Improving Energy Efficiency of Brownfield Plants

By Brendan Sheehan, Honeywell Process Solutions
Table of Contents

Introduction........................................................................................................................................................................3

Global Regulations and Trends..............................................................................................................................................3

Methods to Improve Efficiency and Reduce Greenhouse Gas Emissions..............................................................3

Energy Efficiency with Process Redesign: Heat Integration...............................................................................................4

Energy Efficiency with Process Redesign: Advanced Process Technology .............................................................4

Energy Efficiency with Process Redesign: Managing Emissions..................................................................................5

Energy Efficiency with Online Monitoring and Control: Online Monitoring...........................................................5

Energy Efficiency with Online Monitoring and Control: Online Control.................................................................7

Energy Efficiency with Online Monitoring and Control: Online Control of Utilities.........................................................9

Energy Efficiency - Sustaining Benefits: .........................................................................................................................10

Summary of Benefits........................................................................................................................................................12

Conclusion:..........................................................................................................................................................................12
Introduction

Reducing the carbon footprint brought on by plant inefficiencies and population growth and over-consumption, with the goals of reducing plant costs, achieving energy efficiency and security, and abating greenhouse gases (GHGs) – of which carbon dioxide (CO₂) is the main culprit – are the challenges faced by today’s leading industrial producers.

It is predicted the world’s population will increase by 1.4 billion people from 2007 to 2028, equating to an approximate 60 percent increase in the demand for all types of energy for transportation, electricity generation and to fuel industry, to name only a few. Add to this statistic the potential for fuel price escalation and encroaching or already implemented environmental regulations, and heavy industry is faced with implementing cost- and energy-saving solutions in a hurry.

On top of this, many existing energy intensive industrial facilities are facing significant challenges while competing in a global marketplace. With increased competition and increased capacity coming on-line in regions with significant cost advantages, there is renewed interest in improving and sustaining the performance of existing assets. An established producer is forced to focus relentlessly on reducing costs while serving its customers better.

This paper will explore effective ways to produce energy more cost effectively, purchase energy more economically and reduce overall energy usage, contributing to significant reductions in greenhouse gas emissions.

Global Regulations and Trends

International environmental groups concerned with the phenomenon of global warming are proposing strict regulations to which energy-intensive industries such as chemicals, metals/minerals/mining, pulp/paper, petrochemical, power and refineries would have to adhere. In some cases, these regulations are a reality and include amounts by which manufacturers must reduce GHGs as well as associated time limits to do so, and they offer guidelines for reaching target goals along the way.

Popular global regulations and/or trends include the following:

**Kyoto Protocol:** Implemented in 2005, the 175 countries that have entered into this agreement vow to decrease GHGs by an average of 5% during the timeframe of 2008 to 2012, versus GHGs emitted in 1990.

**20-20-20 (European Union Energy Pact):** This European Union (EU) agreement vows to decrease CO₂ emissions by 20%, to produce 20% of energy using renewable resources, and to reduce energy consumption by 20%, all by the year 2020, compared to 1990. CO₂ emissions will be decreased by 30% if other non-EU nations sign on. This plan picks up where the Kyoto Protocol leaves off in 2012 and has a sliding scale based on countries’ energy use and stage of economic development.

**Carbon Emissions:** Carbon credits, Carbon Emissions Trading, and Carbon Taxes are all programs in place or proposed in various geographies to constrain the emissions of CO₂, the single largest offending GHG emission, as well as other offending gasses.

With increasing economic development and populations relying more heavily on energy production, the above regulations and trends can be cause for concern to heavy industrial producers. Add to that the public relations quagmire industrial producers face with the delicate balancing act of hitting regulatory targets, while still deploying full-capacity energy production to meet supply.

Methods to Improve Efficiency and Reduce Greenhouse Gas Emissions

It is generally understood that reducing the effect of GHG emissions on global warming is a multifaceted issue, which takes a multifaceted approach to solve. Some things to consider include reducing energy usage by becoming more efficient in power generation as well as industrial consumption, carbon capture and/or destruction and utilizing cleaner alternative sources of energy.

Honeywell Process Solutions can help industrial plants reduce energy consumption by up to 10%, and help abate GHG emissions. The greatest contribution in GHG abatement is energy efficiency. By implementing HPS energy efficiency and process optimization solutions, the industrial sector has seen energy savings such as the following:
A comprehensive energy management solution combines energy conservation, process optimization, new technologies and innovative energy sources with products, solutions and services to measure, improve and sustain improved environmental performance. Figure 1 identifies in more details where some of these strategies can be employed.

**Energy Efficiency with Process Redesign: Heat Integration**

One of the primary ways of improving energy efficiency within existing facilities is by revamping the process to increase heat recovery within and across process units. Heat is recovered from waste heat streams and used to provide preheat to process streams that are heated with fossil fuels in furnaces or boilers. While this is a generally desirable, the difficulty comes in deciding which streams should be preheated and by how much, which should be cooled and by how much and where the excess heating and cooling should come from.

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. It should be noted that the best design for an energy efficient heat exchanger network is usually a result of a trade-off between equipment and operating costs. Process consultants (such as those at UOP - a Honeywell company) apply these applications along with a practical methodology which not only considers value and cost of improved heat recovery but also the impact in terms of operating flexibility, especially with respect to startup, shutdown, maintenance and control.

Projects to improve process unit heat recovery can typically improve energy efficiency by 4 to 8%.

**Energy Efficiency with Process Redesign: 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 others 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 optimization as can be seen in the following example. In a study of an FCC unit with 60,000 bbl/day 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
Improving Energy Efficiency of Brownfield Plants

has a net energy benefit of $14 MM per year.

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 to 8% for a typical 100,000 BPSD refinery.

**Energy Efficiency with Process Redesign: Managing Emissions**

Increased focus on environmental regulations, while generally necessary as energy consumption increases globally, can have unintended consequences when restrictions in one area can cause increased emissions on another. For example tighter controls in NOx emissions that help prevent acid rain, has encouraged some producers to install low-NOx burners in their process heaters and boilers. However the lower flame temperature and longer flame length that is common with low-NOx burners have required the operation to run much higher excess air in order to maintain flame stability. His has meant that although NOx emissions are reduced, energy efficiency is reduced and GHG emissions increased. However, recent improvements in this area, by Callidus, a Honeywell company, to produce the CUB-LX burner that runs with a proprietary ledge stabilization design, allows for the burner to maintain flame stability even at sub-stoichiometric conditions and still maintain <15ppm NOx emissions.

Aside from improving energy efficiency to reduce CO2 emissions while minimizing other emissions like NOx, companies are also tackling the emissions problem by focusing on increasing the amount of renewable energy processed. This not only helps meet the EU directive for 20% renewable energy by 2020, but also improves profitability by the resulting carbon credits that can be obtained.

The installation of a bio-fuels unit can lead to significant GHG savings by reducing an entity’s carbon footprint. An example is the UOP/ENI Ecofining™ process which converts vegetable oil such as soybean, palm and rapeseed to green diesel but could also process other low cost materials such as tallow oil, fish oils, and waste greases. The process de-oxygenates the feed and uses hydrogen to convert the oil to a branched paraffin rich diesel fuel. Water and CO2 formed by the de-oxygenation process are separated from the product, while excess hydrogen is recovered and recycled back to the reactor to maintain the minimum required hydrogen partial pressure.

Only fossil fuel derived GHG emissions are considered in the EU directive, so the biomass energy is considered to be neutral with respect to GHG emissions.

Consequently, while total energy required to produce green diesel is slightly higher than petroleum diesel, the energy consumed by fossil fuels only is 77% less than petroleum diesel and the GHG emissions are 84% less.

The reduction in GHG emissions for a 2000BPSD Ecofining unit is worth 116000MT/yr of carbon credits.

**Energy Efficiency with Online Monitoring and Control: Online Monitoring**

Process revamps require capital funding to implement energy efficiency solutions. There are also a variety of operational improvements that can be applied to ensure the process is operated as efficiently as possible. The first step in developing an online energy management solution is to develop an energy dashboard to measure real-time energy consumption against a reasonable set of benchmarks. This involves capturing energy data related to the process and organizing 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 hierarchy of views is provided by the energy dashboard 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 color 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 which are developed from a combination of process simulation, historical data and know-how of experienced consultants. These predicted energy targets are automatically adjusted to reflect current operating conditions such as production level, operating mode, feed composition, 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 time, the 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.
Energy Efficiency with Online Monitoring and Control: Online Control

Many recommendations for improvements to energy efficiency can be achieved by the operator directly changing the 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 optimization strategy.

Maxon, a Honeywell company, has a long history of providing burners and burner controls for heaters in a variety of industries. Maxon’s patented SMARTFIRE technology provides cross-limited, self compensating, air-to-fuel ratio control that can tightly control firing across a very broad operating range. The turn-key solution combines the burner technology with mass-flow meters and intelligent valve actuators in a distributed architecture that can standalone within a packaged, skid mounted application, or readily connect to a larger distributed control system as used by the refining and petrochemical industry. It has recently been applied very successfully in the paper industry being used by Kimberley-Clark in their dryers during paper tissue manufacturing.

Multivariable, predictive control and optimization applications such as Honeywell’s Profit Controller have been commonly applied to industrial 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 maximize throughput, maximize yields and minimize 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 minimizing energy is not done at the expense of maintaining yields of most valuable products.

Case study of improved energy efficiency: Catalyst, Elk Falls paper mill in Canada used Honeywell’s advanced process control to optimize their Thermo-mechanical pulping (TMP) operation. TMP is a complicated, highly interactive process, and the Profit Controller was able to improve their paper quality so much they eliminated expense kraft pulp from their furnish mix saving an approximate $3M per year. In addition to this, they reduced motor load by 53% for an additional $750k-$1M in energy savings per year, along with the associated reduction in GHG emissions.

Case study of GHG emissions reduction: Canada’s nitric acid plant Saskferco implemented Honeywell Process Solutions’ Profit Controller on the Experion Application Server to control its NOx and methane emissions thereby attaining the goals of maximizing and controlling nitric acid production. The results were the combustor’s energy consumption reduction of 5%, tight control of NOx emissions to spec and reduced methane emission of 25%, increased production capacity of 3%, and the process improvement of operational stability.
There are many energy saving strategies that can be incorporated into a multivariable control applications such as:

- Furnace pass-balancing and excess O₂ control.
- Distillation column quality controls combined with pressure minimization to maintain yields of most valuable products while minimizing energy consumption up to constraints such as tower flooding.
- Reactor conversion control
- Feed preheat maximization
- Separator and recycle control.

**Case study of energy efficiency in petrochemicals:** An example of a large multivariable control strategy was applied to an ethylene complex. This involved a total of seventeen multivariable controllers that were linked together by an over-arching optimization 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 minimizing excess O₂ in the furnaces.

This resulted in a project that showed a payback of less than 5 months.

Opportunities to operate process units more efficiently exist in most heavy industrial processes. In Honeywell’s experience, little or no capital operational solutions can improve energy efficiency by 2 to 4%. For example, in a typical 100,000 BPSD refinery, these improvements can reduce CO₂ emissions by 24 to 48,000MT/yr.
Energy Efficiency with Online Monitoring and Control: Online Control of Utilities

In addition to using energy more efficiently in the process, another common strategy is to produce energy more efficiently. Many heavy industrial manufacturers have their own on-site industrial power plants that primarily exist to provide steam and power to the process units but may also supply electricity to the grid at times of excess capacity. One of the keys to reducing energy costs in utilities plants is to balance changing energy demands from the process with adequate supply from the utilities plant without wasting energy by keeping spare capacity on standby. Honeywell has recently released its Advanced Energy Solutions for industrial power producers. Built on the same foundation as Honeywell’s Profit Suite solution, Advanced Energy Solutions is an integrated but modular advanced control solution that has been specifically designed for industrial steam and power plants.

It is made up of a number of components that can be combined to address the needs of a broad set of utilities unit configurations and operating modes.

The components including the following:

- Advanced Combustion Control (ACC) for solid, liquid or gas fuel fired boilers. A sophisticated optimizer is used to tightly control fuel to air ratio while continuously evaluating emissions using measurements of flue gas components (O2, CO, NOx)
- Master Pressure Control (MPC) that uses a dynamic model to stabilize multiple header pressures by predicting future manipulated variable moves.
- Economic Load Allocations (ELA) of boilers and turbines. ELA-B for boilers uses boiler efficiency curves to distribute the total heat requirement amongst all the boilers in the lowest cost manner. However it also aims to maintain the widest effective steam production range. Combined with the master pressure control, this strategy allows for the fastest dynamic response while always trending to the most economic steady state position

Figure 4: Honeywell’s Advanced Energy Solution for Industrial Power Producers
Supply and demand optimization is achieved by a simulation of the utilities plant that can take a set of process forecasted demands from the production schedule and determine the configuration and operating profile of the boilers and turbines to meet demand while taking into account tiered pricing, power contracts to the grid, and environmental limits on NOx and CO2 emissions. The simulation can include cases for changing discrete variables to determine the best choice of fuel to boilers or energy input to dual drive motors.

**Case study of producing energy less expensively:** An example of where this suite of applications was applied was at a petrochemical site in Korea. The plant had 3 oil fired boilers and 3 backpressure steam turbines that provide steam and power to the process units and also supplied excess power to the national grid. The solution used the Advanced Combustion Controls, the Master Pressure Controls for 3 headers and Economic Load Allocation across the boilers and the turbines.

The results from the implementation led to significant reduction (>10%) in CO2 and NOx emissions and improved boiler efficiency leading to overall benefits of more than $1 million/year.

**Energy Efficiency - Sustaining Benefits:**

To truly improve business performance, industry leaders know that whatever energy efficient solution they choose that it must sustain and increase benefits throughout its lifecycle. Honeywell Process Solutions is a trusted service provider to multiple heavy industries, offering the needed expertise to improve safety, reliability and efficiency. As technology evolves and grows increasingly complex, Honeywell brings all the needed intelligence together into a real-time system to help manage entire operations while maximizing the return on equipment investments with continuous lifecycle support.

Honeywell is the only automation services provider that continues to support products developed and installed as much as 30 years ago—third-party systems as well as previous Honeywell products. Honeywell’s unique combination of Experion technology and continuous lifecycle support lets customers decide how much longer they want to maintain an existing system and what new components they want to invest in.
Figure 5 indicates an ideal value curve that shows how many projects, if not supported, fail to provide the level of benefits that were realized shortly after commissioning. Honeywell can help with proactive component monitoring and maintenance services that boost performance, extend component lifecycles, and lower your overall cost of ownership. Installations supported by Honeywell typically experience maintenance cost reductions as much as 30%. Some of details of these offerings that are worth noting:

**Technology Refresh with Lifecycle Management** – Lifecycle Management (LCM) is a multi-year service agreement that guarantees asset support for Honeywell hardware and software products in your plant or mill until they are modernized or retired. The goal of an LCM agreement is to establish a committed automation roadmap leading to either electronic refresh or a complete migration during the term of the contract. With LCM, you can start down the path to modernization today and get there incrementally as your plant or mill needs and schedule dictates. Some examples include, migrating existing graphics to ASM compliant views that enable operators to respond faster to upsets; intelligent alarm systems that prevent flooding and provide views that combine alarm events with process history; incorporating automated procedures into the control system to ensure consistent and timely execution of infrequently executed operations. Lifecycle management is the most cost effective method of ensuring that assets are supported, kept technologically up-to-date and protected from obsolescence.

**Performance Management Services with BGMax** – Benefits Guardianship Maximum (BGMax) is a flexible and comprehensive service for advanced control and optimization applications designed to maximize ROI of technology investments. BG Max services fall into the following areas:

- **Attainment services** establish the baseline for measuring current performance of existing APC applications.
- **Revive services** restore the performance of existing applications to original levels.
- **Reactive services** offer quick response to identify and address control problems.
- **Proactive services** enable preemptive maintenance activities to occur that address emerging APC problems before they impact process performance.
- **Opportunity Assessment services** evaluate and identify additional prospects for increasing APC performance that may have been outside the original scope.

BG Max services are designed to monitor and sustain benefits through a field proven combination of Profit Expert analysis and guidance by Honeywell engineers. Profit Expert provides a wide array of technical analysis while the Honeywell experts add proper context and actionable steps to drive improved performance.

**Remote Performance Monitoring** - To further deliver solution value, Honeywell combines UOP technology with Experion PKS technology to improve plant performance. Remote Performance Management (RPM) is a solution that aids in monitoring, optimizing and sustaining the performance of a variety of process units. RPM provides:

- Continuous high-fidelity monitoring of process condition
- Routine process and equipment model tuning
- Early identification of economic opportunities
- Model based scenario analysis (What if)
- Planning function support (automated LP vector generation)
- Kinetic and constraint based optimization of process conditions
- Sustainability of the platform infrastructure

The solution provides timely access to information and recommendations, allowing producers to make better economic decisions on how they operate their assets. The RPM Solution brings UOP engineering and process modeling resources to bear on specific process assets. Process data is remotely accessed, encrypted, and securely transmitted to our calculation servers. The data is then validated and reconciled before being processed using customized models hosted and maintained by HPS and UOP. The results of the analyses
and processing are then stored in a secure database and made available to customers engineering staff via ultra-secure Internet browsing tools.

**Summary of Benefits**

The table below combines all of the potential energy and GHG emissions initiatives to provide a perspective on the level of benefits a typical refinery or large petrochemical site could achieve by adopting a comprehensive energy management program.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Area of Saving</th>
<th>Energy Improvement %</th>
<th>Energy Saving MM$/yr</th>
<th>CO₂ Reduction kMt/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Redesign</td>
<td>Heat Integration</td>
<td>4-6</td>
<td>3-5</td>
<td>48-108</td>
</tr>
<tr>
<td></td>
<td>Incorporate advanced Process Technology</td>
<td>3-7</td>
<td>5-9</td>
<td>36-84</td>
</tr>
<tr>
<td>Online Monitoring and Control</td>
<td>Online Monitoring</td>
<td>1-2</td>
<td>0.75-1.5</td>
<td>12-23</td>
</tr>
<tr>
<td></td>
<td>Supply side control</td>
<td>1-3</td>
<td>1-1.5</td>
<td>12-23</td>
</tr>
<tr>
<td></td>
<td>Demand side control</td>
<td>2-5</td>
<td>1.5-3.5</td>
<td>24-60</td>
</tr>
<tr>
<td>Sustaining Benefits</td>
<td>Sustaining Benefits</td>
<td>1-2 additional over time</td>
<td>0.75-1.5</td>
<td>12-22</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>12-25</td>
<td>12-20</td>
<td>144-320</td>
</tr>
</tbody>
</table>

* Based on a 100 kBPSD refinery; natural gas cost @ $6/MMbtu

**Conclusion:**

This paper highlights the need for heavy industrial manufacturers to put emphasis on reducing GHG emissions to comply with existing regulations, or ones that will be implemented in the near future. The most appropriate way to achieve this is to focus on reducing energy costs and emissions by:

- Redesigning and revamping the process to incorporate energy efficient and emissions reducing technologies.
- Improving energy efficiency by optimizing operations with online monitoring and advanced multivariable control strategies.
- Producing energy less expensively by employing industrial utilities optimization techniques.
- Sustaining benefits over the long term with life cycle management solutions that maintain and enhance performance of advanced applications.

Honeywell’s experience has shown that up to 12 to 25% energy reduction is achievable by implementing a comprehensive energy management solution with attractive returns on investment.
More Information
For more information about Honeywell's offshore oil production process, visit our website at www.honeywell.com/ps or contact your Honeywell account manager.

Automation & Control Solutions
Process Solutions
Honeywell
2500 W. Union Hills Dr.
Phoenix, AZ 85027
Tel: 877.466.3993 or 602.313.6665
www.honeywell.com/ps