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The Use of Big Data in The Oil and Gas Upstream Industry: A Comparison Between Norway And Indonesia

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Abstract. A study has been done to perceive the uptake and impact of Big Data in the exploration and production of oil and gas in Indonesia compared to Norway. Interviews were conducted to officials in the Ministry of Energy and Mineral Resources (MoEMR) and the state regulator, SKK Migas. In both industries, more data is being generated more than ever in exploration, production, drilling, and operations, indicating potential application of Big Data. However, approach towards data has remained classical with physical models in opposed to common Big Data approach, which is data-driven analytics. Several impacts of Big Data in both industries are highlighted, including new demand for data analysts, the need for regulations surrounding cyber-security, improvement of safety and environment (which hasn't been considered in Indonesia), and growing need for more trust and regulations towards open data. Open data in the two industries has seen two different trajectories with Indonesia only implementing it very recently, while the NCS has seen open data drives competition since 1999. This study produced recommendations for the government of Indonesia on open data and how uptake and application of Big Data analytics in EOR could potentially increase national petroleum production to desired levels.

Keywords: Big Data, open data, oil and gas in Indonesia, Norway Continental Shelf, data analytics, EOR

1. Introduction

Big data is often discussed as the collection of large data gathering and application, giving relevant insights, to ultimately improve decision-making. It could be considered an ambiguous term to describe the application of new techniques and tools to digital information on a scale completely different to conventional approaches (Perrons & Jensen, 2015). Big Data is different to traditional approaches of data, just as the ocean is inherently different to a deeper swimming pool, on account of the "three Vs": volume, velocity, and variety (Laney, 2001) (Stephenson, 2018). Big Data is even argued to be able to reinvent the way capitalism and how the economy work with the emergence of data-rich markets with a radical prediction of the end of the firms as an economic institution (Mayer-Schönberger & Ramge, 2018).

Industries have embraced this idea of data sharing, the oil and gas industry, specifically, have been reluctant. Concerns over data ownership, trust issues, cyber-security, and national energy security have lead to the status quo (Vega-gorgojo, Fjellheim, Roman, Akerkar, & Waaler, 2016). Although by most measurements, data in the petroleum upstream industry is already 'big', particularly seismic data, current estimates predict that in terms of size alone, more is yet to come (Perrons & Jensen, 2015) as more data (seismic, drilling, production, etc.) is being produced than ever before as technologies are becoming increasingly sophisticated (Feblowitz, 2013).

This paper aims to review the extent of the use and effects of Big Data already beginning to take place in the upstream industry. It will discuss the main points concerning Big Data, why it has been gaining momentum, what the new technology entails, and the effects it has had on industries, specifically the

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Indonesian petroleum upstream industry. A similar research has been done previously (Vega-gorgojo, et. al., 2016) with a case study of the Norwegian Continental Shelf, which will serve as a basis and main reference for this paper. A similar methodology of qualitative research has been adopted to maintain a credible result.

The objective of this research is to provide a comparison of how Big Data technology is being used in two different oil provinces, the general approach of the two governments towards data, and impacts of Big Data on the industry. Several ways the utilization of Big Data have assisted petroleum activities in Norway could serve as a reference for the petroleum upstream industry in the Indonesian archipelago. Recommendations in this paper could be used by policymakers and operators in the Indonesian petroleum upstream industry to better prepare for Big Data application.

2. Case Study Overview

2.1. Big Data

Big Data as an increasingly used technology, has become possible to several innovations and new concepts that acts in a highly corresponding way (Perrons & Jensen, 2015). Significant technological advances include:

a. An exponential decline in data storage costs. High storage costs have previously limited companies and firms to selectively keep essential data and discard useless data. However, as costs plummeted from US$200,000 per GB in 1980 to US$0.03 by 2017, it has become cheaper to store every kind of data generated rather than to filter and discard it. A new challenge of managing abundant data replaced the challenge of managing scarcity of data. Companies are keeping all data, if that data might prove useful in the future through new insights (Stephenson, 2018). Figure 1 illustrates the fall of data storage costs from 1980 to 2009.
b. Constant growth in processing speeds of computing devices. The number of transistors on integrated circuits has doubled approximately every two years unalterably since it was first observed and predicted in Moore's Law since the 1970s, as observed in Figure 2. The computing prowess in devices for commercial use has followed at an equivalent rate.
c. Numerous breakthroughs in relevant areas of mathematics have enabled digital information to be stored in noisy, messy, raw, unstructured, and dynamic forms, while traditional data sets have historically needed to be structured, orderly, and static to some extent. Developments in mathematics, specifically geometry, have enabled Big Data practitioners to see through the disorderliness of the new data sets to find useful information, relationships, and insights.
d. The development of software platforms and open-source technologies for coordinating computers, particularly the Hadoop and MapReduce software framework. These software frameworks made it possible to scale storage costs linearly through breaking large data sets into smaller portions that can be delegated to several computing devices which can then be re-integrated at the end of the process. A cloud computing infrastructure is frequently used in this approach as a platform for transferring these data portions to different computing devices and then bringing back the results.

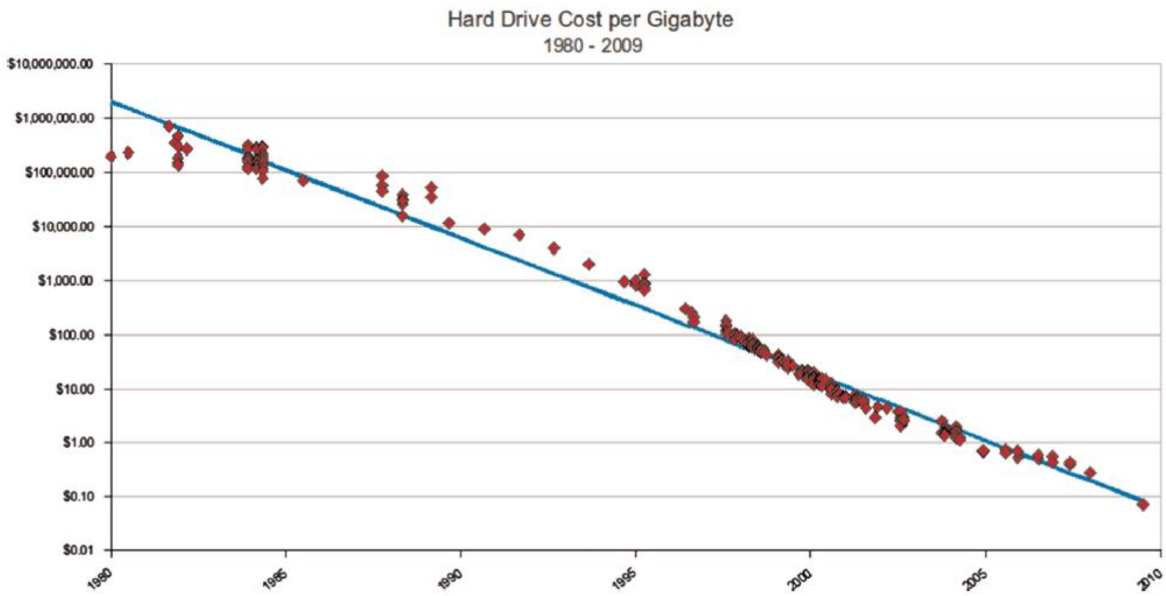

Figure 1. Data Storage Costs, 1980-2009 (from (Perrons & Jensen, 2015))

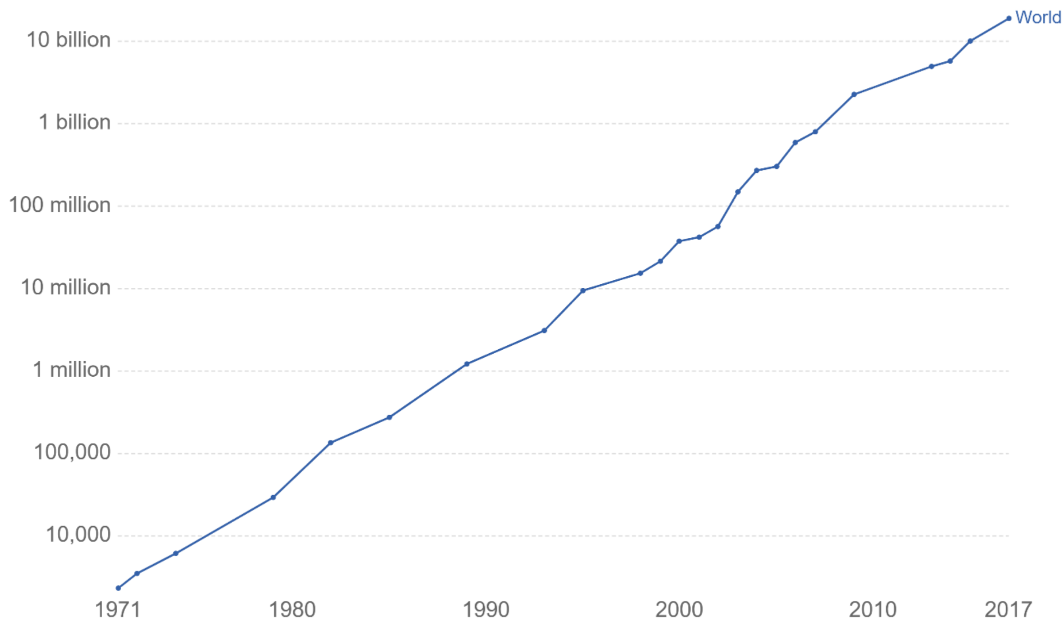

Figure 2. Moore's Law: Transistors per microprocessor. Increase in availability of computing power, 1971-2016 (from (Roser & Ritchie, 2018))

Big Data as a concept has been defined to include the "three Vs" (Laney, 2001), described as: "high-volume, high velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making". Other organizations and Big Data practitioners have extended the three Vs model to a four V model that adds in the new V as value (Koseleva & Ropaite, 2017). The concepts can be further elaborated as below and in Figure 3:

a. Volume: refers to the sheer quantity of data that is stored. Gathering, processing, and analyzing these large amounts of data poses benefits and challenges in gaining valuable knowledge and insights for people and companies.
b. Velocity: refers to how rapidly data accumulates. Larger volumes of data are now able to move with increasing velocities such that a high number of system variables can be monitored in nearly near-time (Perrons & Jensen, 2015).
c. Variety: refers to the type and nature of data collected via sensors, data logs, etc. These data could be structured or unstructured in format all stored together in a data lake.

d. Value: refers to the process of extracting valuable information from large sets of data. Value is the most crucial characteristic of any Big Data application as it allows the generation of useful business insights and information. Data could be meaningless unless its value is explored and mined (Koseleva & Ropaite, 2017).

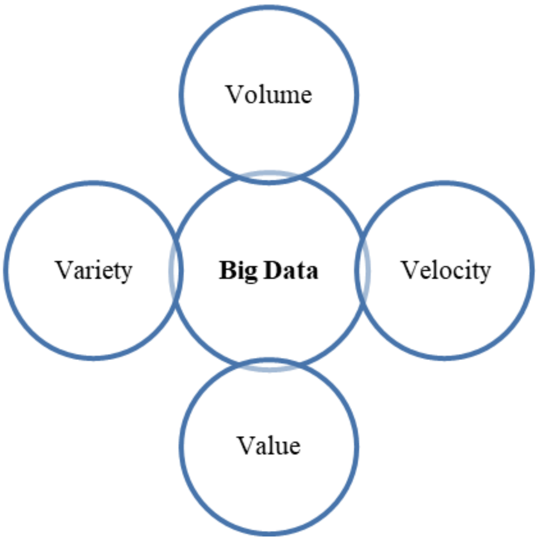

Figure 3. Characteristics of Big Data (after (Koseleva & Ropaite, 2017))

2.2. The Oil and Gas Upstream Industry in Norway and Indonesia

Oil and Gas has been historically important for the economies of both Norway and Indonesia. Norway has been exploring and producing for petroleum since the 1960s and has grown significantly since then. The industry alone constitutes to around 25% of Norway's current GDP and Norway's petroleum exports include a 46% share of its total exports in the year 2000 (Regjeringen, 2001). As of 2016, Norway has exported 6.3 BCM in LNG and 109.8 BCM through pipelines, mainly to neighbouring European countries (British Petroleum Company, 2017). As a testament to the contribution of the industry to the economy of Norway, the Government Pension Fund of Norway, a sovereign wealth fund created by the Norway government in 1990 to manage the surplus state revenue from the petroleum sector, reached a valuation of US$1 trillion in assets (Kottasová, 2017). The government employs a royalty/tax scheme which gives more freedom to the operators.

During its peak in 1970s, Indonesia was producing more than 1.5 million of barrels per day. However, since the 1990s, oil production on a national scale has been declining, due to maturing fields, which meant that Indonesia changed from a net-exporter to a net-importing country in 2002 (British Petroleum Company, 2017). Natural gas, however, has seen a steady rise in production and remain an export commodity. Nowadays. the petroleum sector makes up 6% of the total GDP of Indonesia in 2012 (it has fallen significantly due to the oil price decline in 2014) and still has a significant contribution of 25% to the state revenue in 2006 (PricewaterhouseCoopers, 2017). Failures in finding commercially-viable reserves between 2002-2016 exacerbated the situation with US$4billion worth of investments lost. The decline in petroleum exploration has also been attributed to excessive regulation that disincentivize investors (Indonesia Investments, 2017). The industry has turned to Enhanced Oil Recovery (EOR) to maintain its current production levels, with the government setting targets for operators on how much petroleum they produce. Indonesia employs a Production Sharing Contract (PSC) through a cost-recovery scheme which means the government plays a deciding role in operators' activities.

To give a more comparable outlook, Figure 4 compares the reserves of petroleum in Norway and Indonesia and Figure 5 compares the production levels (British Petroleum Company, 2017). Indonesia's natural gas reserves is larger than Norway's, however Norway's production significantly exceeds Indonesia's since the mid-2000s. Oil reserves and production are on a general decline for both Norway and Indonesia, however Norway shows a promising increase in the last few years.

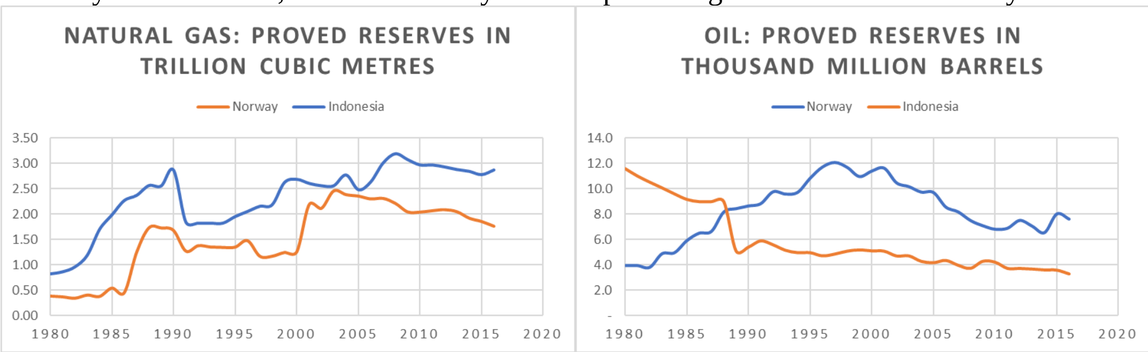

Figure 4. Proved Reserves of Oil and Gas in Norway and Indonesia (after BP Statistical review of World Energy 2017)

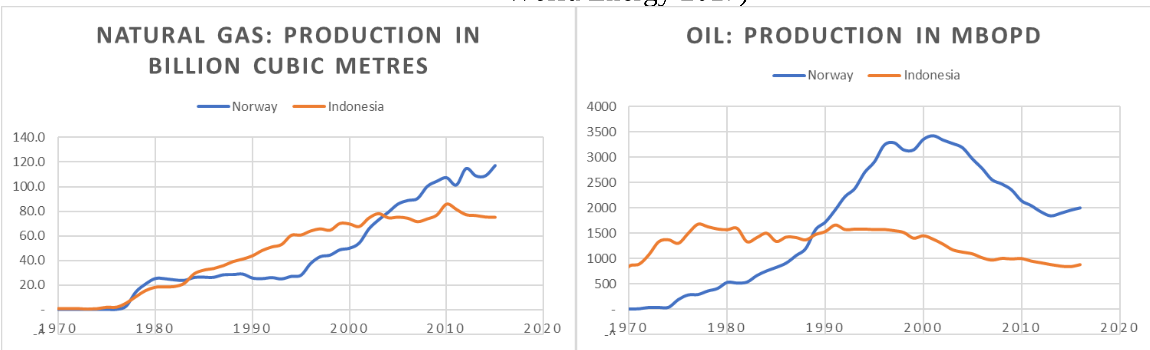

Figure 5. Production of Oil and Gas in Norway and Indonesia (after BP Statistical review of World Energy 2017)

2.3. Methodology of Data Collection

This research focuses on the use of Big Data in the petroleum upstream industry. It takes on a qualitative approach and a case study approach. The case studies undertaken is how Big Data is being used in the Norway Continental Shelf, and the conditions of Big Data in petroleum activities in the Indonesian archipelago. Due to the harsh conditions, and expensive capital expenses of the NCS, long-term Research and Development of technology have thrived (Vega-gorgojo, et. al., 2016). This makes it a reliable case study for a study on Big Data. Indonesia, on the other hand, even though also a net exporter of natural gas, have behaved differently due to the different constraints surrounding the industry.

Processes of Big Data uptake and its impacts in the upstream petroleum industry will be uncovered through a qualitative approach. Multiple sources will be employed to ensure the validity of the data gathered. The following questions that will be used in the interviews are listed in the table below, adopted after Vega-gorgojo, et. al., (2016).

Table 1. Questions asked in the interview

No.	Questions Regarding Big Data Uptake
1.	Which are the main data sources?
2.	What are the uses of the data generated/collected?
3.	Which are the main data challenges?
4.	Which are the data sharing practices of your organization?
5.	What are the ongoing or future plans for open data?
6.	Which other parties are involved in your data value chain?
7.	Which are the main collaborations and the inter-party's data exchanges taking place?
	Questions Regarding Impacts of Big Data
8.	How is Big Data changing the oil & gas landscape?
9.	Which are the main legal issues with respect to Big Data?
10.	Which are the main risks with respect to policies and legal issues?
11.	Does the practitioners in the industry consider the social implications of Big Data? i.e. Do you use personal or private data in your operation?

These questions will be asked in an interview to individuals working as operators, regulators, and policymakers in the Indonesian oil & gas upstream industry. The qualitative data obtained allows a comparison and that could identify and explain the underlying differences in the two industries. These questions will be asked in an interview to individuals working as operators, regulators, and policymakers in the Indonesian oil & gas upstream industry. The qualitative data obtained allows a comparison and that could identify and explain the underlying differences in the two industries. Table 2 lists the individuals from various companies and organizations (Table 3 Table 2) that has agreed to participate in the research. The president of IATMI (Indonesian Petroleum Engineers Association), a lecturer in Bandung Institute of Technology, offers the viewpoint as an academic and consultant to both operators and policymakers. An official of SKK Migas talks from a regulator's point of view. The Directorate General of Oil and Gas from the Ministry of Energy and Mineral Resources (MoEMR) discusses the issue from a policymaker's perspective.

Organizations included in the research are classified by the its technology adoption stage and the impact of information technology (IT) in industry (evaluation of the organizations' current and future needs for information systems). It can be classified into four roles (Vega-gorgojo, et. al., 2016):

a. Support role (defensive): current IT is not critical for operations, and new IT would not pose strategic changes.
b. Factory role (defensive): current IT is critical for operations, but new IT will offer strategic changes.
c. Turnaround role (offensive): current IT is not critical for operations, but new IT will be fundamental for the future.
d. Strategic role (offensive): current IT is critical for operations and new IT will be fundamental for the future.

Table **4** shows additional information that has been gathered for the research: an online talk held in April 2018 by the UK branch of IATMI that discuss the role of open data and its future in Indonesia.

Table 2. Interviewees involved in the study

Code	Organization	Designation	Knowledge	Position	Interest
I-IAT	IATMI	President	Very high	Supporter	High
I-SKK	SKK Migas	-	Medium	Supporter	Medium
I-ESD	ESDM (MoEMR)	Directorate General	Very high	Supporter	High

Table 3. Organizations involved in the study

Organization	Industry Sector	Technology Adoption Stage	Impact of IT in Industry
IATMI	Oil & gas professionals association in Indonesia	-	-
SKK Migas	Oil & gas regulator in Indonesia	Early majority	Strategic role
ESDM (MoEMR)	Oil & gas policymaker in Indonesia	Early majority	Turnaround role

Table 4. Additional information sources

Code	Source	Event	Description
E-MS	Muhammad Sani (Deputy of R&D in ADPM)	The role of open data in increasing the reserves and production of oil & gas in Indonesia	Online talk held by IATMI UK
E-TA	Tutuka Ariadji (President of IATMI)	The role of open data in increasing the reserves and production of oil & gas in Indonesia	Online talk held by IATMI UK

3. Big Data in the Oil and Gas Upstream Industry: Norway and Indonesia

3.1. Data in the Oil and Gas Industry

The main data types that are collected and used in the various stages of petroleum exploration and production were asked to the interviewees. These data are identified and elaborated below (Vega-gorgojo, et. al., 2016)

a. Seismic data is the main type of data used in petroleum exploration. Collecting seismic data is expensive and companies tend to be protective of it, however, governments of oil provinces are usually highly interested of the seismic data collected. The regulatory framework in Indonesia dictates that seismic data collected by a company is owned by the government [I-IAT] and companies are given a limited time to hand over data in stages, while companies in NCS are obliged to hand in seismic data to the government.
b. Production data is particularly important for oil companies since it is highly commercial-sensitive. Sensors are installed in every piece of equipment and produce large amounts of data that poses a challenge in velocity, how to send 1 TB of data per day. Reservoir monitoring, done through shooting seismic waves creating 4D models of the subsurface, and reservoir simulation, computer intensive process employed to evaluate how much oil is produced in a well, are also main data sources for operators. For regulators, such as SKK Migas, production data is invaluable as it serves as the main reference for PSCs in Indonesia [I-IAT]. [I-IAT] mentions the possibility of Big Data having a role in EOR through sensors and monitoring injections, saturations, and production data. Exploration activities are also done around production wells to look for pockets of reservoirs.
c. Drilling generates high-volume and high-velocity data which are analyzed in real time for safety reasons and to detect the drilling process such as to determine whether the reservoir has been hit or not. Non-productive is very expensive for operators and analyzing data real time prevents that and could cut costs significantly. Well integrity monitoring is also done with geological models employed.
d. Operations could be where Big Data has the most impact. Condition-based maintenance is a recent phenomenon that is particularly receiving more attention. Equipment is instrumented to collect data and early detection of potential failures are applied through analytics. This type of maintenance is then more efficient than conventional reactive or calendar-based models. Operators and suppliers are driven to reduce costs and improve

the lifetime of an equipment. Data-driven new products (e.g. Åsgard subsea compressor, system a product that can increase pressure in a reservoir (Kleynhans, Brenne, Kibsgaard, & Dentu, 2016)) has been developed partly due to the analysis of operational data. Integrated operations through analytics of different integrated datasets could be very powerful, leading to better and faster decisions in operations. SKK Migas is selecting established technologies from service companies to be used in current petroleum activities [I-SKK]

3.2. Approach towards Open Data: Norway and Indonesia

In 1998-1999 the NPD began to publish open data of the NCS, an effective system to make available their data to interested parties, whereas previously companies had to directly ask NPD for the data. Open data is seen as a driver for competition in the NCS. Norway aims to attract investors to compete in the industry. The FactPages, reference datasets published by the NPD (Norwegian Petroleum Directorate), provides an easy method to assess available opportunities in the NCS by making production figures, discoveries, and licenses openly available. Promoting the openness of data and resources, the NPD pursues to obtain as much data as possible and promote competition among petroleum operators. Companies are obliged to send the seismic data to the Norwegian government which is incorporated to NPD’s Petrobank i.e. the Diskos database. Companies in the NCS are slightly reluctant to open data, but there are developing incentives, specifically in operations data. One concern is commercially sensitive information being exposed for both operators (in terms of fiscal measures) and suppliers in terms of equipment and services. However, open data could be regarded as an opportunity for commercial benefit as operators have many incentives to share operations data (since privacy concerns are low) and there are many opportunities to obtain efficiency in operations, resulting in ongoing open data pilots and sharing data collaborations (Vega-gorgojo, et. al., 2016).

The current focus of the government of Indonesia is how to maintain production levels on a national level and increase reserves through exploration activities and incentives for foreign and domestic investors. As the global economy is moving from scarcity to abundance, and petroleum reserves are increasing, which the opposite is true in the Indonesian archipelago [E-MS]. Since 2016 the state regulator, SKK Migas, has been collecting exploration, reserves, and production data from operators that amounted to more than 70 TB of data, before regulations on open data has taken place [I-IAT]. The main purpose of this is to analyse and process all the raw data which can then be used to auction to future investors [I-ESD]. However, with the industry moving towards open data, the government is looking at removing obstacles towards access to data.

Regulations from the MoEMR, which touches upon the issue of open data has only been implemented and enforced since 2017 (Ministry of Energy and Mineral Resources, 2017). [E-TA] explains that future investors can see easily how much investment is needed to increase the desired reserves through the new implementation of open data. [E-MS] identifies the key to an abundant petroleum economy is: openness of data; ownership, not possessiveness, of data and assets; and massive technology to reduce costs. The General Plan for National Energy (Government of Indonesia, 2017), an Presidential Regulation which also outlines the implementation of open data, describes the effect of EOR and Exploration on current and future reserves and production levels (Figure 6 and Figure 7). Current production levels without exploration (grey area) and EOR (orange area) would see a massive decrease in oil production levels to 10% and gas production to 25% of current levels by 2050. The role of open data is crucial in encouraging investors to explore and increase current reserves.

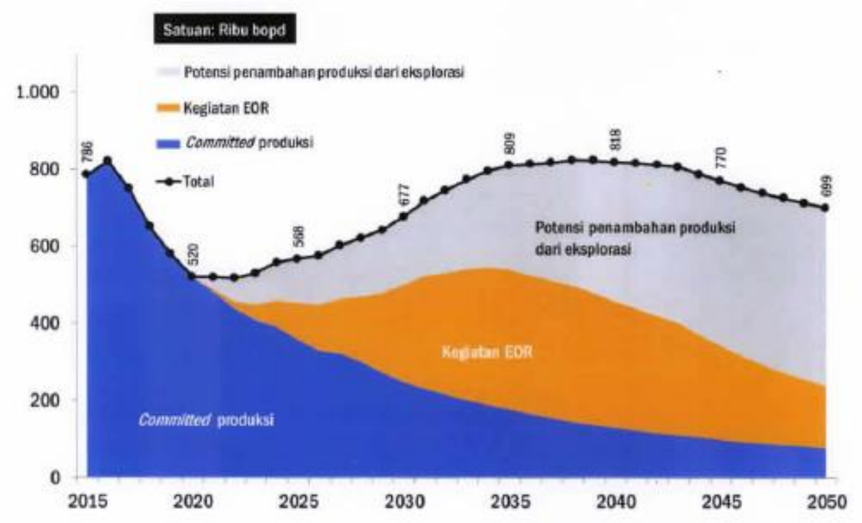

Figure 6. *Production profile of oil in Indonesia 2015-2020 (in MBPOD) (from (Government of Indonesia, 2017))*

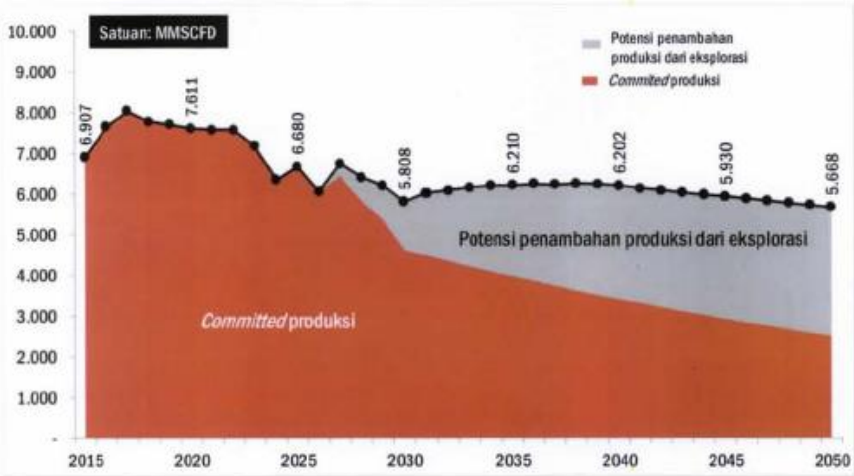

Figure 7. *Production profile of natural gas 2015-2050 (in MMSCFD) (from (Government of Indonesia, 2017))*

The current state of open data in Indonesia, according to [E-MS] can be highlighted in several issues: (1) the government still treat data utilization as direct state non-tax revenue, which hinders the optimal access and use of data; (2) weak regulation surrounding collection of data from general surveys, studies, exploration, and exploitation activities; (3) not enough coordination regarding the tasks and function on institutions involved in data management between government bodies (SKK Migas, MoEMR, PUSDATIN/Data and Information Center); (4) the government not being ready in terms of infrastructure to accommodate the data collected or given by companies and is now stored and maintained by private companies [I-ESD]; (5) Utilization of results from research in universities has not been optimal in supporting exploration activities.

Figure ***8*** describes the flow of data that is generated in the industry. Operators are obliged to hand in any data collected to the state regulator SKK Migas, which will then be forwarded to the MoEMR, and stored by the Data Information Center (DIC). Future or current investors can then access the data through the DIC.

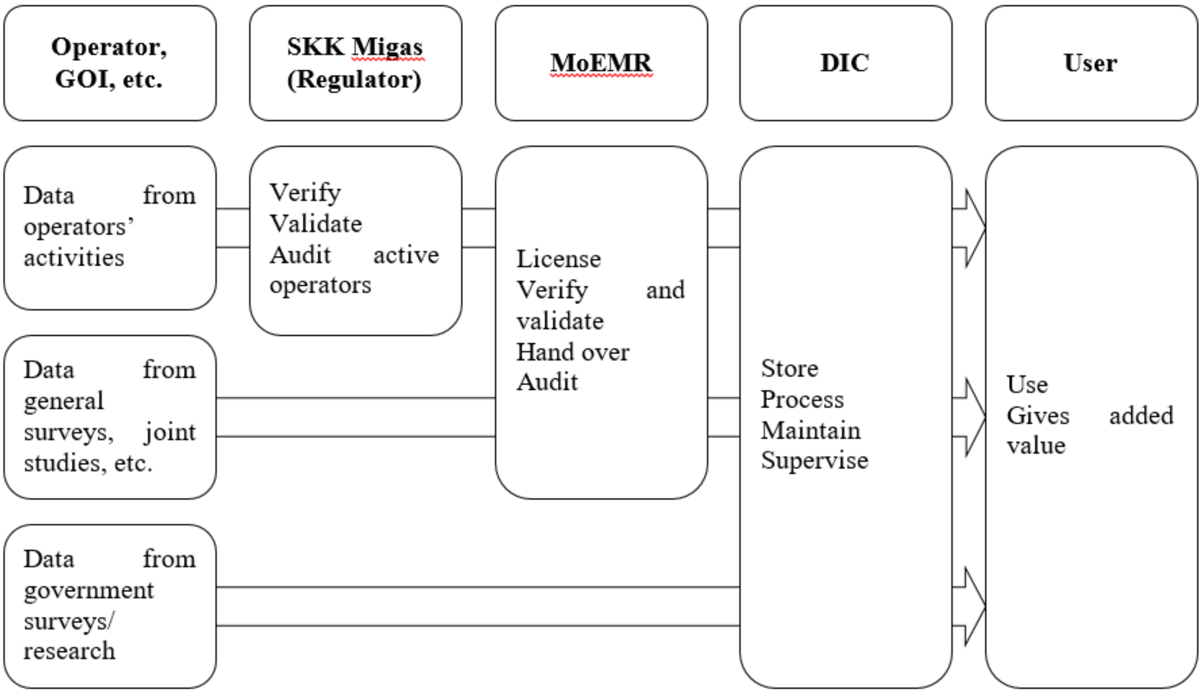

Figure 8. *Flow of data in the Indonesian petroleum upstream industry (after [E-MS])*

3.3. Impacts of Big Data in the Oil and Gas Upstream Industry

The impacts of the application of Big Data in the two industries are identified in Table 5. The findings in the research lists a growing demand for data analysts both in Norway and Indonesia, where companies are recruiting people with suitable skills for data analytics. Personal privacy is not a concern in both industries as they do not deal with personal data. However, more data could make it possible to identify poor decisions by people, e.g., human operators. Companies in Norway has started to look for ways in which Big Data could potentially improve safety and environment, while Indonesia has not done the same. Trust between parties is an issue for companies in Norway as not all data exchanged is thoroughly understood by the receiving party, while SKK Migas has a problem in trusting whether companies have handed in all the data generated or keeping some datasets hidden. Regulations in both industries have not caught up with the emerging uptake of Big Data and no clear legislation has taken place.

Table 5. *Impacts of Big Data in the Norwegian and Indonesian oil and gas upstream industry*

Finding	Norway Source (Vega-gorgojo, et. al., 2016)	Indonesia Source from interviewees
A growing demand for data analyst jobs	Changes in recruitment practices particularly in recruiting people with competencies for data. Not enough data scientists are entering the oil and gas industry.	Companies are starting to hire more data analysts [I-ESD]
Personal privacy is not a concern	Human error could be more easily detected.	Not an issue[I-IAT]
Cyber-attacks and confidential datasets	Hacking is a serious issue for NPD, as companies trust them to keep their data. Companies and NPD take measures to protect their data from cyber-attacks.	No regulations have been laid down in place to combat cyber-attacks. Companies in general, trusts SKK Migas to keep the confidentiality of their data [I-IAT] If exploration data is hacked, it would be fine if it leads to increased investments [I-ESD]
Improvement of safety and environment	Big data could reduce incidents such as detecting oil leakages, equipment damages. Control systems contains lots of alarms that is unable to be collectively analyzed manually, something software can do. Monitoring damage or unwanted effects to environment such as fisheries, corals, and the seabed can also be done with Big Data	-
Concerns about trust and data	The data ecosystem is complex, many communication exchanges between oil companies and suppliers. It is difficult to trust data by another party if the underlying reality is not understood.	State regulator SKK Migas collects all data pertaining exploration and production, but cannot ensure vendors and operators doesn't hide any data from government or each other [I-ESD]
Regulation of Big Data	The ownership of data is dependent on the contract, which makes it a complicated ecosystem. Legislation of data is still unclear, specifically with respect to Big Data. Regulating raw data must be judged on the criticality of the risk.	No regulations on Big Data yet, all data ownership still belong to the government [I-IAT] Companies having a time limit on owning and holding on to generated data, needs to update regulation to ensure easiness of access to data [I-ESD]

4. Discussion

4.1. Big Data Developing Differently in the Oil and Gas Industry

The petroleum industry, whether upstream or downstream, is heading towards a future of not only significantly more data in terms of quantity, but also larger use and uptake of Big Data. However, the industry approach towards data has not been significantly different than its traditional method, applying the "same attitude and analytical techniques that have been in the industry for years" (Perrons & Jensen, 2015). A lot of theoretically valuable data collected from upstream activities is not receiving the attention it deserves, or simply discarded (Feblowitz, 2013). Furthermore, where the data stored could also pose an issue as it is often stored by the service companies, the party that collected or generated the data, rather than the operator who oversees managing the asset in the long-term.

Other industries or sectors, however, has seen Big Data developing differently. Several other industries such as healthcare, financial, retail, and media, have learned that valuable and novel insights could be obtained through utilization of new techniques and analytics to analyze data sets in ways that were not possible with smaller ones (Perrons & Jensen, 2015). This is possible due to advanced, analytical techniques being applied to massive numbers of variables that initially seem to have no correlation, rather than testing variables whose relationship are already well-understood. A well-known example of this is the U.S. retailer Target who knows, through behaviourial analytics, when a woman is pregnant without her explicitly disclosing it (Mayer-Schönberger & Ramge, 2018). Many practitioners of Big Data are not creating value by monitoring existing relationships but testing and finding patterns and making predictions based on complex relationships that were formerly unfamiliar. Rather than trying to identify and explain the causality and devices behind the relationships found between variables, users of Big Data focuses more on the "what" rather than the "why".

The way the petroleum upstream industry manages data has not reflect the approach numerous other industries have taken. It tends to view data as information that describes the state of an asset whereas leaders in Big Data (such as Facebook and Google) realize that "data is a valuable asset in and of itself" (Perrons & Jensen, 2015). Although business models behind retail, social networks etc., are fundamentally different than the petroleum industry, and specifically data delivers value differently, the petroleum industry is massively and increasingly more reliant on information technologies and computing power. Many petroleum companies do not consider digital information to be mission-critical to their profitability (Feblowitz, 2013) and will need to change to face the age of Big Data.

4.2. Insights towards current uptake of Big Data

Big Data uptake in the Indonesian petroleum upstream industry is in its early stages, with not much of a difference compared to Norway. Companies both in NCS and Indonesia is generating as much data as possible which shows more awareness in the potential of Big Data. With more data being made available in the petroleum field, new technologies such as condition-based monitoring in the NCS that generates a constant stream of data in real time, will pose a challenge in terms of volume. Velocity and variety are becoming important challenges, specifically in how to send a large quantity of data in as little time as possible, to ensure the data could be analyzed in real-time. Technologies selected by SKK Migas would need to factor in how much data is being generated and how it would be stored and transported effectively and efficiently.

The open data movement fundamentally pursues to open up data for wider use and providing easy-to-use research tools which is built upon three principles: openness, participation, collaboration. Open data creates transparency and accountability, productivity, innovation, and wealth creation (Kitchin, 2014). It has been implemented since 1999 by the NPD to increase competition between operators in the NCS. Indonesia, on the other hand, has only recently applied open data in its industry (2017). The government of Indonesia is in the middle of a transition from treating data as a source of direct revenue, to data being part of a soft infrastructure to increase petroleum exploration and production activities. Companies in both industries are somewhat reluctant to open data, specifically commercially sensitive information, which poses a challenge to open data. However, companies in the NCS have started to see the commercial benefit of sharing operations data that could increase efficiency in operations. The Indonesian industry would have to see similar successful examples coupled with strong regulations for open data to be truly implemented.

Most analytics done in the industry are computed with current and known physical models. An alternative is to employ data-driven models, although it is still in its early stages and have not been fully proved. As mentioned previously, this is the opposite of "letting the data speak for itself" (Mayer-Schönberger & Cukier, 2013). Machine learning models have been tested against physical models but failed to perform better, however machine learning models are constantly evolving (Vega-gorgojo, et. al., 2016). Total E&P, for example, is developing AI technology in combination to subsurface data to explore and assess fields more effectively through the delegation of various work to an AI personal assistant (Zborowski, 2018). Big Data could potentially serve as a solution to the government of Indonesia's conundrum of increasing production levels through EOR. Analytics applied to seismic, drilling, and production data has the potential to "help reservoir engineers map changes in the reservoir over time and provide decision support to production engineers for making changes in lifting methods", i.e. EOR (Feblowitz, 2013).

There seems to be resistance to change both in the Norwegian and Indonesian industry. The technology is readily available, but changes to business models are making decision takers hesitant. In Indonesia, since the government plays a large part in operations due to the kind of contract employed, new technologies are selected by the state regulator. The government is conservative about novel methods since potential failures could affect much-needed state revenue significantly. In effect, innovations such as Big Data are slower in the uptake. Effectiveness of Big Data in the industry must be proved and examples of successful uses in Big Data and data-driven analytics need to happen to demonstrate the advantages of Big Data.

5. Conclusions

Big Data is the application of novel technology to how data is transforming in volume, significantly larger datasets are being stored; velocity, how fast data is gathered; and variety, the increasing types of data gathered; which creates value, useful business insights and information being extracted from data analytics. Many industries and sectors have embraced Big Data, such as in healthcare, retail, and media. With the petroleum industry generating data more than ever, it would seem inevitable that Big Data would gain traction in the industry. More data in exploration, production, drilling, and operations leads to better informed and quicker decisions. Nevertheless, Big Data has not had the same uptake as other industries due to hesitant decision-makers using the classical methods of usage of data instead of the approach taken by Big Data practitioners. Big Data has had several impacts in the industry, including new jobs, growing concerns over cyber-security, improvement of safety and environment, and the need for more trust and regulations towards open data. The NCS and Indonesia has embraced the need for open data in the petroleum upstream industry. The NCS, having implemented it from 1999, sees open data as a driver for competition, seeing some success with more activities and collaborations taking place, while Indonesia have only issued open data very recently. It is still up to its government to bring companies to participate in the open data movement with strong regulations and successful examples. Big Data still need to prove its effectiveness to be fully utilized wholly in the industry.

Recommendations to the government of Indonesia on increasing the role of open data and Big Data in the Indonesian petroleum upstream industry are elaborated below:

a. A foundation of trust to be built through open and continuous communication between investors and the government. Predictability is needed from every party involved for the data management needed. Data openness creates communication, more studies, and more understanding and this leads to a reasonable certainty for investors.

b. Empower institutions that manage data, including building suitable infrastructure to accommodate such activities, optimal funding by the government, and clear regulation of data collection.
c. Developing a new paradigm that data is part of the non-physical or soft infrastructure to support exploration activities and not an object for direct revenue, in turn its access and use will be easy and non-expensive. This has been stated in (Government of Indonesia, 2017), however its implementation is yet to be seen.
d. Recognize the advantages of Big Data for safety and environmental reasons and include it within regulations.
e. Update regulation regarding Big Data, specifically to incentivize the use of Big Data analytics for EOR, to increase production on maturing fields.
f. Consider taking more risk with novel technology that has the potential to increase production or reduce costs.

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