12.
Industrial pollution

Key messages

- Industry contributes significantly to the emissions of many pollutants and greenhouse gases into the European environment. Releases of pollutants by European industry have generally decreased during the last decade and are expected to continue to do so.

- Environmental policy has been the main driver of reductions in industrial emissions in the past decade, especially for emissions to air for which the reductions are larger than those for emissions to water.

- However only emissions of historically important pollutants are reported by industry, and information on emerging pollutants is lacking. A lack of robust data does not allow assessment of progress towards overall clean production processes.

- The impacts and costs of pollution from industry to the environment and human health remain high. Existing policy instruments are expected to lead to further reductions in industrial emissions but current policies do not address the full scope of the industrial pollution load to the environment.

- Decarbonisation of industry stimulated by climate change mitigation policies is expected to be the main driver of reductions in industrial air pollutant and greenhouse gas emissions in the medium and long term. However there is clear scope for further integration of environmental objectives into the EU's industrial policy.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets
	Past trends (10-15 years)	Outlook to 2030	2020
Pollutant emissions from industry	Improving trends dominate	Developments show a mixed picture	☐ Partly on track
Clean industrial technologies and processes	Improving trends dominate	Developments show a mixed picture	☐ Partly on track

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 12.3, Key trends and outlooks (Tables 12.2 and 12.4).

12.

Industrial pollution

12.1 Scope of the theme

Industry is a key component of Europe's economy and plays a significant role in society's economic well-being. It accounts for 17.6 % of gross domestic product (GDP) (Eurostat, 2018b) and directly employs 36 million people (Eurostat, 2018a) in the 28 EU Member States (EU-28). At the same time, industrial activities are a source of pressure on the environment in the form of emissions to the atmosphere and water ecosystems, generating waste and consuming resources. This chapter assesses the trends in and outlooks for these pressures as well as the progress towards implementing clean industrial technologies and processes.

This assessment addresses the energy supply, extractive and manufacturing industry sectors as well as waste and waste water management. Please refer to the EEA's recent work on mapping emission inventories for more details (EEA, 2018b). Here, the extractive and manufacturing sectors are grouped into heavy industry (ferrous and non-ferrous metal processing, extractive industry) and light industry (food and drink, pulp, paper and wood, other manufacturing).

Industry contributes significantly to pollutant emissions into Europe's environment.

The European Pollutant Release and Transfer Register (E-PRTR) (EEA, 2019h) is the main data source for this chapter. It is supplemented by the Large Combustion Plant (LCP) inventory (EEA, 2018c), the data reported under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) (EEA, 2019f), and the Greenhouse Gas (GHG) inventory (EEA, 2019g), reported under the European Monitoring Mechanism Regulation (MMR; EU/ 525/2013).

The assessment covers a range of key industrial air pollutants and GHGs, namely those reported to the E-PRTR between 2007 and 2011 by at least 5 % of all the facilities in each industrial sector (see Section 12.3.1 and Figure 12.3). Emissions of GHGs contribute to climate change (Chapter 7), while air pollutants have various health and environmental impacts (Chapter 8).

All reported substances released to water are taken into account rather than choosing specific key pollutants (see Section 12.3.1 and Figure 12.5). The various pollutants in the overarching pollutant groups can have a variety of impacts (Chapters 4 and 6). Persistent and mobile substances that cannot be removed by waste water treatment plants are covered in more detail in Chapter 10.

More details on sources as well as the potential health and environmental

TABLE 12.1 Selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Industrial Pollution			
'...to prevent or, where that is not practicable, to reduce emissions into air, water and land and to prevent the generation of waste, in order to achieve a high level of protection of the environment taken as a whole'	IED (EU, 2010)	Permanent	Binding legislation
'By 2020, [...] significantly reduce [the release of chemicals] to air, water and soil in order to minimize their adverse impacts on human health and the environment'	SDG 12.4 (UN, 2015)	2020	Non-binding commitment
'By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes...'	SDG 9.4 (UN, 2015)	2030	Non-binding commitment
'...uptake by industry of best available techniques and emerging innovations...'	7th EAP (EC, 2013)	2020	Non-binding commitment
Increase resource efficiency of industry	IED (EU, 2010)	N/A	Non-binding commitment

Note: 7th EAP, Seventh Environment Action Programme; N/A, non-applicable.

impacts of the pollutants covered are also available on the E-PRTR website ([1]).

Not all pollutants released into the environment by industry are monitored or reported, which limits the scope of this chapter. For example, more than 22 600 chemical substances are registered for use under the Regulation on registration, evaluation, authorisation and restriction of chemicals (REACH Regulation; (EC) No 1907/2006; ECHA, 2019), while the European industrial policy requires regular emission reporting of only 91 specific pollutants. REACH and other legislation governing the use and placing on the market of chemicals are addressed elsewhere (Chapter 10). Likewise, the resource efficiency of industry is assessed in detail in Chapter 9. In addition, the EEA indicator 'Industrial waste in Europe' provides additional information (EEA, 2019d). Industrial pollutant releases to land (see Chapter 5) and the resulting soil contamination, industrial waste (see Chapter 9) and industrial accidents are not covered in this chapter either.

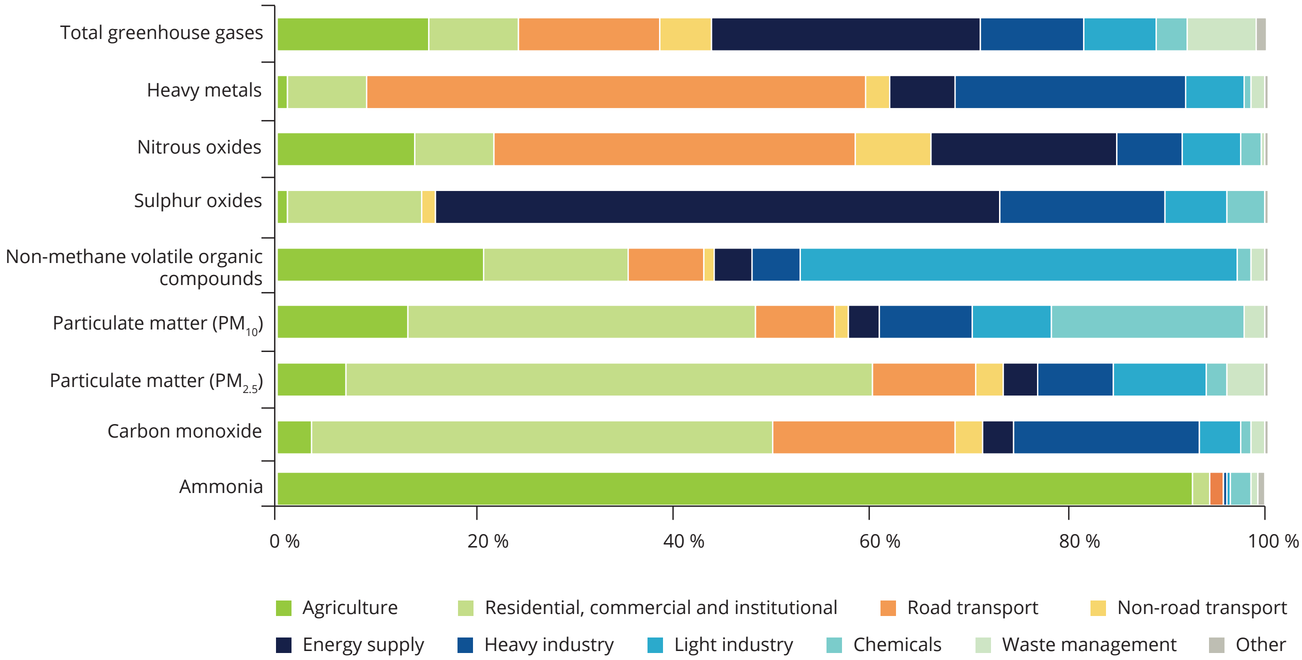
12.2 Policy landscape

Regulation of industrial pollution in the EU started in the 1970s, addressing especially transboundary air pollution and aiming to ensure a level playing field in the EU internal market (Hey, 2005). Even at that time, European industrial pollution policy was in many ways designed to support objectives established in other policy themes. Today, examples of this include:

- national pollutant emission ceilings established by the National Emission Ceiling (NEC) Directive (2016/2284/EU; Chapter 8);
- the binding commitment to achieve good ecological and chemical status of all water bodies in Europe in accordance with the Water Framework Directive (WFD, 2000/60/EC) as well as the requirement to treat urban waste water under the Urban Waste Water Treatment Directive (UWWTD; 91/271/EEC; Chapter 4);
- climate change mitigation policy objectives and targets, for example in the EU 2020 climate and energy package (EC, 2009), the EU 2030 climate

([1]) https://prtr.eea.europa.eu/#/home

FIGURE 12.1 **Air pollutant and greenhouse gas emissions as a percentage of total EEA-33 pollutant emissions in 2017, by sector**



Notes: Heavy metals include arsenic, cadmium, chromium, copper, lead, mercury and zinc and are aggregated by mass. Only those air pollutants covered by the CLRTAP are included.

Sources: EEA (2019g) for total GHGs and EEA (2019f) for air pollutants.

and energy framework (EC, 2014) or the European Commission long-term strategy for a climate neutral economy (EC, 2018) (Chapter 7);

- the policy framework provided by the EU circular economy action plan (EC, 2015), which also relies on sectoral policies to achieve widespread implementation (Chapter 9).

The Industrial Emissions Directive (IED; 2010/75/EU) contributes towards achieving many of these and other policy objectives and forms the centrepiece of industrial pollution policy. The IED is designed to take the entire environmental performance of industrial installations into account and introduces a mechanism that identifies the most cost-effective means of achieving emission reductions for a host of different industrial activities (so-called best available techniques; see also Section 12.3.2). In order to monitor progress regarding industrial pollutant emissions and to give the public access to these environmental data, the EU established the E-PRTR via the E-PRTR Regulation (EC) No 166/2006. The IED to-date does not cover all industrial activities such as mining and quarrying (which is covered by the E-PRTR).

Table 12.1 summarises the most important policy objectives and targets that relate specifically to industrial pollution. The EU's overarching industry policy, which covers everything from access to markets, competitiveness and cybersecurity to circularity and the low-carbon economy is also of relevance (EC, 2017). The United Nations Sustainable Development Goals (SDGs; UN, 2015) also address industrial pollution, for example via SDG target 9.4 and 12.4.

Greenhouse gas emissions from industry on the other hand are addressed separately by the EU emissions trading system (EU ETS; Directive 2003/87/EC) (see Chapter 7).

12.3 Key trends and outlooks

12.3.1 Pollutant emissions from industry

► See Table 12.2

Contribution of industry to air emissions

Industry was responsible for more than one quarter of nitrogen oxide (NO_x), particulate matter (here as particles ≤ 10 µm, PM_{10}) and carbon monoxide (CO) emissions and more than half of total GHG, sulphur oxide (SO_x) and non-methane volatile organic compound (NMVOC) emissions in 2017 (Figure 12.1). The relative importance

BOX 12.1 Success in reducing sulphur dioxide emissions across the EU-28

The acidifying characteristics of sulphur dioxide (SO_2) (as well as other pollutants such as NO_x) led to the well-known environmental problem of 'acid rain', which resulted in acidification of soils and freshwaters, losses of fish stocks and harm to forests across many parts of Europe. This problem was first addressed through policy during the 1970s and 80s by the United Nations Economic Commission for Europe Convention on Long-range transboundary Air Pollution, CLRTAP (UNECE, 1979) and the first and second sulphur protocols. The 1999 Gothenburg Protocol under CLRTAP and the corresponding EU National Emission Ceilings Directive later introduced binding emission ceilings for four key pollutants including SO_2. The Large Combustion Plant (LCP) Directive (2001/80/EC) on the other hand aimed to address SO_2 emissions from the activity contributing the most to total emissions in the EU: coal burning in power plants.

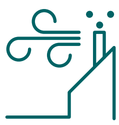
Figure 12.2 shows SO_2 emissions per unit of solid fuel (mostly coal) burned (a so-called 'implied emission factor') for those EU Member States that have such power plants. The requirements of the LCP Directive came into force in 2008 and their effect on SO_2 emissions is clearly visible in the decrease in the emission factor between 2005 and 2010. Countries with high emission factors in 2005, namely Bulgaria, Romania, Spain, Greece and Portugal, all experienced a sharp decline during that time (between -92 % in Portugal and -36 % in Romania).

Countries with medium-high emission factors for SO_2 — such as Poland, Belgium, Ireland and Italy — also achieved significant reductions by 2010. In addition, even the best performers, such as Finland, Slovenia, Germany, Denmark, the Netherlands and Austria, managed to reduce their already low emission factors further.

Further significant reductions in emission factors between 2010 and 2015 in Bulgaria, Romania, Estonia, Greece, France and Italy are likely to be linked to new stipulations coming into force under the Industrial Emissions Directive (IED; 2010/75/EU) in 2016.

New, binding and more ambitious emission limits were adopted in 2017 under the IED and will need to be reflected in permits by 2021 at the latest. This is more closely examined in Section 12.4.1 and in an EEA briefing (EEA, 2019a). The environmental performance of power plants can be tracked via the EEA indicator on emissions from large combustion plants (EEA, 2017a). ■

Sources: UNECE (1979); EEA (2017a, 2018c, 2019c).



In 2017, over half of CO_2 emissions came from industry.

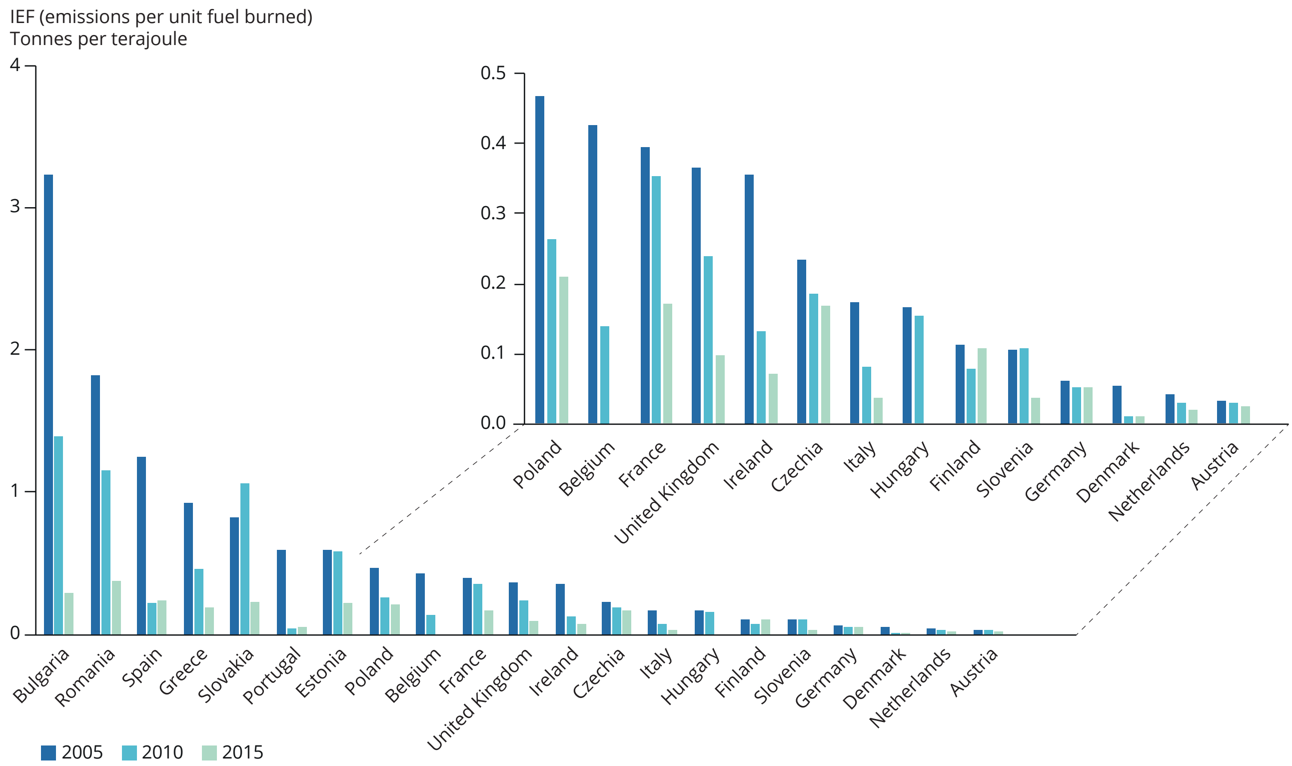
of each subsector in the context of pollutant emissions has not changed significantly since 2007 (EEA, 2019f, 2019g).

Emissions to air are often associated with the combustion of fossil fuels, which may, for example, result in emissions of SO_x, NO_x, PM_{10}, heavy metals including mercury and GHGs such as carbon dioxide (CO_2) and nitrous oxide (N_2O). This obviously applies to power plants but also to many other industrial activities that may have their own electricity or heat production on site, such as iron and steel manufacturing or cement production. Activities during which dust is generated also contribute to air emissions of, for example, particulate matter. Solvent use (e.g. during metal processing or chemical production) may lead to emissions of NMVOCs among others.

Industrial air emission trends

Reported air emissions from industry decreased for all key air pollutants and GHGs in the respective industrial sectors over the decade leading up

FIGURE 12.2 **Implied emission factors (IEFs) for SO_2 emissions from power plants burning predominantly solid fuel in 2005, 2010 and 2015, EU-28**



Note: Countries listed according to their 2005 rank. Includes only power plants for which solid fuel constitutes more than 95 % of fuel input. Countries that do not feature have no such power plants. No 2005 and 2010 data available for Sweden and Croatia. United Kingdom value for 2005 replaced by first reported value from 2007. Slovakia value for 2015 replaced by 2016 value to account for maintenance work at largest Slovakian coal power plant.

Source: EEA, 2017a

to 2017. Overall SO_x emissions have declined by 54 % since 2007, NO_x by more than one third and emissions of GHGs from industry by 12 % (Figure 12.3).

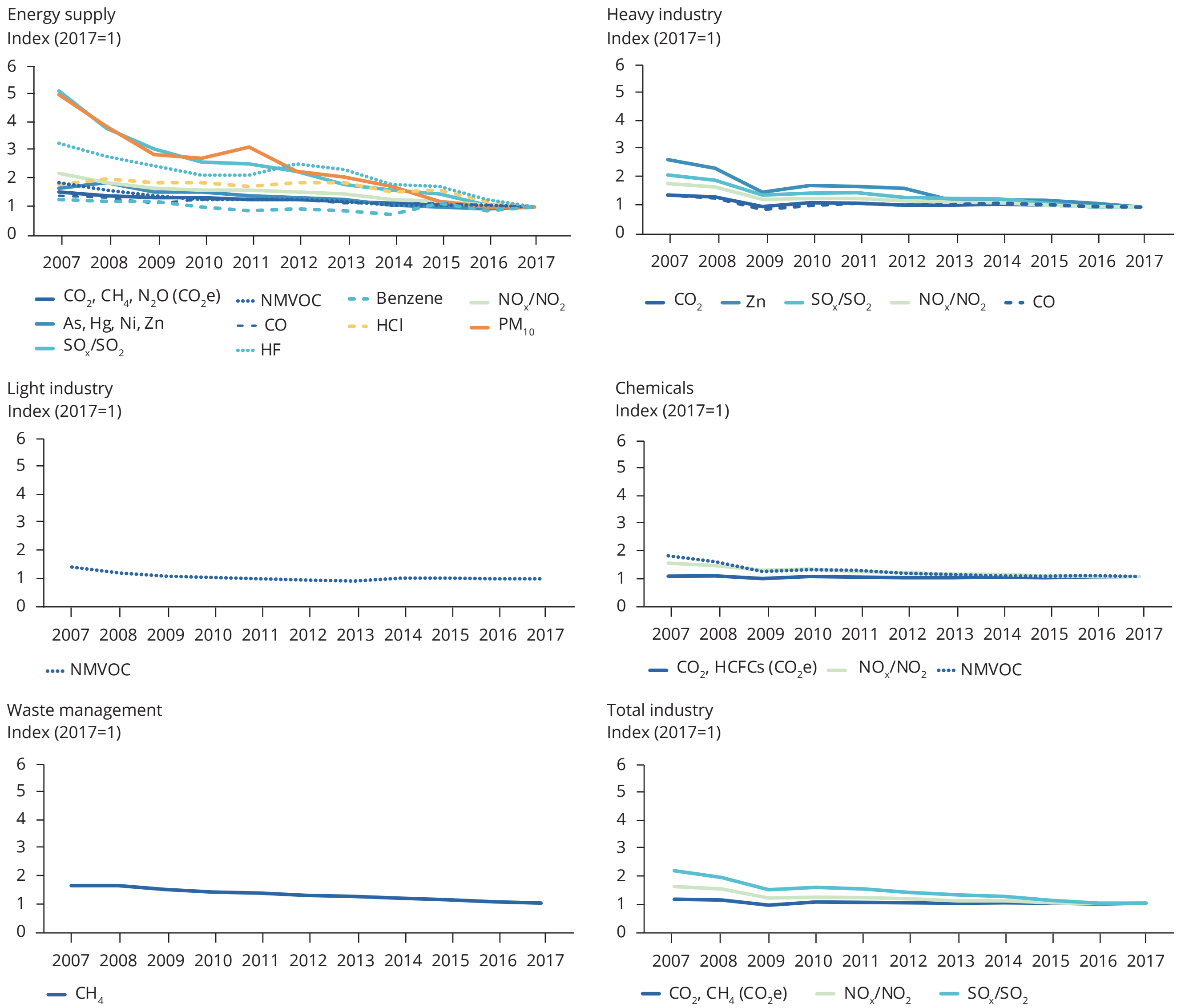
Each of the industry sectors has seen reductions in emissions of its main pollutants. Emissions of pollutants from power plants in the energy supply sector have all decreased since 2007, especially for SO_x, PM_{10} (by 80 % each) and NO_x (by about half). Other emissions were also reduced including fluorine (as hydrogen fluoride) and chlorine (as hydrogen chloride), both by-products of coal burning, heavy metals (arsenic, mercury, nickel and zinc) and to a lesser extent GHGs and CO. NMVOC and benzene emissions largely associated with refineries in the energy supply sector have also been reduced, albeit less significantly.

Key pollutants in heavy industry also tend to relate to fossil fuel combustion and were all reduced including zinc (by almost two thirds), and SO_x and NO_x (by around half). In the chemical sector, both NMVOC (associated with solvent use) and NO_x emissions dropped significantly but CO_2 emissions less so.

The reduction in methane emissions from the waste management sector reflects the decrease in the number of landfill sites in operation (Eurostat, 2018c) and waste being landfilled (Chapter 9) as well as the improvements in recovering methane from these sites (EEA, 2019a).

Air pollution and its effects on the environment and humans are addressed in detail in Chapter 8 and industry's role in climate change mitigation in Chapter 7. It should be noted that releases of many emerging air pollutants are currently not monitored. Chapter 10 explores this issue in more depth.

FIGURE 12.3 Emissions of key industrial air pollutants and GHGs for the EEA-33, 2007-2017, by industry sector



Notes: The E-PRTR does not contain data for Turkey. As, arsenic; CH_4, methane; CO, carbon monoxide; CO_2e, carbon dioxide equivalent; HF, hydrogen fluoride; Hg, mercury; Ni, nickel; NMVOC, non-methane volatile organic compounds; NO_2, nitrogen dioxide; N_2O, nitrous oxide; NO_x, nitrogen oxides; PM_{10}, particulate matter; SO_2, sulphur dioxide; SO_x, sulphur oxides; Zn, zinc.

Source: EEA (2019h).

Information is lacking on emerging pollutants, as industry only reports on emissions of pollutants of historic importance.

Contribution of industry to water emissions

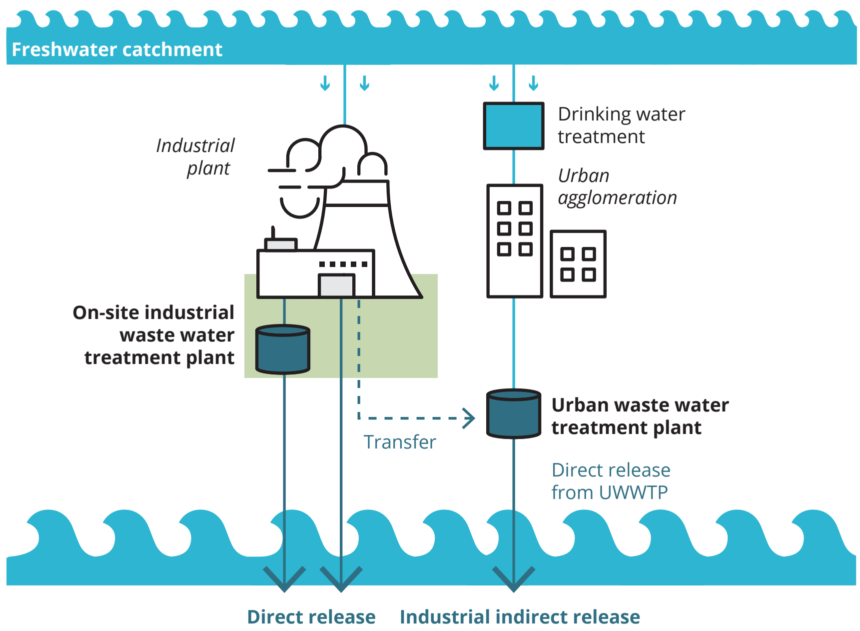
There are a host of industrial activities that use water, for example for the generation of steam in power plants, in scrubbers to remove pollutants from combustion gases or during manufacturing to clean equipment between batches. In many cases this results in waste water that is later returned to the environment, often after undergoing treatment.

Recent national assessments suggest that 18 % of surface water bodies

BOX 12.2 Understanding industrial releases of waste water

Direct releases to water by industry often require on-site treatment (Figure 12.4) but may also be possible without any treatment if the waste water is benign to the receiving water body (e.g. waste water from process cooling). In many cases, industry transfers waste water to urban waste water treatment plants (UWWTPs). These are in turn not the original source of pollution and simply end up releasing part of the pollutant load post-treatment (here referred to as indirect releases to the environment). It is also important to note that UWWTPs receive waste water that may contain pollutants from other non-industrial sources, including commercial activities and households. ■

FIGURE 12.4 Direct releases by industry versus transfers to waste water treatment plants



Source: EEA (2019e).

in the EU-28 countries are affected by chemical pollution from point sources (EEA, 2018a). More specifically, chemical releases from urban waste water treatment plants (UWWTPs) are reported as a pressure for 12 % and releases from industry for 5 % of these water bodies. Industry therefore contributes to the poor ecological status of European waters but to a lesser degree than other diffuse sources (Chapter 4). Box 12.2 explains industrial releases of waste water. The implementation of waste water treatment can be tracked via the EEA indicator on urban waste water treatment (EEA, 2017b).

Data in the E-PRTR (EEA, 2019h) allow an assessment of the relative contribution to these pressures by industry sectors (see next section below).

18 %

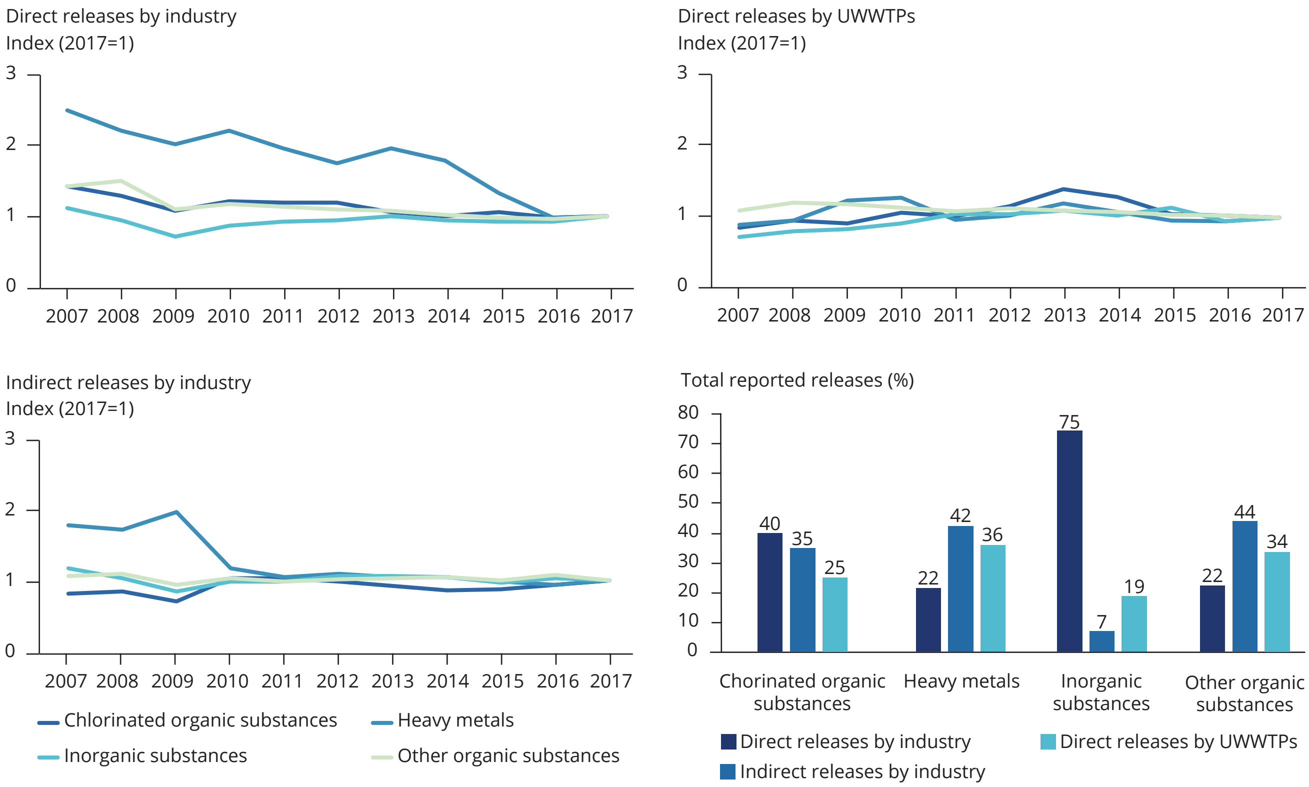
of surface water bodies in the EU are affected by chemical pollution from point sources.

Failure to achieve good chemical status (Chapter 4), however, is linked to legacy pollution with mercury, polybrominated diphenyl ethers and polycyclic aromatic hydrocarbons. Regarding surface waters, these substances are largely linked to past industrial activity (e.g. atmospheric deposition of mercury), and for ground water they are linked to past mining activity and seepage from contaminated industrial sites (see also EEA, 2018a).

Industrial water emission trends

Reported direct releases of pollutants by industry in the EEA-33 have decreased (slightly or more significantly) since 2007 for most pollutant groups, while indirect releases (i.e. transfers from industry to UWWTPs) have marginally

FIGURE 12.5 **Total pollutant emissions to water and transfers to UWWTPs by industry for the EEA-33, 2007-2017, by pollutant group**



Notes: The E-PRTR does not contain data for Turkey. Trends are in some cases strongly influenced by releases reported by individual facilities.

Source: EEA (2019h).

increased (EEA, 2019h). Findings from a recent report on industrial waste water (EEA, 2019e) are briefly summarised below and in Figure 12.5:

- Inorganic substances (and in particular nitrogen and phosphorus) account for the large majority of total direct and indirect releases of pollutants overall to surface waters (about 98 % of the total by mass). Chemical production is responsible for more than half of direct inorganic chemical releases in recent years, followed by UWWTPs and extractive industries (around 20 % each). Both chemicals and extractive industries also dominate indirect releases of inorganic substances. Releases (direct or indirect) of these substances do not necessarily represent the largest environmental pressure. Chlorides, for example, may exist at higher levels naturally and large releases (1) may merely be a result of that rather than industrial processes and (2) may not have a negative impact on the ecosystem as a result.

There has been more progress in reducing industrial emissions to air than to water.

- Chlorinated organic substances are directly released largely by light industry (pulp, paper and wood in particular) followed by UWWTPs. They account for less than 1 % of total direct releases by mass. Chemical production on the other hand is responsible for the majority of indirect releases of these substances.

BOX 12.3 The concept and development of best available techniques

The concept of best available techniques (BATs) dates back to the Integrated Pollution Prevention and Control Directive (IPPCD, 96/61/EC, replaced by the Industrial Emissions Directive, IED, in 2010). It stipulated that industrial installations must be issued with integrated permits that take into account emissions to air, water and soil, use of raw materials, energy efficiency, site restoration, noise and prevention of accidents.

To support authorities in Member States in charge of issuing permits, the European Commission created the European Integrated Pollution Prevention and Control Bureau with the task of steering information exchange on BAT. This information-sharing system remains in place today. The bureau publishes comprehensive reference documents (known as best available technique reference documents or BREFs) for specific industrial activities. They contain information on the techniques and processes used in a specific industrial sector in the EU, current emission and consumption (e.g. water, energy, materials) trends, and techniques to consider for determining BATs, as well as emerging techniques (see also Evrard et al., 2016, for an analysis of the whole process). During the time that the IPPCD was in force, Member State authorities were able to set emission limit values and other permit conditions that deviated from what was recommended in these documents. This flexibility resulted in notable differences in the emission limits for comparable industrial processes across the EU-28 (Entec, 2011).

To guarantee a level playing field and harmonise the emission limits across European industry, the more recent IED has since required the bureau to draw up conclusions for each of these reference documents (the BAT conclusions). These conclusions contain various elements that Member States need to implement, such as limits on emissions and other stipulations. This constitutes one of the major improvements introduced through the IED with a view to increasing the uptake of clean and environmentally sound technologies and processes. BAT conclusions, however, also include benchmarks of expected environmental performance, for example ratios between process inputs and outputs or levels of expected waste generation for specific processes. An up-to-date list of the documents containing the emission limit values and other reference values for a host of different industrial activities can be found on the website of the Joint Research Centre (JRC, 2018).

Some EEA-33 countries go further and develop country-specific BATs. This is the case in Estonia, where a BAT for the oil shale industry was developed to address one of the country's main emitting sectors. ■

Sources: Entec (2011); Evrard et al. (2016); JRC (2018).

- Other organic substances account for the second largest total of direct releases (2 %) [2]. They are directly released predominantly by UWWTPs and light industry (especially pulp, paper and wood). Light industry and chemical production also indirectly release them. Toxic substances that feature more prominently include phenols, nonylphenols and nonylphenol ethoxylates (NP/NPEs, used, for example, in detergents), di(2-ethylhexyl)phthalate (DEHP, used, for example as softeners in plastic) and fluoranthene (a biomass combustion residue).

- Direct releases of heavy metals can largely be attributed to UWWTPs. E-PRTR data show that this is at least in part the case because an amount of heavy metals of the same order of magnitude as total direct releases is transferred to UWWTPs by industry. Some of the prominent heavy metal

In many cases, industry transfers waste water to urban waste water treatment plants.

(2) Such releases include total organic compounds, which are in fact not pollutants per se but a measure of how much organic matter is being released.

TABLE 12.2 Summary assessment — pollutant emissions from industry

Past trends and outlook		
Past trends (10-15 years)		Improving trends dominate, as industrial emissions to air and water have decreased in the past decade. There has been particular progress in reducing emissions to air related to energy supply and emissions to water related to the metal production and processing sector. However, some industrial emissions have increased, such as emissions to water of other organic substances by extractive industries. Overall, progress has been more pronounced for air than for water.
Outlook to 2030		Continued progress is expected as implementation of current policies to mitigate industrial emissions continues. Full implementation of policies is required to deliver improvements. Importantly, climate change legislation will play an important role in driving further greenhouse gas (GHG) and air pollutant releases from industry. However, many emerging pollutants are often not adequately monitored but require increased attention to address environmental and health risks.
Prospects of meeting policy objectives/targets		
2020	☐	Europe is making progress towards the policy objective of significantly reducing emissions of pollutants. Although current policies and measures are delivering pollution control, the release of hazardous chemicals to air and water remains problematic. Even though current policy addresses major pollutants and GHGs and many industrial activities, the industrial pollution load to the environment is not covered entirely.
Robustness		Information on industrial emissions comes from data reported by countries. These are only available for a subset of industrial activities and for a limited number of pollutants. Emissions are often estimated or calculated by industrial facility operators. Outlooks are based on a number of separate assessments in the energy supply sector, which estimate future emissions and determine the impact of existing (and, therefore, future) policy measures. The outlooks for water are qualitative in nature with greater uncertainties. The assessment of outlooks and prospects of meeting policy objectives also rely on expert judgement.

emission trends are driven largely by individual facilities. This is the case for releases from metal production and processing. The fact that a large aluminium production site in France installed abatement technology after 2014 is clearly reflected in the overall downward trend in releases of heavy metals. The trend for heavy metals in extractive industries is further dominated by a Polish mine. Similarly, a large chemical works producing basic organic chemicals in Austria dominated European transfers of heavy metals to UWWTPs during the period 2007-2009. Non-industrial sources of heavy metals in water that may be sent to UWWTPs for treatment include run-off from roads as well as domestic waste water.

An unknown number of emerging water pollutants is currently not reported to the E-PRTR. This includes some of the pollutants currently treated as priority hazardous substances under the Water Framework Directive daughter Directive 2013/39/EU, such as dicofol (a pesticide related to DDT), quinoxyfen (a fungicide) and hexabromocyclododecane (HBCDD, a brominated flame retardant). These substances may be released to European waters by UWWTPs. Please refer also to Chapters 4 and 10 for further information.

12.3.2 Clean industrial technologies and processes

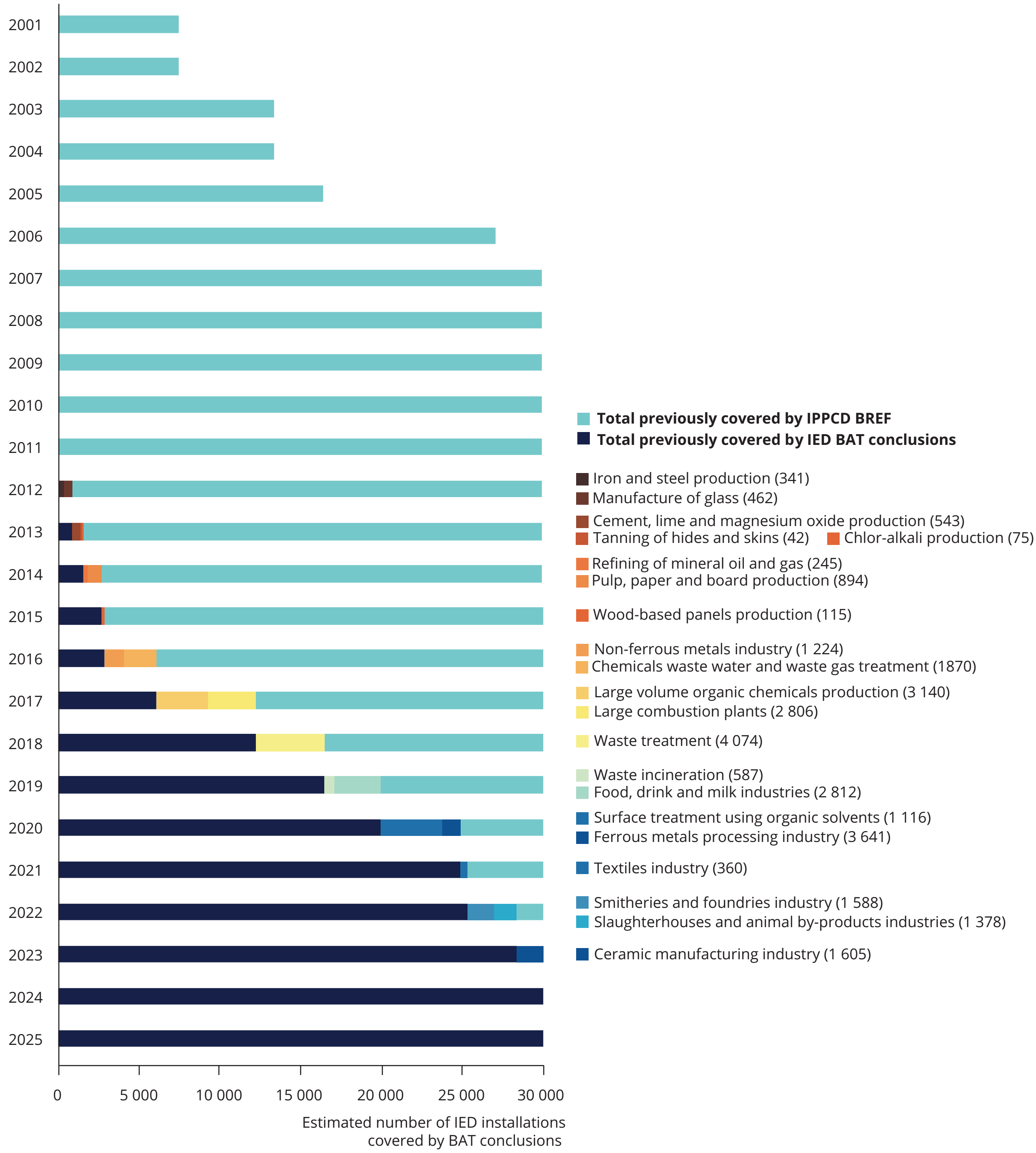
► See Table 12.4

The adoption of clean and environmentally sound technologies and processes features as an objective in both SDG 9 and the EU Seventh Environment Action Programme (7th EAP). This section assesses progress with respect to this objective.

> Decarbonisation of industry is expected to be a major driver of air pollutant emission reductions.

The number of industrial installations covered by best available technique (BAT) reference documents (known as BREFs) and their conclusions (Box 12.3) serves as a proxy to assess trends in establishing clean technologies and processes in industrial activities across Europe. Figure 12.6 shows that BREFs were developed for the most polluting industrial activities between 2001 and 2007 (under the precursor to the IED, namely the Integrated Pollution Prevention and Control Directive, IPPCD, 96/61/EC). These reference documents

FIGURE 12.6 **Estimated number of installations covered by the IED and by BAT conclusions**



Notes: This overview is based on data from an IPPCD implementation report and thus excludes installations in Croatia. Intensive rearing of pigs and poultry is also excluded because of how industry is defined in Section 12.1. The number of installations for 'Production of chlor-alkali' and 'Wood-based panels production' are based on the respective BREFs rather than the implementation report referenced in the figure source line. Discrepancies arise because IPPCD and IED activities cannot be mapped entirely and various BAT conclusions do not cover entire IED activities. There is also overlap in IED activities between different BAT conclusions. As of 2019, new reporting requirements under the EU Registry on Industrial Sites will provide more accurate data in the near future. Estimates for dates in the future are based on expert judgement.

Source: AMEC Foster Wheeler (2016b).

TABLE 12.3 Examples of references to environmental performance other than emissions in BAT documents developed under the IED

Area	Activities	Example measures
Energy efficiency	Large combustion plants, cement production and production of milk	Relevant BAT conclusions specify associated energy efficiency levels (BAT-AEELs)
	All IED activities	Energy efficiency BREF: any industrial activity should include a minimum standard of energy efficiency management, continuous environmental improvement and a map of energy efficiency aspects in any given installation as well as potential for improvement
Material use	Sinter production (iron and steel manufacturing), non-ferrous metal alloy production and recovery, and paper-making	Relevant BAT conclusions establish raw material versus product output ratios
	Production of chlor-alkali	BREF bans mercury from the production process
	Polymer production	Polymer BREF establishes associated environmental performance levels (BAT-AEPLs) for monomer consumption
	Processing of crushed seeds or beans	Food, drink and milk BAT conclusion establishes BAT-AEPLs for hexane consumption
Waste generation	Sinter production (iron and steel manufacturing) and non-ferrous metal alloy production	Relevant BAT conclusions provide amounts of waste typically produced per unit of production
	Polymer production	Polymer BREF establishes BAT-AEPLs for the amounts of waste produced
	Chlorine production	Chlor-alkali BAT conclusion establishes BAT-AEPLs for sulphuric acid residue per unit of chlorine produced
	Refineries, tanning of hides and skins, and cement production	Relevant BAT conclusions provide recommended content of hazardous chemicals in final products and/or waste

Source: EEA, based on JRC (2018) and Ricardo Energy & Environment and VITO (2019).

will remain in place until they are revised under the IED, when binding conclusions are also added (Box 12.3). Most BREFs will have been revised by 2020 while a few are only likely to be developed by 2025.

Figure 12.6 clearly shows that there is continued progress with respect to establishing a regulatory push to improve the uptake of BATs by issuing permits to installations, at least within the scope of industrial activities covered by the IED. The examples of large combustion plants, and iron and steel manufacturing installations presented in Section 12.4.1 further show that such regulation has improved the environmental performance of industry regarding pollutant emissions in the past. However, decisions on investment with respect to pollutant abatement are not only driven by environmental regulation but are often tied to scheduled maintenance and technological upgrades that may have occurred regardless of whether regulation is introduced or not (Ricardo Energy & Environment, 2018).

Environmental policy has led to reductions in industrial emissions in the past decade.

The environmental performance benchmarks contained in various BAT conclusions provide an important link to resource efficiency (see also Ricardo Energy & Environment and VITO (2019)). The circular economy package (EC, 2015; Chapter 9) stipulates the incorporation of guidance on energy and resource use into the BREFs and their conclusions. Table 12.3 presents selected examples. Such benchmarks are, however, currently

TABLE 12.4 Summary assessment — clean industrial technologies and processes

Past trends and outlook		
Past trends (10-15 years)		An increasing number of industrial facilities are covered by emission limits and other environmental requirements. There is evidence that this has led to reductions in emissions of pollutants, but it is less clear whether this has resulted in improvements in general environmental management in industry.
Outlook to 2030		Further progress is expected regarding the environmental performance of industry. By 2025 more stringent best available technique (BAT) conclusions are expected to cover all industrial activities currently regulated by the Industrial Emissions Directive. Industry's transition to a low-carbon economy is predicted to contribute further to emission reductions. However, uncertainties remain over whether general environmental performance beyond air and water pollution abatement will be fully implemented and thus whether the objective of implementing clean industrial technologies and processes can be achieved. Therefore, industrial pollution is likely to continue to adversely impact human health and the environment.
Prospects of meeting policy objectives/targets		
2020	☐	Europe is making good progress towards the policy objective of securing industry's adoption of clean and environmentally sound technologies and industrial processes. Although these are delivering pollution control, release of pollutants remains problematic.
Robustness		The scope of the Industrial Emissions Directive is not all-inclusive and a number of industrial processes are not covered. The number of installations covered by each BAT reference document and BAT conclusion is an estimate based on reported data, which may be incomplete. The overarching objective of implementing clean industrial technologies and processes is generic and does not provide a clear target. Therefore, the assessment of past trends, outlooks and prospects of meeting policy objectives also relies on expert judgement.

not applied systematically or in a harmonised way across the EU, indicating considerable potential for improvement and also for contributing to the circular economy and energy efficiency goals. A comprehensive assessment of the integration of environmental performance beyond emissions to air and water will be possible only once permits become accessible through the forthcoming implementation of the EU Registry on Industrial Sites. This registry incorporates reporting obligations under the IED and the E-PRTR and will be operational from late 2019 onwards.

A number of BAT conclusions also attempt to guide operators to think about establishing synergistic relationships with other industrial stakeholders, for example by capturing waste materials or surplus energy resulting from processes that may be of value to others. This concept of industrial symbiosis (e.g. Bilsen et al., 2015) is enshrined in BAT for tanneries with respect to chromium, for solid residues from steel production and for sludge or filter dust from non-ferrous metal production.

Industrial pollution is likely to continue to adversely impact human health and the environment.

Other drivers towards more clean and environmentally sound technologies include environmental policies and regulations that aim to reduce GHG emissions and thus affect, for example, the energy mix in the power sector (Chapter 7). The EU Emissions Trading System (ETS) and the Renewable Energy Directive (2009/28/EC) are examples of this. There may also be additional incentives for reducing the environmental impact of industrial installations such as cutting energy use and thereby operating cost, displaying better corporate social responsibility via voluntary green initiatives or taking advantage of associated governmental funding initiatives (e.g. as reported for emerging technologies by 12 Member States in the context of IED implementation reporting; AMEC Foster Wheeler, 2016a).

The European Commission reviews legislation to ensure that it continues to be fit for purpose and provides benefits to society. The IED is currently being assessed as part of that review process and a conclusion is expected in early 2020. Both its integration with other EU policies and progress on implementing environmental performance benchmarks contained in BAT conclusions may be touched upon during this review.

12.4 Responses and prospects of meeting agreed targets and objectives

12.4.1 Policy responses to tackle industrial pollution

Industrial pollution has been addressed at the national and regional levels across Europe for decades, and it is beyond the scope of this chapter to summarise all of these policy responses. Instead, the IED serves as a recent example of increasingly integrated regulation of industrial pollution at the European level.

Policy coherence and relevance

The IED has been explained in detail throughout this chapter (see, for example, Box 12.3). The Directive is very much a technical piece of legislation that regulates industrial point source emissions and aims to increase environmental performance cost-effectively through BREFs. The IED already represents an integration of multiple pieces of legislation that previously existed side by side. Section 12.2 further highlights that, by regulating the industrial sector, the IED contributes to objectives set by a host of other policies on air pollution, water quality and the circular economy, to name a few. These connections to other policy arenas are currently not evident in the IED itself due to its age. There is therefore potential to further improve this integration through the ongoing review of the IED (Section 12.3.2).

Another important aspect of the IED is that GHG emissions from industry are not included in its scope. They are instead addressed by the EU ETS (for a critique of this separation see, for example, Peeters and Oosterhuis, 2014) (see also Section 12.2 and Chapter 7). There is nonetheless a clear link between policies and legislation that aim to establish a low-carbon economy in Europe and industrial pollution (and industrial air emissions in particular; see, for example, EC, 2018).

A 2019 EEA report on industrial waste water (EEA, 2019e) concluded that a revision of the activity and pollutant lists and reporting thresholds of the E-PRTR Regulation could help to better monitor progress towards controlling pollution from installations covered by the IED. In this context, emerging pollutants should also be considered. These pollutants are touched upon in more detail in Chapters 4 and 10. Industry releases thousands of different chemicals into the European environment and only a small fraction of them are currently monitored. Such a revision could also help to better align reporting on waste water treatment plants under the UWWTD and the E-PRTR. The presence of reporting thresholds in general hampers the interpretation of the data reported and therefore complicates sound policymaking. Activity lists and pollutants subject to reporting under national and regional pollutant release and transfer registers (PRTRs, e.g. the E-PRTR) as well as associated reporting thresholds are currently also being reviewed (see, for example, UNECE, 2018).

The contribution of the Industrial Emissions Directive to circular and low-carbon economy could be improved.

It should further be noted that our understanding of the impact of substances on the environment and human health is developing over time. This in turn can determine whether or not these impacts are addressed by specific policy instruments and, for example, monitored. It is therefore currently possible to assess progress towards reducing industrial pollutant emissions for only the harmful substances for which emissions are reported. An assessment of whether or not policy is relevant (or effective) therefore changes over time along with our understanding of the substances released by industry. Certain aspects of industrial pollution policy are therefore reactive by definition (Chapter 10).

The 2017 European Commission industrial policy strategy (EC, 2017) identifies a number of sector policy priorities, such as competitiveness, cybersecurity and skills, but fails to mention the IED or in fact the topic of pollution at all. The environmental aspects highlighted are limited to decarbonisation and resource efficiency. This underlines that industrial pollution considerations need to be further integrated across different policy areas (see also Sanden, 2012) and should be considered during the ongoing development of a new industrial policy strategy for the EU.

Another good example of this is the contribution that the IED is intended to deliver with respect to the Commission's circular economy package. The analysis above (Section 12.3.2) shows that, although some BAT conclusions mention best practices for increasing energy efficiency, improving material use and reducing waste generation, incorporating these environmental performance benchmarks into operating permits varies across Member States and a fully-fledged assessment of their effectiveness is currently hampered by a lack of data. It is very likely that the potential contribution of the IED to the circular and low-carbon economy could be improved (Ricardo Energy & Environment and VITO, 2019). This is of particular relevance because a transition from a linear to a circular model of production is required to help minimise future emissions and material throughput. This is evident in the European Commission's recent long-term strategy for a climate neutral economy (EC, 2018), in which industry plays a central role in the transition to a low-carbon and circular economy. Incrementally stricter emission limits on their own will not achieve this feat in the long term (Ghisellini et al., 2016). Instead, this transition can take place only when resource scarcity implications and economic benefits are as much a focus as environmental benefits (see also EEA, 2016; Lieder and Rashid, 2016). In addition, the transition to a circular and low-emission industrial sector in

Europe will require additional regulatory approaches that address new industrial processes and material cycles.

The IPPCD had been criticised for being a soft regulation that relies on industrial as well as regulatory capacities in Member States to set permit conditions that improve the environmental performance of installations rather than setting top-down emission limits that apply across Europe (Koutalakis et al., 2010). Although some of these perceived shortcomings have been addressed via the IED, some argue that these changes did not go far enough to ensure completely effective control of industrial emissions (Lange, 2011; Conti et al., 2015; Lee, 2014). Permit conditions may therefore still differ between similar installations in similar settings as long as either their emissions are within the range outlined in the BAT conclusion or they are covered by a derogation.

A recent report by the European Topic Centre for Air Pollution, Transport, Noise and Industrial Pollution (ETC/ATNI, 2019) further shows that, while the level of production in heavy industry has remained stable in Europe, emissions of pollutants to air from that production have decreased as a result of pollution abatement. Additional European demand over the past few decades has, however, been met by production outside Europe, resulting in a potential outsourcing of associated pollutant emissions.

Effectiveness of existing policy

The effectiveness of policy can only be assessed properly if its goals and objectives are clearly defined, measurable and reliable, as well as if relevant data are available for this purpose. These conditions are to a certain extent met with respect to pollutant emissions from specific industrial sectors that will serve as examples in this section. For many other industrial sectors, the data available are not sufficient to properly evaluate the effectiveness of policy.

There is clear scope for further integration of environmental objectives into the EU's industrial policy.

An *ex post* assessment of the Large Combustion Plants Directive (LCPD) (EEA, 2019b) is one example of a policy effectiveness assessment. It identified some of the drivers behind past emission releases to air from combustion units in the energy supply sector (i.e. power plants), heavy industry (most prominently in iron and steel and metal processing), light industry (e.g. pulp, paper and wood) and waste management (co-incineration of waste). The assessment found that past improvements in the relative emissions from these units was the dominant factor in reducing the emissions of SO_2 (such improvements alone led to a 71 % reduction between 2004 and 2015), NO_x (38 %) and dust (75 %, which includes PM_{10}). These improvements in turn are the result of a stricter compliance regime coming into effect in 2008 for existing power plants under the LCPD. In particular, countries with previously very high emission factors for these three air pollutants saw significant reductions around that time.

Other factors identified by the assessment as having an impact on emissions from power plants included a reduction in the energy intensity of economic sectors (contributing to a 7-9 % reduction for the three pollutants between 2004 and 2015), a rise in economic activity (5-6 % increase) and shifts in the energy mix (12-15 % decrease) (compare with Figure 12.2 and Figure 12.3). Another contributing factor was the switch from fossil fuels to biomass, which was in part driven by the EU ETS as well as by the implementation of renewable energy targets in the Renewable Energy Directive. Stricter emission limit values and new BAT conclusions in the IED had probably already had an effect on emission reductions up until 2015 (see also Box 12.1).

A second recent assessment for the European Commission (Ricardo Energy & Environment, 2018) analysing the iron and steel sector also found a strong link between BATs published for the sector in 2012 under the IED and reductions in air pollutants achieved on the ground. According to the study, air pollutant emissions reported to the E-PRTR by iron and steel manufacturers decreased compared with what they would have been based on 2016 steel production data and emission factors from 2012 (per unit of steel produced). The authors of the study found that emissions of SO_x had been reduced by 29 %, of NO_x by 14 %, of PM_{10} by 25 % and of mercury by 26 %.

The relatively small contribution of large industrial point sources to overall environmental pressure on European surface waters is noted in Section 12.3.2. These point sources are almost all regulated by the IED. However, underlying data also suggest that small point sources not regulated by the IED appear to exert greater pressure on the quality of surface waters (EEA, 2019e).

In the waste management sector, the EU Landfill Directive (1999/31/EC) (with its provisions on technical requirements on landfill sites and for diverting waste from landfill), as well as EU waste policies (aiming to move waste towards reuse and recycling), worked hand in hand with emission control policies, leading to reductions in methane emissions (Figure 12.3 and Chapter 9).

Such examples as those outlined above show that broadly effective industrial pollution policy is in place for many large industrial sectors. The example of the power plants in particular highlights that the introduction of strict, ambitious emission limits can be an effective driving force to reduce pollutant emissions. More data are needed to assess the effectiveness of current policies to regulate emissions from other industrial activities (and for other pollutants), including those not yet covered by the IED.

However, the lack of a comprehensive EU industry policy that addresses environmental performance as an integrated aspect of the sector, as well as the limited scope of existing data on pollutant releases from all industrial activities, indicates potential for further policy integration. The importance of this is underlined by the ongoing costs that pollution from the sector imposes on Europe's society. An earlier study examining the costs of air pollution from industry in Europe (EEA, 2014) found that the then levels of emissions caused damage in the order of at least EUR 59 billion (or EUR 115 per capita) in 2012.

12.4.2 Prospects for meeting agreed targets and objectives

Incorporating more efficient, clean technologies and processes within Europe's industrial sectors will be important to ensure continued reductions in emissions of pollutants and improved environmental and climate performance.

Historical industrial pollutant emissions have been decreasing, especially with respect to emissions to air. Decreases have been most dramatic with respect to SO_2, NO_x and dust (or PM_{10}) emissions associated with combustion processes. A recent assessment for the EEA (ETC/ACM and Dauwe, 2018) shows that emissions of SO_2 and NO_x from power plants could be reduced by at least two thirds by 2030 and dust emissions by more than half over the same period as a result of new emission limits for the sector. According to the assessment, future emission trends in the power sector will in particular be driven by EU climate and energy policy (Section 12.4.1). It should be noted that, although the power sector can arguably meet these strict new pollutant emission limits by retrofitting a number of existing plants while replacing others with new, more efficient ones, it will also be necessary to decommission some of these plants to meet EU targets for decarbonisation (Chapter 7) (see EEA, 019c).

> Existing and incoming EU policy instruments are expected to further reduce industrial emissions.

While more waste water is now receiving some form of treatment before being released into the environment, decreases in pollutant emissions to water have been more modest. Although overall reported releases of waste water by industry and UWWTPs have decreased slightly since 2007, real progress has been achieved only with respect to heavy metal loads. The current trend to further control indirect emissions of pollutants by industry under the IED (i.e. waste water that is treated at UWWTPs before being released to the environment) may lead to reduced pollution of European surface waters in the future, but whether or not this materialises remains to be seen (EEA, 2019e).

Further reductions in industrial pollution — at least regarding the currently reported pollutants — are nonetheless likely to be due to the regulation mentioned throughout this chapter. Under the IED regime, a host of new BAT conclusions have been or will be published, with each coming into effect within a 4-year window. This effectively means that mandatory emission limits for industrial activities ranging from pulp, paper and wood to refineries, non-ferrous metals, waste treatment and chemicals, as well as power plants, will be lowered further overall between now and 2030 (see also Ricardo Energy & Environment, 2017). This applies to emissions to both air and water. Transfers of pollutants to UWWTPs will also be increasingly regulated under the IED, which in turn may lead to a reduction in the pollutant load entering the environment from UWWTPs. The ongoing European Commission fitness checks of the UWWTD and WFD are also expected to further address the regulatory gap with respect to emissions to water.

These findings are reassuring, but there are a number of important caveats. In the E-PRTR only releases of specific pollutants above an accompanying threshold have to be reported. Monitoring of concentrations of pollutants in surface waters is also limited to a specific list of pollutants (Chapter 4). Chapter 10 therefore points to the fact that a multitude of emerging pollutants is still being released into Europe's environment without being subject to monitoring. Such releases may have significant, but as yet unknown, impacts on the environment and human health.