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BRAZILIAN AND CANADIAN OIL&GAS INDUSTRIES – SIMILARITIES, DIFFERENCES, CHALLENGES AND PERSPECTIVES FOR A SUSTAINABLE INDUSTRY

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Abstract: The Brazilian and the Canadian Oil and Gas industries are facing similar challenges now: both countries are developing huge oil fields; as a result, companies, governments and policy makers have started to invest escalating resources in projects and regulations. These efforts have provided both countries with a significant increase in their oil production. Brazil discovered the Pre-Salt field, located off its Southeastern coast, what resulted in complex technical researches whose outcome will guarantee a safer and more environmentally friendly production. The oil sands in the western Canada, along with the shale formations, despite the abundance, have been utterly criticized by environmentalists who report the possible impacts of the methods used to extract the oil. This paper aims to analyze the similarities, differences and challenges that both countries have to confront. In addition, as many companies in other sectors, the oil and gas industry has taken the initiative to demonstrate that their activities are in accordance with the best practices of sustainability by seeking the optimal efficiency in water consumption, energy and waste management; as well as minimizing carbon emissions to reduce the greenhouse effect. Nevertheless, the oil and gas industry still has to face the common sense that their activities cannot be innovated to reduce environmental impacts and therefore be aligned with the best sustainable practices. Analogous to the movement that has led the AEC industry to create the "green buildings", two proposals on how to address the sustainability of these projects is presented.

1 INTRODUCTION

Despite the recent fall in oil prices, which have been striking the oil and gas industry, some projects in Brazil and Canada will be postponed or even canceled and yet many will still continue to the next phases. Brazilian and Canadian oil and gas industries are in continuing evolution and are expected to maintain it for a long time. Nevertheless, in today's environment, more and more corporations are willing to demonstrate that their activities are in accordance with the best practises of sustainability so as to guarantee the optimal efficiency in water consumption, energy and waste management as well as to minimize carbon emissions and hence reduce the greenhouse effect. This is much expected from the Brazilian and Canadian oil and gas industry because of the reliance of global oil demand on their non-conventional oil and gas resources, as noted by Kerr (2011; 2012a; 2012b). Furthermore, sustainable development also involves an appropriate balance between environmental solutions, and social and economic issues. As a result, stakeholders, clients, investors and government parts have been demanding dramatic changes in the way companies are investing in new projects.

Aiming for better sustainable results, the oil and gas industry has a key role by addressing new practices that have been widely used to develop sustainable rating systems like the ones that have been extensively utilized to assess the green buildings such as LEED and BREEAM. However, the specific characteristics of the oil and gas industry do not permit a full application of building rating systems into industrial projects. Although many rating systems are vastly used to analyse the sustainability of green buildings, few attempts to assess the sustainability of oil and gas projects has been adopted so far. Compared to buildings, industrial projects are typically larger, have a longer lifetime, take longer to construct and consume more energy and water overall.

As part of industrial projects, the oil and gas industry has to challenge the common sense that its projects cannot be designed to reduce environmental impacts and therefore comply with the best practices of sustainability. Thus, despite the outstanding initiatives of the sector, the oil and gas industry should incorporate in its projects the valuable concepts of green buildings projects. In this work, we present two different proposed researches on how to address the sustainability of oil and gas projects. The first is the development of a universal green rating system framework that could be implemented in the oil and gas sector. The second proposal focuses on the main causes of the climate change. A method using BIM – Building Information Modelling to calculate and optimize the embodied energy and corresponding emissions of oil and gas projects is proposed.

2 CURRENT SCENARIO OF MAIN BRAZILIAN AND CANADIAN OIL AND GAS PROJECTS

A comparison between the Brazilian and Canadian oil and gas projects is structured below according to subareas of the oil and gas industry such as upstream (oil); downstream (refining); and natural gas, liquefied natural gas (LNG) and transportation.

2.1 Upstream – Oil

Brazil is the eleventh oil producer of the world (EIA, 2013), with a daily average production of 2.6 millions of barrels of oil equivalent. The Brazilian oil and gas industry is comprised of many players, with the state-owned Petrobras as the largest one. Founded in 1953, the company is already present in seventeen countries. It is controlled by the Ministry of Mines and Energy of Brazil and has operations in exploration and production, refining, oil and natural gas trade, transportation, petrochemicals, retail distribution, electricity, biofuels and renewable resources among others (Petrobras, 2014a). Located in the Atlantic ocean off the southeastern coast, the Pre-salt province discovered in 2006 (Petrobras, 2014c) has already increased Brazilian proven reserves to 15.6 billions of barrel (ANP, 2014), and it is expected to double until 2022 (Folha de Sao Paulo, 2014). The Pre-salt and other domestic demands have caused a boom in the number of proposed offshore projects in Brazil: 38 platforms (including drillships), of which 7 are already in operation, 49 vessels and 20 waterway convoys among others (Petrobras, 2014b).

Canadian crude oil reserves is the third largest in the world with 173.6 billions of barrels (EIA, 2014), just behind Saudi Arabia and Venezuela, thanks to the oil sands located in the western provinces, accounting for 167 billion barrels or nearly 96% of overall Canadian reserves. As opposed to Pre-sault in Brazil, the potential of oil sands has been widely known for decades, but they became economically viable just when oil price reached around sixty US-dollars at the beginning of the 2000's. This permitted massive investments in *in-situ* and pit mining projects, increasing the Canadian daily oil production from slightly over 2 million barrels at the early years of last decade to 3.7 million in 2014 (NEB, 2015). Besides the oil sands projects, Canada has also seen investments in the offshore fields along the Atlantic coast and Western Union Sedimentary Basin. However, the offshore projects do not seem to represent a significant increase in the current level of oil output compared with the potential of oil sands (EIA, 2014).

Despite the difference of size of both national reserves, the main similarity of the Brazilian and Canadian oil reserves relies on the fact that many experts anticipate a delay in global oil peak, alleging the potential of these future oil prospects and others. They call this type of oil production non-conventional, since it cannot be produced by the well-known conventional extraction methods. However, some authors are skeptical regarding the future of the oil and gas industries of these countries, as the increase in their production will heavily depend on developing technologies and a relatively high breakeven oil price that

justifies new investments (Sorrel et al., 2010; Sorrell et al. 2012). Furthermore, the expected improvements in technologies are not only to implement oil outcome but also to guarantee a safe and environmental friendly operation.

2.2 Downstream – refining

As the Pre-salt is expected to boost the Brazilian production to about four million barrels per day until 2022, the surplus of oil should be either processed or exported. As a result, four new refineries and revamps have been proposed, which will increase the Brazilian refining capacity from currently 2.1 million to 3.3 million barrels per day (Petrobras, 2014d). One refinery, Rnest, located in the state of Pernambuco, is already under operation since December 2014. Two other projects are on hold. Brazilian downstream projects have been demanding a great effort from the owner and contractors, as refining projects are very capital intensive, require high-skilled workers, demand excellence in quality assurance and therefore a remarkable supply chain. The last refinery had been constructed more than thirty years before Rnest started up.

As opposed to the Latin American country, Canada opts to export its oil surplus to the U.S., where the actual installed refining capacity is larger, underused and more suitable to process the viscous and heavy sand oil (MacLellan, 2014). This strategy is highly controversial, as opposers argue that new refineries would generate more post jobs, more investments; and reduce the price of fuels and the international dependency on processed products, such as gasoline and diesel (Mendleson, 2013). One of the few exceptions is North West Redwater Partnership, a refinery that is under construction in Alberta and with startup expected to late 2017 (North West Redwater Partnership, n.d.).

2.3 Natural gas, liquefied natural gas – LNG and transportation

Brazil has already concluded some of the major projects considered strategic for the natural gas pipeline network. Concluded in 2010, GASCAC, or Cacimbas/Catu gas pipeline, is a 954-kilometer-lengh stretch, which permitted the integration between the southeast and northeast gas pipeline networks. As a result, natural gas that is imported from Bolivia can also supply the region Northeast of the country.

Brazil has also opted to construct three LNG import terminals. These facilities permit the import of natural gas on ships, opening new import markets and, consequently, reducing the dependency on the current inland natural gas imports.

Canada is already a natural gas exporter with the U.S. as the only buyer of the Canadian gas. With the significant findings of shale gas in the U.S. and Canada in the last years, Canadian market is shifting the strategy and seventeen LNG export facilities were proposed, entering the regulatory process (Natural Resources Canada, 2014). However, due to the recent fall in oil prices, only two projects sponsored by Chevron/Woodside Petroleum and Shell respectively may proceed, with the former expected to start up in 2021 (Hussain, 2015). Both projects are located in the Western Coast, British Columbia.

In Canada, there are also proposed improvements in the transport network such as Keystone XL. Under lively debate because of the allegedly environmental impact, Keystone XL pipeline, with 529 km in Canada, is expected to increase the offer of the crude oil produced in Alberta to the U.S Golf Coast refining system, whose refineries are considered more suitable to process the viscous and heavy sand oil. However, the issuance of a U.S. presidential permit has delayed its construction (TransCanada, n.d.).

2.4 Summary of projects

Table 1 provides a summary of the main projects of the Brazilian and Canadian oil and gas industries. The projects presented in this work and on the table below were selected based on their level of relevance as well as the similarities between both countries. Thus, the main goal is to illustrate the current general status of the oil and gas industry in both countries and the correlation with future challenges concerning sustainability that will be presented later. It is not intended to list all current oil and gas projects in Brazil and Canada.

Table 1: Main Brazilian and Canadian oil and gas projects

Project	Type	Country	Status	Observation
Pre-sault portfolio	Upstream	Brazil	Ongoing	Increase oil production to 4 million bbl/day
In-situ and open mining sand oil projects	Upstream	Canada	Ongoing	Increase oil production to 5 million bbl/day
Refining system resizing	Downstream	Brazil	Phase 1 RNEST concluded	Increase processed oil to 3.3 million bbl/day
North West Redwater refinery	Downstream	Canada	Ongoing	Increase processed oil in 150,000 bbl/day
GASCAC/GASENE	Natural gas	Brazil	Concluded	Permit network integration
Shale gas development	Natural gas	Canada	Ongoing	Increase NG production/export
Import LNG terminals portfolio (3 terminals)	LNG	Brazil	Concluded	LNG import facilities
Export LNG terminals portfolio (2 terminals)	LNG	Canada	Ongoing	LNG export facilities
Keystone XL	Transport	Canada	On hold	Oil export pipeline to US

3 TOWARDS A MORE SUSTAINABLE INDUSTRY

3.1 Green buildings vs. the oil and gas industry

Green buildings are designed to minimize the potential impacts of constructions on the environment, to contribute to the reduction of the emissions of greenhouse gases and thus to a long-term sustainable development. The concept of such buildings aims for environmental responsibility throughout its whole life cycle, from the design until the demolition. The main consolidated issues covered by sustainable designs are (Building Research Establishment n.d.; US Green Building Council n.d.):

- Energy efficiency
- The efficient use of water
- The environmentally efficient use of materials
- Impacts of construction methods
- Indoor environmental quality
- Operation and maintenance
- Waste management

With the advent of green constructions, the necessity of developing sustainable rating systems have been arisen so as to assess how sustainable and environmentally friendly these new projects are. Rating systems are benchmarking codes and one important step to be taken by corporations that intend to demonstrate to society that its projects are effectively green. Sustainable rating systems are structured, decision-making tools in support of measuring environmental performance throughout the project life cycle and verified by third-parties (Poveda, 2014).

Examples of factors that should be considered when developing a rating system assessment throughout the life cycle of projects should include the project size, kind of industry, surroundings, codes, standards, regulations and the stakeholder's requirements. The majority of rating systems have been developed considering these aspects. The most popular rating systems worldwide are ATHENA (Canada), BEAT 2002 (Denmark), BREEAM (UK), CASBEE (Japan), LEED (USA, Canada, Mexico), DGNB (Germany),

NABERS (Australia), HQE (France), ENVEST 2 (Netherlands) and others. In Brazil, more recently, the ratings systems AQUA (Vanzolini Foundation, n.d.) and LEED Brazil have been launched.

Adaptation from a green building rating system to industry has no efficacy, since the specific characteristics of industrial projects do not permit a full and integrated application of building rating system. Moreover, the impacts on the environment of industrial projects are far more critical than in buildings, including the phases of demolition and disposal at the end of the economic life of the project.

Although engaged in several remarkable sustainable projects, the oil and gas industry should advance and incorporate the green philosophy already found in the building industry. As one of the first precursors, Poveda (2014) developed a rating system to measure the environmental performance of oil sands and heavy oil projects in Canada, called the WA-PA-SU project sustainability rating system. However, due to the large variety of projects of the oil and gas sector around the globe, a full application of Poveda's framework, which was based on the oil sands in Alberta, should be carefully verified before extended to other oil and gas projects.

3.2 Is ISO 14000 series enough?

Many oil and gas companies in Brazil and Canada are certified ISO 14001, the most popular environmental management standard; and also demands the use of this code from its subcontractors. Based on the PDCA (Plan, Do, Check and Act) cycle, however, ISO 14001 is an environmental code that certifies the corporate management processes and does not ensure the quality of the final product since it does not define goals and indicators, which should be established, planned, measured and controlled by the certified entity. Rondinelli and Vastag (2000) point out that ISO 14001 does not measure the actual environmental performance of a plant or company. In fact, it ensures that the company has a management system to deal effectively with its environmental impacts, meet regulatory mandates and go beyond legal requirements to achieve continuous environmental improvements, but there is no way of externally verifying that such improvements actually occur.

3.3 Building Information Modelling (BIM) and Sustainable Engineering

Building Information Modelling (BIM) represents the development and use of n-dimensional models to simulate the planning, design, construction and operation of the future facilities (Azhar, 2007). BIM carries all information related to the model including its physical and functional features and project life cycle information as "smart objects". According to Azhar (2007), a building information model can be used for the following purposes:

- 3D visualisation of the model
- Detailed design drawings for construction and purchasing of the different facilities such as MEP systems
- Code reviews, like those done by fire departments
- Forensic analysis by simulating potential failures, such as leaks, evacuations plans etc.
- Operation/maintenance of facilities, including the use of the model for planning renovations and maintenance operation
- Cost estimating (materials quantities are automatically extracted and changed when any changes are made in the model)
- Construction sequencing (used to create material ordering, fabrication and delivery schedules for all project components)
- Conflict, interference and collision detection, for models are created in 3D space, hence all major systems can be visually checked for interferences.

More and more, for projects pursuing green certifications, designers have to conduct in-depth sustainability analysis based on a building's form, materials, context, and mechanical-electrical-plumbing (MEP) systems, as the most important decisions regarding a sustainable project are made during the design and planning stages (Azhar et al., 2011). BIM is also a powerful tool used to optimize the use of passive solar energy for lighting, ventilation, heating and cooling and therefore reduce overall energy use

of the building. In addition, BIM is also employed to perform life cycle energy assessment simulations so as to provide designers, owners and engineers with valuable information on energy, emissions and impacts over the lifetime of the project.

3.4 Embodied energy of industrial projects

According to Harvey (2010:35), buildings account for more than one third of total energy use in world, whereas industry also represents at least one third of total energy consumption. Agriculture and transport sectors are responsible for the remaining one third. Although buildings and industry demand approximately the same amount of energy, most works involving sustainable design are just related to buildings. This is probably due to the higher level of complexity of industrial processes, more complex design and the immense variety of materials used in industry. All these aspects make it difficult to create a unique and standard green code, such as LEED, for industry.

Embodied energy is the total primary energy used to extract, process, manufacture, deliver and construct materials, assets, equipment or facilities; and should also include the feedstock energy, which is the energy value of energy commodities that eventually are incorporated in the final product (Harvey, 2010:331). Yung et al. (2013) published a literature review of 38 works involving 206 cases and concluded that the initial embody energy represents from 7.5 to 7.8 years of the total energy use in buildings' life. It can be an indicator of the overall environmental impact of projects, since energy use produces carbon dioxide and therefore contributes to the greenhouse effect. Embodied energy approach considers only the total primary energy spent until the point in which the installation is commissioned and ready to start-up, not including the operation or decommissioning. As of this phase, the facility is operational and all energy use is classified as process energy, whose efficiency is examined by the related process engineering.

Contrary to the embodied energy approach, the life cycle assessment evaluates all the impacts over the whole life of a material or element (from cradle to grave). Although the main goal is to reduce the embodied energy of an installation, one of the most important observations derived from the embodied energy perspective is to consider embodied energy over the whole lifetime of a project, since an increase in the embodied energy might lead to a reduction in the operational energy over the lifecycle and therefore a reduction in the total energy use of the project. This trade-off relationship will depend on the percentage use of recycled materials, the performance of the individual systems, the avoidance of wastes, construction methods and many other aspects that can influence the operation and maintenance of the facility. In this sense, this method resembles the preliminary study of economical viability of the project, with energy instead of cost.

Likewise sustainable rating systems, the embodied energy analysis has been already in use by the building industry, although a great effort is still necessary to fill up the existing research gaps (Ariyaratne and Moncaster, 2014). In most works, BIM was utilized as the main tool to calculate embodied energy and respective carbon footprint. Articles, works or case studies related to the use of the embodied energy approach by the oil and gas industry could not be found until the conclusion of this work.

4 DISCUSSIONS

Based on the situation cited earlier, two proposals were identified to address the sustainability of oil and gas projects. These proposals are presented below.

4.1 Universal oil and gas green rating system

As observed earlier, the complexity and the variety of the industry do not permit a full application of current green building codes. Contrary to the industry, the building sector is a more standard-based sector. In the oil and gas industry, besides the variety of projects (plataforms, refineries, power plants and much more), the list of regulatory requirements is often longer, which demands more resources and effort to be met. In addition, most of these projects are located in remote areas, posing a higher potential impact on the environment when compared with buildings.

A universal framework of a green rating system for the oil and gas industry that could cover all types of projects around the globe is desirable. This would permit the comparison of similar projects by means of a quantitative analysis. As mentioned earlier, Poveda (2014) concluded a valuable research project about a sustainable rating system that can be applied on the oil sands and heavy oil industry in Canada, the WA-PA-SU. However, further analysis is necessary in order to evaluate the applicability of the proposed framework into other types of projects and in other parts of the globe. In addition, Hunt (2005) developed a sustainable rating system for bridges based on the LCA and replicating several existing criteria of the LEED certification. Envision 2.0 (Graduate School of Design – Harvard University, n.d.), a rating system for sustainable infrastructure covers civil infrastructure projects such as roads, bridges, pipelines, railways, airports, landfills and others. These previous works suggest that the academic community have already identified promising improvements in the effort of the industry to become more sustainable, and that a green rating system for each sector may be a coherent evolution.

4.2 The use of BIM to optimize the carbon footprint of oil and gas projects

Instead of looking for a green rating system that would address all concerning dimensions of sustainability, as the ones already mentioned in section 3.1, another proposal is to focus on the carbon footprint of oil and gas projects. The challenging emission levels, which perhaps will be agreed on the next United Nation Climate Change Conference in November 2015 by attending nations, will not tolerate the current emissions provided by business as usual – BAU. As a result, carbon caps or tax will be probably levied in many nations and therefore the lifecycle energy in industrial projects should be taken even more seriously than nowadays. This issue will be considerably more challenging in developing countries, such as the BRICS – Brazil, China, Russia and South Africa, where the current infrastructure is still under development, demanding huge amounts of equipment, construction sites and energy intensive materials, such as concrete, steel, aluminium and copper.

As seen in the AEC industry, BIM as a tool to perform a lifecycle energy analysis in oil and gas projects will play an important role due to its ability to integrate geometric features of the model with non-geometric attributes. In addition, BIM also has the ability to generate schedules and simulate the construction site, which will also interfere in the overall embodied energy of the project. All these features facilitate changes in the model, which are accomplished in a consistent and automatic way.

4.3 The role of project management in sustainable engineering

With so many requirements to be fulfilled by green projects, the role of project management has to be stressed, since the project team also have to meet the planned cost, conclude it on schedule and guarantee the quality requisites in order to be considered economically viable. One of the main complaints of owners is that green buildings normally lead to cost overruns and schedule delays. Figure 1 illustrates the main aspects discussed in this work, showing the main categories of projects (building; energy, in which oil and gas projects are included; and infrastructure) and the role of the best practices of project management to ensure that green projects will not only achieve the goals of sustainability but also guarantee their compliance with cost, schedule and quality requirements agreed with the owner and other stakeholders.

The additional sustainable requirements make projects even more challenging than traditionally they are, and only benchmarking practices of project management can assure green projects will be supported, sponsored by owners and therefore will have the chances of success of the project maximized. Once the various constraints are incorporated in the preliminary design, such as the ones mentioned in items 4.1 and 4.2, in both proposal (not only on the lifecycle energy assessment), the model can be implemented in a BIM system, for example, and used as an optimization tool in order to find the most suitable conditions allied with cost, schedule, quality assurance and sustainable indicators.

The choice for one of the proposals presented above and the respective research development is part of first author's Ph.D. program, and further findings will be partially published later on.

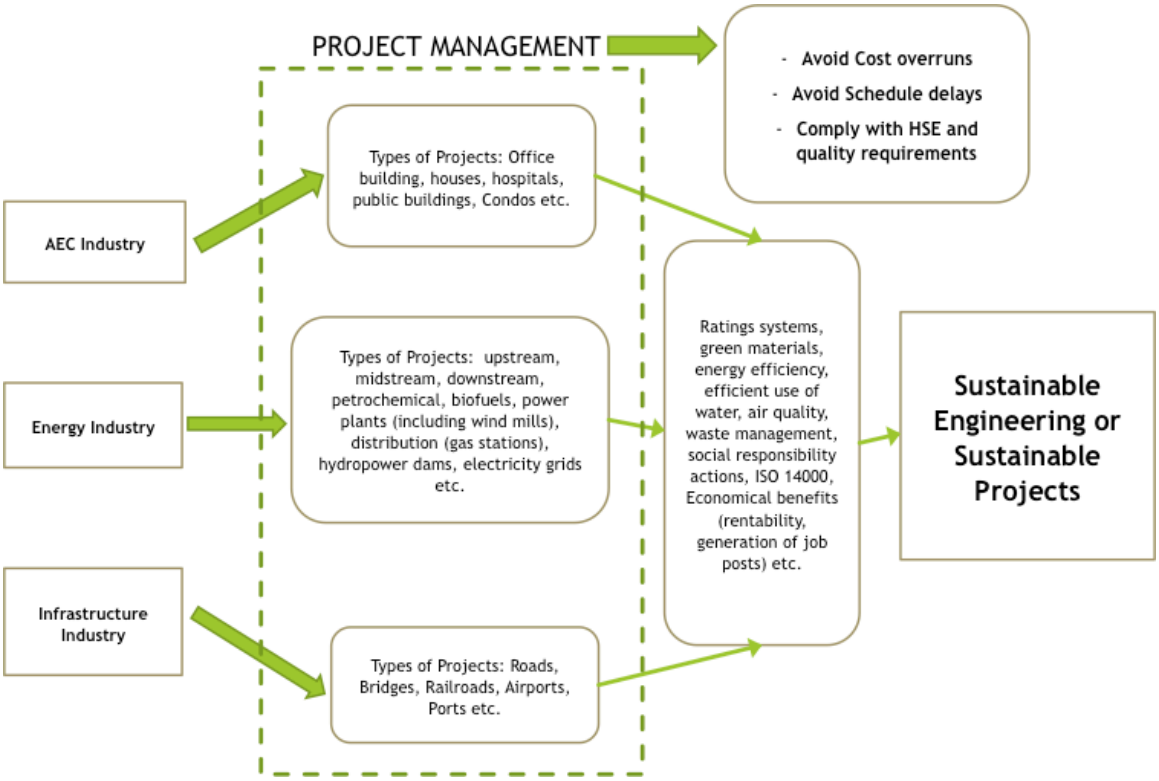

Figure 1: Sustainable engineering interfaces with types of industry, sustainable goals and project management

5 CONCLUSION

Although the recent fall in oil prices, many oil and gas projects around the world are expected to advance to the next phases. Regarding Brazil and Canada, oil and gas specialists and corporations are growing expectations due to the potential contribution of their national oil outcomes to maintain the global oil demand in the near future. In fact, even with the claims to reduce the fossil fuel dependency and with the restrictions that can arise with international agreements at the end of 2015, the oil and gas sector will still have an important role to guarantee the global energy offer for a long period.

In this sense and despite the recognizable performance of the sector, the oil and gas industry has to go further and adopt new concepts such as the green philosophy that is more mature in the building industry, for industry and buildings are responsible for equally energy emissions and energy use. Two proposals on how to address the sustainability of oil and gas projects were presented. They will be deeply analysed on a Ph.D program and published later on. The first is an attempt to develop a universal green rating system for the oil and gas industry. The framework proposed by Poveda (2014) will be considered as an initial point. The second is the use of BIM to assess the initial embodied energy and respective carbon footprint of oil and gas projects. The latter is more closely related to climate change due to the carbon emission goals that may likely arise soon, whereas the former deals with all dimensions of sustainability more broadly. In both proposals, the role of the best practices of project management has to be underlined, for green projects still have to comply with cost, schedule and quality requirements in order to be considered viable.

Finally, the challenges of the oil and gas sector are not few, since the industry has to confront the common sense that the exploration and production of oil and gas cannot occur without reducing environmental impacts and therefore without complying with the best practices of sustainability. However,

based on notable actions, the sector has demonstrated to be open to new changes; willing and aligned with the society to evolve to achieve benchmarking results in sustainability, thereby contributing with the global efforts to guarantee the climate stabilization and the sustainable development.

References

Ariyaratne, C. I. and Moncaster, A., 2014. Stand-alone calculation tools are not the answer to embodied carbon assessment. In: Ecological Built Environment Research and Enterprise (EBERE), *International Conference on Sustainability in Energy and Buildings 2014*. Cardiff, Wales, UK, 25-27 June 2014. N.d.: Elsevier Ltd.

Azhar, S.; Hein, M. and Sketo, B., 2007. *Building information modeling (BIM): Benefits, risks and Challenges. Building Science*, **18**(9), pp. 2-5.

Azhar, S.; Carlton, W. A.; Olsen, D. and Ahmad, I., 2011. *Building information modeling for sustainable design and LEED rating analysis*. Automation in Construction, **20**, pp. 217-224.

ANP – Agência Nacional de Petróleo, 2014. *Anuário Estatístico Brasileiro do Petróleo, Gás Natural e Biocombustíveis 2014 – Tabela 1.1 – Reservas provadas de petróleo, segundo regiões geográficas, países e blocos econômicos – 2004-2013*. [online] Available at <http://www.anp.gov.br/?pg=71976#Se__o1> [Acessed February 10, 2015].

Building Research Establishment, n.d. *What is BREEAM? Building Research Establishment*. [online] Available at <http://www.breeam.org/page.jsp?id=66> [Accessed January 22, 2015].

EIA – U.S. Energy Information Administration, 2013. *Brazil – Countries Analysis Brief Overview*. [online] Available at <http://www.eia.gov/countries/country-data.cfm?fips=BR&trk=m> [Acessed February 10, 2015].

EIA – U.S. Energy Information Administration, 2014. *Canada – Overview*. [online] Available at <http://www.eia.gov/countries/cab.cfm?fips=CA> [Acessed February 10, 2015].

Folha de Sao Paulo, 2014. *Reservas provadas de petróleo do Brasil devem dobrar até 2022, diz ANP*. [online] Available at <http://www1.folha.uol.com.br/mercado/2014/05/1454358-reservas-provadas-de-petroleo-do-brasil-devem-dobrar-ate-2022-diz-anp.shtml> [Acessed February 10, 2015].

Graduation School of Design – Harvard University, n.d. *Envision Graduation School of Design – Harvard University*. [online] Available at <http://www.gsd.harvard.edu/research/research_centers/zofnass/zofnassratingsystem.html> [Accessed January 22, 2015].

Kerr, R., 2011. Peak Oil Production May Already Be Here. *Science*, **331**(March), pp. 1510-1511.

Kerr, R., 2012a. Technology Is Turning U.S. Oil Around But Not the World's. *Science*, **335**(February), pp. 522-523.

Kerr, R., 2012b. Are World Oil ' s Prospects Not Declining All That Fast ?. *Science*, **337**(August), p. 633.

Harvey, D. L. D. (2010). *Energy and the New Reality 1 – Energy Efficiency and the Demand for Energy Services*. London: Earthscan.

Hunt, L. R., 2005. *Development of a rating system for sustainable bridges*. Unpublished dissertation (MSc), Massachusetts Institute of Technology.

Hussain, Y., 2015. *Only two B.C. LNG projects to proceed as industry faces 'anxiety attack': analyst*. [online] Available at < http://business.financialpost.com/2015/01/21/only-two-b-c-lng-projects-to-proceed-as-industry-faces-anxiety-attack-analyst/?__lsa=3764-2a76> [Acessed February 10, 2015].

Ivanhoe, L. and Leckie, G. (1993). Global oil, gas fields, sizes tallied, analyzed. *Oil & Gas Journal*, **91**, pp. 87-91.

MacLellan, D. A., 2014. *Opinion: Why building new refineries in Canada is uneconomic and undesirable*. [online] Available at < http://business.financialpost.com/2014/01/17/opinion-why-building-new-refineries-in-canada-is-uneconomic-and-undesirable/?__lsa=3764-2a76> [Acessed February 4, 2015].

Mendleson, R. (2013). *Why Aren't We Building Refineries In Canada? Because It's Too Late, Experts Say*. [online] Available at < http://www.huffingtonpost.ca/2012/05/23/canada-oil-refineries_n_1539701.html> [Acessed February 5, 2015].

Natural Resources Canada, 2014. *Canadian LNG Projects*. [online] Available at < http://www.nrcan.gc.ca/energy/natural-gas/5683> [Acessed February 7, 2015].

NEB – National Energy Board, 2015. *Estimated Production of Canadian Crude Oil and Equivalent – historical data available on worksheets*. [online] Available at <https://www.neb-one.gc.ca/nrg/sttstc/crdlndptrlmprdct/stt/stmtdprdctn-eng.html> [Acessed February 10, 2015].

Northwest Redwater Partnership, n.d. *The project – location and timing*. [online] Available at < https://www.nwrpartnership.com/location-and-timing> [Acessed February 2, 2015].

Petrobras, 2014a. *Profile*. [online] Available at <http://www.petrobras.com.br/en/about-us/profile/> [Acessed February 10, 2015].

Petrobras, 2014b. *Petrobras 2030 Strategic Plan – powerpoint presentation*. [online] Available at <http://www.petrobras.com.br/en/about-us/strategy/business-and-management-plan/> [Acessed February 10, 2015].

Petrobras, 2014c. *Pre salt*. [online] Availabe at <http://www.petrobras.com.br/en/our-activities/performance-areas/oil-and-gas-exploration-and-production/pre-salt/> [Acessed February 11, 2015].

Petrobras, 2014d. *Refining*. [online] Available at < http://www.petrobras.com.br/en/our-activities/performance-areas/refining/> [Acessed February 02, 2015].

Poveda, C. A., 2014. *An integrated approach for sustainability assessment: the Wa-Pa-Su project sustainability rating system*. Ph.D. University of Alberta.

Rondinelli, D. and Vastag, G., 2000. *Panacea, common sense or just a label? The value of ISO 14001 environmental management systems*. European Management Journal, **18**(5), pp. 499-510.

Sorrel, S., Speirs, J., Bentley, R., Brandt, A. and Miller, R., 2010. Global oil depletion: A review of the evidence. *Energy Policy*, **38**(9), pp. 5290-5295.

Sorrel, S., Speirs, J., Bentley, R., Miller, R. and Thompson, E., 2012. Shaping the global oil peak: A review of the evidence on field sizes, reserve growth, decline rates and depletion rates. *Energy*, **37**(1), pp. 709-724.

TransCanada, n.d. *Keystone XL Pipeline – About the project*. [online] Available at <http://keystone-xl.com/about/the-keystone-xl-oil-pipeline-project/> [Acessed February 11, 2015].

U.S. Green Building Council, n.d. *LEED is transforming the way we think about how buildings and communities are designed, constructed, maintained and operated across the globe*. [online] Available from: <http://www.usgbc.org/leed/rating-systems/credit-categories> [Accessed January 22, 2015].

Vanzolini Foundation, n.d. *Processo AQUA Vanzolini Foundation*. [online] Available at <http://www.vanzolini.org.br/hotsite-aqua.asp> [Acessed January 22, 2015].

Yung, P., Lam, K. C. and Chenyun, Y., 2013. *An audit of life cycle energy analyses of buildings*. Habitat International, **39**, pp. 43-54.