THE FIRST STEP

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The global trends and challenges driving the need for industry to improve energy efficiency are well known. The growing population and economic development in many countries throughout the world has caused energy and transportation fuel consumption to increase. Refiners around the world are increasing capacity to meet these needs. Higher oil and gas prices, especially over the past two years, have greatly increased energy related operating costs and emphasised the need to increase energy efficiency. Many countries want to increase energy security, which has encouraged the search for alternative energy sources and has been another driver for energy efficiency. Recognition of global warming has increased environmental regulations and carbon taxes, setting a new trend that will continue to grow during the coming years. This will add to the operating costs of all energy intensive industries, including refineries and petrochemical companies.

Simply stated, today's refiners face many challenges. However, technology driven solutions now exist that can address these challenges and help achieve energy optimisation. Honeywell's experience has shown that a 12 - 25% energy reduction is achievable by implementing a comprehensive energy management solution with attractive returns on capital investment. A significant portion of the energy efficiency results and reduction of greenhouse gas (GHG) emissions within a refinery/petrochemical complex can be achieved through improvements to plant processes. This article identifies the major process improvement opportunities and proposes a novel work process methodology to achieve them.

Saving energy and reducing GHG emissions

If a refiner wants to reduce energy costs and GHG emissions, which areas should demand the most attention and what should proposed solutions look like?

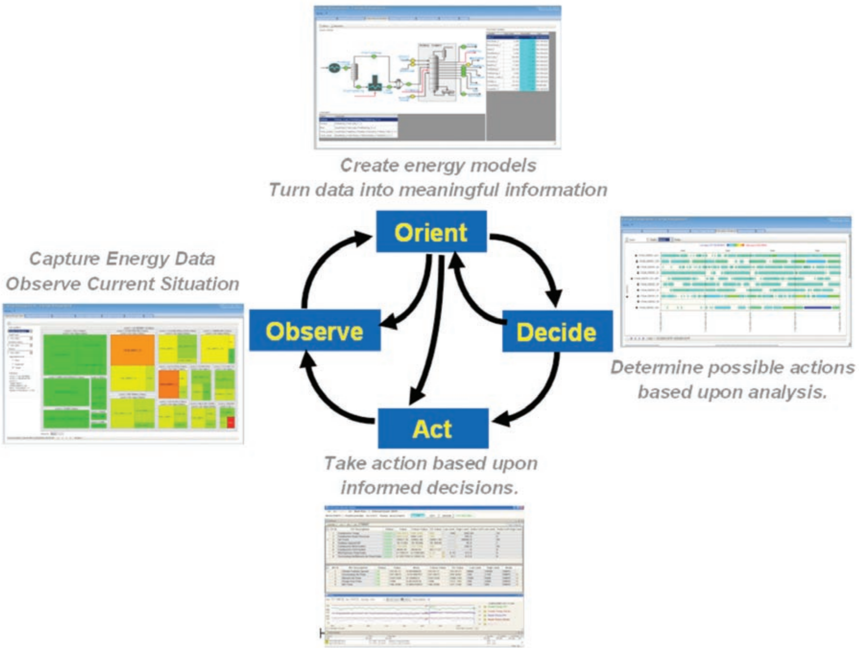

Figure 1. Energy monitoring OODA loop.

Table 1. Potential benefits achievable through the use of Honeywell energy efficiency solutions			
Area of saving	**Energy improvement (%)**	**Energy saving (US$ million/y)**	**CO_2 reduction (000 tpy)**
Improved operation and control	2 - 4	1.5 - 3	24 - 48
Improved heat recovery	4 - 8	3 - 6	48 - 96
Incorporate advanced process technology	3 - 8	2.5 - 6	36 - 96
Utilities optimisation	2 - 3	1.5 - 2.5	24 - 36
Improved planning	1 - 2	1 - 1.5	12 - 24
Incorporate renewables (2000 bpd ecofining unit)	CO_2 credit	4	116
Total	12 - 25	13.5 - 23	260 - 416

CO_2 emissions vary from refinery to refinery depending on feedstock type, fuel specifications and refinery complexity. A typical 100 000 bpd refinery emits 1.2 - 1.5 million tpy of CO_2. Approximately 50% of that amount is from the process heaters, 35% comes from the FCC and hydrogen plants and the rest is from steam and power systems. Similarly, the energy consumed within a refinery also varies with configuration and feedstock but the major energy consumers are the crude unit, the FCCU, the reformer and the utilities.

At present, focusing on reducing energy costs is the best way to reduce GHG emissions as it removes the concern of where the future value of carbon credits will settle. There are a number of methods refineries can use to reduce energy costs including improving energy efficiency within plant processes, buying energy more cheaply or leveraging environmental policies to gain carbon credits to offset energy costs. However, this article will focus on the first method: reducing energy consumption through improving energy efficiency within plant processes.

Improving energy efficiency within plant processes is an action that can be used independently as a cost effective first step towards reducing energy consumption, and also as part of an energy management solution combining elements of other energy reduction methods mentioned earlier. Three key ways in which improved energy efficiency can be achieved within plant processes are:

- Operational improvements to optimise the process.
- Recovering more heat by improving the heat integration of the process.
- Adopting new process technology that fundamentally improves the efficiency of the operation.

Optimise operation

The first step in developing an energy management solution to optimise the process is to be able to measure what energy consumption looks like against a reasonable set of benchmarks. This involves capturing energy data related to the process and organising it in a way that allows operations to quickly identify where the big energy consumers are and how well they are doing.

To determine how well a plant or a unit is doing, it is necessary to be able to compare current energy use against a consumption target that reflects the current operations. Only then is it possible to do some analysis to determine the cause of deviations from target and take appropriate remedial action.

A good energy monitoring solution should perform like John Boyd's OODA loop[1] which allows the user to quickly observe the situation and assess the relative performance of multiple units; orient oneself by being able to drill down to get more details on key energy indicators of the most critical areas; decide on a set of possible actions based upon the determination of possible causes for deviation from target; act quickly and decisively based upon a set of well informed decisions. The loop allows for rapid internal feedback to allow the user to quickly observe the impact of actions taken and hence reorient and decide on any further actions. Figure 1 shows an example of how this feedback loop can be applied to an energy monitoring solution.

A hierarchy of views is provided by the energy monitoring application that allows the user to drill down to multiple levels and identify possible actions. These include:

- Unit overview. Shows the relative size of energy consumption and/or GHG emissions in each unit. Also uses colour coding to indicate which units are furthest away from target.
- Unit view. Shows the value of key energy indicators (KEIs) that describe the energy performance of the unit against targets that are developed from a combination of process simulation, historical data and know how of experienced UOP consultants. These predicted energy targets are automatically adjusted to reflect current operating conditions such as production level, operating mode, feed composition, product qualities etc.
- Trend KEIs. Allows the trending of the calculated value of KEIs against both the planning target and the predicted energy target.
- Review deviations. In this display, the operator can review over the time periods when KEIs deviated significantly from their expected range and what the major causes of the deviations were according to the selected reason codes. By building up a history of causes, it is possible for the user to look back over time and see the most common causes for deviations. This can lead to recommendations about modifications to improve energy performance.

Many recommendations for improvements to energy efficiency can be achieved by the operator directly changing the plant conditions by adjusting the set point of key variables. In some cases it may be possible to incorporate these recommendations into an online advanced control and optimisation strategy.

Multivariable, predictive control and optimisation applications such as Honeywell's Profit Controller have been commonly applied to refinery and petrochemical processes. The ability to take models derived from process data and configure them in a highly flexible manner allows the engineer to design controllers that can be suitable for many purposes. The same controller can be used to maximise throughput, maximise yields and minimise energy just by changing cost factors in the objective function. This environment is very suitable for incorporating energy strategies into overall operating objectives. In fact, it is generally advisable to add energy efficiency objectives into existing strategies, as it is important that minimising energy is not done at the expense of maintaining yields of most valuable products.

In more complex solutions rigorous simulation models can be used to update data models within the controller.

There are many energy saving strategies that can be incorporated into multivariable control applications, such as:

- Furnace pass balancing and excess O_2 control.
- Distillation column quality controls combined with pressure minimisation to maintain yields of most valuable products while minimising energy consumption up to constraints such as tower flooding.
- Reactor conversion control.
- Feed preheat maximisation.
- Separator and recycle control.

An example of a large multivariable control strategy was applied to an ethylene complex. This involved 17 multivariable controllers that were linked together by an over arching optimisation strategy that included the use of a non-linear cracking model to predict product yields.

The result of the project was to enable the customer to increase feed rate by 3% over the previous best rate by being able to operate the process up against multiple constraints simultaneously. In addition, the application was also able to reduce energy consumption by 3.25% by reducing steam consumption in the fractionators and minimising excess O_2 in the furnaces. This resulted in a project that showed a payback of less than five months.

Opportunities to operate process units more efficiently exist in most refineries. In Honeywell's experience, little or no capital operational solutions can improve energy efficiency by 2 - 4%. These improvements can reduce CO_2 emissions by 24 000 to 48 000 tpy for a typical 100 000 bpd refinery.

Better heat recovery

Using monitoring and optimisation software to improve energy efficiency usually results in pushing the process up against multiple physical constraints. To reach the next level of energy efficiency requires capital cost modifications to increase heat recovery within and across process units. Indeed, one of the key values of implementing operational solutions first, is that it more clearly highlights where the physical constraints to the process are. Once specific units have been identified for improved heat integration, pinch technology in software such as Honeywell's Unisim Design can be applied to efficiently screen and select from a variety of possible heat recovery networks. UOP process consultants use a practical methodology which not only considers value and cost of improved heat recovery but also the effects to process such as product quality, operating flexibility, especially with respect to startup, shutdown, maintenance and control.

A typical example of redesigning for improved heat recovery involved an older 1970s vintage diesel hydrotreating unit, which had a combined feed exchanger, charge heater, one reactor and a stripper. When UOP process consultants studied this unit they recommended adding four heat exchangers to recover more heat from the process and also generate steam. This scheme can capture the waste heat lost in product run downs and reaction air cooler, which result in reduced fired heater duty and increased high pressure steam generation. The capital cost for this project was estimated to be US$ 3 million but resulted in energy savings of US$ 4.5 million/y.

Projects to improve process unit heat recovery can typically improve energy efficiency by 4 - 8%. The CO_2 reduction for a typical 100 000 bpd refinery that results from these projects is 48 000 - 96 000 tpy.

Advanced process technology

Improved heat recovery is the most common type of capital project implemented to improve energy efficiency. However, recent work by UOP has identified other areas less commonly explored that may provide significant opportunities. Many of these areas make use of advanced process technology offered by UOP such as enhanced heat exchangers, high capacity fractionator internals, new reaction internals, power recovery turbines, improved catalysts and other design features.

Power recovery often represents a good opportunity for economic energy optimisation, as can be seen in the following example. In a study of an FCC unit with 60 000 bpd throughput, the FCC catalyst regeneration flue gas was being used for steam generation alone via a waste heat steam generator. A power recovery system was quickly identified as a method for significant energy efficiency improvement as the flue gas could be used for both steam and power generation simultaneously. Further improvement could be achieved by installing a power recovery turbine (PRT) combined with a steam turbine. The goal was to generate electricity from the regenerator flue gas but also produce electricity from HP steam let down to produce the MP and LP steam required in the FCC unit. Compared to a base case that does not include a PRT and uses a condensing steam turbine to drive the main air blower, this scheme has a net energy benefit of US$ 14 million/y.

There are a variety of advanced technologies that can be applied, which vary in terms of cost to implement and return on investment. Careful evaluation of each of these solutions is required as capital is always limited, so it is necessary to select only the best opportunities that provide the highest return on capital employed. Although these solutions can vary greatly, typical improvements to energy efficiency are in the range of 3 - 8% for a typical 100 000 bpd refinery. The CO_2 reduction is on the order of 36 000 - 96 000 tpy.

Summary of potential savings

Table 1 outlines all the potential benefits that can be achieved with Honeywell solutions for energy efficiency. The red sections combine the potential energy and GHG emissions benefits a typical refinery of 100 000 bpd could achieve by using energy more efficiently within the plant process.

Conclusion

There is a growing need for refineries and petrochemical producers to put an emphasis on reducing GHG emissions, especially in Europe, given the European Union's commitment to reducing GHG emissions by 20% below 1990 levels by 2020. At present, focusing on reducing energy costs is the best way to reduce GHG emissions. In many cases, improving energy efficiency also improves processes in terms of throughout and yields as well as reliability. This article has outlined three ways in which energy consumption can be reduced through improving energy efficiency within plant processes: optimising plant operations, improving heat recovery and implementing advanced process control technology. Optimising energy efficiency within plant processes can be used as a first step or as part of a comprehensive energy management solution to reduce plant energy consumption and ultimately reduce emissions.

References

1. CONRAN, Robert, Boyd: The Fighter Pilot Who Changed the Art of War, 2002.