POWER PLANT EFFICIENCY

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SUMMARY OF CONCLUSIONS

The Ivanpah Solar Electric Generating System (ISEGS), if constructed and operated as proposed, would generate 400 megawatts (MW) (maximum net output) of electricity. This project would consist of two 100 MW plants (Ivanpah 1 and Ivanpah 2) and one 200 MW plant (Ivanpah 3), employing advanced solar power and modern steam turbine technologies. The ISEGS would use solar energy to generate up to 95 percent of its capacity, and natural gas to generate up to five percent of its capacity.

The project would decrease reliance on fossil fuel, and would increase reliance on renewable energy resources. It would not create significant adverse effects on fossil fuel energy supplies or resources, would not require additional sources of energy supply, and would not consume fossil fuel energy in a wasteful or inefficient manner. No efficiency standards apply to this project. U.S. Bureau of Land Management (BLM) and Energy Commission staff (hereafter jointly referred to as staff) therefore conclude that this project would present no significant adverse impacts on fossil fuel energy resources.

The ISEGS, if constructed and operated as proposed would occupy over nine acres per MW of power output, a figure about double that of some other solar power technologies. Employing a less land-intensive solar technology, such as the Compact Linear Fresnel Reflector technology or linear parabolic trough technology, would potentially reduce land-related impacts by approximately 50 percent. However, staff recognizes there is a wide range of environmental issues to analyze to compare the merits and impacts of one technology compared to another. This is done in more detail in the **Alternatives** section of this document. In conclusion, ISEGS would utilize solar energy potential from a site that is currently not being harnessed for power production. Thus from an efficiency perspective, ISEGS would not result in a less efficient utilization of the site's solar energy potential than is occurring currently.

Conditions of Certification referred to herein serve the purpose of both the Energy Commission's Conditions of Certification for purposes of the California Environmental Quality Act (CEQA) and BLM's Mitigation Measures for purposes of the National Environmental Policy Act (NEPA).

INTRODUCTION

FOSSIL FUEL USE EFFICIENCY

One of the responsibilities of the California Energy Commission (Energy Commission) is to make findings on whether the energy use by a power plant, including the proposed ISEGS power plant, would result in significant adverse impacts on the environment, as defined in CEQA. If the Energy Commission finds that the ISEGS' energy consumption creates a significant adverse impact, it must further determine if feasible mitigation

measures could eliminate or minimize that impact. In this analysis, staff addresses the inefficient and unnecessary consumption of energy. Power plant efficiency is not normally considered under NEPA.

In order to support the Energy Commission's findings, this analysis will:

- examine whether the facility would likely present any adverse impacts upon energy resources;
- examine whether these adverse impacts are significant; and if so,
- examine whether feasible mitigation measures or alternatives could eliminate those adverse impacts or reduce them to a level of insignificance.

SOLAR LAND USE EFFICIENCY

Solar thermal power plants typically consume much less fossil fuel (usually in the form of natural gas) than other types of thermal power plants. Therefore, common measures of power plant efficiency such as those described above are less meaningful. So far as staff can determine, methods for determining the efficiency of a solar power plant have yet to be standardized; research has uncovered no meaningful attempt to quantify efficiency. The solar power industry appears to have begun discussing the issue, but a consensus is forthcoming (CEC 2008n). In the absence of accepted standards, staff proposes the following approach.

Solar thermal power plants convert the sun's energy into electricity in three basic steps:

- Mirrors and/or collectors capture the sun's rays.
- This solar energy is converted into heat.
- This heat is converted into electricity, typically in a heat engine such as a steam turbine generator or a Stirling Engine-powered generator.

The effectiveness of each of these steps depends on the specific technology employed; the product of these three steps determines the power plant's overall solar efficiency. The greater the project's solar efficiency, the less land the plant must occupy to produce a given power output.

The most significant environmental impacts caused by solar power plants result from occupying large expanses of land. Even in a desert environment, disturbing and shading hundreds or thousands of acres of land can impact biological, cultural and paleontological resources, and can affect drainage, runoff and percolation of rainfall. The extent of these impacts is likely in direct proportion to the number of acres affected. For this reason, staff will evaluate the land use efficiency of proposed solar power plant projects. This efficiency will be expressed in terms of power produced, or MW per acre, and in terms of energy produced, or MW-hours per acre-year. Specifically:

- Power-based solar land use efficiency is calculated by dividing the maximum net power output in MW by the total number of acres impacted by the power plant, including roads and electrical switchyards and substations.

- Energy-based solar land use efficiency is calculated by dividing the annual net electrical energy production in MW-hours per year by the total number of acres impacted by the power plant. Since different solar technologies consume differing quantities of natural gas for morning warm-up, cloudy weather output leveling and heat transfer fluid freeze protection (and some consume no gas at all), this effect will be accounted for. Specifically, gas consumption will be backed out by reducing the plant's net energy output by the amount of energy that could have been produced by consuming the project's annual gas consumption in a modern combined cycle power plant. (See **EFFICIENCY Appendix A**, immediately following.) This reduced energy output will then be divided by acres impacted.

LAWS, ORDINANCES, REGULATIONS, AND STANDARDS

No federal, state, or local/county laws, ordinances, regulations, and standards (LORS) apply to the efficiency of this project.

SETTING

The applicant proposes to build and operate the ISEGS, a solar thermal power plant facility, comprised of Ivanpah 1, Ivanpah 2, and Ivanpah 3, producing a total of 400 MW (maximum net output), and employing BrightSource's Distributed Power Tower (DPT) advanced solar power technology (BSE 2007a, AFC §§1.1, 1.2, 2.1). Ivanpah 1 and Ivanpah 2 would each consist of a heliostat solar field, a solar receiver boiler, a reheat steam turbine generator, an air-cooled condenser, and associated equipment. Ivanpah 3 would consist of a heliostat solar field, five solar receiver boilers, a reheat steam turbine generator, a solar reheater boiler, an air-cooled condenser, and associated equipment (**CH2ML2009f**).

The project's power cycle would be based on a steam cycle (also known as the Rankine cycle) with three pressure stages. Each plant would include a small package natural gas-fired start-up boiler to provide heat for plant start-up and during temporary cloud cover. The heliostat mirrors are arranged around each solar receiver boiler. Each mirror tracks the sun throughout the day and reflects the solar energy to the receiver boiler. Steam is generated in the boilers and is expanded through the steam turbine to generate electricity. No intermediate fluid is used.

The solar field and power generation equipment are started each morning after sunrise once solar radiation builds up, and are shut down in the evening when solar radiation drops below the level required for keeping the steam turbines online. As explained above, natural gas-fired boilers would be used to bring the system up to operating temperature in the morning and periodically to keep system temperatures up when clouds briefly block sunlight. Natural gas would be delivered to the ISEGS via a new 6-mile-long, 4- to 6-inch diameter natural gas distribution pipeline that would provide natural gas from the Kern River Gas Transmission (KRGT) line to the project (BSE 2007a, AFC §§1.2, 2.1, 2.2.6).

ASSESSMENT OF IMPACTS — FOSSIL FUEL ENERGY USE

METHOD AND THRESHOLD FOR DETERMINING THE SIGNIFICANCE OF FOSSIL FUEL ENERGY RESOURCES

CEQA guidelines state that the environmental analysis "…shall describe feasible measures which could minimize significant adverse impacts, including where relevant, inefficient and unnecessary consumption of energy" (Title 14 CCR §15126.4[a][1]). Appendix F of the guidelines further suggests consideration of such factors as the project's energy requirements and energy use efficiency; its effects on local and regional energy supplies and energy resources; its requirements for additional energy supply capacity; its compliance with existing energy standards; and any alternatives that could reduce the wasteful, inefficient, and unnecessary consumption of energy (Title 14, CCR §15000 et seq., Appendix F).

The inefficient and unnecessary consumption of energy, in the form of non-renewable fuels such as natural gas and oil, constitutes an adverse environmental impact. An adverse impact can be considered significant if it results in:

- adverse effects on local and regional energy supplies and energy resources;
- a requirement for additional energy supply capacity;
- noncompliance with existing energy standards; or
- the wasteful, inefficient, and unnecessary consumption of fuel or energy.

PROJECT ENERGY REQUIREMENTS AND ENERGY USE EFFICIENCY

The ISEGS would burn natural gas at a nominal rate of approximately 833 million British thermal units (MMBtu) per hour, LHV, during maximum load operation, for a total annual consumption of 432,432 MMBtu LHV (BSE 2007a, AFC Tables 5.1-13, 5.1-15). Compared to a typical natural gas-fired power plant of equal capacity, this rate is very low. Further, average daily operation of the natural gas boilers would be limited to one hour. Therefore, staff considers the impact of the project's fuel consumption on energy supplies and energy efficiency to be less than significant.

ADVERSE EFFECTS ON ENERGY SUPPLIES AND RESOURCES

The applicant has described its sources of natural gas for the project (BSE 2007a, AFC §§1.2, 2.1, 2.2.6). Natural gas would be delivered to the ISEGS via a new 6-mile-long, 4- to 6-inch diameter natural gas distribution pipeline that would provide natural gas from the Kern River Gas Transmission (KRGT) line to the project site. Natural gas would be used to generate only up to five percent of the project's capacity. The KRGT system is capable of delivering the gas that the ISEGS would require; this natural gas supply constitutes a reliable source of natural gas for this project. Therefore, it appears highly unlikely that the project would create a substantial increase in natural gas demand.

ADDITIONAL ENERGY SUPPLY REQUIREMENTS

Natural gas fuel would be supplied to the project by the KRGT via a new pipeline connection (BSE 2007a, AFC §§1.2, 2.1, 2.2.6)). There appears to be little likelihood that the ISEGS would require additional supply.

COMPLIANCE WITH ENERGY STANDARDS

No standards apply to the efficiency of the ISEGS or other non-cogeneration projects.

ALTERNATIVES TO REDUCE WASTEFUL, INEFFICIENT, AND UNNECESSARY ENERGY CONSUMPTION

The ISEGS could create significant adverse impacts on energy resources if alternatives reduced the project's fuel use. The evaluation of alternatives to the project (that could reduce wasteful, inefficient, or unnecessary energy consumption) requires the examination of the project's energy consumption. Even though staff does not believe the project's fuel consumption would be significant, staff evaluates alternatives that could reduce or eliminate the use of natural gas.

Efficiency of Alternatives to the Project

The Ivanpah SEGS' objectives include the generation of electricity using BrightSource's DPT solar power technology (BSE, 2007a, AFC §6.6).

Alternative Generating Technologies

Alternative generating technologies for the ISEGS are considered in the AFC (BSE 2007a, AFC §6.6). For purposes of this analysis, natural gas, oil, coal, nuclear, biomass, hydroelectric, and wind technologies are all considered. Given the project objectives, location, air pollution control requirements, and the commercial availability of the above technologies, staff agrees with the applicant that the selected solar thermal technology is a feasible selection.

Alternative Heat Rejection System

The applicant proposes to employ a dry cooling system (air-cooled condensers) as the means for rejecting power cycle heat from the steam turbines (BSE 2007a, AFC §§1.2, 2.1). An alternative heat rejection system would utilize evaporative cooling towers.

The local climate in the project area is characterized by high temperatures and low relative humidity (low wet-bulb temperature). In low temperatures and high relative humidity (low dry-bulb temperature), the air-cooled condenser performs relatively efficiently compared to the evaporative tower. However, at the project area (low wet-bulb temperature and high dry-bulb temperature) the air-cooled condenser performance is relatively poor compared to that of an evaporative cooling tower. Furthermore, the performance of the heat rejection system affects the performance of the steam turbine, impacting turbine efficiency. However, to conserve water in the project site's desert environment, the applicant proposes to employ dry cooling. Even though evaporative cooling can offer a higher efficiency rating for this project, staff believes the applicant's selection of dry cooling is a reasonable tradeoff as it would prevent potentially significant environmental impacts that could result from consumption of the large quantities of water required by wet cooling.

Staff, therefore, believes that the ISEGS would not constitute a significant adverse impact on fossil fuel energy resources compared to feasible alternatives.

ASSESSMENT OF IMPACTS — SOLAR LAND USE

The solar insolation falling on the earth's surface can be regarded as an energy resource. Since this energy is inexhaustible, its consumption does not present the concerns inherent in fossil fuel consumption. What is of concern, however, is the extent of land area required to capture this solar energy and convert it to electricity. Setting aside hundreds or thousands of acres of land for solar power generation removes it from alternative uses. Constructing buildings, solar collector foundations and roads can disturb and destroy cultural and paleontological resources. Shading large tracts of land can destroy its use as habitat for flora and fauna. Finally, the earthwork involved in leveling large areas for optimum solar energy collection can disturb the drainage, runoff and percolation of rainfall.

As discussed above, staff is unaware of any accepted standard for evaluating the efficiency of a solar power plant such as ISEGS. Accordingly, staff proposes to tabulate the land use efficiency of the project (described above) and compare it to similar measures for other solar power plant projects that have passed through, or are passing through, the Energy Commission's siting process.

METHOD AND THRESHOLD FOR DETERMINING THE SIGNIFICANCE OF SOLAR LAND USE ENERGY RESOURCES

Staff proposes to compare the land use of a solar power plant project to that of other solar projects in the Energy Commission's siting process. It has not been determined how great a difference in land use would constitute a significant difference; staff proposes to compare the five solar projects currently in the process.

As this is written, there are currently five solar power plant projects in the Energy Commission siting process. These projects' power and energy output, and the extent of the land occupied by them, are summarized in **EFFICIENCY Table 1**, below. The solar land use efficiency for a typical natural gas-fired combined cycle power plant is shown only for comparison.

Adverse Effects on Land Use

While the Energy Commission customarily requires full mitigation for such impacts, such mitigation is generally regarded as less effective in protecting resources than avoiding the impact entirely. A solar power project that occupies twice as much land as another project holds the potential to produce twice the environmental impacts.

PROPOSED PROJECT – LAND USE

The ISEGS would produce power at the rate of 400 MW net, and would generate energy at the rate of 960,000 MW-hours net per year, while occupying 3,744 acres (CH2ML2008g, pp. 2-3). It would consume 432,432 MMBtu LHV of natural gas annually. Staff calculates power-based land use efficiency thus:

Power-based efficiency: 400 MW ÷ 3,744 acres = **0.11 MW/acre** or **9.4 acres/MW**

Staff calculates energy-based land use efficiency thus:

Energy-based efficiency: 960,000 MWh/year ÷ 3,744 acres = **256 MWh/acre-year**

Natural gas proxy: 432,432 MMBtu/year ÷ 3,413 Btu/kWh = 126,701 MWh/year
126,701 MWh/year x 53.7%[1] = 68,039 MWh/year
960,000 MWh/year – 68,039 MWh/year = 891,961 MWh/year

Energy-based efficiency (net of natural gas use):
891,961 MWh/year ÷ 3,744 acres = **238 MWh/acre-year**

[1] See EFFICIENCY Appendix A, immediately following

EFFICIENCY Table 1 — Solar Land Use Efficiency

Project	Generating Capacity (MW net)	Annual Energy Production (MWh net)	Annual Fuel Consumption (MMBtu LHV)	Footprint (Acres)	Land Use Efficiency (Power-Based) (MW/acre)	Land Use Efficiency (Energy – Based) (MWh/acre-year)	
						Total	Solar Only[1]
Ivanpah SEGS (07-AFC-5)	400	960,000	432,432	3,744	0.11	256	238
Carrizo Energy (07-AFC-8)	177	375,000	0	640	0.28	586	586
Beacon Solar (08-AFC-2)	250	600,000	36,000	1,321	0.19	454	450
SES Solar Two (08-AFC-5)	750	1,620,000	0	6,500	0.12	249	249
SES Solar One (08-AFC-13)	850	1,840,000	0	8,200	0.11	224	224
Avenal Energy (08-AFC-1)[2]	600	3,023,388	24,792,786	25	24.0	120,936	N/A

[1] Net energy output is reduced by natural gas-fired combined cycle proxy energy output; see **EFFICIENCY Appendix A**.

[2] Example natural gas-fired combined cycle plant.

As seen in **EFFICIENCY Table 1**, ISEGS, employing solar power tower technology, is roughly half as efficient in use of land as the Compact Linear Fresnel Reflector technology and the linear parabolic trough technology. The Stirling Energy Systems Solar One and Two projects match Ivanpah SEGS in solar land use efficiency.

Proposed Project – Closure and Decommissioning and Mitigation

The closure or decommissioning of the ISEGS project would not maintain utilization of a solar renewable energy resource and could cause an increase in the reliance on fossil fuel. While this would not be the case if another solar power generation project were to follow in the place of ISEGS, this potential outcome is not assured at this time. Therefore, the closure and decommissioning of ISEGS could result in a potentially negative impact in discontinuing to utilize renewable solar resources for power production. However, this impact would not be the responsibility of the project owner to mitigate.

TECHNOLOGIES THAT WOULD REDUCE SOLAR LAND USE IMPACTS

While building and operating a natural gas-fired combined cycle power plant would yield a much higher land use efficiency than any solar power plant (see **EFFICIENCY Table 1**), it would not achieve the basic project objective, to generate electricity from the renewable energy of the sun. While building a solar power plant employing a different technology, such as the Compact Linear Fresnel Reflector technology or the linear parabolic trough technology, would appear to nearly double the solar land use efficiency of the ISEGS site or approximately halve the land use to accomplish the same generation capacity, there is a wide range of environmental issues to analyze to compare the merits and impacts of one technology compared to another. This is done in more detail in the **Alternatives** section of this document.

The applicant expressed concern in its Preliminary Staff Assessment (PSA) comments that staff presented a comparative measure of land use efficiency with other representative generation technologies as shown in **EFFICIENCY Table 1.** The applicant expressed that a comparison of efficiency based solely on capacity is misleading as it ignores energy production and site-specific conditions that affect the capacity factor of a project and thus the potential energy production potential (CH2ML2009a, Page 6.3-2 and 6.3-99, Solar Land Use Efficiency).

Staff has presented the relative comparison of land use efficiency from the perspective of both capacity and annual energy production, and believes that while this is a gross indicator, it is still a telling one. Staff has also explained that so far as staff can determine, methods for determining the efficiency of a solar power plant have yet to be standardized; research has uncovered no meaningful attempt to quantify efficiency. The solar power industry appears to have begun discussing the issue, but a consensus is forthcoming. In the absence of accepted standards, staff has proposed an approach it believes is reasonable and necessary for its Efficiency analysis. ISEGS would utilize solar energy potential from a site that is currently not being harnessed for power production. Thus from an efficiency perspective, ISEGS would not result in a less efficient utilization of the site's solar energy potential than is occurring currently.

No Project / No Action Alternative

In the No Project / No Action Alternative, the proposed action would not be undertaken. The BLM land on which the project is proposed would continue to be managed within BLM's framework of a program of multiple use and sustained yield, and the maintenance of environmental quality [43 U.S.C. 1781 (b)] in conformance with applicable statutes, regulations, policy and land use plan.

The results of the No Project / No Action Alternative would be the following:

- The impacts of the proposed project would not occur. However, the land on which the project is proposed would become available to other uses that are consistent with BLM's land use plan, including another solar project.
- The benefits of the proposed project in reducing greenhouse gas emissions from gas-fired generation would not occur. Both State and Federal law support the increased use of renewable power generation.

If this project is not approved, renewable projects would likely be developed on other sites in the Mojave Desert or in adjacent states as developers strive to provide renewable power that complies with utility requirements and State/Federal mandates. For example, there are three large solar projects proposed on BLM land in Nevada within a few miles of the Ivanpah site. In addition, there are currently 66 applications for solar projects covering 611,692 acres pending with BLM in the California Desert District.

CUMULATIVE IMPACTS

A project may result in a significant adverse cumulative impact where its effects are cumulatively considerable. "Cumulatively considerable" means that the incremental effects of an individual project are significant when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects (California Code Regulation, Title 14, section 15130). NEPA states that cumulative effects can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR §1508.7).

There is the potential for substantial future development in the Ivanpah Valley area and throughout the southern California desert region. Analysis of cumulative impacts is based on data provided in the following maps and tables (see **Cumulative Scenario** section of this document):

- Cumulative Impacts Figure 1, Regional Renewable Applications;
- Cumulative Impacts Figure 2, Regional Renewable Applications (Detail);
- Cumulative Impacts Figure 3, Ivanpah Valley Existing and Future/Foreseeable Projects;
- Cumulative Impacts Table 1, Regional Renewable Energy Projects;
- Cumulative Impacts Table 2, Existing Development in the Ivanpah Valley; and
- Cumulative Impacts Table 3, Future Foreseeable Projects in the Ivanpah Valley Area.

Nearby power plant projects include the existing gas-fired, combined cycle Big Horn Generating Station near Primm, and the foreseeable potential for four proposed power plants consisting of the 300 MW GEN-3 photovoltaic (PV) solar energy project that would be immediately east of ISEGS on 4,160 acres, the 500 MW gas-fired combined cycle Ivanpah Energy Center near Primm, and two wind energy projects on Mountain Pass.

Staff believes that the construction and operation of ISEGS would not create indirect impacts (in the form of additional fuel consumption) that would not have otherwise occurred without this project. Because the ISEGS would consume significantly less natural gas than a typical natural gas-fired power plant, it should compete favorably in the California power market and replace fossil fuel burning power plants. The project would therefore not impact the cumulative amount of natural gas consumed for power generation. ISEGS would also utilize solar energy from a site that is currently not being harnessed for power production, as would the proposed GEN-3 PV project. Thus from an efficiency perspective, ISEGS would not contribute to a cumulatively considerable impact resulting in a less efficient utilization of the site's solar energy potential than is occurring currently.

NOTEWORTHY PUBLIC BENEFITS

The ISEGS would employ an advanced solar thermal technology. Solar energy is renewable and unlimited. The project would have less than significant adverse impact on nonrenewable energy resources (natural gas). Consequently, the project would help in reducing California's dependence on fossil fuel-fired power plants.

RESPONSES TO AGENCY AND PUBLIC COMMENTS

Staff has received the following agency and public comments regarding power plant efficiency.

Comments from Jenny Wilder (letter dated January 14, 2009): Where is the demand/need for the power to be produced by this project? How much electrical power is 400 megawatts? How many homes would that serve and where are those homes/businesses located? Can that amount of electric power (which requires water and natural gas) be produced more efficiently and without destroying habitat in some other way such as at the place of demand (houses or businesses)?

Staff's Response: One of the project objectives is to assist in increasing electrical generation from renewable energy in conformance with the state's policy. 400 MW of electricity can serve approximately 320,000 homes. Approximately five percent would be produced from natural gas. The quantities of natural gas used to generate this capacity would be insignificant compared to a typical natural gas plant of 400 MW. A solar power plant uses the renewable energy of sun. For the most part (95 percent of its capacity), ISEGS would use the sun's energy. Therefore, from an energy resources perspective, ISEGS would offer one the most efficient power plant technologies

available. Placing the plant near the demand center may mean placing it in populated areas, where the large open lands necessary for a solar power plant may not be available.

Comment from Basin Range and Watch (letter dated January 31, 2009): For the natural gas-fired start-up boiler- What percentage of the megawatts would be from natural gas?

Staff's Response: Approximately five percent of ISEGS annual generation would be produced from natural gas.

CONCLUSIONS AND RECOMMENDATIONS

FOSSIL FUEL ENERGY USE

The Ivanpah SEGS, if constructed and operated as proposed, would use solar energy to generate up to 95 percent of its capacity, and natural gas to generate up to five percent of its capacity. The project would decrease reliance on fossil fuel, and would increase reliance on renewable energy resources. It would not create significant adverse effects on energy supplies or resources, would not require additional sources of energy supply, and would not consume energy in a wasteful or inefficient manner. No energy standards apply to this project. Staff therefore concludes that this project would present no significant adverse impacts on energy resources.

No cumulative impacts on energy resources are likely. Facility closure would not likely present significant impacts on electric system efficiency.

LAND USE AND SOLAR RESOURCE UTILIZATION

The ISEGS, if constructed and operated as proposed, would occupy over nine acres per MW of power output, a figure about double that of some other solar power technologies. Employing a less land-intensive solar technology, such as the Compact Linear Fresnel Reflector technology or linear parabolic trough technology, would potentially reduce land-related impacts by approximately 50 percent. However, staff recognizes there is a wide range of environmental issues to analyze to compare the merits and impacts of one technology compared to another. This is done in more detail in the **Alternatives** section of this document. In conclusion, ISEGS would utilize solar energy potential from a site that is currently not being harnessed for power production. Thus from an efficiency perspective, ISEGS would not result in a less efficient utilization of the site's solar energy potential than is occurring currently.

MITIGATION MEASURES/PROPOSED CONDITIONS OF CERTIFICATION

No conditions of certification are proposed.

REFERENCES

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CH2ML2009f – CH2M HILL / J. Carrier (tn 51597). Data Response Set 2I – Project Description and Stormwater Plans. Dated on 05/18/2009. Submitted to CEC / J. Kessler on 05/18/2009.

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EFFICIENCY Appendix A

Solar Power Plant Efficiency Calculation
Gas-Fired Proxy

In calculating the efficiency of a solar power plant, it is desired to subtract the effect of natural gas burned for morning startup, cloudy weather augmentation and Therminol freeze protection. As a proxy, we will use an average efficiency based on several recent baseload combined cycle power plant projects in the Energy Commission siting process. Baseload combined cycles were chosen because their intended dispatch most nearly mirrors the intended dispatch of solar plants, that is, operate at full load in a position high on the dispatch authority's loading order.

The most recent such projects are:

Colusa Generating Station (06-AFC-9)
Nominal 660 MW 2-on-1 Combined Cycle with GE Frame 7FA CGTs
Air cooled condenser, evaporative inlet air cooling
Efficiency with duct burners on: 666.3 MW @ 52.5% LHV
Efficiency with duct burners off: 519.4 MW @ 55.3% LHV
Efficiency (average of these two): **53.9% LHV**

San Gabriel Generating Station (07-AFC-2)
Nominal 696 MW 2-on-1 Combined Cycle with Siemens 5000F CGTs
Air cooled condenser, evaporative inlet air cooling
Efficiency with duct burners on: 695.8 MW @ 52.1% LHV
Efficiency with duct burners off: 556.9 MW @ 55.1% LHV
Efficiency (average of these two): **53.6% LHV**

KRCD Community Power Plant (07-AFC-7)
Nominal 565 MW 2-on-1 Combined Cycle with GE or Siemens F-class CGTs
Evaporative cooling, evaporative or fogging inlet air cooling
Efficiency with GE CGTs: 497 MW @ 54.6% LHV
Efficiency with Siemens CGTs: 565 MW @ 56.1% LHV
Efficiency (average of these two): **55.4% LHV**

Avenal Energy (08-AFC-1)
Nominal 600 MW 2-on-1 Combined Cycle with GE Frame 7FA CGTs
Air cooled condenser, inlet air chillers
Efficiency with duct burners on: 600.0 MW @ 50.5% LHV
Efficiency with duct burners off: 506.5 MW @ 53.4% LHV
Efficiency (average of these two): **52.0% LHV**

Average of these four power plants: **53.7% LHV**