# Mind the gap

## A study into the costs of long-term nuclear waste storage in the Netherlands

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**About this report**

This report was researched and written by Lucas Rocha de Almeida and Daan Welling and is published by WISE Nederland (World Information Service on Energy). It estimates the volume and cost of long-term storage and disposal of Dutch radioactive waste under three nuclear-development scenarios, and assesses whether the funds set aside for disposal cover the resulting liability. All cost figures are estimates built on published sources; Chapter 4 sets out the methodology and Chapters 5 to 7 the derivations and their limitations. Corrections and comments are welcome via wisenederland.nl. The report may be quoted with attribution.

## Table of contents

## Abbreviations

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| ANVS | Autoriteit Nucleaire Veiligheid en Stralingsbescherming – the Dutch nuclear regulator |
| COVRA | Centrale Organisatie Voor Radioactief Afval – the state radioactive-waste company |
| DGD / DGR | deep geological disposal / deep geological repository |
| EPZ | Elektriciteits-Produktiemaatschappij Zuid-Nederland – operator of the Borssele plant |
| ERDO | European Repository Development Organisation |
| HABOG | COVRA's high-level waste treatment and storage building |
| HICP | Harmonised Index of Consumer Prices |
| HLW | high-level (radioactive) waste (hoogradioactief afval) |
| ILW / LLW | intermediate-level / low-level (radioactive) waste |
| KCB | Kerncentrale Borssele (the Borssele nuclear power plant) |
| kgHM | kilogram of heavy metal (unit for nuclear fuel quantities) |
| LILW | low- and intermediate-level waste (laag- en middelradioactief afval) |
| NORM | naturally occurring radioactive material |
| NPP | nuclear power plant |
| SMR | small modular reactor |
| VRF | volume reduction factor |

# Nederlandstalige samenvatting van het rapport

**Het kabinet wil de kerncentrale Borssele na 2033 openhouden en daarnaast vier nieuwe grote kerncentrales en enkele kleine modulaire reactoren (SMR's) bouwen. Voor de bouw is €14,5 miljard gereserveerd door voorgaande coalities. Energie-experts schatten de werkelijke bouwkosten van één centrale overigens al op zo'n €20 miljard.**

Maar de kosten van kernenergie eindigen niet wanneer de centrale opgetuigd is. Al het Nederlandse radioactieve afval gaat naar staatsdeelneming COVRA in Zeeland, waar het ruwweg een eeuw bovengronds wordt opgeslagen. Daarna moet het definitief de diepe ondergrond in: een geologische eindberging, honderden meters diep, waar Nederland nog geen plan voor heeft. Er is nog geen locatie of opbergmethode (zout of klei) gekozen. De keuze voor nieuwe kerncentrales is losgehaald van de kosten voor de eindberging, en er bestaat geen rapport of documentatie wat de eindberging gaat kosten (in het geval van uitbreiding van kernenergie in Nederland), een studie die rekening houdt met de kosten van eindbergingen in op dit moment gerealiseerde projecten in vergelijkbare landen, en hoe dit gefinancierd zal worden.

Dit rapport berekent wat de eindberging van het Nederlandse kernafval werkelijk gaat kosten. We vertrekken vanuit de afvalprognoses uit COVRA's Masterplan 2050, de kostenramingen die COVRA in 2025 publiceerde. We berekenen de afvalproductie op basis van de door COVRA geschetste scenario's en op basis van een mogelijke uitbreiding van de kernreactorvloot met 4 conventionele kerncentrales (KCs) en 4 Small Modular Reactors (SMR), als operationalisering van de Routekaart 7GW van de overheid.

Het Masterplan telt de afvalproductie tot 2050. Een reactor die in 2038 in bedrijf komt en tachtig jaar draait, produceert afval tot ver in de volgende eeuw. Wij hebben daarom de volledige afvalberg in beeld gebracht, met COVRA's eigen jaarlijkse productiecijfers, doorgetrokken over de volledige levensduur van elke installatie.

Vervolgens is gekeken naar de mogelijke kosten. In de wetenschappelijke literatuur over megaprojecten loopt negen van de tien grote projecten over budget, en nucleaire projecten vormen daarbinnen de slechtst presterende categorie: in een vergelijking van 401 elektriciteitsprojecten in 57 landen kwamen kernreactoren gemiddeld 117 procent boven budget uit, en overschreed 97 procent van de onderzochte reactoren de raming. Voor nucleaire afvalprojecten specifiek vindt de literatuur hetzelfde risicoprofiel, met dikke staarten waarin extreme overschrijdingen geen uitzondering zijn maar een te verwachten uitkomst. Om deze informatie te staven hebben we drie case studies uitgevoerd van landen die al verder zijn in het proces van eindberging: Finland, Zweden en Frankrijk. In geen van de eindbergingsprogramma's van Finland, Zweden en Frankrijk is onder zijn vroege ramingen uitgekomen. De kosten stegen reëel met 26 procent in Finland, dat vrijwel klaar is, 46 procent in Frankrijk, dat nog moet beginnen met bouwen, en 142 procent in Zweden, gemeten over het hele programma. Nederland staat vroeger in het proces dan elk van deze drie landen, zonder locatie, zonder gesteentekeuze en zonder ontwerp, en dat is precies het stadium waarin ramingen historisch het verst van de uitkomst liggen. Die waargenomen bandbreedte van 26 tot 142 procent hebben we toegepast op COVRA's eigen ramingen. Zo komen we per scenario tot een bandbreedte van mogelijke kosten.

Daarna hebben we naar de dekking gekeken. Naast het niet ingecalculeerde risico van kostenoverschijdingen wijzen nog twee zaken op een mogelijk tekort in de financiering van de eindberging. Ten eerste blijkt uit parlementaire stukken dat de langjarige contracten die COVRA sluit met de producenten van kernafval beperkingen kennen: de prijzen liggen jaren vast, kennen geen risico-opslag en zijn vertrouwelijk, waardoor stijgende kostenramingen niet bij de vervuiler terechtkomen. De toezichthouder ANVS stelde al in 2020 vast dat hierdoor feitelijk anderen de risico's van de nucleaire sector droegen, en waarschuwde dat een regelgevend kader voor de financiering van de eindberging ontbreekt. Ten tweede ontstaat er een risico wanneer de bouw van de eindberging naar voren wordt gehaald, wat een logisch voorneembaar gevolg is van de keuze om de locatiekeuze naar 2050 te halen. Het fonds van COVRA kan dan minder lang renderen, wat een groter financieringsgat oplevert.

### De drie scenario's

Dit rapport maakt gebruik van cijfers van COVRA om het afvalvolume in te schatten, en gebruikt deze cijfers om een drietal scenario's door te rekenen. De afvalvolumes komen uit COVRA's Masterplan 2050. Dat plan telt echter maar tot 2050. Een reactor die in 2038 in bedrijf komt en tachtig jaar draait, produceert afval tot 2118; tellen tot 2050 vangt dus maar zo'n vijftien procent van zijn werkelijke afvalproducti. Dit rapport trekt COVRA's eigen jaarlijkse afvalproductiecijfers daarom door over de volledige levensduur van elke installatie, tot aan het beoogde bergingsjaar 2130.

Drie scenario's zijn doorgerekend:

**Minimum: geen nieuwbouw.** Alleen de bestaande installaties: Borssele tot 2034, de onderzoeksreactor in Petten (HFR) tot 2035 met opvolger PALLAS, Urenco, en de afvalskosten die vrijkomen bij ontmanteling . Hoogradioactief afval (HRA) over de volledige levensduur: **225 m³**.

**Plus: het scenario dat COVRA zelf heeft doorgerekend.** Bestaande installaties, plus twintig jaar levensduurverlenging van Borssele, twee nieuwe reactoren van 1.600 MW (tachtig jaar bedrijf) en vier SMR's van 350 MW (vijftig jaar). HRA: **18.977 m³** bij directe berging, **3.777 m³** als al het nieuwe afval wordt opgewerkt.

**Huidig beleid: de uitgesproken kabinetsambitie.** Als Plus, maar met víér grote reactoren. Dit scenario heeft COVRA niet doorgerekend en er bestaat geen officieel kostencijfer voor de eindberging; dit rapport construeert het op exact dezelfde grondslag als de andere twee. HRA: **33.057 m³** direct, **6.737 m³** na opwerking.

Ter vergelijking: de Zweedse eindberging in Forsmark is ontworpen voor circa 16.000 m³.

Naast het hoogradioactieve afval groeit ook de berg laag- en middelradioactief afval (LMRA): van zo'n 311.000 m³ (Minimum) tot 395.000 m³ (huidig beleid) in 2130, waarvan circa 158.000 m³ NORM-afval uit de uraniumverrijking bij Urenco. Die volumes zijn in dit rapport geraamd, maar niet in geld uitgedrukt, omdat geen bruikbare kostenbasis voor dit afval gevonden is.

## Wat eindberging gaat kosten

### COVRA's eigen cijfers

Het startpunt zijn COVRA's eigen ramingen. In november 2025 publiceerde COVRA een technische evaluatie: een eindberging voor alleen het bestaande afval kost €3,3–3,5 miljard; met de nieuwe reactoren uit het Plusscenario erbij €10,0–10,3 miljard. COVRA's jaarrapport 2024 zet de verwachte eindbergingsuitgaven op €10,9 miljard, tegen €2,31 miljard een jaar eerder.

Voor het vier-reactorenprogramma bestaat geen cijfer. Dit rapport leidt zo'n cijfer af uit COVRA's twee gepubliceerde kostenpunten: die impliceren een vaste kostencomponent (de berging zelf) plus een variabele component per afvalcontainer. Doorgetrokken naar de volumes van het huidig-beleidscenario geeft dat een basisraming van circa €12,9 miljard.

### Case studies uit andere landen

Ramingen die zó vroeg in een bergingsprogramma worden gemaakt – Nederland heeft nog geen locatie, geen gesteente, geen ontwerp, omdat het proces tot 2050 loopt – zijn stelselmatig te laag gebleken. In plaats van daar een aanname over te doen, gebruikt dit rapport de gedocumenteerde kostengroei van drie Europese programma's met een staat van dienst:

**Finland** bouwde als eerste ter wereld een eindberging, Onkalo, die rond 2027 in gebruik gaat. Van de raming van 2003 tot de meest recente totaalcijfers stegen de kosten, gecorrigeerd voor inflatie, met circa **26%**. Dat is het laagste cijfer van de drie onderzochte landen, en in Finland is het proces het verste afgerond.

**Frankrijk** is voor zijn eindbergingsproject Cigéo nog niet gaan bouwen, maar zag de officiële referentieraming al reëel met **46%** stijgen. Dit rapport gebruikt bewust het ministeriële referentiebedrag als basis – het cijfer dat de Franse financiële voorzieningen wettelijk beheerste – omdat ook in Nederland de officiële cijfers, niet ramingen van derde partijen, bepalen wat er daadwerkelijk wordt gereserveerd.

**Zweden** herijkt zijn programmakosten elke drie jaar. Tussen Plan 2001 en Plan 2022 verdubbelden de geraamde totale programmakosten, naar SEK 221 miljard (≈ €19,8 miljard): gemiddeld **4,3% reële groei per jaar**, oftewel cumulatief **142%**, bij gelijkblijvende wettelijke reikwijdte (de kosten van beheer, berging én ontmanteling zitten in dit plan verwerkt). Omdat dit het hele programma betreft en de kostenstijging niet uitgesplitst is, gebruikt dit rapport het bedrag als bovengrens.

## De uitkomst

Om in te schatten met welke realistische kosten Nederland rekening zal moeten houden pwassen we de kostenstijgingen uit de drie onderzochte landen toe op de kostencijfers die het COVRA hanteerd (aangevuld met afvalvolumes op basis van de hele levensduur van kerncentrales). De toepassing van die bandbreedte (26–142%) op de Nederlandse basisramingen staat in onderstaande tabel:

| Scenario | HRA (volledige levensduur) | Kosten eindberging HRA |
|---|---|---|
| Minimum: alleen bestaande installaties | 225 $m^3$ | **€4,1–8,5 miljard** |
| Plus: verlenging Borssele + 2 reactoren + 4 SMR's | 3.777–18.977 $m^3$ | **€12,6–24,9 miljard** |
| Huidig beleid: verlenging + 4 reactoren + 4 SMR's | 6.737–33.057 $m^3$ | **€16,2–31,2 miljard** |

Onze hoofdconclusie komt voort uit het verschil tussen de twee kolommen: het huidig beleidsvoornemen van het kabinet (7GW opwek via 4 kerncentrales) voegt grofweg €12 tot 23 miljard aan opbergkosten toe ten opzichte van niets bouwen. Dat is vergelijkbaar met –

en mogelijk méér dan – het complete bouwbudget van €14,5 miljard uitgetrokken voor de eerste twee kerncentrales.

Omgerekend: uitgesmeerd over alle stroom die de nieuwe reactoren en de Borssele-verlenging ooit zullen opwekken (circa 4.700 terawattuur) is dat 0,35 tot 0,70 cent per kilowattuur, één à twee procent van een huishoudelijke stroomprijs. Dit gaat om ruwweg €1.900 tot €3.700 per Nederlands huishouden.

Er zijn nog onzekerheden. Niet meegeteld qua kosten zijn: de berging van de honderdduizenden kubieke meters LMRA en NORM; de bovengrondse opslag gedurende de eeuw vóórdat er een eindberging is; transport, beveiliging en eeuwenlange monitoring; en als voor opwerking wordt gekozen om het volume van afval te verlagen opwerkingskosten in de orde van €30 tot 60 miljard.

## Wat er gespaard is

Tegenover deze verplichting staat een eindbergingsreserve van **€133 miljoen** (begin 2025) op de balans van het COVRA. Deze reserve heeft als doelstelling om tot 2130 te groeien naar een kostendekkend fonds. Het beleid ging daarbij uit van een locatiebesluit rond 2100 en een eindberging rond 2130; dat gaf de reserve een eeuw om te renderen (COVRA rekent met 2,3% reëel per jaar). In 2024 haalde het kabinet het locatiebesluit naar voren naar circa 2050 om te voldoen aan de EU Green Taxonomy regels omtrent het financieren van kernenergie. Daarmee is de verwachting in dit rapport dat de bouw ook naar voren gehaald wordt. Het rapport rekent met een scenario waarin 10 jaar na de locatiekeuze gebouwd wordt, in lijn met beleid in Finland.

Onderstaande tabel is weergegeven in reëele bedragen, prijspeil 2026 aan zowel de kosten als de uitgavenkant.

| | Berging rond 2060 | Berging rond 2130 |
|---|---|---|
| Reserve (reëel) | €0,3 mld (€0,6 mld bij voortgezette stortingen) | €1,4 mld (≈ €3 mld bij voortgezette stortingen) |
| Kosten Minimum | €4,1–8,5 mld | €4,1–8,5 mld |
| Kosten Plus | €4,1–8,5 mld nu; €8,5–16,4 mld uitgesteld | €12,6–24,9 mld |
| Kosten huidig beleid | €4,1–8,5 mld nu; €12,1–22,7 mld uitgesteld | €16,2–31,2 mld |
| Dekking | ≈ 4–14% (alle scenario's) | ≈ 17–35% (Minimum); 5–12% (uitbreiding) |

| | Berging rond 2060 | Berging rond 2130 |
|---|---|---|
| Benodigde jaarlijkse storting om de rekening te dekken | €70-155 miljoen (bestaand afval, berging vanaf 2060) | €6-16 mln (min) / €26-55 mln (Plus) / €35-70 mln (huidig beleid) |

Bij dit scenario is het belangrijk te vermelden dat een berging rond 2060 alléén het afgekoelde afval van de dan bestaande installaties kan bergen. De €8,5 tot 22,7 miljard aan kosten voor de afval van nieuw gebouwde kerncentrales verdwijnt daarmee niet, maar verschuift naar een uitgestelde rekening voor een latere bergingsfase (berging 2130 in de tabel). Ten tweede: in het scenario in 2130 met voortgezette stortingen en gunstige rendementen, dekt de reserve in de uitbreidingsscenario's minder dan een kwart van de rekening.

## Waarom het stelsel dit gat niet dicht

Het Nederlandse financieringsstelsel blijkt geen werkend mechanisme te bevatten dat betalingen aan de verplichting koppelt. Afvalaanbieders betalen COVRA tarieven die verwerking, opslag én eindberging moeten dekken. Voor ziekenhuizen, laboratoria en industrie zijn die tarieven openbaar en aanpasbaar, en na jaren van verliezen zijn ze tussen 2016 en 2020 bijna verdubbeld. Maar het hoogradioactieve afval van de nucleaire sector valt onder langlopende commerciële contracten met EPZ (Borssele), NRG (Petten) en Urenco, waarvan de prijzen jaren vooruit vastliggen, geen risico-opslag kennen en vertrouwelijk zijn. Stijgende kostenramingen komen dus terecht bij de kleine tariefbetalers.

De toezichthouder heeft dit risico zelf vastgesteld. In 2020 concludeerde de ANVS na inspectie dat ziekenhuizen feitelijk financiële risico's droegen die bij de exploitanten van Borssele en Petten thuishoren, hetgeen in strijd is met het beginsel 'de vervuiler betaalt' uit het Nationaal Programma. De ANVS bereidde een dwangsom van €90.000 tegen COVRA voor, trok die na overleg weer in, en waarschuwde de staatssecretaris dat een regelgevend kader voor de financiering van de eindberging ontbrak.

In maart 2024 volgde de ANVS-beleidsregel toezicht COVRA-tarieven. Die verduidelijkt hoe de ANVS toeziet op transparante, objectieve en niet-discriminerende tariefstelling, maar de ANVS stelt zelf dat haar toezicht de wíjze van tariefstelling betreft, niet de hoogte. Toen consultatiepartijen aankaartten dat ziekenhuizen met almaar stijgende kosten zitten, antwoordde de ANVS dat dit signaal buiten haar toezichtstaak valt.

Daarmee ontbreekt in Nederland alles wat in de drie onderzochte landen betaling en verplichting verbindt: een heffing per opgewekte kilowattuur (Finland en Zweden storten zo in een geoormerkt fonds; het Franse EDF reserveert 0,14 cent per kWh onder wettelijk toezicht), een periodieke herijking (Zweden herrekent elke drie jaar en past de bijdragen aan), en zekerheden (Zweden houdt SEK 81 miljard aan garanties aan voor het geval een exploitant omvalt voordat zijn afval betaald is). Dat laatste risico is in Nederland uitgekomen: toen de eigenaar van Dodewaard de ontmanteling niet kon financieren, kocht de staat in 2023 de aandelen en nam de verplichting over. Eindberging is betaalbaar als zij wordt doorberekend over de looptijd van een kerncentrale. Wanneer dit niet gebeurt is het risico dat de rekening dus later bij burgers landt.

## Aanbevelingen

Het rapport doet zes concrete aanbevelingen, gericht aan kabinet, parlement, COVRA en de verantwoordelijke ministeries.

**1. Publiceer een volledige opbergkostenrekening, ook voor mogelijke nieuwbouwscenario's.**

Voordat de regering over gaat tot keuze over het bouwen van nieuwe reactoren of SMR's dient in ieder geval een complete kostenraming van de opbergverplichting die elke optie schept en te benoemen wie haar betaalt. Tegenover de €14,5 miljard voor de bouw staat nu geen enkel gepubliceerd bedrag aan de afvalkant, terwijl de opbergrekening bij de nucleaire ambities van dit kabinet van vergelijkbare omvang is als de bouwkosten.

Door nieuwbouwbesluiten vervalt daarnaast de optie voor een internationale eindbergingsroute via ERDO, waar ook mogelijk meerkosten bij komen. Ook de financiële en maatschappelijke kosten van het wegvallen van een internationale route dienen te worden uitgewerkt.

**2. Voer een bergingsheffing op nucleaire elektriciteit in.** Met 0,35 tot 0,7 cent per kilowattuur is de volledige HRA-bergingsrekening van het huidige beleid te financieren uit de stroom die haar veroorzaakt. Finland en Zweden belasten hun exploitanten al per eenheid productie, in een geoormerkt fonds; Nederland rekent zijn nucleaire producenten in plaats daarvan contractprijzen die jaren vastliggen en niet meebewegen met de kostenramingen.

**3. Maak een einde aan de vertrouwelijkheid van de kernafvalcontracten.** Publiceer de langlopende contracten tussen COVRA en de exploitanten van Borssele en Petten, ten minste wat betreft prijs en risicoverdeling. Zolang zij geheim zijn kan het parlement niet controleren of het beginsel 'de vervuiler betaalt' uit het Nationaal Programma wordt nageleefd.

**4. Richt een onafhankelijke periodieke kostentoets in, met de bevoegdheid om bijdragen aan te passen.** Het Zweedse model – elke drie jaar een herrekende kostenbasis, getoetst door de Riksgälden, die vervolgens heffingen én zekerheden vaststelt – verdient een Nederlandse vertaling.

**5. Verlang financiële zekerheden van nucleaire exploitanten.** Zweden houdt naast zijn fonds SEK 81 miljard aan garanties aan, juist omdat een exploitant kan omvallen voordat zijn afval betaald is. Dodewaard – waar de staat uiteindelijk de centrale kocht toen de eigenaar de ontmanteling niet kon dragen – bewijst dat dit risico in Nederland niet hypothetisch is.

**6. Bereken de ontbrekende helft van de rekening: LMRA en bovengrondse opslag.** Dit rapport becijfert alleen hoogradioactief afval, omdat in geen van de vier onderzochte landen een bruikbare kostenbasis voor LMRA bestaat. Een gespecifieerde kostenbasis voor acceptatie, opslag en berging van LMRA zou bijdragen aan een volledigere analyse van de kostenplaatje. In dit rapport blijven deze kosten tot nu toe buiten beschouwing.

## Verantwoording en onzekerheid

Vrijwel elk getal in dit rapport komt van de overheid of van haar eigen afvalbedrijf: COVRA's Masterplan en kostenevaluaties, aangevuld met de officiële programma's van Finland, Zweden en Frankrijk. Een precieze Nederlandse raming is voor nu onmogelijk: er is geen locatie en de keuze tussen zoutkoepels en klei ligt nog open. COVRA hanteert daarom zelf ±30% marge. Maar de onzekerheid in de kostenraming is niet symmetrisch: geen vergelijkbaar Europees programma is ooit onder zijn vroege ramingen uitgekomen, en de overschrijdingen waren het grootst wanneer bij het ramen de minste stappen waren gezet. Nederland heeft van alle onderzochte landen de minste stappen gezet.

# 1. Management summary

**The Dutch cabinet intends to keep the Borssele nuclear power plant open beyond 2033 and to expand nuclear capacity with four new large reactors and up to four small modular reactors. A total of €14.5 billion has been earmarked for construction. No figure has been published, anywhere in the decision-making so far, for what disposing of the resulting radioactive waste will cost, or for who will pay it. This report fills that gap. It estimates the waste volumes and disposal costs of the cabinet's nuclear plans under three scenarios, compares the outcome with what has actually been set aside, and examines how the Dutch financing system would absorb the difference.**

### Approach

The report deliberately builds on the government's own numbers. Waste volumes are taken from the 2050 Masterplan of COVRA, the state company responsible for all Dutch radioactive waste, and extended over the full operating life of each installation – the Masterplan itself stops counting in 2050, which for a reactor commissioned in 2038 and running eighty years captures only about fifteen percent of the waste it will actually produce. Three scenarios are modelled: a Minimum scenario with no new construction; a Plus scenario with the Borssele life extension, two new reactors and four SMRs, which COVRA has itself modelled; and a Current-policy scenario with four new reactors and four SMRs, reflecting the cabinet's stated ambition, which COVRA has not modelled and which this report constructs on the same basis as the other two.

Disposal costs start from COVRA's own published estimates: €3.3–3.5 billion for a repository holding only the waste of the existing installations, and €10.0–10.3 billion once new reactors are included – a figure COVRA's 2024 annual report puts at €10.9 billion, up from €2.31 billion a year earlier. For the four-reactor programme, for which no official figure exists, the report extends COVRA's two published cost points using the fixed-and-variable cost relationship they imply, giving a base estimate of approximately €12.9 billion.

Because estimates made this early in a disposal programme have consistently proven too low, these base figures are then adjusted using the documented cost growth of the three European programmes far enough advanced to have a record. In Finland, where the Onkalo repository is essentially complete, like-for-like costs rose approximately 26%. In France, where the Cigéo project has not yet begun construction, the official baseline rose 46% in real terms. In Sweden, the projected cost of the waste programme as a whole more than doubled between Plan 2001 and Plan 2022 – average real growth of 4.3% a year, on a constant statutory scope – a cumulative 142%, used here as the upper bound. The Netherlands, which has not yet chosen a site or a host rock, stands earlier in the process than any of the three, at the stage where estimates have historically been furthest from outturn.

**What disposal will cost**

Applying that overrun range to the Dutch base estimates gives the report's central results for high-level waste disposal:

| Scenario | Full-life HLW inventory | Disposal cost (2026 prices, incl. overrun range) |
|---|---|---|
| Minimum – existing installations only | 225 $m^3$ | €4.1–8.5 billion |
| Plus – KCB extension, two reactors, four SMRs | 3,777–18,977 $m^3$ | €12.6–24.9 billion |
| Current policy – KCB extension, four reactors, four SMRs | 6,737–33,057 $m^3$ | €16.2–31.2 billion |

The inventory ranges reflect the choice between reprocessing (lower volumes, but with reprocessing charges of the order of €30–60 billion not included above) and direct disposal. The current-policy programme thus adds roughly €12–23 billion in disposal costs compared with building nothing – an amount comparable to, and possibly exceeding, the entire €14.5 billion construction budget, and absent from every published figure supporting the nuclear programme.

These are lower bounds, not worst cases. They cover high-level waste only. Low- and intermediate-level waste – between roughly 311,000 and 395,000 $m^3$ by 2130 depending on scenario, including some 158,000 $m^3$ of NORM waste from uranium enrichment – is projected in volume in this report but not costed, because no Dutch or comparator programme publishes a usable cost basis for it. Interim storage for the century before a repository exists, transport, security and long-term monitoring are likewise excluded.

**What has been set aside**

Against this liability stands a final-disposal reserve of €133 million at the start of 2025, accumulated over five decades of Borssele, thirty years of Dodewaard, sixty years of the Petten research reactor and the entire history of enrichment at Urenco. It has grown from €68 million at the end of 2014 – net additions in the mid-single-digit millions per year. It covers between 1.6 and 3.2 percent of the disposal bill for the waste the Netherlands has already produced, and under one percent of the current-policy bill.

The timing makes the gap worse rather than better. Dutch policy long assumed a siting decision around 2100 and an operating repository around 2130, giving the reserve a century to compound; in 2024 the government pulled the decision forward to around 2050, precisely because of its nuclear ambitions. Whilst the decision would be made in 2050, we assume construction may start earlier than in 2130, as public participation processes would be hurt by leaving 80 years between decision and construction, as people who face the construction costs would not be born at the time the decision was made. The report models both horizons. A repository with a construction completion in 2060 could accept only the cooled waste of the existing installations – none of the new-build waste would be old enough – so its cost is essentially the Minimum-scenario cost in every scenario, €4.1–8.5 billion, against a reserve that will by then have reached roughly €0.3–0.6 billion: coverage of 4–14%, whatever is decided about new reactors. The €8.5–22.7 billion of new-build disposal cost does not disappear in that case; it shifts to a deferred balance for a later disposal phase. By 2130, with the full inventory eligible, the reserve reaches €1.4 billion without further contributions, or roughly €3 billion with them – covering perhaps a sixth to three-quarters of the Minimum bill, but only 5–12% under the expansion scenarios.

**How the gap is currently financed**

The report also examines the financing structure itself, and finds that it lacks any mechanism to close such a gap. Producers pay COVRA a tariff intended to cover full processing, storage and eventual disposal. For hospitals, laboratories and industry these tariffs are published and adjustable, and after years of losses they nearly doubled between 2016 and 2020. The nuclear operators' high-level waste, by contrast, is governed by long-term commercial contracts whose prices are fixed years ahead, carry no risk premium, and are confidential. When cost estimates rise – fivefold in one year, in COVRA's latest accounts – nothing in this arrangement passes the increase to the operators whose waste dominates the liability. The regulator has documented the consequence: in 2020 the ANVS established that hospitals were in effect bearing financial risk belonging to the operators of Borssele and Petten, judged this incompatible with the polluter-pays principle, prepared a penalty order against COVRA and withdrew it – while warning the state secretary that a regulatory framework for financing final disposal was lacking. A 2024 ANVS policy rule has since clarified tariff oversight, but does not tie what nuclear operators pay to what disposal will cost. The precedent for where unfunded liabilities then land is Dutch: when the owner of the Dodewaard plant could not fund its dismantling, the state bought the shares and took over the obligation.

Spread across all the electricity the proposed reactors and the Borssele extension would generate – roughly 4,700 terawatt-hours over their lifetimes – full high-level-waste disposal under current policy amounts to 0.35–0.7 cent per kilowatt-hour, on the order of one to two percent of a household electricity price. Expressed per Dutch household, the unfunded bill is roughly €1,900–3,700. Disposal is, in other words, affordable if charged to the electricity that causes it; the finding of this report is that it is not being charged, and that the bill will accordingly fall on citizens later, through energy prices or taxation, without that choice ever having been made explicitly.

**Uncertainty**

No Dutch repository can currently be costed precisely: no site has been chosen, the choice between salt and clay host rock is open, COVRA attaches a ±30% margin to its own central estimate, and the four-reactor cost base is extrapolated rather than published. But the uncertainty is not symmetrical. No comparable European programme has come in below its early estimates; all have cost more, and most cost overrun was documented where the fewest steps had been taken when the estimate was made.

**Recommendations**

Chapter 9 develops six recommendations: no irreversible new-build decision until the full disposal liability of each option – including low- and intermediate-level waste, NORM and interim storage – is published; a disposal levy on nuclear electricity of 0.35–0.7 cent per kilowatt-hour, as Finland and Sweden already charge their operators; publication of the confidential waste contracts between COVRA and the nuclear operators; an independent periodic review of the disposal-cost estimate with the power to adjust what producers pay, on the Swedish model; financial collateral from nuclear operators against the risk of failure before their waste is paid for; and publication of a full cost basis for the low- and intermediate-level waste that this report, like every programme it examined, could not cost.

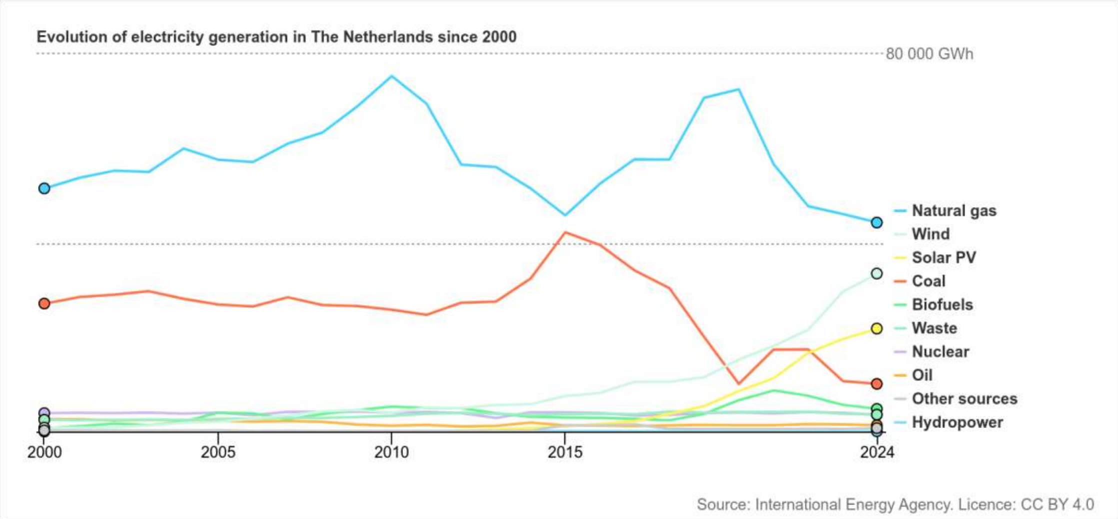
# 2. Introduction

**Climate change requires power sources beyond the established oil, gas and coal models (IPCC, 2023). At the same time, the war in Ukraine and the conflict around Iran have squeezed the supply of natural gas and oil, and energy security has moved up the political agenda as a matter of national importance (ECSAP, 2025; McIlroy, 2026).**

According to the International Energy Agency, the Netherlands is seeing electricity generation from natural gas and coal decline, compensated by growth in solar, wind and other renewables, which now account for 26.4% of domestic energy production (IEA, n.d.). The Synthesis Report of the Intergovernmental Panel on Climate Change (2023) shows that renewable electricity generation is increasingly price-competitive globally, with solar and wind sources becoming a cheaper option than fossil sources in many regions of the world. Despite this trend, in 2024 the government cabinet of the Netherlands proposed investments in nuclear energy.

**Figure 1**

*Evolution of electricity generation in the Netherlands. Wind energy production outgrew coal in recent years, which was later followed by solar PV energy.*



This decision raises doubts, because recent experience with building new nuclear power plants (NPPs) has been one of delays and costs far above the initial estimates, from the United States to Japan (Koenis, 2024). Vogtle units 3 and 4 in the United States were approved with a budget of $14 billion and a seven-year construction schedule; the reactors were completed roughly seven years late, at a total cost of around $35 billion (Atlanta Journal-Constitution, 2024). Similar problems affected Hinkley Point C in the UK, Olkiluoto 3 in Finland and the Monju plant in Japan (Flyvbjerg, 2021). The starkest case is France's Flamanville 3, which was connected to the grid thirteen years late, at costs more than six times the original estimate (Frederik, 2024).

Currently, the only working nuclear power plant in the Netherlands is the one in Borssele in Zeeland. This power plant was commissioned in 1973 and provides about 3 percent of the annual electricity consumption in the Netherlands (Koenis, 2024). The plant was due to close in 2033, but in 2024 the governing coalition decided not only to keep it open longer but also to expand nuclear capacity: four new large reactors instead of the two planned by the previous cabinet, alongside the possibility of multiple small modular reactors (Koenis, 2024; Sleiderink, 2025). The coalition parties earmarked an additional €9.5 billion for developing and building the new NPPs, on top of the €5 billion set aside by the previous government – €14.5 billion in total. Energy experts, however, put the average cost of a single new plant at around €20 billion, implying a gap of €65.5 billion for a four-reactor programme (Stolwijk, 2024).

This decision came together with changes regarding the management of nuclear waste in the Netherlands. Currently, the waste produced is cooled down, transported to a specialist reprocessing plant in France, and then stored above ground in Zeeland at the Central Organization for Radioactive Waste (COVRA) for a period up to a hundred years. The following step should be moving this waste to a long-term storage facility, a Deep Geological Repository, where the waste will progressively lose its radiation in a process that can take hundreds of thousands of years (Rathenau Instituut, 2024; Ministerie van Economische Zaken en Klimaat, 2023).

However, at the present moment, there is no permanent underground repository for Dutch radioactive waste available in the country, and the intentions are to be able to use one around the year 2130. This factor has received far less attention than its significance warrants: waste management remains one of the most challenging aspects of any continued use or expansion of nuclear power (Kvashnina et al., 2024). This complexity is associated with significant costs of construction, operation, monitoring, and decommissioning. Deep geological disposal (DGD), currently the internationally accepted best practice for the ultimate disposal of High-Level Waste/Hoogradioactief Afval (HLW), comes with even higher costs, due to the complex engineering and rigorous safety standards required (Budzier et al., 2019). Adding to this complexity, in COVRA's 2024 annual report the reserve for final disposal stood at €133 million – far below the funds of countries that are actually planning or building deep geological repositories (COVRA, 2024; Laka, 2026).

# 3. Research Objective

**This report calculates the construction and other costs of long-term storage and disposal of nuclear material in the Netherlands, in three scenarios, with a cost range for each. The three scenarios refer to the nuclear waste from:**

1) Minimum Scenario: Only existing power plants

2) Plus Scenario: Borssele + Dodewaard (B+D) + 2 new nuclear power plants and 4 SMRs.

3) Current policy proposition: B+D + 4 new nuclear power plants and 4 SMRs.

## 3.1 Research questions

Based on the project's objective, the following research questions are formulated:

1. What are the volume and cost of long-term storage for the Netherlands' full mix of radioactive waste streams – spent fuel and other high-level waste from existing and proposed nuclear power plants, together with waste from medical-isotope production, research reactors, decommissioning, and uranium enrichment (NORM) – under each of the three scenarios?
2. What are the likely costs for long-term storage of nuclear waste in the Netherlands?

These questions will help to answer the main research question: **Will the COVRA fund, as currently structured and funded, cover the disposal liability generated under each scenario?**

In this context, it is important to understand that the decision on the location and management method for the long-term storage facility has itself been brought forward: rather than being taken around 2100, as previously anticipated, it is now expected around 2050 (Section 5.5.1). The facility's operational target of around 2130 has not itself changed. This acceleration implies that decisions on new NPPs and other waste sources need to be addressed in the coming years, so that they are taken with an appropriate disposal capacity in mind. Besides that, storage costs should be considered when estimating the costs of these projects, especially since producing more nuclear waste reduces the possibilities of, and cost savings from, multinational final disposal.

# 4. Methodology

**To answer the research questions, this report combines a comparative literature review of established nuclear-waste disposal programmes with a bottom-up estimate of Dutch waste volumes and disposal costs under three nuclear-development scenarios.**

## 4.1 Literature review and cross-country comparison

Relevant literature on the long-term costs of nuclear waste storage was collected for three national programmes – Finland, Sweden and France – selected for their governance similarity to the Netherlands and, deliberately, for representing established practices at different stages of project maturity: Finland's Onkalo repository is essentially complete, Sweden's Forsmark repository began construction in January 2025, and France's Cigéo repository has not yet reached its construction decree (Chapter 5). For each country, the original published cost estimate was compared against the most recent published estimate on a like-for-like basis, to establish how far cost projections have moved as each project has progressed (see Section 4.3 for how this comparison is converted into the overrun range applied to the Dutch case).

## 4.2 Waste volume estimation

The COVRA 2050 Masterplan (COVRA, 2024) is the primary data source for projected Dutch radioactive waste volumes (NORM, LILW and HLW) to 2050, and provides the basis for the Minimum Scenario (continuation of existing installations only) and the Plus Scenario (Borssele plus Dodewaard, two new nuclear power plants and four SMRs, as suggested in the COVRA 2050 Masterplan. This report extends the Masterplan's figures in two ways: first, by applying COVRA's own annual waste-generation rates across each installation's full operating life rather than only to 2050 (Sections 6.1 and 6.2); second, by constructing a third, Current Policy Proposition scenario – four new nuclear power plants plus four SMRs – that COVRA has not itself modelled, built on the same basis as the other two (Section 6.3.3). This scenario is a suggestion of a pathway to 7GW of nuclear power generation, as announced by the Jetten government in 2026.

Where the Masterplan does not cover a particular waste stream, this report relies on external reference values. Each carries a scope limitation that should be read as a qualification on the resulting figures, rather than as a Netherlands-specific estimate:

**Decommissioning waste for new nuclear power plants** is estimated using a reference value of 5,000 $m^3$ LILW reported by the German Federal Office for the Safety of Nuclear Waste Management (BASE, 2024). This figure does not specify reactor capacity or type, so it is used only as an indicative reference; this report also assumes, in the absence of explicit information to the contrary, that COVRA's own inventory figures represent operational waste only.

**SMR decommissioning waste** is derived from Yildirim et al. (2024)'s assessment of the NuScale Power Module, scaled to COVRA's reference 350 MWe / 50-year SMR via lifetime thermal energy production. Because this scales a single reference design's waste-intensity factors onto a generic reactor class, the resulting values (approximately 16–30 $m^3$ of long-lived and 386 $m^3$ of short-lived LILW) should be read as indicative rather than predictive; decommissioning waste is also shaped by reactor geometry, shielding configuration and material composition, which do not necessarily scale linearly with thermal output.

**HOR and PALLAS research-reactor decommissioning waste** is proxied using the HFR Petten decommissioning assessment (Commission of the European Communities, 1997), chosen for its co-location and comparable thermal capacity, in the absence of reactor-specific decommissioning inventories for either facility.

**NORM waste beyond 2050** is extrapolated at a constant average annual accumulation rate, calculated from the 2024–2050 COVRA trend, through to 2130. This assumes future uranium-enrichment activity at Urenco follows a broadly similar trajectory to the historical rate, which may not hold if enrichment capacity changes materially.

We made the choice to work with official government and IAEA numbers, although there is significant uncertainty in the literature about the volume of SMR waste, with risk the volume may be higher than modelled in this report (see Krall, Macfarlane & Ewing (2022)).

## 4.3 Cost estimation and overrun methodology

Repository costs are estimated in two stages. First, a cost-overrun range is derived from the three case-study countries using the formula in Budzier et al. (2019):

Cost Overrun = (Actual Cost / Estimated Cost) − 1

For each country, the original and most recent published cost estimates are converted to a common 2026 price basis using euro-area HICP before this ratio is calculated, so that overruns reflect real cost growth rather than inflation (Section 6.4.1). Second, this overrun range is applied to COVRA's own published cost estimates for the Netherlands (COVRA, 2025) to derive a plausible cost range for each of the three Dutch scenarios.

Reprocessing costs (Section 6.4.2) are estimated separately, using published benchmark unit costs from the wider reprocessing-economics literature (Bunn et al., 2003), since the Orano–EPZ contract price for reprocessing Borssele's spent fuel is not public. The France-specific benchmark is used preferentially, since Borssele's fuel is reprocessed at the same La Hague facility as the benchmark study's reference case.

**Scope.** This report estimates disposal costs for high-level waste (HLW) only. Costs of managing low- and intermediate-level waste (LILW), and of interim storage, are outside its scope, due to time and data limitations (Section 6.4). The resulting cost ranges are also expressed per household and per kilowatt-hour of nuclear electricity in Section 6.4.3.

The chosen case studies vary about the technical aspects of long-term storage. This report does not make any pronouncements about differential costs due to these technical considerations (such as storage methods), nor does this report comment on the desirability of these choices.

The choice of case studies for three countries was made to give an indication about realistic cost overrun scenarios, which could prepare policymaking in The Netherlands for a variety of scenarios.

# 5. Overview of current practices

**To better understand how the Netherlands is situated, it is important to investigate the existing practices and changes at a broader scenario. By creating an overview of nuclear waste disposal and its costs in different countries, a base is created for the estimation of state of art costs for the expansion of long-term storage facilities for the new proposed NPPs in the Netherlands.**

## 5.1 Current global state of the art

### 5.1.1 Definitions

According to the U.S. Nuclear Regulatory Commission (2002), nuclear waste is a by-product of nuclear reactors, fuel-processing plants, hospitals and research facilities. Nuclear waste is also generated while decommissioning and dismantling nuclear reactors and other nuclear facilities. Waste is classified into categories that reflect its level of radioactivity and the length of time it remains hazardous. As elaborated by Cetina (2024), COVRA (2024) and the IAEA (n.d.), from highest to lowest radioactivity, the classifications used in this report are:

- **High-level waste (HLW**; in Dutch: hoogradioactief afval**)**: waste from the use and reprocessing of nuclear fuel. It is intensely radioactive, generates heat, and requires shielding, cooling and, ultimately, isolation from the biosphere for very long periods.
- **Intermediate-level waste (ILW)**: waste with substantial activity that requires shielding and engineered disposal, though no cooling. It typically includes reactor components, contaminated parts left over after decommissioning, and by-products such as sludges, resins, filters and decontamination residues.
- **Low-level waste (LLW)**: waste with low activity that produces no heat. It still requires controlled handling and authorised disposal, but no shielding under normal conditions; it includes contaminated clothing such as protective shoe covers, floor sweepings, and paper and plastic from NPPs, research laboratories, hospitals, industry and defence. Because the two categories follow similar disposal routes, Dutch practice groups low- and intermediate-level waste together as LILW (laag- en middelradioactief afval), and this report follows that convention.
- The Netherlands also defines **naturally occurring radioactive material (NORM)**, treated as a subcategory of LILW: naturally occurring radioactive materials that become concentrated through industrial processes, such as the processing of uranium or phosphate ores.

Besides HLW, significant volumes of ILW and LLW arise from the growing worldwide use of radioisotopes in medicine, industry, agriculture, research, defence and new technologies. The most important source, however, is nuclear energy production, which generates large volumes in every category and, in the case of HLW, waste that remains active for thousands or even hundreds of thousands of years (NEA, n.d.).

While every category of nuclear waste requires safe disposal, it is worth noting that low- and intermediate-level waste makes up about 97% of the volume but only 8% of the radioactivity; high-level waste, at 3% of the volume, accounts for the remaining 92%. Given its risks to humans and the environment, a high degree of isolation from the biosphere is required for a long period of time. Currently, the most accepted solution is DGD, which involves burying the waste in a stable geological formation, typically hundreds of meters below the surface (IAEA, n.d.).

### 5.1.2 Management practices

The Nuclear Energy Agency (n.d.) defines radioactive waste management as the safe treatment, storage and disposal of liquid, solid and gas discharge from nuclear industry operations with the goal of protecting people and the environment. Disposal of LLW and ILW is already implemented in several countries and are usually at or near the surface, with some of ILW that contains long lived radioactivity being disposed at greater depths, of the order of tens of metres to a few hundred metres (IAEA, n.d.).

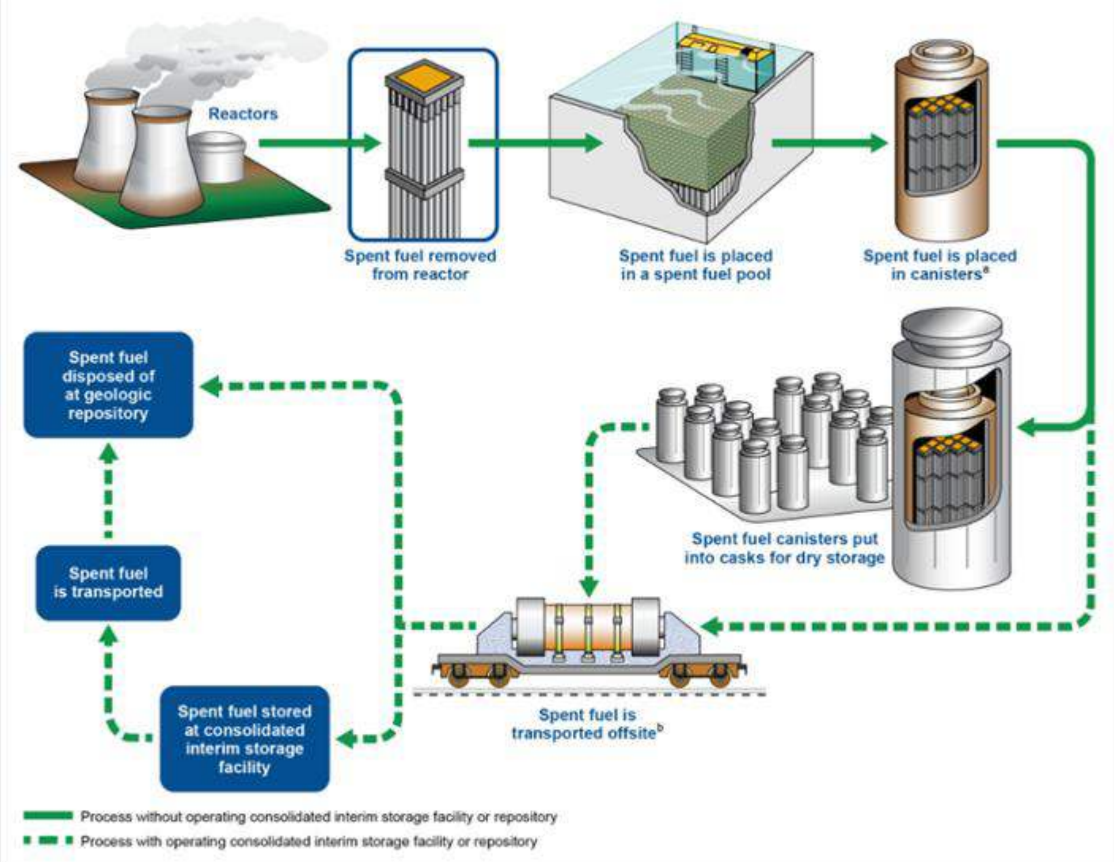
However, up to this date, no permanent storage facility is available for HLW, and for most of the world the primary method of managing spent nuclear fuel is interim storage. This approach provides a temporary solution while permanent geological repositories are developed and constructed (IAEA, n.d.). Two primary methods are used for interim storage (U.S. Nuclear Regulatory Commission, 2002; IAEA, n.d.):

- Wet storage: spent fuel is placed into pools of water at the reactor site, typically for at least five years. The water serves two crucial purposes: it cools the fuel rods, which generate significant heat even after the reactor is shut down, and it shields the radiation emitted by the fuel. The water is constantly circulated and cooled.
- Dry cask storage: after a period of cooling in the pools, the spent fuel can be transferred to dry cask storage systems – massive, heavily shielded containers of steel and concrete, sealed and placed on a concrete pad. Dry casks rely on air circulation for cooling and provide a robust barrier against radiation release.

The IAEA estimates that in 2024 there was around 301,000 tonnes of spent nuclear fuel in interim storage across the world, with the majority of it at reactor sites (Fisher, 2024). About 70% of the world's spent fuel is in wet storage, with the rest in concrete-and-steel containers called dry casks (Benke, 2023).

**Figure 2**

*Process for Managing Commercial Spent Nuclear Fuel, from Removal and Storage at a Reactor Site to Transportation to a Consolidated Interim Storage Facility or Permanent Repository (GAO, 2021).*




Note. a: Without an operating consolidated interim storage facility or geologic repository, pools at commercial reactors have largely reached their maximum capacities and cooled fuel therefore generally must be transferred to dry storage. Theoretically, spent fuel removed from a pool could be directly transported to consolidated interim storage facilities or a geologic repository if they existed. b: If a consolidated interim storage or permanent geologic repository is developed and authorized to accept commercial spent nuclear fuel, spent fuel canisters may be transported via truck, rail, and/or barge from reactor sites directly to a permanent geologic repository for disposal or to one or more consolidated interim storage facilities before being transported to a permanent geologic repository.

#### 5.1.2.1 Deep Geological Disposal (DGD)

The internationally accepted best practice for the ultimate disposal of High-Level Waste (HLW) is deep geological disposal. This involves burying the waste in a stable geological formation, typically hundreds of meters below the surface. The aim is to isolate the waste from the biosphere for thousands of years, preventing any potential release of radioactivity. Key criteria for site selection are:

- Geological Stability: The site must be in a tectonically stable area with minimal risk of earthquakes or volcanic activity.
- Low Groundwater Flow: The rate of groundwater flow through the repository site must be very low to minimize the potential for radionuclides to be dissolved and transported away from the waste.

- Favourable Rock Properties: The host rock must be capable of withstanding the heat generated by the waste and must have low permeability to prevent the migration of groundwater. Common rock types considered include granite, clay, and salt.
- Long-Term Isolation: The site must provide a high degree of confidence that the waste will remain isolated from the biosphere for thousands of years.

**Multi-Barrier Approach**

The primary risks associated with nuclear waste storage include leaks from storage containers, contamination of groundwater, and release of radioactivity into the environment (IAEA, n.d.). Most of these risks come from the eventual corrosion of the copper canisters that contain the spent nuclear fuel. While there are different scientific opinions about how fast this process can happen, it is a consensus that this should mostly affect future generations. An attempt to mitigate this generational issue has been studied by the field of nuclear semiotics, which considers developing warning signs that can be understood by humans 10,000 years from now (Brooks & Liechtenstein, 2026).

Geological repositories are designed to minimize these risks through rigorous site selection criteria and a multi-barrier approach, which involves multiple layers of protection to prevent the release of radioactivity:

- The Waste Form: The spent fuel itself is a barrier, as it is in a solid form that is resistant to dissolution.
- The Canister: The spent fuel is encased in robust, corrosion-resistant canisters, typically made of steel or copper.
- The Backfill Material: The space between the canisters and the surrounding rock is filled with a backfill material, such as bentonite clay, which swells when it encounters water, creating a tight seal and further impeding groundwater flow.
- The Host Rock: The surrounding rock formation acts as the final barrier, providing a natural barrier against the migration of radionuclides.

Nuclear waste in interim storage is routinely monitored and inspected to ensure the integrity of the storage containers and the safety of the surrounding environment. In geological repositories, after emplacement, the site is sealed and monitored. Long-term monitoring programs are typically implemented to detect any potential release of radioactivity. While the goal is passive safety, monitoring provides assurance and early warning.

Alternative methods are also currently in study, Norway, for example, is considering deep borehole disposal, where waste would be lowered in canisters to a much deeper 3,500m in thin boreholes without construction tunnels (Benke, 2023) Alternatives exist, such as deep borehole disposal (burying waste in very deep, narrow boreholes) and transmutation (converting long-lived radioactive isotopes into shorter-lived or stable isotopes). However, these alternatives are still under development and face significant technical and economic challenges. Space disposal, though often mentioned, remains prohibitively expensive and carries unacceptable launch risks. Against this background of common practice, the following sections turn to the three case studies.

## 5.2 Finland

The Finnish Onkalo repository is expected to be the first permanent disposal facility for HLW in the world. The Geological Disposal Facility (GDF) lies 450m deep inside the Olkiluoto island in the southwest of the country, and its location was chosen for its migmatite-gneiss bedrock, which is known for its high stability and low risk of earthquakes (Benke, 2023; Brooks & Liechtenstein, 2026). With space for 6,500 tonnes of uranium, Onkalo is aimed at providing permanent storage for spent fuel from Finland's five nuclear reactors up to the year 2120 (Brooks & Liechtenstein, 2026). The waste currently cooled in water pools at an interim storage site at the Olkiluoto power plant will be first to be deposited while the possibilities for disposal of international waste are seen as a small-scale possibility (Brooks & Liechtenstein, 2026; Korkman, 2026).

The waste that will be disposed in Onkalo will not go through reprocessing, which produces reusable nuclear material and reduces waste volume, because the process is considered technically demanding and expensive (Benke, 2023). Instead, the repository is based on the Swedish KBS-3 and will create three barriers around nuclear waste. The first, the waste goes inside copper canisters with an inner shell made of cast iron and an outer shell made of 5cm thick copper. The second barrier is sealing the canisters with bentonite and as a last measure, they are buried in tunnels deep in the bedrock (Benke, 2023). Five dead-end deposition tunnels have been built so far, all 350m long, with other 85 to be constructed over the years as the facility fills up. Each deposition tunnel has around 40 vertical circular holes in its floor, each 8m deep and 2m wide. In total, there's room for about 3,000 canisters, one for each vertical hole (Benke, 2023). Once each disposal tunnel is filled, it will be sealed with a steel-reinforced concrete plug (Korkman, 2026).

With its construction plans approved by the Finnish government in December 2000, official construction began in 2004, and in 2026 the Finnish Radiation and Nuclear Safety Authority (STUK) is due to give its final assessment. The operator, Teollisuuden Voima Oyj (TVO), expects the site to be ready for use by the start of 2027 – nearly 27 years after the project’s approval (Benke, 2023; Korkman, 2026). The project has been commissioned and paid for by the Finnish nuclear power companies (Benke, 2023). Its cost overruns have nonetheless increased the total investment, leading to loans, and the additional costs will most likely be passed on to consumers.

According to Matt Fisher of the International Atomic Energy Agency, almost 430,000 tonnes of spent fuel have been produced globally since the 1950s; roughly two-thirds – about 300,000 tonnes – remains in temporary storage, with the rest reprocessed. Disposing of the stored inventory alone would require more than 45 repositories the size of Onkalo, and spent fuel continues to be generated at around 10,000 tonnes per year

(Fisher, 2024). These figures do not yet reflect the expected worldwide increase in nuclear investment (IAEA, 2024).

### 5.2.1 Political Decision Process

Finland's nuclear waste management programme dates to 1983, shortly after the country's four original reactors entered commercial operation, when the government set out the overall disposal concept and an indicative timetable. The 1987 Nuclear Energy Act gave this legal form: it created the State Nuclear Waste Management Fund under the Ministry of Trade and Industry (now the Ministry of Economic Affairs and Employment) and established the three-stage licensing process that has governed the project ever since – a political decision-in-principle (DiP), followed by a construction license and finally an operating licence (World Nuclear Association, 2026a; Nuclear Engineering International, 2024).

The 1994 amendment to the Act, which bars the import and export of nuclear waste, was the decisive step that took deferral off the table. Until then, spent fuel from the Loviisa plant had been shipped back to the Soviet Union under a 1969 bilateral agreement; that arrangement wound down as the 1994 ban took effect. 'Before the legal change in 1994, the spent nuclear fuel was exported to, for example, Russia,' Climate and Environment Minister Sari Multala told AFP (Korkman, 2026). Posiva Oy, the joint venture Fortum and TVO founded the following year to run the programme (Section 5.2.3), then began the site-selection and licensing process the 1987 Act had set out.

Site investigations had been under way since the 1980s at several locations; Posiva narrowed the field and, in 1999, selected Olkiluoto in the municipality of Eurajoki, based on its bedrock characteristics and the fact that the municipality already hosted TVO's power plant. The choice followed an environmental impact assessment carried out in 1995–1997 that was, at the time, unusually extensive for its inclusion of socio-economic impacts and multi-level public consultation (Posiva, 2023). A public hearing was held in Eurajoki in November 1999, and in November 2000 the municipal council voted 20 to 7 in favour of hosting the facility – a margin its own members attributed to decades of trust built up around the existing power plant, and to the jobs and tax revenue it had brought the municipality (Posiva, 2023).

The Finnish Government issued its decision-in-principle at the end of 2000, and on 18 May 2001 the Finnish Parliament ratified it – the first such ratification anywhere in the world for a spent-fuel repository (OECD/NEA, 2002). Construction of the underground characterisation facility that became Onkalo began in June 2004; the Government granted the formal construction licence for the disposal facility itself in 2015, and construction of the encapsulation plant began in 2019. Posiva submitted its operating licence application in December 2021, and STUK's final safety assessment is due in 2026, as set out above (Nuclear Engineering International, 2024; Power Magazine, 2024).

Onkalo's scope – spent fuel from Finland's own reactors only, with international waste treated as at most a small-scale future possibility – follows from this institutional structure rather than from any technical judgement that mixed waste streams are unsafe to co-locate. Posiva is a joint venture of TVO and Fortum, funded through the waste-liability system described above around their own reactor fuel; the 1994 ban on importing or exporting nuclear waste then closed off the alternative of taking material from elsewhere. This distinction matters for the Dutch case: unlike Onkalo, a Dutch repository will need to accept spent fuel, vitrified high-level waste returned from reprocessing, research-reactor waste, medical-isotope waste, decommissioning waste and NORM, from a considerably wider set of producers than in Finland or France (Section 5.5.2). A mixed inventory of this kind means more waste-acceptance criteria, more package types, more handling routes and a broader licensing case – all of which are cost and schedule drivers that Chapters 6 and 7 return to when evaluating overrun risk and repository sizing for the Netherlands.

### 5.2.2 Funding arrangements

The National Nuclear Waste Management Fund, established under the 1987 Nuclear Energy Act and operated under the Ministry of Economic Affairs and Employment, exists to ensure that Finnish society has sufficient funds and competence to arrange nuclear waste management under all circumstances. The Fund consists of two separate parts, the Financial Provision Fund and the Research Fund for Nuclear Energy Expertise (Posiva, n.d.; Finnish Government, 2026).

Contributions are set annually by the Ministry, based on each operator's share of accumulated waste liabilities net of what it has already invested directly in waste management; in practice, the charge has amounted to roughly 10% of nuclear electricity production costs (World Nuclear Association, 2026a). Four entities currently pay into the Fund – Fortum, TVO, Posiva and the VTT Technical Research Centre of Finland – and the Financial Provision Fund held approximately €2.8 billion at the end of 2023 and roughly €3.0 billion at the end of 2025, after returning a profit of about €100 million that year (Finnish Government, 2026; World Nuclear Association, 2026a). As recently as 2012, the Fund's assets (€2.27 billion) tracked within 2% of the Ministry's own undiscounted liability estimate (€2.3 billion).

### 5.2.3 Cost evaluation

#### Budget for waste management

Posiva Oy, founded in 1995 by TVO and Fortum, is responsible for both the interim and final disposal of spent fuel from Finland's five operating reactors at Olkiluoto and Loviisa, funded through the National Nuclear Waste Management Fund described in Section 5.2.2 (Helsinki Times, 2025).

#### Cost of interim storage (with additional values of waste until the DGR is ready)

Spent fuel is cooled in water pools at the reactor sites before eventual transfer to Onkalo; the cost of this interim storage is carried within each operator's own liability to the Fund rather than reported as a separate line item in the sources available for this report.

#### Cost of construction of DGR (that should operate for 100 years)

Posiva's original 2003 cost programme (TKS-2003) put the investment cost of the disposal facility – the above-ground encapsulation plant and the underground repository together – at €503 million, against total lifecycle costs, including 100 years of operation and eventual closure, of €2,542 million (Kukkola & Saanio, 2005). A 2025 Helsinki Times report adds to this the lifecycle costs, stating that construction had already cost €900 million with a further €4 billion still needed to complete the project, bringing the total to nearly €5 billion.

#### Cost of maintenance of DGR

TKS-2003 put 100-year operating costs at €1,923 million and decommissioning and closure costs at a further €116 million, together more than three-quarters of the original total lifecycle estimate (Kukkola & Saanio, 2005). Onkalo is designed to keep receiving waste until around 2120, after which these ongoing costs, along with eventual closure, will continue to be drawn from the National Nuclear Waste Management Fund described in Section 5.2.2.

## 5.3 Sweden

Sweden has occupied the role of one of the main references on the topic of nuclear waste management, with 12 power plants, of which 6 are still active, the country has been developing research on storage practices for over 40 years. The Swedish Nuclear Fuel and Waste Management Company (SKB) was responsible for developing the KBS-3 method and for exporting it to other countries in the World (Dahlström, 2025).

However, similarly to the rest of the World, Sweden is also keeping its nuclear waste in interim storage at least until the end of the 2030s, where the under-construction Forsmark final repository is supposed to start its operations (Johnson, 2025). With a more ambitious project than its Finnish counterpart, it will be the final home for 12,000 tonnes of spent nuclear fuel with 60 km of tunnels buried 500 metres down in 1.9-billion-year-old bedrock, all within 150 kilometers north of Stockholm (Johnson, 2025).

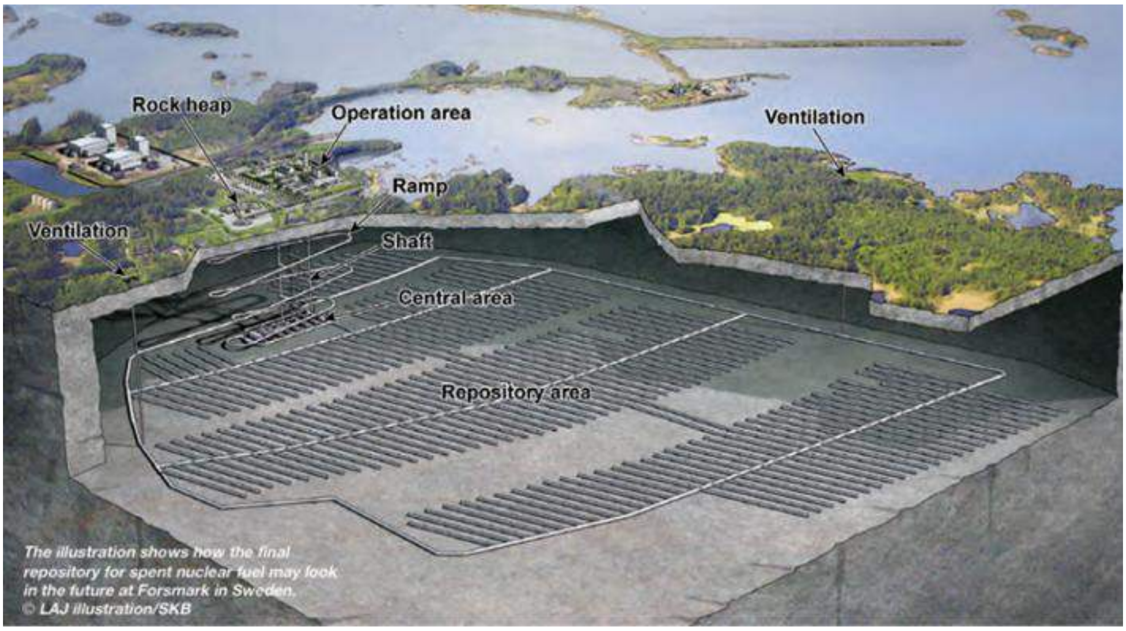
The facility is expected to be completed by 2080 and aims to permanently store the spent nuclear fuel produced by Sweden's twelve commercial reactors, six of which are still in operation. The amount of waste to be stored is based on today's existing nuclear power programme, i.e. the repository corresponds to the waste that exists or will be produced by existing reactors in Sweden. If new nuclear power is added, a new final repository system will also be needed (Johnson, 2025).

The waste will be stored under the KBS-3 method, starting with encasing it in 5 meter long, corrosion-resistant copper capsules that will be packed in clay and buried. The first step is to encapsulate the waste in copper canisters – five meters long and one meter in diameter – which are then welded shut. This is planned to take place in an encapsulation plant built next to the interim storage facility at Oskarshamn. The plan is to build the encapsulation plant next to the interim storage facility at Oskarshamn (SKB, 2025). With capacity for 16,000 cubic metres of waste, approximately 6,000 copper canisters will be stored in the final repository, each containing two tonnes of waste (Johnson, 2025).

Construction officially began in January 2025, but the work leading up to it has been even longer, not least because of protracted permit processes. As early as 2011, The Swedish Nuclear Fuel and Waste Management Company (SKB) applied to build the nuclear fuel repository in Forsmark. It was not until 2022 that the application was approved by the Swedish government. The process, however, could still be delayed. MKG, a Swedish non-governmental organization working on nuclear waste, has lodged an appeal with a Swedish court calling for further safety checks. It said research from Sweden's Royal Institute of Technology showed the copper capsules could corrode and leak radioactive elements into the ground water (Johnson, 2025).

**Figure 3**

*Sketch of how the final repository for spent nuclear fuel may look in the future at Forsmark in Sweden (IAEA, n.d.)*




### 5.3.1 Political Decision

Political measures are understood to have played an important role in the advances of research and construction of waste facilities in Sweden. After the accident at the Three Mile Island nuclear power plant near Harrisburg, Pennsylvania, in 1979, the Swedish government required that all reactor owners, to obtain a start-up permit, also have a reliable plan for the final disposal of nuclear waste. The solution was geological final disposal, with the owners paying a fee into a fund whose financial resources would be used for the construction of disposal facilities (Johnson, 2025).

On March 16th, 2011, after three decades of carrying out research, developing technology and conducting surveys, SKB applied to the authorities for permission to build a repository for spent nuclear fuel in Forsmark and an encapsulation plant in Oskarshamn (SKB, n.d.). In January 2022, the Swedish government granted permission to build the encapsulation plant in Oskarshamn. The case was then referred back to the Swedish Radiation Safety Authority (SSM) and the Land and Environment Court (MMD), which are responsible for setting conditions for the facility under the Environmental Code and the Nuclear Activities Act. In October 2024, MMD issued an environmental permit for the plant. To move forward, a building permit from the Municipality of Oskarshamn is also required. SKB hopes to begin construction during the 2020s. If so, the facility could be ready for operation around the same time as the Spent Fuel Repository, approximately ten years later. (SKB, 2025)

#### 5.3.1.1 Site Selection

When the site identification process began in 1992, SKB therefore chose to base it on voluntary responses. Enquiries about participation were sent to every municipality in

Sweden. Storuman and Malå were the first to respond positively and pilot studies were carried out in the two municipalities. In the local referendums, however, their inhabitants voted against continuing the surveys. SKB left both locations immediately. Protests took place in a number of places, and at Almunge outside Uppsala, demonstrations took place against SKB's drills (SKB, 2025).

Pilot studies were also made in Nyköping, Älvkarleby, Hultsfred, Tierp, Oskarshamn and Östhammar, the last two municipalities had a stronger local support. At the same time SGU, the Geological Survey of Sweden, was conducting survey studies of the whole of Sweden that showed that there were potentially suitable sites in most of the country's municipalities (SKB, 2025).

Finally, SKB chose to undertake thorough site investigations with trial drilling in Östhammar and Oskarshamn. The site investigations lasted for five years, from 2002 until 2007. They involved studies of the geology, hydrology, ecology and social impact. The basic requirements are that the repository must meet the requirements in the Nuclear Activities Act and the Environmental Code, and the local political and public support must be broad and stable. Municipal participation in the process was voluntary. The reason why it finally chose Forsmark is because of the dry rock with few deep fractures to be found there (SKB, 2025).

#### 5.3.1.2 Final repository decision

The licensing process is governed by the Nuclear Activities Act (nuclear safety and radiation protection) and the Environmental Code (environmental impact, precautionary measures, public participation), and required parallel review by two authorities: the Swedish Radiation Safety Authority (SSM), which assesses nuclear safety, and the Land and Environment Court, which reviews environmental impact and sets permit conditions. SKB submitted applications to build the Forsmark repository, the Oskarshamn encapsulation plant, and an expansion of the Clab interim storage facility simultaneously in 2011 (SKB, 2025).

The review took eleven years. SSM and the Court both found the project permissible in January 2018, but the Court required additional evidence on the long-term durability of the copper canister system. SKB submitted supplementary evidence in 2019, which SSM accepted after further review in 2021, and the Swedish Government approved the project in January 2022, finding it permissible under both the Nuclear Activities Act and the Environmental Code (Strålsäkerhetsmyndigheten; n.d.).

Government approval did not authorise operation outright: SSM must approve safety documentation separately before each subsequent phase (construction, testing, operation, closure) can proceed, and the repository is expected to keep receiving waste for roughly 70 years before final closure, after which responsibility transfers to the Swedish state. Since 2020, the Nuclear Activities Act has made this state responsibility, and the requirement for a separate government permit before permanent sealing, explicit (Strålsäkerhetsmyndigheten; n.d.).

Throughout the process, the Government required SKB to hold annual consultation meetings with Östhammar and Oskarshamn, the same municipalities engaged during site selection, plus relevant agencies and environmental organisations, extending the consent-based model described in Section 5.3.1.1 into the licensing phase (Strålsäkerhetsmyndigheten; n.d.).

### 5.3.2 Cost evaluation

Sweden's radioactive waste programme is costed on a three-year cycle: SKB submits an updated cost basis to the Swedish National Debt Office (Riksgälden), which sets the following period's waste fee and collateral requirements on that basis (SKB, 2025h; Riksgälden, 2023).

#### Budget for waste management

Financing follows the same polluter-pays logic as elsewhere in this chapter: nuclear operators pay a per-kilowatt-hour fee into the government-run Kärnavfallsfonden (Nuclear Waste Fund), set at SEK 0.08/kWh for 2025, with reactors that have already shut down still liable for an ongoing fee (SKB, 2025h). The Fund held approximately SEK 83 billion (roughly €7.5 billion) at the end of 2024 (Riksgälden, 2025; SKB, 2025h). Operators must additionally post SEK 81 billion in financial guarantees, a separate collateral mechanism intended to protect the Fund if an operator cannot meet its obligations (SKB, 2025h).

#### Cost of interim storage (with additional values of waste until the DGR is ready)

As with Finland, Sweden does not appear to break out interim storage as a separate budget line: of the roughly SEK 64 billion already spent on the programme, SKB attributes the total to combined research and development, and the construction and operation of the Clab central interim storage facility, the SFR repository for short-lived waste, and the associated transport system, without a published split between them (SKB, 2025h).

#### Cost of construction of DGR (that should operate for 100 years)

Unlike the whole-programme figures elsewhere in this section, the Forsmark repository and Oskarshamn encapsulation plant have a specific, publicly stated construction cost:

SKB put the investment in the final repository system at approximately SEK 19 billion (roughly €1.7 billion) when the Swedish Government approved construction in January 2022, a project the company describes as creating around 1,500 jobs (SKB, 2023).

### Cost of maintenance of DGR

The remaining programme cost, covering operation and eventual closure alongside decommissioning of Sweden's reactors, has grown across successive submissions: Plan 2019 put the remaining cost at SEK 110.0 billion, and Plan 2022 raised this to SEK 124.1 billion (approximately €11.1 billion) (WNN, 2022). Over a longer horizon, the National Debt Office calculates that the total programme cost of SEK 221 billion implied by Plan 2022 is more than double the equivalent Plan 2001 estimate just over twenty years earlier – corresponding to an average annual real cost growth of 4.3% (Riksgälden, 2023). Both plans are drawn up under the same statutory scope: the Swedish financing system covers the management and disposal of waste and spent fuel *and* the decommissioning and dismantling of the plants (WNN, 2022; Riksgälden, 2023), so the doubling reflects real cost growth on a constant scope.

## 5.4 France

France is the second country in the world with the highest nuclear power installed capacity, with 57 reactors and approximately 63 GW of capacity, just behind the United States. However, France leads the world in the share of its electricity generated by nuclear power, at about 67%, against 18% in the United States (World Nuclear Association, 2026b).

France's present electricity generation mix is the result of a 1974 government decision, taken just after the first oil shock, to rapidly expand the country's nuclear capacity using Westinghouse-derived technology. The decision reflected France's substantial heavy engineering expertise but limited indigenous energy resources: nuclear power, for which fuel cost is a relatively small share of total cost, offered a way to reduce import dependence and improve energy security. By 2026, France had 14 shutdown reactors alongside its 57 operating units (World Nuclear Association, 2026b).

Unlike Finland and Sweden, France reprocesses the great majority of its spent fuel rather than disposing of it directly. At the La Hague plant, spent fuel is chemically separated into reusable uranium, reusable plutonium and a residual waste fraction of roughly 4% of the original mass; the recovered plutonium is blended into mixed-oxide fuel used in part of the reactor fleet (Orano, 2026; World Nuclear Association, 2026b). The high-level liquid waste left over from reprocessing is vitrified – cast into borosilicate glass in stainless-steel canisters – and held in interim storage, mainly at La Hague and Marcoule, pending disposal (Andra, 2026).

The word "reusable" warrants caution, however. France's Court of Audit describes the cycle as at best semi-closed: recycled MOX accounts for only about 10% of the fuel loaded into French reactors – less than 1% of the material by mass – spent MOX fuel is not itself reprocessed but accumulates in storage, and the re-use of reprocessed uranium was suspended entirely between 2013 and 2023, leaving a stockpile that is not expected to begin shrinking before mid-century (Cour des comptes, 2019; HCTISN, 2018). Most separated "reusable" material is, in practice, stored rather than recycled.

In January 2023, the French National Agency for Radioactive Waste Management (Andra) submitted a license application for construction of a deep geologic repository in the Meuse/Haute-Marne region. Andra expects that construction of the Cigéo repository and a pilot phase of operations could start around 2027. Handling of radioactive waste packages would begin around 2035–2040. Full-scale disposal operations would begin around 2040–2050 and would last about 100 years. Cigéo, excavated in 160-million-year-old claystone at a depth of 500 meters, will hold approximately 10,000 m3 of high-level radioactive waste and 73,000 m3 of long-lived intermediate-level waste.

The site sits within the Callovo-Oxfordian clay formation, a layer roughly 150 metres thick formed 160 million years ago, at a depth of about 500 metres (Andra, 2026). Cigéo's reference inventory, based on existing facilities and an assumed average reactor lifespan of 50 years, corresponds to approximately 10,000 $m^3$ of HLW and 73,000 $m^3$ of ILW, about 83,000 $m^3$ in total, roughly half of which had already been generated as of Andra's most recent cost assessment (Andra, 2026; Collet, 2025). Waste will be transported to the site mainly by rail, then lowered via a 4 km inclined ramp to underground disposal cells: HLW canisters go into lined cells about 80 cm in diameter and 150 m long, while ILW is placed in wider cells up to 500 m long. The facility is designed to remain reversible, which allows waste packages to be retrieved, for at least 100 years of operation (Andra, 2026).

Andra submitted Cigéo's construction licence application on 16 January 2023. Following its technical review, the French Authority for Nuclear Safety and Radiation Protection (ASNR) published a favourable opinion on 4 December 2025, and a public inquiry is scheduled for the second half of 2026; the construction decree could be issued in late 2027 or early 2028 (Andra, 2026). That decree would authorise only the first construction phase, disposal of waste packages requires a separate commissioning licence, with routine ILW disposal not expected to begin until 2050, itself a delay from the 2035–2040 window originally foreseen, and the HLW disposal area not expected to be operational until 2080

(Andra, 2026; Collet, 2025). France therefore remains a step behind Finland and Sweden, which have already secured construction and operating approval respectively.

### 5.4.1 Political Decision Process

French radioactive waste policy rests on three successive laws. The 1991 Waste Management Act (the Bataille Act) created Andra as an agency independent of the waste producers and set three parallel research tracks to be evaluated after fifteen years: DGD, partitioning and transmutation, and long-term surface storage (Andra, 2026). Following the National Evaluation Commission's recommendation that the clay formation at Bure was the best candidate site, the 2006 Nuclear Materials and Waste Management Programme Act formally declared deep geological disposal the reference solution for high-level and long-lived waste, extended Andra's and the evaluation commission's mandate to all waste types, and set an original target of licensing a repository by 2015 and opening it by 2025, dates that have since slipped twice, first to a working assumption of 2035–2040 and now to 2050 (World Nuclear Association, 2026b; Collet, 2025). A third law, passed in 2016, added the principles that now define Cigéo's design: a mandatory industrial pilot phase and a guarantee of reversibility for at least 100 years after emplacement (Andra, 2026). The same 1991 Act also established the cost-review procedure discussed in Section 5.4.3: Andra submits a costed evaluation to the government, which is reviewed by the nuclear safety authority and the National Evaluation Commission and by the waste producers themselves, before the responsible minister fixes a reference cost by ministerial order, to be revised again ahead of the next major project milestone.

As in Sweden, local consent has been built into the French process, though through consultation rather than a veto-holding referendum. Ahead of the 2026 public inquiry, the Prefect of the Meuse department asked 74 local authorities, 56 communes plus the local information committee (CLIS), for their opinion on Andra's application; by the December 2025 deadline, 27 had responded positively, seven were neutral, and seven were unfavourable (Andra, 2026). This is a narrower form of consent than Sweden's voluntary site-selection process, where municipalities could and did withdraw outright (Section 5.3.1.1): in France the site was effectively fixed by the Bure laboratory's geology well before this consultation stage, and the local opinion is advisory input into a licensing decision the state ultimately makes.

France's financing model is also a useful point of contrast for the Dutch case. Rather than paying into a shared external fund of the kind COVRA administers, French law requires each waste-producing operator, principally EDF, to hold its own segregated, but internally managed, provision under a polluter-pays principle (Andra, 2026; World Nuclear

Association, 2026b). This avoids the single-fund concentration risk raised for the Netherlands in Section 5.5.2, but shifts risk instead onto the financial durability of individual operators over a project horizon measured in decades.

### 5.4.2 Storage practices

Pending Cigéo's commissioning, France's HLW and ILW packages are held in interim storage at their production sites: mainly Orano's La Hague plant, the CEA sites at Marcoule and Cadarache, EDF's Iceda facility at Bugey, and, in smaller volume, the CEA site at Valduc (Andra, 2026). Some HLW packages will need decades of further cooling in these facilities before they can be moved to Cigéo, since the repository's post-closure safety case caps the temperature the surrounding clay may reach at 100°C (Andra, 2026).

Lower categories of waste are already routed to permanent surface disposal rather than held in interim storage. Very low-level waste – contaminated soil, concrete and protective equipment from decommissioning – goes to the CIRES landfill facility; short-lived low- and intermediate-level waste, such as filters, resins and tools from routine operations, is disposed of in near-surface concrete vaults at the Centre de l'Aube (World Nuclear Association, 2026b). Only the long-lived intermediate-level and high-level fractions, which together make up a small share of total volume but the great majority of total radioactivity, require the deep geological route described in Section 5.1.2.1.

### 5.4.3 Cost evaluation

#### Budget for waste management

Financing is producer-based rather than pooled in an external fund, following the polluter-pays principle set out in French law (Section 5.4.1). EDF sets aside 0.14 cents per kWh of nuclear electricity generated; at the end of 2020 its dedicated back-end fund held €24.6 billion in provisions, split between €11.3 billion for spent fuel management and €13.3 billion for long-term radioactive waste management (World Nuclear Association, 2026b).

#### Cost of interim storage (with additional values of waste until the DGR is ready)

France does not appear to publish interim storage as a separately budgeted line; it is bundled into the spent fuel management portion of the back-end fund cited above. This is a scope difference worth flagging against the Finnish and Swedish figures used elsewhere in this chapter, since it means the French figure cannot be cleanly split into an 'interim storage only' cost for direct comparison.

### Cost of construction of DGR (that should operate for 100 years)

Public cost figures for Cigéo come from several stages of the project's development and should be read differently from the Finnish overrun case in Section 5.2.3, since Cigéo has not yet begun construction – the changes below reflect revised estimates rather than realised cost growth. Andra's first full assessment, submitted in October 2014, put total lifecycle cost at €33.8 billion. After review by the nuclear safety authority, the National Evaluation Commission, and the waste producers, the responsible minister – Ségolène Royal, then Minister of Ecology, Sustainable Development and Energy – set a lower official reference cost of €25 billion (2011 economic conditions) by ministerial order in January 2016, covering the period 2016–2156 (Ministère de la Transition écologique, 2026). On 12 May 2025, as required ahead of the construction licence decision, Andra submitted an updated evaluation putting total lifecycle cost – construction, roughly a century of operation, and closure – at €26.1–37.5 billion, expressed in 2012 economic conditions to allow comparison with the earlier figure; restated in late-2023 conditions, the range widens to roughly €33–45 billion (Collet, 2025). This is an increase of between 4.4% and 50% over the 2016 official figure depending on the assumptions used, though Andra described the update as broadly consistent with its own 2014 estimate. Andra also noted that tax and insurance assumptions alone can shift the total by up to €7.4 billion (Collet, 2025).

### Cost of maintenance of DGR

The same evaluation put the combined cost of operation and closure – roughly a century of operation followed by about 20 years of decommissioning – at a further €16.5–25.9 billion (2012 conditions), for a total of €26.1–37.5 billion together with construction (Ministère de la Transition écologique, 2026). This has not yet been tested against actual spending, since routine disposal is not due to begin until 2050. For context, this repository cost is separate from EDF's reactor decommissioning provisions, which stood at €20.2 billion at the end of 2020 against an estimated total decommissioning cost of €75 billion from 2035 onward (World Nuclear Association, 2026b) – a reminder that the Cigéo figures above cover only the waste repository, not decommissioning of the reactor fleet that produces the waste.

## 5.5 The Netherlands

Currently, the Netherlands has one nuclear power plant (NPP Borssele) in operation, one NPP (Dodewaard) in safe enclosure, two research reactors (HFR Petten and The Higher Education Reactor (HOR) in the Technical University Delft), one enrichment plant (Urenco) and one central storage facility for radioactive waste (COVRA). Construction of the PALLAS reactor, replacing HFR Petten for medical isotope production, started in 2023. The HOR reactor in Delft is expected to be closed in 2050 leading to an immediate start of the dismantling of the reactor.

The first development in the nuclear industry in the Netherlands was in 1960, when operations began on the Netherlands' own research reactor, the High Flux Reactor (HFR) at Petten. This reactor has provided about half of Europe's market of medical radioisotopes and has had its lifespan extended from 2015, to 2025 and now to 2035 (COVRA, 2024; World Nuclear Association, 2026c).

Regarding nuclear energy, Dodewaard was the Netherlands’ first power plant and had a boiling water reactor with a capacity of 58 MWe, which was primarily intended to provide experience in the operation of nuclear power plants. It was connected to the grid in October 1968 and operated until 1997, and since the plant was not designed for commercial, profit-oriented operation it was shut down for economic reasons (Thierfeldt et al; 2009). The last nuclear fuel was removed from the plant in April 2003 which then led to the partial demolishment of the plant and to a status of safe confinement since July 2005. The dismantling of the plant should start around 2045, 40 years after the start of safe confinement, and last for about ten years (NOS, 2024; WNN, 2024). The owner, the Dutch Electricity Administration Office (NEA), did not have enough money to bear the costs of the dismantling and management of the former nuclear power plant, and in 2023 it was announced that the government would take over the shares from the NEA (NOS, 2024).

The Borssele power plant followed immediately, having the beginning of its construction in 1969 and being first connected to the grid in 1973. The power plant counts with a Pressurized Water Reactor (PWR) that has a net generation capacity of 482 MWe (PRIS, 2026). Starting in 1994, debates regarding the phase out of the power plant took place, from an early phase out in 2003, a new closure date in 2013 up to the operations until 2034 on the condition of safety standards and investments in sustainable energy projects. The current license will expire in 2033, however, in 2024 the government cabinet decided to keep the plant open longer and technical studies are being carried out by the Authority for Nuclear Safety and Radiation Protection (ANVS) to determine if the extension is feasible (World Nuclear Association, 2026c). Meanwhile, in its 2050 Masterplan, COVRA estimated the extension to add twenty more years to the power plant and produce energy until 2053 (COVRA, 2024).

On the other side of the equation, in the 1970s the Dutch government adopted a policy of reprocessing spent fuel from both the Borssele and Dodewaard reactors. In 1984 it decided on a policy of long-term (100 years) interim storage of all the country's radioactive waste;

and a research strategy for its ultimate disposal. Used nuclear fuel from Dodewaard was recycled at the UK's Thorp facility at Sellafield, and that from Borssele at France's La Hague. Orano Cycle, operators of La Hague, held a contract to recycle Borssele used fuel until 2015, and 375 tonnes had been reprocessed there to mid-2014. Under the Preconditions for New Nuclear Power Plants (Randvoorwaarden voor nieuwe kerncentrales) memorandum submitted to parliament in September 2006, used fuel from new plants would be stored until 2025 when a decision would be taken by government to choose between the preferred treatment of partition and transmutation, or recycling, or direct disposal.

In September 2003, COVRA's HABOG facility – an interim storage for high-level waste (HLW) – was commissioned by Queen Beatrix. HABOG has two compartments, one for medium-level waste such as canisters containing fuel element claddings after reprocessing of their uranium contents; and one for the vitrified HLW returned after used fuel reprocessing (fission products and transuranics). It stores all the HLW from Dodewaard fuel reprocessed at Sellafield in UK, and all the waste returned from reprocessing Borssele fuel at La Hague.

Government policy is to eventually store HLW underground and to move towards that goal in a way such that each step is reversible. In 2001, the Government-sponsored Committee on Radioactive Waste Disposal (CORA) concluded that geological retrievable disposal is technically feasible in a safe manner, on several sites in the Netherlands. In 2006, the government proposed to make a decision about the siting for final disposal by 2016, but this did not happen.

In September 2006 the environment minister on behalf of the economics minister submitted to parliament a document entitled, Conditions for New Nuclear Power Plants. The document stated, among other things, that no later than 2016 the government needed to decide on a disposal strategy for existing high-level waste. It also claimed that used fuel should be stored until 2025, when a choice would be made between direct disposal, reprocessing, or partitioning and transmutation; plants should be dismantled promptly after closure, and decommissioning funds clearly earmarked; uranium should be sourced from certified, environmentally responsible mining operations, with in-situ leaching (ISL) preferred due to its low environmental impact.

However, in 2026, still without an official answer on the definitive disposal, the government cabinet announced its ambition to increase the share of nuclear energy in the energy matrix by extension of the Borssele activity to the construction of new reactors (World Nuclear Association, 2026c).

### 5.5.1 Political Decision Process

In the 2016 National Programme for Radioactive Waste (NPRA) four principles have been set:

- Minimization of the generation of radioactive waste;
- Safe management of radioactive waste;
- No unreasonable burdens on the shoulders of later generations;
- The perpetrators of radioactive waste bear the costs of its management.

Under the 2011/70/Euratom directive, every EU member state must produce and update these principles at least once every ten years. The Netherlands' second NPRA was due by September 2025; a draft was open for public consultation between 11 February and 24 March 2025, and the government is still processing the responses (Rijksoverheid, n.d.). The 1963 Nuclear Energy Act sets out the basic rules for the use of nuclear materials in the Netherlands. There have been no major changes in this Act since. The Ministry of Economic Affairs is responsible for energy, including nuclear power.

The clearest illustration of how political decisions on Dutch nuclear policy get reopened as governing coalitions change is the Borssele phase-out saga, set out in Section 5.5.1: a 1994 parliamentary vote to close the plant by 2003 ran into legal difficulties, was pushed back to 2013 by the incoming coalition in 2003, and was abandoned altogether in 2005 (World Nuclear Association, 2026c). The same pattern – a decision taken, then reopened – recurs, on a much longer timescale, in the siting of a final repository.

Unlike Sweden, where voluntary site selection eventually produced a location both the municipality and the state accepted (Section 5.3.1.1), Dutch attempts to site an underground repository have repeatedly been proposed and then withdrawn under local and regional opposition. Salt domes (zoutkoepels) in the northern provinces of Drenthe and Groningen were first identified as candidate sites in the 1970s. Plans to test-drill the salt dome at Gasselte drew a demonstration of several tens of thousands of people in June 1979, and were shelved – though never formally cancelled – in the face of continued local resistance; an opposition coordination group, the 'zoutkoepeloverleg', formed in 1986 to keep monitoring the threat of underground storage (NMF Drenthe, 2023).

The same site resurfaced almost exactly as before once the government's accelerated timeline made siting research active again. In early 2025, more than 3,000 formal objections and 6,000 signatures were submitted against the draft NPRA, chiefly from Groningen and Drenthe; the provincial government and the municipalities of Stadskanaal and Westerwolde formally opposed storage under their soil, and a motion blocking the storage of nuclear waste in Groningen's salt domes passed the House of Representatives with cross-party support (RTV Noord, 2025). Independent research commissioned around the same time concluded that the Gasselte-Drouwen salt dome remained the only formation still under active consideration for a trial borehole, meaning the 2025 dispute and the 1979 one concern substantially the same location, 46 years apart (RTV Drenthe, 2025). For the Netherlands, unlike Sweden, no candidate community has yet accepted host status; the siting process itself, rather than the technical feasibility of disposal, is the persistent constraint.

Against this backdrop, the decision on where and how to build a final repository was, until recently, not due until around 2100, with the facility operational by 2130 (Rijksoverheid, n.d.). In September 2024, responding to the Rathenau Instituut's advisory report on the decision-making process, then State Secretary for Infrastructure and Water Management Chris Jansen announced the government's intention to bring this decision forward by roughly 50 years, to around 2050, with a stepwise, participatory decision process beginning in 2028 (Rijksoverheid, n.d.; Rathenau Instituut, 2024). COVRA's own public-facing materials had not yet been updated to reflect this acceleration as of early 2026, continuing to describe a 2100 decision date alongside the government's newer 2050 target – itself a small but telling sign of how unsettled the process still is (COVRA, 2026a).

### 5.5.2 Storage practices

Financing follows principle four above: producers pay COVRA a tariff, set per volume and waste category, that is intended to cover the full cost of processing, interim storage and eventual final disposal. COVRA invests this tariff revenue in a dedicated, low-risk reserve, held largely in Dutch treasury paper, against its future obligations (Rijksoverheid, n.d.).

COVRA currently holds around 110 $m^3$ of high-level waste (HLW) at HABOG, growing by roughly 4.5 $m^3$ a year; across all categories combined, COVRA's inventory is in the order of 34,000 $m^3$ – illustrated on its own materials as about a twentieth the volume of a large container ship (Rijksoverheid, n.d.; COVRA, n.d.).

This waste is genuinely heterogeneous in origin. High-level waste is 67% from nuclear power generation, 29% from medical isotope production and 4% from research and education, while low- and intermediate-level waste is spread across nuclear energy (24%), medical isotopes (22%), oil and gas extraction (17%), the medical sector (13%), smoke detectors (8%), industry (4%), scrap metal (2%) and other sources (1%) – a considerably wider set of producers than in Finland or France (Ministerie van Economische Zaken en Klimaat, 2025).

As in those countries, the hazard is concentrated in a small fraction of the total volume: NORM waste and low/intermediate-level waste together make up 99.7% of national volume but only 0.24% of total radioactivity, while high-level waste is just 0.3% of volume and 99.76% of radioactivity (Ministerie van Economische Zaken en Klimaat, 2025).

COVRA is investigating two possible host rocks for a future repository: rock salt, found mainly in the central and northern Netherlands, including the salt domes discussed in Section 5.5.1; and clay, found in some form under most of the country. Both are being researched in parallel under COPERA (2020–2025), the latest in a series of Dutch disposal research programmes stretching back to ICK (1972–1979), OPLA (1982–1992), CORA (1995–2001) and OPERA (2010–2017) (COVRA, 2026b). A repository would sit roughly 200 to 1,000 metres deep; COVRA's safety case work concludes that even after several hundred thousand years, the resulting radiological risk would be under 1% of the Netherlands' average natural background dose of 1.6 mSv per year (COVRA, 2026a).

Alongside a purely national repository, COVRA is also pursuing a multinational option through the European Repository Development Organisation (ERDO), an initiative it helped found together with Norway and Denmark. A shared facility is presented as a way for countries that generate comparatively little waste, such as the Netherlands and Denmark, to spread the very high fixed cost of building a repository across several producers (COVRA, 2026a). That fixed cost is the central open question for this report.

Chapter 6 builds on this starting point to model how the funding gap develops under the scenarios introduced in Section 5.5.3.1.

### 5.5.3 COVRA 2050 Masterplan

Given the context from overall definitions and practices and an overview of the countries selected for the case study, this section examines the COVRA 2050 Masterplan (COVRA, 2024). The Masterplan provides projections of radioactive-waste volumes requiring storage in the Netherlands up to 2050 and therefore forms the principal data source for the waste-volume calculations in this study.

The Masterplan considers a Dutch nuclear sector undergoing substantial development. Key developments include the construction of two new large nuclear power plants, the potential deployment of Small Modular Reactors (SMRs), the commissioning of the PALLAS reactor, expansion of uranium-enrichment activities at Urenco, and the extension of the operational lifetime of the Borssele Nuclear Power Plant (KCB). At the same time, several existing nuclear facilities are expected to undergo decommissioning. These developments affect the future generation of NORM, LILW and HLW and, consequently, the storage capacity required at COVRA.

The existing KCB has an electrical capacity of 485 MW and, under the Masterplan assumptions, is complemented by two new 1,600 MW nuclear power plants commissioned in the late 2030s. The reactors are assumed to operate for 80 years. In addition, four SMRs with an electrical capacity of 350 MW each and an assumed operating lifetime of 50 years are considered in the COVRA 2050 Masterplan. The SMRs are scheduled for deployment in 2037, 2042 and 2047, with the third and fourth units commissioned in 2047. Waste-generation and waste-transfer dates depend on reactor operation and, for spent fuel, on the required cooling and reprocessing periods. These assumptions are incorporated into the calculations presented in Section 5.5.3.2.

All radioactive waste requiring centralized management is ultimately processed, conditioned and stored by COVRA, although NORM waste is partly managed through alternative disposal routes. The Masterplan therefore provides an important basis for assessing both future waste inventories and the infrastructure required to accommodate them.

#### 5.5.3.1 Scenario Definition

The COVRA 2050 Masterplan distinguishes between a **Minimum Scenario** and a **Plus Scenario**. In this study, these scenarios are used as the basis for assessing future waste volumes. The Minimum Scenario represents the continuation of current nuclear activities and developments that are already planned, whereas the Plus Scenario additionally incorporates a more extensive expansion of nuclear generation and associated waste-management infrastructure.

**Minimum Scenario**

The Minimum Scenario assumes the continuation of the existing Dutch nuclear sector and currently planned developments. The main assumptions are:

- The HFR in Petten ceases operation in 2035, followed by decommissioning.
- The PALLAS reactor becomes operational in 2030 and replaces the HFR for medical-isotope production, while medical-isotope production by Curium continues unchanged.
- The GKN plant at Dodewaard remains in safe enclosure until decommissioning begins in 2045.
- The KCB ceases operation in December 2033, followed by dismantling.
- The HOR in Delft ceases operation in 2050, followed by decommissioning.
- Urenco remains operational beyond 2050 and expands its uranium-enrichment capacity.
- COVRA continues to process LILW using its existing high-pressure compaction and encapsulation process.

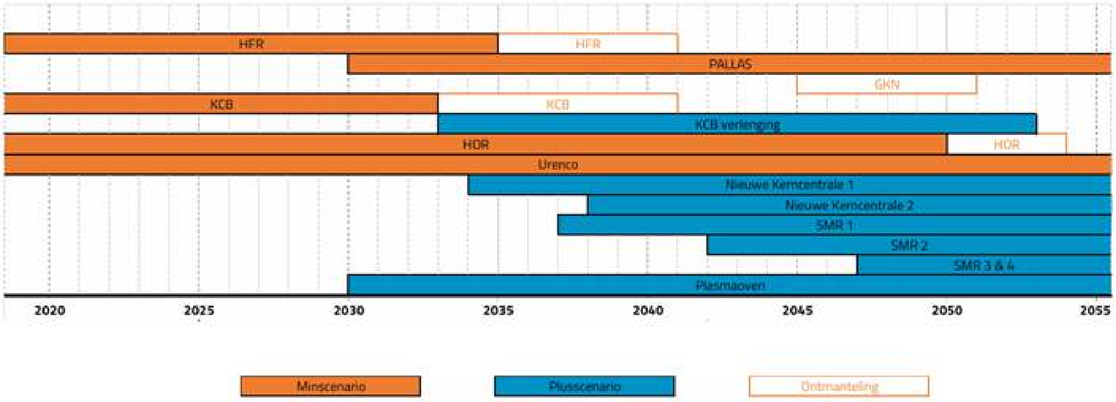
**Plus Scenario**

The Plus Scenario retains the assumptions of the Minimum Scenario and additionally considers a larger expansion of nuclear generation and waste-treatment capacity. The additional developments are:

- A 20-year extension of the KCB operating lifetime, with closure at the end of 2053 and decommissioning beginning in 2054.
- Construction of two new 1,600 MW nuclear power plants, commissioned in 2034 and 2038.
- Deployment of four 350 MW SMRs between 2037 and 2047.
- Commissioning of a plasma-furnace facility around 2030 to reduce the volume of eligible LILW requiring storage.

**Figure 4**

*Scenario visualization graph.*




Note. The graph does not include Borssele Nuclear Power Plant decommissioning time.

#### 5.5.3.2 Expected Waste Volumes by 2050

The expected waste inventory in 2050 was calculated separately for NORM, LILW and HLW. For the Minimum Scenario, the calculations primarily use COVRA's projected inventories and existing waste streams. For the Plus Scenario, additional waste generated by the KCB lifetime extension, two new nuclear power plants and four SMRs was added to the Minimum Scenario inventory. For HLW, the timing of waste transfer to COVRA was also considered because spent fuel requires cooling and, where applicable, reprocessing before final storage.

##### 5.5.3.2.1 Minimum Scenario

Under the Minimum Scenario, COVRA projects approximately **76,000 m³ of NORM waste** requiring storage by 2050, primarily associated with uranium-enrichment activities.

The projected **LILW inventory is approximately 17,200 m³** by 2050, based on a linear extrapolation of historical COVRA waste data using the assumptions described in Section 6.1. Additional LILW from the PALLAS reactor contributes approximately **2,000 m³**, while decommissioning of the KCB, HFR and GKN is estimated to contribute a further **2,500 m³**.

The **HLW inventory is projected at approximately 195 m³** by 2050. PALLAS is expected to contribute an additional approximately **10 m³**, based on an annual generation rate of 0.5 m³ from 2030 to 2050. Expected inventories of LILW and HLW are summarized in Table 1 and 2, respectively.

**Table 1**

*Overview of COVRA's estimated LILW amounts by 2050 (Minimum scenario).*

| Development | Quantity ($m^3$) |
|---|---|
| NORM | 76,000 |
| Regular LILW flow | 17,200 |
| PALLAS | 2,000 |
| Decommissioning | 2,500 |
| Total | 97,700 |

Note. Decommissioning value includes KCB (from 2033), HFR (from 2035), and GKN (from 2045), all of them are shown in the report to be expected to finish by 2055. Values potentially do not include GKN final decommissioning year, of the six expected. Additional waste that was not included were HOR decommissioning and PALLAS and Urenco waste production until end of operations and decommissioning.

**Table 2**

*Overview of COVRA's estimated HLW amounts by 2050 (Minimum scenario).*

| Development | Quantity ($m^3$) |
|---|---|
| KCB (2034) + Others | 195 |
| PALLAS | 10 |
| Total | 205 |

#### 5.5.3.2.2 Plus Scenario

Under the Plus Scenario, no additional NORM-generating activities are assumed. The NORM inventory therefore remains approximately **76,000 m³** in 2050.

**LILW**

Additional LILW volumes were calculated for each nuclear development using the waste-generation assumptions described in Section 6.1. The 20-year extension of KCB results in approximately **800 m³** of additional LILW, based on an annual generation rate of 50 m³.

For the two new 1,600 MW nuclear power plants, LILW generation is assumed to scale proportionally with the capacity of KCB. Each reactor therefore generates approximately **160 m³/year**, resulting in approximately **4,500 m³** of additional LILW by 2050 given the assumed commissioning dates.[1]

[1] The Covra 2050 masterplan assumess two new nuclear power plants to be operational in 2034 and 2038. Since its publication, these dates have been revised to 'late 2030s'. For the calculation of total waste volume in 2060, this would make for a small downward revision

Each 350 MW SMR is assumed to generate approximately **40 $m^3$/year** of LILW. Based on the deployment schedule described above, the four SMRs contribute approximately **1,100 $m^3$** by 2050.

The resulting LILW inventories are summarized in Table 3. The table also presents the corresponding volumes after application of the plasma-furnace treatment assumed under the Plus Scenario.

**HLW**

HLW volumes depend on the treatment pathway adopted for spent fuel. Two pathways are therefore considered for the new nuclear power plants and SMRs: **direct disposal without reprocessing** and **reprocessing prior to disposal**. The former results in a larger HLW volume, whereas reprocessing reduces the volume requiring DGD. Spent fuel from KCB is assumed to be reprocessed under both scenarios.

The 20-year KCB lifetime extension generates approximately **89 $m^3$ of additional HLW**, based on an annual generation rate of 5.6 $m^3$.

For the two new nuclear power plants, direct disposal without reprocessing results in approximately **88 $m^3$/year per reactor**. After accounting for the required five-year cooling period, the combined HLW inventory transferred to COVRA by 2050 is estimated at approximately **1,584 $m^3$**. Under the reprocessing pathway, each reactor generates approximately **18.5 $m^3$/year**. Accounting for the assumed approximately 10-year cooling and reprocessing period, approximately **146 $m^3$** is expected to have reached COVRA by 2050.

For the four SMRs, direct disposal results in approximately **19 $m^3$/year per reactor**. After the five-year cooling period, approximately **212 $m^3$** is expected to have reached COVRA by 2050. Under the reprocessing pathway, each SMR generates approximately **4 $m^3$/year**. Given the assumed deployment and processing periods, only waste from the first SMR is expected to have reached COVRA by 2050, resulting in approximately **12 $m^3$**. The resulting HLW inventories are summarized in Table 4.

**Table 3**

*Expected LILW nuclear waste amount per project, with considerations of usage of plasma oven method to reduce volume.*

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compared to this report. For 2130, the total waste generation remains as expected with an expected lifespan of 80 years per reactor.

| Development | Quantity (thousand $m^3$) | Quantity with Plasma oven (thousand $m^3$) |
|---|---|---|
| Regular LILW | 17.2 | 15.5 |
| PALLAS | 2.0 | 0.8 |
| Extension of KCB | 0.8 | 0.3 |
| 2 New Nuclear Power Plants | 4.5 | 1.8 |
| 4 SMRs | 1.1 | 0.4 |
| Total | 25.6 | 18.8 |

**Table 4**

*Overview of estimated HLW amounts in 2050 (plus scenario).*

| Development | Quantity ($m^3$) | Quantity with Reprocessing ($m^3$) |
|---|---|---|
| Existing Installations | 195 | 195 |
| PALLAS | 10 | 10 |
| Extension of KCB | 89 | 89 |
| 2 New Nuclear Power Plants | 1584 | 146 |
| 4 SMRs | 212 | 12 |
| Total | 2090 | 452 |

Note. The values in this table were retrieved directly from COVRA Masterplan. Using COVRA’s individual values, results were particularly different for the NPPs (2464 $m^3$) and SMRs (209 $m^3$).

#### 5.5.3.3 Implications for Waste-Storage Infrastructure

The projected increase in radioactive waste volumes has direct implications for COVRA's storage infrastructure. Under current projections, the depleted-uranium storage facility VOG-2 is expected to require expansion by approximately 2034, with construction activities beginning before 2029. VOG-2 is subsequently expected to reach capacity approximately eight years after completion, requiring the construction of VOG-3 around 2042. Additional LILW storage capacity is expected to be required around 2050 through the construction of a second LOG facility, while expansion of the HABOG facility is anticipated by approximately 2040. Given an estimated construction period of ten years, preparations for the HABOG expansion would need to begin around 2030.

The existing COVRA LILW storage site is projected to reach full capacity around 2070. Strategic expansion could extend storage availability to approximately 2100 (COVRA, 2024). In addition, COVRA announced the development of the Multifunctional Storage Building (MOG), intended to accommodate historical radioactive waste currently stored at the NRG site in Petten as well as future decommissioning waste from Dutch nuclear installations. The facility is expected to provide storage capacity through approximately 2050 (World Nuclear Association, 2026c).

**Plasma Furnace Implementation**

The Plus Scenario assumes that COVRA commissions a plasma furnace around 2030 to treat eligible LILW. Approximately two-thirds of LILW is assumed to meet the chemical and radiological acceptance criteria for plasma treatment. The effectiveness of the treatment is represented by the Volume Reduction Factor (VRF), defined as the ratio between the waste volume before and after treatment.

The VRF applied in this study is based on operational experience from the Kozloduy plasma facility in Bulgaria, which achieved an average VRF of approximately 26 between 2018 and 2020. This is substantially higher than the approximate 2.5 VRF associated with the high-pressure compaction technology currently used by COVRA. Consequently, plasma treatment can substantially reduce the volume of eligible LILW requiring storage. Waste streams that do not meet the plasma-furnace acceptance criteria are assumed to continue being processed using the existing compaction method.

Applying these treatment assumptions to LILW generated between 2030 and 2050 results in an estimated 16,300–18,800 $m^3$ of LILW requiring storage at COVRA in 2050, depending on the nuclear-development scenario. This estimate assumes sufficient plasma-treatment capacity to process all eligible waste. Figure 5 illustrates the difference in volume reduction achieved by the existing high-pressure press and the assumed plasma-furnace technology.

**Figure 5**

*Schematic representation of the volume reduction factors of the current high-pressure press and the plasma oven.*


*Figure 3 Schematic representation of the volume reduction factors of the current high-pressure press and the plasma oven.*

When these factors are applied to the LILW expected between 2030 and 2050, approximately 16,300 to 18,800 m³ of LILW will be stored at COVRA in 2050, depending on developments in the nuclear sector. This estimate assumes that there is sufficient incineration capacity to process all the expected waste. Figure 6 provides an overview of the expected LILW flows until 2050 for the various developments included in this report (COVRA, 2024).

### 5.5.4 Cost evaluation

#### Budget for waste management

Financing follows principle four of the 2016 National Programme for Radioactive Waste (Section 5.5.1): producers pay COVRA a tariff, set per volume and waste category, intended to cover the full cost of processing, interim storage and eventual final disposal. COVRA invests this tariff revenue in a dedicated, low-risk reserve, held largely in Dutch treasury paper, against its future obligations (Rijksoverheid, n.d.). As of early 2025, that reserve held approximately €133 million – up only modestly from €68 million at the end of 2014, despite decades of tariff contributions from Borssele, Dodewaard, HFR and Urenco (Laka, 2026; Kamerstuk, 2016).

#### Cost of interim storage (with additional values of waste until the DGR is ready)

As with Finland, Sweden and France, COVRA does not appear to publish interim storage as a cost line separate from the tariff and reserve mechanism described above.

#### Cost of construction of DGR (that should operate for 100 years)

COVRA's November 2025 technical evaluation estimates the "overnight" cost of a repository – construction, operation and closure, in 2022 prices, with no allowance for inflation or the time value of money – at roughly €3.3–3.5 billion for its existing installations alone, depending on host rock (COVRA, 2025). Scaled to the Masterplan 2050 inventory (two new NPPs, an extended Borssele lifetime, and continued Urenco enrichment), the same estimate rises to €10.0–10.3 billion; COVRA has adopted €10.3 billion, based on the clay estimate, as its own reference cost, with a ±30% uncertainty band (COVRA, 2025). Its 2024 annual report puts this more starkly still, recording that expected final-disposal expenditure rose from €2.31 billion (2023 prices) to €10.9 billion (2024 prices) within a single reporting year (as cited in Laka, 2026). COVRA's own €10.3 billion figure is built on two new reactors, not the four-reactor, four-SMR programme in Chapter 6; under that larger build-out, true cost is more likely to exceed this figure than fall short of it.

#### Cost of maintenance of DGR

COVRA's published estimates are "overnight" lifecycle figures – construction, operation and closure combined – rather than broken out by phase, so a separate maintenance/operation cost is not available in the sources used for this report.

### 5.5.5 Tariff structure and regulatory oversight

How the gap between tariff income and disposal liability is policed matters as much as its size. COVRA charges suppliers of "standard" radioactive waste – hospitals, laboratories and industry – published tariffs that it can adjust; after years of losses, those tariffs nearly doubled between 2016, when COVRA first published them, and 2020 (Laka, 2020). The high-level waste of the nuclear sector is treated differently: COVRA concludes long-term commercial contracts with EPZ and NRG, the operators of the Borssele plant and the Petten reactor, whose prices are fixed many years ahead, carry no risk premium, and are not public (Laka, 2020; Kamervragen, 2020). When COVRA's costs rise, the increase therefore lands on the tariff-paying small suppliers – not on the nuclear operators whose waste dominates the disposal liability.

The regulator has documented this. Following an inspection, the ANVS established in 2020 that hospitals were in effect bearing financial risks belonging to the operators of Borssele and Petten, and judged this incompatible with the polluter-pays principle laid down in the National Programme. The ANVS prepared a penalty order (*dwangsom*) of €90,000 against COVRA, then withdrew it after discussions with COVRA, deeming enforcement not opportune – while advising the state secretary that a regulatory framework for financing the final disposal of radioactive waste was lacking and needed to be developed (Laka, 2020; Kamervragen, 2020). The underlying documents became public only after Laka won a court case against COVRA's attempt to keep them confidential (Laka, 2020).

The government's answer to that warning is the Beleidsregel toezicht COVRA-tarieven, adopted by the ANVS in March 2024 after public consultation (Staatscourant 2024, 6454) (ANVS, 2024a, 2024b). The policy rule spells out how the ANVS interprets the three statutory requirements, and confirms that its supervision covers the whole tariff, cost price and margin alike (ANVS, 2024c). Its limits, however, are equally explicit. The ANVS itself states that COVRA, not the regulator, determines what the tariff actually is: supervision governs the *manner* of tariff-setting, not the level (ANVS, 2024a). When consultation respondents flagged that tariffs had risen sharply in recent years and that hospitals faced ever higher costs, the ANVS replied that this signal falls outside the scope of its supervisory task (ANVS, 2024c).

What the Dutch framework still lacks is thus every element that ties payments to the liability in the three programmes studied in this chapter. There is no output-based charge: Finland's operators pay into a ring-fenced national fund against a liability reassessed annually for each operator (Section 5.2.2), Sweden's pay fees recalculated every three years by the National Debt Office on the basis of a fresh cost estimate (Section 5.3.2), and France's EDF sets aside 0.14 cent per kilowatt-hour of nuclear electricity under legally supervised provisions (Section 5.4.3). There is no periodic recalibration: when COVRA's expected final-disposal expenditure rose from €2.31 billion to €10.9 billion between two annual reports (Section 5.5.4), no mechanism existed to translate that revision into higher payments by the producers responsible. And there is no collateral: Sweden holds SEK 81 billion in guarantees against the risk that an operator fails before its waste is paid for (Section 5.3.2), a risk the Netherlands has already seen materialise at Dodewaard (Section 5.5.1), where the state ended up buying the plant. The 2024 policy rule improves oversight of *how* tariffs are set; it is not a mechanism that ties what nuclear waste producers pay to what disposal will actually cost.

# 6. Dutch Case Study: Scenarios and Calculations

## 6.1 Waste generation assumptions

The values provided by COVRA 2050 Masterplan were used to calculate expected nuclear waste volume for the lifespan of both scenarios. The assumptions used in the original report were also adopted for this report. Examples of this are the selection of an SMR with a capacity of 350 MWe and an operating life of 50 years and the two new NPP to have a 1,600 MW capacity and an operating life of 80 years. The values of the NPPs were also used for the current policy proposition scenario developed in this report. Most importantly, COVRA calculates the amount of LILW and HLW waste of both NPPs and SMRs to be proportional to the capacity of the KCB.

The projected volume of NORM waste beyond 2050 was estimated using inventory data and future storage requirements reported in the COVRA 2050 Masterplan. The current NORM waste inventory at COVRA was estimated based on the reported occupancy of the Container Storage Building (COG) and the depleted uranium storage facilities (VOG-1 and VOG-2), resulting in an estimated stored volume of approximately 24,600 m$^3$ in 2024. COVRA projects that approximately 76,000 m$^3$ of NORM waste will require storage by 2050. Therefore, the increase in stored NORM waste between 2024 and 2050 was estimated at approximately 51,400 m$^3$. Assuming a constant average accumulation rate over this period, this corresponds to approximately 1,977 m$^3$/year. Due to the absence of long-term projections beyond 2050, this study assumes that this average annual accumulation rate remains constant until 2130, although future uranium enrichment activities and associated depleted uranium production may change over time. Applying this rate over the 80-year period between 2050 and 2130 results in an additional estimated 158,154 m$^3$ of NORM waste. The regular LILW flow was also derived in a similar manner, as displayed by Table 6.

**Table 5**

*Expected NORM waste volume.*

| Reference | Quantity (m³) |
|---|---|
| COG | 6,500 |
| VOG-1 | 13,500 |
| VOG-2 | 4,600 |
| Total in 2024 | 24,600 |
| Expected Volume in 2050 | 76,000 |
| Difference (2050 – 2024) | 51,400 |
| Total per Year | 1,976.9 |
| Cumulative by 2130 | 158,153.8 |

**Table 6**

*Expected flow of Regular LILW.*

| Reference | Quantity (m³) |
|---|---|
| Values up to 2050 | 17,200 |
| Total per year | 661.5 |
| Total by 2130 | 52,923 |

Additional sources were also used for the waste volume calculations. For the decommissioning process of nuclear power plants, the estimate of 5,000 m³ LILW provided by the Federal Office for the Safety of Nuclear Waste Management from Germany (2024) was used. And additional support to this assumption is that this waste would only start to be stored as early as 2087, after the end of the expected 50 years operation, and the report only included waste streams up to 2050.

Likewise, decommissioning waste from the SMRs was estimated using the assessment conducted by Yildirim et al. (2024), which quantified long-lived and short-lived intermediate-level waste generated from the decommissioning of the NuScale Power Module. The NuScale design was selected as a representative reference for a mid-size light-water SMR, as it represents one of the most advanced commercially developed SMR concepts and shares similar reactor characteristics with several SMR designs currently under development. The reported waste intensities were derived from detailed Monte Carlo neutron transport and activation simulations that explicitly account for reactor geometry, material composition and neutron spectrum. To estimate long-term activation, Yildirim et al. (2024) assumed a constant neutron flux corresponding to 100% reactor capacity over a 60-year operating lifetime, representing a conservative estimate of the maximum theoretical neutron activation.

Yildirim et al. (2024) report decommissioning waste intensities normalized by lifetime energy production ($m^3$/GWth-year). As the COVRA reference SMR is defined only by its electrical capacity (350 MWe) and operating lifetime (50 years), its lifetime energy production was converted to the same metric used by Yildirim et al. Assuming a thermal-to-electric conversion efficiency comparable to the NuScale design (approximately 31%), the reference reactor corresponds to approximately 1.12 GWth and 56 GWth-years of lifetime energy production. The waste intensity factors reported by Yildirim et al. were subsequently adopted as representative values for a generic light-water SMR, resulting in an estimated 16–30 $m^3$ of long-lived LILW and approximately 386 $m^3$ of short-lived LILW over the reactor lifetime.

Similarly, decommissioning waste from the HOR and PALLAS research reactors was estimated using the decommissioning assessment of the High Flux Reactor (HFR) at Petten published by the Commission of the European Communities (1997). The HFR was selected as the reference reactor because it is located at the same site, belongs to the same class of research reactors, and has a thermal capacity (45 MWth) comparable to the PALLAS reactor (55 MWth).

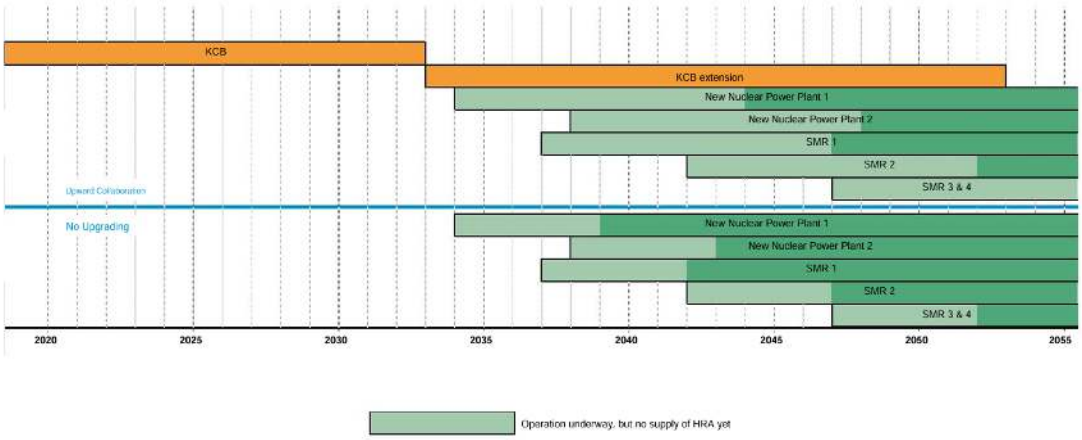
## 6.2 Scenario Definition and Volume calculations

COVRA's Masterplan provides development-specific waste volumes for both LILW and HLW, and these form the starting point for this report's calculations. However, the values previously displayed in Tables 1 and 2, which were extracted from the Masterplan, represent the total LILW and HLW volume up to 2050 – when most of the new developments would only just have started operating, as displayed in Figure 6. This subsection will provide a waste volume estimate for both LILW and HLW for the different scenarios considering the total lifespan of proposed developments.

Scenarios were developed using COVRA's 2050 Masterplan as reference. The scenarios are: Minimum scenario, with only existing nuclear power plants and research reactors, Plus scenario, with two new NPP and four SMRs, and Current policy proposition, with four new NPP and four SMRs.

**Figure 6**

*Schematic representation of the expected supply of nuclear waste from nuclear power plants.*




Note. Upgrading refers to reprocessing, in which the fuel assemblies are first cooled for a period and then reprocessed. The HLW is not transferred to COVRA until 10 years later.

**LILW**

Numbers were derived from COVRA's Masterplan and, when missing, supplemented by those reported by the Federal Office for the Safety of Nuclear Waste Management from Germany (2024), Yildirim et al. (2024), Commission of the European Communities (1997).

**HLW**

Numbers were derived from COVRA's Masterplan and, when missing, supplemented by those reported by the Federal Office for the Safety of Nuclear Waste Management from Germany (2024), Yildirim et al. (2024), Commission of the European Communities (1997). For HLW analysis in the Plus and Current policy proposition scenarios, one additional row was added to represent how much of the capacity of Sweden's Forsmark final repository – about 16,000 $m^3$ of long-lived waste – the total HLW volume would occupy. This comparison is illustrative only: Forsmark is designed for a specific inventory of Swedish spent-fuel canisters, whereas the Dutch inventory would mix vitrified reprocessing waste, spent fuel and other high-level waste with different packaging. This report is agnostic as to which direction the difference runs – a mixed Dutch inventory could require more space and cost per cubic metre just as easily as less.

## 6.3 Scenario volume estimates

### 6.3.1 Minimum Scenario

For this scenario, most of the information on the waste volume was already available at COVRA's Masterplan, with only the PALLAS and Urenco research reactors extending their lifespan beyond 2050.

**Table 7**

*Overview of estimated LILW amounts in 2130 (Minimum scenario). The treated-volume columns are illustrative upper bounds – they apply each volume-reduction factor (VRF) uniformly, although not every stream is eligible for treatment – and are not carried into the cost calculations.*

| Development | Quantity ($m^3$) | **High-pressure press (VRF 2.5)** | **Plasma Furnace (VRF 26)** |
|---|---|---|---|
| Values up to 2050 | 97,700 | 39,080 | 3,757.7 |
| NORM | 158,153.8 | 63,261.5 | 6,082.8 |
| Regular LILW flow | 52,923.1 | 21,169.2 | 2,035.5 |
| PALLAS | 2,000 | 800.0 | 76.9 |
| Decommissioning | 600 | 240.0 | 23.1 |
| Total | 311,376.9 | 124,550.8 | 11,976.0 |

**Table 8**

*Overview of estimated HLW amounts in 2130 (Minimum scenario).*

| Development | Quantity ($m^3$) |
|---|---|
| Values up to 2050 | 205 |
| PALLAS | 20 |
| Total | 225 |

## 6.3.2 Plus Scenario

Derived from COVRA's 2050 Masterplan, it is an intermediate scenario, with construction of two power plants and four SMRs.

**Table 9**

*Overview of estimated LILW amounts in 2130 (Plus scenario).*

| Development | Quantity ($m^3$) | **High-pressure press (VRF 2.5)** | **Plasma Furnace (VRF 26)** |
|---|---|---|---|
| Minimum Scenario | 311,376.9 | 124,550.8 | 11,976.0 |
| Extension of KCB | 1,000 | 400 | 38.5 |
| 1st Reactor | 12,800 | 5,120 | 492.3 |
| 2nd Reactor | 12,800 | 5,120 | 492.3 |
| 1st SMR | 2,400 | 960 | 92.3 |
| 2nd SMR | 2,400 | 960 | 92.3 |

| Development | Quantity (m$^3$) | **High-pressure press (VRF 2.5)** | **Plasma Furnace (VRF 26)** |
|---|---|---|---|
| 3rd SMR | 2,400 | 960 | 92.3 |
| 4th SMR | 2,400 | 960 | 92.3 |
| Complete Decommissioning (after 2050) | 12,144 | 4,857.6 | 467.1 |
| Total LILW (m$^3$) | 359,720.9 | 143,888.4 | 13,835.4 |

**Table 10**

*Overview of estimated HLW amounts in 2130 (Plus scenario).*

| Development | Quantity (m$^3$) | **Reprocessing consideration** |
|---|---|---|
| Minimum Scenario | 225 | 225 |
| Extension of KCB | 112 | 112 |
| 1st Reactor | 7,040 | 1480 |
| 2nd Reactor | 7,040 | 1480 |
| 1st SMR | 1,140 | 120 |
| 2nd SMR | 1,140 | 120 |
| 3rd SMR | 1,140 | 120 |
| 4th SMR | 1,140 | 120 |
| Total HLW (m$^3$) | 18,977 | 3,777 |
| % of reference capacity | **119%** | 24% |

### 6.3.3 Current policy proposition Scenario

Nuclear expansion scenario as proposed in 2024 by the Netherlands cabinet, with four new nuclear power plants with the possibility of multiple small modular reactors.

**Table 11**

*Overview of estimated LILW amounts in 2130 (Current policy proposition scenario).*

| Development | Quantity (m$^3$) | **High-pressure press (VRF 2.5)** | **Plasma Furnace (VRF 26)** |
|---|---|---|---|
| Minimum Scenario | 311,376.9 | 124,550.8 | 11,976.0 |
| Extension of KCB | 1,000 | 400 | 38.5 |

| Development | Quantity (m³) | **High-pressure press (VRF 2.5)** | **Plasma Furnace (VRF 26)** |
|---|---|---|---|
| 1st Reactor | 12,800 | 5,120 | 492.3 |
| 2nd Reactor | 12,800 | 5,120 | 492.3 |
| 3rd Reactor | 12,800 | 5,120 | 492.3 |
| 4th Reactor | 12,800 | 5,120 | 492.3 |
| 1st SMR | 2,400 | 960 | 92.3 |
| 2nd SMR | 2,400 | 960 | 92.3 |
| 3rd SMR | 2,400 | 960 | 92.3 |
| 4th SMR | 2,400 | 960 | 92.3 |
| Complete Decommissioning (after 2050) | 22,144 | 8,857.6 | 851.7 |
| Total LILW (m³) | 395,320.9 | 158,128.4 | 15,204.6 |

**Table 12**

*Overview of estimated HLW amounts in 2130 (Current policy proposition scenario).*

| Development | Quantity (m³) | **Reprocessing consideration** |
|---|---|---|
| Minimum Scenario | 225 | 225 |
| Extension of KCB | 112 | 112 |
| 1st Reactor | 7,040 | 1480 |
| 2nd Reactor | 7,040 | 1480 |
| 3rd Reactor | 7,040 | 1480 |
| 4th Reactor | 7,040 | 1480 |
| 1st SMR | 1,140 | 120 |
| 2nd SMR | 1,140 | 120 |
| 3rd SMR | 1,140 | 120 |
| 4th SMR | 1,140 | 120 |
| Total HLW (m³) | 33,057 | 6,737 |
| % of reference capacity | **207%** | 42% |

## 6.4 Cost evaluation

Expected nuclear waste volume was calculated for both LILW and HLW. With these numbers, external references were used to assess the cost of storage and disposal given the expected volumes. For LILW and Interim storage, due to time and data limitations, this report does not calculate the associated costs of management. For HLW, on the other hand, Sweden's deep geological repository, with capacity for 16,000 m$^3$ of waste, was used as reference due to volume data availability (see the caveat on this comparison in Section 6.2). In addition to that, given the relevance of cost overrun estimation shown by literature, the values reported by Finland, Sweden and France were used to calculate an overrun range from a similar project in the Netherlands.

Cost overruns were calculated using the formula provided by (Budzier et al, 2019):

### 6.4.1 Associated cost of DGR

To enable like-for-like comparison, both the original cost estimate and the most recently reported cost for each case study were converted to 2026 terms using the Harmonised Index of Consumer Prices (HICP).

For Finland, the comparison is lifecycle-to-lifecycle: the TKS-2003 total of €2,542 million (2003 prices) inflates to roughly €3.9 billion in 2026 terms, against the €4.9 billion total reported by Helsinki Times (2025) – an overrun of approximately 26%, the lowest of the three overrun figures used in this report. This comparison assumes the more recent figure covers the same lifecycle scope as TKS-2003; to the extent it covers less, the true Finnish overrun would be higher. For France, the €25 billion official reference cost (2011 economic conditions) and the €37.5 billion Andra estimate (2012 economic conditions) were inflated to 2026 terms using euro-area HICP, yielding an overrun of 46%. The ministerial reference cost is used as the baseline deliberately: although Andra's own 2014 assessment was higher, the ministerial figure is the one that legally governed French financial provisioning between 2016 and 2025 – just as, in the Netherlands, it is the government's and COVRA's official figures, rather than any outside estimate, that define what is actually provisioned for. Measured against the official planning baseline, the French case shows how far the governing number itself moved, which is the relevant comparison for a Dutch fund likewise calibrated to official estimates. Sweden's total nuclear waste programme is projected to cost SEK 221 billion (≈€19.8 billion) from start to finish under Plan 2022 – more than double the Plan 2001 estimate some 21 years earlier, corresponding to an average real annual cost growth of 4.3% (Riksgälden, 2023), or a cumulative overrun of approximately 142%. Both plans are drawn up under the same statutory scope, covering waste management and disposal *and* reactor decommissioning

(WNN, 2022; Riksgälden, 2023), so this is real cost growth on a constant scope; because it describes the whole programme rather than the spent-fuel repository alone, it is applied in this report as the upper bound of the overrun range.

For the existing nuclear waste production, COVRA estimated €3.3–3.5 billion, which could rise to €10.0–10.3 billion with construction of new NPPs and SMRs. These values were estimated to reflect the full lifecycle costs – construction, operation and closure of the final repository. Considering the corrected range of overrun depicted by the case studies, this value could turn out to be within €4.1–8.5 billion in the minimum scenario to €12.6–24.9 billion for two new NPPs and four SMRs.

COVRA does not publish a cost estimate for the four-reactor current-policy scenario. Fitting a fixed-cost-plus-variable-cost model to COVRA's own two data points – €3.01 billion fixed, plus approximately €397,000 per CSD-V/CSD-C canister – and extrapolating to the canister count implied by this report's current-policy waste volumes (Section 6.3.3) gives a base repository cost of approximately €12.9 billion, or approximately €16.2–31.2 billion once the overrun range is applied. This fixed-plus-variable extrapolation rests entirely on COVRA's own two published cost points (COVRA, 2025); it is the same relationship between cost and inventory that COVRA's figures themselves imply.

The assumption that a Dutch repository will cost more than currently estimated is not a pessimistic scenario choice but the documented base rate for projects of this kind. Four decades of megaproject research show that cost underestimation in large public works is systematic rather than incidental: roughly nine out of ten projects run over budget, the size of the underestimation has not improved in seventy years, and the causes – optimism bias in early estimates and the strategic incentive of promoters to present low numbers at the approval stage – are strongest precisely in the phase the Netherlands now occupies, before a site, a design or a licensing record exists (Flyvbjerg, Holm & Buhl, 2002; Flyvbjerg, 2014). Within this general pattern, nuclear projects are the worst-performing class of energy infrastructure: in a comparative assessment of 401 electricity projects across 57 countries, nuclear reactors showed a mean cost escalation of 117% of budget – higher than any other technology – with 97% of the reactors in the sample exceeding their estimates (Sovacool, Gilbert & Nugent, 2014). Budzier et al. (2019), whose overrun formula this report applies, find the same fat-tailed risk profile for nuclear waste storage specifically, meaning that extreme overruns are not freak events but an expected feature of the distribution. The three disposal programmes examined in this chapter confirm that even mature, well-governed programmes are no exception: not one has come in below its early estimates. Against that record, the assumption requiring justification is not that

Dutch costs will rise, but the opposite – that the Netherlands, with no site, no host-rock choice, no design, and a more heterogeneous waste inventory than any comparator, would become the first country to build a repository at its earliest estimate. Applying an empirically observed overrun range from comparable completed and advanced programmes, as this report does, is precisely the reference-class correction the forecasting literature prescribes for estimates made at this stage (Flyvbjerg, 2014).

### 6.4.2 Cost of reprocessing HLW

Actual reprocessing prices are not published. Orano's contract with EPZ was most recently renewed in 2012 to cover Borssele's spent fuel through to the plant's planned 2033 shutdown, with volumes fixed contractually rather than priced in any public document; used fuel delivered under this arrangement is approximately 96% recyclable material and 4% residual waste, which is vitrified and shipped back to COVRA (Orano, 2026). In the absence of a published Orano–EPZ price, this section follows the approach used in the wider reprocessing-economics literature and applies published benchmark unit costs instead.

Reported unit reprocessing costs for La Hague-type plants vary widely with the financing assumptions used. An OECD/NEA analysis of the comparable THORP plant at Sellafield put the cost at $570 per kilogram of heavy metal (kgHM) assuming a 5% return on capital, rising to $750/kgHM at a 10% return; a review of actual contract prices at THORP and the La Hague UP3 plant found a range of roughly $600–1,400/kgHM (National Research Council, 1996). A French government study specific to La Hague-type reprocessing put the price at 8,000 French francs per kgHM in 2000 terms, equivalent to approximately $1,240/kgHM in 2003 dollars – the most directly relevant published benchmark for Borssele's fuel, since it is reprocessed at that same facility (Bunn et al., 2003). None of these figures are adjusted here for inflation to a current price year; that adjustment should follow whatever price-year convention is used elsewhere in Chapter 6.

By comparison, the present-value cost of storing spent fuel pending direct disposal, without reprocessing, has been estimated at around $200/kgHM (Bunn et al., 2003) – roughly a sixth of the French reprocessing benchmark above, before either figure is converted to the HLW volumes used in Section 6.3. This gap is consistent with the direction, though not necessarily the exact magnitude, of the volume difference already assumed between the 'with reprocessing' and 'without reprocessing' branches of the scenarios in Section 6.3: reprocessing costs more per kilogram of heavy metal processed, but is assumed elsewhere in this report to leave a smaller final volume of HLW requiring disposal (Section 6.3).

Applying the France-specific reprocessing benchmark (~$1,240/kgHM; Bunn et al., 2003) – the most relevant given Borssele's fuel is reprocessed at the same La Hague facility – and converting via the standard CSD-V vitrified-waste canister specification (170 L per canister, 0.74 canisters per tHM reprocessed; COVRA, 2024; AREVA data), reprocessing costs equate to roughly €8.5 million per m³ of vitrified HLW. Applied to the reprocessing-pathway volumes in Tables 10 and 12, choosing reprocessing over direct disposal for the Plus and current-policy scenarios would add on the order of €30–60 billion to total waste-management costs – a substantial expense, but one traded off against a repository requiring roughly a fifth of the volume (24% vs. 119% of Forsmark's reference capacity under the Plus scenario; 42% vs. 207% under current policy) that direct disposal would require. For this reason, even considering a lower waste volume because of successful reprocessing, this practice implies additional costs that can be as high as the construction of a geological repository – adding further to the costs of the nuclear energy expansion. One caveat runs in one direction only: the benchmark used here dates from 2003 and is not adjusted to current prices, and actual La Hague contract prices are confidential. The €30–60 billion range should therefore be read as an order of magnitude, and real reprocessing costs may well be higher.

### 6.4.3 The bill per household and per kilowatt-hour

To make the scale of these figures concrete, we derive a per-household and per-kilowatt-hour bill. Our assumption is that the cost of nuclear waste disposal is reflected in the electricity price paid for nuclear, and therefore increases the electricity bill for consumers.

**Per household.** The current-policy disposal cost of €16.2–31.2 billion, less the €133 million reserve, divided across 8.4 million Dutch households, comes to roughly €1,900 to €3,700 per household. This expresses scale, not a payment schedule: the actual outlays would be spread across this century and the next.

**Per kilowatt-hour.** The same cost can be set against all the electricity the proposed programme would generate over its lifetime. Four 1,600 MW reactors operating for 80 years, four 350 MW SMRs operating for 50 years, and the 20-year Borssele life extension (485 MW), all at a 90% load factor[2], together produce roughly 4,700 TWh. Spread over that output, disposal costs 0.35 to 0.7 cent per kilowatt-hour – on the order of one to two

[2] A t the capacity factors the global fleet has actually realised (a world average of 83% in 2024, and just above 80% over the past two decades (World Nuclear Association, 2025) ) lifetime generation falls to roughly 4,200–4,350 TWh and the required levy rises to approximately 0.4–0.75 cent per kilowatt-hour. The 0.35–0.7 cent range used in this report's summary is therefore a lower bound.

percent of a typical household electricity price. This cost is added to building cost and other system costs for running nuclear.

# 7. Results and Discussion

**COVRA's 2024 annual report shows a reserve for final disposal of €133 million at the start of 2025 (Laka, 2026). By the end of 2025, by contrast, the Financial Provision Fund in Finland held approximately €3.0 billion, while Sweden's Kärnavfallsfonden held approximately €7.5 billion at the end of 2024. France's dedicated back-end fund held €24.6 billion in 2020. Even against Finland's fund – the smallest of the three, and the one the Netherlands might reasonably aspire to first – COVRA's reserve is only about 4% of the size; against France's, it is under 1%. For a country in which nuclear power supplies only about 3% of electricity, that starting position is perhaps unsurprising – but it is precisely this position that the cabinet proposes to change, without changing how disposal is financed. The money will ultimately have to come from Dutch energy consumers or taxpayers.**

Regarding the political process, the pace in Finland is the clearest point of contrast with the other case studies. Finland reached a parliamentary decision-in-principle in 2001, two decades before Sweden's operating licence and while France remains pre-construction; the Netherlands, by comparison, has yet to secure agreement on a single candidate site (Section 5.5.1). Finnish officials point to public trust as the deciding factor, but the country differs from the Netherlands in the respect Eurajoki's own council members highlighted: Finland's repository sits beside a power plant the host community already lived with for decades, while the sites under discussion in the Netherlands – including the Gasselte salt dome discussed in Section 5.5.1 – have no comparable existing relationship with the nuclear or energy sector to draw on.

Regarding the volume of nuclear waste, through the estimations done in this report, the plus and current policy proposition scenarios could potentially, without reprocessing, occupy 119–207% of the reference final repository's total capacity of 16,000 $m^3$ (see the caveat on this comparison in Section 6.2). This means that the equivalent of two or even three such repositories would need to be built in the Netherlands, with important financial, social and environmental consequences. Even with the continuation of reprocessing, which reduces the volume of the waste, equivalent costs are in return added to the waste management.

The scale of this expansion also affects the multinational disposal route COVRA is pursuing through the European Repository Development Organisation (Section 5.5.2). ERDO's shared-repository model is aimed at countries that generate comparatively little high-level waste, such as the Netherlands and Denmark, spreading a largely fixed repository cost across several small producers. At 225 $m^3$ of HLW under continued operation of existing facilities, the Netherlands fits that profile. Under the Plus or current-policy scenarios, however, projected HLW volumes rise to somewhere between 19,000 and 33,000 $m^3$ if disposed of directly, or 3,800–6,700 $m^3$ if reprocessed – a producer of that size looks considerably less like ERDO's target profile and considerably more like a country that needs a full-scale repository of its own. COVRA's own cost estimates (Section 6.4.1) already assume a standalone national repository rather than a shared one, so this isn't a change to the cost figures themselves – but it does mean that expanding the nuclear programme may forgo the one route by which the Netherlands could otherwise have avoided most of the fixed cost identified in Section 6.4.1, not just add to the waste needing disposal.

The value of that foregone option can be estimated with this report's own cost model. In the Minimum scenario, roughly €3.0 billion of the €3.3–3.5 billion bill is fixed cost (Section 6.4.1). Shared equally among the three ERDO founding countries, the Dutch base bill falls from roughly €3.4 billion to about €1.5 billion; across the seven countries currently participating in ERDO, to below €1 billion. Even if the Netherlands, as the largest of the founding inventories, bore half the shared fixed cost, the saving would still be around €1.5 billion at base costs. The option foreclosed by expansion is thus worth on the order of €2–6 billion once the overrun range of Section 6.4.1 is applied: roughly half of the entire no-new-build disposal bill, and 15 to 45 times the current reserve. This is consistent with the European feasibility literature: the EC-funded SAPIERR II economic study estimated collective savings of at least €15 billion from a shared European repository (Arius Association, 2009). A multinational repository is an option rather than a certainty. No host site exists and the political path is untested. But it is an option the Netherlands co-founded, whose secretariat COVRA itself administers, and which official Dutch policy explicitly keeps open under its dual-track approach; expansion would close one track of standing policy without that closure ever appearing as a cost in any decision document.

Through the analysis of the total life-cycle costs of a DGR and using a cost overrun range provided by an analysis of the case studies, it was possible to estimate that the decision to commit to two new NPPs and four SMRs could lead to a cost of €12.6–24.9 billion for the Plus scenario. COVRA's own cost assessment does not extend a separate estimate to the four-NPP current-policy scenario. Scaling COVRA's two published data points against the growth in canister count implied by this report's waste-volume estimates (Section 6.3) – rather than assuming proportionality, which COVRA's own figures do not support – gives a base repository cost of approximately €12.9 billion, and a cost range of roughly €16.2–31.2 billion once the overrun range from Section 6.4.1 is applied.

France's comparatively low overrun likely reflects project stage rather than superior cost control: Cigéo has not yet reached its construction decree, so the French figures are successive estimates rather than an estimate tested against realised spending. Sweden and Finland, by contrast, both carry real, spending-tested cost growth – but in opposite directions from what construction progress alone would predict. Sweden, which only began construction in January 2025, shows the largest tested overrun (142%); Finland, whose repository is essentially complete, shows the smallest (approximately 26%). Overrun size does not, therefore, track construction progress monotonically. The more plausible driver is scope: Onkalo's inventory is narrow by institutional design – spent fuel from Finland's own reactors only, funded and licensed around two producers, with international waste closed off by a 1994 legal ban (Section 5.2) – while Sweden's Forsmark programme has had to absorb a broader set of technical and regulatory contingencies, including an eleven-year licensing review and additional evidence required on copper-canister durability, over a much longer institutional history.

This is consistent with the broader megaproject-cost literature this report already draws on for its overrun methodology (Budzier et al., 2019), where cost growth tracks a project's technical, institutional and stakeholder complexity at least as closely as its calendar stage. Since the Dutch repository will need to accommodate a genuinely mixed inventory with no equivalent institutional narrowing (Section 5.2), Sweden – not Finland – is the more relevant comparator for how far a Dutch estimate might still move. Combined with the fact that the Netherlands has not yet chosen a site, earlier in the process than any of the three case studies, this argues for reading current Dutch cost estimates as closer to the upper end of the range than the lower – for reasons of scope and institutional complexity, not construction stage alone.

Considering the expected volumes of high-level waste in the plus and current policy scenarios, the Netherlands would go from being a small producer of high-level nuclear waste to a substantial one (from 225 $m^3$ to between 19,000 and 33,000 $m^3$), most likely ending the possibility of exporting high-level waste and relying on the infrastructure of other countries.

## 7.1 How big is the funding gap?

The size of the funding gap identified above depends on when a repository construction starts, because two things move at once: the reserve keeps compounding, and the share of the waste that is old enough to emplace keeps growing. This section models that timing using only figures established elsewhere in this report: COVRA's reserve of €133 million at the start of 2025 (Section 5.5.4), the reserve's own target real growth rate of 2.3% per year (4.3% nominal less 2% assumed inflation; Kamerstuk, 2016), and the scenario cost ranges from Section 6.4.1.

**The fund side.** All amounts in this section are in real terms (2026 prices), on both the fund side and the cost side: expressing both in the nominal euros of 2120 would multiply each by roughly a factor of eight at 2$ inflation: the reserve to about €11 billion, in line with the COVRA fund, and the current-policy cost of storage to €130-250 billion. With no further contributions, €133 million compounding at 2.3% real reaches roughly €0.3 billion by 2060 and €1.4 billion by 2130. Contributions at their recent pace do not change the order of magnitude of a shortfall: the reserve grew from €68 million at the end of 2014 to €133 million at the start of 2025, implying net additions in the mid-single-digit millions per year. Continued at that pace, they would lift the fund to roughly €0.6 billion by 2060 and €3 billion by 2130, which is still below the cost of any expansion scenario. The return assumption matters at least as much: at a more conservative 1.5% real return, the 2130 fund without new contributions would be around €0.6 billion, while even an optimistic 3.0% yields about €3 billion.

The cost side, however, moves in the opposite direction. Spent fuel needs decades of cooling before it can be emplaced. A repository opening around 2060 could therefore accept, at most, the inventory of the existing installations: none of the waste from any new reactor would be old enough, since the first new plant would still be operating. This is the same model as exists in the Finnish scenario, where the facility does not store waste that is currently produced, but only waste accrued historically. The cost basis of a 2060 facility is thus essentially the Minimum-scenario cost – €4.1–8.5 billion including the overrun range – in *every* buildout scenario. Against a fund of €0.3 billion, that is a shortfall of roughly €3.8–8.2 billion, and coverage of about 4–7%, whatever the cabinet decides about new reactors.

By 2130, with all waste of projected nuclear power old enough to be included, costs range from €4.1–8.5 billion (Minimum) through €12.6–24.9 billion (Plus) to €16.2–31.2 billion (current policy), against a fund of €1.4 billion. Coverage improves to roughly 17–35% in the Minimum scenario, but only to about 6–12% under Plus and 5–9% under current policy; continued contributions at the recent pace roughly double these ratios. In the Minimum scenario, compounding plus contributions could thus eventually cover a substantial share of the bill. Under the expansion scenarios, even the most favourable combination of returns, contributions and outturn costs covers less than a quarter of it. Later is better – but better here still means at least three-quarters of the expansion bill uncovered.

Therefore in table 13 the amount of average coverage required to cover the gap for financing nuclear waste storage was computed.

**Table 13**

*Funding gap at two candidate repository dates, by scenario.*

| | **2060 (existing-installations facility)** | **2130 (full inventory)** |
|---|---|---|
| COVRA reserve, real terms (no further contributions) | €0.3 billion | €1.4 billion |
| – if contributions continue at the recent pace | ≈€0.6 billion | ≈€3 billion |
| Repository cost – Minimum | €4.1–8.5 billion | €4.1–8.5 billion |
| Repository cost – Plus | €4.1–8.5 billion, plus €8.5–16.4 billion deferred | €12.6–24.9 billion |
| Repository cost – Current policy | €4.1–8.5 billion, plus €12.1–22.7 billion deferred | €16.2–31.2 billion |
| Shortfall (no further contributions) | €3.8–8.2 billion | €2.7–7.1 bn (Min) / €11.2–23.5 bn (Plus) / €14.8–29.8 bn (Current policy) |
| Coverage (no further contributions) | ≈4–7%, all scenarios | ≈17–35% (Min) / ≈6–12% (Plus) / ≈5–9% (Current policy) |
| Annual contribution required to close the gap | €70-155 million (existing waste; deferred new-build bill additional | €6-16 million (min) / €26-55 million (plus) / €35-70 million (current policy |

*Note.* Repository costs include the overrun range derived in Section 6.4.1. “Deferred” is the additional cost of disposing of new-build waste, which a 2060 facility could not yet accept and which would fall to a later disposal phase.

The more consequential finding sits underneath the headline numbers. Building more reactors barely changes the 2060 arithmetic – not because a larger nuclear programme is cheaper to dispose of, but because none of its waste is old enough to be counted yet. That waste does not disappear from the bill; it moves into a deferred balance of €8.5–22.7 billion that a 2060 facility cannot accept and a later phase would have to cover – cost that exists whether or not it appears in the 2060 arithmetic. Accelerating the repository decision, in other words, does not make an expanded nuclear programme show its true cost sooner; it mainly changes which bucket the cost sits in.

These figures carry the uncertainties already described. COVRA's own central estimate has a ±30% (P15–P85) band, the host rock has not been chosen, and the four-reactor cost base is extrapolated rather than published (Section 6.4.1). None of these plausibly closes the financing gap observed in the COVRA report.

# 8. Conclusion

**This report estimated the volume and cost of long-term nuclear waste storage in the Netherlands under three capacity scenarios and assessed whether the COVRA fund can cover the resulting liability.**

Waste volume increases substantially between scenarios: from approximately 225 $m^3$ of HLW under continued operation of existing facilities to 19,000–33,000 $m^3$ under the Plus and current-policy expansion scenarios if disposed of directly, or 3,800–6,700 $m^3$ if reprocessed (Sections 6.3.1–6.3.3). Projected repository costs rise correspondingly from COVRA's own €3.3–3.5 billion baseline to €12.6–24.9 billion under the Plus scenario, and to approximately €16.2–31.2 billion under the current-policy scenario (Section 6.4.1). Expanding the programme also likely forecloses the multinational disposal route smaller producers can otherwise use to share a repository's largely fixed cost (Chapter 7). As no policy is determined how contributions will work for new nuclear sites, there is currently a funding gap. Similarly, the lack of cost overrun estimates also represent a risky liability.

How quickly this gap needs to be closed depends on when a repository actually opens. Modelling COVRA's own reserve and cost-scaling method at two candidate dates – a possible 2060 opening and the official 2130 target – shows the fund would cover only about 4–7% of the repository's cost basis at 2060, rising by 2130 to roughly 17–35% under the Minimum scenario but only 5–12% under expansion. The improvement with time reflects the fund compounding, not the underlying liability shrinking. Expanding the nuclear programme, meanwhile, leaves the 2060 shortfall essentially unchanged, since new-build waste is not old enough to be included by then – but it adds €8.5–22.7 billion of high-level waste disposal that a 2060 facility would have to defer to a later phase, a cost that stays real even where it does not yet appear (Section 7.1).

As established in Section 5.2, the gap between Finland's low overrun record and the Dutch case has a structural cause, not just a maturity one: Onkalo's inventory boundary is institutional, and the Netherlands has no equivalent boundary to draw on. Sweden and

France, which manage more heterogeneous inventories, offer closer reference points for cost and schedule risk.

Three limitations qualify these estimates. First, SMR waste volumes were derived by scaling per-GWth-year factors linearly with assumed lifetime output, though the literature underlying those factors notes that decommissioning waste is driven by activated shield concrete, which scales with reactor geometry rather than power output; the resulting figures should be read as indicative. Second, NORM waste – projected at approximately 76,000 $m^3$ by 2050 and included in this report's volume estimates (Section 6.1) – is not costed here, and neither is any other LILW or the century of interim storage. The cost totals in this report are therefore lower bounds.

Third and finally, this report estimates LILW volumes under all three scenarios (Section 6.3) but does not cost them, primarily due to time and data constraints within the scope of this research. This is not only a limitation of this report: none of the three case-study countries publish a clean, separately itemised LILW or interim-storage cost either. Sweden bundles it with R&D and transport into a single undifferentiated total (Section 5.3.2); Finland carries it within each operator's own liability to its national fund rather than as a reported line item (Section 5.2.3); France folds it into the broader spent-fuel management portion of EDF's back-end fund (Section 5.4.3). Unlike high-level waste, where COVRA, Posiva, SKB and Andra each publish a comparable headline repository cost, no equivalent benchmark exists for LILW – which is why the overrun-based methodology used for high-level waste (Section 4.3) could not be extended to it with the same confidence, independent of how much time this research had available. Closing that gap is taken up as a recommendation in Chapter 9.

# 9. Recommendations

**The findings of this report point to six concrete steps. They are addressed to the cabinet, to parliament, and to COVRA and its supervising ministries.**

**1. No irreversible new-build decision without a full disposal-cost accounting.** Before any construction decision could feasibly be made on new reactors or SMRs, the government should first publish a complete estimate of the disposal liability each option creates – including LILW, NORM and interim storage – and state who will pay for it and how. The €14.5 billion earmarked for construction currently has no published counterpart on the waste side, even though the disposal bill of the four-reactor programme is of comparable size (Chapters 6 and 7).

This accounting should also include the option value that a new-build decision forecloses: under this report's cost model, the multinational (ERDO) disposal route is worth on the order of €2–6 billion to the Netherlands on its existing inventory alone (Chapter 7).

**2. Introduce a disposal levy on nuclear electricity.** At 0.35 to 0.7 cent per kilowatt-hour (Section 6.4.3), the full high-level-waste disposal bill of the current policy could be funded from the electricity that produces it. Finland and Sweden both charge their operators per unit of output into a ring-fenced fund (Sections 5.2.2 and 5.3.2); the Netherlands instead charges its nuclear operators contract prices fixed years ahead that do not move with the cost estimates (Section 5.5.5).

**3. End the confidentiality of the nuclear waste contracts.** The long-term contracts between COVRA and the operators of Borssele and Petten should be published, at minimum in their price and risk-allocation terms. As long as they are secret, parliament cannot verify that the polluter-pays principle of the National Programme is honoured – and the ANVS has already documented that it is not (Section 5.5.5).

**4. Create independent periodic cost review with the power to adjust what producers pay.** Sweden's model – a cost basis recalculated every three years and reviewed by the National Debt Office, which then sets fees and collateral (Section 5.3.2) – should be adapted for the Netherlands. The ANVS's 2024 policy rule on tariff oversight is a first step, but it governs how tariffs are set, not whether they cover the liability (Section 5.5.5).

**5. Require financial collateral from nuclear operators.** Sweden holds SEK 81 billion in guarantees alongside its fund precisely because an operator may fail before its waste is paid for (Section 5.3.2). The Dodewaard precedent – where the state ultimately bought the plant when its owner could not fund dismantling – shows that this risk is not hypothetical in the Netherlands (Section 5.5.1).

**6. Publish the missing half of the bill: LILW and interim storage.** This report costs high-level waste only, because no clean cost basis for LILW exists in any of the four countries studied (Chapter 8). COVRA and the responsible ministries should publish a full, itemised cost basis – tariff schedule included – for LILW acceptance, interim storage and disposal. The volumes are established in this report; what is missing is the cost side, which would likely require primary data rather than published international comparators. Its publication would allow, for the first time, a complete assessment of the total cost of the nuclear choice.

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