Final report

LOCALISATION PERSPECTIVES OF A NETHERLANDS NUCLEAR NEWBUILD PROJECT

NRG PALLAS
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Cover photo

Installation of the reactor pressure vessel at Hinkley Point C unit 1 on 3 December 2024.
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Executive summary

Topic	1. Objectives and approach

Summary	**This study provides estimates of the potential NL shares of the foreseen large twin PWR unit nuclear new build project in the Netherlands (NNB-NL project).**
	• The potential NL shares are also affected by opportunities presented by future export opportunities and by opportunities for providing services to a future NL nuclear installed base, leading to the following research questions:
	  ○ What are the positions of the NL industry in the domestic & international nuclear supply markets and how could these change in the near future?
	  ○ To what extent could the current and possible capabilities of the NL industry meet the requirements of the NL nuclear new build project?

	The approach to estimate NL shares followed similar endeavours in other European countries, with key elements: • Breakdown of the project cost and scope of supply into EPC and Owner scopes and further (e.g. plant equipment, construction), resulting in a project cost breakdown model. • Assessment of the capabilities of the NL supply industry versus requirements, informed by industry consultations, review of company information and literature. • Assessment of the extent to which the NL industry would be capable to deliver the goods, resulting in an estimate of the NL share. • Two indicative scenario's were examined, one based on current NL supply chain capabilities (A) and one based on potential capabilities (B). **and in addition** • Comparison with the UK industry share estimates of UK NNB projects. • Reviews by external experts.
	NL share is defined as referring to scope of supply involving companies located in the NL, including branches of foreign companies, • which would contribute to achieving national localization objectives e.g. technology transfer; establishing a national industrial knowledge base.
	It proved necessary to adopt a reference technology and reference site for the project. • Determining national share requires items of the scope to be identified and their technical properties and requirements to be defined. • The present study did not allow to address differences between the potential sites and three technologies involved in the Technical Feasibility Study (TFS). **The UK EPR and Borssele were chosen respectively as reference technology and reference site.** • Of the three technologies, most information was available for the UK EPR. The Borssele site was chosen on similar grounds.

Topic	2. Position of the NL industry in the nuclear supply chain

Summary

The nuclear construction project supply chain is characterized by a tiered structure hierarchy, with Tier 1 at the highest level, down to Tier 4 and below

- The tier levels relate to the scope of supply for which a company can accept the responsibilities, risks and liabilities.
- The level a particular company holds in this hierarchy is determined by its experience with nuclear construction projects, capabilities, size and riskabsorbing ability, as perceived by in particular vendors and owners.
- Typical Tier 1 contracts include the complete Nuclear Steam Supply System plus auxiliaries and control systems; the turbine-generator set; and individual work packages for civil engineering and construction.

There are no NL companies that qualify as Tier 1 or 2 NPP equipment supplier, but some approach qualification as Tier 1 or 2 supplier for parts of the civil works

- The NL industry has a minor position as supplier of nuclear equipment and conventional power generation equipment in both the domestic and global nuclear markets.
- Specific parts of civil works for an NNB project abroad were supplied by the local subsidiary of an NL company.
- Some NL companies are currently supplying non-nuclear components to NPPs in the NL and abroad, such as pumps and valves.

The expected increase in nuclear construction demand in the European market may give rise to only limited export opportunities to the NL industry

- The established nuclear equipment supply chain is likely able to largely accommodate the increase in demand, in particular for special nuclear equipment and turbine-generator sets.
- Export opportunities for the NL industry may arise for specific non-classified groups of components, such as valves, pipes and cables.
- Civil engineering and construction works is seen as the main export opportunity.
- Urenco NL is an established global supplier of enrichment services.

Future operating NL NPPs do not offer a basis for a viable NL nuclear MRO services and/or nuclear equipment industry, but opportunities for NL companies for providing other reactor services are likely

- Maintenance Repair and Overhaul (MRO) services of main equipment of future operating NL NPPs are unlikely to be contracted to the new entrant NL companies.
- Urenco NL is well qualified for providing enrichment services to future operational NL NPPs. This also holds e.g. for in service inspection services

Topic	3. New build project cost breakdown model

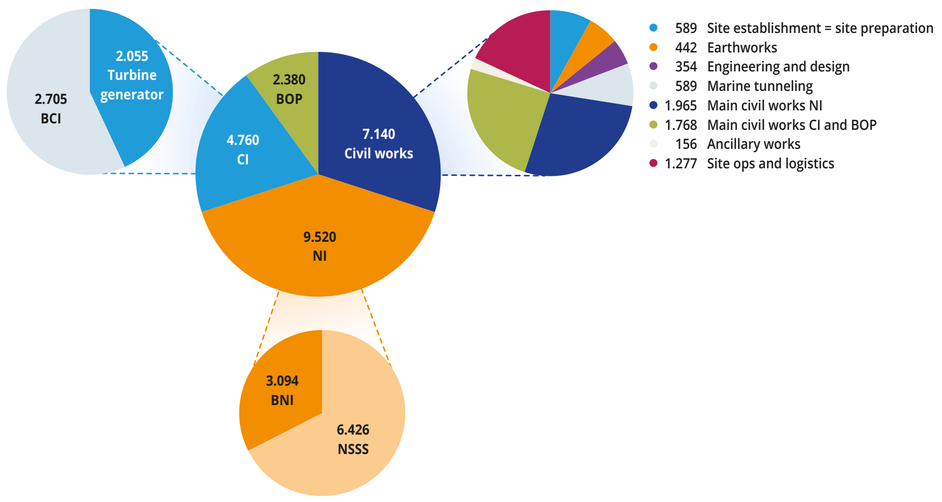
Summary

The study required a project cost/cost-breakdown model for various reasons.

- Local share estimates require assessing national industry capabilities versus technical requirements of individual procurement packages, and their values.
- Procurement packages values will be based on disclosed contract values of Tier 1 packages, and on cost balances derived from a total project value. Hence applied contract values should be consistent with this total project value.

The EPC costs adopted in the present study amount to 23,8 bn EUR.

- The project cost was split into EPC cost and Owner cost.
- The EPC cost estimate corresponds to the EPC cost estimate for Sizewell C (SZC), which is the most recent, relevant, disclosed data.
- The corresponding total project cost is consistent with recent OCC data from the OECD and others in Europe/USA.
- The adopted EPC cost is coupled to the capacity power of the EPR and leads to upper bounds on estimated NL share values. These are translated to lower bounds by multiplication with the AP1000/EPR capacity power ratio.
- The EPC cost breakdown is based on Vendor cost breakdown data, disclosed contract data for Hinkley Point C (HPC), cost estimates for SZC and equipment/labour cost split reported by the OECD and others.



The adopted Owner costs amount to 580 m EUR.

- The adopted Owner scope is based on the TFS and international NNB practice.
- The corresponding Owner cost includes only uncontroversial activities, for which sufficiently reliable lower bound cost estimates were available.

Localization introduces benefits and risks for the Owner and Vendor.

- Localisation may provide those benefits due to competitive local procurement.
- Technology vendors and the Owner face several additional risks with localisation. A less productive and capable local industry may put the project's budget and schedule at risk.

The potential NL share addressed in this report refers to the share for which the NL industry's capabilities match the project requirements or could do so with the investments as indicated.

Topic	4. Civil works
Summary	**Civil works comprise 30% of the EPC value (7 bn EUR). Following the SZC plan, the scope was split into 8 work packages. These can be arranged into 3 equally-valued groups of increasing degree of "nuclear"-content.**

I. Site establishment; main earthworks; construction of the ancillary buildings; site operations and logistics.

- In appearance mainly regular civil construction work and site logistics.
- The high standards for nuclear construction translate into high requirements on work quality and use of advanced methods e.g. for soil improvement.

The NL industry would be capable of suppling considerable parts of the works, at an estimated share of 80-85%.

- The Tier 1 supplier will need recent NNB project experience. NL companies have to form joint ventures with foreign companies.
- Special equipment is to be used and upskilling of workforce needed.
- The unusually large scale of operations and various aspects (soil improvement, deep excavation, piling) classify the works as high-end/high-risk, requiring participation of experienced foreign companies.

II. Construction of the conventional island and BOP; Marine and Tunnelling.

- Involves large-scale civil works such as construction of the turbine building, transformer buildings, pumphouse, subterranean cooling water inlet and outfall systems and cooling pipes under the seabed.
- Several main buildings are nuclear seismic classified.

Various NL companies are capable of suppling major parts of the scope. Several factors limit the NL share to 60-75%:

- The scale and demands of the works. For similar projects, NL companies tend to form joint ventures e.g. for access to technology and risk-sharing, with foreign companies, reducing potential NL share.
- The Vendor will require recent experience with nuclear new build works, thus necessitating forming joint ventures with foreign companies;

III. Engineering and design; construction of the nuclear island (NI).

- Engineering mainly involves adaptation of the reactor building and other nuclear buildings to local soil conditions and seismic hazards.
- The Reactor Building is highly complex, both interior (e.g. reactor pool) and exterior (steel lined, double concrete shell dome structure).
- Quality standards for all 10-15 buildings are very demanding e.g. concerning concrete composition and pouring, quality of welding.

The NL industry is capable of delivering sizeable parts of the work, but lacks crucial qualifications. NL share is estimated at 50-70%.

- Extensive experience of engineering and design work of NI buildings is required, such as for the reactor cavity, which NL companies do not have.
- The responsible contractor should have a proven track record of meeting the stringent construction quality standards.
- NL companies will need significant upskilling in e.g. in nuclear safety, quality assurance, concrete techniques, welding and digital techniques.

Topic	5. Nuclear Island
Summary	**The Nuclear Island (NI) concerns equipment supply and on-site installation. It is split into the Nuclear Steam Supply System (NSSS) (6,4 bn EUR) and Balance of Nuclear Island (BNI) (3,1 bn EUR).**

NSSS

NSSS equipment includes heavy critical reactor components requiring highly specialized manufacturing facilities and certification to nuclear standards and installation by experts.

- The NSSS encompasses the Reactor Pressure Vessel, pressurizer, steam generators, main coolant pumps and interconnecting piping, several I&C systems (e.g. the reactor protection system), HVAC systems, the first fuel load and equipment such as polar cranes.
- The manufacture of the heavy components needs specialized large manufacturing facilities, critical controlled metallurgical processes and costly and lengthily certification to nuclear standards.
- Installation of the majority of NSSS equipment requires thorough and prolonged training and extensive (nuclear) experience.

The NL share is limited to providing various services, resulting in a modest potential NL share of 6-10%:

- The NL currently has no NSSS equipment or I&C manufacturing capability.
- Building up capabilities would require large investments in facilities and certification, whereas sufficient established suppliers exist in the market.
- The NL would be well capable of supplying enrichment services for the first fuel and some specific equipment and support for on-site installation
- On site installation requires various support services such as in service inspection of welds, scaffolding and craning and lifting which the NL industry can deliver.

BNI

BNI equipment entails all equipment of the Nuclear Island other than the NSSS, and comprises nuclear safety-related as well as non-safety-related equipment.

- Safety related systems include diesel generators and UPS, fuel handling systems, radioactive waste processing facilities, control rooms and support facilities.
- In addition, considerable volumes of piping, valves, pumps and cables are needed, denoted as large-volume components.
- Design, manufacturing and installation of most BNI equipment requires management systems aligned to nuclear standards. A minor fraction of BNI large-volume components will be to industrial standards.

NL companies may supply part of the BNI equipment, including some of the safety-related components, and support for on-site installation, resulting in an estimated 30-50% NL share.

- The NL has capability for manufacturing specific BNI safety-related systems such as the polar crane.
- NL companies could deliver part of BNI systems such as the ventilation stack, waste storage facilities and the hot workshop and a significant part of the non-safety related BNI large-volume components.

Topic	6. Conventional Island
Summary	**The Conventional Island (CI) encompasses equipment supply and installation and is split into the Turbine-Generator set (2 bn EUR) and the Balance of Conventional Island (BCI) (2,7 bn EUR).**
	Turbine-generator set
	The turbine-generator set is an integrated package consisting of • The steam turbine, the generator, the deaerator, moisture separator reheater, the condenser, and the shaft line control system. • The electrical power per reactor unit is to be delivered through a single set. Hence the power output of the machine is very large.
	Only a few companies in the world are capable of supplying the Turbine-Generator for large PWRs: • The work encompasses supply of the equipment as one integrated package. • Manufacturing of the turbines require highly specialized and large manufacturing facilities and mastering of specialist metallurgical technologies. • The deaerator and the moisture separator/reheater are large pressure vessels. The main condensers are to be delivered as fully tubed modules and house the first two stages of low pressure heaters • On site installation poses high risks and is usually done by technicians of the equipment supplier.
	The potential NL share is limited to providing workforce and services in support of on-site installation, and is estimated as 3% or less. • There are presently no credible NL manufacturers of turbine generator packages for PWRs. NL companies may qualify for providing workforce support for on-site installation, heavy lifting, scaffolding and inspection.
	BCI
	BCI equipment is functionally largely similar to that of conventional power stations, but some is nuclear safety or seismic classified. • The equipment includes major systems such as feedwater pumps and main steam and feedwater pipes, unit and auxiliary transformers and generator circuit breaker and connections. Some mechanical components are of the highest seismic category and/or nuclear safety category. • In addition the BCI includes multiple electrical, instrumental and I&C equipment such as switchboards, sensors, actuators, and marshalling cabinets; and large-volume components such as pipes, pumps, valves and cables, which is partly safety classified.
	NL companies are capable of supplying a significant part of the BCI scope, with an estimate share of 25-40% of equipment supply and 30-50% of on-site installation. • The NL industry is capable of providing several major parts e.g. feedwater pumps, non-classified electrical, instrumental and I&C equipment and large volume components, but not the safety or seismic classified mechanical equipment. • NL companies are not qualified as Tier 1 supplier for larger BCI Mechanical, Electric or HVAC equipment supply and installation contracts.

Topic	7. Balance of Plant

Summary	**The Balance of Plant (BOP) scope broadly represents the standard scope of the BOP for an EPR (2,4 bn EUR).**
	• There is no uniform definition of the Balance of Plant. For consistency, the EPR BOP definition was applied.
	• The applied scope and specifications are based on disclosed information from HPC and SZC.
	• The thus defined scope of the BOP entails the equipment and installation of four groups of facilities:
	  ○ cooling water infrastructure;
	  ○ fuel and water management facilities;
	  ○ ancillary plant and storage facilities; and
	  ○ offices/access facilities.
	• Offices/access facilities are largely part of the Owner scope as per TFS.

	BOP equipment and its on-site installation are largely the same as for other highly regulated industries. It is generally considered as one of the first parts of the scope suitable for localization. • The cooling water equipment infrastructure encompasses the equipment housed in the pumphouse, feedwater intake station, outfall pond, and the fire-fighting water distribution building and supply channels. • This equipment is not different from similar equipment for conventional thermal power plants, but the capacities and dimensions of equipment are larger. • The fuel and waste management facilities serve for interim storage and management of received fresh fuel, spent fuel and low level waste before shipment to national waste storage. This equipment is similar to equipment at the COVRA facilities. • The major part of storage and handling equipment of the type will be to EN (NEN) standards and only some to nuclear code requirements. • The majority of the mechanical, electrical and HVAC installation work will involve typical building services installations.
	Multiple NL companies are capable of suppling the major part of the BOP equipment and its on-site installation. • NL companies are capable of providing the major part of the cooling water infrastructure. This includes the large cooling water pumps (CVC pumps). • The equipment for the fuel and waste management facilities is similar to equipment at the COVRA facilities supplied by NL companies. **The NL potential share of the BOP scope supply is estimated as 73-83%.**

Topic	8. Owner Scope
Summary	**The adopted Owner Scope and associated costs of 600 m EUR are likely lower bounds on their actual values.**

The applied Owner Scope is strictly based on currently available information from the TFS . It is restricted to Owner's costs and activities which were judged as "certain", based on the TFS and international NNB practice and experience.

Specifically, the following Owner scope activities, were not considered for the indicated reasons:

- Site preparation works. Uncertain scope of likely limited size and costs.
- Site characterization. These concern additional works, of which the cost could be considerable, but with yet unknown scope and costs.

The assumed Owner scope entails specialist nuclear services for licensing support and for providing the Owner's Engineer

- Support for obtaining the site, construction and the operations licenses will involve technical work and legal support. This requires in-depth knowledge of the NL legal and regulatory context and of Gen-III PWR technology and recent experience with licensing of NNB projects.
- The Owner's Engineer entails providing support in a number of specialist areas such as development of Bid Invitation Specification, Constructability Review and Technical Integration. It requires expertise in a multiplicity of nuclear engineering disciplines.

... and regular, non-nuclear building construction and connection to the national HV grid works.

- Construction of the >10 non-technology-related buildings which are part of the Owner scope involves regular higher-end building engineering, construction and office infrastructure.
- Grid connection requires regular EPCM, civil construction and equipment manufacturing and installation capabilities for HV grid works.

The NL industry is capable of supplying significant parts of the licensing support and Owner's Engineer, but will need to form joint ventures with foreign companies to do so

- Several major NL companies are capable of preparing the site license.
- Only a few NL companies have the required expertise for delivering support to obtaining the construction and operation licenses and for providing the Owner's Engineer. These need to form joint ventures with companies from elsewhere for recent experience with licensing for NNB projects and the complement of nuclear engineering disciplines.

... and has the capabilities for providing the major part of the building construction and HV transmission network works.

- Many NL civil engineering and construction companies are capable of performing the building construction work.

The HV transmission network works could be readily included in ongoing transmission network extension contracts with NL companies.

resulting in an estimated NL share of 62-75%.

Topic	9. Summary and recommendations
Summary	**Despite limited capability in some areas of the supply chain, the NL could deliver 33% of project value, rising to around 43% if barriers were removed.**

- The project scope was split into various, commonly used, areas of project activity.
- Estimates for each area were informed by consultations with industry experts and NRG's in-house knowledge of the nuclear supply chain.

Activity	Value	Scenario A share (value)	Scenario B share (value)
Civil works	7,1	61 (4,4)	75 (5,3)
Nuclear Island	9,5	8 (0,8)	15 (1,4)
Conventional Island	4,8	16 (0,75)	26 (1,2)
Balance of Plant	2,4	73 (1,7)	83 (2,0)
Owner's scope	0,6	62 (0,4)	75 (0,4)
Totals	24,4	33 (8,0)	43 (10,4)

(shares in %; values in bn EUR)

The potential values of 8 - 10 bn EUR represent upper bounds.

- The above potential localization values refer to the capacity power of 1.650 MWe of the EPR, the highest of the three technologies involved in the TFS.
- Lower bound potential shares corresponding to the lowest capacity power of 1.100 MWe of the AP1000 amount to 5,3 to 6,9 bn EUR.

The results of the study were subjected to a process of review by industry experts.

- The results were reviewed by external specialists with practical expertise in relevant areas, including building up the supply chain of a NNB project. As such they are based on industry views and independently quality assured by experts.
- However, there will still be some margin of error and uncertainty and as a result the estimates should be viewed as indicative.

The potential scope for the NL industry to deliver a significant share of the foreseen NNB-NL project will not be realized without proper additional actions.

A first engagement with vendors, NL industry and stakeholders involved in recent NNB projects elsewhere, provided indications of what are considered to be the key issues to be addressed to achieve the potential share of the NL nuclear supply chain. These issues concern four main areas:

- Market access, concerning barriers to entry and access to the project supply chain;
- Fit for nuclear, concerning safety culture and management system issues and company processes in particular concerning bidding for nuclear projects;
- Technical skills and training, referring to technical skills for manufacturing but in particular for on-site installation;
- Establishment of an NL suppliers list.

1 Objectives and approach

This study quantifies the potential share of the NL industry in a future nuclear new build project in the Netherlands and the potential impact associated with developing the capabilities of the NL nuclear supply chain.

The study is focussed on the Nuclear New-Build project launched by the NL government comprising a twin-large PWR unit Nuclear Power Plant in the Netherlands at a location yet to be defined (Nuclear New Build - Netherlands, in short NNB-NL). Developments of this scale could present significant opportunities to the NL nuclear sector from which the NL supply industry can benefit.

The study takes place against the backdrop of the increased interest of the NL government in nuclear power as part of the NL's future energy mix, as expressed by the intent of the current cabinet for realizing a second twin-large unit nuclear power plant and by explorative studies into Small Modular Reactors by various provincial administrations.

OBJECTIVES

The primary objective of this study is to provide estimates of the NL share of the planned NNB-NL project, as currently the most tangible nuclear new build project within the NL.

The opportunities presented by the NNB-NL project cannot be seen apart from the wider context of the growth of nuclear generating capacity in the coming decades elsewhere, as foreseen by the IEA. This may provide export opportunities to NL supply companies which could affect their decision to invest in the nuclear market. In this context, additional opportunities for the NL industry to provide reactor services to a future NL nuclear installed base are important. This leads to addressing the following research questions in this study:

- What is the position of the NL industry in the domestic and international nuclear equipment and services supply markets and how could this change due to the foreseen global increase in construction demand?
- To what extent could the current and potential capabilities of the NL industry meet the requirements of the nuclear new build industry in a competitive way and what are potential development areas?
- What could be the current and potential levels of NL share of the NNB-NL project value, taking the above into account?

APPROACH AND METHODS

The approach adopted for quantifying the potential share of the NL industry is informed by methods of similar endeavours in other European countries, e.g. in the UK[1], Poland[2], the Czech Republic[3] and Italy[4]. The key elements of the adopted approach – to be detailed in subsequent chapters – are:

- A breakdown of the project cost and scope of supply into Vendor (Engineering, Procurement & Construction or EPC) scope and Owner scope. Each breakdown is then split by component or activity group (e.g. plant equipment, construction) and includes technical and other requirements. This results in a final project cost breakdown model.
- An assessment of the capabilities of the NL supply industry concerning the above mentioned requirements. This assessment uses industry consultation, a review of company provided information and relevant literature to determine capability.
- Based on the above, an assessment of the extent to which the NL industry would be capable to deliver the goods at the required specifications, resulting in an estimate of the share of the NL industry in the value of the goods including:
  - Whether the NL has existing capability to deliver in each of the packages.
  - Whether the NL has the potential to expand capabilities to meet requirements.
  - Competitiveness of NL companies against global supply chain.
  - Identification of the barriers to expanding capacity and capability.

  Two indicative scenarios around the NL's supply chains share of the new build activity were examined, one based on current NL supply chain capabilities (Scenario A) and one based on views about the potential for the NL to increase its share due to actions taken by organisations involved or with an interest in the NNB-NL project (Scenario B).
- An appreciation of the reasonableness of the obtained estimates from comparison with the UK industry share estimates in UK NNB projects (see footnote 1), based on an appreciation of the capabilities of the NL industry in comparison to those of the UK industry[5].

Both approach and results were subjected to a process of reviews by external experts who are knowledgeable in relevant areas including equipment of nuclear power plants, international nuclear construction project supply chain management, and the NL supply industry.

The views of consultees and in-house experts were informative in deriving the necessary set of estimation assumptions. It is acknowledged that the estimate ranges expressed in this report represent one view of potential NL activity. It is no more or less valid than other views which various industry groups may hold. It is also recognized that government and industry may set out voluntary ambitions or targets similar to those set in the UK. In doing so, the subsequent value captured by the NL supply industry could differ somewhat from the ranges of results presented within this report.

1 Oxford Economics/Atkins 2013, The economic benefit of improving the UK's nuclear supply chain capabilities; Oxford Economics 2023, The economic impact of the civil nuclear industry.
The 2013 Oxford Economics/Atkins report is to our knowledge the only published estimate based on a breakdown of the scope of an NPP construction project into equipment and activity groups, including their values, comparable to the present study. Concerning the capabilities of the UK supply industry, the OE/Atkins report is primarily based on the NIA reports "The UK Capability to Deliver a New Nuclear Build Programme" (2006) and "The Essential Guide to the new build nuclear supply chain" (2011). Also the successor reports of these were consulted in the present report (see footnote 5).

2 Ministry of Climate and Environment, Republic of Poland, Polish Industry for Nuclear Energy, Edition 2021.

3 Ministry of Industry and Trade, Possibilities of involvement of the Czech industry in upcoming NNS projects in the CR and other countries in individual projects, maintenance of professional background of suppliers from the CR for the construction of NNS and future service 2015; Ministry of Industry and Trade of the Czech Republic, Ministry of Finance of the Czech Republic, 22 May 2015, National Action Plan for the Development of the Nuclear Energy Sector in the Czech Republic.

4 NEA and IEA 2015, Technology Roadmap, Annex: Nuclear Energy Case Studies, Case study 16: Preparing for a new build programme in an industrial country: supply chain survey.

5 NIA 2012, Capability of the UK new build supply chain; NIA 2019, The essential guide for the nuclear new build supply chain.

It should be noted that the actual accessible NL shares in the project's work packages will also be determined by other factors than those addressed above. These are in particular the selected Vendor's assessment of the NL industry capabilities and its appreciation of the risks of localisation to project cost and schedule. Also of importance is the appetite of the NL industry for participation in the project, which includes its appreciation of the project's opportunities versus alternative opportunities which is affected by required upfront investments and long-term certification obligations among others.

Therefore the primary purpose of the subsequent analysis was to demonstrate, under a range of assumptions, the potential magnitude of value that could accrue to the NL supply industry from the NNB-NL project. Notwithstanding the inherent uncertainty in analyses of this type, the clear and transparent assumptions employed in this study enabled such an assessment to be made. The results of this analysis should be viewed as illustrative of a range of possible outcomes and dependent on a number of assumptions.

Definition of NL share

There is no straightforward way to define what should be understood by NL industry and what in that context should be understood by NL content and NL share, due to such developments as merging of NL companies into large globally operating, often foreign owned, conglomerates and offshoring of parts of the product value chain. What should be understood by national content in a project is usually seen in close relation to the objectives of localisation. The objectives which governments usually aim to achieve with localisation are[6]:

1. Technology transfer for securing technological advancements, reducing cost and improving productivity.
2. Increasing local sourcing for establishing a national industrial knowledge base and stimulating innovation through access to goods and materials.
3. Expanding local presence and ownership for enabling local companies to focus on developing best practice competencies and competitive advantages.
4. Developing local workforce for upskilling of the local workforce in technology and engineering and into managerial positions.

These objectives are closely related to the domestic industrial skills and knowledge base in the technology areas concerned that are perceived to be commensurate with national aspirations and associated interests.

The above objectives can also be discerned in the Meerjarig Missiegedreven Innovatieprogramma Kernenergie (Multiannual Mission-driven Innovation programme Nuclear energy)[7] initiated by the NL government for strengthening the national nuclear skills and knowledge infrastructure with a view to the foreseen growth of nuclear generating capacity in the Netherlands.

The above considerations led to define NL content in this report as referring to scope of supply provided by or through or involving companies located in the NL, including branches or subsidiaries of foreign companies, in a way which would contribute to achieving the above mentioned objectives.

6 See e.g. Arthur D. Little 2021, Finding the true north for local content definition in the nuclear industry; PWC 2020, Local Value Creation.

7 MMIP Kernenergie in een CO_2-vrije energievoorziening in 2050; Appendix to "Kamerbrief betreffende voortgang ontwikkeling nucleaire kennis- en innovatiestructuur" of the Minister of Economische Zaken en Klimaat, 20 December 2023. The Education and Training domain of the TNO - NRG Pallas 2024 research programme is embedded within the framework of the MMIP.

Foreseen newbuild project in the Netherlands

The development of the Nuclear New-Build Project in the Netherlands concerns construction of a twin-PWR unit NPP at a location yet to be defined. As of today, the main characteristics are as follows[8]:

- Commercial Operation Target Date: 2035 (1st unit);
- Technology: PWR state of the art Gen-III[9];
- Net Power: 1.000 MWe to 1.650 MWe (or above) per unit;
- Location: currently under investigation as part of the project development phase;
- Client: the current client, the Ministry of Climate Policy and Green Growth (further KGG[10]) is creating a Special Purpose Company which will take over the project development from 2024 on (hereafter also referred to as "the Owner");
- The Scope of Work is expected to be on an EPC turnkey basis.

The NL government has invited EDF (European variant of the EPR, 1.600 MWe), KHNP (APR1400 variant adapted to European requirements, 1.350 MWe) and Westinghouse (AP1000, 1.100 MWe) to participate in a (paid) Technical Feasibility Study (TFS). The TFS serves to obtain an early idea of the way the vendors foresee the project and to clarify the economic and technical feasibility of the NNB-NL project. The TFS is based on construction at a well-defined site in Borssele near the existing Borssele NPP. Results from the TFS are foreseen to be used in the Bid Invitation Specification (BIS).

As stated in the TFS, it is foreseen that the Vendor will deliver the NNB-NL project as a turnkey (EPC) project, i.e. the Vendor is overall responsible for engineering, procurement and construction. Part of the civil works will be carried out by the Owner before transfer of the construction site to the Vendor (see section 3.4 for the complete Owner's scope).

Reference plant design

The approach adopted for estimating the NL share requires that the various groups of items of equipment, components and on-site labour can be identified and that their technical properties and requirements can be sufficiently defined. Only on the basis of that information, would it be possible to assess to what extent the NL industry would be capable of delivering these supply packages. In order to translate these capability results into a share of total project expenditure, it is in addition necessary to have values of individual supply packages.

Although the three plant designs included in the TFS all concern PWR technology, there are differences between them. It was not possible to accommodate these differences within the present study. Hence it was decided to adopt a reference technology for the current study.

Of the three technologies involved in the TFS, by far most information was available for the UK EPR, currently under construction as Hinkley Point C (HPC) and foreseen for Sizewell C (SZC). For HPC and SZC, both technical descriptions of several procurement packages as well as contract values have been disclosed. For this reason, the UK EPR was used as the reference plant for the present study.

8 Ministry of Economic Affairs and Climate Policy/Assystem, Technical feasibility study scope of work & deliverables, Document Number AEOS-FEET-EZK-RE-0001 Rev B.

9 Gen-III in this report is equivalent to Gen3+ as specified in the TFS.

10 Ministerie van Klimaat en Groene Groei, formerly Ministry of Economic Affairs and Climate Policy.

The differences between the three technologies involved in the TFS lie, besides the generated nominal power, mainly with the nuclear island. These differences will not greatly affect the overall obtained NL estimates, as will be shown below. It should be stressed that the above choice for the reference plant merely refers to the purposes of the present study and in no way should be understood as a preference for a certain technology.

Reference construction site

As stated above, a number of potential construction sites are currently under investigation as part of the project development phase, including a site near the existing Borssele NPP. These sites share a number of main features, but also show some differences. These would be mainly of relevance for the civil works parts of the project, but are not expected to have a major effect on the potential NL shares obtained in this study. Whereas it was judged unnecessary to address these differences within the present study, using specific site characteristics would be beneficial to illustrate some of the civil works parts of the project. Hence, as for the technology, it was decided to adopt a reference construction site for the current study. For this the Borssele site was selected, since for this location information relevant for Vendors for construction of the plant was available through the TFS specification, whereas similar information was lacking for the other sites. It must be emphasized that this adoption of the reference site merely refers to the purposes of the present study and by no means should be interpreted as a preference for a certain site.

Features of the Borssele site

The Borssele site currently under consideration as one of the possible construction sites for the NNB-NL project is situated in the Sloegebied industrial area Vlissingen-Oost (see Figure 1) near the existing nuclear power plant Borssele 1 (Kerncentrale Borssele or KCB; see Figure 2) at about 500 metres from the Westerschelde. It is located north of Europaweg-Zuid, west of Europaweg-Oost and railroad track, and east of the Westerschelde[11]. The Sloegebied area is a completely developed industrial area including a road network and offering easy connections to all public utility networks. Besides railroad, a number of harbours such as the Van Cittershaven are available for docking, handling and transport of large plant equipment for the project. Protection of the site from the sea is compliant to the prevailing requirements set by the Rijkswaterstaat[12].

Cooling water will assumedly be taken either from the harbour (Van Cittershaven) or directly from the Westerschelde. Vendors involved in the TFS were asked to propose a cooling system avoiding the usage of a cooling tower.

The site is currently owned by EPZ. The northern areas presently house a solar power plant and two wind turbines.

11 Ministry of Economic Affairs and Climate Policy of the Netherlands, Workstream 2 – site specifics, site information package. https://www.overkernenergie.nl/documenten/publicaties/2023/12/13/document-1-ths

12 Rijkswaterstaat is a Directorate-General of the Ministry of Infrastructure and Water Management of the Netherlands.

Figure 1. The potential Construction Site for the NNB-NL plant in Borssele (see footnote 11).

A:
Construction areas (delineated in orange) and existing buildings including the Borssele NPP (dark grey shaded).

B, C, D:
Cut-outs with the construction areas (orange shaded) respectively nearest to the existing Borssele NPP, the top-left area and the top-right area.

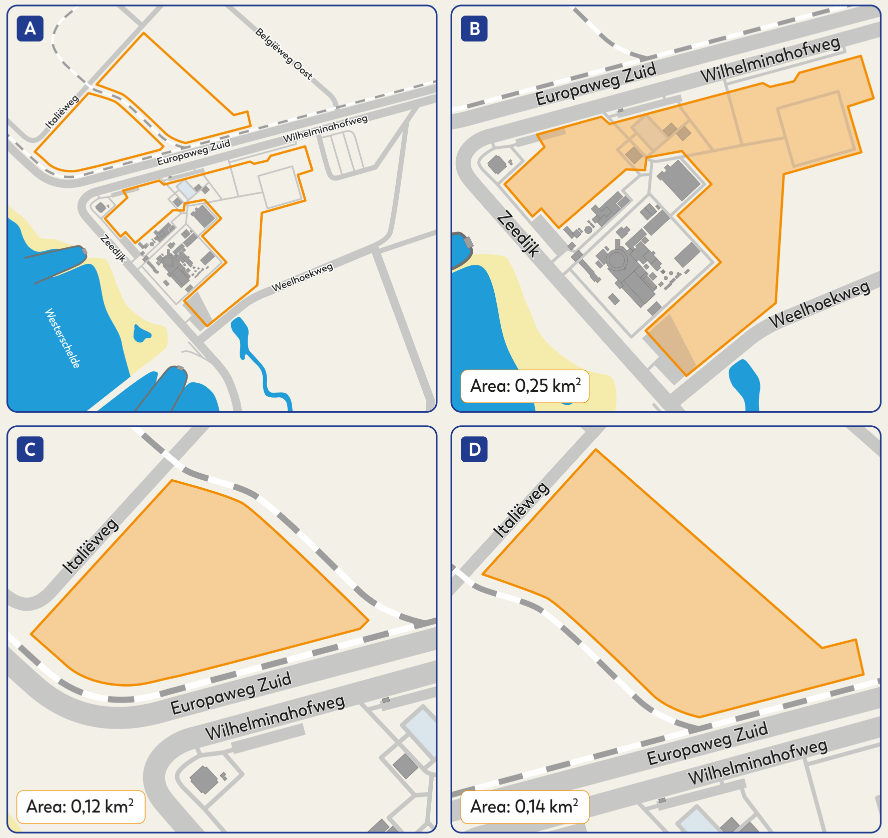


Figure 2. Location of existing NPP (KCB) and artist impression of possible location of two new units. Shown are two EPR units, which have the largest footprint of the three technologies included in the TFS. (Rozendaal, 2023)

2 Position of the NL industry in the nuclear supply chain

This chapter addresses the position of the NL industry in the nuclear supply chain. First, the current position as perceived by domestic customers and the international industry is summarized. Subsequently, export opportunities for the NL supply industry due to the foreseen growth in global and European nuclear construction demand are addressed. These affect the profitability of possible investments required for an aspired share of the national industry in the NNB-NL project. In this respect, opportunities for the NL industry to provide services during the operational phase of new NPPs are also of interest. These will be discussed in the last section of this chapter. But first, the characteristics of the international supply chain for nuclear construction projects will be summarized.

2.1 CHARACTERISTICS OF THE NUCLEAR CONSTRUCTION SUPPLY CHAIN

In this report 'the nuclear supply chain' denotes the supply chain of an NPP new build project. This also encompasses the supply chain of major equipment, such as pipes and other components for steam generators. The new build project supply chain refers to the sourcing, purchase and logistics of all individual equipment, components and services that are needed for the construction of the NPP[13].

The nuclear construction project supply chain is characterized by a tiered structure hierarchy, with levels relating to the scope of supply for which a company can accept the risks and liabilities (see *Figure 3*). The level a particular company holds in this hierarchy is determined by its experience with NPP construction projects, its capabilities, competencies, size and risk-absorbing ability, as perceived by vendors and owners.

Access to the nuclear supply chain is typically concerned with how the Tier 1 and technology vendors set up and manage their supply chains, i.e. Tier 2, 3 and 4 contractors. Both an EPC turnkey contract and a split work package project will have a limited number of Tier 1 suppliers as illustrated in *Figure 4*. Note that the project supply chain necessarily corresponds to the project structure.

The Tier 1 suppliers usually source out part of their scope to subcontractors at Tier 2 level, which in turn may subcontract to Tier 3 suppliers etc. The value of the Tier 1 contracts will amount to several billion Euros, with the value of contracts decreasing for lower tier level contracts. As a consequence, the nuclear project supply chain corresponds to a value chain, in which value is added by subsequent higher tier-suppliers.

13 Note that the nuclear supply chain which is of interest in this report is different from "de nucleaire keten" (the nuclear chain) as described in the 2022 Technopolis report (Technopolis Group, 2022, De arbeidsmarkt in de Nederlandse nucleaire sector, September 2022). This "nucleaire keten" concerns all activities necessary for transforming uranium ore to a material which can be applied for some purpose (the report mentions isotope production) and to handle the residual materials and produced waste streams.

Figure 3. Tier hierarchy of the nuclear new build market supply chain adopted in the early phase of the UK new build programme[14].

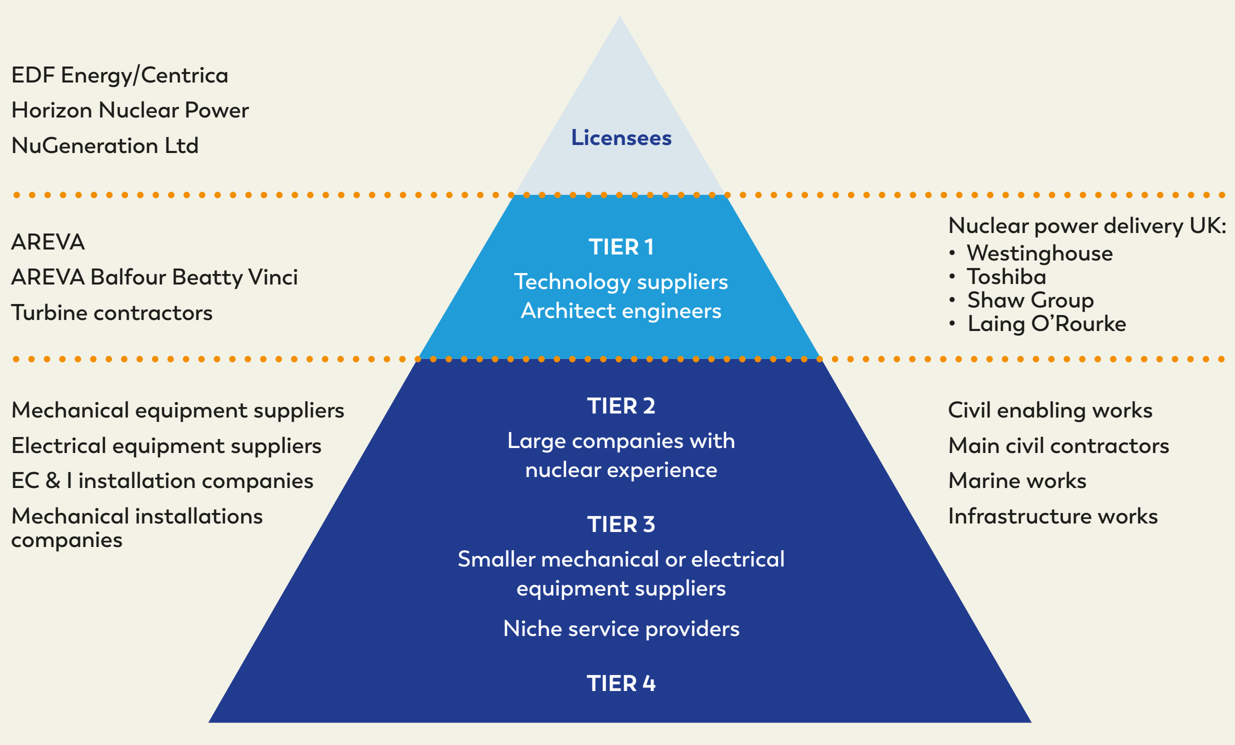
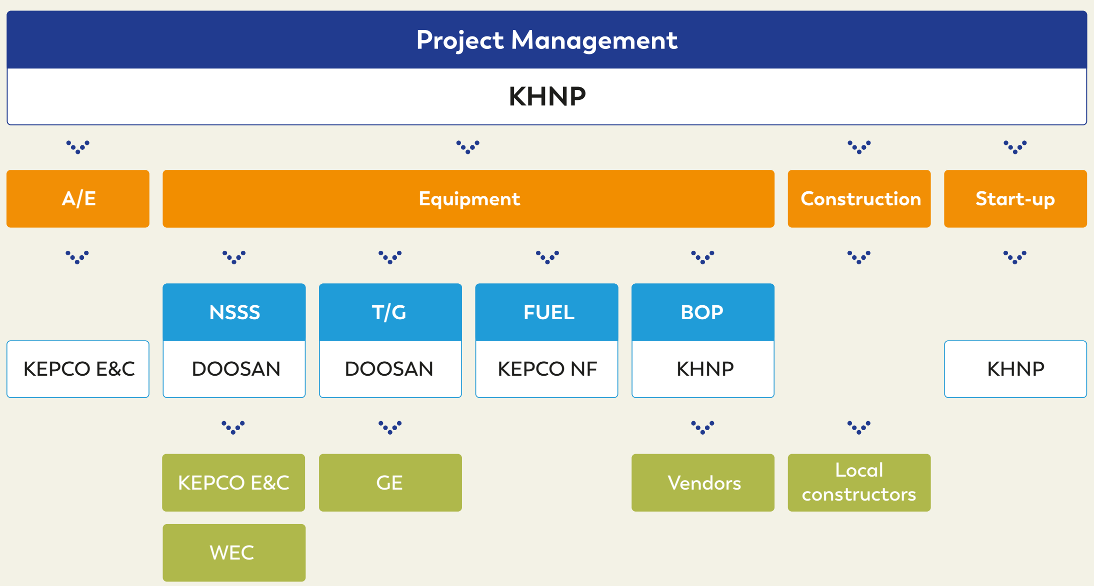


Figure 4. Supply chain of Shin Kori 3,4 construction project (APR1400). (Jong, 2013)

Tier 1 suppliers include KEPCO, Doosan, and KHNP.
Tier 2 suppliers entail Westinghouse Electric Corporation (WEC), General Electric (GE) and a larger number of vendors and local constructors.



14 NIA, 2019, The essential guide for the nuclear newbuild supply chain, stage three, June 2019. https://www.niauk.org/wp-content/uploads/2021/10/NIA_EGuide-2019_web.pdf

The following broad definitions of the tier-levels apply *(see footnote 14)*:

Tier 1: Contractors
Major companies who cover large parts of the scope of equipment supply of the project, have considerable experience in the global nuclear market and have the financial strength to accept the risks and liabilities associated with up to several billion Euros valued contracts. Tier 1 contractors have extensive experience of supply chain management. Nuclear safety culture is firmly embedded in their organisation and their management, safety and quality systems are in place and robust. *Figure 5* shows the profile of Doosan, Tier 1 supplier of Barakah-1 (UAE) and HPC and SZC (UK) projects.

Figure 5. Scope of supply and global manufacturing plants (bottom) of Doosan Enerbility Company[15] *(top).*

15 J. Kim, Doosan Heavy Industries & Construction Co., Ltd., 2018, Supplier Evaluation Program, Nuclear Supply Chain Management Workshop, 5-6 November 2018, NEA. https://www.oecd-nea.org/nsd/workshops/nscm2018/presentations/

Tier 2: Contractors
Large companies who have considerable experience of the nuclear construction market and can accept the risks and liabilities associated with up to several 100 m EUR valued contracts. They usually subcontract some of their activities to Tier 3 and Tier 4 contractors. Like Tier 1 contractors, they fully understand the workings of the nuclear construction industry including Nuclear Safety culture and have robust management, safety and quality systems in place.

Tier 3: Contractors
Larger companies with limited experience of working in the nuclear industry or smaller companies with some experience in the industry. They are not able to accept the larger contracts directly. They are likely to have accreditation to the national and international standards for the management of their business and operate proven QHSE systems. However, all suppliers for safety relevant items must generally have the appropriate nuclear accreditation.

Tier 4: Contractors
Usually smaller companies with little experience in the nuclear industry and thus likely to need support of higher tier contractors to deliver the required quality and safety arrangements. They are unlikely to understand many of the 'flow down' requirements and their staff may need training as to what it means to work in the nuclear industry.

2.2 CURRENT POSITION OF THE NL INDUSTRY IN THE NUCLEAR SUPPLY CHAIN

Position in the domestic market

This section addresses supply of equipment and services provided by the NL industry to the existing NL nuclear facilities. It is informed by consultations with EPZ and other operators of NL nuclear facilities[16]. The position of the national industry in the domestic nuclear equipment and services market is often seen as an indicator of the position of this industry in the nuclear supply chain and its perspectives in domestic construction projects (see e.g. footnote 5).

Supply and installation of equipment
Several NL companies supply specific equipment or components to the Kerncentrale Borssele (KCB). These includes Flowserve, which has a large facility for manufacturing pumps and valves and the European test laboratory for pumps in the NL. However, most nuclear replacement equipment for the KCB has been provided and installed by foreign companies, in particular OEMs (Original Equipment Manufacturers). For some equipment EPZ finds difficulty in sourcing replacement components since these are no longer supported by the OEMs, and is investigating sourcing from other suppliers including NL companies.

16 This review is predominantly based on the view of EPZ. This is motivated by the fact that the scope of equipment supply to the other – non-NPP – NL nuclear facilities is either not relevant for the scope of supply to an NPP new construction project or is only a minor fraction of it. This is due to such circumstances as: process conditions (pressure, temperature, flow rates) and applied materials in power reactors are very different from those in the other installations (including research/isotope production reactors); the Nuclear Safety requirements of the other facilities are considerably lower than for NPPs, reflected in the graded approach for the former; and power plants include equipment such as the turbine generator set which the other facilities do not.

Supply and installation of non-nuclear equipment
This refers to conventional island and BOP equipment, which are largely similar in technology and requirements to those in conventional thermal power plants. The turbine generator set and most other equipment for the latest conventional coal-fired power plants constructed in the NL were supplied by foreign companies, however. EPZ sources components for conventional island equipment of the KCB from OEMs, but is lately also exploring alternative suppliers including NL ones. For equipment specified to codes applied in the oil, petrochemical and pharmaceutical industries such as ASME VIII or ASME B31.3 or EN standards, NL operators also tend to contract NL companies.

Project management and technical support and services
For project management, the NL operators seek specific expertise in the global market, depending on the project at hand. Examples are the owner's engineer contract for the Pallas construction project and the EPCM contract for the replacement of the Reactor Control and Limitation System of the KCB.
For several technical support and services, the operators have established long-term relations with NL companies. Examples of recent contracts concern licensing of the use of MOX and recycled uranium based fuels in the KCB, Long Term Operation of the KCB and In Service Inspections (ISI) of welds of NSSS components for the KCB. It is noted that NL companies also provide ISI services to NPPs abroad (see section 2.4 below).

Civil engineering and construction works
NL companies have recent experience of delivering civil construction works for NL fuel cycle facilities. This includes the extension of the interim HLW storage building of COVRA and the construction of a new production hall for Urenco Nederland N.V. The nuclear concrete works for the Pallas reactor are delivered by Belgian company Besix with significant involvement of their NL branch. The NL has a well developed civil engineering and construction industry, which has some recent experience with preparatory civils works for NNB projects, but is lacking experience with the major construction works for NPPs (nuclear island, turbine island).

Outage services
Maintenance Repair and Overhaul (MRO) is normally done during periodic reactor outages. The MRO services for the KCB are contracted to the OEMs. These activities require a considerable workforce and the OEMs usually source workforce partly from regional subcontractors because of cost reasons. Scaffolding and other rentals are also generally obtained from local suppliers.

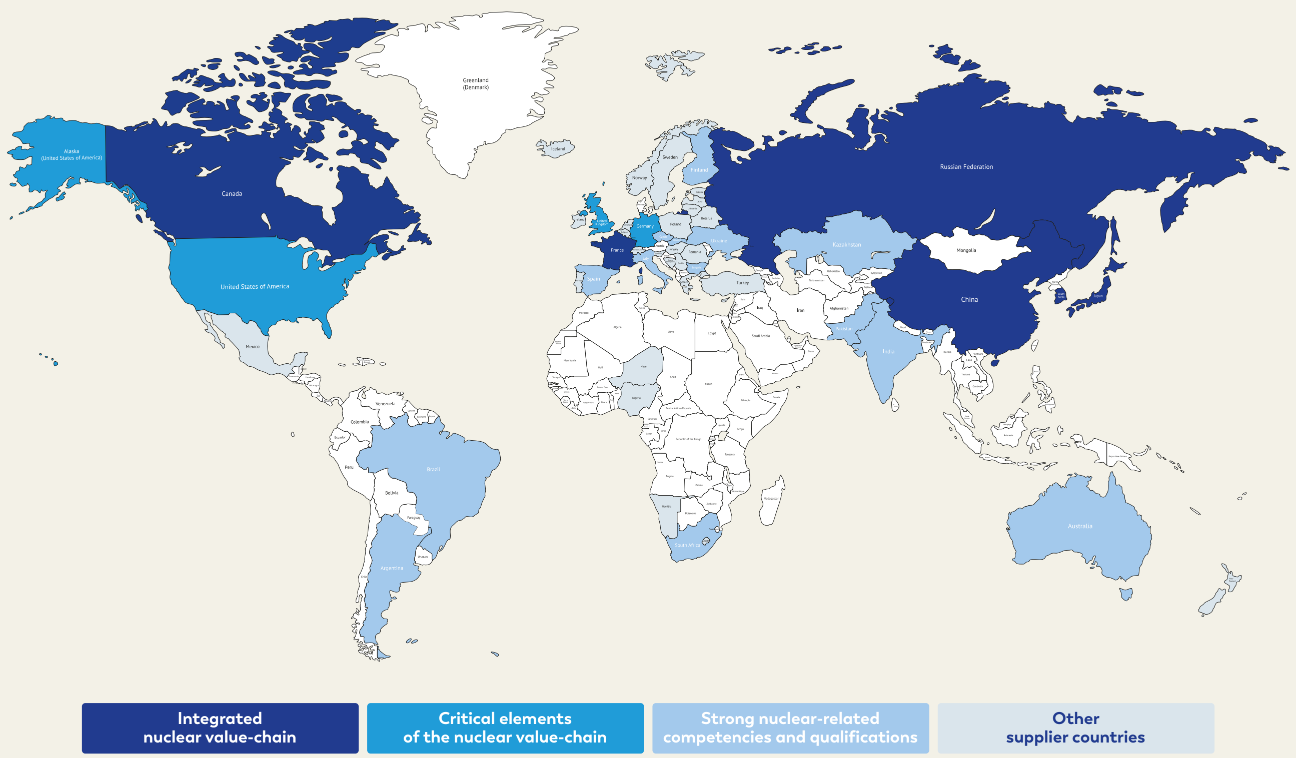
Position in the global market

Nuclear equipment and services
The position of the NL in the global nuclear suppliers market as perceived by the international industry is shown in *Figure 6*[17]. The map illustrates the international playing field for the NL industry in the NNB-NL project supply chain. The NL is positioned on the map as a country in the category "other supplier countries".

The highest ranked category concerns countries with an integrated nuclear-value chain, capable of supplying the entire set of competences for a nuclear construction project. This value chain is provided by globally operating Vendor companies with a complete domestic supply chain for the Nuclear Steam Supply Systems (NSSS), the conventional island, civil construction works and the Architect Engineer role, and which would qualify as Tier 1 suppliers.

17 World Energy Council (WEC) 2019, World Energy Scenarios 2019; the report is based on contributions from the World Nuclear Association and the Paul Scherrer Institute (CH).
https://www.worldenergy.org/assets/downloads/Scenarios_FINAL_for_website.pdf

Figure 6. Global nuclear skills and capabilities map (sourced: WEC); see footnote 17.



At the next level are countries with companies having broad experience, qualifications, and capacity in nuclear energy. These companies serve domestic markets of significant size and also export markets, and would qualify as Tier 1 or Tier 2 suppliers.

The subsequent level encompasses countries with some advanced nuclear value chain elements, such as Argentina, Brazil, Finland, India and Spain, provided by companies serving their domestic markets and to some extent export markets and which would mainly qualify as Tier 3 suppliers.

The NL is placed in the group of some 40 "other supplier countries", which are attributed a variety of non-core nuclear-related competencies and qualifications, spreading across the value chain from engineering, construction, and equipment manufacturing to operation and decommissioning, as well as across the nuclear fuel cycle from uranium mining to spent fuel and radioactive waste management. For the NL, the latter would concern Urenco NL as a global supplier of uranium enrichment services.

It is noted that the assessment does not address that the NL has recognized high level expertise in specific areas such as In Service Inspection (ISI), Long Term Operation and advanced fuel management methods and is an international supplier of services in these areas.

The above picture of the position of the NL industry in the global nuclear supply market is consistent with the relative size of the NL nuclear industry. This industry concerns organisations with activities related to nuclear reactors and includes EPZ, Urenco, NRG (HFR, Pallas), Delft University of Technology (HOR), COVRA and the ANVS and suppliers of reactor equipment and services. It corresponds largely to

the "smalle nucleaire sector" in the Technopolis report[18]. The limitation of the nuclear industry to the "smalle nucleaire sector" is in line with the approach followed in similar studies in other countries on their national nuclear industries. The NL nuclear industry in this sense employs around 1.800 persons according to the Technopolis report. This can be compared to the UK, where more than 64.000 people are directly employed in the civilian nuclear industry, with around 7.500 in operation and maintenance of the current NPP fleet, 18.000 in decommissioning and clean-up, 4.500 in research and development, some 23.000 in the nuclear supply industry and 11.000 in facility and other support services[19].

Non-nuclear equipment and services

Major parts of the NPP construction project value include regular civil engineering and construction works and non-nuclear equipment and services such as for the conventional island and Balance of Plant. BAM Nuttal, the UK daughter of Royal BAM, provided the site preparation and earthworks for the HPC project. Various NL companies are currently suppling non-nuclear components such as pumps and valves to NNB projects.

Summary and conclusions

The NL industry currently has a minor position as supplier of nuclear equipment and conventional power generation equipment. This holds for both the domestic and the global markets. This implies that there are no NL companies which would qualify as Tier 1 or Tier 2 suppliers for these equipment.

Some NL companies are currently suppling non-nuclear components to NPPs in the NL and abroad, such as pumps and valves.

Civil engineering and construction for NL nuclear fuel cycle facilities' projects is usually provided by NL companies. Specific parts of civil works to an NNB project abroad were supplied by an NL company.

MRO services during outages for the KCB are supplied by the OEMs. EPZ obtains several technical support and In Service Inspections during outages from NL suppliers, but EPCM services for replacement projects from foreign companies.

18 This report further addresses "de brede nucleaire sector", which encompasses many other organisations with activities somehow related to radioactive substances, in particular for medical purposes. However, the capabilities for these activities have little in common with those required for NPP construction.

19 Oxford Economics, 2023, Delivering value; the economic impact of the civilian nuclear industry.

2.3 EXPORT OPPORTUNITIES FROM THE FORESEEN GROWTH IN NUCLEAR CONSTRUCTION DEMAND

Of interest for the present study is also the projected future demand for nuclear construction and the opportunities it may offer to the NL supply industry, since these may affect decisions on possible investments in extended capabilities.

Global market

The IEA's World Energy Outlook 2023 (WEO)[20] projections provide insights in the expected global growth of nuclear generating capacity. In the WEO, scenarios are explored that reflect different assumptions about the actions taken by governments in the coming years to shape energy systems and reduce energy-related carbon dioxide (CO2) emissions, using the latest data for energy markets, policies and technologies. All energy technologies are included, i.e. coal, oil, natural gas, renewables and nuclear.

The projections for the development of global nuclear capacity until 2050 are summarized in *Figure 7* and refer to the three adopted scenarios: 'Stated Policies' (STEP), 'Announced Pledges' (APS), and 'Net Zero Emission' (NZE).

Planned construction following stated policies would result in 622 GWe generating capacity in 2050 from 417 GWe in 2022, requiring 205 GWe of added generating capacity (7,3 GWe/yr). Announced pledges would result in 769 GWe in 2050, requiring 352 of added generating capacity (12,5 GWe/yr). Stated policies and announced pledges both fall short of the capacity increase of 499 GWe to a capacity of 916 GWe in 2050 (17,8 GWe/yr) required for reaching net-zero carbon emissions in 2050.

The above refers to nuclear construction required for the foreseen growth of generating capacity only. To this should be added nuclear construction required for compensating capacity put out of operation. The replacement of existing generating capacity to be taken out of operation in the period 2022 - 2050 could lead to an estimated additional construction of around 200 GWe (7,1 GWe/yr) in that period[21]. However, the current general trend is for Long Term Operation of the installed base, extending lifetimes to 60 years and beyond. Since replacement demand is thus left as quite uncertain it is not further included in the quantitative discussions in this report.

The generating capacity put into operation in a given period is indicative of equipment demand in that period. The above figures should be compared to global new build of around 65 GWe (50-60 reactors) in the period 2003 - 2022 (3,4 GWe/yr). Although the future demand is uncertain, a growth in global new

20 International Energy Agency (IEA), 2023, World Energy Outlook.

21 Based on: IAEA, Nuclear Decommissioning Market Set to Boom, IAEA Bulletin 64-1, 2023; Denis Iurchak, Energy Post Events, February 11, 2020 (https://energypost.eu/200-400-nuclear-reactors-to-be-decommissioned-by-20400; Deloitte, Decommissioning of Nuclear Facilities Market Overview and Forthcoming Challenges for Plant Operators, 2018.

build capacity from this current level is likely to be needed. This concerns both manufacturing capacity as well as workforce size.

In the STEP scenario only a small increase in construction capacity is needed, whereas for NZE the global nuclear supply market will need to increase capacity by a factor of 5 over a period of 20 years (8%/yr). This led the WNA to state that the expansion of the nuclear power sector at the speed and scale required to meet net-zero, energy security and sustainable development targets will necessitate sustained and coordinated investment in the global nuclear supply chain[22].

European market

The global nuclear market currently consists effectively of two disjunctive markets concerning both supply and demand: Western-oriented countries (the EU countries, the USA, Japan, Korea and part of the Middle East) and non-Western countries. Vendors serving the non-Western countries (Russian and Chinese vendors) are for geo-political reasons excluded from the Western-oriented markets[23] and vice versa. In addition, Western-vendors find difficulty in competing in non-Western markets. Consequently, for this study, the construction market projections for the Western-oriented market, in particular in the European countries, are more relevant for the global market projections discussed above.

Currently three technology vendors are operating in the European nuclear construction market: EDF/Framatome, KHNP and Westinghouse. This situation may change in the future, e.g. due to the entry of SMRs in the market. However, the vendors of SMR designs which are at the most advanced stages of development, such as GE (BWRX-300) and Rolls Royce (UK SMR), already have established their main-equipment suppliers and/or co-developer partnerships during the design phase and are currently in the process of completing their supply chains. Hence, also for these SMRs, NL companies will be effectively new entrants and their position in the supply chain is not much different from that for the large PWRs.

Together the three large-PWR unit vendors currently have globally 5 reactors under construction (≈ 1 construction starts/year in the period 2017-2024) out of ≈ 60 reactors worldwide.

Figure 8 shows the number of reactors to be constructed in the period 2024 - 2045 in the Western-oriented countries based on data from the WNA country profiles. These data translate to 1,5 construction starts per year on average between 2024 and 2028; 3,4 between 2028 and 2035; and slightly over 4,2 between 2035 and 2045.

It follows from the above that a significant increase of construction capacity in the Western-oriented market will be needed. In the period 2024-2028 a ramp-up by 10%/year would be required, followed

22 https://world-nuclear-news.org/Articles/Supply-chain-must-expand-to-meet-new-build-plans.

23 With the exception of Hungary where Atomstroyexport is executing the Paks II construction project.

Figure 7. Global projected nuclear generating capacity (GWe) for three scenarios.

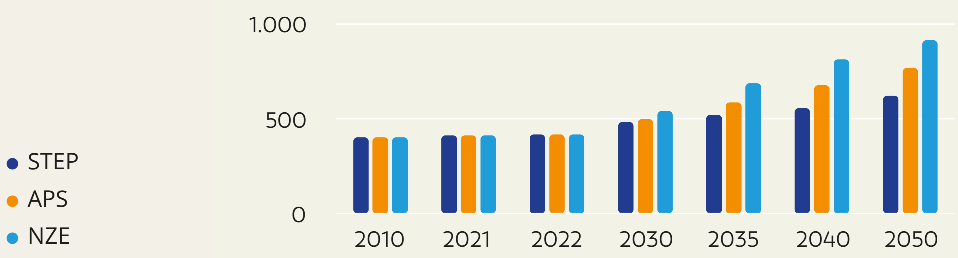


Figure 8. Numbers of nuclear reactors planned and proposed in Western-oriented countries (source: WNA).

by 12%/year in the period 2028 - 2035 and 2% after 2035. These growth rates concern both production volumes of nuclear equipment and workforce size.

These figures can be put into perspective by comparison with the peak number of 24 reactors under construction in France in the period 1971 - 1995, ramping up from 1 construction starts/yr in the period 1971 - 1973 to a peak ≈ 7 construction starts/year in the period 1978-1980[24], corresponding to a ramp-up rate of ~30%/year, indicating that such a ramp-up of capacity of the supply chain is feasible.

However, the French programme concerned a centrally, state directed, endeavour for constructing a large series of identical reactors in which the capital-intensive, heavy equipment manufacturers were state-owned companies and were fully aligned from the start with the programme. Also, the programme offered high certainty for investments to the private sector supply industry.

The current European new build demand market is fragmented, involving about 8 different countries with individual purchase policies and involvement and with planned or proposed projects at various levels of maturity. In addition, the supply market is fragmented into multiple vendors. This market therefore has a considerably higher level of uncertainty for vendors and their supply chains affecting investments in increasing their capacity.

Potential export opportunities for the NL industry

Of interest for the present study is the extent to which the above situation could lead to export opportunities for the NL industry.

Civil engineering and construction
Nuclear construction projects entail a large volume of civil works, ranging from enabling works for establishing site infrastructure to the main construction works encompassing construction of the buildings of the nuclear and conventional islands. NL companies are considered to be well qualified for delivering significant parts of the civil works for NNB projects abroad.

Equipment supply
NPP equipment may be divided into three broad categories:

1. *Specialised heavy nuclear island equipment and turbine generator set*
   Specialized nuclear island equipment includes e.g. the reactor pressure vessel and the steam generators. Total manufacturing capacity in Western-oriented countries for this equipment has increased in recent years. For example, capacity for RPVs increased to approximately 20 RPV sets per year (Japan: 12; South Korea: 5; France: 2, 7)[25]. According to the WNA, current global capacity for this group of equipment is sufficient for serving future demands. Due to this and the high investments needed, it is judged that this market is unattractive for new entrants. These key items are likely to be supplied from the few companies in the world that have this capability.
2. *High technology components and safety critical equipment*
   A considerably larger number of established suppliers are already designing and building this kind of equipment for new nuclear power stations, have completed the design work and developed their supply chains. This means that they will not have to do this preparatory work to fully incur the associated expenditure and should have learned from their past experience. They are also likely able to expand their production capacity within due time, if the need occurs. Also for these items it is likely that they will be supplied by the companies in the world that already have the capability to do so although the investments for new entrants are lower than for the first group.

24 WNA, Country profiles - Nuclear Power in France, updated Tuesday, 21 May 2024.
25 WNA, 2021, Heavy Manufacturing of Power Plants.

3. *Non-safety critical equipment and ancillaries*
   This group concerns major volumes of components such as non-safety classified piping, pumps and cables for which the quality requirements are comparable to those in regular industries such as conventional power stations, oil and gas and the pharmaceutical industry and which do not require significant additional volumes of design work and certification efforts. This market is more accessible to NL vendors, but competition is also larger.

On-site installation of equipment
Nuclear construction projects require an on-site equipment installation workforce of considerable size. *Figure 9* shows the expected development of the on-site workforce for the SZC project, split into labour for civil works and for installation of mechanical, electrical and I&C and HVAC (MEH) equipment.

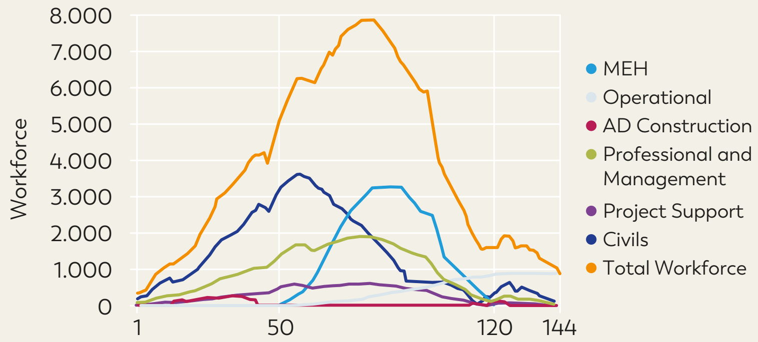
Vendors and main contractors may source part of the required on-site workforce locally for cost and other reasons. This will not be the case for installation of the NSSS and the turbine generator set, for which specialist personnel from the OEM suppliers will be required. Other equipment is mostly installed on-site under supervision of the equipment supplier. Supplying on-site labour for the NNB-NL project may provide an important opportunity for NL companies. However, it is not judged likely that NL companies will want to supply this workforce for projects abroad.

Summary and conclusions

Demand for nuclear construction from the European market is expected to increase considerably as inferred from current new build proposals and plans. However, the established nuclear equipment supply chain is likely able to largely accommodate this increase, in particular for the small volumes of special nuclear equipment.

The market may give rise to export opportunities for the NL industry for specific non-classified groups of components, such as valves, pipes and cables.
Civil engineering and construction works for foreign NNB projects is seen as the main export opportunity.

***Figure 9.* Primary areas of the workforce population over the course of the SZC project[26].**
(MEH: Mechanical Electric and HVAC construction; AD construction: Associated Developments construction)



26 EDF Energy, 2020, The Sizewell C Project 6.3. Revision: 1.0. Volume 2 Main Development Site. Chapter 9 Socio-economics. Appendix 9a: Workforce profile, May 2020 (DCO application). https://national-infrastructure-consenting.planninginspectorate.gov.uk/projects/EN010012

2.4 OPPORTUNITIES IN A FUTURE DOMESTIC REACTOR SERVICES MARKET[27]

Of interest for the present study are also potential opportunities for NL companies for providing reactor services to future domestic operational NPPs. In this section, the installed base arising from the currently planned and announced new (large unit) NPPs in the NL is considered, i.e. a possible installed base of SMRs is not addressed. The assessment is mainly based on interviews with operators, in particular EPZ.

Maintenance, repair and overhaul (MRO) services

The total MRO cost of a twin 1.650 MWe unit NPP would be around 120 m EUR per year[28]. MRO is usually done during the periodic (e.g. annual) 4-6 weeks refuelling outages. Activities may include the overhaul of main equipment such as main coolant pumps or the turbine generator set. Operator/owners are likely to contract maintenance of this main equipment to the OEMs, since they have the best knowledge of their equipment. These companies also operate on a global scale enabling them to attain considerable competitive advantages in economies of scale compared to other suppliers. It is therefore judged that building up a nuclear MRO industry in the NL would economically not be viable. Related to this, it is judged as unlikely that MRO services could provide a basis for a viable NL nuclear equipment supply industry.

Other services

Urenco Netherlands, as a global provider of enrichment services, will be well positioned for providing these services also to envisaged future operational NPPs in the NL.

Besides to EPZ (KCB), NL companies currently supply in service inspections to several plants abroad, including Swedish, Swiss and Finnish NPPs. This is done in competition with companies from other European countries, including reactor vendors. It is likely that these NL companies will also be successful in offering these services to future operational NPPs in the NL and elsewhere in Western-Europe.

NL companies will also be capable of providing other services during outages, such as scaffolding, and of providing supplementary workforce.

Summary and conclusions

Maintenance, repair and overhaul (MRO) of main equipment of future operating NL NPPs is unlikely to be contracted to NL companies. The foreseen future domestic market for these services does not offer a basis for a viable nuclear MRO service business and/or nuclear equipment industry.

Urenco Netherlands will be well capable of providing enrichment services to envisaged future operational NPPs in the NL.

Other services, such as ISI, are likely to be contracted to NL suppliers.

27 This section is informed by consultations with CEZ and EPZ.
28 Based on the USA EIA "Average Power Plant Operating Expenses for Major U.S. Investor-Owned Electric Utilities, 2012 through 2022 (Mills per Kilowatthour)".

3 New build project cost breakdown model

3.1 INTRODUCTION

Local share estimates of a nuclear construction project value require, in one form or another, an assessment of national industry capabilities versus technical requirements of the project scope of supplies[29, 30]. Therefore, a breakdown of NNB-NL project scope into separate supply items including their values was needed for the present study.

Besides a cost breakdown, an estimate of project value of the project was found necessary for the present report for several reasons. First, the applied breakdown of project cost is to be largely based on disclosed contract values of Tier 1 work packages. These contract values should be consistent with the adopted total project value. Second, more than the potential percentage shares in the NNB-NL project, individual potential NL supplier companies will be interested in the turnover opportunity which shares will offer them.

3.2 ADOPTED PROJECT VALUE

The following cost discussion is meant to serve to identify possible cost components and cost factors and the adopted cost estimates are merely working hypotheses for the purpose of the present study. It should be stressed that this report makes no attempt to estimate cost of nuclear new build projects, whether in the Netherlands or elsewhere, or in any other way to benchmark project costs or cost components and proportions for budgetary purposes.

Owner cost and EPC cost

The project value refers to the Overnight Cost of Construction (OCC)[31, 32] which is broken down into two main components, EPC costs and Owner cost[33]. These can be defined as cost corresponding to EPC

29 Oxford Economics, 2013, The economic benefit of improving the UK's nuclear supply chain capabilities.
30 Idom 2019, Supply Chain Localization in FOAK reactors and supplier challenges. https://igeos.pl/images/materialypokonferencyjne/Fidel_Semumaga.pdf. Retrieved: 19-05-2024.
31 The OCC covers all the costs of building the asset independently of the time necessary for its design and construction. In other words: the cost for construction of the plant if no interest was incurred during construction, i.e. as if the project was completed "overnight."
32 The use of the OCC is consistent with the TFS which states that the CAPEX estimates to be provided by the Vendors involved in the TFS shall refer to overnight construction cost.
33 OECD 2020, Unlocking reductions in the construction of nuclear. https://www.oecd-nea.org/upload/docs/application/pdf/2020-07/7530-reducing-cost-nuclear-construction.pdf In the report also contingency costs are included as a separate cost category. These pertain to the initial cost estimates for investment decisions are are therefore ignored in the present study.

scope and cost corresponding to Owner scope respectively. The EPC scope includes all activities related to plant design, procurement, construction, commissioning and handover to the operator.
The Owner scope in the above sense includes all other activities, i.e. activities not directly related to plant construction, including connection of the plant to the national grid high voltage transmission system[34]. The scope delineation of the NNB-NL project differs somewhat from the above as will be discussed in section 3.4 below.

In the TFS[35], the project scope is split into three scopes: Vendor scope, Owner scope and Tennet scope. In the terminology applied in the present study, the Tennet scope is part of the Owner scope and the Vendor scope corresponds to EPC scope.

The terms "EPC scope" and "Owner scope" refer to more or less generic scopes of activities. These can be applied to any NNB project, irrespective of the project delivery method, since largely the same activities have to be done for every NNB project.

Owner costs may account for 12-20% of OCC[36]. The Owner scopes for NNB projects may be different however, e.g. due to differences in site conditions and off-site infrastructure conditions. This is likely to be the case for the Sizewell C project in the UK in comparison to the NNB-NL project. Consequently also their Owner costs may differ. Their EPC scopes are likely to be largely similar however. Consequently, largely the same EPC cost estimate would be applicable to both projects.

Construction costs of recent NNB projects

Table 1 presents an overview of OCC of recent NNB construction projects, normalised to capacity and expressed in USD/kWe. Note that the table includes the three technologies/Vendors involved in the TFS. The table suggests that there is not a single generally valid value for the OCC or market price of a NNB NPP.

As follows from Table 1 the realized OCC of recent NNB projects show a wide spread, varying from 2.410 USD/kWe[37] in Rest of the World (ROW) to over 5.000 USD/kWe for NNB projects in Europe and the USA. The differences in OCC between Europe/USA and ROW are attributed to design maturity, supply chain maturity, labour productivity, and stability of the regulatory framework (OECD, footnote 33); to differential labour costs, more experience in the recent building of reactors, economies of scale for building multiple units, and streamlined licensing and project management (WNA[38]); and to highly focused, deliberate and intentional programmes to drive down costs and drive up performance over time in ROW (ETI[39]).

34 IAEA, 2011, Invitation and evaluation of bids for Nuclear Power Plants, NG-T-3.9, para 3.9.2.
35 Ministry of Economic Affairs and Climate Policy of the Netherlands and Assytem, Workstream 3 – NPP delivery model battery limits & scope of supply, Appendix to TFS - Scope of Work & Deliverables.
36 ETI, 2018, The ETI Nuclear Cost Driver Project: Summary Report, 20 April 2018.
37 Cost values in 2018 USD.
38 WNA, 2023, Economics of Nuclear Power, updated Friday, 29 September 2023.
39 The Energy Technologies Institute (ETI), 2020, The ETI Nuclear Cost Drivers Project, Full Technical Report.

Table 1. ***Construction costs in 2018 USD per kWe of recent Gen-III NNB projects according to OECD data (see footnote 33) and extended with recent data on the Barakah-1 and Hinkley Point C projects.***

Type	Country	Unit	Construction start	Initial announced construction time	Ex-post construction time	Power (MWe)	Initial announced budget (USD/kWe)	Ex-post construction cost (USD/kWe)
AP 1000	China	Sanmen 1,2	2009	5	9	2×1.000	2.044	3.154
	United States	Vogtle 3,4	2013	4	8/9	2×1.117	4.300	8.600
APR 1400	Korea	Shin Kori 3,4	2012	5	8/10	2×1.340	1.828	2.410
	UAE	Barakah-1	2016	6	6	4×1.340	5.600	5.600
EPR	Finland	Olkiluoto 3	2005	5	16	1×1.630	2.020	> 5.723
	France	Flamanville 3	2007	5	15[a)]	1×1.600	1.886	8.620
	UK	Hinkley Point C	2018	7	9+	2×1.630	7.800	12.800
VVER 1200	Russia	Novovoronezh II-1&2	2008	4	8/10	2×1.114	2.244	[b)]

[a)] Estimate. [b)] No data available.

Project cost adopted for the NNB-NL project

EPC cost
It is likely that the conditions for the NNB-NL project will be more similar to the conditions of recent NNB projects in Europe/USA than to those in the rest of the world. The EPC cost of the NNB-NL project was therefore derived from the current EPC cost estimate for the SZC project, being the most recent planned project for which such a cost estimate is disclosed. Additionally, the SZC project concerns the construction of a large twin-PWR unit NPP similar to the NNB-NL project. Moreover, of recent nuclear construction projects, by far most data - including cost data - is publicly available for this project and its predecessor, the Hinkley Point C (HPC) project. These data were supplemented by data from other sources, such as vendors, the OECD, WNA and the ETI.

The costs for the SZC project were estimated in 2020 by the owner EDF Energy at 20 bn GBP[40].
EDF Energy stated that this cost estimate has been informed by contributions from a variety of sources, including budget quotations, expert advice and industry recognised rates based upon experience of national frameworks and by learning from Hinkley Point C. The scope covered by this cost largely corresponds to the EPC scope as used in this report. This cost estimate was therefore adopted as EPC cost estimate for the NNB-NL project.

Based on the above, the EPC cost for the NNB-NL project adopted in the present study amounts to 23,8 bn EUR[41].

40 EDF Energy, 2020, The Sizewell C Project, 4.2 Funding Statement, Revision: 1.0.
41 2020 price levels; adopting a GBP to EUR exchange rate of 1,19.

Owner cost
Concerning Owner cost, the UK government has made provisions for investing a total of 5,5 bn GBP in SZC to cover development expenditure costs up to and including Final Investment Decision (FID)[42]. These will support ongoing preparatory works such as improvements to roads and rail lines around the construction site. However, these costs were not adopted as the Owner cost for the NNB-NL project because of differences in the Owner scopes between both projects, but serve here merely as a reference amount. Instead, the Owner cost adopted in the present study are based on the disclosed and available information on the NNB-NL project (see further section 3.4 below).

Reasonableness assessment of the adopted EPC cost
Adopting an OECD average of 12% Owner cost of total project cost, the above quoted cost estimate for the EPC scope for the project of approximately 23,8 bn EUR (2020) translates into a total project cost of 27 bn EUR. The corresponding OCC amounts to 8.810 USD (2018)/kWe[43]. This value fits into the range of ex-post OCC values in Europe/USA reported by the OECD and included in Table 1 above.

Reference technology and estimated potential localization values
In the subsequent chapters, potential localization values will be estimated based on the adopted project cost, in particular the EPC cost of 23,8 bn EUR. Of the three technologies considered in the TFS, the EPR has the largest nominal capacity power of 1.650MWe, compared to 1.100MWe for the AP1000 and 1.350MWe for the APR1400. The EPC cost of the AP1000 and APR1400 based options are likely lower than the cost of the EPR based option, since EPC cost usually increases with increasing power capacity. The estimated potential localization values will therefore present upper bounds. Lower bounds can be obtained by multiplication of these values by a factor of 0,67[44].

While there is no basis to assume that the NNB-NL project would encounter the above cost for the EPR-based option in a competitive process, this is the only available recent relevant benchmark reference data available and with some level of transparency. The actual cost may be considerably different, which can also be inferred from the large spread in the actual cost of recent NNB projects shown above. In view of this, the cost estimates adopted in this report may present upper bounds when deriving potential localization values.

42 UK Government, 2024, Notice Sizewell C Development Expenditure (Devex) Subsidy Scheme, Published 30 August 2024.
43 Adopting a construction cost index ratio 2018 to 2020 of 0,97 (source: Eurostat, 2023, Construction producer price and construction cost indices overview, Data extracted in July 2023); EUR to USD exchange rate of 1,11; total plant power of 3.300 MWe.
44 The factor of 0,67 is the ratio of the power capacities per unit of the AP1000 and EPR, i.e. 1.100/1.650. Use of this factor implicitly assumes that the same OCC (in USD/kWe) applies for the EPC cost of all three reactor technologies. The causes of the variations in the ex-post OCC of large-reactor NNB projects have been analyzed in various studies. The effect of differences in power capacity per unit on OCC was ignored in these studies. The assumption is therefore considered as justified. See e.g.: Philip Eash-Gates et al, 2020, Sources of Cost Overrun in Nuclear Power Plant Construction Call for a New Approach to Engineering Design, Joule 4, 2348–2373; Jessica R.Lovering et al, 2016, Historical construction costs of global nuclear power reactors, Energy Policy 91, 371–382; Jonas Kristiansen Nøland et al, 2024, Cost Projections of Small Modular Reactors: A Model-Based Analysis, Energy Volume 313, 133827.

3.3 BREAKDOWN OF EPC COST

The cost of the EPC scope of the NNB-NL project adopted in the present report of 23,8 bn EUR (2020 price levels) is based on recent cost data for the UK twin-EPR unit SZC project. Consistent with this, the applied cost breakdown structure of the EPC scope is based on the cost breakdown of a multi-unit EPR NPP, as specified by the Vendor, as follows[45]:

- Civil Works (30%);
- Nuclear Island (NI): 40%;
- Conventional Island (CI): 20%;
- Balance of Plant (BOP): 10%.

These are comprehensive costs, including all costs associated for the part of the project concerned, i.e. direct costs for equipment supply and installation and indirect costs related to engineering and design, supply chain qualification and certification, procurement, project management, field supervision, quality assurance, testing, commissioning and start-up (see footnote 33).

The indirect costs can contribute to over 50% of the total EPC cost (see footnote 33). In a turn-key project, most of the indirect costs are absorbed by the EPC and Tier 1 contractors. This lowers the potential share of project value accessible to Tier 2 and lower tier suppliers.

Civil works

The scope of civil works was structured into eight work packages, based on the structure of the civil works of the SZC project[46]. A description of these work packages will be provided in Chapter 4 of this report.

The adopted values of these work packages for the NNB-NL project are included in Table 2 below. These values are obtained from the corresponding values for the SZC project (see footnote 46), corrected for scope differences between both projects and subsequently scaled to add to a total of 30% of the total EPC cost. Scope differences concern Marine and tunnelling in particular. For example, the SZC scope includes the construction of beach landing facilities, which are not needed for the NNB-NL project, for example due to the presence of the "Van Cittershaven" deep sea port[47] (maximum depth 17 m) near the Borssele construction site. Also the cooling tunnel requirements for NNB-NL are likely to be different from those for SZC, as explained in Chapter 4 below.

Table 2. Cost and cost breakdown structure of civil works.

Work package	Cost (m Euro)	(%)
Site preparation	589	8
Main earthworks	442	6
Engineering and design	354	5
Marine and tunnelling	589	8
Construction, NI	1.965	28
Construction CI and BOP	1.768	25
Ancillary works	156	2
Size operations and logistics	1.277	18
Total	**7.140**	**100**

45 See e.g. EDF, 2023, Laurent Olivier Coudeyre; Jaitapur: des opportunités clé pour la filière nucléaire française.
46 Sizewell C Supply Chain, 2023, Building the Sizewell C Supply Chain, Down Hall, Hertfordshire, 5th September 2023. Note that civil works for the SZC project also inc+lude three work packages which consistent with the TFS are part of the Owner scope: 1. Advanced works; 2. Enabling works; and 3. Offsite associated developments.
47 Deep sea port means the ports where sea-going vessels with draught of at least 13.72 meters and above may harbour within a port limit determined by notification (https://www.lawinsider.com/dictionary/).

Nuclear Island equipment

The scope of the Nuclear Island (NI) is usually split into the Nuclear Steam Supply System (NSSS), encompassing the reactor and safety and auxiliary systems, and the Balance of Nuclear Island (BNI), encompassing all other equipment of the NI. This split was also applied in the present study resulting in the cost split included in Table 3. Although this cost breakdown is still coarse, it connects to the division of the scope of equipment supply of a nuclear construction project into three broad categories of degree of localization, i.e. shallow, medium and deep. These categories relate to the maturity of the national industry and to supplier qualification and investment requirements[48] (see also footnote 30).

The cost of the NSSS were estimated from the contract value of the NSSS for HPC (2017)[49], corrected for inflation by the 2020/2017 construction cost index ratio[50]. This is consistent with the 2020 cost estimate for SZC which is also based on HPC data.

In the HPC project, the NSSS was contracted as one single Tier 1 work package to the reactor technology vendor Framatome. This will likely also be the case for SZC. However, it may be different for APR1400 and AP1000 projects, e.g. the complete NI equipment may be the responsibility of one consortium partner.

The costs of the NSSS and of the BNI were both split into equipment cost (70%) and cost for on-site installation labour (30%) (not shown in Table 3) based on footnote 33.

***Table 3.** EPC cost breakdown structure.*

Main works/island	Major parts	Cost (m Euro)	Cost (m Euro)
Civil works	See Table 2		7.140
Nuclear Island	NSSS	6.264	
	BNI	3.094	
			9.520
Conventional Island	Turbine-generator	2.055	
	BCI	2.705	
			4.760
BOP			2.380
Totals			**23.800**

The first fuel load is often included in the OCC (see e.g. Oxford Economics/Atkins in footnotes 29 and the WNA in footnote 38). It is set at 1,5% of the OCC[51] in the present study. Since the first core is likely to be designed by the NSSS supplier and the NSSS supplier is often requested to also bid for the first fuel load, in this report the corresponding cost are included in the NSSS part of the cost.

48 EDF, 2020, Laurent-Olivier Coudeyre, Managing the risks of the supply chain from a vendor's perspective, IGEOS webinar -10/12/2020.

49 Blackridge, 2024, Project Profiles: Hinkley Point C Nuclear Power Station Set To Become UK's Largest Nuclear Power Project, 8 January 2024.

50 Eurostat, 2023, Construction producer price and construction cost indices overview, Data extracted in July 2023.

51 The WNA states that the first fuel load contributes 3% to the OCC (see footnote 38). This percentage of 3% is related to a specific OCC value, which is not specified in the text, but which is likely the OECD-average OCC value of 4.400 USD (2018)/kWe adopted in footnote 33. It is likely that the fuel cost are not affected by the factors which cause the large variations in OCC values addressed in section 3.2 above and are largely the same everywhere. This leads to the contribution of the first fuel load related to the OCC of 8.800 (2018 USD)/kWe adopted in this report of 1,5%.

Conventional Island equipment

The scope of the Conventional Island (CI) is usually split into the turbine generator package, the major cost item, and the Balance of Conventional Island (BCI), encompassing all other equipment, such as auxiliary systems, pumps and piping. Note that the sea water pumping house equipment is considered part of the BOP. Adopting this split in the present study resulted in the cost split included in Table 3. The cost of the turbine generator set were estimated from the 2017 contract value for HPC[52], corrected for inflation as described above for the NSSS.

There are only a few companies worldwide able to supply the turbine generator package for large PWRs. Equipment of the BCI however is similar to some extent in design and requirements to conventional thermal power plant equipment and can be supplied by more companies. Thus, as for the Nuclear Island, the above breakdown - although coarse - connects to the division of the scope of equipment supply of a nuclear construction project into the three broad categories of degree of localization mentioned before.

As for NI equipment, the costs for the turbine generator and for BCI equipment are both split into equipment and materials supply (70%) and on-site installation labour (30%).

BOP equipment

The Balance of Plant (BOP) refers to all items outside the Nuclear Island and Conventional Island and includes a large number of systems and equipment. These can be grouped in various ways and contracted to separate contractors. For example, KHNP has about 400 qualified vendors for the BOP and issues a procurement schedule for a specific project. This schedule contains the number of procurement packages, specification issue date, Invitation To Bid (ITB) issue date and the contract awarding date. The BOP equipment is grouped into 190 packages based on various parameters, e.g. quality class, and equipment type[53].

However, for the HPC and SZC project, EDF Energy has combined the scope of all BOP, BNI and BCI contracts (equipment supply and installation) together into a single Tier 1 work package, denoted as MEH scope (Mechanical, Electrical and HVAC installation). The estimated contract value for SZC amounts to 5,8 bn EUR[54]. This scope is split into a large number of separate contracts on lower Tier levels. For example, Bilfinger SE was awarded the contract for the fabrication and installation of pipe systems (around 56 kilometres, 70 m EUR)[55] and Altrad Motherwell Bridge for the BOP storage tanks (156 walled-in tanks for various fluids including coolant, oil, effluents and additives, contract value not disclosed). The complete cost split for the BOP works is not available and cost data on BOP contracts are in general lacking. It is therefore not possible to present a sufficiently reliable cost breakdown of the BOP scope per equipment (group). The cost of the BOP was therefore merely split into equipment and materials supply (70%) and on-site installation labour (30%), in the same way as the costs for the NSSS, BNI, turbine generator and BCI.

52 https://www.ge.com/news/press-releases/ges-steam-power-systems-deliver-19-billion-contract-hinkley-point-c-nuclear-power.

53 IAEA, 2012, Project Management in Nuclear Power Plant Construction: Guidelines and Experience, NP-T-2.7, pp. 106.

54 Sizewell C - CompeteFor, 2024, Procurement overview (latest Final) 08-242024, Issue Date: 01 July 2024 Version: 01.

55 Blackridge, 2024, Project Profiles: Hinkley Point C Nuclear Power Station Set To Become UK's Largest Nuclear Power Project (8 January 2024).

3.4 BREAKDOWN OF OWNER COST

The average Owner cost of 12-20% of OCC reported by the OECD (see footnote 33) would, for an EPC cost of 23,8 bn EUR, correspond to a value between 3,2-5,4 bn EUR. Several considerations lead to adopt a considerably lower Owner cost for arriving at NL share estimates in the NNB-NL project:

- A nuclear construction project usually involves the construction of new or extended site access infrastructure such as bridges, roads, railroads and harbour facilities, which can also involve adaption of existing transport networks. This is the case for the SZC project, for which the cost of these associated developments were estimated at 580 m EUR. These investments are not needed for the NNB-NL project, since the required off-side infrastructure is already present.
- The same holds for the connections to the utility networks (electricity, potable water, sewage).
- A major part of the Owner scope concerns building up of the permanent Owner organisation. This activity presents internal costs and will not lead to significant opportunities for contractors.
- This also holds for such parts of the Owner scope as land acquisition and insurance fees[56].

The remaining Owner scope of the NNB-NL project depends on various factors, which are only partly unknown. This concerns especially the Owner and its organisation which determine the support the Owner will need from contractors.

The Owner scope and associated cost adopted in this report are primarily based on the currently available information, in particular the delineation of the project scope as specified in the TFS (see footnote 35), and on international practice concerning the Owner's role in nuclear new build projects.

Accordingly, as specified in the TFS, the construction of some permanent plant buildings is part of Owner scope. As said before, grid connection and extension are assigned to "Tennet scope" in the TFS, but are included in the current study in the Owner scope for convenience.

Site preparation works

The following services and installations foreseen for the site preparation, the construction and commissioning phases are part of the Owner scope:

- Preliminary preparation of the site such as land reclamation, clearing, demolition;
- Temporary site security and access control installations and services including the temporary and permanent site fences and gates (temporary fences and gates within the site e.g. in the case of different Vendor zones of work);
- The temporary centralized medical services during the construction and commissioning phases.

These activities are thought to be of limited size and their cost as being relatively low. They were therefore ignored in this study.

Site characterization

Site characterization data on site geomorphology, geology, soil layers geotechnical parameters, meteorology, hydrogeology, seismology and human induced events for the Borssele site were provided to the Vendors as part of the TFS. These included older studies from 2011-2012 as well as recent

56 Operators of nuclear power plants are liable for any damage caused by them, regardless of fault. They therefore normally take out insurance for third party liability, and in most countries they are required to do so (https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/liability-for-nuclear-damage). Insurance fees of operating plants in the US are reported as 658 mUSD (NRC, Backgrounder on Nuclear Insurance and Disaster Relief.)

studies undertaken by Deltares (especially cooling water, meteorological and natural hazard studies). The Vendors were asked to review the available data, to identify the missing site characterization, investigations results and site data information to complete the TFS and the BIS and to present recommendations for further (design) site characterization. This concerns in particular a design/foundation investigations program & laboratory tests work plan for geophysical investigations, the locations of borehole drillings, and necessary complementary soil testing and ground water monitoring on the plant area.

It is therefore possible that site characterization will be needed, also for the Borssele site. The cost for these can be considerable, judging from the cost of 200 m GBP for these for SZC (see footnote 46), but are also highly uncertain. They were therefore not included in the present study.

Licensing

Licensing is largely part of the Owner scope, as specified in the TFS (see footnote 35, items 100-115). It refers to all permits and licenses to be obtained for the NNB-NL project and all procedures to be followed. These largely emanate from the Environmental and Planning Act (EPA; Omgevingswet) and the Nuclear Energy Act (Kernenergiewet, KEW). The EPA regulations refer mainly to the Project Procedure. The Project Procedure requires the submission of various major documents in particular an EIA (the plan-MER). The Nuclear Energy Act (Kernenergiewet, KEW) requires a construction license before start of construction and an operating license before start of operation/commissioning.

There are no recent data available on the licensing cost of new NPPs in the NL. Data on licensing of new reactors are limited to the PALLAS research reactor construction project in Petten. For NNB-NL, largely the same procedures have to be followed as for the PALLAS project. However, due to various factors such as the size and technical complexity of the NNB-NL plant and the potential hazards of an NPP relative to a Research Reactor, the required level of detail of the NNB-NL license applications and of the supporting studies is likely to be considerably larger than for the PALLAS project and hence also the volume of documents and their cost.

Broadly speaking, the licensing processes for nuclear construction in all countries are largely similar. Statistics on licensing costs of NPPs in the US provide total costs ranging between 120 and 160 m USD[57] (110 - 150 m EUR). This cost range was adopted for the purpose of the present study. It is realized that licensing cost for the NNB-NL may deviate from these, however.

Owner's engineer

The Owner activities include such activities as selection of the EPC contractor, overseeing project management and supply chain contract management, provision of the Design Authority and other Intelligent Customer functions as well fulfilling regulatory aspects. The Owner is unlikely to be able to set up these largely in part temporary functions within its own organisation and will likely hire contractors for these. These are designated here as the Owner's engineer.

The implementation of all functions associated with the 'knowledgeable customer' ('intelligent customer' or 'smart buyer') concept partially fulfils the IAEA requirement that during construction, the licensee should retain responsibility for all activities that could affect the safety of the installation. This refers in particular to the Design Authority functions, which are included in the intelligent customer concept.

57 Licensing costs for nuclear power plants in the United States as of 2023, by license type; https://www.statista.com/statistics/1450555/us-nuclear-power-plants-licensing-cost-by-type/

However, as is generally accepted[58], the Owner also has joint responsibility for the success of the construction project, even in a turnkey EPC project delivery. This entails that the Owner supports the contractor and enforces the contract fairly, measures the effectiveness of the project, and assures that the project is fulfilling the requirements[59]. This implies that the Owner also has to understand and define the needs of the programme. This goes beyond the IAEA requirements on the Intelligent Customer function concerning Nuclear Safety only.

Based on data from the HPC project, the intelligent customer function was estimated to require approximately 260 experts[60, 61]. The Owner is likely to find difficulty in the first phase of the project to source these from their own staff and hence will need to hire these largely from contractors. Since the knowledge corresponding to the DA function has to be transferred to the Owner, the number of contracted personnel will drop during the construction period. Based on this, it was estimated that the Owner will source on average 110 FTE[62] from contractors during the project. Assuming a project preparation phase of 2 years and construction time of 7 years, this translates into 990 job years[63], and an associated cost of approximately 170 m EUR[64].

Construction of buildings

As specified in the TFS, the Owner scope includes the construction of approximately eleven buildings, mentioned under "Ancillary Buildings (permanent)" and "Other Buildings & Monitoring" (see footnote 35). Based on information from SZC, these buildings are likely to be of modest size each, with a total floor space of approximately 40.000 m^2 at maximum. Total costs were estimated to be between 50 - 80 m EUR for this study, based on benchmark cost data[65] and the cost for Ancillary Works of SZC (see footnote 46).

Connection to the national grid HV transmission system

There is considerable uncertainty about the possible cost for connection of the plant to the national grid high voltage transmission system. These may go beyond the construction of the power transmission infrastructure (HV substations and connections to the transformers) and may include extension of the capacity of the HV transmission network. Based on cost data for the HV substation of HPC, the cost for the HV substations were estimated at 120 m EUR[66]. At the request of the NL government, Tennet investigated the extension of the national HV transmission grid that would be needed for accommodating a newly built twin-unit NPP at Borssele, but cost estimates were not disclosed. For HPC, these cost amounted to 660 m GBP (770 m EUR)[67]. In view of these uncertainties, a total cost estimate of 200 m EUR for connection to the national grid HV transmission system was adopted.

58 This was one of the lessons learned from the OL3 project. See: STUK, 2006, Management of safety requirements in subcontracting during the Olkiluoto 3 nuclear power plant construction phase, Investigation Report 1/06, Nuclear Reactor Regulation Translation 1.9.2006.
59 Nuclear Industry Safety Directors Forum (SDF), 2019, The UK Nuclear Industry Guide To Intelligent Customer Role (Sept. 2019).
60 This is based on p. 28: 87% filled and 34 vacancies leads to 260 persons in total; and assuming 50% hired at project start.
61 The client organisation for the Hinkley Point C project - NNB Generation Company (HPC), a subsidiary of EDF Energy - is embedded in a much larger existing nuclear utility organisation. Depending on the project owner for the NNB-B project, the UAE or Polish model could be more appropriate, in which case the Owner Engineer will be more important than for HPC and will require more resources and cost.
62 Assuming that at the start of the project, the Owner sources 40 of the in total 260 required experts from own staff or direct recruitment and sources 220 experts from consultants, and a linear decrease during the course of the project of the number of hired experts to zero at start of operation.
63 One job year is defined as one person in employment for one year.
64 1.400 hours per FTE per year, hourly rate of € 120.
65 www.heembouw.nl/artikelen/blog/wat-kost-een-kantoor-op-maat/; www.brainsandbricks.nl/kengetallen-kosten-kantoorinrichting/.
66 ABB Press release 2017-10-19, www.new.abb.com/news/detail/2270/abb-wins-130-million-power-order-in-the-uk.
67 www.ofgem.gov.uk/press-release/ps60-million-savings-new-hinkley-point-c-grid-link.

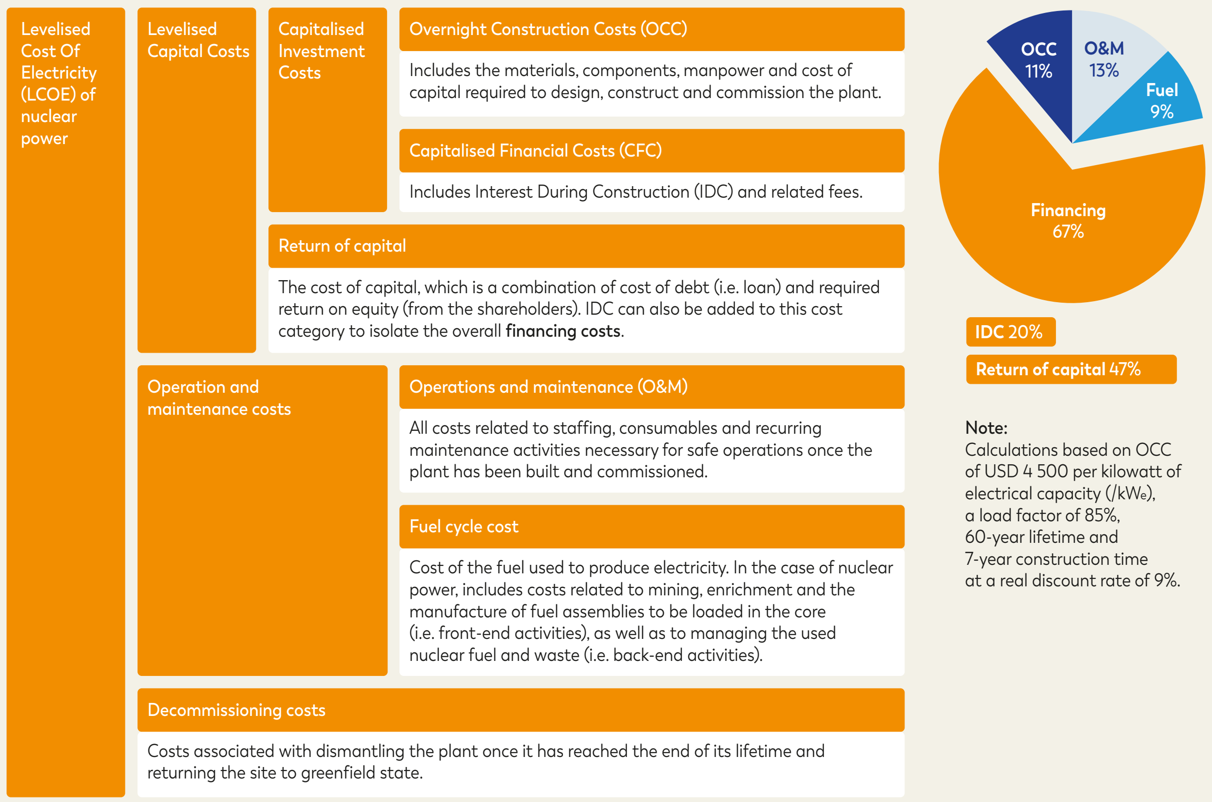
3.5 PROJECT COSTS AND LOCALISATION

Localisation may provide different benefits depending on the stakeholder. From the host country's government and industry's perspectives, localisation offers opportunities for economic activity, employment and turnover. For the technology vendor, localisation may also provide benefits due to competitive local procurement. However, technology vendors and the Owner also face several additional risks with localisation[68]. The local industry may be less productive and may lack the necessary capabilities and skills, putting the project's budget and schedule at risk.

Extended construction durations have a two-part effect on increasing costs for nuclear projects[69]. The first is the direct effect of increased costs for rental, temporary construction facilities, construction management and other construction related costs. The second is the financing costs from interest accrued during construction (IDC). IDC is a significant fraction of the total capital cost for nuclear projects (see Figure 10). For example, in the UK, the IDC for large energy infrastructure projects as set by Ofgem varied between 6 and 8% in the past decade[70]. The increase of construction delays on IDC has been shown to be of the order of 8% per year (see footnote 36). This would amount to a cost increase of 2 bn EUR/year for the NNB-NL project at the cost estimate adopted.

68 See Box 8 in footnote 33 on p. 59.
69 W. Robb Stewart, Koroush Shirvan; 2023, Construction schedule and cost risk for large and small light water reactors, Nuclear Engineering and Design 407 (2023) 112305.
70 The Office of Gas and Electricity Markets (Ofgem), 2023, Guidance on our approach to the Economic Regulation of Sizewell C; for further information, see www.ofgem.gov.uk.

Figure 10. Cost breakdown for nuclear power Levelised Cost of Electricity; OCC contributes 11% and IDC 20%. (See footnote 33 for further data).



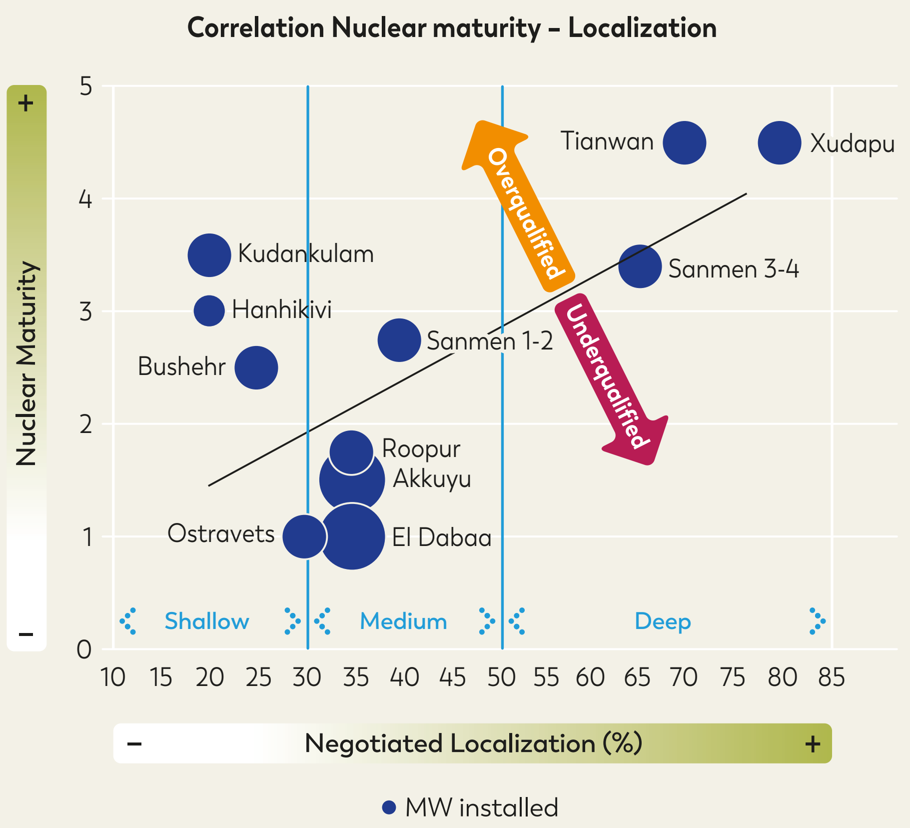
This suggests that deciding on the local content for a NNB project involves finding a match between the national industry's capabilities and the project requirements. This is illustrated in Figure 11 below, in which the straight line represents situations where the national industry's capabilities match the scope of supply corresponding to the agreed local share. The regions denoted as 'underqualified' and 'overqualified' respectively represent those situations in which the local industry's capabilities are not sufficient to deliver this share to the project's requirements, and those situations in which the local industry's capabilities are more than sufficient to do so.

The potential NL share addressed in this report refers to the share for which the current NL industry's capabilities match the project requirements (Scenario A) or could do so with the investments as indicated (Scenario B). This potential share would be the maximum share for which localization would not introduce additional risks to Owner and Vendor.

Obviously, the Owner and Vendor would make their own risk assessment, based on their own assessment of the industry's capabilities and risk appreciation, and may thus arrive at different conclusions.

Figure 11. Relation plot of nuclear maturity (the degree of development of nuclear skills and capabilities of the local industry) and negotiated degree of localization (non-exhaustive). *(Source: see footnote 30).*

Deep localization would encompass manufacture of key reactor components; shallower localization entails manufacture of 'non-nuclear' pumps, valves and other components and involvement in civil engineering aspects[71].



71 IAEA, 2013, Approaches for assessing the economic competitivenessof small and medium sized reactors, NP-T-3.7.

4 Civil works

This chapter is structured following the assumed scope and work package structure of the civil works adopted from the SZC project. Both the SZC and NNB-NL projects concern twin-unit large PWR NPPs, are located near the sea, will use no cooling towers and their site conditions show similarities. The scopes of the civil works for both projects are therefore largely similar, with some exceptions to be addressed below. In addition, this chapter is informed by information from the civil works for the HPC project.

It is likely that one of the EPC Vendor consortium partners will be responsible for the complete Civil Works (see e.g. *Figure 4*). This company may subcontract individual work packages to other companies. These suppliers, which are responsible for a work package, are also denoted as Tier 1 suppliers here. The consortium partner who is overall responsible for the Civil Works is likely to maintain a strong supervisory role in each work package however.

4.1 SITE PREPARATION

Scope

Site preparation includes the construction of all infrastructure within the fence perimeter, including the fence itself and the preparation for earthworks. The work will take approximately two calendar years, based on the indicative SZC Construction Timeline[72], and the value was estimated to amount approximately 600 m EUR.

The scope of work can be grouped into four parts:
i) fencing;
ii) roads and networks (on-site infrastructure);
iii) structures; and iv) platforms, galleries and slopes[73].

Permanent perimeter fencing
The permanent perimeter fencing around the station provides security to the site and protection to the general public. The design of the fence and associated equipment must be to the satisfaction of the ANVS. The design is normally a double fence with a 3 metres illuminated central reservation which is fitted with intruder trembler alarms and is monitored by remotely controlled security cameras manned from a security office.

72 NNB Generation Company (SZC) Limited, 2021, DCO application for the Sizewell C Project, 6.3 Revision: 3.0, Volume 2 Main Development Site, Chapter 3 Description of Construction, Appendix 3D of the Environmental Statement: Construction Method Statement, September 2021.

73 Kier-BAM, 2018, Hinkley Point C Earthworks and site preparation case study: overview June 2018.

On site infrastructure
The on-site infrastructure includes construction of site roads and site networks. Road work may entail approximately 20 km of roads, 300 km of ducts and 20 km of drainage; over 1.000 associated chambers and manholes; 500 street light columns and 2,5 km of surfacing earthing. The electricity network encompasses establishing a series of ring mains/substations that are either serviced by the local electricity grid or generators.

Structures
Structures encompass the groundwater cut-off wall, water management zones, and seawall structure. The cut off wall would be constructed near the perimeter of the nuclear licenced site boundary in reinforced concrete to create a watertight box around the main construction area. It will also perform an earth retaining function.

A considerable campaign of instrumentation and monitoring can be foreseen in order to understand the effectiveness of the cut off wall and of any potential movements. It is likely that the anchors from the cut off wall will need to be improved and engineered. Therefore, early contractor engagement and trialling solutions are required.

The construction of an on-site sewage treatment plant, included in the scope for SZC and HPC, is part of the Owner scope for the NNB-NL project[74]. These works may not be needed for the NNB-NL project, depending on the selected site. The Borssele site for example is part of the "Zeehaven- en industrieterrein Sloe 2018" which is already included in the public sewage network.

The three reactor technologies involved in the TFS are not designed to be able to withstand a flooding event such as occurred in the Zeeland region in 1953. Hence, the site needs to be elevated above the expected maximum flooding level which requires considerable filling, or a protective sea wall (or coastal defence) needs to be constructed. For both HPC and SZC the latter option was selected, as a new hard coastal defence of approximately 800 metres length. For NNB-NL, a sea wall could not be acceptable and filling would be needed.

Platforms, galleries and slopes
Establishment of the platforms[75] will entail construction of (drainage) galleries, slopes and establishment of piles for soft strata support during cut-off wall installation. The depth has yet to be established, but will possibly exceed the 12 metres adopted for SZC. The work could entail over 30.000 m^3 of sprayed concrete, over 80.000 m^2 of protected slopes and 45.000 m^3 blinding[76] and substitution concrete. The site may encompass several platforms (e.g. main platform with the power station itself; power transmission platform with switchgear building and transformers).

Required resources, skills and facilities

The work is in appearance mainly regular civil construction work. However, due to the high standards for nuclear construction, high requirements are imposed on the quality of the works, requiring geotechnical surveys and the application of advanced soil improvement techniques[77]. Soil improvement may apply rigid inclusions (Controlled Modulus Columns), or alternative methods such as deep soil mixing or potential surcharging. The work will therefore entail an accredited on-site laboratory with a significant capacity for performing tests ranging from soils classification to spray concrete flexural beam testing (typically 20.000 earth tests and 3.600 concrete cubes per annum).

Also, special equipment is likely to be used and upskilling of some of the workforce to be needed, as in the HPC project[78].

The work hence represents a multifaceted civil construction project of a large scale. It requires the capability to take overall responsibility for road, track and path construction; paving manholes; earthwork and foundation engineering; hydraulic engineering, coastal and flood protection; special civil engineering and soil improvement methods; and the use of special construction machinery.

The Tier 1 contractor will be required to have experience from similar recent NPP construction projects.

Typically 600 staff and 1.500 operatives will be required.

NL capability

The larger NL civil engineering and construction companies are expected to have the skills and capacity/resources required for carrying out the work. These companies are of a size comparable to the Tier 2 contractors involved in the HPC and SZC projects (respectively the Kier-BAM Joint Venture, and Balfour Beatty and Laing O'Rourke). Also the numbers of such companies in the UK and the NL are similar (4-6).

Note however, that the required workforce is quite large to NL standards (e.g. the peak workforce for the major Afsluitdijk renovation project was around 900 persons). Thus a joint venture between several NL companies may have to be established.

Note also that the Tier 1 party for the contracts for the UK projects is the BYLOR joint venture of Bouygues with Laing O'Rourke. This reflects the importance of including experience from similar recent nuclear construction projects into the bidding consortia.

NL share estimate

Based on the above, it is concluded that NL companies are capable of performing the major part of the work, but that forming cooperations with foreign companies with recent experience is essential. Also, the responsible consortium Tier 1 partner will be involved for supervision and other construction management activities. The potential NL share of the value of the works is therefore estimated to be in the range of 80 to 85%.

74 Ministry of Economic Affairs and Climate Policy of the Netherlands and Assytem, Workstream 3 – NPP delivery model battery limits & scope of supply, Appendix to TFS - Scope of Work & Deliverables; item 61.

75 Building platform means the area created by limited imported filling or by excavation and subsequent filling on the site on which a building is to be constructed. The project encompasses the main and the auxiliary platforms.

76 Blinding involves creating a level and flat surface for the foundation of a building or structure. It is a layer of plain concrete that is typically 50 to 100 mm thick and is laid over the prepared soil surface prior to the construction of the foundation.

77 One of the learnings from HPC has led to carrying out more extensive ground investigation campaigns for Sizewell C. The campaigns have included approximately 1,500 locations, with numerous boreholes, trials pits and in situ mechanical tests undertaken through progressive investigations. Overall, this has covered 5,000 in situ tests and 5,000 laboratory tests, as well as roughly 69 km of seismic profiles.

78 E.g. the use of innovations as for the HPC project, such as modular, self-contained grouting trailers and the Ground Nail Installation Beam.

4.2 MAIN EARTHWORKS

Scope

Earthworks concern excavation of areas including the main reactor dig, and the processing and placement of engineered and landscaped fills for the main platforms. Approximately 5,5 million m^3 of soil and overburden is to be excavated. The scope includes treatment and reuse of the material. Deep dig entails deep excavation for the primary plant and will sink to approximately 31 metres. Soil nailing (98.000 m) and spray concreting (32.000 m^3) operations have to be undertaken during the construction of the excavation faces.

For facilitating the deep dig / excavation works, a dewatering system will need to be installed and operated. The dewatering installation programme is likely to comprise of multiple pumped dewatering wells (see footnote 73).

For the NNB-NL project site, all buildings (platforms) and structures, including sea water cooling tunnels, need to be completely piled to a considerable depth.

Required resources, skills and facilities

The work is related to the site preparation work and requires largely the same resources, skills and facilities. Also for the main earthworks, the responsible Tier 1 contractor will need experience from similar recent NPP new build projects.

NL capability

The work for site preparation and earthworks for the HPC project were carried out by the same contractors. This is also foreseen for the SZC project. Hence the same NL companies mentioned above for site preparation are expected to qualify for the work.

NL share estimate

The NL share of the value of the works is estimated to be in the range of 80 to 85% on the same grounds as described above for the site preparation works.

4.3 ENGINEERING AND DESIGN

Scope

This work package encompasses the civil detailed (engineering) designs. Although the buildings will be of a standardised design, the designs may need adaption to local soil conditions and seismic hazards. This concerns, in particular, the nuclear island buildings, including the reactor building with the reactor cavity (see Figure 12) and the fuel and safeguarding buildings. These are the most complex and important structures, needing to meet extremely high safety and safeguarding standards including seismic requirements. The work may comprise:

- Civil engineering studies for the buildings;
- Formwork execution drawings and steel framework of the execution works;
- Execution of the construction drawings for the pool liners and steel structure;
- On-site technical support during construction.

The turbine building and the cooling water intake structures need to be designed and constructed according to seismic category 2 requirements[79, 80] in which local site conditions should be taken into account.

79 ANVS, 2017, Seismic Design and Qualification for Nuclear Power Plants, June 2017, 103103.

80 The main part of the cooling water flow serves for condenser cooling, which is not safety relevant, and a small part for the component cooling system, which is safety relevant. This is reflected in the seismic requirements.

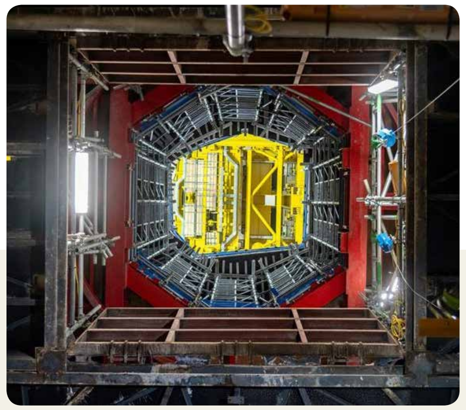
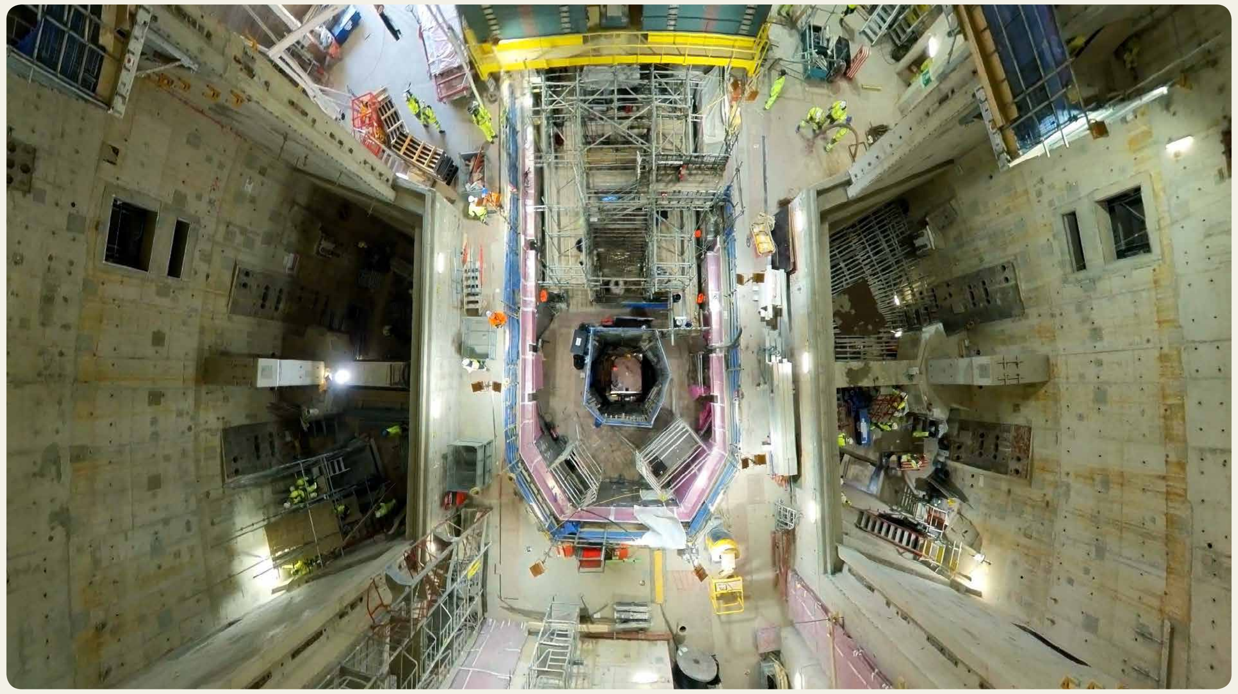


Figure 12. EPR reactor cavity. (Lane, 2024)



Required resources, skills and facilities

The nuclear island civil engineering and design work would require expertise and experience in previous NPP construction, including in a number of areas such as:

- Developing the technical guidelines and civil engineering principles (codes, tools, methodologies).
- Determining the requirements for the nuclear island building construction (e.g. definition and application of safety requirements, application of codes, installation interfaces).
- Overall design of nuclear island buildings: building architecture, functional specification, multi-discipline technical coordination and technical installation.
- Cross-functional and dimensioning studies: licensing, safety studies, structural dimensioning calculations, seismic studies, impact and explosion studies.
- Carrying out and/or managing civil engineering design studies (reinforced concrete, steel structures).
- Carrying out and managing structural dynamics studies (seismic, impacts) and drawing up methodology notes for structural analysis.

For the HPC and SZC projects, the nuclear island engineering and design work package was contracted to the ICOSH consortium made up of Egis, Jacobs UK, SETEC TPI and Tractebel Engineering. All of these companies have extensive experience in engineering and design of nuclear power plant buildings to seismic requirements.

Engineering and design for the turbine building and several other buildings require experience in seismic design. For a number of other buildings which do not contain safety-related equipment and which are classified as non-seismic, skills similar to regular power plant and industrial buildings are required.

NL capability

There are no NL civil engineering companies with the skills required for the engineering and design of the nuclear island buildings. This also pertains to the seismic class 2 buildings. For the engineering and design of the other buildings, a considerable number of NL companies would qualify. However, this entails a small fraction of the work package.

NL share estimate

Based on the above the NL share of the value of the works is estimated to be less than 5%.

4.4 MARINE AND TUNNELLING WORKS

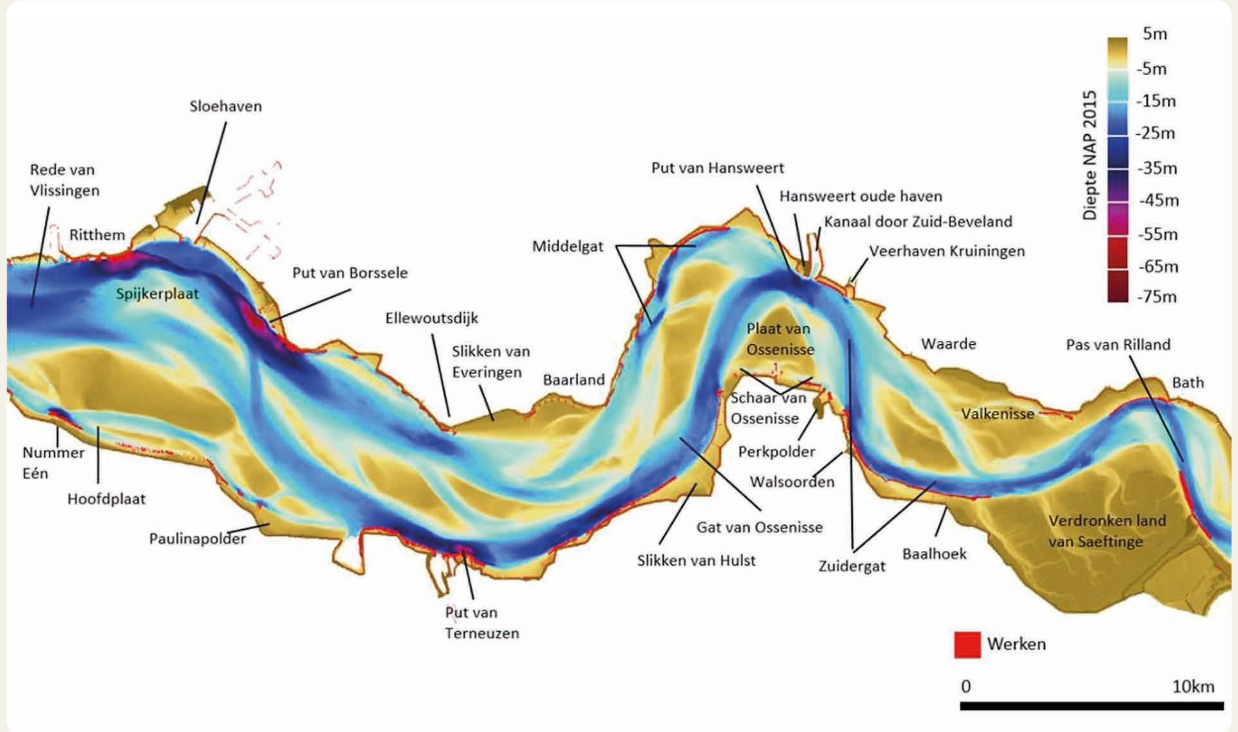
Scope

The marine and tunnelling works for the NNB-NL project mainly concern the construction of the cooling water tunnels and their connection to the cooling water pumphouse. Other likely parts of the scope include desalination plant intake and outfall, combined drainage outfall and fish recovery return outfalls. The scope of these works for the NNB-NL project is considerably smaller than the scope of these works for the SZC project, which also includes a beach landing facility, Marine Bulk Import Facility and temporary coastal defences[81]. For these reasons, the adopted value of this work package was based on half of the value for the SZC project.

However, the actual scope and value can be even less than this. In the TFS it is suggested that for the Borssele site, cooling water could be drawn either from the Westerschelde or from the De Citters harbour, the option to be decided by the Vendor[82]. As a third option, water could be taken in from the harbour and discharged to the Westerschelde. In case of the first option, the two cooling water intake tunnels and the outfall tunnel would extend less than 1 km offshore to the Oostgat trench, which reaches its maximum depth of 67 metres near Borssele (see Figure 13) and which would allow the outfall tunnel opening to be positioned above the openings of the intake tunnels, avoiding recirculation of discharged water to the intake. All three options are likely to be less costly than the corresponding works for SZC.

81 Association (www.sizewellc.com/wp-content/uploads/2024/05/240416-Main-Development-Site-Forum-Presentation-Pack.pdf).
82 During operation, the SZC intakes would abstract seawater at a rate of ca. 131.8 m3/s (two x 65.9m3/s for each intake tunnel) during standard operating procedures; see footnote 83.

Figure 13. Depths of the Westerschelde with the deepest point near Borssele (the "Put van Borssele")[83].



83 Deltares 2020, Moeilijk-erodeerbare lagen in de Westerschelde. https://www.deltares.nl/expertise/publicaties/moeilijk-erodeerbare-lagen-in-de-westerschelde-onzekerheden-en-gevolgen-voor-morfodynamiek

The discussion below is based on the first option, i.e. both cooling water intake from and outfall to the nearest suitable coastal inlet. The off-shore cooling water infrastructure would then consist of subterranean intake tunnels (typically two) and one outfall tunnel[84]. Work would commence to construct the marine launch chambers and bore the intake and outfall tunnels from adjacent to the cooling water pumphouse at the main platform[85].

The tunnels would be bored using tunnel boring machines (TBM; see Figure 14) from land at depths of approximately 30 metres under the seabed. The tunnels would be typically lined with concrete segments forming lining rings. The specific tunnel boring machine method is dependent on the underlying geology. A tunnel boring machine slurry method would be a likely scenario for tunnelling.

Connections between the intake and outfall structures and the bored tunnels could be made via lined vertical shafts bored from the seabed down to the tunnels and capped with large intake and outfall heads, each weighing close to 5.000 tonnes. The heads will likely be transported by barge to the site from their construction site. They have to be lowered into place by large marine cranes mounted on large surface barges or jackup vessels.

The intake and outfall headworks would be prefabricated off-site and floated into position. Prior to the installation of the headworks small scale dredging will need to be done to remove surficial sediments to the underlying bedrock.

Required resources, skills and facilities

The marine cooling works tunnelling works require in particular tunnel boring experience and associated machinery. In addition, specific large offshore vessels and equipment are needed for installing the heavy cooling heads.

NL capability

There are a number of major, internationally operating and renown NL companies with the required capabilities, including Ballast Nedam, Boskalis, Deme, Van Oord and Dutch Offshore and which would be fully qualified to realize the works. The Westerschelde tunnel however was built by a consortium consisting of foreign (Frankl NV, Philipp Holzmann AG and Wyss & Freytag AG) and NL companies (BAM Infrabouw BV, Heijmans NV and Voormolen BV), which would indicate that specific capabilities from elsewhere could be needed.

NL share estimate

For the major construction works, joint ventures with foreign companies experienced in NPP new build will be necessary. This also includes the tunnelling works. Based on the above, the NL share of the value of the works is estimated to be in the range of 60-75%.

84 Sizewell C, 2020, The Sizewell C Project 6.3 Revision: 1.0. Volume 2 Main Development Site, Chapter 22, Marine Ecology and Fisheries, Appendix 22M - Sizewell C Marine Ecology and Fisheries Final Scoping Report. Edition 2 (part of the EIA application).

85 Sizewell C, 2020, The Sizewell C Project 6.3. Revision: 1.0. Volume 2 Main Development Site, Chapter 3, Description of Construction (part of the DCO application).

Figure 14. TBM used for HPC, giving an impression of dimensions. (Taylor, 2020)

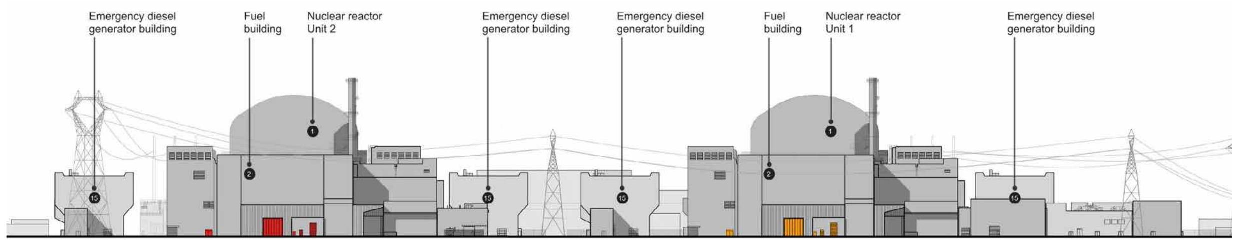
Figure 15. Tunnelling for the outfall and intake systems at Hinkley Point C, showing prefabricated concrete liner segments. (Moore, 2019)

4.5 CONSTRUCTION OF THE NUCLEAR ISLAND

Scope

The nuclear island (see Figure 16) will comprise a number of buildings (sixteen for the UK EPR), of which the Reactor Building is by far the most complex one. The other buildings are arranged around the Reactor Building or are adjacent to it (see Figure 17). Other safety-related buildings include the Nuclear Auxiliary Building, two emergency Diesel Buildings, the Radioactive Waste Processing Building, and Emergency Service Water (ESW)[86] intake structures, which are located on individual basemats.

*Figure 16. **SZC Nuclear island west elevation at 1:2.400. (EDF Energy, 2011)***



The Reactor Building is housed within a protective, steel lined, double concrete shell structure (see Figure 18) that withstands external hazards, such as earthquake and explosion loading, whilst the reactor dome itself provides a 'double enclosure' to resist events such as aircraft impact.

The dome shaped top part of the steel inner liner (or inner containment) typically weighs 245 tonnes and is 14 m in height. It is placed on the steel cylinder lower part, measuring 47 m in diameter and 30 m in height. Sections of the liner will be pre-fabricated within either the main platform or the temporary construction area and craned into position.

All nuclear island buildings will be constructed with reinforced concrete of the highest structural grade. Its surface must be accessible and available for regular visual inspection or maintenance. The concrete will be mixed using onsite batching plants in the temporary construction area. The concrete would be cast in-situ.

Required resources, skills and facilities

The works require the capabilities to execute high quality high standard reinforced concrete construction (see Figure 19). In addition, a considerable volume of high quality welding is involved. The total work volume may comprise 10.000 job years[87] as can be inferred from *Figure 9*.

The high quality standards of nuclear construction pose specific challenges to the concrete construction works as illustrated by the difficulties experienced during the OL3 and FL3 projects. The concrete quality should meet relatively narrow margins concerning composition and homogeneity. In addition, the geometries of the concrete pours can be very complex, necessitating specific concrete pour and monitoring methods.

86 The function of the ESW system is to remove heat from plant components which require cooling during normal operation (component cooling), for the safe shutdown of the reactor, and following a design-basis accident.

87 One job year is defined as one person in employment for one year.

*Figure 17. **The base for the first reactor, "J-Zero" at Hinkley Point C power station showing the quadrant structure of the nuclear island. (Taylor, 2020)***

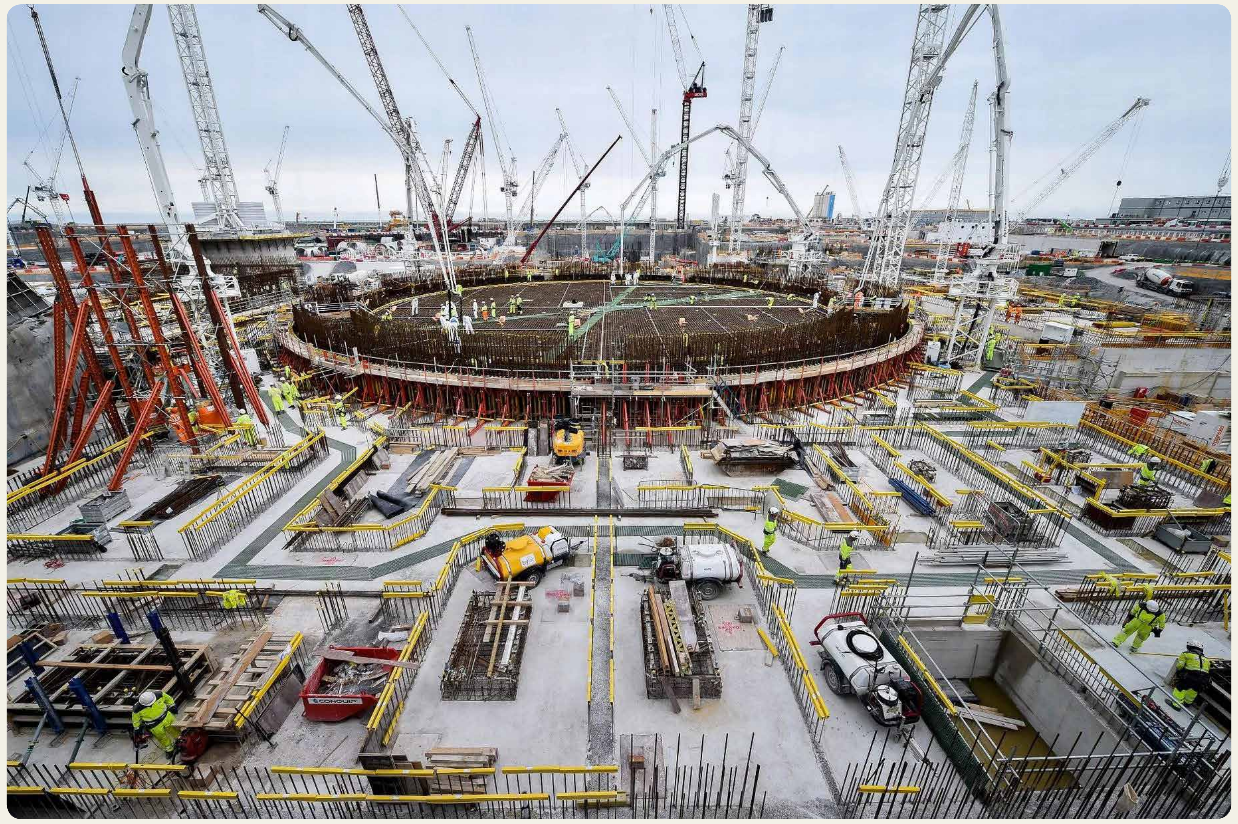


*Figure 18. **Lifting the dome of HPC unit 1. The dome weighs 245 tonnes and measures 47 metres in diameter and is made up of 38 prefabricated panels that were shipped to the construction site and welded together onsite using around 900 metres of welds. (Lane, 2024)***

Proficiency in advanced digitization methods is required. Extensive use will be made of advanced data management digital tools to achieve the required precision and speed. This refers for example to tracking and tracing of concrete batches. Every location of concrete needs to be traced back to the concrete production batch and its quality measurement record. Also the work in the field is executed on the basis of and supported by digital field information systems.

NL capability

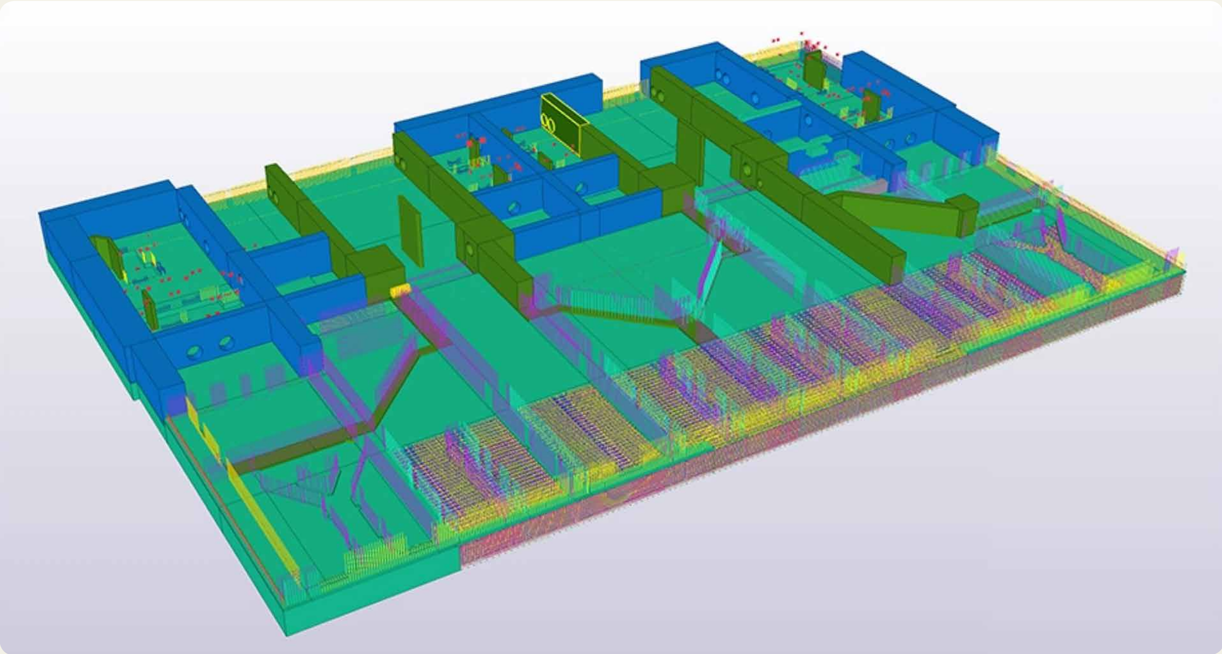
There are several large NL civil engineering companies, operating on major projects including internationally, with the capability to carry out much of the nuclear island construction work, in a capacity for taking responsibility for major parts of the scope of work (i.e. not merely supplying on-site workforce). These include Royal Bam Group (BAM), Ballast Nedam, Dura Vermeer, Heijmans, Visser-Hanab and Strukton.

However, these companies have no experience with the construction of nuclear island buildings, which is required because of the complex geometries, high quality standards including material homogeneity and traceability requirements, and site safety standards. It is therefore anticipated that much of the work will be delivered through joint ventures involving both NL and international companies, with foreign companies having a larger role than for the other civil works. In addition, the NL companies need upskilling, in particular in Nuclear Safety, nuclear quality assurance e.g. of concrete works and welding, and possibly also digital methods.

NL share estimate

Based on the above the NL share of the value of the works is estimated to be in the range between 50 to 70%.

Figure 19. Model of cast-in-place concrete structures at Hinkley Point C. (Tekla, n.d.)



4.6 CONSTRUCTION OF THE CONVENTIONAL ISLAND AND BOP

Scope

The conventional island (see Figure 20) consists of a group of buildings which includes the turbine halls, conventional island electrical building and the power transmission platform, all housing conventional island equipment.

The work also includes construction of several buildings such as the cooling water pumphouse (see Figure 21 and Figure 22) which are part of the BOP[88]. The pumphouse harbours the condenser cooling water pumps which supply the cooling water for the main steam turbine condensers and the service water system and are part of the BOP equipment scope of supplies.

The turbine halls and cooling water pumphouse would be classified in seismic category 2. The turbine buildings would be approximately 30m high, the turbine generator and associated plant would be located at lower levels, with support equipment and pipeline systems on intermediate floors around the periphery of the building. The upper section above the turbine floor would contain heavy handling equipment including overhead cranes and two gantries for installation as well as space for maintenance and replacement of this equipment.

Construction of pylons within the main platform would generally require excavation around the pylon base for foundations and hardstanding areas, for erection of the pylon by crane.

Figure 20. SZC main transformer platform (left) and conventional island unit 1 structures. (EDF Energy, 2011)

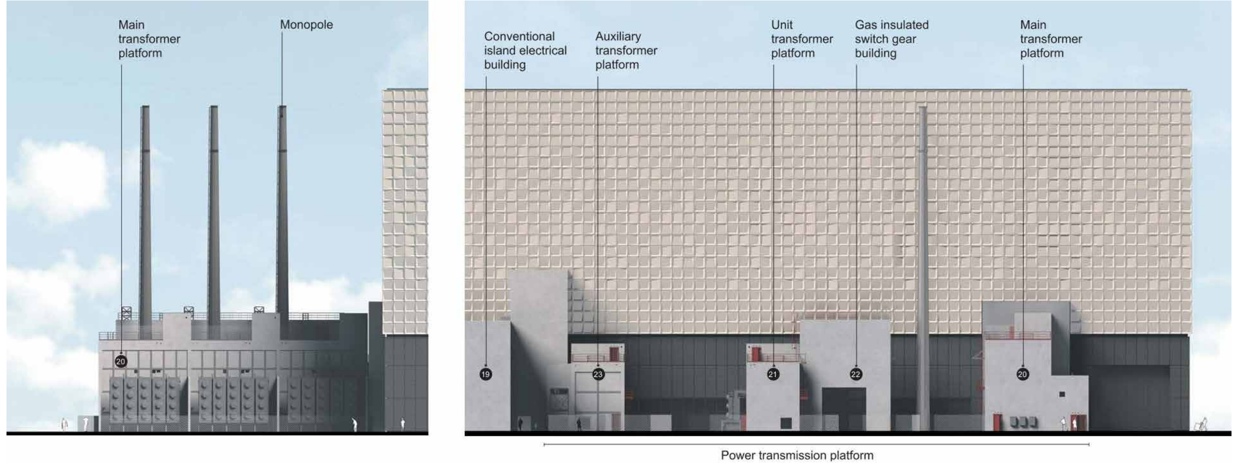
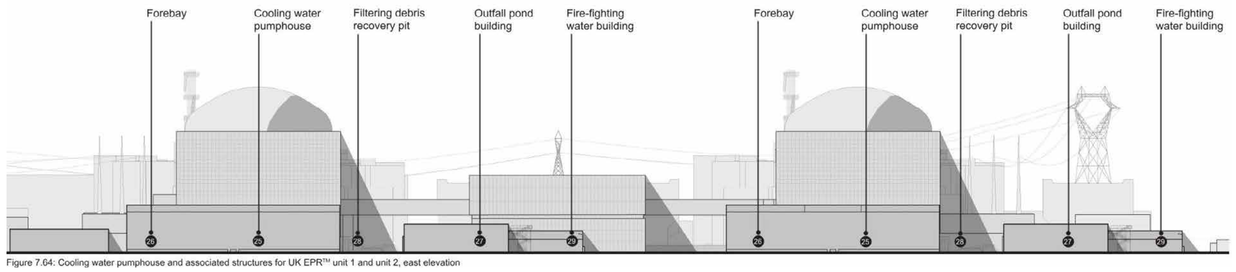


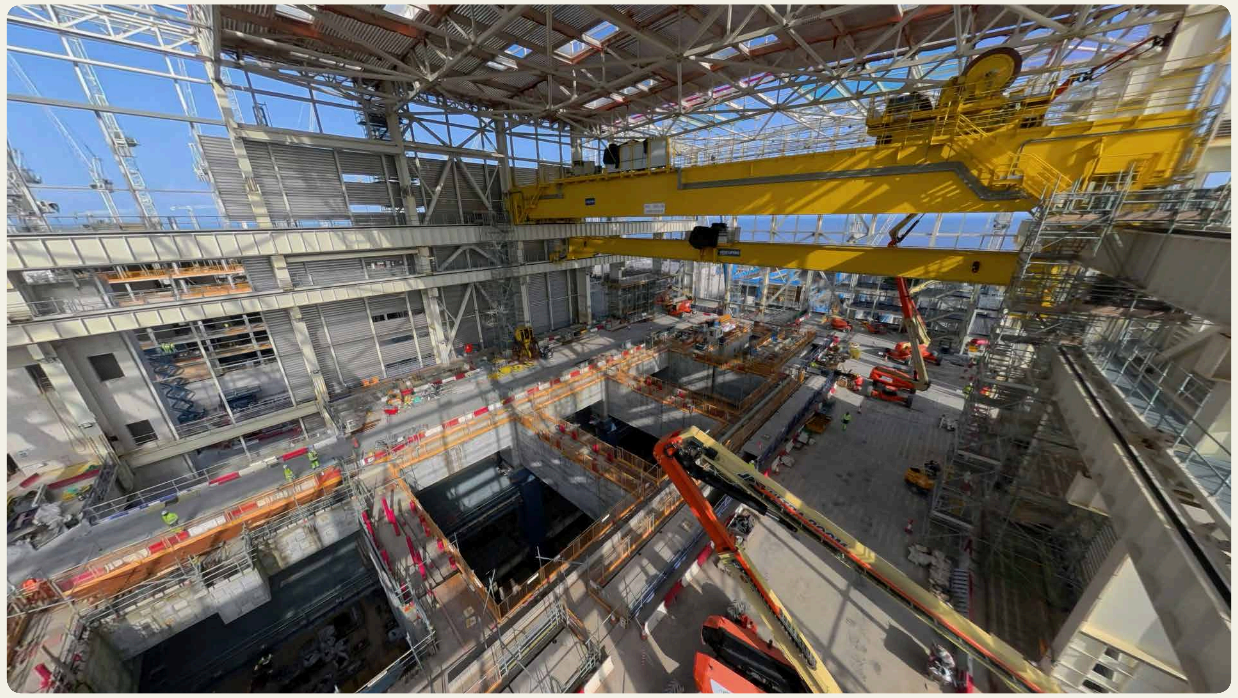
Figure 21. SZC cooling water pumphouse and associated structures. (EDF Energy, 2011)



88 Inclusion of the cooling water pumphouse in this work package is a consequence of the use of the work package structure of the civil works for SZC with the corresponding scopes and cost estimates.

Figure 22. HPC Unit 1 pumphouse. (Lane, 2024)

Figure 23. Inside the turbine hall of HPC unit 1 during construction. (Lane, 2024)



The majority of the conventional island buildings annexed to the turbine halls would be relatively small in scale and reflect the industrial nature of their function.

Concrete buildings within the conventional island would be constructed using similar methods to the nuclear island buildings.

Required resources, skills and facilities

The works largely require regular civil construction capabilities similar to those applied in construction of conventional power plants, and large industrial buildings for process industries. However, construction of the turbine buildings and cooling water pumphouse requires experience in construction of nuclear seismic classified buildings.

NL capability

The main civil construction companies as mentioned in section 4.5 above would also qualify for executing major parts of the work. However, the Eemshaven coal-fired plant, one of the last power stations built in the NL, was built by the Arge VIMA consortium, consisting of Visser & Smit Bouw (NL) and Mainka VOF, indicating that NL companies may seek foreign partners, e.g. for expertise on large construction projects and risk-sharing. It should also be noted that the Eemshaven project involved a large number of both NL and German sub-contractors, showing that companies tend to sub-contract to known trusted partners.

Several specialist NL companies have experience with civil construction work for conventional power plants. For example, Doka provided the formwork solutions to build the turbine building, silo building, steam generator plant and main switchgear building for the Eemshaven coal-fired station.
The responsible Vendor consortium partner is likely to be involved in construction management.

NL share estimate

For the major construction works, joint ventures with foreign companies experienced in NPP new build would be necessary. This also includes the conventional island and some BOP buildings. Based on the above the NL share of the value of the works is estimated to be in the range of 60 to 80%.

4.7 ANCILLARY WORKS

Scope

The ancillary works include a group of buildings containing a broad range of support structures and facilities which maintain the daily function of the power station. The buildings house BOP equipment, such as the demi station, auxiliary boilers, hydrogen storage, hydrazine storage, NI and CI water storage tanks, chlorination plant, the Operational service centre, and fuel and waste management buildings.

The buildings surround the nuclear and conventional islands and although they have certain adjacencies, the majority are flexible in their location when compared to the nuclear and conventional island structures. They are predominantly above ground structures and can therefore be sited in the space between more fixed prominent structures (see Figure 24).

For the NNB-NL project, a number of ancillary buildings are assigned to the Owner scope (see section 8.3) and the SZC cost estimate for these works is split into EPC and Owner scope accordingly.

The applied building material may consist of exposed in-situ concrete which requires inspection and maintenance and in a similar nature to the structural grade finish of nuclear island buildings.

Figure 24. Ancillary buildings aerial overview of SZC including plant and storage facilities. (EDF Energy, 2011)

Required resources, skills and facilities

The ancillary works concern regular industrial buildings. The construction of these buildings requires regular civil construction capabilities similar to those applied in construction of industrial buildings constructions of varying sizes.

NL capability

The main civil construction companies as mentioned in section 4.5 above would also qualify for executing major parts of the work. In addition, many smaller civil engineering and construction companies would qualify. However, also for these works, the responsible Vendor consortium partner is likely to be involved in construction management.

NL share estimate

Based on the above the NL share of the value of the works is estimated to be in the range of 80 to 85%.

4.8 SITE OPERATIONS AND LOGISTICS

Scope

Site operations and logistics refer to supply and on-site transport of bulk materials and products, heavy lifting, equipment supply services, logistics and freight management, accommodation and bussing, and site infrastructure and facilities.

For the continuous supply of the large quantities of concrete needed for the civil construction works including foundation piling at the required quality standards, a number of high-standard on-site concrete batching plants are required during the construction period. Typically, a nuclear power station will require 3.000.000 tonnes of aggregates during the construction[89].

Approximately 230.000 tonnes of steel reinforcement will be required. This comprises steel in various sections and sizes together with the associated fabrication. The steel has to be cut, bent and fixed to tight tolerances to form the reinforcing matrix around which the concrete is poured.

Approximately 60.000 tonnes of structural steel will be required. Building cladding may be applied to make the buildings weather and watertight and generally protect them from the elements. The nuclear industry uses existing branded products which are well understood, well specified and have proven design lives.

89 The construction of Eemshaven Power Station required approximately 360.000m³ of concrete, 8.000 driven piles, 1.000km of cables and 56.000t of reinforced steel.

Required resources, skills and facilities

This work package does require technical and logistics skills and facilities similar to those required for regular large construction works. However, the sheer size of the project, involving various construction activities with multiple contractors to proceed in parallel, imposes unusually high demands.

The construction requires high performance, low carbon concrete mixes which are achieved by precise and robust concrete mix designs and consistent, quality raw materials.

The production of concrete requires specific temporary on site batching plants, with combined single pour capacity of typically 9.000 cubic metres in five days. Multiple high volume - high quality batch-production units will be required, operating simultaneously achieving a standard deviation of e.g. two per cent or less. The design for the plants for the HPC project could be applied (D&C Engineering as subcontractor to Hanson Aggregates on behalf of contractor BYLOR).

The safety standards at a nuclear construction site are among the highest in the industry, of quite another nature than those for most regular construction works. Full and continuous compliance and commitment to the standards is of critical importance to project success.

NL capability

The same companies as mentioned in section 4.5 above would also qualify for executing major parts of the onsite logistics works. In addition, several specialised companies such as Peinemann and VolkerWessels would qualify. NL companies that would qualify for delivering the lifting works include Mammoet, Wagenborg Nedlift and Sarens. Several NL based companies are capable of supplying the aggregates for the project, such as Cementbouw, De Hoop and Putman group.

The concrete mixes for the HPC project were developed by Sika Limited working in partnership with BYLOR and concrete supplier Hanson. There are NL firms capable of providing the raw materials and the high quality mixes, including the NL branch of Sika.

NL share estimate

Based on the above the NL share of the value of the works is estimated to be in the range of 80 to 85%.

4.9 SUMMARY

The above estimates of the NL shares of the work packages of civil engineering and construction works are summarized in *Table 4* below. The overall NL share in the civil works is estimated to be in the range of 61-75%.

Civil works is generally considered as one of the parts of an NNB project most accessible to national companies in countries with a well-developed civil engineering and construction sector like the NL, which can deliver the required capabilities and achieve on-site labour workforce cost savings.
This is reflected in the relatively large NL shares in the civil works. On the other hand, NL companies do not have recent NPP construction experience, and hence do not qualify as Tier 1 supplier or as Tier 2 supplier on their own. Also NL companies cannot offer the full required scope of capabilities for a number of the major work packages, including main construction works and Marine and Tunnelling. Hence, NL companies need to form joint ventures with foreign companies experienced in nuclear new build will be necessary, which limits the potential NL share.

***Table 4.* Overview of NL share estimate for civil works**

		Scenario A		Scenario B	
Work package	**Cost (m Euro)**	**NL share (%)**	**Value (m Euro)**	**NL share (%)**	**Value (m Euro)**
Site preparation	589	80	471	85	501
Main earthworks	442	80	354	85	376
Engineering and design	354	0	0	5	18
Marine and tunnelling	589	60	354	75	442
Construction, NI	1.965	50	982	70	1.375
Construction CI and BOP	1.768	60	1.061	80	1.414
Ancillary works	156	80	125	85	133
Size operations and logistics	1.277	80	1.022	85	1.085
Totals	**7.140**	**61**	**4.368**[90]	**75**	**5.344**

Reasonableness assessment
The UK share estimates of civil construction and installation for UK nuclear new build projects were estimated in 2012 by Oxford Economics and Atkins as lying between 60% and 76%[91]. As stated above, the relevant capabilities of the civil engineering and construction industries of both countries are judged as being largely equivalent. Moreover, BAM has obtained experience of site preparation and earthworks in the HPC project, which the UK industry did not have in 2012. In addition, the Oxford Economics study resulted in an overall UK project share in the range of 44% to 59%, whereas for HPC an actual share of 63% is reported and for SZC an estimated share of 70%. This indicates that the Oxford Economics' estimates, which were used to determine the value of the UK nuclear supply industry to the UK economy, are conservative in nature.

From this it is concluded that the estimates of the overall NL share of the civil works of the NNB-NL project of 62% to 77% obtained in this report are consistent with the above mentioned UK estimates and can be considered as being reasonable.

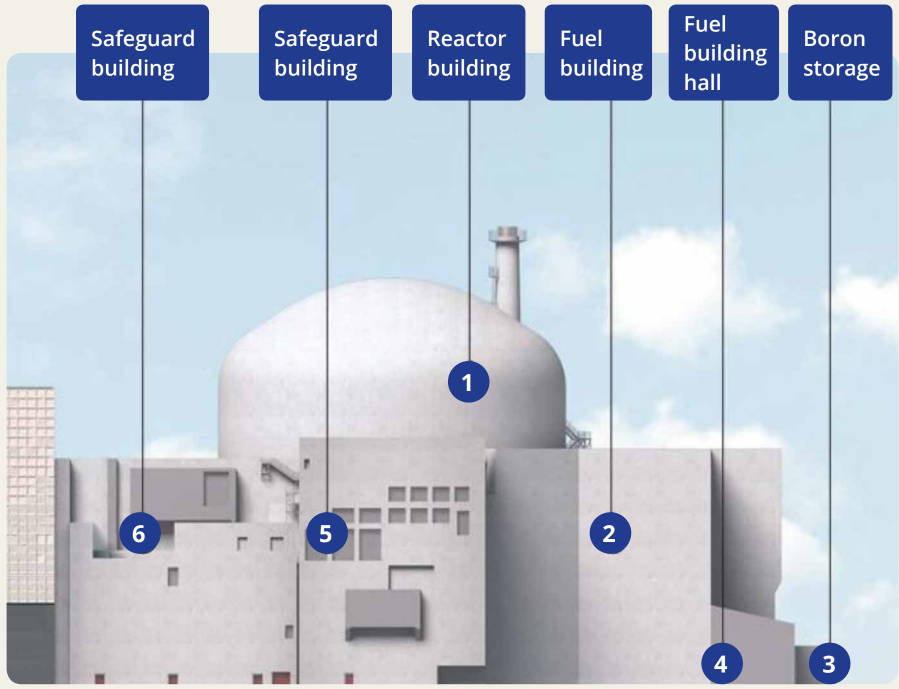
90 Here and in other similar tables the values reported in the table are rounded numbers and their summed totals may therefore differ slightly from the values reported in the Totals row.
91 Oxford Economics, 2013, The economic benefit of improving the UK's nuclear supply chain capabilities.

5

Nuclear island

The Nuclear Island (NI) work packages concern the supply and on-site installation of all equipment housed in the nuclear island buildings (see *Figure 25*). For the purpose of the present study, the scope is split into the Nuclear Steam Supply System (NSSS) and the Balance of Nuclear Island (BNI). The NSSS includes the reactor and is located in the containment enclosed reactor building. The BNI concerns various equipment necessary for the operation and safety of the reactor, located in buildings surrounding or adjacent to the reactor building (see *Figure 25*). This equipment includes safety systems, auxiliary systems, facilities for the receipt and interim storage of fuel and radioactive waste processing and storage. As said before, the discussion in this chapter is based on the EPR, which was adopted as the reference design for this report because of the availability of detailed information.

Figure 25. Nuclear island buildings for SZC, showing reactor building housing the NSSS and the auxiliary building housing the BNI equipment. (EDF Energy, 2011)



5.1 NUCLEAR STEAM SUPPLY SYSTEM

Scope

Core components
The core components of the Nuclear Steam Supply System (NSSS) include the reactor pressure vessel, steam generators, pressuriser, main coolant pumps and coolant lines (pipes).

Typically, a large PWR RPV will weigh 500 Tonnes and be 5m in diameter (inner), 13 metres high to the top flange and have 250 mm wall thickness. The closure head, containing all the penetrations for control rods, weighs around 90 tonnes and is bolted to the top of the RPV. The basic building blocks of an RPV are large and ultra-large forgings which can only be made in a few places throughout the world.

The steam generators (SGs) are vertical U-tube heat exchangers contained in high quality ferritic steel pressure vessels. The tubes are of special material (Inconel 690), welded into a thick tube plate and supported by special support and anti-vibration bars. Steam generators are delivered as complete equipment at the construction-site. An EPR steam generator weighs approximately 500 tonnes, is 25 metres high and is 5,5 metres in diameter with vessel wall thickness of around 250 mm.

The primary circuit main reactor coolant pumps are approximately 10 metres tall and weigh about 100 tonnes each. Hot, radioactive and pressurised water enters the pump from the bottom through the suction nozzle, passes through the impeller (rotating at 1.485 rpm) and exits through the diffuser and discharge nozzle to one side, at a rate of 20-28.500 m^3/h. The casing is an integral casting from austenitic-ferritic stainless steel. The other parts are made from forgings.

Instrumentation and control systems
The NSSS is generally supplied as one work package with a number of high integrity instrument and control (I&C) systems not located in the reactor building. For the EPR these include the Protection System which is the main I&C line of defence and performs the automatic safety-related (Safety category A[92]) functions that are needed to bring the plant to a controlled state if a design basis event occurs, and the Process Information and Control System, which performs Safety category A functions, besides lower level functions. The UK EPR in addition has a third analog back-up system.

Supply of the safety I&C systems typically encompasses design and engineering of some 150 I&C cabinets and manufacture, assembly and cabling of over 12.000 analog cards[93].

The NSSS work package usually also includes safety-related in-core neutron flux instrumentation, ex-core instrumentation, Flux Mapping Instrumentation, Reactor Pressure Vessel Level Instrumentation and Rod Position Measurement instrumentation.

HVAC systems
The Heating, Ventilation and Air Conditioning Systems (HVAC) systems function to contain radioactive substances and reduce radioactive releases to the environment for normal operating modes and transients, as well as abnormal events.

Various equipment, systems and structures
A very large polar crane will be supplied and installed within the containment buildings of each unit. These are used for heavy equipment installation and subsequent plant operations.

92 Classification according to IAEA, 2014, Safety Classification of Structures, Systems and Components in Nuclear Power Plants, SSG-30.
93 https://www.technicatome.com/en/our-activities/nuclear-reactors-and-facilities/hinkley-point-c-epr-ncss/

On-site installation
The installation of the various equipment will require large volumes of mechanical (in particular welding), electrical and instrumentation and HVAC on-site installation work.

Besides these, several services will be needed as part of the installation work such as:

- Automated Inspection of Welds. This is an integral part of the quality assurance and structural integrity of critical components in nuclear power plants. These inspections are carried out at various stages in manufacture (in manufacturing inspection, IMI), before plants go into operation (pre service inspection, PSI) and at various stages during the plant's operational life (in service inspection, ISI). For safety critical components, high integrity automated and manual non-destructive testing will be required. Typical components are: Reactor Pressure Vessel welds; Reactor Pressure Vessel nozzle shell welds; Steam generators vessel welds; Steam generator internals; Pressuriser; Pumps; Associated primary circuit pipework.
- Scaffolding is required for the construction of the majority of the main structure; extensive scaffolding is anticipated for the installation of mechanical and electrical equipment. Scaffolding can be classified as either for access or for support. The latter normally utilises proprietary systems and will be designed to suit the construction and installation processes. Access scaffolding is much lighter and is built to meet the relevant construction activity.
- A considerable number of tower cranes, mobile cranes and other specialised lifting equipment will be needed for the lifting and installation of e.g. the RPV, internals, and steam generators.

Required skills, resources and facilities

Manufacturing facilities
Both RPV and RPV closure head are fabricated from high quality ferritic steel forgings specifically developed to give the necessary tensile strength and toughness. The inside of the vessel and head are clad with stainless steel weld metal for corrosion resistance.

The Integrated Head Package comprises the Reactor Pressure Vessel head forging, the shroud assembly, the missile shield and the Control Rod Drive Mechanisms (CRDMs). This package is a critical, specialized package requiring extremely high quality and precision machining and assembly.

The manufacture of large and ultra-large forgings requires critical controlled metallurgical processes plus large melting furnaces and heavy equipment to manipulate the large, heavy, hot steel ingots. When the ingots have been forged into their approximate final shape large lathes are required to machine them to their final shapes and critical dimensions. It is a highly technical business involving large, specialised and expensive equipment. The increase in size from smaller equipment to large power station RPVs poses many metallurgical and manufacturing challenges.

A large PWR SG pressure vessel is manufactured from large ring and hemispherical forgings which are produced by only a few companies throughout the world. The U-tubes must be manufactured to tight tolerances. Only a few companies have this capability.

A main coolant pump consists of over 1.000 parts. The build requires approximately 2.500 manufacturing and inspection operations; some components' tolerances are down to microns. Manufacturing typically takes four years to complete. There are only a few companies worldwide capable to produce these pumps.

Certification to quality codes and standards
The NSSS systems are all classified as safety systems or safety relevant systems. Nuclear codes, such as the French RCC-M and US ASME III, will be used for the design, manufacture and installation of the mechanical NSSS equipment and e.g. IEEE 323-2003 and RCC-E for I&C and electrical systems and components. Primary circuit components, such as the reactor vessel, steam generators and primary pipework, are designated as nuclear safety class 1 components.

Only companies with strong metallurgical knowledge and experience of procurement and manufacture to top level nuclear standards (e.g. RCC-M Class 1, ASME III) would have the capability to supply NSSS components.

ASME III refers the users to the NQA-1 Quality Assurance Requirements for Nuclear Facility Applications (see footnote 14). Consequently, manufacturers of ASME-III equipment need certification (NQA-1 stamp)[94]. This requires a considerable effort of several years duration. The ASME Quality and Quality Control process is based on an exhaustive range of company and facility specific, generic prequalification assessments, which then enable the manufacturer to obtain a specific stamp, e.g. the 'N' stamp for nuclear components. There are also stamps for nuclear installers, nuclear parts and Nuclear Safety valve manufacturers. These stamps certify that companies have the right quality systems and work control practices to make the quality grade of components allowed by the stamp. ASME III, including certification to ASME III, is applied and accepted in many supplier and owner countries besides the USA, such as Korea and the Emirates[95]. This facilitates manufacturers to distribute the costs for obtaining and maintaining NQA-1 stamps over multiple export projects.

Unlike the ASME code, RCC-M does not include a manufacturer accreditation and certification system. This means that provisions for quality assurance equivalent to NQA-1 will have to be arranged by the Vendor as well as by the Owner/licensee, since they cannot revert to the NQA-1 provisions. Qualification of manufacturers of RCC-M equipment will therefore not be simpler or less costly than of manufacturers of ASME III equipment. To illustrate this, quality requirements in RCC-M are covered in Section A5000, which is brief compared with ASME III. In practice, additional requirements over and above that specified in RCC-M are imposed in France through French Law. The use of RCC-M outside of France could therefore be that the Vendor and Owner/licensee implement these additional measures by other mechanisms. These could include supplementing the RCC-M requirements with an 'RCC-M Adaptation Document' that will contain requirements corresponding with those embedded in French law (see footnote 14). These requirements will then be made available by the prospective Licensee to inform the supply chain of the additional measures required for use of the RCC-M under e.g. an NL licensing regime. RCC-M is internationally not as widely applied as ASME III. Qualified manufacturers of RCC-M equipment, in particular suppliers of French reactor technology equipment, are obviously already compliant to the existing, above mentioned, requirements.

On-site installation
Installation of the major NSSS equipment will require thorough and prolonged training and extensive experience. The NSSS supplier is therefore likely to use its own specialist engineering teams for installation of safety-critical components within the nuclear island. However, the supplier may need support and utilise NL partners or specialist subcontractors for supplementing workforce. These will need to be trained and qualified for nuclear construction labour concerning quality and safety standards. In addition, component specific training courses and facilities would be needed. This also holds for inspection services, lifting services, and scaffolding, which will be required for on-site equipment installation.

94 The QA requirements for ASME Section III are contained in Article NCA-4000 in Subsection NCA; specifically, paragraph NCA-4134. There are 18 sub-paragraphs that reference the 18 Requirements of Part 1 of the ASME Standard NQA-1 "Quality Assurance Program for Nuclear Facilities". Because NCA-4134 addresses the requirements for Section III, for many of the elements there are additional requirements, and these are identified in each sub-paragraph. A certificate will be granted only after the applicant successfully demonstrates the adequacy and effective implementation of their quality program.

95 https://www.enec.gov.ae/suppliers/supplier-education/supplier-development/nuclear-quality-assurance-nqa-1-/

NL capabilities

Equipment manufacture and classified I&C
The NL currently has no NSSS equipment and safety-classified I&C manufacturing capability. Neither do NL companies supply mechanical equipment and components for the NSSS of existing reactors nor are involved in nuclear construction projects. There are no NL companies that are certified to ASME NQA-1 or compliant to the equivalent RCC standards. The same holds for I&C and electrical equipment.

The investments required to realise this capability are significant as can be understood from the above. For example, steam generator (SG) manufacture involves mechanical design, manufacturing the pressure vessel from ring/hemispherical forgings, installing all tubes by welding them to the tube plate and fitting anti-vibration bars, installing the steam/water separation and steam drying equipment. To achieve this, a team of engineers and technicians has to be trained in factories of existing suppliers and special jigs and fixtures have to be manufactured in a factory in the NL. Such investments are only profitable if follow on SGs will be manufactured for other NL PWRs and for export. The latter is unlikely to happen given that current manufacturing capacity worldwide is more than sufficient for any realistic market prognosis.

First fuel load
As stated in Chapter 3, in this report the first fuel load is included in the NSSS cost. Urenco Netherlands is a globally significant supplier of enrichment services, well capable of supplying these services for the first fuel load of the new NL plant. Enrichment services would contribute 1,3% of the NSSS cost[96].

Cranes and lifting equipment
The NL could supply these items through the NL branches of global suppliers such as KoneCranes. The same holds for other types of crane and lifting equipment.

On-site installation
Bilfinger, VINCI/Actemium, Equans and SPIE could provide qualified teams by combining technicians with experience in nuclear construction from their mother companies with technicians from their NL daughters.

Automated inspections of welds
NL companies play a significant part in the European market for In Service Inspections of operational nuclear reactors. They are at the forefront of technology for the provision and performance of state of the art automated and manual NDT inspections of critical nuclear power plant components. These companies are supported by an infrastructure of smaller NL and European companies supplying specialised non destructive testing (NDT) equipment and services. Several of the NL companies have cooperation arrangements with other European and international inspection companies and often work together to supply teams for specific inspection projects.

Heavy lifting services
There are several large NL heavy lifting companies with experience in NPP construction and major large component replacement projects, in particular of steam generators. These include Mammoet and Sarens. They can be supported by several major logistics companies also offering heavy lifting services.

96 As stated in Chapter 3, the first fuel load would amount to 1,5% of the OCC. According to the WNA, enrichment contributes 24% to total fuel costs (WNA, 2023, Economics of Nuclear Power, updated Friday, 29 September 2023). The NSSS cost are 27% of total OCC.

Scaffolding
Major specialised scaffolding companies in the NL include Hertel, currently supplier of KCB/EPZ. These companies have the required resources, safety record and nuclear project experience to be considered for these projects. These companies are capable of providing scaffold design services, along with suitably qualified personnel both managerially and operationally, to successfully supply the necessary services for the NNB-NL project.

NL share estimate

Equipment supply
Equipment supply and installation of the NSSS is in practice contracted as one work package to one of the few vertically integrated reactor technology providers worldwide. For example, the NSSS contracts for the OL3, FL3, HPC and SZC EPR NNB projects, covering the supply and installation of the nuclear steam supply systems plus safety and I&C systems, were awarded to Framatome.

The NSSS supplier may subcontract specific parts of their scope of supply to other companies. For HPC, Framatome contracted Bilfinger for design, fabrication and installation of the core meltdown stabilisation system. Bilfinger would therefore also be capable of supplying such systems to the NNB-NL project through its NL daughter company Stork.

The NL industry's potential share of delivering NSSS equipment supply for the NNB-NL project is therefore assessed as ranging from 2% to 5%.

On-site installation
NL companies could deliver part of the on-site installation workforce and the larger part of services, in particular for in service inspection, heavy lifting and scaffolding. The potential NL share is estimated as ranging from 15% to 20%. The latter would require a substantial effort in skills training and in nuclear construction practices, in particular Nuclear Safety.

5.2 BALANCE OF NUCLEAR ISLAND

Scope

The Balance of Nuclear Island equipment encompasses a variety of systems, including safety related systems, fuel handling systems, waste processing facilities and support facilities. In addition, considerable volumes of piping, valves, pumps and cables are needed, denoted here as large-volume components.

Safety related systems
These systems carry out critical safety functions, either associated with power generation or with safeguard protection. Consequently, these systems will be designed, manufactured and installed in accordance with the various codes and standards mentioned above. The mechanical parts of the system may be designed and manufactured to a nuclear design code, such as RCC-M class 2 or 3 or ASME B&PV section III under the requirements for code class NC and ND. In addition to the code requirements there are often requirements for the systems to be qualified to operate under various environmental, radiological and seismic conditions.

Typical safety critical systems for a PWR are:

- Safety injection systems (passive and pumped injection);
- Chemical control and clean-up systems;
- Cooling water systems;
- Rapid boration systems;
- Post-LOCA containment spray systems;
- Decay heat removal systems.

Diesel generators and UPS
In addition to the main power train there would be a requirement for standby or emergency diesel generators (EDGs) to provide back-up electricity in the event of a loss of grid supply. For the EPR, there is a requirement for 30 MWe capacity (4 x 7,5 MWe units, each with thermal input of 17,6 MW). There will also be a requirement for two ultimate emergency backup (station black out – SBO[97]) generators, each to generate 2,5 MWe (6 MW thermal input). As the AP1000 has passive safety features which do not rely on emergency back-up electricity, the standby diesel generators are smaller. The generators could be equipped with safety-classified digital diesel engine governors for NPP applications. The diesel generators are part of the On-Site Power System which also comprises Emergency Uninteruptable Power Supply (EUPS) batteries to provide power for typically two hours to loads connected to the category A distribution equipment required to place and maintain the plant in the safe shutdown condition, without utilization of the battery charger.

Refuelling water storage tanks
These tanks are essentially open pools within a partly immersed building structure. The wall of the tanks is lined with an austenitic stainless steel liner to avoid interaction of the boric acid and concrete structure and to ensure water tightness. Each of the four safety-related and two non safety related trains of a reactor is provided with a separate sump suction connection to the tanks.

97 Plant condition with complete loss of all AC power from off-site sources, from the main generator and from standby AC power sources important to safety to the essential and non-essential switchgear buses.

Fuel storage facilities
The fuel storage facilities include the water-filled storage pool for new and recently spent fuel and associated handling equipment and ventilation systems. The major components of the system are the Refuelling Machine, the Spent Fuel Handling Machine, the Fuel Transfer System, and the New Fuel Elevator.

Radioactive waste facilities
These encompass the majority of the processing and storage facilities for radioactive liquid and solid radioactive waste produced on-site, and include equipment for the hot laundry facility (laundering radiologically contaminated garment). These also include:

- Hot workshop for engineering work on radiologically activated or contaminated plant components such as valves, pipes and pumps.
- Hot warehouse for storage of activated or contaminated tools and components such as the multi-stud tensioner or spare reactor coolant pump motors.
- Facilities for decontamination, i.e. reduction or removal of radioactive contamination from tools, components or wastes.

Ventilation stacks
A stack will be installed on each unit. These are 30-40m tall. Each ventilation stack houses measurement equipment and temperature sensors, to survey gaseous waste released during the operational phase. The stacks will be installed on the roofs of each of the fuel buildings within the Nuclear Island.

Control rooms
The UK EPRs have two digital main control rooms and an emergency control room. The Heating, Ventilation and Air Conditioning Systems (HVAC) systems function to ensure habitability of the Main Control Room (MCR) and Emergency Control Room (ECR) during all states.

Large-volume components
The scope of work comprises the supply of some 110km of piping systems and considerable numbers of valves, pumps and tanks including their installation for each reactor unit. Part of these components is related to the safety-related equipment mentioned above, and is safety-classified. These components including their drivers are designed to pressure equipment codes RCC-M or ASME and are capable of operating during and after seismic events.

A number of BNI systems contain tanks, pressure vessels and heat exchangers. A limited number of these are nuclear safety class 2 (see footnote 92) but many are class 3 or non safety critical equipment. The size ranges from 4m diameter by 10m high, down to small vessels less than 1m diameter and the wall thicknesses are usually less than 30mm.

Some of the shell and tube heat exchangers are complex with some tube sheets up to 300mm thick. There are also some industrial standard tube and plate heat exchangers.

The work will require large-volume electrical and HVAC components, the supply of which is included as part of the installation contracts. The electrical components comprise power and instrumentation cables, cable containments, switchboards and lights. HVAC components include supports, in line fans, ducts, dampers and filters.

On-site installation
The BNI scope of work requires a considerable workforce of mechanical, electrical and I&C and HVAC installation technicians. Besides installation of equipment, this concerns installation of all interconnecting piping and associated valves and pumps, as well as cables, cabinets and HVAC equipment. In addition, the work will require in service inspection, lifting and scaffolding services.

Required skills, resources and facilities

Safety related systems
The safety related system equipment will need to be designed, manufactured and installed by companies which have a robust quality management system accredited to ISO 9001 and which are aligned with the requirements of ASME NQA-1, RCC-M/E or IAEA-GS-R3 or GSR Part 2. Besides skills, an established status as supplier for nuclear construction is important. For the FL3 and HPC projects, all BNI equipment was supplied by established suppliers of nuclear components and systems.

Fuel storage facilities
The equipment needs to be designed and constructed to specific nuclear standards[98].
The emergency diesel generators

By industrial standards the diesel generators required on a nuclear power station are relatively large and need to be highly reliable. The diesel generators have to comply to Nuclear Safety standards, e.g. IEEE 387 and the digital engine governor to the requirements of the Nuclear Safety standard IEC 60880 for software based category A systems (see also footnote 92 concerning the generic categories of safety functions with letter A, B or C and classification of components with Figures 1, 2 or 3.)

Control rooms
In practice, the main control rooms, emergency control rooms and full-scope simulators are contracted to reputed established suppliers. For example, the two Main Control Rooms for HPC were supplied by the French Efinor – EES-Clemessy consortium in one contract together with the full-scope simulator. The main control rooms were manufactured at the suppliers manufacturing facilities, shipped as one module to the construction site and lifted in place.

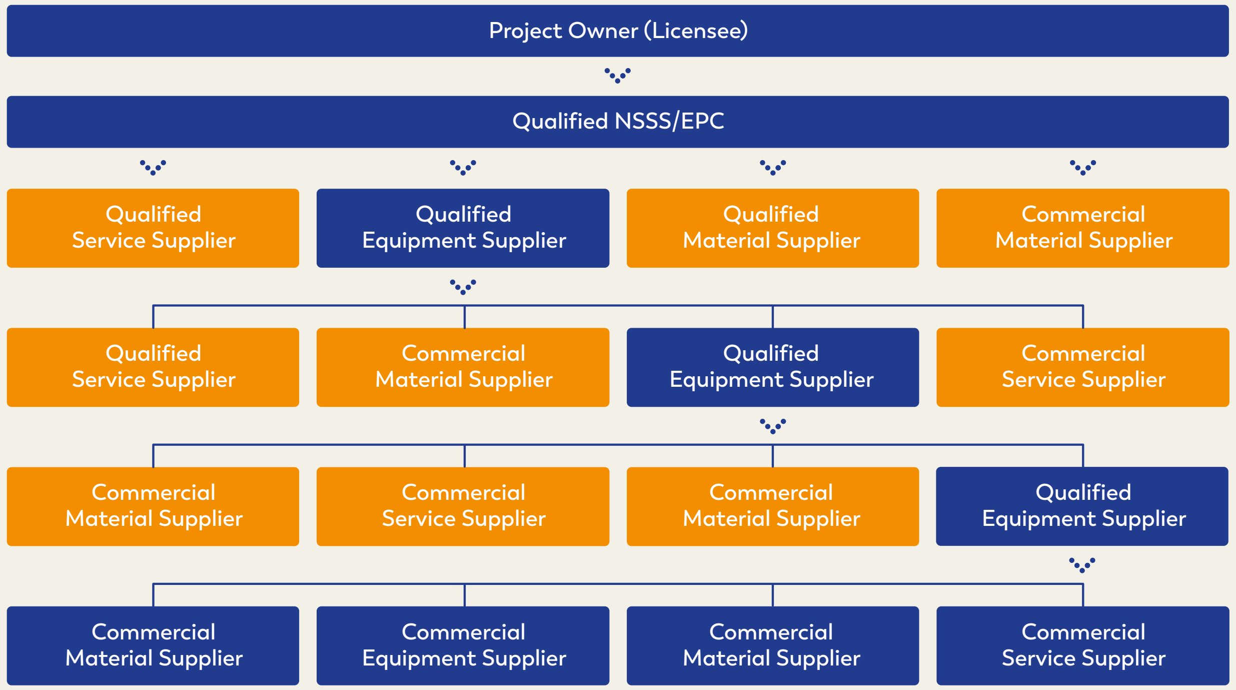
Certification to quality codes and standards
Safety related equipment for BNI components are designated Class 2. Other BNI equipment is designated as Class 3 components, having a lesser Nuclear Safety significance. The sourcing of the various classes of components from the supply chain is shown Table 5. Figure 26 shows how nuclear quality standards propagate down the supply chain. It is very unlikely that lower tier contractors will require the above stamps.

Table 5. ***The sourcing of the various classes of components from the supply chain*** *(see: footnote 14).*

Designation	Type of Company	Applicable Codes	Tier of Supplier
Class 1	Technology Provider	Nuclear Codes such as RCC-M, ASME III, RCC-E plus additional requirements	Technology Provider and specialist manufacturers
Class 2	Nuclear experienced companies with proven Quality Systems certified to ISO 9001 and equivalent to ASME NQA-1	Nuclear Codes such as RCC-M, ASME III, RCC-E plus additional requirements	Tier 1 and Tier 2
Class 3	Companies with experience of producing high quality equipment with QMS arrangements certified as being compliant with ISO 9001		Tier 2 and Tier 3
Industrial Equipment	General industrial companies with QMS that meet ISO 9001 requirements	EN or National Standards; Pressure Equipment Directive and Regulations	Tier 2 and Tier 3

98 These could include American Society of Mechanical Engineers, Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder), ASME NOG-1, American National Standards, New York (2015) or equivalent codes.

Figure 26. Propagation of nuclear quality standards down the supply chain. (SDF, 2017)



Large-volume components

Large-volume components will partly be to ASME or RCC-M/E specifications and partly to industrial standards.

On-site installation

The skills requirements for installation of the safety classified equipment pertain to quality requirements and are largely similar to those for NSSS equipment. As for the NSSS equipment, installation of safety critical BNI equipment will require thorough and prolonged training and extensive experience. The equipment suppliers are therefore likely to use their own specialist engineering teams for installation of safety-critical components within the BNI. The supplier may need support and utilise NL partners or specialist subcontractors for supplementing workforce.

NL companies may qualify for providing larger parts of the workforce needed for the installation of the interconnecting piping, and associated valves and pumps, cables, cabinets and HVAC equipment. However, these will in part need to be installed to seismic standards. Workforce needs to be qualified for nuclear construction labour concerning quality and safety standards, requiring adequate training and preferentially experience in NPP construction works. This also holds for inspection services, lifting services, and scaffolding.

NL capabilities

The NL currently has no capability for manufacturing BNI safety-related systems. The investments and time required to realise a significant capability are similar to those mentioned above for NSSS equipment.

NL companies could deliver part of BNI systems such as the ventilation stack, waste storage facilities and the hot workshop.

The NL industry could also provide a significant part of the BNI large-volume components. This holds for tanks and heat exchangers, which could be supplied by NL companies such as Schelde Exotech and Alfa Laval currently supplying to other highly regulated and sensitive industries such as oil, gas and petrochemical. This would require upgrading of quality systems to those required for nuclear construction however. In addition, piping could be supplied by Bilfinger SE through Stork. Also, SPIE Nederland could qualify for the delivery of electric equipment through its French mother company.

The EUPS batteries for HPC were provided by Hoppecke UK and likewise the NL branch could supply this equipment to the NNB-NL project.

Moreover, a significant part of the BNI equipment installation could be supplied by NL companies such as Stork and SPIE, through the nuclear construction expertise of their mother companies. These could be supported by several larger companies active in industrial installation, such as BAM Industry and CroonWolterDros-TBI.

NL share estimate

Based on the above, the potential NL share of supplying equipment for the BNI is estimated to be in the range of 5 to 15%.

For on-site installation, the potential NL share is estimated as ranging from 30 to 50%.

5.3 SUMMARY

The above estimates of the NL shares of equipment supply and installation activities for the Nuclear Island are summarized in Table 6 below.

As said before, the actual accessible NL shares in the work packages will also be determined by other factors than the factors addressed above. These are in particular the Vendor's assessment of the NL industry capabilities and his appreciation of the risks of localisation to project cost and schedule.

Table 6. Overview of NL share estimates for the nuclear island equipment supply and installation activities.

		Scenario A		Scenario B	
Activity	Cost (m Euro)	NL share (%)	Value (m Euro)	NL share (%)	Value (m Euro)
NSSS Equipment supply	4.498	2	90	5	225
NSSS Equipment installation	1.928	15	289	20	386
NSSS total	**6.426**	**7**	**379**	**12**	**610**
BNI Equipment supply	2.166	5	108	15	325
BNI Equipment installation	928	30	278	50	464
BNI total	**3.094**	**13**	**387**	**20**	**789**

Reasonableness assessment
The estimates for the UK share of the NSSS of new build projects in the UK reported by Oxford Economics and Atkins[99] are lying between 10% and 22% and of the BNI between 30% and 54%. The actual UK shares are likely larger, judging from comparison of the realized total share of 63% reported by EDF Energy for HPC and the expected share of 70% for SZC with the 44% to 59% as adopted in the Oxford Economics/Atkins study.

The larger UK shares reflect the presence of several Tier 1 and 2 suppliers of NSSS and BNI equipment and installation works in the UK, some of which are NQA-1 certified. Such companies are absent in the NL.

From this it is concluded that the estimates of the overall NL share of nuclear island works of the NNB-NL project summarized in Table 6 are consistent with the above mentioned UK estimates and the relative positions of the nuclear supply industries in both countries.

99 Oxford Economics, 2013, The economic benefit of improving the UK's nuclear supply chain capabilities.

6 Conventional island

The Conventional Island (CI) scope of work concerns the supply and on-site installation of all equipment located in the conventional island buildings. This equipment comprises all electricity generation installations and consists of the turbine generator and a number of smaller systems. This non-nuclear part of the plant is largely similar to the corresponding part of a conventional thermal power plant.

The Conventional Island can be grouped into three major systems:

1. Turbine Generator Package. Includes the steam turbine and its auxiliary equipment, the generator and its auxiliary equipment, the moisture separator reheater, the condenser, and the shaft line control system.
2. The Feedwater Plant Package. Reheats the condensate before it enters the nuclear steam supply system. Includes condensate pumps, heaters, feedwater tank, and feedwater pumps.
3. The Power Evacuation System. Exports power to the grid. Includes circuit breakers, transformers and switchgear.

For the purpose of this study, the scope is split into the Turbine-Generator Package and the Balance of Conventional Island (BCI) equipment (groups 2 and 3 above). The BCI equipment comprises all equipment except for the turbine generator package.

6.1 TURBINE GENERATOR PACKAGE

Scope

Turbine generator set
Water cooled reactors produce saturated steam at lower pressures than fossil-fired plants. Hence their steam systems and turbine are somewhat different. The steam supplied to the high pressure turbine is actually at an intermediate pressure so the steam volume is greater and the governor and stop valves larger. There are usually multiple parallel pipes conveying the steam from the steam generator to the turbine and provision is made for steam isolating valves in the steam lines at the reactor containment boundary to seal off the reactor in the event of an accident.

For the three PWR designs involved in the TFS, the electrical power per reactor unit is to be delivered through a single turbine generator unit so the power output of the machine is very large by power plant standards. For the EPR design, the power train has an electrical output of around 1.650MW per reactor. The turbine generator set is based on the ARABELLE™ turbine, originally developed by Alstom, now supplied by the EDF group. For the AP1000 design the power output is less at around 1.100MW; and for the APR1400 in between those. Current suppliers for the AP1000 and APR1400 are Toshiba and Mitsubishi, respectively.

Deaerator and the Moisture Separator/Reheater[100]
The Deaerator and the Moisture Separator/Reheater (MSR) are large pressure vessels, typically 10 metres in diameter and 30 metres long. They are each 200–250 tonnes in weight. The deaerator contains a series of internal buffers and the moisture separator/reheater contains a series of internal tube bundles. In some cases these items are installed as complete units but in other cases they are transported to site in sections and welded together in situ. There is usually one deaerator and two moisture separators/reheaters per reactor.

The deaerator and Moisture Separator/Reheater are sometimes be supplied as one integrated package in order to save space. This allows for more compact and less costly Turbine Island buildings and this is included in the building's design.

Condenser
The exhausted steam from the LP turbines is condensed by passing over tubes containing water from the ultimate heat sink (sea water from the coastal inlet). There is a main condenser unit under each LP turbine, sometimes below the turbine. The plant also contains an auxiliary condenser to condense steam from steam-driven feedwater pumps.

In practice, the main condensers are to be delivered as fully tubed modules, so that little welding is required on site. Also the condenser houses the first two stages of low pressure heaters for simplified arrangement of the turbine building.

Installation
The turbine generator supplier will normally take responsibility for the turbine generator installation and supply its own specialist engineers and technicians. Support will probably be required from NL subcontractors. This includes heavy lifting, scaffolding and NDT inspection.

Required skills, resources and facilities

It follows from the above that the required skills encompass manufacturing of the complete turbine generator package, including the deaerator and MSR and the condenser, are very demanding. The manufacture of these items will require large fabrication areas, mastering of special metallurgical technologies and manufacturing facilities with high capacity craneage. The key skills are machining, assembly of heavy sections, welding and post-weld heat treatment.

NL capabilities

At present there are no credible NL manufacturers of large turbine generator packages for PWRs.

There is no recent experience in the NL of the manufacture of the pressure vessels of the size and thickness of the deaerator and moisture separator and reheaters. Companies with ship fabrication facilities could possibly manufacture these vessels but they would require additional support from experienced pressure vessel manufacturers. This equipment has already been manufactured by established suppliers, such as EDF Arabelle Solutions for recently completed and ongoing EPR construction projects in Europe, Turkey, the UAE and the UK. It will obviously be possible for these companies to supply the equipment to the NL market. NL companies will find it difficult to compete because the existing suppliers will have developed all the design, the weld procedures, quality systems and manufacturing method statements.

100 Reheating is required at the lower steam cycle conditions to ensure adequate steam quality at the turbine exhaust. With the larger steam volume to be handled it is not practical to return the steam to its source for reheating and reheating is done locally in independent reheaters using some high pressure steam. Reheating is preceded by the removal of excess moisture from the steam leaving the high pressure turbine. Reheating with high pressure steam limits the maximum temperature of the reheated steam but there is still sufficient superheat to ensure that the low pressure turbine exhaust steam wetness is not more than about 10% wet.

Installing these vessels on-site is a complex task and no NL companies have the experience of the site erection of such large items at a plant. Installation of the turbine generator equipment will require heavy lifting, scaffolding and NDT. As for the Nuclear Island packages, there are NL companies qualified for delivering these services. NL companies such as Stork may qualify for providing workforce support for on-site installation.

NL share estimate

Based on the above, the potential NL share of equipment supply for the turbine generator package is estimated as negligible and of on-site installation as ranging between 5 and 10%.

6.2 BALANCE OF CONVENTIONAL ISLAND

The Balance of Conventional Island (BCI) includes supply of several major systems and large-volume components as well as mechanical, electric/I&C and HVAC installation works.

Scope

Major mechanical components
These include the feedwater pumps and main steam and feedwater pipes. Feedwater pumps serve to pump feed water in the secondary circuit from the de-aerator to the SGs. For the EPR there are three high-pressure electric motor-driven pumps, each with a capability of providing 33% of the rated flow[101].

Also standby pumps are required, which in the event of a fault with a main feed water pump are brought into service with further back up from emergency feed water pumps.

The feed water pumps have to be designed to be capable of continuous operation with total reliability and availability with little drop-off in performance, even during system transients. For the EPR, depending on customer requirement, the main feed water pumps can operate at constant speed or be equipped with a variable speed controller.

Pump sets have to be equipped with instrumentation which monitors and records all the major service and performance functions of the pumping set. This allows station engineers to monitor pump performance trends and obtain extended periods between major maintenance overhauls – usually 8/9 years.

The Main Steam System (MSS) delivers steam from the two SGs to the HP turbine during normal power operation through typically four main steam pipes. Each main steam pipe is provided with a main steam isolation valve for positive isolation against forward steam flow and isolation against reverse flow. Overpressure protection of the shellside of the SGs and main steam line piping is provided by spring-loaded main steam safety valves. In addition, the MSS will be provided with a main steam atmospheric dump valve on each of the main steam lines. These are part of the ultimate heat sink and hence are designated as safety category A.

101 Areva, 2011, Status report 78 - The Evolutionary Power Reactor (EPR).

Unit and auxiliary transformers

Each unit will comprise a unit transformer, an auxiliary transformer and a standby transformer[102]. The unit transformer transforms the generator voltage (26kV) to the voltage level (400kV) required for transmission. A unit transformer can be manufactured in one large single three phase unit, or three separate single phase units (see Figure 27). For HPC, the transformers were supplied by ABB, as six 700 Megavolt ampere generator transformers and six auxiliary transformers.

The auxiliary or generator transformer is part of the on-site power system and takes the generated power via the generator connections and step-down the voltage to a voltage level for use within the power station HV and LV electrical distribution system. Normally two auxiliary transformers are required for each power station unit.

The standby transformer is also part of the on-site power system and functions as a back-up for the auxiliary transformers.

Generator Circuit Breaker and Generator Connections

The power station exports power from the generators to the generator transformer via the power train, which comprises a set of generator connections and a generator circuit breaker. Normally during run up conditions, power is imported from the grid to the power station unit with the generator circuit breaker in the open position. At the appropriate time the unit is then synchronised by use of the generator circuit breaker and power is then exported from the unit. The generator connections and the generator circuit breakers are strategic pieces of equipment key to delivering power from the power station.

Electrical and I&C equipment

This grouping contains a number of supply only equipment contracts and a number of supply and installation contracts. The equipment is located throughout the turbine island, but also throughout the nuclear island and balance of plant, but is addressed here in order to avoid duplication.

102 NNB Generation Company, 2020, The Sizewell C Project, 8.1 Main Development Site Design and Access Statement – Clean Version – Part 2 of 3.

Figure 27. ***400 kV, 500 MVA single phase generator transformer in operation in a nuclear power plant. (ABB, 2011)***

Electrical equipment includes High Voltage (HV; 10kV) and Low Voltage (LV; 400 or 690V) switchboards, HV/LV (10kV/720V or 10 kV/420V) and LV/LV regulated transformers (400V/400V-230V) for the Nuclear Island, Conventional Island and balance of plant areas on both units. The equipment is part of the electrical power distribution and control distribution scheme. It provides secure, segregated, power and control supplies to the power plant. The scope would typically include supply of 22 HV switchboards per unit.

Within a nuclear power station the HV switchboards are Nuclear Safety related equipment located within the nuclear island. The LV switchboards are located within the nuclear island for strategic nuclear island and turbine island loads, and within the turbine island for normal power plant operations. The work includes technical qualification of products, manufacturing and installation supervision and commissioning supervision.

I&C equipment includes the supply of a variety of instrumentation equipment that will be installed across the site. The plant and materials supplied are intended for the control and safety functions, control and test measurements necessary for the normal and continuous operation of the industrial processes throughout the two units.

The I&C encompasses marshalling cabinets housing the electronic circuitry for the plant and linking the power station's control systems together. The work would encompass design, manufacture, and possibly installation of several thousands of cabinets, including 3.500 safety classified ones in case of the UK-EPR.

Large-volume components

These include mechanical, electrical and HVAC-components, as mentioned earlier in this report. The scope includes the fabrication and installation of approximately 4.500m meters of pipework, ranging from 0,1 to 0,5m with a mix of both carbon and stainless steel along with supports. Piping encompasses high-pressure piping and their supports, intermediate-pressure and low-pressure piping, and HDPE and GRP piping as well as their supports.

In general, an NPP contains large numbers of pipes, pumps, valves and cables, of which the major part is non-classified, as illustrated in the table below. Power cables in general need to comply to fire behaviour (IEC 60332-2-23) and fire reaction (IEC 607754-1 and -2) standards and filling and sheaths must be without halogen.

Table 7. ***Lengths and numbers of large-volume components of Shin-Kori 1,2.***
(OPR-1000, the predecessor of the APR1400 from KHNP) (Koo, 2015)

Total pipe length (km)	Safety	Non-safety	Total
Large pipes (>2,5 inch)	26,36	127,68	154,04
Small pipes (< 2,5 inch)	16,58	122,84	139,42
Total	42,94	250,52	283,46
Total cable length (km)	**Safety**	**Non-safety**	**Total**
Control cables	365,91	2.349,30	2.715,21
Instrument cables	364,06	1.397,03	1.761,09
Power cables	90,06	679,02	769,08
Total	820,03	4.425,35	5.245,38
Pumps and Valves	**Safety**	**Non-safety**	**Total**
Pumps	80	248	328
Valves	6.997	26.216	33.213

Required skills, resources and facilities

Major mechanical components
The major mechanical components of the secondary system such as pumps and piping are similar to those in conventional power stations and industrial facilities. However, the main steam piping, its isolation valves, safety and vent valves and part of the supports are seismic Category 1 and the safety function of the vent valves is safety category A. They are also designed in accordance with ASME Section III, Class 2 and 3 to provide access to welds and in accordance with ASME Section XI to have removable insulation in areas that require in service inspection, or the equivalent RCC-M requirements.

Transformers and Generator Circuit Breaker and Generator Connections
The equipment needs to be qualified according to IEEE 323-2003 and 344-2013 standards and the specifications will include climatic and seismic tests according to IEEE standards.

HV/LV Switchgear, Electrical/I&C Control and Distribution Panels
The components and functionality of the panels do not differ greatly between industries and the safety related testing is not heavier for the nuclear industry than that of the oil and gas industry.

Large-volume components
These components are largely similar to those used in other highly regulated and sensitive industries. The non-classified equipment will need to be designed, manufactured and installed using robust quality management systems using a well trained SQEP workforce.

Tanks, vessels and heat exchangers of the applied types are routinely produced for the offshore, petrochemical, power, and pharmaceutical industries. Most of these will be to EN standards or ASME code requirements. The level of inspection, verification and documentation required will be much more extensive than most companies currently employ.

NL capabilities

Major mechanical components
The feedwater pumps and other pumps of the conventional island could be provided through the NL branches of Flowserve and of KSB, which have manufacturing plants certified to all relevant standards including nuclear standards such as ASME NQA-1. Both companies are reputable suppliers of pump systems for nuclear power plants, encompassing both the conventional island as well as the nuclear island. The valves could be supplied through the NL branch of Flowserve.

Transformers
SGB-Smit delivers transformers of the required ratings. In practice, the transformers are often contracted together with the Generator Circuit Breaker and Generator Connections. Moreover, the transformers could be combined into one procurement package with switchgear, control and MicroScada systems and transmission feeds, which was the case for the HPC project.

Generator Circuit Breaker and Generator Connections
There are no NL companies currently manufacturing generator connections and generator circuit breakers and there are only a few companies in the world in this market. These components could however to supplied from such companies as ABB and Siemens through their respective NL branches.

HV/LV Switchgear, Electrical/I&C Control and Distribution Panels
The switchgear equipment can be provided through the NL branches of manufacturers including ABB, Siemens and Schneider Electric, including safety-classified equipment.

There are a number of other NL companies manufacturing non safety-classified I&C panels, electrical distribution panels and cabinets for various NL and overseas industries.

Large-volume components
The type of required mechanical components is currently being manufactured by NL companies for power, oil and gas, pharmaceutical and petrochemical plant worldwide. For tanks and heat exchangers this includes Schelde Exotech and Gpi tanks. FLowserve offers a full range of pumps and valves for nuclear power plants, including safety-classified equipment. Tata and Leemberg Pijpleidingen could deliver the piping systems.

Non-classified electrical equipment can be delivered through main NL contractors such as BAM Industry, VINCI Energies/Actemium, Equans (Bouygues) and CroonWolterDros-TBI.

NL share estimate

From the above it is inferred that the NL industry is currently capable of supplying part of the major equipment of the BCI. This includes parts of the main steam supply and feedwater systems. The NL is also capable to provide the unit and auxiliary transformers. The formation of joint ventures with foreign companies could be required to be able to supply a complete procurement package including e.g. generator circuit breakers.

However, NL companies do not qualify as the Tier 1 supplier responsible for the Conventional Island scope of supply (usually a consortium partner) or as a Tier 2 supplier (companies responsible for large procurement packages). These higher tier suppliers are likely to absorb the largest share of the indirect costs, which can amount up to 50% of total EPC cost (see section 3.3).

Besides equipment supply, the NL industry is well able to provide for major parts of the Mechanical, Electrical and HVAC (MEH) installation works, including the supply of large-volume MEH equipment.

Based on the above, the NL share of BCI equipment supply is estimated to be between 25 and 40%, and of on-site installation between 30% and 50%.

6.3 SUMMARY

The above estimates of the NL shares of equipment supply and installation activities for the Conventional Island are summarized in Table 8 below.

The actual accessible NL shares in the work packages will be the result of factors other than those addressed above.

Table 8. Overview of NL share estimates for the conventional island equipment supply and installation activities.

		Scenario A		Scenario B	
Activity	**Value (m Euro)**	**NL share (%)**	**NL value (m Euro)**	**NL share (%)**	**NL value (m Euro)**
Turbine generator Equipment supply	1.439	0	0	0	0
Turbine generator Equipment installation	617	5	31	10	62
Turbine generator total	**2.055**	**2**	**31**	**3**	**62**
BCI Equipment supply	1.893	25	473	40	757
BCI Equipment installation	811	30	243	50	406
BCI total	**2.705**	**27**	**717**	**43**	**1.163**

Reasonableness assessment
The share estimates for the UK share of the Conventional Island works in new build projects in the UK reported by Oxford Economics and Atkins are in the range between 30% and 54%[103] (separate estimates for the turbine generator and BCI are not reported). The actual UK shares are likely larger than these estimates for the same reasons as mentioned above for the nuclear island works.

The larger UK shares relative to the estimated NL shares summarized in Table 8 reflect the presence of several Tier 1 and 2 suppliers of BCI equipment and installation works in the UK, which are absent in the NL.

From this it is concluded that the estimates of the overall NL share of conventional island works of the NNB-NL project reported in this study are consistent with the above mentioned UK estimates and the relative positions of the relevant industries in both countries.

103 Oxford Economics, 2013, The economic benefit of improving the UK's nuclear supply chain capabilities.

7 Balance of plant

The Balance of Plant (BOP) concerns the supply and installation of equipment in the BOP part of the plant. There is no uniform definition of BOP. The Balance of Plant (BOP) area of an EPR plant is shown in Figure 28. It defines a number of buildings and the equipment located in these buildings together is denoted in this report as the BOP equipment. These systems and equipment assigned to the BOP for an EPR are identifiable and present in any PWR based NPP and therefore also identify the BOP equipment for the other technologies.

The scope of the BOP used in this study is based on information from HPC[105] and SZC[106]. This broadly represents the standard scope of the BOP for an EPR. Referring to Figure 28, the electric switchyard is assigned to the Owner scope in the TFS[107] and will not be addressed in this chapter. Also, the standard BOP scope includes several buildings and equipment which for the NNB-NL project are assigned to the Owner's scope. It concerns "Other buildings & monitoring systems (permanent)" (see footnote 107 items 60-64) and facilities such as the meteorological station and the permanent sewage plant. These are addressed in the next chapter on Owner Scope. The delineation between Vendor and Owner scope for the NNB-NL project may deviate from the standard one. Given other uncertainties in the adopted values, the possible effect of this on the cost breakdown of the Vendor (EPC) scope is ignored.

104 AREVA/Framatome ANP, 2005, EPR (brochure). Legend: 1: Reactor Building; 2: Fuel Building; 3: Safeguard Buildings; 4: Diesel Buildings; 5: Nuclear Auxiliary Building; 6: Waste Building; 7: Turbine Building. https://web.archive.org/web/20071129121411/http://www.areva-np.com/common/liblocal/docs/Brochure/EPR_US_%20May%202005.pdf

105 EDF Energy, 2011, Development Consent Order application, Environmental Statement Volume 2 – Hinkley Point Development Site.

106 Sizewell C, 2021, 8.1 Main Development Site Design and Access Statement - Clean Version - Part 2 of 3.

107 Ministry of Economic Affairs and Climate Policy of the Netherlands and Assytem, Workstream 3 – NPP delivery model battery limits & scope of supply, Appendix to TFS - Scope of Work & Deliverables.

Figure 28. The three areas distinguished for a single-unit EPR NPP, including the BOP area[104].

For a twin-unit EPR the BOP scope covers the equipment located in the in total 22 buildings and structures summarized in the table below.

*Table 9. **Buildings and structures in the BOP area of a twin-unit EPR including maximum dimensions and heights.** (From footnote 105).*

Building and Structures	Number	Maximum dimensions (mxm)	Maximum height (m)[108]
Operational Service Centre	Shared	83 x 67	36
Cooling Water Pumphouse	One per unit	84 x 57	19
Forebay	One per unit	79 x 41	4
Outfall Pond	One per unit	47 x 43	11
Filtering debris recovery pit	One per unit	27 x 9	2
Fire-fighting water building	One per unit	46 x 31	7
Attenuation pond	Shared	17 x 11	3
Demi station	Shared	39 x 32	14
Auxiliary boilers	Shared	26 x 34	18
Hydrogen storage	Shared	45 x 14	4
Oxygen storage	One per unit	14 x 14	4
Chemical products storage	Shared	30 x 26	7
Conventional island water storage	Shared	38 x 38	20
Nuclear island water storage	Shared	12 x 12	13
Spent fuel building	Shared	150 x 65	25
ILW interim store	Shared	137 x 37	16

Scope

The facilities listed in Table 9 are grouped into four categories: cooling water infrastructure; fuel and water management facilities; ancillary plant and storage facilities; and offices/access facilities, following footnote 106.

Cooling water infrastructure
The cooling water infrastructure encompasses the equipment housed in the pumphouse, feedwater intake station, outfall pond building, Filtering Debris Recovery Pit, fire-fighting water distribution building and supply channels.

The main equipment concerns the cooling water pumps, housed in the cooling water pumphouse, in concrete cases, and denoted as Concrete Volute Pumps (CVP, see Figure 29).

The pumps draw sea water from the forebay via a series of screens (drum, band and self-raking) which are also included in the scope of supply. For an EPR, the intake rate is approximately 131,8 m^3/s (two x 65,9 m^3/s for each intake tunnel) during standard operating procedures[109]. The drum and band screens remove debris including marine organisms from the cooling water flow in order to prevent blockage of condensers and other heat exchangers.

108 Height from the appropriate platform.
109 EDF Energy, 2020, Sizewell C Marine Ecology and Fisheries Final Scoping Report Edition 2.

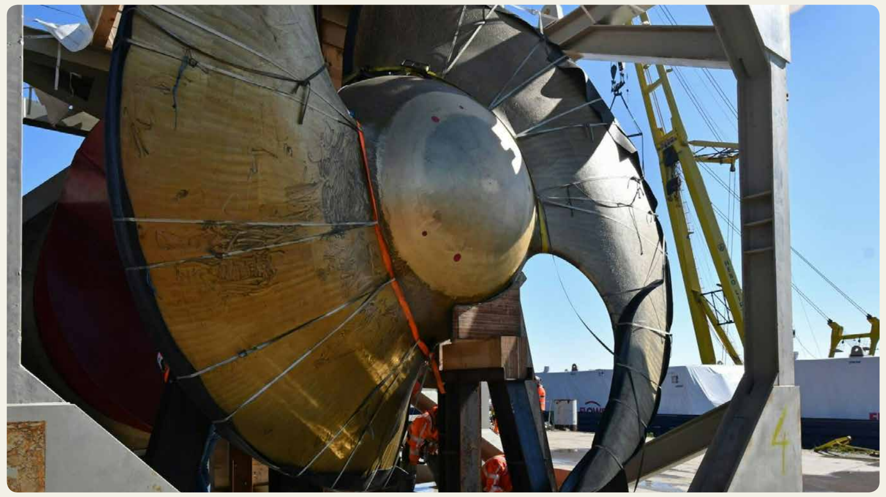


Figure 29.
Vanes of a large CVP pump with maximum capacity of 46 m^3/s. (Rijkswaterstaat, 2024)

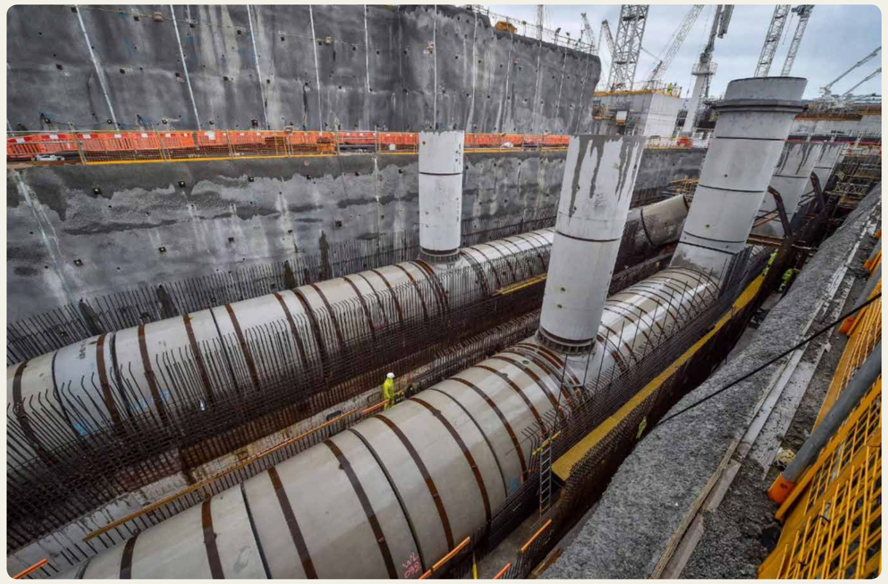


Figure 30.
The two cooling water inlet pipes leading to the cooling water pumphouse at Hinkley Point C. (Taylor, 2020)

The cooling water is supplied to the condenser via large pipes (see Figure 30). Part of the cooling water is supplied to the nuclear and conventional islands' auxiliary cooling water systems. The pipes and pipe connections are also part of the scope, including welding and other on-site installation work.

The fire-fighting water distribution supply for a reactor unit and a facility for providing emergency water supplies to the nuclear island also belong to this group of equipment. It contains a number of water storage tanks, piping and valves.

Fuel and waste management facilities
These facilities serve for interim storage and management of received fresh fuel and of spent fuel. They also provide storage of intermediate and low level waste on-site before these are shipped outside the plant. They comprise transfer handling and storage facilities and equipment for decontamination, such as tanks and containers. The facilities would be similar to the facilities in the nearby central waste handling facility and other nuclear facilities in the NL.

Ancillary plant and storage facilities
These facilities would include a variety of equipment and infrastructure to service the site, comprising the demineralisation station; desalination station; auxiliary boilers; hydrogen, oxygen and chemicals storages; the nuclear island water storage tank; conventional island water storage tanks; chlorination plant; degassed water storage tanks; and cooling water discharge shaft.

The electro-chlorination plant would produce chlorine on-site by the electrolysis of seawater and is optional. Alternatively, hypochlorite could be transported to site from outside[110].

The demineralisation station processes water delivered to the site via the local water company mains for use in the reactor units. The water would then be stored for use in the nuclear island and conventional island water storage tanks. The building would accommodate warehousing, processing space and a laboratory and demineralisation plant control room. The equipment encompasses valves for the operation of the demineralisation station and to prevent floodwater propagation between buildings in the event of an extreme seismic event.

Auxiliary boilers are required for providing steam for heating the deaerator and for turbine gland sealing for start-up the reactor units.

The hydrogen, nitrogen and oxygen storage equipment is regular equipment for storage of compressed gas cylinders. The hydrazine storage consists of dedicated tanks and an equipment room in association with the tanks.

The raw and potable water storage/supply will comprise a balancing (buffer) tank for the raw water supply from the local water company and will also supply raw water to downstream users. The potable water supply stores and boosts the pressure of the main potable supply. The raw and potable water storage/supply is underground.

The nuclear island water storage tank would store treated water, which is required for use within the nuclear island. The scope also includes two conventional island water storage tanks, which house treated water for use in the steam cycle which powers the turbines. The nuclear and conventional island tanks would be formed from steel panels and be cylindrical in shape with a set of metal stairs running down the tanks' side.

Finally, there will be one degassed water storage tank per unit to store degassed water for the demineralisation station in order for the degasser to work effectively and to provide a water supply for effluent treatment.

Other ancillary facilities
This part of the scope encompasses building installation work for the garage and handling facilities, the oil and grease building and the Vendor warehouse.

Large-volume components
The scope of the supply includes predominantly non-classified mechanical, electric and HVAC components.

Mechanical components will include pipes of various dimensions and materials and valves and pumps of various types. Electric components will include e.g. low voltage switchboards and medium voltage/low voltage and low voltage/low voltage transformers supervision and approximately 13 km of cables.

110 Chlorination is not applied in the cooling water tunnels of the KCB nor was applied in the collocated coal-fired plant (closed in 2015). The tunnels of the KCB are cleaned annually; those of the coal-fired plant were coated with an extremely smooth anti-fouling coating, which proved effective.

Conventional HVAC systems are provided for the BOP offices, workshops and buildings outside radiation and contamination controlled areas. However, nuclear HVAC is required within the radwaste processing buildings. Nuclear HVAC is typically an integrated system consisting of air supply and process and building extract elements, made up of safe-change filters, high-specification fans, dampers, ductwork and high integrity control systems. HVAC equipment will comprise:

- Fans, centrifugal or axial;
- Dampers, including fire and smoke dampers and isolating dampers;
- Heating and heaters (electrical or hot water supply);
- Air filters, including HEPA filters;
- Air handling units;
- Ductwork, including airtight and fire-proof.

On-site installation
The scope of supply of the equipment supplier will include technical qualification of products, manufacturing and installation supervision and commissioning.

The majority of the installation work will involve typical building services installations, with limited requirements for personnel suitably qualified and experienced in working within areas of high integrity.

The main cooling water pump supplier will normally take responsibility for the installation and supply its own specialist engineers and technicians. Support will probably be required from NL subcontractors, e.g. for welding, heavy lifting and in service inspection.

For most BOP equipment, different from Nuclear Island and Conventional Island, it is likely that the contractor will – besides supply and installation – also be in charge of a major part of EPCM tasks, such as management of contract interfaces, inspection, testing and commissioning.

Required resources, skills and facilities

The cooling water equipment is not different from similar equipment for conventional thermal power plants. However, the cooling water demands are significantly higher than those for conventional power plants and consequently the capacities and dimensions of equipment are larger.

The major part of storage and handling equipment of the type used in the BOP will be to EN (NEN) standards and only some to ASME code requirements. These conventional systems are comparable to systems provided for other highly regulated and sensitive industries such as oil and gas and the petrochemical industries. Nuclear HVAC systems are required for buildings where radioactive materials are handled or stored. These need to be designed within a Nuclear Safety regime.

Also the fire-fighting water distribution system is not different from similar equipment used in other highly regulated and sensitive industries.

The majority of the mechanical, electrical and HVAC installation work will involve typical building services installations.

NL capabilities

Cooling water (CVC) pumps of the largest capacity are designed and manufactured by Flowserve in the Netherlands. Flowserve supplied the large CVC pumps for the Afsluitdijk renovation project which are similar in design, performance and requirements to NPP cooling water pumps.

The level of workmanship and quality levels required for manufacturing of equipment for BOP applications are not significantly greater than is currently being used within the NL manufacturing industry supplying the oil and gas industry. The level of inspection, verification and documentation needed will be more extensive than most companies currently employ.

The major part of storage and handling equipment of the type used in the BOP is routinely produced by many companies in the NL for industries such as the offshore, petrochemical, power and pharmaceutical.

There are many NL companies capable of supplying the large-volume components, such as Camfil for HVAC components.

There are many NL companies capable of providing the major part of on-site installation work, including BAM Industry, Equans, CroonWolterDros-TBI, SPIE and Actemium. These companies are also well capable of performing major parts of the EPCM tasks. Many smaller NL companies are capable to act as subcontractors to these larger companies.

NL share estimate

Based on the above, the NL industry share of the supply of BOP equipment is estimated to be between 70 and 80%. This takes into account that the CVC pumps, including the major part of on-site installation, can be supplied by NL companies.

The NL industry share of the supply of on-site installation of BOP equipment is estimated to be between 80 and 90%, since this work will mainly involve regular building services installation work which can very well be sourced locally. The above estimates are summarized in Table 10 below.

Reasonableness assessment
Local estimate data from NNB projects in other countries could not be found and therefore the obtained estimates could not be compared with estimates from elsewhere. However, BOP equipment and installation works are similar in nature and requirements to work in other highly regulated and sensitive industries. High levels of localization for BOP equipment are therefore generally considered to be feasible in countries with well developed industries such as the NL. The obtained share estimates for the BOP scope of work are hence considered as reasonable.

Table 10. Overview of NL share estimates for the BOP equipment supply and installation activities.

		Scenario A		Scenario B	
Activity	Value (m EUR)	NL share (%)	NL value (m EUR)	NL share (%)	NL value (m EUR)
Equipment supply	1.666	70	1.166	80	1.333
Equipment installation	714	80	571	90	643
Total	**2.380**	**73**	**1.737**	**83**	**1.975**

8 Owner scope

This chapter concerns the potential share of the NL industry in delivering the Owner scope. It draws on the Owner scope adopted for this study as described in section 3.4 of this report. This scope is based on the currently available information and on international practice concerning the Owner's role in nuclear new build projects. As said before, the Owner scope depends on various factors, in particular the Owner and its organisation, which are yet unknown. The actual Owner scope is likely to be considerably larger than the scope adopted in this report. However, this also concerns such major activities as building up of the permanent Owner organisation, which will not lead to significant opportunities for contractors.

8.1 LICENSING

Scope

The Owner scope concerning licensing as summarized in section 3.4 above encompasses obtaining the site license, the construction license and the operations license as major components. The Owner may need support for the licensing activities, which will involve technical work but also a considerable volume of legal support.

According to the current schedule issued by the NL government, the licensing processes will start during the process for tendering for the EPC works and will continue after completion of the tendering process[111]. Part of the documents needed for the license applications need to be prepared by the vendor, in particular various substantiation studies. It is assumed that not all of these documents will be included in the EPC scope. Consequently part of the Owner scope of supply for licensing will still be contracted to the vendor.

As the Owner is ultimately responsible for the facility, the documents provided by the vendor will need to be reviewed and accepted by the Owner. The Owner also has to prepare the license applications, provide for the communications with the regulator, carry out the activities related to the licensing processes including public relations and address the legal aspects.

111 Ministerie van Economische Zaken en Klimaat, 2022, Nadere uitwerking van de afspraken uit het coalitieakkoord op het gebied van kernenergie, brief van 9 december 2022 aan de voorzitter van de Tweede Kamer der Staten Generaal.

Required skills, resources and facilities

This activity requires in-depth knowledge of various main areas. These include the NL legal, institutional and regulatory context and of Gen-III PWR technology, in particular of safety related systems. Also the capability to perform calculational analyses in various areas such as off-site radiological consequences is required. The Owner's Engineer is likely to require recent experience with licensing for NPP new build projects.

NL capabilities

There are several major NL engineering consultancy companies capable of performing major parts of the site licence preparations, including the studies required. There are only a few NL companies with the required knowledge and expertise for delivering support to obtaining the construction and operation licenses. These may need to form joint ventures with companies from elsewhere who can bring recent experience with licensing for NPP new build projects.

NL share estimate

The NL supply chain is capable of providing a considerable part of the licensing scope. However, part of the licensing scope may need to be provided by the Vendor outside the scope of the EPC contract; that part is estimated to amount to 20% of the value of licensing scope. Not all of the remaining 80% is accessible to NL companies, who lack recent experience with licensing of NPP new build, and which hence must be obtained from elsewhere. The NL share of the remaining 80% is therefore, conservatively, estimated to be in the range of 50-70%, which would correspond to 40% to 56% of the total value of the licensing scope.

8.2 OWNER'S ENGINEER

Scope

The owner may need support from the pre-construction phase of the project onwards in a number of areas such as:

- Development of BIS & Owners' Requirements;
- Constructability Review;
- Technical Integration, issuing multidisciplinary synthesis reports and ensuring technical consistency of the project;
- Development of a robust project execution strategy that may include owner's engineer/architect engineering/construction management capabilities, depending on the specific strategy the developer selects and that will enable the Owner to act as an intelligent customer and full-fledged partner of the vendor;
- Setting up a waste and decommissioning strategy;
- Recruitment, training and skills development;
- Business planning and financial modelling.

Whereas the EPC contractor is responsible for adapting the design, preparing the corresponding documentation and maintaining the plant configuration control during construction and commissioning, the owner/operator has its own responsibility in these areas. The Owner as license holder is ultimately responsible for the safety of the plant. For this, the Owner needs to be independently fully capable of reviewing the documents produced by the Vendor and take responsibility for them. This capability is commonly denoted as the Design Authority (DA). It is the counterpart of the team within the EPC contractor responsible for plant design, the Responsible Designer.

In addition, the Owner will need support for overseeing the implementation of the contract signed with the vendor (EPC contractor). This activity requires expert knowledge in different areas, such as:

- Safety, health and environmental management;
- Quality management including quality assurance and quality control;
- Developing operator capability;
- Consolidated industrial relations;
- Risk management;
- A cost planning and cost control capability;
- Operational Readiness support;
- EPC & Engineering Oversight.

Required skills, resources and facilities

The Owner's Engineering role encompasses the multiplicity of engineering disciplines required to assess the development of the design for the site-specific characteristics and the progress of construction activities. Recent international experience of NPP new build will prove valuable for an owner to improve both business planning and the deliverability of the project on time and budget.

The Owner will need to have a design authority (DA) capability, responsible for demonstrating it is in control of the integrated detailed design of the plant. In addition, the DA has an important role in assuring the complete transfer of the design basis from the Vendor to the Owner and should execute this role from the start of the project onwards.

The Design Authority requires a range of Nuclear Safety and engineering disciplines such as[112]:

- Normal Operations.
- Design Basis fault studies of the NNB-NL safety case and achieving compliance with owner's requirements and safety principles. Includes oversight of safety doctrine, acceptance criteria, process of fault identification, Fault Studies transient analyses and development of safety case structure.
- Operating procedures for normal, abnormal and (severe) accident conditions.
- Thermal Hydraulics for providing support to the NNB-NL safety case and PSAR, structural integrity assessment of the primary components and dry fuel storage analysis. It requires proficiency in a range of computational tools such as sub-channel codes, system codes and CFD.

112 James Dyrda and Richard Morrison, 2021, Overview of the Hinkley Point E EPR project 'J0' and beyond, EPJ Web of Conferences 247, 20001 (2021) PHYSOR2020.

- Fuel & Core Components Engineering, dealing with the engineering design and performance of fuels, cladding, assembly materials and other core components such as control rods, thimble plug assemblies and neutron sources. Performance during cycle, fuel pond storage and long term dry storage. This requires expertise in the use of phenomenological and empirical computational modelling tools.
- Criticality Safety and Reactor Physics, responsible for ensuring defence against unintended criticality of nuclear fuel during receipt, storage and handling. Provides support to operational and transient analysis through the fuel management schemes, reactivity control functions, depletion studies, radiation instrumentation, decay heat and shielding calculations.
- Severe Accidents, including calculations involving molten corium progression (in- and ex-vessel), Molten-Core Concrete Interaction (MCCI), CFD hydrogen distribution and combustion and, containment pressure and temperature loads.
- Radiological Consequences. Assessment of the detriment to workers and members of the public of any potential release of radioactive material from the site. The calculations involve atmospheric dispersion modelling, dose evaluations, and risk estimates based on probabilistic meteorological models for the Level 3 Probabilistic Safety Analysis (PSA).

NL capabilities

For many engineering disciplines required for fulfilling the Owner's Engineer role such as mechanical it is expected that the NL has sufficient capability to support the programme. Other disciplines will require some specialist knowledge where it is expected that NL capability is insufficient on its own and specialist contractors with international experience will be required. Examples include control and instrumentation, where, in general, the NL has sufficient capability, but there is limited capability and capacity for the high safety grade nuclear element, and civil and structural, where recent international experience of NPP new build is critical to an owner to de-risk the project.

NL share estimate

The NL supply chain is capable of supporting this activity and to cover major parts of the work. However, it is not capable to cover the full scope and it cannot provide recent experience of NPP new build. It is therefore anticipated that provision for the Owner's Engineer for the NNB-NL project will come in part from the global market with recent experience of NPP construction projects, with support from NL companies through joint ventures. The NL share is therefore estimated to be in the range between 40 and 60%.

8.3 CONSTRUCTION OF BUILDINGS

Scope

As specified in the TFS[113], the Owner scope includes the construction of approximately eleven buildings, mentioned under "Ancillary Buildings (permanent)" and "Other Buildings & Monitoring" (see footnote 113). These are listed in the table below, together with the corresponding buildings of the HPC plant including their dimensions[114].

Table 11. Overview of buildings assigned to the Owner scope (first two columns) and the corresponding buildings of Hinkley Point C with dimensions. Likely number of floors indicated in brackets in column Maximum height.

Item	Item description	Building and structures	Maximum floor (m×m)	(m²)	Maximum height (m)	
42	Security access building	Main Access control building	39 × 36	1.404	6	2
43	Entry relay store	Entry relay building	39 × 17	663	6	2
44	Security force control centre	Not mentioned				
45	Medical centre	Medical centre	41 × 38	1.558	5	1
46	Restaurant	Not mentioned				
48	Training centre	Simulator building/Training centre	99 × 40	3.960	11	3
49	Public information centre	Public information centre	32 × 31	992	19	4
50	Operational service centre/ owner administration buildings	Operational service centre	83 × 17	1.411	36	6
51	Owner permanent site office	Owner site offices	65 × 65	4.225	10	2

All buildings are shared between both units, i.e. one building for the plant. The total floor space amounts to approximately 40.000 m². The work will encompass the design, engineering and construction of the buildings, including installation work concerning electrical, HVAC and instrumentation and ICT infrastructure.

Required skills, resources and facilities

The work involves typical regular higher-end building engineering and construction and building infrastructure equipment supply and installation services.

NL capabilities

There are many NL civil construction companies capable of performing the work. These include major construction companies such as BAM, Ballast Nedam, Heijmans, Dura Vermeer and Strukton, as well as a much larger number of smaller companies.

NL share estimate

The potential NL share of this part of the Owner scope is estimated as 100%.

113 Ministry of Economic Affairs and Climate Policy of the Netherlands and Assytem, Workstream 3 – NPP delivery model battery limits & scope of supply, Appendix to TFS - Scope of Work & Deliverables.

114 EDF Energy, 2011, Development Consent Order application, Environmental Statement Volume 2 – Hinkley Point Development Site.

8.4 CONNECTION TO THE NATIONAL GRID HV TRANSMISSION SYSTEM

Scope

It will be necessary to provide an electrical connection between the plant and the national grid to export the electrical output of the units of the new plant. As part of this work, a national grid substation would be constructed, collocated with or located adjacent to the existing substation of the Borssele NPP. Transport of power from the transformers of the new plant to the substation could take place underground via power cables in galleries. Alternatively pylon supported overhead power lines could be applied.

In addition, possible extension of the capacity of the HV grid will be required. Tennet, the NL Transmission Service Operator has investigated the investments needed for connecting the plant to the grid for the Boressele site on request of KGG. Extension of the capacity of the HV transport system could be needed for the envisaged plant.

Required skills, resources and facilities

The work will require regular EPCM, civil construction and equipment manufacturing and installation capabilities related to large HV transmission infrastructure. Equipment encompasses large HV-step-up transformers, various HV equipment such as isolators, HV transport cable pylons and HV transport cables (possibly of considerable length).

NL capabilities

There are a few manufacturers of the required HV equipment worldwide, including the SGB-SMIT group, but also foreign companies such as Siemens and ABB, with NL branches.

Tennet itself has extensive HV station EPCM capability. Companies with NL HV station construction capability to support the new nuclear build programme include SPIE Nederland, Croonwolter & dros and Arcadis.

Concerning HV transport works, Tennet recently concluded a long-term contact with BAM Infra Nederland, Strukton Wegen & Beton and VolkerWessels Hoogspanning Civiel for the civil work for large overhead power transport projects in the Netherlands. In addition, back-up contracts were concluded with VOLTA Civiel (an alliance of Mourik Infra and Dusseldorp Infra, Sloop en Milieutechniek BV) and Dura Vermeer. The contracts are part of the extension of the national HV grid capacity made necessary by the increasing demand for electricity as a result of the energy transition. The main contract with a value of 2,5b EUR has an initial duration of four years with three options for extension by two years. The grid works for the new Netherlands' NPP could likely be included in this existing contract.

NL share estimate

The range of the potential NL share of this part of the Owner scope is estimated as 80 to 90%.

8.5 SUMMARY

The above estimates are summarized in Table 12 below.

Table 12. Overview of NL share estimates for delivering Owner scope.

		Scenario A		Scenario B	
Activity	**Cost (m Euro)**	**NL share (%)**	**Value (m Euro)**	**NL share (%)**	**Value (m Euro)**
Licensing	130	40	52	56	73
Owner Engineer	170	40	68	60	102
Buildings	80	100	80	100	80
Tennet scope/ HV infrastructure	200	80	160	90	180
Total	**580**	**60**	**347**	**73**	**421**

9

Summary and recommendations

9.1 SUMMARY AND OVERALL NL PROJECT SHARE ESTIMATE

The estimates obtained in this study for the various categories of project activity were informed by consultations with industry experts and in-house knowledge of the nuclear supply chain. The resulting estimates were reviewed by external specialists with practical expertise in relevant areas, including building up the supply chain of a NNB project. As such they are based on industry views and independently quality assured by experts. However, there will still be some margin of error and uncertainty and as a result, the estimates should be viewed as indicative.

The shares disaggregated by project part refer to:

- Scenario A: how much of the NNB-NL project expenditure the NL industry could capture at present, given current capabilities; and
- Scenario B: what the NL industry could feasibly achieve if barriers limiting the amount of NL content were to be alleviated.

The shares for each category of activity are summarized in the Table below. By applying the adopted cost breakdown structure, the profile of value shares of the project was obtained, leading to the cumulative shares reported in table.

Table 13. ***Values and share captured by the NL supply chain (values in million Euro; 2020 price basis).***

		Scenario A		Scenario B	
	Value	NL share (%)	Value (m Euro)	NL share (%)	Value (m Euro)
Civil Works	7.140	61	4.368	75	5.344
NSSS	6.426	6	379	10	610
BNI	3.094	13	387	26	789
Turbine-generator	2.055	2	31	3	62
BCI	2.705	27	717	43	1.163
BOP	2.380	73	1.737	83	1.975
Owner scope	580	62	360	75	435
Totals	**24.380**	**33**	**7.979**	**43**	**10.378**

From these results it is concluded that the NL industry will be able to deliver 33% of project value, rising to around 43% if barriers were removed. These shares correspond to values around 8 bn EUR, possibly rising to over 10 bn EUR.

As stated in the introduction, the differences between the three technologies involved in the TFS lie, besides the capacity power, mainly with the nuclear island. As shown in the table, the NL shares for the nuclear island equipment supply and installation parts (NSSS and BNI) are likely to be relatively low. It is therefore judged that the overall NL share estimates are not greatly affected by the choice of the reference technology, and largely apply for all three technologies.

As stated in section 3.2 above, the above potential localization values present upper bounds due to the capacity power of the adopted EPR being the largest of the three technologies involved in the TFS. Lower bound values can be obtained by multiplication of the values shown in the table by a factor of 0,67. The resulting lower bound potential shares amount to 5,3 - 6,9 bn EUR.

9.2 LESSONS LEARNED FROM NNB PROJECTS IN OTHER COUNTRIES

With a view to the foreseen growth of nuclear power generating capacity in the Netherlands including the planned NNB-NL project, the NL government has already initiated a programme for strengthening the national nuclear skills and knowledge infrastructure within the framework of the *Meerjarig Missie-gedreven Innovatieprogramma Kernenergie* (Multiannual Mission-driven Innovation programme Nuclear energy)[115]. Localisation, expressed through an NL share of the NNB-NL project, would contri-bute to strengthening the industrial nuclear skills base and thus to realising the objectives of this programme.

Although there is scope for the NL industry to deliver a significant share of the foreseen NNB-NL project, this potential will not be realized without proper additional actions.

A first limited engagement with the vendors, the NL industry and stakeholders involved in recent NNB projects in foreign countries, provided indications of what are considered to be the key issues to be addressed in order to achieve the potential share of the NL nuclear supply chain in the NNB-NL project. These issues are organised into four main areas:

- Market access, concerning barriers to entry and access to the project supply chain;
- Fit for nuclear, concerning safety culture and management system issues and company processes in particular concerning bidding for nuclear projects.
- Technical skills and training, referring to technical skills for manufacturing but in particular for on-site installation;
- Establishment of an NL suppliers list.

The issues can be seen as the links of a chain and therefore need to be considered in their entirety. The recommendations below address these issues and concern critical enablers, covering the important activi-ties needed to support the NL industry in realizing the potential NL share of the foreseen NNB-NL project.

Market access

A first consultation of the vendors indicated that a main obstacle for involving the NL national supply industry in the foreseen Netherlands' new build project is the absence of a central point of contact with the national nuclear supply industry. Through and in cooperation with such a central point of contact, the vendors can organise events in the present early stages of the project to establish contacts with the individual NL companies. A central NL industry contact serves the important role of stimulating the individual NL companies to attend those events and to tailor those events to attract those companies. In these events, the vendors can provide information on their qualification processes and their views on the opportunities for the local NL industry; and set out how the NL industry should prepare for bidding for possible tenders.

115 MMMIP Kernenergie in een CO_2-vrije energievoorziening in 2050; Appendix to "Kamerbrief betreffende voortgang ontwikkeling nucleaire kennis- en innovatiestructuur" of the Minister of Economische Zaken en Klimaat, 20 December 2023.

Examples of such national central points of contact are the Nuclear Industry Association (NIA) in the UK[116] and GIFEN in France. The NIA has been active in preparing the UK industry for the nuclear construction programme from its incipience in the early 2000s onwards. This included the preparation of guidelines for the industry to prepare itself for nuclear construction projects[117] and the establishment of contacts with the Owner organisations of the UK new build projects.

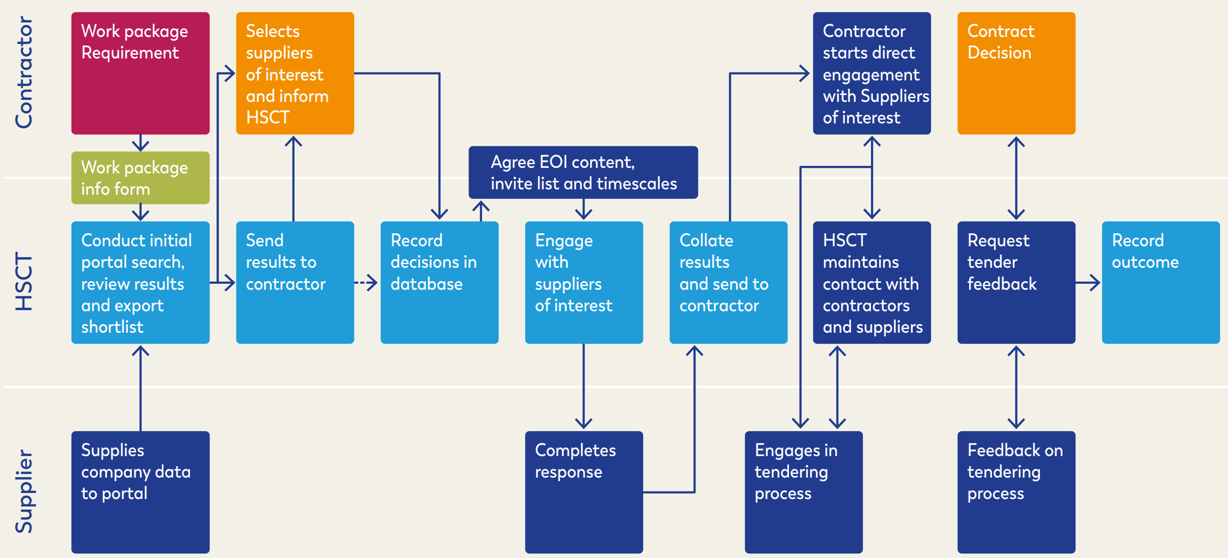
A second aspect concerns access of NL companies to tendering for the NNB-NL project. In view of the tiered structure of the nuclear supply chain, the Vendor's supply chain will comprise multiple Tier 1 and Tier 2 companies. It is not practical for all of those companies to individually search for local suppliers and to set up tender processes. For the HPC and SZC projects, specific arrangements were agreed between the Owner and the Vendor consortium partners to facilitate access of the local nuclear supply industry to the project supply chain. In this, the local Chambers of Commerce played a central role.

For Hinkley Point C, to this end a central organisation was set up, denoted the HPC Supply Chain Team (HSCT), for organising qualification of local suppliers, registration of tenders and the selection of suitable local companies (see Figure 31). Instrumental for this was a central database for registration of local suppliers and their capabilities, and of vendor companies and issued tenders. The Hinkley Supply Chain Team has been commissioned by EDF to help manage the local supply chain. Working with Tier 1 and Tier 2 contractors, the team identifies work packages and clarifies the requirements that can be matched to the capabilities within the local supply chain. Mapping work package requirements allows for identifying appropriate suppliers. Those suppliers are subsequently supported through the process detailed below.

116 UK NIA members include internationally reputed companies such as Altrad (several subsidiaries including Altrad Babcock Ltd, formerly Doosan Babcock, since 2022 part of Altrad), Balfour Beatty and Rolls Royce (several subsidiaries).

117 E.g. NIA, 2019, The essential guide for the nuclear new build supply chain, Stage three, June 2019; NIA, Industry Link, various issues; NIA, 2023, Delivering value; the economic impact of the civil nuclear industry, January 2023.

Figure 31. Workflow diagram of project brokerage service between Contractors (Vendor consortium and their Tier 1 partners) and potential Suppliers for the UK HPC project (EOI: Expression Of Interest). (HSCT, 2025)



Fit for nuclear

Fit For Nuclear (F4N) refers to the activities that are needed for companies to get ready to bid for work in the nuclear supply chain. The term was coined in the UK, denoting the programme launched in 2011 by the UK government, industry and EDF Energy to help UK manufacturing companies to prepare for work in the nuclear supply chain[118].

The central concept is that F4N lets companies measure their operations against the standards required to supply the nuclear industry in new build and take the necessary steps to close any gaps. Participating companies benchmark their performance against the standards demanded by the nuclear industry's top tiers, and drive business improvements through a tailored action plan. For a participating company the programme typically takes a few months. Companies who successfully complete the programme obtain the F4N status.

The UK F4N programme is executed by the Nuclear Advanced Manufacturing Research Centre (Nuclear AMRC) and is funded by the UK Department for Business and Trade.

An NL F4N service would be instrumental in preparing potential NL supplier companies to meet the quality standards required for nuclear construction projects.

Technical skills and training for on-site installation work

Project success critically depends on workforce experience beyond general (nuclear) skills training and extending to the actual components in the situations occurring in the plant. This concerns skills such as welding and components such as pipes, valves and pumps and the geometries and sizes that will be used in the plant. The actual situation during construction obviously depends on the vendor processes and technology selected and will need the cooperation of both vendor and owner, to be formally agreed and prepared well before start of equipment installation.

To realise the above for HPC, the Construction Skills and Innovation Centre (CSIC) was built in partnership between local vocational training colleges, vendor and owner. CSIC replicates a real-life construction site, with industry-standard plant, machinery and equipment. Construction site behaviours and standards are learned alongside specific technical knowledge and skills. The CSIC incorporates:

- The Mechanical Centre containing realistic replicas of parts of the Hinkley Point C site – where recruits are trained and tested in pipefitting and steelwork.
- The Welding Centre providing training in the high standards demanded by nuclear projects – with people recruited via contractors, apprenticeships, or the government's Bootcamp Training Scheme.
- The Electrical Centre which is designed to support the electrical fit out of the power station.

Successfully passing training in the CSIC will allow technicians to improve quality, efficiency and effectiveness and will contribute to realizing project planning targets.

118 It should be noted that the UK programme could build on a pre-existing strong nuclear industry awareness and cohesion, which dated back to the construction of the Magnox and AGR reactors and continues into the current day support to the long-term operation of EDF Energy's existing reactor fleet; and in addition on substantial efforts by the UK government and industry since the early 2000s to prepare the UK nuclear supply industry for nuclear construction.

NL suppliers list

The Dukovany-5 (DKV-5) project is similar to the NNB-NL project in the sense that the project delivery method for both twin PWR unit NPP new build projects will be EPC (turn key). This is different from HPC and SZC, for which the split work package delivery was chosen, with the owner EDF Energy being responsible for procurement and construction management. The mechanisms governing localization for the NNB-NL project are therefore more likely to be similar to those for the DKV-5 project than to those for HPC and SZC.

The Czech industry and the national government have actively pursued the interests of the local nuclear supply industry in the DKV-5 project[119]. One of the main actions concerned establishing a comprehensive list of local companies and their capabilities for supplying items for the future NNB project. This list was prepared with funding from the national government, published as a report and made available on the internet far before the ITB for DKV-5 was issued. The owner included the above list as a reference in the introductory text of the ITB, to inform the vendors of the possibilities of involving local companies as suppliers and inviting the vendors to consult the list when preparing their bids.

For the DKV-5 project, the owner and the vendors performed a thorough assessment of the capabilities of the local nuclear industry, e.g. based on the equipment breakdown schemes presented in IAEA TRS 275/396[120]. In the negotiations leading to the final bid, owner and the selected vendor analysed the experience of the different suppliers in order to assess the reliability of the information provided, as is common practice (see e.g. IAEA TRS 396). In these discussions, which were done item by item, localization was addressed, with a view to achieving benefit for the project. For this purpose, both owner and the selected vendor applied their lists of the domestic industry's capabilities.

It is concluded from the above that preparing a national NL suppliers list is an important instrument for serving both the interests of the project, the vendor, the owner and the national supply industry in the NNB-NL project. It is therefore recommended that a similar NL suppliers list is also prepared. The list will be of use in an early stage of the project preparations to involve potential NL companies, to facilitate vendors to select national companies in the bid phase and for the agreement on localisation in the final bid negotiation phase.

119 The well developed Czech nuclear industry includes a number of internationally reputed companies such as Skoda JS (fully owned by the ČEZ Energy Group since 2022) and Doosan Skoda Power (fully owned by the Doosan Group since 2009).

120 This is explicitly recommended in IAEA TRS 396, see page 14.

ACKNOWLEDGEMENTS

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The findings and conclusions of this study will serve as input for the Nuclear Academy, a cooperation between NRG PALLAS and Delft University of Technology, which aims to support educational institutions and stakeholders in training students and employees in the field of nuclear technology.

NUCLEAR ACADEMY

Acronyms and abbreviations

AMRC	Advanced Manufacturing Research centre
ANVS	Autoriteit Nucleaire Veiligheid en Stralingsbescherming (Nuclear Safety and Radiation Protection Authority)
APS	Announced Pledges
ASME	American Society of Mechanical Engineers
BCI	Balance of Conventional Island
BIS	Bid Invitation Specification
BNI	Balance of Nuclear Island
BOP	Balance Of Plant
CAPEX	Capital Expenditure
CFD	Computational Fluid Dynamics
CI	Conventional Island
CRDM	Control Rod Drive Mechanism
CSIC	Construction Skills and Innovation Centre
CVC	Concrete Volute Pump
DA	Design Authority
DCO	Development Consent Order
DKV-5	Dukovany unit 5 Nuclear Power Plant
DTI	Department of Trade and Industry (UK or Czech Republic)
EDF	Electricité de France (French electric utility company)
EDG	Emergency Diesel Generators
EIA	Environmental Impact Assessment
EN	European technical standards
EPA	Environmental and Planning Act in the NL (in Dutch: Omgevingswet)
EPC	Engineering, Procurement & Construction contract or project delivery method
EPCM	Engineering, Procurement & Construction Management contract or project delivery method
EPR	European Pressurised Reactor

EPZ	Electriciteits Productiemaatschappy Zuid-Nederland (Electricity Production Company South-Netherlands), operator of the KCB
ETI	Energy Technologies Institute (former UK NGO)
EZK	Economische Zaken en Klimaat (Dutch Ministry of Economic Affairs and Climate Policy); currently KGG.
F4N	Fit For Nuclear
FID	Final Investment Decision
FL3	Flamanville unit 3 NPP
FTE	Full Time Equivalent
GRP	Glass Reinforced Plastic
HDPE	High Density Polyethylene
HP	High Pressure
HPC	Hinkley Point C NPP
HV	High-Voltage
HVAC	Heating, Ventilation and Air Conditioning
I&C	Instrumentation and Control
IAEA	International Atomic Energy Agency
ICT	Information and Communication Technology
IDC	Interest During Construction
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMI	In-manufacturing inspection
ISI	In-service inspection
ITB	Invitation To Bid
KCB	Kerncentrale Borssele (Borssele NPP)
KHNP	Korea Hydro & Nuclear Power (Korean electric utility company)
KGG	NL Ministry of Green Growth and Climate (Ministerie van Groene Groei en Klimaat)
LOCA	Loss Of Coolant Accident
LP	Low Pressure
MCCI	Molten-Core concrete Interaction
MCR	Main Control Room
MEH	Mechanical, Electrical and HVAC installation works
MSR	Moisture Separator Reheater
MSS	Main Steam System

NDT	Non-Destructive Testing
NEA	Nuclear Energy Agency
NI	Nuclear Island
NIA	Nuclear Industry Association (the trade association for the UK's civil nuclear industry)
NNB-NL	Nuclear New Build – Netherlands' project
NPP	Nuclear Power Plant
NQA	Nuclear Quality Assurance
NSSS	Nuclear Steam Supply System
NZE	Net Zero Emission
OCC	Overnight Cost of Construction
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
OL3	Olkiluoto unit 3 NPP
PSA	Probabilistic Safety Analysis
PSAR	Preliminary Safety Analysis Report
PSI	Pre-Service Inspection
PWR	Pressurised Water Reactor
QA	Quality Assurance
QHSE	Quality, Health, Safety and Environment
RCC-E	Règles de Conception et de Construction des matériels Électriques (French electrical and I&C systems and equipment design code issued by AFCEN)
RCC-M	Règles de Conception et de Construction des matériels Mécaniques (French mechanical components design code issued by AFCEN)
RD	Responsible Designer
ROW	Rest Of the World
SG	Steam Generator
SPC	Special Purpose Company
SQEP	Suitably Qualified and Experienced Person
STEP	Stated Policies
SZC	Sizewell unit C NPP
TBM	Tunnel Boring Machine
TCO	Technical Client Organisation
TFS	Technical Feasibility Study
TSO	Transmission System Operator
WNA	World Nuclear Association

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