

INDEPENDENT EVIDENCE-BASED STUDY

Environmental Future of Kuzbass — Three Scenarios

Initial state, scenarios for 5, 15, 30 and 50 years, public health, water, land, waste, methane, cost of work and reproducible calculations

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AI participation is part of the Experiment project.

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Document principle. The article tells the story; the PDF provides the evidence needed to verify or challenge it. Published indicators, scenario assumptions and calculated results are indicated separately.

What's in this PDF

3

conditional scenarios without assigned probabilities

4

common time horizons: 5, 15, 30 and 50 years

106

entries in the indicator source register

4

machine-readable datasets, reproduced in full in the appendix

The main research question: which consequences already require action in any future of Kuzbass, and which depend on political, economic and environmental decisions in the coming years?

The document does not derive disease or death from the mass of waste. For health, the conditional PM_{2.5} model and its limitations are presented separately. Apanas is used as a specific documented example, and not as a characteristic of all objects in the region.

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From the author



Natalia Alexandrovna Zubkova.

For many years, I have spoken about the price people pay for coal. To me, the heat and energy it produces when burned do not justify what its extraction leaves behind: torn-up land, dust, burning waste heaps, problems with water, and fear for our health. Coal burns away, but the consequences remain for decades.

Now, amid an economic and political crisis, it is especially difficult to see how this coal story will end for Russia. And what will happen to the people who live in Kuzbass when

production falls, mines and other operations shut down, but the accumulated damage does not disappear.

My greatest concern is for the children: those growing up there now and those who have not yet been born. They did not choose this industry. They did not decide to extract and sell coal, and they did not profit from it. Yet they may inherit land that was reshaped for coal over many decades—and the task of dealing with what was left behind.

I want to understand how their lives will be affected by this era, when coal was mined in vast quantities and sold without including the consequences for local people in its price. What can still be changed? How much time and money will it take? And what will happen if everything is left as it is? That is why I consider three possible scenarios for the future of Kuzbass.

SECTION 1

Research Basis

Status: research basis for Natalia's authorial article. This is a scenario study, not a prediction of political events or an estimate for the recovery of an entire region.

Main conclusion

The future of Kuzbass depends not only on how much coal will be mined. Extraction determines how quickly new disturbed lands, rocks, drainage, dust and methane are added to the old legacy. But a significant part of the obligations already exists. In any scenario, you will have to figure out where the dangerous objects are, who is responsible for them, where the water is moving, where the gas is coming out, which waste heaps are heating up and which houses cannot be safely left nearby.

Therefore, stopping mining and ecological restoration are not the same thing. A closed mine may still require water and methane monitoring for decades. A waste heap does not disappear when an operation shuts down. Vegetation on the surface does not prove that the slope is stable, the fire has gone out, and the soil has restored its functions. Conversely, continued mining under strict controls may theoretically be accompanied by an environmental program, but it continues to add new sites and future obligations.

The three scenarios differ primarily in whether this legacy is managed and whether its physical volume continues to grow.

1. What do we consider the initial state

Waste: the flow is not equal to the stock

In 2025, Russia recorded 7.841 billion tonnes of waste generated under Form 2-TP (Waste). Kuzbass accounted for 2.189 billion tonnes, or about 27.9% of the Russian total. This is an annual flow, not the mass of all waste lying on the territory.

The Kuzbass series is 3.805 billion tonnes in 2021, 4.039 billion tonnes in 2022, 4.081 billion tonnes in 2023, 3.311 billion tonnes in 2024, and 2.189 billion tonnes in 2025. This decline cannot be entirely interpreted as a decrease in the physically transported rock mass. Following legislative changes, some overburden and host rock may no longer be reported as waste when it is used as specified in an approved project. A physical scenario therefore requires two series: waste statistics and separate mining data on the volume of rock moved.

For 2025, the regional report gives the following figures:

Operation	Volume, million tonnes	What does
Generated	2,189.063	waste recorded as generated during the reporting year
Processed	0.330	preliminary treatment; not the same as recovery or disposal
Recovered	338.032	use of waste to produce goods, perform work, provide services or generate energy, under the applicable accounting rules
Rendered harmless	0.132	reduction of hazardous properties; a separate operation from recovery
Placed	1,762.093	sent for storage or disposal at waste storage and disposal facilities
Including storage	1,694.353	storage pending subsequent recovery, treatment or disposal
Including disposal	67.740	isolation without intended further use

Waste recovery does not mean land reclamation, and the amount placed during one year is not the same as the accumulated stock.

At the beginning of 2024, the regional waste-management plan reported 27.556 billion tonnes of accumulated non-municipal waste. This is the total industrial stock, not a specified mass of coal waste only. A professional publication reports 27.5 billion tonnes of accumulated coal-mining waste at the end of 2024 and 3.2 billion tonnes generated during that year. These two rounded values are left provisional for now: the primary industry-by-territory table has not been found.

For 2024, the official regional document attributes 3.256 billion tonnes, or 98.3% of all waste generated in Kuzbass to mineral extraction. The category is broader than coal, but shows that the mass of the regional flow is determined by the mining industry.

Land: the direction is clear, the continuity of the series is broken

The 2024 report gives 96.471 thousand hectares of disturbed land at the beginning of the year. During the year, 4.768 thousand hectares were disturbed, 2.083 thousand hectares were reclaimed, the balance at the end of the year was 99.156 thousand hectares.

The 2025 report begins the following year with 120.280 thousand hectares. The difference between these consecutive official balances is 21.124 thousand hectares. The sections reviewed do not explain it. It cannot be argued that this entire area was physically disturbed between the two

dates: the reporting coverage, methodology, or previously unreported information may have changed. Until the discrepancy is explained, the stock figures cannot be treated as one continuous series.

Flows within each year are comparable. In 2025, 4.620 thousand hectares were disturbed, of which 4.015 thousand hectares were disturbed by mineral extraction; reclaimed 1.265 thousand hectares. The area newly disturbed was approximately 3.65 times larger than the area recorded as reclaimed. The balance at the end of the year is 123.634 thousand hectares.

The word “reclaimed” means the completion and acceptance of the intended work. It does not guarantee the return of previous soils, hydrology, biodiversity or the possibility of previous land use.

Air, dust and methane

In 2025, stationary sources in Kuzbass reported 1.427 million tonnes of recorded emissions. Coal mining enterprises accounted for 888.918 thousand tonnes, or 62.3%, including 52.270 thousand tonnes of solids. The mass of emissions from a facility is not equal to the concentration of PM_{2.5} or PM₁₀ at a particular home. Assessing living conditions requires a network of measurements, meteorology, dust chemistry and individual proximity to sources.

Reported methane emissions from all stationary sources were 796.914 thousand tonnes. The report connects the main part with coal mining, but the general series includes other sources. From 2014 to 2025, the indicator ranged from 754.278 to 1,086.561 thousand tonnes; in 2024, it was 901.320 thousand tonnes. This is a regional total, not a site-by-site model.

After a mine is closed, methane emissions usually decrease, but do not stop on the day of shutdown. The rate depends on residual gas content, permeability, sealing and flooding. Gas can escape through shafts, wells, cracks and communications. Therefore, before the shutdown, measurements and a gas control design are needed, and after it, monitoring according to the measured shutdown criteria is needed.

Water: large volumes do not reveal the fate of each river

In 2025, coal enterprises withdrew 382.736 million m³ of water, and 97.25% of the intake was from underground sources. Fresh water used was 86.846 million m³, waste water was discharged 329.401 million m³. 298.996 million m³ entered surface water bodies.

The direct table classifies 12.067 million m³ of surface discharge as polluted and 283.196 million m³ as adequately treated. In 2024, these figures were 13.988 and 267.829 million m³, respectively, with a total surface discharge of 285.723 million m³. Thus, the total volume has increased, and the volume counted as contaminated has decreased.

These categories do not show the mass of each substance, the change in flow of a particular river, or the cumulative effect of watershed restructuring. Water classified as “adequately treated” meets the established requirements at the control point, but does not automatically answer the question about the total load for a large volume of discharge.

Recirculation and sequential reuse of water in the coal industry amounted to 209.408 million m³ versus 207.873 million m³ in 2024. It cannot simply be subtracted from withdrawals or discharges without a complete water balance.

Enterprises: different registers count different units

On 2 October 2026 the regional ministry reported 150 operating coal enterprises: 38 mines, 55 open-pit mines and 57 processing plants and screening plants. In August 2025 the media, citing the ministry, reported on 15 temporarily suspended mining enterprises - 6 mines and 9 open-pit mines.

In an interview published in early 2025, the Siberian Department of Rostekhnadzor reported 275 hazardous production facilities in the coal industry. Of the 60 Class I coal-mine hazardous production facilities, 39 were operating, 11 were mothballed, 9 were undergoing closure, and 1 was under construction. The 210 Class II hazardous production facilities comprised 119 open-pit mines, 56 processing plants, and 35 tailings facilities and waste heaps. Status figures for open-pit mines and processing plants were reported only as a combined group.

These numbers do not automatically contradict each other: an enterprise, a licence, a subsoil plot, and a hazardous production facility are different units of account. But they do not yet provide a named picture for one date. For the closure scenario, you need a register “operating — temporarily suspended — mothballed — undergoing closure — closed” with a responsible person, drainage, degassing and financial support.

The Rosprirodnadzor review adds an important caveat. The 2015–2023 program provided for the closure of 22 mines in Prokopyevsk, Kiselevsk and Anzhero-Sudzhensk, but the very inclusion of a mine in the programme does not confirm the completion of all safe work. The agency reported that of more than 3.5 thousand hectares of land subject to reclamation, more than 1.9 thousand hectares were excluded from these obligations after the transfer of land to other persons without the obligation of reclamation or after changes in design decisions. The disappearance of an obligation from a document does not mean restoration of the territory.

Dumps: known cases are not a census

The regional cadastre contains 482 waste disposal sites of all types. This does not mean that there are 482 coal waste heaps or 482 burning sites. The Russian BAT directory lists 312 waste heaps containing overburden, coal-processing waste and host rock registered in GRRORO throughout the country; This is also not the number of physical dumps in Kuzbass.

The working register contains confirmed specific cases, including Apanas, individual objects of the Krasnobrodsky and Bachatsky branches, dump No. 2 of the Vakhrushevsky field, object “Mine No. 12” and others. The scientific study measured temperatures and gases in 15 wells on the dumps studied; temperatures at a depth of 0.5 m ranged from 35–433°C. This confirms the existence of dangerous hot spots and the need for instrumental diagnostics, but does not allow us to calculate the proportion of burning dumps in the entire region.

2. Three conditional future trajectories

Scenario A: will, independent control and money appear

The first step is not to cover sites indiscriminately with soil, but to conduct an inventory. For each object, geometry, temperature, gases, water, stability, proximity to housing, owner, obligations and intervention history are recorded. The data is published so that independent experts can verify the measurements.

The second is protecting people. Emergency zones are fenced off, drinking water sources are checked, and families are relocated from areas where it is technically and economically impossible to ensure safe living. Compensation should not depend on a person's ability to prove a chemical cause for a pre-existing illness.

The work then proceeds in order of risk: burning and unstable waste heaps; drainage and water treatment; methane; slope stability; creation of a root-supporting soil layer; vegetation; and long-term maintenance.

This scenario is compatible with two mining policies. With gradual reduction, the rate of adding new facilities decreases, but the challenges of safe closure increase. As mining continues, stringent requirements may reduce some of the impact per tonne of coal, but new volumes of rock, earth, and future closures continue to emerge. In both options, the program is considered to exist only when independent measurements, milestones, responsibilities, and funding are secured for maintenance after construction.

Scenario B: production falls sharply, while the legacy is not managed systematically

In the first years, explosions, coal transportation, operation of equipment and the formation of new dumps may decrease. This is a real improvement over current sources. But at the same time, operators may reduce road watering, drainage repairs, dewatering, cleaning, degassing, and slope inspections.

After the pumps stop, the mine workings are filled with water. This does not always lead to the same result. Flooding can reduce the availability of oxygen and, over time, reduce some of the reactions and the release of methane. But rising water can cause polluted overflow to the surface or movement into neighboring horizons and watercourses. The timing - from months to decades - depends on the connectivity of the workings, inflow and discharge marks.

Dust may decrease after work stops and the surface is secured with vegetation. It may persist or worsen locally if exposed surfaces remain dry, maintenance is interrupted, or collapses or burning inside the waste heap occur. It cannot be said in advance that all dumps will burn more intensely; it can be said that without monitoring, dangerous changes will be discovered later.

The main feature of scenario B is not the maximum flow of new harm, but the loss of controllability. Responsible companies disappear or become insolvent, data is lost, and costs are passed on to municipalities and the next generation.

Scenario C: production returns to a high level, while the old legacy remains

The documented benchmark is 2018: 255.3 million tonnes according to the regional source and 255.7 million tonnes according to the federal program. For comparison, the regional ministry reported 190.7 million tonnes in 2025. A return to the regional level of 2018 would mean an increase of about 64.6 million tonnes, or 33.9%.

It is impossible to mechanically multiply official waste by 1.339: the rules for accounting for rocks have changed, and the mining conditions of the sites are different. Therefore, only sensitivities with explicit assumptions are applied:

- with an assumed stripping ratio of 6.1–11.5 m³/t, additional production 64.6 million tonnes corresponds to approximately 0.39–0.74 billion m³ of additional stripping per year;
- a linear extension of the 2025 land-disturbance rate would give about 1.33 thousand hectares of additional disturbance per year, but the indicator applies to all mining and land development is non-linear;
- with a constant production structure, the conditional water intake would increase by approximately 126.7 million m³ per year, wastewater discharge - by 108.9 million m³;
- registered emissions from the coal industry would conventionally increase by approximately 294.2 thousand tonnes per year, including solid emissions by 17.3 thousand tonnes.

These are not forecasts. They show the order of sensitivity if the 2025 coefficients are held constant. Actual values depend on which mines and open-pit operations increase production, on depth, water inflow, methane content, overburden and treatment equipment.

Income growth does not guarantee recovery. This requires separate obligations, financial security, control over execution and the inadmissibility of transferring land to another person without the obligation to eliminate the harm.

3. Same horizons: 5, 15, 30 and 50 years

Horizon	A: managed recovery	B: decline without management	C: high production without sufficient work with the legacy
5 years	registry, protection of people, first dumps and water schemes; some of the current risks are reduced	fewer new emissions from work, but failures in drainage, cleaning and degassing are possible	new flows of rocks, water and emissions are growing rapidly; old objects remain
15 years	the first portfolio of major works has been completed; part of the land has stable cover; mine-water treatment and methane control continue on an ongoing basis	the consequences of flooding appear; some surfaces are overgrown, some dangerous objects are degrading	old and new legacies are being added up; future closing price increases

Horizon	A: managed recovery	B: decline without management	C: high production without sufficient work with the legacy
30 years	soil functions return in the best areas; part of the water and gas systems are still being serviced	some sites revegetate naturally, while others retain chronic water problems and no responsible operator	large areas remain in the early stages of recovery because new disturbances continue
50 years	the immediate hazard of most priority sites has been reduced, but recognized ongoing liabilities remain	some of the damage has become more difficult or impossible to completely eliminate; emergency expenses go to children	largest reserve of future obligations; late closure requires more money and time

People

In scenario A, the first criterion for success is not the number of trees planted, but reduced human contact with hazardous areas, clean water and the possibility of resettlement. In Scenario B, some of the current impact is reduced, but deterioration in service may create new localized threats. In Scenario C, jobs and incomes may temporarily stabilize, but the population continues to live alongside a growing legacy.

What can happen to health

Health does not change simultaneously with the production schedule. If the air becomes cleaner, the number of exacerbations of asthma and COPD and some cardiovascular events may begin to decrease in the coming days, months and years. Chronic diseases that have already arisen do not disappear. Changes in lung cancer risk occur much more slowly—usually over decades. For congenital malformations, exposures before conception and during critical weeks of pregnancy are important: changing conditions may affect the outcomes of subsequent pregnancies, but a robust conclusion requires a long-term registry of all outcomes, not just diagnoses, in live-born children.

Outcome	A: management and recovery	B: decline without legacy management	C: high production without sufficient work with the legacy	When to expect change
Heart attack, stroke and hypertension	With a proven reduction in PM2.5, smoke and dust, the risk of new events should decrease; aging may keep the absolute number of cases high	Fewer current emissions, but fires, dust, stress, unemployment and deterioration of care produce mixed results	If actual exposure remains or increases, risk remains or increases; percentage is not derived from tonnes of production	Acute events - days to months; sustainable shift - years

Outcome	A: management and recovery	B: decline without legacy management	C: high production without sufficient work with the legacy	When to expect change
Asthma and COPD	Fewer symptoms and exacerbations; with a long-term decrease in PM2.5 - fewer new cases. Already existing COPD remains	Industrial dust may be reduced, but abandoned surfaces and combustion remain a localized risk	New and old sources add up; occupational exposure of workers is taken into account separately	Symptoms - quickly; asthma - years; COPD - Years to Decades
Lung Cancer	Future risk decreases, but early years stats may not improve due to past dose, smoking and aging	Some future exposure fades, some may linger; leaving does not erase the previous dose	Continued exposure is added to the accumulated one; the effect may appear after the end of mining	Primarily 15–30 years and longer
Congenital malformations	Protection of both parents before conception and the woman during the critical weeks and a complete register of outcomes allows testing for changes in risk; the percentage has not yet been determined	Impacts can decrease and persist simultaneously; worsening diagnostics may mask cases	There is no reason to expect systemic decline without reducing impact; numerical prediction is not possible	From subsequent pregnancies; reliable trend - several years

In Kuzbass, for a real numerical forecast, the main connecting link is still missing - a continuous spatial series of population impact. The mass of emissions is not equal to PM2.5 at home, the volume of mine water is not equal to the dose of pollutant, and a tonne of waste does not turn into a percentage of disease.

Therefore, the quantitative part is constructed as conditional sensitivity. The WHO guideline HRAPIE-2 (2025) proposes risk functions for each 10 µg/m³ average annual PM2.5. If future measurements confirm a decrease in PM2.5 by 5 µg/m³, central functions correspond to a decrease **in new cases of a specific disease**: acute myocardial infarction - by approximately 5.9%, stroke - by 5.5%, hypertension - by 7.2%, COPD - on 7.9%, childhood asthma - on 13.6% and lung cancer - on 7.2%. When decreasing by 10 µg/m³, the central estimates are 11.5%, 10.7%, 13.8%, 15.3%, 25.4% and 13.8%, respectively.

Simply put, this is not a percentage reduction in all diseases and is not an already calculated result for the residents of Kuzbass. Each percentage refers only to new cases of the named diagnosis in a comparable age group for a given change in PM2.5. To obtain the number of cases for Kuzbass, we also need actual concentrations, the size and age of the population and the initial incidence according to the same definition.

This is not a promise for scenario A and not a forecast for the entire Kuzbass. We do not yet know whether such a concentration difference will be achieved, and for COPD the WHO function is proposed for the range of annual average PM_{2.5} 5–25 µg/m³. If local exposure is outside the range of the original studies, mechanical transfer is not acceptable. In scenario B, a single concentration difference cannot be assigned: the working equipment may disappear, but the local burning dump will remain. In scenario C, production growth is not equal to PM_{2.5} growth; The steps +5 and +10 µg/m³ show only the sensitivity that can be applied after measurements and a dispersion model.

The absolute number of cases is not currently calculated. It requires population age groups, underlying new cases by the same definition, actual exposure, and stable enrollment. Reductions in diagnoses due to people moving away, medical offices closing, or worsening detection cannot be passed off as an improvement in health. Smoking, occupation, length of service, poverty and access to treatment must be considered along with environmental exposure.

For water, the quantitative limit is even stricter. Without a specific substance, concentration in the consumer's water, duration and proportion of the population that actually drinks it, it is impossible to calculate the risk of disease from the total volume of discharge. For congenital malformations, we do not assign a percentage change: there is no suitable Kuzbass model of individual exposure during critical weeks of pregnancy. Detailed formulas, confidence intervals and a table of conditional cases are given in [16 HEALTH SCENARIO ANALYSIS.md](#) and [17 HEALTH CONDITIONAL CALCULATIONS.csv](#).

Water and river basins

Local effects can be associated with specific streams, rivers, wells and mine workings. Basin distribution requires flow, chemistry, sedimentation, and dilution data. The mere fact that a river flows into a larger river does not prove measurable harm far downstream. The global water effect cannot be deduced from this connection.

Soil and vegetation

Stopping immediate danger, technical reclamation and ecosystem restoration are three different results. It can take years to stabilize a slope. Creating a stable soil and vegetation cover can take years or decades. It is often impossible to restore the original ecosystem due to new topography, rocks, hydrology and loss of soil profile.

Climate

Methane and CO₂ have a global impact regardless of where they are released. But the mass of local dust cannot be combined with climate gases. Reduced production reduces the future flow of coal mine methane, but closed mines will require control for decades to come. Capturing and using gas is not possible everywhere; the decision is made on the flow, composition, stability and safety of a particular object.

4. Money and terms

Why there is no single honest total

The region does not have an open, complete register in which the volume, condition, responsibility and project of work would be known for each dump, mine, water system, dangerous slope and house. Multiplying 123.634 thousand hectares by one hectare price would create false precision. A quiet overgrown area, a burning dump, a mine with contaminated water and a house above the mined area have different cost items.

The estimate must therefore be built from the bottom up: inventory; protection of people; emergency sites; water; methane; land; and maintenance.

Verified landmarks

Work	Observed landmark	Limits of applicability
Apanas	at least 50.66 million rubles. under the contracts identified for 2020–2024	paid stages, not the full price of the object
Extinguishing the dump No. 13-bis of the Ayutinskaya mine	initial price 190.57 million rubles, 2021	one project, not a representative average
Extinguishing dump No. 1 of the same mine	about 509.43 million rubles, 2021	another object shows the spread of cost
Corporate reclamation program 500 ha	more than 3.2 billion rubles, 2021–2023; roughly 6.4 million rubles/ha	cost composition is not fully disclosed
Planned reclamation of more than 1,200 hectares	about 5 billion rubles. up to 2028 year; roughly 4.17 million rubles/ha	the company's plan, not the result of independent acceptance
Complex old dump 100 hectares	0.4–1.8 billion rubles. in 2026 scenario prices	author's model, not an estimate and not an average rate
Mine water, British experience	about £2.9 million in construction and £0.1 million per year for one future scheme, estimates 2020–2021 years	shows the structure of capital and fixed costs, not Russian price
British portfolio of water and monitoring	£203 million for 8 years: 82 schemes, 10 pumping stations, more than 700 points, contract 2026 year	cannot be divided only by the number of schemes and transferred at the rate
Eastern Germany, LMBV	about €12 billion from 1995 year; €1.44 billion for 2023–2027 years	multi-decade scale, but different coal, law and scope of work

Illustrative portfolio of the first five years

This is neither a proposal to “restore all of Kuzbass” nor a programme budget. This is a way to show the bottom order of only part of the work after inventory.

If the priority group includes 10 burning or dangerously heating dumps and 1,000 hectares of planned reclamation, then applying the observed Russian benchmarks directly gives:

- dumps: approximately 0.4–5.1 billion rubles. in mixed prices 2020–2021;
- land: approximately 4.2–6.4 billion rubles. in mixed prices 2021–2024;
- together: 4.6–11.5 billion rubles. before adjustment to a common price year.

This amount **does not include** inventory, design of all facilities, resettlement, mine water, methane, roads, land purchase, reserve of unforeseen works, independent control and subsequent maintenance. It shows why even a limited portfolio quickly reaches billions of rubles and why a false “total price” without a register is dangerous.

For the water part, it is more correct to keep separate currency and experience for now. Conditional 10 schemes according to the old British average would mean about £29 million in construction and £5 million in operation in the first five years after commissioning, but such a calculation is not the price for Kuzbass: geology, water quality, standards, labor and equipment differ. Its function is to show that the construction creates a permanent expense item.

When can you see the result

- 0–1 year: emergency access restrictions, temporary water supply, continuous measurements at the most dangerous sites;
- 1–2 years: priority register, hydrogeological and gas models, resettlement and first works projects;
- 2–5 years: noticeable reduction in immediate danger in the first group of dumps, launch of the first water and methane systems, resettlement from part of the zones;
- 5–15 years: the first full cycle of major works, stable vegetation cover on some areas;
- 15–50 years: water and gas maintenance, slope testing, re-interventions, soil and ecosystem development;
- for more than 50 years or indefinitely: separate water schemes, drawdowns and gas risks, if measurements do not allow it to safely stop monitoring.

5. Quantitative stress test of the scenarios

After preparing the initial balance, a separate piecewise linear model was built for 5, 15, 30 and 50 years. It does not extend the 2025 figure in a straight line: A assumes a controlled reduction in production, B - a stop for 5–10 years, C — reaching 230–255.3 million tonnes per year and maintaining this level as a stress test.

Main order of results:

Scenario	In 15 years	In 50 years
A	23–41 billion tonnes of new waste equivalent; 35–70 thousand hectares of work; remainder of disturbed lands 95–143 thousand hectares	34–85 billion tonnes of new flow; with a long-term program 120–180 thousand hectares of work; arithmetic remainder of disturbed lands 5–117 thousand hectares, not equal to the area of the unrestored ecosystem
B	new flow has almost stopped: total 5.5–9.3 billion tonnes; however, 30–179 million m ³ of mine water per year may require monitoring	the new flow is not growing, but 15–90 million m ³ of water per year and 0.005–0.12 million tonnes of CH ₄ per year may persist
C	38.5–59.1 billion tonnes of new waste equivalent; remainder of disturbed lands 171–195 thousand hectares	131–203 billion tonnes of new flow; 287–370 thousand hectares of disturbed lands; 20.5–25.1 billion m ³ of accumulated water intake by operating mining at 90–100% of the 2025 water-withdrawal intensity

The word “waste equivalent” is important here: the range is obtained from the ratio of accounted waste to production and is not an accurate physical forecast of stripping after changes in legislation. The “no decision” ranges are conditions for the execution of scenarios, and not an established property of each tonne.

The full table, annual loads, formulas, methane in CO₂ equivalent, water, dust and applicability limits are listed in [13 QUANTITATIVE SCENARIO MODEL.md](#). Inputs and results are stored in [14 SCENARIO INPUTS.csv](#) and [15 SCENARIO RESULTS.csv](#).

6. What remains unknown

1. The exact accumulated balance of coal waste as of the last date and its composition.
2. Physical volume of overburden and surrounding rocks after changes in legal accounting.
3. A complete inventory of coal dumps and the number of confirmed burning or self-heating objects.
4. Explanation of the gap 21.124 thousand hectares in the official number of disturbed lands.
5. A unified named register of operating, temporarily suspended, mothballed, closing and closed mines and open-pit mines.
6. Site-by-site balance of mine and quarry waters, connectivity of workings and timing of possible water rise.
7. Site-by-site methane emissions and degassing status after closure.
8. Continuous map of PM_{2.5}/PM₁₀ and dust composition in human habitation areas.
9. Number of homes and families for which on-site protection is not possible.

10. Financial security for existing obligations and the procedure for liability in the event of bankruptcy or change of owner.

These gaps are not a reason to do nothing. They define the content of the first stage of scenario A.

7. What actions are needed in any scenario?

Regardless of the price of coal and the political trajectory, it is necessary to:

1. create an open object-by-object register;
2. protect residents in areas of immediate danger;
3. do not stop drainage and degassing without a transition period project;
4. measure water, gas, temperature and stability, and do not replace measurements with a report on work performed;
5. secure money and a person responsible for the entire life cycle of the object;
6. store original data for decades;
7. distinguish between the completion of construction, the cessation of danger and the restoration of the ecosystem.

Major policy choices influence the size of the future legacy and the rate at which it diminishes. But having to deal with pre-existing harm is no longer a choice.

8. Navigating the Evidence Appendix

- definitions of indicators: [01_INDICATOR_DICTIONARY.md](#);
- table of initial values: [02_BASELINE_LEDGER.csv](#);
- sources: [03_SOURCE_REGISTRY.md](#);
- accounting gaps: [04_GAPS.md](#);
- scenario logic: [05_SCENARIO_FRAMEWORK.md](#);
- brief established results: [06_INITIAL_FINDINGS.md](#);
- cost and timing: [07_COST_AND_TIME_MODEL.md](#);
- detailed matrix 5/15/30/50 years: [08_SCENARIO_MATRIX.md](#);
- reproducible calculations: [09_CALCULATIONS.md](#);
- confirmed specific dumps: [10_KNOWN_DUMPS_REGISTER.md](#).
- quantitative model: [13_QUANTITATIVE_SCENARIO_MODEL.md](#);
- parameters and assumptions: [14_SCENARIO_INPUTS.csv](#);
- results for 12 combinations of scenario and horizon: [15_SCENARIO_RESULTS.csv](#);

- full health module and article-ready comparative table: [16 HEALTH SCENARIO ANALYSIS.md](#);
- machine-readable conditional calculations PM2.5: [17 HEALTH CONDITIONAL CALCULATIONS.csv](#).

SECTION 2

Dictionary of Indicators

Waste

Generated during the year

Flow of waste generated by reporting business entities for the calendar year in the form 2-TP (waste). It is not the mass of all materials physically moved during mining, nor is it the accumulated residue.

Treated

Waste that has undergone preliminary preparation for subsequent recovery, treatment, disposal or transport. Processing in itself does not mean returning the material to economic circulation.

Recovered

Waste used for the production of products, performance of work, provision of services, including reuse for its intended purpose. The value cannot automatically be equated with environmentally sound restoration of the area.

Rendered harmless

A mass of waste whose hazards have been reduced by physical, chemical or biological methods. This is not the same as recovery or disposal.

Placed

The amount of waste sent for storage and disposal at waste disposal sites for the period. Not equal to the accumulated mass at the end of the year.

Storage

Storage of waste for a period of more than eleven months for subsequent disposal, neutralization or burial.

Disposal

Isolation of waste that is not subject to further disposal in special storage facilities to prevent harmful substances from entering the environment.

Accumulated at the beginning or end of the year

Stock of waste held by reporting entities and at waste storage and disposal facilities as of a certain date. To check the balance we need waste received, generated, treated, recovered, rendered harmless, transferred, received from other entities, and placed. You cannot obtain savings by simply adding up the annual amounts generated.

Overburden and host rocks

Rock mass removed to access a mineral or accompanying mining. Legal status depends on the terms of use and applicable regulations. After changes in legislation, some of these rocks used in approved projects may not be reported as waste. Therefore, the time series 2-TP (waste) after 2023 has a break in comparability.

Coal-processing waste

Materials remaining after separation of the mined rock mass and production of coal concentrate. Their properties and placement methods differ from overburden; You cannot combine categories without decoding.

Facilities

Waste disposal facility

Legal and statistical category, including specially equipped facilities for storing or disposing of waste. An entry in the regional cadastre does not prove that the site is a coal dump, is currently operating, or is burning.

Rock dump

Technogenic accumulation of rocks and other materials formed during mining or processing. Scenarios require separate inventory of geometry, composition, temperature, gases, stability, water, and proximity to people.

Burning or self-heating object

An object in which combustion or self-heating is confirmed by inspection, temperature measurements, gas control, thermal photography, inspection report or other verifiable document. Visual smoke or affiliation with the coal industry alone does not provide a complete inventory of burning objects.

Land

Disturbed during the year

The area of land that has lost its economic or environmental value as a result of activities during the reporting year. This is an annual flow.

Disturbed lands at the beginning/end of the year

The area of previously disturbed and not yet deregistered as reclaimed lands as of a certain date. This is the accumulated stock, not the area newly disturbed during the year.

Reclaimed during the year

The area on which the complex of works provided for by the project has been completed and which has been accepted in the prescribed manner. The indicator does not demonstrate restoration of the original ecosystem, soil functions or biodiversity.

Air and climate

Emissions from stationary sources

Mass of pollutants reported by reporting stationary sources. This is not the concentration in the air of a populated area and not the individual dose of a person.

Methane from stationary sources

Accounted mass of methane from stationary sources. In Kuzbass, the main part is related to coal mining, but the indicator also includes other sources. For climate comparisons, CH₄ mass must be separately converted to CO₂ equivalent with an explicit choice of time horizon and coefficient.

Water

Water abstraction

Water withdrawn from surface and underground water bodies. Not equal to the use of fresh water due to losses, transfer and other elements of water balance.

Discharge of waste, transit and other waters

The total volume of water discharged into surface water bodies. It includes categories that vary in need and degree of purification.

Polluted wastewater

The sum of untreated and insufficiently treated water that requires treatment. A decrease in volume does not indicate restoration of the watercourse and may depend on production volumes, drainage, classification and reporting.

Mine and open-pit water

Groundwater and surface water entering mine workings and pumped out for safe work. After drainage stops, the water level can rise, changing the direction of underground flow, chemical composition and discharge points. The exact outcome depends on the geology, the connectivity of the workings, the composition of the rocks and the quality of closure management.

SECTION 3

Quantitative Model

Status: addition to the study. All numbers below are conditional ranges for explicitly specified trajectories. This is not a production forecast, a government estimate, or an estimate of the number of diseases.

1. How to read the model

The model starts counting after the base year 2025 and shows two different types of quantities:

- **annual load** - flow in the selected year: production, water, emissions, new land disturbance;
- **cumulative total** is the sum of flows from the beginning of the scenario to the horizon 5, 15, 30 or 50 years.

Fifty years is not obtained by simply multiplying the 2025 figure by 50. Each scenario has its own piecewise linear production trajectory. Between node years, production varies linearly.

Numbers are rounded to two or three significant figures. The input parameters are in [14 SCENARIO INPUTS.csv](#), the results are in [15 SCENARIO RESULTS.csv](#).

2. Conditional production trajectories

A - controlled reduction and environmental program

For the quantitative main version, the option of gradual production reduction was chosen. This does not mean that the program is not possible with continued production; this option will have a higher gross load and can be assessed between A and C.

Horizon	Annual production, million tonnes	Cumulative production, billion tonnes
5 years	150–180	0.852–0.927
15 years	80–140	2.002–2.527
30 years	20–80	2.752–4.177
50 years	0–30	2.952–5.277

B - a sharp reduction without systematic management of the legacy

The lower limit assumes a stop by the fifth year. Upper - residual 20 million tonnes in the fifth year and termination by the tenth.

Horizon	Annual production, million tonnes	Cumulative production, billion tonnes
5 years	0–20	0.477–0.527
15 years	0	0.477–0.577
30 years	0	0.477–0.577
50 years	0	0.477–0.577

C — return to high production without sufficient attention to the legacy

Over five years, production increases to 230–255.3 million tonnes and then conditionally remains in this range. A continuation of this level for 30–50 years is **a stress test** and not a statement of demand, inventory or policy.

Horizon	Annual production, million tonnes	Cumulative production, billion tonnes
5 years	230–255.3	1.052–1.115
15 years	230–255.3	3.352–3.668
30 years	230–255.3	6.802–7.498
50 years	230–255.3	11.402–12.604

If high production lasts only 15 years, C values after the 15th year cannot be used: a new closure trajectory will be required.

General formulas

For each linear segment of production:

coal per segment = (mining at the beginning + production at the end) / 2 × number of years .

Next:

- **new waste equivalent = accumulated production × 11.5–16.1 t/t ;**
- **new disturbance = accumulated production × 20.9–21.5 hectares per 1 million tonnes ;**
- **arithmetic balance of disturbed lands = 123.634 thousand hectares + newly disturbed land – completed reclamation ;** a separate artificial minimum is not introduced, and the resulting balance is not equated to the area of the ecologically restored territory;
- **methane of existing production = production × (0.796914 / 191.8) × estimated coal share × residual intensity ;**
- **CO₂ equivalent = methane × 29.8 ;**
- **water intake = production × 1.995 m³/t × change factor water intensity .**

For B, the flow of closed objects is added separately to the methane and water of the first years of production. For A it is added after being reduced by the estimated effects of capture, oxidation, purification and controlled flooding. This does not allow one to “write off” the heritage by reducing production.

3. Comparative quantitative total

The values for waste, land, methane and water are conditional and have different limitations, explained after the table.

Scenario and horizon	New equivalent waste, billion tonnes	Of which without a confirmed solution on the horizon, billion tonnes	New land disturbance, thousand hectares	Reclamation work, thousand hectares	Estimated balance of disturbed land, thousand hectares	Methane, accumulated, million tonnes CH ₄	GWP100, million tonnes CO ₂ -eq.	Water intake by existing production, cumulative, billion m ³
A, 5 years	9.8–14.9	5.4–11.2	17.8–19.9	10–20	121–134	1.38–3.27	41–98	1.44–1.76
A, 15 years	23.0–40.7	9.2–26.4	41.8–54.3	35–70	95–143	2.67–10.32	80–307	2.94–4.47
A, 30 years	31.6–67.2	7.9–33.6	57.5–89.8	80–140	41–133	3.12–15.42	93–459	3.68–6.94
A, 50 years	33.9–85.0	5.1–29.7	61.7–113.5	120–180	5–117	3.19–18.61	95–555	3.82–8.36
B, 5 years	5.5–8.5	4.4–8.1	10.0–11.3	1.5–5	129–133	1.19–2.19	35–65	0.95–1.05
B, 15 years	5.5–9.3	4.4–8.8	10.0–12.4	2.5–10	124–134	2.14–7.18	64–214	0.95–1.15
B, 30 years	5.5–9.3	4.4–8.8	10.0–12.4	4–17.5	116–132	2.86–11.36	85–339	0.95–1.15
B, 50 years	5.5–9.3	4.4–8.8	10.0–12.4	6–27.5	106–130	3.15–14.55	94–434	0.95–1.15

Scenario and horizon	New equivalent waste, billion tonnes	Of which without a confirmed solution on the horizon, billion tonnes	New land disturbance, thousand hectares	Reclamation work, thousand hectares	Estimated balance of disturbed land, thousand hectares	Methane, accumulated, million tonnes CH ₄	GWP100, million tonnes CO ₂ -eq.	Water intake by existing production, cumulative, billion m ³
C, 5 years	12.1–18.0	9.7–17.1	22.0–24.0	2.5–7.5	138–145	2.62–4.63	78–138	1.89–2.22
C, 15 years	38.5–59.1	30.8–56.1	70.1–78.9	7.5–22.5	171–195	8.36–15.24	249–454	6.02–7.32
C, 30 years	78.2–120.7	62.6–114.7	142.2–161.2	15–45	221–270	16.96–31.15	505–928	12.21–14.96
C, 50 years	131.1–202.9	104.9–192.8	238.3–271.0	25–75	287–370	28.42–52.37	847–1,561	20.47–25.14

The lower bound of 5 thousand hectares for A in 50 years is an arithmetic balance of the initial balance, a new disturbance and the accepted volume of work, and not a forecast of the area of a fully restored ecosystem. Remediation performed does not guarantee the return of the original soil, hydrology, biodiversity or previous use. Therefore, the fictitious “irreducible” balance is not added to the balance, but its environmental meaning is limited separately.

4. Waste

Initial data

- in 2025: 2.189 billion tonnes of recorded waste and 190.7–191.8 million tonnes of coal;
- simple ratio: about 11.5 tonnes of accounted waste per tonne of coal;
- a professional source for 2024: about 16.1 tonnes of coal mining waste per tonne of coal.

Range **11.5–16.1 t/t** used only as “current accounting equivalent.” This is not a universal physical factor: the lower numerator contains other industries, the upper is based on a rounded secondary value, and the rules for overburden classification have changed.

Formula:

accumulated production × 11.5–16.1 = new waste equivalent .

What does “without a confirmed solution” mean?

In 2025, 15.4% of generated waste was recycled or neutralized. It does not follow from this that the remaining 84.6% are placed dangerously: placement may be by design, and disposal does not guarantee restoration of the ecosystem.

For the model it is accepted:

- B and C: 80–95% of the new flow to the horizon remains without confirmed disposal, neutralization or final safe closure;
- A: The residual share decreases from 55–75% after 5 years to 15–35% after 50 years. The reduction involves working with old volumes, so the lower balance after 50 years may be less than after 30 years.

This is **the target execution range of the program**, not a statistical prediction. The tonnage of the existing 27.556 billion tonnes of accumulated non-MSW has not been added to the new flow because the composition and safe use of each portion are unknown. It is more rational to stabilize many dumps in place than to physically move them and declare them “disappeared” by weight.

Annual flow at the selected horizon

Horizon	A, billion tonnes/year	B, billion tonnes/year	C, billion tonnes/year
5 years	1.73–2.90	0–0.32	2.65–4.11
15 years	0.92–2.25	0	2.65–4.11
30 years	0.23–1.29	0	2.65–4.11
50 years	0–0.48	0	2.65–4.11

In B the new flow almost stops, but the old stock remains. At A, the flow is reduced and at the same time the unresolved remainder is reduced. Under scenario C, an amount on the same order as the region's current annual recorded waste total is added each year.

5. Disturbed and restored lands

Coefficient of new disturbance

- 2024: 4.264 thousand hectares during mining and 198.4 million tonnes of coal - 21.5 hectares per 1 million tonnes;
- 2025: 4.015 thousand hectares and 191.8 million tonnes - 20.9 hectares per 1 million tonnes.

The model uses **20.9–21.5 hectares per 1 million tonnes of coal**. This is sensitivity: area refers to the entire mining operation, and land development occurs in uneven stages.

Pace of work

In A, 10–20 thousand hectares of technical and biological reclamation are expected in the first five years, 35–70 thousand hectares by the 15th year, 80–140 thousand hectares by the 30th year and 120–180 thousand hectares by the 50th year. The first stage requires 2–4 thousand hectares per year - approximately 1.6–3.2 times more than the official 1.265 thousand hectares in 2025.

Only individual projects and emergency work remain in B: 6–27.5 thousand hectares in 50 years. Self-overgrowth is not included in this area: a green surface does not prove engineering safety and soil restoration.

In scenario C, 0.5–1.5 thousand hectares of work per year are assumed - around the current lower level with significantly higher production. After 50 years, the estimated stock of disturbed lands reaches approximately 287–370 thousand hectares, compared to 123.634 thousand hectares at the end of 2025.

What cannot be deduced from hectares

The model does not claim that every reclaimed hectare has become forest or agricultural land of the same quality. This requires separate indicators: slope stability, thickness and composition of the root layer, erosion, water, vegetation and further use.

6. Methane and climate effect

Base and uncertainty

In 2025, all stationary sources of Kuzbass produced 0.796914 million tonnes of CH₄. The report says that methane is mainly associated with coal mining, but does not give an exact share.

Therefore, the model tests a wide conditional range: **60–100%** of regional methane emissions are associated with the coal system. The lower bound is a sensitivity assumption, not a specified proportion.

For conversion, the model uses the IPCC GWP100 factor for fossil methane: 29.8 according to the IPCC is used:

1 t CH₄ = 29.8 t CO₂ eq. on the horizon 100 years .

This is not a CO₂ mass or a temperature forecast. For a 20-year horizon, the IPCC gives a higher coefficient of 82.5, so GWP100 shows a weaker indication of the near-term climate effect.

In the table, the accumulated emissions from different years are simply summed up and multiplied by GWP100, as in accounting sensitivity. This result does not reproduce the actual time trajectory of concentrations and warming: a tonne of methane in the first and fiftieth year has an impact in different calendar periods.

Scenario Assumptions

- A: As production is measured, degassed, captured and reduced, 65–85% of the original intensity remains in the first 5 years, 40–70% in the next decade, 20–50% in the 15–30 year period, and 10–35% in the 30–50 year period. Residual methane from abandoned mines is expected to be 50–90% lower than the unmanaged option through capture, oxidation, or controlled flooding.
- B: after closure, new operational emissions disappear, but methane from old mines continues. The average residual emission is assumed to be 20–60% of the original coal fraction in years 5–15, 10–35% in years 15–30, and 3–20% in years 30–50.
- C: Intensity remains around 2025 levels and production increases. Cumulative range - stress test without degassing improvement.

UNECE and EPA confirm the direction - a rapid initial decline with a long tail, dependence on flooding and sealing - but do not provide a coefficient for specific Kuzbass mines. Therefore, range B is especially wide.

Annual emissions on the horizon

Horizon	A, million tonnes CH ₄ /year	B, million tonnes CH ₄ /year	B, million tonnes CH ₄ /year
5 years	approximately 0.24–0.64 plus the first closed facilities	approximately 0.08–0.48	0.57–1.06
15 years	0.08–0.41 plus 0.01–0.16 legacy	0.05–0.32	0.57–1.06
30 years	0.01–0.17 plus up to 0.08 legacy	0.01–0.20	0.57–1.06
50 years	0–0.04 plus up to 0.06 legacy	0.005–0.12	0.57–1.06

The main difference between A and B is not that gas exists only when inactive. It exists in both cases. In A it is measured and part is captured or destroyed; in B, a wide range escapes into the atmosphere and can migrate to buildings.

7. Water

Active production

Coefficients for 2025:

- intake - 1.995 m³ per tonne of coal;
- total wastewater discharge - 1.717 m³/t;
- discharge into surface waters - 1.559 m³/t.

These are not physical constants. Water inflow depends on depth, geology, precipitation, connectivity of workings and stage of development.

In A, a gradual decrease in water intensity relative to 2025 is assumed: by 5–15% in the first five years, by 15–35% in the next decade, by 25–50% in the period 15–30 years and by 35–65% in the period 30–50 years. Therefore, the accumulated withdrawal from existing production is estimated at 1.44–1.76 billion m³ after 5 years and 3.82–8.36 billion m³ after 50 years.

In the case of maintaining the water intensity of 2025 or improving it by no more than 10%, the accumulated withdrawal reaches 20.47–25.14 billion m³ in 50 years. The lower limit includes a coefficient of 0.90, the upper - 1.00. This is circulation through systems, and not irreversible consumption of the entire mass.

Stop and mine water

In B, active intake almost stops after the first five to ten years. But this does not mean zero water load. For the stress range, it is assumed that after shutdown, the volume of water requiring diversion, control or treatment is:

- after 5 years: 20–80% of the current surface discharge of the coal industry;
- in 15 years: 10–60%;
- in 30 years: 5–40%;
- in 50 years: 5–30%.

With a current base of 298.996 million m³, this is approximately:

Horizon	Possible annual volume of legacy mine and open-pit water, million m ³
5 years	60–239
15 years	30–179
30 years	15–120
50 years	15–90

This is not a forecast of contaminated discharge. Some of the water may be clean, some may require purification; some may accumulate underground until the unloading mark is reached. The lower and upper bounds are needed to show the cost of not having a hydrogeological model.

Comparison of annual load

Horizon	A: existing production + serviced legacy, million m ³ /year	B: residual production + legacy, million m ³ /year	C: current production, million m ³ /year
5 years	approximately 224–373	60–280	no less than 413–509
15 years	approximately 108–343	30–179	no less than 413–509
30 years	approximately 34–204	15–120	no less than 413–509
50 years	approximately 10–110	15–90	no less than 413–509

In A, the upper limit may be temporarily higher than B, because the program does not stop draining without replacement and purifies water that, if not acted upon, could simply not be taken into account until overflow occurs. The volume of water managed does not equal the volume of environmental damage.

8. Dust, burning dumps and housing

Solid emissions from operating enterprises

In 2025, the coal industry reported 52.270 thousand tonnes of solid emissions. Conventional intensity is 0.273 kg per tonne of coal.

Horizon	A, thousand tonnes/year	B, thousand tonnes/year from operating enterprises	B, thousand tonnes/year
5 years	20–37 with a decrease in intensity by 25–50%	0–5.5	56–70
15 years	6.5–23	0	56–70
30 years	1–11	0	56–70
50 years	0–3.3	0	56–70

These are not the concentrations of PM_{2.5} and PM₁₀ in the population. After closure, some industrial dust sources disappear, but dust remains on open surfaces, roads and dumps, and these sources may be recorded differently or incompletely in regional enterprise totals.

Burning dumps

The number of objects in the region is unknown, so it is impossible to turn tonnes of rock into the number of fires. For quantitative management, a portfolio of the top ten most hazardous sites is proposed:

- A, 0–2 years: 10 out of 10 surveyed by drilling, thermal imaging, gases, water and stability;
- A, 5 years: engineering measures have been completed at 5–10 sites; all 10 are under continuous or seasonal control;
- A, 15 years: 8–10 are transferred from the active phase to the observation mode if measurements confirm a decrease in temperature and gases;
- A, 30–50 years: reheat control maintained; an object is not deregistered just because the surface is overgrown.

In B, the supply of fresh coal-containing mass after stopping decreases, which can reduce the number of new outbreaks. At the same time, loss of control, cracking, water and collapses can change the access of oxygen. The direction of change for each waste heap can be determined only by measurements.

In C, the volume of newly moved rock and the number of future service objects increases, but the probability of self-heating cannot be calculated without coal and sulfur content, temperature, geometry, compaction and air access.

Territories near housing

The draft federal report for 2024 provides a limited outline of gas-dynamic monitoring of closed mines: 58 residential properties in Kuzbass, of which 14 are in hazardous and 44 in endangered areas. This is not a census of all the houses near the mine or the number of families to relocate.

Therefore, the quantitative result for housing is formulated as a verification program:

- in A the first 58 already known objects are checked and decisions are received in the first 1–2 years; in parallel, a complete register of houses near dumps, sides, undermined areas and gas routes is being formed;
- in B the number of houses where the risk actually remains may not decrease even after stopping production, if there is no relocation, control of gas, water and subsidence;
- In C, new zones can be added to old ones, but their number cannot be obtained from production tonnage.

9. What will become better and worse

Scenario	Will it become better	Will it become worse or remain a risk	When
A	appears, the annual waste-equivalent flow by 30 years will be lower by about 40–90% relative to the 2025 value; solid emissions can be reduced to 1–11 thousand tonnes/year; 80–140 thousand hectares undergoing work	water and methane from closed mines require decades; full return of ecosystems is impossible on part of the area	immediate safety 1–5 years; earth 5–30; water and methane up to 50+
B	after 5–10 years new waste, new land disturbance and emissions from operating enterprises almost cease	4.4–8.8 billion tonnes of new flow of the first years remain without a confirmed solution; 15–90 million m ³ of water per year may require control even after 50 years; responsibility is lost	current emissions are falling rapidly; water and gas effects last for months to decades
C	employment and income are possible; technical improvement of individual enterprises is not excluded	over 50 years, approximately 131–203 billion tonnes of equivalent waste, 238–271 thousand hectares of new disturbance and 20.5–25.1 billion m ³ of water intake are added; the remainder of disturbed lands can reach 287–370 thousand hectares	a new flow begins immediately and accumulates throughout the entire period

10. What the numbers do not allow us to assert

- It is impossible to deduce the number of diseases or deaths from tonnes of waste, hectares or mass of emissions.
- The entire accumulated stock cannot be considered toxic to the same extent.
- It is impossible to call all disposed waste “abandoned” or “dangerously stored”.
- Every reclaimed hectare cannot be considered a restored ecosystem.
- All regional methane cannot be considered coal-fired; the share of 60–100% is sensitivity only.
- The entire volume of mine water cannot be considered contaminated.
- It is impossible to deduce the number of burning dumps from the volume of overburden.
- It is impossible to estimate the number of resettled families based on 58 monitoring sites.

11. Data that will most narrow the ranges

1. Industry series of the physical volume of overburden and its use after the law change.
2. Site-by-site composition and volume of accumulated waste.
3. Complete register of dumps with temperature, gases, area and housing.
4. List of mines with methane consumption before and after closure.
5. Hydrogeological models of connected groups of mines and points of future unloading.
6. Register of houses in dangerous, endangered and sanitary protection zones.
7. Independent verification of reclamation results after 5, 10 and 20 years.

Until this data becomes available, ranges are more honest than one precise number.

SECTION 4

Public Health

Status: scenario research module for a future original article. This is not a medical forecast of the number of cases or a conclusion about the cause of a particular person’s illness.

Short conclusion for the article

Health does not change simultaneously with the production schedule. If the air becomes cleaner, the number of exacerbations of asthma and COPD and some cardiovascular events may begin to decrease in the coming days, months and years. But chronic diseases that have already arisen do

not disappear, and changes in the risk of lung cancer become noticeable only over a long horizon. For congenital malformations, impacts before conception and during critical weeks of pregnancy are important: a potential change in outcomes may appear earlier than a change in cancer statistics, but for Kuzbass there is no data to assign a fair percentage to it.

Therefore, the three scenarios differ not only in future production volumes. They differ in whether PM_{2.5} and other pollutants will be measured where people live; will mine water be treated; whether personal and professional impacts will become known; whether medical care will continue; whether the system will record all pregnancy outcomes, and not just diagnoses in live-born children.

In scenario A, risk reduction becomes a verifiable goal. In scenario B, some of the current emissions from operating enterprises can quickly decrease, but uncontrolled dumps, fires, dust, mine water and the collapse of medical surveillance can hide or cancel out part of the gain. In scenario C, high production without sufficient work on the legacy maintains or increases the impact; Moreover, the percentage of future diseases cannot be obtained by multiplying today's incidence by production growth.

What is already known about Kuzbass - and what these data do not prove

- In Kiselevsk, there were no regular state network observations of air pollution during the period studied. One-time measurements in 2020 detected pollution, but do not restore the average annual PM_{2.5} for a particular home, much less the personal dose for previous years (SRC-KISELEVSK-AIR-CORPUS).
- A regional environmental report for 2007 reported that in 2003–2007, the newly identified incidence of diseases of the circulatory system doubled in adults, 1.7 times in adolescents, and 45.9% in children. This is a regional historical signal, not proof of the role of coal and not a source series for forecasting (SRC-KUZ-HEALTH-2007).
- The accessible municipal series of Kiselevsk covers all newly diagnosed malignant neoplasms, and not just lung cancer: 258.4 cases per 100 thousand inhabitants in 2007, 302.9 in 2020, 479.2 in 2023 and 440.8 in 2024. These are crude, non-age-standardised rates and depend on detection; they cannot calibrate a lung cancer model (SRC-KISELEVSK-CANCER-2025).
- Kuzbass studies of congenital malformations contain territorial signals, data on registered diagnoses, prenatal detection and genetic vulnerability. They do not combine in one sample the source, the personal dose of both parents, the critical weeks of pregnancy and all pregnancy outcomes (SRC-KUZ-VPR-CORPUS).
- Regional volumes of emissions and wastewater describe the environmental load, but not the human dose. For water, you first need specific substances, concentrations in the drinking water supply, route of entry, duration and consumption. Without this, the mass or volume of

discharge cannot be translated into the number of diseases (SRC-WHO-DRINKING-WATER-2026).



Krasny Kuzbass mine field, 9 December 2018. An extended white cloud is visible above the dark areas of the snow-covered disturbed territory. Still frame from Natalia Zubkova's video; GPS: 54.0297° N, 86.5490° E. The composition of the cloud or its effect on health cannot be determined from the image.

Compact comparison chart

Outcome	A: management, control and financing	B: sharp decline in production without legacy management	B: high production, legacy without enough attention	When to look for change
Acute myocardial infarction, stroke and hypertension	With confirmed reductions in PM2.5, smoke and dust episodes, a reduction in new events is expected; relocation from the most dangerous areas enhances the effect. An aging population may keep the absolute number of cases high.	Emissions from operating factories and transport may decrease, but local fires, dust, stress, job loss and deterioration of care can have mixed results. A decrease in reported cases due to travel or unavailability of a physician is not an improvement.	If exposure continues or increases, the risk remains elevated or increases. The increase in production in itself does not determine the percentage of the disease: the actual concentration in the population is needed.	Exacerbations and part of the events - days to months; sustained change in morbidity and mortality—several years or more.
Asthma and COPD	Fewer dust and smoke episodes means fewer symptoms and flare-ups; reducing long-term PM2.5 may reduce new cases of childhood asthma and COPD. Once existing COPD does not go away.	Current production dust can decrease quickly, but without maintenance dry surfaces, combustion and dust remain; medical monitoring may deteriorate. The result depends on the specific settlement.	New and old sources add up; Workers separately retain professional exposure, which cannot be confused with citywide exposure.	Symptoms - days to months; new cases of asthma - years; COPD and changes in lung function—years to decades.

Outcome	A: management, control and financing	B: sharp decline in production without legacy management	B: high production, legacy without enough attention	When to look for change
Lung Cancer	Reducing PM2.5 and carcinogenic mixtures reduces future risk, but early years statistics may not improve due to long lag, past exposures, smoking and aging.	Closure reduces some of the future impact, but legacy and fires may keep it local. Departure changes the numerator and denominator, not the previous dose.	Continued exposure is added to the already accumulated dose. Even with subsequent improvement, excess cases may persist for decades.	Usually not the next few years; the main horizon is 15–30 years or longer.
Congenital malformations	Protection before conception and during the critical weeks, data from both parents and a complete outcome registry allows for earlier detection of changes in risk. The percentage for Kuzbass has not yet been calculated.	Reducing current emissions may reduce some of the impacts, but water, fires, dust and surveillance decay make the direction unclear. Fewer registered congenital malformations due to the departure of pregnant women or worsening diagnosis does not mean a lower risk.	If impacts persist, there is no reason to expect a systemic reduction in risk; Numerical prediction without dose and a suitable model is impossible.	Individual outcomes - from the next year after the change in exposure; A reliable trend is several years and generations of pregnancies.

How to read horizons of 5, 15, 30 and 50 years

After 5 years

- **A:** with a really confirmed decrease in concentrations, symptoms, visits, hospitalizations and some cardiovascular events should change first. In childhood asthma, the number of new cases may begin to change. For lung cancer, this is too short a period for the main effect.
- **B:** quick gains are possible from fewer explosions, transportation and operating equipment, but it will not be the same. Where dust suppression, fire control, drainage or medical monitoring cease, the recorded statistics may become either worse or artificially lower.
- **C:** Without improved control, exposure remains or increases, but increased waste mass does not translate into increased disease without an exposure model.

In 15 years

- **A:** A more sustained change in cardiovascular and respiratory risk can be expected if the reduction in PM2.5 is measured and not offset by smoking, aging and occupational exposure. Some of the lung cancer gains are starting to show up.

- **B:** The consequences of mine flooding, chronic water problems and the degradation of hazardous sites are becoming visible. The departure of young people changes the age structure of the remaining population.
- **C:** continuous exposure is added to the old one; distinguishing environmental contributions without individual data becomes even more difficult.

After 30 years,

- **A:** the cumulative gains in chronic disease and lung cancer should be most noticeable in people who have lived a significant portion of their lives after exposure has been reduced. Residual risks and consequences of the previous work remain.
- **B:** health reflects the mosaic of territories: somewhere, self-overgrowth and cessation of work have reduced dust, somewhere water, combustion and poverty have created a persistent risk. A simple regional average hides this difference.
- **C:** a new accumulated dose and a new generation of obligations are formed; diseases also depend on who left, who stayed and who worked in the industry.

In 50 years

- **A:** The gain is most fully evident in generations whose lives and pregnancies were spent with less exposure. But it remains conditional on long-term maintenance of water, methane and reclaimed facilities.
- **B:** Some sources weaken naturally, some become chronic. Poor recording can make damage statistically invisible.
- **C:** highest potential cumulative burden and longest tail of future consequences; the exact number of cases still requires data on concentrations, people and medicine.

Conditional quantitative model of PM_{2.5}

Why is this not a concentration forecast

In Kuzbass there is no continuous spatial series of PM_{2.5} that we found that would allow us to assign concentrations in the population to each scenario. Therefore, we do not claim that scenario A will reduce average annual PM_{2.5} by exactly 5 or 10 µg/m³, and scenario B will increase it by the same amount. We specify these changes as **sensitivity test steps**. Once measurements and a dispersion model are available, the conditional stage can be replaced by the actual stage.

Recognized risk functions

WHO in HRAPIE-2 (2025) recommends relative risk functions for every 10 µg/m³ of average annual PM_{2.5} for estimating morbidity. The table below shows the central estimates and 95% confidence intervals. Applicability is limited to the concentration ranges and ages of the original

studies.

Outcome	Age	RR by +10 µg/m³ PM2.5	Concentration range for which the WHO proposes the function
Childhood asthma, new cases	0–18 years	1.34 (1.10–1.63)	5–40 µg/m³
COPD, new cases	30 years and older	1.18 (1.13–1.23)	5–25 µg/m³
Acute myocardial infarction	30 years and older	1.13 (1.05–1.22)	5–65 µg/m³
Stroke	30 years and older	1.12 (1.05–1.20)	5–35 µg/m³
Hypertension	30 years and older	1.16 (1.05–1.30)	5–75 µg/m³
Lung cancer, new cases	30 years and older	1.16 (1.10–1.23)	5–45 µg/m³

Source: SRC-WHO-HRAPIE2-2025, Figure 5 and Section 3.1. For mortality, WHO separately provides RR per 10 µg/m³ PM2.5: diseases of the circulatory system 1.13; non-malignant respiratory diseases 1.14; COPD 1.14; cancer of the trachea, bronchi and lung 1.09. Mortality and morbidity rates should not be mixed.

Formula

For the selected outcome:

$$\beta = \ln(RR_{10}) / 10$$

As the concentration increases by ΔC :

$$\text{ratio of the new number of cases to the original} = \exp(\beta \times \Delta C) = RR_{10}^{(\Delta C/10)}$$

As the concentration decreases by ΔC , the conditional fraction averted is:

$$1 - \exp(-\beta \times \Delta C) = 1 - RR_{10}^{(-\Delta C/10)}$$

The formula assumes that the function applies to the original and new concentrations, the particle composition and other conditions are comparable, and the base rate refers to the same age group and outcome definition.

What would the steps of 5 and 10 µg/m³ mean?

Outcome	Decrease of 5 µg/m³: conditional change in new cases	Decrease of 10 µg/m³	Increase of 5 µg/m³	Increase by 10 µg/m³
Childhood asthma	–13.6%	–25.4%	+15.8%	+34.0%
COPD	–7.9%	–15.3%	+8.6%	+18.0%

Outcome	Decrease of 5 $\mu\text{g}/\text{m}^3$: conditional change in new cases	Decrease of 10 $\mu\text{g}/\text{m}^3$	Increase of 5 $\mu\text{g}/\text{m}^3$	Increase by 10 $\mu\text{g}/\text{m}^3$
Acute myocardial infarction	-5.9%	-11.5%	+6.3%	+13.0%
Stroke	-5.5%	-10.7%	+5.8%	+12.0%
Hypertension	-7.2%	-13.8%	+7.7%	+16.0%
Lung Cancer	-7.2%	-13.8%	+7.7%	+16.0%

Each line refers only to **new cases of the specified disease** in the corresponding age group. This is not the percentage reduction of all diseases, not the share of the entire population, and not the result already calculated for Kuzbass. For example, for 1,000 initial new cases of COPD in a matched population, a reduction in PM_{2.5} of 5 $\mu\text{g}/\text{m}^3$ corresponds to approximately 79 cases of COPD conditionally averted; at 10 $\mu\text{g}/\text{m}^3$ - 153. For lung cancer, the corresponding central estimates are about 72 and 138 per 1,000 initial new cases of lung cancer, but the manifestation is distributed over a long time horizon.

The 95% intervals of the function itself give a wide range. For a reduction of 10 $\mu\text{g}/\text{m}^3$, it is approximately 9.1–38.7% for childhood asthma, 11.5–18.7% for COPD, 4.8–18.0% for heart attack, 4.8–16.7% for stroke, 4.8–23.1% for hypertension, and 9.1–18.7% for lung cancer. For a conditional increase of 10 $\mu\text{g}/\text{m}^3$, the corresponding intervals are 10.0–63.0%, 13.0–23.0%, 5.0–22.0%, 5.0–20.0%, 5.0–30.0% and 10.0–23.0%. This is the statistical uncertainty of the published function, but does not include the additional uncertainty of the transfer to Kuzbass.

Full machine-readable calculations are in [17 HEALTH CONDITIONAL CALCULATIONS.csv](#).

How the model relates to the three scenarios

- **A:** Once the observation network is created, the actual reduction in annual average PM_{2.5} can be plugged into the formula. Before this, the table shows what magnitude of change in risk would correspond to a confirmed reduction of 5 or 10 $\mu\text{g}/\text{m}^3$. The program must separately measure short-term peaks: the annual average does not describe all exacerbations.
- **B:** one regional ΔC cannot be assigned. Reducing business operations can reduce background noise, and leaving a burning or dusty object behind can increase local exposure. A calculation is required for settlements and zones of influence.
- **C:** production growth is not equal to PM_{2.5} growth. Conditional **+5** and **+10** $\mu\text{g}/\text{m}^3$ shows health sensitivity, but can only become a scenario after emissions, dispersion and measurement models.

Water: direction can be described, number of cases - not yet

Scenario A reduces the risk only when the inventory leads to the protection of water intakes, chemical analysis, treatment and control of the result. In scenario B, the cessation of drainage may change the movement of mine water and create new discharge points; at the same time, stopping operations may reduce some of the current discharges. In scenario C, drainage and discharges remain the same or increase along with production if technology does not change.

None of these outputs provide a number of diseases. For quantitative assessment, you need at least: a specific pollutant; concentration before and after cleaning; the proportion of the population that actually drinks this water; consumption and duration; other routes of exposure; toxicological or epidemiological function; age and vulnerability. The World Health Organization bases its assessment of drinking water on the hazard and likelihood of exposure - concentration, duration and actual consumption - and not on the total volume of discharge.

Why registered cases can deceive

In each scenario, the following must be taken into account simultaneously:

1. **Age and gender.** Aging increases the absolute incidence of cardiovascular disease, COPD, and cancer, even as environmental risk decreases. It is necessary to compare age-standardized indicators and individual age groups.
2. **Migration.** The departure of young families can reduce the number of births and registered congenital malformations, and the departure of patients can reduce the number of observed cases. This is a change in population composition, not necessarily health.
3. **Smoking.** For lung cancer, COPD and cardiovascular diseases, smoking status and, if possible, cumulative consumption should be known. Smoking does not cancel the effect of air pollution, but without it it is impossible to correctly separate the contribution of factors.
4. **Profession.** Worker exposure to mine and coal dust differs from urban background exposure. You need your profession, experience, area, protective equipment and work history.
5. **Medicine.** Office closures, physician shortages, or worsening screening may reduce the number of diagnoses found when health remains the same or worse. Improved diagnostics may temporarily increase reported incidence.
6. **Social conditions.** Income, housing, heating, stress, nutrition, and access to medications may change at the same time as industry and influence the same outcomes.

Minimum data set for this forecast

- daily and annual PM_{2.5}, PM₁₀, NO₂, SO₂, ozone, benzo(a)pyrene and dust composition by populated areas;
- address residence history and, for employees, professional route;
- age, gender, smoking, profession, income and access to medical care;
- age-standardized new cases, hospitalizations and deaths by cardiovascular and respiratory diagnoses;
- separate oncological series for lung cancer, stage and morphology;
- register **of all** pregnancy outcomes: live birth, stillbirth, early loss, termination after prenatal diagnosis;
- information about both parents before conception and about the mother during the critical weeks of pregnancy;
- concentrations of specific substances in drinking water and actual population coverage;
- constant or documented changing diagnostic and recording system.

Without this, you can honestly describe the direction of risk and calculate conditional sensitivity. A change in the number of registered diagnoses cannot be passed off as a proven change in health.

Module sources

- SRC-WHO-HRAPIE2-2025 Module Sources - PM_{2.5} Concentration-Risk Functions and Temporal Outcome Types.
- SRC-WHO-DRINKING-WATER-2026 - Principle of chemical hazards in drinking water: substance, concentration, duration and actual exposure.
- SRC-KUZ-HEALTH-2007 - historical regional indicators of diseases of the circulatory system.
- SRC-KISELEVSK-CANCER-2025 - municipal crude indicators of all malignant neoplasms.
- SRC-KUZ-VPR-CORPUS - Kuzbass and international studies of VPR and their limitations.
- SRC-KISELEVSK-AIR-CORPUS — lack of a regular series and one-time air measurements in Kiselevsk.

SECTION 5

Money and Timing

Status: first evidentiary version. This is not an estimate of the entire Kuzbass.

Why it is not yet possible to name one total amount

For the regional estimate there is no complete open register of mines, open-pit mines, dumps, polluted waters, burning zones, unstable slopes, houses for relocation and legally enforceable obligations. It would be methodologically incorrect to multiply the area of disturbed land by one “price per hectare”: a quiet overgrown dump, a burning massif, a flooded mine and an area next to houses require different works.

Therefore, the calculation is built from the bottom up:

1. inventory and design;
2. protection of people and emergency work;
3. typical objects for individual classes;
4. annual maintenance of water, methane and monitoring;
5. long-term restoration of lands and ecosystems.



Natalya Zubkova on a rock dump near Apanas during the filming of the film “Black Snow”, 8 November 2020.
Archive of Natalia Zubkova.

Real landmarks

Object or program	Scope of work	Price and year	What can be used	What cannot be done
Apanas, Kuzbass	extinguishing fires, construction control, later engineering surveys	at least 50.66 million rubles. in contract prices for 2020–2024	the lower documented volume of actually paid stages of a specific complex object	be described as the full cost of closure, reclamation or damage
Dump No. 13-bis of the Ayutinskaya mine, Rostov region	implementation of a project to extinguish a burning rock dump	initial price 190.57 million rubles, 2021	order of cost of one extinguishing project	transfer the amount to any Kuzbass dump without area, volume and project
Dump No. 1 of the Ayutinskaya mine	extinguishing another burning dump	about 509.43 million rubles, 2021	shows the intra-site difference between two objects	considered as the average price of a dump

Object or program	Scope of work	Price and year	What can be used	What cannot be done
Program of Stroyservis JSC, Kuzbass, first stage	work announced by the company on 500 hectares	more than 3.2 billion rubles, 2021–2023; roughly 6.4 million rubles/ha	observed budget of a large corporate program	considered comparable to extinguishing or complete restoration of the ecosystem; the composition of costs is not fully disclosed
Program of Stroyservis JSC, second stage	reclamation plan for more than 1,200 hectares until 2028	about 5 billion rubles, announced in 2024; roughly 4.17 million rubles/ha	benchmark for large-scale planned reclamation	automatically apply to old ownerless and burning objects
Conditional complex old dump 100 hectares	safety, engineering work, root layer, vegetation, 20-year control	0.4–1.8 billion rubles. in prices of the 2026 scenario model; 4–18 million RUR/ha	transparent range to check the scale of a complex project	pass off as market estimate, average price or Apanas estimate
UK, future mine water schemes	average construction and operation of deferred projects according to Coal Authority	£2.9 million construction + £0.1 million/year, estimates 2020–2021	separation of capital and fixed operating prices	transfer UK value to Kuzbass at exchange rate
UK, mine water portfolio	operational support 82 schemes, 10 pumping stations and more than 700 monitoring points	£203 million for 8 years, contract 2026	shows that water requires continuous long-term management	divide the amount only by the number schemes: the contract includes different types of objects and data
Germany, LMBV	reorganization of the non-privatized heritage of the East German lignite industry	about €12 billion from 1995 year; €1.44 billion for 2023–2027 years	scale of the multi-decade state program	transfer the amount to Kuzbass: a different type of coal, law, territory and scope of work
UK, Mining Remediation Authority	reserve for mine water, safety, subsidence and other obligations	£1.709 billion reserve; £4.0604 billion of undiscounted future flows at 31.03.2025	the need to recognize future liabilities in advance	to consider the cost of only water or only dumps

Typical ranges for scenario A

All ranges below are an order of magnitude for portfolio planning, not a ready-made budget request.

1. Burning rock dump

- documented Russian extinguishing projects provide a broad guideline of approximately **40–510 million rubles. to the object** in 2020–2021 prices;
- the bottom point of Apanas refers to the completed stage, and not to the entire life cycle;
- a complex 100-hectare facility in a scenario model with land and 20-year support gives **0.4–1.8 billion rubles.** in 2026 prices.

Main price factors: volume and geometry, hearth depth, oxygen access, the need to move mass, water, slope stability, proximity to housing, the need for a new location, control of reheating.

2. Planned reclamation of disturbed land

- corporate programs of Kuzbass give a rough observed order **4.2–6.4 million rubles/ha** in mixed prices 2021–2024;
- the scenario model of a complex old dump gives **4–18 million rubles/ha** in 2026 prices;
- The first group refers to large company programs, the second includes more difficult engineering assumptions. They cannot be averaged.

3. Mine water

British experience shows two layers of costs:

- capital construction of a separate scheme on the order of several million pounds;
- operating costs on the order of hundreds of thousands of pounds per year for each scheme, sometimes for indefinite periods of time.

The Mining Remediation Authority's report calculates cash flows over 100 years, as some of the contaminated mine water does not see a time when cleanup can safely stop. This illustrates the time horizon, not a price for Kuzbass.

4. Methane

The cost has not yet been estimated at a general rate. First, for each closed shaft you need:

- measurement of gas flow and composition;
- forecast of decline, flooding and leaks;
- assessment of collection, use, flare or catalytic destruction;
- control of migration to buildings and communications.

UNECE emphasizes that emissions can continue for decades, and the suitability of the project depends on residual gas content, permeability, flooding and the ability to control air leakage.

The first five years of the program

For now, it is fair to set the regional amount as a portfolio formula:

Five years = inventory + protection of people + priority dumps + priority water schemes + methane + lands + exploitation and open data.

Minimum content of the program

Block	What must be paid in the first 5 years	When the first result is visible
Inventory	satellite and ground imaging, drilling, temperature and gases, hydrogeology, liability register, open database	1–2 years for priority register; updating constantly
People	inspection of houses and risk areas, temporary protection, property assessment, relocation where the risk cannot be reduced on site	immediately for emergency measures; 2–5 years for the resettlement program
Burning dumps	projects and work on the first group of sites, control of reheating	months to years to reduce immediate hazards; does not equal ecosystem restoration
Water	continuous monitoring of levels, temporary dewatering, treatment projects, first structures	1–5 years to prevent part of the discharges; operation can continue for decades
Methane	measurements before shutting down the mine, maintaining degassing, pilot projects for use or destruction	1–3 years at sites with sufficient and controlled flow
Land	slope stabilization, drainage, erosion control works, first stage of root layer and vegetation	reduction of dust and erosion possible for seasons; soil functions - decades

How to calculate a portfolio after inventory

An example of a form, not a selected budget:

$N1 \times \text{cost of extinguishing a simple or moderately complex waste heap}$

$+ N2 \times \text{price of heavy dump}$

$+ \text{hectares of planned reclamation} \times \text{corresponding rate}$

$+ N3 \times \text{construction of mine water schemes}$

$+ \text{annual operation of water-treatment and methane-control systems} \times 5 \text{ years}$

$+ \text{resettlement based on the number of homes and compensation standard}$

+ 15–25% uncertainty reserve at an early stage.

The reserve of 15–25% is still a scenario parameter and should be replaced by an accuracy class after pre-project surveys.

Result timeline

Result	Realistic horizon	Approval boundary
cessation of immediate danger at an individual site	months–5 years	possible after engineering work; reheating requires control
technical reclamation and sustainable vegetation cover	approximately 3–15 years	depends on substrate, water and care; green slope does not prove soil restoration
development of soil structure and functions	20–40 years or more	individual processes last 56–65 years; return of original soil is not guaranteed
mine water	from several years to constant operation	some systems require monitoring and treatment for decades or without a specific end date
methane of closed mines	sharp decline in the first years is possible, residual emissions - decades	trajectory depends on gas content, sealing and flooding

Next calculation step

For the publication assessment of the first five years, you need to select a transparent notional portfolio, for example:

- all confirmed housing properties;
- first 10 burning or self-heating objects at risk;
- first 5 mine water systems;
- first 2,000 hectares of disturbed lands;
- specific number of houses for relocation.

Before the appearance of the registry, the number of objects in such a portfolio will be the author's scenario, and not the established need of the region.

SECTION 6

Confirmed Dumps: Completeness Limit

This is a working list of specific objects from the already assembled corpus. **It is not a complete register of Kuzbass dumps** and does not allow us to name the share of burning objects.

Kuzbass

Object	What is confirmed	Confirmation period	What we don't know
Apanassky dump of the former Listvyansky open-pit mine	object published as a burning dump; state of emergency 2020; extinguishing, gas control, engineering surveys; repeating Landsat surface thermal anomaly; at least 50.66 million rubles. tracked public expenditures	2008–2025, distance series 2016–2025	modern internal geometry of the fire, full cost, final result and responsible person
Burning rock dumps of the Krasnobrod branch	combustion and emissions appeared in surveillance materials and the court case; incomplete elimination of violations	2016–2017	number and coordinates of all individual dumps, temperature, current state, cost
Burning rock dumps of the Bachatsky branch	are included in the same supervisory and judicial case	2016–2017	number of individual objects, current status and cost
Dump No. 2 of the Vakhrushevsky field of the Krasnobrodsky open-pit mine	filling 2012–2014, design volume about 50.1 million m ³ ; long-term thermometry; one well showed 60–79°C at 1.5 m and 67–76°C at 2.5 m	measurements described as 2016–2019; publication 2025	work contains internal period discrepancy; one measurement does not prove the combustion of the entire massif
Southern field of Mine No. 12 LLC	authorities reported on hot spots of self-heating, an extinguishing project, biological reclamation of 68 hectares and acceptance of plots	no later than 2016–2025	the hot spots, 68 hectares and two transferred plots cannot be proven to be combined into one object; no full cost
Internal floodplain dump of the Sibirginsky open-pit mine	the minister in 2021 named hotspots of self-heating and work on the project at the expense of the enterprise	2021	no open coordinates of hotbeds, temperatures, estimates, acts and modern results

2024 research sample

A study by Portola, Protasova and Seregina reports 15 wells on the studied Kuzbass dumps; at a depth of 0.5 m, temperatures of 35–433°C were measured and CH₄, CO, SO₂, H₂S and O₂ were monitored. This confirms the existence of high-temperature zones in the studied objects, but the number of wells cannot be converted into the number of burning dumps in the region.

Other numbers that cannot be replaced by the regional registry

- **482 objects** — the entire regional cadastre of waste storage and disposal facilities in Kuzbass, not only coal dumps and not only existing facilities.
- **312 objects** - dumps of overburden, waste and enclosing rocks from coal mining registered in the GRRO in Russia according to ITS 17-2024; this is not the number of physical dumps in Kuzbass.
- **6 lines of objects above** is the number of documented cases in our previous study, not an estimate of their total number.

What should the inventory of scenario A provide?

A separate card is required for each physical array:

1. constant identifier and coordinates;
2. boundary polygon and terrain model;
3. volume, age, filling method and composition;
4. owner, successor, land status and financial security;
5. depth temperature, gas composition and re-survey history;
6. slope stability, subsidence and erosion;
7. surface and ground water;
8. distance to housing, roads, communications and watercourses;
9. completed work, its cost and subsequent result;
10. risk category and date of next control.

Only after this can you answer how many dumps there are in the region, how many of them are burning, how many are potentially dangerous and how much money is required in the first place.

SECTION 7

Calculations and reproducibility

All calculations are separated from published original values. Rounding is performed only after calculation.

1. Share of Kuzbass in Russian waste, 2025

Initial values:

- Russia: 7.841 billion tonnes;
- Kuzbass: 2.189063297 billion tonnes.

Calculation:

$$2.189063297 / 7.841 \times 100 = 27.918\% .$$

Publication formulation: **about 27.9%, or almost 28%.**

2. Balance of disturbed lands, 2025

Initial values:

- beginning of the year: 120.280 thousand hectares;
- disturbed during the year: 4.620 thousand hectares;
- reclaimed: 1.265 thousand hectares;
- end of year: 123.634 thousand hectares.

Check:

$$120.280 + 4.620 - 1.265 = 123.635 \text{ thousand hectares} .$$

The official total differs by 0.001 thousand hectares, that is, 1 hectare, which can be explained by rounding of components.

Ratio of annual flows:

$$4.620 / 1.265 = 3.652 .$$

Publication formulation: **in 2025 the area of new disturbance was approximately 3.7 times larger than the area recorded as reclaimed.**

Net change in rounded flows:

$4.620 - 1.265 = 3.355$ thousand hectares .

Gap between two annual reports

- end of 2024 in the 2024 report: 99.156 thousand hectares;
- beginning of 2025 in the 2025 report: 120.280 thousand hectares.

$120.280 - 99.156 = 21.124$ thousand hectares .

This is a diagnostic difference between sources, and not an estimate of the area physically disturbed during the transition moment. Until the source explains the revision, the balances of the two years cannot be combined into one continuous series.

3. Coal-industry discharge categories, 2025

Baseline: 298.996 million m³ discharged into surface waters.

Published shares:

- contaminated: 4.04%;
- adequately treated: 94.72%;
- compliant without treatment: 1.24%.

Direct values of table 2.2:

- 12.067 million m³ polluted;
- 283.196 million m³ of adequately treated.

They are preferable to products of the total volume and rounded percentages. The remainder after subtraction is **$298.996 - 12.067 - 283.196 = 3.733$ million m³**; it is close but not identical to the product of the published 1.24% (3.708 million m³) due to rounding of fractions and possibly original components. Therefore, a separate volume for water classified as “compliant without treatment” is not published as an exact source value without a full line of the primary form.

4. The difference between the production of 2018 and 2025

For consistency, the regional series of the Ministry of Coal Industry is used:

- 2018: 255.3 million tonnes;
- 2025: 190.7 million tonnes

Absolute difference:

$255.3 - 190.7 = 64.6$ million t/year .

Relative difference to 2025:

$(255.3 / 190.7 - 1) \times 100 = 33.88\%$.

Publication formulation: **A return to 2018 levels would mean approximately 64.6 million tonnes, or 33.9%, more annual production relative to 2025.**

The federal source gives 255.7 million tonnes for 2018; when using it, the difference will be 65.0 million tonnes. Two versions cannot be mixed in one table without explanation.

5. Why it is impossible to proportionally predict officially recorded waste

Diagnostic relationships of general waste generation to coal mining:

Year	Regional waste	Coal mining	Simple relationship
2023	4.0807 billion tonnes	214.2 million tonnes	19.05 tonnes of recorded waste per 1 tonne of coal
2024	3.3110 billion tonnes	198.4 million tonnes	16.69 t/t
2025	2.1891 billion tonnes	190.7 million tonnes	11.48 t/t

The numerator includes not only the coal industry, but after 2023 year it is affected by the legal reclassification of overburden and host rocks. Therefore, these ratios cannot be used as a physical waste generation coefficient.

Even the narrower ratio for 2024—3.2 billion tonnes of coal waste to 198.4 million tonnes of coal, or about 16.13 t/t—is still based on a rounded secondary source.

6. Sensitivity of scenario C for overburden

In the previous scenario model, the range of stripping coefficient was used: 6.1–11.5 m³ per 1 tonne of coal. This is not the average value for the entire Kuzbass.

With 255.3 million tonnes of coal:

- $255.3 \times 6.1 = 1.557.33$ million m³ ;
- $255.3 \times 11.5 = 2.935.95$ million m³ .

An increase of 64.6 million tonnes relative to 2025 with the same conditional range:

- $64.6 \times 6.1 = 394.06$ million m³ ;
- $64.6 \times 11.5 = 742.90$ million m³ .

Acceptable formulation: **conditional sensitivity gives about 0.39–0.74 billion m³ of additional stripping per year relative to production in 2025, if the development structure and stripping ratio fall within the selected range.**

This is not a forecast of waste in tonnes. To convert volume into mass, the density of specific rocks is needed, and for statistical status, rules for their use and accounting are needed.

7. Sensitivity of scenario C for land

For an internally consistent calculation, the values of one report are taken:

- 4.015 thousand hectares disturbed during mining in 2025;
- 191.8 million tonnes of coal are indicated in the same report.

Conditional intensity:

$$4,015 \text{ ha} / 191.8 \text{ million t} = 20.933 \text{ hectares per 1 million tonnes of coal} .$$

At 255.3 million tonnes:

$$255.3 \times 20.933 = 5,344.3 \text{ ha/year} .$$

Conditional increase:

$$5,344.3 - 4,015 = 1,329.3 \text{ ha/year} .$$

Limitations: the land-disturbance indicator covers all mineral extraction, not just coal; land is disturbed in uneven stages and does not have to be linear in production. Therefore, the result is used only as the sensitivity of the upper scenario.

8. Sensitivity of scenario C for water and emissions

All coefficients below are derived from the 2025 environmental report data and applied to 255.3 million tonnes only assuming a constant production structure.

Water

- intake: $382.736 / 191.8 = 1.995$ m³/t ;
- conditional at 255.3 million tonnes: **509.4 million m³/year** ;
- conditional increase: **126.7 million m³/year** .

- total wastewater discharge: $329.401 / 191.8 = 1.717 \text{ m}^3/\text{t}$;
- conditional at 255.3 million tonnes: **438.3 million m³/year** ;
- conditional increase: **108.9 million m³/year** .

Boundary: water inflow depends on hydrogeology and development stage, so this is not a forecast.

Reported emissions from the coal industry

- all substances: $888.918 \text{ thousand t} / 191.8 \text{ million t} = 4.635 \text{ kg/t}$;
- conditional at 255.3 million tonnes: **1,183.1 thousand t/year** ;
- conditional increase: **294.2 thousand t/year** .
- solid substances: $52.270 \text{ thousand t} / 191.8 \text{ million t} = 0.273 \text{ kg/t}$;
- conditional at 255.3 million tonnes: **69.6 thousand t/year** ;
- conditional increase: **17.3 thousand t/year** .

Boundary: methane content of layers, depth, mining method, degassing, dust suppression and cleaning change intensity. The mass of solid emissions is not equal to the concentration of PM_{2.5} or PM₁₀ in the population.

9. What is allowed to be included in the article

Firmly:

- the scale of the difference in production between 2018 and 2025;
- official volume of waste, land, water and emissions for selected years;
- change in legal accounting of waste;
- inability to obtain a reliable regional price without inventory.

Only as conditional sensitivity:

- additional overburden;
- linear increase in disturbed land, water and emissions;
- portfolio expenses by number of typical objects.

10. Extended model 5/15/30/50 years

Piecewise linear production trajectories, ranges of new waste, land, water, methane and solid emissions are given separately:

- method and tables - [13 QUANTITATIVE SCENARIO MODEL.md](#) ;
- all parameters - [14 SCENARIO INPUTS.csv](#) ;
- final 12 lines - [15 SCENARIO RESULTS.csv](#) .

Such the separation prevents the published baseline values from being inadvertently mixed with the scenario assumptions we have chosen.

Correction of land and water balance

For scenario A after 50 years, the artificial residual land minimum does not apply:

$$123.634 + 61.7 - 180 = 5.334 \text{ thousand hectares} .$$

Publication lower limit is rounded to 5 thousand hectares. This is only an arithmetic remainder of the area, and not proof of complete restoration of the ecosystem.

For scenario C, the lower bound of cumulative water withdrawal includes the scenario-based 10% improvement in water intensity:

- 5 years: $1.052 \times 1.995 \times 0.90 = 1.889 \text{ billion m}^3$;
- 15 years: $3.352 \times 1.995 \times 0.90 = 6.019 \text{ billion m}^3$;
- 30 years: $6.802 \times 1.995 \times 0.90 = 12.212 \text{ billion m}^3$;
- 50 years: $11.402 \times 1.995 \times 0.90 = 20.474 \text{ billion m}^3$.

The upper bound uses a factor of 1.00 and remains accordingly 2.22; 7.32; 14.96 and 25.14 billion m³ after rounding.

SECTION 8

Major unknowns and accounting gaps

1. Accumulated waste stock

An official general indicator was found: at the beginning of 2024, in Kuzbass there were 27.556 billion tonnes of accumulated non-municipal waste. We need a primary official indicator at the end of the latest year, broken down at least by type of economic activity. A professional source

reports 27.5 billion tonnes of accumulated coal mining waste by the end of 2024, but the original table has not yet been found. Annual generation figures cannot be added together to reconstruct the stock.

2. Physical flow of overburden after changes in legislation

After 2023, some of the overburden and surrounding rock may not be reported as waste. For physical balance, indicators of the volume of overburden and the use of rocks from mining reports are needed, separately from 2-TP (waste).

3. Complete register of coal dumps

The number 482 from the regional cadastre applies to all waste disposal sites. No open register has yet been found that simultaneously shows for each coal dump:

- coordinates and boundaries;
- owner and liability status;
- active, closed or abandoned status;
- volume and composition;
- temperature, gases and combustion history;
- slope stability and water regime;
- proximity to housing;
- completed reclamation and subsequent monitoring.

4. Number of confirmed burning objects

There are documented cases and scientific sampling, but this is not a complete regional account. It is not possible to extrapolate the proportion of burning objects from the research sample to all dumps.

5. Operating, temporarily suspended, mothballed, closing and closed mines and open-pit mines

As of October 2, 2026, the regional ministry reported 38 operating mines and 55 open-pit mines. As of August 20, 2025, the same department reported through the media about the temporary suspension of 6 mines and 9 open-pit mines. These numbers cannot be mechanically added:

dates and statuses differ. We need a register for a single date with names and definitions of statuses. The number of legal entities, licenses, subsoil plots and production units are different indicators.

An interview with the Siberian Department of Rostekhnadzor, published at the beginning of 2025, partially fills the gap on industrially hazardous facilities: 39 operating coal-mine hazardous production facilities, 11 mothballed and 9 undergoing closure; For open-pit mining and processing, the status breakdown is given as a general group, and not separately by section. This is a useful snapshot, but a hazardous production facility is not the same as an enterprise, and “undergoing closure” does not mean “closed.” There is still no complete name register for one date.

The programme to close 22 mines in three cities also does not replace such a register: it shows the planned coverage of 2015-2023, and not the final safe status of each site. The inspection by Rosprirodnadzor, on the contrary, revealed monitoring gaps and a reduction in part of the project obligations for reclamation.

6. Discrepancy in the reported area of disturbed land

The report for 2024 indicates 99.156 thousand hectares of disturbed lands at the end of the year. The report for 2025 indicates 120.280 thousand hectares at the beginning of 2025. The difference between these consecutive stock figures is 21.124 thousand hectares, although these positions should be comparable. In the sections checked, the reason is not stated. Possible explanations include a change in the reporting population, the inclusion of previously unrecorded areas, or another methodological revision, but you cannot choose an explanation without a document. Until clarification is received, it is impossible to construct a continuous series of residuals and attribute the entire jump to physical disturbance of the lands in one year.

7. Mine water and future drainage

Site-by-site information is needed on the connectivity of workings, flood elevations, water quality, pumping volume, treatment, discharge points and long-term liability. The regional balance sheet 2-TP (vodkhoz) does not answer these questions.

8. Air quality in the population

The regional mass of emissions does not replace stationary and route measurements of concentrations in cities and towns. The scenarios require an observation map, series continuity, PM_{2.5}/PM₁₀, dust composition and meteorological conditions.

9. Methane after closure

Site-by-site estimates of methane emissions from active and closed mines, degassing work, methane use and a model of changes in emissions after production shutdown are needed. Reducing production does not mean an immediate cessation of gas emission.

10. Cost of protection of people and resettlement

Without a list of priority areas, number of houses, legal status of the property, infrastructure and the chosen standard of compensation, the total amount cannot be honestly arrived at.

11. Cost of restoration of the region

A reasonable regional amount is impossible without an inventory of objects. At the first stage, the following are acceptable:

- the cost of the inventory itself and the open monitoring system;
- ranges for generic objects;
- portfolio of priority sites;
- annual operating costs for drainage, cleaning, degassing and observations.

12. Spatial pathways of impact outside of Kuzbass

Harm cannot be automatically declared “for all of Eurasia.” Each statement requires specific pathways: river basin, atmospheric transport, commodity chain, or global climate effect, as well as data limits.

13. Population exposure and air quality

The mass of emissions from enterprises does not give the average annual or daily PM_{2.5} for a particular home. Quantitative health prediction requires spatially continuous measurements of PM_{2.5}, PM₁₀, NO₂, SO₂, ozone, benzo(a)pyrene and dust composition, meteorology, dispersion model and address history. For now, changes of 5 and 10 µg/m³ are used only as conditional sensitivity steps, and not as forecasts assigned to scenarios.

14. Comparable medical series

We need age-standardized new cases, hospitalizations and deaths for cardiovascular diseases, asthma, COPD and lung cancer with a constant definition of the indicator. Migration, smoking, occupation and access to care need to be taken into account. A decrease in reported diagnoses due to out-migration, medical office closures, or worsening detection cannot be considered an improvement in health.

15. All pregnancy outcomes

To predict congenital birth defects, the register of diagnoses in children of the first year of life is not enough. A register of live births, stillbirths, early losses and terminations after prenatal diagnosis is needed, as well as data on both parents before conception and on the mother during the critical weeks. Without a suitable impact model, the percentage of change in IRR for scenarios is not assigned.

16. Water and health

Regional withdrawal and discharge volumes do not allow the number of disease cases to be calculated. We need specific substances and their concentrations in water intakes and consumer water, duration, actual consumption and population coverage. Before this, the direction of possible risk for water is described, but not the number of cases.

SECTION 9

Validation map

This is the navigation layer of the appendix. Complete numbers are in [02_BASELINE_LEDGER.csv](#), formulas are in [09_CALCULATIONS.md](#), bibliographic information and references are in [03_SOURCE_REGISTRY.md](#).

Data Statuses

Status	Value
verified	value directly found in an official document or primary source
verified_secondary	value reported by a source close to the primary, but open primary table or upload not found

Status	Value
provisional	plausible value from a professional secondary source requiring primary verification
calculated	our reproducible calculation from published source values

No calculation should be cited as a source line.

Map of main statements

Study section	Main sources	Key boundary
Waste from Russia and Kuzbass, 2025	SRC-RPN-WASTE-2025 , SRC-KUZ-REPORT-2025	legal accounting is not equal to all physically moved rock
Change in accounting after 2023	SRC-RPN-WASTE-2024	part of the decrease in the series may be classification
Accumulated stock	SRC-KUZ-WASTE-SCHEME-2026 , SRC-MINING-INTERVIEW-2026	official indicator applies to all non-MSW; coal breakdown preliminary
Land, 2024–2025	SRC-KUZ-REPORT-2024 , SRC-KUZ-REPORT-2025	unexplained gap of 21.124 thousand hectares between neighboring remains
Alienation of reclamation obligations	SRC-RPN-KUZ-INSPECTION-2024	legal exclusion of work does not mean physical restoration
Air and methane	SRC-KUZ-REPORT-2025 , SRC-UNECE-AMM , SRC-EPA-AMM	mass of emissions is not equal to the concentration near the house; closure does not eliminate methane emissions
Methane climate equivalent	SRC-IPCC-AR6-GWP	GWP100 = 29.8 for fossil CH ₄ ; this is a comparative metric, not a mass of CO ₂
Coal industry water	SRC-KUZ-REPORT-2025 , SRC-UK-MINE-WATER-REBOUND	regional discharge categories do not replace site-by-site hydrogeology
Operating and closed facilities	SRC-KUZ-COAL-STRUCTURE-2026 , SRC-KUZ-SUSPENDED-2025 , SRC-ROSTEKH-INTERVIEW-2025	enterprises and hazardous production facilities are different units; dates and statuses cannot be added
Dumps and combustion	SRC-DUMPS-CORPUS , SRC-PORTOLA-2024 , SRC-ITS-COAL-2024	known sample is not a regional census
High production scenario	SRC-KUZ-COAL-2019 , SRC-RU-COAL-PROGRAM-2035 , SRC-KUZ-COAL-2025	sensitivities are not a forecast

Study section	Main sources	Key boundary
Cost of land and dumps	SRC-DUMPS-CORPUS , SRC-AYUTINSKAYA-13BIS-2021 , SRC-STROYSERVICE-RECLAMATION-2024	prices refer to different years and different composition of work
Long price of mine water	SRC-UK-COAL-AUTHORITY-2020-21 , SRC-UK-MINE-WATER-O&M-2026 , SRC-UK-MRA-2024-25	foreign amounts show the structure and duration obligations, and not the price for Kuzbass
Housing in zones affected by closed mines	SRC-RU-ENV-REPORT-DRAFT-2024	58 objects - monitoring circuit, and not all houses near coal objects
PM2.5 and cardiovascular/respiratory morbidity, lung cancer	SRC-WHO-HRAPIE2-2025	the risk function is applied only at a known concentration, in specified age and concentration ranges
Historical health indicators of Kuzbass	SRC-KUZ-HEALTH-2007 , SRC-KISELEVSK-CANCER-2025	regional series cannot be passed off as city; All cancers cannot be passed off as lung cancer; rough indicators do not replace age standardization
VPR	SRC-KUZ-VPR-CORPUS	without individual exposure in critical weeks and register of all pregnancy outcomes percentage forecast is not built
Water and health	SRC-WHO-DRINKING-WATER-2026 , SRC-KUZ-REPORT-2025	volume of discharge is not equal to dose: substance, concentration, route, duration and population are needed

Quantitative scenario model

The study extension is in five files; each of them is presented in full in the corresponding section of this PDF:

- [13_QUANTITATIVE_SCENARIO_MODEL.md](#) — section 3 “Quantitative model”: explanation of calculations and comparative tables;
- [14_SCENARIO_INPUTS.csv](#) — Section 10.2: each initial coefficient and scenario assumption;
- [15_SCENARIO_RESULTS.csv](#) — section 10.3: 12 lines of results, three scenarios × four horizons;
- [16_HEALTH_SCENARIO_ANALYSIS.md](#) — Section 4 “Population Health”: health scenarios, timing of manifestation and conditional model of PM2.5;
- [17_HEALTH_CONDITIONAL_CALCULATIONS.csv](#) — Section 10.4: reproducible results for steps ±5 and ±10 µg/m³.

Quantitative results have status **conditional scenario sensitivity**, even when the original value is official. The official framework does not turn the selected future trajectory into a forecast.

Arithmetic control

1. Share of Kuzbass in Russian waste in 2025: $2.189063297 / 7.841 \times 100 = 27.918\%$.
2. Land balance 2025: $120.280 + 4.620 - 1.265 = 123.635$ thousand hectares ; the discrepancy with the published total of 1 hectare is explained by rounding.
3. Break of land row: $120.280 - 99.156 = 21.124$ thousand hectares ; it is a difference of sources, not a physical flow.
4. Correlation of new disturbance and reclamation: $4.620 / 1.265 = 3.652$.
5. Return of production from 190.7 to 255.3 million tonnes: $+64.6$ million tonnes , or $+33.88\%$.

Full sensitivity assumptions for overburden, water, land and emissions are given in [09 CALCULATIONS.md](#).

What should not be done when preparing an article

- call 27.556 billion tonnes by exact mass of coal waste alone;
- consider a statistical reduction in waste as evidence of a similar reduction in rock movement;
- to connect the remainder of the land 99.156 and 120.280 thousand hectares without a break mark;
- call all 482 objects coal dumps;
- call all known dumps burning;
- call 200 OPO two hundred cuts;
- consider the normatively cleared volume as evidence of the good condition of the river;
- transfer the cost of the German or British program into rubles at the exchange rate and declare it to be the price of Kuzbass;
- call conditional linear sensitivity a forecast;
- consider the cessation of mining as the completion of reclamation.
- deduce the percentage of diseases from the growth of production, mass of waste or total volume of wastewater;
- consider a drop in the number of diagnoses when the population leaves or a deterioration in detection as an improvement in health;
- apply PM2.5 functions outside the WHO specified range without separate justification;
- assign the percentage of change in VPR without exposure in critical weeks and a suitable model.

SECTION 10

Machine-readable tables

Purpose of the section. Here are all the rows of the four tables on which the scenario calculations are based. English-language service fields are preserved without editorial paraphrase so that the values can be checked against the original CSVs. They do not replace Russian explanations in the main sections.

10.1. Initial register of indicators: 02_BASELINE_LEDGER.csv

106 records. Year, territory, unit, definition, source, status and limitation are stored separately.

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
W-RU-2025-01	waste generated	Russia 2025	7.841 billion tonnes	Waste generated under federal statistical Form 2-TP (Waste)	SRC-RPN-WASTE-2025 official release	verified Legal reclassification of some overburden host rock and by-products affects comparability
W-KUZ-2025-01	waste generated	Kemerovo Oblast-Kuzbass 2025	2,189.063297 million tonnes	Waste generated under Form 2-TP (Waste)	SRC-KUZ-REPORT-2025 printed p.256 / PDF page marker 256	verified Does not equal all physically moved rock
W-KUZ-2024-01	waste generated	Kemerovo Oblast-Kuzbass 2024	3,311.0 million tonnes	Waste generated under Form 2-TP (Waste)	SRC-KUZ-REPORT-2025 chart printed p.257	verified Series affected by post-2023 legal classification changes
W-KUZ-2023-01	waste generated	Kemerovo Oblast-Kuzbass 2023	4,080.7 million tonnes	Waste generated under Form 2-TP (Waste)	SRC-KUZ-REPORT-2025 chart printed p.257	verified Series affected by post-2023 legal classification changes

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
W-KUZ-2022-01	waste generated	Kemerovo Oblast-Kuzbass 2022	4,038.8 million tonnes	Waste generated under Form 2-TP (Waste)	SRC-KUZ-REPORT-2025 chart printed p.257	verified Check continuity against original 2022 form
W-KUZ-2021-01	waste generated	Kemerovo Oblast-Kuzbass 2021	3,804.6 million tonnes	Waste generated under Form 2-TP (Waste)	SRC-KUZ-REPORT-2025 chart printed p.257	verified Check continuity against original 2021 form
W-KUZ-2025-02	waste processed	Kemerovo Oblast-Kuzbass 2025	0.329621 million tonnes	Waste treated under Form 2-TP (Waste)	SRC-KUZ-REPORT-2025 printed p.256	verified Not the same as recovered
W-KUZ-2025-03	waste utilized	Kemerovo Oblast-Kuzbass 2025	338.032401 million tonnes	Waste recovered under Form 2-TP (Waste)	SRC-KUZ-REPORT-2025 printed p.256	verified Reported recovery does not by itself demonstrate ecosystem restoration
W-KUZ-2025-04	waste neutralized	Kemerovo Oblast-Kuzbass 2025	0.132267 million tonnes	Waste rendered harmless under Form 2-TP (Waste)	SRC-KUZ-REPORT-2025 printed p.256	verified Separate from recovery
W-KUZ-2025-05	waste placed	Kemerovo Oblast-Kuzbass 2025	1,762.093067 million tonnes	Placed at operating waste-disposal facilities	SRC-KUZ-REPORT-2025 printed p.256	verified Flow during year; not accumulated stock
W-KUZ-2025-06	waste stored	Kemerovo Oblast-Kuzbass 2025	1,694.353131 million tonnes	Stored at operating waste-disposal facilities	SRC-KUZ-REPORT-2025 printed p.256	verified Subset of placed waste
W-KUZ-2025-07	waste buried	Kemerovo Oblast-Kuzbass 2025	67.739936 million tonnes	Buried at operating waste-disposal facilities	SRC-KUZ-REPORT-2025 printed p.256	verified Subset of placed waste
W-KUZ-2025-08	waste utilized_plus_neutralized_share	Kemerovo Oblast-Kuzbass 2025	15.4 percent of generated waste	Ratio reported in regional report	SRC-KUZ-REPORT-2025 printed p.257	verified Do not add treated waste because categories and flows may overlap

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
W-KUZ-2025-09	waste waste_disposal_facilities_in_regional_cadastre	Kemerovo Oblast-Kuzbass 2025	482 facilities	Regional waste cadastre entries	SRC-KUZ-REPORT-2025 printed p.257	verified Not a count of coal dumps; not a count of burning dumps; operating status not established by this number
W-KUZ-2024-10	waste accumulated_start_of_year_non_msw	Kemerovo Oblast-Kuzbass start of 2024	27,556.325766 million tonnes	Accumulated non-municipal-solid-waste at start of 2024	SRC-KUZ-WASTE-SCHEME-2026 table 4	verified All non-MSW categories; not coal-only; not end-of-2024 stock
W-KUZ-2024-11	waste generated_mineral_extraction	Kemerovo Oblast-Kuzbass 2024	3,256 million tonnes	Generated by mineral-extraction enterprises under 2-TP waste	SRC-KUZ-CIRCULAR-2026 program baseline section	verified Mining broader than coal; value rounded in source
W-KUZ-2024-12	waste mineral_extraction_share	Kemerovo Oblast-Kuzbass 2024	98.3 percent of regional generated waste	Share of mineral-extraction enterprises	SRC-KUZ-CIRCULAR-2026 program baseline section	verified Not identical to coal share
W-KUZ-2024-13	waste coal_mining_generated	Kemerovo Oblast-Kuzbass 2024	3,200 million tonnes	Coal-mining waste generated	SRC-MINING-INTERVIEW-2026 interview text	provisional Secondary professional source cites official statistics but primary table still required; rounded
W-KUZ-2024-14	waste coal_mining_accumulated_end	Kemerovo Oblast-Kuzbass end of 2024	27,500 million tonnes	Accumulated coal-mining waste	SRC-MINING-INTERVIEW-2026 interview text	provisional Secondary professional source; rounded; apparent proximity to all non-MSW start-2024 stock requires reconciliation
L-KUZ-2025-01	land disturbed_stock_start	Kemerovo Oblast-Kuzbass start of 2025	120.280 thousand hectares	Disturbed-land stock at beginning of year	SRC-KUZ-REPORT-2025 printed p.111-112	verified All causes represented; coal-only share not yet extracted
L-KUZ-2025-02	land newly_disturbed	Kemerovo Oblast-Kuzbass 2025	4.620 thousand hectares	Land disturbed during year	SRC-KUZ-REPORT-2025 printed p.111-112	verified Annual flow

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
L-KUZ-2025-03	land newly_disturbed_mineral_extraction	Kemerovo Oblast-Kuzbass 2025	4.015 thousand hectares	Land disturbed during mineral extraction	SRC-KUZ-REPORT-2025 printed p.111-112	verified Mineral extraction is broader than coal unless source states otherwise
L-KUZ-2025-04	land reclaimed	Kemerovo Oblast-Kuzbass 2025	1.265 thousand hectares	Land reclaimed during year	SRC-KUZ-REPORT-2025 printed p.111-112	verified Administrative reclamation does not equal recovery of original ecosystem
L-KUZ-2025-05	land disturbed_stock_end	Kemerovo Oblast-Kuzbass end of 2025	123.634 thousand hectares	Disturbed-land stock at end of year	SRC-KUZ-REPORT-2025 printed p.111-112	verified Balance differs by 0.001 thousand ha due to rounding
A-KUZ-2025-01	air total_emissions_all_sources	Kemerovo Oblast-Kuzbass 2025	1,502.230 thousand tonnes	Registered stationary plus mobile-source emissions	SRC-KUZ-REPORT-2025 printed p.26-27	verified Mass emissions are not ambient concentrations
A-KUZ-2025-02	air stationary_source_emissions	Kemerovo Oblast-Kuzbass 2025	1,427.499 thousand tonnes	Registered emissions from stationary sources	SRC-KUZ-REPORT-2025 printed p.26-27	verified Includes multiple industries and substances
A-KUZ-2025-03	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2025	796.914 thousand tonnes CH ₄	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 printed p.37	verified Mostly attributed to coal mining by report but includes other sources
A-KUZ-2025-04	air methane_share_stationary	Kemerovo Oblast-Kuzbass 2025	55.8 percent	Share of methane in registered stationary-source emissions	SRC-KUZ-REPORT-2025 printed p.37	verified Mass share in reporting; not toxicity or personal exposure
A-KUZ-2025-05	air coal_mining_stationary_emissions	Kemerovo Oblast-Kuzbass 2025	888.918 thousand tonnes	Registered stationary-source emissions from coal-mining enterprises	SRC-KUZ-REPORT-2025 printed p.234-235 table 1.6	verified Mass across substances; does not equal ambient concentration or health dose

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
A-KUZ-2025-06	air coal_mining_share_stationary	Kemerovo Oblast-Kuzbass 2025	62.3 percent of stationary-source emissions	Coal-mining share of registered stationary-source emissions	SRC-KUZ-REPORT-2025 printed p.234 table 1.6	verified Dominated by gaseous and liquid substances including hydrocarbons
A-KUZ-2025-07	air coal_mining_solids_emissions	Kemerovo Oblast-Kuzbass 2025	52.270 thousand tonnes	Registered solid emissions from coal-mining enterprises	SRC-KUZ-REPORT-2025 printed p.234 table 1.6	verified Not equivalent to PM2.5 or PM10 ambient exposure
V-KUZ-2025-01	water withdrawal	Kemerovo Oblast-Kuzbass 2025	1,594.696 million cubic metres	Withdrawal from surface and groundwater sources under 2-TP water	SRC-KUZ-REPORT-2025 printed p.87 and p.443	verified Regional total; not coal-only
V-KUZ-2025-02	water fresh_water_use	Kemerovo Oblast-Kuzbass 2025	1,219.279 million cubic metres	Fresh water used under 2-TP water	SRC-KUZ-REPORT-2025 printed p.87 and p.443	verified Regional total; not coal-only
V-KUZ-2025-03	water discharge_surface_waters_total	Kemerovo Oblast-Kuzbass 2025	1,271.574 million cubic metres	Wastewater, transit water and other water discharged to surface water bodies	SRC-KUZ-REPORT-2025 printed p.87-88 and p.443	verified Includes categories not requiring treatment; not all polluted
V-KUZ-2025-04	water polluted_wastewater	Kemerovo Oblast-Kuzbass 2025	51.670 million cubic metres	Untreated plus insufficiently treated wastewater requiring treatment	SRC-KUZ-REPORT-2025 printed p.87-88 and p.443	verified Regional total; decline does not by itself prove recovery
V-KUZ-2025-05	water adequately_treated_wastewater	Kemerovo Oblast-Kuzbass 2025	478.569 million cubic metres	Wastewater treated to regulatory standard at treatment facilities	SRC-KUZ-REPORT-2025 printed p.87-88 and p.443	verified Reported category; requires sector breakdown
V-KUZ-2025-06	water water_protection_and_management_spending	Kemerovo Oblast-Kuzbass 2025	7,721.2383 million rubles	All reported water-protection and water-management work in region	SRC-KUZ-REPORT-2025 printed p.443	verified Not coal remediation spending and not all capital cost

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
V-KUZ-2025-07	water coal_mining_with drawal	Kemerovo Oblast-Kuzbass 2025	382.736 million cubic metres	Water withdrawn by coal-mining enterprises	SRC-KUZ-REPORT-2025 printed p.253	verified 97.25 percent reported as groundwater withdrawal; withdrawal includes mine drainage context but exact composition needs source table
V-KUZ-2025-08	water coal_mining_fresh_water_use	Kemerovo Oblast-Kuzbass 2025	86.846 million cubic metres	Fresh water used by coal-mining enterprises	SRC-KUZ-REPORT-2025 printed p.253	verified Different from total withdrawal
V-KUZ-2025-09	water coal_mining_wastewater_discharge_total	Kemerovo Oblast-Kuzbass 2025	329.401 million cubic metres	Wastewater discharged by coal-mining enterprises	SRC-KUZ-REPORT-2025 printed p.253	verified Includes discharge destinations other than surface waters
V-KUZ-2025-10	water coal_mining_surface_water_discharge	Kemerovo Oblast-Kuzbass 2025	298.996 million cubic metres	Wastewater from coal mining discharged to surface water bodies	SRC-KUZ-REPORT-2025 printed p.253	verified 4.04 percent classified as polluted in report
V-KUZ-2025-11	water coal_mining_polluted_share_surface_discharge	Kemerovo Oblast-Kuzbass 2025	4.04 percent	Share of coal-mining surface-water discharge classified as polluted	SRC-KUZ-REPORT-2025 printed p.253	verified Does not describe pollutant loads or condition of receiving waters
P-KUZ-2018-01	production coal_production	Kemerovo Oblast-Kuzbass 2018	255.3 million tonnes	Annual coal output reported by regional coal ministry	SRC-KUZ-COAL-2019 official 2019 results	verified Federal coal program gives 255.7 million tonnes; discrepancy to be retained and reconciled
P-KUZ-2025-01	production coal_production	Kemerovo Oblast-Kuzbass 2025	190.7 million tonnes	Annual coal output reported by regional coal ministry	SRC-KUZ-COAL-2025 official results release	verified Environmental report states 191.8 million tonnes; definitions or revision require reconciliation

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
P-KUZ-2025-02	production coal_production_environment_report	Kemerovo Oblast-Kuzbass 2025	191.8 million tonnes	Annual coal output stated in environmental report	SRC-KUZ-REPORT-2025 printed p.234	verified Conflicts by 1.1 million tonnes with coal-ministry result
P-KUZ-2025-03	production coal_processed_all_facilities	Kemerovo Oblast-Kuzbass 2025	144.7 million tonnes	Processing by preparation seasonal and crushing-screening plants	SRC-KUZ-COAL-2025 official results release	verified Broader facility scope than preparation plants alone
P-KUZ-2026-04	industry enterprises_working	Kemerovo Oblast-Kuzbass 2 October 2026	150 enterprises	Coal enterprises described as working by regional coal ministry	SRC-KUZ-COAL-STRUCTURE-2026 official ministry news	verified Includes mines pits and processing facilities; not licenses
P-KUZ-2026-05	industry mines_working	Kemerovo Oblast-Kuzbass 2 October 2026	38 mines	Coal mines described as working	SRC-KUZ-COAL-STRUCTURE-2026 official ministry news	verified Operational status may differ from temporary safety stoppages within individual workings
P-KUZ-2026-06	industry open_pits_working	Kemerovo Oblast-Kuzbass 2 October 2026	55 open pits	Coal open pits described as working	SRC-KUZ-COAL-STRUCTURE-2026 official ministry news	verified Does not enumerate temporarily idle enterprises
P-KUZ-2026-07	industry processing_facilities_working	Kemerovo Oblast-Kuzbass 2 October 2026	57 facilities	Preparation plants and sorting units described as working	SRC-KUZ-COAL-STRUCTURE-2026 official ministry news	verified Combined category
P-KUZ-2025-08	industry temporarily_suspended_mines	Kemerovo Oblast-Kuzbass 20 August 2025	6 mines	Enterprises reported by ministry as having suspended activity	SRC-KUZ-SUSPENDED-2025 press reports relaying ministry response	verified_secondary Names were not disclosed; not the same as liquidation or a short safety suspension
P-KUZ-2025-09	industry temporarily_suspended_open_pits	Kemerovo Oblast-Kuzbass 20 August 2025	9 open pits	Enterprises reported by ministry as having suspended activity	SRC-KUZ-SUSPENDED-2025 press reports relaying ministry response	verified_secondary Latest comparable public count still to be found

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
L-KUZ-2024-01	land disturbed_stock_start	Kemerovo Oblast-Kuzbass start of 2024	96.471 thousand hectares	Disturbed-land stock at beginning of year	SRC-KUZ-REPORT-2024 printed p.127 / PDF page 125	verified All causes; source attributes data to Rosprirodnadzor
L-KUZ-2024-02	land newly_disturbed	Kemerovo Oblast-Kuzbass 2024	4.768 thousand hectares	Land disturbed during year	SRC-KUZ-REPORT-2024 printed p.127 / PDF page 125	verified Annual flow
L-KUZ-2024-03	land newly_disturbed_mineral_extraction	Kemerovo Oblast-Kuzbass 2024	4.264 thousand hectares	Land disturbed during mineral extraction	SRC-KUZ-REPORT-2024 printed p.127 / PDF page 125	verified Mineral extraction is broader than coal
L-KUZ-2024-04	land reclaimed	Kemerovo Oblast-Kuzbass 2024	2.083 thousand hectares	Land reclaimed during year	SRC-KUZ-REPORT-2024 printed p.127 / PDF page 125	verified Administrative reclamation does not establish ecosystem recovery
L-KUZ-2024-05	land disturbed_stock_end	Kemerovo Oblast-Kuzbass end of 2024	99.156 thousand hectares	Disturbed-land stock at end of year	SRC-KUZ-REPORT-2024 printed p.127 / PDF page 125	verified Does not match 120.280 thousand ha reported as beginning-of-2025 stock in next annual report
L-KUZ-2025-DQ1	data_quality land_series_discontinuity	Kemerovo Oblast-Kuzbass between end 2024 and start 2025	21.124 thousand hectares	Difference between consecutive official annual-report stocks	SRC-KUZ-REPORT-2024 + SRC-KUZ-REPORT-2025 printed p.127 versus printed pp.111-112	calculated No explanation located in the examined passages; do not treat annual stock series as continuous until reconciled
A-KUZ-2014-CH4	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2014	756.366 thousand tonnes CH4	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 chart printed p.37	verified All stationary sources; report says methane is mainly associated with coal mining

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
A-KUZ-2015-CH4	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2015	768.741 thousand tonnes CH4	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 chart printed p.37	verified Series can reflect reporting changes as well as physical emissions
A-KUZ-2016-CH4	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2016	754.278 thousand tonnes CH4	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 chart printed p.37	verified Series can reflect reporting changes as well as physical emissions
A-KUZ-2017-CH4	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2017	839.846 thousand tonnes CH4	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 chart printed p.37	verified Series can reflect reporting changes as well as physical emissions
A-KUZ-2018-CH4	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2018	789.839 thousand tonnes CH4	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 chart printed p.37	verified Series can reflect reporting changes as well as physical emissions
A-KUZ-2019-CH4	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2019	1,086.561 thousand tonnes CH4	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 chart printed p.37	verified Series can reflect reporting changes as well as physical emissions
A-KUZ-2020-CH4	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2020	982.559 thousand tonnes CH4	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 chart printed p.37	verified Series can reflect reporting changes as well as physical emissions
A-KUZ-2021-CH4	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2021	979.577 thousand tonnes CH4	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 chart printed p.37	verified Series can reflect reporting changes as well as physical emissions

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
A-KUZ-2022-CH4	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2022	932.486 thousand tonnes CH4	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 chart printed p.37	verified Series can reflect reporting changes as well as physical emissions
A-KUZ-2023-CH4	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2023	786.059 thousand tonnes CH4	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 chart printed p.37	verified Series can reflect reporting changes as well as physical emissions
A-KUZ-2024-CH4	air methane_stationary_sources	Kemerovo Oblast-Kuzbass 2024	901.320 thousand tonnes CH4	Registered methane from stationary sources	SRC-KUZ-REPORT-2025 chart printed p.37	verified All stationary sources; not a mine-by-mine inventory
V-KUZ-2024-COAL-01	water coal_mining_withdrawal	Kemerovo Oblast-Kuzbass 2024	369.885 million cubic metres	Water withdrawn by coal-mining enterprises	SRC-KUZ-REPORT-2025 printed p.249 table 2.1 and p.253	verified Previous-year comparator reproduced in 2025 report
V-KUZ-2024-COAL-02	water coal_mining_fresh_water_use	Kemerovo Oblast-Kuzbass 2024	85.739 million cubic metres	Fresh water used by coal-mining enterprises	SRC-KUZ-REPORT-2025 printed p.249 table 2.1	verified Different from total withdrawal
V-KUZ-2024-COAL-03	water coal_mining_wastewater_discharge_total	Kemerovo Oblast-Kuzbass 2024	321.631 million cubic metres	Wastewater discharged by coal-mining enterprises	SRC-KUZ-REPORT-2025 printed p.249 table 2.1 and p.253	verified Includes discharge destinations other than surface waters
V-KUZ-2024-COAL-04	water coal_mining_surface_water_discharge	Kemerovo Oblast-Kuzbass 2024	285.723 million cubic metres	Wastewater from coal mining discharged to surface water bodies	SRC-KUZ-REPORT-2025 printed p.250 table 2.2 and p.253	verified 13.988 million cubic metres classified as polluted
V-KUZ-2024-COAL-05	water coal_mining_polluted_surface_discharge	Kemerovo Oblast-Kuzbass 2024	13.988 million cubic metres	Coal-sector surface-water discharge classified as polluted	SRC-KUZ-REPORT-2025 printed p.250 table 2.2	verified Regulatory category does not state pollutant load or receiving-water condition

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
V-KUZ-2024-COAL-06	water coal_mining_adequately_treated_surface_discharge	Kemerovo Oblast-Kuzbass 2024	267.829 million cubic metres	Coal-sector surface-water discharge classified as adequately treated	SRC-KUZ-REPORT-2025 printed p.250 table 2.2	verified Regulatory classification
V-KUZ-2024-COAL-07	water coal_mining_reuse_and_recycling	Kemerovo Oblast-Kuzbass 2024	207.873 million cubic metres	Water used in circulating and sequential-reuse systems by coal mining	SRC-KUZ-REPORT-2025 printed p.249 table 2.1 and p.253	verified Not subtraction from withdrawal without a full water balance
V-KUZ-2025-12	water coal_mining_polluted_surface_discharge	Kemerovo Oblast-Kuzbass 2025	12.067 million cubic metres	Coal-sector surface-water discharge classified as polluted	SRC-KUZ-REPORT-2025 printed p.250 table 2.2	verified Use direct table value rather than deriving from rounded 4.04 percent
V-KUZ-2025-13	water coal_mining_adequately_treated_surface_discharge	Kemerovo Oblast-Kuzbass 2025	283.196 million cubic metres	Coal-sector surface-water discharge classified as adequately treated	SRC-KUZ-REPORT-2025 printed p.250 table 2.2	verified Use direct table value rather than deriving from rounded percentage
V-KUZ-2025-14	water coal_mining_reuse_and_recycling	Kemerovo Oblast-Kuzbass 2025	209.408 million cubic metres	Water used in circulating and sequential-reuse systems by coal mining	SRC-KUZ-REPORT-2025 printed p.249 table 2.1 and p.253	verified Not the same as wastewater treatment
P-KUZ-2025-OPO-01	industry coal_industry_hazardous_facilities	Kemerovo Oblast-Kuzbass early 2025	275 hazardous production facilities	Coal-industry facilities under Siberian Rostekhnadzor supervision	SRC-ROSTEKH-INTERVIEW-2025 interview in Ugol Kuzbassa issue 1 2025	verified_secondary Hazardous production facilities are not identical to enterprises or licences
P-KUZ-2025-OPO-02	industry coal_mine_hazardous_facilities_active	Kemerovo Oblast-Kuzbass early 2025	39 Class I coal-mine hazardous production facilities	Operating coal-mine hazardous production facilities	SRC-ROSTEKH-INTERVIEW-2025 interview in Ugol Kuzbassa issue 1 2025	verified_secondary Different accounting basis and date from ministry enterprise count

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
P-KUZ-2025-OPO-03	industry coal_mine_hazardous_facilities_conservation	Kemerovo Oblast-Kuzbass early 2025	11 Class I coal-mine hazardous production facilities	Coal-mine hazardous production facilities that are mothballed	SRC-ROSTEKH-INTERVIEW-2025 interview in Ugol Kuzbassa issue 1 2025	verified_secondary Mothballing is not closure
P-KUZ-2025-OPO-04	industry coal_mine_hazardous_facilities_liquidation	Kemerovo Oblast-Kuzbass early 2025	9 Class I coal-mine hazardous production facilities	Coal-mine hazardous production facilities undergoing closure	SRC-ROSTEKH-INTERVIEW-2025 interview in Ugol Kuzbassa issue 1 2025	verified_secondary Does not count all mines closed in the past
P-KUZ-2025-OPO-05	industry open_mining_and_processing_facilities_total	Kemerovo Oblast-Kuzbass early 2025	210 Class II hazardous production facilities	Open-pit mining and processing hazardous production facilities	SRC-ROSTEKH-INTERVIEW-2025 interview in Ugol Kuzbassa issue 1 2025	verified_secondary Comprises 119 open-pit mines, 56 processing plants, and 35 tailings facilities and waste heaps; status figures group open-pit mines and plants together
P-KUZ-2025-OPO-06	industry open_mining_and_processing_facilities_active	Kemerovo Oblast-Kuzbass early 2025	200 Class II open-pit mining and processing facilities	Operating open-pit mining and processing facilities	SRC-ROSTEKH-INTERVIEW-2025 interview in Ugol Kuzbassa issue 1 2025	verified_secondary Not 200 pits; group includes processing plants
P-KUZ-2025-OPO-07	industry open_mining_and_processing_facilities_conservation	Kemerovo Oblast-Kuzbass early 2025	1 Class II hazardous production facility	Open-pit mining or processing facility that is mothballed	SRC-ROSTEKH-INTERVIEW-2025 interview in Ugol Kuzbassa issue 1 2025	verified_secondary Type not stated in quoted aggregate
P-KUZ-2025-OPO-08	industry open_mining_and_processing_facilities_liquidation	Kemerovo Oblast-Kuzbass early 2025	8 Class II hazardous production facilities	Open-pit mining or processing facilities undergoing closure	SRC-ROSTEKH-INTERVIEW-2025 interview in Ugol Kuzbassa issue 1 2025	verified_secondary Type not stated in quoted aggregate
P-KUZ-2015-23-LIQ-01	industry mines_in_staged_liquidation_program	Prokopyevsk Kiselevsk and Anzhero-Sudzhensk 2015-2023 program stages	22 mines	Mines covered by the integrated phased closure and resident-resettlement programme	SRC-RPN-KUZ-INSPECTION-2024 official inspection release	verified Programme scope does not prove that every mine had been fully closed by the end date

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
L-KUZ-2024-OBL-01	land reclamation_obli gation_reviewed	Kemerovo Oblast- Kuzbass 2024 inspection	3.5 thousand hectares	More than this area was described as subject to reclamation in inspected mine- closure projects	SRC-RPN-KUZ- INSPECTION-2024 official inspection release	verified Lower-bound wording more than 3.5 thousand ha
L-KUZ-2024-OBL-02	land reclamation_obli gation_excluded	Kemerovo Oblast- Kuzbass 2024 inspection	1.9 thousand hectares	More than this area was removed from reclamation obligations after transfer of land or changes to project decisions	SRC-RPN-KUZ- INSPECTION-2024 official inspection release	verified More than 54 percent of the originally due area; legal/project obligation change not proof of physical restoration
H-KUZ-2024-01	people_and_legacy residential_objects_in_gas_dynamic_monitoring	Kuzbass closed-mine areas 2024	58 residential objects	Residential objects included in gas- dynamic monitoring	SRC-RU-ENV-REPORT- DRAFT-2024 table 5.4	provisional Draft federal report; monitored subset not a regional count of all homes near coal facilities
H-KUZ-2024-02	people_and_legacy residential_objects_danger_zones	Kuzbass closed-mine areas 2024	14 residential objects	Monitored residential objects classified in danger zones	SRC-RU-ENV-REPORT- DRAFT-2024 table 5.4	provisional Classification scope and household count require underlying monitoring register
H-KUZ-2024-03	people_and_legacy residential_objects_threatened_zones	Kuzbass closed-mine areas 2024	44 residential objects	Monitored residential objects classified in threatened zones	SRC-RU-ENV-REPORT- DRAFT-2024 table 5.4	provisional Does not cover homes near active pits dumps or other environmental exposure zones
HL-WHO-2025-01	health_crf childhood_asthma_incidence_rr	WHO evidence base 2025	1.34 RR per 10 ug/m3 PM2.5	Incidence age 0-18 applicable exposure range 5-40 ug/m3	SRC-WHO-HRAPIE2- 2025 section 3.1 figure 5	verified 95% CI 1.10-1.63; conditional function not a Kuzbass exposure forecast
HL-WHO-2025-02	health_crf copd_incidence_rr	WHO evidence base 2025	1.18 RR per 10 ug/m3 PM2.5	Incidence age 30+ applicable exposure range 5-25 ug/m3	SRC-WHO-HRAPIE2- 2025 section 3.1 figure 5	verified 95% CI 1.13-1.23; smoking and occupational exposure must be accounted for

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
HL-WHO-2025-03	health_crf acute_myocardial_infarction_incidence_rr	WHO evidence base 2025	1.13 RR per 10 ug/m3 PM2.5	Incidence age 30+ applicable exposure range 5-65 ug/m3	SRC-WHO-HRAPIE2-2025 section 3.1 figure 5	verified 95% CI 1.05-1.22; requires local baseline incidence and exposure
HL-WHO-2025-04	health_crf stroke_incidence_rr	WHO evidence base 2025	1.12 RR per 10 ug/m3 PM2.5	Incidence age 30+ applicable exposure range 5-35 ug/m3	SRC-WHO-HRAPIE2-2025 section 3.1 figure 5	verified 95% CI 1.05-1.20; requires local baseline incidence and exposure
HL-WHO-2025-05	health_crf hypertension_incidence_rr	WHO evidence base 2025	1.16 RR per 10 ug/m3 PM2.5	Incidence age 30+ applicable exposure range 5-75 ug/m3	SRC-WHO-HRAPIE2-2025 section 3.1 figure 5	verified 95% CI 1.05-1.30; detection depends strongly on access to primary care
HL-WHO-2025-06	health_crf lung_cancer_incidence_rr	WHO evidence base 2025	1.16 RR per 10 ug/m3 PM2.5	Incidence age 30+ applicable exposure range 5-45 ug/m3	SRC-WHO-HRAPIE2-2025 section 3.1 figure 5	verified 95% CI 1.10-1.23; long latency and major confounding by smoking and occupation
HL-KUZ-2007-01	health_signal circulatory_first_diagnosed_change_adults	Kemerovo Oblast 2003-2007	2.0 ratio	First-diagnosed circulatory disease adult rate change reported by regional environmental report	SRC-KUZ-HEALTH-2007 section 5.1	verified_secondary Regional historical signal not age-standardized scenario baseline and not causal attribution
HL-KUZ-2007-02	health_signal circulatory_first_diagnosed_change_adolescents	Kemerovo Oblast 2003-2007	1.7 ratio	First-diagnosed circulatory disease adolescent rate change reported by regional environmental report	SRC-KUZ-HEALTH-2007 section 5.1	verified_secondary Regional historical signal not a Kiselevsk series and not causal attribution
HL-KUZ-2007-03	health_signal circulatory_first_diagnosed_change_children	Kemerovo Oblast 2003-2007	45.9 percent increase	First-diagnosed circulatory disease child rate change reported by regional environmental report	SRC-KUZ-HEALTH-2007 section 5.1	verified_secondary Regional historical signal not a Kiselevsk series and not causal attribution

ID	Topic / indicator	Territory / year	Value	Definition / scope of	Source / location of	Status / limitation of
HL-KIS-2007-01	health_signal all_malignant_neoplasms_first_diagnosed_crude_rate	Kiselevsk 2007	258.4 per 100,000 residents	All malignant neoplasms not lung cancer	SRC-KISELEVSK-CANCER-2025 municipal table	verified_secondary Crude non-age-standardized incomplete series dependent on detection
HL-KIS-2020-01	health_signal all_malignant_neoplasms_first_diagnosed_crude_rate	Kiselevsk 2020	302.9 per 100,000 residents	All malignant neoplasms not lung cancer	SRC-KISELEVSK-CANCER-2025 municipal table	verified_secondary Crude non-age-standardized incomplete series dependent on detection
HL-KIS-2023-01	health_signal all_malignant_neoplasms_first_diagnosed_crude_rate	Kiselevsk 2023	479.2 per 100,000 residents	All malignant neoplasms not lung cancer	SRC-KISELEVSK-CANCER-2025 municipal table	verified_secondary Crude non-age-standardized incomplete series dependent on detection
HL-KIS-2024-01	health_signal all_malignant_neoplasms_first_diagnosed_crude_rate	Kiselevsk 2024	440.8 per 100,000 residents	All malignant neoplasms not lung cancer	SRC-KISELEVSK-CANCER-2025 municipal table	verified_secondary Crude non-age-standardized incomplete series dependent on detection

10.2. Model parameters: 14_SCENARIO_INPUTS.csv

60 parameters and ranges. The values in this registry are model inputs, not automatically established facts about the future.

Parameter	Subject	Range	Use in model	Source / status	Constraint
BASE_COAL_2025	coal production	190.7–191.8 million tonnes per year	starting production level	SRC-KUZ-COAL-2025 and SRC-KUZ-REPORT-2025	two official publications differ

Parameter	Subject	Range	Use in model	Source / status	Constraint
WASTE_PROXY	waste	11.5–16.1 tonnes reported-waste-equivalent per tonne coal	sensitivity for new waste	calculated from 2025 regional total and provisional 2024 coal-specific value	not a physical coefficient; legal classification changed; lower numerator includes other sectors
UNRESOLVED_BAS E	waste	0.80–0.95 fraction of new waste	scenarios B and C	scenario assumption anchored to the 84.6% not reported as recovered or rendered harmless in 2025	placement is not automatically unsafe, and recovery is not automatically restoration
A_UNRESOLVED_Y EAR5	waste	0.55–0.75 fraction of cumulative new waste remaining	scenario A performance envelope	scenario assumption	includes treatment of some earlier flow
A_UNRESOLVED_Y EAR15	waste	0.40–0.65 fraction of cumulative new waste remaining	scenario A performance envelope	scenario assumption	not observed performance
A_UNRESOLVED_Y EAR30	waste	0.25–0.50 fraction of cumulative new waste remaining	scenario A performance envelope	scenario assumption	not observed performance
A_UNRESOLVED_Y EAR50	waste	0.15–0.35 fraction of cumulative new waste remaining	scenario A performance envelope	scenario assumption	not observed performance
LAND_PROXY	land	20.9–21.5 hectares per million tonnes coal	sensitivity for newly disturbed land	calculated from 2024-2025 official reports	mineral extraction broader than coal; non-linear land take
LAND_STOCK_STAR T	land	123.634–123.634 thousand hectares	starting disturbed-land stock	end-2025 official report	official 2024-2025 stock series contains an unexplained 21.124 thousand ha break
METHANE_TOTAL_2025	methane	0.796914–0.796914 million tonnes CH ₄ per year	regional stationary-source baseline	SRC-KUZ-REPORT-2025	includes non-coal sources

Parameter	Subject	Range	Use in model	Source / status	Constraint
METHANE_COAL_SHARE_ASSUMPTION	methane	0.60–1.00 fraction of regional stationary methane	conditional sensitivity only	scenario assumption from report wording mainly	not an observed sector share
METHANE_GWP100	methane	29.8–29.8 tonnes CO ₂ e per tonne fossil CH ₄	climate-equivalent calculation	SRC-IPCC-AR6-GWP	not mass CO ₂ or temperature forecast
A_METHANE_INTENSITY_Y0_5	methane	0.65–0.85 fraction of 2025 intensity retained	scenario A first segment	scenario performance assumption	combines controls and production mix
A_METHANE_INTENSITY_Y5_15	methane	0.40–0.70 fraction of 2025 intensity retained	scenario A second segment	scenario performance assumption	combines controls and production mix
A_METHANE_INTENSITY_Y15_30	methane	0.20–0.50 fraction of 2025 intensity retained	scenario A third segment	scenario performance assumption	combines controls and production mix
A_METHANE_INTENSITY_Y30_50	methane	0.10–0.35 fraction of 2025 intensity retained	scenario A fourth segment	scenario performance assumption	combines controls and production mix
B_ABANDONED_METHANE_Y5_15	methane	0.20–0.60 fraction of attributed 2025 methane per year average	scenario B legacy segment	scenario stress range	mine-specific decay unknown
B_ABANDONED_METHANE_Y15_30	methane	0.10–0.35 fraction of attributed 2025 methane per year average	scenario B legacy segment	scenario stress range	mine-specific decay unknown
B_ABANDONED_METHANE_Y30_50	methane	0.03–0.20 fraction of attributed 2025 methane per year average	scenario B legacy segment	scenario stress range	mine-specific decay unknown

Parameter	Subject	Range	Use in model	Source / status	Constraint
A_LEGACY_METHANE_VS_B_Y5_15	methane	0.15–0.50 fraction of unmanaged legacy emission	scenario A managed legacy	scenario performance assumption	capture oxidation and controlled flooding effects combined
A_LEGACY_METHANE_VS_B_Y15_30	methane	0.10–0.40 fraction of unmanaged legacy emission	scenario A managed legacy	scenario performance assumption	capture oxidation and controlled flooding effects combined
A_LEGACY_METHANE_VS_B_Y30_50	methane	0.10–0.50 fraction of unmanaged legacy emission	scenario A managed legacy	scenario performance assumption	capture oxidation and controlled flooding effects combined
WATER_WITHDRAWAL_INTENSITY	water	1.995–1.995 cubic metres per tonne coal	active-production sensitivity	2025 report calculation	depends on hydrogeology and mine mix
WASTEWATER_INTENSITY	water	1.717–1.717 cubic metres per tonne coal	active-production sensitivity	2025 report calculation	not all discharged water is polluted
SURFACE_DISCHARGE_INTENSITY	water	1.559–1.559 cubic metres per tonne coal	active-production sensitivity	2025 report calculation	does not describe pollutant loads
SOLID_EMISSION_INTENSITY	air	0.273–0.273 kilograms per tonne coal	active-production sensitivity	2025 report calculation	registered solids are not ambient PM2.5 or PM10
A_WATER_INTENSITY_Y0_5	water	0.85–0.95 fraction of 2025 intensity	scenario A first segment	scenario performance assumption	legacy mine water additional
A_WATER_INTENSITY_Y5_15	water	0.65–0.85 fraction of 2025 intensity	scenario A second segment	scenario performance assumption	legacy mine water additional
A_WATER_INTENSITY_Y15_30	water	0.50–0.75 fraction of 2025 intensity	scenario A third segment	scenario performance assumption	legacy mine water additional
A_WATER_INTENSITY_Y30_50	water	0.35–0.65 fraction of 2025 intensity	scenario A fourth segment	scenario performance assumption	legacy mine water additional

Parameter	Subject	Range	Use in model	Source / status	Constraint
C_WATER_INTENSITY	water	0.90–1.00 fraction of 2025 intensity	scenario C all segments	scenario sensitivity assumption	lower bound assumes at most 10 percent improvement; upper bound unchanged intensity
B_LEGACY_WATER_YEAR5	water	0.20–0.80 fraction of 2025 coal surface discharge per year	scenario B	scenario stress range	not all water polluted
B_LEGACY_WATER_YEAR15	water	0.10–0.60 fraction of 2025 coal surface discharge per year	scenario B	scenario stress range	not all water polluted
B_LEGACY_WATER_YEAR30	water	0.05–0.40 fraction of 2025 coal surface discharge per year	scenario B	scenario stress range	not all water polluted
B_LEGACY_WATER_YEAR50	water	0.05–0.30 fraction of 2025 coal surface discharge per year	scenario B	scenario stress range	not all water polluted
A_LEGACY_WATER_YEAR5	water	0–50 million cubic metres per year	scenario A annual total table	scenario assumption	requires mine inventory
A_LEGACY_WATER_YEAR15	water	20–120 million cubic metres per year	scenario A annual total table	scenario assumption	water managed rather than allowed to rebound
A_LEGACY_WATER_YEAR30	water	20–100 million cubic metres per year	scenario A annual total table	scenario assumption	water managed rather than allowed to rebound
A_LEGACY_WATER_YEAR50	water	10–80 million cubic metres per year	scenario A annual total table	scenario assumption	some schemes may be permanent

Parameter	Subject	Range	Use in model	Source / status	Constraint
A_WATER_ENDPOINT_FACTOR_YEAR5	water	0.75–0.90 fraction of 2025 intensity	scenario A annual horizon value	scenario assumption	different from segment-average factor used for cumulative total
A_WATER_ENDPOINT_FACTOR_YEAR15	water	0.55–0.80 fraction of 2025 intensity	scenario A annual horizon value	scenario assumption	different from segment-average factor used for cumulative total
A_WATER_ENDPOINT_FACTOR_YEAR30	water	0.35–0.65 fraction of 2025 intensity	scenario A annual horizon value	scenario assumption	different from segment-average factor used for cumulative total
A_WATER_ENDPOINT_FACTOR_YEAR50	water	0.20–0.50 fraction of 2025 intensity	scenario A annual horizon value	scenario assumption	different from segment-average factor used for cumulative total
SOLID_CONTROL_FACTOR_A_YEAR5	air	0.50–0.75 fraction of 2025 solids intensity retained	scenario A annual horizon value	scenario performance assumption	registered solids not ambient particulate concentration
SOLID_CONTROL_FACTOR_A_YEAR15	air	0.30–0.60 fraction of 2025 solids intensity retained	scenario A annual horizon value	scenario performance assumption	registered solids not ambient particulate concentration
SOLID_CONTROL_FACTOR_A_YEAR30	air	0.20–0.50 fraction of 2025 solids intensity retained	scenario A annual horizon value	scenario performance assumption	registered solids not ambient particulate concentration
SOLID_CONTROL_FACTOR_A_YEAR50	air	0.10–0.40 fraction of 2025 solids intensity retained	scenario A annual horizon value	scenario performance assumption	registered solids not ambient particulate concentration
A_COAL_YEAR5	coal production	150–180 million tonnes per year	scenario A endpoint year 5	scenario assumption	controlled decline variant; strict-continuation variant requires separate sensitivity
A_COAL_YEAR15	coal production	80–140 million tonnes per year	scenario A endpoint year 15	scenario assumption	not a forecast

Parameter	Subject	Range	Use in model	Source / status	Constraint
A_COAL_YEAR30	coal production	20–80 million tonnes per year	scenario A endpoint year 30	scenario assumption	not a forecast
A_COAL_YEAR50	coal production	0–30 million tonnes per year	scenario A endpoint year 50	scenario assumption	not a forecast
B_COAL_YEAR5	coal production	0–20 million tonnes per year	scenario B endpoint year 5	scenario assumption	sharp phase-out
B_COAL_YEAR10	coal production	0–0 million tonnes per year	scenario B endpoint year 10	scenario assumption	upper path reaches zero after residual output
C_COAL_FROM_YEAR5	coal production	230–255.3 million tonnes per year	scenario C sustained stress-test	scenario assumption anchored to 2018 high level	50-year continuation is a stress test not a market forecast
A_RECLAMATION_YEAR5	land	10–20 thousand hectares cumulative	scenario A managed work	scenario performance assumption	technical and biological reclamation not original ecosystem recovery
A_RECLAMATION_YEAR15	land	35–70 thousand hectares cumulative	scenario A managed work	scenario performance assumption	capped by eligible sites
A_RECLAMATION_YEAR30	land	80–140 thousand hectares cumulative	scenario A managed work	scenario performance assumption	capped by eligible sites
A_RECLAMATION_YEAR50	land	120–180 thousand hectares cumulative	scenario A managed work	scenario performance assumption	arithmetic land balance has no invented floor; reclaimed hectares are not equivalent to restored ecosystem hectares
B_RECLAMATION_RATE	land	0.1–1.0 thousand hectares per year	scenario B weak and declining work	scenario assumption	spontaneous vegetation counted separately and does not prove reclamation
C_RECLAMATION_RATE	land	0.5–1.5 thousand hectares per year	scenario C insufficient work	scenario assumption	below or near recent official annual flow

10.3. Model results: 15_SCENARIO_RESULTS.csv

12 combinations of scenario and time horizon. One wide machine table is divided into three readable tables without changing the values.

Extraction, waste and water

Scenario	Years	Coal production, billion tonnes	New waste-equivalent, billion tonnes	Without a confirmed decision, billion tonnes	Water withdrawal by active operations, billion m ³
A	5	0.852–0.927	9.8–14.9	5.4–11.2	1.44–1.76
A	15	2.002–2.527	23.0–40.7	9.2–26.4	2.94–4.47
A	30	2.752–4.177	31.6–67.2	7.9–33.6	3.68–6.94
A	50	2.952–5.277	33.9–85.0	5.1–29.7	3.82–8.36
B	5	0.477–0.527	5.5–8.5	4.4–8.1	0.95–1.05
B	15	0.477–0.577	5.5–9.3	4.4–8.8	0.95–1.15
B	30	0.477–0.577	5.5–9.3	4.4–8.8	0.95–1.15
B	50	0.477–0.577	5.5–9.3	4.4–8.8	0.95–1.15
C	5	1.052–1.115	12.1–18.0	9.7–17.1	1.89–2.22
C	15	3.352–3.668	38.5–59.1	30.8–56.1	6.02–7.32
C	30	6.802–7.498	78.2–120.7	62.6–114.7	12.21–14.96
C	50	11.402–12.604	131.1–202.9	104.9–192.8	20.47–25.14

Disturbed and restored lands

Scenario	Years	Newly disturbed land, thousand hectares	Reclaimed, thousand hectares	Remaining disturbed lands, thousand hectares
A	5	17.8–19.9	10–20	121–134
A	15	41.8–54.3	35–70	95–143
A	30	57.5–89.8	80–140	41–133
A	50	61.7–113.5	120–180	5–117
B	5	10.0–11.3	1.5–5	129–133
B	15	10.0–12.4	2.5–10	124–134
B	30	10.0–12.4	4–17.5	116–132
B	50	10.0–12.4	6–27.5	106–130
C	5	22.0–24.0	2.5–7.5	138–145
C	15	70.1–78.9	7.5–22.5	171–195
C	30	142.2–161.2	15–45	221–270
C	50	238.3–271.0	25–75	287–370

Methane and climate effect

Scenario	Years	Methane, million tonnes	Climate effect (GWP100), million tonnes CO ₂ e
A	5	1.38–3.27	41–98
A	15	2.67–10.32	80–307
A	30	3.12–15.42	93–459

Scenario	Years	Methane, million tonnes	Climate effect (GWP100), million tonnes CO ₂ e
A	50	3.19–18.61	95–555
B	5	1.19–2.19	35–65
B	15	2.14–7.18	64–214
B	30	2.86–11.36	85–339
B	50	3.15–14.55	94–434
C	5	2.62–4.63	78–138
C	15	8.36–15.24	249–454
C	30	16.96–31.15	505–928
C	50	28.42–52.37	847–1561

10.4. Conditional health calculations: 17_HEALTH_CONDITIONAL_CALCULATIONS.csv

6 outcomes. These are risk functions for individual new cases of specific diseases for a given change in PM_{2.5}, and not a ready-made forecast for the population of Kuzbass.

Initial risk functions

Outcome	ICD-10	Age	RR at 10 µg/m ³	95% CI	WHO range, µg/m ³
Childhood asthma	J45	0–18	1.34	1.10–1.63	5–40
COPD	J41–J44	30+	1.18	1.13–1.23	5–25
Acute myocardial infarction	I21–I22	30+	1.13	1.05–1.22	5–65

Outcome	ICD-10	Age	RR at 10 µg/m³	95% CI	WHO range, µg/m³
Stroke	I60–I64	30+	1.12	1.05–1.20	5–35
Hypertension	I10–I11	30+	1.16	1.05–1.30	5–75
Lung Cancer	C34	30+	1.16	1.10–1.23	5–45

Conditional change in risk, %

Outcome	–5 µg/m³	–10 µg/m³	+5 µg/m³	+10 µg/m³	Cases prevented per 1000 initial
Childhood asthma	13.6	25.4	15.8	34.0	–5: 136 –10: 254
COPD	7.9	15.3	8.6	18.0	–5: 79 –10: 153
Acute myocardial infarction	5.9	11.5	6.3	13.0	–5: 59 –10: 115
Stroke	5.5	10.7	5.8	12.0	–5: 55 –10: 107
Hypertension	7.2	13.8	7.7	16.0	–5: 72 –10: 138
Lung Cancer	7.2	13.8	7.7	16.0	–5: 72 –10: 138

Formulas, sources and limitations

Outcome	Formula	Source	Status	Constraints
Childhood asthma	$1-RR^{(-\Delta C/10)}$	SRC-WHO-HRAPIE2-2025	conditional	Not a Kuzbass forecast; wide interval; base rate of new cases and actual PM2.5 required
COPD	$1-RR^{(-\Delta C/10)}$	SRC-WHO-HRAPIE2-2025	conditional	Do not apply outside the suggested range without separate justification; smoking and occupation required for interpretation
Acute myocardial infarction	$1-RR^{(-\Delta C/10)}$	SRC-WHO-HRAPIE2-2025	conditional	Age structure, baseline incidence and stable recording required
Stroke	$1-RR^{(-\Delta C/10)}$	SRC-WHO-HRAPIE2-2025	conditional	Age structure, baseline incidence and stable recording required
Hypertension	$1-RR^{(-\Delta C/10)}$	SRC-WHO-HRAPIE2-2025	conditional	Detectability highly dependent on access to primary care and blood pressure measurement
Lung Cancer	$1-RR^{(-\Delta C/10)}$	SRC-WHO-HRAPIE2-2025	conditional	Long lag; smoking, occupation, age and past exposure; do not use the municipal series of all crayfish as the basis

SECTION 11

Source register

SRC-KUZ-REPORT-2025

Document: “Report on the state and protection of the environment of the Kemerovo region - Kuzbass in 2025.” Ministry of Natural Resources and Ecology of Kuzbass, Kemerovo, 2026.

Public PDF: <https://kuzbassec.ru/wp-content/uploads/2026/04/%D0%94%D0%9E%D0%9A%D0%9B%D0%90%D0%94-2025-%D0%BD%D0%B0-01.05.2026.pdf>

Local copy: [research/soil-restoration/papers/KUZ-010_Kuzbass_environment_report_2025.pdf](#)

Sections used:

- atmospheric air: printed p. 26–38;
- water: printed p. 60–103, especially 87–88 and the conclusion on p. 443;
- disturbed lands: printed p. 111–112;
- waste: printed p. 256–261;
- conclusion: printed p. 442–444.

Status: official regional summary report. Many values are based on federal statistical survey forms. For the coal sector, sectoral cross-section tables are needed when available.

SRC-RPN-WASTE-2025

Document: Rosprirodnadzor, “Rosprirodnadzor has generated official statistics on waste management in 2025.”

URL: https://rpn.gov.ru/press/news/rosprirodnadzor_sformiroval_ofitsialnuyu_statistiku_ob_obrashchenii_s_otkhodami_v_2025_godu/

Basic values: waste generation in Russia - 7.841 billion tonnes; recycling - 1.873 billion tonnes; neutralization - 9.8 million tonnes; storage - 3.873 billion tonnes; disposal - 1.896 billion tonnes.

Limitation: the final publication does not replace the original table 2-TP (waste), necessary for a detailed sectoral and regional breakdown.

SRC-KUZ-REPORT-2024

Document: “Report on the state and protection of the environment of the Kemerovo region - Kuzbass in 2024.” Ministry of Natural Resources and Ecology of Kuzbass, Kemerovo, 2025.

Public PDF: https://kuzbassec.ru/wp-content/uploads/2025/07/doklad_v2_.pdf

Section used: disturbed lands, printed p. 127, PDF-p. 125–126.

Data: at the beginning of 2024 - 96.471 thousand hectares of disturbed land; 4.768 thousand hectares were disturbed during the year, including 4.264 thousand hectares during field development; 2.083 thousand hectares were reclaimed; at the end of the year - 99.156 thousand hectares.

Critical limitation: the next annual report already indicates 120.280 thousand hectares at the beginning of 2025. The gap of 21.124 thousand hectares between two neighboring official remains in the audited sections is not explained. Therefore, the balances from 2024 and 2025 cannot be combined as a continuous series without additional methodological explanation from Rosprirodnadzor or the compilers of the report.

SRC-RPN-WASTE-2024

Document: Rosprirodnadzor, “The results of Form 2-TP (waste) for 2024 have been summed up.”

URL: https://rpn.gov.ru/press/news/podvedeny_itogi_po_forme_2_tp_otkhody_za_2024_god/

Basic values: 8.5 billion tonnes of waste in Russia in 2024; about 90% came from mining.

Key disclaimer: decrease relative to 2023 is partly due to changes in legislation - part of the overburden and host rocks, when used according to subsoil use rules, ceased to be counted as waste, and some materials received the status of by-products.

SRC-WATER-CORPUS

Case: materials from the study “Where does the water go.”

Main text: `src/content/water-kuzbass-ru.md`

Public article: <https://www.nataliazubkova.com/en/work/where-the-water-goes/>

Purpose in the new study: mechanisms of open-pit drainage, changes in watersheds and channels; documented cases; the absence of a single open series “initial state → forecast → result” for some objects.

SRC-SOIL-CORPUS

Case: `research/soil-restoration/`

Key files:

- `RESEARCH_SYNTHESIS_HANDOFF.md`;
- `SOIL_RESTORATION_EVIDENCE_RU_V1.0_SOURCE_REGISTRY.md`;
- `SCENARIO_ECONOMIC_MODEL.md`;
- `ECONOMIC_MODEL_INPUTS.md`.

Limitation: the previous model of a 100-hectare complex dump is a scenario, and not an estimate for Apanas or the entire Kuzbass. Monetary rates require updating and confirmation by comparable projects before use in a new article.

SRC-DUMPS-CORPUS

Case: “Coal price - rock dumps of Kuzbass”, version 1.2.

Path: Готовые издания/Цена угля — породные отвалы Kuzbass/v1.2/Исходники/

Key tables:

- assets/data/16_Полная_таблица_доказательств.csv ;
- assets/data/09_Сравнительные_кейсы_Kuzbass.csv ;
- assets/data/08_Апанас_финансы.csv ;
- assets/data/07_Апанас_хронология.csv .

Purpose: confirmed specific objects, temperature and gas measurements, administrative and judicial documents, contracts and costs for Apanas.

Limitation: The selection of known sites does not constitute a complete regional inventory of burning or self-heating waste dumps.

SRC-KUZ-WASTE-SCHEME-2026

Document: Resolution of the Government of Kemerovo Oblast — Kuzbass dated 11.03.2026 No. 127, new edition of the territorial waste management scheme.

URL: <https://kemerovo-pravo.ru/postanovlenie/2026/03/11/n-127/>

Table 4: for 2024; At the beginning of the year, 27,556.325766 million tonnes of waste not related to MSW were accumulated.

Limitation: this is the stock of all accounted non-MSW, and not just coal waste; the table does not show the finished balance of coal waste at the end of 2024.

SRC-KUZ-CIRCULAR-2026

Document: Resolution of the Government of Kemerovo Oblast — Kuzbass dated 05.02.2026 No. 61, the comprehensive regional programme “Circular Economy”.

URL: <https://kemerovo-pravo.ru/postanovlenie/2026/02/05/n-61/>

Data: in 2024, the region generated 3.3 billion tonnes of waste; Mining enterprises produced 3.256 billion tonnes, or 98.3%.

Limitation: "mining" is broader than coal mining.

SRC-MINING-INTERVIEW-2026

Material: “The coal industry - from the phenomenon of restructuring to modern problems and ways to solve them,” “Mining Industry” magazine.

URL: <https://science.mining-media.ru/ru/article/interview/20111-ugolnaya-otrasl-ot-fenomena-restrukturizatsii-do-sovremennykh-problem-i-putej-ikh-resheniya>

Data: 3.2 billion tonnes of coal mining waste in Kuzbass in 2024; 27.5 billion tonnes accumulated by the end of the year; 65.9% and 91.0% of the corresponding Russian industry values.

Status: professional secondary source. Until the original official table is found, the values are used as preliminary and rounded values.

SRC-KUZ-COAL-2025

Document: Kuzbass Ministry of Coal Industry, “Key Indicators of the Kuzbass Coal Industry in 2025”, 23.01.2026.

URL: <https://mupk42.ru/ru/press-center/news/novosti-ministerstva/osnovnye-pokazateli-ugolnoy-otrasli-kuzbassa-v-2025-godu/>

Data: production 190.7 million tonnes; processing 144.7 million tonnes; shipment 168.3 million tonnes.

SRC-KUZ-COAL-2019

Document: Ministry of Coal Industry of Kuzbass, results of 2019.

URL: <https://www.mupk42.ru/ru/press-center/news/novosti-ministerstva/258530/>

Data: 250.1 million tonnes in 2019 and 255.3 million tonnes in 2018; for 2018, separately 165.8 million tonnes by open pit and 89.5 million tonnes by underground method.

SRC-RU-COAL-PROGRAM-2035

Document: Development program of the Russian coal industry for the period until 2035, new edition.

URL:

https://minenergo.gov.ru/upload/iblock/ee4/ngpuwtmbm0h7iz66p6mzig3h2iinntai/Programa_razvitiya_ugolnoy_promyshlennosti_Rossii_na_period_do_2035_goda_novaya_redakciya.pdf

Data: for Kuzbass in 2018, 255.7 million tonnes are indicated. The difference from 255.3 million tonnes in the regional message should be preserved and explained if a methodological reason is found.

SRC-KUZ-COAL-STRUCTURE-2026

Document: Kuzbass Ministry of Coal Industry, announcement concerning the Fifth Russian Coal Summit, 02.10.2026.

URL: <https://www.mupk42.ru/ru/press-center/news/novosti-ministerstva/v-rossiyskiy-ugolnyy-sammit-strategicheskaya-ploshchadka-dlya-dialoga-i-resheniy/>

Data: 150 operating coal enterprises - 38 mines, 55 open-pit mines, 57 processing plants and sorting plants.

Limitation: wording does not provide a register of names and does not explain the relationship with previously reported temporarily suspended enterprises.

SRC-KUZ-SUSPENDED-2025

Materials: media reports dated 08/20/2025 with reference to the response from the Ministry of Coal Industry of Kuzbass.

URL: <https://kuzbass.aif.ru/money/v-kuzbasse-uvlichilos-chislo-priostanovivshih-rabotu-ugolnyh-predpriyatiy>

Data: 15 enterprises temporarily suspended operations - 6 mines and 9 open-pit mines.

Limitation: is not the ministry's primary published table; names not disclosed; “suspended” must not be translated as “closed.”

SRC-ROSTEKH-INTERVIEW-2025

Material: interview with the head of the Siberian department of Rostekhnadzor in the magazine “Coal of Kuzbass”, No. 1, 2025, “At the highest level”.

PDF: <https://www.uk42.ru/assets/files/IMG/2025/01/UK-2025-01-WEB.pdf>

Web version: <https://www.uk42.ru/index.php?id=18847>

Data: There were 275 hazardous production facilities in the coal industry under the supervision of the department. These included 60 Class I “coal mine” hazardous production facilities: 39 operating, 11 mothballed, 9 undergoing closure and 1 under construction. The 210 Class II hazardous production facilities comprised 119 open-pit mines, 56 processing plants, and 35 tailings facilities and waste heaps. The status breakdown for open-pit mines and processing plants was reported only in aggregate: 200 operating, 1 mothballed, 8 undergoing closure and 1 under construction.

Limitations: This is an interview with the supervisory authority published in an industry journal and not a government register download. A hazardous production facility is a unit of industrial supervision, not necessarily a legal entity, enterprise or license. The combined total of 200 operating facilities cannot be described as 200 operating open-pit mines. These data have a different date and accounting basis than the regional ministry’s report of 38 mines, 55 open-pit mines and 57 processing facilities in October 2026.

SRC-RPN-KUZ-INSPECTION-2024

Document: Rosprirodnadzor, “Rosprirodnadzor, on behalf of the Government of the Russian Federation, checked the activities of subsoil users in Kuzbass,” 2024.

URL:

https://rpn.gov.ru/press/news/rosprirodnadzor_po_porucheniyu_pravitelstva_rossiyskoy_federatsii_proveril_deyatelnost_nedropolzovat/

Data: a comprehensive program provided for the closure of 22 mines in Prokopyevsk, Kiselevsk and Anzhero-Sudzhensk in two stages - 2015–2020 and 2021–2023. When checking more than 3.5 thousand hectares of land subject to reclamation, more than 1.9 thousand hectares, or over 54%, were excluded from obligations due to the transfer of land to other persons without obligations for reclamation and the exclusion of work from design decisions. Inappropriate monitoring of deformations and movements of the earth's surface and the absence of part of the geological and surveying documentation were also noted.

Limitation: The number 22 describes the scope of the mine-closure programme, not the confirmed number of mines that have been fully and safely closed to date. A change in legal or design obligation does not prove physical restoration of the land.

SRC-UK-MRA-2024-25

Document: Mining Remediation Authority, Annual report and accounts 2024–2025.

URL:

https://assets.publishing.service.gov.uk/media/68a6ebb09e1cebdd2c96a083/Mining_Remediation_Authority_annual_report_and_accounts_2024_to_2025.pdf

Data: liability reserve £1.709 billion; undiscounted future cash flows £4.0604 billion; for mine waters - cash flows for 100 years due to the lack of a foreseeable opportunity to stop part of the treatment.

SRC-UK-MINE-WATER-O&M-2026

Document: Mining Remediation Authority O&M contract 2026.

URL: <https://www.gov.uk/government/news/new-operation-and-maintenance-contract-awarded-to-alpheus>

Data: £203 million over eight years for 82 mine-water treatment schemes, 10 pumping stations, and more than 700 monitoring points with continuous support.

SRC-UK-COAL-AUTHORITY-2020-21

Document: Coal Authority annual report and accounts 2020–2021, financial statements.

URL: <https://www.gov.uk/government/publications/the-coal-authority-annual-report-and-accounts-2020-2021/the-coal-authority-annual-report-and-accounts-2020-to-2021-financial-statements>

Data: for 54 deferred schemes average construction estimate £2.9m and operation £0.1m per annum; general mine water reserve £2.010 billion; Calculation of cash flows for 100 years.

SRC-UNECE-AMM

Document: UNECE, Best Practice Guidance for Effective Methane Recovery and Use from Abandoned Coal Mines.

URL: <https://unece.org/sites/default/files/2024-01/BPG%20on%20AMM.pdf>

Data: Methane from closed mines can be released for decades; the value depends on the residual coal and gas, the disturbed massif, flooding and the ability to control leaks.

SRC-EPA-AMM

Document: US EPA, Methane Emissions from Abandoned Coal Mines: inventory methodology.

URL: https://www.epa.gov/system/files/documents/2022-02/amm_final_report_v2.pdf

Data: emissions decline rapidly in the first years after closure, then flatten over the decades; Shaft size, flooding, sealing, permeability and water saturation are significant.

SRC-IPCC-AR6-GWP

Document: IPCC, Sixth Assessment Report, Working Group I, Chapter 7, table 7.15.

URL: <https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-7/>

Data: for fossil methane GWP₂₀ is 82.5, GWP₁₀₀ is 29.8. The quantitative model uses GWP₁₀₀ = 29.8 tCO_{2e}. per 1 t CH₄.

Limitation: CO₂-equivalent is a comparative climate metric, not a CO₂ mass or a direct temperature forecast. The result depends on the selected horizon; for the short-term effect of methane, GWP₂₀ is significantly higher.

SRC-RU-ENV-REPORT-DRAFT-2024

Document: draft state report on the state and protection of the environment of the Russian Federation for 2024, edition 06.11.2025, table 5.4; The source of the table is data from the Russian Ministry of Energy.

PDF: <https://xn--e1ajfjnk8a.xn--p1ai/wp-content/uploads/Proekt-Gosudarstvennogo-doklada-06.11.2025.pdf>

Data: for Kuzbass in the gas-dynamic monitoring of closed mines, 58 residential properties are listed: 14 in hazardous and 44 in endangered areas; a total of 69 controlled objects, 808 measurements and 42 samples.

Limitation: is a draft report, and not the final official version we found. The monitoring sample is not equal to the number of all houses near mines, open pits and dumps and should not be used to estimate the total number of families resettled.

SRC-UK-MINE-WATER-REBOUND

Document: Environment Agency, review of mine water rebound forecasting.

URL: <https://assets.publishing.service.gov.uk/media/5a7ccf88ed915d63cc65cfa3/str-w179-e-e.pdf>

Data: cessation of drainage causes flooding of workings; surface discharges of contaminated water and flow into neighboring aquifers are possible; timing requires a hydrogeological model of a specific object.

SRC-AYUTINSKAYA-13BIS-2021

Document: purchase No. 0173100008321000008 for extinguishing the dump No. 13 bis of the Ayutinskaya mine.

Official card: <https://zakupki.gov.ru/epz/order/notice/oku504/view/common-info.html?regNumber=0173100008321000008>

Reserve card: <https://poisktenderov.ru/item/0173100008321000008/>

Data: starting price RUB 190.572.857, 2021.

SRC-STROYSERVICE-RECLAMATION-2024

Material: message about the advanced reclamation program of Stroyservis JSC.

URL: <https://www.interfax-russia.ru/siberia/news/kuzbasskiy-stroyservis-rekultiviruet-eshche-1-2-tys-ga-otrabotannyh-uchastkov-ugledobychi>

Data: first stage - more than 3.2 billion rubles. and 500 hectares in three years; second stage - about 5 billion rubles. and more than 1,200 hectares until 2028.

Limitation: message is based on company data; the full composition of costs and environmental performance criteria are not disclosed in the open communication.

SRC-ITS-COAL-2024

Document: ITS 17-2024 “Disposal of production and consumption waste”, section on coal industry facilities.

URL: https://meganorm.ru/mega_doc/norm_update_29032025/zaklyuchenie/0/its_17-2024_informatsionno-tekhnicheskoy_spravochnik_po.html

Data: GRRORO across Russia has registered 312 dumps of overburden, waste and enclosing rocks from coal mining.

Limitation: the registry number for Russia is not equal to the number of physical dumps and does not give the number of objects in Kuzbass or the number of burning objects.

SRC-PORTOLA-2024

Document: Portola, Protasov, Seregin, study of spontaneous combustion of rock dumps, 2024.

DOI: <https://doi.org/10.30686/1609-9192-2024-4-140-145>

Data: 15 wells on the studied Kuzbass dumps; temperature at a depth of 0.5 m 35–433°C; CH₄, CO, SO₂, H₂S and O₂ measurements.

Limitation: the sample and number of wells do not represent a regional census of burning dumps.

SRC-WHO-HRAPIE2-2025

Document: World Health Organization Regional Office for Europe. *Health risks of air pollution in Europe: HRAPIE-2 project. Updated guidance on concentration–response functions for health risk assessment of air pollution in the WHO European Region.* 2025.

Official page: <https://www.who.int/publications/i/item/9789289062633>

Data: section 3.1 and figure 5 suggest relative risk functions of disease for every 10 µg/m³ of annual mean PM_{2.5}: childhood asthma 1.34 (95% CI 1.10–1.63), COPD 1.18 (1.13–1.23), acute myocardial infarction 1.13 (1.05–1.22), stroke 1.12 (1.05–1.20), hypertension 1.16 (1.05–1.30), lung cancer 1.16 (1.10–1.23). Table 2 shows the mortality functions separately.

Limitation: are functions for assessing risk for a known change in concentration, and not an emission model or PM_{2.5} forecast for Kuzbass. WHO provides age and concentration ranges of applicability. The transfer requires local exposure, baseline incidence, population, and enrollment data.

SRC-WHO-DRINKING-WATER-2026

Document: World Health Organization. *Guidelines for drinking-water quality: fourth edition incorporating the first, second and third addenda*. 2026.

Official page: <https://www.who.int/publications/i/item/9789240121225>

Data: Chemical risk assessment is based on the specific hazard, concentration, likelihood and duration of exposure and actual water consumption; the recommendations use risk management from the catchment to the consumer and independent oversight.

Limitation: The guidance does not allow the number of diseases to be inferred from the total volume of mine or industrial discharge without the chemical composition and actual exposure of the population.

SRC-KUZ-HEALTH-2007

Document: environmental report of the Kemerovo region for 2007, section 5.1 on public health.

URL: <https://kuzbasseco.ru/002/5.1.html>

Data: report reports changes in the newly identified incidence of diseases of the circulatory system in 2003–2007: an increase of two times in adults, 1.7 times in adolescents and 45.9% in children.

Limitation: historical regional indicators are not near Kiselevsk, do not standardize future scenarios and do not separate the contribution of industrial pollution from age, behavior, profession, diagnosis and other factors.

SRC-KISELEVSK-CANCER-2025

Document: regional program of the Kemerovo region - Kuzbass “Fight against cancer” for 2025–2030.

URL: <https://base.garant.ru/412627749/>

Data: found municipal indicators of newly diagnosed malignant neoplasms in Kiselevsk: 258.4 per 100 thousand inhabitants in 2007, 302.9 in 2020, 479.2 in 2023 and 440.8 in 2024.

Limitation: these are all malignant neoplasms, not lung cancer; the series has gaps, is rough, is not standardized by age and depends on the diagnosis and completeness of registration. It is not used as the basis for a quantitative model of lung cancer.

SRC-KUZ-VPR-CORPUS

Materials: collected body of research “Congenital malformations in Kuzbass”, including publications by A. V. Bachina, P. E. Saltykova and co-authors, works by O. Gulyaeva and international studies of coal areas.

Public article and list of primary sources: <https://www.nataliazubkova.com/en/work/vpr-kuzbass/>

Local master: ../vpr-kuzbass/ARTICLE_VPR_KUZBASS_RU_PUBLICATION_V1.0.md

Data: official registered diagnoses of congenital malformation, area studies, prenatal outcomes and studies of possible vulnerability; international positive, null and contradictory results.

Limitation: For Kuzbass, no study was found that combines in one sample the individual exposure of both parents, critical weeks of pregnancy, a specific defect and all pregnancy outcomes. The corpus does not provide functions for percentage forecast of CDF for scenarios.

SRC-KISELEVSK-AIR-CORPUS

Material: “The Day When the Air Was Measured” - a study of official responses and measurements in Kiselevsk.

URL: <https://www.nataliazubkova.com/en/work/air/>

Data: response from the Kemerovo Central State Medical Station dated April 22, 2020 reports that regular state network observations of air pollution in Kiselevsk and the district were not carried out; The material discusses one-time measurements of December 2020 and their limitations.

Limitation: single measurements do not reconstruct the population's average annual PM_{2.5}, past pregnancies, or personal dose. Therefore, they do not calibrate a quantitative risk function.