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Techno-Economic Analysis of Amine Sweetening Units in Refinery and Petrochemical Plants

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Abstract: - Nowadays, in an environment where technology is constantly developing and competition is intense, especially in refinery, petrochemical and gas processing plant projects, project leaders and project stakeholders need to perform a three-way integrated analysis not only with operations and cost calculations but also with environmental impact. Project assessments, including carbon footprint and environmental impacts, are now seen as the only real way to reach true economic feasibility tables for projects and processes in the long run. In this context, techno-economic evaluations simulate the technological, economic and environmental impacts of the processes and provide the most realistic cash flow and financial statements. Techno-economic evaluations reveal the long-term competitive strength of processes and technologies, making it easier for project leaders to make decisions. In this study; In this case, techno-economic analysis of amine sweetening units used in the purification of H2S and CO2 contaminated gases in refinery and petrochemical plants is explained with a case study. Amine sweetening units are important units for reducing carbon footprint for refineries, petrochemicals and gas processing plants. However, these units (if not required by environmental regulations) are not preferred because of their high energy and raw material requirements. In this context, how an amine sweetening process can be economically feasible in many different technological and operational scenarios has been studied and the most effective process can be selected by comparing energy + raw material consumption, operation and maintenance costs and fixed costs of the process. Thus, in an exemplary application, techno-economic analysis of the amine sweetening unit with the obtained concrete data was made and it was facilitated in deciding the installation of these units.

Key-Words: - Amine sweetening units, decisions on projects, purification of H2S and CO2, techno-economic analysis

I. INTRODUCTION

Project preparation consists analyzing and developing processes of an idea and/or view into a real-life project to ready for execution. All projects have a project cycle that shows the community of the projects, the schematic representation of the main elements and the sequence of their relations with each other. [1,2]. The precise formulation of the project cycle and its phases depends on process type or company profile, but the basic components of project preparation cycle is shown in Figure 1.

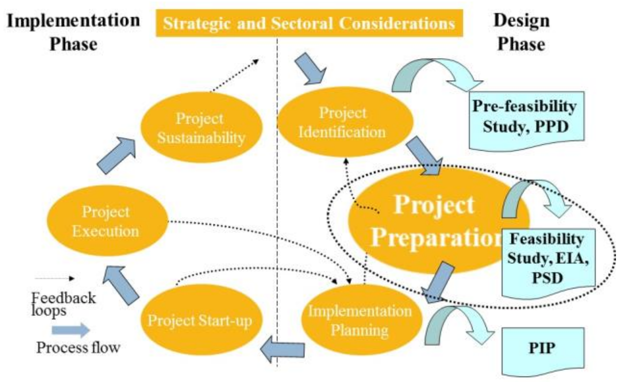

Figure 1. Schematic view of a project cycle [3].

As shown in Figure 1, project preparation phase has to include feasibility study which covers all assessments such as technological, financial, logistical, environmental, political and human factors. To make a brief summary for feasibility studies of projects, Figure 2 shows an overview of feasibility studies.

As shown above Figure 2, technic and economic analysis that means techno-economic assessment is the core of a feasibility study.

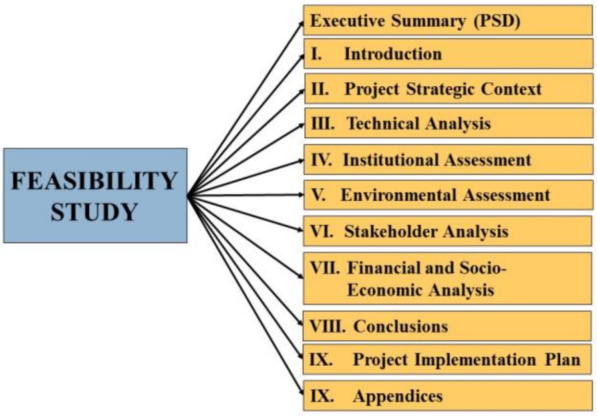

Figure 2. Overview of feasibility study contents and outline [3].

Techno-economic evaluation (TEA) is in principle a cost-benefit comparison using different options. An integral tool for both research and commercial project development, TEA combines process modeling and engineering design with economic evaluation [4]. It helps to evaluate the economic development of the project and provides guidance, research, development, investment and policy formulation. It integrates well with the stage board analysis used by the world's private sector, engineering companies and R&D centers for project development. In order to be completely effective, it is necessary to make planning on this subject since there is a lot like TEA, literature, researches and vendor characteristics.

Eliminating bottlenecks and optimizing the process is a high priority in scale-up research and TEA is a powerful tool that helps us solve these problems. In principle, TEA is a cost-benefit comparison using different methods. Examples of areas where these assessments are used are [5, 6]:

- Assess the economic feasibility of a particular project,
- Investigate cash flows (eg financing issues) over the life of the project,
- Evaluate the possibility of different technology scales and applications,
- Compare the economic quality of the current project with different technology applications that provide the same service.

Detailed TEA assessments and reports should be based on the needs of the project leader to include the following:

- Market Data: It covers projected future sales revenue based on estimated sales volumes and price.
- Raw Materials & Energy Consumption Data: It estimates the quality and quantity of raw materials for the project and the adequacy of energy consumption, calculating the estimated cost of all these inputs.
- Plot Plan, Location & Infrastructure Data: It evaluates the necessary infrastructure development works to establish the project with the existing infrastructure and the actions that will be needed for it. Also, plot plan drawings are made with this data.
- Project Technical Concept Data: This data is a core delivery product of the project and all process descriptions. It should include plant capacity, equipment dimensioning, warehouses, auxiliary facilities, system engineering, electrical engineering, civil engineering, control and automation engineering, quality control and assurance, captive power plant and waste heat recovery system (WHR) according to the project needs.
- Logistics Data: The work should include inbound and outbound logistics data and general logistics planning.
- Environmental Data: The report should include the legal obligation framework to be implemented and the environmental impacts of the project.
- Implementation Planning Data: It should consist of time scheduling and milestones of the project.
- Human Resources Data: This data should cover human requirement and labor cost.
- Investment Cost Data: This data should cover capital costs and funding needs.
- Operating Cost Data: It covers general expenses such as raw materials and utility expenses such as energy, water, steam and labor expenses.
- Financial Appraisal Data: Project profitability, IRR, NPV, reimbursement etc. risks. It acts as a Risks and Mitigation report.

In this study, techno-economic evaluation of projects for refineries, petrochemical plants and natural gas plants is analyzed and a case study is also performed. The case study is about amine sweetening unit that is used to clear off gas from H_2S and CO_2. Different case scenarios and options are compared and evaluated according to techno-economic assessments. Techno-economic analysis evaluates and estimates the economic, as well as operability and sustainability performance of alternative processes; hence, decision-making support for project alternatives could be easily executed by this way. Financial and technical assessment methods are used to achieve selection of the best option for amine sweetening projects.

II. Literature Review

Techno-economic assessment is widely used in refinery, petrochemical or gas plants of an investment or project to measure the technical and economic performance of an investment based on the financial return of the investment or the operational performance of the process. Techno-economic results are often associated with uncertainty due to the fluctuation of economic parameters, and these uncertainties may arise from fluctuations in raw material stocks or final products (ready-for-sale) and energy costs [7]. In order to prevent these fluctuations and economic uncertainties, techno-economic results should be supported by sensitivity analysis and / or Monte Carlo simulation. Sensitivity analysis is applied to reveal the effect of different parameters and to find the dominant ones; Monte Carlo simulation is used to calculate the probability distribution of the results, taking into account the variability of the effective parameters.

Some project models use simulation programs for refinery and petrochemical plant processes for total capital and variable cost estimations. ASPEN Plus® ‘Cost Estimator Tool’ is one of the most useful tools for oil & gas and petrochemical processes to obtain material and energy balance data to help determine labor requirements, operational size and number of equipment, and price and process costs of the required operational equipment [8]. Total capital investment and variable operating costs can be determined based on the final product and energy data generated by process simulation in ASPEN Plus®, and material and energy unit prices quoted by the ‘Cost Estimator Tool’ can be calculated. Through this program, labor costs are determined based on factors such as fixed operating costs, including maintenance and management costs, facility scale, fixed capital investment, total capital investment and annual sales.

Market analysis of final product costs, regulations and market shares is the first step in techno-economic assessments. An appropriate market model should also include information such as regulatory content, competitive issues, customer preferences, as well as fluctuations in economy and macroeconomic parameters [9]. Estimates for product ranges included in demand modeling and calculations are key inputs for all business case analyzes. Based on inputs from market analysis, performance parameters such as production capacity, energy consumption of the production process, operability and sustainability, and process reliability can be calculated. Using these technical indicators, techno-economic evaluation could be made easily.

Life Cycle Assessment (LCA) to demonstrate how a new technology can contribute to the reduction of carbon foot-print and environmental impact of the process, and how the Techno-Economic Assessment can demonstrate how the technology can be offered competitively in carbon and fossil fuel-based processes such as refineries and petrochemical plants on the market. Together LCA and TEA are valuable toolkits for incentive eco-friendly process and technology development for oil & gas and petrochemical sectors.

The decision to implement new process technologies on a refinery and/or petrochemical & gas plant usually take into account three main parameters; technological, economic and environmental criteria. While TEA generally aims to examine technological feasibility and economic profitability, LCA generally aims to compare the environmental impact of processes and technologies and reduce carbon fingerprints [10]. Therefore, by integrating the results of TEA and LCA, solutions can be found to provide a balance on economic and environmental results. Both TEA and LCA results are complementary to the final decision-making process, providing interpreted indicators for criteria (TEA) and impacts (LCA). By aligning or integrating the two assessments, for example by selecting the same objective and functional unit for the study, it is possible to interpret the LCA and TEA results together and make a final decision on the applicability of the process to project leaders. However, if the LCA and TEA outputs are interpreted in a combination without proper alignment, interpretation difficulties and results that result in unreliable outputs may be obtained. Therefore, in general, an approach is proposed for the smooth and effective combination of CCU TEA and LCA. After harmonized studies, combined environmental and economic indicators can be calculated and multi-criteria decision analysis can be performed.

Multi-criteria decision analysis ensures that the balance between economic and environmental impacts is considered together to find the most appropriate result. For example, increasing the temperature of a stream in a given process can result in increased profitability (by increasing product yields), but this change in the process may aggravate environmental impacts; therefore, multi-criteria decision analysis helps determine the optimal temperature in the process that balances both effects [11, 12].

On the other hand, TEA might need to be evaluated in different ways for the economic viability of renewable energy projects because renewable energy technologies need to be taken into account in terms of energy security for countries, renewable raw material resources and environmental advantages (such as low CO2, NOx and SOx emissions). Even if power generation from renewable energy has higher prices, it should be evaluated differently due to the long-term advantages over conventional energy in the current energy price scenario [13-15]. In the long term, as the costs associated with fossil fuel prices will increase due to depletion of fossil fuel resources and the gap between demand and supply, the price of renewable energy will reach its breaking point and be cheaper than conventional energy sources such as coal, natural gas and oil. Although renewable energy prices are currently higher than those of conventional ones, this is related to the operating and investment costs of higher emission reduction processes and lower fuel price sensitivity of renewable resources. Projections for 2020 show that renewable energy prices will fall significantly in the near future and will compete with coal, oil and natural gas prices [13].

In order to maintain the competitive power of a refinery or petrochemical plant in an advantageous position in global markets, it has become increasingly important to achieve a sustainable high-performance process. Uncertainties and fluctuations in environmental or economic considerations may occur due to incorrect measurements, lack of data, and incorrect or unreliable model assumptions if decision makers / project leaders decide which direction the project should go. Some of the proposed approaches are how to deal with error propagation and sustainable risk assessments for projects such as fuzzy logic and Gaussian formulas as the most widely used methods for spreading parameter uncertainty [16, 17].

III. Problem Solution Assessment Methods

It is widely accepted that not only programs and portfolios, but also individual projects should be linked to high-level objectives and strategies (i.e. group goals are more important than individual goals). In this context, the project management community is increasingly concerned about how projects create value and benefit [18, 19]. Some forecasting models focus on the front end, while others discuss benefit management throughout the project life cycle (LCA). Project managers were forced to shift their attention beyond the 'iron triangle' of increasing cost, time and quality in order to gain a broader and more strategic perspective of the projects. Projects are implemented to create benefits and value for end users (community or stakeholders, etc.), parent organization and / or society in general. Conducting financial assessments ensures that the processes, systems and regulations required to ensure efficient selection and presentation of relevant and applicable projects can be obtained clearly.

Whether an industrial project can be successfully implemented depends primarily on the investors' confidence in the project and the economic benefits of the project that will encourage decision-making [20-22]. Internal rate of return (IRR) is one of these methods to measure the profitability of a process. IRR is a parameter that expresses the discount rate where cash inflows are equal to cash outflows. When IRR is higher than the basic discount rate (BDR), the project is considered to be economically viable; otherwise, the project loses its economic feasibility. When the IRR is equal to the BDR, the project's starting point and NPV methods should also be considered as other economic evaluation parameters to verify economic performance under current technical and cost levels.

The integrated assessment method is a mixed method (focusing on the carbon fingerprint) which includes technical assessment, economic assessment and environmental assessment. The integrated system assessment includes mass and energy balance data for the technical assessment side; data on capital investments (CAPEX) and operating expenses (OPEX) for the financial evaluation party; on the environmental assessment side, it includes climate impact and carbon fingerprint data from raw material to final product in all processes [24]. Process simulations can be performed with Aspen Plus® by estimating all technical data including the mass and energy balance data of the process and the characteristics of the different units. Economic assessments can be calculated using the Aspen Process Economic Analyzer®, using this program to estimate investment, energy, maintenance and operating costs. To predict climate impacts, the hybrid LCA approach can be applied by combining physical process data from technical assessment and economic data from techno-economic assessment.

A project manager and / or project stakeholders cannot be absolutely certain of the accuracy of the financial estimate of a particular project. This is a great handicap for project management. Therefore, the creation of project cash flows is very important for both stakeholders and project managers. In the implementation phase of a project, cash flow is very important for the assessment of working capital requirements because the necessary capital reserves are determined from the difference between project expenditures and payments [25]. In addition, a correct cash flow is necessary to perform the project cost versus benefit analysis in order to determine the project financing requirements and perform the earned value analysis.

In the cash flow analysis, using average fuzzy techniques, project cash flow generation and accurate financial analysis tables can be obtained [26, 27]. For the analysis of various quantitative and qualitative factors in which knowledge is subjective and based on uncertainty, the evaluation of working capital requirements can be done using average fuzzy methodology. Fuzzy technique is used to find an optimal corporate cash flow path with minimum resource usage. In the traditional method, stochastic S curves in probable monitoring and project performance estimation are used to determine the cash flow of the project; on the other hand, fuzzy techniques can provide early warning for cash flow forecasting and multi-stage project programs. In this way, the real cash flow management model facilitates financial decisions.

Finally, it can be said that project-based evaluations relate to the fact that projects and project-based operations are a means of determining, creating and presenting value. The value is perceived in the most general sense as the "value in of the project, and relates to both the output of the project and the resulting data (i.e., the lifecycle benefits and the willingness of the recipient to pay for the project to be delivered over time) [28-31].

Integrated assessment models are also widely used in the analysis of the environmental impacts of large-scale projects, and the outcomes of these assessments not only inform national decision-makers, but also contribute to international scientific assessments. Integrated assessment models of environmental impact have become increasingly important in informing the debate about climate policy and processes on carbon fingerprints. In addition, as an important step, it paves the way for the creation of suitable projects that will open the door to new developments that will conform to future technological assessments. Evaluation reports are also used in political impact assessments and environmental legislation analysis reports of government agencies [32, 33]. In addition, several national level integrated assessment models have been used to report governments' decisions to prepare nationally determined contributions to climate negotiations towards Paris-COP21 in 2015 [34]. At this stage, all processes, including the emissions from the supply chain, should be evaluated extensively to reveal the environmental impact of the projects and all processes in the project phases. While the carbon footprint of the project becomes predictable in the environmental assessments, the overall profitability analysis of the project is revised by adding the carbon tax to the calculations [35, 36].

IV. Case Study

Whether an industrial project can be successfully implemented depends primarily on the investors' confidence in the project and the economic benefits of the project that will encourage decision-making [20-22]. Internal rate of return (IRR) is one of these methods to measure the profitability of a process. IRR is a parameter that expresses the discount rate where cash inflows are equal to cash outflows. When IRR is higher than the basic discount rate (BDR), the project is considered to be economically viable; otherwise, the project loses its economic feasibility. When the IRR is equal to the BDR, the project's starting point and NPV methods should also be considered as other economic evaluation parameters to verify economic performance under current technical and cost levels.

As mentioned above, techno-economic assessment case is about a project for implementation of new amine sweetening unit to refineries, petrochemical plants or natural gas plants.

Amine sweetening units are one of the most common methods of treating plant off gases for the removal of H2S and CO2 [37]. A simple process block diagram for amine sweetening unit is shown in Figure 3 [38].

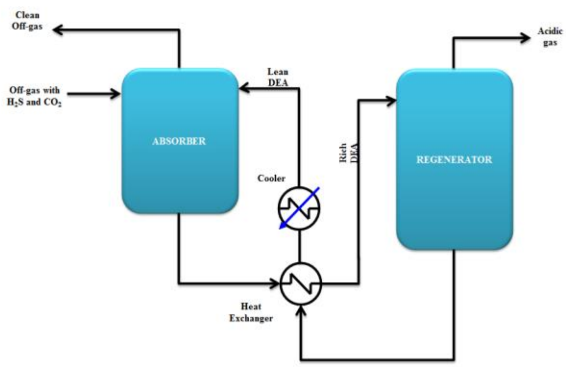

Figure 3. Simple block diagram of amine sweetening unit.

A typical amine sweetener unit is comprised of two parts, mainly an absorber section and a regeneration section. In the absorber section (this column generally includes packaging materials), the downstream amine solution absorbs H2S and CO2 from the upstream dirty gas to produce a stream of sweetened gas (clean gas) as a product. The rich amine solution (amine containing H2S and CO2) is then directed to a regenerator column (a stripper column with a reboiler heater) to produce lean amine

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(amine solution without H2S and CO2) which is recycled for reuse in the absorber section.

The solvent used in an amine sweetening unit is usually an alkanolamine of which the following are the most frequently employed:

- •Monoethanolamine (MEA)
- •Diethanolamine (DEA)
- •Di-isopropanolamine (DIPA
- •Methyl diethanolamine (MDEA)

The aim of this case study is to present various possible options for the proposed new amine sweetening unit (using DEA), carryout techno-economic comparison with respect to ballpark capital cost, number of equipment, utility requirement, etc. for all those different options so that owner company of the project could select the best option.

A. Possible Regenerator Options

There are two aspects for the proposed amine sweetening unit. One is boosting the off gas pressure at outlet of existing barometric seal drum to overcome the increased pressure drop of proposed amine contractor and the other is optimum scheme for downstream amine treatment.

Various possible schemes are developed for proposed off gas treatment unit taking into account both the above aspects. Considering the stringent product specification (clean off gas) of below 40 ppm H2S content in treated off gas, the lean amine loading needs to be considerably low, leading to higher reboiling duty for a conventional single stage amine regenerator. To reduce the reboiling duty another option of two stage regenerator is considered. The 1st stage regenerator will be designed with normal lean amine loading, whereas the 2nd stage regenerator with only about 10-20% of total circulating amine solution will be designed with much lower lean amine loading. A brief comparison of single stage regenerator vs. two stage regenerator is given following section.

B. Single Stage vs. Two Stage Regenerator

Single regenerator system is a typical amine sweetening process which is illustrated above in Figure 3 before. On the other hand, new proposed system two stage regenerator system is a new alternative process. Two stage regenerator system block diagram is shown in Figure 4.

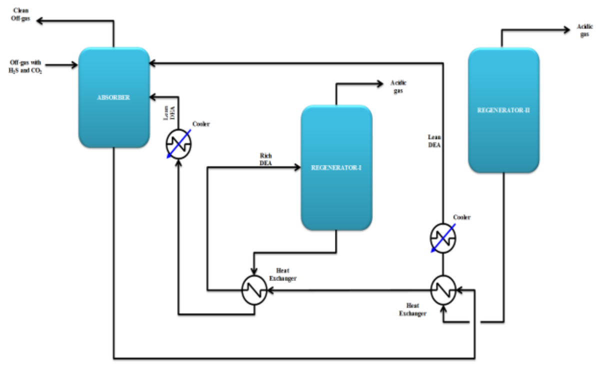

Figure 4. Two stage regeneration block diagram of amine sweetening unit.

Its aim to reduce capital costs and also operating cost with decreasing of utilities such as electric power, cooling water and steam.

A comparison table of utilities required for single stage and two stage regenerator system is given below in Table 1.

Table 1. Utilities consumption comparison of one stage and two stage regenerator systems.

Utilities	Single stage vs. Two stage regeneration utility consumption change (%)
Electric Power	22.81
Steam	-57.55
Cooling Water	-58.24

As per the above table, power requirement for both cases is comparable since the pump flow rates have not been changed significantly. However, steam consumption is quite high in single stage regeneration due processing of total rich amine to a desired low lean amine loading. In two stage regeneration approximately 10-20% of rich amine is processed in 2nd regenerator to a relatively low lean amine loading than in 1st regenerator, hence the combined reboiler loads for two stage regeneration is lower than that of single stage. Due to high condensing load for single stage regenerator system, cooling water flow is substantially high for single stage regenerator.

An indicative comparison of estimated ballpark capital cost for both the options as well as associated chemical & utility consumption considering 20 years' life time is provided below in Table 2.

Table 2. Cost based comparison of one stage and two stage regenerator systems.

	Single stage vs. Two stage regeneration cost change (%)
Ballpark Capital Cost	-33.3
Cost for Utilities	-56.0

The above tables and calculations clearly indicates estimated capital cost as well as operating cost for a single stage regenerator is much higher than that of two stage regenerator. The main reason for increasing capital cost is due to lower amine loading for single stage regenerator resulting into higher surface area for heat exchangers.

C. Options for Pressure Boosting

The major challenge for an amine sweetening project is to boost the dirty off gas pressure at outlet from another plant to amine treatment plant to overcome the increased pressure drop of proposed amine system.

Five different options are developed for boosting the dirty off gas pressure, these are listed below:

Option-1: Modification of existing dirty off gas system

Option-2: Addition of a liquid jet eductor downstream of existing dirty off gas system using circulating amine solution as motive fluid

Option-3: Addition of an ejector downstream of existing dirty off gas system using natural gas as motive fluid

Option-4: Addition of an ejector downstream of existing dirty off gas system using fuel gas as motive fluid

Option-5: Addition of liquid ring compressor at downstream of existing dirty off gas system using

The percentage comparison of utility requirement for options 1 to 5 is summarized in Table 3 (compared to two stage regenerator utility consumptions):

It is evident from the below Table 3 that power requirement for Option-2 is quite high in comparison to other options. This is mainly due the high capacity amine eductor pump. However, the steam requirement of Option-2 is lowest while that of Option-1 is maximum as the replaced last stage ejector requires considerable amount of additional steam. The cooling water requirement for Option-3 & 4 are much higher than other options as circulation amine flow rate is higher for these options.

CAPEX and OPEX for options 1 to 5 is summarized in Table 4. The above comparison table clearly indicates that CAPEX for Option-2 is the lowest one followed by Option-3 with NG ejector. Whereas Option-5 with Liquid Ring Compressor which requires highest CAPEX. The OPEX for Option-1 is highest due to considerable steam requirement.

Comparison of other parameters (plot plan requirements, operability and maintainability options and process reliabilities) for options 1 to 5 is summarized below in Table 5.

Table 3. Utility consumption comparison of one stage and two stage regenerator systems

	Option-1	Option-2	Option-3	Option-4	Option-5
Description	**Modification of Existing System**	**Addition of Liquid Jet Eductor**	**Addition of NG Ejector**	**Addition of FG Ejector**	**Addition of Liquid Ring Compressor**
Electric Power	0.0	321.4	12.5	12.5	142.9
Steam	0.0	0.0	40.3	40.3	0.0
Cooling Water	0.0	0.0	42.7	42.7	8.4

Table 4. Economic comparison of one stage and two stage regenerator systems.

	Option-1	Option-2	Option-3	Option-4	Option-5
Description	**Modification of Existing System**	**Addition of Liquid Jet Eductor**	**Addition of NG Ejector**	**Addition of FG Ejector**	**Addition of Liquid Ring Compressor**
Ballpark Capital Cost	46.2	11.5	26.9	26.9	96.2
Cost for Utilities	60.6	15.2	37.9	37.9	7.6

Table 5. Comparison of other options for one stage and two stage regenerator systems.

	Option-1	Option-2	Option-3	Option-4	Option-5
Description	**Modification of Existing System**	**Addition of Liquid Jet Eductor**	**Addition of NG Ejector**	**Addition of FG Ejector**	**Addition of Liquid Ring Compressor**
Plot Area Requirement	+	++	+	+	+++
Operability& Maintainability	+	++	+	+	+++
Reliability	++	+	++	+	++

The number of equipment required for all the above options are almost same and hence not mentioned here. Accordingly, the plot area requirement is almost same, except for Option 5 with liquid ring compressor which required considerable plot area. For Option-2 also the plot area requirement is slightly more due to two numbers circulating amine eductor pumps. The operation and maintenance cost for Option-5 is considerably higher due to the liquid ring compressors. In terms of reliability, Options-1, 3 and 4 are most reliable, whereas that of Options-2 and 4 are comparatively low. For Option-4, the composition of fuel gas normally varies with refinery and petrochemical plants operation leading to continuous fluctuation of off gas pressure which is not desirable. Similarly, Option-2 has comparatively less practical application.

D. Recommendations Between Options

The comparison tables provided under Section 4 clearly indicates that Option-5 with liquid ring compressor has highest capital expenditure. Moreover, the liquid ring compressor requires considerable plot area and considerably higher operation and maintenance cost. Hence, this option could not be a preferred one.

The CAPEX for Option-1 with modification of existing system is also considerably higher. Moreover, this option required significantly higher amount of utilities leading to highest OPEX. Hence, this option also could not be considered. Options 2, 3 & 4 have comparable CAPEX. However, Option 4 with fuel gas ejector is not a preferred option as the pressure is quite low resulting higher flow requirement and thereby higher diameter absorber column. Moreover, since the composition of fuel gas normally varies with refinery and petrochemical plant operating option, it might lead to continuous fluctuation of dirty off gas pressure and thereby not desirable.

Among Option 2 & 3, the CAPEX is slightly higher for NG ejector due to higher dimension of absorber column. The OPEX for Option-3 is also slightly higher side due to circulation of higher amine solution resulting into higher reboiler & condenser duties.

When we consider plot plan area requirement, operability and maintainability of the processes and reliability of the operations, Option 2 liquid jet eductor becomes less desirable than Options 3 & 4.

Finally with all comparisons above, we could easily say that Options 3 has the most advantageous project option after the techno-economic evaluations.

V. Conclusions

Today, in which technology is constantly developing and competition is intense, project leaders and project stakeholders must ensure the continuity of their processes and projects by producing efficient and effective outputs in terms of operability and economy as well as environmental issues. For this purpose, it is becoming increasingly important that techno-economic evaluations including operations, finance and environmental trio are conducted simultaneously. In techno-economic assessments, the workflows of the process, all processes between input and output (including logistics activities) are determined step by step, resulting in an economic and environmentally friendly process, while increasing output efficiency.

In this study; the techno-economic evaluation of the project of the installation of amine sweetening unit holding H2S and CO2 from the dirty gas which reduces the carbon footprint of the refinery and petrochemical plants was carried out. In many different operational scenarios, the outputs of the process, the effect of the inputs and the energy + utility consumptions of the process were compared and the most effective process (in terms of economic + operability) was selected. Therefore, with the concrete data obtained, it is shown with a sample application how much can be facilitated by techno-economic analysis for the project manager and the stakeholders of the project.

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