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Impacts of U.S. Environmental Regulations on Industry

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Abstract

This paper analyzes the impacts of U.S. environmental regulations on industry, focusing on command-and-control environmental regulations (CCER) and market-based environmental regulations (MBER). Drawing on empirical data from the Environmental Protection Agency (EPA) spanning over four decades, we examine key legislation such as the Clean Water Act (CWA), Clean Air Act (CAA), and the Resource Conservation and Recovery Act (RCRA), while also discussing more recent frameworks like the Inflation Reduction Act (IRA). Our findings suggest that, although penalties under CCER contribute to immediate compliance, they often fail to elicit long-term changes in corporate behavior. In contrast, MBER, exemplified by the IRA, encourages investments in green technologies and promotes a shift toward sustainable practices. Through a comprehensive analysis of case studies, including Volkswagen's violations of the Clean Air Act and BP's breach of the Clean Water Act, this study evaluates how regulatory penalties incentivize firms to adopt greener practices, reduce environmental harm, and foster a stronger culture of compliance within industries. Ultimately, the paper advocates for a multifaceted regulatory approach that balances corporate responsibility, cost-efficiency, and environmental protection.

1. Introduction

Academic insights enrich the significance and controversy of U.S. environmental regulations on business innovation and costs. This analysis draws on studies–such as Lin and Zhao (2023), who illustrate how command-and-control environmental regulations foster green innovation, and Becker (2005), who discusses the financial burdens of compliance–to delve into the nuanced relationship between environmental policy, corporate behaviour, and economic outcomes.

Environmental regulation is commonly grouped into command-and-control environmental regulation (CCER) and market-incentive-based environmental regulation (MBER). CCER penalties can have an immediate impact; their effectiveness in promoting long-term behavioural change may be limited (Gunningham & Sinclair, 1999). Meanwhile, MBERs, such as taxes and subsidies, are increasingly recognized for their significant potential to encourage compliance and cost-effectively promote environmental protection (Hahn & Stavins, 2013). For example, Yurdakul and Kazan (2020) highlighted that environmental funding can drive eco-innovation, which contributes to pollution prevention, resource-saving, and recycling, and indirectly enhances a firm's economic performance by reducing costs.

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By analyzing the Environmental Protection Agency (EPA) civil case data across 12 fundamental laws from 1972 to 2023, we find that, except for the IRA, most U.S. environmental acts are CCER-type regulations. This report reveals that significant environmental penalties do not necessarily hinder economic performance across firms, suggesting that well-designed regulations can spur economic performance while addressing climate goals. We also examine how MBER regulation, specifically the 2022 Inflation Reduction Act (IRA), can assist green transitions in various sectors, especially the energy sector.

This report's structure proceeds as follows: Section II describes the overview of key environmental regulations in the United States; Section III displays cases of command-and-control environmental regulation; Section IV discusses the market-incentive-based case; Section V summarizes academic research related to key legislation; Section VI concludes.

2. Timeline of Key Environmental Acts

We demonstrate vital environmental acts from 1947 to 2023 (Figure 1). Among them, the Clean Water Act (CWA) and Clean Air Act (CAA) have a significantly large number of cases and amount of penalties. In 1963, CWA was issued to protect the environment and public health, restoring and maintaining the integrity of the nation's waters by regulating discharges of pollutants and ensuring water quality standards are met. There are 13,466 cases and substantial cumulative penalties exceeding $7.8 billion under CWA. Meanwhile, the CAA was issued in 1972 to control air pollution on a national level by authorizing the EPA to set limits on the emission of specific pollutants that can be released into the atmosphere. There are 13,452 cases and penalties amounting to over $4.6 billion under CAA.

Similarly, the Resource Conservation and Recovery Act (RCRA), established in 1976, has been involved in 10,104 cases, accruing penalties of over $600 million for its significant impact on waste management. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) has addressed 985 cases with total penalties nearing $276.8 million, playing a critical role in the remediation of contaminated sites. Finally, the Emergency Planning and Community Right-to-Know Act of 1986 has seen 5,303 cases with penalties amounting to over $123 million, supporting emergency planning and fostering community engagement in chemical safety matters.

The timeline also includes other notable policies. It commences with the Federal Insecticide, Fungicide, and Rodenticide Act of 1947, with 5,409 cases and penalties exceeding $133 million. Other key policies include the Toxic Substances Control Act and the Safe Drinking Water Act, from 1976 and 1974, respectively, which were enforced through 7,307 and 1,582 cases, with associated penalties nearing $290 million and over $96 million. The Act to Prevent Pollution from Ships, enacted in 1980, exhibits enforcement through 95 cases with penalties exceeding $71 million. Additionally, the timeline documents the Marine Protection, Research, and Sanctuaries Act from 1972, which has a modest 59 cases and penalties of approximately $5 million.

The timeline concludes with the Inflation Reduction Act (IRA) of 2022. The IRA underscores contemporary efforts to supplement environmental legislation and ensures policies evolve. It is unique because it does not involve penalties; subsidies are distributed to foster investments in renewable energy, energy security, and climate change initiatives.

Figure 1: Overview of the Timeline, Total Cases, and Penalties for Key Environmental Acts

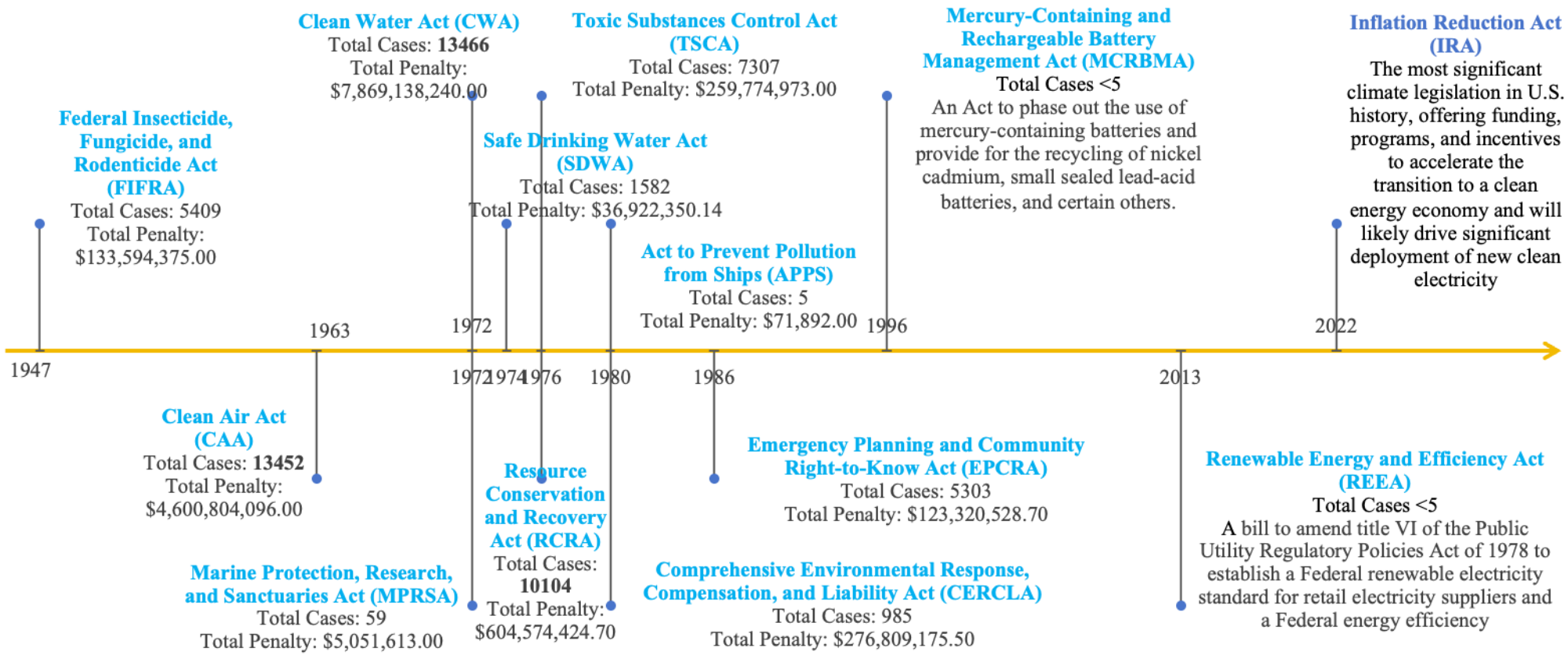


Table 1. Changes in Total Fines Every Five Years

CAA

Period	Time		Penalty
1st 5-year	1973/1/1	1977/12/31	$1,050,550.00
2nd 5-year	1978/1/1	1982/12/31	$28,735,108.00
3rd 5-year	1983/1/1	1987/12/31	$50,093,351.00
4th 5-year	1988/1/1	1992/12/31	$64,600,511.00
5th 5-year	1993/1/1	1997/12/31	$183,367,010.00
6th 5-year	1998/1/1	2002/12/31	$218,345,502.95
7th 5-year	2003/1/1	2007/12/31	$182,246,188.25
8th 5-year	2008/1/1	2012/12/31	$302,349,105.58
9th 5-year	2013/1/1	2017/12/31	$1,830,871,720.61
10th 5-year	2018/1/1	2022/12/31	$1,588,051,272.95
11th 5-year	2023/1/1	2024/2/20	$151,093,776.06

CWA

Period	Time		Penalty
1st 5-year	1974/1/1	1978/12/31	$12,298,106.00
2nd 5-year	1979/1/1	1983/12/31	$14,659,208.00
3rd 5-year	1984/1/1	1988/12/31	$38,343,997.00
4th 5-year	1989/1/1	1993/12/31	$112,304,797.00
5th 5-year	1994/1/1	1998/12/31	$112,368,339.00
6th 5-year	1999/1/1	2003/12/31	$128,400,488.81
7th 5-year	2004/1/1	2008/12/31	$123,430,552.85
8th 5-year	2009/1/1	2013/12/31	$147,834,710.46
9th 5-year	2014/1/1	2018/12/31	$7,010,604,462.41
10th 5-year	2019/1/1	2023/12/31	$167,574,638.82
11th 5-year	2024/1/1	2024/2/20	$1,318,940.00

RCRA

Period	Time		Penalty
1st 5-year	1983/1/1	1987/12/31	$4,654,126.00
2nd 5-year	1988/1/1	1992/12/31	$31,058,694.00
3rd 5-year	1993/1/1	1997/12/31	$85,622,898.00
4th 5-year	1998/1/1	2002/12/31	$94,863,566.37
5th 5-year	2003/1/1	2007/12/31	$179,809,893.81
6th 5-year	2008/1/1	2012/12/31	$66,107,600.01
7th 5-year	2013/1/1	2017/12/31	$69,733,129.86
8th 5-year	2018/1/1	2022/12/31	$60,491,207.95
9th 5-year	2023/1/1	2024/2/20	$9,211,008.73

CERCLA

Period	Time		Penalty
1st 5-year	1981/1/1	1985/12/31	$5,827,831.00
2nd 5-year	1986/1/1	1990/12/31	$7,890,489.00
3rd 5-year	1991/1/1	1995/12/31	$69,239,735.00
4th 5-year	1996/1/1	2000/12/31	$24,495,123.25
5th 5-year	2001/1/1	2005/12/31	$110,756,622.35
6th 5-year	2006/1/1	2010/12/31	$22,365,924.33
7th 5-year	2011/1/1	2015/12/31	$16,382,891.97
8th 5-year	2019/1/1	2023/12/31	$18,472,647.00
9th 5-year	2024/1/1	2024/2/20	$11,533.00

In Table 1, we conducted a more detailed comparative analysis of the four most representative laws: CAA, CWA, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and RCRA. We summarized the changes in total fines every five years for these four laws. Following a substantial fine, we found a noticeable reduction in the frequency and severity of penalties across these laws. This tendency may imply that heavy penalties lower the frequency of related environmental issues because they act as a deterrent to comparable businesses and the whole sector.

3. Cases in the Comment-and-Control Environmental Regulations (CCER)

This section will describe the EPA cases with the highest penalties under primary legislation and explain their impact on the companies and industries involved. These cases are updated as of February 2024 and were sourced from the official EPA website.

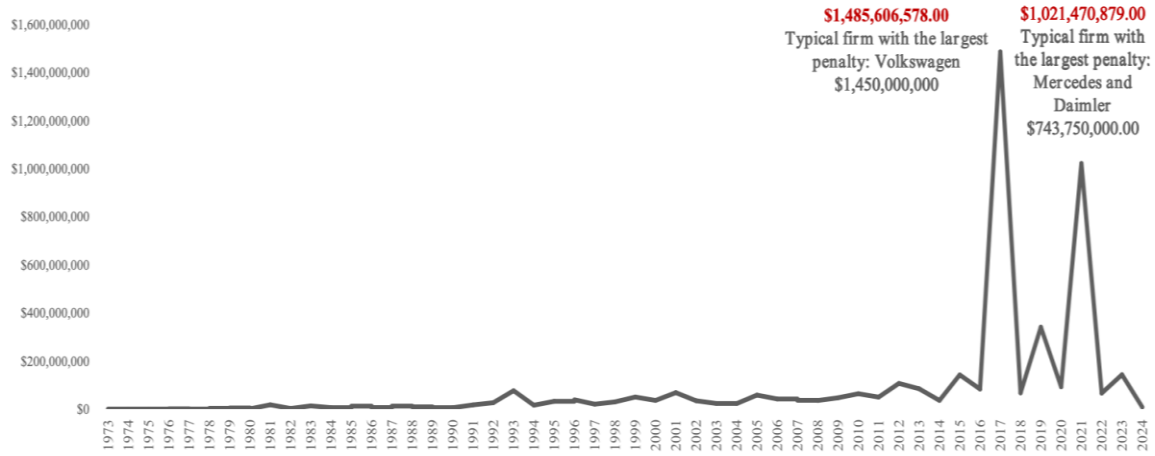
3.1 Volkswagen AG's Violation of the Clean Air Act (CAA)

The CAA is crucial for reducing air pollution and protecting public health in the United States. It sets national air quality standards, regulates emissions from industrial and mobile sources, and mandates the reduction of hazardous air pollutants. As one of the earliest and most significant current environmental laws in the United States, this legislation was passed in 1963 and has undergone several amendments since then.

The EPA reports that the CAA has effectively reduced pollution in the U.S. while the economy has grown. Between 1990 and 2020, air quality improved significantly due to decreased emissions: carbon monoxide dropped by 73%, lead by 86% (since 2010), nitrogen dioxide by 61%, ozone by 25%, coarse particles by 26%, fine particles by 41% (since 2000), and sulphur dioxide by 91%.

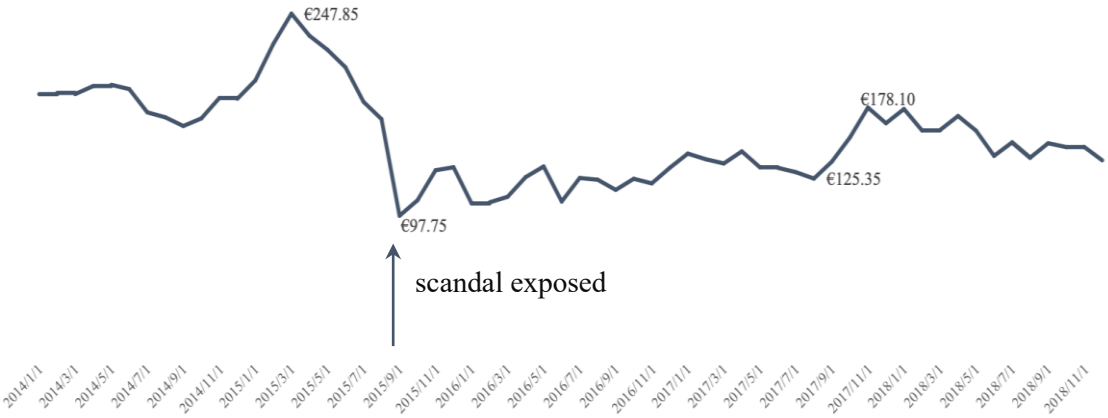
Between 1973 and 2023, the most substantial penalty under the CAA was levied against Volkswagen AG in 2017 following the revelation of diesel emissions cheating by installing "defeat devices" and sophisticated software in nearly 11 million vehicles worldwide since May 2014 (Figure 2). This violation involved almost 600,000 diesel vehicles sold in the U.S. between 2009 and 2016.

Figure 2. CAA: Federal Penalty (1973-2024)



After the scandal was exposed in September 2015, Volkswagen's stock price experienced significant volatility, reflecting the immediate financial impact and uncertainty regarding the company's future (**Figure 3**).

Figure 3. Volkswagen AG Close Price (2014-2018)



In response to criticisms and legal challenges, Volkswagen embarked on substantial reforms to reshape its corporate culture and address its environmental impact. This transformation was marked by a dramatic increase in the automaker's investment in electric vehicles (EVs) and sustainable technologies. According to the yearly Volkswagen Group Annual Report, the Volkswagen Group's automotive division's research and development spending rose to approximately $11.30 billion (€10.18 billion) in 2013, up from $24.18 billion (€21.80 billion) in 2023, signalling a strategic shift towards electric mobility.

To further ensure compliance and ethical behaviour, Volkswagen introduced external monitoring mechanisms, including a whistleblower system and structural adjustments, reinforcing its dedication to governance and environmental responsibility. This comprehensive response and the settlement with the EPA in 2017

mitigated the public relations crisis and helped recover Volkswagen's stock market valuation by the end of that year.

After this scandal, the global shift towards electric vehicles gained momentum in 2016, as the total number of electric cars surpassed 2 million—a 60% increase from the previous year (International Energy Agency, 2017). This trend was supported by findings from Wang et al. (2019), which indicated that environmental penalties could lead to increased investments in green technologies among competing firms within an industry.

The ripple effects of Volkswagen's scandal were observed in the industry years later. In 2021, Mercedes-Benz Group AG (formerly Daimler AG) faced similar allegations of violating the Clean Air Act by failing to disclose illegal defeat devices in about 250,000 diesel vehicles in the United States.

In response, Mercedes-Benz significantly increased its investments in electric vehicles, committing over $42 billion to expand its EV portfolio by 2030 (Mercedes-Benz Group, 2021). This strategic pivot was showcased during the company's first digital Environmental, Social, and Governance (ESG) Conference in 2022, emphasizing its commitment to transparency and sustainability. That same year, Mercedes-Benz also issued its inaugural green bond in China, further underlining its dedication to sustainable practices (Mercedes-Benz Group, 2022).

Over the years 2021 to 2023, the Mercedes-Benz Group progressively increased its capital expenditure allocation towards the production of low-carbon vehicles and sustainable development initiatives, from 21% in 2021 to 22% in 2022 and maintained at 24% in 2023 (Mercedes-Benz Group, 2021, p. 94; Mercedes-Benz Group, 2022, p. 123; Mercedes-Benz Group, 2022b, p. 32). These actions reflect the company's long-term strategy to mitigate climate change and promote eco-friendly transportation solutions.

However, the recurring emissions violations by major automotive manufacturers like Mercedes-Benz underscore the complexities surrounding the efficacy of financial penalties in enforcing environmental compliance. According to Smith and Thomas (2020), while such penalties can prompt immediate compliance improvements, they are less effective in driving long-term behavioural changes in corporate environmental practices. This suggests that relying solely on financial penalties may not be an adequate deterrent. Additionally, meeting stringent environmental standards while maintaining engine efficiency underscores the need for a more comprehensive approach, which may include a combination of technological innovation, stricter enforcement, and incentives for adopting cleaner technologies (Bates, 2021).

3.2 BP Exploration & Production Inc.'s Violation of the Clean Water Act (CWA)

The CWA is fundamental for protecting the water quality in the United States. It aims to prevent, reduce, and eliminate pollution in the nation's waterways, ensuring that surface waters meet standards safe for human health and the environment. The CWA regulates discharges of pollutants into waters and sets quality standards for surface

waters, significantly contributing to the preservation of aquatic ecosystems and the safety of drinking water, maintaining both public health and environmental integrity.

According to reports from state water quality agency partners, 36% of the watersheds monitored under the National Water Quality Initiative exhibited improvements in at least one monitored pollutant from 2017 to 2020 (National Resources Conservation Service, n.d).

Figure 4. CWA: Federal Penalty (1974-2024)

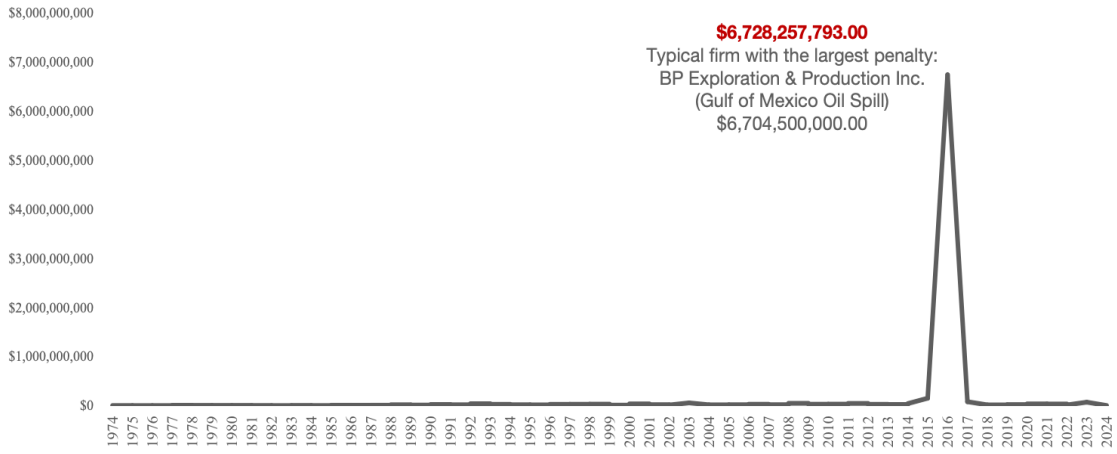


Figure 4 reveals that in 2016, BP Exploration & Production Inc. incurred the most extensive single environmental fine ever recorded under CWA. On April 20, 2010, the oil drilling rig Deepwater Horizon, operating in the Macondo Prospect in the Gulf of Mexico, exploded and sank, resulting in the death of 11 workers on the Deepwater Horizon and the largest spill of oil in the history of marine oil drilling operations. As reported in a 2020 study published in Nature, fish in the Gulf of Mexico continue to exhibit contamination by polycyclic aromatic hydrocarbons (PAHs) (Murawski et al., 2020).

This massive violation of the CWA by BP Exploration and Production Inc. led to significant legal, financial, and operational impacts on the company. BP faced extensive cleanup costs, paid billions in fines and settlements to address environmental and economic damages, and implemented operational changes to comply with stricter safety and environmental regulations. The event also spurred broader industry-wide changes, promoting more rigorous safety and environmental standards in offshore drilling operations (Bureau of Ocean Energy Management, 2011). For instance, the European Commission introduced the Offshore Directive in 2013, designed to minimize the likelihood of significant accidents in offshore oil and gas operations and mitigate their impact (Health and Safety Executive, n.d).

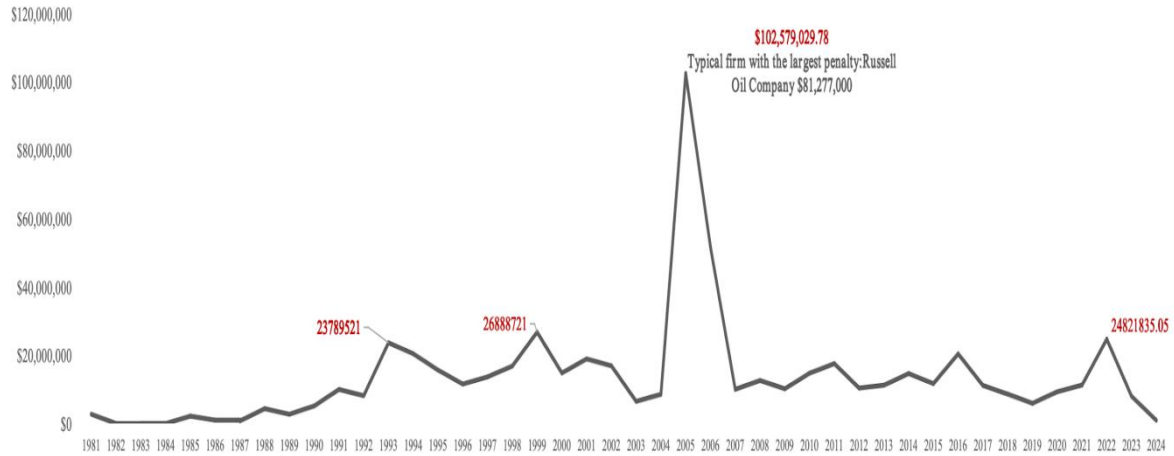
3.3 Russell Oil Company's Violation of the Resource Conservation and Recovery Act (RCRA)

The RCRA, enacted in 1976, is the principal federal law in the United States governing solid and hazardous waste disposal. The RCRA has profoundly impacted

the United States' environmental protection and waste management. Its most significant contribution is establishing a comprehensive framework for managing hazardous and non-hazardous solid waste.

According to the project and landfill database of the EPA, as of 2023, there are approximately 2,635 municipal solid waste landfills in the United States. MSW landfills decreased over the past decades, from about 1,900 in 2009 to around 1,269 in 2018. This trend reflects RCRA's ongoing impacts towards more sustainable waste management practices, including increased recycling and waste reduction initiatives.

Figure 5. RCRA: Federal Penalty (1981-2024)



On April 19, 2005, the U.S. EPA issued a civil penalty order against Russell Oil Company in Oklahoma, proposing a $81,277,000 penalty for leak detection and repair violations (Figure 5). The EPA cited Russell Oil Company for multiple compliance failures, including inadequate corrosion protection and release detection for tanks and piping, insufficient testing of automatic line leak detectors on pressure piping, and the lack of overfill prevention equipment. Although no leaks were detected during the inspection, the absence of these safeguards could lead to undetected releases, potentially causing significant soil and groundwater contamination and other hazards like explosions.

This case led to the amendment and implementation of the Energy Policy Act of 2005, which revised the RCRA to enhance regulations for underground storage tanks. The changes focused on preventing leaks and enforcing more rigorous inspections and corrective actions, becoming part of a broader effort to improve environmental safety and operational accountability for hazardous materials facilities.

3.4 Palmetto Recycling Inc's Violation of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

The CERCLA, commonly known as Superfund, was enacted by Congress in 1980 in response to the threat of hazardous waste sites. The CERCLA protects public health and the environment from hazardous waste sites. It authorizes the EPA to identify

sites contaminated with hazardous substances and facilitate their cleanup by compelling responsible parties to perform cleanups or using federal funds for remediation when necessary. The CERCLA also establishes a legal framework for recovering cleanup costs from those responsible, ensuring the polluter pays principle.

As of the most recent 2023 update, there are currently 874 Superfund sites undergoing cleanup, which are governed by 1,436 enforcement agreements and orders. For the fiscal year 2023, the EPA secured approximately $988.2 million in commitments from potentially responsible parties for future cleanup activities.

Figure 6. CERCLA: Federal Penalty (1981-2024)

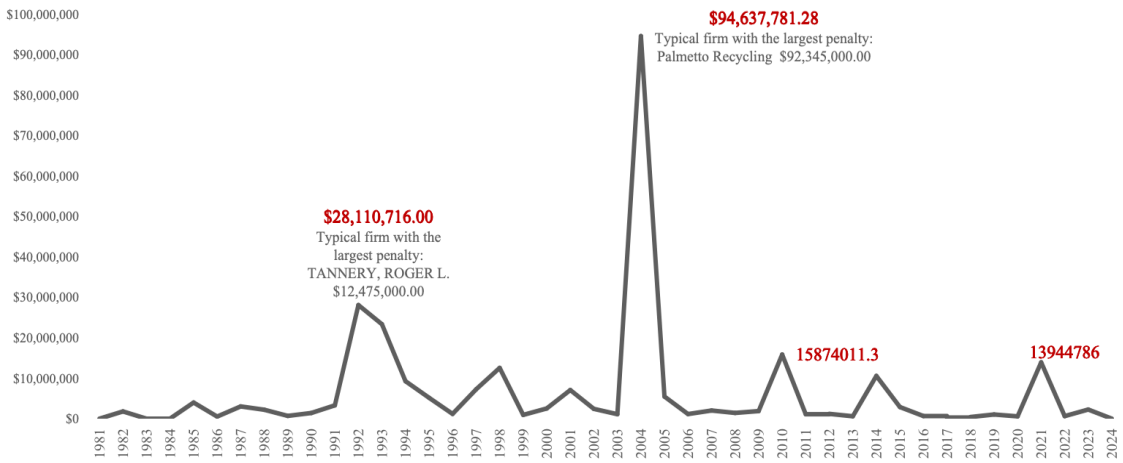


Figure 6 uncovers the case of a CERCLA violation by Palmetto Recycling Inc. in Columbia, South Carolina. Palmetto Recycling Inc. had hosted a battery reclamation facility from 1979 to 1983. Due to soil contamination from the facility's operations, the U.S. EPA added the site to the Superfund program's National Priorities List in 1987. In 1997, the EPA negotiated legal agreements with one Potentially Responsible Party to conduct the cleanup. Demonstrating the EPA's dedication to eliminating environmental hazards and revitalizing sites, the site was removed from the National Priorities List in 2000. It completed a five-year review in 2004, concluding that it no longer presented a risk to public health or the environment.

4. Case in the Market-Incentive-Based Environmental Regulation

The Inflation Reduction Act of 2022 is a significant legislative effort in the United States that incorporates elements of market incentive-based regulations. It includes substantial investments in renewable energy and energy efficiency, aims to lower prescription drug prices, and introduces tax changes intended to fund these initiatives while reducing the deficit (Inflation Reduction Guide Book, 2022).

Rather than imposing mandatory regulations or direct government control, the IRA uses financial incentives to encourage market-driven shifts towards cleaner technologies. These incentives lower the barriers to entry for clean energy investments, encouraging competition and innovation in the renewable sector.

According to a statistical report on clean energy investing in America published by Cleanpower (2023), since the introduction of the IRA law in August 2022, investment in clean energy has reached the total sum of the years 2008 to 2022. We selected the top 5 funding from the existing environmental funding programs until November 28, 2023 (see Table 2). The table shows relatively high funding amounts for these programs, particularly when considering the scale of investment across multiple sectors to reduce greenhouse gas emissions and foster a transition to a low-carbon economy.

Table 2. Top Five Environmental Funding Programs from the IRA

Program	Program Description	Funding Amount
Greenhouse Gas Reduction Fund – National Clean Investment Fund	To provide grants to 2—3 national nonprofit financing entities to create national clean financing institutions capable of partnering with the private sector to provide accessible, affordable financing for tens of thousands of clean technology projects nationwide.	$14,000,000,000.00
Empowering Rural America (New ERA)	To fund the construction of electric distribution, transmission, and generation facilities for rural electric cooperatives, including system improvements and replacements that achieve the greatest reduction in greenhouse gas emissions in rural areas, as well as demand side management, energy conservation programs, and on–grid and off–grid renewable energy systems.	$9,700,000,000.00
Environmental Quality Incentives Program (EQIP)	To support the Environmental Quality Incentives Program (EQIP), which provides technical and financial assistance to producers and Indian tribes to address natural resource concerns and deliver environmental benefits such as improved water and air quality, conserved ground and surface water, increased soil health and reduced soil erosion and sedimentation, improved or new wildlife habitat, and mitigation against drought and increasing weather volatility.	$8,450,000,000.00
Greenhouse Gas Reduction Fund – Solar for All Program	To provide up to 60 grants to States, Tribal governments, municipalities, and nonprofits to expand the number of low–income and disadvantaged communities that are primed for residential and community solar investment—enabling millions of families to access affordable, resilient, and clean solar energy.	$7,000,000,000.00
Greenhouse Gas Reduction Fund – Clean Communities Investment Accelerator	To fund two to seven hub nonprofits with the plans and capabilities to rapidly build the clean financing capacity of specific networks of public, quasi–public and non–profit community lenders—including community development financial institutions (including Native CDFIs), credit unions, green banks, housing finance agencies, and minority depository institutions—to ensprovide grants to 2—7 hub nonprofits that will provide funding and technical assistance to specific industry networks of public, quasi–public, not–for–profit, and nonprofit community lenders, supporting the goal that every community in the country has access to the capital they need to deploy clean technology projects in their homes, small businesses, schools, and community institutions. These community lenders could include community development financial institutions (including Certified Native CDFIs), credit unions, green banks, housing finance agencies, minority depository institutions, and other types of lenders.	$6,000,000,000.00

5. Academic Study

Environmental issues affect every individual and sector, making environmental legislation a subject of significant academic interest. In this section, we will provide an overview of critical academic articles on primary pieces of legislation discussed in Section III, focusing on those published in top-tier journals. However, we will exclude discussions on the IRA due to its relatively recent enactment and lack of substantial empirical data on its effects within the industry.

5.1 Research on the Clean Air Act (CAA)

In the article "The Impact of Car Pollution on Infant and Child Health: Evidence from Emissions Cheating," Alexander and Schwandt (2022) study the detrimental effects of excess pollution on infant and child health using Volkswagen's scandal case as a natural experiment. Their empirical results reveal that counties with higher concentrations of diesel cars that cheated on emissions tests suffered significant increases in air pollution, leading to higher rates of low birth weight and infant mortality.

The authors argue that manipulating emissions testing violated regulatory standards and had severe public health implications, particularly for vulnerable populations like infants and young children. They emphasize the need for stricter enforcement of environmental regulations and suggest that the health costs of such environmental fraud are vastly underestimated. Alexander and Schwandt call for more robust oversight mechanisms to prevent similar future violations and to protect public health more effectively.

5.2 Research on the Clean Water Act (CWA)

A study titled "Consequences of the Clean Water Act and the Demand for Water Quality" by David Keiser and Joseph Shapiro (2019) explored the overall impact of CWA grants to municipal wastewater treatment plants. These grants, which account for much of CWA spending, have significantly reduced water pollution. However, the study finds that the cost of making a river-mile fishable was approximately $1.5 million (in 2014 dollars), with limited effects on housing values despite the enormous expenditures. Thus, the authors argue that while the CWA has significantly improved water quality, the economic benefits may not fully justify the high implementation costs.

They suggest that the act has effectively reduced pollution from point sources like factories but is less successful in addressing non-point source pollution, such as agricultural runoff. Keiser and Shapiro emphasize the importance of balancing regulatory costs with public health and environmental benefits and suggest that future policies should focus on more cost-effective approaches to improve water quality further.

5.3 Research on the Resource Conservation and Recovery Act (RCRA)

In recent academic research titled "Regulating Hazardous Wastes under U.S. Environmental Federalism: The Role of State Resources," Blundell et al. (2024)

explore the impact of variations in state environmental agency budgets on hazardous waste regulation, specifically under the RCRA. The authors investigate how different state funding levels affect monitoring and enforcement efforts at extensive dangerous waste facilities across the United States. They find that states with more resources enforce environmental regulations stringently, leading to varied regulatory outcomes. The study indicates that budget constraints can lead to an increased violation rate at hazardous waste facilities, potentially leading to lower overall environmental quality.

The authors advocate for increased federal oversight or funding to bridge these enforcement gaps and ensure effective monitoring and enforcement of hazardous waste regulations across all states.

5.4 Research on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

In the article "Does Hazardous Waste Matter? Evidence from the Housing Market and the Superfund Program," Greenstone and Gallagher (2008) discuss a pivotal event in U.S. environmental history that led to the creation of the Superfund program. During the 1940s and 1950s, the Hooker Chemical Company, a subsidiary of Occidental Petroleum, disposed of over 21,000 tons of chemical waste in a canal in Niagara Falls, New York, now known as Love Canal. When the area was later developed into a neighborhood, serious health problems arose. For example, high white-blood-cell counts, a potential sign of leukemia, were found in many Love Canal residents and were under close medical observation since then (Beck, 1979). This crisis prompted federal intervention and the creation of the CERCLA, commonly known as the Superfund law, to manage hazardous waste nationwide.

Under CERCLA, the EPA held Occidental Petroleum responsible for the site's cleanup costs, citing the company's significant control over Hooker Chemical's operations. In September 1983, the EPA added Love Canal to the first-ever National Priorities List, marking it as one of the country's most dangerous hazardous waste sites.

In 1986, the Superfund Amendments and Reauthorization Act (SARA) further strengthened the Superfund law, mandating that the EPA oversee property acquisitions and livability investigations related to the Love Canal Emergency Declaration Area (EDA). The Love Canal case was instrumental in shaping the Superfund program, empowering the EPA to compel responsible parties to remediate hazardous sites or reimburse the government for cleanups conducted by the agency.

However, Greenstone and Gallagher's (2008) findings challenge the economic impact of the Superfund program on local communities. Their study reveals that hazardous waste cleanups resulted in only minor, statistically insignificant changes in housing prices, rental rates, housing supply, and population growth near the remediated sites. Given the substantial resources required for these cleanups—averaging $43 million per site—the study raises concerns about the cost-efficiency of the Superfund program and questions whether the economic benefits justify the high expenditures on hazardous waste remediations.

In the article "The Limits of Limited Liability: Evidence from Industrial

Pollution," Akey and Appel (2021) also focus on regulatory frameworks' economic and environmental consequences, particularly regarding how liability and responsibility are distributed between firms and the government. Their study concludes that firms shielded by limited liability are more likely to engage in riskier environmental practices, externalizing pollution costs to society. The authors argue for reforms to limited liability laws, such as environmental insurance mandates, to ensure firms take more financial responsibility for their environmental impact.

5.5 Research on Spillover Effects of EPA Enforcement Actions

"Joining Forces: The Spillover Effects of EPA Enforcement Actions and the Role of Socially Responsible Investors," by Sudipto Dasgupta, Thanh D. Huynh, and Ying Xia (2023), explores how socially responsible mutual funds (SRMFs) enhance the effects of EPA enforcement actions on corporate emissions. Using data from the EPA's Toxics Release Inventory, the Integrated Compliance Information System, and other sources, the authors apply a difference-in-differences framework to analyze how peer firms reduce emissions following enforcement actions against nearby plants. The study finds that proximity to SRMFs amplifies these effects, leading to sustained reductions in toxic emissions.

The authors highlight that SRMFs complement EPA enforcement by encouraging firms to maintain lower emissions through engagement and divestment strategies. This study underscores the potential of socially responsible investing to generate positive environmental spillovers, showing that financial markets and investors can enhance regulatory efforts to curb pollution.

6. Conclusion

The United States has a long-standing history of environmental legislation that plays a crucial role in regulating corporate and industrial behaviour. However, relying solely on higher fines and stricter penalties to curb corporate pollution has proven insufficient. Research shows that while financial penalties may enforce short-term compliance, they do not necessarily bring about long-term changes in corporate behaviour regarding environmental violations. Therefore, a more comprehensive strategy is needed to emphasize strong corporate governance, investment in green technologies, and a genuine commitment to environmental compliance in conjunction with modern, well-crafted environmental protection laws.

Programs like the IRA's funding initiatives can catalyze technological innovation, enhance energy efficiency, and help build a circular economy, supporting the country's environmental goals for 2050. Policymaking must evolve with the times, prioritizing cost-efficiency and long-term sustainability, while corporations are encouraged to take greater responsibility for environmental protection.

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Appendix

Enforcement Cases Summary

	Primary Law	Number of Case	Enactment Time	Trigger for Enfocement	Penalty for Violations	Most Fed Penalty	Case Name	Filed Time	Seplemental Envinronmental Projects Cost	First Case Filed	Case Name	Penalty Cost
1	REEA (Renewable Energy and Efficiency Act)	1	2013 the bill under Public Utility Regulatory Policies Act of	This bill requires (1) electric utilities to obtain a minimum percentage of the electricity they sell in 2021 through 2039 from	PENALTY FOR FAILURE TO DOCUMENT ADEQUATE SAVINGS. If a retail electricity supplier or a retail natural gas supplier fails to demonstrate compliance with an applicable performance standard under subsection	$411,269.00	POLLUTION ABATEMENT SVCS (REFA)	07/19/1977	0	07/19/1977	POLLUTION ABATEMENT SVCS (REFA)	411269
2	APPS (Act to Prevent Pollution from Ships)	5	1980	APPS makes it a crime to knowingly violate certain provisions of MARPOL and other oil pollution laws.	The civil penalties for noncompliance under APPS are significant. A vessel owner or operator can be liable up to $25,000 for each violation and civil penalties for making false or fraudulent statements can reach $5,000 for each statement made.	$17,163.00	Four Bay, IMO Number: 9015060	03/10/2016	0	03/10/2016	Lady Maria Luisa, IMO Number: 9427031	14767
3	MPRSA (Marine Protection, Research, and Sanctuaries Act)	77	1972 amended in 1988 (The Ocean Dumping Ban	also referred to as the Ocean Dumping Act generally prohibits (1) transportation of material from the United States for	The Act authorizes the EPA to assess civil penalties of not more than $50,000 for each violation of a permit or permit requirement, taking into account factors such as gravity of the violation, prior variations, and demonstrations of good faith.	$525,000.00	PORT OF LOS ANGELES	04/28/1998	0	09/09/1985	NL INDUSTRIES, INC. (MPRSA)	30000
4	CERCLA (Comprehensive Environmental Response, Compensation, and	984	passed in 1980 and modified in 1986 by the Superfund Amendments	commonly known as Superfund. This law created a tax on the chemical and petroleum industries and provided	The maximum amount has been increased to $69,733 in 2023. 2024 Revised Penalty Matrix of CERCLA Civil penalty policy	$92,345,000.00	Palmetto Recycling	04/30/2003	0	12/20/1979	HOOKER CHEM-HYDE PARK	1500000
5	SDWA (Safe Drinking Water Act)	15509	1974 with amendments added in 1986 and 1966	to ensure public health protection through compliance by public water systems with federal drinking water standards,	SDWA penalties against federal agencies may be up to $32,500 per day per violation after January 12, 2009. (The Federal Civil Penalties Inflation Adjustment Act of 1990 requires EPA to revise every four years the penalty amounts available under	$2,500,000.00	ANCO OPERATING COMPANY	09/16/1993	0	09/19/1979	ALDER CREEK WATER CO	6200
6	EPCRA (Emergency Planning and Community Right-to-Know Act)	5317	1986 Section 2018 of the America's Water Infrastructure	To reduce the likelihood of such a disaster in the United States, Congress imposed requirements for federal, state, and local	EPCRA section 325 allows civil and administrative penalties ranging up to $10,000 - $75,000 per violation or per day per violation when facilities fail to comply with the reporting requirements.	$1,522,015.00	Andersons Marathon Holdings, LLC	08/16/2022	0	10/16/1988	COLONIAL SUGARS, INC.,	33000
7	FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act)	15697	1947 with amendments in 1972, 1983, 1988,1996 and	The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is the Federal statute that governs the registration,	https://www.epa.gov/enforcement/criminal-provisions-federal-insecticide-fungicide-and-rodenticide-act-fifra	$6,991,400.00	Electrolux Home Products, Inc.	09/22/2020	0	12/16/1976	N. JONAS & COMPANY	2500
8	TSCA (Toxic Substances Control Act)	11541	1976 with amendment in 2016	The Toxic Substances Control Act of 1976 provides EPA with authority to require reporting, record-keeping	TSCA Section 16(b) authorizes EPA to seek criminal penalties against any person who "knowingly or willfully" violates any provision of TSCA Section 15. EPA can seek criminal fines of up to $50,000 for each day the violation continues and/or	$15,000,000.00	TEXAS EASTERN TRANSMISSION CORPORATION	06/06/1988	0	10/03/1978	GENERAL ELECTRIC CO (WATERFORD)	25000
9	RCRA (Resource Conservation and Recovery Act)	13181	1976 which amended the Solid Waste Disposal Act of 1965	The Resource Conservation and Recovery Act (RCRA) gives EPA the authority to control hazardous waste	§3008(a)(3): Compliance Orders Any penalty assessed in the order may not exceed $37,500 per day of noncompliance for each violation of a Subtitle C requirement.	$81,277,000.00	RUSSELL OIL COMPANY	10/26/2004	0	07/09/1979	SALSBURY LABS/LA BOUNTY SITE, CHARLES CITY, IA	300000
10	CAA (Clean Air Act)	20318	1963 with major revisions in 1970, 1977 and 1990 replace Air	To protect public health and welfare nationwide, the Clean Air Act requires EPA to establish national ambient air quality	https://www.epa.gov/enforcement/criminal-provisions-clean-air-act	$1,450,000,000.00	Volkswagen	01/04/2016	0	02/06/1973	HANEY CHEVROLET	500
11	CWA (Clean Water Act)	30674	1948 Federal Water Pollution Control Act 1972 significant	Pollutants are discharged into U.S. waters from point sources without a permit. It also sets criteria for pollutants in surface	Knowing Violations: A person knowingly violating provisions like discharging pollutants without a permit can face fines ranging from $5,000 to $50,000 per day of violation, or imprisonment for up to 3 years. For subsequent convictions, these penalties	$3,352,250,000.00	BP EXPLORATION/MOEX/TRANSOCEAN DEEPWATER/TRITON/GULF OF	12/15/2010	10000000	02/29/1972	RESERVE MINING CO	1037500
12	MCRBMA (Mercury-Containing and Rechargeable Battery Management Act)	1	1996	An Act to phase out the use of mercury in batteries and provide for the efficient and cost-effective collection and recycling or		$0.00	PK ELECTRONICS, INC.	na				
13	IRA (Inflation Reduction Act)	/	2022	IRA is the most significant climate legislation in U.S. history, offering funding, programs, and incentives to accelerate the transition to a clean energy economy								