



**CLIMATE &
CLEAN AIR
COALITION**
TO REDUCE SHORT-LIVED
CLIMATE POLLUTANTS



GLOBAL METHANE ASSESSMENT

Summary for Decision Makers



Copyright © United Nations Environment Programme, 2021

This publication may be reproduced in whole or in part and in any form for educational or non-profit purposes without special permission from the copyright holder, provided acknowledgement of the source is made. The United Nations Environment Programme would appreciate receiving a copy of any publication that uses this publication as a source.

No use of this publication may be made for resale or for any other commercial purpose whatsoever without prior permission in writing from the United Nations Environment Programme.

DISCLAIMER

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning delimitation of its frontiers or boundaries. Moreover, the views expressed do not necessarily represent the decision or the stated policy of the United Nations Environment Programme, nor does citing of trade names or commercial processes constitute endorsement.

Suggested citation: 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.

ISBN: 978-92-807-3854-4

Job No: DTI/2352/PA

ACKNOWLEDGEMENTS

ASSESSMENT CHAIR

Drew Shindell

AUTHORS

A. R. Ravishankara, Johan C.I. Kuypenstierna, Eleni Michalopoulou, Lena Höglund-Isaksson, Yuqiang Zhang, Karl Seltzer, Muye Ru, Rithik Castelino, Greg Faluvegi, Vaishali Naik, Larry Horowitz, Jian He, Jean-Francois Lamarque, Kengo Sudo, William J. Collins, Chris Malley, Mathijs Harmsen, Krista Stark, Jared Junkin, Gray Li, Alex Glick, Nathan Borgford-Parnell

AFFILIATIONS

Duke University: Drew Shindell, Yuqiang Zhang, Karl Seltzer, Muye Ru, Rithik Castelino, Krista Stark, Jared Junkin, Gray Li, Alex Glick

NASA Goddard Institute for Space Studies/Columbia University: Greg Faluvegi
Geophysical Fluid Dynamics Laboratory (GFDL): Vaishali Naik, Larry Horowitz, Jian He

National Center for Atmospheric Research (NCAR): Jean-Francois Lamarque

Nagoya University: Kengo Sudo

University of Reading: William J. Collins

Stockholm Environment Institute (SEI): Johan Kuypenstierna, Chris Malley, Eleni Michalopoulou

Colorado State University, Fort Collins: A. R. Ravishankara

International Institute for Applied Systems Analysis (IIASA): Lena Höglund-Isaksson

Netherlands Environmental Assessment Agency (PBL): Mathijs Harmsen

Climate and Clean Air Coalition (CCAC): Nathan Borgford-Parnell

TECHNICAL REVIEWERS

Valentin Foltescu (Climate and Clean Air Coalition); Yangyang Xu (Texas A&M University, USA); Durwood Zaelke (Institute for Governance & Sustainable Development), Kristin Campbell (Institute for Governance & Sustainable Development); Gabrielle Dreyfus (Institute for Governance & Sustainable Development); Ben Poulter (National Aeronautics and Space Administration, US); Kathleen Mar (Institute for Advanced Sustainability Studies); Ilse Aben (Netherlands Institute for Space Research); Christopher Konek (United Nations Environment Programme); Vigdis Vestreng (Norwegian Environment Agency); Arif Goheer (Global Change Impact Studies Centre, Pakistan), Shaun Ragnauth (United States Environmental Protection Agency).

Technical Advisor for the Global Change Assessment Model (GCAM):
Daniel Loughlin (United States Environmental Protection Agency)

COPY EDITOR: Bart Ullstein

MANAGING EDITOR: Tiy Chung

GRAPHIC DESIGN AND LAY-OUT: Katharine Mugridge

An aerial, top-down view of a large industrial or manufacturing facility. The image shows several large, rectangular buildings with blue roofs and walls. The ground is paved with light-colored concrete, and there are prominent red and green painted walkways or lanes. Various pieces of industrial equipment, pipes, and structures are visible throughout the site. The lighting is bright, suggesting daytime.

EXECUTIVE SUMMARY

Reducing human-caused methane emissions is one of the most cost-effective strategies to rapidly reduce the rate of warming and contribute significantly to global efforts to limit temperature rise to 1.5°C. Available targeted methane measures, together with additional measures that contribute to priority development goals, can simultaneously reduce human-caused methane emissions by as much as 45 per cent, or 180 million tonnes a year (Mt/yr) by 2030. This will avoid nearly 0.3°C of global warming by the 2040s and complement all long-term climate change mitigation efforts. It would also, each year, prevent 255 000 premature deaths, 775 000 asthma-related hospital visits, 73 billion hours of lost labour from extreme heat, and 26 million tonnes of crop losses globally (Figure ES1).

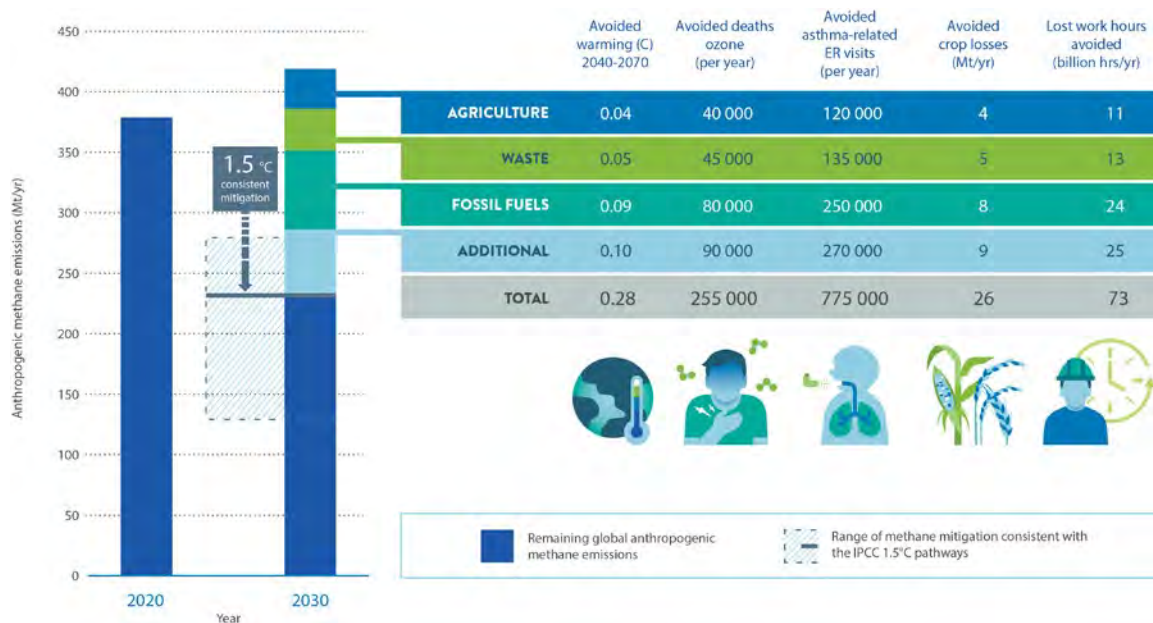


Figure ES1: Current and projected anthropogenic methane emissions and the identified sectoral mitigation potential in 2030 along with several benefits associated with sectoral-level methane emissions mitigation. Avoided warming occurs in the 2040s, other impacts are annual values beginning in 2030 that would continue thereafter.

The findings in this assessment are the result of modelling that uses five state-of-the-art global composition-climate models to evaluate changes in the Earth's climate system and surface ozone concentrations from reductions in methane emissions. Results allow for rapid evaluation of impacts from methane emissions and the benefits from mitigation strategies to the climate and ground-level ozone formation and, air quality, public health, agricultural and other development benefits. The assessment results are also available in a web-based decision support tool¹ that allows users to input different methane emissions reduction goals to calculate the multiple benefits at a national level.

THE OPPORTUNITY

- **More than half of global methane emissions stem from human activities in three sectors: fossil fuels (35 per cent of human-caused emissions), waste (20 per cent) and agriculture (40 per cent).** In the fossil fuel sector, oil and gas extraction, processing and distribution account for 23 per cent, and coal mining accounts for 12 per cent of emissions. In the waste sector, landfills and wastewater make up about 20 per cent of global anthropogenic emissions. In the agricultural sector, livestock emissions from manure and enteric fermentation represent roughly 32 per cent, and rice cultivation 8 per cent of global anthropogenic emissions. (Sections 1, 2.1 and 4.1)
- **Currently available measures could reduce emissions from these major sectors by approximately 180 Mt/yr, or as much as 45 per cent, by 2030. This is a cost-effective step required to achieve the United Nations Framework Convention on Climate Change (UNFCCC) 1.5° C target.** According to scenarios analysed by the Intergovernmental Panel on Climate Change (IPCC), global methane emissions must be reduced by between 40–45 per cent by 2030 to achieve least cost-pathways that limit global warming to 1.5° C this century, alongside substantial simultaneous reductions of all climate forcings including carbon dioxide and short-lived climate pollutants. (Section 4.1)
- **There are readily available targeted measures that can reduce 2030 methane emissions by 30 per cent, around 120 Mt/yr.** Nearly half of these technologies are available to the fossil fuel sector in which it is relatively easy

1. <http://shindellgroup.rc.duke.edu/apps/methane/>

to reduce methane at the point of emission and along production/transmission lines. There are also available targeted solutions in the waste and agricultural sectors. Current targeted solutions alone, however, are not enough to achieve 1.5° C consistent mitigation by 2030. To achieve that, additional measures must be deployed, which could reduce 2030 methane emissions by another 15 per cent, about 60 Mt/yr. (Sections 4.1 and 4.2)

- **Roughly 60 per cent, around 75 Mt/yr, of available targeted measures have low mitigation costs², and just over 50 per cent of those have negative costs – the measures pay for themselves quickly by saving money** (Figure SDM2). Low-cost abatement potentials range from 60–80 per cent of the total for oil and gas, from 55–98 per cent for coal, and approximately 30–60 per cent in the waste sector. The greatest potential for negative cost abatement is in the oil and gas subsector where captured methane adds to revenue instead of being released to the atmosphere. (Section 4.2)
- **The mitigation potential in different sectors varies between countries and regions.** The largest potential in Europe and India is in the waste sector; in China from coal production followed by livestock; in Africa from livestock followed by oil and gas; in the Asia-Pacific region, excluding China and India, it is coal and waste; in the Middle East, North America and Russia/Formal Soviet Union it is from oil and gas; and in Latin America it is from the livestock subsector. A majority of these major abatement potentials can be achieved at low cost, less than US\$ 600 per tonne of methane, especially in the waste sector and the coal subsector in most regions and for the oil and gas subsector in North America. (Section 4)
- **Mitigation potential from all measures is expected to increase between 2030 and 2050, especially in the fossil fuel and waste sectors.** (Section 4.2)
- **The levels of methane mitigation needed to keep warming to 1.5° C will not be achieved by broader decarbonization strategies alone.** The structural changes that support a transformation to a zero-carbon society found in broader strategies will only achieve about 30 per cent of the methane reductions needed over the next 30 years. Focused strategies specifically targeting methane need to be implemented to achieve sufficient methane mitigation. At the same time, without relying on future massive-scale deployment of unproven carbon removal technologies, expansion of natural gas infrastructure and usage is incompatible with keeping warming to 1.5° C. (Sections 4.1, 4.2 and 4.3)

2. Less than US\$ 600 per tonne of methane reduced, which would correspond to ~US\$ 21 per tonne of carbon dioxide equivalent if converted using the IPCC Fifth Assessment Report's GWP100 value of 28 that excludes carbon-cycle feedbacks.

WHY ACT

- **Methane, a short-lived climate pollutant (SLCP) with an atmospheric lifetime of roughly a decade, is a potent greenhouse gas tens of times more powerful than carbon dioxide at warming the atmosphere.** Methane's atmospheric concentration has more than doubled since pre-industrial times and is second only to carbon dioxide in driving climate change during the industrial era. (Section 1.1)
- **Methane contributes to the formation of ground-level ozone, a dangerous air pollutant.** Ozone attributable to anthropogenic methane emissions causes approximately half a million premature deaths per year globally and harms ecosystems and crops by suppressing growth and diminishing production. (Section 1.1 and 3.3)
- **The atmospheric concentration of methane is increasing faster now than at any time since the 1980s.** In the absence of additional policies, methane emissions are projected to continue rising through at least 2040. Current concentrations are well above levels in the 2° C scenarios used in the IPCC's 2013 Assessment. The Paris Agreement's 1.5° C target cannot be achieved at a reasonable cost without reducing methane emissions by 40–45 per cent by 2030. (Sections 1.1 and 4.1)
- **The growing human-caused emissions come from all three sectors: fossil fuels, agriculture and waste.** (Section 1 and 4.1)
- **Methane's short atmospheric lifetime means taking action now can quickly reduce atmospheric concentrations and result in similarly rapid reductions in climate forcing and ozone pollution.** Lower methane concentrations would rapidly reduce the rate of warming, making methane mitigation one of the best ways of limiting warming in this and subsequent decades. Doing so would also help limit dangerous climate feedback loops, while simultaneously delivering important health and economic benefits from reducing ground-level ozone. (Sections 1.1 and 5)
- **This assessment found that every million tonnes (Mt) of methane reduced:**
 - **prevents approximately 1 430 annual premature deaths due to ozone globally.** Of those, 740 would have died from respiratory disease and 690 from cardiovascular disease. Every million tonnes of reduced methane emissions could also avoid approximately 4 000 asthma-related accident and emergency department visits and 90 hospitalizations per year. (Section 3.4)
 - **avoids losses of 145 000 tonnes of wheat, soybeans, maize and rice ozone exposure every year.** This is roughly equivalent to increased global yields of 55 000 tonnes of wheat, 17 000 tonnes of soybeans, 42 000 tonnes of maize, and 31 000 tonnes of rice annually for every million tonnes of methane reduced. (Section 3.5)
 - **avoids the annual loss of roughly 400 million hours of work, approximately 180 000 years, globally due to extreme heat³.** Employment within those sectors of the economy that are affected by heat exposure varies between genders, leading to disparities in the impacts for men and women that differ across countries. (Section 3.4)

3. Labour impacts of heat exposure are the most dependent on the size of the methane emission changes, as well as background temperatures, and thus the linear scaling used here to obtain impacts per million tonnes is only approximate.

- **The global monetized benefits for all market and non-market impacts are approximately US\$ 4 300 per tonne of methane reduced⁴.** When accounting for these benefits nearly 85 per cent of the targeted measures have benefits that outweigh the net costs. The benefits of the annually avoided premature deaths alone from a 1.5°C-consistent-methane mitigation strategy is approximately US\$ 450 billion per year. (Sections 3.5 and 3.6)
- **In addition to the benefits quantified here, methane reduction measures also contribute to multiple Sustainable Development Goals (SDGs),** including climate action (SDG13), zero hunger (SDG2), good health and well-being (SDG3). Additionally, they provide cost reductions and efficiency gains in the private sector, create jobs, and stimulate technological innovation. (Sections 1.1, 4.4 and 5)

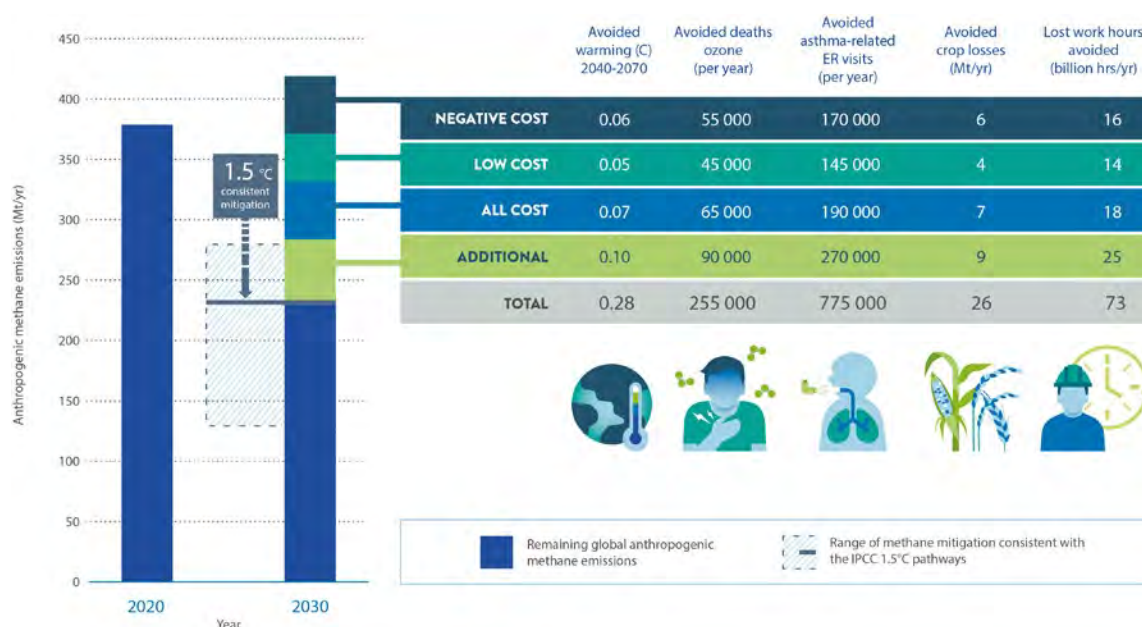


Figure ES2: Current and projected anthropogenic methane emissions and the identified mitigation potential in 2030 of targeted controls and their costs (low cost is greater than zero and less than 2018 US\$ 600 per tonne of methane) as well as a set of additional measures, such as energy efficiency and fuel switching, plus behavioural changes, such as reduced food waste, dietary modification and energy demand management, that are consistent with the 1.5° C long-term maximum warming target. The cost of implementation of all-cost measures is more than 2018 US\$ 600 per tonne of methane. Avoided warming is in 2040, other impacts are annual values beginning in 2030 that would continue thereafter.

4. Monetary values are in 2018 US\$. Fossil methane emissions are valued at ~\$4 400 per tonne of methane.

HOW TO DO IT

Trends in methane emissions need to be reversed to achieve a multitude of benefits by 2030. Targeted measures can be rapidly deployed to reduce methane emissions from the fossil fuel and waste sectors, with a majority at negative or low cost. To achieve targets consistent with keeping warming to 1.5° C, a combination of targeted measures and additional measures which reduce methane but do not primarily target it, are needed for all sectors, especially the agricultural one. There are many potential strategies that would facilitate the implementation of these measures including, for example, a price on emissions or an emissions reduction target. There are also barriers. These include addressing the lack of financing, enhancing awareness and improving education, changing production methods, developing new policies and regulations, and changes in consumption and consumer behaviour. Increased political will and private sector engagement and action are needed.

The specific measures include the following.

- **Oil, gas and coal:** the fossil fuel sector has the greatest potential for targeted mitigation by 2030. Readily available targeted measures could reduce emissions from the oil and gas sector by 29–57 Mt/yr and from the coal sector by 12–25 Mt/yr. Up to 80 per cent of oil and gas measures and up to 98 per cent of coal measures could be implemented at negative or low cost. (Section 4.2)
- **Waste:** existing targeted measures could reduce methane emissions from the waste sector by 29–36 Mt/yr by 2030. The greatest potential is in improved treatment and disposal of solid waste. As much as 60 per cent of waste-sector targeted measures have either negative or low cost. (Section 4.2)
- **Agriculture:** existing targeted measures could reduce methane emissions from the agricultural sector by around 30 Mt/yr by 2030. Methane emissions from rice cultivation could be reduced by 6–9 Mt/yr. The targeted mitigation potentials from livestock are less consistent, ranging from 4–42 Mt/yr. Average cost estimates vary across the available analyses. Behavioural change measures and innovative policies are particularly important to prevent emissions from agriculture, given the limited potential to address the sector's methane emissions through technological measures. Three behavioural changes, reducing food waste and loss, improving livestock management, and the adoption of healthy diets (vegetarian or with a lower meat and dairy content) could reduce methane emissions by 65–80 Mt/yr over the next few decades. (Sections 4.2 and 4.4)

- **Additional measures, which reduce methane emissions but do not primarily target methane, could substantially contribute to methane mitigation over the next few decades.** Examples include decarbonization measures – such as a transition to renewable energy and economy-wide energy efficiency improvements. Various implementation levers exist. Emissions pricing, for example, can be an effective policy which could incentivize substantial methane mitigation and support the broad application of methane reduction measures. A rising global tax on methane emissions starting at around US\$ 800 per tonne could, for instance, reduce methane emissions by as much as 75 per cent by 2050. (Section 4.3)
- **Incomplete knowledge and monitoring of emissions in some sectors limits the potential for technical mitigation innovation and strategic decision making to efficiently reduce methane emissions.** While there is enough information to act now, addressing emissions at the scale and in the timeframe necessary to meet the 1.5° C target will require an improved understanding of methane emissions levels and sources. Continued and improved cooperation to create transparent and independently verifiable emissions data and mitigation analyses is needed. Such cooperative efforts would enable governments and other stakeholders to develop and assess methane emissions management policies and regulations, verify mitigation reporting and track emissions reductions. (Section 5)
- **Greater regional and global coordination and governance of methane mitigation would support the achievement of the 2030 abatement levels identified here.** While methane reductions are increasingly being addressed through local and national laws and under voluntary programmes, there are few international political agreements with specific targets for methane. The Climate and Clean Air Coalition (CCAC) leads global efforts to drive high-level ambition, and strengthens national actions, policies, planning, and regulations around methane mitigation. (Section 5)

AN INTEGRATED APPROACH

Urgent steps must be taken to reduce methane emissions this decade. Given the wide range of impacts from methane, the societal, economic, and environmental benefits of acting are numerous and far outweigh the costs. The existence of readily available, low-cost, targeted measures, and methane's short-lived atmospheric lifetime means significant climate and clean air benefits can be achieved by 2030. Targets and performance indicators to reduce methane must address the combined and multiple impacts methane has on climate, air quality, public health, agricultural production and ecosystem health. Assessment methodologies should be commonly agreed upon and transparent. An integrated approach to climate and air quality mitigation is required to put the benefits of methane reductions into context. To keep warming to 1.5° C, focused strategies specifically targeting methane emissions need to be implemented alongside substantial and simultaneous mitigation of all other climate pollutants including carbon dioxide and short-lived climate pollutants.



TARGETED MEASURES	
FOSSIL FUEL SECTOR (OIL, GAS, AND COAL)	Upstream and downstream leak detection and repair
	Recovery and utilization of vented gas: capture of associated gas from oil wells; blowdown capture; recovery and utilization of vented gas with vapor recovery units and well plungers; Installation of flares.
	Improved control of unintended fugitive emissions from the production of oil and natural gas: regular inspections (and repair) of sites using instruments to detect leaks and emissions due to improper operations; replace pressurized gas pumps and controllers with electric or air systems; replace gas-powered pneumatic devices and gasoline or diesel engines with electric motors; early replacement of devices with lower-release versions; replace compressor seals or rods; cap unused wells.
	Coal mine methane management: pre-mining degasification and recovery and oxidation of ventilation air methane; flooding abandoned coal mines.
WASTE SECTOR	Solid waste management: (residential) source separation with recycling/reuse; no landfill of organic waste; treatment with energy recovery or collection and flaring of landfill gas; (industrial) recycling or treatment with energy recovery; no landfill of organic waste.
	Wastewater treatment: (residential) upgrade to secondary/tertiary anaerobic treatment with biogas recovery and utilization; wastewater treatment plants instead of latrines and disposal; (industrial) upgrade to two-stage treatment, i.e., anaerobic treatment with biogas recovery followed by aerobic treatment.
AGRICULTURAL SECTOR	Improve animal health and husbandry: reduce enteric fermentation in cattle, sheep and other ruminants through: feed changes and supplements; selective breeding to improve productivity and animal health/fertility
	Livestock manure management: treatment in biogas digesters; decreased manure storage time; improve manure storage covering; improve housing systems and bedding; manure acidification.
	Rice paddies: improved water management or alternate flooding/drainage wetland rice; direct wet seeding; phosphogypsum and sulphate addition to inhibit methanogenesis; composting rice straw; use of alternative hybrids species.
	Agricultural crop residues: prevent burning of agricultural crop residues.
ADDITIONAL BENEFICIAL MEASURES	
FOSSIL FUEL SECTOR (OIL, GAS, AND COAL)	Renewables for power generation: use incentives to foster expanded use of wind, solar, and hydro power for electricity generation.
	Improved energy efficiency and energy demand management: (residential) use incentives to improve the energy efficiency of household appliances, buildings, lighting, heating and cooling, encourage rooftop solar installations; (industrial) introduce ambitious energy efficiency standards for industry; improve consumer awareness of cleaner energy options.
WASTE SECTOR	Reduced consumer waste and improved waste separation and recycling, improved sustainable consumption.
AGRICULTURAL SECTOR	Reduced food waste and loss: strengthen and expand food cold chains; consumer education campaigns; facilitate donation of unsold or excess food.
	Adoption of healthier diets: decrease intake where consumption of ruminant products is above recommended guidelines.

Table SDM1 Measures To Reduce Methane By 45 Per Cent By 2030

Note: The classification of measures as 'targeted' or 'additional' broadly reflects whether the measure's focus is on methane reductions or whether reductions occur largely as a co-benefit of measures with another primary purpose, but final categorization is governed by the underlying literature on mitigation.



**CLIMATE &
CLEAN AIR
COALITION**
TO REDUCE SHORT-LIVED
CLIMATE POLLUTANTS

UN 
**environment
programme**



For more information, contact:
The Climate and Clean Air Coalition
Hosted by the United Nations Environment Programme
1 rue Miollis, 75015 Paris, France
email: secretariat@ccacoalition.org
Website: www.ccacoalition.org

ISBN: 978-92-807-3854-4
Job No: DTI/2352/PA

