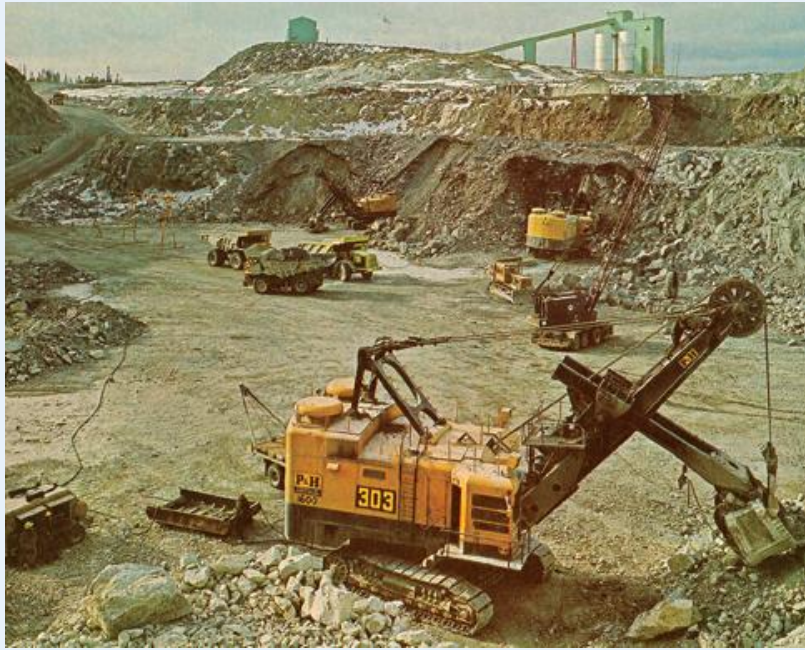




[1]



[2]

The Last Shift

Click to start



By the end of this DTM, you will be able to:

- Define the main components of sustainable mine closure
- Describe different post-mining land use strategies
- Examine rehabilitation approaches using real-world cases

How to study this DTM

Your path through the DTM:

1. Look for interactive buttons 
2. Start at the main hub and click an item to see its details.
3. Use the Return buttons to jump back to a hub at any time.
4. Open another hub to explore the topic from a new angle.
5. Click an item to open its detailed profile page.
6. Visit each content hub to explore the full topic.
7. Finish with the Key Takeaways.

Continue



Time needed

About 60 minutes in total

Target group

Secondary level, intermediate

Format

Interactive self-study

How to explore

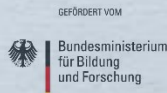
Follow along the Hubs to answer the questions

Files

Interactive slides and quiz
(NEXPERT website)



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GEFÖRDERT VOM



Grønlands Naturinstitut
Pinngortitaleriffik · Greenland Institute of Natural Resources



AARHUS UNIVERSITY



UNIVERSITY OF
EASTERN FINLAND



Institute of
Mineral
Resources
Engineering



The 100-Year Question



[3]



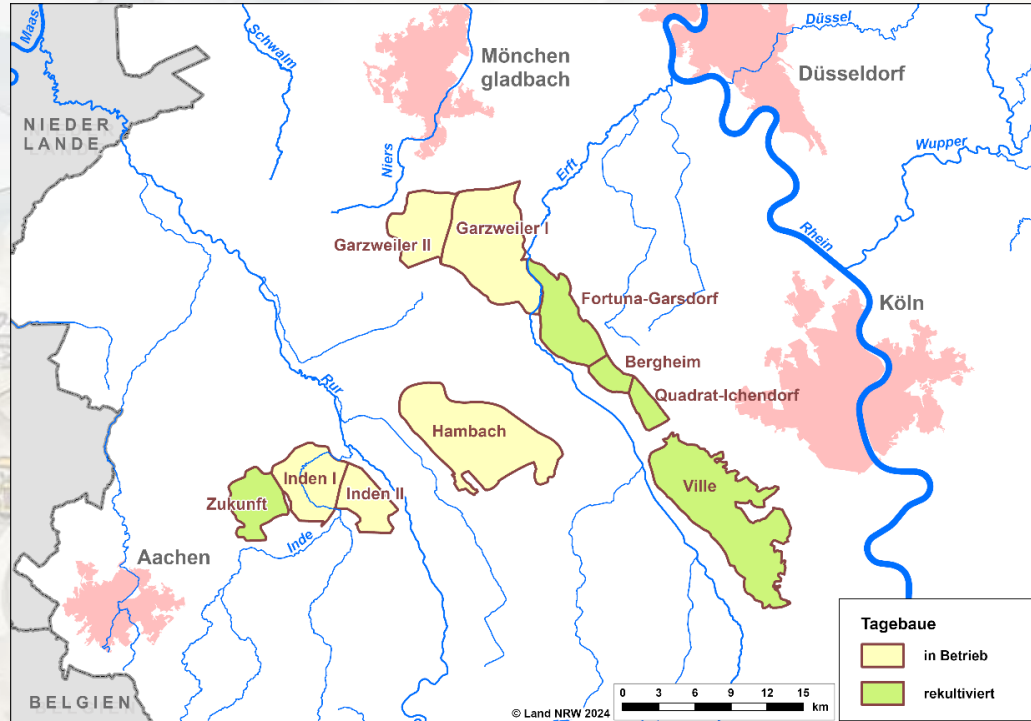
[4]

What to do with a hole in the ground when the mining operation ends?

Learn more about sustainable mine closure, its components and why it is essential to think about closure before mining starts.



Where this is happening: the Rhenish lignite basin



Active Pits (yellow):

HAMBACH

Active 1978 → planned closure 2030

GARZWEILER

Active 1983 → planned closure 2030

INDEN

Active 1957 → planned closure 2030

These three mines have supplied Germany's electricity for decades.

Together, these mines have shaped the Rhenish landscape for decades. Their closure will transform huge areas once again.

Closure and post-closure management can continue for decades after mining ends.

Let's explore what happens to a mine after the resources were

Mining changes the landscape forever



[6]

Mining removes a non-renewable resource over decades.

The landscape, soil profile and groundwater flow are permanently changed.



How can nature be restored after extracting its valuable materials?

Click below to explore the main phases when closing a mine



The four components of sustainable mine closure

Mining & environment:

Major changes occur during several years of mining affecting the ecosystem.

In the past, when mining ended, mine sites were often left on their own.

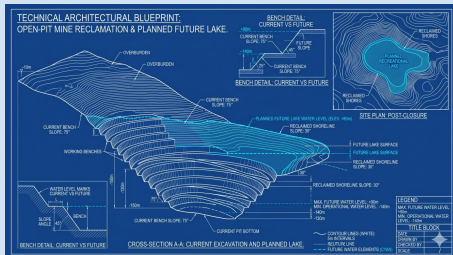
Mine waste and mine water can interact with the environment, leaving degraded landscapes and difficult conditions for new ecosystems.

Sustainable closure & land use:

Today, we know more about sensitive ecosystems and the importance of intact nature.

At the same time, population growth and the transition to renewable energy increase demand for a wide range of raw materials.

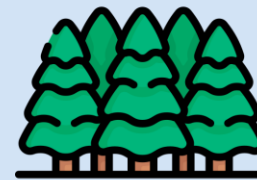
Plan



Close



Restore



Watch



Click to explore the different components of mine closure

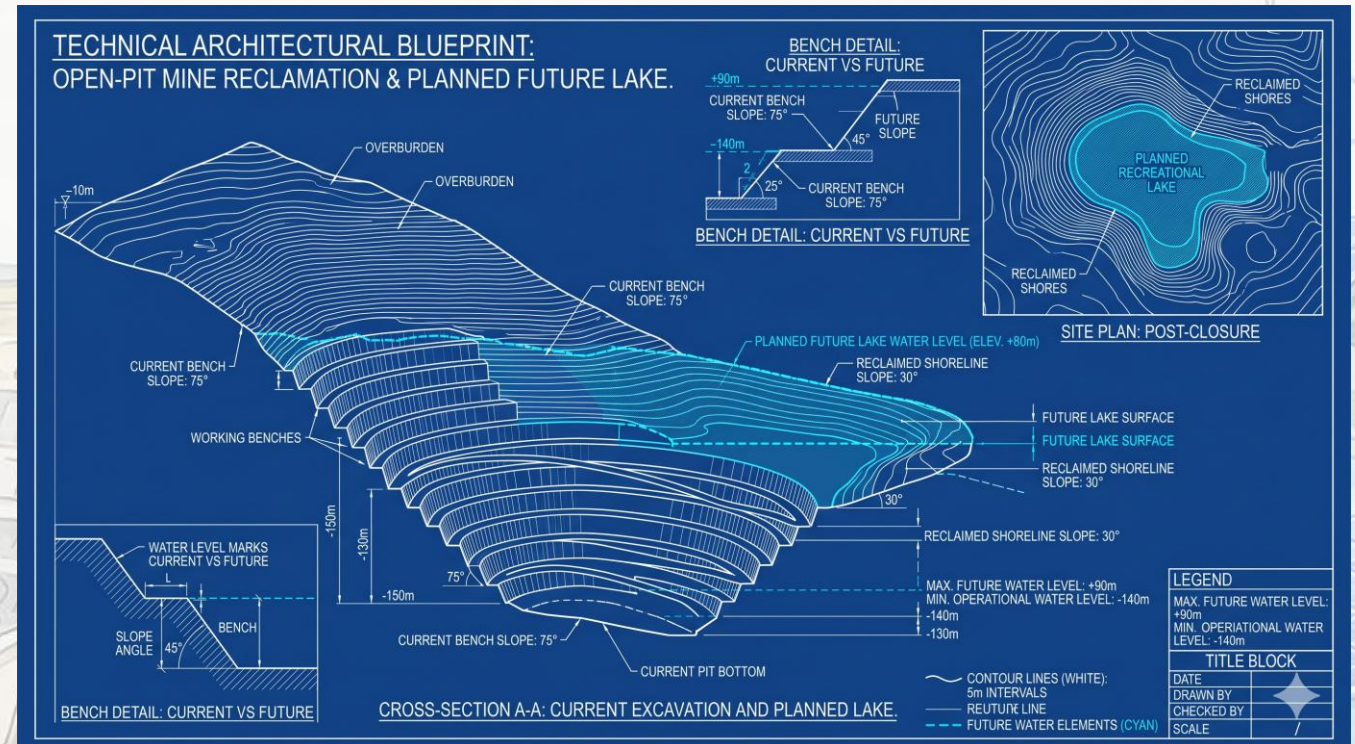


Closure-by-Design

For most of mining history, the plan was simple: **dig, then leave.**

Today the smarter approach is to design the ending before the first cut: the final shape of the pit, where the waste goes, and what the site becomes.

Planning closure early can avoid costly redesign and long-term liabilities later.



[7]

The Last Shift

When a mine reaches the end of its life, several closure options can be considered.

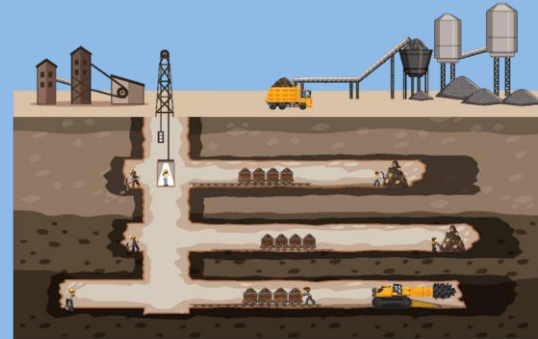
The mining type decides which options are available:



[9]

The hole in the ground

The open-pit closure path



[10]

The Swiss Cheese

The underground closure path



Choose one path to explore what can be done with holes in the ground:



Closing an open pit mine



An open pit leaves a large surface void.

Before the site can be reused, the slopes must be stabilised and the future water regime planned.

Let's use Hambach to see how this works.



[9]

Hambacher See: a lake on paper



Hambach open pit mine
Operated by RWE
Lignite
Active 1978–2030 (German coal phase-out)

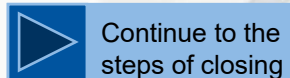
[11]



Hambach is a major example of planned pit-to-lake closure in Germany.

[12]

But before a hole can become a lake, landscape engineering is required to ensure long-lasting shoreline stability



Closing an open pit mine, step by step:

Stabilise the slopes

Once mining ends, pit walls are shaped to a long-term stable angle and loose material is compacted. Without stabilisation, rising water can increase the risk of slope

Fill the void

Water is introduced through three combined sources: rainfall, controlled river diversion, and natural groundwater rebound.

Engineer the shoreline

Shorelines are not left to form themselves. Reedbeds can help filter remaining contaminants, gently sloped beaches



Think of **closure before mining** for the most sustainable solution!

Large pit lakes can take decades to fill.
But why does it take so long?

Why can filling a pit lake take decades?



[13]

Huge volume



Large pits need enormous amounts of water.

Limited inflow



Rivers and groundwater can only supply water gradually.

Water quality matters



Rock and water chemistry may require treatment and monitoring.



Closing a mine you can't see:

1. Remove equipment

Take out fuels, cables and equipment that could contaminate water or obstruct safe closure.

2. Backfill the voids

Backfill selected workings where support is needed to reduce collapse and surface settlement.

3. Seal the shafts

Close shafts and decide how rising mine water will be managed after pumping stops.



Closing the entrance is quick. Managing ground stability and water can last much longer.



Underground mines leave a smaller visible void, but shafts, water and ground stability can remain long-term closure issues.

The underground can sometimes also be reused.



Back to
close hub

From hole to habitat.

Four primary land-use pathways have proven viable:



LAKES & TOURISM

Beaches, sailboats, holiday flats.



FOREST & BIODIVERSITY

Pioneer species thrive on poor soil.



SOLAR & WIND

Sunny, open, already grid-



INDUSTRY & INNOVATION

Use the underground for something

But first, make it safe again.

Come on and explore how soil, water and mine waste are treated!



Lake Zwenkau:



Zwenkau shows that pit-to-lake conversion can work at large scale, transforming the landscape.

Lake Hambach will be roughly four times the size of Lake Zwenkau.

Thus, filling will take much longer, around 2070



But what about the mines we don't see anymore when mining has ended?

Return to the main hub to learn about underground mine closure.



Lausitzer Seenland: one of Europe's largest man-made lake districts



[17]



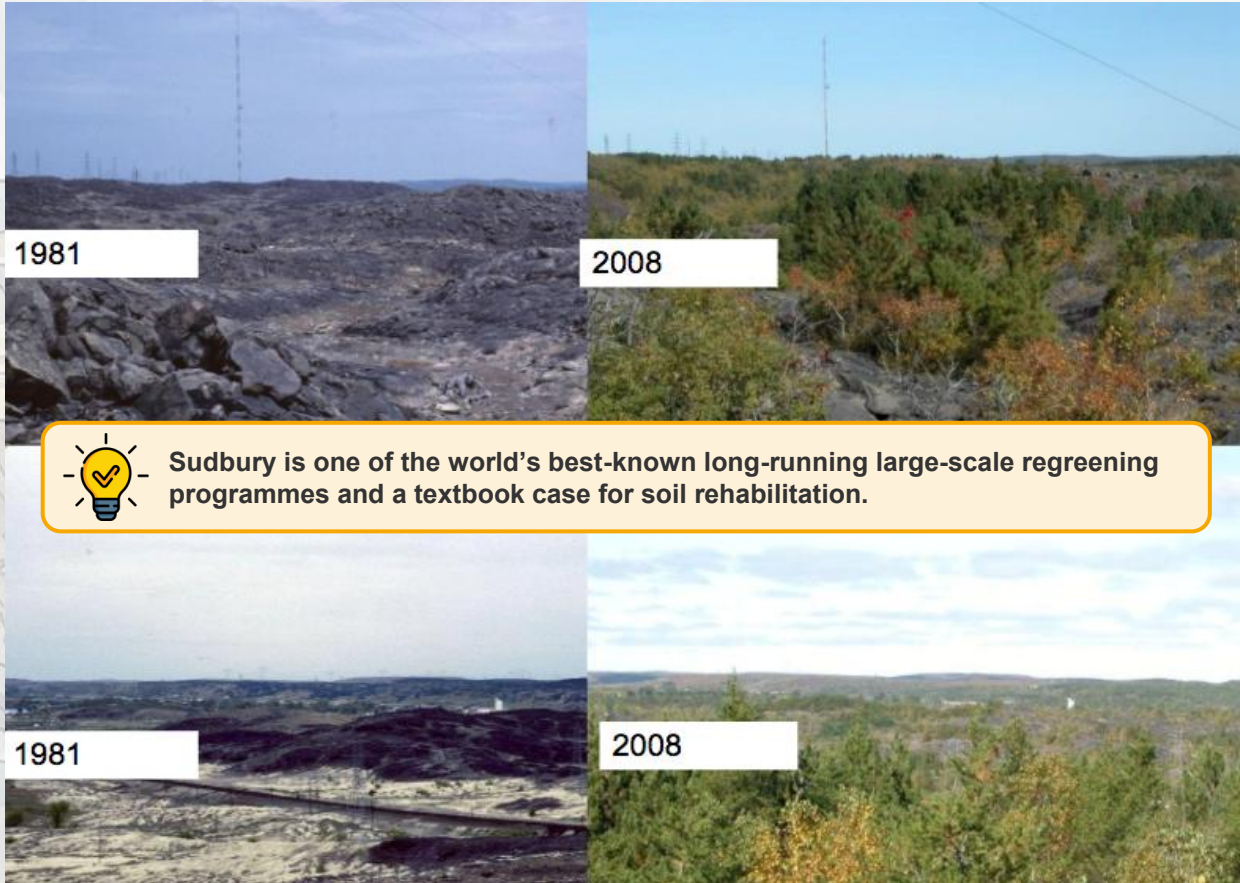
[18]

Former lignite pits across the Lausitz have been flooded, connected and transformed into a new lake landscape for recreation, tourism and nature.

Rehabilitation and water management are still continuing: a transformation spanning several decades.



Sudbury: from astronaut training moonscape to forest



Sudbury is one of the world's best-known long-running large-scale regreening programmes and a textbook case for soil rehabilitation.

Sudbury Basin, Ontario, Canada

Nickel mining since the 1880s; mining remains active today (including Vale and Glencore)

The Sudbury Regreening Program has run continuously since 1978, supported by municipal funding, mining companies and an active volunteer base.

Rehabilitation here became a long-term partnership between industry, science and the community.

How do we get vegetation back?



From damaged ground to living soil



Mining-affected soils can be acidic, metal-rich or compacted. Improving the soil conditions is the first step towards new vegetation.



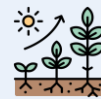
Prepare the ground

Spread crushed limestone to neutralise acid.



Fertilise & seed

Add organic matter and seed a grass mix to build new soil



Pioneer plants

Birch, alder, lupine are species that tolerate poor soil and help rebuild soil fertility for the next generation.



Native trees

Once soil conditions improve, trees and other native species can establish.

See biodiversity



Biodiversity in post-mining landscapes

Sand lizard

Lausitz, DE: warm, sparse ground



[21]

Bee orchid

Central Europe: calcareous, poor ground



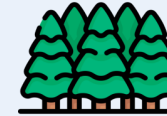
[22]

Jack pine

Sudbury, CA: pioneer tree on bare rock



[23]



Forest



Wetlands



Grassland



Open water



Post-mining land can create unusual habitats. Warm, nutrient-poor and open ground may support specialised species that have become rare in intensively used landscapes.

A mix of dry, wet, open and wooded areas can support very different species.



Tailings: the waste stream of mining

Ingredients of mine wastes:



Residual minerals

Sulfides and metals can react with air and water.



Process chemicals

Some processing methods leave chemical residues.



Water

Tailings often contain large amounts of water that must be safely contained and managed.

Tailings are the finely ground rock and process water left after valuable minerals have been separated.

Depending on the ore and process, they may contain residual minerals, process chemicals and large amounts of water.

Safe management therefore remains part of mine closure.

How are tailings managed?



Mining generates billions of tonnes of tailings each year, making tailings one of the world's largest industrial waste streams.



Tailings: the largest waste stream in mining.

How are tailings stored?

Surface storage

Tailings slurry is stored in an engineered facility. Water levels, drainage and dam stability must be controlled.

Filtered / dry stack

Much of the water is removed before the tailings are placed and compacted.

Backfill

Some tailings can be mixed into a paste and returned underground to fill mined-out voids.



[24]

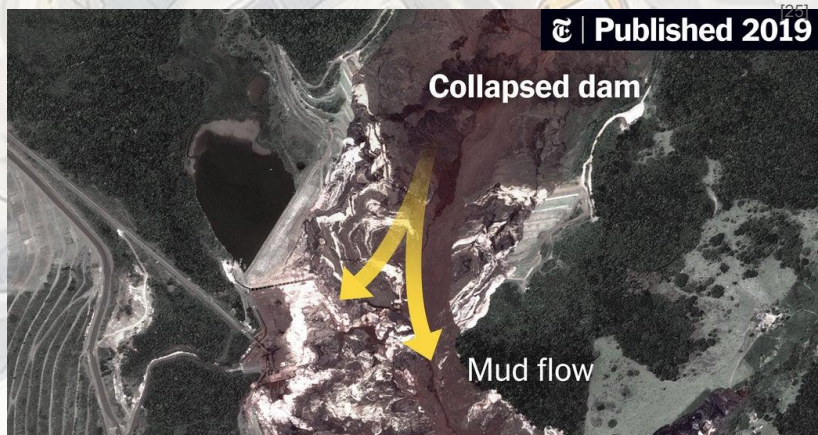


There is no single best method. The safest storage solution depends on the tailings, climate, geology and site conditions.

But what happens when storage fails?



What happens when a dam fails:



[26]

Brumadinho, 2019

An upstream tailings dam failed in Brazil in 2019. The tailings flow destroyed facilities, downstream areas and killed 270 people.



After the failure, Brazil banned new upstream dams and the disaster helped trigger the Global Tailings Review.



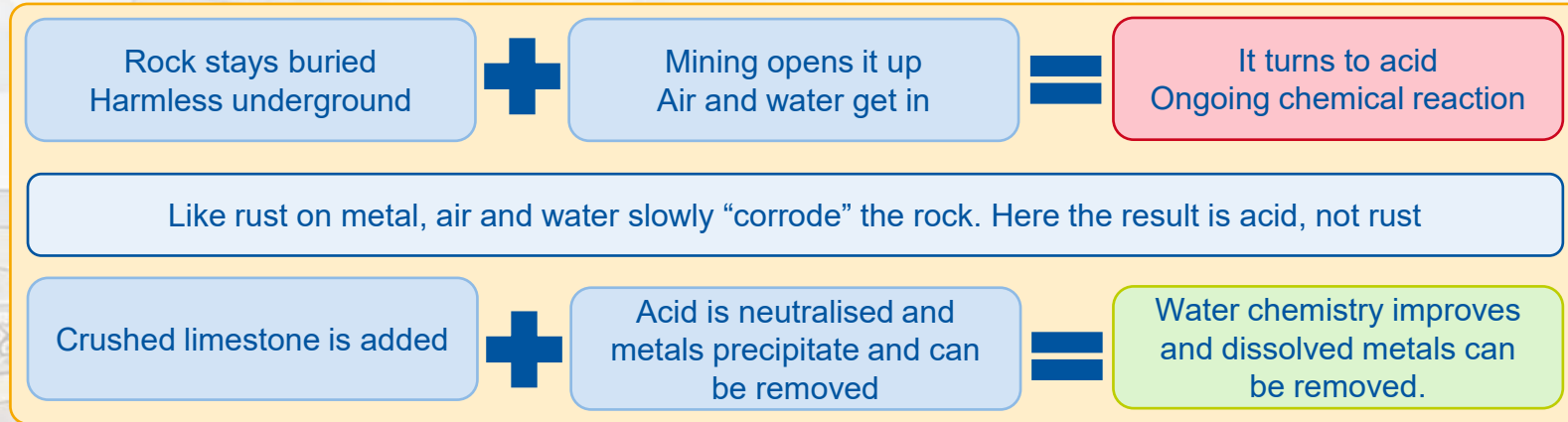
Tailings facilities remain engineered structures even after deposition stops. Stability, drainage and seepage still have to be monitored.



A dam failure is not the only risk. What happens when mine waste reacts with water?



Why mine water turns acidic, and how it's fixed:



[27]

The Río Tinto in Spain is extremely acidic; centuries of mining have strongly intensified metal-rich drainage in the basin.

Its blood-red water inspired the name of the global

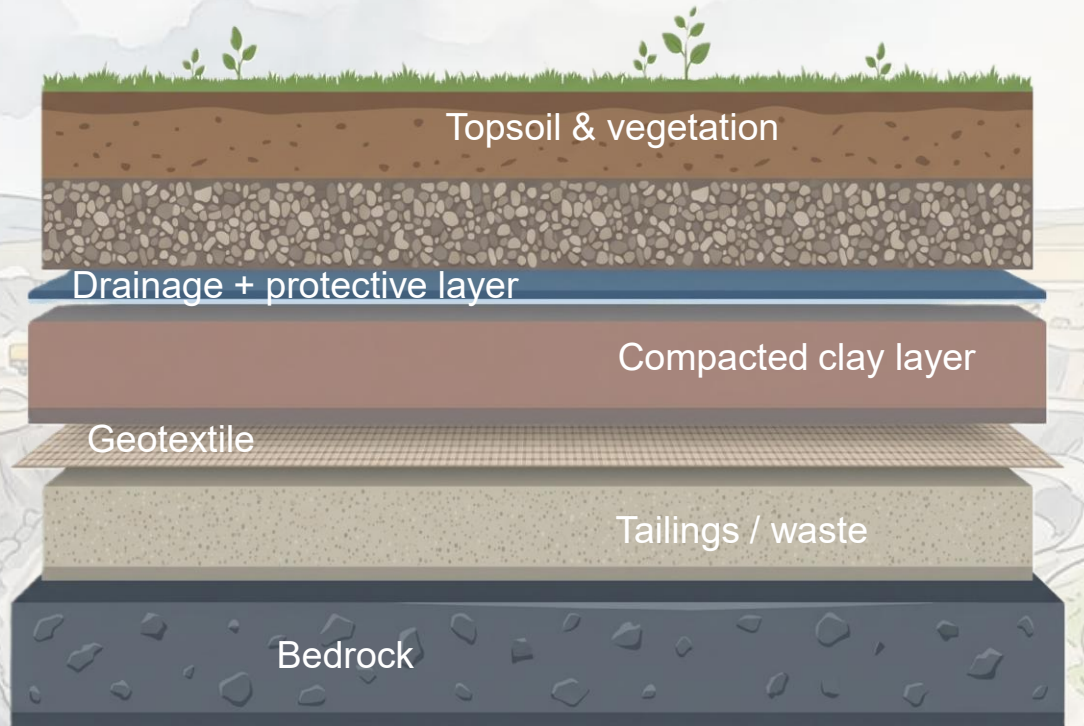


Locking waste away after closure

Some sulfide minerals react when mining exposes them to air and water.
This can produce acidic drainage and release dissolved metals.



Locking the waste away



After closure, reactive waste must be isolated from water and oxygen.

Water cover

Keep reactive material submerged so little oxygen reaches it.

Dry cover

Use low-permeability layers, drainage and vegetation to reduce water and oxygen entering the waste.

Monitor

Check seepage, erosion and vegetation and repair the cover if necessary.



A water cover and a capped tailings pile use different barriers, but both aim to limit sulfide oxidation. Water covers restrict oxygen access; dry covers also reduce



Why former mines can be ideal for solar power

→ Photovoltaic capacity is being built on the same mines that will become lakes.



Open land

Few trees and buildings create shade.

Grid connection

Existing electrical infrastructure can often be reused.

Already transformed land

New energy use can avoid developing untouched land elsewhere.

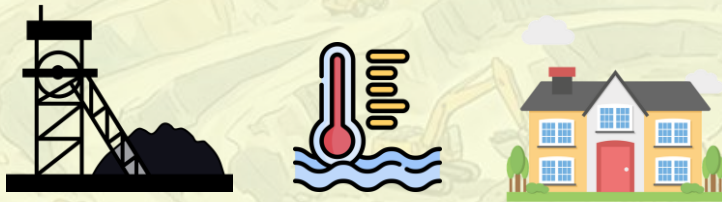
A closed mine can generate new economic value before restoration is complete.



Can a closed underground mine become an energy system?

HEERLEN, NL Minewater 2.0

Warm mine water is used in a district heating and cooling network.



PROSPER-HANIEL, DE pump-storage

A pumped-storage system using old underground workings was studied but not realized.



Old mine workings can be reused, but only where geology, infrastructure and economics fit.



The mine never sleeps:

A restored landscape still has to prove that it works. Water, ground stability and ecosystems are monitored until remaining risks are under control.

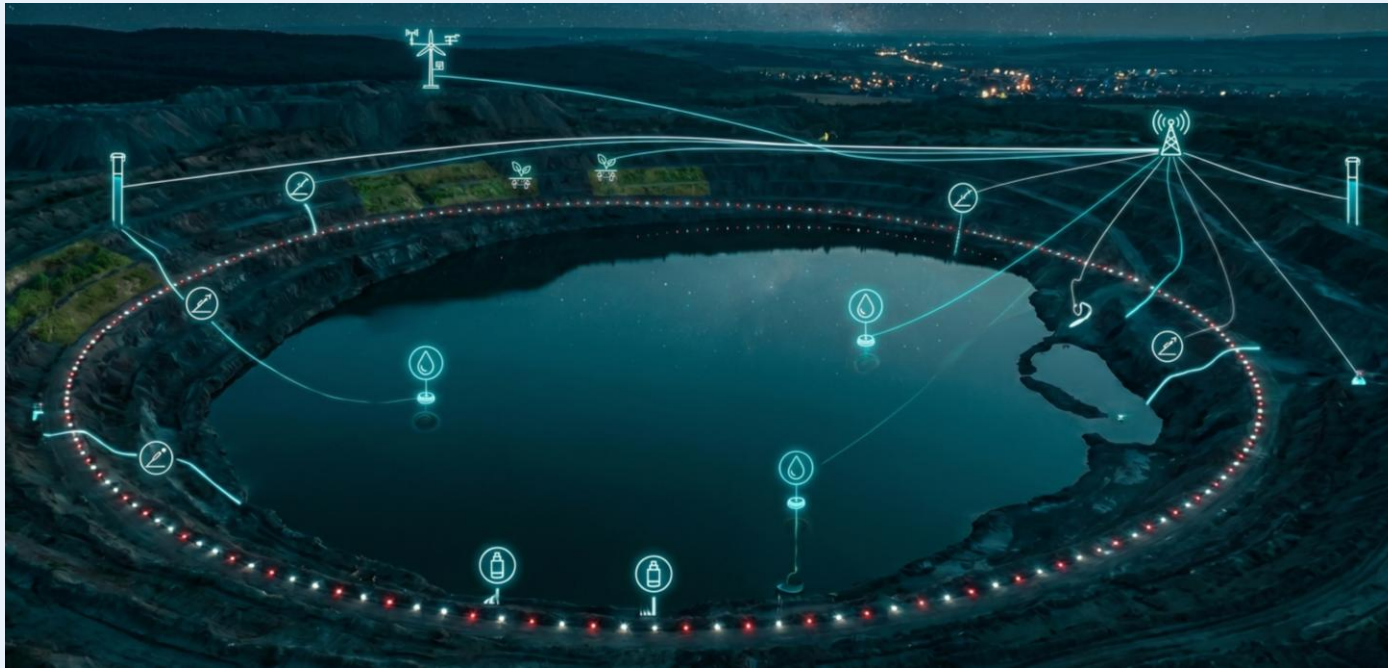
Closure is not the endpoint.



What do we keep measuring?



Things to keep monitoring after mine closure:



[30]



Post-closure monitoring continues for as long as the remaining risks require it.

Mine gases: methane and CO₂

Settlement: movement of the ground

Water chemistry: acidity and metals

Vegetation: signs of ecosystem stress

Groundwater: flow and quality

Today, mine closure is addressed in permitting and has become a specialist field of its own



Mine closure industry

Closure consultancies

Engineers and environmental specialists plan, assess and monitor closure.



In-house closure teams

Major mining companies increasingly maintain dedicated closure expertise.



Public rehabilitation bodies

Public organisations manage large post-mining landscapes and long-term rehabilitation.



Closure needs engineers, ecologists, hydrologists, authorities and financial planning.

See what happens when long-term management never ends



Why can't the Ruhr region simply switch the pumps off?

Underground: Mine water

Water keeps entering old mine workings. Its level must remain controlled to protect groundwater resources.

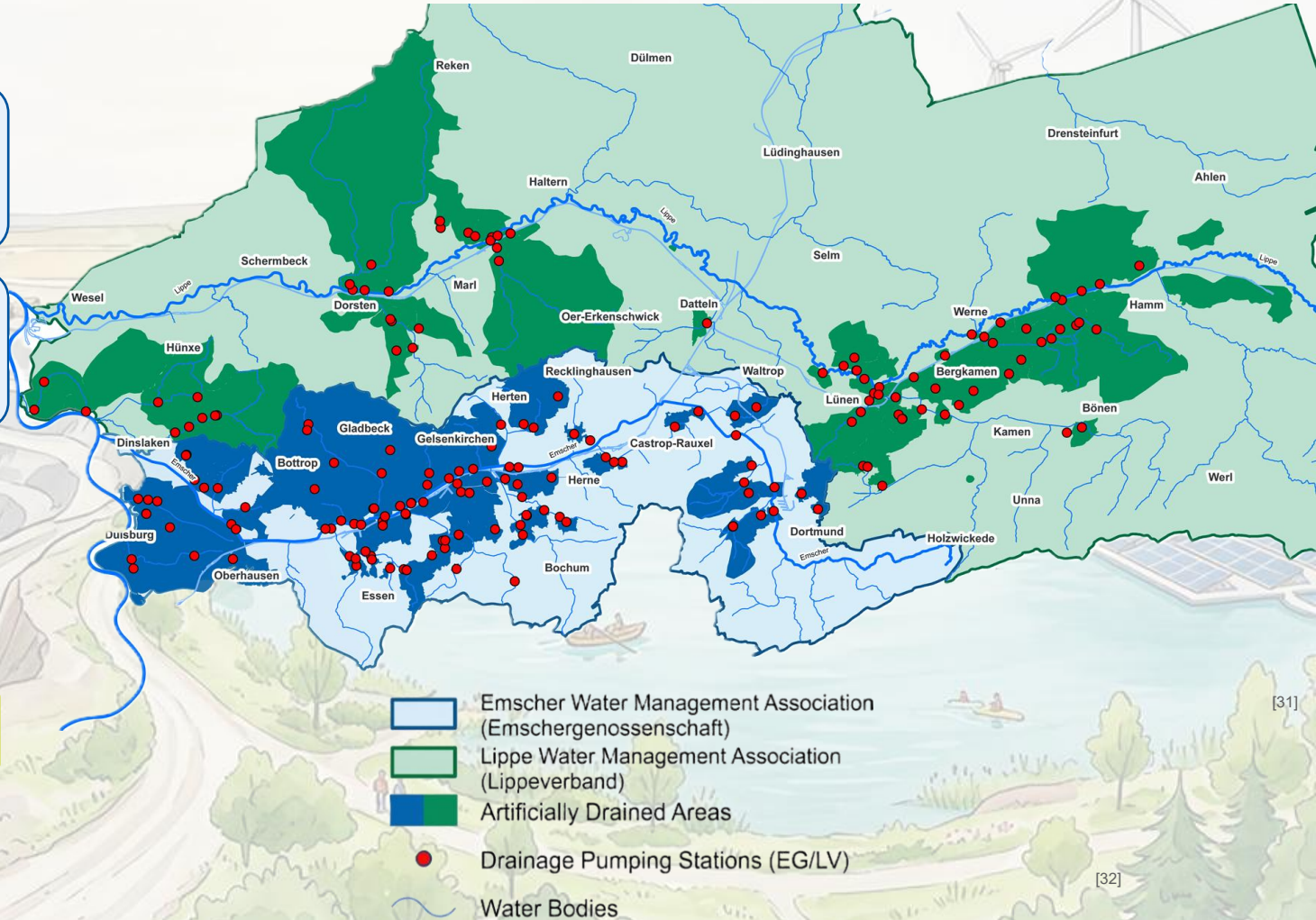
At the surface: Subsidence

Mining lowered parts of the landscape. Some areas therefore need permanent artificial drainage.

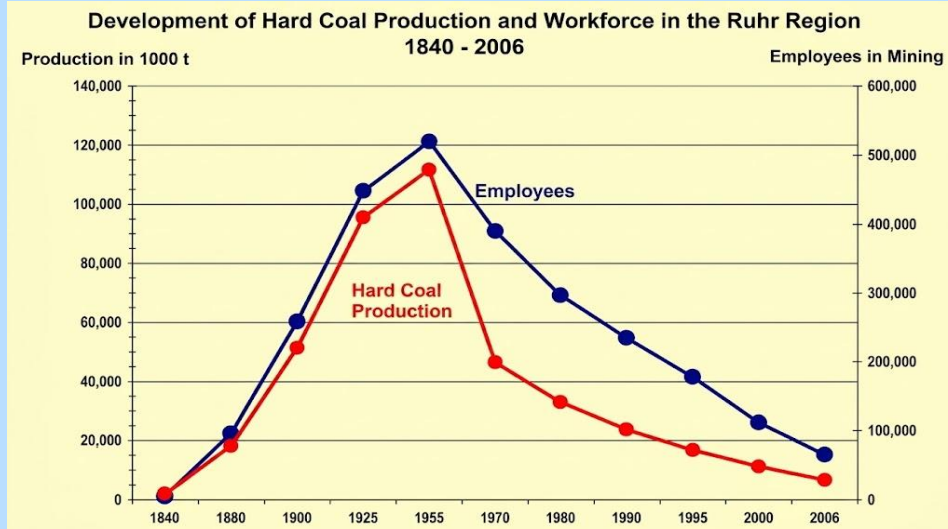


Around 70 million m³ of mine water are pumped each year in the Ruhr region. Enough to fill over 25,000 Olympic pools.

How did this happen?



A short glimpse of mining history: 150 years of mining with lasting consequences



Deep coal mining

Coal was extracted through an extensive underground network

The surface changed

Mining caused subsidence and altered drainage conditions.

Mining ended

Mine water and surface drainage remain long-term tasks.

Why does the water still cost money?

Water continues to enter old mine workings. Pumping and controlled discharge keep mine-water levels below sensitive aquifers and help protect water resources.

Who pays for the never-ending costs?

The RAG-Stiftung was created in 2007 to finance the permanent post-mining water-management tasks from investment returns.



Ewigkeitsaufgaben: "forever-costs"

Long-term post-mining responsibilities such as mine-water management, polder measures and groundwater treatment.

Let's compare!



Two regions, two approaches to closure

RUHR: UNDERGROUND

Extensive underground workings

Water remains a long-term task

Open-ended management & costs

RHEINLAND: OPEN-PIT

One large surface void

Planned flooding and reshaping

Defined future landscape & ending costs



Different mining methods leave different closure challenges.

Do you remember the key points of sustainable closure?



Key takeaways



Plan closure from the beginning: the final land use already affects mining decisions.



Closure depends on the mine type: an open pit leaves different problems and opportunities than an underground mine.



Stabilise before you reuse: water, soil and mine waste must be made safe first.



Post-mining land can create new value: for nature, recreation, energy or other uses.



Responsibility continues after mining ends: monitoring and funding may be needed long after production stops.

See lake Hambach

Return to Start



Hambacher See

planned final water level ~2070

[Back to Start: The Last Shift](#)

Sources & further reading

Data sources & case studies

Hambach post-mining landscape, RWE

Future lake, water filling and landscape design.

Lausitzer pit lakes, LMBV

Flooding, rehabilitation and ongoing post-mining water management.

Sudbury Regreening Program

Official City of Greater Sudbury rehabilitation programme, active since 1978.

Ruhr region, RAG-Stiftung

Perpetual post-mining tasks and mine-water management.

Brumadinho, Vale

Official information on the 2019 dam failure and reparation.

Mijnwater Heerlen, Euroheat & Power

Mine-water based heating and cooling network.

Further reading & standards

ICMM, Integrated Mine Closure

Updated good-practice guidance for integrated closure planning (3rd ed., 2025).

Global Industry Standard on Tailings Management

Global Tailings Review / UNEP–PRI–ICMM standard.

EU mine-closure guidance

Closure activities and financial guarantees under the Extractive Waste Directive.

NEULAND HAMBACH: path to the lake

Regional overview of Hambachsee development and the ~2070 final water level.

LMBV: flooding & water management

Technical background on flooding and management of post-mining lakes.

Río Tinto: scientific background

Review of acid drainage, sulfide oxidation and mining influence in the Río Tinto basin.