Societal Benefits of Methane Mitigation

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EXECUTIVE SUMMARY

Methane is a potent, short lived greenhouse gas (GHG) emitted through energy, agriculture, and waste activities and it's responsible for nearly half of the current observed increase in global temperatures. Due to methane's high global warming potential—around 80 times that of carbon dioxide (CO_2) over a 20-year period—and additional negative health and environmental impacts, investment in methane abatement will generate immediate climate and societal benefits. And, because of its outsize impact, **cutting methane emissions is the fastest and most effective opportunity to slow the rate of global warming** and buy time for additional long-term action to reduce CO_2.

Methane emissions sources are highly dispersed and historically difficult to track, requiring solutions that vary widely in terms of costs and ease of deployment. Fortunately, over half of these solutions are available now at low costs and ready to be scaled up for widespread adoption. However, despite their benefits, methane abatement solutions across the top methane-emitting sectors are severely underfunded. Due to the urgency of the climate crisis, targeted investments in methane solutions must be prioritized to keep global temperatures from breaching the critical 1.5°C threshold.

In this white paper, Abt Associates illustrates the social benefits of prioritizing investments in methane abatement. Abt explored 16 out of over 40 methane abatement solutions in the energy, agriculture, and waste sectors. Collectively, these 16 technologies have the potential to reduce 20 percent of annual methane emissions by 2050, based on a 2017 baseline. We analyzed the social benefits of these solutions and compared the results to the social benefits of investing in renewable energy—specifically solar photovoltaics (PV) and wind.

Our analysis estimates that the social benefit of reducing 1 ton of methane is over 60 times that of reducing a ton of CO_2 from wind and solar PV. The difference in social benefits is due to the high social cost of methane and comparatively low methane abatement costs.

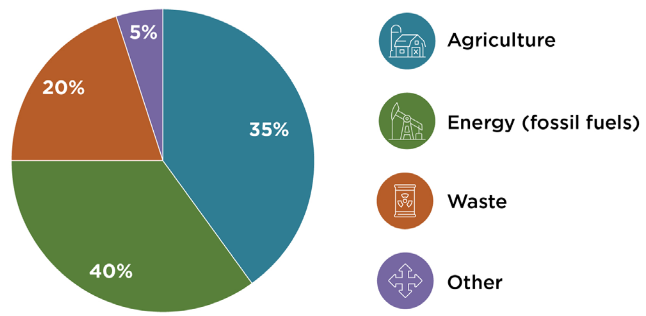
This cost-benefit comparison makes a strong case for policymakers and investors to take immediate action on methane emissions. Concentrating investment on methane abatement will yield a higher societal benefit while buying time for the long-term clean energy investments needed to stay on the pathway to 1.5°C.

Introduction

Methane is a potent, short lived greenhouse gas (GHG) that accounts for about half of the current observed global warming of 1.0°Celsius (°C).[1] Approximately half of all global methane emissions are the result of human activity, commonly referred to as anthropogenic sources. Within anthropogenic sources, three sectors account for almost all methane emissions: the energy, agriculture, and waste sectors.[2] Methane has a global warming potential that's more than 80 times higher than carbon dioxide (CO_2) over a 20-year period, resulting in a stronger immediate influence on global warming.[3]

Given this influence, methane abatement solutions are one of the fastest, most effective strategies to address the climate crisis. McKinsey research found that all existing solutions in the energy, agriculture, and waste sectors could be used to reduce global methane emissions by 20 percent by 2030 and 46 percent by 2050.[4]

Figure 1: Three sectors make up 95% of anthropogenic methane emission sources.

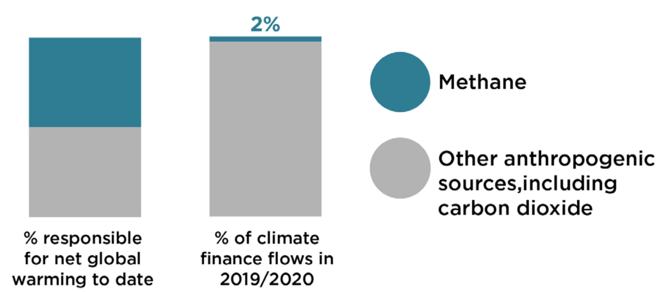


Source: United Nations Environment Programme and Climate and Clean Air Coalition (2021). Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions. Nairobi: United Nations Environment Programme.

Methane's short atmospheric lifespan, combined with its high global warming potential, means frontloading investments in methane abatement technologies now will deliver significant climate benefits in the near term while simultaneously providing long-lasting human health and environmental co-benefits. Many of the currently available methane abatement solutions recover and use biogas for beneficial energy uses. The energy benefits from methane abatement are quickly realized and can complement the more time-consuming transition to a decarbonized energy system and other climate mitigation strategies. Additionally, methane is a key precursor gas to the formation of tropospheric ozone, an air pollutant detrimental to human health and agricultural productivity. Reducing methane emissions can prevent an estimated 255,000 premature deaths from air pollution, 73 billion hours of lost labor from extreme heat, and 26 million metric tons (MMt) of crop losses annually.[2]

Despite the substantial climate and public health benefits, methane abatement solutions are severely underfunded. The Climate Policy Institute (CPI) found that, while methane was responsible for almost half of net global warming in 2020, finance for methane abatement represented less than 2 percent of total climate finance flows despite their climate mitigation potential.[5] Key barriers to increasing finance for methane abatement include the lack of policies and regulatory schemes to track methane leaks, difficulties in measuring methane emissions, finance data gaps, and lack of support for innovation.

Figure 2: Methane is responsible for almost half of net global warming but receives less than 2% of total climate finance flows.



Source: Rosane, P. et al. (2022). The Landscape of Methane Abatement Finance, Summary for Decision Makers. Climate Policy Initiative and Global Methane Hub.

Fortunately, roughly 60 percent of all readily available methane abatement technologies have low costs, and over half of these have negative costs. Targeted investments in these solutions must be prioritized now to avoid nearly 0.3°C of warming over the next two decades.[3] In this paper, Abt Associates builds on existing research to further illustrate the social benefits of prioritizing investment in methane abatement. The remainder of this paper is organized as follows:

- Section 2 examines the social cost of methane and carbon
- Section 3 explores a selection of methane abatement solutions and estimated costs between 2020 and 2050, the best available date range for the analysis
- Section 4 discusses the abatement costs for wind and solar PV
- Sections 5 and 6 discuss the results of the analysis and present conclusions

Social Cost of Methane and Carbon

The social cost of a specific GHG measures the monetary damage of emitting an additional ton of that gas into the atmosphere in a given year. It incorporates the cost of climate change impacts on society, including—but not limited to—changes in net agricultural productivity, human health effects, property damage from natural disasters, energy systems disruptions, conflict risk increases, and environmental migration. In a cost-benefit analysis, the social cost of a GHG can be used to determine the social benefits in terms of avoided social costs as measured in dollars per metric ton ($/ton) of a GHG reduced from regulatory or technological implementation.

Abt used the social cost of methane (SCM) and the social cost of carbon (SCC) in this analysis to quantify the social benefits of methane abatement. In 2021, the U.S. Interagency Working Group (IWG) on the Social Cost of Greenhouse Gas published a study that estimates SCM and SCC using 2.5 percent, 3 percent, and 5 percent discount rates, which are used to put costs and benefits that will occur in the future in present value terms. A higher discount rate means that future impacts are valued much less than present impacts, whereas a lower one means that they are valued more equally. Abt chose to use a 3 percent discount rate for this analysis for both SCM and SCC based on guidance by the U.S. Office of Management and Budget.[6]

Table 1 summarizes SCM and SCC from 2020 to 2050. By 2050, one ton of methane released causes over 35 times the economic damage caused by one ton of CO_2. The cost of releasing methane is much higher because methane is not only a powerful GHG that accelerates global warming, but also a harmful air pollutant that contributes to millions of premature respiratory deaths and decreases agricultural productivity.

Table 1: Social Cost of Methane ($/ton) and Carbon ($/ton) using a 3% discount rate, 2020-2050

Year	Social Cost of Methane	Social Cost of Carbon
2020	$1,500	$51
2025	$1,700	$56
2030	$2,000	$62
2035	$2,200	$67
2040	$2,500	$73
2045	$2,800	$79
2050	$3,100	$85

Methane Abatement Costs

Methane abatement technologies vary by sector and source of emissions. In this section, we explore 16 methane abatement solutions by sector and compile estimated costs of each from 2020 to 2050—the emissions year range with the best available data. Collectively, these solutions have the potential to reduce 20 percent of annual methane emissions by 2050, based on a 2017 baseline.[4]

Energy—Oil and Gas

Oil and gas operations contribute to roughly 23 percent of total global anthropogenic methane emissions.[2] Of these emissions, around 80 percent come from the upstream segment—onshore and offshore oil and gas production. The downstream segment, including refining, transmission, storage, and distribution operations, accounts for the remaining 20 percent.[7] Venting and leakages are the two main sources of methane from both upstream and downstream oil and gas operations. Gas flaring—the burning of natural gas to de-pressurize equipment during oil extraction—is also a major source of methane emissions in the upstream segment.

According to the International Energy Agency (IEA), the abatement potential in the oil and gas sector is high; deploying all available methane abatement technologies from this sector alone can avoid nearly 0.1°C of warming by mid-century—the equivalent of immediately cutting the GHG emissions of all cars, trucks, buses, and two- and three-wheelers in the world.[8]

Below, we analyze two solutions to reduce oil and gas methane: optical gas imaging for leak detection and repair (LDAR) for upstream and downstream operations, and electric leak controllers for upstream operations. A wide variety of other affordable and mature technologies are available to reduce methane emissions from oil and gas operations. Vapor recovery units are small compressors used to capture methane emissions that would otherwise be vented from crude oil or distillate storage tanks. Electrical pneumatic pumps can replace gas-driven pumps, which vent methane during upstream operations at well sites.[9]

Leak Detection and Repair

Optical Gas Imaging (OGI) for LDAR is an example of an effective, new, and market-ready methane abatement technology to detect and prevent leakages from the upstream and downstream segments of the oil and gas sector. OGI infrared cameras can be hand-held or operated remotely from ground-mounted installations or mobile deployment to scan large and hard-to-reach areas at facilities. This data is then used to visualize the source of methane leaks to enable immediate repairs and prevent further leaks. OGI cameras eliminate the need for manual, on-the-ground, monitoring of methane leaks, which is often costly, time-consuming, and unsafe.[10]

Electric Valve Controls

Replacing gas-driven pneumatic valve controllers—which operate valves based on measures of temperature or pressure—with electric valve controllers is another readily available methane abatement solution for addressing leakages from upstream oil and gas operations. Gas-driven pneumatic valve controllers run a high risk of methane leakage, whereas controllers powered directly by solar, or energy drawn from the grid, have zero risk of leakage.[11]

Table 2 summarizes the estimated abatement costs in dollars per metric ton ($/ton) of methane avoided for OGI and electric controllers.

Table 2: Estimated Costs ($/ton of methane avoided) for Oil and Gas Methane Abatement Technologies, 2020–2050

Year	Electric Controllers	Optical Gas Imaging
2020	$64.20	$795.36
2025	$54.86	$490.53
2030	$47.07	$302.53
2035	$40.40	$186.58
2040	$34.66	$115.07
2045	$29.75	$70.97
2050	$25.53	$43.77

Source: Analysis Group. (2022). Environmental Defense Fund. (2018).

Abt estimated the OGI costs based on a U.S. Environmental Protection Agency (U.S. EPA) cost study, which accounts for the gas cost savings from leak prevention. We estimated the cost of electric controllers based on a 2022 study on methane abatement technologies by the Analysis Group.[12] The declining costs to 2050 are based on the annual cost changes derived from the U.S. EPA and the Analysis Group studies. Investing in these technologies is an opportunity to not only mitigate climate change by limiting methane emissions but also generate revenues from gas leakage savings by capturing methane and selling it on the market. By 2050, the total methane mitigation potential for LDAR OGI and Electric Valve Controls is approximately 18.5 MMt of CO_2 equivalent (CO_2e) per year, which is around 5 percent of total annual methane emissions and equivalent to roughly 4 million gasoline-powered passenger vehicles driven for one year.[13]

Agriculture

Agricultural methane emissions are the largest reported methane emissions source. Within the roughly 40 percent of total anthropogenic global methane emissions attributed to agriculture, rice cultivation makes up 8 percent; the remaining 32 percent of emissions come from livestock, predominantly through enteric fermentation, but also through manure management practices.[1,14] Solutions to reduce methane from agriculture used in our analysis include improved animal feed and husbandry, livestock manure management, and rice cultivation management.

Enteric Fermentation

Cattle, sheep, and other ruminants produce emissions through enteric fermentation, a natural mammalian digestive process where gut microbes produce methane that the animal exhales. Rapid and large-scale implementation of improved livestock feeding strategies has the potential to reduce enteric fermentation methane emissions by up to 20 percent by 2030.[2]

Options for emissions abatement include feed grain processing to improve digestibility and feed supplements, especially antimethanogens, which reduce methane generation from enteric fermentation.

Additional natural and synthetic feed supplements, such as seaweed supplements, offer the potential for reducing methane emissions from the livestock sector but are currently considered experimental and are therefore not included in most abatement potential analyses. However, recent studies have demonstrated reductions in methane production from enteric fermentation by 30 percent-80 percent in sheep and cows.[15] Further research is needed to confirm dietary supplement benefits and explore the potential for scaling up these practices as well as fully characterizing potential effects on animal health and the long-term persistence of the identified potential benefits. Other strategies to mitigate enteric fermentation emissions included in our analysis are breeding to improve animal productivity and animal health improvements.

Manure Management

Livestock emissions are produced from the decomposition of livestock and poultry manure stored or treated in systems that promote anaerobic conditions (e.g., slurry or liquid in ponds, lagoons, tanks, or pits). The primary abatement strategy considered for manure management is the adoption of farm-scale anaerobic digesters for manure from cattle and pigs, which can reduce affiliated emissions by up to 22 percent by 2030.[16] There are four types of anaerobic digestion systems with widespread abatement potential included in our analysis: complete-mix, plug-flow, fixed-film digesters, and covered lagoons.

While not included in our analysis due to insufficient cost and mitigation information, other methane emissions abatement strategies to be considered are decreased manure storage time; improved manure storage covering; improved housing systems and bedding; and manure acidification.

Rice Cultivation

The anaerobic decomposition of organic matter—the breakdown of organic matter in the absence of oxygen—in flooded rice fields produces methane. When fields are flooded, aerobic decomposition of organic material gradually depletes the oxygen present in the soil and flood water, causing anaerobic conditions in the soil to develop. Once the environment becomes anaerobic, methane is produced through anaerobic decomposition of soil organic matter by methanogenic bacteria. Several factors influence the amount of methane produced, including water management practices and the quantity of organic material available to decompose. Full implementation of intermittent aeration of continually flooded rice paddies (known as alternate wetting and drying cultivation) could reduce global emissions from rice production by over 30 percent.[2]

Other measures—such as direct wet seeding, phosphogypsum and sulphate addition to inhibit methanogenesis; composting rice straw, and use of alternative hybrids—also have demonstrated potential to mitigate methane emissions and are included in our analysis. UNEP estimates the methane emissions abatement potential for rice cultivation to be 6–9 MMt per year.[2]

Table 3 shows the average estimated costs for methane abatement strategies under manure management, enteric fermentation, and rice cultivation. The total mitigation potential for the identified abatement strategies for manure management, enteric fermentation, and rice cultivation is 35 MMt of CO_2e per year, equivalent to roughly 9 percent of annual methane emissions, by 2050.[4] For each methane abatement solution, Abt used the 2030 cost estimates from the U.S. EPA's 2016 Non-CO_2 Greenhouse Gas Emission Projections and Mitigation report, and the 2050 estimates from McKinsey's 2021 Curbing Methane Emissions report.[17] To estimate costs for all other years, Abt interpolated the 2030 and 2050 costs linearly. This table demonstrates that agricultural methane abatement strategies are less than $1/ton of methane avoided and are expected to remain relatively stable from 2020 to 2050.

Table 3: Estimated Costs ($/ton of methane avoided) for Agriculture Methane Abatement Technologies, 2020–2050

Year	Manure Management	Enteric Fermentation	Rice Cultivation
2020	$0.76	$0.15	$0.40
2025	$0.77	$0.17	$0.30
2030	$0.80	$0.20	$0.20
2035	$0.82	$0.22	$0.10
2040	$0.83	$0.24	$0.01
2045	$0.85	$0.25	-$0.09
2050	$0.86	$0.27	-$0.19

Source: McKinsey (2021). U.S. EPA (2016).

Waste—Municipal Solid Waste

Globally, the waste sector (which includes municipal solid waste and wastewater) makes up about 20 percent of global anthropogenic methane emissions.[2] As is the case with energy and agriculture, technical solutions for the waste sector are readily available. According to UNEP, as much as 60 percent of waste-sector methane abatement measures have either negative or low costs, highlighting a significant opportunity in the sector.[2] Municipal solid waste generation is projected to increase by 70 percent by 2050, especially with a growing and rapidly urbanizing population.[16]

Around the world, between 64 percent and 68 percent of waste generated is organic, including food scraps, yard trimmings, wood, and wastepaper.[15] Methane is a major component of the landfill gas (LFG) emitted as these organic materials decompose in anaerobic conditions at open dumpsites and landfills. The release of methane from these dumpsites and landfills has the same warming impact as the CO_2 emissions from about 950 million gasoline passenger vehicles per year.[18] Utilizing readily available technology, up to 80 percent of methane emissions from landfills and dumpsites can be eliminated by diverting organic materials to composting sites or anaerobic digestion facilities.[19] Additionally, LFG captured directly from landfills can be utilized for power generation, vehicle fuel, or renewable natural gas.

Composting

Composting is a cost-effective solid waste management solution. It involves optimizing the natural decomposition of food, garden, and agricultural wastes into a fertilizer-like product to enrich the soil on farms, public lands, and gardens. Vermicomposting—where worms process organic materials in bins—is an example of a small-scale composting solution. In-vessel composting is a medium-scale solution that involves using a mechanized machine to process organic materials. Large-scale solutions include aerated windrow composting—where organic materials are structured in rows and regularly aerated and aerated static pile composting—through which static piles of organic materials are aerated internally with blowers.[20]

Anaerobic Digestion

As with agriculture residues and manure, anaerobic digestion is another mature and proven technology for methane abatement in the solid waste sector. An engineered anaerobic digestion system creates a controlled environment for the anaerobic digestion process—the breakdown of organic materials without the presence of oxygen—to produce biogas for beneficial use. Conventional anaerobic digestion—including completely mixed digesters, covered lagoons, plug flow digesters, and modified plug flow digesters—processes organic wastes in a liquid state. High-solids anaerobic digestion processes dry solid wastes in batches by stacking them into loose piles in sealed containers and saturating them with digestate.[21]

LFG Energy Capture and Use

To prevent methane from escaping into the air, LFG at landfills and dumpsites can be directly captured, converted, and used as a renewable energy source. LFG is extracted from landfills using a series of wells and vacuum systems. This system directs the gas to a central point where it is processed and treated for electricity generation or direct use. There are 2,633 dumpsites and landfills in the United States; only 538 of them have landfill gas capture systems.[22] The U.S. EPA estimates that an LFG energy project will capture between 60 and 90 percent of a site's methane emissions, depending on the system design.[23]

Table 4: Estimated Costs ($/ton of methane avoided) for Municipal Solid Waste Methane Abatement Technologies, 2020–2050

Year	Composting	AD	LFG to Power
2020	$1.88	$81.58	$0.42
2025	$1.56	$68.39	$0.35
2030	$1.25	$55.20	$0.28
2035	$0.94	$42.01	$0.21
2040	$0.63	$28.82	$0.14
2045	$0.31	$15.63	$0.07
2050	$0.00	$2.44	$0.00

Source: McKinsey (2021). U.S. EPA (2016).

Table 4 shows the estimated costs for composting, anaerobic digestion, and LFG in order to power projects. The total mitigation potential for the identified abatement strategies for composting, AD, and LFG to power is 22 MMt of CO_2e per year, equivalent to 6 percent of annual methane emissions, by 2050.[4] As in the agriculture section of this paper, Abt used the 2030 cost estimates from the U.S. EPA's 2016 Non-CO_2 Greenhouse Gas Emission Projections and Mitigation report, and the 2050 estimates from McKinsey's 2021 Curbing Methane Emissions report. Abt interpolated the costs for all other years linearly. The abatement cost for AD is projected to decrease to only $2.44/ton of methane avoided by 2050, while the costs for composting and LFG to power are poised to reach $0/ton, highlighting the cost-effectiveness of these technologies in avoiding methane emissions.

Wind and Solar PV Abatement Costs

Solar and wind energy are at the forefront of climate change abatement. The Climate Policy Institute (CPI) estimated that solar PV and wind received $296 billion in funding in 2019 and 2020, 26 times that received by methane abatement solutions.[24] Since 2010, the cost of solar PV electricity has fallen by more than 80 percent, and the cost of wind electricity has decreased by more than half, making them cost-competitive with fossil-fuel-generated electricity.[25] In a net-zero scenario, IEA estimates that solar PV and wind capacity are expected to increase more than eightfold by 2050, making up around 70 percent of the power grid by 2050.[26]

In the United States, electricity generation from utility-scale PV was 89.2 billion kilowatt-hours (kWh) and accounted for 3 percent of total U.S. electricity generation in 2020. Considering the rapidly decreasing costs of utility-scale PV, it is expected to account for 20 percent of total U.S. electricity generation in 2050.[27] The levelized cost of energy generated via utility-scale solar PV is currently estimated to be $0.46/kWh but is expected to reach $0.3/kWh in 2030 and could drop to around $0.15/kWh in 2050.[28] The abatement cost for utility-scale solar is expected to be around $50/ton CO_2e avoided in 2030 and $31/ton CO_2e avoided in 2050.[29]

Meanwhile, electricity generation from wind energy was 337.94 billion kWh and accounted for around 9 percent of the total U.S. electricity generation in 2020.[28] The estimated cost of electricity generation from wind energy was around $0.4/kWh in 2020 and is expected to drop as much as 49 percent by 2050.[30] The abatement cost for wind energy is expected to be around $79/ton of CO_2e avoided in 2030 and $35/ton of CO_2e avoided in 2050.[31]

Table 5 shows the estimated CO_2e abatement cost in $/ton for solar and wind energy. In this analysis, Abt used the 2030 and 2050 values for both solar and wind energy from the Marginal Abatement Cost Curves for U.S. Net-Zero Energy Systems 2021 report prepared by Evolved Energy Research for the Environmental Defense Fund. Abt performed a linear interpolation for the costs for all other years. While the costs of solar PV and wind have declined markedly over the past few decades, grid integration of these technologies remains a challenge. The continued reliance on fossil-fueled generation to compensate for solar PV and wind intermittency influences the carbon abatement potentials of these renewable energy technologies.

Table 5: Estimated Abatement Costs ($/ton CO_2e avoided) for Solar PV and Wind, 2020–2050

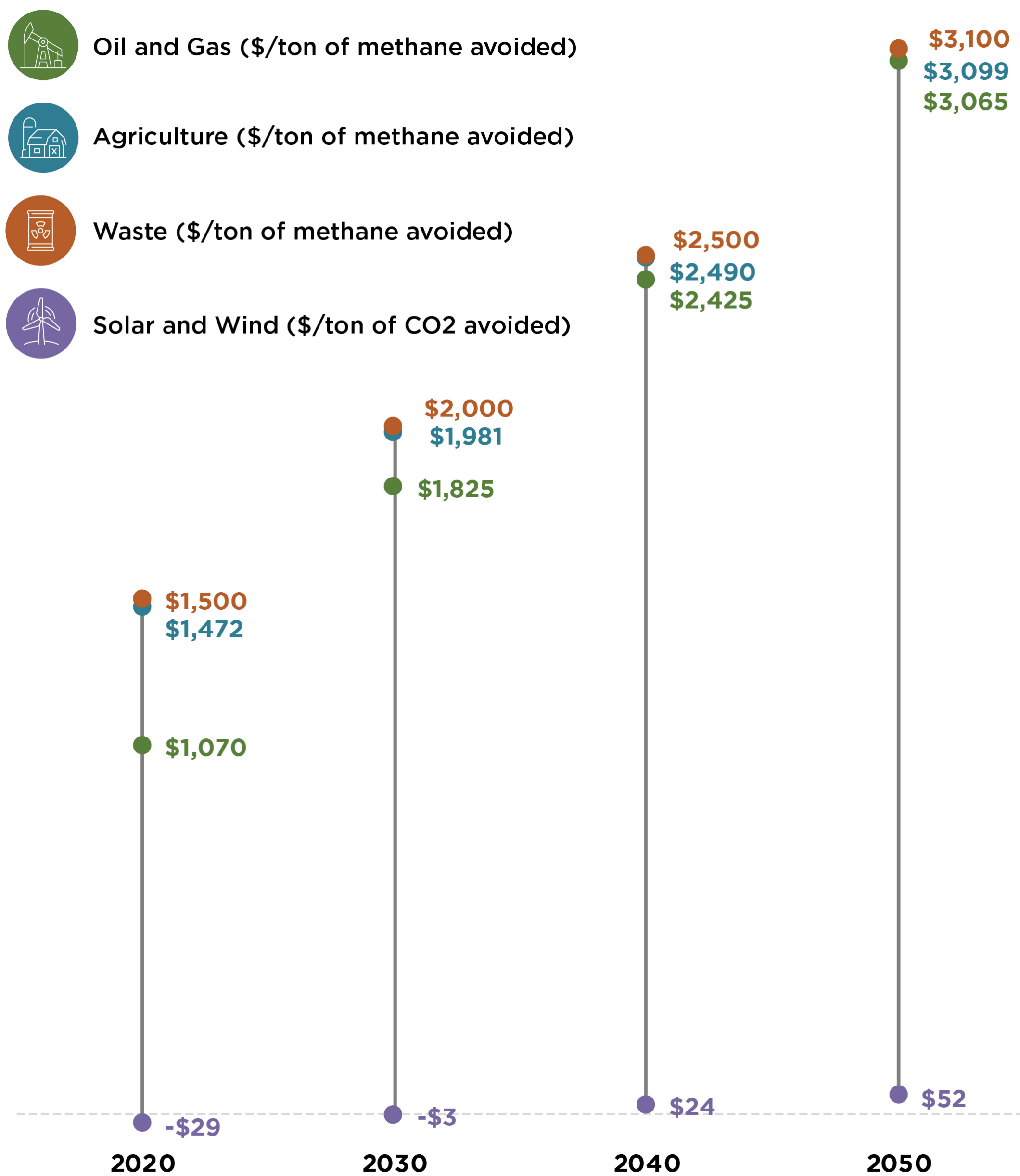
Year	Solar PV	Wind
2020	$59.50	$101.00
2025	$54.75	$90.00
2030	$50.00	$79.00
2035	$45.25	$68.00
2040	$40.50	$57.00
2045	$35.75	$46.00
2050	$31.00	$35.00

Source: Evolved Energy Research and Environmental Defense Fund (2021).

Results

The results of this analysis show that the identified methane abatement solutions provide substantial social benefits. Figure 3 compares the social benefits of methane abatement with those of wind and solar PV from 2020 to 2050. The social benefits of methane abatement—the difference between the SCM and the average costs of methane solutions from each sector—will increase from 2020 to 2050 as the cost of methane abatement technologies falls and the social cost of methane rises. By 2050, the social benefits of eliminating methane could be between $3,000 to $3,100 per ton, signifying the monetary value of the harm that could be avoided if methane emissions are reduced.

Figure 3: The social benefits of identified methane abatement solutions are expected to be nearly 60 times higher than installation of solar and wind energy by 2050. The identified waste sector solutions generate the highest social benefits.



The social benefits of solar PV and wind—the difference between the SCC and abatement costs of solar PV and wind generation—are much less than those of methane. The integration of solar PV and wind into the grid to displace fossil-fueled generation will inevitably be a challenge within the next several decades. This means that the social benefits of these technologies will not be realized in the near term, as shown by the negative social benefits in 2020 for solar PV and through 2035 for wind. **By 2050, the social benefits of reducing 1 ton of methane through the 16 identified methane abatement technologies could be worth almost 60 times those of reducing 1 ton of CO_2 through wind and solar PV.**

Policymakers and investors should keep in mind the high SCM when doing a cost-benefit analysis for a methane abatement strategy. SCM estimates by the U.S. IWG on the Social Cost of Greenhouse Gas are roughly 35 times higher than those of SCC, which means reducing a ton of methane with a low-cost strategy will likely bring more social benefits. Furthermore, several studies have found that the current SCM estimates are undervalued and should be even higher.[32] One study found that SCM should be weighted across countries, depending on their relative wealth, because methane results in a greater loss in well-being for low-income regions relative to wealthy ones. The study estimates SCM to rise to $8,040/ton for industrialized countries like the United States, almost 8 times the current SCM.[33]

Conclusions

Investments in economically viable existing methane abatement solutions must be a priority to reduce short-lived climate emissions and lessen the immediate impacts of climate change. Recent studies by McKinsey, IEA, and CPI have found that methane abatement technologies are affordable, but investments in these solutions are inadequate. This white paper builds on these studies by showing the substantial benefits of investing in methane abatement solutions. Policymakers and investors must account for the high cost of emitting methane when conducting a cost-benefit analysis of a methane abatement strategy. While methane abatement is one of the many tools in the climate toolbox, it must be urgently prioritized to immediately slow global warming and minimize negative impacts on human health and the environment.

Learn More About Our Methane Mitigation Work

https://www.abtassociates.com/insights/spotlight-on/methane

Endnotes

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