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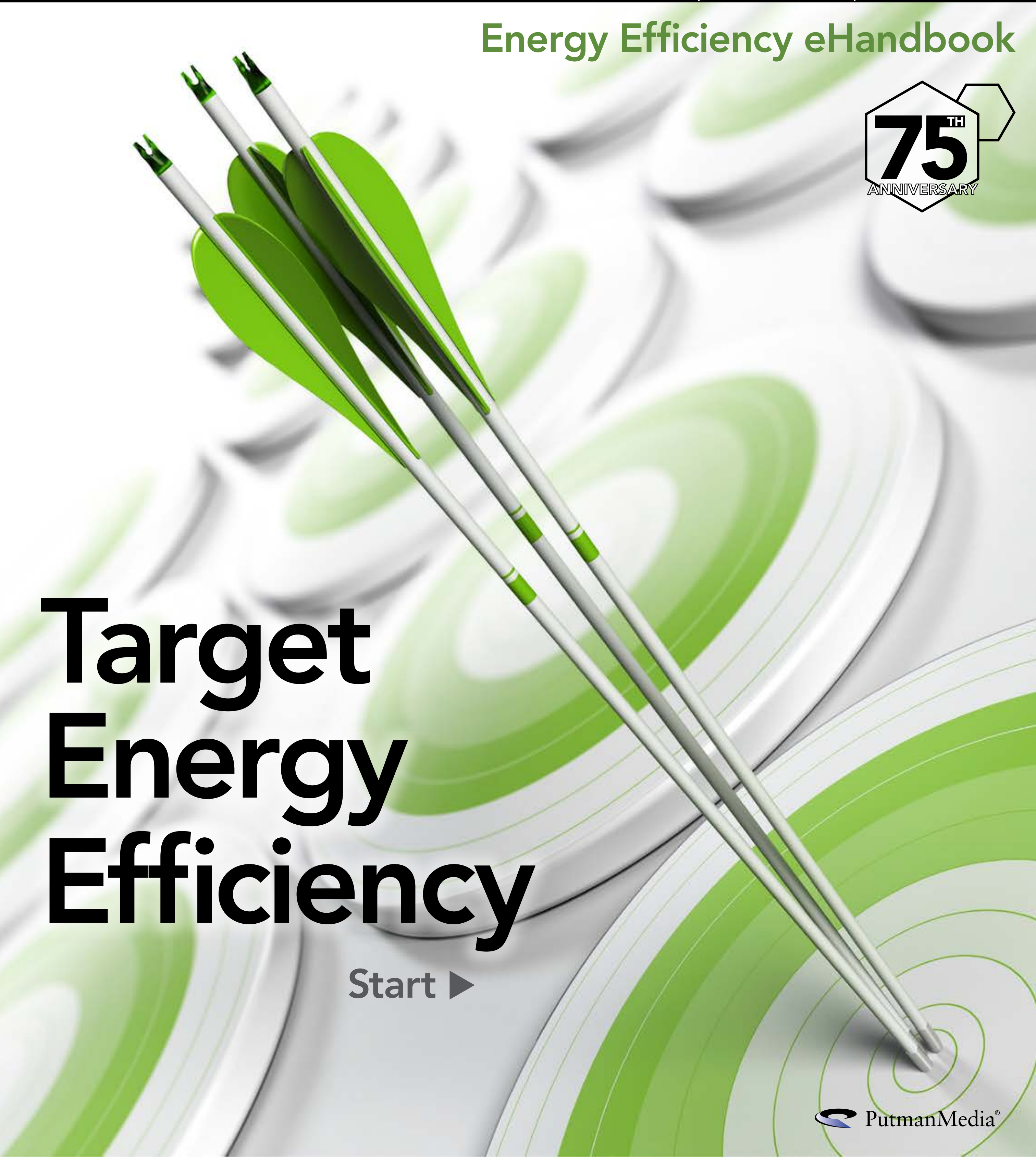

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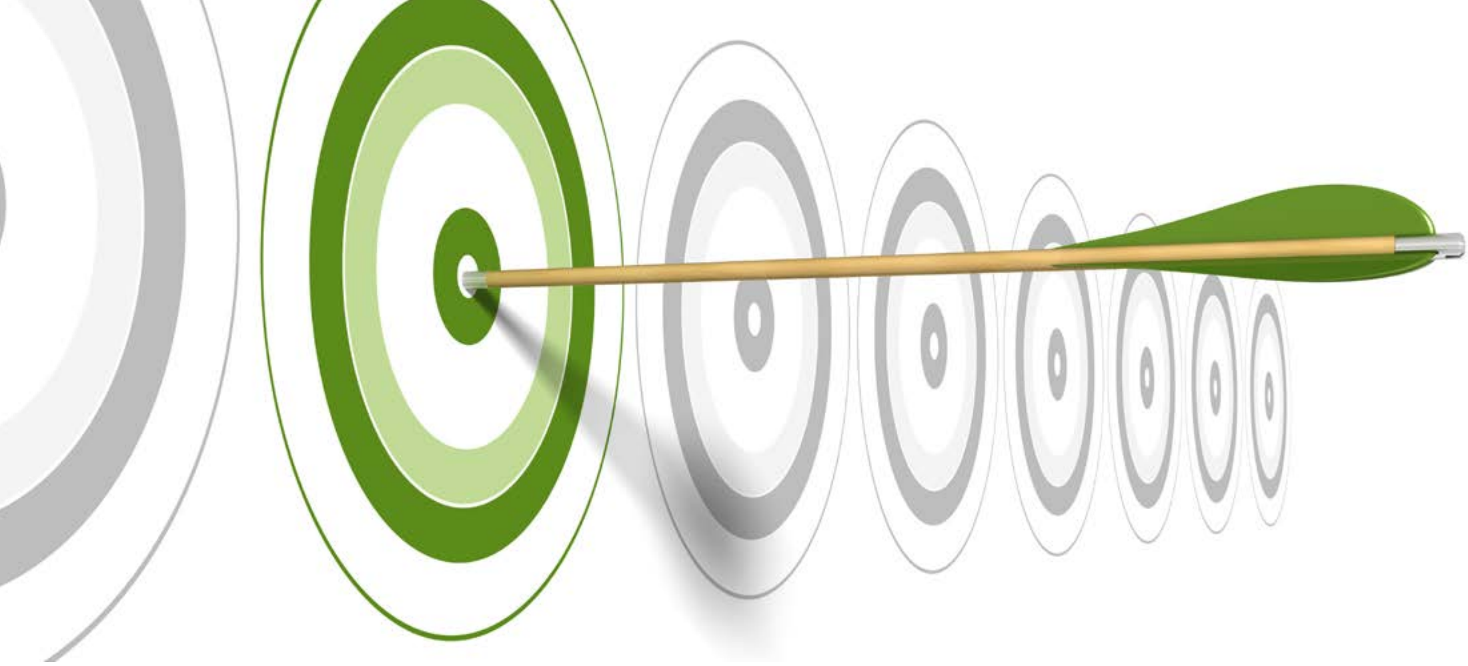

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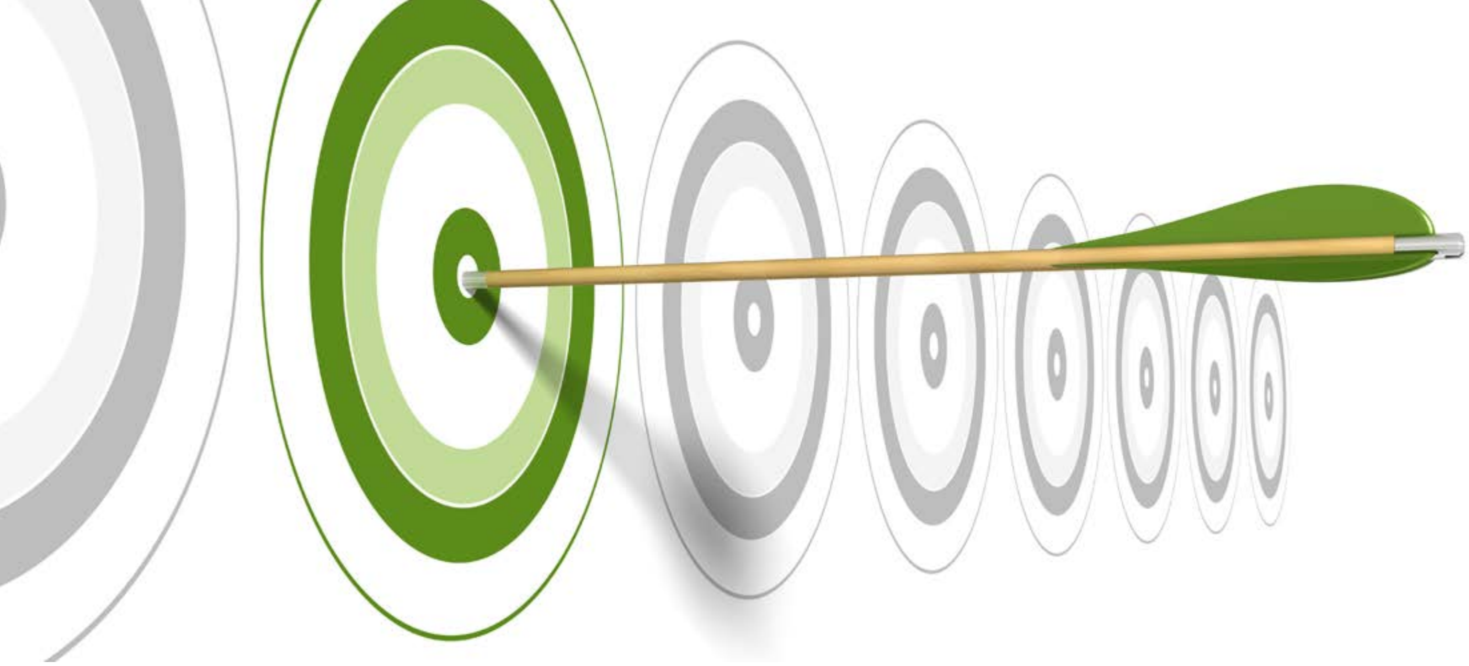

Roadmap Aims to Catalyze Better Energy Efficiency

International initiative foresees catalytic processes playing a key role in cutting consumption and emissions

By Seán Ottewell, Editor at Large

THE CHEMICAL industry potentially can vastly decrease energy use and greenhouse gas (GHG) emissions with the help of game-changing technology and strong support from policymakers, says a roadmap published in June. "Energy and GHG Reductions in the Chemical Industry via Catalytic Processes" was jointly developed by the International Energy Agency (IEA), Paris, France, the International Council of Chemical Associations (ICCA), Brussels, Belgium, and the German Society for Chemical Engineering and Biotechnology (Dechema), Frankfurt, Germany.

The roadmap focuses on the role of catalytic processes in cutting energy use and GHG emissions in the chemical industry — and demonstrates how savings of up to 13 eJ (exajoules) could be made by 2050. This is equivalent to the current annual primary energy use of Germany.

The roadmap is the second phase of a three-part process that originally kicked off with a 2009 McKinsey study sponsored by the ICCA. "Earlier top-down estimates of improvement potential of reducing energy and GHGs, such as the McKinsey study, suggested that catalysis could play a key role in reducing energy and GHGs, but were vague as to how this could be accomplished. This roadmap attempts an innovative combination of bottom-up data collection and top-down evaluation," explains Claus Beckmann, head of energy and climate policy, communications and government, for BASF, Lugwigshafen, Germany. Beckmann was one of four co-chairs on the core team responsible for the roadmap.

This two-pronged approach involved: studying bottom-up technical improvements, implementation strategies, and emerging and game-changing technologies; and top-down global scenarios using country-submitted data covering factors such as potential economic growth.

To gather its data, the team used market research information, discussions with licensors, publicly available literature, and responses to questionnaires about the top 40 energy-consuming chemical processes sent to chemical and catalyst manufacturers as well as academics.

"Many of our stakeholders, including policymakers, are very surprised to learn that while the chemical industry is the biggest industrial energy user, it is also a major contributor to cutting GHGs. This was a fact that we wanted to explain to a broader audience — about exactly what the chemical industry can and cannot do," says Rus-

sel Mills, global director for energy and climate change policy, for Dow, Geneva, Switzerland. Mills also was a co-chair of the core team while his colleague Ed Rightor, director, strategic projects, at Dow in Midland, Mich., was the company's technical expert on the team and also its leader.

KEY FINDINGS

The roadmap offers a number of crucial conclusions:

- the manufacture of 18 products (among thousands) accounts for 80% of energy demand in the chemical industry and 75% of GHG emissions;
- catalyst and related process improvements could reduce energy intensity for these products by 20–40% as a whole by 2050 if all the measures in the roadmap were acted upon. In absolute terms, such improvements could save as much as 13 eJ and 1 gigatonne (gt) of carbon dioxide equivalent per year by 2050 versus a "business-as-usual" scenario;
- in the short-to-medium term (i.e., to 2025), steady progress in implementing incremental improvements and deploying best practice technologies (BPTs) could provide substantial energy savings and emissions reductions compared to business as usual;
- achieving deeper cuts in energy consumption and emissions will require developing and deploying emerging technologies that exceed the capacity of current BPTs;
- making a step change in the sector's energy consumption and GHG emissions depends upon development of game-changing technologies, such as sustainable biomass feedstocks and hydrogen from renewable energy sources, which haven't yet reached commercial maturity;
- and, therefore, long-term investment and support for research and development (R&D) to enable innovation is warranted to continue making advances in new technologies.

However, the roadmap notes that getting onto the right path to achieve these goals requires immediate effort by all stakeholders, both individually and jointly, to develop long-term strategies and corresponding mechanisms to spur action and measure progress.

For example, it calls on policymakers to develop and implement policies to more highly reward energy-efficiency investments and remove barriers for new investments, as well as to create a long-term policy framework that encourages investments to reinvigorate catalyst/process improvement and R&D for high-energy-consuming processes.

The roadmap also calls on policymakers to introduce enabling policies for best practices in regions where new facilities are built, especially in developing countries, and to eliminate energy subsidies that undermine use of more-energy-efficient technology. In the case of BPTs, overcoming barriers to deployment, including high capital costs, replacement challenges and competing investments, may demand policy measures, it says.

It also urges the chemical industry to identify top catalyst/process-related opportunities and accelerate R&D and capital investments that improve energy efficiency. The industry also should facilitate R&D on game-changers with partners to lower barriers and operating costs, and promote global and regional co-operation on reducing energy and emissions via industry associations.

In addition, the roadmap calls upon academia and research organizations to undertake or stimulate university and national laboratory research on large-volume/high-energy-use processes, and to take action with industry leaders to identify top prospects for reducing technical barriers.

Finally, it points to the role financial institutions should play — urging such institutions to work together with the chemical industry to better understand changes in funding requirements of a low-carbon chemical sector and the funding opportunities of such a transition.

KEY ENERGY CONSUMERS

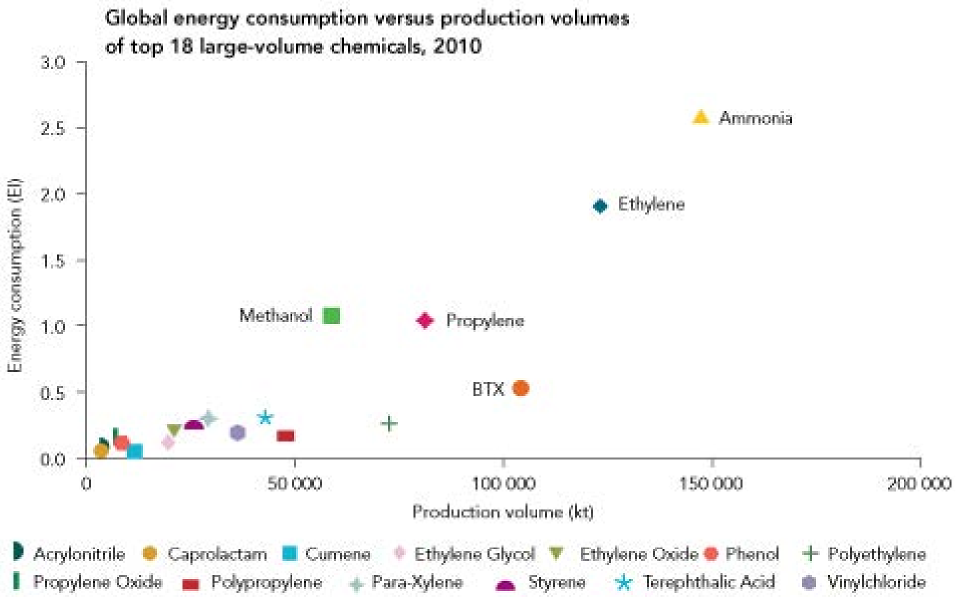

Figure 1. Five large-volume chemicals dominated chemical industry energy consumption in 2010. *Source: Dechema.*

“Concerted, long-term action of all stakeholders is critical to realizing the vision and impacts described in this roadmap. Governments can help create a favorable environment by creating a long-term policy framework that encourages investments in R&D,” notes Beckmann.

“They can also help by publicizing the report and talking about it: showing that there is real engagement at the government level. This is one of the reasons for our engagement with policymakers — and why the roadmap itself is only 60 pages long. The deep technical detail used to create it is contained in ten separate annexes,” adds Mills.

FOUR SPECIFIC TARGETS

Among large-volume chemicals, four — olefins, ammonia, BTX aromatics (benzene, toluene, xylenes) and methanol — represent about 80% of energy demand. The roadmap specifically targets these four because all are or can be produced through catalytic processes (Figure 1).

The roadmap outlines how incremental improvements such as better heat integration and catalyst tweaks can reduce energy demand of the four and then moves on to the benefits of adopting BPTs such as better catalysts and separation technologies.

“The biggest opportunities are obviously new builds; this means primarily the Gulf Coast in the U.S., driven by shale oil and gas developments, the Gulf region, and Asia — especially China. In each case, we can tackle two things in parallel: we can

drive efficiency, and we can help with decisions over BPTs. One of the most obvious ones mentioned in the report is ammonia. If more gas and less coal was used as a feedstock it would be very beneficial from an emissions point of view. For countries with large coal reserves, of course, the arguments are not straightforward — which is why interactions with intergovernmental bodies such as the IEA is helpful in discussing all the alternatives that they could use," explains Mills.

MILESTONES

MILESTONE	STEPS OF CATALYTIC TECHNOLOGY ADVANCES	TIMEFRAME
Advance catalytic cracking to commercial implementation.	• Catalysts with increased low-olefin yield and lower byproduct yield; • Decrease coking; • Management of spent catalyst.	2018-23
Advance catalytic oxidative dehydrogenation of low alkanes to ethylene to demonstration scale.	• Prevent further oxidation, partial oxidation or thermal cracking at higher reaction temperature; • Increased olefin yield at increased conversion.	2023-28
Hydrogen by water electrolysis.	• Efficiency of 80% and higher; • Flexible dynamic operation.	2018-23

Figure 2. The roadmap provides timeframes for technology improvements in key processes.
Source:"Energy and GHG Reductions in the Chemical Industry via Catalytic Processes."

The roadmap then turns to the game-changers, defined as processes that essentially re-invent the way something is done. Again particularly for the benefit of policymakers, it outlines the role of catalysis in the Haber-Bosch ammonia process. Then it moves on to catalysts' more recent involvement in new processes to improve hydrogen generation for steam methane reformers, upgrade bio-oils and light alkanes, synthesize aromatics from lignin and directly synthesize hydrogen peroxide from hydrogen and oxygen.

Noting there are many such "dream reactions" and they will need a long time to develop fully, the roadmap says two potential game-changers warrant specific mention: use of hydrogen from renewable energy sources to produce ammonia and methanol, and use of biomass as feedstock.

Hydrogen generation is one of the largest energy-consuming steps in the production of ammonia and methanol. Using hydrogen from renewable energy sources potentially could reduce the fossil-fuel use and GHG footprint of these processes significantly. Catalysis could enable efficient hydrogen generation, particularly via techniques such as photocatalysis or photovoltaic-assisted water electrolysis.

According to the roadmap, this option warrants further investigation along three lines: production of hydrogen from electrolytic water cleavage using electricity from renewable sources; ammonia synthesis from hydrogen and nitrogen, omitting steam reforming or water-gas shift from gas or coal; and methanol synthesis from hydrogen with either coal or carbon dioxide as the carbon source.

"Breakthroughs will be required for the generation of hydrogen at significantly lower energy demand and for providing significant excess hydrogen from renewable energy sources for this game-changer to become a realistic option in the future," notes the roadmap.

Like the hydrogen game-changer, wide use of bio-based routes for large-scale chemicals production depends upon significant improvement in overall energy consumption and cost. In addition, there's growing concern about the amount of arable land required for a high-volume bio-based chemical feedstock infrastructure, and potential competition with food production. Additional research clearly is needed, says the roadmap.

The long-term nature of the work to be carried forward warrants establishing high-level milestones

(Figure 2), while the substantial technical hurdles and high investment costs (particularly for areas with a high return-on-investment threshhold) create a need for collective effort on the part of all stakeholders including academia, research institutes and industrial partners. Governments must play an enabling role by establishing policies to encourage the necessary long-term collaborations and investments, stresses the roadmap.

"Game-changers such as the use of biomass or hydrogen as feedstock could theoretically yield additional reductions in GHGs, but would increase energy use and require huge investments to develop, tackle technical hurdles and lower operational costs. Commercial maturity is not reached. So it is obvious that further research and development to enable innovation in these technologies is needed in the future," Beckmann concludes.

Mills agrees: "The Roadmap makes it clear that we won't get close to the bigger targets without game-changers. Equally these will take 10–20 years to materialize — and even then, you will still need both technical breakthrough and political support. The massively increased amount of agricultural land needed for biomass is just one example of challenges being faced. For biomass and hydrogen, the political challenges are every bit as demanding as the technological ones. This is one of the reasons that we have intentionally tried not to spell out in great detail how we would get to the game-changers."

CURRENT EFFORT

Phase Three of the energy efficiency drive, just started, focuses on disseminating the roadmap. "We are very consciously making this a two-way process; rather than telling people what to do, we are presenting alternatives and engaging in dialogue," notes Mills. This approach, he says, was very well received at a recent meeting in China.

"We have also visited the Gulf region. Five years ago, the concept of energy efficiency — and, therefore, any reduction in oil and gas consumption by customers — would have been considered an economic threat. That perception is different today and resource efficiency as a concept has been fundamentally embraced, but it always has to be a two-way process in order to work," he adds.

He also is pleased with the response from Brazil, where industry has already paid for the roadmap to be translated in Portuguese. "It is a very reassuring sign that they are taking the report very seriously. Local language is key to convey the information in the roadmap to local policymakers. On our next visit to China later this year it will be interesting to see what plans they have with regards to translation into local dialects, too."

Efforts for the rest of this year and all of 2014 will focus on global outreach to raise awareness of the existing opportunities such as BPTs cited in the roadmap, and also to clarify interest in further work — including selected game-changers. This also involves assigning particular responsibilities for such work to specific companies in major chemical-producing regions around the world. Mills says it's currently too early in the process to name names.

Overall, Mills gives the impression of great confidence in the roadmap process. "I am upbeat, but with the proviso of timing. It won't be a fast process," he acknowledges.

The roadmap is available free at www.iea.org/publications/freepublications/publication/Chemical_Roadmap_2013_Final_WEB.pdf.

The ten annexes, covering topics such as process routes for propylene oxide, hydrogen option, biomass-based process routes, refineries, and research needs, are available http://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergyandGHGReductionsintheChemicalIndustryviaCatalyticProcesses.pdf. ●

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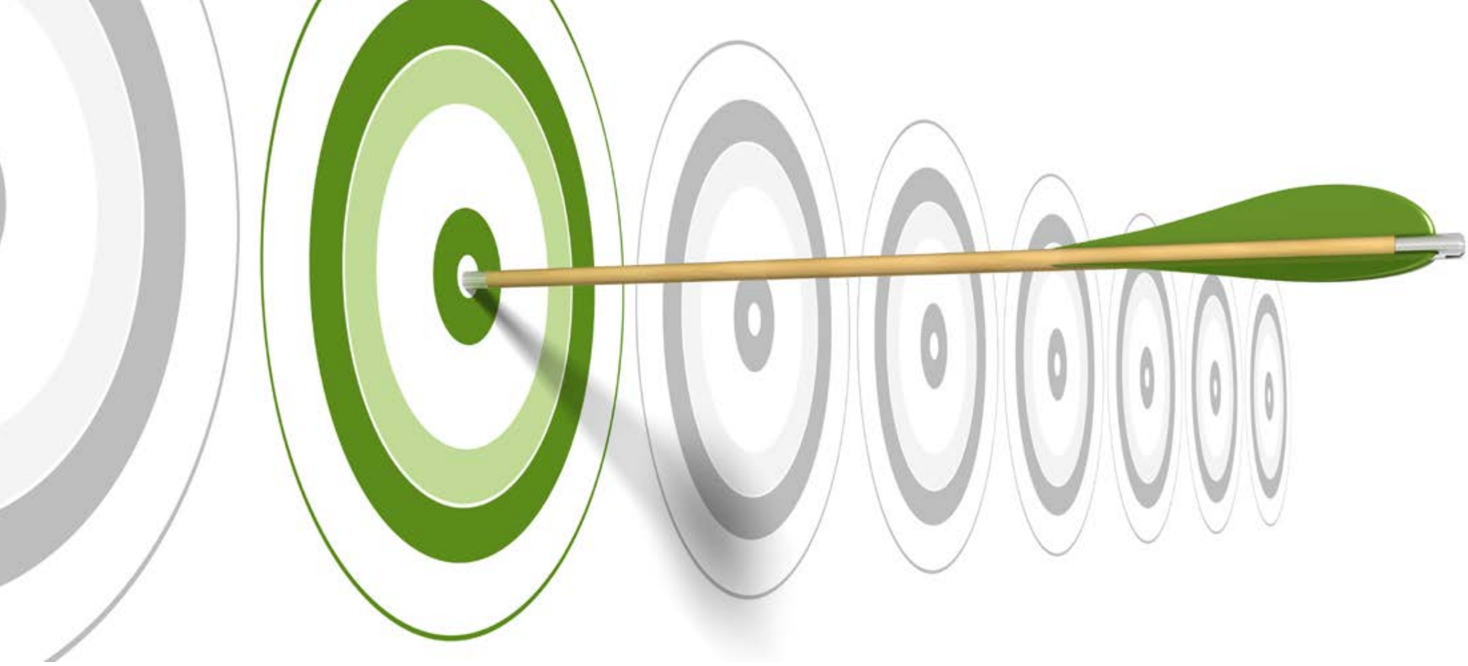

Optimize Boiler Loads

A boiler's limited turndown ratio causes huge dollar losses

By Ven V. Venkatesan, Energy Columnist

BOILERS AND heaters account for a significant share of a plant's purchased fuel cost. Combustion air fans are necessary to provide enough combustion air to the boiler or heater's burner system. Louvers, inlet guide vanes or variable speed drives control the amount of air allowed into a boiler. Configuring a combustion air fan to allow the proper amount of air into the burner can improve boiler efficiency, yielding energy savings and better system reliability. In this case study, a nitrogen-based fertilizer plant saved more than $420,000 annually by optimizing its steam system cost.

PCS Nitrogen is the U.S. subsidiary of Potash Corp of Saskatchewan, Inc., a major producer of three agricultural fertilizers: nitrogen, phosphate and potash. PCS Nitrogen's Augusta, Ga., plant is the largest producer of nitrogen-based chemical and fertilizer products in the eastern United States. This highly integrated manufacturing site uses natural gas to manufacture a range of intermediate and end-user products.

The plant's steam system operates a 150,000-lb/hr auxiliary boiler with a normal generation rate of 45,000 lb/hr. A 300-hp motor-driven fan delivers combustion air to the burner. Improvements to the plant's heat recovery capacity significantly lowered the need for steam from the auxiliary boiler. However, the combustion air fan's inlet louvers wouldn't seal tightly, causing excessive air leakage at low loads. Thus, engineers had to mechanically set the boiler's low-load limit at 28,000 lb/hr (19%) to maintain proper flame conditions and prevent boiler shutdown. Actual steam demand goes as low as 50% of the minimum steam generation; therefore, up to 14,000 lb/hr of steam was vented. In addition, because the fan speed wasn't adjustable, when the louvers closed, turbulence and vibration ensued, causing stress on the fan system bearings. Also, the boiler feed water pumps operated at a higher output level to provide adequate feed water to the boiler.

Plant engineers knew fan speed control could lower the turndown steam load, while keeping the auxiliary boiler running. However, installing a variable-frequency drive (VFD) to vary motor speed wasn't cost effective as it required considerable electrical work and reconfiguration of the fan system and the boiler room. In addition, the project would demand the boiler be shut down for at least two weeks, which would result in an unacceptable amount of production downtime.

After doing some research, the engineers opted to install a mechanical speed control device that uses magnetic induction to induce eddy currents that transmit motor energy in the form of torque. Because the eddy current drive (ECD) was

mechanical, it had fewer sensitive electronic parts and didn't require an inverter, extensive wiring or boiler room reconfiguration. The ECD cost one-third the price of a similarly sized VFD and would take just three days to install. So, plant engineers timed the installation to coincide with the boiler's annual maintenance stoppage, when the boiler is offline for about four days. The engineers enlarged the fan base to accommodate the ECD. Because the fan motor was directly coupled, the ECD could easily be placed in line with the fan shaft. The engineers installed a new actuator for the ECD and set a minimum fire rate of 14,000 lb/hr with the louvers in the minimum fire position. The ECD reduced the louvers' leakage rate, allowing the boiler's normal firing rate to be cut in half while maintaining a stable flame in the boiler.

The ECD allowed the boiler to control the combustion air flow to the burner and modulate the fan motor speed to respond to changing load patterns with greater precision. As a result, plant personnel were able to lower the boiler's minimum turndown limit from 28,000 lb/hr to 22,000 lb/hr (19% to 15%), reducing vented steam by 6,000 lb/hr. The first phase of the project yielded annual energy cost savings of $420,000 and energy savings of 76,400 MMBtu. In addition, the ECD eliminated turbulence and vibration, reducing stress on the fan motor and bearings. Reduced venting also cut down on boiler feed water consumption. The plant recovered the $65,000-project cost in less than two months. The simpler maintenance needs of the ECD provide an added advantage.

Optimal control of combustion air is essential for efficient performance of boilers or heaters. When VFD installations are cost-prohibitive, alternative speed-control options such as ECDs, slip-resistance controllers and DC motors could achieve the same objective and spin-off benefits.

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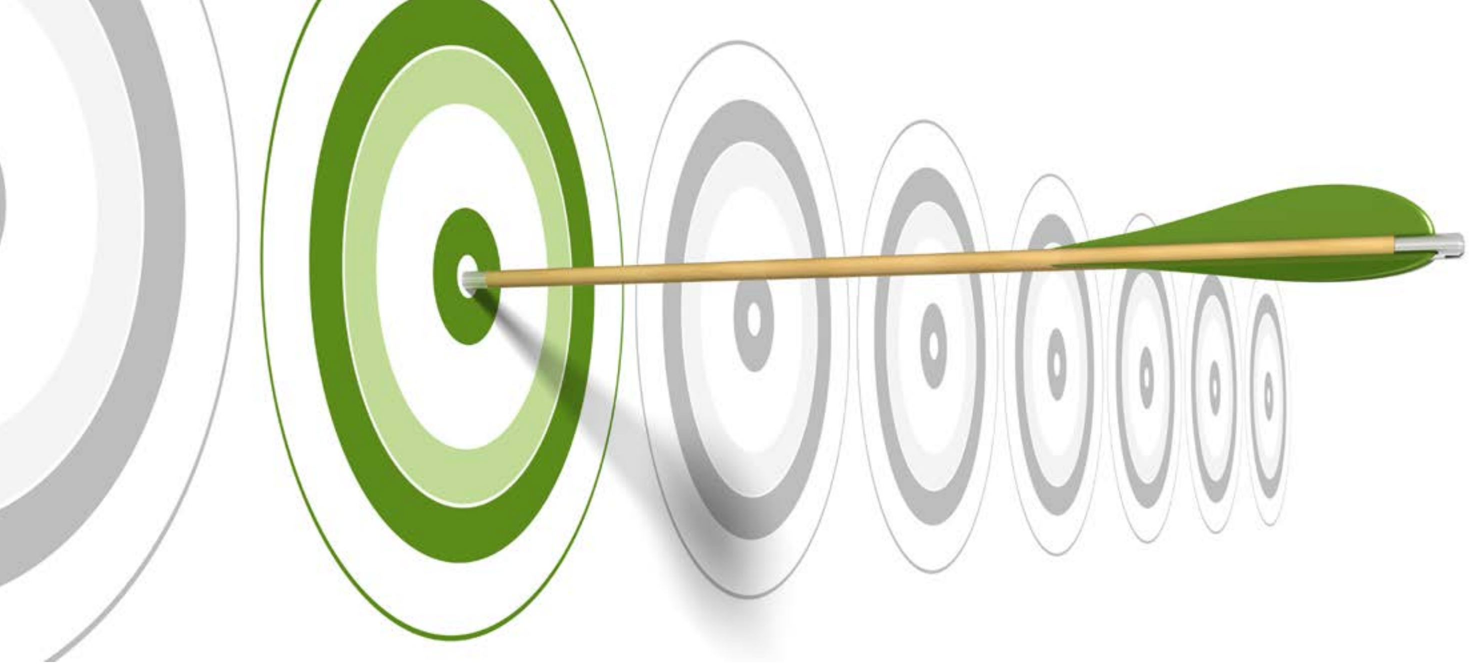


Increase Sustainability with Thermal Oxidation

The right emission control system can help meet compliance and reduce energy costs

By Jon Hommes, Durr Systems, Inc.

INSTALLING NEW production processes, or upgrading and expanding existing lines today requires a review of the expected emissions. The right emission control system for Hazardous Air Pollutants (HAPs) and Volatile Organic Compounds (VOCs) can help efficiently and economically dispose of these environmentally hazardous wastes. Over the last 20 years, as emission limits have tightened and authorities have taken a more "holistic", plant-wide approach to air permits, the trend in CPI has been to collect multiple waste streams plant-wide for control in a single thermal oxidation system, despite the required additional source ducting and piping. This trend has been driven by an array of factors, including:

- Rising fossil fuel prices
- Tightening of emission limits for VOCs, HAPs, NO_x and CO
- Goals for the reduction of a plant's carbon footprint
- Increasing cost for disposal of organic waste liquids
- Minimizing the number of control systems to be maintained and points of emission monitoring and testing.

All of these are key for companies increasingly committed to energy efficient, sustainable production. The benefits of a single, centralized thermal oxidation system can be best illustrated with a case study of a plant that recently added emission controls to many existing production processes.

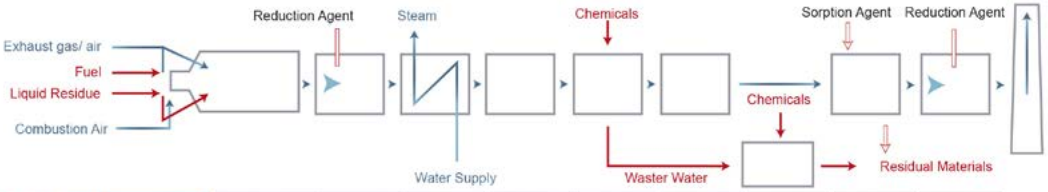
Two types of thermal oxidizers are most frequently applied in the chemical process industry: Regenerative thermal oxidizers (RTOs) and direct fired thermal oxidizers (DFTOs), also known as afterburners. RTOs offer high thermal efficiency and very low fuel requirements for plants that generate dilute air streams contaminated with low concentrations of VOCs and HAPs. However, a DFTO is the best choice when:

- Production processes demand steam energy
- Required destruction efficiency is greater than 99.5%
- Highly caloric off gases with low oxygen must be handled
- High loading of halogenated or sulfurous compounds are expected (acid generators)
- Destruction of waste liquids is needed.

Many excellent guides and articles address the selection process between different types of oxidizers. This paper focuses on the DFTO exclusively.

A company manufacturing organic intermediates for the pharmaceutical and fertilizers industry decided to install a DFTO system to handle all liquid and gaseous waste streams from their many small to mid-size process reactors and storage tank vents. The DFTO is designed to handle a wide range of wastes including organic compounds containing halogens, sulfur and nitrogen.

WASTE LIQUIDS



	Combustion Chamber	SNCR-Stage	Steam Boiler	Quench	Scrubber	Aerosolseparator	Waste Water Treatment	Adsorption	SCR stage Dedioxination	Stack
Organic Solvents	X		X							
Halogenated Compounds	X		X	X	X	X	X	X	X	
Nitrogenous Compounds	X	X	X						X	
Sulfurous Compounds	X		X	X	X	X	X			
Heavy Metals	X		X	X	X	X	X	X		
Saline Liquids	X		X	X	X	X	X			
Particles in Liquids	X		X	X	X	X	X			

Table 1. Components in a modular direct-fired thermal oxidizer system can be selected based upon the waste stream contaminants.

The system consists of the required liquid pipe trains and storage tanks, process off gas pipe trains including explosion protection equipment, oxidation chamber, fire tube waste heat steam boiler, economizer, scrubber for acid gas removal, selective catalytic reduction (SCR) system for NO_x removal, an induced draft system fan and stack including emission monitoring system.

WASTE LIQUIDS AND OFF GAS SOURCES

The liquid wastes are accumulated from a number of sources across the plant and collected in a storage tank. The small storage tank was sized to accommodate the effluents from periodic tank cleaning processes. At this particular plant, all of the waste liquids are purely organic and have a consistent high caloric value which allows them to be fired directly through the thermal oxidizer's dual fuel burner system. After start-up, these systems can run entirely on the waste liquid fuel. Although not needed at this facility, a second system is sometimes used to collect liquid wastes with low or inconsistent caloric value or high water content. These wastes are atomized into the oxidation chamber adjacent to the burner through secondary injection lances.

In addition to the liquid wastes, a total of six process off gas streams are controlled by the thermal oxidizer system. Each off gas is handled by an independent control train and injected separately into the oxidation chamber (Figure 1). One stream is drawn from nitrogen-blanketed storage tanks using a blower, designed to handle potentially explosive gases, to maintain a slight negative pressure. The remaining streams come from process reactors under pressure and can be routed to the oxidation chamber without blowers. The volume of off gas and VOC caloric content of each stream is highly variable, especially for several batch reactors and for the storage tanks which

vent the most VOC during filling operations. These large variations of flow and loading lead to the first major benefit of a single, centralized DFTO system.

During preliminary engineering of the emission controls, consideration was given to multiple, smaller DFTO systems installed local to each process gas source. This arrangement has the advantage of minimizing the cost of the off gas collection system duct work and keeping each process fully independent. However, as the off gas sources were analyzed, it was determined that each DFTO would need to be designed for the peak off gas volume and caloric content required for that source under startup or upset conditions resulting in large oxidizer size. Furthermore, the much lower "normal" off gas flow is then difficult to handle efficiently in the large oxidizer. Designing for this high turndown is especially challenging for the several batch reactor processes.

Bringing all of these off gas streams to a single, centralized DFTO makes it possible to design for the peak VOC loading on several, but not necessarily all, processes simultaneously, reducing overall system size and capital cost, while improving turndown and DFTO efficiency under normal operation. The availability of the organic waste liquids to the centralized DFTO also has a stabilizing effect on operation as the storage tank allows injection of liquids to cease during periods of maximum off gas loading (while collection in the tank continues) and to resume providing supplemental heat during periods of low off gas loading. The overall impact of the centralized DFTO is a significant reduction in natural gas (or other supplemental fuel) usage and thus the plant's utility budget. By minimizing supplemental fuel usage, a corresponding reduction in the plant's carbon footprint is achieved. Whether greenhouse gas (GHG) emission reductions are mandated, as they are in Europe, or whether they are voluntary, this is an increasingly important consideration for many companies.

PROCESS STEAM

Many chemical plants generate and use steam on site for various process and heating requirements. The flue gas from a DFTO oxidation chamber is a source of high quality waste heat at 1,600 to 2,200°F that's easily convertible to saturated or superheated steam to supplement the facility's gas, oil or coal-fired boilers and reduce their fossil fuel usage. To do this, the refractory-lined oxidation chamber of the DFTO is simply transitioned to mate up to the boiler inlet. Numerous considerations affect the boiler design and selection including:

- The desired steam pressure
- Requirement for superheated steam
- Presence of halogens or sulfur that generate acid gases
- The presence of silicon, phosphorous, metals and other dust-forming compounds.

In this case, the system includes a fire tube waste heat boiler to generate medium pressure-saturated steam, followed by a super-heater and an economizer

CONTROL TRAIN

Figure 1. The thermal oxidizer system controls six process off gas streams, each handled by multiple skid-mounted off gas piping control trains.

for preheat of boiler feed water (Figure 2). High concentrations of hydrochloric and hydrobromic acid in the oxidizer flue gas result in a design that limits the heat recovery in the economizer to keep the outlet temperature above acid dew point under all operating scenarios. In addition, due to the distance from the facility's main boiler house, the system included a boiler feed water tank with redundant pumps and a deaerator for returning condensate.

Once again, a single, centralized DFTO when compared to multiple local units is significantly more beneficial. To achieve the same steam production, the capital cost is much lower for a single waste heat boiler system with high utilization than for multiple boilers connected to localized DFTOs. Waste heat boilers for localized DFTOs must be designed and sized for the peak flow and heat load from each oxidizer but will normally operate at just a fraction of that design capacity. It's obvious the boilers themselves are capital intensive, but a single centralized waste heat boiler also minimizes installation costs associated with piping for boiler feed water, steam supply and blow down. The number of boiler startup and shutdown cycles is reduced, increasing the longevity of the equipment, and minimizing the time demands on boiler operators. The net effect is an improvement in the pay back that justifies waste heat recovery as steam. By choosing to recover waste heat, the plant further reduced their overall fossil fuel consumption and carbon footprint.

ACID SCRUBBER

After exiting the economizer, the flue gas is directed to a quench and acid scrubber (Figure 3). The quench cools and saturates the flue gas stream with water spray nozzles and flooded walls. The quench discharges the flue gas and water into the base of a vertical flow, packed column scrubber where HCl, Cl_2, HBr, Br_2, HF and SO_2 are absorbed and neutralized with NaOH solution. The scrubber removes over 99% of these contaminants; however,

FIRE TUBE STYLE BOILER

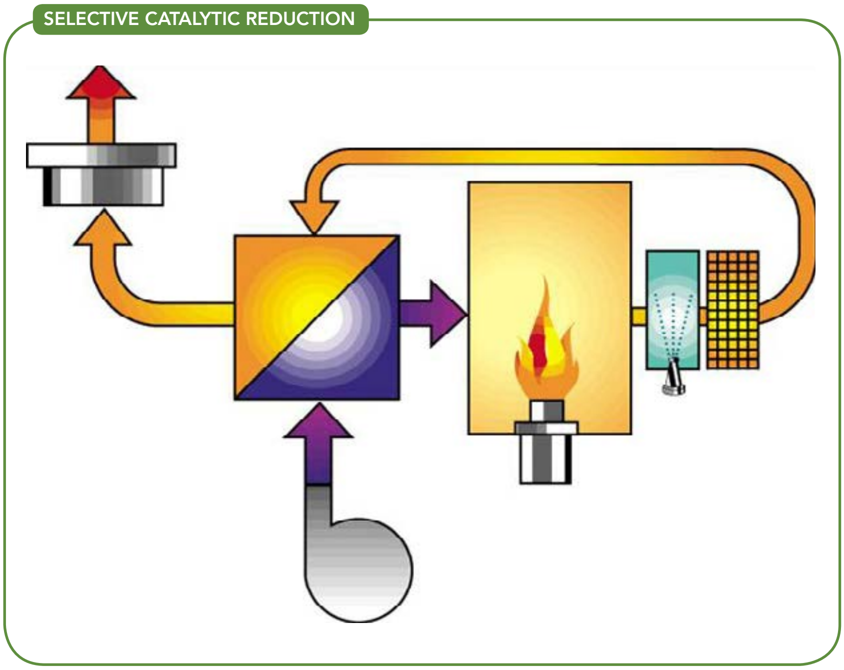
Figure 2. The system includes a fire tube, single pass waste heat boiler to generate medium pressure saturated steam.

QUENCH AND ACID SCRUBBER

Figure 3. After exiting the economizer, the flue gas is directed to a quench and acid scrubber, much like this one.

taller columns and multiple stages can be used to achieve greater than 99.9% removal. This facility includes 50% NaOH as a utility and feeds a day-tank from which redundant pumps dose it into the recirculated scrubber wash water to control the pH.

The waste liquid and three of the six off gas streams currently contain halogens requiring scrubbing downstream of the oxidizer with the vast majority coming from methylene chloride in the waste liquid. Prior to installation of the new DFTO system, these halogenated liquids were transferred to tanker trucks and disposed of offsite at significant expense ($0.20 to $0.50 per gallon). As with the waste heat boiler, adding a scrubber to the single centralized DFTO system has a significant capital cost advantage over scrubbing on multiple smaller units.



SELECTIVE CATALYTIC REDUCTION

Figure 4. This diagram highlights the process flue gas takes in a selective catalytic reduction (SCR) system for NO_x control.

SELECTIVE CATALYTIC REDUCTION

In recent years, regulatory authorities have focused more and more on reducing NO_x emissions from combustion processes, and oxidizers are no exception. In the case of a boiler or process heater, the majority of NO_x emissions form as “thermal NO_x” from N_2 in the flame front of gas and oil-fired burners. In the case under study here, the vast majority of the expected NO_x comes from the oxidation of amines and other VOCs containing nitrogen in the plants off gases and waste liquids. Several alternative approaches for NO_x reduction were evaluated, including non-catalytic reduction in the oxidation chamber, before SCR was selected based on the high conversion efficiency required to meet the very low emission targets. SCR also offers the advantage that the catalyst used to reduce NO_x also favors the destruction of trace dioxins and furans formed during the oxidation of chlorinated compounds.

Because the flue gas exiting the scrubber is saturated and contains trace acids, the SCR system begins with a pre-heater module to raise the flue gas temperature above its dew point by mixing a small volume of hot air recirculated from downstream. This module is constructed in alloys resistant to chloride corrosion. The DFTO system’s redundant draft fans follow the pre-heater and are operated on variable frequency drives to maintain a pressure in the oxidation chamber slightly negative to atmosphere. The flue gas then enters a recuperative heat exchanger that recovers heat from the SCR outlet (the reduction process is exothermic) to

bring the flue gas up to reduction temperature. Finally, an aqueous ammonia reducing agent is sprayed into stream, metered precisely to match the measured incoming NO_x, before the flue gas enters the catalyst beds where greater than 95% of the NO_x is converted to N_2 and H_2O. The flue gas then passes through the other side of the heat exchanger on its way to the system stack where it exhausts to atmosphere at about 200°F. Continuous emissions monitoring equipment in the stack, as required by the plant's air permit, tracks exhaust concentrations of total hydrocarbon, hydrochloric acid and NO_x to confirm proper operation of the system.

The low NOx emission required was another factor in the selection of a single, centralized DFTO system over a multiple system. The SCR system is capital intensive, including expensive precious metal catalyst, heat exchanger, and flue gas analyzers and strongly favored installing just one.

COMPLETE DFTO SYSTEM VIEW

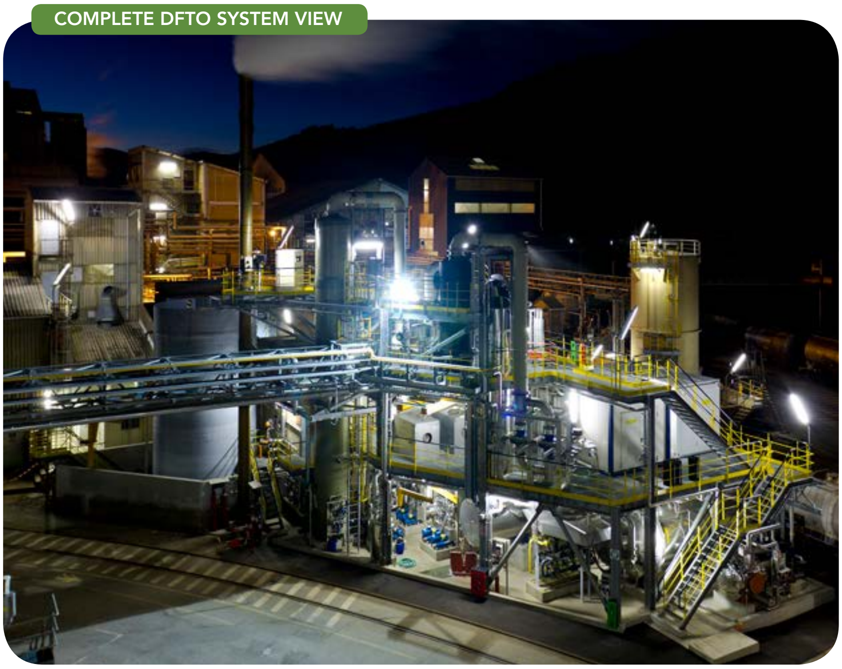


Figure 5. This DFTO system helped reduce fossil fuel use in boilers and eliminate offsite waste disposal costs.

MEETING COMPLIANCE

For this manufacturer of organic chemicals operating many smaller processes, a single centralized thermal oxidizer system was the most cost-effective path to expand production while meeting new emission controls requirements. The resulting DFTO system benefited them by:

- Maximizing the destruction efficiency of VOCs and HAPs
- Reducing NO_x emissions well below their permit limits
- Eliminating operating expenses for offsite waste liquid disposal
- Reducing plant-wide fossil fuel demand by using the caloric value of their wastes to generate steam
- Minimizing maintenance costs by installing just one system.

Taken all together, the plant's annual savings by reducing fossil fuel use in their boilers and eliminating offsite waste disposal costs actually exceed the operating costs of their new emission control system. Over its design life, the DFTO system provides a net pay back to the plant, proving that "being green" does not have to come at the expense of the bottom line. ●

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