The Impact of Solar Powered Oil Production on California's Economy

An economic analysis of Innovative Crude Production Methods under the LCFS

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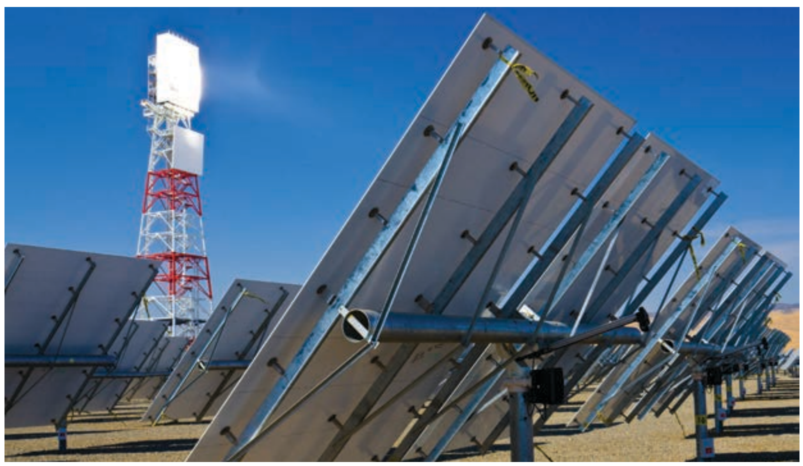
Solar Electric Power Generation



Solar Steam Generation
Central Receiver, Coalinga, CA

Solar Steam Generation
Enclosed Trough, Amal, Oman

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Executive Summary

The California Air Resources Board (CARB) staff   as proposed to re-adopt the Low Carbon Fuel Standard (LCFS), reaffirming its original target of a 10% reduction in the carbon intensity (CI) of transportation fuels used in California by 2020 and subsequent years. While most of the expected CI reductions will be derived from imported low-CI fuels, the regulation and the re-adoption proposal include provisions to promote innovations in crude oil production methods that reduce the CI of petroleum.

Of the potential innovative methods, the use of solar energy is the lowest-cost, lowest-risk, and largest-scale opportunity to reduce the CI of petroleum fuels produced and used in California. Solar powered oil production technologies—solar steam generation and solar electric power generation—have the potential to contribute to California's economy signifi antly while reducing costs and risks associated with meeting the LCFS. Solar steam generation used in thermal enhanced oil recovery (EOR) displaces imported natural gas that that would have otherwise been combusted. Solar electricity generated on-site at production facilities displaces electricity that would have otherwise been purchased from a utility provider. These solar technologies have the potential to reduce the carbon intensity of California's crude oil, thereby boosting investment in California-based industries, and helping shift LCFS compliance from importing low carbon fuels from out-of-state towards in-state investments and operations of low carbon infrastructure. Investment in these technologies can lead to job growth, increased industry activity, and increased state and local tax revenues. Furthermore, by reducing the carbon intensity of California crude oil, these solar technologies have the potential to preserve California refinery operations while fully meeting the emissions reductions goals of the LCFS.

ICF employed IMPLAN, an input-output model, to calculate the economic impacts of deploying solar steam generation and solar electric power generation technologies. ICF developed *steady* and *accelerated* deployment scenarios for each technology, capturing 5% and 30% of their respective markets (as measured by volume of steam or electricity consumption). ICF also considered the economic impacts of keeping LCFS credits generated by solar steam and solar power in California, rather than having the value of those credits transferred to low carbon fuel providers in other regions. Furthermore, we considered the impacts on refiners as a result of being able to maintain margins that would have otherwise been impacted by reduce crude runs or reduced margins from having to export the refined products.

Exhibit 1. Economic Contributions of Solar Oil Production in California

Cumulative Solar Impact 2015-2020	*Steady*	*Accelerated*
	$25/ton	$150/ton
Total Jobs	**11,000**	**44,900**
Income per Worker	$72,000	$77,900
GSP ($M)	**$1,160**	**$5,090**
Industry Activity ($M)	$2,910	$11,350

In the *accelerated* deployment scenario, where solar energy provides 30% of the state's EOR steam needs or onsite production electricity, ICF concluded:

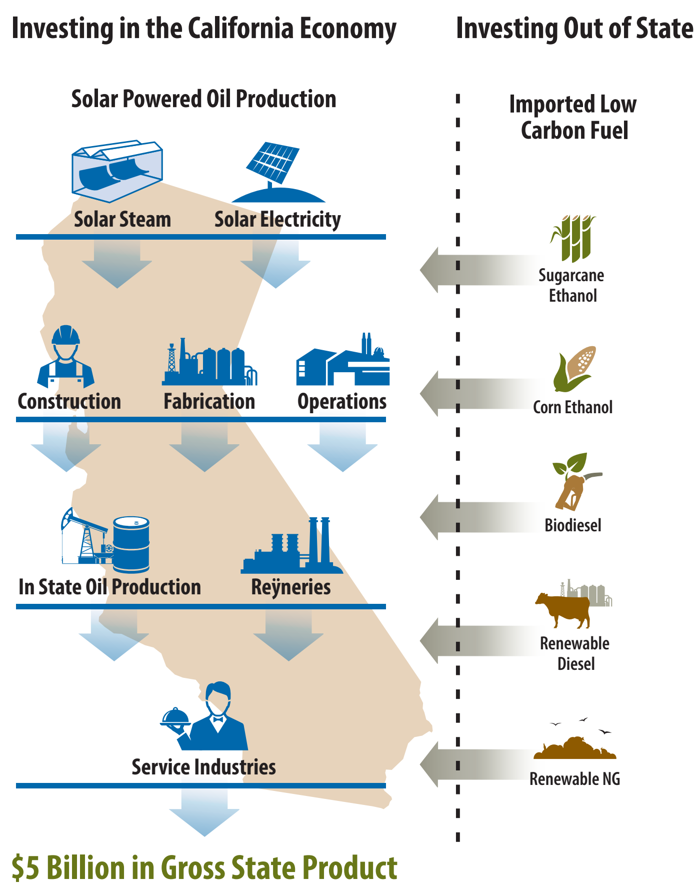
- Innovative crude oil production using solar energy adds 32,100–44,900 cumulative jobs to California's economy from 2015 through 2020, depending on LCFS market conditions.
- These are high value jobs, with labor income per job created in the range of $75,000 per job. Many of the jobs were created in sectors tied to upstream oil production, as well as construction, engineering related services, and fabrication/manufacturing.

- For every job created through investment in solar powered oil production, about 2.5–2.7 jobs are created in supporting industries (indirect) and via spending by employees that are directly or indirectly supported by the industry (induced).
- The deployment of these technologies leads to increased state and local tax revenues in the range of $117–575 million.

Solar steam has greater potential than solar electricity to deliver LCFS credits because 90% of the energy used in California oil production is in the form of steam. In the *accelerated* deployment scenario, solar steam generation has the potential to generate as many credits as some of the most promising low carbon fuel pathways by 2020, including renewable diesel, renewable natural gas, and low carbon intensity biodiesel (e.g., from corn oil). Solar electricity has the potential to generate LCFS credits in line with contributors like electricity and natural gas.

ICF also finds that solar powered oil production technologies may help stabilize the LCFS market in several ways. Firstly, these LCFS credits may help stabilize credit prices by offering a lower cost solution than importing low carbon fuels for compliance. Secondly, we find that these credits may hedge California's exposure to uncertainty in the federal Renewable Fuel Standard market. With the potential for RIN prices to be depressed because of uncertainty in that market, biofuel providers may seek higher LCFS credit prices to pick up the slack in market pricing. However, the deployment of solar powered oil production technologies will provide some buffer against credit price increases. Thirdly, solar powered oil production technologies will provide regulated parties, particularly integrated energy firms with oil production and refining investments, an opportunity to limit their exposure to the LCFS credit market.

Solar powered oil production technologies are commercially available today with low development risk, and unlike some low carbon fuel options, innovative crude methods tap into the existing petroleum supply chain without delay for infrastructure modifi ations or rollouts. The emissions reduction potential of the technologies will deliver credits to the oil producer and reduce the CI of petroleum fuels. Therefore, innovative crude offers the unique advantage of fully complying with the LCFS and achieving the state's GHG reduction goals without hindering the petroleum supply chain. These emissions reductions are available as a "drop in" option using today's fuel production, distribution, and vehicle infrastructure, with minimal infrastructure costs, development risk, and deployment timelines.



ICF's analysis demonstrates that investments in solar powered oil production will yield benefits up to $5 billion in Gross State Product, with jobs created in sectors such as construction, fabrication, oil field operations, and the service industry, while retaining jobs in the refining industry. This contrasts sharply with some of the alternative LCFS compliance pathways, whereby dollars (via commodity pricing and LCFS credits) are exported out of California to pay for low carbon fuels produced elsewhere.

1 Innovative Crude Oil Production

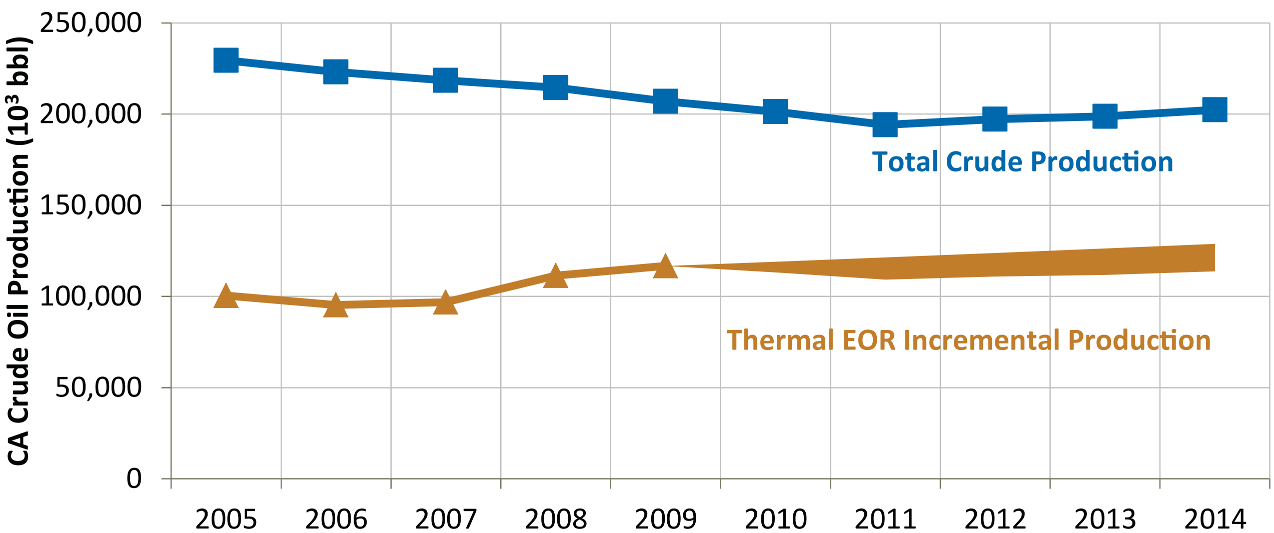
The California Air Resources Board (CARB) staff as proposed to re-adopt the Low Carbon Fuel Standard (LCFS) program in 2015, and to include updates and revisions to the regulation.[1] The regulation and the re-adoption proposal include provisions to promote innovations in crude oil production methods that reduce greenhouse gas (GHG) emissions. In this section, we briefly summarize California's Oil and Gas Sector, its outlook in the near- to mid-term as a result of carbon constraining regulations in the state, and review the relevant innovative crude oil production technologies.

1.1 California's Oil and Gas Sector

Excluding federal offshore areas, California ranks third in the United States in crude oil production. As recently as 2012, nearly 4,700 new wells were drilled in California, bringing the statewide total to 88,500 active wells, operated by 570 companies.[2] A recent report by the Los Angeles Economic Development Corporation (LAEDC) highlights some of the critical parameters characterizing the impact of the Oil and Gas Sector on California's economy, including:[3]

- About 70,000 direct jobs in California are tied to oil and gas production
- Oil and gas production contribute about 0.5% of total California labor income
- The average wage of the component industries in the oil and gas production sectors are considerably higher than the median private industry wage in California

Exhibit 2. Crude Oil Production in California, 2005-2014[4]



1 http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs2015.htm

2 Division of Oil, Gas and Geothermal Resources of the California Department of Conservation (DOGGR)

3 Oil and Gas in California: The Industry and Its Economic Contribution in 2012, LAEDC, April 2014, http://laedc.org/wp-content/uploads/2014/04/OG_Contribution_20140418.pdf

4 Based on data from EIA and DOGGR. The crude oil production for 2014 is an estimate made by ICF based on data reported through September. Note that production data via TEOR are not yet available past 2009. The shaded range is an estimate based on ICF analysis.

California's Low Carbon Fuel Standard

The LCFS requires a 10 percent reduction in the carbon intensity (CI) of transportation fuels used in California. Carbon intensity is a measure of the lifecycle GHGs of transportation fuels, and includes emissions over the entire fuel supply chain. The LCFS is implemented using a system of credits and defi its: Defi its are generated by fuels that have a carbon intensity greater than the standard and credits are generated by fuels that have a carbon intensity lower than the standard. At the end of each year, defi it-generating parties (generally refiners and fuel importers) must balance their defi its with credits.

Despite several years of reductions in overall crude production since 2005, crude produced from thermal enhanced oil recovery (EOR)[5] or steam injection has been increasing since 2006, as shown in Exhibit 2. Crude Oil Production in California, 2005-2014 above. Steam injection, which reduces the viscosity of oil and increases mobility, has been used commercially in California since the 1960s. Today, more than 40% of California's crude is produced with thermal EOR and is expected to account for half of production in the next few years. As an emitter of GHGs, the oil and gas production industry is impacted by CARB's implementation of the Global Warming Solutions Act of 2006, commonly known as AB 32. The LCFS and light-duty tailpipe GHG standards (originally referred to as Pavley standards) are both part of California's suite of GHG reduction policies under AB 32, and will both lead to reductions in demand for petroleum-based transportation fuels. Although the refinery sector is commonly identifi d and analyzed as one of the primary industry sectors to be impacted by AB 32, upstream oil and gas production sectors will likely experience the effects of the regulation as well.

This report focuses on a potential opportunity included in the proposed re-adoption of the LCFS: "Innovative Crude Production Methods". Operators who produce crude for California's refineries and employ a GHG-reducing "innovative method" in the recovery or extraction process can generate LCFS credits corresponding to the avoided GHG emissions.

1.2 Introduction to Innovative Crude Production Methods

The current proposed LCFS re-adoption regulation identifi s the following technologies as innovative methods for crude production:[6]

Technology	Image	Description	Technology Maturation	LCFS Considerations
Solar steam generation		Uses solar arrays to concentrate the sun's energy to heat water and generate steam for thermal EOR.	Deployed in multiple locations; several vendors.	Steam must be used onsite at the crude oil production facilities.
Carbon capture and storage		Captures CO_2 emissions produced from processing; prevents the CO_2 from entering the atmosphere.	Limited commercial deployment; no commercial deployment at oil field .	Carbon capture must take place onsite at the crude oil production facilities.
Solar or wind electricity generation		Electricity generation from solar technology or wind turbines. Electricity to be used on-site for production-related activities.	Solar PV technology is ubiquitous for non-residential installations. Wind technology is mature, but generally deployed in larger rather than on a smaller scale.	Qualifying electricity must be produced and consumed onsite or be provided directly to the crude oil production facilities from a third-party generator and not through a utility owned transmission or distribution network.
Solar heat generation		Uses solar arrays to concentrate the sun's energy for heat generation.	Concentrating solar technology that can produce process heat (similar to steam generation).	Heat must be used onsite at the crude oil production facilities.

The language also includes provisions regarding year of implementation (no earlier than 2010 for solar steam or CCS; no earlier than 2015 for electricity and heat generation projects), project registration, and minimum GHG reduction thresholds (a carbon intensity reduction of at least 0.10 gCO_2e/MJ or a reduction of at least 5,000 metric tons CO_2e per year).

5 Thermal EOR is a process whereby heat is introduced to the reservoir in order to reduce the viscosity of the crude, and increase its permeability.

6 Initial Statement of Reasons, II-17ff. Available online at: http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15isor.pdf

"Solar powered oil production technologies—solar steam generation and solar electric power generation—have the potential to contribute to California's economy significantly while reducing costs and risks associated with meeting the LCFS."

Technologies Selected For Further Analysis

For the purposes of this report, ICF narrowed our consideration of innovative crude methods to *solar steam generation* and *solar electricity generation* based on factors such as commercial availability of the technology, consideration of California oil fi ld characteristics, and industry interest. Other qualifying innovative technologies, including carbon capture and storage (CCS), wind electricity generation, and solar heat generation, were not considered due to limitations or uncertainty in market demand.

- **Solar steam generation.** The technology is commercially available and has been demonstrated by both GlassPoint Solar and BrightSource Energy. These companies have demonstration projects in Kern County and Fresno County, California, respectively. GlassPoint Solar also has deployed its technology in Oman at the Amal West oilfield (in partnership with the national oil company, Petroleum Development Oman, PDO). With about 492 million barrels of steam injected for thermal EOR in California in 2012, there is significant potential for solar steam generation in California. For such thermal EOR projects, steam is the primary energy requirement, with 185 million MMBtu of natural gas required to produce the 492 million barrels of steam injected for thermal EOR. This natural gas is the primary source of GHG emissions associated with oil production. The potential for the technology is limited by factors such as geography and the deployment of efficient combined heat and power (CHP) units at oilfields, which may be difficult to displace depending on when the units were installed and the operators' willingness to displace the technology given the investment. However, ICF anticipates sufficient demand for solar steam generation deployment as part of LCFS compliance.
- **Solar electricity generation.** Solar electric power generation is ubiquitous in California, with more than 8,500 MW of solar energy currently installed, and about 2,750 MW of that installed in 2013. Multiple photovoltaic (PV) technologies have experienced significant declines in installed cost over the last several years, with the average installed system price reported at about $2.27/W for a non-residential system.[7] The location and electricity demands at oilfields will likely be a good match for solar PV deployment. The regulation restricts credits from potential solar electricity deployment to electricity which is produced and consumed onsite or is directly provided to the facility via third-party generator, not through the utility grid. As oil production operations are generally continuous, there are limits for the fraction of total energy provided by solar PV deployment without concomitant investments in energy storage. Despite these limitations, ICF anticipates that solar PV installations at oil fields will increase substantially between now and 2020 as part of a LCFS compliance strategy based on the cost competitiveness of the technology and the desirable onsite characteristics of oil production fields (e.g., sufficient solar radiation).

[7] US Solar Market Insight: Q3 2014, GTM Research and SEIA, available online: http://www.seia.org/sites/default/files/ esources/iV39f8059N.pdf; assumes a 200-300 kW rooftop installation at a non-residential facility.

2 Economic Impacts of Solar Powered Innovative Crude Production

ICF employed an input-output (I-O) economic model to calculate the economic benefi s of deploying solar steam generation and solar electricity generation in California. We considered several elements associated with the deployment of these technologies, including the following:

- **Capital expenditures.** ICF considered the capital expenditures associated with deploying the technologies in two scenarios (*steady* deployment and *accelerated* deployment). The capital expenditures include the labor and materials associated with building the solar steam installations and solar PV installations.
- **LCFS credit generation.** ICF also considered the value of LCFS credits generated via the deployment of these technologies in California. ICF assumed that the generation of credits would have otherwise been completed outside of California. This is a reasonable assumption given the structure of the LCFS program and a review of CARB's proposed LCFS compliance scenario, which relies heavily on biofuels (e.g., biodiesel, renewable diesel, and renewable natural gas). Given the limited in-state production of low carbon fuels, ICF made the reasonable assumption these innovative crude production technologies will create credits in-state from investments made in-state, versus credit revenues being exported out-of-state for imported low carbon fuels. We valued the credits in two scenarios: a low price of $25/ton and a high price of $150/ton.[8]
- **Refi ery margins.** Depending on the strategy employed, LCFS compliance may lead to significant demand destruction for gasoline and diesel. For instance, CARB's proposed compliance scenario includes about 900 million gallons of diesel replacements being consumed in 2020, representing about 20% of the projected diesel demand. Conversely, CARB's illustrative compliance scenario only projects about 110 million gallons of gasoline replacements being consumed in 2020, in a fuel market with projected demand of about 13.5 billion gallons. Regardless of the compliance strategy, it is highly likely that there will be reduced refinery margins as a result of the LCFS. ICF broadly categorizes these losses into two areas: 1) lost refinery margin and 2) reduced refinery margins as a result from having to export product.

Depending on the chosen means of LCFS compliance, varying levels of decreases occur in gasoline and diesel consumption in California. Although the reduction of petroleum consumption has positive impacts via improved energy security and increased fuel diversity, the decreased consumption of petroleum will also have direct negative impacts on the refining industry—in the same way that the investments in alternative fuels and advanced vehicles will yield positive impacts in the corresponding industries. ICF treated the reduction in gasoline and diesel consumption in the modeling as follows:

- **ICF assumed that there were lost margins on 50% of those crude runs that are assumed to be displaced entirely as a result of the LCFS.** These margins were estimated based on an ICF analysis of the 3-2-1 crack spread for California-based refiners (estimated at about $15/bbl).
- **ICF assumed that the remaining 50% of crude runs representing the reduction in gasoline and diesel consumption in California are exported, rather than displaced entirely.** For these exports, ICF assumed a corresponding decrease in revenue in the export markets because of increased freight costs and competitiveness on pricing (estimated at a combined $5/bbl).

Using CARB's illustrative compliance scenario, each credit generated in 2020 leads to a demand destruction of about 120-130 diesel gallons equivalents.[9]

8 LCFS credit values traded around $25/ton for all of 2014, and likely are below forward credit prices considering the uncertainty associated with the LCFS program throughout 2014 and rising compliance obligations. The high value of $150/ton was selected for illustrative purposes; the program is capped at $200/ton via a cost compliance mechanism.

9 The demand destruction is presented as a range because it ultimately depends on the carbon intensity of the low carbon fuels deployed in CARB's illustrative compliance scenario. Available online at http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15appb.pdf

Exhibit 3. Overview of Solar Powered Oil Production Scenarios

Technology Penetration	Solar Steam		Solar Electricity	
	Steady	*Accelerated*	*Steady*	*Accelerated*
Capital Expenditures ($ millions)	$1,900	$5,600	$390	$1,200
LCFS Credits / GHG Emission Reductions	1.4 million	4.3 million	160,000	490,000
LCFS Credit Value ($ millions)	$35–210	$108–645	$4–24	$12–74

Technology penetration notes:

- Solar Steam: About 492 million barrels of steam were injected at California oilfields for thermal EOR in 2012. ICF assumed that solar steam technology providers could capture 5% of the market for steam generation in a *steady* deployment scenario and 30% in an *accelerated* deployment scenario,[10] in accordance with CARB estimates. Note that ICF held the volume of steam injected constant throughout the analysis (2015-2020), despite the very likely possibility that the amount of steam injected into California oilfields will continue to increase over time. The *steady* and *accelerated* levels of solar steam technology deployment amount to about 16 million MMBtu and 49 million MMBtu of steam, respectively, in 2020.
- Solar Electricity: California oil producers purchased about 3.2 terawatt hours (TWh) of electricity as recently as 2012.[11] ICF made the same assumptions for solar PV as were made for solar steam regarding technology penetration: We assumed that solar PV could capture 5% and 30% of the market for electricity purchased by California oil producers by 2020 in *steady* and *accelerated* deployment scenarios, respectively. ICF estimated the deployment of solar PV that would be required to achieve this level using a capacity factor of 20%. In other words, to capture 30% of the market in 2020, ICF assumed that an installed capacity of about 550 MW would be able to provide 0.96 TWh operating at a 20% capacity factor.[12]

Capital expenditure notes:

- Solar Steam: ICF developed estimates for capital expenditures to achieve this level of deployment using data provided by GlassPoint and previous economic assessment of solar steam by Ernst & Young.[13]
- Solar Electricity: We assumed a starting price of $2.33/W[14] with modest decreases over time.[15]

The economic contribution of solar steam and solar electricity deployment are characterized by employment, labor income, value added, and value output.

- **Employment** is reported in terms of annualized job-years. The employment numbers are broken down by direct, indirect, and induced. We also present an employment metric referred to as a **jobs multiplier**, which is the sum of job-years (included direct, indirect, and induced) divided by the direct job-years. This is an indicator of the type of employment activity statewide that is generated by investment in a technology. We also present **labor income** and **labor income per worker**. The latter is a coarse estimate of the value of jobs created by the corresponding investment.
- **Statewide impacts.** We present several metrics measuring the impacts on California's economy, including Gross State Product (GSP), industry activity, output, and taxes.
  - ***Industry activity*** measures the value of goods and services.
  - The ***output multiplier*** mirrors the ***jobs multiplier*** and represents the total industry activity (including direct, indirect, and induced) divided by the direct industry activity. This is an indicator of the type of industry activity statewide that is generated by investment in a technology.
  - The values for ***taxes*** are based on the sum of taxes calculated by IMPLAN, including those associated with employee compensation, proprietor income, tax on production and imports, households, and corporations.

Exhibit 4 below summarizes the results for the *steady* deployment scenarios, with each technology capturing 5% of its respective market (as measured by volume of steam or electricity consumption). Note that for both solar steam and solar electricity, LCFS credits were modeled at values of $25/ton and $150/ton—the results from both LCFS credit pricing scenarios are shown in the table below.

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10 Industry discussions and ISOR, II-19 Available online at: http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15isor.pdf

11 Personal communication with CARB staff who que ied the California Energy Consumption Database by county and NAICS code associated with crude petroleum extraction (211111).

12 There are some limitations to these assumptions, considering that crude oil producers are base loading operations. Further, there are no net metering provisions in the proposed language from CARB, and is effectively prohibited because the electricity cannot be purchased from a utility-owned transmission or distribution network. In reality, to capture 30% of the market for electricity consumption by crude oil producers, solar PV technology would have to be deployed in parallel with complementary technologies like solar trackers and energy storage (e.g., batteries) to level out the energy supply with the base loaded demand. To simplify our analysis and the comparison between solar PV and solar steam as innovative crude production technologies, however, we have not considered the expenditures that would likely be required to achieve this level of electricity consumption using solar PV. Rather, we simply quantified the xpenditures that would be required to deploy a given megawatt target of PV.

13 Ernst & Young, "Solar enhanced oil recovery: An in-country value assessment for Oman", 2014, available online: http://tinyurl.com/EY-solar-EOR

14 US Solar Market Insight: Q3 2014, GTM Research and SEIA, available online: http://www.seia.org/sites/default/files/ esources/iV39f8059N.pdf

15 Feldman, D et al., Photovoltaic System Pricing Trends: Historical, Recent, and Near-Term Projections, 2014 Edition, SunShot, US Department of Energy. NREL/PR-6A20-62558

Exhibit 4. Modeling Results for Steady Deployment Scenarios, Cumulative 2015-2020

Economic Parameter	Solar Steam		Solar PV Electricity	
	$25/ton	$150/ton	$25/ton	$150/ton
Employment				
Direct	3,300	4,900	1,100	1,300
Indirect	2,300	2,900	800	800
Induced	2,600	4,200	900	1,100
Total	**8,200**	**12,000**	**2,800**	**3,200**
Jobs Multiplier	2.72	2.56	2.61	2.56
Labor Income ($M)	$590	$930	$200	$240
Income per Worker	$72,000	$77,500	$71,400	$75,000
Statewide Activity ($ millions)				
GSP	$860	$1,360	$300	$350
Industry Activity	$2,260	$3,070	$650	$740
Output Multiplier	1.53	1.59	1.73	1.74
Taxes	$89	$158	$27	$35

The values are shown as cumulative over the analysis period (2015-2020).

ICF notes that by reporting these numbers cumulatively, we may be double-counting jobs i.e., a single person could conceivably account for six job-years assuming that s/he is employed in each year as a result of a particular technology's deployment.

Summary of Economic Contributions

Direct: Impacts of capital expenditures to deploy innovative crude production technologies and the employees hired by the industry itself.

Indirect: Impacts that stem from the employment and business revenues motivated by the purchases made by the industry and any of its suppliers.

Induced: Impacts generated by the spending of employees whose wages are sustained by both direct and indirect spending.

Exhibit 5 summarizes the results for the *accelerated* deployment scenarios, with each technology capturing a 30% of its respective market (as measured by volume of steam or electricity consumption).

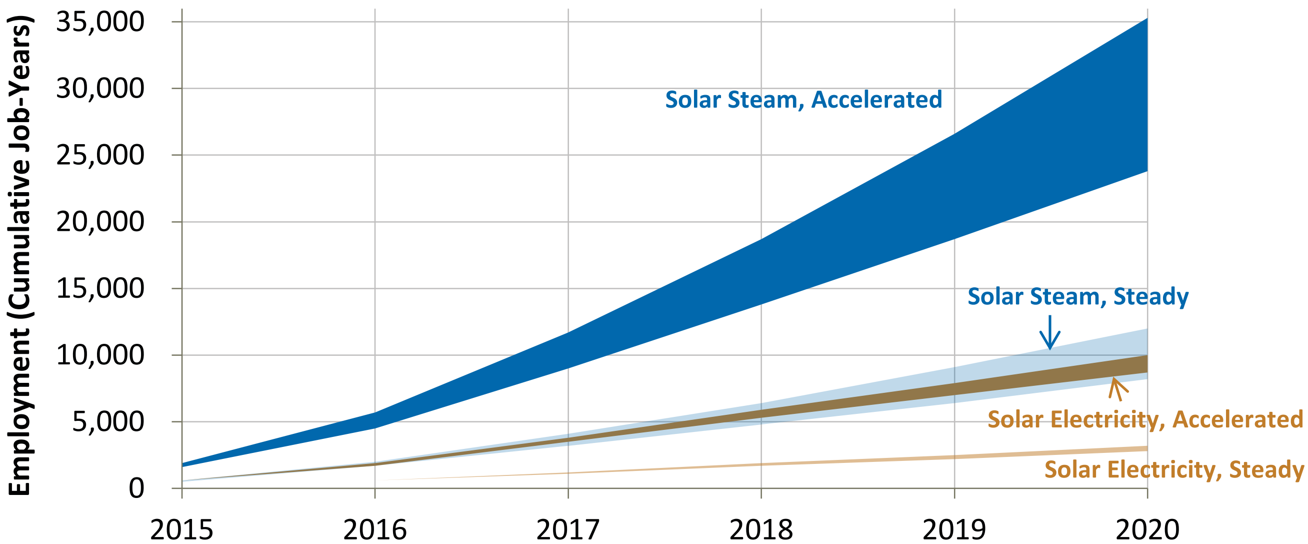
Exhibit 5. Modeling Results for Accelerated Deployment Scenarios, Cumulative 2015-2020

Economic Parameter	Solar Steam		Solar Electricity	
	$25/ton	$150/ton	$25/ton	$150/ton
Employment				
Direct	9,500	14,400	3,300	3,900
Indirect	6,600	8,600	2,300	2,500
Induced	7,700	12,300	2,700	3,200
Total	**23,800**	**35,300**	**8,300**	**9,600**
Jobs Multiplier	2.73	2.56	2.61	2.56
Labor Income ($M)	$1,720	$2,750	$610	$730
Income per Worker	$72,300	$77,900	$73,500	$76,000
Statewide Activity ($ millions)				
GSP	$2,520	$4,030	$890	$1,060
Industry Activity	$6,660	$9,120	$1,950	$2,230
Output Multiplier	1.53	1.59	1.73	1.74
Taxes	$263	$470	$81	$105

The solar steam technology deployment leads to signifi antly higher employment and statewide economic activity, largely as a result of higher capital expenditures associated with capturing the same market share (5% or 30%). The technologies yield similar results in terms of the multipliers for jobs and industry activity / output. In other words, the higher values for solar steam deployment are more of a reflection of the higher overall market opportunity for solar steam rather than something unique about deploying the technology. Solar PV technology has a slightly higher output multiplier, in part because a significant portion (upwards of 55%) of the expenditures associated with solar steam deployment occur outside of California, mainly as imported materials.

Exhibit 6 below shows how the cumulative employment impacts over time for both solar PV and solar steam technologies in the *steady* and *accelerated* scenarios. The range of impacts represents the low and high LCFS credit pricing.

Exhibit 6. Cumulative Employment Impacts in California of Solar Powered Oil Production



The IMPLAN Model

The IMPLAN model is a static input-output framework used to analyze the effects of an economic stimulus on a pre-specifi d economic region; in this study, the State of California. The IMPLAN model tracks economic activity across more than 500 industrial sectors using region-specific ultipliers to trace and calculate the fl w of dollars from the industries that originate the impact to supplier industries. The industrial sectors are based on the North American Industry Classifi ation System (NAICS). The IMPLAN model is one of the most widely used input-output impact models in the United States. For instance, IMPLAN was recently used to estimate the economic contribution of the oil and gas industry in California.

Oil and Gas in California: The Industry and Its Economic Contribution in 2012, LAEDC, April 2014

The IMPLAN model includes more than 500 industry sectors; the table below highlights the sectors that experienced the highest employment impacts. These sectors have been grouped broadly into three categories: oil and gas production industries, solar powered oil production technologies, and indirect and induced sectors. As noted previously, the indirect and induced sectors are those that are impacted by direct investments in the solar powered oil production technologies oil and gas production industries via linkages and increased household incomes. Across both solar steam and solar electricity technology penetration scenarios that were modeled, the construction sector and the drilling oil and gas wells sector captured the highest percentages of employment, accounting for as much as 15-20% of the total employment.

With a larger market penetration, solar steam also has more potential for LCFS credit generation—generating a cumulative 4.4 million and 13.3 million LCFS credits in the *steady* and *accelerated* deployment scenarios compared to just 0.5 million and 1.5 million LCFS credits generated in the *steady* and *accelerated* solar electricity deployment scenarios, respectively.

Exhibit 7. Most Impacted Industry Sectors via Solar Powered Oil Production Technology Deployment

Industry	IMPLAN Sector
Oil and Gas Production Industries	*Drilling oil and gas wells*
	Extraction of natural gas and crude petroleum
	Support activities for oil and gas operations
	Wholesale trade
Solar Powered Oil Production Technologies	*Construction of other new nonresidential structures*
	Architectural, engineering, and related services
	Fabricated pipe and pipe fitting manufa turing
	Semiconductor and related device manufacturing
	All other miscellaneous electrical equipment and component manufacturing
Indirect & Induced Sectors	Real estate
	Full-service restaurants
	Limited-service restaurants
	Employment services
	Employment and payroll of state govt, non-education

The higher market potential for solar steam also leads to higher retention of refinery margins attributed to increased refi ery runs and reduced exports of refined products. The retention of these refinery margins manifests itself in the modeling results primarily as increased output and industry activity, and to some extent labor income, rather than employment. Despite not having a significant impact on employment, this is due in part to the nature of the modeling exercise.

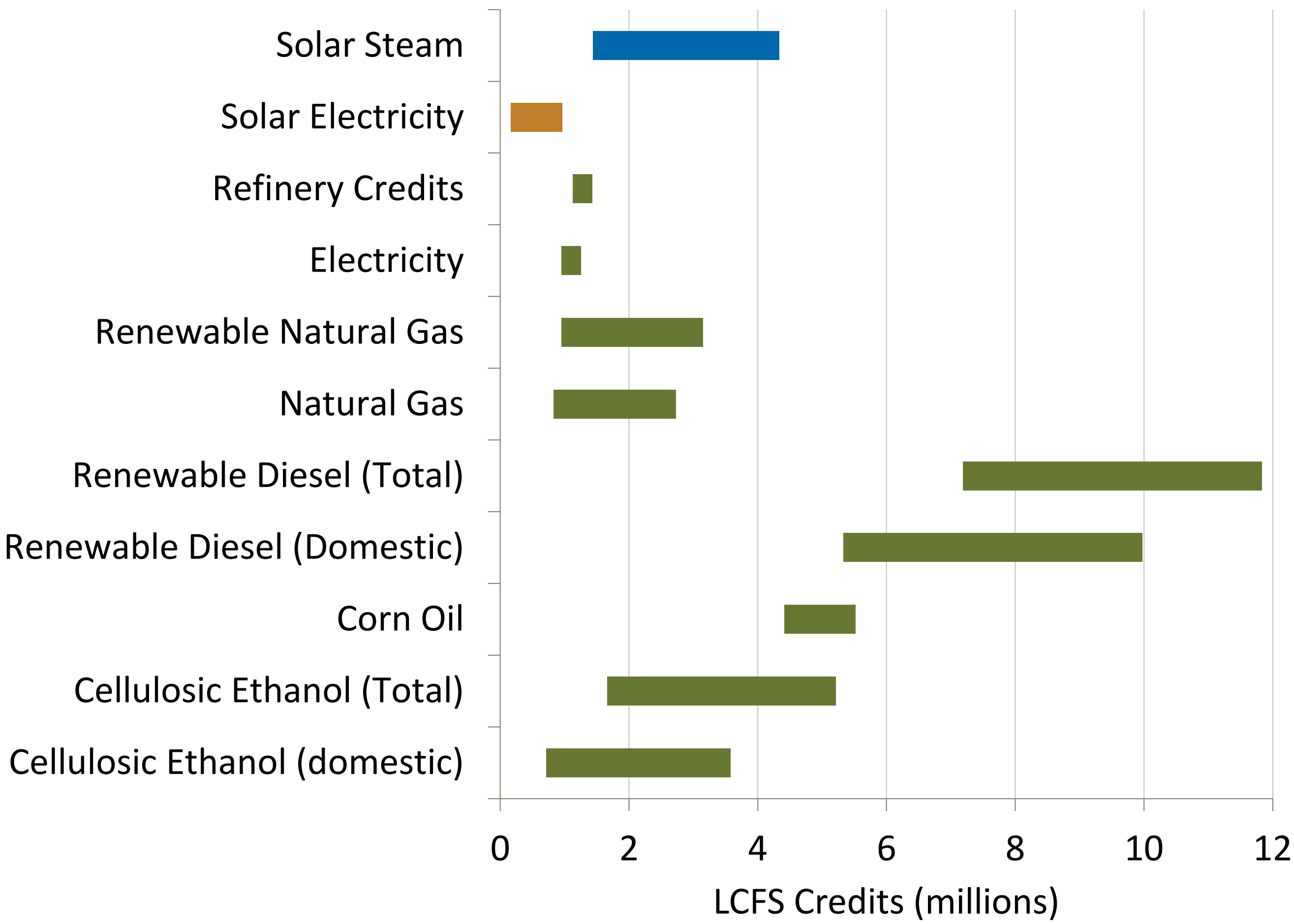
To some extent, the I-O model assumes "full" employment at refineries in the baseline case. In other words, the baseline case—against which the impacts of solar powered oil production technologies are measures—is not assuming that there will be refinery closures as a result of programs like the LCFS or the cap-and-trade program. Furthermore, an increased allocation of expenditures to the refinery sector in the modeling is not going to lead spontaneously to the opening or expansion of an existing refinery in California, thereby generating signifi ant new employment in the sector. Rather, it will lead to enhanced labor income, industry activity, and industry output.

"Solar steam [deployment] leads to higher retention of refinery margins attributed to increased refinery runs and reduced exports of refined products."

3 Solar Powered Innovative Crude in Context

As part of the re-adoption package, CARB staff eveloped alternative transportation fuel production capacity estimates in various cases (e.g., low, medium, and high).[16] These estimates were used to develop an illustrative LCFS compliance scenario. Exhibit 8 below captures the technical potential for various alternative transportation fuels compared to solar powered oil production technologies in 2020. Note that these values represent the number of LCFS credits that would be generated using the low and high projected estimates published by CARB staff or total fuel volumes available in 2020, not the values assumed for a specific compliance scenario.

Exhibit 8. Total LCFS Credit Potential from Various Compliance Pathways



[16] Available online at http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15appb.pdf

Solar steam has the potential to generate credits comparable with the technical potential of significant pathways that CARB staff se to illustrate compliance, such as domestic cellulosic ethanol. Solar electricity has more limited potential, but is comparable to other contributors to compliance like electricity (used in plug-in electric vehicles) and potential credits generated by energy efficiency improvements at refineries.

While Exhibit 8 focuses on the overall technical potential of various pathways, Exhibit 9 shows the specific deployment potential of solar steam and solar electricity compared to CARB's illustrative compliance scenario for the years 2016-2020.

The potential for innovative crude production technologies is significant: In the *accelerated* deployment scenario, solar steam and solar electricity have the potential to generate 25% and 2%, respectively, of the total cumulative credits required in CARB's illustrative compliance scenario. This puts solar steam on par with pathways such as renewable diesel and renewable natural gas; solar electricity would make a contribution comparable to conventional natural gas. Even in the *steady* deployment scenarios, the LCFS credits generated by solar steam and solar electricity are on par with low carbon fuels like corn oil biodiesel and tallow biodiesel, respectively. Regardless of the deployment scenario, both solar steam and solar electricity have the potential to make material contributions towards LCFS compliance in the 2020 timeframe.

As highlighted in the table above, CARB's illustrative compliance scenario is largely dependent on importing low carbon fuels to California, including corn ethanol (15% of credits), cane-based ethanol (15%), and renewable diesel (22%). To date, nearly all of the renewable natural gas supplied to California for LCFS compliance has been from out-of-state. ICF anticipates that a significant portion of the renewable natural gas will continue to be imported to California from other parts of the United States in the near- to mid-term future (at least through 2018).[17]

Exhibit 9. Estimated LCFS Credit Generation, 2016-2020[18]

Pathway		LCFS Credits (millions) 2016-2020	
Gasoline Substitutes CARB Illustrative Compliance Scenario[17]	Corn Ethanol	9.03	
	Cane Ethanol	7.28	
	Sorghum/Corn Ethanol	1.02	
	Sorghum/Corn/Wheat Slurry Ethanol	0.88	
	Cellulosic Ethanol	1.42	
	Molasses Ethanol	1.49	
	Renewable Gasoline	0.30	
	Hydrogen	0.29	
	Electricity	3.96	
Diesel Substitutes CARB Illustrative Compliance Scenario	Soy Biodiesel	0.43	
	Waste Grease Biodiesel	3.11	
	Corn Oil Biodiesel	5.04	
	Tallow Biodiesel	0.43	
	Canola Biodiesel	0.11	
	Renewable Diesel	13.02	
	Natural Gas	1.39	
	Renewable Natural Gas	7.07	
	Electricity for HDVs and Rail	1.01	
	Refine y Credits	3.16	
	Total	**60.43**	
Solar Powered Oil Production Technologies *Steady* and *Accelerated* Deployment	Solar Steam	4.42	13.28
	Solar Electricity	0.50	1.50

Many of these compliance options are likely to command a significant premium in the market, especially liquid biofuels, thereby pushing credit prices up. California's regulated entities, absent other options, are largely price takers in the low carbon fuel market. In principle, LCFS credit prices will be determined by the marginal abatement cost (assuming a liquid market, and other indicators of a robust market). ICF estimates that the marginal abatement cost associated with the fuel pathways in CARB's illustrative scenario is greater than the abatement cost of the innovative crude production technologies considered here—solar steam and solar PV.

[17] CARB staff estim tes about 50 million diesel gallon equivalents (dge) of RNG consumption in 2014, and used 240 million dge of RNG in 2020 for the illustrative compliance scenario.

[18] Note that these values are calculated by ICF based on our assessment of information presented by CARB, available online at http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15appb.pdf

In other words, ICF believes that in either the *steady* or *accelerated* technology deployment scenarios, innovative crude production technologies have the potential to:

- reduce the marginal abatement cost in the LCFS program in 2020,
- decrease credit prices, and
- reduce California regulated parties' status as a price taker.

ICF estimates that in the *accelerated* deployment case for solar steam, for instance, the credits generated may reduce credit prices by as much as $20-$25/ton in 2020.[19]

Credits from innovative crude production offer a potential hedge against uncertainty in the federal Renewable Fuel Standard (RFS2) market. The RFS2 market has experienced significant volatility. The US Environmental Protection Agency (EPA) sets targets (renewable volume obligations, or RVOs) for the blending of renewable fuels on an annual basis. In November 2014, the EPA announced that they would postpone setting the 2014 RVO targets until 2015, extending a period of regulatory uncertainty in the marketplace. The RFS2 market has also experienced other volatility, such as the availability of federal tax credits. The role of biodiesel, for instance, in the market fluctuates significantly without certainty regarding the availability of a $1.00 per gallon blender's tax credit. This credit has expired and been re-instated retroactively several times in the last five years, creating a difficult investment atmosphere for producers and regulated parties. The uncertainty in the RFS2 market has led to and may continue to lead to volatility of Renewable Identification Numbers (RINs) pricing, the currency of the RFS2 market. For instance, if the RFS2 market is scaled back significantly (via reduced RVOs), it may decrease the price of RINs, and liquid biofuel providers may look to the LCFS program to pick up some of the slack in market pricing. This could lead to an increase in LCFS credit prices.

The credit streams arising from solar powered oil production may provide regulated parties in the LCFS market a buffer against such price volatility. This is dependent, however, on timely deployment of innovative crude production technologies as a compliance diversifi ation strategy.

ICF believes that innovative crude production technologies may provide regulated parties an opportunity to limit their exposure to the LCFS credit market via an integrated investment-based approach. Today, for instance, the majority of LCFS credits are purchased at the point of blending ethanol into gasoline and blending biodiesel or renewable diesel into conventional diesel. In some cases, the LCFS credit value paid is transparent. By and large, however, the LCFS credit market lacks liquidity and transparency in part because some transactions bundle the LCFS credit price paid with fuel price, or refl ct longer-term arrangements. Some market participants have various investments in both refining and low carbon fuels and transfer credits internally. CARB reports, for instance, that one-in-five LCFS credit transactions have $0 credits being transacted.[20] ICF regards this activity as an ordinary part of market participants seeking competitive advantage, and a means to limit their exposure to a potentially volatile LCFS credit market.

The innovative crude provisions of the LCFS allow regulated parties to co-invest in or otherwise source credits from production facilities that reduce the carbon intensity of crude oil, which will durably reduce emissions from upstream crude oil production. These investments will reduce forward uncertainty for all market participants and create economic growth in California, shifting a portion of investment in low-carbon energy facilities from out-of-state to in-state.

"Solar steam has the potential to generate credits comparable with the technical potential of significant pathways that CARB staff use to illustrate compliance, such as domestic cellulosic ethanol."

[19] Note that the economic contributions of such price reductions were not considered under this study's methodology.

[20] CARB, October 27, 2014 LCFS Workshop on Proposed Compliance Curves and Cost Compliance Provision.

Appendix

LCFS Credit Calculations

Solar Steam

The LCFS credits that could be generated for solar steam were calculated using the methodology outlined by CARB in the proposed language:

$$Credits_{innov\_SolarSteam} = 29{,}360 \times V_{steam} \times f_{solar} \times V_{crude\_produced} \times V_{innov\_crude} \times C$$

where $Credits_{innov\_SolarSteam}$ is the amount of LCFS credits generated in metric tons by the volume of crude oil produced and delivered to California refineries for processing; V_{steam} is the volume in barrels of cold water equivalent of steam injected, f_{solar} is the fraction of steam injected that was produced using solar energy; $V_{crude\_produced}$ is the volume (in barrels) of crude oil produced using the innovative method; V_{innov_crude} is the volume (in barrels) of crude oil produced using the innovative method and delivered to California refineries for processing; and C is the constant to convert from metric tons to grams (where 1 MT=106 gCO_2e). The constant at the outset of the equation, 29,360, is the emissions factor associated with the natural gas that would have otherwise been consumed in once through steam generators (OTSGs).21

Solar PV

The LCFS credits that could be generated by solar PV deployment were calculated using the methodology outlined by CARB in the draft language:

$$Credits_{innov\_SolarSteam} = 511 \times \frac{E_{electricity} \times f_{renew}}{V_{crude\_produced}} \times V_{innov\_crude} \times C$$

where $Credits_{innov\_SolarSteam}$ is the amount of LCFS credits generated in metric tons by the solar PV used to produce crude oil and delivered to California refineries for processing; $E_{electricity}$ is the electricity consumption to produce the crude (in units of kWh), and f_{renew} is the fraction of renewable electricity that was produced using solar or wind energy.

[21] ICF notes that the emissions factor for natural gas is derived from a draft version of the CA-GREET model and is subject to modific tion upon further CARB review.

Model Description

In this analysis, the economic impacts were calculated using the IMPLAN[22] (IMpact analysis for PLANning), Version 3.0 input-output model. IMPLAN is developed and maintained by the Minnesota IMPLAN Group (MIG). The IMPLAN model is a static input-output framework used to analyze the effects of an economic stimulus on a pre-specified economic region; in this case, the State of California. IMPLAN is considered static because the impacts calculated by any scenario by the model estimate the indirect and induced impacts for one time period (typically on an annual basis).

The modeling framework in IMPLAN consists of two components—the descriptive model and the predictive model.

- The **descriptive model** defines the local economy in the specifi d modeling region, and includes accounting tables that trace the "flow of dollars from purchasers to producers within the region".[23] It also includes the trade flows that describe the movement of goods and services, both within, and outside of the modeling region (i.e., regional exports and imports with the outside world). In addition, it includes the Social Accounting Matrices (SAM) that trace the flow of money between institutions, such as transfer payments from governments to businesses and households, and taxes paid by households and businesses to governments.

[22] IMPLAN was developed by the Minnesota IMPLAN Group (MIG). There are over 1,500 active users of MIG databases and software in the United State as well as internationally. They have clients in federal and state government, universities, as well as private sector consultants. More information is available at http://www.implan.com.

[23] IMPLAN Pro Version 2.0 User Guide.

- The **predictive model** consists of a set of "local-level multipliers" that can then be used to analyze the changes in final demand and their ripple effects throughout the local economy. IMPLAN Version 3.0 uses 2008 data and improves on previous versions of model by implementing a new method for estimating regional imports and exports - a trade model. This new method of estimating imports looks at annual trade fl w information between economic regions; thereby allowing more sophisticated estimation of imports and exports than the traditional econometric RPC estimate used by the previous, Version 2. Additionally, this new modeling method allows for multi-regional modeling functions, in which IMPLAN tracks imports and exports between selected models allowing the users to assess how the impact in one region can impact additional regional economies.

The IMPLAN model is based on the input-output data from the U.S. National Income and Product Accounts (NIPA) from the Bureau of Economic Analysis. The model includes 440 sectors based on the North American Industry Classification System (NAICS). The model uses region-specific multipliers to trace and calculate the flow of dollars from the industries that originate the impact to supplier industries. These multipliers are thus coefficients that "describe the response of the economy to a stimulus (a change in demand or production)."[24] Three types of multipliers are used in IMPLAN:

- Direct—represents the impacts (e.g., employment or output changes) due to the investments that result in final demand changes, such as investments needed for cleanup and/or redevelopment efforts.
- Indirect—represents the impacts due to the industry inter-linkages caused by the iteration of industries purchasing from industries, brought about by the changes in final demands.

Induced—represents the impacts on all local industries due to consumers' consumption expenditures arising from the new household incomes that are generated by the direct and indirect effects of the final demand changes.

[24] Ibid.

The total impact is simply the sum of the multiple rounds of secondary indirect and induced impacts that remain in California (as opposed to "leaking out" to other areas). IMPLAN then uses this total impact to calculate subsequent impacts such as total jobs created and tax impacts. This methodology, and the software used, is consistent with similar studies conducted across the nation.

Inputs and Model Parameters

The direct economic impacts presented in the report are based on: a) investments required to deploy solar steam and solar PV technologies at oilfields in California, b) the value of LCFS credits being generated in-state, rather than exported to low carbon fuel producers outside of California, and c) the value of increased refinery runs and decreased exports that would have otherwise occurred as a result of LCFS compliance. ICF modeled the impacts of the investments for each individual year of the time period (2015-2020).

Output

Whenever new industry activity or income is injected into an economy, it starts a ripple effect that creates a total economic impact that is much larger than the initial input. This is because the recipients of the new income spend some percentage of it and the recipients of that share, in turn, spend some of it, and so on. The total spending impact of the new activity/income is the sum of these progressively smaller rounds of spending within the economy. This total economic impact creates a certain level of value added (GSP), jobs, called the total employment impact, and also tax revenue for state and local governments.

Due to the static nature of the IMPLAN model, the employment impacts must be presented in terms of annual job-years as the model calculates the annual impact of an annual investment. It is likely that once the job is created, it will be sustained, however to ensure that the impact is not overstated; it is conservatively assumed that the job impact is annual. The annualized GSP and tax impacts can be accrued over the program's duration to identify the total impact of the EB-5 program. These dollar values represent the investments that were placed into the economy each year aggregated over time.

Detailed Modeling Results

As noted previously, ICF used the IMPLAN model to calculate the economic impacts of solar powered oil production in California. The data provided in the body of this report have been aggregated into cumulative numbers. The tables below include selected outputs from IMPLAN—employment (in job-years), labor income, industry activity, and GSP—on an annual basis.

Exhibit 10. Changes in Employment, All Scenarios

Solar Technology	Deployment	LCFS	2015	2016	2017	2018	2019	2020
Solar Steam	*Steady*	Low	500	1,100	1,500	1,600	1,700	1,700
		High	600	1,400	2,100	2,400	2,600	2,900
	Accelerated	Low	1,600	3,000	4,500	4,700	4,900	5,100
		High	1,900	3,800	6,100	7,000	7,900	8,700
Solar Electricity	*Steady*	Low	200	400	600	600	500	500
		High	200	400	600	600	700	700
	Accelerated	Low	600	1,200	1,700	1,700	1,600	1,600
		High	600	1,200	1,900	1,900	2,000	2,000

Exhibit 11. Changes in Labor Income, All Scenarios ($ millions)

Solar Technology	Deployment	LCFS	2015	2016	2017	2018	2019	2020
Solar Steam	*Steady*	Low	40	80	110	110	120	130
		High	50	100	150	180	210	240
	Accelerated	Low	100	200	310	340	360	390
		High	130	280	460	550	630	710
Solar Electricity	*Steady*	Low	10	30	40	40	40	40
		High	10	30	50	50	50	50
	Accelerated	Low	40	80	120	120	120	120
		High	50	90	140	150	150	160

Exhibit 12. Changes in Industry Activity, All Scenarios ($ millions)

Solar Technology	Deployment	LCFS	2015	2016	2017	2018	2019	2020
Solar Steam	*Steady*	Low	90	240	380	450	520	580
		High	110	300	490	610	730	830
	Accelerated	Low	270	670	1110	1330	1540	1740
		High	330	850	1450	1820	2170	2490
Solar Electricity	*Steady*	Low	40	80	120	130	130	140
		High	40	90	140	150	160	170
	Accelerated	Low	120	250	370	390	400	420
		High	120	270	410	450	470	500

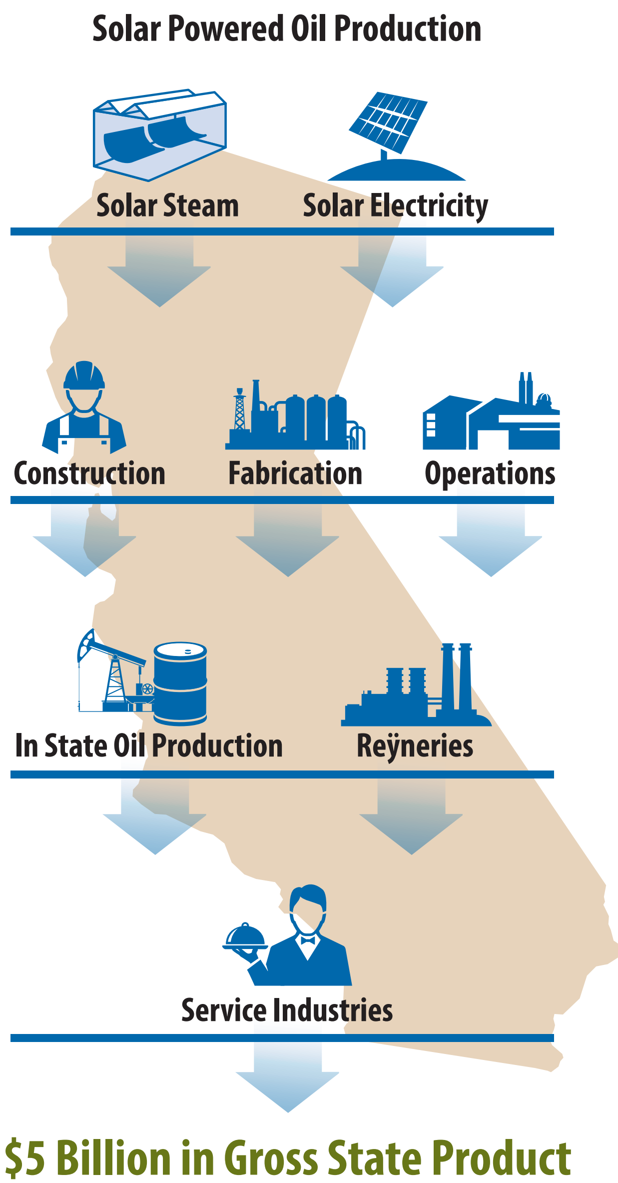
Exhibit 13. Changes in Gross State Product, All Scenarios ($ millions)

Solar Technology	Deployment	LCFS	2015	2016	2017	2018	2019	2020
Solar Steam	*Steady*	Low	50	100	150	170	190	200
		High	60	140	220	270	310	360
	Accelerated	Low	140	280	450	500	550	600
		High	170	390	650	810	940	1070
Solar Electricity	*Steady*	Low	20	40	60	60	60	60
		High	20	40	70	70	70	80
	Accelerated	Low	60	120	180	180	180	180
		High	60	130	200	210	220	230

List of Abbreviations and Acronyms

CARB	California Air Resources Board
CCS	Carbon Capture and Storage
CI	Carbon Intensity
DGE	Diesel Gallon Equivalent
EOR	Enhanced Oil Recovery
GHG	Greenhouse Gas
GSP	Gross State Product
I-O Model	Input-Output Model
LCFS	Low Carbon Fuel Standard
NAICS	North American Industry Classifi ation System
OTSG	Once Through Steam Generator
PV	Photovoltaic
RFS2	Renewable Fuel Standard
RIN	Renewable Identifi ation Number
RVO	Renewable Volume Obligation (reference to RFS2)

Investing in the California Economy



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