

Chapter one

Introduction

1.1 Introduction:

Thermal enhance oil recovery consider one of the most important method of extracting heavy oil, however this process consume large amounts of energy which is required for heating water to be hot water or steam that at the end will be injected into the well, normally the water is heated by fossil either by burning gas or light oil or any other fuel if the economic conditions are appropriate, typically the cost of heating water is up to 60% of the total cost of the process.

Since the end of 1970s several studies have been published about the potential of concentrating solar power (CSP) for EOR purposes but no commercial output has emerged until recently where studies and pilots of the technology have proved to be economical and effective.

Solar EOR technology is based on reflecting the sun rays into one concentrated point heating the water that directly injected into the well or fluid that exchange heat with water and then injected it into the well.

1.2 History overview:

Sudan first Exploration effort initiated in 1959 by Italy's Agip oil company in the Red sea area, several oil companies followed Agip in exploration including shell but none were successful in their exploration efforts.

In 1974 chevron start exploration and several gas wells have been discovered in Red Sea area Bshaier 1 and Bshaier 2 but sadly chevron suspended its operation in 1984 and entirely ended its 17 years long involvement in Sudan by sealing its interests to Sudanese company Concrop in 1992[oil and gas magazine 2003] , in 2000 Sudan start commercial production reaching an all-timerecord as high as 520 BBL/D/1K in November 2007 and lost 70% in 2011 due to the separation of south Sudan , and know hardly producing 110 BBL/D and its expected will be depending on EOR by 50% of total production in 2020 [CSP today 2013]

Most of Sudan's proved reserve of oil and natural gas are located in Muglad and Melut Basins according to oil and gas journal (OGJ), Sudan had 1.5 billion barrels of proved oil reserves, as of January 2014, despite the discovery of natural gas wells and 3 trillion (scf) proved reserve of gas, currently Sudan doesn't produces or consumes dry natural gas, natural gas associated with oil production is flared or reinjected into wells to increase the oil output rates, approximately 11.8 billion cubic feet of natural gas, according to the latest data from the national oceanic and atmospheric administration (NOAA), representing about 0.2 % of the total gas flared globally.

Extraction of heavy oil by TEOR is related to burning large amounts of fossil fuel to satisfy the heat requirement, however burning fuel is connected to concerns about fuel cost, future supply of fuel, CO₂ emissions, these concerns could be minimized through recent studies by the use of Solar Energy as a replacement of burning fuel (wheatear it was crude oil or natural gas) to supply the required energy,

However the use of Solar TEOR technology is very recent and limited to specific location with high solar radiation, which limits the deployment of such projects.

Sudan has a very high amount of Solar Power to capture since it's placed in zone known as Solar Belt, which led to invest great efforts to use these power in Electricity generation and water desalination, while no research related to use it in EOR application have been made it.

1.3 Problem statement:

Decline of production and low recovery of cold production in FNE heavy oil field encourage the implementation of T-EOR projects. However, thermal EOR projects have many operational concerns such as fuel cost, future supply of fuel and CO₂ emissions.

1.4 Objective:

1.4.1 General Objective:

Conduct the first study in Sudan of using Solar Steam generated for EOR purposes, through focusing on solar requirement to generate steam, reservoir responds for various operation scenarios and highlight the economic and environmental impacts for each scenario.

1.4.2 Specific Objectives:

1. Study the field compatibility to Thermal EOR and CSP Specifications.
2. Study the effectiveness of solar T-EOR for each proposed scenario from a reservoir prospective.
3. Steady the effect of seasonal variation for the proposed scenario.
4. Analyze the outputs for each scenario, in addition to highlights to the economic and environmental effects.

1.5 Project Layout:

Chapter one : Introduction

This chapter introduces the idea of the project and the problem statement, objective and the scope of the project

Chapter two : literature Review

This chapter review some presented work in recent years that is relate to the main aspect of the research such as CSP technology, solar EOR in Oman and the economical impact of using similar technology in Addition to over view the common techniques that used to concentrate solar power and FNE location description and model description

Chapter three : Methodology

This chapter explain the principles, assumptions, techniques and software's involved in the research.

This chapter we will discuss all the results obtained in the research

Chapter five: Conclusion and Future

This Chapter shows the study conclusion and the recommendations based on the research output

This part contain all the figures related to the result in addition to the referencing

Chapter two

Theoretical Background and Literature Review

2.1 Theoretical Background:

This part of the research present brief description of the solar thermal Enhance Oil Recovery (EOR) technology and overview the concentrating solar power requirements , in addition to main information about the field the research target.

2.1.1 Thermal Enhance Oil Recovery:

Enhanced oil recovery (EOR) processes include all methods that use external sources of energy and/or materials (injection of gases or chemicals or thermal) into the reservoir to recover oil that cannot be economically produced by conventional means [Don. Green .et al 1998].

In mature oilfield most of the easy oil is already produced as well as the production reached the peak years ago

There are four main types of thermal EOR namely:

1. Steam Injection.
2. Cyclic Steam Stimulation (CSS).
3. Insitu Combustion (ISC).
4. Steam Assisted Gravity Drainage (SAGD).

Steam flooding:

Is a pattern drive, similar to water flooding, steam is injected continuously with a certain quality to the reservoir having shallow depth which is preferred.

It forms a steam zone which advances slowly in the reservoir heating the oil and reducing its viscosity.

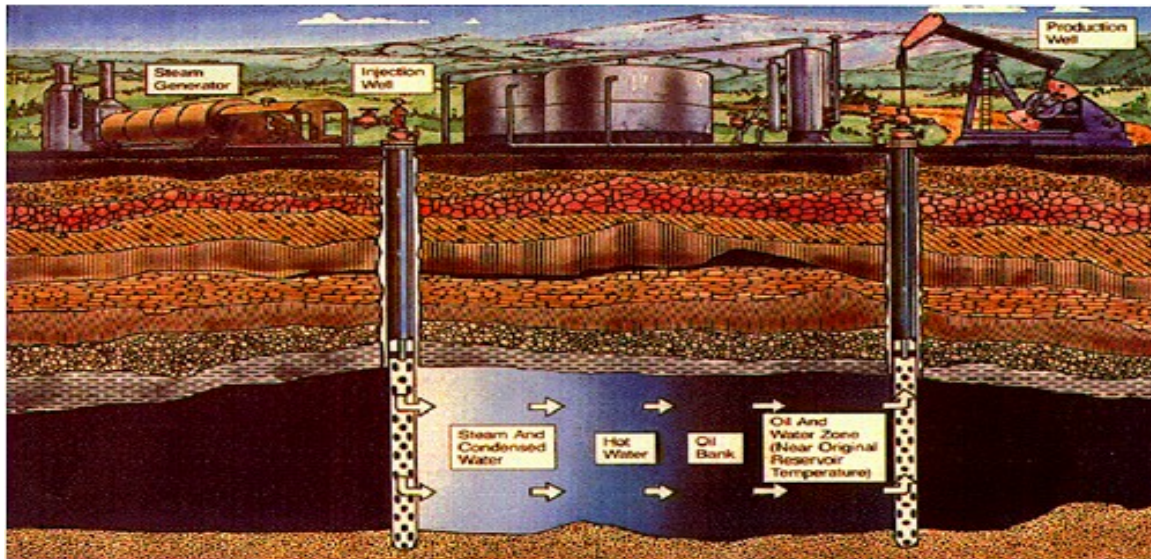


Figure (2.1)

2.1.2. Solar Thermal Enhance Oil Recover:

Solar Thermal Enhance Oil Recovery is a form of thermal enhanced oil recovery (EOR), a technique applied by oil producers to extract more oil from maturing oil fields, Solar thermal EOR (abbreviated solar EOR) uses solar arrays to concentrate the sun's energy to heat water and generate steam. The steam is injected into an oil reservoir to reduce the viscosity, or thin, heavy crude thus facilitating its flow to the surface. Thermal recovery processes, also known as steam injection, have traditionally burned natural gas to produce steam. Solar EOR is proving to be a viable alternative to gas-fired steam production for the oil industry. Solar EOR can generate the same quality steam as natural gas, reaching temperatures up to 750°F (400°C) and 2,500 PSI.

While typical fuel-fired steam flooding operations inject steam into the ground at a constant rate, research conducted by leading oil producers shows that variable rate steam injection has no negative impact on production levels. In effect, solar EOR could supply up to 80 percent of a field's annual steam requirements, by injecting solar generated steam during the sunny hours, and a reduced amount of gas-fired steam at night or in less sunny weather or climates. This method of integrating solar EOR will displace larger amounts of gas consumption without affecting oil output.

2.1.3. Concentrated Solar Power Technology (CSP):

Concentrated Solar Power Technology Is a type of solar thermal technology that uses mirrors to concentrate the sun's rays to heat water and generate steam. The steam is directly fed to the oil well or used in driving a turbine to generate power in the same way as conventional power plants.

CSP is commercially proven in power generation with an installed capacity of 2.8GW at the end of 2012. There are four main variants of CSP technologies, three of which to date are being adapted to produce steam for solar thermal EOR [EY Oman]. These are:

- 1 Solar tower
- 2 Parabolic trough
- 3 Linear Fresnel
- 4 Stirling dish

Here brief descriptions of the two main technologies that are operate in solar thermal EOR projects by 2013, which are:

2.1.3.1. Solar Tower Technology:

In the solar tower design an array of flat, movable mirrors (heliostats) follow the movement of the sun throughout the day. Solar energy is reflected from the mirrors onto a solar receiver at the top of a tower. The receiver is used to directly or indirectly heat a boiler filled with water

2.1.3.2. Parabolic Trough Technology:

Parabolic trough collectors (PTC) consist of solar collectors (mirrors), heat receivers and support structures. The parabolic-shaped mirrors are constructed by forming a sheet of reflective materials into a parabolic shape that concentrates incoming sunlight onto a central receiver tube at the focal line of the collector

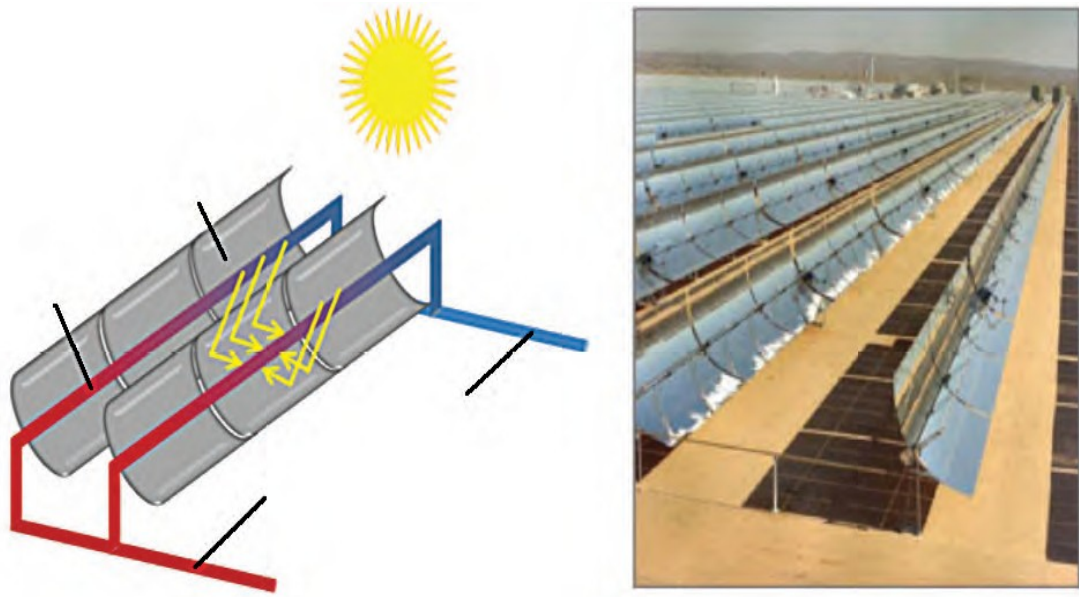


Figure (2.2)

An advanced parabolic trough technology was developed by GlassPoint, called the “enclosed trough.” The enclosed trough was designed from the ground-up for the oil and gas industry, rather than for power generation.



Figure (2.3)

According to Solar Energy Industries Association (SEIA) the key requirement to concentrating solar power plans includes:

- **Areas of high direct normal solar radiation** – In order to concentrate the sun’s energy, it must not be too diffuse. This feature is captured by measuring the direct normal intensity (DNI) of the sun’s energy.
- **Contiguous parcels of land.**
- **Access to water resources.**

The research disuse the solar radiation at the field location, were based only on satellites data and no ground measurements were made at this point. The type of solar radiation data used in this research as well as the software involved will be discusses in the next chapters.

2.1.4 Differencesfor CSP for power and EOR applications:

Most prior technology deployment in CSP has been in support of thermal electric power generation. The efficiency of steam turbines in such configurations strongly depends on the inlet steam temperature; accordingly, engineering efforts have focused on the delivery of superheated steam at the highest practicaltemperature. Such system universally employs very pure water, simplifying the selection of materials of construction. Since electricity can be economically moved thousands of kilometers, solar arrays can be sited at the cleanest, highest-radiation, remote locations where land is inexpensive.

Thermal EOR however, universally employs saturated steam, at pressures determined by formation characteristics but broadly within a range of 60 to 130 bar. Given the “once-through” nature of EOR operations, the minimization of water retreatment costs is critical factor, requiring the boiler design to accept thousand-fold higher mineral content. Since steam can be economically move only a few kilometers, the solar array must operate using the lowest possible land footprint, and be tolerant of the dirt and solar radiation conditions which prevail at the oilfield itself.

Fundamentally these are different sets of design requirements, and they ultimately result in different designsolutions. While previous solar EOR trials and pilots have utilized state of the art CSP technologies developed or optimized for electrical power generation and applied them to EOR, the resultant systems have been found to be too costly to build and to operate. For solar power generation, the system can be located in a position with ideal solar and climactic conditions. These include: the highest possible solar radiation, low peak wind speeds, and low average operating wind speed, low dust and particulate levels and no blowing sand. The locations are chosen where there are large areas of unused flat land. To generate electrical power the highest possible temperatures are generated to maximize the efficiency of the steam turbine used. Thermal storage is also used to allow the plant to dispatch power when the sun is not shining.

In the case of solar EOR, the location is determined by the location of oilfield. The solar technology must be designed to cope with the harsh desert environment in a cost effective manner. The operation temperature can be designed to match the steam conditions of the oilfield steam distribution network, which is generally in the range of (280°C to 330°C). Although land around desert oilfields may be plentiful, many factors limit the land freely available for solar deployment. These factors include terrain, pipeline and utility corridors, drill sites, and future developments of oil and gas.

From this comparison it can be seen that concentrating solar systems for EOR and for electrical power applications are likely to diverge in their engineering solutions. Solar EOR requires a system optimized for wind, dust and minimum footprint with lower operating temperature and storage requirement CSP for electrical generation is being designed for “ideal environments” and pushed to higher and higher temperatures and larger storage volumes to provide “dispatch-able” electrical power during peak times.

2.1.5 Current Projects:

2.1.5.1 21 Z in McKittrick, California

GlassPoint Solar partnered with Berry Petroleum, California's largest independent oil producer, to deploy the world's first commercial solar EOR project. Commissioned in February 2011, the project is located on a 100-year old McKittrick Oil Field in McKittrick, California. Coined the Kern County 21Z Solar Project, the system spans roughly one acre and will produce approximately one million Btus per hour of solar heat, replacing natural gas used for steam generation. The solar EOR project was constructed in less than six weeks and is the first installation of GlassPoint's enclosed trough technology in an oil field.

2.1.5.2 Coalinga in Coalinga, California

In October 2011, Chevron Corp. and BrightSource Energy revealed a 29-megawatt solar- to-steam facility at the Coalinga Oil Field in Fresno County, California. The Coalinga solar EOR project spans 100 acres and consists of 3,822 mirror systems, or heliostats, each with two 10-foot (3-meter) by 7-foot mirrors mounted on a 6-foot steel pole focusing light on a 327-foot solar tower. BrightSource was contracted to provide the technology, engineering and production and construction services, and Chevron Technology Ventures will manage operations of the project. The facility began construction in 2009. It was reported that Chevron spent more than its \$28 million on the contract, and BrightSource has lost at least \$40 million on the project and disclosed it will lose much more.

2.1.6 Petroleum Development Oman:

In May 2013, GlassPoint Solar and Petroleum Development Oman (PDO) commissioned the Middle East's first solar EOR project.[7] PDO is a joint venture between the Sultanate of Oman, Shell and Total. The 7 MW solar EOR facility produces a daily average of 50 tons of emissions-free steam that feeds directly into existing thermal EOR operations at PDO's Amal West field in Southern Oman. The system is 27 times larger than GlassPoint's first installation at Berry Petroleum's 21Z oil field. Reports by Petroleum Development Oman indicate that the pilot was delivered on-time, under-budget, and above contract output specifications, with zero

lost time injuries. In the first year of operations, the fully automated system successfully exceeded all performance tests and production targets. The system recorded a 98.6% uptime, significantly exceeding PDO's expectations. Even during severe dust and sandstorms, the system has proven to maintain regular operations.

2.1.7 Block 6, Fula North East (FNE) oil field:

FNE Oilfield is geographically located in the southwest of Sudan, about 700 km from the capital, Khartoum; structurally located in the northeast of Fula sub-basin of Muglad basin and in the southwest of the Moga Oilfield.

Oilfield exploration began in 1989. In 2005, through FNE-1 well, it was found one of the largest heavy FNE oil fields in PE Area 6.

The oilfield was put into development in June 2010. By May 2011, a total of 43 had been drilled, of which a horizontal well was drilled; 36 wells have been put into operation, of which 23 are for the natural energy mining, and 13 for steam stimulation; 33 wells were opened, with a daily oil production of 5722bbl, a daily fluid production of 6097bbl, a water cut of 6.1%, and a stage recovery percent of reserves of 0.75%. The average daily production for steam stimulation is 2 to 3 times of that for natural energy production as the steam stimulation effect is obvious, PE commissioned Great Wall Drilling Co., Ltd. to conduct further research on thermal recovery, to carry out steam drive pilot test, the project began in April 2011.

The heavy oil reservoir is mainly developed in the Aradeiba and Bentiu formations of Cretaceous system, of which, Bentiu1 main reservoir is a reservoir of the bottom water structure. Main geological features include:

(1) Bentiu oil layer stratigraphic features and layer group classification: Bentiu oil layer is mainly composed of braided river deposited thick sandstone and a small amount of mudstone interlayer, divided into three intervals: Bentiu1, Bentiu2 and Bentiu3, of which the main oil layer Bentiu1 interval is further divided into five sandstone groups: a, b, c, d and e.

(2) Structural features: FNE Oilfield is of broken anticline structure which is complicated by faults. There are two faults developed in the oilfield, cutting the oilfields into three fault block: one is in the north-south direction, trending east, with a fault displacement of 60m, extending 4.8km, across the entire oil block, belonging to the regional control fault. Another fault is developed in the FNE-6 north direction toward the north west, trending southwest, with a small fault displacement.

(3) Reservoir features: Bentiu1 reservoir source is from the North-West, of braided river deposits, mainly developed channel sand microfacies. Oil-bearing strata are of good reservoir physical property, with a porosity of 29% to 34%, 31% in average. The core horizontal permeability is 1000md ~ 10000md, 5500md in average; belonging to reservoirs of high porosity and high permeability.

(4) Reservoir features: FNE oilfield bentiu1 reservoir is a reservoir of bottom water structure, with a unified oil and water interface (-575m), an original formation pressure of 3.91 MPa, the pressure gradient of 0.74 MPa/100m, the reservoir depth of 529m, temperature of 43.7°C, and the temperature gradient of 2.65°C/100m.

3P oil geological reserves of bentiu1 reservoir is 235.99 MMSTB, of which, P1-class oil geological reserves is 235.99 MMSTB, P2-class oil geological reserves is 0 MMSTB, P3-class oil geological reserves is 0 MMSTB, and EV geological reserves is 235.99 MMSTB.

2.2 Literature Review

HushamElbaloulaetal (2016) Advanced thermal EOR simulator was developed to simulate steam flood, using a wide range of grid and porosity models in both field and laboratory scale.

The pilot area has been cut it as sector model from static model, the initial models two phase model (oil, water) with 34 layers in K direction and the Grid Step is $DX=DY=20m$ and $Dk=2m$ and the Grid cell number is $57 \times 137 \times 34 = 265506$ the model include Cold production history which is FNE -7 and five CSS wells (FNE-34, FNE-35, FNE -36, FNE-37 and FNE-38), Steam injection temperature of $270^\circ C$, with $5 \sim 7$ MPa injection pressure , steam injection quality of 0.6 , steam injection rate of $115 \text{ m}^3/\text{day}$, pay depth 550m , pay thickness 30m ,porosity 32%,oil saturation 70% , dea oil viscosity $661 \text{ m Pa.s}(50^\circ C)$,and reservoir pressure 610psi ; were used as steam flooding parameters for all simulation cases .

In the selected(FNE-35,36,37)and 38 wells group, with different well patterns and well spacing ,design 6 scenarios for numerical simulation has been conducted, and from the Numerical Model results comparison of parameters at the different cases which showed that the most likely two cases to be the optimum cases is case 5 and 6 , and in order to select the best case a detail design has been conduct for each case include the following :

- Converting time form CSS to SF
- Injection-production Ratio Optimization
- Oil Recovery factor from each case

From that case 6 has been selected for steam flooding implementation

This research methodology modify this model to meet solar requirement

They concluded that the result from screening show that FNE oilfield is suitable for thermal recovery, steam flooding pilot test area and wells groups have been selected well pattern and well spacing have been studied for six cases and case six have been selected for implementation and nine additional well have been drilled, reservoir simulation modeling was conducted and steam flooding parameter and time to convert from CSS to SF was optimized

Mohsen et al (2015) studied and investigated about viability of using solar energy to generate steam instead of using conventional steam generators in a Venezuelan extra heavy oil reservoir, various scenarios of steam injection on Hamaca-Venezuelan heavy oil reservoir-have been investigated using commercial thermal simulator software and the main results of oil production for similar time periods (5 years) are compared, To compensate the energy needed for the steam generators during the night time, dual types steam generators were proposed to utilize solar and fossil energies during day-time and night time respectively.

The simulation results for this extra heavy oil reservoir indicated that the oil production was not significantly improved when solar method is used regardless of the amount of the nightly injection of fossil-fuel generated steam for flow back prevention. This finding illustrated high economic efficiency for solar-generated steam injection compared to dual type (solar and fossil-fuel) steam generator method. Furthermore, the results indicated that in typical imposed cyclic steam injections in integrated solar thermal projects, there is no significant difference in oil productions in various scenarios with different pattern and rate of steam injection if the total amount of injected steam is constant. In addition, this study shows the significant reduction of CO₂ and Sulfur Oxides emissions if this new technology is implemented. Besides, various scenarios (with and without natural gas backup) were designed for exact day light duration profile in vicinity of the reservoir in order to optimize the oil production as well as accurate economic and environmental evaluation for each scenario.

Antoon et al (2010) Using analytical modeling and thermal reservoir simulation, the study investigates the impact of the daily and seasonal cycles in steam rate on oil recovery. They compare the oil recovery from solar-generated steam and the recovery resulting from a continuous and constant-rate steam-injection, as obtained by burning gas, for instance. Using thermal reservoir simulation, they also compare oil recovery from two representative models of realistic reservoirs: a fractured reservoir (recovery mechanism: thermally-enhanced gas-oil gravity drainage) and a non-fractured reservoir (recovery mechanism: steam-drive), for both steam-injection profiles: constant-rate and cyclic-rate. Our simulations show that the seasonal cycles in the solar-generated steam rate are reflected as seasonal cycles in the oil-rate.

The simulation results indicate that for the same cumulative amount of steam injected (during the same time-span), the oil recovery from solar-generated steam-injection and that from constant-rate steam-injection are essentially the same, both for the fractured reservoir and for the non-fractured reservoir. Therefore, from a subsurface oil-recovery point of view, solar-generated steam provides a viable alternative to constant-rate steam-injection.

The limitation of this study that they don't take other driving mechanism in consideration.

Timothy Anderson et al (2014) They study and analyzes the cost effectiveness of solar-based TEOR in comparison with traditional TEOR setups in both the early-time (first ~30 years of production) and late-time (after capital has been paid out) production stages. For the early-time, production data from the Kern River Oil Field was analyzed, as this field has a typical TEOR setup and complete record of steam injection and oil production data over its lifetime. The early-time analysis focused on the effect that optimization of the size of a steam generation setup has on the net present value (NPV) of various solar-based and traditional TEOR setups. The late-time analysis focused on deriving and analyzing a cost model for TEOR in the late-time, the cost model was based on calculating the total energy needed by the system (heating, lift, and maintenance), and then calculating the cost of this energy.

The results of the analysis for the early-time and late-time were that a 100% solar setup is the most economical setup in both cases. In the early-time, the analysis showed that 100% solar TEOR consistently had the highest NPV for various scenarios of optimizing the production data. NPV for 100% solar was also the highest except at moderate (~8%) interest rates. In the late-time, 100% solar was the least costly, as it had the lowest operations and maintenance costs, assuming that these costs were the same for all solar fractions. Further work would include a more rigorous analysis of the maintenance costs and efficiency degradation of TEOR systems in the late-time. This analysis can be carried out once industry data becomes available for maintenance costs and efficiency degradation. This study shows that solar-based TEOR is not only environmentally viable, but also offers substantial economic advantages. Overall,

TEOR is a very promising technology that offers an opportunity to make petroleum extraction cleaner, more economical, and more effective.

[D. Testa et al \(2015\)](#) they reported about a technical-economical feasibility study on the integration of Concentrating Solar Power (CSP) technology into the enhanced recovery of heavy oil from complex field by thermal method. A case study was chosen and the preliminary dimension and efficiency of the solar plant as well as the expected increases on oil production were estimated for different scenarios (different hot fluid temperatures, different percentages of the total thermal energy supplied by the solar resource).

The results showed that it is possible to greatly enhance the recovery of heavy oil by this thermal method. Besides the estimated recovery is higher than those achievable by electrical heating as it is possible to reach very high temperatures (390°C) of the circulating oil. This thermal method represents also an efficient exploitation of the solar energy for EOR applications. From the economic point of view, the results are encouraging also if the comparison with a fossil solution is very sensitive to the location of the plant (different direct solar irradiance) and the gas price. As solar plant requires large land, for off-shore applications the described thermal method is suitable only if a fossil fuel is employed to heat the oil.

[Marwan Chaar et al \(2014\)](#) they calculates the steam cost for three methods: 1) once-through steam generator (OTSG) 2) once-through heat recovery steam generator (OT-HRSG) and 3) solar steam generator (SSG), And they have created detailed performance and economic models of the steam generation methods and used them to calculate the levelized cost of energy and the Fuel Break Even (FBE). They explore the environmental and economic burdens on the cost of steam generation. The effect of fuel price on the cost of steam is also analyzed with a focus on the marginal fuel price.

The analysis shows that the fully burdened steam costs using \$6/MMBTU fuel, for OTSG, OT-HRSG, and SSG are \$27/ton, \$20/ton, and \$17/ton, respectively. The FBE for SSG vs. OTSG is \$4.95/MMBTU when the OTSG is unburdened and decreases to \$2.25/MMBTU when the environmental burden of Carbon Cost is added. The FBE for SSG vs. OT-HRSG is \$7.70/MMBTU when burdened with

Power Opportunity Cost and \$4.50/MMBTU when the additional burdens of Carbon Cost and Water Opportunity Cost are accounted for, Finally they analyze the limitations of OT-HRSG in an isolated oilfield where the electric: thermal demand necessitates electricity-matched cogeneration. This limitation along with the steam cost at the marginal fuel price provides the decision maker with a steam supply curve.

Richard et al (2015) they focus in particular on three preeminent challenges for solar generation reducing the cost of installed solar capacity,

ensuring the availability of technologies that can support expansion to very large scale at low cost, they considers grid-connected electricity generation by photovoltaic (PV) and concentrated solar (or solar thermal) power (CSP) systems , they also focused on (PV) technology and (CSP) technology from aspect of installations and economics of solar generation and integration of solar generation in whole sale and subsidizing solar technology deployment and they report about advancing solar technology .

But they should focused on materials science, that would allow higher-temperature operations, and on the development of improved systems for collecting and receiving solar energy.

Yegane Mohsen Mirzaie et al (2015) they investigate about viability of using solar energy to generate steam instead of using conventional steam generators in a Venezuelan extra heavy oil reservoir. Limited gas production policy of the Venezuelan government is the major challenge for utilizing gas steam generators for extra heavy oil reservoirs in this country. Besides, the efficient daylight duration, economic and environmental advantages, are the main features to propose solar-generated-steam injection in Venezuelan extra heavy oil reservoirs. In this study, various scenarios of steam injection on Hamaca-Venezuelan heavy oil reservoir-have been investigated using commercial thermal simulator software and the main results of oil production for similar time periods (5 years) are compared. To compensate the energy needed for the steam generators during the night time, dual types steam generators were proposed to utilize solar and fossil energies during day-time and night time respectively.

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Daniel et al (2014) presented performance result and learning from the first solar enhanced oil recovery (EOR) project in the NENA region, and the motivation for solar EOR in Oman , description of the enclosed trough design employed in Amal field operations and performance data in the Oman desert environment integration with oilfield operation and an update on results at the time of publication , they discuss performance verses model and the enhancements implemented during the year to improve steam production and quality . and also the oilfields of Oman lie in a region with about fifteen times higher dust or “soiling rate” than locations where concentrating solar power(CSP) is typically deployed The performance of the system in extreme weather was tested.

The system has proven its performance in a typical desert location in Oman. The passing dust storms and sand storms do not adversely affect the enclosed trough design. The roof washing system proved particularly effective in all-weather events experienced during the first year of operation.

This study focuses on the dilation and compaction behaviors associated with continuous but variable-rate solar generated steam injection, their approach integrates geomechanical models with the reservoir simulation model. The challenge with integrating geomechanics with reservoir models is to find accurate and sufficient data

for stress field and orientation, dilation and compaction pressures, and the fracture pressure for the formation.

Coupled reservoir-Geomechanical simulation was runs with continuous variable steam injection were compared with the base-case uncoupled Tulare Sand steamflood project. Sensitivity analyses for dilation parameters were studied to understand their effects on the overall oil recovery and breakthrough times. Significant pore pressure variation to trigger compaction was not observed for reasonable day-time injection rates of up to 1000 BBL cold-water equivalent (CWE)/d in high permeability formations. The injection pressures were maintained much below the fracture pressure of the formation in all cases. To summarize, they conclude that a solar thermal steam generation approach for thermal enhanced oil recovery is a promising technique for supplementing steam generation in areas with large solar insolation.

B. Bierman et al (2013) they introduced an Enclosed Trough solar once-through steam generator (OTSG) system designed for challenging environments and to meet all requirements for solar thermal enhanced oil recovery (EOR). Parabolic trough collectors are enclosed within a modified agricultural glasshouse, which protects the collectors from wind, sand and dust common in oilfield environments, and eliminates energy losses due to wind. Automatic glasshouse washing and air filtration equipment dramatically reduce soiling and related losses. The once-through boiler process allows the use of feed water with total dissolved solids as high as 30,000 ppm while producing 80% quality steam at 100 bar, matching typical EOR specifications. The construction of a 17,280m² pilot plant in southern Oman is reviewed. Construction was completed in 11 months, on time and on budget, with zero lost time injuries. And they reports about the plant design and construction methodologies and measurements of construction labor productivity compared to long term build speed and cost objectives.

Joel Sandler et al (2012) they study The viability of a solar thermal steam generation system (with and without natural gas back-up) for thermal enhanced oil recovery (TEOR) in heavy-oil sands was evaluated in this study. Using the San Joaquin Valley as a case study, the effectiveness of solar TEOR was quantified through reservoir simulation, economic analysis, and life-cycle assessment of oil-

recovery operations. Reservoir simulation runs with continuous but variable rate steam injection were compared with a base-case Tulare Sand steam flood project. Reservoir properties and well geometries were drawn from the literature. For equivalent average injection rates, comparable breakthrough times and recovery factors of 65% of the original oil in place were predicted, in agreement with simulations in the literature. Daily cyclic fluctuations in steam injection rate do not greatly impact recovery for this reservoir setting. Oil production rates for a system without natural gas back-up to moderate injection rates do, however, show seasonal variation. Economic viability was established using a discounted cash flow model incorporating historical prices and injection/production volumes from the Kern River oil field. This model assumes that present day steam generation technologies could be implemented fully at TEOR startup for Kern River in 1980, for the sake of comparison against conventional steam generators and cogenerates. All natural gas cogeneration and 100% solar fraction scenarios had the largest and nearly equal net present values (NPV) of \$12.54 B and \$12.55 B, respectively, with production data from 1984 to 2011. Solar fraction refers to the steam provided by solar steam generation. Given its large capital cost.

The 100% solar case shows the greatest sensitivity to discount rate and no sensitivity to natural gas price because it is independent of natural gas. Because there are very little emissions associated with day-to-day operations from the solar thermal system, life-cycle emissions for the solar thermal system are significantly lower than conventional systems even when the embodied energy of the structure is considered. Here, they estimate that less than 1 g of CO₂/MJ of refined gasoline results from the TEOR stage of production if solar energy provides all steam. By this assessment, solar thermal based or supplemented steam generation systems for TEOR appear to be a preferred alternative, or supplement, to fully conventional systems using natural gas (or higher carbon content fuels), especially in areas with large solar insolation.

Csptoday (2013) they discuss two exciting opportunities that are under consideration: Enhanced Oil Recovery (EOR) and desalination. And where and how this integration process makes sense, as well as case studies on where it has already been done before.

And 7 different sites (Aqaba, Agadir, Abu Dhabi, Malta, Al Khawkha, Gaza and Hurghada) were investigated with a target production of 24000m³/day with 21MW net power production. For this rated fresh water production capacity, the electricity required for desalination was found to vary between 2.11 MW and 5.60 MW, with a final grid power delivery of 20.9 to 25.2 MW. The CAPEX associated with such projects, using RO, was found to be €76.4M while the same throughput using MED required an investment of €84.9M .

Esmap (2011) they investigate about assessment of the Local Manufacturing Potential for Concentrated Solar Power (CSP) Projects in Middle East and North Africa (MENA) Region.

They result was (MENA CSP) is well placed to benefit from the massive scale-up of concessional climate financing envisaged under the United Nations Framework Convention on Climate Change (UNFCCC), and recently reaffirmed at the Copenhagen and Cancun conferences .

Christian Breyer¹ et al (2009) the paper presents the global energy supply potential of concentrating solar thermal power (CSP). Based on the DLR-ISIS data for global direct normal irradiance, an estimate is derived for global potential CSP areas and their electricity supply potential. Assumptions are included for land use restrictions and land use efficiency. Including data of global distribution of population distances of centers of CSP electricity supply to human electricity demand are estimated. Performance characteristics of high voltage direct current (HVDC) power transmission is used for analyzing global energy supply potential of CSP.

Results are shown for different regions in the world, different distances to potential CSP areas and for electric and non-electric energy needs. The outcome clearly shows that CSP has the potential to become a major source of global energy supply. This supports an important assumption in the DESERTEC concept, which assigns large fraction of power supply to CSP.

David Barlev et al (2011) this work focuses on innovation in CSP technologies over the last decade. A multitude of advancements has been developed during this period, as the topic of concentrated solar power is becoming more mainstream. Improvements have been made in reflector and collector design and materials, heat

absorption and transport, power production and thermal storage. Many applications that can be integrated with CSP regimes to conserve (and sometimes produce) electricity have been suggested and implemented, keeping in mind the environmental benefits granted by limited fossil fuel usage

Peter Viebahn (2010) Made an integrated technology assessment shows that CSP plants could play a promising role in Africa and Europe, helping to reach ambitious climate protection goals. Based on the analysis of driving forces and barriers, at first three future envisaged technology scenarios are developed. Depending on the underlying assumptions, an installed capacity of 120GW_{el}, 405GW_{el} or even 1,000GW_{el}, could be reached globally in 2050. In the latter case, CSP would then meet 13–15% of global electricity demand. Depending on these scenarios, cost reduction curves for North Africa and Europe are derived. The cost assessment conducted for two virtual sites in Algeria and in Spain show a long-term reduction of electricity generating costs to figures between 4 and 6 ct/kW in 2050.

The paper concludes with an ecological analysis based on lifecycle assessment. Although the greenhouse gas emissions of current (solar only operated) CSP systems show a good performance (31gCO₂-equivalents/kW_{hel}) compared with advanced fossil-fired systems (130–900CO₂-eq./kW_{hel}), they could further be reduced to 18gCO₂-eq./kW_{hel} in 2050, including transmission from North Africa to Europe.

Nadejda Komendantova et al (2009) they identifies a number of risks as barriers to investment, and they examine these in the particular context of renewable energy development. They conducted three stages of interviews with stakeholders to learn their perceptions of the risks most likely to affect renewable energy projects. Three class of risks—regulatory, political, and force majeure (which includes terrorism) stand out as being of high concern. Of these, regulatory risks are perceived as being the most consequential, and the most likely to occur. This suggests that attention to building the capacities of North African countries to develop, implement, and enforce sound regulations in a transparent manner could be an important step in promoting renewable energy cooperation with Europe.

Kyle Stuart Herman (2013) he discuss significant challenges in investment in CSP , beside the high capital cost of solar collection system, that limit the wide adoption of CSP technology for large-scale power generation.

He concludes that the biggest challenges are Low production capacity factor due to the intermittent nature of solar energy. This intermittent nature of solar energy results in the CSP plants uses costly steam turbine cycle systems being idle as much as 75% of the time. The low utilization of the power island results in a very low return on investment (ROI) of the power system and, therefore, negatively impacts the economics of the CSP plant , The need for new transmission and the remote locations of CSP resources are key challenges for large-scale deployment of CSP, The addition of large amounts of renewable power into the grid often necessitates the addition of natural gas based backup or reserve capacity in order to offset the intermittent nature of renewable energy and provide stability to the grid. From the perspective of grid operators and consumers, this redundancy in capacity is another hidden source of high cost of electricity as a result of adding more renewable power to the grid.

Sean Pool et al (2013) In their report they detail why the United States should invest in concentrating solar power and delineate the market and regulatory challenges to the innovation and deployment of CSP technology, they also offer low-cost policy solutions that can reduce risk, promote investment, and drive innovation in the CSP industry.

They concluded that concentrating solar power promises to become a keystone technology in America's renewable-energy portfolio. CSP enjoys rapidly falling costs, few bottlenecked supply chains, relatively low land and water requirements, and a rapidly growing international market. It presents a great opportunity for U.S. energy and manufacturing industries.

Irena (2012) the reports provide valuable insights into the current state of deployment, types of technologies available and their costs and performance. The analysis is based on a range of data sources with the objective of developing a uniform dataset that supports comparison across technologies of different cost indicators - equipment, project and levelised cost of electricity – and allows for technology and cost trends, as well as their variability to be assessed.

Their result showed that concentrating solar power (CSP) plants are capital intensive, but have virtually zero fuel costs, Parabolic trough plant without thermal energy storage have capital costs as low as USD 4 600/kW, but low capacity factors of between 0.2 and 0.25. Adding six hours of thermal energy storage increases capital costs to between USD 7 100/kW to USD 9 800/kW, but allows capacity factors to be doubled. Solar power plants can cost between USD 6 300 and USD 10 500/kW when energy storage is between 6 and 15 hours. These plant can achieve capacity factors of 0.40 to as high as 0.80.

The papers are not a detailed financial analysis of project economics. However, they do provide simple, clear metrics based on up-to-date and reliable information which can be used to evaluate the costs and performance of different renewable power generation technologies.

Which lead GlassPoint with the permeation from PDO to perform the first Enclose trough for solar steam generation pilot in Amal oilfield.

H.L. Zhang et al (2013) They briefly reviews CSP technologies and STC advantages; (ii) presents a methodology to predict hourly beam (direct) irradiation from available monthly averages, based upon combined previous literature findings and available meteorological data; (iii) illustrates predictions for different selected STC locations; and finally (iv) describes the use of the predictions in simulating the required plant configuration of an optimum STC.

The methodology and results demonstrate the potential of CSPs in general, whilst also defining the design background of STC plants.

Ricardo Guerrero-Lemus (2013) they study the major technology for producing solar electricity. Generally, CSP and uses of concentrating high-reflective mirrors to generate high-temperature thermal energy that is fed into conventional steam or gas turbines for the production of utility-scale power. Within CSP systems, the most mature are the parabolic trough systems, which concentrate the energy from the sun by means of long cylindrical mirrors of parabolic cross section. Next in popularity is the tower systems, which use a large field of numerous flat mirrors (heliostats) to concentrate the solar direct radiation into a receiver located at the top of the tower. Also, parabolic dishes and linear Fresnel reflectors must be considered. These

technologies are described and grid parity is analyzed and expected to be reached soon for locations with strong solar direct irradiation. Finally, in relation to CSP, they emphasizes how thermal storage as well as natural gas hybridization can be easily added, thus practically eliminating the power intermittencies of other important renewable technologies.

All mentioned studies covered different part of the world and motivate the implementation of solar projects unlike the mentioned studies new approach for studding the seasonal effect was introduced.