REDUCING METHANE EMISSIONS FROM THE SOLID WASTE SECTOR:

Lessons from California's Experiences

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Summary for Policymakers

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About the California-China Climate Institute

The California-China Climate Institute was launched in September 2019 and is a University of California-wide initiative housed jointly at UC Berkeley's School of Law (through its Center for Law, Energy, and the Environment) and the Rausser College of Natural Resources. It is chaired by Jerry Brown, former Governor of the State of California, and vice-chaired by the former Chair of the California Air Resources Board Mary Nichols. The Institute also works closely with other University of California campuses, departments, and leaders. Through joint research, training, and dialogue in and between California and China, this Institute aims to inform policymakers, foster cooperation and partnership, and drive climate solutions at all levels.

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SUMMARY FOR POLICYMAKERS

Methane is a short-lived greenhouse gas with more than 80 times the global warming impact of carbon dioxide over 20 years in the atmosphere. Therefore, reducing methane emissions is key to slowing climate change in the near term. Currently, solid waste landfills account for 20% of global anthropogenic methane emissions and are the third largest source of anthropogenic methane emissions in the United States.

Reducing methane emissions from solid waste landfills is a challenge because it requires a dramatic reduction of waste generation, effective enforcement of regulations, and large amounts of investment in infrastructure. However, the benefits of addressing this issue are huge: mitigating solid waste methane emissions will significantly slow climate change in the near term, as well as contribute to improving clean energy adoption and reducing food insecurity.

Within the U.S., California stands out as the first state to develop comprehensive reduction strategies for solid waste methane. In California, the solid waste sector is a key source of methane emissions, contributing 22% of the state's total methane emissions of 38.85 million metric tons of carbon dioxide equivalent (MMT CO_2e) in 2020. In recognition of the importance of reducing solid waste methane emissions, California first introduced its Landfill Methane Regulation in 2010. Since then, policies and programs have been developed and implemented to reduce methane emissions from municipal solid waste landfills.

Policies and programs have focused on two main approaches to reducing methane emissions from municipal solid waste landfills: (1) diverting organic waste from landfills, and (2) reducing methane emissions from existing landfills.

Policies, regulations, and financial incentives have been created to support this dual approach to reducing methane emissions. While California has made significant progress in landfill methane reduction, it is still behind in meeting its goals. This paper analyzes policies and programs, implementation mechanisms, and lessons learned from California in reducing methane emissions from the solid waste sector. California's lessons and experiences help provide insights for other regions on best practices that could be adopted, as well as existing challenges and gaps to achieve methane reductions.

DIVERTING ORGANIC WASTE FROM LANDFILLS

Diverting organic waste from landfills is a strategy California has implemented to avoid and reduce landfill methane generation in the first place, as landfill organic waste is converted to methane through biological decomposition. California's regulations on organic waste diversion started with mandatory municipal solid waste recycling as early as 2008, followed by mandatory recycling of organic waste beginning in 2014. In September 2016, California passed Senate Bill 1383, which aimed to reduce the disposal of organic waste in landfills by 50% of 2014 levels in 2020 and by 75% in 2025, and to recover at least 20% of disposed edible food by 2025. With this important legislation, California established a comprehensive regulatory system with clear targets supported by various financial approaches, including procurement programs, fees, credits, and market expansion, to reduce the disposal of organic waste.

Although California has taken a series of actions to divert organic waste from landfills, it still has not achieved the 2020 goals required by law (Table SPM-1). This slow progress could lead to annual methane emissions being higher through 2030 than originally anticipated by the latest Short-Lived Climate Pollutant Reduction Strategy published in 2017.

Table SPM-1 | Overall progress of California's organic waste diversion		
Criteria	**Goal**	**Progress**
Solid Waste Recycling Rate	75% by 2020	42% in 2020
Organic Waste Disposal Reduction Rate	50% by 2020 (compared to 2014 baseline)	11% in 2021 (compared to 2014 baseline)

The failure to achieve these 2020 targets is mainly because regulations under SB 1383 were not adopted until fall of 2020, they were prohibited from taking effect until January 2022, and local jurisdictions cannot enforce them until January 2024. In fact, state agencies relied on voluntary and incentive-based mechanisms to achieve the 2020 targets in the early years of SB 1383 implementation.

Despite the slow enforcement timeline, California has made significant progress in expanding organic waste processing infrastructure and the market for recovered organic waste products as a result of actions undertaken in support of SB 1383. Organic waste processing infrastructure has been expanding, meaning that more organic waste can be diverted from landfills in the future. Organic waste processing capacity has increased by about 400,000 tons in the past few years, and it is estimated that by 2025, California will be able to process 10 million tons of organic waste currently disposed of in landfills. At the same time, markets for recovered organic waste products, such as compost and biomethane, are growing.

However, key challenges still exist for achieving a level of organic waste diversion sufficient to meet California's future goals. Those challenges include slow progress in establishing waste collection and recycling services, a lack of and insufficient organic waste collection and processing infrastructure to meet anticipated needs,[1] and limits to market development for compost and biomethane (Table SPM-2).

REDUCING METHANE EMISSIONS FROM EXISTING LANDFILLS

Reducing methane emissions from existing landfills is also important since landfill methane will escape and become fugitive emissions if not effectively controlled. Since the Landfill Methane Regulation was issued in 2010, California has developed a holistic policy framework for reducing methane emissions from existing municipal solid waste landfills. Three types of measures are adopted to reduce methane from landfills:

- Regulations: The Landfill Methane Regulation sets standards for installing and operating gas collection and control systems, surface methane concentrations and component leak monitoring, emission exceedances correction, information reporting, and recordkeeping.
- Financial Mechanisms: Financial incentives and grants, enforcement equipment loans, and fees are adopted in California to encourage landfill gas recovery projects and support local enforcement agencies.
- Quantifying and Understanding Landfill Methane Emissions: Model estimation, methane hotspot research using a "tiered observation system" of remote sensing and ground verification, and regional inventory analysis are used to measure methane emissions at different scales and identify emission sources.

There is mixed progress in controlling landfill methane emissions. On the one hand, landfill methane emissions in California have increased slightly from 7.79 MMT CO_2e in 2010 to 8.44 MMT CO_2e in 2020. On the other hand, landfill methane emissions per ton of municipal solid waste in California shows a decreasing trend, despite the increasing amount of municipal solid waste disposal, which

[1] Approximately 18 million additional tons of organic waste will need to be processed at compost, anaerobic digestion, chip-and-grind, or other organic waste processing facilities in 2025 to meet the SB 1383 targets. However, based on current capacity projections, California's infrastructure will be able to process only about 10 million tons of the 18 million additional tons.

Table SPM-2 | Summary of key challenges to organic waste diversion		
Measures	**Key Challenges**	**Underlying Causes**
Establish Waste Collection and Recycling Services	Slow progress	• Regulations under SB 1383 did not take effect until January 2022
Infrastructure Expansion	Lack of organic waste processing infrastructure to meet anticipated needs	• Lack of funding • Lack of long-term feedstock contracts • Competition from lower-priced disposal alternatives • Increased environmental regulatory cost for facility development • Increased costs from contaminated feedstock
Recovered Organic Waste Product Market Development	Limits to compost market expansion	• Farmers in California might not have access to agricultural compost • Contaminated feedstock
	Limits to biomethane market expansion	• High capital expenses for distribution and connection • Market uncertainty for biogas projects • Ineffective pricing mechanism

is a sign of significant progress (Figure SPM-1). This progress can be attributed to the fact that a significant proportion of landfills in California have installed landfill gas collection and control systems. In addition, advanced technologies were utilized to monitor significant methane sources across the state and ensure compliance with the Landfill Methane Regulation.

However, despite California's progress, challenges still exist in quantifying and incentivizing greater reductions in landfill methane emissions. Technical factors responsible for these challenges include a lack of continuous methane leakage monitoring, simplified estimation models with limited validation of emission estimates, and the slow pace of technology innovation in improving landfill methane emission control.

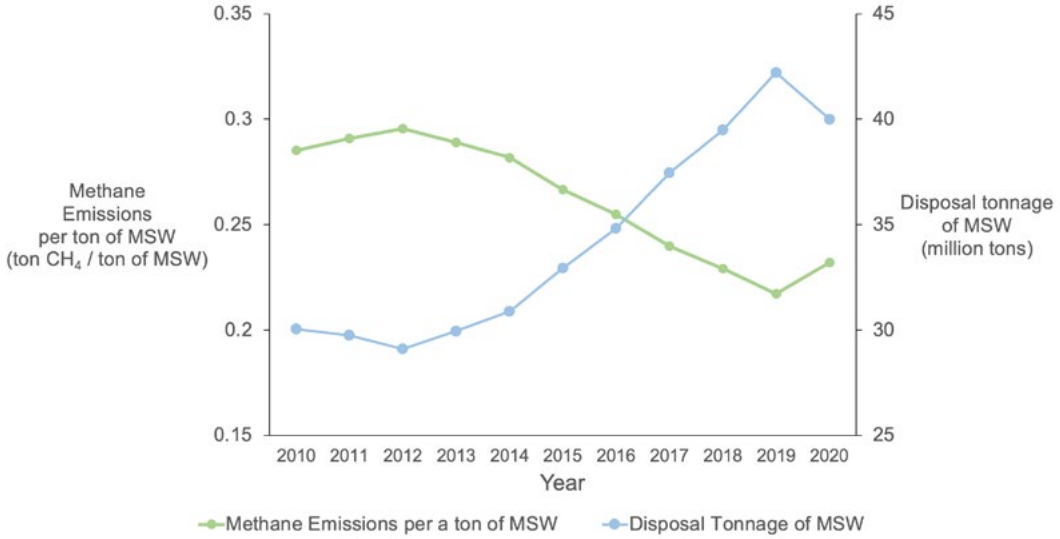
POLICY RECOMMENDATIONS

In support of the greenhouse gas reduction goals set in California's plan to reach carbon neutrality by 2045, more emphasis on landfill waste methane reduction will be needed. Existing policies and programs have resulted in some progress in organic waste diversion and limiting landfill methane emissions, but key targets for the solid waste sector remain unmet.

To effectively divert organic waste from landfills, the state government should focus on improving local jurisdictions' waste management systems and increase grant funding through CARB or CalRecycle programs to support infrastructure expansion. Local jurisdictions can consider organic waste treatment options beyond composting and anaerobic digestion. Education and outreach programs should be conducted widely because such programs can change people's behavior, which is important for reducing food waste and lowering the cost of organic waste diversion. The development of recovered organic waste product markets is also important for infrastructure expansion because higher demand for recovered organic waste products can drive production and will encourage infrastructure expansion.

In addition to the expansion of organic waste treatment facilities, more work needs to be done to effectively control methane emissions from existing landfills. These efforts will increase the collection of landfill methane as well as the supply of clean electricity. Currently, the cost

Figure SPM-1 | California Annual Municipal Solid Waste Disposal and Landfill Methane Emissions per Ton of Municipal Solid Waste[1]



[1] CARB, 2022a; Department of Resources Recycling and Recovery, n.d.-g

of inspection, equipment installment, landfill methane estimation model inaccuracy, and slow progress in methane control technology innovation are major barriers to landfill methane control. More financial support from the state government is necessary to develop new tools for field inspection. More research on landfill methane capture and collection technologies is needed to stimulate innovation and lower the cost of landfill methane control.

As the first state to develop comprehensive methane reduction strategies for the solid waste sector, California is uniquely positioned to spearhead global efforts to address the significant climate impacts of the solid waste sector. California's comprehensive landfill methane reduction framework, consisting of regulation, financial incentives, and many other policy instruments, provides a possible template for achieving solid waste methane reduction in other jurisdictions worldwide. Challenges that California is currently facing should be considered and addressed in the future when other jurisdictions devise policies to reduce solid waste methane.

Below are five policy recommendations for other jurisdictions based on lessons and experiences from California:

- A comprehensive methane policy package should include policy, regulations, financial incentives, and behavioral change-focused programs.
- Organic waste recycling and edible food recovery are critical components of solid waste methane mitigation strategies, as they reduce the overall financial and infrastructural burden on waste management systems while reducing potential methane emissions.
- As organic waste continues to increase, more infrastructure capacity is necessary to divert waste from landfills. It is important for subnational governments to consider and address the negative impacts of some organic waste treatment options (such as compost and anaerobic digestion) through available technologies and to explore new treatment options.
- Advanced monitoring systems, accurate inventory models, and financial support for technology innovation are needed to track and reduce methane emissions from existing landfills.
- Given the role of municipalities in waste management in many subnational jurisdictions (such as states and provinces), enforcing local compliance with state or national regulations is essential to implement methane reduction strategies.