The Right of Mongolian Citizens to Live in a Healthy and Safe Environment: The Need to Improve the Legal Framework for Reducing Air Pollution

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CONTENT

Abstract

This study examines the legal framework, policy, and management system for combating air pollution in Mongolia, drawing on international and U.S. best practices, with the aim of identifying pathways for improvement tailored to the Mongolian context. It compares the experiences of developed countries in phasing out coal, transitioning to clean technologies, and implementing integrated, cross-sectoral policies, while analyzing the applicability of the U.S. science-based system model for air quality management in Mongolia.

The findings highlight that reducing air pollution requires not only the involvement of environmental institutions but also strong coordination and accountability across diverse stakeholders—including law enforcement, health, education, information, local government, civil society, and the private sector. Moreover, establishing a science-based, multi-stage system of planning, implementation, and monitoring is crucial to achieving sustainable outcomes.

For Mongolia, it is essential to model air pollution policies and the legal environment at a systemic level and enhance policy implementation through a PDCA (Plan–Do–Check–Act) cycle-based scientific framework. Furthermore, the application of artificial intelligence, data analytics, and simulation techniques can help evaluate policy impacts more precisely, strengthen accountability mechanisms, and increase citizen participation—paving the way for a transparent, inclusive, and collaborative governance model. The study recommends assigning clear responsibilities for recording pollution sources, measuring and monitoring emissions, reporting improvements, and ensuring continuous accountability through professional institutions.

From state procurement to public agencies, local governments, enterprises, and households, compliance requirements and performance verification should be systematically enforced to improve implementation. In terms of technology and investment, appropriate models from both public and private sectors should be adopted—expanding opportunities for private companies to generate, transmit, and supply electricity and heat, and creating competitive, market-based infrastructure to improve access. Financially, it is necessary to establish clearer standards and methodologies for calculating polluters' compensation and restoration costs, and to ensure that collected payments are directly allocated to air pollution reduction efforts.

Learning from international practices, Mongolia should classify and regulate emission sources, chemical releases, smoke, and dust by building, equipment, and vehicle type, while ensuring compliance through comprehensive monitoring. The active involvement of local authorities and broad participation from civil society organizations is key to enforcing these standards and strengthening their impact.

1. Introduction

1.1. Research Rationale

Article 16 of the Constitution of Mongolia guarantees the fundamental rights and freedoms of its citizens:

- the right to life; and
- the right to live in a healthy and safe environment, protected from pollution and ecological imbalance.

However, in Ulaanbaatar, air quality has deteriorated severely. During winter, air pollution levels exceed the World Health Organization's recommended threshold by up to 27 times, leaving citizens in urban areas unable to fully exercise their constitutional rights to life and a healthy environment.

As of January 2024, Mongolia scored 48.2 on the Environmental Performance Index, ranking 145th globally for air pollution. By December 12 of the same year, Ulaanbaatar's daily Air Quality Index (AQI) fluctuated between 78 during daytime hours and 152 at peak heating times, placing it among the world's most polluted cities. Based on the 2024 annual global AQI ranking, Mongolia was listed 19th among the countries with the highest levels of pollution.

The main causes of this situation can be summarized as follows:

- Extensive coal burning in ger districts, heating plants, and buildings with poor insulation.
- Key pollutants: PM2.5, PM10, CO, NO_2, SO_2, O_3, and volatile organic compounds.
- According to UNDP data, households in ger areas operate approximately 194,900 small stoves, while the city also relies on 320 large boilers and 2,830 medium-sized boilers.

The following table compares the WHO's 2021 Air Quality Guidelines with the air quality levels recorded in Ulaanbaatar, Mongolia, as of January 2025[1].

Table 1-1. Comparison of WHO Standards and Mongolia's Actual Levels (January 2025)

Indicator (Air Pollutant)	Measurement Period	WHO Guideline	Ulaanbaatar (Jan 2025)	Exceedance
PM2.5 (Fine Particulate Matter)	24-hour mean	15 µg/m³	400+ µg/m³	≈ 27 times higher
	Annual mean	5 µg/m³	~70–100 µg/m³	14–20 times higher
PM10 (Coarse Particulate Matter)	24-hour mean	45 µg/m³	~250–300 µg/m³	5–7 times higher
	Annual mean	15 µg/m³	~100–150 µg/m³	7–10 times higher
NO_2 (Nitrogen Dioxide)	24-hour mean	25 µg/m³	~90–120 µg/m³	3–5 times higher
	Annual mean	10 µg/m³	~40–50 µg/m³	4–5 times higher
SO_2 (Sulfur Dioxide)	24-hour mean	40 µg/m³	~150–200 µg/m³	4–5 times higher
CO (Carbon Monoxide)	24-hour mean	4 mg/m³	~6–10 mg/m³	1.5–2.5 times higher
O_3 (Ozone)	8-hour mean (summer)	60 µg/m³	~20–40 µg/m³ (lower in winter)	Not exceeded (in winter)

Note: *PM2.5 levels in Ulaanbaatar exceed WHO's permissible limits by* ***27 times****, indicating a situation of environmental disaster.*

The following table presents the Air Quality Index (AQI) levels and their health impacts, as defined in the World Health Organization's 2021 Air Quality Guidelines.

Table 1-2. WHO Standards and Mongolia's Actual Levels (January 2025)

AQI Score	Air Quality Index	Health Impact

[1] WHO. Air Quality Guidelines, 2021. Link

0–50	Good	Safe for health
51–100	Moderate	May cause minor effects on sensitive groups
101–150	Unhealthy for Sensitive Groups	Harmful to individuals with respiratory diseases, children, and the elderly
151–200	Unhealthy	Health risks for all; serious risks for sensitive groups
201–300	Very Unhealthy	Severe health impacts for the population; requires special precautions
301–500	Hazardous	Emergency level – severe health damage for everyone

In Mongolia, AQI data for January–December 2024 was recorded on the **World Air Quality Index (WAQI)** platform, covering Ulaanbaatar, Darkhan, Dalanzadgad, Choibalsan, Ölönthiin Dugana, and Sukhbaatar.

The results show that:

- In **Ulaanbaatar**, air quality remained between 51–100 throughout most of the year, deteriorating to 142–200 during winter peaks.
- In **Darkhan**, air quality was clean during the three summer months, moderately polluted (51–100) in spring and autumn, and reached 100–200 during winter[2].

These findings indicate that all residents are at risk of health impacts, while children, the elderly, and individuals with respiratory illnesses are exposed to particularly harmful conditions.

The figure below illustrates the air quality index (AQI) levels of Mongolian cities as recorded in the global database.

Figure 1-1. Air Quality Index of Mongolian Cities as Reported in Global Records

Rank	City	2024 Avg.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
220.	Olonteyn Dugang, Mongolia	104	228	198	119	68	50	52	55	57	43	46	90	153
425.	Darkhan, Mongolia	91	180	153	100	73	60	45	47	50	52	56	103	141
442.	Wuhai, China	91	107	119	105	108	98	86	77	66	75	77	88	89
508.	Dalanzadgad, Mongolia	87	171	131	86	79	80	50	54	63	59	33	67	115
549.	Sukhbaatar, Mongolia	86	173	151	93	64	51	46	48	49	51	40	90	139
574.	Ulaanbaatar, Mongolia	85	135	116	87	77	74	64	51	59	67	66	83	142
619.	Choibalsan, Mongolia	83	92	92	96	74	69	69	96	100	129	37	52	106

The consequences of air pollution pose severe threats to public health. According to World Health Organization (WHO) indicators, the global average mortality rate attributable to outdoor and indoor air pollution is **92 deaths per 100,000 population**, while in Mongolia the figure reaches **132 deaths per 100,000 population**[3].

[2] Air Quality Index for Mongolia, 2024. Link
[3] WHO's 2018 Recommendations on Reducing Health Impacts of Air Pollution in Mongolia. Link

A study conducted under the EU-funded UNDP project *"Improving Health and Environmental Sustainability through Pollution Reduction"* estimated that in Mongolia, air pollution causes 7,139 premature deaths annually, leading to an economic loss of 4.8 trillion MNT each year[4].

In the most polluted zones, 844,646 residents—53% of Ulaanbaatar's population—are directly exposed. During winter months, when pollution levels reach hazardous thresholds, the entire population experiences negative health impacts. Once individuals develop conditions such as smoke- and dust-related allergies, asthma, cardiovascular, or cerebrovascular diseases, they become part of the "health-vulnerable group." For these people, whenever air quality exceeds an AQI of 51, their pre-existing conditions are likely to worsen, putting them at continuous health risk. Therefore, it can be concluded that all citizens living in Mongolia's cities, towns, and provincial centers are experiencing a serious violation of their constitutional right to live in a healthy and safe environment.

1.2. Subject and Scope of the Study

This study aims to evaluate the effectiveness of legal and regulatory measures in addressing Mongolia's winter air pollution, drawing comparisons with international experiences.

The scope of the study includes:

- Selection of countries with similarly cold climates, located in northern and southern latitudes, where heating demand is high during winter. These countries were chosen based on their prior experience with severe air pollution, but which have successfully mitigated it through legal reforms and effective policy implementation.
- When selecting comparison countries, population size, economic development, and differences in legal systems were not the primary criteria. Instead, the focus was on approaches to tackling air pollution and the impacts of associated legislative changes. To identify lessons applicable to Mongolia, the study examines countries with large territories, multiple administrative regions, and subnational divisions where air pollution has been effectively managed.
- The study analyzes the outcomes of policies and legal measures in these countries, comparing them with Mongolia's current regulatory framework to identify the strengths and weaknesses of Mongolia's legal environment.
- This research provides a foundation for further in-depth analysis of policy effectiveness in Mongolia, the development of alternative policy scenarios, and the application of lessons learned from other countries' experiences to improve Mongolia's air pollution management.

1.3. Research Aim and Objectives

Main Research Question:

How have countries with cold climates implemented legal reforms to reduce air pollution, and how do the outcomes of these reforms differ from the measures currently implemented in Mongolia?

Aim:

To develop recommendations for improving Mongolia's legal framework to ensure citizens' constitutionally guaranteed right to live in a healthy and safe environment, with a particular

[4] B. Azbayar, Research: Air Pollution Causes 7,139 Annual Deaths in Mongolia, 2024. Link

focus on enhancing the effectiveness of legislation and policies aimed at reducing winter air pollution.

Objectives:

1. **High-level screening:**
   Identify countries worldwide that have successfully reduced winter air pollution and collect information on their legal and policy reforms.
2. **Benchmarking comparison:**
   Systematically compare and analyze the laws, policies, and implementation outcomes of the selected countries.
3. **Case study analysis:**
   Based on the benchmarking results, select one (or several) country(ies) with the most successful legal and policy experiences and conduct an in-depth case study (e.g., the United States).
4. **Checklist development:**
   Develop a "best practice criteria checklist" to determine which legal and policy reforms Mongolia should consider. Use this checklist to compare Mongolia's current situation with international best practices.
5. **Practical recommendations:**
   Based on the benchmarking and checklist analysis, formulate actionable legal and policy recommendations suitable for implementation in Mongolia.

2. Literature review

2.1. Methodologies for Measuring the Effectiveness of Air Pollution Reduction Policies

Recent studies have highlighted effective methods for measuring and mitigating air pollution in cities, particularly during the winter season.

Quantitative methods include:

- Using difference-in-differences (DiD) analysis to evaluate policy impacts (Weng et al., 2022).
- Combining IoT technology with predictive models to create pollution "heat maps" (Govea et al., 2024).

Qualitative methods include:

- Studying international best practices for improving air quality (Quarmby et al., 2019).
- Evaluating the effectiveness of local policies aimed at reducing emissions (Pisoni et al., 2022).

Effective policy interventions typically involve:

- Transitioning to cleaner heating systems (Weng et al., 2022).
- Establishing low-emission zones.
- Implementing traffic restrictions.

Urban green spaces have been shown to effectively reduce airborne particulate matter, with a variety of measurement methodologies applied to assess their impact (Vigevani et al., 2023).

Machine learning algorithms have proven effective for precise forecasting of air pollution (Mitreska Jovanovska et al., 2023).

Combining quantitative and qualitative policy analysis methods is essential for addressing urban planning and environmental challenges effectively (Clark, 1986).

Table 2-1. Comparison of Policy Analysis Methods

Research Title	Summary	Main Findings	Methodology
Air Quality Strategies and Technologies: A Rapid Review Sarah Quarmby et al., 2019	Strategies and technologies for improving air quality: Rapid review	Reviewed effective policy interventions to improve urban air quality.	- Active mobility infrastructure, roadside barriers, low-emission zones, and speed-limited areas were most effective. - Measures such as public transport, cycling networks, and incentives for electric transport are effective when implemented together. - SO2 emissions in the UK decreased by 98% since 1970.
Effect of Cleaner Residential Heating Policy Zhixiong Weng et al., 2022	Effect of clean heating policies	Studied the reduction of winter air pollution in China through clean heating policies.	- PM2.5 decreased by 7.32%, PM10 by 2.62%, SO2 by 3.98%, NO2 by 4.67%. - Implementation level and distance from city center influenced results.
Methods for Urban Air Pollution Measurement and Forecasting Elena Mitreska Jovanovska et al., 2023	Measuring and forecasting urban air pollution	Studied methods for measuring and forecasting urban air pollution using machine learning.	- Identified effective ML models for predicting pollutants. - ML technology provides actionable solutions for policymakers.
Methods to Quantify Particle Air Pollution Removal by Urban Vegetation Vigevani et al., 2023	Methods to quantify particulate matter reduction by urban green spaces	Reviewed methods for measuring PM reduction capacity of green spaces.	- Gravimetric methods are most widely used (40%). - Standardized measurement methods are lacking.
Assessing the Impact of Local Policies on PM2.5 E. Pisoni et al., 2022	Evaluating the impact of local policies on PM2.5	Evaluated the effect of local policies on PM2.5 reduction in 10 European cities.	- Some cities more effective at reducing PM2.5 at low levels, others at high levels. - Inter-city collaboration needed.
Integration of Data and Predictive Models Jaime Govea et al., 2024	Integration of data and predictive models	Proposed a policy decision-making approach using IoT and ML to evaluate air quality and noise.	- High pollution near industrial zones and traffic. - Used CNN and decision trees for high-accuracy predictions.
Basic Methods of Policy Analysis and Planning Pat Clark, 1986	Basic methods of policy analysis and planning	Overview of quantitative and qualitative policy analysis and planning methods.	Main results not specified (theoretical lesson/manual).
Effects of Traffic Policies on Air Pollution and Health J. Boogaard, 2007	Effects of traffic policies on air quality and health	Evaluated the impact of traffic policies on air quality and health.	- LEZ policy alone was insufficient. - Reducing traffic on a single street decreased NO2, soot, and smoke, improving lung function by 3–5%.
Assessing the Effectiveness of Local Transport Policies D. Nuvolone et al., 2009	Evaluating local transport policy effectiveness	Reviewed methods to assess the impact of local transport policies on air quality and health.	- Multiple factors influence effectiveness; single-value conclusions are difficult. - Improved monitoring tools required.
Urban Air Pollution Control Policies and Strategies Ahmad Jonidi Jafari et al., 2021	Urban air pollution control policies and strategies	Overview of global policies and strategies to reduce urban air pollution.	- Transport policies dominate (bike lanes, electric transport, fuel control). - Coal phase-out and renewable energy are important.
Air Pollution Control Policies and Impacts Tong Feng et al., 2024	Air pollution control policies and impacts	Reviewed trends in air pollution policy research.	- Research covers methodology and health impact. - Ex-post evaluation and modeling dominate.
Analyzing Effectiveness of Environmental Policies Leticia Abarca Velencoso, 2021	Analyzing the impact of environmental policies	Evaluated outcomes of emissions-reduction policies using the Russian model.	- Policies like taxes and limits were ineffective, but feed-in tariffs supported renewable energy.

Methods for Evaluating Environmental Health Impacts J. Benavides et al., 2022	Methods for evaluating environmental health impacts	Reviewed stepwise methods to evaluate urban policies' health impacts.	- Specific methods needed for each stage of policy development. - Combined methods (simulation + observational) increasingly used.
Clean Air Action in Beijing T. Vu et al., 2019	Beijing Clean Air Action Plan	Evaluated the impact of Beijing's clean air plan using ML.	- Climatic conditions strongly affected policy outcomes. - Policy reduced PM2.5, PM10, NO2, SO2, CO.
Diminishing Effects of Winter Heating Junfeng Wang et al., 2022	Reducing the impact of winter heating	Studied the effect of China's winter heating policies on air quality.	- PM2.5, PM10 reductions more observable during 2014–2017. - Policy more effective in large cities.
Evaluating Air Quality Regulations Lucas Henneman et al., 2017	Evaluating air quality regulations	Reviewed methods and accountability frameworks for assessing air quality regulation outcomes.	Main results not detailed.

2.2. Overview of Research on Winter Air Pollution in Mongolia

2.2.1. Previous studies on winter air pollution levels in Mongolia and international scientific articles

Mongolian cities, especially Ulaanbaatar, continue to experience the highest air pollution among cold-climate regions during the winter season. PM2.5 concentrations in the central districts reached 148 µg/m³, while ger district areas exceeded 2000 µg/m³, far surpassing the WHO 2021 guidelines and levels in other countries. In Ulaanbaatar, central monitoring points recorded 148 µg/m³ of PM2.5, while ger districts burning raw coal exceeded 2000 µg/m³, which is 3–100 times higher than the recommended levels.

Policy context:
Between 2019–2020, air quality temporarily improved due to certain policy measures. Prohibitions on raw coal use and stove replacement programs in Ulaanbaatar reduced PM2.5 levels by 30–44%. However, data after 2022 are not included, and by 2025 air quality had deteriorated again, as described in the background section of this study.

Methodology:
This study reviewed 499 publications from Elicit, ResearchRabbit, and ResearchGate, including reports and scientific articles, of which 39 were screened using seven selection criteria. Some reports from Inner Mongolia (China) and Kazakhstan were excluded due to overlap. Using five main indicators, nine articles were selected for in-depth review. The key characteristics of these included articles are presented in the following section.

Additionally, two publicly reported studies from electronic databases were found and compared.

Table 2-2. Included Studies

№	Study	Location	Study Period	Measurement Method	Main Pollutants Measured
1	Allen et al., 2011	Ulaanbaatar, Mongolia	1 June 2009 – 31 May 2010	Land-use regression model, mobile monitoring	PM2.5, PM10, NO2, SO2
2	Kim et al., 2022	Ulaanbaatar, Mongolia; Beijing, China; Sosan & Seoul, South Korea; Noto, Japan	15 Dec 2020 – 15 Jan 2021	Not specified	PM2.5, organic aerosols, nitrate, sulfate
3	Tuvjargal et al., 2022	Ulaanbaatar, Mongolia	Winters 2017 & 2020	Not specified	PM2.5, black carbon
4	Gunchin et al., 2019	Ulaanbaatar, Mongolia	2014–2016	X-ray fluorescence spectrometer, reflectometer	PM2.5, PM2.5–10, black carbon
5	Dickinson-Craig et al., 2025	Ulaanbaatar, Mongolia	Since May 2019	Not specified	PM2.5, PM10, SO2, CO

6	Batmunkh et al., 2015	Ulaanbaatar, Mongolia	1 Jan – 31 Dec 2012	Not specified	PM10, SO2, NO2
7	Anonymous, 2019	Ulaanbaatar, Mongolia	Winter & Spring (year unspecified)	Not specified	PM2.5
8	Gombojav et al., 2014	Ulaanbaatar, Mongolia	Jan–Mar 2014	Mobile monitoring with nephelometer	PM2.5
9	Baldoj, Sato, 2017	Ulaanbaatar, Mongolia	Oct 2015 (2 weeks)	Filter sampling	PM2.5
10	Sumiya, Erdenesukh, 2022	Ulaanbaatar, Mongolia	2022	Not specified	PM2.5, PM10, SO2, NO2, black carbon
11	Tseren-Ochir, Soyol-Erdene, 2021	Ulaanbaatar, Mongolia	2014–2021	Statistical analysis, climate modeling	PM2.5, PM10, SO2, NO2, O3, black carbon

The above 11 studies cover the period 2009–2022. The most frequently measured pollutants were PM2.5, PM10, SO2, NO2, CO, and O3.

Internationally, additional pollutants such as trace elements, primary and secondary pollutants, black carbon, nitrate (NO3), sulfate (SO4), chloride (Cl), arsenic (As), nitrogen oxides (NOx), organic and inorganic compounds, and various chemical substances are also monitored, but these were not included in Mongolian studies.

The levels of fine particulate matter (PM) and other main pollutants were categorized as shown in the table below. During winter, Ulaanbaatar has consistently had the highest air pollution. PM2.5 concentrations generally exceeded 100 $\mu g/m^3$, with some studies recording levels above 1000 $\mu g/m^3$.

Table 2-3 Quantitative Results: Air Quality Measurements

Study	Location	Winter PM2.5 Level ($\mu g/m^3$)	Compliance with WHO Guidelines	Heating Type
Allen et al., 2011	Ulaanbaatar, Mongolia	148 (central), up to 250 (ger districts)	Exceeded	Coal, wood
Badarch et al., 2021	Ulaanbaatar, Mongolia	>2000 (peak)	Exceeded (80×)	Ger district coal use
Warburton et al., 2018	Ulaanbaatar, Mongolia	Not specified	Exceeded (100×)	Household coal burning
Suriya et al., 2022	Ulaanbaatar, Mongolia	Not specified	Not specified	Coal heating
Bayart et al., 2024	Ulaanbaatar, Mongolia	Not specified	Exceeded	Coal briquettes
Nakao et al., 2017	Ulaanbaatar, Mongolia	86.4 (average)	Exceeded (3–5×)	Solid fuels (coal, wood)
Byambajav et al., 2021	Ulaanbaatar, Mongolia	161 (Jan 2019), 88 (Jan 2020)	Exceeded	Coal briquettes (2020)
Lodoyasamba & Pemberton-Pigott, 2011	Ulaanbaatar, Mongolia	300–620 (coal-burning districts)	Not specified	Coal burning
Warburton et al., 2013	Ulaanbaatar, Mongolia	350 (hourly maximum)	Exceeded (>200×)	Ger district coal use
Sumiya, Erdenesukh, 2022	Ulaanbaatar	PM10: avg. ~150–300[1]	Exceeded (~10–20×)	Coal, briquettes
Tseren-Ochir, Soyol-Erdene, 2021	Ulaanbaatar	PM2.5: Winter >100 avg.[2]	Exceeded (~10–15×)	Coal, heating plant

2.2.2. Previous Projects and Organizational Studies on Winter Air Pollution Levels in Mongolia

The first systematic observations of Ulaanbaatar's air pollution began in the early 2000s. The main research periods can be categorized as follows:

Research Periods (historical timeline)

- **2000–2010:** Early monitoring; use of raw coal fuel predominated, not meeting standards.
- **2010–2018:** Pilot measures such as clean stoves and briquettes were introduced.
- **2019–2023:** Decisions to ban raw coal were implemented, and reductions in PM2.5 were observed.
- **2024–2025:** Introduction of new policies, including electric heaters and "smokeless technologies."

Measurement Methodology
Air pollution has been measured using the following main methodologies:

- **Fixed stations:** 12 automatic stations operate in Ulaanbaatar, recording hourly PM2.5, PM10, NO_2, CO, SO_2, and O_3 concentrations.
- **Portable monitors:** Research teams conduct temporary on-site measurements.
- **Spectroscopy and laser sensors:** Widely used in recent years for measuring fine particulates and gases.
- **Open data platforms:** International platforms such as IQAir and AirVisual are increasingly used.

Results and Main Pollutants (highlighted values)
Main pollutants:

- **PM2.5:** Reaches 300–600 µg/m³ in densely populated ger districts during winter.
- **PM10:** 5–10 times higher than the internationally accepted limit (50 µg/m³).
- **NO_2, SO_2, CO:** High in city centers and along major roads due to coal combustion.

Table 2-4. Consolidated Table of Research, Policies, and Projects Implemented to Reduce Air Pollution in Mongolia

№	Organization / Source	Year	Main Content / Topic	Key Measures, Conclusions / Highlighted Results
1	WHO	2020	Strategy to reduce health impacts	Ban on raw coal and waste fuels; improve home insulation
2	UNDP	2021–2023	Multiple projects, platforms, technologies used	Haze Gazer, "From Coal to Sun" project, investment studies
3	World Bank	2011	Air pollution and health	PM2.5 exceeded 35×; 1,600 annual deaths
4	CCAC – SNAP project study	2018–2022	Integrated SLCPs and GHG calculations	Strategies to reduce GHG 22.7%, Black Carbon 12%, Methane 23%
5	UN, UNDP, EU, international consortium	2023	Integration of air pollution and climate change	Policies with co-benefits developed
6	JICA	2015	Ulaanbaatar AQI study	Main source of air pollution: raw coal in ger districts
7	World Bank / Asian Development Bank joint study	2018	Health risks, vulnerable groups	Pregnant women and children most affected; smoke reduces Human Development Index (HDI)
8	MUST – Research institute	2019	Study on effects of coal briquettes	Risks (toxicity) coexist with benefits (smoke reduction)
9	UNEP	2021	Policy coherence and institutional coordination	Inter-sectoral policies needed to improve air quality
10	SEIS (Finance & Economics University)	2023	Electric heating and economic impact	Zero subsidies effective, but insufficient infrastructure and supply

2.2.3. Research Gaps and Assessment

Although many studies have been conducted on winter air pollution in Mongolia, particularly in Ulaanbaatar, a unified, long-term, science-based monitoring and research system has not yet been established. Although the CCAC-SNAP project (2018–2022) introduced reforms and advancements, quantitative data, policy implementation monitoring, and local-level studies since 2020 remain limited. New methodologies (LEAP-IBC) and SLCPs (e.g., black carbon, methane) were integrated, but internal monitoring, sustainable implementation, and a centralized data system are lacking. The 2024–2025 “Smoke Audit” highlighted systemic governmental errors, lack of accountability, and issues with outcome reporting.

Table 2-5. Summary Table of Main Research Gaps and Progress

Content	Description
Research progress	CCAC-SNAP project implemented; long-term forecasting, new pollutants (SLCPs), and LEAP-IBC model introduced.
Gap 1	Limited regular air quality monitoring since 2020
Gap 2	No transparent, centralized data system
Gap 3	Few local-level studies
Gap 4	Long-term effects of fine chemical pollutants not studied
Gap 5	Weak policy implementation monitoring and evaluation
Gap 6	Methodologies and platforms not institutionalized; dependence on international projects

2.2.4. Conclusions on Reviewed Literature

Based on international reports measuring research and policy outcomes, Mongolia lacks studies that systematically analyze programs, plans, projects, and policy documents using scientific evidence. In particular, there is a need for calculations, simulations, and performance measurements evaluating legal reforms and their impacts in other countries. Although the National Program to Reduce Air and Environmental Pollution (2017–2025) has been approved, its outcomes remain unclear, reflecting policy decisions made without sufficient research or quantitative analysis.

In recent years, cold-climate countries have implemented effective laws and policies to reduce air pollution, using science-based assessments. The basis for their success includes scientific calculations, phased implementation, public engagement, and monitoring systems with real performance indicators.

In Mongolia, these mechanisms are not fully developed, and systematic research assessing policy implementation and impacts scientifically is limited. Comparative studies based on experiences of similar countries are also scarce. Some developing countries’ experiences were not fully successful and therefore cannot be directly replicated.

Although international research has comparatively well analyzed experiences of countries that faced winter smoke problems, updated their legal frameworks, and implemented effective policies, there are very few studies comparing legal frameworks in countries with conditions similar to Mongolia (e.g., cold climate, centralized heating, high coal consumption).

Therefore, this study highlights the need to screen international experiences using “policy success criteria,” conduct benchmarking comparisons, and select the most optimal and instructive countries for in-depth case studies. This approach enables the comparison of Mongolia’s current laws and policy measures with successful practices elsewhere, allowing gap analysis. The findings will provide a concrete foundation for proposing legal reforms that ensure citizens’ rights to live in a healthy and safe environment, as guaranteed by the Mongolian Constitution.

3. Research Methodology

3.1 General Rationale of Methodology

The main objective of this research is to identify opportunities to localize international best practices for improving the legal and policy effectiveness of air pollution reduction in Mongolia. The overall methodology is qualitative, using international benchmark models for comparison, followed by detailed case studies of selected countries, executed through a qualitative mixed-method design**.**

The study employed the following three main methodological components:

1. Policy Outcome Evaluation – In Chapter 2, the current level of air pollution in Mongolia and the effects of existing policies were analyzed using policy outcome evaluation methods.
2. Benchmark-based Comparative Case Study – In Chapter 4.1, international experiences were analyzed comparatively to identify common best practices, and countries for detailed study were selected based on evidence.
3. Policy-Legal Best Practice Identification – In Chapter 4.2, U.S. case studies were used to identify best practices in policy and legal frameworks.
4. Comparative Analysis for Mongolia – In Chapter 5 (Conclusions) and Chapter 6, selected indicators were used to compare the U.S. and Mongolia, highlighting gaps and providing a checklist for further research (Policy–Legal Gap Analysis).

Combining these approaches allows assessment of Mongolia's air quality-related laws and policies against international standards and mechanisms, providing a basis for evidence-based recommendations.

3.2 Research Strategy

The research applied the following qualitative strategies:

Table 0-1. Research Strategy

Methodological Strategy	Description
Document analysis	Analyzed the structure, coherence, and implementation of Mongolia's air pollution-related laws and policy documents.
Secondary quantitative analysis	Used data from WHO, IQAir, EPI, etc., to study pollution trends.
Case study	Compared experiences from the U.S., Japan, South Korea, Poland, and other countries in a policy context.
Gap analysis	Identified gaps between Mongolia's Constitution and policy implementation; developed checklist questions to compare with the U.S. policy system.
Impact logic modeling	Evaluated policy outcomes using Input → Process → Output → Outcome → Impact logic model. Recommended using design approaches, process mapping, and process design to further policy analysis, development, and evaluation of alternatives.

3.3 Main Methods Used in the Research

3.3.1 Policy Performance Evaluation

Primary document: *National Program to Reduce Air and Environmental Pollution (2017–2025)*

Other documents: International organization reports, recommendations, and studies evaluating policy implementation.

Evaluation framework:

- **Input**: Funding, structure, organization
- **Process**: Implementation stages
- **Output**: Updated standards, technical instruments
- **Outcome**: Trends in PM2.5 and PM10 reduction
- **Impact**: Health indicators, improved living environment

3.3.2 Benchmark-based Comparative Case Study

- **Selected countries**:
  - Countries located in the northern and southern hemispheres with cold climates, experiencing winter cold, requiring heating, and exposed to air pollution from coal use were selected and evaluated based on their level of smoke reduction. From these, the following countries' experiences were examined in detail:
    - Common law system countries: United Kingdom, USA, Canada, New Zealand, Australia
    - Civil law system countries: Germany, Finland, Sweden, Poland, South Korea, Japan
    - Neighboring countries: Russia, China
- **Comparative criteria**:
  - Structure and fundamental principles of legal reform
  - Air quality standards, monitoring systems, and observed results
  - Public participation, reporting, and transparency
  - Coordination of economic, technical, and institutional regulations
  - Policy effectiveness measured by citizens' health

3.3.3 Policy–Legal Gap Analysis

Base documents used: Constitution of Mongolia (1992), Article 16, Clause 2 ("Right to live in a healthy and safe environment")

Objective: Identify gaps between constitutional rights and actual implementation

Indicators: Monitored and analyzed based on WHO and EPI indicators

Root cause analysis:

- Insufficient scientific basis in policy documents
- Limited monitoring and unclear performance indicators
- Weak accountability and oversight of implementation

3.4 Validation of Research Methods

Using a mixed qualitative methodology provided the possibility to validate and triangulate the research results. This includes:

- Ensured coherence between quantitative and qualitative data;
- Cross-checked multiple sources and international data;
- Evaluated all stages of the policy cycle;
- The evaluation criteria were comparable and measurable.

3.5 Research Limitations

- Sampled only countries with cold climates that experienced winter air pollution, showed improvements, and implemented legal reforms;
- Air quality data were seasonally variable and limited to one year;
- In-depth interview data on policy implementation were limited;
- Policy analysis in Mongolia was conducted at a limited depth, based on outcomes of reduced air pollution, so not all documents were analyzed individually;
- For some country cases, monitoring results were used from secondary sources.

4. Research Findings

4.1. International Benchmarking

4.1.1. Common Law Countries

The table below summarizes and compares the legal regulations, implementation measures, and key features for reducing winter air pollution in common law countries (UK, USA, Canada, New Zealand, Australia).

Table 4-1. Legal Regulations for Reducing Winter Air Pollution in Common Law Countries – Comparative Table

Country	Main Legal Regulations	Responsible Agencies	Implementation Measures	Key Features
United Kingdom (UK)	- Clean Air Strategy - Air Quality Standards Regulations 2010 - Gothenburg Protocol - EU Directive 2008/50/EC - Clean Air Act (1956)	- Local authorities - Environmental agencies - Government	- Clean Air Zones (CAZ) - Air Quality Management Areas (AQMA) - Fines - Subsidies and support	- Based on international and EU laws - Clear allocation of implementation responsibilities - Long-term goals
USA	- Clean Air Act (CAA) - NAAQS (National Ambient Air Quality Standards) - SIPs (State Implementation Plans)	- EPA (Federal) - State and local authorities	- Stationary and mobile source control - Fuel standards - Transport management - Waste incineration limits	- High responsibility at state and local level - Strict enforcement mechanisms - Winter-specific regulations
Canada	- CEPA (1999) - CAAQS (Canadian Ambient Air Quality Standards) - Clean Fuel Regulations	- Ministry of Environment - Provincial and territorial authorities	- Industrial and mobile source limits - Fuel quality control - Building code updates	- Strong coordination between federal and provincial levels - Cooperation with USA - Integrated with urban planning and insulation policies
New Zealand	- Resource Management Act (1991) - National Air Quality Standards (2004, 2011)	- Ministry of Environment - Local authorities - Private service providers	- PM10 limits - Gradual restriction on fuel-burning devices - Financial subsidies and investments	- Policies aligned with Maori traditions - Centralized local implementation - Support for residential areas
Australia	- National Clean Air Agreement (2015) - State Environment Protection Acts - AS/NZS 4012, 4013 standards	- Federal and state EPA - Local authorities - Private sector	- Heating device standardization - Usage restriction regulations - Subsidies and grants - "Burn Right Tonight" awareness campaign	- Joint central-state policy - Strong public-private coordination - Economic policies supporting green jobs

Observations from the table:

- USA regulates detailed central and state cooperation through law and implements strict enforcement mechanisms.
- UK follows a strategy aligned with international and EU laws.
- Canada integrates urban planning, fuel quality control, and provincial coordination.
- New Zealand emphasizes traditional culture and social participation, with centralized local implementation.
- Australia combines state coordination with standards, restrictions, and public information campaigns.

This table compares the countries' geographic location, climate conditions, coal use, building heating, and history of air pollution.

Table 4-2. Comparison of Air Pollution History by Heating Source

Country	Geographic Location	Time Period	Coal Usage	Heating Method	History of Air Pollution	Implemented Laws and Regulations
United Kingdom	Europe, cold climate	1952	High in winter	Coal fuel, steam boilers	Great Smog of London (1952)	Clean Air Act (1956)
USA, Los Angeles	North America, cold climate	1970	High in winter	Coal fuel, natural gas	Los Angeles Smog (1970)	Clean Air Act (1970)
USA, Chicago	Central North USA	1940s–1950s	High in winter	Coal fuel, steam boilers	Coal smoke, industrial pollution	Air Pollution Control Act (1959)
USA, Cincinnati	Southern Ohio	1900s–1940s	High in winter	Coal fuel, steam boilers	Coal smoke, industrial pollution	Smoke Abatement Ordinance (1907)
Canada	North America, cold climate	1970	High in winter	Coal fuel, natural gas	Toronto, Vancouver smog (1970)	Canadian Environmental Protection Act (1999)
New Zealand	South Pacific, cold climate	1990s	High in winter	Coal fuel, natural gas	Smog in multiple cities (1990s)	Resource Management Act (1991)
Australia	South Pacific, warm climate	2000–2010	High in winter	Coal fuel, natural gas	Smog in Melbourne, Sydney (2000–2010)	National Clean Air Agreement (2015)

4.1.2. Countries with Civil Law Systems

The table below summarizes the comparison of laws and policies to reduce winter air pollution in selected countries with civil law systems, highlighting key features, legal measures, and policy directions.

Table 4-3. Legal and Policy Comparison for Reducing Winter Air Pollution in Civil Law System Countries

Country	Key Legal Acts	Central Policy	Key Measures	Conclusion
Germany	BImSchG, Climate Act	Emission control, air quality standards	National ETS, climate strategy, emission caps	System based on technological advancement with strict legal control
Finland	Climate Act, Coal Ban Act	Renewable energy, regulation of wood fuel	Coal ban from 2029, hydrogen technology	Coal phase-out, clear goals, based on clean technology
Sweden	Climate Act, EU ETS	Net-zero emission target (2045), public participation	“Polluter pays” principle, fuel quality	Harmonized law, international obligations, and citizen involvement
Poland	“Anti-smog” Act, EU BAT standards	Strict fuel ban, local decision-making	“Clean Air” program, smog alerts	Combined central and local authority with financial support
Russia	Law on Protection of the Atmosphere	Reduction of industrial emissions in cities	“Clean Air” project, quotas, judicial oversight	Centralized regulation, focused on infrastructure modernization
South Korea	Clean Air Conservation Act	Removal of diesel vehicles, support for EVs	Emission trading (Seoul NOx/SOx), public transport support	Combination of regulation and economic incentives
Japan	Air Pollution Control Act, PCA	NOx/PM control, voluntary agreements	PCA, vehicle emission standards, fluorocarbon regulation	Law, business collaboration, flexible enforcement

From the table:

- EU member states (Germany, Finland, Sweden, Poland) follow common EU mechanisms (EU ETS, BAT, Ambient Air Quality Directive) supplemented by national legislation.
- East Asian countries (Japan, South Korea) prefer flexible regulation (PCA, RIA) and technical/economic measures (EV incentives, diesel removal).
- Countries like Russia and Poland focus on centralized policies addressing industrial pollution.
- Sweden and Germany have model systems based on sustainable development, human rights, and public participation.

The table below shows the periods during which these countries used coal and experienced air pollution.

Table 4-4. Historical changes in coal consumption and heating in countries

Country	City	Geographical location	Period	Usage pattern	Heating method	History of air pollution	Implemented laws/regulations	Current status (2020–2025)
Germany	Berlin	Central Europe	1940s–1980s	Coal was the main energy source, widely used for electricity and heating	Coal, steam boilers	☑ High air pollution	BImSchG, Climate Law	Shifting to natural gas and renewable sources. Ruhr region polluted with smoke and sulfur dioxide
Finland	Helsinki	Scandinavian Peninsula	1970–1985	Heating systems operated with coal	Coal, electricity	⚠ Limited	Climate Law, Coal Ban Law	Since 2020, coal has been fully banned
Sweden	Stockholm	Scandinavian Peninsula	1940s–1970s	Coal was used in small amounts	Coal, electricity	✖ Relatively low	Climate Law, EU ETS	Today, coal use is basically eliminated
Poland	Warsaw	Central Europe	1980–2000	Coal was the main fuel, nearly 100% used for building heating	Coal, steam boilers	☑ Very high	“Anti-Smoke” Law, EU BAT standard	Coal dominated until 2020, now decreased. Winter smog in Warsaw was catastrophic
Russia	Moscow	Eastern Europe, Asia	1950s–1990s	Coal was the main fuel in northern regions	Steam boilers, coal	☑ High in cities	Air Protection Law	Coal remains in rural areas; cities use more gas/electricity
South Korea	Seoul	Northern Asia	1980s–2000s	Coal and diesel were used together	Diesel, coal	☑ High air pollution	Clean Air Protection Law	Now shifting to electricity and gas, but old car emissions remain an issue
Japan	Tokyo	Eastern Asia	1950s–1980s	Coal used in industry and power plants	Diesel, coal	☑ High in cities	Air Pollution Control Law, PCA	Natural gas and electricity now dominate

Conclusion: The peak coal consumption period in most countries was between the 1960s and 2000, coinciding with industrialization peaks. Most countries used steam boilers and coal-based heating systems. Air pollution reached high levels.

4.1.3. Neighboring country – China

Most of the studies conducted in Mongolia are noted to have been carried out in Ulaanbaatar city. 60% were conducted in Ulaanbaatar, while 40% were conducted in cities of Inner Mongolia or other cities in China.

Table 4-5. Policy comparison between China and Mongolia

Category	Mongolia	China (PRC)	Difference / Conclusion
Study location	60% Ulaanbaatar, 40% Inner Mongolia, other Chinese cities	Nationwide, implemented at major cities	Most studies in Mongolia conducted in UB; China implemented nationwide
Policy type	Fuel switching/banning (2), national program evaluation (2), policy defined/implemented (6)	Comprehensive policies for national air pollution prevention, monitoring plans, technology, standards	Mongolia mainly short-term, temporary measures; China implements long-term, comprehensive plans
Main outcomes	3 out of 10 studies showed positive public health changes; smoke reduction, did not include winter 2023–24	PM2.5 reduced by 35%; coal use restricted; air quality improved	Outcomes in Mongolia unclear; China shows stable improvements
Legal environment	2011: night electricity tariff reduction (did not fully cover most fuel use) 2019: raw coal ban (strict regulation)	Laws enacted from 1987, updated in 2000, 2015, 2018, 2019; system to control industry, transport, local areas	Mongolia's legal framework relatively short-term; China's is long-term, comprehensive, strict
Fuel policy	Ban raw coal, propose improved fuel	Transition to clean fuel, natural gas, electricity infrastructure	Mongolia has temporary solutions; China has long-term sustainable solutions
Heating technology	Supported replacing household stoves	Supported businesses using energy-saving, smokeless technology	Mongolia relies on traditional stoves; China promotes innovation and smokeless tech
Electricity price	Night tariff 50% discount	System incentivizing off-peak electricity use	Mongolia has short-term policy; China has more detailed tariff regulation
Seasonal policy	Not available	Seasonal environmental policy (AEPEW) implemented	Mongolia has no seasonal policy; China has seasonal strategy
Inter-sector coordination	Not available	Integrated policies across sectors in national plan	Mongolia lacks sector coordination; China fully coordinated
Long-term planning	Short-term, fire-extinguishing measures until 2024	Long-term plan with specific targets	Mongolia mostly short-term; China has long-term, phased plan
Public information & participation	Not available	Public education, local participation, policy implementation supported	Mongolia has weak information and participation; China well supported
Monitoring & enforcement	PM2.5 measured, but enforcement evaluation weak	Air quality monitored, strict enforcement mechanisms	Mongolia has weak monitoring and enforcement; China strict and consistent

4.1.4. Overall Comparative Results of International Benchmarking

Based on the information presented in previous sections, comparing the duration since air pollution reduction, the countries' legal systems, reforms, implemented policies, their effectiveness, and responses, the following picture emerges.

Table 4-6. Policy reforms against air pollution and the period of impact

Country	Legal system / Act	Reform / Policy	Implemented measures	Period since air pollution reduction	Outcome / Lessons learned
USA	Clean Air Act (1970)	Sustainable development policy, industrial standards	Control of stationary and mobile sources, fuel standards	From late 1970s, air quality improvement	High-control measures reduced air pollution, set international benchmark
Germany	BImSchG, Climate Law	Emission control, air quality standards	National ETS, climate strategy, emission caps	From 1990s, air pollution decreased	Technology-driven, strict control reduced air pollution
Finland	Climate Law, Coal Ban Law	Renewable energy, wood fuel regulation	Coal ban from 2029, hydrogen technology	From early 2000s, air pollution decreased	Coal phased out, clear targets, based on clean technology
Sweden	Climate Law, EU ETS	Zero emissions target (2045), public participation	"Polluter pays" principle, fuel quality	From mid-2000s, air pollution decreased	Integrated law, international obligations, and citizen participation
Poland	"Anti-Smog" Law, EU BAT standards	Strict fuel bans, local decisions	"Clean Air" program, smoke warnings	Air pollution reduced by 2010–2015	Combined central and local authority, with financial support
Russia	Law on Air Protection	Reduce industrial pollution	"Clean Air" project, quotas, judicial oversight	From late 2000s, air pollution decreased	Centralized regulation, focused on infrastructure modernization
South Korea	Clean Air Conservation Act	Phase out diesel cars, promote EVs	Emissions trading (Seoul NOx/SOx), public transport support	From early 2000s, air pollution decreased	Combines regulation and economic incentives
Japan	Air Pollution Control Act, PCA	NOx/PM control, voluntary agreements	PCA, vehicle emission standards, fluorocarbon regulation	From 1980s–1990s, air pollution decreased	Law, business cooperation, and flexible control

A table comparing the scope, focus, and differences of national policies of countries is as follows.

Table 4-7. Differences in Policy Scope and Focus

Country	Policy Scope	Focus	Differences / Features
USA	Global, all sectors	Air pollution, energy, transport, waste	Comprehensive, multi-sectoral approach, special state and local regulations
Russia	Central, regional	Industrial pollution, air quality	Centralized authority, high coal and fuel use
China	National, provincial	Air pollution, coal, energy, transport	Rapid development, high coal use, energy reform
Australia	Nationwide, by state	Air quality, renewable energy	Public-private partnership policy, energy security
Canada	National, provincial	Air pollution, renewable energy	Dependence on coal and oil exports, international cooperation
UK	Nationwide, international	Air quality, coal phase-out	Sustainable development programs, implementation of international agreements

New Zealand	Nationwide, local	Air pollution, energy, water use	Environmental protection law, local collaboration
Germany	Nationwide, EU	Air pollution, energy, restoration	Aligned with EU requirements, advanced environmental technologies
Finland	Nationwide, EU	Air quality, renewable energy	Focused on raw material limits, renewable energy sources
Sweden	Nationwide, EU	Air pollution, renewable energy	Zero emissions target, environmentally progressive policy
Poland	Nationwide, EU	Air pollution, coal, energy	Coal-dependent, compliant with EU standards
South Korea	Nationwide	Air pollution, electric vehicles, energy	Use of new technology, economic incentives
Japan	Nationwide	Air pollution, energy, transport	Technological advancement, global air quality management

From this table, the following conclusions can be drawn:

- The USA has a broad, multi-sectoral policy approach combining public-private partnerships and local decision-making.
- Russia has a centralized system with high coal and fuel use, operating under domestic and foreign oversight.
- China addresses energy, coal, and air pollution issues rapidly, often requiring transformative measures; rapid development and international projects are characteristic.
- Australia, Canada, and the UK focus more on ecological reform and renewable energy development.
- New Zealand emphasizes environmental protection and local collaboration, aligned with international best practices.

All countries have pursued energy sector reforms, imposed additional responsibilities on transport, construction, and industrial sectors, and implemented evenly improving policies. Investment priorities and the use of public-private partnerships indicate the countries' main areas of effort.

Table 4-8. Use of Public-Private Partnerships (PPP)

Country	Form of PPP	Coverage	Outcome / Features
USA	PPP and investment projects	Infrastructure (roads, bridges, energy networks), air pollution control	Saves public funds, encourages private investment, enhances public services
Germany	PPP projects, partnerships in digital networks and energy	Energy supply, infrastructure projects (roads, bridges), natural resource management	Supports new energy and renewable sources, strict legal regulation of partnerships
Sweden	Renewable energy partnerships, environmental protection	Renewable energy, environmental policy implementation	Results in advanced energy networks and ecological processing
Finland	PPP in manufacturing and energy supply	Energy supply, renewable energy, technological innovation	Focused on clean energy projects, partnership in ecological reform
Poland	Energy partnership, PPP against air pollution	Energy sector, air pollution reduction programs	Air pollution control, modernization of electricity sources
South Korea	Energy partnership, air quality improvement projects	Infrastructure, air pollution, energy use	Technological advancement, air quality control projects
Japan	Technology development, energy partnership, ecological processing	Energy supply, air pollution reduction strategy	Increases clean energy use, implements environmental standards

From the table, all countries have long-term policies to phase out coal, shift to natural gas and electricity heating technologies, and move toward clean technology, i.e., renewable energy. To implement this, PPP projects were initiated to attract substantial investment. The following table compares the outcomes of these policies.

Table 4-9. Comparison of Health and Social Impacts

Country / City	Heart Attack Change (%)	Respiratory Change (%)	Stroke Change (%)	Allergy Level Change (%)	Maternal / Infant Mortality (%)	Mental Health (%)	Social Stress Indicator	Reduction in Household Costs (%)	Data Collection Agency	Measurement Method
UK (Manchester)	↓ 35%	↓ 50%	↓ 20%	↓ 30%	↓ 25%	↑ 15% (improved)	Stress levels decreased	↓ 25%	DEFRA, NHS, Local Health Agencies	Hospital records, air monitoring, surveys
USA (Multiple Cities)	↓ 30%	↓ 45%	↓ 15%	↓ 25%	↓ 20%	↑ 12%	Moderate improvement	↓ 20%	EPA, CDC, State Health Agencies	Health records, epidemiological studies
Canada (Vancouver)	↓ 40%	↓ 55%	↓ 25%	↓ 35%	↓ 30%	↑ 20%	Significant improvement	↓ 30%	Environment and Health Ministries	National surveys, hospital data, modeling
Finland (Helsinki)	↓ 50%	↓ 60%	↓ 30%	↓ 40%	↓ 35%	↑ 25%	Significant improvement	↓ 35%	Health Institutes, Ministry of Health	National registry, direct monitoring system
Sweden	↓ 45%	↓ 55%	↓ 25%	↓ 35%	↓ 30%	↑ 22%	Intensive improvement	↓ 30%	Environment and Health Agencies	Epidemiology, hospital reports
Germany	↓ 50%	↓ 60%	↓ 30%	↓ 40%	↓ 35%	↑ 25%	Resilient improvement	↓ 35%	Federal Health Office, UBA	Long-term studies, monitoring
Poland (Krakow)	↓ 25%	↓ 40%	↓ 10%	↓ 20%	↓ 15%	↑ 8%	Slight improvement	↓ 10%	Krakow Health, Environmental Ministry	Research, health data analysis
Russia (Moscow)	↓ 20%	↓ 35%	↓ 8%	↓ 15%	↓ 10%	↑ 5%	Slight improvement	↓ 8%	Federal Ministry of Health, City Administration	Centralized data collection, reports
Kazakhstan	↓ 15%	↓ 25%	↓ 5%	↓ 12%	↓ 8%	↑ 4%	Moderate improvement	↓ 5%	National Health Ministry, UNDP Partnership	Research, hospital data
Uzbekistan	↓ 12%	↓ 20%	↓ 4%	↓ 10%	↓ 6%	↑ 3%	Slight improvement	↓ 5%	Ministry of Health, International Partnerships	Health surveys, epidemiological data

Table 4-10. Comparison of Legal Systems, Policy Start, and Outcome Timelines

Country / City	Legal System	Policy Start Year	Reduction in Harmful Smoke (%)	Time to Show Results	Public Health Improvement	Happiness Index (2023)
UK (Manchester)	Common Law	1956 (Clean Air Act)	~70% (by 2010)	~50 years	Respiratory diseases significantly decreased	#17
USA (Multiple Cities)	Common Law	1970 (Clean Air Act)	~60%	~30–40 years	Urban life expectancy improved	#15
Canada (Vancouver)	Common Law	1999 (CEPA)	~65%	~20 years	Asthma and respiratory disease noticeably decreased	#13
New Zealand	Common Law	2004 (Air Quality Standards)	~50%	~15–20 years	Indoor air quality and public health improved	#10
Australia (Canberra, Hobart, Ballarat)	Common Law	2015 (Clean Air Agreement)	~40%	~10–15 years	Respiratory illness levels decreased	#12
Finland (Helsinki)	Civil Law	2008 (Energy Strategy)	~80%	~10–15 years	Quality of life greatly improved	#2
Sweden	Civil Law	1999 (Environmental Code)	~75%	~20 years	High health indicators	#7
Poland (Krakow)	Civil Law	2016 (Anti-Smoke Act)	~55%	~7–10 years	Noticeable improvement	#39
Russia (Moscow)	Civil Law	2014 (Clean Air Program)	~45%	~10 years	Some positive outcomes, uneven	#70
South Korea	Civil Law	1990 (Clean Air Act)	~60%	~20–30 years	Urban health significantly improved	#57
Japan	Civil Law	1968 (Air Pollution Control Law)	~70%	~30–40 years	Life expectancy noticeably increased	#47
Germany	Civil Law	1974 (Chimney Control Act)	~75%	~20–30 years	High health outcomes	#16
Kazakhstan	Civil Law	2007 (Environmental Code)	~30%	~10–15 years	Moderate improvement, persistent issues	#64
Uzbekistan	Civil Law	1996 (Air Protection Law)	~25%	~15 years	Gradual improvement but limited resources	#54
Ukraine, Georgia, Armenia	Civil Law	From 2000s	~25–40%	~10–20 years	Health gradually improved but steadily	#90+ (varied)

Note: Happiness ranking — taken from the 2023 World Happiness Index.

Based on data from 2020–2025, the following table compares countries' geographic location, heating energy usage during the winter season, and air pollution levels over time.

Table 4-11. Comparison of Countries' Heating Solutions

Country	Consumption Characteristics	Peak Coal Use Year / Location	Residential Heating	Air Pollution
Germany	Coal, natural gas, electric heating	1960s: coal consumption peaked. 1970s: coal use gradually declined. 1990s: coal-fired power plants were closed, promoting natural gas and renewable energy sources. 2023: Germany's CO_2 emissions reduced by 46% since 1990; share of renewable energy reached 56%	According to the 2022 census, 75% of German households use natural gas (56%) and oil (19%) for heating. District heating accounts for 15%, while renewables and heat pumps cover 7%	In 2024, 31% of Germany's total CO_2 emissions came from the energy sector (highest share), followed by industry (25%) and transport (17%)
United Kingdom	Coal, natural gas, wood fuel	1956: 221 million tons of coal used, peaked. By 2024: reduced to 2.1 million tons. 2012–2022: wood stove use increased by 19%	Natural gas, renewables, wood stoves	PM2.5 from wood stoves increases air pollution. Coal banned, shifted to natural gas and renewable energy
USA	Coal, natural gas	2020: increased use of electric heating. Nuclear and renewable energy projects implemented	Natural gas, electric heating	In 2020, 69 million households primarily used electric heating, while 58 million used natural gas
Canada	Coal, natural gas	19th century–1980s: coal used; from 2000: coal consumption declined sharply. Electric heating increased. Transport, oil, and industry are major pollutants	Natural gas, electric heating	Planning to expand renewables, natural gas, nuclear, and bioenergy sources
Australia	Natural gas, electric heating	Australia was a leading coal producer and consumer globally until early 21st century. Coal use began declining in early 2000s. Late 2010s: coal-fired power plants started closing. 2023: coal consumption 92.4 million tons, down 5.1% from 2022. 2022: energy sector accounted for 31% of total CO_2 emissions, followed by industry (25%) and transport (18%)	Most households use natural gas and electricity for heating. Renewables' share is increasing but still only 9% of total energy consumption	39% of residents used natural gas heating
Japan	Natural gas, electric heating	2020: increased use of electric heating	Natural gas, electric heating	39% of residents used natural gas heating
South Korea	Natural gas, electric heating	2020: increased use of electric heating	Natural gas, electric heating	39% of residents used natural gas heating

Current Trends (2020–2025):

- European countries have sharply reduced coal use and shifted policies toward renewables and natural gas.
- Asian countries show progress, but due to development gaps, older technologies remain in use.
- Coal consumption is being phased out gradually and intelligently, with green energy becoming dominant.

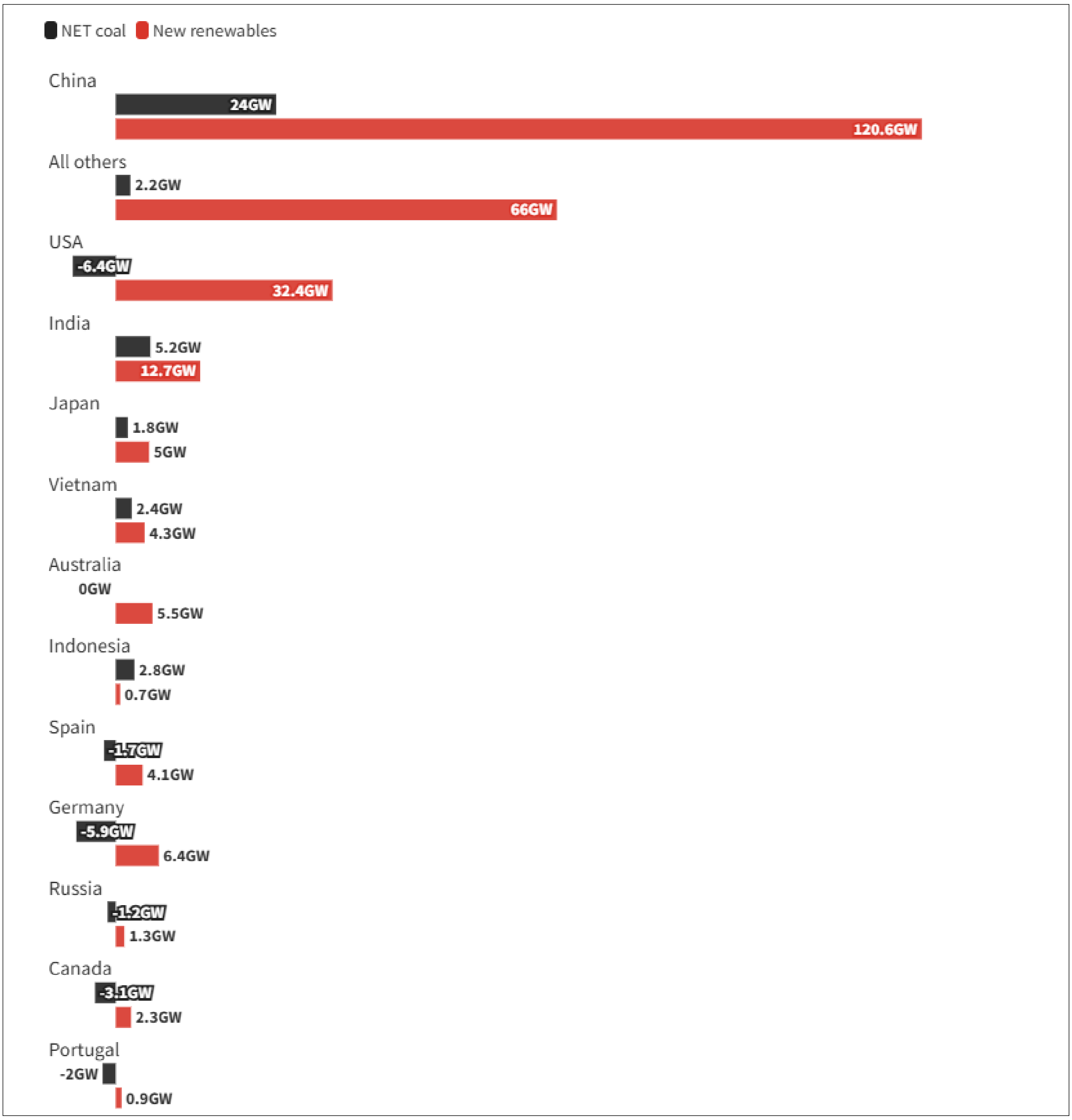
As of 2021, countries have largely stopped producing electricity and heat from coal and are investing heavily in renewable energy projects. In the figure below, black indicates investment in coal-fired electricity and heat production, while orange shows investment in renewable energy projects. In particular, solar, wind, recovered energy (from waste incineration), and nuclear energy research and development projects are advancing rapidly. In some countries, older coal-fired plants are deteriorating faster than new renewable plants can be built, accelerating the need for investment. Globally, policies to phase out coal are driven by goals to reduce air pollution, slow global warming, and support sustainable development.

Countries that have succeeded in reducing air pollution have implemented effective measures such as switching to clean heating systems (Weng et al., 2022), establishing low-emission zones, and regulating road traffic. Urban green spaces also significantly reduce particulate matter in the air (Vigevani et al., 2023), highlighting the ongoing need to improve measurement methodologies. To evaluate policy impacts, combined methods including simulations, observations, and AI-based modeling are increasingly applied (Clark, 1986; Benavides et al., 2022).

A. Blakers in *Global Coal Use in 2022* reported country-level investments in the energy sector, distinguishing between coal and brown coal versus renewable energy projects, as illustrated in the figure below. Key investment strategies include:

- There was no policy to relocate people from rural fenced houses to apartment blocks. Instead, investments focused on connecting each household to electricity, heat, water, and sewage systems, ensuring regular access to natural gas, electricity, and renewable energy.
- Energy sector reforms aimed to make centralized power plants coal-free where possible, implement filters for remaining coal plants, and establish small local sub-stations to provide electricity and heat, preferably supplied from renewable energy projects.

Figure 4-1. Investment in renewable (orange) versus coal-based (black) energy projects (A. Blakers, Global Coal Use in 2022)



4.1.5. Conclusion

From the above information, it can be concluded that global policies to phase out coal are effectively reducing air pollution. To implement these policies, legal systems have been improved, comprehensive laws enacted, and enforced across sectors. Policy focus is placed on the most polluting sectors, and planning and implementation are regularly monitored.

Table 4-12. Benchmarking of Country Policies

Main Category	Key Content	Explanation / Example
1. Core Policy	- Phase out coal, adopt clean technologies, renewable and nuclear energy - Continuous monitoring of law and standard compliance - Use third-party certified products - Ban or install filters on coal-fired plants and stoves - Strict regulation of businesses with enforcement measures	Legal reforms and sector-specific implementation
2. Country Differences	- Scandinavia, Germany: consistent policies, improved health, low coal use - Canada, Japan: long-term effectiveness, sectoral differences - Post-Soviet countries: infrastructure and governance challenges	Variations in governance systems, characteristics, and outcomes
3. Measurement & Outcomes	- Measure air pollution via specific chemicals - Health indicators (disease incidence, life expectancy) - Citizen satisfaction and happiness index	Continuous monitoring and reporting of results
4. Timeframe	- Developed countries: improvements over 15–30 years - Post-Soviet countries: longer periods required	Implementation in Mongolia may also require extended time
5. Case Study Basis	- Russia: centralized legal system, energy resources, old technology obstacles - China: centralized planning, legal regulation, 40–50% pollution reduction, limited public participation - Europe (Germany, Finland, Sweden): civil law, EU-wide policies, temperate climate - USA: independent legislation, multi-stage monitoring, climate similar to Mongolia - Japan, South Korea: different climate	Legal system and climate differences suggest USA and Russia as suitable examples for Mongolia
6. Examples from Common Law Countries	- UK (~70%, 50 years) - USA (~60%, 30–40 years) - Canada (~65%, 20 years) - New Zealand (~50%, 15–20 years) - Australia (~40%, 10–15 years)	Comparison of law enactment year, pollution reduction percentage, and timeframe

4.2. USA: Case Study

According to the analysis presented in section 0, among countries with a common law system, those that successfully improved air quality through legislative reforms and policy implementation are ranked as follows:

- United Kingdom: reduced air pollution by 70% over 50 years
- United States (USA): reduced by 60% over 30–40 years
- Canada: reduced by 65% over 20 years
- New Zealand: reduced by 50% over 15–20 years
- Australia: reduced by 40% over 10–15 years

Observing the timeline of policy initiation, the USA enacted the Clean Air Act in 1963, with amendments in 1970, 1977, and 1990. The UK, following the 1952 London "Great Smog" disaster, passed the Clean Air Act in 1956, with further amendments in 1968 and 1993. Canada introduced its legislation in 1999, New Zealand in 2004, and Australia in 2015.

Thus, the UK and the USA implemented policies early and served as examples for other countries. However, the UK's legislation was strongly influenced by EU membership requirements at the time and had to be revised after Brexit. Given Mongolia's need for independent policy management and its climate and geography being more similar to the northern regions of the globe than a small island nation like the UK, the USA was selected as the case study.

The USA also developed extensive regulations and standards to ensure law enforcement, which later became a valuable reference for the UK.

4.2.1. Core Methodology: Design Approach to Combat Air Pollution

Policy-wise, the USA applied a **"Design Approach"**. This methodology involves systematically planning and structuring all processes from drafting legislation and setting standards to implementation, monitoring, and improvement. It can also be translated as a "Model-Based Approach", essentially meaning that decision-making was visualized and structured from the outset.

International management system standards, such as PDCA cycles, recognize this approach. Widely used standards like ISO 9001, ISO 14001, and ISO 45001 can be applied by any organization, regardless of size or sector—ranging from large institutions with thousands of employees to a single-person household enterprise.

These international management standards commonly employ the **Plan–Do–Check–Act (PDCA)** cycle. Applying this approach, analyzing the USA's experience in reducing air pollution provides policymakers with a structured and instructive framework.

Accordingly, the following table breaks down the USA's air quality policies and legislation according to the PDCA cycle, showing what was done at each stage, who was responsible, what was reported, and what outcomes were achieved.

Table 4-13. PDCA Cycle Model for Addressing Air Pollution in the USA

Stage	Actions Taken	Responsible Agency	Reporting & Transparency	Outcomes
Plan	- Drafted legislation and standards (1965, 1967, 1970) - Established NAAQS (National Ambient Air	- EPA (from 1970) - HEW (1960s) - State	- Federal policies publicly accessible - Open discussions	- Clear, measurable goals - Planning system with state participation

	Quality Standards) - Required each state to develop an air quality plan	environmental agencies	and science-based rationale	
Do	- Installed pollution control devices (catalytic converters, scrubbers) - Enforced emissions standards for vehicles and industries - Introduced unleaded gasoline - States implemented air quality plans	- EPA (federal standards) - States (local implementation) - Industries, auto manufacturers	- Implementing industries reported to EPA - States reported implementation progress	- Pollutants (CO, SO_2, Pb) reduced ~60–99% - Technological innovation advanced and influenced markets
Check	- National air quality monitoring - Compliance inspections and audits - Vehicle emissions testing - Risk assessments and data analysis	- EPA (air quality monitoring) - States (local enforcement) - Research centers under NAAQS	- Monitoring data publicly available - Annual *Air Trends Report* published	- High transparency - Improved ability to evaluate policy effectiveness
Act	- Amendments to laws in 1977, 1990 - Required technological upgrades - Flexible approaches for regional conditions - Enforcement actions against non-compliant organizations	- EPA - Congress (legislative amendments) - Input from states	- Assessments of law enforcement - New policies based on outcomes	- Stricter pollution reduction requirements - Policies became more precise - Technological advancement incentivized

The USA applied a **"federal–state cooperative implementation model"**, allowing policies to be adapted locally while maintaining accountability. Reporting and transparency were critical in improving policies—citizens, scientific organizations, and NGOs actively participated. After each legislative update, environmental status reports were used to refine policies, demonstrating practical application of the PDCA cycle.

A key pillar of this model was **public-private partnerships (PPP)**, where federal, local authorities, and private sector entities collaborated with clearly defined roles and responsibilities.

Table 4-14. Public–Private Partnership in the US "Federal + State Cooperative" Implementation Model

Element	Role of Government	Private Sector Participation
Standards & Legislation	- EPA sets national standards (e.g., NAAQS) - Conducts risk assessments and sets limits	- Private sector manufactures equipment and implements technologies according to standards
Implementation (Local Level)	- States and municipal authorities develop State Implementation Plans (SIPs) - Provide permits and enforce compliance	- Industries, energy, and transport companies invest locally to comply - Adopt clean energy and fuels, improve operational practices
Technology & Investment	- Federal and state funding provides incentives and tax breaks - Programs support green technologies	- Technology firms supply control technologies (BACT, MACT) - Invest in pollution reduction measures
Research & Innovation	- EPA and states fund R&D projects - Provide guidance for policies and information	- Universities and R&D organizations collaborate to develop new technologies
Transparency & Participation	- Government ensures public access to information - Publishes monitoring and compliance reports	- Civil society and private entities participate in reporting - Support systems that maintain transparency

4.2.2. Air Pollution Control Legislation

The economic Great Depression that began in the United States in 1929 ended alongside World War II in 1941. However, afterward, population growth and increased industrial and transport activity led to emerging air pollution problems. By 1970, air pollution had reached its peak, and post-1929 economic recovery policies were recognized as having adverse environmental effects. As a result, the U.S. strengthened its legislative requirements and established strict regulations, which in turn led to a sharp reduction in air pollution.

Between 1930 and 1950, countries with significant industrial development experienced peak air pollution from coal combustion. The main solution involved shifting from brown coal to cleaner fuels. For example, switching to oil and gas, which emit fewer pollutants, had a significant impact. By 1881, cities like Chicago and Cincinnati had introduced regulations to control smoke emissions, resulting in improvements.

In Los Angeles, California, during the 1940s, smog-covered skies were found to result not just from primary pollutant sources but also from secondary sources: chemical residues on surfaces that reacted with sunlight, water, and other factors to produce new pollutants, as noted by Professor A.J. Haagen-Smit. To address this, in 1946, the Los Angeles city government established the Air Pollution Control District (APCD), imposing strict control over smoke and other pollution sources.

Another example occurred in Donora, Pennsylvania, in 1948, where a four-day air pollution episode caused illness in 7,000 people and 20 deaths. All fatalities were individuals with bronchitis, emphysema, or cardiovascular diseases, demonstrating that vulnerable populations are the first to be affected by air pollution and face the highest risk of death.

The timeline of legislation and regulations addressing air pollution is outlined as follows:

a) By 1955, after states and cities began tightening their regulations, the U.S. enacted the Air Pollution Control Act, establishing funds for federal research and technical assistance.

- This supported extensive scientific research to find solutions based on quality evidence rather than rushed measures. Politically, debates continued over whether federal enforcement and funding were appropriate, with states and cities often preferring local decision-making.
- The federal government emphasized that air pollution and air currents are not confined by local or state boundaries and advocated for unified, effective management at national and even international levels, creating the basis for today's pollution-free environment in the U.S.
- This approach laid the groundwork for sustainable development policies, emission reductions, and climate change mitigation, with the U.S. taking a leadership role supported by scientists, policymakers, NGOs, and international organizations.
- Key policy measures focused on reducing harmful energy emissions, promoting solar energy generation and distribution according to regional sunlight availability, and regulating fossil-fuel-based power plants to limit atmospheric pollutants. Technologies such as amine-based CO_2 capture allowed for carbon capture, storage, or alternative use, even if relatively costly, but were considered effective strategies for reducing air pollution.

b) 1963 – Clean Air Act replaced the 1955 law, marking a policy shift from reactive responses to proactive prevention of emissions.

c) 1965 – Motor Vehicle Air Pollution Control Act

- Improved manufacturing standards for vehicles and established over 50 emission control rules. Initially based on "1968 technology," standards were updated as technology evolved.

d) 1967 – Air Quality Act

- Expanded federal roles in R&D and reinforced the importance of control technology alongside research-based management.
- The Department of Health, Education, and Welfare (HEW) was tasked with regional planning, implementation, and oversight of control programs.
- Established science-based air quality criteria to assess health, agricultural, and material impacts and costs for mitigation measures.

e) 1970 – Amendments to the Clean Air Act

- Led to the National Environmental Policy Act, the establishment of the Environmental Protection Agency (EPA), and, in 1972, the Council on Environmental Quality.
- Required states to develop detailed State Implementation Plans (SIPs).
- Senate-endorsed standards became mandatory, setting deadlines to upgrade technologies and materials. Known as the "Technology-Forcing Law," this approach was formally incorporated into the 1970 Clean Air Act amendments.
- Aimed for a 90% reduction in vehicle emissions, including CO, hydrocarbons, and NO_2, with phased goals between 1970–1975. Initial five-year targets proved unrealistic, requiring subsequent legal adjustments.
- EPA established New Source Performance Standards (NSPSs), strengthening compliance and fostering inter-state competition for air quality performance. Noncompliance carried heavy fines and penalties.

f) 1977 Amendments to the Clean Air Act

- Introduced a five-year EPA review cycle of air quality standards and set sector-specific environmental performance requirements for industries, construction, transportation, and energy.
- Added preventive provisions categorizing urban areas into I, II, and III zones, restricting pollution sources accordingly.
- Established an emissions "offset trading" system allowing facilities to offset their emissions through reductions elsewhere, creating tradable carbon credits.
- EPA oversaw verification and compliance before granting operational permits.

g) 1990 Amendments to the Clean Air Act

- Covered 11 sectors across 750 pages, addressing urban smog, mobile source emissions, hazardous pollutants, acid rain, and ozone layer protection.
- Tightened vehicle and truck standards and accounted for international pollution impacts.
- Introduced detailed air quality zoning and control measures for all emission sources.
- Established Maximum Achievable Control Technology (MACT) rules for major hazardous air pollutant sources.
- Defined major sources as facilities emitting 10 tons/year of a single toxic chemical or 25 tons/year of multiple chemicals, including large industrial plants, small operations, and even personal equipment like printers.
- Addressed acid rain by targeting SO_2 reductions from 1980 onward, promoting energy-efficient appliances, clean coal technologies, and market-based incentives.

- Required state-level permitting programs for all emission sources, ensuring compliance through inspection, reporting, and potential revocation of operational or property rights for noncompliant entities.
- Controlled ozone-depleting substances under the Montreal Protocol, phasing out CFCs, Halons, and CCl_4 by 2000, replacing them with hydro-chlorofluorocarbons that degrade more quickly in the lower atmosphere.
- Simplified enforcement mechanisms with strict civil and criminal penalties; administrative fines began at $200,000, with EPA oversight to ensure adherence.
- These measures continue to be enforced today, requiring ongoing compliance efforts and affecting daily life, including higher-quality fuels, chemical-safe household practices, and reduced emissions from electrical appliances, reflecting a fundamental shift in public health and environmental protection principles.

4.2.3. Regulations and Standards Related to Air Quality

After laws were passed in the United States, Government Regulatory Agencies conduct detailed studies related to the implementation of those laws and develop regulations to ensure they are feasible. In countries with a unified legal system, "Legislation & Law" refers to legal or highest-level requirements, which are generally applicable across all sectors and introduce general and principle-based requirements. In accordance with these, detailed sector-specific requirements are developed in documents called Regulations, which are referred to in English as "Regulation." These function similarly to mining laws, meaning that businesses, individuals, and government organizations strictly follow them like law. For environmental issues, smoke, air pollution, and clean air, the Environmental Protection Agency (EPA) is responsible for developing these regulations and ensuring their enforcement before Congress.

1. National Ambient Air Quality Standards (NAAQS)

Regarding standards, the National Ambient Air Quality Standards (NAAQS) organization is responsible, operating under the EPA. The EPA commissions this organization to develop standards and oversees their scientific basis and feasibility for implementation. Since this standardization organization specializes solely in air quality standards, it has the advantage of focusing only on this issue. Protecting public health is its primary goal (primary standards aim for this), while ensuring public well-being is its secondary goal (secondary standards are developed for this purpose).

The table below shows the allowable levels of six major air pollutants monitored under the NAAQS established by the U.S. Environmental Protection Agency (EPA).

Table 4-15. Allowable Levels of Air Pollutants

Pollutant	Type of Standard	Averaging Period	Allowable Level	Measurement Method/Condition
Carbon monoxide (CO)	Primary (health)	8 hours	9 ppm	Not to be exceeded more than once per year
		1 hour	35 ppm	
Lead (Pb)	Primary & Secondary	3-month average	0.15 µg/m³	Must not be exceeded daily
Nitrogen dioxide (NO_2)	Primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	Primary & Secondary	Annual	53 ppb	Annual average
Ozone (O_3)	Primary & Secondary	8 hours	0.070 ppm	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years

Fine particulate matter ($PM_{2.5}$)	Primary	Annual	9.0 µg/m³	Annual average, last 3 years
	Secondary	Annual	15.0 µg/m³	Annual average, last 3 years
	Primary & Secondary	24 hours	35 µg/m³	98th percentile, last 3 years
Coarse particulate matter (PM_{10})	Primary & Secondary	24 hours	150 µg/m³	Not to be exceeded more than once per year over 3 years
Sulfur dioxide (SO_2)	Primary	1 hour	75 ppb	3-year 99th percentile
	Secondary	3 hours	0.5 ppm	Not to be exceeded more than once per year

Notes:

- ppm (parts per million) — parts per million, expressing air concentration.
- ppb (parts per billion) — parts per billion.
- µg/m³ — micrograms per cubic meter, weight of particles in a unit volume of air.
- 98th percentile of 1-hour daily maximum concentrations, averaged over 3 years — For example, if the highest pollution in a day occurs on Monday from 22:00–23:00, that is the maximum 1-hour concentration for that day. Over 365 days, the highest 1-hour concentration is measured daily. Considering each hour's maximum as 100%, the top 2% is excluded, and the 98th percentile is used.
- Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years — Measures the highest 8-hour period each day, then analyzes the top four highest days in a year over the last three years, taking the fourth-highest value as the standard.

These NAAQS standards apply only in the U.S. as specific requirements; other countries such as Mexico, Brazil, Indonesia, and the World Health Organization often apply stricter standards.

2. World Health Organization Air Quality Guidelines, 2021

The World Health Organization's (WHO) Air Quality Guidelines, updated in 2021, serve as global reference documents. They are not legally binding and are presented as voluntary recommendations. The key recommended limits are shown below.

Table 4-16. WHO Air Quality Guidelines, 2021

Pollutant	Averaging Period	Recommended Limit (µg/m³)	Notes
$PM_{2.5}$ (fine particulate matter)	Annual	5 µg/m³	Most harmful particulate matter
	24-hour	15 µg/m³	Not to be exceeded more than 3–4 days
PM_{10} (coarse particulate matter)	Annual	15 µg/m³	
	24-hour	45 µg/m³	
Ozone (O_3)	8-hour	100 µg/m³	≈ 50 ppb
Nitrogen dioxide (NO_2)	Annual	10 µg/m³	≈ 5.3 ppb
	24-hour	25 µg/m³	
Sulfur dioxide (SO_2)	24-hour	40 µg/m³	
Carbon monoxide (CO)	24-hour	4 mg/m³ (4000 µg/m³)	

3. New Source Performance Standards (NSPS), 2024

The NSPS (New Source Performance Standards) were first established in 1971 under the U.S. Clean Air Act. They set initial comprehensive requirements for newly built industrial sources to reduce air pollution.

Table 4-17. Historical Overview of NSPS

Event	Year / Description
Legal Basis	Clean Air Act, Section 111. Purpose: To limit emissions from newly built or significantly modified sources using the most effective and cost-efficient technology.
First Implementation	1971 — EPA established the first NSPS for major industrial sources.
Amendments	Continuously updated since the 1970s, adding new source categories and technologies.
Latest Updates	2023–2024: NSPS updated for various sources, including: • CO_2 emissions for power plants (Subpart TTTT) • Oil and natural gas extraction (Subpart OOOOb, OOOOc)

Notes:

- Applicability: Power plants, oil refineries, cement and glass factories, and other industrial sources.
- Each source category is codified in 40 CFR Part 60 under specific Subparts.
- Updates depend on industry type and address emerging issues like climate change, methane, and greenhouse gases.

Table 4-18. Key Features of NSPS

Characteristic	Description
Scope	Only applies to newly built or significantly modified sources.
Standard Basis	Based on Best System of Emission Reduction (BSER), technically and economically feasible.
Pollutants Covered	PM, NOx, SO_2, CO_2, VOCs, etc.
Industry-specific	Emission standards are tailored by source type (e.g., Subpart Da for power plants).
Legal Requirement	Mandatory under U.S. law; violations may result in fines or enforcement actions.
Examples	- New natural gas power plant must control CO_2 emissions per NSPS. - Upgraded cement kiln must have particulate filter meeting NSPS.

NSPS are legally binding standards aimed at reducing emissions from new and modified industrial sources using modern technology, playing a key role in improving air quality and protecting human health.

In Mongolia, coal-fired power plants are relevant. The NSPS for coal-fired power plants set by the U.S. EPA include strict requirements for particulate, gas, and smoke control systems. These NSPS standards (Subpart Da) are part of 40 CFR Part 60, implemented since 1978 and updated multiple times, most recently in 2015 and 2023. Key limits are shown below.

Table 4-19. Main Pollutants and Limits

Pollutant	Standard Limit	Control Technology
Particulates (PM)	~0.015 lb/MMBtu (≈15 mg/m^3)	Electrostatic Precipitator (ESP), Baghouse filter
Sulfur dioxide (SO_2)	~1.0 lb/MMBtu or >95% reduction	Wet/dry limestone scrubbers
Nitrogen oxides (NO_x)	~0.11–0.15 lb/MMBtu	Low-NOx combustion, Selective Catalytic Reduction (SCR)
Carbon dioxide (CO_2)	1,400 lb/MWh (for new plants, 2015 NSPS)	Carbon capture and storage (CCS) – optional but supported

Table 4-20. Key Control Technologies

Technology	Function
Electrostatic Precipitator (ESP)	Removes particulate from flue gas using electric charge.
Baghouse filter	High-efficiency filtration using woven bags.

Scrubber (wet/dry)	Absorbs soluble gases like SO_2, HCl.
Selective Catalytic Reduction (SCR)	Reduces NO_x via catalytic reaction with nitrogen and water.

Additional Notes:

- New coal-fired plants must have NSPS-compliant filters and control systems.
- Non-compliance can result in fines or operational shutdown by the EPA.

4. National Emission Standards for Hazardous Air Pollutants (NESHAPs)

NESHAPs are U.S. air quality standards aimed at controlling and reducing emissions of hazardous air pollutants (HAPs). They are established by the U.S. Environmental Protection Agency (EPA) under Section 112 of the Clean Air Act.

Objectives:

- Limit emissions of 187 chemicals that are harmful to human health, cause cancer, birth defects, or affect the immune and nervous systems.
- Key substances include benzene, formaldehyde, mercury, lead, arsenic, dioxins, cadmium, chromium, etc.

Table 4-21. Key Features of NESHAP

Feature	Description
Scope	Industrial sources such as oil refineries, chemical plants, metal processing, power plants, auto repair, hospitals, construction, etc.
Focus	Highly toxic substances even at very low concentrations in the air.
Comparison with NSPS	NSPS targets common pollutants (PM, NOx, CO_2), whereas NESHAP focuses on highly toxic chemical pollutants.
Technology Basis	Maximum Achievable Control Technology (MACT).
Legal Enforcement	Mandatory; violations can result in fines or license revocation.

Table 4-22. Examples of NESHAP Standards by Source

Source	Hazardous Pollutant	Requirement
Metal smelting	Lead, cadmium	Install MACT, monitoring and measurement
Medical waste incinerator	Dioxins, mercury	Filters, temperature control, monitoring
Auto body shop	Toluene, xylene, VOCs	Air filtration, paint booths, ventilation systems

For Mongolia, mining is particularly relevant. NESHAP standards provide strict measures to reduce chemical pollutant emissions, requiring precise technology in high-pollution sectors to protect human health and the environment. Although not directly enforced in Mongolia, these standards can serve as an international model for industrial control and filtration systems.

Table 4-23. Examples of Mining-Related NESHAP Applications

Mineral Sector	Potential HAPs	Applicable NESHAP / Control	Control Measures
Gold	Mercury (Hg), cyanide vapors, VOCs	40 CFR Part 63, Subpart EEEEEEE (Gold Mine Processing)	Mercury filters, closed systems, emission control
Silver	Mercury, SO_2	Similar to gold standards	Limit volatilization, capture emissions

Copper	Arsenic, lead, SO_2	Subpart QQQ (Primary Copper Smelting)	Flue gas filters, scrubbers, SO_2 emission limits
Iron	PM, VOCs	Subpart RRRRR (Iron and Steel Foundries)	Baghouse, filtration, emission control
Coal	Dust, VOCs, CO, NOx	Subpart Y (Coal Preparation and Processing Plants)	Dust suppression, absorption, humidification
Fluorite	HF, dust	Common mining standards	Closed transport, dust suppression, PPE
Gypsum	Dust ($CaSO_4$), quartz (SiO_2 – silicosis risk)	OSHA/NIOSH-aligned	Dust control, ventilation, filtration, PPE

Implementation Benefits:

- Protects worker safety and local residents' health.
- Ensures quality standards for export compliance.
- Aligns with international ESG (Environmental, Social, Governance) requirements.
- Provides quick reporting capability for improved performance when countries avoid purchasing environmentally harmful coal.

5. Ideal Gas Law and Gas Concentration Measurement Methods

Under normal conditions, dry clean air contains approximately 20.94% oxygen, 78.08% nitrogen, 0.93% argon, 0.04% carbon dioxide, and trace other gases.

The Ideal Gas Law is expressed as:

PV=nRTPV = nRTPV=nRT

Where:

- PPP = pressure (atm or Pa)
- VVV = volume (L or m^3)
- nnn = number of moles
- RRR = gas constant (0.08206 L·atm/mol·K or 8.314 J/mol·K)
- TTT = temperature (K)

Gas concentrations can be measured in:

- Molar concentration: mol/m^3 or mol/L
- Mass concentration: mg/m^3, µg/m^3
- Volume ratio: ppm (parts per million), ppb (parts per billion), etc.

The maximum allowable concentrations for chemical species in air were presented in Section 1.

4.2.4. Results of Legal, Regulatory, and Standard Changes

1) Positive outcomes under the law

To illustrate how air quality has improved in the U.S., the effects of the following key legislation can be considered: the 1965 *Motor Vehicle Air Pollution Control Act*, the 1967 *Air Quality Act*, and the 1970 *Clean Air Act* (with major amendments in 1977 and 1990). These laws allow analysis of trends in greenhouse gas emissions and air pollutant concentrations.

1. 1965 Motor Vehicle Air Pollution Control Act
Objective:

- The first federal law in U.S. history regulating motor vehicle exhaust emissions.
- From 1968, set limits on carbon monoxide (CO) and hydrocarbons (HC) in automobile exhaust.

Impact:
- Emissions of CO and HC from new cars gradually decreased.
- Technologies such as catalytic converters were developed.

Summary of results:
- Between 1970–1980, CO emissions from vehicles fell by approximately 40% despite increasing traffic volumes.

2. 1967 Air Quality Act
Objective:

- Expanded the federal government's role in monitoring and controlling air pollution.
- Required states to designate air quality regions and prepare management plans.

Impact:
- Established a national air quality monitoring network.
- Initiated local and regional studies and regulations on smog.
- Provided a foundation for stricter future measures.

Results:
- Allowed systematic monitoring of pollution sources and distribution. Studies in cities like Los Angeles identified the contribution of transportation and industry.

3. 1970 Clean Air Act (Amended 1977, 1990)
Objective:

- Established National Ambient Air Quality Standards (NAAQS).
- Authorized the U.S. Environmental Protection Agency (EPA) to regulate emissions from vehicles, industries, and power plants.
- 1990 amendments addressed acid rain, ozone depletion, and toxic pollutants.

Impact:
- Reduced emissions from all types of sources.
- Advanced pollution control technologies (e.g., unleaded gasoline, tailpipe filters, power plant scrubbers).

Table 4-23. Percentage Reduction in Pollutants (1970–2020)

Pollutant	Reduction (%)	Notes
CO (carbon monoxide)	-85%	Mostly due to vehicle regulations
NO_2 (nitrogen dioxide)	-61%	From transportation and industry
SO_2 (sulfur dioxide)	~91%	From coal-fired power plants
PM2.5 (fine particulate matter)	~40% (since 2000)	Industry and diesel transport
Lead (Pb)	~99%	Phased out from gasoline
O_3 (ozone)	~30%	Varies by season and region

Conclusion:

- The 1965 and 1967 laws were preparatory regulations, focusing mainly on observation, research, and standard setting.
- The 1970 Clean Air Act introduced strict regulation, enforcement, and tangible emission reductions.
- As a result, U.S. air quality improved dramatically, even as population and vehicle use increased.

2) Positive Outcomes from Standards

The table below summarizes the objectives, improvements, results, responsible agencies, and implementing sectors for three key air quality standards in the U.S.:

Table 4-24. Comparison of Key Air Quality Standards

Standard	Objective / Scope	Pollutants Reduced	Developed by	Implemented by	Actual Outcomes
NAAQS (National Ambient Air Quality Standards)	Protect public health; set limits for six major ambient pollutants	CO, NO_2, SO_2, O_3, PM2.5, Pb	EPA (scientifically based)	State environmental agencies, local governments, industries, vehicle manufacturers	☑ NO_2 ~60% reduction ☑ Lead ~99% reduction ☑ PM2.5 reduction decreased cardiovascular disease
PSD (Prevention of Significant Deterioration)	Prevent emissions increase from major new or expanded sources in clean areas; requires Best Available Control Technology (BACT)	PM2.5, NOx, SO_2, VOCs	EPA (federal standard)	Industries, engineering consultancies, state agencies (permit review)	☑ Emissions from new facilities in clean areas limited ☑ New facilities began installing BACT
NESHAP (National Emission Standards for Hazardous Air Pollutants)	Limit emissions of 187 hazardous air pollutants (e.g., formaldehyde, benzene); set special standards for high-risk sectors	Benzene, Formaldehyde, Mercury, Chromium, etc.	EPA (hazard assessment using modeling)	Chemical plants, metal processing, medical waste incinerators, power plants	☑ ~90% reduction in hazardous pollutant emissions ☑ High-cancer-risk areas reduced ☑ Medical waste incinerator emissions down ~80%

Summary:

- **NAAQS** – National-level target levels applicable to all sectors.
- **PSD** – Defines proper siting and technology requirements for new projects and facilities.
- **NESHAP** – Sets special standards for sectors emitting highly toxic or hazardous substances.

To apply these lessons in Mongolia, a localized model could be developed:

- **NAAQS** → National ambient air quality standard (baseline for all).
- **PSD** → Restrictions integrated with urban planning and land use.
- **NESHAP** → Control for hazardous waste incineration, mining, and heavy industry near settlements.

At the national level in the U.S., key air quality standards—NAAQS, NSPS, and NESHAP—have improved air quality and positively impacted public health in cities such as Los Angeles, Chicago, and Cincinnati. The following tables illustrate the observed health improvements:

Table 4-25. Health Improvements from Standards – Los Angeles

Standard	Health Impact	Notes	Source
$PM_{2.5}$ (NAAQS)	Reduced cardiovascular disease, lung disorders, mortality	In 2024, EPA revised the standard from 12 µg/m³ → 9 µg/m³, significantly lowering pollution	EPA, 2024
NO_2 (NAAQS)	Reduced respiratory illness	NO_2 dropped 64% between 2005–2021	NASA AirQuality

Table 4-26. Health Improvements from Standards – Chicago

Standard	Health Impact	Notes	Source
$PM_{2.5}$ (NAAQS)	Reduced respiratory and cardiovascular disease	Measures taken to comply with new standards	EPA, 2024
O_3 (NAAQS)	Lung disease from ozone exposure decreasing	Some districts still experience high ozone levels	Chicago.gov, 2024

Table 4-27. Health Improvements from Standards – Cincinnati

Standard	Health Impact	Notes	Source
$PM_{2.5}$ (NAAQS)	Reduced cardiovascular disease, hypertension, kidney damage	Air quality improved and $PM_{2.5}$ levels steadily decreased	Cincinnati.gov, 2024

3) Agencies Responsible for Implementing Changes

Passing laws and setting standards alone is not sufficient; without proper enforcement, tangible results cannot be achieved. In the U.S., specialized agencies, legal oversight, and accountability systems have been established to address this issue comprehensively.

The table below shows the agencies responsible for enforcing each law and their main functions:

Table 4-28. Agencies Responsible for Enforcing U.S. Air Quality Laws

Law / Period	Responsible Agency	Main Functions
1965 – Motor Vehicle Air Pollution Control Act	U.S. National Highway Traffic Safety Administration (NHTSA) and the Department of Health, Education, and Welfare (HEW, at that time)	- Set automobile emissions standards- Collect reports from manufacturers and conduct oversight
1967 – Air Quality Act	HEW + State Environmental Agencies	- Designate air quality regions- Develop monitoring and management plans for each state
1970 – Clean Air Act	EPA (Environmental Protection Agency)	- Set standards (NAAQS, emissions from industry, vehicles)- Conduct monitoring and inspections (air quality network)- Identify violations and issue fines or shut down facilities- Oversee state-level implementation
State Level	State Environmental Agencies	- Implement EPA policies locally- Conduct emissions inspections, issue permits- Develop local air quality plans
Judicial & Law Enforcement	U.S. Department of Justice (DOJ) and State Attorneys	- Enforce compliance- Take legal action for violations

Key Highlights:

- **EPA** serves as the primary national-level enforcer.
- States develop independent plans that are approved and monitored by the EPA.
- Judicial decisions, fines, and administrative enforcement were highly effective (e.g., major penalties imposed on auto manufacturers).
- Annual reporting and public transparency in monitoring significantly influenced compliance.

In addition to federal responsibilities, each state enforces its own laws and regulations. This study also examined which agencies held enforcement responsibility in the three cities included in the analysis.

Table 4-29. Relevant Laws and Standards

Year	Law / Standard
1965	Motor Vehicle Air Pollution Control Act
1967	Air Quality Act
1970	Clean Air Act (CAA) + NAAQS, NSPS, NESHAP

Table 4-30. Classification of Responsible Agencies (1965–1970)

Responsibility	Responsible Agency	Note
Establish standards, develop policy	U.S. Department of Health, Education, and Welfare (HEW) → later EPA (from 1970)	EPA was newly established in 1970
Implement standards locally	State and local environmental agencies (e.g., California Air Resources Board, Illinois EPA, Ohio EPA)	Varies by city
Training, guidance, and manuals	HEW (1965–1970), EPA Training Division, Public Health Service	Develops manuals, training programs
Oversight, audits	EPA Regional Offices + GAO (Government Accountability Office)	Regional EPA offices
Measurement and monitoring	Local Air Monitoring Networks + National Air Surveillance Network (NASN)	Uses technical and laboratory resources
Data collection and reporting	EPA, State Air Quality Management Agencies	Policy based on collected data
Public outreach and information dissemination	EPA Outreach Programs, Local Public Health Departments, Media	Education, public awareness activities

Table 4-31. Agencies Responsible in Selected Cities

City	Local Implementing Agencies	Measurement Agency	Audit & Reporting	Training
Los Angeles	California Air Resources Board (CARB), South Coast AQMD	South Coast Air Quality Monitoring Stations	EPA Region 9, CARB	UCLA, CARB
Chicago	Illinois EPA (IEPA)	IEPA Monitoring Stations	EPA Region 5, IEPA	UIC School of Public Health
Cincinnati	Ohio EPA, Cincinnati Health Department	Hamilton County Air Quality Division	EPA Region 5, Ohio EPA	University of Cincinnati EH&S

4.2.5. Case Study: City of Chicago

1) City Air Pollution Control Policy – Design Approach

Between 1964 and 1984, Chicago shifted from traditional command-and-control strategies to economic regulatory strategies, improving air quality while significantly reducing implementation costs. In his 1964–1978 study, O'Neill reported that Chicago's pollution control legislation reduced and stabilized total suspended particulate (TSP) levels, though some unidentified sources remained. Later, a multi-district study covering 1975–1984 by Seskin et al. (1983) compared command-and-control measures with economic instruments (e.g., emission fees, tradable permits) for reducing nitrogen dioxide (NO_2). Their results showed that economic instruments reduced NO_2 levels by 18%, met the standard, and achieved the goal at one-tenth the cost of traditional methods, potentially saving $100 million annually.

Max S. Peters (1958) noted: *"Theoretical understanding, practical application, economic constraints, common sense, and tangible results are the requirements of design engineering, and these should be integrated systematically when addressing urban issues."* This principle has guided Chicago and other U.S. cities in policymaking. In particular, the use of **process modeling**—or process design—aligned national-level Design Approach Policy with systematic strategy, allowing tactical planning at the city level and effective operational implementation.

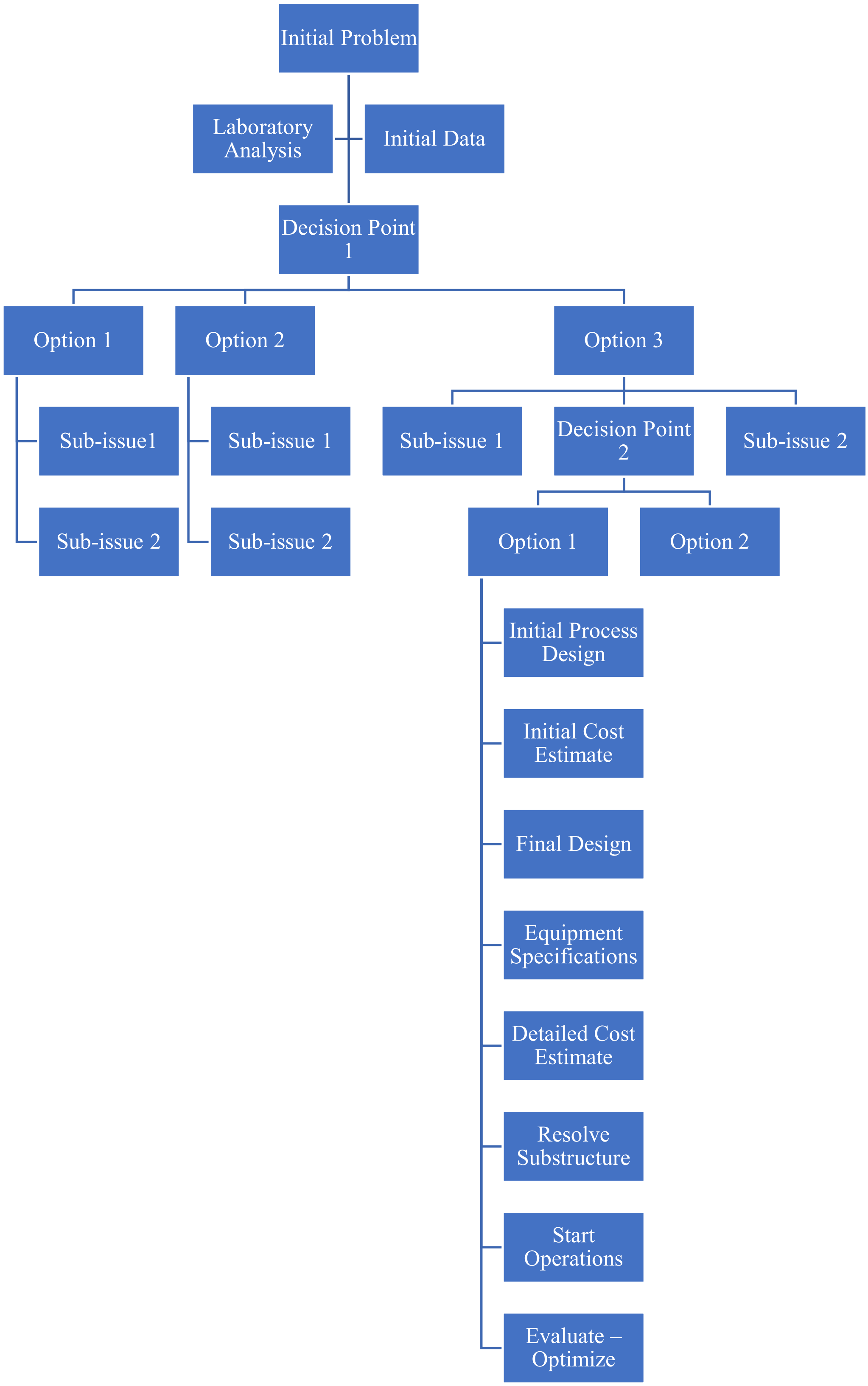
A key recommendation from scholars is: *"Policy development should involve professional agencies and personnel to generate alternative options. Each alternative should assess additional risks, so that technically and economically feasible options with social and environmental benefits can be selected and implemented."*

This is known as **finding the decision point**, where each problem is analyzed for actual and potential risks, simulations are performed using software, and tested, proven approaches are implemented. This ensures policies address issues with significant public, health, and environmental impacts, serving as a policymaking "axiom."

2) City Air Pollution Control Policy – Process Management

Process modeling, as described in management standards like ISO 9001, involves mapping all major steps of production or operations on a single diagram to show how problems are addressed in each process. The example diagram below illustrates this concept. At a high level, this model can be applied to policy research to verify whether solutions are effective. At a lower level, it can guide a single organization in modifying exhaust technology, installing new equipment, or other operational improvements. The key is **repeatedly verifying whether the problem is resolved** and identifying the correct solution point.

Figure 4-2. Process Mapping for Identifying the Solution Point



The outline process design shown in the figure will be further developed into a process flow diagram, breaking down each individual task, estimating the resources and workforce required at each stage, identifying training needs, implementing programs to inform and report to external stakeholders, and establishing financial and legal incentives. This and other similar methods are not the focus of this study and will therefore not be described in detail.

Once the legal framework has been clarified, the methodology for implementing activities becomes a separate topic. This includes conducting cost–benefit analysis, identifying the relationship between social benefits and environmental impacts, and applying economic models in air pollution control policies, among others. The main point emphasized here is the idea of developing policy alternatives for decision-making, and analyzing both their benefits and drawbacks using a systems approach.

In the case of the city of Chicago, it was emphasized that every individual, every household, and every organization must make efforts to combat air pollution and ensure clean air, with requirements embedded in all aspects of living and working there. For instance, requirements were set for obtaining operational permits, establishing companies, conducting business activities, acquiring land, purchasing or transferring real estate, as well as for households regarding cooking, waste disposal, driving cars or cycling. Among these, the requirements relevant to organizations are outlined below, including those for government agencies, state-owned enterprises, local self-governing bodies, all tenders and budget-funded projects implemented by the state, and for private entities regarding the construction of new buildings, housing, facilities, purchase of equipment, vehicles, and road usage.

1) Allocation of Responsibilities for Addressing Urban Air Pollution

The table below shows the stakeholders required under U.S. decision-making processes and those included in the Chicago model.

Table 4-32. Stakeholders – Chicago

Organization / Stakeholder	PDCA Role	Description
EPA (Environmental Protection Agency)	Plan / Check / Act	Develops policies, conducts research, sets standards, monitors compliance, issues improvement recommendations
IEPA (Illinois Environmental Protection Agency)	Plan / Do / Check	Oversees air quality at the state level, issues permits, sets standards
CDPH (Chicago Department of Public Health)	Do / Check	Reviews permits, investigates violations, monitors air quality in the city
DPS (Chicago Department of Procurement Services)	Plan / Check	Integrates environmental criteria into government procurement, sets requirements
Chicago Municipal Code – Environment Chapter	Plan	Codifies air quality standards and permitting requirements
City Councils, District Mayors	Plan / Act	Establish policies for the city and decide on penalties for violations
Construction & Mining Companies	Do	Operate in compliance with laws and permits, meet standards
HOAs (Homeowners' Associations)	Do / Act	Implement resident-focused initiatives to improve air quality
Secretary of State (Business Registration)	Plan / Check	Sets requirements depending on business type and location
Energy Star Certification Bodies	Check	Certify and inspect energy-efficient products
Renewable Energy Providers, Utilities	Do	Produce and supply clean energy
Private Sector Investors & Innovators	Do / Act	Develop technologies and innovations to meet climate goals
Public Campaigns, Media, AQI Alerts	Do / Act	Disseminate air quality information, promote public participation

Universities (UIC, University of Chicago)	Plan / Check / Act	Conduct research, participate in policy development, provide assessments, propose new solutions
Attorney General, Courts, Law Enforcement	Check / Act	Enforce legal accountability for violations, impose fines
NEPA (National Environmental Policy Act)	Plan / Check	Evaluate and oversee major federal projects for environmental impacts

PDCA Role Definitions:

- **Plan:** Develop strategies, standards, laws, policies
- **Do:** Implement and participate in actions
- **Check:** Monitor, evaluate, grant permits
- **Act:** Correct violations, impose sanctions, initiate systemic reforms

2) Public–Private Partnerships in the Energy Sector

The table below presents the ownership structure, competition, and market arrangements of organizations providing electricity and heat supply in Chicago.

Table 4-33. Public–Private Ownership of Electricity and Heat Supply Organizations in Chicago

Organization / Activity	Ownership	Energy Type	Regulation / Requirements
ComEd (Commonwealth Edison) – Electricity Distribution	Private (Exelon Corporation)	Nuclear (50%), natural gas, wind, solar	Regulated by the Illinois Commerce Commission
Peoples Gas – Heat Distribution	Private (WEC Energy Group)	Natural gas	Gas prices regulated by ICC; geothermal transition proposed
Fisk Generating Station – Electricity Production	Private (Midwest Generation)	Coal	Closed in 2012 due to air pollution concerns
Crawford Generating Station – Electricity Production	Private (Midwest Generation)	Coal	Closed in 2012 due to environmental pollution
Prairie State Energy Campus – Electricity Production	Public (IMEA & 9 municipal owners)	Coal	Mandated to reduce CO_2 by 45% by 2035 and 100% by 2045
Double Black Diamond Solar Project – Solar Energy	Private (Swift Current Energy)	Solar	593 MW capacity; aims to power city buildings with 100% renewable energy
Geothermal Heating Projects – Heating	Public–private partnerships	Geothermal	Eco-friendly, efficient, increasing consumer adoption
Illinois Municipal Electric Agency (IMEA) – Public Power Supplier	Public (non-profit)	Coal, minor renewables	Goal: carbon-free system by 2050

3) Structure of Electricity and Heat Supply Services in Chicago

- **Electricity service:** 1 main provider — ComEd (subsidiary of Exelon).
- **Heat service:** 1 main provider — Peoples Gas (subsidiary of WEC Energy Group).

These companies are the dominant suppliers in their respective sectors and operate in a non-competitive market.

Market Competition and Regulation:

- ComEd and Peoples Gas are regulated by the Illinois Commerce Commission (ICC), responsible for protecting consumer rights, ensuring service quality, and regulating prices.

- IMEA coordinates municipal electricity systems as a non-profit agency, supplying power to its member municipalities.
- Renewable energy projects such as the Double Black Diamond Solar Project are funded by private investments, and their effectiveness depends on both project developers and local government cooperation.

Sources replacing coal currently include:

- **Nuclear energy:** Illinois is the leading U.S. state in nuclear power generation, producing 53.3% of its total electricity.
- **Renewable energy:** Wind (13.1%), solar (1.5%) are in use.
- **Geothermal energy:** Used for residential heating and roadway heating projects.
- **Natural gas:** Remains the main heat supply source but is being reduced to meet carbon reduction targets.

4) Role of Law Enforcement Agencies

Law enforcement and judicial agencies in Chicago and Illinois ensure compliance, oversee legal processes, detect violations, impose fines, enforce compensation, and pursue litigation.

Table 4-34. Law Enforcement and Judicial Agencies in Chicago and Their Roles in Air Pollution Response

Organization	Main Function	Role in Air Pollution
US Environmental Protection Agency (US EPA)	Federal air quality, standards, monitoring	Issues licenses, fines, refers cases to court
Illinois Environmental Protection Agency (Illinois EPA)	State-level environmental regulation	Grants permits, conducts measurements, suspends rights, opens violations
Illinois Attorney General's Office	State law enforcement, civil & criminal cases	Prosecutes environmental violations, seeks compensation, halts operations
Cook County State's Attorney's Office	County-level prosecution, criminal investigations	Initiates criminal cases against companies (e.g., intentional emissions, false reporting)
Chicago Department of Law (City Legal Dept.)	City's legal representation	Litigates violations on behalf of the city
Illinois Pollution Control Board	Environmental dispute resolution	Determines damages, penalties, and remediation deadlines
Circuit Court of Cook County	State court (civil, criminal, administrative)	Hears environmental claims and fines
Federal District Court (Northern District of Illinois)	Federal cases	Imposes fines, injunctions, plant closures based on US EPA claims
Defense Council & Public Defender's Office	Legal defense	Represents defendants in environmental cases
Chicago Police Department	Law enforcement, patrol	Provides investigative support (not directly involved in air cases)
Illinois State Police	State police	Handles hazardous waste transport and related violations
Illinois National Guard	State National Guard	Responds to major air pollution incidents (e.g., plant explosions, chemical spills)

Air pollution enforcement mechanisms involve three main tiers:

1. **Regulation & Permit Revocation** – When Illinois EPA or US EPA detects violations:
   - Revoke licenses
   - Issue warnings based on inspection and monitoring reports
   - Issue "Notice of Violation (NOV)" official notices

2. **Judicial Actions:**
    - Compensation for damages and court-ordered operational shutdown
    - Criminal prosecution for deliberate false reporting or concealed emissions (e.g., Volkswagen emission case)
3. **Citizen Suits:**
    - Civil society and residents can collectively file "Citizen Suits" under the Clean Air Act in federal court

Restoration & Costs:

- Companies may be required to fund remediation measures and implement community environmental plans in addition to fines.

Examples:

- **Midwest Generation LLC (Chicago coal plants):** Fined and forced to permanently close two plants in 2012 following lawsuits by Illinois EPA and civil society (with Illinois Attorney General and Environmental Law & Policy Center involved).
- **Volkswagen USA:** Chicago residents filed a citizen lawsuit for excessive emissions and standard violations, resulting in fines and a large-scale vehicle recall.

4.3. Comparison and Gap Analysis between the U.S. and Mongolia

4.3.1. Legal System and Standards

When comparing the legal framework of the United States with Mongolia's existing laws and standards, it is clear that Mongolia's regulatory framework is incomplete, with measurement requirements being mostly general and several detailed standards missing. Therefore, legal reforms and a comprehensive approach are needed, as summarized in the table below.

Table 4-35. Comparison of Air Quality Laws and Standards: U.S. vs Mongolia

№	U.S. Law / Standard	Role & Function	Mongolian Regulation	Exists?	Remarks
1	**Clean Air Act (1970, with amendments)**	- Primary federal law on air quality - Sets national policy and standards for reducing air pollution - Title V Permit Program - National Ambient Air Quality Standards (NAAQS)	- Law on Air (2012) - Law on Environmental Protection - Special Use Permit Procedure	⚠️ Exists but weak	Law exists but is general; program and standards are weak. No permit program tied directly to air quality. Air quality monitoring standards do not provide equivalent functions.
2	**NAAQS – National Ambient Air Quality Standards**	- Sets limits for 6 major pollutants (PM2.5, PM10, SO_2, NO_2, CO, O_3) - Enforced nationwide	- MNS 4585:2016 – Air Quality Basic Indicators and Ambient Standards	⚠️ Exists	Specific pollutant limits exist but measurement and monitoring are underdeveloped, with weak temporal criteria.
3	**NSPS – New Source Performance Standards**	- Sets emission limits for new industrial sources - Defines required technologies	None	❌ Missing	Mongolia lacks specific standards for new emission sources.
4	**NESHAPs – National Emission Standards for Hazardous Air Pollutants**	- Regulates emissions of 189 hazardous substances - Sets facility-level limits	None	❌ Missing	Mongolia has very limited hazardous emission standards.
5	**Motor Vehicle Emission Standards**	- Limits vehicle emissions - Establishes fuel standards - Defines technical requirements	- MNS 4593:2016 – Fuel Standard - Vehicle Technical Inspection (legal framework)	⚠️ Exists (outdated, limited)	Mongolia's standards are outdated and need alignment with international norms.
6	**PDCA – Plan-Do-Check-Act System for Environmental Management**	- Plans, enforces, monitors, and improves standards systematically - Applied in environmental and air quality management	- ISO 14001 implemented in some organizations - Environmental management system in development	⚠️ Limited	Applied mainly in large companies and government agencies; not a nationwide system.
7	**State Implementation Plans (SIPs)**	- Requires each state/locality to develop and implement air quality plans - Approved by EPA	- Local governments develop air quality plans but lack standardized process	❌ Missing	Mongolia has local air quality plans but no SIP-equivalent system.
8	**Title V Operating Permits**	- Issues operating permits for each emission source - Ensures monitoring and compliance	- Special Use Permit Procedure (limited) - Weak inspection/control system	❌ Missing (limited)	Mongolia's permitting system is restricted and needs enhancement.

9	**Monitoring & Reporting Requirements**	- Requires industries and emission sources to monitor and report data	- Legal requirements for environmental monitoring exist - Reporting system developing	⚠️ Exists (limited)	Monitoring and reporting system is developing but not fully automated.
10	**HAPs Control Technologies (BACT, MACT)**	- Requires best available and maximum achievable control technologies based on cost-benefit analysis	None	❌ Missing	Mongolia lacks specific technological requirements; outdated equipment is common.

Specifically, when comparing the **NAAQS air quality standards of the U.S.** with Mongolia's current standards, Mongolia monitors and registers primary sources but lacks a regulatory framework for secondary sources. Moreover, U.S. measurement systems are designed to prevent data manipulation by human bias and to ensure accurate, reliable data collection and analysis through systemic and technological means. In Mongolia, only annual averages are regulated, with no established requirements for finer temporal measurement frequencies, resulting in weak monitoring obligations. This gap prevents effective evaluation of whether legal instruments produce real outcomes.

See the following table for reference.

Table 4-36. Comparison of Air Quality Laws and Standards: U.S. vs. Mongolia

№	U.S. Law / Standard	Role & Function	Mongolian Regulation	Status	Key Remarks
1	**Clean Air Act (CAA), 1970 & amendments**	• Main federal law regulating air quality• Establishes national policies and emission standards• Title V permit program• National Ambient Air Quality Standards (NAAQS)	• Law on Air (2012)• Law on Environmental Protection• Special utilization permit regulations	⚠️ Exists (general)	No air-quality-linked permitting system; monitoring standards do not provide equivalent enforcement functions.
2	**NAAQS – National Ambient Air Quality Standards**	• Sets limits for six major pollutants: $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, O_3• Nationwide enforcement	• MNS 4585:2016 – Basic Indicators for Air Quality (ambient norms)	⚠️ Exists	Pollutant limits exist but monitoring is underdeveloped; lacks strong time-bound criteria.
3	**NSPS – New Source Performance Standards**	• Defines emission limits for new industrial sources• Establishes required technologies	None	❌ Missing	No specific standards for new sources in Mongolia.
4	**NESHAPs – National Emission Standards for Hazardous Air Pollutants**	• Controls 189 hazardous pollutants• Facility-level limits	None	❌ Missing	Very limited hazardous emission standards.
5	**Motor Vehicle Emission Standards**	• Sets vehicle emission and fuel standards• Defines technical inspection requirements	• MNS 4593:2016 – Fuel Standard• Vehicle technical inspection system	⚠️ Exists (outdated)	Needs updating to match global standards; limited enforcement.
6	**PDCA – Plan-Do-Check-Act**	• Framework for planning, implementing, monitoring, and improving air quality management	• ISO 14001 implemented selectively• Developing environmental management systems	⚠️ Limited	Applied in some organizations; no national-level system.
7	**State Implementation Plans (SIPs)**	• State/local air quality plans approved by EPA	• Local plans exist, unstandardized	❌ Missing	Mongolia lacks SIP-equivalent structured planning and enforcement.

8	**Title V Operating Permits**	• Operating permits for emission sources• Compliance and monitoring mechanism	• Special utilization permit procedure (limited)• Weak inspection/control system	❌ Missing (limited)	Needs comprehensive permitting and compliance mechanism.
9	**Monitoring & Reporting Requirements**	• Mandatory monitoring and reporting for emission sources	• Mandated by law• Partial reporting system	⚠️ Exists (limited)	Monitoring is not fully automated; reporting fragmented.
10	**HAPs Control Technologies (BACT, MACT)**	• Requires best available and maximum achievable control technologies• Cost-benefit driven	None	❌ Missing	Outdated technologies remain; no defined technology standards.

4.3.2. Stakeholders

To address air pollution, requirements and criteria must be set for all societal stakeholders, along with active public information dissemination. In Mongolia, the participation of institutions with functions equivalent to those in Chicago's air pollution management solution has been evaluated, as shown below.

Table 4-37. Stakeholders – Comparison of Institutions: Chicago vs. Mongolia

Chicago Requirement	Relevant Chicago Institution	Comparable Institution in Mongolia
Air Pollution Control Permit All new and modified equipment/operations require a permit.	Chicago Dept. of Public Health (CDPH), Environmental Protection Agency (EPA)	Ministry of Environment, Capital City Department for Combating Air and Environmental Pollution
Annual Operating Certificate Facilities with permits must obtain annual operating certification.	CDPH – Chicago Dept. of Public Health	Ministry of Environment, Environmental Pollution Control Agency
Air Quality Impact Study Certain sectors (e.g., recycling, SMEs, large industries) must conduct impact studies.	CDPH, Dept. of Planning and Development (DPD)	Ministry of Environment, Urban Development and Planning Department, Ministry of Road and Transport Development
Traffic Impact Study Projects must assess their traffic-related air pollution impacts.	Chicago Dept. of Transportation (CDOT)	Ministry of Road and Transport Development, Urban Development and Planning Department
Public Participation Public hearings must be held for projects.	CDPH, DPD	Ministry of Environment, Citizens' Representative Khural, Civil Society Organizations
Planned Development Zoning Approval Projects >10 acres or near residential areas require special permits (green space, pedestrian areas, emission impacts assessed).	DPD, City Council	Urban Development and Planning Department, Local Authorities
Annual Air Pollution Report Facilities with permits must submit yearly reports.	Illinois EPA (IEPA)	Ministry of Environment, Environmental Pollution Control Agency
Restricted Emission Zones Certain zones restrict permits, building certificates, and land/property certificates.	CDPH, IEPA	Ministry of Environment, Local Authorities, State Registration Agency
Special Requirements for Sensitive Areas Projects near schools/hospitals must meet stricter requirements.	CDPH, DPD	Ministry of Environment, Ministry of Health, Ministry of Education & Science

Table 4-38. U.S. vs. Mongolia – Institutions Responsible for Air Quality

Indicator / Level	United States	Mongolia	Difference / Remarks
1. National Level	**EPA** – Federal agency. Sets NAAQS. Approves state/local plans.	**Ministry of Environment** – Central government agency. Develops and implements air quality policy. Approves standards, manages monitoring and databases.	In the U.S., EPA focuses on policy & standards (PDCA "P" stage). In Mongolia, the Ministry manages policy, implementation, and enforcement (PDCA "PDC").
2. State / Province Level	**Illinois EPA (IEPA)** – State agency. Issues permits under EPA authorization.	**Aimag Governors & Environment Departments** – Local government bodies.	In the U.S., state agencies grant permits and enforce compliance. In Mongolia, local bodies mainly

	Monitors emissions and enforces compliance.	Oversee compliance and conduct inspections.	monitor and inspect, with limited permitting authority.
3. City / District Level	**CDPH** – City health department. Monitors air quality, informs the public, implements local initiatives.	**Soum/District Governors** – Local administration. Implements local air pollution plans, fuel control, fines.	U.S. city agencies actively monitor, inform, and implement projects. In Mongolia, fuel control dominates; other measures are underdeveloped.
4. Professional Institutions	National labs & research centers (e.g., NASA, NOAA, AIRNow). Provide technical support, monitoring, research. Collaborate with private sector, independent.	**Meteorology & Environmental Monitoring Agency (NAMEM)**. Collects air quality data, conducts research.	U.S. has multiple independent labs conducting policy-relevant analysis. In Mongolia, National Agency for Meteorology and Environmental Monitoring (NAMEM) mainly collects data, limited advisory role.
5. Public Participation & NGOs	NGOs (e.g., EDF, NRDC) conduct initiatives, monitoring, and influence policy. Have legal standing in city/state hearings.	NGOs like "Smoke-Free Ulaanbaatar," "Breathe Air," "Khureelen." Participate in discussions and propose recommendations.	U.S. NGOs conduct professional analyses and legal advocacy. Mongolian NGOs provide input but lack detailed research or impactful policy influence.

For example, the activities of NGOs such as the Environmental Defense Fund (EDF) and the Natural Resources Defense Council (NRDC) were compared with the involvement of Mongolian NGOs, as shown below:

Хүснэгт 4-1. Comparison of NGO Involvement in Air Quality Policy between the U.S. and Mongolia

Area	NRDC, EDF (U.S.)	Mongolia (NGOs)	Remarks / Differences
Policy Analysis	☑	✕ (limited)	U.S. NGOs conduct in-depth research and analysis on the implementation of laws and policies. Mongolian NGOs have limited capacity and lack rigorous studies in this area.
Monitoring	☑	✕ (limited)	In the U.S., NGOs monitor air quality and climate issues using their own instruments and research networks. In Mongolia, monitoring exists but tools, scale, and clear responsibility allocation are limited.
Advocacy	☑	✕ (limited)	In the U.S., NGOs develop science-based requirements, influence government, and draw public attention. In Mongolia, initiatives exist but often lack scientific justification.
Litigation	☑	✕	U.S. NGOs can file lawsuits against organizations violating laws. In Mongolia, such activities are rare, and legal leverage is weak.
Public Engagement	☑	☑	In the U.S., NGOs involve citizens widely through training, campaigns, and membership. In Mongolia, engagement exists but is less extensive and less sustainable.
Technology & Innovation	☑	✕	EDF proposes market incentives and innovative methods to reduce air pollution. In Mongolia, this field is limited.
Policy Demands	☑	✕ (limited)	U.S. NGOs formally submit policy demands and proposals. In Mongolia, feedback exists, but formal policy demands to government bodies are rare and unsystematic.

Table 4-39. Comparison of the Location, Ownership, Energy Type, and Regulation of Energy and Heat Production, Transmission, and Distribution Organizations in Chicago and Illinois with Similar Organizations in Mongolia

Organization / Activity	Location	Public or Private Ownership	Energy Type	Regulation / Requirements	Comparable Organization in Ulaanbaatar
ComEd (Commonwealth Edison)	Chicago and most of Northern Illinois	Private (Exelon Corporation)	Nuclear, natural gas, wind, solar	Regulated by Illinois Commerce Commission. Serves 3.8 million customers.	No natural gas or renewable energy power plants in Ulaanbaatar.
Peoples Gas	Serves all customers in Chicago	Private (WEC Energy Group)	Natural gas	Regulated by Illinois Commerce Commission. Serves 894,000 customers.	
Fisk Generating Station	Pilsen neighborhood, Chicago	Private (Midwest Generation)	Coal	Closed in 2012 due to air pollution.	State-owned "CHP-3", "CHP-4", "CHP-2", "Ulaanbaatar Heating Network", "Amgalan CHP" JSC – no CO_2 reduction requirements.
Crawford Generating Station	South Lawndale neighborhood, Chicago	Private (Midwest Generation)	Coal	Closed in 2012 due to environmental pollution.	
Prairie State Energy Campus	Near Marissa, Illinois (rural area)	Public-owned (9 municipalities via IMEA)	Coal	Required by law to reduce CO_2 emissions by 45% by 2035 and 100% by 2045.	Bureltjuit Thermal Power Plant under construction in Bayanjargalan, Tuv province – no CO_2 reduction requirements enforced.
Double Black Diamond Solar Project	Morgan and Sangamon counties, Illinois	Private (Swift Current Energy)	Solar energy	800 MW capacity; aimed at supplying renewable energy to all public buildings in Chicago.	
Geothermal Heating Projects	Chicago and other parts of Illinois	Public-private partnerships	Geothermal heat	Environmentally friendly, efficient, growing public support.	No implementation of geothermal heating from Earth's natural heat.
Illinois Municipal Electric Agency (IMEA)	32 cities in Illinois	Public (non-profit)	Coal with some renewable sources	Target to transition to a zero-CO_2 system by 2050.	No comparable stations in Tuv province or surrounding settlements near Ulaanbaatar.

Analysis and Recommendations:

The comparison shows that, unlike in Mongolia where most power stations are concentrated only in Ulaanbaatar, Illinois and Chicago have a more distributed energy infrastructure, including public-private partnership (PPP) models. Mongolia should consider establishing power stations in all populated provinces and settlements, utilizing PPP frameworks. To improve air quality, coal-fired plants must be subject to emission reduction requirements with clear deadlines, including mandatory filtration technology implementation. Furthermore, renewable energy projects such as solar, wind, and geothermal sources should be researched and adopted. Most importantly, the government should avoid centralizing all operations under state control and instead encourage private investment and operational participation.

4.3.3. Public-Private Partnerships (PPP)

In Chicago, electricity, heat, and water supply are divided among several private and local organizations for each sector, operating under competitive and detailed regulatory principles. In contrast, in Mongolia, these sectors are highly centralized under state ownership, with little variety of services, competition, or consumer choice. Learning from Chicago's experience, opening the market to private sector participation and providing proper regulation could help address economic constraints.

Table 4-40. Structure, Ownership, and Competition in Engineering Services: Chicago vs. Mongolia

Sector	Chicago (Example: one district)	Ownership Type	Mongolia (Example: Ulaanbaatar)	Ownership Type
Electricity Supply	1. ComEd – electricity transmission and distribution2. 20+ small renewable energy providers (solar, wind, etc.)3. Illinois Municipal Electric Agency (IMEA) – local public utility	Private + Local public ownership	1. State-owned CHP "CHP-3, 4" JSC2. "Electricity Distribution Network" JSC3. Limited private renewable energy companies	Predominantly state-owned
Heat Supply	1. Peoples Gas – natural gas2. Geothermal Services Inc. & other private geothermal companies3. Multiple private suppliers depending on district	Mostly private	1. Ulaanbaatar Heating Network JSC2. Amgalan Heating Plant JSC3. Bayaankhoshuu & Sharkhad district centralized heating systems	100% state-owned, no market
Water Supply & Wastewater	1. Chicago Department of Water Management – drinking water & wastewater2. Metropolitan Water Reclamation District (MWRD) – regional management3. Some districts have separate contracted companies	City-owned + autonomous administrative agencies	1. Water Supply Management JSC – Ulaanbaatar2. Local government-owned agencies in provinces & districts	100% state-owned
Air Pollution Control	1. Illinois EPA – state environmental protection agency2. US EPA – federal environmental oversight & licensing3. High civil society and judicial oversight	Mixed: state regulation + judicial oversight + private monitoring companies	1. Ministry of Environment & Climate Change, General Agency for Specialized Inspection, City Council2. Private monitoring is almost absent; public participation weak	Highly centralized by the state
Waste Management	1. City of Chicago contracts multiple private companies2. Waste sorting, recycling, biogas production	Administrative-centered with contracted private companies	1. City Waste Management Office (state-owned)2. Few private companies, no contractual responsibility system	Highly centralized, limited private participation

In summary, the involvement of the public and private sectors differs as follows.

Table 4-41. Differences in Public-Private Involvement: Chicago vs. Mongolia

Indicator	Chicago	Mongolia
Multiple providers in one area?	☑ Yes (competition exists)	✖ No (single state-owned service)
Private sector participation	☑ Key participant	✖ Limited
Potential for competitive market	☑ Full	✖ Almost none

Consumer choice	☑ Available (gas, electricity, geothermal, renewable)	✖ Not available
Dependence on government	⚖️ Only at the regulatory level; implementation dominated by private sector with market-based competition	✖ At structural and implementation level; state highly involved

4.3.4. Comparison of Systems for Assessing Environmental Damage and Determining Compensation

The table below compares Mongolia and the United States in terms of methods and regulations for evaluating environmental damage and calculating compensation.

Table 4-42. Comparison of Public and Private Sector Involvement in the United States and Mongolia

Indicator	Mongolia	United States
Legal basis	- Law on Environmental Protection (1995) - Regulation on Assessment and Analysis of Environmental Damage (2023) - Environmental Compensation Methodology (UNDP, 2020)	- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) - Clean Air Act (CAA), Clean Water Act (CWA) - National Environmental Policy Act (NEPA)
Accountability system	Central government administration, courts, and supervisory authorities assess damage and impose compensation	Relevant government agencies (EPA, DOI) identify responsible parties and require compensation and restoration
Assessment methodology	Static assessment (by area, plants, trees, etc.) Compensation calculated using socio-economic–ecological methods	Natural Resource Damage Assessment (NRDA) – dynamic model based on ecosystem restoration for damaged resources
Type of damage	- Plants, soil, forest, water resources - Negative impacts from mining - Land use and pollution damage	- Land contamination, toxic substance loss - Damage to animals, plants, ecosystems - Health and economic impacts
Measurement units	- m², ha, pieces, tons, etc. - Calculated per type of damage/pollution	- Monetary value of damage (USD) - Cost of restoration - Lost use value
Form of compensation	- Direct monetary fines - Obligation to restore the environment	- Environmental restoration trust funds - Direct actions to remove damage
System characteristics	- Assessments are relatively general; comprehensive economic calculations are rare - Low public participation; high public distrust and opposition	- Damage assessment models are science-based and detailed - High participation of the public and civil society
Transparency and oversight	Limited transparency; information reaching the public is minimal	Agencies such as EPA and DOJ provide public reports and disclose every damage decision

From this comparison, Mongolia's system for assessing environmental damage and imposing compensation is limited in several ways. It does not ensure full restoration, nor does it require measurements that fairly reflect the monetary value of damage, lost opportunities, human health, and economic impacts. Unlike the U.S., Mongolia does not calculate lost use values or implement restoration trust funds, direct remediation measures, or detailed, dynamic ecosystem restoration models. Additionally, the lack of public transparency and disclosure leads to strong opposition from citizens and communities, especially regarding high-impact activities such as mining.

4.3.5. Proposal for a Gap Analysis Evaluation Checklist

It is possible to develop an evaluation checklist to assess Mongolia's own policies, implementation, and institutional capacity in comparison with the United States.

The U.S. design methodology (PDCA cycle), the combined federal–state implementation model, and air pollution policies based on public–private partnerships could serve as a model for Mongolia to some extent. Based on this, Mongolia can develop an evaluation checklist to assess its own policies, implementation, and institutional capacity in comparison with the U.S. experience.

The table below presents a checklist that Mongolia could use to evaluate its air pollution policies and legislation, drawing on U.S. experience and structured around the PDCA cycle and public–private partnership model. It is recommended to further expand and utilize this checklist for conducting a detailed policy impact assessment.

Table 4-43. Evaluation Checklist: Assessing Mongolia's Air Pollution Policies Compared to the United States

Stage / Element	Criteria Derived from U.S. Experience	Situation in Mongolia / Evaluation Questions
1. Planning (Plan)	- Are NAAQS standards established? - Has each state developed a plan? - Is scientific evidence and public consultation included?	- Are national air quality standards established? - Does each province/city have an environmental plan? - Were scientific analyses and academic publications considered in drafting laws? - Are laws implemented systematically nationwide, at provincial/city, and district levels? - Is the legal framework for developing and implementing air pollution reduction plans fully established at the local level? - Are policies and plans based on research, scientific assessment, and public participation?
2. Implementation (Do)	- Are monitoring technologies implemented? - Is there a system for enforcing standards? - Has implementation been organized in each locality?	- Are smoke reduction technologies deployed? - How many organizations comply with the standards? - Can localities implement independently? - Are technical standards and technologies legally applied to pollution sources (plants, stoves, utilities) to prevent air pollution? - Are incentives and penalties balanced across policy, budget, and implementation levels? - Do enterprises prepare, implement, and report air pollution reduction plans? - Are pollution fees and taxes used effectively for air quality improvement and environmental protection (e.g., tree planting, constructing reservoirs, ponds, or canals)?
3. Monitoring (Check)	- Is air quality regularly monitored? - Are reports and information transparent? - Are audits and evaluations conducted regularly?	- Is there a national network for regular multi-point air quality measurement? - Are measurement data publicly available, clear, and usable? - Are measurements conducted at city, district, sub-district, province, and local levels? - Does the national monitoring system operate consistently? - Is information accessible to the public? - Are regular audits conducted? - Do government agencies and enterprises conduct internal monitoring and audits of activities affecting air quality? - Are independent professional organizations conducting external audits and evaluations? - Do citizens, NGOs, and researchers have sufficient legal authority and mechanisms to monitor air quality? - Are costs proportionate to environmental damage accurately measured and reported?
4. Improvement (Act)	- Are laws and standards updated? - Are technological incentives in place? - Are violators held accountable? - Are restoration costs fully covered and environmental damage addressed in the short and long term?	- Are air pollution laws, policies, and standards regularly updated based on implementation results? - Are regulations, rules, and standards compared to WHO benchmarks and updated accordingly? - Are studies and evaluations of human health and environmental risks conducted regularly? - Is the policy impact assessed using public health indicators and reported? - Are incentives provided to the private sector for clean technologies and pollution reduction innovation? - Are measures taken against non-compliant organizations (e.g., permit suspension, accountability enforcement)? - Is there a legal framework for courts to impose compensation and product/service recalls? - Are there legal mechanisms to address violations affecting others' rights to clean, safe living environments

		(e.g., smoke, noise, odor)? - Do citizens have the right to claim compensation for health or family losses caused by air pollution?
5. Public–Private Partnership		
5.1 Standards and Legislation	- EPA sets standards; private sector implements. - EPA takes violators to court. - EPA operates independently, without political influence.	- Does Mongolia have clearly defined responsibilities for conducting air quality research, setting detailed standards, and enforcing them? - Can the private sector and professional organizations participate effectively? - Does the government agency in charge of environmental issues operate independently and enforce standards without external influence? - Can law enforcement agencies (courts, prosecutors, police) hold violators accountable effectively?
5.2 Local Implementation	- States develop SIP plans.	- Do provinces and the capital have separate implementation plans? - Is there authority for independent decision-making?
5.3 Technology and Investment	- Invest in BACT/MACT technologies.	- Are technology companies providing smoke control solutions in Mongolia? - Are government incentives available? - Does the government procure and support private businesses' technological initiatives?
5.4 Research and Innovation	- EPA collaborates with R&D institutions.	- Do research institutions and the government collaborate? - Is innovation supported? - Are research and development grants announced and funded?
5.5 Transparency and Participation	- Reports are public; stakeholders actively involved. - Media informs the public, ensures transparency, participates in policy discussion, verifies facts, investigates independently, and remains free from political influence.	- Are environmental reports from government and private companies publicly available? - Are public reports from state-owned companies transparent? - Can civil society and businesses monitor effectively? - Is public participation ensured at all stages of policy development, implementation, and monitoring? - Are statistics, data, and information transparent and accessible? - Do media outlets have full rights to investigate, access, and disseminate information, performing their Fourth Estate function? - Are journalists' safety and freedom of publication protected?

In the U.S., the system for evaluating the impact of air pollution policies and laws in relation to human health is based on an integrated methodology combining science, statistics, and economic assessment. The table above illustrates this linkage and provides examples of tools and practices used.

Table 4-44. Linkage between Air Pollution Policy and Health Outcomes Based on the U.S. Example

№	Evaluation Focus	Indicators / Methodology Used	Data Sources	Practical Application / Example	Checklist Questions for Mongolia
1	Clinical statistics and mortality data	- Respiratory disease incidence - Mortality rates (all-cause & cause-specific) - Chronic disease trends	CDC, EPA, State Health Departments	Between 1990–2020, after updates to NAAQS, asthma and lung disease incidence steadily declined	Does Mongolia regularly report the correlation between air quality and respiratory diseases? Does it track other common conditions such as neurological, cardiovascular diseases?
2	Air Quality Index (AQI) and exposure levels	- PM2.5, O_3, NO_2, etc. - Average population exposure levels	EPA – AirNow.gov, NASA/NOAA data	Implementation of new standards reduced the number of high AQI days	Is AQI and human exposure data regularly and openly accessible? Are real-time measurements from satellites integrated?
3	Health–economic benefits	- Lost workdays - Hospital cost savings - Value of Statistical Life (VSL) based on mortality	EPA BenMAP, OMB Regulatory Impact Analysis	Amendments to the Clean Air Act saved up to $2 trillion annually	Does Mongolia calculate and report economic losses and labor productivity reductions due to air pollution? Are household and individual costs considered?
4	Environmental justice assessment	- Exposure of poor and minority populations to pollution - Health inequities mapped geographically	EPA EJScreen, HIA tools	Peripheral neighborhoods showed 2–3 times higher illness rates	Are risk assessments conducted for vulnerable areas to ensure environmental justice? Are maps showing the distribution of vulnerable populations available?
5	Temporal trends – policy update linkage	- Policy implementation timeline - Causal inference models (e.g., Time-series, SCM)	Harvard Chan School, CDC BRFSS	PM2.5 reductions linked to an average 1.6-year increase in life expectancy in cities (Pope et al., 2009)	Does Mongolia analyze the temporal connection between air quality policies and health outcomes? Are scientifically validated models used to assess policy impact? Is the information publicly available?

5.2. Conclusions from the U.S. Case Study

The U.S. experience in air quality management shows that a science-based, participatory system implements policies that are directly linked to measurable human health outcomes.

For Mongolia, a science-based, multi-stakeholder, integrated evaluation system with transparency is essential. Adopting international best practices at the research level and tailoring policies to Mongolia's context, while strengthening the capacity to scientifically assess implementation, will provide the foundation for future policy success.

Air pollution is not merely a technological issue; it is a socio-economic and health crisis rooted in deficiencies in policy, enforcement, accountability, and participation. Experience from developed countries such as the U.S. demonstrates that sustainable reductions in air pollution are achievable when these challenges are addressed collectively through:

- centralized planning combined with local implementation,
- public–private partnerships,
- health risk assessment, and
- a PDCA (Plan–Do–Check–Act) system for monitoring, evaluation, and improvement.

Using a design approach, national legal frameworks can be modeled, and process designs can be created at the state and city levels. These can then be expanded into process diagrams that define stepwise actions, responsible and participating institutions, assigned duties, accountability, and coordination mechanisms.

The U.S. model is based on key principles that produced measurable results:

- National standards (NAAQS), state implementation plans (SIP), technological controls (BACT/MACT), performance standards for new energy production and pollution sources (NSPS), hazardous air pollutant standards (NESHAP), and detailed monitoring of chemicals, plants, factories, and sectors; all implemented with integrated macro–micro–mini level PDCA systems.
- Legal frameworks for public–private partnerships that make private actors both standard implementers and innovation developers. This includes privatization and investment in electricity and heat generation, transmission, and distribution systems, promoting innovative technology adoption and market-based competition to reach consumers.
- Policies and laws developed based on public health impacts (e.g., as shown in Los Angeles, Chicago, and Cincinnati case studies).

A comprehensive and sustainable solution for reducing air pollution requires collaboration not only among environmental agencies but also among multi-functional, multi-accountable institutions. These institutions can include—but are not limited to—the following sectors: environmental regulation, law enforcement, inspection agencies, standardization and licensing bodies, health, education, finance, local governance, civil society, and private sector stakeholders. This preliminary list is based on international best practices, and each policy area should be further studied to identify all relevant stakeholders fully.

5. Conclusion

5.1. Conclusions from International Comparative Experience

Globally, efforts to combat air pollution demonstrate that integrated policies—featuring coal phase-out, transition to clean technologies, comprehensive legal reforms, intersectoral coordination, and strict enforcement—are most effective. These policies not only address environmental concerns but also encompass economic, health, and technological development. Key lessons include:

- Policies phasing out coal represent the most effective step for reducing air pollution. The international trend shows a strong shift from traditional fuels such as coal and wood toward electricity, renewable energy, and low-emission technologies.
- Effective policy implementation requires comprehensive legal reform, including the development of standards, enforcement mechanisms, and information systems. This involves establishing emission limits, legally addressing high-risk sources, and requiring third-party product verification.
- Targeted, strict policies addressing major air pollutant sectors (transportation, energy, industry, household use) are widely applied—for example, banning polluting stoves, requiring vehicle filtration, and creating systems to measure, openly report, and evaluate performance using public health and quality-of-life indicators.
- Experience from developed countries indicates that significant air quality improvements typically require 15–30 years of sustained implementation, broad institutional participation, and integrated coordination of law, technology, and planning.
- Reducing air pollution effectively requires not only environmental agencies but also law enforcement (courts, prosecutors, police), regulatory authorities (e.g., General Agency for Specialized Inspection), registration and standard agencies (e.g., Civil Registration, Standardization Bureau, licensing ministries), health, education, tax systems, local governments, civil society, and private sector participation. This highlights the importance of multi-institutional coordination and accountability mechanisms.

6. Recommendations

The U.S. and Chicago case studies indicate that reducing air pollution is not merely a technological issue; it is a complex matter closely linked to government policy, legal frameworks, multi-stakeholder participation, accountability mechanisms, and systemic integration.

6.1. Recommendations for Policy Formulation and Evaluation Principles

When developing detailed policy options based on the above recommendations, it is important to avoid temporary mechanisms such as ad-hoc committees. Instead, long-term decision-making should be emphasized through legislation, the appointment of permanent responsible institutions, and structured policy frameworks. Each suggested element should be analyzed in detail through dedicated research to inform the policy design.

Compared to international experience, Mongolian policies have historically been short-term and focused primarily on fuel and stove regulation, falling short of the comprehensive 50–100-year integrated approaches seen in other countries. Although policies for implementing mega-projects are commendable, centralizing decision-making and project management under government administration limits the use of market mechanisms and impedes private sector investment and market-based competition.

It is therefore recommended that policies adopt a long-term perspective, establish phased targets and evaluation criteria every 3–5 years, and include mechanisms to update policies based on progress or emerging challenges. This should involve:

- Leveraging expertise from professional agencies, researchers, and universities.
- Integrating efforts of international organizations and NGOs into a transparent system.
- Maintaining a continuous, publicly accessible information system.

Policy options should be developed by policy experts, who can select between enforcement-oriented, incentive-based, or hybrid approaches. Local authorities should implement flexible regulatory measures based on policy outcomes, and independent audits should verify implementation using reliable data.

Table 6-1. Key Recommendations for Policy Content

No.	Recommendation / Description
1	Clearly define roles, responsibilities, and accountability of stakeholders in the implementation system. Designate professional agencies as responsible bodies and establish independent oversight free from political influence.
2	Develop a management system based on the PDCA (Plan–Do–Check–Act) principle, with defined responsibilities and reporting systems for all stakeholders.
3	Conduct system simulations to estimate the impact of air pollution policies, considering technological investment, health improvements, energy costs, and environmental damage.
4	Map policy implementation processes, specifying stages, responsible agencies, human resources, legal frameworks, and stakeholder mechanisms.
5	Develop sector-specific evaluation checklists and indicator frameworks. Build models to assess combined socio-economic, health, and environmental impacts, to be applied at both national and local levels.

6.2. Recommendations for Policy Implementation

Table 6-2. Recommendations for Policy Implementation

No.	Recommendation / Description
1	Clearly define roles, responsibilities, and accountability of stakeholders. Assign professional agencies as responsible entities and ensure independent oversight.
2	Establish a PDCA-based management system with clear stakeholder duties and reporting structures.
3	Conduct system simulations to estimate policy impacts on technology investment, health improvement, energy costs, and environmental damage.
4	Visualize policy implementation as process maps showing stages, responsible institutions, human resources, legal regulations, and stakeholder mechanisms.
5	Develop sectoral evaluation checklists and indicator frameworks. Model combined socio-economic, health, and environmental effects for implementation at both government and local levels.

Table 6-3. Long-Term Policy Planning Model Example

Section	Summary

Scope, Duration, Goals	Ulaanbaatar and other major cities; 2025–2100 (75 years, 5 cycles); aim to drastically reduce air pollution.
Problem	Winter air quality exceeds WHO limits by 27 times; coal burning, heat loss, industrial and transportation emissions.
Impacts	Respiratory illnesses, mortality, school absenteeism, decreased productivity, rising health costs.
Targets	Reduce air pollution by 50% by 2040, 100% by 2070; increase district heating and electricity access; phase out coal; improve legal framework.
Solutions & Phases	Short-term (2025–2030): coal ban, transition to electricity and solar energy, public awareness campaigns. Medium-term (2030–2045): integrate into centralized systems, create coal-free cities, monitor emissions. Long-term (2045–2100): improve air quality, implement monitoring and legal regulations.
Evaluation Indicators (every 15 years)	2025–2030: reduce coal use by 30%; 2030–2045: 50% of ger districts connected to centralized heating; 2045–2060: 80% connected; 2060–2075: winter smoke reduced by 90%; 2075–2100: reduce pollution in small cities by 70%.
Organization	Legislation, multi-source financing, social participation, accountability, and technology utilization.
Learning from U.S. Experience	Legal frameworks, standards, PDCA management, pollutant standards, technology requirements, permitting systems, monitoring, and control technologies.
Technology & Measures	Install filters, build substations, create coal-free zones, use simulations.
Phased Implementation for Ulaanbaatar	2025–2027: data collection and zoning; 2028–2030: coal ban, start substations; 2031–2035: heat 50% of ger districts with decentralized solutions; 2036–2040: industrial filtration; from 2040: 100% smoke-free city with legal enforcement.

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