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NEW CHALLENGES UNDER THE REVISED INDUSTRIAL EMISSIONS DIRECTIVE: FROM IPPC TO IED 2.0

Abstract: *The European Union's revised Industrial Emissions Directive (IED), introduces significant enhancements aimed at reducing pollution from large industrial installations and intensive livestock farms. This modernization aligns with the European Green Deal's Zero Pollution ambition, targeting a healthier environment and promoting industrial innovation. The updated IED extends its regulatory reach to additional sources of emissions. Notably, it now encompasses more large-scale intensive livestock farms, including the largest pig and poultry operations. This expansion is essential in mitigating nitrogen pollution across air, water, and soil. The Directive also brings the extraction of metals and large-scale battery production under its purview, addressing emerging industrial activities with significant environmental footprints. To analyze the impact and effectiveness of the updated IED, an online systematic review was conducted using peer-reviewed literature, official EU reports, and policy evaluations from 2020 to 2025. A comparative analysis was carried out to assess key changes against the previous IED (2010/75/EU), using case studies and reported data. Findings from the review highlight several important aspects of the directive, like stricter emission limits and target reductions. In a concluding sense, IED 2.0 success will depend on effective enforcement, industry cooperation, and technological innovation. Future research should focus on digital monitoring tools, financial sustainability models, and regulatory refinements to ensure long-term compliance and impact.*

Keywords: Integrated pollution prevention and control, Industrial emissions, Integrated permit, Operators

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INTRODUCTION

The genesis of the European Union's Integrated Pollution Prevention and Control (IPPC) Directive traces back to the mid-1990s, a time when the EU recognized the fragmentation and inconsistency of environmental regulation across Member States. Environmentally, the directive was conceived in response to the growing realization that industrial pollution was not a compartmentalized phenomenon. Rather than being confined to air, water, or soil separately, pollutants were increasingly found to migrate across environmental media, challenging the efficacy of traditional, single-medium regulatory approaches (Krämer, 2007). Throughout the 1970s and 1980s, a series of ecological crises such as the Seveso chemical disaster and extensive transboundary air and water pollution events highlighted the interconnectedness of environmental systems and the inadequacy of fragmented regulation. These events amplified the urgent need for a comprehensive, cross-media regulatory framework capable of addressing complex industrial impacts on the environment as a whole (Jordan, 1999). Parallel to these environmental concerns, social dynamics were shifting in ways that fostered receptivity to a more integrated regulatory instrument. Public awareness and environmental consciousness were rising steadily, particularly in Western Europe, where citizens and civil society organizations exerted increasing pressure on governments and supranational bodies to enforce stricter pollution control. The dissemination of the 1987 Brundtland Report and the proceedings of the 1992 Earth Summit in Rio de Janeiro were vital in reframing environmental degradation as a global challenge that required sustainable development and integrated solutions (Bruntland, 1987). Within the European context, the formation and deepening of the European Union brought with it new aspirations for policy harmonization, environmental equity, and cohesion among Member States. The IPPC Directive responded directly to the need to avoid regulatory discrepancies that could undermine both environmental protection and the competitiveness of European industry. Technological progress also played an essential role in enabling and necessitating the IPPC framework. By the 1990s, advances in environmental engineering, monitoring systems, and process optimization had given rise to the concept of Best Available Techniques (BAT), which became the cornerstone of the IPPC regulatory architecture. The increasing availability and sophistication of cleaner production technologies made it both technically and economically feasible to reduce emissions at the source, rather than relying solely on end-of-pipe solutions. Moreover, digital data collection and environmental reporting tools began to allow for more integrated and transparent oversight of industrial operations, thus supporting the practical implementation of cross-media assessments and permitting procedures.

The convergence of these environmental, societal, and technological trajectories created the momentum for a paradigm shift in European industrial pollution control. Adopted in 1996 as Directive 96/61/EC, the IPPC Directive marked a paradigmatic shift from media-specific permitting (i.e., air, water, waste) toward an integrated approach to environmental protection. It mandated that industrial installations with significant pollution potential obtain integrated permits that considered the entire environmental performance of a facility. This holistic concept was grounded in the application of Best Available Techniques (BAT), which aimed to ensure a high level of environmental protection while taking into account economic and technical feasibility (EC, 1996).

The initial implementation of the IPPC Directive revealed both strengths and challenges. It successfully initiated a framework for industrial pollution control based on integration, but it also encountered uneven implementation across Member States. Varying interpretations of BAT, differences in permit conditions, and inadequate public participation mechanisms hindered its effectiveness. Moreover, the directive's flexibility, while politically expedient, led to regulatory asymmetry, undermining the level playing field among European industries (Firoiu et al, 2023).

In response to these deficiencies, the European Commission initiated a comprehensive review in the early 2000s. This effort culminated in the publication of the Thematic Strategy on Air Pollution and the review of the IPPC Directive and six related sectoral directives (collectively referred to as the "IPPC Daughter Directives"). These included directives on waste incineration, large combustion plants, and solvent emissions, among others. The review concluded that a unified legislative framework was necessary to enhance coherence, improve enforceability, and update environmental standards based on the evolving state of science and technology (EC, 2007).

This led to the adoption of the Industrial Emissions Directive (IED), Directive 2010/75/EU, which entered into force in 2011. The IED repealed and replaced the IPPC Directive and its daughter directives, consolidating and streamlining industrial emissions legislation within the EU. The IED strengthened the role of BAT, notably through the mandatory use of BAT conclusions (published as Commission Implementing Decisions), which became binding benchmarks for permit conditions. Importantly, the directive introduced the concept of “BAT-AELs” (BAT-associated emission levels), narrowing the scope for Member State discretion and improving environmental outcomes. The IED also enhanced provisions for compliance monitoring, public participation, and access to justice, aligning more closely with the principles of the Aarhus Convention. It incorporated stricter measures for environmental inspections and introduced the requirement for baseline reports and soil and groundwater monitoring for installations handling hazardous substances. These provisions addressed long-standing concerns about legacy pollution and the restoration of industrial sites. Between 2011 and 2020, the IED’s implementation prompted further alignment among Member States and catalysed the development of sector-specific BAT reference documents (BREFs) across key industrial sectors. Nevertheless, challenges remained, particularly in terms of administrative burdens, the pace of BAT updates, and the integration of climate objectives. As the EU’s environmental policy evolved toward decarbonisation and circular economy goals, the limitations of the IED in addressing greenhouse gas emissions and resource efficiency became more apparent (EC, 2010).

Recognizing these gaps, the European Commission launched a revision process in line with the European Green Deal and the Zero Pollution Action Plan. This culminated in a proposal for a revised IED in April 2022, which introduced several forward-looking provisions (EC, 2020). The proposed revision aimed to expand the scope of the directive to include more industrial sectors, notably extractive industries and large-scale livestock farming, which were previously either excluded or insufficiently regulated. Furthermore, it proposed a more dynamic, innovation-driven permitting process and stronger integration of environmental and climate performance benchmarks (EC, 2022).

Side activities significantly influenced the evolution of the IPPC and IED framework. These included the development of the EU’s Environmental Technology Verification (ETV) scheme, horizontal strategies like the 7th and 8th Environmental Action Programmes, and environmental information systems such as the European Pollutant Release and Transfer Register (E-PRTR). The European Environment Agency (EEA) and the Joint Research Centre (JRC) played vital roles in knowledge consolidation, capacity building, and methodological support, particularly through the Seville Process, which coordinates the drafting of BREFs (EC, 2022).

From 1996 to 2025, the trajectory of the IPPC and IED directives reflects a gradual but determined shift toward a more integrated, enforceable, and science-based approach to industrial pollution control in the EU. Their evolution demonstrates how regulatory frameworks can adapt to technological progress, socio-political pressures, and emerging environmental imperatives, moving from fragmented control to systemic governance of industrial emissions (Vasovic et al, 2016).

IPPC/IED IN NUMBERS

The number of installations regulated under IPPC and later IED has steadily increased. By the time IED entered into force in 2011, approximately 50,000 sites across industry types from energy and chemicals to farming held integrated permits (Pettersson & Söderholm, 2014). As of 2025, it's estimated that around 60,000 installations across the EU remain subject to IED permit requirements incorporating expanded activities like intensive livestock farming (Bjerg et al, 2019). Larger economies naturally host more regulated installations. Germany, France, Italy, Spain, and Poland each account for 5,000–7,000 permitted sites, while smaller Member States such as Slovenia or Malta have fewer than 500 IPPC/IED installations.

Table 1. *Estimated Number of IPPC/IED Permitted Installations (EU-BRITE, 2024)*

Year	Approx. number of operators
1996	35,000
2005	45,000
2011	50,000
2020	58,000
2025	60,000

Data collected during BREF reviews in sectors like waste-water, large combustion plants (LCPs), and animal farming indicate progress toward BAT-AEL compliance, though variance remains, for instance in:

- Waste-water treatment (2020): Typical BATAEL: Total P ≤ 0.4–5 mg N/l Many high-capacity plants report values towards upper limit, but several exceed it.
- Large Combustion Plants (2009 baseline): Dust: 77.6 kt actual → potential 55.1 kt under IED ELVs → lower BATAEL target yields further reductions (not quantified).
- Animal production (e.g., Sweden): Ammonia emissions per 'animal place' are ~1.83 kg NH_3/year-below the upper BAT-AEL of 2.6 kg NH_3/animal-place/year.

From 2005–2019, the EU-27 achieved:

- $PM_{2.5}$ ↓ 29%, PM_{10} ↓ 27%
- SO_2 ↓ 76%, NO_X ↓ 36%
- CH_4 ↓ 17%, NH_3 ↓ 8%
- Heavy metals like Ni, Hg, Pb all declined by 33–50%.

These reductions align broadly with the phased implementation of BAT-AELs under IED and demonstrate better-than-media-directive outcomes. For example, case studies suggest compliance with upper-end BAT range can reduce SO_2 by ~2,747 t/year and dust by ~286 t/year thus yielding monetized health benefits of €20–60 million annually in sectors like TiO_2 production (EU-BRITE, 2024).

100 ┤

90 ┤ ■■■■■■■■■■■■■■■■■—— 2010

80 ┤ ■■■■■■■■■■——— 2015

60 ┤ ■■■■■——— 2020

24 ┤ ■■——— 2025 approx.

SO_2 NO_X PM_{10} Hg, Cd

Figure 1. *EU-27 Air Pollutant Emissions Index (EU-BRITE, 2024)*

With the adoption of the IED, installations subject to IPPC/IED (≈ 60,000 across the EU) have been required to report pollutant discharges to water annually via the Industrial Emissions Portal (IEP), replacing the E-PRTR. These reports capture both direct emissions to surface waters and off-site transfers via sewage systems:

- In 2021, installations reported approximately 4.2 Mt of pollutants transferred to wastewater, including key substances like heavy metals, nitrogen, phosphorus, and persistent organics environment.
- This represents a 15 % decline from 2016 levels (≈ 4.9 Mt), highlighting improved source controls and tighter BAT-AELs for wastewater emissions.

Table 2. *EU-27 Wastewater Pollutant Discharges by IPPC/IED Installations (IEP, 2024)*

Year	Total Pollutants to Wastewater (Mt)	Change vs. Previous
2016	4.9	–
2018	4.6	– 6%
2020	4.4	– 11%
2021	4.2	– 15% vs. 2016

These reductions align with BAT-based permitting and sectoral BREFs that set stringent benchmarks on industrial wastewater treatment, nutrient removal, and heavy metal minimization, particularly in chemicals, metal production, and pulp-and-paper sectors. Uptake of end-of-pipe treatments, closed-loop systems, and water recycling also accelerated post-2010.

Beyond air and water, the IED also standardizes the management and off-site transfer of industrial waste generated by these installations. According to E-PRTR/IEP data and BREF guidance, IPPC/IED sites consistently report:

- In 2016, EU operators collectively transferred ≈ 12 Mt of industrial waste off-site, including both hazardous and non-hazardous streams.
- By 2021, that figure was around 11 Mt, a modest 8 % decline, reflecting gradual improvements in material efficiency, waste prevention, and on-site recycling promoted by BAT conclusions.

However, unlike air pollutant trends, the waste sector shows less rapid progress, partly due to heterogeneous implementation of BAT waste-management measures and the complexity of tracking waste streams.

Table 3. *EU-27 Industrial Waste Transfers via IPPC/IED (E-PRTR/IEP, 2024)*

Year	Total Industrial Waste Transferred (Mt)	% Recovered vs. Disposed
2016	12	~65 % recovered
2018	11.7	~67 %
2020	11.3	~70 %
2021	11.0	~72 %

Recovery rates, including materials recycled, composted, or used in energy recovery, increased from ~65 % (2016) to ~72 % (2021), signaling significant advances in circular-economy integration. These findings emphasize that while air pollution saw dramatic reductions under IPPC/IED, wastewater and industrial waste improvements, though real, were comparatively slower, underscoring ongoing challenges in resource efficiency and integrated pollution control.

Anyway, over the 1996–2025 period, the EU's IPPC and IED frameworks oversaw a 20,000–25,000 increase in regulated installations, with Germany, France, Italy, Spain, and Poland accounting for the majority. The progressive introduction of binding BAT-AELs, especially via sectoral BREFs, correlated with substantial emission declines: SO_2 (-76%), $PM_{10}/_{2.5}$ (~28%), NO_X (-36%), and heavy metals (~40–50%) from 2005 to 2019. Compliance with BAT-levels yields measurable health and environmental gains in many millions of euros annually while requiring annual corporate and public investment on the order of €1–3 billion. As of 2025, IPPC/IED remains instrumental in driving both technological deployment and deep emission reductions across EU heavy industry (*E-PRTR/IEP, 2024)*.

IED 2.0 KEY FEATURES

One of the most transformative aspects of IED 2.0 is the strengthening of the Best Available Techniques (BAT) framework, with a reinforced link between environmental performance levels and innovation trajectories. By extending the scope of BAT-associated environmental performance levels (BAT-AEPLs) and BAT-associated emission levels (BAT-AELs), and by introducing stricter compliance mechanisms, the directive incentivizes the continuous technological advancement of industrial installations. The directive explicitly promotes frontrunner technologies like emerging techniques (ETs) as part of an innovation-oriented regulatory design, enabling quicker deployment of cleaner and more efficient solutions through the Early Identification of Emerging Techniques (EDET) mechanism. This transformation logic is further embedded through the requirement that competent authorities must consider innovation potential in permitting decisions, thus mainstreaming eco-innovation within industrial modernization strategies (Truijens, 2021).

IED 2.0 also introduces the Industrial Emissions Portal (IEP) as a central tool for digital transformation, enabling the transparent monitoring of industrial pollution through enhanced data reporting, real-time emissions tracking, and greater public accessibility. This digital transition will facilitate data-driven decision-making, while also promoting accountability and benchmarking among states and industrial operators. Moreover, the extended application of the directive to new agro-industrial sectors and medium combustion plants broadens the regulatory coverage, ensuring that a larger portion of emissions-intensive activities are subjected to innovation-driven environmental performance improvements (Kunes et al, 2022).

Another critical outcome is the directive's contribution to circular economy transitions. IED 2.0 integrates resource efficiency indicators and mandates reporting on water, energy, and raw material usage, as well as on the generation and management of waste and by-products. This systemic approach promotes cross-sectoral synergies, encouraging industries to valorise waste streams, optimize input consumption, and reduce dependency on primary resources. In doing so, IED 2.0 reinforces the integrative approach to sustainable resource management, aligning emissions control with climate mitigation, biodiversity conservation, and zero-pollution targets (Kimmel, 2016).

Furthermore, the revised directive supports the development of environmental performance transformation plans (EPTPs) for installations with suboptimal compliance records. These plans are expected to create long-term innovation roadmaps tailored to each facility, linking regulatory obligations with research, investment, and deployment of cleaner technologies. Financially, the directive is anticipated to trigger increased investment in environmental technologies, retrofitting, and digital solutions, while also guiding public and private funding mechanisms, including the EU Innovation Fund and Just Transition instruments. In this way, IED 2.0 establishes a robust regulatory infrastructure to accelerate the industrial transition toward a more sustainable, innovative, and digitally integrated future. Through enhanced emission control, proactive innovation promotion, and synergies with circular economy strategies, the directive is expected to yield significant environmental, technological, and socio-economic impacts across the European industrial area and beyond (Chen, 2024; Daddi et al, 2013).

CONCLUSION

In conclusion, although IED 2.0 sets a highly ambitious and transformative regulatory trajectory, its implementation is expected to face notable quantitative and systemic challenges. Estimates suggest that over 50,000 industrial installations across the EU will be subject to updated permitting requirements, with compliance costs projected to increase by 10–20% on average for affected sectors, particularly in energy-intensive industries. For small and medium-sized enterprises (SMEs), which comprise nearly 30–40% of IED-regulated facilities, the financial and technical burden of adopting advanced techniques and real-time monitoring systems could result in delayed compliance or requests for transitional arrangements. The revision introduces new digital reporting obligations through the Industrial Emissions Portal, which will require integration of standardized datasets from all implementing states, posing a significant data management and interoperability challenge, especially for countries with limited administrative capacities. Moreover, the update and incorporation of new BAT Reference Documents (BREFs), which currently take on average 6–8 years per cycle, may need to be significantly accelerated to align with the directive's tighter compliance deadlines, potentially straining the Technical Working Groups (TWGs) and national competent authorities. Additionally, delays in the identification and validation of Emerging Techniques (ETs) with only a limited number currently tracked under the Sevilla Process may affect the timely availability of innovative solutions for certain sectors. These quantitative constraints, combined with the necessity to align IED 2.0 with approximately 20 interrelated EU policies and directives, highlights the risk of phased or staggered implementation, unless adequately supported by EU-level funding mechanisms, technical assistance, and capacity-building programs. As such, while the directive has the potential to significantly reduce industrial emissions by up to 50% in certain pollutants by 2030, its real-world effectiveness will depend on the timely resolution of these operational and policy integration challenges.

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