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Combination of renewable energy in the refinery, with carbon emissions approach

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ABSTRACT

With increasing global energy demand and lower energy efficiency for inverted energy (EROEI) for crude oil, global energy consumption by the O&G industry has increased dramatically in recent years. Moreover, this increased energy has led to an increase in greenhouse gas emissions, which has had negative environmental impacts. On the other hand, generating electricity through renewable resources has become a relatively competitive cost for fossil energy sources in a "cleaner" way. In this study, renewable energy is optimally combined into the refinery, taking into account costs and carbon dioxide emissions. Using Aspen HYSYS, a refinery in the Middle East was stimulated to estimate energy demand by different processing units. The L.P. problem is formulated based on the existing solar energy systems and wind potential in the region. The multipurpose function, which reduces cost and CO_2 emissions, was resolved using GAMS to determine the optimum energy distribution from each power source to units inside the refinery. Besides, an economic feasibility study was conducted to determine the feasibility of implementing a renewable energy technology project to bypass the refinery's energy requirements. Electricity generation through all renewable energy sources considered (i.e., solar P.V., CSP, and wind) was considered feasible based on the low cost of electricity (LCOE). The payback period for the CSP project, which has an annual capacity of about 411 GWh and a useful life of 30 years, was ten years. In contrast, the solar P.V. and wind recovery periods were calculated at 7 and 6 years, respectively. This opens up possibilities for incorporating renewable energy into the refining sector, as well as for improving multiple energy transmission systems in the crude oil industry.

Keywords: *Oil refinery; green oil; Combined Renewable and Oil Refinery Process; CRORP; Carbon emission; Levelized cost analysis*

1. INTRODUCTION

Renewable energy is defined as "energy generated from natural resources that can be naturally replenished in the environment" through sustainable energy resources. These resources include hydroelectric, wind, biomass, geothermal, and solar energy [1]. The depletion of fossil fuel reserves has caused increased demand and prices for petroleum vehicles. Fossil fuels account for 88% of total primary energy consumption with oil (35%), coal (29%), and natural gas (24%) as the primary fuel [2]. Besides, 28% of the world's primary energy is consumed in the transportation sector. Moreover, the demand for transportation fuel is expected to increase by up to 40% by 2040 [3, 4]. However, the truth is that fossil fuels are scarce, non-renewable energy resources [5].

In general, the production of oil yields enormous amounts of energy. Oil refining is one of the most complex processes in the oil and gas industry. It includes many unit operations and subsidiary facilities. Most of the refineries are different from each other and have a unique composition and arrangement of units. It is energy-intensive due to its high production capacity. The capacity of modern oil refineries generally ranges from 800,000 to 900,000 barrels of crude oil per day [6, 7]. Since the mid-twentieth century, petroleum products have become a dominant source of energy, surpassing the demand for coal. The current scenario focuses on addressing future challenges to meet energy demand worldwide in developed countries. Renewable energy resources have been used in research to overcome this problem in the past decades. It plays an essential role in the production of "clean" energy that reduces greenhouse gas emissions, especially carbon dioxide, compared to fossil fuels. This study aims to determine the feasibility of optimal integration of renewable energy in a refinery in the Middle East. Accurately, a filter simulates to determine the energy demand of various units within the environment. Also, developing a model to find the optimum energy distribution. Finally, check the economic viability of such integration.

2. MATERIALS AND METHODS

2.1. Method selection.

2.1.1. Net present value method.

This index is one of the reduction indicators of project value, and to evaluate a project by its net present value method, all revenues and expenses must first be converted to present value. From the difference between income and expenses, the net present value of benefits must be obtained. If the NPV is less than zero, the project is uneconomical, but if the NPV is positive, it is an economic project, which means that the current value of the costs is less than the current value of the revenue.

$$NPV(i,N) = \sum_{i=0}^{N} \frac{R_t}{(1+i)^t} \qquad (1)$$

t: cash flow period i: interest rate Rt: net cash flow

2.1.2. Internal rate of return method.

It is the rate at which the net present value of the project is zero. In order to calculate this rate, the above relation is set to zero. The rate (number i) obtained from solving this equation is, in fact, the internal rate of return of the project.

2.1.3. Levelized Cost Method (Annual Equal Cost).

In the equilibrium cost method, a similar approach to the current value method is used. In this way, costs are converted into regular annual payments. In other words, the aligned cost is a fixed amount of revenue per unit of product that can cover all project costs over a lifetime of service.

2.1.4. Comparison of methods and selection of final method.

Internal rate of return method and current value method only examine the profitability of projects and increase the value of the initial investment. While from the government's point of view, investment is generally made in projects that have a lower cost. In other words, for the government, a power plant in which the cost of producing an electric unit is lower is a priority. As a result, indicators such as profitability and net present investment value are the next indicators for evaluation.

Explaining this, it can be added that the internal rate of return method is used in financial analysis and decision making to enter or not to invest in the project and does not talk about the cost so that this method returns the rate at which the investor is willing to invest. It is in the project, it determines. Since the purpose of this research is to obtain the total cost of power plant power from the government's point of view, it is not appropriate to use the internal rate of return method to address this issue. Also, in the current value model, joint life should be considered for projects to compare projects. Due to the variable lifespan of gas and wind power plants, therefore, economic evaluation of the cost of electricity of these power plants that have different life cycles, it is not appropriate to use this method. Therefore we ignore it, so considering these conditions, the method The aligned cost is used as the method used in the economic analysis of power plant projects.

In this method, project costs are calculated using annual costs during the life cycle of the power plant and include initial costs (design, certification, installation), operating costs, maintenance costs, and external costs. The discount rate is usually used to calculate the current value of the expenses, which is expressed as a percentage and annually.

Costs are divided into two parts: electricity generation costs and costs imposed on society during electricity generation. Variables in electricity generation costs include initial investment, maintenance costs, and fuel costs. Because maintenance costs and fuel costs increase with inflation and fuel prices, respectively, growth rates can be included in the calculations. Maintenance costs fall into two categories: fixed and variable.

In the second part, as an example, the equalized cost of electricity production is the cost imposed on society, which includes the costs of external effects of electricity production. For example, the cost of damage caused by the emission of pollutants by fossil fuel power plants has a significant effect on the equalized cost of generating electricity for these power plants but does not affect the cost of generating electricity for wind power plants. Considering these factors, the final equation for the cost of generating electricity can be written as follows.

$$LCOE = C_k + [\sum_{t=0}^{PL} \frac{C_{O\&M}\cdot(1+e_{O\&M})^t}{(1+r)^t} + \sum_{t=0}^{PL} \frac{C_{fuel}\cdot(1+e_{fuel})^t}{(1+r)^t}] \cdot \frac{r(1+r)^{PL}}{(1+r)^{PL-1}} + C_{EC} \qquad (2)$$

In this regard, CEc represents the costs imposed on society (external impact costs) by polluting gases such as CO_2, SO_2, and NOx. The EF pollution factor indicates the amount of pollution per unit of fuel energy consumed. HR is the thermal rate of power plants, and VED indicates the value of the rate of environmental degradation. EF and HR are real values that can be calculated, while VEDs can be calculated by directly estimating costs or reducing costs or combining them. VED is an essential parameter for analyzing regulatory rules, but it is usually difficult to calculate. The cost of external effects in the generated power unit using these factors and their inclusion in the LCOE formula is calculated directly. As can be seen in the above relationships, LCOE can be defined based on the total cost of capital, the cost of maintenance, the cost of fuel, and the cost of external effects. Since LCOE is the measure of electricity generation in a plant's life cycle, all costs must be included in the final cost calculation. Z

To calculate these parameters, information such as power plant operating parameters, power plant construction and implementation costs, energy market parameters, and macroeconomic parameters are required. Table 3 presents the list of variables used in the above equation.

2.2. Model development.

The superstructure, which describes the available energy resources, as well as the energy required by each unit, is designed within the refinery, as shown in Figure 1. These energy sources are limited due to their availability within the Middle East region. Moreover, it is assumed that the electricity supplied through the grid is produced by natural gas.

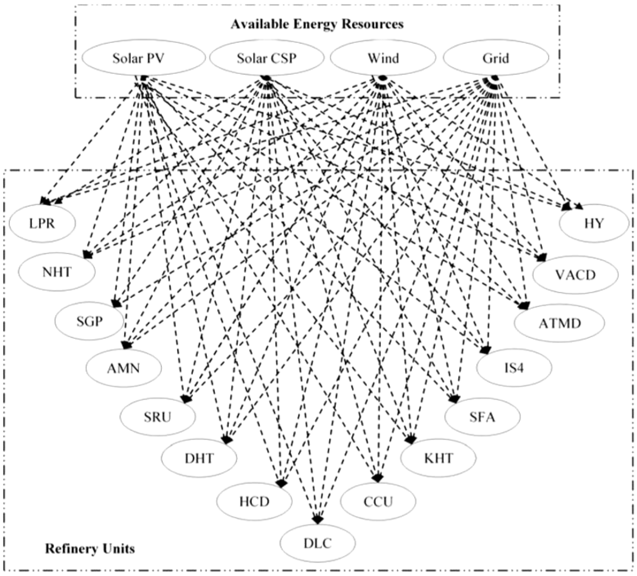

Figure 1. Superstructure diagram for the crude oil refinery units connected with all available energy resources [1].

Each filtered unit was simulated in Aspen HYSYS, and the required amount of energy was determined for each unit. Besides, the literature was surveyed to find the carbon emissions produced by each unit. Table 1 shows data on energy demand and carbon dioxide emissions, obtained from these two sources (see table 1).

Table 1. The energy required per unit and carbon dioxide emissions per unit of the refinery.

Refinery unit	Abbreviation	MJ/year	g CO_2/ MJ
Hydrogen plant	HYD	3.38 x10^7	0.362
Sulfur Recovery Unit	SRU	2.42 x10^8	0.056
Amine plant	AMN	2.53 x10^7	0.056
Saturated Gas Plant	SGP	1.00 x10^8	0.168
Naphtha Hydrotreater	NHT	1.63 x10^7	0.187
Reformer	LPR	1.34 x10^8	0.998
Kerosene Hydrotreater	KHT	7.07 x10^6	0.187
Diesel Hydrotreater	DHT	8.50 x10^6	0.187
Hydrocracker	HCD	1.80 x10^8	0.561

Refinery unit	Abbreviation	MJ/year	g CO_2/ MJ
Delayed Coker	DLC	3.31×10^7	0.312
Catalytic Cracking	CCU	3.29×10^8	0.686
Sulfur Acid Alkylation	SFA	2.35×10^8	0.000
C4 Isomerization	IS4	2.20×10^7	0.062
Unsaturated Gas Plant	UGP	1.11×10^8	0.168
Atmospheric Distillation	ATMD	2.06×10^5	1.684
Vacuum Distillation	VACD	4.01×10^6	0.561

Table 2 shows the available and potential energy sources in the region with carbon dioxide emissions due to electricity generation and Levelized Electricity Cost (LCOE) [8-10]. It is noted that the most significant amount of carbon dioxide emissions were produced from the grid's energy source (that is, natural gas) compared to other renewable energy sources (see table 2).

Table 2. Potential energy sources in Abu Dhabi with CO_2 emissions due to electricity generation and the Levelized Cost of electricity.

Source(MJ/year)	g_{CO2}/MJ	LCOE $/kWh	Capacity
Solar CSP	9.2	0.18	7.6×10^8
Solar PV	36.8	0.27	6.3×10^7
Wind	2.2	0.07-0.13	7.2×10^6
Grid	119.04	0.05-0.07	3.7×10^{11}

The following assumptions were made during model development:

- Feed 100 million barrels of crude oil per day of crude oil.
- The cost of electricity generated from each source is independent of the unit that is consumed.
- Energy Intermittent energy is stored and is therefore available for use throughout the year.

The eps (epsilon) restriction method was used when the energy cost was determined as an objective function, and the amount of carbon dioxide emissions was raised as restrictions. Therefore, the mathematical expression of this problem statement is to minimize the cost (objective function), taking into account the constraints of inequality and equality evidenced by the constraints on energy supply and demand, and the number of emissions, respectively. It is generally written as the following linear programming problem (LP):

$$\min z = \sum_{p=1}^{6} \sum_{d=1}^{16} lco_{p,d} x_{p,d} \quad (3)$$

subject to

$$\sum_{p=1}^{6} x_{p,d} - b(d) \geq 0 \quad (4)$$

$$(1-\alpha) 7.92 * 10^7 \leq g \leq \alpha (5.44 * 10^8) \quad \alpha \epsilon [0,1] \quad (5)$$

$$\sum_{d=1}^{16} x_{p,d} - a(p) \leq 0 \quad (6)$$

$$g = \sum_{p=1}^{6} \sum_{d=1}^{16} ghg_{p,d} x_{p,d} \quad (7)$$

where:

- z total cost of producing electricity
- x(p,d) energy from an energy supplier to energy demand
- p energy supplier (i.e., solar CSP, solar PV, grid, and wind)
- d energy demand (i.e., refinery units)
- a(p) production capacity of energy supplier (MJ / year)
- b(d) energy demand by each unit in the refinery (MJ)
- ghg(p,d) carbon dioxide emission by each energy supplier (CO_2 g / MJ)
- lcoe(p,d) cost of energy production (USD / MJ)
- α weight varying between 0 and 1

3. RESULTS

The results obtained from the simulation filter unit are displayed, in addition to improving the developed model. Carbon dioxide emissions were raised as a limitation of a specific weight, α, from 0 to 1. The value α = 0 means the focus on reducing carbon dioxide emissions regardless of cost. Conversely, the value of α = 1 means focusing on reducing costs without taking into account CO_2 emissions. Figure 2 illustrates changes in cost and carbon dioxide emissions, where alpha varies between 0 and 1. The cost is minimal when emissions are maximum, and vice versa.

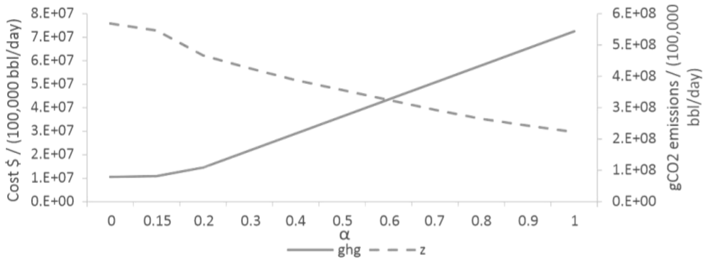

Figure 2. Cost and CO_2 emissions concerning alpha

Additionally, a Pareto interface was created, based on the results obtained from the developed model, as shown in Figure 3. The Pareto curve shows this optimal cost corresponding to the CO_2 emissions from the refinery when renewable energy is optimally combined.

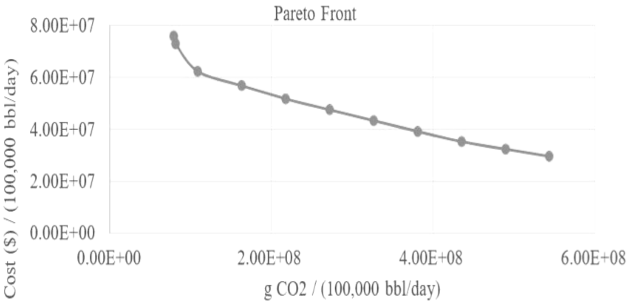

Figure 3. Cost and optimum carbon dioxide emissions

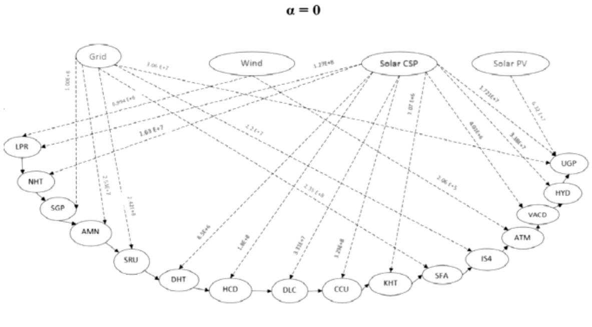

Figure 4. The optimum power distribution of the filter units at α = 0.

Moreover, Figures 4 and 5 show the energy distribution between the energy sources and the filter units in α equal to 0 and 1, respectively:

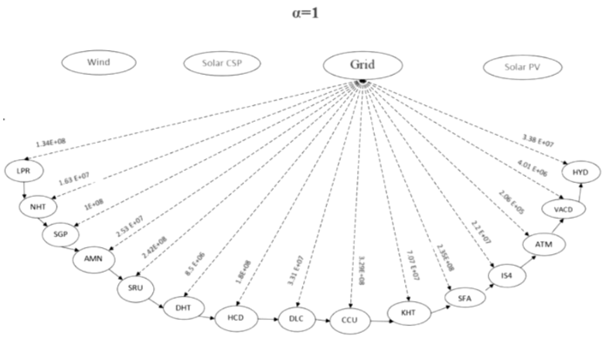

Figure 5. The optimum power distribution of filter units at α = 1

The economic feasibility has been examined to integrate the renewable energy sources in the Abu Dhabi refinery. Photovoltaic, concentrated solar, and wind energy sources are studied for high and calculated electricity costs (LCOE). However, LCOEs are dynamically rated for power generation using the following mathematical formulas [11]:

$$CRF = \frac{D(1+D)^N}{(1+D)^N - 1} \qquad (8)$$

$$LCOE = \frac{capital\ Cost * CRF * (1 - TD_{pv})}{8760 * Capacity\ factor * (1-T)} + \frac{fixed\ O\&M}{8760 * Capacity\ factor} + \frac{Variable\ O\&M}{1000 * \frac{kw}{mw}} \qquad (9)$$

where

- Capital cost: cost of plant
- CRF: capital recovery factor
- T: tax rate paid
- DPV: present value of depreciation
- 8760: number of hours in a year
- Capacity factor: yearly average percentage of power as a fraction of total capacity
- Fixed O&M: fixed operating, and maintenance cost
- Variable O&M: variable operating and maintenance cost

As shown in Table 3, all renewables are economically viable at a lower LCOE cost, with winds being more sustainable and having less concentrated solar power.

The sensitivity analysis was performed, in concentrated solar energy, to determine how critical parameters affect the recovery period and the LCOE with changes in capital cost and capacity. Other renewable technologies yielded similar results.

Therefore, it is not presented in this document. As can be seen from the above table (see Table 4), the higher the cost of capital, the more direct operating costs, and the payback period. Moreover, since the projected useful life of each project is 30 years, the possible cost of capital is 3000. On the other hand, with the power factor increases, the LCOE is significantly reduced.

Therefore, it indicates that technical improvements can help reduce LCOE significantly.

Table 3. Calculated economic and environmental parameters for available renewable energy resources at different LCOE.

Source	Solar PV(low)	Solar PV(high)	Solar CSP(low)	Solar CSP(high)	Wind(low)	Wind (high)	unit
LCOE	0.0475	0.532	0.038	0.2185	0.038	0.114	-
Carbon credit value w/renewable	8.246	8.246	8.246	8.246	8.246	8.246	\$/ton fo CO_2
CO_2 emission w/grid	516.249	516.249	516.249	516.249	516.249	516.249	tons
CO_2 w/source	159.0775	159.0775	159.0775	159.0775	159.0775	159.0775	tons
Total Capital cost	66.975	372.4	81.7	491.15	53.58	177.65	\$MM
Daily capacity	44.65	44.65	44.65	44.65	44.65	44.65	MWh
Total fixed Cost	0.33725	4.94	2.2135	5.13	0.4579	2.679	\$MM
Fixed cost per year	11.21	163.59	73.625	171	15.295	89.3	\$M
Price per kWh in Abu Dhabi Industrial	0.038	0.038	0.038	0.038	0.038	0.038	\$
Annual Cost of 17564 MWh Grid Electricity	15.675	15.675	15.675	15.675	15.675	15.675	\$MM
Total Amortized Payments	161.5	900.6	196.65	1186.55	129.2	431.3	\$MM
Total savings per year	15.675	15.485	15.58	15.485	15.58	15.58	-
Payback period	7	83	10	77	6	40	year
lifetime	30	30	30	30	30	30	year

Table 4. Sensitivity analysis of the capital cost and power factor in the LCOE and payback period.

Capital Cost	LCOE	Payback period(year)	Capacity factor	LCOE
1738.5	0.038	10	24.035	0.2755
1900	0.076	11	28.5	0.228
2850	0.095	29	38	0.171
3800	0.1235	40	47.5	0.1425
4750	0.1425	50	57	0.114
5700	0.171	59	66.5	0.1045
6650	0.1995	69	76	0.0855
7600	0.2185	79		
8550	0.247	89		
9500	0.2755	99		
10450	0.2945	100.8		

4. DISCUSSION

4.1. Policy frameworks.

The first key step in any energy improvement initiative is to create a strategic and centralized energy management program that helps identify and implement energy efficiency criteria, organize across methods, and ensure continuous improvement [20, 21]. In steam supply units of a petrochemical complex, the production of additional steam can be reduced by process integration and improved steam flow management[22, 23]. Replacing the normal investment cycle may provide opportunities to switch to higher-efficiency steam systems. When designing new steam distribution systems, it is important to consider speed and pressure drop[8]. This reduces the risk of increasing the size of the steam pipe, which is not only an economic issue but also leads to a further drop in temperature[9]. A tiny tube may cause more corrosion and pressure drop. Steam installations and demand do not change over time, which may lead to incomplete use of steam distribution capacity and higher heat loss[24]. However, optimizing the system for the demand for altered steam is very costly[25]. Examining or blocking additional distribution lines is still an affordable way to reduce steam distribution losses. For all the energy efficiency criteria in this study, factories need to do more research in economics as well as the application of different techniques to their unique production methods to evaluate the feasibility of implementing these measures[26, 27]. The road can be expensive and inefficient, in the nine end-of-pipeline solutions, while energy saving can be a cheap opportunity to reduce the rules and spread other pollutants[28]. For example, heat from furnace exhaust gases can be used as heat) for Quench boilers wasted in waste heaters (steam production or operations that require lower heat, which is part of the total factory and optimal heat demand). Manufacturing is thermal energy. Proper monitoring, proper installation, and proper maintenance of pumps and compressors can increase the profitability and reduce the costs of petrochemical industries[11]. For example, in some units of chemical industries, 20% of The initial price, 80% of power consumption, and 40% of repair costs are related to pumps and compressors. Low pump efficiency not only increases maintenance problems but can also increase energy consumption, increase parts consumption, and costs. On the other hand, by optimizing the energy consumption of the pump and compressor and proper operation. Moreover, it makes perfect sense, both in terms of initial costs and current costs (energy consumption, maintenance costs, production line stopping costs), while the expected savings in communication are Some may be small, but unique actions may have a relatively collective effect[14].

These actions can potentially affect the entire plant. The vessel. Some of the measures in question are short-lived, and as a result, have relatively attractive, relatively economical repayment capital based on merit. Continuous assessment of these measures will help identify more cost savings in ongoing energy management programs[15, 17].

4.2. Suggestions.

For public and private companies alike, rising energy prices are driving up costs and devaluing value-added. Fortunately, investing inefficient energy technologies and how to meet the challenges of low production costs is cost-effective considering maintaining the quality of output products. Efficient energy technologies often generate surplus benefits, such as increasing company output and reducing greenhouse gas emissions, so it is imperative[29].

In different sections of this study, we will look at solutions, energy-efficient furnaces for steam systems and process heaters, distillation towers, and pumps and compressors in petrochemical industries, which have the bulk of energy consumption. The following is a description of these systems[9, 30]. Steam is used throughout the chemical industry. About 73% of all energy consumption in the chemical industry in the United States in 1998 was in the form of steam. Steam can be generated by steam boilers, energy loss from processes, and simultaneous production of electricity[31]. If it is not possible to reduce the steam production pressure, then it may be possible to recover energy through an expansion or steam turbine. In some systems, where turbo steam is produced at higher pressures, it is allowed to operate efficiently by simultaneously generating electricity and in heat-return turbines [2, 32]. Steam, like any other secondary energy carrier, is expensive to produce and supply. The use of steam must be carefully evaluated and examined. Vapor is often produced at pressures higher than required or at volumes greater than required at a given time. These inefficiencies may result in steam systems being reduced to lower pressures or even atmospheres. Therefore, it is strongly recommended that the steam system be evaluated using appropriate pressure levels and production schedules [3, 33]. Steam is used for a wide range of purposes and, most importantly, process heating, such as drying, condensing, steam cracking, and distillation, although the use of a steam source, improving steam efficiency, distribution, and ultimate function, It is also possible. A recent study by the US Department of Energy estimated that the overall potential for energy savings in the chemical industry is 21.4% by the steam generators used to produce steam [1, 34]. It is essential to take a systematic approach to evaluate steam systems, where and how steam is identified. In this paper, we focus on the energy consumption of steam production in steam boilers (including headers on the heat in them) and the distribution of steam. About 30% of the fuel used in the petrochemical industry is used by furnaces and thermal heaters. The average thermal efficiency of furnaces is estimated at 75 to 90%. Because heat loss is inevitable, but considering the dew point, the maximum efficiency of the furnace theory reaches 92%. This indicates that the average savings are about 10%, which can be achieved in the furnace, torch design, and operation. In the following sections, various opportunities for efficiency improvement, including improving heat transfer properties, increasing radiation and flame, optimal installation control, are discussed. Designing new burners to improve fuel and air mixing is one of the most effective goals in improving heat transfer[9, 12].

On the other hand, the design of burners and furnaces is fundamental to address environmental concerns [4, 34]. In the petrochemical industry, distillation is an essential separation process. In distillation, the products are separated based on the difference in their boiling point. The first input feed is divided into two parts: a condensed vapor that is rich in more volatile components and another part of the remaining liquid that contains the other components. Distillation can be done according to operating conditions (discontinuous or continuous), operating pressure (vacuum, atmosphere, and high pressure), several equilibrium steps, use of inert gases, and use of additional compounds to help separate, under the branches Divided differently [5, 15]. Heat or energy is provided by processor steam heaters. While process integration is a crucial parameter, the issue of energy efficiency in heating and using optimization of the distillation tower is also essential. About 26 percent of the total electricity consumed in the petrochemical industry is spent on engines, almost 16 percent of the total electricity in the chemical industry. However, air compression pumps and systems can be considered one of the largest consumers of electricity in the chemical industry. Pumps are used in all industries to generate fluid pressure and displacement [17].

Studies have shown that in manufacturing industries, an average of 20% of the energy consumed by these systems can be shared equally between equipment or control system changes, which almost reduces the speed or controllability of hegemony and other system efficiency measures saved. Air compression systems consume 28% of the engine's energy consumption and 18% of the total electricity consumption in the chemical industry. Air is probably the most expensive compressed energy in an industrial unit due to reduced productivity. Typically, the efficiency of air compression systems from the beginning to the end is about 10% [18, 20].

It should be noted that the initial cost of a pump system. Only a fraction of the recurring costs of energy costs and sometimes operating and maintenance costs are beneficial in the lifetime costs of a system. In general, for a pump system with a lifespan of 20 years, 2.5% of the total cost of the initial capital of the pump and motor is just the cost. Depending on the type of pump used, energy costs may account for about 95% of a pump's lifespan. Therefore, the initial choice of a pump system should be dependent on energy cost considerations rather than initial costs. In optimizing the design of a pumping system, the focus should be on improving return costs [22, 27].

However, for future work, the following areas must be combined in the scope:

- energy hubs and centers; electricity is only considered through the network and renewable sources. A network of multiple energy centers can be developed that have an additional energy contribution, such as on-site natural gas generators, thermal currents, etc[29].
- The intermittent nature of renewable energy; the average annual potential of renewable sources such as solar and wind energy has been considered. A more detailed study can be undertaken that takes into account daily, monthly, or seasonal changes in these energy sources and determines the optimum conditions for work[30].
- Storage systems may be considered in future work to improve reliability in integrating renewable energy systems with existing energy systems [33].

5. CONCLUSIONS

In this study, a model was developed to determine the optimal production planning for an oil refinery while reducing greenhouse gas emissions. The model includes daily production, supply, and demand for energy, supply, and demand for each product, as well as a restriction of carbon dioxide. An oil refinery is simulated with a range of different processing units using Aspen HYSYS with the ability to refine 100,000 barrels of crude oil mixture that is refined daily. From this filter, energy consumption per unit is estimated. Besides, the superstructure is designed to display units inside the refinery connected to available power sources that can meet energy demand. Besides, the CO_2 emissions per unit inside the refinery and the cost of the available energy sources were estimated. Moreover, the developed model was used to determine the optimum energy distribution to the different units within the refinery using GAM, which was then expressed using the Pareto curve. This curve shows the optimal cost for a power supply against CO_2 emissions from various sources. Finally, economic feasibility studies and sensitivity analyzes were conducted in this work for integrated renewable energy sources in Abu Dhabi based on various factors. According to this study, it is possible to incorporate renewable energy into the refinery.

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