CALIFORNIA ENERGY COMMISSION EPIC BENEFITS: RENEWABLE ENERGY GENERATION

Gross Benefits: EPIC contribution is not isolated from other potential factors

EPIC's Renewables and Grid Integration (RGI) research area invests in renewable energy technologies with the potential to increase renewable energy generation and reduce the cost of renewable sources; these include solar, bioenergy, geothermal, and wind technologies. From 2014-2019, CEC invested $127 million in grants in this research area.

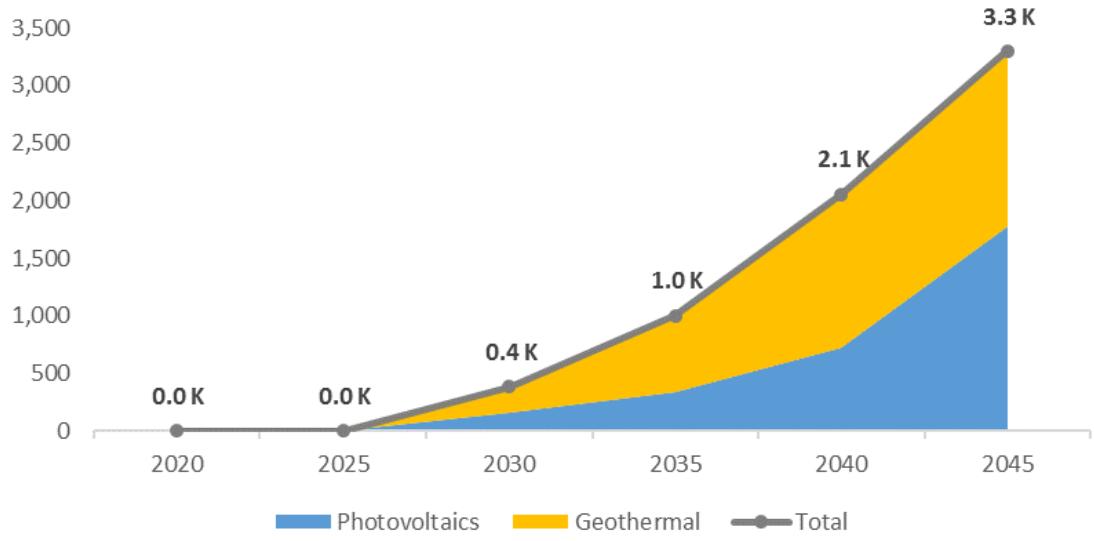
The Commission and its consultant, IEc, used a Delphi Panel to forecast market uptake of 14 technologies from grants made between 2014-2019; investment in these grants totaled $32 million. These 14 technologies had sufficient technical information available and generally focus on technology improvement, as opposed to forecasting or energy planning software (see last page for list of grants included). For each EPIC-supported technology, panelists provided projections on: (1) installed capacity through 2045 and (2) observed capacity factors. The projections presented in this document reflect the **minimum** of the Delphi Panel experts' estimates for each technology. IEc combined these projections to forecast the annual amount of energy generated by each technology. IEc also analyzed the benefits of energy generated by these technologies, presented below, including system-level avoided costs; avoided health impacts; and avoided social costs of carbon.

This analysis shows that EPIC's investment of $127 million in the RGI research area is more than paid for by benefits of these 14 technologies alone, including avoided costs to utilities of approximately $440 million, and total social welfare benefits of between $280 and $1,900 million, driven by avoided health impacts.

Energy Generation

The results presented here reflect the estimated annual energy generated between 2020-2045; by 2045 we estimate **3,301 GWh** of energy generated by the 14 EPIC-supported technologies.

Annual estimated energy generated in GWh



Annual and cumulative estimated energy generated in GWh

GWh (Thousands)	2020	2025	2030	2035	2040	2045
Total	**0.0**	**0.0**	**0.4**	**1.0**	**2.1**	**3.3**
Photovoltaics	0.0	0.0	0.2	0.3	0.7	1.8
Geothermal	0.0	0.0	0.2	0.7	1.3	1.5
CSP	0.0	0.0	0.0	0.0	0.0	0.0
Bioenergy	0.0	0.0	0.0	0.0	0.0	0.0
Pre-2000 Wind	0.0	0.0	0.0	0.0	0.0	0.0

System-Level Avoided Costs

Total NPV estimate at 7% discount rate:

$440 Million

Values reflect two broad categories of avoided costs to utilities: avoided energy procurement (including losses and ancillary services) and peak load reduction benefits (including avoided capital costs for new generation capacity, transmission, and distribution). The avoided costs are likely conservative as the calculations assume a fixed capacity factor and therefore only reflect 80 percent of the cumulative energy generation projected by the Delphi Panel. The calculations also assume no storage or flexibility associated with this generation. Net present value (NPV) is calculated using a 7% discount rate which is an accepted discount rate for a typical investor-owned utility's cost of capital. All hourly analysis is based on the System-Level Savings Calculator, which uses hourly marginal cost inputs from CPUC's Avoided Cost Calculator.

Notably, the system-level avoided costs represent gross values which are not net of program, technology, installation and system integration costs due to the limited information available on such costs for the technologies included in the Renewable Energy Delphi Panel and the difficulty in projecting these costs over the analyzed timeframe.

System Level Avoided Costs		
	NPV	Levelized $/MWh[1]
Total	$440 M	$77.53

[1] The $/MWh values are levelized over 26 years, such that the annual MWh of load reduction result in the cumulative net present value of avoided costs from 2020 to 2045, in 2020 nominal dollars.

Social Welfare Benefits: Benefits to Society

Two primary societal benefits are considered: health effects and the social cost of carbon. The social welfare benefits reflect society's willingness-to-pay for reductions in human health and climate risks due to the reductions in air pollutant and GHG emissions. While both are measured in dollars, the social welfare benefits are a measure of *economic value* whereas the system-level avoided costs describe *financial costs*. As they reflect different concepts, these social welfare values should not be summed with the dollar values for system-level avoided costs to utilities. Values reflect present value (PV) benefits at a 3% discount rate (2020-2045).

Total Social Welfare Benefits		
	Low	High
Total	**$280 M**	**$1,900 M**
Health Effects	$190 M	$1,600 M
Social Cost of Carbon	$87 M	$310 M

Health Effects

Total estimate for all energy sources with PV at 3% discount rate:

$190 – 1,600 Million

The range in the value of health effects from the EPIC Health Benefits Calculator is driven by two factors: (1) assumptions about what generation sources are displaced due to the addition of new renewable energy to the grid and (2) a range in the expected health outcomes associated with the *change* in air pollutant (NO_x, SO_2, $PM_{2.5}$) emissions. The range in expected health outcomes is driven by uncertainty regarding the epidemiological risk coefficient used to estimate the relationship between $PM_{2.5}$ exposure and mortality. The EPIC Health Benefits Calculator accordingly includes the range recommended by EPA's benefit-per-ton emissions value guidance. Values reflect PV benefits at a 3% discount rate (2020-2045). This is a commonly applied discount rate for benefit-cost analysis of health outcomes and is recommended by the U.S. Office of Management and Budget as an estimate of the social rate of time preference, which defines the rate at which society values the present relative to the future. Social discount rates are used for discounting when future costs and benefits are experienced broadly or by the public in general.

Health Effects – All Pollutants		
	Low	High
PV	$190 M	$1,600 M
Annualized	$10 M	$89 M

Social Cost of Carbon

The EPIC Social Cost of Carbon (SCC) Calculator evaluates the socioeconomic benefits of EPIC investments that reduce or mitigate greenhouse gas (GHG) emissions (CO_2, CH_4, N_2O). The social cost of carbon reflects societal willingness-to-pay for reduced risks of global climate change-related damages—including effects to agricultural productivity, energy use, health, infrastructure, and ecosystem services—resulting from marginal changes in atmospheric carbon levels. The range in the values reflects assumptions about what generation sources are displaced due to the addition of new renewable energy to the grid. Values reflect PV benefits (2020-2045) and, consistent with best practices, are presented at a range of discount rate scenarios reflecting the uncertainty inherent in these values.

Total estimate for all energy sources with PV at 3% discount rate:

$87 - 310 Million

Social Cost of Carbon								
	2.5% Discount Rate		3% Discount Rate		5% Discount Rate		95th Percentile	
	Low	High	Low	High	Low	High	Low	High
PV	$130 M	$470 M	$87 M	$310 M	$21 M	$73 M	$260 M	$934 M
Annualized	$6.9 M	$24 M	$4.7 M	$17 M	$1.4 M	$4.8 M	$14 M	$51 M

Due to the increasing magnitude of future climate-related damages over time, social cost estimates are highly sensitive to the chosen discount rate. Best practices generally dictate estimating the effects using the full range of discount rates and climate risk scenarios to reflect this uncertainty. Thus, social cost values are presented at 2.5%, 3%, and 5% discount rates, as well as a 95th percentile estimate reflecting a high climate risk scenario.

Renewable Energy Grants Included in Analysis

Technology Category	Number	Title
Photovoltaics	EPC-14-025	Mass-manufactured, Air Driven Trackers for Low Cost, High Performance Photovoltaic Systems
	EPC-17-015	Installation and Soft Cost Reduction for Horizontal Single Axis Trackers (Stage II)
	EPC-14-040	Self-Tracking Concentrator Photovoltaics for Distributed Generation
	EPC-16-035	High-Performance Cu-Plating for Heterojunction Silicon Cells, Based on Ultra-Low-Cost Printed Circuit Board (PCB) Technology (Stage II)
CSP	EPC-14-003	Low-Cost Thermal Energy Storage for Dispatchable CSP
	EPC-14-047[1]	Dairy Waste-to-Bioenergy via the Integration of Concentrating Solar Power and a High Temperature Conversion Process
	EPC-16-016[1]	Commercializing a Disruptively Low-Cost Solar Collector
Bioenergy	EPC-14-045	Advanced Recycling to 1-MW Municipal Solid Waste of Electricity Generation
	EPC-14-046	Lowering Food-Waste Co-digestion Costs through an innovative Combination of a Pre-Sorting Technique and a Strategy for Cake Solids Reduction
	EPC-14-022[2]	The Lakeview Farms Dairy Biogas-to-Electricity Project
	EPC-14-029[2]	The West Star North Dairy Biogas-to-Electricity Project
	EPC-14-084[2]	ABEC #4 Renewable Combined Heat and Power Project
	EPC-14-051	Cleaner Air, Cleaner Energy: Converting Forest Fire Management Waste to On Demand Renewable Energy
	EPC-14-024	Modular Biomass Power Systems to Facilitate Forest Fuel Reduction Treatment
Geothermal	EPC-14-002	Investigating Flexible Generation Capabilities at the Geysers
	EPC-16-020	Recovery of Lithium from Geothermal Brines
Pre-2000 Wind	EPC-16-019	21st Century Solutions for 20th Century Wind Projects

Notes:

1. These two grants support a single type of CSP technology.
2. These three grants support a single type of dairy waste bioenergy technology.