Nederlands Materialen Observatorium

Progress Report: Implementation of the National Exploration Programme for Critical Raw Materials in the Netherlands 2026

TNO Public ⟩ TNO 2026 R16610
15 June 2026

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TNO 2026 R16610 – 15 June 2026

Progress Report: Implementation of the National Exploration Programme for Critical Raw Materials in the Netherlands 2026

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Report classification	TNO Public
Title	Progress Report: Implementation of the National Exploration Programme for Critical Raw Materials in the Netherlands 2026
Report number	060.59331 (number of pages 19)

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1 Introduction

In the first half of 2025, at the request of the Ministry of Economic Affairs (EZK), the Netherlands Materials Observatory (NMO) drew up the National Exploration Programme (NEP) entitled *“Critical Raw Materials Potential in the Netherlands’ Subsurface”* (van Geffen et al., 2025), as stipulated under the European Critical Raw Material Act (CRMA, 2024). This document was delivered by EZK to the European Commission on 24 July, 2025. The NEP document provides an overview of existing knowledge and data on minerals, and associated critical raw materials (CRM), in the Dutch subsurface. Based on this knowledge, a plan was drawn up to investigate how the geological CRM potential can be examined. The CRMA requires each EU Member State to submit a final report on implementation of the NEP latest by May 2030, with annual progress reporting in the interim.

In this report, the NMO presents the progress of the activities carried out over the past 12 months within the framework of the NEP, as well as the key results, insights, and development directions. The NEP has the specific aim of systematically examining CRM potential in the Dutch subsurface and in secondary sources, so that policymakers and implementing parties can rely on an up-to-date, scientifically substantiated knowledge base in this area.

In the original NEP document, an initial inventory was made of known and suspected CRM-hosting materials for which the geological potential for occurrence in the Dutch subsurface is not zero, a priori. Subsequently, work continued to strengthen and expand datasets, conduct targeted exploratory studies within all NEP themes, and consider collaborations with knowledge institutes, companies, and government organisations. Activities range from geochemical and geophysical analyses, data mining, laboratory research, to preparing follow-up studies. This report provides, per theme, an overview of the work carried out and the resulting new insights. Based on the main conclusions, recommendations are made for setting priorities in the further implementation of the programme. This report further serves to supplement and provide context for the NEP Reporting Template 2026 that was issued by DG GROW (Appendix 1).

2 Summary of Activities by Theme

Below is a selection of key activities carried out over the past 12 months, with the most important results elaborated in more detail in Chapter 3, from which conclusions can be drawn for next steps.

General, preparatory, positioning, outreach, and supporting activities (“Theme 0”):

- Sediment compositions from the Geological Survey of the Netherlands (GDN) database for quantitative borehole data (DINO, 2026) were prepared for data analysis.
- Development of large language models (LLM) to scrape, collect, and present analytical data from drill reports.
- Development of a digital map viewer tool for an overview of maps and data related to the NEP.
- Assessment of available public geophysical data suitable for CRM indication.
- Presentation of the NEP at the EC *CRM Board – Subgroup Exploration* in Kraków, Poland.
- Public presentations:
    - NWO-NAC (Netherlands Earth Science Congress) in Noordwijk,
    - CRM Symposium at TU Delft,
    - Guest lectures at Vrije Universiteit Amsterdam and Utrecht University.

2.1 Theme 1 – Mineral Sands

Archived mineral-sand profile

An initial chemical analysis of a garnet-sand layer in a lacquer-peel profile of a storm-induced beach-sand deposit from the TNO-GDN archive of geological specimens shows, among other things, considerable titanium contents in the heavy-mineral fraction that sporadically washes ashore along the Dutch coast.

Working visit to IHC Mining

Following publication of the NEP (van Geffen et al., 2025), the NMO had a discussion with IHC Mining to explore possible avenues for mineral-sand extraction in the Netherlands, for which IHC builds and deploys dredging and mineral-separation equipment, currently operational in Brazil and Australia.

Discussion with TU Delft

TU Delft (faculty of Geosciences & Engineering) approached the NMO regarding opportunities for collaboration on the topic of heavy minerals separation from sand-winning activities, requesting sample materials for laboratory research as part of an MSc project.

Geophysical data analysis

Assessment of available geophysical data revealed the availability of magnetometry data of the North Sea seabed that could potentially be used to map the spatial distribution of the heavy-mineral fraction in licensed extraction areas for sand suppletion. An important next step is the ability to locate this heavy mineral fraction offshore in sand-extraction areas.

Drilling programme for coastal sand suppletion

In collaboration with Deltares, GDN describes and archives sand samples from sand-extraction areas, which could potentially be used to investigate the chemical and mineralogical composition of the heavy mineral fraction.

2.2 Theme 2 – Concretions

No concrete activities undertaken – planned for 2028.

2.3 Theme 3 – Waters and Brines

Brine – salt water in the deep subsurface

TNO-GDN manages a public database (DINO, 2026) that includes, among others, chemical compositions of deep saline groundwater (also referred to as formation water or brine). In addition to the existing dataset, new drilling reports have been submitted to TNO-GDN in recent years by hydrocarbon producers. Work is currently underway to develop a procedure to use data mining routines to detect tables of chemical water compositions in these documents and add them to the TNO-GDN dataset.

Participation in steering committee of the Flemish Geological Service

Exploratory study of the potential for lithium and other critical raw materials in the Flemish subsurface, which is geologically contiguous with the Dutch subsurface and may provide valuable information cross-border to complement the studies for the Netherlands (Laenen et al., 2026).

2.4 Theme 4 – Sulphides

Kupferschiefer

Through an internship assignment carried out in collaboration with Utrecht University portable X-ray fluorescence (pXRF) measurements were carried out on 32 drill cores in the core repositories of TNO and NAM where the Kupferschiefer has been catalogued, to determine its copper content.

Lead-zinc minerals

The NMO gained access to the ore collection of Naturalis. Lead and zinc minerals originating from the Limburg coal mines are part of this historical collection. This provides the NMO with an important set of hand specimens of rock and minerals available for analysis for the possible presence of critical raw materials such as antimony, arsenic, bismuth, gallium, and germanium.

2.5 Theme 5 – Mined Materials

Magnesium salt

Through another internship assignment carried out in collaboration with Utrecht University, investigations were carried out to predict the presence of magnesium and potassium salts from existing well-log data and thereby spatially model the potential presence of these salts in the Dutch subsurface. These salts can be positively identified using three out of five well-log parameters, which will serve as a basis for the spatial modelling of the magnesium-salt potential.

2.6 Theme 6 – Residual Materials

Internal TNO database on steel slags and incineration ashes

TNO-GDN has an internal dataset of mineralogical and chemical compositions of residual materials, including steel slags and waste-incineration ashes. An initial selection has been made based on CRM concentrations.

3 Results & Insights

3.1 Theme 1 – Mineral Sands

3.1.1 Garnet sand

Sediments in the North Sea supplied by various river systems, largely ancient systems draining from northeastern Europe, are locally rich in heavy minerals. These mineral sands that are initially deposited offshore, occasionally wash up on the beach during storm surges. A stored beach-sand profile contains such a band of “garnet sand” (Figure 1). An initial analysis of the chemical composition using portable X-ray fluorescence (pXRF; Figure 2) shows that, besides garnet (mostly almandine, a pink to red iron-aluminium silicate), the dark minerals also contain considerable titanium (>10% TiO_2), likely in the form of ilmenite ($FeTiO_3$) or ulvöspinel (Fe_2TiO_4), as well as chromium, zirconium, niobium, vanadium, and rare earth elements such as neodymium (Figure 3).

Figure 1: Lacquer-peel profile of beach sand with a 3-5 cm layer of dark-coloured “garnet sand”. Vertical dimension of the full profile is approximately 30 cm.

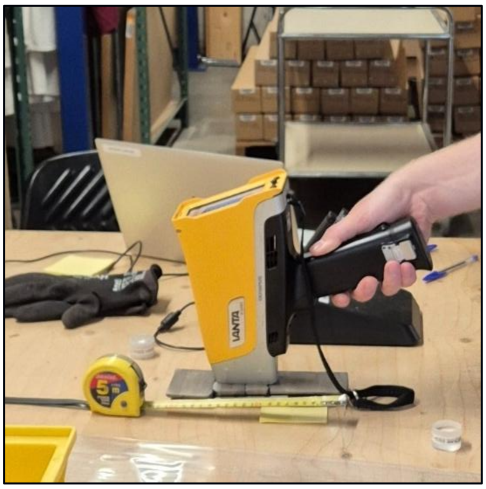

Figure 2: Determining chemical composition using a portable X-ray fluorescence spectrometer (pXRF).

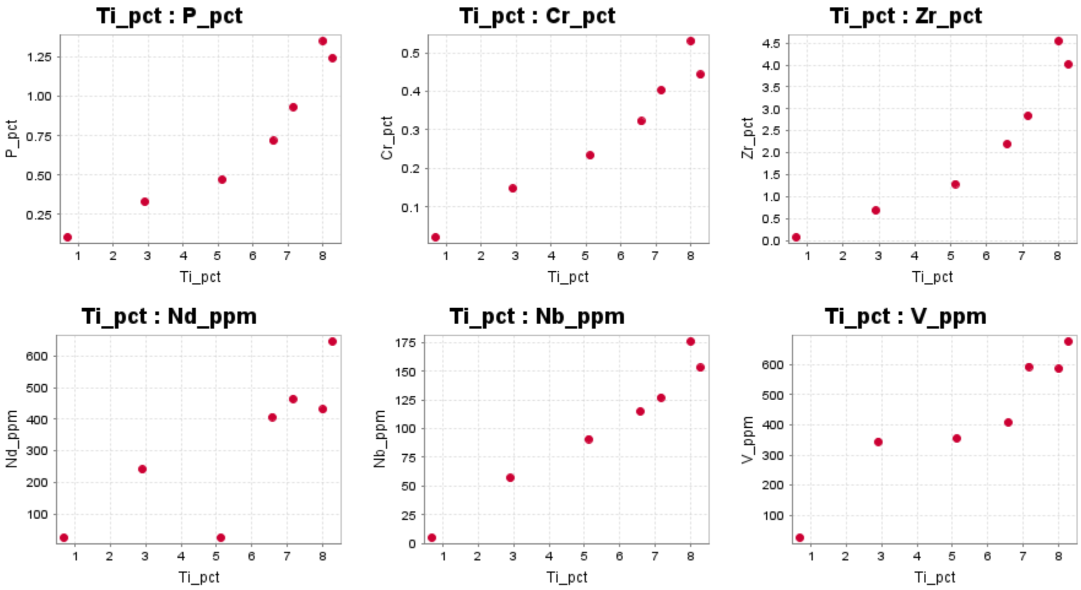

Figure 3: selected CRM elements plotted against titanium from pXRF measurements of “garnet sand” from the Dutch coast. In addition to garnet, this also contains other minerals resulting in elevated levels of titanium and zirconium, as well as chromium, vanadium, niobium and rare earths (e.g., neodymium).

3.1.2 New approach for follow-up study

In the NEP document (van Geffen et al., 2025), it was proposed to map the distribution of heavy-mineral sands along the coast using radiometric techniques and then sample them to determine chemical and mineralogical compositions. However, apart from lacking reasonable prospects of eventual economic extraction as the coastal zone is protected under the EU Natura 2000 legislation, these occurrences are generally small-scale, secondary deposits. Following discussions with TU Delft, IHC, Deltares and TNO-GDN colleagues, an alternative approach is now proposed that is based on already available geophysical data (e.g., magnetometry) and models of the North Sea seabed, combined with existing and planned sampling of coastal suppletion sand from allocated and licensed extraction areas. In this way, the study is focused on those areas where sand extraction is already permitted and can therefore provide a more reliable analysis of the spatial distribution of heavy-mineral sands and their CRM potential.

3.2 Theme 2 – Concretions

Due to the presumed low potential and the modest criticality of the intended raw materials, no further work has yet been carried out under this theme.

3.3 Theme 3 – Waters and Brines

Available data on CRM concentrations in groundwater and brine were submitted by operators to the GDN under the Mining Act. In total, 1,100 water analyses are available, originating from 275 of the more than 6,000 existing oil and gas wells. In 2025, preparatory work was carried out to merge these data with already available data, a necessary step in determining the CRM potential of these sources, mostly lithium. However, not all of these water analyses included lithium or other relevant CRM data.

3.3.1 Salt water in the deep subsurface

Data cleaning

Quality control (QC) and data cleaning were carried out in preparation for merging data from different sources into the TNO-GDN DINO database (DINO, 2026). From this database, the potential of various CRMs in groundwater and brine can be determined. As part of QC, well names and depth data were checked and corrected where necessary. To ensure data quality, an assessment was made of possible contamination of water samples, which can lead to anomalous concentrations (Figure 4). Contamination can occur when water samples are collected from a well during or shortly after drilling (e.g., Richards et al., 2015). Residues of drilling mud used in the drilling process can remain in the wellbore and, when starting oil, gas, or water production, can be produced to the surface. The dataset also contains samples of pure drilling mud, allowing for the assessment of possible contamination of a sample. In some reports of water compositions, this is also indicated explicitly. Nevertheless, it is often impossible to correct measurements for contamination and data on the chemical composition of contaminated samples are therefore excluded from the public database.

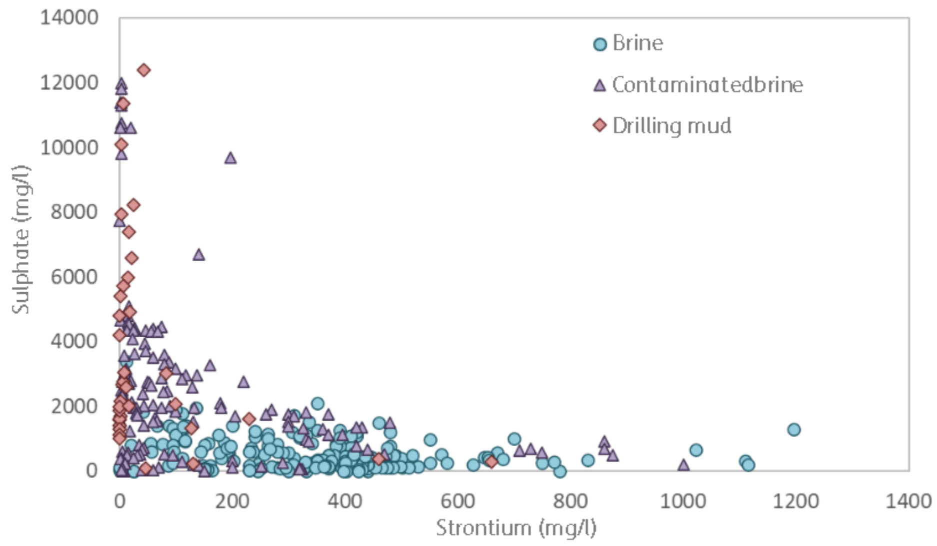

Figure 4: Strontium and sulphate concentrations in groundwater that indicate possible contamination of the sample. A high sulphate content is characteristic of drilling mud, whereas a high strontium concentration indicates uncontaminated formation water.

Expanding the dataset

The NMO is working on developing an AI workflow that can recognise and retrieve lithium data from unstructured digital documents. This tool was tested on documents in the TNO-GDN archive, identifying 22 documents containing data that were still missing from the existing DINO database (DINO, 2026). In addition, external reports were obtained from oil and gas operators, including a large dataset from NAM and a water-compositions dataset from Wintershall, and data were added from the Pressure SNS database, available via the NLOG portal (NLOG, 2026).

3.3.2 Lithium in brine

An overview of registered lithium concentrations was generated. This overview consists of approximately 150 analyses of lithium in formation water, originating from 70 different wells. The influence of possible contamination on the measurements was assessed. For example, an analysis of 90 mg/l lithium was filtered out of the results (measured lithium concentrations range between 0 and 60 mg/l) due to contamination with lithium chloride from drilling mud. In formation water, characterised by low sulphate and high strontium concentrations, the highest lithium value found so far is 64 mg/l. For perspective: technological feasibility of lithium production at concentrations from 40 mg/l may be possible, although the economic feasibility of DLE projects (*direct lithium extraction*) globally is still focused on concentrations (well) above 100 mg/l. For example, the Neptune Energy lithium resource identified at Altmark, Germany, reported an average of 375 mg/l (Neptune, 2025). In recent years, however, the technological lower bound has been gradually dropping lower. Whether economic recovery of low-concentration lithium can be achieved in the high-salinity environment of typical Dutch reservoirs remains to be investigated.

3.3.3 Shallow groundwater

In addition to data from deep brines, TNO-GDN also has archived lithium concentrations in shallow groundwater. A first assessment of these data, however, indicates a large number of suspiciously high lithium values. Additional quality control is recommended for this dataset before the data can be used reliably.

3.3.4 Deep dive: direct lithium extraction (DLE)

In 2025, a literature review was undertaken to identify the most relevant types of DLE technology (*direct lithium extraction*) that could potentially be applicable for production from Dutch sources, such as brines. A consistent framework of performance indicators (selectivity, recovery, stability, scalability, *technology readiness level* (TRL), energy consumption and costs) was established to benchmark amenable DLE technologies for sustainable lithium production.

The applicability of DLE techniques for Dutch brines depends on the technology's efficiency of processing low lithium concentrations in high-salinity brines. The review failed to discriminate the most applicable DLE technology as based on the predetermined performance indicators. Additional well data and further data analysis is required to support ranking of the most suitable methods in the Dutch context.

3.4 Theme 4 – Sulphides

Using portable X-ray fluorescence, drill-core samples of the Kupferschiefer in the Netherlands and hand specimens of lead-zinc occurrences from the historical South Limburg coal mines were analysed. This work was carried out as part of an internship project by an MSc student from Utrecht University, supervised by the NMO. The study shows that local copper enrichment exists in the Dutch Kupferschiefer and identifies South Limburg lead-zinc minerals as potential sources of CRM. Further research using higher-resolution analytical techniques is recommended to determine metal concentrations more accurately.

3.4.1 Kupferschiefer

The Kupferschiefer is a stratigraphic package at the base of the Zechstein Group, which mainly consists of carbonate rocks and locally contains abundant rock salt (e.g., Vaughan et al., 1989). The Zechstein acts as a cap rock for the sandstones of the Rotliegend Formation, which host the Dutch natural gas reserves. As a result, the Kupferschiefer has often been intercepted during deep drilling for gas exploration and production, at depths from 700 m in the southeast of the Netherlands to more than 6,000 m in the northwest beneath the Dutch part of the North Sea. Although the Kupferschiefer is therefore well known in the Dutch subsurface geology, albeit as a *marker horizon*, this is the first time the copper content of this rock is being systematically investigated.

As a first-pass assessment of copper values in the Dutch section of the Kupferschiefer layer, the portable XRF spectrometer (pXRF) was used directly on cut-core surfaces to measure its chemical composition. Although the average copper assay values – combined with the considerable depth (>2 km) and limited thickness (<1 m) – are insufficient for conventional mining methods (Figure 5), the locally elevated copper values (up to >8%) show that the copper potential of this unit may be small but not zero. Potentially relevant extraction techniques such as in-situ recovery are not yet sufficiently developed for this to be considered an economic opportunity today, but they present a reasonable prospect of possible future exploitation. Further work to assess the Kupferschiefer copper potential and its spatial distribution in more detail is therefore warranted.

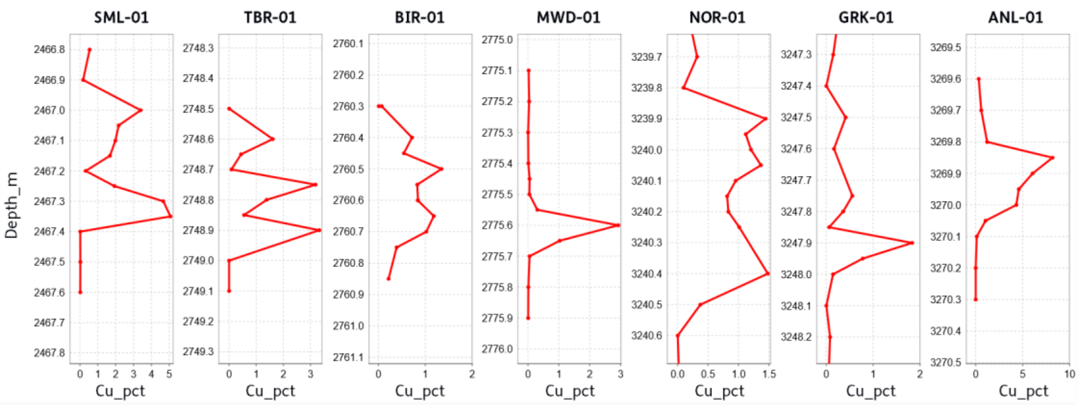

Figure 5: Copper contents in 1-metre cut or slabbed core intervals representing the stratigraphic unit ZEZ1K (Kupferschiefer), as measured by pXRF.

To enhance the spatial modelling of the Kupferschiefer layer in the Netherlands, the NMO has joined a consortium of various universities, national geological surveys, and industry representatives, in a EU Horizon proposal (submitted in April 2026 under call HORIZON-CL4-2026-01-MAT-PROD-11).

3.4.2 Lead-zinc minerals

Lead-zinc mineralisation in South Limburg is considered a distal occurrence of the regional Mississippi Valley Type mineral systems, which are found in several places in Belgium along the northern border of the Ardennes. The lead-zinc occurrences in South Limburg are small in size, discontinuous, and located in the lower levels of historical coal mines that are no longer accessible today. Nevertheless, hand specimens from the Naturalis Biodiversity Centre's mineral collection (Naturalis, 2025) have been made available for analysis and hence allowing the CRM potential in the lead-zinc minerals to be assessed. The main CRM associated with these lead-zinc minerals are antimony, arsenic, bismuth, gallium, and germanium. Antimony and arsenic can be measured well with pXRF, whereas bismuth values are mostly below its detection limit. The handheld instrument is not calibrated for gallium and germanium, which would require laboratory analysis.

With a view to more detailed research in the future to quantify these critical trace elements, a selection of representative samples has already been made based on multivariate statistics, availability per mine location, mineralisation present, and museum value (i.e., objects with higher museum value, both aesthetically and in terms of uniqueness, were not retained). Subsequently, a loan- and sampling request was submitted to and approved by Naturalis, and a selection of lead-zinc minerals was temporarily transferred to GDN. In collaboration with Utrecht University, a MSc research project examining the exact chemical composition of these samples has been initiated. The associated location data of the above-mentioned samples in the historical coal mines were verified using available mine maps from the TNO-GDN archive.

3.5 Theme 5 – Mined Materials

3.5.1 Magnesium salts

Through an internship assignment carried out at NMO in collaboration with Utrecht University, a MSc student has investigated whether magnesium salt deposits can be detected in existing well data from the public NLOG database.

The potential presence of magnesium salts in the Dutch subsurface, outside the known production facilities in Veendam, was investigated using well data from historical oil and gas wells. Of the 6,665 wells, 1,548 reached the base of the Zechstein Group, in which the magnesium salt may occur. Based on the three most widely available log variables, natural gamma radiation (GR), acoustic slowness (DT) and bulk density (RHOB), a reliable indication of magnesium-bearing salts was produced (Figure 6). Logs of the less widely available neutron porosity (NPHI) and photoelectric factor (PEF) contributed little to identifying the (potassium-) magnesium salts.

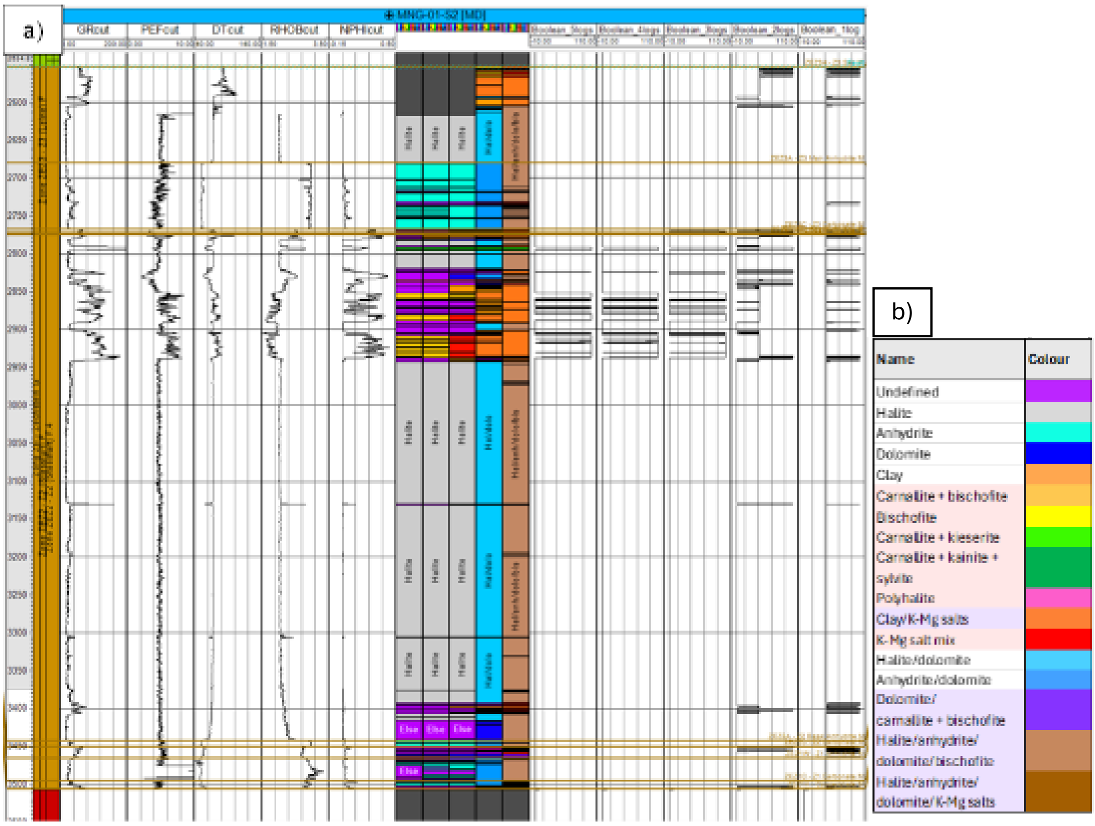

Figure 6: a) Example of well logs (GR > DT > RHOB > NPHI > PEF) with interpreted lithology (coloured columns in the middle), based on five, four, three, two and one log(s), with an indication of K-Mg salt potential, also based on 5 to 1 indicators (100: K-Mg salt, 40: 'potential' K-Mg salt, or 0: no K-Mg salt); b) Legend of interpreted lithology.

The spatial distribution of the main recoverable magnesium salt types bischofite (magnesium chloride, $MgCl_2 \cdot 6H_2O$) and carnallite (potassium-magnesium chloride, $KMgCl_3 \cdot 6H_2O$) will be used to generate a 3D model of the forecast K-Mg salt contents. Occurrences of bischofite-only are more difficult to detect in well-log data than the combined K-Mg salts, mainly

because potassium – which occurs in carnallite but not in bischofite – gives off a strong gamma signal, whereas magnesium does not.
The ability to forecast the presence of K-Mg salts based on the combined well-log data will be used to generate a 3D spatial model of the probability of these salts occurring throughout the Zechstein Group in the Dutch subsurface and to generate a first-pass calculation of their geological potential.

3.5.2 Silica sand and coking coal

Apart from the information delivered last year in the original NEP document, no further research has yet been carried out on the remaining potential of silica sand (possible feedstock for silicon metal) or coking coal in the Netherlands. Contact has been established with silica-sand producers with the aim of obtaining a better estimate of its geological potential. This preparatory work will be continued in 2026.

3.6 Theme 6 – Residual Materials

This theme is mainly concerned with the residues from steel production and waste incineration that have applications as aggregate or fill materials in civic infrastructure, such as roads and dykes, where they are exposed to the natural environment. As various government departments and industrial parties are involved in the production, handling, permitting, and application of slags and ashes, it will require a collective effort to assess the potential of CRM-recovery from these material streams, which remains to be initiated in the context of the CRMA.

3.6.1 TNO database

TNO and its predecessors, in collaboration with DHI and Vanderbilt University, collected compositional data from 2005 to 2018 on leaching of metals and other contaminants from waste streams in an extensive database. Because most of the analytical data were generated within third-party assignments, they remain largely confidential. The database contains both pH-dependent leaching data and total analyses of various industrial and municipal waste products. Materials with CRM potential were selected from this database for further data analysis in 2026.

4 Conclusions & Next Steps

In implementing the NEP, the first steps have been taken toward mapping the geological potential for critical raw materials in the Dutch subsurface. Over the past year, the NMO gained many new insights from existing data and available materials at TNO-GDN. Most of the materials and archived datasets were originally collected for other purposes such as oil and gas exploration, extraction of salt, sand, gravel and clay, or exploratory drilling for geothermal energy, but they now form a valuable basis for research into the CRM potential.

4.1 Key conclusions by theme

The following statements represent insights gained over the first year of the NEP implementation (2025-2026) and must be interpreted as preliminary. As set out in the NEP document (van Geffen et al., 2025), some themes are planned to commence later in the program. At this stage, the focus is on positive identification of the presence of CRM (i.e., their geological potential), not their concentrations or quantities. Apart from magnesium (which is being mined as salts, but not currently produced in metallic form), all NEP themes are in the pre-exploration stage (Figure 7).

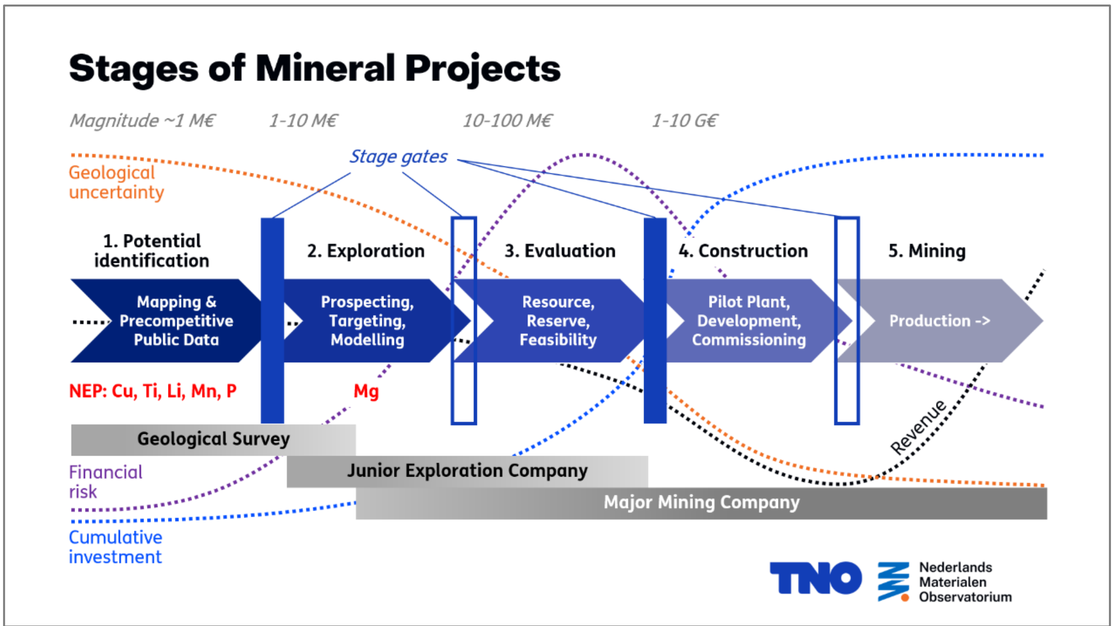

Figure 7: Schematic representation of the stages of mineral-project development, from precompetitive geological potential assessment to production (closure and post-closure stages not relevant in the Dutch context), with relevant CRM marked in red.

1. **Mineral sands:** indication of CRM, in particular titanium, chromium, zirconium and rare earth elements. An alternative research methodology, based on existing magnetometry data and samples for sand suppletion, makes future research into potential on the North Sea seabed more efficient and targeted. The aim is to develop a model in 2026 to locate mineral sands based on magnetometry and to analyse a selection of sand samples for mineralogical and chemical composition.

2. **Concretions:** Given the limited expected value of these materials, no further activities were carried out in 2025 and 2026. The expectation is that research under this theme will start from 2028.

3. **Groundwater and brines:** 1,100 water analyses were cleaned, categorised, and prepared for integration into DINO (DINO, 2026). Data cleaning shows that contamination can substantially affect the reliability of lithium values, requiring strict quality control. The highest confirmed lithium value found so far in deep formation water is 64 mg/l. DLE technologies were examined for applicability in the Dutch context but failed to be discriminative for low lithium concentrations in high-salinity brines. In 2026, coverage of lithium analyses in brines will be expanded as much as possible, with all collected data safeguarded in a database so that a more detailed and reliable map of lithium distribution can be produced.

4. **Sulphides:** Kupferschiefer analyses confirm elevated copper values at various locations, with an outlier of >8% Cu. Although conventional extraction is not feasible with current technology, opportunities for future co-production with geothermal energy remain of interest. South Limburg lead-zinc minerals were identified as potential carriers of CRM in trace elements. Follow-up research starts in 2026.

5. **Mined materials:** Using measurement data from 1,548 deep wells, three previously unknown clusters with significant magnesium and potassium salt potential were identified. Bischofite occurs less frequently and at lower concentrations; potassium-bearing carnallite dominates.

6. **Residual materials:** An internal TNO database was screened to identify secondary, CRM-rich material streams. An initial selection of steel slags and incineration ashes was made for follow-up research on CRM recovery. In 2026, a workshop will be organised in collaboration with the associated Ministries and broader expertise to further investigate recovery potential from steel slags and to enable a coordinated follow-up on this current theme.

4.2 Next steps

- Targeted follow-up research on promising themes:
    - Implement a new, more efficient way of identifying mineral sands for mineralogical analysis;
    - Increase coverage of lithium data in brines;
    - Conduct more in-depth research into copper potential and continuity of the Kupferschiefer; and
    - Perform detailed analysis of CRM in samples of lead-zinc minerals from the Naturalis collection.
- Optimise and integrate datasets: Complete integration of all available brine-chemistry data into the DINO database (DINO, 2026). Standardise quality controls for shallow groundwater to enable reliable lithium estimates.
- Improve the resolution of the Kupferschiefer mineral-system model and propagate its petrophysical properties throughout the Dutch subsurface by reinterpreting well-log data with advanced analytics (ML/AI) and integrating the outcomes with seismic data.
- Evaluate advancements in in-situ recovery (ISR) technology, including precision drilling and benign reactants, for copper recovery from the deep and thin Kupferschiefer beds.

- Expand on the outcomes of the magnesium-salt forecasting by mapping and modelling of magnesium-salt potential throughout the Zechstein stratigraphy.
- Work with government, industry and research institutions on CRM recovery from residual streams.
- Establish a raw-materials database for storage, management and provision of NEP results within the Geological Survey's data repository (GDNR).
- Strengthen cross-border collaboration with Belgian, German, and Danish surveys to harmonise geological models and methods for estimating the integrated CRM potential. We recognize the importance to approach some geological systems on a regional scale in order to estimate the geological potential within the Netherlands. Existing initiatives include:
  - The NMO's participation in the steering committee on lithium potential in the Belgian Brabant Massif at the Flemish Geological Survey (Laenen et al., 2026),
  - The formation of a Zechstein Basin Regional Group within EuroGeoSurveys, to assess copper-sulphide potential across northern Europe (Poland to England),
  - Participation in a consortium on a EU Horizon proposal in collaboration with various universities, national geological surveys, and industry representatives, to enhance the modelling of the Kupferschiefer mineral system (submitted in April 2026 under call HORIZON-CL4-2026-01-MAT-PROD-11).

Depending on new results, planned activities for 2026-2030 will be further elaborated and, if necessary, adjusted. Once the CRM potential of specific components from the NEP has been sufficiently determined based on available knowledge and data, a final report will be prepared.

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