Energy Saving Opportunities in the Oil Production Sector

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ABSTRACT

Throughout the United States, the oil production sector continues to be a challenging market segment for energy efficiency penetration efforts. Any changes in equipment create down-time in production and impact cash-flow. Proper planning and a better understanding of impacts on energy consumption, production rates, and equipment lifetime will help overcome this market barrier.

The primary purpose of this study is to summarize energy savings opportunities in the oil production sector. The study is based on energy efficiency measure (EEM) installations in 339 oil production wells that took place between 2008 and 2012 in Southern and Central California. Each energy efficiency measure is presented, followed by a technical and economic analysis considering energy savings and payback period. All installations are divided into the four individual measures and an "Other" measure category. These measure groups are then compared based on various quantitative and qualitative parameters. Most of the energy efficiency measures are applicable to either electrical submersible or rod beam pumping units which constitute more than 90% of all oil well pumping units in California. Annual energy savings and peak load reduction is calculated using standard engineering principles and/or field data monitoring of key parameters.

Based on these 339 oil wells, it is determined that pump-off controllers has the lowest payback period followed by the water shut-off controls and high efficiency electrical submersible pumping systems measure. The results provide clear direction for electric utilities throughout the United States with significant oil production customer bases to design cost-effective demand side management strategies.

Introduction

Energy required for extracting oil and gas from wells is continuously increasing due to conventional source depletion (Brandt 2011). Between 1990 and 2009, as reported by Energy Information Association (EIA) data on the Petroleum Industry, daily output of crude oil production per well in the United States has dropped from 12.2 barrels to 10.1 barrels per day while the average well depth has increased from 4,602 to 6,084 feet (EIA 2009). Energy return on investment (EROI), the ratio of energy delivered to energy cost, increased from 100:1 in 1930 to 20:1 in 2005 for oil extraction (Cleveland 2005). Investment in more efficient energy technologies is often the most cost-effective way of improving the EROI and cutting emissions of greenhouse gases and air pollutants (McKinsey 2006). Despite high energy costs, many oil production facilities use energy inefficiently. There are many reasons for this including but not limited to higher crude oil prices, lack of awareness, risk averseness and high cost of production interruptions. As a result, a few utilities have established targeted energy efficiency (EE) programs in the oil production sector, however most electric utilities in the U.S. are designing EE programs that generally target commercial and industrial customers without an emphasis on oil production.

Southern California Edison (SCE) electric utility in California offers various market segment specific EE programs to its residential and non-residential customers. SCE provides financial incentives for the installation of high-efficiency equipment and/or systems. One of these programs is designed specifically for SCE's Oil and Gas Production customers. The program is open to all oil and gas production customers who (1) receive electric services from SCE, and (2) pay the Public Purpose Program (PPP) surcharge on the electric meter on which the energy efficient equipment is proposed.

This paper compares various EEMs installed through this program between 2008 and 2012 with respect to the number of installations, energy and peak demand savings, and simple payback period. Also, a qualitative comparison is made for indirect parameters such as maturity of the technology, average well downtime during installation, and effective useful life. The list of EEMs considered in this work is included below:

- High Efficiency Electric Submersible Pumps (ESP)
- Pump Off Controllers
- Water Shutoff Controls
- Variable Speed Drives
- Other Measures
  - Injection Pump Impeller Re-sizing
  - High Efficiency Motors
  - Long Stroke Pumping Units

Only a limited number of studies are available in the literature related to the EEMs specific to the oil production sector. J.E. Johnson published an article in the Society of Petroleum Engineering Journal on electrical savings in oil production sector based on several field tests and customer surveys in California's Kern County (Johnson 1988). The scope of this study was limited to potential EE measures on rod beam pumps. Results showed that energy savings can be achieved by installing pump off controllers, improving volumetric pump efficiency, and using multi-mode motors on rod beam pumps.

Alex Lee and Jay Zarnikau did a study to explore energy efficiency opportunities in the Texas oil and gas production industry (Lee & Zarnikau 1996). This study compared EEMs like high efficiency motors, adjustable speed drives, pump off controllers, and pump impeller re-sizing. It concluded that the pump-off controller EEM provides the highest energy savings potential and the lowest payback period. It also concluded that adjustable speed drives were generally not cost-effective. However, its results were predictive and not based on actual field data. Some other articles related to site specific impacts of the pump off controller measure were also found in the literature (Marietta College 2005).

This study is different from the work discussed above for three main reasons. First, it includes technical and economic impacts based on actual installations; second, the results are based on data from the last four years reflecting the current industry environment; and third, it includes EEMs such as water shutoff controls and long stroke pumping systems that were not considered in any of the previous studies.

Data Collection and Analysis

This study is based on customized energy efficiency measure installations on 339 oil production wells that took place between 2008 and 2012 in Southern and Central California.

These were energy efficiency rebate applications submitted by the project sponsor (typically customer or their authorized representative) and reviewed by SCE assigned technical reviewers to evaluate energy savings and incentive potential. The energy savings calculations were based on industry accepted engineering principles as well as baseline and installed measurements of critical parameters. Providing calculation methodologies for each measure type is outside the scope of this study. In general, incentives are paid on the energy savings and demand reduction above and beyond baseline energy performance, which include state-mandated codes, federal-mandated codes, industry-accepted performance standards. During the program period, incentive was calculated based on the quantity of kWh saved over a 12-month period (at $0.09/kWh) and peak KW reduced (at $100/kW) up to 50 percent of the total project cost.

This study reviewed all these applications to collect information regarding the type of energy efficiency measure, baseline and installed pumping system type and specifications, baseline and installed oil and water production rate, control technologies, annual energy and peak kW reduction, measure cost, and program incentive. This data set was further analyzed to obtain various quantitative performance characteristics for each measure type as presented in the next section.

Energy Efficiency Measure Description

The section below provides a brief description of each of the measures considered in this paper.

High Efficiency ESP

The ESPs are used to provide artificial lift for oil production. With time, their performance drops due to changes in the well characteristics and equipment degradation. The installation of a properly sized high efficiency ESP unit results not only in lower energy use due to improved pumping efficiency but also increases the fluid production rate. The ESPs used in oil wells generally operate throughout the year except for some maintenance time. The reduction in energy consumption depends on the efficiencies (kWh/bbl metric) of the existing and installed pumps and the annual production capacity (bbls/year). High efficiency ESP units are designed to match the well production capacity and utilize high strength shaft materials and abrasive resistant bearings and other pump components.

During the study period this measure resulted in an average energy savings of 0.44 kWh per barrel of water and oil (emulsion) production. Installation of new ESPs also resulted in about 18% increase in the oil production rate and 32% increase in the water production rate. The increase in energy consumption due to higher water production rate was off-set by higher revenue due to increased oil production.

Pump Off Controller

Rod beam pumping is one of the oldest methods of artificial lift in the petroleum industry. More than 80% of oil production wells operating in the Western U.S. use rod beam pump system.

Generally, oil wells have a rod beam pump capacity that exceeds the production rate of the well. Rod pumps operate most efficiently and at a lower cost if they operate at rated capacity. Many rod beam pumps operate continuously or use percentage timers without taking in to account the amount of fluid in the well bore. Pump off controllers (POCs) optimize the pump run time so that it only operates when there is enough fluid in the well. The main benefits of POC are an increase in the pump life and a decrease in energy usage since the pump operates less. In addition, new POC technology incorporates digital runtime recording, and may include optional remote telemetry that allows oil field personnel to monitor and diagnose oil well conditions from a central location.

During the study period this measure resulted in average annual energy savings of about 1,200 kWh per hP of the drive motor capacity and an average pump run hour reduction of 45%.

Water Shutoff Controls

A serious problem in oil-producing reservoirs is increasing water cut. A significant percentage of oil production wells in California have water-to-oil ratios exceeding 95%. The heterogeneous nature of the rock causes water and oil in the reservoir to follow paths of least resistance. Various types of chemical or mechanical water shutoff methods such as equalizers, gels, and selective casing allow plugging water rich zones. This not only increases the percentage of oil content in the emulsion but in most cases also enhances the oil recovery rate. Reducing the amount of water lifted to the surface saves the energy that is needed to lift, transport, treat, and re-inject the excess water. Reduction in energy consumption is highly dependent on the oil-to-water ratio before and after the water shutoff control is installed.

The reduction in water cut observed during this study was highly variable as presented in Figure 1 (based on results from seventeen production wells). On an average, installation of the water shutoff controls reduced the water content in the emulsion from 93% in the baseline to 75% in the installed case.

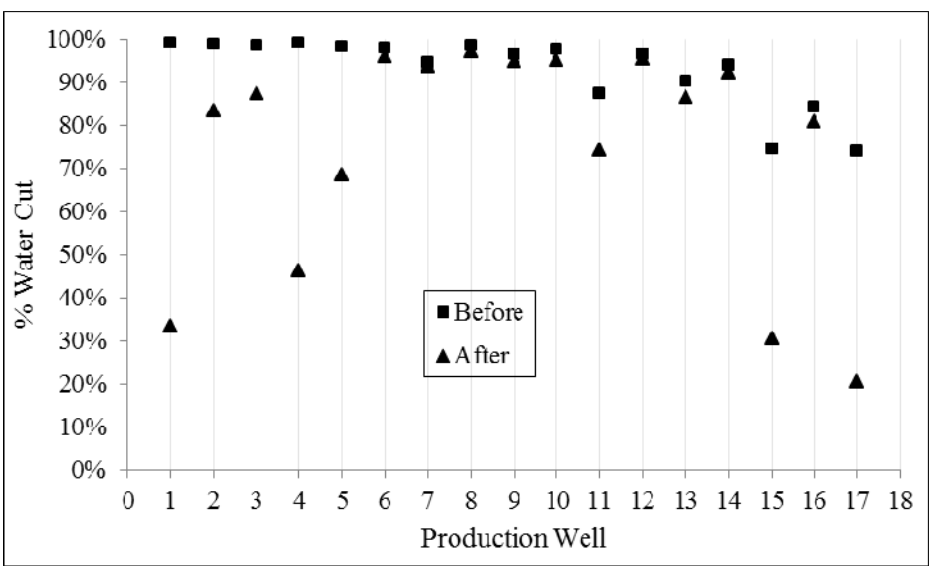


Figure 1. Impact of the water shutoff strategy on water content in oil production wells

Variable Speed Drive

Most of the existing ESPs and water injection units use throttling controls (choke valves) to match the well capacity/water requirement with the pump capacity. In the case of rod beam pumping units, timers or POCs are also used. This measure involved installing Variable Speed Drives (VSDs) on electric drive motors for pumps with variable load profiles or that were oversized. Based on the pump loading, a variable speed drive electronically varies the speed of an electric motor by adjusting the frequency of the motor input so that the pump performance matches the present load. VSDs allow the pumps to follow varying demand by operating pumps at lower speeds during low pumping demand and increasing the speed as needed during high pumping demand.

During the study period this measure was installed on rod beam pumps, submersible pumps, and on a few water injection pumps. Overall, an average of 1,350 kWh of annual energy savings per horsepower of the drive motor capacity was observed (1,500 kWh/hP for rod beams; 1,200 kWh/hP for ESPs; 1,550 kWh/hP for water injection pumps).

Other Measures

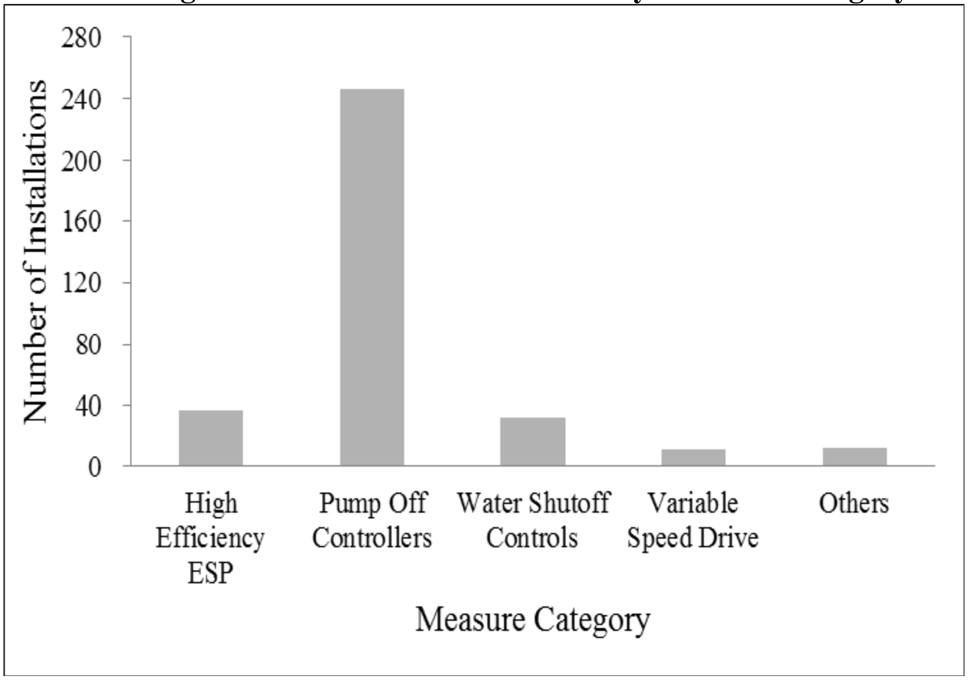
The study period also included a small number of projects with EEMs such as water injection long stroke pumping units, pump impeller re-sizing, and high efficiency motors.

Long stroke pumps are able to pump more fluid than a conventional rod beam pump unit. The significantly longer stroke compared to a conventional rod beam pump allows this type of pump to operate at higher efficiency and at capacities up to the low range of electric submersible pumps. Water injection pumps impeller re-sizing measure reduces the throttling power loss. Oversized and throttled pumps that produce excess pressure are excellent candidates for impeller re-sizing/replacement. Installation of high efficiency motors (NEMA premium) improves overall pumping efficiency by 1 to 5 percent. Cost premiums for high efficiency motors range from 10 to 25 percent.

Technical and Economic Comparison

This section compares the various technical and economic parameters for each measure category. As shown in Figure 2, the pump off controller EEM was the most common during the study period representing about 73% of all installations. High efficiency ESP (11%) and the water shutoff (9%) took the next two spots, respectively. The higher share of the POC measure is primarily due to the higher share of rod beam pumping units (about 80%) installed on oil production wells in California. In addition, more and more oil producers feel confident in the POC technology due to its increased presence in the market over the last 30 years.

Figure 2. Number of Installations by Measure Category



The POC measure also ranked best in cost effectiveness ($/kWh saved, and $/kW saved) with values of $0.07/kWh and $620/kW as shown in Figure 3 and 4, respectively. The dollar value in the cost effectiveness analysis represents the gross measure cost. These numbers make it a compelling case to install POCs on all rod beam pumps unless restricted by other factors such as well condition, safety, etc. High efficiency ESP and water shutoff fared about the same at $0.21/kWh and $0.22/kWh, respectively. The "other measures" category which includes high efficiency (HE) motors, long stroke pumps, and HE water injection pump measures was the least cost-effective at close to $1.00/kWh. The HE motor measure does not save enough incremental energy because, as per the SCE's customized program guidelines, the baseline is based on existing federal minimum motor efficiencies (Energy Policy Act of 2005 and Energy Independence and Security Act of 2007) and not from actual installed motors. Similarly long stroke pumping units have a small incremental efficiency improvement over the standard rod beam pumps compared to the incremental cost.

Figure 3. Average Cost per kWh of Energy Saved by Measure Category

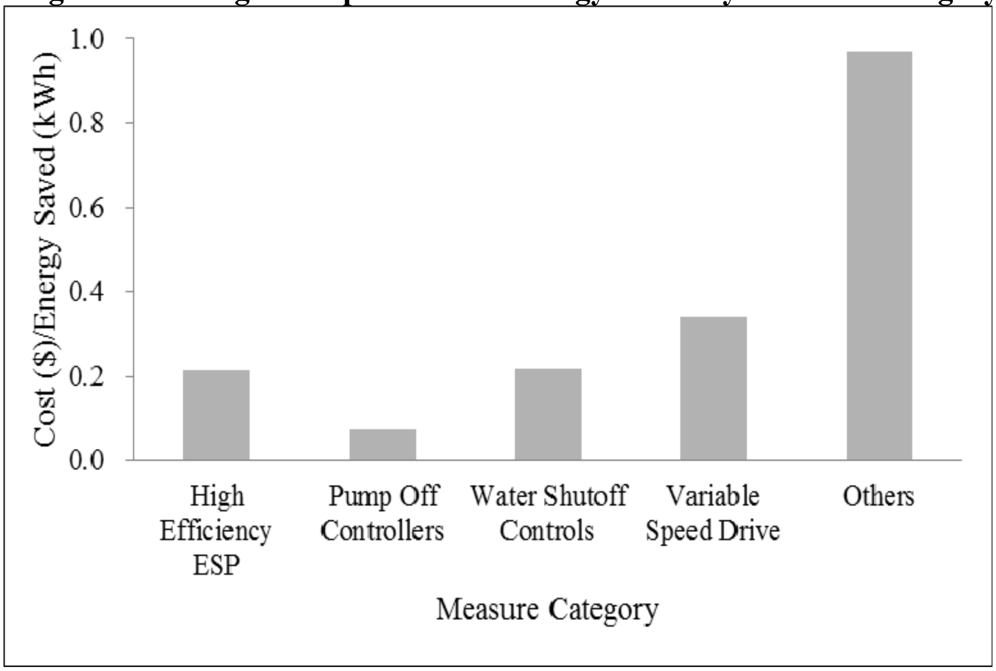
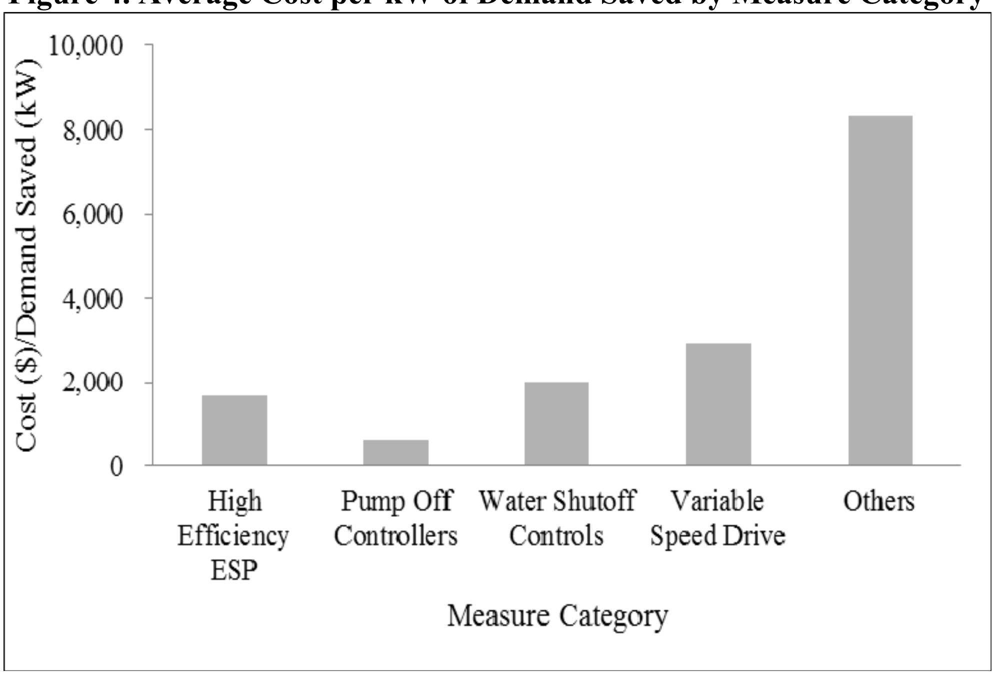
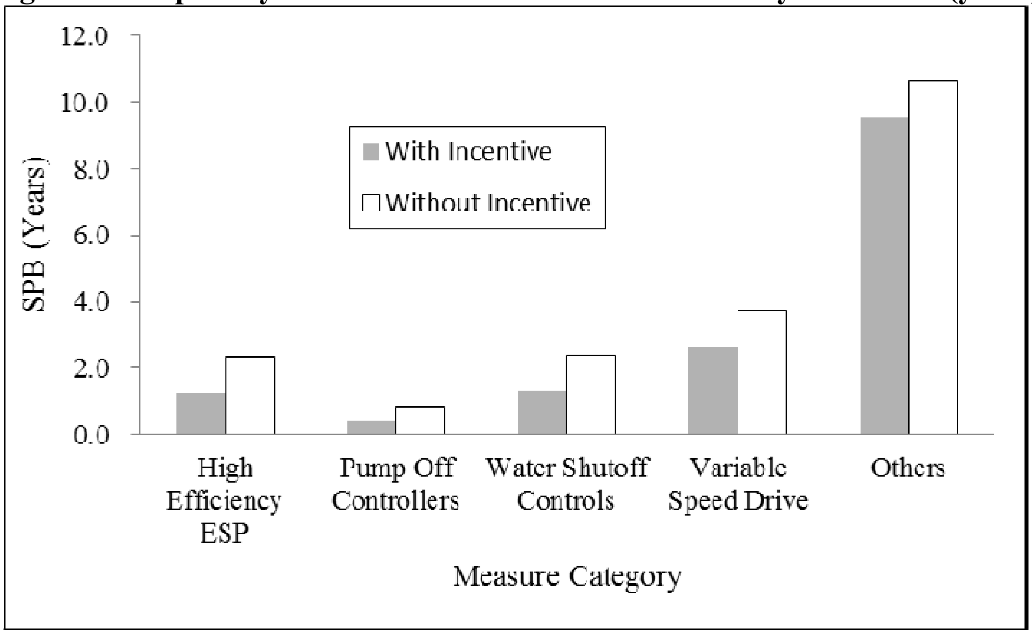


Figure 4. Average Cost per kW of Demand Saved by Measure Category



The simple payback (SPB) period for each EE measure with and without utility incentive is presented in Figure 5. The average electricity price for industrial customers in California is estimated to be $0.0991/kWh (EIA 2013). The payback period calculation does not consider potential electricity price escalation and savings due to higher production or lower maintenance due to newer/efficient equipment. The installation of POCs has a payback period of less than six months, ranking it the lowest among all of the measures. It is also important to note that with the advent of automation in the oilfield, POC is becoming an industry standard and utilities are already starting to limit incentive for this measure in California. Typically, any measure with less than three (3) years of payback period is considered a good investment and all measures except the "other measures" category meet this criterion.

Figure 5. Simple Payback Period With and Without Utility Incentives (years)



Qualitative Comparison

For many oil producers, implementing a corrective measure to their existing system or installing a new system is more than an energy savings or simple pay back issue. Most oil producers dislike uncertainty due to high cost of production interruptions and are generally risk averse. Also, new technologies may require skill and abilities beyond their capabilities. Table 1 below shows a qualitative comparison of various measure categories as it relates to the other factors impacting installation of the five EE measures. Some other general factors that may affect customer participation in utility rebate programs are their utility interaction experience, internal EE budget, technical support, local EE equipment vendors, and their own previous experience with implementing new technology.

Table 1. Qualitative Comparison of Various EEMs

Measure Category	High Efficiency ESP	Pump Off Controller	Water Shutoff Controls	Variable Speed Drives
Maturity of Technology	First use in oil production in late 1990s.	Exists since early 1980s.	Exists for many decades but continuously improving.	Matured but adoption is mostly in last decade.

Well down-time during installation	4-10 days	1 -2 days	10 - 30 days	1 -2 days
Effective Useful Life	5-8 years	10 - 15 years	10 - 20 years	10 – 15 years

Conclusions

A quantitative and qualitative performance comparison of the most common energy efficiency measure categories was carried out based on installations to 339 oil production wells between 2008 and 2012 in Southern and Central California.

The installation of pump off controllers has the lowest payback period, but this technology is quickly becoming an industry standard and California utilities have already started to phase-out customer incentives for this measure. The water shutoff controls and the high efficiency ESPs also have less than two years payback period (without utility incentives). The payback period for HE motors, long stroke pumping system, and water injection system are close to 8 years. Although it was not considered in this analysis, increased oil production due to these measures can also provide significant additional revenue to oil producers.

For many oil producers, implementing a corrective measure to their existing system or installing a new system remains more than an energy savings or payback issue. Production interruption fear and lack of technical support is limiting the adoption of new EE technologies. Utilities can influence the transformation of the oil production sector by designing EE programs to meet their expectations and providing the necessary technical support.

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