

Analysis of National Nuclear Workforce Estimation Models for Newcomer Countries: The IAEA NPHR Modelling Tool and Alternative Approaches

HanSuk KO^{a*}

^a Nuclear Training and Education Center, Korea Atomic Energy Research Institute
hsko@kaeri.re.kr

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1. Introduction

For a country embarking on its first nuclear power programme, Human Resource Development (HRD) is the most demanding of the infrastructure issues in the IAEA Milestones Approach, because of the long lead time and budget required to educate, train and license a competent workforce for a nuclear power plant (NPP).

Workforce estimation is decisive for newcomer countries. First, HRD is a critical-path item: an insufficient supply of qualified staff can delay licensing, weaken owner oversight and deepen dependence on vendors and consultants in a first-of-a-kind national project [1, 2]. Second, staffing decisions interact with contracting strategy, which determines how much capability must exist domestically [3]. Third, the supply side—secondary graduates, vocational and technician training, and university programmes—responds only slowly to national policy, so gaps identified late cannot be closed in time [2, 4]. A defensible national plan therefore requires a model that connects the programme schedule, organizational staffing demand, the national labour market and the education pipeline in a single time-phased framework.

This paper analyzes the IAEA Nuclear Power Human Resources (NPHR) modelling tool—its input data, embedded assumptions and outputs—and compares it with alternative national workforce planning models, in order to draw implications for newcomer countries preparing a national nuclear workforce plan.

2. The IAEA NPHR Modelling Tool

2.1 Structure and method

The NPHR modelling tool, provided to the IAEA by the United States, is a system dynamics simulation implemented in the commercial Stella Architect environment with a Microsoft Excel workbook as its external data file. It is built on the Milestones Approach and represents four key organizations—the NEPIO, the owner/operator, the regulatory body and the EPC(Engineering, Procurement and Construction) contractor—embedded in a national workforce that includes TSOs(Technical Support organizations) and related industries, all fed by the national education system [5].

2.2 preconditions

Several preconditions shape the validity of NPHR results. (i) Reference data are largely Anglo-American: education and national workforce defaults are scaled from US statistics, the construction profile comes from Hinkley Point C, operating staffing follows the PWR example in IAEA document, and the regulatory model mirrors the US NRC [2, 5]. Where national data are missing, the tool scales US data by population ratio, which the manual itself cautions is illustrative rather than accurate [5]. (ii) All rates must be supplied as decimal fractions with strictly matching variable definitions, and enrolment data must correspond to the simulation start year. (iii) The default simulation horizon is 2050, covering planning through early operation rather than the full lifecycle. (iv) The tool models headcounts at the level of skill fields and skill levels rather than named positions, so its outputs are aggregate demand by skill category, not organization charts. (v) The demand side is essentially deterministic once the programme schedule and contract model are fixed; uncertainty is explored through scenario comparison, not stochastic analysis.

2.3 Outputs

For each simulated year, the IAEA NPHR tool produces: total and skill-level workforce demand for the regulator, operating organization, construction and decommissioning(optional); the split between domestic and vendor-supplied workers under the chosen contract; enrolment and graduation in nuclear-relevant craft, technician and professional programmes; the percentage of the national workforce in a given skill absorbed by the nuclear programme (a direct indicator of labour-market strain); workforce age distributions as a sustainability indicator; and the depletion of experienced recruiting pools, shown as shifts in the hiring mix across TSO, related-industry, qualified and experienced pools [5].

3. Alternative Workforce Planning Models

3.1 European models

EHRO-N (European Human Resources Observatory for the Nuclear Energy Sector), established in 2009 and operated by the EU Joint Research Centre, monitors the supply of and demand for nuclear experts across EU member states using a bottom-up survey of nuclear employers, complemented by a top-down model developed with NRG (Netherlands) that extrapolates workforce demand from nuclear energy scenarios—converting projected reactor construction, operation,

long-term operation and decommissioning into staff requirements using per-plant workforce models [6, 7]. Its strength is empirical grounding in employer data and EU-wide coverage; its limits are the survey burden, the focus on 'nuclearized' experts rather than the full craft workforce, and a regional rather than single-country design.

The UK Nuclear Workforce Assessment (NWA), produced by Cogent Skills for the Nuclear Skills Strategy Group since 2015, combines employer-supplied demand data from the civil and defence project pipeline with a system dynamics model of workforce supply that represents inflows from education, apprenticeships and adjacent sectors, and outflows through attrition and retirement, disaggregated by occupation and region [8, 9]. The 2023-2024 assessments quantified a need on the order of 40,000 additional jobs by 2030 and, accounting for attrition, well over 100,000 recruits, directly informing the UK Nuclear Skills Plan [9]. The NWA demonstrates what a mature, data-rich national programme can achieve, but it presupposes an established industry able to report demand—an asset newcomers lack.

3.2 US regulatory and industry mechanisms

The United States offers less a single estimation model than a set of institutional mechanisms that define and discipline staffing demand. On the regulatory side, minimum licensed-operator shift staffing is fixed by rule with review guidance in NUREG-1791, while the NRC's internal Strategic Workforce Planning process projects the regulator's own staffing gaps against projected workload and attrition [10]. On the industry side, INPO's National Academy for Nuclear Training and the independent National Nuclear Accrediting Board accredit utility training programmes against ACAD objectives and criteria, standardizing the qualification content behind each headcount [11], while Nuclear Energy Institute's industry workforce strategic plan aggregates utility staffing, attrition and pipeline data for the operating fleet [12]. For newcomers these mechanisms matter because they convert model outputs into enforceable staffing and training requirements—the demand-side standards that any quantitative estimate must ultimately satisfy—and because the NPHR tool's regulatory staffing module is itself derived from the NRC.

4. Discussion

The European models and US mechanisms of approaches are complementary rather than competing. For a newcomer country at Phase 1, the NPHR tool is the most appropriate backbone: it is free of charge (apart from the Stella licence), aligned with the Milestones Approach, and designed around exactly the decisions—contract model, programme schedule, education initiatives—that a NEPIO must make. Its main weakness, dependence on Anglo-American reference data, should be remedied by systematically replacing default worksheets with national education

and labour real statistics based on the newcomer country.

As the programme matures and a domestic industry emerges, an European employer survey can progressively replace modelled demand with reported demand, turning the national HRD plan from a simulation into an evidence-based monitoring system. Throughout this progression, regulatory staffing rules and training accreditation standards of the kind institutionalized in the United States discipline the demand side, ensuring that modelled headcounts are ultimately translated into enforceable staffing and qualification requirements.

5. Conclusion

National workforce estimation is not an optional appendix to a newcomer's nuclear programme but the quantitative core of HRD planning under the IAEA Milestones Approach. The IAEA NPHR modelling tool provides a purpose-built, decision-oriented simulation whose value depends critically on the quality of national input data and on awareness of its embedded Anglo-American reference assumptions. Comparative analysis shows a natural sequencing: general national manpower statistics feed the NPHR tool in the early phases, while employer-based observatories of the European type become feasible and preferable as the domestic nuclear sector grows. For Korea, whose institutions already operate both nuclear training infrastructure and national manpower projection systems, supporting newcomers in localizing the NPHR data file and building the statistical bridge between general and nuclear-specific forecasting is a concrete and high-value avenue of international cooperation.

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