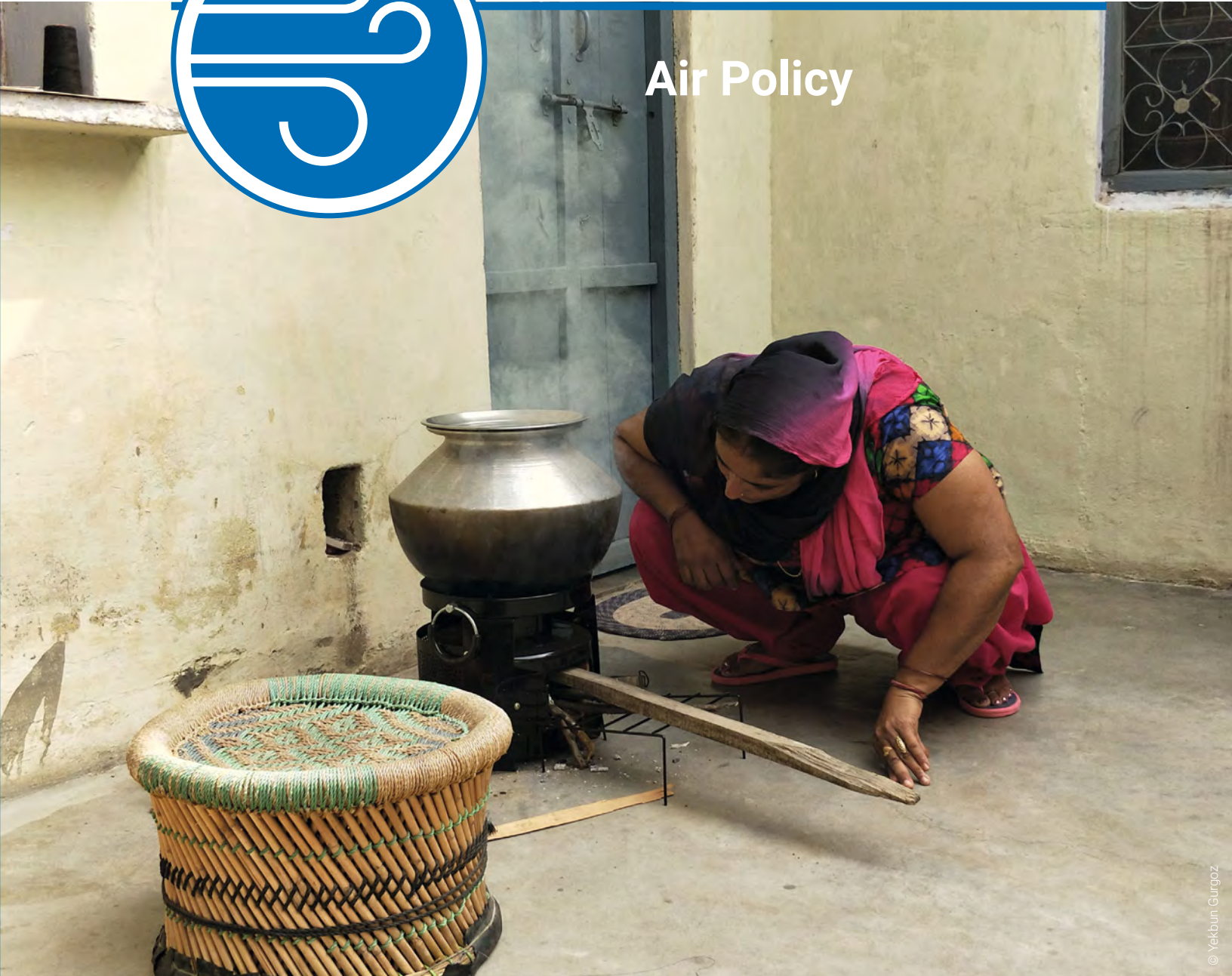


Chapter 12



Air Policy



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Executive summary

Institutional capacity to manage air pollution, climate change, stratospheric ozone depletion and persistent bio-accumulative toxic substances varies significantly across the world (*well established*). In some regions and countries (e.g. North America, Western Europe, East Asia), there are well-developed federated systems of national, provincial and local policies and enforcement programmes. In other regions, international agreements or national legislation may exist, but implementation and enforcement are weak due to a lack of institutional capacity at the national or subnational scale (*established but incomplete*). In some regions, city governments are leading the way with benefits for other parts of their countries {5.5, 12.2}.

Different investments are needed to improve management capacity in different regions. For example, the GEO-6 regional assessments identified improving air quality monitoring infrastructure as a priority for Africa and Latin America and improving the use of benefit–cost analyses of climate change and air pollution mitigation measures as a priority for Asia and the Pacific {5.1}.

Traditional regulatory approaches, including the use of emissions and technology standards, have been successful in addressing some pollution sources (*established but incomplete*). Successes are evident in declining trends in emissions and increasing trends in economic activity and production. However, such approaches rely on adequate human resources and effective enforcement and legal systems, which may not exist {12.2.1, 12.2.2}.

There is no single global agreement addressing air pollution, but there is a patchwork of regional intergovernmental agreements and initiatives focused on public–private partnerships (*unresolved*). Global agreements have been adopted to address climate change, stratospheric O₃ depletion, persistent organic pollutants, and mercury {5.5, 12.2.5}.

National commitments on climate change under the United Nations Framework Convention on Climate Change (UNFCCC) processes are still insufficient to meet the agreed global temperature stabilization goals, and options are foreclosing (*established but incomplete*). The 2015 Paris Agreement on climate change set a limit to the average global temperature rise in this century well below 2 degrees Celsius, with the ambition to achieve 1.5 degrees or less, as a means of transiting towards a low-carbon and resilient future. To date, the set of national commitments and their implementation is not on track to avoid dangerous to catastrophic climate change, and delayed ambitions will lead to greater risks to the economy and to overall planetary health {5.5}.



12.1 Introduction

The composition of Earth's atmosphere is one of the major determinants of a healthy planet, influencing the climate, ecosystems and human health. This is highlighted by the existence of a direct or indirect link between the challenges of air pollution, climate change, stratospheric ozone depletion, persistent bioaccumulative and toxic (PBT) chemicals and each of the Sustainable Development Goals (SDGs) (United Nations 2015).

A plethora of international, national, subnational and regional policies have been deployed to address these challenges. The fundamental forms include:

- i. technology or emissions standards, commonly referred to as 'command and control';
- ii. planning regimes;
- iii. market interventions;
- iv. public information; and
- v. cooperative forums, including international agreements.

The various policy instruments that are used in each of these approaches are discussed in the following sections along with a case study to illustrate each approach. Key features of each case are highlighted using the methodology described in section 10.6. The case studies are selected from a diverse range of geographical contexts, spatial scales and implementation time frames. The case studies are not intended to be all encompassing, but highlight the context-specific nuances, generic patterns and issues that require attention from relevant stakeholders to elicit better policy outcomes. They are not intended to be replicable without considering the local context.

Policies enacted to address air pollution, climate change, stratospheric ozone depletion and PBTs should account for the mix of emissions, the atmospheric or environmental lifetime of the pollutant and its associated benefits and trade-offs (Melamed *et al.* 2016). Pertinent questions include:

- i. how can goals for affordable, clean and reliable energy across spatial scales (local, national, regional, global) be achieved by considering possible synergies and trade-offs?;
- ii. what synergies and co-benefits between climate policy and air pollution control can be identified?; and
- iii. how will emissions of greenhouse gases (GHGs) and air pollutants co-evolve in scenarios with and without policy interventions, such as context-specific regulation of PBTs, climate policy and air pollution control?

From a systems perspective, the existence of various policy instruments and regimes at a range of spatial and temporal scales brings into sharp focus the complexity of addressing air quality challenges in an integrated and comprehensive manner. This makes it imperative to take an integrated approach to address potential conflicts and define trade-offs between environmental policy objectives, as well as to isolate and consolidate policies with possible co-benefits such as improved energy security, urban air quality and human health (see Section 11.3).

12.2 Key policies and governance approaches

12.2.1 Planning regimes

Planning regimes (or frameworks) establish ambient targets (e.g. concentration standards, total pollutant loads or a change in global mean temperature) and emissions budgets (or ceilings). Clusters of policies are then developed and implemented to meet the targets or budgets. Progress towards these is monitored, and if necessary, additional policies are developed or existing policies are revised. Planning regimes are often considered to be fundamental to managing air pollution, climate change, ozone-depleting substances (ODSs) and PBTs, as they provide a strategic policy framework within which specific actions can be integrated.

Ambient concentration standards or other environmental targets define the desired state of the environment, often linked to cause-effect relationships in relation to human health. Emissions budgets, pollutant loads or ceilings are the estimated levels of pressure that still enable achievement of the desired state, or present a no-effect threshold (e.g. critical loads/levels). As an example, the US National Ambient Air Quality Standards (NAAQS) are standards for harmful pollutants established by the US Environmental Protection Agency (EPA) under authority of the Clean Air Act (42 U.S.C. 7,401 *et seq.*). These standards are applied for outdoor air throughout the country (United States Environmental Protection Agency 2016) and aim to protect human health from harmful air pollution.

Emissions budgets can be related to environmental targets using quantitative (e.g. atmospheric or climate) models properly evaluated against field observations. In the case of secondary pollutants (which are created in the atmosphere) or pollutants that have long lifetimes in the environment, the relationship between emissions and ambient concentrations may not be linear. Making a causal linkage between emissions

Table 12.1: Typology of policy and governance approaches described in this chapter

Governance approach	Policy instrument(s)	Case study
Planning regimes	Ambient standards, emissions budgets	United Kingdom of Great Britain and Northern Ireland Climate Act and carbon budgets
Technology and emissions standards	Emissions standards, fuel quality standards, efficiency standards, best available control technology	Diesel emissions standards in Europe
Market interventions	Subsidies, tax policy, tradeable credits/allowances	Improved cookstoves in Kenya (Global Alliance for Clean Cookstoves)
Public information	Information, forecasts, labelling and branding	Provision of real-time air quality data and forecasts
International cooperation	Multilateral and bilateral binding agreements, voluntary organizations	ASEAN Agreement on Transboundary Haze



and the desired state is often important to justify the extent or costs of emissions controls or other policies and requires a significant amount of information (as inputs to the model) and expertise. However, in cases where emissions are high and the government's technical planning capacity is low, it is often not necessary to quantify the linkage between policies and the desired state to justify some control measures on the largest sources of emissions. It may be sufficient to qualitatively demonstrate that the sources contribute to adverse impacts and that there would be benefits from controls, with progress towards long-term objectives being achieved through implementation.

Linked to emissions budgets, emissions trading schemes have been introduced in particular for GHGs, where the location of emissions matters less in contrast to air pollutants. In December 2017, China launched its emissions trading system (United Nations Framework Convention on Climate Change [UNFCCC] 2017a), which will initially cover only the electricity sector. However, it is set to be the world's largest system of its sort and accounts for approximately 3 billion tons of traded CO₂. A similar system is in place in Europe, with approximately 2 billion tons traded (European Commission 2018). Similar trading schemes exist in several countries and regions (Carbon Market Data 2018). By setting emissions budgets, which may gradually be constrained further, prices for traded emissions may be adjusted.

As noted in section 5.5, countries have identified different ambient concentration standards based on their own interpretation of the epidemiological evidence on relationships between environmental state and health effects; their existing levels of air pollution; and their own perceptions about their ability to achieve decreases in air pollution. The World Health Organization (WHO) has established guidelines and interim targets (WHO 2018) that countries can use to establish their own standards and targets. As WHO and individual countries establish or revise their ambient standards based on new information, other countries often take note of the changes and consider whether to make similar changes to their own standards. For the protection of sensitive habitats and ecosystems, critical loads and critical levels have been set in the context of the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP), initially focusing on acidification in the early 1980s, and later extended to include nutrient critical loads and ammonia (NH₃) critical levels based on growing evidence of ecosystem damage and biodiversity losses even at lower concentration and deposition levels, stemming, for instance, from agricultural NH₃ emissions (Sutton, Reis and Baker eds. 2009).

Emissions budgets and ceilings not only provide a way of evaluating whether a suite of policies would be expected to achieve the relevant environmental targets; they also provide a way of apportioning responsibility for achieving environmental targets among regions, jurisdictions, sectors or individual sources. For example, emissions budgets have been applied at the national and state level in air pollution planning and at the national level in international agreements to mitigate ODS emissions. Within Europe and the UNECE region, the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (as amended) under CLRTAP (UNECE 2018) as well as the European Union (EU) National Emission

Ceilings Directive (European Environment Agency [EEA] 2016a) present recent examples of national emissions ceilings agreed for pollutants known to contribute to a range of environmental and human health effects.

In the following case study, emissions budgets are applied to long-lived GHG emissions in the United Kingdom.

Case study: The United Kingdom of Great Britain and Northern Ireland's energy and climate policies

The 2008 Climate Change Act (United Kingdom of Great Britain and Northern Ireland [UK] Government 2008a; UK Government 2008b) is an example of how a national policy can be established within an international framework to tackle climate change (including targets and timeframes, carbon prices and emissions trading). Legally binding targets aim to progressively reduce emissions through five-year carbon budgets up to 2050, with significant benefits such as international market competitiveness, resource conservation, cost-effective removal of barriers, support to low-carbon technologies, promotion of carbon capture and storage and considerations of social implications such as fuel poverty. To achieve such aims, practical measures included mandatory cap-and-trade schemes, standards, financing and taxing, innovation strategies and technology deployment (UK, Department of Trade and Industry 2007).



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Table 12.2: Summary of assessment criteria: United Kingdom of Great Britain and Northern Ireland's energy and climate policies

Criterion	Description	References
Success or failure	GHG emissions reduced by 5 per cent/year since 2012, reaching 42 per cent below 1990 levels in 2016, with the economy growing by 60 per cent. Between 2008 and 2015 GHG per capita emissions fell from 8.22 to 5.99 tCO ₂ , GHG per GDP (0.20 to 0.15 tCO ₂ /2010 US\$, or 0.22 to 0.16 tCO ₂ /2010 US\$ PPP); per capita energy use as total primary energy supply in tons of oil equivalent (TPES 3.37 to 2.78 toe/person), TPES per GDP (0.08 to 0.07 toe/1,000 2010 US\$) and electricity consumption per capita (6.01 to 5.08 MWh/person).	UK, Department for Business, Energy & Industrial Strategy 2016; International Energy Agency [IEA] 2017; UK, Committee on Climate Change 2017
Independence of evaluation	Official Report to Parliament, supported by statistics.	
Key actors	Mainly government bodies (including devolved administrations).	
Baseline	1990 economy-wide GHG emissions, plus other associated baselines such as shares of renewable energy.	
Time frame	GHG cuts of 80 per cent by 2050, with other interim targets (50 per cent by 2025), based on five-year carbon budgets, set 12 years in advance to allow preparation; other goals in the energy sector (renewable electricity and biofuels, transport efficiency, phase-in of electric vehicles, and others, including carbon capture and storage).	
Constraining factors	Slow GHG curbs in transport and buildings sectors, very limited carbon capture and storage.	
Enabling factors	The main driver was a reduction in the use of coal by 75 per cent in the power sector. The Act had strong support due to lower energy bills, salience of scientific evidence, public awareness, political responses following innovation outside government, technology improvements, value of institutional innovation, use of evidence reframing climate change as an economic issue and the importance of leadership.	
Cost-effectiveness	Costs will be around 1–2 per cent of GDP in 2050, with significant business opportunities from a low-carbon economy (in 2009 a market worth GBP112 billion, with over 900,000 jobs).	
Equity	Contraction and convergence approach.	
Co-benefits	Improved market access, innovation, infrastructure resilience, energy supply security and system flexibility (storage, interconnection), take-up of new technologies, quality of life (air, water, health and well-being, land use).	
Transboundary issues	Necessary policy realignment depending on exit from the EU and more ambition to fulfil the Paris Agreement goals.	
Possible improvements	Scale-up low-carbon power generation, accelerated uptake of electric vehicles, more low-carbon heat alongside energy efficiency, restart work on carbon capture and storage, address land management practices, improve and clarify combinations of policy instruments (carbon pricing, standards and regulations, research and development funding, subsidies, market design and taxation).	

The Climate Change Act of the United Kingdom of Great Britain and Northern Ireland was the world's first legal instrument to set a long-range and significant carbon reduction target with a legally binding framework. Its approach considers a socio-technical transition and equity under a contraction and convergence model (Lovell, Bulkeley and Owens 2009; UK, Department for Business, Energy and Industrial Strategy 2016; Global Commons Institute 2018), with carbon budgets (caps in GHG emissions) used as an umbrella policy with strong direction for all the main economic sectors.

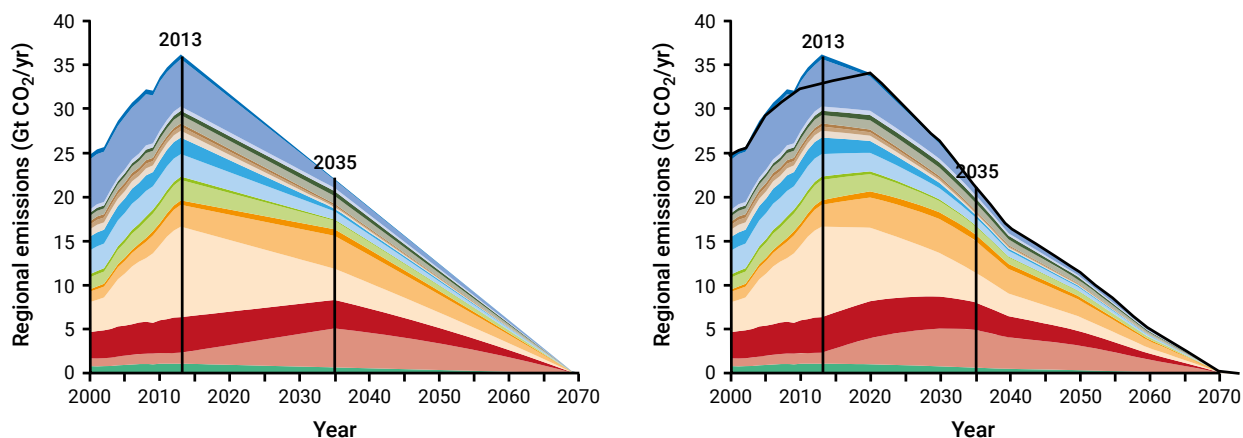
The importance of carbon budgets in guiding climate policies is illustrated by **Figure 12.1**, which allocates limits to cumulative emissions by country. A global carbon budget translates the

atmospheric carrying capacity to withstand anthropogenic GHG emissions within the goals set by the UNFCCC 2015 Paris Agreement (1.5–2°C), based on representative concentration pathways (RCPs). According to the Intergovernmental Panel on Climate Change [IPCC] (2014), for the period 2011–2100, limits range around 1,000 GtCO₂ (750–1,400 for 2°C with >66 per cent probability, or 550–600 Gt CO₂ for the 1.5°C goal with a >50 per cent chance).

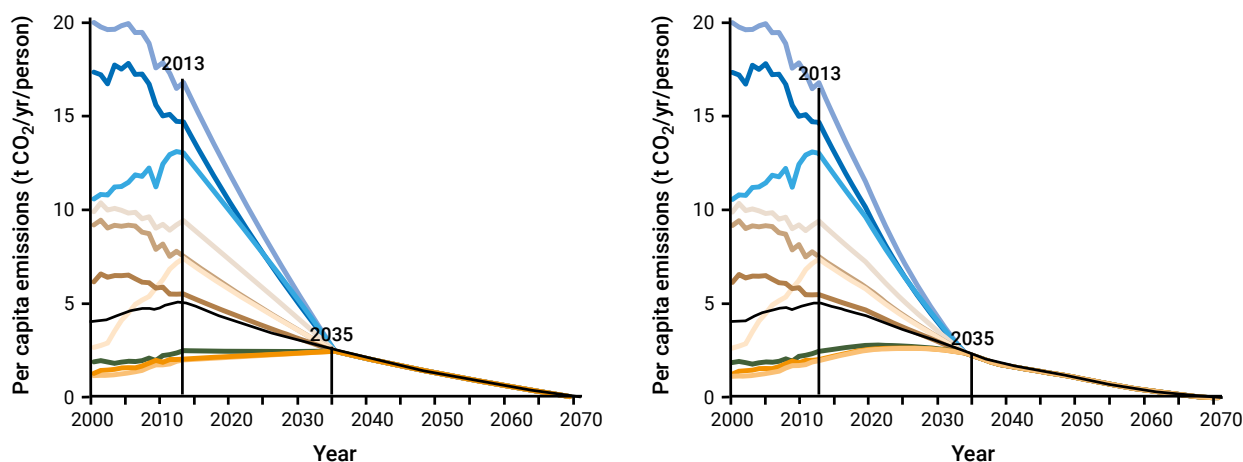
Despite being an important lesson for other countries, the United Kingdom is still only partly on track to achieve its GHG emissions targets. The cluster of policies that have been implemented have been moderately successful in some sectors, such as transport and buildings. Entrenched interests,



Figure 12.1: Regional allocation of cumulative CO₂ emissions



- Canada
- United States
- Rest of North America
- Brazil
- Rest of Latin America
- France
- United Kingdom
- Germany
- Russia
- Rest of Europe
- Oceania
- Middle East
- Indonesia
- India
- China
- Rest of Asia
- Africa
- Bunkers
- RCP2.6



- United States
- Canada
- Russia
- Germany
- United Kingdom
- China
- France
- Brazil
- Indonesia
- India
- World

	2035 Convergence	2050 Convergence
Canada	8	10
United States	78	97
Rest of North America	15	14
Brazil	21	18
Rest of Latin America	35	33
France	8	9
United Kingdom	9	10
Germany	13	15
Russia	27	33

	2035 Convergence	2050 Convergence
Rest of Europe	51	54
Oceania	7	8
Middle East	51	55
Indonesia	27	23
India	133	114
China	197	214
Rest of Asia	133	125
Africa	155	136
Bunkers	30	30

Note: The regional allocation of cumulative CO₂ emissions following a linear emissions decrease to zero (left) and the RCP 2.6 global emission scenario (right). Per capita convergence occurs in 2035, and total cumulative emissions after 2013 are equal to 1,000 Gt CO₂, for both scenarios. The side table compares regional cumulative emissions allocation (values in Gt CO₂ from 2014 onwards) from the RCP 2.6 scenario, for per capita convergence in 2035 and 2050 (Gignac and Matthews 2015).



such as coal-fired power plants and the transport sector, are not changing as quickly as needed to achieve the targets and additional policies to accelerate change will be needed to achieve the mandatory emissions cuts. Finally, since much of the country's existing environmental legislation arises from membership of the EU, a wide range of new policies and programmes would be needed after the British exit (UK, Committee on Climate Change 2017).

12.2.2 Technology and emissions standards

One of the most common approaches to address challenges related to air quality and climate change is to define emissions standards or other performance standards for specific industrial processes, equipment or products. Such standards may mandate that a process, piece of equipment or product should not emit more than a specified mass of emissions of a given pollutant per unit of time, input or output. For example, boilers used to generate electricity may be limited to a mass of emissions per kilowatt-hour generated; vehicles are typically limited to certain emissions per kilometre (km) travelled. Alternatively, a standard may require the application of a specific type of technology or a specific operational practice. For example, to limit emissions of fugitive dust from a construction site, vehicles leaving the site may be required to go through a wheel wash station. In most cases, standards are designed to be neutral with respect to the choice of fuel or to the choice of a control manufacturer, but the general principle is that the polluter is responsible for attaining the standard and hence should bear the cost of emissions control. For example, polluters are responsible for retrofitting existing technologies, where specific equipment needs to be installed to achieve existing or new emissions standards. Where emissions control technologies are integrated into new equipment—for example, in the case of vehicles that comply with Euro emissions standards, which must pass type approval at production—the costs of emissions control are included in the unit price.

The implementation and enforcement of technology and emissions standards present a direct measure affecting 'pressures' and contribute to the attainment of the emissions targets and budgets, the desired 'state' established in a planning regime (see Figure 1.2, Chapter 1). Often referred to as 'command and control' regulations, technology and emissions standards may be implemented and enforced through permit programmes, type approval schemes, inspections and audits, and reinforced by emissions monitoring and reporting requirements. Technology and emissions standards, however, may also be developed and applied voluntarily by industry groups, self-policed or subject to third-party verification, and associated with branding programmes (see section 12.2.4). Lifestyle choices and consumption patterns may play a vital role in determining the effectiveness of voluntary approaches.

Different standards in jurisdictions in the same geographical market increase the costs to manufacturers of products and equipment, which are required to meet the various standards. Although regulatory compliance costs are only one factor that affects business location decisions, a lack of harmonization of standards can lead to shifts in economic activity and associated emissions between jurisdictions as businesses seek locations with lower overall compliance costs. Therefore, standards are typically defined at the national level, taking into account standards in other countries, jurisdictions and markets.

Under the US Clean Air Act, New Source Performance Standards (NSPS) define a minimum level of air pollution control for all major new industrial emissions sources across the country, but more stringent standards may be applied depending on the level of existing pollution. To prevent the deterioration of air quality in areas already meeting the National Ambient Air Quality Standards (NAAQS) short-term exposure to air pollution, new major sources are required to use Best Available Control Technology (BACT), which is determined on a case-by-case basis as part of a permitting process and is at least as stringent as the NSPS. In polluted areas that already exceed the NAAQS, major new sources are required to meet the Lowest Achievable Emission Rate (LAER), which reflects the most stringent requirements in practice. Existing sources in such areas are required to meet the less stringent standard of Reasonably Available Control Technology (RACT). The USEPA maintains a database of these standards and case-by-case determinations in what is known as the RACT/BACT/LAER Clearinghouse (United States Environmental Protection Agency 2018b). As technology evolves, so do the RACT/BACT/LAER determinations, but by making the information public, the standards in different jurisdictions can evolve together. Likewise, the Industrial Emissions Directive (2010/75/EU) regulates industrial activities in Europe and also uses a legally binding concept of 'Best Available Techniques' (BAT) to set environmental performance levels which industry must achieve (European Commission 2018b). The definition of a BAT is done through a transparent exchange of information between industry, non-governmental organizations (NGOs) and regulators, and is recognized beyond the EU.

For marine shipping emissions, the International Maritime Organization (IMO) and the International Convention for the Prevention of Pollution from Ships (MARPOL, Annex VI) (International Maritime Organization [IMO] 2018) set standards for a global limit for sulphur in fuel oil used on board ships of 0.50 per cent m/m (mass by mass), to enter into force on 1 January 2020, representing a fuel-based standard. Compliance can be achieved by ships using low-sulphur compliant fuel oil. In contrast, a nitrogen oxide (NO_x) Emission Control Area (NECA), which will enter into force for the North Sea and the Baltic Sea from 1 January 2021, will require all vessels built after 2021 to comply with emissions standards aimed to reduce NO_x emissions by 80 per cent compared to present levels. Compliance can only be achieved in practice by equipping vessels with catalysts or using liquefied natural gas (LNG) fuels. Existing emission control areas for sulphur oxide (SO_x) cover the Baltic Sea (19 May 2006) and the North Sea (22 November 2007), and for SO_x and NO_x the North American east and west coasts (1 August 2012) and the US Caribbean Sea (1 January 2014).

The effectiveness of technology and emissions standards depends on the level of compliance, affordability and the extent to which the standards reflect the real-world impact of the emissions sources. The level of compliance, in turn, depends on the level of education, as well as monitoring and enforcement, among other factors. However, in countries or jurisdictions where the government has little capacity to enforce standards through inspections and audits, compliance with standards can be low. Even in countries where sophisticated inspections and audits are routine, some businesses and individuals may violate standards to gain a competitive economic advantage.



Cost–benefit analyses, such as that conducted by Åström *et al.* (2018), can provide an insight into the cost-effectiveness and the distributional effects of setting standards, for both *ex ante* and *ex post* evaluations.

Finally, the use of solid fuels, including biomass, in residential boilers is gaining more attention recently, as other key sectors have been regulated in the past decades. For example, the European Commission has established performance standards for solid-fuel space heaters with a nominal heat output of 50 kW or less, which have so far been mostly unregulated and may contribute to local air quality problems due to emissions of NO_x and particulate matter less than 2.5 µm (PM_{2.5}) (European Union 2015). Similarly, the EU Ecodesign-Directive (Directive 2009/125/EC) establishes a framework for setting ecodesign requirements for energy-related products, household appliances, and information and communications technologies.

The following case study illustrates the effectiveness of emissions standards through a type approval scheme through the example of the Euro 6 vehicle emissions standards, the difference between how compliance is measured and

real-world performance, and the efforts of some businesses to thwart compliance testing.

Case study: Excess diesel emissions in Europe

Since the 1970s, the key mechanism for regulating vehicle air pollutant emissions in Europe has been a regulatory/command and control policy that has progressively set increasingly stringent standards for emissions of air pollutants and GHGs (since 2009). A series of directives, known as Euro standards, define the acceptable limits for exhaust emissions of new road vehicles sold in the EU. The Euro standards, starting with the release of Euro 1, which entered into force in 1993, have since been amended regularly. The most recent Euro standard is Euro 6 for light passenger and commercial vehicles, which came into force in 2014 (Commission Regulation (EU) No 582/2011).

The aim of this policy is to contribute to reductions in actual or real-world emissions from road transport, an important source of GHG and air pollutant emissions. However, road transport enables people to access employment, education, goods and services. Manufacturers of road vehicles in the EU also contribute to the economy and employment. Hence, the policy aims to achieve a balance across these objectives.

Table 12.3: Summary of assessment criteria: Excess diesel emissions in Europe

Criterion	Assessment	Reference
Success or failure	The Euro standards have been successful in decreasing emissions of air pollutants and GHGs per unit of travel and decreasing measurable air pollution concentrations, especially close to roads. However, real-world reductions fall short of the potential reductions measured in laboratory testing.	EEA 2015; EEA 2016a; EEA 2016b; EEA 2017
Independence of evaluation	Independent evaluations of overall progress have been conducted.	
Key actors	Associations of car owners and vehicles manufacturers, NGOs etc. were highly involved. It was a long process with a high level of stakeholder involvement.	
Baseline	Quantitative baselines were established and updated with each amendment.	
Timeframe	Policies were implemented on time, but some intended targets were missed because of the inadequacy of the test cycle and wide-ranging exceptions enabling manufacturers to switch off emissions control technologies under certain ambient conditions.	
Constraining factors	Lobbying from industry has led to delays and weakening of the policy. In some cases, manufacturers have circumvented the standards designing cars to have lower emissions during testing than on the road.	Grice <i>et al.</i> 2009; Guerreiro <i>et al.</i> 2010, p. 3; Hotten 2015;
Enabling factors	The European regulatory and governance structure was key to enabling policy implementation. Some countries lacked the resources to independently verify emissions reported by manufacturers. The level of participation in policy development was high, leading to high levels of public approval.	
Cost-effectiveness	Costs and benefits, including impacts on health, agriculture and ecosystems, are considered carefully in the process of European policy development, aiming at high cost-effectiveness.	European Commission 2018
Equity	The impacts can be considered positive for everyone, but they particularly benefit people living close to roads, who may be economically disadvantaged.	
Co-benefits	The Euro standards set an example for the world. Industry is driven to innovate. Fuel efficiency increased, improving energy security and decreasing GHG emissions. Some national policies providing incentives to purchase diesel vehicles led to increases in NO ₂ emissions. Transport subsidies may offset the reduction of emissions.	Franco <i>et al.</i> 2014; European Commission 2015; EEA 2015
Transboundary effects	As the Euro standards progressively penetrated the international second-hand vehicle market, vehicle emissions were lowered in countries without similar regulations.	
Possible improvements	Reduce the margins of technical uncertainty in testing, eliminate test flexibilities, and increase emissions checks of cars in circulation.	



The main objective of the original European standards was the reduction of emissions of NO_x, carbon monoxide (CO), PM_{2.5} and volatile organic compounds (VOCs), as well as carbon dioxide (CO₂) and other pollutants, and subsequent amendments have implemented further limits. Furthermore, increasingly strict Euro standards require cleaner petrol and diesel fuels (the quality of which was regulated by Directive 2003/17/EC, e.g. low sulphur content), leading to, for example, lower PM emissions. These regulations have been driven primarily by air pollution effects on human health and—to a lesser extent—natural and semi-natural ecosystems, in addition to climate change. These increasingly stringent emissions standards have achieved positive results. They have led to the introduction of new vehicle technologies, which have achieved significant reductions in vehicle emissions over recent decades in Europe. For example, the latest standard (Euro 6) for diesel cars requires a reduction of almost 97 per cent of PM emissions compared to the Euro 1 standard for a 20-year-old vehicle.

The Euro standards have been successful in decreasing emissions of air pollutants and GHGs per unit of travel, as well as reducing overall transportation emissions even while transportation activity has increased (EEA 2015, pp. 25, 30, 32, 33, 37, 38, 46; EEA 2017, p. 19). They have also led to a measurable decrease in air pollution concentrations, especially close to roads (EEA 2016b, pp. 31, 43, 77–79, 82). However, these reductions fall short of the targets outlined in the policy, due to differences between real-world behaviour and emissions under laboratory testing conditions (EEA 2015, p. 46; EEA 2016a, pp. 27–37). These differences have increased considerably since 2000, especially for CO₂ and NO_x emissions in diesel cars, mainly due to:

- i. the test procedure, which did not reflect real-world driving conditions;
- ii. flexibilities in the procedures, which allowed manufacturers to achieve lower fuel consumption and emissions values during testing;
- iii. several in-use factors, such as driving style and environmental conditions; and
- iv. the use of 'defeat devices' designed to lower emissions measured during vehicle testing in the laboratory but not on the road.

Only after the diesel-gate scandal in 2015 (Hotten 2015) was there enough political awareness and will to change the laboratory test cycle to better reflect real-world emissions (European Union 2016).

In view of the shortcomings of the implemented standards, the test cycles were reviewed, and new and more reliable emissions tests in real driving conditions, as well as improved laboratory tests, were introduced for new car models sold in Europe in 2017. In addition, the European Commission presented a new proposal in 2018, aiming to reduce the margins of technical uncertainty in testing, eliminate test flexibilities and increase emissions checks of cars in circulation.

12.2.3 Market interventions

As a potential alternative to mandating lifestyle and technology choices, governments can also guide lifestyle and choices by creating economic incentives (e.g. subsidies, tax credits,

loans or price guarantees) or disincentives (e.g. fees or taxes) in existing markets or by creating new markets for rights or commodities that have not been traded (e.g. emissions reduction credits or renewable energy credits). All these types of market interventions have been used to some extent to mitigate air pollution, climate change, ODSs or PBTs.

In the DPSIR framework (Figure 1.2, Chapter 1), market interventions affect the 'drivers' of environmental issues, which in turn affect the 'pressures' and the environmental 'state'.

Although market interventions do not directly decrease emissions or ambient concentrations, they provide regulated individuals and businesses with flexibility and can create an incentive to improve performance and lower costs. Thus, a properly designed and adjusted market intervention may achieve emissions reductions more efficiently than 'command and control' approaches.

Markets are affected by many factors which are beyond government control. Therefore, market interventions must be adjusted periodically to reflect changing conditions. It is helpful if those adjustments can be made within the context of a planning regime (see section 11.3) so that progress towards a desired state can be evaluated and tracked.

In some cases, government interventions are needed to bring new technologies to a given market. Once the technology is introduced to the market and provided with a foothold, such as through initial subsidies or loans, it should be able to compete with other technologies without government assistance. The following case study explores how the Government of Kenya helped introduce clean cookstoves and fuels to reduce residential air pollution.

Case study: Improved cookstoves in Kenya

Household air pollution from the use of traditional fuel sources (wood, dung and charcoal) for cooking is a leading contributory factor to the global burden of disease (Lim *et al.* 2012; Cepeda *et al.* 2017; Landrigan 2017, see Section 5.2.4). A range of chronic illnesses such as cataracts, lung cancer and bronchitis are associated with smoke from cooking, with women and children most affected (Cepeda *et al.* 2017). Beyond this, black carbon (a household air pollutant) has been identified as the second most important anthropogenic emission that significantly affects the world's climate (Bond *et al.* 2013; Myhre *et al.* 2013).

The adverse effects of the dependence of the developing world on traditional renewable energy for cooking has necessitated the timely intervention by the Global Alliance for Clean Cookstoves (the Alliance), a public–private partnership geared towards the creation of a global market for improved, clean and efficient household cooking solutions in a bid to reduce the carbon footprint of highly polluting traditional stoves. The Alliance was launched in 2010 with an ambitious 10-year goal to foster the adoption of clean cookstoves and fuels in 100 million households by 2020. It partnered with NGOs, foundations, women's cooperatives, trade associations, academic institutions, investors and entrepreneurs to expand markets for clean cookstoves. Given the extensive use of unprocessed fuelwood in rural sub-Saharan Africa in particular, the Alliance is operational in a number of countries in this region, including Kenya, where 84 per cent of the population



use solid fuel for cooking and 16,500 deaths annually have been attributed to exposure to indoor air pollutants (Global Alliance for Clean Cookstoves 2012a).

Kenya's development, marketing and distribution of clean cookstoves is the most advanced in the sub-Saharan African region, having emerged in the 1980s led by development of the Kenyan Ceramic Jiko (United States Agency for International Development and Winrock International 2011). Yet by 2007, the penetration rate in the Kenyan market for cookstoves was approximately 36 per cent, and adoption in rural areas was quite low. Since then the Alliance has made notable inroads in the Kenyan cookstoves market through its partnership with the Clean Cookstoves Association of Kenya (CCAK) to encourage government officials to adopt market incentives—for example, abolishing or minimizing taxes and tariffs that impede the growth of the clean cooking sector. A notable accomplishment was the reduction in the import duty on efficient cookstoves from 25 per cent to 10 per cent by the Kenyan Government in 2016. The Alliance has also provided grants to boost brand-

building and marketing efforts and has supported two women-owned businesses through its Women's Empowerment Fund.

Carbon financing for clean cookstoves has not only been beneficial to Kenyans but has also enabled international companies to achieve their emissions reduction goals through carbon trading, which allows for carbon credits to be used to comply with emissions reduction obligations under cap-and-trade schemes or for voluntary reduction schemes (Lambe *et al.* 2015).

An evaluation of six types of biomass stove highlighted the need to address key factors that contribute to reducing emissions—namely: the cookstove design and performance; other potential sources of emissions; the availability and cost of cookstoves; ventilation; and the strategies to ensure the adoption and use of clean cookstoves (Pilishvili *et al.* 2016). The results of the evaluation showed that the biomass stoves did reduce emissions compared with the three-stone traditional stove baseline. However, the reduction in emissions did not reach thresholds where public health benefits could be maximized.

Table 12.4: Summary of assessment criteria: Improved cookstoves in Kenya

Criterion	Description	Reference
Success or failure	Approximately 37 per cent (3.5 million) households use improved biomass cookstoves (ICSs), while over 50 per cent (approximately 5 million) households still use traditional biomass cookstoves. Between 240,000 and 300,000 ICSs are sold to new customers annually. The Kenyan Government aims to achieve 50 per cent of abatement potential (i.e. approx. 2.6 MtCO ₂ e) by 2030.	Kenya, Ministry of Energy and Petroleum and Sustainable Energy for All 2016; Kenya, Ministry of Environment and Natural Resources 2017
Independence of evaluation	Green Climate Fund, a UNFCCC funding mechanism.	
Key actors	Over 80 per cent of the market share for biomass ICSs is dominated by artisanal fabricated stoves.	Green Climate Fund 2018
Baseline	The project started in 2010, and by April 2016 the Global Alliance for Clean Cookstoves project had sold approximately 251,000 cookstoves across Kenya.	Natural Capital Partners 2018
Timeframe	GHG emissions mitigation objective of 30 per cent by 2030 in relation to the business-as-usual (BAU) scenario of 143 MtCO ₂ e. Of this, ICS interventions are considered to have an abatement potential in 2030 of 5.6 Mt CO ₂ e.	Global Alliance for Clean Cookstoves 2014; Green Climate Fund 2018
Constraining factors	Underdeveloped ICS supply chain; communities that collect wood for free; costs and risks associated with investment to cover remote rural areas; weak consumer awareness; regulatory constraints (i.e. import duties, taxes and poorly targeted subsidies); limited product testing capacity to enforce standards; and insufficient investment into product improvement.	Global Alliance for Clean Cookstoves 2012b; Green Climate Fund 2018
Enabling factors	Kenya removed the 16 per cent value added tax (VAT) on LPG, reduced the import duty on efficient cookstoves from 25 per cent to 10 per cent, and placed a zero-rating VAT on improved cookstoves, raw materials and their accessories.	Global Alliance for Clean Cookstoves 2016
Cost-effectiveness	Design of cookstoves does not offer the full benefit of fuel savings and reduced emissions and high quality cookstoves are not easily distinguished from their competitors.	
Equity	Households in the poorest quintile, women in younger age groups and people living in remote areas are less likely to adopt and install improved cookstoves.	Silk <i>et al.</i> 2012; Kapfudzaruwa, Fay and Hart 2017
Co-benefits	Livelihood improvements, social impacts (including gender), reductions in co-pollutants (ozone damage to crops), among others.	
Transboundary effects	Lessons learned can be applied to other sub-Saharan African countries.	
Possible improvements	Customer segmentation studies are needed to understand customer needs and tailor financial products for purchasers. Existing non-cookstove distribution and wholesale networks need to be used to improve consumer access and affordability.	(Global Alliance for Clean Cookstoves 2013; Kenya, Ministry of Energy and Petroleum 2015)



Overall the clean cookstove market in Kenya shows promise, but there is a strong need for policy intervention in rural areas to scale up the adoption and use of cookstoves. Human health could be better integrated within this policy in the future by clearly delineating the health indicators of local and global significance that need to be monitored periodically to effectively track progress in health benefits spatially and temporally.

12.2.4 Information policies

In addition to using regulatory mandates and market incentives, governments can, at times, aim to support a change in lifestyle to either reduce emissions or exposure to harmful levels of air pollution by providing the public with better information. This goes in line with an improved understanding of the hazards and risks of exposure to air pollution in recent years (Kelly and Fussel 2015), although the importance of public education for air pollution control was raised more than 50 years ago by Auerbach and Flieger (1967). One example of such an approach is the provision of near real-time air quality observations and forecasts. The posting of near real-time air quality data online is increasingly common in many nations and major cities around the world. Some locations also provide air quality forecasts, predicting air quality levels for one or more days into the future. This information is often further circulated via other websites, social media, smart phone apps, newspapers, local radio and television. These dynamic media may be complemented by educational posters and pamphlets. The objective of providing such information is to encourage citizens to change their lifestyle to:

- decrease their exposure to pollution and, consequently, lower the risk of adverse health effects (e.g. by avoiding exercise outdoors during peak concentrations, or for especially vulnerable individuals to stay indoors); and
- decrease their emissions (e.g. commute via public transportation instead of personal transport or curtail use of wood fires or other biomass burning during forecast pollution episodes).

Air quality forecasts and real-time values may be used to complement other air pollution control policies. For example, some localities in the United States impose wood-burning restrictions when a pollution episode alert has been issued, while in Europe several large cities, such as Paris, have issued restrictions for private car use during high pollutant concentration episodes in recent years. For the severest of episodes, governments may shutdown factories and other non-essential activities. In China, several cities impose a ban on trucks and other high emission vehicles during the day to manage air quality.

Other examples of providing information to guide behaviour are labelling and branding. In this context, labelling refers to providing information on a product about its environmental impacts, such as its relative emissions or energy consumption, to inform consumers' choices. Such labels may be required by government regulations (e.g. emissions and fuel economy estimates are required on the labels for new cars in the United States) or may be voluntarily provided by the manufacturer. Branding, in this context, involves associating a logo or symbol with a product or service that indicates to consumers that the

product or service has met some set criteria for environmental performance (e.g. Energy Star). Such brands have been established by governments, industry associations or public advocacy groups as voluntary programmes, and often involve independent testing.

These approaches need to reach a threshold level of awareness and recognition across their target populations before they can have much effect on environmental pressures (consumption and other emissions-generating behaviour) and impacts (exposure-related behaviour). However, once the threshold is reached, citizens and consumers may begin to expect and demand such information. Moreover, increasing awareness of the sources and impacts of pollution may increase public demand for cleaner air, lower emitting products and services, and more stringent policies.

Access to information also promotes innovation. In the past, most of the information on ambient air quality originated from regulatory bodies. With the curiosity of the public to know more about the ambient air quality and its linkages to human health, there is now a new market of non-regulatory air quality monitors, which are providing the same information as the regulatory monitors at lower cost. While the data quality produced by (often referred to as low-cost) air quality sensors for crowdsourcing of air quality information is at times questionable (Lewis and Edwards 2016; Thompson 2016), the empowerment of citizens to take ownership of environmental data should not be underestimated (see Section 25.2). This serves society with information and lets the public make informed decisions on when to go out, when to spend more time outdoors etc., and is further supported by activities to make air quality information openly available and easily accessible—for instance, through the OpenAQ initiative (<https://openaq.org>), which aims to “enable previously impossible science, impact policy and empower the public to fight air pollution through open data, open-source tools, and cooperation”.

The need for more information has led to the establishment of private organizations as well as regulatory agencies taking charge of experimenting with novel ways to generate information most suitable for consumption. Experimentation is feasible to expand, and there is room for the regulatory bodies to step in and endorse the emerging technologies for further expansion.

With the wide use of smart phones and open applications, this information is now serving everyone with access to a phone, in addition to traditional dissemination channels. Due to the wide spread use of mobile applications, citizens' awareness of and access to information is increasing rapidly. As a consequence, the public has generated a demand for change. The availability of targeted information can further empower individuals to be prepared and manage health risks in response to environmental hazards, illustrated, for example, by the Know and Respond information system in Scotland, or the United Kingdom of Great Britain and Northern Ireland-wide air pollution forecast provided by the UK, Department for Environment, Food and Rural Affairs (2018). Know and Respond is a free service to subscribers in Scotland that sends registered users an alert message if air pollution in their area is forecast to be moderate, high or very high (Air Quality in Scotland 2018).



Case study: AirNow, real-time air quality data and forecasts

In 1995, the American Lung Association of Maryland, a non-governmental advocacy group, began to create a daily map of ozone observations from the monitors operated by the State of Maryland (state and local governments are responsible for operating air quality monitoring stations in the United States). In 1997, the daily ozone maps were expanded to 14 north-eastern states. In 1998, the USEPA took over the operation of the central data system, added seven more states and named the system AirNow (<http://airnow.gov/>).

Over the next 10 years, AirNow grew as more states and local agencies contributed their data. By 2008, agencies in all 50 US states, 4 Canadian provinces and the national government, and 2 Mexican states were submitting data. Over time, the data system and product delivery were improved incrementally, experimenting with new products and services. In 2009, the system architecture and software tools were overhauled to allow the software to be implemented in different settings. The new software, branded AirNow-International, was deployed in Shanghai, China, for the 2010 World Expo, and in Monterrey, Mexico in 2012.

AirNow currently gathers and distributes observations and forecasts from more than 130 federal, state and local agencies.

Data for the United States is provided to the public and the media using the Air Quality Index (AQI), a colour-coded and numerical scale based on the US National Ambient Air Quality Standards. An applications programming interface (API) has opened the data system to smart phone applications, which have proliferated. AirNow-International has increased its scope geographically, and the US Department of State has begun providing air quality observations from selected US embassies and consulates around the world.

As an information policy, the US EPA AirNow programme provides a low-cost but high-benefit example. By building on existing structures, such as monitoring networks and state or local air quality agencies, the programme leverages infrastructure in a new way. The primary benefit of this information policy comes by helping individuals reduce or avoid exposure to high levels of pollution. Timely information encourages citizens to take mitigative actions to reduce their contributions to pollution. In addition, the provision of information creates an awareness of air pollution, a demand for cleaner air and greater acceptance of other regulatory and market policies to decrease pollution. While no formal evaluation of the programme exists, various studies show that air quality information has an impact on awareness and lifestyle.

Table 12.5: Summary of assessment criteria: AirNow, real-time air quality data and forecasts

Criterion	Assessment	Reference
Success or failure	Studies have demonstrated increased awareness due to alerts, but changes in lifestyle (e.g. decreased driving, energy consumption) are more difficult to quantify.	Blanken, Dillon and Wismann 2001; Henry and Gordon 2003; Mansfield and Corey 2003; Kansas Department of Health and Environment 2006; Mansfield, Johnson and von Houtven 2006; McDermott, Srivastava and Croskell 2006; Semenza <i>et al.</i> 2008; Mansfield, Sinha and Henrion 2009; Neidell 2008
Independence of evaluation	Various studies.	
Key actors	National, state/provincial and local governments.	
Baseline	Depends on the location.	
Timeframe	Between 1995 and 2008, the system evolved from an effort by one state to a system involving agencies in all 50 US states, 4 Canadian provinces and the national government, and 2 Mexican states. Currently, more than 130 federal, state and local agencies are participating.	
Constraining factors	Air quality information can generate anxiety about potential health effects and may encourage some people to seek unnecessary medical attention. Moreover, once information is made freely available, a variety of uses may be devised that were not envisioned when the system was created. Policies and attitudes about data transparency and openness can be important constraints.	
Enabling factors	A prerequisite is an effective air quality monitoring infrastructure and data collection and dissemination programme.	
Cost-effectiveness	Additional costs of the data management and dissemination are small compared to the costs of the monitoring activity and the value of the media coverage.	
Equity	Access to air quality information is not uniform. People who are poorly educated or without access to the Internet may be excluded.	
Co-benefits	Creates a greater demand for air quality and improves acceptance of air quality management policies.	
Transboundary effects	The programme is expanding internationally under the auspices of the Group on Earth Observations.	
Possible improvements	As access to various types of information increases, expectations for access to air quality information also rise.	



12.2.5 International cooperation

No one can live without air, and its quality is indispensable. However, 90 per cent of the global population is now forced to live with unhealthy air, particularly in Asia and Africa (WHO 2018). Air pollution and PBTs are of particular concern, as they travel locally, internationally, regionally and globally. International cooperation plays an important role when air pollution crosses borders or needs to be addressed across borders.

International cooperation can take many forms, ranging from formal to informal, bilateral to multilateral diplomacy. Governments are one of the key actors to align their actions—negotiating and concluding multilateral environmental agreements (MEAs) in a tangled web of national interests, providing international aid, conducting capacity-building/technical assistance under or beyond the agreement, monitoring and modelling air pollution to improve scientific knowledge with help from a community of experts, sharing information with the public, raising awareness and engaging in voluntary efforts for further cooperation to reduce air pollution. Formal training, technology demonstration, and cooperative research and assessment activities provide more effective knowledge-sharing and capacity-building opportunities. These activities may have the most significant long-term influence on environmental outcomes, but their immediate impact is difficult to quantify. Local governments are important actors to implement national environmental policies. Cooperation from business and industry is crucial to increase the effectiveness of the policies. Considerable progress on policy cooperation, emissions control and reporting, and ecosystem recovery has been achieved under the eight legally binding CLRTAP Protocols. The application of the effects-oriented critical load concept with regional cost minimization of science-based mitigation measures, technical as well as structural, has offered a sophisticated but successful way forward for participating countries.

A relatively recent approach to international cooperation on air-related issues has been the development of public-private initiatives, such as the Partnership for Clean Fuels and Vehicles, the Global Alliance for Clean Cookstoves (see Section 12.2.3), the Global Research Alliance on Agricultural Greenhouse Gases, and the Climate and Clean Air Coalition for the Reduction of Short-Lived Climate Pollutants (CCAC). These initiatives bring together interested national governments, intergovernmental organizations, private-sector companies, civil society organizations and philanthropic foundations to advance specific pollution mitigation efforts. For example, CCAC was founded in 2012 by the United Nations Environment Programme (UNEP) and the governments of Bangladesh, Canada, Ghana, Mexico, Sweden and the United States, to catalyse action to decrease emissions of black carbon, methane and hydrofluorocarbons. CCAC now has more than 100 state and non-state partner organizations participating in 11 different initiatives. This could contribute to cleaner fuels and technologies in the homes of 3 billion vulnerable people suffering from household air pollution (Apte and Salvi *et al.* 2016).

International financial institutions such as the World Bank, the Asian Development Bank, the African Development Bank, the Global Environmental Facility and the Green Climate Fund play major roles in project funding. Financial assistance and cooperative implementation of control measures can have a clear and demonstrable effect on decreasing emissions in the short term, but the long-term impacts may be much larger if the control measures are replicated.

Regional organizations can function in two ways. One, like the EU, is taking the leading role in negotiations as a global actor and an increasing role in environmental politics, while the other, like the Association of South East Asian Nations (ASEAN), is to function as an international forum. Both provide opportunities to set regional agendas, learn new knowledge and perspectives, share information and discuss common issues. Treaty secretariats could influence the negotiation process among States under the accords. Like-minded groups, alliances and friends of the Chairs could also lead, mediate or slow down negotiations. Some of these cooperation processes could also be activated by environmental NGOs, green parties and citizens as well as international organizations such as WHO, the World Meteorological Organization (WMO), the Organisation for Economic Co-operation and Development (OECD), the International Energy Agency (IEA), the International Maritime Organization (IMO), the International Civil Aviation Organization (ICAO) and UNEP, helping to set the environmental agenda, framing environmental issues or providing resources for international cooperation.

As introduced in Section 5.5, global MEAs which have linkages to air pollution are those targeting climate change (UNFCCC), stratospheric ozone depletion (Vienna Convention and Montreal Protocol), mercury (Minamata Convention) and persistent organic pollutants (Stockholm Convention). Although there is no global convention on air pollution, several regional MEAs and bilateral agreements exist. One of the oldest regional MEAs is the 1979 CLRTAP negotiated under UNECE. Considerable progress on policy cooperation, monitoring and modelling, emissions control and reporting, and ecosystems recovery has been achieved under the eight legally binding CLRTAP Protocols.

It is difficult to evaluate the impact of international agreements. Compliance with legal commitments can be evaluated, but it is not always clear that emission decreases that occur are a result of an international agreement or if they would have occurred in the absence of the agreement. Furthermore, perfect compliance may be an indication of unambitious targets that require little more than business as usual efforts.

None of the MEAs identified above have an effective international enforcement mechanism. Depending on a country's own laws, a national government may be taken to court in its own country for not abiding by its international treaties. However, this kind of action is rare, and ensuring compliance with international commitments mostly relies on diplomatic or peer pressure.

The following case study explores the progress made under the regional agreement on transboundary haze negotiated under ASEAN in 2002. This case provides valuable lessons on the challenges of international cooperation.



Case study: ASEAN Agreement on Transboundary Haze Pollution

Haze or smoke-haze as used in Southeast Asia is synonymous with air pollution from land and forest fires and agriculture-waste burning from rural populations. Transboundary haze pollution refers to haze pollution whose physical origin is situation wholly or in part within an area under the national jurisdiction of one country and which is transported into

the area under the jurisdiction of another country (ASEAN Agreement on Transboundary Haze Pollution). The worst haze episodes occur in years affected simultaneously by the climatological anomalies of *El Niño*—Southern Oscillation and Indian Ocean Dipole. The most recent severe haze event in 2015 was caused in part by the dryness triggered by both anomalies in the region, particularly on the Indonesian islands of Sumatra and Kalimantan (Koplitz *et al.* 2016).

Table 12.6: Summary of assessment criteria: ASEAN Agreement on Transboundary Haze Pollution

Criterion	Description	References
Success or failure	Mixed view on effectiveness and achievement of goals.	
Independence of evaluation	No consensus in evaluations	
Key actors	Governments, the ASEAN Secretariat and its agencies, NGOs, foreign governments, industries and international/regional organizations.	
Baseline	The Agreement does not provide a specific baseline.	
Timeframe	The Agreement is expected to remain in force perpetually with the active participation of all ASEAN member states, with the goal of achieving a haze-free ASEAN by 2020.	Haze Action Online 2018
Constraining factors	Logging and clearing land by burning creates employment for less fortunate people due to limited employment in other sectors. Oil palm and pulpwood industries have thus largely flourished under weak law enforcement by local authorities. Once cleared to make room for plantations, peat forests tend to smoulder underground for weeks even after surface fires are fully extinguished.	
Enabling factors	Singapore collaborated with Jambi in Indonesia between 2007 and 2011 to implement action programmes to prevent and mitigate land and forest fires. Malaysia cooperated with an NGO, the Global Environmental Centre, to reduce the risks associated with peatland fires. The 2005 cloud-seeding project in Riau and West Kalimantan conducted by Indonesia, Malaysia and Singapore indicated cooperation. An environmental partnership between Singapore and Indonesia from 2009 to 2011 enables fire management and extinction in Riau. The institutional arrangements and collaboration have been key enabling factors, as was the willingness of the Parties to commence action even prior to Indonesia's ratification. Programmes to improve peatland management and control haze pollution have been welcomed by member states.	Haze Action Online 2017
Cost-effectiveness	The cost of 2010–2014 ASEAN Peatland Forests Project was US\$5.9million. The project successfully scaled up the management and rehabilitation of critical sites in Philippines and Viet Nam. An estimate of the cost to control Indonesian haze is put at US\$5.7 billion, and another to address forest fires is US\$1.2 billion, but this does not include losses from peatland burning, which the World Bank puts at US\$16 billion for the 2015 fires alone.	World Bank 2016; Nazeer and Furuoka 2017; Hans 2018
Equity	Haze contributes to respiration difficulties and other haze-related illness, particularly in children and in poor people.	Malaysian Nature Society Science and Conservation Unit 1997; Gordon, Mackay and Rehfuess 2004
Co-benefits	Associated impacts from haze include CO ₂ emissions, losses of wildlife and potential benefits from nature preservation and biodiversity; impacts are linked to the Sustainable Development Goals such as goals 3, 11 and 12. The ASEAN peatland management strategy and the SEA peat project include contributions to climate change mitigation (2006–2020). The Agreement is relevant to the achievement of national air quality targets. E.g., in Singapore, where targets for 2020 have been adopted, effective management of peatlands and the control of haze pollution in neighbouring countries have a direct impact on the quality of air.	Asia Pacific Clean Air Partnership [APCAP] 2015, p. 2; World Wide Fund for Nature [WWF] 2018
Transboundary effects	Smoke from wildfires and burning agricultural waste travels to and adversely affects other countries.	
Possible improvements	Development of a zero-burning policy, accomplishment of ASEAN Community Vision 2025, and raising political will for further cooperation; could gain potential benefit through collaboration with other initiatives such as the Acid Deposition Monitoring Network in East Asia, the Climate and Clean Air Coalition and the Asian Co-benefits Partnership.	



Haze is a health issue, worsening existing heart and lung conditions (WHO 2016). It caused acute respiratory infections in over 500,000 people and 19 deaths in 2015. The economic cost was estimated at US\$16 billion, affecting the transportation (US\$372 million), tourism (US\$399 million), trade (US\$1.3 billion), manufacturing and mining, and mass education sectors (World Bank 2016, pp. 1–2, 4–8). Emissions from burning peatlands contained 90 gases with high levels of toxicity from formaldehyde, acrolein, benzene, carbon monoxide and nitrogen dioxide (Stockwell *et al.* 2016).

The first severe haze episode in 1997-1998 called for regional action. Following the Asian Development Bank's major damage assessment (Qadri *ed.* 2001), the ASEAN Agreement on Transboundary Haze Pollution was adopted in 2002 and entered into force in 2003 (Haze Action Online 2018; UNEP 2010).

The Agreement attempts to change the governance arrangements towards an ASEAN haze-free region by preventing and monitoring transboundary haze pollution as a result of land/forest fires mitigated through concerted national efforts and intensified regional and international cooperation. (ASEAN Agreement on Transboundary Haze Pollution). The ASEAN Specialised Meteorological Centre has been mandated as the regional centre to monitor and assess the weather and smoke haze situation and provide early warning on the occurrence of transboundary haze. Malaysian Meteorological Department provides information on fire risk through a Fire Danger Rating System. National Monitoring Centres are designated within each country to monitor the fire and haze situation locally (Velasco and Rastan 2015).

There are mixed views on the effectiveness of the Agreement in achieving its goals. In 2003, it became the first regional environmental agreement under ASEAN to enter into force, but not all ASEAN countries ratified the agreement until 2014. Some international cooperative activities and national policies were initiated following entry into force, but major haze events have continued to occur, with notable episodes in 2013 and 2015. Like many MEAs, the Agreement has no sanctions clause on failure to meet stipulated obligations.

Some progress has been observed since 2015. Brunei has developed its own transboundary haze forecasting system.

Singapore has enacted a law to enhance the country's ability to deal with transboundary haze by holding companies accountable for haze pollution in Singapore due to activity which had occurred within or outside of Singapore. Indonesia implemented regulations to protect primary forests and peatland, building on a moratorium on new concessions started in 2011. This policy is expected to avoid 7.8 Gt of CO₂ emissions by 2030 (Republic of Indonesia 2015, pp. 5–6).

Activities under the Agreement can also support other cooperation in the region, not least the coordination of monitoring networks, such as through the Asia Pacific Clean Air Partnership (APCAP). APCAP brings together the ASEAN Haze Agreement, the Malé Declaration, the East Asia Network for Acid Deposition and the Atmospheric Brown Cloud initiatives.

12.3 Indicators

As discussed in Chapter 5, atmospheric change (including air pollution, climate change, stratospheric ozone depletion and PBT pollution) is directly or indirectly related to each of the SDGs (see Figure 5.2). These issues are also addressed by a collection of global and regional MEAs, as well as policies at the national, provincial and municipal level. To evaluate the effectiveness or sufficiency of any given policy or suite of policies, it is useful to have measurable indicators. Ideally, such indicators should be sensitive to the policy changes of interest but not confounded by other influences. However, the indicator should also be relatable to impacts of the policy change that society values. These two objectives point to either end of the DPSIR framework (Figure 1.2) used in the preceding chapters, suggesting that selecting one best indicator is often a compromise. The compromise might be different if the intent is to evaluate the effectiveness of a specific policy (such as in the case studies above) versus the sufficiency of a suite of policies (including policies at different geographical scales).

This section describes three indicators of atmospheric change that are intended to track progress towards the SDGs and compare the sufficiency of existing policies at the national scale. The indicators chosen focus on air pollution, stratospheric ozone depletion and climate change. The data available for emissions and concentrations of PBTs are not sufficient for evaluating the effectiveness of policies globally or at the national level.

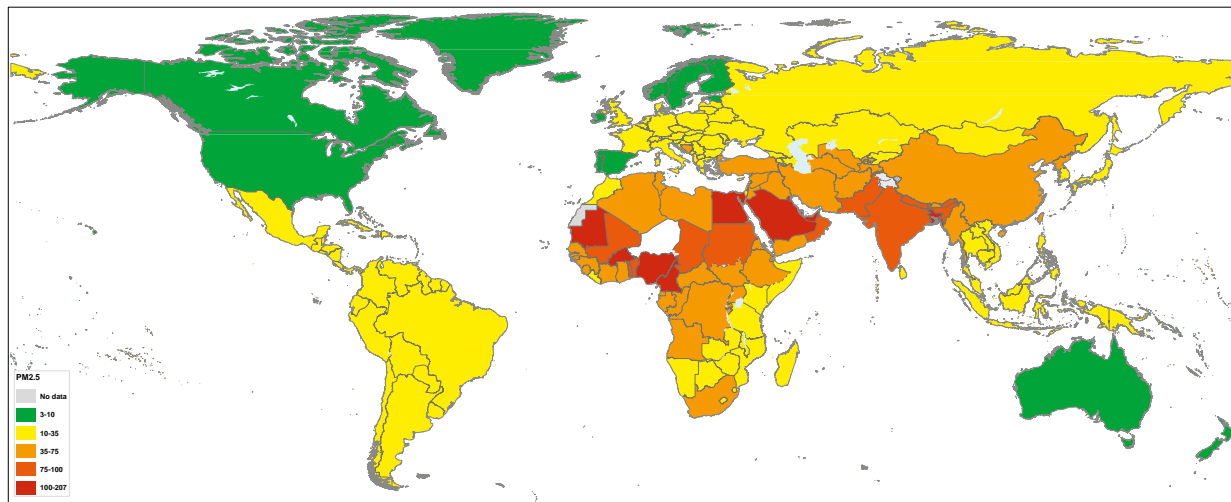


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12.3.1 Indicator 1: Population-weighted annual mean concentration of PM_{2.5}

Figure 12.2: Population-weighted annual country-wide mean concentration of PM_{2.5} in 2016



This map combines data from satellite observations, surface monitors and an atmospheric chemistry and transport model.

Source: Adapted from Health Effects Institute (2017); Shaddick *et al.* (2018).

Policy relevance/causal chain

PM_{2.5} concentrations are state variables that are driven by emissions of pollutants, but also by meteorology and climate. PM_{2.5} is directly emitted but also formed in the atmosphere from emissions of precursor gases. Policies impact PM_{2.5} concentrations by changing emissions and, over the long term, climate. PM_{2.5} concentrations are related to exposures and impacts on human health, ecosystems, visibility and short-term climate forcing.

Ambient PM_{2.5} concentrations can be monitored at surface locations and also estimated from observations from satellite-based instruments. The best characterization of the distribution of PM_{2.5} concentrations is developed by combining information from surface observations, satellite observations and computer models. The resulting concentration field can be combined with the population distribution to estimate the population-weighted annual average.

Exposure to PM_{2.5} concentrations leads to a variety of human health impacts, including premature mortality. Weighting the average concentration by population distribution creates an indicator that is focused on the concentrations to which people are exposed.

Emissions of PM_{2.5} and its precursors come from a wide variety of anthropogenic sources, including electricity generation, transportation, residential combustion, industrial processes and agricultural burning. These sources can be managed using a wide variety of policy approaches.

Other factors

PM_{2.5} concentrations are also affected by weather, wildfires, windblown dust and volcanoes. Weather is subject to significant inter-annual variability, decadal cycles and long-term trends. The contributions of wildfires, windblown dust and volcanoes also vary from year to year. These influences must be accounted for when attributing observed trends to the impact of control policies.

Observed trends can be quantitatively apportioned to changes in anthropogenic emissions, natural emissions and weather, using computer models of atmospheric chemistry and dynamics. However, the uncertainty in model estimates can be as large as the impact of a change in policy.

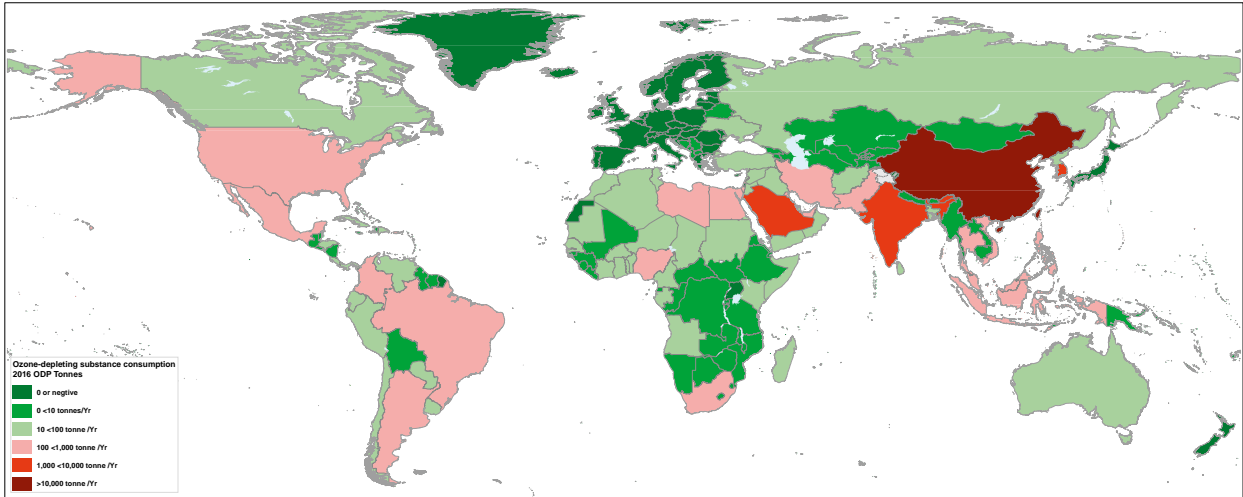
Possible alternatives

PM_{2.5} concentrations are well-accepted metrics for air pollution. WHO has established a guideline value and interim targets for maximum annual average PM_{2.5} concentrations. Under the SDGs, the population-weighted annual mean level of PM_{2.5} or PM₁₀ was selected as an indicator of progress towards sustainable cities. Weighting concentrations by the population exposed focuses the metric on the overall impact on the population. However, a population weighted average may mask the number of people exposed to the most extreme air pollution levels. Thus, absolute concentrations provide another alternative metric.

Direct emissions of PM_{2.5} and its gaseous precursors (including SO₂, NO_x and NH₃) are alternative indicators. Emissions are more directly affected by policy changes, but more distantly related to health impacts. For many sources, measurement of emissions is impractical, and estimates are highly uncertain.



Figure 12.3: Ozone-depleting substance consumption in ozone depletion tons in 2016



Source: UNEP (2017)

Policy relevance/causal chain

The manufacture and use of ODSs lead to emissions that affect the concentration of ozone in the stratosphere and, as a result, the level of ultraviolet (UV) radiation reaching the Earth's surface. Increases in UV exposure adversely affect human health and ecosystems. ODSs vary in the extent to which they deplete stratospheric ozone. The effectiveness of policies to limit the manufacture and use of ODSs can be measured using ODS emissions estimates weighted by the ozone-depleting potential (ODP) of each compound (2014). ODP-weighted ODS emissions are reported to the Secretariat of the Vienna Convention and Montreal Protocol.

Other factors

ODS emissions are directly linked to the effectiveness of policies to eliminate their manufacture, use and improper disposal.

The relationship between ODS emissions, stratospheric ozone concentrations, UV exposures and health effects can

be estimated using models which account for atmospheric chemistry and dynamics, exposure behaviours and population characteristics. These model estimates can be evaluated by comparing them to observed ozone concentrations, UV levels and disease incidence rates.

Possible alternatives

Other metrics have been used to gauge the success of efforts to protect stratospheric ozone, including the minimum observed stratospheric ozone concentration, changes in UV radiation levels and the spatial extent of the Antarctic ozone 'hole'. These metrics are influenced by ODS policies over the long term, but also by inter-annual variability, decadal climate cycles and long-term climate change.

ODS emissions could be compared on a per capita or per gross domestic product (GDP) basis, each of which implies a different assumption about what constitutes an equitable distribution of the burden of additional controls.

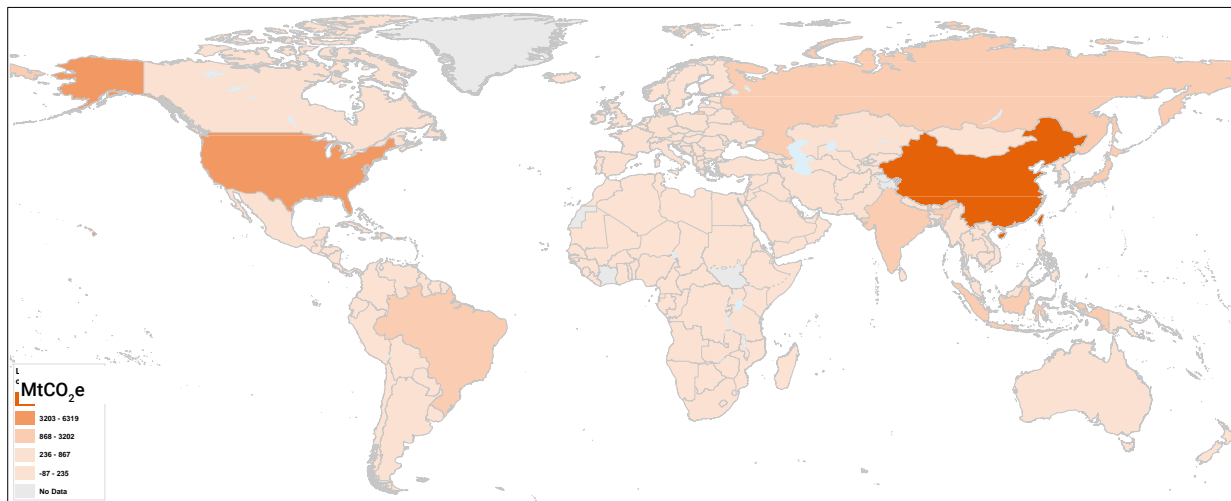


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12.3.3 Indicator 3: Anthropogenic emissions of long-lived greenhouse gases (CO₂ equivalents)

Figure 12.4: National total GHG emissions in 2014 in MtCO₂e, including land-use change and forestry sources and sinks



Source: World Resources Institute (2017). Climate Analysis Indicators Tool: WRI's Climate Data Explorer. Washington, DC: World Resources Institute. Available at <http://cait.wri.org/historical/>. Note these are derived from several sources including Food and Agriculture Organization of the United Nations [FAO] 2016; IEA 2016; UNFCCC 2017b).

Policy relevance/causal chain

Long-term climate change is primarily driven by emissions of GHGs, including CO₂, methane (CH₄), nitrous oxide (N₂O) and fluorinated gases. The contribution of each of these pollutants to climate change can be compared in terms of CO₂ equivalents using the Global Warming Potential (GWP) index, which accounts for the pollutants' different atmospheric lifetimes. GWPs are calculated for a specific time-horizon, with 100 years being the most common for comparing the impact of long-lived GHGs.

Anthropogenic emissions of GHGs come from a wide range of sources but are primarily associated with the production and consumption of energy, land-use change and deforestation. Different types of policies can directly or indirectly affect energy production and consumption behaviours and technologies and thus the generation of GHG emissions. Anthropogenic emissions are quantified and reported at the national level to the UNFCCC and provide an aggregate indicator of the effectiveness of policies. Annual emissions data from 1990 to the present are available from the UNFCCC for industrialized countries or economies in transition (called Annex I Parties under the Convention). Under the Paris Agreement, all countries are required to submit emissions inventories every two years.

Other factors

In addition to policies, anthropogenic GHG emissions are also affected by economic, social and technological trends. GHG emissions are also generated by natural sources. Both natural and anthropogenic sources are affected by natural meteorological and climate variability.

The relationship between GHG emissions, radiative forcing, changes in climate and climate variability and downstream impacts on human health, ecosystems and infrastructure can be estimated using Earth system models that must account for a significant number of processes and feedbacks.

GHG emission estimates can be compared to observations of GHG concentrations from *in situ* measurements and satellite-borne instruments, although it can be difficult to attribute small changes in specific anthropogenic sources to changes in the observed distribution.

Possible alternatives

GWP-weighted long-lived GHG emissions are well-accepted metrics of climate policy effectiveness under the UNFCCC.

There are long lag times between changes in emissions and changes in atmospheric concentrations, radiative forcing or climate state variables (temperatures, precipitation etc.), which make these state variables less useful for assessing policy effectiveness.

Emissions of short-lived climate pollutants (such as black carbon and hydrofluorocarbons) could be included in the aggregation, and other indices (such as a Global Temperature Potential (GTP) or a GWP over a 20-year horizon) could be used to weight the contribution of different pollutants.

GHG emissions could be compared on a per capita or per GDP basis, each of which implies a different assumption about what constitutes an equitable distribution of the burden of additional controls.

12.4 Discussion and conclusions

A wide variety of policy approaches, including but not limited to planning regimes, emissions and technology standards, market interventions, public information and international cooperation, have been applied to the problems of air pollution, climate change, ODSs and PBTs. Lessons can be learned about each type of policy approach from applications to the four different problems at different geographical scales.

One lesson is that policy approaches must be adapted to specific contexts. There is no single model policy that is most appropriate for all settings. High-income countries rely on information-rich planning regimes and regulatory approaches backed by government enforcement capacity. These approaches may not be the most appropriate for settings where information is poor and enforcement capacity is lacking. In such settings, voluntary standards, market

interventions and public information may prove more effective in decreasing emissions and hazardous exposures. To improve the effectiveness of such attempts to strengthen climate finance and reduce air pollution, development assistance will play a crucial role in capacity-building and green economy development. Capacity-building should focus on strengthening the technical and planning capabilities at local and national levels that are most relevant for anticipating the potential impacts of climate change and developing appropriate policy responses. Air quality measures need to be combined with climate and energy measures, agricultural policy, transport policy and urban planning, with a focus on improving health and biodiversity. A key message and challenge is how to ensure that climate policies do not increase health risks (e.g. from biomass burning and diesel) and that air quality policy is climate neutral. Also, it is imperative to consolidate a multi-scale governance approach that aligns international, national and local actions (Maas and Grennfelt eds. 2016).





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