Low Investment Energy Cost Reduction Methodology Consistently Delivers

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Introduction

Energy often accounts for almost half of refinery operating cost, and energy savings have significant impacts on refinery margins while also decreasing environmental footprint. Refiners commonly assume that they have already implemented low-cost energy-saving opportunities. Experience, however, frequently reveals that assumption to be ill founded—mostly attributable to unrecognized opportunities.

In the last decade it seemed that Shell, along with other refiners, had stopped looking for the next energy efficiency breakthrough. This was also a period of (particularly in Europe) high demands for capital investment to meet new gasoline and low sulfur diesel specifications, while capital was limited. Energy took a double hit: 1) capital for energy efficiency wasn't available and 2) as a result of the increased processing to meet higher fuel standards the plant energy consumption increased.

In order to revive the long run improvement in Shell in energy efficiency, a new innovative approach, called Energise™, was proposed which tackles energy use site wide tailored to a site's resources, goals, and challenges. The Energise program has helped Shell and other companies to embrace change and achieve sustainable energy cost reductions at refineries and petrochemical plants, at no or low capital investment, and to sustain the savings in the longer term. By late 2005, Shell Global Solutions' energy efficiency methodology has been initiated at some 29 refineries and petrochemical complexes worldwide. Our experience in Europe, Asia Pacific, and North America has averaged energy cost reductions in the range of 3% to 7%.

Energy performance is not only about utilities systems, it's also about the energy use in process units, good housekeeping, and the company work culture, available tools and management systems. The same energy saving rules as are valid for residential and commercial users also apply to refiners when it comes to plant lighting, air conditioning, and equipment such as computers. This is where some refiners have started their energy use focus. Such improved housekeeping can certainly help change the mindset of the people and thereby assist in achieving a sustained improvement in the energy use in the manufacturing plants. It is in the manufacturing plants however that the larger potential savings can be found. The savings revealed by the methodology have typically been found in various process and utility areas, from simple equipment improvements to more complex adjustments of, for example, distillation targets and heat integration opportunities.

Good energy efficiency goes together with being a good neighbor e.g. minimum hydrocarbon venting, flaring only in case of operational upsets, and optimized carbon emissions. Around the world many plants have had increased pressure from local authorities to tighten their performance in terms of venting, flaring, and carbon emissions.

The Energise Method

The Energise approach is simple and straightforward, the degree of difficulty is high, and the results are consistent. Specialists with experience of operations and energy apply a tried and tested delivery process to map energy use and energy efficiency, organizational and operational practices, and therefore identify opportunities for energy improvements. Once identified, the opportunities are reviewed with site operations and technical support, and a portfolio of projects is approved by the client, to be taken forward. The projects are then developed using a combination of resources depending on the nature of the project. Implementation of all projects is done within the site's own safety, environmental, and technical integrity processes. The most difficult aspect to manage is the human factor – the biggest blocker to timely results is lack of ownership of the problem. To sustain the savings in the longer term, tools are put in place to keep the savings measurable, visible and controllable for operators through to plant management.

Why is it difficult to save energy in energy intensive processes? Complexity. The schematic in Figure 1 shows the potential inputs and outputs for a refinery, all of which are in some way related to energy or impact energy use.

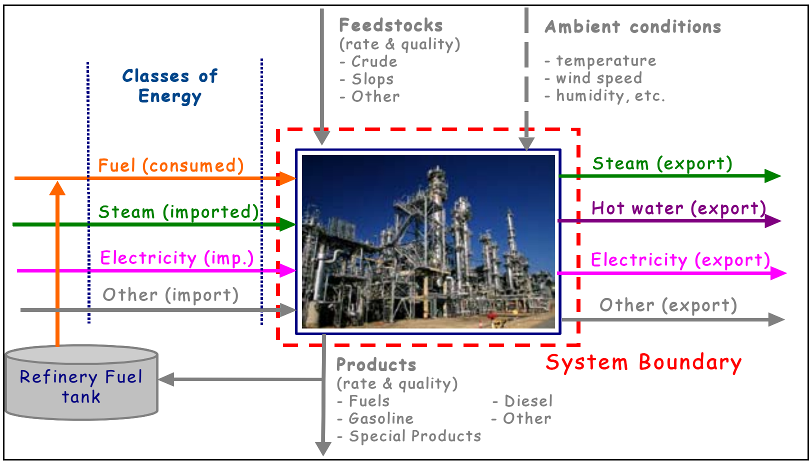

Figure 1: Plant energy streams

A primary concern for refineries, after health, safety and environmental issues, is managing its production plan. Energy often comes a poor second. In addition, changes in one process or piece of hardware can cascade to hard to foresee consequences, some may improve site wide energy use but others may have a negative impact on site wide energy use or robustness of operations. In order to properly evaluate the total impact of identified energy improvements, 2-3 months are used to perform a detailed assessment of opportunities and selection of the portfolio of projects. The early focus is on data collection and understanding the key plant profitability drivers, process parameters, economic premises, and main concerns and constraints. The focus on operational excellence and minor capital/fixed cost type changes typically means a program implementation phase of 12 – 15 months in order to achieve results.

Whilst the focus is energy, the experience to date is that operational energy improvement projects often also deliver additional benefits in improved throughput and/or yield. The gained knowledge of the energy profile of the plant can also be used to identify other energy improvement projects such as projects that require capital investment or a future plant shutdown.

Such opportunities can be identified in parallel with the regular program, and can form the starting point for a longer term energy master plan for the site.

Refinery energy opportunities

What we have found repeatedly are problems with effectively managing a number of well known targets for energy efficiency initiatives such as:

1. steam traps and steam leaks
2. furnace flue gas excess oxygen levels
3. burner maintenance
4. steam header control

Most refiners have had several campaigns in these areas in the past but for various reasons they have not been able to fully sustain the focus and the commitment in the following years. Competitive pressures on particularly budgets and staff responsibilities are frequently causing deteriorating performance with time which can go somewhat unnoticed when plant performance management systems do not include sufficient detail on relevant energy data and management attention is occupied elsewhere. Not surprisingly therefore reviving of programs in e.g. steam traps and leaks area have been a part of several of the refinery Energise programs. The value captured has proven significant.

Refinery fractionation opportunities

Another area where opportunities are frequently found is fractionation, from stripping steam optimization to adjusted fractionation settings on main columns in both primary distillation and major conversion units.

Thermal conversion combi tower operation

One project successfully reduced top overhead heat losses to cooling water, by modifying pump around targets of the main combi tower in a thermal gasoil unit and thus reduced its required heat duty. Optimizing pump around targets improved heat recovery but with the same temperature profile over the main fractionation columns meaning no change in fractionation sharpness between a top stream of cracked naphtha minus which is sent to recontacting and gas/naphtha separation, and a lower stream of cracked middle distillate. By doing this change the heat duty of the combi tower could be reduced while fractionation requirements were still met. Via heat integration the reduced heat duty translated to lower fuel demand in the crude furnace. The estimated savings were some 170,000 USD/yr in lower fuel input. This is an example of an operational excellence type improvement requiring close cooperation between distillation specialists, plant technologists and the energy specialist.

Crude unit operation

This refinery has multiple crude units that are already equipped with advanced process control systems. Upon investigating one of the crude units it was found that the overflash in the main crude column could be reduced to increase Light Gas Oil (LGO) recovery and achieve fuel savings in a related process heat furnace. This involved maximization of the ASTM 95% boiling point of the LGO by increasing a lower circulating reflux return temperature. Figure 2 illustrates the control system.

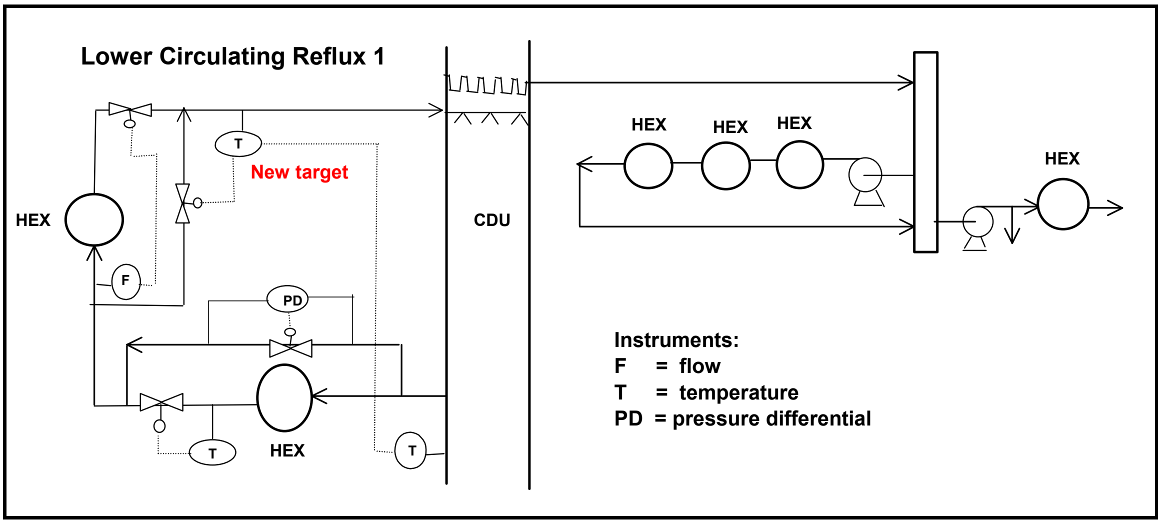

Figure 2: Lower circulating reflux control system

As part of the evaluation, process simulations were run to match operational data and to define the areas of opportunity. This was followed by live tests that confirmed that energy savings were possible without really affecting the ASTM 95% distillation point. However, the final boiling point of the LGO was increased. It was confirmed by the refinery that this was not a problem in gas oil blending as the specification is limited to the 95% distillation point and did not include a final boiling point limit. The LGO distillation target optimisation was implemented as an additional strategy to the existing Advanced Process Control (APC) system. The controller model was adjusted so that the lower circulating reflux return temperature is maximized basis economic criteria.

It was also found that the Light Kerosene (LK) dew point margin in the main crude column was typically operated significantly higher than the desired target. The objective of minimizing the dew point margin is to minimize LK production. The LK is routed to hydrotreating while the heavy kerosene fraction is routed to Merox treatment. The latter consumes significantly less energy compared to hydrotreatment, and the Merox unit has spare capacity. Effectively the LK dew point margin in the crude unit is the operational limit. However, the shift of kerosene from light to the heavy fraction can only be done when the refinery is on low sulphur crudes such as some Far East crudes.

Also here process simulations were run to match operational data and to define the areas of opportunity. Live tests followed to confirm simulation projections. The existing APC system was already set up to optimize the LK dew point margin. However, the control was not robust, and as a result, operations would use a wider set range for dew point margin to reduce controller fluctuations. The APC system was retuned to make it more stable and the dew point calculation needed to be modified to make it more accurate. Then, the desired sharper operation became feasible.

The total energy savings from both the LGO and LK improvements was estimated at some 80,000 USD/a in lower fuel use in the crude unit and in reduced hydrotreater fuel use. To sustain the benefits it was advised to monitor both APC systems in terms of online availability more closely and to work on further controller tuning to possibly enhance the results further. Although, the kerosene dew point margin calculation was improved it was advised to investigate further possible accuracy enhancements. The refinery is planning to implement these improvements also on the remaining crude units in the refinery.

Fuel gases

A recurring theme is to scrutinize the fuel gases produced in the refinery. Their original production rate (in major conversion units etc.) is often not the remit of the energy specialist, but how such gases are subsequently processed and routed is within the remit of addressing fuel supply and demand. For example, are sufficient propanes (C3) and butanes (C4) removed from gases to be routed to fuel, and could such gases be more profitably routed elsewhere etc.

Work has been done to reduce the total amount of own generated fuel gases to ensure that identified energy savings lead to real savings. Obviously there is no real value in saving fuel in one part of the refinery just to end up with a total excess of fuel gases and an increased risk of approaching flaring of such excess fuel gases. Real fuel savings result in e.g. less import of natural gas to balance the fuel gas system, less propane vaporization, or reduced use of liquid fuel etc.

Reduce vent gases sent to fuel

At one North American refinery treated vent gases were being split between being used as refinery fuel gas (RFG) and as feed to hydrogen production. However, the amount of vent gases that can be utilized as feed for hydrogen production is limited by feed pretreatment capacity restrictions. The project rerouted some of the vent gases, using an existing header, to hydrogen production feed instead of to RFG. The scope of work comprised adding piping with isolation valves and essential flow meters and control valves to facilitate the new routing option while safeguarding the functionalities of both the original and the new routing options. Implementation was performed in a single step and process tests were unnecessary. The impact of the changed feed diet on hydrogen production was evaluated using simulation tools.

To sustain the savings, KPIs were added that target the minimum use of natural gas as hydrogen feed and, at the same time, sending the minimum volume of vent gases to RFG. The value of using vent gases as feed for hydrogen production is greater than that of using natural gas as feed.

The project improved the molecular management of the gases sent as feeds to hydrogen production and the gases sent to the RFG system. The overall savings on an annualized basis were some $1.9 million per year and were based on the differential value of rerouting about 4.5 MMscf/d of vent gases from RFG to hydrogen production feed, taking into account both the fuel value and the resulting processing credits.

Reduce C3/C4 sent to fuel

In a North American refinery vent gases from hydroprocessing units are sent to a rectified absorber column where C3/C4 are recovered before the hydrogen rich vent gases are routed to a PSA unit for further hydrogen purification. The ability of the rectified absorber column to recover C3 and C4 components is largely determined by the flowrate of lean oil that is circulated and by the temperature of the bottom trays in the column. The latter temperature is controlled high enough to prevent any ethane from being pulled out the bottom of the column, but then the lean oil flowrate must also be increased to prevent too much C_4 from going out the top of the column as dry gas. These two control strategies however tend to work against each other and result in higher lean oil circulation and lower C_3/C_4 recovery.

Process simulations were run to match operational data and to define the areas of opportunity and then live test runs were executed to confirm simulation projections. It was found that good operation of the absorber can be obtained using adjusted control settings on lean oil flowrate and column temperature that result in a higher C3, C4 recovery without losing ethane to column bottoms. The estimated savings on an annualized basis are some 2 million USD per year taking into account both heating value (less C3 and C4 from PSA to fuel) and processing credits.

Recover and reroute C4's and send less to fuel

The FCC Gas plant at this North American refinery recovered C4's from the fuel gas stream but a certain amount of C4's were left in the fuel gas and it was believed that column constraints made this necessary. A simplified sketch of the gas plant configuration is shown in Figure 3.

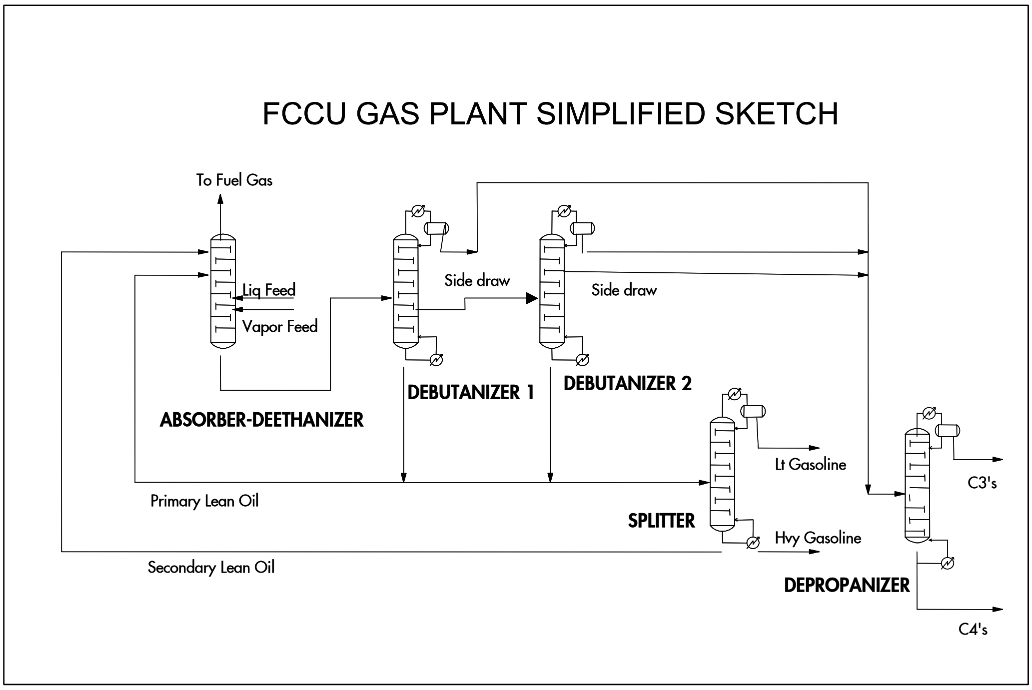

Figure 3: Gas plant simplified configuration

The C4's recovery was not sufficiently deep due to the debutanizer 2 column inadequately separating C4's from the bottoms stream, hence sending C4 rich lean oil to the absorber-deethanizer column and hence limiting C4's recovery in this column. Process simulations were run to match operational data and to define the areas of opportunity. The reason for poor C4 separation in the debutanizer was due to poor tray efficiency, tray weeping. This was not obvious, and in fact operations believed the trays were flooding. However, the root cause showed up when analyzing the simulation results. This was followed by live test runs that confirmed that good operation of the debutanizer 2 column can be obtained if the column vapor load is kept high enough, thus lowering the absorber recycle lean oil C4 content and increasing C4 recovery from the fuel gas stream, without increasing the amount of pentanes in alkylation feedstock.

The proper valuation of this project proved a true learning experience for all. It took a lot of discussions to define the realistic routing of the extra C4's recovered taking seasonal differences and other refinery constraints into account. The benefits realized are coming from the alternative value of the use of the C4's above that of using it as refinery fuel, mainly as alkylation feedstock but in winter also partly in mogas blending. An additional analysis was needed to arrive at an informed understanding on the fuel gas balance situation now, and in the near future. The latter was predicted to be one of fuel gas surplus, and the extra C4 recovery would help alleviate that situation. The total benefits from this improved molecular management of C4's was estimated at some 5.4 million USD per annum in margin uplift value and improved fuel balance.

Other refinery opportunity examples

Increase condensate recovery

Increasing the overall condensate recovery to save both energy and conserve water has proven interesting for some refineries, particularly if their water plants are highly loaded. The routing of steam condensate streams could be changed to enable an enhanced overall condensate recovery for one refinery in North America. Implementation required operating instructions for some diverter valves within a thermal conversion unit and training of relevant operators. The value of the change was estimated at some 200,000 USD/yr. This opportunity depended heavily on vital input and insight from an experienced client operations staff. This is thus an excellent example of what can be achieved together when individual input is leveraged.

Increase own power generation at peak power price

At a refinery in North America with own power generation as well as import from the grid (net importer) an opportunity was identified to adjust own power generation sharper versus the fluctuations in the price of the power imported to fill the total plant demand. This way the refinery could capture savings while of course staying within the constraints of the site wide steam/power balance. One prerequisite was that it was possible to make reporting of power price peak opportunities available to operations as they occurred, another prerequisite were the state of the art control systems installed on the relevant turbo-generators.

As part of this project the operating limits of the turbo-generators with respect to extraction and condensing capabilities were updated as well as the turbine efficiencies to set heat rates and to establish the cost of own power generation. The relevant turbo-generators have demonstrated the ability to respond to the required increased demand.
A procedure was developed that would be used by operations to "chase" peaks in power prices using a tool with information on the price of power imported, the cost of own power generation etc. Training of the operators was conducted in the proper use of the procedure.

Power generation from the turbo-generators is thus adjusted to increase production through increased condensing when power prices make this economically interesting. Actual savings by the end of 2005 have been over 1 million USD on an annualized basis.

Overall results

Energy efficiency is often associated with utility systems. In fact for refineries (and petrochemicals), the energy efficiency potential is site wide. Experience has shown that most of the improvements can be found in processing units; e.g. adjustments on distillation targets, heat integration changes, and rotating equipment improvements. A significant part of the savings is typically found on the interfaces between process and utilities.

The figures 4 and 5 below show examples from the Asia Pacific region and Europe. It can be noted that the percentage for process savings stays the largest. However, it is worthwhile to pay attention to utilities, as already a small improvement can have a large value due to the large energy volumes involved at a refinery.

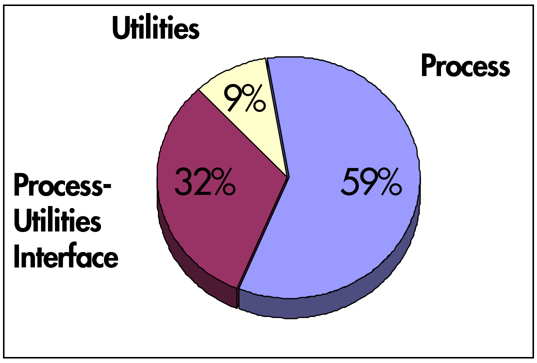

Figure 4: Breakdown of savings, Asia Pacific region

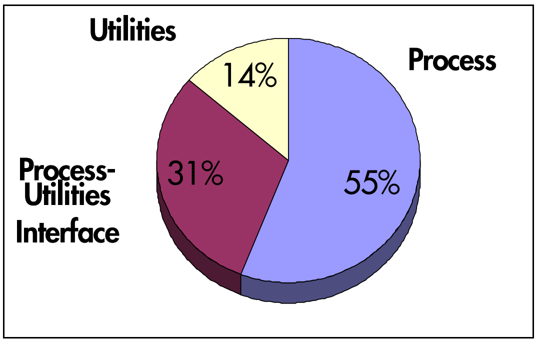

Figure 5: Breakdown of savings, European region

At one European refinery however the majority of savings realized were in utilities systems, in fact as much as 92% of savings were realized in utilities. In this case some of the improvements in utilities also involved the interface between the refinery and nearby plants to which steam is exported.

An example from the North American region is shown in Figure 6. Here clearly most of the savings were captured in the process area.

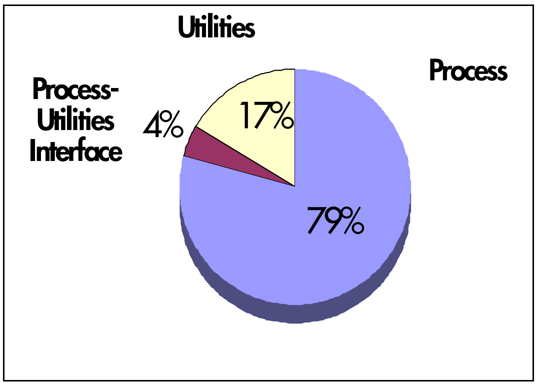

Figure 6: Breakdown of savings, North American region

At another North American refinery the picture is very similar with 73% of the savings captured in process and the remainder of the savings captured in utilities. It can be noted that in North America just as in Europe, with a more seasonal climate, the breakdown of savings can show a higher percentage in utilities than in a tropical climate, due to more scope for seasonal optimizations, but this trend is not very strong.

Overall the global experience, as illustrated by the examples shown, is thus that more often the most energy savings are captured in the process units, and not in the utilities.

The table below illustrates a few examples of approximate program results at some refineries at the end of each program.

Refinery location	Type Result	Quantified Result
Europe A	Reduction	6.5 % on energy use
	Realized savings (1)	1.5 million USD/a
Europe B	Reduction	6.8% on equivalent fuel
	Realized savings (1)	3.5 million USD/a
North America A	Reduction	5 % on energy use
	Realized savings (1)	20 million USD/a
North America B	Reduction	5% on energy cost
	Realized savings (1)	22 million USD/a

(1) The approximate, validated total value at end of each program, the aggregate of all completed projects. Also includes non-energy benefits where applicable

Although the table shows individual examples it can be said that in general we have found that the scope for energy savings and other benefits in conjunction with this is somewhat larger in North America compared to other parts of the world. This is probably an effect of an even higher pressure over a longer period of time on refiners outside North America to cut their energy costs and reduce their carbon emissions.

The Key to Program Results

To achieve a successful Energise program requires team work. Shell Global Solution's experience has shown that by combining knowledgeable personnel, who aren't involved in site operations, and the use of a reproducible process together with local site personnel, who do know operations intimately, can provide breakthrough performance. To greatly facilitate that the projects are owned by the site, it is also very important to execute their identification and evaluation as a single team. Joint review sessions with site personnel are at the heart in this, and they are crucial to a successful program outcome.

The amount of effort required to develop the conceptual projects into fully implementable projects and then to get the projects completed is often very underestimated. In order to gain buy-in from the site organization and be approved for execution the projects have to be adequately documented during the development. Documented to meet the needs of a variety of stakeholders, for example including the case for change, an estimate of benefits, estimates of capital expenditure (if any) and operating costs, enablers and blockers, and the technical details. Project execution will have to follow all requirements of the site's own safety, environmental, and technical integrity processes, and project execution may not negatively impact on normal operations of the plant.

The Keys to sustainable improvements

Implementation of the projects is not the end but in fact only the beginning. At that point the savings, the payback, for the changes completed is only just beginning. Only if the completed projects are left with suitable data monitoring, technical support and ownership will they deliver their potential in the longer term. Change management clearly needs to address both technical and soft issues. Sustaining realized improvements is a matter of consistently practicing operational excellence and to enable the required clarity in target setting, target tracking and personnel responsibilities. Therefore, systems and processes are put in place at the site that serve all stakeholders (from operators through to management) to keep the saving measurable and visible, and therefore more likely to be actively managed.

Typically project specific Key Performance Indicator (KPI) tools are established and then included in the refinery's distributed control system (DCS), process information data bases, and existing management of information systems. These tools are thus fully integrated with existing management of information systems used to monitor and optimize operation of the plant (such as end of shift reports, regular performance reports etc.), and build on what has been successful at other sites and the site's own requirements.

The approach of fully integrating the sustainment tools within the existing site systems for operations monitoring and optimization is repeatedly fully endorsed by refinery management. For example, operators have the operational target information and guidance they need, where they are used to finding it, and can act upon it in the usual way. Operators can be made responsible for energy targets they can influence. Any conflicts with margin value can be dealt with at the lowest possible level using worked out guidance on best actions to take to handle the daily variabilities and daily disturbances that every refinery encounters. Other staff and management can more easily track the performance of completed projects and propose remedial action, if necessary, as well as further improvements in operational excellence. Technical support and management can be made responsible for energy targets they can influence. Deviations from set targets are visible to all and can be discussed in operations meetings and performance review meetings.

To further facilitate, organizational change may be required to ensure that there is ownership at all levels, clear roles and responsibilities, and continued management attention for energy efficiency. A plant management committed to energy efficiency targets for the longer term are essential. At the end of the day it is proper resource allocation that enables sustainment of savings.

Footnote:

(1) Shell Global Solutions is a network of independent technology companies in Royal Dutch Shell plc. In this material, the expression 'Shell Global Solutions' is sometimes used for convenience where reference is made to these companies in general, or where no useful purpose is served by identifying a particular company.