Measure, Application, Segment, Industry (MASI):

New Opportunities for Oil and Gas Extraction and Produced Water Management and Recycling

Prepared for:
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Introduction

The New Opportunities for Oil and Gas Extraction and Produced Water Management and Recycling study explores new program opportunities that specifically target oil and gas extraction and water management and recycling (North American Industry Classification System (NAICS 211 and 213). In alignment with the Project Coordination Group's (PCG) indicated interests, the study characterizes major and minor oil producers[1] [2] [3] and identifies market barriers, drivers, and trends. The study discusses codes and standards, as well as the customer decision-making processes. It evaluates existing energy efficiency opportunities and the potential for future energy efficiency savings, determining whether utility programs and incentives can effectively promote new energy efficiency technologies and practices in this market segment.

Energy Saving Opportunities

Oil and gas extraction, inclusive of water management and recycling, is a well-established field with limited new energy saving opportunities. However, from conversations with facility managers and industry experts, Navigant and ASWB Engineering developed a list of potential energy saving opportunities. Opportunities were ranked by new energy savings potential based on the following factors: market saturation, ease of adoption, cost to implement, and return on investment. An important observation is that the remaining energy efficiency opportunities vary for major and minor producers due to different energy efficiency measure adoption rates and Industry Standard Practices (ISPs), which impact the recommendations. These opportunities are explained in detail in Sections 2.4 and 2.5 of the report.

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[1] Major and minor producers are defined in California Public Utilities Commission (CPUC) Energy Division 2013 industry standard practice study for pump control measures in the oil well industry. A major producer is defined as a producer that contributes greater than 2.5% of annual oil production in the State of California. A minor producer is defined as a producer that contributes less than 2.5% of annual oil production in the State of California. In terms of production statistics from recent years, this equates to roughly greater than or less than 14,000 barrels daily.

[2] Southern California Edison, Oil Industry Major and Minor Guidance, http://www.caasupport.com/2013/09/oil-industry-major-minor-company-guidance/.

[3] PG&E has an agreement with the ED that the cutoff point for majors is 15,000 barrels of oil produced per day.

Table 1-1. Energy Saving and Water Management Opportunities for Oil and Gas Extraction[4]

Measure	Major Producers*	Minor Producers*	New Savings Potential	Availability Status*****
Pump Off Controller	85%-100% Saturation******	0%-30% Saturation	High**	Fully Developed
MotorWise® Controller	Not Applied	Not Applied	High	Being Evaluated
Water Shutoff	50%-70% Saturation	15%-35% Saturation	Medium	Fully Developed
High Efficiency Steam Generators	60%-80% Saturation	25%-50% Saturation	Low	Fully Developed
Heat Recovery/Exchanger	0% Saturation	0% Saturation	Low	Needs Evaluation
Cogeneration	50%-70% Saturation	0%-10% Saturation	Low	Fully Developed
Pipe Resizing	70%-90% Saturation	10%-30% Saturation	Low	Fully Developed
Electrical Distribution	80%-100% Saturation	0%-10% Saturation	Low	Fully Developed
VFDs on ESPs[5] and Injection Pumps[6]	85%-100% Saturation	60%-80% Saturation	ISP***	Fully Developed
Smart Wells	40%-60% Saturation	10%-25% Saturation	Under ISP Investigation****	Fully Developed
Unicel® IGF with VFD	5%-10% Saturation	0% Saturation	Low	Fully Developed
Increase Treatment Capacity	5%-15% Saturation	0% Saturation	Low	Needs Evaluation

* See section 2.4 for explanation of "Saturation".
** Pump off controllers are considered Industry Standard Practice for major producers and, therefore, major producers cannot receive incentives for them. They are not considered Industry Standard Practice for minor producers, which can be incentivized. Also varies between new and old wells.
*** Variable frequency drives (VFDs) on electrical submersible pumps (ESPs) and injection pumps are considered ISP and ineligible for incentives for both major and minor producers.
**** Smart wells are under investigation by Southern California Edison to determine if they are Industry Standard Practice. See section 2.8.
***** Availability Status: Needs Evaluation - Needs cost effectiveness evaluation, Being Evaluated - Currently being evaluated by the IOUs, Fully Developed - the technology is commercially available - see section 2.4 for further explanation.
******Saturation: Defined in section 2.4.

[4] The adoption rates, both major and minor, for each measure listed in Table 1, are based on secondary literature, subject matter experts, and ASWB Engineering's energy audits of oil fields.

[5] Itron, Inc. 2013. *Industry Standard Practice Assessment for Artificial Lift Pump Control Technologies*.

[6] California Public Utilities Commission. 2013. *Oilfield WW Pump Controls Summary_v1_Sanitized*.

Recommendations

Detailed in Section 3, Navigant provides the following recommendations for targeting the energy efficiency opportunities identified in the oil and gas extraction sector, including opportunities in water management and recycling.

- **Major Oil Producers Continue to Utilize Existing Energy Efficiency Programs:** It is recommended that the IOUs continue to utilize existing energy efficiency programs targeted to these customers because there remain opportunities for technical assistance between IOUs and major oil producers. Technical acceptance of energy efficiency measures by majors continues to enable minor producers to accept technical feasibility and improves economies of scale.
- **Minor Oil Producers Benefit from Education, Technical Assistance, and Incentives**: Navigant recommends that the IOUs develop energy efficiency programs for minor oil producers since they account for approximately 20 percent[7] of the oil produced in California and have extremely limited resources to pursue energy efficiency opportunities in both oil and gas extraction and water management and recycling.[8] Based on California Energy Almanac data, the total for North American Industry Classification System (NAICS) 211 and 213 (majors and minors) per the Quarterly Fuel and Energy Report (QFER) is 4,155 GWh and 192 MM therms in 2013. [9]
- **Evaluate Advanced Pump Motor Controllers:** It is recommended that the IOUs evaluate MotorWise, the advanced pump motor controller. This technology claims to provide 25% or more savings for rod-beam pumps, which could be significant since 92 percent of oil field pumps in California are currently rod-beam pumps.[10]
- **Energy Efficient Technologies for Produced Water Treatment and Recycling Yield Further Investigation:** According to **o**ne of the IOUs, it is currently evaluating smart well technology for Industry Standard Practice for major producers (see Section 2.8), who have dedicated teams to explore cost-effective energy efficient technologies. Among minor producers, smart wells are low in penetration (~20%), with other energy efficiency technologies also low in penetration relative to major suppliers (see Table 2-5). It is recommended that the IOUs further investigate education and incentives for minor producers to adopt energy efficient technologies such as smart wells in addition to best practices for increasing the capacity of water treatment facilities.

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[7] Department of Conservation. 2009. *Oil and Gas Produced by Operator, California, 2009* and Oil Industry Major Company Guidance, http://www.caasupport.com/2013/09/oil-industry-major-minor-company-guidance/EC8BE5E87A8F/0/OilFieldArtificialLiftISP_Report__final.pdf, Accessed February 17, 2015.

[8] Department of Conservation. 2009. *Oil and Gas Produced by Operator, California*.

[9] California Energy Commission QFER – 1304 Plant Owner Operating Database, http://energyalmanac.ca.gov/electricity/web_qfer/. Accessed February 16, 2015.

[10] Itron Inc., Industry Standard Practice Assessment for Artificial Lift Pump Control Technologies, http://www.cpuc.ca.gov/NR/rdonlyres/F6E2974F-6220-4B9E-B6DC-EC8BE5E87A8F/0/OilFieldArtificialLiftISP_Report__final.pdf, February 2013.

1. MASI Description

1.1 Study Overview

The New Opportunities for Oil and Gas Extraction and Produced Water Management and Recycling study explores new program opportunities that specifically target oil and gas extraction and water management and recycling in the mining sector. This study relates to NAICS 211 and 213. In alignment with the Project Coordination Group's (PCG) indicated interests, the study characterizes major and minor oil producers and addresses the following objectives:

1. Drivers, barriers, and market trends for existing energy efficiency opportunities
2. Potential for future energy efficiency savings
3. Determination of whether a utility program can effectively promote new energy efficiency technologies in these market segments

This study evaluates the energy efficiency opportunities associated with oil and gas extraction and water treatment, including: process improvements, pump improvements, enhanced oil recovery (EOR) techniques, steam generation to support EOR, and water management and recycling improvements.

The California Public Utilities Commission's 2013 California Energy Efficiency Potential and Goals Study (2013 Potential Study) estimated that economic electric and natural gas energy saving potential exists for the petroleum subsector. The study included a range of energy efficiency interventions, accounting for Common Practice[11] estimates and how these differ between major and minor producers. These interventions include retrofits and upgrades for wellhead pump motors, injection pump motors, and process steam generators; the study also explored water treatment processes. Specifically, the study examined pump off controllers (POC), variable speed drives, motor replacements, generator replacements, generator improvements and the industry standard practices associated with all of the above. Navigant's 2013 Potential Study economic analysis, which did not include an evaluation of water management and recycling, estimated savings of roughly 13 percent of the sector's electric energy consumption and 19 percent of the sector's gas energy consumption.[12]

1.2 Methodology

This study relied on program manager, facility manager, and subject matter expert interviews. Secondary literature including market databases and program tracking data from the utilities

[11] Common Practice is defined as practices that were commonly observed from literature and industry interviews. The term "industry standard practice" is used when an ISP report discussing practice or technology has been completed.

[12] *2013 California Energy Efficiency Potential and Goals Study, Appendix Volume I (A-J).* Available at: http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M088/K662/88662017.PDF. Accessed January 12, 2015.

supplemented interviews to address the research items outlined in our scope of work. Navigant worked with ASWB Engineering[13] to collect information for this study.

This study estimated energy efficiency measure implementation rates for both major and minor producers as detailed in Table 2-1 and Table 2-2. These estimates are based on past ISP studies and have been updated with recent information collected from seven oil producer interviews and several energy audits conducted in oil fields by ASWB Engineering.

1.2.1 Literature Review

Navigant and ASWB Engineering conducted a literature review on oil and gas extraction and water management and recycling for new opportunities in the petroleum sector. The literature sources included Industry Standard Practice Study reports, oil and gas industry research, manufacturer white papers, and oil and gas statistics from State of California agencies, which are listed in the Appendix A.

An important oil and gas industry secondary source of information is the website petrowiki.org,[14] a web-based wiki application that presents content from the Petroleum Engineering Handbook (PHE)—a long recognized comprehensive reference book to the Petroleum Industry published by the Society of Petroleum Engineers.

1.2.2 In-Depth Interviews

The majority of our findings and recommendations come from in-depth interviews with seven facility personnel and four subject matter experts (SMEs[15]), which offer deep industry insight to support our industry insights.

Navigant and ASWB Engineering interviewed:

- Two program managers from the investor-owned utilities (IOUs) to determine the current state of the industry's energy efficiency efforts. These interviews revealed that most energy-saving opportunities in the industry exist above ground because the cost to raise underground equipment above the ground to modify or replace makes efficiency upgrades cost-prohibitive (e.g., electrical submersible pumps). Both program managers stated that due to variations in the geology and viscosity of the oil in California between the central coast, (primarily Pacific Gas & Electric Company territory) and southern California (primarily Southern California Edison territory), differing practices are employed to extract the oil. For example, due to high oil viscosity, central California and the central coast utilizes steam injection to produce oil.

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[13] ASWB Engineering, Navigant's subcontractor on the MASI project. Company website: http://www.ASWB Engineering-engineering.com/html/index.htm.
[14] Petrowiki.org is founded and managed by the Society of Petroleum Engineers International. www.spe.org. Accessed February 12, 2015.
[15] Person who works in the oil and gas sector and has expertise in the field related to industry operations and energy and water efficiency.

- Four SMEs to understand energy efficiency efforts in the industry. SMEs include: a director of utility programs from a third-party program administrator, a vice president from a new technology developer, an oil field expert that provides consulting to the utilities and the major oil producers, and an energy manager at a major oil producer. These SMEs agreed that when it comes to new energy efficiency technology the major producers maintain a “wait and see” attitude until a technology has yielded widely recognized and proven energy efficiency benefits. Additionally, producers tend to hold off energy efficiency technology investments to determine if IOUs will provide incentives to adopt new technologies. One SME stated that most opportunities are in the extraction process versus the water treatment process.
- Three major and four minor oil producers to understand the steps utilities can take to improve energy efficiency. In general, these interviews revealed that major producers have taken significant steps to improve energy efficiency in one to two year payback projects as it applies to oil and gas extraction. The minor producers have limited technical and financial resources to pursue energy saving practices, leaving opportunities unexploited. This trend is pervasive across the industry; for instance, POCs have been implemented for years across the major should delete producer’s oil fields, while minor producers still have some production wells that could benefit from this technology.

1.2.3 Database and Program Documentation Review

Navigant and ASWB Engineering examined program data to understand current and previous California program activities. The team requested customer data from program managers and explored the rate of adoption of previous program technologies. To supplement the program data analysis, Navigant extracted information from the 2013 Potential Study mining sector Measure Input Characterization Sheet (MICS). The MICS gathered various secondary sources and input from SMEs on a range of topics including equipment specifications and baselines. This MASI study built on that existing research.

This study draws from existing California data and research efforts including the California Department of Conservation’s Preliminary Report of California Oil and Gas Production Statistics[16] and a recent ISP study conducted by Itron[17] that established Industry Standard Practices for various pumping technologies.

1.2.4 Report Format

This report begins by characterizing the oil and gas extraction industry and the importance of energy efficiency throughout the oil extraction process. Additionally, the report identifies produced water

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[16] Department of Conservation. 2013. *Preliminary Report of California Oil and Gas Production Statistics, California*. Available at: ftp://ftp.consrv.ca.gov/pub/oil/annual_reports/2013/PR03_PreAnnual_2013.pdf. Accessed January 5, 2015.

[17] Itron Inc., Industry Standard Practice Assessment for Artificial Lift Pump Control Technologies, http://www.cpuc.ca.gov/NR/rdonlyres/F6E2974F-6220-4B9E-B6DC-EC8BE5E87A8F/0/OilFieldArtificialLiftISP_Report__final.pdf, February 2013.

management and recycling opportunities. Navigant and ASWB Engineering identified customer decision-making behaviors as well as key drivers and barriers to energy saving opportunities. The report concludes with recommendations based on secondary research and in-depth interviews.

2. Market and Industry Analysis

2.1 Industry Characterization

As shown in Figure 2-1, there are six oil and gas districts in California and the onshore[18] oil extraction industry is mainly concentrated in districts one, four, which align with the Los Angeles Basin, and southern part of the San Joaquin Valley, respectively. Gas extraction is concentrated in district 3. In 2012, the five largest oil fields in California,[19] which are all located around Bakersfield in Kern County, produced 54% of the state's oil. Figure 2-1 highlights the highest oil producing counties in California based on 2009 data.

Figure 2-1. Oil and Gas District Boundaries [20]

[18] Off-shore oil and gas extraction is excluded from this study

[19] Oil fields include Midway-Sunset, Belridge South, Kern River, Cymric, and Elk Hills.

[20] Department of Conservation, Division of Oil, Gas & Geothermal Resources Well Finder, http://maps.conservation.ca.gov/doggr/index.html#close.

Table 2-1. Highest Oil Producing Counties[21]

District	County	Oil Production (bbl.)	Percent of Statewide (2009)	Primary Electric IOU	Primary Gas IOU
1	Los Angeles	24,586,465	12%	SCE	SCG
1	Orange	4,338,283	2%	SCE	SCG
4	Kern	154,760,153	75%	PG&E/SCE split	SCG
1-6	Remainder	23,775,183	11%		
	Statewide	207,460,084			

Most of California's working oil fields have been producing oil for more than 50 years, and typically Enhanced Oil Recovery (EOR) techniques are used to enable oil production at most locations, according to oil producers in California. Navigant's 2013 Potential Study analysis indicated that the oil and gas extraction industry accounts for about 2 percent of California's industrial electricity and natural gas usage. [22]

EOR uses water and steam to improve the mobility of oil remaining in the producing formations, thereby enabling that oil to flow to the producing wells. The water co-produced with the oil must then be managed, treated, recycled, waterflooded or reinjected; that injection process is estimated to utilize as much as 25 percent to 30 percent of the total energy consumed in the oil and gas extraction industry.[23]

As older oil wells fail to produce enough oil to operate economically, they are taken out of commission and new wells are drilled. In 2012, an estimated 2,195 new wells were put into production, while notices were filed for the abandonment of 2,811 wells.[24]

Oil extractors are divided into two categories: major producers and minor producers. In a 2013 ISP study for pump control measures in the oil well industry, the California Public Utilities Commission (CPUC) defined major producers as producers that yield more than 2.5 percent of total annual oil production in

[21]Department of Conservation, April, 2013, CA Dept. of Conservation. 2012 Preliminary Report of California Oil and Gas Production Statistics. Last accessed: March 2015, ftp://ftp.consrv.ca.gov/pub/oil/annual_reports/2012/PR03_PreAnnual_2012.pdf, Department of Conservation. 2009 Annual Report of the State Oil and Gas Supervisor. Last accessed: March 2015 ftp://ftp.consrv.ca.gov/pub/oil/annual_reports/2009/PR06_Annual_2009.pdf.

[22] Energy Consumption Data Management System, California Energy Consumption Database, http://ecdms.energy.ca.gov/, Accessed March 18, 2015.

[23] *2013 California Energy Efficiency Potential and Goals Study.* Appendix Volume I (A-J). Available at: http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M088/K662/88662017.PDF.

[24] Department of Conservation, April 2013. This data encompasses both on- and off-shore well activity and is not inclusive of shut-in closures.

the State of California and minor producers as producers that yield less than 2.5 percent of total annual production.[25]

The oil and gas extraction industry involves a number of discrete processes and each of them could provide opportunities for energy efficiency technologies. This study evaluates energy efficiency practices common to the industry to understand how possible new technologies might be utilized.

2.2 Oil and Gas Extraction Process

All oil field operators interviewed stated that energy efficiency is important since the cost of energy directly impacts their profits. All three interviewees from major oil producers all stated that their companies have dedicated energy efficiency departments that research new opportunities, evaluate them for economic feasibility, and orchestrate their implementation. In addition, they explained that all energy efficiency projects are ranked based on Return on Investment (ROI) payback period with utility incentives included in their payback calculation. Those projects having the shortest payback are ranked the highest.

The 2013 Potential Study evaluated the major end uses within the oil and gas extraction subsector, which included an array of electric and natural gas-consuming equipment. The Navigant team focused on the significant energy-consuming equipment, which accounts for roughly 65 percent of the electric and natural gas consumption within the mining sector. Please reference the 2013 Potential Study, Appendix I for further explanation on how the Navigant team estimated this consumption.[26]

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[25] Southern California Edison, Oil Industry Major and Minor Company Guidance, http://www.caasupport.com/2013/09/oil-industry-major-minor-company-guidance/. Accessed February 24, 2015.

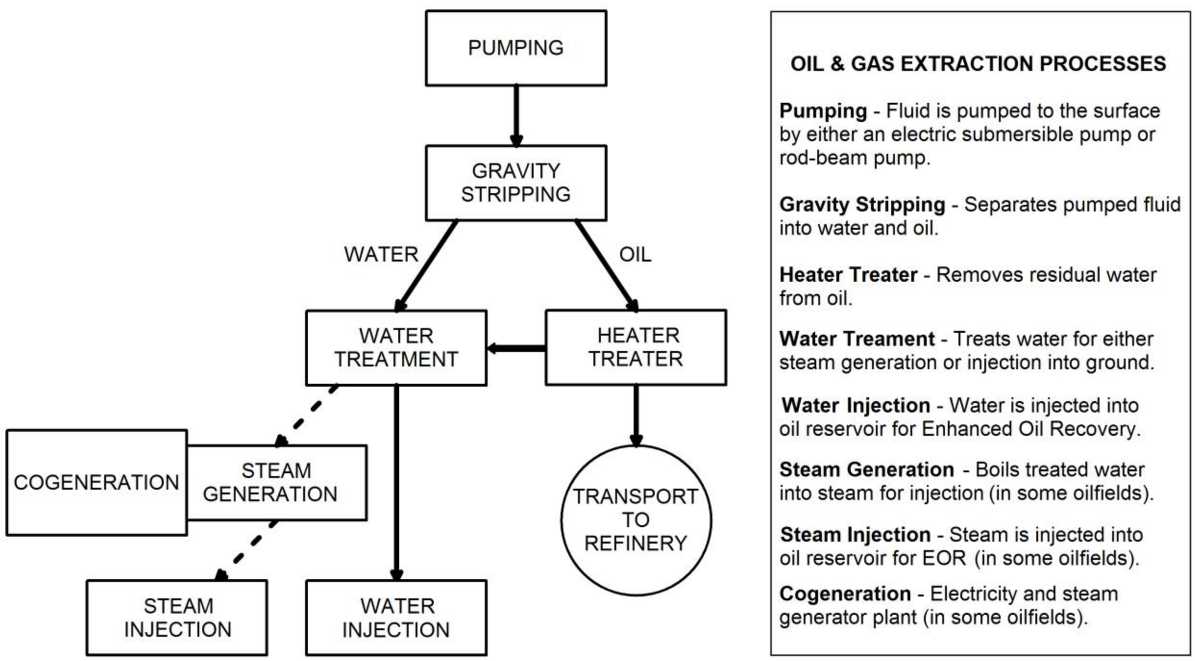
[26] Navigant Consulting. February, 2014. *2013 California Energy Efficiency Potential and Goals Study*. Available at: http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M088/K662/88662017.PDF. Accessed February 10, 2014.

Table 2-2. Estimated Oil and Gas Extraction Major End Uses and Energy Consumption, Statewide[27]

Major End Use	Description	Portion of Sector Consumption	
		Electricity	Natural Gas
Stripper Wells	Electric motor-driven, low-volume- producing wells	5%	0%
Regular Wells	Electric motor-driven, regular-volume- producing wells	38%	0%
Injection Wells	Electric motor-driven pumps for steam/water injection wells that support production	22%	0%
Steam Generators	Natural gas steam generator that produces steam for injection wells	0%	65%[28]
Water Treatment	Water and oil separation activities	5%-10%[29]	Not Calculated[30]

The general oil and gas extraction process is diagramed in Figure 2-2.

Figure 2-2. Oil and Gas Extraction Processes[31]



[27] Ibid.

[28] Based on best available information at the time of the 2013 PG study. This is 65% of the mining sector, but it is 80% of oil and gas extraction.

[29] 2013 Energy Efficiency Potential and Goals study did not focus on the minor energy consumers, hence this range is estimated. 2015 analysis is currently investigating these numbers more in detail.

[30] 2013 PGT study did not measure gas consumption for this activity.

[31] Figure developed based on ASWB Engineering industry research, 2015.

2.3 Produced Water Management and Recycling

The seven oil and gas operators interviewed for this report stated that they are motivated to reduce the amount of water produced in the mining and extraction process, which can reduce treatment and recycling costs and improve profit margins. According to an industry expert, when extracting oil and gas from California oil fields, both onshore and offshore, a significant amount of water is co-produced, meaning that water is extracted alongside the desired oil and gas products. From 2009 to 2012, the ratio of water to oil extracted ranged from 13.5 bbl. to 15.6 bbl., according to California Oil & Gas Production statistics from 2009 to 2012. Detailed figures are listed in Table 2-3.

Table 2-3. Annual Barrels Oil and Water Extracted in California

Year	Oil (bbl.)	Water (bbl.)	Bbl. of Water per bbl. of Oil
2012 (Prelim)[32]	197,510,442	3,083,038,501	15.6
2011 (Actual)[33]	196,793,017	2,943,889,975	15.0
2009 (Actual)[34]	203,009,519	2,736,426,995	13.5

In most cases, as the ratio of water to oil (or the water cut) increases over the production life of oil fields and the energy required to pump a barrel of oil increases. As additional amounts of water are co-produced, that water must be managed, treated, and recycled or reinjected, and the cost of oil production increases.[35]

Water that is pumped to the surface with the oil and gas must be separated and processed for reinjection then re-used or disposed (see below).[36] Figure 2-3 illustrates the water treatment process, which involves one to several treatment steps based on the contaminants in the water being pumped up from the well and the required quality of the water after treatment.

- Primary treatment: Remove oil droplets and suspended matter
- Secondary (polishing) treatment: Remove small oil droplets and hydrocarbons
- Tertiary treatment: Remove dissolved matter and harmful compounds

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[32] State of California Department of Conservation, Division of Oil, Gas and Geothermal Resources. April, 2014. *2012 Preliminary Report of California Oil and Gas Production Statistics* (p. 7/24).

[33] Ibid, (p. 7/24).

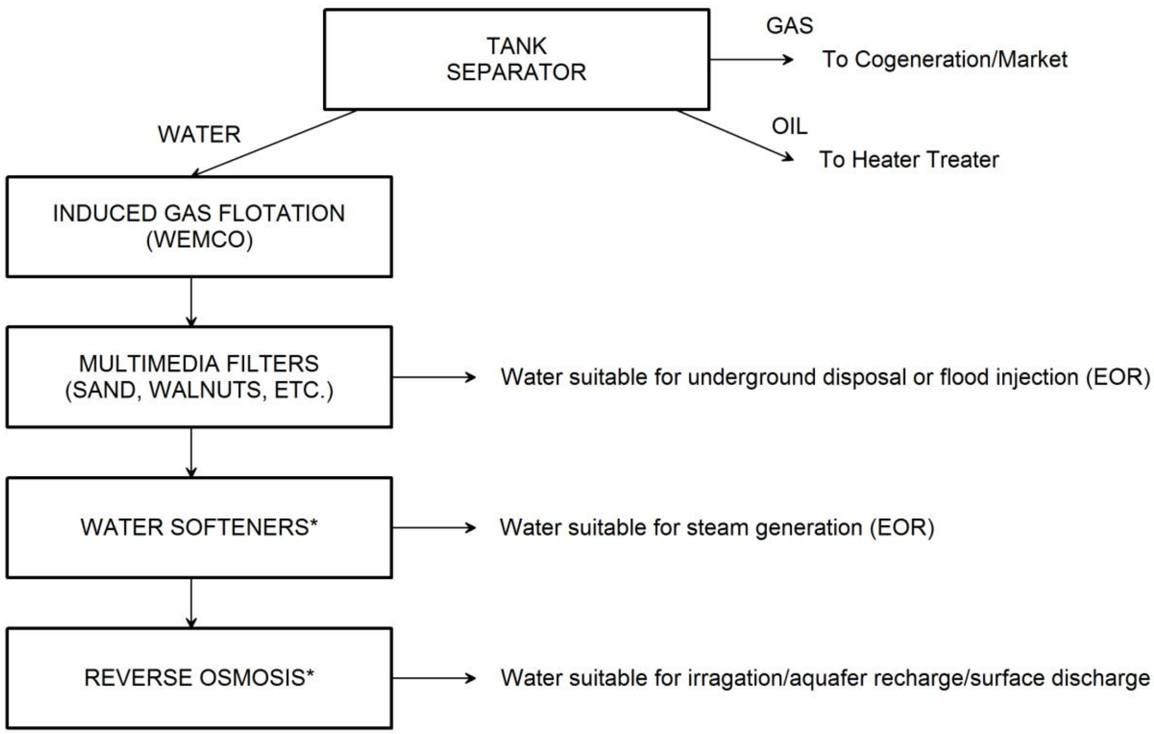
[34] State of California Department of Conservation, Division of Oil, Gas and Geothermal Resources. January, 2010. *2009 Preliminary Report of California Oil and Gas Production Statistics* (p. 73/274).

[35] Production also becomes more difficult with the increasing water cut. Common problems are scale formation in treatment facilities, corrosion of metals in the production piping networks, and increased sand content from producing wells, among many other issues. From Oilfield Wiki, Produced Water, http://oilfieldwiki.com/wiki/Produced_water. Accessed January 20, 2015.

[36] ALL Consulting. "Technical Summary of Oil & Gas Produced Water Treatment Technologies". Available at: www.all-llc.com/publicdownloads/ALLConsulting-WaterTreatmentOptionsReport.pdf, Accessed February 22, 2015.

- Water softening: To remove calcification minerals

Figure 2-3 Water Treatment Process



BASIC WATER TREATMENT PROCESSES

Tank separator - Separates fluid stream into water, gas and oil.

Induced Gas Floatation (IGF) - Removes oil droplets and fine solids.

Multimedia Filters - Removes small droplets and dissolved matter.

Water Softeners* - Reduce water hardness.

Reverse Osmosis* - Tertiary Treatment to meet discharge restrictions.

*Based on the composition of the water stream and the final water quality requirements, some processes may be omitted and added as required.

Additionally, the steps involved in the water treatment process are dependent on the intended use of the water after it is treated. Given the environmental regulatory requirements in California, three possible recourses or uses for treated water exist, including:

- **Injection into disposal wells that prevent interaction of the treated water with production wells or any underground water tables or aquifers.** As the recovery cycle ends and the oil field is taken out of production, the produced waters will need to be treated, cleaned, and disposed of adequately, typically in water disposal wells. This permanent disposal of water imposes the fewest requirements for treatment since the disposal of water is intended to minimize any environmental impact.[37]
- **Injection of water or steam into wells to enhance oil recovery.** Waterflodding and steam injection are the most common use for water in oil fields, due the common use of EOR for oil production in California. For steam injection, additional processing may be required to prepare the water for boiling and prevent damage to steam generators.
- **Recycle/reuse to replenish underground water tables or aquifers, or irrigation for agriculture**. This option requires the most extensive water treatment processes since the water must meet certain U.S. Environmental Protection Agency (EPA) standards, listed in Section 2.7 "Codes and Standards", in order for it to be discharged into a potential potable water stream. According to a major producer, the reuse of water from oil and gas extraction at present only takes place in Kern County and San Luis Obispo County due to the unique high quality of water after treatment and the close proximity of agricultural fields and oil production. This practice occurs typically during the summer months when irrigation water is in highest demand. In some cases, water is reused from oil and gas extraction year round for local agriculture and aquifer re-charge.

2.4 Energy Saving Opportunities in the Extraction Process

All SMEs in the oil and gas industry interviewed for this report agreed that the industry is considered mature, and there have been few new viable energy efficiency innovations introduced to the extraction process in recent years. Program managers that were interviewed reiterated the concern of existing energy saving opportunities.

Table 2-4 lists potential energy saving measures that can be used in the oil and gas extraction sector for major and minor producers. These measures were derived from conversations with industry experts and are explained in more detail below. A distinction is made between major and minor oil producers due to the fact that energy efficiency measure adoption rates and Industry Standard Practices for major and minor producers are not automatically the same, which is further explained in Sections 2.8 and 2.9 of this report. The column "New Savings Potential" rates the measure based on multiple factors, including market saturation, ease of adoption, cost to implement, and payback period.

For the purposes of this report, "Saturation" is defined as the percentage of installations to which a particular technology is both applicable, appropriate and has been applied. For some installations, a technology may be applicable but not necessarily appropriate; i.e. Pump off Controllers can be installed on any rod-beam pump but it may be inappropriate for some rod-beam pump applications, such as those wells that maintain full production flow of oil and do not need an off time to replenish the

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[37] U.S. Environmental Protect Agency. *Industrial & Municipal Waste Disposal Wells (Class I).* Available at: http://water.epa.gov/type/groundwater/uic/wells_class1.cfm. Accessed January 29, 2015.

downhole. A saturation of 100% indicates that all possible opportunities that are appropriate have been implemented.

Measures with the greatest statewide savings and payback are ranked highest and listed at the top of the table. The identified measures that are described in the "Industry Standard Practice" Section 2.8 are ranked at the bottom of the list, as these measures have no new potential for energy efficiency savings and are, therefore, not suitable for the development of a utility energy efficiency program. The specific measures are discussed individually below.

When referring to the status of a technology, the following standards are applied to the definitions:

- Fully developed: The technology has been commercialized and has a strong market presence.
- Being evaluated: The technology is commercialized and lacks independent third-party evaluation, measurement, and verification (EM&V) data, but studies are underway. Determining a unit energy savings value is a component of verification.
- Needs evaluation: No third-party EM&V data, and no study underway.

Table 2-4. Energy Saving Opportunities in the Extraction Process[38]

Measure	Major Producers	Minor Producers	New Savings Potential	Availability Status***
Pump Off Controller	85%-100% Saturation	0%-30% Saturation	High*	Fully Developed
MotorWise® Controller	Not Applied	Not Applied	High	Being Evaluated
High Efficiency Steam Generators	60%-80% Saturation	25%-50% Saturation	Low	Fully Developed
Heat Recovery/Exchanger	0% Saturation	0% Saturation	Low	Needs Evaluation
Cogeneration	50%-70% Saturation	0%-10% Saturation	Low	Fully Developed
Pipe Resizing	70%-90% Saturation	10%-30% Saturation	Low	Fully Developed
Electrical Distribution	80%-100% Saturation	0%-10% Saturation	Low	Fully Developed
VFDs on ESPs[39] and Injection Pumps[40]	85%-100% Saturation	60%-80% Saturation	ISP**	Fully Developed

* Pump off controllers are considered Industry Standard Practice for major producers and, therefore, major producers cannot receive incentives for them. They are not considered Industry Standard Practice for minor producers, which can be incentivized. Also varies between new and old wells.
** Variable frequency drives (VFDs) on electrical submersible pumps (ESPs) and injection pumps are considered ISP and ineligible for incentives for both major and minor producers.
*** Availability Status: Needs Evaluation - Needs cost effectiveness evaluation, Being Evaluated - Currently being evaluated by the IOUs, Fully Developed - the technology is commercially available

2.4.1 Pump off Controller (POC)

A pump is put into place to provide the artificial lift necessary to bring oil to the surface. . The most common type of artificial lift pump used at the surface is a rod-beam pump that converts rotary motion (from the prime mover, generally an electric motor) to the up-and-down motion needed for the downhole portions of the pump. This type of pump is used in 92% of major and minor oil producer's production wells.[41]

The electric motor used on these types of pumps must start under heavy load conditions, as the pump offers the highest mechanical resistance when starting. The motors that are used for this purpose are

[38] The adoption rates, both major and minor, for each measure listed in Table 2-1 are based on secondary literature (ISP Study reports), SME interviews, and ASWB Engineering oil field energy audits.
[39] Itron, Inc. 2013. *Industry Standard Practice Assessment for Artificial Lift Pump Control Technologies*.
[40] California Public Utilities Commission. 2013. *Oilfield WW Pump Controls Summary_v1_Sanitized*.
[41] Itron, Inc. 2013. *Industry Standard Practice Assessment for Artificial Lift Pump Control Technologies*.

specifically designed for high starting torque and are referred to as National Electrical Manufacturers Association (NEMA) Design D motors. NEMA Design D motors do not meet EPACT[42] premium efficiency standards and are not regulated by the recent Energy Independence and Security Act (EISA)[43] 2007 update due to their inherent design limitations. A utility representative indicated that in PG&E territory, NEMA B, C and D motors are utilized.

POCs, which are an advanced control technology, selectively run the pump so that it only operates when there is sufficient oil in the well for effective pumping. POCs decrease energy use per barrel of oil produced with the added benefit of extending the life of the pump and electric motors due to reduced operating hours that, in turn, reduce operations and maintenance (O&M) requirements. POCs also reduce the coincident demand of an oil field by reducing the likelihood that pumps are all operating at the same time. This technology has been available for many years, and many major producers have already implemented POCs. Minor producers have limited financial resources and, therefore, have limited adoption of this technology. POCs also enable remote sensing and performance monitoring of the individual wells; optimizing maintenance and further reducing costs and resource use. A typical POC costs between $3,000 and $5,000 installed.

2.4.2 MotorWise Controller

A potentially viable advanced control technology is the thyristor switching technology, known as a MotorWise controller, which can save energy used by rod-beam pumps. MotorWise is an electronic switching technology that appears to have promise and has been trialed on 2,000 wells in the Permian Basin in Texas.[44] The technology benefits electric-motor-driven devices that have large load variability such as oil field rod-beam pumps. The MotorWise device can switch off the power to the motor during portions of the cycle when the motor is unloaded and switch the power back on as the motor begins to take on load. The manufacturer claims that the Texas trials have resulted in pumping electricity savings of at least 25 percent. According to the manufacturer and an oil field expert, this technology is currently being tested in California.

2.4.3 Cogeneration

A cogeneration plant makes electric power and steam for use in Enhanced Oil Recovery; the natural gas fuel used in this plant may be co-produced from the oil field itself or purchased from a pipeline company. Many oil fields co-produce natural gas that cannot be economically marketed due to quality or transportation difficulties. This gas must be either used to fuel a generating asset, such as a micro-turbine generator, or other heating purposes. Steam from cogeneration is typically used to enhance oil recovery by injecting it into the underground oil reservoir. Cogeneration can be more efficient than generating steam and electricity separately.

Heat recovery from cogeneration and steam generator operations could also be used during the heater treater step in the oil separation process to remove any residual water from the oil before it is transported to the refinery; heat recovery from cogeneration may warrant for research.

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[42] Energy Policy Act of 1992, 102nd U.S. Congress, Effective 1992.

[43] Energy Independence and Security Act of 2007, 110th U.S. Congress, 2007.

[44] Technowise Group. 2012. *MotorWise Technology White Paper*.

2.4.4 Pipe Resizing

Oil production can either increase or decrease over the life of the well due to factors such as increased water to oil ratio or just the natural fall off of oil production. Transport pipes are sized based on the initial output flow of the well. If the output increases, as is common with growing amounts of co-produced water, the pipes will produce more resistance to pumping. By resizing pipes to match the higher output flow, friction losses will be reduced and pump motors will require less energy.

2.4.5 Electrical Distribution

In an oil field, multiple wells are drilled throughout the site to maximize oil production. Each well has its own motors and controls that require electricity to be delivered to them through power lines that are owned and maintained by the oil producers. Since electricity is in high demand for pumping, having an efficient electrical distribution system is key to reducing electrical losses.

To obtain the greatest efficiencies, a system-wide approach with multiple measures must be applied to the distribution network:

- Proper sizing of power lines
- Power lines in good condition; not damaged
- High efficiency transformers to reduce losses
- Power factor correction to maximize power utilization
- Harmonic filtering to reduce losses and electrical noise
- Locating transformers close to their load to reduce voltage drops

Implementing these measures will reduce electrical losses throughout the network and provide the most usable power to the site.

2.4.6 Heater Treater Heat Recovery/Exchanger

The heater treater[45] is one of the first steps in the oil-water separation process before the oil is transported to a refinery. In a heater treater, most of the remaining oil is separated from the water by means of heating the fluid. After passing through the heater treater, the oil will retain most of the heat that was used for the separation process. If a heat-exchange system were to be installed, the heat from the outgoing hot oil stream could be transferred to the ingoing fluid stream.[46]

2.4.7 High Efficiency Seam Generators

Steam injection is a form of EOR that is used primarily in central California, including the central coast. An SME stated that oil is viscous and difficult to extract in this part of California, so to achieve higher

[45] An essential piece of equipment in the production process that breaks up oil-water emulsions, separating the crude oil from water and other foreign materials through the use of heat.

[46] Gas may be provided by a third party other than the California IOUs. Source: Conversation with major oil producers in California.

production rates oil producers inject steam into the underground oil reservoir, which allows the oil to flow more easily to the producing well. Steam can either be generated by a gas-fired steam generator, or produced as a complementary product from the cogeneration plant, if present.

The IOUs already have an incentive program in place for high efficiency steam generators to encourage oil field operators to purchase efficient steam generators with efficiencies greater than 80% boiler efficiency level.[47]

2.5 Energy Saving Opportunities in Produced Water Management and Recycling

All SMEs and program managers stated that there are limited new energy saving opportunities for produced water management and recycling in the oil and gas industry. They all explained that the water treatment process is small relative to the extraction process, resulting in limited energy efficiency potential.

Table 2-5 lists potential energy saving measures that can be used in the oil and gas water management and recycling sector for major and minor producers. These measures were derived from conversations with industry experts and are explained in more detail below. A distinction is made between major and minor oil producers due to the fact that energy efficiency measure adoption rates and the Industry Standard Practice for major and minor producers is not always the same.[48] The column, "New Savings Potential," rates the measure based on multiple factors, including market saturation, ease of adoption, cost to implement, and payback period. Measures with the greatest statewide savings and minimal capital investment are ranked highest and listed at the top of the table.

Table 2-5. Energy Saving Opportunities in the Water Treatment Process[49]

Measure	Major Producers*	Minor Producers*	New Savings Potential	Availability Status****
Water Shutoff	50%-70% Saturation	15%-35% Saturation	Medium	Fully Developed
Smart Wells	40%-60% Saturation	10%-25% Saturation	Under ISP Investigation**	Fully Developed
Unicel® IGF with VFDs	5%-10% Saturation	0% Saturation	Low	Fully Developed
Increase Treatment Capacity	5%-15% Saturation	0% Saturation	Low	Needs Evaluation

* See section 2.4 for explanation of "Saturation".
** Smart wells are under investigation by Southern California Edison to determine Industry Practice classification, see Section 2.8.
*** Availability Status: Needs Evaluation - Needs cost effectiveness evaluation, Being Evaluated - Currently being evaluated by the IOUs, Fully Developed - the technology is commercially available - see section 2.4 for further explanation.

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[47] ASWB Engineering. May, 2014. *Oilfield Steam Generators Combustion Efficiency Baseline Study*.

[48] Itron, Inc., 2013. Full reference please—for consistency

[49] The adoption rates, both major and minor, for each measure listed in Table 2-5 are based on secondary literature (ISP Study reports), SME interviews, and ASWB Engineering oil field energy audits.

2.5.1 Water Shutoff

Water shutoff is a technique where unwanted water production can be reduced within a particular zone downhole in the well, thus increasing the percent of oil recovered. Either through cement, valves or chemicals water shutoff has proven successful in cases in which geological faults intersect the wellbore, causing a channel for water flow. Water shutoff techniques result in less water being lifted to the surface and, therefore, less water that needs to be treated and pumped back into the ground, ultimately saving energy.[50]

2.5.2 Induced Gas Flotation (IGF)

As depicted in Figure 2-3, the first step in the water treatment process is to clarify the water, removing oil droplets and suspended matter by way of induced gas flotation (IGF) units. Since the 1960s, WEMCO® IGF units have been the go-to standard in the oil and gas industry and are considered the baseline for IGF units, according to an oilfield industry expert. These units are the most economical to purchase but not necessarily the most efficient, and can result in a bottleneck in the treatment process. There are, however, more efficient IGF units made by a variety of manufacturers, such as Unicel. Oil and gas producers that use Unicel IGF units in their water treatment plant can reduce the amount of energy used. Also, with the addition of a VFD to a Unicel IGF unit, additional energy savings can be realized.

One SME from a major producer stated that, in general, producers are reluctant to replace operational WEMCO IGF units with Unicel IGF units due to high cost; hence, penetration is currently low, and adoption will be contingent upon existing asset lifecycles. One needs to consider the potential in new construction applications as well.

2.5.3 Increase Treatment Capacity

Over the production life of an oil well, it is common to expand water treatment facilities in order to process increasing amounts of co-produced water. With these expansions, there are potential opportunities to adopt more efficient technologies. When considering expanding the capacity of the water treatment facilities, there are several technologies that can treat water in higher volumes depending on what contaminants are present. No one definitive technology exits that can handle all contaminants with higher flow rate; for example, some technologies are efficient at removing small oil droplets while others are not. These technologies need to be evaluated on a case-by-case basis, warranting further research, which could provide guidance as to what technology options are most appropriate for energy efficiency program development.

One technology that an oilfield industry expert recommended is increasing the size of the media filters that process the water, removing suspended solids. Larger filters can process the same amount of water

[50] Oilfield Wiki. "Produced Water". Available at: http://oilfieldwiki.com/wiki/Produced_water. Accessed January 29, 2015.

but have a lower pressure drop[51] than smaller filters. With a lower pressure drop, the motors that pump the water through the filters do not require as much horsepower and can save energy.

Some other technologies that can eliminate bottlenecks in the water treatment flow include centrifuges and hydrocyclones. A disc-stacked centrifuge is a device to separate oil, water, and solids in a single stage based on differing densities—e.g., oil, water, and salts. A hydrocyclone is a device to separate liquids of differing densities. Both devices are used on continuous flow systems to eliminate bottlenecks in water treatment process.[52]

2.5.4 Water Softeners

Water used in the extraction process can go through additional processing to make it suitable for either steam injection or reuse. For steam generation or water reuse, this involves a water softening process to remove minerals. This is an ion exchange process and requires energy for pumping. Given that this process does not have an identified potential energy saving measure; it is not included in Table 2-5.

2.6 Initiatives to Date

Initiatives to promote the use of energy efficient technologies in the extraction of oil and gas and treatment of water are segmented between federal/state and utility-promoted incentives.

2.6.1 Federal and California Initiatives

At the federal and State of California level, currently no programs exist that promote energy efficient technologies in the oil and gas extraction sector.

2.6.2 Utility-Based Initiatives

The IOUs in California have energy efficiency programs in place for the oil and gas extraction industry.

Pacific Gas & Electric Company (PG&E) offers the following measures for oil and gas extractors:[53]

- Premium efficient motors
- Oil well artificial lift conversions
- Rod-beam POCs
- Process VFDs
- Oil well water shutoff (smart wells)
- Field process optimization

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[51] Pressure drop is defined in Wikipedia as, "the difference in pressure between two points of a fluid carrying network. Pressure drop occurs when frictional forces, caused by resistance to flow, act on a fluid as it flows through the tube." Available at: http://en.wikipedia.org/wiki/Pressure_drop, Accessed February 24, 2015.
[52] Oilfield Wiki. "Produced Water". Available at: http://oilfieldwiki.com/wiki/Produced_water. Accessed January 25, 2015.
[53] PG&E. April, 2013. *Energy Efficiency Services for Oil and Gas Production*.

- Steam generators
- Water flood
- Oversized piping
- Solar Jack
- Motor Wise
- Rod beam VFDs
- High Efficiency Steam Generators
- Pipeline internal coating and non-metallic piping
- Recommissioning program

In February 2015, PG&E announced a contract opportunity titled “PG&E 3P EE Industrial Sector Programs.” The oil field program focuses on energy efficiency upgrades for oil field customers, with 2016 energy saving targets of 25 GWh and 2.5 MW.[54]

Southern California Edison (SCE) offers the following measures for oil and gas producers:[55]

- Conversion of outdated well pumping systems
- Well pumping optimization through POCs
- Other motor controllers
- Proper sizing of motors and pumps
- Specification of premium efficient motors
- VFDs and controllers
- Water reduction technologies (smart wells)
- Load balancing on rod pumps
- Retro-commissioning, if applicable
- Splitting water injection systems into high pressure and low pressure systems

Note that these measures come from energy efficiency programs from the 2013–2014 program cycle; some measures may now be considered Industry Standard Practice and, therefore, are no longer eligible for incentive programs.

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[54] PG&E. *Contract Opportunity Announcement PG&E 3P EE Industrial Sector Programs, Purchasing Policy No. 3 Exhibit 1, 62-0760*, Accessed February 25, 2015.

[55] SCE. 2013. *Customer Energy Efficiency Program Implementation Plans*.

2.7 Codes and Standards

Typically, oil producers in California need permits at the federal (only in federal waters), state, and county levels. In addition, counties are able to impose additional restrictions on permitting, which can vary significantly from county to county.

There are no codes or standards that directly regulate the energy efficiency of the oil and gas extraction industry. Indirectly, electric motors—used in oil and gas pumping, water injection, and steam injection—are subject to EISA, which requires NEMA premium efficiency motors.[56] Please reference the *Measure, Application, Segment, Industry: Motors Baseline and Opportunities in the Industrial, Food Processing, and Agricultural Sectors, and Early Motor Retirement in Refineries Study* for a detailed discussion about motor codes and standards.

At the federal level, the oil and gas industry is heavily regulated by the EPA on what it discharges into the environment—i.e., produced water. The primary set of codes that regulate oil and gas extraction are within Title 40 (Protection of Environment), Part 435 (Oil and Gas Extraction Point Source Category) of the Code of Federal Regulations.[57] Overseen by the EPA, the Division of Oil, Gas & Geothermal Resources (DOGGR) controls permits that are required in order to drill wells, including production wells, injection wells, and disposal wells.

On top of the EPA and DOGGR set of codes, there are acts at the federal level that regulate the release of water in to the environment:

- Federal Clean Water Act[58]
- Safe Drinking Water Act[59]

These acts ensure safe water for drinking and prevent water sources from being contaminated or polluted.

At the State of California level, there are two sets of codes that regulate water use:

- California Water Code[60]
- California Environmental Quality Act[61]

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[56] Refers to NEMA Design A and B motors, Design D motors are not subject to the same stringent standards.
[57] Protection of Environment, Oil and Gas Extraction Point Source Category. Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=303717dcc1d4ac7f3d5a43c0b3cc4765&tpl=/ecfrbrowse/Title40/40cfr435_main_02.tpl. Accessed February 22, 2015.
[58] Senate as S. 2770. Clean Water Act. Available at: http://www.gpo.gov/fdsys/pkg/STATUTE-86/pdf/STATUTE-86-Pg816.pdf. Accessed February 11, 2015.
[59] Senate as S. 433. Safe Drinking Water Act. Available at: http://www.law.cornell.edu/uscode/42/300f.html. Accessed February 22, 2015.
[60] State of California Law, California Water Code. Available at: http://www.leginfo.ca.gov/cgi-bin/calawquery?codesection=wat&codebody=&hits=20. Accessed February 22, 2015.
[61] California Public Resources, California Environmental Quality Act. Available at: http://resources.ca.gov/ceqa/docs/2014_CEQA_Statutes_and_Guidelines.pdf. Accessed February 22, 2015.

California's internal environmental regulatory body is the California Environmental Protection Agency, or Cal/EPA, which can regulate oil and gas production.

The California Department of Conservation is heavily involved with California's oil and gas industry through its DOGGR and regulates and approves permits for wells for production, injection, and disposal, as well as notices for the abandonment of wells.

Under California's Groundwater Quality Monitoring Act of 2001, the State Water Resources Control Board is required to integrate "existing monitoring programs and design new program elements, as necessary, to establish a comprehensive monitoring program capable of assessing each groundwater basin in the state through direct and other statistically reliable sampling approaches." The most recent addition of the Act, SB-004, was signed into law in September 2013. It requires wells to be monitored and approved on a well-by-well or regional basis, requiring:

- California's DOGGR to consult with multiple state government agencies and local air districts and develop regulations, including disclosure requirements, and to delineate applicable state regulatory authority
- The Secretary of California's Natural Resources Agency to complete an independent scientific study evaluating the hazards and risks associated with well stimulation treatments
- DOGGR to implement a new permitting system for oil and natural gas well operators
- Oil and gas well operators to disclose to DOGGR and the public the identity and quantity of every chemical used in hydraulic fracturing and acid well stimulation fluids[62]

2.8 Industry Standard Practice

When an oil field technology is considered to be Industry Standard Practice, oil producers typically install that technology without assistance from the IOUs and that technology is not eligible for incentives.

According to SMEs and IOU program managers, Industry Standard Practice classification for the oil and gas extraction industry can be different between major and minor oil producers. For instance, POCs are currently only incentivized for the minor producers, as this measure is considered Industry Standard Practice for the major producers.

The following technologies and measures are currently considered, or are under evaluation, for Industry Standard Practice classification:

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[62] California Environmental Law and Policy Center, UC Davis School of Law. June, 2014. *Senate Bill 4: A Past and Future Look at Regulating Hydraulic Fracturing in California*. Available at: https://law.ucdavis.edu/centers/environmental/files/CELPC-SB4-report.pdf. Accessed February 23, 2015.

- **VFDs.** VFDs are placed on pumps to provide variable speed control. This speed control allows the oil producer to match or adjust to dynamic flow conditions that wells go through during their production life. VFDs used on electrical submersible pumps and injection pumps and most water injection pumps are considered ISP and ineligible for incentives for all oil and gas producers.[63]
- **POCs.** POCs are considered ISP only for major producers.[64] They are an advanced control technology, selectively running the pump so that it only operates when there is sufficient oil in the well for effective pumping. POCs decrease energy use per barrel of oil produced with the added benefit of extending the life of the pump and electric motors due to reduced operating hours. This technology has been available for many years and SMEs stated that many major producers have already implemented POCs. Minor producers have limited financial resources and, therefore, have limited adoption of this technology.
- **Smart Wells.** Currently, smart wells are under investigation to determine if they are Industry Standard Practice for major and minor oil producers.[65] A smart well is a downhole technology that utilizes sensors to monitor reservoir conditions and uses valves to control the inflow of fluids from the reservoir to the well. Smart wells are capable of selectively drawing oil from strata that is high in oil and blocking strata that has too much water. Incentives for smart wells are on hold until an ISP investigation is complete and determines whether or not they are considered Industry Standard Practice.
- **Motor Efficiency.** The average efficiency for electric motors in the industry (except for the NEMA Design-D motors) has been increasing since the adoption of EISA 2007. The use of premium efficiency motors is quite widespread and can be considered Common Practice and ineligible for incentives for all oil and gas producers. Please reference the *Measure, Application, Segment, Industry: Motors Baseline and Opportunities in the Industrial, Food Processing, and Agricultural Sectors, and Early Motor Retirement in Refineries Study* for a detailed discussion about premium efficiency motors.

2.9 Decision-Making

Decision-making throughout the oil and gas extraction industry is driven by profit margins, compliance and permitting, safety and GHG emissions some of which translates into maximizing production while minimizing costs in the oil field. According to industry stakeholders interviewed for this report, the major oil producers by and large have committed to minimizing long-term operating costs wherever possible, whereas the minor producers often do not have this capability due to a lack of up-front capital for energy efficient technologies. Four minor oil producers interviewed for this report stated that smaller companies generally have fewer employees, which can limit their in-house energy expertise to promote energy efficiency. As a result, adoption of energy efficient technologies lags behind the major producers by several years, as commented by a minor oil producer.

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[63] Itron, 2013.

[64] PG&E. *2013-2014 Energy Efficiency Portfolio 3rd Party PIP, Energy Efficiency Services for Oil and Gas Production* (p/ 2).

[65] SCE is conducting this ISP study.

2.9.1 Market Actors

The oil and gas extraction industry is segmented between major and minor producers. According to program managers interviewed, most major producers have dedicated efficiency departments that interface with IOU personnel to help make equipment upgrade decisions based on extensive cost-benefit analysis that integrates upgrade technology investments, incentives, and potential energy efficiency savings. Minor producers stated that their efficiency decisions are often determined by the company owner, who generally has a much larger role than simply focusing on improving energy efficiency for oil field extraction.

2.9.2 Customer Awareness and Experience

All three major producers stated that they implement energy efficient technologies where possible, however, from conversations with utility program managers, this is referred to as "bragging bias" as from the utility's perspective many untapped opportunities still exist. On the other hand, minor producers stated that they adopt energy efficient technologies when a technology becomes common or is promoted by the utilities through incentives. One SME indicated, "If the utilities performed a study on a particular product or class of products, the products would be considered more closely by the oil producers."

2.10 Key Drivers

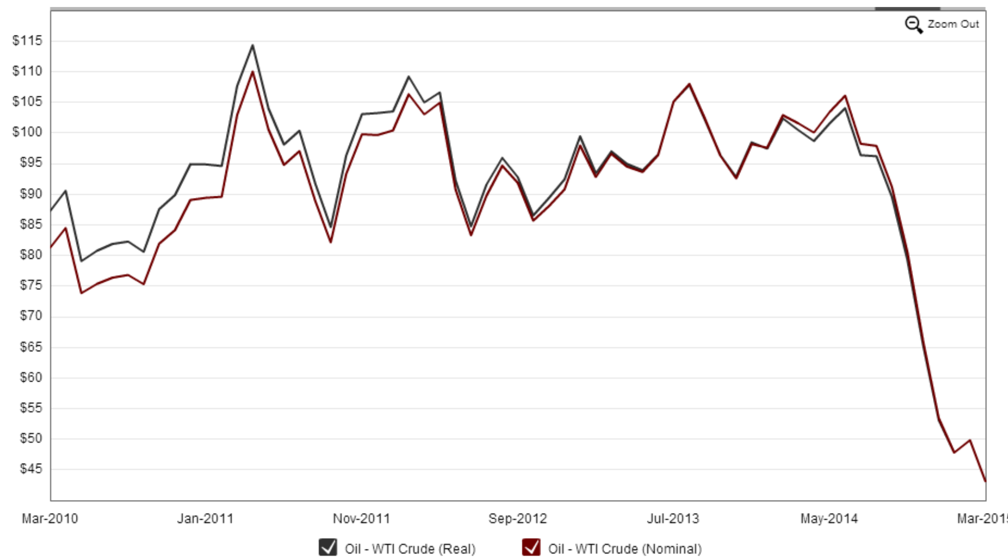
In the oil and gas extraction industry, increased oil production is the main driver for upgrading equipment, as the industry goal is to maximize profit. As oil fields in California are depleted and the majority of the fluid that is extracted is water, producers are eager to reduce overall costs and will invite any energy efficiency measures. Major and minor oil producers interviewed reiterated that any new technology that can increase oil production and cut costs gains attention.

2.11 Market Trends

As shown in Figure 2-4 , the recent drop in oil prices ($/barrel)[66] has increased pressure on oil producers to reduce the cost of production.

[66] WTI Crude Oil, $46.39/barrel. Available at: http://www.oil-price.net/. Accessed January 20, 2015.

Figure 2-4. Crude Oil Prices from 2010 to 2015 ($/barrel) [67]



One of the minor oil producers stated that their business models rely on a moderate oil price that allows them to extract oil from wells that are exhausted and considered unprofitable by many major producers. Although this low market price is believed to be short lived, many minor producers will shut down operations either temporarily or permanently. Based on conversations with one major oil producer in California, it costs them about $36 to produce a barrel of crude oil. [68] During this time of uncertainty, cash flow for minor producers will be low and interest in updating equipment will be even lower. Any energy efficiency program developed during this market lull should take this into consideration.

2.12 Key Barriers

Technical, market, and regulatory barriers could prevent the development of a new opportunities program.

2.12.1 Technical Barriers

The main technical barrier is the lack of new energy efficient technologies being developed. Both program managers and major oil producers stated that they see limited opportunities for new products that will generate meaningful savings since most energy saving measures have been discovered.

As stated by an industry SME, another barrier to adoption of new technologies in California is that many wells share a revenue meter, making energy savings on a single installation difficult to quantify.

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[67] Crude Oil Price History Chart. Available at: http://www.macrotrends.net/1369/crude-oil-price-history-chart. Accessed January 28, 2015.

[68] Based on an interview conversation.

Additionally, Navigant's findings indicate that customers expect an incentive on all valid projects, perhaps waiting for the IOUs to validate new technologies before adopting them.

2.12.2 Market Barriers

The major oil and gas producers have invested in energy efficiency over the production life of their oil fields, and most of these fields have been in production for a long time. Over that time, the major producers have taken advantage of many of the available energy efficiency technologies to such a degree that they are no longer being incentivized for many of the technologies as the implementation of these technologies has become Industry Standard Practice. For the minor producers, some utility incentives are still available, such as for POCs and several others

2.12.3 Regulatory Barriers

The oil and gas producers are heavily regulated for environmental concerns, such as air pollutants and wastewater contamination. Of the new opportunities listed in Table 2-4and Table 2-5, environmental regulations would impact the cogeneration measure and steam generator measures which burns either natural gas or co-produced gas, emitting nitrous oxides, carbon monoxide, and greenhouse gases, which are typically regulated by the California Air Resources Board.[69] Additionally, the presiding county can also impose another layer of regulations on top of the California Air Resource Board's regulations.

Before implementing cogeneration, the oil producer must investigate if its cogeneration plant emissions will be regulated and whether emission controls will be required. These regulations vary greatly from county to county and air district to air district—some counties do not regulate at all while other counties regulate emissions strictly, typically in counties near urban centers.

For water discharge, contaminants such as hydrocarbons and minerals are heavily regulated—at both the federal and state level. Regulatory agencies, such as the EPA, attempt to minimize the impact that discharged water has on the environment. In California, regulations vary based on the location of the well. An industry expert stated that some producers avoid the high cost of treatment, which meets these strict standards, by opting to reinject the water back to the oil producing interval.

[69] California Global Warming Solutions Act of 2006, AB 32-STATS, 2006. Chapter 488.

3. Recommendations

Based on secondary research and conversations with the industry, Navigant has the following recommendations for targeting energy efficiency opportunities in the oil and gas extraction sector.

3.1 Major Oil Producers Should Continue to Utilize Existing Energy Efficiency Programs

Of the seven oil producers that were interviewed, three are considered major oil producers in California. All three major oil producers uniformly stated that they were actively pursuing all available energy efficiency opportunities that have feasible paybacks; typically the major producers consider feasible payback periods to be within two years. Opportunities with longer payback periods, greater than two years, and in some cases even projects with payback periods shorter than two years may require incentivizing to get major producers to implement them.

Major producers consider energy efficiency an integral component of their operations, primarily due to the size of their operations and the significance of energy costs for oil extraction. They play an indispensable role in developing and proving new energy efficient technologies. Collaborating with the IOUs, major oil producers willingly provide personnel, resources and well sites to develop, evaluate and verify new technologies.

Minor producers, who have limited personnel, time and production capacity, are unable to divert valuable resources to test new technologies. They typically look to the major producers to prove new energy efficient technologies and then where economically possible follow the majors lead by adopting new energy efficient technologies or practices. Consequently, as stated earlier, the major producers lead the minor producers by several years in adopting these new energy efficient technologies and practices.

It is recommended that major oil producers continue to utilize existing energy efficiency programs since their participation is indispensable, in both developing new technologies for the industry and improving the economies of scale of energy efficiency opportunities for both major and minor producers.

3.2 Minor Oil Producers Benefit from Education, Technical Assistance, and Incentives

All minor oil producers interviewed stated that they have extremely limited resources to pursue energy efficiency opportunities. Due to their small size, they do not have the personnel to research which energy efficiency technologies should be considered or the technical resources to install and operate such technologies. They also have limited financial resources for the upfront investment in new energy efficient equipment and often rely on insight from major producers regarding energy efficient measures and practices worthy of implementation.

It is recommended that the IOUs develop energy efficiency programs for minor oil producers since they account for approximately 20 percent of the oil produced in California.[70] For the minor oil producers to upgrade their facilities, for oil and gas extraction, water management and recycling, they need:

- **Education:** To learn what energy efficient practices and technologies they should install, particularly in regards to energy efficiency best practices for well expansion
- **Technical Assistance:** To implement and operate energy efficient technologies
- **Incentives:** To offset the upfront costs of purchasing and installing energy efficient equipment; it is recommended that incentives be awarded on a case-by-case basis to ensure cost effectiveness

3.3 Evaluate Advanced Pump Motor Controllers

It is recommended that the IOUs evaluate MotorWise, the advanced pump motor controller. This technology claims to provide 25 percent or more savings for rod-beam pumps. This product is a recent development and has only been operating in Texas according to its manufacturer. Although pricing has not been quoted by the manufacturer, the company claimed that a payback period of 15 months is possible with their product.

If the savings potential is valid and the IOUs can develop an incentive program to promote this technology, energy savings could be significant since 92 percent[71] of oil field pumps in California are currently rod-beam pumps. This is a great opportunity for IOUs to incentivize majors for a short period of time to adopt this new technology, hopefully providing a demonstration of a new technology's success and ultimately serving as a showcase for minor producers. This technology could provide a near term example of majors leading minors down the path of adopting a new energy efficient technology.

However, prior to developing a program it is recommended that evaluations for this technology include a preliminary evaluation on potential savings, an in-depth market assessment, and field pilot testing/pilot EM&V. Assuming positive results, this technology can benefit both major and minor producers.

3.4 Water Treatment Savings

Interviews with major and minor oil producers indicated that opportunities to promote energy efficiency within the water treatment and management aspect of oil and gas extraction are limited and fragmented according to the size of the producer's business.

As noted in previous sections of this report, major producers that were interviewed agreed that they were independently incentivized to pursue energy efficient practices based upon measured payback and

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[70] Department of Conservation. 2009. *Oil and Gas Produced by Operator, California, 2009* and Oil Industry Major Company Guidance, http://www.caasupport.com/2013/09/oil-industry-major-minor-company-guidance/

[71] Itron Inc., Industry Standard Practice Assessment for Artificial Lift Pump Control Technologies, http://www.cpuc.ca.gov/NR/rdonlyres/F6E2974F-6220-4B9E-B6DC-EC8BE5E87A8F/0/OilFieldArtificialLiftISP_Report__final.pdf, February 2013.

technical collaboration with IOUs, both in the extraction processes and water treatment. These producers currently fund R&D for energy efficiency within all operations because their business requires it for either compliance with current codes and standards or for profit maximization. In contrast, minor producers that were interviewed indicated that they did not have the same resources to pursue energy efficient practices to maintain operations.

Based on report findings, Navigant Consulting and ASWB Engineering both recommend additional research and evaluation on potential education and incentives for minor oil producers to adopt energy efficient strategies for water management and recycling. Further investigation includes:

- **Smart Wells** as a high potential energy efficiency improvement. According to minor producers interviewed, smart wells are at a relatively low penetration rate within this segment of the industry and could be beneficial from both energy efficiency and profitability perspectives. It is recommended that incentives be awarded on a case-by-case basis in order to avoid investing in projects where economic conditions can result in shut-off activity.
- **Unicel IGF with VFDs** is a more efficient oil flotation and water cleanup apparatus that uses fewer motors than the baseline WEMCO therefore using less power.
- **Energy efficiency technologies and best practices** for water treatment facility capacity expansion and payback periods on implementing these technologies with restricted operating budgets.

Appendix A. References

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Appendix B. Program Manager Interview Guide

B.1 Technology and Process Characterization Questions

1. What are the topics, equipment, and processes that interest you?
    a. *Operations: Pumping operations, surface/support operations, waste water treatment operations*
2. Has the term major vs. minor oil producer been defined statewide?

B.2 Market Assessment and Program Activities Questions

<u>PROGRAMS:</u>

3. Do you currently have or previously had any incentive programs that target oil and gas extraction? Can you describe historic/current program activities?
    a. Program history, targeted equipment, barriers to participation, etc.

<u>MARKET BARRIERS/LESSONS LEARNED:</u>

4. Tell us about any lessons learned or best practices developed during current and/or historical program activities.
5. Are there any technical or market barriers you are currently facing?
    a. Examples: Technology or supplier limitations, upfront or lifecycle cost barriers, educational barriers, limited data, etc.

<u>ECONOMIC/REGULATORY DRIVERS:</u>

6. What are the most significant trends and drivers in the California oil and gas industry?
    a. Examples: Costs (first, lifecycle, operational), reduction in equipment downtime, state and/or federal regulations, sustainability goals, managing water usage during the California drought, Air Quality Districts, etc.

<u>OPERATIONAL PRACTICES:</u>

7. Can you talk about any industry standard practices (ISPs) you are currently focusing on or ISPs that concern you?
    a. Are there variations in ISP perceptions among major vs. minor producers?

B.3 Identify New Opportunities Questions

8. Do you have ideas for programs or programs that you are planning to launch in the near future that would be applicable across the oil and gas extraction sector?
    a. Pumping
    b. Enhanced oil recovery
    c. Transportation
    d. Surface operations
    e. Water management and recycling
9. Besides energy or water savings, what are the drivers behind these efforts to pursue new opportunities for equipment or process changes?
    a. Example: Maintenance (cost & time) savings, environmental concerns, etc.

   b. Do opportunity drivers differ across electric vs. natural gas opportunities?
   c. For water recycling opportunities, what barriers exist?
10. Do you know of any new emerging technologies or processes not yet discussed that provide new opportunities for the oil and gas extraction industry?

B.4 Market Actors

11. Who are the main decision makers/ market actors in the industry?
12. Can you identify any subject matter experts and/or trade allies that you would recommend we interview?
    a. *Suppliers and vendors, regulators, state and federal organizations, trade organizations, etc.*
13. Can you tell us about any other specific resources (market actors or other) you use to support your work in this area?

B.5 Concluding Questions

14. Do you have any additional comments or concerns?

Appendix C. Subject Matter Expert Interview Guide

C.1 Technology and Process Characterization Questions

1. What are the topics, equipment, and processes that interest you?
    a. *Operations: Pumping operations, surface/support operations, waste water treatment operations*
2. What are the early retirement or replacement practices for oil and gas extraction equipment? What are the costs and drivers associated with replacing vs. repairing equipment?
3. Can you talk about the enhanced oil recovery (EOR) techniques used in the industry? Are there differences in techniques/processes among regions and utilities?
    a. Steam generation
    b. Water heating
    c. EOR pumping

C.2 Market Assessment and Program Activities Questions

<u>MARKET BARRIERS/LESSONS LEARNED:</u>

4. Tell us about any lessons learned or best practices developed during current and/or historical program activities.

<u>ECONOMIC/REGULATORY DRIVERS:</u>

5. What are the most significant trends and drivers in the oil and gas extraction industry?
    a. Examples: Costs (first, lifecycle, operational), reduction in equipment downtime, state and/or federal regulations, sustainability goals, etc.
6. Are there any technical or market barriers the industry is currently facing?
    b. Examples: Technology or supplier limitations, upfront or lifecycle cost barriers, educational barriers, available data, etc.
7. What are the most important regulations governing this industry?
    c. Do any of these regulations affect market decisions in the industry?

<u>OPERATIONAL PRACTICES</u>

8. Can you talk about any industry standard practices (ISPs) that the industry is currently focusing on or practices that concern you?
9. During the last 10 to 15 years, can you highlight important changes in the oil and gas extraction industry?
    a. Examples: Significant energy efficiency improvements taking place in the industry, trends and market transformations, etc.?
10. We would like to understand if any energy efficiency or operational practices are considered standard by your organization?

a. Tell us about some things you may be doing that may not be supported by regulation or a current utility program.

C.3 Identify New Opportunities Questions

11. Can you tell us about any new opportunities being pursued in oil and gas extraction?
12. What specific resources and services are supporting these efforts?
    a. Example: Who are the market actors and influencers on energy efficiency, O&M activities, new technologies and equipment, etc.?
13. What are the drivers behind these efforts to pursue new opportunities for equipment or process changes?
    a. Example: Energy savings vs. maintenance (cost & time) savings, etc.
14. Do you know of any new emerging technologies or processes not yet discussed that provide new opportunities for the industry?

C.4 Market Actors

15. *Data request: Can you identify any subject matter experts and/or trade allies that you would recommend we interview?

C.5 Concluding Questions

16. Do you have any additional comments or concerns?

Appendix D. Facility Manager Interview Guide

D.1 Technology and Process Characterization Questions

1. What are the topics, equipment, and processes that interest you?
    a. *Operations: Pumping operations, surface/support operations, waste water treatment operations*
2. Can you elaborate on the most important things for successfully meeting your bottom line:
    a. Do you look at ROI, first cost, utility bills, production rates, maintenance impacts, down times, etc.?

<u>OPERATIONAL PRACTICES</u>

3. We would like to understand your views on a number of business and energy related topics:
    a. How important are energy costs and energy savings?
    b. What are the most important energy saving technologies in the industry?
    c. Where do utility costs rank on your list of operational expenditures?
    d. What do you currently do to mitigate energy use, if anything?
    e. What are the efficiencies of your current equipment?
    f. What do your O&M programs look like at your facility/company?
    g. How do you leverage utility programs?
4. How do you approach equipment replacements and/or upgrades?
    a. Example: Do you have a phased schedule or bulk replacement strategy, replace-on-burnout, green motor rewind, repair versus replace views, etc.?
    b. What are the costs and drivers associated with replacing vs. repairing equipment?
5. Can you talk about any industry standard practices (ISPs) you are currently focusing on or ISPs that concern you?
    b. Identify how ISP relates to:
        i. Electric vs. gas
        ii. Pumping and EOR processes
        iii. Surface operations
    c. Are there variations in ISP perceptions among major vs. minor producers?
6. We would like to understand if any energy efficiency or operational practices are considered standard by your organization?
    a. Tell us about some things you may be doing that may not be supported by regulation or a current utility program.

MARKET BARRIERS

7. What are the key barriers you face and how are they addressed:
    a. Related to deployment of specific technologies from an organizational perspective?
    b. What are the key reasons to adopt these technologies?
    c. Are there any other technical or market barriers you are currently facing?
        a. Examples: Technology or supplier limitations, upfront or lifecycle cost barriers, educational barriers, or limited data.

D.2 Identify New Opportunities Questions

8. Can you tell us about any energy efficient new opportunities you are pursuing in oil and gas extraction?
9. What specific resources and services do you use to support these efforts?
    a. Example: How do you inform yourself about energy efficiency, O&M activities, new technologies and equipment, etc.
10. What are the drivers behind the efforts to pursue new opportunities for equipment or process changes?
    a. Example: Energy savings vs. maintenance (cost & time) savings, etc.
11. Do you know of any new emerging technologies or processes not yet discussed that provide new opportunities for the industry?
12. Do you have ideas for programs or recommendations for program designs that would be applicable across California?
    a. Example: What would you like to see from your utility?
13. What is the likelihood that you or other facilities in the oil and gas extraction sector will participate in utility efficiency programs? What can the utility do to increase participation?

D.3 Market Actors

14. *Data request: Are there any other facility managers, suppliers, vendors, or other individuals that might be interested in sharing information with Navigant on this topic?