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E-WASTE FROM TECHNOLOGY USE IN THE OIL AND GAS SECTOR: THE SNEAK PEEK

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ABSTRACT

Electronic Waste (E-Waste) generation has been escalating since the past decade. Soundly managing this particular type of waste is one of the methods in creating a more sustainable world for the future. The terms digitization, digitalization, and digital transformation are spurring across all the industries vertically and horizontally. In aligning the business strategy and information technology strategy, cooperation from various industries is investing in the latest and advanced technologies to stay forefront with the movement of Industry 4.0. This reflects the input which is one end of the product value chain. Meanwhile, another end of the product value chain is the output. The output is signified by the amount of E-Waste generated, once Electrical & Electronics (E&E) equipment and Internet-Of-Things (IoT) hardware, electronic circuits, and sensors reached the End-of-Life (EOL). This paper will provide a sneak peek into how much E-Waste is highlighted in the oil and gas industry. It is a part of research that studies the management of E-Waste in the oil and gas industry. Design Thinking is introduced into the methodology that is implemented simultaneously with the single case study approach. The research model is based on the DPSIR Model, which stands for Driver-Pressure-State-Impact-Response Model.

Keywords: *E-Waste, Internet of Things, Environmental Sustainability, Oil and Gas Sector, DPSIR Model*

1. INTRODUCTION

Technology these days strives to make living daily lives as easy and as effortless as possible. One of the Information Technology (IT) concept that represents that is the Internet of Things (IoT). IoT refers to when devices are connected through the internet and can generate, communicate and receive data with little human assistance as possible [1]. This concept is a huge hit in the technology industry thus making the amount of IoT devices available increase as the day goes by.

Currently, IoT devices do not stop at RFID but there are sensors, smartphones, and drones too just to name a few [2]. That article furthermore elaborated that this technology is allowing machines to become smarter by the day and at present times, they are skillful enough to process data that can be used for more efficient and effective communication. The latest focus concerning IoT is Green IoT. Green IoT refers to efficiently using IoT while ensuring that it is as environmentally friendly as possible [3]. This concept is gaining an increasing amount of interest due to its alignment with the Sustainable Development Guidelines founded by the United Nations.

This study will be focusing on the electronic wastes (E-Waste) generated from industrial devices. From here on, the term E-Waste will be used to refer to the mentioned focus. The study also aims to use an oil and gas company as a case study to deeply understand this matter. The oil and gas industry is one of the many industries that are highly dependent on the advancement of technology to carry out their daily business activities. The

industry is speeding up in taking the initiative to implement the latest technology available [4,5]. Thus, IoT technologies have only been widely implemented these past few years.

Unfortunately, this seems to have created a domino effect on the generation of E-Waste. The wide implementation of IoT in the industry surely allowed the companies to carry out their daily business activities with fewer efforts. However, this also increased the rate and amount of electronics that one organization goes through thus making E-Waste generated from the usage of IoT grow in amount as we speak [6]. E-Waste that is not properly managed will negatively impact the state of environmental sustainability.

This paper will focus on understanding how E-Waste is related to environmental sustainability by using the oil and gas sector in Malaysia as a case study. To understand this, the author will elaborate on how much coverage that E-Waste has in this aforementioned sector.

In Malaysia's oil and gas industry, there is a lack of guidelines for E-Waste management. The lack of awareness on how E-Waste can negatively impact environmental sustainability may be contributed by the lack of a proper guideline. IoT devices are being used extensively in the oil and gas industry. So far, public awareness seems to be limited to just understanding that this technology will make daily activities easier and smarter. Most users all around the world tend to forget that these devices have their end-of-life dates which will then turn them into waste once not in use.

E-Waste has been dubbed one of the fastest-growing sources of waste worldwide by researchers [7,8]. The main reason being the fast pace of technological growth in the current world we are living in. Generally, E-Waste in the majority comes from home appliances and handheld devices that are outdated by the newer released devices [8].

In an industry that focuses on exploring and producing energy, E-Waste mostly refers to sensors that allow for real-time data monitoring and specialized networks such as Low-Powered Wide Area Network (LPWAN) [9]. With the amount of IoT devices used throughout the industry, it is bound to be responsible for negative impacts on environmental sustainability to a certain extend. The authors hope that by using a specific industry in Malaysia, a clearer understanding of E-Waste awareness can be achieved.

Studies on E-Waste have been in abundance due to the fast-changing pace of technology which results in a high device turn-over rate [7,8]. In the context of this study, Industrial E-Waste refers to E-Waste produced from unwanted or end-of-life IoT embedded devices that include all the hardware parts, electronic circuits and sensors used that are produced in an industrial setting. Cambridge Dictionary defines industrial as "in or related to the industry or having a lot of industry and factories". This work will be studying the management of Industrial E-Waste in an oil and gas industry by using Company A as a case study. An exploration by using research questions will be conducted upon a selected Company A plant throughout the research duration.

The oil and gas sector is chosen as a focus because it is still one of the biggest players in economic growth [4,5,10]. The world is still very reliant on this mature industry as an energy source provider. The usages of raw oil and gas materials cover road transportation, air transportation, chemicals for lab usage, and even daily products like cosmetics. This industry is also currently moving towards digitization, digitalization, and digital transformation [4,10]. The pressure of meeting the demand of consumers has resulted in the industry using the latest technology to make the most of the remaining raw fuel for exploration [11].

The research will be carried out by asking the following three questions. (1) How is Industrial E-Waste managed in the oil and gas sector? (2) What are the most suitable Industrial E-Waste management practices for oil and gas plants? And lastly, (3) How to enhance the management of Industrial E-Waste in the oil and gas sector?

Correspondingly, three objectives have been identified and they are (1) To investigate current practices of Industry E-Waste management for the oil and gas sector, (2) To propose Industry E-Waste management guidelines for the oil and gas sector, and (3) To recommend good practices for Industry E-Waste management implementation for the oil and gas sector.

The findings for this study aim to be helpful for oil and gas companies by showing the difference in management actions taken by other companies in Industrial E-Waste management. This particular information is obtained from preliminary studies carried on existing research articles. The difference can be eye-opening and thus prompting other companies to make necessary changes as well. Meanwhile, policymakers can use the findings to

create a guideline for Industrial E-Waste management in the oil and gas industry. Finally, this study hopes to inspire other researchers and ultimately results in further studies carried out in this area of study.

2. LITERATURE REVIEW

The following section will be consisting of a few subsections that were observed from reviewing multiple articles. The subsections are Industry 4.0, IoT, Green IoT, E-Waste Management, E-Waste Management in the Oil and Gas Sector, Related Policies in Malaysia, and Environmental Sustainability in the Oil and Gas Sector.

2.1 Industry 4.0

The fourth industrial revolution or more commonly known as Industry 4.0 has been the talk of towns since it was first mentioned in 2011 [12]. This concept was first planned for assisting Germany in building up its economy. It was well accepted more universally than expected. Since then, the term has been used globally when discussing modern industrial development. Despite its wide acceptance across the globe, academicians have failed to come up with one definition that is agreed by all. Not only is Industry 4.0 defined differently depending on the area of knowledge, but it is also interchangeably used with other terms such as "Industrial Internet", "Factories of the Future", Digital Factory" and "Smart Factory" [11].

The term Industry 4.0. is defined as intelligent manufacturing that is the result of information and communication technologies integrating with industrial technology [13], or the implementation of several information technologies into one [14,15]. On the other hand, IoT is "the integration of complex physical machinery and devices with networked sensors and software, used to predict, control and plan for better business and societal outcomes" according to Consortium II. [16].

Despite having several representations on the definition, it ultimately carries the same message which is a development approach that focuses on upgrading the automation process by using a set of enabling technologies, digitalization, and the Internet [11]. Internet of Things (IoT) is one of the technologies that is encompassed in Industry 4.0. Others include Radio Frequency Identification (RFID), Enterprise Resource Planning (ERP), and Big Data. The following subsection will elaborate on IoT.

2.2 Internet of Things (IoT)

Internet of Things (IoT) has been highlighted as one of the main drivers of Industry 4.0. Integrating IoT into manufacturing systems has been said to help in solving the world's challenges in resource and energy efficiency [15]. This technology endorses that all electrical devices in this world can and should be connected because it can allow for better communication, easier knowledge or information transfer, and less hassle for data gathering [17]. Communication of devices is made possible due to the internet, sensors embedded in the devices, and software [18]. The use of IoT in the industry is called Industrial IoT.

Hewlett Packard Enterprise (HPE) and Morgan Stanley both defined the Industrial Internet of Things (IIoT) as the connection of machinery and robots using the network of sensors and the internet [19,20]. HPE further mentioned that IIoT devices range from tiny environmental sensors to big complex industrial robots. Industries like oil and gas have been depending on IIoT to assist in their daily business activities. IIoT has assisted the oil and gas industry in refinery monitoring, cargo shipping, and Supply-Chain Management, just to name a few. This technology has improved efficiency and reduced downtime during operations for the industry [21]. In recent years, a variation of IoT which is Green IoT has been gaining a lot of attention for highlighting a looming environmental problem in an IT concept.

2.3 Green IoT

As mentioned earlier, Green IoT is a variation of IoT that refers to efficiently using IoT while ensuring that it is as environmentally friendly as possible [3,22]. Researchers have proposed a variety of solutions for Green IoT such as Green Cloud Computing, Green Datacenters, Green Sensor Networks, and Green RFIDs [23–27]. Green IoT has two classifications of techniques which are based on software and hardware [3]. As the name suggests, changes can be made by using a greener option for software and hardware during the implementation of IoT.

This need for a greener option came about after researchers realized that the increased use of IoT will subsequently increase the generation of E-Waste, increase energy consumption, and increase Carbon Dioxide (CO_2) emissions [28]. The article further suggested that Green IoT sheds its focus on two aspects. First is "designing IoT computing devices, communications protocols, and networking architectures" and the second is finding the best practices with IoT technology implementations that

at the same time will not cause too much harm to the environment. The next subsection of the literature review will focus on E-Waste management which is the focus of this work.

2.4 E-Waste Management

Appropriately managing waste is a constant challenge that is faced by various industries in the world. Recent studies have shown that recycling waste or particularly electronic waste would bring benefits not only to the environment but also to the economy [29]. This study will be focusing on electronic waste. Electronic waste (E-Waste) is also known as waste electrical and electronic equipment (WEEE). E-Waste is defined as any device that functions by depending on electricity or electromagnetic field but is not in use anymore [6].

IoT is a part of information technology that depends on the ability of machines to keep up with the ever-changing technology advancement. Due to the fast pace of technology evolvement and their related devices, there are bound to be wastes produced along the way. Currently, E-Waste is one of the fastest-growing types of waste in the world. It was estimated that the amount of E-Waste will increase by 3% to 5% each year thus accumulating to about 30 to 50 million tons per year in the next few years [29]. The Department of Environment Malaysia (DOE) estimated that Malaysia alone would produce approximately 24.5 million units of E-Waste by 2025 [30].

Proper waste management strategy differs depending on where the country is located. Developed countries such as the US, China, and countries in Europe have made E-Waste management a high priority due to the amount of E-Waste that they produce annually [31]. Managing E-Waste is different from managing general waste due to the elements that make up one device and different device is made up of different elements. Thus, specially curated directives or policies are essential in implementing E-Waste management. Directives such as the WEEE Directive (Directive 2012/19/EU) which was created for managing End of Life (EoL) devices are widely used in European countries. The mentioned directive stated that EoL E-Waste must follow the waste management procedures created due to it containing hazardous substances [29,32].

Implementing a suitable policy or directive is not enough, one must use a management facility that can contain the possible hazardous gas released during the process of recycling. E-Waste is widely known to be one of the most valuable kinds of waste generated out there. This has encouraged a lot of unofficial business activities to carry out without the knowledge of the country's government [6]. Open burning may release polybrominated diphenyl ethers (PBDE) and polybrominated biphenyls (PBBs) toxin which would eventually release carbon dioxide (CO2) [31,33]. Large amounts of CO2 would heat the Earth's atmosphere and trigger bigger climate change but if E-Waste is properly recycled, Greenhouse Gas (GHG) emissions would go down by 10% [34]. Most developed countries that lack suitable management facilities eventually resort to exporting waste to developing countries. Managing E-Waste itself is a great task so imagine if it was in the context of the oil and gas sector.

2.5 E-Waste Management in the Oil and Gas Sector

It has been established from previous works of literature that managing E-Waste is very challenging. However, it is especially harder for the oil and gas industry because most waste that is produced within this industry is contaminated or has a high risk of being contaminated with hazardous chemicals [35]. E-Wastes originating from this industry is more hazardous than the average household E-Waste due to the environment that it was surrounded by [35]. Shell Nigeria once shared that oil and gas companies struggle to manage their wastes because wastes generated from the exploration and production of oil and gas (E&P) require specialized technologies and facilities [36]. Shell at that moment like most companies addresses E-Waste as WEEE which is a part of hazardous wastes.

China National Offshore Oil Corporation (CNOOC) in Uganda mentioned in one of their waste management assessment reports that WEEE falls under associated hazardous wastes [37]. Other technology-related waste includes batteries, transformers, and capacitors. Due to the non-alarming amount that is expected to be produced during development, CNOOC suggests that WEEE either be imported to a different country or dumping at a local landfill. Given the nature of Uganda, specialized landfills are not available [37].

A study released in 2015 discussed the challenges of waste management in oil and gas [35]. The author highlighted WEEE and mentioned batteries as part of E-Waste commonly found at oil rigs. Members of the oil and gas industry all across the globe are using the classic approach that includes source reduction, reuse, recycling, or recovery and treatment [35,37]. Reuse of E-Waste

is a positive option because most of the time, devices used in industries are replaced due to it not performing optimally despite it still working. Certain substances in the devices may be extracted and used for a different device. Reduce simply means minimizing the unnecessary purchase of devices. Recycling is sending the wastes to specialized facilities to be dismantled and repurposed at different places.

Treatment refers to breaking down or neutralizing wastes through specific processes [37]. A popular option for oil and gas E-Waste is the supplier take-back scheme because it meets all the mentioned approaches just now [36]. Oil and gas companies all around the world would buy a huge amount of electronics at one time. Recently as an effort for responsible waste management, these suppliers would suggest that the companies return the electronics after it reaches EOL. It is a beneficial situation where the waste is now under the suppliers' responsibility instead.

Since specialized E-Waste management facilities are hard to come by in most countries, transboundary disposal is another preferred option for waste management [36]. Transboundary disposal refers to companies exporting E-Waste that they produced to other countries. This E-Waste is usually dumped in third-world countries [38]. Despite laws implemented in targeted dumping countries, E-Waste is still being exported illegally due to its profitable nature. Based on Malaysia's EQA, electronics that had gone over 3 years from the manufacturing date are not allowed into the country [39].

With the growing amount of waste by the day, major oil and gas companies are looking into increasing initiatives to improve their waste management efforts. Royal Dutch Shell mentioned that in 2018, their logistics, information technology, and waste support team developed waste management software [40]. They believe that this development will be able to bring positive change through an automated and centralized system.

BP has been looking into implementing a circular economy into its businesses for the last few years [10]. From producing jet fuel using household waste to renewable gas from food and agricultural waste, BP is on the top of its environmental sustainability game. However, based on their 2018 Sustainability Report, there has been little to no mention of E-Waste management. Same situation with PETRONAS where their current focus in waste management is chemical wastes and wastewaters [4].

2.6 Related Policies in Malaysia

This part of the literature review will discuss existing policies that are related to E-Waste in Malaysia. So far, Malaysia is using Environmental Quality (Amendment) 2012 – Act A1441 to guide waste management in general [41]. This is the main legal document that is acting as a guide to companies based in this country. Despite being amended a few times over the years, the document still lacks focus on E-Waste. There is currently no separate regulation or policy specifically for E-Waste but in 2010, the Department of Environment (DoE) released the updated version of the "Guidelines for the Classification of Used Electrical and Electronic Equipment in Malaysia" [32]. The guideline was released to assist parties involved in E-Waste management to identify equipment that is eligible to be classified as E-Waste.

DoE has classified the types of E-Waste found in Malaysia based on their origin. E-Waste falls under the code SW 110, "waste from electrical and electronic assemblies containing components such as accumulators, mercury-switches, glass from cathode-ray tubes…" and a few other chemicals. Another source listed the types of electrical and electronic equipment that can be classified as SW 101. Examples are used electric cable, used cathode ray tube, used motherboard, used hard disk drive, and a few more [32]. Waste management facilities, companies, and household communities use the act and guidelines to collect specific types of E-waste.

2.7 Environmental Sustainability in the Oil and Gas Sector

Over 30 years ago, the United Nations described sustainability as satisfying the current needs of society without sacrificing the rights of future generations in meeting their own needs [42]. Environmental sustainability is important especially for the oil and gas industry. 2019 Society of Petroleum Engineers (SPE) President Sami Alnuaim talked about where environmental sustainability sits in the oil and gas industry.

Environmentally sustainable development refers to carrying out business activities while minimizing negative impacts on the surrounding environment. This industry is working hard towards enhancing environmental performance. One of the initiatives implemented by industry players is incorporating the best environmental practices throughout the business phases [43]. Being a part of an industry that exploits a finite amount of natural resources, it is a requirement that a company in this industry integrates environmental regulations

related to the area that the business will be located at [44].

Companies in the industry that carry out production activities are very likely to use an existing environmental policy inside their organization while a selected few would write up a policy that is customized to their company's needs. Federal Mineral Resources Act in the United States specified that sustainable use of natural resources includes the act of pollution prevention during exploration. Exploring and extracting raw oil from the sea floors tend to create hazards such as the discharge of sludge into the seawater. Sludge waste is created from water, product residuals, and solids such as sands and rust [35].

SPE President further mentioned that when it comes to environmental sustainability, oil and gas concerns have been climate change and carbon dioxide (CO2) for a while now [43]. The general public has the impression that those are the only problems regarding the environment that this industry is concerned about. However, there are more risks and problems that the oil and gas companies have to deal with. Right, and sound management of waste is becoming a growing concern in the industry which further highlights the need for a standard guideline for IoT E-Waste in the oil and gas industry.

This literacy review has been a sneak peek into what are the current practices of E-Waste management in the oil and gas sector which is the first objective of this research study. Unfortunately for Malaysia, there has not been an extensive number of acts, guidelines, rules, and regulations for E-Waste management. This extends to the oil and gas industry as well because the industry will implement any acts and regulations that the DOE creates.

3. RESEARCH METHODOLOGY

This section of the paper consists of three sections. The first section will talk about how the literature in this paper is retrieved. Meanwhile, the second section is Research Design where the method on how that the study is carried is explained. Lastly is the detail on the research model selected for this study with elaboration on the use of Design Thinking.

3.1 Literature Source and Collection

For the writing of this paper, multiple searches were carried out on several databases namely Google Scholar, ScienceDirect, IEEE, and ResearchGate. Writers aimed for credible publications in the form of journals, textbook chapters, conference proceedings, and official newsletters. It is arguable whether conference proceedings can be a reliable source of literature, but it is very useful as grey literature. Grey pieces of literature are good tools to decrease publication bias and increase balance in the overall summary of accessible publications [45].

Grey literature is mostly retrieved from Google Scholar and IEEE. These databases are great in helping the writer to understand the current trend of papers and gaps in research [46]. As this paper is exploring the topic of E-Waste management in the oil and gas industry, some relevant information is available on the companies' official websites.

Various search strings were used to search for suitable publications that were published recently and contained strings which are listed in **Table 1**. To help with the writing of this paper, the researcher changed a few search strings such as instead of just "oil and gas industry", the search is simplified to just "industry" to increase the number of publications returned. Results are also restricted to publications from 2015 and later only.

Table 1: Overview of search results and study selection.

Search Strings	After Selection Criteria (Abstract)	After Selection Criteria (Full-Text)	After Quality Assessment
E-Waste Impacts	42	32	11
Waste Management in Oil and Gas	23	16	8
Environmental Sustainability in Oil and Gas	7	6	4
Waste Management Policies	5	2	2
Waste Management Policies in Malaysia	3	3	3
Industry 4.0	32	21	10
Green IoT	24	10	7
Others (Information on Oil and Gas Companies)	17	11	4
Total	153	101	49

The pieces of literature used in this paper are not limited to the search results only. A few sources are from personal reading, sharing, and referenced from existing works. The works of

literature chosen to be used in this paper are subject to relevance regarding the aim of this paper which is to study E-Waste management in the oil and gas industry.

3.2 Research Design

For this study, a qualitative research methodology is implemented. This research is conducted using semi-structured interviews by using a plant as a case study. This method is highly recommended by Robert K. Yin in his 2003 book, "Case Study Research: Design and Methods" due to its ability to "…retain the holistic and meaningful characteristics of real-life events…". This method strives to understand the experiences of participants, the context of actions, the reason for such event, and why it occurs rather than factors and causes [47]. The use of a case study is also appropriate because it helps examine "how" questions in a research where the researcher has little to no control over events [48]. This is in line with Research Objective 1 which is to investigate current practices of Industry E-Waste for the oil and gas sector in Malaysia.

Below is the flowchart of research activities for this study.

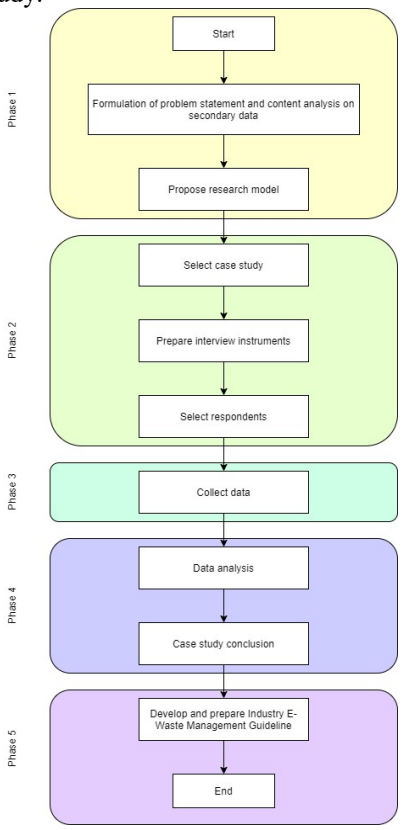

Figure 1: Flowchart of Research Activities

As Figure 1 suggests, 9 steps are then divided into 5 phases. These steps were formulated based on the book by Robert K. Yin, "Case Study Research Method" and altered to match the requirements of this project.

Phase 1:

As this is an exploratory study, Phase 1 requires the formulation of a problem statement and a content analysis to be carried out on secondary data. Secondary data in this context may refer to and not be limited to sustainability reports, environmental policies, and journal articles. Studying these data will help establish research gaps thus coming up with a good problem statement. A suitable model is then formulated and proposed based on the analysis carried out. This model serves as a guide during data collection and is not final. For this study, the Driver-Pressure-State-Impact-Response (DPSIR) model is proposed to guide in research.

Phase 2:

This study is using the single-case study research method thus the author must select a case study to be used in this phase of the research. Phase 2 looks into selecting a case study, preparing interview instruments, and selecting respondents. The author has chosen to use a semi-structured interview as the method to carry out data collection. This method works well with qualitative studies as suggested by Robert K.Yin [48]. Company A will be the case study for this research and employees from various expert areas are the respondents.

Phase 3:

Phase 3 looks into the actual data collection. As mentioned previously, data is collected through semi-structured interviews. Due to the pandemic, site visit and a face-to-face interview was not the best option for data collection. The interview sessions are carried out online and recorded after receiving consent from the respondents.

Phase 4:

Steps 7 and 8 in Phase 4 are for data analysis. Data collected are then transcribed and will be analyzed using the software Atlas.ti. Atlas.ti is a computer software that is mainly used in qualitative data analysis. Responses received from each interview will be processed and analyzed before the next interview is carried out.

Phase 5:

Finally, Step 9 will be the development phase of the whole research. A specially curated guideline for Company A will be developed based on the data analyzed.

3.3 Research Model

The proposed research model is based on the DPSIR model. DPSIR stands for Driver-Pressure-State-Impact-Response model. This model was first developed as a stress-response model but in later years, the Organization for Economic and Cooperation Development (OECD) implemented it as a Pressures-State-Response (PSR) model [49]. European Environment Agency (EEA) then implemented this model as a guide for reporting to assist policymakers in identifying cause-effect relationships between humans and the environment [50].

As the model suggests, driving forces refer to activities or processes that cause pressure. Driving forces or sometimes known as drivers in certain documents refer to the social, demographic, and economic development taking place in societies [51]. Driving forces generate pressures which are human activities that are carried out to fulfill the needs. The activities are called pressures because of the intentional or unintentional pressures that put a strain on the environment. Thus, in this study, pressure is the act of Exploration and Production (E&P) from onshore/offshore plants and platforms of oil corporations. State refers to the current state of the ecosystem.

Depending on the amount of pressure applied by the surrounding society, the state of the ecosystem may vary. Certain Exploration and Production (E&P) activities release waste substances or waste products that alter the state of the environment. Impacts are provoked by states thus it refers to the effects that a previous condition has induced on the environment. Simply, it refers to the changes in the quality or functions of the ecosystem which eventually negatively impact the surrounding society. The final component is responses. Responses refer to the decisions made by humans in response to the impacts upon the environment from the production of IoT E-Waste from onshore/offshore plants and platforms. This study will propose the best practice as well as a guideline E-Waste management for Oil and Gas Corporations.

The DPSIR model is illustrated in Figure 2.

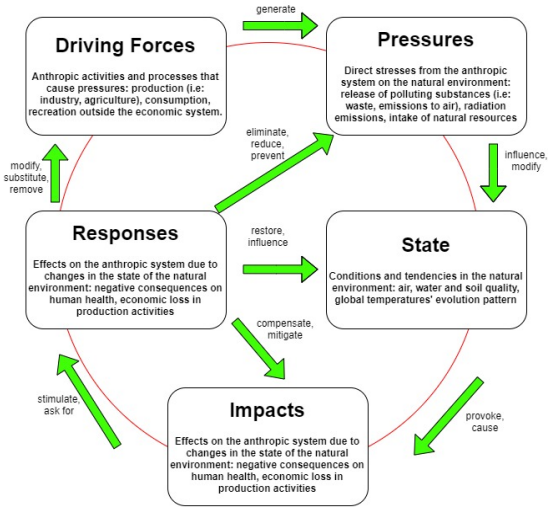

Figure 2: DPSIR Model

Simultaneously, this research implements the Design Thinking approach, which inclusively incorporates the single-case study method. Design Thinking is the process of where an individual works towards understanding the user, defy assumptions and reconsider problems of a certain topic [52–54]. The five phases that construct Design Thinking are (1) Empathize, (2) Define, (3) Ideate, (4) Prototype, and (5) Test. At the Empathize Phase, the researcher works toward gaining an emphatic understanding of the problem of user/customer/employee/top management of the chosen Oil and Gas Corporation in Malaysia. Detailed research and on-site observations are carried out such as interviews, observations with recordings through photos or even videos.

Whilst, the Define phase is establishing a problem statement that is derived from the emphatic understanding achieved from the previous phase. Next, the phase Ideate is carried out with the user/customer/employees/top management. This method strives to understand the needs and experiences, the context of actions, the reason for such event, and why it had occurred [47,55]. The proposed best practices and development of the guideline on E-Waste Management will be conducted at the Prototype Phase. The prototype (best practices and guidelines) will be validated with the experts and user/customer/employee/top management at the Test Phase.

4. DISCUSSION

This work is a part of the effort on better understanding the awareness on E-Waste management in the industrial settings of Malaysia. As mentioned previously, household E-Waste

management is more highlighted and discussed because a huge percentage of E-Waste generated around the world is from households. By changing the focus on industries, it is hoped to offer a different perspective to the body of knowledge. Company A from the oil and gas industry is chosen to be the case study in this stage of the study because researchers want to focus on fully understanding how E-Waste management is carried out within the entity. The data that will be collected from this Company A will be a sneak peek on the awareness of E-Waste management in the Malaysian oil and gas sector.

As per the literature review in subsection 2.5, E-Waste management have been discussed by oil and gas companies from different parts of the world (10,35–37,56). However, there has yet been a paper that focuses on industrial E-Waste in Malaysia and with Company A specifically. Hence, the authors decided to focus this paper in discussing E-Waste management within the context of Malaysia and the oil and gas sector of Malaysia. It has resulted in a very niche focus area of knowledge. However, this may be a disadvantage from a different perspective. Due to a very niche area, the amount of data that is collectable and comparable is limited. Despite broadening the context to within Malaysia, the information obtained is still lesser compared to developed countries. Nonetheless, the literature review subsection titled *E-Waste Management* discussed the negative impact that can be observed through climate change (31,33,34).

5. LIMITATIONS AND FUTURE DIRECTIONS

This paper has highlighted the subject of E-Waste in the context of the oil and gas industry. However as mentioned in the literature review section, the number of legal documents surrounding E-Waste management in Malaysia is very limited. Another limitation is in the sense of information made public by oil and gas companies across the globe. As discussed in the subsection titled *Environmental Sustainability in the Oil and Gas Industry*, this industry is concerned about the negative impacts that they may add to the environment. Unfortunately, their press releases and sustainability reports rarely highlight E-Waste management. Sound management of E-Waste is more discussed in the household context making it not relevant for this paper.

For future directions, the authors suggest a deeper study on how oil and gas companies are putting effort into maintaining environmental sustainability. One may start with other oil and gas companies in Malaysia then expand from there. A study that solely focuses on E-Waste awareness in this industry would be a good approach as well.

CONCLUSION

This study aims to study the management of E-Waste in the oil and gas industry. Therefore, a case study on Company A centering around Industrial E-Waste management is carried out during the research period. So far, preliminary data collection has shown the lack of a specific management guideline for this type of waste within the industry hence the problem statement.

The process of digitization, digitalization, and digital transformation is spreading rapidly across industries. Being agile and technologically advanced will enable any cooperation to stay competitive and niche for a strong market positioning for the longest time. The oil and gas sector is not only investing in new products and services but also in technology advancement in providing the facilities of future for the vessels, platforms, and plants on both onshore and offshore activities. However, it is a given that there is a consequence for every single action.

The said research aims to collect the appropriate data to suggest best practices in increasing awareness among the employees and surrounding society. The road towards ensuring environmental sustainability is an uphill walk but creating awareness in this matter will sure have a positive outcome in the long run.

REFERENCES:

[1] Rose K, Eldridge S, Chapin L. The Internet of Things: An Overview. Internet Soc. 2015;80.

[2] Alsamhi S, Ma O, Ansari S, Meng Q. Greening Internet of Things for Smart Everythings with A Green-Environment Life: A Survey and Future Prospects. 2018.

[3] Khan N, Sajak A, Alam M, Mazliham M. Analysis of Green IoT. In 2020.

[4] PETRONAS. PETRONAS Sustainability Report 2018. 2019.

[5] PETRONAS. PETRONAS ACTIVITY OUTLOOK 2019 - 2021. PETRONAS; 2018.

[6] Böni H, Hernández C, Schluep M, Valdivia S, mendez-fajardo S. A practical guide for the systemic design of WEEE management policies in developing countries. 2017.

[7] Kumar S, Singh V. E-waste: generation, environmental and health impacts, recycling

and status of e-waste legislation. J Emerg Technol Innov Res [Internet]. 2019;6(4):592–600. Available from: https://www.researchgate.net/profile/Vinti_Singh/publication/332874565_E-WASTE_GENERATION_ENVIRONMENTAL_AND_HEALTH_IMPACTS_RECYCLING_AND_STATUS_OF_E-WASTE_LEGISLATION/links/5ccfc9f692851c4eab8616d5/E-WASTE-GENERATION-ENVIRONMENTAL-AND-HEALTH-IMPACTS-RECYC

[8] Perkins DN, Drisse M-NB, Nxele T, Sly PD. E-Waste: A Global Hazard. Ann Glob Heal [Internet]. 2014;80(4):286–95. Available from: http://www.sciencedirect.com/science/article/pii/S2214999614003208

[9] Joshi N. Refining The Oil and Gas Industry with IoT. Forbes [Internet]. 2019 Sep; Available from: https://www.forbes.com/sites/cognitiveworld/2019/09/17/refining-the-oil-and-gas-industry-with-iot/#75dde49179f9

[10] BP. BP Sustainability Report 2018. 2019.

[11] Büchi G, Cugno M, Castagnoli R. Smart factory performance and Industry 4.0. Technol Forecast Soc Change [Internet]. 2020;150:119790. Available from: http://www.sciencedirect.com/science/article/pii/S004016251931217X

[12] Lu Y. Industry 4.0: A survey on technologies, applications and open research issues. J Ind Inf Integr [Internet]. 2017;6:1–10. Available from: http://dx.doi.org/10.1016/j.jii.2017.04.005

[13] Zhou K, Liu T, Zhou L. Industry 4.0: Towards future industrial opportunities and challenges. In: 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD). 2015. p. 2147–52.

[14] Chiarello F, Trivelli L, Bonaccorsi A, Fantoni G. Extracting and mapping industry 4.0 technologies using wikipedia. Comput Ind [Internet]. 2018;100(September 2017):244–57. Available from: https://doi.org/10.1016/j.compind.2018.04.006

[15] Henao-Hernández I, Solano-Charris EL, Muñoz-Villamizar A, Santos J, Henríquez-Machado R. Control and monitoring for sustainable manufacturing in the Industry 4.0: A literature review. IFAC-PapersOnLine [Internet]. 2019;52(10):195–200. Available from: http://www.sciencedirect.com/science/article/pii/S2405896319308778

[16] Maresova P, Soukal I, Svobodova L, Hedvicakova M, Javanmardi E, Selamat A, et al. Consequences of Industry 4.0 in Business and Economics. Economies [Internet]. 2018;6(3). Available from: https://www.mdpi.com/2227-7099/6/3/46

[17] Benkhelifa E, Abdel-Maguid M, Ewenike S, Heatley D. The Internet of Things: The eco-system for sustainable growth. In: 2014 IEEE/ACS 11th International Conference on Computer Systems and Applications (AICCSA). 2014. p. 836–42.

[18] i-SCOOP. The Internet of Things (IoT) - essential IoT business guide [Internet]. i-SCOOP. Available from: https://www.i-scoop.eu/internet-of-things-guide/#Defining_IoT_8211_many_approaches

[19] Hewlett Packard Enterprise. HPE: What is IIoT? [Internet]. Hewlett Packard Enterprise. [cited 2019 Nov 20]. Available from: https://www.hpe.com/my/en/what-is/industrial-iot.html

[20] Morgan Stanley. The Internet of Things and the New Industrial Revolution [Internet]. Morgan Stanley. Available from: https://www.morganstanley.com/ideas/industrial-internet-of-things-and-automation-robotics

[21] i-SCOOP. The Industrial Internet of Things (IIoT): the business guide to Industrial IoT [Internet]. i-SCOOP. Available from: https://www.i-scoop.eu/internet-of-things-guide/industrial-internet-things-iiot-saving-costs-innovation/#The_definitions_of_Industrial_IoT_and_IIoT

[22] Rani S, Talwar R, Malhotra J, Ahmed SH, Sarkar M, Song H. A novel scheme for an energy efficient internet of things based on wireless sensor networks. Vol. 15, Sensors (Switzerland). 2015. p. 28603–26.

[23] Farahnakian F, Ashraf A, Pahikkala T, Liljeberg P, Plosila J, Porres I, et al. Using Ant Colony System to Consolidate VMs for Green Cloud Computing. IEEE Trans Serv Comput. 2015;8:187–98.

[24] Chiang Y-J, Ouyang Y-C, Hsu C-H. An efficient green control algorithm in cloud computing for cost optimization. IEEE Trans Cloud Comput. 2015 Apr;3(2):145–55.

[25] Li S, Xu L Da, Wang X. Compressed Sensing Signal and Data Acquisition in Wireless Sensor Networks and Internet of Things. IEEE Trans Ind Informatics. 2013 Nov;9(4):2177–86.

[26] 26. Kiourti A, Lee C, Volakis JL. Fabrication

of Textile Antennas and Circuits with 0.1 mm Precision. IEEE Antennas Wirel Propag Lett. 2016;15:151–3.

[27] Pang Z, Chen Q, Han W, Zheng L. Value-centric design of the internet-of-things solution for food supply chain: Value creation, sensor portfolio and information fusion. Inf Syst Front [Internet]. 2015;17(2):289–319. Available from: https://econpapers.repec.org/RePEc:spr:infosf:v:17:y:2015:i:2:d:10.1007_s10796-012-9374-9

[28] Dalal S. Futuristic investigative study of IoT/Green IoT as a driving force for sustainable development. Indian J Sci Technol. 2021;14:738–51.

[29] Cucchiella F, D'Adamo I, Koh SCL, Rosa P. Recycling of WEEEs: An economic assessment of present and future e-waste streams. Renew Sustain Energy Rev [Internet]. 2015;51:263–72. Available from: http://www.sciencedirect.com/science/article/pii/S1364032115005808

[30] Department of Environment Malaysia. What is E-waste? [Internet]. Department of Environment Malaysia. 2021 [cited 2021 Jul 25]. Available from: https://ewaste.doe.gov.my/index.php/what-is-e-waste/

[31] Mmereki D, Li B, Baldwin A, Hong L. The Generation, Composition, Collection, Treatment and Disposal System, and Impact of E-Waste. In 2016.

[32] Forti V, Baldé K, Kuehr R. E-waste Statistics: Guidelines on Classifications, Reporting and Indicators, second edition. United Nations University; 2018. 71 p.

[33] Adams R. E-waste and How to Reduce It [Internet]. 2018. Available from: https://climate.org/e-waste-and-how-to-reduce-it/

[34] Grasso M. Oily politics: A critical assessment of the oil and gas industry's contribution to climate change. Energy Res Soc Sci [Internet]. 2019;50:106–15. Available from: http://www.sciencedirect.com/science/article/pii/S2214629618306376

[35] Abdel-Sabour M. Oil & Gas industry Waste Management. 2015.

[36] Derefaka J. Waste Management Challenges in the Oil & Gas Industry with Special Focus on Limited Disposal Infrastructures: Shell Companies in Nigeria (SCiN) Challenges and Lessons Learnt. 2014.

[37] Africa GA. Kingfisher Oil Project, Hoima District, Uganda - Waste Management Specialist Assessment. 2017.

[38] Green K. Marine E-Waste: Gold Rush or Shipwreck? [Internet]. 2017. Available from: http://emag.nauticexpo.com/article-long/marine-electronics-waste-gold-rush-or-shipwreck/

[39] Aja O, Al-Kayiem H, Zewge M, Selowara Joo M. Overview of Hazardous Waste Management Status in Malaysia. In 2016.

[40] Royal Dutch Shell. Shell Sustainability Report 2018 [Internet]. 2019. Available from: https://reports.shell.com/sustainability-report/2018/responsible-business/environment/waste.html

[41] Department of Environment Malaysia. Household E-Waste [Internet]. [cited 2019 Dec 1]. Available from: http://www.doe.gov.my/hhew/

[42] United Nations. Sustainability [Internet]. [cited 2019 Dec 17]. Available from: https://academicimpact.un.org/content/sustainability

[43] Alnuaim S. What Does Sustainability Mean for Oil and Gas ? 2019;(December 2018):10–1.

[44] Matyugina EG, Pogharnitskaya O V, Grinkevich LS, Belozerova DS, Strelnikova AB. Oil and gas company policy regarding the concept of sustainable development (water resources). {IOP} Conf Ser Earth Environ Sci [Internet]. 2016 Mar;33:12055. Available from: https://doi.org/10.1088%2F1755-1315%2F33%2F1%2F012055

[45] Paez A. Gray literature: An important resource in systematic reviews. J Evid Based Med. 2017;10(3):233–40.

[46] Halevi G, Moed H, Bar-Ilan J. Suitability of Google Scholar as a source of scientific information and as a source of data for scientific evaluation—Review of the Literature. J Informetr [Internet]. 2017;11(3):823–34. Available from: https://www.sciencedirect.com/science/article/pii/S1751157717300676

[47] Bhattacherjee A. Social Science Research: Principles, Methods and Practices. University of South Florida; 2012. 159 p.

[48] Yin RK. Case study research : design and methods 3rd Edition. 3rd ed. Thousand Oaks, CA, US: SAGE Publications; 2003.

[49] Lewison RL, Rudd MA, Al-Hayek W, Baldwin C, Beger M, Lieske SN, et al. How the DPSIR

framework can be used for structuring problems and facilitating empirical research in coastal systems. Environ Sci Policy [Internet]. 2016;56:110–9. Available from: http://www.sciencedirect.com/science/article/pii/S1462901115301027

[50] European Environment Agency. Figure 1: The DPSIR framework. European Environment Agency; 2008. p. 4.

[51] US EPA. Module 2 - DPSIR Overview. p. 20.

[52] Dam RF, Teo YS. What is Design Thinking and Why Is It So Popular? [Internet]. Interaction Design Foundation. 2020 [cited 2020 Feb 2]. Available from: https://www.interaction-design.org/literature/article/what-is-design-thinking-and-why-is-it-so-popular

[53] Razzouk R, Shute V. What Is Design Thinking and Why Is It Important? Rev Educ Res. 2012;82:330–48.

[54] 54. Müller-Roterberg C. Handbook of Design Thinking. 2018.

[55] Chaiklin H. Case Study Research: Design and Methods. In: Bickman L, Rog DJ, editors. The Journal of Nervous and Mental Disease. Third Edit. SAGE Publications; 1991. p. 115.

[56] Royal Dutch Shell. Shell: Managing Waste [Internet]. [cited 2019 Aug 20]. Available from: https://www.shell.com/sustainability/environment/our-approach-sustainability/managing-waste.html