shutdowns)

Roadmap Development

A successful energy management program requires several decisions that affect the payback period and return on investment. Figure 3 illustrates the develop-

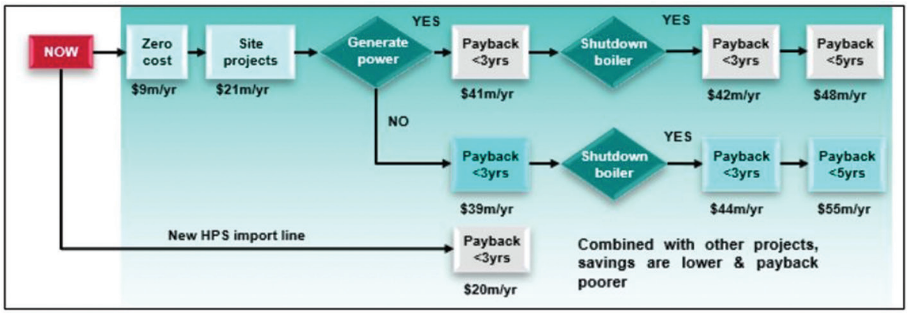

Figure 3. Roadmap Example

ment of a strategic energy road-map that sequences all future projects according to their attractiveness, in harmony with the site's power and steam balances.

Implementation Support

The energy roadmap tracks all of the project activities from kickoff to completion to:

- Support onsite test runs to verify recommended operational and quick win improvements
- Provide inputs for taking the capital projects to the basic engineering stage

Overall, the project's success hinges on the ability to convert ideas into benefits during the implementation stage.

Digital Energy Management

To sustain value, a comprehensive digital energy management system needs to be implemented using next generation gas combustion measurement, modern control technologies, and furnace optimization to detail combustion and improve fired heater performance.

A digital energy management system is designed to support all levels of the organization, from operators to top management, with the necessary information, analytical tools, and implementation processes. This approach enables key stakeholders to focus their efforts on achieving decarbonization and energy reduction goals while saving money. These systems lead to automated idea generation, achievement, and sustainability.

Combining real-time data with a single asset-wide digital twin and analytic capabilities provide automatic identification of opportunities and performance gap closures. This analysis applies to the whole utility system and processing equipment. With accurate projections, operators can track the efficacy of planned capital projects to make faster informed decisions about capital allocation throughout the implementation cycle.

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The digital energy management system has three basic high-level needs: Visualize, Analyze and Realize as depicted in Figure 4. The effectiveness of the system is a function of the data and technologies that work in the background to actualize it.

Figure 4. Digital Energy Management System

Visualize Monitor energy performance of the process units and refinery infrastructure to identify areas for improvement.

Analyse Calculate lost opportunities in the process plant and site utility systems. This sub-system uses monetary values to prioritize improvement opportunities and reveal the optimum path(s) to reach targets.

Realize Tack capital projects, create roadmaps, install advanced process control systems and other closed-loop systems as necessary to implement improvement initiatives and sustain the best energy efficiency.

Value Proposition

Asset owners often know where the improvement opportunities can be found but lack a comprehensive solution to track and continually evaluate them. Thus, the value of a digital energy management system lies in its ability to drive better and faster decisions via accelerated benefit realization, consistent year-over-year improvement and greater human productivity.

Typically, a site conducts energy studies sequentially. First, a baseline is established. Then, screening options are reviewed. Next, selections are evaluated. Finally, the system is designed. A key component of a digital energy management system is the ability to track energy improvement opportunities in real time, both for operational changes and capital investment items. This is just as important for individual projects as it is for entire energy reduction roadmaps where project interactions are considered. As a result, key data can then be presented to the organization, such as rolling average payback periods and determining how project paybacks vary for each opportunity.

Often the way energy is supplied to process units is complex with many levels and variables in the overall utility system. Changes in utility pricing is also a key factor that requires constant changes in the operating strategy. The benefits depend on the degree of flexibility in the system, but typically over 4% of the energy cost can be sustainably achieved. In the best performing averaged-sized complex refinery, the expected realized benefit is $10 million per year. Other improvement areas and the associated value can be seen in Table 1.

Real-time energy management solutions integrate data, analytics, and business intelligence to help drive and execute energy efficiency, energy management, and energy cost reduction initiatives. To sustain performance levels, energy systems must be constantly monitored and managed to assure energy availability and minimize energy loss. The key to achieving this goal is to continuously adjust the operations and equipment to remain within a predefined range based on real-time data.

Case Study

Recently, an energy improvement program was implemented in an international oil company that has multiple refining assets across the globe. The central energy team needed to drive a consistent approach to energy improvements and be able to sustain their energy performance with a reduced effort. They also needed an energy management system to help them facilitate effective capital deployment from the corporate budget.

Table 1. Value Realizations

Improvement Areas	Typical Delivered Value
Minimize energy demands while meeting process requirements	3% to 5% of site energy cost
Eliminate production constraints due to energy systems	2% to 3% increase in production on key units
Drive energy capital investments through implementation	10% to 15% of site energy cost
Reduce the cost of power and steam in real time	2% to 5% of site energy cost
Optimize cleaning costs and minimize energy loss due to fouling	1% to 2% of site energy cost
Reduce carbon emissions overall and save carbon tax	10% to 15% of CO_2 reduction

The first phase of the project focused on the digital energy management system visualizing and analyzing areas with two of their process units at two different refineries. A digital twin of the two process units was constructed and connected to the data, allowing visibility of the performance to both the corporate teams and the site teams. As a result, the company has real-time access to current energy gap breakdowns at the unit, system and equipment level. To make sound decisions, the team identified and prioritized opportunities to determine capital expenditures and automatically calculate benefits in real time. The realization of the project is anticipated to provide benefits of US$100m per year sustained cost reduction, and savings of 1.0 MM ton per year of CO_2 as shown in Figure 5.

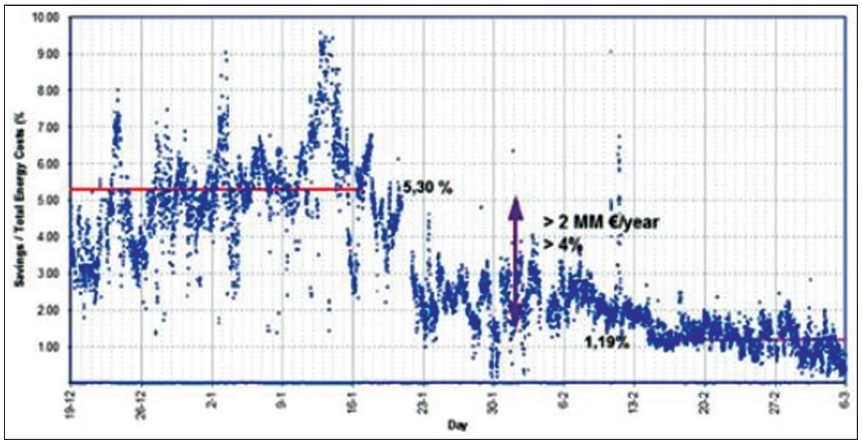

Figure 5. Real Time Benefit Tracking: Example of a Medium Complexity Refinery

Conclusion

The energy industry is undergoing a major evolution as it steps toward net zero. To achieve this change, a comprehensive digital energy management solution was implemented that sustains performance based on real-time data. The energy system blends reconciled data with decarbonization opportunities and advanced process control systems. In addition, it provides an end-to-end solution with aspects of benchmarking, gap analysis, opportunity identification, roadmap development, implementation support and digital energy management tools such as digital twins and energy monitoring software. With integrated solutions in data collection, data processing, data analysis, data reconciliation and optimization, organizations can effectively manage their energy and environmental impacts while delivering value to stakeholders.