

Report

European experience in the development of the monitoring, review, and verification (MRV) systems for clean air plans

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Table of contents

Abstract.....	4
About the authors	5
Glossary	6
1 Introduction	8
1.1 Background	8
1.2 Contents of this report	8
2 The EU air quality policy framework.....	9
3 The Ambient Air Quality Directive (AAQD).....	11
3.1 Concept.....	11
3.2 Key obligations.....	12
3.2.1 Monitoring	12
3.3 Experience.....	15
4 The National Emission Ceilings (NEC) Directive.....	20
4.1 Concept.....	20
4.2 Key obligations.....	20
4.2.1 Monitoring	20
4.2.2 Reporting	21
4.2.3 Verification	24
4.2.4 Enforcement	26
4.3 Experience.....	27
4.3.1 Monitoring	27
4.3.2 Reporting.....	28
4.3.3 Enforcement	28
5 Source-specific emission legislation	30
5.1 The Industrial Emissions Directive (IED)	30
5.1.1 Concept	30
5.1.2 Key obligations.....	31
5.1.3 Experience	33
5.2 The Medium Combustion Plant Directive (MCPD).....	35
5.2.1 Concept	35
5.2.2 Key obligations.....	35
5.2.3 Experience	36
5.3 The Ecodesign directive	36
5.3.1 Concept	36
5.3.2 Key obligations.....	37
5.3.3. Experience	38
5.4 Performance standards for mobile sources	38
5.4.1 Concept	40
5.4.2 Key obligations.....	40

5.4.3 Experience	42
Summary and conclusions	43
References	44
Appendix -1	47

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Abstract

Over the last decades the European Union has established strict air quality objectives, together with a comprehensive legal framework that should facilitate the achievements of these objectives. As a consequence, air quality has drastically improved in Europe, although the long-term objectives are still not met.

The EU clean air legislation played an important role in these air quality improvements. Most importantly, the legal framework provided an effective response mechanism strategy to manage the complex interlinkages between the multitude of pollution sources and the regionally dispersed impacts on air quality which span across different legislation. These connections, which are a direct consequence of the physical nature of the key air pollutants (i.e., their long residence time in the atmosphere), make response strategies that extend beyond individual cities and countries indispensable.

In order to implement effective policy responses, the area of the European Union is now considered as one airshed containing 27 Member States, and action needs to be coordinated between countries, regions, and city administrations. The clean air legislation of the EU acknowledges that the European Union as a supra-national institution has to play an important coordinating role in the policy response. It has been found practical to combine three legal pillars into a comprehensive EU clean air legislation framework:

- The Ambient Air Quality Directives,
- The National Emission Ceilings Directive, and
- Source-specific performance standards.

One important feature of EU policy that contributed to the success is that, in addition to the key obligations for reaching air quality standards and reducing emissions, all directives contain specific requirements and mechanisms for monitoring, reporting, validation and enforcement.

Although the recent nature of some of the directives does not always allow for practical experience, systematic stock-taking on the strengths and weaknesses of older legislation has been recently conducted. This report summarizes the findings emerging from these assessments and indicates options for improvements that could be of interest for the design of effective clean air policies in other parts of the world.

While the EU legal framework has obviously been developed for the EU situation, there might be important lessons, particularly on monitoring, review and verification, that could provide relevant insights for other countries which face similar complexities in air quality management, e.g., the need to involve multiple governance levels across State borders.

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Glossary

Term or acronym

Meaning or definition

Policies

AAQ Directives	Ambient Air Quality Directives (Directive 2008/50/EC and Directive 2004/107/EC as amended by Commission Directive (EU) 2015/1480)
NEC Directive	Directive on the reduction of national emissions of certain atmospheric pollutants (Directive (EU) 2016/2284)
IED Directive	Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)
CAP	EU common agricultural policy
Air Convention (CLRTAP)	UNECE Air Convention (Convention on Long-Range Transboundary Air Pollution)
MARPOL	International Convention for the Prevention of Pollution from Ships
NEDC	New European Driving Cycle
PEMS	Portable emission measurement system
RDE	Real-driving emission

Pollutants

SO ₂	Sulphur dioxide
NO ₂	Nitrogen dioxide
NO _x	Nitrogen oxides (i.e. sum of NO and NO ₂)
PM ₁₀	Particulate matter, aerodynamic diameter < 10 µm
PM _{2.5}	Fine particulate matter, aerodynamic diameter < 2.5 µm
PN	Particle number emissions
O ₃	Ozone
C ₆ H ₆	Benzene
Pb	Lead
CO	Carbon monoxide
As	Arsenic
Cd	Cadmium
Ni	Nickel
BaP	Benzo(a)pyrene

Units

mg/m ³	Milligram(s) per cubic metre (= 1 000 µg/m ³)
µg/m ³	Microgram(s) per cubic metre (= 1 000 ng/m ³)
ng/m ³	Nanogram(s) per cubic metre

Abbreviations

AAQ	Ambient Air Quality
AAQD	Ambient Air Quality Directives
AQI	Air Quality Index

CAMS	Copernicus Atmosphere Monitoring Service
EC	European Commission
ECA	European Court of Auditors
EEA	European Environment Agency
EIONET	European Environment Information and Observation Network
EU	European Union
EUROSAI	European Organization of Supreme Audit Institutions
FAIRMODE	Forum for AIR quality MODElling
GAINS	Greenhouse gas – Air pollution Interactions and Synergies Model
HARMO	Harmonization within atmospheric dispersion modelling for regulatory purposes
IIASA	International Institute for Applied Systems Analysis
JRC	Joint Research Centre
CLRTAP	Convention on Long Range Transboundary Air Pollution
MS	Member States
NAPCP	National Air Pollution Control Plan
NECD	National Emissions Ceilings Directive
NFR	Nomenclature for Reporting
NFPs	National Focal Points
NGO	Non-governmental organization
OECD	Organization for Economic Co-operation and Development
PaMs	Policies and Measures
UNECE	United Nations Economic Commission for Europe
WHO	World Health Organization

1 Introduction

1.1 Background

Clean air is essential to human health and for the protection of ecosystems. The scientific evidence of harmful effects of air pollution is well-established, robust and points to a clear need for action. However, developing effective policy strategies to reduce emissions of harmful air pollutants faces a number of complexities:

- Air pollution comprises a cocktail of different substances that are emitted into the air. Some of them are directly harmful to humans and ecosystems, others interact with each other in the atmosphere to form secondary pollutants with harmful impacts. Effective responses must develop integrated strategies for all relevant pollutants, in order to maximize synergies between emission control measures and to avoid potential trade-offs.
- Due to their physical features, the most harmful air pollutants remain in the atmosphere for several days, during which they are transported over several hundreds to thousands of kilometres, often crossing administrative boundaries. As a consequence, air quality at a given site is influenced by emissions from a large area usually spanning the jurisdictions of different national or sub-national governments. Effective clean air strategies need to coordinate action across these different regional authorities.
- While these physical features call for regionally coordinated clean air policies, national governments, sub-national administrations, and city authorities have important roles in the implementation, monitoring and verification of effective policy responses. It is essential that the responsibilities of the various institutions at the different levels are clearly defined and enforced. At the same time, it is important that the administrative burden is kept at a minimum.

Over the last decades European Union (EU), which currently comprises 27 Member States, has developed an integrated air quality policy framework that has led to a successful reduction of air pollution in Europe. Based on scientific evidence, the EU clean air legislation represents today a practical regional policy framework for minimizing harmful impacts of air pollution in the most effective manner that coordinates roles and responsibilities of different policy institutions at the various scales. Most importantly, by now the EU has gained substantial experience on implementation of this framework, and in particular with the various mechanisms for monitoring, reporting and verifications of the various obligations.

1.2 Contents of this report

Most relevant for India, this review focuses on the system established in the European Union, as a supra-national institution that manages air quality across different national and sub-national administrations. Section 2 provides a brief introduction into the EU air quality policy framework and lays out the conceptual design how the various regulations interact with each other. The following Sections review the arrangements for monitoring, reporting, review, and verification of the three key directives, i.e., on ambient air quality, national emission ceilings, and source-specific performance standards. Conclusions are drawn in Section 6.

2 The EU air quality policy framework

The European Union has established a framework for clean air policy that reinforces national policies for those aspects of the air quality problem that Member States cannot handle effectively or efficiently alone. Progress in the implementation of air quality management plans is regularly monitored through a complex system of directives, regulations, and reporting obligations.

Basic obligations are laid down in a number of EU directives and regulations, which are legal acts of the European Union, but implemented and enforced in different ways. EU directives require Member States to accomplish a particular set of goals without dictating the means to do it. In other words, they outline certain rules which must be met, but each Member State decides how to ensure compliance through national laws. Directives specify an exact date by which they must be implemented (or transposed) into national law. In contrast, EU regulations are binding legislative acts that have direct implications for all Member States. They are applied in their entirety across the EU, meaning that they are directly applicable in every Member State and can be immediately enforced through law like any piece of local legislation. Regulations are equally pertinent to every Member State of the EU.

The European Commission (EC) is tasked to regularly monitor compliance of all Member States with these regulations and, if necessary, initiate infringement procedures that could end up at the European Court of Justice.

Owing to the strong international dimension of air pollution in Europe caused by the residence times of the key air pollutants, air quality management is organized as a hierarchical process, with clear but differentiated responsibilities for the

- international (Europe/EU-wide) institutions,
- national governments,
- regional/subnational governments, and
- city administrations.

The EU air quality management system rests on three pillars:

- ambient air quality standards for key pollutants, which need to be achieved at all locations,
- national emission ceilings, in order to limit the inflow of pollution from other countries,
- EU-wide emission limit values (or minimum performance standards) and product standards for all major emission source categories.

For each of these three pillars, complex systems are now in force to monitor, review and verify the implementation of these regulations at a regular basis. Specific rules and procedures for the monitoring, review and verification are laid down in a host of Directives, including

- Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (EC, 2008)
- Directive (EU) 2015/2193 of the European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants (EU, 2015)

- Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants (EU, 2016a), amending Directive 2003/35/EC and repealing Directive 2001/81/EC
- Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations (EC, 1999)
- Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants (EC, 2001a)
- Directive 2001/95/EC of the European parliament and of the council of 3 December 2001 on general product safety (EC, 2001b)
- Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel, and polycyclic aromatic hydrocarbons in ambient air (EC, 2004)
- Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (EC, 2009a)
- Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (EU, 2010)
- Directives on the Type Approval and In-use Compliance of Motor Vehicles with respect to the exhaust emissions of pollutants. Currently in force are standards EURO 6 for light duty vehicles (Directive 2007/715/EC as amended by Directive 2008/692/EC and EURO VI for heavy duty vehicles (Reg EC N°: 595/2009 (EC, 2009b) and implementing regulations (EU) N° 582/2011 and 64/2012) as well as Stage V emission controls for non-road mobile machinery (Regulation (EU) 2016/1628) (EU, 2016b)
- The vehicle exhaust emission standards are complemented, sometimes enabled, by standards on fuel quality (currently Directive 2009/30/EC), in particular banning lead, reducing the sulphur levels to no more than 10 ppm, and setting requirements for composition and physical properties of the fuels on the market (EC, 2009c).

3 The Ambient Air Quality Directive (AAQD)

3.1 Concept

Two EU Ambient Air Quality (AAQ) Directives (Directives 2008/50/EC and 2004/107/EC) set air quality standards and requirements to ensure that Member States monitor and/or assess air quality in their territory in a harmonised and comparable manner. They are guided by the overarching need to reduce air pollution to levels which minimize harmful effects on human health, the environment as a whole and the economy, taking into account relevant guidelines, i.e., by the World Health Organization (WHO). A basis for effective air pollution reduction is proper monitoring and assessment of air quality, whereas providing information to the public can support the minimization of harmful health effects and help raise awareness.

Guided by the principle of subsidiarity, the AAQ Directives leave the choice of means to achieve their air quality standards to the Member States, but explicitly require that exceedance periods be kept as short as possible.

In particular, the 2008 Ambient Air Quality Directives (AAQD) lays down specific provisions for

- monitoring,
- reporting,
- establishing non-compliance with the ambient air quality limit values, and
- rules in case of established non-compliance.

First, the AAQ Directives set common methods and criteria to assess air quality in all Member States in a comparable and reliable manner: Member States must designate zones and agglomerations¹ throughout their territory, classify them according to prescribed assessment thresholds, and provide air quality assessments underpinned by measurement, modelling and/or objective estimation, or a combination of these.

Second, the AAQ Directives define and establish objectives and standards for ambient air quality for 13 air pollutants to be attained by all Member States across their territories against timelines laid out in the Directives. These include sulphur dioxide (SO₂), nitrogen dioxide (NO₂) and nitrogen oxides (NO_x), particulate matter (PM_{1.0} and PM_{2.5}), ozone (O₃), benzene, lead, carbon monoxide, arsenic, cadmium, nickel, and benzo(a)pyrene.

Third, the Directives require Member States to monitor air quality in their territory. Member States need to report to the Commission as well as to the general public the results of air quality assessment on an annual basis, 'up-to-date' air quality measurements, as well as information on the plans and programmes they establish. It is the responsibility of Member States to approve the measurement systems required and ensure the accuracy of measurements.

¹ According to Directive 2008/50/EC a 'zone' shall mean part of the territory of a Member State, as delimited by that Member State for the purposes of air quality assessment and management; 'agglomeration' shall mean a zone that is a conurbation with a population in excess of 250 000 inhabitants or above a given population density per km² to be established by the Member States.

Fourth, where the established standards for ambient air quality are not met, the Directives require Member States to prepare and implement air quality plans and measures (for the pollutants exceeding the standards). These air quality plans need to identify the main emission sources responsible for pollution, detail the factors responsible for exceedances, and spell out abatement measures adopted to reduce pollution. Abatement measures can include, for example, measures to reduce emissions from stationary sources (such as industrial installations or power plants, as well as medium and small size combustion sources, including those using biomass) or from mobile sources and vehicles (including through retrofitting with emission control equipment), measures to limit transport emissions through traffic planning or encouraging shifts towards less polluting modes (including congestion pricing or low emission zones), promoting the use of low emission fuels, or using economic and fiscal instruments to discourage activities that generate high emissions.

3.2 Key obligations

3.2.1 Monitoring

3.2.1.1 Monitoring requirements

The EU Air Quality Directive 2008/50/EC requires that as a minimum one rural background station is installed every 100,000 km² for measuring PM_{2.5} in order to get data on the total mass concentration and the chemical speciation (EC, 2008). This minimum is larger than the total surface area of several Member States. The Directive further states that Member States shall set up at least one measuring station or may by agreement with adjoining Member State set up together one or several common measuring stations. It is recommended to identify types of rural background areas relating to climatic and topographic conditions that can be considered representative for large parts of the Member State's territory (EC, 2011). Existing stations or potential new sites can then be selected in such a way that a maximum percentage of the territory is covered. Subsequently, agreement with neighboring Member States on appropriate common stations should be sought.

3.2.1.2 Reference measurement methods

For each regulated pollutant, a reference measurement method is prescribed. At the time of the adoption of directives, standardized methods had not been developed for all pollutants. The situation has since developed, and the updated list of reference measurement method is shown in Table 0.1.

Table 0.1: Standard methods for the measurement of air pollutants

Pollutant	Reference	Title
SO ₂	EN 14212:2012	Ambient air - Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence
NO ₂ and NO	EN 14211:2012	Ambient air - Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence
Pb, Cd, As and Ni	EN 14902:2005	Ambient air quality - Standard method for the measurement of Pb, Cd, As and Ni in the PM ₁₀ fraction of suspended particulate matter
PM _{2.5} /PM ₁₀	EN 12341:2014	Ambient air - Standard gravimetric measurement method for the determination of the PM ₁₀ or PM _{2.5} mass concentration of suspended particulate matter
Benzene	EN 14662:2005	Ambient air quality - Standard method for measurement of benzene concentrations
CO	EN 14626:2012	Ambient air - Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy
OC/EC	EN 16909:2017	(WI=00264164) Ambient air - Measurement of elemental carbon (EC) and organic carbon (OC) collected on filters

Source: <https://www.cen.eu/cenorm/members/members/index.asp> accessed on 01/07/2020

3.2.1.3 Equivalence

Non-reference measurement methods can also be used provided they respect provisions for equivalence set out in the Directives (see for example Directive 2008/50/EC, Annex VI). A Commission Working Group on Equivalence has prepared a document describing principles and methodologies to be used for the demonstration of the equivalence of alternative (non-reference) measurement methods to the reference methods described by the EN² Standard methods. The air quality committee established under Directive 2008/50/EC endorsed the new guidance for the implementation of the Directive 2008/50/EC (EC, 2008). The corresponding tool to facilitate the use of the guidance (in particular for checking the equivalence of non-reference methods for PM-monitoring) has been developed in MS-Excel³.

² Each European Standard is identified by a unique reference code which contains the letters 'EN'. A European Standard is a standard that has been adopted by one of the three recognized European Standardization Organizations (ESOs): CEN, CENELEC or ETSI. It is produced by all interested parties through a transparent, open and consensus-based process.

³ See: <https://ec.europa.eu/environment/air/quality/legislation/pdf/Equivalence%20Tool%20v10.xlsm>

3.2.1.4 Modelling

In the AAQ Directive, modelling is considered to provide supplemental information to air quality monitoring and is to be used where monitoring is not mandatory. Modelling is becoming a principal assessment tool that is validated by monitoring. It provides much more comprehensive information as regards public exposure, identification of sources, and future projections of air quality based on different policy measures scenarios.

Use of modelling has been also developed under specific initiatives such as the 'Harmonization within atmospheric dispersion modelling for regulatory purposes' project (HARMO). Under the 6th Research Framework programme an Air4EU project (<https://www.air4eu.nl/>) has been concluded which facilitates combined use of monitoring and modelling for the air quality assessment through the developed guidance and IT tools.

3.2.1.5 Objective estimation

Objective estimation is reserved for the air quality zones with very good air quality and no large conurbations. It is usually combined with modelling. By identification of local pollution sources and information of regional air quality an estimation of concentration of a regulated pollutant is made.

3.2.1.6 Ensuring quality of assessment information

Ensuring the quality of assessment information either generated through monitoring, modelling or objective estimation is one of the paramount provisions of the directives. Data quality objectives are prescribed which define maximum allowed uncertainty, time coverage and data coverage. While Member States are responsible for appropriate quality assurance of the assessment as well as for appropriate quality control of the information provided to the public and through assessment reports, the Commission set-up a community-wide process managed by the Joint Research Centre (JRC). JRC organizes comparison exercises for the national reference laboratories and manages the AQUILA⁴ (European Network of National Air Quality Reference Laboratories) network which monitors the implementation of assessments by monitoring, serves as exchange forum, and provides expert advice to the Commission.

3.2.2 Reporting

Member States have to send validated monitoring data to the Commission once a year, and to continuously transmit up to date (near real-time) air quality data. Reporting obligations include monitoring data and information about sampling points and assessment methods, exceedance situations and alerts, about contributions from natural sources, road sanding and salting, about air quality plans and measures.

Since 2013, the requirements for the reciprocal exchange of information and reporting on ambient air quality are governed by Implementing Decision 2011/850/EU⁵. Accordingly, data is by now submitted via e-reporting through the Reporting Obligation Database (Central Data Repository) of the European Environment Information and Observation Network (EIONET), hosted by the European Environment Agency (EEA).

⁴ See: <https://ec.europa.eu/jrc/en/aquila>

⁵ Implementing Decision 2011/850/EU laying down rules as regards the reciprocal exchange of information and reporting on ambient air quality applies since 1 January 2014 (i.e. for data observed in 2013).

In this manner, all Member States report information on zones and agglomerations (Dataflow B), on assessment regimes (Dataflow C), on assessment methods (Dataflow D), on primary validated assessment data (Dataflow E1a), and on the attainment of environmental objectives (Dataflow G)⁶. By 2019, 26 Member States reported primary up-to-date assessment data (Dataflow E2a). For 2017, 12 Member States reported also modelled data (Dataflow E1b).

Based on the data reported by Member States, the EEA provides online access to all reported air quality data, statistics, and maps, and publishes an annual air quality report summarizing key findings. It also provides access to this data via online information services such as the European Air Quality Index.

This information has been increasingly made available and accessed by a wider public. In addition to the official air quality data and information that is made available to a wider public at EU-level and by national authorities, the availability and popularity of so-called low-cost air quality sensors has increased over the past few years. The current generation of low-cost sensors, however, tends to deliver measurements of lower data quality than monitoring carried out in accordance with the AAQ Directives (JRC, 2017). Recently, citizen science monitoring campaigns have successfully used low-cost sensors to increase public awareness and public engagement on air quality issues (<https://curieuzeneuzen.be/>).

3.2.3 Enforcement

The AAQD requires Member States to take appropriate measures to ensure compliance with the limit and target values within a specified deadline and/or to maintain compliance once the limit and target values have been met. Therefore, air quality plans are required for polluted zones and agglomerations where air quality standards are exceeded and/or for zones and agglomerations where there is a risk of exceedances. These plans must aim to reduce concentrations of air pollutants to below the legislative limit and target values specified in the Directives in the shortest possible time. Details of the plans must be reported by Member States to the European Commission via the EEA. When and where concentrations of pollutants in ambient air exceed the relevant target values or limit values, the AAQ Directives require Member States to develop air quality plans and/or take appropriate measures (depending on the pollutant), so that the related target values or limit values are achieved in the respective zones and agglomerations, and that exceedance periods are kept as short as possible.

3.3 Experience

3.3.1 Overall experience

The European Commission has recently completed a Fitness Check of the two EU Ambient Air Quality (AAQ) Directives (Directives 2008/50/EC and 2004/107/EC). The fitness check also considered the corresponding Implementing Decision 2011/850/EU and Commission Directive (EU) 2015/1480. It drew on the experience in all Member States, focusing on the period from 2008 to 2018 (i.e., the period in which both Directives were in force) and covered all articles and provisions of the two Directives, looking at the role they have played in

⁶ European air quality Portal (Available at: <https://aqportal.discomap.eea.europa.eu/products/submission-monitoring/data-monitor-all-except-e2a/> accessed on 03/07/2020).

meeting the objectives. The fitness check evaluated the relevance, effectiveness, efficiency, coherence, and EU added value of the AAQ Directives, in line with Better Regulation requirements.

It has been found that the AAQ Directives have guided the establishment of a representative high-quality monitoring of air quality, set clear air quality standards, and facilitated the exchange of reliable, objective, comparable information on air quality, including to a wider public. They have been less successful in ensuring that sufficient action is taken by Member States to meet air quality standards and keep exceedances as short as possible. Nevertheless, the available evidence indicates that the AAQ Directives have contributed to a downward trend in air pollution and reduced the number and magnitude of exceedances. This partial delivery allows to conclude that the AAQ Directives have been broadly fit for purpose – while at the same time pointing to the need for improvements to the existing framework such that good air quality be achieved across the EU. In particular, it emerges from this fitness check that additional guidance, or clearer requirements in the AAQ Directives themselves, could help to make monitoring, modelling and the provisions for plans and measures more effective and efficient.

Air quality standards have been set for a total of 13 air pollutants: Sulphur dioxide (SO₂), nitrogen dioxide (NO₂) and nitrogen oxides (NO), particulate matter (PM₁₀, PM_{2.5}), ozone (O₃), benzene, lead (Pb), carbon monoxide (CO), arsenic (As), cadmium (Cd), nickel (Ni), and benzo(a)pyrene (BaP). Their relevance and the underpinning scientific evidence on their harmful effects has been reconfirmed and reinforced. For other air pollutants, not covered by the AAQ Directives, such as ultrafine particles or black carbon, the current scientific evidence on adverse health effects remains inconclusive and does not lend itself to setting standards.

While the air quality standards have been instrumental in driving concentrations downward and reducing exceedance levels, two contradictory shortcomings remain: firstly, EU air quality standards are not fully aligned with well-established health recommendations (and they do not feature an explicit mechanism for adjusting air quality standards to the latest technical and scientific progress)⁷; while secondly, due to insufficiently effective air quality plans and lack of commitment to take appropriate measures by Member States, there have been and continue to be substantial delays in taking appropriate and effective measures to meet the air quality standards. Thus, while the number and magnitude of exceedances above air quality standards has decreased over the past decade, it is also clear that they have not been kept as short as possible to date.

The AAQ Directives have been only partially, and therefore insufficiently, successful in meeting this objective. While action to reduce the impact of air quality has been taken, resulting in a reduced number and magnitude of exceedances, 20 Member States still report exceedances above EU limit values for at least one pollutant, and often for several. One reason for this is that improvements in air quality critically depend on action taken to address the sources of air pollution, and typically require action in the transport, energy (including domestic heating) and agricultural sectors or by industry. At national, regional, and local level, this has not translated in sufficient level of commitment. At the EU-level, synergies with climate, energy and transport policies have been strengthened over the past decade, and require coherent action at national, regional, and local levels. Notwithstanding the important shortcoming of the remaining implementation gap to meet the air quality standards for all pollutants and throughout the EU, the clear requirement to take remedial action when and

⁷ The *WHO Guidelines* are currently under revision with an expected publication date in the early 2020s, the Commission is following this process closely.

where exceedances are observed has been decisive in triggering improvement in air quality, yet often with delay.

3.3.2 Monitoring

3.3.2.1 The monitoring network

Across the EU, Member States have established an air quality monitoring network with some 16,000 sampling points for specific pollutants (often grouped, at more than 4,000 monitoring stations) based on common criteria defined by the AAQ Directives. This extensive network can be considered a success in itself. Concerns have been raised that the criteria on monitoring offer too much leeway and present some ambiguity to competent authorities, resulting in instances where air quality monitoring does not live up to the criteria set by the AAQ Directives. A key challenge here is to ascertain that air quality sampling points indeed provide information for where the highest concentrations of air pollutants occur. This, however, does not appear to amount to systemic shortcomings in the EU-wide monitoring network. Overall, the monitoring network by and large adheres to the provisions of the AAQ Directives and ensures that reliable and representative air quality data is available.

3.3.2.2 Selection of monitoring stations

Experience shows that, when monitoring is being used for the assessment, it is extremely important to select appropriately the siting of the monitoring station. Siting is bearing on the ability to use the monitoring information to assess compliance in the specific area and to obtain further information as regards exposure, source apportionment that supports further development of air policy as well as air pollution management in the area.

The AAQ Directives set criteria for the minimum number of the sampling points and for their site locations. However, the site location provisions involve multiple criteria and offer a degree of flexibility which can make verification more difficult. They require Member States to locate sampling points both “where the highest concentrations occur” (with traffic or industrial type stations) and in other areas which are “representative of the general population’s exposure”⁸ (with background type stations). As a result, Member States do not necessarily measure air quality near major industries or main urban traffic routes. Complying with the Directive may be easier when the number of traffic or industrial stations is low.

For example, Brussels has only two traffic stations, while Stuttgart had eight and Milan had 11 (only six within the city limits, two of which were inside the Low Emission Zone). Similarly, the Ostrava air quality zone has significant industrial facilities in its territory, but only one of its 16 monitoring stations is “Industrial”. A similar situation occurs in Krakow, where only one of the six monitoring stations is “Industrial”. Sofia has no “Industrial” monitoring stations, even though power plants and other industrial facilities are located there⁹.

⁸ See: Section B.1. of Annex III of the AAQ Directive.

⁹ Information based on the 2015 official data reporting to the EEA.

3.3.2.3 Exchange of information

The AQUILA network has prepared an extensive document (AQUILA, 2009) that summarizes the roles and responsibilities of the national reference laboratories and of the network itself, describes the quality assurance procedures and EU-wide comparisons. The document also includes the interpretation of obligations for the national reference laboratories and the monitoring networks under the Directive.

The European Environment Agency together with its Topic Centre is supporting the efforts through further quality control of the reported assessment information and through facilitating exchange of best practices by the data providers within EIONET¹⁰.

To improve the modelling capacity in Member States for the purposes of the AAQD, a Forum for AIR quality MODElling (FAIRMODE) of modellers and users has been established. It supports the widespread and harmonized use of models through model validation and intercomparison exercises and through the management of the modelling network. The FAIRMODE webpage contains links to current activities (see: <https://fairmode.jrc.ec.europa.eu/>).

3.3.3. Reporting

The provisions on reporting have prompted the establishment of improved and more efficient e-reporting systems to report both validated air quality data as well as up-to-date data. The air quality data reported by Member States is made available to the public by the EEA, including via an Air Quality Index (AQI) based on near-real time data. The AAQ Directives have facilitated the availability and accessibility of objective and comparable air quality data and information across the EU. Further harmonization of the way air quality information is presented, especially at Member State level, would be possible and provide further EU added value, and help ensure even higher comparability of air quality information across all geographical scales and all regions of the EU.

3.3.4 Enforcement

According to the Fitness Check of the EU Ambient Air Quality Directives (2008/50/EC, 2004/107/EC), enforcement action is seen as a positive contributor to the achievement of the objective, in particular enabled by provisions in Article 23(1). The introduction of this new obligation in Directive 2008/50/EC represented a significant improvement of the previous regulatory framework and it has been key in driving actions against air pollution across Europe. Enforcement actions from individuals, non-governmental organizations (NGOs) and the Commission have been one of the key drivers in relation to the recent developments and improvements in air quality in the EU. Legal actions would not have been possible without the existence of the obligation to adopt air quality plans that set out appropriate measures to achieve compliance as soon as possible (Article 23(1), second subparagraph).

¹⁰ The European Environment Information and Observation Network (EIONET) is a partnership network of the European Environment Agency (EEA) and its 38 member and cooperating countries. The EEA is responsible for developing Eionet and coordinating its activities together with National Focal Points (NFPs) in the countries. Further details are available at: <https://www.eionet.europa.eu/>

In terms of breach of the requirements in articles related to monitoring networks, the Commission has in 2017 taken action against Slovakia and Romania. Romania has been issued a letter of formal notice, titled "AIR - Bad Application of Directives 2008/50/EC (EC, 2008) and 2004/107/EC (EC, 2004) and of the Commission Implementing Decision 2011/850/EU" [D65]. According to the relevant press release, Romania "has failed to establish a monitoring network compliant with EU standards and requirements to effectively assess and improve air quality".

A similar letter was issued to Slovakia in October 2017 [D65]. A Clean Air Dialogue meeting was held between the Commission and Slovakia, to discuss the approach to clean air policy in Slovakia [R86]. The conclusions from this meeting state that efforts to improve the monitoring network are underway, including 14 more sampling points of the fixed measurement network. There is no information on the type of these additional sampling points, or about the pollutants that will be measured.

4 The National Emission Ceilings (NEC) Directive

The National Emissions Ceilings (NEC) Directive (2016/2284/EU) entered into force on 31 December 2016 (EU, 2016a), replacing earlier legislation (i.e., Directive 2001/81/EC). The ambition level of the 2016 NEC directive is to cut EU-wide emissions of SO₂ by 79%; NO_x by 63%; NMVOCs by 40%; ammonia (NH₃) by 19%; and particulate matter (PM_{2.5}) by 49%, compared to the emission levels in the base year 2005. For each Member State and pollutant, country-specific emission reduction commitments are laid down in the NECD.

4.1 Concept

In order to limit the inflow of pollution from other countries and to enable Member States to reach the ambient air quality limit values through domestic action, the National Emission Ceilings Directive sets national emission reduction commitments for Member States for the five main precursor emissions of PM_{2.5} in ambient air: nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO₂), ammonia (NH₃) and fine particulate matter (PM_{2.5}).

In addition to these emission reductions, the Directive requires Member States to

- regularly report their emissions in a standardized format,
- regularly draw up, adopt and implement national air pollution control programmes (NAPCPs) so that the commitments are met,
- to monitor ecosystems impacts in their territory.

The European Commission is tasked to assess the NAPCPs and to report to the European Parliament.

4.2 Key obligations

4.2.1 Monitoring

To provide the knowledge base for the assessment of the effectiveness of the NEC-Directive in protecting the environment, Article 9 of the Directive requires Member States to develop and implement a monitoring system to identify negative impacts of air pollution on ecosystems (acidification, eutrophication and ozone damage), covering the representative Member State's habitats/ecosystem types.

The principal obligations on Member States for monitoring under the NEC-Directive are as follows:

- To ensure the monitoring of negative impacts of air pollution upon ecosystems based on a network of monitoring sites that is representative of their freshwater, non-forest natural and semi-natural habitats, and forest ecosystem types, taking a cost-effective and risk-based approach (Article 9 (1) first subparagraph);
- To report every four years to the Commission and the EEA, the location of the monitoring sites and the associated indicators used for monitoring air pollution impacts (Article 10(4)(a));
- To report every four years to the Commission and the EEA key monitoring data.

The Commission shall report every four years to the European Parliament and the Council on the progress towards the Union's biodiversity and ecosystem objectives in line with the 7th Environment Action Programme (7th EAP)¹¹ (Article 11(1)(a)(iii)).

4.2.2 Reporting

The NEC Directive highlights the importance of Member States regularly reporting air pollutant emission inventories for assessing progress in reducing air pollution in the EU and for ascertaining whether Member States are in compliance with their commitments. These reports must include:

- Air pollutant emissions and projections (annually)
- National air pollution control programmes (every four years).
- Monitoring of impacts, i.e., the location of monitoring sites and indicators, and selected monitoring data (every four years).

4.2.2.1 Emission inventories

Member States are obliged to report national emission inventories for the emissions of several pollutants:

- the five main air pollutants NO_x, NMVOCs, SO₂, NH₃ and PM_{2.5} as well as carbon monoxide (CO),
- in addition to PM_{2.5}, also PM₁₀ particulate matter and, if available, black carbon (BC) and total suspended particulate matter (TSP),
- heavy metals cadmium (Cd), lead (Pb) and mercury (Hg) and, if available, the additional heavy metals arsenic, chromium, copper, nickel, selenium and zinc),
- persistent organic pollutants (POPs) including selected polycyclic aromatic hydrocarbons (PAHs), dioxins and furans, polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB).

Inventories have to be reported to the European Commission and the European Environment Agency (EEA). The EEA makes the data available on the EEA's National Emission Ceilings Directive webpage¹².

To ensure that inventories are comparable between countries, do not contain double counting or omissions, and that the time series reflect actual changes in emissions, and thereby to provide a robust basis for subsequent verification and enforcement procedures, the submitted inventories have to follow a common set of key concepts, criteria and definitions. These are specified in EMEP/EEA Air Pollutant Emission Inventory Guidebook (EEA, 2019a), which is regularly reviewed and updated¹³. The guidebook establishes the following principles and definitions:

Accuracy

Accuracy means that emission estimates should be accurate in the sense that they are systematically neither over nor underestimate true emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Appropriate methodologies should be used to promote accuracy in inventories.

¹¹ Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet' (OJ L 354, 28.12.2013, p. 171).

¹² See: <https://www.eea.europa.eu/themes/air/air-pollution-sources-1/national-emission-ceilings>

¹³ The latest 2019 Guidebook is available at: <https://www.eea.europa.eu/publications/emep-eea-guidebook-2019>

Comparability

Comparability means that estimates of emissions reported by Parties in their inventories should be comparable. For that purpose, Parties should use the accepted methodologies as elaborated in the Reporting Guidelines and the Nomenclature for Reporting (NFR) formats for making estimations and reporting their inventories.

Completeness

Completeness means that an annual inventory covers at least all sources, as well as all pollutants, for which methodologies are provided in the latest EMEP/EEA air pollutant emission inventory guidebook (EEA, 2019a) or for which supplementary methodologies have been agreed to by the Executive Body of the CLRTAP Convention. Completeness also means the full geographical coverage of the sources of a Party.

Consistency

Consistency means that an annual inventory should be internally consistent for all the reported years for all elements across sectors, categories, and pollutants. An inventory is consistent if the same methodologies are used for all of the years of the inventory and if consistent data sets are used to estimate emissions. For projections, consistency also means that a year of the submitted inventory is used as a base year.

Decision trees

Decision trees, for each category, help the inventory compiler navigate through the guidance and select the appropriate tiered methodology for their circumstances based on their assessment of key categories. In general, it is good practice to use higher tier methods for key categories, unless the resource requirements to do so are prohibitive.

Good practice

In order to promote the development of high-quality inventories, a collection of methodological principles, actions and procedures have been defined and collectively referred to as good practice. Inventories consistent with good practice are those that contain neither overestimates nor underestimates, so far as can be judged, and in which uncertainties are reduced as far as practicable.

Inventory year and time series

National inventories contain estimates for the calendar year during which the emissions to the atmosphere occur. Where suitable data to follow this principle are missing, emissions may be estimated using data from other years and applying appropriate methods such as averaging, interpolation and extrapolation. A sequence of annual inventory estimates (e.g. each year from 1990 to 2019) is called a time series. Given the importance of tracking emissions trends over time, countries should ensure that a time series of estimates is as consistent as possible.

Inventory reporting

Inventory reporting consists of the submission of a set of standard reporting tables for specified substances, for the requisite source, for a given reporting year. The LRTAP Reporting Guidelines provide standardized reporting tables, but the content of the tables and written report may vary according to, for example, a country's obligations as a signatory to individual Convention protocols.

Key category

A key category means a source category of emissions that has a significant influence on a Party's total emissions in terms of the absolute level of emissions of a given substance, the trend in emissions over a given time period or the uncertainty in the estimates for that Party. The concept of key categories is an important aspect in inventory development in that it helps to identify priorities for resource allocation in data collection and compilation, quality assurance/quality control and reporting.

Pollutants

The Guidebook is designed to cover all the substances that Parties to the Convention's protocols need to report, plus a number of additional substances for which reporting is voluntary as defined in the Reporting Guidelines.

Sectors, categories, and sources

Pollutant emissions estimates are divided into sector groupings of related processes and sources. These sectors include energy, industrial processes and product use, agriculture, waste, and other. Each sector comprises individual source categories (e.g., transport) and subcategories (e.g., passenger vehicles). Ultimately countries will construct an inventory from the subcategory (source) level because this is the level at which data tend to be available, and total emissions will be calculated by summation. A national total is calculated by the summation of emissions for each pollutant and category as defined in the respective reporting requirements. An exception is for so-called 'memo-items', those sources which, following political agreement, are not included in national totals (which may be used to assess compliance with protocol requirements) but which are reported separately. An example of a memo-item includes the emissions caused by fuel combustion from international shipping.

Tiers

A tier represents a level of methodological complexity. Usually three tiers are provided: tier 1 is the simple (most basic) method; tier 2 the intermediate; and tier 3 the most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate.

Transparency

Transparency means that the data sources, assumptions, and methodologies used for an inventory should be clearly explained, to facilitate the replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of the information. The use of the NFR tables and the preparation of a structured informative inventory report (IIR) contribute to the transparency of the information and facilitate national and international reviews.

4.2.2.2 National Air Pollution Control Plans

As a principal governance tool under the National Emission Ceilings (NEC) Directive, Article 6(1) requires Member States to adopt a National Air Pollution Control Programme (NAPCP) to show how they intend to limit their annual anthropogenic emissions in view of their emission reduction commitments. This should allow Member States to coordinate and agree their policies and measures (PaMs) to ensure national emission reduction commitments are met. Its preparation requires consultation and involvement of competent authorities at different levels and of several different sectors, such as environment, agriculture, energy, climate, transport,

industry, or finance. Emphasis is put on coherence with plans and programmes under all relevant policy areas. Furthermore, the NAPCP is a tool to communicate a Member State's pollution control policies and to involve the public in the process of policymaking.

In accordance with Article 6(10) of the Directive, the Commission has specified the format of the NAPCP in Commission Implementing Decision (EU) 2018/152224 setting out mandatory and optional content, based on Article 6 and Annex III Part 1 to the Directive. The additional PaMs selected for adoption by Member States to further reduce emissions constitute an essential part of that mandatory content. These additional PaMs have to be reported via the 'EEA-PaM Tool', a web-tool developed by the EEA. The Commission has also prepared guidance for the development of NAPCPs¹⁴, in accordance with Article 6(9) of the Directive. The guidance supports Member States in drawing up an NAPCP in line with the format and in compliance with the requirements of the Directive. The first NAPCPs were due by 1 April 2019. NAPCPs must be updated at least every four years and earlier if new data so requires.

All roles relevant to the development of the NAPCP are the responsibility of authorities at a national level, requiring collaboration between government ministries across sectors). Implementation, enforcement, reporting and monitoring at national level is supported by county and city administrations. Where relevant, the source sectors under the responsibility of the authority described are reported (covering climate and the environment, agriculture, energy, industry, transport and the built environment).

4.2.3 Verification

4.2.3.1 Emission inventories

The European Commission has set up a systematic process for the review of the air pollution emission data submitted by Member States (MS) under the European Union's National Emissions Ceilings Directive (NECD) (Directive (EU) 2016/2284) in line with their emission reporting obligations. Methods and procedures are specified in the Air Emission Inventory Review Guidelines.

The review process and principles should ensure consistency in the review of the Member State submissions via a thorough and comprehensive technical assessment of national inventories. The review checks and assesses Member State data submissions to ensure that the European Commission (EC) has available adequate and reliable information on annual inventories and emissions trends and to enhance the quality of emission data and associated information reported. It also seeks to achieve a common approach to prioritising and monitoring inventory improvements under the NECD with those of other organizations with similar interests such as the UN/ECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). The review process is intended to be transparent and carried out in close cooperation with the nominated national contact point and national experts from Member States.

¹⁴ Communication from the Commission on Guidance for the development of National Air Pollution Control Programmes under Directive (EU) 2016/2284 of the European Parliament and the Council on the reduction of national emissions of certain atmospheric pollutants, OJ C 77, 1.3.2019, p. 1.

The technical review process includes two steps, i.e., initial checks” and the “comprehensive review” (Figure 0.1):

- Initial checks are undertaken in an attempt to quickly identify the issues identified in previous NECD reviews that have been addressed. These semiautomated checking procedures focus on completeness, consistency, and comparability of data. Findings are provided to the technical expert review team to inform their work in undertaking the comprehensive review.
- The Comprehensive Review is undertaken by a technical expert review team in two stages. First, nominated national contact points, supported by national experts, have the opportunity to clarify issues or provide additional information related to their inventory. First, the technical expert review team checks submitted inventories and Informative Inventory Reports and generates and issues questions for the Member States, and Member States provide responses. Subsequently, in the centralized review the technical expert review team raises questions for Member States, assesses responses from Member States, gives recommendations, considers whether revised estimates or technical corrections are necessary, calculates necessary technical corrections and drafts the Initial Outcomes Report. This includes recommendations on improvements, including technical corrections to be applied to national emissions estimates.

Subsequently, the European Commission evaluates the final review reports, communicates them to the Member States, and takes further action on technical corrections that are still disputed by Member States. Member States have an opportunity to provide comments on the review reports.

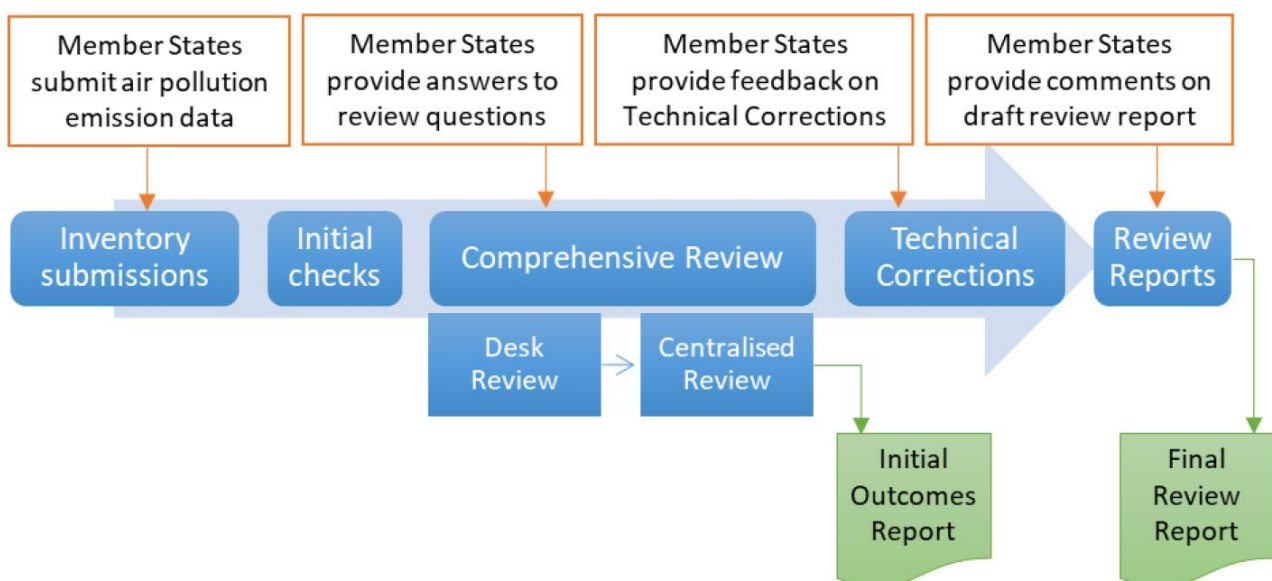


Figure 0.1: The review process of national emission inventories

4.2.3.2. National Air Pollution Control Plans (NAPCPs)

Under Article 6(10) of the NEC Directive, the Commission is required to review and assess the National Air Pollution Control Plans of all Member States and to make the review publicly available. To facilitate this review, the Commission has specified the reporting format of the programme by means of an implementing act (Commission Implementing Decision (EU) 2018/1522). The legal provisions on which the guidance is based are

primarily contained in Article 6 and Annex III, Part 1 of the Directive. These require Member States to, when drawing up, adopting and implementing the programme:

- Assess the extent to which national emission sources are likely to have an impact on air quality, nationally and in neighboring Member States,
- take account of the need to reduce air pollution emissions to reach compliance with the air quality objectives,
- prioritize emission reduction measures for black carbon when taking measures to reduce PM2.5,
- ensure coherence with other relevant plans and programmes established under EU or national legislation,
- include the mandatory measures, and may include the optional measures, in Part 2 of Annex III (agricultural measures).

The NAPCP also has to cover, at least:

- the policy framework in which it has been developed (policy priorities, allocation of responsibilities, projected developments on business-as-usual),
- the policy options considered and eventually adopted so as to comply with the reduction commitments (including how coherence with other policy areas is ensured),
- the identified reduction trajectory between 2020 and 2030.

4.2.4 Enforcement

If an EU country fails to communicate measures that fully transpose the provisions of directives or does not rectify the suspected violation of EU law, the Commission may launch a formal infringement procedure. The procedure follows a number of steps laid out in the EU treaties, each ending with a formal decision:

- The Commission sends a letter of formal notice requesting further information to the country concerned, which must send a detailed reply within a specified period, usually two months.
- If the Commission concludes that the country is failing to fulfil its obligations under EU law, it may send a reasoned opinion: a formal request to comply with EU law. It explains why the Commission considers that the country is breaching EU law. It also requests that the country inform the Commission of the measures taken, within a specified period, usually two months.
- If the country still does not comply, the Commission may decide to refer the matter to the Court of Justice. Most cases are settled before being referred to the court.
- If an EU country fails to communicate measures that implement the provisions of a directive in time, the Commission may ask the court to impose penalties.
- If the court finds that a country has breached EU law, the national authorities must take action to comply with the Court judgment.

If, despite the court's judgment, the country still does not rectify the situation, the Commission may refer the country back to the court.

When referring an EU country to the court for the second time, the Commission proposes that the court impose financial penalties, which can be either a lump sum and/or a daily payment. These penalties are calculated taking into account:

- the importance of the rules breached and the impact of the infringement on general and particular interests
- the period the EU law has not been applied
- the country's ability to pay, ensuring that the fines have a deterrent effect
- The amount proposed by the Commission can be changed by the court in its ruling.

4.3 Experience

4.3.1 Monitoring

One of the innovations of NECD is Article 9, which mentions the issue of “monitoring air pollution impacts” on ecosystems. According to this article, “Member States shall ensure the monitoring of negative impacts of air pollution upon ecosystems through a cost-effective and risk-based approach, based on a network of monitoring sites that should be representative of their freshwater, natural and semi-natural habitats and forest ecosystem types”. Annex V of NECD reports a series of indicators for monitoring air pollution impacts, although the choice among them is not mandatory. These indicators should be monitored based on the methodologies proposed by the CLRTAP and its International Cooperative Programs (e.g. ICP Forests, ICP Waters). Member States that do not use the optional indicators will need to explain how the selected indicators fulfill the objective of Article 9.

In 2019, the European Environment Agency (EEA) reviewed the progress made by the European Union (EU) and its Member States in meeting the 2010 emission ceilings of Directive 2001/81/EC. It was found that:

- In 2017, the most recent year for which data were reported, the total emissions of four main air pollutants — nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO₂) and ammonia (NH₃) — were below the respective ceilings set for the EU as a whole.
- For the fourth consecutive year, emissions of NH₃ increased. From 2016 to 2017, emissions increased by 0.4 % across the EU. Over the period 2014-2017, the overall increase was about 2.5 %. These increases are because of the lack of emission reductions in the agriculture sector.
- Six Member States exceeded their national ceilings for at least one pollutant in 2017; all were not in compliance with their NH₃ ceiling, whereas one of them exceeded its ceiling for NMVOC.
- In 2017, the aggregated EU emissions for two pollutants (NMVOCs and SO₂) were already below the relevant EU 2020 emission reduction commitments. To meet the 2020 reduction commitments for NH₃ and fine particulate matter (PM_{2.5}), further reductions of 2.3 % and 1.3 % respectively are required. An additional reduction of 3.2 % is necessary to meet the target set for NO_x at EU level.
- Sixteen Member States do not consider themselves on track to meet their 2020 reduction commitments for one or more pollutants.
- More substantial reductions are needed for all pollutants if the EU is to achieve its emission reduction commitments for 2030. Reductions of around 15 % are required for NMVOC and NH₃, more than 30 % for PM_{2.5} and SO₂, and almost 40 % for NO_x. Twenty Member States are not on track to meet one or more 2030 emission reduction commitments on the basis of their current policies.

Overall, since 2010 the Commission has referred more than 100 cases related to air pollution legislation to the European Court. Related to the NEC Directive, three infringement procedures against Member States have been

started on non-compliance with Directive 81/2001 (deadlines of the 2016/2284/EU Directive are not yet applicable).

4.3.2 Reporting

A review (Anderson et al., 2020) of the first NAPCPs which were due by 1 April 2019 observed that only seven Member States submitted both their projections and NAPCPs in line with the deadlines set in the NECD. There were more delays for reporting of NAPCPs compared to reporting on projections. All Member States met the mandatory content requirements when reporting emission projections in the Annex IV template (in terms of pollutants and years), although not all included reference year data. However, for many Member States the information on methodologies for preparation of air pollutant emission projections was very limited. Where available, it was often spread across multiple documents e.g. IIR, NAPCPs, separate methodology reports or other documents. The lack of complete reporting required the review team to pose numerous questions to the Member States. Two cases were identified (Sweden, United Kingdom) where the With Additional Measures (WAM) scenarios was not submitted with the projections, even though additional PaMs were selected for adoption in the NAPCP.

Many quality issues raised in the review were associated with misallocation of emissions sources in the projections, and exclusion from the projections of some small emission sources present in the historical inventory. These typically had relatively small impacts on projected national total emissions of NECD pollutants. However, for a limited number of Member States, inconsistencies were identified between the emissions reported in the reference year in projection submissions and the values included for that year in the historical inventory. These inconsistencies may have a more significant impact on national totals.

Not all Member States used the latest set of projections and emissions from the latest historical emission inventory to inform the development of their NAPCPs. Where differences between the latest projections and those used in NAPCPs are large this can lead to different conclusions on compliance with emission reduction commitments.

The implementation and monitoring of the national emission reduction programmes should see involvement of the authorities with responsibilities at various levels in the emission-producing sectors covered by national reduction commitments (such as transport, industry, agriculture, energy, civil heating) or in related areas (air quality, climate), since the action of these Authorities must be consistent with the programme's objectives.

In general, it is found that an enhanced role of the national government overseeing air pollution matters would facilitate coordination between sectors and regions (Anderson et al., 2020). Regional and local involvement in implementation, enforcement, reporting and monitoring can strengthen implementation through more targeted action.

4.3.3 Enforcement

In 2019, Member States were requested to report emission inventory data and an informative inventory report (IIR). All Member States, except Greece, provided air emission inventories. For the Greek data set and for other

countries where data were missing for certain years or pollutants, a gap-filling procedure was applied to obtain a European inventory which was as complete as possible.

By 9 May, 26 Member States had provided IIRs and 23 Member State had submitted projection data. The reporting of projections has been requested in 2019, but not the submission of gridded and LPS data. However, Denmark, Finland, Germany and Spain have provided gridded data. Finland and Spain also reported LPS data in 2019 (EEA, 2019b).

In 2012, the Executive Body of the LRTAP Convention decided that adjustments to emission-reduction commitments, or to inventories for the purposes of comparing them with total national emissions, may be applied in some circumstances, if such a circumstance contributes to a Party being unable to meet one of its reduction commitments. Under the Gothenburg Protocol, the European Monitoring and Evaluation Programme (EMEP) Steering Body Board accepted inventory adjustment applications for emissions from seven countries in 2014, 2015, 2016, 2017 and 2018. Circumstances that allow adjustments to emission inventories are defined as follows:

- There are additional categories of emission sources that were not accounted for when the emission-reduction commitments were set.
- Emission factors used to determine emission levels for particular source categories for the year in which emission-reduction commitments are to be attained are significantly different from the emission factors applied to these categories at the time the emission-reduction commitments were set.
- The methods for determining emissions from specific source categories have changed significantly between when emission-reduction commitments were set and the year they are to be attained.

5 Source-specific emission legislation

5.1 The Industrial Emissions Directive (IED)

Industrial production processes account for a considerable share of the overall pollution in Europe due to their emissions of air pollutants, discharges of wastewater and the generation of waste. Directive 2010/75/EU of the European Parliament (EU, 2010) and the Council on industrial emissions (the Industrial Emissions Directive or IED) is the main EU instrument regulating pollutant emissions from industrial installations.

5.1.1 Concept

The IED aims to achieve a high level of protection of human health and the environment taken as a whole by reducing harmful industrial emissions across the EU, in particular through better application of Best Available Techniques (BAT). Around 50,000 industrial installations are required to operate in accordance with a permit (granted by the authorities in the Member States). This permit should contain conditions set in accordance with the principles and provisions of the IED. The IED is based on several pillars, in particular (1) an integrated approach, (2) use of best available techniques, (3) flexibility, (4) inspections and (5) public participation:

1. The **integrated approach** means that the permits must take into account the whole environmental performance of the plant, covering e.g. emissions to air, water and land, generation of waste, use of raw materials, energy efficiency, noise, prevention of accidents, and restoration of the site upon closure.
2. The permit conditions including emission limit values must be based on the **Best Available Techniques (BAT)**. In order to define BAT and the BAT-associated environmental performance at EU level, the Commission organizes an exchange of information with experts from MS, industry and environmental organizations. For certain activities, i.e. large combustion plants, waste incineration and co-incineration plants, solvent using activities and titanium dioxide production, the IED also sets EU wide emission limit values for selected pollutants.
3. The IED allows competent authorities some **flexibility** to set less strict emission limit values. This is possible only in specific cases where an assessment shows that achieving the emission levels associated with BAT described in the BAT conclusions would lead to disproportionately higher costs compared to the environmental benefits due to the geographical location or the local environmental conditions or the technical characteristics of the installation. The competent authority shall always document its justification for granting such derogations. Furthermore, Chapter III of the IED on large combustion plants includes certain flexibility instruments (Transitional National Plan, limited lifetime derogation, etc.).
4. The IED contains mandatory requirements on **environmental inspections**. Member States shall set up a system of environmental inspections and draw up inspection plans accordingly. The IED requires a site visit to take place at least every 1 to 3 years, using risk-based criteria.
5. The IED ensures that the **public has a right to participate** in the decision-making process, and to be informed of its consequences, by having access to permit applications, permits and the results of the monitoring of releases.

In addition, through the [European Pollutant Release and Transfer Register \(E-PRTR\)](#) emission data reported by MS are made accessible in a public register, which is intended to provide environmental information on major industrial activities.

BAT conclusions are the technical basis for national authorities in EU countries to set permit conditions for large industrial installations. Within four years the authorities must ensure that the permit conditions are reconsidered and, if necessary, updated. If the authorities use the BAT conclusions to set permit conditions at the lowest end of the indicated emission level ranges, this can drive a sizeable reduction of emissions.

Best available techniques (BAT) conclusions aim at achieving a high level of protection of the environment as a whole under economically and technically viable conditions. They cover not only the emission levels and other environmental performance of several (production) techniques but also include standards for how the technology is used and the way in which the installation is designed, built, maintained, operated and decommissioned. The so-called Seville process defines the production and the adoption of the Best Available Techniques (BAT) Reference Document and its subsequent BAT conclusions.

The drafting of the BAT conclusions has been led by the European Commission's Joint Research Centre (JRC) through its European Integrated Pollution Prevention and Control Bureau (EIPPCB) and drawn up with the involvement of experts from industry, EU public authorities, environmental NGOs and the European Commission.

5.1.2 Key obligations

5.1.2.1 Monitoring

The monitoring of emissions to air and water represents an important element in preventing and reducing pollution from industrial installations and in ensuring a high level of protection of the environment taken as a whole. Therefore, the Industrial Emissions Directive (Directive 2010/75/EU) addresses the monitoring of emissions in a number of instances, including the following:

- BAT conclusions contain the emission levels associated with the best available techniques (BAT) and the associated monitoring (Directive 2010/75/EU, Article 3 (12)).
- The exchange of information on BAT for the drawing up and review of BAT reference documents shall address the techniques used and the associated monitoring (Directive 2010/75/EU, Article 13 (2) (b)).
- Permits shall contain suitable emission monitoring requirements (Directive 2010/75/EU, Article 14(1)(c) and (d)).
- Monitoring requirements in permits shall, where applicable, be based on the conclusions on monitoring as described in the BAT conclusions (Directive 2010/75/EU, Article 16(1)).
- The competent authority shall make publicly available the results of emission monitoring as required under the permit conditions and held by the competent authority (Directive 2010/75/EU, Article 24(3)(b)).

The continuous measurements carried out above shall include the relevant process operation parameters of oxygen content, temperature, pressure and water vapour content. The continuous measurement of the water vapour content of the exhaust gases shall not be necessary, provided that the sampled exhaust gas is dried before the emissions are analyzed.

Representative measurements, i.e., sampling and analysis, of relevant pollutants and process parameters as well as reference measurement methods to calibrate automated measurement systems shall be carried out in accordance with CEN standards as soon as they are available. If CEN standards are not available ISO standards, national or international standards which will ensure the provision of data of an equivalent scientific quality shall apply.

Continuous measuring systems shall be subject to control by means of parallel measurements with the reference methods at least every year.

The values of the 95% confidence intervals of a single measured result shall not exceed the following percentages of the emission limit values:

- Sulphur dioxide 20%
- Nitrogen oxides 20%
- Dust 30%

The validated hourly and daily average values shall be determined from the measured valid hourly average values after having subtracted the value of the confidence interval specified above.

5.1.2.2 Reporting

Article 13 of Directive 2001/80/EC states that the Member States shall take appropriate measures to ensure that the operator informs the competent authorities within reasonable time limits about the results of the continuous measurements, the checking of the measuring equipment, the individual measurements and all other measurements carried out in order to assess compliance with this Directive.

The competent authorities shall be informed of substantial changes in the type of fuel used or in the mode of operation of the plant. They shall decide whether the monitoring requirements laid down in paragraph 2 are still adequate or require adaptation.

5.1.2.3 Verification

Competent authorities shall require continuous measurements of concentrations of SO₂, NO_x, and dust from waste gases from each combustion plant with a rated thermal input of 100 MW or more. Continuous measurements may not be required in the following cases:

- for combustion plants with a life span of less than 10 000 operational hours;
- for SO₂ and dust from natural gas burning boilers or from gas turbines firing natural gas;
- for SO₂ from gas turbines or boilers firing oil with known sulphur content in cases where there is no desulphurization equipment;
- for SO₂ from biomass firing boilers if the operator can prove that the SO₂ emissions can under no circumstances be higher than the prescribed emission limit values.

Where continuous measurements are not required, discontinuous measurements shall be required at least every six months. As an alternative, appropriate determination procedures, which must be verified and approved by the competent authorities, may be used to evaluate the quantity of the above-mentioned pollutants present in the emissions. Such procedures shall use relevant CEN standards as soon as they are available. If CEN standards

are not available ISO standards, national or international standards which will ensure the provision of data of an equivalent scientific quality shall apply.

In the case of plants which must comply with the desulphurization rates fixed by Article 5(2) and Annex III, the requirements concerning SO₂ emission measurements established under paragraph 2 above of this point shall apply. Moreover, the sulphur content of the fuel which is introduced into the combustion plant facilities must be regularly monitored.

5.1.2.4 Enforcement

Regulations provide for applications for licenses, reviews of licenses or revised licenses, consideration by the Agency of objections, including the holding of oral hearings, public participation procedures associated with the industrial emissions licensing system administered by the Agency and the contents of the register of licenses. To ensure the effective implementation and enforcement of the IED, operators should regularly report to the competent authority on compliance with permit conditions. Member States should ensure that the operator and the competent authority each take necessary measures in the event of non-compliance with this Directive and provide for a system of environmental inspections. Member States should ensure that sufficient staff are available with the skills and qualifications needed to carry out those inspections effectively.

Regulators may at any time revoke a permit, in whole or in part, by serving a "revocation notice" on the operator (Regulation 22 of the Environmental Permitting Regulations). If a regulator is of the opinion that an operator has contravened, is contravening or is likely to contravene any condition of his permit, the regulator may arrange for steps to be taken to remove that risk or may serve an "enforcement notice" (Regulation 26 of the Environmental Permitting Regulations). If a regulator is of the opinion that the operation of the installation or mobile plant involves an imminent risk of serious pollution, it shall serve a "suspension notice" on the operator (Regulation 37(2) of the Environmental Permitting Regulations).

5.1.3 Experience

Industrial experience has been gained concerning techniques and equipment for the measurement of the principal pollutants emitted by large combustion plants; the European Committee for Standardization (CEN) has undertaken work with the aim of providing a framework securing comparable measurement results within the Community and guaranteeing a high level of quality of such measurements.

A common approach has been identified and it is recommended that this should be applied to ensure that key components of the self-monitoring reports are included in the analysis. The assessment of the self-monitoring report submitted by the operator should usually cover the following aspects:

- whether the report was submitted by the agreed date and according to the required frequency of reporting as set out in the permit conditions
- the use of appropriate templates for reporting, if required
- the completeness of data and parameters required including frequency and extent of measurements
- the adequacy of the operator to self-monitor its emissions: whether measurements were carried out on-site or not, by the required person or institution (internal or external laboratories, with appropriate quality control, with certification or accreditation, if necessary), by appropriate sampling at specified

locations, using appropriate analytical methods and instrumentation, at a clearly defined operation status of the installation

- a review of calculations and statistical analysis of the monitoring data (especially in more complex reports).

The nature and scope of the analysis should include, as a minimum, an assessment of compliance with the emission limit values set out in the permit. It may also include:

- a check of overall compliance of the installation with environmental permit conditions
- an analysis of the trends in environmental parameters (e.g. material and energy consumption, emissions, amount of waste produced) in order to check the operational performance of the installation so that timely action can be taken to ensure that it continues to operate within the definition of BAT
- an assessment of critical conditions to be focused on in the next inspection
- a comparison of the performance of the installation with other installations in the specific sector
- a comparison of the performance of the installation with BAT.

Useful tools for the analysis are:

- appropriate templates for the assessment and reporting on self-monitoring reports to simplify and standardize the analysis
- use of a (national) database for the storage and exchange of the operator reports and of the assessment process (which may involve several experts)
- independent monitoring to cross-check the operator self-monitoring, e.g. by analyzing samples taken during on-site visits, including split samples.

As far as the output of the self-monitoring report analysis is concerned, the Industrial Emissions Directive (IED) has no specific requirements for the preparation of the report of the evaluation. Consequently, EU Member States use different approaches in the reporting of the results of the analysis of the operator's self-monitoring:

- some produce the report according to a standard template and others take a free-form approach,
- some produce the report as a separate document outside the site-inspection, and others incorporate the self-monitoring analysis with the reports from on-the-spot inspections,
- in some countries the reporting of the evaluation is a formal requirement, but in others it is not.

In some countries a report on the analysis of the self-monitoring report is produced only in cases where non-compliances have occurred. In others, a report is produced even if no non-compliances are reported or detected. In these cases, the document provides evidence that supports confirmation of compliance with the conditions of the permit and the requirements of the regulations (such as: compliance with ELVs and other required parameters set in the permit, operator monitoring equipment and regime, accreditation of laboratory, time limit for reporting, frequency of reporting, use of required template for reporting).

There are also differences in practice over the notification and release of the inspector's report to the operator and other competent authorities. In some countries, the inspector may only provide notification that the report has been produced (and that it may have been placed on an inspection database). In others, the inspector's report is submitted directly to the operator or to the competent authority. Templates for report of the self-monitoring analysis have been developed in some countries.

In Ireland the Competent Authority (CA) has developed an online system called LEMA (Licensing, Enforcement, and Monitoring and Assessment system). Non-compliances must be reported to the CA through this module. Where a non-compliance is notified to the CA, an Inspector initially considers whether it has the potential to be significant. This is undertaken through a compliance investigation online process and assigned a risk score. All risk scores above a specified value are considered to 'pose an immediate danger to human health or threatens to cause an immediate significant adverse effect upon the environment' (Armstrong et al., 2016).

5.2 The Medium Combustion Plant Directive (MCPD)

5.2.1 Concept

To fill the regulatory gap at EU level between large combustion plants, covered by the Industrial Emissions Directive (IED) and smaller appliances (heaters and boilers) covered by the Ecodesign Directive, The Medium Combustion Plant Directive ((EU) 2015/2193)) on the limitation of emissions of certain pollutants into the air regulates pollutant emissions from the combustion of fuels in plants with a rated thermal input equal to or greater than 1 Megawatt thermal (MW_{th}) and less than 50 MW_{th} . The MCPD focuses on regulating emissions of SO_2 , NO_x and dust.

There are estimated to be around 143,000 Medium combustion plants (MCPs) in the EU. They are used for a wide variety of applications (for example electricity generation, domestic or residential heating and cooling, providing heat or steam for industrial processes).

5.2.2 Key obligations

5.2.2.1 Monitoring

Directive (EU) 2015/2193 on the limitation of emissions of certain pollutants into the air from medium combustion plants recommended that

1. Periodic measurements shall be required at least:
 - every three years for medium combustion plants with a rated thermal input equal to or greater than 1 MW and less than or equal to 20 MW,
 - every year for medium combustion plants with a rated thermal input greater than 20 MW.
2. As an alternative to the frequencies referred in point 1, in the case of medium combustion plants which are subject to Article 6(3) or Article 6(8), periodic measurements may be required at least each time the following numbers of operating hours have elapsed:
 - three times the number of maximum average annual operating hours, applicable pursuant to Article 6(3) or Article 6(8), for medium combustion plants with a rated thermal input equal to or greater than 1 MW and less than or equal to 20 MW,
 - the number of maximum average annual operating hours, applicable pursuant to Article 6(3) or Article 6(8), for medium combustion plants with a rated thermal input greater than 20 MW.

The frequency of periodic measurements shall in any case not be lower than once every five years.

3. Measurements shall be required only for: (a) pollutants for which an emission limit value is laid down in this Directive for the plant concerned; (b) CO for all plants.
4. The first measurements shall be carried out within four months of the grant of a permit to, or registration of, the plant, or of the date of the start of the operation, whichever is the latest.
5. As an alternative to the measurements referred to in points 1, 2 and 3(a), as regards SO₂, other procedures, verified and approved by the competent authority, may be used to determine the SO₂ emissions.
6. As an alternative to the periodic measurements referred to in point 1, Member States may require continuous measurements. In the case of continuous measurements, the automated measuring systems shall be subject to checking by means of parallel measurements with the reference methods at least once per year and the operator shall inform the competent authority about the results of those checks.
7. Sampling and analysis of polluting substances and measurements of process parameters as well as any alternatives used as referred to under points 5 and 6 shall be based on methods enabling reliable, representative, and comparable results. Methods complying with harmonised EN standards shall be presumed to satisfy this requirement. During each measurement, the plant shall be operating under stable conditions at a representative even load. In this context, start-up and shut-down periods shall be excluded.

5.2.2.2 Reporting

Member States are required to report to the Commission in 2021, 2026 and 2031 on various aspects of emissions from MCPs. The Commission will regularly report on implementation of the MCPD. It will address further issues, such as energy efficiency and carbon monoxide emissions, as required by its review clauses.

In order to limit the burden for small and medium-sized enterprises operating medium combustion plants, the administrative obligations on operators concerning the provision of information, monitoring and reporting should be proportionate and avoid duplication, while still allowing for effective compliance verification by the competent authority.

5.2.3 Experience

Due to the recent nature of the MCP, no practical experience has been accrued to date.

5.3 The Ecodesign directive

5.3.1 Concept

The EU legislation on eco-design (Directive 2009/125/EC) and energy labelling (Regulation (EU) 2017/1369) aims at improving the energy efficiency of products. It helps eliminate the least performing products from the market, significantly contributing to the EU's 2020 energy efficiency objective. It also supports industrial

competitiveness and innovation by promoting the better environmental performance of products throughout the internal market.

The eco-design directive provides consistent EU-wide rules for improving the environmental performance of products, such as household appliances, information and communication technologies or engineering. The directive sets out minimum mandatory requirements for the energy efficiency of these products. This helps prevent creation of barriers to trade, improve product quality and environmental protection. The energy labelling regulation may complement those eco-design requirements with mandatory labelling requirements.

The eco-design directive and the energy labelling regulation also establish a consultation forum to consult stakeholders on the implementation of the directive and regulation. The list of members includes representatives from EU countries, industry and civil society. The group is open for observers from candidate and European Free Trade Association (EFTA) countries, and from organizations that have a legitimate interest in the discussion.

The eco-design directive is implemented through product-specific regulations, directly applicable in all EU countries¹⁵. Eco-design and energy labelling regulations are complemented by harmonized European standards. These technical specifications indicate that a product complies with the mandatory requirements. Only then can the manufacturer affix the CE marking and sell it in the EU¹⁶.

The Energy Labelling Directive is another key measure for tapping European energy efficiency potentials. With the so-called energy label, products on the market are labelled accordingly, are easier to compare and the end user kept sufficiently informed. The energy label specifies the heating capacity, efficiency class and sound power level as well as the energy consumption using a color scale from green (efficient) to red (wasteful). The Directive for Energy-related Products – ErP Directive - enables efficiency and emissions comparisons for different types of heaters (or “lots” of heater).

The first ecodesign Directive 2009/125/EC (EC, 2009a) aimed at environmental compatibility of energy-consuming products. In 2013, an extension for heaters came into effect after previous enhancements of pumps and air conditioning units. Today, ecodesign requirements also apply to lighting appliances, heating appliances and cooking appliances.

5.3.2 Key obligations

5.3.2.1 Monitoring

The Directive 2009/125/EC establishing a framework for the setting of ecodesign requirements for energy-related products clearly states that self-regulatory initiatives must contain a well-designed monitoring system, with clearly identified responsibilities for industry and independent inspectors (EC, 2009a). The European

¹⁵ See the lists of all [ecodesign and energy labelling regulations](#) and the list of all [voluntary agreements](#).

¹⁶ List of [harmonised standards for ecodesign and energy labelling](#)

Commission, in partnership with the parties to the self-regulatory initiative, must be invited to monitor the achievement of the objectives. The plan for monitoring and reporting must be detailed, transparent and objective. It must remain for the Commission services, assisted by the Committee, to consider whether the objectives of the voluntary agreement or other self-regulatory measures have been met (EC, 2009a).

The responsibilities of the European Commission include monitoring the implementation progress at national level, in addition to overseeing the market surveillance conducted in the Member States. As part of the review process, the European Commission has to systematically monitor and report on the impact of the Ecodesign and Energy labelling measures.

5.3.2.2. Enforcement

National market surveillance authorities are charged to verify whether products sold in the EU follow the requirements laid out in ecodesign and energy labelling regulations.

5.3.3. Experience

The Ecodesign Impact Accounting study (Aarts et al., 2016) included sources that account for approximately 53% of total EU-28 gross energy consumption in 2010. It is projected that by 2020, the primary energy savings due to the combination of the Ecodesign Directive and the Energy Labelling Directive will be 18% for the average product, compared to the business-as-usual scenario. This is equivalent to 7% lower greenhouse gas emissions in the EU, based on 2010 figures. By 2030, primary energy savings are predicted to be 30% for the average product, compared to the business-as-usual scenario, resulting in 11% less greenhouse gas emissions. While this calculation assumes all products on the market to be in conformance with the Directive, it is recognised that an estimated 10-25% of products on the market do not comply with ecodesign and energy labelling requirements. As such, this is calculated as an approximate energy savings loss of 10%.

5.4 Performance standards for mobile sources

Air pollutant emissions from transport are a main contributor to air quality problems in Europe. Vehicle emissions of particulate matter (PM), nitrogen oxides (NO_x), unburnt hydrocarbons (HC) and carbon monoxide (CO) are regulated in the EU. Emission regulations are adopted as part of the EU framework for the type approval of cars, vans, trucks, buses, and coaches as well as powered two- and three-wheelers and quadricycles. Successive "Euro" standards are designated by Arabic numerals for light-duty vehicles (cars and vans) and Roman numerals for heavy-duty vehicles (trucks, buses, and coaches). The latest standards are Euro 6 for light-duty, and Euro VI for heavy-duty vehicles, and Euro 5 for powered two- and three-wheelers and quadricycles.

- Directive 2007/46/EC provides a common legal framework for the type approval of cars, vans, trucks, buses, and coaches.
- Euro 5 and Euro 6 [Regulation 715/2007/EC](#) sets the emission limits for cars for regulated pollutants, in particular nitrogen oxides (NO_x, i.e. the combined emissions of NO and NO₂) of 80 mg/km.
- Regulation [692/2008/EC](#) implements and amends Regulation (EC) No 715/2007 on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information.

- Regulations [2017/1151 \(Worldwide Harmonised Light Vehicle Test Procedure\)](#) and [2018/1832 \(Real-Driving Emissions 4\)](#) are defining the new test procedures for vehicle type approval and enable real world testing, including testing by independent certified laboratories.
- Regulation [595/2009/EC](#) requires new heavy duty vehicles and engines to comply with new emission limits and introduces additional requirements on access to information.
- Commission Regulation [\(EU\) 582/2011](#) implements and amends Regulation (EC) No 595/2009 with respect to emissions from heavy duty vehicles (Euro VI).
- Latest emission limit value for powered two- and three-wheelers and quads are set in Regulation (EU) No 168/2013 of the European Parliament and of the Council of 15 January 2013 on the approval and market surveillance of two- or three-wheeled vehicles and quadricycles.

Exhaust emission standards have been tightened roughly every five years balancing-off and effectively outpacing growth in traffic volumes. This has led to a very significant decline in emissions of all regulated pollutants (exhaust PM, NO_x, various hydrocarbons including the cancerogenic benzene, and CO), both at the level of individual vehicles as well as total pollutant emissions. The one exception is NO_x emissions from diesel light-duty vehicles: Emissions of NO and NO₂ have increased in real driving up to Euro 5 although exhaust emission standards have become tighter nominally. In the same period (1996 to 2015) the number and use of diesel passenger cars has strongly increased throughout Europe. Together this has offset NO_x emission reductions from other sectors and contributed to widespread exceedances of the NO₂ ambient air quality standards along major roads (EEA, 2017). The key discrepancy is that diesel vehicles have complied with ever tighter exhaust emission standards in the laboratory testing during type-approval, but that vehicle software reduced NO_x emission controls when driven on the road. This has become known as the "diesel emission scandal" and attributed largely to deliberate actions of manufacturers in conjunction with inadequate legislation, monitoring and enforcement of real-world emission performance (EP, 2017a). Catalyzed by these findings the EU system of type-approval, testing and monitoring for light duty vehicles has been revised substantially.

The latest Euro 6 emission standard for light duty vehicles has been introduced in several steps between 2014 and 2022. Fundamentally, the type approval emission testing procedure has added on-road testing in real-driving conditions (RDE) with a portable emission measurement system (PEMS). This new test procedure and the associated limit values applies for NO_x as well as PM and PN (particle mass and number) emissions (EC, 2018a). Thus, driving and ambient conditions are more random in order to resemble real driving, with only certain boundary conditions like dynamics, maximum speeds, trip characteristics and length prescribed. At the same time, the driving cycle for chassis dynamometer testing has been updated from the so-called New European Driving Cycle (NEDC) to the so-called World harmonised Light vehicle Test Procedure (WLTP). This is intended to represent more realistic driving conditions and is used in particular for the CO₂ testing (EC, 2017). It is also a move to harmonize type approval globally. In addition, in-use conformity testing has been revised, i.e. the monitoring of vehicle during their lifetime, to be discussed below. These revisions are part of the European Commission's wider work for a clean, sustainable, and competitive car sector as laid down in the Commission Communication 'Europe on the Move' (EC, 2018b). Commission initiatives include air quality and CO₂ standards, the improvement of emission testing for cars or the support for alternative fuels and battery production.

5.4.1 Concept

Vehicles' pollutant emissions are controlled through several mechanisms:

- Manufacturers have to demonstrate that their vehicles comply with the exhaust and evaporative emission limits in force when the vehicles are newly produced and before being placed on the market. This is the type approval testing procedure, performed at individual vehicle models.
- Manufacturers further have to guarantee that vehicle produced do conform to the same emission limits (within uncertainties) as the prototype tested. This is the so-called Conformity of Production; it allows that only selected vehicles are tested and not every single one.

These two elements address emission controls for new vehicles. Vehicles in use are subject to the following regulations:

- Manufacturers have to guarantee the durability of the emission controls for a certain minimum vehicle lifetime or mileage. With Euro 6/VI the durability limits are required for 5 years or 160,000 km for light duty vehicles and 7 years or 500,000 km for HHDV, whichever is first.
- Member States are required to test a certain number of in-use vehicles each year to monitor the so-called "in-service conformity", i.e. to check whether emission controls are actually working as intended.

In addition, test results from Third Parties will also be considered in the "in-use" monitoring, when a certain testing quality is assured.

Type-approval focuses on pre-market compliance checks of vehicles that come off the manufacturing assembly line. The manufacturer makes available about a dozen or more pre-production cars that are equal to the final product. If all relevant requirements are met, a designated type approval authority delivers certificate to the manufacturer authorizing the sale of the vehicle type in the whole of the EU. Every vehicle produced is accompanied by a Certificate of Conformity which is like the car's birth certificate and indicates that the vehicle corresponds to an approved type. On the basis of this document, the vehicle can be registered.

The primary obligation to ensure compliance resides with the manufacturer. National authorities are responsible to carry out (or supervise) the type-approval testing. In-use compliance assessments have so far been the sole responsibility of the national authority that has originally granted type approval. With the Euro 6 legislation type approval authorities, independent parties and the Commission will be able to perform officially recognized tests through accredited laboratories and technical services.

5.4.2 Key obligations

5.4.2.1 Monitoring

For testing these prototypes Member States and the Commission carry out compliance verification spot-checks of vehicles already on the market. All Member States have to carry out a verification test on at least one car for every 40,000 new motor vehicles that have been registered. Although the focus is on emission testing, safety is also checked. Given that in 2017 almost 17.5 million new motor vehicles were registered in the EU, this would mean that in the future at least 435 vehicle market surveillance checks would have to be carried out spread over the Member States to meet the new obligations.

The Commission will carry out compliance and conformity checks through its Joint Research Centre. It will be the technical arm of the supervisory system of the Commission and will carry out selected regulatory emissions testing in the laboratory and on the road, as well as perform vehicle safety checks in line with the applicable regulations. This will allow the Commission to make an informed and unbiased judgement on any non-compliance. There is no minimum number of checks for the Commission, but future cases will be selected on the basis of risk assessment, suspicion and indication of compliance issues in the field.

5.4.2.2. Reporting

Manufacturers of light duty vehicles must report the CO₂ emissions from type approval tests since 2010. Data are collected and published by the EEA (2020). This will also be introduced for the reporting of CO₂ emissions from heavy duty vehicles in the EU. With the Euro 6 emission legislation manufacturers must make RDE test results publicly available (for instance, ACEA 2019). Else, registration of new vehicles along with their technical characteristics is reported by national registration authorities and – in part – also transmitted to the European Statistical Office.

5.4.2.3. Verification

Type approval authorities are required to verify emission tests, conformity of production and in-use compliance for the vehicles. They can do so themselves or by accredited technical services. In addition, test by the European Commission and third parties have also become officially recognized with the Euro 6 legislation. If a suspicious emission performance is indicated by such tests national authorities are required to follow-up with investigations. Other Member States will be able to challenge a designation when something is wrong. The Commission will have the power to suspend, restrict or withdraw the designation of technical services that are underperforming and too lax in applying the rules.

Vehicle manufacturers must demonstrate that vehicles comply with the test procedures specified in a series of Annexes to the Implementing Regulation (Art. 3.4). These procedures serve a number of purposes, including the verification of average exhaust emissions as well as crankcase gas emissions and the determination of CO₂ emissions and fuel consumption. Furthermore, vehicles are subject to the tests specified in a table contained in Annex I listing the different types of tests applicable for the different vehicle types (vehicles with positive ignition engines or with compression ignition engines; mono-, bi- or flex-fuel vehicles) for which OEMs are obliged to provide the responsible technical service with a vehicle that is representative of the type submitted for approval (Art. 5 par. 8).

5.4.2.4 Enforcement

In the future, Member States will also be subject to greater scrutiny. They will have to regularly review the functioning of their market surveillance activities and make the results publicly available. National type-approval authorities will be subject to peer evaluations if they assess their own technical services instead of the national accreditation bodies, but they will always be subject to an independent assessment carried out directly by the Commission to ensure that the relevant rules are implemented and enforced rigorously across the EU.

An Enforcement Forum will coordinate the network of national authorities responsible for type-approval and market surveillance. It will also have an advisory role to promote good practices, exchange of information on

enforcement problems and penalties, cooperation, development of working methods and tools, development of an electronic information exchange platform, evaluation of harmonized enforcement projects and joint audits. Member States will nominate their representatives in the Forum.

The tasks and composition of the Forum will be further specified by a Commission delegated act. Existing market surveillance platforms, such as Rapid Alert System (RAPEX) and the Information and Communication System on Market Surveillance (ICSMS) will be further used and strengthened for exchange of information of market surveillance activities.

In parallel, the Commission continues to monitor whether EU law in this area was correctly enforced by Member States in the past. It opened infringement procedures against eight Member States for breaching EU type approval legislation in December 2016 and May 2017.

5.4.3 Experience

The European experience with emission controls from vehicles has been largely a success, but also seen some noteworthy failures: Pollutant emissions per vehicle have decreased by about two orders of magnitude since the application of common Euro emission standards. This has been more than enough to outpace the initial strong growth in traffic volumes; after early years of increasing total pollutant emissions they have now been decreasing throughout Europe. The notable failure is the “diesel emission scandal” that has brought to light several important shortcomings of the previous legal emission testing framework (EP, 2017a). Several improvements have been suggested as consequence (EP, 2017b), among others:

- Type approval testing should move away from narrowly prescribed test cycles to real-driving testing.
- In-use conformity testing should account for any credible test and not depend on a single national type approval authority.
- The European Commission should have oversight and the right to intervene in case of inaction or insufficient action by national authorities.
- Penalties need to be specified for infractions of the emission legislation.

Technical progress for in-use monitoring of vehicle emissions e.g. by PEMS or remote sensing allows for a much more comprehensive assessment of the performance of the fleet, individual models and vehicles.

Summary and conclusions

Over the last decades the European Union has established strict air quality objectives, together with a comprehensive legal framework that should facilitate the achievements of these objectives. As a consequence, air quality has drastically improved in Europe, although the long-term objectives are still not met.

The EU clean air legislation played an important role in these air quality improvements. Most importantly, the legal framework provided an effective response mechanism strategy to manage the complex interlinkages between the multitude of pollution sources and the regionally dispersed impacts on air quality which span across different legislation. These connections, which are a direct consequence of the physical nature of the key air pollutants (i.e., their long residence time in the atmosphere), make response strategies that extend beyond individual cities and countries indispensable.

In order to implement effective policy responses, the area of the European Union is now considered as one airshed containing 27 Member States, and action needs to be coordinated between countries, regions, and city administrations. The clean air legislation of the EU acknowledges that the European Union as a supra-national institution has to play an important coordinating role in the policy response. It has been found practical to combine three legal pillars into a comprehensive EU clean air legislation framework:

- The Ambient Air Quality Directives,
- the National Emission Ceilings Directive, and
- Source-specific performance standards.

One important feature of EU policy that contributed to the success is that, in addition to the key obligations for reaching air quality standards and reducing emissions, all directives contain specific requirements and mechanisms for monitoring, reporting, validation and enforcement.

Although the recent nature of some of the directives does not always allow for practical experience, systematic stock-taking on the strengths and weaknesses of older legislation has been recently conducted. This report summarizes the findings emerging from these assessments and indicates options for improvements that could be of interest for the design of effective clean air policies in other parts of the world.

While the EU legal framework has obviously been developed for the EU situation, there might be important lessons, particularly on monitoring, review and verification, that could provide relevant insights for other countries which face similar complexities in air quality management, e.g., the need to involve multiple governance levels across State borders.

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Appendix -1

Table A.1. Air quality standards for different pollutants according to the AAQ Directives

Pollutant	Concentration	Averaging period	Legal nature	Date entering into force	Permitted exceedances each year
Sulphur dioxide (SO ₂)	350 µg/m ³	1 hour	Limit value	38353	24
	125 µg/m ³	24 hours	Limit value	38353	3
Particulate matter (PM ₁₀)	50 µg/m ³	24 hours	Limit value	1.1.2005**	35
	40 µg/m ³	1 year	Limit value	1.1.2005**	n/a
Fine particulate matter (PM _{2.5})	25 µg/m ³	1 year	Target value	1.1.2010	n/a n/a
			Limit value	1.1.2015	
Nitrogen dioxide (NO ₂)	200 µg/m ³	1 hour	Limit value	1.1.2010*	18
	40 µg/m ³	1 year	Limit value	1.1.2010*	n/a
Lead (Pb)	0.5 µg/m ³	1 year	Limit value	1.1.2005***	n/a
Carbon monoxide (CO)	10 mg/m ³	Max daily 8 hours mean	Limit value	38353	n/a
Ozone	120 µg/m ³	Max daily 8 hours mean	Target value	40179	25 days averaged over 3 years
Benzene	5 µg/m ³	1 year	Limit value	1.1.2010**	n/a
Arsenic (As)	6 ng/m ³	1 year	Target value	41274	n/a
Cadmium (Cd)	5 ng/m ³	1 year	Target value	41274	n/a
Nickel (Ni)	20 ng/m ³	1 year	Target value	41274	n/a
Benzo(a)pyrene (BaP)	1 ng/m ³	1 year	Target value	41274	n/a

*Under Directive 2008/50/EU, the MS could apply for a postponement of a maximum of five years (i.e. maximum up to 2015) in specific zones; subject to an assessment by the Commission.

**Under Directive 2008/50/EU, MS were able to apply for an exemption to apply these limits until 11 June 2011 in specific zones; subject to assessment by the Commission.

*** Or 1.1.2010 in the immediate vicinity of specific, notified industrial sources; and a 1.0 µg/m³ limit value applied from 1.1.2005 to 31.12.2009.