DOCUMENT OF THE INTER-AMERICAN DEVELOPMENT BANK

REGIONAL

SUSTAINABLE ENERGY FACILITY (SEF) FOR THE EASTERN CARIBBEAN EXPANDED (SEF EXPANDED)

(RG-L1112)

AND

GREEN CLIMATE FUND (GCF) GRANT FOR THE SUSTAINABLE ENERGY FACILITY FOR THE EASTERN CARIBBEAN EXPANDED - (SEF EXPANDED)

(RG-G1013)

AND

REPUBLIC OF ITALY (REI) GRANT FOR SUSTAINABLE ENERGY FACILITY FOR THE EASTERN CARIBBEAN EXPANDED - (SEF EXPANDED)

(RG-G1015)

Cost Benefit Analysis of the Pipeline of Projects Potentially Funded by the SEF Expanded

August 2017

This Document was prepared by: Nils Janson, Maria Jimena Cordoba, and Scarlett Santana from Castalia Strategic Advisors.

Table of Contents

Appendices

Tables

Figures

1 Introduction

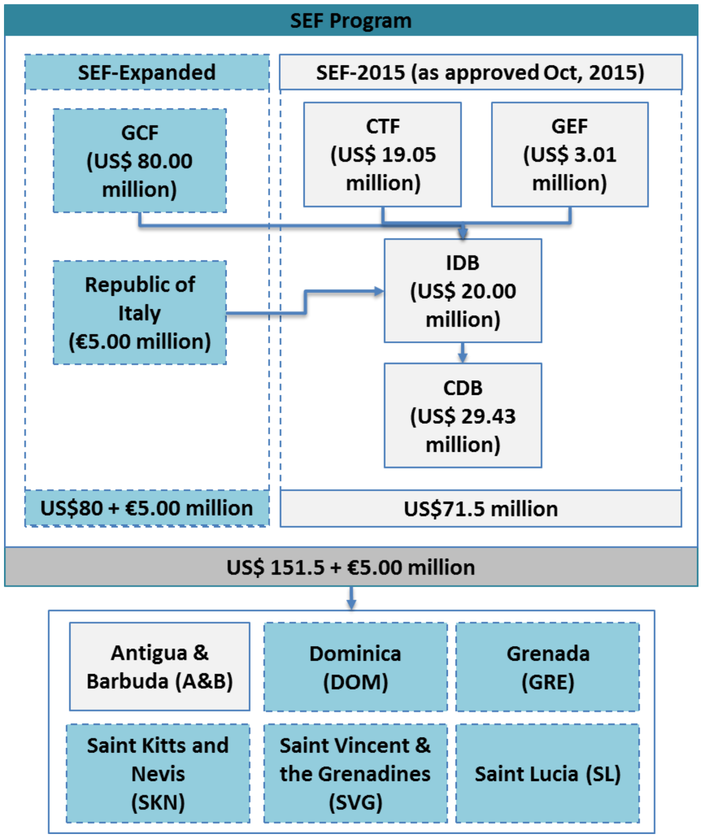
Electricity tariffs in the six independent Eastern Caribbean Countries ('ECC') are among the highest in the world. The small and isolated systems that comprise the energy sectors in the ECC do not have the scale necessary to import lower cost fossil fuels. As a result, the energy matrices in the ECC are mainly dependent on diesel-based generation, which result in high cost and volatile electricity prices for consumers. All the ECC have available sustainable energy (SE) resources that could largely offset fossil fuel generation and generate significant savings.

The IDB and other donors seek to contribute to reducing electricity prices in the ECC. They plan to do so by supporting the diversification of energy matrices and the installation of energy efficiency ('EE') measures. The Sustainable Energy Facility (SEF) for the Eastern Caribbean was approved by the Inter-American Development Bank (IDB) in October 2015 as a Global Credit Loan to fund SE in the ECC. Hereinafter referred to as SEF-2015, this operation is now being complemented with a new IDB operation, the Sustainable Energy Facility for the Eastern Caribbean Expanded (SEF-Expanded). Together, the SEF-2015 and the SEF-Expanded comprise the SEF Program.

The objective of the SEF Program is to radically change the energy matrix of the six Eastern Caribbean Countries (ECC), namely Antigua and Barbuda (A&B), Dominica (DOM), Grenada (GRE), Saint Kitts and Nevis (SKN), Saint Lucia (SL), and Saint Vincent and the Grenadines (SVG) by reducing their dependency on fossil fuels for power generation and the cost of electricity.

The SEF Program places emphasis on developing Geothermal Energy (GE), a RE source for which five ECC have potential (all except A&B) and which has the largest potential for displacing fossil fuels in the region. The SEF-Expanded, complements the SEF-2015 by increasing the funds available for GE development in these five ECC with resources from the Green Climate Fund (GCF) for which the IDB applied and obtained approval on October 2016. The SEF-Expanded also includes co-financing resources from the Republic of Italy mainly for exploratory drilling. Figure 1 below shows how SEF-Expanded resources will be added to the total pool of resources already available under the SEF-2015 enabling the SEF Program to: (i) provide a larger share of the investment needs for GE development in the region; and (ii) provide more risk mitigation instruments for GE projects unlocking private investment.

Figure 1: SEF Program (SEF-2015 & SEF-Expanded)



The Program will provide loans to fund EE measures, institutional strengthening, and renewable energy projects, with an emphasis in geothermal power.

This document presents the Cost Benefit Analysis ('CBA') of the pipeline of GE projects that the SEF Program could potentially finance as included in the Indicative Project Pipeline. The IDB has identified the indicative project pipeline in meetings with local Governments, the Caribbean Development Bank, and potential private project sponsors during a mission to the six ECC in June 1-10, 2015, again in May 2017, and during conversation with them that have taken place thereafter to date. As such, the indicative project pipeline is the current forecast of the potential demand for SEF Program funds.

To carry out the CBA, we use a methodology that complies with the IDB Guidelines for Economic Analysis. Specifically, we find the present values (PV) of the projects' net benefits. To do so we estimate the PV of the projects' benefits and costs. For calculating the projects' benefits, we estimate the savings in electricity expenditures and the monetary value of greenhouse gas emissions displaced by the projects. For calculating the projects' costs, we estimate the full economic costs of implementing the projects, including the costs not financed by the SEF Program. We then find the difference between these two values and find the present value of that difference. That PV is the result of the CBA. If the PV is positive, the project is economically viable.

This CBA suggests that the SEF Program generates an aggregate Present Value of net benefits of **US$255.9 million**[1] over a 40-year period for the geothermal projects and 20-year period for the energy efficiency projects. This is the PV of the projects compared to a business-as-usual (BAU) scenario that involves no changes in the generation matrices of the ECC, nor additional investments in retrofitting street lights. The aggregate PV of net benefits is composed of **US$252.9 million from five geothermal projects** and US$3 million from two street lighting projects. The CBA for the SEF-2015 presented in some detail the results of EE projects. This CBA however, will focus solely on the five GE projects. The internal rate of return of the five geothermal projects is 18.2 percent. The benefits of the Program will stem from the monetary value of avoided greenhouse gas emissions related to the displaced electricity from diesel based generation, and the reduced cost of electricity generated from geothermal power.

In this document, we present our analysis in detail as follows:

- **Pipeline of Projects Potentially Funded by the SEF-Expanded**—presents the GE projects included in the indicative project pipeline, upon which this CBA is based (Section 2)
- **Cost Benefit Analysis of the Geothermal Projects**—shows that the geothermal projects financed through the SEF Program are economically viable. It does so by showing that the net economic benefits of the potential geothermal projects are positive and the internal rate of returns exceed the discount rate. The section also presents the assumptions and methodology used to calculate these results (Section 3)

[1] Assuming a discount rate of 12 percent.

2 Pipeline of GE Projects Potentially Funded by the SEF-Expanded

This section presents the projects that are included in the Cost Benefit Analysis ('CBA'). The projects included in the CBA are those that were identified in the indicative project pipeline. The IDB developed the indicative project pipeline based on information from local Governments, the Caribbean Development Bank, and potential private project sponsors during two missions to the ECC, one in June 2015 and the other in May 2017. As such, the indicative project pipeline is a current forecast of the potential demand for SEF Program funds from the ECC Governments and private sponsors.

Table 2.1 presents the details of the five geothermal projects[2] that could potentially be funded by the SEF Program. The five geothermal projects consist of 60MW of installed capacity and a total capital investment of about US$517.5 million. The three geothermal projects that are included in the shorter-term indicative project pipeline are the projects in Grenada, Nevis and Saint Vincent and the Grenadines. Total capital investment for these three projects has been estimated at US$291 million. The countries in the five ECC with geothermal potential have advanced at different rates in developing their geothermal resources. As such the estimated date for the power plants to come on line and the stages still to be developed varies by country. The earliest and latest are Dominica (Phase 1) in 2017 and Grenada and Saint Lucia in 2019.

Table 2.1: Pipeline of Potential Geothermal Projects

Project	Plant size (MW)	Total Capex (US$ Million)	Estimated Generation Start Year	Stages Done	Stages to be Done
Dominica Phase 1	10	67.0	2019	▪ Pre-investment ▪ Exploration ▪ Production Drilling	▪ Continue production drilling ▪ Power plant construction ▪ T&D and Access Roads
Grenada	10	102.3	2021	Pre-investment (studies in progress)	▪ Exploration ▪ Production Drilling ▪ Power plant construction ▪ T&D and Access Roads
Nevis	10	92.1	20120	Pre-investment	▪ Exploration (to begin) ▪ Production Drilling ▪ Power plant construction ▪ T&D and Access Roads
Saint Lucia	20	159.3	2021	Pre-investment	▪ Exploration ▪ Production Drilling

[2] The projects in Saint Vincent and Nevis were identified as the two geothermal projects that the SEF would likely fund among the total five projects.

Project	Plant size (MW)	Total Capex (US$ Million)	Estimated Generation Start Year	Stages Done	Stages to be Done
				(studies) (in progress)	▪ Power plant construction ▪ T&D and Access Roads
Saint Vincent and the Grenadines	10	96.8	2020	Pre-investment (studies)	▪ Exploration (to begin soon) ▪ Production Drilling ▪ Power plant construction ▪ T&D and Access Roads
Total	**60**	**517.5**			

(1) SVG plans to skip slim holes and begin directly with Exploration.

3 Cost Benefit Analysis of Geothermal Projects

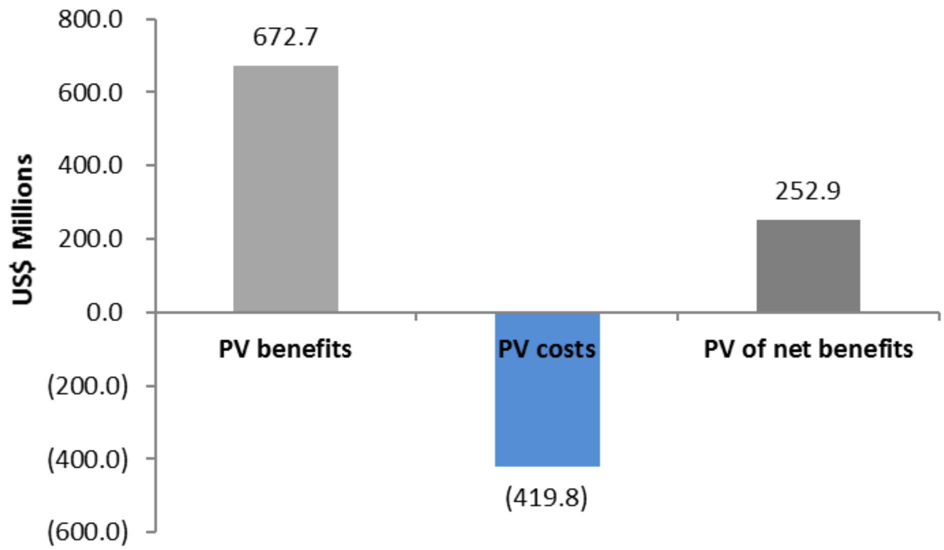
The purpose of this section is to determine whether the GE Component[3] of the SEF Program ('Program') is economically viable. To determine the GE Component's economic viability, we perform a Cost Benefit Analysis ('CBA') of the geothermal projects that it will potentially fund. We find that that the geothermal projects have an aggregate economic net present value of approximately **US$252.9 million** and internal economic rate of return of **18.2 percent**. That is, the projects are economically viable. Therefore, the Governments and the donors should proceed with implementing the geothermal projects.

In this section, we present the results of the five geothermal projects financed in the first phase. Our analysis excludes the second phases of the geothermal projects in Nevis/Saint Kitts and Dominica (Phase 2) because they will not be funded by the Program. We present our analysis as follows:

- Methodology and Assumptions (3.1)
- Economic Costs, Economic Benefits, and Net Economic Benefits of the Geothermal Projects (3.2)
- Sensitivity Analysis of Geothermal Projects (3.3).

[3] Part of Component III of the SEF-2015 & Component I of the SEF-Expanded will fund GE projects

Figure 3.1: Net Economic Benefits of the Geothermal Projects in the five Eastern Caribbean Countries



3.1 Methodology and Assumptions

The objective of the CBA methodology is to determine whether The GE Component of the Program is economically viable. We do so by estimating the net benefits of the indicative geothermal projects that will be financed by the Program.

To determine the projects' economic viability, the present values (PV) of the projects' net benefits are calculated. We calculate the projects' benefits by finding the difference in the electricity costs incurred and greenhouse gas emissions (GHG) emitted between the Program scenario and the counterfactual scenario. The counterfactual scenario is when no geothermal projects are implemented and the electricity sectors in the ECC remain predominantly based on diesel and heavy fuel oil.

The steps to calculate the net benefits of the Program are:

- Estimate the economic costs of geothermal projects (3.1.1)
- Estimate the economic benefits of geothermal projects (3.1.2)
- Estimate the present value of the geothermal projects net economic benefits (3.1.3).

We discuss each of these steps and the assumptions used in their calculation (3.1.4) in more detail below:

3.1.1 Economic Costs of Geothermal Projects

The economic costs of the geothermal projects are composed by:

- **Capital Expenditures (Capex)**—these are the capital investments needed to complete the project stages that are pending. Specifically, we include the costs for completing the pre-investment stages (first slim hole drillings), the exploration stage (test drilling), and the field development stage (production drilling and power plant construction). The costs for developing access roads

and/or transmission lines connecting GE projects to the local grid were also considered. The IDB provided estimation of Capex per stage of development.

3.1.2 Economic Benefits of Geothermal Projects

The economic benefits of the geothermal projects are composed by:

- **Savings in generation costs**—generating electricity from geothermal resources potentially cost less than generating electricity from fuel oil. Therefore, the country will save in generation costs by replacing fuel oil generation with geothermal generation. We estimate the savings to the country as the difference between the Total Avoided Cost ('TAC') of fuel oil generation and the Total Operating Costs ('TOC') of geothermal generation. The TAC is the long run marginal cost of diesel generation. We use the following formulas to calculation the savings in generations costs:

$$TAC\ (US\$) = Avoided\ Cost\ of\ Fuel\ Oil\ Generation\ \left(\frac{US\$}{kWh}\right) \times Generation\ from\ Geothermal\ (kWh)$$

$$Avoided\ Cost\ of\ Fuel\ Oil\ Generation\ \left(\frac{US\$}{kWh}\right) = \frac{Total\ Fuel\ Cost\ (US\$)}{Total\ Energy\ Sold\ (kWh)}$$

$$TOC(US\$) = Operating\ Costs\ from\ Geothermal\ \left(\frac{US\$}{kWh}\right) \times Generation\ from\ Geothermal\ (kWh)$$

- **Reduction in CO_2 emissions**—generating electricity from geothermal resources produces less CO_2 emissions than generating electricity with fuel oil. We calculate the economic benefit of the reduction in CO_2 emissions as the product of the expected reduction in CO_2 emissions and the social cost of CO_2 emissions. The expected reduction in CO_2 emissions is the product of the CO_2 emissions per unit of electricity produced from fuel oil and the units of electricity produced from geothermal generation.

3.1.3 Net Economic Benefits of Geothermal Projects

After we estimate the project's economic costs and benefits, the next step is to calculate the PV of the project's net benefits. To do so, we subtract the PV of the project's costs from the PV of the project's benefits. To determine the PV of the projects costs and benefits, we use a social discount rate of 12 percent (in real terms). If the PV of the project's net benefits is greater than zero, the PV of economic benefits is greater than the PV of economic costs. That means that the geothermal project is economically viable and, therefore, the Government and the donors should proceed with implementing it.

3.1.4 Assumptions for Geothermal Projects

To determine the geothermal project's net benefits, we estimate the annual economic costs and benefits of the geothermal project, for a period of 40 years. Table 3.1 presents the assumptions used to calculate the economic costs and benefits of the geothermal projects.

Table 3.1: Assumptions Used to Determine the Economic Costs and Benefits of the Geothermal Projects

Variable	All Projects	DOM	GRE	Nevis	SL	SVG
Plant size (MW)	60	10	10	10	20	10
Plant availability (%)	85					
Total Capex (US$ million)	517.5	67.0	102.3	92.1	159.3	96.8
Pre-investment	12.0		6		6	
Exploration	58.3		14	14	14	17
Production Drilling	115.7	7	21	21	42	25
Power Plant Construction	263.1	45	45	45	81	47
T&D and Access Roads	68.4	15	16	12	16	8
Operating cost of electricity from geothermal generation (US$/kWh)	0.02[4]					
Social Cost of one ton of CO_2 emissions (US$/t$CO_2$)	10[5]					
Pounds of CO_2 emissions per kWh of electricity produced from fuel oil (No.2) (tCO_2/MWh)	0.76[6]					
Avoided cost of fuel oil generation (US$)[7] (fuel						

[4] Office of Energy Efficiency & Renewable Energy. U.S. Department of Energy. "Geothermal FAQS." http://www1.eere.energy.gov/geothermal/faqs.html (accessed on 9 December 2014).

[5] The Department of Energy assigns a range for the social cost of CO_2 from $0 to $20 per ton of CO_2. We use the median value of this range and perform a sensitivity analysis on it. See following source:

Department of Energy. Chapter 9: Emissions Monetization. Pg. 2 https://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/ch_9_ashrae_nopr_tsd.pdf. (accessed on 4 December 2014)

[6] U.S. Energy Information Administration. "Frequently Asked Questions: How much carbon dioxide is produced per kilowatt-hour when generating electricity with fossil fuels?" http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11. Accessed on 4 December 2014.

[7] The CBA includes yearly avoided cost of fuel oil generation that are based on the EIA´s 2017 forecast for the price of oil for the period 2017 to 2055. For 2056 and 2057 we use the forecast of 2055. This table includes a sample of the avoided cost of fuel oil generation used for the years 2017, 2020, and 2030.

Variable	All Projects	DOM	GRE	Nevis	SL	SVG
cost + capital + variable and fixed O&M) 2017 2020 2030		0.163 0.194 0.233	0.172 0.204 0.246	0.172 0.205 0.247	0.205 0.246 0.299	0.172 0.205 0.247
Discount rate (%)	12					

The assumptions are based on studies from reliable sources and estimations based on the indicative project pipeline. For example, our assumptions on plant sizes are based on the proposed geothermal projects included in the indicative project pipeline. The indicative project pipeline was developed by the IDB and Castalia based on information from Governments and project sponsors in the ECC. Our assumptions for capital expenditures are based on each country's stage of geothermal development, and the estimated average costs for developing each geothermal stage from the IDB and the Energy Sector Management Assistance Program (ESMAP) and the financial model of the SVG project.[8] Our assumptions for avoided cost of fuel oil generation are based on the capital, operating, and maintenance costs of diesel-based generation in the Eastern Caribbean.[9] The avoided cost of fuel generation is also based on the EIA's 2017 yearly oil price projections and the cost of fuel reported in the utilities' financial statements. The 12 percent discount rate is in line with the discount rates used in ESMAP's Geothermal Handbook.

3.2 Economic Costs, Economic Benefits, and Net Economic Benefits of the Geothermal Projects

This section presents the results of the CBA. When aggregating the economic cost and benefits of the geothermal projects, we find that the aggregated net benefits are positive. Also, each project individually has positive net benefits. That means that the implementation of the Program will allow the development of geothermal projects that generate net economic benefits for each of the countries and the region.

Table 3.2 presents the economic costs and benefits of the each of the five projects and the net aggregated economic benefits for the region. Each of the geothermal projects has positive net economic benefits and an internal rate of return ('IRR') that exceeds the 12 percent cost of capital. Therefore, all the geothermal projects are economically viable.

Table 3.2: Economic Costs and Benefits of the Geothermal Projects

Project	PV Benefits (US$M)	PV Costs (US$M)	PV of net benefits (US$M)	IRR (%)
Dominica Phase 1	113.0	60.6	52.5	21.3%

[8] The Energy Sector Management Assistance Program (ESMAP). "Geothermal Handbook: Planning and Financing Power Generation." June 2012 and West Japan Engineering Consultants, Inc., "Study on Current Status of Geothermal Development in the Eastern Caribbean Islands." March 2014.

[9] Our assumption for avoided cost of fuel oil generation is based on the capital, operational, and maintenance expenses for generating one kWh of electricity from diesel technology in Barbados (included in the Barbados Integrated Resource Plan). The power plants in the five Eastern Caribbean states are similar size, and so the capital and O&M costs should be comparable.

Project	PV Benefits (US$M)	PV Costs (US$M)	PV of net benefits (US$M)	IRR (%)
Grenada	98.8	78.9	19.9	14.7%
Nevis	109.3	78.3	31.1	16.1%
Saint Lucia	242.2	119.9	122.2	22.2%
Saint Vincent and the Grenadines	109.3	82.1	27.2	15.5%
Total	**672.7**	**419.8**	**252.9**	18.2%

A detailed schedule of the annual benefits and costs for each project is included in Appendix A.

3.3 Sensitivity Analysis of Geothermal Projects

We conducted a sensitivity analysis to estimate the impact that changes in the values of some key variables used in the CBA would have on the expected economic viability of the projects. The independent variables we included in our sensitivity analysis are the price for monetizing CO2 emissions, the capital expenditures, and the avoided cost (price of oil). We selected these variables based on the likelihood that these variables could change and the size of the impact that the variables would have if they did change.

We find that the projects remain economically viable when the key variables change to extreme values. The projects in Grenada, Nevis, and Saint Vincent and the Grenadines have the smallest although positive, net present values when the CAPEX is increased by 20 percent and the low price of oil (avoided cost) scenario is used. These projects have smaller net benefit margins and so have less room to absorb increases in costs and decreases in benefits. In this section, we show in more detail the effects of changes in:

- Price of CO_2 Emissions
- CAPEX (cost overruns)
- The price of oil.

Additionally, in this section we assess the effect of having additional funding from the SEF-Expanded to complement the SEF-2015 on the net economic benefits. Specifically, the Green Climate Fund ('GCF') is considering contributing funds to the SEF Program. We examine the potential effects on having additional funds for the SEF Program, by assessing the effects of delays in projects on the net economic benefits. Having more funding available makes it more viable for the Program to finance projects thorough their development stages, which reduces the probability that projects are delayed due to lack of financing. Project delays reduce the net economic benefits of projects. Therefore, having more funding available increases the probability of realizing the net benefits of projects. We measure this effect by estimating the reductions in net economic benefits due to project delays.

Table 3.3 presents the results of changing the price of CO2 emissions. We present the PV of the costs, benefits, and net benefits of the geothermal projects for a high case (increasing the price to US$15 per ton of Co2) and low case (decreasing the price to US$6 per ton of Co2) as well as the base case (US$10 per ton of Co2). The table shows that even after lowering the price of CO2 emissions, each of the geothermal projects remain

economically viable, with an aggregate NPV of US$243.5 million. In the high price scenario, the aggregate NPV increases to US$266.1 million.

Table 3.3: CBA Sensitivity to Changes in Price of CO_2 Emissions

	Scenario	Dominica Phase 1	Grenada	Nevis	Saint Lucia	SVG	All 5 projects
(US$000)	US$/tCO2						
PV benefits	**Base: 10**	**113,008**	**98,828**	**109,327**	**242,185**	**109,327**	**672,676**
	15	115,081	102,947	111,175	245,480	111,175	685,859
	6	111,350	96,719	107,848	239,549	107,848	663,315
PV costs	**Base: 10**	60,571	78,873	78,270	119,995	82,082	419,792
	15						
	6						
PV of net benefits	**Base: 10**	**52,437**	**19,955**	**31,057**	**122,190**	**27,245**	**252,884**
	15	54,510	24,073	32,906	125,485	29,093	266,067
	6	50,778	17,846	29,579	119,554	25,766	243,523
IRR	Base: 10	21.3%	14.7%	16.1%	22.2%	15.5%	18.2%
	15	21.7%	15.2%	16.4%	22.5%	15.7%	18.5%
	6	21.0%	14.4%	15.9%	22.0%	15.3%	18.0%

Table 3.4 presents the results of increasing capital expenditures ('CAPEX'); that is, facing cost overruns. We present the PV of the costs, benefits, and net benefits of the geothermal projects for a high case where CAPEX increases by 20 percent and a medium case where CAPEX increases by 10 percent. The results show that for the high cost overruns, each of the geothermal projects remain economically viable, with an aggregate PV of net benefits remains positive at US$168.9 million.

Table 3.4: CBA Sensitivity to Changes in Capex (Cost Overruns)

	Scenario	Dominica Phase 1	Grenada	Nevis	Saint Lucia	SVG	All 5 projects
(US$000)	**Capex Overrun**						
PV benefits	**Base: No**	113,008	98,828	109,327	242,185	109,327	672,676
	10%						
	20%						
PV costs	**Base: No**	**60,571**	**78,873**	**78,270**	**119,995**	**82,082**	**419,792**
	10%	66,629	86,761	86,097	131,995	90,290	461,771

	20%	72,686	94,648	93,924	143,994	98,499	503,750
PV of net benefits	**Base: No**	**52,437**	**19,955**	**31,057**	**122,190**	**27,245**	**252,884**
	10%	46,380	12,067	23,230	110,191	19,037	210,905
	20%	40,323	4,180	15,403	98,191	10,828	168,925
IRR	Base: No	21.3%	14.7%	16.1%	22.2%	15.5%	18.2%
	10%	19.5%	13.5%	14.9%	20.5%	14.2%	16.8%
	20%	18.0%	12.5%	13.8%	19.0%	13.2%	15.6%

Table 3.5 presents the results of changes in the avoided cost of generation due to changes in the price of oil. The high oil price scenario is based on the EIA's high oil price projections. The 20 percent below reference scenario is calculated by reducing the EIA's reference projections by 20 percent. A lower oil price means that the avoided cost of diesel-based generation is lower and so the economic benefits from geothermal power are lower, and vice versa. The table shows that the projects remain economically viable when there are changes in the price of oil. The projects in Grenada, Nevis, and Saint Vincent and the Grenadines have the smallest present values for all scenarios observed. These projects are smaller and farther behind in developing their geothermal resource, and so will need to still make the investments and thus see smaller net benefit margins. At an aggregate level, the projects remain economically viable at the 20 percent below the reference scenario, with a US$137 million PV of net benefits and a 15.5 percent internal rate of return.

Table 3.5: CBA Sensitivity to Changes in Avoided Cost Due to Changes in Oil Price

(US$000)	Avoided Cost with Oil Price (US$/barrel)	Dominica Phase 1	Grenada	Nevis	Saint Lucia	SVG	All 5 projects
PV benefits	**Base: EIA 2017 Ref**	**113,008**	**98,828**	**109,327**	**242,185**	**109,327**	**672,676**
	High	223,755	186,964	205,108	373,927	205,108	1,194,860
	Ref - 20%	94,025	81,938	90,688	199,500	90,688	556,838
	Low	62,083	53,251	59,118	126,999	59,118	360,568
PV costs	**Base: EIA 2017 Ref**	60,571	78,873	78,270	119,995	82,082	419,792
	High						
	Ref - 20%						
	Low						
PV of net benefits	**Base: EIA 2017 Ref**	**52,437**	**19,955**	**31,057**	**122,190**	**27,245**	**252,884**
	High	163,183	108,090	126,838	253,932	123,025	775,068

	Ref - 20%	33,454	3,065	12,418	79,504	8,606	137,046
	Low	1,511	(25,622)	(19,152)	7,004	(22,965)	(59,224)
IRR	Base: EIA 2017 Ref	21.3%	14.7%	16.1%	22.2%	15.5%	18.2%
	High	38.7%	25.0%	27.3%	31.9%	26.2%	29.6%
	Ref - 20%	18.0%	12.4%	13.7%	18.9%	13.1%	15.5%
	Low	12.3%	8.3%	9.2%	12.6%	8.8%	10.4%

We measure the effect of having more funding available by estimating the effects in net economic benefits caused by project delays. Increasing the amount of funding available for projects reduces the probability of project delays, which in turn increases the probability of realizing higher net benefits of projects. Having GCF funds in the Program will increase the availability of funding. This means that the Governments and private sponsors would need to obtain less funding outside of the SEF Program. This makes project delays due to lack of financing less likely.

Table 3.6 presents the impact of delays in projects timelines on the net benefits of the projects. The table shows that the present value of the net benefits decreases when the timelines of projects are pushed back. A later start date means that the net benefits of the projects are received at a later point in time and therefore its net present values are lower. In other words, lower net benefits are realized when projects are delayed. The projects remain economically viable with a delay of four years, with an aggregate PV of net benefits of US$183 million.

Table 3.6: Impact of Delays in Project Start Dates

(US$000)	Length of delay	Dominica Phase 1	Grenada	Nevis	Saint Lucia	SVG	All 5 projects
PV benefits	**Base: No delay**	**113,008**	**98,828**	**109,327**	**242,185**	**109,327**	**672,676**
	2 year delay	93,158	80,767	89,675	198,101	89,675	551,376
	4 year delay	76,111	65,823	73,145	161,577	73,145	449,801
PV costs	**Base**	**60,571**	**78,873**	**78,270**	**119,995**	**82,082**	**419,792**
	2 year delay	48,287	62,877	62,396	95,660	65,435	334,656
	4 year delay	38,494	50,125	49,742	76,259	52,165	266,785
PV of net benefits	**Base**	**52,437**	**19,955**	**31,057**	**122,190**	**27,245**	**252,884**
	2 year delay	44,871	17,890	27,279	102,442	24,239	216,721
	4 year delay	37,617	15,697	23,403	85,318	20,980	183,016
IRR	Base	21.3%	14.7%	16.1%	22.2%	15.5%	18.2%
	2 year delay	22.2%	15.0%	16.6%	22.9%	16.0%	18.8%
	4 year delay	22.9%	15.4%	17.1%	23.6%	16.4%	19.3%

In some cases, the IRR of net benefits are higher when the project is delayed. This is due to the profile of the net benefits. Specifically, benefit flows are closer in time to cost flows, though both later in time with respect to the beginning of the project. Although annual IRRs may be higher, when projects are delayed those returns are realized for a shorter period and later in time. The net present value is a more robust measure of the value of economic benefits (as well as financial benefits). The net present value adequately reflects the reduction in net economic benefits due to project delays, because it is not affected by the profile of the flows. The net present value also reflects the fact that net benefits won´t be realized until later in time for an investment project incurred in today or already incurred in the past.

Appendix A: Annual Economic Costs and Benefits of the Geothermal Projects

This Appendix presents the schedule of the annual economic costs and benefits of the geothermal projects in each country. The schedules show the annual net cash flows from the geothermal projects and the net present value and internal rates of return. We find that each of the geothermal projects has positive net economic benefits and an internal rate of return (‘IRR’) that exceeds the 12 percent discount rate. Therefore, all the geothermal projects are economically viable.

Table A.1: Schedule of Annual Economic Costs and Benefits of Geothermal Project in Dominica (Phase 1)

Dominica Phase 1		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Geothermal Monetary Savings											
Geothermal generation	MWh	0	0	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460
Reduction in CO_2 emissions	tCO_2	0	0	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403
+ Saved cost of generation with diesel/fuel oil	US$ '000	0	0	13,771	14,426	14,918	15,296	15,528	15,740	16,111	16,453
- O&M of geothermal generation	US$ '000	0	0	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489
+ Reduction in CO_2 emissions	US$ '000	0	0	564	564	564	564	564	564	564	564
Benefits	US$ '000	0	0	12,845	13,501	13,993	14,371	14,602	14,815	15,186	15,528
PV benefits	US$ '000	**113,008**									
Geothermal Costs											
Geothermal Capital Expenditures	US$ '000	7,000	60,000	0	0	0	0	0	0	0	0
PV costs	US$ '000	**60,571**									
Benefits - Costs	US$ '000	-7,000	-60,000	12,845	13,501	13,993	14,371	14,602	14,815	15,186	15,528
Cost-benefit of geothermal project	US$ '000	**52,437**									
IRR	%	21.3%									

2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460
56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403
16,666	16,767	16,972	17,334	17,672	18,073	18,091	18,357	18,460	18,879	18,957	19,127	19,380	19,524	19,624
1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489
564	564	564	564	564	564	564	564	564	564	564	564	564	564	564
15,741	15,842	16,047	16,409	16,747	17,148	17,165	17,432	17,535	17,954	18,031	18,202	18,455	18,599	18,699
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15,741	15,842	16,047	16,409	16,747	17,148	17,165	17,432	17,535	17,954	18,031	18,202	18,455	18,599	18,699

2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055
74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460
56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403
19,653	19,742	19,822	19,915	20,056	20,222	20,257	20,471	20,621	20,621	20,621	20,621	20,621	20,621
1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489
564	564	564	564	564	564	564	564	564	564	564	564	564	564
18,728	18,816	18,896	18,990	19,131	19,297	19,332	19,546	19,696	19,696	19,696	19,696	19,696	19,696
0	0	0	0	0	0	0	0	0	0	0	0	0	0
18,728	18,816	18,896	18,990	19,131	19,297	19,332	19,546	19,696	19,696	19,696	19,696	19,696	19,696

Table A.2: Schedule of Annual Economic Costs and Benefits of Geothermal Project in Grenada

Grenada		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Geothermal Monetary Savings											
Geothermal generation	MWh	0	0	0	0	74,460	74,460	74,460	74,460	74,460	74,460
Reduction in CO_2 emissions	tCO_2	0	0	0	0	56,403	56,403	56,403	56,403	56,403	56,403
+ Saved cost of generation with diesel/fuel oil	US$ '000	0	0	0	0	15,748	16,153	16,401	16,629	17,027	17,394
- O&M of geothermal generation	US$ '000	0	0	0	0	1,489	1,489	1,489	1,489	1,489	1,489
+ Reduction in CO_2 emissions	US$ '000	0	0	0	0	564	564	564	564	564	564
Benefits	US$ '000	0	0	0	0	14823	15228	15476	15704	16101	16469
PV benefits	US$ '000	**98,828**									
Geothermal Costs											
Geothermal Capital Expenditures	US$ '000	6,000	14,000	21,000	61,300	0	0	0	0	0	0
CO_2 emissions	tCO_2										
PV costs	US$ '000	**78,873**									
Benefits - Costs	US$ '000	-6,000	-14,000	-21,000	-61,300	14,823	15,228	15,476	15,704	16,101	16,469
Cost-benefit of geothermal project	US$ '000	**19,955**									
IRR	%	14.7%									

	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Geothermal generation	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460
Reduction in CO_2 emissions	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403
+ Saved cost of generation with diesel/fuel oil	17,622	17,730	17,950	18,338	18,701	19,130	19,149	19,435	19,545	19,994	20,077	20,260	20,531	20,686	20,793
- O&M of geothermal generation	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489
+ Reduction in CO_2 emissions	564	564	564	564	564	564	564	564	564	564	564	564	564	564	564
Benefits	16697	16805	17025	17413	17775	18205	18224	18509	18619	19069	19152	19335	19606	19761	19868
Geothermal Capital Expenditures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benefits - Costs	16,697	16,805	17,025	17,413	17,775	18,205	18,224	18,509	18,619	19,069	19,152	19,335	19,606	19,761	19,868

	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055
	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460
	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403
	20,824	20,919	21,004	21,105	21,255	21,433	21,472	21,700	21,862	21,862	21,862	21,862	21,862	21,862
	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489
	564	564	564	564	564	564	564	564	564	564	564	564	564	564
	19899	19994	20079	20179	20330	20508	20546	20775	20936	20936	20936	20936	20936	20936
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	19,899	19,994	20,079	20,179	20,330	20,508	20,546	20,775	20,936	20,936	20,936	20,936	20,936	20,936

Table A.3: Schedule of Annual Economic Costs and Benefits of Geothermal Project in Nevis

Nevis		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Geothermal Monetary Savings											
Geothermal generation	MWh	0	0	0	74,460	74,460	74,460	74,460	74,460	74,460	74,460
Reduction in CO_2 emissions	tCO_2	0	0	0	56,403	56,403	56,403	56,403	56,403	56,403	56,403
+ Saved cost of generation with diesel/fuel oil	US$ '000	0	0	0	15,262	15,791	16,198	16,447	16,675	17,074	17,443
- O&M of geothermal generation	US$ '000	0	0	0	1,489	1,489	1,489	1,489	1,489	1,489	1,489
+ Reduction in CO_2 emissions	US$ '000	0	0	0	564	564	564	564	564	564	564
Benefits	US$ '000	0	0	0	14,337	14,866	15,273	15,522	15,750	16,149	16,517
PV benefits	US$ '000	**109,327**									
Geothermal Costs											
Geothermal Capital Expenditures	US$ '000	14,000	21,000	57,100	0	0	0	0	0	0	0
PV costs	US$ '000	**78,270**									
Benefits - Costs	US$ '000	-14,000	-21,000	-57,100	14,337	14,866	15,273	15,522	15,750	16,149	16,517
Cost-benefit of geothermal project	US$ '000	**31,057**									
IRR	%	16.1%									

	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Geothermal Monetary Savings															
Geothermal generation	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460
Reduction in CO_2 emissions	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403
+ Saved cost of generation with diesel/fuel oil	17,672	17,780	18,001	18,390	18,754	19,185	19,204	19,490	19,601	20,052	20,135	20,319	20,591	20,746	20,853
- O&M of geothermal generation	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489
+ Reduction in CO_2 emissions	564	564	564	564	564	564	564	564	564	564	564	564	564	564	564
Benefits	16,747	16,855	17,076	17,465	17,829	18,259	18,279	18,565	18,676	19,127	19,210	19,393	19,666	19,821	19,928
Geothermal Costs															
Geothermal Capital Expenditures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benefits - Costs	16,747	16,855	17,076	17,465	17,829	18,259	18,279	18,565	18,676	19,127	19,210	19,393	19,666	19,821	19,928

2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055
74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460
56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403
20,885	20,980	21,066	21,166	21,318	21,496	21,535	21,764	21,926	21,926	21,926	21,926	21,926	21,926
1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489
564	564	564	564	564	564	564	564	564	564	564	564	564	564
19,960	20,055	20,141	20,241	20,393	20,571	20,609	20,839	21,001	21,001	21,001	21,001	21,001	21,001
0	0	0	0	0	0	0	0	0	0	0	0	0	0
19,960	20,055	20,141	20,241	20,393	20,571	20,609	20,839	21,001	21,001	21,001	21,001	21,001	21,001

Table A.4: Schedule of Annual Economic Costs and Benefits of Geothermal Project in Saint Lucia

Saint Lucia		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Geothermal Monetary Savings											
Geothermal generation	MWh	0	0	0	0	148,920	148,920	148,920	148,920	148,920	148,920
Reduction in CO_2 emissions	tCO_2	0	0	0	0	112,807	112,807	112,807	112,807	112,807	112,807
+ Saved cost of generation with diesel/fuel oil	US$ '000	0	0	0	0	38,013	39,039	39,666	40,240	41,246	42,174
- O&M of geothermal generation	US$ '000	0	0	0	0	2,978	2,978	2,978	2,978	2,978	2,978
+ Reduction in CO_2 emissions	US$ '000	0	0	0	0	1,128	1,128	1,128	1,128	1,128	1,128
Benefits	US$ '000	0	0	0	0	36,163	37,188	37,815	38,390	39,395	40,323
PV benefits	US$ '000	**242,185**									
Geothermal Costs											
Geothermal Capital Expenditures	US$ '000	6,000	14,000	42,000	81,000	16,300	0	0	0	0	0
CO_2 emissions	tCO_2										
PV costs	US$ '000	**119,995**									
Benefits - Costs	US$ '000	-6,000	-14,000	-42,000	-81,000	19,863	37,188	37,815	38,390	39,395	40,323
Cost-benefit of geothermal project	US$ '000	**122,190**									
IRR	%	**22.2%**									

Saint Lucia	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Geothermal Monetary Savings															
Geothermal generation	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920
Reduction in CO_2 emissions	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807
+ Saved cost of generation with diesel/fuel oil	42,751	43,022	43,580	44,561	45,476	46,561	46,609	47,331	47,609	48,746	48,955	49,417	50,102	50,493	50,764
- O&M of geothermal generation	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978
+ Reduction in CO_2 emissions	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128
Benefits	40,900	41,172	41,730	42,710	43,626	44,710	44,759	45,481	45,759	46,896	47,105	47,566	48,252	48,643	48,913
Geothermal Costs															
Geothermal Capital Expenditures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benefits - Costs	40,900	41,172	41,730	42,710	43,626	44,710	44,759	45,481	45,759	46,896	47,105	47,566	48,252	48,643	48,913

2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055
148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920	148,920
112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807	112,807
50,843	51,082	51,299	51,552	51,933	52,383	52,479	53,057	53,465	53,465	53,465	53,465	53,465	53,465
2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978	2,978
1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128	1,128
48,993	49,232	49,448	49,701	50,083	50,533	50,629	51,207	51,615	51,615	51,615	51,615	51,615	51,615
0	0	0	0	0	0	0	0	0	0	0	0	0	0
48,993	49,232	49,448	49,701	50,083	50,533	50,629	51,207	51,615	51,615	51,615	51,615	51,615	51,615

Table A.5: Schedule of Annual Economic Costs and Benefits of Geothermal Project in Saint Vincent and the Grenadines

Saint Vincent and the Grenadines		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Geothermal Monetary Savings											
Geothermal generation	MWh	0	0	0	74,460	74,460	74,460	74,460	74,460	74,460	74,460
Reduction in CO_2 emissions	tCO_2	0	0	0	56,403	56,403	56,403	56,403	56,403	56,403	56,403
+ Saved cost of generation with diesel/fuel oil	US$ '000	0	0	0	15,262	15,791	16,198	16,447	16,675	17,074	17,443
- O&M of geothermal generation	US$ '000	0	0	0	1,489	1,489	1,489	1,489	1,489	1,489	1,489
+ Reduction in CO_2 emissions	US$ '000	0	0	0	564	564	564	564	564	564	564
Benefits	US$ '000	0	0	0	14,337	14,866	15,273	15,522	15,750	16,149	16,517
PV benefits	US$ '000	**109,327**									
Geothermal Costs											
Geothermal Capital Expenditures	US$ '000	16,278	24,657	47,145	8,718	0	0	0	0	0	0
PV costs	US$ '000	**82,082**									
Benefits - Costs	US$ '000	-16,278	-24,657	-47,145	5,619	14,866	15,273	15,522	15,750	16,149	16,517
Cost-benefit of geothermal project	US$ '000	**27,245**									
IRR	%	15.5%									

	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Geothermal Monetary Savings															
Geothermal generation	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460
Reduction in CO_2 emissions	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403
+ Saved cost of generation with diesel/fuel oil	17,672	17,780	18,001	18,390	18,754	19,185	19,204	19,490	19,601	20,052	20,135	20,319	20,591	20,746	20,853
- O&M of geothermal generation	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489
+ Reduction in CO_2 emissions	564	564	564	564	564	564	564	564	564	564	564	564	564	564	564
Benefits	16,747	16,855	17,076	17,465	17,829	18,259	18,279	18,565	18,676	19,127	19,210	19,393	19,666	19,821	19,928
Geothermal Costs															
Geothermal Capital Expenditures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benefits - Costs	16,747	16,855	17,076	17,465	17,829	18,259	18,279	18,565	18,676	19,127	19,210	19,393	19,666	19,821	19,928

2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055
74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460	74,460
56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403	56,403
20,885	20,980	21,066	21,166	21,318	21,496	21,535	21,764	21,926	21,926	21,926	21,926	21,926	21,926
1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489	1,489
564	564	564	564	564	564	564	564	564	564	564	564	564	564
19,960	20,055	20,141	20,241	20,393	20,571	20,609	20,839	21,001	21,001	21,001	21,001	21,001	21,001
0	0	0	0	0	0	0	0	0	0	0	0	0	0
19,960	20,055	20,141	20,241	20,393	20,571	20,609	20,839	21,001	21,001	21,001	21,001	21,001	21,001