United States Environmental Protection Agency
Office of Atmospheric Programs (6207J)
Washington, DC 20005

EPA-430-S-14-001
March 2014

Global Mitigation of Non-CO_2 Greenhouse Gases: 2010-2030

Executive Summary

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Introduction

Climate change is influenced by a number of social and environmental factors. The change in our Earth's climate is largely driven by emissions of greenhouse gases (GHGs) to the atmosphere. While some GHG emissions occur through natural processes, the largest share of GHG emissions come from human activities. GHG emissions from anthropogenic sources have increased significantly over a relatively short time frame (~100 years) and are projected to grow appreciably over the next 20 years.

Policy development and planning efforts are underway at all levels of society to identify climate change strategies that effectively reduce future greenhouse gas emissions and prepare communities to adapt to the Earth's changing climate. GHG mitigation analysis continues to play an important role in the formation of climate change policy. A large body of research has been dedicated to analyzing ways to reduce carbon dioxide (CO_2) emissions.

While this work is critical to developing effective climate policy, other GHG gases can play an important role in the effort to address global climate change. These non-carbon dioxide (non-CO_2) GHGs include methane (CH_4), nitrous oxide (N_2O), and a number of industrial gases such as fluorinated gases.

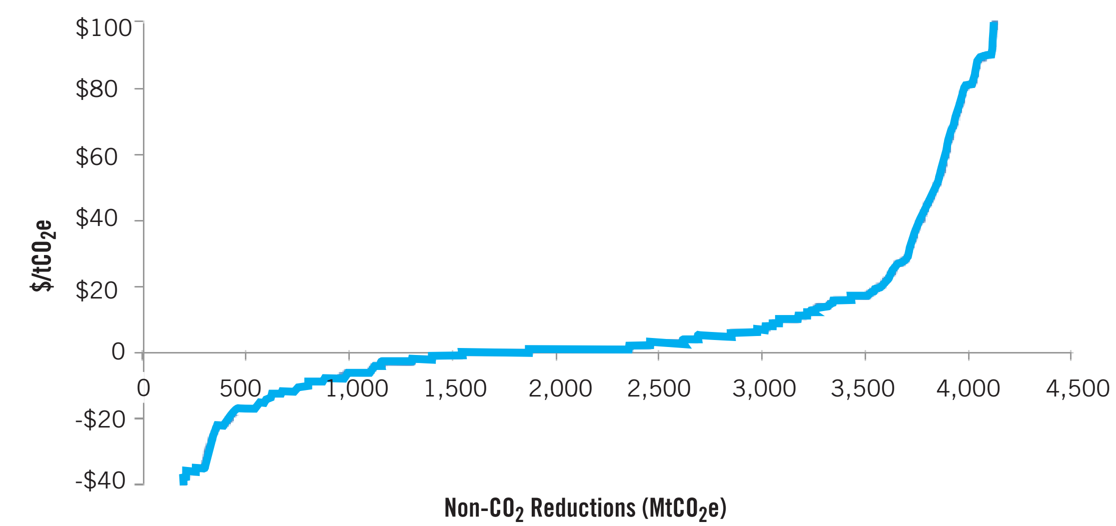
Non-CO_2 greenhouse gases are more potent than CO_2 (per unit weight) at trapping heat within the atmosphere. Global warming potential (GWP) is the factor that quantifies the heat trapping potential of each GHG relative to that of carbon dioxide (CO_2). For example, methane has a GWP value of 21 which means that each molecule of methane released into the atmosphere is 21 more times effective at trapping heat compared to an equivalent unit of CO_2. The table shows the list of GHG gases with their GWP values that are considered in this report.

Marginal abatement cost curves (MACCs) are an analytical tool commonly used in mitigation analysis to assist policy makers in understanding the opportunities for reducing GHG emissions and the relative cost of implementation. MACCs provide information on the amount of emissions reductions that can be achieved as well as an estimate of the costs of implementing the GHG abatement measures. This figure shows the Global MACC for all non-CO_2 GHGs in 2030. Worldwide, the potential for cost-effective non-CO_2 GHG abatement is significant. The figure shows the global total aggregate MAC for the year 2030. Without a price signal (i.e., at \$0/tCO_2e), the global mitigation potential is greater than 1,800 million metric tons of CO_2 equivalent (MtCO_2e), or 12% of the baseline emissions. As the break-even price rises, the mitigation potential grows. Significant mitigation opportunities could be realized in the lower range of break-even prices. For example, the mitigation potential at a price of \$10/tCO_2e is greater than 3,000 MtCO_2e, or 20% of the baseline emissions, and greater than 3,600 MtCO_2e or 24% of the baseline emissions at \$20/tCO_2e. In the higher range of break-even prices, the MACC becomes steeper, and less mitigation potential exists for each additional increase in price.

As the figure shows, higher levels of emissions reductions are achievable at higher abatement costs expressed in dollars per metric ton of CO_2 equivalent (\$/tCO_2e) reduced. The quantity of emissions that can be reduced, or the abatement potential, is constrained by the availability and effectiveness of the abatement measures (emission reduction technologies).

Greenhouse Gases	Abbreviation	GWP (100 year)
Carbon Dioxide	CO_2	1
Methane	CH_4	21
Nitrous Oxide	N_2O	310
Hydrofluorocarbons	HFCs	140 to 11,700
Sulfur Hexafluoride	SF_6	23,900

Global MACC for Non-CO_2 Greenhouse Gases in 2030



About this Report

USEPA has recently updated its International MACC model for the Non-CO_2 anthropogenic sources that include energy, waste, industrial processes, and agricultural activities. The results of this analysis are published in the EPA report *Global Mitigation of Non-CO_2 Greenhouse Gases: 2010-2030* and include improved country-level resolution and increased transparency in the economic and technological assumptions underlying the abatement measures considered in the analysis. This report is intended to provide a brief summary of the abatement potential and costs of implementing specific abatement technologies. Readers interested in more technical details of the analysis should refer to the full technical report, which is available at EPA's International Non-CO_2 Mitigation web page.[1]

[1] The Global Mitigation of Non-CO_2 Greenhouse Gases: 2010-2030 report is available at: http://www.epa.gov/climatechange/EPAactivities/economics/nonco2mitigation.html

Coal Mining

CH_4 Emissions from Underground Coal Mining

Key Points

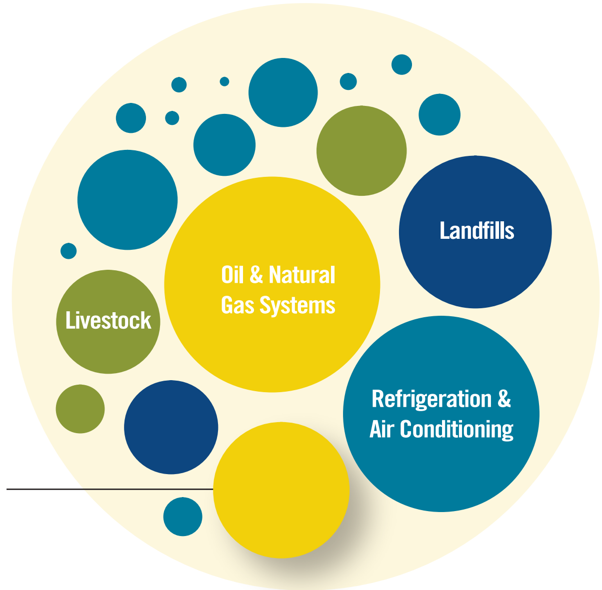
- Coal mining accounted for 8% of total global anthropogenic methane emissions in 2010, and these emissions are projected to increase by 33% to 784 $MtCO_2e$ by 2030.
- The global abatement potential is projected to be 50 to 468 tCO_2e, or 6 to 60% of baseline emissions, in 2030. Cost-effective abatement potential ($0 break-even price) is 77.7 tCO_2e, or 10% of baseline.
- The technological maximum potential ($100+ break-even price) is 467.6 tCO_2e, or 60% of baseline.

Sector Description

Coal is an important energy source for many of the world's economies; it is used for energy generation or as a feedstock for industrial production. However, coal mining is a significant source of anthropogenic GHG emissions. Extracting coal through underground and surface mining releases methane (CH_4) stored in the coal bed and the surrounding geology. According to the U.S. Energy Information Administration's most recent international energy outlook, coal production is projected to increase by 22% between 2012 and 2040, reflecting continued economic and industrial development of the world's emerging economies.

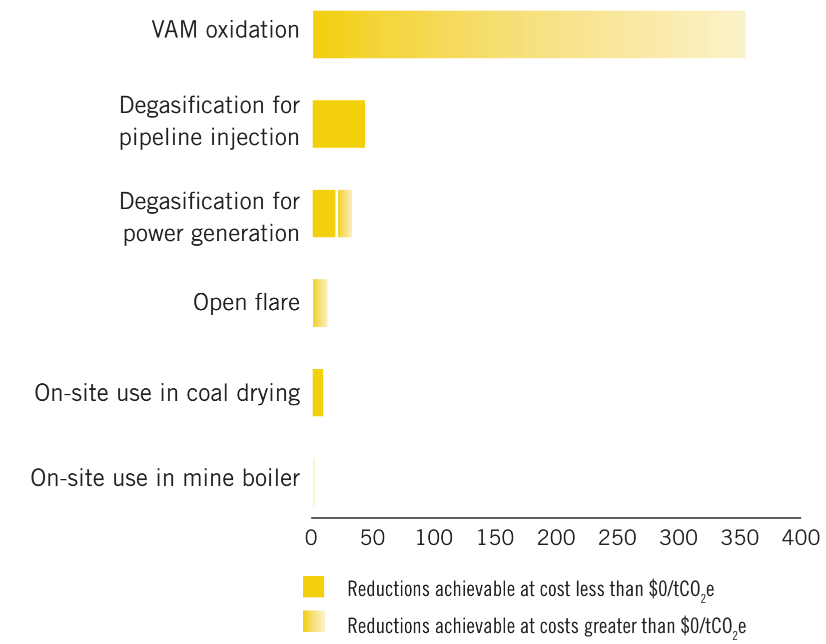
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the coal mining sector could be reduced by up to 468 $MtCO_2e$ in 2030. This accounts for 10% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



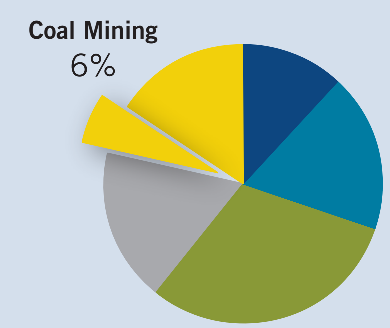
Abatement Measures

Five abatement measures were considered in this analysis, including recovery for pipeline injection, power generation, process heating, flaring, and catalytic or thermal oxidation of ventilation air methane (VAM). These reduction technologies consist of one or more of the following primary components: 1) a drainage and recovery system to remove methane from the underground coal seam, 2) the end-use application for the gas recovered from the drainage system, and 3) the VAM recovery or mitigation system.

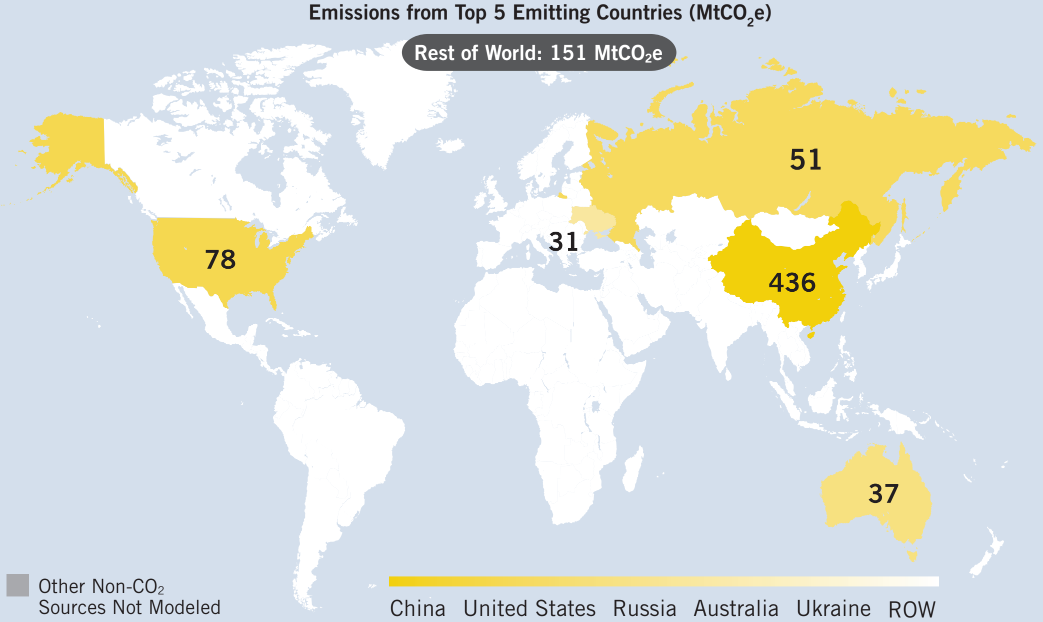
Projected Emissions in 2030

Global Non-CO_2 Emissions

Coal Mining sector baseline emissions are estimated to be 589 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 784 $MtCO_2e$ or 6% of total non-CO_2 emissions.

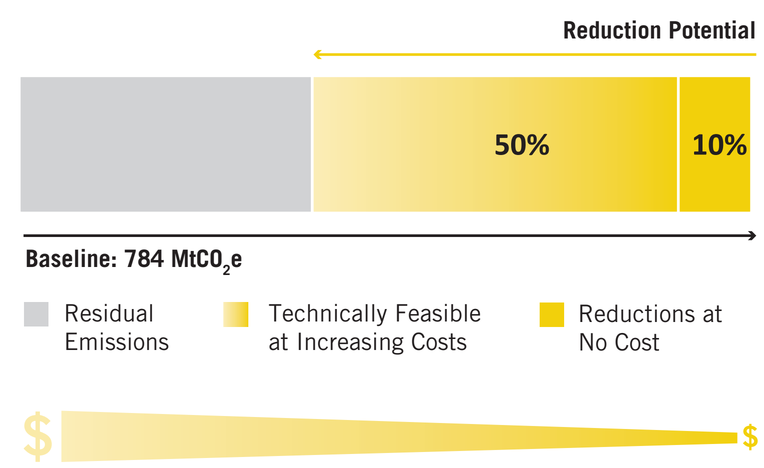


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 10%, compared to the baseline, in 2030. An additional 50% reduction is available using technologies with increasingly higher costs.



Abatement Potential

Approximately 60% of total annual emissions in 2030 can be reduced through the adoption of the suite of abatement measures considered. The marginal abatement cost curve (MACC) results suggest that significant reductions in CH_4 emissions can be achieved at break-even prices at or below $10/$tCO_2e$. Furthermore, reductions of approximately 78 $MtCO_2e$ are cost-effectively achievable at a break-even price of $0/$tCO_2e$.

Oil and Natural Gas Systems

CH_4 Emissions from Oil and Natural Gas Systems

Key Points

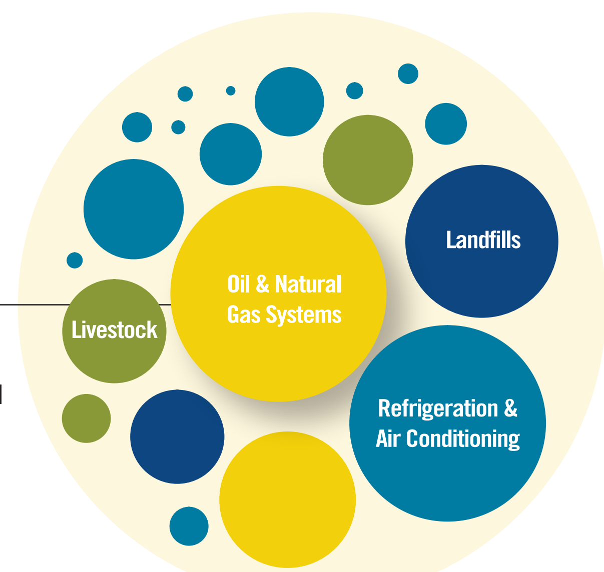
- **The technological maximum for emissions reduction potential in oil and gas is 1,219 $MtCO_2e$, approximately 58% of projected emissions in 2030.**
- **Because of the energy value of the methane captured, EPA estimates that 747 $MtCO_2e$, or 40% of the baseline emissions, can be cost-effectively reduced.**
- **Over 26% of total abatement potential is achieved by adopting abatement measures in the oil and gas production segments.**

Sector Description

Oil and natural gas systems are one of the leading emitters of anthropogenic CH_4, releasing 1,677 $MtCO_2e$, or 23% of total global CH_4 emissions in 2010. The top five CH_4 emitters from oil and natural gas systems in 2010 were Russia, the United States, Iraq, Kuwait, and Uzbekistan. Global emissions from the oil and natural gas system are projected to grow 26% between 2010 and 2030, with Brazil and Iraq experiencing the highest growth rate at 128% and 100%, respectively.

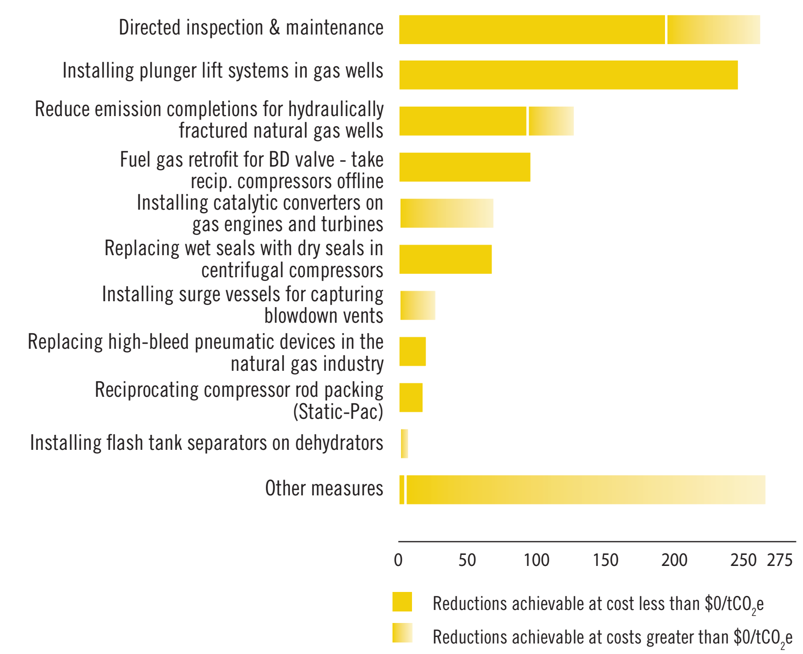
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the oil and natural gas systems sector could be reduced by up to 1,219 $MtCO_2e$ in 2030. This accounts for 26% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



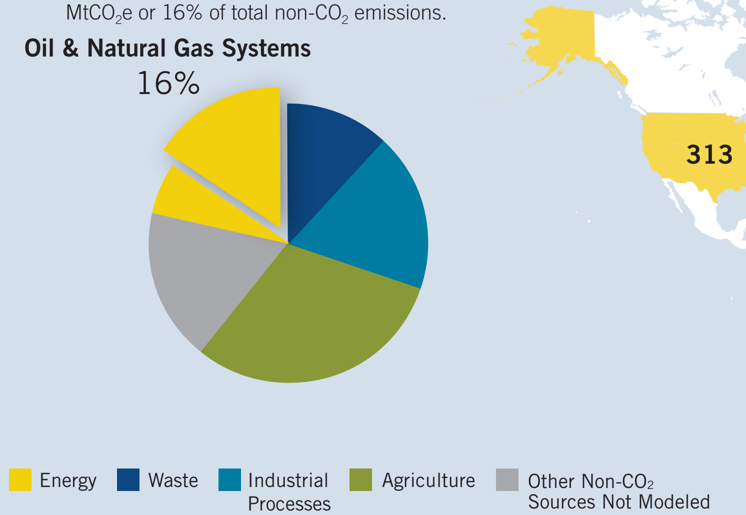
Abatement Measures

Numerous abatement measures are available to mitigate CH_4 emissions across the four oil and natural gas system segments of production, processing, transmission, and distribution. The measures may be applied to various components or equipment commonly used in oil and natural gas system segments. The abatement measures typically fall into three categories: equipment modifications/upgrades; changes in operational practices, including direct inspection and maintenance; and installation of new equipment.

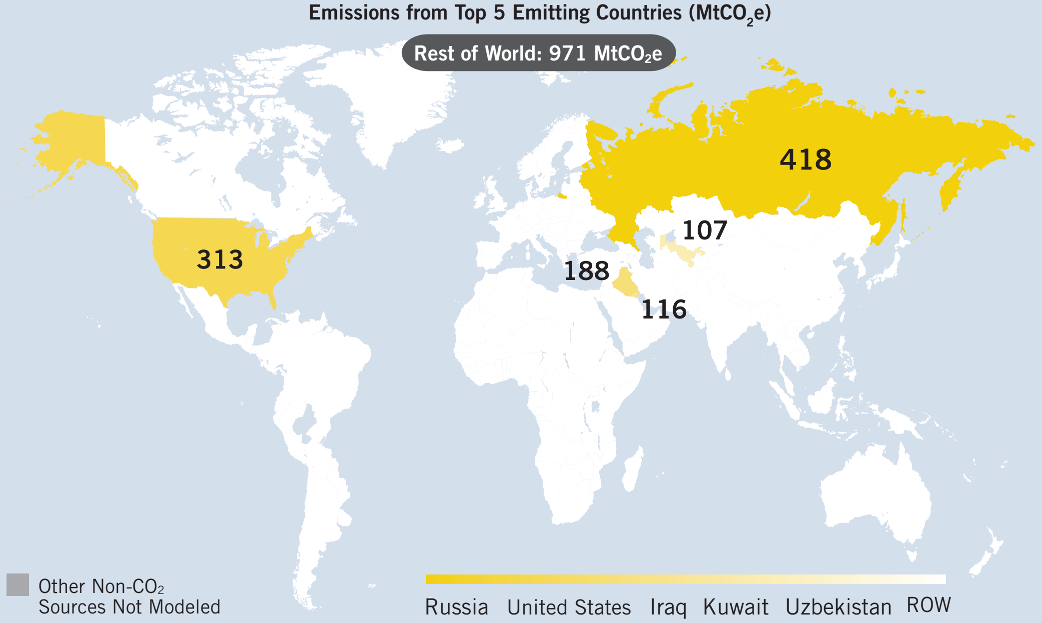
Projected Emissions in 2030

Global Non-CO_2 Emissions

Oil and Natural Gas Systems baseline emissions are estimated to be 1,677 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 2,113 $MtCO_2e$ or 16% of total non-CO_2 emissions.

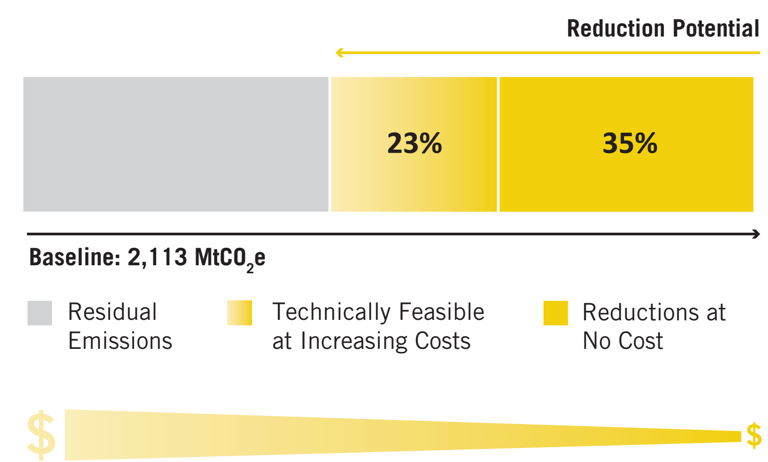


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 35%, compared to the baseline, in 2030. An additional 23% reduction is available using technologies with increasingly higher costs.



Abatement Potential

In 2010, the global abatement potential in the oil and natural gas sector is projected to be 997 $MtCO_2e$, or 60% of total emissions. The abatement potential increases over time growing to 1,103 and 1,218 $MtCO_2e$ in 2020 and 2030, respectively. Nearly 70% of the emissions reductions in 2030 are achievable at break-even prices at or below $5.

Landfills

CH_4 Emissions from Municipal Solid Waste (MSW) Landfills

Key Points

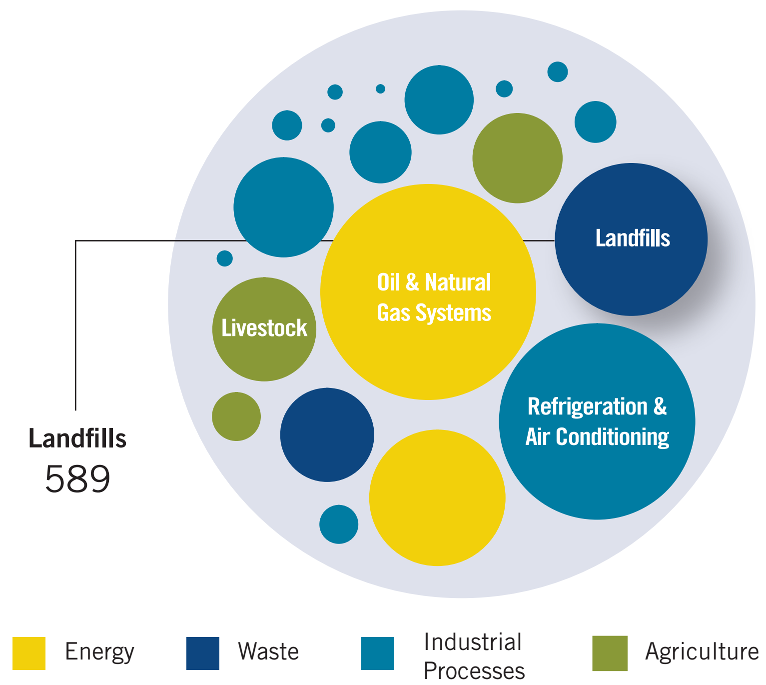
- Global abatement potential from landfills is 589 $MtCO_2e$, roughly 61% of projected baseline emissions in 2030.
- Abatement measures with costs below $20/$tCO_2e$ can achieve a 30% reduction in baseline emissions.
- Abatement measures include (1) conversion of landfill gas to energy and (2) waste diversion projects that use waste in the production of new products.

Sector Description

Landfills produce methane in combination with other landfill gases (LFGs) through the natural process of bacterial decomposition of organic waste under anaerobic conditions. LFG is generated over a period of several decades with gas flows usually beginning 1 to 2 years after the waste is put in place. The amount of methane generated by landfills per country is determined by a number of factors that include population size, the quantity of waste disposed of per capita, composition of the waste disposed of, and the waste management practices applied at the landfill.

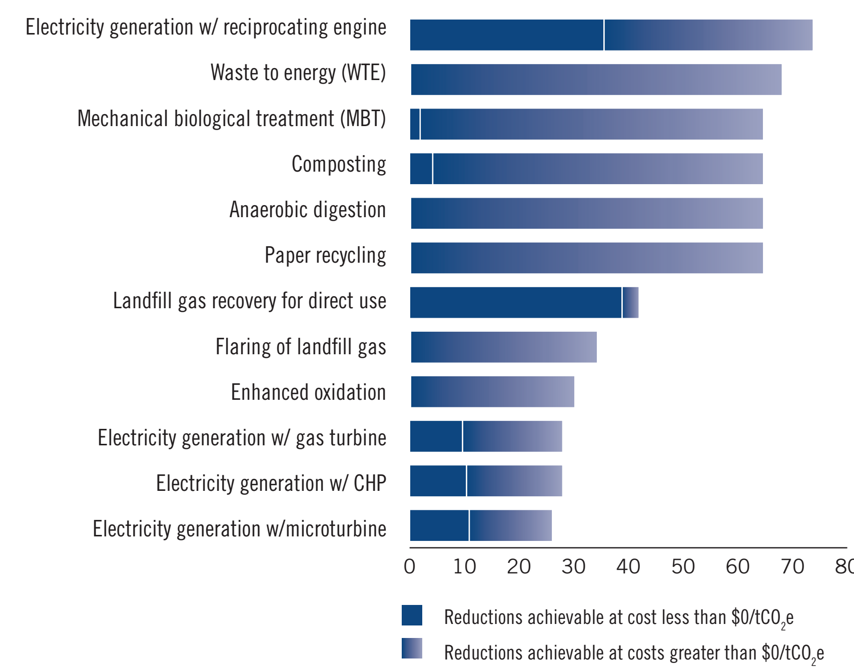
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the landfill sector could be reduced by up to 589 $MtCO_2e$ in 2030. This accounts for 13% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

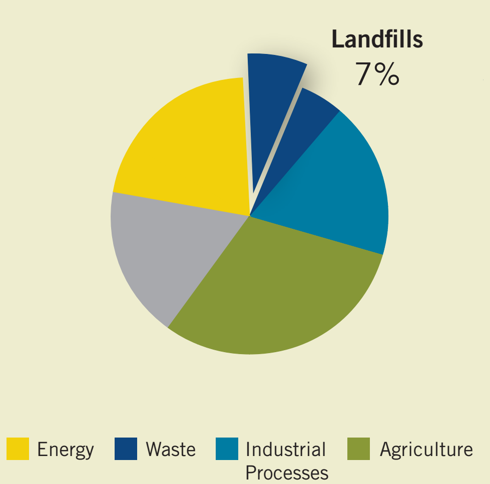
Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



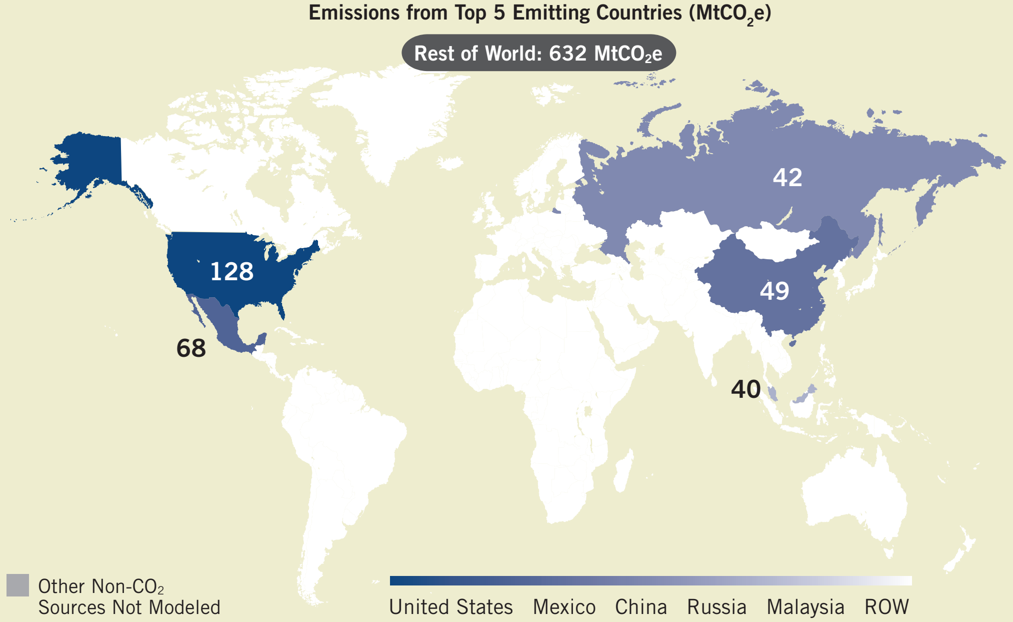
Projected Emissions in 2030

Global Non-CO_2 Emissions

Landfills sector baseline emissions are estimated to be 847 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 959 $MtCO_2e$ or 7% of total non-CO_2 emissions.

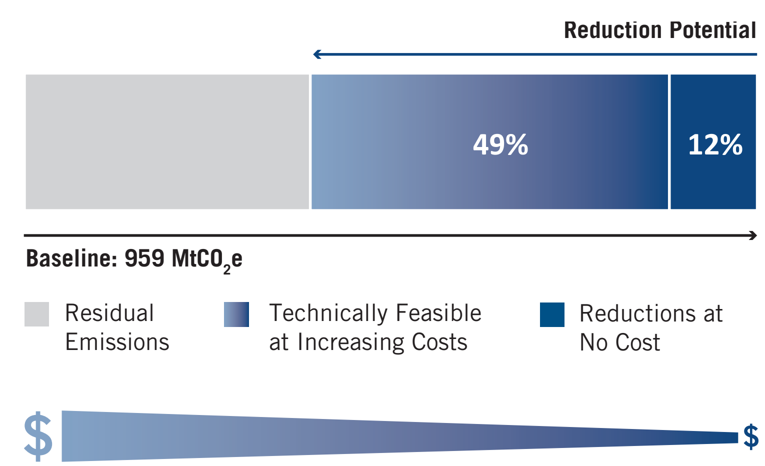


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 12%, compared to the baseline, in 2030. An additional 49% reduction is available using technologies with increasingly higher costs.

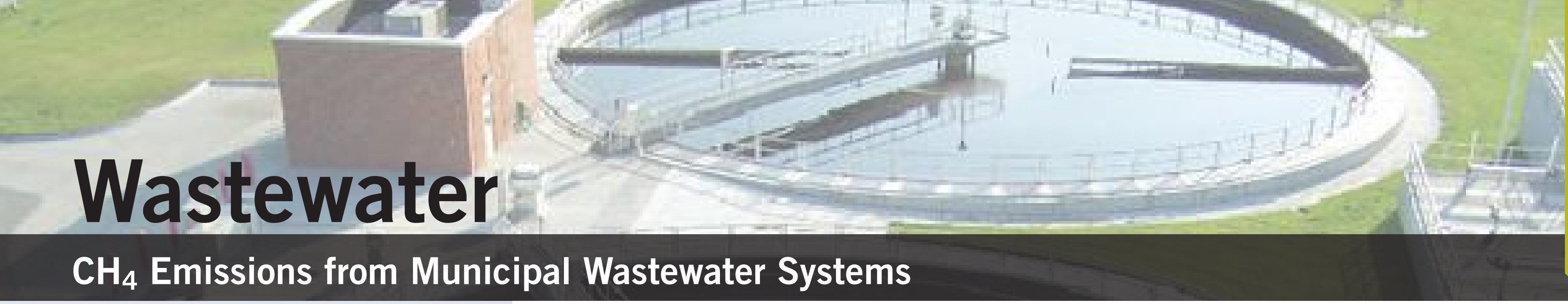


Abatement Measures

Several abatement measures are available to control landfill methane emissions, and they are commonly grouped into three major categories: (1) collection and flaring, (2) LFG utilization systems (LFG capture for energy use), and (3) enhanced waste diversion practices (e.g., recycling and reuse programs). Although flaring is currently the most common abatement measure, LFG utilization options may be more cost-effective. Under favorable market conditions, recycling and reuse or composting alternatives may provide additional means for reducing emissions from landfills.

Abatement Potential

Global abatement potential in the solid waste landfill sector is estimated to be approximately 589 $MtCO_2e$ of total annual emissions in 2030, or 61% of the baseline emissions. The marginal abatement cost curve results suggest that there are significant opportunities for CH_4 reductions in the landfill sector at costs below $20 per tCO_2e emissions reduced. Furthermore, approximately 70 to 80 $MtCO_2e$ of reductions are cost-effective at current energy prices.



Wastewater

CH_4 Emissions from Municipal Wastewater Systems

Key Points

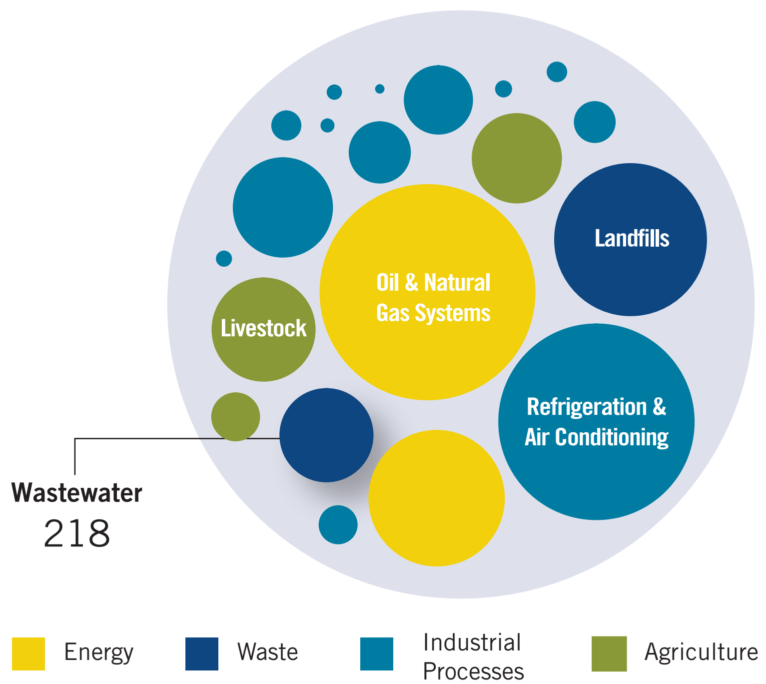
- Methane (CH_4) emissions from wastewater treatment accounted for over 500 $MtCO_2e$ in 2010 and are projected to grow 20% by 2030.
- The estimated maximum abatement potential in 2030 is 218 $MtCO_2e$, or 36% of projected emissions.
- Abatement measures with costs less than \$30 tCO_2e can achieve a 15% reduction in CH_4 emissions in 2030.

Sector Description

Wastewater is the fifth largest emitter of anthropogenic CH_4, accounting for more than 500 $MtCO_2e$ in 2010; wastewater treatment is also a source of N_2O emissions. Domestic and industrial wastewater treatment activities can lead to venting and fugitive emissions of CH_4, which are produced when organic material decomposes under anaerobic conditions of wastewater in a facility. Most developed countries use aerobic wastewater treatment systems to minimize the amount of CH_4 generated, but many developing countries rely on systems such as septic tanks, latrines, open sewers, and lagoons, which allow for greater levels of anaerobic decomposition.

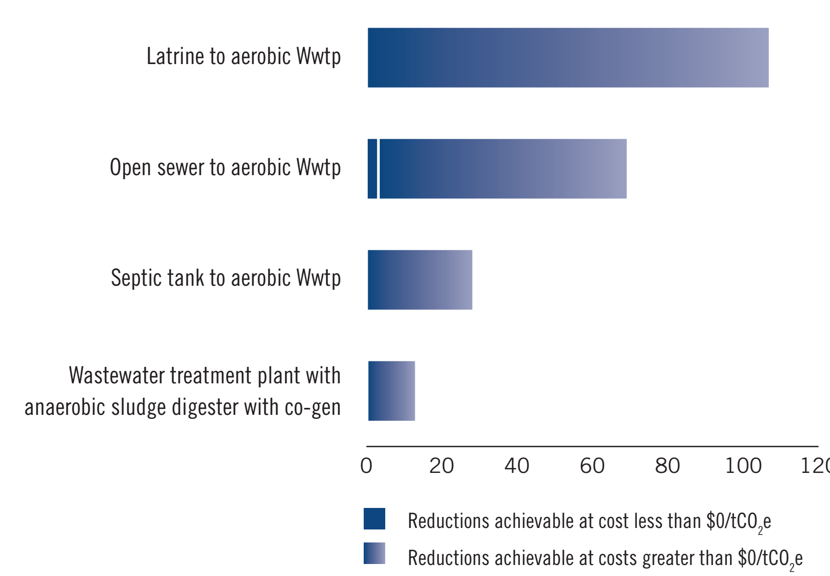
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the wastewater sector could be reduced by up to 218 $MtCO_2e$ in 2030. This accounts for 5% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

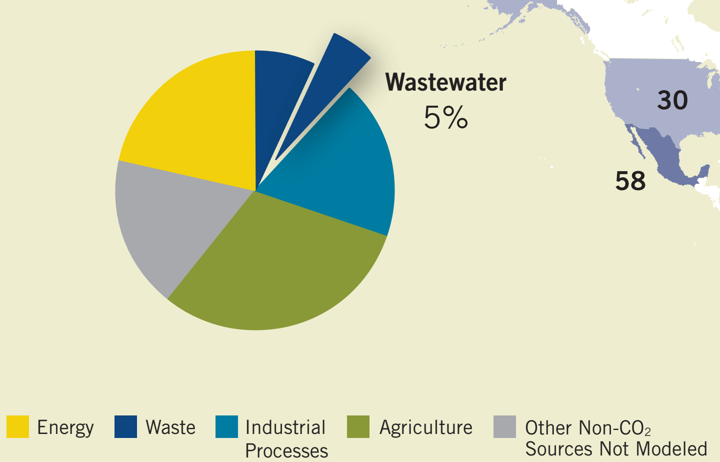
Emissions reductions by technology in 2030 at \$0/tCO_2e and at higher prices.



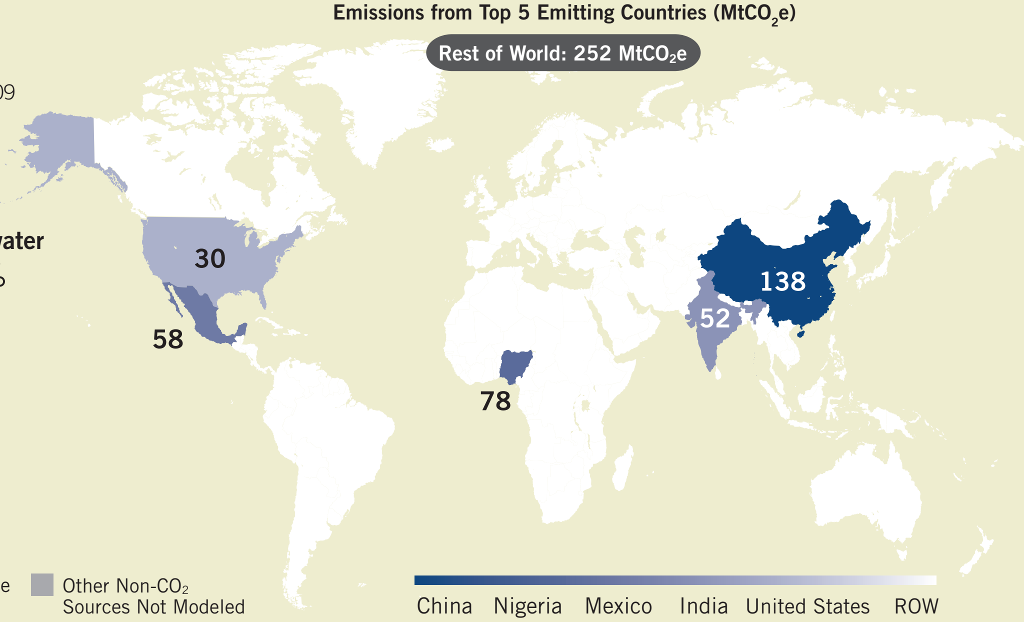
Projected Emissions in 2030

Global Non-CO_2 Emissions

The Wastewater sector baseline emissions are estimated to be 512 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 609 $MtCO_2e$ or 5% of total non-CO_2 emissions.

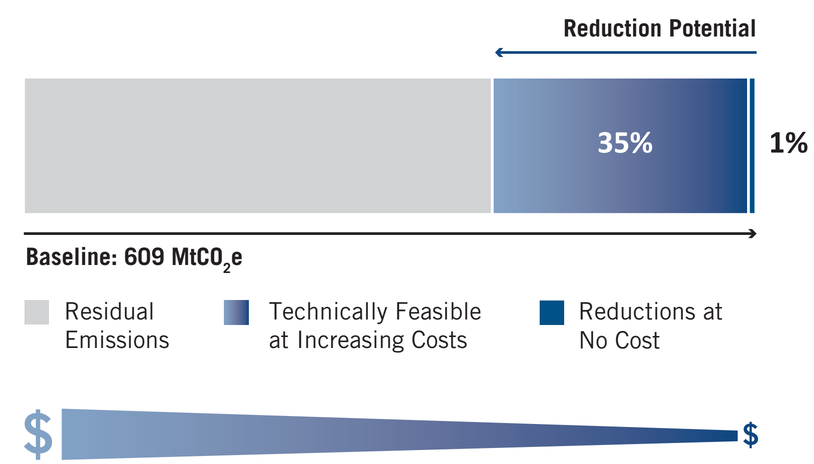


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 1%, compared to the baseline, in 2030. An additional 35% reduction is available using technologies with increasingly higher costs.



Abatement Measures

CH_4 emissions from wastewater can be significantly reduced through improvements to infrastructure and equipment. Abatement measures available in the wastewater sector include installing aerobic wastewater treatment plants on an individual or centralized scale and installing anaerobic wastewater treatment plants with cogeneration. Factors such as economic resources, population density, government, and technical capabilities are important in determining the potential for mitigating emissions from the wastewater sector.

Abatement Potential

The global abatement potential of CH_4 from wastewater treatment is 138 $MtCO_2e$ in 2020 rising to 218 $MtCO_2e$ in 2030. This level of CH_4 mitigation is considered to be the technological maximum abatement potential because high-cost abatement measures in the wastewater treatment sector significantly constrain the abatement achievable at lower carbon prices. Cost-effective emissions reductions are limited to 3.4 $MtCO_2e$—less than 1% of business as usual (BAU) emissions in 2030.

Nitric and Adipic Acid Production

N_2O Emissions from Nitric and Adipic Acid Production

Key Points

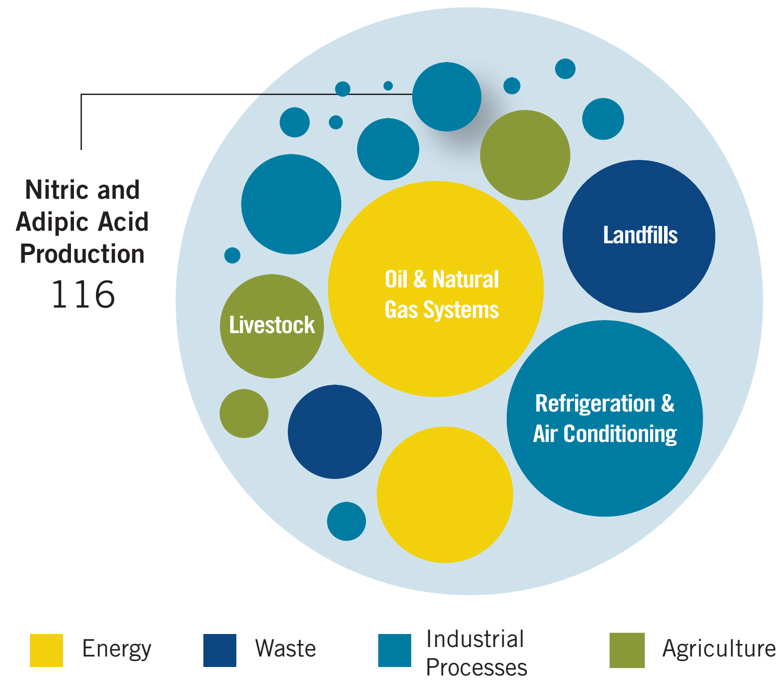
- The global abatement potential is 116 $MtCO_2e$, or 79% of projected emissions in 2030.
- A 65% reduction in emissions is achievable at break-even prices below $20.
- Abatement measure selection is driven by facility design constraints and/or operating costs.

Sector Description

Nitric and adipic acid are commonly used as feedstock in manufacturing a variety of commercial products, particularly fertilizer and synthetic fibers. The process used to produce nitric and adipic acid generates significant quantities of nitrous oxide (N_2O) as a by-product. The production of nitric and adipic acid is expected to increase over time, driven by continued growth in demand for fertilizer and synthetic fibers.

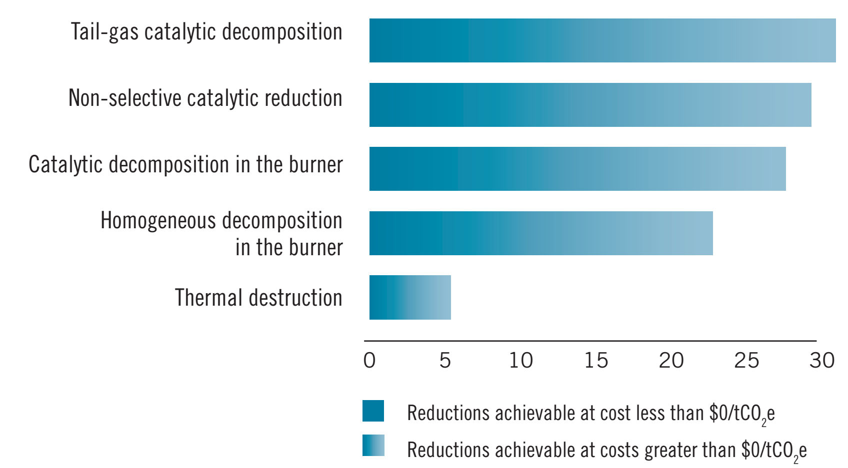
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the nitric and adipic acid production sector could be reduced by up to 116 $MtCO_2e$ in 2030. This accounts for 3% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



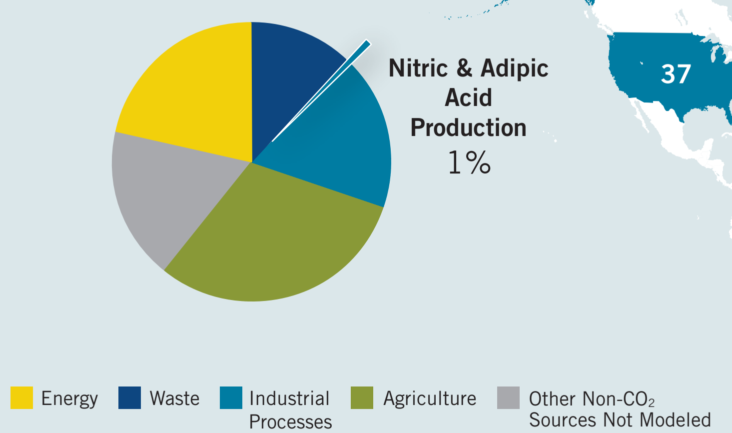
Abatement Measures

N_2O emissions can be mitigated through a number of alternative abatement measures. In nitric acid production, reduction technologies are categorized by their location in the production process. Secondary reduction technologies, such as homogeneous thermal decomposition and catalytic decomposition, are installed at an intermediate point in the production process. Tertiary reduction technologies, such as catalytic decomposition and nonselective catalytic reduction units, are applied to the tail gas streams at the end of the production process. The implementation of one technology over another is driven largely by facility design constraints and/or cost considerations. Thermal destruction is the single abatement measure considered in this analysis.

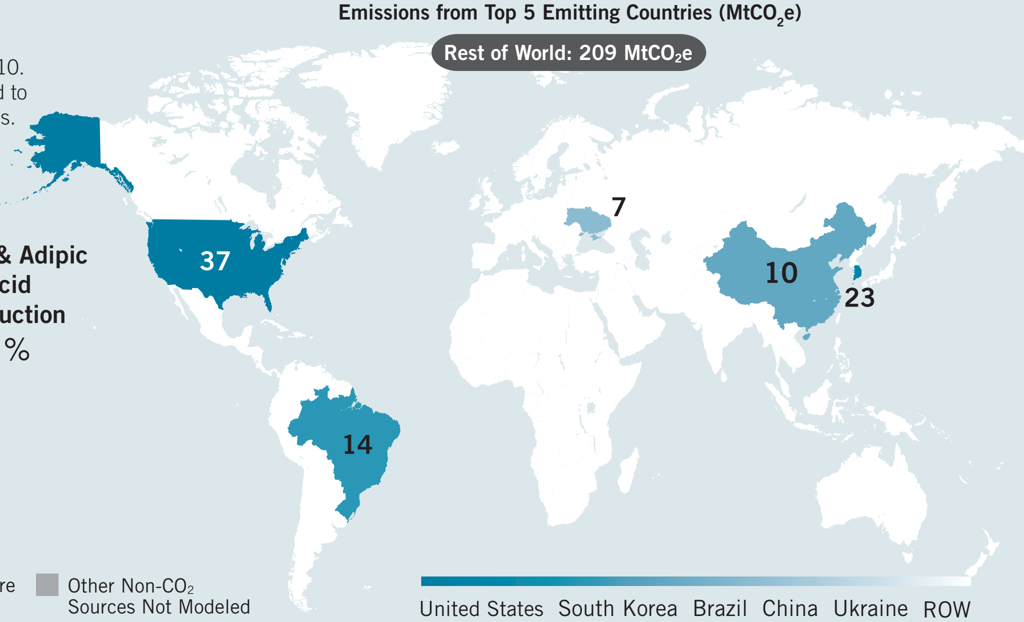
Projected Emissions in 2030

Global Non-CO_2 Emissions

Nitric and Adipic Acid Production baseline emissions are estimated to be 118 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 147 $MtCO_2e$ or 1% of total non-CO_2 emissions.

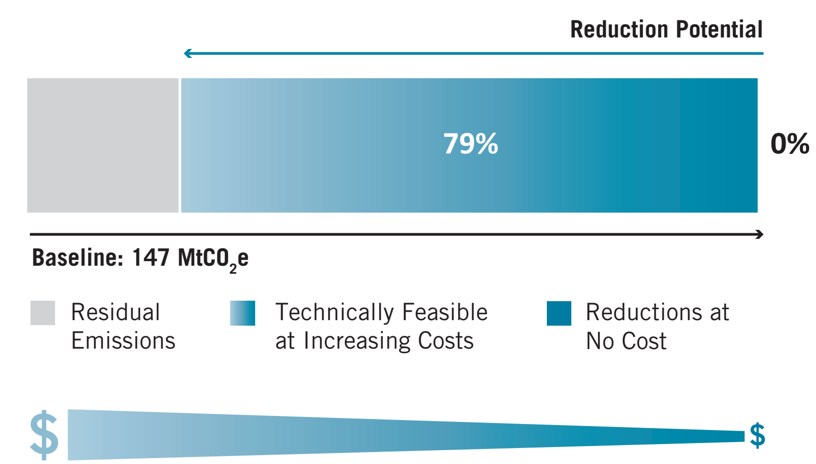


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 0%, compared to the baseline, in 2030. An additional 79% reduction is available using technologies with increasingly higher costs.



Abatement Potential

The global abatement potential in the nitric and adipic acid sector is approximately 116 $MtCO_2e$ of total annual emissions in 2030, or 79% of projected baseline emissions. The marginal abatement cost curve results show that maximum reduction potential is achievable at break-even prices below $50/$tCO_2e$. Over two-thirds of the abatement potential is achievable at break-even prices between $0 and $20.

Refrigeration and Air Conditioning

HFC Emissions from Refrigeration and Air Conditioning Systems

Key Points

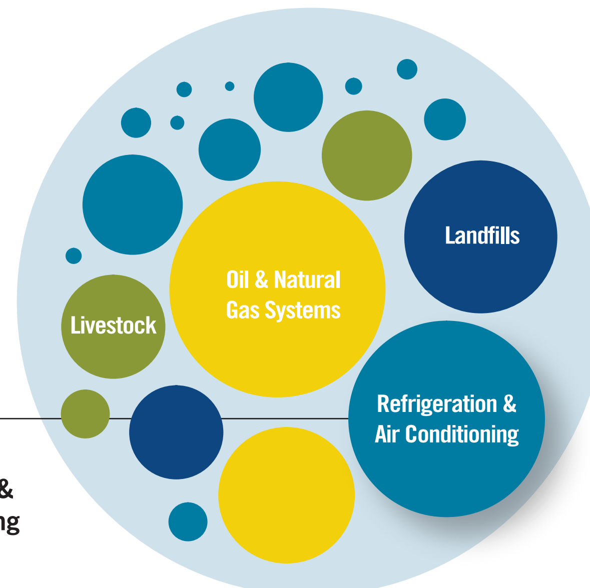
- The global abatement potential from the options quantified is 994 $MtCO_2e$, 62% of projected emissions, in 2030.
- 30% of the baseline 2030 emissions can be abated from cost-effective mitigation measures ($0 per tCO_2e).
- This sector accounts for the single largest source of non-CO_2 abatement potential accounting for over 20% of total abatement potential across all non-CO_2 emitting sectors in 2030.

Sector Description

Hydrofluorocarbons (HFCs) used in refrigeration and air conditioning (AC) systems are emitted to the atmosphere during equipment operation, repair, and disposal, unless recovered, recycled, and ultimately destroyed. Equipment is being retrofitted or replaced to use HFCs that are substitutes for ozone-depleting substances. Some of the most common HFCs include HFC-134a, R-404A, R-410A, R-407C, and R-507A.

Emissions Reduction Potential

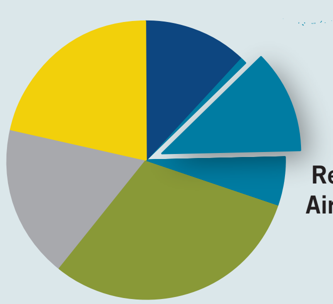
Assuming full implementation of current technology, emissions in the refrigeration & air conditioning sector could be reduced by up to 994 $MtCO_2e$ in 2030. This accounts for 22% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



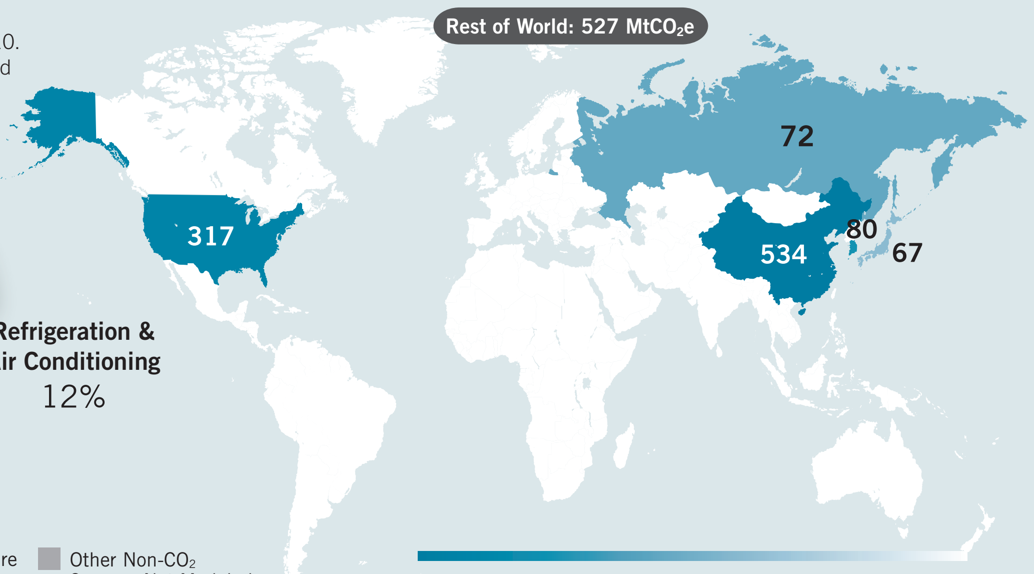
Projected Emissions in 2030

Global Non-CO_2 Emissions

Refrigeration & Air Conditioning sector baseline emissions are estimated to be 349 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 1,596 $MtCO_2e$ or 12% of total non-CO_2 emissions.

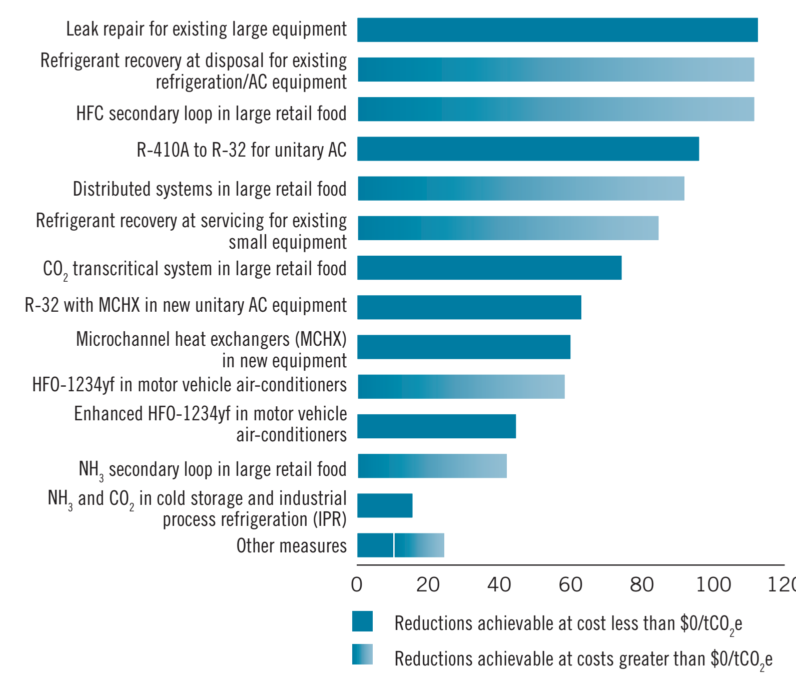


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



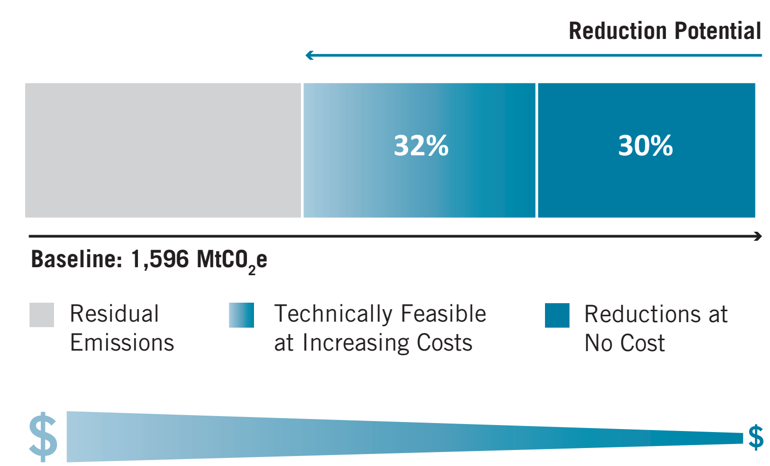
Abatement Measures

Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 30%, compared to the baseline, in 2030. An additional 32% reduction is available using technologies with increasingly higher costs.



Abatement Measures

HFC abatement measures are categorized into three categories: (1) retrofit of existing systems to utilize lower GWP refrigerants; (2) new cooling systems to use lower GWP refrigerants and/or reduce the charge size; and (3) better refrigerant management practices that reduce emissions during use, servicing, and disposal. Such options are analyzed for end-uses including retail food refrigeration systems, window and unitary AC equipment, motor vehicle AC equipment, motor vehicle AC systems, and other types of cooling systems.

Abatement Potential

The global abatement potential from refrigeration and AC abatement is calculated to be 994 $MtCO_2e$ in 2030, or 62% of baseline emissions; additional uncalculated options are explored qualitatively. The marginal abatement cost curve results show that 479 $MtCO_2e$, 30% of 2030 emissions, can be reduced at a cost of $0 by implementing "no-regret" options. At a cost of $20 per tCO_2e, an estimated 910 $MtCO_2e$, or 57% of baseline emissions, could be abated. All abatement options quantified are achievable at mitigation costs below $100/$tCO_2e$.

Solvents

HFC Emissions from Solvent Use

Key Points

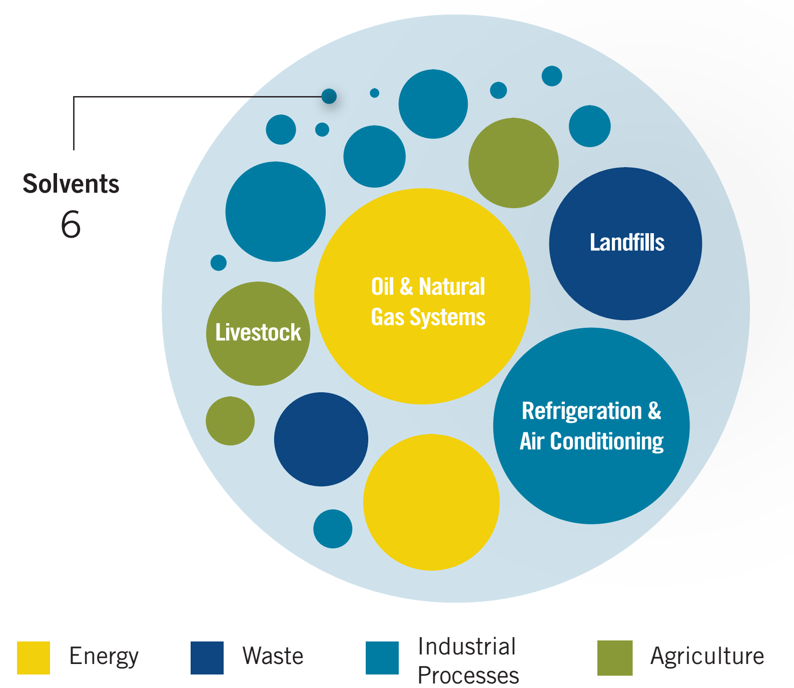
- By 2030, emissions from the solvents sector are expected to approximately double, reaching 10 $MtCO_2e$.
- The maximum abatement potential in the solvents sector from the options analyzed is estimated to be 6 $MtCO_2e$, or 59% of the projected baseline in 2030.
- 5 $MtCO_2e$ of emissions reductions in 2030 are cost-effective (i.e., $0/$tCO_2e$ or lower break-even prices).

Sector Description

HFC solvents are primarily used in precision cleaning applications and electronic cleaning applications. Precision cleaning requires a high level of cleanliness to ensure the satisfactory performance of the product being cleaned, and electronics cleaning is defined as a process that removes contaminants, primarily solder flux residues, from electronics or circuit boards. It is assumed that eventually approximately 90% of the solvent consumed in a given year will be emitted, while 10% of solvent will be disposed of with the sludge that remains.

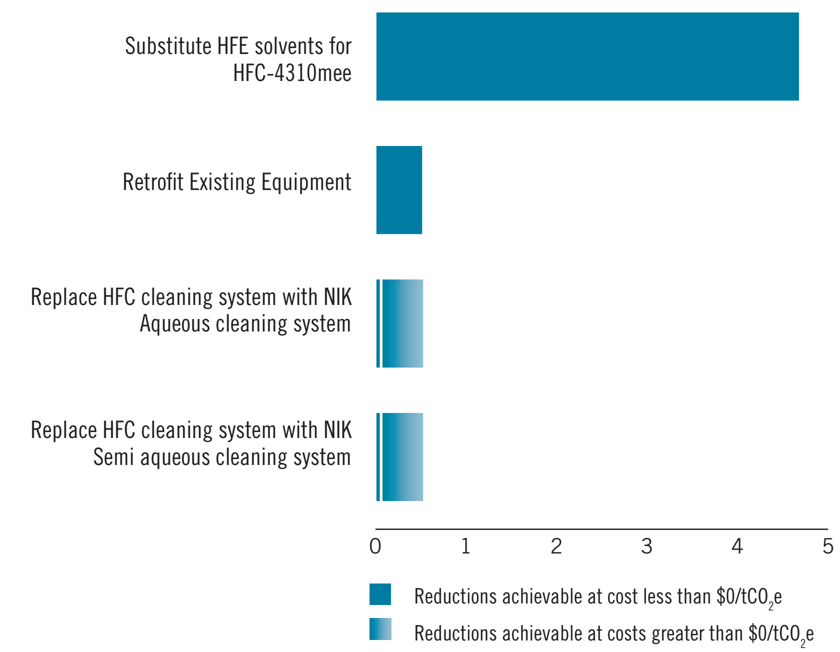
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the solvents sector could be reduced by up to 6 $MtCO_2e$ in 2030. This accounts for 0.12% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

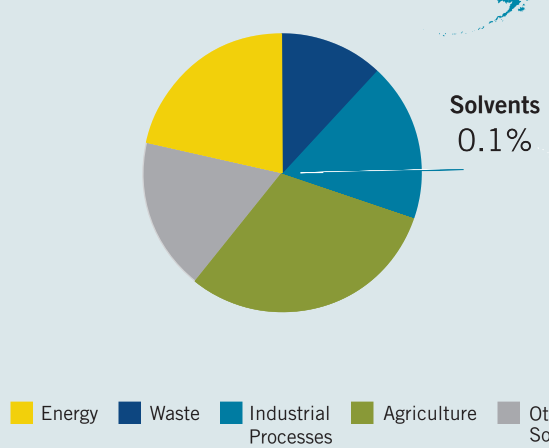
Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



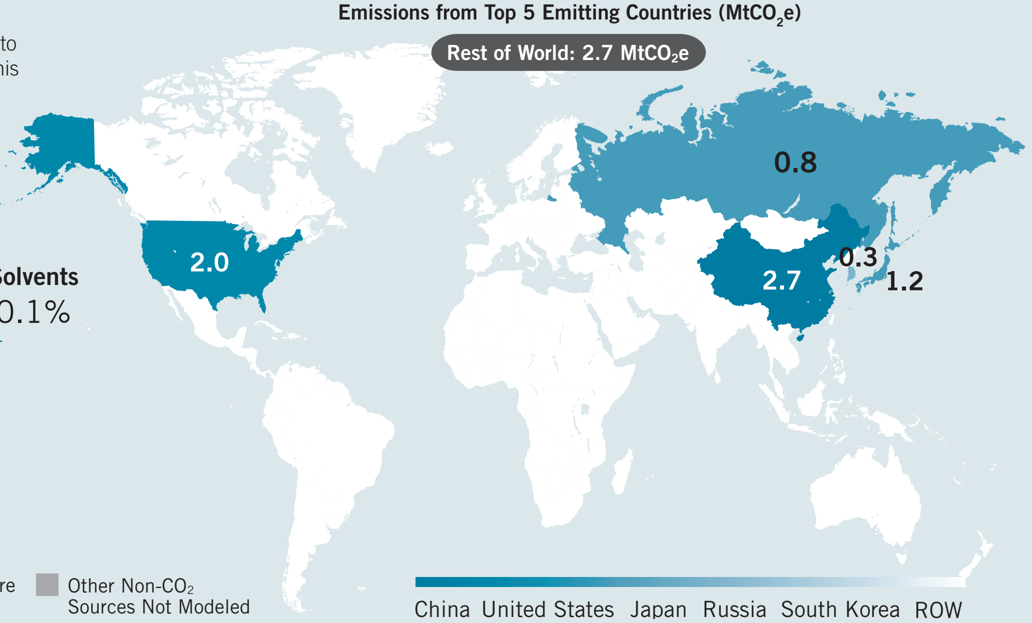
Projected Emissions in 2030

Global Non-CO_2 Emissions

Solvents sector baseline emissions are estimated to be 5 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 10 $MtCO_2e$ or 0.1% of total non-CO_2 emissions.

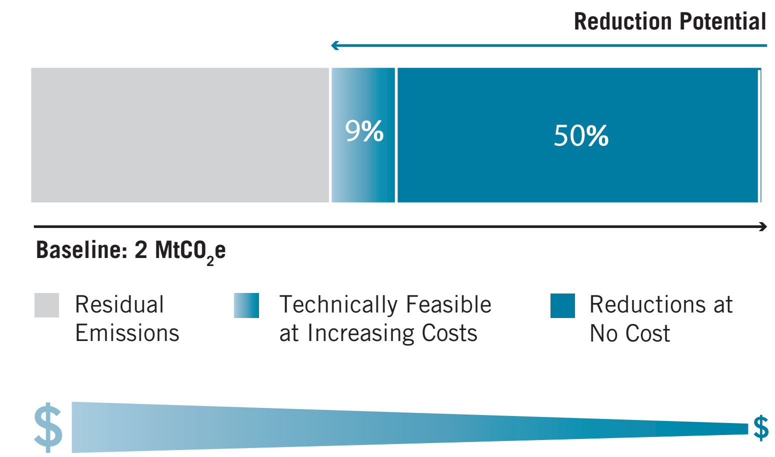


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 50%, compared to the baseline, in 2030. An additional 9% reduction is available using technologies with increasingly higher costs.



Abatement Measures

Four abatement options were identified for the solvents sector: (1) replacement of HFCs with HFEs, (2) retrofitting of vapor degreaser equipment to reduce emissions, (3) transition to not-in-kind (NIK) aqueous cleaning, and (4) transition to NIK semi-aqueous cleaning. These technologies have reduction efficiencies of between 50% and 100%. Retrofitting equipment and controls is limited to facilities that have not already been retrofitted. Transition to NIK aqueous and NIK semi-aqueous applicability is limited to some electronic cleaning processes.

Abatement Potential

The global abatement potential in 2020 and 2030 is 3.0 and 5.7 $MtCO_2e$, respectively. In 2030, reduction of 4.8 $MtCO_2e$, or 50%, of total projected emissions, is achievable at mitigation costs below $0/$tCO_2e$. Additional abatement of approximately 1 $MtCO_2e$ is achievable at mitigation costs greater than $50/$tCO_2e$.

Foams

HFC Emissions from Foams Manufacturing, Use, and Disposal

Key Points

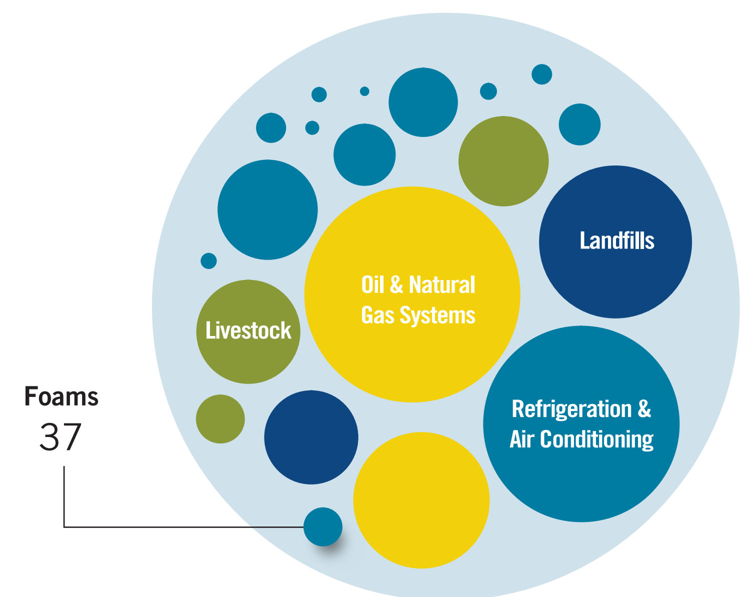
- HFC emissions from foams are projected to quadruple over the next 20 years.
- Abatement measures include replacing HFCs with low-GWP blowing agents and proper recovery and disposal of foam present in existing systems at their end of life.
- In 2030, the global abatement potential quantified is 27 $MtCO_2e$ (29.4% of BAU emissions from the foams sector) at cost-effective prices ($0 per tCO_2e). At higher prices, the abatement options analyzed have the potential to abate up to 37 $MtCO_2e$ (40.3% of BAU emissions) in 2030.

Sector Description

Foam is used as insulation in a wide range of equipment, structures, and other common products. Foams were historically produced with ozone-depleting substances (ODS), which have been phased out under the Montreal Protocol in developed countries and are being phased out in developing countries. In some end-uses, HFC blowing agents have largely replaced ODS. HFC emissions from the foams sector were approximately 22 $MtCO_2e$ in 2010 and are projected to increase substantially to 52 $MtCO_2e$ and 92 $MtCO_2e$ by 2020 and 2030, respectively.

Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the foams sector could be reduced by up to 37 $MtCO_2e$ in 2030. This accounts for 1% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.

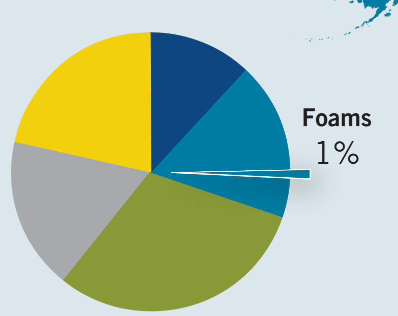


Energy Waste Industrial Processes Agriculture

Projected Emissions in 2030

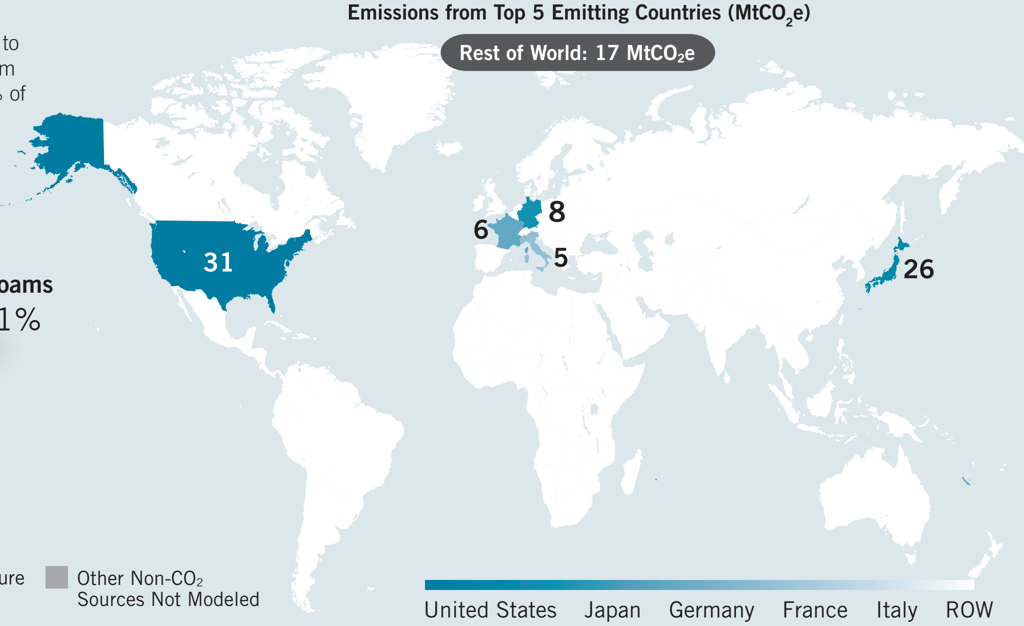
Global Non-CO_2 Emissions

Foams sector baseline emissions are estimated to be 22 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 92 $MtCO_2e$ or 1% of total non-CO_2 emissions.



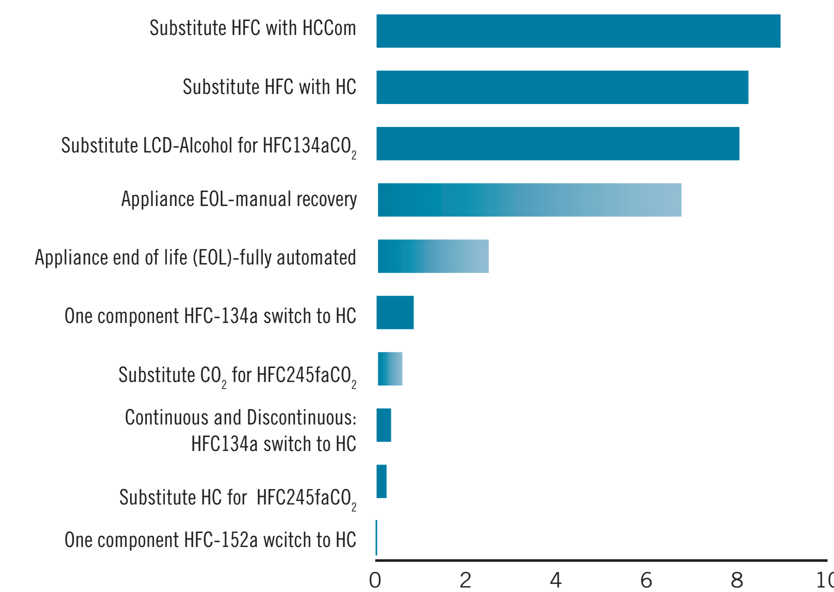
Energy Waste Industrial Processes Agriculture Other Non-CO_2 Sources Not Modeled

Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Abatement Measures

Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



Reductions achievable at cost less than $0/$tCO_2e$

Reductions achievable at costs greater than $0/$tCO_2e$

Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 29%, compared to the baseline, in 2030. An additional 11% reduction is available using technologies with increasingly higher costs.

Residual Emissions Technically Feasible at Increasing Costs Reductions at No Cost

Abatement Measures

Abatement options considered include replacing HFCs with various low-GWP blowing agents and properly recovering and disposing of foam contained in equipment and other products after their useful life. More specifically, the use of hydrocarbon or carbon dioxide blowing agents instead of HFCs is assessed quantitatively as an abatement measure in the foams sector noting that other low-GWP agents (e.g., HFO-1234ze, -1233zd(E)) would achieve similar abatement levels.

Abatement Potential

The total abatement potential in the foams sector from the options explored is 37 $MtCO_2e$—40% of total annual foams sector emissions in 2030—while 27 $MtCO_2e$, or 30%, is achievable at cost-effective carbon prices for the same year. Total replacement of HFC blowing agents in foams is limited in the near term by the installed base of foam products. All abatement options analyzed replace blowing agents in newly manufactured foams or destroy the blowing agent only at the foam's natural end of life.

Aerosols

HFC Emissions from Aerosol Product Use

Key Points

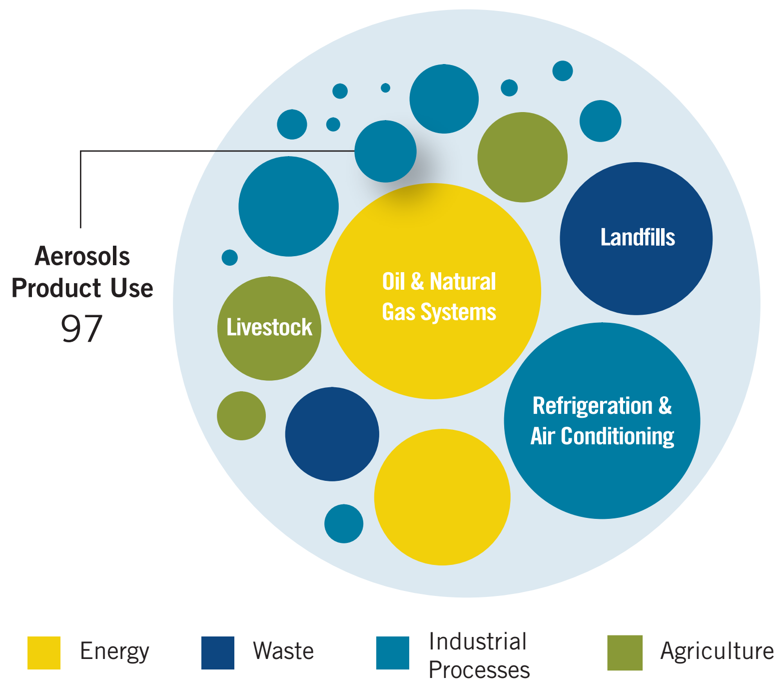
- Global baseline emissions in 2010 for aerosols were estimated at 45 $MtCO_2e$ and projected to climb to 100 $MtCO_2e$ and 146 $MtCO_2e$ by 2020 and 2030, respectively.
- Five abatement measures were considered for the aerosols sector, including transitioning away from HFC use to lower GWP propellants and producing alternative non-aerosol consumer products, such as a stick or roller.
- Relatively low cost abatement measures (≤ $5/$tCO_2e$) are projected to be capable of mitigating 53% of the sector emissions in 2030.

Sector Description

Aerosol propellant formulations containing HFCs are present in a wide variety of consumer products—such as hairsprays, deodorants, and cleaning supplies—as well as technical and medical aerosols. Baseline HFC emissions from aerosols were estimated at 45 $MtCO_2e$ in 2010 and are expected to increase to 146 $MtCO_2e$ by 2030. This rapid growth is primarily driven by the increased use of aerosols containing HFCs in developing countries.

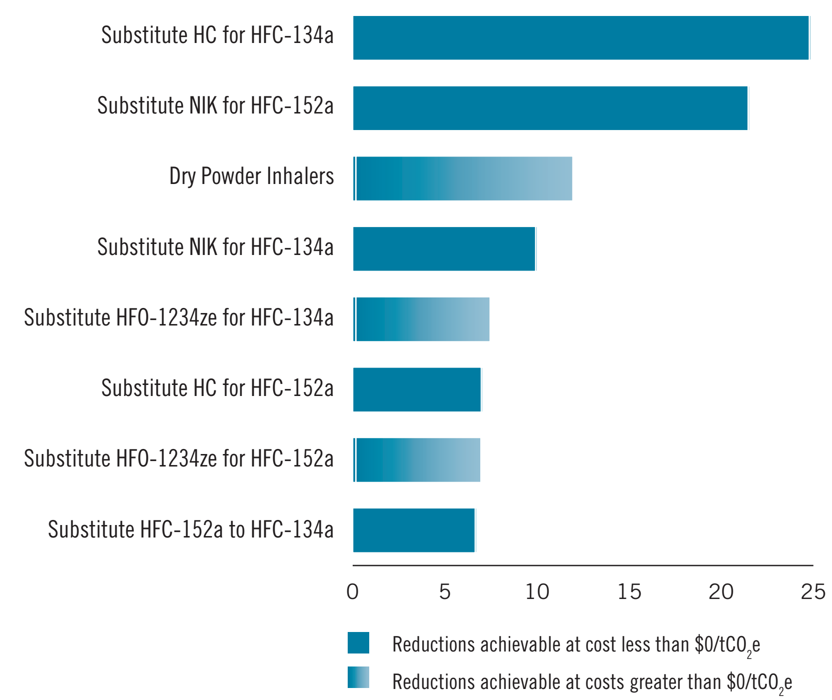
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the aerosols product use sector could be reduced by up to 97 $MtCO_2e$ in 2030. This accounts for 2% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



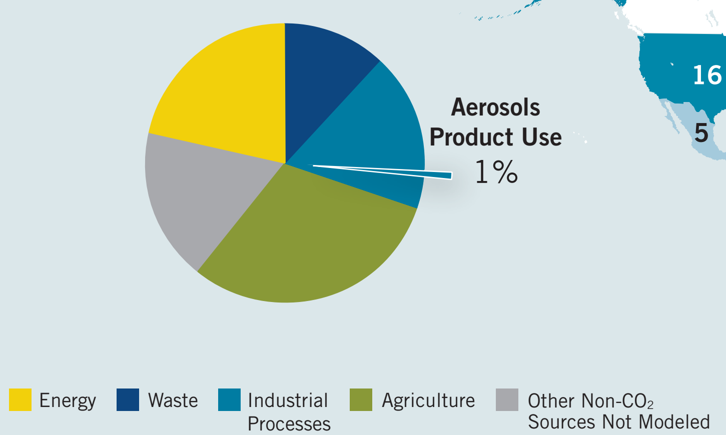
Abatement Measures

Abatement options available to reduce emissions for consumer aerosol products include transitioning to replacement propellants with lower GWPs—HCs, HFO-1234ze, and HFC-152a (where HFC-134a is used)—and converting to a not-in-kind (NIK) alternative, such as sticks, rollers, or finger/trigger pumps.

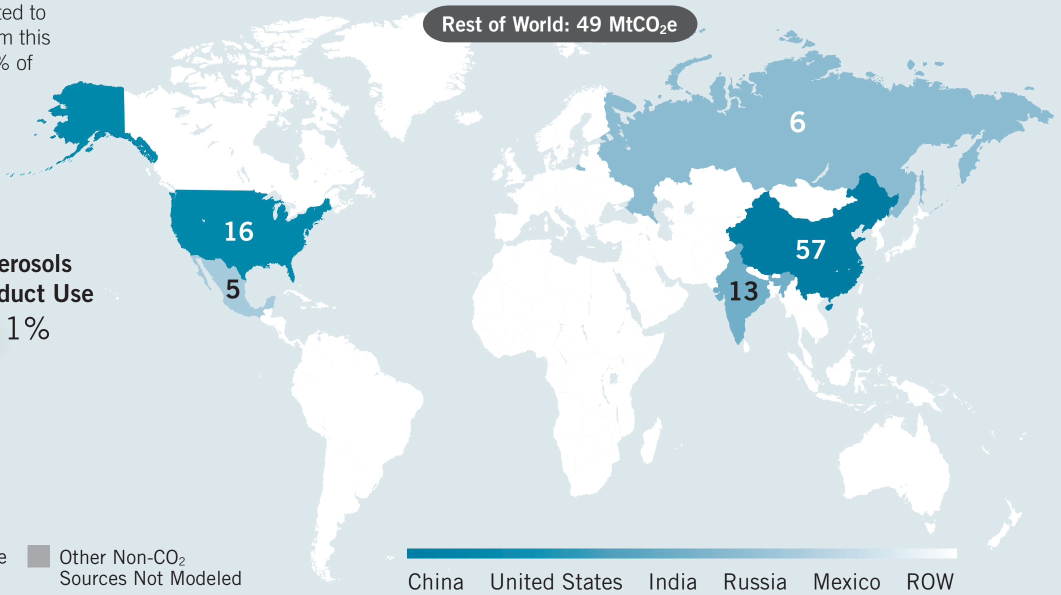
Projected Emissions in 2030

Global Non-CO_2 Emissions

Aerosols sector baseline emissions are estimated to be 45 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 146 $MtCO_2e$ or 1% of total non-CO_2 emissions.

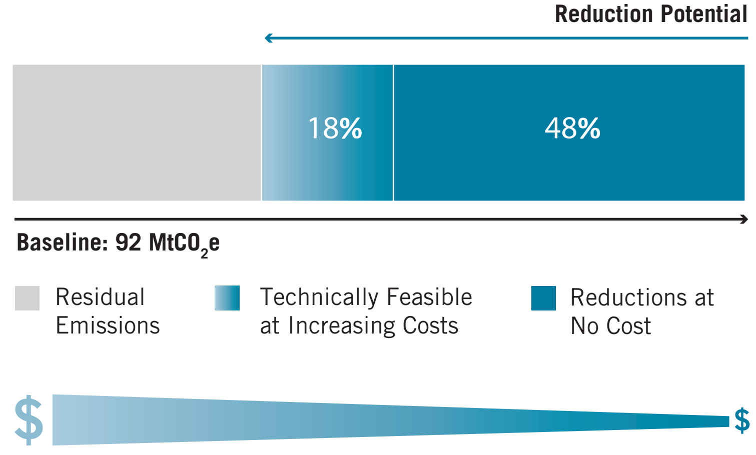


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 48%, compared to the baseline, in 2030. An additional 18% reduction is available using technologies with increasingly higher costs.



Abatement Potential

The global abatement potential from aerosols containing HFCs is estimated to be 96.7 $MtCO_2e$—66% of BAU emissions from this sector and 5% of total annual emissions from all sectors that use ODS substitutes in 2030. At $5 per tCO_2e, the abatement potential is estimated to be 53.4% of baseline emissions, or 77.8 $MtCO_2e$. Furthermore, the abatement potential at prices ≤ $0 per tCO_2e is forecasted to be 70 $MtCO_2e$ (48.2% of BAU emissions) for 2030.

Fire Protection

HFC and PFC Emissions from Fire Protection Equipment

Key Points

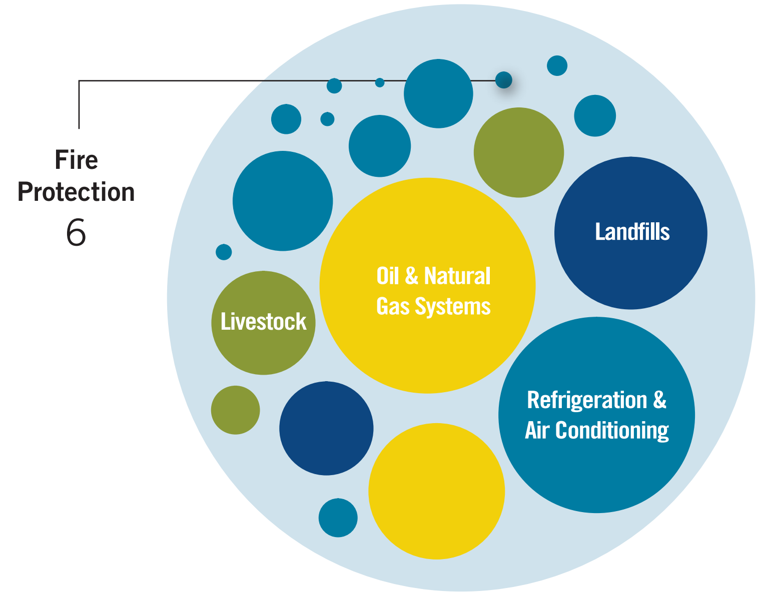
- GHG emissions from fire protection equipment are projected to nearly triple between 2010 and 2030.
- Total flooding fire suppression abatement options involve replacing hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) with lower-GWP alternatives, including both in-kind and not-in-kind measures.
- Any abatement potential in the fire protection equipment sector in 2030 is projected to cost $39 per tCO_2e or more. To reduce emissions by 4.6 $MtCO_2e$ or more, costs of $50 per tCO_2e or more are projected.

Sector Description

The fire protection sector emits HFCs and PFCs when total flooding fire suppression systems and portable fire extinguishers are used. GHG emissions from this sector were estimated at 21 $MtCO_2e$ in 2010. Under the baseline scenario, emissions are projected to increase significantly to 59 $MtCO_2e$ in 2030.

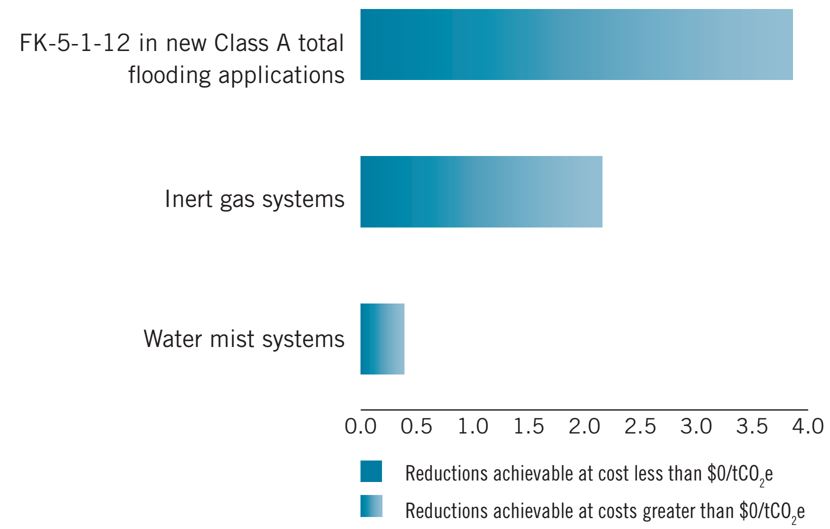
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the fire protection sector could be reduced by up to 6 $MtCO_2e$ in 2030. This accounts for 0.14% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

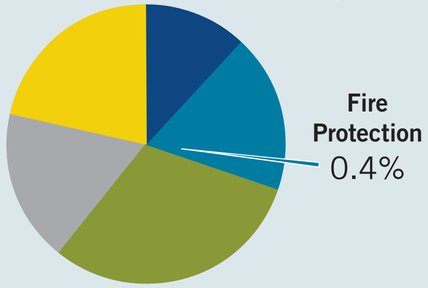
Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



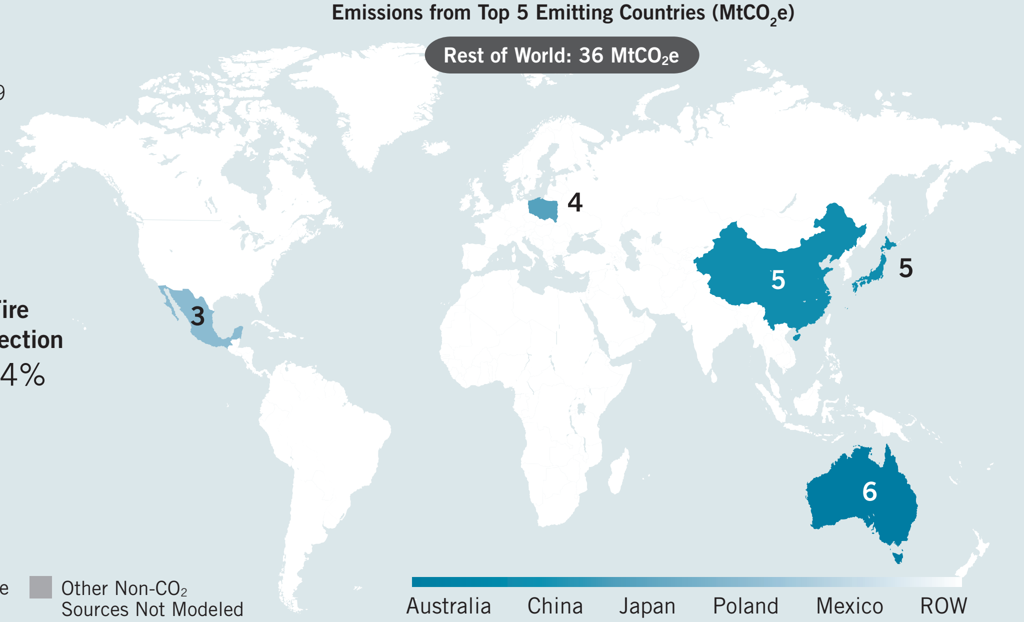
Projected Emissions in 2030

Global Non-CO_2 Emissions

Fire Protection sector baseline emissions are estimated to be 21 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 59 $MtCO_2e$ or 0.4% of total non-CO_2 emissions.

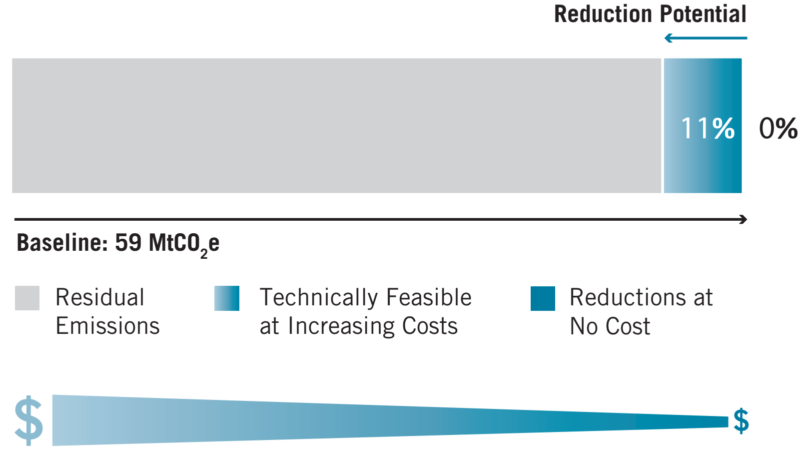


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 0%, compared to the baseline, in 2030. An additional 11% reduction is available using technologies with increasingly higher costs.



Abatement Measures

The abatement options explored replace HFCs and PFCs with zero- or low-GWP extinguishing agents to reduce CO_2e emissions from the fire protection sector's total flooding equipment. The alternatives to HFCs and PFCs in total flooding equipment are both in-kind gaseous agents and not-in-kind options. The in-kind gaseous alternatives include CO_2, inert gases, and fluorinated ketones, and the not-in-kind alternatives include varying materials and systems such as dispersed and condensed aerosol extinguishing systems, water sprinklers, water mist, foam, and inert gas generators.

Abatement Potential

From the options quantified, global abatement potential of emissions from total flooding fire suppression applications is projected to be 6.4 $MtCO_2e$, or nearly 11% of baseline emissions, in 2030. There is little abatement potential at break-even prices below $50 per tCO_2e in 2030, which is projected to have the potential to abate 4.6 $MtCO_2e$ from the fire protection sector, or 8% of baseline emissions.

Aluminum Production

PFC Emissions from Primary Aluminum Production

Key Points

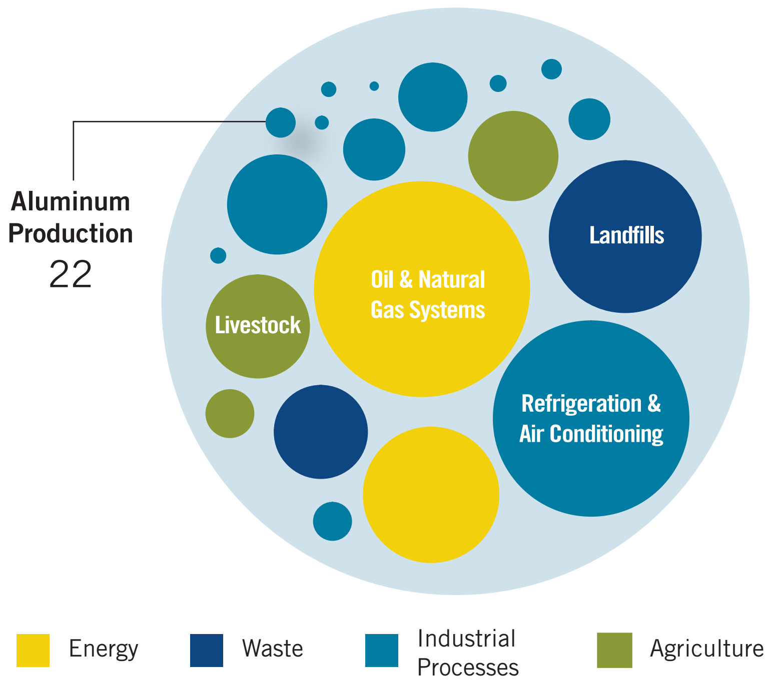
- PFC emissions from aluminum production represent the third largest source of fluorinated greenhouse gas (F-GHG) emissions in the industrial sector.
- Primary abatement measures include installation of or upgrades to process computer control systems and the installation of systems to allow more precise alumina feeding.
- Abatement measures in this sector have the potential to reduce over half of the projected baseline emissions.

Sector Description

The aluminum production industry produces perfluorocarbon (PFC) emissions during brief process upset conditions in the aluminum smelting process. Despite a decline in global emissions of PFCs from primary aluminum production between 2000 and 2010, baseline emissions are projected to grow by 42%, from 26 $MtCO_2e$ in 2010 to 37 $MtCO_2e$ in 2030.

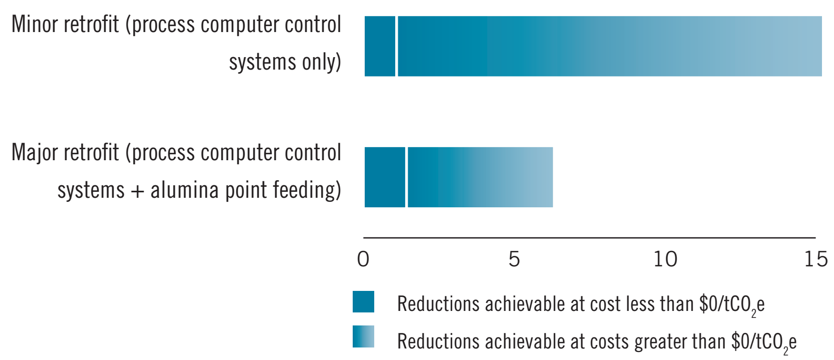
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the aluminum production sector could be reduced by up to 22 $MtCO_2e$ in 2030. This accounts for 0.47% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



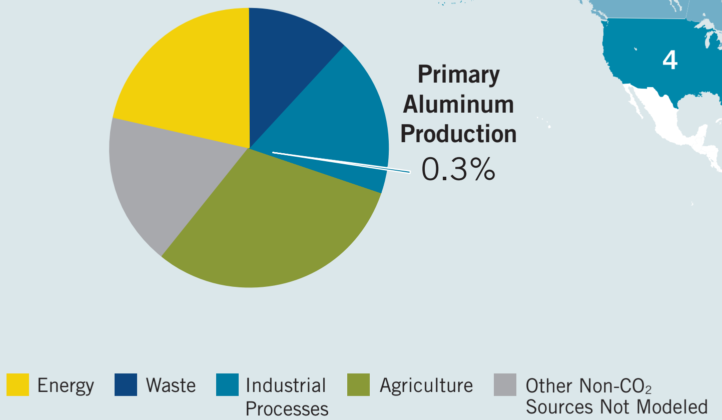
Abatement Measures

Abatement options in the primary aluminum production sector are primarily associated with installing or upgrading process computer control systems and alumina point-feed system. The options considered involve (1) a minor retrofit to upgrade the process computer control systems and (2) a major retrofit to the process computer control systems coupled with the installation of alumina point-feed systems.

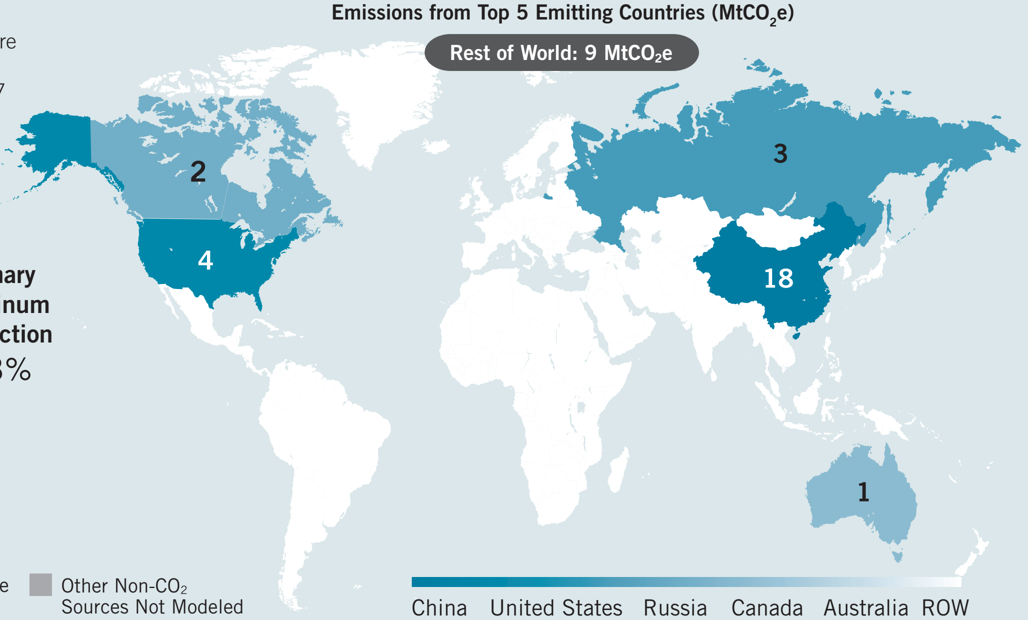
Projected Emissions in 2030

Global Non-CO_2 Emissions

Aluminum Production sector baseline emissions are estimated to be 26 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 37 $MtCO_2e$ or 0.3% of total non-CO_2 emissions.

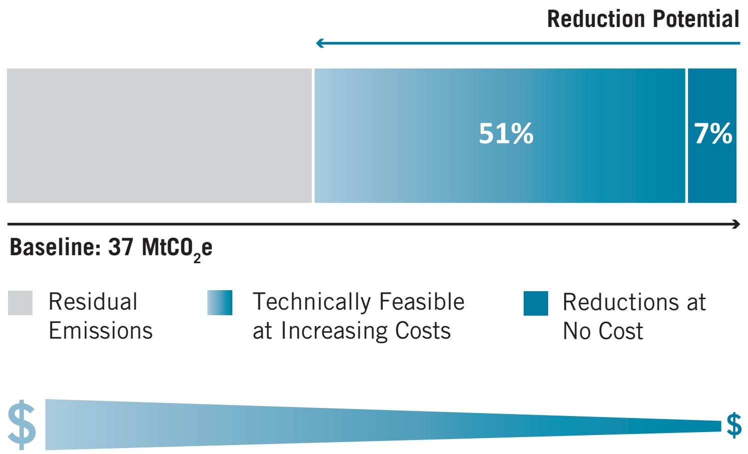


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 7%, compared to the baseline, in 2030. An additional 51% reduction is available using technologies with increasingly higher costs.



Abatement Potential

Global abatement potential in the primary aluminum sector is projected to be 21.6 $MtCO_2e$, or nearly 58% of baseline emissions in 2030. In the absence of any policy incentive to reduce PFC emissions, cost-effective abatement of 2.5 $MtCO_2e$ is available. Additional mitigation is feasible with the adoption of more costly mitigation measures. In 2030, mitigation measures with costs less than or equal to $30/$tCO_2e$ have the potential to reduce emissions by 17 $MtCO_2e$, or 80% of the total abatement potential.

HCFC-22 Production

Fluorinated Greenhouse Gas (F-GHG) Emissions from HCFC-22 Production

Key Points

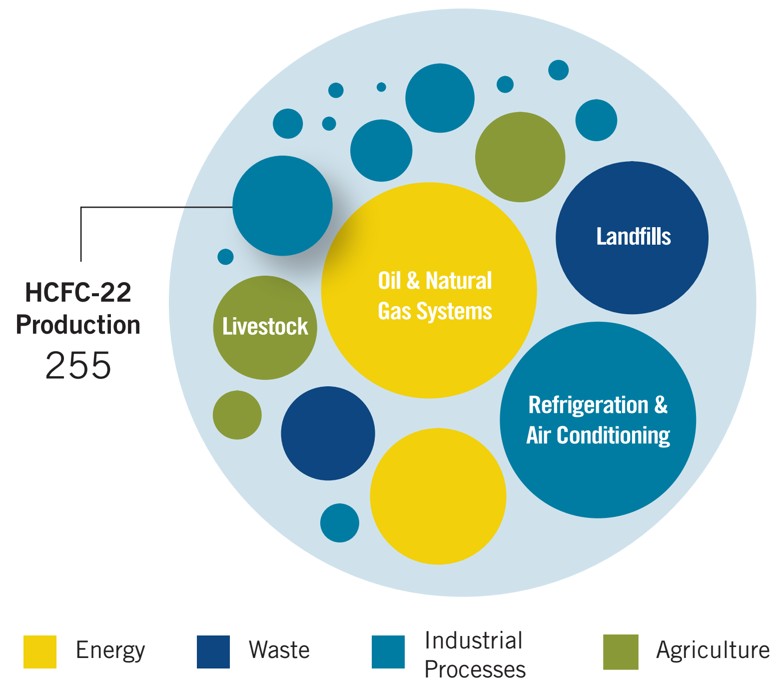
- Global abatement potential in the HCFC-22 production sector is 228 $MtCO_2e$ and 255 $MtCO_2e$, in 2020 and 2030, respectively, which equates to a 90% reduction from projected baseline emissions.
- Thermal oxidation is the only abatement option considered for the HCFC-22 production sector.
- The maximum abatement potential is achievable at costs below $1 per tCO_2.

Sector Description

Chlorodifluoromethane (HCFC-22) is used in emissive applications (air conditioning and refrigeration) as well as in feedstock for synthetic polymer production. The production of HCFC-22 generates HFC-23 as a by-product, which is separated as a vapor from the condensed HCFC-22; emissions occur through HFC-23 venting to the atmosphere. HFC-23 emissions were estimated at 128 $MtCO_2e$ and are projected to increase to 259 and 286 $MtCO_2e$ in 2020 and 2030, respectively. Because HCFC-22 depletes stratospheric ozone, its production is being phased out under the Montreal Protocol in areas apart from feedstock production.

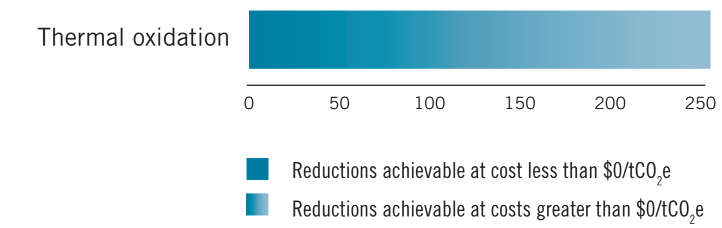
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the HCFC-22 production sector could be reduced by up to 255 $MtCO_2e$ in 2030. This accounts for 6% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



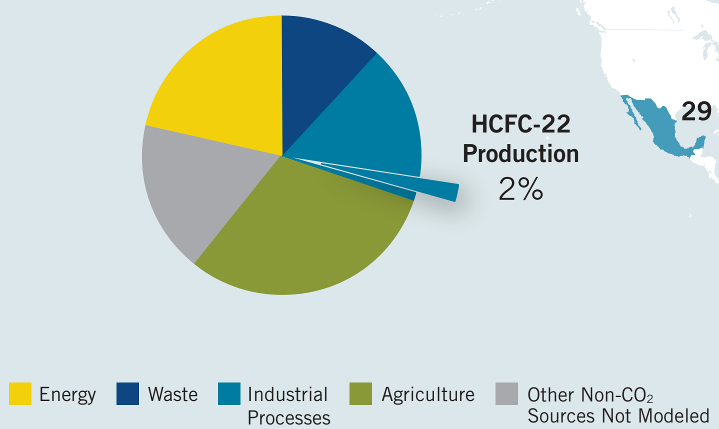
Abatement Measures

Thermal oxidation is the only abatement option considered in this analysis for the HCFC-22 production sector. Thermal oxidation is a demonstrated technology that oxidizes HFC-23 to carbon dioxide (CO_2), hydrogen fluoride, and water for the destruction of halogenated organic compounds. This process is assumed to be compatible with all facilities.

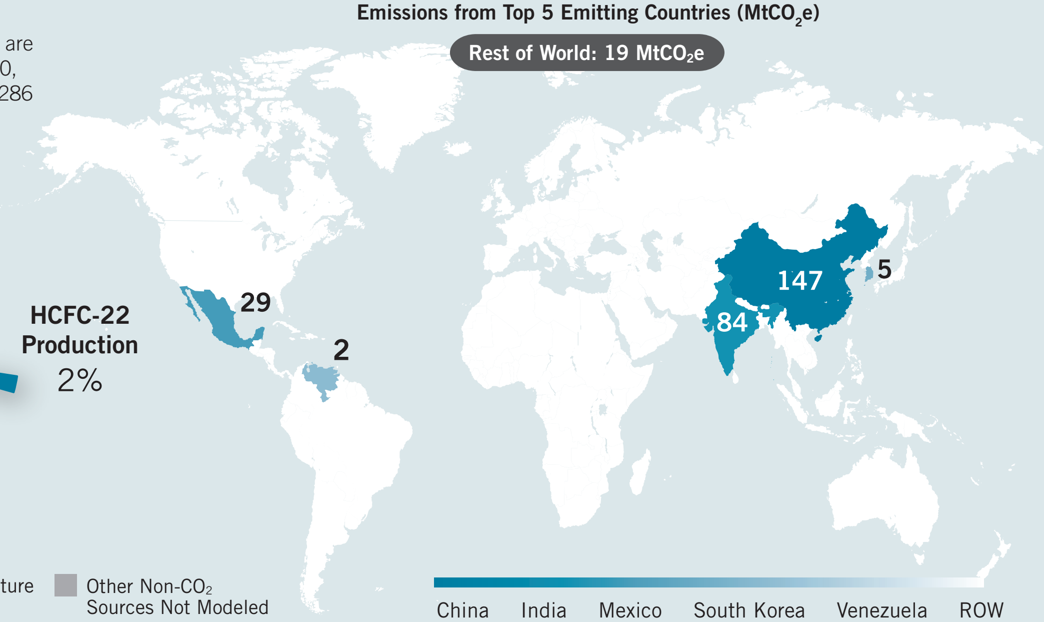
Projected Emissions in 2030

Global Non-CO_2 Emissions

HCFC-22 Production sector baseline emissions are estimated to be 128 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 286 $MtCO_2e$ or 2% of total non-CO_2 emissions.

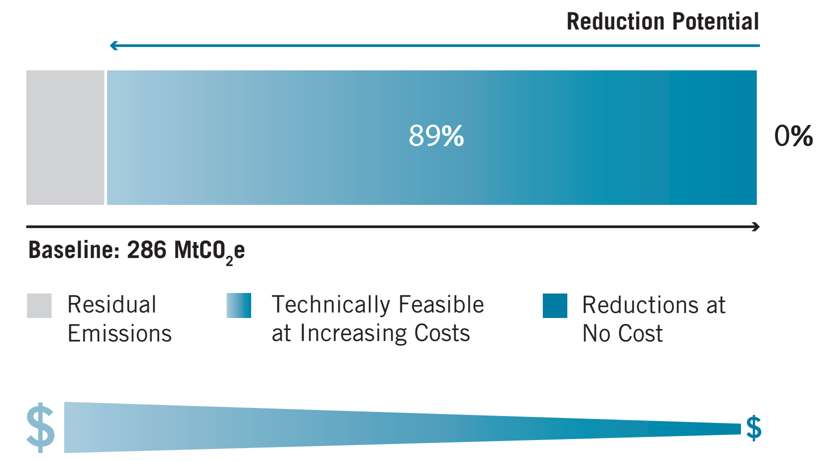


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 0%, compared to the baseline, in 2030. An additional 89% reduction is available using technologies with increasingly higher costs.



Abatement Potential

Global abatement potential of HFC-23 in 2030 is 255 $MtCO_2e$, approximately 89% of projected baseline emissions. The analysis assumes that facilities in most developed countries have already adopted abatement measures. As a result, abatement potential is limited to developing countries. Maximum abatement potential is achievable at a cost of between $0 and $1 per tCO_2e.

Semiconductor Manufacturing

Fluorinated Greenhouse Gas Emissions from Semiconductor Manufacturing

Key Points

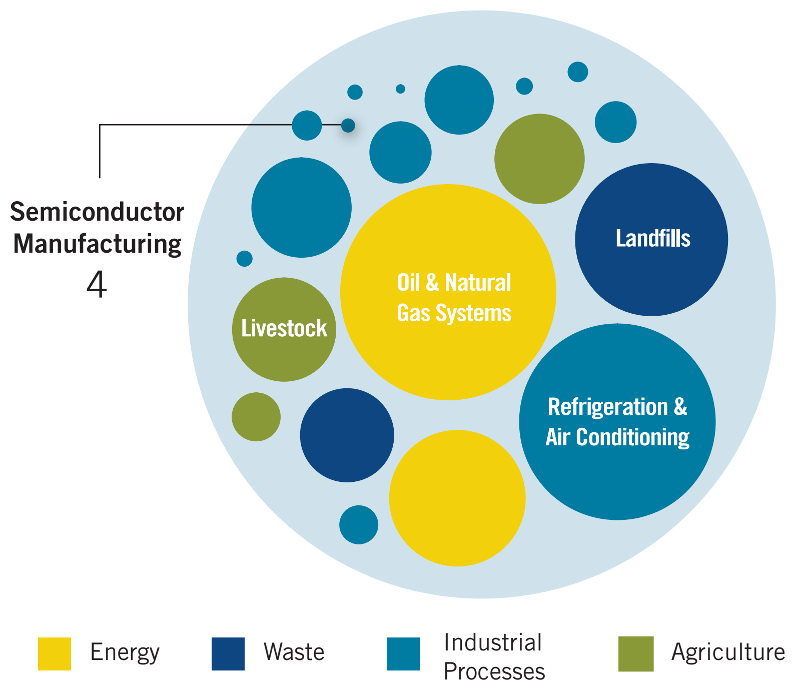
- **Baseline emissions from semiconductor manufacturing are projected to increase slowly from 18 $MtCO_2e$ in 2010 to 22 $MtCO_2e$ in 2030.**
- **The global abatement potential ranges from 0.2 $MtCO_2e$ at today's forecasted energy prices to the technological maximum potential of 4.2 $MtCO_2e$.**
- **20% of the total abatement potential in this sector is achievable at costs at or below $30/$tCO_2e$.**

Sector Description

The semiconductor manufacturing industry uses several fluorinated greenhouse gases (F-GHGs), including sulfur hexafluoride (SF_6), nitrogen trifluoride (NF_3), and perfluorcarbons during fabrication. Trace amounts of these gases are incidentally released into the atmosphere through normal fabrication activities. In 2010, 18 $MtCO_2e$ of emissions were produced from the semiconductor manufacturing sector.

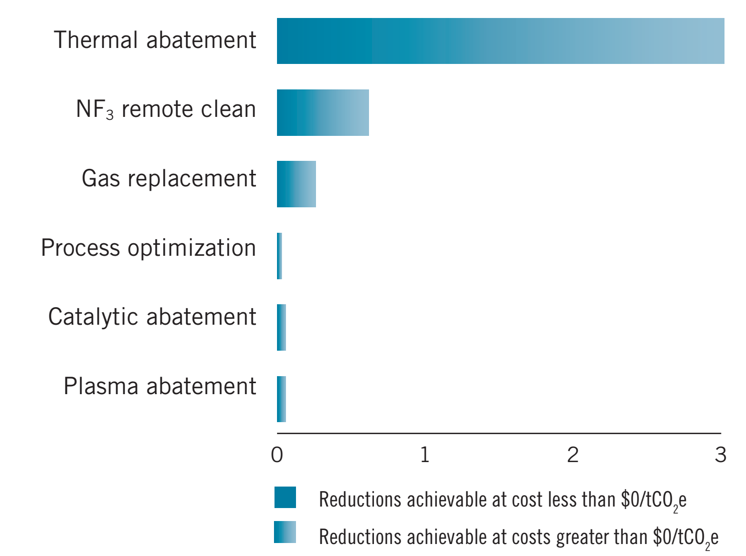
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the semiconductor manufacturing sector could be reduced by up to 4 $MtCO_2e$ in 2030. This accounts for 0.09% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

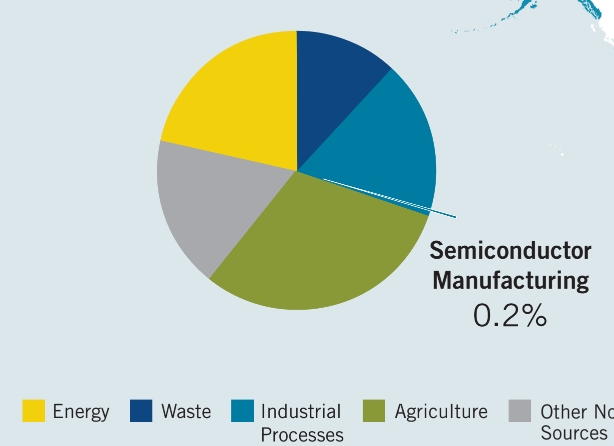
Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



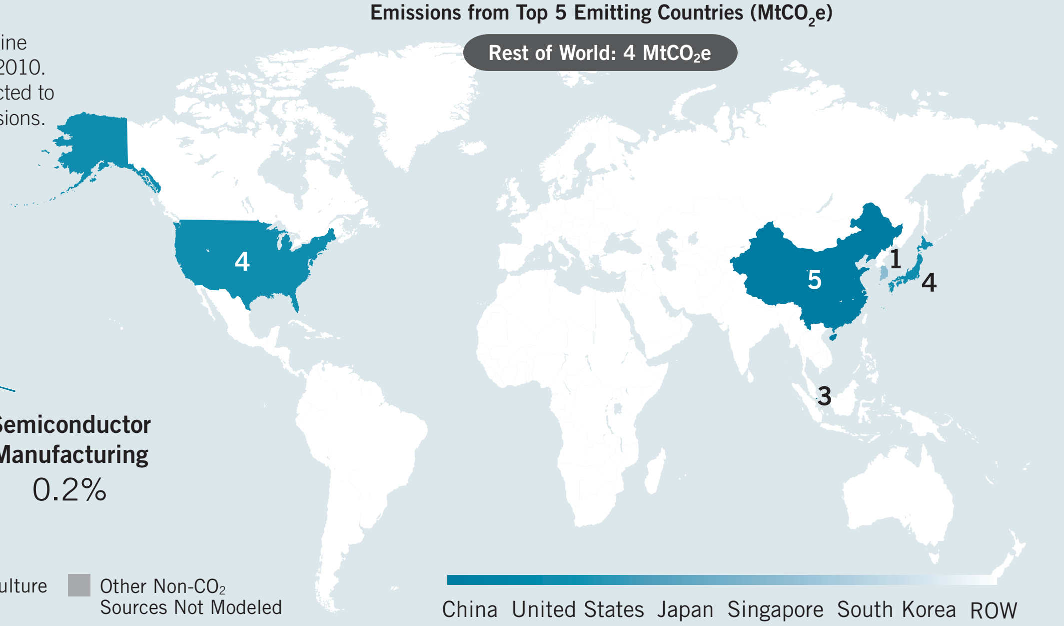
Projected Emissions in 2030

Global Non-CO_2 Emissions

Semiconductor Manufacturing sector baseline emissions are estimated to be 18 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 22 $MtCO_2e$ or 0.2% of total non-CO_2 emissions.

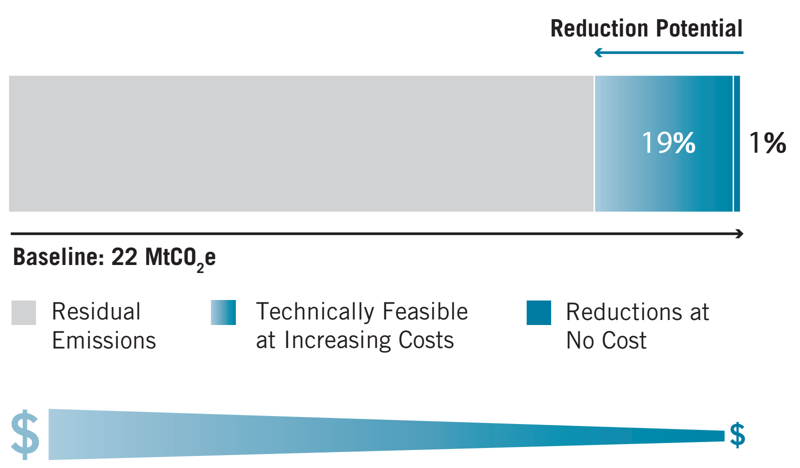


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 1%, compared to the baseline, in 2030. An additional 19% reduction is available using technologies with increasingly higher costs.



Abatement Measures

Despite rapid growth between 2000 and 2010, the semiconductor manufacturing industry experienced a stark decline in F-GHG emissions, decreasing from 28 $MtCO_2e$ in 2000 to 18 $MtCO_2e$ in 2010. This decline can be attributed to voluntary emissions reduction goals set by the World Semiconductor Council. Additionally, six abatement technologies were considered to further reduce emissions from this sector: thermal abatement systems, catalytic abatement systems, plasma abatement systems, NF_3 remote chamber clean process, gas replacement, and process optimization.

Abatement Potential

Global F-GHG abatement potential in the semiconductor manufacturing industry is estimated to be 4.6 $MtCO_2e$ and 4.2 $MtCO_2e$ in 2020 and 2030, respectively, which correspond to 23% and 20% of business as usual (BAU) emissions from this sector. In 2030, the abatement potential of 1 $MtCO_2e$, or 4%, is achievable at abatement costs below $30 per tCO_2e.

Electric Power Systems (EPS)

SF_6 from Electric Power Systems

Key Points

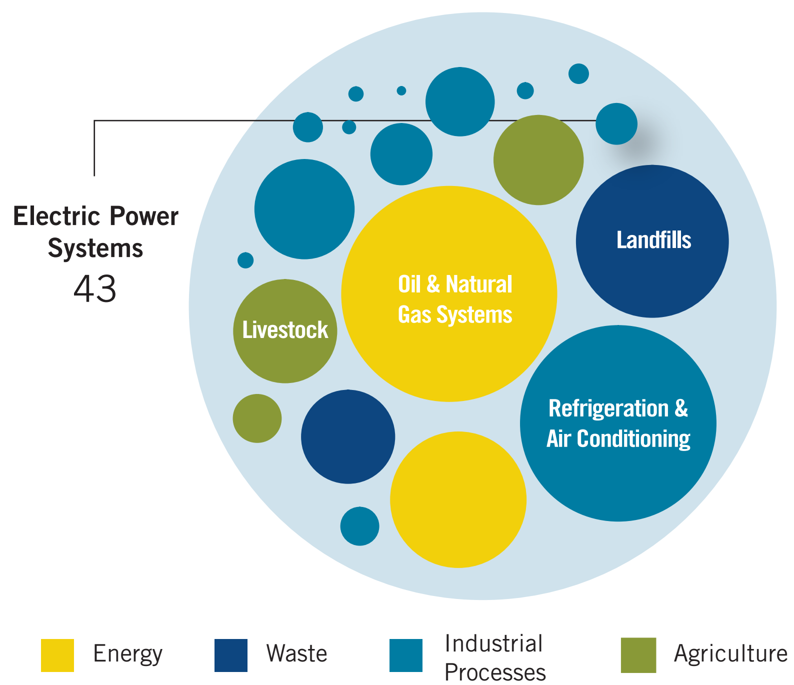
- The global abatement potential ranges from 7.5 $MtCO_2e$ to 42.8 $MtCO_2e$ in 2030.
- Abatement measures include technologies and handling practices to manage SF_6 emissions and prevent leakage during servicing and disposal.
- The abatement potential at cost-effective carbon prices ($5/$tCO_2e$) is projected to reduce baseline emissions by 56% in 2030.

Sector Description

Electric power systems (EPSs) use transmission and distribution equipment that contains sulfur hexafluoride (SF_6), a potent GHG with a global warming potential 23,900 times that of carbon dioxide. Emissions occur through unintentional leaking of equipment and improper handling practices during servicing and disposal. Global baseline emissions from this sector were estimated at 44 $MtCO_2e$ in 2010. Emissions are projected to increase to 64 $MtCO_2e$ in 2030, a 45% increase.

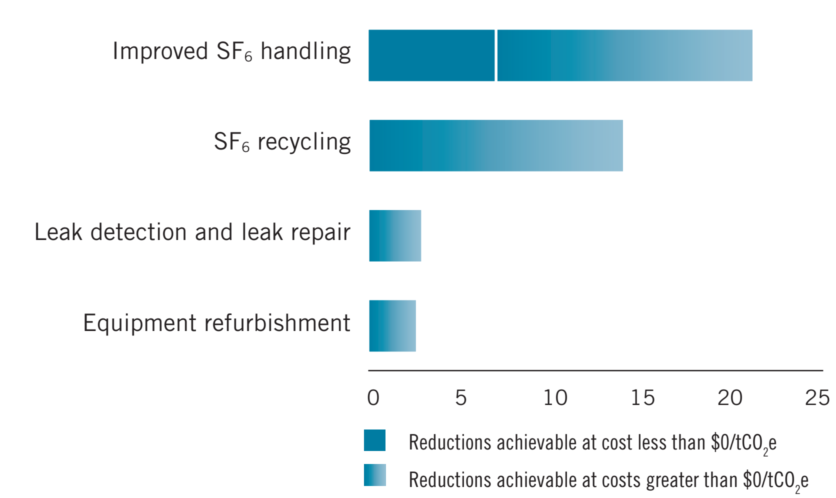
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the electric power systems sector could be reduced by up to 43 $MtCO_2e$ in 2030. This accounts for 1% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



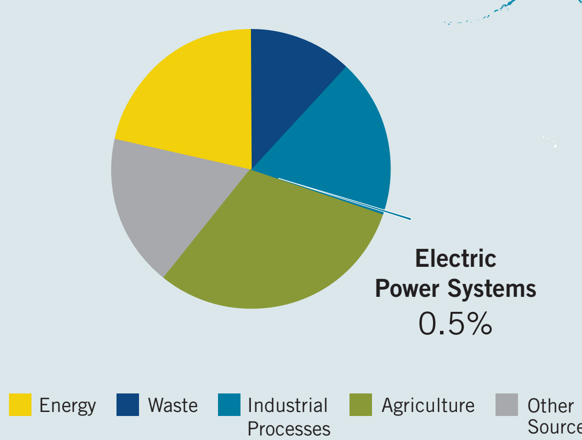
Abatement Measures

Abatement measures that reduce emissions in the EPS sector include SF_6 recycling, leak detection and repair (LDAR), equipment refurbishment, and improved SF_6 handling. These new technologies and handling practices have largely been adopted in Europe and Japan. SF_6 recycling is commonly practiced in the United States, but there remains significant potential for further reductions through improved SF_6 handling and upgraded or refurbished equipment.

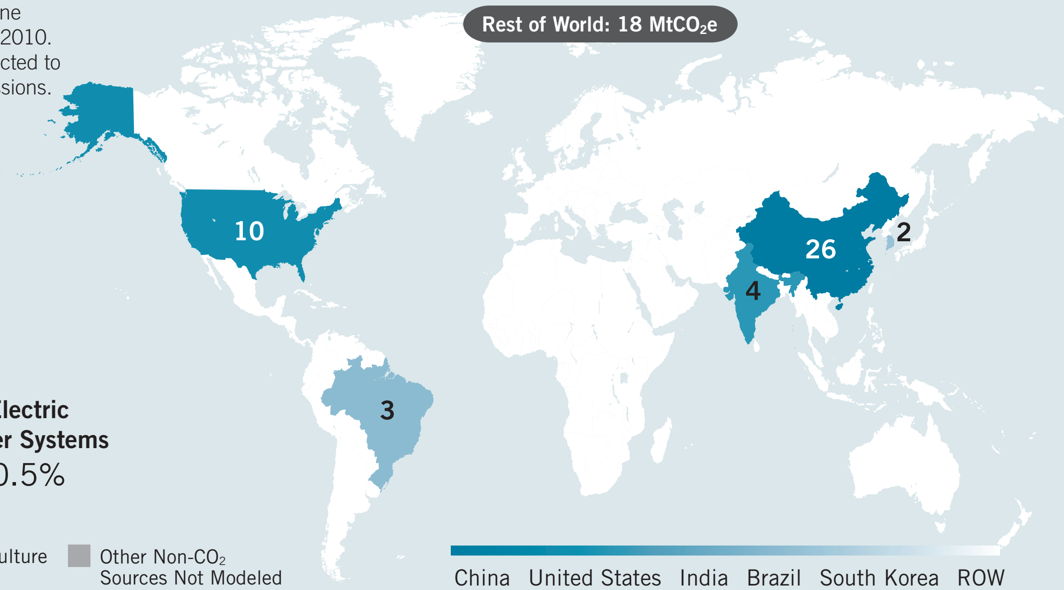
Projected Emissions in 2030

Global Non-CO_2 Emissions

The Electric Power Systems sector baseline emissions are estimated to be 44 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 64 $MtCO_2e$ or 0.5% of total non-CO_2 emissions.

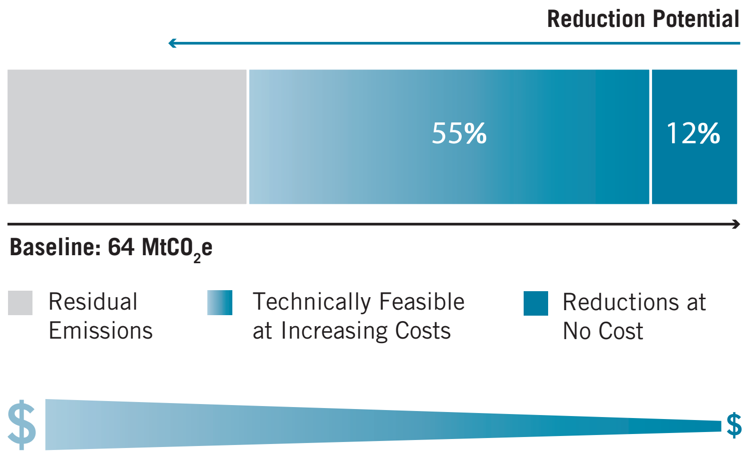


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 12%, compared to the baseline, in 2030. An additional 55% reduction is available using technologies with increasingly higher costs.



Abatement Potential

Global abatement potential in this sector is projected to be 34 $MtCO_2e$ in 2020 and 43 $MtCO_2e$ in 2030, which corresponds to approximately two thirds of the business as usual (BAU) baseline emissions, respectively. Significant reductions are available at relatively low cost. For example, emission reduction technologies that cost up to $5 per tCO_2e, can reduce emissions by 35 $MtCO_2e$, accounting for 84% of the technologically feasible emissions reductions in 2030.

Magnesium Production

SF_6 Emissions from Magnesium Production

Key Points

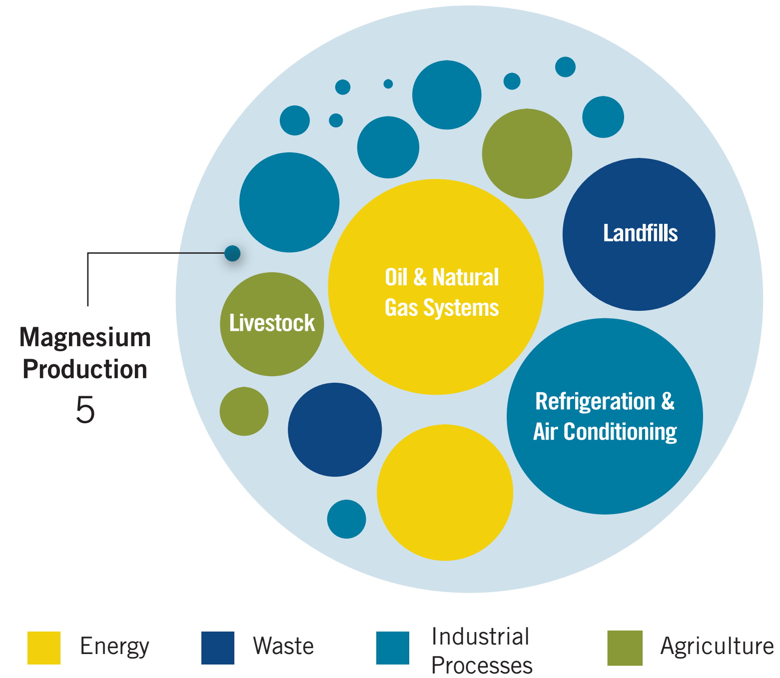
- The global abatement potential of 98% is achieved through three abatement measures that substitute SF_6 with alternative gases.
- From 2010 to 2030, SF_6 emissions are projected to stay in the range of 5 $MtCO_2e$.
- Full abatement potential can be achieved at break-even prices of $5/$tCO_2e$ or less.

Sector Description

Magnesium production uses sulfur hexafluoride (SF_6) as a cover gas during production and casting to prevent spontaneous combustion of molten magnesium in the presence of air. The use of SF_6 can result in fugitive emissions during manufacturing processes. Advanced initiatives in the magnesium industry to phase out the use of SF_6 have resulted in a 50% reduction in global SF_6 emissions from 10 $MtCO_2e$ to 5 $MtCO_2e$ between 2000 and 2010.

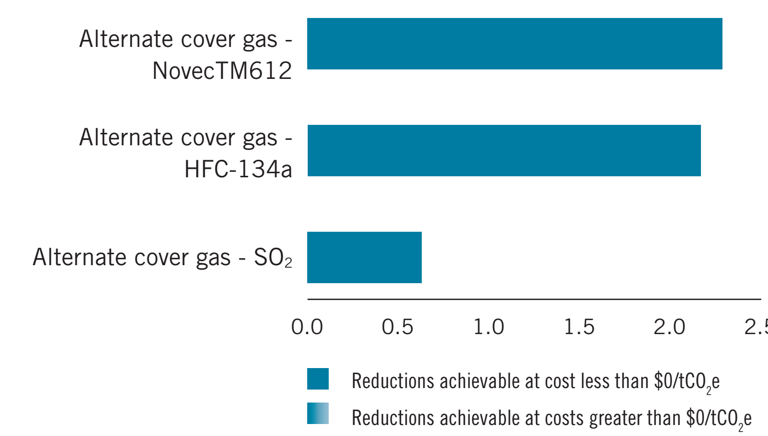
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the magnesium production sector could be reduced by up to 5 $MtCO_2e$ in 2030. This accounts for 0.11% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

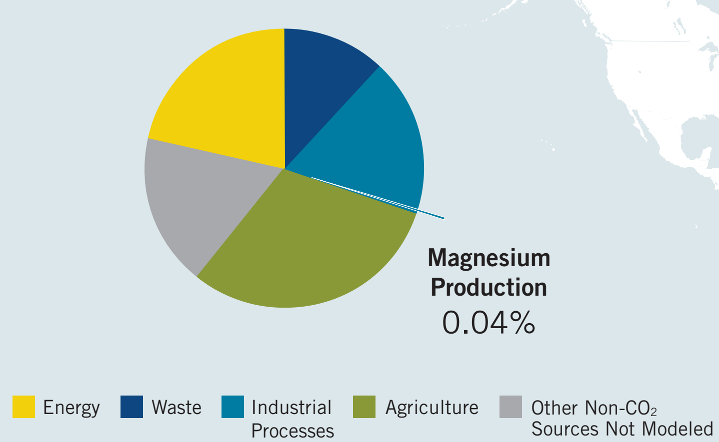
Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



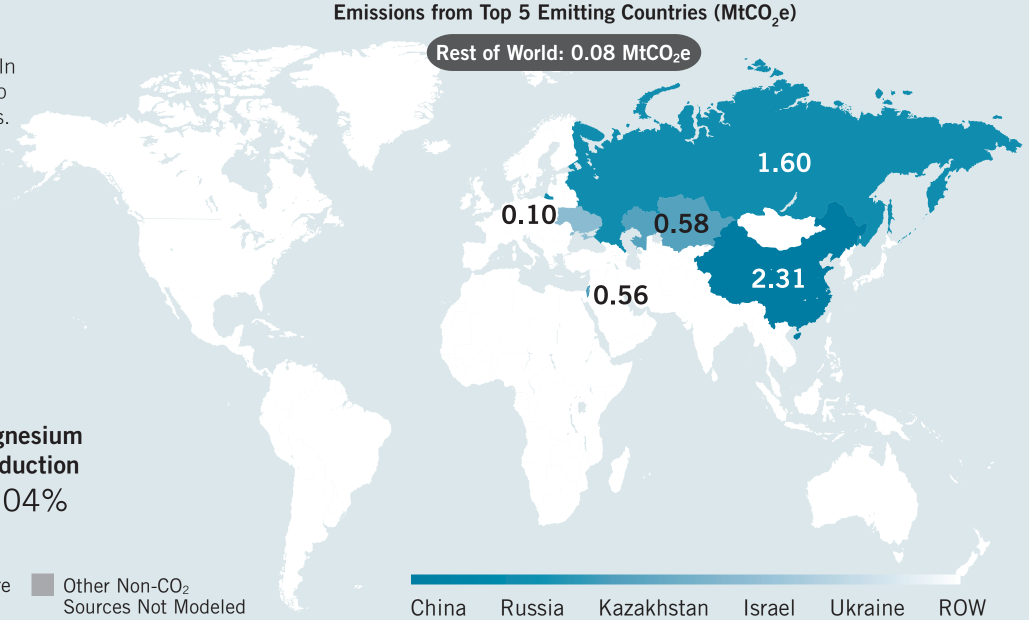
Projected Emissions in 2030

Global Non-CO_2 Emissions

The Magnesium Production sector baseline emissions are estimated to be 5 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 5 $MtCO_2e$ or 0.04% of total non-CO_2 emissions.

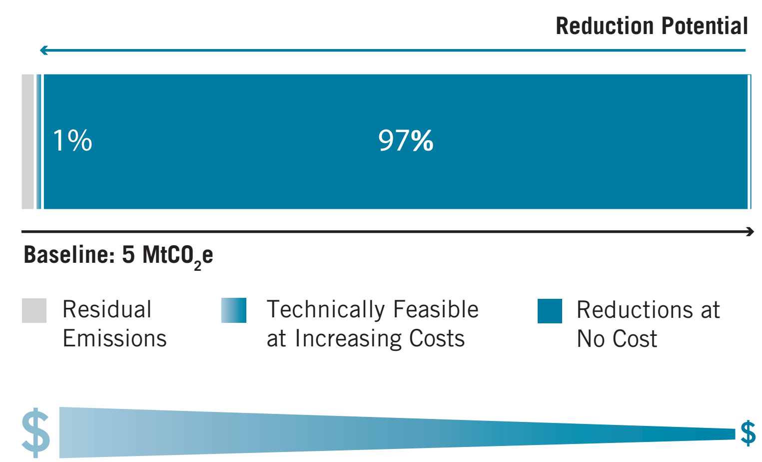


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 97%, compared to the baseline, in 2030. An additional 1% reduction is available using technologies with increasingly higher costs.



Abatement Measures

Three abatement measures are available for reducing SF_6 emissions in production and processing, all of which involve replacing SF_6 with an alternative cover gas: SO_2, HFC-134a, or Novec 612. Although toxicity, odor, and corrosive properties are a concern of using SO_2 as a cover gas, it can potentially eliminate SF_6 emissions entirely through improved containment and pollution control systems. HFC-134a, along with other fluorinated gas, contains fewer associated health, odor, and corrosive impacts than SO_2, but it does have global warming potential. Novec 612 is currently being used in a diecasting facility, and the replacement of SF_6 with Novec 612 is under evaluation.

Abatement Potential

The global abatement potential of SF_6 emissions in the magnesium sector is 5 $MtCO_2e$, approximately 98% of projected emissions. The maximum reduction potential for the suite of reduction technologies is 98% of projected emissions in 2030. These reductions can be achieved at a cost of less than $5/$tCO_2e$.

Photovoltaic Cell Manufacturing

Fluorinated Greenhouse Gas Emissions from Photovoltaic Cell Manufacturing

Key Points

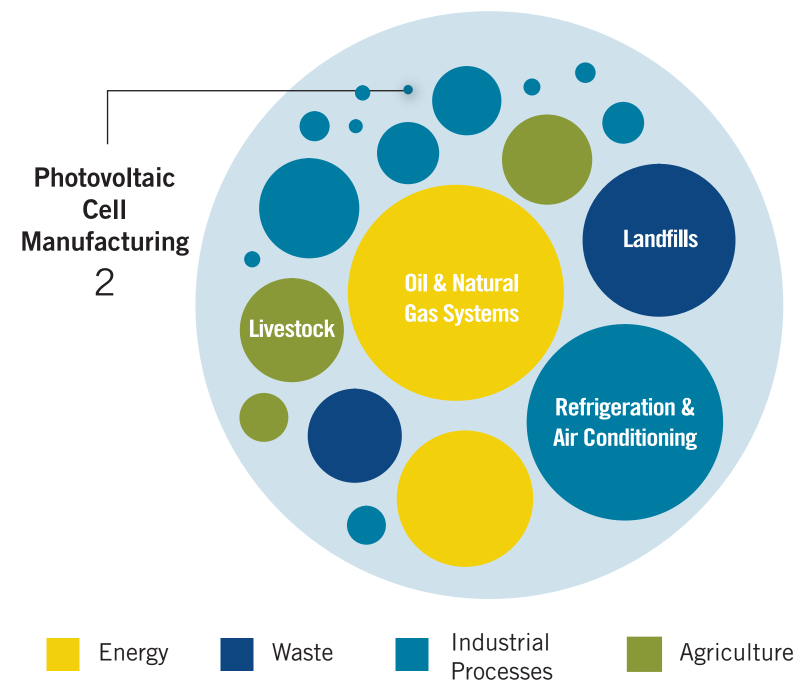
- The global abatement potential in the photovoltaic (PV) manufacturing sector ranges from less than 0.1 $MtCO_2e$ to 1.7 $MtCO_2e$ in 2030.
- Reduction technologies include technologies that reduce fluorinated greenhouse gas (F-GHG) emissions through etch and/or chamber cleaning processes.
- The high costs of emissions reduction technologies combined with low emissions reductions lead to abatement costs greater than $200/t CO_2e.

Sector Description

The PV cell manufacturing process often uses multiple F-GHGs during production, some of which are released into the atmosphere. Baseline emissions were estimated at 2.3 $MtCO_2e$ in 2010. A reduction in baseline emissions is anticipated in both 2020 and 2030, declining to an estimated 2.1 $MtCO_2e$ and 1.9 $MtCO_2e$, respectively.

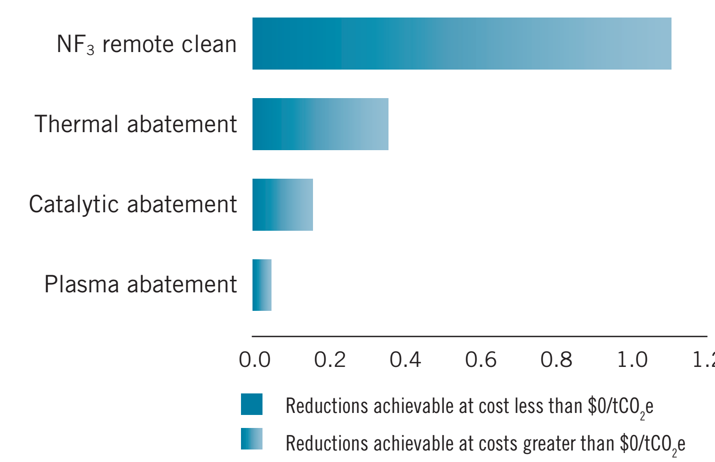
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the photovoltaic cell manufacturing sector could be reduced by up to 2 $MtCO_2e$ in 2030. This accounts for 0.04% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

Emissions reductions by technology in 2030 at $0/t$CO_2e$ and at higher prices.



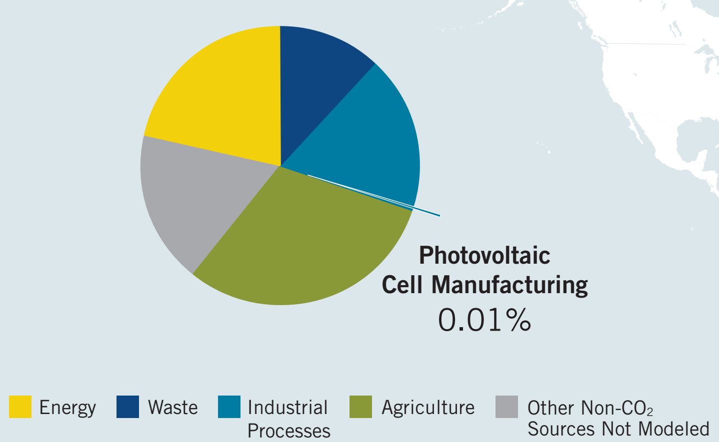
Abatement Measures

Abatement measures considered for reducing F-GHG emissions from the PV manufacturing sector include thermal abatement systems, catalytic abatement systems, plasma abatement systems, and the nitrogen trifluoride (NF_3) remote chamber clean process. These technologies have the potential to reduce emissions from etch and/or chamber clean processes by 90%.

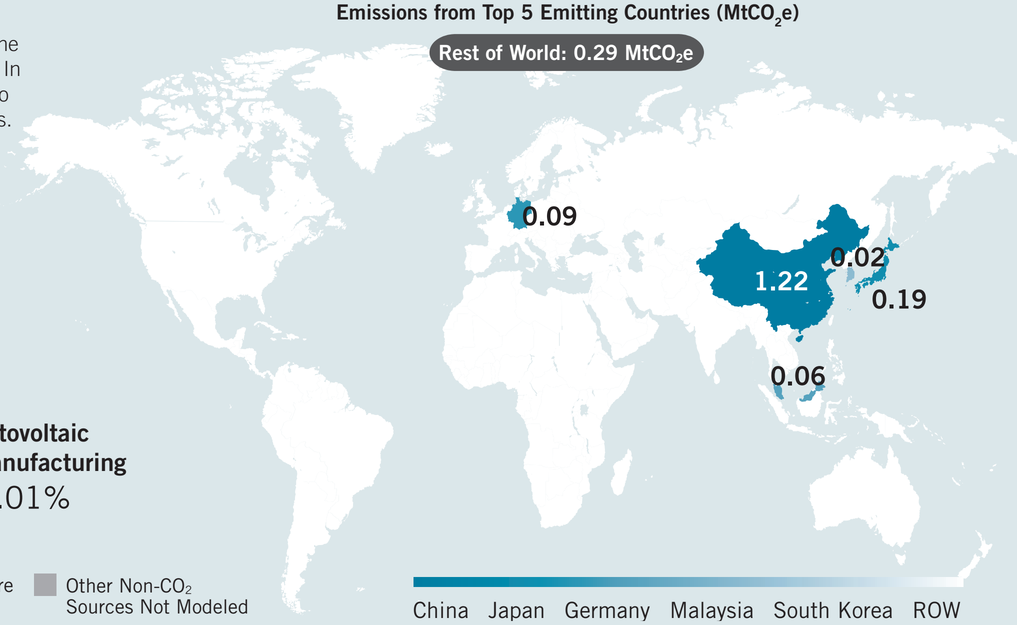
Projected Emissions in 2030

Global Non-CO_2 Emissions

The Photovoltaic Cell Manufacturing sector baseline emissions are estimated to be 2 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 2 $MtCO_2e$ or 0.01% of total non-CO_2 emissions.

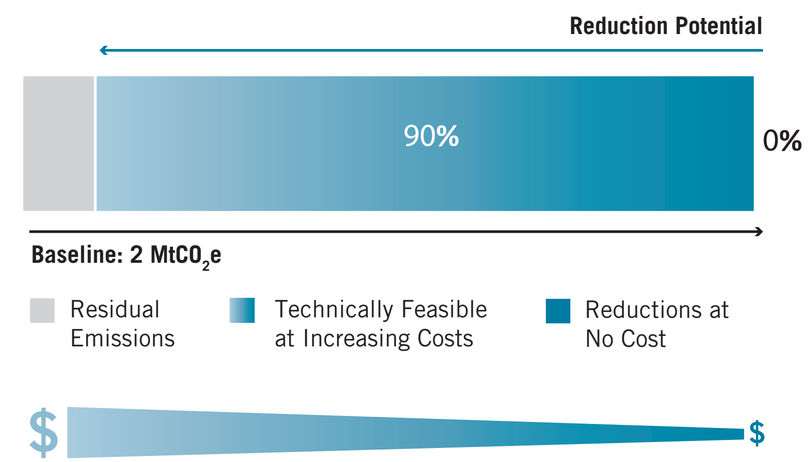


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 0%, compared to the baseline, in 2030. An additional 90% reduction is available using technologies with increasingly higher costs.



Abatement Potential

The global abatement potential in the PV manufacturing sector is estimated to be 1.9 $MtCO_2e$ in 2020 and 1.7 $MtCO_2e$ in 2030, or 90% of baseline emissions in each year. High capital costs and low emissions reductions associated with the available abatement measures result in abatement costs greater than $200/t$CO_2e$. No statistically significant emissions reductions are available at abatement costs below $200.

Flat Panel Display Manufacturing

Fluorinated Greenhouse Gas Emissions from Flat Panel Display Manufacturing

Key Points

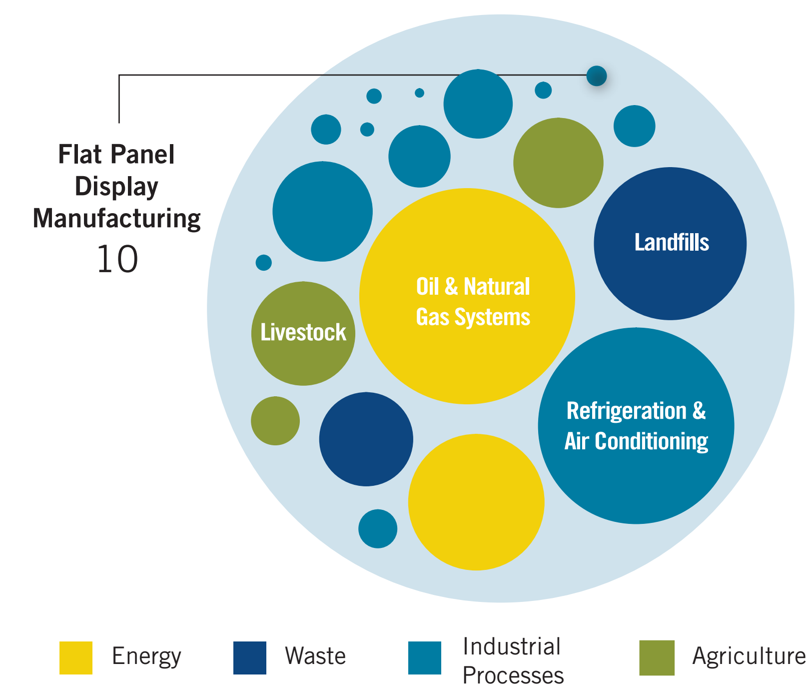
- The global abatement potential of flat panel display (FPD) manufacturing processes is 10 $MtCO_2e$ in 2030, 80% of baseline emissions.
- Six abatement options were analyzed to reduce emissions from etch and/or clean processes.
- No abatement potential is achievable at carbon prices below $25/$tCO_2e$.

Sector Description

FPD manufacturing processes produce fluorinated greenhouse gas (F-GHG) emissions, including sulfur hexafluoride (SF_6), nitrogen trifluoride (NF_3), and carbon tetrafluoride (CF_4). Global baseline emissions from the FPD manufacturing sector in 2010 were estimated at 7 $MtCO_2e$. Baseline emissions for 2020 are projected to increase to approximately 12 $MtCO_2e$ and remain at 12 $MtCO_2e$ through 2030.

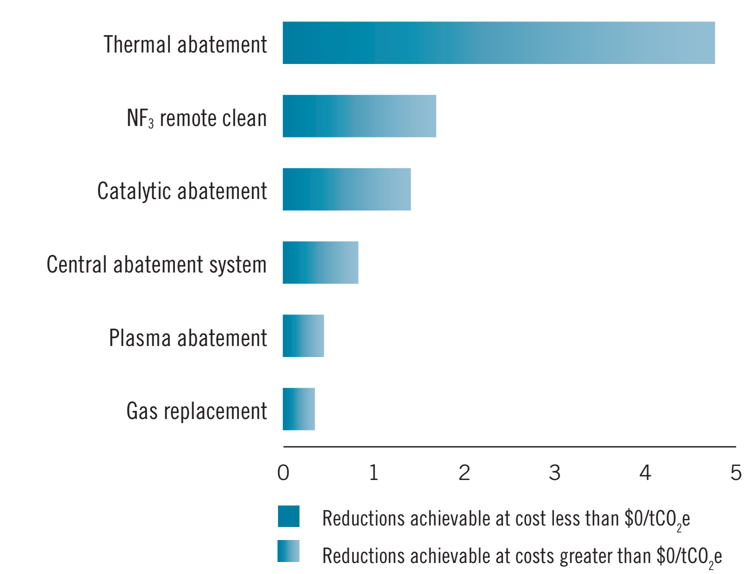
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the flat panel display manufacturing sector could be reduced by up to 10 $MtCO_2e$ in 2030. This accounts for 0.21% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



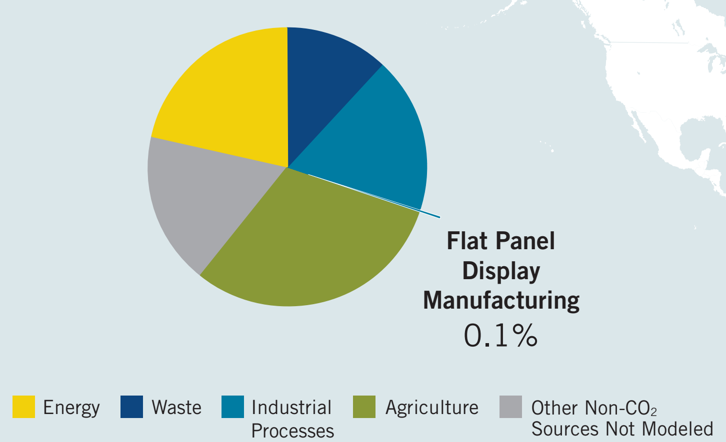
Abatement Measures

Six abatement options were considered for the FPD manufacturing sector: central abatement, thermal abatement, catalytic abatement, plasma abatement, NF_3 remote chamber clean, and gas replacement. These systems are applicable to reducing emissions from etch and/or clean processes. Thermal abatement systems represent the largest abatement potential, accounting for 40% of emissions reductions in the FPD manufacturing sector.

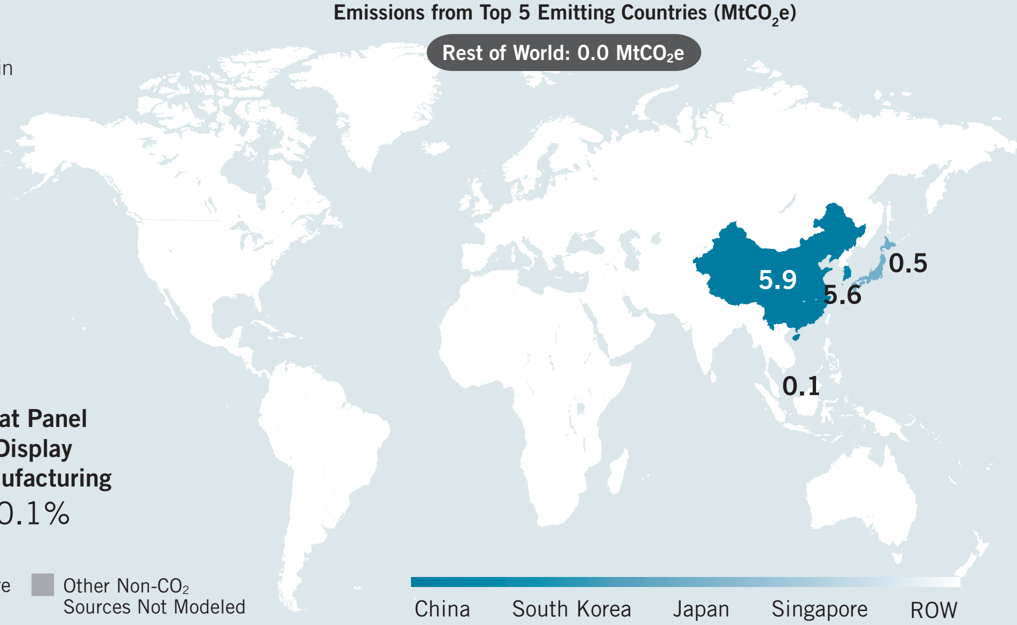
Projected Emissions in 2030

Global Non-CO_2 Emissions

The Flat Panel Display Manufacturing sector baseline emissions are estimated to be 7 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 12 $MtCO_2e$ or 0.1% of total non-CO_2 emissions.

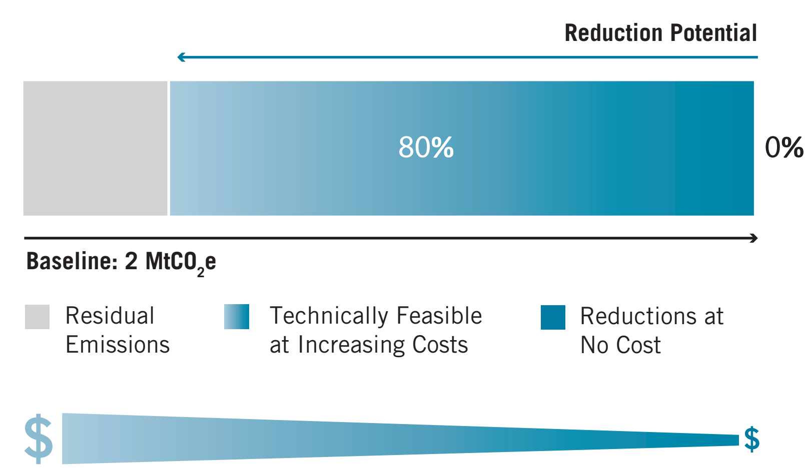


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 0%, compared to the baseline, in 2030. An additional 80% reduction is available using technologies with increasingly higher costs.



Abatement Potential

Global abatement of F-GHGs in the FPD manufacturing sector is estimated to be 9 $MtCO_2e$ in 2020 and 10 $MtCO_2e$ in 2030, which equates to 80% abatement from projected baseline emissions. At a break-even price of $30, just over 2 $MtCO_2e$ in emissions reductions is achievable in 2030. No emissions reductions are possible at prices below $25.

Livestock

Emissions from Livestock Operations

Key Points

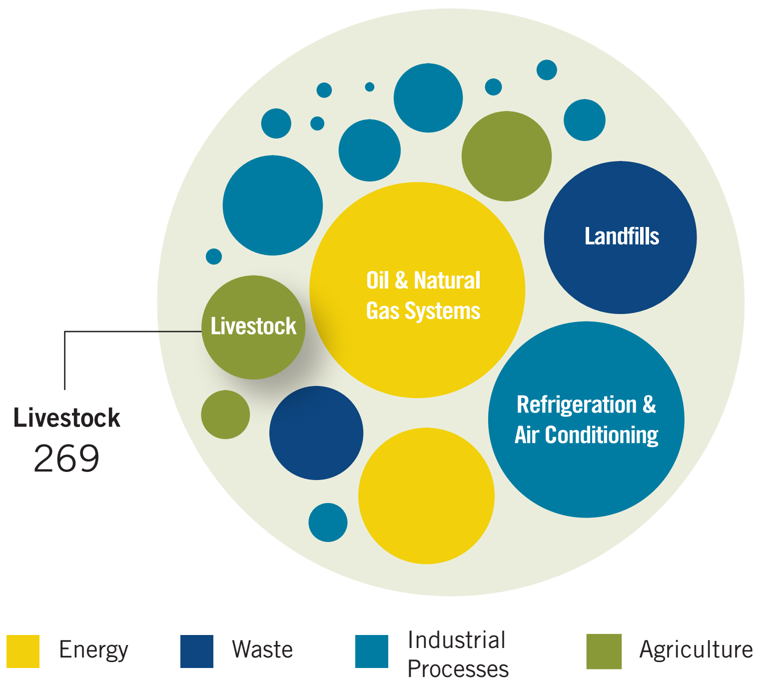
- The livestock sector accounts for 21% of baseline non-CO_2 emissions in 2030.
- The largest low-cost reductions in emissions resulted from implementation of strategies to improve feed conversion efficiency, incorporate feed supplements, and increase the use of small-scale anaerobic digesters.
- The technologically feasible abatement potential of the livestock sector is 267 $MtCO_2e$ in 2030, 10% of baseline emissions.

Sector Description

Livestock operations generate methane (CH_4) and nitrous oxide (N_2O) emissions. The greenhouse gas (GHG) emissions mainly come from two sources: enteric fermentation and manure management. Methane is produced as a by-product of the digestive process in animals through a microbial fermentation process. Manure N_2O emissions result from nitrification and denitrification of the nitrogen that is excreted in manure and urine. Global baseline emissions from the livestock sector were estimated to grow from 2,202 to 2,729 $MtCO_2e$ from 2010 to 2030.

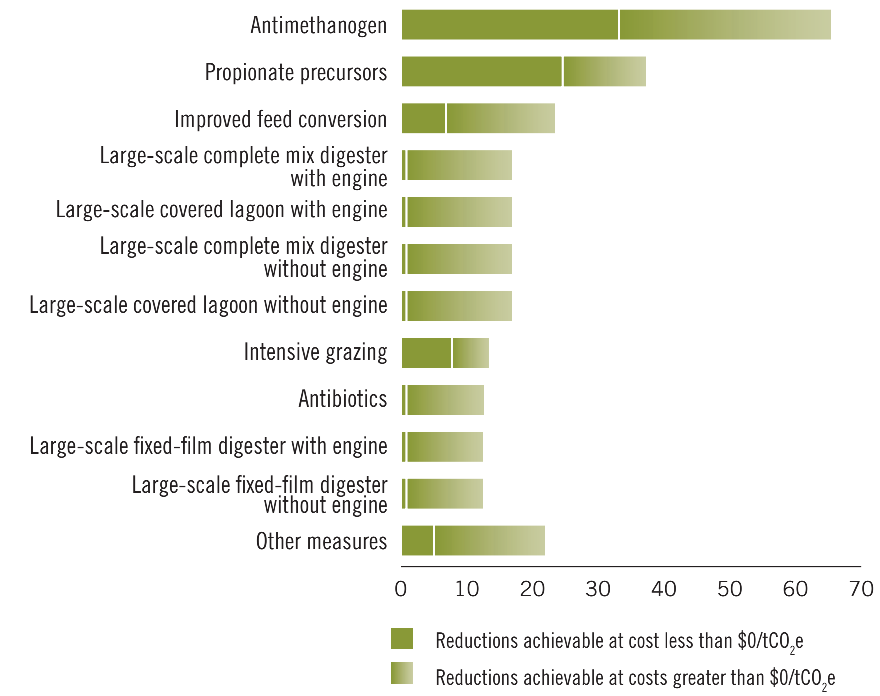
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the livestock sector could be reduced by up to 269 $MtCO_2e$ in 2030. This accounts for 6% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

Emissions reductions by technology in 2030 at $0/tCO$_2$e and at higher prices.



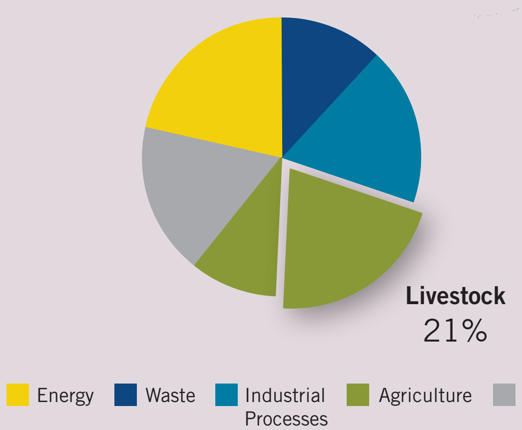
Abatement Measures

The report considered six enteric fermentation (CH_4) abatement measures: improved feed conversion efficiency, antibiotics, bovine somatrotropin (bST), propionate precursors, antimethanogen vaccines, and intensive pasture management. It also included two manure management (N_2O) abatement measures: small and large digesters (complete-mix, plug-flow, fixed film) and covered lagoons. The largest reductions resulted from implementation of antimethanogen vaccines, propionate precursors, and small digesters.

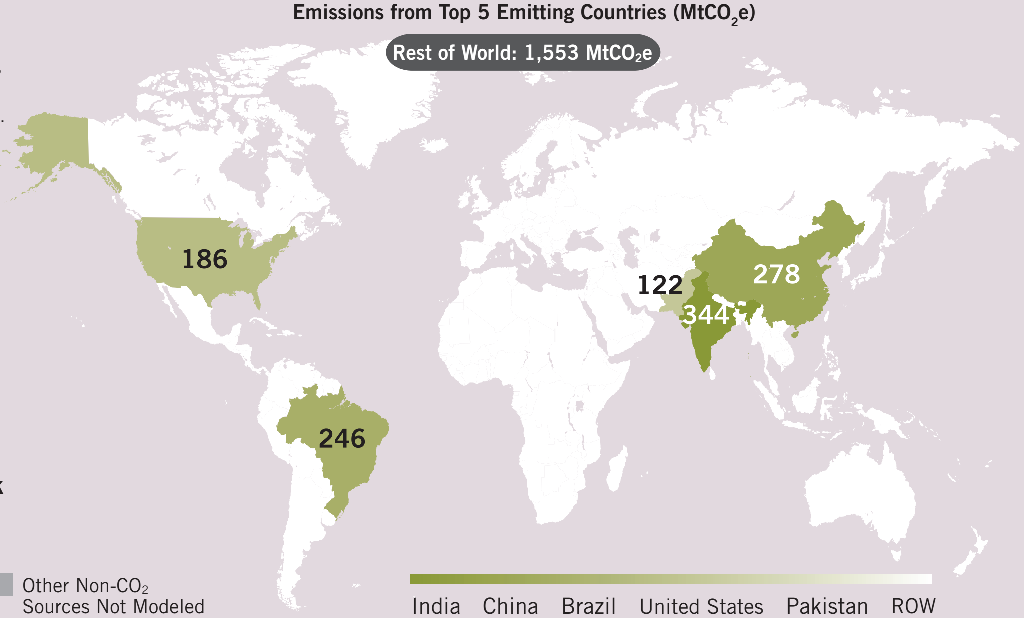
Projected Emissions in 2030

Global Non-CO_2 Emissions

The Livestock sector baseline emissions are estimated to be 2,286 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 2,729 $MtCO_2e$ or 21% of total non-CO_2 emissions.

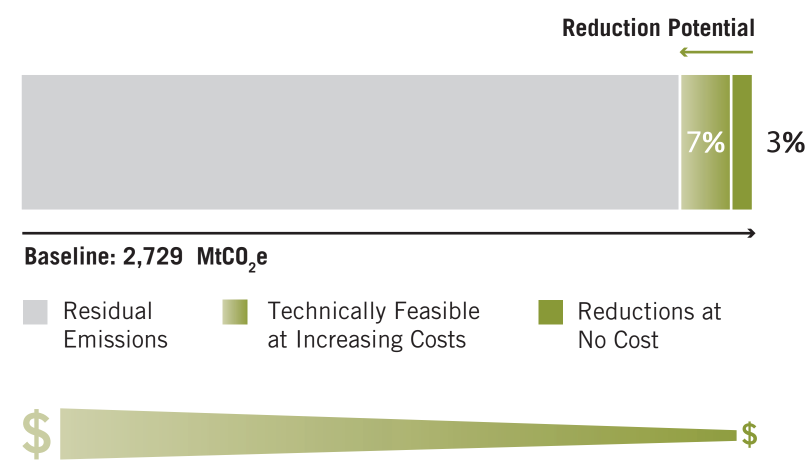


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 3%, compared to the baseline, in 2030. An additional 7% reduction is available using technologies with increasingly higher costs.



Abatement Potential

Technologically feasible global abatement potential for the livestock sector was estimated at 267 $MtCO_2e$ in 2030, a 10% reduction compared to the baseline. In 2030, a reduction of 58 $MtCO_2e$ is cost-effective under current projections and 162 $MtCO_2e$ would be possible at an abatement cost of $30/t$CO_2$e.

Rice Cultivation

Methane (CH_4) and Nitrous Oxide (N_2O) Emissions from Rice Cultivation

Key Points

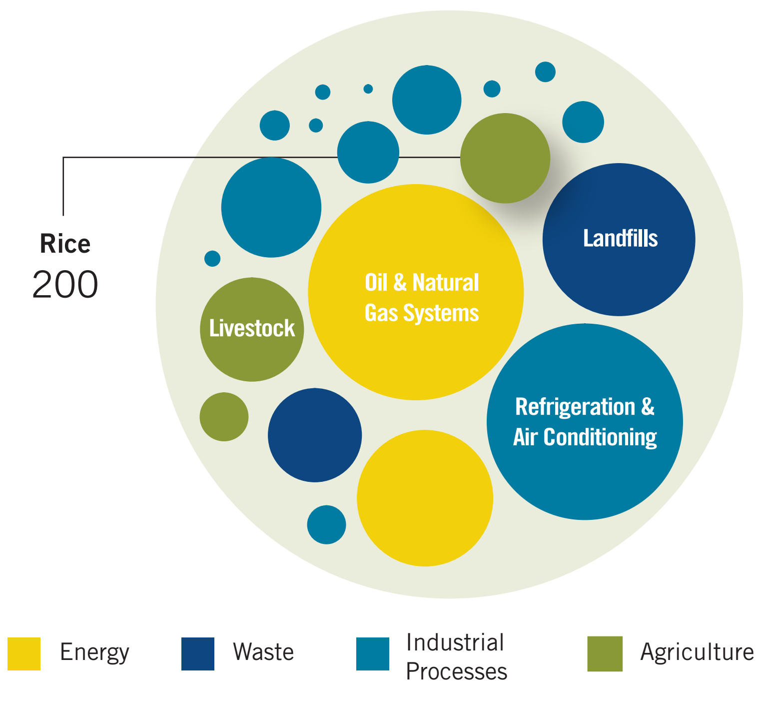
- The rice cultivation sector accounts for 6% of baseline non-CO_2 emissions in 2030.
- Among five abatement measures evaluated, switching to dryland production provides the largest emissions reductions.
- The technologically feasible reduction potential of the rice cultivation sector is 200 $MtCO_2e$ in 2030, 26% of baseline sector emissions.

Sector Description

Rice cultivation is a source of methane (CH_4) and nitrous oxide (N_2O) emissions, and changes in soil organic carbon (C) stocks. When paddy fields are flooded, decomposition of organic material depletes the oxygen in the soil and floodwater, causing anaerobic conditions. Human activities influence soil N_2O emissions (use of fertilizers and other crop management practices) and soil C stocks (residue and crop yield management). Global baseline emissions from the rice cultivation sector were estimated to grow from 565 to 756 $MtCO_2e$ from 2010 to 2030.

Emissions Reduction Potential

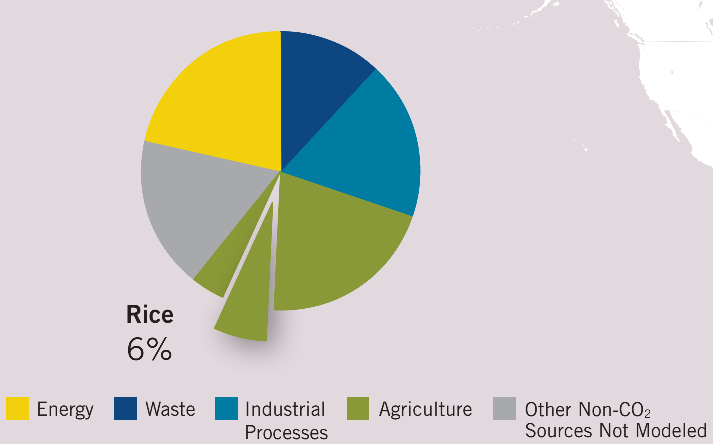
Assuming full implementation of current technology, emissions in the rice sector could be reduced by up to 200 $MtCO_2e$ in 2030. This accounts for 4% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



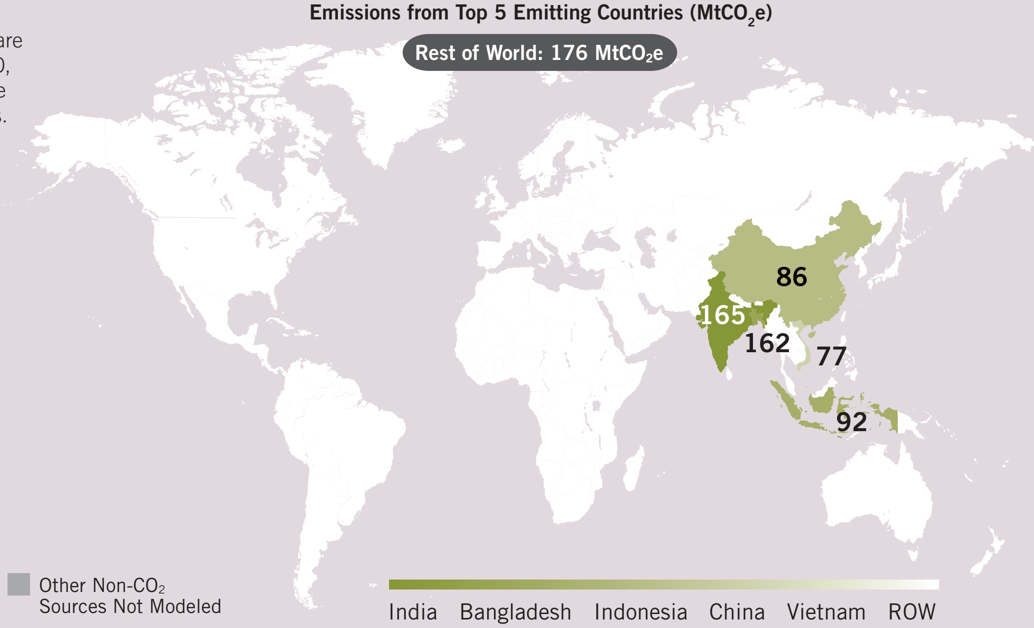
Projected Emissions in 2030

Global Non-CO_2 Emissions

The Rice Cultivation sector baseline emissions are estimated to be 565 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 756 $MtCO_2e$ or 6% of total non-CO_2 emissions.

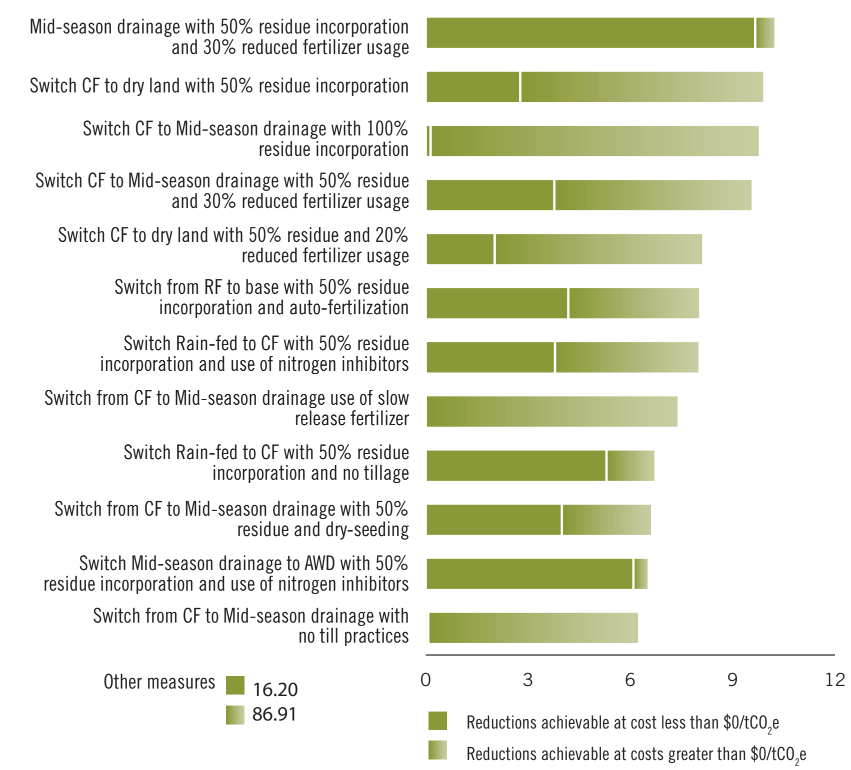


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



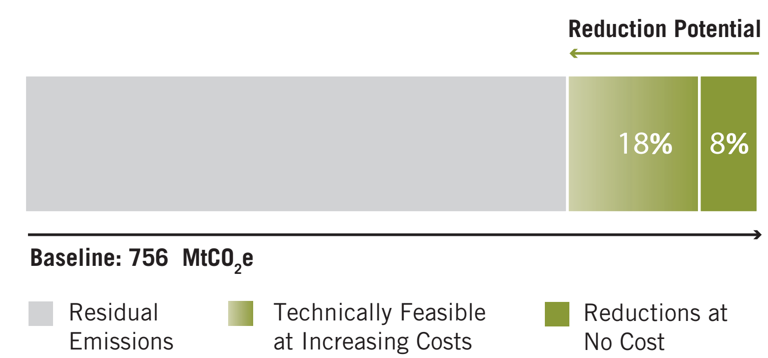
Abatement Measures

Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 8%, compared to the baseline, in 2030. An additional 18% reduction is available using technologies with increasingly higher costs.



Abatement Measures

Five types of abatement measures were considered: paddy flooding (continuous, mid-season, alternating, dry), crop residue incorporation (50% and 100%), tillage (conventional and no-till), fertilization application (conventional, ammonium sulfate, nitrification inhibitor, slow-release, reduced use, auto fertilization), and direct seeding. Switching to dry-land production provides the largest emissions reductions, though it results in major reductions in rice yield.

Abatement Potential

Technologically feasible global abatement potential for the rice cultivation sector was estimated at 203 $MtCO_2e$ in 2020 and 200 $MtCO_2e$ in 2030, 28% and 26% reductions compared to the baseline. In 2030, a reduction of 58 $MtCO_2e$ at an abatement cost of $0/$tCO_2e$ and 135 $MtCO_2e$ would be possible at a cost of $30/$tCO_2e$.

Croplands

Non-rice Croplands

Key Points

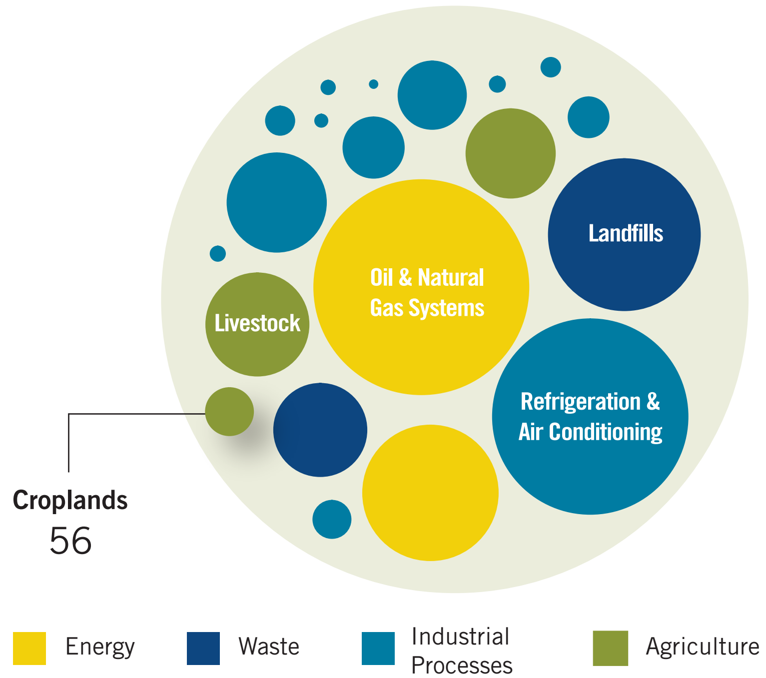
- **The global emission reduction potential of the croplands sector is 56 $MtCO_2e$ in 2030, 12% of baseline emissions.**
- **Seven abatement options were analyzed to reduce soil management emissions.**
- **Over 80% of reductions result from the implementation of no-till cultivation and reduced fertilizer applications.**

Sector Description

Land management in croplands influences soil nitrous oxide (N_2O) emissions (influenced by fertilization practices, soil drainage, and nitrogen mineralization), methane (CH_4) fluxes, and soil organic carbon (C) stocks (and associated carbon dioxide [CO_2] fluxes to the atmosphere). The report considers only major crops (barley, maize, sorghum, soybeans, and wheat) and minor crops closely related to these (rye, lentils, other beans, and oats). Global baseline emissions from the croplands sector in 2010 were estimated at 474 $MtCO_2e$. Projected emissions are relatively constant, decreasing to approximately 460 $MtCO_2e$ in 2020 and rebounding to 472 $MtCO_2e$ by 2030.

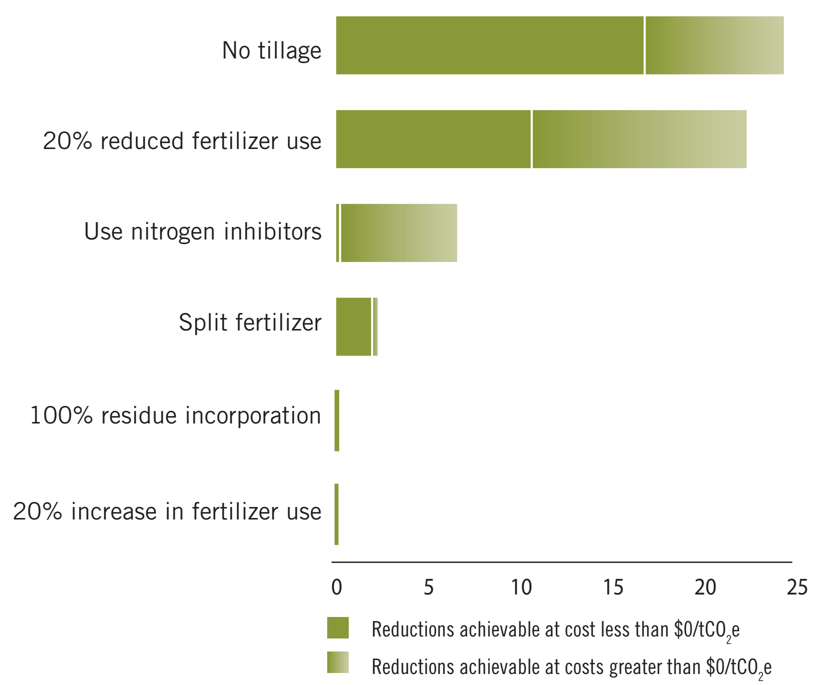
Emissions Reduction Potential

Assuming full implementation of current technology, emissions in the cropland sector could be reduced by up to 56 $MtCO_2e$ in 2030. This accounts for 1% of the 4,615 $MtCO_2e$ in global reduction potential in 2030.



Abatement Measures

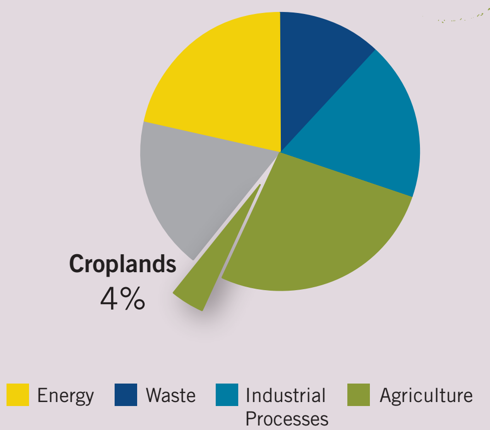
Emissions reductions by technology in 2030 at $0/$tCO_2e$ and at higher prices.



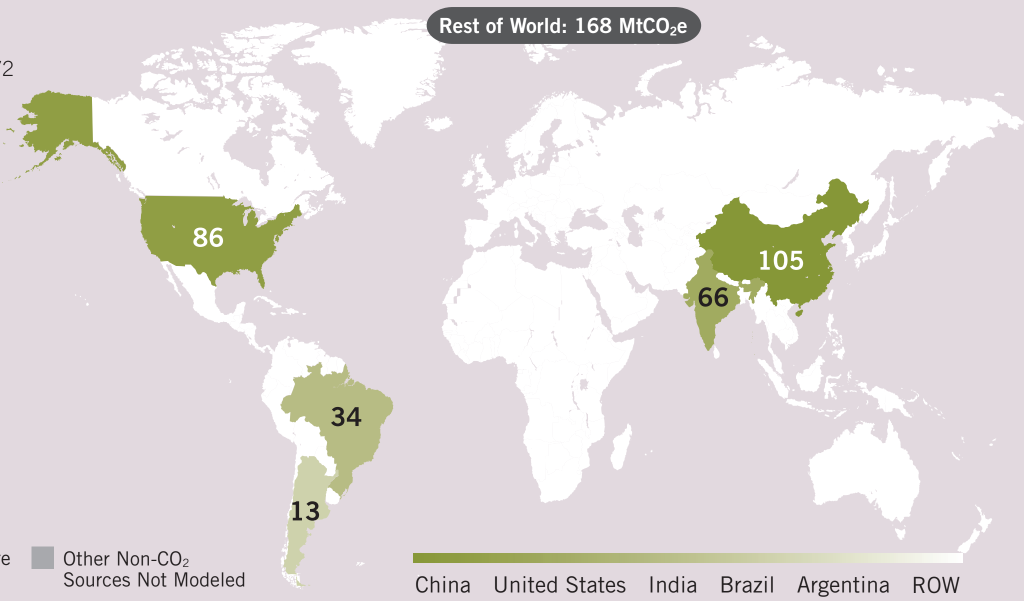
Projected Emissions in 2030

Global Non-CO_2 Emissions

The Croplands sector baseline emissions are estimated to be 474 $MtCO_2e$ in 2010. In 2030, emissions from this source are projected to be 472 $MtCO_2e$ or 4% of total non-CO_2 emissions.

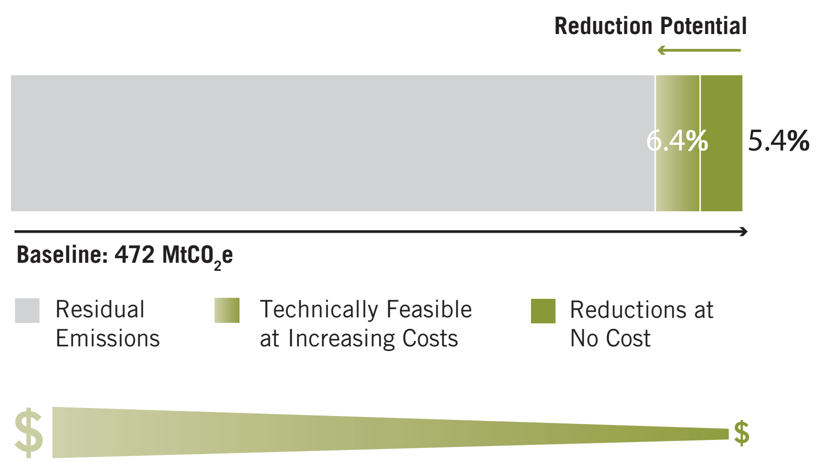


Emissions from Top 5 Emitting Countries ($MtCO_2e$)



Emissions Reduction Potential, 2030

It would be cost-effective to reduce emissions by 5.4%, compared to the baseline, in 2030. An additional 6.4% reduction is available using technologies with increasingly higher costs.



Abatement Measures

Six abatement measures were considered for the croplands sector: adoption of no-till cultivation, reduced fertilizer application, increased fertilizer application, split nitrogen fertilization, application of nitrification inhibitors, and crop residue incorporation. Before 2020, the majority of reductions result from the implementation of no-till cultivation (70% in 2010, 60% in 2020). In 2030, the majority of reductions (96%) are shared between no-till, reduced fertilization, and nitrification inhibitors.

Abatement Potential

Technologically feasible global abatement potential in the croplands sector is estimated to be 70 $MtCO_2e$ in 2020 and 56 $MtCO_2e$ in 2030, representing 15% and 12% reductions compared to the baseline. In 2030, abatement measures that break even (i.e., ≤ $0/$tCO_2e$) can reduce nearly 30 $MtCO_2e$. Additional reductions are achievable with the inclusion of more costly abatement measures. For example, the level of reduced emissions increases to 37 $MtCO_2e$ by including abatement measures with implementation costs less than or equal to $30/$tCO_2e$.

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