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Renewable Energy and Sustainable Development (RESD) is a biannual international peer-reviewed journal, which presents a global forum for dissemination of research articles, case studies and reviews focusing on all aspects of renewable energy and its role in sustainable development. The topics of focal interest to RESD include, but are not limited to, all aspects of wind energy, wave/tidal energy, solar energy, as well as energy from biomass and biofuel. The integration of renewable energy technologies in electrical power networks and smart grids is another topic of interest to RESD. Experimental, computational and theoretical studies are all welcomed to RESD.

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Overall process for publishing a paper will be taken approximately 4 months after initial submission. Reviewing process will take about 2 months, and then publishing process will not exceed 2 months.

1. Initial manuscript evaluation

The Editor first evaluates all manuscripts. It is rare, but it is entirely feasible for an exceptional manuscript to be accepted at this stage. Those rejected at this stage are insufficiently original, have serious scientific flaws, have poor grammar or English language, or are outside the aims and scope of the journal. Those that meet the minimum criteria are passed on to at least 2 experts for review.

Authors of manuscripts rejected at this stage will normally be informed within 2 to 3 weeks of receipt.

2. Type of Peer Review

This journal employs single blind reviewing, the author identity is disclosed to the referee, while the referee remains anonymous throughout the process.

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Referees are asked to evaluate whether the manuscript support followings key points related to scientific content, quality and presentation:

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Energy Consumption and Transportation in Developing Countries: Need for Local Scenario-Based Energy Efficiency Plans

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Like several other sub-topics of urban planning and mobility research, research on the impacts of (urban) transportation on energy consumption is mainly based on the outcomes of studies on high-income and often Western countries. Developing countries and emerging markets have a smaller share of the international research on the topic, while policymaking based on local empirical research, they could cut a percentage of unnecessary energy overuse. The benefits of policymaking based on empirical transportation / energy research do not remain limited to energy efficiency; it also has positive effects on environmental pollution control. Moreover, transportation [1] and urban planning [2,3,4] policies can limit both energy use and air pollution, however such efficiency improvements may be most effective when they are derived from the vernacular conditions. This is important because the energy consumption of the transportation sector is rapidly increasing. In a country as populated and large as China, the oil consumed by transportation corresponded to 49.6% of oil use in the whole country in 2006 [5], while the results of a study undertaken only four years later shows that 60.1% of the Chinese petroleum end-use is caused by transportation [6]. Out of the large part of overall energy use share caused by transportation sector, private cars are important users. In Mexico, private vehicles account for 31% of transport energy consumption [7]. The Chinese energy consumption and CO_2 emission conditions need further improvements in the transportation sector [8].

The conditions are the same in several other comparable countries. Even though studies on developing countries and emerging markets are not comparable to those of high-income countries, still a few studies have been conducted on the relations between urban transportation and energy consumption in these geographical contexts. For instance, it has been shown that renewable energy use Granger-cause energy consumption in road transportation in Malaysia [9]. There is a unidirectional causality from transport infrastructure to energy consumption in India [10]. Furthermore, there is a bi-directional causality between transport energy consumption, FDI and CO_2 emissions in Thailand and Malaysia [11]. Nevertheless, a causal relationship between transport energy use and all environmental emissions has not been found, e.g. in Pakistan no evidence for the role of transport energy consumption on CO_2 emission has been recognized [12].

In many developing countries, fast urbanization is related to transportation energy use. The reason lies in the close relationship between urbanization and urban sprawl on the one hand and motorization rate and traffic generation on the other hand. Although many years ago it has been observed in several international cities that urban densities are positively correlated with transport energy consumption [13,14], it has also been shown that this relation exists only on the urban level. On a regional level, this relation is weak, as it has been shown in certain regions of Iran [15]. In Tunisia, vehicle fuel intensity, vehicle intensity, GDP per capita, urbanized kilometers and national road network were the main causes of transport energy consumption between 1990 and 2006 [16]. In China, the road transportation energy consumption rises by 1.26 percentage points for every percent increase in urbanization [17], hence changing urban morphology can theoretically result in different urban transport energy consumption [18]. The association of urbanization and energy consumption is unsurprising, as urban growth and development is an essential attribute of economic growth. A recent empirical study on the countries of the Middle East and North Africa (MENA) countries confirms the existence of associations of transport energy consumption and transport infrastructure with economic growth [19].

The overall conclusion of this editorial note is that although the number of recent studies on the connections of transportation and energy use in developing countries and emerging markets may look considerable, it is still not consistent and comprehensive because the mentioned studies are only considerable in number when they are accounted as a whole, as well as being focused generally on a very large geographical and cultural context. However, when investigating the smaller-scale correlation between transportation and energy use, it becomes clear that the number of reliable empirical studies in each country do not provide consistent and usable results for policymaking. The example of such studies have been produced for example on India, the results of which shows that “if rail could capture 50% modal share in the years 2005–2006 and 2020–2021, it would save nearly 35% energy consumption and emissions compared to the situation when existing patterns of modal split are allowed to continue without policy intervention.” [20]. In the example above, policymakers have received recommendations for controlling energy use and emissions based on scenario planning using the data and conditions of the local context, but the number of such studies are not enough for a population of 1.35 billion inhabitants accommodated in a wide cultural and geographical diversity. Another example of energy consumption reduction strategies based on urban transportation local scenario planning, which many developing countries need, has been done on Beijing, the results of which necessitates development of public transport in order to gain energy savings and emission reductions [21]. Finally, the third example is on Greater Cairo, where impact assessment was undertaken applying the energy efficiency and greenhouse gases reduction scenario with the assumption of “metro did not exist” for the time period of 1987-2001. In conclusion, still much more research is needed to facilitate policymaking in countries listed as developing countries and emerging markets based on local data, analyses, and scenario planning.

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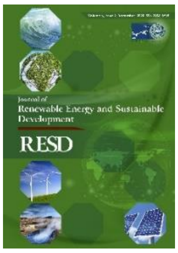

Biokerosene Analysis from the Latex Distillation as an Alternative Solution to National Energy Crisis

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Abstract **-** The energy crisis is ready to whack, according to the fact that about 66% of the earth's fuel comes from fossils. The urgency for alternative fuels discovery is increasing, one of such these fuels is being natural rubber latex. This material has a potential as an alternative fuel because of its high hydrocarbon content. This study was to determine rubber latex activity as biokerosene. In this study, the distillation of fresh natural rubber latex was performed and the process produces an average of 0.196 L of distillate per 0.5 kg of latex. The distillate was separated to obtain pure biokerosene. Latex biokerosene analysis shows yellow color, strong odor, nonpolar properties, flammability, yellow flame color and black smoke, 873.9 kg/m^3 density, Rf=0.641 (4% methanol as mobile phase) *and* Rf=0.883 (N-hexane and acetone as mobile phase) of the thin layer chromatography. It can be concluded that latex has the potential as a biokerosene and can be an alternative solution against the national energy crisis.

Keywords **-** Latex, Biokerosene, Energy Crisis.

I. INTRODUCTION

Every aspect of life requires the energy provided by fuel. Unfortunately, in many parts of the world, including Indonesia, the condition of the energy crisis is becoming a protracted issue. Based on the calculation from Indonesian Energy Outlook, Indonesia's oil reserves in 2014 is about 3.6 billion barrels and it is expected to be exhausted by 2026 [1]. That phenomenon is based on many factors such as population and economic growth [2]. The energy crisis is also related to the fact that around 66% of the world's energy consumption in 2014 comes from non-renewable fossil fuels [3]. Attempts to overcome this energy crisis are crucial to preventing future downturns. One of the efforts exerted is to use material from nature such as latex as one kind of alternative energy that can be used as fuel to provide better productivity and decrease pollutants.

Latex potential as an alternative fuel is based on high rubber hydrocarbon content that reaches 30-40% [4], which has not been harnessed optimally. The hydrocarbon potential of rubber latex can be an alternative solution to help prevent the energy crisis. The potential of this renewable energy is based on a relatively short harvesting preparation period compared with its quite long harvesting period (five years of preparation and up to 35 years of harvesting period, though Food and Agriculture Organization recommended that the harvesting period be up to 28 years) [5], [6]. In addition to its long harvesting period, rubber latex tapping can be done very frequently, ranging from twice a day to every four days depending on the season, soil (geographic area), and tree age [7].

South Sumatera Province, especially Banyuasin Regency, is one of the largest rubber-producing areas in Indonesia, evidenced by the statistics in 2015 from the South Sumatra Forestry Department that shows the rubber (*Hevea braziliensis*) farms in Banyuasin Regency covering 248,501.86 hectares (ha) with rubber production reaching 239,707.79 tons [8]. Based on these data, every hectare of rubber farms can produce about 1 ton/ha latex. In Indonesia, this number is ranging from 892 kg/ha to 1.542 kg/ha annually [9]. This ratio shows a relatively high prospect in rubber production.

In the meantime, the use of rubber is limited to tire production. It is a very huge problem especially with the phenomenon of scrap rubber tire generation which is exceeding 800 million pieces annually [10].

The recycling process is not going as expected and we must search for a new way of utilizing rubber latex to optimize community activities. One of the ways that can be adopted is to develop latex biokerosene as a renewable fuel. The researchers in this study are analyzing latex biokerosene and its value as an alternative energy source.

II. METHODS AND MATERIALS

The research method is based on laboratory experiments. The study took four months and was carried out at the Biomolecular Laboratory of the Faculty of Medicine, Sriwijaya University, and the Sriwijaya State Polytechnic Chemical Laboratory.

1. Chemicals and Materials

In the process of making the biokerosene, the researchers used 2.5 kg of latex (rubber sap) from rubber farm in Banyuasin, South Sumatera as the main component, standard kerosene (Pertamina®) as comparison substance, 6 liters of Paraffin (Sigma-Aldrich®) and distilled water (Sigma-Aldrich®) in the distillation process, methanol (99.8%, Sigma-Aldrich®), N-hexane (98.5%, Sigma-Aldrich®), acetone (99.8%, Merck®), silica gel thin-layer plate (TLC Silica gel 60G F254, Merck®) for the thin layer chromatography, cut into 5 cm (height)×2 cm (width) [11], and aluminum foil (Sigma-Aldrich®).

2. Tools

There are some tools used in this research including distillation apparatus, oil bath, temperature regulator, thermometer, stative and clamps, Erlenmeyer flask 250 mL (Pyrex®), separator funnel, measuring cylinder in the distillation procedure, pycnometer for the density analysis, glass beaker (Pyrex®), dropping pipette (Pyrex®), capillary pipette (Pyrex®) for thin-layer Chromatography(TLC), ruler and Ultraviolet (UV) reader (Eppendorf®) for the determination of retardation factor (Rf).

III. RESEARCH PROCEDURE

1. Biokerosene production

The procedure of biokerosene production from latex is as follows: (1) put 0.5 kg of latex into the distillation flask, make five experimental samples, (2) set the distillation apparatus and the temperature regulator, (3) put the distillation flask on the oil bath and fill the oil bath with 3L paraffin, (4) put Erlenmeyer flask (250 mL) at the end of the distillation apparatus, (5) heat the distillation flask containing the latex to 130°C, (6) dispose of the initial distillation product (water), increase the temperature to 150-165°C[12] and the later distillation product as the result of the distilled latex is stored in the form of kerosene (but is still mixed with water), (7) finally, separate the oil and water with separator funnel [13]. The distillation process was done for three hours for 500 grams of raw material and stopped when there is no distillate produced in the distillation apparatus.

2. Analysis

Analysis for the biokerosene was done using physical examination (volume, color, smell, combustion capability, the color of the flame and smoke color), relative density measurement using a pycnometer at a temperature of 18°C and 28.8°C and thin layer chromatography test for the determination of retardation factor (Rf). The retardation factor in planar chromatography which is used in this research is defined as the ratio of the distance traveled from the center of the spot to the distance simultaneously traveled by the mobile phase as compared with the solvent [14]. Thin-layer chromatography was analyzed by using Ultraviolet (UV) reader at 254 nm wavelength [15]. Research procedures are simplified in figure 1.

IV. RESULTS

1. Distillation Products Volume

From five distillation experiments, the average results were 0.196 liters per 0.5 kg of latex or about 2.55 kg of latex to obtain 1 liter of distillate. It is comparable with 39.2% of oil-yield (ratio of distillate per raw material dry weight). The results of distillation products can be seen in table 1.

Table 1. Data of Latex Distillation Product.

Distillation process	Latex mass	Distillates
1	0.5 kg	0.190 L
2	0.5 kg	0.180 L
3	0.5 kg	0.195 L
4	0.5 kg	0.205 L
5	0.5 kg	0.210 L
Average	0.5 kg	0.196 L

2. Macroscopic Examination

The distillate is observed macroscopically and then

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compared with Pertamina (*Perusahaan Pertambangan Minyak dan Gas Bumi Negara*) kerosene. The researchers examined the oil color, smell, insolubility in water, combustion capability, the color of the flame, and its smoke. The macroscopic analysis showed that the produced biokerosene has relatively the same physical characteristics except for its smell and smoke color. The complete results are depicted in table 2.

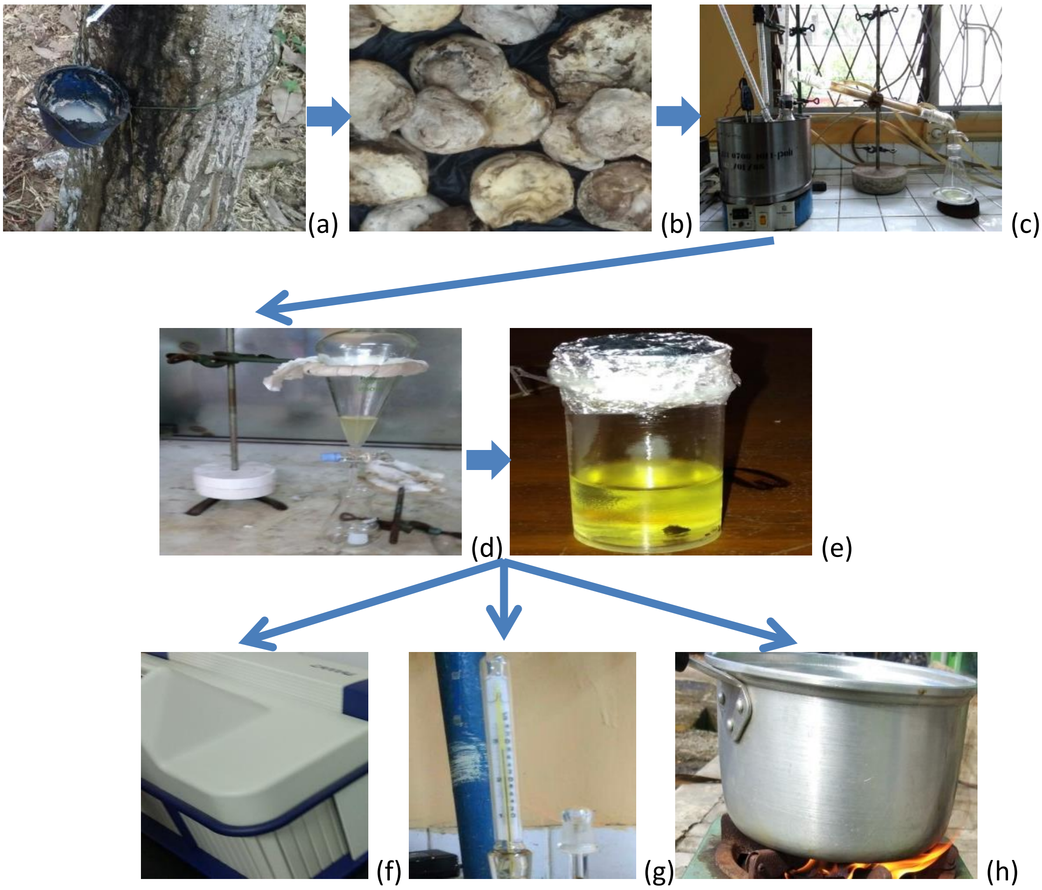

Fig. 1. Research procedure. (a) Rubber sap gathering, (b) latex dried for one week to reduce its water content, (c) distillation procedure, (d) water and oil separation using separatory funnel, (e) latex biokerosene, then followed with outcome measurement (f) TLC analysis using UV reader, (g) density measurement, (h) combustion capability measurement.

Table 2. Macroscopic Properties Comparison between Latex Biokerosene and Pertamina.

Parameter	Latex Biokerosene	Pertamina Kerosene
Oil color	Yellow	Yellow
Smell	Stinky (++)	Stinky (+)
Insolubility in water	Negative	Negative
Combustion capability	Flammable	Flammable
The color of the flame	Yellow	Yellow
Smoke color	Black (++)	Black (+)

3. Density Measurement

The experimental procedure was examining biokerosene density at two different temperatures, 18^{O}C and 28.8^{O}C as the room temperature. There was no density difference between the two temperatures with 873,9 g/cm^3 value.

4. Thin Layer Chromatography

The distillate was then analyzed using thin-layer chromatography. Thin-layer chromatography is performed by using two solvent (mobile phase/eluent), 4% methanol, and the mixture of n-hexane and acetone at 8:2 ratio. The average Rf value for the produced biokerosene was slightly different with a smaller number for methanol solvent (0.641 vs. 0.696) and higher for n-hexane and acetone (0.883 vs. 0.815). The full result of the retardation factor calculation is shown in table 3. The thin layer chromatography result is shown in figure 2.

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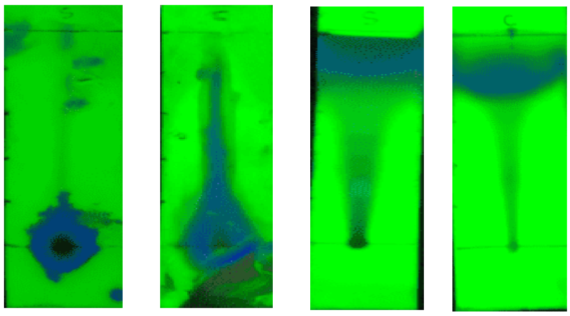


(1.a) (1.b) (2.a) (2.b)

Fig .2 Results of thin layer chromatography. (1.a) Latex biokerosene-methanol, (1.b) Kerosene-methanol; (2.a) Latex biokerosene-hexane & acetone (2.b) Kerosene-hexane & acetone.

Table 2. Retardation Factor (Rf) for Latex Biokerosene and Pertamina Kerosene.

No	Rf Sample 1	Rf Standard 1	Rf Sample 2	Rf Standard 2
1	0.600	0.700	0.900	0.800
2	0.580	0.750	0.890	0.850
3	0.625	0.680	0.843	0.833
4	0.650	0.675	0.910	0.790
5	0.750	0.675	0.870	0.800
Average	0.641	0.696	0.883	0.815

Note: 1 = using methanol 4% as mobile phase, 2 = using N-hexane + acetone (8:2) as mobile phase

5. Utilization Testing

A biokerosene utilization test was done by boiling 100 mL of water. Then it was compared to Pertamina® kerosene. Boiling time using biokerosene is five minutes with 2,5 mL of biokerosene as fuel. It is 25% slower than boiling time using Pertamina kerosene (four minutes) with the same amount of fuel. This was examined by using a standard oil stove.

V. DISCUSSION

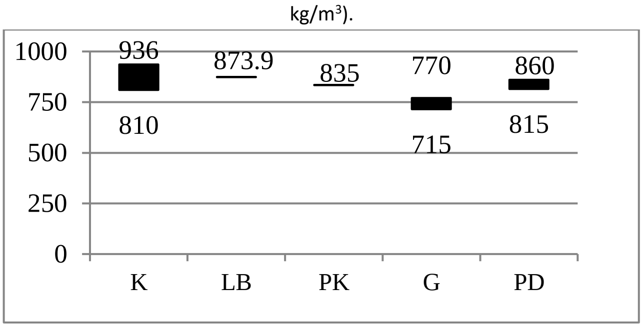
Based on the measurement of pure rubber latex distillation results, no significant difference is found in every distillation process. The maximum difference per experiment is 0.03 liters. The result of distillation ranged from 0.18 liters to 0.21 liters. As stated above, the produced biokerosene return oil yields about 39.2%. Biokerosene from waste cooking oil distillate has a 20% oil yield [16]. Meanwhile, the analysis of rubber seed showed the highest yield of 32,4% [17].

On the macroscopic examination, it is found that distillate color is clear yellow and visually similar to kerosene. The combustion capability shown by the lamplight test is also quite good as compared to kerosene. This is due to the considerably high hydrocarbon content, which is about 30-40% [4]. The combustion process results in sufficient black smoke due to its main hydrocarbon content which is in the form of cis-1.4-polyisoprene [18]. Meanwhile, the color of the yellow flame that appears is similar to kerosene.

The distillates show practically insoluble properties in the water, like nonpolar compounds, such as kerosene. Latex biokerosene odor is quite foul-smelling because of the existence of several compounds, like low molecular weight fatty acids such as acetic acid, butyric and isovaleric acids; long-chain fatty acids such as stearic acid and aromatic compounds such as p-xylene and phenol as well as unexpected compounds such as isoamyl alcohol, benzyl alcohol, benzaldehyde, benzoic acid and phenolic acids [19].

From density measurement, the kerosene density obtained is about 873,9 kg/m3, slightly higher than Pertamina kerosene density which has a maximum value of 835 kg/m3 [20]. This density value is still in the range of kerosene density reference value according to the U.S. Department of Health and Human Services, where kerosene is known as number 1 fuel with density between 810-936 g/cm3 [21]. Past research on *Jatropha curcas* biokerosene in Nigeria showed a very small difference in density with the product (ρ= 874.7 kg/m3) [22] of this research. The higher density values are due to the existence of contaminants that need to be separated furtherly. Researchers also compared the density of latex biokerosene with other fluid as shown in graph 1 [9],[10].

Graph 1. Latex biokerosene and other fuel density comparison (in kg/m^3).



K = Kerosene, LB = Latex iokerosene, PK = Pertamina® Kerosene, G = Pertamina® Gasoline, PD = Pertamina® Diesel. Data comparison [9],[10].

The analysis of thin-layer chromatography was done by using a UV reader at 254 nm wavelength to read and calculate the retardation factor (Rf). The first experiment is done by using 4% methanol as the mobile phase and shows an average value of 0.641, on the other hand, Pertamina kerosene control has an average Rf of 0.696. Based on the data from Ko et. al., the biokerosene reaches a value of 0.641 by using 4% methanol as a mobile phase is included in the kerosene Rf range, i.e. 0.6-0.7 [11]. In this experiment, there are two readings, which can be concluded as the result of impure latex biokerosene. The second experiment was done by using a mixture of n-hexane: acetone (8:2) as a mobile phase and resulting in an average Rf value of 0.883 for latex biokerosene, besides Pertamina kerosene control has a mean Rf value of 0.815. The results of the sample test showed that there are movements of fluid on the silica paper due to the mobile phase and the stationary phase interaction. However, based on Ramteke et. al., biokerosene Rf value of 0.883 is more than expected, which is 0.8 [23] because the distillate is not pure and still has some contaminants. The semi-quantitative method above shows that the distillate may contain biokerosene, although it needs to be purified further. Future research also must assess the functionality of this biokerosene product.

Latex biokerosene utilization was assessed by boiling water in the standard oil stove. It was proved that latex biokerosene has a 25% slower time to boil the water as compared with standard kerosene (Pertamina®) and can, therefore be used for household activity although it needs more improvement. The researchers did not find a suitable comparison for the utilization test. On the other hand, we found a burning test for efficiency testing of biokerosene from used frying palm oil as compared with standard kerosene (110 mL/minute vs. 92 mL/minute). It is concluded that standard kerosene is still better in efficiency considering the potential of biokerosene from used frying oil [24].

In the future, biokerosene implementation should be on a larger scale to fulfill national needs or even worldwide use. When we are talking about latex production especially in Indonesia, it is estimated that 3.229.861 tons of rubber latex generated yearly [25]. Based on these data, latex biokerosene, if effectively produced, can reach more than 1.2 billion liters or about 7.8 million barrels annually. It is exceeding kerosene demand in Indonesia by 2014 which is 4.620.000 barrel [1] and it can be concluded that latex biokerosene can be used as an alternative for facing a national energy crisis.

The produced biokerosene is still far from large scale production due to its basic method and high cost related to its production process. We need to implement some strategies before such biokerosene can be produced on a large (mass) scale. It includes enlarging biomass resource basis, providing better agricultural technology and biomass production, a greater combination of biomass production and its marketing, in addition to maximizing assessment of sustainability criteria throughout the overall provision chain [26].

VI. CONCLUSION

Biokerosene from latex distillation has relatively similar characteristics as standard kerosene and therefore has the potential to be used as an alternative source of energy. According to scarcity of Pertamina kerosene in Indonesia, biokerosene production can be optimized as a newer option although in the meantime calculation of its production cost is still high due to the small scale production.

VII. ACKNOWLEDGEMENT

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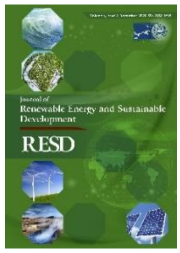

Decision Support System for Solar Energy Adoption

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***Abstract* -** A decision support system (DSS) is a computerized information system that combines models and data to solve unstructured or semi-structured problems with intense user involvement. DSSs have high applicability in several business areas and enable users without technical knowledge in computing to manipulate the information needed for a more assertive decision-making process. This study presents a DSS to support the decision process of installing a photovoltaic solution that considers the contracted power, the monthly expenses in electricity, and the location of the installation. The return on investment is estimated considering the annual savings in electricity and the return on investment. The findings indicate the relevance of the application to support the user in choosing the best solution and reveal that geographical location is a determining factor in the potential energy savings. Furthermore, the payback period decreases by increasing users' monthly consumption and is also potentiated by the increase in contracted power.

***Keywords* -** decision-making process, investment return, photovoltaic panels, renewable energy, solar radiation, sustainability.

I. INTRODUCTION

The limited lifetime of fossil fuels and the consequences of their adoption (e.g. global warming, climate change, and security risks) are driving a change in the global energy landscape. Following this change, new government policies in support of renewable energy to replace fossil fuels have emerged. This solution, of natural and virtually inexhaustible source, has the potential to fully replace electricity generation in the most diverse areas (e.g. home, business, and transportation) traditionally generated from fossil fuels. According to Peterson et al. [1], this approach enables a secure transaction for a low carbon economy. Furthermore, Greiner et al. [2] point out that renewable energy, being endogenous, can lead to a decrease of energy from abroad.

Forecasts point to strong worldwide growth in electricity generation from renewable energy sources. According to the International Energy Agency (IEA), renewable energy capacity is expected to expand by approximately 50% between 2019 and 2024. Photovoltaic will be the main driver of this growth accounting for almost 60% of the expected growth in this period [3].

Photovoltaic systems are based on panels or modules composed of photovoltaic cells. These devices capture the energy of sunlight and produce electrical power. This current produced by photovoltaic modules is collected and processed by electronic inverters, which allow consumers to reduce electricity costs and become totally or partially independent in electrical energy [4].

Self-production electricity systems based on photovoltaic systems are very advantageous in light of rising electricity tariff inflation. Jordan and Kurtz [5] note that a home or business, by installing a photovoltaic system, are immune to increases in energy prices and guarantees the supply of electricity for a period of 25 to 30 years, which is the minimum estimated lifetime of a photovoltaic system. Therefore, the investment that the citizen makes in this system is paid back in a few years with the produced energy.

Grid-connected photovoltaic systems supply electricity to the consumer from the grid. All electricity produced by this means can be used for own consumption. When there is sunlight, the consumer can fully use his own electrical energy. In periods when there is no sunlight, the consumer continues to be supplied normally by the public electricity grid. Finally, in periods when consumption is low, surplus energy can occur. In this case, the consumer can export energy to the public grid, becoming an electricity generator.

McAtee [6] and Yadav and Bajpai [7] consider that the growth in the efficiency levels of photovoltaic panels and the reduction of their costs, combined with the demand for clean energy that ensures energy sustainability, has made consumers increasingly look to solar energy as an energy alternative within their reach. Nevertheless, many consumers, especially those with less technical knowledge in the area of renewable energy, have difficulties in estimating the profitability of these investments. Several questions arise, including: How much will we one be able to save? What is the ideal level of panels? What kind of photovoltaic cell material should we one choose? When will we one be able to recover the investment made? In this sense, and to help the consumer in taking this decision, a decision support system (DSS) has been developed that enables the user to simulate energy savings according to their level of consumption, type of installed photovoltaic panels, and geographical location of their home or business.

This study is structured as follows: first, a literature review is carried out on the process structure of a DSS and its application to planning and energy consumption. Next, the methodology of the study is outlined and the process of building the DSS is defined, considering its requirements and architecture. After that, the results of the study are presented regarding two scenarios (i.e., Porto and Beja). Finally, the main conclusions are enumerated, and the relevance and limitations of this study are explored.

II. LITERATURE REVIEW

A. The Concept of a DSS

Making good decisions is rarely an easy task. The concept of decision making is involved in a problem-solving process in which the decision-maker will set his/her preferences. Arnott and Pervan [8] point out that several elements can make the decision-making processes difficult, such as uncertainty, complexity, multiple goals, and different points of view.

A DSS is a subclass of an information system that helps the decision-maker to make better use of his/her knowledge and enable the generation of new knowledge. A DSS combines models and data to solve semi-structured problems and some unstructured problems, with intense user involvement [8]. A DSS is necessarily an interactive process that requires stakeholder dialogue [9]. Carton et al. [10] refer to a DSS as an organized set of people, procedures, software, databases, and devices used to help make decisions that solve problems. Consequently, the main emphasis of a DSS should be on improving the effectiveness of the decision process rather than seeking operational efficiency.

DSS came from various disciplines such as operational research, management, accounting, applied mathematics, databases, and artificial intelligence. Through the use of a DSS, it is expected to obtain useful and relevant information that enables decisions to be made, to give advice on the correct action to be taken and to monitor the decisions made through a simulation process that enables the consequences of the actions taken to be measured [11]. Furthermore, Chung et al. [12] refer to the usefulness of a DSS to store and manage knowledge, thus overcoming human limitations to information processing.

DSS has several characteristics, such as [11; 13]: (i) dealing with large volumes of data from different sources; (ii) supporting analysis and exploring data in detail; (iii) performing a complex and comparative analysis between various alternatives; (iv) supporting both optimizing and heuristic approaches; (v) performing analysis simulation; and (vi) presenting information flexibly and using both textual and graphical elements. A DSS has generically three main components [14]: (i) database management system, which allows decision-makers to perform an analysis of the vast data stored in an external database or repository; (ii) model base, which allows exploring the relationship between internal and external data; and (iii) user interface, which allows users to interact with the DSS to obtain information.

Finally, Table I performs a comparative analysis between the typical features of an information system vs. DSS. In short, the main difference between an information system and a DSS is the high flexibility and adaptability that the latter presents in the face of the changes that occur, not only in the focus of the problem but also in the context in which the problem is embedded.

B. DSS for Energy Consumption and Planning

In the field of energy planning, several studies aggregate data at national and regional levels for the establishment of public policies. Banerjee et al. [16] present a DSS that uses a geographic information system and enables the optimization of regional energy network planning sustained in four levels: household, village, block, and district. A more recent study, and in this case based on clean energies, was conducted by Hettinga et al. [17], which aims to facilitate neighborhood energy planning. In this DSS, the process has to be initiated by a local authority with the involvement of multiple stakeholders with different perspectives, which contributes to the achievement of climate targets pre-defined by a municipality.

Another area of strong application of DSS is its adoption in the planning of smart cities. According to Eremia et al. [18], connectivity, responsible use of resources and autonomy are to be the main investments of smart cities. The diffusion of the smart grid concept requires original solutions where the inclusion of renewable energies in telecommunications, controls and new devices will have to be massive. DSS can play an important role in this field by making the services offered more efficient and enabling customers to be more participatory in their energy consumption. The study performed by Papastamatiou et al. [19] presents a DSS for smart cities to significantly reduce CO2 emissions. The approach of this study is based on two pillars: (i) assessment that allows identifying sectors with low energy performance; and (ii) optimization, which includes a proposal of specific action plans that can be used by the decision-makers of a city. Another study was also applied to smart cities, but in this case focus on the energy management of building consumption is presented by Stamatescu et al. [20]. In this study, a DSS it is proposed, where renewable energy sources (e.g. wind turbine, photovoltaic panels) and a procedural decision algorithm are adopted to a microgrid.

Table 1. INFORMATION SYSTEMS VS. DSS (adapted from Marakas and O'Brien [15]).

Feature	Information System	Decision Support System
Decision support type	Provides information about the organization's performance.	Provides information and decision support techniques for problem analysis or identification of specific opportunities.
Frequency and form of the information provided	Regular and specific answers and reports.	Interactive queries and answers.
Information format	Pre-defined and fixed.	Adaptable and flexible.
Information processing methodology	Information produced by extraction and manipulation of corporate data.	Information produced by analytical modeling of business data.

III. METHODOLGY

A. Research Design

The aim of this study is to propose a DSS that allows consumers less familiar with solar energy to estimate the return on investment they can obtain from the installation of photovoltaic panels considering multiple perspectives, namely the initial investment, type of panels, and the weather conditions of the installation site. In carrying out this study, a multiphase approach was considered to model the problem at an early stage and, after that, build a functional prototype and test its applicability in different contexts. Fig. 1 shows the structure of the research. The first phase is fundamental to conduct a literature review in the field of decision support systems, with a focus on their application to the planning and control of renewable energy systems. Next, the problem is modeled considering the approach defined by Sharda et al. [13], in which it becomes fundamental to use analytical models, which implement the "what-if" approach, to explore semi-structured and unstructured problems. Still, during the preliminary phase of the study, a specification of the functional and non-functional requirements of the prototype is performed and its logical and physical architecture is defined. The last phase of the preliminary stage is responsible for the design of the scenarios that will assess the potential impact of this prototype in a productive environment.

The second phase of the research design is the fieldwork stage. In this phase, the prototype was developed using a waterfall methodology. According to Mohamed and Darwish [25], this software development model works sequentially, as the next step is performed after the previous one is completed. For this model to work properly all project requirements must be well defined. For this study, the waterfall model works correctly because in the preliminary stage the prototype requirements are already specified. After the development of the prototype is completed, acceptance tests are performed. These tests aim to verify if the software is ready to be used by users and all functionalities are fully implemented. The approach of performing formal acceptance tests as suggested by Cangussu et al. [26] was followed, in which when the prototype was specified the test cases were also defined, with the indication of the inputs, outputs, and process of performing the acceptance tests.

The last phase is the evaluative stage. In this phase, the previously defined scenarios have been executed and their results collected. These results were analyzed using the SPSS V.21 software. Then, the findings were discussed considering the context of each scenario and the existing literature on the subject. Finally, the findings were identified and summarized. Also, in the conclusions, it was possible to draw summary conclusions about the theoretical and practical impact of this study.

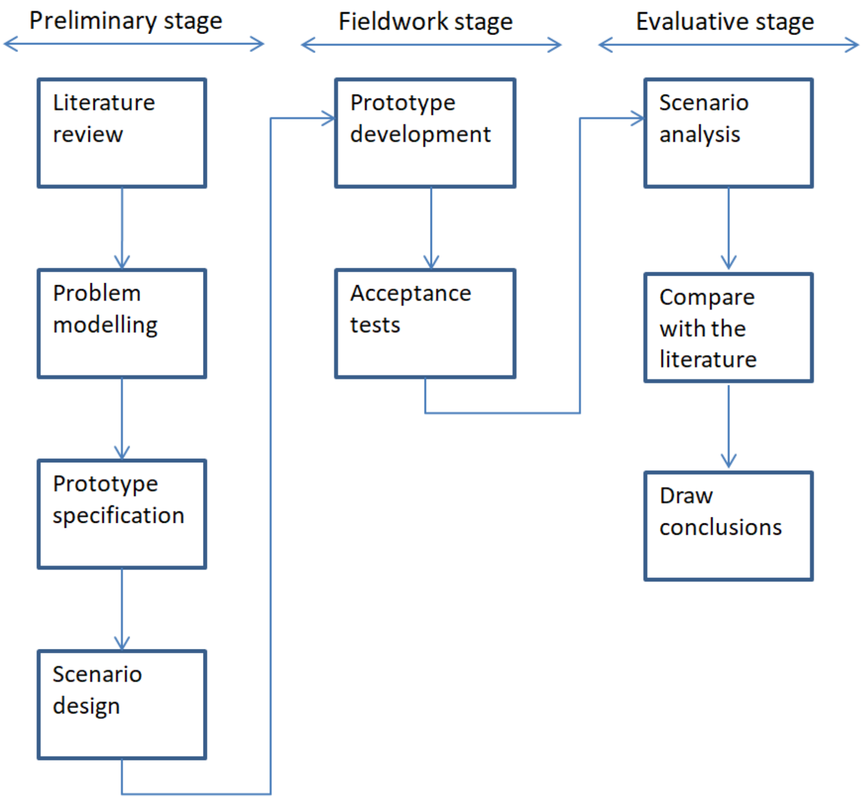

Fig. 1. Research phases and dependencies.

B. Modeling

In problem modeling, potential elements that have an impact on the choice of the photovoltaic equipment to be installed in a house or company were considered. The first element is the available area in the house/company (total surface, *ts*) to install the photovoltaic equipment. Equation (1) shows that the area occupied by the panels (total panel area, *tpa*) results from the size of each panel (individual panel area, *ipa*) and has to be equal or less than *ts.*

$$\mathrm{tpa} = \sum_{k=1}^{n} \mathrm{ipa} \ \leq \mathrm{ts} \qquad (1)$$

Another restriction of the problem is the energy consumption of the house/company. We know that the savings from the adoption of photovoltaic panels (total savings, *ts*) must be necessarily equal or lower than the energy costs of that location (energy costs, *ec*). Accordingly, the researchers have defined equation (2):

$$\mathrm{ts} \leq \mathrm{ec} \qquad (2)$$

Another restriction of the model is the weather conditions. However, unlike the other two restrictions that are deterministic and could be easily calculated through line optimization, atmospheric conditions are probabilistic depending on each geographic location and random factors. To estimate the atmospheric conditions, namely the solar radiation of a region, the NASA POWER API [27] was used to determine the solar radiation (*sr*) of a given location based on its latitude and longitude. Information from the last 10 years was collected to allow an inferential estimation of solar radiation over several months of the year. A significance level of 5% (i.e., Z0.95) was adopted in the estimation process of this interval, as established in equation (3):

$$sr = sr(i) \pm Z0{,}95 \times \frac{\sigma}{\sqrt{n}} \quad (3)$$

This approach is distinct from machine learning techniques that seek to identify patterns in data and pursue continuous improvement of processes [28]. Moreover, these solutions are characterized as requiring a high computational load [29]. In this solution, the challenge is lesser since the data regarding the weather conditions are stable and verifiable, being only used to estimate the weather conditions of that location in the next years. In this sense, the use of inferential statistics through confidence intervals is an easy and fast approach that allows the researchers to meet the challenges of the problem.

After the restrictions were identified, the objective of the problem was represented, which consists of simultaneously maximizing the *ts* and minimizing the payback period of the investment. These two objectives may, in some cases, be contradictory, because a solution that obtains high savings may necessarily have too high an initial investment and only obtain a return for too long a period. In this sense, and as Arnott and Pervan [8] state, the DSS should have a broad dialogue with the user and allow these decisions to be made by the decision-maker. In this sense, the prototype developed does not seek to replace the decision-maker, but only to give him/her more information on the potential and limitations of each proposed solution.

The existence of probabilistic elements in the problem modeling made this study represent the problem through a decision tree. Decision trees are diagrams capable of enumerating all logical possibilities of a sequence of uncertain decisions and occurrences [30]. They show schematically the whole set of alternative actions and possible events throughout a project. When it is possible to know the probabilities associated with each branch, then the expected value of a decision can be calculated. The representation of the problem in this study according to a decision tree is done in Fig. 2. In this scheme, and for simplification purposes, only two solutions are represented. Based on the weather forecast (*wf*) performed for the user location, the expected value (*ev*) is calculated according to the solar radiation probability (*p*).

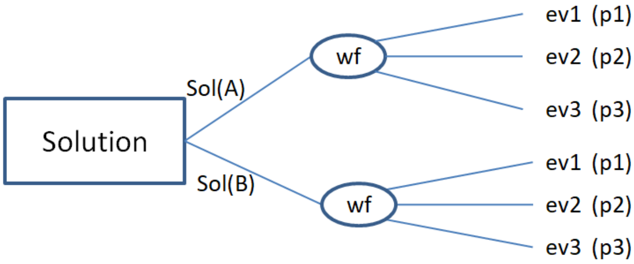

Fig. 2. Representation of the problem in a decision tree.

C. *Functional and Non-functional Requirements*

According to Hamad et al. [31], it is relevant to organize requirements considering their importance for end-users. The objective is to prioritize the implementation of the requirements starting with those with a higher degree of importance. Furthermore, it becomes relevant to distinguish between functional and non-functional requirements. Sommerville [32] considers the behavior of a system towards the client's business process as a functional requirement, while everything concerning the general characteristics of a system (e.g. cost, usability, performance, safety, etc.) are non-functional requirements. Table II presents the functional and non-functional requirements considered in the implementation of this project. The priority of requirements has been defined according to the stakeholders of the project which includes the business sector and public agencies.

D. *Physical and Logical Architecture*

The application was developed in C# and uses the Net Framework V4.8. SQL Server is the DBMS used to store the application data (e.g., simulations, equipment, and users). This choice, based on Microsoft technologies, facilitates communication between the two technologies and allows optimizing the performance of connections with the database [33]. Fig. 3 presents the physical architecture of the application. The communication between the client and the server is performed through TCP/IP. The SQL Server database is stored on the server-side.

The logical architecture is in turn useful for understanding the structure and organization of the system design. It can also be used to describe the workflows between the functionalities implemented in the application. Fig. 4 presents the logical architecture of the application. The access to the application by the user is done through the "login" component. From this component, it is possible to register a new user or access the main menu. Another central component in logical architecture is the "simulation" component. After performing a simulation, the user interacts with the "dashboard" and "export simulation" components. These two components are responsible for showing the simulation results and exporting it them to an external application (if desired by the user).

Table 2. FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS.

Feature	Priority	Description
Functional requirements		
Register in the application	High priority	A user must log in to the application to be able to use it later.
Authentication in the application	High priority	Only an authenticated user can run a new simulation.
Dashboard drawing	High priority	Customized statistical table for each user where information on the simulations performed can be accessed.
Import weather conditions	Moderate priority	The weather information is obtained from the Power by Nasa API providing the user's latitude and longitude. The monthly average of solar radiation considering the last 10 years is calculated.
Export results	Low priority	The simulation results can be exported to JSON and CSV.
Access to history	Low priority	The user must see all performed simulations on the platform, and if desired, export them to a file. To access this requirement, the user needs to have at least one simulation completed.
Non-functional requirements		
Usability	High priority	Navigation in the application should be concise and user-friendly to let the user easily access all functionalities.
Security	High priority	The data stored by the application must be backed up daily and must comply with the rules established by the General Data Protection Regulation (EU GDPR).
Reliability	High priority	The application must provide an actual and accurate simulation. The user must have a reliable source of information to make precise decisions.
Performance	Moderate priority	The information disclosed to the user from the simulation process shall have a response time fewer than 3 seconds. Furthermore, the navigation on the dashboard must have an immediate response time.
Interoperability	Moderate priority	The application must be able to communicate with external APIs and store the data in a Database Management System (DBMS).
Scalability	Low priority	The development of the program should follow a modular structure to facilitate the inclusion of new features without breaking the entire project.

E. Prototype

Technology products must be used by a wide range of people. Furthermore, Rusu et al. [34] consider that design has a close relationship with user satisfaction, so it is important to build an application in which its features are easily identifiable by a new user. Therefore, the concept of user experience (UX) emerges, which is an element responsible for gaining and retaining user loyalty [35]. Consequently, the application presents a simplistic design to be used by any type of user to cover a larger number of people.

The application provides a traditional authentication system based on the email and password model. The access credentials are unique for each user. The password is encrypted in the database using SHA-3. The application also provides a registration system for new users. The dashboard is displayed after a successfully authentication (Fig. 5). The dashboard shows the version of the installed application, the number of simulations performed and the number of panels available in the database. From the dashboard, it is possible to perform a new simulation or see the history of performed simulations.

The key functionality offered by the application is the realization of new simulations. Fig. 6 shows the process of running a new simulation. Three groups of data are requested from the user: (i) property details; (ii) power details; and (iii) financial details. The indication of the location of the user's house/company is done by requesting the zip code or enabling the location to be found by georeferencing. Information on consumption data is then requested, namely the total bill, % of the energy used during the night, price per kwh, average consumption, and the use of batteries. Finally, the user has to specify his/her budget and the importance given to the quality of the panels, batteries, and inverters.

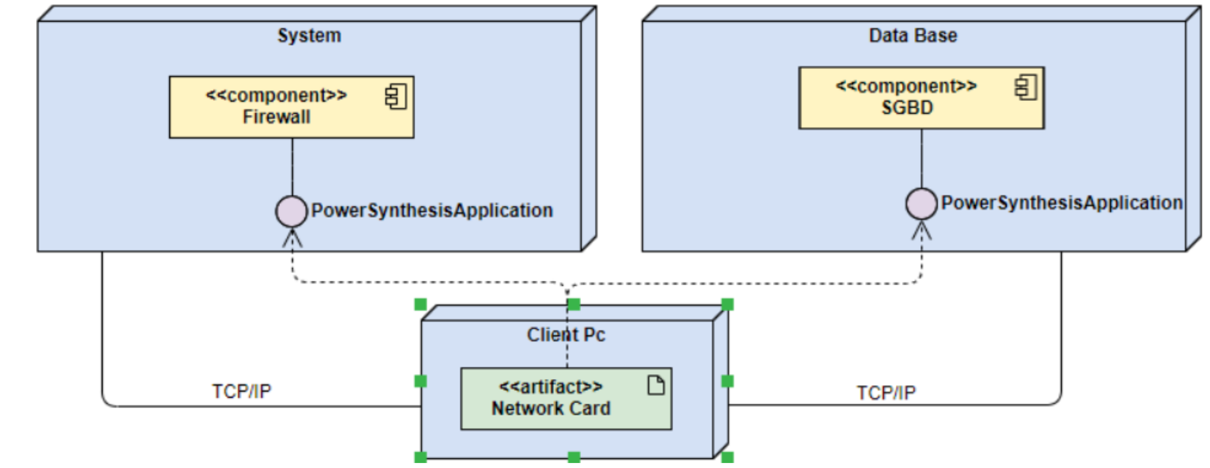

Fig. 3. Physical architecture.

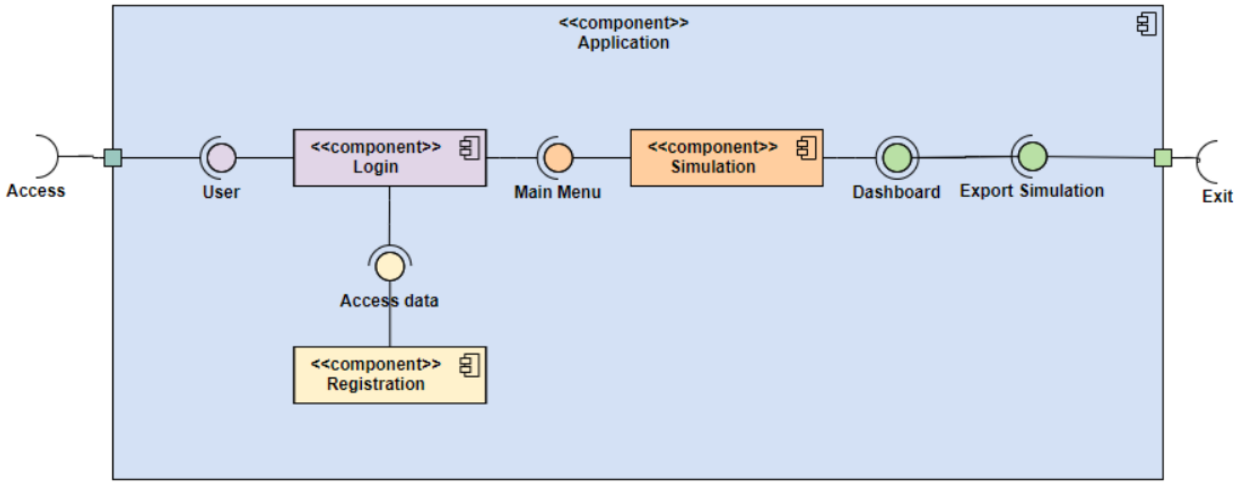

Fig. 4. Logical architecture.

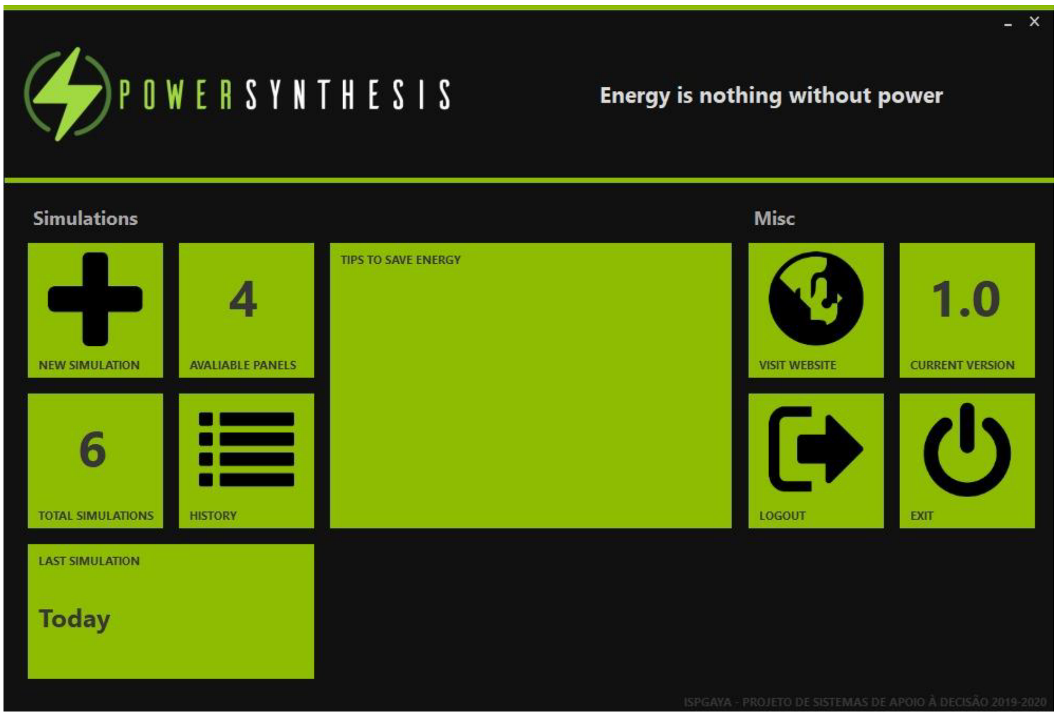

Fig. 5. Dashboard.

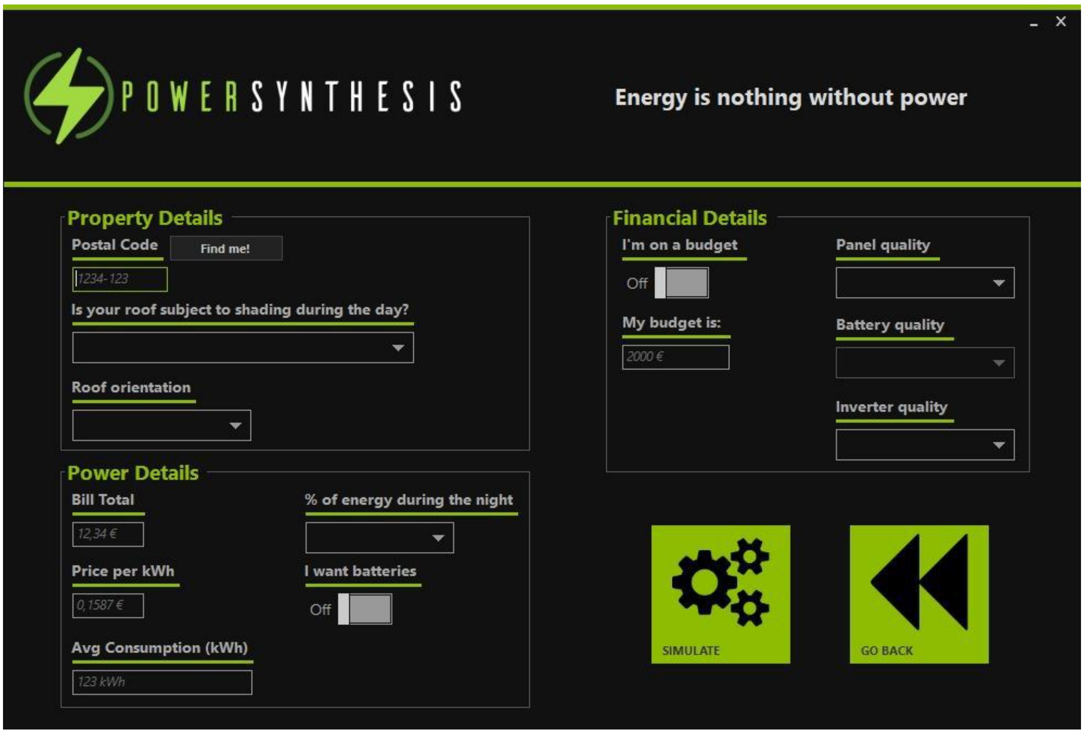

Fig. 6. Conducting a new simulation.

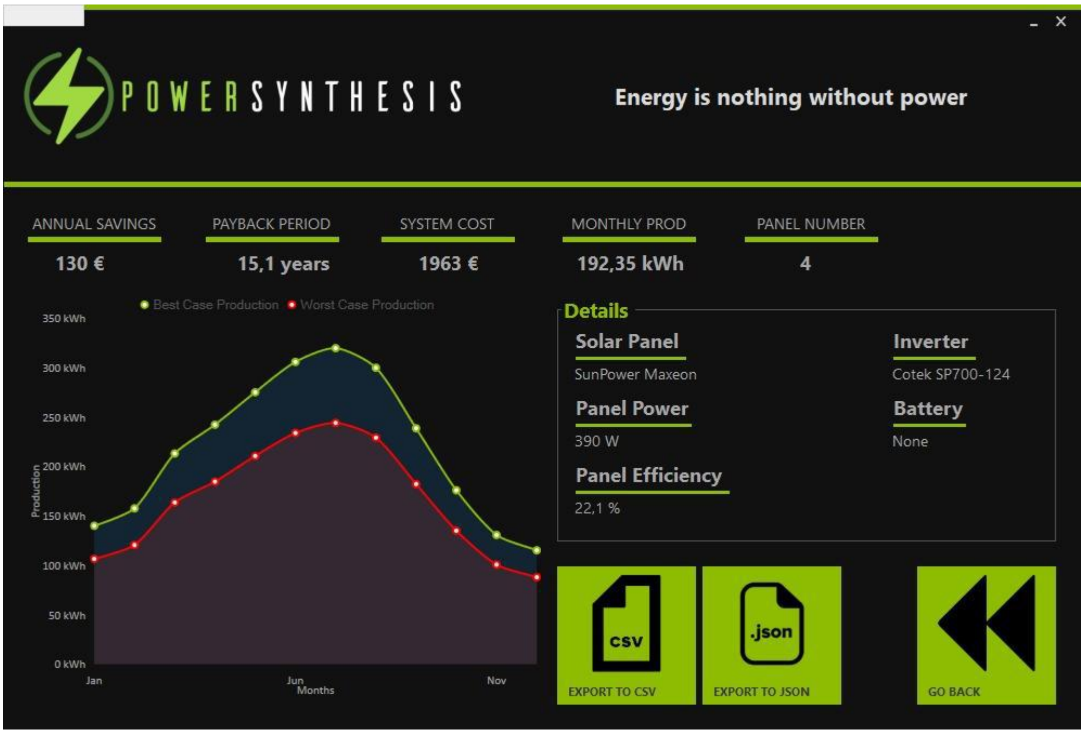

Fig. 7. Results of the simulation process.

After a simulation is performed, its results are made available considering several analysis parameters, as shown in Fig. 7. The user is provided with information on the types of panels, batteries, and inverters to be purchased. Furthermore, information is provided on the efficiency of the panel. The following information is provided as financial indicators of return on investment: (i) annual savings; (ii) payback period; and (iii) system cost. Moreover, relevant technical information like the number of panels and monthly production in kwh is also made available. Finally, and since profitability estimated over one year is not deterministic, a graph is made available indicating the worst and best case considering the weather conditions at the installation site. The findings of each simulation can be exported to JSON and CSV.

IV. RESULTS AND DISCUSSION

The application was tested in Portugal considering two geographical environments with specific particularities. The city of Porto (latitude = 41.1496 and longitude = -8.6110) is located in the North of Portugal, has an average elevation of 89.53 meters and an annual average of solar radiation of 3.93 kw-hr/m^2/day. The city of Beja (latitude = 38.0151 and longitude = -7.8632) is located in the South of Portugal, has an average elevation of 189.94 meters and an annual average of solar radiation of 4.57 kw-hr/m^2/day. For each geographic region, two independent variables were defined: (i) contracted power; and (ii) total bill. As dependent variables they were considered: (i) system cost (SC); (ii) panel number (PN); (iii) minimal and maximum annual savings (MN/MX); and (iv) payback period (PP). The number of photovoltaic panels considered ranged from 2 to 5. There were no restrictions regarding the weight and size of the photovoltaic panels.

A. City of Porto

Table III presents the simulation results for the city of Porto. Several levels of contracted power (from 3.45kw to 17.25kw) and monthly expenses (from 30 to 180 euros) were considered in the energy bill. For each scenario, SC, PN, MN, MX, and PP were calculated. The number of panels required and, consequently, the initial investment grows as energy consumption increases. On the opposite, the period of return on investment decreases as monthly consumption increases. This information confirms the data obtained by studies [36-37], in which it is concluded that the payback period of investments in solar photovoltaic is correlated with the consumption pattern. The increase in contracted power is another factor that also shortens the payback period of the investment. This occurs because this is a fixed amount paid on the energy bill and, consequently, the use of solar energy will decrease the need of energy consumption from an energy supplier. Thornhill [38] considers that despite the instability in energy prices and the investment made by energy distribution companies in renewable energy, investment in photovoltaic panels remains profitable, even if the process of selling energy to the public grid entails higher upcoming costs for the citizen.

B. City of Beja

Table IV presents the simulation results for the city of Beja. The findings obtained for Beja are similar to those obtained for Porto. The found oscillations result from different weather conditions between the two both cities. This situation causes a decrease in the recovery time of the investment. For example, considering a contracted power of 3.45kw and a monthly expenditure of 30 euros, we have there is a reduction of 0.8 years in the recovery period of the investment between the two both cities. However, this reduction is not uniform and low to 0.5 years for a contracted power of 17.25kw and a monthly expenditure of 180 euros. The impact of geographical location on the profitability of a photovoltaic energy project is also mentioned by Castillo et al. [39]. In this study, the regional potential for solar power generation in EU-28 is measured: (i) south of Portugal; (ii) south of Spain; and southeast of Italy. When the researchers combined the results obtained by Castillo et al. [37] and this study, they found that Beja is located in an area of high potential for solar energy investments, while the city of Porto is in an area with moderate potential. In this sense, the results obtained in this study are consistent with the solar energy potential offered by these two cities.

C. Comparative Analysis

Fig. 8 shows the evolution of the return of investment in years (y axis) considering the monthly expenses in euros (x axis). It allows us the researchers to compare the recovery rate of the investment considering three scenarios for each city. SN1 considers a contracted power equal to 3.45kw, while in SN2 the value is 10.35kw and for SN3 it is 17.25kw. Regardless of the contracted power, the value of the return on investment in a city with a high potential for solar power generation is higher than in a city with moderate potential. The evolution of PP follows a decreasing logarithm function, with higher variability in PP for relatively low monthly energy expenses. For higher values of energy consumption, the maximum limit imposed in the simulation of five solar panels becomes insufficient to make the investment in the same proportion profitable. The developed application enables users to indirectly define the maximum number of panels by indicating their budget. Considering that the potential user of this application is an ordinary citizen without specific knowledge in the field of photovoltaic panels, it was decided to define a maximum limit in the user's budget.

Table 3. SIMULATION FOR THE CITY OF PORTO.

Monthly expenses (€)							
		30	**60**	**90**	**120**	**150**	**180**
Contracted power (kw)	**3.45**	SC=1243€ PN=2 MN=107€ MX=143€ PP=9.9y	SC=2683€ PN=5 MN=255€ MX=340€ PP=9y	SC=2683€ PN=5 MN=296€ MX=395€ PP=7.8y	SC=2683€ PN=5 MN=316€ MX=422€ PP=7.3y	SC=2683€ PN=5 MN=331€ MX=442€ PP=6.9y	SC=2683€ PN=5 MN=346€ MX=461€ PP=6.6y
	6.9	SC=1243€ PN=2 MN=112€ MX=150€ PP=9.5y	SC=2203€ PN=4 MN=226€ MX=302€ PP=8.3y	SC=2683€ PN=5 MN=302€ MX=402€ PP=7.6y	SC=2683€ PN=5 MN=326€ MX=435€ PP=7.1y	SC=2683€ PN=5 MN=341€ MX=455€ PP=6.7y	SC=2683€ PN=5 MN=356€ MX=474€ PP=6.5y
	10.35	SC=1243€ PN=2 MN=112€ MX=150€ PP=9.5y	SC=2203€ PN=4 MN=226€ MX=302€ PP=8.3y	SC=2683€ PN=5 MN=302€ MX=402€ PP=7.6y	SC=2683€ PN=5 MN=326€ MX=435€ PP=7.1y	SC=2683€ PN=5 MN=341€ MX=455€ PP=6.7y	SC=2683€ PN=5 MN=356€ MX=474€ PP=6.5y
	13.8	SC=1243€ PN=2 MN=114€ MX=152€ PP=9.3y	SC=2203€ PN=4 MN=229€ MX=306€ PP=8.2y	SC=2683€ PN=5 MN=305€ MX=407€ PP=7.5y	SC=2683€ PN=5 MN=329€ MX=439€ PP=7y	SC=2683€ PN=5 MN=344€ MX=459€ PP=6.7y	SC=2683€ PN=5 MN=359€ MX=478€ PP=6.4y
	17.25	SC=1243€ PN=2 MN=115€ MX=154€ PP=9.2y	SC=2203€ PN=4 MN=232€ MX=309€ PP=8.1y	SC=2683€ PN=5 MN=309€ MX=411€ PP=7.5y	SC=2683€ PN=5 MN=332€ MX=443€ PP=6.9y	SC=2683€ PN=5 MN=347€ MX=462€ PP=6.6y	SC=2683€ PN=5 MN=362€ MX=481€ PP=6.4y

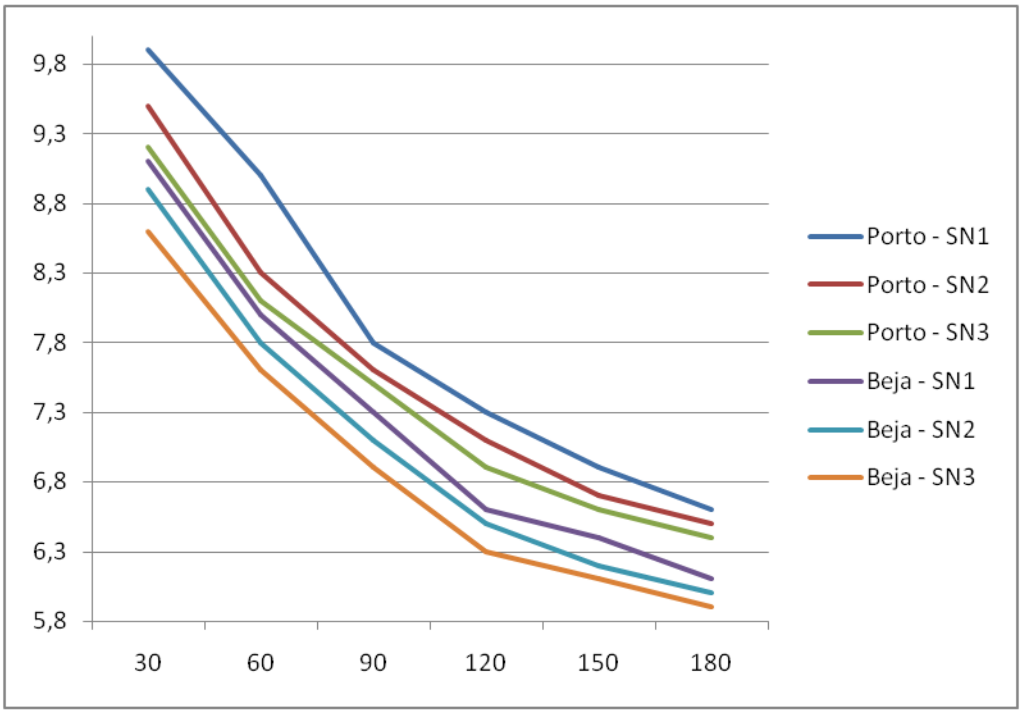

Fig. 8. Analysis of the payback period between Porto and Beja.

Table 4. SIMULATION FOR THE CITY OF BEJA.

Monthly expenses (€)							
		30	60	90	120	150	180
Contracted power (kw)	3.45	SC=1243€ PN=2 MN=117€ MX=156€ PP=9.1y	SC=2203€ PN=4 MN=235€ MX=313€ PP=8y	SC=2683€ PN=5 MN=316€ MX=421€ PP=7.3y	SC=2683€ PN=5 MN=346€ MX=461€ PP=6.6y	SC=2683€ PN=5 MN=360€ MX=481€ PP=6.4y	SC=2683€ PN=5 MN=375€ MX=500€ PP=6.1y
	6.9	SC=1243€ PN=2 MN=119€ MX=159€ PP=8.9y	SC=2203€ PN=4 MN=240€ MX=320€ PP=7.9y	SC=2683€ PN=5 MN=323€ MX=430€ PP=7.1y	SC=2683€ PN=5 MN=355€ MX=473€ PP=6.5y	SC=2683€ PN=5 MN=371€ MX=495€ PP=6.2y	SC=2683€ PN=5 MN=386€ MX=515€ PP=6y
	10.35	SC=1243€ PN=2 MN=120€ MX=160€ PP=8.9y	SC=2203€ PN=4 MN=242€ MX=322€ PP=7.8y	SC=2683€ PN=5 MN=325€ MX=433€ PP=7.1y	SC=2683€ PN=5 MN=356€ MX=474€ PP=6.5y	SC=2683€ PN=5 MN=371€ MX=495€ PP=6.2y	SC=2683€ PN=5 MN=386€ MX=515€ PP=6y
	13.8	SC=1243€ PN=2 MN=122€ MX=163€ PP=8.7y	SC=2203€ PN=4 MN=246€ MX=328€ PP=7.7y	SC=2683€ PN=5 MN=330€ MX=439€ PP=7y	SC=2683€ PN=5 MN=360€ MX=480€ PP=6.4y	SC=2683€ PN=5 MN=374€ MX=499€ PP=6.1y	SC=2683€ PN=5 MN=389€ MX=519€ PP=5.9y
	17.25	SC=1243€ PN=2 MN=124€ MX=165€ PP=8.6y	SC=2203€ PN=4 MN=249€ MX=332€ PP=7.6y	SC=2683€ PN=5 MN=333€ MX=445€ PP=6.9y	SC=2683€ PN=5 MN=363€ MX=484€ PP=6.3y	SC=2683€ PN=5 MN=378€ MX=504€ PP=6.1y	SC=2683€ PN=5 MN=393€ MX=524€ PP=5.9y

V. CONCLUSION

Solar photovoltaic panels enable the production of clean and renewable energy and, at the same time, contribute to reducing the ecological footprint and the electricity bill. Generating free and clean electricity during the day will allow citizens to cover part of their energy needs at home or in their business. By having this extra source of electricity, consumption during the day will amortize the need for grid energy use. Furthermore, savings on the electricity bill can be increased by the existence of batteries that can accumulate the surplus produced. Moreover, it is also feasible to have financial return with the generation of electricity from the sun, because depending on the production, the surplus that is injected into the grid can be paid by the electricity supply company.

This study proposed the development of a DSS to support the decision process of a photovoltaic installation supporting it in defining the installed capacity and estimating the return on investment. With this, it is intended to have a solution with a relevant impact on the environmental and financial perspectives, and it contributes to the sustainable development of cities. Using the application, the user can indicate his budget limit and, based on this information, estimate the annual savings on the electricity bill. Furthermore, the application considers the location of the user, hence the return on investment is also determined based on this information.

The obtained results considered the use of this DSS by users in two Portuguese cities (i.e. Porto and Beja). These cities are in two distinct areas of potential for solar power generation. The findings indicate that geographical location is a determining factor in energy savings and the period of return on investment decreases as monthly consumption increases. Furthermore, the decrease in this period of return on investment is greater for high values of contracted power.

This study offers essentially practical contributions by providing a DSS for decision support in solar migration using photovoltaic panels. This DSS is flexible by allowing proposed solutions to be parameterized according to the contracted power, monthly energy bill and geographical location of the installation. This study also presents several limitations that should be highlighted. Firstly, only one type of panel was considered and only the purchase price of the panel was registered. Next, the dashboard is still relatively basic, there being no saving indicators considering other alternative solutions. Finally, the tests carried out considered only two cities in Portugal and it is recommended that more tests can be carried out considering other geographical areas in the EU. As future work, we the researchers intend to automate the process of collecting information from photovoltaic panels, considering several types of solar panels like polycrystalline, monocrystalline, or with advanced efficiency solar modules. Furthermore, the dashboard should be redesigned to ensure that the information provided is more relevant to the user, namely indicating for each solution several alternatives and comparing the return on investment offered by them.

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GREEN SUPPLY CHAIN PRACTICES FRAMEWORK FOR PETROCHEMICALS IN EGYPT

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Abstract **-** The aim of this study is to determine the extent of green supply chain management (GSCM) practices used by Shell and Co-operation (Co-op) Petroleum Companies in Egypt and to evaluate the effect of GSCM practices on the operational performance of both companies. A conceptual framework was developed to link the GSCM practices and operational performance. The framework consisted of three GSCM practices (green procurement, green manufacturing, and reverse logistics) as independent variables and four operational attributes (quality, safety, delivery, and flexibility) as dependent variables. The data were collected through on-site surveys, using eighteen-item-questionnaire with the relevant departments in both companies from the three managerial levels (i.e. strategic, tactical, and operational). Further, the results, based on benchmarking, were statistically analyzed by Fischer analysis. The results offer guidelines to petroleum and lubricant manufacturers to enhance their operational performance and customer satisfaction while employing GSCM practices throughout their entire supply chain (SC).

Keywords **-** green supply chain management, operational performance, reverse logistics, green procurement, green manufacturing.

I. INTRODUCTION

The increase in greenhouse gas emissions, global warming and environmental pollution by companies has increased the need for organizations to reorganize their SC processes to improve the operational performance of enterprises and thus products in accordance with the requirements of environmental regulations [1]). Furthermore, environmental pollution and the increase in greenhouse emissions have led to an increased demand for organizations to reorganize SC operations, thereby conserving scarce resources. The GSCM is an important organizational philosophy to achieve corporate profit and market share objectives by reducing environmental risks and impacts while improving the ecological efficiency of these organizations and their partners [2]. As a synergistic joining of environmental and supply chain management (SCM), the competitive and global dimensions of these two topics cannot go unnoticed by organizations. Likewise, the rise in environmental missions and concerns lead to the need to reduce environmental pollution resulting from industrial development with SCM [3]). Moreover, Monshiwa [4] acknowledged that any competitive advantage obtained or can be obtained by applying the green approach and accordingly, this creates pressure on companies not to ignore these green initiatives.

With the increase in environmental concerns during the past decade, a consensus is growing that environmental degradation issues accompanying industrial development should be addressed together with SCM, thereby contributing to GSCM [5]).

Egypt is one of the developing countries in the world and is becoming increasingly industrialized and this makes Egypt faces a heavy burden on the environment. Likewise, multinational organizations and developed countries use the developing countries as a point of disposal of endemic products and this has environmental impact [6]. For this reason, this research attempts to answer the following questions: (1) What are the current state of GSCM practices adoption by Shell and Co-op petroleum companies in Egypt? (2) How have the GSCM practices affected the operational performance at Shell and Co-op petroleum companies? And (3) What are the drivers of GSCM practices in Shell and Co-op petroleum companies?

Hence, this research will help local companies operating in the lubricant industry, such as Co-op petroleum company, to be more involved in implementing the GSCM concept. Additionally, the management will be able to identify GSCM practices that will develop and improve the operational performance of the Co-op company besides all local companies operating in this controversial area. Besides, how these companies can benefit from the implementation of Shell's GSCM practices and their effective impact on their operational performance. It has been noted that previous studies on the evaluation of operational performance and the effect of implementing GSCP in this field are few, especially in developing countries, such as Egypt. Thus, this research is urgently needed to determine how the operational performance of companies in the lubricant industry is affected by the implementation of GSCM practices.

The remainder of the paper is organized as follows. In Section 2, the literature is briefly discussed. In Section 3, the methodology section is introduced. Then in Section 4, the analysis and findings are presented. Finally, Sections 5 and 6 conclude the study, including the theoretical contributions and managerial implications of the findings.

II. LITERATURE REVIEW

Environmentally sustainable GSCM has emerged as organizational philosophy to achieve corporate profit and market share objectives by reducing environmental risks and impacts while improving the ecological efficiency of these organizations and their partners [7];[2]. Likewise, it is necessary to integrate the organizational environmental management practices into the entire SC to achieve a sustainable SC and maintain a competitive advantage [8]; [9]. The GSCM practices should cover all the SC activities, from green purchasing to integrate lifecycle management, through to manufacturer, customer, and closing the loop with reverse logistics [10]. Thus, the literature review section presents an overview on all the previously mentioned concepts and thoughts and is divided into two main sections: GSCM concepts and paradigms, and the GSCM practices and operational performance, all discussed respectively.

1. Green Supply Chain Management Practices

The full concept of GSCM was first proposed by the Michigan State University Manufacturing Research Association (MRC) in 1996 to comprehensively consider environmental impacts and improve the resources of manufacturing chains (Handfield, 1996). This means that it aims to reduce the environmental impacts of products at the end of use by tracking and controlling purchases of raw materials, in order to ensure compliance with environmental rules and regulations. Furthermore, awareness of environmental pollution has increased among people around the world, making them curious about protecting the environment. As a result, people are planning to buy green products, and the concept of GSCM is becoming more popular and gradually became the new concept of sustainable development of enterprises.

The first series of green SCs emerged in the context of 1989 when [1] first published how to develop an ideal forecasting system for organizations to predict reusable products, and the first book of green design literature came into context in 1991. Later, the article, published by [11] was the first to examine the need for green design to reduce the impact of waste products. While [2] came to context and expanded the green design framework. According to Beamon [12] , wastes from industrialization and the use of natural resources contribute to environmental pollution. In addition, scarcity of resources is another factor that enterprises and industrial companies must study. Therefore, the GSCM is the only way to deal with these environmental problems because GSCM has its primary role in dealing with environmental degradation, for example, the contraction of raw material resources, the lack of scientific and professional treatment with waste, and the increasing level of pollution [13].

The GSCM practices is frequently used for various activities implemented by any company to diminish the negative impacts on the environment [14]. These activities vary from green purchasing to integrated SCs flowing from suppliers to the manufacturer, to customers and reverse to logistics, which is named as "closing the loop" [8] as shown in Figure 1.

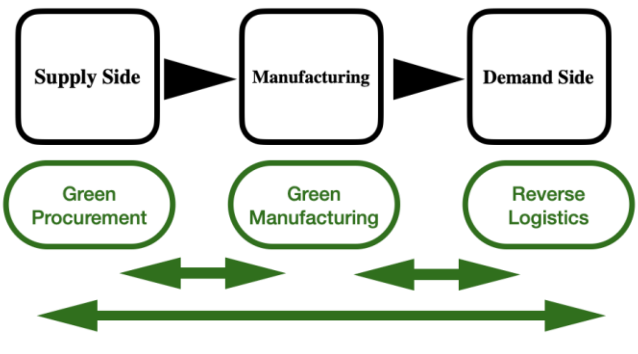

Fig .1 The areas of literature associated with GRSC
Source: Zhu and Sakris, 2006. [8]

When empirical studies on GSCM are assessed, it has been found that there are several GSCM dimensions discussed by different researchers, such as green purchasing, green manufacturing, green logistics, green packaging, green marketing, green building, green education, investment recover, eco-design, etc. [15]; [8]; [16]; [17]; [18]. In light of this researches, three dimensions were selected to be included in this study as shown in Table 1 and further will be briefly described in the next sub-sections.

Table 1. GSCM DIMENSIONS.

Dimension	Definition	Author(s)
Green Purchasing	The integration of environmental efforts, purchasing activities and environmental objectives of the firm	Foo [19] et al., 2019 ; Zhang [20] et al., 2018
Green Manufacturing	The planning and implementation of energy-saving resources in the production process to produce environmentally friendly products with the least resources	Ma et al., 2018 [21]; Karimi et al., 2019 [22]
Reverse Logistics	Managing how products and/or materials are returned to the original manufacturer or agent for reuse, recycling or re-manufacture.	Bottani et al., 2019 [10]; Bai and Sakris, 2019 [23]

A. *Green purchasing*

The green purchasing implicates a company evaluating the environmental performance of their vendors, which requires these vendors to implement all necessary operation measures to ensure the environmental quality [7]. Furthermore, this step is considered to be the first step in the value chain that positively affect the operational performance of the entire chain [24]. [18] acknowledged that green purchasing entails all organizations in the entire chain to get attention towards the eco-labeling of all purchased items, supplier's cooperation to attain the environmental objectives, supplier's environmental audit, supplier's International Standards Organization (ISO) 14000 accreditation, supplier's environmentally friendly practice assessment, and finally, providing the required environmental design specification to the suppliers. Chen [25] also points out that green procurement has beneficial effects on the corporate pollution control system and can promote the successful implementation of the company's quality and environmental standards. Likewise, [24] signified that green purchasing involves a procurement function through various SC activities, such as life cycle analysis (LCA) and 3R model - reduction, reuse, and recycling that belong to the product design and process part. The first is to reduce waste received from products and to guide consumers to reduce their waste by purchasing their own needs only and purchasing goods made from recyclable materials rather than non-recyclable materials. The second R is to reuse any wastes to reduce environmental pollution and global warming. Finally, the third R is to recycle the disposed waste by segregating the materials from each other.

B. *Green manufacturing*

The green manufacturing is considered the significant step in all GSCM activities in any industry to continuously improve their operational performance such as reducing cost, the quality of the products, and the environmental risks, all of which bring a competitive advantage to the product [22]. Sezen [26] affirmed that pollution can be reduced or mitigated through continuous improvement strategies that focus on green design and manufacturing. Nevertheless, Dubey [27] added that green manufacturing is a system that connects all problems associated with the design, planning, and manufacturing matters efficiently to control the emerged waste amounts to be consistent with the environmental standards and procedures.

C. *Reverse logistics*

As reverse logistics is gaining increasing interest and relevance, the question becomes whether it is enough to limit greening efforts to one segment of the SC and single companies or choosing to expand these efforts to the entire chain. Greening can start right at the source with supply conditions and can work its way through storage and packaging practices to distribution and end-consumers [28]. However, the reversed flow can take different forms, from collection to return shipments into the distribution channel, followed by disassembly and re-use of selected parts. Alternatively, used goods could be shredded and scrapped and re-entered into production as raw materials. Returned goods, or elements of the product, could even be returned to suppliers and supply chain partners for them to re-manufacture [23]. Those possible SC applications should be taken into consideration. One step further, dis-assembly operations in the reversed flow might call for a proactive design for dis-assembly right in the initial product design stage of both supplier and customer [10].

Of all green activities, it is relatively easier to repair existing products and run renovations. More and more companies pay attention to yield management or product recovery management. Reverse logistics aims to ensure the return of materials and products from the user to the product for reuse, recycling, and regeneration [29]. However, for most companies, they do not put reverse logistics in their planning strategies initially, although they will take action to respond to the requirements of customers or members of the final channel.

2. The Relationship between GSCM Practices and Operational Performance

There are several impacts of GSCM practices on performance outcomes. Generally, the adoption of GSCM practices by manufacturing organizations lead to improved environmental performance and economic performance, and on operational performance [18]. Laws, procedures, standards, and incentives regulated by regulatory institutions make corporate responsibility more environmentally friendly [30]. Sarkis [31] discussed the impact of persistent pressures through laws and regulations on improving awareness in developed countries such as the United States of America where large industrial companies often face scrutiny by environmental activists [7]. Thus, companies and organizations are under pressure from their competitors, forcing companies to implement green supply chain practices to reduce competition and make them competitive [32] . Additionally, consumers are increasingly aware of the environmental impacts, which leads to the selection of the goods they receive and ask companies to apply the minimum green standards in their product design and thus to preserve the environment [33]. Companies take societal responsibilities into society as companies believe they must commit themselves to society to conform to expectations and standards that lead to accepted business behaviors [34]. Thus, implementation of GSCM practices can result in a set of advantages for the company itself, for procurement and supply, and for the community itself.

Green procurement and supply can be improved to the extent that green supply facilitates information exchange and flow and cooperative relationships in the supply chain [35]; [36]. The benefits of green supply to society begin with a green environment, reduce hazardous and harmful substances, use scarce resources more efficiently, and avoid waste. Green supply also helps to spread environmental knowledge through green marketing and best practices. Environmental initiatives in the industrial supply chain should focus on the production and processing processes used by the supplier [37].

According to [33], the operational performance was summarized in four factors:

- Quality: Evaluate the product or service that meets customer satisfaction and expectations.
- Safety: Evaluate both the health and the working environment of the staff.
- Delivery: Evaluate the business unit with its achievement in a proper time based on customer requirement.
- Flexibility: This means that this requires a great deal of flexibility in different processes, such as reducing the number of back orders, lost sales, and late orders.

Additionally, [5] indicated the positive relationship between the GSC and multi-operational performances in cost, delivery, quality, and flexibility. While [38] signified the impact of customers' involvement in green practices on improving the customer satisfaction. Additionally, [39] affirmed that the GSCM practices lead to significant operational performance increase in terms of quality, cost, and flexibility, however, it does not have any impact on the delivery aspect. Accordingly, for this study, Figure 2 presents the initial conceptual framework to link the three GSCM practices previously identified and the four operational performance attributes adopted by [33].

III. METHODOLOGY

Benchmarking is an assessment process on best performing corporate goods, services and procedures [40]. Benchmarking concept is also associated with individual corporations' attempts to recognize and emulate best practices in their own industry. Moreover, benchmarking has also been cited as an effective method to constantly enhance organizational performance, overall management of quality and competitive advantage [2]; [41].

Benchmarking as a mechanism to identify operating performance measures and compares SCs in relation to selected measures. Accordingly, this study used descriptive research design by using benchmarking between Shell and Co-op companies in Egypt. In this study, descriptive research design based on two types of benchmarking; best-in-class and operational benchmarking. In order to achieve this aim, both approaches were used to explain the relationship between the GSCM practices and operational performance by benchmarking the factors that influence the impact of effective GSCM between Shell and Co-op companies in Egypt. The performance measurement methodology is defined as an effective tool for managing change; it can be described as an ongoing process to identify, understand and evaluate industry best practices to improve the performance of an organization [42]. This is usually done by studying other organizations that carry out similar operations [43]. In contrast, performance measurement is an external activity that can enable the organization to move away from tradition. However, standard measurement and comparative analysis should not be confused. In the comparative comparison group, the metrics for similar elements are compared between organizations or within the organization, and this is simply one step in the normative assessment process [44].

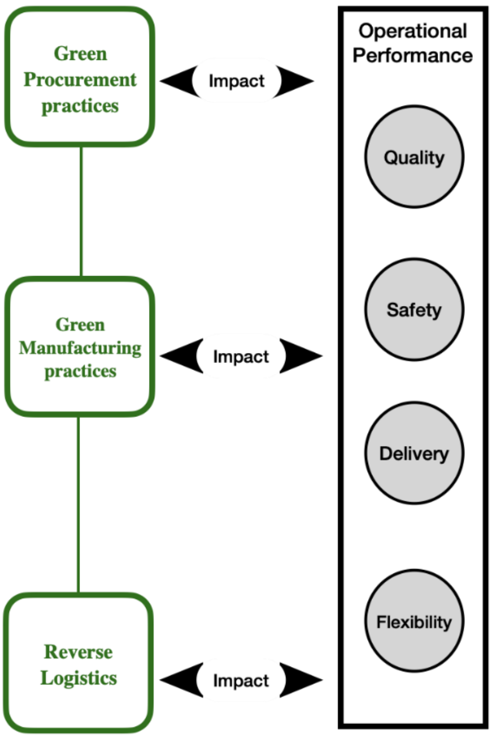

Fig .2 Initial Conceptual framework to link GSCM practices and operational performance
Source: developed by the authors

Shell and Co-op companies have been chosen for the purpose of this study as one of them is a multinational company operating in Egypt (i.e. Shell), and the other was a local Egyptian company (i.e. Co-op). The reason behind that is to drill down into performance gaps to recognize areas for improvement [42]. Figure 3 presents the overall research design.

1. Data Collection

This study focuses on the relationship between GSCM practices, and the SC operational performance. The target sample was managers in both companies from the three managerial levels (i.e. strategic, tactical, and operational). Accordingly, the targeted departments were procurement, production, marketing, quality assurance, and logistics departments. There was an intention to engage a larger sample, however, if a large sample is used, data may become repetitive [45]. Owing to the nature of this benchmarking study, saturation was not applied on less than 25 face-to-face conducted questionnaires. The data collection was conducted in person for four months from August 2019 to November 2019. Ethical issues have been considered through gaining well-versed consent and making confirmation that the data will be treated as confidential to be used only for research purpose. All surveys were conducted on-site, using an eighteen-item- questionnaire for collecting data and were guided by the objectives of the study. The questionnaire scale was in the range from – to ++++ where respondents required to indicate their views on this scale. This scale was chosen by the researcher because it allowed the respondents to express their views more clearly and openly.

At the beginning, the survey questions were assessed by five professors from the SC management field. Then a pilot test was conducted with seven SC management consultants and industry experts. Minor modifications were received from the experts. However, most of the remarks were related to the wording of the questions, so they were re-written to be easily understood. The questionnaire consisted of two sections: section I; included, practices of GSCM, and section II; the operational performance with regards to implementation of GSCM practices.

2. Data analysis

Researchers are indeed concerned in recognizing significant cells relationships following a statistically valid chi-squared test [46]. Two test statistics are widely used to test the value of each cell. The first test is a standardized residual that is measured as a raw residual divided by a square root of the expected value, where the raw residual is defined. The discrepancy between the observed value and the predicted value. The second test shall be modified residual: raw residual divided by its standard error. Both experiments adopt the normal standard distribution asymptotically.

In this study, statistical analysis was performed using a statistical program (GMP for Windows version 5.1, SAS Institute, Cary, NC, USA). For data analysis, use the Fisher's exact test to compare Shell and the Co-op company to GSC; green procurement, green manufacturing, reverse logistics and operational performance; quality, safety, delivery and, flexibility. Data were analyzed as - = 0, + = 25, ++ = 50, +++ = 75, ++++ = 100. At the end, the results were considered significant at P <0.05 which is considered acceptable to achieve the objectives of the study. The reason behind using Fisher's exact test in data analysis is that in case of small samples, the Fisher Exact test is considered an effective tool used instead of the chi square test for 2 in 2 tables.

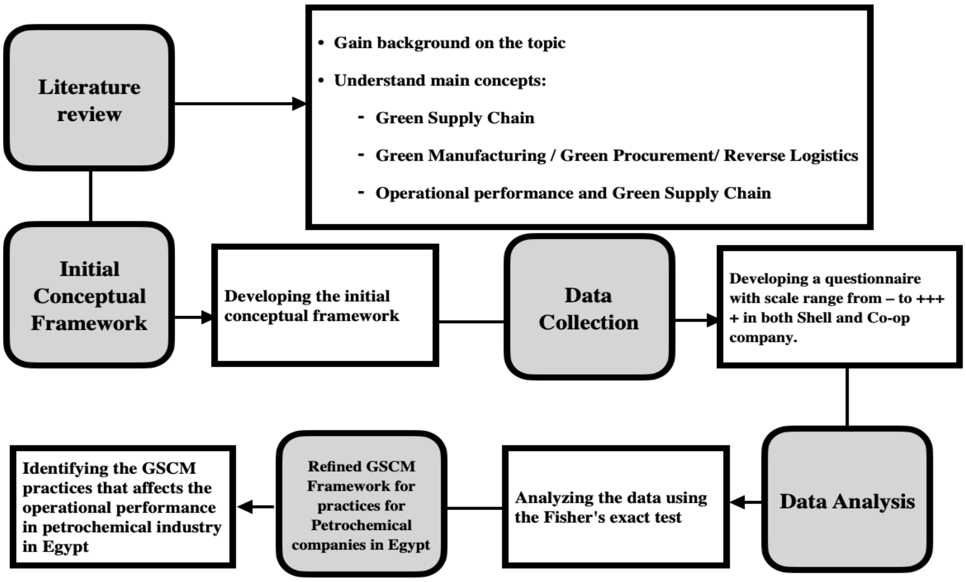

Fig. 3. Overall research design
Source: developed by the authors.

IV. ANALYSIS AND FINDINGS

This study was carried out to determine the effect of green supply chain practices on operational performance of benchmarking study between Shell Egypt and Co-op Petroleum Company working in the lubricant industry. The study had two objectives. The first is to determine the extent of GSCM practices used by Shell and Co-op Petroleum Company in Egypt; the second objective is to establish the relationship between green supply chain management practices and operational performance of Shell and the Co-op Petroleum Company in Egypt. Accordingly, in the subsequent sections, the detailed descriptive analysis of the questionnaires conducted was analyzed using Fisher's exact test.

1. Green Procurement

The results of extent the firm practice green procurement are demonstrated in Table 2. The results showed that suppliers are required to have ISO 14001, Shell Company had significantly higher extent the firm practice green procurement than the Co-op company ($p < 0.0001$). Likewise, for purchasing materials that contain green attributes, the results revealed that Shell Company had significantly higher extent firm practice Green Procurement than the Co-op Company ($p < 0.00001$).

Furthermore, the Fisher's exact test results unveiled that evaluate suppliers on specific environmental criteria, Shell Company has significantly higher extent the firm practice green procurement than the Co-op company ($p< 0.0001$). Likewise, the results showed that procure products that are made using recycled packages, Shell Company had a significantly higher extent the firm practice Green Procurement than the Co-op company ($p< 0.0001$).

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The SC network starts in Shell Egypt with the suppliers who are mainly raw material suppliers (base oil and additives) and packaging materials. Suppliers are evaluated based on their commitment to environmental standards according to the Rider Center for SC Management (2008) that protects the environment from all aspects (as mentioned earlier). Base oils are supplied to the plant by refineries either inside or outside of Egypt. Additives are delivered to the Lubricant Oil Blending Plant (LOBP) through Alexandria port from Europe. All packaging material supply is locally supplied to the plant. These raw and packaging materials are used to manufacture a wide range of portfolio of products. Once products are produced, they are shipped to the distribution center in 6th of October waiting its turn to be shipped to the customers. Thus, the results revealed that Co-op company was not committed to environmental standards according to the regulations that protects the environment from all aspects.

Table 2. THE EXTENT AT WHICH THE FIRM PRACTICES GREEN PROCUREMENT.

Green Procurement practices	Shell	Co-op
Requiring suppliers to have ISO 14001	75***	25
Purchasing materials that contain green attributes	75***	0
Evaluating suppliers on specific environmental criteria	75***	0
Procuring products that are made using recycled packages	75***	0

Source: Research Data (2019) by using Fisher's exact tes.

Table 3. EXTENT AT WHICH THE FIRM PRACTICES GREEN MANUFACTURING.

Green Manufacturing Practices	Shell	Co-op
Producing products that have packages which can be recycled	75***	25
Using life cycle assessment to evaluate environmental load	75	75
Replacing hazardous substances with that which are environmentally friendly	66***	33
Minimizing the use of materials in packaging	75***	0
Encouraging reuse of products and recycled materials	75***	25
Reducing the size of packaging	75***	0
Cooperating with suppliers to standardize packaging	75***	0

Source: Research Data (2019) by using Fisher's exact test.

2. Green Manufacturing

Results of the extent at which the firm practices green manufacturing are shown in Table 3. The Fisher's exact test results revealed that produce products that have packages which can be recycled, Shell company has significantly higher extent the firm practice of green manufacturing than the Co-op company ($p<0.0001$). Likewise, the result of using life cycle assessment to evaluate environmental load showed non-significant difference between both companies. Furthermore, the results of replacing hazardous substances which are environmentally friendly showed that Shell company has significantly higher extent to which the firm practices green manufacturing than the Co-op company ($p<0.0001$). Moreover, concerning the minimization of the use of materials in packaging, it was clear that Shell company had a significantly higher extent at which the firm practices green manufacturing than the Co-op company ($p< 0.0001$). On the other hand, Shell Company has significantly higher extent at which the firm practices green manufacturing than the Co-operation Company ($p< 0.0001$) in encouraging the reuse of products and recycled materials. Likewise, concerning reducing the size of packaging, it was found that Shell Company had significantly higher extent at which the firm practices green manufacturing than the Co-operation Company ($p< 0.0001$). Finally, the results indicated that Shell company has significantly higher extent at which the firm practices green manufacturing than the Co-op company ($p<0.0001$) in cooperating with suppliers to standardize packaging.

In Shell, the inputs are divided into two main groups; raw materials (base oils and additives) and Packaging material (bottles, packs, drums, caps, pallets, pails, stretch wrap and cartons). All these materials are recycled and reused. These inputs are discharged into main storage holding tanks (base oil and additives) and warehouses (packing material) to be used later on throughout the whole manufacturing cycle. The base oil and additives are blended with certain percentages according to the final product's bill of materials (BOM) and required a specification for each product. After blending, the mixed product is pumped through a system of pipelines that transfers it to the filling lines. The product is then dispensed in the designated packaging containers to be then transported to the finished products warehouse for storage until being shipped outside the facility to customers LOBP. It is notably to mention that using life cycle assessment in Co-op Company is under the responsibilities Petro Trade Company. Concerning replacing hazardous substances, Shell company is concerned with recycling both the used oil and packages, while the Co-op is concerned basically with recycling the used oil only.

3. Reverse logistics

The results of the extent of the firm practices of reverse logistics are shown in Table 4. The results of dealing with disposal indicated that Shell company had significantly higher extent as regards the firm practice of reverse logistics than the Co-op company ($p< 0.0001$). Regarding the processing of returned merchandise, the results showed that Shell company has significantly higher extent of the firm practice of reverse logistics than the Co-op company ($p< 0.00001$). Finally, the analysis results revealed that Shell company had significantly higher extent of the firm practice of reverse logistics than the Co-op Company ($p<0.0001$) in repackaging product.

Shell's SC is adopting the lean strategy as it is always working on minimizing if not eliminating the waste. This includes all types of daily wastes with the concentration on inventory reduction on both the raw materials side as well as the finished product side. There are lots of efforts exerted in this area especially qualifying six sigma professionals to be able to assist in the company's strategy and be even leaner according to [47]. On the contrary, Co-op company (and all local companies) are charged of collecting used oil from distributing companies. Thus, establishing Petro Trade Company to collect used oil from all resources to increase the amount of collected oil will be a significant recommendation besides obliging service stations to establish land tanks for collecting used oil.

Table 4. EXTENT OF THE FIRM Practices OF REVERSE LOGISTICS.

Reverse Logistics	Shell	Co-op
Dealing with Disposal	66***	33
Processing Returned Merchandise	75***	25
Repackaging Product	75***	0

Source: Research Data (2019) by using Fisher's exact tes.

4. Operational performance with regards to implementation of GSCM practices

The results of operational performance with regards to implementation of GSCM practice are shown in Table 5. The result indicated that the quality at Shell company has significantly higher extent in green procurement practices than the Co-op company ($p< 0.0001$). Furthermore, the safety at Shell Company revealed significantly higher extent of the firm practice of green procurement than that of Co-op company ($p< 0.00001$). Additionally, the delivery at Shell company had significantly higher extent the firm practice green procurement than the Co-op Company ($p< 0.0001$). Finally, the flexibility at Shell company had a significantly higher extent the firm practice green procurement than that of the Co-op company ($p< 0.0001$). Finally, as shown in the Table 5, the overall effects of GSCM practices on operational performance reflected on quality, safety, delivery and flexibility.

The competency relies always to the delivery on time of their wide range of portfolio as well as providing several after-sales technical support services which made them currently the market leader lubricants' supplier for eight years in a row. Nevertheless, Shell is the highest spender on research and development reaching an annual spend of 1.3 billion dollars to be able to come up with the products that fulfill today's customers' needs. As mentioned above, the majorities of the raw materials supplied to the SC in Egypt as well as other countries are imported goods and have strict environmental specifications. Moreover, sometimes finished goods themselves are imported (or exported from other plants in the world) to satisfy a certain need in another operating unit. It is worth mentioning that planning is based on the historical statistical forecast of the products' range. In other words, based on the finished product forecast, the material requirement planning (MRP) tools are used to explore the bill of materials (BOM) and accordingly know the requirements from all BOM components. Based on the forecast as well, the company usually plans for all its capacities and requirements. Accordingly, a sourcing plan with the companies' suppliers is constructed to fulfill the requirements of the customers. The raw and packaging materials are then converted to the finished product during the manufacturing stage. After this step, the finished product is sent to the distribution center to and be arranged and then sent to customers. In case of any faulty delivery, the company accepts returns from customers as per the service level agreement with the customer.

Table 5. OPERATIONAL PERFORMANCE WITH REGRADS TO IMPLEMENTATION OG GSCM PRACTICES.

Impact	Shell Company	Co-op
Quality	75***	25
Safety	66***	33
Delivery	75***	25
Flexibility	75***	0

Source: Research Data (2019) by using Fisher's exact tes.

5. Discussion of theoretical and managerial implications

According to [48], GSCM is increasing expanding enthusiasm among specialists and professionals of operations and SCM. The developing significance of GSCM is driven principally by the expanding crumbling of nature; that is, reducing crude material assets, flooding waste locales and expanding levels of contamination. Actually, the GSCM is a business esteem driver and not a cost focus [45];[17].

A successful way for SC managers to strengthen the reliability of SCs is to complete a benchmarking exercise to assess how well their SC is performing. In order to complete such an exercise, a benchmarking approach for GSC performance can help benchmark SCs based on their impact on the operational performance factors.

Based on the data collected and analyzed, Figure 4 presents the refined conceptual framework for GSCM practices for petrochemical companies in Egypt.

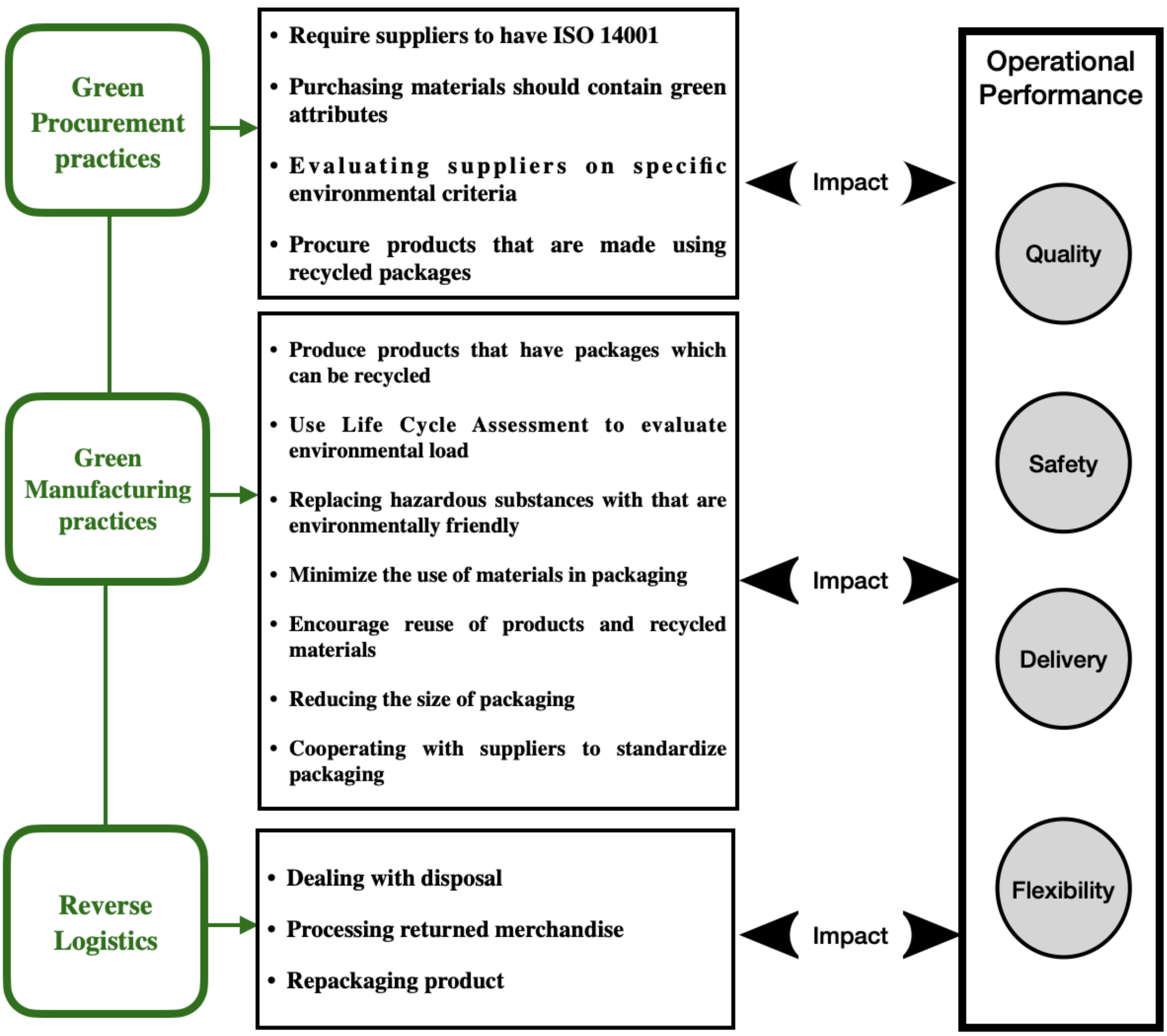

Fig. 4. Conceptual framework for GSCM practices for petrochemical companies in Egypt.
Source: developed by the authors.

The empirical results fulfilled the objectives of the study and generated adequate evidence for practitioners and decision makers to understand the various kinds of GSCM practices and to what extent the adopted practices influence the operational performance. Moreover, the research strongly supported the view that to green the environment requires collective responsibility and cross-functional cooperation for environmental improvements by the petrochemical's companies.

Likewise, this study specifies several empirical evidences for the impact of three dimensions of GSCM practices (green purchasing, green manufacturing, and reverse logistics) on four operational performance dimensions (quality, safety, delivery, and flexibility) and customer satisfaction. Based on the analysis of the comebacks collected from the respondents of the study, Shell Egypt has already begun to implement GSCM practices such as deliberating suppliers‟ ISO 14000 certification; purchasing materials that contain green attributes; evaluating the suppliers on specific environmental criteria; replacing hazardous substances with those that are environmentally friendly, etc. Consistent with the current literature, GSCM practices drives the entire chain stakeholders to deal effectively with environmental problems, from the beginning of product design, development, and production, to reach the end user [22]; [7] . Thus, these implications offer guidelines to petroleum and lubricant manufacturers to enhance their operational performance and customer satisfaction while employing GSCM practices throughout their entire SC.

V. CONCLUSIONS AND RECOMMENDATIONS

This study was carried out to determine the effect of GSC practices on operational performance using a benchmarking study between Shell Egypt and Co-op Petroleum Company working in the lubricant industry. The study had two objectives. The first was to determine the extent of GSC practices used by Shell and Co-op Petroleum Company in Egypt; the second objective was to establish the relationship between green SC management practices and operational performance of Shell and the Co-op Petroleum Company in Egypt. The study showed that Shell Egypt, which operates in the lubricant industry, appreciates the role of green supply chain practices. The company practices green procurement. Most practices are to ensure that suppliers comply with their environmental goals, purchase green materials, purchase energy-saving equipment, and other green manufacturing practices adopted by Shell. Furthermore, Shell also uses recycling and collaboration with suppliers to standardize packaging and then reduce package size. Shell has faced challenges in implementing green supply chain practices but has access to the tools and techniques needed to measure the performance of green supply chain management. This corresponds to the challenges identified by the Rider Center for Supply Chain Management (2008). The three independent variables of GSCM practices have clearly improved recycling and reuse opportunities, as well as improved operational performance and thus customer loyalty. As for the Co-op Petroleum Company, it is clear that they used raw materials and packaging materials that cannot be recycled and that are non-reusable, although the Co-op Company has realized the importance of GSCM practices. Environmental issues are not used in the selection criteria of suppliers because of the company's lack of appropriate technology, which is a major challenge. It also lacks the GSCM, which had a direct negative impact on customer loyalty.

Therefore, GSCM is an operational innovation that petrochemical firms may adopt to address environmental concerns, such as, complying with stringent environmental regulations, addressing the environmental concerns of their suppliers and customers, and to mitigating the environmental impact of their production and service activities. In the future, implementing a GSC will be even more important than it is today. Reasons for this are: Concentrating on more government legislation, growing awareness of environmental issues and motivating consumers to be more sustainable. Thus, greening the SC is not an alternative, it is becoming a norm.

The area of GSCM is relatively young and is still suffering from a shortage of information. This research will help to bring forth unknown information in the petroleum industry that will go a long way in facilitating further understanding of GSCM practices adoption. Future researchers will empirically test the relationships suggested in this paper in different companies to enable comparative studies. A larger sample would also allow detailed cross-sectoral comparisons which are not possible in the context of this study. To be efficient and effective in GSCM, collaboration among important stakeholders in the petroleum marketing firms supply chain must be strongly concerned. This study recommends the creation of awareness of the role of GSCM practices for the benefit of all the stakeholders and for sustainable economic and environment development.

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