Energy Efficiency – The “hidden” fuel

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Abstract

Over the last 20 years, the “Hidden Fuel” became the “First Fuel” in the 11 member countries of IEA. Saved energy resulting from Energy Efficiency (EE) programs, which are developed since 1974, was equal to 1.52 billion tons of oil equivalent (toe) in 2010 while the oil consumption of the 11 countries was only 1.04 billion toes.

The energy bill can reach up to 60% of the OPEX in a refinery, and even more in petrochemical plants. Any decrease of this bill has a direct impact on the margin.

Axens uses dedicated methodology to identify these opportunities and propose solutions. Individual processes are examined from the perspective of Axens' sophisticated operations know-how to fully understand the process complexity, interaction and needs, including Pinch analysis assessment.

First step is the Site Survey where the information required is collected. If needed, an Instrumental Survey can be arranged to gather missing information. Through interviews, the specific needs for the process are taken into account.

One of the main strengths of Axens proposed methodology is the understanding of the interactions between process units. In-house developed software is used for optimizing Heat Exchanger (HE) networks and Process Integration development.

Types of solutions considered for minimizing energy consumption include: recovering heat through a network of HE, modifying equipment operating conditions, reducing or eliminating energy needs, re-thinking steam network pressure, reviewing utility systems, synergies between units and/or nearby plants, etc.

Introduction

Hydrocarbons are essential to prosperity and sustainable economic development for years to come. Global oil demand averaged an estimated 93.6 million barrels per day in the first half of 2015 and is expected to continue to grow.

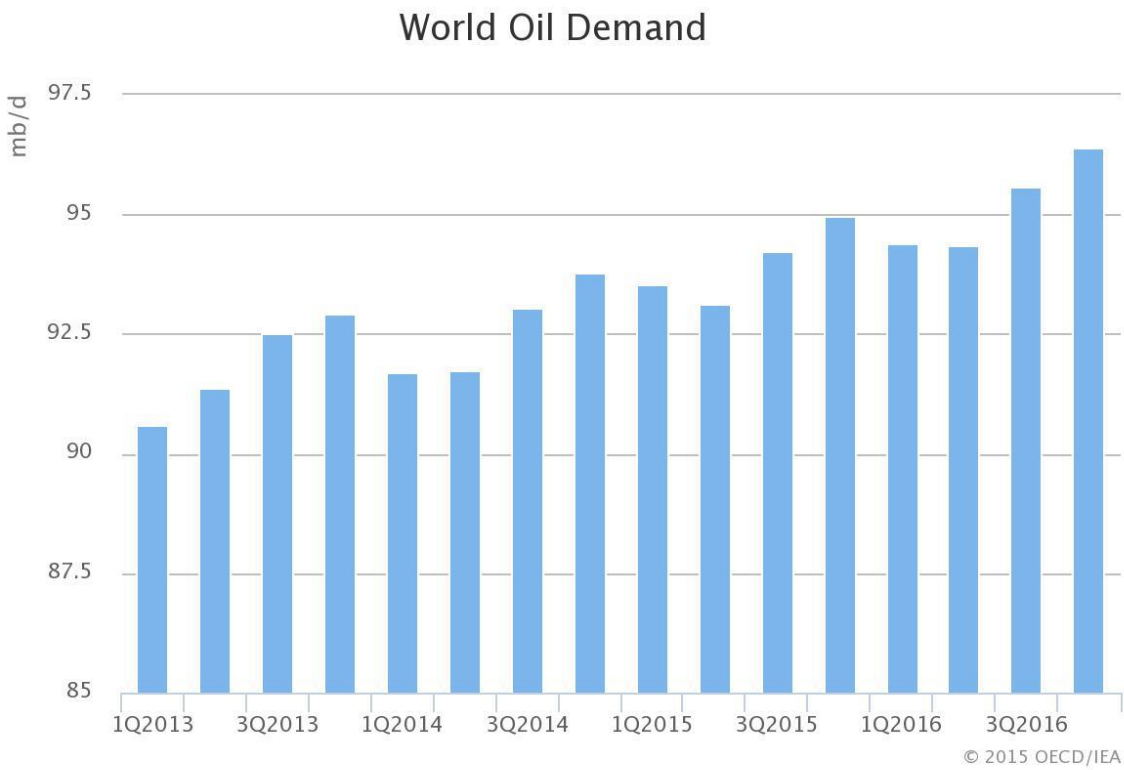

Figure 1 – World oil demand forecast by IEA

Meeting the world's growing need for energy must reconcile a secure energy supply with environmental constraints.

Refiners worldwide face an increasingly competitive global business environment and therefore must seek any and all opportunities to reduce the production costs without negatively impacting the yields or quality of their products. Successfully, cost-effective target investments into energy efficiency solutions will satisfy both these criteria. Another important axe to take into account is the company's environmental policy. Energy efficiency solutions are often more efficient and less expensive solutions to reduce pollutant emissions than end-of-pipe solutions.

When assessing energy efficiency projects, the overall impact must be considered during the economic evaluation phase. Ultimately, deep process understanding is vital to safe, efficient and cost effective design and operation.

Axens follows an audit methodology which takes into account the performance of all relevant equipment individually, the unit performance, its specificity and heat integration possibilities, the interaction of the unit with the surrounding units and utility systems and the performance of the entire refinery, utility systems and off-sites. Each solution is Taylor-Made in order to take into account all of Client's specific requirements.

Development

Energy use in refineries varies over time due to changes in the type of crude processed, the product final specifications, environmental constraints, sulfur content, increase in the refinery complexity, new products demand. Other factors, such as equipment age and maintenance, changes in energy management policy, influence the energy use in the refinery over time, etc.
Energy wise, major areas for improvement in existing refineries are the utilities system (which can be overlooked in global when adding a new unit), furnaces, process optimization, heat exchangers and rotating equipment. These are also the areas where we can find the largest number of low to no CAPEX solutions for energy efficiency. For the average 60% weight of energy in the OPEX, nearly 80% of it is tied to furnaces & boilers, air coolers and cooling water. In other words, anything that can be saved by effective heat integration will immediately have a significant weight on overall energy saving and OPEX reduction. Recently (2015), Axens has performed several energy audits in Refineries that were dedicated mainly to no or low-CAPEX solutions (quick wins).

In average, depending on the size, complexity and age of the refinery, 60 to 80 independent propositions are submitted, resulting in a reduction of 12 to 25% of the global energy consumption of the refinery.

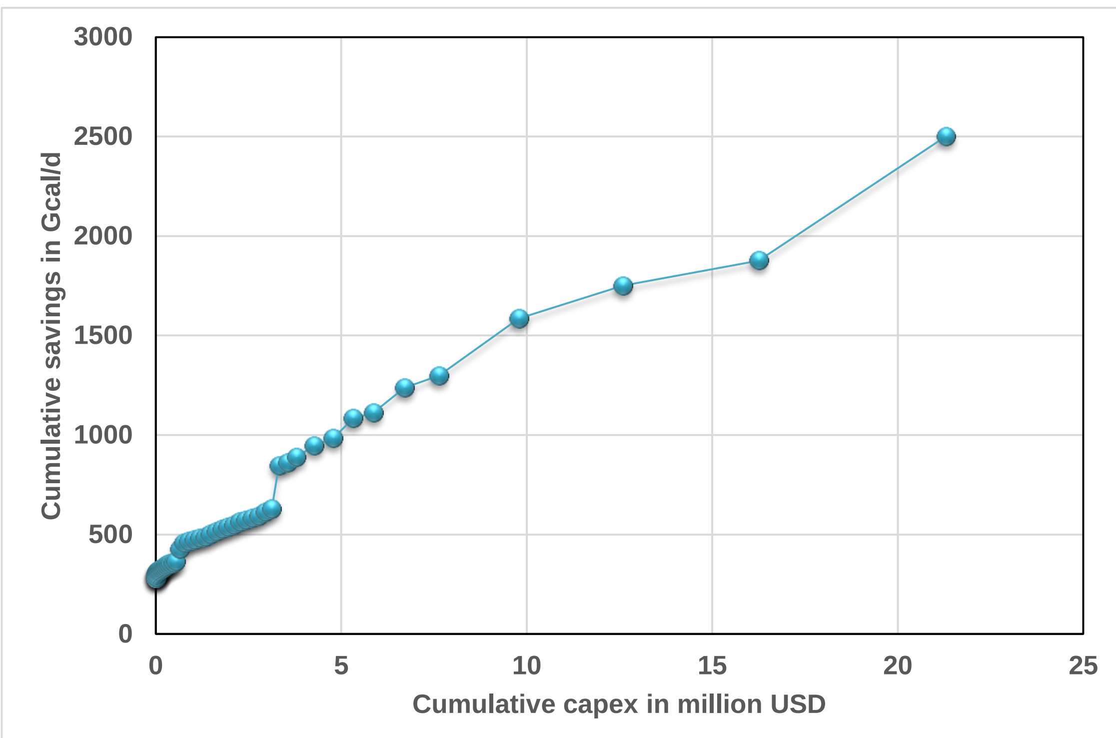

Figure 2 – Cumulative savings (Gcal/d) versus cumulative CAPEX (million USD) for a refinery in Kazakhstan (2015)

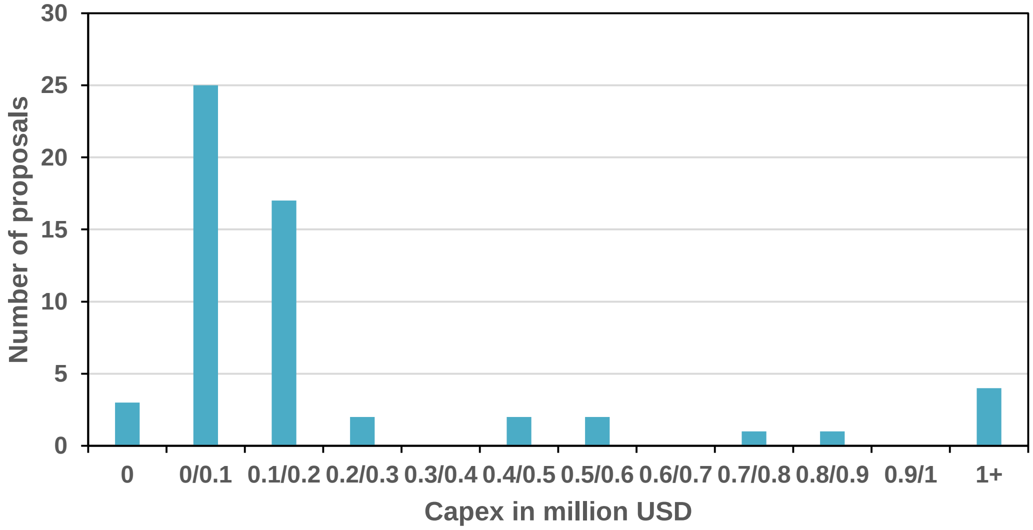

Figure 3 – Number of recommended solutions versus required investment (million USD)

As it can be seen in the figures, the more the refinery is willing to invest, the more savings it will obtain. Nevertheless, it is worth noticing that most of the recommendations are at no or low investment (under 0.2 million USD).

The most attractive Energy Efficiency opportunities identified and systematically studied by Axens are:

- Boilers & Furnaces: efficiency monitoring, draft control, air preheating, new burners design, flue gas heat recovery, boiler feed water preparation, reduced excess air, insulation improvement…
- Process units: optimizing operating conditions, process integration (inter-units and with the utilities), heat integration, give-away,…
- Rotating equipment: overhault, variable speed drives install, power factor control, sealing, monitoring, repair & maintenance, compressor efficiency improvement,…

The utility system is also a privileged focus of attention, resulting almost systematically in recommendations for fuel gas network optimization, steam network optimization, cogeneration attractiveness assessment, etc…

In the next figure it can be seen the savings split per activity, for a 2015 refinery energy audit performed by Axens.

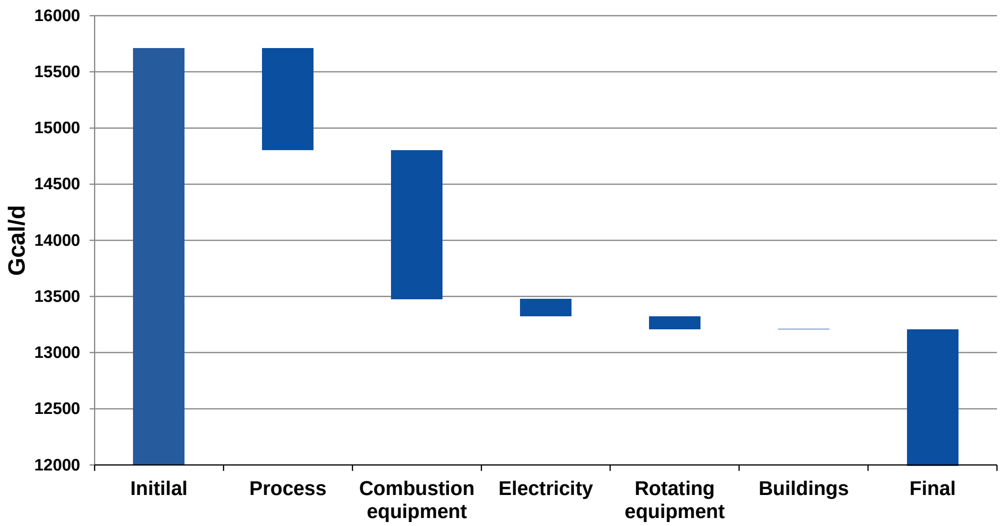

Figure 4 – Savings split per activity for the global refinery consumption (2015 project)

Some case studies will be presented for some of the solutions mentioned before.

Case Study 1 - Pinch analysis and Heat Exchanger Network (HEN) optimization

Pinch analysis is a systematic methodology for energy saving based on thermodynamic principles developed by Linnhoff March in the late 70's. It needs limited information about material and heat balance.

Pinch analysis methodology for energy consumption minimization considers both the needs for cooling and heating of the process and allows assessing the theoretical savings potential.

Typical energy savings for existing units in refineries and petrochemical plants range from 15 to 25%. Savings will vary depending on the level of existing heat integration and process flexibility required in operation. One of our strengths is the understanding of the interactions between process units. Some process constraints are crucial to process operability and therefore limiting to the heat recovery that is possible. Process integration is always taken into account.

In order to get the best from Pinch analysis, Axens associates it with dedicated in-house developed software named CREO, which enables imposing process flexibility constraints to optimize heat exchanger network.

CREO is a Linear Programming model developed by IFPEN, our mother company, to determine the optimal heat exchanger network solutions for process flow schemes, while taking into account operational and flexibility constraints. These constraints are specific to the process technology and the performance objectives.

The CREO model objective is used to develop an energy conservation solution that offers the best compromise between CAPEX and OPEX, while affording customized operational flexibility.

When applying the optimization methodology to an existing facility, it is taken into account the Plot Plan limitations, minimizing the shut-down time for re-works, limiting the CAPEX (by maximizing the use of existing assets) and keeping the heat integration, if any already exists. All solutions proposed are reviewed by a Lead Process Engineer and an Expert with more than 20 years' experience running a refinery, in order to assure the solutions proposed is fully satisfactory from a technical and an operational point of view.

Here below is the example of the optimization of the feed preheating train to a bitumen unit. This project has been selected by the refinery and will be taken into account in the next year budget.
The unit is composed by two sections, the vacuum distillation and the oxidation section. Only the vacuum distillation section was taken into account for the analysis, since it's the only section operating non-stop all year long.
Currently, the feed, arriving from the crude distillation unit at around 95°C, is split in two streams that are preheated in two sets of heat exchangers against circulating reflux, Vacuum Gasoil (VGO) run-down and vacuum residue. It is then heated up in a furnace for partial vaporization, reaching 375-380°C.

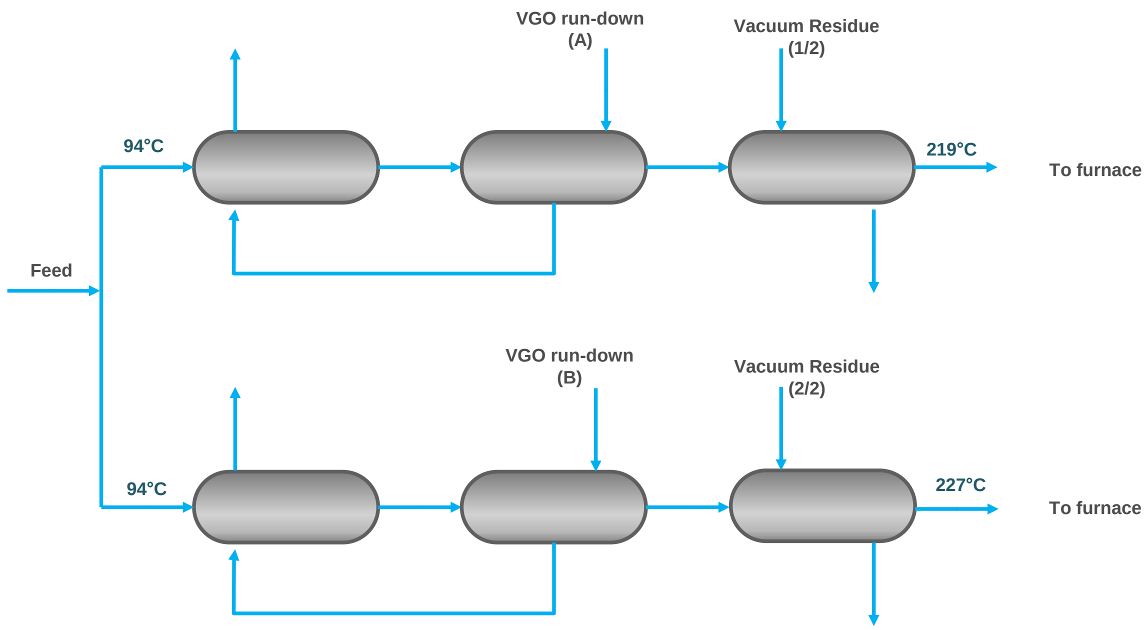

Figure 5 – Current preheating trains' configuration for Bitumen Unit

When evaluating the potential for heat integration by using pinch analysis, the energy consumption reduction potential was evaluated at 23% of the furnace current consumption.

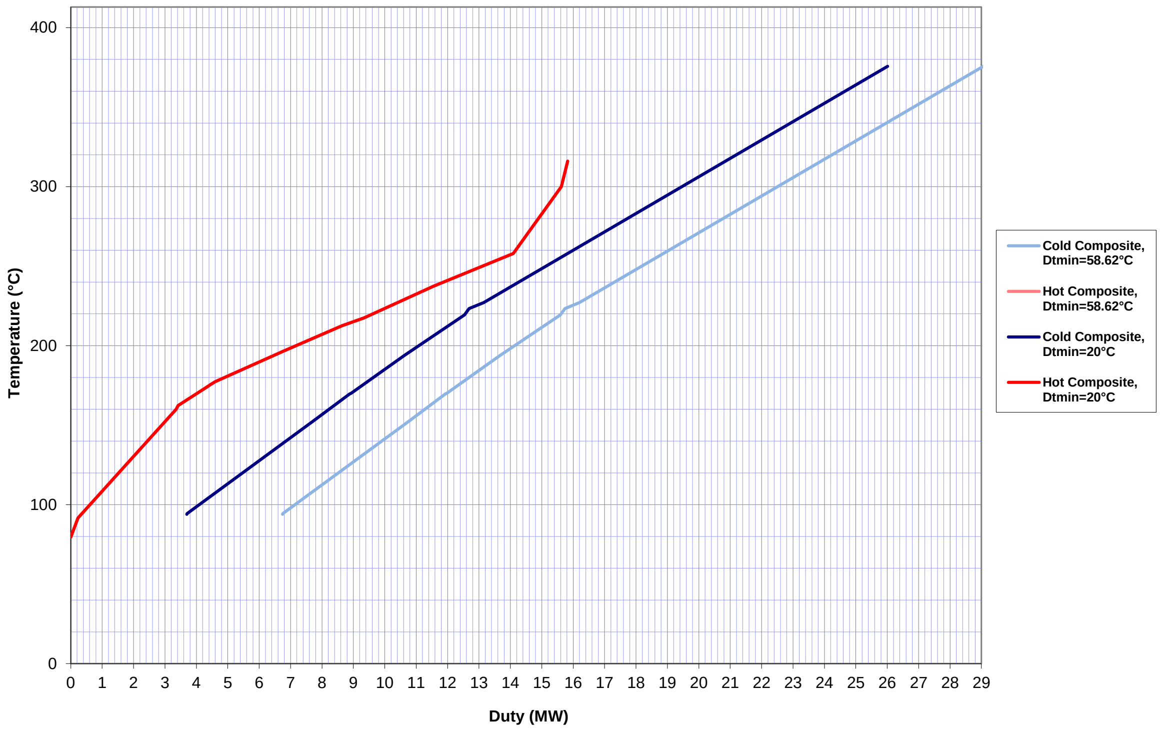

Figure 6 – Difference in pinch composite curves for current and optimized case

In this specific case, the Client requested the minimum reworks as possible and to try to keep the same number of heat exchangers, due to severe plot plan constraints.
Using CREO, Axens has proposed a solution with minimum investment, by reassigning new services to existing heat exchangers, while maintaining the existing feed stream split already in place and no new equipment added apart piping.

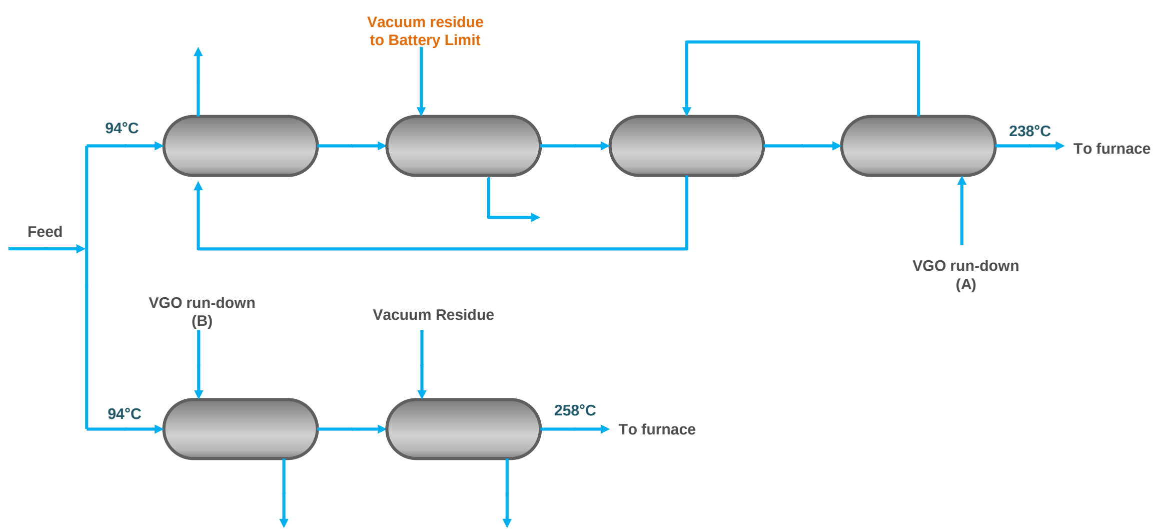

Figure 7 – New optimized configuration for the preheating trains

The main difference for the optimized solution is the use of the stream of vacuum residue that is currently further cooled down in an immersion pool before leaving the unit. This stream will

exchange with the first train of feed, and the main stream of vacuum residue that is currently split between both trains, will be used for preheating the second feed train only.
The existing heat exchangers surface was calculated to be enough for this new configuration, with one heat exchanger for the second train of preheating (that requires now only two) to be reassigned to the first preheating train.
This change is enough to achieve the target consumption, allowing a 23% energy savings on the unit. In a more energy consuming unit, the results are even more pronounced.

Case Study 2 - Reduce Flaring

A recent audit performed by Axens on a Petrochemical Plant, lead to new challenges in energy efficiency since the Plant was not producing the chemical components it was originally designed to. This lead to several identified energy inefficiencies due to the use of equipment that was overdesigned for the current service. Revamping actions did not take into account the energy efficiency angle and the result was a severe constant amount of flaring. Not only this leads to product loss by the Plant, but also has costs associated with the environmental constraints and the pollution generated by the flaring. Evidently the first recommendation was to reduce the flaring by ensuring a proper operation. This should be the most effective and inexpensive solution. Nevertheless, due to the use of equipment designed for other purposes and its age, Axens has provided a recommendation that considered the continuous flaring.
Of the four existing flares, one of them represented 75% of the flaring and was worth concentrating our efforts, especially since the gas flared originated from vents at storages.
The recovery facilities for flared gas could be designed either to use the recovered gas as a fuel gas instead of importing natural gas, or to recover the LPG's and convert those into commercial products. The first option is more geared towards reducing the energy bill and is hereafter described, but it is likely that the second option would be economically more attractive, since it allows to increase the margin and to reduce the energy bill.

The recovery facilities proposed can be described by the following scheme:

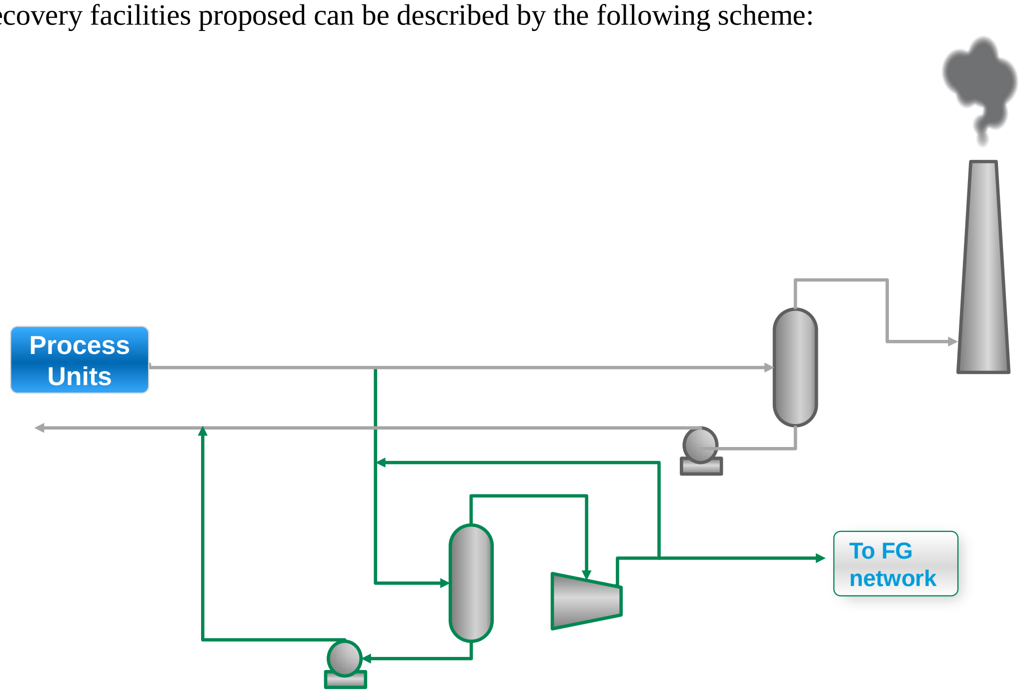

Figure 8 – Flare Gas recovery facilities

The system is made of a KO-drum and a compressor, driven by a motor, which brings up the pressure of the flared gas from the operating pressure of the flare system (about 50 mbarg) to the pressure of the fuel gas network. It has been considered here that only 80% of the flared gas of this stack could be recovered, and still the mass savings in natural gas amount to 29% of the annual purchase by the Plant.

Case Study 3 - Furnace Efficiency Improvement

Modern process furnaces show efficiency figures up to 89% or more. For an existing furnace with lower efficiency to reach this performance level, the furnace technology should be enhanced by one or more of the following means:

- Forced draft instead of natural draft,
- Air preheating by flue gas,
- Better O_2 control in the flue gas by means of automated control of the gas rate and of the air to gas ratio,
- Reduction of the flue gas temperature to the stack by increasing the duty of the convection section.

Axens specialists' systematically perform a deep audit of the furnaces since they represent the biggest source of heat losses in a refinery.

Even wall lining replacement on furnaces, when required, can lead to energy savings.

In a more energy consuming unit, the results are even more pronounced. The audit of a Delayed Coker Unit (2012) lead to an energy intensity index reduction of 57%, mainly by changes in the furnace (such as O_2 control and burners replacement) to increase its efficiency. The identified solutions are currently being implemented and are expected to generate 6.8 million USD a year in OPEX savings.

Case Study 4 - Steam Pressure Network – change in pressure

Occasionally, units' revamping over the years is performed without looking at the utility system in their global. It was the case of a Petrochemical Plant where steam was produced at 13.1 bara and 225°C. The steam is then dispatched to the consuming units and facilities. Before it is consumed, it is first let down in static valves to get to the pressure required by the relevant process. Each unit is equipped with a "pressure reduction unit". The recommendation consists in producing the steam at the pressure required by the processes, rather than to produce it at the same pressure of 13.1 bara for all processes and then reduce this pressure.

The units' requirements could be divided into 2 groups, a first group requiring a steam pressure of more than 8 bara and a second group requiring a steam pressure of 6 bara (which also includes the storage facilities).

In this proposed configuration, the boilers dedicated to the second group would raise steam up to 6 bara only, thus requiring less energy from the fuel. In group 2, the pressure reduction units will remain as is, depending on the required steam pressure. In order to implement it, the modifications required are quite simple and inexpensive: a new low pressure steam collector, with new connections to the units consuming low pressure steam; a connection between the two collectors to cater for any failure shortage of generated steam, either low or medium pressure; and the control loops will have to be adapted so that the boilers dedicated to group 1 may raise steam up to 6 bara only, and also to enable this same boilers to resume generation of medium pressure steam in case any failure would happen on boilers of group 2.

Other recommendations that will save energy at low investment are to install steam traps or the insulation of non-insulated valves of the steam network. The latter is particularly important in rough winter conditions countries.

Case Study 5 - Changes in operating conditions – reducing pressure at FCC Gas Plant Column

This type of energy saving solution is typically the case where no investment is required and the benefits are not only in terms of energy, but also in terms of give-away reduction. Nevertheless, it is the type of recommendation that requires a unique knowledge of the process and specificities of the operation.
Reducing the pressure of a mixture of hydrocarbons results in an increased difference in the volatilities of these hydrocarbons. On this basis, reducing the pressure of distillation columns makes it possible to perform the same separation of the products at lower energy consumption, i.e. at lower reboiling duty and therefore also at lower condensing duty. The separation quality in a distillation column depends heavily on the reboiling and reflux ratios. Increasing the reboiling ratio will consume energy and any separation above the required quality will consume more energy than required.
This giveaway is the result of a better stripping than needed. By deleting this give-away, some reboiling duty can be saved. Using process simulations and taking into account the quality of the products and its margin to the required specification, it was possible to reduce the reboiler duty for the stripper column of approximately 20% without changing any other operating conditions.
On the debutanizer and depropanizer columns, not only the give-away reduction was possible, but also possible to reduce the pressure, without compromising the production flowrate or product quality. In this case, the reboiling duty was reduced of 11 and 65%, respectively. Since no investment is required, all saving here are net saving.

Other almost no-CAPEX solutions are changes in the energy management, to raise awareness from top management down, to invest in repair & maintenance training for operators in charge of rotating equipment, to monitor pumps performance, to install variable speed drivers and power factor correction units,…

Case Study 6 - By-passing of intermediate tanks

Quite often, when a new unit is added to an existing complex, or even at the design stage, each unit is considered a stand-alone, with feed characteristics, product specifications and battery limit data as input. Intermediate tanks give operation flexibility but it comes at a cost. Often we are faced with situations where a stream is cooled down to be sent to the tank and then heated up to be used as feed for the next unit. This energy loss can be very important depending on the volume of the streams. It is part of our recommendations in some cases to by-pass the intermediate tanks of around 90% and that only 10% would be sent through storage.
In a recent case (2015) for a Delayed Coker Unit (DCU), fed with atmospheric and vacuum residue, all the feed was being cooled down upstream the unit, in order to be stored. It was then heated again to be used as feed. It was split into two trains and exchanged against pumparounds and light cycle gasoil (LCGO) and heavy cycle gasoil (HCGO) before entering the furnace.
If the temperature of the feed is increased at the inlet of the unit, the amount of heat extracted from the pumparounds by the two trains will be reduced. In order to extract the same amount of heat from the pumparounds so that the operating conditions of the fractionator column are not changed, it is necessary to heat up more the Boiler Feed Water (BFW) in the "steam generator". This will save energy. Moreover, the duty of the furnaces will be impacted because also the preheated feed will be hotter at the inlet to the furnaces.

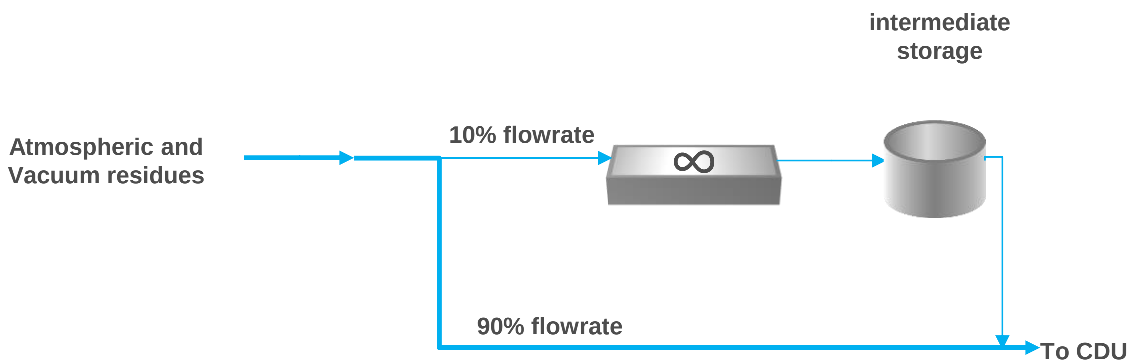

Figure 9 – Proposed by-passing of intermediate storage

The new proposed configuration was simulated and the results showed that the amount of heat lost in the cooling of the residue upstream of the tank amounts to 88.4 Gcal/d. The investment comprised a new pipe line for by-passing the tank and the coolers upstream, instruments and valves. The works are minimal and do not require the unit shutdown.

Case Study 7 - Recovery of process heat

Process heat, especially at a low thermal level, is difficult to use in process-process exchanges and generally ends up lost. This can be an excellent option for heating up the water for process tracing, buildings heating or even boiler feed water preheating.

In a recent studied case (2015) the refinery was importing heat from an outside Power Plant (PP) for buildings heating and process tracing. After a complete analysis of the remaining “hot” streams available in the refinery, several good candidates were identified. All this low thermal level heat is currently being lost to coolers. One of the identified streams is a gasoil stream currently being cooled in an immersion pool, without eat recovery. The proposal consists in recovering some lost energy in the refinery and using the hot water network as a medium to transfer this heat to a user. The recovered heat will automatically come in subtraction to purchased heat (hot water).

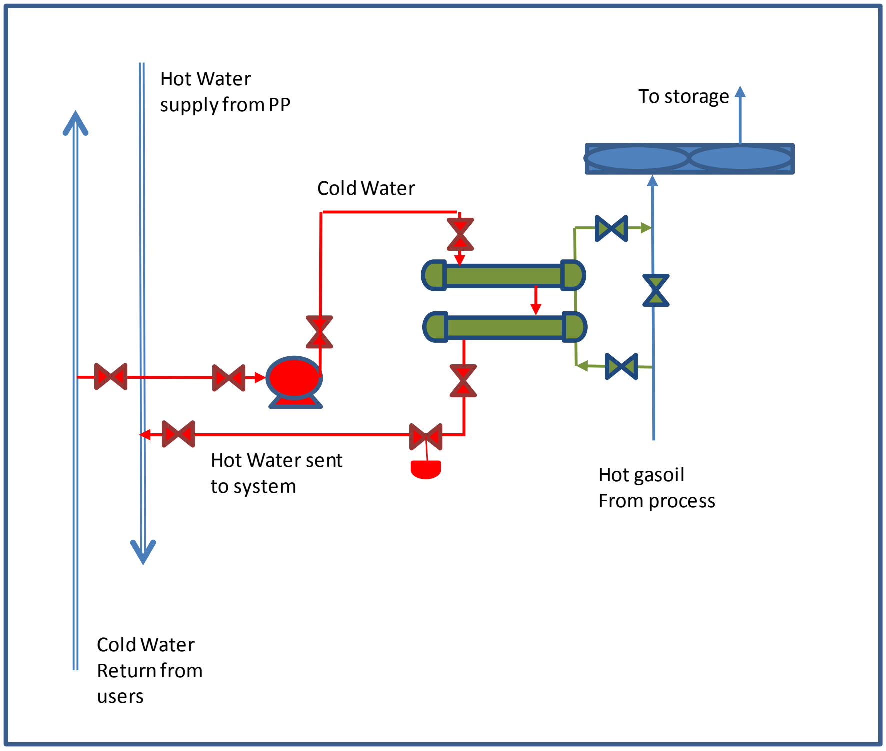

Figure 10 – Schematics for a hot water circuit using process heat

This is a medium investment option, for it requires new heat exchangers, new pumps, piping and associated instrumentation; as well as plot plan considerations to be taken into account. Nevertheless, since the existing supply system from the Power Plant to the refinery passed near the chosen gasoil stream, it made the proposal attractive and with a good pay-out time.

Conclusions

Refineries, chemical and petrochemical plants have opportunities to significantly save energy and reduce their OPEX. Axens uses dedicated methodology to identify these opportunities and proposes solutions thanks to its:

- Knowledge on technology and thermal equipment
- Experience in consulting services
- In-house IT tools

Axens' position as a Licensor puts it in a unique perspective to fully understand the process complexity, interaction and needs among other energy issues faced by the refineries. The Client is walked through the entire process and is given the keys to successfully implement energy efficient solution.

Axens' services on Energy Efficiency are fully customized to cover customer's requirements and constraints in terms of duration, costs, etc, from the individual equipment to the vision of the entire complex.

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