Assessing California's Climate Policies—Agriculture

LAO

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AN LAO REPORT

LEGISLATIVE ANALYST'S OFFICE

Executive Summary

Chapter 135 of 2017 (AB 398, E. Garcia) requires our office to annually report on the economic impacts and benefits of California's greenhouse gas (GHG) reduction targets. In this report, we assess the effects of the major programs within the agricultural sector that are aimed at reducing emissions and sequestering carbon, as well as make recommendations to the Legislature that, if implemented, could help inform its future policy and budget decisions.

Agriculture Is Significant Source of GHG Emissions. The California Air Resources Board (CARB) estimates that agriculture is responsible for the emission of 32 million metric tons of carbon dioxide equivalent (MMTCO2e), making it the fifth largest source of California's GHG emissions. Most—about 70 percent—of the emissions from the agriculture sector are methane emissions from livestock.

Several State Agricultural Programs to Reduce GHG Emissions and Sequester Carbon. The state has several programs within the agricultural sector that aim to reduce emissions and sequester carbon. In this report, we assess the following programs, which are administered by the California Department of Food and Agriculture: (1) Dairy Digester Research and Development Program, (2) Alternative Manure Management Program, (3) Healthy Soils Program, and (4) State Water Efficiency and Enhancement Program. Through 2020-21, the state has provided a total of $383 million to support projects from these programs, and CARB estimates that the projects funded to date provide a total of 2.5 MMTCO2e benefits annually. (The 2021-22 budget included an additional $340 million over two years for these programs.)

Overarching Takeaways From Review of Major Agricultural Programs. Overall, we find that each of the four programs assessed in this report have significant potential to provide GHG benefits as intended. However, we also find that—for varying reasons—the magnitude of GHG benefits estimated for each program could be overstated. To the extent the Legislature continues to fund these programs, we recommend that state departments be directed to conduct additional evaluation and research to better assess the GHG benefits. Improved information could then be used to help the Legislature target limited state funding to cost-effectively achieve its policy goals—that is, to maximize GHG and methane reductions at the lowest cost possible. Additional evaluation and research activities likely would result in additional state costs. However, we find that in many cases, these costs would be modest compared to the amount of total state spending on these programs and could be covered within departments' existing research programs or future program augmentations.

The figure on the next page provides an overview of our major findings and recommendations for each program.

Summary of Major Findings and Recommendations

Program	Findings	Recommendations
Dairy Digester Research and Development Program (DDRDP). Provides grants to dairy operations and developers for the implementation of digesters that result in methane emission reductions.	While GHG reduction estimates for DDRDP are significant, there are key assumptions that likely overstate these GHG benefits, such as not considering the effects of other state and federal programs that also incentivize the use of digesters.	Direct CARB to update its GHG quantification methodology to more accurately estimate the GHG benefits associated with DDRDP.
Alternative Manure Management Program (AMMP). Provides grants to implement non-digester practices that reduce methane emissions at dairy and livestock operations.	Unclear the extent to which grant recipients are implementing AMMP projects consistent with what was assumed when the GHG benefits were estimated, potentially resulting in innaccurate cost-benefit calculations.	Direct CDFA to conduct more robust monitoring and reporting of how AMMP projects are being implemented.
Healthy Soils Program (HSP). Provides grants to increase statewide implementation of various practices that improve soil health, sequester carbon, and reduce GHG emissions.	Estimated carbon sequestration benefits might be overstated for a few reasons, including (1) uncertainty regarding whether grantees are continuing practices after program funding has expired and (2) the likelihood that some grant recipients would have undertaken similar actions even in the absence of receiving state funding.	Direct CDFA to evaluate the extent to which GHG benefits are overstated, including tracking whether grantees are continuing practices after incentives end. Also consider supporting other areas of research related to program outcomes, including on the soil sequestration benefits of practices when implemented across different combinations of crops, climate, and soil types.
State Water Efficiency and Enhancement Program (SWEEP). Provides grants to agricultural operations to implement irrigation and pumping systems that reduce on-farm water use and GHG emissions.	Estimated water and GHG benefits could be overstated to the extent that on-farm efficiencies achieved allow operations to extend irrigated acreage or switch to more water-intensive crops over the long run, also know as a “rebound effect.”	Direct CDFA to research (1) the extent to which subsidizing on-farm water efficiencies results in a rebound effect, (2) the magnitude of the potential rebound effect, and (3) the degree to which GHG emissions are affected.

GHG = greenhouse gas; CARB = California Air Resources Board; and CDFA = California Department of Food and Agriculture.

INTRODUCTION

Chapter 135 of 2017 (AB 398, E. Garcia) requires our office to report annually on the economic impacts and benefits of the state's greenhouse gas (GHG) reduction targets. In this report, we assess the effects of four programs within the agricultural sector that are aimed at reducing emissions and sequestering carbon. Our assessment is largely based on our review of available program data; agency reports; academic studies; and interviews with state officials, program participants, and researchers. We begin the report by providing background information on the state's GHG goals and emissions within the agricultural sector. Then, for each of the four agricultural programs to reduce emissions and sequester carbon, we (1) provide an overview of the program; (2) assess the costs and benefits; and (3) identify recommendations designed to improve the state's understanding of the programs' effectiveness, as well as their outcomes.

BACKGROUND

State Has Ambitious GHG Reduction Goals. Chapter 488 of 2006 (AB 32, Núñez/Pavley) established the goal of limiting GHG emissions statewide to 1990 levels—431 million metric tons of carbon dioxide equivalent (MMTCO2e)—by 2020. (CO2e is a standardized unit of measurement that is used to compare emissions from different GHGs—such as CO2, methane, and nitrous oxide—based on their global warming potentials.) In 2016, Chapter 249 (SB 32, Pavley) extended the limit to 40 percent below 1990 levels—to 259 MMTCO2e—by 2030. As shown in **Figure 1**, emissions have decreased since AB 32 was enacted and were below the 2020 target in 2019. However, the rate of reductions needed to reach the SB 32 target are much greater.

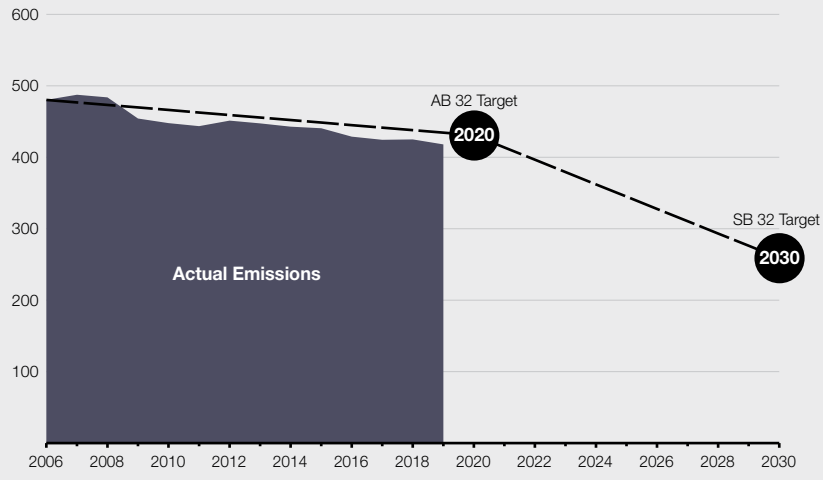
Agricultural Sector Is Fifth Largest Source of State GHG Emissions. The California Air Resources Board (CARB) maintains a GHG inventory that estimates emissions from most sectors of the state. According to the inventory, there were 418 MMTCO2e emitted in California in 2019. **Figure 2** on the next page shows the total amount of emissions from each sector in CARB's inventory. As shown in the figure, the agricultural sector is estimated to emit 8 percent—32 MMTCO2e—of statewide GHGs, making it the fifth largest source of emissions. (We note that in prior years, our office has published reports evaluating state programs to reduce GHG emissions from the transportation and electricity sectors.)

Emissions from the agricultural sector come from a variety of activities. In recent years, roughly

Figure 1

State Has Met 2020 Goal, but 2030 Goal More Ambitious

MMTCO2e



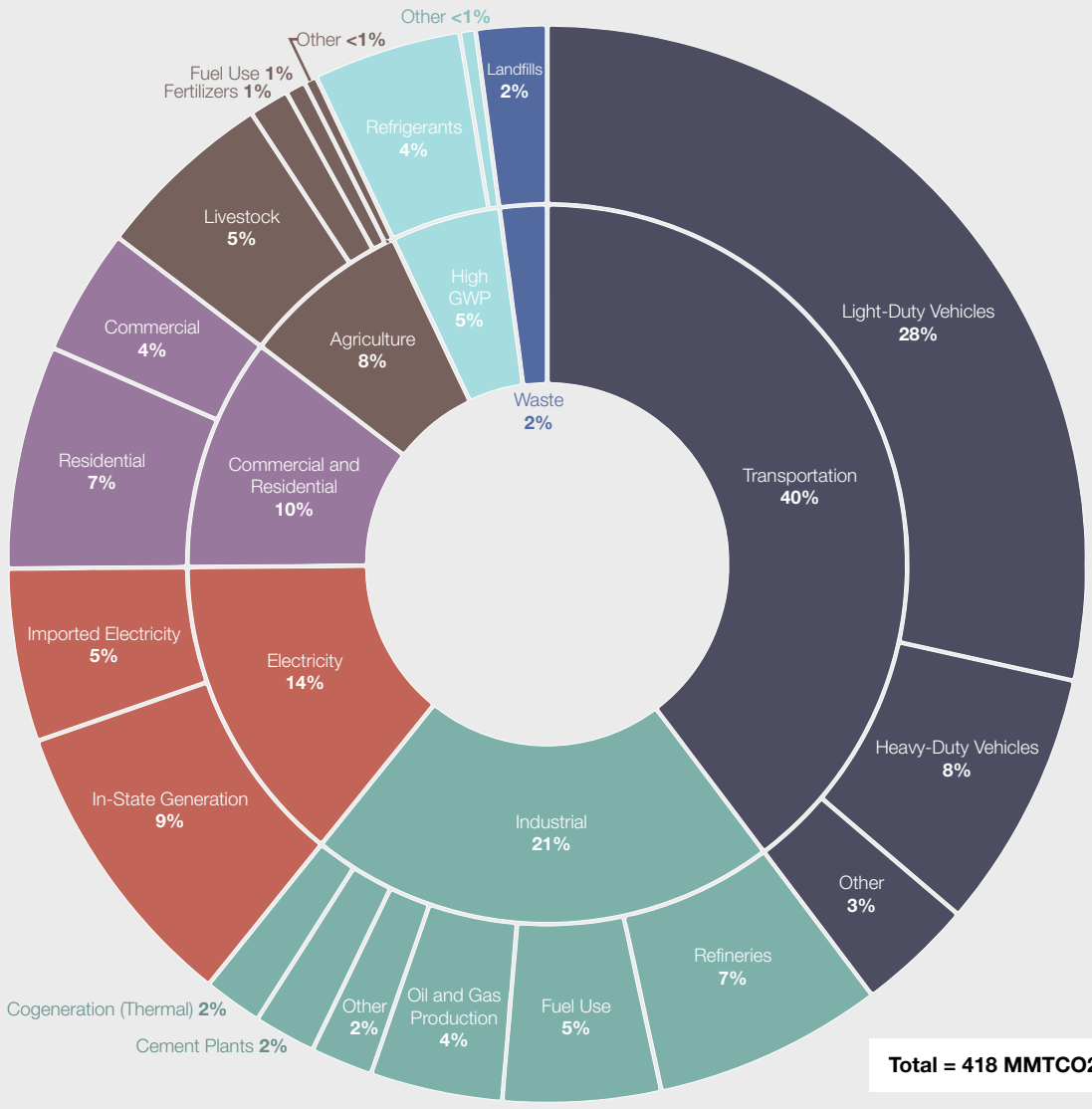
MMTCO2e = million metric tons of carbon dioxide equivalent.

70 percent of emissions from the agricultural sector (or 5 percent from all sectors) are related to livestock. Livestock emissions are mostly from methane generated from enteric fermentation and manure management (discussed more below). Other significant sources of agricultural emissions are fertilizers (16 percent)—mostly in the form of nitrous oxide—and fuel use (8 percent)—mostly CO2.

Agriculture Is State's Largest Source of Methane Emissions. Methane is one of the GHGs referred to as Short-Lived Climate Pollutants, which remain in the atmosphere for a much shorter period of time than longer-lived climate pollutants such as CO2. The atmospheric lifetime of methane is about 12 years. (CO2 has a variable atmospheric lifetime since some portion of excess CO2 is absorbed quickly by the oceans and terrestrial

Figure 2

Agricultural Sector Is Fifth Largest Source of State GHG Emissions
2019



GHG = greenhouse gas; GWP = global warming potential; and MMTCO2e = million metric tons of carbon dioxide equivalent.

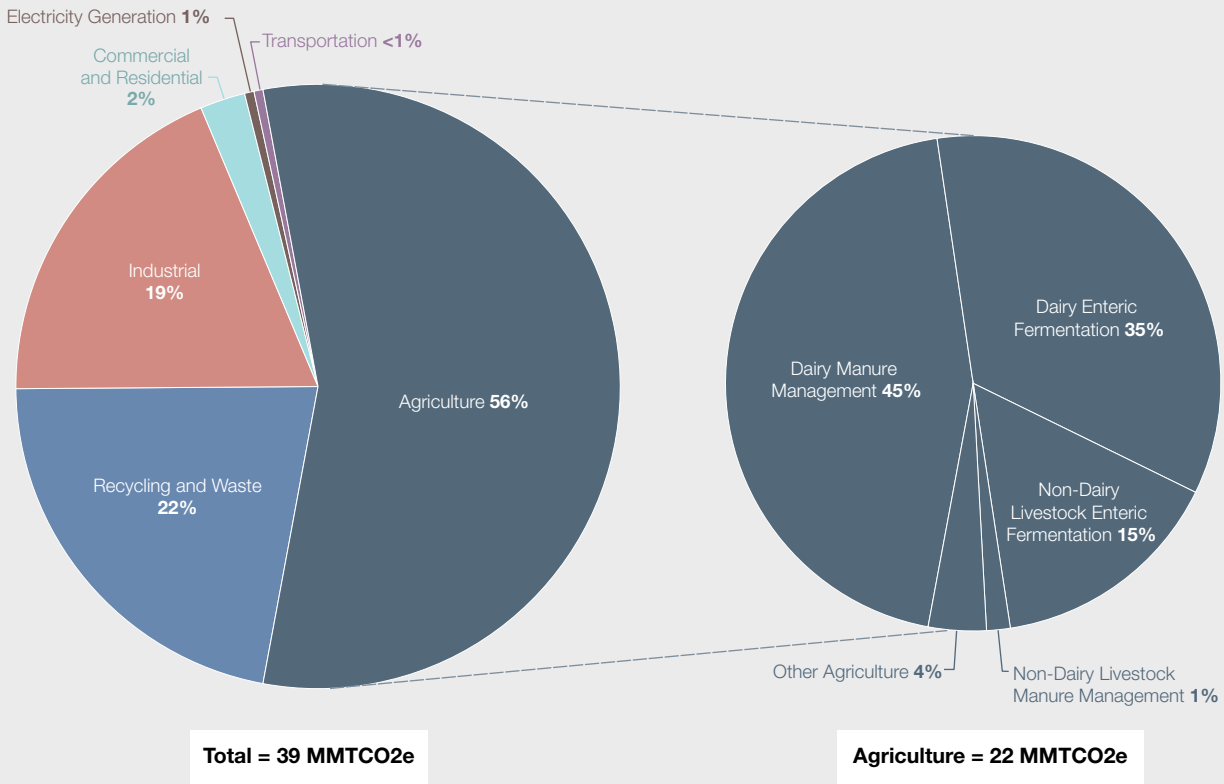
vegetation, while some remains in the atmosphere for thousands of years.) Despite the comparatively short period that it remains in the atmosphere, methane is a potent GHG that is 25 times more effective at trapping heat in the atmosphere than CO2 over a 100-year period.

According to CARB, methane accounted for 39 MMTCO2e (9 percent) of GHG emissions in 2019, making it the second largest source in the state. (CO2 accounted for 83 percent of total GHG emissions in 2019.) As shown in **Figure 3**, the agricultural sector is the largest source of methane emissions in the state, producing 22 MMTCO2e in 2019 or 56 percent of statewide methane emissions.

Livestock Are Primary Sources of Agricultural Methane. In 2019, a total of 96 percent of methane emissions from the agricultural sector came from dairy and other livestock. The two largest sources of methane emissions from livestock were (1) manure management from dairies (45 percent) and (2) enteric fermentation from dairies (35 percent). Methane is produced from manure management when manure is stored in anaerobic conditions—those that lack oxygen. Manure management systems can be broadly divided into "liquid" and "dry" systems. Liquid systems—such as manure that is flushed from barns to open lagoons—create an anaerobic environment that is ideal for methane production, while dry systems—such as solid storage and animal grazing—tend to produce smaller amounts of methane. Enteric fermentation is the natural production and release of methane mostly through eructation (burping) as ruminant animals (cattle, sheep, and goats) digest their feed.

Figure 3

Statewide Methane Emissions Largely From Agriculture
2019



MMTCO2e = million metric tons of carbon dioxide equivalent.

In California, most methane emissions from livestock are related to dairy. The high amount of methane emissions is largely due to the dairy cow population and the widespread use of flush water lagoon systems at these operations. The sector is supported by 1,300 dairies that house 1.7 million dairy cows. California led the nation in total milk production in 2019 with 40.6 billion pounds, valued at $7.3 billion.

State Has Methane-Specific Reduction Goals for Dairy and Livestock. Chapter 395 of 2016 (SB 1383, Lara) established the goal of limiting methane emissions statewide to 40 percent below 2013 levels—to 24 MMTCO2e—by 2030. (The legislation also established statewide goals for black carbon and hydrofluorocarbons.) In addition, the legislation established a methane reduction goal for dairy and livestock manure management operations to 40 percent below 2013 levels by 2030.

Senate Bill 1383 also directed CARB, in consultation with the California Department of Food and Agriculture (CDFA), to adopt regulations no earlier than January 1, 2024 to achieve the dairy and livestock reduction goals—provided that CARB and CDFA determine the regulations are technologically and economically feasible, as well as cost-effective. The legislation also requires that future regulations be designed to minimize and mitigate the shift of emission sources to other states or countries (referred to as "leakage") and an evaluation of the achievements made by state programs.

Several State Agricultural Programs to Reduce GHG Emissions and Sequester Carbon. In this report, we assess the following programs, all of which are administered by CDFA: (1) Dairy Digester Research and Development Program (DDRDP), (2) Alternative Manure Management Program (AMMP), (3) Healthy Soils Program (HSP), and (4) State Water Efficiency and Enhancement Program (SWEEP). As shown in **Figure 4**, these programs provide financial incentives to reduce the costs of adopting technologies and practices that reduce GHG emissions and sequester carbon.

We note that in addition to these four programs, the state oversees several other programs that likely do provide some GHG emission reduction benefits in the agricultural sector. However, they are not included in this report because they are not

Figure 4

Overview of Major GHG Programs in Agriculture

(Dollars in Millions)

Program	Description	Year Established	Funding[a]	Number of Projects	Annual MMTCO2e Reductions
Dairy Digester Research and Development Program	Grants to dairy operations and developers for the implementation of digesters that result in methane emission reductions.	2015	$195	117	2.1
Alternative Manure Management Program	Grants to implement non-digester practices that reduce methane emissions at dairy and livestock operations.	2017	67	114	0.2
Healthy Soils Program	Grants to increase statewide implementation of various practices that improve soil health, sequester carbon, and reduce GHG emissions.	2017	40	675	0.1
State Water Efficiency and Enhancement Program	Grants to agricultural operations to implement irrigation and pumping systems that reduce on-farm water use and GHG emissions.	2014	81	828	0.1

[a] Reflects funding through 2020-21. The 2021-22 budget provided an additional $340 million over two years for these programs, but grants had not yet been awarded to new projects at the time this report was prepared.

GHG = greenhouse gas and MMTCO2e = million metric tons of carbon dioxide equivalent.

targeted specifically to the agricultural sector, are primarily intended to reduce criteria air pollutants, or are smaller in scale than the programs we analyze. For example, the Funding Agricultural Replacement Measures for Emission Reductions (FARMER) Program—which provides financial incentives to purchase cleaner heavy-duty trucks and agricultural equipment—is primarily intended to reduce air pollutants, such as particulate matter (PM) and nitrogen oxides (NOx). Additionally, the Carl Moyer Program—which provides financial incentives for the replacement of engines and other equipment—also primarily is intended to reduce air pollutants and is not specifically targeted within the agricultural sector.

In the following section, we provide our overarching takeaways from the programs assessed in this report. Then, for each individual program, we (1) provide an overview of the program; (2) discuss our assessment of its costs and benefits; and (3) identify recommendations designed to improve the state's understanding of the program's effectiveness, as well as its outcomes.

OVERARCHING TAKEAWAYS FROM REVIEW OF MAJOR PROGRAMS

Merit in Having Agricultural Programs That Reduce GHG Emissions and Sequester Carbon. Overall, we find that the four programs assessed in this report have merit in providing GHG benefits. We find that they are appropriately targeted to meeting state GHG emission goals by seeking emission reductions and carbon sequestration within the agricultural sector, which is a significant source of statewide emissions, particularly from methane. Moreover, despite certain limitations that we identify for the programs (discussed more below), our review of the academic literature and interviews with researchers indicate that each program is a reasonable approach with significant potential to incentivize GHG emission reductions or carbon sequestration statewide.

Overall GHG Benefits for Programs Likely Are Overstated. While the programs assessed in this report likely are resulting in some GHG reductions, we find that there are several instances where the magnitude of these benefits likely is overstated. In many cases, program benefits are overstated due to (1) shortcomings in the methodologies used to calculate GHG benefits, (2) uncertainty regarding whether projects are being implemented in ways that achieve the projected level of GHG reductions, and (3) uncertainty regarding the degree to which practices being implemented to achieve GHG benefits are maintained over the long term.

Additional Research Needed to More Accurately Assess GHG Benefits of Programs. To the extent the Legislature continues to fund these programs, we recommend that state departments be directed to conduct additional evaluation and research to better assess the GHG benefits. Additional research could improve the amount and quality of information available on the costs and benefits of each program, including specific subcomponents of programs (such as for different types of practices to sequester carbon in soils). Improved information could then be used to help the Legislature target limited state funding to cost-effectively achieve its policy goals—that is, to maximize GHG and methane reductions at the lowest cost possible. Additional evaluation and research activities likely would result in additional state costs. However, we find that in many cases, these costs would be modest compared to the amount of total state spending on these programs and could be covered within departments' existing research programs or future program augmentations.

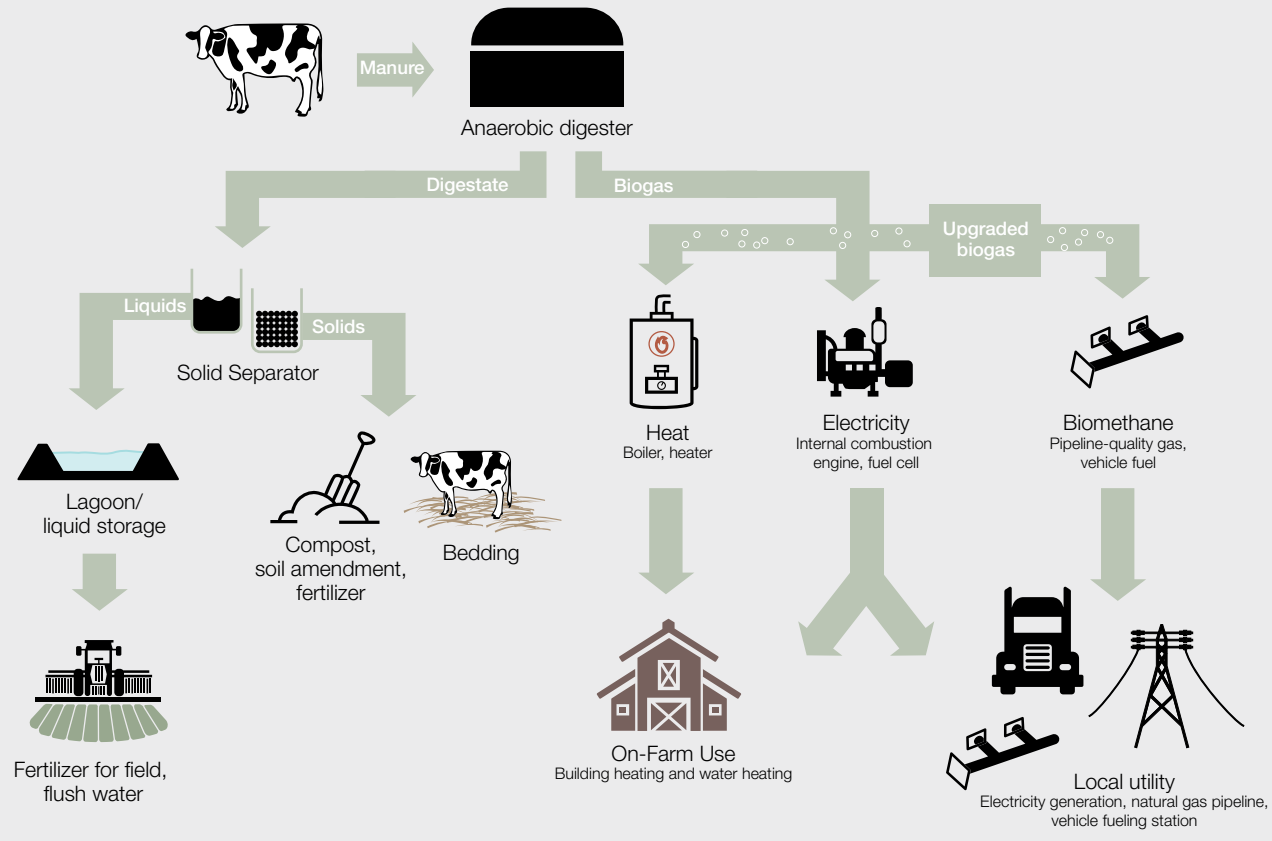
DAIRY DIGESTER RESEARCH AND DEVELOPMENT PROGRAM

Overview of DDRDP

Anaerobic Digesters Capture Methane. An anaerobic digester is a closed structure that captures methane from organic matter, such as livestock manure. The specific design of digesters can vary, but on dairy farms they are usually large engineered tanks or impermeable covers placed over existing lagoons. Manure that has been flushed from animal stalls is fed into the digester and contained for a period of time as anaerobic bacteria decompose the manure to produce several outputs, including biogas (largely methane with some amounts of CO2 and other trace gases), liquid effluent, and dry matter. As shown in **Figure 5**, the captured biogas can be used to generate heat or electricity, which can be used on site or sold to a local utility. Alternatively, the biogas can be upgraded to biomethane—pipeline-quality gas that is fully interchangeable with conventional fossil natural gas—and sold to a local utility to be used for several purposes, such as transportation fuel. (We note that biomethane sometimes is referred to as renewable natural gas.) Additionally, the liquids and dry matter can be used for other purposes such as fertilizer, soil amendments, and animal bedding.

Figure 5

Anaerobic Digester Overview



DDRDP Funds the Installation of Digesters on Dairy Operations. DDRDP provides competitive grants to dairy operations and developers for the implementation of digesters that result in methane emission reductions. Projects must use the captured biogas for energy production or transportation fuel. The program funds up to 50 percent of the total project costs, with the maximum grant amount capped at $3 million per project during the initial years of the program and $2 million per project in 2020. In recent years, the average project cost has been around $5 million.

Most digesters funded under DDRDP are owned by a partnership established between the digester developer and dairy operation. The digester is generally operated and maintained by the developer, with the dairy operation being responsible for supplying manure. Different arrangements exist for how revenues are split between the developer and the dairy operation. In most cases, the developer receives revenues from selling biomethane or electricity and environmental credits (discussed more below). The dairy operation generally receives lease payments from the developer, and in some cases, will receive a portion of the revenues generated from the digester.

Over 100 Projects Funded Since 2015. The program has provided a total of $195 million in grants to 117 digester projects. (We note that the 2021-22 budget provided an additional $80 million from the General Fund over two years for DDRDP and AMMP—with budget bill language providing funding priority to AMMP.) At the time of this report, 60 digester projects have been completed while the remaining projects are still in the construction and development phases. All of the digesters funded through DDRDP have been covered lagoon digesters. Prior to 2021-22, DDRDP has been funded entirely from the Greenhouse Gas Reduction Fund (GGRF), which is supported by proceeds of the state's cap-and-trade program on GHG emissions.

Environmental Credits Incentivize Use of Biogas for Transportation Fuel. In California, there are two major financial incentives to implement digester projects: (1) revenues generated from selling biomethane (or electricity generated from biogas) and (2) environmental credits. Digester projects are able to receive environmental credits under the state's Low Carbon Fuel Standard (LCFS) Program and the federal Renewable Fuel Standard (RFS) Program, each of which are designed to incentivize the production of alternative transportation fuels with lower carbon content than traditional fossil fuels. (Please see the nearby box for a more detailed description of LCFS and

Key State and Federal Incentive Programs for Alternative Fuels

There are two major environmental credits that digester projects are able to receive when captured biogas is upgraded to biomethane and sold as transportation fuel.

Low Carbon Fuel Standard (LCFS) Program. The purpose of the state's LCFS program is to reduce the average carbon intensity of transportation fuels in the state by incentivizing the production and use of low carbon fuels. The program establishes statewide carbon intensity standards for transportation fuels supplied. Entities that supply fuels below the standard (such as biomethane) generate credits that can be sold to entities generating deficits by supplying fuels above the standard (such as fossil gasoline or diesel). At the time of this report, market prices for LCFS credits were about $175 per metric ton of carbon dioxide equivalent. (Please view our report *Assessing California's Climate Policies—Transportation* to view our analysis on the cost and benefits of LCFS.)

Federal Renewable Fuel Standard (RFS) Program. RFS is a federal program that requires a certain volume of renewable fuels to replace or reduce the quantity of petroleum-based transportation fuels supplied nationally. Under the program, producers of renewable fuels earn credits that can be sold to refiners or importers of petroleum-based fuels in order to meet specified renewable volume requirements under the program. At the time of this report, market prices for RFS credits were about $3 per gallon of renewable fuel produced.

RFS and how the credits work.) According to a recent CARB report, LCFS and RFS credit sales can make up roughly 60 percent and 35 percent of a digester project's revenues, respectively, with the remaining amount coming from biomethane sales. Consequently, 92 percent of all DDRDP-funded projects (including those in progress) upgrade captured biogas to biomethane to be used as transportation fuel. (We also note that some of the digesters that produce electricity can earn LCFS credits if the energy generated is used for electrical vehicle charging.)

Assessment of Costs and Benefits

DDRDP Projects Are Estimated to Provide Significant GHG Reductions. CARB estimates that all DDRDP projects (including those funded but not yet implemented) will provide significant GHG reductions totaling 2.1 MMTCO2e annually. The estimated emission reductions for each project will vary based on several factors, particularly the amount of manure flushed into the digester and the end use of the biogas captured. CARB estimates that the program reduces emissions at a state cost of $9 per ton, which is one of the lowest cost-per-ton estimates among GGRF-funded programs. (For context, allowances under the cap-and-trade program—which puts a price on each ton of GHG emissions in the state—sold for about $28 per ton at the November 2021 auction.)

In CARB's methodology, emission reductions for DDRDP projects come from two major sources. First, estimates include reductions associated with avoided methane emissions—specifically, the methane emissions captured by the digester that otherwise would have been released into the air. According to information provided by CARB, more than 75 percent of the estimated emission reductions are from avoided methane, though the amount can vary depending on the project.

Second, estimates include reductions associated with avoided CO2 emissions, which are based on the assumption that fossil fuels are displaced by the biogas (and biomethane) produced by a digester. (We note that the combustion of biogas [and biomethane] produces CO2 emissions, but these emissions are not included in the state's GHG inventory because they are biogenic rather than from fossil fuels.) Given that most digester projects upgrade biogas to biomethane for transportation fuel, avoided CO2 emissions for most projects largely come from the displacement of fossil fuels used in the transportation sector. The current methodology also includes avoided CO2 emissions for projects that displace fossil fuels in natural gas pipelines and in electricity and heat generation.

Estimated GHG Reductions for Program Likely Are Overstated. While CARB's GHG reduction estimates for DDRDP are significant, we find that the department relies on a couple of key assumptions that likely overstate the benefits of the program. First, CARB's quantification methodology assumes that reductions for a project are completely attributable to DDRDP and does not account for any impacts from other state and federal programs. This assumption likely would overstate the benefits of the program since other programs also incentivize the development of digester projects and are thus responsible for some portion of the resulting GHG benefits. In particular, LCFS and RFS provide substantial revenue incentives for the development of digesters in the state. We note that the various programs support different phases of a digester project. For instance, DDRDP specifically supports capital costs, while LCFS and RFS provide revenues after the project is built. However, even with this distinction, it is unlikely that the same number of digester projects would be built in the absence of LCFS and RFS.

Second, estimated GHG benefits for the program likely are overstated due to assumptions made when quantifying the emission reductions from digester projects that upgrade biogas to biomethane for transportation fuel. CARB's quantification methodology assumes that all of the biomethane produced will offset diesel fuel used in heavy-duty vehicles. In our view, it is uncertain the degree to which this offset occurs in practice. A direct offset is unlikely to occur since diesel heavy-duty vehicles in the state cannot refuel with natural gas. Instead, the biogas produced from dairy digesters simply increases the supply of natural gas available for vehicles. Additional supply could indirectly incentivize businesses to purchase heavy-duty vehicles that run on natural gas instead of diesel by reducing the cost of natural gas fuel.

However, it is unlikely that digester-produced biogas is fully offsetting the use of diesel as is currently assumed in CARB's methodology.

Air Pollution Benefits Also Likely Are Overstated. CARB also estimates co-benefits related to reductions in air pollutants, such as NOx and PM. Most of these reductions are associated with the assumption that biomethane produced by a digester will displace diesel fuel in heavy-duty vehicles, which is a significant source of these air pollutants. Because we find that the estimates of diesel offsets likely are overstated, it is similarly likely that CARB's estimates overstate the air pollution benefits of the program.

We note that dairy operations are also a major source of statewide ammonia and volatile organic compounds, which are precursors to PM and ozone, respectively. To the extent that the increased revenue produced by operating digesters creates a financial incentive for dairies to become larger, this could potentially increase the amount of emissions that come from these operations.

Program Has Potential to Reduce Nitrate Contamination. Manure is commonly used as a source of nutrients for plants given that it is high in nitrogen, phosphorus, and potassium, which are all essential for plant growth. However, the storage of manure in lagoons can lead to nitrate (the oxidized form of dissolved nitrogen) contamination in groundwater if not properly contained. Based on conversations with researchers, one potential benefit of DDRDP is that the program's requirements could reduce the occurrence of such contamination. This is because the program requires all covered lagoon digester projects to be double lined, which is the highest regulatory standard in the state. To the extent that these lagoons were otherwise not double lined or had some level of seepage prior to the installation of the digester, there could be water benefits from the program. However, we are not aware of any research on the magnitude of this benefit.

Recommendations

Require CARB to Update Quantification Methodology. We recommend the Legislature direct CARB to make a couple of updates to its methodology for quantifying the GHG benefits associated with DDRDP. First, the methodology should be updated to better reflect the share of GHG benefits associated with DDRDP relative to other state and federal programs. The current methodology likely overstates the benefits of the program by attributing all of the GHG benefits to DDRDP and assuming no impacts from other programs. Second, the methodology should be updated to better reflect emission reductions associated with the use of biomethane as transportation fuel. As we discussed above, the current methodology likely overstates the benefits of the program by assuming that all of the biomethane produced by a digester project will offset diesel fuel used in heavy-duty vehicles. (We note that updates to the methodology also would enable revised air pollution estimates.)

Once completed, revised GHG reduction estimates should be calculated for all previously funded DDRDP projects. Doing so should provide the Legislature and administration with more accurate estimates of the program's emission impacts and cost-effectiveness—information which can assist in future budget decisions and policymaking. We find that the one-time costs associated with updating the methodology are likely to be small and could be covered with existing resources within CARB.

Consider Research on Other Impacts of Program. We also find that it is largely unknown the degree to which the program (1) contributes to additional air pollution by creating an incentive for larger dairy operations and (2) reduces nitrate contamination from lagoons. To the extent that the Legislature is interested in obtaining more information on these potential impacts, it could consider providing additional funding to research these questions further.

ALTERNATIVE MANURE MANAGEMENT PROGRAM

Overview of AMMP

Funds Alternative Management Practices on Smaller Dairy and Livestock Operations. Digester projects are not feasible on every dairy operation for various reasons, such as the lack of herd size needed to make a digester financially viable. Accordingly, the state created AMMP to provide competitive grants to implement non-digester practices that reduce methane emissions at dairy and livestock operations. While large dairies are eligible under the program, AMMP generally supports projects on smaller dairies. AMMP provides up to 100 percent of the total cost to implement alternative manure management practices, with a maximum grant of $750,000.

Specifically, AMMP funds technologies and specific management practices that increase the amount of manure that is managed in dry form, thus limiting the amount of methane emissions that result from manure being stored in anaerobic conditions. To be eligible for funding, an operation previously must have been producing methane emissions from manure stored in a lagoon or other predominantly liquid anaerobic environments. As shown in **Figure 6**, there are several eligible activities that can receive funding under the program.

Over 100 Projects Funded Since 2017. The program has provided $67 million from GGRF to 114 projects. (We note that the 2021-22 budget provided an additional $80 million from the General Fund over two years for both DDRDP and AMMP—with budget bill language providing funding priority to AMMP.) At the time of this report, 78 AMMP projects have been completed, while the remaining are still in the development and construction phases. Roughly 60 percent of the funded projects are for the installation of solid separators, with the remaining projects implementing compost bedded pack barns (26 percent) and flush to scrape systems (14 percent).

Assessment of Costs and Benefits

AMMP Projects Are Estimated to Provide Small GHG Reductions. CARB estimates that all projects funded from AMMP (including those still under development) will provide GHG reductions totaling 0.2 MMTCO2e annually. The estimated emission reductions are almost entirely avoided methane. CARB estimates that the program reduces emissions at a state cost of $61 per ton—making it one of the more cost-effective GGRF-funded programs. Importantly, current program reports do not provide estimates of the emission reduction benefits or cost-effectiveness broken out by individual AMMP project type. This makes it difficult to know if certain AMMP activities are more cost-effective than others.

While AMMP is estimated to have resulted in significantly lower emission reductions than DDRDP, we find that AMMP has potential value

Figure 6

Overview of Activities Funded Under AMMP

Activity	Description	Number of Projects
Solid separation[a]	Installation of technology that separates manure solids prior to entry into a wet/anaerobic environment (such as a lagoon).	68
Alternative manure treatment and storage	Installation of a compost bedded pack barn or slatted floor pit storage manure collection.	30
Flush to scrape[a]	Installation of technology that collects manure from scraping (such as with an automated scraper or vacuum truck) instead of flushing with water.	16
Pasture-based management	Conversion of a non-pasture dairy or livestock operation to pasture-based management and/or increasing the amount of time livestock spend at pasture at an existing pasture operation.	—

[a] Must be implemented in conjunction with some form of drying or composting collected manure.

AMMP = Alternative Manure Management Program.

because it is consistent with the statutory goal of reducing methane emissions from manure management and because digesters generally are not economically feasible for most small operations. However, while AMMP and DDRDP are focused on reducing methane emissions from manure management, there is currently no state program to reduce methane emissions from enteric fermentation. (Please see nearby box for a more detailed description of emerging strategies to address methane emissions from enteric fermentation.)

Program Likely Main Driver in Adopting Alternative Manure Management Practices. In most cases, the types of practices funded by AMMP do not otherwise provide sufficient cost savings or revenues to incentivize implementation. In contrast to digesters, AMMP projects reduce—rather than capture—methane emissions and, therefore, cannot generate revenues from the sale of the biogas and biomethane or environmental credits through LCFS and RFS. Additionally, under the state's current cap-and-trade regulation, AMMP projects cannot receive carbon offset credits—environmental credits generated by nonregulated entities that can be sold to regulated

Addressing Methane Emissions From Enteric Fermentation

Enteric fermentation and manure management from livestock are the two major sources of methane emissions from the agricultural sector. While the state has two programs—the Alternative Manure Management Program and the Dairy Digester Research and Development Program—that address emissions from manure management, there are currently no programs to reduce emissions from enteric fermentation. Enteric fermentation emissions are 50 percent (11 million metric tons of carbon dioxide equivalent) of methane emissions from the agricultural sector and represent a significant opportunity to reduce methane emissions statewide. Potential ways to reduce enteric fermentation emissions include breeding of low-methane producing animals and including feed additives into existing diets. Based on several reports, feed additives provide the most promising way to reduce enteric fermentation emissions due to their ability to potentially deliver methane emission reductions shortly after adoption.

There are no commercially available feed additives at this time. However, recent research has resulted in progress in finding a feed additive that could reduce enteric fermentation emissions from livestock. For instance, early studies have tested potential feed additives that show methane emission reductions between 20 percent and 40 percent. Given that research is still in the testing phase, there is still some uncertainty regarding when one will become commercially available. Some reports indicate that a feed additive could be available within the next few years, while others indicate that it will take a decade or more. Overall, a viable feed additive will need to (1) show long-term effectiveness, (2) not have significant negative impacts on animal health and productivity, (3) be widely available, (4) be cost-effective for dairy and livestock operations, and (5) have limited external impacts on the environment and surrounding communities.

Enteric fermentation emission reduction strategies—specifically feed additives—will be an important issue for the Legislature to track as the state tries to reach its methane and overall greenhouse gas reduction goals. As part of its oversight in achieving statewide goals, the Legislature could request regular updates from various stakeholders—administration, academics and industry—on the development of enteric fermentation emission reduction strategies and the progress that academia and industry are making in producing a viable feed additive for the dairy and livestock sector. Additionally, the Legislature could support additional research or demonstration projects if future feed additives seem promising—with results helping inform future policies and programs.

entities. According to CARB, this exclusion is due to difficulties in quantifying methane emission reductions relative to facility baseline emissions.

Instead, the incentives to develop AMMP projects rely on potential revenues from selling value-added manure products or cost savings from using products to offset expenditures. Value-added manure products include soil amendments and compost made from separated solids. In many cases, these financial incentives are not enough for dairy operations to implement projects given the high up-front costs to construct, as well as uncertainty regarding the degree to which the practices will result in savings or additional revenues. For instance, dairy operations must be able to find an end user who wants the value-added manure products and is willing to pay a price that covers the cost of storage, processing, and transport. Given these constraints, it is likely that a large portion of these projects would not have been undertaken in the absence of AMMP funding.

Unclear Whether AMMP Projects Are Implemented in Ways That Achieve Estimated GHG Benefits. Emission reduction estimates for AMMP projects are largely based on the projected amount of manure that will go from being managed under anaerobic conditions to dry conditions. Therefore, projects must be operated in accordance with operational assumptions in order to meet estimated reductions. However, various reports indicate that operation-specific factors can make actual emission reductions for projects highly variable. For instance, the emission reductions from a solid separator will depend on many variables, such as how well the system is maintained, the composition of the manure, and whether the flow of manure is exceeding the system's throughput capacity. These operation-specific implementation factors result in varied emission reduction outcomes between projects, even when operations employ similar technologies and equipment. At the same time, conversations with researchers suggest that there may be instances where operators are not utilizing equipment as expected. In particular, high costs associated with running equipment—such as electricity costs associated with solid separators—could affect an operator's willingness to utilize equipment as intended to meet estimated emissions. While CDFA currently confirms whether projects are operational and being utilized, it does not confirm that the equipment is consistently being operated for the duration and at the capacity assumed when the emission reduction estimates were developed. Therefore, it is unclear whether current estimates accurately capture the extent to which projects are meeting estimated GHG benefits.

Recommendations

Direct CDFA to Make Monitoring of Implementation and Reporting More Robust. We recommend that the Legislature direct CDFA to conduct more robust monitoring of how AMMP projects are being implemented. Specifically, this could include more detailed and frequent reporting by grantees and site inspections from CDFA. Additionally, we recommend that the Legislature direct the department to report on the emission reductions and cost-effectiveness of each type of project in future program reports. More robust monitoring could provide greater confidence that projects are being incorporated by dairy and livestock operations as expected and meeting estimated emission reductions. Similarly, reporting on the effectiveness of the different AMMP activities could provide the Legislature with better information on how to target future funding. We find that costs to implement these changes are likely to be small and could be done by using a small share of future AMMP funds.

HEALTHY SOILS PROGRAM

Overview of HSP

Promotes Adoption of Practices That Sequester Carbon in Soils. The objectives of HSP are to increase statewide implementation of practices that improve soil health, sequester carbon, and reduce GHGs. The program attempts to achieve this through two categories of projects: (1) incentive projects and (2) demonstration projects. Incentive projects provide competitive grants of up to $100,000 to farmers and ranchers to implement one or more eligible HSP practices (discussed below). Demonstration projects provide competitive grants of up to $250,000 to partnerships of farmers, ranchers, and collaborating entities—such as universities and nonprofits—to implement similar on-farm practices with the additional requirement that the grantees collect data on carbon sequestration and other co-benefits and/or create outreach to promote healthy soil practices to other farmers and ranchers.

As show in Figure 7, the program supports the implementation of a wide variety of management practices. In general, the program promotes carbon sequestration in soils by funding practices that are known to increase organic matter inputs or reduce soil disturbance. Common examples include conservation tillage and the use of cover crops. Conservation tillage is a set of practices that limit or reduce tillage and increase the amount of plant residue remaining on fields, while cover crops are non-cash crops, often over the winter, that will be left in place as residue or incorporated into the soil.

Projects Also Intended to Achieve Other On-Farm Benefits. In addition to GHG benefits, practices funded under HSP can provide economic benefits to farm operations, as well as environmental benefits. In particular, research has shown that several healthy soil practices, such as conservation tillage, can improve crop yields over time. Some practices have also been found to provide on-farm water benefits. For instance, cover crops have been shown to improve water infiltration rates and soil water-holding capacity by improving soil structure over time. We note the magnitude of these benefits will vary between practice and in many cases, will materialize as practices are continued over the long run.

Over 650 Projects Funded Since 2017. The program has provided $40 million to 675 projects. Incentive projects have made up roughly 90 percent of the total projects. (We note that the 2021-22 budget provided an additional $160 million over two years for HSP—$135 million from the General Fund and $25 million from GGRF.) Prior to 2021-22, the program largely has been funded through GGRF, but has received some funding from the Proposition 68 (2018).

Assessment of Costs and Benefits

Research Suggests Potential for Carbon Sequestration in Soils. Research suggests that there has been a significant loss of carbon in soils over time due to changes in land use

Figure 7

Overview of Common HSP Practices

Practice	Description	Number of Projects[a]
Compost	Application of compost (organic material added to soil).	459
Cover crop	Planting of non-cash crop for seasonal soil cover.	212
Hedgerow planting	Planting of dense vegetation in a linear design consisting of shrubs, low growing trees, woody herbs, or tall bunchgrasses.	104
Mulching	Application of plant residues or other suitable materials to the land surface.	88
Conservation tillage	Reduced frequency or intensity of soil disturbance.	65
Other practices	Includes conservation cover, riparian forest buffers, and others.	177

[a] Some grants fund multiple practices per project.

HSP = Healthy Soils Program.

and management. Moreover, agriculture could provide an opportunity for sequestration because the vast majority of agricultural lands are not managed optimally for soil carbon storage under traditional agricultural management practices. For instance, most annual croplands limit carbon storage by leaving fields in bare-fallow conditions outside of the main crop-growing season and by employing intensive tillage practices that result in soil carbon being lost into the air. However, there are several practices available that research has shown to increase carbon stocks in soils and have been successfully practiced by farmers and ranchers. In many cases, these practices are not implemented due to implementation costs, the long-term maintenance needed to experience benefits, and unfamiliarity in utilizing practices.

One academic study found that implementing carbon sequestration practices on agricultural lands in the state could sequester nearly 40 MMTCO2e. We note that this number likely represents a maximum potential that the state is unlikely to be able to achieve since it would require practices to replicate results from academic studies and be adopted and maintained indefinitely on all harvestable irrigated lands in the state.

HSP Projects Are Estimated to Provide Small GHG Reductions. CARB estimates that incentive and demonstration projects funded from HSP will provide relatively small GHG benefits totaling 0.1 MMTCO2e annually. CARB estimates that the program reduces emissions at a state cost of $118 per ton. Importantly, current program reports do not provide estimates of the GHG benefits or cost-effectiveness broken out by individual HSP project type. This makes it difficult to know if certain HSP activities are more cost-effective than others.

Carbon Sequestration Might Be Overstated in Some Cases. We find that the estimated GHG benefits of HSP likely are overstated for several reasons. First, while research is promising about potential carbon sequestration, actual benefits are not yet well researched for all variations of crops, climate, and soil types in the state. While the program extrapolates previous research findings to estimate the impacts of HSP projects, based on our conversations with researchers, there is still significant uncertainty regarding the extent to which estimated benefits are accurate across different projects and locations. We note that the demonstration projects under HSP attempt to address this issue, along with research that is being conducted by academic institutions and other research organizations. However, only 25 percent of HSP funding has gone towards demonstration projects.

Second, research indicates that carbon sequestration benefits for many of the healthy soil practices are highly dependent on being maintained long term. For example, converting a field from conventional tillage to no-till will sequester carbon over time as the practice is continued. However, a significant portion of the benefits gained will be lost if the field is reverted back to conventional tillage. It is unclear whether grantees are maintaining practices after funding from the program has ended. (The program provides funding for one to three years depending on the practice.) As of now, CDFA does not currently track whether grantees continue practices, which brings uncertainty on the permanence of the estimated GHG benefits of the program.

Third, the program might also face “free-rider” issues that limit the degree to which the program is actually resulting in increased adoption of new practices. (The term free rider refers to the situation where program participants would have taken similar actions even in the absence of receiving funding from the state.) For instance, conversations with grantees indicate that some already implemented healthy soil practices on a small part of their operations and are using the program to expand usage to other fields. To the extent that those receiving funding might have expanded practices even if the program did not exist, then the carbon benefits associated with the program would be overstated, and the cost-per-ton estimates would be understated. We note that CDFA prevents applicants from using program funding on fields that already utilize eligible practices. However, this does not eliminate issues related to using HSP funding to implement expansions that would have happened otherwise.

Unclear Whether Program Promotes Statewide Adoption of Healthy Soil Practices. One of the main objectives of HSP is to promote the adoption of healthy soil practices statewide. However, it is currently unclear the extent to which the program is meeting this goal. This is because the state currently does *not* track statewide usage rates of HSP practices. Without this information, it is difficult to determine whether farmers and ranchers are changing their practices across the state, as well as whether HSP is having any effect on statewide adoption over time.

Recommendations

Direct Share of Funding to Track Long-Term Adoption in Grantees. Given that the GHG benefits of HSP often are highly dependent on practices being maintained long term, we recommend the Legislature provide additional funding to CDFA to track whether grantees are continuing practices after program incentives end. Additionally, we recommend that the Legislature direct the department to report on the emission reductions and cost-effectiveness of each type of project in future program reports. Understanding the degree to which grantees continue practices would provide greater confidence on the permanence of the estimated GHG benefits of the program. Increased accuracy of GHG benefits would provide the Legislature with better information on the cost-effectiveness of the program and individual practices, which could inform future budget and policy choices. We find that the amount of funding necessary to track this information should be small and could be set aside as a part of future augmentations for HSP.

Consider Research for Other Identified Issues. We also note uncertainty with (1) the degree to which current GHG estimates for each HSP practice accurately reflect the full range of crops, climate, and soil types in the state and (2) the degree to which the program faces the free-rider issue. Additional research on these topics could help inform the accuracy of the state's emissions estimates. Therefore, the Legislature could consider directing additional funding to CDFA to research these issues further.

Direct Share of Funding to Track Statewide Adoption of Healthy Soil Practices. Despite increasing the adoption of healthy soil practices statewide being one of the program's main objectives, the state does not currently track how the use of these practices has increased as a result of HSP. Therefore, we recommend the Legislature provide additional funding to CDFA to track this data long term. We find that funding to collect this information periodically should be modest and could be set aside as a part of future augmentations for HSP.

STATE WATER EFFICIENCY AND ENHANCEMENT PROGRAM

Overview of SWEEP

Funds On-Farm Energy and Water Efficiencies. SWEEP provides competitive grants to agricultural operations to implement irrigation and pumping systems that reduce on-farm water use and GHG emissions. As shown in **Figure 8**, the program provides funding to several different activities. Projects generally utilize more than one activity to achieve both water and GHG benefits. Depending on the grant cycle, the maximum amount awarded to projects has ranged from $50,000 per project to $200,000 per project.

Over 800 Projects Funded Since 2014. The program has provided a total of $81 million in grants to 828 projects. (We note that the 2021-22 budget provided an additional $100 million from the General Fund over two years for SWEEP.) According to a recent report from CDFA, nearly all projects incorporate some form of irrigation scheduling technology as a water reduction strategy, while roughly half include the conversion to micro-irrigation or drip systems. Common GHG reduction strategies for projects include improved pump energy efficiency (65 percent) and pump fuel conversion (46 percent). Prior to 2021-22, the program largely has been funded through GGRF, but has received some funding from Proposition 68.

Assessment of Costs and Benefits

State Estimates Small GHG and Modest Water Benefits. CARB estimates that all funded projects from SWEEP will provide small GHG reductions totaling 0.1 MMTCO2e annually. Based on this estimate, the program reduces emissions at a state cost of roughly $95 per ton. Additionally, the program is estimated to provide moderate water savings of 117,000 acre-feet (or 37.5 billion gallons) annually, which is a state cost of roughly $70 per acre-foot over the lifespan of all funded projects.

As part of CDFA's required program evaluation of SWEEP, the department collects water and energy use data from a random sample of projects to measure the actual benefits achieved over a three-year period after project implementation. Data is collected from 10 percent of funded projects for the purpose of this evaluation. The evaluation compares actual post-project water and energy use data with reductions originally estimated prior to project implementation. CDFA has completed this evaluation from the early rounds of SWEEP.

Figure 8

Overview of Activities Funded Under SWEEP

Activity	Description
Water Reductions	
Micro-irrigation or drip systems	Conversion to micro-irrigation or drip systems from flood irrigation.
Sensors for irrigation scheduling	Installation of flow meters, soil moisture or plant sensors, weather gauges, evapotranspiration-based scheduling, and related components that allow the electronic communication between devices.
GHG Reductions	
Fuel conversion	Installation of pumps that use less carbon intensive fuels (such as replacing a diesel pump with an electric pump). Installation of renewable energy on-site (such as solar) to offset fuel use.
Improved pump energy efficiency	Efficiency improvements from retrofitting or replacing pumps. Installation of variable frequency drives to reduce energy use and match pump flow to load requirements.
Low-pressure systems	Installation of low-pressure irrigation systems to reduce pumping and energy use, such as the conversion of a high-pressure sprinkler system to a low-pressure micro-irrigation system or lower-pressure sprinkler system.
Reduced pumping through water reduction activities	Reduced pump demand resulting from water reductions, such as improved irrigation scheduling leading to reduced pump operation times.

SWEEP = State Water Efficiency and Enhancement Program and GHG = greenhouse gas.

Overall, these results indicate that SWEEP projects are meeting estimated GHG and water reductions and show evidence that some projects are exceeding expectations.

Long-Term Benefits Could Be Overstated. Despite results indicating that SWEEP is meeting estimated benefits, there is still uncertainty on whether the outcomes will persist over the long run. In particular, some research has found that operations that benefit from water irrigation efficiency programs, similar to SWEEP, might respond by utilizing the saved water in other ways, such as by switching to more water intensive crops or expanding their irrigated acreage. This type of response is known as a "rebound effect." Depending on the size of the potential rebound effect, increases in water usage could have an effect on GHG emissions—such as through increased pumping compared to what was estimated. CDFA tries to limit the potential of a rebound effect in the short run by requiring that grantees do not expand acreage under the program. However, this is likely not sufficient in the long run given that expansion or changes in cropping practices can occur after program funding is complete.

Recommendation

Direct CDFA to Research Potential Rebound Effect of SWEEP. Given the potential rebound effect associated with water efficiency programs, we find that it is important for the state to better understand whether estimated water and GHG reduction benefits from SWEEP persist over the long run. Therefore, we recommend the Legislature direct CDFA to research (1) the extent to which subsidizing on-farm water efficiencies results in a rebound effect from operations increasing irrigated acreage or switching to more water intensive crops in the long run, (2) the magnitude of the potential rebound effect, and (3) the degree to which GHG emissions are affected. Doing so should provide the Legislature and administration with more accurate estimates of the program's emission and water impacts and cost-effectiveness—information which can assist in future budget decisions and policymaking. Funding could initially be needed on a one-time basis to assess the rebound effect for past projects. We find that the costs for the analysis are likely to be small and could be covered using a share of future SWEEP funding. Alternatively, a one-time augmentation could be provided for research specifically for this purpose.

CONCLUSION

The state's climate programs in the agricultural sector provide funding to a wide variety of activities that attempt to reduce GHG emissions and sequester carbon. Based on our review, we find that the programs have merit in providing GHG benefits to the state. However, we find that benefits are likely overstated for various reasons, such as shortcomings in the methodologies used to calculate GHG benefits and uncertainty in project implementation. In light of these findings, we identify recommendations for additional evaluation and research to better assess the benefits of these programs. Improved information could then be used to help the Legislature target limited state funding to cost-effectively achieve policy goals—that is, to maximize GHG and methane reductions at the lowest cost possible.

LAO PUBLICATIONS

This report was prepared by Frank Jimenez, and reviewed by Brian Brown and Anthony Simbol. The Legislative Analyst's Office (LAO) is a nonpartisan office that provides fiscal and policy information and advice to the Legislature.

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