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Sustainability Improvements in Egypt’s Oil & Gas Industry by Implementation of Flare Gas Recovery

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ABSTRACT

According to satellite data of the National Oceanic and Atmospheric Administration, Egypt has consistently ranked 20\textsuperscript{th} among the world’s top 20 gas flaring countries during the period 2007 to 2011, where aggregate quantities of flared gas were estimated at 8.1 Billion Cubic Meters, which represents annual lost revenues of approximately USD 4.2 billion. As an alternative to flaring, the gaseous by-products are already being captured by some refineries and are utilised for their energy content. However, viability of flare gas recovery projects is restricted in many countries by high project development costs, lack of funding and energy subsidies. The Clean Development Mechanism (CDM) can play a pivotal role in overcoming barriers facing flare gas recovery projects in developing countries like Egypt, especially in view of the low energy prices due to energy subsidies provided by the government. This paper reports on research conducted on Egypt’s first refinery flare gas recovery project, which could improve sustainability and promote Cleaner Production within the Egyptian Oil & Gas industry. Since the project was foreseen for implementation under CDM, the project was analysed from a triple bottom line perspective. In addition to the potential annual greenhouse gas emission reductions yielding expected yearly revenues of around USD 1.5 million, the project can contribute to capacity building and employment opportunities in Egypt’s Oil & Gas industry. Registering the project under CDM improves its economic feasibility and can provide impetus to overcome the identified project barriers. However, since the project’s Internal Rate of Return is highly sensitive to the local gas price, removing the energy subsidies renders the project economically attractive without considering CDM revenues. From a future perspective, this project represents a major steppingstone for implementing zero flaring in Egypt.

Keywords:
Clean Development Mechanism
Cleaner Production
Egypt
Flare Gas Recovery
Governmental Energy Price Subsidies
Oil and Gas Industry
1. **Introduction**

Within the Oil & Gas industry (O&G), gas flaring describes the process of safe disposal of associated or waste gas by burning at the flare. Whereas, associated gas is excess gas produced during oil exploration and production activities, waste gas is the by-product of the different oil refining processes. On one hand, gas flaring is a non-routine safety procedure that takes place in case of emergency shutdowns, maintenance or operational upsets to clear the hydrocarbon gas inventory from facilities’ pipelines or equipment. On the other hand, normal gas flaring refers to the continuous discharge of gas to the flare during routine plant operations (World Bank, 2002). Since the primary focus of this article is on normal (continuous) flaring of refinery waste gas, subsequent use of the term gas flaring or flaring will primarily refer to normal flaring of refinery waste gas.

From an environmental perspective, gas flaring is associated with considerable greenhouse gas (GHG) emissions; hence, it contributes to global warming. Based on the data compiled by the World Bank’s Global Gas Flaring Reduction (GGFR) Public Private Partnership, global gas flaring has been persistent at around 150 Billion Cubic Meters (BCM) during the period from 1994 to 2009, representing about 30% of the European Union’s yearly gas consumption and resulting in annual emissions of some 400 Million Tons of Carbon Dioxide Equivalent (MtCO2e) into the atmosphere (World Bank, 2012b). From a social perspective, gas flaring poses a threat to human health and to ecosystems at sites adjacent to the flare. From an economic perspective, gas flaring is a dissipation of non-renewable natural resources since the flared gas has an energy content (calorific value) that is wasted without use as soon as the gases are combusted at the flare (Peterson et al. 2007). Accordingly, flaring implies that the most cost-beneficial refinery operation is not achieved (Zadakbar et al., 2008).

According to satellite data of the National Oceanic and Atmospheric Administration (NOAA), Egypt consistently ranked 20th among the world’s top 20 gas flaring countries during the period 2007 to 2011, where aggregate quantities of flared gas were estimated at 8.1 BCM representing total lost revenues of around USD 4.2 billion (World Bank, 2012a).

Mourad et al. (2009) and De Gouvello (2010) outlined several alternatives to flaring that primarily rely on the recovery of the otherwise flared gases. Following inception in Norway in 1994, concepts and technologies of flare gas recovery have been proven and extensively applied in offshore oil and gas production facilities (Christiansen, 2001). However, as reported by the World Bank (2005), economic viability of flare gas recovery projects are constrained in many countries mainly due to high project development costs, lack of funding and lack of distribution infrastructure.

Another significant factor affecting economic feasibility of flare gas recovery projects is the energy subsidy that many governments provide. In the case of Egypt, industrial (and domestic) energy consumers continue to enjoy substantial subsidies provided by the Government of Egypt (GoE), which were approximately USD 16 billion in 2011, representing about 7% of GDP and 24% of State Budget expenditures (Central Bank of Egypt, 2011). As highlighted by Abouleinien et al. (2009), energy subsidies and the current energy pricing approach set by the GoE resulted in tremendously wasteful consumption of energy and have driven energy producers away from minimizing energy waste and implementing energy efficiency/recovery measures, including flare gas recovery.

In addition to these unfavourable economic factors, flare gas recovery projects have been impeded by a number of technical challenges. Peterson et al. (2007) described these challenges as a combination of highly variable flow rates and composition, low heating value and low pressure of the waste gases.

The aim of this article is to highlight efforts to improve the sustainability of the Egyptian O&G industry by using the energy content of the waste gases through flare gas recovery. Outcomes of research conducted on Egypt’s first refinery flare gas recovery project undertaken by Suez Oil Processing Company are presented. Since the project was foreseen for implementation under the Clean Development Mechanism (CDM), the project was analysed from a Triple Bottom Line (TBL) perspective in that context.
In the subsequent sections of this article, a review of the materials and methods utilised for the analysis of the gas flare recovery project is outlined in Section 2. The outcomes of the project’s TBL analysis are presented in Sections 3 & 4. Finally, the conclusions are presented in Section 5.

2. Project context, description and analysis

2.1 Clean Development Mechanism

CDM is one of the three market-based mechanisms established under the Kyoto Protocol (KP) to the United Nations Framework on Climate Change (UNFCCC) (Sterk and Wittneben, 2006; UNFCCC, 2010a). CDM’s raison d’être as defined under Article 12 of the KP is to assist both Annex I countries in achieving their emission reduction commitments and non-Annex I countries in realizing sustainable development (UNFCCC, 1998). Annex I countries referred to in the KP are the industrialized (developed) countries that are committed to reduce GHG emissions according to binding limits set against their 1990 emission levels. On average, GHG emissions reductions should be 5% below 1990 levels for countries that ratified the protocol and should take place over the protocol’s first commitment period from 2008 to 2012 (UNFCCC, 2010a).

From an economic perspective, CDM allows Annex I countries to fulfill their emission reduction commitments by facilitating investments in activities yielding emission reduction ‘credits’ at non-Annex I countries where the investment cost is lowest (Grubb et al., 1999). These reduction credits are termed Certified Emission Reductions (CERs) and are traded within the carbon market established under the KP (Ferrey, 2009). Eligibility of projects for CDM is governed by several criteria stipulated within the Marrakesh Accord (UNFCCC, 2002) and later refined within the Conference Of Parties (COP) meeting report 11 (UNFCCC, 2006a). The main eligibility criteria contained in these two reports are summarized as follows:

1. Identification of project baseline scenario:
   Using the CDM terminology of the COP 11 report, the baseline scenario is defined as ‘the scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gases that would occur in the absence of the proposed project activity’ (UNFCCC, 2006a). Therefore, the baseline is established to compute both the emission reductions brought about by realization of the proposed project and the CERs thereafter.

2. Demonstration of project additionality:
   To meet the additionality criterion, it is required to illustrate that the GHG emissions saved by the project are additional to any reductions that would have naturally occurred anyway from business-as-usual (without implementing the project).

3. Sustainable development in host country
   Since promoting sustainable development is one of the main drivers of CDM, projects qualifying for CDM must illustrate the means through which sustainable development is achieved by the project activity. Accordingly, Designated National Authorities assigned by the CDM Executive Board were tasked with assessing any proposed CDM project against predetermined national sustainable development criteria of the host country (Olsen, 2007).

4. Stakeholders comments
   In order to fulfill the CDM’s sustainable development goal at all levels within host countries’ communities, local stakeholder comments on the project activities must be solicited. A summary of the comments received and a report of how such comments were addressed must be presented as part of the CDM project registration process.

In order to obtain the CDM Executive Board approval, which is mandatory for issuance of the tradable CERs, projects proposed under CDM follow a predefined process. This process is commonly referred to as the CDM project cycle and comprises the following processes: Prior consideration, Letter of no objection, Design, Approval, Validation and registration, Monitoring, Verification and registration, and CERs issuance (Paulsson, 2009).
2.2 Project description

The Suez Oil Processing Company (SOPC) is one of the landmark companies in the history of Egypt’s O&G industry. It was the first national oil refining company established in Egypt, second only to the previously foreign owned Nasr refinery. Construction of SOPC was begun in 1921 and the refinery was commissioned in 1923. SOPC enjoys a strategic location on the Gulf of Suez coast, just downstream of the Suez Canal international waterway. The refinery was designed to handle three million tons of crude oil annually and has a yearly production capacity of 900,000 tons of high quality products. Currently, excess off-gases released from the four processing units (waste gases) are continuously discharged to the flare via two separate flare headers.

At present, SOPC is planning to install a complete flare gas recovery system in order to minimize the quantity of waste gas normally discharged to the flare and to use it internally as fuel gas for the heaters that supply the refinery’s heating requirements.

From the flared gas analysis developed by SOPC, it was clear that the waste gas contains carbon dioxide (CO$_2$) and hydrogen sulphide (H$_2$S), which are both weakly acidic gases and become corrosive in the presence of water (Garverick, 1994). Accordingly, in order to utilize the recovered gas in the refinery, it is necessary to scrub the sour gases to prevent corrosion and to satisfy the pre-set specifications of the process heaters’ fuel gas. The flare gas recovery system will therefore include a treatment unit for gas ‘sweetening’. In order to undertake the project monitoring process for CDM, the volume of recovered gases must be measured and recorded subsequent to implementation of the project. Hence, a gas meter will be installed within the recovery system as well. A simplified block flow diagram showing the existing facilities and the envisaged new flare gas recovery system including the gas meter, compressor and treatment unit is depicted in Figure 1. During normal operation of the new flare gas recovery system, all the waste gas is routed for recovery. However, in case of malfunction of the new system or during its maintenance, all the waste gas will be routed to the flare without recovery. It is imperative to highlight that the existing flare headers carrying waste gas from both the distillation units/lube oil complex and the coker/reformer complexes to the flare will be decommissioned and isolated (not used) after operation of the new flare gas recovery system to ensure that all normally flared waste gas is routed to the new flare gas recovery system.

2.3 Project analysis

2.3.1 GHG emission reduction calculations

In order to calculate the expected GHG emission reductions for SOPC flare gas recovery project and since the project was foreseen for implementation under CDM, a methodology approved by the CDM Executive Board was used. Upon review of the Approved Methodologies (AM) database provided on the CDM UNFCCC website (2010b), four methodologies were found relevant for flare gas recovery. Since AM 0055 version 01.2 (UNFCCC, 2008a) considers recovery of flared waste gas and is applicable for large scale projects, it was identified as the applicable methodology for SOPC flare recovery project in view of the magnitude of potential emission reductions.

The GHG emission reductions per year ($ER_y$) were calculated as the difference between the yearly project baseline emissions ($BE_y$) and project emissions ($PE_y$) as shown in equation (1). In the case of SOPC, the baseline is continued flaring of waste gases and generating heat for use within the refinery (process heating) by burning natural gas (fuel source).

$$ER_y = BE_y - PE_y$$

(1)

The baseline emissions from process heating in year $y$ ($BE_{ph,y}$) measured in tons of carbon dioxide equivalent per year (tCO2e/y) were calculated using equation (2):
where \( Q_{wg,y} \) is the quantity of flared waste gas that replaces the process heating fuel in year \( y \), \( LHV_{wg} \) the Lower Heating Value of the flared waste gas and \( EF_{phf} \) the emissions factor of the fuel used for process heating (natural gas) measured as grams of carbon dioxide gas emitted per kilocalorie of process heating gas. To calculate \( LHV_{wg} \), the weight per cent (Wt) of waste gas component \( i \) is multiplied by its corresponding \( LHV \), and the resulting values summed, as shown in equation (3).

\[
LHV_{wg} = \sum LHV_i \times Wt_i
\]

(3)

\( EF_{phf} \) is calculated from the carbon content of the natural gas used in the refinery, which is obtained as the product of the weight per cent of natural gas component \( i \) and its corresponding carbon fraction using equation (4). To express \( EF_{phf} \) in terms of its heat content (kCal), the carbon content was divided by the \( LHV \) as illustrated in equation (5).

\[
CarbonContent_{phf} = \sum CarbonFraction_i \times Wt_i
\]

(4)

\[
EF_{phf} = \frac{CarbonContent_{phf}}{LHV_{phf}}
\]

(5)

The first source of project emissions was identified as the electricity consumption of the flare gas recovery system compressor. To calculate these emissions, the Tool to calculate baseline, project and/or leakage emissions from electricity consumption was used (UNFCCC, 2008b). Equation (6) illustrates the formula depicted in that tool for computing the annual project emissions from electricity consumption (\( PE_{EC,y} \)), where \( EC_{PJ,j,y} \) is the amount of electricity consumed by the project electricity consumption source \( j \) in year \( y \) and \( EF_{EL,j,y} \) is the emission factor for electricity generation for source \( j \) in year \( y \) (in this case, there is only one electricity consumption source).

\[
PE_{EC,y} = \sum_j \left( EC_{PJ,j,y} \times EF_{EL,j,y} \right)
\]

(6)

To calculate the compressor electricity consumption, the brake horsepower (BHP) was calculated using equation (7) obtained from Mokhatab et al., 2006:

\[
BHP = 0.0854 \times Z_{avg} \times \left[ \frac{\left( \frac{Q_{G,SC}}{E \times \eta} \right)^{k}}{k-1} \right] \left( \frac{p_2}{p_1} \right)^{\frac{k-1}{k}} - 1
\]

(7)

where \( Z_{avg} \) is the average compressibility factor, \( Q_{G,SC} \) the standard volumetric gas flow rate, \( T_s \) the suction temperature, \( E \) the parasitic efficiency, \( \eta \) the compression efficiency, \( k \) the isentropic exponent, \( p_1 \) and \( p_2 \) the suction and discharge pressures, respectively.

Another source of project emissions not considered in AM 0055 was attributed to power and steam consumption of the treatment unit within the flare gas recovery system. Whilst emissions from electricity consumption of the treatment unit were computed using equation (6), emissions from steam generation (\( PE_{Steam} \)), measured in tCO2e/y, were calculated using the steam flow rate (\( m \)), measured in kilograms of steam per year, saturated steam specific enthalpy (\( h_s \)), expressed as calories per kilograms of steam, steam boiler efficiency (\( \eta_{boiler} \)), and waste gas emissions factor (\( EF_{wg} \)), measured as grams of carbon dioxide emitted per kilocalorie of waste gas, as depicted in equation (8):
2.3.2 Economic analysis

To assess the financial feasibility of SOPC flare recovery project independently and considering the revenue from sale of CERs if the project is registered under CDM, capital budgeting techniques were applied. As defined by Brigham & Gapenski (1994), capital budgeting is the process of assessing projects and identifying which ones to select for planned expenditures on fixed assets. Out of the five primary methods outlined by the authors, the internal rate of return (IRR) method was selected. Essentially, the IRR is the discount rate at which the present value of a project’s revenue returns equates to the present value of the project’s costs. The IRR method was particularly chosen to evaluate the SOPC project since it provides a direct metric for comparing and ranking the project’s attractiveness based on the computed IRR under the different cash flow scenarios. Within a similar context, financial evaluations performed by Rahimpour et al. (2012) for utilizing gases recovered from a refinery flare were also based on IRR calculations.

2.3.3 Social Analysis

In line with the social sustainability metrics developed by Thorne & La Rovere (1999) to assess the social impact of projects considered under CDM and actual social benefits of CDM projects reported by Austin and Faeth (1999), the social aspect of the project was examined in terms of local employment generation. This metric was also reported under the social aspect of Egypt’s sustainable development criteria.

2.4 Research material

Data on the composition of the normally flared gases at SOPC was extracted from the tender document for the supply of a flare gas recovery system. Natural gas was considered as the only fossil fuel combusted to generate process heat in the existing SOPC refinery heaters. Since electricity is sourced from the national grid within SOPC, the emissions factor for electricity generation \( (EF_{EL}) \) was cited from the Project Design Document (PDD) of the Zafarana KfW IV Wind Farm Project, where it was computed as 0.571 tCO\(_2\)/MWh (UNFCCC, 2010c).

3. Results

3.1 GHG Emission Reductions

3.1.1 Baseline emissions

The baseline emissions of the proposed SOPC flare gas recovery project were calculated as the sum of the emissions from burning the waste gas at the distillation units & lube oil complex flare (flare 1) and the coker & reformer complexes flare (flare 2). The results of the baseline emissions calculations are shown in Table 1.

3.1.2 Project emissions

The compressor BHP amounted to 772 hp, or around 580 kW and based on the assumed electric motor driving efficiency, the required compressor motor power equated to about 5,420 MWh. Using the value of \( EF_{EL} \) mentioned in Section 2.3, the project emissions from the flare gas recovery system compressor amounted to 3,095 tCO\(_2\)/yr (circa 3,100). Project emissions from steam generation amounted to 3,320 tCO\(_2\)/yr (circa 3,300), where the quantity of steam required for treating the recovered waste gas was considered as generated from a steam boiler that uses the recovered waste

\[
P_{E,\text{Steam}} = \left( \frac{m \times h_f}{\eta_{\text{boiler}}} \right) \times \left( \frac{1}{LHV_{wg}} \right) \times EF_{wg}
\]
gas as a fuel. Using the same $EF_{el}$, the project emissions from electricity consumption of the treatment unit were found to be 2,398 tCO$_2$/yr (circa 2,400).

Table 1
The baseline emissions of the proposed flare gas recovery project at the Suez Oil Processing Company in Egypt.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Unit</th>
<th>Flare 1</th>
<th>Flare 2</th>
<th>Fuel Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Flow Rate</td>
<td>$Q$</td>
<td>tgas/hr</td>
<td>2</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Lower Heating Value</td>
<td>$LHV$</td>
<td>kCal/kg</td>
<td>11,086</td>
<td>11,898</td>
<td>11,013</td>
</tr>
<tr>
<td>Carbon Content</td>
<td>CarbonContent</td>
<td>tC/tgas</td>
<td>0.82</td>
<td>0.74</td>
<td>0.71</td>
</tr>
<tr>
<td>CO$_2$e ratio</td>
<td>-</td>
<td>CO$_2$/C</td>
<td>3.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO$_2$ Content</td>
<td>-</td>
<td>tCO$_2$/tgas</td>
<td>3.00</td>
<td>2.70</td>
<td>2.61</td>
</tr>
<tr>
<td>Emission Factor</td>
<td>$EF$</td>
<td>gCO$_2$/kCal</td>
<td>0.271</td>
<td>0.227</td>
<td>0.237</td>
</tr>
<tr>
<td>CO$_2$ Emissions (Baseline Emissions)</td>
<td>$BE$</td>
<td>tCO$_2$/yr</td>
<td>44,191</td>
<td>118,570</td>
<td></td>
</tr>
</tbody>
</table>

3.1.3 Total emission reductions

The results of the total emission reductions computed as the difference between the baseline emissions and the project emissions amounted to around 154,000 tCO$_2$ per annum as presented in Table 2.

Table 2
Total emission reductions from the proposed flare gas recovery project at Suez Oil Processing Company in Egypt.

<table>
<thead>
<tr>
<th>Emission Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Emissions</td>
<td>163,000 tCO$_2$/yr</td>
</tr>
<tr>
<td>Project Emissions</td>
<td>8,800</td>
</tr>
<tr>
<td>Compressor electricity consumption</td>
<td>3,100</td>
</tr>
<tr>
<td>Treatment unit electricity consumption</td>
<td>2,400</td>
</tr>
<tr>
<td>Steam generation for treatment unit</td>
<td>3,300</td>
</tr>
<tr>
<td>Total Emission Reductions</td>
<td>154,200 (circa 154,000)</td>
</tr>
</tbody>
</table>

3.2 Project IRR and sensitivity analysis

Considering CER prices of around USD 10 per tCO$_2$ as recorded in 2010 when the project was considered for implementation under CDM, revenues of around USD 1.5 million could be generated yearly as a result of the emission reductions accrued from the proposed flare gas recovery project.

Based on the results of the economic analysis performed using Egypt’s subsidised natural gas price of 1.5 USD per Million British Thermal Unit (MMBTU), the IRR of the project without considering CDM was found to be 13%, whereas it reached 25% by including revenues from sale of CERs. According to SOPC performance metrics compiled by Arab Capital (2009), the company’s net profit margin and IRR were projected as 19% and 20%, respectively. Therefore, since the project IRR without CDM is less than 20%, it is highly unlikely that senior management will consider it for implementation. To quantify the project’s unfeasibility in the absence of CDM, a sensitivity analysis was performed for variations of investment costs, utilities costs and gas prices. Table 3 outlines the results of the sensitivity analysis on the IRR.

3.3 Social benefits

Regarding the social perspective, the project can create employment opportunities for local engineering and construction companies that will be contracted to design and execute the project. Moreover, as a new application of flare gas recovery in Egypt, the project can serve as an exemplar for the viability of such projects within the O&G industry. Hence, it is foreseen that the project could
be mimicked across all petroleum facilities thereby resulting in further employment opportunities and local capacity building benefits.

Table 3
Sensitivity analysis for the proposed flare gas recovery project where the impact of varying investment costs, utilities costs and gas prices on the project IRR were analysed with and without considering revenues from CDM.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Variation</th>
<th>Without CDM</th>
<th>With CDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment Cost</td>
<td>+10%</td>
<td>11</td>
<td>23</td>
</tr>
<tr>
<td>Utilities Cost</td>
<td></td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Gas Price</td>
<td></td>
<td>16</td>
<td>28</td>
</tr>
<tr>
<td>Investment Cost</td>
<td>-10%</td>
<td>14</td>
<td>28</td>
</tr>
<tr>
<td>Utilities Cost</td>
<td></td>
<td>13</td>
<td>26</td>
</tr>
<tr>
<td>Gas Price</td>
<td></td>
<td>9</td>
<td>23</td>
</tr>
</tbody>
</table>

3.4 Project barriers

Barriers affecting the implementation of SOPC flare gas recovery project as well as the diffusion of flare gas recovery technology in Egypt arise from technological, administrative and common practice issues.

From the technological aspect, the design of flare recovery systems entails several technical challenges due to the following constraints:

a. **Technology not sourced from local suppliers**: Since international suppliers would provide the recovery system’s know-how, SOPC is faced with limited choices for sourcing technology and maintenance services. After installation, SOPC would have to rely solely on the supplier(s) for future repairs and queries concerning operation of the system.

b. **Inadequate internal capability and experience**: Despite SOPC’s long running history and expertise in refinery operations, there is a lack of familiarity with the operation and technology of flare recovery systems amongst the refinery’s operations team.

c. **Safety and operational considerations**: Positive pressure at the compressor suction must be maintained constantly to prevent any air backflow, which would otherwise cause an explosive mixture. Moreover, because the recovery system is an alternative way for safe disposal of waste gas without flaring, it should be regularly maintained to ensure its safe and efficient performance.

d. **Equipment performance vis-à-vis waste gas**: The pressure, composition, and flow rate of the recovered gas is subject to wide fluctuations since it is a by-product of various oil refining processes. This high variability poses a technical challenge in designing the recovery system and exposes refinery personnel to high operational uncertainties. During periods of low waste gas flow, the recovery system will operate below design conditions and its efficiency could be negatively affected. Hence, performance of the recovery system is subject to high risks and uncertainty owing to variability of waste gas conditions.

e. **Power consumption**: By virtue of its compression mechanism, electricity consumption of the liquid ring compressor (if selected within the flare gas recovery system) is constant irrespective of the waste gas flow rate. Such constant power consumption must be considered in the design of the electrical distribution and management system.

In addition to these aspects, export of the recovered gases to other users outside SOPC facilities is currently impeded by high variability of the waste gas composition. Therefore, SOPC will not be able to maintain a constant recovered gas composition to meet the requirements of prospective external buyers. To improve its energy efficiency performance, SOPC could rather use the recovered gas onsite. However, since electricity for SOPC users is sourced from the local grid, there are currently no power generation turbines within the refinery. Thus, it is unlikely for SOPC to use the option of onsite electricity generation using the recovered waste gas.
It is imperative to note that during the concept design of the project, the engineering contractor was asked to obtain preliminary bids for the flare gas recovery system compressor from several compressor vendors. However, due to specificity of the waste gas conditions, only one vendor, Garo, provided a bid. The compressor type proposed by Garo is a liquid ring compressor. A similar case also occurred in Barauni Refinery flare gas recovery project where only the bid provided by Garo was technically acceptable (UNFCCC, 2006b). Such a limited response from the solicited vendors might lead to a sole (single source) bid, which entails additional administrative efforts during bid evaluation and award. Moreover, sourcing of spare parts as well as maintenance services could be time consuming due to limited availability, and subjects SOPC to risks of monopolistic prices.

As highlighted in the La Plata Refinery Project PDD (UNFCCC, 2007) and reiterated by Worrell & Galitsky (2005), the majority of refinery gas flaring projects were implemented in industrialised countries, especially in the United States, and few similar projects have been implemented in developing countries. Accordingly, business-as-usual in oil refineries in Egypt is gas flaring and this clarifies why the SOPC project is not common practice in Egypt.

4. Discussion

From an environmental perspective, SOPC flare gas recovery project could result in a reduction of GHG emissions from the refinery since normal waste gas flaring will be eliminated. In addition, by eliminating the emissions of the flare, the project will soften the impacts of the refinery on the surrounding environment, particularly the Gulf of Suez coastline adjacent to the flare.

On an aggregate level, GHG emission reduction within SOPC also means that the global GHG emissions attributed to gas flaring will also be reduced. In other words, this project fulfils the GGFR partnership’s overarching objective of reducing gas flaring globally. As a steppingstone towards implementation of the zero flaring concept in Egypt, where the gas used for the flare pilot is also recovered, SOPC flare gas recovery project could, in turn, result in additional future GHG emission reductions in Egypt’s O&G industry.

By virtue of reducing gas flaring, the project can enable Egypt to become an active member of the GGFR partnership. As a member, Egypt will gain access to global best practices of the industry and receive support and know-how conducive of expanding applications of flaring reduction projects. If selected for SOPC project, this will mark the first application of the liquid ring compressor type in Egypt’s O&G sector. This exposure will assist in capacity building and enhancing the level of skills within the Egyptian O&G sector. Through transfer of proven flare gas recovery technology and installation of state-of-the-art equipment, the project will modernize the SOPC refinery facilities and enhance its operability. Similar benefits will also accrue across the entire sector because it is expected that this project will be replicated within other refineries.

Notwithstanding the project barriers described in Section 3.3, it is anticipated that registering the project under CDM will enhance its appeal as a major milestone in the O&G industry and provide the project with the impetus needed to overcome these barriers. In addition, the environmental, social, and economic benefits identified previously will all accrue following realization of the project under CDM.

In view of the results of the sensitivity analysis performed, it is evident that the project’s IRR is highly sensitive to the local price of gas since its variation resulted in the most profound changes in IRR values. The GoE’s prevailing highly subsidised energy pricing policy considered in the IRR analysis rendered the project economically unattractive without considering CDM revenues. Nonetheless, in view of the recent trend towards rationing public expenditures by reducing energy subsidies and the decision taken by the GoE in 2012 to import gas to supply the new industrial consumers, the local price of gas is expected to increase from USD 1.5 to at least USD 4 per MMBTU. Such a price, although lower than the expected average import price of USD 10 per MMBTU, will render the flare gas recovery project highly profitable even without any revenues from CDM.
In light of the preceding discussion, the CDM eligibility of the proposed SOPC flare gas recovery project is summarized in Table 4. As outlined in the table, the additionality of the emission reductions expected from the project were asserted in view of economic, technical and regulatory factors pertaining to the state of Egypt’s O&G industry at the time of the analysis. In line with the three pillars of sustainable development, Egypt’s sustainable development criteria are built upon environmental, economic and social aspects. Since the TBL analyses of the project revealed several merits under each of the three aspects, the project fulfils Egypt’s sustainable development criteria. Although not currently a common practice in Egypt’s O&G industry, the flare gas recovery technology is applied worldwide in other refineries. Accordingly, the proposed project is technically feasible and can yield considerable emission reductions. Since the project will potentially be executed within an existing facility, an Environmental Impact Assessment (EIA) will not be required as stipulated by Egypt’s environment Law 4/1994.

As a prerequisite for CDM registration and following the stakeholder consultation performed by the Suez Governorate in 2011, the Letter of No Objection and Letter of Approval were obtained from Egypt’s Designated National Authority and the project was subsequently submitted for validation. As of November 2013, the project passed the validation stage successfully and became registered as Egypt’s first large scale CDM application in the O&G industry and the country’s first refinery flare gas recovery project.

5. Conclusions

Drawing on the results of the CDM analysis, it was concluded that the project promotes sustainable development along the TBL aspects of the environment, society and economics. Accordingly, it fulfils the sustainable development criteria of Egypt (the host country). The project was found to not be a common practice in Egypt’s O&G industry. If implemented as CDM, it was foreseen that the technical, operational and administrative barriers would be overcome. Moreover, annual revenues generated from sale of CERs amounting to USD 1.5 million render the project economically feasible under CDM. From an innovation standpoint, it was emphasized that the project will expose SOPC to state-of-the-art applications in the petroleum industry. Hence, the project can be a major steppingstone towards implementation of zero flaring in Egypt’s O&G industry.

Considering the untenable financial burden of energy subsidies on the GoE budget, local energy prices should be re-assessed. Raising local energy prices, particularly for industrial consumers, will catalyse adoption of energy efficiency/improvement measures, decrease energy consumption, and free more financial resources for the GoE to allocate to other public services (health services, education or public transport).

Accordingly, Suez Oil Processing Company should actively pursue the realization of the flare gas recovery project. The project is fully eligible for CDM and sustainable development benefits will ensue from its realization.

Although Egypt is not yet a member of the GGFR Partnership, it is highly recommended for the country to seek membership of this global initiative to benefit from the experience of member organizations and tap global best practices on flare reduction through recovery. Upon personally inquiring about membership procedures, it was advised that members have to endorse the GGFR charter and the Voluntary Standard for Global Gas Flaring and Venting Reduction in addition to committing to provide data and resources including annual gas flaring volumes. Egypt’s fulfilment of these requirements is deemed to be feasible.
Table 4
CDM eligibility criteria for the proposed flare gas recovery project at Suez Oil Processing Company in Egypt.

<table>
<thead>
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<th>Criteria</th>
<th>Justification</th>
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| Additionality of Emission Reductions (ERs)                              | • Economic:  
  o Project IRR is less than Suez Oil Processing Company profit margin and IRR.  
  • Technical:  
  o Flared gas is sour and wet and requires further processing to render it useful; thus few alternative outlets exist for gas use;  
  o Proposed recovery compressor type (liquid ring) is unprecedented in the Egyptian Oil & Gas industry;  
  • Regulation / Market:  
  o There are no government targets for elimination of normal gas flaring;  
  o Egypt is not currently a member of the GGFR partnership;  
  o Absence of environmental or market regulations to incentivize reduction or prevention of gas flaring;  
  o Prospect of sole bidding of compressor limits appeal of implementation.  |
| Promotes Sustainable Development                                        | • Environmental:  
  o Reduces GHG emissions;  
  o Contributes positively towards GGFR goals of reducing flaring worldwide.  
  • Economic:  
  o Reduces on-site fuel consumption; thus volume of fuel gas replaced could be exported at international prices to generate more revenues;  
  o Expands energy supply at Suez Oil Processing Company;  
  o Modernizes production facilities at Suez Oil Processing Company by installation of state-of-the-art equipment;  
  o Contributes in technology and skills transfer to enhance capacity within the Egyptian petroleum sector.  
  • Social:  
  o Project will deploy local contractors for engineering and construction services, thus it will create opportunities for direct and indirect employment;  
  o Project can be an exemplar to demonstrate applicability of flare gas recovery; therefore, it can trigger similar installation at other facilities;  
  o It can enable Egypt to become an active member of the GGFR partnership;  
  o It could be a step towards implementing zero normal flaring at Egypt.  |
| Technical Feasibility                                                   | • Gas treatment technologies are proven, low risk and manageable;  
  • Liquid ring compression technology has been proven globally albeit not yet in Egypt.  |
| Measurable Emission Reductions (ERs)                                    | • Emission reductions from direct elimination of gas flaring are measured by the volume of gas recovered & compressed for further use as fuel gas.  |
| Environmental Impact Assessments (EIA)                                 | • Not required since the project is within the boundaries of the existing refinery.  |
| Stakeholders’ Comments                                                 | • Stakeholder consultation was conducted within Suez governorate in 2011.  |
| Host Country Approval                                                  | • Letter of No Objection and Letter of Approval obtained from Egypt’s Designated National Authority.  |
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Captions

Fig. 1. Simplified block flow diagram showing the existing and proposed new facilities associated with the flare gas recovery project at Suez Oil Processing Company in Egypt.
• Gas flaring is a major source of anthropogenic greenhouse gas emissions within the oil and gas industry.
• Flare gas recovery is a viable technology to recover the flared gas and utilize the energy content of the gas; however, this technology is not common practice in Egypt’s oil and gas facilities.
• The Clean Development Mechanism can facilitate implementation of flare gas recovery in Egypt’s refineries.
• The Government of Egypt should change its current energy subsidy and energy pricing approach in order to catalyze adoption of energy efficiency/improvement measures and decrease energy consumption.