Energy Efficiency and Greenhouse Gas Abatement for Heavy Industry

Brendan Sheehan, Honeywell Process Solutions
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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.

This paper will highlight global GHG abatement regulations and trends, and uncover a number of solutions to reduce industry’s contribution to global warming with energy efficiency strategies. It will explore effective ways to produce energy more cost effectively, purchase energy more economically and reduce overall energy usage, contributing to significant reductions in 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.

**Greenhouse Friendly™:** In 2001 the Australian Government Department of Climate Change implemented this carbon-friendly plan, which provides the opportunity for consumers and businesses to buy and sell “GHG-neutral” products and services, which have no greenhouse impacts. The government agency not only educates consumers on climate change issues, it endorses, thus effectively marketing, GHG-neutral companies, termed Greenhouse Friendly™ Abatement Providers.

**Regional Greenhouse Gas Initiative:** In this United States cap-and-trade initiative, 10 Northeastern and Mid-Atlantic states have agreed to cap and then reduce the power sector’s CO₂ emissions by 10% by the year 2018. It allows for trading of emissions offsets generated by other sectors, with auction dates and clearing prices published on its website.

**Western Climate Initiative:** This North American initiative is in its infancy as it is in the process of identifying, evaluating and implementing collective and cooperative ways to reduce GHGs, with a focus on the cap-and-trade system. It is a collaboration of seven Western United States governors and four Canadian Premiers.
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.

**Ways to 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.

McKinsey & Company clarified this strategy in its December 2007 report *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?* The report suggests that for the industrial sector, as much as 620 megatons of GHG reductions will involve pursuing a wide array of abatement options such as pursuing process and product innovations; recovering and/or destroying non-CO$_2$ GHGs; capturing and storing carbon; and increasing combined heat and power for more efficient power generation.

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:

- Chemicals: 1–3%
- Metals/Mining: 3–10%
- Power Generation: 1–3%
- Pulp/Paper: 1–5%
- Refining/Petrochemical: 2–4%

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.
The first step in developing an energy management solution to optimize 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 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 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 so the user can quickly observe the impact of actions taken and hence re-orient and decide on any further actions. Figure 2 shows an example of how this feedback loop can be applied to an energy monitoring solution.

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\(^1\) Robert Coran, *Boyd: The Fighter Pilot Who Changed the Art of War*, 2002
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 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.

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.
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 combuster’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.

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 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.

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.

**Improve Energy Efficiency: Better Heat Recovery**
A widely recognized energy efficiency process involves recovering heat from waste heat streams and using it to preheat process streams that would otherwise be heated with fossil fuels in furnaces or boilers. 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.
To tackle this problem, the first thing to do is to get an accurate picture of the energy flows around a unit and be able to measure the energy and material flow associated with each stream. Next we can extract the necessary thermal data from flow sheets. Then Pinch Analysis principles can be applied using simulation packages such as Honeywell’s UniSim design to identify the energy saving potential for the process and subsequently to aid the design of the heat exchanger network to achieve a specific targeted saving.

By using several monitoring and optimization software solutions to improve energy efficiency, one usually finds that they are pushing the process up against multiple physical constraints. And getting to 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 highlights where the physical constraints to the process are more clearly. Once specific units have been identified for improved heat integration, pinch technology, can also be applied here to efficiently screen and select from a variety of possible heat recovery networks.

Improved heat recovery is the most common type of capital project implemented to improve energy efficiency. However, in refining particularly, recent work by UOP, a Honeywell Company, 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.

**Produce Energy Less Expensively: Industrial Utilities Optimization**

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.
Figure 3: Honeywell’s Advanced Energy Solution for Industrial Power Producers

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. ELA-T for turbines can operate in either pressure control mode where the set of turbines aim to maximize power generated while maintaining steam pressure; or in power generation mode where steam consumption is minimized while maintaining a total generated power target.
- 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.

**Buy Energy Less Expensively: Improved Planning and Scheduling**

The primary mechanism for buying cheaper energy is to use planning and scheduling applications to optimize how the plant meets forecasted demand over an extended period. Planners consider the variety of fuels that can be used in their units and how they might be blended, to keep the plant full and still meet demand. Information about yield and quality data of different crude fractions provides input to the operational plan along with knowledge of process unit configuration, material availability and price. A good planning tool can incorporate product mix limits, energy costs and even CO2 emissions limits or costs to find the feedstock that optimizes profitability of the plant.

This planning application helps determine how much of a particular feedstock should be run but it does not provide the granularity necessary for detailed operating instructions.

The plan is executed by converting it into a sequence of feasible activities over a short time horizon of a few days or weeks. This can be a complex step and many planners will use spreadsheets to help them come up with a feasible operating schedule. They will often adopt the first feasible solution that they find knowing that it may have to be updated on a regular basis. The use of a scheduling model enables the user to find the optimal schedule that maximizes profitability while honoring quantity, quality and logic constraints. This model can be run as often as required to reflect any changes in conditions in the plant or in feedstock availability.

**Case study of planning and scheduling benefits:** An example of where planning was used to select the best feedstock for the plant involved a new ethylene plant that wanted to figure out how they should keep the new unit full. They considered options of buying in naphtha feed or feeding Atmospheric Gas Oil (AGO) to the ethylene tower. They also considered how things would change if a new crude atmospheric tower was added, thus increasing the amount of crude feedstock that could be processed. The solution involved considering a range of options in both configuration and feedstock selection and integrated the changing energy costs. For constant throughput, (i.e. no new atmospheric tower) they found that buying naphtha was cheaper than feeding AGO to the ethylene unit. However the answer changes if company decides to increase crude throughput by adding a 2nd atmospheric tower, it creates an excess of AGO available and it is best to run it through the ethylene plant rather than buy in additional naphtha.

**Partnering for Success**

A provider of energy & CO2 solutions to the refining industry needs several capabilities to be effective. The provider needs deep domain expertise in the areas of energy efficiency and process technology across the process units and in particular how they interact with the utilities system. Given that industrial processes often have many opportunities for energy savings, the ability and experience to benchmark the plant and identify practical solutions is critical. It is important to be able to differentiate between realistic solutions, and those that indicate potential savings but reduce operations flexibility during start-up, shutdown or emergency procedures, making them ultimately impractical.

Operations expertise is required to help identify and implement no-capital cost operational solutions. Advanced automation expertise is required to be able to automate data gathering, convert the data into useful information and provide easy to use interfaces that enable operators to quickly identify deviations from expected energy performance and the potential causes. Experience in simulation, advanced control and optimization solutions enable the implementation of strategies designed to continually push the plant towards its most energy efficient state which will help to highlight where the physical process bottlenecks exist.

The provider of energy solutions should also be experienced and capable of providing the detailed engineering services to design equipment and additional automation solutions to relieve these bottlenecks.

Finally, aftermarket software and services are required to help sustain the energy benefits and continuously improve performance over time.
Honeywell Process Solutions considers itself the right partner to help plants achieve their objectives, and can help industrial manufacturers reduce GHG emissions and increase energy efficiently using a variety of the strategies we have mentioned above.

**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 could achieve by adopting a comprehensive energy management program.

<table>
<thead>
<tr>
<th>Level Of Offering</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>Level 1 – Energy Benchmarking and Monitoring</td>
<td>Improved operation and control</td>
<td>2-4</td>
<td>1.5-3</td>
<td>24-48</td>
</tr>
<tr>
<td>Level 2 – Implement and Sustain Energy Efficiency Applications</td>
<td>Utilities Optimization</td>
<td>2-3</td>
<td>1.5-2.5</td>
<td>24-36</td>
</tr>
<tr>
<td></td>
<td>Improved Planning</td>
<td>1-2</td>
<td>1-1.5</td>
<td>12-24</td>
</tr>
<tr>
<td></td>
<td>Improved heat recovery</td>
<td>4-8</td>
<td>3-6</td>
<td>48-96</td>
</tr>
<tr>
<td>Level 3 - Add Capital Projects with UOP or 3rd Party EPC</td>
<td>Incorporate advanced Process Technology</td>
<td>3-8</td>
<td>3-6</td>
<td>36-96</td>
</tr>
<tr>
<td></td>
<td>Incorporate Renewables (1000 BPD Ecofining Unit)</td>
<td>CO2 credit</td>
<td>4</td>
<td>116</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>12-25</td>
<td>14-23</td>
<td>144-416</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 implemented in the near future. The most appropriate way to achieve this is to focus on reducing energy costs and emissions by:

- Improving energy efficiency by optimizing operations and better heat recovery
- Producing energy less expensively by employing industrial utilities optimization techniques
- Buying energy less expensively using improved planning and scheduling tools
- Leveraging environmental policies and taking advantage of carbon credits and trading

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.

To find out more, visit our website at www.honeywell.com or contact your local Honeywell account manager.

For More Information
For more information about Energy Efficiency and Greenhouse Gas Abatement for Heavy Industry, 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
1Hwww.honeywell.com/ps