

Waste as a useful circular economy indicator

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ABSTRACT

Waste is often defined as unwanted or unusable material generated in business. The authors advocate an approach that prevents or reduces waste creation at every step in a process. A rationale is presented for using waste as a good indication of circular economy development applicable to all industries, with examples from the oil and gas sector. With a design focus on waste prevention, engineers can examine each process and system design to increase resource intensity and lower costs across entire asset and product lifecycles.

INTRODUCTION

The oil and gas industry's current view of waste is both narrow and cost driven. A compelling argument can be made to broaden the concept of waste as a profit center within a finely tuned circular system framework that is both progressive and positive.

This paper will substantively examine how waste is defined in the oil and gas industry and how that actually works in practice both operationally and within its business case assumptions. Use of a definitive and progressive approach towards a 'circular economy' system - as applied by other select industries dealing with waste issues and challenges - will help the oil and gas industry to develop a more nuanced and profit centered approach to waste.

Cases for looking at waste in a more holistic way are presented to best address the specific challenges facing the oil and gas industry within its own progressive version of a circular economy framework. A look at the asset decommissioning stage in the oil and gas industry provides a lens through which the industry can view how lack of focus on waste reduction creates very real economic and regulatory challenges.

A progressive approach to waste within a 'circular economy' framework will expand the scope of how the oil and gas industry treats waste. There should be an awareness that organizational maturity¹ will determine a company's ability to adopt some of the practices proposed to close the loop. Most importantly, such focus could drive the case for sustainability.

WASTE IN THE OIL AND GAS INDUSTRY

Oil and gas operators typically engage in one or a multiple of the activities in the petroleum products lifecycle: the extraction of crude oil and gas from the ground, or exploration and production (upstream), the transportation to refineries and product distribution center (midstream), the refining of

¹ Moon, F., Theys, S. 2017. *Performance Framework for Evolving Sustainability Strategies*, SPE-184447-MS

crude oil and gas into intermediate or finished products (refining, or downstream) and the marketing and sales of the products to consumers (distribution). Each of these phases operate as separate sectors (or streams), using different human skills, infrastructure, processes, at different locations and proceed along different timelines. In 2015, the petroleum industry explored and produced worldwide 4 361.9 million tons (91 670 bpd) of crude oil and 3 199.5 million tons oil equivalent of natural gas². More than 2 500 refined products, as well as feed stocks for the petrochemical industry are the direct result of the petroleum industry. Petroleum is vitally linked to all aspects of our society - primarily for transportation and heating³. Consequently, the oil and gas industry impacts society, the environment and the economy in innumerable ways. Waste is one of these impacts. In the oil and gas industry, waste is defined as

a material (solid or liquid) intended to be disposed of, reused, recycled or recovered either on-site or off-site that is the result of company operations. Includes domestic waste and other discarded material from offices and commercial (e.g. retail) activity. It does not include regulated or authorized water discharges such as effluent from water treatment plants or produced water from oil and gas production⁴.

The following table gives a non-exhaustive overview of the types of waste which receive special focus in the oil and gas industry, with a reference to some of the most significant regulations tied to them, and representative means for managing impacts.

Table 1. Current oil and gas industry waste concerns.

Activity	Waste	Regulations	Impact managed through
Upstream	Incineration residues Sludge, scale and cuttings Chemicals NORM and TENORM ⁵	EU 2008/98/EC directive, Annex III	Life Cycle Assessment (LCA) Risk management Energy auditing Air quality and noise management
Midstream	Spent catalysts Heavy ends WEEE ⁶ Plastics and packaging Paper	EPA530-F-98-014	Site investigation and remediation Decontamination, decommissioning, demolition Water, wastewater and waste management
Downstream	Metals Medical waste Spills Radioactive sources		Energy recovery Re-injection Bioremediation, evaporation pits Landfilling
Distribution	Ozone depleting substances Fluorinated greenhouse gases Used or contaminated land Wastewater		

² BP. 2016. *BP Statistical review of world energy*, Pages 8 and 22

³ *World Energy flow in 2011*, Lawrence Livermore National Laboratory

⁴ IPIECA – API – IOGP. 2015. *Oil and gas industry guidance on voluntary sustainability reporting*, 3rd edition, Page 72

⁵ Naturally Occurring Radioactive Material (NORM) and Technically Enhanced Naturally Occurring Radioactive Material (TENORM)

⁶ Waste Electrical and Electronic Equipment (WEEE)

Often, these waste sources have a hazardous component which is subject to strict regulation. Accordingly, companies focus primarily on compliance with local waste laws and on all waste materials minimization.

Environmental regulations around waste are patchy. In the past 10 years, regulations have become increasingly strict and are applied more broadly. Still, a long list of exceptions often accompanies the law, leaving companies free to handle actual waste in the most opportunistic way. Regulations are particularly focused on the effect of waste over water. Hence, for offshore activities, each state has its own waste discharge laws that follow regional guidelines (OSPAR Convention for the North-East Atlantic, China RoHS, etc.). Regulations differ from one geographical region to another, from one type of waste to another, allowing businesses to create discrete indicators that fragment definitions of and treatment of waste as opposed to comprehensive definitions and treatment, thus making it nearly impossible to manage effective programs of waste prevention.

During the period of 2000-2015 waste volumes consistently increased⁷, whether one is looking on a per company basis or a geographical region or by type of asset operated. This is partly due to better reporting but also because of growing upstream sector's operational waste, plug & abandon activities, cleaning rigs before stacking, and decommissioning activities. It is also recognized that this trend in waste volumes or weight will continue to grow as decommissioning^{8 9} will take greater importance as maturing oil reserves go off line. Most alarmingly, only 5% of decommissioning waste is reused, 95% of its volumes are recycled. Companies' efforts in minimizing waste - and hence controlling volumes of waste and energy required for recycling - will thus be a more and more challenging endeavor.

Volume or weight of waste may arguably not reflect best the environmental impact, as observed through the case of disposal of decommissioning waste. Hence, the Global Reporting Initiative (GRI), an internationally recognized reference in corporate sustainability reporting, proposes monitoring waste by type of waste, disposal method, or destinations. The International Petroleum Industry Environmental Conservation Association (IPIECA) has adapted sustainability reporting for the upstream and downstream segments and makes the distinction between hazardous and non-hazardous as the determining factor, as dictated by regulations.

From the industry perspective, waste is narrowly defined. Most efforts are focused on isolating specific process "waste" outputs and minimizing them.

CREATING CLOSED LOOPS SYSTEMS

What is the rationale for separating waste from other unusable outputs in the petroleum life cycle? A century or more of narrowly defined thinking about waste in the oil and gas industry will present hurdles that need to be addressed and overcome.

⁷ Review of several 2000 through 2015 sustainability reports of major oil and gas players

⁸ Wilby B. 2016. *Decommissioning Market to Boom from 2016 to 2040*, Douglas-Westwood

⁹ 2004. *Part B: Opportunities and Markets in the UK: Refineries and Fossil Fuel Power Stations Forecast*, UK government national web archive

Closing loops will require that companies rethink how they use material, equipment, processes and manpower to generate products - which have a positive value. Currently the industry regards waste as a cost center. If waste is viewed as completely integral to the business system and can be defined as unusable output, companies will have increased incentives to either eliminate waste completely from business models or create value with the waste output. Regulations, hazard levels or volumes become secondary. If waste is integral to the business system, the question is how to transform waste - unusable output - into a net positive that is both progressive and profitable?

Waste, as much as the product or service that is generated for profit, will affect environmental, economic and social sustainability of the business. Company performance viewed through material input, energy utilization, water utilization, biodiversity, emissions, etc. will require additional labor, affect occupational health and safety, demand special training and education.

The various stakeholders of the oil & gas industry, and particularly operators covering the whole petroleum life cycle, are encouraged to work together in tackling waste by improving the design and engineering of assets, processes, handoffs between segments and the produced products themselves. The following concepts are found in various businesses and are proposed as a basis for redesigning the value chain of petroleum.

Go Lean

In the automobile industry, Toyota¹⁰ aims to eliminate waste from its manufacturing. Waste is defined as an activity which does not add value. Transport, inventory, motion, waiting, overproduction, over processing and defects are considered waste. Manufacturing is also affected by unnecessary stress and fluctuation of demands on assets, resources and processes. Many lean tools and principles are used to help eliminate waste. This entails not only technical changes but also cultural adaptation, as the behavior of employees can lead to continuous improvement in the business. Lean manufacturing involves never ending efforts to eliminate or reduce waste throughout all the processes: it promotes doing more with less. Kaizan teams are regular fixtures in many oil and gas companies today.

Think Circular

Eliminating waste within the oil and gas linear “take, make, dispose” model will quickly show its limits. While one of the founding principles of circular economy is that waste does not exist, the waste in the current state of operations can be reconceived as a “nutrient” which reenters the operations and regenerates continually without interfering with the environment or is returned to the environment in a safe form. Recirculated waste - which, in this new state of operations becomes a positive and valued nutrient - helps at the same time to reduce material input, energy utilization, emissions, or other aspects of the petroleum lifecycle.

¹⁰ Liker, J. 2004. *The Toyota Way, 14 Management Principles from the World's Greatest Manufacturer*, New York: Mc-Graw Hill

It is said that around 80%^{11 12} of a product’s environmental impact is fixed by its design. Choices made at the design stage also determine what materials are used and how easily they can be repaired, recycled, retaken or reused.

Upstream spend between 2000 and 2013 has grown by 287%, while oil and gas production has increased only by 24% and oil prices by 281%¹³. This means basically more spend for less production. A move to a circular economy - even with a vision requiring several decades - is an opportunity to control these costs.

Integrate

Thinking circular implies going beyond one’s perimeters of operations. The best way to close system loops is to find the best stakeholder who uses the waste in its operations. Partnerships involving businesses working along the value chains - make one company’s waste another company’s material input - or expansion outside of the traditional the value chain are critical. To enhance the communication between oil & gas streams, each needs to think holistically, where upstream takes in account the consequences of its production for distribution, midstream considers its ties outside of its logistics role, etc.

BASF’s Verbund¹⁴ model - German for “concatenation of all kinds” - are integrated chemical production plants where products manufactured in one plant can serve as feedstock for another. The company partners with other chemical businesses as well as utilities providers in order to continuously improve its products, rationalize flows of resources and parcel out energy required for operating different industrial assets. Communication between various businesses that share industrial nutrients and energy has proven to be a very profitable and efficient way to cut cost and reduce the collective environmental footprint. Figure 1 shows the cost advantages of BASF’s Verbund model.

Verbund cost advantages - breakdown

	%
1 Logistics Verbund	60
2 Energy Verbund	30
3 Infrastructure Verbund	10



<https://www.basf.com/en/company/about-us/strategy-and-organization/verbund/production-verbund.html>

Figure 1. The Verbund cost advantage.

¹¹ Ulrick, K. A., Pearson, S. A. 2003. *Does product design really determine 80% of manufacturing costs?*, Working Paper # 360-93, Massachusetts Technical Institute

¹² 2012. *Ecodesign your future*, European Commission

¹³ 2015. *Global Economic Trends and market outlook for the OSV sector*, Douglas-Westwood

¹⁴ BASF company website. www.basf.com/en/company/about-us/strategy-and-organization/verbund.html

Make it sustainable

The final integration principle is to keep the consumers in mind, not only from an economic perspective but with consideration of consequences to their environment and wellbeing. The regulatory shift from consumers' responsibility to producers should provide an incentive for the oil and gas industry to develop strategies for waste avoidance and exploitation of waste outputs. Benefits of this approach extend beyond the consumer to the environment (increased products recycling rates, carbon reduction, optimized energy use, etc.).

THE CASE OF DECOMMISSIONING

In practical terms, how can the oil & gas industry implement such an alternative view of waste? The case of decommissioning of oilfield assets is provided for illustration.

Decommissioning is a rising challenge and brings questions as to the actual engineering of assets. Assets for producing petroleum are a great tool during their lifetime. But what is to be done with them when they are no longer of use? This is the question that arises from decommissioning rigs, pipelines, refineries, floating vessels, gas stations, etc. Decommissioning does not necessarily equate to the end of safe use of an asset. More likely it is the negative value of further exploitation of an oilfield or producing refined goods at a specific location as the economics become non-viable or the market is no longer there.

Life Cycle Assessments (LCA) are a common practice in the oil and gas industry to understand the interaction of products outputs with the environment. This should be the inevitable step at the start of new capital expenditure projects or changes to brownfield sites. Arriving at the decommissioning stage, operators employing a (late) LCA will likely be confronted by challenges unforeseen in the design of the asset and environmental issues with the site. Decommissioning of an offshore platform in the North Sea could cost up to 2 billion USD¹⁵. Applying the lessons learned from LCAs at decommissioning¹⁶ stage will help the industry build smarter assets and processes.

Reuse

In the UK, up to 98% of offshore rig components are currently being recycled¹⁷. Zero Waste Scotland wants to refocus efforts towards reuse practices which would lead to higher resource efficiencies. The Royal Society for the encouragement of Arts, Manufactures and Commerce (RSA)¹⁸ developed a thorough list of offshore rig components and equipment and corresponding opportunities for reuse. Reuse options go beyond the oil & gas industry itself and have applications in sectors such as renewable energy, construction, agriculture, and recreation to name a few. To minimize potential costly remediation or rejection of components upon an asset's end of life, a rigorous maintenance plan will extend and preserve its economic value into its new life use. Logistics optimization is also critical to

¹⁵ 2015. *The real cost of decommissioning*, OE Digital

¹⁶ Cole, D., Kar, J., Lock E., Diederik N. 2015. *From late-life operations to decommissioning*, McKinsey

¹⁷ Perella, M. 2014. *Can North Sea installations be recycled, or decommissioned sustainably?*, The Guardian

¹⁸ The RSA Great Recovery & Zero Waste Scotland Programme. 2015. *North Sea Oil and Gas Rig Decommissioning & Re-use Opportunity Report*, Aberdeen, UK.

making the reuse economy viable. Finally, OilMac¹⁹ in the UK or the United States Materials Marketplace²⁰ are examples of internet sharing sites where engineers can place components available for reuse and serve a market for replacement of malfunctioning parts on current assets.

Remanufacturing

Remanufacturing is an alternative which results in reduced resource and energy consumption than necessary for making new components. Like reuse, it is a viable economic and viable option. Caterpillar²¹ started remanufacturing diesel engines in the 70s and established a take back program in order to enhance productivity. Concerns over quality and safety of remanufactured parts are mitigated through inspection and testing to determine whether components meet acceptable standards. However, engineers will realize that remanufacturing processes are more complicated than manufacture of new components: the processes of disassembling parts, cleaning, material management and inventorying have to be accounted for which may require dedicated teams to manage these new activities. New business opportunities are possible, as well.

Recycling

There are a number of options for recovering (recycling) components materials and equipment. While the industry may doubt the health and safety record of such solutions, note that Rolls-Royce implemented its closed loop recycling program Revert²² over 10 years ago to recover high value metals. Almost half of a used jet engine are now recycled. The quality of the recovered material is high enough to safely use the metals again to make entirely new engines for the aeronautics industry.

Drill cuttings are used to produce cement in Oman²³ (Petroleum Development Oman) or to make asphalt and other road base in Pennsylvania²⁴ (Marcellus shale exploitation). NORM or TENORM are hazardous wastes that can be diluted for safe reuse in road construction or cement inclusion²⁵. To exploit more opportunities like these, the oil and gas industry may need to review warranties and insurance coverage for adoption of material recovery.

Designing for reuse, remanufacturing and recycling

Oil & gas companies that have shifted to reuse, remanufacturing and recycling practices will still be left with liabilities from decommissioning activities - expensive or non-adapted disassembly and lifting capacities until all assets are redesigned with end use in mind. The end goal is the plug-and-play adaptability of a Lego like system that will produce savings during operation through to reuse.

Stakeholder engagement. Engaging suppliers earlier in the conception and construction of assets will ensure the intrinsic efficient performance (aiming for the best quality, efficiency and retrofitting at

¹⁹ <http://www.oilmac.com/>

²⁰ <http://materialsmarketplace.org/>

²¹ Caterpillar Company website:

<http://www.caterpillar.com/en/company/sustainability/remanufacturing/benefits.html>

²² Rolls-Royce Company website: <http://www.rolls-royce.com/sustainability/performance/case-studies/revert.aspx>

²³ 2016. *Going Circular in Oman*, <http://www.delivered.dhl.com/en/articles/2016/09/going-circular-in-oman.html>

²⁴ Rance, A., Mueller, D. 2014. *Recycling & Reuse of Marcellus Shale Drill Cuttings*, PennState Extension, CleanTeach

²⁵ Welbergen, J., Tsurikov, N. 2014. *The reuse of NORM residues*, Brasil: Simposio Minerios & Radioatividade

decommissioning stage) instead of looking for the lowest commoditized component solution. Earlier collaboration will also help in commercial alignment by avoiding overdesign, large scrape and decommissioning costs. Contracts between stakeholders can be established with this end in mind, thus mitigating the technical and economic risk. If designed for easy disassembly and reassembly, remanufacturing and reuse can be much more profitable than purchasing new components. Currently, this is often not the case as remanufacturing and reuse are not in mind during design.

Substitution. Design applies not only to the asset itself but also to the processes traditionally used and the products obtained as output. Substitution of materials may be the best alternative for emissions reduction. For example, Statoil is investigating the means to replace water with liquefied CO₂ to hydraulically fracture wells²⁶: this will reduce water intake, which is particularly important in water stressed environments, and provides reuse for intensive CO₂ emissions activities.

Standardization. Standardization will also enhance the capabilities for substituting parts more easily. Oil & gas has traditionally customized its projects to operate under extreme weather conditions, extracted fluid conditions in response to strict in-house standards. While retaining uncompromisingly high levels of health and safety, engineers may be able to use more standardized parts to ensure better interchangeability between installations within and outside the industry.

Innovation. Digital and technology innovations championed by companies like General Electric or Siemens are providing the oil and gas industry with the opportunity to overcome the complexity of materials and deconstruction of output products. There are more and more machine to machine sensors accompanied by data analytics to enable operators to optimize the condition of their assets, process and products. Engineering can be done in a “digital twin”²⁷ - or 3D model which collects all physical data of an asset and can facilitate the running of simulations in real time or alternate operating modes. Operations could even be run remotely through the digital twin, a potential safety enhancement. This is a technology platform that will facilitate more collaborative efforts between stakeholders within the petroleum lifecycle.

The circular advantage. Current efforts in decommissioning options such as rigs-to-reef (recycle) and reuse of specific products²⁸ are recommended for integration of older (more than 15 years) oil and gas assets into the circular economy. The circular economy will manifest as new designs of oil and gas assets consider the full life cycle of the asset. Thinking circular, with decommissioning in mind right at the Front End Engineering and Design (FEED) stage of a capital expenditure / greenfield project is particularly pertinent when companies want to control costs and time, given uncertainty of oil or gas prices.

²⁶ 2015. *Cleaning up fracking with carbon*, London, UK: II-Energy

²⁷ Bell, D. 2015. *Digital Twins Could Offer Greater Insight for Oil, Gas Assets*, Rigzone

²⁸ The RSA Great Recovery & Zero Waste Scotland Programme. 2015. *North Sea Oil and Gas Rig Decommissioning & Re-use Opportunity Report*, Aberdeen, UK

CONCLUSION

The oil and gas industry need to develop coherent waste strategies that consider all activities that do not add value to a company across the entire value chain. With this kind of focus, waste strategies become sources of profitable benefit through security of supply (resource management), optimized transformation of material and energy flows, integrated analysis and mutually beneficial partnerships. Waste strategies will be instrumental in helping "close the loop."

These ideas allow us to think in more systemic, holistic ways to come up with innovative engineering solutions, starting from the design stage. To move forward, engineers can contribute to the industry by:

- Assessing the lifecycle of end products and outputs destined to consumers,
- Analyzing each step of the value chain to find ways of reducing or removing waste
- Reusing final products to regenerate new products or reuse through different applications.

This way of thinking will require a complete overhaul of the way we design assets, processes and the products themselves, through lean manufacturing techniques, circular thinking, connecting the usually silo-ed sectors of the industry, working with nontraditional partners to extend/expand value chains and consideration of the wellbeing of people.

REFERENCES

- Moon, F., Theys, S. 2017. *Performance Framework for Evolving Sustainability Strategies*, SPE-184447-MS
- IPIECA, API, IOGP. 2015. *Oil and gas industry guidance on voluntary sustainability reporting*, 3rd edition
- Liker, J. 2004. *The Toyota Way, 14 Management Principles from the World's Greatest Manufacturer*, New York: Mc-Graw Hill.
2006. *Environmental management – Life cycle assessment – Principles and framework*, ISO 14040:2006 (E), 2nd edition
- Decom North Sea, Zero Waste Scotland, ABB. 2015. *Offshore Oil and Gas Decommissioning: Platform Removal Methods, Inventory Characterisation and Re-use Solutions Report and Recommendations*. Aberdeen, UK
- The RSA Great Recovery & Zero Waste Scotland Programme. 2015. *North Sea Oil and Gas Rig Decommissioning & Re-use Opportunity Report*, Aberdeen, UK.
2014. *Waste management solutions by the cement industry*, Geneva, Switzerland: WBCSD.
1993. *UNEP Industry and Environment, E&P Forum*. 2004. *Environmental management in oil and gas exploration and production: an overview of issues and management approaches*, UNEP IE/PAC technical report 37, E&P Forum report 2.72/254