🟦 SLIDE 3 — Nuclear Power Plant Lifecycle (Reference Case: EPR – Flamanville)

Nuclear Power Plant Lifecycle – From Construction to Long-Term Operations

Sous-titre

Reference case: **EPR-type reactor (~1.6 GW)** – European context

Contenu du slide (visuel simple, très clean)

1. Construction phase (CAPEX-heavy | multi-year)

- Duration: **8–10 years**
- Highly subcontracted
- Strong exposure to **raw materials & energy prices**
- Front-loaded commodity risk

👉 **Key exposures**
Steel, cement, copper, aluminium, energy (diesel, electricity), specialized alloys

2. Electricity generation phase

- Operating life: **40–60 years**
- Revenues linked to **power prices**
- Strong interaction with:
  - Fuel costs
  - Carbon pricing
  - Wholesale power markets

👉 **Key exposures**
Electricity prices, carbon (indirect), fuel costs

3. Maintenance & fuel cycle (OPEX | recurring)

- Continuous over plant lifetime
- Predictable but long-term exposures

- Attractive for **rolling hedging strategies**

👉 **Key exposures**
Metals, energy, uranium, logistics, replacement parts

Each phase presents distinct and hedgeable commodity exposures, creating opportunities for structured, long-term client solutions.

🟦 SLIDE 4 — Focus on Construction Phase: Scope & Segmentation

(transition naturelle vers le dur)

Titre

Construction Phase – Scope Breakdown (EPR-type plant)

Objectif du slide

Expliquer **comment** on découpe la construction **avant de chiffrer**.

Contenu

Construction is not a single project, but a combination of industrial packages

Proposed segmentation for commodity exposure analysis:

1. **Civil engineering & heavy infrastructure**
2. **Electrical infrastructure & cabling**
3. **Piping & fluid systems**
4. **Conventional island (turbines, alternators)**
5. **Nuclear island (reactor core & specific materials)**

👉 Segmentation aligned with:

- Subcontracting reality
- Distinct commodity baskets

🟦 SLIDE 5 — Construction (1/5): Civil Engineering & Heavy Infrastructure (EPR Flamanville – order of magnitude)

Scope (civil works)

Reactor & containment structures, auxiliary/safety buildings, machine hall foundations, cooling structures, earthworks, temporary works.

Key materials basket (more complete)

Concrete & binders: ready-mix concrete, cement, SCMs (fly ash / slag), admixtures
Reinforcement & structures: rebar, structural steel, wire rod
Aggregates: sand, gravel, crushed stone
Energy & site consumables: diesel (earthworks/cranes/generators), electricity (site), bitumen/asphalt (roads/platforms)
Temporary works: formwork systems (steel/plywood), scaffolding, water

Input (hedgeable / proxy)	Quantity (indicative)	How the number is built	Indicative unit price	Commodity exposure (€)
Concrete poured *(non-traded → proxy via cement/energy)*	**~400,000 m³**	Reported site figure	—	—
Cement embedded in concrete	**~120,000 t**	400,000 m³ × **0.30 t cement/m³** (typical mix order of magnitude)	**~€150/t**	**~€18m**
Aggregates (sand + gravel + crushed stone)	**~720,000 t**	400,000 m³ × **1.8 t aggregates/m³** (typical density)	**~€15/t**	**~€11m**
Rebar / reinforcement steel *(traded proxy: rebar / scrap / iron ore)*	**~50,000 t**	Reported site figure ("armatures")	**~€600/t**	**~€30m**
Structural steel (frames, embeds, supports) *(proxy: HRC / plate)*	**~10,000–20,000 t**	Rule-of-thumb add-on vs rebar for heavy industrial civil works	**~€700/t**	**~€7–14m**
Diesel – construction equipment & generators *(traded proxy: gasoil)*	**~15–25m liters**	Earthworks + lifting + on-site generation (range, multi-year)	**~€1.62/L**	**~€24–41m**
Bitumen/asphalt (platforms, roads, waterproofing) *(proxy: crude / bitumen)*	**~10–20kt**	Site access roads + platforms (range)	**~€500/t**	**~€5–10m**

🟦 SLIDE 6 — Construction (2/5): Electrical Infrastructure

Embedded Copper & Aluminium Exposure

(EPR – Flamanville reference | Order of magnitude)

Scope (electrical infrastructure)

- Internal power distribution (LV / MV / HV)
- Safety & redundancy systems (Class 1E)
- Instrumentation & control (I&C) networks
- Switchyard & grid connection interface
- Grounding & earthing systems

Commodity exposure principle (1 phrase, très importante)

*Finished cables are non-traded products; commodity exposure refers to the **embedded copper and aluminium content**.*

Methodology (how quantities are derived)

1. Estimate **installed cable length** for an EPR-scale plant
2. Convert km of cables → **metal tonnage** using average weights per km
3. Split exposure between **copper-based** and **aluminium-based** conductors
4. Convert metal tonnage → € **exposure** using indicative market prices

Embedded metal (hedgeable)	Quantity (indicative)	Assumption / build-up	Indicative price	Commodity exposure (€)
Copper (LV, MV, I&C cables)	**~15,000 – 20,000 t**	~1,500–2,000 km of Cu cables × **8–10 t Cu/km** (mixed sections)	**~€8,500/t**	**~€130 – 170m**
Aluminium (HV, large cross-section cables)	**~8,000 – 12,000 t**	Long-distance & HV conductors (lighter vs Cu)	**~€2,300/t**	**~€18 – 28m**
Steel (trays, supports, earthing) *(proxy)*	**~8,000 – 12,000 t**	Cable trays, ladders, fixings across buildings	**~€700/t**	**~€6 – 8m**

✅ **Total embedded metal exposure (electrical infrastructure): ~€155m – €205m**

Hedging logic

Copper exposure → direct hedge via LME copper

- **Aluminium exposure** → LME aluminium
- **Non-traded finished cables → proxy hedging on embedded metals**
- Possibility to structure hedges:
    - By **construction milestones**
    - By **progressive cable installation schedule**

Electrical infrastructure represents a **large, early and highly hedgeable metal exposure**, dominated by copper content.

🟦 SLIDE 7 — Construction (3/5): Piping & Fluid Systems

Embedded Stainless Steel & Nickel Exposure

(EPR – Flamanville reference | Order of magnitude)

Scope (fluid & piping systems)

- Primary & secondary cooling circuits
- Steam lines and condensate systems
- Safety-related fluid networks
- Auxiliary cooling and water treatment systems
- Valves, fittings, pumps casings (metallic parts)

Key materials involved

Stainless steels: austenitic grades (304 / 316 equivalents)
Alloy steels: low-alloy & high-spec steels
Critical alloying metals: nickel, chromium, molybdenum
Carbon steel: for non-safety auxiliary systems

Commodity exposure principle

*Piping systems are non-traded industrial products; commodity exposure refers to the **embedded metal content**, in particular stainless steel and its alloying elements.*

Methodology (how quantities are derived)

1. Start from **installed piping length & diameter** typical of EPR plants
2. Convert piping scope → **total steel tonnage**
3. Split tonnage between **carbon steel** and **stainless steel**
4. Decompose stainless steel → **nickel content** (key hedgeable driver)
5. Convert metal tonnage → € **exposure**

Embedded material (proxy-hedgeable)	Quantity (indicative)	Assumption / build-up	Indicative price	Commodity exposure (€)
Total piping steel (all systems)	**~45,000 – 60,000 t**	Large-diameter steam + extensive safety piping	—	—
Carbon steel (auxiliary systems)	**~25,000 – 35,000 t**	~55–60% of total piping	**~€700/t**	**~€18 – 25m**
Stainless steel (primary & safety systems)	**~15,000 – 20,000 t**	~30–35% of total piping	**~€3,000/t**	**~€45 – 60m**
Nickel embedded in stainless steel	**~1,200 – 2,000 t**	~8–10% Ni content (304/316-type)	**~€17,000/t**	**~€20 – 34m**

✅ **Total piping-related metal exposure (illustrative): ~€85m – €120m**

Hedging logic

- **Finished pipes are not traded**
- Cost is driven by:
  - **Stainless steel prices**
  - **Nickel content** (major volatility driver)
- **Proxy hedging strategy**:
  - Direct nickel hedge (LME)
  - Partial steel hedge (HRC / scrap proxies)
- Suitable for:
  - **Phased hedging** (aligned with piping installation)
  - **Long lead-time procurement coverage**

One-line takeaway

Piping systems create a **material, mid-construction exposure to stainless steel and nickel**, with strong proxy hedgeability via LME nickel.

🟦 SLIDE 8 — Construction (4/5): Conventional Island

Turbines, Alternators & Mechanical Systems

(EPR – Flamanville reference | Order of magnitude)

Scope (conventional island)

- Steam turbines
- Alternators / generators
- Condensers
- Heat exchangers
- Mechanical auxiliaries (shafts, casings, supports)

👉 Partie **non nucléaire**, mais **forte intensité matière** et **valeur unitaire élevée**.

Key materials involved

Carbon & alloy steels: forged steel, plates, shafts
Copper: alternator windings
Special alloys: nickel-based & chromium steels (high temperature / stress)
Aluminium: secondary mechanical components

Commodity exposure principle

*Equipment is not traded; commodity exposure reflects the **embedded metals** used in turbines and generators.*

Methodology (how quantities are derived)

1. Identify **main rotating equipment** (turbine + alternator)
2. Estimate **mass of each equipment** (industrial benchmarks)
3. Split mass by **material type** (steel vs copper vs alloys)
4. Convert embedded metals → € **exposure**

Steel (turbines, casings, shafts)	**~45,000 – 60,000 t**	Turbine + condenser + mechanical systems	**~€700/t**	**~€32 – 42m**
Copper (alternator windings)	**~3,000 – 5,000 t**	Large alternator coils (high purity Cu)	**~€8,500/t**	**~€26 – 43m**
Alloy steels / Ni-based alloys	**~2,000 – 4,000 t**	High-stress / high-temp components	**~€4,000/t**	**~€8 – 16m**
Aluminium (secondary components)	**~1,000 – 2,000 t**	Frames, cooling systems	**~€2,300/t**	**~€2 – 5m**

✅ **Total conventional island metal exposure (illustrative): ~€70m – €105m**

Hedging logic

- **Steel exposure** → proxy via HRC / scrap / iron ore
- **Copper exposure** → direct hedge via LME copper
- **Alloy exposure** → partial hedge via nickel
- Long manufacturing lead times → **pre-hedging opportunities**

One-line takeaway

The conventional island concentrates **high-value embedded metals**, combining **steel mass** and **copper intensity**, making it a strong candidate for structured hedging.

🟦 SLIDE 9 — Construction (5/5): Nuclear Island

Fuel, Zirconium & Strategic Materials Exposure

(EPR – Flamanville reference | Order of magnitude)

Scope (nuclear island)

- Reactor pressure vessel & internals
- Fuel assemblies (initial core loading)
- Control rods
- Fuel cladding
- Nuclear-grade structural components

👉 Partie **hautement réglementée**, peu standardisable, mais **exposition matière réelle**.

Key materials involved

Fuel cycle: uranium (U_3O_8 → enriched fuel)
Cladding: zirconium alloys (zircaloy)
Structural metals: nuclear-grade steels
Absorbers: boron (control systems)

Commodity exposure principle

*Nuclear materials are not fully hedgeable through standard markets; exposure analysis is primarily **strategic and economic**, rather than trading-oriented.*

(Phrase très importante pour te protéger)

Methodology (how quantities are derived)

1. Define **reactor power**: EPR ~1.6 GW
2. Estimate **initial core fuel load**
3. Identify **key metallic components** required for fuel assemblies
4. Translate into **indicative commodity exposure**, where possible

Material	Quantity (indicative)	Assumption / build-up	Indicative unit price	Economic exposure (€)
Uranium (natural U_3O_8 equivalent)	**~450 – 550 t**	Initial core + fuel cycle conversion	**~€70/kg**	**~€30 – 40m**
Enriched uranium (fuel assemblies)	**~90 – 110 t**	After enrichment (3–5%)	—	—
Zirconium alloys (fuel cladding)	**~400 – 600 t**	Cladding for full core	**~€40,000/t**	**~€16 – 24m**
Nuclear-grade steels	**~15,000 – 20,000 t**	Reactor internals & structures	**~€3,000/t**	**~€45 – 60m**
Boron-based materials	**Marginal**	Control rods / chemistry	—	—

✅ **Total nuclear island economic exposure (illustrative): ~€90m – €125m**

Hedging & strategic considerations (important nuance)

- **Uranium**:
  - Illiquid vs LME metals
  - Long-term contracts dominate
  - Price risk is **real but managed differently**

- **Zirconium**:
  - Highly specialized market
  - No direct hedging instruments
- **Steel**:
  - Partial proxy hedging possible

👉 This phase is **less trading-oriented**, but **critical for full lifecycle risk mapping**.

One-line takeaway

The nuclear island represents a **strategic, less liquid exposure**, completing the construction risk map even if standard hedging solutions are limited.

🟦 SLIDE 10 — Electricity Generation Phase

Power Price Exposure & Revenue Risk

(EPR – Flamanville reference | Order of magnitude)

Scope (power generation phase)

- Electricity production and sales
- Interaction with wholesale power markets
- Long-term revenue exposure over plant lifetime (40–60 years)

Commodity exposure principle

*During the generation phase, exposure shifts from input commodities to **electricity price risk** and revenue volatility.*

Methodology (how figures are derived)

1. Define **installed capacity**: EPR ≈ **1.6 GW**
2. Apply **load factor** (capacity factor)
3. Convert into **annual electricity output (MWh)**
4. Translate production into € **revenue exposure** using power price assumptions

Indicative electricity production

- Installed capacity: **1.6 GW**
- Load factor (long-term average): **80–90%**
- Annual operating hours: **8,760 h**

👉 **Annual electricity production**
≈ **11 – 12.5 TWh / year**

Indicative revenue exposure

Power price assumption	Annual revenue exposure
€50 / MWh	**€550 – 625m / year**
€70 / MWh	**€770 – 875m / year**
€100 / MWh	**€1.1 – 1.25bn / year**

(illustrative ranges – no price forecast implied)

Risk drivers

- Wholesale power prices
- Regulatory frameworks (CfD, price caps, state support)
- Demand–supply balance (baseload vs intermittent renewables)
- Fuel & carbon price interactions (indirect)

Hedging & structuring logic

- Long-term power price exposure → **forward sales / structured hedges**
- Possibility to design:
  - Fixed-price revenue profiles
  - Floor / collar structures
  - Progressive hedging over operating life

One-line takeaway

Electricity generation creates a **large, recurring revenue exposure**, opening the door to **long-dated power hedging and structured solutions**.

🟦 SLIDE 11 — Maintenance & OPEX Phase

Recurring Commodity Exposure Over Plant Lifetime

(EPR – Flamanville reference | Order of magnitude)

Scope (operations & maintenance)

- Routine and heavy maintenance
- Replacement of mechanical & electrical components
- Fuel reload cycles
- On-site logistics and services
- Auxiliary power consumption

👉 Phase **moins visible**, mais **très intéressante commercialement** car **récurrente et prévisible**.

Commodity exposure principle

*Unlike construction CAPEX, OPEX exposures are **recurring**, creating opportunities for rolling and long-term hedging strategies.*

Methodology (how figures are derived)

1. Identify **annual maintenance drivers**
2. Translate maintenance activities into **material consumption per year**
3. Convert into **annual € exposure**
4. Extrapolate over plant lifetime

Indicative annual OPEX commodity exposure

Commodity (proxy-hedgeable)	Annual quantity (indicative)	Use case	Indicative price	Annual exposure (€)
Steel & alloys	**~3,000 – 5,000 t / year**	Replacement parts, piping sections	**~€1,200/t**	**~€4 – 6m**
Copper	**~300 – 500 t / year**	Electrical maintenance,	**~€8,500/t**	**~€2.5 – 4m**

Nickel (embedded in	**~80 – 120 t / year**	Corrosion-resistant	**~€17,000/**	**~€1.5 – 2m**
Uranium (reload	**~20 – 25 t U_3O_8**	Fuel replacement	**~€70/kg**	**~€1.4 – 1.8m**
Diesel & fuels	**~3 – 5m liters / year**	Backup generators,	**~€1.60/L**	**~€5 – 8m**
Electricity	**Indirect**	Pumps, cooling,	—	—

✅ **Total recurring OPEX commodity exposure: ~€15m – €25m per year**

Lifetime perspective

- Operating life: **40–60 years**
- Cumulative OPEX commodity exposure:
  👉 **€600m – €1.2bn** (undiscounted, illustrative)

Hedging & structuring logic

- Rolling hedges on:
  - Metals (Cu, Ni, steel proxies)
  - Energy (diesel, power)
- Long-term fuel supply contracts
- Potential for:
  - Multi-year frameworks
  - Index-linked pricing
  - Portfolio-level hedging (fleet of reactors)

One-line takeaway

Maintenance transforms nuclear assets into **long-duration, repeatable commodity clients**, well-suited for structured and rolling hedging solutions.

🟦 Option alternative — Actor-based segmentation (how to do it)

1️⃣ Project owner / architect-engineer

- **EDF**
- Porte :
    - vision globale
    - planning
    - parfois une partie du risque long terme (fuel, power)

👉 **Exposition** : uranium, power prices
👉 **Hedging** : long-term, strategic

2️⃣ Civil works contractors

- **Bouygues Construction**
- **VINCI Construction**
- **Eiffage Génie Civil**

👉 **Exposition directe** :

- acier
- ciment
- diesel

👉 **Très bons clients hedging** (volumes élevés, marges sensibles)

3️⃣ Electrical & cabling manufacturers

- **Nexans**
- **Prysmian Group**

👉 **Exposition** :

- cuivre
- aluminium
- énergie

👉 **Hedging clair et liquide**

4️⃣ Mechanical & turbine suppliers

- **Arabelle Solutions**
- **Siemens Energy**
- **Ansaldo Energia**

👉 **Exposition** :

- acier forgé
- cuivre
- alliages

5️⃣ Nuclear engineering & fuel

- **Framatome**
- **Westinghouse**

👉 **Exposition** :

- inox
- nickel
- uranium (partiel)

👉 **Hedging plus stratégique**