Appendix M Greenhouse Gas Emissions Technical Appendix

This appendix documents the technical analysis of greenhouse gas (GHG) emissions to support the impact analysis in the *Environmental Impact Statement* (EIS).

M.1 Background Information

This section presents an overview of the greenhouse effect and climate change, and potential sources of GHG emissions and information related to climate change and GHG emissions in California. GHG emissions and their climate-related impacts are not limited to specific geographic locations, but occur on global or regional scales. GHG emissions contribute cumulatively to the overall heat-trapping capability of the atmosphere, and the effects of the warming, such as climate change, are manifested in different ways across the planet.

M.1.1 Greenhouse Gas Emissions Regulations and Analyses

Global warming is the name given to the increase in the average temperature of the Earth's near-surface air and oceans since the mid-twentieth century and its projected continuation. Warming of the climate system is now considered to be unequivocal (California Department of Water Resources [DWR] 2010) with global surface temperature increasing approximately 1.33 degrees Fahrenheit (°F) over the last 100 years. Continued warming is projected to increase global average temperature between 2°F and 11°F over the next 100 years.

The causes of this global warming have been identified as both natural processes and as the result of human actions. The Intergovernmental Panel on Climate Change (IPCC) concludes that variations in natural phenomena such as solar radiation and volcanoes produced most of the warming from pre-industrial times to 1950 and had a small cooling effect afterward. However, the IPCC has concluded that human influence has warmed the global climate system after 1950, and that solar forcing, volcanoes, and internal variability are no longer the strongest drivers of warming (IPCC 2013). These basic conclusions have been endorsed by more than 45 scientific societies and academies of science, including all of the national academies of science of the major industrialized countries.

Increases in GHG concentrations in the Earth's atmosphere are thought to be the main cause of human-induced climate change. GHGs naturally trap heat by impeding the exit of solar radiation that has hit the Earth and is reflected back into space. Some GHGs occur naturally and are necessary for keeping the Earth's surface inhabitable. However, increases in the concentrations of these gases in the atmosphere during the last 100 years have decreased the amount of solar radiation that is reflected back into space, intensifying the natural greenhouse effect and resulting in the increase of global average temperature (DWR 2010).

The principal GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs), in accordance with the California Health and Safety Code Section 38505(g) (DWR 2010). This EIS considers only CO_2, CH_4, and N_2O because the project has no sources of SF_6, PFCs, or HFCs. Each of the principal GHGs has a long atmospheric lifetime (1 year to several thousand years). In addition, the potential heat-trapping ability of each of these gases varies significantly from one another, and vary over time. For example, CH_4 is 30 times as potent as CO_2, while SF_6 is 23,500 times more potent than CO_2 with a 100-year time horizon (IPCC 2013).

For calculating emissions, the California Air Resources Board (ARB) (2018) uses a metric developed by the IPCC to account for these differences and to provide a standard basis for calculations. The metric, called the global warming potential (GWP), is used to compare the future climate impacts of emissions of various long-lived GHGs. The GWP of each GHG is indexed to the heat-trapping capability of CO_2, and allows comparison of the global warming influence of each GHG relative to CO_2. The GWP is used to translate emissions of each GHG to emissions of carbon dioxide equivalents, or CO_2e. In this way, emissions of various GHGs can be summed, and total GHG emissions can be inventoried in common units of metric tons per year of CO_2e. Most international inventories, including the United States inventory, use GWP values from the IPCC Fourth Assessment Report, per international consensus (IPCC 2007; U.S. Environmental Protection Agency [USEPA] 2012).

The primary human-made processes that release these GHGs are the burning of fossil fuels for transportation, heating, and electricity generation; agricultural practices that release CH_4, such as livestock grazing and crop residue decomposition; and industrial processes that release smaller amounts of high GWP gases such as SF_6, PFCs, and HFCs (DWR 2010). Deforestation and land cover conversion have also been identified as contributing to global warming by reducing the Earth's capacity to remove CO_2 from the air and altering the Earth's albedo or surface reflectance, allowing more solar radiation to be absorbed.

M.1.2 Overview of the Greenhouse Effect

The greenhouse effect is a natural phenomenon that is essential to keeping the Earth's surface warm (DWR 2010). Like a greenhouse window, GHGs allow sunlight to enter and then prevent heat from leaving the atmosphere. Solar radiation enters the Earth's atmosphere from space. A portion of this radiation is reflected by particles in the atmosphere back into space, and a portion is absorbed by the Earth's surface and emitted back into space. The portion absorbed by the Earth's surface and emitted back into space is emitted as lower-frequency infrared radiation. This infrared radiation is absorbed by various GHGs present in the atmosphere. While these GHGs are transparent to the incoming solar radiation, they are effective at absorbing infrared radiation emitted by the Earth's surface. Therefore, some of the lower-frequency infrared radiation emitted by the Earth's surface is retained in the atmosphere, creating a warming of the atmosphere.

M.1.2.1 *Global Climate Trends and Associated Impacts*

The rate of increase in global average surface temperature over the last 100 years has not been consistent (DWR 2010). The last three decades have warmed at a much faster rate than the previous seven decades—on average 0.32°F per decade. Nine of the 10 warmest years have occurred since 2005, with the last 5 years (2014–2018) ranking as the 5 warmest years on record (National Oceanic and Atmospheric Administration 2019).

Increased global warming has occurred concurrently with many other changes in other natural systems (DWR 2010). Global sea levels have risen on average 1.8 millimeters per year; precipitation patterns throughout the world have shifted, with some areas becoming wetter and while others become drier; tropical storm activity in the North Atlantic has increased; peak runoff timing of many glacial and snowfed rivers has shifted earlier; as well as numerous other observed conditions. Though it is difficult to prove a definitive cause and effect relationship between global warming and other observed changes to natural systems, there is high confidence in the scientific community that these changes are a direct result of increased global temperatures.

M.1.2.2 *Overview of Greenhouse Gas Emission Sources*

Naturally occurring GHGs include water vapor, CO_2, CH_4, and N_2O. Water vapor is introduced to the atmosphere from oceans and the natural biosphere. Water vapor introduced directly to the atmosphere from agricultural or other activities is not long lived, and thus does not contribute substantially to a warming effect (National Academy of Sciences 2005). Carbon and nitrogen contained in CO_2, CH_4, and N_2O naturally cycle from gaseous forms to organic biomass through processes such as plant and animal respiration and seasonal cycles of plant growth and decay (USEPA 2012). Although naturally occurring, the emissions and sequestration of these gases are also influenced by human activities, and in some cases, are caused by human activities (anthropogenic). In addition to these GHGs, several classes of halogenated substances that contain fluorine, chlorine, or bromine also contribute to the greenhouse effect. However, these compounds are the product of industrial activities for the most part.

CO_2 is a byproduct of burning fossil fuels and biomass, as well as land-use changes and other industrial processes (USEPA 2012). It is the principal anthropogenic GHG that contributes to the Earth's radiative balance, and it represents the dominant portion of GHG emissions from activities that result from the combustion of fossil fuels (e.g., industry, electrical generation, and transportation).

M.1.3 California Climate Trends and Greenhouse Gas Emissions

Maximum (daytime) and minimum (nighttime) temperatures are increasing almost everywhere in California but at different rates. The annual minimum temperature averaged over all of California has increased 0.33°F per decade during the period 1920 to 2003, while the average annual maximum temperature has increased 0.1°F per decade (DWR 2010).

With respect to California's water resources, the most significant impacts of global warming have been changes to the water cycle and sea-level rise. Over the past century, the precipitation mix between snow and rain has shifted in favor of more rainfall and less snow, and snow pack in the Sierra Nevada is melting earlier in the spring (DWR 2010). The average early spring snowpack in the Sierra Nevada has decreased by about 10% during the last century, a loss of 1.5 million acre-feet of snowpack storage. These changes have significant implications for water supply, flooding, aquatic ecosystems, energy generation, and recreation throughout the state.

During the same period, sea levels along California's coast have risen. The Fort Point tide gauge in San Francisco was established in 1854 and is the longest continually monitored gauge in the United States. Sea levels measured at this gauge and two other West Coast gauges indicate that the sea levels have risen at an average rate of about 7.9 inches/century (0.08 inch/year) over the past 150 years (Bay Conservation and Development Commission 2011). Continued sea-level rise associated with global warming may threaten coastal lands and infrastructure, increase flooding at the mouths of rivers, place additional stress on levees in the Sacramento–San Joaquin Delta (Delta), and intensify the difficulty of managing the Delta as the heart of the state's water supply system (DWR 2010).

M.1.3.1 *Potential Effects of Global Climate Change in California*

Warming of the atmosphere has broad implications for the environment. In California, one of the effects of climate change could be increases in temperature that could affect the timing and quantity of precipitation. California receives most of its precipitation in the winter months, and a warming environment would raise the elevation of snow pack and result in reduced spring snowmelt and more winter runoff. These effects on precipitation and water storage in the snow pack could have broad implications on the environment in California.

The following are some of the potential effects of a warming climate in California (California Climate Change Portal 2007):

- Loss of snowpack storage will cause increased winter runoff that generally would not be captured and stored because of the need to reserve flood capacity in reservoirs during the winter.
- Less spring runoff would mean lower early summer storage at major reservoirs, which would result in less hydroelectric power production.
- Higher temperatures and reduced snowmelt would compound the problem of providing suitable cold water habitat for salmonid species. Lower reservoir levels would also contribute to this problem, reducing the flexibility of cold water releases.
- Sea-level rise would affect the Delta, worsening existing levee problems, causing more saltwater intrusion, and adversely affecting many coastal marshes and wildlife reserves. Release of water to streams to meet water quality requirements could further reduce storage levels.
- Increased temperatures would increase the agricultural demand for water and increase the level of stress on native vegetation, potentially allowing for an increase in pest and insect epidemics and a higher frequency of large, damaging wildfires.

Future climate scenarios have also been evaluated in the U.S. Global Change Research Program National Climate Assessments. The most recent assessment, *Fourth National Climate Assessment Volume II: Impacts, Risks, and Adaptation in the United States*, was released in 2018 (U.S. Global Change Research Program 2018). For the southwest region of the United States (defined by the National Climate Assessment as Arizona, California, Colorado, Nevada, New Mexico, and Utah), the report projects that water supply availability would be reduced compared to recent conditions due to reduced snowpack and declining stream flows. Rising temperatures in the future would increase disruptions to electricity generation, which could further reduce water availability. The National Climate Assessment also indicates that mitigation policies and other factors have lowered the United States' nationwide GHG emissions in recent years; however, substantial global emissions reductions are needed to avoid many of the predicted consequences. A considerable amount of planning for resilience and adaptation is underway, but implementation of adaptive measures has been limited in scope.

M.1.3.2 *Current California Emission Sources*

The recent California's GHG emission inventory was released on July 11, 2018. The GHG emissions in California have been estimated for each year from 2000 to 2016, and are reported for several large sectors of emission sources. The estimates for 2016 are summarized in Table M.1-1, reported by sector as metric tons per year of CO_2e (ARB 2018).

Table M.1-1 California Greenhouse Gas Emissions by Sector in 2016

Sector	Total Emissions[1] (metric tons/year of CO_2e)	Percent of Statewide Total Gross Emissions
Agriculture and Forestry	33.84	8
Commercial and Residential	51.28	12
Electric Power	68.95	16
Industrial	100.37	23
Transportation	174.01	41
Solvents and Chemicals[2]	0.79	<1
Total	429.4	100

Source: ARB 2018.

[1] Table includes human-caused GHG emissions only.

[2] Solvents and chemical use are not attributed to an individual sector.

CO_2e = carbon dioxide equivalent

Total gross statewide GHG emissions in 2016 were estimated to be 429.4 metric tons per year of CO_2e. The two largest sectors contributing to emissions in California are transportation and industrial. The agricultural sector represents only 8% of the total gross statewide emissions. The agricultural sector includes manure management, enteric fermentation, agricultural residue burning, and soils management.

The California Global Warming Solutions Act of 2006 (California Assembly Bill [AB] 32) requires California to reduce statewide emissions to 1990 levels by 2020. Executive Order EO B-30-15, signed by Governor Jerry Brown in 2015, established a goal for 2030 of reducing GHG emissions by 40% below 1990 levels.

In December 2007, in accordance with AB 32, ARB adopted an emission limit for 2020 of 427 metric tons per year of CO_2e. Increases in the statewide renewable energy portfolio and reductions in importation of coal-based electrical power will contribute to meeting California's near-term GHG emission reduction goals. The ARB estimates that a reduction of 82 million metric tons net CO_2e emissions below the business-as-usual would be required by 2020 to meet the 1990 levels (ARB 2018). This amounts to approximately a 16% reduction from projected business-as-usual levels in 2020.

M.2 Evaluation of Alternatives

This section describes the technical background for the evaluation of environmental consequences associated with the action alternatives and the No Action Alternative.

M.2.1 Methods and Tools

Potential GHG emissions impacts were assessed for each component of each alternative. Where possible, the direction (positive or negative effect on GHG emissions) and magnitude of change were identified. The predominant potential effect is changes in GHG emissions from fossil-fueled powerplants. The primary actions that could affect GHG emissions are described in this section.

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

The action alternatives would change operations of the Central Valley Project (CVP) and State Water Project (SWP), which could change river flows and reservoir levels. These changes could affect the amount of power the hydroelectric facilities in the system could generate. Where flows increase on rivers that have hydroelectric facilities then hydropower generation could increase. The additional hydroelectric power is expected to displace power that must be purchased from suppliers connected to the regional electric system (grid). To the extent that the displaced power would have been generated by fossil-fueled powerplants, emissions of GHGs from these plants would decrease. (In 2016, approximately 50% of grid electricity in California was generated by fossil-fueled plants [USEPA 2018].) Conversely, if hydropower generation decreases, the decrease must be offset by purchased power from the grid to meet demand for power. To the extent that the additional purchased power would have been generated by fossil-fueled powerplants, GHG emissions from these plants would increase.

Operations of the CVP and SWP also entail transfers of water. Many, but not all, transfers require water to be pumped. For those transfers that require pumping, changes in the quantities of water transferred could affect GHG emissions by changing the amount of electricity required. If the amount of water transferred increases, the electrical energy required for pumping also would increase. To the extent that the increased electricity would be purchased from the grid and would be generated by fossil-fueled powerplants, GHG emissions from these plants would increase. Conversely, if the amount of water transferred decreases, the electrical energy required for pumping also would decrease. To the extent that the amount of purchased electricity that is generated by fossil-fueled powerplants decreases, GHG emissions from these plants would decrease. Under Alternatives 1, 2, 3, and 4, the quantities of water transferred would be the same as under the No Action Alternative. Consequently, there would be no change in GHG emissions associated with water transfers.

GHG emissions from fossil-fueled powerplants resulting from changes in hydropower generation (including power required for water transfers), and consequently in the demand for grid power, were evaluated. Emissions of the principal GHGs (CO_2, CH_4, and N_2O) were reported as well as the CO_2e emissions for each alternative, consistent with the USEPA GHG inventory. For the details of the power modeling on which the GHG emission analysis was based, see Appendix U, *Power Technical Appendix*. The power modeling estimated energy usage in terms of *net generation*, defined as the difference between the amount of electricity generated by CVP/SWP hydropower facilities and the amount of electricity used by CVP/SWP for water transfers and facility operations. A positive value for net generation means that CVP/SWP generated more power than it used, and the excess was sold to the grid. A negative value for net generation means that CVP/SWP used more power than it generated, and offset the deficit by purchasing the additional power from the grid. Table M.2-1 summarizes the results of the power modeling and shows the estimated net generation for each alternative for a long-term average year. The GHG emissions calculations reflect net generation for the entire CVP/SWP system, as shown in the last line in the table.

Table M.2-1 Summary of Power Modeling Results

Facilities	Energy Component	Energy (Gigawatt-hours per average year)				
		No Action	Alt 1	Alt 2	Alt 3	Alt 4
CVP	Energy Generation[1]	4,533	4,539	4,609	4,610	4,489
	Energy Use[2]	1,207	1,322	1,420	1,415	1,117
	Net Generation[3]	3,326	3,217	3,189	3,195	3,372
SWP	Energy Generation[1]	4,074	4,349	4,679	4,658	3,971
	Energy Use[2]	7,304	8,377	9,630	9,557	6,972
	Net Generation[3]	-3,230	-4,028	-4,951	-4,898	-3,001
Total	Energy Generation[1]	8,607	8,888	9,288	9,269	8,459
	Energy Use[2]	8,511	9,698	11,050	10,972	8,088
	Net Generation[3]	96	-810	-1,762	-1,703	371

Source: Appendix U: Power Technical Appendix.

[1] Hydropower generated

[2] Energy used for facility operation and water transfers

[3] Net generation equals hydropower generation minus energy use. Net generation of zero would indicate that hydropower generation exactly equals energy use. Negative net generation values indicate that energy use exceeds energy generation and the additional energy needed is purchased from the grid. Positive net generation values indicate that energy generation exceeds energy use and the additional energy generated is sold to the grid.

Alt = Alternative
CVP = Central Valley Project
SWP = State Water Project
1 gigawatt-hour = 1,000 megawatt-hours = 1,000,000 kilowatt-hours

The changes in annual net generation estimated by the power modeling were multiplied by emission factors (mass of GHG emitted per unit of energy generated) to derive annual emissions. Emission factors for GHGs were obtained from USEPA eGRID model and represent averages for the California statewide mix of powerplants in 2016, which is the most recent year of data available (USEPA 2018). Table M.2-2 lists the emission factors that were used in the GHG emission analysis.

Table M.2-2 Emission Factors Used in GHG Emission Analysis

Pollutant	Electric Generation (lb/Mwh)	Diesel Pump Engines (g/hp-hr)
CO_2	452.541	568.299
CH_4	0.026	0.038
N_2O	0.003	0.0038
CO_2e	454.085	570.372

Sources: USEPA 2018; South Coast Air Quality Management District (SCAQMD) 2017.

g/hp-hr = grams per horsepower-hour
lb/Mwh = pounds per megawatt-hour
CO_2 = carbon dioxide
CH_4 = methane
N_2O = nitrous oxide
CO_2e = carbon dioxide equivalent

Table M.2-3 shows the estimated GHG emissions from fossil-fueled grid powerplants associated with net generation, based on the net generation values given in Table M.2-1. Figure M.2-1, *GHG Emissions from*

Grid Power Generation, and Figure M.2-2, *Changes in GHG Emissions from Grid Power Generation Compared to the No Action Alternative*, show the emissions of CO_2e for grid power generation and the changes compared to the No Action Alternative, respectively.

Table M.2-3 GHG Emissions from Net Generation

Pollutant	Emissions (metric tons per average year)				
	No Action	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
CO_2	-19,773.8	166,348.9	361,605.9	349,615.7	-76,113.0
CH_4	-1.1	9.6	20.8	20.1	-4.4
N_2O	-0.1	1.1	2.4	2.3	-0.5
CO_2e	-19,841.2	166,916.5	362,839.6	350,808.6	-76,372.7

Values represent the GHG emissions effects of net generation, that is, CVP/SWP hydropower generation minus CVP/SVP energy use. Emissions of zero would indicate that CVP/SWP hydropower generation exactly equals CVP/SWP energy use. Negative emission values indicate decreases in GHG emissions because net generation is positive and displaces grid power; positive emission values indicate increases in GHG emissions because net generation is negative and CVP/SWP purchases the needed power from the grid.
Alt = Alternative
CO_2 = carbon dioxide
CH_4 = methane
N_2O = nitrous oxide
CO_2e = carbon dioxide equivalent

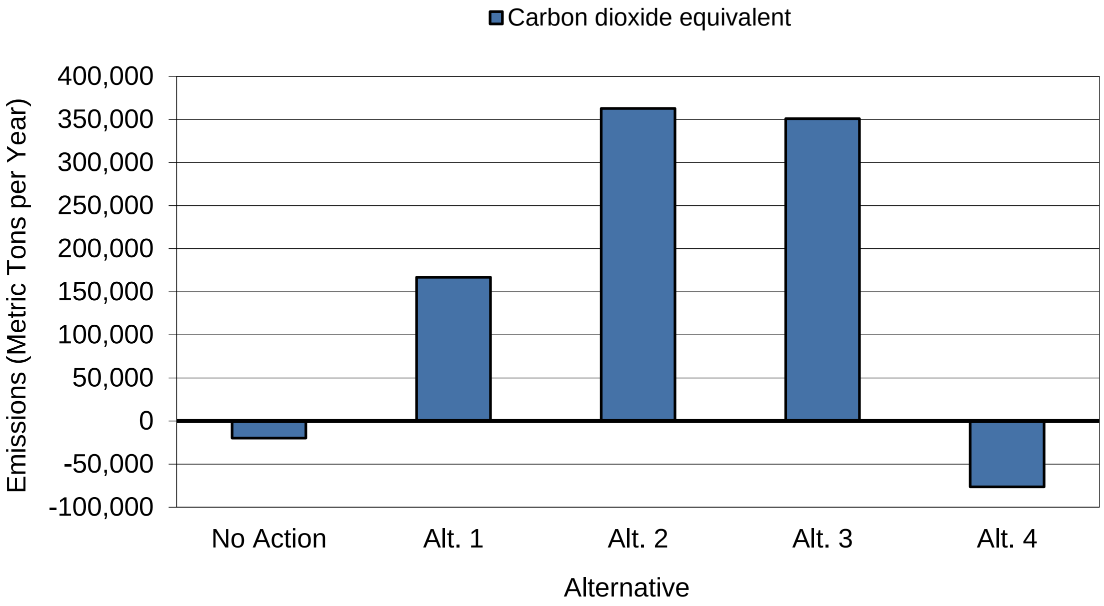

Figure M.2-1 GHG Emissions from Grid Power Generation

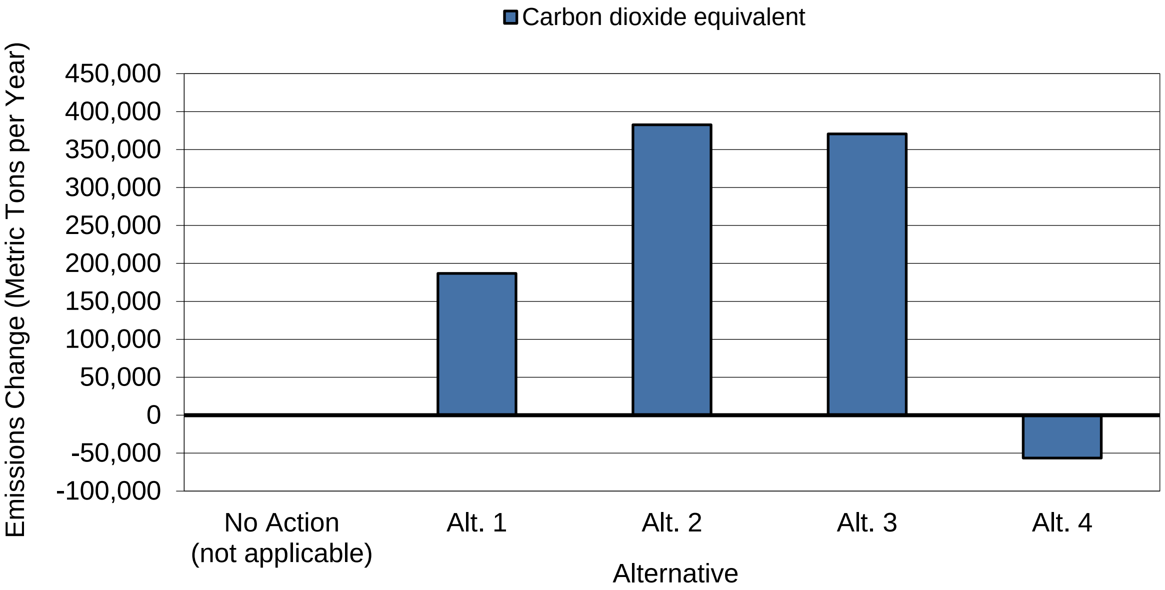

Figure M.2-2 Changes in GHG Emissions from Grid Power Generation Compared to the No Action Alternative

Under Alternative 1 in an average year, net generation would decrease compared to the No Action Alternative, as shown in Table M.2-1. As a result, GHG emissions from fossil-fueled grid powerplants would increase, as shown in Table M.2-3. Under Alternative 2 in an average year, net generation would decrease more than under Alternative 1 and GHG emissions would increase more. The GHG emissions increase under Alternative 2 would be roughly twice that under Alternative 1, compared to the No Action Alternative. Under Alternative 3 in an average year, net generation would decrease and GHG emissions would increase compared to the No Action Alternative. The GHG emissions increases under Alternative 3 would be greater than under Alternative 1 but less than under Alternative 2. In contrast with the other action alternatives, under Alternative 4 in an average year, net generation would increase compared to the No Action Alternative. As a result, GHG emissions from fossil-fueled grid powerplants would decrease.

Potential changes in emissions from fossil-fueled powerplants (groundwater pumping)

The action alternatives would change operation of the CVP and SWP, which could change river flows and reservoir levels. These changes could affect the amount of water available for agricultural irrigation. If surface water availability decreases, farmers could make up the difference in water supply by increasing groundwater pumping. Approximately 85% of groundwater pumps are electric (U.S. Department of Agriculture [USDA] 2014), so increased pumping would increase the demand for grid power. To the extent that the additional purchased power would be generated by fossil-fueled powerplants, GHG emissions from these plants would increase. Although the specific power purchases that the CVP and SVP may make in the future are not known, approximately 50% of the grid electricity in California was generated by fossil-fueled plants in 2016. Approximately 15% of groundwater pumps are powered by engines (USDA 2014), so increased use of these pumps would increase GHGs from engine exhaust emissions. Conversely, if surface water availability increases, farmers could decrease the amount of groundwater they pump, which would lead to a decrease in GHG emissions.

GHG emissions from the fossil-fueled powerplants (for electrically-powered pumps) and GHG emissions from engines (for engine-powered pumps) resulting from changes in groundwater pumping were evaluated. Emissions of the principal GHGs (CO_2, CH_4, and N_2O) were reported as well as the CO_2e emissions for each alternative, consistent with the USEPA GHG inventory. For the details of the groundwater modeling on which the GHG emission analysis was based, see Appendix I, *Groundwater Technical Appendix*. The groundwater modeling estimated that for a long-term average year, the quantities of water pumped would be 7,111,000 acre-feet under the No Action Alternative, 6,847,000 acre-feet under Alternative 1, 6,577,000 acre-feet under Alternative 2, 6,598,000 acre-feet under Alternative 3, and 7,137,000 acre-feet under Alternative 4.

The quantities of water pumped estimated by the groundwater modeling were converted to the amounts of energy required and the result was multiplied by emission factors to derive annual GHG emissions. The amount of energy required to pump water varies widely due to several factors, among them: the depth to groundwater (i.e., the amount of lift) that the pump has to overcome, which varies greatly spatially; the design of the well; the efficiency of the pump engine or motor; and the efficiency of the pump itself. A reasonable range for the average amount of energy required in California is 400 to 1,200 kilowatt-hours per acre-foot (Kwh/ac-ft) (CEC 2015). For this analysis the midpoint of the range (800 Kwh/ac-ft) was assumed.

For an electric pump, the energy requirement of 800 Kwh/ac-ft represents the electricity usage at the pump motor. There are energy losses in the electric distribution system from the powerplant to the motor, so that to deliver a particular amount of energy to the pump, the powerplant must generate slightly more energy. The California statewide average loss rate is approximately 4.23% (USEPA 2018). The energy requirements for electric pumps were adjusted by this percentage for this analysis. The resulting GHG emissions from fossil-fueled powerplants were calculated in the same way as explained above, using the number of acre-feet of water pumped, the adjusted energy requirement, the fraction of pumps that are electric (85%), and the emission factors listed in Table M.2-2.

For an engine-powered pump, the energy requirement of 800 Kwh/ac-ft represents the energy supplied to the pump by the engine, and is expressed in horsepower-hours per acre-foot (hp-hr/ac-ft). As noted above, approximately 15% of groundwater pumps are powered by engines: 13% diesel-fueled and 2% fueled by natural gas, LP gas, propane, and butane (USDA 2014). Of these fuels, diesel generally has the highest GHG emissions, so to produce a conservative (high) estimate of GHG emissions all engine-powered pumps were assumed to be diesel-fueled.

Table M.2-4 shows the estimated energy usage for groundwater pumping. The energy requirements for pump engines are shown in two units: kilowatt-hours per year (Kwh/yr) (consistent with the unit for electric pumps), and horsepower-hours per year (hp-hr/yr) (consistent with the emission factor unit for engines).

Table M.2-4 Estimated Energy Usage for Groundwater Pumping

Energy Source	Unit	No Action	Alt 1	Alt 2	Alt 3	Alt 4
Electric pumps (energy at powerplant)	Kwh/yr	5,040,094,139	4,852,660,662	4,661,214,163	4,676,309,490	5,058,617,807
Pump engines (energy at pump)	Kwh/yr	853,332,416	821,598,275	789,184,693	791,740,465	856,468,637
	hp-hr/yr	1,144,318,770	1,101,763,286	1,058,296,673	1,061,723,963	1,148,524,442
Sum	Kwh/yr	5,893,426,556	5,674,258,937	5,450,398,855	5,468,049,955	5,915,086,444

Source: Appendix H, *Water Supply Technical Appendix*. Water quantities were converted to energy usage using an average rate of 800 Kwh/ac-ft (CEC 2015).
Alt = Alternative
Kwh/ac-ft = kilowatt-hours per acre-foot
Kwh/yr = kilowatt-hours per year
hp-hr/yr = horsepower-hours per year

The energy usage for groundwater pumping shown in Table M.2-4 was multiplied by the emission factors shown in Table M.2-2 to derive annual GHG emissions. Emission factors given in Table M.2-2 for engines were obtained from the ARB-approved CalEEMod model (SCAQMD 2017). CalEEMod provides emission factors specific to calendar year and horsepower range, and the values corresponding to 2019 and an average pump rating of 96 horsepower (USDA 2014) were used in this analysis.

Table M.2-5 shows the estimated GHG emissions from groundwater pumping. Figure M.2-3, GHG *Emissions from Groundwater Pumping*, and Figure M.2-4, *Changes in GHG Emissions from Groundwater Pumping Compared to the No Action Alternative*, show the CO_2e emissions and the changes compared to the No Action Alternative for groundwater pumping, respectively.

Table M.2-5 GHG Emissions from Groundwater Pumping

Pollutant	Emissions (metric tons per average year)				
	No Action	Alt 1	Alt 2	Alt 3	Alt 4
Electric Pumps					
CO_2	1,034,570	996,096	956,798	959,897	1,038,373
CH_4	59	57	55	55	60
N_2O	7	7	6	6	7
CO_2e	1,038,100	999,495	960,063	963,172	1,041,915
Diesel Pumps					
CO_2	650,315	626,131	601,429	603,377	652,705
CH_4	43	42	40	40	44
N_2O	4	4	4	4	4
CO_2e	652,687	628,415	603,622	605,577	655,086
Total Pumping Emissions[1]					
CO_2	1,684,886	1,622,227	1,558,227	1,563,274	1,691,078
CH_4	103	99	95	95	103
N_2O	11	11	10	10	11
CO_2e	1,690,787	1,627,909	1,563,685	1,568,749	1,697,001

[1] Sum of individual values may not equal total due to rounding.
Alt = Alternative
CO_2 = carbon dioxide
CH_4 = methane
N_2O = nitrous oxide

CO_2e = carbon dioxide equivalent

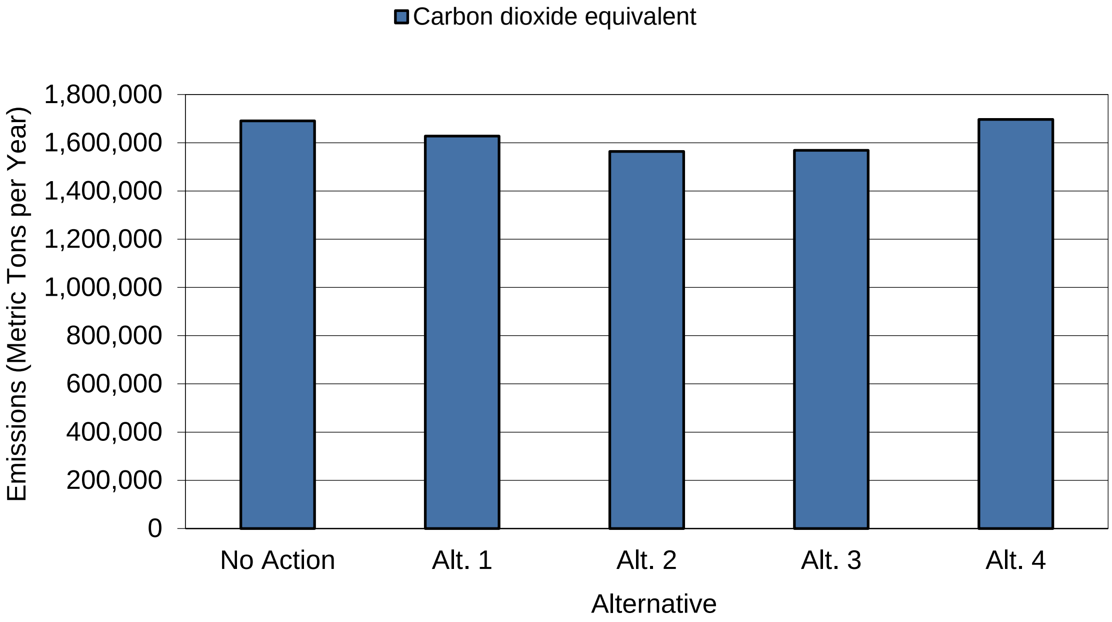

Figure M.2-3 GHG Emissions from Groundwater Pumping

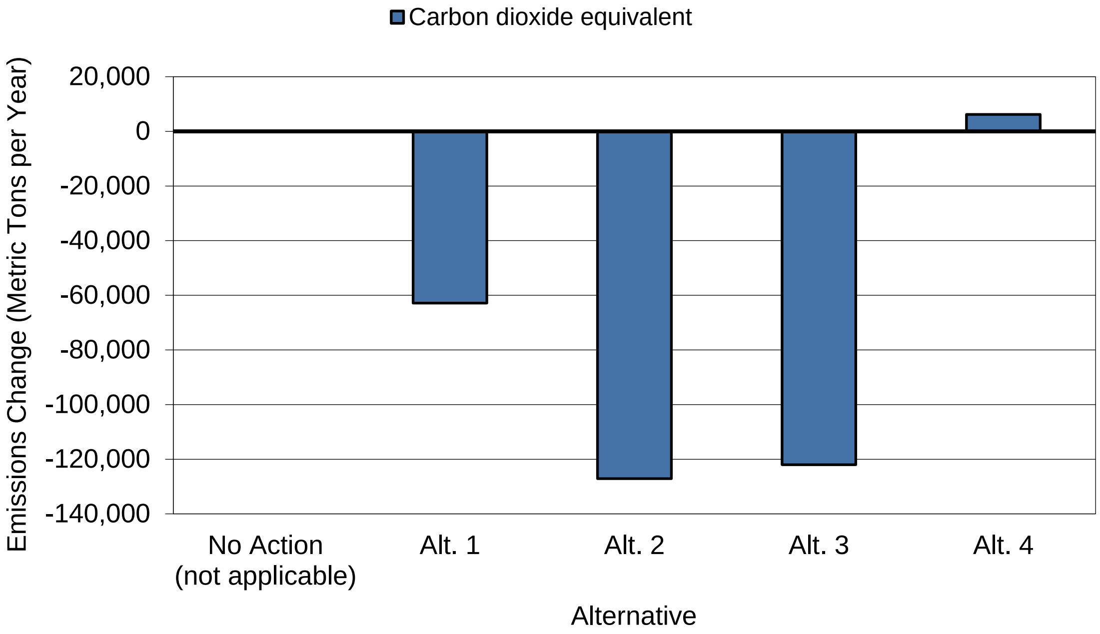

Figure M.2-4 Changes in GHG Emissions from Groundwater Pumping Compared to the No Action Alternative

Under Alternative 1 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated GHG emissions also would decrease, as shown in Table M.2-5. Under Alternative 2 in an average year, groundwater pumping and GHG emissions would decrease more than under Alternative 1. The GHG emissions decrease under Alternative 2 would be roughly twice that under Alternative 1, compared to the No Action Alternative. Under Alternative 3 in an average year, groundwater pumping and GHG emissions would decrease compared to the No Action Alternative. The GHG emissions decreases under Alternative 3 would be greater than under Alternative 1 but less than under Alternative 2. In contrast to the other action alternatives, under Alternative 4 in an average year, groundwater pumping would increase compared to the No Action Alternative. As a result, the associated GHG emissions also would increase.

The total GHG emissions associated with the project are the sum of the GHG emissions from net generation (Table M.2-3) and groundwater pumping (Table M.2-5). Table M.2-6 shows the estimated total project GHG emissions for a long-term average year. Figure M.2-5, *GHG Emissions from All Sources*, and Figure M.2-6, *Changes in GHG Emissions from All Sources Compared to the No Action Alternative*, show the overall CO_2e emissions for all emission sources, and the changes in CO_2e emissions compared to the No Action Alternative, respectively.

Table M.2-6 Total Project GHG Emissions

	Emissions (metric tons per average year)				
Pollutant	**No Action**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
CO_2	1,665,112	1,788,576	1,919,833	1,912,889	1,614,965
CH_4	102	109	116	116	99
N_2O	11	12	13	13	11
CO_2e	1,670,946	1,794,826	1,926,525	1,919,558	1,620,629

Values represent the sum of GHG emissions from fossil-fueled powerplants (for CVP/SWP purchases of grid power and for electrically-powered groundwater pumps) and GHG emissions from diesel engines (for engine-powered groundwater pumps).
Alt = Alternative
CO_2 = carbon dioxide
CH_4 = methane
N_2O = nitrous oxide
CO_2e = carbon dioxide equivalent

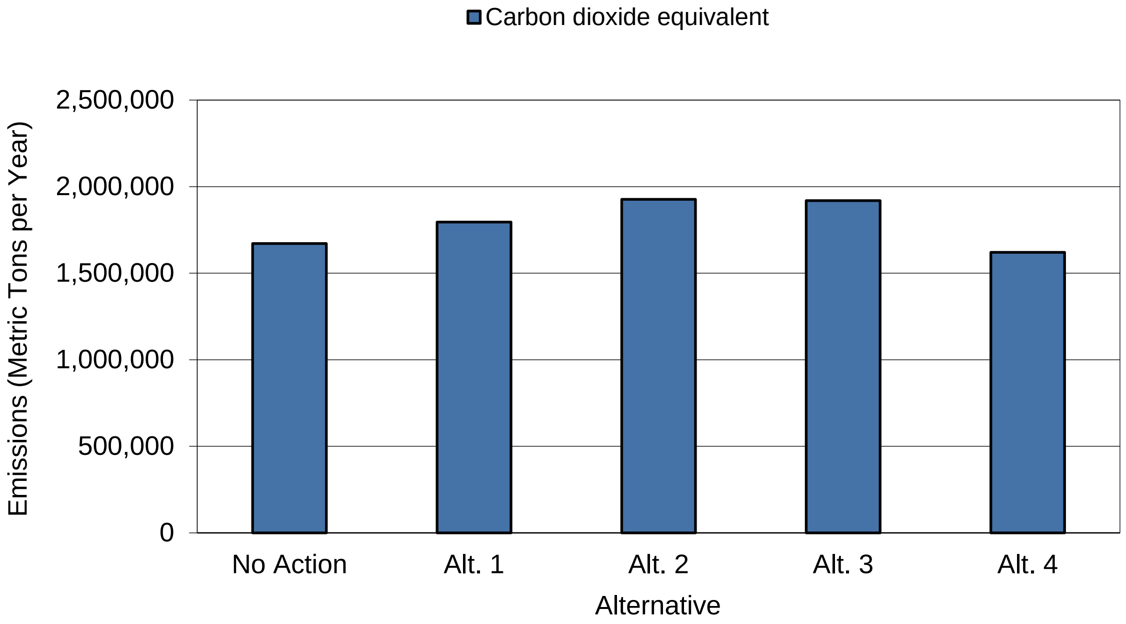

Figure M.2-5 GHG Emissions from All Sources

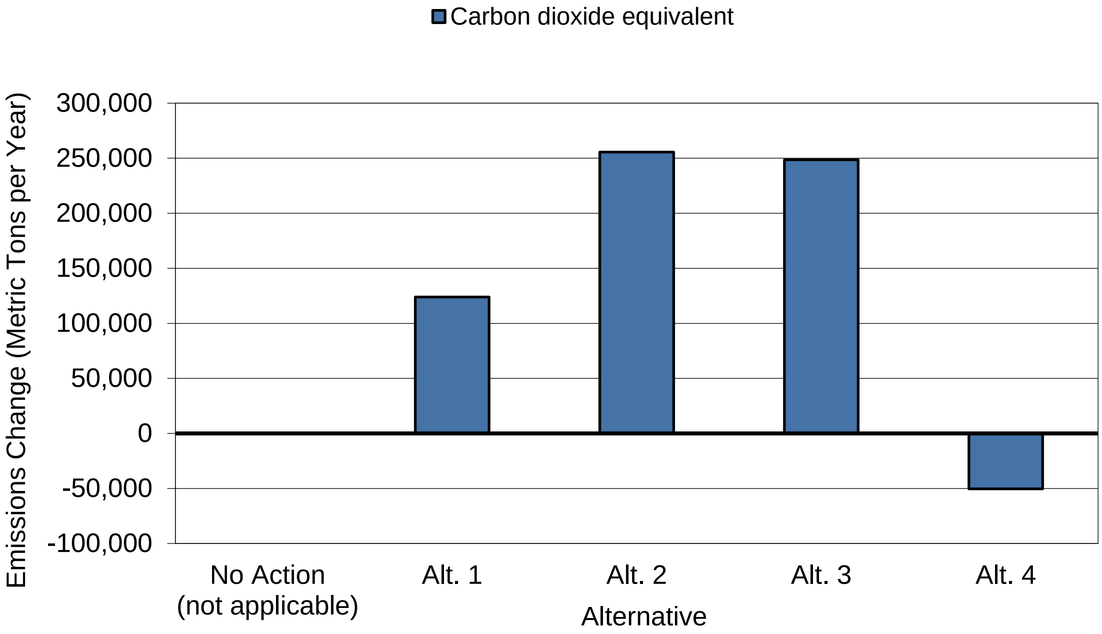

Figure M.2-6 Changes in GHG Emissions from All Sources Compared to the No Action Alternative

Under Alternative 1 in an average year, overall GHG emissions would increase compared to the No Action Alternative, as shown in Table M.2-6. Under Alternative 2 in an average year, GHG emissions would increase more than under Alternative 1. Under Alternative 3 in an average year, GHG emissions would increase compared to the No Action Alternative. The GHG emissions increases under Alternative 3 would be greater than under Alternative 1 but less than under Alternative 2. In contrast to the other action alternatives, under Alternative 4 in an average year, overall GHG emissions would decrease compared to the No Action Alternative.

Potential for exhaust GHG emissions from engines of construction equipment and vehicles

Because the details of construction and transport activities are unknown at present, construction-related impacts were assessed qualitatively. Construction activities would produce temporary increases in GHG emissions from the use of motorized construction equipment. These increases can be lessened through implementation of mitigation measures. Section M.2.7.2, *Construction*, provides a mitigation measure that could be implemented to reduce GHG emissions from construction.

M.2.2 No Action Alternative

Under the No Action Alternative, the actions described under Alternatives 1 through Alternative 4 would not take place. The CVP/SWP system would continue to be managed in accordance with current plans and programs. The population of the regional study area is expected to grow over time. Development in the region to accommodate the population growth, including residential, commercial, industrial, transportation, and other projects, would continue under the No Action Alternative and result in associated effects on GHG emissions. These effects would contribute to regional GHG emissions and global climate change. Climate change action plans and emission control programs administered by the state and the respective air quality management districts would remain in place to address GHG emission rates in the region and statewide.

M.2.3 Alternative 1

The potential effects on GHG emissions of Alternative 1 are described in the following sections.

M.2.3.1 *Project-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 1, CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce hydropower generation, leading to increases in grid power generation and the associated GHG emissions. Estimated increases in GHG emissions for an average year are included in Table M.2-3.

Actions in the upper Sacramento Trinity/Clear Creek, Feather River, American River, Stanislaus, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 1 in an average year, net generation would decrease compared to the No Action Alternative. As a result, GHG emissions from fossil-fueled powerplants would increase compared to the No Action Alternative, as shown in Table M.2-3.

If the Summer-Fall Delta Smelt Habitat action includes operations of the SMSCG or a Fall X2 action, the water requirements in summer and fall could be greater than estimated for Alternative 1. Increased water releases could increase the amount of hydropower generated and decrease the demand for grid electricity and the associated GHG emissions. Alternative 1 estimates increased GHG emissions compared to the No Action Alternative. In years with operations of the Suisun Marsh Salinity Control Gates (SMSCG) or a Fall X2 action, actual GHG emissions may be less than those estimated in Table M.2-3.

Fish intervention actions would not change the amount of hydropower generation, so there would be no change in GHG emissions due to these actions under Alternative 1.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions under Alternative 1.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated GHG emissions. Such GHG emission increases from these actions would be included within the overall decreases shown in Table M.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 1 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated GHG emissions also would decrease, as shown in Table M.2-5.

If the Summer-Fall Delta Smelt Habitat action includes operations of the SMSCG or a Fall X2 action, the water requirements in summer and fall could be greater than estimated for Alternative 1. Increased water releases could increase the amount of available irrigation water and lead to decreased groundwater pumping and the associated GHG emissions. Alternative 1 estimates decreased GHG emissions from groundwater pumping actions compared to the No Action Alternative. In years with operations of the SMSCG or a Fall X2 action, actual emissions may be less than those estimated in Table M.2-4.

Fish intervention actions would not change the amount of groundwater pumping, so there would be no change in GHG emissions due to these actions under Alternative 1.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions under Alternative 1.

Potential for exhaust GHG emissions from engines of construction equipment and vehicles

Under Alternative 1 there would be no construction associated with project-level actions, and therefore, no effects on GHG emissions.

M.2.3.2 *Program-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level effects on hydropower generation associated with actions under Alternative 1, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level effects on groundwater pumping associated with actions under Alternative 1, and therefore, no effects on GHG emissions.

Potential changes GHG emissions from fossil-fueled powerplants (water transfers)

There would be no program-level effects on water transfers associated with actions under Alternative 1, and therefore, no effects on GHG emissions.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Program-level actions that include construction or repair of facilities or the transport of fish or materials are proposed in the upper Sacramento River, American River, Stanislaus River, and San Joaquin River regions, as well as for habitat restoration, facility improvements, and fish intervention actions. The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate Best Management Practices (BMPs) are implemented. Section M.2.7.2 provides a list of typical BMPs that could be implemented as mitigation to reduce GHG emissions from construction.

There would be no program-level CVP/SWP-wide actions, and no program-level actions in the Trinity/Clear Creek, Feather River, and Bay-Delta regions.

M.2.4 Alternative 2

The potential effects on GHG emissions of Alternative 2 are described in the following sections.

M.2.4.1 *Project-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 2, CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of hydropower generated and increase the demand for grid electricity and the associated GHG emissions. Estimated increases in GHG emissions for an average year are included in Table M.2-3.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 2 in an average year, net generation would decrease compared to the No Action Alternative. As a result, GHG emissions from fossil-fueled powerplants would increase compared to the No Action Alternative, as shown in Table M.2-3.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region under Alternative 2.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated GHG emissions. Such GHG emission increases from these actions would be included within the overall decreases shown in Table M.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 2 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated GHG emissions also would decrease, as shown in Table M.2-5.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region under Alternative 2.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

Under Alternative 2, the quantity of water transferred would be the same as under the No Action Alternative, so there would be no change in GHG emissions associated with water transfers.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Under Alternative 2 there would be no construction associated with project-level actions, and therefore, no effects on GHG emissions.

M.2.4.2 *Program-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level actions under Alternative 2, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level actions under Alternative 2, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

There would be no program-level actions under Alternative 2, and therefore, no effects on GHG emissions.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

There would be no program-level actions under Alternative 2, and therefore, no effects on GHG emissions.

M.2.5 Alternative 3

The potential effects on GHG emissions of Alternative 3 are described in the following sections.

M.2.5.1 *Project-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 3, CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of hydropower generated and increase the demand for grid electricity and the associated GHG emissions. Estimated increases in GHG emissions for an average year are included in Table M.2-3.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 3 in an average year, net generation would decrease compared to the No Action Alternative. As a result, GHG emissions from fossil-fueled powerplants would increase compared to the No Action Alternative, as shown in Table M.2-3.

Fish intervention actions would not change the amount of hydropower generation, so there would be no change in GHG emissions due to these actions under Alternative 3.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions under Alternative 3.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated GHG emissions. Such GHG emission increases from these actions would be included within the overall decreases shown in Table M.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 3 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated GHG emissions also would decrease, as shown in Table M.2-5.

Fish intervention actions would not change the amount of groundwater pumping, so there would be no change in GHG emissions due to these actions under Alternative 3.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

Under Alternative 3, the quantity of water transferred would be the same as under the No Action Alternative, so there would be no change in GHG emissions associated with water transfers.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Under Alternative 3 there would be no construction associated with project-level actions, and therefore, no effects on GHG emissions.

M.2.5.2 *Program-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level effects on hydropower generation associated with actions under Alternative 3, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level effects on groundwater pumping associated with actions under Alternative 3, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

There would be no program-level effects on water transfers associated with actions under Alternative 3, and therefore, no effects on GHG emissions.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Program-level actions that include construction or repair of facilities or the transport of fish or materials are proposed in the upper Sacramento River, American River, Stanislaus River, and San Joaquin River regions, as well as for habitat restoration, facility improvements, and fish intervention actions. The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate BMPs are implemented. Section M.2.7.2 provides a list of typical BMPs that could be implemented as mitigation to reduce GHG emissions from construction.

There would be no program-level actions that include construction of facilities or the transport of fish or materials in the Bay-Delta regions.

There would be no program-level CVP/SWP-wide actions, and no program-level actions in the Trinity/Clear Creek or Feather River regions.

M.2.6 Alternative 4

The potential effects on GHG emissions of Alternative 4 are described in the following sections.

M.2.6.1 *Project-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 4, CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of hydropower generated and increase the demand for grid electricity and the associated GHG emissions. Such emissions increases from these actions would be included within the overall decreases in an average year, as shown in Table M.2-3.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 4 in an average year, net generation would increase compared to the No Action Alternative. As a result, GHG emissions from fossil-fueled powerplants would decrease compared to the No Action Alternative, as shown in Table M.2-3.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region under Alternative 4.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated GHG emissions. Estimated increases in emissions are included in Table M.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 4 in an average year, groundwater pumping would increase compared to the No Action Alternative. As a result, the associated GHG emissions also would increase, as shown in Table M.2-5.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region under Alternative 4.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

Under Alternative 4, the quantity of water transferred would be the same as under the No Action Alternative, so there would be no change in GHG emissions associated with water transfers.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Under Alternative 4 there would be no construction associated with project-level actions, and therefore, no effects on GHG emissions.

M.2.6.2 *Program-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level effects on hydropower generation associated with actions under Alternative 4, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level effects on groundwater pumping associated with actions under Alternative 4, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

There would be no program-level effects on water transfers associated with actions under Alternative 4, and therefore, no effects on GHG emissions.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Program-level actions to increase water use efficiency for CVP and SWP contractors south-of-Delta include construction actions. The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate BMPs are implemented. Section M.2.7.2 provides a list of typical BMPs that could be implemented as mitigation to reduce GHG emissions from construction.

There would be no program-level actions in the upper Sacramento, Trinity/Clear Creek, Feather River, American River, Stanislaus River, San Joaquin River, or Bay-Delta regions.

M.2.7 Mitigation Measures

M.2.7.1 *Energy*

Fossil-fueled powerplants are subject to the air quality permitting requirements of the air quality management district in which they are located. Permit conditions may include requirements to reduce or minimize GHG emissions. Under AB 32, California regulations require utility companies to ensure that one third of their electricity comes from the sun, the wind, and other renewable sources by 2030, a portion that will rise to 50% by 2030. Therefore, no additional mitigation is proposed for energy-related GHG emissions.

M.2.7.2 *Construction*

Mitigation Measure GHG-1: Minimize Potential Increases in GHG Emissions from Exhaust Associated with Construction Activities

BMPs are recommended to minimize potential increases in GHG emissions from exhaust associated with construction activities. The following are common BMPs that may be applicable depending on the activity and the equipment being used. These or similar practices are often required by air quality management districts and local jurisdictions to minimize construction impacts on GHG emissions.

1. Ensure that all equipment and vehicles are maintained regularly to meet manufacturer specifications to achieve efficient combustion and minimum emissions.
2. Ensure that all diesel engines are properly fueled (i.e., ultra-low sulfur diesel with a maximum 15 parts per million sulfur content).
3. Limit idling of engines to no more than 5 minutes unless necessary for proper operation.
4. Where feasible, use electric rather than engine-powered equipment. This may include using electric starting aids (such as block heaters) to warm engines.
5. Develop and implement a traffic management plan.
6. Where offsite traffic congestion is a concern, limit use of vehicles on public roads during peak traffic hours.
7. Where offsite traffic congestion is a concern, or to limit vehicle volumes traveling to remote sites, require workers to park in designated areas and provide shuttle buses to work sites.

M.2.8 Summary of Impacts

Table M.2-7 shows a summary of impacts and potential mitigation measures for consideration.

Table M.2-7. Impact Summary

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes in hydropower generation could affect GHG emissions from fossil-fueled powerplants (Project-Level)	No Action	No impact	-
	1	Increase in GHG emissions compared to No Action Alternative.	-
	2	Increase in GHG emissions compared to No Action Alternative. Greater increase than under Alternative 1.	-
	3	Increase in GHG emissions compared to No Action Alternative. Greater increase than under Alternative 1 but less than under Alternative 2.	-
	4	Decrease in GHG emissions compared to No Action Alternative.	-

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes in the amount of groundwater pumping could affect GHG emissions from fossil-fueled powerplants (Project-Level)	No Action	No impact	-
	1	Decrease in GHG emissions compared to No Action Alternative.	-
	2	Decrease in GHG emissions compared to No Action Alternative. Greater decrease than under Alternative 1.	-
	3	Decrease in GHG emissions compared to No Action Alternative. Greater decrease than under Alternative 1 but less than under Alternative 2.	-
	4	Increase in GHG emissions compared to No Action Alternative.	-
Potential changes in pumping for water transfers could affect GHG emissions from fossil-fueled powerplants (Project-Level)	No Action	No impact	-
	1	Impact is included within that of changes in hydropower generation and grid emissions above.	-
	2	Impact is included within that of changes in hydropower generation and grid emissions above.	-
	3	Impact is included within that of changes in hydropower generation and grid emissions above.	-
	4	Impact is included within that of changes in hydropower generation and grid emissions above.	-
Changes in river flows and reservoir levels could result in a combined impact of hydropower generation, grid emissions, groundwater pumping, and water transfers (Project-Level)	No Action	No impact	-
	1	Increase in GHG emissions compared to No Action Alternative.	-
	2	Increase in GHG emissions compared to No Action	-

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
		Alternative. Greater increase than under Alternative 1.	
	3	Increase in GHG emissions compared to No Action Alternative. Greater increase than under Alternative 1 but less than under Alternative 2.	-
	4	Decrease in GHG emissions compared to No Action Alternative.	-
Actions that include construction of facilities or the transport of fish or materials require the use of construction equipment and vehicles, which would produce GHG emissions from engine exhaust (Project-Level)	No Action	No impact	-
	1	No impact	-
	2	No impact	-
	3	No impact	-
	4	No impact	-
Potential changes in hydropower generation could affect GHG emissions from fossil-fueled powerplants (Program-Level)	No Action	No impact	-
	1	No impact	-
	2	No impact	-
	3	No impact	-
	4	No impact	-
Potential changes in the amount of groundwater pumping could affect GHG emissions from fossil-fueled powerplants (Program-Level)	No Action	No impact	-
	1	No impact	-
	2	No impact	-
	3	No impact	-
	4	No impact	-
Potential changes in pumping for water transfers could affect GHG emissions from fossil-fueled powerplants (Program-Level)	No Action	No impact	-
	1	No impact	-
	2	No impact	-
	3	No impact	-
	4	No impact	-

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Changes in river flows and reservoir levels could result in a combined impact of hydropower generation, grid emissions, groundwater pumping, and water transfers (Program-Level)	No Action	No impact	-
	1	No impact	-
	2	No impact	-
	3	No impact	-
	4	No impact	-
Actions that include construction of facilities or the transport of fish or materials require the use of construction equipment and vehicles, which would produce GHG emissions from engine exhaust (Program-Level)	No Action	No impact	-
	1	The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate mitigation/BMPs are implemented.	GHG-1
	2	No impact	-
	3	The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate mitigation/BMPs are implemented.	GHG-1
	4	The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate mitigation/BMPs are implemented.	GHG-1

GHG = greenhouse gas
BMP = best management practices

M.2.9 Cumulative Effects

The cumulative effects analysis considers projects, programs, and policies that are not speculative and that are based upon known or reasonably foreseeable long-range plans, regulations, operating agreements, or other information that establishes them as reasonably foreseeable. Appendix Y, *Cumulative Methodology*, presents a list of actions that could have cumulative effects.

The No Action Alternative would not result in any changes to facility operations and so would not have impacts on GHG emissions. Thus, no cumulative effects of the project on GHG emissions would occur under the No Action Alternative.

As described above, Alternative 1 would lead to increases in regional emissions of CO_2, CH_4, N_2O, and CO_2e, compared to the No Action Alternative. Past, present, and reasonably foreseeable projects, described in Appendix Y, may have cumulative effects as well, to the extent that they could increase regional GHG emissions. The cumulative projects include actions across California to develop new water storage capacity, new water conveyance infrastructure, new water recycling capacity, and the reoperation of existing water supply infrastructure, including surface water reservoirs and conveyance infrastructure. The cumulative projects also include ecosystem improvement and habitat restoration actions to improve conditions for special status species whose special status in many cases constrains water supply delivery operations. Some of the projects described in Appendix Y could increase GHG emissions through the same mechanisms discussed above for the action alternatives, that is, if the projects lead to increases in grid power generation, groundwater pumping, and use of construction equipment and vehicles. The GHG emissions from Alternative 1 are expected to be relatively small compared to the emissions from past, present, and reasonably foreseeable projects. Consequently, the impacts of Alternative 1, when combined with those of past, present, and reasonably foreseeable projects, are not expected to lead to significant cumulative impacts on global climate change. Accordingly, no mitigation is proposed for cumulative GHG emission impacts of Alternative 1.

Alternatives 2 and 3 would have cumulative impacts similar to those of the Alternative 1. Compared to the No Action Alternative and Alternative 1, Alternative 2 would result in greater emissions of CO_2, CH_4, N_2O, and CO_2e. Alternative 3 also would result in greater emissions of these pollutants compared to the No Action Alternative and Alternative 1, but the increases would be less than under Alternative 2. As with Alternative 1, the GHG emissions from Alternatives 2 and 3 are expected to be relatively small compared to the emissions from past, present, and reasonably foreseeable projects. Consequently, the cumulative GHG emission impacts of Alternatives 2 and 3 along with past, present, and reasonably foreseeable projects are not expected to lead to significant cumulative impacts on global climate change. Accordingly, no mitigation is proposed for cumulative GHG emission impacts of Alternatives 2 and 3.

Alternative 4 would lead to decreases in regional emissions of CO_2, CH_4, N_2O, and CO_2e, compared to the No Action Alternative. Because GHG emissions would decrease under Alternative 4, the cumulative GHG emission impacts of Alternative 4 along with past, present, and reasonably foreseeable projects are not expected to lead to significant cumulative impacts on global climate change. Accordingly, no mitigation is proposed for cumulative GHG emission impacts of Alternative 4.

GHG emissions from construction activities are temporary. The GHG emissions from construction under Alternatives 1, 2, 3 and 4 are expected to be relatively small compared to the emissions associated with past, present, and reasonably foreseeable projects. Consequently, the cumulative GHG emission impacts of construction under Alternatives 1, 3, and 4 (Alternative 2 does not include construction) along with past, present, and reasonably foreseeable projects are not expected to lead to significant cumulative impacts on global climate change. Accordingly, no mitigation beyond the BMPs recommended in Section M.2.7.2 above is proposed for cumulative GHG emission impacts from construction activities of Alternatives 1, 3, and 4.

M.3 References

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